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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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 report is the result of a groupwork of four students Hydraulic Engineering of the University of Technology Delft. It is an advice to the municipality of Manado, Indonesia. The demand of the client was to investigate the effects of a planned reclamation on the environment of 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 Tondano River, which has a high risk of flooding. Also the garbage treatment problem of the city, which results into large quantities of garbage in the rivers, has to be investigated.

This research is a part of the study Civil Engineering and when the result is satisfying the students get a reward of 10 ECTS, which is equivalent to the work of seven weeks. The project is supported by the companies VanOord and Deltares. Also some funds contributed to the research expenses like tickets and research material: the Hydraulic Engineering Department of the TUDelft, the University Fund Delft and Students4Sustainability.

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 place to work. 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 and welcoming us to Manado. Finally we want to thank all the other people that made our stay in Manado worthwhile.

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

Wednesday, 16 October 2013. Manado
ABSTRACT

Manado, the capital city of North Sulawesi in Indonesia, is rapidly developing. The last years Manado has been extending into the sea, which changed the hydraulics and morphology of Manado Bay. This had negative effects on the currents, inducing erosion along the coast. Also Manado has problems with the presence of garbage in the rivers and river flooding. Now the municipality is planning to build a new reclamation, which might even increase these problems. Based on the requests of our client Mr. Assa, head of the Planning Department of the City Manado, the following project goal has been formulated.

Project Goal
‘The goal of the project is to give a research-based advice on the erosive and littering influences on Manado’s surrounding nature, induced by hydraulic and morphological changes caused by the planned land reclamation, and to describe measures to mitigate the detrimental effects to support Manado’s vision of becoming a model city of ecotourism.’

Present situation
The Bunaken National Park in front of Manado Bay contains unique coral reefs. Also there is a valuable mangrove forest present in the north of Manado. However, these mangroves have been eroded as a result of human harvesting and the construction of the Bailang harbour, leading to a coastline retreat of around 100 meters.

The tide is of great influence on the coastline. The coastline is subject to a mild wind and wave climate, due to the sheltered location and the very large depth of the bay. The wind set up is negligible, but the wind induced current is important for the garbage flow in the direction of Bunaken National Park. The construction of the land reanimations and the Bailang harbour breakwater, caused significant changes in the dominant alongshore sediment transport directions.

The Tondano River has flooded about 10 times over the past 20 years, with high consequences. There is already a plan to improve the river banks, which will reduce the flood risk. The people produce a lot of garbage, of which a considerable amount ends up in the rivers and in the coral reefs.

The effects and their solutions
The to be constructed land reclamation is expected to have the following effects on its environment:

- Sedimentation and garbage settlement at the mouth of Tondano River are likely to happen. This will lead to an increase of flood risk upstream. Which can be prevented by dredging the river mouth;
- Both sedimentation and erosion are expected near the Tumumpa Dua coastline. By implementing a beach in the reclamation design the sedimentation can be used beneficial and also the erosion will be stopped;
- Increased erosion and mangrove retreat due to the construction of the new land reclamation is not expected. But a cure for the existing erosion and mangrove retreat is proposed and designed;
- The proposed canal between the existing coastline and the new land reclamation is expected to be silted within a few years. Placing the canal above sea level can prevent this.
A step forward on solving the existing problems of Manado can be made by implementing the following solution plans:

- The erosion and disappearance of mangroves north of the Bailang river mouth can be restored by implementing the Erosion Prevention Plan;
- A garbage rack in combination with improved education, will lead to a significant reduction of the garbage outflow of Tondano River;
- The River improvement plan by the firm of Yachiyo Engineering will lead to the reduction of the flood risk within Manado City.

By adapting the design at some points the new land reclamation can create additional value without high additional costs.

**Final conclusion**

A new reclamation will have large influences on the environment of Manado Bay. Sedimentation and garbage settlement at several spots around the reclamation are likely, coral reefs will be affected during its construction and higher water levels on Tondano are also expected.

All the researched negative effects of the planned land reclamation can be prevented or mitigated separately by above mentioned measures. But failure to implement one of these preventing or mitigating measures will result in a large threat for the people or the environment of Manado. This risk might only be justified if a demand for further city expansion has been proven and if all other development options for unused land within Manado city and less preferably the mountainous hinterland have been excluded.
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1 INTRODUCTION

Manado is the capital city of the province Sulawesi Utara, situated in a bay of the Celebes Sea. Manado has about 500,000 inhabitants which are mostly Christian. In Manado bay the Bunaken National Park is found (see Figure 1.1). This is a protected nature reserve which houses an extraordinary ecosystem and therefore is a very popular diving location. The city is rapidly expanding, which has led to the construction of several land reclamations around the coast. The hereby created area is mostly used for shopping malls and other business. The land reclamations have also led to a change in the hydraulic conditions in the Manado Bay, which has had several negative effects. Nowadays the municipality is planning a new reclamation in the north of the city.

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

1.1 Problem definition

In consultation with the client the present problems of Manado have been classified into the categories coastal erosion, garbage and Tondano River flooding. These will be elaborated below. Besides the effects of the new planned reclamation also the current problems will be considered.

1.1.1 Coastal erosion

Since the existence of the already completed land reclamations, the coastline north of Manado is experiencing moderate erosion. As a result of this, 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.

1.1.2 Garbage

The garbage treatment of Manado is not sufficient. The rivers bring a lot of garbage towards the sea, especially during high discharges after intense rainfall. This garbage flows towards Bunaken National Park. Since the coral belongs to a protected nature reserve, a very popular diving location, this should be prevented by getting the garbage out of the river before it enters the Manado Bay.
1.1.3 Tondano river flooding
The Manado climate contains a rainy period which leads to higher discharges in the rivers that run through Manado and the surrounding area. Increasing population of Manado has led to uncontrolled habitation of the lower river banks. Since this cultivation has decreased the room for the river, and thereby increasing the flooding probability, this has become a problem.

1.1.4 New land reclamation
The municipality of Manado has planned a new land reclamation north of the existing ones. The client wants to know what the effects will be of the land reclamation on the hydraulics and morphology in Manado Bay. It should be investigated whether these effects are of negative influence to the currently existing problems.

1.2 Project Goal
The goal of the project takes both the current situation and the given plans for the reclamation into account. It has to be investigated whether the land reclamation will influence the sediment balance, the nature of currents and the risk of flooding of the Tondano River. Also the effects of these changes have to be elaborated. If necessary, measures are proposed to mitigate any negative effects the design has on the surroundings. Also a research to possible improvements of the reclamation will be executed.

Project Goal
‘The goal of the project is to give a research-based advice on the erosive and littering influences on Manado’s surrounding nature, induced by hydraulic and morphological changes caused by the planned land reclamation, and to describe measures to mitigate the detrimental effects to support Manado’s vision of becoming a model city of ecotourism.’

1.3 Research methodology
The first step in this research is to gain a good understanding and description of the existing coastal system by going on a fieldtrip with a local expert and by talking to local people. Also digital information will be used. This contains all described problems and their causes and effects in a qualitative way. As far as possible, parameters are quantified based on other research. Then the planned land reclamation is placed into this analytical model. This new land reclamation changes the parameters of this model, leading to effects on the coast, the garbage flow and water levels in Tondano River. Once these effects are known, further investigation can clear whether they are desirable, where after possible solutions will be derived and advised to mitigate the effects.

1.4 Boundary conditions
In order to be able to finish the project within the prescribed time some boundaries have been set. The project is bounded by spatial boundaries and thematical boundaries.
Figure 1.2: Project boundaries on macro and meso scale

The spatial boundaries are defined twice; i.e. on macro and meso scale. Our project is divided into two systems, namely Manado Bay, including the Bunaken National Park, and the coast of Manado, including the outlets of the rivers. The project boundary on macro and meso scale are shown in Figure 1.2 with the green line.

A multidisciplinary coastal zone management problem like this acts on multiple levels: i.e. on a technical, ecological, economic, political, etc. Thematically we bounded ourselves to research the theme’s that are directly related to the water an ecological issues of Manado and lead to a valuable research for the client. These themes can be hydrological studies, morphological studies or advices related to the garbage or tourist issues of Manado.

1.5 Accuracy
The research was highly dependent on data provided by different resources. Some of this have been provided by research institutes or the client and these are assumed to be accurate. Some other data have been found on the internet. Like most of the times during a research project, not all the data was available, and therefore assumptions had to be made. One can think about detailed information about the currents, the actual sediment properties and transport, the garbage distribution in the rivers and in Manado Bay, discharges of Tondano River and the influence of the present ecology. The results of the research on the hydraulics and morphology are mainly based on gained knowledge of Coastal Engineering and are only qualitative. The executed calculations are made by hand.

1.6 Structure of the report
The report begins with a short introduction about Manado, after which it continues with an analysis of the present situation of the functions in the area, the hydraulics and morphology, the properties of Tondano River, the ecology and the garbage problem. In chapter 3 the future situation refers to Manado Bay with the construction of a new land reclamation. The effects of the reclamation on the hydraulics and the morphology are elaborated, together with other, but smaller, effects. In chapter 4 several solutions for the occurring problems are described, followed by advices for the client in Chapter 5. Chapter 6 gives the conclusion for the whole project. Finally chapter 7 gives recommendations for further research. The used resources are mentioned in the bibliography in chapter 8. All research and detailed designs can be found in the appendices.
2 PRESENT SITUATION

Manado city and its coast are rapidly developing. Megamalls were built on reclaimed land and many construction projects are being executed. The present state of the Manado Bay area is investigated in order to get a good understanding of the current coastal system. Once it is known what the essential performance parameters along the coast of Manado are, it is possible to check how they might change with the appearance of the new reclamation. Therefore the area is researched on its most important aspects, including by the use of a fieldtrip (see Appendix A). Because the land will be reclaimed from the sea, the morphology, hydraulics and ecology are investigated. The client also asked for a solution for the garbage in the Tondano River, the main river of Manado.

2.1 Manado and its surroundings

The Manado coastal zone houses important economic and ecological functions. In Manado a large amount of the 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 (the red circles in Figure 2.1). There are two exceptions, namely the main harbour next to the Tondano River and the Bailang Harbour. The function of these harbours is also to moor ferry lines. They are drawn in Figure 2.1 as squares.

![Figure 2.1: Overview of Manado Bay with the main functions and outlets.](image)

The largest reclamation at the middle of the Manado bay is the Marina Plaza land reclamation, which is still partly under construction. This reclamation, with multiple megamalls, has become the heart of the city’s business, shopping and leisure sector. A lot of people think this reclamation was the devil in the change of the currents in Manado Bay that caused the transporting of garbage towards the Bunaken. The bulb in the middle of the Marina Plaza reclamation holds probably the most blame, because it extends far into the sea.
2.2 Ecological assets
North Sulawesi is especially known for its diverse coral reefs, but also other important ecosystems are present in the area like mangrove forests along the coast and the fruitful tropical forests between the volcanoes.

2.2.1 The coral reefs
The coral reefs within Bunaken National Park provide the region with some valuable ecosystem services. The coral reefs protect the shoreline against waves and provide the people with fish and construction material. Besides that the 2500 different species of fish, turtles and large numbers of different corals attract a lot of tourists every year. At last the coral reefs play an important role in the nutrients cycle and the food supply for the fish. The services can also be monetized with caution according to (UNEP-WCMC, 2006) Annual values per km² have been calculated at US$100 000-600 000 for reefs in general. So protecting the Bunaken National Park will also be fruitful financially!

In Manado Bay a lot of valuable coral reef is present (see Figure 2.1). The coral reef is located at about five kilometres out of the coast (World Fish). The coral reefs closer to the coast of Manado have partly been destroyed by former land reclamations. Active threats for the reefs are generally human induced: like coral mining, irresponsible diving, garbage pollution originating from Manado, overfishing and a lack of professionalism of the Bunaken Park authority.

2.2.2 Mangroves
The mangroves around Manado provide the region with some valuable ecosystem services defined according to Ecosystems and Human Well-being: Synthesis (Millennium Ecosystem Assessment, 2005). This assessment states mangroves protect the beaches and shoreline against waves, surges and floods. Mangroves also provide area for fish, wood and herbs. The mangroves give shelter to a lot of fish species that also live in the corals of Bunaken National Park.

Active threats to Manado’s mangroves are also mainly human induced, of which the largest are clearing of mangroves, overharvesting and garbage pollution. Aquaculture is not an active threat to the mangroves in Manado, since only in the past shrimpfarms where operated and only on a small scale. For other threats a reference is made to Chapter 5 in Appendix B.

North of Bailang River mangroves have retreated for almost a hundred meters over a length of 500 meters. A combination of human threats like overharvesting and the construction of the Bailang Harbour caused this erosion. 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 Bailang Harbour breakwater. This breakwater led to sedimentation is front of the Bailang River outflow, pushing a large flow of freshwater through the mangroves.

2.3 Important players
For the initiator of the project it is a must to know which parties are able to really influence the project and whether it is in a positive or a negative way. In Appendix D a summation of all the stakeholders and their relationship to each other is described. These relations show the importance of each particular stakeholder.
The municipality of Manado is the stakeholder with the highest influence and the strongest arguments pro the reclamation. The municipality has a monthly meeting with the NGO’s concerning the environment which gives the NGO’s a not to be underestimated influence on the project. They are against a new reclamation, unless the result of the project is highly positive for both the economy and the environment (NGO-representative, 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, despite any negative effects on the environment. These three parties form the core of the different interests in the new reclamation.

The citizens that are now living at the coastline will get influenced by the reclamation the most. Their influence is considered to be reasonable. They can protest against a new reclamation which already has been done successfully in the south of Manado. However, normally citizens seem to be reasonable against new plans, so the chance they will protest is not very high.

2.4 The hydraulics of Manado Bay

The important events which formed the coastline over the years, are the wind and wave attack, the tide and the currents. These events are important to take into account by adapting this coastline. These events could cause extra effects, like wind set up in Tondano River, which could be detrimental.

The tide is on great influence of the coastline of Manado. North of the city mangroves are situated, whose health is depended on the tide. The largest difference between high and low water is 2,4 m. The tide comes up in a counter clockwise direction through the Bay.

The wave heights in the Manado Bay are not very high, i.e. 1,5 to 2,0 meters. Two reasons for this are the sheltered location and the very large depth of the bay. The dominant wave direction in the area is directed of coast. For the waves directions that can enter the Manado Bay, most common direction is the North-West, the second most common direction is the West-North-West. These directions are very important for the sediment transport, shown in Figure 2.2. It is indicated by the client that Manado is situated in a tsunami prone area.

Wind causes waves, currents and set-up. The winds causing the waves occur offshore, so these will not be considered, since they are implemented in the wave data. But the dominant wind directions in the Manado Bay are coming from the south and the south-south-east. These are especially important for a current in the bay which drives garbage to the Bunaken National Park (the green arrow in Figure 2.2).

The flow pattern in front of the coast of Manado is very complex. It has changed in the years since the construction of land reclaims in front of Manado. Especially the bulb in the large Marina Plaza reclamation had a big influence on the current pattern. Important currents are the tidal, rip and alongshore currents, because they drive the sediment transport, but also bring the garbage flow into the wind current. In the Hydraulic Analysis in Appendix B, these effects are described carefully. An overview of the dominant occurring events is shown in Figure 2.2. The flow directions of Figure
2.2 are based on 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.

![Figure 2.2: Hydraulic and morphological system of Manado Bay.](image)

2.5 **Morphological system**

Most of the problems occurring at Manado’s coast are part of the morphological system. The erosion and sedimentation on certain locations, are caused by the differences between incoming and outgoing sediment transport at those locations.

Even before the construction of the planned reclamation, problems are present along the coast. As described in paragraph 2.2.2 mangroves North of Bailang River have retreated several hundreds of meters. Also the construction of the large breakwater of the Bailang harbour caused erosion at the coastline of the residential area Tumumpa Dua south of it. Sedimentation is clearly visible in front of both the Bailang and the Tondano River mouths.

The construction of the land reclamations and the Bailang harbour breakwater, caused significant changes in the dominant alongshore sediment transport directions. Due to two alongshore currents meeting each other at some locations, rip-currents occur, which drive the sediment off shore. Strong tidal currents can turn the sediment transport around, but the directions indicated in Figure 2.2, are the dominant and most common directions. Important to notice is that the wind induced current in the bay doesn’t have influence on the sediment transport, because it only affects at the top layer, just under the surface, where the sediment is not situated. The morphodynamics are elaborated more in Morphological Analysis in Appendix B.
2.6 Tondano River

The Tondano River meanders from Tondano Lake upstream through the heart of the city Manado to the outlet north of the Manado harbour. It confluences with Tikala river inside Manado city. Both rivers originate from multiple branches which confluence mostly just outside the city border. The Tondano River has a highly varying river profile, due to the meandering and the space it was given by the people of Manado. For the technical properties of Tondano River a reference is made to Chapter 4 in Appendix B.

2.6.1 The problem of Tondano River

The Tondano River has flooded about 10 times over the past 20 years, killing multiple people each time and damaging more than 10,000 houses last time. The problem of the river is its narrow branches inside the city centre and the fact that during high tide the effect of the sea level is noticeable within the whole city. The tidal range is up to 2,4 meter and apparently most of the floods occurred during high water in the sea. The water is also blocked by the large amount of obstacles, mainly at the river banks. People constructing houses at the river side and in the floodplains, have constricted the river into a very small profile and thereby endanger themselves and the other inhabitants of Manado.

Three upstream dams have been constructed in the last years, completely upstream the storage capacity of Tondano Lake has decreased and excavation works in the hills might have led to extra sediment and more peaked discharges.

The high discharges are mainly caused by intense rainfall. Because (green) retention areas are missing in the city the water flows immediately into Tondano River, giving it a more peaked discharge. The below described plans are based on an observed peak discharge of 300-350 m³/s, although there is still discussion about the actual peak value.

2.6.2 Improvement plan

The municipality is already making plans for the improvement of the river profile. Basically they are going to smoothen the river banks with concrete sheetpiles over the last 7,2 kilometre of Tondano River. Small dikes will be constructed along the river topped with a crownwall, but biggest advantage of this plan is that it widens the river a little bit. An example profile of this plan is shown in Figure 2.4.
Figure 2.4: Cross-section of the Tondano River plan and a summary of the Tondano River

2.7 Improved garbage

The main river outlets are also drawn in Figure 2.1. During an inspection a lot of the garbage was discovered in the south of Manado in the direction of Malalayang. 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 is observed that the garbage is still thrown away in the rivers. Until now a real solution for keeping the water clean has not been implemented.

A research of the Research Triangle Institute from America gave some detailed information about the garbage problem in the Manado area. The garbage collection in the streets has been improved a lot the last few years. The total uncollected waste everyday was estimated to be 484 m³. It is assumed that half of this ends up in Manado Bay by the rivers, rounded to the number of 250 m³. With the sea current taking into account, it is likely that at least 63 m³ ends up in Bunaken National Park.

The problem of the garbage is not only that it is very unhealthy, it also gives a bad smell. After the municipality build a garbage collection point in the river, that smell was the reason for people living close to the collection point to demolish it. This must therefore be prevented. Another very good reason to get rid of the garbage is the blocking of the discharge of the river and the drainage canals. The garbage has a visible effect on the discharge.
3  FUTURE SITUATION
A new land reclamation is planned at the northern part of the city. Past reclamations have been made in the southern and middle part of the coast of Manado, leading to economic development in these areas. The new reclamation should give a same impulse to the northern part of the city.

3.1  New land reclamation outline
All information about the new land reclamation design originates from a presentation with multiple sketches and images on this latest design. The most essential parts are presented below in the form of a few drawings and some key issues translated from the Indonesian presentation.

3.1.1 Location
The new land reclamation will be located 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 3.1.

3.1.2 Dimensions
The planned reclamation will have a total length of 2.9 km and will stretch into the sea for about 250 to 300 meters as shown in Figure 3.2. In this figure the total area is indicated to be 0.662 km². It also shows that the sea has a maximum depth of -2 to -5m below the reference level. If a canal of 20 meters width is included between the coastline and the reclamation is implemented, as described in 3.1.5, the land reclamation extends more than 300 m into the sea up to the -20 meter contour line.

Figure 3.1: Location of the planned reclamation

Figure 3.2: Depth at reclamation site, Source: (Assa, 2013)
3.1.3 Construction method
Traditionally the land reclamations along Manado’s coast are constructed of large rocks and sand. Large volcanic rocks from the mountains are sufficiently available. They are used to construct a rubble mound revetment as the new coastal defence. At the same time the land reclamation is filled up with sand from the hinterland. Here land is excavated to flatten the land and make it available for urban development.

3.1.4 Green belt
The municipality wants to increase the amount of green within the new land reclamation as indicated in Figure 3.3. For this they have looked at several examples from all over the world where green belts have been applied successfully. The green areas could improve the value of the area, by increasing its liveability, but also give shadow against the sun. The green belts could also host small retention basins or canals for excess rainwater.

Figure 3.3: Artist Impressions city proposed green, Source: (Assa, 2013)

3.1.5 Canal
At former reclamations the new river mouth was subjected to a lot of siltation. This, together with the associated extension of the river increased the flood risk upstream. According to the latest update of the plans of the new land reclamation there will be a canal between the present coastline and the reclamation. Its main function is to reduce the length of the rivers toward the sea. The canal will also have a function in drainage and aesthetics. Because of the canal, the new land will be connected to the mainland by bridges. In Figure 3.4 the location of the canal is indicated in blue and possible bridges are indicated in red. The effect of including such a canal at the reclamation is described in chapter 3.3.

Figure 3.4: Location of a possible canal in the new land reclamation
3.2 Considered effects of the new land reclamation

A quantitative analysis was executed about the effects of the planned reclamation. Since the main coastal processes are described in chapter 2, it is possible to check how the land reclamation changes the current situation. The three main subjects garbage, erosion and flooding of Tondano River, were mainly considered. A brainstorm resulted in effects that are probable to occur. The numbers in Figure 3.5 give the location of occurrence of the considered effect.

![Figure 3.5: Locations that are possibly effected by the planned land reclamation.](image)

In the figure the reclamation area is indicated in orange. The outcome of the brainstorm session is shown in Table 3.1. In this table the effects are divided into the categories Garbage, River, Erosion and Planned reclamation. The last category contains effects that do not belong to the first three categories. These are also of importance for this research since they also affect the coastal zone and the environment of Manado, and the people living there.

For all effects it is evaluated whether they are positive or negative, what the magnitude of their impact is and what their probability of occurrence is. The influences are generally negative. The most important effects will be investigated and if necessary a solution will be elaborated.

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<th>Theme</th>
<th>Location</th>
<th>Effect</th>
<th>Positive/Negative</th>
<th>Impact [High/Low]</th>
<th>Probability [High/Low]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>1</td>
<td>Garbage Settlement</td>
<td>-</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>R</td>
<td>1</td>
<td>Sedimentation</td>
<td>-</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>Erosion</td>
<td>--</td>
<td>L</td>
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<tr>
<td>P</td>
<td>3</td>
<td>Increase of wave reflection</td>
<td>-</td>
<td>LL</td>
<td>H</td>
</tr>
<tr>
<td>R/P</td>
<td>4</td>
<td>Siltation of drainage canal</td>
<td>-</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>R</td>
<td>5</td>
<td>Flooding due to silation at [1]</td>
<td>--</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>P</td>
<td>6</td>
<td>Increase of safety against the sea</td>
<td>++</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>P</td>
<td>7</td>
<td>Reduce of mooring facilities</td>
<td>--</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>P</td>
<td>8</td>
<td>Damaging coral due to construction works</td>
<td>--</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>P</td>
<td>9</td>
<td>Disappearance of nautical habitat</td>
<td>--</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>E</td>
<td>10</td>
<td>Violation of the mangroves</td>
<td>--</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>E</td>
<td>11</td>
<td>Diversion of the current</td>
<td>+</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>R</td>
<td>12</td>
<td>Storm surge</td>
<td>-</td>
<td>H</td>
<td>L</td>
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<tr>
<td>G</td>
<td>13</td>
<td>Garbage distribution</td>
<td>+-</td>
<td>H</td>
<td>M</td>
</tr>
</tbody>
</table>
3.3 Likely effects of the planned land reclamation
An analysis of all possible effects gave as a result that the following effects can be classified as likely of very likely. Most of these effects also have a relatively high impact. The statement whether these effects are likely or not is mostly based on a small quantitative model, a few calculations or multiple expert statements.

3.3.1 Sedimentation at the Tondano River mouth
In the present situation the sea right in front of the river mouth is already very shallow due to sediment outflow from Tondano River merging with alongshore sediment flows from two directions. The new land reclamation will lead to increased sedimentation at Tondano River mouth, as can be seen in Figure 3.6, due to two processes:

- The new land reclamation places the river mouth further into the sea, which will lead to a new equilibrium inducing a positive bed level step at the river mouth.
- With the construction of the reclamation, the space where sedimentation already occurred, will decrease. This causes that the sedimentation concentrates in front of the river mouth.

![Figure 3.6: Sedimentation near Tondano River mouth](image)

3.3.2 Increased flood risk due to sedimentation
If sedimentation near the mouth of Tondano River occurs this may have major consequences to the upstream parts of the river. Sedimentation around other land reclamations has led to an extension of the river. Due to backwater effects this led to an increased bed level upstream and thereby increasing the flood risk upstream. If the sedimentation around the river mouth is not treated properly this might also happen here.

In the case of Tondano River this means that the river mouth will be relocated 250 m into the sea. This will cause a bed level step if the sedimentation in the mouth of Tondano River and an increase in the bed level upstream of 4,2 cm. This may not seem much, but taking the current flood risk into account this is an increase that will increase the severity of the presently occurring floods. This can have major consequences like loss of property or even fatalities.

3.3.3 Erosion and Sedimentation at Tumumpa Dua
Between the Bailang harbour and the planned reclamation, there will be an indent in the coastline in front of Tumumpa Dua. Due to the blockage of sedimentation by the reclamation, the sediment cannot leave the indent. An eddy already brings the sediment in the corner of the Bailang harbour
and the coastline. This process will continue, because the harbour breakwater that causes it, will not change. So there will be accretion in the indent, because the inflow of sediment is higher than the outflow. This doesn’t look nice next to a brand new structure and also could block the canal, which is described in paragraph 3.1.5.

Due to sheltering of waves by the Bailang harbour, no sediment is supplied to the coastline in front of the residential area Tumumpa Dua. Because there is no protection here the coast will erode. After the construction of the reclamation this could still occur, unless the above described sedimentation is very large and overrules the erosion at this location. If this will not happen, measures need to be taken against the erosion. Both events are illustrated in Figure 3.7.

![Figure 3.7: Future effects around the Bailang harbour](image)

3.3.4 Garbage Settlement at the Tondano River mouth
Due to the same processes as described in 3.3.1 not only sediment, but also garbage will clog up at Tondano River mouth. This will of course result in a smell and a non-attractive view. However, not the settlement of garbage is the problem, but the existence of the garbage in the river is the real unwanted problem. Therefore not this settlement is treated, but a solution to get the garbage out of the Tondano and Tikala River is considered.

3.3.5 Siltation of the canal
Between the new reclamation and the original coast there will be a canal, as visible in Figure 3.4. It is important to note that this canal is at sea level and under tidal influence.

![Figure 3.8: Rivers at new land reclamation(left) and flooding potential(right), Source: (Assa, 2013)](image)

There is high confidence that there will be significant settling of sediment into this canal. This is because there are sources for sediment like tidal currents and some rivers(Figure 3.8) are present,
but the processes that could take away the sediment are absent. The canal is very sheltered from wave action, so the amount of sediment that will be stirred up is minimal. Also the flow velocity of the river is too small to fulfil this function, because the canal is multiple times wider than the river. This would lead to a shadow effect for the canal in which accretion will take place. A rough calculation leads to the expectation that the canal will be completely filled with sediment within three years!

![Figure 3.9: Canal system(blue) including entries(red)](image)

3.3.6 Damaging of coral reefs due to construction works

There are lots of coral reefs present in Manado Bay. Sediment that is stirred up during construction can stay in suspension very long so that it might reach a coral reef. Also limestone materials break in very fine particles and spread over a large area. This blocks the sun and this impacts the coral and can lead to a reduction of the growth rate, bleaching or even mortality and changes in species. Also the construction works itself can damage coral reefs if it is performed near the coral reef. According to (World Fish) the closest coral reef lies 5 km away from the construction site but this information is very coarse. There are several ways to prevent the damaging of corals during construction; this will briefly be discussed in chapter 5.1.

3.3.7 Disappearance of nautical habitat

Due to the new reclamation a piece of sea of 0.68 km² in Manado bay, with a large amount of submarine life, will be removed. The destruction of habitat for fish is a negative, 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. A measure could be to apply “nature compensation”, as explained in chapter 5.1.

3.3.8 Increase of protection against the sea

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 breakwater. When the waves are high these parts of town might be subject to overtopping. Some parts close to the sea suffer from this when flooding occurs. The new land reclamation will very likely diminish the chance of getting flooded by the sea, since it will become sheltered from wave attack, making the homes of the people that live close to the sea safer.
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.

3.3.9 Decline of mooring facilities
Due to the new land reclamation, fisherman that used to moor along the existing coastline won’t be able to do that after construction of the new land reclamation. The new land reclamation design doesn’t facilitate sufficient suitable mooring locations. A quick count shows about 90 fishing ships are affected by the new land reclamation. A solution for the loss of mooring facilities of the fisherman needs to be found, because not doing so, could lead to social disruption in the large fishing community. In chapter 5.3 the final solution can be found.

3.4 Non-likely effects or non-excludable effects of the new land reclamation
An analysis of all possible effect gave as a result that the following effects can be classified as unlikely of very unlikely. Also the effects that couldn’t be excluded to happen, for example because of a lack of information, are listed over here.

3.4.1 Mangrove retreat (Non-likely)
The hydraulic analysis in Appendix B shows that the construction of the new land reclamation doesn’t change the direction or velocity of the currents north of the Bailang River. The mangrove trees are morphologically upstream of the considered new land reclamation, as visible in Figure 3.11. (Any Mangrove trees south of the city are too far away to be influenced.) The direction of the current changed in the past due to construction of a harbour. The breakwater of the Bailang harbour changed the river outflow leading to mangrove erosion at this location. The effect of this breakwater is much larger than any effect the new land reclamation will have.
3.4.2 Increase of storm surge (Non-likely)
It was suggested that due to the form of the new land reclamation, the amount of wind set-up at Tondano river mouth could change. An increased water level at Tondano River mouth could lead to higher water levels upstream and increase the flooding possibilities. It has been concluded in Appendix B that this additional storm surge height, due to the construction of the land reclamation, is not expected. The wind set-up is presently negligible due to the deep foreshore. In the future this will also not change.

3.4.3 Different garbage distribution (non-excludable)
Some people say that due to land reclamations build in the past the garbage flows are more diverged over Manado bay. The new land reclamation could change the way garbage from Tondano River is spread over the bay into the sea. Since the river mouth is placed further into the sea, you could say the garbage is picked up further into the sea by the wind induced current. Therefore it might not end up at a local beach, but further away. Unfortunately, the understanding of the change in current at Tondano River mouth and of the garbage drift, is not detailed enough to make a statement on this point.

But what can be stated is that any garbage flow into the sea is unwanted in any direction. Therefore it is advised to spend most attention and money into preventing garbage from flowing out of the Tondano River instead of diverting it into another direction. In chapter 4.2 and more elaborate in Appendix F a solution is presented, to conquer the garbage problem.
4 SOLUTIONS
The already existing problems that need a cure are the erosion of the coastline and the garbage flow from the rivers into the sea. The found solutions for these will first be described in this chapter. The new reclamation is also expected to bring some problems with it. For some of these problems solutions are elaborated. Also the solutions for the sedimentation at several locations around the reclamation will be described in this chapter. The locations are in front of Tumumpa Dua, in front of the river mouth and in the designed canal between the mainland and the reclamation.

4.1 Erosion Prevention Plan
A solution to prevent erosion and disappearance of mangroves north of the Bailang river mouth, is to build a groyne perpendicular to the coastline. This groyne will block the river outflow to the north and in this way stop an important cause of the erosion. The alongshore sediment transport will be like it originally was, before the erosion and the construction of the Bailang breakwater; from the north to the south. This way the groyne will block sediment coming from the north and cause accretion at the eroded area. So not only the erosion will be stopped, but the lost land will even be reclaimed.

By implementing a mangrove restoration plan, the coastline has a possibility to get its original look again. The restoration will be done by building brushwood dams to catch sediment, where the mangrove propagules could settle again. The new mangroves will protect the coast against erosion, like they used to. The plan is further elaborated in Appendix E. An overview of the Plan is shown in Figure 4.1.

![Figure 4.1: Overview Erosion Prevention Plan.](image)

4.2 Garbage Racks
In chapter 1 it was already mentioned the daily amount of garbage in the rivers is likely to be 250 m$^3$. Because Tondano River has by far the largest service area, it is assumed that, with the contribution of
Tikala River, the daily amount of garbage floating out of Tondano River is 200 m$^3$. This daily amount of garbage must be caught. Out of the solutions presented in Appendix F the different garbage racks in Tondano and Tikala River are considered as the best solution.

The garbage racks are designed for different locations, mainly because it must be possible for boats to enter the Tondano River. The upstream garbage rack has a side canal of 9 meters wide, as presented in Figure 4.2 which is necessary to mitigate the negative effects on the discharge capacity induced by the steel frame. In Figure 4.3 the downstream rack is shown that will still provide a gap for the boats. The capacity of it is 14,64 m$^3$ per rack and must be cleaned every two days. The racks over the full width must be implemented at the locations indicated in Appendix F and the garbage rack as in Figure 4.3 at the river mouth.

4.3 Beach Plan

By implementing a beach in the reclamation design the sedimentation at the indent in front of Tumumpa Dua can be used beneficial. The sediment will flow into the indent between the reclamation and the Bailang harbour, and can form a beach at the reclamation. The sediment transport will do most of the work, by supplying sand at the north side of the reclamation. By use of groynes on both sides of the beach, the sand can be kept at its place. At the same time the north-east groyne will shelter the Tumumpa Dua coastline from waves and so prevent erosion there. In Appendix E this design is be further elaborated. An overview of the solution is shown in Figure 4.4.
4.4 Preventive dredging

Due to the construction of the new land reclamation sedimentation will occur near the river mouth of the Tondano River. Since this could lead to an increase in flood risk upstream as described in chapter 3, this sedimentation has to be treated. Out of all solutions, preventive dredging has the most advantages.

This dredging has as a goal to remain the present outflow conditions for the Tondano River so that there will be no consequences upstream. It also removed sand that is accumulating in the corner of the land reclamation, because this is not pretty and therefore unwanted. After three years the sedimentation will have reached a state that can be dangerous for the river upstream. Since the dredging works are preventive they should be repeated every two years so the flood risk upstream will not be increased. The area to be dredged is indicated in Figure 4.5. Since the area is very shallow the dredging has to be executed with small equipment. This will take approximately two weeks.

![Figure 4.5: Area to be dredged.](image)

4.5 Two ways to implement a drainage canal

The proposed canal between the existing coastline and the new land reclamation is expected to be silted within a few years. A design choice whether to implement the canal or not has to be made by the client.

4.5.1 The original plan: A canal on sea-level

The first option is to construct as described on sea-level. Siltation of this canal is expected within three years. Therefore this solution is not preferred. Advantages of this solution are that the possibility to moor along the existing coastline remains and that the drainage of the low laying city parts along the existing coastline is still possible. A large disadvantage is that frequent dredging is required in this solution to maintain drainage trough this canal.

4.5.2 The proposed solution: Canalization

This solution proposes that canals can and should be implemented in the new reclamation. But they should be placed above sea-level so that unrestricted outflow is always possible. This requires the land reclamation to be placed about 4.75 m above Chart Datum. A drainage canal can be implemented easily into the existing land reclamation design and requires a width between 8 and 18 meters.
A large advantage of this solution is that it will be more effective in discharging excess rainwater, and that is more resistant to threats as storm surges, tsunamis and sea-level rise. By placing a weir at the sea-side of the canal a small water level can be maintained at all times in the canal, making navigation for small pleasure boats possible.

Disadvantage of this proposed solution are the higher costs because of an increased bottom level. It also requires a few drainage canals that drain at the existing coastline to be diverted or to be solved by pumping, as visible in Figure 4.7.
5 ADVICES

The advice of this report toward the client consists of three parts. The first part is the heart of this research: the negative effect of the land reclamation and how they can be prevented. The second chapter the advices on the existing problems of Manado; coastal erosion, garbage and river floods. The third part are advices on the design of the new land reclamation, which came up during the research, but are not the core of it.

5.1 Preventing negative environmental impact from the possible land reclamation

The following advices should be implemented to prevent negative influences caused by the planned land reclamation. Failure to implement one of these preventing or mitigating measures will result in a large threat for the people or the environment of Manado.

Sedimentation and garbage settlement at the mouth of Tondano River is likely to happen and will lead to higher water levels upstream. This can be prevented by the Preventive Dredging Plan. The land reclamation will catch sediment that is flowing out of the river mouth which leads to sedimentation. This will lead to an extension of the river and to an increase of the bed level upstream, which increases the flood risk. Since this is a result of the sedimentation, the increase of flood risk can be prevented by treating the sedimentation around the river mouth. The best way to do this is to execute preventive dredging works. This is elaborated in Appendix G.

Both sedimentation and erosion are expected near the Tumumpa Dua coastline. By implementing a beach in the reclamation design the sedimentation can be used beneficial. The sediment which will flow into the indent between the reclamation and the Baitang harbour, could form a beach at the reclamation. The sediment transport will do most of the work, by supplying sand against the north side of the reclamation. By use of groynes on both sides of the beach, the sand can be kept at its place. At the same time the north-east groyne will shelter the Tumumpa Dua coastline from waves and so prevent erosion there. In Appendix E this design is further elaborated.

The proposed canal between the exiting coastline and the new land reclamation is expected to be silted within a few years. One of the two elaborated solutions should be implemented. A design choice has to be made whether the canal must be implemented or not. In case the canal is constructed on sea-level as described, quick siltation is expected and frequent dredging will be required. A better solution might be to place a drainage canal on a higher level, that it is not influenced by the sea.

Damage to coral reefs by construction works is likely to happen. This should be prevented by hiring a qualified dredging company. By adopting sound planning, impact assessment, monitoring and management practices the effects of dredging on coral reefs can be reduced. Select a decent dredging company that has provable experience in dredging environmental friendly next to a coral reef. By constructing first the rock out layer of the land reclamation, sediment impact can also be minimized.
The reduction of the nautical habitat by the construction of the land reclamation is should be compensated by increasing Bunaken National Park. A way to compensate for the lost habitat or natural environment is by declaring an another area at least equal the size of the land reclamation protected, so there is no fishery allowed and the ecosystem can remain healthy.

5.2 General problem advices
A step forward on solving the existing problems of Manado can be made by implementing the following solution plans:

To prevent erosion and disappearance of mangroves north of the Bailang river mouth, it is advised to implement the Erosion Prevention Plan. The northern part of the coast of Manado has suffered from erosion caused by the construction of the Bailang Harbour. The construction of the new land reclamation does not change the direction or velocity of the currents north of the Bailang River. The Erosion Prevention Plan consists of a groyne and a mangrove restoration plan. This plan is further elaborated in chapter 4.

It is advised to implement a garbage rack in combination with improved education. Today there is a lot of garbage flowing through Tondano River. The building of a garbage rack will decrease this amount significantly. A design for this rack is presented in chapter 4. Also it is highly advised to invest more in prevention, like proper education about the effects of garbage.

The River Improvement Plan by Yachiyo Engineering will reduce the flood risk within Manado City, therefore it is advised to implement this plan. Currently some parts of Manado have a high risk of flooding. There currently is a plan to reinforce the river banks over the whole length in the city to decrease the flood risk. Although it might not be the cheapest and most aesthetic option this plan is considered to be effective.

5.3 Design advices on the new land reclamation
Besides the effects of the reclamation on the environment, this section will advise on the reclamation design in general. During the analysis of the plans, a few remarkable things were noticed and are advised to reconsider in the next design step of new land reclamation, because they might lead to a land reclamation that is cheaper, safer, of higher living quality and more ready for the future.

Implement new mooring facilities for fishermen. The reclamation will expel the fishermen from the existing coastline. A count indicated that around 100 fishing boats are present at the coastline. If the municipality really wants the canal, it is advised to give the fishermen mooring facilities at the existing coastline. To avoid congestion problems in the canal just like in Venice, it is recommended to also dedicate some room in the newly planned harbour in the reclamation.
Green is good, but give it enough room. The plan for the new land reclamation has high ambitions on the field of greening the city, which is positive. Nevertheless the amount of surface now reserved for green is rather limited to call the streets ‘green belts’. Implementing wider green stretches, rather than the traditional tree between the road and the walkway, has advantages on ecology, safety and drainage.

Make sure the new land reclamation does not increase the already existing traffic problem. Make sure that the harbour bridge is finished before starting with the construction of the new land reclamation. Think about the road design in the design of the new land reclamation. Adapt the land reclamation to the mikrolet system. Maybe even make the land reclamation a quiet place without cars.

Revise the sea defence design. It is advised to rethink the current sea defence with a crown wall. A crownwall is anaesthetic and risky. A combination of increasing the bottom level height of the reclamation and placing a green stretch with no houses after the sea defence is safer, more beautiful and maybe even cheaper.

![Figure 5.1: Alternative for coastline](image)

Place the new reclamation on a slightly higher bottom level. Constructing the new land reclamation just a single meter higher than existing land reclamations has many advantages; it makes a coastline with no crownwall possible, it improves drainage possibilities and it increases the resilience of the reclamation against threats as tsunamis and future sea level rise.

Give the new land reclamation time to settle. Many buildings on existing reclamation are devaluing rapidly due to numerous cracks. Many of the cracks in buildings on existing land reclamations might be due to unequal settling of soil. 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.

Make the reclamation as self-sufficient as possible. Make sure the new land reclamation does not pose an additional load on already overloaded networks and facilities. Think about the electricity, sewage, drinking water and garbage handling. 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. It is recommended to implement a garbage collection system especially for the reclamation area.
6 CONCLUSION
The to be constructed land reclamation is expected to have the following effects on its environment:

- Sedimentation and garbage settlement at the mouth of Tondano River is likely to happen. This will lead to an increase of flood risk upstream. This can be prevented by dredging the river mouth;
- Both sedimentation and erosion are expected near the Tumumpa Dua coastline. By implementing a beach in the reclamation design the sedimentation can be used beneficial and also the erosion will be stopped;
- Increased erosion and mangrove retreat due to the construction of the new land reclamation is not expected. But a cure for the existing erosion and mangrove retreat is proposed and designed;
- The proposed canal between the existing coastline and the new land reclamation is expected to silt within a few years, but a solution is available.

A step forward on solving the existing problems of Manado can be made by implementing the following solution plans:

- The erosion and disappearance of mangroves north of the Bailang river mouth can be restored by implementing the Erosion Prevention Plan;
- A garbage rack in combination with improved education, will lead to a significant reduction of the garbage outflow of Tondano River;
- The River improvement plan by the firm of Yachiyo Engineering will lead to the reduction the flood risk within Manado City.

By adapting the design at some points the new land reclamation can create additional value without high additional costs.

A new reclamation will have large influences on the environment of Manado Bay. Sedimentation and garbage settlement at several spots around the reclamation are likely, coral reefs will be affected by its construction and higher water levels on Tondano are also expected.

All the researched negative effects of the planned land reclamation can be prevented or mitigated separately by above mentioned measures. But failure to implement one of these preventing or mitigating measures will result in a large threat for the people or the environment of Manado. This risk might only be justified if a demand for further city expansion has been proven and if all other development options for unused land within Manado city and less preferably the mountainous hinterland have been excluded.

This report focuses mainly on the littering and eroding effects of the planned land reclamation in a qualitative way. Without further research it is not possible to exclude negative environmental effects by other dynamics than the technical coastal system, as described in chapter 7, recommendations.
7  RECOMMENDATIONS

This report focuses on describing the effects of a new land reclamation in a qualitative way. Since most designs are on a functional level, often further research is required to implement all the advices. Therefore some recommendations were given.

This report only focuses on the erosive and littering influences on Manado’s surrounding nature, induced by hydraulic and morphological changes caused by the planned land reclamation. This leads to the fact that the politics, economic and social aspects are not taken into account by forming an advice.

Some general recommendations for the reclamation and the Manado coast will be described. For some designs and advices there are also some recommendations which mostly advise that further, more specific, research is necessary.

7.1  General recommendations
The exact locations of coral reefs in Manado Bay have to be found. A crucial recommendation is to map the locations of the coral reefs, to make sure the location for the reclamation is free of coral reefs. If coral reefs are present it will be discouraged. The current source on the location of the reef (World Fish) provides not the required detail.

Manado is said to be in a tsunami prone area, but the exact risk is unknown and measures to protect Manado’s citizens lack. Since there is a tsunami risk for Manado, it is recommended to make an evacuation plan and maintain a solid warning system.

7.2  Design improvement recommendations
For the design of the groyne at the Bailang river mouth, it is important to do further research on the effects in the Bailang river. After completion of the groyne, more flooding could occur in the upstream area of the river. Residents are living along the river, especially on the first 1,5 kilometres, so it is important that their safety does not decrease. Like described in the report the design could be adapted to the situation.

It needs to be ensured that no polluted sediments and garbage will litter the beach. Geotechnical research could give a view to the quality of the sediments that will form the beach. For the garbage there could be looked to implementation of racks into the Bailang river, just as advised for the Tondano river.

The sedimentation in the Tondano river mouth could create a funnel shape. Due to the shape the effects of a storm surge might increase, this needs to be further investigated.

Also the process of sedimentation in front of the river mouth needs to get researched in detail, taking sediment transport quantities and effects of waves and currents into account. This way a more exact estimation of the amount of sedimentation will be retrieved, and the solution can be adapted to that result.
The hydraulic resistance caused by the implementation of the garbage racks in the river needs to be researched. This might induce an increase of the water level upstream in the river. The design of the new smoothened river profile and the garbage system have to be adapted to each other. A detailed model for this, which also contains sediment transport data, has to be produced.

For the solution of the garbage problem, the properties and behaviour of garbage in the water needs to be further investigated. This could for instance lead to garbage racks, which do not reach all the way to the bottom. This way not only costs could be saved, but also the resistance in the river would decrease, which is preferable. An important consideration for locating the garbage racks, is until where boats can go upstream the river. By closing of the river for navigation at a certain location with a garbage rack over the full span, the amount of garbage flowing out of the river, could be minimized.
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