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Conceptual Model of Water Pollution Control Strategies in the Lower Sentani Watershed Post Flash Flood Using the Swot Method

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ABSTRACT

The problem that occurs downstream of the Jembatan Dua river is that it has been polluted by the parameters of BOD, COD and PO_4 with the results of the measurements being 3 mg/L, 37 mg/L, and 0.3 mg/L, respectively. This study aims to analyze the conceptual model of pollution control strategies in the downstream Sentani watershed. The method used in this research is the SWOT (Strength, Weakness, Opportunities, Threats) method with four SWOT strategies, namely SO (Strength-Opportunities), WT (Weakness-Threats), and WO (Weakness-Opportunities). The results showed that the pollution load of TDS and TSS continued to increase from 2016–2019. The conceptual model of the strategy for controlling water pollution in the downstream Sentani watershed is the SO (strength-opportunities) strategy with coordinates (0.26; 0.18). This SO strategy needs to be implemented in the short term, namely: utilizing internal strengths to capture external opportunities. SO strategies include: Increasing environmental law enforcement, increasing leadership commitment and the role of government institutions in handling pollution and mainstreaming sustainable development, and making the lake an ecotourism area by keeping the lake unpolluted.

Keywords: pollution, conceptual model, SWOT, Sentani Lake

INTRODUCTION

Lakes are basins that occur due to natural events or are intentionally made by humans to accommodate and store water from rain, springs, and or rivers. Or a lake is a large natural body of water surrounded by land and not connected to the sea, except through rivers. Lakes can be in the form of basins that occur due to natural events which then accommodate and store water from rain, springs, seepage, and or river water. Indonesia has about 500 large and small lakes scattered in various regions. Indonesia also has around 162 artificial reservoirs built for agricultural irrigation, clean water needs, and hydroelectric power plants. The area of natural lakes is about 5,000 km^2 or about 0.25% of Indonesia's land area while the area of artificial lakes is about 16,000 km^2. One of the lakes in Indonesia is Lake Sentani, which is located in Papua Province.

The status of the water quality of Lake Sentani at the Kalkote location has been heavily polluted with a pollution index value of 18.22, Ayapo Village has been lightly polluted with a pollution index value of 4.88, and Ifale Village has a pollution index value of 5.60 which means it has been moderately polluted [1]. The high water pollution in Lake Sentani shows the quality of the lake water does not meet the carrying capacity to meet the lives of living things and humans. The high level of water pollution will have an impact on the occurrence of diseases for humans due to consuming fish that live in Lake Sentani.

The study of water pollution research states that the burden of river pollution is caused by the bad habits of the people around the river, where the community around the river throws domestic waste, both liquid waste and solid waste into the river. The main priority in watershed management is conservation of upstream watersheds and protection of riverbanks [2]. Efforts to control water pollution require firmness in complying with applicable laws and regulations [3]. Water pollution control must also pay attention to organic pollution. Alternatives for controlling organic pollution are public awareness about environmental sanitation, procurement of wastewater treatment plants, environmental law enforcement and waste cleaning [4]. However, in some previous studies, the analytical hierarchy process (AHP) method is still used, the weakness of this method is that it cannot determine the right strategy in controlling water pollution. The method developed in this study is the SWOT method which can determine the right strategic position, which is analyzed from four SWOT strategies, namely SO (strength-opportunities), WT (Weakness-Threats), SO (Strength-Opportunities) and WO (Weakness-Opportunities). Opportunities). The advantage of the SWOT method is that it produces a new policy strategy model in controlling water pollution at Lake Sentani. The results of this study are very important to be implemented in order to preserve the environment and in line with the mission of the regional medium-term development plan of the Jayapura government in 2013–2033, namely controlling environmental pollution and protecting conservation areas. The results of this study are also very important because they are in line with the concept of sustainable development, namely building a balance of environmental, economic and social aspects as well as an effort to leave good natural resources for future generations.

MATERIALS AND METHODS

The research is located in the Sentani watershed and Sentani Lake. Research time March – May 2021. Sampling locations: Small and Large Asey, Yabaso, Ifale, Yahim and Babrongko (Fig. 1). The materials used in this research are SWOT questionnaire (Table 1). The fields of expertise interviewed are: environmental biology experts, ecologists, environmental chemistry experts, environmental and resource management experts.

Table 1. SWOT matrix

Internal / External	Strength (S)	Weakness (W)
Opportunity (O)		
Threat (T)		

Calculating pollution load:

$$BP = QC \text{ (Chapra, 1983)} \quad (1a)$$

$$BP = \sum Q_i \cdot C_i \cdot 3600 \cdot 24 \cdot 30 \cdot 1 \cdot 10^{-6} \quad (1b)$$

where: BP – pollution load from rivers (tons/month),

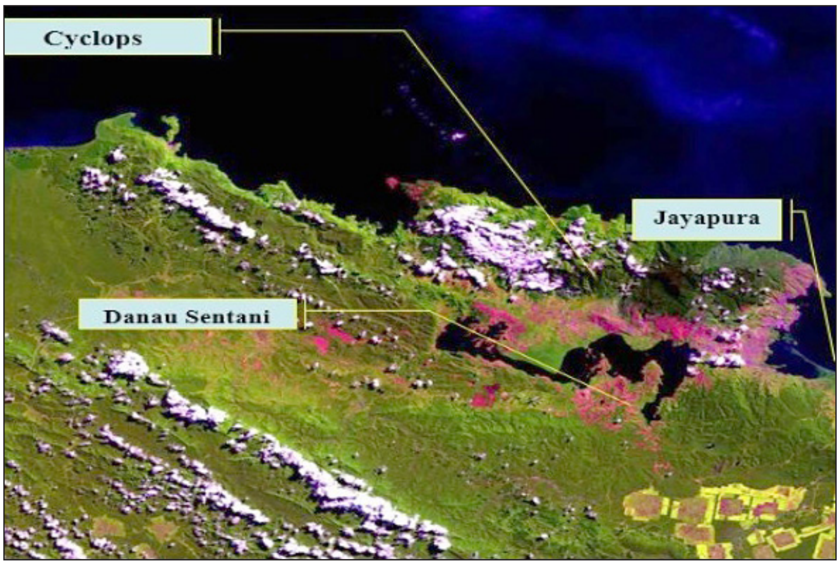

Figure 1. Research locations in the Sentani watershed

Q_i – debit of river (m^3/second),
C_i – waste concentration parameter i (mg/l).

Calculating the assimilation capacity using the regression equation:

$$y = a + bx \quad (2)$$

where: x – parameter value at the mouth of the river,
y – parameter value in lake water,
a – mean/general mean,
b – regression coefficient for parameter in river.

The stages in the SWOT analysis are [5]:
1. Compile a SWOT matrix table,
2. Determine the priority weights of the SWOT components,
3. Determine the priority weights of the SO, WO, ST, and WT strategy components,
4. Fill in the rating based on the opinion or expert judgenet,
5. Determine the strategic position of the Sentani watershed damage management.

RESULTS AND DISCUSSION

Pollution index of the Bridge Two river, in conditions before and after flash floods are shown in Figure 2. The index value of the water pollution index of the Bridge Two river since 2016 has decreased from 4.54 to 2.3, but the status of the water quality remains in a lightly polluted condition. The pollution index value after flash floods increased from 1.3 to 2.3 but the status of the water quality remains lightly polluted. The increase in the value of the pollution index after a flash flood is due to parameters that have exceeded the water quality standard according to Government Regulation No. 22 of 2021, namely BOD, COD, and PO_4.

Bridge two river pollution load (Hubay)

Based on the Figure 3, it can be seen that the TDS and TSS pollution loads in the Bridge Two river continued to increase from 2005–2019. The TDS pollution load increased from 263.09 tons/month to 29764.71 tons/month. However, during the banjir bandang, the pollution load decreased from 68115.39 tons/month to 29764.71 tons/month. TSS pollution load increased from 13451.36 tons/month to 11447.96 tons/month. Likewise, after the flash flood, the pollution load increased from 10016.97 tons/month to 11447.96 tons/month. However, the TDS and TSS parameters after flash floods have not exceeded the water quality standards according to Government Regulation No. 22 of 2021, where the results of TDS and TSS measurements are 104 mg/L and 40 mg/L, respectively. The increase in the pollution load can be caused by the increase in the concentration of TDS and TSS parameters in the Bridge Two river.

Based on the Figure 4, it can be seen that the pollution load of PO_4 and NO_3 in the Bridge Two river continued to increase from 2005–2019. The PO_4 pollution load increased from 0.26 tons/month to 85.86 tons/month. Likewise, during a flash flood, the PO_4 pollution load increased from 57.24 tons/month to 85.86 tons/month. NO_3 pollution load increased from 0.39 tons/month to 25.76 tons/month. However, after the flash flood, the NO_3 pollution load decreased from 228.96 tons/month to 25.76 tons/month. The water quality parameter PO_4 after the banjir bandang has exceeded the water quality standard according to Government Regulation No. 82 of 2001, where the results of the PO_4 measurement are 0.3 mg/L. The increase in the pollution load can be caused by the increase in the concentration of PO_4 and NO_3 parameters in the Bridge Two river.

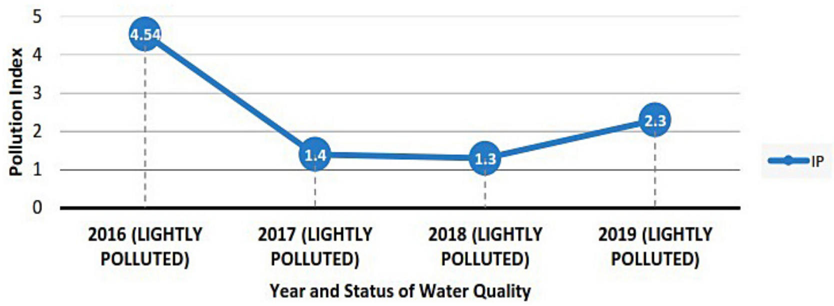

Figure 2. Pollution index of the Bridge Two river

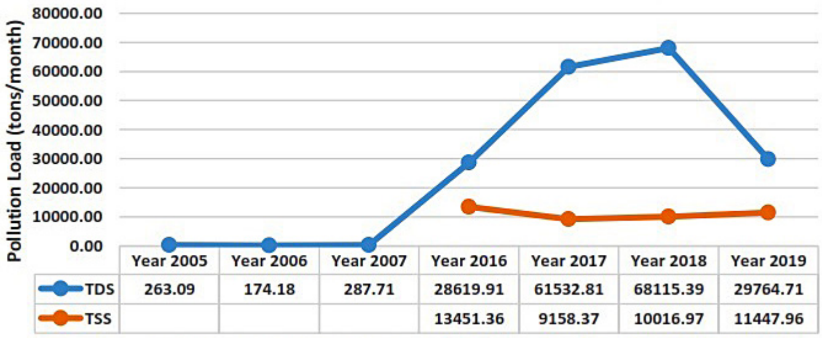

Figure 3. Pollution loads of TDS and TSS on Bridge Two

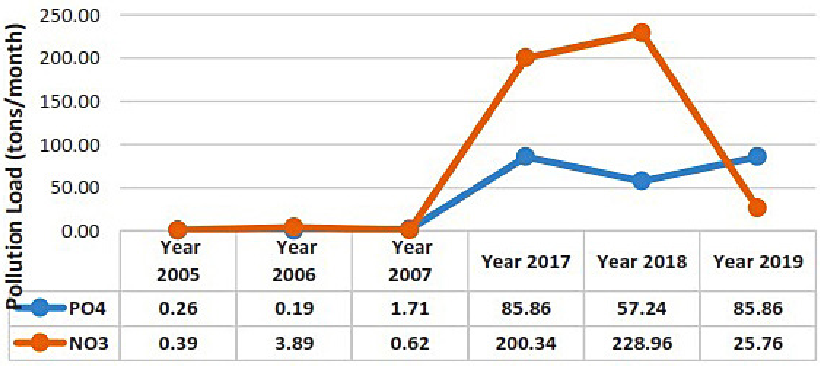

Figure 4. Pollution loads of PO_4 and NO_3 on Bridge Two

Assimilation capacity of Lake Sentani water around the Bridge Two river

The value of TDS assimilation capacity in Lake Sentani of 2126600 tons/month was obtained based on the regression equation $y = 0.0045x + 149.36$ (Fig. 5). The value of the pollution load in Lake Sentani is to the right of the assimilation capacity value, this indicates that Lake Sentani has been polluted by the TDS parameter [23,24,25]. This condition also shows that Lake Sentani is not capable of self-purification of the TDS parameter. This is because the river discharge carrying the TDS is quite large, namely 110.416325 m^3/second. Figure 5 also shows that the TDS parameter is below the quality standard of Government Regulation No. 22 of 2021.

The value of TSS assimilation capacity in Lake Sentani of 14609.8 tons/month was obtained based on the regression equation $y = 0.0045x – 15.744$ (Fig. 6). The value of the pollution load in Lake Sentani is to the left of the assimilation capacity value, this indicates that Lake Sentani has not been polluted by the TSS parameter [25]. This condition also shows that Lake Sentani is capable of self-purification of the TSS parameters. Figure 6 also shows that the TSS parameter is below the quality standard of Government Regulation Number 82 of 2001.

The value of BOD assimilation capacity in Lake Sentani of –13391.6 tons/month was obtained based on the regression equation $y = 0.0005x + 9.6958$ (Fig. 7). The value of the pollution load in Lake Sentani is to the right of the assimilation capacity value, this indicates that Lake Sentani has been polluted by the BOD parameter. This condition also shows that Lake Sentani is not capable of self-purification of the BOD parameter. Figure 7 also shows that the BOD parameter does not meet the quality standard of Government Regulation Number 82 of 2001.

The value of COD assimilation capacity in Lake Sentani of 12038.2 tons/month was obtained based on the regression equation $y = 0.0011x + 11.758$ (Fig. 8). The value of the pollution load in Lake Sentani is to the left of the assimilation capacity value, this indicates that Lake Sentani has not been polluted by COD parameters. This condition also shows that Lake Sentani is still capable of self-purification of COD parameters. Figure 8 also shows that in 2017–2018 there were several points where the COD parameter still met the quality standard of Government Regulation No. 82 of 2001, but in

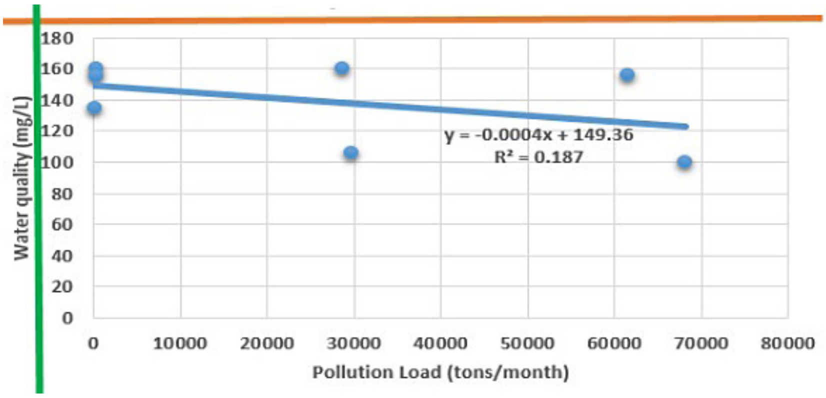

Figure 5. Assimilation capacity of TDS parameters

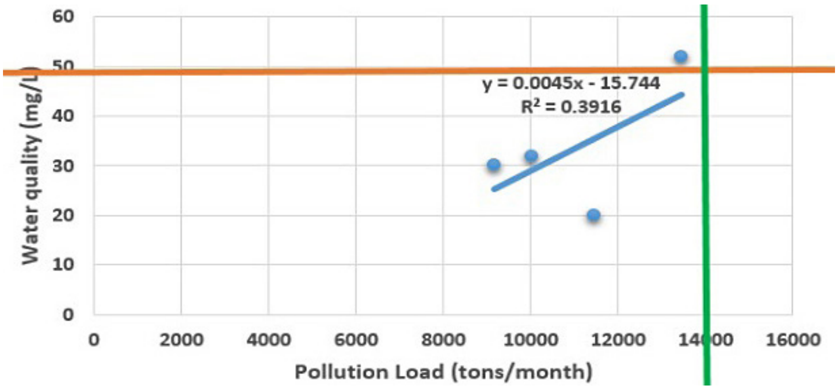

Figure 6. Assimilation capacity of TSS parameters

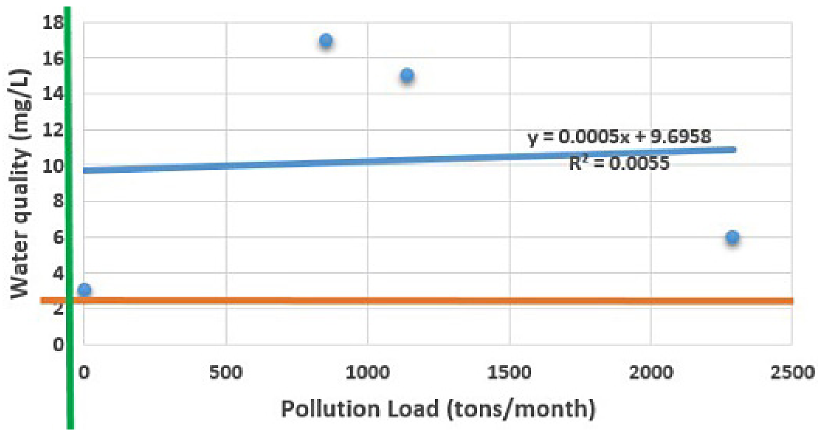

Figure 7. Assimilation capacity of parameter BOD

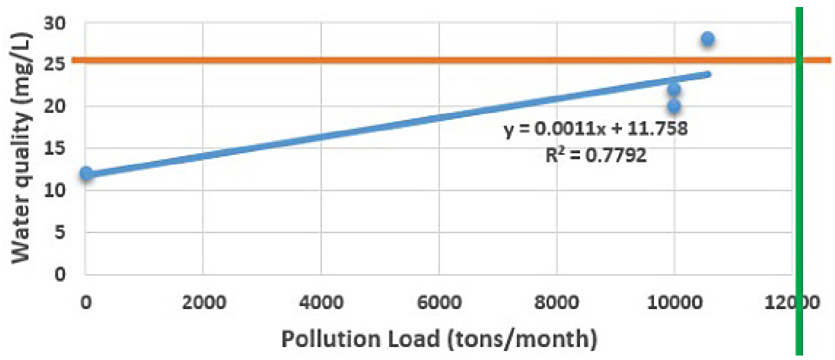

Figure 8. Assimilation capacity of COD parameter

2019 after the flash flood the COD parameter had exceeded the quality standard.

Based on Figure 9 shows the value of the assimilation capacity of the PO_4 parameter is 89.83 tons/month. The pollution load value is to the left of the assimilation capacity line, indicating that since 2007 Lake Sentani is still capable of self-purification of the PO_4 parameter. There are two points of lake water quality that are above the PO_4 quality standard (0.2 mg/L), namely in 2007 and 2017.

The value of NO_3 assimilation capacity in Lake Sentani of –6316.53 tons/month was obtained based on the regression equation $y = -0.0015x + 0.5252$ (Fig. 10). The value of the pollution load in Lake Sentani is to the right of the assimilation capacity value, this indicates that Lake Sentani has been polluted by the NO_3 parameter. This condition also shows that Lake Sentani is not capable of self-purification of the NO_3 parameter. Figure 10 also shows that the NO_3 parameter still meets the quality standard of Government Regulation Number 82 of 2001.

The value of NO_2 assimilation capacity in Lake Sentani of 36.33 tons/month was obtained based on the regression equation $y = 0.0003x + 0.0091$ (Fig. 11). The value of the pollution load in Lake Sentani is to the left of the assimilation capacity value, this indicates that Lake Sentani has not been polluted by the NO_2 parameter. This condition also shows that Lake Sentani is still capable of self-purification of the NO_2 parameter. Figure 11 also shows that the NO_2 parameter still meets the quality standard of Government Regulation No. 82 of 2001.

Component Strength (S) are:

1. Implementation of environmental regulations (S1) [6].
2. Implementation of environmental projects (S2) [7].
3. Ability to cooperate in each district and agency (S3).
4. Government arrangement and lake environment related agency (S4) [7].

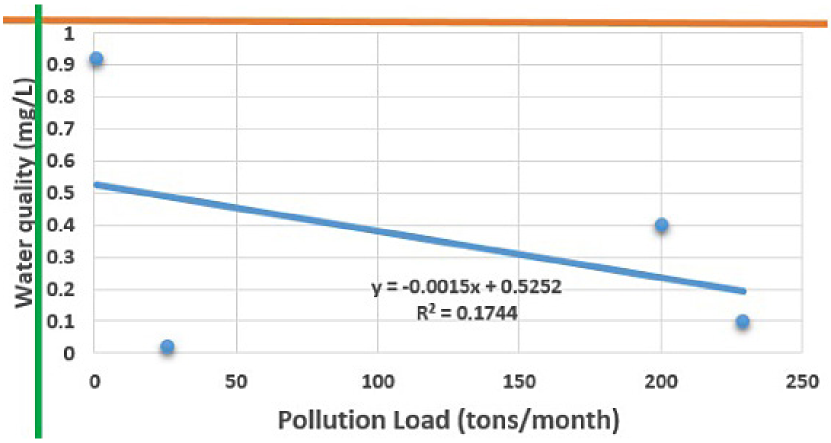

Figure 9. Assimilation capacity of PO_4 parameter

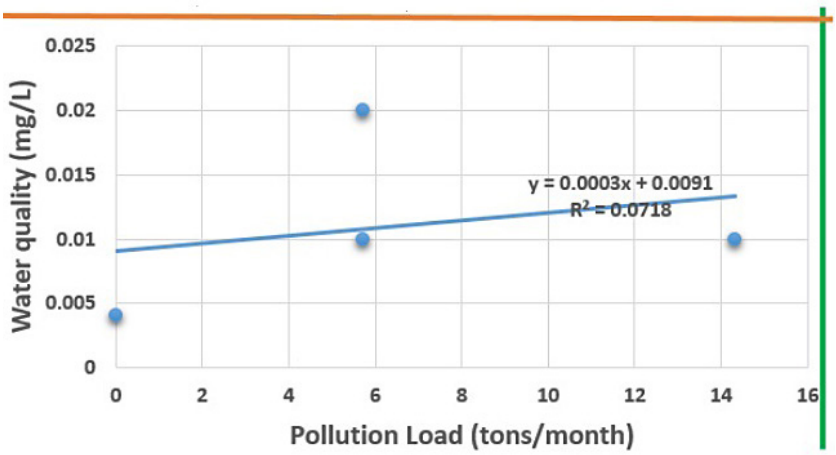

Figure 10. Assimilation capacity of NO_3 parameter

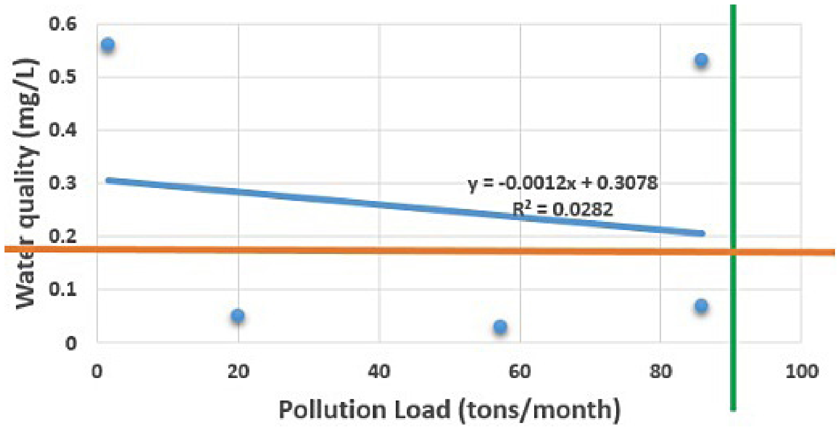

Figure 11. Assimilation capacity of NO_2 parameter

5. Job creation (S5) [7].
6. Saving the community and the environment (S6) [7].
7. The beauty of the landscape and the Lake Sentani Festival (S7) [8].
8. Biodiversity (S8) [8].

The implementation of environmental regulations related to lake management in Indonesia is the existence of Law Number 32 of 2009 concerning environmental protection and management, and Government Regulation No. 82 of 2001 concerning water quality management and water pollution control. Environmental projects at Lake Sentani are: Lake Sentani Festival, there are 15 priority lakes for management in Indonesia, and others.

The components of Weaknesses (W) are:

1. The occurrence of pollution (W1).
2. Weak support from business owners (W2) [7].
3. Weak law enforcement (W3) [7].
4. Policy implementation is not effective (W4) [7].
5. Weak coordination and management of cooperation between Government Agencies (W5) [7].
6. Weak stakeholder coordination with Government Agencies (W6) [9].
7. Planning that is not in accordance with the local wisdom of the community (W7) [9].
8. Weak visitor management (W8) [8].
9. Weak environmental education program (W9) [8].
10. Weak handling of waste water (septic tank) (W10) [8].
11. Land use change (W11).
12. Existence of mining excavation C (W12).
13. People do not have knowledge about waste management (W13) [10].
14. Communities are not involved in pollution planning and control (W14) [10].

The status of the water quality of Sentani lake which is around Yoka and Waena villages is 92% polluted and 8% meets the quality standard, where the status is lightly polluted to moderately polluted. This shows that most of the lake water locations are moderately polluted[15]. The status of water quality that meets the quality standard is only at Kampung Yoka Pier. Lake Sentani has been polluted by 1.57 tons/year of Cu and 40 mg/kg of sediment Pb [11, 12, 14, 17, 18]. The constraint that causes the decline in water quality in Lake Sentani is due to weak law enforcement [13].

Threats components are:

1. Pollution caused by settlements (T1).
2. High water pollution due to population growth (T2).
3. Increased pollution by type of business (T3) [7].
4. Effects of climate change (T4) [8].
5. Communities and Types of businesses violate regulations (T5) [10].

Pollution in Lake Sentani can be caused by population growth and residential waste in the form of household waste and feces, livestock waste, industrial waste and erosion upstream[16]. Erosion value of the Sentani watershed is 4.71 mm/year and sedimentation is 2.95 tons/ha/year. The high sediment discharge is caused by erosion and land conversion upstream [19].

The Opportunities Components are:

1. Support of business owners who have an effect on handling pollution (O1) [4].
2. Construction of wastewater infrastructure by business owners (O2) [7].
3. Treatment of wastewater before discharge into water bodies (O3) [7].
4. Monitoring biodiversity (O4) [8].
5. New management development (O5) [8].

6. Application of new technology (O6) [8].
7. Ecotourism development (O7) [8].
8. There is a City/Regency Perda regarding water pollution control (O8) [10].
9. Disposal of type of business waste does not endanger the environment because it has gone through processing (O9) [10].
10. The lake has a high economic value (O10).

Pollution control strategies are prioritized on increasing the role of the general public, farmers, and industry through community-based sanitation, reducing the use of fertilizers and pesticides and managing industrial waste [20]. Therefore, the role of the business community around Lake Sentani is needed in controlling water pollution. The business world around Lake Sentani is Floating Net Karamba entrepreneurs, hotel entrepreneurs, fishermen and others.

The position of the Lake Sentani pollution management strategy is on the SO (strength-opportunities) strategy with coordinates (0.26; 0.18), meaning that the conceptual model of this strategy needs to take advantage of internal strengths to capture external opportunities. So the conceptual model of water pollution control strategy in Lake Sentani is the SO strategy. This SO strategy needs to be implemented immediately in the short term. The SO strategies are:

1. Improving Environmental Law Enforcement (S1 O1).
2. Increasing leadership commitment and the role of government institutions in handling pollution and mainstreaming sustainable development (S1 O1,2).
3. Making the lake an ecotourism area by keeping the lake unpolluted (S1 O1,2,3,4).
4. Implement waste management socialization and training (Wiriani, E.R.E., et al. 2018) (S1 O1,2,3) [10].
5. Analyze and determine the capacity of the pollution load (S1 O8,9).
6. Improve the guidance and supervision of waste water disposal (Wiriani, E.R.E., et al. 2018) (S1 O5,6,8,9) [10].
7. Increase socialization, guidance and supervision of environmental destruction (S1 O8,9).
8. Build a Communal Wastewater Treatment Plant and a Business Type Wastewater Treatment Plant
9. Involving the community in planning and controlling pollution (Wiriani, E.R.E., et al. 2018) (S1 O2–10) [10].
10. Increase the number of environmental documents of the type of business (S1 O2–10).

Based on the dynamic modeling in Figure 12 and Figure 13, it can be seen that the pollution index in 2017–2027 increased from lightly polluted to moderately polluted, and from 2005–2024 the water pollution load was above the assimilation capacity value, meaning that Sentani Lake was unable to carry out cell growth. purification. Therefore, a water pollution control model is needed in the downstream Sentani rivers and lakes. Based on the SWOT analysis and the Dynamic Model (SWOTMIC Analysis), the water pollution control strategy model is shown in Figure 14.

Water pollution can be caused by domestic waste, both liquid waste and solid waste. The community and businessmen must comply with environmental documents that have been prepared, both environmental impact analysis and environmental management efforts – environmental monitoring efforts. Technical strategies for reducing domestic waste include the development and optimization of communal wastewater treatment plants and integrated waste management [21].

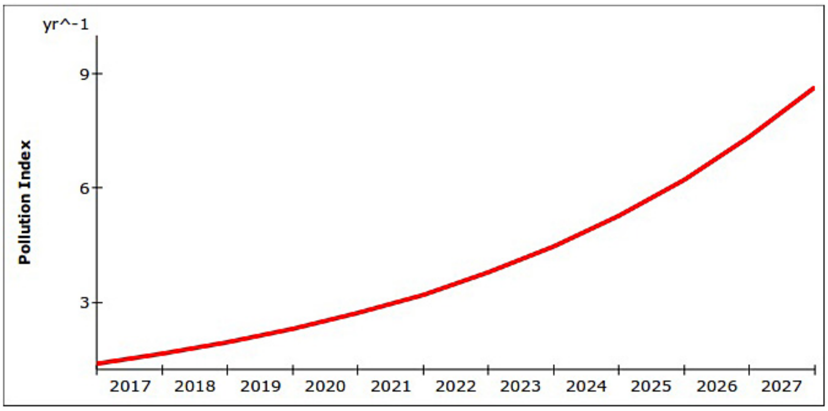

Figure 12. Dynamic modeling of pollution index

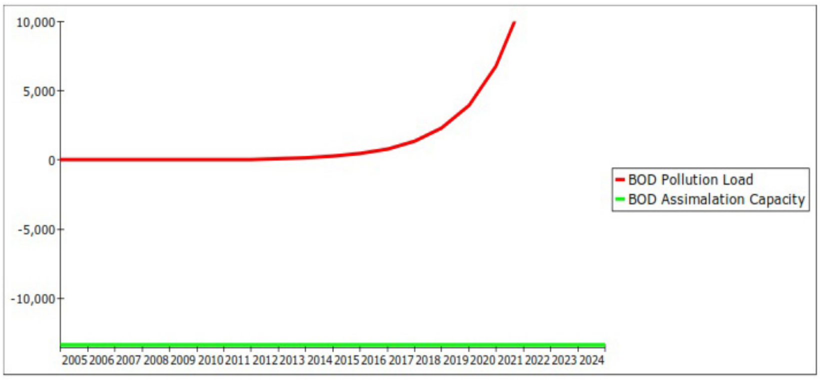

Figure 13. BOD pollution load and BOD assimilation capacity

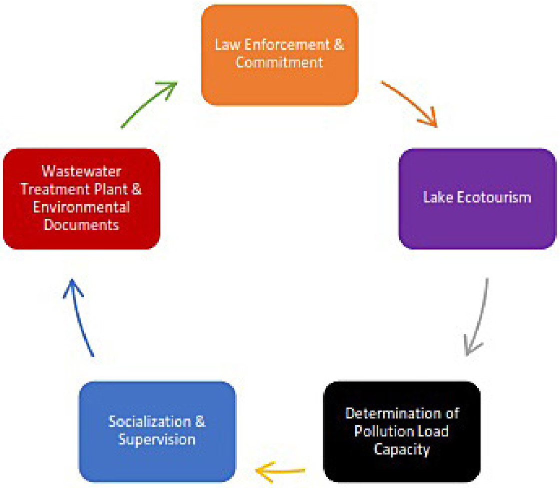

Figure 14. Model of water pollution control in downstream river

The commitment of the leadership and the role of government institutions need to be increased in handling pollution and mainstreaming sustainable development. Social strategies for reducing domestic waste pollution include community empowerment, strengthening local communities, and optimizing formal institutions. The government plays a very important role, especially in enforcing laws, government regulations, regional regulations, governor or regent decisions. Environmental regulations change a lot and increase from year to year, therefore it is necessary to continue to carry out socialization both directly and indirectly to the community [22].

CONCLUSIONS

Downstream of the Bridge Two river has been polluted by parameters BOD, COD and PO_4 with the results of measurements 3 mg/L, 37 mg/L, and 0.3 mg/L, respectively. The conceptual model of the strategy for controlling water pollution in the downstream Sentani watershed is the SO (strength-opportunities) strategy with coordinates (0.26; 0.18). This SO strategy needs to be implemented immediately in the short term, namely: utilizing internal strengths to capture external opportunities. SO strategies include: Increasing environmental law enforcement (S1 O1), Increasing leadership commitment and the role of government institutions in handling pollution and mainstreaming sustainable development (S1 O1, 2), and Making the lake an ecotourism area by keeping the lake unpolluted. (S1 O1,2,3,4)

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