University of San Carlos, Talamban, Cebu City, Philippines
Rotterdam University of Applied Sciences, Rotterdam, The Netherlands

"METRO CEBU RIVER SCAN CHALLENGE 2023"
RESEARCH REPORT AND INNOVATIVE SOLUTION PROPOSAL

Presented to the Faculty of the Department of Civil Engineering
In Partial Fulfillment of the Requirements for the A.Y. 2022-2023

Submitted by:

Abaigar, Marc Julius
Avisado, Elissa Nea
Batocael, Maelle Kate
Borres, Andre Miguel
Co, Waynne Mathew
Estrella, Michea Rafael
Gaviola, Glainne Atasha
van Hulten, Iris
Llego, Rem Rhys
Monleon, Renois Johnne
Monterola, Justin Bill
Murillo, Renz Miko
Porpayas, Fernando Miguel
Saniel, Sandrey Amador
Sarvida, Najelle
Tauto-an, Christian
Ulan, Andrea Gail
Villarino, Dwynpearl
Villas, Klien Mark
Yu, Jonathan Conrad

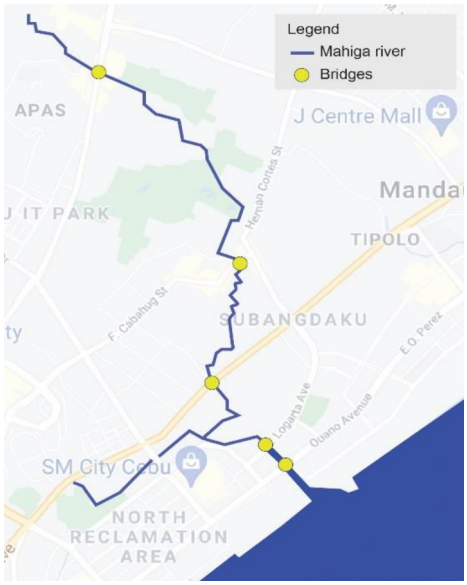
Submitted to:
Department of Civil Engineering Faculty

April 26, 2023

PART A. RESEARCH REPORT

A.1 | Introduction

Mahiga River. Cebu City houses 7 major rivers: Guadalupe, Kinalumsan, Mahiga, Lahug, Estero de Parian, Bulacao, and Butuanon (Saavedra, 2023). Mahiga River, particularly its downstream portion, is a river situated in between Cebu City and Mandaue City, Philippines, and is generally considered as one of Cebu's 9-kilometer danger zones (Cotejo, 2022).



Mahiga River location map

According to Ms. Kay G. Espinosa who tackled Relevant Policies, Water Quality of Cebu City Rivers, and Initiatives on River Rehabilitation during her discussion last April 18, 2023, Mahiga River (downstream) was established as a Class D river. This river is navigable, but ultimately not for public use, which is also the lowest class considered.

The Mahiga River is currently heavily contaminated with plastics, industrial garbage, and human waste. This leads to a number of issues, including flooding due to obstructions in the immediate region, a dead river devoid of oxygen, and no life beneath the water since the ecology is no longer viable (Climate Scan, 2019).

In the year 2022, after Metro Cebu experienced a downpour on July 8, Mahiga Creek produced 2 tons of garbage and about 56 kilograms of recyclable plastic bottles. In addition to this, Barangay Subangdaku's Captain Ernie Manatad announced that they frequently clean up Mahiga Creek, using 1 to 3 dump trucks on average. Every weekend, they collect a mean of 6 tons of trash and 50 to 150 kilograms of recyclables from the river (Cotejo, 2022).


Mahiga River near SM Mabolo (left) and Hypermarket (right)

River Scan Challenge. The River Scan Challenge 2023 program aims to promote river conservation by encouraging university students and faculty alike to conduct surveys of their local rivers. The challenge involves various teams of students from the University of San Carlos (Philippines), Rotterdam University of Applied Sciences (The Netherlands), and Hanze University of Applied Sciences (The Netherlands). The participants collected data on various aspects of the river, such as water quality, ecology assessment, river stream velocity, and the like.

The objectives of conducting this study are the following:

- Assess the river's health through the guidelines provided in the manual,
- Identify the specific problems and areas that require attention, and
- Create and propose solutions to the problems identified.

The main research question of the study is: How to solve the flooding problem of Mahiga River's nearby communities while simultaneously improving its water quality? Further questions to supplement this are:

- What are the main sources of pollution in the Mahiga River and how do these wastes impact water quality and flooding?
- What is the current state of water quality in the Mahiga downstream portion of the river and how has it changed over time?
- What are the most effective strategies for reducing pollution and improving Mahiga River's overall water quality?

The River Scan Challenge involves several stages, including preparation for the data-gathering, the actual assessment of the river itself, and the data analysis. Participants are provided with the necessary equipment and resources to conduct the surveys and receive support and guidance from experts in the field. By collecting data and identifying areas of concern, the students are able to help in the policy and decision-making that will impact the future of Cebu's Mahiga River and the ecosystems it supports.

A.2 | Methods

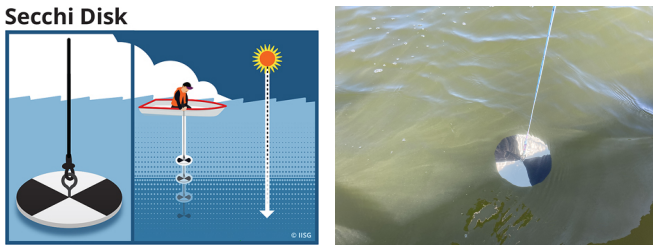
The government has not turned a blind eye and has been exerting efforts to restore the river over the past years by finding solutions for the issues at hand. Several initiatives have been launched in the past to mend Mahiga River's situation and mitigate the potential hazards it may pose, such as ***Gubat sa Baha.*** According to Attorney Gerard Carillo, the "Task Force Gubat sa Baha" *(war against floods)* aims to resolve difficulties between common inhabitants who live along riverbanks and commercial entities situated along the river (Saavedra, 2023).

The River Scan Challenge 2023 continues to strengthen these efforts initiated by the government and volunteers alike through the introduction of even more innovative solutions to the river's problems and issues. With that being said, prior investigation and assessment were directed to pinpoint the specific issues of the Mahiga River.

For the investigation and assessment, the technical dimensions set in the study in order to acquire the answers and vital data needed for the formulation of solutions (and its specific parameters) are the following:

- **Water Quality** – In order to assess the water quality, the following properties of Mahiga River were determined, namely: Turbidity, stream velocity, pH level, dissolved oxygen level (DO), and presence of nitrates and/or phosphates.
- **Bioindicators** – An EPT index was used to quantify the pollution tolerance of macroinvertebrates.
- **Social Aspect** – A survey was used to examine the social, cultural, and economic aspects of the riverside dwellers, as well as the policies.
- **Plastic Waste** – Plastic wastes were observed, which provided a snapshot of the community's approach to managing solid trash in the riverside area.

Turbidity. The river's level of murkiness is gauged by its turbidity. Turbidity rises as a result of any clouding of the water (Government of Northwest Territories, n.d.). A ***Secchi disk*** was utilized to identify the river's turbidity. A line is coupled to a Secchi disk, which has quadrants that alternate between black and white. In order to gauge the water's turbidity, the line coupled to the disk is used to drop the disk into the body of water. The measurement is made at the depth at which the disk is no longer visible (Limno Loan, n.d.).



Visual representation and actual secchi disk

Stream Velocity. The stream surface velocity of the river was measured with the use of a floating object, in this case, an orange. The orange was dropped from the bridge and let it freely flow together with the river. The timer started from the zero mark and stopped at the 6-meter mark. This was done with 4 trials and then it was averaged for a more precise measurement. Afterwards, the river flow rate was calculated by multiplying the computed average velocity to the area of the riverbank.

Maximum Flood Heights. The locals were consulted regarding the river's water level during a severe flood. By using a measuring tape, the height of water level relative to the river embankment was recorded. Photos were taken in order to document the maximum flood height.

pH level. The pH level of the river is determined so as to identify how acidic or alkaline the river water is. The scale ranges from 0 to 14. The lower the pH number, the stronger the acid is. In contrast, the higher the number, the stronger the base. Determination of the pH is relevant as it affects most chemical and biological processes.

Water samples were collected at two stations of the Mahiga Downstream: the 1st sample was taken near Makina Show Exchange, 6000 F. Cabahug St, Cebu City and the 2nd sample is from F.E. Zuellig Avenue, Mandaue City, Cebu. Acquisition of the water sample is done with the use of a 500ml water bottle which will be brought to the University laboratory for further testing.

Dissolved Oxygen Level. As the color or murkiness of the river water is an indicator to the stated parameter, the results of the dissolved oxygen test are determined using the same process as the turbidity test. The amount of turbidity in the water impacts photosynthesis and light absorption, which in turn affects the concentrations of dissolved oxygen.

Presence of Nitrates and Phosphates. 500 mL water samples were taken in the following stations, namely: 1) Near SM Mabolo, and 2) Near Hypermarket. Nitrate strips were dipped in the respective water samples. The colors generated on the strip were then compared to the colors shown in the packaging in order to identify the river's nitrate levels.

Ecology of the River. A circular net attached to a long rod is dipped in the river, scooping out parts of the riverbed. This process was repeated and continued for 5 minutes, moving from one random area to another. After 5 minutes, the net was lifted out of the water, and it was settled down on the ground to tick the checklist prepared by miniSASS used to assess the river's ecology by identifying organisms using specific guidelines. It is based on the composition of macro-invertebrates, which are small animals that live in rivers, and on how sensitive each animal species is to the quality of the water. A scoring sheet was employed to add up the sensitivity scores and determine the average score.

Interview with the Locals. Residents living around the vicinity of the river were interviewed to get a good glimpse and understanding of their situation, and the problems that they encounter on a daily basis. A set of questions were prepared beforehand, and documentations (photos and videos) were ensured for an accurate basis of the data gathered.

Riverine Plastic Waste Pollution. A stretch of riverbank of 50-m length in the two portions of the Mahiga River downstream was selected, and 5-10 sample quadrants were chosen using a randomizer app. Pictures were taken of each quadrant and all the items inside are counted and registered according to the different categories and types given in the OSPAR forms.

A.3 | Results

This part presents the different results of the tests regarding the stream velocity, water quality parameters, ecology of the river, and the riverine plastic waste pollution of the Mahiga River.

Stream Velocity

Trials	***Time (s)***	***Velocity (m/s)***
1	27.52	0.22
2	26.54	0.23
3	29.89	0.20
4	30.85	0.19
Average	28.70	**0.21**

Average Velocity	***River Area***		***Discharge***	***Unit***
	Average Width	***Average Depth***		
0.21 m/s	47.97 m	0.52 m	**5.2**	**m^3/s**

The average stream velocity of the downstream portion of the Mahiga river is 0.21 m/s. This was then multiplied to the area of the riverbank, which is 24.95 m^2, to determine the water discharge of the river. The average width of the river was computed to be 47.97 m and the average river depth was determined to be 0.52 m from the trials done. Based on the calculation, the discharge of the river is 5.2 cubic meters per second.

Water Quality Levels

Parameters	***Sample 1***	***Sample 2***	***Class C Water Quality Criteria***	***Remarks***
Nitrate/Nitrite (ppm)	0	0	< 7	Passed
pH Level	8.4	8.1	6.5 – 9	Passed
Alkalinity (ppm)	240	240	> 20	Failed

Parameters	*Sample 1*	*Sample 2*	*Class C Water Quality Criteria*	*Remarks*
Nitrate/Nitrite (ppm)	0	0	< 7	Passed
Total Hardness, $CaCO_3$ (ppm)	425	425	< 500	Passed
Total Chlorine (ppm)	0.1	0.1	< 4.0	Passed
Free Chlorine (ppm)	0.2	0	< 4.0	Passed
Phosphate (ppm)	35	35	< 0.5	Failed

The results of the water quality detection test strips are compared to the Water Quality Guidelines and General Effluent Standards of 2016 of the Department of Environment and Natural Resources (DENR) and the US Environmental Protection Agency (EPA) 2015 guidelines for water quality criteria and standards. The downstream portion of the Mahiga creek failed the standard for the phosphate. The high level of phosphate leads to eutrophication which depletes the dissolved oxygen and causes harm to aquatic life.

Ecology of the River Near SM Mabolo (1) and Hypermarket (2)

Groups	*Sensitivity Score (1)*	*Sensitivity Score (2)*
Flatworms	0/3	0/3
Worms	0/2	0/2
Leeches	0/2	0/2
Crabs or shrimps	0/6	0/6
Stoneflies	0/17	0/17
Minnow mayflies	0/5	0/5
Other mayflies	0/11	0/11
Damselflies	0/4	0/4
Dragonflies	0/6	0/6
Bugs or beetles	0/5	0/5
Caddisflies (cased & uncased)	0/9	0/9
True flies	0/2	0/2
Snails	0/4	0/4
TOTAL SCORE	**0**	**0**
NUMBER OF GROUPS	**13**	**13**
AVERAGE miniSASS score	**0/13 = 0**	**0/13 = 0**

Based on the table presented, it is shown that there is no presence of ecology found in both stations of the river. The entire river is a sandy type, which means that if the average score is less than 4.8, the river is in **VERY POOR CONDITION.** However, there were some signs of ecology spotted around, but not within the net scooped out of the river. There were dragonflies and bugs found in the water body's vicinity, on land.

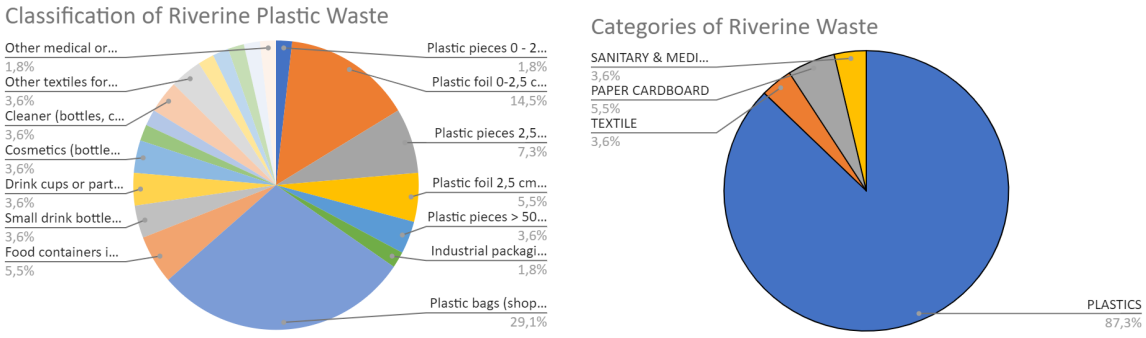
Ecological category (Condition)		River Category	
		Sandy Type	Rocky Type
	NATURAL CONDITION (Unchanged/untouched – Blue)	> 6.9	> 7.2
	GOOD CONDITION (Few modifications – Green)	5.9 to 6.8	6.2 to 7.2
	FAIR CONDITION (Some modifications – Orange)	5.4 to 5.8	5.7 to 6.1
	POOR CONDITION (Lots of modifications – Red)	4.8 to 5.3	5.3 to 5.6
	VERY POOR CONDITION (Critically modified – Purple)	< 4.8	< 5.3

Turbidity Levels

Station	***Secchi Depth***
Station 1	40 cm
Station 2	28 cm

Based on the table above, Station 1's Secchi depth is 40 centimeters, while Station 2's Secchi depth is 28 centimeters. In order to contrast the disk against the water and not bottom sediments, lakes or ponds should ultimately be 50% deeper than the average Secchi depth measurement (Green et. al, 1995). In this case, since the river's average depth is 52 centimeters which is 77% for Station 1 and 54% for Station 2 which exceeds 50%, the river is very turbid.

Riverine Plastic Waste Pollution



Riverine Litter Composition along the Mahiga River

Based on the left pie chart which is the classification of riverine plastic waste, the type that has the highest percentage is the plastic bags garnering 29.1% of the total riverine plastic waste while other medical or sanitary items, plastic items less than 2.5 cm, and industrial packaging and plastic sheeting have the lowest percentage, 1.8%. On the other hand, the right pie chart about the percent composition of the categories of riverine waste shows that plastics have the highest percentage of 87.3%. It can be inferred that most of the riverine waste comes from the domestic or residential sector. This has been evidently seen during the ocular inspections done on the river site where various types of used plastics can be found floating.

The findings are then cross-referenced with the plastic waste category index. It can be found out that there were 550 pieces per 100-m riverbank which falls under the category of Class D having a remark of being severely polluted.

A.4 | Conclusion

Overall, the River Scan Challenge involves analyzing the location and features of a river to identify potential hazards or issues, and then designing a solution to address these challenges. To recontextualize the objectives and research question of this study, which are the following:

- Assess the river's health through the guidelines provided in the manual,
- Identify the specific problems and areas that require attention, and
- Create and propose solutions to the problems identified.
- How to solve the flooding problem of Mahiga River's nearby communities while simultaneously improving its water quality?

The aforementioned objectives and the research question were achieved throughout the entire study. Mahiga River's health was assessed through water quality tests. The specific problems were identified which were flooding, informal settlements, and solid wastes which led to poor water quality, and a proposed solution was subsequently created to combat the issues determined.

The design of the solution will typically involve considering a range of factors, such as available resources, stakeholder needs, and the potential impact of different interventions. The goal is to create a sustainable and effective solution that improves safety, reduces environmental impact, and enhances recreational opportunities.

The River Scan Challenge plays an important role in maintaining the health and safety of waterways, and can have a significant impact on the communities that rely on them for recreation, transportation, and other activities. By combining location analysis with careful design of solutions, this can help to ensure that our rivers remain healthy and sustainable for generations to come.

A.5 | Recommendations

1. ***Improve safety measures.*** The location analysis may reveal potential hazards or obstacles in the river that pose a risk to boaters or other users. Based on this information, recommendations may be made to improve safety measures, such as installing warning signs or buoys, or implementing speed limits or other regulations.

2. ***Implement environmental protections*.** The river scan may identify areas of the river that are particularly vulnerable to environmental damage, such as erosion or pollution. Based on this information, recommendations may be made to implement environmental protections, such as restoration projects or regulations to limit harmful activities.

3. ***Enhance recreational opportunities*.** The river scan may identify areas of the river that have potential for recreational activities, such as fishing or boating. Based on this information, recommendations may be made to enhance these opportunities, such as creating access points or developing facilities for visitors.

4. ***Support scientific research*.** The data gathered through the river scan may be valuable for scientific research, such as studying changes in water quality or the effects of climate change. Recommendations may be made to support scientific research and data collection to further understand the river environment.

5. ***Collaborate with stakeholders.*** The river scan challenge may involve collaboration with a range of stakeholders, such as local communities, government agencies, and environmental organizations. Recommendations may be made to foster collaboration and communication between these groups to ensure that everyone's needs and concerns are taken into account in decision-making processes related to the river.

A.5 | References

Climate Scan. (2019). *Mahiga River Downstream Factsheet*. https://climatescan.nl/uploads/projects/6121/files/675/Factsheet.pdf

Limno Loan. (n.d.). *Secchi disk.* https://limnoloan.org/waterquality/secchi-disk

Cotejo, H. (2022, July 11). *Mahiga creek yields tons of trash.* https://www.sunstar.com.ph/article/1934569/cebu/local-news/mahiga-creek-yields-tons-of-trash

Government of Northwest Territories. (n.d.). *Turbidity*. https://www.ecc.gov.nt.ca/sites/ecc/files/turbidity.pdf

Green, L., Addy, K., & Sanbe, N. (1995). *Measuring Water Clarity.* https://web.uri.edu/wp-content/uploads/sites/1667/Secchi.pdf

Saavedra, J. R. (2023, April 13). *Cebu City riverbank settlers to get housing instead of cash aid*. https://www.pna.gov.ph/articles/1199333

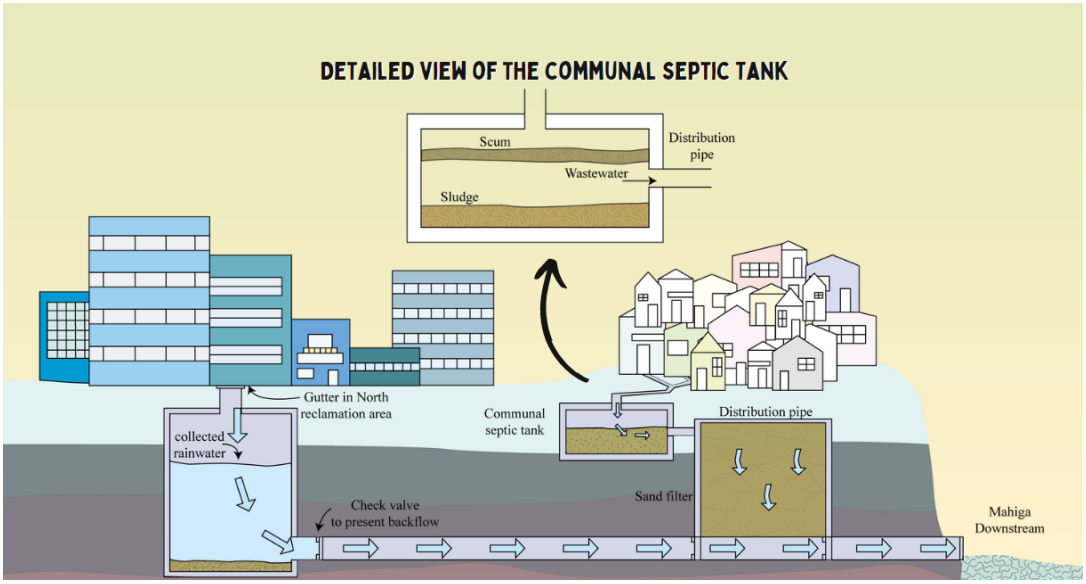
PART B. PRACTICAL SOLUTION

The essential and most vital part of coming up with a solution to address issues with regards to the river is the analysis of the current condition of the Mahiga River, specifically the downstream portion, through various tests tackling the river's physical characteristics and water quality coupled with the immediate identification of the problems faced by the nearby areas based on site ocular inspections and interviews. This part of the study specifically tackles the solutions to be implemented to alleviate the situation of the nearby areas and improve the quality of the Mahiga River water.

B.1 | Design of the Solution

By means of data gathering and thorough assessment, the problems of Mahiga River water quality and the flooding of its nearby areas can be addressed not just by a stand-alone solution but by a system or a series of solutions strengthened by the efforts of the LGU, concerned organizations, and the residents of the nearby areas. Hence, the group proposed a 3-phased solution that is done continuously over the course of time. The 1st phase is the implementation of the catch basins, the 2nd phase is the installment of communal septic tanks, and the 3rd and last phase is the *Kaamgohan* Program.

- ***1st Phase: Catch Basin and Check Valve.*** The 1st phase of the solution is the strategic installation of catch basins below the existing manholes or gutters per block of the North Reclamation Area. These catch basins are installed in a manner that does not disrupt the flow in the existing pipe system below the North Reclamation Area.



- ***2nd Phase: Communal Septic Tank.*** The 2nd phase of the solution is focused towards minimizing the human waste being discharged into the river. It involves the installation of the communal septic tank wherein it functions as a collection tank for the solid wastes. The liquid waste will then be filtered through a permeable layer via the distribution pipes. Finally a cleaner water will be traveling through a pipe and will be discharged into the river.

- ***3rd Phase: Kaamgohan Program.*** The "Kaamgohan Program" aims to:
  - Raise awareness of the overall problems and issues faced by the people due to the deterioration of Mahiga River, and
  - Distribute information regarding the river's water quality levels, water pollution at hand, and the like.

  This involves the nearby residents of Mahiga River, along with the intervention of professionals such as engineers and environmentalists. Seminars will be conducted, and the **C2K System** will be introduced and explained as well to the participants of the program for transparency purposes. Assessments will also be done to acquire the residents' comments and suggestions, which will be part of the basis for maintenance and improvement of the solution and program.

B.2 | Locational Analysis

The ***"C2K System"*** is an underground system that catches stormwater in order to avoid flooding within the North Reclamation Area and helps utilize Mahiga River to its full potential. A catch basin, also known as a storm drain inlet or curb inlet, is a structure used to collect rainwater and other surface runoff from streets, parking lots, and other paved surfaces. It is typically a large, open box-like structure with a grate or filter on the top to prevent large debris from entering the basin. The catch basin will help in delaying and storing rainwater as the stored water can be used in other ways such as vegetation. With the existing one way pipe system straight to the river, each area within 50 meters below will be installed with Catch Basins.

Map of the North Reclamation Area

As seen on the image above, each yellow square symbol in the map symbolizes the Catch Basin. The pink rectangle symbol is where the group will make communal septic tanks wherein residents' waste will go through a filtration device that involves minerals that filter the water, allowing clean water to flow through the connected pipes from the catch basin from north Reclamation area. The blue dotted symbols are manholes within the area that will serve as the waypoint of stormwater to enter the Catch Basin.

B.3 | Social Cost-Benefit Analysis with Explanation

B.3.1 | Bill of Materials (Communal Septic Tanks)

A cluster system, where most households' sewers are linked to one centralized communal septic tank will generally cost 384,000 PHP for the initial install. For most households, the costs for a small sewage treatment plant start between 168,000 PHP and 216,000 PHP. Together with the installation costs, the total costs are approximately 336,000 PHP to 384,000 PHP.

Lifespan. Any type of new septic system, if built and used properly, has the potential to last 20, 30, 40 years or more. Some systems will need pumps replaced periodically and treatment media rejuvenated.

Empty Costs.
Bigger than $3m^3$ →14,400 PHP or more (every 3 years)
Lifespan Septic System: 40 years □ (14,400 PHP x 34 = $ 489,000)

Purchasing Costs	*Initial Instal Costs*	*Lifespan*	*Empty Costs*
168,000 PHP	168,000 to 216,000 PHP	20, 30, 40 Years or More	489,000 PHP (40 years x 34)
TOTAL COSTS	**873,000 PHP**		

Table 1. Cost of the Septic System

Filtration System. The filtration system is just a process of excavating and backfilling with sand and gravel with varying sizes.

B.3.2 | Bill of Materials (Catch Basins)

Item	Description	Quantity	Unit	Unit price	Subtotal
Sand	Washed	3	cu.m	₱1,500.00	₱4,500.00
Gravel	3/4"	6	cu.m	₱1,930.00	₱11,580.00
Cement	OPC	63	bags	₱245.00	₱15,435.00
Rebars	12mm , 6m	55	lengths	₱218.00	₱11,990.00
Excavation	Earth	10	cu.m	₱340.39	₱3,403.90
				TOTAL	₱46,908.90

The catch basins to be installed are all going to be made of concrete for more longevity. As for the costs, the variables involved are the aggregates and cement needed for the concrete mix, the rebars for more support from transverse loads. The costs are estimated to be around 46,908.90 Php. The cost may also vary from the dimensions of the catch basin.

B.3.2 | Bill of Materials (Kaamguhan Program)

"Kaamguhan Program" is a series of promotions to let the public know the purpose of the project to the community. The cost may vary depending on the prices on the market.

Item No.	*Description*	*Quantity*	*Unit*	*Unit Cost*	*Total Cost*
Tarpaulin					
A1	Design			1,000	1,000
A2	Printing	5	pcs	1,000	5,000
Flyers					
A1	Design			1,000	1,000
A2	Printing	200	pcs	40	8,000
Seminars					
B1	Snacks	100	pax	30	3,000
B2	Professional Fee	2		3,000	6,000
				TOTAL	**24,000**

B.3.3 | Bill of Labor (Excavation/Installment of Catch Basins and Communal Septic Tanks)

The labor cost for the project will be ***11,362,500.00 PHP.*** With the target completion of 5 months for the 5 units of catch basins and 3 months for the 2 units of the communal septic tanks near the North Reclamation Area.

Item	Description	Quantity			Unit price	Subtotal
Labor (Catch Basin)	Excavation	5 days	10 people	5 units	Php 1,000.00	Php 250, 000.00
	Installation	145 days	10 people	5 units	Php 1,000.00	Php 7,250,000.00
	Mobilization	45 days	3 people	5 units	Php 2,500.00	Php 1,687,500.00
Labor (Septic Tank)	Excavation	5 days	10 people	2 units	Php 1,000.00	Php 100, 000.00
	Installation	85 days	10 people	2 units	Php 1,000.00	Php 1,700,000.00
	Mobilization	25 days	3 people	2 units	Php 2,500.00	Php 375,000.00
					Grand Total	Php 11,362,500.00

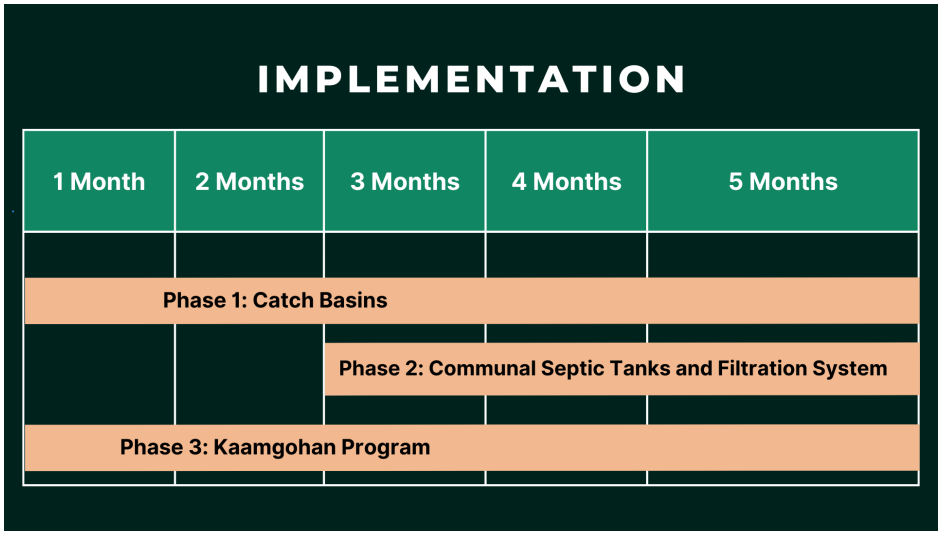
B.3.4 | Cost-Benefit Analysis

Overall, the cost of the whole system is in several millions, comparable to the cost of installations of dams. The main difference is that the whole system solves three problems at the same time in the Mahiga Downstream Portion (Flooding in North Reclamation Area, Water Quality of the Downstream Portion of Mahiga Creek, and the improvement of the lives of everyone settling nearby the river. However, the main goal of the whole C2K System is to make the river water usable to the community nearby the downstream portion of Mahiga River, and mitigating floods at the North Reclamation Area at the same time. This whole system improves the drainage and sewage system on areas nearby the downstream portion of Mahiga Creek. The whole cost of this project is a small price to pay when compared to the improvement of the lives of everyone residing nearby the downstream portion of Mahiga River.

B.4 | Planning

In the implementation of the solution, the Local Government Units (LGUs) should be able to inform the public, especially the affected residential and commercial areas, regarding the construction of the adopted solution. It is important to note that this plan is made with the assumption that there are solutions for the river quality on the Upstream and Midstream portions of Mahiga Creek.

The plan also includes street cleaners regularly checking on the solid wastes that are potentially clogging the pipes in the system. The plan to rehabilitate including the funding for the Mahiga river is done by the national government. The LGUs are the ones who are responsible for implementing the proposed plans like for example conducting the clean-up drives regularly. Flooding has occurred to the sitio's beside the Mahiga River which is why illegal settlers are taken out of the area and a budget has been proposed to widen the Mahiga River to its original width to stop the flooding.



The first phase is focused on the flooding of the North Reclamation Area by placing 5 underground catch basins in a specified location the flood/water runoff will be directed to the river. In this phase, the construction of underground catch basins that will collect rainwater that passes through the manholes is undergone. In these catch basins, most of the solid wastes will be settled at the bottom and the remainder of the wastewater will pass through the pipes.

The Mahiga River's wastewater issue will be addressed in the second phase by installing communal septic tanks. Before proceeding, informal settlers will be consulted to ensure their input is taken into account. Although they will need to provide their own toilets, the placement of the septic tanks will be taken care of. The duration of this process may take up to three months and will depend on the agreements reached with the informal settlers.

Throughout the Kaamgohan Program, nearby schools will offer educational programs to residents of the informal settlement areas. This aims to change their behavior and promote awareness of the issues in the area. They will also be encouraged to report any other problems to the local government unit (LGU) more easily. After the installation of garbage containers and communal septic tanks, residents will be expected to take responsibility for cleaning up the river. They have been provided with the necessary facilities by the LGU and other parties, and therefore, they will be required to clean up their own waste. In return, they will not be penalized for any harm caused to the river.

B.5 | Stakeholders Involved

The stakeholders involved in the implementation of the proposed solution are the following, namely: Residents, land owners, LGUs, DPWH.

Stakeholders	***Influence***	***Interest***	***Reason***
Residents	Normal	High	The residents play a key role in the project because they are part of the communities involved when the project is being implemented.
Department of Public Works and Highways (DPWH)	High	High	They are responsible for fundings and budget given by the government and donors.
Large Companies	High	High	They aid the LGU and the DPWH in alotting the budget for the proposed project.
University of San Carlos & Rotterdam University	Low	High	Responsible for the proposal of the solutions to the current problem.
LGU	Normal	High	Responsible for the implementation of programs in a microlevel for example carrying out the suggested measures, such as holding regular clean-up drives.

B.6 | Operation and Maintenance

The operation will be supervised by the University of San Carlos (USC) team, composed by professors, professionals, and undergraduate students. The USC team will coordinate with the LGUs, Cebu City Planning and Development Office (CPDO), Department of Public Works and Highways (DPWH), Department of Transportation (DOTr), City Engineer's Office (CEO), and Metropolitan Cebu Water District (MCWD). Through the coordination of the different organizations the team can set safety and regulations that have been set by the government and also the sustainability of the project.

One of the main focuses in maintaining the "C2K System" solution is the check valve and the steps required in maintaining it are the following:

- ***Step 1: Keep it clean.*** Take precautions to avoid check valve damage by maintaining a clean environment. All you should need, if you can get to the valve, is a towel to remove dirt and dust. Use a wire brush if there is caked-on debris.

- ***Step 2: Be vigilant.*** Conducting routine inspections of your equipment is another simple tip. It's a good way to identify potential issues before you need to make costly repairs.

Checking the check valve:

- Verify for leaks
- Keep an eye out for any corrosion, rust, or mineral buildup.
- If there are significant leaks or worn/broken parts, replace the valve.
- To check if the valves are not seizing, open and close them.
- Examine the fluid's temperature and pressure.
- Make sure they aren't too close to or above the valves' rated limit.

NOTE: High-stress and high-pressure valves should be checked more frequently.

- ***Step 3: Clean up everything.*** The valve needs to be removed and disassembled so that you can inspect it for dirt and scratches. Hydraulic fluid or any other fluid used in your pipe system should be used to clean all the components. Look for rust, damage, or a rough surface on the housing. Rough surfaces can benefit from buffing.

- ***Step 4: Continue lubricating the valve.*** Use the proper lubricant for your system, please. Each system has unique requirements, and if the wrong one is used, the valves could be harmed. For instance, lubricants containing clay or other solid-based thickeners have a tendency to harden and leave behind residue.

For the septic tank the team should pump the septic tank regularly, inspect for leaks, and clean filters for the groundwater usage.

B.7 | References

CPV Manufacturing (2015), *The Check Valve Maintenance Guide.*
https://www.cpvmfg.com/news/the-check-valve-maintenance-guide/

Timothy Dale (2022), *Essential Tasks To Do Regularly for Septic Tank Maintenance*
https://www.thespruce.com/regular-tasks-for-septic-tank-maintenance-5213314