FINAL PROJECT – RC 14-1501

PATEROS RIVER RESTORATION IN REFERENCE OF ITS CAPACITY, MAINTENANCE AND SUSTAINABILITY

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2016

TUGAS AKHIR – RC 14 - 1501

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PATEROS RIVER RESTORATION IN REFERENCE OF ITS CAPACITY, MAINTENANCE, AND SUSTAINABILITY

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Abstract

The Municipality of Pateros suffers flooding every year. There are several problems causing flood in Pateros, such as bad drainage system, river problem, social problem, and maintenance problem. The objective of this thesis is reducing the flood problem by analysis of the river capacity in every 500 m. The analysis of stormwater and wastewater which is the water source of the river and the capacity of the river conducted in every point. There are 5 points in the river that need to be redesign. This thesis also provide briefly possible solution based on SWOT analysis. Finally, the analysis of Maintenance is carried to protect, maintain, and sustain the river for the future.

Keywords: river, waterquantity, capacity, stormwater, wastewater, maintenance, watermanagement

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RESTORASI SUNGAI PATEROS BERDASARKAN KAPASITAS, PEMELIHARAAN, DAN KEBERLANJUTAN

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Abstrak

Kotamadya Pateros, Metromanila mengalami banjir setiap tahunnya. Banjir yang terjadi di kawasan tersebut disebabkan oleh banyak hal, seperti buruknya system drainase, masalah pada saluran primer atau sungai, masalah social dan edukasi, dan masalah pemeliharaan. Tujuan dari skripsi ini adalah mengurangi potensi banjir atau kelebihan air dengan cara analisis kapasitas sungai setiap 500 meter. Analisa air masuk seperti dari air hujan dan air limbah, serta analisa kapasitas di sungai dilakukan di tiap titik. Hasil dari analisis ini adalah adanya 5 titik di sungai yang memiliki kapasitas yang kurang memadai. Tesis ini juga menyajikan solusi-solusi ringkas disetiap titik untuk menanggulangi masalah yang ada berdasarkan analisis SWOT. Diakhir dari skripsi ini, juga disediakan analisa pemeliharaan untuk menjaga dan mempertahankan kelangsungan sungai Pateros dimasa yang akan datang.

Kata kunci: sungai, jumlah air, kapasitas, air hujan, air limbah, pemeliharaan, manajemen air

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The author completely understand that this report still needs to be improved and he really hopes that this report will be useful and easily understandable for whom it may concern.

Groningen, May 2016
Author

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CHAPTER I
INTRODUCTION

1.1 Background Information

Metropolitan Manila has a total land area of approximately 636 square kilometers, it lies along the flat fluvial and deltaic lands in the west and the rugged lands of Marikina Valley and the Sierra Madre mountains in the east. It is bordered by the Manila Bay in the west, the larger and fertile plains of Central Luzon in the north, and Laguna de Bay in the south, the provinces of Bulacan to the north, Rizal to the east, Cavite to the southwest and Laguna to the south. Metro Manila's primary waterway is the Pasig River, which bisects the peninsula. (http://www.asianhumannet.org/)

Extreme floods are common in Metro Manila, generally occurring at least once a year during the rainy season (Lagmay, 2015). There are a lot of causes of flooding in Manila such as: Manila is a low lying delta city surrounded by highlands. Therefore, almost all of the water from the highlands drive down into Manila before they off to the sea. Second, Manila has a tropical climate which occur high intensity of rain as it did in 2013 recorded staggering 326 mm of precipitation (http://www.aljazeera.com/) and typhoon. Lastly, bad drainage system and public indifference about the channel as it found a lot of garbage that impede the flow of water.

Apart from devastating floods like those spawned by Tropical Storm Ondoy in 2009 (Lagmay et al., 2010) and the typhoon-enhanced southwest monsoon rains in 2012, 2013 (Lagmay et al., 2014) and 2014, which brought the entire metropolis to a standstill, more frequent and short-lived thunderstorms that affect portions of Metro Manila also paralyze the nation’s capital because of the heavy traffic they cause. Also, loss of life, properties, moneys cannot be prevented. According to a JICA report, traffic jams due to thunderstorm-related flashfloods cost the Philippine economy PhP 2.4 billion (€ 46.000.000) a day from waste of gasoline during traffic and lost opportunities (Rodis, 2014).

Because of the high impact of flood stated above, Flood Free Manila Project is conducted. It is one of the projects that developed by the Kenniscentrum Noorderruimte, Hanzehogeschool Groningen. It is a bilateral collaboration between Dutch (Hanzehogeschool, Rotterdam Hogeschool, Hogeschool van Amsterdam and Wageningen Hogeschool) and Filipino (University of the Philippines) researchers and young professionals for the Flood and Pollution Free Manila project. The MoU was signed last November 2015. It was agreed that efforts should be undertaken to organize joint events of young professionals in the period 2016-2018. This would enhance the university collaboration between Dutch and Filipino knowledge institutes in the fields of climate adaptation and urban planning with the involvement of many partners from both countries.

The second Flood Free Manila project was conducted from 18 April 2016 until 25 April 2016. The municipality of Pateros was the chosen study area of this project. This area was chosen because as you can see in the picture beside, most area of the Municipality of Pateros is flood prone. Besides, the Municipality of Pateros was seeming like a disregarded area. Bad urban planning, transportation system, drainage system, narrow street, illegal settler, etc. This municipality had lot of problems which needed to be solved.

To narrowed it down, the Flood Free Manila project and this thesis project focuses on the river problem in Pateros. Pateros River, which is the only waterways for 20 barangays in 3 different cities and 1 municipality was the main problem why flooding always occurred in that area. The barangays are provided in Appendix 1 After conducted field study and interview last April. These are the main problem in Pateros river:

1. Undersize and bad maintenance system of the primary river (Pateros River),
2. Rubbish and waterlilies inside the river
3. Rising of the population and irresponsible attitude of people living nearby the river
4. Disunion work of every barangays
5. Climate Change / Heavy rainfall

To take care of the rubbish and waterlilies out to the river is the focal point of Flood Free Manila workshop. After a week brainstorming and solution-making between young professionals of Dutch and Philippines student, “Longganisa” was produced, a flexible floating ‘sausage’ to collect the rubbish and waterlilies from the river. This simple yet innovative and eco-friendly solution can be applied easily in every spot of the river. The poster of “Longganisa” can be seen in the Appendix 3 The main idea is to collect the garbage and transport them to the nearest segregation center. On the other hand, this thesis project is focused in the capacity of the Pateros river. Analyzing how much water from rain and human use will come and the capacity of the river in every 500 m after the rubbish and waterlilies is no longer in the river. The motivation of this dissertation is because of the flooding that occurs yearly and resulting many losses in the Municipality of Pateros. It is heartbreaking seeing people suffer continuously and they can even do nothing. Therefore, this thesis wants to know if the capacity of Pateros river enough against the discharge water.

Some actions need to be applied in every spot which the river is lack in the capacity. Therefore, the mitigation of flooding which is the main objective of the thesis can be fulfilled

Figure 1. Flood Prone Area
Source : www.expatch.org

1.2 Objectives

Calculating the capacity of Pateros river every 500 m to find some spots in the river which has deficiency of capacity in the river and develop a sustainable and adaptive solution to reduce the water problems so that it will mitigate the possibility of flooding and the damages in the Pateros, Metromanila, Philippines

1.3 Scope of Work

Because of the limited time to collect the data and finish the research, boundaries of this project are made:

1. This graduation project is only focuses on water quantity of the Pateros River
2. The water quality of Pateros river is not within the scope of this graduation project since the study is done by another student (Lotte de Jong and Sije Kloppenburg)
3. Secondary data will be used for the analysis during this research. Internet search, field observation, case study, and interview with local and expert will be the methods of collecting data
4. The rainfall data that used is depends on the acquired data from PAGASA. The rainfall data obtained is solely from NAIA (Ninoy Aquino International Airport) rain gauges' station.
5. The actual discharge for the drainage system is only from stormwater and wastewater. Groundwater seepage will be ignored because research found it only takes small part of the drainage discharge.
6. Due to lack of data in Pateros, the slope will be assumed. The slope rising only up to 2.5% slanting downward towards Laguna Lake (tagalog-dictionary.com)
7. Every height of the river is calculated in plain view
8. The catchment area in every spot is roughly estimated
9. The dimension of the river is calculated roughly
10. The slope of river is roughly analyzed by 0.02

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CHAPTER II
LITERATURE REVIEW

2.1 General Review

Literature review is made to observe the parameters and formulas that will be used in this graduation project. This is done by reviewing theories that found in literatures and also in the site information. A literature review discusses published information in a particular subject area, and sometimes information in a particular subject area within a certain time period. (http://writingcenter.unc.edu/)

To complete this thesis project of assessing a drainage system, many theories and calculations need to be done, such as:

- Determination of Catchment area
- Rainfall area
- Rainfall Frequency Analysis
- Rainfall intensity
- Flood discharge design
- Wastewater discharge
- Capacity of the river
- Room for the river

2.2 **Determination of Catchment Area**

Catchment area is a boundary of land area which all the water (stormwater and wastewater) in that area is drained by drainage system to the Pateros river.

Figure 2 Catchment area
Source: floodsite.net

2.3 Rainfall Frequency Analysis

Rainfall data is one of the most important part of analyzing a drainage system and primary channel. Sometimes, the obtained data is acquired from many rain gauge stations. The quality of the obtained rainfall data depends on the location of the station and what kind of tool they use. The more obtained rainfall data is the more accurate analysis for the design rainfall discharge.

Figure 3 Automatic rainfall monitoring system
Source: phametechnology.com

2.3.1 Arithmetic Mean Method

This is the simplest method of computing the average rainfall over a basin. This method is calculating the average of rainfall data which is obtained in many different stations in the same time. This method is dependable if the distributions of rainfall gauges is uniform and the same time data from one and another station is similar.

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_n}{n} = \sum_{i=1}^{n} \frac{R_1}{n}$$

Where:

$\bar{R}$ = Mean rainfall data (mm)
$R_1, R_{2,} R_n$ = Rainfall data from station 1,2, …, n (mm)
n = Number of station

2.3.2 Polygon Thessien Method

This method based on weighted average. This method is more dependable than arithmetic mean method. The rainfall is never uniform over the entire area of the basin or catchment, but varies in intensity and duration from place to place. Thus, the rainfall recorded by each rain gauge station should be weighted according to the area, it represents.

$$C = \frac{A_i}{A_{total}}$$

$$\bar{R} = \frac{A_1R_1 + A_2R_2 + \cdots + A_nR_n}{A_1 + A_2 + \cdots + A_n}$$

Where:

C_t = Theissen Coefficient

A_i = Bisectional area (km^2)

A_{total} = Total catchment area (km^2)

$\bar{R}$ = Mean rainfall data (mm)

R_i = Rainfall data from each station (mm)

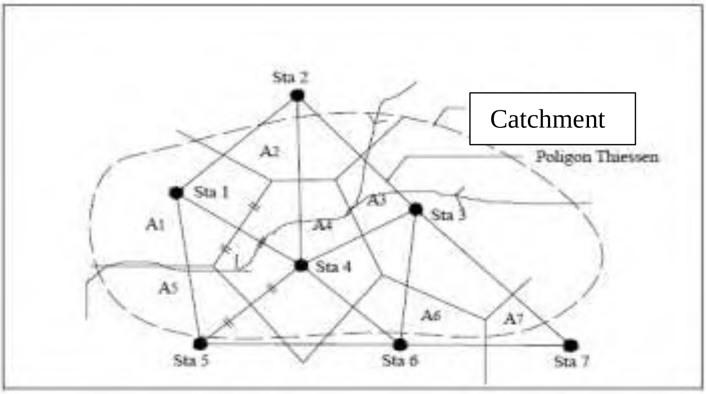

Figure 4 Thessien Polygon method (Soemarto,1999)

2.4 Rainfall Intensity Analysis

Design rainfall is the probability of rainfall intensity that will happen in designated return period. The analysis of design rainfall is called rainfall frequency analysis. Systematically, the calculations sequences of design rainfall are:

- Statistic parameter
- Frequency analysis distribution method
- Test for fit of a distribution
- Calculation of design flood discharge

2.4.1 Statistic Parameter

There are used parameter for analyzing rainfall frequency:

- Mean value

$$\bar{x} = \sum \frac{R_x}{n}$$

- Standard deviation

$$S_d = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

- Coefficient of variation

$$C_v = \frac{S_d}{\bar{x}}$$

- Skewness

$$C_s = \frac{n \sum_{i-1}^{n} \{(x_i) - \bar{x}\}^3}{(n-1)(n-2)sd^3}$$

- Coefficient of kurtosis

$$C_k = \frac{n(n+1)}{(n-1)(n-2)(n-3)} * \frac{\sum_{i-1}^{n} \{(x_i) - \bar{x}\}^4}{sd^4} - \frac{3(n-1)^2}{(n-2)(n-3)}$$

Where:

$\bar{x}$ = Mean daily maximum rainfall intensity from n year
x_i = Daily maximum rainfall intensity
n = Amount of years
Sd = Standart deviation
Cv = Coefficient of variation
Cs = Skewness
Ck = Coefficient of kurtosis

2.4.2 Frequency Analysis Distribution Method

There are many distributions method for rainfall frequency analysis. To make sure the processed distribution data is accurate, calculation of 2 methods are conducted. That 2 methods are:

- Gumbel Type I Method
- Log Pearson Type III Method

2.4.2.1 Gumbel Type I Method

To calculate design rainfall intensity with Gumbel method type I, use empirical frequency distribution equation as follows (Soemarto, 1999)

$$X_T = \bar{X} + \frac{S_d}{S_n}(Y_T - Y_n)$$

$$Y_T = -\ln\left[-\ln\frac{T-1}{T}\right]$$

$$T = \frac{1}{P}$$

$$P = \frac{m}{N+1}$$

Where:

X_T = Value of design rainfall with return period T (mm)

$\bar{X}$ = Mean of rainfall data (mm)

S_d = Standart Deviation

Y_T = Reduced variate from the probability of occurrence for return period T

Y_n = The average of reduced variate, the value is depended on the amount of data (n),

S_n = Standart deviation from reduced variate (reduced standart deviation), the value is depended on the amount of data.

T = Return period (year)

P = Probability that rainfall event will be occurred in every year

m = Rank

N = Amount of Data

Step by step calculation:

1. Rank the maximum rainfall every year obtained descending (the highest rainfall will be the first rank
2. Find m and N
3. Find the probability of rainfall event will be equaled from data obtained in every year (P)
4. Find return period from the data obtained in every year (T)
5. Find the reduced variate based on the formula above (Y_T)
6. From the result of reduced variate of every year, make a scatter plot graph between rainfall amount in y axis and reduced variate in x axis and find the linear equation of it
7. Find the reduced variate of the desire return period and put that into the equation found in step 6. The rainfall with desire return period is found.

2.4.2.2 Log Pearson Type III Method

This method if drawn in logarithmic paper, the result will be straight-line equation. Therefore, so it can be expressed as a mathematical model with the following equation (Soemarto, 1999)

$$Y = \bar{Y} + k.Sd$$

Where:

Y = Logarithmic value of X (log X)

X = Rainfall intensity

$\bar{Y}$ = Mean value of Y

Sd = Standard deviation of Y

k = Characteristic of Log-Pearson type III, as displayed on table 1

Step by step calculation:

1. Change the rainfall intensity data (X1, X2, X3,…,Xn) into log(X1), log(X2), log(X3),…,log(Xn)
2. Calculate mean value by using this equation:

$$\overline{\log X} = \frac{\sum_{i-1}^{n} \log(Xi)}{n}$$

Where:

$\overline{\log X}$ = Value of mean logarithmic

n = Amount of data

Xi = Value of rainfall intensity of every year (R_{24} max) (mm)

3. Calculate the Standart deviation

$$\overline{S_d \log x} = \sqrt{\frac{\sum\left(\log x_i - \overline{\log x}\right)^2}{n-1}}$$

4. Calculate the Skewness coefficient

$$C_s = \frac{n\sum_{i-1}^{n}\left\{log(x_i) - \overline{logx}\right\}^3}{(n-1)(n-2)sd^3}$$

5. Calculate logarithmic design rainfall with return period T with this equation

$\log X_T = \overline{\log X} + G.Sd$

Where:

X_T = Design rainfall intensity with return period T (mm)

G = Value obtained from value of acquired Cs, as displayed on table 1

6. Calculate kurtosis coefficient with this formula:

$$C_k = \frac{n^2 \sum_{i-1}^{n} \left\{(\log(x_i)) - \overline{\log(x)}\right\}^4}{(n-1)(n-2)(n-3){S_1}^4}$$

7. Calculate variance coefficient with this formula:

$$C_v = \frac{S_1}{\overline{\log X}}$$

Where:

Cv = Variance coefficient

S_1 = Standard deviation

Skewness (Cs)	Periode Ulang Tahun							
	2	5	10	25	50	100	200	1000
	Peluang (%)							
	50	20	10	4	2	1	0,5	0,1
3,0	-0,396	0,420	1,180	2,278	3,152	4,051	4,970	7,250
2,5	-0,360	0,518	1,250	2,262	3,048	3,845	4,652	6,600
2,2	-0,330	0,574	1,284	2,240	2,970	3,705	4,444	6,200
2,0	-0,307	0,609	1,302	2,219	2,912	3,605	4,298	5,910
1,8	-0,282	0,643	1,318	2,193	2,848	3,499	4,147	5,660
1,6	-0,254	0,675	1,329	2,163	2,780	3,388	3,990	5,390
1,4	-0,225	0,705	1,337	2,128	2,706	3,271	3,828	5,110
1,2	-0,195	0,732	1,340	2,087	2,626	3,149	3,661	4,820
1,0	-0,164	0,758	1,340	2,043	2,542	3,022	3,489	4,540
0,9	-0,148	0,769	1,339	2,018	2,498	2,957	3,401	4,395
0,8	-0,132	0,780	1,336	2,998	2,453	2,891	3,312	4,250
0,7	-0,116	0,790	1,333	2,967	2,407	2,824	3,223	4,105
0,6	-0,099	0,800	1,328	2,939	2,359	2,755	3,132	3,960
0,5	-0,083	0,808	1,323	2,910	2,311	2,686	3,041	3,815
0,4	-0,066	0,816	1,317	2,880	2,261	2,615	2,949	3,670
0,3	-0,050	0,824	1,309	2,849	2,211	2,544	2,856	3,525
0,2	-0,033	0,830	1,301	2,818	2,159	2,472	2,763	3,380
0,1	-0,017	0,836	1,292	2,785	2,107	2,400	2,670	3,235
0,0	0,000	0,842	1,282	2,751	2,054	2,326	2,576	3,090
-0,1	0,017	0,836	1,270	2,761	2,000	2,252	2,482	3,950
-0,2	0,033	0,850	1,258	1,680	1,945	2,178	2,388	2,810
-0,3	0,050	0,853	1,245	1,643	1,890	2,104	2,294	2,675
-0,4	0,066	0,855	1,231	1,606	1,834	2,029	2,201	2,540
-0,5	0,083	0,856	1,216	1,567	1,777	1,955	2,108	2,400
-0,6	0,099	0,857	1,200	1,528	1,720	1, 880	2,016	2,275
-0,7	0,116	0,857	1,183	1,488	1,663	1,806	1,926	2,150
-0,8	0,132	0,856	1,166	1,488	1,606	1,733	1,837	2,035
-0,9	0,148	0,854	1,147	1,407	1,549	1,660	1,749	1,910
-1,0	0,164	0,852	1,128	1,366	1,492	1,588	1,664	1,800
-1,2	0,195	0,844	1,086	1,282	1,379	1,449	1,501	1,625
-1,4	0,225	0,832	1,041	1,198	1,270	1,318	1,351	1,465
-1,6	0,254	0,817	0,994	1,116	1,166	1,200	1,216	1,280
-1,8	0,282	0,799	0,945	0,035	1,069	1,089	1,097	1,130
-2,0	0,307	0,777	0,895	0,959	0,980	0,990	1,995	1,000
-2,2	0,330	0,752	0,844	0,888	0,900	0,905	0,907	0,910
-2,5	0,360	0,711	0,771	0,793	0,798	0,799	0,800	0,802
-3,0	0,396	0,636	0,660	0,666	0,666	0,667	0,667	0,668

Table 1 Value of K for Log Pearson Distribution (Soemarto,1999)

2.4.3 Fit Test for Distributions

Fit test was conducted to determine the distribution methods most suited to the rainfall data. Test methods done by testing the fitness of distribution that is intended to determine whether the

probability distribution equation may represent samples of the statistical distribution of data analyzed. (Soewarno, 1995).
There are 3 methods of testing the fitness of the distribution, Chi Square fit test, Smirnov Kolmogorov fit test, and Anderson Darling. The calculation of fit test is accomplished by computer program called EasyFit 5.6 Standard. With this program, the better distribution can also be known, so it is very useful and convenience program.

2.4.4 Intensity of Rainfall

Intensity of rainfall is very important part to calculate the flood discharge design, especially on rational method. Intensity of rainfall is the height of rain that concentrate in a certain time. This analysis can be processed using the history of rainfall in some place. The formula to find the intensity of rainfall is using Dr. Mononobe formula (Soemarto,1999).

$$I = \frac{R_{24}}{24} * \left[\frac{24}{t}\right]^{\frac{2}{3}}$$

Where:

I = Intensity of rain (mm/hour)

R_{24} = Maximum rainfall in 24 hours (mm)

t = Time of rainfall concentration (hour)

2.4.5 Time of Concentration

Time of concentration is how long time the water comes from the upstream to the downstream. It is calculated by this formula:

$$W = 72 * \left(\frac{\Delta H_r}{L}\right)^{0.6}$$

$$t_c = \frac{L}{W}$$

Where:

t_c = time of concentration (hour)

W = velocity of water (km/hour)

L = Length of channel (km)
ΔH_r = Difference height of the upstream to the downstream(km)

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L = Length of channel (km)
ΔH_r = Difference height of the upstream to the downstream(km)

2.5 Flood Discharge Design

For determining flood design discharge, there are many methods. For this thesis project, the methods that will be used are rational method

$$Q_s = \frac{1}{3.6}.C.I.A$$

Where:
Q_s = Flood design discharge (m^3/sec)
C = Rational method runoff coefficient
I = Intensity of rainfall (mm/hour)
A = Catchment area (km^2)

2.5.1 Rational Method Run-off Coefficient

For run-off coefficient, it depends on what the land area is used. The value of 'C' is provided in table 2 below.

Land use		**C value**	**Land use**		**C value**
Business	Downtown areas	0.7-0.95	Agricultural land	Bare packed soil	
	Neighborhood areas	0.5-0.7		Smooth	0.3-0.6
Lawns	Sandy soil, flat 2%	0.05-0.1		Rough	0.2-0.5
	Sandy soil, avg 2-7%	0.1-0.15		Cultivated rows	
	Sandy soil, steep 7%	0.15-0.2		Heavy soil, no crop	0.3-0.6
	Heavy soil, flat 2%	0.13-0.17		Heavy soil, with crop	0.2-0.5
	Heavy soil, avg 2-7%	0.18-0.22		Sandy soil, no crop	0.2-0.4
	Heavy soil, steep 7%	0.25-0.35		Sandy soil, with crop	0.1-0.25
Residential	Single-family areas	0.3-0.5		Pasture	
	Multi units, detached	0.4-0.6		Heavy soil	0.15-0.45
	Multi units, attached	0.6-0.75		Sandy soil	0.05-0.25
	Suburban	0.25-0.4		Woodlands	0.05-0.25
Streets	Asphaltic	0.7-0.95	Industrial	Light areas	0.5-0.8
	Concrete	0.8-0.95		Heavy areas	0.6-0.9
Park, cemeteries		0.1-0.25	Drives and walks		0.7-0.85
Unimproved areas		0.1-0.3	Roofs		0.75-0.85
Playgrounds		0.2-0.35	Railroad yard areas		0.75-0.95

Table 2 Runoff Coefficient for Rational Method (Loebis,1987)

2.6 Wastewater Discharge Analysis

Wastewater is used water. It includes substances such as human waste, food scraps, oils, soaps and chemicals. In homes, this includes water from sinks, showers, bathtubs, toilets, washing machines and dishwashers. Businesses and industries also contribute their share of used water that must be cleaned. (http://water.usgs.gov/edu/wuww.html).

Calculation about wastewater in a certain area depends on climate, living standard, socio-economic level, industrial activity, price of clean water, etc (Fair,1966).

To calculate wastewater discharge, these following data should be known:

- Amount of user (Population)
- Water consumption (liter/person/day)
- Spent water (liter/person/day)

2.6.1 Amount of User

This is how much the population in Pateros. The latest available data is the Pateros population in 2010. To make the calculation accurate, the projection of the total population at the 2010 to the present time or future based on the development of the region need to be conducted. The formula is:

$$FV = PV(1 + i)^n$$

Where:

FV = Population in the future (person)

PV = Population in the present (person)

i = Growth rate (%)

n = number of year

2.6.2 Water Consumption

Water consumption consist of many things, such as:

a. Average daily water requirements for survival (drinking)

b. Water requirements for food preparation (cooking and dish washing)
c. Water requirements for bathing
d. Water requirements for sanitation
e. Water requirements for laundry

2.6.3 Spent Water

Spent water is part of water consumption which will be drained to the urban drainage system. This is approximately 60-70% from the water consumption (Fair,1966)

The formula for calculating the wastewater is(Fair,1966):

$Q_w = \frac{Sw}{24*3600} * P$ (liter/sec)

In 1 year, there is 1 day which has a maximum wastewater discharge, it is estimated to be 25.5% higher than average wastewater discharge, therefore(Fair,1966):

$Q_{w\,max} = 1.255 * Q_w$ (liter/sec)

Or H.M.Gifft (1945) method can be used:

$Q_{w\,max} = \frac{5}{P'^{\frac{1}{6}}} * Q_w$ (liter/sec)

Where:

Sw = Spent water (liter/person/day)
Q_w = Average wastewater discharge (liter/sec)
$Q_{w\,max}$ = Maximum wastewater discharge (liter/sec)
P = Population
P' = Population in thousand

2.7 Capacity of the River

Pateros river is man-made river. Therefore, it's capacity of river is based on its dimension. The formula is:

$Q_c = v * A$

$v = C * \sqrt{R * S}$

$$C = \frac{1}{n} * R^{\frac{1}{6}}$$

$$R = \frac{A_r}{P_r}$$

$$A_r = \frac{1}{2} * (a + b) * h$$

$$P_r = b + 2 * \sqrt{x^2 + h^2}$$

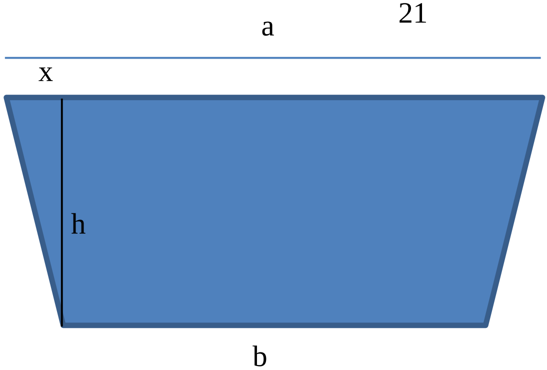


Figure 5 Trapezoidal Shape

Where:

Q_c = Capacity of the river (m3/sec)

v = Velocity of the river (m/sec)

C = Cheezy Coefficient

R = Hydraulic Radius (m)

S = Slope of the river

A_r = Wet area of the river (m2)

P_r = Wet circumference of the river (m)

2.8 Room for the River

In this part provides some theory of making room for the river. Every river is different (size, deepness, and surrounding environment), therefore requires an individual solution in order to make room for the water. This page provides possible solutions to make room for the river. (ruimtevoorderivier.nl)

1. *Lowering the flood plain*

   Lowering sections of the flood plain gives the river more space during periods of high water. Over the past few centuries, the natural process of sedimentation has gradually raised the level of the flood plain. Excavating the top layers of the flood plains makes them lower, which in turn contributes to making room for the river.

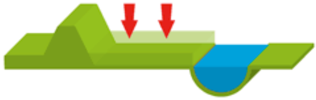


Figure 6 Lowering the Flood Plain (ruimtevoorderivier.nl)

2. *Deepening the summer bed*

   Using dredge tool, the summer bed of the river is deepened, so this will create more room for the river as the capacity of the river increased

Figure 7 Deepening the Summer Bed (ruimtevoorderivier.nl)

3. *Water retention*

   Create some water retention facilities like lake or pond which will serve as a temporary water storage area to retain excess river water, such as when the river is discharging large volumes of water because of heavy rainfall, this water retention facility could be the best solution.

Figure 8 Water Retention (ruimtevoorderivier.nl)

4. *Dyke relocation*

   Relocating a dyke land-inwards increases the width of the flood plains and provides more room for the river. This entails exposing land that hand once been protected by the dyke to high water in order to expand the river's winter bed

Figure 9 Dyke Relocating (ruimtevoorderivier.nl)

5. *Lowering perpendicular groynes and building attracting groynes*

   By lowering the groynes in the river and building parallel barriers, the river will be able to drain excess water easier. A perpendicular groyne is constructed at a right angle to the flow of the river. These groynes will be lowered or removed. Attracting groynes are constructed parallel to the flow of the river.

Figure 10 Lowering Perpendicular Groynes and Building Attracting Groynes (ruimtevoorderivier.nl)

6. *High water channel*

   A high water channel is a branch of a river used to drain high water via a different route. The channel is not excavated below the water table, but rather formed by building two dykes in the landscape

Figure 11 High Water Channel (ruimtevoorderivier.nl)

7. *De-poldering*

   The dyke on the river side is moved land-inwards, so that the river can flow into the area during periods of high water

Figure 12 Depoldering (ruimtevoorderivier.nl)

8. *Removing Obstacles*

   Removing or modifying obstacles in the river wherever possible helps increase the flow rate for the river water. Removing obstacles includes work such as lowering or eliminating ferry pier banks, widening bridge openings and removing or lowering quays and flood-free areas

Figure 13 Removing Obstacles (rumtevoorderivier.nl)

9. *Strengthening dykes*

   In several areas where widening of the river is not an option due to lack of space, the dykes may be strengthened instead

Figure 14 Strengthening Dykes (ruimtevoorderivier.nl)

CHAPTER III
METHODOLOGY

3.1 Flowchart

In this chapter, a flow chart to do this graduation project will be pointed out. Afterwards, every step will be explained briefly

3.2 Identification of the Problem

Problem is something that prevents us to reach our goal. Identification of problem is the first step need to be taken to solve a matter. A good and complete identification means better output of the research. In this study, the author did a field observation and interviews to the residents nearby the river, local governments, and experts.

3.3 Data Collection

The data used for this study is mainly a secondary data. It means that the data collected is from someone who was collecting than the user. To finish "Rehabilitation of Pateros Rives as Reference of Its Capacity, Maintenance, and Sustainability". Some data need to be acquired, such as:

3.3.1 Topographic Map

Topographic map is a detailed, accurate graphic representations of features that appear on the Earth's surface of some location. This map will be used for finding the slope of Municipality of Pateros. This data is acquired from the website of National Mapping and Resource Information Authority (NAMRIA) (www.namria.gov.ph). This product can be seen in Appendix 4

3.3.2 Climatology Data (Rainfall Data)

Rainfall data is a measured amount of rain by rain gauges. It can be measure in every minutes, hour, daily, monthly, or else based on the type of rain gauge. This data is used to find how much precipitation will be in connected to the return period. Thus, with this data we can plan, design, and analyze many things in correlation to water building such as dam, drainage system, dykes, pumping station, channel, etc. In this case, the data is used for analyzing the primary river, Pateros River. The retrieved data is daily rainfall data solely from Ninoy Aquino International Airport (NAIA) rain station. The data is provided from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Rainfall data can be found in Appendix 5

3.3.3 Demographic Data

Demographic data is a population data. How many person(s) live in some area. This data is used for calculating wastewater production. Because the wastewater production is in liter/person/day. This data is gathered from Philippine Statistic Authority's (PSA) website (psa.gov.ph). This data can be seen in Appendix 6

3.3.4 River Cross-Section Data

This thesis is calculating the river capacity every 500 m from approximately 10 km long. The dimension of the river is known from the cross-section data. This data is mainly collected from field calculation and observation. The wide of the river is calculated from google maps whereas the deep of the rivers are collected from field observation and assumption. The documentation of field observation in provided in Appendix 17

3.3.5 Wastewater Data

Wastewater data is how many water consumptions per person per one day. This data was coming from the discussion paper from Philippines Institute of Development Study. The daily water requirement data can be found in chapter 4 and Appendix 7

3.4 Hydrology Analysis

3.4.1 Stormwater Analysis

Stormwater analysis is calculating how much water from the precipitation will come to the Pateros river. The steps are:

1. Processing the daily rainfall data obtained to be a yearly daily maximum rainfall data (R24)
2. Determine the return period of the rain. Return period is known as a recurrence interval or an estimate of the likelihood of an event. In this graduation project, the return period calculated are 2,5,10,25,50,100 years
3. Using Gumbel type I and Log Pearson type III distribution methods to find the rainfall (mm) of each return period.
4. Check the distribution methods above with fit tests such as Chi-Squared test, Smirnov Kolmogorov test, and Anderson Darling test to find if the distributions can be used for design and analyze and picking one of those distributions which is fitter with the current situation.
5. Find the intensity of the rain (I) with the formula stated in chapter 2
6. Find the catchment area of every 500 m in the river
7. Find the runoff coefficient (C) based on the land-usage in the Municipality of Pateros
8. Define the return period needed for analyze and design of primary channel and find the stormwater discharge using Rational Formula

3.4.2 Wastewater Analysis

The steps of calculating the wastewater is stated below.

1. Find the population every Pateros river's affected barangays. In this thesis, the calculation of it will be explained below.
   a. Find the growth rate in Philippines by using linear regression in 2010-2015 Philippines population. The Philippine population data is stated in Appendix 6

   b. Using Future Value formula which is stated in Chapter 2 to find estimated population of every barangay affected in 2016
2. With the water usage data from appendix 7 and using wastewater discharge formulas in chapter 2, the maximum discharge of wastewater can be found.

3.5 Analysis of Pateros River

3.5.1 River Capacity Analysis

This part is calculating the capacity of the river every point which is reviewed (every 500m). The capacity of every point is different because the divergent of the wideness and deepness in every point. The slope of the river is assumed to be 0.2% based on the average of The formula for calculating the discharge capacity is using continuous formula, stated in chapter 2.

3.5.2 Capacity vs Demand

After the discharge capacity and the discharge demand which are combination of stormwater and wastewater discharge are found of each point, these two measurements need to be compared. If the capacity is bigger than the demand, there is no overflow in the river and if the capacity is smaller, river protection solution shall be made.

3.5.3 Formulating Solutions

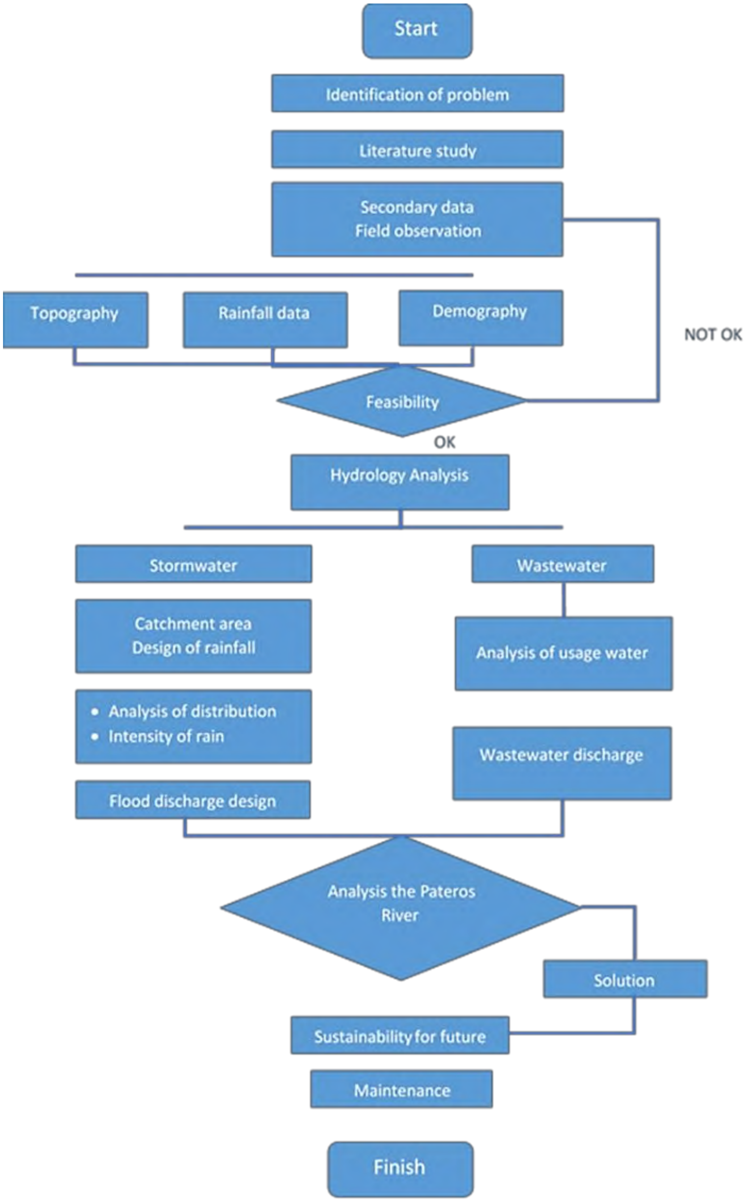
As stated above, this measure is only being done if the demand is bigger than the capacity. Every point of the river might be having different suitable solution. It is depending on the space available, surrounding environment, etc. Possible solutions are stated in room of the river in Chapter 2. Strength Weakness Opportunity and Threat method (SWOT) of solutions are conducted to find the most reasonable solution.

3.5.4 Sustainabiliyy of Pateros River in the Future

The sustainability of the river depends on many things. This is analysis about how to sustain the Pateros river for the future. For example, when the author investigated the river, there were massive amount of rubbish. It could be concluded if the awareness people for the river is bad. Therefore, the river awareness education is badly needed. Secondly, the street in the Municipality of Pateros is too narrow, this might be a problem when they want to put a heavy machine in the river for maintenance. Therefore, a construction of bigger road is advised, etc.

3.5.5 Maintenance Plan

This sector is planning about the maintenance of the river, so the river can always work properly. The maintenance planning depends on the situation in the river, the people awareness of the river, waterlilies growth time, trash and rubbish in the river, sediment movement in the river bed, etc. This is analysis about the maintenance problems, the needed equipment(s), and the schedule. This can be seen in Appendix 15


Start
Identification of problem
Literature study
Secondary data
Field observation
Topography
Rainfall data
Demography
NOT OK
Feasibility
OK
Hydrology Analysis
Stormwater
Wastewater
Catchment area
Design of rainfall
Analysis of usage water
• Analysis of distribution
• Intensity of rain
Wastewater discharge
Flood discharge design
Analysis the Pateros River
Solution
Sustainability for future
Maintenance
Finish

CHAPTER IV
CALCULATION AND DATA ANALYSIS

4.1 General Review

In this part, a summary of what are calculated is provided. For evaluating the primary river, these are the calculations and analysis:

I. Stormwater Discharge, consist of:
   a. Yearly maximum daily rainfall data processing (R24)
   b. Design intensity rainfall analysis with assigned return period
   c. Design stormwater discharge calculation

II. Wastewater Discharge, consist of:
   a. Projected calculation for 2016 population of every barangay relate to the river
   b. Design wastewater discharge calculation

III. Pateros River Discharge Capacity

IV. Soil Classification

V. Formulating solutions made up from Solution's SWOT analysis

VI. Maintenance Planner

4.2 Stormwater Discharge Calculation and Analysis

4.2.1 Rainfall Data Analysis

Data obtained solely from Ninoy Aquino International Airport (NAIA) rain station because that is the only one station nearby the study area. Rainfall data used is planned for 47 years, starting from 1949 to 1992, 2011, 2012, and 2013. The maximum yearly daily rainfall data of NAIA station is shown in table 4 below.

No	Year	Rainfall R24 (mm)	No	Year	Rainfall R24 (mm)	No	Year	Rainfall R24 (mm)	No	Year	Rainfall R24 (mm)
1	1949	86.6	13	1961	225.3	25	1973	129	37	1985	316.8
2	1950	110.5	14	1962	166.1	26	1974	144.1	38	1986	321.4
3	1951	84.3	15	1963	228.9	27	1975	218.3	39	1987	103
4	1952	228.6	16	1964	277.9	28	1976	256	40	1988	158.2
5	1953	140	17	1965	65.3	29	1977	199	41	1989	102
6	1954	117.9	18	1966	145.3	30	1978	274.5	42	1990	280.2
7	1955	84.1	19	1967	100.4	31	1979	104	43	1991	130.8
8	1956	146.6	20	1968	114.5	32	1980	87	44	1992	191
9	1957	119.1	21	1969	81.4	33	1981	76.4	45	2011	151.5
10	1958	353.8	22	1970	198.5	34	1982	69.4	46	2012	107
11	1959	111.5	23	1971	119	35	1983	112.2	47	2013	326
12	1960	229.1	24	1972	472.4	36	1984	93.2			

Table 1 Yearly Daily Maximum Rainfall Data (R24)

4.2.2 Rainfall Intensity Analysis

From yearly daily maximum rainfall data above is necessary to determine the possibility of a recurrence of the daily rainfall to determine the maximum flood discharge plan.

4.2.2.1 Statistic Parameter

Could not be denied that most of hydrology variables have different value with the average value. There is a possibility that the value of variable below or exceed the average value. The dispersion can be measured by statistical parameter such as $(X_1\text{-}X)$, $(X_1\text{-}X)^2$, $(X_1\text{-}X)^3$, $(X_1\text{-}X)^4$. Where:

X_i = Rainfall value (mm)

X = Average maximum rainfall value (mm)

Calculation of statistical parameters are shown in table 5 below

Num	Year	Rainfall (Xi)	Mean (X)	Xi-X	(Xi-X)2	(Xi-X)3	(Xi-X)4
1	1972	472.4	169.3213	303.079	91856.71	27839815	8437655646
2	1958	353.8	169.3213	184.479	34032.4	6278254	1158204208
3	2013	326	169.3213	156.679	24548.22	3846184	602615221.4
4	1986	321.4	169.3213	152.079	23127.94	3517267	534901521.3
5	1985	316.8	169.3213	147.479	21749.97	3207658	473061362.8
6	1990	280.2	169.3213	110.879	12294.09	1363153	151144681
7	1964	277.9	169.3213	108.579	11789.34	1280071	138988518.2
8	1978	274.5	169.3213	105.179	11062.56	1163546	122380319.1
9	1976	256	169.3213	86.6787	7513.201	651234.7	56448190.63
10	1960	229.1	169.3213	59.7787	3573.496	213619	12769872.03
11	1963	228.9	169.3213	59.5787	3549.624	211482.1	12599832.55
12	1952	228.6	169.3213	59.2787	3513.967	208303.5	12347964.42
13	1961	225.3	169.3213	55.9787	3133.617	175415.9	9819558.473
14	1975	218.3	169.3213	48.9787	2398.915	117495.8	5754794.839
15	1977	199	169.3213	29.6787	880.8266	26141.81	775855.5396
16	1970	198.5	169.3213	29.1787	851.3979	24842.7	724878.3833
17	1992	191	169.3213	21.6787	469.967	10188.29	220869.0266
18	1962	166.1	169.3213	-3.2213	10.37662	-33.426	107.6743029
19	1988	158.2	169.3213	-11.121	123.6828	-1375.51	15297.43331
20	2011	151.5	169.3213	-17.821	317.5979	-5660	100868.4258
21	1956	146.6	169.3213	-22.721	516.2564	-11730	266520.681
22	1966	145.3	169.3213	-24.021	577.0217	-13860.8	332954.0761
23	1974	144.1	169.3213	-25.221	636.1128	-16043.6	404639.4856
24	1953	140	169.3213	-29.321	859.7373	-25208.6	739148.1583
25	1991	130.8	169.3213	-38.521	1483.889	-57161.3	2201925.824
26	1973	129	169.3213	-40.321	1625.805	-65554.5	2643243.024
27	1957	119.1	169.3213	-50.221	2522.177	-126667	6361374.917
28	1971	119	169.3213	-50.321	2532.231	-127425	6412193.221
29	1954	117.9	169.3213	-51.421	2644.148	-135965	6991516.989
30	1968	114.5	169.3213	-54.821	3005.372	-164758	9032263.068
31	1983	112.2	169.3213	-57.121	3262.84	-186378	10646126.43
32	1959	111.5	169.3213	-57.821	3343.3	-193314	11177655.07
33	1950	110.5	169.3213	-58.821	3459.943	-203518	11971202.66
34	2012	107	169.3213	-62.321	3883.942	-242052	15085001.7
35	1979	104	169.3213	-65.321	4266.869	-278717	18206172.57
36	1987	103	169.3213	-66.321	4398.512	-291715	19346905.43
37	1989	102	169.3213	-67.321	4532.154	-305110	20540422.44
38	1967	100.4	169.3213	-68.921	4750.142	-327386	22563852.51
39	1984	93.2	169.3213	-76.121	5794.449	-441081	33575636.32
40	1980	87	169.3213	-82.321	6776.793	-557874	45924917.68

41	1949	86.6	169.3213	-82.721	6842.81	-566046	46824043.24
42	1951	84.3	169.3213	-85.021	7228.617	-614586	52252910.58
43	1955	84.1	169.3213	-85.221	7262.666	-618934	52746317.2
44	1969	81.4	169.3213	-87.921	7730.151	-679645	59755232.6
45	1981	76.4	169.3213	-92.921	8634.364	-802316	74552235.54
46	1982	69.4	169.3213	-99.921	9984.262	-997640	99685478.03
47	1965	65.3	169.3213	-104.02	10820.43	-1125555	117081618.5
Sum		7958.1		-4E-13	376172.9	40951363	12,477,851,075.40

Table 2 Statistic Parameter

The calculations of dispersion are following below:

A. Standard Deviation (S_d)

The formula of standard deviation is taken from chapter 2

$$S_d = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

$$S_d = \sqrt{\frac{376172.9}{47-1}} = 90.43$$

B. Skewness (C_s)

The formula of skewness is taken from chapter 2

$$C_s = \frac{n \sum_{i-1}^{n} \{(x_i) - \bar{x}\}^3}{(n-1)(n-2)sd^3}$$

$$C_s = \frac{47 * 40951363}{(46)(45)90.43^3} = 1.257$$

C. Coefficient of Kurtosis (C_k)

The formula of kurtosis coefficient is taken from chapter 2

$$C_k = \frac{n(n+1)}{(n-1)(n-2)(n-3)} * \frac{\sum_{i-1}^{n} \{(x_i) - \bar{x}\}^4}{sd^4} - \frac{3(n-1)^2}{(n-2)(n-3)}$$

$$C_k = \frac{47(47+1)}{(47-1)(47-2)(47-3)} * \frac{12{,}477{,}851{,}075.4}{90.34^4} - \frac{3(47-1)^2}{(47-2)(47-3)} = 1.415$$

D. Variance Coefficient

The formula of variance coefficient is taken from chapter 2

$$C_v = \frac{S_d}{\bar{x}}$$

$$C_v = \frac{90.34}{169.3213} = 0.534$$

The calculations of dispersion are following below:

E. Standard Deviation (S_d)

The formula of standard deviation is taken from chapter 2

$$S_d = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

$$S_d = \sqrt{\frac{376172.9}{47-1}} = 90.43$$

F. Skewness (C_s)

The formula of skewness is taken from chapter 2

$$C_s = \frac{n\sum_{i-1}^{n}\{(x_i) - \bar{x}\}^3}{(n-1)(n-2)sd^3}$$

$$C_s = \frac{47 * 40951363}{(46)(45)90.43^3} = 1.257$$

G. Coefficient of Kurtosis (C_k)

The formula of kurtosis coefficient is taken from chapter 2

$$C_k = \frac{n(n+1)}{(n-1)(n-2)(n-3)} * \frac{\sum_{i-1}^{n}\{(x_i) - \bar{x}\}^4}{sd^4} - \frac{3(n-1)^2}{(n-2)(n-3)}$$

$$C_k = \frac{47(47+1)}{(47-1)(47-2)(47-3)} * \frac{12{,}477{,}851{,}075.4}{90.34^4} - \frac{3(47-1)^2}{(47-2)(47-3)} = 1.415$$

H. Variance Coefficient

The formula of variance coefficient is taken from chapter 2

$$C_v = \frac{S_d}{\bar{x}}$$

$$C_v = \frac{90.34}{169.3213} = 0.534$$

4.2.2.2 Gumbel Type I Method

The formula of Gumbel Type I Method can be found in Chapter 2. Based on step by step provided in Chapter 2, the table 6 below provides the result of the calculation of reduced variate:

Rank	Year	Rainfall (Xi)	P	T (Return Period)	y (Reduced Variate)
		mm	m/(N+1)	1/P	Y=-ln(ln(1-P))
1	1972	472.4	0.020833	48	3.860692775
2	1958	353.8	0.041667	24	3.156849494
3	2013	326	0.0625	16	2.740493007
4	1986	321.4	0.083333	12	2.441716399
5	1985	316.8	0.104167	9.6	2.207266775
6	1990	280.2	0.125	8	2.013418678
7	1964	277.9	0.145833	6.857143	1.847511462
8	1978	274.5	0.166667	6	1.701983355
9	1976	256	0.1875	5.333333	1.571952527
10	1960	229.1	0.208333	4.8	1.454081455
11	1963	228.9	0.229167	4.363636	1.345985401
12	1952	228.6	0.25	4	1.245899324
13	1961	225.3	0.270833	3.692308	1.152478524
14	1975	218.3	0.291667	3.428571	1.064673327
15	1977	199	0.3125	3.2	0.981647055
16	1970	198.5	0.333333	3	0.902720456
17	1992	191	0.354167	2.823529	0.827332944
18	1962	166.1	0.375	2.666667	0.755014863
19	1988	158.2	0.395833	2.526316	0.685367162
20	2011	151.5	0.416667	2.4	0.6180462
21	1956	146.6	0.4375	2.285714	0.552752143
22	1966	145.3	0.458333	2.181818	0.489219929
23	1974	144.1	0.479167	2.086957	0.42721209
24	1953	140	0.5	2	0.366512921
25	1991	130.8	0.520833	1.92	0.306923616
26	1973	129	0.541667	1.846154	0.248258101
27	1957	119.1	0.5625	1.777778	0.190339326
28	1971	119	0.583333	1.714286	0.132995836
29	1954	117.9	0.604167	1.655172	0.076058454
30	1968	114.5	0.625	1.6	0.019356889

31	1983	112.2	0.645833	1.548387	-0.037283903
32	1959	111.5	0.666667	1.5	-0.094047828
33	1950	110.5	0.6875	1.454545	-0.151132538
34	2012	107	0.708333	1.411765	-0.208755483
35	1979	104	0.729167	1.371429	-0.267161703
36	1987	103	0.75	1.333333	-0.32663426
37	1989	102	0.770833	1.297297	-0.387508677
38	1967	100.4	0.791667	1.263158	-0.45019365
39	1984	93.2	0.8125	1.230769	-0.515201894
40	1980	87	0.833333	1.2	-0.583198081
41	1949	86.6	0.854167	1.170732	-0.655077053
42	1951	84.3	0.875	1.142857	-0.732099368
43	1955	84.1	0.895833	1.116279	-0.816144641
44	1969	81.4	0.916667	1.090909	-0.910235093
45	1981	76.4	0.9375	1.066667	-1.019781441
46	1982	69.4	0.958333	1.043478	-1.156269006
47	1965	65.3	0.979167	1.021277	-1.353564798

Table 3 Reduced Variate Gumbel Type I Method

To make the reader better understanding of return period (T), the graph between maximum rainfall (Xi) and return period is provided in appendix 8

The graph below shown about how much rainfall will happen in certain return period. From the result of reduced variate of every year, make a scatter plot graph between rainfall amount in y axis and reduced variate in x axis and find the linear regression equation of it. To find rainfall with our desire return period, first we need to transform our desired return period to become desired reduced variate. Then, with the equation found from graph below. X_i is amount of rainfall and Y_t is desired reduced variate.

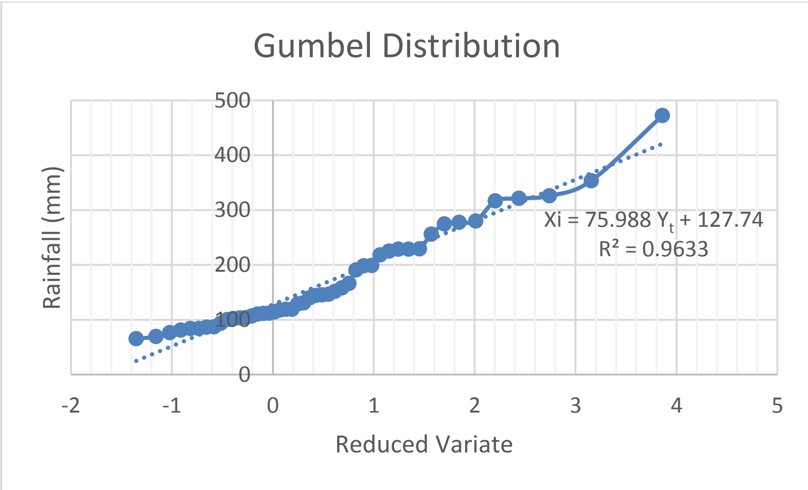


Figure 1 Graph of Reduced Variate vs Rainfall Gumbel Type I Method

T	P	q	Y_t (reduced variate)	**Rainfall X_i (mm)**
2	0.5	0.5	0.366512921	**155.5905838**
5	0.2	0.8	1.499939987	**241.7174397**
10	0.1	0.9	2.250367327	**298.7409125**
25	0.04	0.96	3.198534261	**370.7902215**
50	0.02	0.98	3.901938658	**424.2405147**
100	0.01	0.99	4.600149227	**477.2961394**
200	0.005	0.995	5.295812143	**530.1581731**

Figure 2 Rainfall Amount Based on Desired Return Period (T) with Gumbel Type I Method

4.2.2.3 Log Pearson Type III Method

Calculating rainfall amount with certain return periods using Log Pearson Type III method. The basic formula is:

$Y = \bar{Y} + k.Sd$

Because Y is *log X* then the formula will be

$\log X = \overline{\log X} + k.\log Sd$

All statistic parameter is need to be recalculate because all of them need to be transformed to logarithmic value. Based on the logarithmic statistic parameter in chapter 2, the new value of it and the calculation is displayed in table 7 & 8 following below:

$S_d \log x$ = 0.213784 C_k = -0.78279

C_s = 0.382304 C_v = 0.045704

Rank	Year	Rainfall (Xi)	Log Xi	Log Xi-avg(log(Xi))^2	Log Xi-avg(log(Xi))^3	Return Period	Exceedence Probability
						[(n+1)/m]	1/P
		mm					
1	1972	472.4	2.6743099	0.2492061	0.1244051	48	0.021
2	1958	353.8	2.5487578	0.1396169	0.0521683	24	0.042
3	2013	326	2.5132176	0.1143206	0.0386533	16	0.0625
4	1986	321.4	2.5070459	0.1101852	0.0365750	12	0.083
5	1985	316.8	2.5007852	0.1060680	0.0345443	9.6	0.104
6	1990	280.2	2.4474681	0.0741820	0.0202045	8	0.125
7	1964	277.9	2.4438885	0.0722449	0.0194183	6.857	0.146
8	1978	274.5	2.4385423	0.0693996	0.0182825	6	0.167
9	1976	256	2.4082400	0.0543522	0.0126714	5.333	0.1875
10	1960	229.1	2.3600251	0.0341957	0.0063235	4.8	0.208
11	1963	228.9	2.3596458	0.0340565	0.0062847	4.364	0.229
12	1952	228.6	2.3590762	0.0338456	0.0062266	4	0.25
13	1961	225.3	2.3527612	0.0315619	0.0056072	3.692	0.271

14	1975	218.3	2.3390537	0.0268794	0.0044069	3.429	0.292
15	1977	199	2.2988531	0.0153137	0.0018951	3.2	0.3125
16	1970	198.5	2.2977605	0.0150445	0.0018453	3	0.333
17	1992	191	2.2810334	0.0112210	0.0011886	2.824	0.354
18	1962	166.1	2.2203696	0.0020489	0.0000927	2.667	0.375
19	1988	158.2	2.1992065	0.0005809	0.0000140	2.526	0.396
20	2011	151.5	2.1804126	0.0000282	0.0000001	2.4	0.417
21	1956	146.6	2.1661340	0.0000805	-0.0000007	2.286	0.4375
22	1986	145.3	2.1622656	0.0001648	-0.0000021	2.182	0.458
23	1974	144.1	2.1586640	0.0002703	-0.0000044	2.087	0.479
24	1953	140	2.1461280	0.0008396	-0.0000243	2	0.5
25	1991	130.8	2.1166077	0.0034219	-0.0002002	1.92	0.521
26	1973	129	2.1105897	0.0041621	-0.0002685	1.846	0.542
27	1957	119.1	2.0759118	0.0098392	-0.0009760	1.778	0.5625
28	1971	119	2.0755470	0.0099117	-0.0009868	1.714	0.583
29	1954	117.9	2.0715138	0.0107310	-0.0011116	1.655	0.604
30	1968	114.5	2.0588055	0.0135254	-0.0015730	1.6	0.625
31	1983	112.2	2.0499929	0.0156529	-0.0019584	1.548	0.646
32	1959	111.5	2.0472749	0.0163404	-0.0020888	1.5	0.667
33	1950	110.5	2.0433623	0.0173560	-0.0022865	1.455	0.6875
34	2012	107	2.0293838	0.0212345	-0.0030943	1.412	0.708
35	1979	104	2.0170333	0.0249865	-0.0039496	1.371	0.729
36	1987	103	2.0128372	0.0263306	-0.0042726	1.333	0.75
37	1989	102	2.0086002	0.0277236	-0.0046161	1.297	0.771
38	1967	100.4	2.0017337	0.0300574	-0.0052111	1.263	0.792
39	1984	93.2	1.9694159	0.0423077	-0.0087022	1.231	0.8125
40	1980	87	1.9395193	0.0555003	-0.0130751	1.2	0.833
41	1949	86.6	1.9375179	0.0564473	-0.0134111	1.171	0.854
42	1951	84.3	1.9258276	0.0621389	-0.0154898	1.143	0.875
43	1955	84.1	1.9247960	0.0626543	-0.0156829	1.116	0.896
44	1969	81.4	1.9106244	0.0699497	-0.0185003	1.091	0.917
45	1981	76.4	1.8830934	0.0852704	-0.0248999	1.067	0.9375
46	1982	69.4	1.8413595	0.1113857	-0.0371744	1.043	0.958
47	1965	65.3	1.8149132	0.1297377	-0.0467304	1.021	0.979
		169.321	2.1751044	2.1023713	0.1645164		
		Average		Sum			

Table 4 Frequency Distribution with Log Pearson Type III Method

T	$K_{(1)}(0.3)$	$K_{(2)}(0.4)$	$K_{(2)}-K_{(1)}$	$K_{(x)}(0.3823)$	Log (Rainfall)	**Rainfall (mm)**
2	-0.05	-0.066	-0.016	-0.0632	2.1616	**145.0774**
5	0.824	0.816	-0.008	0.8174	2.3499	**223.7974**
10	1.309	1.317	0.008	1.3156	2.4564	**285.9932**
25	1.849	1.88	0.031	1.8745	2.5758	**376.5703**
50	2.211	2.261	0.05	2.2522	2.6566	**453.5019**
100	2.544	2.615	0.071	2.6024	2.7315	**538.8456**
200	2.856	2.949	0.093	2.9325	2.8020	**633.9223**

Table 5 Rainfall Amount with Desired Return Period Using Log Pearson Type III Method

K_1 and K_2 value can be found in table 1 in Chapter 2. The result of rainfall calculation will all of method is shown in table 9 below

T	R24	
	Gumbel	Log Pearson
Year	mm	mm
2	155.5906	145.0774
5	241.7174	223.7974
10	298.7409	285.9932
25	370.7902	376.5703
50	424.2405	453.5019
100	477.2961	538.8456
200	530.1582	633.9223

Table 6 Recapitulation of Rainfall Calculation

4.2.3 Fit Test for Distributions

Fit test is conducted by computer program EasyFit 5.6 Standard, the result will be shown in Appendix 9 In this case, Log Pearson Type III Distribution is better than Gumbel Type I as shown in the test, so Log Pearson Type III rainfall is used for analysis

4.2.4 Stormwater Discharge Analysis

As you can see in the picture below. The red dots are the point where the discharge is calculated. Every section of the river (red dot) has different stormwater discharge because the catchment area is different.

Figure 3 Pateros River Points

Bigger picture of the points is available in the appendix 10

4.2.4.1 Determine Catchment Area

To determine catchment area in the neighborhood area, there are some analyses need to be done, such as slope analysis and drainage system analysis. The water is come from Pasig river to the Laguna Bay. Because lack of data of slope and drainage system, the catchment area of each point is calculated based on the area of barangays that affect the river and rough analysis about slope in Pateros river. the following below is catchment area of every point.

Point	AREA (km2)
1	7.685873
2	7.419473
3	7.153073
4	6.886673
5	6.476273
6	5.15807

Point	AREA (km2)
11	3.36407
12	2.98907
13	2.59544
14	1.56611
15	0.90971
16	0.78618

7	4.93807		17	0.57862
8	4.51407		18	0.7008
9	4.28157		19	0.2766
10	4.04907		20	0.163

Table 7 Catchment Area

4.2.4.2 Time of Concentration

The formula of time concentration is taken from chapter 2. The data obtained are

- Elevation upstream = 8 m
- Elevation downstream = 3.2 m
- ΔH_r = 4.8 m
- L = 9.57 km

Elevation data is obtained from iOS application called Elevation – Find Your Elevation and verified by topographic map obtained from National Mapping and Resource Information Authority (NAMRIA). Length of the river is calculated by Google Maps.

$$W = 72 * \left(\frac{\Delta H}{L}\right)^{0.6} = 72 * \left(\frac{\frac{4.8}{1000}}{9.57}\right)^{0.6} = 0.7543\ km/hour$$

$$t_c = \frac{L}{W} = \frac{9.57}{0.7543} = 12.688\ hour$$

4.2.4.3 Intensity of Rainfalll

The formula for intensity of rainfall as stated in chapter 2 is:

$$I = \frac{R_{24}}{24} * \left[\frac{24}{t}\right]^{\frac{2}{3}}$$

The result of rainfall intensity calculation is in table 11 below

Return Period (T)	I
	Log Pearson Type III
Year	mm/hour
2	9.245737746

5	14.26253347
10	18.22625004
25	23.99870378
50	28.90152945
100	**34.34045382**
200	40.39966075

Table 8 Intensity of Rain

In Indonesia, for planning a primary channel with high risk value usually using 25-year return period of rain. Because Philippine has more typhoon, slightly more amount of rain and for safety reason, the 100-year return period of rain is used for analyzing in this thesis project.

4.2.4.4 Stormwater Discharge Analysis

For calculating storm water discharge using Rational formula as stated in chapter 2, some data should be determined, such as

Runoff Coefficient (C) = 0.6

It is because the Municipality of Pateros is a neighborhood area (0,5-0,7). Moreover, because the area is not developed yet, there are some green area which could filtrate the rainwater. That’s why the 0.6 is chosen.

The formula for calculate the stormwater discharge is:

$$Q_s = \frac{1}{3.6}.C.I.A$$

The result of computation is displayed in table 12 below.

Point	C	I(mm/hour)	A(km^2)	Q_s(m^3/s)
1	0.6	34.34045382	7.6858725	43.98939
2	0.6	34.34045382	7.4194725	42.46468
3	0.6	34.34045382	7.1530725	40.93996
4	0.6	34.34045382	6.8866725	39.41524
5	0.6	34.34045382	6.4762725	37.06636

6	0.6	34.34045382	5.15807	29.52174
7	0.6	34.34045382	4.93807	28.26259
8	0.6	34.34045382	4.51407	25.83587
9	0.6	34.34045382	4.28157	24.50518
10	0.6	34.34045382	4.04907	23.17448
11	0.6	34.34045382	3.36407	19.25395
12	0.6	34.34045382	2.98907	17.10767
13	0.6	34.34045382	2.59544	14.85476
14	0.6	34.34045382	1.56611	8.963488
15	0.6	34.34045382	0.90971	5.206642
16	0.6	34.34045382	0.78618	4.49963
17	0.6	34.34045382	0.57862	3.311679
18	0.6	34.34045382	0.7008	4.010965
19	0.6	34.34045382	0.2766	1.583095
20	0.6	34.34045382	0.163	0.932916

Table 9 Stormwater Discharge

4.3 Wastewater Discharge Calculation and Analysis

4.3.1 Population 2016

The latest information about population available from barangay is in 2010. To find the estimated 2016 population. The data obtained are:

- Philippines population 2010-2015 in million. The data is in table 13 below
- Population every barangay in 2010

To find estimated 2016 population, these steps need to be taken:

1. Find the 2016 growth rate of Philippine population based on 2010-2015 data.

Year	Population	Growth Population	Growth rate (%)
2010	92.6		
2011	94.8	2.2	2.37581

2012	97.1	2.3	2.42616
2013	98.8	1.7	1.750772
2014	100.5	1.7	1.720648
2015	102.2	1.7	1.691542

Table 10 Philippine Population 2010-2015 (tradingeconomics.com)

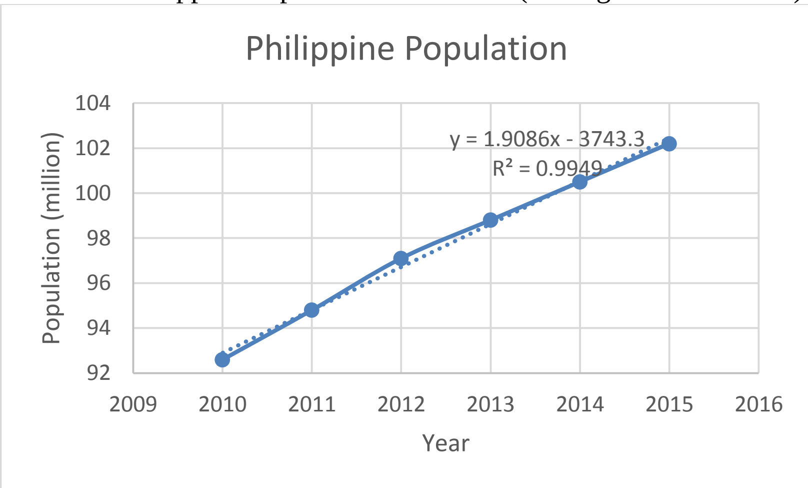


Figure 4 Graph of 2010-2015 Philippines Population

Based on that linear regression in the graph, the 2016 estimated population of Philippines can be found. Thus, the 2016 growth rate also known. Y is population in million and x is the year. For 2016 Philippines population:

$$y = 1.9086x - 3743.3 = 1.9086 * 2016 - 3743.3$$
$$= 104.44\, million$$

For 2016 growth rate:

$$i = \frac{P_x - P_{x-1}}{P_{x-1}} * 100\% = \frac{104.44 - 102.2}{102.2} * 100\% = 2.189$$

2. Using future value equation stated in chapter 2, find estimated 2016 population data. The formula is
   $FV = PV(1 + i)^n$

The result of it will be provided in the table 14 next page, the complete calculation is provided in the appendix 11

Municipality of Pateros			City of Makati			City of Taguig	
Barangays	Pop 2016		Barangays	Pop 2016		Barangays	Pop 2016
Aguho	7835		Comembo	16278.05487		Wawa	9496
Magtanggol	1979		East Rembo	29812.08511		Bambang	8084
Martires Del 96	5553		Pembo	50530.42973		Santa Ana	16781
Poblacion	2677		Rizal	47322.86456		Ususan	36342
San Pedro	2578					Tuktukan	9150
San Roque	5189		City of Pasig				
Santa Ana	30299		Barangay	Pop 2016			
Santo Rosario-Kanluran	6947		Buting	11168			
Santo Rosario-Silangan	5875						
Tabacalera	3413						

Table 11 Barangay Population 2016

Total population for Pateros river in 2016 is **307313** persons

4.3.2 Spent Water

The wastewater production data are(Gleick,1996)

Daily Water Requirement of Metro Manila		
Survival	5	l/p/day
Food Prep	6	l/p/day
Bathing	37.8	l/p/day
Sanitation	60.5	l/p/day
Laundry	38	l/p/day

Table 12 Daily Water Requirement of Metro Manila (Gleick,1996)

Total of daily water requirement = 147,3 liter/person/day

Spent water (S_w) = 0.65 * 147,3

= **95,745** liter/person/day

4.3.3 Wastewater Discharge Analysis

Using formula below, we can find the average wastewater discharge

$$Q_w = \frac{Sw}{24 * 3600} * P = \frac{95,745}{24 * 3600} * 307313 = 340,55 \frac{l}{s}$$
$$= 0.34055 \frac{m^3}{s}$$

For design and analyze, not the average of wastewater is used, but the maximum of wastewater discharge. There are 2 methods of calculating the maximum discharge. Between those two methods, the higher value is used one.

First formula

$$Q_{w\,max} = 1.255 * Q_w = 1.255 * 0.34055 = 0.4274 \frac{m^3}{s}$$

Second formula

$$Q_{w\,max} = \frac{5}{P'^{\frac{1}{6}}} * Q_w = \frac{5}{307.313^{\frac{1}{6}}} * 0.34055 = 0.655475 \frac{m^3}{s}$$

The amount of wastewater discharge is **0.655475 m^3/s**

Point	$Q_{stormwater}$ (m^3/s)	$Q_{wastewater}$ (m^3/s)	Q_{total} (m^3/s)
1	43.98939	0.655475	44.64487
2	42.46468	0.655475	43.12015
3	40.93996	0.655475	41.59543
4	39.41524	0.655475	40.07072
5	37.06636	0.655475	37.72183
6	29.52174	0.655475	30.17722
7	28.26259	0.655475	28.91807
8	25.83587	0.655475	26.49134
9	24.50518	0.655475	25.16065
10	23.17448	0.655475	23.82996
11	19.25395	0.655475	19.90942
12	17.10767	0.655475	17.76315

13	14.85476	0.655475	15.51024
14	8.963488	0.655475	9.618963
15	5.206642	0.655475	5.862117
16	4.49963	0.655475	5.155105
17	3.311679	0.655475	3.967154
18	4.010965	0.655475	4.66644
19	1.583095	0.655475	2.23857
20	0.932916	0.655475	1.588391

Table 13 Calculation Recap of Flood Design Discharge

4.4 River Discharge Capacity Calculation and Analysis

To calculate the capacity of the river in every point (every 500m), these following data need to be acquired:

- Shape of the river
  Based on field observation and calculation, the shape of the river is trapezoidal and the slope of the river bank is 1:4
- Deepness of the river
  The deepness is roughly calculated in the river
- Wideness of the river
  The wideness is calculated by Google Maps
- Slope
  Due to lack of data, the river slope is roughly estimated 0.02%
- Roughness Coefficient / Manning Coefficient

Based on Manning Coefficient table (Chow,1959) provided in appendix 12, Manning coefficient for winding, some pools, weeds and stones main channel is 0.45

The river dimension is provided in table 17 below

Point	b(m)	h(m)
0	43	3.8
1	42	3.5
2	41	3.4
3	40	3.2
4	36	3
5	27	2.6
6	32	2.6
7	22	2.4
8	21	2.2
9	26	2.1
10	14	2
11	18	2
12	24	1.8
13	26	1.8
14	13	1.6
15	17	1.6
16	16	1.7
17	15	1.5
18	17.5	1.55
19	14	1.3
20	15	1.2

Table 14 River Profile

To calculate the river capacity, use very simple basic continuous formula below

$Q_c = v * A$ (m^3/s)

$v = C * \sqrt{R * S}$ (m/s)

$$C = \frac{1}{n} * R^{\frac{1}{6}}$$

$$R = \frac{A}{P} \qquad \text{(m)}$$

$$A = \frac{1}{2} * (a + b) * h \qquad (\text{m}^2)$$

$$P = b + 2 * \sqrt{x^2 + h^2} \quad \text{(m)}$$

Every point has different wet area and wet circumference of the river, causing different hydraulic radius, chezy coefficient, velocity, and the discharge capacity.

The result of calculation is displayed in table 18 below

Point	B(m)	H(m)	A(m2)	P(m)	R(m)	C	I	v(m/s)	Q_o(m3/s)
1	42	3.5	150.06	49.8262	3.0117	26.705	0.0002	0.6554	**98.352**
2	41	3.4	142.29	48.6026	2.9276	26.579	0.0002	0.6431	**91.514**
3	40	3.2	130.56	47.1554	2.7687	26.333	0.0002	0.6197	**80.903**
4	36	3	110.25	42.7082	2.5815	26.027	0.0002	0.5914	**65.202**
5	27	2.6	71.89	32.8138	2.1908	25.325	0.0002	0.5301	**38.111**
6	32	2.6	84.89	37.8138	2.2449	25.429	0.0002	0.5388	**45.74**
7	22	2.4	54.24	27.3666	1.982	24.906	0.0002	0.4959	**26.896**
8	21	2.2	47.41	25.9193	1.8291	24.575	0.0002	0.47	**22.285**
9	26	2.1	55.703	30.6957	1.8147	24.543	0.0002	0.4676	**26.044**
10	14	2.1	30.503	18.6957	1.6315	24.111	0.0002	0.4355	**13.285**
11	18	2	37	22.4721	1.6465	24.148	0.0002	0.4382	**16.213**
12	24	1.8	44.01	28.0249	1.5704	23.958	0.0002	0.4246	**18.686**
13	26	1.8	47.61	30.0249	1.5857	23.997	0.0002	0.4273	**20.346**
14	13	1.6	21.44	16.5777	1.2933	23.196	0.0002	0.3731	**7.9982**
15	17	1.6	27.84	20.5777	1.3529	23.37	0.0002	0.3844	**10.703**
16	16	1.7	27.923	19.8013	1.4101	23.532	0.0002	0.3952	**11.035**
17	15	1.5	23.063	18.3541	1.2565	23.084	0.0002	0.3659	**8.4396**
18	17.5	1.55	27.726	20.9659	1.3224	23.282	0.0002	0.3786	**10.498**
19	14	1.3	18.623	16.9069	1.1015	22.583	0.0002	0.3352	**6.242**
20	15	1.2	18.36	17.6833	1.0383	22.362	0.0002	0.3222	**5.9163**

Table 15 Capacity of the River

After calculating the capacity of the river above, comparison of it and stormwater and wastewater discharge is conducted. The table 19 below shows the comparison of it.

Q_{storm} (m³/s)	Q_{waste} (m³/s)	Q_t (m³/s) $Q_{storm}+Q_{waste}$	Q_c(m3/s)	Q_c-Q_t	Info
43.989	0.6555	44.645	98.352	53.707	OK
42.465	0.6555	43.12	91.514	48.394	OK
40.94	0.6555	41.595	80.903	39.308	OK
39.415	0.6555	40.071	65.202	25.131	OK
37.066	0.6555	37.722	38.111	0.3888	OK
29.522	0.6555	30.177	45.74	15.563	OK
28.263	0.6555	28.918	26.896	-2.022	NOT OK
25.836	0.6555	26.491	22.285	-4.207	NOT OK
24.505	0.6555	25.161	26.044	0.8834	OK
23.174	0.6555	23.83	12.311	-11.52	NOT OK
19.254	0.6555	19.909	16.213	-3.696	NOT OK
17.108	0.6555	17.763	18.686	0.9232	OK
14.855	0.6555	15.51	20.346	4.8357	OK
8.9635	0.6555	9.619	7.9982	-1.621	NOT OK
5.2066	0.6555	5.8621	10.703	4.8404	OK
4.4996	0.6555	5.1551	11.035	5.8797	OK
3.3117	0.6555	3.9672	8.4396	4.4725	OK
4.011	0.6555	4.6664	10.498	5.8313	OK
1.5831	0.6555	2.2386	6.242	4.0034	OK
0.9329	0.6555	1.5884	5.9163	4.3279	OK

Table 16 Comparison Q_c vs Q_t

As you can see in the table 19 above, there are 5 points in the river that need to be rehabilitate. Every point's problem maybe has different solution. Therefore, analysis of solution needs to be made.

Point	B(m)	H(m)	A(m²)	P(m)	R(m)	C	I	v(m/s)	Q(m³/s)
7	22	2.4	54.24	27.3666	1.982	24.906	0.0002	0.4959	26.896
8	21	2.2	47.41	25.9193	1.8291	24.575	0.0002	0.47	22.285
10	14	2	29	18.4721	1.5699	23.957	0.0002	0.4245	12.311
11	18	2	37	22.4721	1.6465	24.148	0.0002	0.4382	16.213
14	13	1.6	21.44	16.5777	1.2933	23.196	0.0002	0.3731	7.9982

4.5 SWOT Analysis of Solutions

There are 5 points that need some capacity improvements. The basic solution of deficient capacity is making the river bigger by deepening the river bed or widening the river bank. Of course, to make a proper solution need deeper investigation, in this part below, provides only the brief solution made by the author.

4.5.1 Point 7 and 8

Based on the fact that point 7 and 8 have insufficient capacity, it can be assumed that the capacity between that points are lacking as well. The detail and picture analysis about these points are provided in Appendix 13

Because there is a big free space of the area between point 7 and 8, making a storage for excess rainwater is advised. The cost is not that much because it is a free space, there is no need to dealing with the residences or with illegal settlers. Besides, it is very sustainable for the future and easy to maintenance because there is a wide road if big machineries are needed.

The free area can be designed as the water square in the Rotterdam. During the summer season, the square functioned as recreational park. People can have a good time there with friends or family and during the wet/rainy season, the square functioned as rainwater storage.

4.5.2 Point 10 and 11

Same on above, with the fact that point 10 and 11 have insufficient capacity, it can be assumed that the capacity between that points are lacking as well. The picture of about these points and SWOT analysis are provided in Appendix 14

On this spot, the main problems are the narrow size of the river (point 10 is only 14m and point 11 is only 18m) and illegal settlers. Therefore, the best way is to widening and deepening the river by moving the illegal settler to new place.

As in Indonesia, the illegal settlers were moved to the apartment which were designed for them by the government. This solution does require a lot of funds, but it has been proven there that this solution is suitable in that kind of problems. It is also sustainable for the future, because there will be no more of illegal settlers in the river so that the capacity of the river is fulfilled and also can rehabilitate the bad water quality in the river. The analyzing water quality of Pateros River is studied by my colleagues, Lotte De Jong and Sije Kloppenburg. To comply the discharge requirement, the wideness from point 10 and 11 should be widened until 22 m.

4.5.3 Point 14

This is the smallest size of the river. Actually in this point, there is only slightly insufficient of capacity and by moving illegal settlers as stated in the previous point, the widened process can be executed. To fulfill the discharge requirement, the wideness for point 14 should be widened until 17 m

4.6 Maintenance Planner

Maintenance planning are the most important part to sustain Pateros River. We cannot just make the usual maintenance planner for the river. One thing that should be considered is the rapidly growth of water hyacinth. Based on the study, the growth rate of water hyacinth is among the highest of any plant. In Florida, water hyacinth populations can double in as little as 12 days by sending off short runner stems, which develop new plants. The full planning about the maintenance is provided in appendix 15

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APPENDIXES

6.1 Appendix 1 Pateros River Map and Barangays

City/Municipality	Barangay
Pateros	Aguho
	Magtanggol
	Martires
	Poblacion
	San Pedro
	San Roque
	Sta. Ana
	Sto. Rosario-Kanluran
	Sto.Rosario-Silangan
	Tabacalera
Makati	Comembo
	East Rembo
	Pembo
	Rizal
Taguig	Wawa
	Bambang
	Santa Ana
	Ususan
	Tuktukan
Pasig	Buting

6.2 Appendix 2 The Municipality of Pateros Map

https://www.google.co.id/maps/place/Pateros,+Metro+Manila,+Filipina/data=!4m2!3m1!1s0x3397c89ab827dc07:0xcc609a1a7ca227d1?sa=X&ved=0ahUKEwjF-omnl6fOAhUHuI8KHZS5DaoQ8gEIHjAA

6.3 Appendix 5 Rainfall Data

Year	Month												Total Rainfall (mm)	Maximum Rainfall (mm)
	1	2	3	4	5	6	7	8	9	10	11	12		
1949	1.5	0.3	8.6	4.3	16.3	86.6	61.5	48	56.6	33.5	33.8	20.8	371.8	86.6
1950	14.5	16.5	25.9	0.8	57.9	33.5	41.4	63	33.5	71.1	52.8	110.5	521.4	110.5
1951	0.3	0	0	5.3	26.4	58.2	83.3	84.3	50.8	46.7	80.5	46	481.8	84.3
1952	13.2	2	5.6	0	44.4	65	18	228.6	27.7	52.6	4.1	18.5	479.7	228.6
1953	1	1.3	1	49	36.3	140	56.9	128.2	96	122.4	44.7	27.2	702	140
1954	2.5	3.6	2.5	0.8	53.8	34.8	53.1	85.3	58.4	38.6	117.9	12.7	464	117.9
1955	18.8	1	0	10.9	45	23.4	25.4	30.2	84.1	32.8	57.9	8.4	337.9	84.1
1956	5.1	8.1	6.1	57.2	33	13.7	69.6	38.1	146.6	25.4	28.2	30	461.1	146.6
1957	15.7	2.3	0.5	3.6	1.5	119.1	47.8	83.6	28.2	102.6	13	4.8	422.7	119.1
1958	4.3	5.6	2.8	2.3	33.8	353.8	194.6	78.2	47.5	30.5	19.3	1.8	774.5	353.8
1959	22.4	1	6.1	0	25.7	2.5	60.7	70.4	46	36.6	111.5	18	400.9	111.5
1960	11.4	8.6	16	33.3	229.1	122.7	35.6	204.7	95.5	125.2	61.5	4.6	948.2	229.1
1961	0.5	2	1.8	9.1	56.4	225.3	67.8	142.4	88.9	129.5	59.2	3.6	786.5	225.3
1962	2	0	1.3	19.8	24.4	45	146.8	49.5	166.1	5.1	34	0.5	494.5	166.1
1963	0.3	0.3	0	0.8	2.5	68.8	48.8	84.6	228.9	24.1	7.6	49.8	516.5	228.9
1964	4.6	2.8	1.3	7.1	12.2	277.9	160	51.9	88.1	38.9	41.9	51	737.7	277.9
1965	1	0.3	1.3	11.7	52.2	41.7	65.3	58.9	36.6	19.8	36.1	11.6	336.5	65.3
1966	11.3	5.8	0	1	90.2	29.2	44.7	48.3	145.3	15.5	94	47.8	533.1	145.3
1967	13.7	6.1	0.5	1	31.5	92	52.1	64.8	58.2	43	100.4	7	470.3	100.4
1968	3.8	0	1.8	0	5.6	45.5	114.5	76.8	65.6	45	10.4	0	369	114.5
1969	0.3	0	5.6	0.2	6.4	22.4	65.7	81.4	41.6	59.4	31.3	21.1	335.4	81.4
1970	55.3	0.8	1.4	0	40.6	38	101.4	81.5	198.5	104	45.5	30	697	198.5
1971	2	0.5	35.5	12.5	21	119	52.5	45	24.8	109	66.5	-2	486.3	119
1972	-2	-2	16.7	0	51.6	143.5	472.4	127.6	33	11.7	18.3	14.6	885.4	472.4
1973	0.5	0	2.3	0.3	12.7	46.2	61	93.4	48.3	129	118.6	29	541.3	129
1974	0	0.5	7.4	0.5	49.6	118	97.1	144.1	15.2	75.5	100	49.6	657.5	144.1
1975	4.3	0	0.5	40.1	3.8	48.2	22.9	104.4	71.4	218.3	73.4	42.3	629.6	218.3
1976	2.8	0	7.4	0	177.8	48.5	73.4	256	85.4	25.6	17	14.7	708.6	256
1977	10.9	7.1	6.1	0	38.9	44	101.3	199	197.2	30.5	121.7	17.6	774.3	199
1978	0	0	0	5.3	41.7	35.7	83.3	115.9	79	274.5	37.1	9.8	682.3	274.5
1979	0	0.8	0	34.3	66	24.9	41.1	104	94.8	22.2	16.1	0	404.2	104
1980	0	0	24.1	0	32.5	28.2	75.6	31.8	87	78.5	78.4	7	443.1	87
1981	1	3	0	3.3	20	69.8	73.8	76.4	68.2	46	65.2	33.4	460.1	76.4
1982	0	0	0.1	50	6.6	28.2	69.4	40.8	52	10.2	22.6	14.2	294.1	69.4
1983	9.7	0	0	0	10	22.6	112.2	65.4	51.1	68.7	22.2	2	363.9	112.2
1984	3	5.2	3.5	1.5	12.8	93.2	39.8	79.8	49	51	10	3.6	352.4	93.2
1985	0	2.8	0	13.8	4	316.8	121.4	41	47	105.7	5.2	12	669.7	316.8
1986	0	2.4	0	19.2	31.3	23	130.8	92.2	125	321.4	66.5	34	845.8	321.4

1987	3.8	0	0	0	6	73.6	36.4	103	82.9	52.4	49.9	57.7	465.7	103
1988	13.4	1.8	0	15.8	69.6	82.8	49.3	62.2	30.2	158.2	57	0	540.3	158.2
1989	12	16.4	7	0	102	31.9	38.5	55	27.1	90.2	15.3	1	396.4	102
1990	2.4	0	13.4	0	60.2	61.4	77.1	280.2	148.8	55.2	51	21	770.7	280.2
1991	2.2	4	9.8	15.5	9.5	14	79.3	130.8	84	8	42.2	5	404.3	130.8
1992	3	1	0	63	22	23.7	122	101.5	88	191	95	6	716.2	191
1993	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1994	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1995	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1996	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1997	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1998	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
1999	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
2000	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
2001	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
2002	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
2003	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-24	-2
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	43.5	0.5	36	4.5	104.5	151.5	83.5	49.5	85.5	70	39.5	46	714.5	151.5
2012	11	21	24.5	4	49.5	11.5	0	0	97	107	3.5	9	338	107
2013	23.5	49	15	17	33	50.5	19.5	326	166	85.5	49	8.5	842.5	326

Actually the acquired data is daily precipitation. Because it requires a lot of space, the author decided to process it into monthly rainfall data as displayed above.

0 and -2 means the data is lost and unrecorded.

6.4 Appendix 6 Population

Municipality/City: PATEROS

Region	NCR - National Capital Region	**Code**	130000000
Province	NCR, FOURTH DISTRICT (Not a Province)	**Code**	137600000
Municipality/City	**PATEROS**	**Code**	137606000
Income Classification:	1st Class	**Registered Voters** (2010): 33,310	
Population : (as of May 1, 2010): 64,147			
District:	lone		

Barangays (Number: 10)

Name	Code	Urban/Rural	Population (as of May 1, 2010)
Aguho	137606001	Urban	6,947
Magtanggol	137606002	Urban	1,755
Martires Del 96	137606003	Urban	4,924
Poblacion	137606004	Urban	2,374
San Pedro	137606005	Urban	2,286
San Roque	137606006	Urban	4,601
Santa Ana	137606007	Urban	26,865
Santo Rosario-Kanluran	137606008	Urban	6,160
Santo Rosario-Silangan	137606009	Urban	5,209
Tabacalera	137606010	Urban	3,026

Municipality/City: CITY OF MAKATI

Region	NCR - National Capital Region	**Code**	130000000
Province	NCR, FOURTH DISTRICT (Not a Province)	**Code**	137600000
Municipality/City	CITY OF MAKATI	**Code**	137602000

Income Classification:	1st Class	**Registered Voters** (2010): 409,126
Population : (as of May 1, 2010): 529,039		
District:	2 LD	

Barangays (Number: 33)

Name	Code	Urban/Rural	Population (as of May 1, 2010)
Comembo	137602004	Urban	14,433
East Rembo	137602007	Urban	26,433
Pembo	137602016	Urban	44,803
Rizal	137602033	Urban	41,959

Municipality/City: TAGUIG CITY

Region	NCR - National Capital Region	**Code**	130000000
Province	NCR, FOURTH DISTRICT (Not a Province)	**Code**	137600000
Municipality/City	TAGUIG CITY	**Code**	137607000

Income Classification:	1st Class	**Registered Voters** (2010): 326,027
Population : (as of May 1, 2010): 644,473		
District:	2 LD	

Barangays (Number: 28)

Name	Code	Urban/Rural	Population (as of May 1, 2010)
Bambang	137607003	Urban	7,168
Tuktukan	137607014	Urban	8,113

Ususan	137607016	Urban	32,223
Wawa	137607017	Urban	8,420
Santa Ana	137607012	Urban	14,879

6.5 Appendix 7 Daily Water Requirement

Daily Water Requirement for Metro Manila		
Range of average daily water requirements for Survival	5	liter/person/day
Estimated Water Requirements for Food Preparation	6	liter/person/day
Estimated Water Requirements for Bathing	37.8	liter/person/day
Estimated Water Requirements for Sanitation	60.5	liter/person/day
Estimated Water Requirements for Laundry	38	liter/person/day

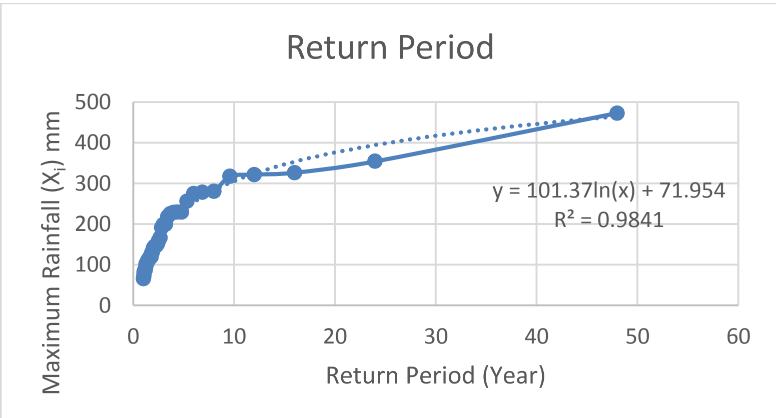
Sources:

Gleick (1996)

UBFHOA (1997)

Dangerfield (1983)

6.6 Appendix 8 Return Period vs Maximum Rainfall Graph



6.7 Fit Test with Easy Fit 5.6 Standard Edition Program

Gumbel Max [#25]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	47 0.12846 0.38706 27				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.15295	0.17481	0.1942	0.21715	0.23298
Reject?	No	No	No	No	No
Anderson-Darling					
Sample Size Statistic Rank	47 0.91076 23				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	4 5.7763 0.21649 32				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	5.9886	7.7794	9.4877	11.668	13.277
Reject?	No	No	No	No	No

Log-Pearson 3 [#39]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	47 0.10745 0.61131 16				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.15295	0.17481	0.1942	0.21715	0.23298
Reject?	No	No	No	No	No
Anderson-Darling					
Sample Size Statistic Rank	47 0.47619 12				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	4 4.2199 0.37707 19				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	5.9886	7.7794	9.4877	11.668	13.277
Reject?	No	No	No	No	No

"Reject? No" means this distribution is allowed (OK), α is level of significant. For this case, the value of α is 0.05 (5%). It can be concluded that the 2 distribution can be used for the discharge calculation. However, because the rank of Log Pearson type III is better than Gumbel Type I, the rainfall value of Log Pearson type III method is used in this dissertation

6.8 Appendix 11 Calculation of Population 2016

Growth rate in Philippines

Year	Population	Growth Population	Growth rate
	Million	Million	%
2010	92.6		
2011	94.8	2.2	2.375809935
2012	97.1	2.3	2.426160338
2013	98.8	1.7	1.7507724
2014	100.5	1.7	1.720647773
2015	102.2	1.7	1.691542289
2016	104.44	2.24	2.189432485

Population 2016

Municipality of Pateros

Barangays	Pop 2010	Pop 2011	Pop 2012	Pop 2013	Pop 2014	Pop 2015	Pop 2016
Aguho	6947	7112	7285	7412	7540	7667	7835
Magtanggol	1755	1797	1840	1873	1905	1937	1979
Martires Del 96	4924	5041	5163	5254	5344	5434	5553
Poblacion	2374	2430	2489	2533	2577	2620	2677
San Pedro	2286	2340	2397	2439	2481	2523	2578
San Roque	4601	4710	4825	4909	4994	5078	5189
Santa Ana	26865	27503	28171	28664	29157	29650	30299
Santo Rosario-Kanluran	6160	6306	6459	6572	6686	6799	6947
Santo Rosario-Silangan	5209	5333	5462	5558	5653	5749	5875
Tabacalera	3026	3098	3173	3229	3284	3340	3413

Total Population 2016: 72347 persons

City of Taguig

Barangays	Pop 2010	Pop 2011	Pop 2012	Pop 2013	Pop 2014	Pop 2015	Pop 2016
Wawa	8420	8620	8829	8984	9138	9293	9496
Bambang	7168	7338	7516	7648	7780	7911	8084
Santa Ana	14879	15232	15602	15875	16148	16422	16781
Ususan	32223	32989	33789	34380	34972	35564	36342
Tuktukan	8113	8306	8507	8656	8805	8954	9150

Total Population 2016: 79854 persons

City of Makati

Barangays	Pop 2010	Pop 2011	Pop 2012	Pop 2013	Pop 2014	Pop 2015	Pop 2016
Comembo	14433	14776	15134	15399	15664	15929	16278
East Rembo	26433	27061	27718	28203	28688	29173	29812
Pembo	44803	45867	46980	47803	48625	49448	50530
Rizal	41959	42956	43998	44768	45539	46309	47323

Total Population 2016: 143943 persons

City of Pasig

Barangay	Pop 2010	Pop 2011	Pop 2012	Pop 2013	Pop 2014	Pop 2015	Pop 2016
Buting	9902	10137	10383	10565	10747	10929	11168

City/Municipality	Population 2016 (persons)
Pateros	72347
Makati	143943
Taguig	79854
Pasig	11168
Total	**307313**

6.9 Appendix 12 Manning Coefficient

Manning's n for Channels (Chow, 1959)

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

6.10 SWOT Solutions for Point 7 & 8

As you can see in the picture below, there is a big free space. Therefore, many solutions can be applied. These are the solutions analysis following:

1. Widening and Deepening the river according to the needs

Point 7 at least needs to extend 3 m to 24, and point 8 needs to extend 4 m to 25 m in wideness.

SWOT Analysis:

Strength	: Easy-build, cheap
Weakness	: Not sustainable for future, increase small amount of capacity
Opportunity	: Possible to extend more

Threat : Illegal settler when in dry season, more space for trash and water hyacinth

2. Water Square

SWOT Analysis:

Strength : Future-proof, increase a lot of capacity, the first water square in Philippines, easy land acquisition because of free space

Weakness : Need lot investment in funds, time, and resource

Opportunity : Recreational spot, possible to improve the area such as making first water center in Philippines, water treatment plan to improve the water quality

Threat : If there is no good management and maintenance, it will become another trash can

3. Long Storage in the River

This solution is basically the same with the first solution, widening the river. However, the difference is this solution make the river become a small lake to storage the excess rainfall water.

SWOT Analysis

Strength	: Need less space than solution 2, increase bigger capacity than solution 1, sustainable for the future
Weakness	: land acquisition is hard, because there is some residential building beside the river, quite expensive, rebuild some local bridges
Opportunity	: expandable
Threat	: More space for trash, water hyacinth, and illegal settler

6.11 Appendix 14 SWOT Solution for Point 10 & 11

As you can see in the picture above, there is no free space left. It is a very dense neighborhood area. Therefore, the possible solution is only widening and deepening the river. The following picture below is Pateros River after widening and deepening.

SWOT Analysis:

Strength : Easy-build, relatively cheap, no need lot workers

Weakness : Not sustainable in the future, redesign some local bridges

Opportunity : Easy to get permission, easy maintenance

Threat : Illegal settler, become trash-bin, growth of water hyacinth

6.12 Appendix 15 Maintenance Planning

There are several parts need to be discuss before planning a maintenance schedule. The following below is the analysis.

1. The Problems

   The maintenance problems of the Pateros river are

   1.1. Rapid growth of the water hyacinth
   1.2. Sedimentation
   1.3. Rubbish and trash
   1.4. Few access of heavy machine

2. Choice of Equipment

A next important question concerns the choice of the equipment. For the selection of our maintenance equipment we used three criteria (Hamster and Jurriens,n.d.):

- Capacity of the equipment;
- Accessibility along the canals;
- Continuity in the use of the equipment.

Because Municipality of Pateros does not have many access of the river, the machine that could work on the water is required. Moreover, the wideness of the river is varies. The narrowest is 13 m and the widest is 43 m. Thus, the big size of machine could not be used. Pateros river needs a small machine that amphibious, can dredge, excavate, harvest and collect water hyacinth. The machine is from Mobitrac. The pictures and technical information is displayed below:

For more detail information about this product, can be found in this link:

http://www.mobitracusa.com/wp-content/uploads/Mobitrac%20USA.pdf

Recapitulation of the required equipment:

1. Mobitrac
2. Dumb truck

3. The Schedule

The current schedule for maintenance the river is 1 time in 3 months for all problems in the river by Metro Manila Development Authority (MMDA). This is not effective because the what they are facing in the river is not only the sediment, but the water hyacinth and the trash. Based on the research, the growth rate of this plant is incredibly high. They can duplicate themselves in approximately 10-14 days. The schedule of maintenance is displayed on table below:

Maintenance type	Schedule	Department in charge
Dredging and Excavation	1 time in 3 months	MMDA
Water Hyacinth Harvest	1 time in 2 months	MMDA
Trash Collection	1 time in month	MMDA

4. The Storage Area

There are 4 types of trash in the Pateros River:

1. Organic
2. Plastic
3. Water Hyacinth
4. Silt sediment

For organic trash, it can be delivered to the segregation center in the Municipality of the Pateros for producing fertilizer. The plastic trash can be recycled to plastic chair and the water hyacinth can be recycled to be a lot of things, such as paper, bag, clothes, biogas, etc by Villar Foundation in Las Pinas, Philippines. For the silt sediment can be stored in the Payatas landfill in Quezon City, Philippines.

6.13 Appendix 16 Research Question and Sub-Questions

dfa Research Question:

What is the current state of the Pateros river and what improvements can be made to reduce future floodings?

Sub questions:

1. What kind river of Pateros river is and how does it works?
2. How does the owner of the river rate the current river?
3. What are the problems of Pateros river which cause flooding in the area?
4. What is the geographical condition of Pateros, Manila?
5. What is the catchment area of each point reviewed in the river (every 500 m)?
6. How much of the precipitation water will come to river for each point?
7. How much is the water usage of people who live there?
8. How is the capacity of the existing primary channel of each point reviewed?
9. Is the capacity enough to compete against the precipitation and water usage of people?
10. If there any spot in the river which is has deficiency in capacity, what solution can be applied?
11. What kind of maintenance should be done to improve the quality of the river?
12. What should be done to make the river future proof?

CHAPTER V
CONCLUSION AND RECOMMENDATION

2.1 Summary

This study was conducted for the purpose of determining the status of Pateros River which is the only waterway of 20 barangays in 3 different cities and 1 Municipality. Quantitative method of research was utilized and the field observation, interview, case study was used for gathering the data.

The study attempted to assess the capability of the river based on its capacity, sustainability and maintenance. Specifically, it endeavored to answer this following research question provided in Appendix 16

Based on the gathered, analyzed and interpreted data. The author came up with the following findings presented in accordance with the research question formulated in the statement of the problem:

1. Pateros river is man-made river, it has different wideness and deepness along the river, the water is coming from Pasig River to Laguna de Bay
2. The owner of Pateros river who are the residences, barangay captains, and mayor rate the river very bad of it quality and quantity. It is because every year they are fighting with the flood because of the overflow of the river.
3. The main problems of the river are undersize and bad maintenance system, rubbish and water hyacinth inside the river, Laodicea attitude of people living nearby the river, and disunion work of every barangay.
4. Pateros is a low-lying area. The whole municipality is almost of flat terrain with slope-rising only up to 2.5% slanting downward towards Laguna Lake. For soil type, there are 2 major soil types

identified in Pateros. These are the Guadalupe series which is formulated from volcanic events and Marikina series which is made from the sedimentation of the river silt called alluvial soil. Due to flatness of the area, Pateros does not possess any erosion potential and can be considered as highly appropriate for urban use

5. The complete catchment area of each point reviewed is displayed in Chapter 4's table 10. The biggest catchment area is in point 1 with the area of7.69 m^2 and the smallest is in point 20 with the area of 0.16 m^2
6. The stormwater for the river is provided in Chapter 4's table 12. The maximum stormwater discharge is 44 m^3/s
7. The wasterwater for the river is 0.66 m^3/s
8. The capacity of existing primary channel is provided in Chapter 4's table 18. The biggest capacity is 98,3 m^3/s
9. For some points the capacity is enough to compete against the combination of stormwater and wastewater. However, there are 5 points that has deficiency in capacity, such as point 7,8,10,11, and 14.
10. Basically, the solution is make room for the river. For point 7&8, building water retention square is advised, for point 10&11 the widening the river and deepening the riverbed can be applied, and for point 14, there is only slight insufficient of capacity and there is space for widening the river, so widening is advised.
11. There are 3 different maintenances for the river. First is harvesting the water hyacinth every 2 months. Secondly, trash collection in every month. Lastly dredging and excavating in every 3 months.
12. Because the problem is not only the water quantity, but the water quality as well, to sustain and maintain the river is not an easy job. The sustainable river is clean, no still water, not stingy, and livable for fish and other fresh water creature. This requires more analysis and more works to do. The important thing is the union

work of each authority, such as the barangays, municipality, MMDA, and the others.

2.2 Conclusion

Based on the study in the previous chapter, a conclusion was made. The current state of the Pateros river is unacceptable. Apart from the big threats of water hyacinth, bad water quality, illegal settler, people mentality and disunion work of every authority of Pateros river, this study proves that the water quantity or the capacity of the river is surprisingly insufficient. There are 5 points that can lead to flooding when abundant amount of rains coming. There are a lot of solutions available, but every spot has different suitable solution which means there is still need more site-investigation to produce the fittest solution. For reducing flood, the solutions are made. From the author perspective, the most sustainable and best solutions are widening the river and building a water square which is inspired by Rotterdam Water Square. Last but not least, a good management for maintenance should not be forgotten.

2.3 Recommendation

This thesis is made in very short time. Thus, some recommendations are need to be made. The recommendations are provided in the following below:

1. Because of the lack of time to gather the data, some assumptions are made. Thus, the further investigation about the site is necessary. For example, the detail about river such as dimension and slope, more detail about the topography map, catchment area of the river, and others.
2. For the solutions that have been made in this paper, the further study such as field availability, soil data, and all things that necessary to realize the solutions need to be conducted.
3. For river maintenance, I would suggest that all of the river authority such as district chiefs/barangay captains, mayors,

MMDA, Department of Public Works and Highway (DPWH), etc should work as one.

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BIOGRAPHY

The author's name is Jevin Dimas Prabowo. He was born at 8th October 1994 in Surabaya. However, the author's childhood live was in Ponorogo. The first school was in the TK Santa Melania Ponorogo (Pre-school), then Sekolah Dasar Katholik Santa Maria Ponorogo (Elementary school), the middle school study was in Sekolah Menengah Pertama Katholik "Slamet Riyadi" Ponorogo, then his high school was in Sekolah Menengah Atas Katholik (SMAK) St. Louis 1 Surabaya. Lastly, he pursued in the Sepuluh Nopember Institute of Technology Surabaya (ITS) by joining the SNMPTN (Seleksi Nasional Masuk Perguruan Tinggi Negeri) test. During his study in the university, the author joined double degree program in partnership with the Hanze University of Applied Science in Groningen. Also, he joined several campuses and social activities such as Civil Expo, PPIG, Flood Free Manila program, and Social Services. For the specialization, he focused on water management. Especially in water quantity problem. The thesis which he was doing was about the water problem in Pateros which is one of the Municipality of Metro manila. With the help of several students and professors, he was able to finish his dissertation project with the title of "Pateros River Restoration in Reference of Its Capacity, Maintenance, and Sustainability". For contact person, the author's email is jevindimas@gmail.com

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