Manado: A Developing Coast [Appendices]

The appendices to the advice report on how to deal with the effects of the development of the coastal zone of Manado.

15 October 2013

Christiaan Tenthof van Noorden, Daan Vermeij, Jelle van Zuijlen and Wilmar Zeelenberg
MANADO: A DEVELOPING COAST

A research based advice on how to deal with the effects of the development of the coastal zone of Manado.

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PREFACE
This document contains the appendices to the advice to the municipality of Manado about the effects of a planned reclamation and how to mitigate some already existing problems in the city Manado. After two meetings it became clear that our client, mr. Assa, the head of the Planning Department of the city Manado, also wanted us to do a research on the main river of Manado and the excessive garbage in it. This river floods almost every year, with high consequences for the citizens.

This research is the result of collaboration between the Universitas Sam Ratulangi and the University of Technology Delft. The Universitas Sam Ratulangi already welcomed a group of students from Delft in 2011. Their report called Manado Waterproof is available in the repository of the TU Delft. This research does elaborate some equal subjects, but the perspective is truly different.

We would like to thank the Universitas Sam Ratulangi for kindly welcoming us to the Fakultas Teknik and giving us a working place for our own. Our mentor mr. Torry Dundu was of great help on the morphology and hydraulics. We would also like to thank him for taking us to some beautiful tourist locations. We also would like to thank mr. Assa for inviting us to Manado.

Christiaan Tenthof van Noorden, Daan Vermeij, Jelle van Zuijlen and Wilmar Zeelenberg

Tuesday, 15 October 2013. Manado
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1 FIELDTRIP COASTAL ZONE MANADO

On Tuesday 27th August we made a fieldtrip through the coastal zone of Manado. By car we travelled past several hydraulic sites which could be of interest for our research. We first visited the Marina plaza land reclamation which is currently under construction. After this we visited the Manado harbour, where the breakwater has recently been reinforced with concrete units. We also visited the outlet of Tondano river and Bailang river. Finally we stopped at the location in northern Manado where there has been a mangrove forest, which has eroded.

1.1 Marina Plaza land reclamation

The reclamation which is under constructing is the final part of the Marina Plaza reclamation and extends the coastline by approximately 100-120 meter seaward. The border of the reclamation towards the sea consists of a rubble mount structure, with sharp volcanic rocks with a nominal diameter of 50 to 150 centimetres. The reclamation consists of yellow clayey sand, which originates from building projects in the east side of the city and the mountains at the edge of the town. Also the rocks for the rubble mount protection are locally available, from quarries in the region and from the aforementioned building projects. Here the sand and rocks are removed to provide flat construction areas. The purpose of this reclamation is to construct a water theme park. A soil expert indicated that there are just small problems with soil settlement on the land reclamation. But there do exist problems with geotextiles which might not have been placed sufficiently. Also the university is doing research on the soil strength effect of salt intrusion.

1.2 Breakwater at Manado harbour

The breakwater has been finished in 2012. The main stability of the breakwater is provided by a concrete wall which is supported by steel driven piles. The piles are connected to the concrete as can be obtained in Figure 1.1. The whole breakwater around 200 meter. The piles have a diameter of around 0.80 meter. The piles are placed under an angle to resist the forces the sea exerts.

Figure 1.1: Breakwater at the main harbour of Manado.

At the front of the concrete wall, a the breakwater was originally built with volcanic rock. These stones do not seem to be well sorted, but just randomly harvested out of the mountains. The structure turned out to be insufficient considering the prevailing conditions, so they applied concrete armour units to reinforce the structure (see Figure 1.3).
The tidal range is pretty large. The tide is semi-diurnal and at high water the water level reaches the top of the concrete structure. Also the waves are often overtopping the breakwater by 2 two 2.5 meters.

The function of the harbour did not change much since the previous group of students was in Manado, in 2011. However, the number of ferries to the surrounding islands and places on North Sulawesi has increased. Also a new powerboat ferry moors at the harbour, which uses jet engines which stir up the bottom sediment.

Missing links, to be analysed further in the report:
- Tidal range

### 1.3 Tondano River

Tondano River is the largest River in Manado. In the past this river has caused several floods. In the wet seasons the discharge of the river increases, causing floods and high discharge of waste up to Bunaken Island. The river is approximately 80 m wide. Our guide Michael told us that the water level of the river would raise approximately 1.5 up to 2 m during high discharge. A simple but very effective measurement with a floating bag teaches us that the river (at surface and in the centre of the river) had a current of 1 m/s. The depth is not known.
At the banks of the river the water was hardly flowing, and on many places there was accumulation of garbage and sediment, decreasing the width of the river, sometimes with several metres. At the columns of the bridge there was also a large accumulation of garbage. At the most outer columns this actually extended all the way up to the banks, considerably decreasing the width of the river.

The location we visited was close to the river mouth, approximately 300m upstream. One thing that was remarkable was that the people all live very close to the river. In front of their houses they have a concrete wall which would just be high enough to prevent them from flooding during high discharge. But in a year with extreme rainfall this area could easily be flooded. This has as the effect that the river has no space to go in case of high discharge (summer/winter floodplain).

Because the part we visited was close to the sea there were some mangrove trees visible near the bank. The river mouth functioned also as a sheltered mooring area for a lot of ships. Since the current was very weak this was easily possible. Whether this is also the case in situations with a higher discharge has to be seen.
Figure 1.8: Multiple ships at the sides of the river, decreasing the current carrying area.

Missing links:
- Actual dimensions (Google Earth)
- Discharge and current velocity at high water
- River flow profile, river storage profile
- Salt intrusion
- Tidal influence (water level, salt)
- Sediment properties, quantities

1.4 Bailang river
This river flows in the most northern part of Manado and the river mouth is located next to a small harbour which is surrounded by a breakwater. The river hardly flows through urban area, giving it less importance regarding flooding.

The river is about 25 to 30 metres wide, and according to local fishermen the depth was between 2m and 4m, depending on the tide. The flow velocity is not known, but very low. The observed location is at approximately 900 meters upstream of the river mouth. Because there are no mangrove trees observed it is also not known how much influence the tide had on the salinity of the water. The banks of this river are protected with gabions in both inner and outer banks.

Figure 1.9: Bed protection consisting of small stones in a wire mesh.
Missing links:
- Flow velocity
- Importance for our research

1.5 Shipyard beach
The last location visited consists of two parts, which are both heavily littered. A beach area and a mangrove forest. The beach area consisted of volcanic sand. The bottom slope of the beach and the mangrove area was very mild, probably about 1:100. The site was located next to the river mouth of the Bailang River.

In the beach area there were clear signs of erosion. There were solely trees far in the sea and a steep slope at the landside of the beach indicating erosion. The beach functioned as yard for renovation of damaged ships and the accompanying steel works. A sand sample was taken from the sea. The sand seems to consist from a mixture of volcanic ash and regular beach sand.

![Image: Some photos of the shipyard beach, with the eroded area clearly visible in the middle.](image)

The present mangrove specie at the location where some mangrove trees are growing is called ‘eaphanoflores’. A sand sample was taken from mud in-between the trees. The area was not very thick planted. In the past there was a mangrove forest, but the coastline has retreated a lot.

In the sea, in front of the river mouth there was a sand bank visible. It is not sure if this is caused by sediment from the river or it is a remainder of the old coastline, kept in equilibrium.

Missing links:
- Beach slope
- Mangrove forest and coastline location
- Cause of the sand bank.
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1 AREAL RESEARCH

The aim of the project is to research the influences of a future land reclamation. To do this, it is necessary to investigate the location of the planned reclamation and the surrounding area. The processes that happen in the environment of the planned building location could be very important for the development of the area in the future.

The research of the area will be executed on three different scales. The reason for this way of researching the area is that the scales have different scopes. The first research is on macro scale, where the scope is to determine where the ecologically vulnerable spots are situated with respect to the city Manado. This analysis will be of help to understand the overall processes in Manado Bay. The second analysis, on meso scale, will be on the Manado coastline. During this research there will be searched for the possible stakeholders at the whole coastline and big structures that might influence the currents or waves in Manado Bay. The last analysis, on micro scale, will be zooming into the northern part at the location of the planned reclamation. It is important to know whether there are outlets of the river or outstanding structures along the coast.

1.1 Manado Bay

Manado is situated at the centre of North Sulawesi in a bay of the Celebes Sea. This sea is very deep, around 2 kilometres at some spots, and houses one of the most extraordinary ecosystems in the world. It was here that Charles Darwin got interested in doing research on organisms to eventually come up with his theory on the origin of species.

![Figure 1.1: Overview of Manado in the Celebes Sea.](image)

While having a look at the situation of Manado, it is directly clear that it is the ultimate base for nature trips. As seen on the small map in the corner of Figure 1.1 the north of Sulawesi is a long peninsula. Manado itself is sheltered into a bay. In red, the most dense populated area is drawn.
1.2 The coastal zone
The Manado coastal zone houses important economic and ecological functions. In Manado the main food supply comes from the sea. Logically there are lot of fishing boats present along the coast. These boats are laying in the protection of small rubble mound breakwaters. There are two exceptions, namely the main harbour next to the Tondano River and the Bailang Harbour. The functions of these harbours is also to moor ferry lines. They are drawn in Figure 1.2 as squares.

![Figure 1.2: Overview of Manado Bay with the main functions and outlets.](image)

The main outlets are also drawn. During an inspection a lot of pollution was discovered in the south of Manado in the direction of Malalayang. The question of the municipality to come up with a solution for the garbage in the bay was first only for the Tondano River. However, there must be looked seriously to the option to extend the system boundary for the subject garbage. As a first impression the city looks really clean. There are garbage bins on the street and people seem to use them well. However, it seems that the garbage is still thrown away in the rivers. Until now a real solution for keeping the water clean has not been implemented.

The Marina land reclamation is still under construction in the north of it. This reclamation is the heart of the city’s business with the megamalls. Also the youth can find the opportunity for recreation in this area, with game halls and clubs. A lot of people think this reclamation was the devil in the change of the currents in Manado Bay that is now transporting the garbage to the Bunaken islands. Looking at the shape the large change is of course the bulb in the middle of the Marina reclamation.

The mangroves in the north are of great importance to the Bunaken, and also for the people of Manado. The mangroves give shelter to a lot of fish species that also live in the coral. But besides this ecological value, the mangroves are the place the fisherman catch crab and other fishes. The absence of the mangroves in the future would therefore also result in a relocation of the fishing location of these people.
In Manado Bay a lot of valuable coral reef is present (see Figure 1.2). The coral reef is located at about five kilometres out of the coast (World Fish). There used to be coral in Manado Bay closer to the coast, but this has been disappeared, according to the owner of a dive resort on Bunaken island.

For the purpose of having a good view on actual extension of the coast, using Google Maps the reclamations in the past until now were measured and graphed (Figure 1.3). This makes it much easier to see how enormous the reclamation drift of Manado has been in the last 15 years.

One of the remarkable points in the graph is the peak around 5800 metres. This is the most seaward point of the Marina reclamation. The influence of this point will be elaborated later. Also one can see that the harbours are of significant influence on the coastline profile, especially the Bailang Harbour. It is very likely this extension had some influence on the currents in Manado Bay.
1.3 Future reclamation area

The future land reclamation will be situated between the main harbour and the Bailang Harbour. The north of the coast of Manado is the less developed area regarding to safety against water. It was obtained that this part has no rubble mound revetment, which is present at the south. In Figure 1.4 the rubble mound revetment is marked with a dark purple line. Between the two large harbours three small fisherman harbours are situated. These harbours are however very crowded by small ships. Also a lot of small boats are present at the coast without revetment. It is very likely these boats are used by the people living directly on to the shore. Before 2011 there was a mudflat present in this part of the coast, used by these same people. The construction of the long breakwater south of the Bailang harbour was the cause of the disappearance of this mudflat. However the ecological value is considered not to be very high, due to the fact people already influenced this area much.

In green the mangrove area is drawn. The mangroves are now at the bright green line. However, in 2003 mangroves were still there in the dark green area. The coastline did change a lot in the last years.
2 HYDRAULIC ANALYSIS

This analysis describes all the assets of the hydraulic system in and around Manado bay. This contains information about waves, tides and currents which are of interest for our research.

2.1 Wind and Wave Climate

Wave and wind data has been retrieved from the webpage waveclimate.com (Argoss, 2013). This service provides satellite and model data about wave height (sea-wind, swell), wave period and wind speed on offshore locations. To get the needed near shore wave data the offshore data can be processed, either by using the near shore service provided on waveclimate.com or using SwanOne, an interface to calculate near shore conditions.

2.1.1 Needed data

The following wind and wave data is of importance in this project:

- **Wind speed and direction**: Is of importance for the amount of wind setup experienced at the shoreline. But wind also influences the waves in the process from offshore to near shore waves.
- **Wave heights, periods and directions**: In this research no design limit state is considered, since no design is made. Therefore only an average wave height and period which gives an indication about the climate is considered. The wave directions are of most importance because they influence the currents and sediment flows, which are very important in this project.

2.1.2 Offshore location

Since there is little information available (see Figure 2.2 and Figure 2.3) in the direct area of Manado (Manado is in the lower right corner of the rectangle), the model data Argoss provides is used. It is now assumed that the outcome of the model is applicable to every point in the rectangle, so also in Manado bay. The model point used to calculate the wave statistics is presented in Figure 2.1.

![Grid points wave model](image)

*Figure 2.1: Grid points wave model*
2.2 Wind climate

Wind data is important to determine waves and wind set-up. In Figure 2.4 it can be seen that the dominant wind directions in our area are coming from the (east-)north-east and from the south-south-east. The winds from south-south-east and east-north-east do have an important influence on the currents that appear. Especially the winds coming from south-south-east will be important for the current in Manado Bay. This will be discussed later in this chapter.

2.2.1 Wind setup

The wind setup is calculated with the method of Heun at the Tondano River mouth. The calculation in Table 2.1 shows that the wind setup is negligible. This is because the stretch with shallow water is very short and after this stretch the water immediately becomes very deep. Although the fetch is very long (up to 800 km!) the depth guarantees very low wind setup. Because the wind setup is negligible its increase is also of negligible order. Different scenarios with alternate depths and calculation methods have been tested, but the wind setup stays in the order of a single centimetre.

But caution should be taken. The calculation methods, cannot include the funnel shape river mouth. This funnel shape is exactly what is expected to cause increased wind setup. Luckily the percentage of days in a year the wind blows 'into the funnel' is less than 5%.

Figure 2.2: Data density SAR

Figure 2.3: Data density altimeter

Figure 2.4: Directional spreading of wind at Manado Bay. Source: (Argoss, 2013)
Appendix B: Present situation

Table 2.1: Wind setup calculation
<table>
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<th>Distance from former coastline [m]</th>
<th>0</th>
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<th>250</th>
<th>300</th>
<th>350</th>
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<td>4,4</td>
<td>7,4</td>
<td>12,4</td>
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<tr>
<td>Depth neap tide</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td>0,0</td>
<td>0,0</td>
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<tr>
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<td></td>
<td>200</td>
<td>50</td>
<td>50</td>
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</tr>
<tr>
<td>deltaz</td>
<td></td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Windsetup [m] 0,003648

2.3 Wave climate
The wave climate and in particular the wave directions are of most importance in this project because they influence the currents and sediment flows.

2.3.1 Offshore waves
The statistics that are most important for determining the effects on the morphology and design parameters are:
- Wave height and occurrence
- Wave height vs. direction and occurrence
An distinction can be made between sea-wind and swell waves. Argoss can also display the total spectrum. Figure 2.6 until Figure 2.7 display the average wave height measured by altimeter, total wave spectrum by SAR (Synthetic Aperture Radar), wind-sea waves by SAR, swell waves by SAR respectively.

Figure 2.6: Wave height altimeter.  
Figure 2.5: Wave height SAR.  
Figure 2.8: Wave height wind-sea SAR.  
Figure 2.7: Wave height swell SAR.
Coastal Engineering Manado

The above figures show that most wave heights in the area of Manado lay between 0 and about 2.0 m, and the dominant wave direction seems to be NE for swell waves and somewhat more random for wind-sea waves. Also Figure 2.9 shows that most of the waves are from north east direction and thus of no importance for this research, since they can never reach Manado Bay. This is in analogy with the dominant wind directions in the same area. The relative distribution of wave heights and directions is presented in Table 2.2. This table also shows that only a very small part of the waves entering Manado bay is higher than 1.5 m. The percentages shown in this table are of all the wave directions.

![Wave height vs direction based on wavemodel](image)

Figure 2.9: Wave height vs direction based on wavemodel

| Percentage of occurrence of wave height (m) in rows versus wave direction in columns |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| lower                           | lower           | 213.75          | 236.25          | 258.75          | 281.25          | 303.75          |
| lower                           | upper           | 236.25          | 258.75          | 281.25          | 303.75          | 326.25          |
| 0.0                             | 0.5             | 0.4             | 0.5             | 0.8             | 0.6             | 0.7             |
| 0.5                             | 1.0             | 0.2             | 0.1             | 0.4             | 0.5             | 0.7             |
| 1.0                             | 1.5             | 0               | 0               | 0.1             | 0.2             | 0.4             |
| 1.5                             | 2.0             | 0               | 0               | 0.0             | 0.1             | 0.1             |
| 2.0                             | 2.5             | 0               | 0               | 0.0             | 0.0             | 0.0             |
| 2.5                             | 3.0             | 0               | 0               | 0               | 0.0             | 0               |
| 3.0                             | 3.5             | 0               | 0               | 0               | 0               | 0               |
| **Total**                       | **0.6**         | **0.6**         | **1.3**         | **1.5**         | **1.8**         |

2.3.2

Figure 2.10 shows the distribution of waves that are important for this project. Since Manado bay lays somewhat sheltered from these dominant wave directions, only attention is paid to the wave directions which can be of meaning for the Manado bay. This is wind blowing from SW (225 deg) to NW (315 deg). These waves do not occur too often and if they do the wave heights are moderate.
2.3.3 Wave height and direction conclusion
In this research no design limit state is considered, since no design is made. The wave directions are of most importance because they influence the currents and sediment flows. The dominant wave direction, which can be of harm in the bay has a direction of 315 degrees.

2.4 Tide
Manado has an M2 tide ranging to about 2.4 m
From Figure 2.11 the different water levels in Manado Bay during a tide can be observed:

- HHWL = 2.5 m
- HWL = 2.1 m
- MWL = 1.2 m
- LWL = 0.4 m
- LLWL = 0.1 m

The tide influences the coastal zone the most in the area of the river mouths. The tide influences the water level in the river mouth, leading to high water levels just upstream of the river mouth. This could lead to flooding in this area. The sea defence against the tide seems to be suitable.
2.5 Currents

The currents in the sea in front of Manado are a crucial factor in this project. They play an important role in the sediment transport, and of course in the garbage flow in the Manado Bay.
2.5.1 Longitudinal current
The longitudinal current drives sediment alongshore the coastline. The current is dominated by wave attack and river outflow. The cross-shore circulation current is also involved in the process, because this stirs up the sediment which is transported by the longitudinal current. The angle between the coastline and the incoming wave rays are most of the time, the determining factor for the direction of the current. But the current could also be in the opposite direction due to a river outlet, which creates a strong enough current to dominate the longitudinal current. In Figure 2.13 the longitudinal current is shown by the orange arrows. Most of the alongshore current is induced by the waves, which come most of the time out of the north-west. Just two places along the coast the direction of the current is different from the wave direction. The first is just north of the Bailang river mouth, where the outflow of the river is stronger than the wave induced current. Also there is a set-up current from the harbour south of the river mouth towards the north of the river mouth, because of wave refraction towards the breakwater of the harbour. The second place is the bulb in the coastline at the Marina Plaza reclamation. Because the bulb is that far out of the coastline, the waves will refract towards it. This refraction towards the bulb creates a higher wave set-up around the bulb. The set-up is quite lower in the coastal area north and south of the bulb, which logically lead to a current from the bulb towards the north and south of it.

2.5.2 Tidal current
The upcoming and outgoing tide brings a current with it. It depends on the circumstances how important this current is. The shape of the coast and of course the difference between high and low tide determine the strength of the tidal current. Since the coast of Manado is situated in a bay, the current will go around it along the shore as shown in Figure 2.13 with the light red arrows. The current is quite strong, because of the tidal range of 2.4 meter. The upcoming tide moves counterclockwise through the bay and vice versa.

2.5.3 Wind induced current
The wind blowing from the south and south-south-east, is the most common in Manado Bay as shown in Figure 2.13 with the green arrow. This current is the strongest at the surface, and becomes weaker towards the bottom of the sea. So the wind induced current barely has any influence on sediment transport, but is very important in this project, because of the large influence on floating garbage.

2.5.4 Rip current
Rip currents occur at the mouths of the four rivers, which are flowing out in Manado city. This isn’t only because the outflow of the river, but also due to the alongshore currents which come together in front of the river mouths. The rip currents are narrow channels where the water can flow back towards the sea, where the flows will split up again. The higher the discharge of the river the further the rip current will reach into the sea. So after high intensity rainfall the rip currents will reach further into the sea, which has important consequences to for instance the flow of garbage. The rip currents are indicated with the dark red arrows in Figure 2.13.
2.6 Tsunami Risk
The presentations of (Assa, 2013) gives a view of which areas of Manado could be influenced by a tsunami, which has been concluded by a prior research. This is visible in Figure 2.14. The blue indicated areas are the more low lying parts of Manado. Important to note is that earthquakes are experienced in Manado rather often, but they are most of the time very mild.

![Figure 2.14: Tsunami risk at Manado](image)

2.7 Sea level rise
The municipality expects 15 cm of sea level rise by 2040 based on the following UNEP-1995 data. Their assumption is based on the diagram in Figure 2.15. The municipality is considered to be not too conservative but is also not overreacting. Because the surface level of the rivers is mainly dependent on the river discharge, this elevation is not taken into account at the section of the Tondano River. Sea level rise is not of high importance in this project. Other factors have a larger contribution to the problems of Manado. Sea level rise is most important for the design height of the revetment of the new land reclamation.

![Figure 2.15: Expected sea level rise.](image)
2.8 Urban drainage
The drainage channels in the city of Manado have too low capacity. Even during a short downpour the drainage channels will exceed their capacity and the streets will be under water. This can happen in less than 15 minutes! Since Manado is built in a hilly area the streets will become rivers, transporting the water towards lower laying areas. During longer periods of high rainfall the water level in the river will become so high that it becomes a serious threat to people around it. Especially the parts in Figure 2.16 indicated in red have a high risk of flooding.

Figure 2.16: Parts with high flood risk.
3 ANALYSIS OF THE MORPHOLOGY
To investigate what the influence of a future land reclamation is on the bathymetry of Manado bay it is important to have a good description of the current situation. The chapter focuses on describing the current morphological processes at Manado’s coast.

3.1 Coastal erosion
In this current situation, the coastline north of Manado experiences moderate erosion. Finding the reasons for this erosion is also important in understanding the current morphological processes.

3.1.1 Problem description
Since the existence of the already completed land reclamations and the harbour at the Bailang river mouth, the coastline north of Bailang river is experiencing extensive erosion. As a result of this very valuable mangrove forest has retreated tens of meters. The disappearance of mangrove forests leads to loss of breeding ground for the coral fishes and could speed up coastal setback, which is unfavourable for the local residents.

The new reclamations might also have an effect on this erosion, further diminishing the state of the mangroves. In the end this might also affect the Bunaken National Park, since the loss of breeding ground will also affect the coral reef, which should be prevented. This new land reclamation might also lead to sedimentation at some unwanted spots, which will be investigated later.

3.1.2 Locations with erosion
Locations where erosion occurred in the environment of the project are north and south of the Bailang river mouth. Other places of the city are already protected against the erosion by rubble mound revetments.

3.1.3 Locations with accretion
The revetments along the existing land reclamations are not a continuous sea defence. The coastline has developed by many small land reclamations until various depths into the sea. Between several indents between these land reclamations accretion is visible. Also accretion occurs in front of the river mouths, this will be discussed later.
3.2 Existing knowledge

3.2.1 Alongshore sediment transport in general
A combination of currents and waves induces the transport of sediment along the coast. Because waves approach the coastline under a certain angle, sediment is transported alongshore. The currents which take the sediment alongshore are caused by the breaking of waves. Erosion and sedimentation can occur, when there are differences in the alongshore transport. If over a certain length the inflow of sediment is higher than the outflow, accretion will occur. And vice versa, erosion will occur.

Besides the currents caused by waves, the tidal current also influences the sediment transport along the coast. Of these two currents, the wave induced currents are dominant. The sediment in the breaker zone will first be stirred up, due to orbital movement near the bed, caused by waves. The orbital movement brings the sediment in suspension, so the alongshore current is able to transport it. The maximum flow velocities of these currents appear at the breakerline, the location where the waves break. The velocity decreases approximately linear between the breakerline and the shoreline, if the slope of the beach is straight.

The maximum sediment transport occurs just inside the breakerzone, but the distribution of the transport is not linear like the current velocity. Because of this combined action of alongshore current and waves, the sediment transport capacity of the alongshore current is much more than the transport capacity of a current in a river.

3.2.2 Prior advice
Previous research hasn’t made any progress in finding the reasons for the erosion north of Manado. The group of 2011 mainly proposed several hypotheses, but any analysis behind the followed solutions is missing. Possible improvements suggested by the group of 2011 were the following: planting mangroves, a submerged dam, emerged dam or a breakwater.

The planting of mangroves will be the most preferable solution. However, before they can be applied the old hydrological conditions must be met. Therefore the submerged dam was proposed. An emerged dam was also a solution they came up with. This emerged dam has a breach to let the tide come into the area. As a last solution there was thought of making a breakwater longitudinal to the coast, starting at the harbour. This was intended to divert the current away from the mangrove forest. A few quarries for the rubble mound are found nearby Manado.

3.2.3 Prior measures taken
Around Manado different solutions have been applied to fight erosion. At some spots outside the city there are still mangrove trees. At most other locations rubble mound revetments, breakwater groynes or T-groynes have been placed. Between some of the T-groynes south of Manado they even started to plant mangroves.
3.3 Available Data
Most of the data comes from our client, the municipality of Manado, especially about the plan and the morphology of Manado Bay.

3.3.1 Bathymetry Manado bay
Below the available data about the bathymetry of Manado Bay is presented in Figure 3.1 and Figure 3.2. It can be seen that the depth at the location of the reclamation varies between 0 and approximately 25 m. The Manado Bay becomes very deep after a short distance out of the coast. This is an important fact for the influence of the reclamation on the currents. The shallow depths might disappear at all. This causes that the sediment transport will be much less than the alongshore sediment transport capacity.

![Figure 3.1: Bathymetry at Manado Bay, Source: (Assa, 2013)](image1)

![Figure 3.2: Bathymetry at new reclamation area, Source: (Assa, 2013)](image2)
3.3.2 Sediment transport data from the Municipality

The presentation about the new land presents some information about sediment transport directions and quantities. Unfortunately this data is far from complete. Important to notice that the sediment transport quantities are not measurements but the result from model computations at the Sam Ratulangi University. But also the quantities of the sediments are incomplete, and so can’t be used for this analysis. Though the figure presented in Figure 3.3 has been very helpful for this analysis.

Figure 3.3: Sediments flows in Manado bay from model computations of Sam Ratulangi University, Source: (Assa, 2013)
3.4 Sediment sinks en sources

3.4.1 Sources
The sediment in the Manado Bay originates from the coast upstream of the alongshore currents, the (dead) coral reefs in the bay itself and of course from the rivers. The tide can bring the sediment in which is created by the coral reefs. This consists out of coral sand and small pieces of dead coral.

3.4.2 Sinks
Most of the sinks of the sediment in Manado Bay are located in front of sources, the river mouths. At these locations rip currents drive the sediment off shore, where it can be picked up by the tidal currents or will sink to the very deep bottom of the sea. These tidal currents don’t just bring in sediment, but they also transport it out of the bay.

3.5 Sediment Transport
The sediment transport in the Manado Bay is quite complex, this is partly because of the appearance of land reclamations along the coast of Manado city. The net sediment transport directions are shown in Figure 3.4. The solid arrows indicate the alongshore sediment transport. Rip currents, indicated with the small dashed arrows, bring the sediment out of the breakerzone into the sea, where the sediment will be picked up by the tidal currents. These are indicated with large dashed arrows, the upcoming tide is going counterclockwise through the Manado Bay and vice versa. The currents have a large influence on the suspended sediment flow outside the breakerzone. The currents in the figure are the dominant, most common currents. The directions could be different in case of waves from the southwest direction and strong tidal currents.

The transport of sediment along the coastline will be described per part of the Manado city coast in the part below. Because of the lack of data about the sediment transport, this analysis doesn’t contain quantities, but is formed by analysing the coastline and a synthesis of: knowledge about coastal processes and how they are affected by the presence of the waves and currents, several coastal expert conversations, several site visits and the existence of some model data from the Sam Ratulangi University.
3.5.1 Erosion and net sediment transport of the former mangrove area

North of the Bailang river mouth, mangroves are located along the coast. The alongshore transport is directing towards the city here, due to the dominant waves coming from the north-west. But just north of the Bailang river mouth these mangroves are disappeared and the land retreated due to erosion. This area is indicated in green in Figure 3.5. The alongshore current is directed to the north-west here. The reason for this change of direction is the outflow of the Bailang river in combination with the appearance of the large breakwater south of the river mouth. The current originating from the river outflow is overruling the wave-induced alongshore current. After a couple of hundred meters the influence of the river outflow is decreased to the same strength as the wave-induced current. At this particular location their will occur a small rip current, which takes the sediment offshore. The erosion of the former mangrove area isn’t just caused by the strong river outflow, which is directed along the area. This phenomenon just increased the erosion after it started.

The most probable cause for the start of the erosion, is the removal of mangroves by the local residents. They wanted to enlarge their living area, but had no idea about the consequences of it. Unfortunately they did this at approximately the same moment as the extension of the breakwater. Because they removed some mangrove trees, the sediment lost its grip on the shore. Before the sediment was settled in the roots of the mangroves. The disappearance of these mangroves induced to erosion of the land and also erosion under the mangroves upstream. These mangroves didn’t have the shelter they were used to have, and suffered from a shortage of sediment. The cause of the retreat of the other mangroves could also be the difference of the salinity in the water, because since the moment the current changes, the water became more brackish, due to the fresh river discharge. The roots of the mangroves are also really sensitive for this. In this way a large area of coast retreated until there became some kind of equilibrium, at the point where the influence of the river outflow is almost disappeared.

The Bailang river outflow is directed to the north by the large breakwater and the flats in front of the river mouth. These flats are inter alia formed by the sediment flow from the sea along the breakwater, but especially by the original alongshore current which is blocked by the breakwater.
Also some sediment from the river outflow ended up at the flats. So the outflow of the river takes nowadays the path of the least resistance, which is northwards. The largest amounts of erosion would be occurring during high river discharges, so after intense rainfall. In Figure 3.5 the original sediment transport directions are indicated with red arrows, this is the transport before the appearance of the breakwater. The dark blue arrows show the present sediment transport as described above. The flats in front of the river mouth are also shown.

![Figure 3.5: Sediment transport around the Bailang rivermouth](image)

3.5.2 Erosion and net sediment transport south of the Bailang river mouth
The building of the large breakwater of the harbour, located directly south of the Bailang river mouth, had an impressive impact on the sediment transport around it. As described above, it already influences the alongshore transport north of it. It also had consequences for the coastline south of it. This area was originally fed by sediment coming from the north. But the supply of sediment is blocked since the extension of the breakwater. This caused some erosion along the coastline south of the harbour, indicated in red in Figure 3.5. This erosion occurs at the coastline where no revetment is built. Some small breakwaters are built to give shelter to fishing boats, but they also prevent erosion at that location. Further southwards the coastline is protected with rubble mound revetments.
3.5.3 Accretion and net sediment transport around the Tondano river mouth
In front of the Tondano river mouth two alongshore currents come together as can be seen in Figure 3.4. In combination with the outflow of the river these create a rip current, offshore directed. Just north and in front of the river mouth the sea is very shallow, due to accretion. This accretion is a result of the two alongshore sediment transport and the sediment coming from the river. The building of the Marina Plaza land reclamation certainly had influence on this, because it brought some critical changes in the current pattern. Just like at the Bailang river mouth the river outflow is also blocked by a breakwater. At this location the breakwater of the Marina is the cause. The flats at the river mouth could give some serious effects for the river upstream, this will be discussed in the River Analysis.

3.5.4 Accretion and net sediment around the Marina Plaza reclamation
The bulb in the Marina Plaza reclamation is a remarkable piece of the coastline of Manado. This somewhat strange shape also brings some variations in the current pattern along the Manado coast. In the past, before the appearance of the reclamation, the alongshore current was directed southwards until the present location of the Bahu Mall reclamation. Nowadays the alongshore current between the Tondano river mouth and the bulb of the Marina Plaza reclamation, is directed towards the north. This is visible in Figure 3.4. This event resulted in the accretion in front of the Tondano river mouth since the building of the reclamation.

South of the bulb there happens what will be expected with the alongshore sediment transport. The transport is directed south until the wave angle has become too small. At this point, just south of the Bahu Mall reclamation, there is also an alongshore sediment transport coming in from the west. Because the wave angle at this point is almost perpendicular to the coastline, no alongshore transport will take place. A rip current drives the sediment off shore and in front of the Malalayang river outlet there will occur some accretion.

Accretion also occurs in the indents between the reclamation areas and inside small harbours along them. On the north side of the bulb these accretions are mostly on the north side of the indents and harbours and on the south side they occur on the southern side of the indents.
4 TONDANO RIVER
The Tondano River meanders from upstream Tondano Lake through the heart of the city Manado to the outlet north of the Manado harbour. It confluences with Tikala river inside Manado city, as shown in Figure 4.1. Both rivers originate from multiple branches which mostly confluence just outside the city border. The Tondano River has a highly varying river profile, due to the meandering and the space it had to offer to the people of Manado. The river bed consists of sand granulates and the discharge is mainly depending on the amount of precipitation.

In this chapter the most important properties, including most relevant and available data, on Tondano and Tikala River are elaborated. Also a short research on the human interference is executed. From this, the factors that have an influence on the Tondano river flooding can be found. The next step will be describing possible changes to the river and do some calculations about its effects. Which in the end can lead to an advice of what measures can be taken to prevent the Tondano River from flooding.

![Image of Tondano and Tikala River in the city of Manado.](image)

4.1 Properties Tondano River
To estimate the influences of certain measures it is obvious one must know what the current properties of that river are. The important things to know are the dimensions, discharges and sediment transport.

4.1.1 Basic dimensions
The river Tondano is separated into six sections for schematization which all lay between boundaries of the Manado Municipality, as shown in Figure 4.2. Within the inner city of Manado the river is highly constricted which leads to floods around stretches II, III and V. At sections II, III and V the river has been constricted to a very narrow path, which also leads to flooding at these branches.
Table 4.1 shows some basic dimensions of the river system. Of course the river width is dependent on the discharge and may vary a bit. Information on bed roughness or grain size has unfortunately not been provided.

### Table 4.1: Basic properties of Tondano River.

<table>
<thead>
<tr>
<th>Section</th>
<th>Width</th>
<th>Length [m]</th>
<th>Lowest point [m]</th>
<th>Highest point [m]</th>
<th>Steepness</th>
<th>Bed roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>±50m</td>
<td>550</td>
<td>-1,5</td>
<td>-0,5</td>
<td>0,0018</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>±20m</td>
<td>1600</td>
<td>-0,5</td>
<td>-0,16</td>
<td>0,0002</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>±15m</td>
<td>3050</td>
<td>-0,16</td>
<td>0,5</td>
<td>0,0002</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>±18m</td>
<td>1975</td>
<td>0,5</td>
<td>3,4</td>
<td>0,0015</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>±15m</td>
<td>2365</td>
<td>-0,16</td>
<td>0,5</td>
<td>0,0003</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>±15m</td>
<td>4825</td>
<td>0,5</td>
<td>3,4</td>
<td>0,0006</td>
<td></td>
</tr>
</tbody>
</table>

Google Earth is used to determine the length of the different stretches and to determine the bottom slope, but also supported by design files of the Japanese engineering firm Yachiyo Engineering CO., LTD. and Associates.

#### 4.1.2 Profiles

The profile of the river has great influence on the discharges. The Tondano River’s profile will be simplified for the calculations. The design files of the Japanese engineering firm Yachiyo Engineering CO., LTD. and Associates provide useful cross-sections of the river at several locations. A typical cross-section is shown in below in Figure 4.3.
4.1.3 Discharge

The Manado climate knows a dry season from May till October, although the river always continues a mild discharge. The wet season is from November till March. During the rainiest month an average precipitation of 420 mm/month is normal and over a complete year an average precipitation of 2760 mm/year is normal.

A computation using the catchment area and a rainfall of 2760 mm/year gives an average discharge of 48 m³/s average period over a complete year. During the fieldtrip the river discharge at Megawati bridge was estimated to be 60 m³/s. This is based on a river an average river depth of 2 meters a river profile width of 30 meters and an average velocity of 1 m/s.

**Design discharge**

Table 4.2 shows several values of the discharges at different return periods. The 5 year return period (RP) discharges are used design criterion in recent river works. It is unknown on which data these design discharge are based.

<table>
<thead>
<tr>
<th>NO.</th>
<th>River Name</th>
<th>Catchment Area (km²)</th>
<th>RP - 5 year (m³/s)</th>
<th>RP - 10 year (m³/s)</th>
<th>RP - 25 year (m³/s)</th>
<th>RP - 50 year (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TONDANO</td>
<td>545</td>
<td>603</td>
<td>690</td>
<td>789</td>
<td>861</td>
</tr>
<tr>
<td>2</td>
<td>TIKALA</td>
<td>93</td>
<td>157</td>
<td>182</td>
<td>208</td>
<td>226</td>
</tr>
</tbody>
</table>

Above data are doubted by another research firm (Padang Sub-Project, 2013) which states that the five years probable discharge could be less than 180 m³/s.

**Observed peak discharge**

A Japanese consultancy firm has calculated a peak discharge of 300-350 m³/s based on a flow section, river heights from eye witnesses and riverbed slope at Kairagi Bridge. For these calculations the cross-section of Figure 4.4 was used.
4.1.4 Sediment transport properties (Transport formula):

Another property that has influence on the flow and discharge of Tondano River is the sediment transport. The faster the flow the bigger the grain size the river can transport. Reversely the velocity says something about the grain size. However, one must keep in mind the Tondano River is highly polluted and the influence of the garbage must therefore be investigated. Unfortunately there are still unknowns about the river. The following data misses to also implement a morphological computation for the river: Sediment transport in Tondano river, its yearly average and peaks; Grain size(D$_{50}$) of the sediment; The density $\rho_s$ of the grains.

4.2 Prior advice

The previous TUDelft students who investigated and presented a flood prevention plan, which was focussing on preventing the river to flood every five years. They separated their advice into short and long term recommendations:

On the short term the most inland point they investigated was Paal Dua. The conclusion of the research was that the bending of 100 degrees will give a rise of the water level upstream. They suggested there must be found solutions to prevent the backwater curve from forming the upstream part of the area. A storm water drain was proposed and the corner to be smoothened. At Ketang Baru, an inland location where there is a large river bend, the problem was the meandering and the presence of fish cages downstream of the river bending. The fourth area was Karame, a part of the Tondano River and therefore very suitable for this project. The investigated area was at a point where the Tikala River joins. The interesting thing was that the Tikala River area did not flood, because it seemed to have a better protection, i.e. a higher protection. At this location it was proposed to widen the river. Because this is not possible everywhere, it was proposed to deepen the river. It was not calculated how much. The area Tikala Baru is also situated inland. This part of the Tikala River has some obstructions and here the river is meandering too. There are realistic solutions possible here for the river to reduce the hydraulic resistance.
On mid-term they advised basically that the rivers must be turned into canals. The group also thought about urban water control. The city Manado suffers from floodings due to the discharge from the river, so entrainment basins were designed nearby and in the city Manado. The group also claimed that these basins also have the advantage that the city then has more water during dry season. This function seems very unlikely, because the basins don’t have the seize to store water for a long period. The water will be released from these basins when the discharges of the river are decreased, so it could be used during the next rainfall period. Besides that, the dry season in this region isn’t really dry, but just less wet than the rest of the year. The water normally flows directly into the sea, especially during ebb. Also the Dutch river engineering was introduced in the manner of the river program “Room for the river”.

Concluding their advice and recommendations were the following: Improve the situation before the next rainfall with minimal structural changes; Make plans for the mid- and long-term situation; The environmental impact should get more attention, especially on the long term; Design the measures in a broad view; i.e. in an integral solution; Even with limited resources the most basic elements of the system must keep running.

4.3 Upstream human intervention
Several activities are taking place near or in the Tondano River upstream of Manado that might have significant effects on the properties of Tondano River. For the power supply three hydropower plants are situated in the river and there is a lot of excavation work executed in the area.

4.3.1 Tondano Lake
A part of the discharge of Tondano river originates from Tondano lake. Tondano lake has problems with eutrophication and siltation limiting its capacity to store excess water. The eutrophication can be described to the large amounts of nutrients which flow into the lake due to use of fertilizers.

4.3.2 Three hydro dams
According to experts there are three hydro dams in upstream parts of the Tondano river. Although they are just minor plants, they do hinder the transport of sediment. They are situated near Tondano Lake, far outside the city. Although it might be very interesting to calculate their influence on the discharge of Tondano River, they will not be elaborated more.

4.3.3 Excavation works
There are excavation works done in the upper parts of town. This is done to flatten the land for housing purposes. A part of this excavated land might end up into the river according to our expert, as a sort of sediment supply. However, its influence will not be considered during this research, due to the lack of data and the limited amount of time.
4.4 Tidal influence

The water level in the mouth of the rivers of Manado are highly influenced by the tide. During the fieldtrip fisherman stated that the tidal difference in the river could easily be two meters, what seems a quite good estimation.

4.4.1 Tidal variation

The tidal range in the river mouth of Tondano River is between 1.5m and 2.4m. High tide rises till about 2.5m above CD. The tide in Manado bay, so at the river mouth, is visible in Figure 4.5.

4.4.2 Combination river floods and ocean floods

According to one of our coastal experts river floods and high ocean water level do correlate. Whether this is the case, affects the ability of the city to get rid of excess rainfall. But apparently the most severe river floods happened at a moment of high tide.

4.5 Flooding Area

The Tondano river has occasionally flooded over the last twenty years. This has had high consequences for the citizens. In the last twenty years the people in the river area suffered a lot due to the floods. In Table 4.3 some data about these casualties are shown.

<table>
<thead>
<tr>
<th>Month/Year</th>
<th>Inundation Area (ha)</th>
<th>Dead</th>
<th>Affected (houses)</th>
<th>Damage Cost (Rp. billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>1,676</td>
<td>15</td>
<td>250</td>
<td>N.A</td>
</tr>
<tr>
<td>Dec, 2000</td>
<td>1,500</td>
<td>27</td>
<td>2,686</td>
<td>300</td>
</tr>
<tr>
<td>Apr, 2001</td>
<td>200</td>
<td>N.A</td>
<td>40</td>
<td>N.A</td>
</tr>
<tr>
<td>Nov, 2001</td>
<td>N.A</td>
<td>11</td>
<td>70</td>
<td>N.A</td>
</tr>
<tr>
<td>Feb, 2004</td>
<td>400</td>
<td>N.A</td>
<td>Thousands</td>
<td>N.A</td>
</tr>
<tr>
<td>Mar, 2004</td>
<td>N.A</td>
<td>N.A</td>
<td>17,539 People</td>
<td>N.A</td>
</tr>
<tr>
<td>Feb, 2006</td>
<td>N.A</td>
<td>39</td>
<td>N.A</td>
<td>180</td>
</tr>
<tr>
<td>Feb, 2013</td>
<td>132</td>
<td>7</td>
<td>11,935</td>
<td>N.A</td>
</tr>
</tbody>
</table>

The city of Manado made some changes in the past like bank protection, but the real problem has not been solved until now. During the flood of February 20 in 2013 40,000 people became victim of
it. A large number of houses were destroyed and more than 8,000 people had to be evacuated. From Figure 4.6 it is clearly visible that the flooding is spread over a large area.

![Figure 4.6: Flooded area during the flood of February 2013.](image)

Despite the fact also the Tikala River has great problems with flooding, regarding the demand of the municipality the main focus will remain on the Tondano River.

4.6 Problems contributing to this flooding
As described above Manado has experienced several floods over the last twenty years. The following factors are rather certain believed to have contributed to these floodings.

4.6.1 High Discharge
Manado has a tropical climate with rainfalls of high intensity. Due to high urbanization of Manado city, rainfall is not able to infiltrate in the bottom, because there is nearly no green space left in the city. So the rainfall is immediately transported into Manado’s drainage canals by overland flow, which mostly haven’t got enough capacity. These end up in the rivers and contribute, an important part, to the river discharge. Leading to peaks with high water levels.

4.6.2 Narrow branches
As described later the river has become restricted to a very small profile in the city centre. This leads to higher water levels at this part of the river, but also to higher water levels upstream, by the backwater effect.

4.6.3 High tide
As described above discharge peak can coincide with high tide, sometimes leading to a flood. This is because of the backwater curve of the high water level at the river mouth, leading to higher water level upstream.
4.6.4 Hydraulic obstacles
At several parts of the Tondano river, there are hydraulic obstacles leading to blockage of the flow. This can be bridge piers, excessive garbage, fish nets, parked boats and plants. They enlarge the flow resistance, so the amount of water that can be discharged will become less. Result of this is that the water level will rise.

4.6.5 Urbanization of floodplains
The high discharges of Tondano river always existed, although they might increase nowadays due to climate change. The floodings that come with these rainfalls never where a huge problem, because Manado had enough high grounds to live and shelter on. But over the last decades people have started to urbanize the floodplains into the extreme. In the heart of Manado city the river has been tremendously constricted by houses and businesses. Of course these houses are the first to be flooded in case of a high discharge.

4.7 Improvement plan
The municipality considers improving the river by fixing its stream over a complete 7,2 km, which is about the whole part that the river is within the city! The design is shown in Figure 4.7. The design includes concrete sheetpiles, a dike construction and crown wall at both sides of the river over the complete 7,2 km stretch. They plan to do this for 42,5 billion rupiah, which is about 2,9 million euro. The plan states that the construction should already have been started, but no signs of construction are visible in the city. The delays are probably attributed to the large amount of people who have to abandon their houses for the dike construction and have to be compensated for this.

Figure 4.7: Typical cross-section of the canalization plan of the Tondano River. (Ministry of Public Works, 2013)
4.8 Summary

Figure 4.8 below shows a small summary of the most important aspects of Tondano River and their locations.

*Figure 4.8: Aspects river Tondano*
5 ECOLOGY

Manado and the surrounding Minahasa district are of course especially famous for their coral reefs, but other important parts of the ecosystem in the area are the mangrove forests along the coast. The coral reefs and the mangrove forests are also very important for each other. In this part the importance, value and the threats of the ecology around Manado will be described. This chapter also describes the inland forests near Manado, which are under threat by the quick expansion of the city of Manado.

5.1 Coral Reefs

The city of Manado is next to the Bunaken National Park. This Park includes most of the high value coral reefs around Manado. It covers a total surface area of 89,065 hectares, 97% of which is overlain by sparkling clear, warm tropical water. The remaining 3% of the park is terrestrial, including the five islands of Bunaken, Manado Tua, Mantehage, Nain and Siladen.

The waters of Bunaken National Marine Park can be extremely deep (till 1500 m in front Manado Bay), clear with up to 40m visibility and have a temperature of 27-29 °C. Oceanic currents may partially explain why Bunaken National Marine Park is such a treasure trove of biodiversity. North-easterly currents generally sweep through the park but abundant counter currents and gyros related to lunar cycles are believed to be a trap for free swimming larvae.

Figure 5.1: Diving Locations around Manado, Source: (WWF, 2009)
5.1.1 Value and functions of the reef
The Coral reefs at Bunaken National Park provide the region with some valuable ecosystem services defined according to Millennium Ecosystem Assessment (UNEP-WCMC, 2006):

- Regulating services: The coral reefs protect the shoreline against waves, storm surges and erosion. This function exists at the mainland of Manado as well on the islands. Coral reefs are especially important to beaches because they protect the shoreline from high waves (Svašek and TUDelft, 2000). Coral reefs are also important to many beaches because they act as a sand source. As a result, sand is formed which may eventually end up on the beach.
- Provisioning: These are services like fisheries and building materials.
- Cultural: The coral reefs are important to a large touristic diving industry.
- Supporting: The coral reef is important in the cycling of nutrients, provide food for fish and provide a fish nursing habitat.

The coral provides some very important described ecosystem services, which also can be monetized. According to (UNEP-WCMC, 2006) economic valuation of ecosystems needs to be treated with caution but annual values per km² have been calculated at US$100 000-600 000 for reefs.

The reefs have this large value because their disappearance has large direct influences on the ecosystem and the local economy: Reduced fish catches and tourism revenue in coastal communities, and potentially even loss of food security and malnutrition due to lack of protein; Loss of export earnings and decline of the tourism industry; Increased coastal erosion and destruction from storms and catastrophic natural events, which affects coastal residents, tourism operations and many other economic sectors.

But besides the concerns for the local society, all over the world already 30 per cent of reefs are already seriously damaged and 60 per cent could be lost by 2030.

5.1.2 Flora & Fauna
The Bunaken national Park is characterized by its high biodiversity. This can be corals, fish, echinoderms or sponges. For example, 7 of the 8 species of giant clams that occur in the world (Board, 2009), occur in Bunaken. The park has around 70 genera of corals, compared to a mere 10 in Hawaii. Although the exact number of fish species is unknown, it may be slightly higher than in the Philippines, where 2,500 species, or nearly 70% of all fish species known to the Indo-western Pacific, are found. A snorkeler or diver in the vicinity of Lekuan or Fukui may spot over 33 species of butterfly fish and numerous types of groupers, damsels, wrasses and gobies. Green turtles and sharks can also be spotted in these areas.

The abundance of hard corals is crucial in maintaining the high levels of diversity in the park. Hard corals are the architects of the reefs; without them, numerous marine organisms would be homeless and hungry. Many species of fish are closely associated with particular types of corals for shelter and egg-laying. Others, like the enormous Bumphead Parrotfish, Bolbometopon muricatum, are "coralivores" and depend on hard corals for their sustenance. Bony mouth parts fused into an impressive "beak" allow these gregarious fish to crunch corals like roasted peanuts.
Besides hard coral also soft coral is present in Bunaken. They are called soft corals because they do not have hard, rigid permanent skeletons. This group is made up of the Gorgonians and the Black Corals.

5.1.3 Threats

Some 20,000 people live on the natural resources of Bunaken National Park and about half a million in Manado. There are some inevitable conflicts between resource protection and use by people. But not all threats come from outside the park. The quality of the management of the park is doubted. Their idea is to promote wise resource usage while preventing overexploitation. Local communities, government officials, dive resort operators, local nature groups, tourists and scientists have played an active role in developing exclusive zones for diving, wood collection, fishing and other forms of utilization. Despite its national park status and significant funding, the park has suffered a bit, due to a number of threats including:

- Human impacts like coral mining, damage by ships anchors, blast fishing and cyanide fishing. Progresses are said to have been made last years on blast fishing.
- Diving is a human cause also leading to damage to the coral reef sometimes. They damage or simply break off pieces of coral simply by touching the delicate corals with their fins.
- Large quantities of trash float from Manado into the direction of the Bunaken national park. This trash mostly doesn’t end up in the coral. But all the trash that does end up in the coral is of course very harmful. The pollution resulting from the trash on the beaches also affects the coral.
- Professionalization of Park authority: The management for coastal zone management within the park area struggles with a lack of professionalism and lack of funds.
- Bleaching: Rising seawater temperatures occasionally give rise to coral bleaching whereby corals turn white. The same phenomenon occurs when fishermen use bleach to stun fish. Large influxes of freshwater may also damage the corals.
- Overfishing: the coral and the fish are dependent on each other, because they exchange a lot of nutrients. Due to overfishing the balance of the ecosystem will be disturbed, and also the corals will retreat from the reefs.
5.1.4 Current state of the reef
The current state of the reef is rather fair to good. There are indications of coral bleaching at the moment at some locations. Young coral is registered to grow at some locations. Former threats of non-native species uncontrolled growth and former anchor damage are under control. Last measurements from 1998 the current state of the bunaken coral reefs according to reefbase.org (reefbase.org, 1998) is categorized as fair till good.

5.2 Mangroves
The shoreline of North Sulawesi consists for a large part of mangrove trees. Around the city of Manado this isn’t different. For this project just the mangroves in the northern part of the Manado bay will be observed. This part of the coast is formed by beautiful mudflats and mangrove trees. The trees have some important functions in the ecosystem and in the life of the inhabitants of the region. These will be discussed in this paragraph.

5.2.1 Value and function of the mangroves
The mangroves around Manado provide the region with some valuable ecosystem services defined according to (Millennium Ecosystem Assessment, 2005):
- Regulating services: The mangroves protect the beaches and shoreline against waves, storm surges and floods. The mangroves also reduce the beach and soil erosion by means of their roots, which keep the soil between them. This way the land is also stabilized. As final regulating service, the mangroves maintain also the water quality.
- Provisioning: The mangroves provide fish for fisheries, wood for construction and fuel wood, some ingredients for traditional medicine and of course aquaculture.
- Cultural: In other parts of the world, mangrove forests also have a recreational function, but in the surrounding area of Manado there isn’t any tourism for the mangroves.
- Supporting: The mangrove forests are important in the cycling of nutrients. Also they provide food and nursing habitats for fish. A lot of these fish will go back to the coral reefs if they don’t need any shelter anymore.

These values and functions show that the mangroves are very important for the area of Manado. Especially the coral reefs and the fisheries will be damaged if a lot of the mangroves will disappear. And since the (diving-)tourism and fishery are two sectors which are very important for the economy of the area of Manado, disappearance of mangroves has to be avoided.

5.2.2 Threats
On a lot of places on earth, the mangrove forests are shrinking or even disappearing. There are several causes of the disappearing of mangroves. Important to notice is that the clearing of mangrove forests for the use of aquaculture is not a threat in the area just north of Manado at the moment. And effort should be taken to keep it this way. There are some shrimp farms further up north, for a couple of years already, but this didn’t seem to harm the mangrove forest in front of it yet. There is no decline of mangroves visible at that location.
Appendix B: Present situation

Threats of the mangroves in the observed area are the following:

- Clearing
- Overharvesting
- Overfishing and retreat of wildlife
- Pollution
- Sea level changes
- Changes in river discharges
- Excessive sediment transport
- Change of wind and wave attack
- Aquaculture

**Clearing of mangroves**

Clearing mangroves is nowadays one of the major causes of mangrove losses in the world. It could have different reasons, why the mangrove areas get cleared. In this case it is possible that the mangroves have to make place for agricultural land, human settlements, tourist developments or infrastructure, like a port. Even a combination of these is possible north of Manado. Tourist developments and infrastructure will be the most common for the mangrove area north of the city. There are already some diving resorts further north and the location is ideal with the Bunaken National Park in short range. The municipality has future plans to build a large port just north of the mouth of the Bailang river, to replace the one south of it. But these plans are not definitive, before there is done research to the results of it on the environment. But this will be certainly a threat for the mangroves.

**Overharvesting**

On several places harvesting of mangrove trees takes place. People use the wood as firewood, construction material, charcoal production and woodchip and pulp production. Harvesting of the mangroves doesn’t have to be harmful, but when too much wood will be chopped, the mangroves will eventually disappear.

**Overfishing and retreat of wildlife**

Mangrove forests are habitats for a lot of fish, shrimps, crabs and molluscs. The roots of the mangrove are an important part of the eco-system. The animals and mangroves exchange important nutrients with each other. If overfishing occurs, the ecologic system is out of balance. This also occurs if the other wildlife leaves the mangrove area. One of the causes that this would occur is described in the following topic: pollution.

**Pollution**

Pollution of the mangrove forest can occur in several ways. The most common way in the observed area will be pollution by floating solid waste. The garbage will get stuck between the mangrove trees and will cause several negative effects. It could block the entrance for the water, so if the water level rises, the water is not able to reach a lot of roots. Animals could get stuck between the garbage and couldn’t reach the mangrove forest any more. Another result of the garbage wash between the mangroves is that the roots of the mangroves cannot get enough oxygen. The roots need to receive oxygen to let the mangrove survive, but when the garbage accumulates on the mangrove roots, they can’t imbibe any oxygen any more.
Sea level changes
Mangroves are very sensitive for water level changes. They need the tidal differences to survive, but if these levels suddenly change the mangroves will retreat. If the sea level drops, the mangroves miss the interaction with the water and the fishes. And if the sea level rises, the roots cannot imbibe enough oxygen.

Changes in river discharge
Due to change of river discharge, the salinity of the water could change. If the discharge will be limited for some reason, for instance a dam or water distraction, the water will be more saline. If the river discharge will increase, the salinity of the water will decrease. The mangroves are very sensitive for these changes, so these can cause retreat of the mangrove forest.

Excessive sediment transport
If the sediment transport will increase significantly, the roots of the mangroves will be buried. This means that the oxygen can’t reach the roots anymore, and the mangrove will die. Excessive sediment transport may occur due to dredge spoil, river floods, storm surge, and for instance the disappearance of woods along the river, whereby a lot of sediment will be flushed into the river during rainfall.

Change of wind and wave attack
If the frontline of the mangroves disappears, the mangroves behind will be the new frontline. The frontline of a mangrove forest have the most wind and wave attack. These trees are stronger and could resist a higher load. If the weaker trees become the frontline, they will be damaged or they will even die, due to the wave and wind attack. This could happen when people harvest on the wrong place.

Aquaculture
One of the biggest threats for mangrove forests all over the world the development of aquaculture. These fish or shrimp farms are a huge threat because they produce a lot of nutrients which harm the mangroves. Also they are mostly located on former mangrove locations. Because of decrease of the water quality by the nutrients, after 4 years the ponds are replaced, and another piece of mangrove forest will be cleared for it. In this way large mangrove areas disappear all over the world. In the area around Manado the threat is not as big as in other parts of the world, but there are a few sites for aquaculture.

5.2.3 Mangrove decline north of Manado
A lot of mangrove disappeared in the first hundred meters north of the Bailang river mouth. The cause of their disappearance is not completely clear, but presumably the most important reason is the harvesting of the forest by villagers. The villagers probably wanted to extend their habitat and get better access to the sea by harvesting the mangroves. This in combination with the changes in sediment flow caused by new structures in the coastal zone, long breakwater and reclamations, caused decline of the mangrove trees. See also the Morphological analysis in chapter 3. The former mangrove area is indicated in dark green in Figure 5.3 and the existing mangroves are shown in light green. In front of the existing mangrove area there are mudflats located, which exchange sediment with the mangroves and get supplied by the alongshore sediment transport. These flats are indicated in light brown in Figure 5.3.
Because of the disappearance of some mangrove trees, the other mangrove trees became vulnerable for attacks they were not used to and the decline of mangroves continued here. Also the salinity of the water on their location could be changed, because of the water from the river made the water more brackish. The roots of mangroves are also very vulnerable for this effect. The boundary of the mangrove filled coast, will be laying at the location where the influence of the river is negligible.

Figure 5.3: Mangrove area north of Bailang river mouth.

5.3 Forests
The third ecological system surrounding Manado city is the tropical forests surrounding Manado. Some of these are within the district of the municipality of Manado and some lay in the Minahasa district. This district includes several volcanoes, but most important: The Tangkoko National Park. This park hosts several unique monkey species.

5.3.1 Value and Functions
Also the forest provides specific functions for the citizens of the Minahasa district.

Regulating services: The forests are important in regulating the discharge downstream into the city of Manado. And the appearance of trees avoids erosion of the soil, during extreme rainfall.

Provisioning: The hinterland of Manado is known for its fertile volcanic soils and large food production. The original reason the Dutch VOC used to come to Manado. And still the forest provides the locals with fruits, animals and building materials.

Cultural: The forest is one of the very few touristic on shore assets of the city of Manado.

5.3.2 Flora and Fauna
The forest most sighted trees are Palm trees and many sorts of Banana trees, of which the resources are used by the local villagers. Tangkoko National Park is known for its sighting of the small Tarsius monkey and the larger Black Macaque. Most common bird species are several families of Kingfisher Birds. Also a lot of other animals like large lizards are living in the jungles of North Sulawesi.

5.3.3 Threats
The city of Manado is expanding more and more. The construction of houses, malls and churches is continuing in all directions around Manado. Most common construction method is to flatten and excavate green mountains and then build housing complexes on this new free areas.
This development has turned lots of forest into housing areas over the last years. Consequence of this urbanization is that rainfall is transported quicker into Manado’s rivers, possibly leading to higher discharge peaks.

The other obvious threat of course the declination of jungle area available for the prior described flora and fauna, leading to fewer animals. The increase of population puts also pressure on the animals in a food chain way, since the Minahassan people are known to eat everything with four legs except the table and chairs.
6 GARBAGE ANALYSIS

Garbage handling is still considered to be one of the main problems of Manado. Manadese people generate a lot of garbage together, more than can be handled with the current system. Although the situation has improved in the past few years, there is still a lot to be done to make the garbage handling in Manado sufficient. The garbage problem is not only on the streets but also in the rivers and in the Manado bay, eventually leading to degradation of the environment.

6.1 Problem description

The problem of the garbage can be divided in three categories: garbage on the streets, garbage in rivers and drainage channels and garbage flowing into the sea towards the Bunaken. The last category is more a result of the former two categories.

6.1.1 Streets

At first sight the garbage on the streets does not seem to be a big problem. Most main streets are clean and there is not a lot of garbage laying around. There are not so much bins but the ones that are there are being used, and are filled with plastics. If there are no bins around there is some garbage on the streets, most of the time this is swept together in a corner. Every morning the streets are cleaned, this garbage is taken to the garbage dump at the end of the city. The streets could still be cleaner but the situation has improved a lot in the past few years. There also is a regulation that people who throw garbage on the streets can get fined.

Domestic garbage can be put in large collection containers from 6 pm until 6 am, when they are emptied. The bins are closed during the day because the heat would cause a very bad smell. In smaller streets outside the city centre there is still more garbage on the streets and in the sewer channels. Sometimes people burn part of their garbage.

6.1.2 Rivers and drainage channels

The rivers in Manado are all very littered. Not only Tondano river but also smaller streams and open sewer- and drainage channels are filled with garbage. A lot of people live along these rivers and streams, and a lot of their plastic waste ends up in the waterways. Although some residential areas do have garbage collection points, a lot of garbage still ends up polluting and even blocking or narrowing the rivers (Figure 6.1).

![Figure 6.1: Garbage clogging up in a channel](image)
At the river outflow points of these rivers there is also a lot of sediment settling, also narrowing the river. This is said to be caused by the land reclamation, which have lengthened the path of the streams by tens or even hundreds of meters, causing the slope to be too flat. The garbage also clogs up against these sediment piles. This causes a lot of problems during periods of high discharge, for example partial flooding of the city. This occurs at least once every year.

Especially during high discharge there is a lot of garbage flowing through the channels. Since the capacity of the drainage system is too low, a lot of garbage is floating in the streets even during a short period (several minutes!) of heavy rainfall. This garbage will eventually end up in the channels, where it is transported to the sea.

The people in Manado, especially those living upstream of the rivers, are not at all aware of the damage they are causing by throwing their waste into the rivers. There also is no regulation about throwing waste into the water – something that could clearly be improved.

The Manadese authorities are aware of the need to clean the rivers. They sometimes organize river clean ups where the garbage is removed from the river. This is a very good short term solution, but there is still very much garbage visible in the river, so this might have to happen more often. The municipality is willing to take long term measures against the garbage in the river.

6.1.3 Bunaken National Park
The rivers, especially Tondano river, bring a lot of garbage and waste towards the sea. This especially happens during high discharges after intense rainfall. In the sea there is a circulation current which drives the waste and sediment towards the Bunaken islands nowadays. A lot of this garbage ends up in the coral reef in Bunaken National Park. This endangers the condition of the coral reef (See also Ecology Analysis in chapter 5). For this reason, and because of the extraordinary biodiversity Bunaken National Park was designated as a protected nature reserve in 1991. Despite of this, the Bunaken is still under a huge threat (Tedjasukmana, 2011).

The amount of garbage is not only bad for the condition of the coral, divers also experience the presence of plastic bags and packages as very unpleasant. Many tourists complain about the presence of garbage in Manado Bay and especially in the coral reef. In a time where internet and social media can rapidly spread negative opinions about travel destinations, this could eventually have an effect on the number of tourists visiting Manado and the Bunaken. This would be a disaster for the tourism industry (RTI, 2004).

The waste is not solely coming from the rivers though. Also ships that sail in the bay dump a lot of their waste in the water. Especially the large ferries sailing toward the Philippines and back leave a large track of garbage behind. This can easily be seen during a boat trip in Manado bay; there is a lot of floating garbage. This garbage also ends up in the Bunaken. There is no regulation about garbage handling yet for these ships, so passengers do not consider the environment and use the sea as a large public garbage bin.
The municipality acknowledges the importance to save the Bunaken, and it supports initiatives to save the area. In 2003 there has been a huge Bunaken clean-up, when about 4,4 tonnes of solid waste has been collected (RTI, 2004). Also tourism entrepreneurs support the handling of garbage by the local government and are even willing to contribute to it (Jenu, 2013).

6.2 Solving

6.2.1 Causes

In the 2004 report of RTI the garbage problem of Manado is subscribed to the following factors:

- Low public awareness and discipline,
- Insufficient transport vehicles for effective collection
- A lack of appropriate technology in its collection system
- Insufficient or improperly collected fees to sustain an effective program
- No law enforcement that prevents littering or indiscriminate dumping of solid waste

The garbage collection and handling service is decentralized, this makes it difficult for the municipality to control the services and enforce regulations.

6.2.2 Prior advices

The former TU Delft group advised to implement the 3R measures; i.e. Recycle, Reuse, Reduce. They indicated three categories for the problem: Garbage on the streets, in the rivers and the garbage handling. Of these three, the garbage on the street has had the most visible effect in Manado. However, the garbage of the river still flows to the surrounding areas, even 15 kilometres from the city. Manado has not enough facilities to handle the garbage itself. They came up with the following solutions:

- Make the people aware of the problem and change their mind-set, by also showing the garbage men.
- Use eco friendly products like biodegradable plastic.
- Promote businesses which use these eco friendly products.
- Catch the river garbage with nets or other construction.

Of the measures only the last one is directly under the responsibility of the planning department. Any progress on these measures has not been noticed in Manado.

6.2.3 Measures taken

According to the citizens of Manado a lot has improved over the last few years. However, regulations that prevent garbage from ending up in the river should be implemented and strictly checked upon. The municipality already recognizes the problem and is willing to take measures to reduce the garbage flow to Bunaken. Most of the citizens are not yet aware of the implications their garbage disposal habits have on the environment and eventually upon their own hygiene and health. This is probably the most important step to be taken. Manado’s government is also in consultation with investors from outside Manado to invest in the garbage management of the city (Priyambodo, 2012).
6.3 Quantification
The problem of the polluting of Manado’s surrounding nature can be quantified. The parameters that have to be analysed that affect this pollution are: garbage generation, handling capacity, transporting currents in the sea. Numbers and tables about garbage generation and handling are derived from RTI (2004).

6.3.1 Garbage generation
This parameter is probably the most important one. The more garbage the city of Manado generates, the more garbage will end up on the streets and in the river. More pollution will lead to worse conditions, both hygienic and environmental. The amount of garbage is of course dependent on the number of households. In 2004 Manado had a population of about 420,000 people, generating about 1.149 m$^3$ garbage daily (Table 6.1). In 2013 Manado has about 500,000 (no exact numbers available, sources indicate between 450,000 and 550,000) inhabitants. Assuming that the garbage produced is proportional with the population growth the generated waste would be about 1368 m$^3$/day.

<table>
<thead>
<tr>
<th>Kecamatan</th>
<th>Waste Generated (m$^3$/day)</th>
<th>Waste Collected (m$^3$/day)</th>
<th>% Collected</th>
<th>Collection Points</th>
<th>Trips to TPA (times/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malalayang</td>
<td>136</td>
<td>80</td>
<td>59%</td>
<td>50</td>
<td>8</td>
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<tr>
<td>Singkil</td>
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<td>32</td>
<td>27%</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>Wanea</td>
<td>146</td>
<td>64</td>
<td>44%</td>
<td>44</td>
<td>6</td>
</tr>
<tr>
<td>Wenang</td>
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<td>162</td>
<td>80%</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>Sario</td>
<td>67</td>
<td>64</td>
<td>96%</td>
<td>37</td>
<td>6</td>
</tr>
<tr>
<td>Tuminting</td>
<td>124</td>
<td>45</td>
<td>36%</td>
<td>33</td>
<td>6</td>
</tr>
<tr>
<td>Mapanget</td>
<td>124</td>
<td>16</td>
<td>13%</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td>Tikala</td>
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<td>62</td>
<td>35%</td>
<td>35</td>
<td>7</td>
</tr>
<tr>
<td>Bunaken</td>
<td>54</td>
<td>13</td>
<td>24%</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>BP Kebersihan</td>
<td>112</td>
<td>112</td>
<td>35%</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Tionghua</td>
<td>44</td>
<td>4</td>
<td>24%</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

The amount of commercial solid waste is assumed to grow with the same rate as residential garbage. In 2004 this was 206 m$^3$/day (Table 6.2), for 2013 it is assumed to be 245 m$^3$.

<table>
<thead>
<tr>
<th>Market</th>
<th>Waste Generated (m$^3$/day)</th>
<th>Waste Collected (m$^3$/day)</th>
<th>% Collected</th>
<th>Collection Points</th>
<th>Trips to TPA (times/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinasungkulan</td>
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<td>44</td>
<td>72%</td>
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<tr>
<td>Berahehi</td>
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<td>37</td>
<td>76%</td>
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<tr>
<td>Orde Baru</td>
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<td>48%</td>
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<td>2</td>
</tr>
<tr>
<td>Tuminting</td>
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<td>12</td>
<td>57%</td>
<td></td>
<td>1</td>
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<tr>
<td>Bahu</td>
<td>21</td>
<td>14</td>
<td>67%</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Total | 206 | 133 | 65% | 4    | 8    |
6.3.2 Garbage handling

Garbage handling (collection) and generation together determine the amount of redundant garbage. A large part of this garbage will eventually end up on the streets and in the rivers. In 2004 the daily amount of garbage collection was 694 m$^3$, 60% of the waste generated by households. The last years there have been improvements in the garbage handling, so it may be assumed that the handling capacity has at least increased over the last year, assumed to have increased until 70%. This would mean that nowadays they will be collecting about 958 m$^3$/day. So every day the residents generate 410 m$^3$ garbage that will end up being burned or thrown away on the streets or in the river. For the commercial waste we assume an absolute increase of 5 % in garbage collection. The commercial solid waste then adds another 30% of uncollected waste of 245 m$^3$, so 74 m$^3$ to this, bringing it to a total of 484 m$^3$ uncollected solid waste every day. It must be noticed that this amount is not per se directly thrown on the streets or into the water; an exact distribution of this garbage is not known. If we would assume that about half would flow through the rivers into Manado Bay this would be about 250 m$^3$ of solid waste entering Manado bay every day.

6.3.3 The sea current

This is mostly important for the garbage that is flowing out of the rivers into the Manado bay. This garbage will be distributed over the Manado bay according to the transport capacity and direction of the current. Part of this garbage will float towards the Bunaken where it will pollute the coral reef. This is the most important part for this research.

For now we will try to estimate the amount of garbage that flows towards Bunaken by a simple estimation. The 250 m$^3$ of solid waste which enters Manado Bay every day is assumed to diffuse over Manado Bay and remain flowing at the surface. Then about one fourth of the garbage from Manado might end up at Bunaken National Park according to Figure 6.2. If there would be no incoming garbage from other areas from other areas, this would mean 63 m$^3$ of solid waste would end up at the beaches and reefs of Bunaken National Park daily.

![Figure 6.2: Spreading of Garbage from Manado](image)
Appendix C: Outline of the new land reclamation
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1 INTRODUCTION

A new land reclamation is planned at the northern part of the city. Past reclamation plans have been made in the southern and middle part of the coast of Manado, leading to economic development in these areas. Until now the north is somewhat stuck behind. The plan is now to give an impulse to the northern part of the city by a new land reclamation.

The research is based on some presentations with plans for a new land reclamation. The most essential parts are presented below in the form of a few drawings and some key issues translated from the Indonesian presentation. The most relevant parts of these presentations are treated and summarized below.

2 CURRENT SITUATION OF THE LOCATION

To get a good understanding of the new reclamation’s plans some understanding of the original area it is placed in is valuable. The location of the planned reclamation is in front of the northern part of the coast of Manado between the mouth of the Tondano River and the small harbour just south of the mouth of the Bailang River as shown in Figure 2.1.

2.1 The surrounding area

The surrounding area and the functions of it are important, when new land shows up with certain functions. Figure 2.2 shows the city of Manado and its most important places of interest like the airport, the Marina and Bunaken Island. Especially the Marina is important in case of the new reclamation, because it’s situated close by. One of the important functions of this harbour is the transfer of locals and tourists from Manado to the islands of Bunaken National Park and the transfer of people to other parts of the country or even to the Philippines with ferries. Of course it’s also the
most important harbour for the fishery in Manado. The new reclamation may not negatively influence this economical important marina.

Figure 2.2: most important places of interest of Manado

Figure 2.3 shows the area without a land reclamation but including its main infrastructure which is now located on this area.

Figure 2.3: Existing Area of Reclamation plans. (Assa, 2013)
2.2 Land use

To get an overview of the area and its functions, Figure 2.4 shows the spatial zoning plan. The following list will describe the locations indicated by the numbers:

1. Fruit Market
2. Residential area, medium population density
3. Space for development of the domestic port
4. Future green area on ground of former oil plant
5. Part of the river where people and goods are loaded and unloaded from the boats
6. Marina, as described earlier
7. The area adjacent to the road is indicated as mixed use.

Other specific described parts of the plan will be treated below.

- In the middle of the coastline a breakwater is visible, this gives shelter to traditional boats of fishermen.
- The grey shaded areas in the middle of the images are cemeteries
- The brown shaded area is for education
- The yellow shaded areas are all residential areas
- The green shaded areas are like number 4, future green areas, but they are not realized yet
- The orange shaded area consists besides the fruit market, also of a trade and service market, traditional market, kiosks, offices and a warehouse.

![Spatial zoning plan Northern Manado](source_url)
2.3 Bathymetry
The level of the bottom of the sea is shown in the bathymetry of the coastal zone. The bathymetry is very important to know, because it determines the volume of material there is necessary to reclaim the land. In Figure 2.5: Bathymetry and depth rays at North Manado City, Source: Figure 2.5 the bathymetry of the project area is represented. The red line indicates the contour of the -2,0m level and the blue line indicates the contour of the -5,0m level. These are the depths in case of mild conditions, and measured from the reference level which is 1,2 m beneath the mean water level(MWL). After the 5m-contourline the bottom will be very steep in to the deepness, since the 10 meter- and 20 meter-contour lines are very close to each other. So there is a certain limit to the distance you can reclaim land into the sea, because it will become too steep and deep to build on.

Figure 2.5: Bathymetry and depth rays at North Manado City, Source: (Asa, 2013)
3 NEW LAND RECLAMATION ASPECTS

The plan of the new land reclamation are not really detailed yet. In this chapter the plan is elaborated as much as possible.

3.1 Preliminary plans

In the preliminary plans of the new reclamation is described that the southern part of the new land is planned to be a residential area and a business area with storey offices, shaded in yellow in Figure 3.1. The northern part is reserved for the tourism industry and government buildings, purple shaded in Figure 3.1, for instance hotels will arise in this area. The area purposed for trade and service business is indicated by the blue shaded parts. These areas will mainly consist out of shops and bank offices for instance.

Figure 3.1: Purpose of the areas on and around the new reclamation
3.2 Canal
Between the present coastline and the reclamation there will be a canal, it’s main function is to reduce the length of rivers toward the sea. The idea is that the river will not get longer because of the reclamation, and the river slope will not decrease at the rivermouth. After former reclamations the rivermouth of the adjacent river was displaced further towards the sea and a lot of siltation occurred. The river became more sensible for flooding, because the rivermouth was not able to discharge the water in times of heavy rainfall. The canal should prevent this lengthening of the rivers, so the floodrisk at least will not increase as a result of the reclamation.

The canal will also have a function in drainage and aesthetics. The drainage function will be in combination with some sub-canals crossing the reclamation, as shown in Figure 3.2. In the image the new drainage canals are indicated with red arrows and the existing drainage canals with blue arrows. Because of the canal, the new land will be connected to the mainland by bridges.

![Figure 3.2: Drainage system with the canal](image)

3.3 Dimensions
The planned reclamation will have a total length of 2.9 km and will stretch into the sea for about 200 to 250 meters as shown in Figure 3.3. In this figure the total area is indicated to be 66.2 km², but of course this must be 0.662 km². It is also good visible in Figure 3.4, that the land reclamation has a maximum depth of -2 to -5m below the reference level. The land reclamation will eventually be elevation about 4 to 5 meters above the reference level. The width of the planned canal between the present coastline and the reclamation would be 20 meter.
Figure 3.3: Depth at reclamation site

Figure 3.4: Rough reclamation contour.

3.4 Buildings

The plans for the new reclamation show that they plan to build mostly high rise buildings in the new areas. This is to accommodate more people on the new area and make it more efficient. Whether this is smart to do on the new loosely compacted sand is unknown. Also whether this form of housing appears to the locals is unknown. Reference project that appear to the project organization are shown in Figure 3.5.
3.5 Green belts
The municipality wants to increase the amount of green within the new land reclamation as in Figure 3.6. For this they have looked at several examples from all over the world where green belts have been applied successfully. Of course this idea is smart. The green areas could improve the value of the area, by increasing its liveability, but also help in preventing floods. The trees also give shadow against the sun, which is quite important for the people when they are out on the streets.

3.6 Open water basins
In a lot of preliminary drawings the reclamation has some water basins included, see Figure 3.7. These are not just for the esthetic value, but could also be used for drainage. Canals will cross the reclamation and end up in the large canal. Small lakes could be buffers and store rainwater during heavy rainfall.
3.7 Traffic
The accessibility of the reclamation is very important for the development of it and the surrounding area. The plans in Figure 3.4 show that the existing roads are continued onto the new reclamation. These plans assume that the bridge over the marina is finished. At the moment the building of it is stopped, because of problems with the funding. But the existence of the road over the bridge will be crucial for the success of the reclamation. Also the roads coming from the residential areas in the northern part of Manado, should be improved. In this way the northern residential area is also possible to benefit from the build of the reclamation.

3.8 Sea defence
The plans already present a detailed design for the interface between land and water in Figure 3.8. Whether this is the best design has to be checked according to the client. The crown wall on top of the revetment seems strange. It will block the view towards the sea and if the revetment is designed properly, no crown wall would be necessary. So there are possible improvements to the border between new land and the sea.

Figure 3.7: Possible design of new land reclamation without the canal, Source: (Assa, 2013)

Figure 3.8: Design coastal protection, (Assa, 2013)
3.9 Construction Method
The municipality didn’t decide yet which construction method they will use. They consider two different types of land reclamation, the polder system and a system called ‘Timbunan’. The second one is making new land completely above the sea level and the polder system only raises dikes around the new land.
The disadvantages of the polder system are the high operation and maintenance costs for the drainage system, because the reclamation is located below sea level. The advantage of this system is that there is a lot less material needed, to build the reclamation. Also settlements under buildings will be very little in case of this system.
The ‘Timbunan’ system is relatively safe to extensive waterlogging, because it’s located above the sea level. But the material needed is a lot more, than by the polder system. Also settlement of the new land under new buildings will bring higher risks.
The preference of the municipality is the ‘Timbunan’, since they used the method in all their other reclamations. Also because they think it’s safer, because in this region of the world people aren’t used to live below sea level and they wouldn’t feel safe. Even if the municipality knows it will be safe, the residents and offices will be sold easier, when the land arises above the sea level.

3.10 Construction Materials
The reclamation will be build up from bottom material and rocks. The bottom material consists of sand, but also crushed recycled material. The sand needs to be delivered with a certain grain size and permeability. The recycled material could be for instance concrete, which is thrown away by demolition of old structures. The sand could be delivered from the sea as well from the inland. The rocks will come from quarries in the inland.
4 OPPORTUNITIES AND THREATS
The new reclamation will give Manado a lot of opportunities. It can give the city a boost in the economy and when implementing green areas not only the new people but also the people currently living in Manado are given a wonderful place to relax. However, with building such a large construction in the sea, there are also threats, which will be in the category of making the new reclamation an isolated part of the city.

4.1 Opportunities
4.1.1 Development of Northern area
The new land reclamation can be an opportunity for the northern part of the city to develop. The citizens of this township are known as less wealthy. The reclamations at the southern part of town have led to interesting shopping malls and popular areas for the people to hang out. With the appearance of the new reclamation and the plans to make improvements in the existing northern part of the city, the quarter had the chance to become more wealthy and develop such as the southern part of the city already did.

4.1.2 Greening the city
The plans really focus on greening the city. At the southern land reclamations there isn’t really thought of this, which results in an area full of buildings and the ground fully covered with asphalt. This isn’t just ugly, but also brings problems as waterlogging. Park areas in the city are rare, and the people could use a place they can walk and hang out in their recreational time. In residential areas this might be combined with playing areas for kids and public sporting facilities.

4.2 Threats
4.2.1 Not connected
The infrastructure of the northern part of Manado is highly under developed. The accessibility of this new city part might be under huge threat. The earlier described bridge is a threat when the building will not continue in time. If the accessibility of the area is not proper, the reclamation could be a financial disaster for the municipality and the investors.

4.2.2 Not preferred city part
The northern part of the city is not known for its wealth, and thereby rather avoided by the other citizens. Since the investors in this new area want to have their condo’s sold, this goal might be under threat. Potentially leading to the failure of this new city area.

4.2.3 Social disruption
The land reclamations are a very well-known subject in Manado. The papers do write about their possible negative effects on the nature around Manado. There are several non-governmental organizations which promise there will be a large protest if this new land reclamation is announced.

Source: all pictures from: Antara Manado Presentasi, 2013
Appendix D: Stakeholders
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1 THE STAKEHOLDERS

A good first step in managing stakeholder is to list the stakeholders and their interest in the problems of Manado and the potential coastal changes. Once the stakeholders have been listed and described different techniques can be used to analyse their interests. The stakeholders will be divided into different groups, i.e. governmental organizations, private organizations, the citizens of Manado and environmental organizations.

1.1 Governmental organizations

One of the properties of governmental organizations is that they have the possibility to change a present situation. They can make spatial plans and have the power to agree or disagree. Of course there is a hierarchy within the government.

1.1.1 Ministry of Tourism and Creative Economy

The Ministry of Tourism and Creative Economy (T&CE) has the responsibility of protecting expanding the tourism industry. Therefore it is very likely they want to protect the Bunaken area. On the other hand, they would love to see more tourists go to the Bunaken. However, not all the tourists can be housed at the Bunaken area and Manado seems to be the perfect base for trips in this wonderful area. This might be a good reason for them to support an extension of Manado for letting it be an impulse for the tourism industry. It is not likely that the Ministry of T&CE will stop the plans if the reclamation will have negative effects on the Bunaken, but they might give financial support for solutions which can prevent this.

1.1.2 Ministry of Environment

The Bunaken National Park is a very vulnerable area which needs the protection of the government. The Ministry of Environment will be suspicious to the new land reclamation since the negative effect on the Bunaken of the previous relocations. The Ministry’s influence might be very high on this project, because the Bunaken is a protected nature reserve. They might be willing to give financial support for the project if extra measures to prevent damage to the Bunaken will bring extra costs.

1.1.3 Municipality of Manado

The initiator of the reclamation project is the municipality of Manado, and so they have the most influence on this project. The city of Manado is growing, but there is not enough space left for new buildings. On the city boundary at the landside, it is very difficult to build, because it is a mountainous area. So the easier way to enlarge the city is to create new land in the sea. The municipality wants to lift the city to a higher level. By attracting more companies, they want Manado to become a trade centre for the entire region.

Besides just growing, the municipality wants to create a model city of Eco-tourism. They want to accomplish this by building ecologically responsible and they aim for no effects on nearby environment like the mangroves and Bunaken National Park. They could achieve this by building certain structures, for instance groins or breakwaters, which prevent that garbage flows to the Bunaken.
1.2 Private organizations
In Manado there are of course also private organizations. It is not sure how much influence they have. A large group of these organizations is formed by the local fisherman. They are an important economic factor. The harbour is of course also an important factor to take into account. For making an economical feasible design it often pays off when the initiator listens to the investors. Good info for the design of the reclamation can also come from the tourist industry. Besides that their role must not be underestimated, since a lot of tourists come here to dive.

1.2.1 Fishermen
One of the culinary specialties of Manado is fish. Fishery is an important part of Manado’s economy, there are a lot of fishermen who sell their fish to restaurants or on local market places. Their ships are often moored in sheltered areas, for instance the Tondano River mouth. For them it is important that the new developments don’t reduce the possibilities to execute their work. Also the health of the fish is important for them. If there will be more garbage in the water and a lot of fish will die, there is less fish to catch and sell. At the location of the new reclamation there is now a small sheltering harbour present. A replacement should be found, in discussion with the fishermen who use this small harbour. According to the fisherman the currents changed since the start of the land reclamations, leading to erosion of the mangroves.

1.2.2 Harbour users
The harbour is used by many people: fishermen, ship owners, small ferry services, etc. For these people it is important that the harbour is still accessible after the planned developments. They are already halfway constructing a bridge, limiting the maximum ship height. But taking the available space into account it is not likely that any large ships would like to moor in the port. These will moor inside the area sheltered by breakwaters at the seaside of the bridge, just as they do at the moment. For the accessibility of the harbour it is important that the entrance will maintain deep enough, so no significant siltation may prolong. Also it is important for the users of the harbour that the access is still safe when the reclamation is there. So there should be no strong crosscurrents near the access.

1.2.3 Commercial bay area investors
The connection between land and water is a valuable asset. The former land reclamations this new area is used by local restaurants and large shopping malls. The coastal development has led and will in the future lead to more opportunities for these businesses. The new reclamation will bring extra space for business offices and other kinds of companies. Since the power is where the money flows, the influence of this group is considered to be convenient.

1.2.4 Tourist industry
Manado does not have a lot to offer for tourists. Most tourists that come to this city will travel to Bunaken, and do not stay in Manado at all. The city itself has very few tourist sites, although in the surrounding area there is enough to see for tourists. Coastal Development could increase Manado’s asset, for example by constructing a beach, interesting shops and markets and tempting restaurant areas.
1.2.5 Diving resorts and research organisations on the Bunaken
For this group it is very important, that no garbage flows towards the Bunaken National Park into the coral reefs. This would be disastrous for them, because the coral will damage and eventually die if there is lot of garbage in the coral area. This would also mean that the thousands different species of fish will leave and the divers won’t come to the Bunaken anymore. For the research organisations there wouldn’t be anything to search for if the coral gets polluted. The diving resorts will also be less attractive if their beaches are littered with garbage.

1.2.6 Small businesses
On the several land reclamation areas there are a lot of small businesses like restaurants and shops. They often have to rent the land for their properties from the large investors who own the land reclamations. These businesses often work together to have a strong voice towards the land owner, so that their rights are not violated and they get what they pay for. Often the land owners apply specific regulations to their land.

1.3 Citizens of Manado
Normally in stakeholder analyses the citizens are not specified into much detail. However, in this project there are a lot of “different” citizens. They can be divided into the regular citizens, the people that live in the mangrove area, the people that live along the river and the traffic commuters.

1.3.1 Citizens
Citizens from the urban parts of the city are not directly influenced by any coastal development. Indirectly they could profit from the new reclamation, because the citizens could have a better chance for work, due the business on the reclamation which creates a lot of new jobs. Not surprisingly Manado has some more wealthy inhabitants and some with fewer assets. This difference also changes their possible influence on any project. In most parts of the city wealthy and poorer people live together. For the people who live on the shoreline in the northern part of Manado, where the reclamation is planned, the view will become a lot different, instead of a beautiful view over the sea, they will see buildings. The influence of the citizens might increase when they will turn against the reclamation with a higher amount of people. It is therefore important that the municipality informs them very well and listens carefully to their complains.

1.3.2 Mangrove area residents
The people in nearby coastal villages are now threatened most by erosion. A large part of their habitat has disappeared into the sea, and the erosion might be higher after building the new reclamation. They probably might not understand which processes are going on, but they have to live with them. Their influence is due to the district very low.

1.3.3 River area residents
There are a lot of poor people living in small districts directly along the rivers. Their living situation is very unhealthy, and there is more criminality than in the rest of Manado. Their houses are located directly along the river and they throw a lot of garbage into the rivers. Although their houses might flood sometimes, they are probably not aware of the flooding risk. Also they will probably not care about the influence their garbage disposal has on the environment as long as there is no direct advantage for them in taking measures. Their influence is not considered to be very high, but the
inhabitants will not be pro or against the reclamation. If they discover the danger for themselves during river floods, that could be increased by the reclamation, they might be against the plan.

1.3.4 Traffic commuters
Coastal Development in the past has led to an improvement of Manado’s road network on the point where it helps the most: the boulevard along the coast. Although city development has led to more traffic, land reclamations make it possible to plan road networks and improve the infrastructure network.

1.4 Environmental organizations
Indonesia houses one of the most amazing natural environments in the world. The people of Indonesia are luckily aware of the treasure they have in their hands and are organized to protect the beauty of their country.

1.4.1 Non-Governmental Organisations (NGO’s) for environment issues
In the area around Manado and the Minahasa district, there are several organisations against the building of (new) reclamations. These NGO’s protested against earlier reclamations and will probably do this again when the building of the new reclamation starts. They stand for a healthy environment, so the mangrove forest and the coral reefs stay alive. Surprisingly the NGO’s do not have any problems with a harbour placed near the mangrove area. The NGO’s think that they have some power themselves. They have stopped a plan of the municipality plan of reclaiming land south to the city of Manado. They don’t think it’s possible to mitigate effects of a land reclamation.
2  RELATIONS AND INFLUENCE STAKEHOLDERS

Identifying the stakeholders can give some information about the involved parties. However, to really get an idea what their importance is, the relation between them must be explained. This can be done in two different ways: influence versus their importance in the project and a diagram which displays the link between them.

2.1  Relations between the stakeholders

The most important stakeholder is the municipality of Manado, due to the large amount of relationships it has with the other stakeholders. Because of that the municipality has the biggest diameter in Figure 2.1. The municipality has the strongest relation with the citizens and the Ministry of T&CE. This is of course obvious, because Manado is of great influence on the tourism industry of Sulawesi and the municipality is at the service of the citizens.

Figure 2.1: Relation diagram of the stakeholders.
In the figure the relations are either red, orange or green. Green means that the relation is positive or neutral (which says nothing more than that they do not bother each other in their interaction). Orange means the stakeholders are not cosy with each other but also do not fight. A red colour indicates a strong opposition in their interests.

The investors have medium conflicting interests with the fisherman along the coastline. This is obvious considering the fisherman are losing their fast connection to the sea. It is not likely they will become the new residents of the reclamation. This issue must be considered seriously, because the fisherman of Manado are playing a large role in the community and have large sympathies of the citizens. Their wishes regarding the new reclamations must be investigated and implemented as far as possible.

During the interview with a representative person of the NGO’s it became clear the NGO’s do not like the, mostly foreign, investors that built the megamalls on the existing reclamations. There is suspicion and it is assumed by them the investors got the construction permission without an Environmental Effects Report and that money was the largest argument for the decision for the contractor.

There is also the relation between the fishermen and the tourists. The Lonely Planet mentions the large role fish plays in the daily consumption. Saying this, sustaining and protecting the fishermen’s life and occupation possibilities can give Manado a name of the typical Indonesian picture tourists come for, while building only large buildings on reclamations and destroying surrounding nature will only wreck the name of the city. Besides the direct contribution to Manado’s economy, the fishermen can attract more people to Manado to enjoy the beautiful coast with its boats.

The relation between the investors and the municipality is assumed to be very strong, due to the fact that Indonesia is a country where the power is where the money flows.

2.2 Power versus interest

For the initiator of the project it is a must to know which parties are able to really influence your project and whether it is in a positive or a negative way. Using a power-interest diagram it is possible to visualize the position of a stakeholder in altering the project outcome.

From Figure 2.1 it is possible to identify the main stakeholders to take into account during our research. It is decided to take them all into account, except both Ministries, the people in the mangrove area and the traffic commuters. This is because of the Ministries are very hard to get informed of and the influence of the people living the mangroves and the traffic commuters are too small to consider.
For the diagram in Figure 2.2 the relations between the stakeholders are used. It shows directly in Figure 2.1 that the municipality of Manado is the stakeholder with the highest influence and the strongest arguments pro the reclamation. The municipality has a medium relationship with the environmental NGO’s. The NGO’s have a monthly meeting with the government which gives them a not to be underestimated influence on the project. Especially because they are mostly against a new reclamation, unless the result of the project is highly positive for both the economy and the environment (Representitive, 2013).

Due to the assumed strong relation with the municipality, the investors will have a large influence on the project, pushing in the direction of a positive advice for the construction permit.

The environmental NGO’s will be against the project in advance, but once the plans are adjusted to support the environment, they will not protest against the project. In the previous part it was mentioned that the project must also have a high economic value for the city. But since the investors are playing a large role this is considered to be no problem.
Appendix E: Coastal effects
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1 INTRODUCTION

The construction of new land in the sea will cause some changes in currents and also in the sediment transport. The estimated new sediment transport pattern is shown in Figure 1.1 and is based on a synthesis of the present currents and possible behaviour of currents, by applying the knowledge of coastal dynamics and advices of local coastal engineering experts. There won’t be an abrupt change in the currents and their directions. In the north the large breakwater already blocked the alongshore transport and the sediment flow out of the Bailang river. At the south of the reclamation the room in front of the river mouth is decreased by the reclamation, but this won’t change the transport directions drastically.

In this chapter first sedimentation is threatened and as second the erosion. For both effect first the problem is analysed, at second possible solutions are presented, as third these solutions are weighted and finally the best solution is chosen and further designed.

![Figure 1.1: Overview sediment transport with the reclamation](image-url)
2 SEDIMENTATION
Due to the construction of the reclamation, on some places accretion will take place. There are spots where this is not desirable, e.g. at the south of the new reclamation. The spots where sedimentation will occur are indicated in orange in Figure 1.1. The flats are indicated in brown.

2.1 Sedimentation at Tondano River mouth
There is a sediment transport directing from the south to the north in front of the latest reclamation. This current is bringing sediment towards the mouth of the Tondano River. From the north, there is also sediment flowing to the river mouth. So nowadays there is already siltation in front of the river mouth, creating flats. But there is some space north of the river mouth, where the sediment also settles. With the appearance of the reclamation, this space will decrease and the sedimentation in front of the river mouth will be larger. This flattening of the river outlet is non-desirable, because of the effects it could have on the river upstream. There will be accretion on the south side of the reclamation in front of the outlet of the designed channel.

So after a while the sedimentation will become a problem, especially at the Tondano river mouth. The path for the river discharge will become smaller, which will have serious consequences for the river upstream. This will be discussed in Appendix G: Tondano River. Solutions for this problem will also be further discussed in Appendix G: Tondano River.

2.2 Sedimentation at Tumumpa Dua
2.2.1 The process
North of the reclamation in front of the Tumumpa Dua quarter, there will also be some accretion, because the sediment flows past the Bailang harbour, partly into the water between the harbour and the reclamation. The waves will try to push the sediment south, but the transport will be blocked by the reclamation. Accretion will occur in the corner in front of the outflow of the designed channel. Due to an eddy current, there will also be some sedimentation against to the harbour. This already is the case due to the eddy in the leeside of the harbour. Eddies are caused by the difference in set up of the water level, so the current is directed to the area, which is sheltered from waves.

2.2.2 Quantification of the problem
Sedimentation quantities are not known, since the data of the sediment transport are insufficient at this scope. But by analysing the current circumstances and the accretion at other locations, there could be concluded that the amount of sediment that will accrete at the location, is significant.

2.2.3 Impact, visibility and probability
The impact of the sedimentation is **moderate**, because fishermen possibly can’t reach the shoreline in front of their residents and possible boats which need to be in the canal couldn’t reach it from the sea. Also the accessibility of the Bailang harbour close to the shore will be threatened by sedimentation. The sedimentation is **highly** visible, especially during low tide a large area will be lay dry. The probability of the sedimentation occurring at this point is **likely**, because the same problem is already visible at the Tondano River mouth and against the Bailang harbour. These locations have partially the same sediment sources.
2.2.4 Need for action
The sedimentation is annoying for fisherman and other users of the Bailang harbour, but also can have a positive effect. This would be discussed by the possible solutions. But it is necessary to undertake action to unplanned sedimentation at a completely new structure, which could cause negative circumstances for surrounding events.
3 POSSIBLE SOLUTIONS: SEDIMENTATION AT TUMUMPA DUA
Three solutions to the problem of sedimentation at this location will be discussed. The first one is building a breakwater in front of the indent of the coastline. The second is to accept the accretion, and make even profit of it, by using it as a beach for instance. The last one which will be discussed is to extend the reclamation all the way to the harbour. The three possible solutions will be described below.

3.1 Breakwater
Building an emerged or submerged breakwater in front of the opening will block the sediment to come into the indent. This could be done by extending the existing Bailang harbour breakwater towards the south, along the coast. But also a single free breakwater could be enough to block the sediment flow. Both options are shown in Figure 3.1. The breakwater would also prevent erosion of the coastline between the two accretions. Another function the breakwater could have is to give shelter to boats which could moor in the created basin between the harbour and the reclamation. The breakwater shouldn’t have to completely close the indent, so boats can go in and out.

Figure 3.1: Left: Extended Harbour breakwater, Right: Emerged single breakwater
3.2 Acceptation of the sedimentation

Accretion of sediment in the corner of the reclamation and the original coastline doesn’t have to be a negative effect. By adapting the north end of the reclamation a bit, a beach could be realised, as illustrated in Figure 3.2. Most of the sediment that accretes will come from the sea and won’t have a too large grain size, so it will be ideal for creating a beach. With the appearance of the beach the value of the reclamation will increase. The location is also preferable, because the north of the reclamation is planned to be used for tourism.

Figure 3.2: Acceptation of accretion with implementation in the reclamation
3.3 Extend the reclamation all the way to the Bailang harbour

The problems at the indent could also be solved by simply making the reclamation larger, all the way up to the Bailang harbour. A simple sketch of this is visible in Figure 3.3. This option costs more money, but it also creates a larger value, because there could be sold more building locations. The accessibility of the harbour needs to be preserved. Also the last part of the present coastline in the northern area of the residential area will be better protected against the sea, just like the rest of the northern area.

*Figure 3.3: reclamation until the Bailang harbour*
4 MCE: SEDIMENTATION TUMUMPA DUA

4.1 Criteria
The criteria, where the possible solutions are evaluated on, are effectiveness, additional value, durability and the accessibility of the Bailang harbour. The effectiveness represents the amount of sedimentation prevention. The additional value is the appearance of something extra that gains more money. The other two criteria are clear. All the criteria are compared to each other in Table 4.1

Table 4.1: Criteria for sedimentation Tumumpa Dua compared to each other

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Additional value</th>
<th>Durability</th>
<th>Accessibility Harbour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Additional value</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Accessibility Harbour</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

4.2 The result
In Table 4.2 the results of the MCE are shown. An adaption to the present design, to create a beach out of the sedimentation is the preferred solution. This solution will be advised and further elaborated in this report. The reason that this solution has the highest value is the best accessibility to the harbour and the high additional value. By extending the reclamation, the accessibility of the Bailang harbour will decrease for the part near the shore.

Table 4.2: Grading for the solutions for the sedimentation at Tumumpa Dua

<table>
<thead>
<tr>
<th></th>
<th>Extended Harbour Breakwater</th>
<th>Single Breakwater</th>
<th>Small adaption and acceptance</th>
<th>Extend reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WF Grade Score</td>
<td>Grade Score</td>
<td>Grade Score</td>
<td>Grade Score</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0,25 4 1</td>
<td>4 1</td>
<td>3 0,75 4</td>
<td>1</td>
</tr>
<tr>
<td>Additional value</td>
<td>0,17 1 0,17</td>
<td>1 0,17</td>
<td>5 0,83 5</td>
<td>0,83</td>
</tr>
<tr>
<td>Durability</td>
<td>0,25 4 1</td>
<td>4 1</td>
<td>4 1 4</td>
<td>1</td>
</tr>
<tr>
<td>Accessibility Harbour</td>
<td>0,33 2 0,67</td>
<td>3 1</td>
<td>4 1 1 3,33</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2,84 3,17</td>
<td>3,91</td>
<td>3,83</td>
<td></td>
</tr>
</tbody>
</table>
5  ADVICE: SEDIMENTATION AT TUMUMPA DUA

Acceptation of the sedimentation in front of Tumumpa Dua could be applied by an adaption to the design of the reclamation. The advice is to accept the sedimentation and adapt the reclamation design a bit, to profit from the circumstances that the sedimentation creates. An example of the design of the north end of the reclamation will be described in this part of the report. There are multiple options to implement a beach at the reclamation, but one option will be described. Of course the success of the beach is also depending on the water quality, so there must be taken care of that no garbage will appear near the beach. If this could all be managed the beach will add value to the city.

5.1  Boundary conditions beach design

The area where the sedimentation takes place is situated at an area that is subject to the influences of Manado Bay. One can think about the bathymetry, the tidal influence and the Bailang River.

5.1.1  Bathymetry

In Figure 5.1 a design of the beach is shown with the original depth contours. It shows that it is impossible that this bathymetry will stay the same after the construction of the reclamation. So by the change of the coastline the bathymetry of the area around it will also change. An estimation of the depth contours with the appearance of the reclamation with a beach is illustrated in Figure 5.2.

![Figure 5.1: Original depth contours around the beach](image1.png)

![Figure 5.2: New estimated depth contours around the beach](image2.png)

5.1.2  Tide

The tide will change the dimensions of the beach, during low tide it will be of course a lot wider than at high tide. But also the outgoing tidal current could drag some sand of the beach with it. To prevent this, there will be taken measures as described later. The tidal elevation is already described in the Hydraulic analysis in Appendix B.
5.1.3 Sediment transport
The beach will be mostly created by the sediment transport. The sediment transport in this area is mostly driven by the waves. The dominant wave direction is towards the south east. The wave direction is shown by a black arrow perpendicular on two lines in Figure 5.3, the second most common wave direction is indicated with the more translucent arrow. By alongshore sediment transport induced by waves, the transport rate is zero when the angle of the shoreline is perpendicular to the wave angle, or almost perpendicular. So the beach is north west directed. In this way people on the beach will have a clear view over the Manado bay and the islands Manado Tua and Bunaken at the horizon.

5.2 Beach design
A small design is made for the beach. The technical details are not very specific, so there are also made some recommendations. The dimensions, material and construction method are described below.

5.2.1 Dimensions
The length of the beach will be approximately 430 meter. It will be north-east directed, because the sediment transport is stable under that angle. So the beach will shape itself for a large part. The width of the beach will depend on the water level, at low tide it will be much wider than at high tide. The width of the beach could be increased, by supplying sand from the land. This will be in favour of possible beach bars and restaurants. Also a wide beach can give some space for sport activities like beach volley or beach soccer.

On the north east side of the beach, a small groyne will be built perpendicular to the coastline. This groyne will prevent the sediment to flow in the canal and shields the coastline for erosion. At the western end of the beach, it has to be closed by a short groyne, which will prevent the sand to flow out of the indent. This all is visible in Figure 5.3.

Figure 5.3: Beach dimensions
5.2.2 Materials
The sediment which will accrete at the location of the beach will be coming from the sea and partly from the outflow of the Bailang River. The sediment coming from the sea is probably consisting of course coral sand and small pieces of dead coral. The sediment coming from the river will consist partly out of sand which is formed by dragging along the river. A combination of both sands is very suitable to build a beach from. Extra sand that could be supplied for widening of the beach could originate from the inland, where also the sand for the foundation of the reclamations is coming from. The small groynes at the west and east end of the beach will be a rubble mound structure, because the rocks are easily available in the region of Manado. And because the northern part of the reclamation needs to be build first the rocks of the breakwater which will have to be demolished can be reused in the new reclamation.

5.2.3 Building method
The construction of the reclamation is preferred to start on the north end, with the sea defence behind the future beach and the two small groynes. In this way it could already catch sediment during the construction phase. The sand for the beach will not all come from the sea and the sediment which will accrete will not be equally distributed along the beach. So the beach would need a little help besides the nature effects. Extra sand for the beach could be brought in and bulldozers could distribute the sand over the whole beach length.

5.3 Recommendations and reconsiderations
The advice to profit from the sedimentation in front of Tumumpa Dua, is not yet a final design. There could be some problems for the beach, like garbage in front of it our polluted sediments. To exclude these threats, it is recommend to do more research to the sediment supply and water quality. Also the location could be reconsidered, because it might be preferable that the beach is stretched over the whole width of the reclamation, but there could be reasons to locate it a bit different. Another recommendation is to do research on the wave attack on the beach during extreme events. How long it will take for the beach to recover after such an event, is an important thing to know. Further the design of the beach depends on the choice of the client for a canal between the reclamation and the shore. But the advice to integrate a beach in the reclamation design will not change, because the value of it is very high. It is difficult to get the beaches back in the Manado coast after the reclamations of the last decennia. The new reclamation creates the circumstances to get one back, and this opportunity needs to be taken. Not just the tourist industry, but also the inhabitants of Manado will profit of the beach. They will have a nice place to spend their free time again, just like they had in the past with the beaches along Manado’s coastline.
6 EROSION
Erosion has been a serious problem since the last fourteen years, for the area around the Bailang river mouth. South of the river mouth a large breakwater for the small harbour was build. This caused erosion on the residential area south of it and erosion on the coastline just north of the Bailang River.

6.1 Mangrove retreat North of Bailang River mouth

6.1.1 The process
In the area north of the river mouth, the coast used to be protected by mangrove forest. But in the first few hundred meters from the river mouth, the mangroves have disappeared and the coastline retreated around hundred meters in the past fourteen years. This event is described in the Morphological Analysis in Appendix B. The location is shown in Figure 1.1 by the dark green shaded area. The retreat of the coastline seems to be stabilised nowadays, because the outflow of the river made its way wide enough, whereby the strength of the outflow is weakened. But there could still be some erosion during high river discharge, which are quite common during the wet seasons.

Increased mangrove decline due to the construction of the new land reclamation is not expected. Since the mangroves are located upstream in the alongshore current from the reclamation. Nevertheless it would be appreciated if there will be find a solution for the decline of mangroves.

6.1.2 Quantification of the problem
Dozens of meters land have eroded and the shoreline has retreated a lot. Also all the mangroves in this part just north of the river mouth are gone and the adjacent mangroves are in a critical condition. Since the mangroves are very important for the environment, is seems obvious that this problem is very big.

6.1.3 Impact, visibility and probability
The location where erosion occurred north of the Bailang River will not undergo significant changes compared to the present situation. But the impact of the process is high to the coastline and its surroundings at the location. The impact of the erosion is also highly visible, since the coastline retreated for dozens of meters and the mangroves are disappeared. The probability of the continuing erosion is unlikely during normal condition, but during extreme events it is very likely. This is because the coastline is unprotected to wave attack and high river discharges.

6.1.4 Need for action
It’s obvious that this problem needs to be solved as soon as possible, because the ecology is in danger. Since a return of mangroves is very difficult to achieve, it is important that the retreat of them will be stopped fast, so less mangroves have to be planted. This could be done by the use of the analysis of this area (Ecology Analysis in Appendix B) and the cause of the decline.
6.2 Erosion at Tumumpa Dua

The places where erosion could occur are indicated in red in Figure 1.1. The spots are north of the Bailang river mouth and between the Bailang harbour and the reclamation, between the two accretion spots. This is in front of the Tumumpa Dua quarter. The last erosion spot is caused by the breakwater of the Bailang harbour and is nowadays without the reclamation, larger than it would be after the build of the new land. Nowadays the land is just at some places protected against the erosion, by some breakwaters which should give shelter to fishing boats. The erosion at this location will decrease by the build of the reclamation, because of the accretion which will occur on both sides of it. There is even the possibility that the amount of accretion will overrule the erosion at this spot.
7  POSSIBLE SOLUTIONS: EROSION NORTH OF THE BAILANG RIVER MOUTH

There will be considered two solutions for the erosion, one by changing the alongshore current, and one without change in the direction of the sediment transport.

7.1  Groyne which leads the river outflow southwards

By building a groyne as shown in Figure 7.1, which will block the river outflow towards the north, the erosion on the north of the Bailang River will be stopped. One of the causes of the erosion is the new northern river outflow, pushing fresh water through the mangrove forest. The river outflow will turn to its original direction, southwards, due to construction of a groyne. In this way, the groyne will also have a positive side effect, namely the blockage of the south directed sediment transport. In this way the land that has been lost the last couple of years, could be reclaimed again. Also the mangroves could be brought back to the area, under good circumstances. They need to be left alone by the locals for a couple of years and they need to be sheltered from wave attack in the first period after a possible plantation, until they are strong enough.

![Figure 7.1: Groyne which sends the river outflow southwards](image)

7.2  Multiple groynes along the eroded coastline

To catch sediment, multiple groynes can be built along the coast between the river mouth and the coast where the mangroves still located. The approximate location is illustrated in Figure 7.2. Where the sediment nowadays have problems to settle along the coastline, the groynes should provide more grip and will cause more accretion, so the erosion will be overruled by the sedimentation...
between the groynes. The alongshore sediment transport will still be directed north, both the groynes might changes the direction of the river outflow a bit, because they provide more resistance to the outflow current. There also could be some unwanted side effects downstream of the last groyne.

*Figure 7.2: Multiple groynes north of the river mouth*
8 MCE: EROSION NORTH OF BAILANG RIVER MOUTH

The criteria for the erosion are effectiveness, constructability, durability, river impact and mangrove impact. In Table 8.1 these are compared to each other. The effectiveness represents the amount of erosion prevention in this case. The river impact is the influences of the solution on the river upstream. The mangrove represents the retreat of mangroves and the possibility to create new mangrove areas.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Constructability</th>
<th>Durability</th>
<th>River Impact</th>
<th>Mangroves impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Constructability</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Durability</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>River Impact</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mangroves impact</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

8.1 The result

In Table 8.2 the results of the MCE are shown. The groyne perpendicular to the coast will be the solution which will be advised and further elaborated. Because this solution is very effective and creates an area where new mangroves could be planted, it came out the MCE with the highest value. The impact on the river upstream is worse for this solution, but the solution could be adapted if further research will find out that this groyne will cause serious problems in the river upstream. The score for reclaiming land and plant new mangroves is quite low, because it is very difficult to construct this, with the present circumstances.

<table>
<thead>
<tr>
<th>Perpendicular groyne</th>
<th>Groynes</th>
<th>Reclaimed land and plant new mangroves</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>Grade</td>
<td>Score</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0,30</td>
<td>4</td>
</tr>
<tr>
<td>Constructability</td>
<td>0,15</td>
<td>4</td>
</tr>
<tr>
<td>Durability</td>
<td>0,15</td>
<td>4</td>
</tr>
<tr>
<td>River Impact</td>
<td>0,15</td>
<td>2</td>
</tr>
<tr>
<td>Mangroves impact</td>
<td>0,25</td>
<td>4</td>
</tr>
</tbody>
</table>

| 2,7                   | 2,55    | 2,25        |
9 EROSION PREVENTION PLAN

To protect the shoreline north of the Bailang river mouth, a groyne could be build. This groyne will prevent the outflow of the river to go southwards, but sends it to the original direction, namely southwards. The alongshore transport north of the groyne will be blocked by the groyne, and cause accretion. This accretion is a positive effect and could restore the erosion of the last 14 years. The retreated coastline could be brought back to its original location in this way, and even mangroves could be planted again in this former mangrove area.

9.1 Requirements and boundary conditions

9.1.1 Requirements

The groyne will not have a water retaining function, so some wave overtopping in case of high water or even storm conditions is allowed. Also it is not a breakwater that needs to provide a sheltered area for ships. HWL is on \( z = +2,1 \) m and HHWL is on \( z = +2,5 \) m. So if the crest of the groyne will be at \( z = +3,0 \) m this will be sufficient.

The lifetime of the groyne will have to be at least 25 years. This may seem short, but the Manado coastline is very dynamic, so there might already be new plans for reclamation by the year 2040. Besides this it is planned that the mangroves will be rehabilitated by this time, and that the redirection of the current by the groyne is no longer an absolute necessity. Since storms cannot be predicted 25 years in advance it is possible that the design wave height will be exceeded within the structures lifetime. The acceptable chance that this happens is chosen at 10%. The frequency of occurrence of the design wave height can be calculated with the Poisson distribution (H.J. Verhagen, 2009):

\[ p = 1 - \exp (-f T_L) \]

\( p \) probability of occurrence of an event one or more times in period \( t_L \)

\( T_L \) lifetime of the structure in years

\( f \) average frequency of the event per year

so \( f = -\frac{1}{T_L} \ln(1 - p) \) gives with \( T_L = 25 \) and \( p = 0,1 \) this gives

\[ f = -\frac{1}{25} \ln(1 - 0,1) = 4.4 \cdot 10^{-3} \approx 1/238 \]

So the design wave height is a 1/238 year storm.

9.1.2 Waves and wind

The wind and wave data are already described in the Hydraulic analysis in Appendix B. Most days of the year, wind and waves are directed away from the coast of Manado. For the waves that remain the dominant wave direction is indicated by the black arrow in Figure 5.3, these waves are coming from the north west. Also the second most common direction is shown here in a bit lighter black, these waves are coming from west-north-west. The wave direction is very important for the sediment transport, and thus for the erosion and accretion.
To determine the design wave height, with a 1/238 chance of being exceeded per year, we should take the measurements from (Argoss, 2013) and make a extreme value distribution. Unfortunately there are only very few measurements for the threatening directions so a correct extreme value distribution cannot be made. Therefore it is not possible to determine the design wave height for this structure. To be able to do some calculations about the stability and grain size of the revetment a design wave height of 3.5 m is taken. This height has a probability of exceedance of 1/1000. Note that this is per wave and not per year! This is the highest wave measured in the whole area. The wave direction is not mentioned. For the deep water wave period also the 1/1000 value is chosen: 13 s (Argoss, 2013).

<table>
<thead>
<tr>
<th>Wave height (m)</th>
<th>Prob. of exc. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>0.5</td>
<td>58.6</td>
</tr>
<tr>
<td>1.0</td>
<td>20.1</td>
</tr>
<tr>
<td>1.5</td>
<td>5.6</td>
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<tr>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
<td>0.8</td>
</tr>
<tr>
<td>3.0</td>
<td>0.3</td>
</tr>
<tr>
<td>3.5</td>
<td>0.1</td>
</tr>
<tr>
<td>4.0</td>
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<td>0.0</td>
</tr>
<tr>
<td>5.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The wind direction chosen is 160 degrees and a wind speed of 10 m/s. See also the Hydraulic analysis in Appendix B for more information about deep water wind and wave data.

9.1.3 SwanOne
The offshore wave data has to be transferred into near shore wave data using SwanOne. With Google Earth a bottom profile is established and the above mentioned data is inserted in the model. This results in the output graphs in Figure 9.1. It can be seen that at x=3000 the wave height and the wave period drop. This is due to the fact that at that point the bottom changes from deep to shallow quite abruptly, and that the slope becomes very flat in front of the river Bailang outlet. The tip of the groyne is located at x = 3000 so the values used in the calculation will be $H_s=0.8$ m and $T_m=6$s.
9.1.4 Bathymetry and water level
The depth of the location where the groyne will be built is very shallow, this will keep the costs of it relatively low. The bathymetry of the area will change a bit, because of the change in sediment transport. The groyne has to block the river outflow during high and low water, so the tidal elevation has to be taken in account. In Requirements it is determined that the crest of the groyne will lie on $z = +3,0$ m. The mean sea level (MSL) lies at $z = +1,2$ m. These are described in the Hydraulic analysis in appendix B.
9.1.5 Sediment transport
The main function of the groyne is to change the alongshore sediment transport to its original direction. Since the construction of the long breakwater of the Bailang harbour, the alongshore transport was changed and that caused some serious problems. The present sediment transport is described in Morphological analysis in appendix B and the expected directions with the appearance of the groyne are shown in Figure 9.2 by light brown arrows. The coast will get supplied with sediment from the north west again and accretion will occur against the north side of the groyne. The possible future coastline is indicated by the dashed black line.

9.1.6 River
An important functions of the groyne is preventing the river outflow to go northwards. By leading the river outflow along the Bailang harbour, the river is actually extended with approximately 450 meters. Possible effects upstream in the Bailang river will not be calculated, since flooding of the Bailang river is not as common as flooding of the Tondano river. Furthermore the riverbeds of the Bailang river are not as inhabited as those of the Tondano river. Just the first 1.5 km of the river from the mouth is adjacent to some residential areas, as shown in Figure 9.2. The boundary conditions important for this structure are the bathymetry at the location, the water level and thus the tidal elevation, wind and waves. These data are all discussed in the Hydraulic and Morphological analysis in appendix B.

![Figure 9.2: overview area of erosion prevention solution](image-url)
9.2 Groyne design

For the design of the groyne estimations have been made about the dimensions and materials.

9.2.1 Dimensions

To block the sediment of the alongshore transport and to guide the river outflow along the Bailang breakwater, the groyne has to reach approximately 450 meters into the sea. At the end the groyne will be curved a bit southwards. The slope will be 1:1,5; this follows from observations in the harbour. Some of them were 1:1 and it could be seen that the rock armour would just disappear sometimes, even large stones. The height of the crest level is as described in Requirements \( z = +3,0 \) m. The groyne has no other function than to redirect the sediment outflow. So it is not necessary that people or machines can move over it, unless it is for maintenance. The crest width has to be at least 3 stones wide. Since the \( d_{50} = 0,84 \times d_{50} = 0,45 \times m \) (see below) the crest width should be 1,35 m. It is not accessible for normal vehicles. In Building method it is described how the construction and maintenance of the groyne can be done.

9.2.2 Materials

The armour layer of the groyne will exist out of quarry rocks. These rocks are easily available in the area around Manado. They need to be graded and sorted in the right seizes, only this way the stability of the structure will be guaranteed. At the rubble mound structures which are present along the Manado coast at the moment, the grading of the rock seizes is very diverse. Small diameter rocks are dumped between rocks with large diameters, this leads to failing of the structure on a lot of places along the coast. The rocks will be flushed away at circumstances with high wave attack. So in this groyne the stones need to be sorted on their seize. The smaller stones will be used in the filter layers, which will increase the stability of the structure. The foundation of the structure will consist of sand.

9.2.3 Armour layer

To determine the grain size of the rocks armour layer needed on the groyne several methods are available. The most common ones about waves are the formulas of Hudson and Van der Meer (Schiereck, 2001). The formula of Hudson reads:

\[
W_{50} = \frac{\rho_s g H_c^3}{K_p \Delta^3 \cot \alpha}
\]

In which:

- \( W_{50} \) median weight of armour stone [N]
- \( \rho_s \) density of rock [kg/m³]
- \( H_c \) Significant wave height [m]
- \( K_p \) stability coefficient [-]
- \( \Delta \) relative density \( (\rho_s - \rho_w) / \rho_w = 2650 - 1025 / 1025 = 1,58) \)
- \( \alpha \) angle of armour slope

The density of rock is 2650 kg/m³, the significant wave height near shore is determined to be 0,8 m. The stability coefficient for natural rock varies between 3 – 4, so 3,5 is used here. The cotangent of the angle of the slope is 1,5. This gives for \( W_{50} \):

\[
W_{50} = \frac{2650 \times 9.81 \times 0.8^3}{3.5 \times 1.58^3 \times 1.5} = 642.8 \text{ N}
\]
The $D_{n50}$ follows from

$$D_{n50} = \frac{3}{4} \left( \frac{W_{50}}{\rho_g g} \right) = \frac{3}{4} \left( \frac{642.8}{9.81 \times 2650} \right) = 0.29 \, m$$

$D_{50} = D_{n50}/0.84 = 0.35 \, m$. That this value looks quite low is due to the fact that the bottom slope in front of the groyne changes from quite steep to very flat, breaking the waves and making them low. Hudson’s method has as a disadvantage that it does not take into account wave period, permeability, number of waves and damage level. Van der Meer has derived a method to take these effects into account, consisting of two equations:

$$\frac{H_{sc}}{\Delta d_{n50}} = 6.2 p^{0.18} \left( \frac{s}{\sqrt{N}} \right)^{0.2} \xi^{-0.5} \quad \text{(plunging breakers)}$$

$$\frac{H_{sc}}{\Delta d_{n50}} = 1.0 p^{-0.13} \left( \frac{s}{\sqrt{N}} \right)^{0.2} \xi^p \sqrt{\cot \alpha} \quad \text{(surging breakers)}$$

In which:

- $P$ a measure for the permeability
- $S$ A measure for the damage
- $N$ the number of waves

For a rock armour layer with permeable core $P = 0.6$. The damage level $S$ is dependent on the damage area, and since damage is not desirable the value $S = 3$, which is a threshold for damage, is used. The number of waves has logically an influence, since more waves mean a greater chance on a large one occurring, and thus on damage. For $N = 7500$ the damage should have reached an equilibrium, since the wave occurrence is $1/1000$ it is plausible that there is indeed damage to the structure after 7500 waves.

Using the same values as in the Hudson formula, the $D_{n50}$ of the rubble is also calculated with the Van der Meer Method. Since this method needs more steps to determine the answer this is done with Cress. Cress gives as a solution for Van der Meer also a $D_{n50}$ of $0.27 \, m$, so $D_{50} = 0.32 \, m$.

These values are a lot smaller than the stone sizes that can be seen at the presently present revetments. This can be attributed to the following reasons:

- The wave data is not sufficient to define a design wave height
- There are only few waves coming from this direction
- The wave rays are almost parallel to the coast
- The used bottom profile is also a very rough estimation since no detailed map is available
- According to the SwanOne output the waves will break/reduce right in front of the groyne

Local restaurant owners in the south of the city have described waves that would flush through their restaurants. This would happen every four years and the wave heights would be about $3 \, m$, in combination with a high water level. Since this is in another point of the city, which is less sheltered
than the location of the groyne it is plausible that the waves are higher there. But since the grain size calculated with Hudson and Van der Meer differs so much from the field observations a safety factor of 1,5 will be used. So the groyne will have an armour layer with a $D_{50}$ of 0,53 m. The armour layer will consist out of two layers of these rocks, so the thickness of the layer will be 1,06 m.

9.2.4 Run-up and overtopping
Run-up and overtopping are of minor importance on this groyne. The groyne will not be accessible for public to walk on and it also doesn’t mind when waves push water over the groyne. The only thing that should be taken care of is that overtopping waves will not lead to instability of the inner slope. Also wave transmission is not important because there are probably no boats on the river during storm conditions and the transmission of the already quite low waves will be negligible.

9.2.5 Filter layers
To ensure that the core of the groyne will not flush out under wave attack it is important to build a proper filter. This can either be a granular or a geotextile filter. Geotextile is a very effective filter layer, but given the availability of rock with different grain sizes in the nearby quarries, the use of multiple granular filter layers will be advised. The filter layers are shown in Figure 9.3.

![Figure 9.3: Preliminary design of the cross section of the groyne](image)

9.2.6 Foundation
To prevent the groyne from sinking into the mud, it is advised to build it on a fascine mattress foundation. A fascine mattress is a woven from brushwood and other locally available twigs and brushes. This usage of natural materials makes the fascine mattresses very environmental friendly, which is important with the nearby mangroves. These mattress will be covered with stones to keep it at the bottom. This foundation will have larger dimensions than just those of the groyne, so they also protect the structure against scour around it. On top of it also toes need to be constructed to prevent the armour layer from sinking into the bottom, because the water level could be very low at the structure the toes should constructed at enough depth, so they are protected from the waves. The preliminary design of the cross section of the groyne is shown in Figure 9.3, where is clearly visible that the fascine mattress is wider than just the groyne structure. Because of the specialty of this part
of the structure and the unavailability of the data needed for it, this design will not further be elaborated.

9.2.7 Building method
For the foundation of the groyne with the fascine mattresses and the toes, some soil needs to be excavated first. Immediately after this the fascine mattresses could be floated one by one to their locations, and will be sunk down by dumping stones on it. After this the core and the toes can be built on it. If this would be done step by step, there is only waterborne equipment necessary to bring the fascine mattresses on their locations.

The core of the structure should be built from the shore into the sea until 0,2 m above HWL, so z=+2,3 m. The width at this level consist of the crest width and two times the slope times the distance between the crest level and the foundation level at that point, which is 0,7 m.

\[ 1,35 \text{ m} + 2 \times 1,5 \times 0,7 \text{ m} = 3,45 \text{ m} \]

The width of the core until this level will be 3,5 meters at that level so the equipment, excavators and dumping trucks, could drive on top of it. This way the groyne can be built up all the way to the end. Immediately after the sand is deposited the filter layers and the armour layer can be placed, so the sand won’t be flushed away, during the construction. The rest of the core and the filter and armour layers at the crest and then will be placed on the way back from the end of the groyne towards the shore. Using this method the groyne can be completely constructed by land based equipment. The construction needs to take place during a period where the probability of storms and extremely high river discharges is low.

9.3 Recommendations and reconsiderations
The location of the groyne, directly north of the river mouth, could have some bad influences on the river. More flooding might occur, so residential areas could be under threat. This risk isn’t taken care of in the design, but the location of the groyne could be adapted. The groyne could be shift up to the north and still keep its function. So it is recommended to do research what the consequences on the Bailang River would be, by the construction of the groyne.

The design of the groyne is not complete enough to construct it right away. There are missing details of the groyne, which have to be carefully researched. For instance the end of the groyne needs to be designed by making use of a mathematical or even a physical model. Also the inner slope of the groyne, needs to be reconsidered, because the cross section is now considered symmetric. This might be lead to oversizing of the design, so costs might be cut here with reconsideration. The foundation and filter layers also need to be carefully designed, so the stability of the structure can be guaranteed.
9.4 Mangrove retreat
After the construction of the Bailang harbour breakwater, not only significant erosion occurred, also ecological very valuable mangrove forest was lost. At the photo in Figure 9.4: Area with mangrove retreat, the present situation of the retreated area is visible. With the construction of the groyne there might be possibilities at this spot to turn the tide and let the mangrove trees flourish again.

![Figure 9.4: Area with mangrove retreat](image)

9.4.1 Retrospect of the mangrove retreat
Just as a small reminder, the Hydraulic and Morphological analysis in Appendix B stipulates the two combined reasons for the mangrove retreat at this area, namely human deforestation and the diverted river flow. Both causes will be shortly described below, to fresh up your memory.

**Human deforestation**
The most probable cause for the start of the erosion is the removal of mangroves by the local residents. They wanted to enlarge their living area, but had no idea about the consequences. Unfortunately they did this at approximately the same moment as the extension of the breakwater. Because they removed some mangrove trees, the sediment lost its grip on the shore. The disappearance of these mangroves induced to erosion of the land and also erosion under the mangroves upstream. These mangroves didn’t have the shelter they were used to have, and suffered from a shortage of sediment.

**Diverted river flow**
The cause of the retreat of the other mangroves could also be the difference of the salinity in the water, because since the moment the current changes, the water became more brackish, due to the fresh river discharge. The roots of the mangroves are really sensitive for this. In this way a large area of coast retreated until there became some kind of equilibrium, at the point where the influence of the river outflow is almost disappeared.

9.4.2 Goal
The goal of the mangrove revitalization plan is to provide a positive environment that creates the ability for mangrove vegetation to flourish in a natural way. Since all active causes that have caused the erosion are gone or are easy to prevent this is realistic to achieve.
9.5 Boundary conditions
Due to the blockage of sediments by the groyne, north of it accretion will occur. The coastline is expected to shift up tens of meters off shore. The original coastline was located there before the erosion started. In Figure 9.2 this expected coastline is indicated by a dashed line. Mud flats will appear again, so this is a great opportunity to restore the lost mangrove forest. So the considered area for the mangrove restoration will be between the current coastline and the dashed line in Figure 9.2.

9.6 Mangrove Restoration
The plan for revitalization of the mangroves consists of three parts. The first one is to take away the active causes for mangrove retreat. This will be done by education and the construction of the groyne. The second part of the plans is to prevent other causes of mangrove retreat from happening. The third part of the plan is to provide an environment that creates the ability for mangrove vegetation to grow again. Only when these three points are finished successfully, you might start to think about planting mangroves.

9.6.1 Remove mangrove reducing causes
First modifications should be assessed of the original mangrove environment, that currently prevent natural regeneration.

Human deforestation
An important reason for the mangrove retreat is the urbanization of the mangrove and the excessive deforestation for human use. Since the amount of inhabitants of this area is limited it could be possible to stop these effects by education. The local villagers also benefit from fruitful mangrove trees as described in the ecology analysis, so they should be willing to cooperate.

Diverted river flow
As shown in Figure 9.2 the fresh water flow of the river will be blocked by the groyne. And the eroded area will be supplied by sediment from the north-east. So it will be just as before the erosion problem, but now the sediment will be blocked so the coastline can recover from the erosion. The accreted sediment provides an area for the replanting of mangroves.

9.6.2 Threats for successful restoration
Aquaculture
There are very little fishponds in the vicinity of Manado. There are only a few northwest of the considered mangrove retreat area. The location is shown in Figure 9.5.
It doesn’t look like these ponds have led to any mangrove decline. Also it doesn’t look like the fishponds are still active, because normally they change locations every four year and the location of the fishponds is the same for already ten years. (Winterwerp, no. 8, 2013) In Figure 9.6 it is visible that the aquaculture site isn’t increased since 2003. Aquaculture is a big threat for mangroves, because of the nutrients they discharge. A big threat is also the replacement of the fishponds every few years, but that is apparently not the case in this area. All aquaculture around Manado should be managed very well! Further aquaculture should be prohibited. Existing aquaculture should be regulated and extinguished fishponds should be revitalized again.

Pollution

Another threat for successful mangrove restoration at Shipwreck beach is the surplus of litter. This garbage leads to pollution poisoning and suffocating the mangrove trees. Because of a possible change of bay currents and especially at the location where mangrove restoration could take place, the littering of the area will reduce. Just some garbage coming from the north-east with the alongshore current is a threat. The present source of garbage flow is the river, which wouldn’t have influence on the restoration area. Still garbage could appear at the area, by a combination of a strong tidal current and high garbage discharge from the rivers.
9.6.3 Positive Mangrove Environment
At the former mangrove area a morphodynamic situation needs to be created in which the tide deposits more mud than the waves remove. First small areas should be created surrounded by small semi-permeable dams just off the coast. These dams can be made out of brushwood and should be about 100 to 200 meters long. The wave energy is dissipated by them, but the water can permeate through them so that the mud is gradually captured. This might be sufficient. In case not enough mud is supplied by the tide, additional mud needs to be suspended into the water column in some way. This way there could be created the ideal circumstances for mangroves to grow. Figure 9.7 shows a possible layout for the dams, which have to catch fine sediments. The dark brown lines represent the dams and the light brown planes represent the mudflats which have to be created for the settlement of mangrove seedlings.

![Figure 9.7: Possible soft groyne layout](image)

9.6.4 Possible Mangrove replants
Winterwerp, 2013, describes six ecological principals which should be met for successful mangrove restoration:
1. Understand the ecology
2. Understand the hydraulics
3. Assess modifications that prevent natural regeneration
4. Restore hydrology and other environmental conditions, that encourage natural return of mangrove propagules and establishment of them.
5. Only consider planting of new mangroves if natural recruitment will not provide enough quantity.
6. Incorporate socio-economic aspects and monitoring requirements
The first four steps have been assessed in these report above, therefore the last two remain. The advised steps above, if implemented correctly should be enough for natural mangrove restoration. Once it has been assessed that steps have provided the required environment, but the restoration rate is not satisfactory step 5, addition mangrove replanting, can be considered. The last step is a task for the municipality of Manado, where they have to collaborate with the local habitants. There could be thought about value for them, for instance fishing in the created mangroves when they are at fully strength.

9.7 Conclusion
The dams provide the preferable circumstances to make the mangroves return on the coastline. By use of the 6 ecological principals to reclaim mangrove forest (Winterwerp, 2013), the ideal circumstances could be created north of the groyne. If the steps will be followed carefully, the mangroves will flourish again and take its place in the important ecological processes.
10 POSSIBLE SOLUTIONS: THE EROSION AT TUMUMPA DUÁ

To protect the coastline for erosion on this location, there are several options. They depend on the measures that would be taken for the other effects and the amount of accretion that will occur.

10.1 Erosion protection by measurements for other problems

If there is a breakwater constructed in front of the indent, there will be no erosion any more at this location. This is of course the same when the reclamation will be extended all the way to the Bailing harbour. If there is much accretion nearby the erosion might decrease also, but this is not expected.

10.2 Building a revetment

A revetment would prevent erosion of the coast at this location. The length of one can be quite short. The material for it could be supplied by the recycling of the rocks of the small breakwaters, which are now place along the original coastline. So this solution is quite easy and will have low costs.

10.3 Conclusion

Since a solution for the erosion at Tumumpa Duá depends on the solution for sedimentation at Tumumpa Duá, the final conclusion for the Tumumpa Duá erosion can be found in chapter 4.2 about the sedimentation at Tumumpa Duá.
CONCLUSION OF THE COASTAL EFFECTS

After a lot of research the conclusion is that most of the problems occurring at the coastline could be solved by taking measures. To start in the north with the erosion and mangrove retreat. These problems could be solved by the combination of the build of a groyne and the mangrove restoration plan. The problem isn’t just solved here, but the retreated land and mangroves could even be reclaimed. The other location where erosion is an issue, will be helped by the design of the measures taken against the sedimentation. The groyne at the north east side of the beach will protect the part of coastline which is nowadays plagued by erosion. Also the sedimentation problem isn’t just solved, actually it isn’t solved, but the effect is reshaped to an extra value for the reclamation. The beach could be one of the highlights of the new land, due to the sedimentation. If the measures will be taken, it will make the Manado coastline development more eco-friendly, than it is at the moment. So one of the goals of the municipality of Manado will came closer, namely being the city of eco-tourism.
Appendix F: Garbage
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1 EFFECT: GARBAGE SETTLEMENT AT TONDANO RIVER MOUTH

The Tondano River meets the sea between the Marina, Manado’s main harbour, and the planned reclamation. Currently the river flow brings the garbage from the city into the sea, where it’s spreading to everywhere in the Manado Bay. The harbour prevents garbage from flowing south directly and since the alongshore current in front of the harbour is heading north, the garbage is likely to end up north of the river mouth. At the Tondano River mouth it meets the sheltered corner created by the land reclamation, where also sediment will settle. At this location it is likely that also garbage will settle. But most of the garbage will be picked up by the rip current, which leads the garbage off shore, as described in the Hydraulic Analysis in Appendix B. The sedimentation of the mouth will “extend” the river with about 250 m towards the sea. Since there will be lower flow velocities it is likely that there will be more garbage settling here.

The drainage canal and the lengthening of Tondano River by the reclamation will result in a lower flow velocity at the Tondano River mouth. Due to the reclamation the river will be extended towards the sea over a length of 250 meters. This results in a decreased slope of the surface, which decreases the velocity of the water. Besides that, the new end of Tondano River will be a very wide river stretch, resulting in a lower flow velocity. The flow velocity might decrease so much, there will appear a garbage settling point, not something preferable.

1.1 Quantification of the problem

For the solution it must first be clear what the amount of garbage to be handled is. In Garbage Analysis in Appendix B it was estimated that a total amount of 250 m³ of garbage ended up in de rivers of Manado. This is not all ending up in Tondano River, which is the river this research focuses on. The Tondano River is a confluence with the Tikala River, which gives it the largest surface area of all the rivers in Manado City. It is assumed that due to the amount of people living along these two rivers 80 percent of this daily amount of garbage is flowing through these rivers. This is not equally spread, because the river widens and the people living upstream in the more rural area are more likely to throw their garbage in the rivers, since the collection service is not so well executed there. It is therefore estimated that the garbage collectors must have a capacity of 1400 m³ garbage per week. Of this amount a small part is coming from the people living upstream of Manado around the Tondano and Tikala River. It is assumed that 15 percent is coming from this upstream area, so 210 m³ per week for the two rivers together at the confluence.

1.2 Impact, visibility and probability

The people of Manado can see the pollution very clear. The garbage is mainly floating on the water surface, but there is also subsurface garbage transport. These two groups need different treatments. The pollution will have a negative effect on the attractiveness of the reclamation, and it can create unhealthy situations for people that live in the direct environment of it. Besides that the outflow of Tondano River will be hindered. Without doing anything it is very likely the garbage settlement will be huge. Already there is a lot of garbage settlement at the sides of the river near the mouth and this is not assumed to become less in the future.
The opposite is also true: it will also be clearly visible to the people when the river is clean again. This will have a large positive effect on the attractiveness of the surrounding area.

1.3 Need for action
Due to the negative effect the garbage now has on the health of the people and because a garbage agglomeration at the reclamation will decrease the attractiveness of the new reclamation rapidly, it must be researched. There must be thought of one or more solutions to recommend to the municipality.

1.4 Solutions
To come up with a solution first the location must be known. The location might influence the possibilities so much, not everything might be suitable. After that the process will be described. For every solution it holds that there must be enough room for the garbage collection service to get all the waste out of the water and transfer it onto a transportation unit: e.g. a truck. The following solutions are considered:

1.4.1 Groynes
During the fieldtrip it was observed that most of the garbage was floating at the sides of the rivers. One can use this by implementing groynes at the river banks. By this a shelter will be created behind the groynes, giving the garbage the opportunity to settle. While implementing a system like this, one must think about a system to take the garbage out of the water easily. In Figure 1.1 two possibilities for the layout of the groynes are shown.

![Figure 1.1: Possible lay outs for the groynes.](image)

Looking at these layouts a few things can be obtained. Figure a shows the groynes causing a sheltered area behind them. This means the groynes must be made out of a solid material like concrete, decreasing the width of the river rapidly. Also just the garbage at the sides of the river will partially be caught by these groynes. Solution b is an inlet, made out of a solid material, with a catchment at the end of it. This will stop the garbage and because of the canal the garbage can be easily scooped out of the water. However it is not clear what the effectiveness is regarding to the shape of the construction. Both solutions will locally narrow the river. This will lead to higher flow velocities and erosion of the bed locally, and globally to higher water levels upstream and eventually to a rise of the river bed (de Vriend, 2011).

1.4.2 Steel frame or net
The easiest way to collect garbage might be a large steel frame in the river. This will definitely influence the flow of the river, most likely as a narrowing of the river profile. One must thus execute some calculations whether it is allowable to implement such structures. The structure is visualized in
Figure 1.2.a, where the garbage is drawn with the gray blocked area. Another option is to implement a large net instead of the steel frame. This net can be more easily removed or emptied when necessary. The steel frame, with or without garbage, will have a negative effect on the river discharge.

Figure 1.2: Possible lay outs for the frames.

In b, c and d a groyne is drawn which is made out of a steel frame. This will increase the width not as rapidly as the groynes of Figure 1.1, but will still be able to catch most of the garbage. Especially option c and d will be very effective, but are negatively influencing the flow also a lot. Option b does not do this, because of the absence of the garbage frame in the middle of the stream. As said before, most of the garbage is flowing at the sides of the river plane, so the most profit can be made there. Therefore the additional caught garbage in the middle of the river at solution c and d, will not compensate the negative effect on the flow capacity of the river. At solution b the garbage can be easily removed, something that is also hard to do at the middle frame of solution c and d. It is assumed that solution b is the best solution of them all, regarding the above mentioned arguments.

1.4.3 Screenings treatment
Screenings treatment is a modern industrial way of cleaning water before a water treatment facility. For the garbage collection it will be wise to execute this into two stages, depending on the size of the garbage. The two groups of garbage are divided at the size of the bottles, a large pollutant of the river. Then everything the same size or bigger than these bottles will be sieved at the first stage. In the second stage, everything bigger than a few millimetres can be removed from the water with a screening treatment plant. Especially when the system is implemented outside the city, this is well possible.
Screenings treatment plants are commonly used over the world, but mostly in combination with water treatment plants for drinking water. However this is not necessarily true. The most screenings treatment plant are plug and play and have capacities up to 15.000 m³/h! With bypasses to prevent flooding it is a safe way for getting the pollution out of the water. However, despite it might be the most effective one, it is not the cheapest solution.
1.4.4 Acceptance of the pollution
This is actually what is happening right now in the city. The city accepted the problem and once in a while they clear the pollution of the rivers, restarting the full process of polluting and cleaning again. Of course this is not the desired situation, but with some better regulation and more often executed clean ups, it might work. The efficiency is however very low and also the sustainability of the solution is considered to be rather low. The impact on the cleanliness of the water is almost zero, because the garbage is still spread over the river since there are no specific catchment locations. However, there is no negative influence on the river flow.

1.4.5 Preventing the pollution
This is the most desired solution, but at the same time also the hardest one to get implemented. Of course one can start with education at churches and schools. This is an essential part in the prevention of garbage ending up in the river. However, because this is not a “hard” solution to the problem is will not be taken into account in the evaluation, also because the previous group elaborated a lot on this subject (Slijk, 2011). This solution need to be established next to the final solution.
2 EFFECT: DIFFERENT GARBAGE DISTRIBUTION

The garbage originating from Tondano River is now spread over the Manado Bay, mainly heading north. By rip currents it flows offshore in the Manado Bay, where it is picked up by a current from south to north. This current is induced by the wind. The current patterns are explained in the Hydraulic Analysis in Appendix B. The result is a net garbage flow to Bunaken National Park, causing negative effects on the ecology there. Also some garbage ends up at the mangroves situated in the north. The garbage flow will get affected in such a way that it will end up somewhat more west of the coastline. When this happens the garbage will be transported directly to the Bunaken and less to the mangroves. The garbage flow is the most depended on the wind induced currents, which come mainly from the south and south-south-east. This thus might have a positive effect on the mangroves, but with a constant amount of garbage this means that more is flowing to the Bunaken National Park.

2.1 Quantification of the problem

Taking the present situation into account, 200 m$^3$ of garbage is flowing out of the river every day (73,000 m$^3$ on yearly basis). This is not all ending up in the Bunaken National Park, but as said before also in the mangroves and along the Manado coast. The mangrove area just north of the city is highly littered. It is estimated that 10 percent of the total garbage will end up in the mangrove area. The rest will flow in the direction of Bunaken National Park, where it will settle or keep floating in the direction of the Celebes Sea. The impact of the reclamation is considered to be giving a decrease of 50 percent so that a total of 3650 m$^3$ ends up in the mangrove area after the construction of the land reclamation and without implementing a garbage collecting system for the river.

2.2 Impact, visibility and probability

The influence of the land reclamation on the garbage flow will not be very high. The rip current, that occurs in front of the river mouth could becomes stronger, directing the garbage further offshore, but this is not very probable. If the effect occurs it might be noticed by the people in the mangroves, observing less garbage landing on shore. However, the impact is considered to be very low, so it is hardly imagined that they will see a real change. The probability this occurs is estimated to be low.

2.3 Need for action

This problem is considered to be so small that it will not be investigated more thoroughly. The best solution is to prevent garbage flowing out of the Tondano River at all. Therefore a solution will be proposed for preventing the outflow of garbage and thereby the garbage distribution in Manado Bay will not be considered anymore.
3 MCE: GARBAGE

Now that there are several solutions, it must be determined which of them is the best fitting solution. The important criteria are effectiveness, the influence on the river flow, the operability, durability and the health and smell the structure will give.

3.1 Results of the evaluation

As can be seen in Table 3.1 the solutions are compared to each other, based on five criteria. The first criterion **effectiveness** is visualizing how large the reduction of the amount of garbage will be. The second one **influence on the river flow** is about how much the river flow is negatively affected. A solution can score high when the influence is very low, or maybe even positive. The **operability** of a solution means whether a solution is easy to operate during the users phase. A solution must be implemented for a long time, the **durability** of a solution is therefore the ruler. The garbage has negative influences on the health and smell in the city, so it is also determined how large the positive influence is on preventing this negative impact of the garbage. The better the solution, the higher the grade.

In Table 3.1 the criteria are compared each time to each other and determined which of the two was more important than the other. Two points are given to the most important, where the points are equally spread when they have the same importance. The final weight factors are given in Table 3.2 in the column WF.

Table 3.1: Criteria for garbage solution weighted against each other.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Influence on the river flow</th>
<th>Operability</th>
<th>Durability</th>
<th>Health and smell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Influence on the river flow</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Operability</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Health and smell</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The most important thing is of course to get the garbage out of the river. This has therefore the highest weight factor. Because the solution of the garbage may not have a negative effect on the river flow, the solutions must be researched on their effects on the river flow, which was also asked by the client. Keeping that last detail in mind, the influence on the river flow is considered to be very important. The operability of the solution is of course important to keep the rivers clean. This however is less important than the effectiveness and the influence on the river, because the problem must be solved, also despite some more effort. The solution must be durable, but not against all cost. The health and smell are as important as the durability, because these are secondary effects of the solution for the garbage problem and are also a bit linked to the first criterion.
The result of the grading is shown in Table 3.2. Only the most striking things will be noticed. First we will consider the final scores at the bottom. On the first hand one would like to implement the screenings treatment, due to the highest score. The other remarkable thing is that acceptance of the problem and let cleaners do the job once in a while is definitely not the preferred option and will therefore not be involved anymore.

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Garbage rack</th>
<th>Groynes</th>
<th>Screenings treatment</th>
<th>Prevention</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>Grade Score</td>
<td>Grade Score</td>
<td>Grade Score</td>
<td>Grade Score</td>
<td>Grade Score</td>
</tr>
<tr>
<td>0.35</td>
<td>4 1.4</td>
<td>3 1.05</td>
<td>5 1.75</td>
<td>3 1.05</td>
<td>1 0.35</td>
</tr>
<tr>
<td>Influence on the river flow</td>
<td>0.30</td>
<td>3 0.9</td>
<td>2 0.6</td>
<td>4 1.2</td>
<td>5 1.5</td>
</tr>
<tr>
<td>Operability</td>
<td>0.15</td>
<td>2 0.3</td>
<td>2 0.3</td>
<td>4 0.6</td>
<td>2 0.3</td>
</tr>
<tr>
<td>Durability</td>
<td>0.10</td>
<td>4 0.4</td>
<td>4 0.4</td>
<td>4 0.4</td>
<td>3 0.3</td>
</tr>
<tr>
<td>Health and smell</td>
<td>0.10</td>
<td>2 0.2</td>
<td>2 0.2</td>
<td>4 0.4</td>
<td>5 0.5</td>
</tr>
</tbody>
</table>

So with four solutions left, one must make a choice between the alternatives. As seen in Table 3.2 the most effective measures are the garbage rack and the screenings treatment. They take the most of the garbage out of the water. The influence on the river flow by implementing the garbage rack is however not so positive, in contrast to the screenings treatment and preventing of the garbage solution. The groynes are affecting the river flow the worst, because they decrease the width dramatically.

The operability of most of the solutions is not so good, because they have to be emptied by hand. The screenings treatment empties it fully automatic, so only a technician must be available. The durability of such a system is considered to be high, but that holds for every solution. Only prevention is considered to be hard to keep up to date, because it must go from generation to generation.

The health and smell will still occur when a garbage is situated in the water. Regarding this aspect the garbage rack and groynes are not the best solution, because the garbage will clog up at one concentrated spot. It will be wise to spread the groynes and/or garbage racks over the city. The screenings treatment can be implemented with a garbage processor, getting the garbage directly out the sight of the city. Of course preventing the garbage to end up in the river will be the desired situation.

3.2 Conclusion

Based on the above mentioned arguments, the screenings treatment will be the favourite solution. However, looking at the cost and the complexity of the system itself, it will be hard to come up with good arguments why this system must be chosen. The system is very expensive to acquire, but also to maintain. In this specific location the high costs of the screenings treatment plant do not compensate for the high quality it offers. The implementation multiple garbage racks is considered to be the best solution for Manado. Besides this solution, steps to prevent the pollution must be taken every single day.

In the next part, a design of a garbage rack will be elaborated. The prevention of garbage pollution in the river will not be treated very deeply.
4 DESIGN OF A GARBAGE RACK

The garbage rack must be located at different locations in the city, because the solution has a limited capacity due to the width of the river. In the previous part already four different configurations of a garbage frame were considered. Only two of them are suitable for Manado, namely the frame over the full span of the river and the solution with the frames at the sides of the river. First the locations of the different racks will be determined, after which a detailed design will be made.

4.1 Location

The garbage must be collected at a location where it has the most effect on Manado. This means two things: the city rivers will get cleaner and the rivers will flow more easily. To achieve this, the proposed solution may not lead to more friction and the location must be chosen so that the citizens of Manado will see the river is cleaned. Taking out all the garbage out of the rivers will have a positive effect on the flow. Another reason to situate the garbage collection outside the flood area is because during a flood of Tikala and Tondano River, also the garbage will flow into the area. Another obvious location would be at the end of the river. Then you know for sure you can collect all the garbage from the Tondano River. However, this will also bring some difficulties with it: there are people living in this area that use the river to store their boats. This continues to upstream of the joint between Tikala and Tondano River. This means a structure spanning the full width of the river will not be suitable.

At location [1] to [3] it is possible to implement a garbage frame over the full width of the river. The locations are situated at the outside of the populated area, and more important, they are situated outside of the flood area. This was important, because the garbage frame will have an inevitable negative effect on the river flow. Getting the garbage out of the river will have a positive effect on the flow, because there will be less friction.
4.2 The rack

The garbage will be sieved by two frames, each with a different grain size. They will be placed three meter after each other, keeping enough room for the garbage to settle. There must be made a bypass, in case the garbage frames are so clogged up no flow is possible any more. This does not have to be a large one, but must be suitable to keep the flow running. Therefore it is assumed it must have the area of the structure of the garbage frame. In that case, no transporting area will be lost. This is of course a large simplification of the reality, because there are more effects that will occur while implementing such type of structure. In Figure 4.6 the grain size is displayed. The rack is made out of steel bars of 10 mm thickness.

![Figure 4.6: Grain size of the first garbage rack.](Image)
Assuming a 10 mm thickness of the bar means that the garbage rack will occupy 29% of the total wet area. That is a large part of the surface area and it is therefore estimated with the help of Figure 4.7 that the side channel must be $0.29 \cdot 160 \text{ m}^2 = 46.4 \text{ m}^2$. The wet area is estimated from the data of the Ministry of Public Works and based on the new plan to improve the river banks.

![Figure 4.7: Cross-section of the Tondano River at collection point 1. (Ministry of Public Works, 2013)](image)

One can think about the most easy solution; widening the river as much as needed at the location of the garbage rack. The water level during low discharge will become much lower, leading to a lower velocity. Because the river must be widened over a semi-long distance, the influence on the river flow upstream will be too negative. Because of this, it is recommended to make a side canal.

The side channel must therefore have a minimum width of 8.75 m, leaving no room for errors. Therefore a channel of 9 meter will be designed. Also in the canal a garbage rack will be present. The canal must only be opened during high discharges. This means at least the upstream opening of the canal must be sealed with a door. This will be designed in the next section.

**4.3 The door**

The locking door of the canal must be fully opened once in a while. This means a system you can control the discharge from time to time is not needed here. There are multiple choices for the door, like an upward sliding door, a sideward sliding door, a normal door, two normal doors (making a V-shape while closed).

It is chosen not to implement the upward sliding door, because this implies a structure to get the door up, hindering the view of the citizens living nearby. A sliding door would be a good solution: there is enough room at [1] and [2] and it will give a nice view to the people. The V-shaped locking doors will be hard to implement here, because they must be opened to the upstream side of the river. That means the doors must be able to “get into the bank improvement”, because otherwise they will have a negative influence on the flow to inside the side canal. In Figure 4.8 the sideward sliding door is shown. As can be seen, the door will slide into a concrete house while opened. The concrete house is built directly behind the bank improvement.
4.4 The canal

The canal is 30 meters long and as can be seen in Figure 4.9 the canal is made fully out of concrete. The cross-section shows also really well how the garbage rack is placed in the canal. It goes fully from the bottom to the top. This is done, because during low discharge, the water depth is only 1 meter and during higher discharges the garbage must be caught too.

in Figure 4.10 and Figure 4.11 the situation during low and high discharges are shown.

Figure 4.8: Sideward sliding door as lock of the side canal.

Figure 4.9: Cross-section plan of the side canal.

Figure 4.11: Garbage rack during normal discharge.

Figure 4.10: Garbage rack during peak discharge.
In the figure it is also shown that there is always water in the canal since it is only closed at the upstream side of the garbage rack. A second door would only cost money, not really improving the situation. It will be a less safe solution, because when the downstream door hesitates during high discharges, the canal does not function anymore. The water is not likely to get polluted and when it does need refreshment the door can be opened a little bit to let water flowing through the canal.

4.5 Garbage rack at the river mouth
At location [4] and the river mouth, another type of garbage catching device must be implemented, due to the fact that boats must still be able to go through the canal. The proposed solution is already mentioned and will be designed in the way as presented in Figure 4.12. The garbage will be caught by large steel frames, each with a capacity of 48.4 m$^3$. It is assumed that the garbage can be stored in a layer up to 30 cm, coming on a total maximum capacity of 14.64 m$^3$ per rack. With four racks this gives a total of almost 60 m$^3$.

![Figure 4.12: Garbage rack at the river mouth and at the joint of the Tikala and Tondano River.](image)

The total amount of garbage every week, is considered to be 180 m$^3$, based on the garbage analysis in Appendix B. However, it is assumed that only 60% of that amount will reach the river mouth after implementation of the garbage racks. Based on these numbers, one can easily conclude the garbage racks must be cleaned at least two times a week. This must be executed and regulated by the municipality.

If the garbage rack will be squeezed into a single wall, it would decrease the width of the river by 2.75 m at each side. This is a total decrease of the width of approximately 10%, not even take the garbage into account. This might have a tremendous effect on the discharge capacity of the river from this point.

On first sight, this type garbage rack does not meet the requirements to catch all the garbage due to the open space in the middle. However, one must know that the garbage is thrown in the river and will take some time to get to the middle of the river. Before it gets that chance, most of it will already be caught by the garbage racks. Considering this, it might not be necessary to implement a full span frame, although that would catch all the garbage for sure.
4.6 Conclusions
The garbage rack must be implemented over the full span at the upstream part of the river at locations [1] to [3] and it is recommended to do that also at location [4]. At the river mouth the rack cannot span the full width because boats must be able to enter Tondano River. Therefore at location [4] and the river mouth the garbage is only caught at the sides of the river.

The solution proposed will of course improve the present situation, but to really get clean water, the screenings treatment plant should be implemented somewhere downstream.

Keeping the functions of Tondano River intact, the design at location [4] and at the river mouth are well designed, although they also do not stop every (small) piece of garbage. As a first estimate the dimensions are well chosen.

4.7 Recommendations
The following recommendations can be made, mostly about the construction and design of the garbage rack.

To prevent the garbage to becoming smelly, the garbage racks must be fully cleaned every two days. This also contributes to the discharge capacity of the Tondano River and letting Manado becoming the desired model city of eco-tourism.

Execute a research how long the garbage will take to get caught by the middle flow of the river. This parameter can be used to determine the needed width of the garbage rack and maybe it turns out it would be better that the garbage racks are placed on a different location.

Reducing the thickness of the frame to 8 mm will have a positive effect on the percentage the rack will occupy, i.e. a decrease to 23.2%. The needed width of the side canal will then also be decreased with 20%, leading to a financially more feasible design. However, it is not calculated whether it is technically possible.

The side canal must be opened every month, to be sure the door is still working properly and to flush the canal.

To take the garbage out of the water there are two possibilities: use mechanical equipment or just man power. The first option means that there must be a structure to hold a grabber. In case of the use of man power there must be a bridge kind of structure for the worker to stand on. This can be just an ordinary beam of concrete on a steel pile.

The influence on the river flow is now considered to be negligible in the situation of the garbage rack at location [4]. It might be the construction is too long and it must be decreased. This is not really calculated and further research is therefore recommended.
Nowadays there are boats moored upstream of location [4]. These are the reason why a full span garbage frame is not suitable. However, as already mentioned the garbage racks do not catch every piece of plastic from the river, due to the open space in the middle. It is possible to implement such a rack, but then no boats can enter the upstream part of Tondano River. Whether this is desirable cannot be determined by us, but is recommended to our client to investigate. If there is too much resistance against closing this part of the river for boats, it is possible to implement a sluice. This is however costly, but of course gives a very good opportunity to maintain the functions of the river and to catch the garbage.

An improvement of the garbage rack at locations [4] and the river mouth is to implement a rotating garbage rack. This garbage rack is visualized in Figure 4.13. The rotating steel frames will push the garbage out of the river in a large container and will then move on. This solution is more expensive and advanced, but it will make the garbage collecting much more easily. Another positive effect is that the garbage can be put out of the water continuously, so no smell will occur. The smell was the reason for a previous garbage rack it was demolished by the people living directly next to it.

Figure 4.13: Rotating garbage rack.
Appendix G: Tondano River
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1 INTRODUCTION

One of the main subjects of this research is the Tondano River. Especially at the downstream parts of the river, where the river flows through the residential areas of Manado, there is high risk of flooding of the river. The construction of the new land reclamation will take place close to the river mouth of the Tondano River. This can have several effects on the river outflow. It can cause severe sedimentation around the mouth, as has also been seen at other river outlets where reclamations were built. The change of outflow conditions can also increase the water level upstream. As a third effect the storm surge can also increase due to the creation of a funnel shape river mouth. Flowing of the garbage will be considered here.
2 EFFECT: SEDIMENTATION AT TONDANO RIVER MOUTH

The morphological situation changes due to the construction of the land reclamation near the mouth of Tondano River. The reclamation is constructed about 150 m north to the river mouth. It is expected that the sediment that is flowing from the river will settle like illustrated in Figure 2.1.

![Figure 2.1: Sedimentation near Tondano River mouth.](image)

2.1 The process

The Tondano river flows out in the sea. Currently, this is is only constricted by the breakwater of the harbour. When the sediment enters the sea it experiences lower flow velocities than in the river. Therefore the sediment will tend to settle. Influences of waves, tide and alongshore currents have led to a large flat area right in front of the river mouth where a lot of sediment is already settled. When the land reclamation is constructed the sediment that flows out to the north will be caught by the reclamation, which would lead to a situation as shown in Figure 2.1.

This also happened at the other reclamations. These either extended the rivers or constricted the river outflow, which led to extensive sedimentation near the new river mouth. This can be seen in Figure 2.2. This sedimentation is also influenced by the waves. Due to the fact that two alongshore sediment flows meet each other at the Tondano River mouth some additional sedimentation is expected as described in more detail in Appendix E.

Since this happened at the other rivers it is likely that the Tondano River will react in a comparable way. It is very difficult to predict how the reclamation will influence the outflow and sediment balance around the river mouth. To give this a certain quantification it is assumed that the change in outflow can be modelled as an extension of the river, resulting in relocation of the river mouth. This is also the process that occurred at the other reclamations, eventually leading to a rise of the bed level upstream.

The reclamation and sedimentation will extend the river with a maximum of 250 m (as far as the reclamation extends into the sea). It is possible that sediment also settles in the new river mouth, and thus fills up the river mouth. This will make it very shallow and flat (as it already is), so there will be low flow velocities in this new part of the “river”. The extra river stretch created by this, is wider than the existing river and has the same discharge. Probably the slope is also smaller, but since this is
hard to estimate it is assumed for the calculation that the slope of the river mouth will be the same as in the river stretch upstream.

Initially the depth in the present river mouth will remain the same. Due to the low flow velocities the sediment will be deposited at the side of the river mouth, and at some point in time this will start to have influence on the river mouth. The outflow profile narrows and in analogy with river engineering theory this leads to higher depths and lower flow velocities. This will lead to more sedimentation right in front of the river mouth. This sedimentation creates the new “river profile”, up to 250 m downstream from the old river mouth. The distance from the breakwater of the harbour to the new land reclamation is 200 m. Assuming that on average half of this distance will be filled up with sediment (Figure 2.1 and Figure 2.2) the new river branch will have an average width of 100 m.

The filling up of the new river mouth by sedimentation will lead to an increased bed level at this location, due to backwater effects. If the slope in the new river branch is the same as in the upstream river stretch, this leads to an increased bed level and a bedlevel step in the old river mouth. Also upstream from this the bed level will increase. This higher bed level in the whole river will increase the chance of flooding.

2.2 Quantification of problem
To get an idea about the impact and probability of the sedimentation a calculation is executed about the amount of sedimentation in the river, by simple hand calculations. These calculations are based on some (very rough) assumptions, and should not be interpreted as accurate predictions. But, they do give a good indication of effects the new land reclamation has on the several processes.
2.2.1 Hand calculation of sedimentation
Since there are no numbers available about the yearly sediment transport of the river, some assumptions have to be made to determine the magnitude of the accretion. The yearly sediment transport is assumed to be a fraction of the yearly alongshore sediment transport, say 10%. This would be 3086,5 m³/year as described in Appendix H. The area that gets accreted is approximately 9350 m² (estimated from Figure 2.1). The depth varies between 0 and approximately 2 m, so if an average depth of 1 m is used this leads to a volume of 9350 m³ sand that accretes in the corner. So it would take approximately 3 years until the accretion has reached the state indicated in Figure 2.1.

2.2.2 Hand calculation of increase of bed level
The river mouth in the present situation has a bed level of CD -1,6 m (Ministry of Public Works, 2013). The mean sea level (MSL) in the mouth is 1,2 m above Chart Datum (Assa, 2013). This gives a depth in the river mouth of approximately 2,8 m. The equilibrium depth in the river stretch can be calculated with the following formula:

\[ h_e = \left( \frac{Q^2}{g B^2} \right)^{1/3} \]

If we assume a river width of 20 m (this is a low estimate!) and a discharge of 60 m³/s the equilibrium depth is 2,79 m, which corresponds to the depth in the mouth. So presently the river is in equilibrium state (Figure 2.3).

If we assume that the river width for the last 250 m (the new part) will be 100 m and the slope will be the same as in the upstream river, the long-term case will have a depth at the mouth of 0,95 m, equal to the equilibrium depth in the new part. This will lead to a bed level step of 1,84 m at the old river mouth. The bed level at this location (and the rest of the river upstream) will be 0,042 m higher than in the old situation (Figure 2.4). The calculations are visible in Table 2.1.
It was already told that the river is presently in equilibrium condition. The depth in the mouth is equal to the equilibrium depth in the river stretch: 2,78 m. This did not include backwater effects due to tidal influence. Table 2.2 shows that the backwater effect from and HHWL (z = +2,5 m) is measurable in the whole river stretch up to the confluence with Tikala River. It can be seen that the extension of the river actually leads to lower water level at the confluence. However this should be doubted, because the tidal intrusion is not so easy to describe with this model. This is because the bed level at the old river mouth is after construction still very much below HHWL.
Table 2.2: Calculations of low and high water level

<table>
<thead>
<tr>
<th>Old situation</th>
<th>New Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHWL Branch</td>
<td>Mouth Branch 2</td>
</tr>
<tr>
<td>Q [m^3/s]</td>
<td>60</td>
</tr>
<tr>
<td>C [m^3(1/2)/s]</td>
<td>60,00</td>
</tr>
<tr>
<td>B [m]</td>
<td>20</td>
</tr>
<tr>
<td>B [m]</td>
<td>20,00</td>
</tr>
<tr>
<td>i [-]</td>
<td>1,67E-04</td>
</tr>
<tr>
<td>h, e [m]</td>
<td>2,78</td>
</tr>
<tr>
<td>h, mouth [m]</td>
<td>4,08</td>
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<tr>
<td>Lhalf [m]</td>
<td>6672</td>
</tr>
<tr>
<td>x0 - x [m]</td>
<td>4800</td>
</tr>
<tr>
<td>h, confluence [m]</td>
<td>3,57</td>
</tr>
<tr>
<td>L, half [m]</td>
<td>6565,58</td>
</tr>
<tr>
<td>x0 - x [m]</td>
<td>4800,00</td>
</tr>
<tr>
<td>h, confluence [m]</td>
<td>3,54</td>
</tr>
<tr>
<td>Bedlevel step at river mouth [m]</td>
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<tr>
<td>Bedlevel rise upstream [m]</td>
<td>0,042</td>
</tr>
<tr>
<td>u, eq [m/s]</td>
<td>1,59</td>
</tr>
</tbody>
</table>

2.3 Impact, visibility and probability

The visibility of this effect is expected to be very high. Because in the present situation this is the river mouth and the sediment flows out freely. The location of the sedimentation is highly visible from the boulevard road. Besides that there are a lot of ships anchored in the river mouth. If they will be unable to exit or enter the river due to the sedimentation they will be highly affected by this. Whether this sedimentation will actually take place in this form is unknown. The morphology at the river mouth is very complex. But if the assumption to model the new river mouth as a part of the river is correct, then sedimentation at the river mouth is likely to happen. This is because the same effect is visible at other river outlets in Manado. The impact of this effect is also high, because of the flooding effect described below.

2.4 Need for action

The sedimentation near the river mouth could have several negative effects. The sedimentation will lead to a change in the river flow, leading to higher bed and water levels upstream (see also chapter 4). This can be very annoying for all the users of the river, and dangerous for the people that live along the river. It will probably block the canal between the new reclamation and the present coast. Also the depth of the new stretch will be very shallow, so it will reduce the accessibility for boats. More generally, the sedimentation does not look nice next to a beautifully designed reclamation. Therefore this sedimentation is unacceptable and a solution must be found.
3 SOLUTIONS FOR SEDIMENTATION AT TONDANO RIVER MOUTH

If there will indeed be sedimentation near the river mouth, man can think of several measures to prevent or diminish the effects it has on the environment.

3.1 Groyne

A single groyne can be used to redirect the outflow of the river (Figure 3.1). This reduces the flow profile, which leads to higher flow velocities. This will lead to less settlement of the sediment. Also the groyne blocks the sediment so that it cannot go into the corner.

![Figure 3.1: Groyne with consequential sedimentation](image)

But since there is a southward directed current along the land reclamation (Figure 3.2) there will probably be some sediment ending up in the corner of the groyne due to waves and alongshore sediment transport (Figure 3.1). The groyne will also have some effect on the upstream flow. It is expected that this effect is less than when there is no groyne.

![Figure 3.2: Currents around Tondano River mouth](image)

The effect of the groyne on the outflow of the Tondano River can be explained by means of a backwater curve and a section of the outflow area in Figure 3.3. Since the groyne constricts the outflow profile of the river there will probably be higher flow velocities than before, which can initially lead to local erosion. But on the long term the water body between the harbour breakwater and the new groyne will start to behave like a river stretch with a width of 70 m. A calculation
comparable with the one in paragraph 2.2.2 is shown in Table 3.1. This shows that a groyne of 200 m (and thus an extension of the river with 200 m) will lead to a bed level rise of about 3 cm in the river.

Table 3.1: Calculation upstream bed level step

<table>
<thead>
<tr>
<th>New Situation</th>
<th>Mouth</th>
<th>Branch 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q [m³/s]</td>
<td>60,00</td>
<td>60,00</td>
</tr>
<tr>
<td>C [m³(1/2)/s]</td>
<td>50,00</td>
<td>50,00</td>
</tr>
<tr>
<td>B [m]</td>
<td>70,00</td>
<td>20,00</td>
</tr>
<tr>
<td>i [-]</td>
<td>1,67E-04</td>
<td>1,67E-04</td>
</tr>
<tr>
<td>h [m]</td>
<td>1.21</td>
<td>2.78</td>
</tr>
<tr>
<td>h, mouth [m]</td>
<td>1.21</td>
<td></td>
</tr>
<tr>
<td>Lhalf [m]</td>
<td>1743,00</td>
<td></td>
</tr>
<tr>
<td>x0-x [m]</td>
<td>200,00</td>
<td></td>
</tr>
<tr>
<td>h, old mouth [m]</td>
<td>1.21</td>
<td>2.79</td>
</tr>
<tr>
<td>L, half [m]</td>
<td>4012,76</td>
<td></td>
</tr>
<tr>
<td>x0-x [m]</td>
<td>4800,00</td>
<td></td>
</tr>
<tr>
<td>h, confluence [m]</td>
<td>2,79</td>
<td></td>
</tr>
<tr>
<td>Nett effect at confluence [m]</td>
<td>0,00</td>
<td></td>
</tr>
<tr>
<td>Bed level step at river mouth [m]</td>
<td>1,58</td>
<td></td>
</tr>
<tr>
<td>Bed level rise upstream [m]</td>
<td>0,033</td>
<td></td>
</tr>
<tr>
<td>u_eq [m/s]</td>
<td>1,41</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.3 shows that the new river stretch will have an initial depth of 2.78 m near the old river mouth. This river stretch has an equilibrium velocity of:

\[ u_{eq} = \frac{h_{eq} \cdot W}{Q} = \frac{1.208 \cdot 70}{60} = 1.41 \, \text{m/s} \]
Since the equilibrium depth in this stretch is 1.2 m and the initial depth is way deeper, the flow velocity in this stretch will be lower than the above mentioned equilibrium velocity, leading to accretion on this place. In the long term this will look like Figure 3.4. What happens downstream of the new river mouth will not be discussed here.

![Figure 3.4: Bed levels and depths future equilibrium](image)

The groyne will thus have negative side effects; the sedimentation in the corner will only be relocated and the flow in the river is negatively influenced. Although the bed level rise in the river is in this situation lower than the estimated bed level rise without the groyne, it still has a negative influence on the flow.

### 3.2 Dredging

One way to decrease the effect of sedimentation near the river mouth is by dredging. Dredging is only a temporary option to cease the effects of accretion or siltation. According to paragraph 2.2.1 the corner indicated in Figure 2.1 is fully accreted after 3 years. So the dredging would have to be repeated more often than every 3 years because the sedimentation around the mouth should be prevented; letting it come to this problematic situation before dredging would be too late.

Not only the corner has to be dredged, also the rest of the area around the river mouth has excessive sedimentation. Removing this with suitable time intervals guarantees a free outflow of the river. Blockage of the river outflow by sedimentation seems to have major upstream effects (2.2.2). So removing this sediment in time will not only guarantee a sand-free river outlet without aesthetically undesirable sand accumulations, it also prevents the river bed from rising, and thus preventing the rise of flood risk in this area. Dredging every 2 years would probably be a good interval. Since it has to be repeated so often this is a very labour intensive, and on the long term probably expensive option.

It is probably not possible to dredge with the most common dredging equipment. Since the area around the river mouth is very shallow the dredging would have to be done using small equipment.
This makes it even more labour intensive. It is in terms of execution not difficult though, there is plenty of small-scale dredging equipment available. Besides that, the quantity to be dredged is not that large that large equipment is required.

### 3.3 Accept sedimentation

The easiest way to deal with the sedimentation in the mouth is to just accept that it is there. Since there are negative side effects in terms of upstream river flood this is probably not the right thing to do though. Only if measures against flooding that can be implemented in the river seem to be cheaper or more efficient than taking measures in the river mouth, acceptance could be an option. The sedimentation could actually be used beneficial, for example as a beach. But that is only if the river water would be clean enough.

### 3.4 Extend land reclamation

Extending the land reclamation all the way to the rivermouth is another way to prevent the sedimentation in the corner near the mouth. In this case there cannot be sedimentation in the corner, simply because the corner is not there. This option will also constrict the outflow of the river. This will probably result in the same as what happened at the other land reclamations; the river gets extended, and there will be a lot of sedimentation in the river mouth (Figure 2.2). According to experience with the other reclamations this could also lead to a bed level rise in the river. This effect will probably be comparable with the groyne option, since the redirection of the flow is very similar.
4 MCE SEDIMENTATION AT TONDANO RIVER MOUTH

4.1 Criteria

The solutions for the sedimentation of the river mouth will be evaluated according to the following criteria. **Effectiveness** describes how accurate the solution cures the problem of sedimentation around the river mouth. **Influence on the river flow** describes how much the solution influences the river upstream, for example by causing a raised bed or water level. **Maintainability** describes how much work is needed to maintain the solution; how much effort has to be put in the maintenance and how costly would repair be. **Durability** is determined by the lifetime of the solution. In Table 4.1 the different criteria are compared to each other to determine which one is more important. It seems that influence on the river flow upstream is the most important factor. The effectiveness is inferior to this, because the sedimentation is not life threatening, whereas upstream effects can actually be very dangerous.

*Table 4.1: Criteria for sedimentation of the Tondano River mouth*

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Influence on the river flow</th>
<th>Maintainability</th>
<th>Durability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Influence on the river flow</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Maintainability</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

4.2 Conclusion

In Table 4.2 the solutions are evaluated on the criteria. It shows that dredging has the best value. This is the only option that actually reduces the amount of sediment that ends up in the corner, although it is just temporary. This solution has the least negative effects on the river upstream. Besides that it is easy to execute. The main disadvantage is that dredging is not so durable, and since it has to be repeated quite often, pretty labour intensive (although this could be an advantage if you want to create jobs).

Constructing a groyne has some major disadvantages, for example that it only moves the location where sedimentation will take place. Besides that this option also has some negative influence on the river upstream, although this is less than when nothing would be done. Acceptance is no solution to prevent the sedimentation and can have major upstream effects. Extension of the reclamation up to the river mouth will prevent sedimentation on the location considered here. But it might have an influence on the river which is comparable to the groyne. Since it extends further into the sea this effect might even be somewhat stronger. When taking costs into consideration the groyne option might be cheaper than the extension of the reclamation. Dredging will only get expensive on the long
term. But since the equipment used will not be very large, the costs will probably not get too high. The dredging solution will be further elaborated.

Table 4.2: Grading of the solutions for sedimentation in the Tondano River mouth

<table>
<thead>
<tr>
<th></th>
<th>Groynes</th>
<th>Dredging</th>
<th>Acceptance</th>
<th>Extend reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>Grade</td>
<td>Score</td>
<td>Grade</td>
<td>Score</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0,17</td>
<td>3</td>
<td>0,5</td>
<td>3</td>
</tr>
<tr>
<td>Influence on the river flow</td>
<td>0,50</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Maintainability</td>
<td>0,17</td>
<td>4</td>
<td>0,67</td>
<td>3</td>
</tr>
<tr>
<td>Durability</td>
<td>0,17</td>
<td>4</td>
<td>0,67</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2,84</td>
<td>3,17</td>
<td>1,51</td>
<td>3,01</td>
</tr>
</tbody>
</table>
5 SOLUTION: DREDGING AT TONDANO RIVER MOUTH

In the Multi Criteria Evaluation it was decided that the solution with dredging is the most accurate solution for the problems about sedimentation around the river mouth. This chapter will further elaborate the process of these dredging works. Besides the location that has to be dredged it will be described (quantitatively) what the effect of the dredging activities will be on the outflow conditions near the river mouth. Also some attention will be given to suitable dredging equipment and some general notices and recommendations will be given.

5.1 Purpose of the dredging

![Figure 5.1: Sedimentation around the river mouth](image)

Figure 5.1 shows the location of the expected sedimentation. This sedimentation is a result of sediment supply from the river and alongshore sediment transport. Similar sedimentation is also visible (Figure 5.2) around older reclamations. It is expected that also at the new reclamation the river outflow will be disturbed by sediment settlement in front of the river mouth. This could have severe consequences upstream on the river as described in chapter 2. This sedimentation has to be removed by dredging in order to mitigate the negative effects.

![Figure 5.2: Sedimentation around another river outlet (Google Earth).](image)
5.2 Outflow conditions
In the present situation there is also some sedimentation around the river mouth. This is caused by the river sediment outflow and the alongshore sediment transport and currents. This is described in Appendix E.

In Figure 5.3 it can be seen that the depth contour with z=0 (MSL = +1.2 m) lies on approximately 250 m from the river mouth. This figure also shows how the shape of the sedimentation around the river mouth is. From this 0 meter depth contour the bottom slope is steeper and the sea gets deeper very fast. It must be noticed that the actual bottom profile between the river mouth and the z=0 depth contour is not known, so this is an assumption. Thereby the data about the bed and water levels in the river and the data about the bathymetry and water levels in the sea come from different sources so they are somewhat modified to fit each other. Nevertheless it can be concluded that the area around the river mouth is very shallow, and there already is some sedimentation. Preventive dredging should guarantee that the outflow conditions will not change negatively due to the land reclamation. If the river can discharge freely there will be no negative effects upstream.

5.3 Dredging location
The reason for the need to dredge around the mouth of the Tondano River is ambiguous. First there is the sediment accumulation in the corner with the reclamation that has to be removed. Besides the fact that this sedimentation influences the outflow of the river it is also removed from an esthetical point of view. Second there is the sedimentation in front of the river mouth. This is already present, and will probably only get worse when the land reclamation will be constructed. This has to be controlled to guarantee a free outflow of the river.

Figure 5.3: Depth around river mouth
Figure 5.4: Area to be dredged

Since the exact depth profile of this location is not known it is hard to estimate the quantity of sediment to be dredged in great detail. Figure 5.4 shows in brown the area that has to be dredged. To make a rough estimate of the quantity that has to be removed the area is divided in two parts: the sedimentation in the corner and the sedimentation in front of the river mouth. In paragraph 2.2.1 it was determined that the sediment to be removed from the corner amounts approximately 9350 m$^3$. The area in front of the river mouth is approximately 24000 m$^2$. The bottom level here varies in the present situation between z = -1.6 m and z = 0. To guarantee a free outflow from the river the sea must at least be as deep as the bed level from the river, which lies at z = -1.6. Therefore it is assumed that over this whole area an average ground layer of 0.8 m has to be removed after some time. This means that this is 19200 m$^3$ sediment, leading to a total of approximately 28550 m$^3$. But it is preferable to dredge already long before the sedimentation around the river mouth reaches this state.

5.4 Dredging equipment
Looking at the situation and the needed dredging capacity it is easy to conclude that this situation does not ask for large equipment. Even the smallest Trailing Suction Hopper Dredgers (TSHD) will not even fit in the small and shallow bay around the river outlet. The minimal draught of the smallest TSHD is 4.0 m. The area to be dredged is nowhere deeper than 2 m, so this will not work.

A cutter suction dredger (CSD) can often be used in areas that are difficult accessible for TSHD’s. But also small CSD’s have a draught of 2.0 m. This would mean the dredging activities can only go through during high water. Thus also a CSD is not suitable.

For this project only small mechanical dredging equipment will be suitable. The very shallow water only allows pontoon with a small draught. One type of equipment that can be used is the backhoe, i.e. hydraulic excavator (Figure 5.5). These are mounted on pontoons and small models have a draught of only 1.5 m. This means that such dredger still cannot access the whole area. But if dredged from deep to shallow this dredging device will create enough depth for itself to get closer to the shore. The backhoe dredger operates together with a floating barge on which it deposits the dredged material. The barge size can be adjusted to fit in this situation. For places that are not easy to reach from the water it might be possible to use a land operated excavator. This can deposit the
sediment in a barge or on a truck. The backhoe dredger has as a main disadvantage that it cannot dredge very deep, but since that is not necessary in this project this is no problem. Small backhoes have a bucket size ranging from 1 to 3 m³. If it can do 1.5 cycles per minute, and is operative 8 hours per day the whole area could be dredged in less than 14 days. If more backhoes are used, for example one water based and one land based machine this will of course be shorter.

Instead of using a backhoe dredger the choice can also be made to use a grab dredger (Figure 5.6). This device is comparable with the backhoe dredger since it is also operated from a pontoon. There are small grab dredgers available for difficult accessible areas. Grab cranes also load the dredged material into pontoons. It is also possible to work with a grab crane from land. The advantage over a backhoe is that a grab crane can reach further. The disadvantage is that with a grab crane one can dredge much less precise. Small grabs have a capacity of 2.5 to 5 m³. If it can do 1 cycle per minute the whole area can be dredged in less than 12 days. Of course also for the grab counts that if more than 1 are used this time will get shorter. Numbers and figures are from (International Association of Dredging Companies (IADC)).
5.5 Transport and disposal

Both backhoe dredgers and grab cranes load the dredged sediment onto a barge. The size of these barges has to be adjusted to the available depth, so in this project the barges will be pretty small. The barge can be pulled or pushed to another location where they can be unloaded. A barge unloading dredger can empty the pontoons and transport the sediment via (floating) pipelines. This is only efficient if the sand is needed somewhere within reasonable distance of Tondano River mouth. The barges can also be transported over a larger distance.

It is likely that the sand is of good condition, there will not be much pollution besides maybe some garbage. The best solution would be to reuse the dredged sand somewhere in the vicinity of Manado. For example if another land reclamation will be built in the future, or to supply sediment on locations where erosion is a problem. If the sand cannot be reused like this it could probably be used for construction. If it is contaminated it has to be treated or stored in a safe place.

5.6 Recommendations

The dredging works have to be repeated periodically. In paragraph 2.2.1 it was calculated that it will take approximately three years for the corner to accrete completely. Since the dredging is preventive, action must be taken before the accretion reaches this state. Based on the available information it will be suitable to dredge every two years.

When executing dredging works it must be investigated if there is any coral reef located in the vicinity of the works. If there is danger to damage or destroy coral there are several measures to be taken. There are so called Environmental dredgers, dredging equipment especially designed to take the environment into account. If a dredging company that has experience with environmental dredging is contracted, they will take the right precautions not to harm the coral.
6  EFFECT: FLOODING DUE TO SILTATION OF RIVER MOUTH
In chapter 2 it was described how the land reclamation can induce extensive sedimentation around the river mouth. As explained before this will lead to a virtual relocation of the river mouth. This affects also the river as it is today.

6.1  The process
If sedimentation near the mouth occurs and/or is not treated properly, it has as an upstream effect that the river bed will elevate approximately 5 cm. This does not seem much, but it must be kept in mind that there is already high risk of flooding in several areas along the river. A raise of water level with 5 cm increases this risk and also the magnitude of the flooding.

6.2  Quantification of problem
As described above there will be a bed level and water level increase at the old river mouth due to shift of the river mouth. Due to this rise in water level there will be a backwater effect raising the water level in the upstream branches of the river. The water level will be 0.042 m higher than in the old situation (Figure 2.4), which follows from the calculation at 2.2.2. The calculations are also visible in Table 2.1.

6.3  Impact, visibility and probability
If a flooding occurs in the city this has a high impact on the citizens of Manado, but they might not know that this flooding has been induced by sedimentation of the river mouth of Tondano River. But since it will also increase the consequences of a flooding (because there will be more water) the effect of the sedimentation will be very visible. The effects of flooding are of course serious and also likely if the above described sedimentation effect is taking place. But since measures will be taken against sedimentation near the mouth an increase of the food risk is not to be expected.

6.4  Need for action
The increased risk of river flooding is certainly a topic that needs more research. If this effect will actually occur it endangers the people of Manado; something that should be prevented! Nowadays the people that live along the river and in certain other parts of the city are in danger of flooding already. The new land reclamation should not increase this risk. So if it does increase the risk, measures should be taken.
7 Solutions for Flooding of Tondano River

If the siltation does happen and is not treated properly, there can also be measures taken against the flooding in the river itself.

7.1 New river plan
There currently is a plan to reinforce all the river banks within the city of Manado as described in the River Analysis in Appendix B. The goal of this project is to smoothen the river and thereby decreasing the water levels in the river. Also it widens the river at some locations and a crown wall is placed along the whole river. This should decrease the risk of flooding. Although this is not the most charming (and cheapest) solution it seems effective.

7.2 Dredging
If lowering of the river bed is a solution to the flooding problem, which it is in this case, dredging could be an option to reach this goal. As already mentioned when discussing dredging in the river mouth, this is only a temporary solution. The dredged area will fill up with sediment again and the dredging works will have to be repeated. So also here dredging is just a temporary, and thus labour intensive and expensive measure. If dredging is chosen as a solution it has to be investigated whether the cheapest and easiest option would be to dredge the river mouth or the river.

7.3 Prevent the siltation in the river mouth
As mentioned in chapter 3 there are several measures to decrease or prevent the sedimentation of the river mouth. Since this is essentially the cause of the elevated river bed and water level upstream, these are all measures to decrease the (enlarged) risk of flooding upstream.
8 MCE: TONDANO RIVER FLOODING
For the river flooding a number of possible solutions are mentioned. These solutions will be
compared to each other. The difference with other solutions is that the flooding is partly a result of
the sedimentation in the river mouth.

8.1 Criteria
The following criteria are used to evaluate the solutions for flooding in the river. Effectiveness
describes how much the solution contributes to the reduction of flood risk in the river.
Constructability determines how easy it is to construct, looking at building method and spatial
planning. Maintainability again describes how much effort has to be put in maintaining the solution.
Durability describes how long the option actually provides a solution against the flooding problems.
Environmental impact describes how much the direct environment of the river has to be changed.
Think for example about people that live along the river that have to make room for the river or river
banks that get enlarged, taking more space.
In Table 8.1 it can be seen that effectiveness is the most important criteria. This is because the main
objective of these solutions is to prevent the river from flooding, and thereby saving the property
and maybe even lives of the people living in the city. Also environmental impact is considered
important because there are a lot of people living close to the river.

Table 8.1: Criteria for flooding in Tondano River

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Constructability</th>
<th>Maintainability</th>
<th>Durability</th>
<th>Environmental impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Maintainability</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Environmental impact</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

8.2 Conclusion
Table 8.2 shows that the prevention of sedimentation in the river mouth has the highest score. This is
inherent to common sense: it is better to prevent a problem than to cure it. The prevention of the
sedimentation in the mouth fights the problem at its source. Thereby this would be the cheapest
option for the river, because there is no need to take extra measures at this location.
Table 8.2: Grading of the solutions for flooding in Tondano River

<table>
<thead>
<tr>
<th></th>
<th>Dredging</th>
<th>Smoothening Banks</th>
<th>Prevent siltation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WF Grade</td>
<td>Score</td>
<td>Grade</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0,35</td>
<td>4</td>
<td>1,4</td>
</tr>
<tr>
<td>Constructability</td>
<td>0,10</td>
<td>4</td>
<td>0,4</td>
</tr>
<tr>
<td>Maintainability</td>
<td>0,10</td>
<td>3</td>
<td>0,3</td>
</tr>
<tr>
<td>Durability</td>
<td>0,20</td>
<td>1</td>
<td>0,2</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>0,25</td>
<td>3</td>
<td>0,75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the other hand, the sedimentation in the mouth will already be solved. In the present situation there is already a risk of flooding. It is wise to also implement some measures at the river so that the risk of flooding will actually diminish. Dredging of the river bed would be the easiest way to reach this goal. But then again there is the need to repeat this periodically. Since there is too little information available about the river bed morphodynamics it is not possible to advise how often these dredging activities have to be repeated, and how much should be dredged every time. Lowering the river bed also has some effect on the upstream river stretch. If dredging would be a desirable solution this has to be researched in detail. But the local government has already decided to implement a general river plan, including the reinforcement of the river banks (Ministry of Public Works, 2013). This plan will smoothen the river banks, leading to higher flow velocities and a decrease of the water level. Since this plan already exists in great detail this will not be further elaborated in this report.
9 EFFECT: ADDITIONAL FLOODING DUE TO INCREASED STORM SURGE

The river mouth of Tondano River is located perpendicular to a straight coast line. But this might change in case of the new land reclamation. In Manado high seawater levels can correlate with high rainfalls leading to floods in the city. The storm surge pushes up the water level in the Tondano River. As the main wind direction in case of the threatening storm surges is blowing from the North West, the funnel shape can lead to more wind setup at the river mouth. This leads to higher water levels in the river, due to the backwater effect.

9.1 Quantification of problem
The amount of wind setup is calculated in the part Wind Setup in the Hydraulic Analysis in Appendix B. It concludes that the wind setup is in the order of a single centimetre. This because of the deep foreshore. But the exact effect of the funnel shape is unknown. It is expected that this will not change due to the reclamation.

Any backwater effect will at the confluence will become a fraction of the wind set up of this centimetre. Because of the low value at the river mouth, this effect is negligible.

9.2 Impact, visibility and probability
The reason why a river level is higher than normal might not be understandable for the citizens of Manado, but the flood they experience is. Therefore it has a moderate visibility and a high impact. But the probability that this effect will have large influences is estimated as unlikely.

9.3 Need for action
There is no necessity to take precautions because of increased water level because of wind setup at the Tondano River mouth is just minor. Further research into the effect of a funnel shape on wind setup can be of additional value.
10 CONCLUSION

The morphological situation at the mouth of Tondano River changes due to the construction of the land reclamation. The reclamation is constructed about 150 m north to the river mouth. It is expected that the sediment will settle at this new mouth location. These last 250 m will be much wider than the original river, leading to low flow velocities, which will induce sedimentation near the river mouth. This also happened at the other relocations. This sedimentation is also influenced by the waves. Due to the fact that to long shore sediment flows meet each other at the Tondano River mouth additional sedimentation is expected as described more elaborate in the Appendix E.

A rough calculation gives a volume of 9350 m$^3$ sand that accretes in the corner. So it would take approximately 3 years until the accretion has reached the state indicated in Figure 2.1. A calculation about the upstream effects shows that the bed level in the original Tondano River will rise 0.042 m, due to the replacement of the river mouth.

It has been concluded that additional storm surge high, due to the construction of the land reclamation, is not expected. The wind set-up is minimal due to the deep foreshore large changes are not expected.

Possible solutions for the sedimentation in the river mouth are constructing a groyne, repeated dredging, the acceptance of the sedimentation and extending the land reclamation. The only solution that fulfils all the criteria is dredging. Only by repeated dredging the long-term bed level step, which leads to higher water levels upstream can be prevented. By dredging periodically the increase of flood risk for the hinterland, induced by the land reclamation can be mitigated. For the already exiting flooding risk, the plan of the municipality to widen the river and smoothen the banks, is a step in the right direction.

A dredging plan is presented to conquer with the sedimentation at Tondano River mouth. It is expected that a volume of 9350 m$^3$ has to be dredged annually and a one-time dredge of 19.200 m$^3$ sediment has to be done to clear the river mouth. This dredging work can preferable be done by a backhoe dredger i.e. hydraulic excavator, which will take about two weeks. This dredging activities have to be repeated approximately every two years to ensure the sedimentation will not get too severe. It is advised to hire a dredging company which has proven experience in dredging environmentally friendly near a coral reef.
11 RECOMMENDATIONS

Additional research will have to be done to see what the effects will actually be after the construction of the land reclamation. Especially the tidal influence is an important unknown. This includes a model with detailed information about:

- Waves around the river mouth
- Sediment transport in the river
- Discharges of the river (average, peak)
- Geometry of the river
- Current bathymetry of the river mouth

Building such a model takes a lot of time if detailed predictions are desirable.

Additional research about the effects of the created funnel shape on wave and wind setup (storm surge) can give additional insight in the processes occurring in the river mouth.

If dredging works are to be applied in this area it is important to be aware of the presence of coral reefs in the vicinity of the works. A qualified dredging company which has experience with this will be able to dredge in an environment friendly way if the location of coral reef is known.

Since there is also a research about treating the garbage that is now present in the river, this should also be taken into account. The placement of garbage collection racks will increase the flow resistance and decrease the flow profile, so this will have upstream effects. More about this is described in Appendix F.
Appendix H: Drainage canal
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   1.2 Impact, visibility and probability
   1.3 Quantification of problem
   1.4 Need for action
2 Possible solutions for siltation of canal
   2.1 Dredging
   2.2 Remove canal
   2.3 Canalization
3 MCE: solutions for siltation of the canal
   3.1 Criteria
   3.2 Score on criteria
4 Design of a Canal system for local urban drainage
   4.1 Boundary Conditions
   4.2 Design bottom level land reclamation
   4.3 Design canal system
   4.4 Redesign existing drainage
5 Conclusion

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1 EFFECT: SILTATION OF THE CANAL

As described in the outlines of the new land reclamation a canal with a width of 20 meters will be constructed between the former coastline and the new land reclamation. This is to reduce the length of the river towards the sea and make drainage of the city possible. It is important to note that this canal is at sea level and under tidal influence. Also some small drainage canals discharge into this canal.

1.1 The process

It is expected that there will be settling of sediment into this canal. This is because there are sources for sediment like tidal currents and a small river, but the processes that could take away the sediment are absent. This would lead to a shadow effect for the canal in which accretion will take place. The sediment of Tondano river might also partly end up in this canal. The canal is very sheltered from wave action, so the amount of sediment that will be stirred up is minimal. And the flow velocity of the river is also too small to fulfil this function, because the canal is multiple times wider than the river.

The process that is described above for sediment nearly is the same for garbage. There are sources of garbage like the river or the people that will use the new land reclamation. But the flow velocities due to the tidal current or the river discharge are very mild. It is expected that these two processes together will lead to clogging up of sediment in this canal.
1.2 Impact, visibility and probability
The most severe impact of possible siltation of this canal is that the small river that discharges into it, will get problems to drain the water from the city. But because this is an area which is not under flood risk at the moment these effects can be annoying, but not life taking. So the impact is characterized as moderate.

Siltation of this canal will be very visible. Multiple bridges connect the mainland with this land reclamation. The land reclamations are visited multiples times a week by the locals, and thereby they cross these bridges often. So if siltation and clogging up of garbage will take place, the citizens are nearly certain going to see it.

The probability of siltation happening and the speed of this siltation, are nearly impossible to predict, because there is too little information about the amount of sediment transported by the rivers. But important to note is that this sedimentation is also happening at other parts of city where sheltered areas have been created by land reclamations. Therefore there is a high probability that the sedimentation will happen.

1.3 Quantification of problem
The calculation below about the flow velocity and bed level rise stipulates the impact and probability of sedimentation of the canal system.

1.3.1 Calculation canal flow velocity due to tidal current
The planned canal will be constructed at a location where the water depth is now about 1 meter, and therefore falling dry during low tide. It might be dredged deeper but this is not considered now. The deepest part of the canal system is at towards the sea, where the depth approaches 5 meters. The width of this canal is planned to be 20 meters.
Table 1.1: Calculation surface area Canal System

<table>
<thead>
<tr>
<th>Part</th>
<th>Width [m]</th>
<th>Length [m]</th>
<th>Surface Area [m^2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal</td>
<td>20</td>
<td>2200</td>
<td>44000</td>
</tr>
<tr>
<td>Yachting</td>
<td>175</td>
<td>425</td>
<td>74375</td>
</tr>
<tr>
<td>Rivermouth</td>
<td>200</td>
<td>175</td>
<td>35000</td>
</tr>
<tr>
<td>Bailang Harbour</td>
<td>185</td>
<td>500</td>
<td>92500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>245875</strong></td>
</tr>
</tbody>
</table>

Using the storage area approach it is possible to make an estimation about the flow velocity into the canal system induced by changing tide.

$$u_v = \frac{A_{\text{Canal system}}}{A_{\text{Canal Mouth}}} \frac{dh}{dt} = 0.1 \text{ m/s}$$

With a tidal difference of 2,4 meter the velocity at the entry of the canal, the velocity at the canal entry and exit then becomes 0,1 m/s. This is a very mild velocity, which will not be able to transport much sediment. Since sediment is introduced into the canal by waves and currents, and there is no force removing the sediment out of the canal, it is very likely that siltation of the canal will occur.

1.3.2 Calculation of bed level rise due to sediment clogging up

Because of the large breakwaters bounding the new land reclamation, the shadow zone created by the land reclamation and the existence of sediment sources within the system it is expected that siltation will occur in the canal system. The amount of sediment that will be trapped in the system is expected to be a fraction of the total yearly sediment transport at this part of the coastline. With this fraction being 10%, which is arbitrary, the yearly bed level increase becomes 0,31 m per year. This means that the canal will be completely filled within three years!

Table 1.2: Calculation siltation, sediment transport from (Assa, 2013)

<table>
<thead>
<tr>
<th>Type of sediment</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly sediment transport alongshore</td>
<td>30865 m^3/year</td>
</tr>
<tr>
<td>Percentage in system</td>
<td>10%</td>
</tr>
<tr>
<td>Sediment into system</td>
<td>3086,5 m^3/year</td>
</tr>
<tr>
<td>Yearly sediment transport onshore</td>
<td>739610 m^3/year</td>
</tr>
<tr>
<td>Percentage in system</td>
<td>10%</td>
</tr>
<tr>
<td>Sediment into system</td>
<td>73961 m^3/year</td>
</tr>
<tr>
<td>Surface canal system</td>
<td>245875 m^2</td>
</tr>
<tr>
<td>Original bed level</td>
<td>0 m</td>
</tr>
<tr>
<td><strong>Yearly bed level increase</strong></td>
<td>0,31 m/year</td>
</tr>
</tbody>
</table>
1.4 Need for action
It is definitely important to find a solution for the possible siltation of the canal. It is a moderate impact, high visibility and high probability case. It is also concluded that the canal will be completely filled up with sediment and garbage within three years. Therefore not taking any action is not acceptable in this case.
2  POSSIBLE SOLUTIONS FOR SILTATION OF CANAL

Some solutions to mitigate or prevent the sedimentation in the canal will be elaborated in this chapter.

2.1  Dredging

The sedimentation is likely to occur in the canal or it might concentrate in a few corners. In that case a good way to decrease the effect of sedimentation in the canal is by dredging. This would have to be repeated periodically. This could be done once per year, or once in a couple of years. The volume to be dredged yearly can be easily calculated and would be about 77.000 m³ yearly.

2.1.1  Cost, effectiveness, maintainability

This is a very labour intensive and expensive option. This is due to the fact that the canals are not very wide and therefore dredging will be difficult to do with large scale equipment. It probably will be done with small equipment on small ships as a nearly temporary process. Therefore this solution is costly to maintain and not sustainable. The dredged material might be used at other locations where erosion is taking place.

2.1.2  Ecology

The possibility might also exist that the dredged material is polluted, for instance with garbage. It might be hard to find areas to dump this material without forming a threat to nature areas.

2.2  Remove canal

Since it has been concluded that placing a canal between new land reclamation and former coastline is not necessary, it might be most effective to remove this idea from the plans. The only reason to hold on to the canal is for local urban drainage and aesthetics for which it has an positive effect.

2.2.1  Cost, maintainability, sustainability

The design of the new land reclamation would then be exactly as described in the plans for the new land reclamation. Which is the original scenario. A land reclamation as such has high costs, but a canal would increase its costs exponentially because of the increase depth at the sea side. A land reclamation like this requires regular maintenance.

2.3  Canalization

Since the canal is not efficient from an morphologic viewpoint as concluded above, you still might want to keep the canal system for aesthetic and local rainwater drainage. A good solution might be to separate the canal system from the influences from the river and the river and the sea.

2.3.1  Effectiveness and sustainability

This plan would include placing the canal system far enough above high water, so it can discharge any time during high rainfalls. By separating the canal system from the river and the sea, there will be no sources of sedimentation for the canal. As long as the new reclamation is built high enough to resist some possible sea level rise, it can be a long term solution. But also for this canal it is likely that garbage will clog up at some locations, so canalization should be incorporated by a good local garbage solution.
2.3.2 Costs and aesthetics

In this way the canal can still be used for drainage, touristic activities and aesthetics. Although constructing an artificial canal comes with some costs, from all solution this one creates probably the most additional value. A weir can be used to discharge the water into the sea.
3  MCE: SOLUTIONS FOR SILTATION OF THE CANAL

After describing the solution it is time to look which of them would be the preferred one in this particular situation.

3.1 Criteria

The solutions are rated based on the following criteria. Effectiveness is the capability of producing a desired result of one of the solutions. When the solution scores high on effectiveness, it means it provides a good solution for the problem. Whether a solution scores high on maintainability is determined by the ease with which a product can be maintained. This can be effected by its ability to prevent unexpected breakdowns, have a long lifetime and takes few maintenance costs and labour. Durability is the ability to endure. It scores high if the solution has a high ability to endure earthquake loads, influence from citizens and water loads. Aesthetics is a branch of philosophy dealing with the nature of art, beauty, and taste, with the creation and appreciation of beauty. A solution scores high on aesthetics if it is expected to appeal to people’s judgments of sentiment and taste about the new land reclamation. The natural environment encompasses all living and non-living things occurring in and around the new land reclamation. A solution scores positive if it has a positive effect on the diversity of living things around the land reclamation or has a positive effect on the wellbeing of people around the new land reclamation. A solution scores high on the criterion extra function if it has the ability to deliver an additional function, which has a high chance of leading to additional value for the client or the users.

Table 3.1: Criteria for siltation of the canal solution weighted against each other.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Maintainability</th>
<th>Durability</th>
<th>Aesthetics</th>
<th>Environment</th>
<th>Extra Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Maintainability</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Durability</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Environment</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Extra Function</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Score on criteria

After defining, weighing and grading the different criteria for each solution the best solution can be found. The solutions ‘removal of the canal’ and ‘closed system’ score equally. A combination of the removal of the canal and the construction of smaller drainage canals in the new land reclamation will lead to the highest values, but also the lowest costs. Therefore this solution will be designed more specific. The dredging solution is less preferable because it has no extra function and is no solution on the long term.
### Table 3.2: Grading of solutions for siltation of the canal.

<table>
<thead>
<tr>
<th></th>
<th>Dredging</th>
<th>Remove canal</th>
<th>Closed system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WF</td>
<td>Grade</td>
<td>Score</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>0.27</td>
<td>4</td>
<td>1.07</td>
</tr>
<tr>
<td>Maintainability</td>
<td>0.13</td>
<td>4</td>
<td>0.53</td>
</tr>
<tr>
<td>Durability</td>
<td>0.30</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>0.10</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Environment</td>
<td>0.10</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Extra Function</td>
<td>0.10</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.9</td>
<td></td>
</tr>
</tbody>
</table>
4 DESIGN OF A CANAL SYSTEM FOR LOCAL URBAN DRAINAGE

The client wants to implement canals into the design of the new land reclamation. Unfortunately, most of the aspects of the canal are not really working as desired by the client. The only wish from the client that remains valid is to make the new land reclamation ‘a sort of Venice’ and therefore it is considered an aesthetic consideration. The canal could also have provided a drainage function for the hinterland, although this was not intended by the client.

Another good reason to still implement this canal system is for the sake of local urban drainage. Manado knows fierce rainfalls that regularly transform Manado’s streets into rivers. It is possible to prevent this by constructing drainage canals on the new land reclamation which can discharge large enough quantities of water.

4.1 Boundary Conditions

Before starting the design, first the most important parameters need to be clarified. For this design this is the rainfall peaks and the basic dimensions of the new land reclamation.

4.1.1 Rainfall

The month with the highest discharge per rainy day is February. On a day that it rains, an average precipitation of 17.4 mm can be expected. During a tropical rainfall this rain on average drops within one hour. This gives a peak rainfall of 17.4 mm/hour.

<table>
<thead>
<tr>
<th>Calculation peak discharge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge in one month (February)</td>
<td>382 mm/month</td>
</tr>
<tr>
<td>Rainfall days in that month (February)</td>
<td>22 days</td>
</tr>
<tr>
<td>Percentage of rain days that rainfall is extreme</td>
<td>21%</td>
</tr>
<tr>
<td>Percentage of rain that falls during extreme days</td>
<td>75%</td>
</tr>
<tr>
<td>Rainfall during extreme rain</td>
<td>62 mm/rainfall</td>
</tr>
<tr>
<td>Rainfall during extreme rain</td>
<td>62 mm/hour</td>
</tr>
<tr>
<td>Duration of one rainfall</td>
<td>1 hours</td>
</tr>
<tr>
<td>Peak factor</td>
<td>2</td>
</tr>
<tr>
<td>Peak rainfall</td>
<td>3.4E-05 m/s</td>
</tr>
<tr>
<td>Area land reclamation</td>
<td>680000 m²</td>
</tr>
<tr>
<td>Part land that discharges in considered canal</td>
<td>50%</td>
</tr>
<tr>
<td>Peak discharge during rainfall with no storage</td>
<td>11.7 m³/s</td>
</tr>
</tbody>
</table>

This calculation can be done multiple times if the canal system will exist of multiple drainage canals. The canal considered here discharges 50% of the land reclamation, which will result in a peak discharge of 11.7 m³/s.
4.1.2 Dimensions of Land reclamation

Different design stages of the new land reclamation shows different dimensions. These dimensions are important because a large surface area leads to more rain to be discharged. In the latest drawing of the reclamation provided by our client, the land reclamation reaches the 20-meters depth contour. This gives the following basic dimensions for the land reclamation:

Length: 2100m
Width: 325m
Surface Area: 0.68 km²

4.1.3 Other dimensions

To calculate the discharge trough the drainage canal a Chèzy value is required. Because the drainage canal is mainly constructed from concrete a value of 75 m¹/²/s is used, which is still rather conservative. A bottom slope of one-in-thousand is used for the drainage canal. This ensures that excessive water will be discharged into the sea quickly, but does not increase the bed level of the land reclamation too much. In one of the later considered cases the drainage canal will be 1 kilometre long, thus leading to an addition bed height of 1 meter.

<table>
<thead>
<tr>
<th>Rainfall during rain</th>
<th>0.062 m/rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olympic pool</td>
<td>2500 m³</td>
</tr>
<tr>
<td>Surface</td>
<td>680000 m²</td>
</tr>
<tr>
<td><strong>Number Olympic pools to be drained</strong></td>
<td><strong>16.8</strong></td>
</tr>
</tbody>
</table>

During a rainfall large amounts of rain fall on the land reclamation, as can be seen in Table 4.2. About 17 Olympic pools full of rainwater have to be drained during one rainfall, which acknowledges the importance of a good drainage system.

4.2 Design bottom level land reclamation

To make sure that dewatering the land reclamation is possible during all tidal situations, the bottom level of the land reclamation should be placed high enough above the water. But the bottom level should also be high enough to be not flooded by high waves during storms. In this way that land reclamation will have a higher reliability, need less maintenance and have a longer lifetime.

4.2.1 Needed bottom level due to sea storms

In the table below the required bottom level for the new land reclamation is calculated based on the water levels from the sea. The bottom level is a combination of the height needed to be above high tide and common waves plus an additional freeboard. Also soil settlement and sea level rise are included for the timescale considered by the client. Wind set-up is negligible as is described in the hydraulic analysis. There is no necessity for additional height for run-up or overtopping since the buildings are above high water level.
Table 4.3: Height of bottom level due to sea storms

<table>
<thead>
<tr>
<th>CD +</th>
<th>2,5 m</th>
<th>HHWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>0,5 x 2 m</td>
<td>Maximum wave height</td>
</tr>
<tr>
<td>+</td>
<td>0,25 m</td>
<td>Soil Settlement</td>
</tr>
<tr>
<td>+</td>
<td>0,25 m</td>
<td>Sea level rise</td>
</tr>
<tr>
<td>+</td>
<td>0,5 m</td>
<td>Freeboard</td>
</tr>
<tr>
<td>CD +</td>
<td>4,5 m</td>
<td>Bottom level land reclamation</td>
</tr>
</tbody>
</table>

4.2.2 Required bottom level due to free discharge requirement

In the table below required bottom level for the new land reclamation is calculated based on the necessity for the discharge canal to always discharge freely into the sea.

Table 4.4: Height of bottom level for free discharge to the sea

<table>
<thead>
<tr>
<th>CD +</th>
<th>2,5 m</th>
<th>HHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>2,00 m</td>
<td>Depth concrete part irrigation canal</td>
</tr>
<tr>
<td>-</td>
<td>1,00 m</td>
<td>Bottom level canal beneath HHWL</td>
</tr>
<tr>
<td>+</td>
<td>1,00 m</td>
<td>Depth grass part irrigation canal</td>
</tr>
<tr>
<td>+</td>
<td>0,25 m</td>
<td>Soil settlement</td>
</tr>
<tr>
<td>+</td>
<td>1,00 m</td>
<td>Height to ensure canal slope</td>
</tr>
<tr>
<td>CD +</td>
<td>5,75 m</td>
<td>Max Bottom level land reclamation</td>
</tr>
</tbody>
</table>

At the highest points of the land reclamation the height can be reduced by not or partly constructing the grass part of the drainage canal. Therefore it is advised to construct the land reclamation at a bottom level of 4,75 m above Chart Datum.

Figure 4.1: Layout of weir
4.3 Design canal system
The design of the canal system exists of a design of the layout of the canal system and a design for the canal profile.

4.3.1 Layout drainage canals
If the design for the land reclamation will be executed as it is drawn now, it is well possible to implement drainage canals between the buildings. Multiple layouts can be drawn, but if you use fewer canals, each individual canal needs to discharge a larger area leading to larger discharges and canals. It is not useful to design the location of the drainage more detailed since the design is not very detailed yet, although the artist impression might sometimes give another idea. If the design is revised in another design step drainage canals can be implemented even more easily.

![Simple drainage canal layout](image1.png)
*Figure 4.2: Simple drainage canal layout*

![More complex drainage canal layout](image2.png)
*Figure 4.3: More complex drainage canal layout*

It is important to notice that the big marina area in the middle of the land reclamation will remain on sea level.

4.3.2 Drainage canal profile
Figure 4.4 gives a good idea of how a profile for a drainage canal can look like. There is still much variation possible in the exact dimensions. The drainage canal itself will be constructed of concreted, but also a different alternative with gabions is possible. The concrete is necessary because of the high flow velocities in the canal. A weir is constructed at the sea side of the canal so their always remains a layer of water in the drainage canal. The upper part will be constructed of grass because this only is used in case of extreme discharges.
4.3.3 Resulting water levels in canal

Resulting water levels can be calculated easily with Chézy, although it is an approximation, because a trapezoidal profile cannot be included easily. It is assumed that the water below the weir is not part of the flow profile.

\[ Q = BCh^{3/2}1^{1/2} \]

<table>
<thead>
<tr>
<th>Table 4.5: Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge</td>
</tr>
<tr>
<td>Canal width</td>
</tr>
<tr>
<td>Chézy coefficient</td>
</tr>
<tr>
<td>Bottom slope</td>
</tr>
<tr>
<td>Equilibrium depth</td>
</tr>
</tbody>
</table>

The calculation using Chézy gives that the water level in case of a normal peak discharge will become 0,6 m above the weir height.
4.3.4 Additional requirements
For a good functioning of the drainage canals it is important that the streets have a small slope, which transports the water into small drainage canals. These canals then will transport the water into the large designed canals. A canal management should make sure that the cannal will not be littered or used for activities which have a negative effect on its discharge capabilities.

4.4 Redesign existing drainage
At the moment multiple local urban drainage canals of Manado discharge into the sea at the location where the land reclamation is constructed. In a case of a design with a concrete drainage canal and no canal in between the land reclamation and old coastline, the canals partly might not be able to discharge any more.

The existing outflows of the existing drainage canals that will not be able to discharge anymore are indicated in red. Their outflow can be redirected by enlarging the already existing drainage canals that are indicated with green arrows in Figure 4.6. Nevertheless most of the existing drainage canals will not have problems discharging since the large marina area in the land reclamation and the Tumumpa Dua basin provide the possibility to remain discharging directly into the sea.

Figure 4.6: Adoption of existing drainage
5 CONCLUSION

As described in the outlines of the new land reclamation a canal with a width of 20 meters will be constructed between the former coastline and the new land reclamation. This is to reduce the length of the river towards the sea and make drainage of the city possible. It is important to note that this canal is at sea level and under tidal influence. Also some small drainage canals discharge into this canal.

After an investigation it was determined that it is not likely the drainage canal will decrease the risk of flooding of the Tondano River. Since this was the main reason for the canal, the cheapest option is to not implement the drainage canal. However, the decision to implement the canal could still be made based on aesthetic reasons and the fact it can be used as a drainage canal.

It is expected that there will be settling of sediment into this canal. This is because there are sources for sediment like tidal currents and a small river, but the processes that could take away the sediment are absent.

Siltation of the canal has a moderate impact on Manado, it is very visible in the city and there is high confidence that it will occur. Therefore it is found necessary to find a solution.

There are different solutions to deal with the negative effect of siltation of the canal. Considered are dredging the canal, removal of the canal from the plan and implementing a drainage canal system. In the multi criteria evaluation is concluded that a combination of removal of the canal from the plan and implementing drainage canal system into the reclamation will lead to the highest value.

On the new land reclamation high tropical rainfalls can be expected just like in the rest of Manado. For the new reclamation it is advisable to discharge this rainwater through drainage canals instead of through the streets. A rainfall peak of 17,4 mm/h is expected to be realistic, which results in an amount of 17 Olympic pools to be drained during a rainfall.

A drainage canal can be implemented easily into the existing land reclamation design. The drainage canal requires a width between 8 and 18 meters. To discharge freely into the sea at all times it is advised to construct the land reclamation at a bottom level of 4,65 m above Chart Datum.
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1 EFFECT: INCREASE OF SEA FLOOD SAFETY
The new land reclamation will be erected in front of the existing coastline. This part of the city is now bordering the sea and protected by a rubble mound revetment. When the waves are high these parts of town might be subject to overtopping. Some parts close to the sea suffer from this when flood occurs. If the new land reclamation is finished, this area will be sheltered from wave attack, by the new land reclamation.

The change in flooding possibility from high rainfalls or river floods, depends on the design of the new land reclamation. A canal should ensure drainage sufficiently. Depending on the design of the new land reclamation some drainage canals need to be adjusted. For a small low laying area even pumping might be necessary.

1.1 Impact, visibility, probability
The new land reclamation will very likely diminish the chance of getting flooded by the sea, making the homes of the people that live close to the sea safer. This is something that is very visible, since there is no more wave overtopping in this part and therefore has a high impact on the people. Since this is a positive effect, so no measures are needed.
2 EFFECT: DAMAGING OF CORAL REEF DURING THE CONSTRUCTION PHASE

The Manado Bay has coral reefs on many places. Not only near the islands in the Bunaken National Park but also closer to the city of Manado. On the place of the reclamation itself there is no big coral reef, the closest coral reef is about 5 km away from the reclamation site (World Fish).

During construction, a lot of sediment will be stirred up. This will be transported with the flow. If it can keep in suspension it might eventually reach the coral reef. If the coral reef gets covered with sand, it gets blocked from the sun and it might eventually die. Also limestone and coral materials break into extremely fine particles when dredged, creating milky white clouds that can stay in suspension for a long time and spread over a large area. This results in significant reduction of light penetration and it can impact corals over a wide area (International Association of Dredging Companies (IADC), 2011). This is of course a negative effect, because coral takes a very long time to grow so it cannot easily be replaced.

2.1 Quantification
Since it is not known where exactly the coral reefs in the vicinity of the reclamation site are, it is nearly impossible to tell how large the influence of the building works can or will be. There are several measures that can be taken to reduce the effects though.

2.2 Impact, visibility, probability
Since it is not known where exactly the coral reef is situated in the direct neighbourhood of the reclamation site it is very likely that some of it could get affected by the construction works. This could happen because of presence of coral reef on the location of the building (project impacts) or due to turbidity and sediment impacts (process impacts). The impact can be lethal; causing mortality and changes in species, or sub-lethal; reducing growth rate, bleaching and reducing reproductive performance of the corals. If the more tolerant species survive and the others die, this leads to a reduction of biodiversity.

The visibility of this effect is high, because divers discover the coral reef every day. If they find out a lot of the coral is dead they will look for another diving location. It is also generally a bad effect if any coral gets destroyed due to the building of the reclamation.

2.3 Measures
It must be prevented that the coral reef gets damaged during construction. There are measures that can be taken to provide this. Experts from PIANC and UNEP (United Nations Environment Program) have stated that by adopting sound planning, impact assessment, monitoring and management practices the effects of dredging on coral reefs can be reduced. Also during dredging the effects on coral reefs can be minimised. For example the use of the proper type of equipment, control over leakage, spill and propeller wash and relocating the dredger when necessary. The selection of a decent dredging company, that has provable experience in dredging environmental friendly next to a coral reef, will definitely contribute to this.
3 EFFECT: DISAPPEARANCE OF NAUTICAL HABITAT
When reclaiming land from the sea this inevitably means that one takes away a piece of nature. In the (quite large) stroke of sea considered here, there is a lot of submarine life. The plants and fishes that live here will have to move. For fish this is not such a big problem: the bay is big enough to move somewhere else. But the plants cannot be moved to another location. In European countries there would be a demand to perform “nature compensation”, but this concept has not yet reached Indonesia.

3.1 Quantification
The amount of fish and coral species affected cannot be quantified exactly. Therefore we quantify this as area “destroyed”. This is equal to the size of the reclamation: 0,68 km².

3.2 Impact, visibility, probability
The destruction of habitat for fish is a negative effect of the reclamation, because it disturbs the ecosystem underwater. This might not be directly visible from above the water, but it might have consequences for fishery; the fish population might relocate. Although most fishermen do not fish too close to the shore this might still affect them.

3.3 Measures
A way to compensate for this is “nature compensation”. This is already common in Europe. It means that when you destroy or take away some habitat or natural environment, you create or protect another area at least equal to it, so that there is no fishery allowed there anymore and the ecosystem in that location can remain healthy. So the municipality should indicate an area in the Manado bay that will be protected, so that the destroyed nature is “compensated” for. This could for example be done by increasing the size of Bunaken National Park.
4  EFFECT: INCREASED WAVE REFLECTION
The new land reclamation places the coastline about 250 meters further into the sea. The sea has a
depth of 2 to 5 meters at this point. At the former coastline the waves would break onto a beach or
plunge onto a breakwater in very shallow water (1 to 2 m). In the new situation the waves are
completely reflected by the new revetment leading to higher waves. This has an impact on the
amount of sediment transport along the coast but also on the design requirements for the new
revetment.

4.1  Quantification of problem
The problem will be quantified by looking at the present and the future situation. The change of
wave reflection might also influence the sediment transport.

4.1.1  Amount of reflection in old situation
In the former situation the waves would break onto a beach or plunge onto a breakwater in very
shallow water (1 to 2 m). During most of the time the tide is too low for the water to plunge onto a
breakwater. Only at high water the water is high enough for the revetment to be necessary. In this
case there is a little bit of reflection, but the amount is negligible.

4.1.2  Amount of reflection in new situation
The amount of reflection to be expected at a breakwater can be calculated using figure 10-1 from
(Verhagen, H.J., d'Angremond, K., Roode, F. van., 2009). The Iribarren-number at the structure is
about 4, which indicates the structure must be of the surging or collapsing type. This shows in the
graph of (Zanuttigh and Van der Meer, 2007) that the reflection coefficient, the Kr-value, of the wave
reflection is about 0,4 for a permeable rubble mound breakwater.

4.1.3  Influence on sediment transport
The influence of placing the revetment further into the sea is hard to quantify. Due to placing the
revetment further into the sea, the depth increases. And due to the reflection the wave height
increases, which could lead to more sediment transport. But by placing the revetment further into
the sea, it has been placed outside of the breakerzone. Since the majority of the sediment transport
takes place in the breakerzone, the amount of sediment transport is likely to decrease. This will have
a larger effect than the increasing wave height, so overall the sediment transport along this part of
the coast will probably decrease. This decrease of sediment transport could even be a positive effect,
since the sedimentation in front of the Tondano river mouth will be a bit less.

4.2  Impact, visibility and probability
All the above described effects have a very low visibility. The changes in sediment transport might
only be visible on the long term. A possible change in a higher design wave height might only be
visible to an expert or an observer once a year. Whether they will occur is not completely certain and
therefore classified as likely. The impact is also not directly noticeable and therefore low. It is only
important that a higher wave height is used in computations for the new revetment.
4.3 Need for action
Due to the low visibility and impact of the above described phenomenon it is not necessary to take immediate action. It is only important to take reflection into account in the revetment calculations.
5 EFFECT: LOSS OF MOORING FACILITIES
Due to the new land reclamation, fishermen that used to moor along the existing coastline won’t be able to do that after construction of the new land reclamation.

5.1 Quantification of problem
A quick count using Google Earth shows 93 fishing ships are affected by the new land reclamation. This number is very uncertain, because it is just a snapshot, it also might have increased over the last years.

![Figure 5.1: Locations of fishery boats along original coastline](image)

5.2 Impact, visibility and probability
The impact of losing the mooring facilities has a high impact for the fishermen. It is very annoying for them, because the need to travel to different places further away, but it is not life threatening. This loss is very visible for everyone in the fishing business, but this is an important and large business in Manado. The probability that this will happen is very high, unless the design for the new land reclamation will be adjusted.

5.3 Need for action
A solution for the loss of mooring facilities of the fishermen needs to be found. Loss of space for the fishermen, probably leads to social disruption in the fishing community. The new coastline certainly does not deliver new mooring facilities automatically. Even the two years ago constructed breakwater must disappear. Also the possibility to leave their ship at the coast will disappear with the arrival of the new reclamation. This must of course be compensated.
6  SOLUTIONS FOR THE REDUCTION OF MOORING FACILITIES
There are of course multiple solutions for this problem of which the most obvious one is to build a new harbour. However, the option to let the fishermen moor in the drainage canal still remains. Also there is an option to construct a breakwater like it exists right now.

6.1  Fishing boats in canal
The design for the new land reclamation contains a canal between the original coastline and the new land reclamation. In this way the fishermen can moor in this canal on their original spots, so that nothing really changes. However, it must be estimated what the effect will be on the canal. It might get too crowded. To let the fishermen moor in the canal, there must be made facilities for them. This is important to do, because else the canal will become a sloppy place. To get the new modern look, this will help. The capacity of the canal is considered to be high enough to let 100 people moor their boat easily, which is high enough considering the analysis above.

6.2  Front of reclamation
The second solution is to give the fishermen room to moor at the front of the reclamation. This will result in a situation where people can enjoy the view at the large amount of boats and seeing the fishermen go to work at dusk. This will conserve the typical charisma of the city’s coastline. However, it must be easy for the fishermen to moor their boat. A big disadvantage is that the new coastline will probably exist of a rubble mound revetment. It is very hard for the fishermen to moor at this coastline. And even more, at the new coastline the wave heights will be higher because of the increased reflection.

6.3  Harbour
Another solution can be to implement a small harbour for the fishermen. Good locations for this can be near the Tondano River outlet or at the Tumumpa Dua coastline. It could be possible to create some additional mooring facilities or just use the sedimentation for the boats to moor on. During the fieldtrip is was observed there is no room left in the harbour for new boats, so an extension will be the only way to give shelter to the fishermen.

6.4  Construct a breakwater
The last solution is to construct a breakwater as there is right now. This could be in front of the outlet canal in the middle of the reclamation. But this solution is rather expensive and blocks the sediment transport along the coast even more.
7 MCE: LOSS OF MOORING FACILITIES

Effectiveness is the capability of producing a desired result of one of the solutions. When the solution scores high on effectiveness, it means it has an intended or expected outcome. Whether a solution scores high on constructability is determined by the ease with which a solution can be implemented in the environment. There are limitations, like the depth of Manado Bay and the available area. Also the way it has to be constructed and the scale the solution must be implemented are influencing the score of the constructability. Durability is the ability to endure. It scores high if the solution has a high ability to endure earthquake loads, influence from citizens and water loads. Aesthetics is a branch of philosophy dealing with the nature of art, beauty, and taste, with the creation and appreciation of beauty. A solution scores high on aesthetics if it is expected to appeal to people judgments of sentiment and taste about the new land reclamation. The natural environment encompasses all living and non-living things occurring in and around the new land reclamation. A solution scores positive if it has a positive effect on the diversity of living things around the land reclamation or has a positive effect on the wellbeing of people around the new land reclamation. A solution is given a high score if it has the ability to deliver an additional function, which has a high chance of leading to additional value for the client or the users.

In Table 7.1 the criteria are compared each time to another and determined which of the two was more important than the other. Two points are given to the most important, where the points are equally spread when they have the same importance. The final weight factors are given in Table 7.1.

Table 7.1: Criteria for the solution of the reduce of mooring facilities weighted against each other.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Effectiveness</th>
<th>Constructability</th>
<th>Durability</th>
<th>Aesthetics</th>
<th>Environmental impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Environmental impact</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The solutions of leaving the boats in a new canal along the coastline or replacing the boats to the new coastline are very similar. Both do not require much construction effort. But these solutions have for different reasons mainly a lower reliability. The solution of implementing a new harbour in the reclamation design might have a slightly higher cost, but delivers definitely a high value as can be seen in Table 7.2. However, putting the boats in the canal will give the highest value, but not very high costs.
Table 7.2: Grading of the solutions for the reduction of mooring facilities.

<table>
<thead>
<tr>
<th></th>
<th>Canal</th>
<th>Front of Reclamation</th>
<th>New Harbour</th>
<th>Breakwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>0,37</td>
<td>5</td>
<td>4</td>
<td>1,47</td>
</tr>
<tr>
<td>Constructability</td>
<td>0,05</td>
<td>3</td>
<td>0,16</td>
<td>2</td>
</tr>
<tr>
<td>Durability</td>
<td>0,26</td>
<td>4</td>
<td>1,05</td>
<td>2</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>0,16</td>
<td>3</td>
<td>0,47</td>
<td>4</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>0,16</td>
<td>4</td>
<td>0,63</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4,15</td>
<td>3,37</td>
</tr>
</tbody>
</table>

The effectiveness of the canal is considered to be the highest, because it solves the problem decently and the location is close to the homes of the fishermen. All the other solutions do create mooring facilities, but this criterion gives the canal the maximum amount of points. However the constructability of the four solutions is, considering the mean, not really good. This indicates it will take more effort to give the fishermen their rightful space. This will of course cost money, but taking this into account before the construction begins, one can cope with it and it will therefore not be a problem. The mooring facilities at the front of the reclamation are not considered to be very durable, because the influence of the sea is very large. The same holds for the breakwater, based on the experiences during a fieldtrip. Of course it will be very beautiful to have those boats in front of the coastline. Due to space related arguments and the fact that sedimentation will occur after constructing a breakwater or a harbour, these are not rewarded with high grades for the environmental impact.
8 CONCLUSION

The evaluation of all the solutions gives one winner, namely the storage of the boats in the canal. The boats in the canal must be able to moor, therefore mooring facilities could be integrated in the design of the wall of the drainage canal. However, this is only applicable if the client decides to construct a canal between the existing coastline and the new reclamation.

The construction of the canal is discouraged, based on the research of Appendix H. In this likely case it will become preferable to use the harbour in the existing plans also for the fishermen’s boats. This will give some extra value to the reclamation: harbours normally are very living places, attracting people to have a relaxing time there.

The final conclusion reads: use the canal and a part of the harbour in the new reclamation. The client wants the reclamation have the same charisma as Venice. However, Venice has a problem with congestion in the canals, because there are simply too many boats. The boats in the canal will contribute to the Venice look, but to prevent the same congestion problem, a part of the harbour must be designed for mooring fishing boats.

In case the municipality abandons the canal plan, it is advised to make room for the fishing boats in the harbour of the new reclamation plan. There is not made a severe advice, so the municipality must look at the possibilities themselves. It is recommended to design it for 120 boats.
Appendix J: Recommendations about the new land reclamation’s design
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1 INTRODUCTION
Besides the effects of the reclamation on the environment, this section will elaborate on the reclamation in general. During the analysis of the plans, a few remarkable things were noticed and it might give some surprising results after a small research.

2 CITY DEVELOPMENT
Manado city is more and more becoming a modern city with higher buildings and nice places for shopping and entertainment. However, this also has a counter side, namely becoming a grey city of concrete and getting clogged up with traffic.

2.1 Green area's
The plan for the new land reclamation has high ambitions on the field of greening the city. It will give a lot of possibilities for recreational purposes and will definitely increase the attractiveness of the city. But the actual plans do not fulfil the promise of greening the city. The amount of surface now reserved for green is rather limited to call the streets ‘green belts’. It must be said that in some designs of the greenbelts between the high-rise buildings, there has to be considered if it is really possible for the vegetation to grow on that areas. It is recommended to rather make one big park than to spread the same amount of green over several tiny lanes in the whole reclamation. Just planting trees in the pavements will not only hinder the walking citizen, but also does it not really contribute to a green feeling like a park will do. And if it’s preferred to implement the trees into the streets, they have to be put on green lanes, so they can easily absorb water from the surrounding areas. If the roots of the trees are covered by asphalt, the absorption of water is more difficult(Figure 2.1). Besides that, more water could be drained by the bottom, so less water will flow in the streets during rainfall.

![Figure 2.1: A tree in the street, also hindering people walking on the sidewalk.](image)
2.2 Traffic
Manado knows also a large traffic problem. The increasing amount of cars tend to overload the city. A good first step is to make sure the new reclamation does not increase the existing problems:

- **Make sure that the harbour bridge is finished before starting with the construction of the new land reclamation.** The accessibility of the new reclamation is very much depending on the bridge, which makes the connection to the malls and the economic well developed areas.
- **Think about the road design in the design of the new land reclamation.** Make sure all roads and connections are of sufficient capacity to facilitate the large amount of inhabitants and visitors of the new land reclamation.
- **Adapt the land reclamation to the mikrolet system.** Their efficiency can be improved if the land reclamation provides a logical and efficient route they can follow, like the marina plaza reclamation. Providing them with assigned parking spots could improve travel time of other road users.
- Aside the road a lot of shops and eating facilities are present. However, the noise and the dirty smell of the traffic does not make it attractive to sit there and relax. The shoreline has the ability to become a very popular place to hang out. In that case, it is suggested to make the area a quiet place without cars.

2.3 Sea life museum
The garbage problem is also related to the lack of education of the people. To make them aware of the valuable ecology that is surrounding Manado a sea life museum might be a nice instrument to make them proud on their natural treasure. The museum is also a beautiful attraction for tourists, which can make them more enthusiastic to go diving.
3 COASTLINE DESIGN
The coastline of the reclamation is now only designed to resist the forces of the sea. However, there might be more possible, by making the sea defence multifunctional with the adoption of a beach. Also it is very important for the aesthetics to remain the view on the bay. After having a better look at the sedimentation in the north of the reclamation it was found out there would be a perfect condition the construct a beach. Therefore this recommendation is described in Appendix E: Coastal Effects.

3.1 Sea defence
The municipality planned to make a crown wall on top of the sea defence of the reclamation. This results in a suitable but anaesthetic design. The crownwall hampers the view on the bay, decreasing the value of the reclamation. Besides that, it is also risky. Concrete failure, as is omnipresent at other land reclamation coastline, could lead to high fatalities if the crownwall fails. It is advised not to implement the crown wall, but implement another option. There are numerous other options to achieve the same safety level, but remain the beautiful view on Manado Bay and might be cheaper as well. Instead of the crownwall in the sea defence design, a green buffer zone combined with a higher bottom level, see chapter 3.3, might be a cheaper way to deal with overtopping. This is at the same time a solution for the green recreation areas. Additional research is however still necessary.

3.2 Tsunami danger
Manado is in a tsunami zone, which means that it is necessary to take some tsunami measures in the design of the land reclamations. This can be done in several ways:

- **Implement an early warning system for tsunamis.** If the tsunami is announced early, people have more time to find a safe place.

- **Make sure there is a sufficient escape route from the reclamation.** The roads should be of sufficient capacity to make people flee from the coming tsunami. Not only on the reclamation itself, but also outside the reclamation.

- **Build a safehouses.** It is recommended to build some big buildings tsunami proof. This building should be high and the lower floors should be constructed so that they can withstand the forces of a tsunami wave. This could be a hotel or large office building and should be easily accessible for many people.
- **Build tsunami proof houses.** There are ways to make houses tsunami proof. Building the living room on the second floor and “sacrificing” the first floor to the tsunami will give people a place to hide. The first floor must be constructed to be able to withstand tsunami forces, so this option might be expensive.

### 3.3 Bottom level
Constructing the new land reclamation just a single meter higher than exiting land reclamations has many advantages. The first one is the sea defence adds to the coastal safety by reducing the chance of wave overtopping or wave run up. Combined with the advice chapter 3.1, the coastline aesthetics will increase and it will have the same safety level. The second advantage is that good urban drainage requires some slope to runoff and quickly discharge into the sea. The third advantage is that a higher bottom level increases the resilience of the reclamation against threats as tsunami’s and future sea level rise.
4 CONSTRUCTION ASPECTS
The construction of a the current reclamation is sometimes not as well as it looked on the design table. Rocks are falling of the sea defence wall and concrete shatters into pieces. Also the municipality considers to construct the reclamation the Dutch way: making a polder.

4.1 Construction method
To make a decision between the two construction methods that were proposed by the municipality, first the purpose of the reclamation must be considered. The municipality wants to create a new area, with nice green areas, beautiful apartments, business units and recreational opportunities. From this it will be a missed chance to construct the reclamation as a polder. A polder implies also a dyke which will reach higher than the land. The result will be a barrier that hindres the view from the reclamation. From this point of view it is recommended to construct the new reclamation as all the other reclamations: the timbunan way.

4.2 Geo-technics
Manadonese people value the lifetime of their bought product very much. They are known for keeping the protection foil on a product for its entire lifetime. Nevertheless lots of their recently constructed buildings are disintegrating very rapidly. One of the reasons for this loss of value is in the field of geo-technics. Therefore it is necessary to make sure the dumped soil for the new land reclamation settles long enough. There are many methods to speed up this process like compaction and drainage. Many of the cracks in buildings on existing land reclamations might be due to unequal settling of soil.

4.3 Sea defence
According to an expert of the university, the collapse of many parts of existing reclamations can be subscribed to the way the sea defence is constructed and designed. The rubble mound sea defence is bearing a geotextile, which gives the structure a higher stability. Also the rubble mound is not applied in such a way the rocks interlock with each other. In order to get a stiff construction, it is very important to check the interaction between the stones by divers. Also the rock sizes need to be sorted, so different layers could be built and will take care of a better stability.
5 RESOURCES
Now a short look is taken at the resources of the reclamation is. The city of Manado struggles with its electricity supply and at some reclamations one can see that there is not thought about everything people need, like parking spaces.

5.1 Facilities
Prior land reclamations sometimes lack essential infrastructure. Other land reclamations have very diverse land uses. Sometimes more design guidance could improve the wellbeing on the land reclamation.
- A diverse use of the land reclamation can improve everyone’s value. By including enough parking spaces, hospitals, sport facilities, shops or a police station nearly all parties benefit. By assigning housing, business, hospitals, shops with logical locations their value can be improved.

5.2 Self sufficiency
Important networks of the city of Manado have problems with reliability and capacity. Think about the electricity, sewage, drinking water and garbage handling. Make sure the new land reclamation does not pose an additional load on these sensitive systems.
- Try to make the new land reclamation as self-sufficient as possible by demanding this strictly from the developer. A land reclamation that is self-supplying for its electricity and its waste water treatment is very realistic. Self-sufficiency on the field of garbage treatment and drinking water is a little bit more difficult or expensive but certainly worth to take a look at.
- Manado already has a great garbage treatment problem. The capacity of garbage handling services is too low and a new reclamation will not be helpful to this. The new shops, restaurants and houses will generate a lot of extra garbage. It is recommended to implement a garbage collection system especially for the reclamation area. This has to be good enough to deal with all the garbage created on the reclamation, so that the reclamation can be garbage-neutral. In this way the reclamation has no effects on the current garbage problems.

5.3 Demand
It is probably worthwhile to take a look at the demand of the people that live in Manado. The land reclamation in the north will probably be a lot more profitable if it meets the demand of the people that live close to it. Thereby the most malls now have a lot of the same shops. It could be investigated whether an extra KFC is really necessary.