A Study Presented to the Faculty of the
Department of Civil Engineering School of Engineering,
University of San Carlos, Cebu, rotterdam university of applied sciences, and Hanze University of Applied Sciences

---

Submitted by:

GROUP 10

Salilin

Magallanes

Rafols

Dawis

Omega

Colegado

Tonacao

Gonzales

Ebarle

Pena

Gono

Nalzaro

Matulac

Lapeciros

Konings

Keizer

Manongiring

I. INTRODUCTION

Rationale

Rivers are bodies of water that flow from a higher elevation to a lower one. It usually flows out into another body of water, such as an ocean, sea, lake, or wetland. Rivers are important for a variety of reasons. Rivers provide food and habitat for many organisms, it also provides transportation and energy in the form of water turbines, and it enables farming since it provides fertile soils (Barrow, 2013).

Urbanization has been on the rise and is expected to continue increasing. As of today, 55% of the human population live in urban areas and may increase to 68% in 2050 (United Nations, 2018). Urbanization caused drastic changes in water quality on bodies of water, may it be underground or above ground. Water quality was worsened by urbanization as pollutants were disposed of, settled, and contaminated rivers and water sources (Priyadarshini, 2022).

Mandaue City is a highly urbanized city in Metro Cebu with a population of 364,116 as determined by the 2020 Census. One of the rivers that pass through the city is the Butuanon River. Due to pollution and contamination, the river was declared dead in 1992 since it can no longer support flora and fauna. However, in 2002, the river was classified as "Class D," referring to bodies of water utilized for agriculture, irrigation, livestock, and industry (Philippine Daily Inquirer, 2014). The industry sector was usually blamed for polluting the river. Existing regulations are weak due to lack of manpower and lack of motivation (Nazareno, 2000).

The severe water pollution within the river needs to be fixed. Despite rehabilitation efforts from Local Government Units (LGU), there is still a large volume of wastes being polluted into the river. A clean-up drive by the Mandaue City Government yielded 50 tons of garbage just from 500 meters to one kilometer in length from the mouth of the river (Butuanon River in Mandaue Yields 50 Tons of Garbage, 2022).

In line with this ongoing predicament, the researchers aim to alleviate the situation by providing information regarding the current condition of the Butuanon River at the midstream portion. In order to formulate plans and policies, information regarding the river is needed, such as its profile, characteristics, and quality. By conducting this study, the researchers will be able to find out the necessary information which can be used to devise plans and policies.

Statement of the Problem

This study aims to assess and investigate the current condition of the midstream portion of Butuanon River in Mandaue City. Moreover, the researchers seek to formulate a solution proposal which helps in cleaning up the Butuanon River.

Specifically, this study answers the following parameters:

1. The profile of Butuanon River based on:
   1.1. Width
   1.2. Depth
   1.3. Cross-sectional Area
   1.4. Maximum Flood Height
2. The characteristics of the midstream portion of Butuanon River based on:
   2.1. Turbidity
   2.2. Stream Velocity and Discharge
   2.3. Urban Water Quality
   2.4. Ecology
   2.5. Amount of plastic wastes
3. The social impacts on the residents along the midstream portion of Butuanon River.

Significance of the Study

The Butuanon River is a major river in Metro Cebu which is utilized for agriculture and industrial purposes. Thus, it is imperative to restore the river so it can be utilized even more effectively. This study plays an important role in the restoration of Butuanon River because the study gathers information needed about the current condition of the river and can be used to devise a plan of action.

Specifically, this study benefits the following:

Residents. This study will be able to help the residents along the midstream portion of Butuanon River by sharing their struggles and insights into this study which can be considered when making decisions for the river.

Mandaue City Government. This study will serve as a milestone in the restoration of the Butuanon River. Its findings can be used by the Mandaue City Government in formulating plans of action and local policies that help to restore the river.

Department of Environment and Natural Resources. The Department of Environment and Natural Resources (DENR) is the executive department of the Philippine Government tasked with the supervision and governance for affairs regarding the natural resources in the country. This study will be able to help by providing the

department with information about the Butuanon River which can be used when implementing plans and/or policies.

Department of Health. The Department of Health (DOH) is the executive department of the Philippine Government responsible for ensuring quality health care for all Filipinos. This study will be able to help by being the first step for restoring the Butuanon River, which will improve the health for all the people utilizing the river.

Researchers. This study will help the researchers be aware of the condition of the Butuanon River and be able to formulate plans to alleviate the river's current condition.

Future researchers. This study may serve as a reference for future researchers who will be studying the Butuanon river. It may also serve as a guide for future plans and policies.

Scope and Limitation

The study was conducted only at the midstream portion of Butuanon River at Barangay Tingub, Mandaue City.

II. METHODOLOGY

Research Design

This study employed the descriptive research design to investigate the current condition of Butuanon River. The researchers conducted a series of on-site tests to assess the river's water quality and ecology as well as the presence of plastic wastes. The researchers will also be conducting interviews with local residents in order to describe the social aspect for this study.

Research Locale

The study was conducted along the midstream of Butuanon River. The station assigned to the researchers is located below the bridge at Mardonio Ceniza Street, between Barangay Tingub and Casuntingan. Specifically, the study took place at 10.34852 degrees north and 123.9355 degrees east.

Figure 1. Satellite image of research locale

Research Instruments

The researchers used different kinds of equipment on each specified task. For the interview, the researchers used their smartphone to record the whole interaction. Rangefinder and tape measure were used for acquiring the river width. Water bottles, test strips and nitrate application were used to examine the urban water quality. Net and miniSASS Form for determining the ecology of the river. Tape measure, stopwatch, and orange were used to obtain the river stream velocity and its discharge.

Research Procedure

The research was conducted at the river banks of Butuanon river at Midstream 2 in Barangay Tingub, Mandaue City. On the first day, the researchers conducted an ocular inspection of the specified area where most of the assumptions about the causes of the garbage and flooding issues as well as possible solutions to these problems were made.

The following days the researchers mainly gathered data using different tools and equipment for later processing and analysis. Most of the initial data gathered were measurements of the river dimensions and identifying suitable areas for the other tests. The researchers measured the width of the river with the use of a smart measure app that is similar to a rangefinder.

For the Urban Water Quality Test the team had recycled three (3) 500ml bottles for collecting water samples from both upstream and downstream parts of the river, which were then analyzed upon returning to the university. The water samples were

tested for nitrate levels using nitrate strips and the Nitrate application. Furthermore, the samples were also tested for alkalinity, hardness, chlorine levels, and phosphate.

The Volume of waste in the river was tested using a 1m x 1m square made from string/cord, which was then placed into a patch of garbage in the river. A photo of the square was taken and the different kinds of waste within were counted, identified, and recorded. This process was repeated 5 times with a specified number of distances between each sample.

For the Maximum flood heights of the river area, the researchers interviewed the local residents for their input regarding the flooding incidents that occur in the area. After multiple answers from different respondents, the identified water level was then measured and recorded.

The River stream Velocity and Discharge was tested using an orange, stopwatch, and tape measure. The process were as follows; 2 specified areas (point A and B) along the river bank was measured using the tape measure, the orange was dropped into the water allowing it to float, the time it took for the orange to reach point A to B was recorded. Three (3) trials were conducted and the data was recorded.

Additionally, the turbidity of the water was also tested with the use of a Secchi disk, it is continuously lowered into the water until it is no longer visible to which the depth of the line is then recorded.

Moreover, for the Ecology of the river, the researchers scoured the area while using a net to move parts of the river vegetation and rocks to reveal the organisms inhabiting the vicinity. Using the miniSASS sheet the organisms identified were recorded and the final score of the test was calculated and recorded.

III. RESULTS AND DISCUSSION

I. Profile of Butuanon River

River Width

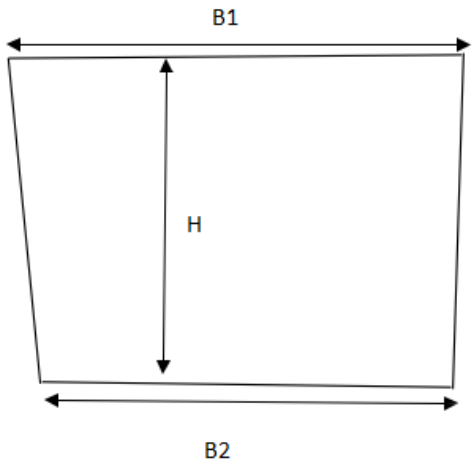


Figure 1.1 Illustration of the Butuanon River width

River Channel Cross Sectional Area

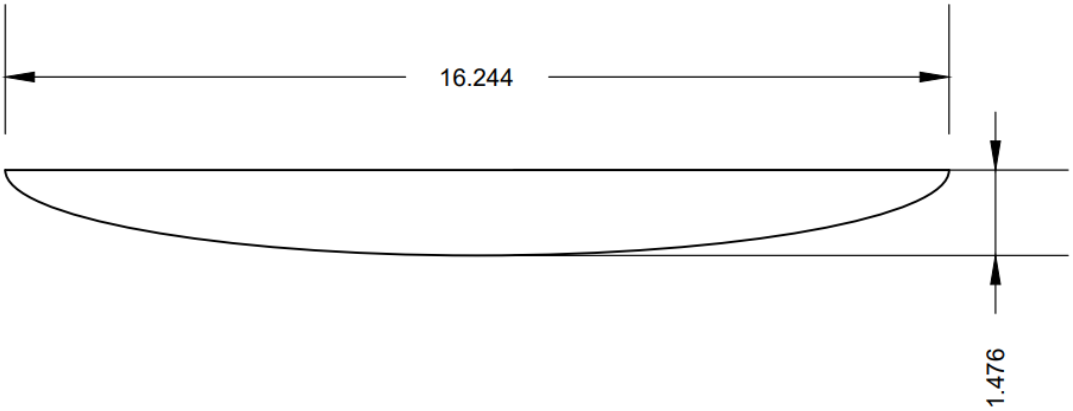


Figure 1.2 Illustration of the Butuanon River cross sectional area

Data Gathered

B1 = 18.451 meters
B2 = 16.244 meters
H = 18.7 meters

$$Area = 1/2\,(18.451 + 16.244)(18.7) = 324.398\,m^2$$

A=8.122 meters

B = 1.476 meters

Area = $1/2(8.122)(1.476)(\pi) = 18.8308\, m^2$

Maximum Flood Heights

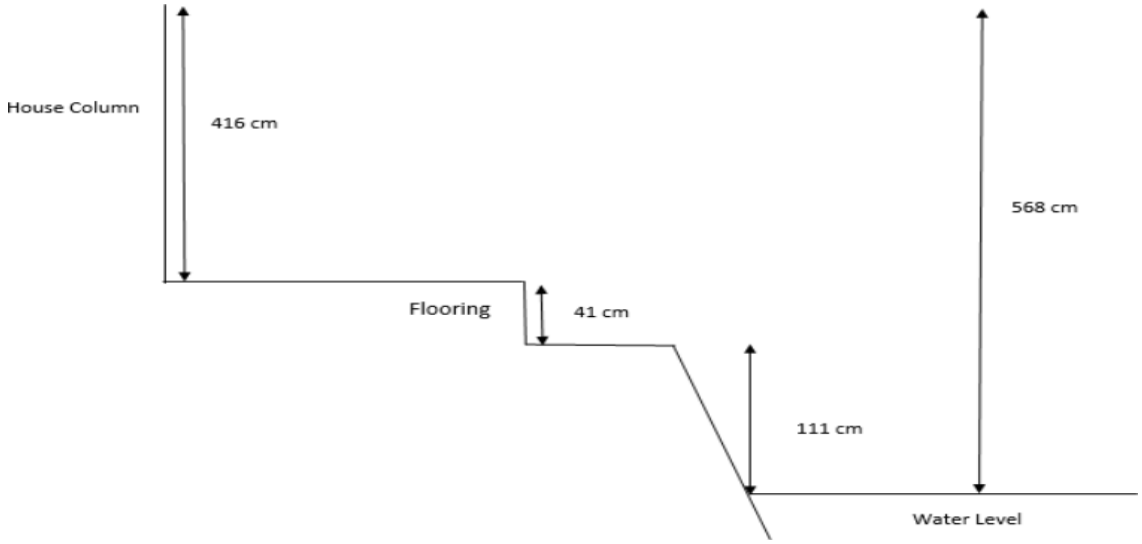


Figure 1.3 Illustration of the Butuanon River maximum flood height

It was recorded back in September 2022, the highest water level that happened at Butuanon river, which our study area was also greatly affected. The figure above shows that the water level reaches beyond the constructed seawall. From the flooring, the water level reaches the second floor of the house or 4.16 m. The residents there stated that during the heavy rain, the water level reached up to a height of 5.68 meters or approximately thrice the height of an adult person, submerging some of their homes and the waste coming from the river fills the inside of their houses.

II. Characteristics of Butuanon River

Table 2.1 Turbidity with Secchi Disk

Trial	1	2	3
Visible Depth (cm)	20	23	27
Not Visible Depth (cm)	31	32	36

Table 2.2 River Stream Velocity and Discharge

Trial	**1**	**2**
Distance (m)	18.7	18.7
Time (s)	527	589
Velocity (m/s)	0.035483871	0.031748727
Discharge (cu.m/s)	1.046445969	0.936293771
Average Velocity (m/s)	0.033616299	
Average Discharge (cu.m/s)	0.63302	
Area (sq.m)	18.8308	

Table 2.3 Urban Water Quality

Parameters	**TEAM 1O**	
Sample #	Sample 1	Sample 2
Nitrate/Nitrite (ppm)	2, 1, 1	2, 1, 2
pH	8.1	6.8
Alkalinity (ppm)	240	240
Total Hardness (ppm)	425	425
Total Chlorine (ppm)	0	0
Free Chlorine (ppm)	0	0
Phosphate (ppm)	22.5	22.5
Remarks	Upstream	Downstream

Two samples were done in this assignment, a sample for the upstream and another sample for the downstream. Averaging the Nitrate/Nitrite data, it is observed that the downstream has more Nitrate/Nitrite compared to the upstream sample, but still both samples have a level of Nitrate/Nitrite that is considered as good for aquatic plants and animals.

The neutral pH level is 7, having a value less than 7 entails that the water is acidic. In contrast, it is considered as base if the value is more than 7. Thus, the downstream sample is more

acidic than the upstream sample since metal residue of a company, located somewhere in the downstream area, is being disposed of there.

Both upstream and downstream samples have the same values for alkalinity level, total hardness, and phosphate level. The presence of alkalinity in water helps to control the acidity in the water. The standard alkalinity level is around 100 to 250, thus making both samples normal. Both samples are considered as very hard water since it falls beyond the moderate hard water range, 60-120 ppm. For the phosphate level, it is very poor since it exceeds the ideal phosphate level of 0.1 mg/L or 0.02

Table 2.4 Ecology of the River Equipment: Net, miniSASS Form

Group	**Sensitivity Score**
Bugs	5
Dragonflies	6
Minnow Mayflies	5
Total Score	16
Number of Groups	3
Average Score	5.33

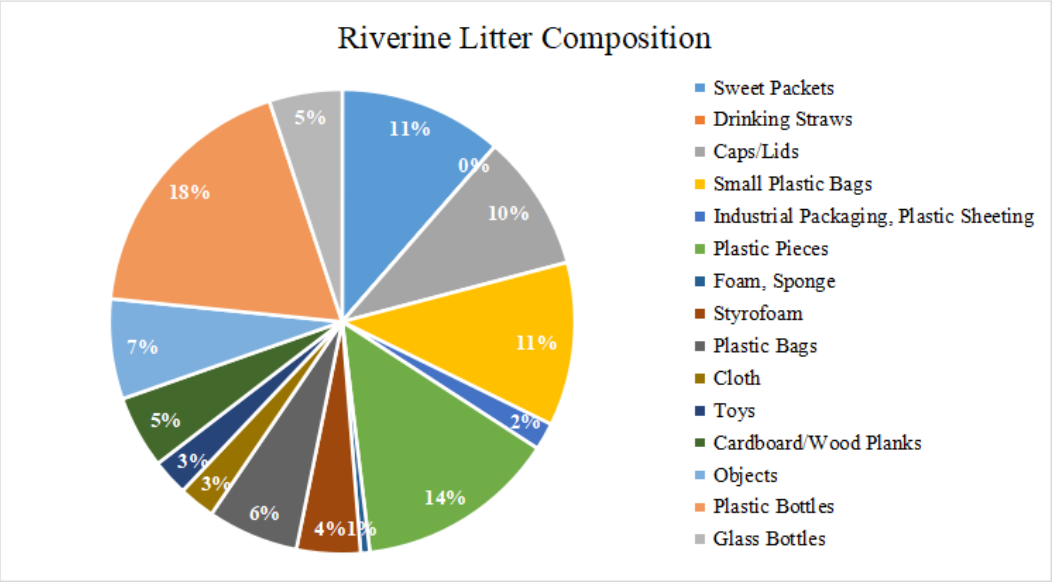
During this time, the researchers were able to identify different groups of organisms namely bugs, dragonflies, and minnow mayflies. Each one of these groups of organisms has its own sensitivity score of 5, 6, and 5, respectively, which total to a sensitivity score of 16 and an average of 5.33. The River Category is Sandy Type and its ecological factor is Poor Condition

Table 2.5 Riverine Plastic Waste Pollution

WASTES	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**TOTAL**
Sweet Packets	5	0	0	12	1	**18**
Drinking Straws	0	0	0	0	0	**0**
Caps/Lids	3	2	1	2	9	**15**
Small Plastic Bags	3	4	2	2	7	**18**
Industrial Packaging,	2	0	0	0	0	**3**

Plastic Sheeting						
Plastic Pieces	0	2	1	4	13	**22**
Foam, Sponge	0	0	0	1	0	**1**
Styrofoam	0	0	0	5	2	**7**
Plastic Bags	0	2	0	3	5	**10**
Cloth	0	0	4	0	0	**4**
Toys	0	4	0	0	0	**4**
Cardboard/Wood Planks	0	1	0	3	4	**8**
Objects	0	4	0	3	4	**11**
Plastic Bottles	0	1	0	17	11	**29**
Glass Bottles	0	1	0	3	4	**8**
TOTAL	**14**	**21**	**8**	**55**	**60**	**158**
Mean Density	**3.5**	**2.1**	**2**	**5**	**6**	

Different types of trash were collected at the riverbank. Plastic bottles amounting to 29 was the most trash collected, and foam sponges was the least amounting to 1. The overall total of trash is 158, having an average of 32 of all quadrants. Basing it on the Riverine Plastic Waste, it implies that the river is severely polluted.



III. Social Impact on the Residents along the River

During the interview, one of the locals stated that one of the benefits that the river can give is their source of food. There was such a huge difference between the amount and size of Tilapia that the fishers were able to get. He added that despite the quality of the water, the taste of the Tilapia is still the same, it's just that it must be thoroughly washed before cooking.

They were also asked about the color and odor that they've experienced or observed in the river, and they said that it has different colors. There was one time that it was clear like the river bed can be seen, and some days the color was pink, blue, green, or black. This is due to the company near the area. There were no bad odors in the river except for one time where there was a strong scent due to the chemicals that was released by the said company, the locals reported it to them and was directly put into action to not further affect the people near the area. The odor can be determined either by going near it or during flooding events.

The river back then was used daily by the locals. Washing their clothes, cleaning their house, and taking a bath are some of the uses that they can get in the river. It was a great necessity to have before it was contaminated.

The main problem of the river, as stated by the interviewee, was the garbage and other debris that was present there. It was said that it causes blockage in the river, thus, resulting in a fast-pace rise of water and no proper water flow.

This problem can't be mitigated since people throw their trash anywhere, making the situation worse. Furthermore, there were no strict policies or violations that were implemented by the government about throwing garbage anywhere. The program that was done in the area was a clean-up drive. It was done a few times, but recently it wasn't being continued.

IV. CONCLUSION AND RECOMMENDATION

Conclusion

According to the data gathered, the values show that the Butuanon River's water quality is poor, with high nitrate levels, alkalinity, hardness, chlorine levels, and phosphate. The ecology of the river is impacted, resulting in the reduction of local species..

The social impact of the pollution on the residents along the river is severe. They are exposed to health risks due to the contaminated water, affecting their daily lives and livelihoods. The fishing industry is also affected, which is a significant source of income for the residents. The high volume of waste in the river also affects the aesthetic value of the area, discouraging tourism and economic growth.

In conclusion, the study provides essential information about the current condition of the Butuanon River in Mandaue City, Philippines. The study highlights the severe impact of pollution on the ecology, health, and livelihood of the residents along the river. The study's findings should be used as a basis for the government to formulate plans and policies to improve the situation and restore the river's ecological balance. The government, together with the residents, should work together to preserve the river for future generations.

Recommendation

The following recommendations are offered based on the findings that were obtained during the 2023 Metro Cebu River Scan Challenge:

1. Research. This research can be expounded through the use of better techniques in gathering the data. With the use of better equipment, we will be able to obtain better and more precise results.

2. Implementation. To improve the situation of the people living in the study area, a strict implementation of laws and regulations is one of the most important things to do since it acts as a reminder that they still have limits to what they can do.

3. Better Programs. People tend to do something that they enjoy, so having a program that can save the environment at the same time people have fun doing it.

4. Proposed Solution. The researchers propose a Vertical Helophyte Filter System in reducing the water pollution and improving the water quality of the river.

References:

Barrow, M. (2013). *Why are Rivers Important?* Retrieved from Help Primary Homework: http://www.primaryhomeworkhelp.co.uk/rivers/importance.html

Chase, K. (n.d.). *Alkalinity*. Retrieved from https://www.thirteen.org/edonline/studentstake/water/UpperHudson/alkalinity/alkalinity.htm

Cotejo, H. (2020, June 21). *Butuanon River in Mandaue yields 50 tons of garbage*. Retrieved from SunStar: https://www.sunstar.com.ph/article/1932564/cebu/local-news/butuanon-river-in-mandaue-yields-50-tons-of-garbage

Enviro Sci Inquiry. (n.d.). *Nitrates*. Retrieved from Enviro Sci Inquiry: https://ei.lehigh.edu/envirosci/watershed/wq/wqbackground/nitratesbg.html

ForsynthTeens. (n.d.). *ACIDS vs BASES pH TESTING*. Retrieved from Forsynth Institute: https://www.forsyth.org/wp-content/uploads/2020/05/AcidsVSBases.pdf

Inquiry, E. S. (n.d.). *Alkalinity*. Retrieved from Enviro Sci Inquiry: https://ei.lehigh.edu/envirosci/watershed/wq/wqbackground/alkalinitybg.html

Ishaani Priyadarshini, A. A. (2022, August 26). *Water pollution reduction for sustainable urban development using machine learning techniques*. Retrieved from ScienceDirect: https://www.sciencedirect.com/science/article/abs/pii/S0264275122004097

Lenntech. (n.d.). *Nitrate and NItrite*. Retrieved from Lenntech.

Liberty Lake Sewer and Water District. (2018, April 1). *Water Hardness*. Retrieved from Liberty Lake Sewer and Water District: https://libertylake.org/water-hardness/

McVean, A. (2019, January 11). *Is hard water dangerous to drink?* Retrieved from McGill Office for Science and Society: https://www.mcgill.ca/oss/article/health-you-asked/you-asked-hard-water-dangerous-drink

Nazareno, P. A. G. (2000). *Assessment of the industrial pollution of the Butuanon River in Mandaue City, Metro Cebu*. Retrieved from Food and Agriculture Organization of the United Nations: https://agris.fao.org/agris-search/search.do?recordID=PH2000100694

United Nations. (2018, May 16). *68% of the world population projected to live in urban areas by 2050, says UN*. Retrieved from United Nations: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

Utah State University. (n.d.). *Alkalinity and Hardness*. Retrieved from Extension Utah State University: https://extension.usu.edu/waterquality/learnaboutsurfacewater/propertiesofwater/alkalinity

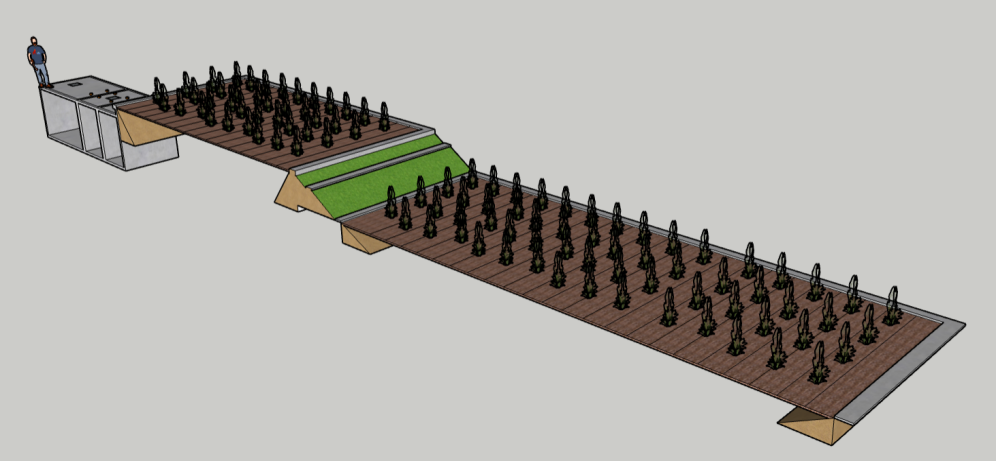
Yap, D. (2014, June 27). *DENR to rehabilitate Cebu's Butuanon River*. Retrieved from Inquirer: https://newsinfo.inquirer.net/614905/denr-to-rehabilitate-cebus-butuanon-river

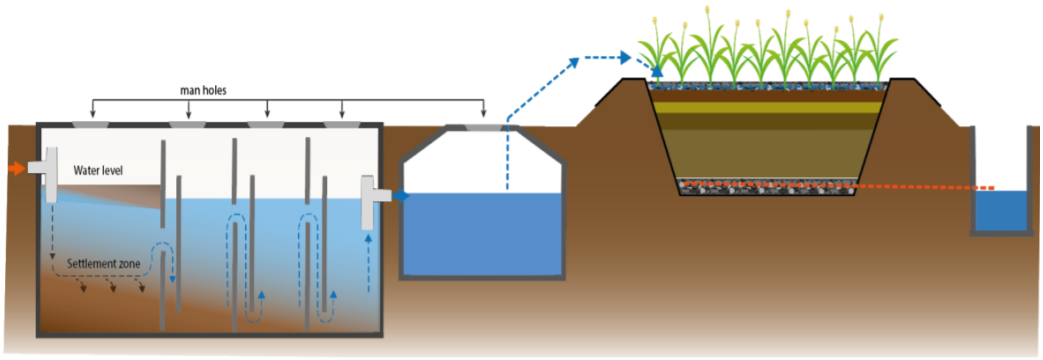
Part B. Practical Solution

Design of the Solution

Vertical Helophyte Filter System

Vertical Helophyte Filter System is a low-cost and nature-based secondary wastewater treatment technology. The project was inspired by the Wastewater Treatment System from the Department of Science and Technology. This solution promotes cleanliness and aims to reduce the river pollution caused by improper wastewater disposal.





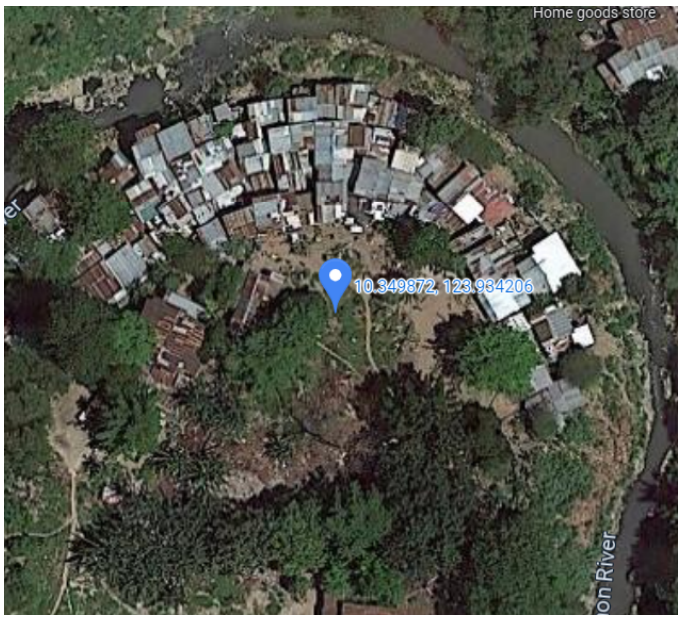
As the waste water from the different public utilities and households is disposed to a drainage system in the septic tank. The septic tank is composed of 3 chambers which will be the pre treatment of the waste water, it is necessary to remove the sludge and scum from the waste water. As the water flows from different chambers the water will be treated anaerobically. In the last chamber where the submersible pump is located will pump the water to a storage tank. From the tank the water will be irrigated in the supply lines, composed of a filter bed with layered substrates with Bulrush and Cattail plants planted on top. The anaerobically treated water flows into the main filter bed by pumping the liquid using pumps and evenly distributed using perforated irrigation pipes. The substrate in a conventional vertical flow constructed wetland is

mostly a mixture of different types of filter media. The water flows vertically through the filter bed into horizontal drainage pipes protected by geotextile cloth that prevents clogging. The treated water flows into a clear water well, where the height of the water can be altered. With a constant water level within the filter bed, the plants distribute oxygen to the water as well as filtering it and neutralizing its pH level. The treated water undergoes post-treatment using the same process again in order to increase phosphate and nitrate levels of the water. The post-treated water is stored in another clear water well. From there, the water can be utilized for different purposes, may it be irrigation, livestock raising, or it can be discharged into nearby bodies of water like rivers.

Locational Analysis

The proposed solution was planned to be located at the Butuanon River at Barangay Tingub. The proposed solution will be located at the dead center. Specifically, the proposed solution will be built at the coordinates 10.349872, 123.934206. The location was chosen from the following factors:

1. The study area which is located 50-m below the proposed area for the solution has a lot of complications such as: dredging and widening of the river are prohibited since focusing on one section can cause problems to the other sections.
2. The previously implemented solutions such as: waste traps and floating gardens were rejected after much consideration due to it being vulnerable to damage caused by strong rains and typhoons which make it less cost-effective.
3. Comparing the population per section, the population near the bridge is less populated compared to the proposed area, which makes it more cost-effective since the number of beneficiaries is larger.
4. The area is unsuitable for the vertical helophyte filter system due to the insufficient space available in the vicinity.



Social Cost-Benefit Analysis and Explanation

The Vertical Helophyte Filter System (VHFS) is a better alternative compared to other waste management solutions such as: waste traps and floating gardens, since the area is prone to flooding and exposed to strong winds and typhoons. It is very likely for these kinds of projects to be easily damaged or destroyed rendering it unusable and costly for repairs and replacements. Whereas the Vertical Helophyte Filter System is durable and sustainable with the benefit of having low maintenance with high efficiency.

Economy

The facility cost estimate ranges from PHP 25, 000 to PHP 50, 000 for a small scale facility, while a larger facility costs around PHP 100, 000 to PHP 150, 000. Cost may vary depending on suppliers, materials, and contractors.

Planning

Vertical Helophyte Filter System will be placed away from the river, with its drainage system flowing towards the river. The system will receive the waste-water from domestic wastes generated by the local community. This includes household and public toilet wastes which will solve the lack of a proper sewage system for the community as well as treating the water before releasing it into the river systems, free from odor, harmful chemicals, and pollutants.

The proposed solution was first implemented in Davao Region by an assistant regional director of the Department of Science and Technology (DOST). It was initially used in small companies, food processing facilities and some animal farms. In order for this solution to be implemented in the study area, the LGU: which includes the Barangay officials, the city officials, the DENR, will collaborate and be the one to reach out to the DOST to create a more comprehensive plan of action.

Stakeholders Involved

Specifically, this solution benefits the following:

Residents. This solution will be able to help the residents along the midstream portion of Butuanon River. With their waste water that will be treated naturally and properly and also providing facilities that they can use in their everyday life.

Mandaue City Government. This solution will serve as a starting point in taking the steps of the restoration of the Butuanon River. The start of producing good water quality and increasing it and through this solution the government

Department of Environment and Natural Resources. The Department of Environment and Natural Resources (DENR) is the executive department of the Philippine Government tasked with the supervision and governance for affairs regarding the natural resources in the country.

This study will be able to help by providing the department with information about the Butuanon River which can be used when implementing plans and/or policies.

Department of Health. The Department of Health (DOH) is the executive department of the Philippine Government responsible for ensuring quality health care for all Filipinos. This study will be able to help by being the first step for restoring the Butuanon River, which will improve the health for all the people utilizing the river.

Operation and Maintenance

Since it will be a newly implemented solution here in Cebu, there are things that need to be done first like providing the nearby citizens some information about it and how they will be benefited by this solution. In addition, seminars will be conducted to the locals in order for them to have an insight about how to maintain the system.

There will be people in DOST that will be assigned in maintaining the proposed solution, Vertical Helophyte Filter System. Furthermore, they can train the locals on how they can sustain the functionality of the system. The aftermath of a heavy rain, maintenance should be at must in order to mitigate the damage, checking the filters, sands, plants, and other essentials.