Flooding in the Tapanahony Region

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(Title page image made by authors)

Flooding in the Tapanahony Region

Course: CEGM3000 Multidisciplinary Project (MDP)

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Preface

This research has been performed for the module CEGM3000 Multidisciplinary Project at the faculty of Civil Engineering and Geosciences of the Technical University of Delft. The project team consists of four students with different backgrounds, which are now specializing in different disciplines: Hydraulic Engineering and Water Resources Engineering. Tracks that are part of the studies Civil Engineering and Environmental Engineering. These two tracks formed an ideal combination to study the water problems of the Tapanahony region and to be more specific the floods happening in this region.

This research was at the request of the Gaanman Bono Velantie and formulated as an assignment of the client Rudi Darson. As there is a desire to develop the region altogether, this research was carried out in a very broad way. Gathering as much data about the region as possible, so that it can serve as a foundation for follow up projects. Data was gathered through interviews and a measurement campaign through the region.

In the past data about discharges and water heights has been gathered, but these stations were destroyed during the civil war, and not any up-to-date data is available. The data that will be gathered during this research will be made public, so that anyone who wants to design or build interventions can make us of it.

The research will end with a couple of development opportunities that are not worked out in much detail but show ideas of what solutions can be implemented and at which scale development is preferable. Next to that, they can act as guidelines in which directions interventions can be worked out.

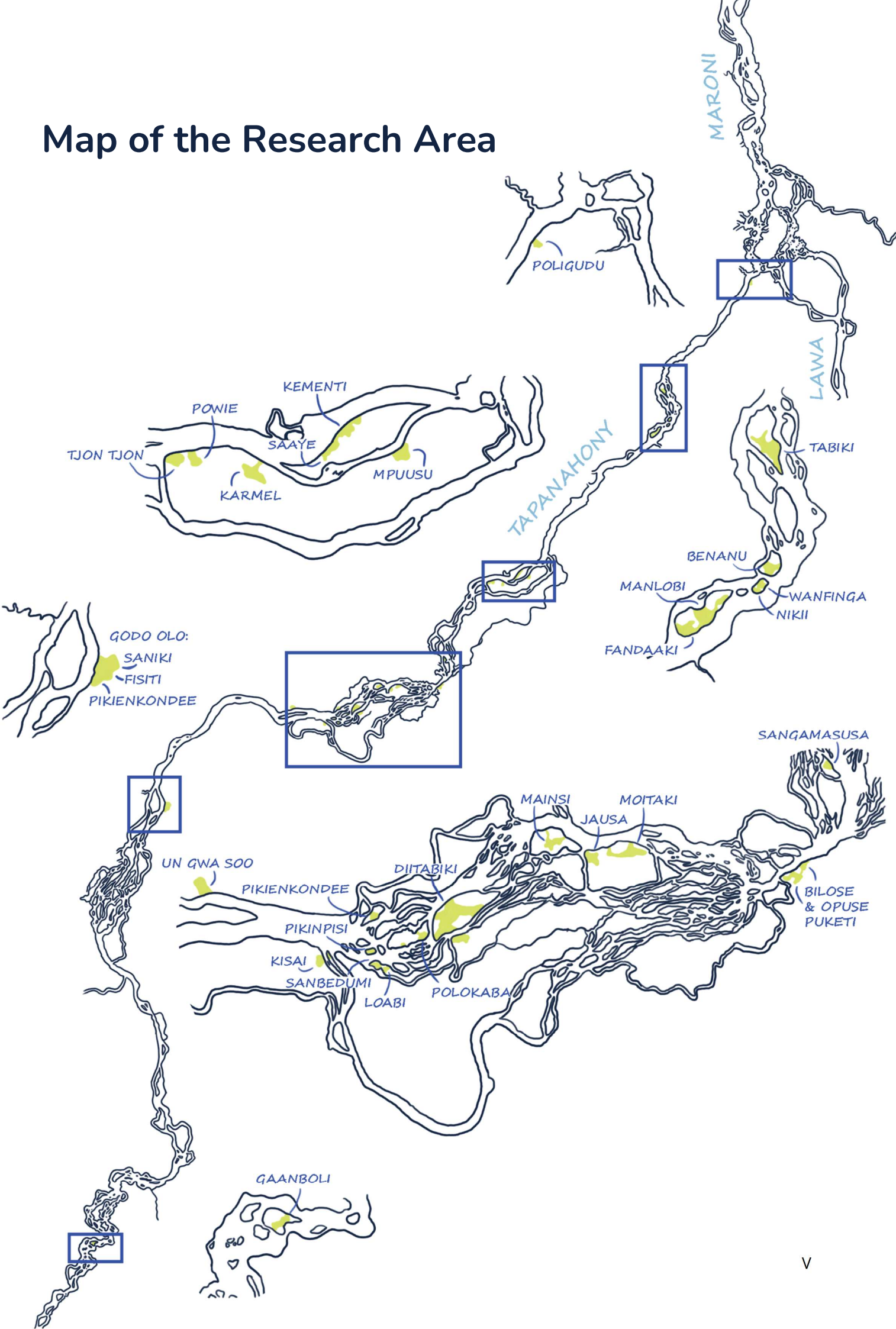
Many thanks go to Gaanman Bono Velantie who gave us the opportunity to perform a project where we were allowed to live for seven weeks among his people. But also, to our client, Rudi Darson, who also helped establish a lot of contacts during our stay in Suriname. This made it for us much easier to get around and focus on our jobs. Lastly, we would like to thank our supervisors from the TU Delft: J.A. Arriaga Garcia, R.J. van der Ent and K.B.J. Dunne for their counselling during our project.

List of Villages

For this research, the 31 Okanisi villages along the Tapanahony are visited. Together with some other test locations, these villages are listed below. Since some of the village names can be found differently spelled in earlier research or sources like Google Maps, they are listed below as well. Finally, the abbreviations used in this study to refer to the different villages are added as well.

Village	Abbreviation	Other names found
Palumeu	PAL	Paloemeu
Apetina	APT	
Gaanboli	GNB	Granbori, Granboridorp, Gaánboli
Pikienkondee	PGDO	Pikinkondee, Pikin Kondee, Pikinkondee-Miánda
Fisiti	FGDO	Fisíti
Saniki	SGDO	
Godo Olo	GDO	Godoölo (PGDO, FGDO, SGDO together)
Un Gwa Soo	UGS	Landbouw, Aan wal gaan (literal translation)
Pikienkondee	PKD	Pikinkondee, Pikin Kondee, Pikienkondre
Pikinpisi	PKP	Pikinpiisiï
Kisai	KIS	
Sanbedumi	SNB	
Loabi	LOA	
Polokaba	PLK	Poölokaba
Diitabiki	DTB	Drietabbetje
Mainsi	MAI	Together MAI, JAU and MOI are sometimes called 'Dii Futu' (three feet)
Jausa	JAU	Yausa
Moitaki	MOI	
Futu Pasi	FTP	Foetoe Pasie
Opuse Puketi	OPU	Poeketi
Bilose Puketi	BPU	
Sangamasusa	SGM	Sangamanusa, Sangamansoesa, Sangamansusa
Tjon Tjon	TJO	Tjontjon, Tyon Tyon, Tyontyon
Powie	POW	Poowi, Pauwie
Karmel	KAR	Karme
Mpuusu	MPU	Mpoesoe
Saaye	SAY	Saye
Kementi	KEM	Keementi
Kiokondee	KIO	Kio Kondre, Kio Kondee, Kiyoökondee, Kiookondee
Fandaaki	FAN	Fandaati, Fandaäki
Manlobi	MAN	
Nikii	NIK	Nikiï
Wanfinga	WAN	
Benanu	BEN	
Tabiki	TBK	Tabbetje
Poligudu	PGD	Poeloegoedoe
Stoelmanseiland	STO	'Stoeli'

Map of the Research Area



Glossary

Okanisi	Aukan people
Ndyuka	Aukan language
Korjaal	A wooden boat used in the inlands of Suriname
Pagaai	A paddle that is used in a small korjaal
Sula	A rapid in the river
Panji	A traditional wrap cloth
Gaanman	Chief of the Okanisi (or another Maroon group), can also be found as: Granman
Kabiten	Captain of a village or region
Basiya	Leading function in the village, under the Kabiten
Lanti	Government
Botoman	Boat driver
Kondee	Land

Abstract

This report documents the impact of floods in the Tapanahony region as a step to start developing the region in a sustainable manner. The Tapanahony region of the Okanisi people harbours descendants of enslaved people that freed themselves during the 1700s. Currently the development of the region is stagnating and the Okanisi experience problems when trying to build a living for themselves and their families.

By conducting interviews in the 28 villages along the river an impression is obtained of the role that the river plays in this area. These results are then combined with a flood vulnerability model for which depth and velocity measurements of the river have been conducted.

This study shows how the lives of the inhabitants are intertwined with the river. It also stresses the severity of the issues at play here. A lack of clean drinking water in the dry season in combination with heavy floods in the wet season make it difficult for people to progress and drives them to turn to goldmining as a source of income. This report also shows that there are solutions to the situation, as long as there is strong collaboration between developers, researchers and especially the villages themselves.

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1 Introduction

1.1 History region

The Tapanahony region has a rich but turbulent history. Before the colonization of Suriname by the Dutch, native people have lived in this region for as long as they can remember. Nowadays the indigenous people have moved, among other places, more upstream in the Tapanahony region, and another people live downstream of this region: the Okanisi, or Ndyuka. From 1650 onwards, enslaved ethnic Africans started fleeing from the brutal working conditions in the Dutch plantations and in doing so, freed themselves. They settled in the forest and later the Okanisi moved to the Tapanahony region and called themselves Ndyuka. Over the course of 400 years, the Ndyuka people started living in many places along the river, currently there are 28 villages located along a stretch of river of 100 km in length. These villages have a big meaning to the current people living in, the spiritual connection with their ancestors is very important. In this time their lives have been far from peaceful, the Dutch slaveholders have hunted them for a long period. Furthermore, the Inland War that started in 1986 caused devastation for the Ndyuka people due to the Surinamese National Army taking revenge on civilians. This war raged through the inlands of Suriname and lasted a couple of years; the schools were closed during this period. Almost a whole generation grew up without ever going to school, these people never got to learn Dutch which is the language of instruction in Suriname. Another result of this war was the drop in tourism of the region, where in the 70's and 80's the region was still frequently visited by tourists, this image has disappeared. The latest development is the rapid expansion of gold mining in the region by western companies, illegal Brazilians, and the Ndyuka themselves. The presence of these goldmines is withholding the comeback of tourism to the region. Knowing all this, it should not come as a surprise that the Ndyuka people living in the Tapanahony region are on their guard when it comes to outsiders.

1.2 Problem Statement

The development of the Tapanahony region has stagnated in the past couple of years, as there are little education possibilities and there is little work available. This makes many fathers leave the area to start working in for example French-Guyana, to provide for their families that stay behind. Although there are many mountainous areas in the region, the villages and agricultural land get flooded regularly. In 2006 and 2008 there were serious floods where many people had been affected by this, in the district Sipaliwini this number was about 3,810 (General Bureau of Statistics (GBS) Suriname, 2024). This lack of job opportunities but also educational possibilities and the river floods, make some families leave their ancestorial homes indefinitely. In the city their chances of a bright future still are slim, as many of them form a part of the underclass.

The nature in the area gets affected by the illegal goldmining and timber concessions. The trees that are cut down next to the river, no longer keep the banks in place as their roots die off (Stichting Planbureau Suriname, 2014). Giving the river free rein and eroding the banks even more quickly. Plus, the mines use heavy metals in their operations, these metals spread through the region, especially mercury as it is volatile and get easily picked up by the wind. For a long time, the knowledge about the danger of this element was not known. The quantities accumulated over the years and are now posing a large threat to the health of the inhabitants of the region. Right now, the use of mercury is forbidden, but there is no enforcement of the law and thus the irresponsible use still continues.

The cutting of the trees also changes the hydrological system of the region and could cause more frequent flash floods in the future. Furthermore, this leads to land degradation as the companies or individuals are not held responsible for the regeneration of these areas.

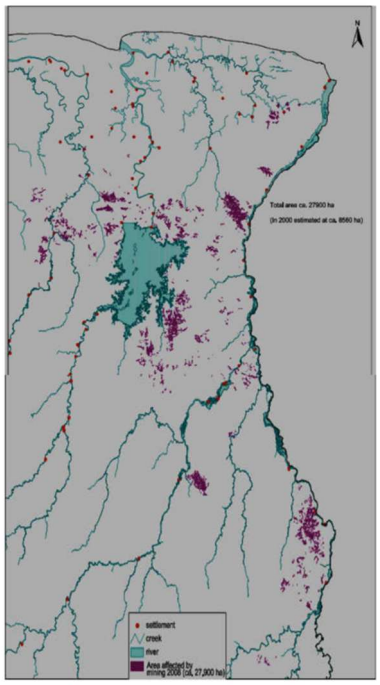


Figure 1: Overview goldmines Suriname (Stichting Planbureau Suriname, 2014)

The four different seasons in Suriname are becoming less predictable, which is evidently a consequence of climate change around the world. Each year it is harder to plan the harvest as they usually plant their new crops during the long drought. Last year, 2024, the short-wet season was skipped altogether, withering away the plants and causing a shortage food in the area. Long droughts also influence the primary transportation system in the region. Since the river serves as a waterway for boats, as there are no roads present in the Tapanahony region. Right now, only tractors and ATVs can reach the region.

In many villages the sanitation is not present, and people do their daily needs in the forests, creeks and rivers. Especially, in the crowded villages this becomes a problem, and poses a threat for the health of the villagers.

There is no system in place for the treatment of waste, and the local inhabitants use the river as trash bin. As the use of plastic in this region is not uncommon, this usually ends up in the river. The accumulation of microplastics could form a threat for people their health.

In general, surface water is used as drinking water, some villages are in possession of rain barrels and even fewer have access to running water. Right now, only Diitabiki and Tabiki have access to running water (see Appendix A). During droughts more villages resort to using the surface water as their source of drinking water, but the quality is not guaranteed to be safe. Earlier mentioned pollution makes the quality of such drinking water uncertain. Suriname in general has a lot of clean freshwaters available for its population. Although, in the inland of Suriname about 91% of the inhabitants have access to improved drinking water sources (General Bureau of Statistics (GBS) Suriname, 2024).

1.3 Project Scope

This research project focuses on documenting the different river functions, this will create a clear image of how the people interact with the Tapanahonyriver. Next to that, the river floods are a primary topic in this project. To create a stable foundation to solve the other problems at hand, it is important that people can live in the region without the fear for floods and losing their livelihood. Another topic that will be studied is the water quality in different parts of the region. These three topics will form the foundation for possible follow-up studies.

1.4 Research Objectives

Earlier in the problem statement, many problems were mentioned, but for the project to succeed in the long term it is essential to have the support of the locals. Therefore, this research will also compel to find out what the biggest problems are of the region according to the inhabitants themselves. This will be found out with the use of interviews. This problem analysis will later help to come up with a strategy to tackle the different problems.

Furthermore, primary data will be gathered, it is the desire to make this data public together with a description on how the data was gathered. So, that other researchers, plan makers or students know what the underlying assumptions were when the data was gathered. This primary data will mainly be depth measurements, a couple of velocity measurements and height maps.

One other objective is to create a flood risk map, with the help of the data gathered during the project, but also including data gathered from other sources. Such a map could proof useful for villagers, deciding where to for example make their agricultural lands or where to put the next polyclinic.

On completion of the just mentioned research objectives a start of a strategy to resolve the problems of the regions can be made. This strategy will also consist of ideas and feedback obtained during the planned workshop with the local inhabitants.

1.5 Project Approach

As this research will serve as preliminary study on many topics, different methods of data gathering will be applied. The problems mentioned will be verified with the help of interviews. The methodology for the interviews can be found in Appendix B. To make an analysis of the rain patterns, remote and historical data is gathered. Ideally, this remote data is verified by the obtained primary data that is going to be gathered during the field work. Next to verifying the remote data, the measured data is also going to be used to calibrate the hydraulic model. This model is used to indicate which villages in the area are more prone to flooding.

1.6 Research questions

In order to come to a comprehensive research different research questions are formulated. The answers to these sub questions on different topics will in the end be brought back together to answer the main research question:

How does flooding impact the Tapanahony region, and what can be done to address this and other existing problems to ensure a sustainable future for the region?

Sub-questions that will help to answer this are:

- What does the Tapanahonyriver mean for the daily life, culture and livelihoods of the Okanisi people?
- What are the main hydraulic and geomorphological characteristics of the Tapanahonyriver and the surrounding environment, such as bathymetry, flow velocity, discharge, and elevation of villages located along the river?
- How do the current climate and projected climate change scenarios influence river dynamics, flooding patterns, and the Tapanahony region?
- What is the current state of water quality in the Tapanahonyriver, and what are the main factors influencing it?
- Which areas along the Tapanahonyriver are most vulnerable to flooding?
- What are the main problems existing in the region that prevent the possibility of sustainable development and what are the first steps to address these problems?



2 The Tapanahony Region

To understand the impact of flooding, droughts and water quality changes of the Tapanahony, it is important to start by understanding the entire Tapanahony region. In this chapter, a comprehensive analysis of the study region is presented with the aim of answering questions such as: What does the catchment look like? Where and how do people live? What functions does the river have? And who is impacted by the problems that arise with flooding, droughts, and poor water quality? This analysis is performed with online research, observations and interviews.

2.1 Geographics

The Tapanahony river originates in the southeast of Suriname, just north of the border with Brazil. From here it winds northward through the country to the eastern border with French Guiana. There, it comes together with the Lawa River to form the Maroni River, which flows along the border all the way to the Atlantic Ocean. The entire Tapanahony catchment, shown in Figure 2, has a total area of 19544 km^2. Roughly 74% of the catchment contributes to the discharge flowing past the first Okanisi village Gaanboli. Subsequently, the village Diitabiki is connected to 96% of the catchment. Accordingly, only an extra 4% is added to the river for the downstream half of the villages. This can give an indication to the discharge variations expected at different villages located along the river, however, due to the very localised rainfall patterns this is not a one-to-one causation.

The mean elevation is roughly 239 m above mean sea level and varies between 39 m and 911 m throughout the river basin (Nurmohamed & Donk, 2013). Figure 3 shows the digital elevation model (DEM) of the entire catchment, using elevation data from the SRTM-Downloader of NASA in QGIS, and a grid resolution of 30 meters. The natural vegetation is high tropical dense forest, covering 99% of the region, apart from the small villages (Global Forest Watch, 2020). Since the last century only one significant change in land use has occurred, and that is the destruction of the forest for goldmining purposes, as can be seen from areal images of the region. Deforestation from mining practices is responsible for 74% of the total tree cover loss in the Tapanahony region from 2001 to 2024, which amounted to 1.7% of the year 2000 tree cover area. This translates to a total tree cover loss of 65.9 kha (Global Forest Watch, 2020).



Figure 2: Tapanahony Catchment

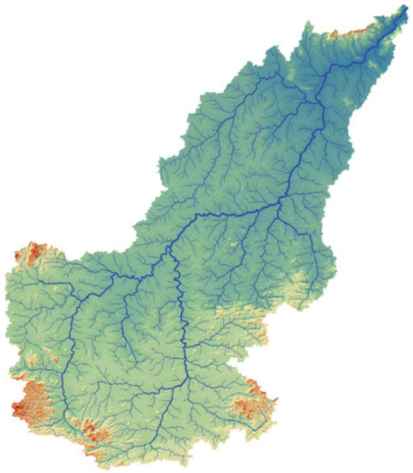


Figure 3: DEM of Tapanahony Catchment

2.1.1 Village Analyses

During this study all 31 Okanisi villages of the Tapanahony region are visited. They are spread out over a distance of approximately 100 km along the river, see the given 'Map of the Research Area'. During these visits, interviews are conducted in 28 of those villages and fieldwork measurements are done, of which the results will be discussed in further chapters. Besides those interviews, a visual analysis is also conducted in the villages, leading to the following village analysis results, refer to Table 1. A more elaborate description of these results can be found in Appendix C.

Table 1: Summary of Village Analysis

	Island/ mainland	Riverbank Erosion	Land Erosion	Relative Height	Flooding*	Surface Area m^2	Elevated Houses
GNB	Island	High	High	High	No	20.000	No
GDO	Mainland	High	High	High	No	200.000	No
UGS	Mainland	High	Low	High	No	40.000	No
KIS	Island	High	High	Low	Partly	30.000	No
PKD	Island	High	Moderate	Moderate	Partly	14.000	No
PKP	Island	High	High	Low	Yes	6.900	Yes
SNB	Island	High	Moderate	Low	Yes	13.000	Yes
LOA	Island	High	Low	Low	Yes	6.500	Yes
PLK	Island	Low	Low	High-Low	Partly	-	-
DTB	Island	High	High	Moderate	Partly	230.000	Some
MAI	Island	High	Moderate	High	No	40.000	No
JAU	Island	Moderate	Low	High	No	28.000	No
MOI	Island	Low	High	High	No	30.000	No
PUK	Mainland	Low	Moderate	High-Low	No	70.000	No
SGM	Island	High	High	Low	Yes	12.000	Some
TJO	Island	High	Low	High-Low	Partly	25.000	Some
POW	Island	High	Low	High-Low	-	18.000	No
KAR	Island	High	Low	High-Low	No	53.000	Yes
MPU	Island	High	Low	High-Low	-	25.000	No
SAY	Island	High	Moderate	Low	Partly	25.000	Some
KEM	Island	High	Low	Low	Partly	34.000	No
FAN	Island	High	Low	High-Low	Partly	53.000	No
MAN	Island	High	High	High-Low	Partly	92.000	Some
NIK	Island	Moderate	Moderate	Low	Partly	13.000	No
WAN	Island	Moderate	Moderate	Moderate	Partly	17.000	Some
BEN	Island	Moderate	Low	Low	Partly	25.000	Some
TBK	Island	Low	High	High-Low	Partly	75.000	Some
PGD	Mainland	Moderate	Low	High	No	28.000	Some

2.2 Demographics

Suriname is divided into ten districts, and each of these districts are further divided into ressorts. Tapanahony is one of the resorts of the Sipaliwini district, the district that covers most of the forested area of the entire country. In Table 2 below, the demographics for this entire district are listed for the years 2004, 2012, 2023, and 2024. It shows that over the last twenty years the population has decreased by several hundreds of people. Furthermore, comparing data from the Algemeen Bureau voor Statistiek Suriname (ABS) census in 2004 to the census in 2012 reveals that a decrease in inhabitants occurred mainly in the young adult age ranges, 15-34 years (Appendix D). This is also a trend that was confirmed in the interviews conducted in the region, which stated that many of the older children, young adults and adults, move to the city for better education and for work. Currently, a new census is being carried out but the results have not been published yet.

Another trend that is visible from the ABS census, is that mostly men remain in the villages, and the women migrate to other regions. This was again confirmed during the interviews, as in some families the women move to the city with the kids and the men stay behind to keep working in the gold mines to provide for their family.

Table 2: Population data Tapanahony Region

	2004*	2012*	2023**	2024**
Men	7159	8300	6323	6273
Women	6634	5508	6403	6688
Unknown	12			
Total	13805	13808	12726	12961

** Data from ABS*
*** Data from CBB*

Located along the downstream part of the river as shown in the map of the research area, from the village of Gaanboli to Poligudu, are the villages of the Okanisi. Further upstream are the villages of the indigenous communities. Data of the number of people living in each village does not exist, so through interviews an estimate of each village's population was made and described in Table 3. This estimate takes into account the people who live in the village year-round, as during the summer months many children and adults return to their village from the city for vacation.

Table 3: Population Data Tapanahony According to Village Analysis

Village	Population
Gaanboli	15-20
Godo-Olo (Pikienkondee, Fisiti & Saniki)	1000
Un Gwa Soo	36
Pikienkondee	11
Pikinpisi	35*
Kisai	70
Sanbedumi	30
Loabi	4
Polokaba	33
Diitabiki	200
Mainsi	85

Jausa	150
Moitaki	100
Puketi (Opuse & Bilose)	60*
Sangamasusa	17
Tjon Tjon	4
Powie	0
Karmel	0**
Mpuusu	0
Saaye	5
Kementi	3
Fandaaki	50
Manlobi	250
Nikii	-
Wanfinga	3
Benanu	5
Tabiki	110
Poligudu	190

** Only adults*

*** Village is abandoned but teachers and nurse still live here*

2.3 Way of living

This chapter describes the way of living of the people in the Tapanahony region based on the data gathered from the interviews.

2.3.1 Okanisi Hierarchy

The Gaanman is the head of the Okanisi people. He oversees everything that happens in the region. A new Gaanman is chosen from his family only when he is on his deathbed. Below him there are Kabitens who oversee a specific village, see Figure 4. Some village clusters also have head Kabitens who oversee a bigger region.

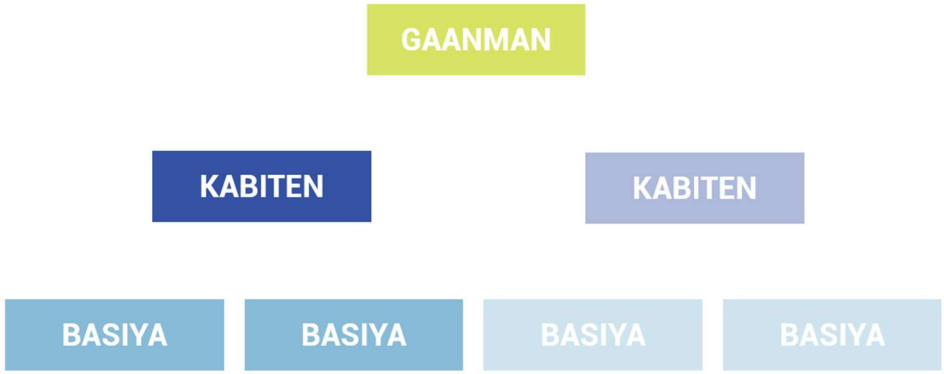


Figure 4: Okanisi Hierarchy

Kabitens and Basiya's have several functions within a village. Many of the interviews in this study were conducted with Kabitens and Basiya's, leading to the following understanding of their roles in the villages.

They fulfil both traditional and governmental functions. In rituals that are part of cultural traditions, for example when someone has died, the Kabiten of a village has a leading role. When conflicts arise between families or between villages, Kabitens are responsible for helping to resolve these disputes. All tasks that would normally be performed by governmental institutions fall under the responsibility of the Kabitens. They act as police, judge, lawyer, soldier, and customs officer all in one.

To assist them, each Kabitens has one male and one female Basiya who support the Kabiten with daily tasks and represent them when they are away. Both are also involved in the maintenance and organisation of the village.

Kabitens and Basiya's are paid by the government, receiving 6000 and 4000 SRD per month respectively. A little over eight months ago, this was only 1800 SRD per month for a Kabiten [MOI]. However, it is still considered too little to live from and to adequately perform their tasks [FAN, MOI].

2.3.2 Housing

Houses were traditionally built right next to the river, as the villages began to expand, they started building further away from the river. Nowadays, people who experience flooding also build at higher grounds or if they can afford the construction they build on poles and live still relatively close to the river.



Figure 5: Traditional Okanisi House

The material used to build the houses went from only using wood, which is available in large quantities, to also building with concrete. Where the steel and cement are brought by boat, and the sand and gravel are collected locally. During floods buildings are also pushed over, they have to open the doors in order for the water pressures to be released [PKP, KIS]. This is one of the reasons why more people started making the first meter out of concrete and above that they use wood. Almost all houses have a roof made from zinc plates. However, if they breed animals, they make the roofs out of palm leaves as this prevents the buildings where these animals are kept from overheating [PKD].

2.3.3 Drinking Water

There are several ways for people get drinking water, such as harvesting rainwater, through a water pipe system, and getting water directly from the river. In all villages except for Godo Olo, rainwater harvesting using a Duro tank seems to be the primary water supply for a majority of the people. However, when they are empty, people are forced to drink water from the river, either directly or pumped through a pipe system.

Rainwater Harvesting

The preferred drinking water source is rainwater, which people collect in Duro tanks. Many of these Duro tanks have been installed by organizations [DTB]. They function well during the wet season when there is

sufficient rainfall to keep them filled. However, some people still mix rainwater with river water, even in the wet season, because otherwise they do not have enough [PGD].

During the dry season, these tanks are often empty within a month without rain [GNB, SGM]. When this happens, people must either drink water from the river, buy water, or bring it from the city. For those who do not have Duro tanks, this is always the case [MOI, SAY, PKP, PKD]. There are also villages without Duro tanks that try to harvest rainwater in other ways [SAY]. Some households have enough water stored in their Duro tank to last through the dry season [BEN].

In some cases, people share Duro tanks [DTB], but this can also cause conflicts [PKP]. In places such as the polyclinic, there is the possibility of pumping filtered river water into the Duro tanks when they are empty, using a portable pumping system from the main medical post in Diitabiki [KAR].

The problem with purchasing Duro tanks is not the price of the tanks themselves, but the cost of transport. People must pay for the amount of gasoline barrels the boat could otherwise have carried and sold [FAN, PKD, SGM]. The large volume of the Duro tank makes it expensive to transport. Installation, however, is not an issue, as there are people in the villages who can handle this [FAN].



Figure 6: Rainwater Harvesting Tank

Water pipe systems

The table below shows what different resources the villages have when it comes to a pipe system for drinking water supply.

Table 4: Drinking water Systems per Village

Filtered river water	Spring water	Not tapped spring	Pipe system not in use
DTB*	GDO	JAU	BEN
MOI		DTB	WAN
JAU		PLK	TBK
MAI		PGD	BPU
FAN		WAN	
MAN			

** At the side of the school in Diitabiki this is not working at the moment of interviewing*

In villages with water pipe systems, see Table 4, people can drink this water and do not need to go directly to the river to collect it. These systems are installed by the Ministry of Natural Resources (*Natuurlijke Hulpbronnen*, NH) [MAI], sometimes in collaboration with the Surinamese Water Supply Company (*Surinaamsche Waterleiding Maatschappij*, SWM) [DTB], and/or the water supply company BOSAQ [FAN, MAI]. To maintain these systems, there is always someone from SWM present in the village [DTB].





Figure 7: Drinking water System Moitaki

Even though people no longer have to physically go to the river, the water coming from the pipes is often still pumped from the river [DTB, MOI, JAU, FAN, MAN, MAI]. This water is filtered, although interviewees questioned the quality of these filters. As a result, some people still boil the water before drinking it [DTB]. When the river water was of better quality in the past, the water from the taps was also much better [DTB].

There is only one village where piped water is directly connected to people's houses, the newer ones, in addition to communal taps throughout the village: Godo Olo [GDO]. In other villages, there are only taps spread across the settlement [DTB, MOI, JAU, FAN, MAN]. In Fandaaki and Manlobi, there is only one tap per village and one for the school [MAN, FAN].

Only one village obtains its drinking water from a spring [GDO] at this moment. In some places, springs have been found, but there are currently no means to pump up the water [DTB, JAU, PLK, WAN]. There are also villages that have a pipe system, but no water is currently coming out of it [BEN, WAN, TBK, BPU].

Drinking directly from the river

For some people, drinking water from the river means finding a nearby creek where the water is relatively clean [MAN, OPU, WAN, TBK], or collecting water from a *sula* [BPU]. However, this is not possible for people from every village [KEM].

It has also been noted that elderly people drink river water more often and do not experience any physical problems related to its quality [KIS]. However, they do experience more difficulties in carrying the water from the river to their homes [GNB, KIS, TBK, PGD, SGM], especially during the dry season when they must walk much further [GNB, TBK]. *"You eat at the house, you drink by the river, because it is too heavy to carry everything up the steep path" [GNB]. "But either way, old or young, you will always need the river" [MOI].*

Boat drivers also tend to drink more river water than others. When they are on the river, most of the time, they do not bring drinking water with them but simply drink from the river as they go [DTB, BPU]. They also do not seem to have any problems with the water quality [DTB, BPU, MAI].

Boiling water before use

Although people are told to boil the water and let the sediments settle before drinking [DTB, BEN, BPU, PGD], not everyone does this [PKP, TBK, KAR, GNB, MAN, KIS]. Some say, *"We have been doing it like this for years, so why do this now?"* [TBK], while others simply do not have enough time [KEM]. Boiling water also requires gas, which is expensive [PGD].

People who partly live in Paramaribo are no longer accustomed to river water and may experience diarrhea when drinking it [PKD, KIS]. The same applies to those used to spring water [GDO]. "*As soon as you come to the inlands, you should start using the river water. Otherwise, if you have no other choice, you will get sick*" [MOI].

2.3.4 Food

Traditionally many people learned how to provide for themselves, either by going hunting in the forest, catching fish in the river or growing food on their own agricultural land. Common crops people grow are cassava, corn, Chinese tayer, bananas, rice and sugar cane. From the most planted crop, cassava, they make cassava bread and kwak which is their most common staple and can be preserved well, see Figure 9.

Interestingly, none of the interviewees use river water for irrigation; they rely entirely on rainfall, making agricultural activities fully seasonal. Almost every year they cut open a new part of the forest to prepare for the next planting season. After a few years, they might return to an area that was cut open before. The locations of these agricultural lands are often situated on higher ground.

Apart from the traditional ways of gathering food there are also some Chinese shops in a few villages. However, these are expensive due to transport costs [DTB] and not always as good [MAI]. People rather bring their supplies from Albina or Paramaribo themselves [MAI, DTB].

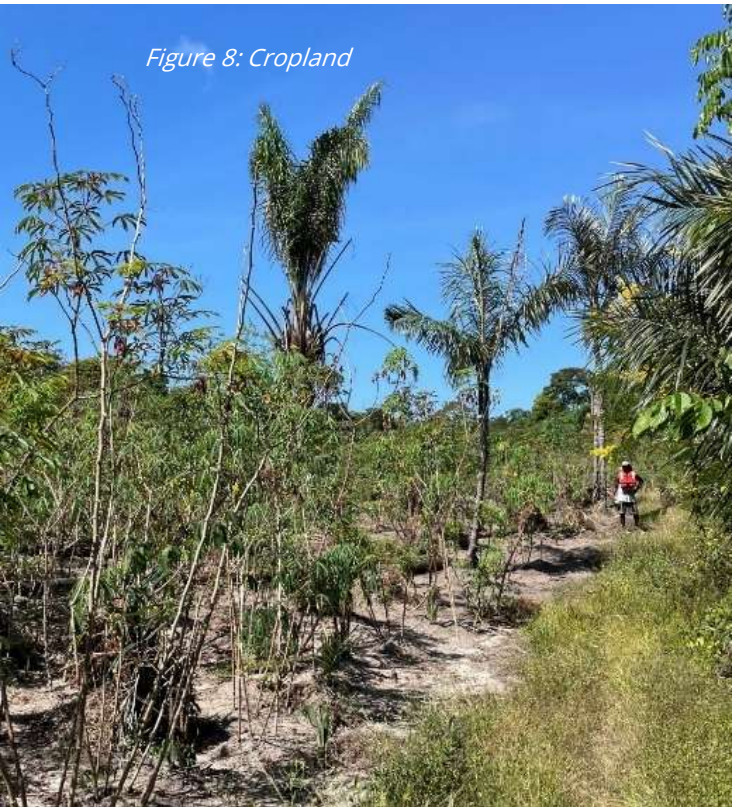


Figure 8: Cropland



Figure 9: Making Kwak in Diitabiki

2.3.5 Sanitation

In some villages, there are no sanitation facilities available at all, meaning that the river or certain designated areas next to it are used as toilets. In other villages, people have private and/or communal toilets, as summarised in Table 5. The communal ones (and sometimes also the private toilets) are often not like those found in the city but consist of a simple hole in the ground, so-called *pit latrines* [GDO, PKD, MAI].

Table 5: Sanitation Facilities per Village

No sanitation facilities	Communal toilets	Private toilet(s)
JAU	BEN (5)*	DTB
GNB	GDO	KAR
PLK	MOI	GDO
PKP	MAN (2)	MAN
SNB	MAI	KIS
	UGS	BPU
	PGD (4)	OPU
	PKD	WAN*
	WAN (1)	TJO
	TBK	SGM**

** Still in the building process*

2.3.6 Occupation

Most people living in the villages along the Tapanahony earn their income from gold mining or the transport sector. In addition, a significant amount of time is devoted to household activities and providing for themselves through crop cultivation and fishing.

Common professions

The interviewees reported a wide range of occupations, including boat driver, gold miner, brickmaker, electrician, nurse, teacher, shop owner, hydraulic engineer, construction worker, government function, Kabiten, and Basiya. Kabitens and Basiya's often combine their leadership roles with other forms of work.

Part time professions

Other sources of income in the region include making *pangi's*, working for the Ministry of TCT at the airstrip, boat building, see Figure 10, and carpentry. Women commonly earn money by producing *pangi's*, *kwak*, cassava bread, or by selling agricultural products.

Figure 10: Man Making Boat



Government work

Some people living in the villages work for the government. They can for example work as resort secretary/coordinator of the Tapanahony, which is the second highest position in the resort. The secretary communicates all plans of the government about the region to the local community. There are also supervisors who report what is going on in the villages to the district chief. Another function that people in the villages working for the government can have is local guide and contact person for government employees that come from the city.

In addition to people from the Tapanahony region that work for the government, there are also people that work for the government in Paramaribo and visit the region as part of their job. Think of people that bring allowances like the general old-age provision (AOV, *Algemene Oudedagsvoorziening*) and electricians that work on the electricity network. In some villages there are houses built where the government employees can stay. Amenities like education, water supply, healthcare and electricity fall under the responsibility of the government, however they do not always succeed to provide to provide this to the region due to for example budget constraints. It is also their job to maintain these amenities, which is usually the bigger problem.

Goldminers

There have been goldmines in the Tapanahony region for a long time. Some are big and of legal companies, like the ones near Sela Creek (Miata Metals is currently exploring exploitation options) and Puketi (Sranan Gold). However, there are also a lot of smaller, sometimes even illegal ones. Everybody knows of their existence, and it is the way many people in this region earn money.

In the civil war (*Binnenlandse Oorlog*) that started in 1986, the goldmining business has grown significantly. Around this time, it also started to use bigger machines [PKP, MAN, PKD]. However, other goldmines started later, like the one near Puketi and Sangamasusa, which started around 2019 [SGM]. There are also mines near Kiokondee, Kisai, Mainsi (Moitaki and Jausa), Godo Olo, and there are a lot of goldmines between Saaye and Poligudu that are not directly located near a certain village. Further away there are also goldmines near the *Lelygebergte*, downstream of the Okanisi villages around Gakaba, and along the Lawa. Upstream of Sela Creek are no mines anymore and the people of Gaanboli work hard to keep it this way [GNB].

The quality of the river water has decreased significantly when people started to mine right near the river, instead of further away in the forest [MAN] and in the river with (illegal) pontons. This is easier*, "People are lazy" [MAN],* and it can be dangerous and expensive to transport gold and equipment through the



Figure 11: Goldmining Installation

woods [MAN]. Although being easier, it also dumps their waste more directly in the river [MAN, PKD]. Additionally, pontons change the riverbed dimensions and impact the river morphology [DTB, PKD, FAN, MAN, MAI, OPU, PGD, WAN].

Working in the goldmines or not, all people recognise that the goldmines pollute the river and its environment. However, the degree of damage it does is not realised by everyone. The biggest impact will only be felt in the future [DTB, PKD, GDO]*. "Mercury does not kill black people" [MAI].*

The problem is that there are not a lot of alternative ways of earning money in the region at the moment [GDO, PKD, DTB, MAN, MOI]. *"You can become angry on someone who works in the goldmines, but he does not have any other source of income to feed his family" [DTB].* It should be noted that there are not only men working in the goldmines, although being the majority, also women work in the mines mostly as cooks [BPU]. In the early days, only men from the region worked in the goldmines. Now a lot of people come here for the gold business from other regions [DTB]. Sometimes children even stop with school when they 10- 15 years, to work in the goldmines [DTB, BPU, GDO, OPU]. However, there is a form of rivalry and ownership of land that plays a role in the gold business, people from one village cannot freely mine in the region of another village. They need to have friends or family there to introduce them [TBK].

The goldminers that come from the villages are mostly using mercury to extract the gold. This is illegal however and mercury needs to be smuggled into the country. Cyanide is used by the Chinese goldminers in the region [FAN, OPU], the locals are against this [GDO]. There are people who think that there should be more strict rules and enforcement to prevent this, and that people should be educated on the impact it has [DTB]. Working with heavy metals does not only pollute the environment, but also the workers working with them [DTB]. In addition to the toxic materials, there are also dangerous accidents happening due to unsafe working conditions [MAI].

When asked about the advantages and disadvantages of the goldmines, the response is along the lines of: *"When you find gold it is an advantage, when you do not find gold and all the other things Aiming at the pollution of river and environment), it is a disadvantage" [BPU, DTB].* People who do not work in the goldmines themselves, often do not see any advantages.

Another disadvantage is that the money does flow back to the people that are the most affected [PKD, FAN, PGD]. There are negotiations with Miata Metals to see if villages that the experience problems caused by the goldmines can be compensated and profit from the mines in some way.

Work in the goldmines is hard work [BPU]. Often people only get paid when they find gold, when they do not, they will not get any money [BPU]. When one does find gold, they can be so lucky to earn a lot of money. *"It is addictive like a gambling game" [PKD].*

Tourism

In the past there had been tourism in the Tapanahony region. A lot of it stopped after the civil war in 1986, and since than it has almost completely disappeared. In the rare occasion that there are tourists, they are mostly stopping for only a night or two on their way to Apetina or further upstream [MAN][LAN][DTB] or they are from the French side and also only stay for a night [BPU][OPU].

Some say the disappearing of tourists is because of the goldmining business and the polluted river water [PKD][MOI]. It has even been mentioned that because of these goldmining activities, government and

travel agencies advice against going to this region [PKD]. They prefer the Saramacca region where there is no goldmining [PKD][GDO]. Going there is also cheaper since the Tapanahony is much further away by boat or plane [DTB][GDO]. Another reason could be that there are simply not enough facilities here to house and entertain tourists [DTB][GNB][KIS]. There have been some people that did organise guided tours. When they died or stopped for other reasons nobody picked it up and their business disappeared [TJO]. "People want to earn money right away and do not want to set up something with what they might earn a lot of money in the future" [PKD][GNB]. People are scared that if they invest in it and no tourists will come, it will have been for nothing [PKP].

There are people that would like to see the tourism come back to the Tapanahony region [DTB][PKD][GDO][MOI]. With the slavery not that far in the past, there have been mixed feelings about European tourist visiting the region in the past. Now however, they would prefer Europeans over people from Paramaribo. There have been some mutual trust issues between the people from the inlands and the ones born and raised in the city. They often feel like they are discriminated by their own country man. However, since so many children have gone to the city to go to school this friction has become less [DTB].

2.3.7 Education

There are a few schools in the villages of the Tapanahony region, listed in the table below.

Table 6: List of Schools in the Region

Primary school	MULO school (secondary school)
MOI	DTB (first two years)
MAN	Stoelmanseiland
DTB	
GDO	
KAR	

The majority of information regarding school structures is gathered through the Gaanman Akontoe Velantie School in Diitabiki. This primary school has 120 students and 12 teachers, divided across eight classes. At this school, there are enough teachers. However, the situation is different in Moitaki and Karmel, where 2–4 teachers are responsible for six classes.

In general, classes run from eight in the morning until one in the afternoon. During the dry season, however, classes end at twelve due to the high temperatures. Around November, the school assesses whether classes can continue until one in the afternoon or if it remains too warm.

During lessons, children are taught mathematics, writing, reading, history, Dutch, nature studies, and other subjects. While textbooks are in Dutch and classes are mostly taught in Dutch, teachers sometimes need to fall back on Ndyuka to ensure students understand the material. This language barrier makes it

more challenging for both teachers and students to make progress, which, according to one teacher, distinguishes studying in the inlands from studying in the city.

Parents pay 75 SRD per child per year for school, which covers supplies used to maintain the school. Several school boats transport students from the surrounding villages to the school and back. These boats are funded by the government, as are the textbooks.



Figure 12: School Moitaki



Figure 13: Children Going to School by Boat

Teachers

To become a teacher, one must have completed primary and MULO education, followed by a four-year teacher training program. Previously, this program included a mandatory two-year internship at a school in the Surinamese inlands. While this is no longer a requirement, many teachers still complete their first teaching term in the inlands. *"If you are lucky, you find a position in the city right away" [DTB].*

When signing a contract, teachers commit to working in a given location for five years. In the inlands, this does not necessarily mean staying at the same school each year, but it does require remaining in the region. After completing their term, teachers can reapply for positions in the city, although exceptions exist that allow teachers to change schools earlier. Conversely, a small number of teachers choose to remain in the inlands, although this is rare.

2.3.8 Health Care

Polyclinics, locally referred to as 'poli', are present in the villages of Benanu, Karmel, Diitabiki, Godo Olo, and Stoelmanseiland. Staff at these posts are employed by and dispatched from the Medische Zending (Medical Mission). Larger posts, such as those in Diitabiki and Stoelmanseiland, have multiple staff members, whereas smaller posts, such as Karmel, often rely on a single nurse. If the nurse is absent, the post is closed, requiring residents to travel to another location for care.

The resources available at the posts vary considerably. While they are equipped to treat minor injuries and provide medication for certain illnesses, the overall capacity to deliver high-quality care is limited. Basic items, including paracetamol [FAN] or a scalpel [MAN], are sometimes unavailable, highlighting persistent resource constraints.

Common illnesses treated at the posts include fever, diarrhoea, and vomiting. Chronic illnesses are also prevalent in the region. Malaria is no longer present, which considerably reduces the disease burden, and cases of dengue are rare. Patients requiring treatment for trauma or chronic conditions beyond the posts' capacity are referred to doctors in the city. Pregnant women who have previously given birth five times are similarly referred, due to higher risk of complications [KAR].

Most staff hold qualifications as healthcare assistants or nurses. Doctors, who are generally of Hindustan origin, prefer to remain in urban areas and are rarely based in the inlands [FAN]. When guidance is required, medical staff rely on remote consultation with these doctors by phone [KAR].

2.3.9 Electricity

Some villages have a light aggregate, using gasoline funded by the government. The villages using a light aggregate mostly only have electricity in the evenings when it is dark. This differs per village but can be from six in the evening till around midnight [GDO, GNB, TJO, TBK] or even till a bit later, like two in the morning [MAN]. In special cases, for instance if someone dies, the village puts money together for gasoline to have electricity till six in the morning on the days of the funeral [FAN, MAN].



Figure 14: Solar Power Plant at Puketi



Figure 15: Electricity Pole

Other villages are connected to the solar panel plant in Puketi, which gives electricity 24 hours per day. The capacity is not big enough to connect more villages to this electricity source at the moment [DTB]. Then there are also villages where it is unknown if they have a connection or not [POW, MPU, NIK].

Godo Olo now uses a light aggregate, but they used to have their own solar panels. Since they stopped working two years ago, nobody has been able to fix them. Appliances like freezers that worked before cannot be used anymore [GDO]. In Benanu, Wanfinga, Poligudu (or Stoelmanseiland), Fandaaki and Manlobi they are also working on their own solar energy installation [BEN, FAN, MAN]. Benanu and Wanfinga are talking about the same installation here, near the poli Agaigoni [BEN]. The latter two villages could be working on an installation together as well, since they are located on the same island.

For the electricity, which is managed by the government, electricians often come from the city when there are problems. These problems are often caused by bad maintenance, falling trees or people that have wrongly connected their houses to the network. There have been occasions where problems were caused by floods. However, this is not systematically the case [DTB].

Table 7: Power Supply per Village

Light aggregate	Solar energy Puketi	Working on solar energy installation
BEN	DTB	BEN
KAR*	BPU	MAN
GNB	OPU	FAN
GDO	JAU	PGD
MAN	MOI	WAN
FAN	MAI	
PGD	UGS	
WAN	KIS*	
TJO	PLK	
TBK	PKP	
SAY	PKD	
KEM	SGM	
	SNB	

** Not working at the time of interviewing*

2.3.10 Socio-cultural dynamics

Something that stands out in the Ndyuka culture is that the mother line is very important. For example, a person has much more right of speaking the village their mother grew up in than the village their father grew up in. For this reason, it is much more common to become a Kabiten or Basiya in the village the mother grew up. It used to be that one could only inherit houses from their mother's line; more and more villages will allow people to nowadays also inherit from the father's line [DTB].

In times of hardship some villages speak and make offers to their oracle [PKP]. As their bond with the ancestors is strongest in the village the settled in, they feel spiritually connected to that place. That is why they will ask for council to their ancestors if they have a hard decision to make.

It is interesting to see that the mother line is so important, because in other aspect women are not always seen as equal to men. It is for instance unusual for woman to compete in football, with young children this is less of a problem. Although some young boys also do not accept it, if a woman wants to play football.

The women are the reason why some villages are still villages; they do the household and raise the children. While the father of the family is busy working in the goldmines or as a boat transporter and is usually not at home. In this case the women also take care of the agricultural land to grow crops. There are no days of rest, which usually is the case if one works as an employee in the rest of Suriname.

2.4 Functions of the Tapanahony River

For people living in the Tapanahony region, the river is essential: *"Without the river we cannot exist" [BEN].* Since their ancestors settled along its banks, life revolves around, in, and on the river, and the communities take pride in this connection. All interviewees rely on the river daily for washing clothes, personal hygiene, doing dishes, and transporting goods and people. The placement of villages next to the river reflects this

dependency: *"Otherwise, the Marrons who fled as slaves would have remained in the middle of the jungle" [DTB].*

Dependence varies between individuals, influenced by drinking water sources, sanitation facilities, and occupation. Boat drivers and fishers are highly dependent on the river and its water levels. People working in goldmines or making pangi skirts have a less high dependence. Access to piped water also changes interactions: households with pipes may have washing machines and do not need to go to the river for laundry [TJO*].

2.4.1 Seasonal differences in river use

The ways people interact with the river change with the seasons. Some interviewees report that their daily routines stay largely the same [DTB], while others notice clear differences. The river remains essential, but how it is used shifts depending on seasonal conditions.

In the dry season, transport decreases because boats cannot reach all locations [DTB, BPU, BEN, PKD, GNB, GDO, MAN]. Certain river branches are navigable only during either the wet or dry season [SGM]. Transporting goods takes more time and boats carry less cargo, which increases costs [DTB, BPU, PKD]. Companies often prepare by stocking up while water levels are still high [DTB, KEM].

Heavy rainfall allows people to use rainwater for washing dishes and clothes in addition to drinking [MOI, MAN]. The wet season can also be dangerous: children are not allowed to swim because the current is too strong [DTB, KIS, PKD, PKP], and sometimes even adults are at risk [BPU, GDO]. Small boats without engines often struggle against the current, making it difficult to travel [JAU, PKP, PLK].

Water quality also changes with the seasons, affecting drinking water use. Most people rely more on the river during the dry season, except those with access to spring water (see Chapter 5). Seasonal hazards and the arrival of outboard engines have also changed river transport [PKD].

2.4.2 Longterm changes in river dependence

Over time, people's interactions with the river have shifted. Many avoid drinking river water due to mercury and other pollution from goldmining [DTB]. Modern houses often include sinks [GDO] or toilets, which reduces reliance on the river for sanitation and dishwashing. Additionally, outboard engines have changed transport dynamics [SNB].

Age also affects interaction: older residents may stop operating boats, either because they are afraid of getting stuck in sula's [BEN, OPU, TBK] and are unfamiliar with outboard engines [TBK]. Waves from motorised boats have made travel in smaller boats like these more difficult [TBK]. Older people tend to focus more on household and cropland tasks rather than transport [JAU, PLK, TBK].

Despite these changes, core daily uses, such as washing, dishwashing, and transport, have remained consistent across generations [DTB].

The fact that no matter the season interactions with the river occur on a daily basis, shows that the Okanisi need the river for their existence. Living further away from the river would take up a lot of time and is for some, and especially elderly, not realistic.

2.5 Problems in the Region

Although the specific challenges vary across villages, the primary issues affecting the region can be clearly identified through the interviews. The table below presents the seven main problems, along with the villages whose interviewees highlighted each issue as a main concern for their community or the wider region:

Table 8: Overview of Problems per Village

Village	Drinking water	Education	Health care	Sanitation	Employment	Waste	Flooding
GNB	■	■	■				
PGDO		■					
FGDO		■	■				
SGDO		■	■				
UGS	■	■					
PKD		■			■		■
PKP	■			■	■		■
KIS	■						
SNB		■			■		■
LOA							
PLK	■			■			
DTB	■	■	■	■	■		
MAI		■					
JAU		■		■		■	
MOI	■	■					
OPU		■	■				
BPU		■					
SGM	■			■			
TJO	■	■			■		
POW							
KAR					■		
MPU							
SAY					■		
KEM							
FAN	■		■				
MAN		■	■				
NIK							
WAN	■						
BEN	■		■				
TBK	■			■			■
PGD	■		■				

The light blue rows are villages where there was either no one present, or there was no time in the interview to determine what the problems are.

It should be noted that even though a lot of interviews mentioned some of the seven problems during the interviews, like waste, flooding and sanitation, they did not always point them out as being one of the main problems. Other problems mentioned that are not included in the Table 8, are listed below:

- A continuously working electricity system [GNB, GDO, WAN].
- Transport is expensive [DTB, GDO, FAN, MOI] making everything else expensive [MOI, DTB]. There is no (good) road or anything public that connects the villages to other parts of the country [GDO] which would make things much cheaper.
- People that move to French Guyana get money from that government (child support), since this is not provided in Suriname, people leave the villages and the country [KAR, DTB, MAN, WAN].
- Almost all villages are located on islands which makes development on regional scale harder to realise and more expensive [JAU, PKD].
- In the goldmines there are people selling drugs and there is prostitution [GDO].
- Riverbank erosion [GDO, WAN].
- The lack of a Krutu place (gathering place) in the village [KIS].
- The need for a jetty [PGD] for old people [PKD].
- Soil erosion caused by heavy rain [PKD, TBK].
- Food supply, especially for elderly [TBK].

2.5.1 Drinking water

There is a lack of drinking water systems and facilities. Therefore, the majority of the people is partially dependent on river water as a drinking water source, especially in the dry period. Both the quality of the water and the distance from the river to the village are problematic. This problem is discussed at length in Section 2.3.3.

2.5.2 Education

There are several challenges in the region's education system. Firstly, there are too few schools, and opportunities for further study and development beyond primary education are very limited. Over the past seven years, the number of children attending the school in Diitabiki has declined from around 300 to 120 [DTB]. In addition, some children (and their parents) relocate to another village or the city for most of the year, returning only during school vacations [GNB].

Secondly, there is a shortage of teachers, and retaining staff in the inlands is difficult. This is due to primitive or poor living conditions and inadequate housing facilities [GDO, PKD], as well as limited opportunities for further education and personal development for both teachers and their children [DTB]. While housing is provided, teachers must repair any damage themselves, such as a leaking roof.

The school buildings themselves are also often in need of renovation [MAN], and there are insufficient textbooks for children to take home and study [DTB]. Some children leave school early, either to earn money [DTB, PKD] or due to teenage pregnancies [PKD], in which case boys often take on the responsibility of providing for the mother and child [PKD].

It has also been noted that *"The teachers are in need of education"* [PKD], indicating that some teachers are not fully qualified to teach. Children who move to the city for better education often fall behind. A key

barrier for village children is Dutch, the language used in lessons and textbooks, which they do not speak at home, unlike children born and raised in the city. *"They are afraid they'll say something wrong and get laughed at. They rather stay here" [DTB].*

2.5.3 Healthcare

There are too few polyclinics, and the ones present often lack sufficient resources to treat people. For a lot of illnesses, they do not have the right medication [DTB, KAR]. Sometimes, they do not even always have electricity or clean water [KAR]. Again, it is hard to keep the employees in the inlands because of the same reasons as keeping teachers in the region.

2.5.4 Sanitation



Figure 16: Communal Toilet

Most homes have no private sanitation facilities, and most villages do also not have any communal sanitation facilities. In the cases where there are toilets, these are usually equipped with a flushing system, which creates the problem of requiring water and that is often not available in sufficient quantity [SGM]. As a result, people need to collect water from the river to use for flushing [DTB].

In villages where only private toilets are available, most inhabitants still use the river as their toilet. When communal facilities are available, these are often insufficient for the whole village [MAN, MAI, PKD] and tend to be broken, full, or too dirty to use [PGD, TBK]. The latter is often caused by children [TBK, PKD]. During periods of high-water levels, toilets with septic tanks are at risk of flooding, which creates additional problems [PKP, DTB, TBK].

For these reasons, people often revert to their old habit of using the river as their toilet [MAN, MAI, PKD, TBK]. There are ongoing efforts to raise awareness about the consequences this has for the river's water quality [GDO]. Not only does this practice pollute the river [GDO], but it also poses difficulties for elderly people [KIS, SGM].

2.5.5 Employment

Earlier, in Section 2.3.6 the current jobs that people can practice were described. For most people this is either in the goldmines or working as a cargo transporter, often mostly for the goldmines located along the Tapanahonyriver. Some people do work daily on their own personal farmland, but this is predominantly for their own use and sometimes they can sell their products locally. So, for them to start growing crops on a larger scale a market should be created. Right now, the transportation costs to the city are acting as a barrier for this market to emerge. As the variety of jobs that people can practice is very limited, many end up leaving the region.

2.5.6 Waste

Even though waste management is not named as the biggest problem in any village, a lot of the villagers would like to do something about the situation. As they experience waste flowing ashore, which comes from other villages upstream. It is therefore included in the list of established problems.

Disposal of waste is seen as a big problem by a lot of the villages. It pollutes the river when it is thrown in, and when it is dumped on land it also gets swept away during high water [GNB, GDO, OPU, PKP]. The biggest problem around waste is that there is no communal overarching form of waste management in the villages, and there is a lack of awareness of what dumping waste in the river does to the living environment. In more than half the villages, there is a place where they collect and burn (a part of) their waste. Villages that have mentioned the owning such a waste collecting point are: Benanu, Diitabiki, Godo Olo, Moitaki, Manlobi, Un Gwa Soo, Kisai, Opuse Puketi, Polokaba, Poligudu, Pikinpisi, Pikienkondee, Wanfinga, Tjon Tjon, Tabiki, Sangamasusa, and Sanbedumi. It should be noted that the subject has not been discussed in all interviews due to the limited time available during some interviews. Even though these collecting points exist, there are still a lot of people who throw their waste into the river [BEN, DTB, JAU, GNB, KIS, PKP]. Especially kids throw it in the river more often [MAN, SGM, DTB]. Some people try to talk point it out when they see someone throw trash in the river [DTB, SNB]. However, not everybody realises that dumping waste in nature is a problem [PKP, DTB]. *"They still have to realise that keeping the river clean is of value to them" [DTB]*. There are also people who do think people have become more aware of this than in the past [TBK]. Nonetheless, there is not someone in each village that is responsible for the correctly disposal of waste, which makes it hard to regulate it [MAN].

Even though waste management is not named as the biggest problem in any village, a lot of the villagers would like to do something about the situation. As they experience waste flowing ashore, which comes from other villages upstream. It is therefore included in the list of established problems.



Figure 17: Waste Dump Near the River

2.5.7 Flooding

While flooding is not often mentioned as being a main problem, it is a very serious problem in some villages. This could also be caused by the timing of this research. With interviews being held in the dry season problems such as clean drinking water are more prudent in people's daily lives, as they are confronted with this issue every day. *"When you would do these interviews while people's houses would be flooded, this would feel like a much bigger problem" [PKD].* The problems around flooding are described at length in Section 4.3.

2.5.8 Depopulation of the Tapanahony region

The main problems such as availability of clean drinking water, sanitation and health care are problems people experience daily. There are no hospitals, only a few medical posts in 4 villages. If someone needs to go to the hospital, they need to take a plane, which is very expensive. Next to that, the education and employment opportunities are so little that people start leaving the region for an indefinite amount of time. This looks to be the biggest overarching problem: an overall decline in population in the region. People downstream of Puketi predominantly move to French-Guyana, and the people upstream from Puketi mainly move to the city Paramaribo [FAN]. Especially, a drain of young people is causing the region to de-develop.

When people want better education for their children, they either find a place with friends or family for them to stay, or the parents move with them to the city [DTB, JAU, MOI]. However, life in the city is expensive [PKD]. It often also happens that the fathers stay behind to earn money in the goldmines or find a job in other districts of the country [KIS]. There are, of course, also possibilities for parents to find work in the city, but the opportunities depend on their own level of education. On top of that, the motivation of children in the region to do well in school is lacking. What a good education can bring them is not visible. What is visible, is boys of a few years older earning money by transporting gasoline for the gold miners for example. This causes children to drop out of school early on in their education, something their parents moved their whole livelihood for.

Children that go to school in the city often stay there because there is not enough work in the inlands and they are used to the way of life in the city. When their parents get old, they either move to the city as well [DTB] or the children have to move back when they cannot care for themselves anymore [SAY]. Since young people often find work in the city the second possibility is very uncommon.

The houses that are built always remain in the family, so when people die or move, they are not sold. They stay empty and slowly break down [DTB]. It is the responsibility of the children to maintain the buildings, but they often do not want to invest their money in renovating the houses [PKD]. Therefore, all the villages have a lot of these empty dilapidated houses.

2.6 Future Development

Future development is needed to deal with the problems described. There are already ideas from the interviewed people and the Gaanman himself how progression can be realised, these will be described in this section.

2.6.1 Gaanman Bono Velantie Campus (GBVC)

The Gaanman has worked on a development plan for the region, first focusing on the development of education in the region. A foundation has been established, the Gaanman Bono Velantie Campus (GBVC), to build a new campus starting in 2026 and planning to be finished around 2030. The aim is to build a school where people can be technically trained, schooled in healthcare and entrepreneurship. With as goal to strengthen the local communities and promoting development, employment and entrepreneurship in the region. In order to prevent further depopulation.

2.6.2 Local Ideas for Future Development

During the interviews the inhabitants were asked if they knew a possible solution to their problems. The ones that were named most are described here, the full list can be found in Appendix I.

Farming and road connection

What is often named in interviews is the need for a road [DTB, JAU, UGS, GDO, PGD]. According to the inhabitants, a road would make prices of products go down [GDO], as well as provide access to the market, making it much easier for people to sell their produce and make a little bit of money. This would then tie into what is also much mentioned during interviews, to farm on a larger scale using either plants or livestock [PKD, MAN, JAU, FAN, PGD, PKP]. According to one interviewee the Okanisi only know how to farm in the traditional way, in which they are very dependent on the seasons. He thinks they should learn professional agricultural ways of planting and harvesting, so they can harvest throughout the whole year. These newer techniques could also help them to deal with the dry seasons. If they would learn how to fertilise the ground, they would not have to open up a new piece of forest every year is what he says [DTB]. Combining large scale farming in combination with a road connection could be a way to move forward. However, people are also scared of the downsides that come with a road connection [GDO, MAN]. Which is quite reasonable as the law enforcement is already negligible in the country, so there is no reason to assume the people and their land would be protected from others looking to exploit it.

Tourism

Tourism is also mentioned in interviews [PKD, DTB, KAR] as an option for development. They mention organizing trainings for tourism for the inhabitants. This is quite a logical path to take, as it is exactly what the Saramacca people also did. The problem is that people also have the idea that tourists would not want to come due to the pollution of the river.

2.6.3 Stakeholder Analysis

This stakeholder analysis will be different due to the special circumstances of this region. The Tapanahony region is remote, and the Surinamese government is known to be corrupt in the past few decades. This combination results in a lack of government involvement. Instead, the region seems to be more governed by money than by rules. At the same time the inhabitants value their culture and religion quite strongly, and they are both tied to the river and the location of the village itself. So, when doing a stakeholder analysis, both interest and influence of stakeholders will mostly be determined by either culture or capital.

Stakeholder classification: interest and influence

- Inhabitants of the Ndyuka villages on the Tapanahony represented by the client Gaanman Bono Velantie

  The interests of the inhabitants differ depending on the village. Several inhabitants are interested in the project because their village is flooded, others are interested because they use the river for drinking water during droughts. The villages are represented by the Gaanman. So, both the interest and the influence of the Gaanman is strong.

- Illegal Gold miners (Ndyuka, Brazilian, Chinese)

  Might be interested in the project because droughts influence transport of goods on the river like gasoline and food. They could have a strong influence on the project due to a combination of their wealth and their connections.

- Gold mining company Miata Metals at Sela Creek

  Might be interested in the water quality component of the project. They also might be interested due to the impact of droughts on their transport line. Could have influence on the project due to their wealth.

- Boat drivers

  These are boat drivers from the area, but also from further downstream. Interested in keeping navigation possible during droughts and floods.

- The government

  The government has not shown considerate interest for flood problems in the region.

Stakeholder Interaction

The figure below illustrates how the stakeholders in this project should be approached. The Ndyuka inhabitants are being engaged and consulted by doing a workshop, conducting interviews and communicating with the client the Gaanman through Rudi Darson the main contact person.

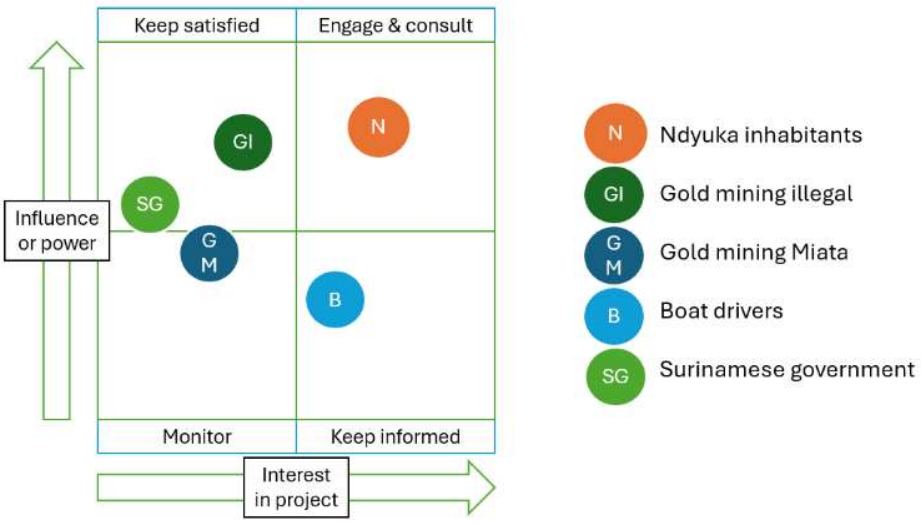


Figure 18: Stakeholder Classification

2.7 Answer to sub-questions 1 and 6

What does the Tapanahonyriver mean for the daily life, culture and livelihoods of the Okanisi people?

From the many interviews and observations, it can be concluded that the Okanisi people depend heavily on the river. They use the river multiple times per day. They cannot be located far from it inside the jungle as everyone uses it for transportation, doing the dishes, bathing, fishing and sometimes drinking.

What are the main problems existing in the region that prevent the possibility of sustainable development and what are the first steps to address these problems?

During the interviews many other big issues, next to flooding, were documented that need immediate attention. First, the availability of clean drinking water is a big problem for many people that are still living in the region. Secondly, the opportunity to develop oneself in school or at work are lacking. There is not one fully equipped Mulo school in the region and other than the goldmining industry there is limited work. This causes a lot of people to leave, consequently providing even less job opportunities.

As mentioned before in this chapter, few people have the facilities to go the toilet instead of going to the river or woods, which causes the river to become more polluted. Another pertinent problem is the lack of good health care. A few villages still have a polyclinic and these often do not have the supplies needed to treat people.

Another problem which is for the people themselves not the most pressing problem, but is in definite need of attention, the treatment of waste. As this is currently still being thrown into the river, this also spreads bacteria through the region. Some villages do gather the trash in the village, but not everyone is taking part in this. Besides during high-water these trash heaps are flooded, and the waste is still entering the river.



3 Climate Analysis

In this chapter, historical data on discharge and precipitation is analysed. Zooming in on the available discharge data, provides an indication of the order of magnitude of the average discharge of the Tapanahony, but more importantly the extremes of both high and low flow. Subsequently, investigating how precipitation patterns and extremes have evolved over time can give an indication into how the climate has changed and what this could potentially mean for the Tapanahony discharge patterns in the future. This perspective on the future is further looked at through reviewing existing climate scenarios for Suriname.

3.1 Historical Data

As preliminary study, research has been conducted to find available historical discharge and precipitation data.

3.1.1 Discharge Data

The data available on the discharge of the Tapanahonyriver is limited. There is one station located at Kiokondee, that reports daily water height data on the HydroPortail of Eaufrance, made available by the French government (Eaufrance, n.d.). This is measured at a certain point in the river using a pressure sensor, which can be seen in the set up in Figure 19. It also reports discharge data from the river, giving the maximum, minimum and average daily values. However, information on how this discharge is determined is unavailable.

Figure 19: Kiokondee Water level Measurement Station





Figure 20 shows the minimum and maximum daily water height measured at Kiokondee. Subsequently, Figure 21 shows the minimum, maximum and average discharge data reported. The data illustrates the seasonal pattern of the data, with high flows usually during the months April to August during the wet season, and low flows during the dry season in September through to November. The maximum measured water height was 3.99 m, with a corresponding discharge of 3000 m^3/s, recorded on the 27th of April 2022. The minimum measured water level was on the 20th of November 2024, amounting to 0.58 m. The minimum discharge reported was 11.4 m^3/s, which occurred three days later. From the 4th of September 2025 onwards, no more data has been recorded by this station.

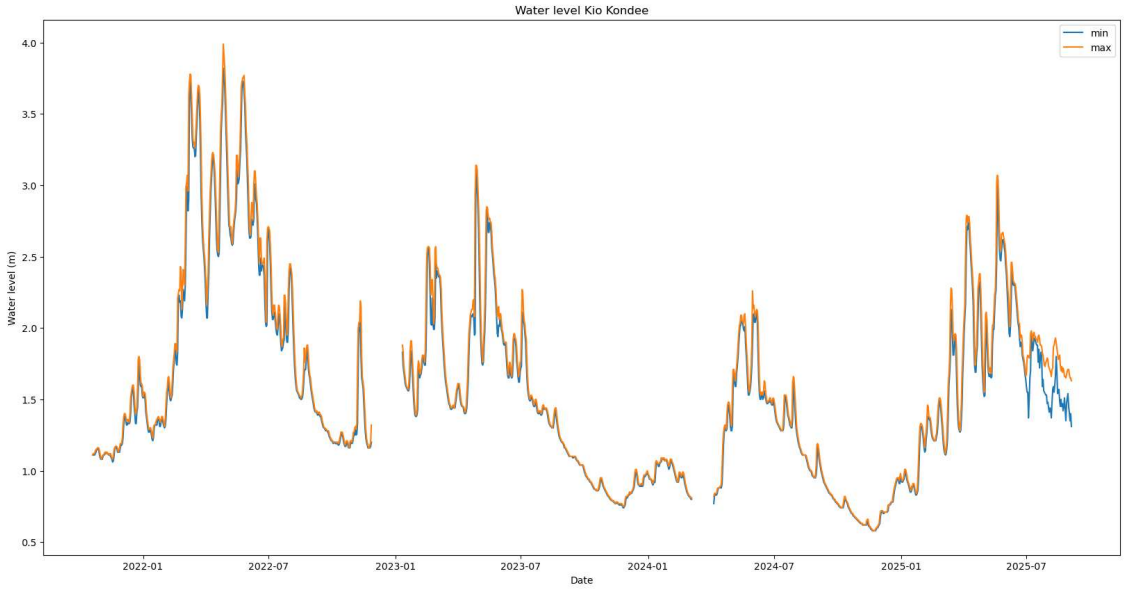


Figure 20: Water level Timeseries Kiokondee

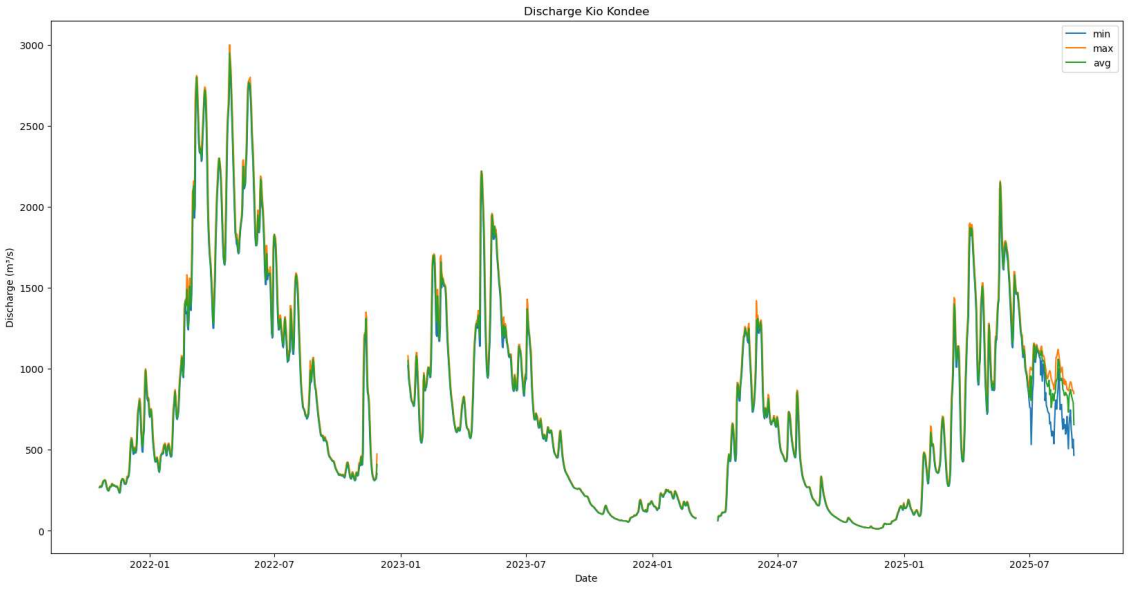


Figure 21: Discharge Timeseries Kiokondee

Besides the hydraulic data from the French government, water height data is available at three other locations along the Tapanahony, reported by the Database for Hydrological Time Series of Inland Waters

(DAHITI) (Deutsches Geodätisches Forschungsinstitut Technische Universität München, 2025). This database uses satellite altimeter data, which measures elevation data of the river's surface. Thus, water level heights are given in comparison to total land cover elevation. In Figure 22, the time series of the DAHITI measurement point closest to Kiokondee is presented. It shows a maximum water height of 49.8 m, recorded on the 25th of March 2022. This is a month before the greatest water height is measured at the Kiokondee station but does show that the highest water levels were recorded in the wet season of 2022. This is also in accordance with what was observed in the interviews conducted, as indicated in Section 4.3. The total difference in water height is 4.05 m, which is approximately 0.5 m larger than the Kiokondee data suggests. Furthermore, the time series illustrates the seasonal pattern of the water height. The time series of the other measurement locations are included in Appendix E.

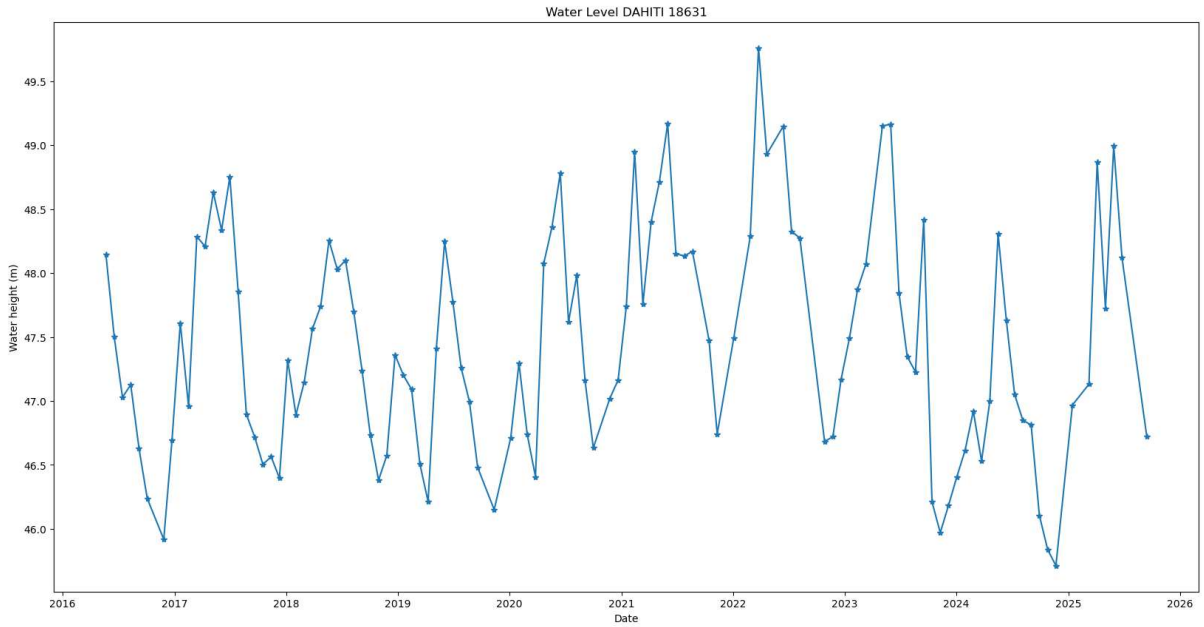


Figure 22: Water level Timeseries DAHITI 18631

A summary of the available discharge data is given in Table 9.

Table 9: Available Discharge Data Tapanahony

Measurement Station	Type of Data	Frequency	Years of data available	Location w.r.t. research area
Kiokondee	WS min, WS max, Q min, Q avg, Q max	Daily	October 2021 – August 2025	In the middle of the research area
DAHITI 18631	WS	Approximately monthly	May 2016 – September 2025	Point most downstream of the research area
DAHITI 22639	WS	Approximately monthly	December 2018 – September 2025	Upstream of research area
DAHITI 22640	WS	Approximately monthly	June 2016 – October 2025	Most upstream of the research area

Data on water heights and discharge before 2016 is scarce, with often only several months or a year of data at most. Additionally, these measurements are related to relative levels of which records were untraceable. Thus, this data was not used in further research in this project, but an overview can be found in Appendix J.

3.1.2 Precipitation Data

Contact with the Department (Meteorologische Dienst Suriname, MDS) resulted in the availability of historical precipitation data of the following stations: Diitabiki, Palumeu, Stoelmanseiland, Alalapadu, Apetina en Tepoe. Due to budget constraints and based on the geographical location of the stations and relevance for the project, a selection of four stations has been made: Diitabiki, Stoelmanseiland, Apetina and Palumeu. Table 10 shows the available years of data, and location with respect to the research area of this project. Where the research area is defined as being between the most upstream and downstream Okanisi village along the Tapanahonyriver.

Table 10: Available Precipitation Data Tapanahony

Measurement Station	Years of data available	Location w.r.t. research area
Diitabiki	1969, 1972-1979, 1982-1985, 1990-2000, 2005-2025	In the middle of the research area
Stoelmanseiland	1961-1970, 1972-1981, 1983-1986, 2005-2025	Point most downstream of the research area
Apetina	1959-1970, 1972-1981, 1983-1987, 1996-2025	Upstream of research area
Palumeu	1969, 1972-1987, 2006-2025	Most upstream of the research area

Data from these stations has been used in this research. The precipitation data of all four stations is plotted in Figure 23. It can be noted that there is a data gap at three out of the four stations, after the civil war that started in 1986. During this war a lot of stations have been destroyed. It has taken some time to repair the damage and build these stations up again. This has been confirmed in personal contact with the Waterloopkundige Afdeling (WLA).

Additionally, it should be noted that the precipitation is measured at the airstrips in the villages. The assumption could be made that these were not in use anymore shortly after the civil war and the precipitation measurements have only started again when the airstrips were used again.

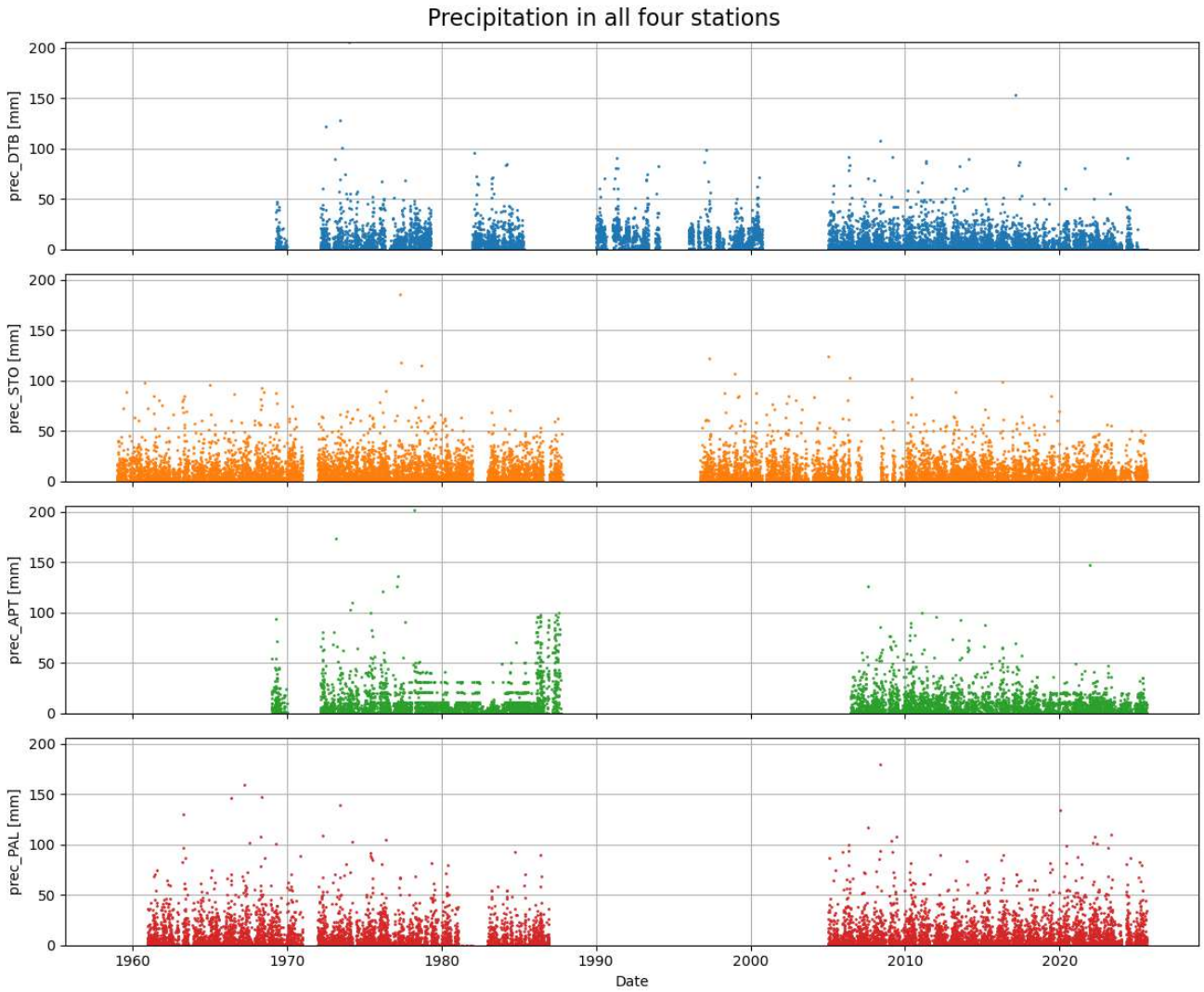


Figure 23: Precipitation Timeseries 4 Stations Tapanahony

The Apetina dataset shows a distinct anomaly or pattern around 1980. The pattern follows horizontal lines while in the rest of the data set(s) this is not the case. An explanation for this could be that the scale used during that time has not been as precise and the values have been rounded off roughly. Resulting in these horizontal lines of data points. However, this is again only an assumption. No information has been found on the specific measurement devices used in the stations over time.

The data shows a clear seasonal pattern with high fluctuations in precipitation intensity. There are also some extreme values that seem to be high even for a tropical climate. The extreme values were not removed from the dataset, as there is currently insufficient information to assess their validity or origin. It remains unclear how precipitation was measured at the time and whether these extremes represent real events or possible measurement errors. Therefore, they were retained in order to avoid introducing subjective bias or unsupported assumptions into the analysis.

3.2 Methodology

In this section, the methods used to perform the climate analysis are described. First, a further analysis of the discharge time series is performed. Subsequently, the precipitation data is looked at to see whether there is a significant change in rainfall before and after the year 2000. Finally, the results are compared to existing climate scenarios of Suriname to provide an outlook on the future.

3.2.1 Discharge Analysis

To understand the interplay between water height and discharge, the stage-discharge relationship of the Kiokondee data was analysed by applying a power law fit. This was compared to literature and to a measurement conducted during this research to visually assess the fit. A further explanation of how this measurement was performed, and how the water height and discharge are calculated can be found in Chapter 4. The water height of the Kiokondee data was noted during the time of measurement, so measured water depth and water height could be linked.

Equation 1: Power Law Fit

$$Q = a(h - h0)^b$$

The discharge data from Kiokondee was then matched to the DAHITI 18631 data points, in order to create a stage-discharge relationship for this location, again using a power law fit. Kiokondee discharge data was used as there are many more data points compared to the uncertainty of one measurement conducted during this research. Subsequently, this was used to extend the discharge time series as the DAHITI data set has five additional years in data and more recent data. Finally, this total time series was analysed to find the maximum discharge measured in the past decade.

3.2.2 Climate Analysis

The historical precipitation data was used to analyse if there has been a significant change in precipitation pattern in the available data set. A comparison was made between data from before and after 2000, looking at seasonal patterns, rainfall frequency, rainfall intensity and dry spells.

Before this analysis was done, the data was processed. First, the dataset was split up in one with all the data before and one with all the data after 2000. A data frame was made with three columns of differently processed data, that were used in the different analyses. The data was processed in the following ways:

1. All the months with no data at all were excluded from the study.
2. From the months with data, all the days without data were given the mean value of that that month, based on all the data in that month over the years.
3. For the third processed data set, the same was done as in the second. However, this time only using months with 25 days of data or more. All other months were excluded. The mean that was used to fill these months therefore only calculated with data from months that fall within that boundary condition.

Seasonal Patterns

To analyse the seasonal patterns, the data is first resampled to a monthly sum. From which the mean value over the years is calculated for each month. Plotting the monthly sum average of all the data before

and after the year 2000 shows the seasonal pattern change if there is any. Three versions of the seasonal trend analysis are calculated, for each using one of the three data sets as described before. In addition, the average amount of rainy days per month has been calculated and compared for the third data set. Within this analysis, a rainy day is considered as one with daily rainfall equal to or exceeding 1 millimeter. Finally, the standard deviation is calculated for the third data set. Indicating the deviation of the data around the mean value.

Intensity Duration Frequency (IDF)

The intensity duration frequency was analysed for a rain event of 1, 2-, 5-, 10- and 20-day duration. Using the data that has been filtered for months without any data (processing method 1), the number of occurrences, number of exceedances and the corresponding rate of exceedance were calculated. This was then translated to the return period of each of the rain events, for a return period of 0.2, 0.5, 1, 2, 5, 5, 10, and years, where the data allowed for such a length. Subsequently, the outcomes for the data pre and post 2000 were compared to get an indication in how precipitation extremes have changed throughout the past five decades.

Dry Spell Analysis

The dry spell analysis looks at the consecutive periods of no rain, where the boundary for a dry day was defined as a day with less than 1 millimeter of precipitation. The probability for these dry spell durations was calculated for the pre and post 2000 precipitation data.

Two methods were used to calculate the dry spell length. The first methods stopped counting the dry days in a dry spell immediately when it reached a NaN value. The second method had a set number of NaN values in a row that it allowed within a dry spell. These days without data were then considered dry days.

3.2.3 Climate Scenarios

Research is done into other studies looking into the climate change in Suriname. These are analysed and compared to the results of the earlier analysis described.

3.3 Discharge

In Figure 24, the stage-discharge relationship of the Kiokondee data is shown, fitted to all data points. The fitted parameters of the power law fit are given in Table 1.

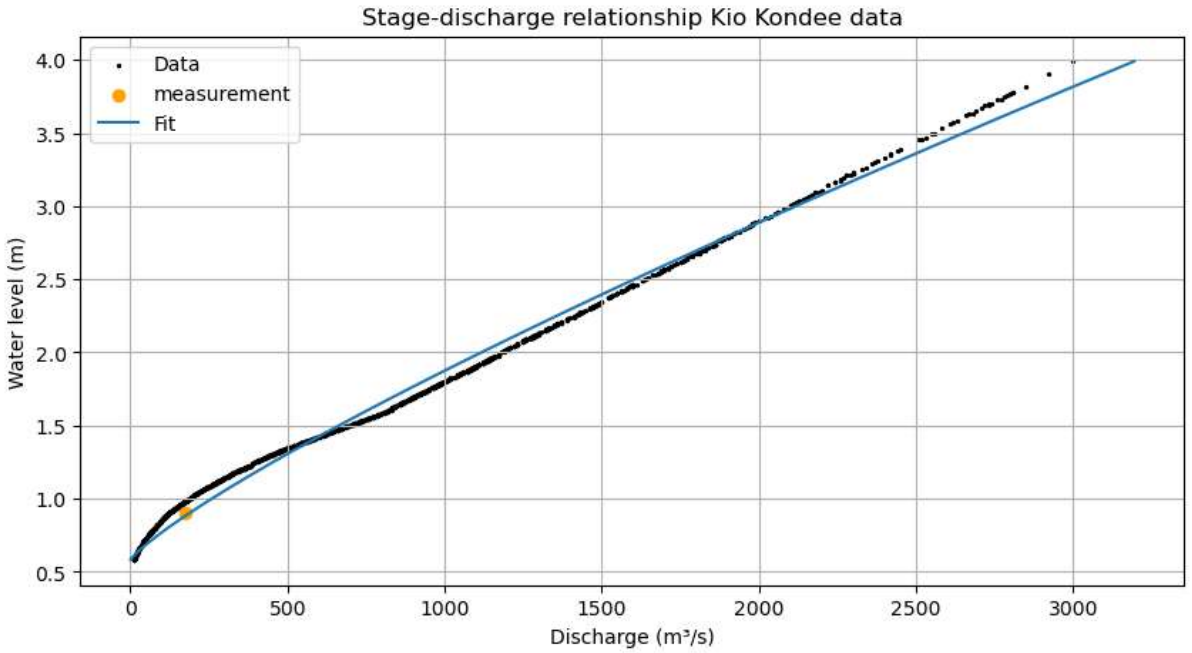


Figure 24: Stage Discharge Relationship Kiokondee

Table 11: Fitted Parameters Stage Discharge Relationship Kiokondee

Parameter	Value
a	733.4
b	1.200
h0	0.580

Surprisingly, at approximately 800 m^3/s a change in the slope of the data can been seen, suddenly going to a linear relationship instead of a declining slope as is the case in most of the literature and that can be noticed in the power law fit (Kim et al., 2016). The orange point in the figure points out the measured water level and discharge and falls close to the line of the power law fit. Apart from the slope, the starting point of the data also calls for some caution as the discharge is reported as 0 m^3/s when the measured water level is not 0 m. Thus, some uncertainties remain in the measured water height and the corresponding discharge.

Figure 25 presents the stage-discharge relationship of the DAHITI water height data using the discharge of the Kiokondee data, and Table 12 provides the parameters corresponding to the power law fit.

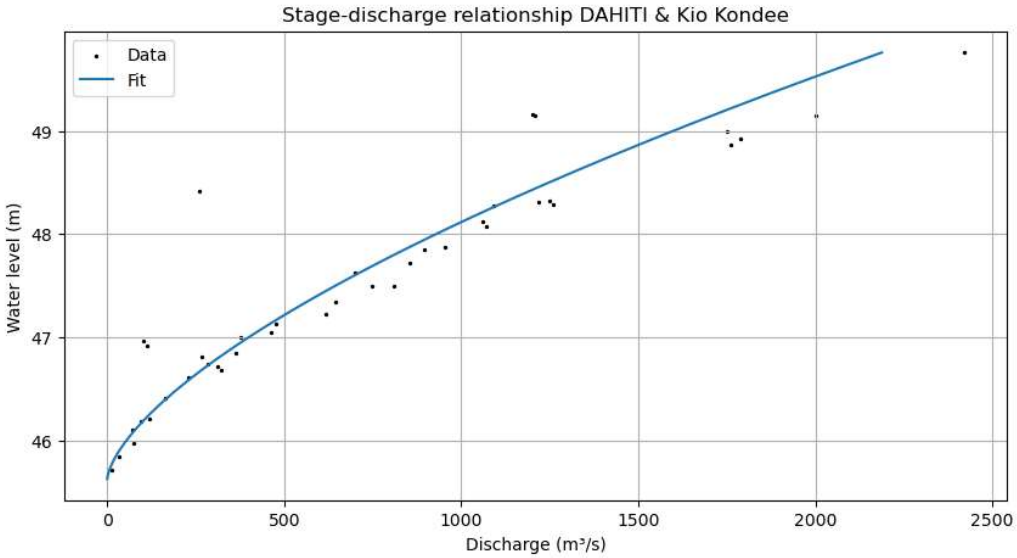


Figure 25: Stage Discharge Relationship DAHITI

Table 12: Fitted Parameters Stage Discharge Relationship DAHITI

Parameter	Value
a	241.9
b	1.549
h0	45.62

Using this stage-discharge relationship to expand the DAHITI discharge, the full discharge time series of the Tapanahony is given in Figure 26. Here the DAHITI data is plotted using the power law fit. The maximum discharge measured remains 3000 m^3/s. Furthermore, it looks like the discharge is lower overall, which also seems the case when inspecting the DAHITI water height data. However, because of the few points throughout the time series and because discharge can vary significantly within a month it is not possible to say this is a definitive difference.

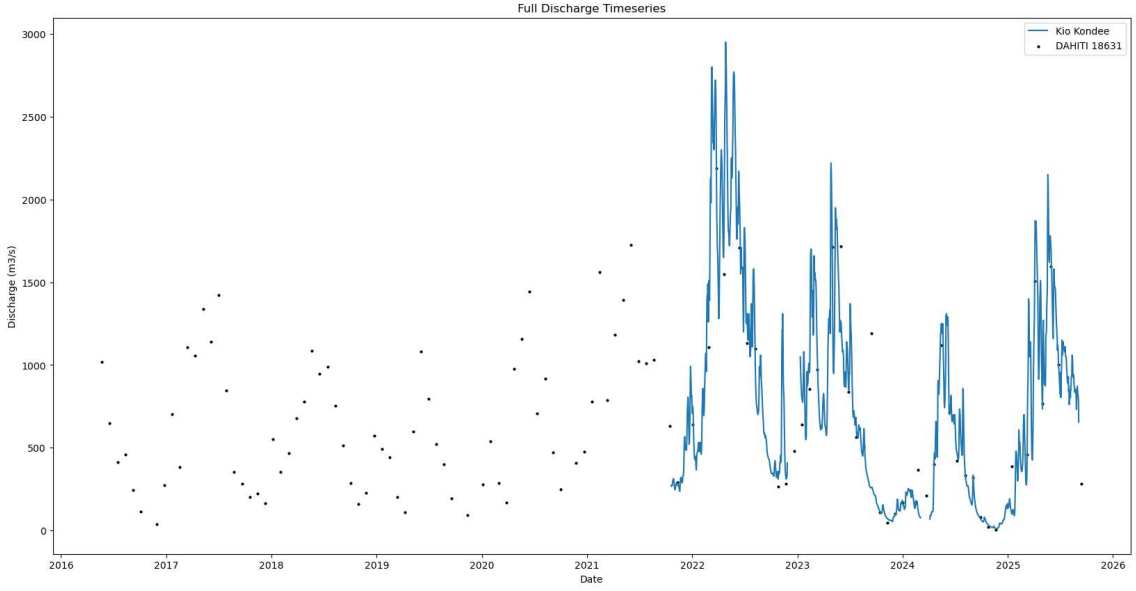


Figure 26: Complete Discharge Timeseries Tapanahony

3.4 Seasonal Patterns

The results of the seasonal pattern calculations using the third data set can be found in Figure 27-30. This method provides the most consistent and reliable approach to handling data gaps. The other results can be found in Appendix E.

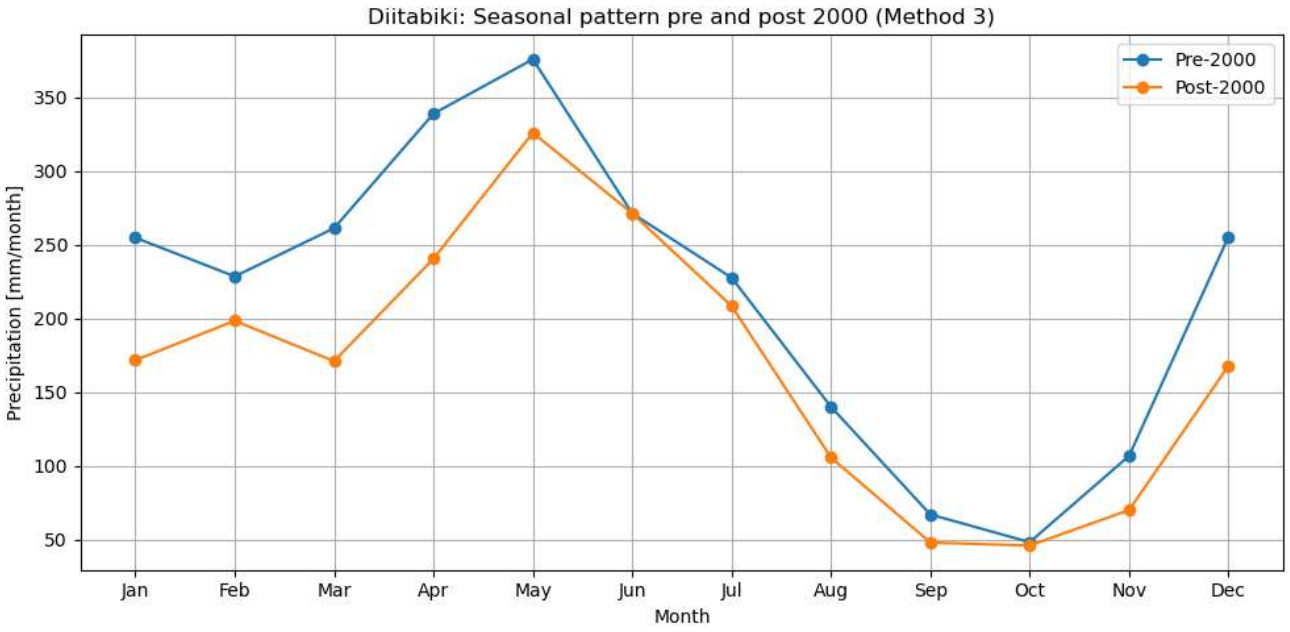


Figure 27: Seasonal Precipitation Pattern Diitabiki

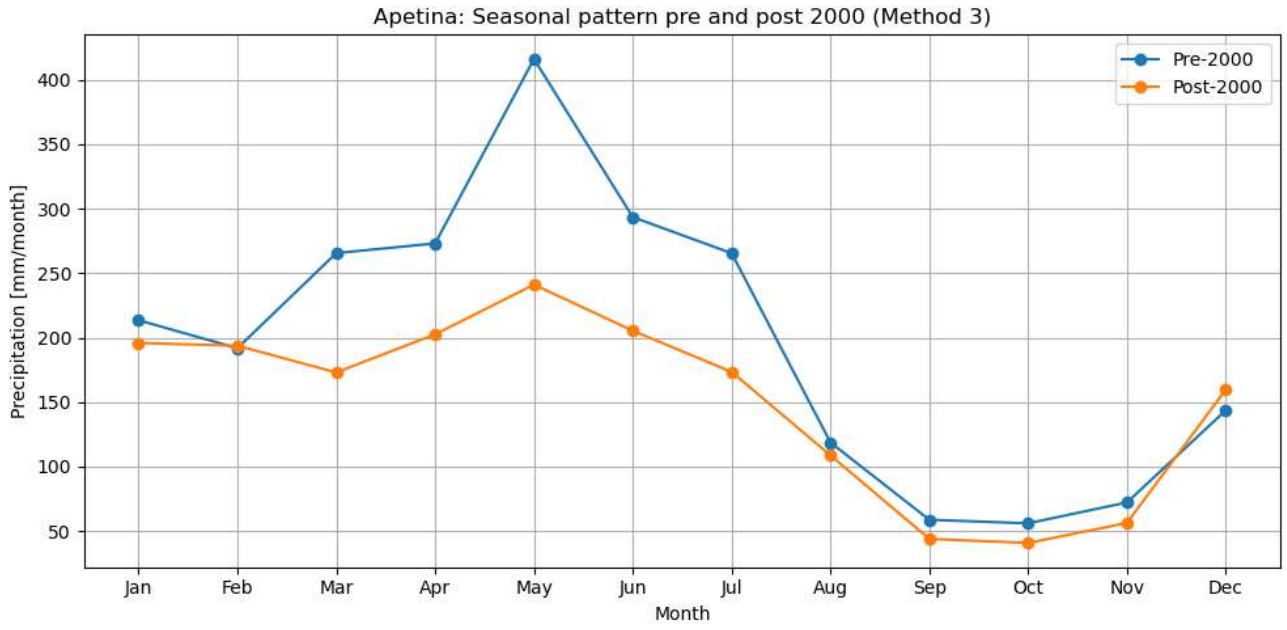


Figure 28: Seasonal Precipitation Pattern Apetina

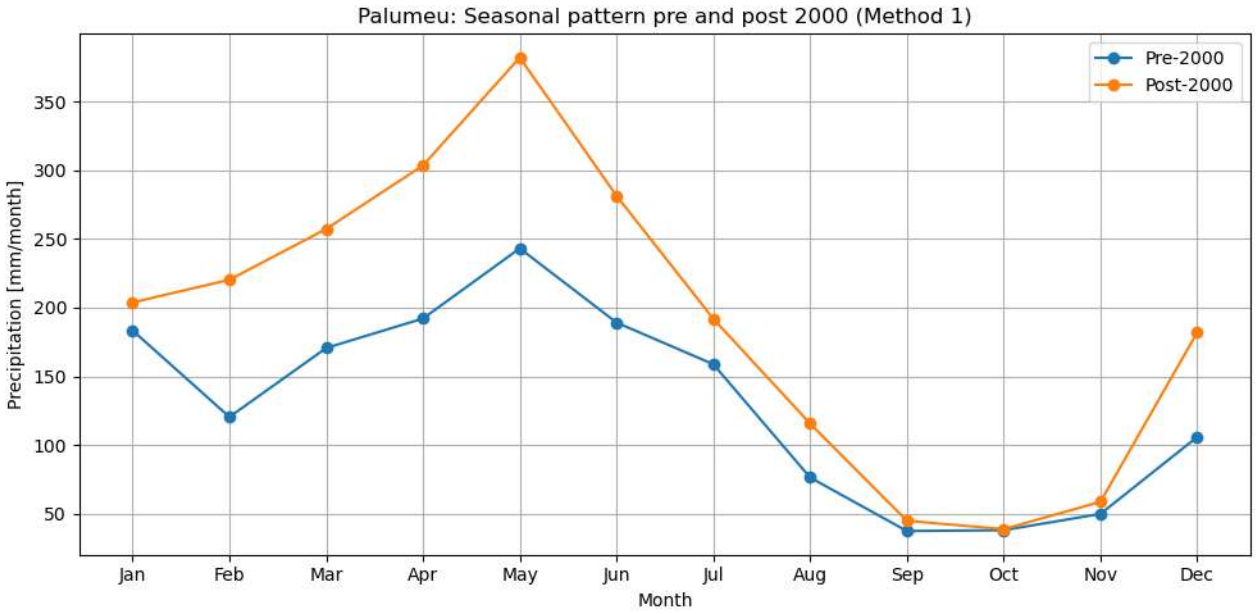


Figure 29: Seasonal Precipitation Pattern Palumeu

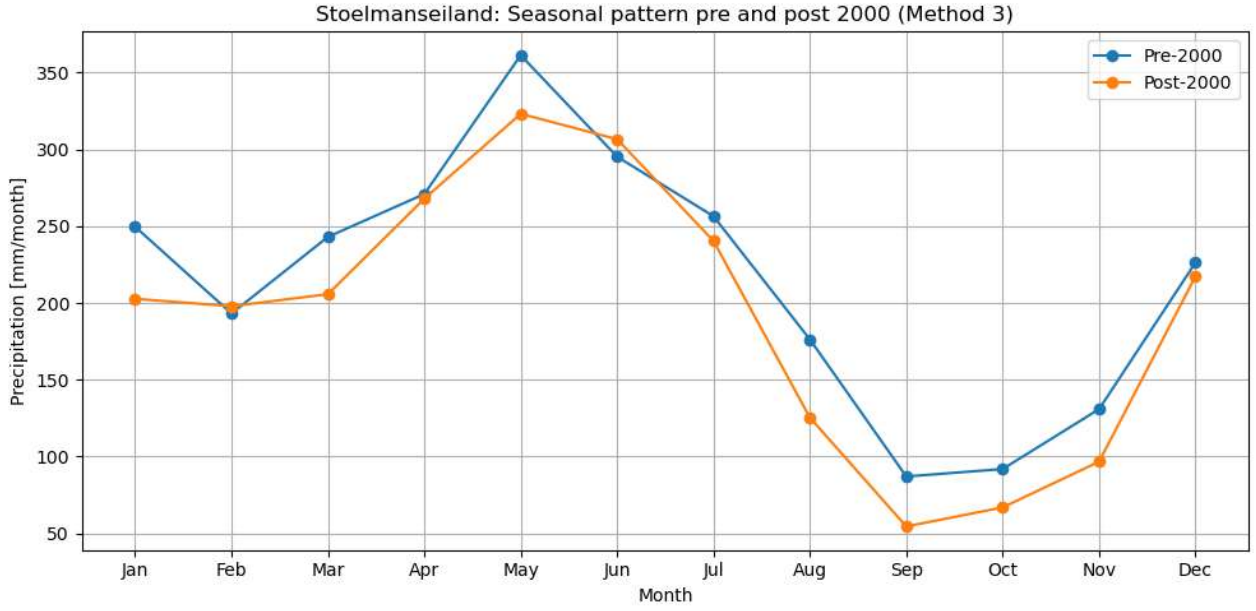


Figure 30: Seasonal Precipitation Pattern Stoelmanseiland

First of all, a seasonal trend can be seen in which the short and longer dry- and wet seasons are clearly visualised in these graphs. The results differ per station, which could infer that rainfall is quite localised. Nevertheless, a general trend of decrease in precipitation can be seen in all stations except for Palumeu. Additionally, the timing maximum and minimum precipitation in the long wet- and dry season has stayed the same over time. However, the timing of the short wet- and dry season seems to have changed between the two time periods. According to the graphs, both the short wet- and dry season have been delayed one month on average in the past 25 years, compared to the available data before the year 2000.

The same overall trend, albeit with a smaller difference, can be seen in Figure 31. Where the average amount of rainy days per season for the Diitabiki station has been plotted. The same plots for the other stations can be found in Appendix E.

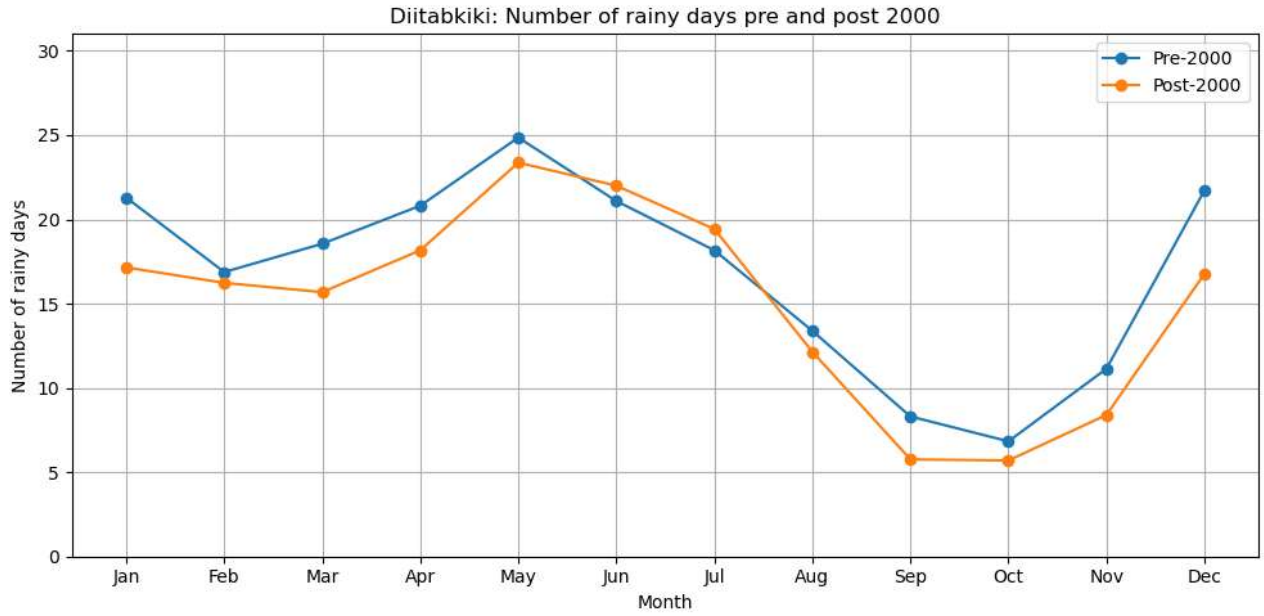


Figure 31: Number of Rainy Days per Month in Diitabiki

The average monthly sum is a combination between the rainfall frequency and intensity. As can be seen in Figure 31, there have been more rainy days on average in July in the 'post 2000' period, while the average precipitation sum has declined. Since the frequency of rain has increased this could be explained by a decrease in rainfall intensity (per rainy day). Similarly, the difference in gap between the two time periods in the analyses of the other precipitation stations can be explained.

The standard deviation of the seasonal precipitation pattern is visualised in Figure 32. As can be seen in these figures, the overall standard deviation has decreased over time. This is similar for the other stations, although the variation between the two time periods does differ for the different stations, refer to Appendix E.

A decrease in standard deviation does not correlate with the general view around climate change. With climate change both the dry- and wet extremes are assumed to go up, leading to a higher standard deviation. The lower standard deviation does comply with the overall increased drought trend seen in the earlier seasonal pattern analysis.

However, it should be noted that the increase in standard deviation could also be (partly) caused the measuring methods that can have changed over time. Since it is not known if the measuring techniques have stayed the same over time, it could be that the past measuring tools have a higher uncertainty than the ones currently used. This could also have an influence on the standard deviation comparison. Additionally, there has been less data measured in the pre-2000 period, which can also impact the results.

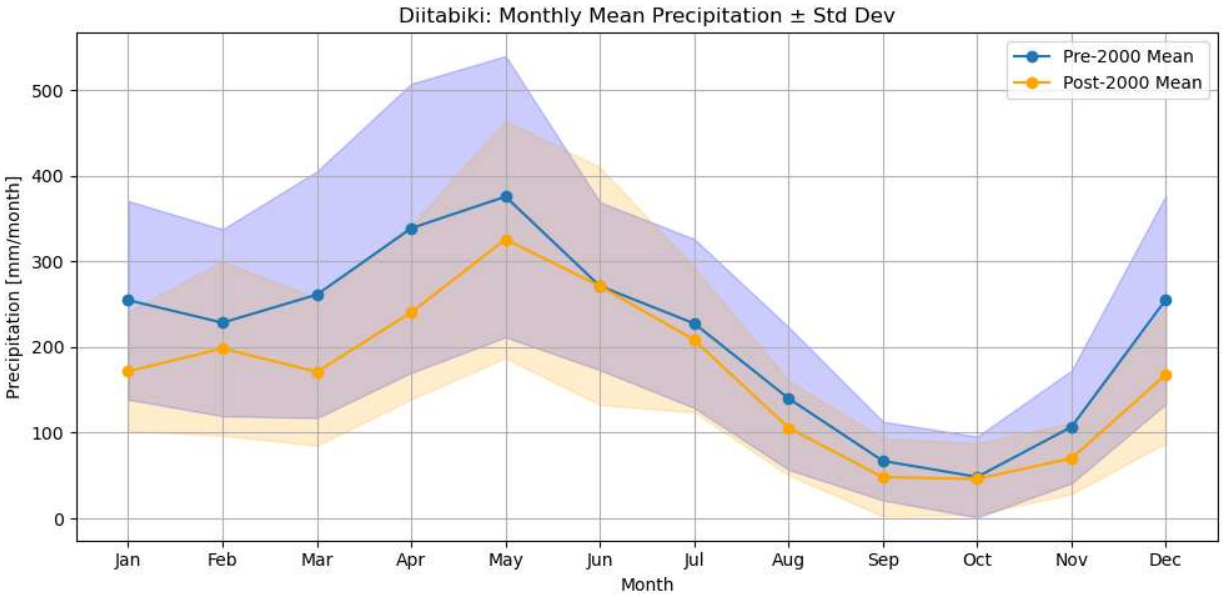


Figure 32: Monthly Precipitation Sum with Standard Deviation Spread Diitabiki

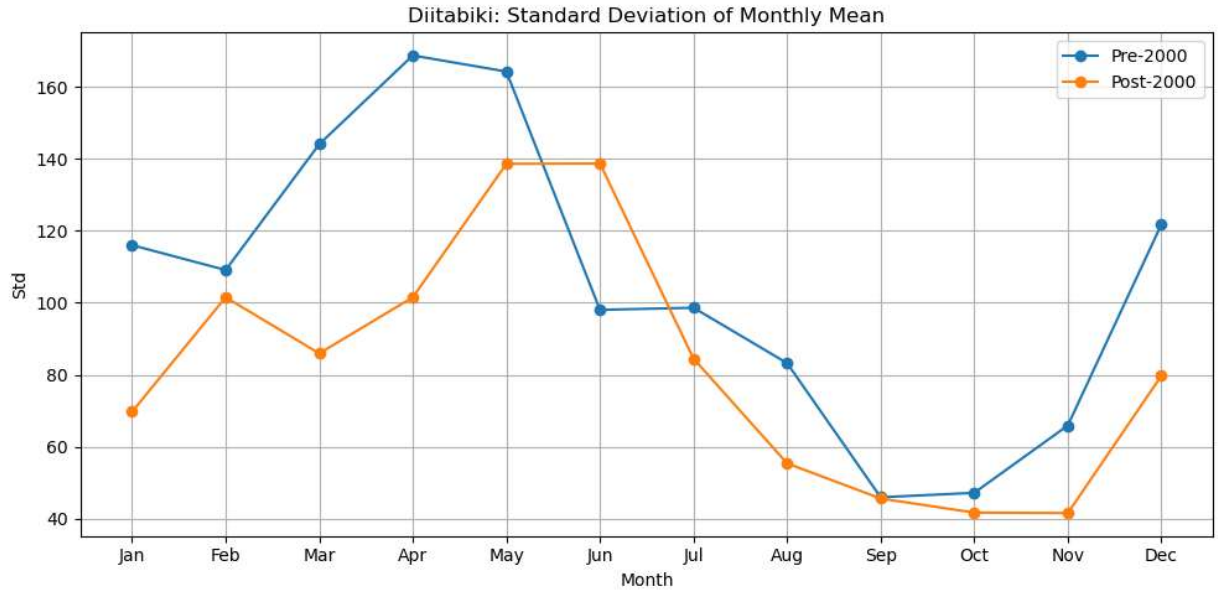


Figure 33: Standard Deviation Monthly Precipitation Sum Diitabiki

3.5 Intensity Duration Frequency

Figure 34 illustrates the results for the IDF analysis of the precipitation data from Diitabiki, looking at the difference between pre and post 2000. The graph shows that for every duration and for every return period the extremes have decreased after 2000. The magnitude of this reduction differs between different durations and return periods but generally shows a larger difference for shorter durations of 1 up to 5 days and smaller differences for the longer durations. Furthermore, higher return periods tend to show larger differences overall, but this is not the case everywhere.

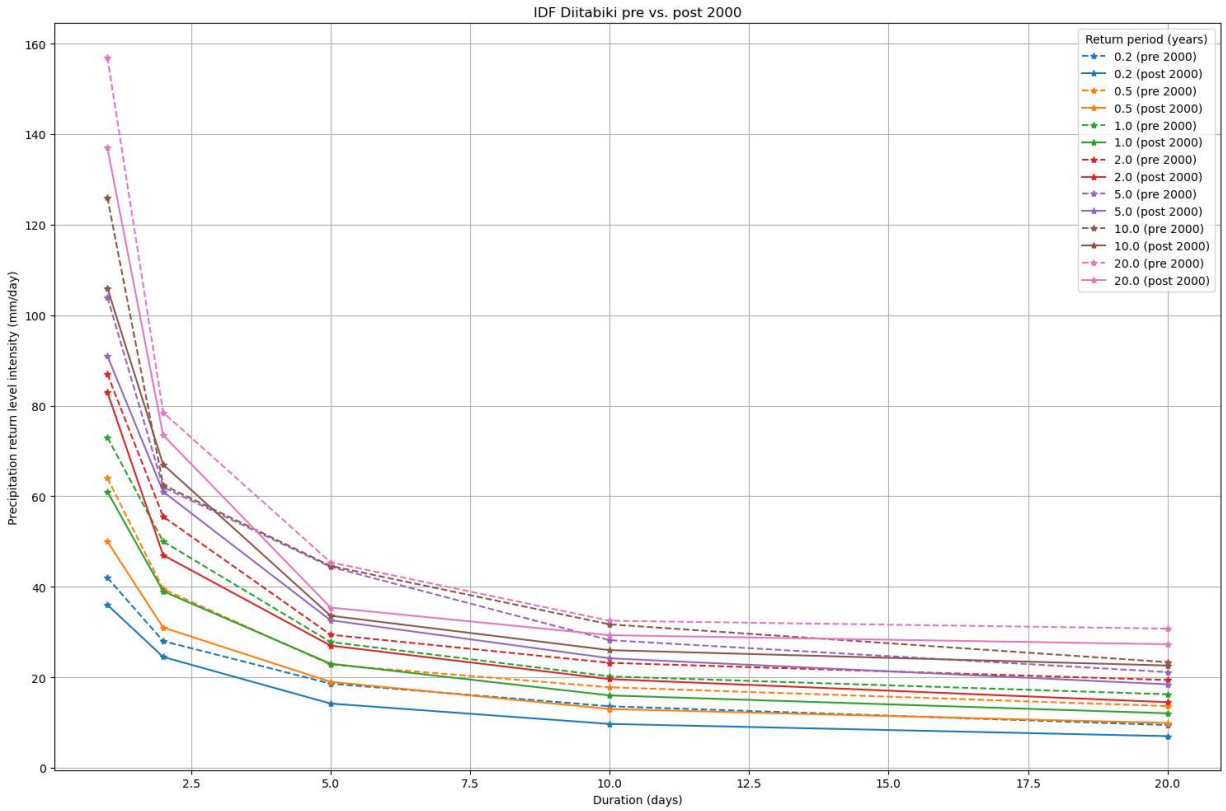


Figure 34: Intensity Duration Frequency Diitabiki

Even though lower extreme precipitation does not necessarily mean an overall reduction in rainfall, as rainfall could be more spread out over the days in a year, combined with the earlier found reduced number of rain days this result does fit in the pattern of overall reduced rainfall in Diitabiki.

Apart from Diitabiki, the IDF analysis was also performed on the data from station Stoelmanseiland, Apetina and Palumeu. A complete figure like that of Diitabiki of each of these results can be found in the Appendix E, but a summary of the results is provided here.

Stoelmanseiland shows an overall reduction of the extremes, with the exception for 5- and 10-year return periods for a 5-day duration. Here an increase in extremes can be noted. The reduction is relatively minor everywhere, but slightly larger at the lower durations. For Apetina the results also show a decrease in extreme rainfall, with larger differences for short durations and for higher return periods. Like Diitabiki, these reduced extremes fit the changes observed in the seasonal pattern of precipitation and number of rain days at these locations. Contrarily, the IDF for Palumeu reveals an increase in extremes, with similar differences for each of the return periods, except for that of 20 years, which shows larger change. This corresponds to the change in monthly precipitation sum, where a slight increase can be seen whereas the number of rainy days remains the same.

Table 13: Length of Data pre and post 2000 Used

Station	N-years pre-2000	N-years post-2000
Diitabiki	16.1	21.0
Stoelmanseiland	19.6	21.5
Palumeu	14.7	20.3
Apetina	15.7	19.0

Table 13 indicates that the number of years of data available pre-2000 is less than post-2000 for each of the stations, which could possibly have an effect on the results as there are less years that can include an extreme value for a certain duration and return period in the years before 2000.

3.6 Dry spells

The results of the dry spell analysis of Diitabiki are shown in Figure 35. For the second method, including a boundary condition of a maximum consecutive days of missing data, three different boundary values are plotted.

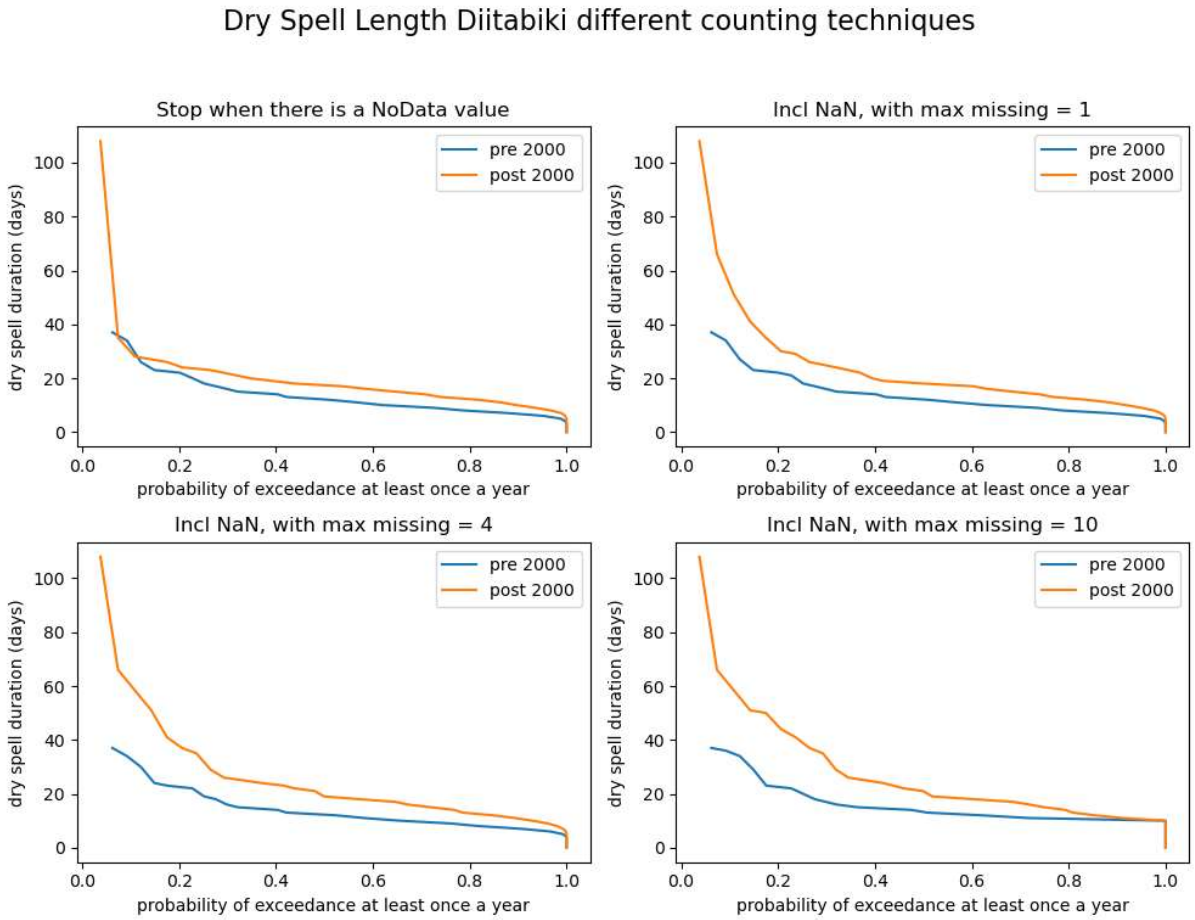


Figure 35: Dry Spell Analysis Diitabiki

As can be seen, the overall trend of an increased dry spell duration for the 'post 2000' period stays the same for all methods for this station. The results for the other stations can be found in Appendix E. They show a similar trend, but some stations show a bigger gap between the dry spell duration between the two time periods than others. Additionally, the most extreme dry spell durations with a probability of exceedance lower than 0.2 do show a decrease in over time for some of the stations. However, these values showcase extremes with a very low probability. Dry spells with a probability less than 0.1 are therefore less significant when looking at a trend over time.

To interpret what this practically means for the people living in these villages, it has been calculated how often the dry spell length of longer than 30 days has occurred according to the dry spell probability as shown in Figure 35. The period of 30 days is chosen based on the interviews, in which people indicated

that their Duro tanks would be empty within one month. Such an event therefore has a large impact on the life of the people living in the region. Based on the dry spell analysis allowing a maximum of four consecutive missing days in the Diitabiki station dataset, the annual probability of experiencing a dry spell lasting 30 days or longer increased from 12.1% to 26.0% between the two time periods. This indicates that such events occurred on average once every eight years before 2000, and approximately once every four years after 2000. Which is a significant increase if this means one will have to find a different source of drinking water whenever this happens. Naturally, there are several assumptions and limitations associated with the dataset, and the analysis relies solely on observations from the Diitabiki station. However, the findings suggest a notable increase in drought frequency.

3.7 Climate Scenarios

To validate the results of this climate change impact on precipitation pattern analysis, it is compared to three other climate change models from earlier research.

The KNMI has developed future climate scenarios for four regions in Suriname: Zanderij, Zorg en Hoop, Nickerie, and Kwamalasamoetoe (Koole et al., 2024). For these regions, a climate analysis was conducted, resulting in four scenarios based on high versus low CO_2 emissions and on either an overall drying or wetting climate. These scenarios were further elaborated to provide projections for the years 2050 and 2100.

Unfortunately, none of these regions are located close to the Tapanahony region studied in this research. Therefore, these climate scenarios cannot be directly applied to this area. However, some general trends observed across all four regions may reasonably be assumed to also apply to the Tapanahony region.

In all four regions, a decrease in precipitation is projected for almost all scenarios, indicating a general trend towards drier conditions. The projected decreases range from –14.6% to –1.8% by 2050, depending on the emission scenario. The only exception is found in the wetting scenarios for Kwamalasamoetoe, located near Suriname's southern border with Brazil, where a slight increase in precipitation of approximately +1.5–2% is expected by 2050.

This decrease in precipitation becomes even more severe in the projections for 2100. In the coastal regions, precipitation is projected to decline by up to 30% under the drying–high emission scenario, while in the inland areas the decrease may reach 24% (Koole et al., 2024).

Another study predicts climate change based on the four SRES emission scenarios of the IPCC, A1, A2, B1 and B2, and using five atmospheric-ocean global circulation models (Nurmohamed & Naipal, 2020). This study shows an increase in precipitation for scenario SRES A2, and a decrease for scenarios SRES A1, B1 and B2. They also predict a change in seasonal patterns due to climate changes. However, the authors emphasize the need for more localised analyses using regional climate models to better assess climate change impacts at smaller spatial scales.

Solaun et al. (2021) has conducted an analysis similar to the precipitation pattern analysis of this study. Based on precipitation data from 1990 to 2014, they find a mean of the monthly accumulated rainfall, in what they call the 'Upper Tapanahony' region, which correspond reasonably well with the values found in this study, see Figure 36 (left).

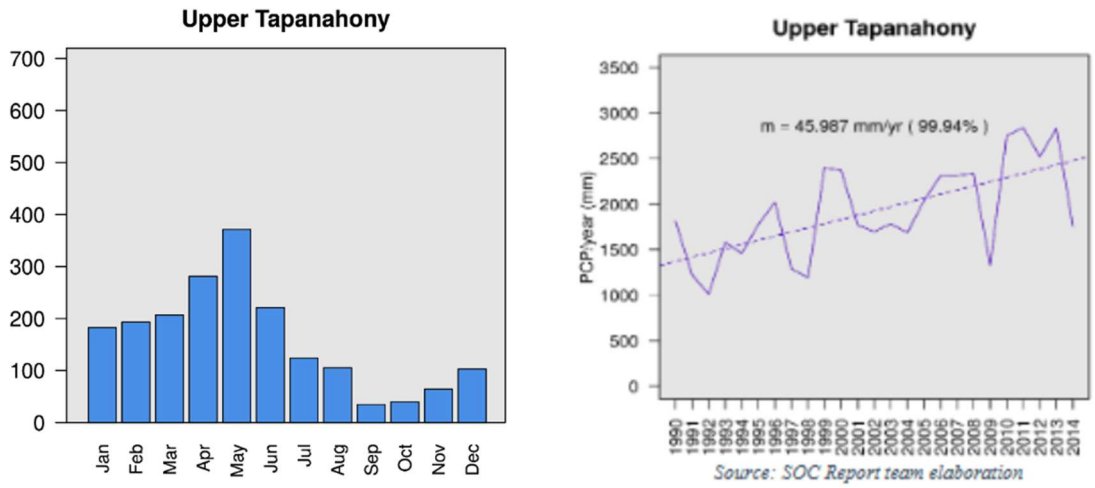


Figure 36: Results Climate Analysis (Solaun et al., 2021)

The same study also shows a trend of increasing precipitation based on the 24 years of data used, see Figure 36 (right). This finding does not correspond with the results reported in the other studies discussed here. Such differences may, for example, result from the limited amount of data available. The large discrepancy between these studies highlights the need for caution when drawing conclusions, both from this research analysis and from the other research described in this section.

Climate change does not only influence precipitation patterns but also has an effect on other important variables such as temperature, wind and humidity. As is also mentioned in the KNMI and Solaun et al. (2021) study on climate change of Suriname. However, these parameters were not included in this study but are important to consider when looking at the effects of climate change on this region in future research.

3.8 Insights

Overall, the remote data analysis provided several important insights into the flow behaviour of the Tapanahony and the weather patterns and their expected trends of the region. First, the maximum discharge measured during the past ten years is 3000 m3/s, which can be used as an input parameter for the flood analysis conducted in Chapter 4. Second, the precipitation analysis reveals a rainfall reduction at Diitabiki, Stoelmanseiland and Apetina. The precipitation extremes are reduced, and the chance of longer dry spells has increased. Nevertheless, this is not the case for Palumeu, which highlights the local impact of the weather and the uncertainty that is still attached to this analysis. Furthermore, future climate scenarios mirror the increased droughts and reduced rainfall, but these too are not unanimous in their predictions as some also claim that precipitation and extremes are going to increase. Thus, it is important to consider a variety of outcomes in order to be prepared for whatever may happen, including an increased discharge.

3.8 Answer to sub-question 3

How do the current climate and projected climate change scenarios influence river dynamics, flooding patterns, and the Tapanahony region?

Analysis into the past climate trend shows a reduction in overall precipitation and precipitation extremes after the year 2000 more most, but not all, measuring locations along the Tapanahony. Additionally, projected climate change scenarios reflect this reduced rainfall, yet are not unanimous about what will happen in the future. It is therefore important to realise that there is a lot of uncertainty in this. So, in planning the interventions for the floods that are happening now, one should be conservative and check if the solutions will also withstand higher discharges.

A drier climate will also lead to a decrease of the clean drinking water available in the region. The precipitation analysis reveals that before once every 8 years a rainwater harvesting tank would run out of water during the long drought, nowadays this could happen once every 4 years.



4 A Kondee Underwater

In this chapter an extensive analysis of flooding in the Tapanahony region is provided. There are two main objectives. The first is to gather data on the hydraulic characteristics of the Tapanahonyriver, such as depth, discharge and height of the surrounding area. The second objective is to identify the villages that are vulnerable to floods. This is done by constructing a hydraulic model of the river and using the gathered data to calibrate this model. The preliminary study for this section has been done and reported in other sections: section 2.1 covers an analysis of the catchment, and section 3 includes an analysis on the climate as well as the historical discharge and water levels. Lastly, interviews with inhabitants are used to substantiate the results and construct a first analysis on flood vulnerability.

4.1 Methodology

In this section, the different research methods will be introduced. Because there is not much (reliable) data available, a wide range of methods is applied. All data is used to develop a 1D hydraulic model of the Tapanahonyriver stretching from the villages Poligudu to Gaanboli.

4.1.1 Interviews

Information about the condition of the river throughout the year is also gathered by conducting interviews in the villages. Information about the frequency, duration and water level during floods can be obtained this way. The full method of the interviews is described in Appendix B, this appendix also includes the specific questions about flooding that were asked.

4.1.2 Fieldwork

In this section is described which fieldwork has been conducted and why. The details of how the measurements are performed can be found in Appendix F: Test Protocols.

In order to gain sufficient information for the hydraulic model, a combination of methods is used. On the river, a cross-sectional area measurement is done in combination with a surface velocity measurement. Also, pictures taken with a drone are used to develop a DEM of the village to complement the cross-sectional depth measurements.

The villages are usually clustered on a group of islands. Each cluster of villages is measured in one or at most 2 days. For each cluster the following steps are taken:

1. Cross-sectional depth and surface-velocity measurements are done upstream and/or downstream of the village where the river is one.
2. Cross-sectional depth measurements are done at the location of each village; this is usually in a branching section. Where possible also surface-velocity measurements are conducted.
3. Cross-sectional depth measurements are done in the remaining branches
4. At each village the drone takes pictures, the pictures also capture the surface of the water.
5. A visual analysis at each village is done.

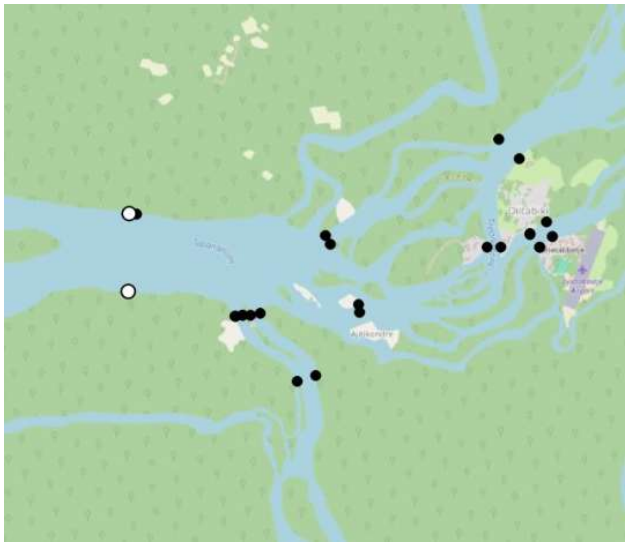


Figure 37: Actual Measurement Locations

An example of the actual measurement locations is shown in Figure 37, with the black dots as the start an end location of the depth measurements, and the white dots the surface velocity measurements. What should be noted is that the complex character of the river, makes it difficult to measure in some places. At several locations the river splits into 2-10 bifurcations which have shallow parts where the flow is supercritical in some places. Due to historical reasons some villages are also located there. So not at every village a discharge measurement or even a depth measurement can be done.

A short explanation on the workings of each measuring method:

Depth

Cross-sectional depth measurements are done by crossing the river with the boat in a straight line and every 10 seconds saving a location and depth with the measuring device, see Figure 8. The result is around 25 datapoints for a river of 270m width.

Discharge

Cross-sectional surface velocity measurements are done by using a floating device which is dropped in the water and picked up after around 2 minutes, see Figure 9. The drop-off locations and pick-up locations are marked with a GPS. By using the distance between these points, the velocity can be determined.

Land profile

The drone is programmed to fly a specific route and take pictures at a regular interval, see Figure. Using the overlapping pictures a DEM can be constructed using MetaShape Pro.

Visual analysis

When walking through the village, any visual marks that indicate impact of the river are written down: flooding marks on houses, erosion of the banks, deposition of sediment, etcetera. An example is shown in Figure.



Figure 38: Depth Measurements



Figure 39: Velocity Measurements

Figure 40: Land Profile Measurements with Drone



Figure 41: Example of Visual Mark



4.1.3 Models

The goal of the hydraulic model is to indicate which villages are vulnerable to flooding in different discharge scenarios. This makes it possible to evaluate the future impact of climate change on floods, but also on droughts. To make use of the full potential of the model, it is necessary to know at which stage of the river each village floods. Therefore, the obtained height with respect to the water level of the river is used, in combination with the obtained cross-sectional area of the river at that location.

Why a 1D model

The river is an anabranching system with sections that have supercritical flow, so the choice for at least a 2D model seems obvious. However, there are two reasons why a 1D model is used. There is only accurate data of the riverbed available from the fieldwork conducted in this project, which is at specific locations. Therefore, there is simply not enough input data available for a 2D model. Secondly, the objective of this research is to evaluate the vulnerability of the villages to floods. In this stage it is not necessary to analyse the flow patterns or the morphology of the river.

Discretization

The 1D hydraulic model has a semi-implicit scheme. The continuity equation is solved explicitly, using central differences to discretize in space and forward Euler to discretize in time. The momentum equation is solved implicitly, using again central differences to discretize in space but now using backward Euler to discretize in time. The advection part of the momentum equation is solved explicitly, separately. At the sula's conservation of energy will be used instead of conservation of momentum to correctly model the flow contraction.

Slope

The slope of the riverbed will be determined by using a satellite DEM to obtain the slope of the river surface. In several sections of the river, the assumption of normal flow can be made. Therefore, the bed slope can be determined. Ideally, drone measurements will help to determine if the water surface slope obtained from the satellite DEM is correct.

Geometry

The geometry of the river is both space and time dependent. In the sections where cross-sections have been measured this can be used to determine geometry. In combination with satellite images some extrapolation is possible for the sections around the villages. However, in some places no measurements have been done. The depth in these places will need to be inferred from the measured branches.

Friction coefficient

In this river system, the friction coefficient is most probably also space and time dependent. This is where a lot of uncertainty enters the model. However, there is historical data available to calibrate the friction coefficient. Additionally, a friction coefficient can be calculated at locations where both the discharge and the cross-sectional area have been measured, for at least that stage.

4.1.4 Flood Risk Analysis

To analyse which villages are most vulnerable, the results from the model can be combined with results from interviews and visual analyses. If there is a sufficient amount of data a flood risk map can be

constructed. If this is not the case a simple summing of results per village can give an indication of the flood vulnerability.

4.2 Interviews

A lot of qualitative data was obtained through the interviews, and in some cases quantitively data was gathered. However, since the number of interviews done per village were limited due to time constraints. It is important to note that there is a lot of uncertainty in these numbers.

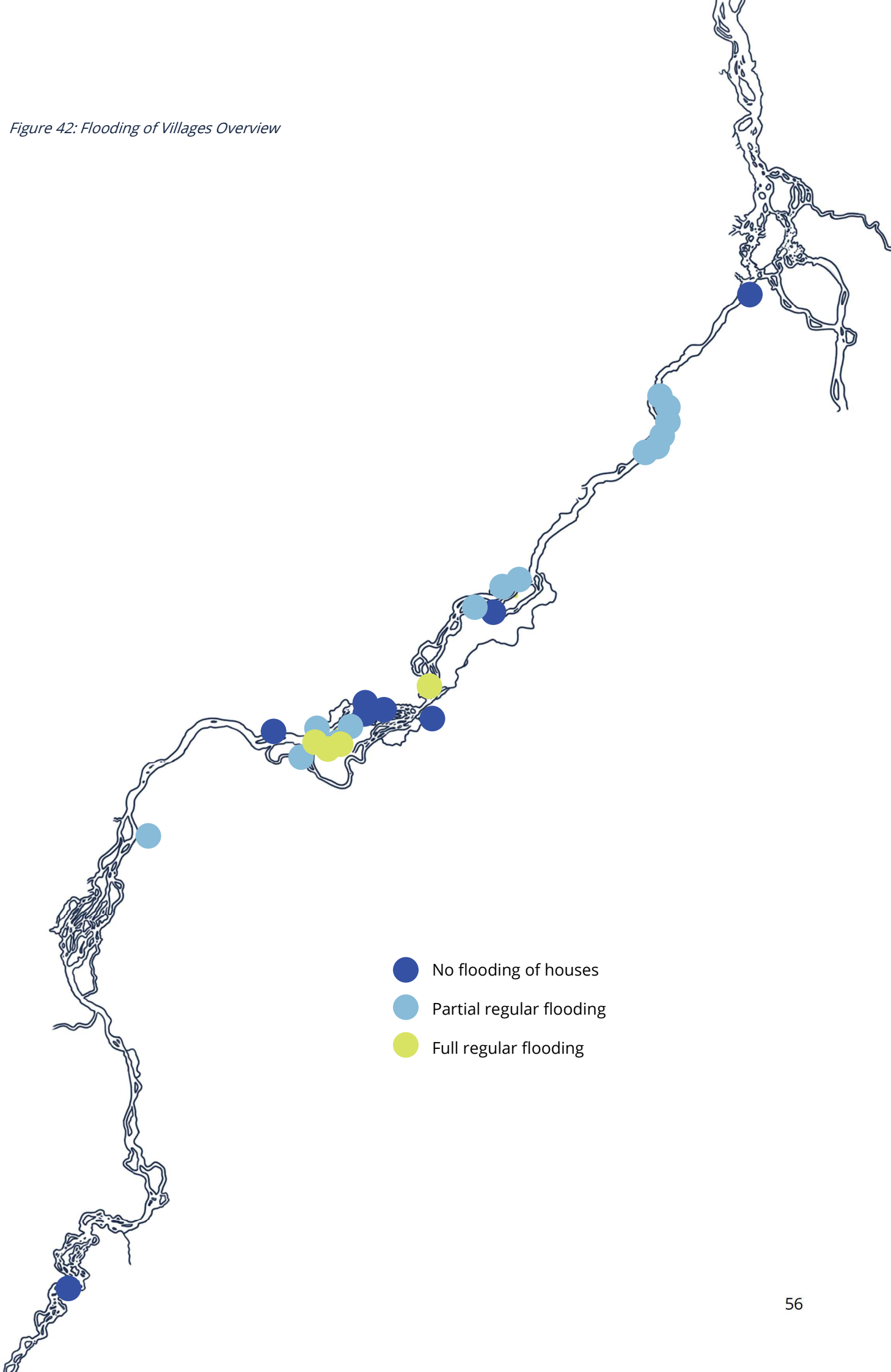
To start off, a table and a figure showing to what degree the villages were flooded is presented.

Table 14: Degree Of Flooding

No flooding of houses	Partial regular flooding	Full regular flooding
BPU	BEN	SNB
OPU	TBK	LOA
KAR*	SAY	PKP
JAU	KEM	SGM
MAI	DTB*	
MOI	GDO	
UGS	MAN	
PGD	KIS	
GNB	PLK	
	PKD	
	WAN	
	TJO	
	FAN	

** There are houses that flood, but nobody is living in them anymore*

Figure 42: Flooding of Villages Overview



High water levels

Not all villages in the Tapanahony region experience flooding, as can be seen in Table 14. "*If this village would flood, a lot of other villages would not exist anymore" [GNB, MAN]*. Even if the villages do not flood themselves, all people do suffer from the impact of high-water levels in other ways. Though their houses might not flood, their croplands located outside of the village can flood and people lose their harvest [BEN, DTB, PKD, JAU, KAR, GDO, FAN, MAN, KIS, PGD, WAN]. Many conclude that this was not such a problem now as it was in the past, as it happens almost every year now [PGD]. Even if someone lives in the city these floods can impact you, since they have to help their family by sending food to them [PKD]. Next to that, if someone does own a house with furniture in the interior of Suriname, they would have to ask their neighbours to move it to a higher location [SAY, KEM].

Additionally, the high-water levels can be dangerous for kids and transportation, and it can cause the electricity network to break. During the flood this cannot easily be repaired, so people can have no light and are unable to use their freezers for a few days when this happens [DTB]. The high-water levels limit their ability to move freely [MAN, TBK]. It also makes it harder to go to school, and when the island of the school at Diitabiki is partially flooded, the school closes [DTB]. The sanitation facilities of the teacher's flood and they are relocated to the city [DTB]. While the water becomes more dangerous for traveling and transport, the flooding has not had any human casualties [DTB]. There are however a lot of animals that have drowned during a flood [DTB].

There are also people who do not experience flooding of their house, that benefit from high water levels. If the water is high, they have to walk less far to the river for their daily chores [KAR].

Flooding of the villages



Figure 43: Crooked House Pikinpisi

When villages do flood, the strategy to deal with it is the same for all villages: move one's belongings and oneself temporarily to a higher place in the village, or to another village. When one is too late, for instance when one is away at the time of the flooding or when it happens at night, it becomes a real problem. *"Sometimes you get out of bed, and all of a sudden you have wet feet."* [DTB] All one's furniture and personal belongings are destroyed and there is a lot of damage. When one has a freezer, this can become even a bigger problem [BEN, DTB, PKP]. Even when one is in time, one has to clean out the house thoroughly before it can be lived again [DTB, TJO].

The flooding does not only damage the inside of people's houses, but the outside is also damaged. On a lot of houses the mark of up to where the water has come is clearly visible. The high flow velocities can also tear planks loose [DTB]. Earlier was already mentioned why people nowadays make the first meter of their house out of concrete. The floods are strong enough to cause people's houses to become crooked, see Figure, so during floods people now open their doors in order to prevent this from happening [PKP]. *"Once I saw a house that had been fully lifted and dragged along by the river."*[OPU]

During these floods motorboats are able to reach the front door, and they drive over the small depth of water [DTB, PKD, OPU]. The walking paths have become waterways for people who own a boat.

Flood prediction

There are some villages that communicate with each other when the water level rises to a risky level, so they can prepare for a flood [SGM, GDO, TBK]. However, this is not the case for all villages, and often it is still too late because they only have contact with the nearest villages [SGM, TBK]. For example, if Saaye floods people in Tabiki know that they probably also will flood, within a day mostly [TBK].

There are also other signs that warn people that the water level has become dangerously high. They have certain stones in the water that they pay attention to. When they are not visible anymore this is a sign that the water has become too high [PKD, SGM]. Another sign is that at Puketi, where it is very deep, a vortex is created when the water is very high. When this makes a whistling sound, this means the river is very dangerous. If this happens, the Gaanman will send a message to all villages that people are not allowed to go in a boat alone [SGM]. This is the same during a flooding event [FAN, MAN].

There is another way how to predict if the houses will flood: *"We see the wood lice go up through the wooden structures of our house; this tells us that the water level in the ground is rising."* [TBK]

Still, it is hard to predict when it will flood. It comes in phases, the water often rises slowly, but they do not know if it will go down again or rise even more. It also happens that people think they have had the highest water level and it start to drop and then all of a sudden, the water starts to rise to an even higher level [DTB, PKP].

Flooding (intensity) trends

Some people see a clear trend of increasing flood frequency and intensity [DTB, GDO, SGM]. As some people describe it: they learned from their grandparents it would flood once every 10-15 years, but now it has become more often every 3-5 years [KEM, KIS, MAN]. It is a wide range, but the trend in these answers is that floods are happening more frequently.

Others find it hard to estimate how often it floods and if this has increased or decreased over the years. They say the seasons have changed and it becomes harder to predict when it will flood [DTB, UGS, GDO]. *"It fluctuates more, low water levels get lower and high water levels get higher."* [GNB] Then there are also people that simply think it has stayed the same [MAN]. Some villages that did not have any flooding problems in the past, do experience flooding now [GDO].

The table below illustrates the frequency of flooding that people experience, when they were able to estimate it.

Table 15: Flooding Frequency

Village	How often	Last big flood
BEN		2023
DTB*	2 times in last 7 years	
KEM		2022
GDO	Not every year	2022
FAN	Every 5-8 years	2022
KIS	Every 3-5 years	2022
PLK	Every 2 years	
PKP	Every 5 years	
PKD	Every 3 years	2020

SAY	Multiple times per year	
SGM	Almost every year	2023
WAN	Every 5-10 years	2022
TBK		2021

** School side*

Flood speeds

When it floods, the water level rises slowly over a longer period. However, the difference between high water and a flood is small, so it still takes people by surprise. How long the flood takes depends on who is asked, but it can be flooded from three days [BEN] up till five months [PKP]. When it goes down, it often goes down fast, which can be just within one day or take a couple of days.

Worst flooding of the past two decades

The flood in 2006 is mentioned as being the biggest of the past two decades [DTB]. Many villages were flooded that year.

"It started to rain very hard during the day around three o'clock. This continued the whole night. When people woke up the next morning, everything was flooded.

Day 1: People went on boats to the neighbouring villages on behalf of the Gaanman to analyse the situation. A lot of people were completely panicked, and many were stranded in their boats. With larger boats, they moved these people to higher areas: Un Gwa Soo (where they had a large shed), Diitabiki and Moitaki.

Day 2: The government came to help with food and water. This aid continued regularly during the first few months after the flood.

After that, it took almost a month for the water to fully recede, as it kept raining continuously.

There was no communication between the villages to warn each other about the rising water." [DTB]

After this flooding occurred, people became more careful, and kids were not allowed to go to the river without any supervision anymore [DTB]. Over the years this has become more flexible again and the villagers have gone back to the old habits.

Rainfall damages and erosion

Not only the high-water levels cause damage, but some damage is also caused by the rainfall itself [KEM], see Figure . Especially when houses do not have rain gutters, erosion around the houses increases [TBK, DTB]. These heavy rainfalls have caused the villages to lose height; sand is taken away by the water and streams form in the villages due to poor drainage systems [GDO, PKP, PKD, SNB, WAN, DTB, BPU]. In a lot of villages, the sandy ground is swept every morning, aiding in this process [PKD].

Erosion does not only take place on land, but the riverbanks are also eroded as well. Some think this is caused by the big motorboats and the waves they produce [PKD, WAN]. The Gaanman has asked the people to go slower by boat next to the villages, without any success [WAN]. The river has become more wide and less deep over the years [UGS, PGDO, PKD], or as a lot of people say: *"The river has come closer."* [GDO, PKD], and smaller islands disappear [PKD].



Figure 44: Erosion on Land Caused by Rainfall in Gaanboli

Help during floods

While in some cases the traditional rules and division of land seem to determine where people can and cannot build or work, when a village floods the people of this village are more than welcome in the other villages [MAN, PKD, UGS]. In these cases, people in neighbouring villages help each other in times of need. In some cases, there is also some help from the government, like food or a tarpaulin to keep their things dry [SGM]. However, this is often not enough and/or to late [PKD]. According to some, these are often more to get political attention, than that they really help the people [PKD]. When they do not get enough support of the government, there is a shortage of food [GDO].

Local solutions for the flooding problems

One question during the interview focused on solutions the people could implement to resolve the flooding issues. The following solutions were proposed:

Moving to higher grounds

Even though some people's houses flood every year, most people do not want to move to a higher piece of land. They feel strongly connected to their ancestors that have brought their people to safety when they fled as slaves. They do not want to move, because they feel they would lose that connection when they do [PKD]. Younger people do not have such issues with moving, although they might also change their mind when they get older [PKD, GNB].

Even when the traditional authorities brought the message from the government to move to higher grounds, people would not listen [DTB]. Besides *"You are used to the place you live in, if you move you don't know what to expect."* [SGM] It is also too expensive for some to move and build a new house somewhere else [KEM]. The government should help people with this according to the interviewees [KAR, SNB].

Un Gwa Soo, a village started in 2004 as response of the yearly flooding of its inhabitants' original houses [UGS], is an exception. There are of course also people that live in areas where it does not flood, some of them say they would move if this would happen every year [DTB]. When they would do so, they would keep the old village for rituals [MAI, SNB]. Others would not be so keen on moving. They can advise others to move but would not do it themselves either [GNB].

In addition, the land in the villages belongs to them and their families, where they can build freely [MAN]. The land outside of it can belong to another village. When people would move to other places, near to each other, conflicts would arise [FAN, MAN, PKD, SAY]. The people in Un Gwa Soo disagree: *"Everybody is welcome here."* [UGS] Thereby, the marrons do have their own laws, but these are not accepted by the Surinamese government. As such, they do not have the ground laws other people have [UGS].

Buildings on poles

When asked what solutions to the flooding problems could be, people have a hard time coming up with ideas. There are people who build their houses on poles (*neuten*) because of the flooding [DTB, PKD, MAN, SGM], or if possible, on higher parts of the village [GDO]. However, only the people that are planning to build a house can do so. People who already have a house, often do not have the money to build a new one [MAN, SGM, PKD]. Thereby, it is more expensive to build on poles, since one needs wood for the floors, instead of just using cement [PKD]. Because of all the wood, it is also more prone to damage or wear [PKD].

Dealing with erosion

Some villages plant or keep their grass on purpose to slow down the erosion due to rainfall [PKD, GNB, JAU, UGS, KIS, OPU, PGD, TBK]. In some places it is just not feasible to grow grass, as these areas are located in large shades of trees [KIS]. In other villages grass is a sign that there are no people living in that part of the village anymore [DTB]. They have also built little walls of wooden planks to keep the sand from washing away in the village and around their houses, which they fill with river sand [OPU, KIS, GNB, SGM, DTB, KIS, BPU]. If they would be able to raise the ground this would help, but they don't have the resources [GDO]. Other villages built small barriers using cement bags [MAN].

To make sure the riverbanks do not erode more, and to keep the entry points of the villages accessible, some villages have put sand and gravel from the riverbed on their banks [GDO]. This sand is taken out of the riverbed by the goldmining pontons in the river [PKD].

There are also people in the villages who have worked in the hydraulic engineering sector. They say that there is enough sand, gravel and people with sufficient expertise to build structures to strengthen the riverbanks. This would need to be designed by an engineer, because the flow velocities are high and it is not something someone can just try to build. Additionally, they would need cement and iron to build reinforced concrete. But they do not have the financial resources to buy this [FAN].

Droughts

Not only are extreme rainfall and flooding of large hindrance to the inhabitants of villages along the Tapanahony, but droughts are also a prominent issue. These droughts have a significant impact on daily life, with negative implications for people's health, food supply, and income. As many people are reliant on rainwater for drinking, long dry spells eventually result in an empty rainwater harvesting tank. Depending on size and use, a dry spell of several weeks to a month can already result in an empty tank, whereafter people have to start buying bottled water or drinking river water instead [DTB, BPU, OPU, SAY]. *"When your tank is empty, you are required to drink from the river; it's as simple as that."* [DTB] As the Tapanahony is a rain-fed river, the discharge during the dry season is very low, resulting in significantly higher concentrations of pollutants and pathogens [PKD, SGM, TAB]. Thus, when people are forced to drink from the river during droughts, they risk becoming sick [SGM, TJO, KAR]. In extreme cases, the water quality is so poor slimy green residue can be seen on the surface and filth on one's skin after bathing in the river [MAN, PKP, TJO], sometimes causing one's skin to itch [PLK]. For cleaner river water, people in the village cluster of Manlobi and Fandaaki go to a nearby creek to collect water for drinking [MAN].

Not only is people's health influenced by the reduced discharge, but the low water levels also impede transport along the river as it becomes harder to navigate boats through the shallow waters [BPU, DTB, GDO]. To limit the weight of the boat and thus its depth below water, boat drivers are forced to transport less cargo with each trip. Furthermore, some sula's are so shallow and rocky that boat drivers are forced to unload part of their cargo, push the boat upstream, and then come back to collect what they left behind [GNB, JAU]. Nevertheless, even with these measures, the boats experience considerable damage from the rocks just below the surface. *"Often you need to buy at least two new propellers and pay for other repairs."* [DTB] This makes the transport of cargo costly, time intensive, and physically exhausting, which has a significant inflation of food and fuel prices as a result [JAU, PKD, MAN, GDO, PKD, PLK, WAN]. In the dry season, the prices for, for example, a bag of rice or a gas cylinder can sometimes be more than three times higher than in the wet season [PKD, PGDO].

Thus, life during the dry season becomes increasingly expensive and people have difficulty to pay for their daily needs of food and gas for cooking [DTB]. This food shortage is further exacerbated by the insufficient supply of water to people's personal crop lands. People use the dry season to prepare their crop lands [MAN, PKD, PGD], some preferring this season over the rain season [KIS, SNB, TAB]. However long droughts cause their crops to dry out, reducing or destroying their crop yields [BEN, DTB, GDO, KEM, UGS, MAN, MOI, PKD, BPU, SAY]. As these croplands are the main reason that people are self-sufficient, lost yields have disastrous impacts on their food supply. Also, in the goldmining industry droughts have a significant impact, as this is a water and fuel intensive business [MOI].

The past year, some people have also noticed an illness that is killing their cassava crops [UGS, PGD, SGM, TAB, TJO]. People from villages along the entire river stretch are experiencing this damage to their cassava crops, and in Godo Olo, people even mentioned that other crops, such as podosiri and banana trees, show similar damage [PGDO]. According to some, the illness is brought to the region by artificially induced rain clouds created by gold miners near Lake Brokopondo during the dry season [PGD, SGM, TAB, TJO]. However, further research is required to investigate what is causing the damage to people's croplands.

The only measure people tend to take against this food shortage is stocking up during the wet season and bringing in their harvest in time [DTB, SGM]. When this is not enough, people have to ask friends and

family to send supplies from Paramaribo [PKD, KAR]. Apart from this, *"It's nature, so what can you do?"* [GNB]

Dry spell 2024

In 2024, the dry season was worse than ever before with transport by boat nearly coming to a full halt, likely as a result of El Nino. Lasting more than 6 months [DTB], the impacts of the prolonged and severe drought became so extreme that the government needed to send food and water to support the inhabitants [DTB, GDO]. However, this was not enough for everyone, making life extremely difficult during this period [DTB, KAR, TAB]. At its worst, the water level was so low that boat drivers could only transport 2-4 barrels of petrol from the Futu Pasi onwards and that people could walk from Diitabiki to Polokaba [DTB], or even from Puketi to Karmel [KIS]. During this time, at some locations a path was cut open through the jungle to the bottom of the Brokopondo lake, along which ATVs and tractors could transport the necessary supplies [GDO, MAI]. However, the journey along these roads was not without risks as the terrain is very rough [MAI]. During the previous century, 1983 and 1986 are remembered as being extremely dry [KIS, PKP, OPU, SAY].

In many villages, people say the dry season changes every year [BEN], with extreme droughts occurring every two to three years [FGDO, SGDO] or every five years [PKP]. Often people say they see an increase in the occurrence and severity of these droughts [GNB, MAN, PGD, TJO], with some even mentioning climate change as a possible explanation. However, there is no unanimous agreement about this trend, as some people believe this is how it has always been [MAN]. Furthermore, few people state droughts do not pose a problem, as they are still able to move around in their paddle boat better than during high water, and do not experience food shortages [KIS, OPU, WAN]. Nonetheless, it can be concluded that droughts have a significant impact on people's lives and that more and increasingly severe droughts can cause extreme problems for people in this region.

4.4 Field Work

During the fieldwork the steps from the methodology section have been followed where it was possible. In total 47 cross-sectional depth measurements have been taken, with 10 discharge measurements. A few of the cross-sections where also a discharge measurement has been done will be shown here, the remaining results can be found in Appendix G.

In Figure 45 the cross-sectional depth and surface flow velocities at Kiokondee are shown. Most results are similar to this one. They have a bed level that varies a lot, that stays around an average. Most likely the highly variant bed level is caused by either the presence of bedrock or goldmining activities in the river.

In this river there are a large number of islands, this also has an effect on the cross section as can be seen in Figure . If a cross section is taken downstream of an island, it often looks like the one in the figure. The sand seems to be deposited due to the lower flow velocities downstream of the island.

An exception to most measurements is the following cross-section taken at Puketi. At this location the river converges from a width of more than 500 m to a width of 130 meters due to geographical constraints. The result is a cross section with a large maximum depth and relatively high flow velocities.

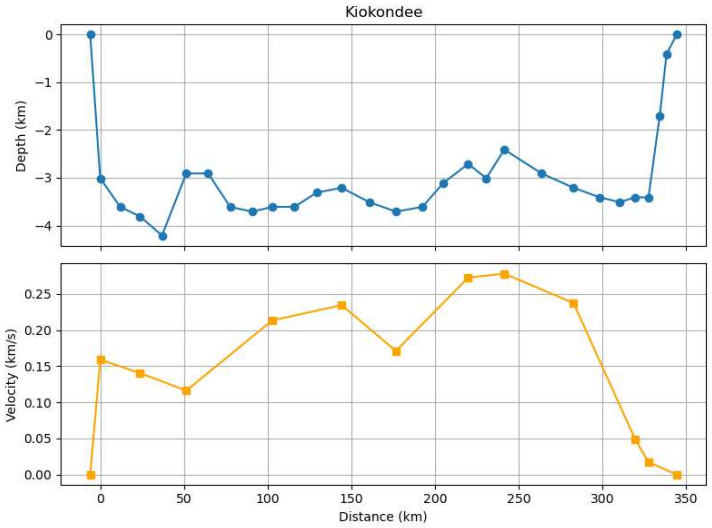


Figure 45: Kiokondee Surface Velocities

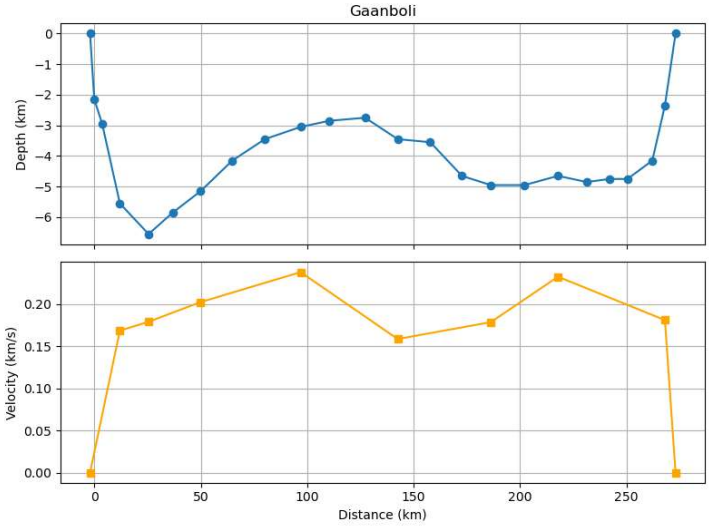


Figure 46: Gaanboli Surface Velocities

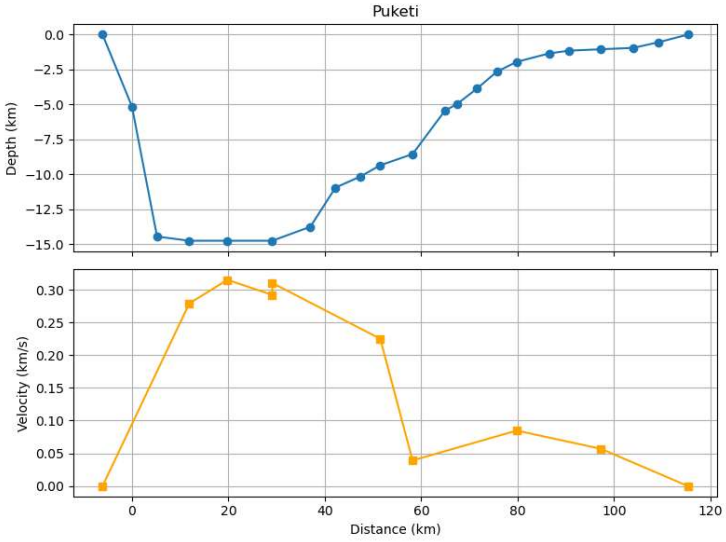


Figure 47: Puketi Surface Velocities

The discharge can be calculated using the surface flow velocities and the cross-sectional depth. This is done by numerically integrating the velocities over the cross-section. The result is shown in the figure below, if a few outliers are taken out of the dataset, a downward trend could be observed. To account for the difference between surface flow velocity and average flow velocity, the discharge is multiplied by alpha = 0.84. This alpha value is recommended when a rough bed level is present (Biggs et al., 2023), as is mostly the case in this river.

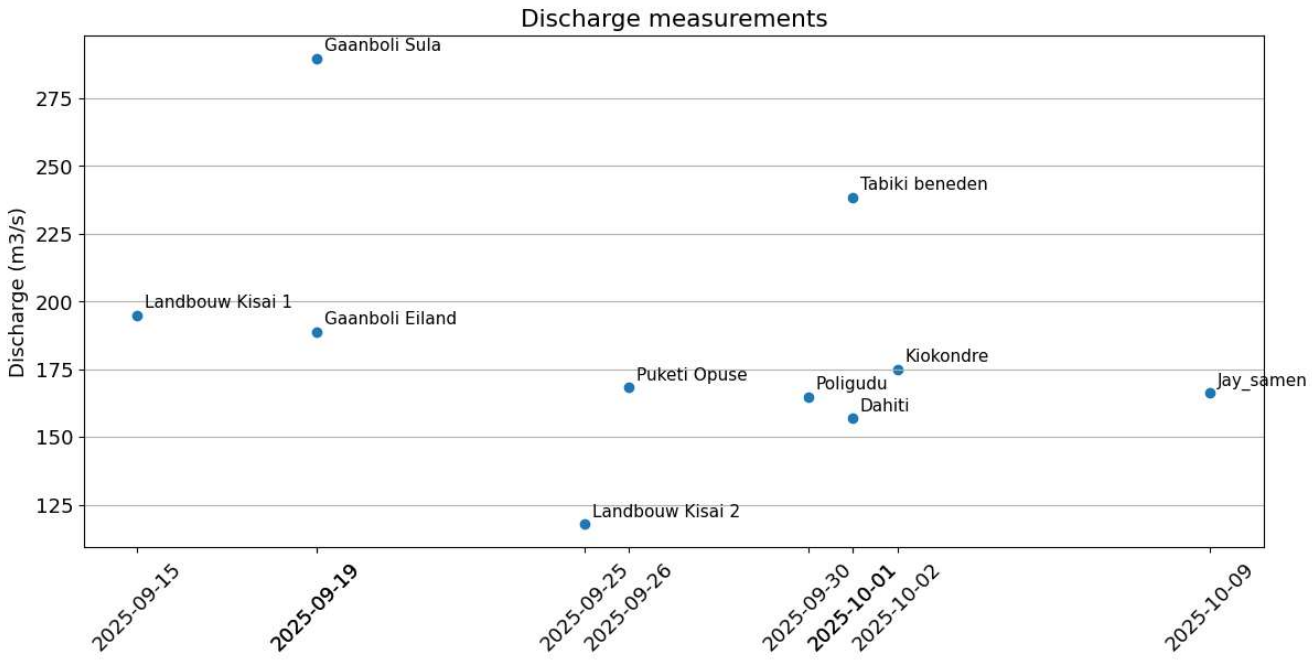


Figure 48: Discharge Measurements

The results of the drone measurements are inconclusive, the DEM's that resulted from it are curved and do not accurately represent ground level of the villages. This can possibly be solved by detrending the DEM's with a sphere form, however due to time constraints this will have to be done at a later instant. The curved DEM's are available however in the added zip file.

4.5 Hydraulic model

As described in the methodology, a hydraulic model can be used to determine which villages are most vulnerable. This is done using the data gathered during fieldwork in combination with a satellite DEM for the slope and existing discharge data for calibration. The model will not be able to predict accurately the water levels at each village. Instead, it should be used as an additional help when determining the vulnerability of the villages. This is done in Section 4.6 Flood Risk Analysis.

To infer the water level a DEM from Copernicus (Copernicus, n.d.) is used. The water level resulting from the satellite DEM is shown in the Figure below. The raw water level from the river had unwanted peaks due to trees above the river. To remove these peaks a function has been used that detects the varying slope using a Savitsky-Golay filter, and afterwards detects the peaks, removes them and interpolates to fill in the gap (Peaks on trend). To further smoothen the signal a moving average filter has been applied.

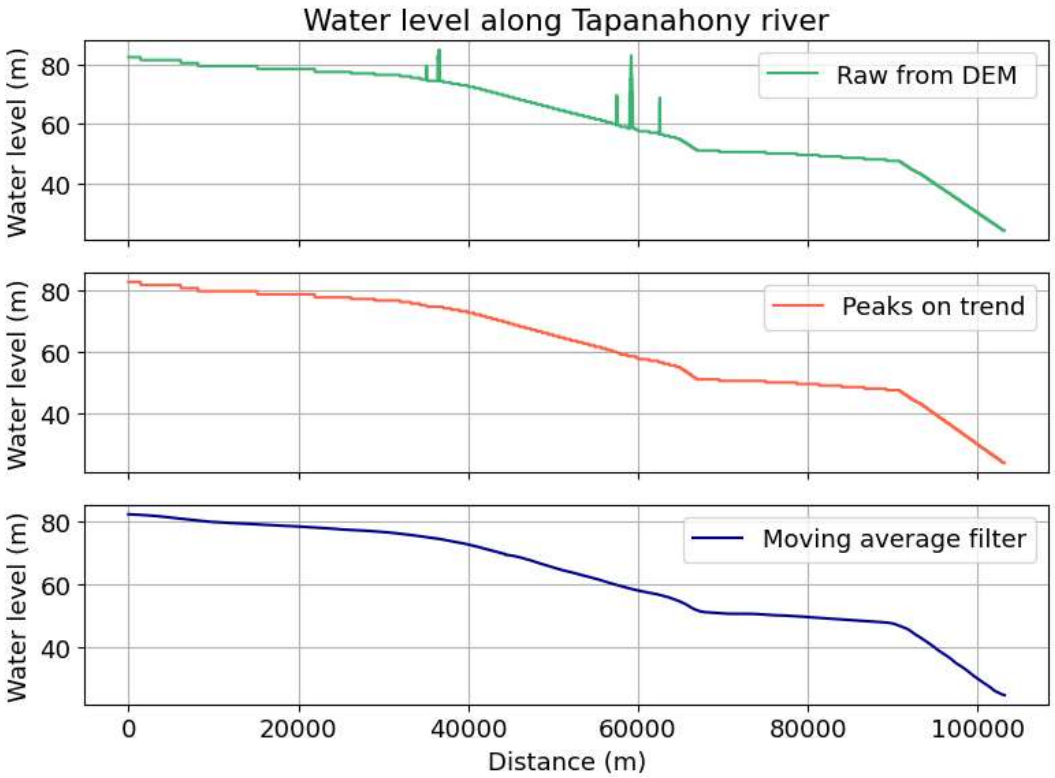


Figure 49: Water level along Tapanahony River

Because not all branches in the river have been measured, a power law fit has been done to estimate the cross section of the remaining branches using the width from Google Earth, see Figure . The problem with the power law fit is that it overestimates the area for low widths. As the low widths are the most interesting, a fit with a square root and an offset has been used instead, setting the depth to zero for the negative cross sections. The choice for a square root fit is made because it approximates a power law fit, but can be translated up and down, which was more practical in this case. Also, only the cross-sections measured with the Fishfinder are used, assuming that the water level has not dropped significantly during the measurement campaign. The discharge measurements also support this assumption, in a rough sense at least. Because only the general slope is known, and not the local slope, the influence of slope on the relation between area and width has not been considered. It is the same case for the friction coefficient.

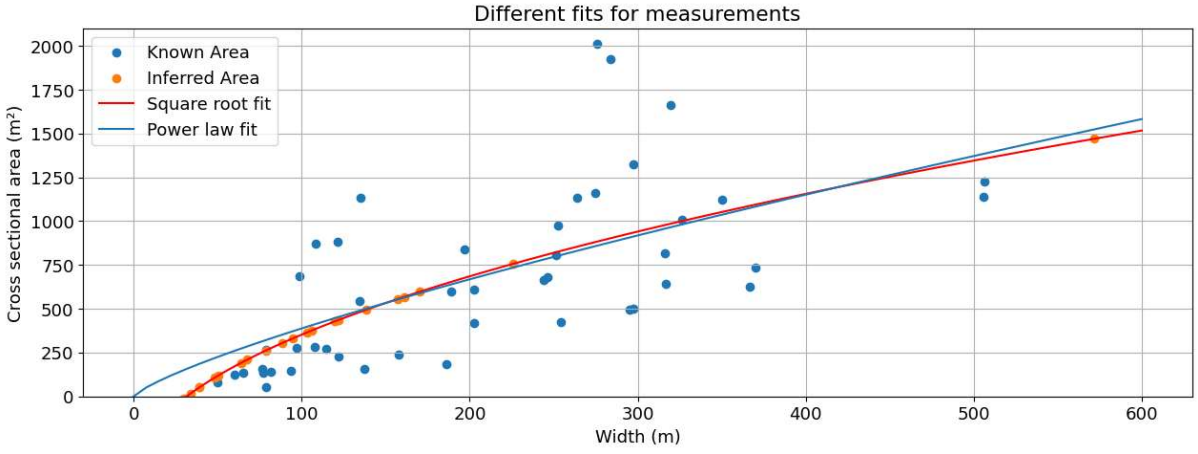


Figure 50: Different Fits For Measurements

At each branching location the cross-sectional areas and widths of the individual branches are added to find the total area and width of the river at that location. A rectangular cross section will be assumed, which allows to calculate an average depth at each location in the river. The result is shown below in Figure . To evaluate the precise water level at each village in the branches, an analysis needs to be done on the distribution of the water going through each branch. Due to time restriction, it was not possible to do this for this project. So, in the model, the branching sections are modelled as one big branch.

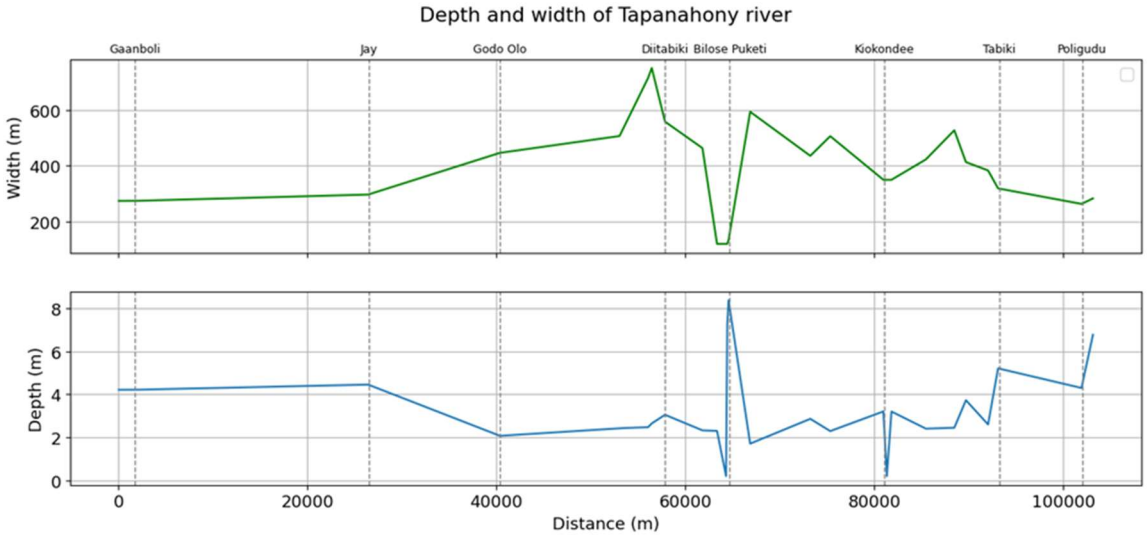


Figure 51: Depth And Width Of Tapanahony River

The bed level can be estimated using the depth calculated above. The assumption is made that the water level from the satellite DEM matches roughly with the water level during the measurement campaign. As the DEM does not have a specific timestamp at which it is made, it is difficult to check this assumption, however. The resulting bed level is shown in Figure .

Also note that the sula's are modelled by setting the average depth to 0.2 at the locations of the sula. This is an estimate obtained visually on site.

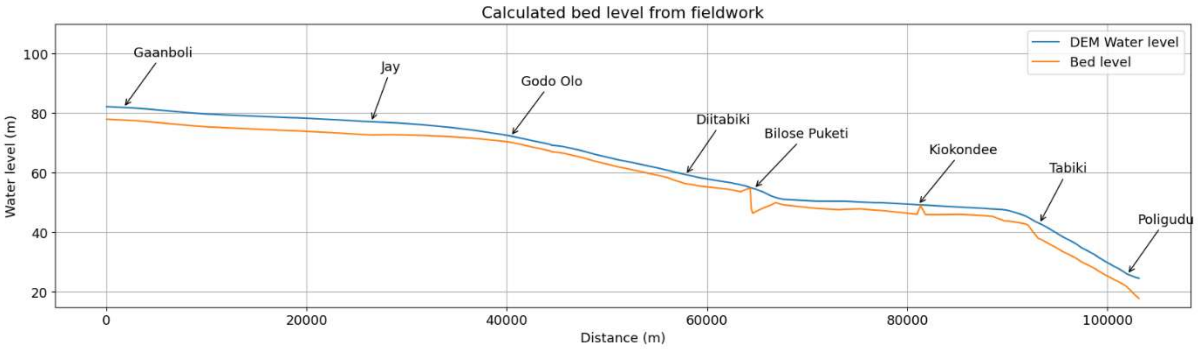


Figure 52: Bed Level

Along large portions of the river, bedrock can be seen protruding the water surface during the dry season, an example is shown in Figure 53. In several places the bedrock forms a sula, which can be seen as a natural weir, the two largest sula's are also added in the model. These are located at Puketi and Kiokondee. A sudden contraction and a following expansion take place at the sula's. As mentioned before, to accurately model the flow at these locations, conservation of energy is applied instead of conservation of



Figure 53: Bedrock Protrudes Water Surface

momentum. This is implemented at the locations at which the change in flow is above a certain threshold, which is at the sula's. These are also indicated in the figures below. Using the depth and discharge measurements the model can be calibrated, see Figure 54. The resulting cf is very high. However, the sula's that are not added can also be seen as locations of increased resistance due to the loss of energy during flow expansion. The bedrock mentioned earlier further adds to the high friction coefficient. In this river it is obvious that the water has a hard time flowing through the channel.

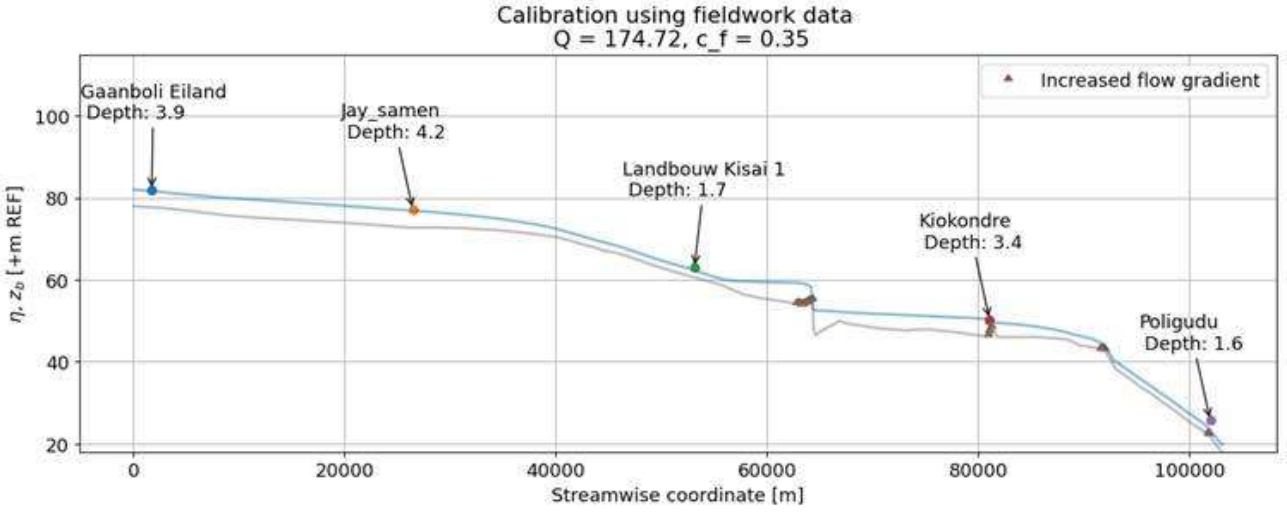


Figure 54: Calibration With Fieldwork Data

Another low flow calibration can be done using a single calibration point at Kiokondee, using the historical data that has been obtained, see Figure 55. This results in a lower c_f value. The fieldwork data differs from the historical data, which explains this difference.

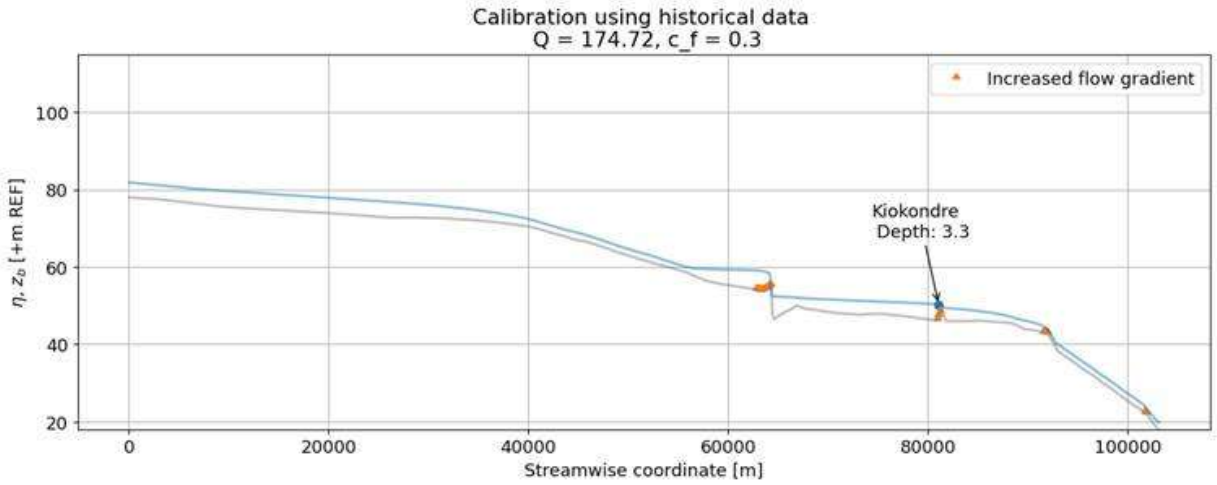


Figure 55: Calibration With Low Flow Data

After having calibrated the model for low flow, a calibration with the maximum flow is done, see Figure 56. The one calibration point from the historical data is again used. The discharge used is the highest discharge ever measured. The resulting c_f value is very low compared to the previous two calibrations. From literature it is expected that the c_f will decrease and the discharge will increase (Kuhanestani et al., 2025). But is most be noted that would not be in the magnitude that is observed here.

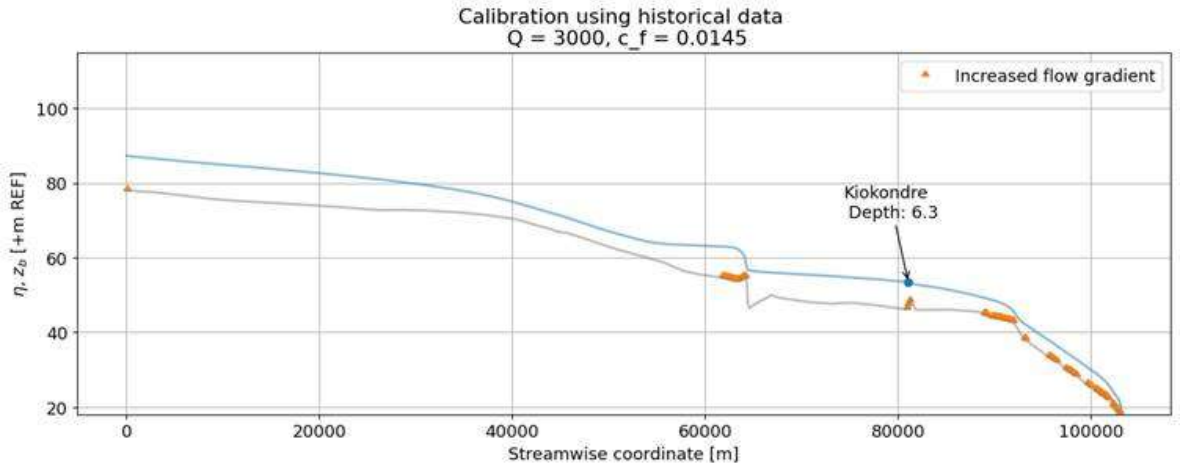


Figure 56: Calibration With High Flow Data

An explanation for the decrease of the friction coefficient could be that the bedrock that protrudes the water surface during low flow, is being submerged during high flow, and thus allows for less obstruction of the flow. For reference, the friction values are also given in other values generally used in practice in Table 16.

Table 16: Friction Parameters

	c_f	Chezy	Manning
Low Q calibration fieldwork data	0.35	5.29	0.232
Low Q calibration historical data	0.3	5.72	0.213
High Q calibration historical data	0.0145	26.0	0.052

In Figure 57, the low water results are compared with original DEM. The difference in water levels at Puketi and Kiokondee suggests an exaggerated reaction of the water levels to the sula's in the model. An explanation could be the fact that the sula is modelled in a simplified way. On the other hand, the measured depth at Poligudu is higher than the modelled depth, indicating that there should be a higher resistance coefficient applied in the model in the section between Poligudu and Kiokondee.

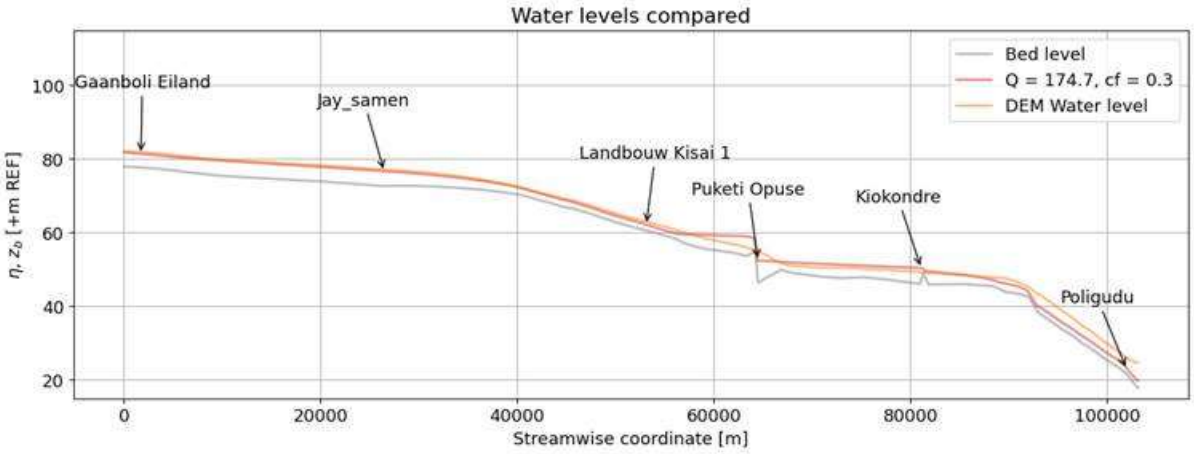


Figure 57: Water Levels Compared

Using the high discharge calibration, a run has been done with a 10% higher discharge than the highest discharge ever measured. The result is shown in Figure 58.

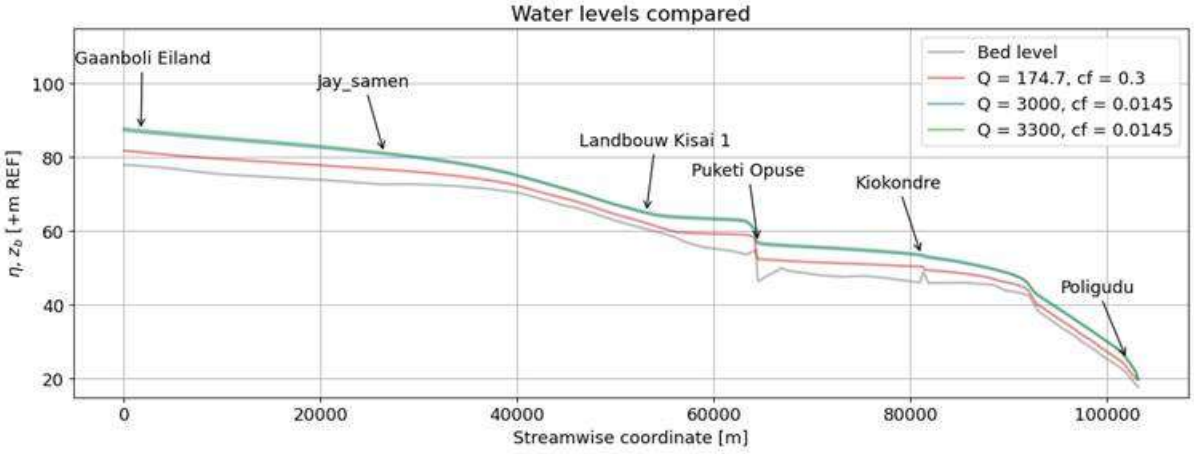


Figure 58: Discharges Compared: Water Level

In order to identify vulnerable areas, the depth has also been plotted below. Figure 59 shows that areas before sula's experience a higher increase in depth due to the backwater effect. And so, villages in the area of Diitabiki and Moitaki, as well as the villages around Kementi are more sensitive to an increase in discharge. This result also coincides with the results from the interviews, indicating that most villages in these areas experience flooding.

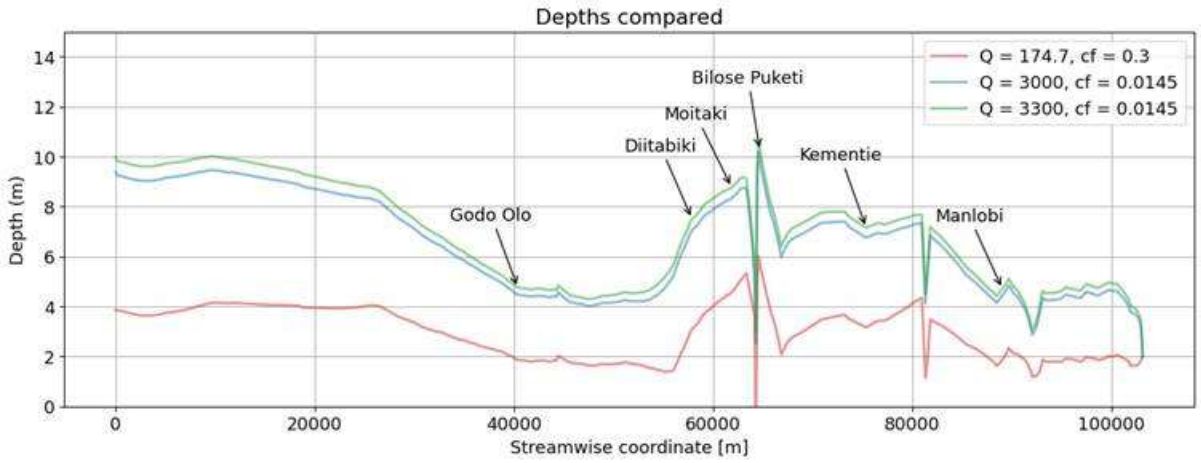


Figure 59: Discharges Compared: Depth

4.6 Flood Risk Analysis

In Figure 60 different results are combined. The figure contains the results of the interviews, of the village analysis and of the hydraulic model. Each criterium can contribute to the vulnerability of floods, with 5 as a maximum score for very vulnerable, and 0 for not vulnerable. Here the 'Island' criterium means if the village is on an island (1) or not (0). 'Relative height' means the height of the village with respect to the water, compared with the other villages, is 1 for low and 0 for high. 'Flooding' means indicated where there are flooding marks visible (1) or not (0). 'Elevated housing' indicated whether there are houses built on columns (0) or not (1). From the 'Flooding problems' criterium can be seen if the inhabitants of the village experience the floods as a problem (1) or not (0). Lastly the 'Water level in model' shows if the depth increase is more than 6 meters (1) or not (0). At the moment for simplicity the decision has been made to give each term the same weight, however this can be changed in further research. For future research another column with number of inhabitants can be added to also scale the vulnerability with the relative impact of a flood.

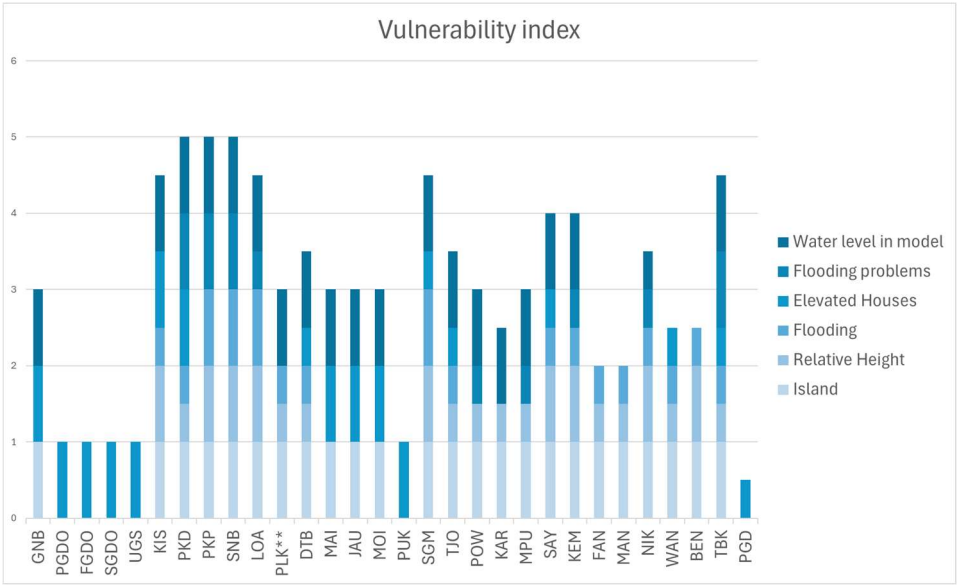


Figure 60: Vulnerability Index

4.7 Answer to sub-questions 2 and 5

What are the main hydraulic and geomorphological characteristics of the Tapanahonyriver and the surrounding environment, such as bathymetry, flow velocity, discharge, and elevation of villages located along the river?

The Tapanahonyriver is an anabranching river, where along almost the entire stretch of the area where the Okanisi people live, bedrock is extending through the water surface. The riverbed consists of both rock and sand, in several places sula's act as a natural weir, constricting the flow and increasing the flow resistance.

During the climate analysis it was found that the maximum discharge passing through the river, which was recorded in the past ten years, amounts to about 3000 m^3/s. The field work resulted in several discharges that occur during the long drought. These were used to determine a stage-discharge relationship of the river, but for the research the maximum discharge is of much more importance.

The table in Section 2.1.1 provides a clear overview of how high the villages are situated with respect to the water level of the river. The villages that are located on islands are more often than not located quite high and vice versa for the villages located on the mainland.

Which areas along the Tapanahonyriver are most vulnerable to flooding?

In Section 4.7 a bar plot is presented, which highlights the villages that are most prone to flooding. Right now, many villages downstream of Puketi often experience floods, since they are located in the geological bottleneck of the region. However, the 1D hydraulic model shows that the villages around Diitabiki, will experience a couple of meters of water depth increase. This happens as these villages are located just before a big sula, which likely causes a backwater effect as is shown in the model.



5 Water Quality

As part of the broader aim of exploring the region and its problems, the water quality of the Tapanahony has been studied. This chapter will describe the results of a preliminary study done into water quality based on earlier research, interviews and testing of several water quality parameters. Based on these results, recommendations will be made for further research, which can be found in Section 9.2.

5.1 Preliminary Study

The Tapanahony River plays a significant role in the daily lives of those living in the villages along its banks. Section 2.4 describes these functions of the river, including washing in and sometimes even drinking the river water. This is both a part of their culture and often their only option, as the climate and remote location of the villages make it difficult to fully replace river water with an alternative source, like rainwater. This means that the quality of the water can have a big impact on the health of the local communities.

5.1.1 Drinking Water Supply

"Access to safe drinking water, sanitation and hygiene (WASH) is essential for good health, welfare and productivity and is widely recognised as a human right." (Ministry of Social Affairs and Public Housing, 2019). The Multiple Indicator Cluster Survey (MICS) of 2018 by the Ministry of Social Affairs and Public Housing (2019) offers statistics of water use in Suriname. This study shows that the main drinking water source for people in Sipaliwini, the district to which the Tapanahony region belongs, is rainwater collection (73%). The second biggest drinking water source of this region is surface water (14%). Only 6% of the people in this region have access to piped water. It should be noted that even if rainwater is the main source of drinking water supply, there is a chance that they will run out of water during the biggest dry season of the year.

The same study surveys the risk of faecal contamination based on the amount of E. coli in the water. The risk level is based on the number of E.coli per 100 ml, with a moderate risk level of 1-10 / 100 ml (Ministry of Social Affairs and Public Housing, 2019). According to this study 85% of the households in Sipaliwini are at moderate risk of contamination, or higher, scoring higher than all other districts in Suriname. Additionally, only 5.5% of the household members uses an appropriate water treatment method.

5.1.2 Drinking Water Initiatives

There are initiatives like the Joint Programme of the SDG fund that have assessed the drinking water supply systems in the region (Joint SDG Fund, 2024). They found that there is only one working treated drink water supply system in the region: a sand filter placed in Moitaki. Other attempts on providing treated water are either broken or leaking. There are water installations in place that distribute the water in the villages, however, they often provide untreated water.

The Joint Program has placed 118 rainwater harvesting tanks in 57 villages along both the Tapanahony and Upper Suriname river (Joint SDG Fund, 2024). According to them, this should provide access to safe drinking water to 4.385 individuals. In practice however, research like van der Ent et al. (2007) shows that

rainwater harvesting tanks are in general often badly placed or when they break or start leaking, people do not have the means or knowledge to repair them, reducing the impact significantly.

Another more recent attempt to improve the drinking water supply in the Tapanahony (and Lawa) region is done by the ministry of Natural Resources (Natuurlijke Hulpbronnen, NH). They have placed surface water treatment installations in Benanu, Wan Finga, Mainsi, Puketi, Manlobi and Fandaaki (Starnews, 2025).

5.1.3 Water Quality Requirements

There are no clear requirements for water quality of the Suriname government. Table 17 shows a few maximum substance concentration requirements of the European Union as and of the United States Environmental Protection Agency (US EPA) as reference (Europese Unie, 2020; US EPA, 2015).

Table 17: Maximum Substance Concentrations EU and US EPA

Parameter	Value (EU)	Value (US EPA)	Unit
E. coli	0	-	Value / 100 ml
Cyanide	50	4	µg/L
Mercury	1	0.3	µg/L
Nitrate	50	10	mg/L
Nitrite	0.50	-	mg/L
Pesticide	0.1	-	µg/L
Chloride	250	20	mg/L
pH	≥ 6.5 and ≤ 9.5	≥ 5 and ≤ 9	-

5.1.4 Pollution of the River

In 2020 67% of the total export of Suriname was gold, making it the number one export product (DTOC, 2023). Even though big scale mining is mostly done downstream of the Tapanahony River and around the Brokopondo lake (DTOC, 2023), the Tapanahony River gets polluted by the persistent gold mining activities around and even in the river, according to the indigenous organization Mulokot (Gallant, 2025). This causes water pollution, mainly because of the mercury used for the mining activities. Which can have serious consequences for the health of humans and animals living in or near the river. As such, water pollution does not only harm the health of the local communities when they are using the river as drinking water source, but also with other interactions with the river, like washing and fishing.

"Our rivers are our lifelines. If they die, we die with them." (Gallant, 2025)

Mercury is often used in smaller illegal goldmines, often irresponsibly (Huisden, 2024). There are several multinational goldmining companies active in Suriname. However, 66 percent of the gold is mined in small- and medium-scale mines. Mercury is used in fluid form but evaporates into the air. This does not only happen by mining activities, also deforestation and other disturbances to the earth can cause mercury stored in organic matter to evaporate. Subsequently, the evaporated mercury in the atmosphere can travel with the wind or precipitation to other 'pristine' areas where there are no goldmining activities or end up in people's rainwater harvesting tank (Ouboter et al., 2012). Additionally, in these areas mercury is more freely available for methylation and bioaccumulation, whereas in goldmining areas mercury is more often attached to sediment particles. Research by Ouboter et al. (2012) also included the

Tapanahony river, showing elevated levels of mercury in the river water and in the local fish species, with one of the main reasons anthropogenic deposition by the gold mining activities taking place along the river (Ouboter et al., 2012).

Goldmining activities do not only lead to mercury pollution but can also cause cyanide pollution. In general, bigger companies use cyanide, while smaller companies use mercury (Huisden, 2024). Both very hazardous for the environment. In 2023 a big cyanide leakage in the Brokopondo lake polluted the water (Jurna, 2023). Leading to cyanide levels 1600 times higher than the norm for drinking water. This has led to the prohibition of cyanide use in goldmining.

Besides goldmining is the dumping of waste a big pollutant of the rivers in the inlands of Suriname. These regions lack any form of waste treatment facilities, and the waste is normally disposed of in the river or open fields (ABS & CIS, 2012). This disposal of waste in the river does not only cause problems by polluting the water quality. According to the head of the Water Supply Service department, part of the ministry of Natural Resources, it causes serious pollution of the water filtering installations in the Tapanahony region (Awanna, 2025). According to them this pollution is caused by human activity, referring to the disposal of household but also chemical waste like (car) batteries. Because of this behaviour, the lifespan of the water filtering installations is shortened significantly, and filters need to be changed more often.

5.2 Methodology

To study the water quality of the Tapanahony River and its implications for the local communities two methods were combined: interviews and fieldwork. Interviews were used to qualitatively study the water quality and how this has changed over time. Additionally, a quantitative study was done on the water quality of the river by testing samples a broad range of substances.

5.2.1 Interviews

The goal of the interviews about the water quality was to find out how the interviewee experiences the water quality and its changes over time. In addition, the interviews were used to study the impacts of the (changing) water quality on the daily life of the local community. This was achieved by posing three open-ended questions, which formed part of a broader interview that also addressed the other topics of this research. The full list of interview questions can be found in Appendix B. By interviewing individuals of various ages and professions across 27 out of 31 villages, the goal was to gain a comprehensive perspective on the perception and impact of water quality on life in the Tapanahony region.

5.2.2 Field work

In addition to the interviews, a quantitative study was done by testing water samples of the river. Samples were taken at the village entry point of all visited villages. Additionally, a water sample was taken at a location in the middle of the river within 1.5 km of the village. If villages were located close to one another, a single water sample was taken from the middle of the river will suffice, provided it met the previously mentioned distance requirement.

All water samples were tested on the following water quality indicating substances:

- Temperature during testing: T [°C]
- Electrical Conductivity: EC [µS]
- Acidity: pH [-]
- Mercury: Hg [µg/L]
- Chloride: Cl^- [mg/L]
- Total Hardness: GH/TH [°]
- Carbonate Hardness: KH [°]
- Nitrate: NO_3^- [mg/L]
- Nitrite: NO_2^- [mg/L]
- Cyanide: CN^- [mg/L]

The tests were done within 48 hours of sampling to prevent possible contamination of the samples that could influence the test results. For the same reason, it was important to rinse the sampling tubes with the sample water prior to filling them.

For this research, sampling bottles of 40ml were used. Due to the number of substances tested, two water samples were taken at each location. The water samples were taken and labelled following the water sampling protocol that can be found in Appendix F. Additionally, this is where the test methods for each of the different water quality tests can be found.

The average, maximum and minimum values of the results over the entire region were analysed and compared to values found in literature. The findings were used as a preliminary study to come up with recommendations for further research into the water quality of the Tapanahony.

Figure 61: Sample Tubes Used During Fieldwork



Figure 62: Testing the Water Samples



5.3 Interviews

The interview part about water quality mainly focused on where people get their drinking water from and how people see the quality of the river water change seasonally and on longer term.

Seasonal Fluctuations

The water quality fluctuates during the year, depending on the season and the amount of rain. Both in the dry and wet season the water quality is poor [PGD, SGM, DTB, GNB, PKD]. When there is a lot of rain, the river water becomes white and muddy due to sediment that is washed away and carried into the river by creeks [KEM, MAN, PGD, GNB, GDO, OPU, BPU, PGD], see Figure 63. This also brings the goldmining chemicals into the river [DTB, UGS, PGD, MOI]. In the dry season, the water quality is bad [PGD, SGM, KAR, GNB, MOI, KEM, SAY] for another reason: water does not flow very fast [PKD], see Figure 64. Since they are more dependent on the river as drinking water source, people get sick [PKD, MOI, SGM, KAR]. When someone lives in the city part time, they get sick quicker [PKD, DTB, KIS]. In between the seasons when the water level is 'normal', the quality is at its best [GNB].



Figure 63: Seasonal Changes in Water Quality, Washing Away of Mud



Figure 64: Seasonal Changes in Water Quality, Dry Season

Changes over the years due to goldmining activities

Changes do not only take place during the different seasons; over the years the water quality has changed as well. *"In the past, the river was real drinking water" [GNB]*. All interviewees agree on the main reason for this: the mining of gold. The interviewees often have different opinions on how the goldmines pollutes the river, most of them argue that the problem is the mud which is flushed into the river during the process. Other agree that the reason is because they use mercury [DTB], cyanide [UGS, OPU] and heavy machinery [MAN, PKD, GDO, PKP, KIS]. The quality has decreased significantly when people started to mine right near the river, instead of further away in the forest [MAN, BEN, PKP]. When the goldmining business was not as big, people used to drink the water from the river. While some still do, others have stopped because of this or boil and/or filter it before drinking [DTB, FAN, PKP, PKD, TBK, BEN, MAN, UGS, BPU, TBK]. It also has an influence on the animals, like crayfish that are seen less and less [WAN].

In the past, people were able to see the riverbed [PKD, JAU, MAN, BPU] till 5 meters deep [WAN]. Each year it becomes worse [PKP], and people are afraid it will get as bad as it is in the Lawa where people can only drink piped filtered water or bottled water [KIS].



Figure 65: Goldmining Activities Near the River

Upstream of Sela Creek, there are no goldmines anymore [DTB, GNB, PKD]. Therefore, the water quality is better in Gaanboli than a lot of the other villages [PGD, PKD, GNB, MOI]. *"Upstream of Sela Creek the water is black, and downstream it is white."* [DTB] This comparison between black and white water, clear and troubled water, is often made to indicate the quality of the water [DTB, PKD, KIS]. Others call it red, because of the red clay in the water [PGD, TBK]. There are people who will not drink water from the river in their own village but do so when they are upstream of Sela Creek [DTB, PKD]. The further downstream, the worse the water quality gets [BPU, PKD]. It is important to note that not all people recognize this quality change over the years [DTB, KAR].

Other causes of water pollution

In section X another reason for water pollution was mentioned, namely waste that is thrown into the river [PKD, GNB]. Additionally, the lack of sanitation forces people to use the river as their toilet, which pollutes the water as well [PKD]. Over the years, the increasing number of outboard engines has also contaminated the river water [GNB, SGM, PKD].

5.4 Results and discussion

The results of all the performed water quality tests are summarized in Appendix H. An overview of the average, minimum and maximum measured values is given in Table 18.

Table 18: Water Quality Test Results

WQ Parameter	Unit	Average	Min	Max
Electrical Conductivity	[µS]	24.3	18.9	115.3
Temperature during testing	[°C]	34.1	29.3	36.4
pH	[-]	5.89	4.63	7.01
Mercury	[µg/L]	4	0	30
Chloride	[mg/L]	-	0	0-0,8
Total Hardness	[°]	-	0	0-3
Carbonate Hardness	[°]	<6	<6	<6
Nitrate	[mg/L]	0,2	0	5
Nitrite	[mg/L]	0	0	0
CO2	[mg/L]	13	8	18
Cyanide	[mg/L]	0	0	0

5.4.1 pH, CO_2, and hardness

The pH values measured suggest the Tapanahony is relatively acidic, with an average value of 5.89, compared to a neutral pH of 7. When compared to other inland rivers in Surinam, it is also relatively low, such as the Suriname River which has a pH of approximately 6.5 (Leentvaar, 1965). In a broader context, in the Amazon the range of the pH of river waters ranges from 4 to 7, depending on the geological differences of the different catchment areas, with lower pH values typically observed in blackwater rivers and higher pH in clearwater or whitewater (Duncan & Fernandes, 2010).

The pH in river flow is influenced by a variety of factors and processes. First, the source of water plays a role in the pH level. The Tapanahony is a rainfed river, which results in a low pH as rainwater is slightly acidic (pH 5.0 – 5.5) (Water Science School, 2024). This is caused mainly by the interaction of precipitation with carbon dioxide from the atmosphere, which has a pH lowering effect through the formation of bicarbonate and weak carbonic acid (US EPA, 2025). Furthermore, the pH of river inflow is influenced by the catchment vegetation. When this is dominated by peat and humus, as is the case for rainforests, the decomposition of organic matter results in a decrease in water pH (Omarjee et al., 2021). Finally, the pH is affected by the catchment geology, as this influences the dissolution of ions such as limestone into the water. This determines the alkalinity of the water and thus its ability to buffer a low pH. This is also illustrated by the water quality measurements, which show a low total and carbonate hardness for all of the measured samples. A low hardness is also common in other rivers in Suriname (Leentvaar, 1965).

As the Tapanahony flow regime is strongly governed by the seasonal rainfall pattern this suggests that the pH varies throughout the year, varying during low and high flow (Byzaakay et al., 2023). However, only one measurement in time was performed during this project so this interplay between pH and seasonality could not be analysed.

The same processes that influence the pH and hardness of river water are also linked to the dissolved CO_2 content, as rainwater interacts with CO_2 in the atmosphere and organic matter decomposition further releases CO_2 into water. The average measured dissolved CO_2 was 13 mg/L, ranging from 8 to 18 mg CO_2/L. However, the measurements solely include dissolved CO_2 and not the complete dissolved inorganic carbon content (DIC) of the water, which consists of HCO_3^- and CO_3^{2-}, CO_2* (i.e. the sum of $CO_{2(aq)}$ and H_2CO_3). This DIC depends on the biogeochemical characteristics of the river such as pH, mineralization, organic matter content, and other parameters, such as, nonetheless to a lesser degree, the temperature of water (Marx et al., 2017). Natural waters can have a DIC varying from 1.2 and 120 mg C/L in freshwater, with lower concentrations usually linked to more acidic waters with a low hardness, and higher concentrations linked to more alkaline hard waters (Cole et al., 2021).

There is no available data on the hardness, dissolved CO_2 and pH of the Tapanahony, and comparable data on other rivers in Suriname is limited, which complicates the possibility of validating the results. Similar pH values and hardness have been measured in other waters in Suriname, nonetheless the results are at the low end of this range (Amatali & Naipal, 1999). However, these were not near the Tapanahony region. Dissolved CO_2 data has not been found.

The reliability of the measurements in this study is also limited by equipment constraints. During testing, the pH measuring device occasionally provided questionable results as it would continue to rise after measuring each sample. Regarding the CO_2 measurements, an aquarium titration kit was used, which lacked precision due to subtle differences in shades of pink between test and control samples, making the determination of the endpoint difficult. Hardness was measured using test strips, that can only provide a rough indication of this parameter. Consequently, the data should be interpreted with caution, and these limitations should be considered when contemplating further use of the data.

5.4.2 EC

The measured electrical conductivity (EC) values ranged from 18.9 to 115.3 µS, with an average of 24.3 µS. The maximum value of 115.3 µS seems to be an outlier, as the second-highest measurement was only 28.5 µS. A possible explanation could be the high turbidity observed in this sample (DAH_B in Appendix H), which could suggest a high concentration of suspended solids that could contribute to an increased concentration of dissolved ions and, consequently, higher conductivity.

Overall, the measured levels are relatively low and suggest a low concentration of dissolved ions that can conduct electricity through the water (DataStream Initiative, n.d.-b). This could be influenced by the inflow of the Tapanahony river, which is predominantly governed by rainwater which has a low conductivity. Similar values have been measured in other rivers in the Amazonian river basin (Ríos-Villamizar et al., 2013). Additionally, water temperature can influence conductivity, with higher temperatures generally increasing the movement of ions in water and resulting in slightly higher EC values (Dewangan et al., 2023). However, with the current setup it was difficult to see if this was the case or not.

5.4.3 Temperature

The measured temperature of the samples is high, ranging from 29.6 °C to 36.4 °C. This is the result of the sample having to be kept in the samples tubes on boats and outside during fieldwork up until the moment of testing, causing them to warm up. Nevertheless, temperature of the river water is also relatively high. Measured at the bank of Diitabiki in the late afternoon, the water temperature was measured at 32.4 °C and indicates that the Tapanahony has a high-water temperature. Only one measurement was taken, and this was during low flow, thus for a better understanding of the temperature dynamics of the river water more measurements in time, both during the day and during the year, should be taken. Furthermore, multiple measurements along the river cross section should be taken to give an insight into the temperature profile of the river. Furthermore, data on surface water temperatures in Suriname is limited, which complicates comparing the measurements to another research.

These high temperatures of the samples can also have an impact on other water quality parameters, such as the pH, EC and biological activity. This is because temperature influences the reaction kinetics of chemical and biological reactions in water. Furthermore, temperature can have an influence on the performance of the measuring equipment (Ducharne, 2008). Thus, this should be taken into consideration when evaluating the results.

5.4.4 Mercury

The average mercury level measured was 4 µg/L, with a range of 0 to 30 µg/L. However, most of the measured values were 0 µg/L, with mercury being detected in 9 of the samples. The test strips used for measuring the mercury level were difficult to read, as the changes in shades of pink that should indicate different concentrations were extremely subtle. When the strips revealed a shade of pink in between two known values, an estimation was made based on visual inspection. Additionally, the differences in concentration between one shade of pink and the other, are still quite close together, going from 0 µg/L to 50 µg/L. Thus, these measurements are better used as an indication whether mercury is present in the water and looking at the concentrations measured should be done with great caution.

The presence of mercury in the Tapanahony is also confirmed by other research by Ouboter et al. (2012), and similar to the results from the interviews can at least partially be attributed to the gold mining activities in the region. Mercury can also be attached to river sediments, which means the total amount of mercury in the river is likely higher than what is measured in the water (Ouboter et al., 2012).

5.4.5 Cyanide

0 mg/L of cyanide was measured in each of the water samples. Furthermore, literature reviewed no available data on the presence of cyanide in the water of the Tapanahony river. Nevertheless, results from the interviews indicated that cyanide is used in certain instances in the goldmining industry [UGS, OPU]. The fact that it is not measured could suggest that cyanide remains in the mining areas and does not leak to nearby water bodies. However, the threshold value of the measuring equipment was relatively high, 1 mg/L, which is considerably higher than the maximum allowable concentration for drinking water as described in Section 5.1. which could also mean that low values of cyanide leakage are not captured by the measuring equipment. Furthermore, it is possible that cyanide is removed from the water through biodegradation which can influence the presence of cyanide in the river (Ebbs, 2004).

5.4.6 NO2 and NO3

The water quality tests show an average NO2 and NO3 value of 0 and 0.2 mg/L respectively. Consequently, no NO2 has been measured in any of the samples, while the NO3 range from 0 to 5 mg/L. However, it should be noted that the NO3 has only been detected within two out of the thirty-nine samples. Since NO2 and NO3 in drinking water pose serious health risks, these low values that lie under the maximum allowed concentration for drinking water as described in Section 5.1, are positive for people drinking the river water (Water Quality Association, 2013).

The presence of these substances in waterbodies can be caused as a result of agricultural activities. When fertilizes are (excessively) used, these nutrients can end up in the river by the runoff water. Another reason for NO3 to end up in the river is from wastewater disposal and other nitrogenous waste such as septic tanks (*GUIDELINES for DRINKING-WATER QUALITY: FOURTH EDITION INCORPORATING the FIRST and SECOND ADDENDA*, n.d.). In some circumstances, NO2 can also be found in groundwater due to natural vegetation.

While the interviews show no use of fertilizers in the area, there is a problem around wastewater disposal, and it often ends up in the river. While this is a problem even in the dry period when the samples have been taken, this problem increases in the wet season. Since then, there is more water used and according to the interviews the septic tanks in the villages can be flooded, causing pollution of the river. This could mean samples taken in the wet season could show a higher concentration.

There is no data is available on NO2 or NO3 values of other studies looking at the water quality of the Suriname rivers. Additionally, due to the measurement method using test strips, the measurements are not highly accurate. Therefore, the values found in this research cannot easily be validated and should again be looked at with caution.

5.4.7 Chloride

The chloride test has been conducted using test strips, giving a value of 0 or between 0 and 0.8 mg/L for all samples, with a majority of the samples measured to have a concentration 0 mg/L of chloride. This is way below the threshold described in Section 5.1. However, there is again some uncertainty associated with the use of these test strips. Additionally, chloride levels may vary with the depth at which samples are taken (DataStream Initiative, n.d.-a). In this study, all samples were collected at the surface of the river, which may therefore have influenced the results.

Chloride is often measured to indicate the salinity of water. It can end up in the river from the weathering of soil and rocks, but also from human industrial and agricultural activities. Additionally, it is also often used as a tracer, because it does not break down (DataStream Initiative, n.d.-a).

No public information was found on chloride levels measured in Tapanahony river. There have been studies done into the salt intrusion from the sea in the Suriname rivers. Based on these studies it can be concluded that no salt intrusion influences the salinity of the Tapanahony since it is too far upstream (Amatali & Naipal, 1999).

When comparing the results of this study to those of a study conducted in Ecuador, the latter shows higher chloride levels in a tropical river (Jerves -obo et al., 2020). However, since the characteristics of river basins

can differ significantly, this comparison does not provide enough insight into the validity of the findings presented here.

5.5 Answer to sub-question 4

What is the current state of water quality in the Tapanahonyriver, and what are the main factors influencing it?

According to many interviews the quality of the water in the river has gone down altogether. Especially, when the goldminers started working with heavy equipment the water became much more turbid. Next to that, the mines are still working with heavy metals and toxic compounds that threaten the health of the inhabitants and the nature present in the area. Furthermore, human and plastic waste is thrown into the river, polluting the water with bacteria and microplastics.

Further research into the water quality of the river is necessary, which should include a variety of parameters as pH, EC, heavy metals, bacteria, microplastics, and cyanide. Accurate test equipment should be used, likely in a laboratory, and tests should be conducting at the same locations various moments in time for a better understanding into the time dynamics of the water quality parameters.



6 Discussion

In this research, an attempt was made to obtain a broad understanding of the life of people in the Tapanahony region in combination with an attempt to characterise the main problems they face through fieldwork. Before this, an analysis was done of data available to understand the river flow and regional climate. However, the available data was extremely limited, which prohibited a comprehensive analysis of these two features of the region, still bringing forth much uncertainty. The interviews that were revealed that the inhabitants experience a wide range of problems. Interestingly, floods were often not perceived as the most significant issue, even in villages where houses are flooded by one meter or more. The lack of clean drinking water is seen as a big problem, as well as the poor quality of education for children and limited opportunities for employment. Even though flooding is often not seen as the biggest problem, it still occurs in more than half of the villages, forcing people to temporarily move away. Therefore, it is necessary to consider this when trying to develop the region.

While the interpretation of some results is relatively straightforward, most results in this research should be seen as indicative rather than conclusive, as a significant amount of uncertainty remains. This is because this research solely forms the basis for a larger project, aiming to collect as much information as possible on a wide range of topics, which limited a deeper investigation into each separate subject. These limitations and others are discussed below.

The decision was made to visit all 28 villages in a timespan of 3 weeks, which often only allowed for one interview per village. Consequently, only one perspective on the issues at play was gathered, often given by a figure with authority such as a Basiya or Kabiten. This could skew the results towards a certain opinion. Furthermore, the interviews had to be translated from Dutch to Ndyuka and vice versa. As translation was not done word-for-word, some things were likely lost in translation. Also, sometimes the translator's opinion or those of earlier interviews could have had an impact on the interview results, for example by steering the conversation to certain topics. In addition, the research was done in the dry season, so it is possible that the interviewees list the current problems as the biggest while downplaying problems that arise during the wet season. Despite these uncertainties, the interviews provide a valuable overview of the problems in the region. What is very clear from the interviews, is that the problems that the inhabitants of the region deal with are serious, have been present for some time and are according to them often the result of neglect on the side of the government.

The broad fieldwork campaign also only allowed for depth and discharge measurements in a few locations along the river, offering an idea of the character of the whole river, but not allowing for precise modelling of the system. The time pressure also had an effect on the quality of the measurements, as there was not always time to locate the most suitable spot for a depth measurement. This resulted in some incomplete cross sections due to the presence rocks or shallow areas. The time pressure also had an effect on the velocity measurements. Ideally, around 20 measurements are done in one cross-section in order to obtain the discharge with adequate resolution. However, delays with boat transport and exhausting weather conditions had an impact on the initial schedule limiting the number of velocity measurements possible per cross section. Nevertheless, where the depth and velocity measurements are lacking in accuracy, they do give a considerable picture of the type of river system. The combination of a river with changing slopes in space and a bed existing of part sand and part bedrock leads to quite a chaotic, anabranching character, with a lot a fast-flowing sections, alternating with slow-flowing sections. It is logical that this leads to strong

differences in stage-discharge relationships depending on the location, which is also revealed by the model.

The hydraulic model of the river is set up in a general way in order for the data obtained to still be of use. This means that the geometry of the river is generated using averages and extrapolations of the width, depth and slope. The model is calibrated in only one location, for two different discharges, using the obtained parameters for the whole river. The DEM's of the villages that had been constructed using the drone were meant to be able to show flood water levels at the villages using the model and construct a flood risk map. However, a calibration issue with the drone used and the time constraints prevented these DEM's from being used in this analysis. Thus, the combination of the methods used cannot say anything about specific water levels at each of the villages, but using the model it is easy to find the villages that are the most vulnerable to high discharges.

When comparing the results from these different sources in the flood risk analysis, it is clear that the final result has quite some uncertainty. However, the difference in water level between some villages is quite significant and the final model outcome could be used for future research to target the more vulnerable villages. When comparing the results from these different sources in the flood risk analysis it is obvious that also the result has quite some uncertainty. Nevertheless, the difference between some villages is very clear and the plot could be used to target future research into the more vulnerable villages.

Regarding the water quality analysis, the testing methods used had a significant impact on the accuracy of the results as mentioned in Chapter 5. Furthermore, the water quality parameters of the river are heavily time dependent. As only one measurement was performed at each location, it was not possible to illustrate this time dynamic. Thus, this study predominantly provided valuable insights into what further research into the water quality of the Tapanahony should include. The parameters that should be analysed, when the tests should be performed and that more accurate methods should be used.

Finally, an important part of this research was looking at possible solutions for the problems in the region with the local community. Many promising ideas were generated; however, these all remain in a very preliminary stage. Further research is needed to determine what stakeholders are involved in each of these development opportunities and what all their responsibilities are. Finally, steps on the short and long term need to be thought out with all parties involved to come to a complete strategy for development.



7 Conclusion

This report tries to answer the following question:

How does flooding impact the Tapanahony region,
and what can be done to address this problem and other existing problems to ensure a sustainable future for the region?

In this research different kinds of measurements were performed in combination with the conducting of interviews. The result of this research lead to the following answer: Floods have a big impact on the lives of the Okanisi of the Tapanahony region: flooding the houses, destroying crops, preventing children from safely going to school and also hindering adults from safely transporting themselves over the river. Many villages in the region are flooded at least partly, a few do not experience floods. People have learned how to live with the floods, however the floods are still impeding further development of the region.

However, there are also other problems in the region that should be addressed to enable sustainable development in the Tapanahony region: limited access to clean drinking water, insufficient employment opportunities, lack of sanitation facilities, poor waste management, poor quality of education and healthcare. Resolving these problems, which are likely to become more severe in the future, could act as a stepping stone to develop the region as a whole.



8 Development Opportunities

This research has clearly presented the way of living and the problems that come with it in the Tapanahony region. Based on the interviews, the main problems of the region are identified to be good quality drinking water, education, healthcare, sanitation, waste management, employment and the flooding of the river. The cumulation of these problems causes a depopulation of the Tapanahony region. On all these aspects development is needed, so the region can start to thrive again, and a sustainable future is made possible.

Since the initial goal of this research was to look at the flooding of the river, the development opportunities of this chapter will be mainly focussed on this problem. Although not the most pressing problem for everybody in the region, it is important to address flooding to lay a sustainable foundation for other future development.

8.1 Problems Around Flooding

Flooding causes problems because people's houses get flooded and their furniture destroyed if they are not in time to move it. However, those are not the only problems that are associated with the high-water levels of the river. Other problems that arise according to the interviews, are listed below:

- The croplands get flooded, destroying the harvest and main food supply.
- Transport without an outboard engine becomes nearly impossible due to high flow velocities.
- High water levels are dangerous for the children, during transportation and washing themselves. Sometimes it is not even possible to go to school.
- Septic tanks get flooded, making them unusable and polluting the river.
- Waste from the villages and the goldmines get washed away into the river, causing pollution of the river water.
- High water levels and flow velocities cause the riverbanks to erode, see 66.

Not only the riverbanks erode. The sand in the villages is also washed away due to the heavy rain and lack of gutters and drainage system. This in return lowers the ground level of the villages, see Figure 3967, causing them to flood more easily. This is not a direct problem caused by flooding, but rather a problem that arises simultaneously and has a negative effect on the flooding risk.

Figure 66: Riverbank Erosion



Figure 67: Ground Level Erosion



8.2 Concrete Needs

There are a few concrete needs expressed by the people of the Tapanahony region that could right away help them during flooding events:

1. Life jackets: for the safety of kids during flooding/high water events.
2. Basic food supply: to help them during the food shortages that are caused by floods.
3. Sanitation: a place for children to wash themselves when the river is too dangerous.

With these three things, it would make the life in the villages easier and safer during a flooding event.

8.3 Short-Term Development Opportunities

The development opportunities proposed in this section can and should be executed on the short term, to (partly) solve some of the problems and to prevent them from getting worse. These are solutions that are sometimes already implemented in some of the villages, but not by all. By starting the conversation about the development of the region, the aim is to encourage participants to inspire and support each other in addressing these challenges.

8.3.1 Riverbank Erosion

To deal with riverbank erosion, two short-time solutions are proposed: sand replenishment and an embankment.

Sand Replenishment

A simple solution that is already seen in some places is sand replenishment, see Figure 68. In several locations gold mining machines are mining gold in the river by sucking up the sand. This sand can be deposited on the banks at the villages to counteract erosion. The sand deposited is quite coarse, which also decreases the erosion capacity of the system in the future. It is unclear what chemicals are used by the gold mining machines, so this is something that would need to be investigated before implementing this measure.

Figure 68: Sand Replenishment Un Gwa Soo



Embankment

Another solution to protect the riverbanks is building embankments. This has not been seen in the region yet. The resources are present in the region, but the placement needs attention. The embankment that is most likely, is made out of wood. The bedrock is very close to the surface in a lot of places, which will likely make it necessary to fix the embankment to the bedrock. When this is done however it will make for a quite robust solution because it will be independent of soil or sediment movement.

8.3.2 Erosion Within the Villages

To prevent further erosion in the villages and the lowering of the ground level, the following four short-time solutions are proposed: gutters, grass, sand traps and sand buffers around houses.

Gutters

Gutters will help prevent the erosion that takes places around the houses due to hard rainfall. This is also already done in some of the houses in the villages, but they are not always working efficiently, see Figure 69. Another problem can arise when all of the rainwater flushes out of a rain pipe, since the water is now so concentrated and the soil will have a higher chance to erode. Placing the gutters should therefore go hand in hand with placing water tanks that will then help again in times of long drought. Increasing the availability of clean drinking water. Solving multiple problems that were found in this research at the same time.



Figure 69: Gutters

Grass

An easy solution to erosion is letting grass grow over the areas that are eroding, see to Figure 70. This is also something that is already done in several villages. However, it should be noted that inhabitants sometimes find grass unsafe because of snakes. When looking at solutions like this, it is important to bring people together who have and have not already implemented it, in order to find out in which situations the solution is applicable and favourable.

Sand Traps

Also sand traps are already a widely applied solution, see Figure 70. A sand trap is made by placing a plank in the ground on the slope that is eroding. The plank is obstructing the flow, and the water slows down. It will then deposit sand, and sand will start to accumulate: a sand trap. A downside is that they sometimes break, or the water escapes on the side.

Sand Buffers Around Houses

Another option to prevent the soil from flushing away around the houses is making a sand buffer, which is consistent out of planks and gravel, see Figure 70. The rain from the roof will directly fall onto the ground, but the heavy small rocks are not displaced, and the water can infiltrate easily into the barrier. This is because the pore sizes are so large that water drains away fast. In some villages this intervention is already applied.





Figure 70: Preventing Land Erosion by using Grass (left), Sand Traps (middle) and Sand Buffers Around Houses (right)

8.3.3 Flooding of Individual Houses

Some villages only have a few houses that are flooding, and these houses are only flooding a few centimetres. In that case placing a small dike around the house would be an option. A simple dike, possibly with timbering in it and grass on top could be sufficient. However, the soil is quite sandy and will allow water to pass through from underneath the dike. How much water will pass through would need to be investigated beforehand. In any case a pump will be necessary to pump the water out of the dike ring. However, the inhabitants already use pumps to empty their slightly leaking boats so it should not feel unfamiliar.



Figure 71: Flooding of Houses (Dagblad Suriname, 2022)



Figure 72: Croplands

8.3.4 Flooding of Croplands

Some croplands are located close to the riverside and flood quite easily. But there are also croplands that are located on higher grounds and these at least do not die because of the floods happening. Something that is a problem is the fact that during floods also the soil on higher grounds becomes very saturated. With the consequence that the roots drown and the too dies off.

8.3.4 Closing of schools

During heavy floods, the schools close because the sanitation facilities of the teachers flood and it is harder for children to get to the schools.

Sanitation for teachers

The floods cause some of the schools in the region to close. The problem is not so much in the schools that are entirely under water. But the homes of the teachers become inhabitable due to the flooding of the sceptic tanks. A solution could be to redirect the drainage pipes to a sceptic tank that is located on higher grounds, although this would require a lot of pressure. Another solution is making the toilets communal and building a separate toilet building that is located on higher ground.

Steppingstones

Even though the schools themselves are not flooded, some parts of the schoolyard are flooded. For example, at the Granman Akontoe Velanti school, the little children have trouble reaching the classrooms due to all the big pools that are present. For this problem steppingstones could be placed, making it easier and safer for the children. This could be real stones from the river, but it could also be done with concrete paths which are higher than the ground level. This is already seen in some places, see 73.



Figure 73: Concrete Paths

8.4 Long-Term Development Opportunities

In addition to the short-term development opportunities, there are several long-term development opportunities. These will be described in this section.

8.4.1 Riverbank Erosion

Moco Moco

A classic nature-based solution against erosion is to increase flow resistance and wave dampening, in this case secondary waves cause by motorboats, by allowing plants like mangrove to grow. The mangrove-like plant in this region is the Moco Moco, a small plant, partially submerged in the water, see 74. It can also be seen as the pioneering species as it is the first plant that grows next to the riverbank. Trapping more sediment and allowing other plants and trees to shoot their roots.

The inhabitants of the villages have cut it away in most places because wild animals can hide in them. The plants also have spines which sting. Apart from these downsides, the plant seems to grow easily, and it is clearly visible that it increases riverbank protection and can thus protect the banks to a certain degree. To what degree this is will need to be investigated, along with good collaboration with the inhabitants of the village to see where and if this is really a viable solution.

Cocos Protection

A well-tried solution for bank erosion in the world is the use of cocos mats. Cocos mats can be easily applied and are quite sustainable. They will guarantee protection of the banks. Which is not something that can be said for the Moco Moco. The advantage here is that the resources can literally be plucked from the trees. The process for creating mats from coconut is another story and will need further investigation. This will only be a good solution if the mats can be created by the people themselves. Since that way if the mats break down or have worn off the villagers themselves can repair them.



Figure 74: Moco Moco



Figure 75: Cocos Protection (Flodi, 2025)

8.4.2 Erosion Within Villages

Earlier was already mentioned gutters as a short-term solution, there it was proposed in combination with the water tanks. However, at some point the water tanks are full during the long-wet season. Causing water to splash down on the ground and moving the problem of soil erosion to another place. In the long-term a drainage system for the entire villages should be designed. Which can be open if it is meant for only rainwater, but designing such a drainage system, also offers another chance to incorporate the sanitation in it, making it a sanitary drainage system. Ideally, the different jobs involved in making such a system are taught at the future technical school in Diitabiki.

8.4.3 Flooding of Individual Houses

Building on 'Neuten'

An obvious solution in this region is to elevate the housing by building on wooden or concrete columns, or 'neuten'. In most villages there is at least one building already built on neuten, in others almost all buildings are elevated. This is a great solution because it allows people to keep dry in the wettest of times.

However, a house on neuten also has some disadvantages. For example, it can be dangerous when having small children. Additionally, building on columns is difficult, and expensive. Wooden flooring is needed in places where most people use the sandy soil as floor. A direction for this solution could be to organise a regional wide course for people how to build on piles, allowing for them to do it themselves instead needing to pay experienced builders.



Figure 76: Building on Neuten

Terp

An old solution for floods in the Netherlands is a terp. This is a small hill, raised just above the flooding water level. This allows for use of the lower lying land during dry times but also creates security during flood season. Some villages in the Tapanahony are completely submerged during high water. Building a terp could be an option for these villages. They could use sand, or other soil for example clay, from the river to create this terp and then build community housing on it. Because flooding is usually not more than 2 weeks, it will be possible for the inhabitants to live on the terp for a short while without needing to leave the village. It is important to prevent erosion of the terp by the rain by planting grass.

Floating Houses

In this region, building floating houses is a viable solution. The houses that are currently used are quite light because they mainly consist of wood. There is also plenty of wood available in the close vicinity of the villages. Tree trunks can be used as floaters, or even more sustainable is the use of bamboo. The problem with this solution is that people might be quite sceptical, and they might not see it as reliable compared to building on 'neuten' even though it can be simpler to implement.

Flood Warning System

From the interviews it became clear that people are often surprised by rising water in the middle of the night. Due to the unpredictability of the floods a lot of damage is done to property because the inhabitants arrive too late to move it to a dry area. A solution for this would be a flood warning system. This is quite easily implementable, the most upstream lying village Gaanboli would have to start contacting the other villages when the water rises above a certain level at their village. Some automatic device would also not be difficult to implement. Even better would be to organise this from the further upstream lying village Apetina, where the indigenous are located around.

Moving to Higher Ground

Another viable but expensive measure can be to move the villages that flood to higher ground. Earlier in the report, the example of Un Gwa Soo was already mentioned, this village was made liveable again after the floods of 2003 occurred through the sponsoring of a foundation. As it is most costly for people to rebuild their houses on a completely different side that must be cut open first and later the ground should be prepared before people can start building there. Next to that, some areas in the Tapanahony region are relatively flat and people would have to move quite far from the river that they are so dependent on.

Furthermore, the moving of villages should be done is such a way that the rituals can still take place in the old village if people desire it. That way the bond with their ancestors remains intact.

8.4.4 Flooding of Croplands and Food Shortage

Agricultural Equipment and Fertilisation

The croplands are often flooding because they are close to the river, and they are close to the river because they need to be easily accessible. In order to use croplands further away from the river there would need to be equipment to transport the produce. This could also be combined with larger scale farming using

fertilizers. This would also reduce the need to cut a new patch of forest down every year. However, fertilizers can have a big impact on the soil so this will need careful implementation.



Figure 77: Road Through the Rainforest

Road Connection

Both during extreme high and low water the prices of boat transport are very expensive, transporting goods by plane is also not cheaper. Connecting the Tapanahony region through a road would lower the prices of food during these extreme events and help in creating a sustainable food supply that is affordable for the inhabitants of the region. However, as is warned during the interviews, there should be sufficient control posts and police patrol to prevent crime from happening on such a road. As the road is also an invitation to the black market to start smuggling their goods through a cheaper transportation system.

8.4.5 Safe Transportation

The problem of safe transportation can in some case be solved by connection two islands in the air. A hanging bridge between two big trees could be set up, or even a zipline, which also allows for use for tourist attractions. Here safety plays a big role because it is such a sensitive construction. There will need to be constant monitoring of the construction by a professional with the resources ready at hand to solve problems when they arise. Nevertheless, the advantages will be quite high, because it will allow for safe transport to school for children, even during flood season. If a pilot is working well, several other villages could be connected, allowing for much easier transport and less reliance on boat transport, which is a big problem in the flood season and during droughts.

8.4.6 Water Distribution

A strong measure for floods would be to deepen and widen branches without villages next to them or alternatively create a new bypass. This would in theory divert the bulk of the discharge away from the branches with villages, lowering the water levels in that location. Before attempting, there should be extensive research into the morphological stability of this measure. It would be important to make sure the branches with villages do not close off completely. Additionally, there should be looked at allowing sufficient water to enter the branches with the villages during low water, to preserve the transportation taking place on the river.

8.5 Local capacity and necessary support

From the interviews it became clear that they do have a lot of manpower willing to work on solutions for the region, most of them with building or transporting experience. They do also have some materials available like sand, gravel, wood and other resources like electricity and gasoline. However, the latter is very expensive due to high transportation costs. Most importantly they have a lot of local experience about the river, area, cultural traditions, way of living and therefore know best what will and will not work.

What they need is materials like cement, steel, zinc and bigger machines. They also do not have the means to pay for it all by themselves. Additionally, they need people with more technical expertise to make sure projects are performed in a way that it leads to safe and sound constructions that can be used for many years.

8.6 Considerations

With all proposed developments opportunities, and all other forms of development in the region, there are a few key things that need to be considered. First, there need to be clear agreements about who is responsible, within villages, between villages, and between the local community and any external organisation or governmental department. This is necessary for good collaboration, which is key in any development project. As described before, the local community has local expertise, where external organisations can bring in technical expertise. These need to be combined carefully for a project to be successful within this rural area. Once people realise, they can also make money doing other things they are well developed in for example building, they could become more eager to pick up projects themselves instead of waiting for an external organisation or the government to initiate projects.

8.7 Development Opportunities for Other Problems

Flooding is only one of the seven main problems of the region. Due to a lack of time and expertise, the other problems are not addressed in as much detail as the flooding problem. However, a brainstorm has been done on possible development opportunities for each of the problems, of which the results can be found in Appendix I. Additionally, employment and drinking water have been discussed during the workshop, as described earlier.

Something that can be noted from the development opportunities for the flooding problems, is that there is an overlap between the different problems and their possible solutions. For example, bad sanitation facilities for teachers lead to bad housing conditions, which in combination with flooding lead to the schools closing. Therefore, solving the sanitation problem addresses a problem caused by flooding but can also improve the quality of education. Moreover, it also decreases the pollution of the river when sanitation is well organised.

Although no specific development opportunities will be provided for each of the six other problems, an overall development direction will be provided.

8.7.1 Drinking water

There are two strategies possible for increasing the water quality of the river: less pollution and water treatment. Both are needed for a sustainable and healthy living environment. However, less pollution can be done on a short term by the people themselves and requires raising more awareness. Water treatment on the other hand requires more expertise and is therefore probably a more long-term solution. Although the need for good quality drinking water is high and therefore it is important to start already with implementing and improving water treatment systems in the region. Looking at the scale of solutions, community level solutions are easier to maintain and less expensive to implement.

8.7.2 Sanitation and Waste Management

For sanitation and waste management the same strategies can be applied to address the problems. First, it is important for both problems to not solve them locally (per village) but to make sure that solutions are found for the whole region. Otherwise, the river will still be polluted. Therefore, it is also important to create awareness around these problems and let people feel like they need to solve these problems together as a community.

On the short term, these issues can be addressed on community level, with communal sanitation facilities and waste disposal places. On the long term it would however be preferred to solve these issues on an individual level. Especially with sanitation, the ideal future situation would be for everyone to have their own toilet and water connection.

Another important thing for both these problems is that at this moment there is no one responsible for waste management or keeping communal sanitation facilities (if they exist) clean. There needs to be some form of responsibility structure in place to solve these problems.

8.7.3 Employment

At this moment transport and goldmines are the main forms of employment in the region. However, working conditions in the goldmines are often bad. There need to be more regulations and stronger enforcements of rules to develop better working conditions. Additionally, it has already often been mentioned that the goldmining has a negative impact on the natural and living environment of the Okanisi. Therefore, it is highly needed to look into better ways to extract the gold, without the use of heavy toxins. French- Guyana is already exploring this and has stricter rules around the goldmining activities in their part of the region. They can be seen as an example and should be collaborated with to make sure the same conditions are met in the whole region.

Additionally, more forms of employment need to be created. There are several options offered by the local community, like agriculture and livestock. However, the main need for any new business is the creation of a market and therefore also transport needs to become less expensive. These are two key elements for creating more employment opportunities.

Finally, tourism offers a new source of income and could potentially benefit the local community. This has already been discussed in Section 2.6.2.

8.7.4 Education and Healthcare

The quality and quantity of both education and healthcare need to be improved. For education this means enough teachers for the schools and more types of education in the region. Think of practical schools and learning opportunities for teachers to develop themselves, increasing the quality of teaching, while motivating them to stay in the region. The same counts for the healthcare employees, who often are with too little and want to develop themselves more and thus leave. What also causes them to leave is the bad housing quality. This is something that needs to be addressed to make working in rural regions more desirable. It is also an option to make the jobs in education and healthcare financially more attractive. This could trigger to keep the teachers that want to stay in their region of origin but also increase the chance

of people from the city to start working here for a few years, to save up some money. Both would help tackle the shortage of teachers and medical schooled in the region.

8.8 Conclusion

A lot of development opportunities are offered within this research, both looking at solutions on the short- and long-term. However, these are merely ideas at this point, which need to be further investigated and discussed before they can be implemented. Good communication between the people in the villages and external parties, agreements about responsibility, and combining local and technical expertise are key in the future developments of these ideas.



9 Recommendations for Future Research

This research was set up in such a way that it provides a broad analysis of the different problems that are present in the Tapanahony region of the Okanisi. However, due to time constraints and this approach to map all the different problems, real in-depth research could not be performed. In this chapter different recommendations are given for follow up studies.

9.1 Flood Risk

The biggest recommendation regarding flood risk is to start gathering data on a regular basis, especially during the rainy season. To start accurately modelling the behaviour of the river, the discharge and water levels during flood events are needed to calibrate the resistance coefficient in the model. Also, at the moment a satellite DEM is used in the flood risk model, which only allows for a very general slope estimation. To obtain the local slope at the measurement locations it is recommended to use a GPS with a base station and start accurately measuring the height profile of the river and the heights of the villages. It would be recommended to start measuring the water level drop at sula's while doing this. The last thing that would be recommended is to measure the depth in the branches that have not been measured.

The data can then be used to start modelling the river system less on a general scale, and more on a local scale. One part of this would be to translate the height measurements to local slopes. Another step would be to model branches individually to determine the water level at the villages. The current modelling of the sula's should also be compared to the water level drop measured and can then be improved. The DEM's of the villages that have been made should also be reviewed and the curve in them could be detrended to determine the exact water level during flooding at each village. Finally, the whole model can be calibrated with data on both the dry season and the wet season to get a friction coefficient more fitting with reality.

The results of the climatological analysis indicate an increased chance on long dry spells in the future, probably between Apetina and Stoelmanseiland. This result, together with the increasing drinking water and transport problems indicated in the interviews forms a clear motivation to not only model floods, but also droughts. When modelling droughts, whichever model is used, it is advisable to first gain insight into the minimum water level and discharge that starts causing serious problems for transport and drinking water. This will most likely differ a lot depending on the village.

The last recommendation regarding flood risk is to find a way to verify the discharge measured at Kiokondee by the French government. This is an important measurement as it is used to calibrate the model. And because the Q-h relation described in section 3.3 looks slightly fabricated, it is essential to check if especially the maximum discharge is correct. This could be done by performing a surface velocity measurement using double floats during high water at that location, with enough measurements to sufficiently decrease the uncertainty. Or likely there is a good model that can take into account the roughness of the bed and vegetation to derive the discharge from the slope and the water level.

9.2 Water Quality

This research project has highlighted the importance of further research into the water quality of the Tapanahony, as it forms the basis of life in the Tapanahony region, supporting activities such as drinking, washing, fishing, and more. The preliminary research conducted has provided several insights into crucial aspects of future research efforts.

First, the uncertainties associated with the measurement equipment and methods used in this preliminary study highlight the need for more accurate measurement methods to analyse the water quality of the river. The measuring equipment sometimes seemed to have a questionable performance, as was the case for the pH measurements. Furthermore, inaccuracies and uncertainties resulted from the strips used to measure many of the other parameters, such as mercury. Determining the shade of the strip and the corresponding concentration proved quite difficult. Finally, the threshold values for some of the parameters, mainly cyanide, were very high, which could result in lower concentration going undetected.

Thus, more accurate and precise measurement equipment and methods should be used during further research. This could entail collecting samples at the location and then having them sent to a lab for analysis. It is important to ensure that once the samples are collected, they are kept out of the sun, in a closed container, at a low temperature to prevent chemical and biological reactions from taking place in the water.

Apart from goldmining, interviews have pointed out that regular and biological (sanitation) waste is also a large problem for the water quality of the river. Therefore, future research should also focus on the biological activity of the water, measuring bacteria, and the presence of microplastics.

Important parameters to analyse are: pH, EC, turbidity, heavy metals (especially mercury), cyanide, E.coli, and microplastics. In some cases, it would also be interesting to look at the presence of degradation products from, for example, mercury or cyanide in the water.

Furthermore, it is important to understand how the different water quality parameters vary in time. As the river flow is governed by rainfall, the different seasons will result in a different water quality of the river. High flows cause dilution, whereas low flows during the dry season lead to higher concentrations. Contrarily, during the wet season, rainfall run-off results in more waste and waste products ending up in the river, which leads to increased concentrations of pollutants in the water. Considering mercury, the moment of testing can have a significant impact on the measured concentration. Thus, future research should include multiple measurements over a longer period of time at a specific location to see the interplay of climate and water quality.

Finally, it is important to look closer at the processes taking place in and around the river, such as goldmining, to be able to determine the expected values of certain parameters. For this, it is important to have a clear understanding of the paths the water flows along. For example, if an estimate is made of the amount of goldmining activities taking place and the amount of mercury used, a mass balance can be made to determine the expected mercury concentration in the water at a certain location. Subsequently, this can be compared to the measured concentrations to investigate whether they match the expected results.

9.3 From Strategy to Local Development

In section 8 the development opportunities are mentioned. These can be further investigated together with the inhabitants. It cannot be stressed enough to keep talking to the local people. Often solutions have been applied without consulting the people there, and then the solution does not work. This has made the inhabitants quite cynical towards the government or other help from outside.

The development opportunities discussed in section 8, mostly describe technical solutions to the flooding problem addressed in this research. Even though these technical solutions are needed, they need to be accompanied by good policies. Maybe even more important, these policies need to be enforced and acted on. This is slowing down the process of innovation at this moment and needs to change.

While this report stresses the need for good communication and encourages discussion between different parties, action is also highly needed. Both the people of the villages and external parties need to become more proactive and not only blame others for the lack of development.

Several problems are highlighted in this report, and they are all in need of a solution. The question remains, where do you start? A lot of the problems can be linked to Sustainable Development Goals (SDGs) that are often used in development strategies. Stockholm Resilience Centre (2016) has created a model based on these SDGs, which can be seen in Figure 78. This shows that there is a need for a sustainable environment as basis for all other developments.

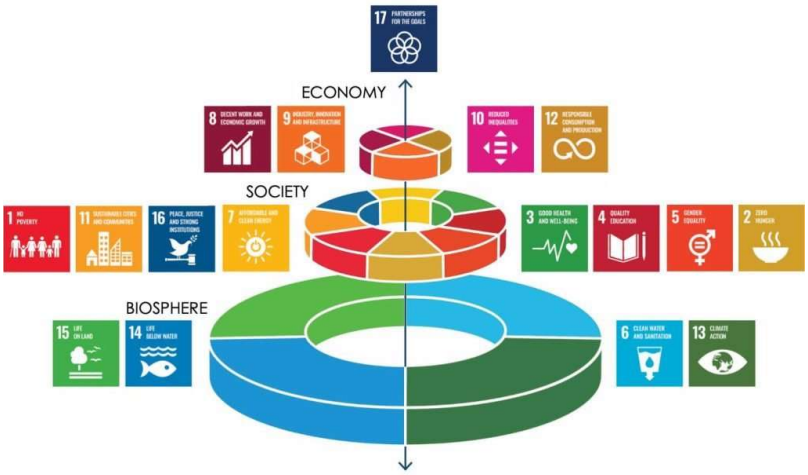


Figure 78: Development Model Based on SDGs (Stockholm Resilience Center (2016)

Applying this to the problems of the studied region, good quality drinking water, sanitation and a safe living environment, addressing the flooding problems, form the basis for further development. After that, societal problems like healthcare and education can be addressed. This is followed by economic growth, which in this case is employment opportunities. It should be noted that this does not mean that problems on a higher level of the model cannot be developed at all before all other problems on lower levels are solved. It simply shows the need for a sustainable basis to make other developments successful on the long term.

Therefore, it would be advised to look at problems like flooding and high-quality drinking water first, providing for a good living environment, while already thinking about the problems around education and employment. Since these are needed to keep the people in the region.

Word of Thanks

This project has been a very special experience for us, most of all because of all the help and enthusiasm we received throughout the entire process. This is why we would like to mention all of those involved who helped make this project have a lasting impact on the development of the Tapanahony region and on our lives.

First of all, without Rudi Darson we would have never made it to Suriname at all. As our main contact person and client in the Netherlands, he was the one who instilled this idea in us and supported us from the beginning during the preparations at the TU Delft all the way until the end with a conference making it to national television.

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The largest part of our project we stayed in the village Diitabiki. This became our home during the seven weeks we stayed there, most of all because of the people we met there. The women we washed our dishes with in the river, the owners of the store where we did our groceries, our neighbours who showed us the way through the village and the surrounding areas, the baker who made delicious beele (bread), and the children who we played endless games of soccer and other games with, and who taught us the local music, language and dance moves. Their welcoming attitude and openness made us feel at home.

Our project brought us through all the Okanisi villages, where we met with many people and talked about life along the Tapanahony. We would like to thank everyone who took the time to talk to us, as without them this project would not have been possible. Below is a list of names of all who have helped throughout this project. However, there are many more who we do not mention due to privacy concerns and other circumstances, but we thank them just the same.

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Ameekan Gagoe
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