Modeling of Cisadane River pollution load capacity using water quality analysis simulation program (WASP)

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***Abstract*— Cisadane river has experienced a decrease on water quality caused by industrialization, urbanization, population growth, and agricultural factors. The main purpose of this study is to analyze predictions of water quality and scenarios for reducing pollutant loads on downstream of Cisadane river in attempt to mantain Cisadane river management using Water Quality Analysis Simulation Program (WASP). The downstream of Cisadane river has exceeded government regulatory quality standards for class II on PP No.22 tahun 2021. The result showed the average differences value of pollutant load capacity and existing pollutant load has negative value, for TSS -197,727 kg/day, -59,920 kg/day for BOD, and -179,677 kg/day for COD. Using WASP, three scenarios conducted on this study to meet class II standard quality by reducing pollutant load of domestic waste water. First scenario used Waste Water Treatment Plant (WWTP) and resulted positive result for average difference value between pollutant load capacity and existing pollutant load with +1831 kg/day TSS, +690 kg/day BOD, and +3667 kg/day COD. Second scenario used the resettlement method with positive result for average difference value between pollutant load capacity and existing pollutant load with +898 kg/day TSS, +740 kg/day BOD, and +4677 kg/day COD. Third scenario used WWTP and resettlement method to reduces had positive result for average difference value between pollutant load capacity and existing pollutant load with +1179 kg/day TSS, +638 kg/day BOD, and +4173 kg/day COD.**

***Index Terms*—River pollution, load capacity, Cisadane river, water quality, WASP**

I. INTRODUCTION

Ministry of Public Works and Housing of Indoneisa listed Cisadane river is one of the national strategic rivers in Indonesia due to its 20% potential of provincial water resources [1]. Rapid population growth affects Cisadane river carrying capacity. Domestic and industrial activities along Cisadane River are the main pollution sources which lead to degradation of Cisadane river water quality [2]. Downstream of Cisadane River had important role for Tangerang city and Tangerang Regency. The utilization of Cisadane river water as raw water for drinking water is one of the important role Cisadane river have to fulfilled in terms of clean water needs for communities [3]. During industrialization era, rivers play an important role in urban resource supply and waste disposal [4]. Study about Cisadane river water quality status conducted by Banten province environmental service in 2017 showed that Cisadane river has “moderate polluted” status.

Total Suspended Solids (TSS) values indicate the amount of erosion that occurs due to degradation of water quality and also high levels of sedimentation in water bodies [5]. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) high values indicate increasing levels of pollutants present in the water [6]. High pollutant load entering Cisadane River can reduce the carrying capacity and the ability to recover itself. Water Quality Analysis Simulation Program (WASP) capable to assess the impact of anthropogenic pollution on water quality on Dunajec River not only on current time but also in the future changes, and provide significat support for decision makers [7]. Indonesian Government has specified quality standards on domestic and non-domestic effluent in attempt of river management, but with increasing number of industry and growing population this regulation is no longer relevant. Using carrying capacity calculation provide in-depth analysis for river management.

This study aimed to analyze predictions of downstream Cisadane river water quality and scenarios for reducing pollutant loads. First objective of this research is to identify potential pollutant sources on downstream of Cisadane River. Second objective is to analyze and determine downstream Cisadane River water quality using Water Quality Analysis Program (WASP). Third objective of this research is to calculate and analyze pollutant load capacity of downstream Cisadane River. The fourth objective of this research is to design scenarions for reducing pollutant loads related to water quality parameters using WASP modelling. There are several scopes that include on this research. This research conducted on segment 5 and 6 of Cisadane River based on Segmentation Map of Cisadane Watershed contained within Minister of Environment and Forestry of Indonesia Decree No. 299 2017.

II. METHODE

This research consist of several stages. First stages was prepartion, that included literature study regarding of potential pollutant loads analysis, hydrological data collection, secondary data collection from related agencies, preparation and inventory of tools and materials for data sampling. Second stages was analyzing Cisadane River characteristic and pollutant load carrying capacity through primary data collection that consist of hydrology and quality of Cisadane River. Samples from primary data were analyze to produce concentration values of pollutant parameters. Existing quality and hydrology data entered to WASP, calibration were needed to get suitable model of Cisadane River. The last stages was the simulation of several scenarios to reduce pollution loads.

2.1. Sampling method

This research conducted at downstream of cisadane river with total length of 30.58 km that spread across Tangerang City and Tangerang Regency areas. This research devided downstream Cisadane River into seven segments and eleven sampling point that showed at Table 1. Sampling method based on Indonesian National Standard 6989:57:2008 used on this research with grab sample. River hydrometry obtained by direct measurement at every sampling point. Map of sampling points provided on Figure 1. Sampling points named with numbers indicate it's located in the main Cisadane River, otherwise sampling points named with alphabetical order indicate it's located in the tributary. There were 11 sampling points in total, with 8 sampling points on the main river and 3 sampling points on the tributaries.

Hydrology data calculation used cross sectional method approach for calculating existing flow discharge. The chosen approaches for channel geometry was semi-circular open channel, thus the calculation of channel shape network was necessary. The exsisting flow discharge was one of the main data needed for WASP modelling. Equation 1 formulated the calculation of discharge and wetted area.

$$Q = A_{wet} \; x \; V \quad (1)$$

$$A_{wet} = A_{network} - A \, \Delta ABC \quad (2)$$

Q = Flow at the monitoring point (m^3/s)
A_{wet} = Wetted Area (m^2)
V = Flow velocity (m/s)

Table 1. Downstream of cisadane river segmentation.

Segment	Upstream Point	Downstream Point	Location
I	1	2	West Panunggangan
II	2	3	Raya Merdeka St
III	3	4	Raya Sangengo St
IV	4	5	Marsekal Suryadarma St
V	5	6	Gaga Kolot St
VI	6	7	Raya Kali Baru St
VII	7	8	Raya Tanjung Burung St
Tributary I	2	A	TMP Taruna
Tributary II	2	B	Jembatan Baru
Tributary III	2	C	Karel S.Tubun

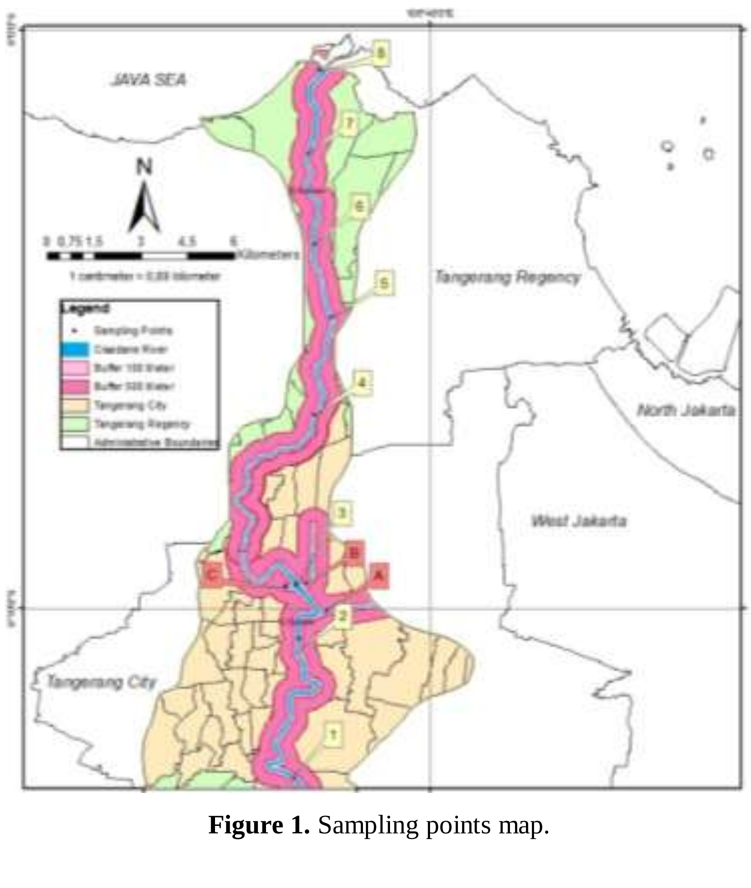

Figure 1. Sampling points map.

2.2. Water quality & pollutant load capacity analysis

Water quality analysis carried out with gravimetric method for TSS and titrimetry method for BOD and COD. Potential source of pollutant analyze by direct survey and building buffer zone (100 meter and 500 meter from water body) on land use map of research area through ArcGIS. Comparison between pollutant load capacity with existing pollutant load is important to analyze self purification of downstream Cisadane River [8]. Pollutant load capacity of downstream Cisadane River and existing pollutant load at every sampling point analyzed by this following equation.

$$PLC\left(\frac{kg}{day}\right) = C \ x \ Q \ x \ f \qquad (3)$$

PLC = Pollutant Load Capacity (kg/day)
C = Class II concentration value of quality parameter (mg/l)
Q = Flow at the monitoring point (m^3/s)
f = Conversion coefficient, 86.4

$$EPL\left(\frac{kg}{day}\right) = C \ x \ Q \ x \ f \qquad (4)$$

EPL = Exsisting Pollutant Load (kg/day)
C = Exsisting concentration of quality parameter (mg/l)
Q = Flow at the monitoring point (m^3/s)
f = Conversion coefficient, 86.4

Water Quality Analysis Simulation Program (WASP) used on this research to predict downstream cisadane river quality. Requirements input for WASP in this research are concentration of potential pollution load, river characteristics, environmental factor, and constant [9]. Potential pollution load on this research devided into four categories which are domestic, agriculture, industry, and solid waste [10]. Following equation is used to calculate potential discharge and load for domestic sources.

$$Q_{dom}\left(\frac{m^3}{s}\right) = TP \ x \ WC \ x \ 75\% \ x \ f \qquad (5)$$

TP = Total Population (person)
WC = Water consumption
f = Converssion factor, $\frac{10^{-3}}{86400}$

$$PPL_{dom} = TP \ x \ EF \ x \ CER \ x \ \alpha \qquad (6)$$

PPL = Potential Pollutant Load (kg/day)
TP = Total Population (person)
EF = Emission Factor (gr/person/day)
CER = City Equivalent Ratio
α = Delivery Load

Agriculture loads on this research divided into three category, garden, unirrigated field, and paddy field. Agriculture discharge depends on rainfall intensity and area of it and potential pollutant load of agriculture depends on land area, emission factor, delivery load, and total productivity day. This following equation used to calculate discharge and loads from agriculture sectors.

$$Q_{Agriculture}\left(\frac{m^3}{s}\right) = C \ x \ I \ x \ A \ x \ f \qquad (7)$$

C = Run off coefficient, 0.15 for agrriculture
I = Rainfall intensity (mm/hour)
A = Land are (ha)
f = Conversion factor, 0.0028

$$PPL_{Agriculture} = \frac{A \ x \ EF \ x \ \alpha}{TPD} \qquad (8)$$

PPL = Potential Pollutant Load (kg/day)
A = Land area (ha)
EF = Emission Factor (kg/ha/productivity day)
α = Delivery load (%)
TPD = Total Productivity Day

Based on Determination of Carrying Capacity of Water Pollutant Loads and Allocation of Pollutant Loads in Cisadane River conducted by Environment and Forestry Ministry of Indonesia on 2017, solid wasted listed as one of the pollutant of Cisadane River. Following equation use to calculate potential pollutant loads caused by solid waste.

$$PPL_{Solid\ waste} = TP \ x \ WGR \ x \ \% \ x \ EF \qquad (9)$$

PPL = Potential Pollutant Load (kg/day)
TP = Total Population (person)
EF = Emission Factor
WGR = Waste generation rate (kg/person/day)
% = Percentage of untreated waste, 39.8%

Potential pollutant from point sources came from industry, hospital, etc. were generated from concentration of pollutant parameter and dischrage derived from secondary data. Following equation use to calculate potential loads caused by industry.

$$PPL_{Point\ Source} = Q\ x\ C\ x\ f \tag{10}$$

PPL = Potential Pollutant Load (kg/day)
Q = m^3/day
C = Concentration (mg/L)
f = Conversion factor, 0.001

Data and graphic information from WASP output was being compared by the actual existing water quality data of downstream cisadane river. The comparison can be calculated by Mean Absolute Percentage Error (MAPE) with targeted value ≤ 20%,this calculation conducted for verification process [11].

$$\%\ Error = \frac{|C\ Data\ (mg/L) - C\ Model\ (mg/L)|}{C\ Data\ (mg/L)} \times 100\% \tag{11}$$

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|C\ Data\ (mg/L) - C\ Model\ (mg/L)|}{C\ Data\ (mg/L)} \times 100\%$$

EASE OF USE

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III. RESULTS AND DISCUSSIONS

3.1. Identification of potential pollution sources

The result of potential sources of pollution could be classified into two cataegories, point source and non point source. Point source includes industries, hotels, hospitals, and on this research tributaries. Non point source includes domestic waste water, agriculture, and untreated solid waste. For the characteristic of downstream cisadane river, it had average value of 81.42 m for width, 5.25 meters for depth, 0.27 meters/second for velocity, and 48.91 cubic meters/second for flow, these data presented on Table 2. Based on the survey, The width of downstream Cisadane river that flows across urban area were more wider that the suburbs and back to wider width slowly towards estuary. Based on the map that presented on Figure 2 and Figure 3, there were change in domination of land use. The upstream of this research dominated by the residential areas whereas slowly towards estuary, downstream is dominated by agriculture areas. There are three tributaries connected to Downstream Cisadane River , East Tributary II and West Tributary goes into the main Cisadane river, where East Tributary I as well known as Mookervart Channel is channeling several discharge out from cisadane river to Angke river.

Table 2. Characteristics value of downstream Cisadane River

Characteristics	Width (m)	Depth (m)	Velocity (m/s)	Flow (m^3/s)
Max	143.06	6.85	0.39	51.50
Min	34.96	3.62	0.19	46.14
Average	81.42	5.25	0.27	48.91

3.2. Water quality and pollutant load capacity of downstream Cisadane River

Downstream cisadane river eksisting condition has exceeded class II quality standard value on Government Regulation No. 22 of 2021, with average TSS value 97.6 mg/L, BOD value 17.8 mg/L, and COD value 69.2 mg/L. Based on this qualities, Cisadane river is not suitable for class II river role such as raw water for drinking water. Tributaries gave major impact to overall water quality of downstream Cisadane River. WASP model result also had exceeded value of class II quality standard with average value of TSS 96.8 mg/L, BOD 17.3 mg/L and COD 67.8 mg/L. The ratio value between the average BOD and average COD of the downstream Cisadane River shows a value of 0.257 so that it can be categorized as non-biodegradable. The difference of pollutant load capacity and existing pollutant load capacity resulted negative value on all key parameters with average value TSS -197,727 kg/day, BOD -59,920 kg/day, COD -179,677 kg/day. These values mean loads on exsisting condition greater that cisadane river pollutant load capacity, it may caused decrease of self purification capabilities of downstream cisadane river. Comparison between eksisting value and model conducted and had given value 0.93% for flow, 2.05% for TSS, 4.47 % for BOD, and 2.42% for COD. Further scenarios of decreasing pollutant load could be conducted through WASP model. Figure 5 and Figure 6 presented graphic of downstream Cisadane River water quality.

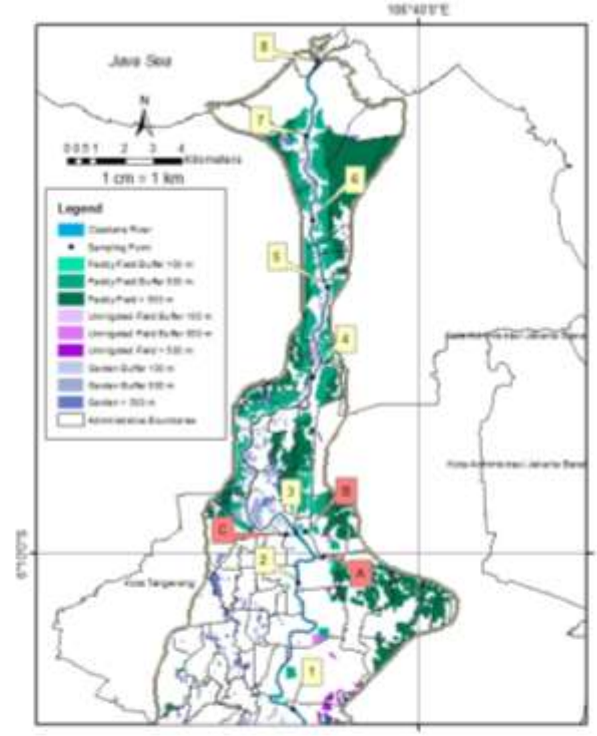

Figure 2. Agriculture source map.

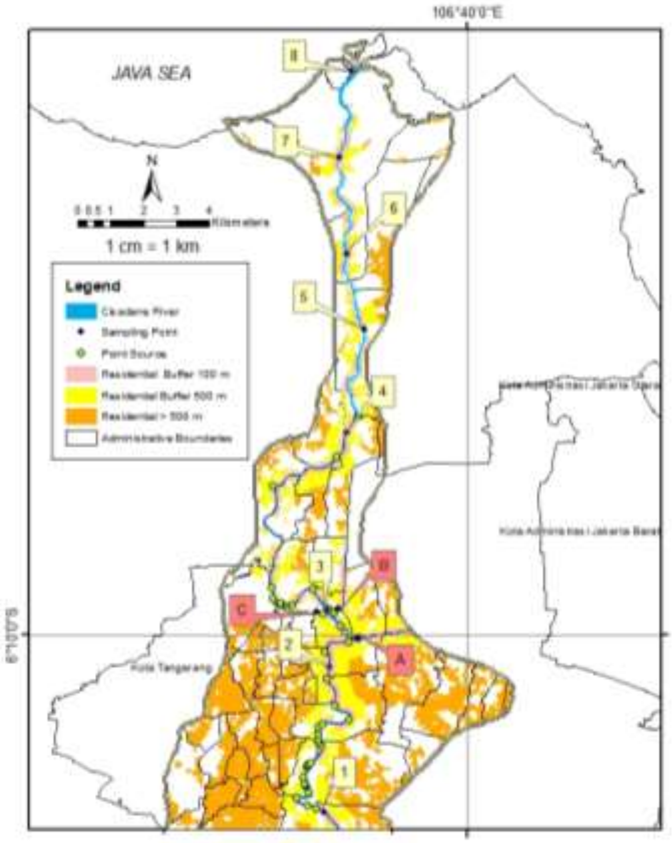

Figure 3. Domestic and point source map.

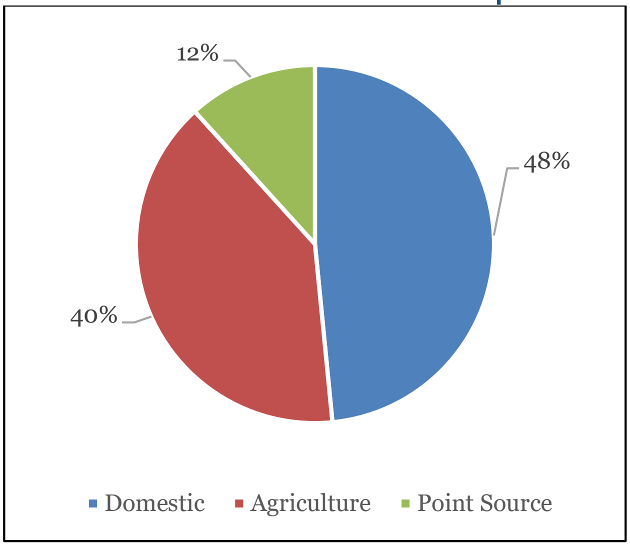

Figure 4. Percentage of potential pollution loads discharge.

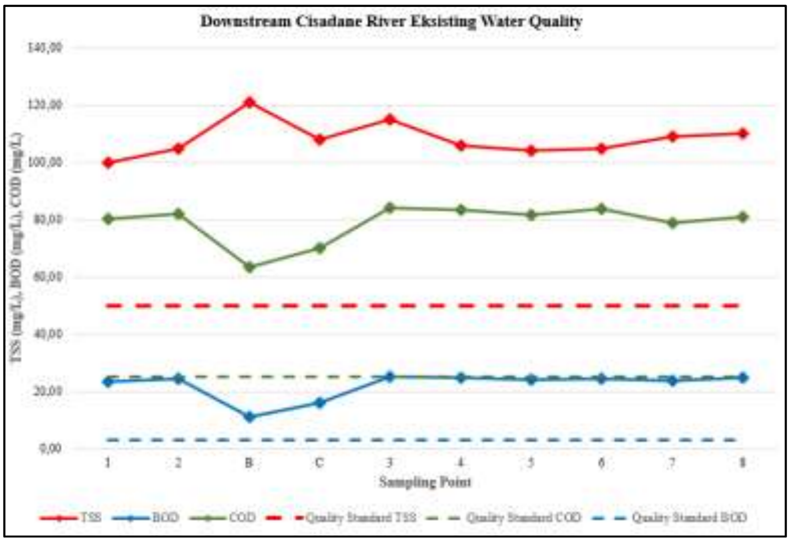

Figure 5. Graphic of downstream Cisadane River eksisting water quality.

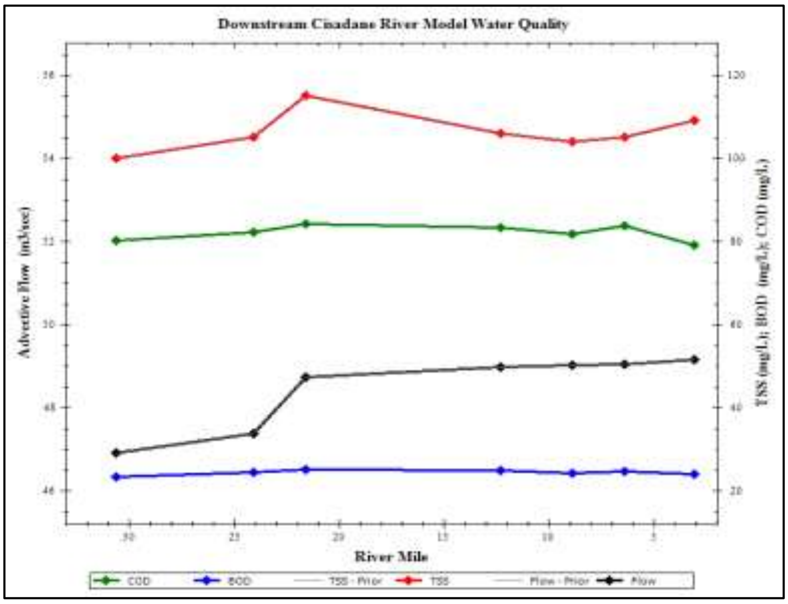

Figure 6. Graphic of downstream Cisadane River model water quality.

3.3. Loads reduction scenarios

There were three scenarios conducted on this research. Load reduction scenarios are calculated using WASP. The selection of provisions in the scenario is carried out in stages. Scenario one used Waste Water Treatment Plant (WWTP) to reduces pollutant load, second scenario used only resettlement of residents to reduce pollutant load, and third scenario used both WWTP and resettlement of residents to reduce pollutant load. Further information about scenarios condition can be seen on the table 3.

Table 3. Loads reduction scenarios

Scenario	Condition	Information
I	• Upstream boundaries & tributary equal to Class II quality standard • Solid waste loads = 0 • Communal domestic WWTP on segment I, II, III, and V	Planned Effluent of WWTP : I : TSS = 30 mg/L II : TSS = 30 mg/L III & V : TSS = 30 mg/l BOD = 12 mg/L BOD = 14 mg/L BOD = 12 mg/L COD = 80 mg/L COD = 100 mg/L COD = 100 mg/L
II	• Existing condition • Resettlement of residents	% Resettlement of Residents : I = 98.74% II = 92.73% III = 95.73% IV = 63.46% V = 68.94%
III	• Upstream boundaries & tributary equal to Class II quality standard • Communal domestic WWTP on segment I, II, III, and V • Resettlement of residents	% Resettlement of Residents: I = 70% II & III =65% IV &V = 55% Planned Effluent of WWTP : I & II :TSS = 30 mg/L III & V : TSS = 30 mg/L BOD = 30 mg/L BOD = 20 mg/L COD = 100 mg/L COD = 100 mg/L

Based on WASP model, all of scenarios above resulted positive value on the differences between pollutant load capacity (based on class II quality standard) and pollutant load that generated using WASP model (Table 3). Second and third scenarios experienced decreasing of pollutant discharge from 12% until 17% due to resettlement of residents (segment I until V). The decreasing percentage value of scenarios had maximum value on third scenario, it was because of this scenario using both resettlement of residents and WWTP on four segments. Standard effluent for WWTP on this research were better than Regulation of Environment and Forestry Minister of Republic Indonesia No. 68 2016 about domestic wastewater quality standards, it was because the water quality value with these standard effluent quality resulted exceeded value to the segments with class II river water quality standard. The numbers calculated for standard effluent of WWTP that conducted on this research were minimum value to maintain the quality of downstream Cisadane River still on class II river water quality standard. WWTP with aerobic extended aeration suitable for downstream of Cisadane River pollution reduction managemnet due to its performanced to reduce BOD and small area requirement [12]. Based on BOD/COD value, tertiary processing unit were require to decrease the COD value, electro-Fenton method which used hydroxyl radicals to oxidize harmful contaminants on downstream Cisadane River water could be adopted to decreasing pollution load [13]. The resettlement of residents could not be done at segment VI and VII, because total pollution loads on these segments not greater than the amount of negative value that resulted from the difference between pollution load capacity based on class II quality standard and pollution load model at certain sampling point.

Table 4. Result of loads reduction scenarios

Scenario	% Decrease				Differences on Average Load (kg/day)		
	Flow	TSS	BOD	COD	TSS	BOD	COD
I	0%	43%	45%	32%	+1831	+690	+3667
II	17%	52%	49%	45%	+898	+740	+4677
III	12%	55%	51%	45%	+1179	+638	+4173

IV. CONCLUTION

Domestic activities loads are the biggest contributor with agriculture comes in second place. Downstream Cisadane River has exceeded Class II water quality standard with eksisting pollutant load has greater value than pollutant load capacity of downstream of cisadane river. Scenarios I, II, and III fulfilled the Pollutant Load Capacity of Cisadane River based on Class II Quality Standard. Quality standard of domestic and non-domestic effluent in related regulations are no longer relevant to sustainable river management approach.

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