

Using QUAL2KW and AHP as Decision Making Tools in Surface Water Quality Assessment and Management: A Case Study of Cikapundung River, Bandung, Indonesia

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Abstract:

The Cikapundung river has faced substantial water pollution in recent decades, primarily due to rapid population growth. This study aimed at using QUAL2KW and AHP as decision making tools in surface water quality assessment and management. The study applies to a combination of qualitative and quantitative methods included primary and secondary data collection. Water quality data collected from six monitoring stations representing upstream, midstream, and downstream of river. Secondary data collected from Government regulations, reports, and similar studies. Parameters such as pH, temperature, conductivity, DO, TSS, ammonia, nitrate, and phosphate simulated using QUAL2KW and validated against field observations. RMSPE of calibrated and validation data showed nearly the same values for pH, temperature, DO, conductivity, nitrate, ammonia, and TSS (i.e., 4%, 8%, 9%, 24%, 26%, 45% and 58% respectively). The scenarios based simulation conducted and the findings indicate that the implementation of integrated pollution reduction measures represented by scenario 3 (90% reduction) provides the most effective strategy for improvement of water quality. Analytical Hierarchy Process (AHP) used for prioritizing strategies for surface water quality management. AHP tool ranked Upgrading Wastewater Treatment Plants with high composite weight of 0.31 and Community-based monitoring and clean-up activities with weight of 0.253. The integrated use of QUAL2KW and AHP tools provides an effective decision-making support tool for sustainable surface water management.

Keywords: *QUAL2KW, Analytic Hierarchy Process, River management, Water quality, Cikapundung River.*

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1. INTRODUCTION

River is polluted by domestic and industrial waste, which is contributed by surrounding communities such as hotels, commercial or shopping areas, agriculture, animal husbandry, printing industries, tofu and tempeh industries, and housing area (Y Ciawi et al., 2022). The equilibrium of ecosystems is disrupted when there is an increase in excess pollutants such as suspended materials and nutrients that will cause eutrophication (TK Nufutomo et al., 2023). Under the dual pressures of global climate change and anthropogenic activities, identifying key thresholds for ecosystem health is essential for biodiversity conservation, climate change mitigation, and regional sustainable development (Xue Li et al., 2025). Most Municipals and Cities are responding by improving watershed development practices and pursuing restoration activities, but few empirical studies have compared their effects to those induced by urbanization and climate change (Jason Sauer, Heejun Chang 2025).

Bandung's rapid urbanization has significantly affected the water quality of its primary river systems, especially the Cikapundung river. Flowing through densely populated areas, the river receives continuous inflow of domestic wastewater, solid waste, and in some locations, industrial discharge. This has led to elevated concentrations of pollutants such as Total Suspended Solids (TSS), ammonium (NH_4), nitrate (NO_3), and phosphate, impacting public health and ecosystem integrity. Based on the studies that have been carried out, it was found that the water quality is quite poor. Poor water quality is caused by a continuous process of pollution, which causes changes in the value of the physical and chemical parameters of water in the Cikapundung watershed. This process is further supported by the occurrence of dilution caused by the high intensity of rain in the city of Bandung as researched by (Peny Supriatno et al., 2022). A robust, scenario-based model like QUAL2KW and AHP has not yet been widely applied for river water quality management in Bandung. This study will assess and simulate water quality using QUAL2KW model and AHP technique as decision making tools in surface water quality assessment and management.

2. RESEARCH METHODOLOGY

2.1 Study location

The Cikapundung river flows from North Bandung and empties into the Citarum River in the south with about 28 km. the Cikapundung River has a catchment area of 111.3 km² in the upstream section, 90.4 km² in the middle section and 76.5 km² in the downstream section. The following are sampling points ST.1 to ST.6 as shown in Figure 1. representing upstream, midstream and downstream of river.

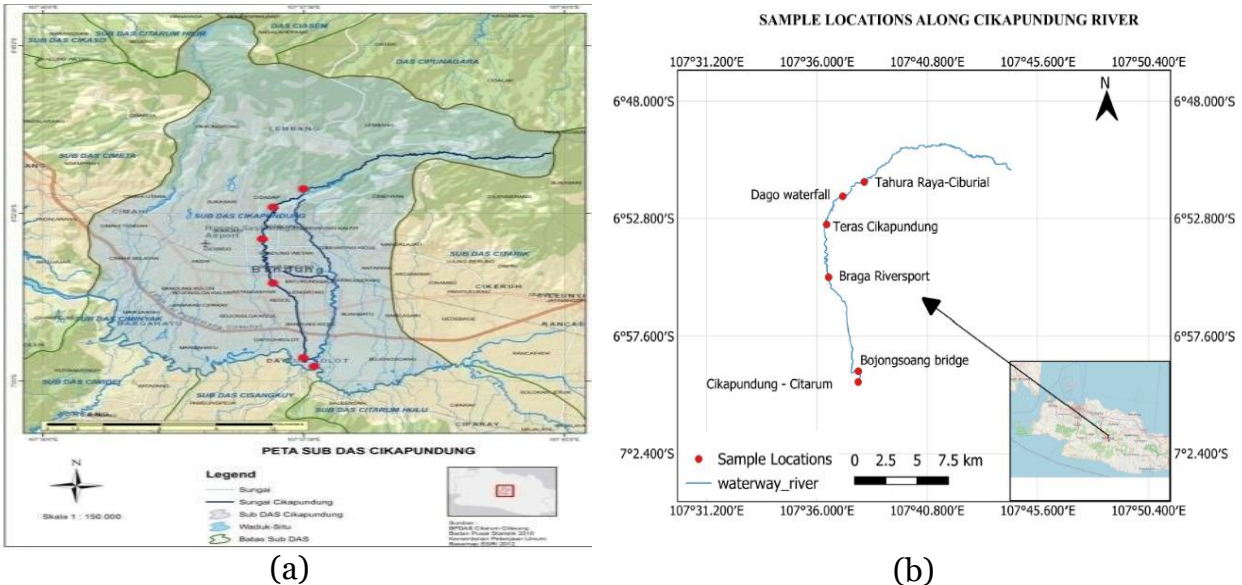


Figure 1. (a) Cikapundung watershed; (b) Sampling points along Cikapundung river.

2.2 Data collection

This study applies to a combination of qualitative and quantitative methods. The collection of data included primary and secondary data collection. Primary field data involved in-situ measurements for parameters such as pH, temperature, conductivity, and Dissolved Oxygen using portable meters. Grab samples were collected and analyzed in a laboratory for TSS, ammonium, nitrate, and phosphate. Sampling and analysis conducted as per Indonesia National Standards (SNI) which adopt the International Standards Procedure (APHA). Stakeholders opinions were collected through questionnaires given to 12 technical experts to gather data for the AHP phase. Collection of secondary data such as meteorological data, wind speed, dew point, solar radiation and air temperature, were sourced from meteorological agencies (BMKG & NASA). Other secondary such as land use, pollutant loads, and demographic trends were collected from relevant institutions and literature such as journals, articles, land use map, Government Regulations and reports.

2.3 Pollution load estimation

Point source and non-point sources pollution were estimated. Non-Point Sources (NPS) pollution load was calculated by using a population-based approach for domestic waste, excretion factors for livestock, and export coefficients for different land-use types (forest, agriculture, urban). Point Sources (PS) pollution load was estimated based on industrial wastewater standards and production data for textile and cocoa industries as shown in Table 1 below.

Table 1. Industrial wastewater quality standards.

No.	Type of Industry	Number of Units	Applicable Regulations	Discharge Standard (m ³ /ton)	Permissible Concentration (mg/L)			
					BO D	CO D	TS S	NH ₃ -N
1	Textile	9	P.80/MENLHK/SETJE N/KUM.1/10/2019 and Permen LH No. 5/2014.	100	60	150	50	8
2	Cocoa	4	P.80/MENLHK/SETJE N/KUM.1/10/2019 and Permen LH No. 5/2014.	10	100	200	100	8

2.4 Data processing and analysis

2.4.1 Water quality parameters

Water quality parameters namely DO, pH, temperature, TDS, TSS, NH₄, NO₂, and NO₃ measured and compared to water quality standards. Water quality parameters comparison with National Standards as per Indonesian Government Regulation No. 22 of 2021 concerning Environmental Protection and Management.

2.4.2 QUAL2KW Modeling and process

Water quality parameters simulated include temperature, conductivity, inorganic solids, DO, NH₄, NO₃, phosphate, pH. The QUAL2Kw model uses Microsoft Excel as an interface. This means that all input and output and model execution are carried out from within Excel (Y Ciawi et al., 2022). The QUAL2KW simulation involves governing the processes as shown in the equations 1 - 2 and Figures 1 - 2 below.

Flow Balance, a steady-state flow balance is implemented for each model reach as shown in Figure 2.

$$Q_i = Q_{i-1} + Q_{in,i} - Q_{ab,i} \quad (1)$$

With:

Q_i = outflow from reach i into the downstream reach $i+1$ [m³/d],

Q_{i-1} = inflow from the upstream reach $i-1$ [m³/d],

$Q_{in,i}$ = is the total inflow into the reach from point and nonpoint sources [m³/d], and

$Q_{ab,i}$ = is the total outflow from the reach due to point and nonpoint abstractions [m³/d].

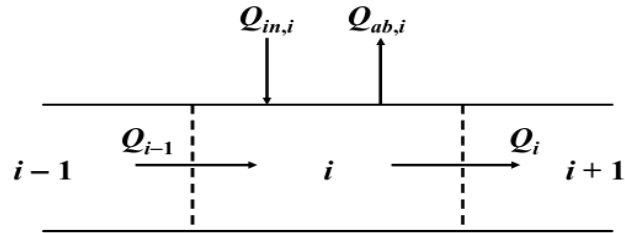


Figure 2. Flow balance in reach segment
Source: Greg Pelletier & Steve Chapra (2008).

Mass Balance, a general mass balance equation for all constituents except the bottom algae within the water column (excluding hyporheic exchange) is shown in Figure 3, which is written as equation.

$$\frac{dc_i}{dt} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{ab,i}}{V_i} c_i + \frac{E'_{i-1}}{V_i} (c_{i-1} - c_i) + \frac{E'_i}{V_i} (c_{i+1} - c_i) + \frac{W_i}{V_i} + S_i \quad (2)$$

With:

- c_i = constituent concentration(mg/L)
- V_i = volume of reach i (m^3/d)
- E'_i = bulk dispersion coefficient between segments (m^3/d)
- W_i = external loading of the constituent into segment i (mg/d)
- S_i = sources and sinks of the constituent attributed to reactions and mass transfer (mg/L/d)

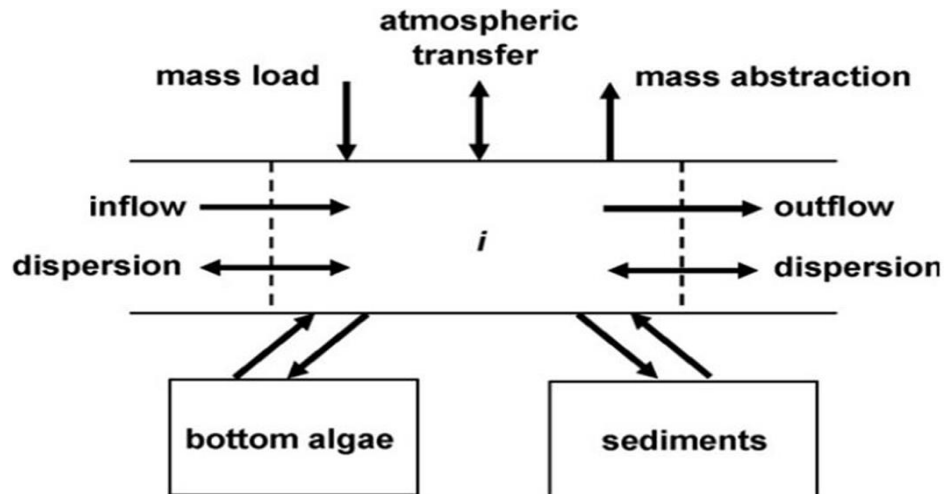


Figure 3. Mass balance in reach segment.
Source: Greg Pelletier & Steve Chapra (2008).

2.4.3 Reaction Kinetic parameters

The ranges of model kinetic parameters were obtained from QUAL2Kw user manual (Pelletier and Chapra, 2005) then kinetic parameters were auto calibrated. The O'Connor-Dobbins equation (1958) used to estimate the reaeration rate coefficient. This rate defines how quickly oxygen from the atmosphere dissolves into the water column to replenish Dissolved Oxygen (DO) levels.

$$k_2(20^\circ\text{C}) = 3.93u^{0.5}h^{-1.5} \quad (3)$$

With: k_2 is reaeration rate coefficient (day^{-1}); u = velocity (m/s) and h = depth (m).

2.4.4 Data Calibration and Validation

The simulated data from QUAL2KW model validated using statistical methods such as Root Mean Square Percentage Error (RMSPE), Root Mean Square Error (RMSE) and Coefficient of Determination (R^2).

$$RMSPE = \sqrt{\frac{1}{n} \left[\sum_{n=1}^n \left(\frac{St-At}{At} \right)^2 \right]} \times 100\% \quad (4)$$

With:

St = model simulated/predicted value at location.
At = actual (observed) data at time or location.
n = number of observations.

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^n (At - St)^2} \quad (5)$$

With:

At = Observed (actual) value at location.
A = Mean of all observed values.
St = Simulated (predicted) value at location.
S = Mean of all simulated values.

$$R^2 = \left[\frac{\sum (At-A) (St-S)}{\sqrt{\sum (At-A)^2} \sqrt{\sum (St-S)^2}} \right]^2 \quad (6)$$

With:

At = Observed (actual) value at location.
A = Mean of all observed values.
St = Simulated (predicted) value at location.
S = Mean of all simulated values.

2.4.5 Scenarios simulation analysis

The study included three scenarios-based simulation analysis such as (i) Simulation 1 for baseline conditions, (ii) Simulation 2 for 50% Load Reduction (cutting PS and NPS inflows), and (iii) Simulation 3 target Management (trial and error control loads to meet Class II water standards).

2.5 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), a well-known method for handling multiple criterion decision-making problems, was introduced by Thomas L. Saaty (1980) as shown

in Table 2. AHP frames decision-making challenges through the identification of goals, standards, and alternatives (Saaty, T.L., 2008; Y Ciawi et al., 2022). Working of AHP is through determine objective goal; set-up criteria; construct the hierarchy; making a pairwise comparison; calculating criteria weight; consistency check ($0 \leq C.R \leq 0.1$); aggregating indicator weight. The AHP standard excel template developed by Klaus D. Goepel, (2013) used in analyzing data.

Table 2. Pairwise comparison scale for AHP preferences.

Numerical Rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Source: Saaty, T.L. 2008, & Y Ciawi et al., 2022

2.5.1 Management alternatives

The main criteria used in pairwise and prioritizing alternatives were technical, environmental, economic and social. The following are the surface water management alternatives considered during prioritizing the optimal strategies.

- i. Upgrading Wastewater Treatment Plants (WWTPs) - Improving municipal treatment before discharge.
- ii. Riparian buffer and greenbelt restoration -Creating vegetative zones to trap pollutants and stabilize riverbanks.
- iii. Community-based monitoring and clean-up - Local community participation in waste management and awareness.
- iv. Strengthened enforcement and penalties - Strictly control of illegal discharges and fines for violators.
- v. Incentive-based pollution control - rewards for individuals adopting cleaner production.
- vi. River reaeration and ecological rehabilitation - Mechanical/nature-based enhancement of dissolved oxygen.

2.6 Study methodology flowchart

This study is implemented as presented in Figure 4 below.

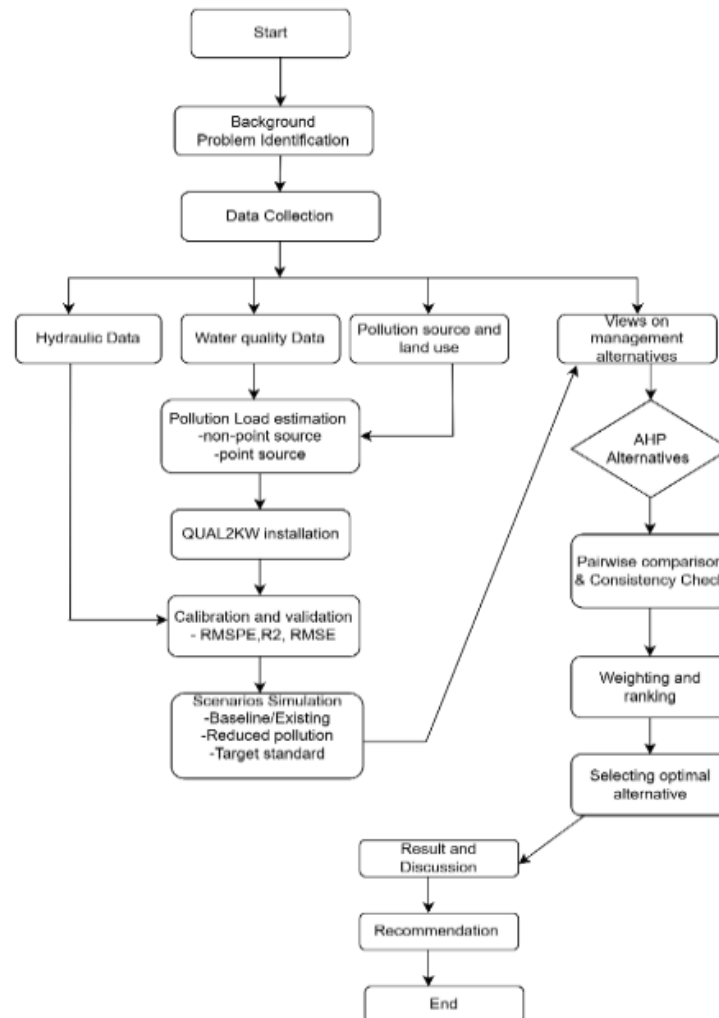


Figure 4. Study implementation flowchart.

3. RESULT AND DISCUSSION

3.1 Water quality Standards

The Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning implementation of Environmental Protection and Management used to compare allowable standards and observed water quality parameters.

3.1.2 Water quality status in Cikapundung River

Field data collected on 01 December 2025 and laboratory analysis conducted at Water Quality Laboratory in Environmental Engineering Department – ITB. Sampling and analysis of parameters conducted as per Indonesia National Standards (SNI) as shown in Table 3.

Table 3. Water quality status measured and compared to Indonesian National Standard (SNI).

Parameter/Section	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	Class II	Status
DO (mg/L)	5.65	5.96	5.13	5.11	4.67	1.56	≥4	Polluted
pH	7.53	7.2	7.65	7.62	7.34	7.34	6-9	Within
Temperature (°C)	20.9	22.1	25.2	23.2	27	28.8	20-30	Within
TDS (mg/L)	81	91	95	130	188	193	≤1000	Within
TSS (mg/L)	66	194	614	125	102	710	≤50	Polluted
Ammonia (mg/L)	0.31	0.64	0.22	1.09	2.03	1.04	0.2	Polluted
Nitrate (mg/L)	4.91	5.34	5.33	5.42	3.03	1.55	10	Within
Phosphate (mg/L)	0.05	0.17	0.36	0.04	0.45	0.13	0.2	Polluted
Conductivity ((μS/cm)	164	181	192	261	385	385	-	Within

The result from observed data indicating that parameters such as pH, Temperature, TDS, Nitrate and Conductivity are within permissible standards while parameters such as DO, Ammonium, TSS and Phosphate exceeded the allowable standards as per Government Regulation No. 22 of 2021 for Class II water source as shown in Figure 5.

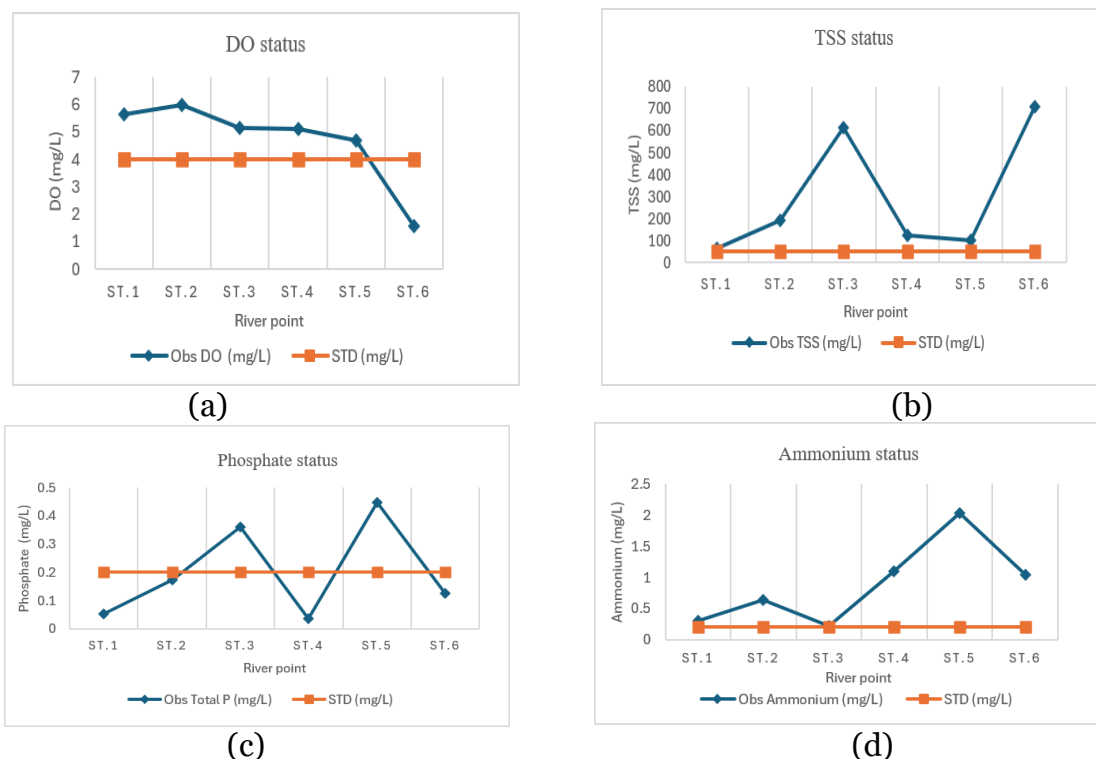


Figure 5. (a) Observed DO; (b) Observed TSS; (c) Observed phosphate; (d) Observed ammonium

3.2 Model calibration and validation

The ranges of model reactions kinetic parameters were obtained from QUAL2Kw user manual (Pelletier and Chapra, 2005) then kinetic parameters were auto calibrated using genetic algorithms. The O'Connor-Dobbins equation (1958) used to estimate the reaeration rate coefficient. The model was run, compare simulated vs. observed for water quality parameters. The statistical measure objective functions (RMSE, RMSPE and R²) used to quantify fit of a model. The calculation values presented in Table 4 below.

Table 4. Calculated values of RMSE, RMSPE and R²).

Parameter	RMSPE (%)	RMSE	R ²
Dissolved Oxygen (DO)	9	0.43	0.99
Temperature	8	1.99	0.99
pH	4	0.31	0.99
Nitrate	26	0.19	0.95
Ammonium	45	0.36	0.86
Conductivity	24	67.41	0.92
TSS	58	251.72	0.57
Total P	715	0.09	0.69

The model simulation results were as follows the parameters that were accepted for validation include Dissolved Oxygen (DO), temperature, pH, conductivity, nitrate and ammonium while TSS, Total P cannot be accepted for validation. These unacceptable validations are due to errors acceptance. Some of the errors in the modelling were unavoidable due to the resource fund, time limits and field work involved collection of single sample at each station.

3.3 QUAL2KW water quality data

The model used Runge-Kutta for integration and the Newton-Raphson method for pH modeling. Input data from laboratory analysis was converted into model-compatible formats. The model simulation data under existing baseline condition used for validation as shown in Table 6 and Figure 6 as follows.

Table 5. Existing baseline condition simulation output.

Parameter/Section	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6
Temperature (°C)	20.90	21.55	22.23	22.83	23.74	23.73
PH	7.83	7.80	7.76	7.72	7.38	7.38
Conductivity (µS/cm)	164.00	210.48	260.00	304.53	261.18	261.18
Dissolved Oxygen, DO (mg/L)	5.65	5.59	5.39	5.28	3.84	3.74
Ammonium -NH ₄ (mg/L)	0.24	0.23	0.24	0.27	2.05	2.04
Phosphate (mg/L)	0.02	0.08	0.14	0.20	0.19	0.19
Total Suspend Solids (mg/L)	80.38	74.64	68.80	63.62	56.07	55.93
Nitrate-NO ₃ (mg/L)	1.11	1.11	1.10	1.11	1.07	1.08

The model fitness value is $0.6931 > 0.5$, which means that the model is reliable and can be continued in scenarios simulation that will be applied next.

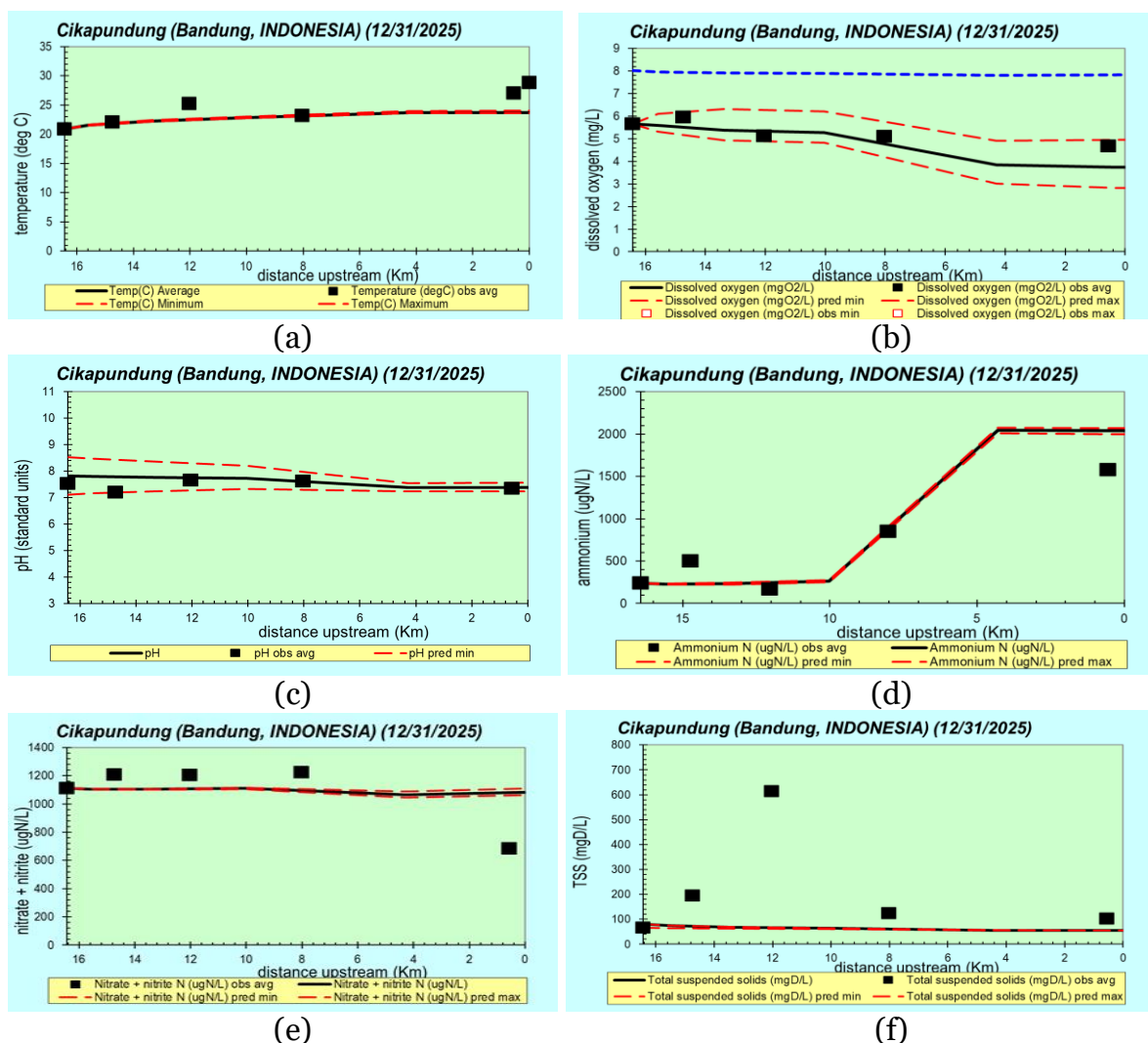


Figure 6. (a) Simulated temperature ; (b) Simulated DO; (c) Simulated pH ; (d) Simulated ammonium ; (e) Simulated nitrate ; (f) Simulated TSS.

3.4 Scenario simulation analysis

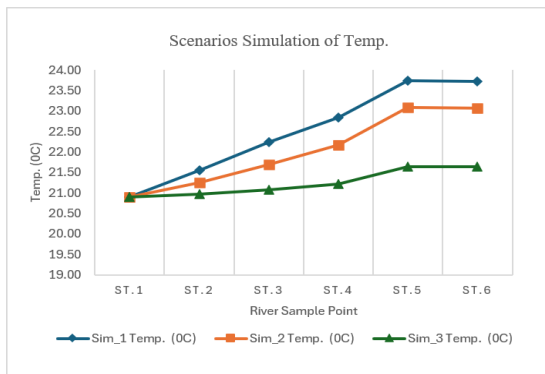
Scenarios simulation reduced pollution scenario-representing load reduction measures and meet the water quality standard. Tables 6, 7 and 8 provide details output data from baseline conditions simulation, reduced 50% of point sources and non-point sources pollution load and the management to water quality standards (trial and error) at 90% load reduction. The results of various scenario simulation in Figure 8. showed that the minimum water quality can be achieved by pollution load modification.

Table 6. PS & NPS load reduction at 50% simulation output

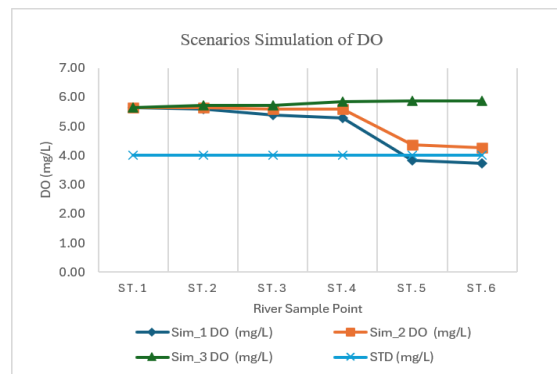
Parameter/Section	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6
Temperature (°C)	20.90	21.25	21.69	22.16	23.08	23.06
PH	7.83	7.81	7.80	7.79	7.48	7.49
Conductivity (µS/cm)	164.00	189.30	221.68	257.15	240.81	240.81
Dissolved Oxygen, DO (mg/L)	5.65	5.64	5.59	5.59	4.36	4.27
Ammonium -NH ₄ (mg/L)	0.24	0.23	0.23	0.24	1.64	1.63
Phosphate (mg/L)	0.02	0.05	0.09	0.14	0.15	0.15
Total Suspend Solids (mg/L)	80.38	76.75	72.48	67.89	59.22	58.99
Nitrate-NO ₃ (mg/L)	1.11	1.11	1.10	1.11	1.09	1.11

Table 7. Management standards simulation output (trial and error).

Parameter/Section	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6
Temperature (°C)	20.90	20.97	21.08	21.22	21.64	21.63
PH	7.83	7.83	7.82	7.83	7.81	7.82
Conductivity (µS/cm)	164.00	169.44	177.75	189.19	192.69	192.69
Dissolved Oxygen, DO (mg/L)	5.65	5.70	5.70	5.85	5.86	5.86
Ammonium -NH ₄ (mg/L)	0.24	0.24	0.23	0.22	0.68	0.66
Phosphate (mg/L)	0.02	0.02	0.03	0.05	0.06	0.06
Total Suspend Solids (mg/L)	81.00	79.36	77.21	74.39	66.59	66.11
Nitrate-NO ₃ (mg/L)	1.11	1.10	1.10	1.09	1.07	1.08



(a)



(b)

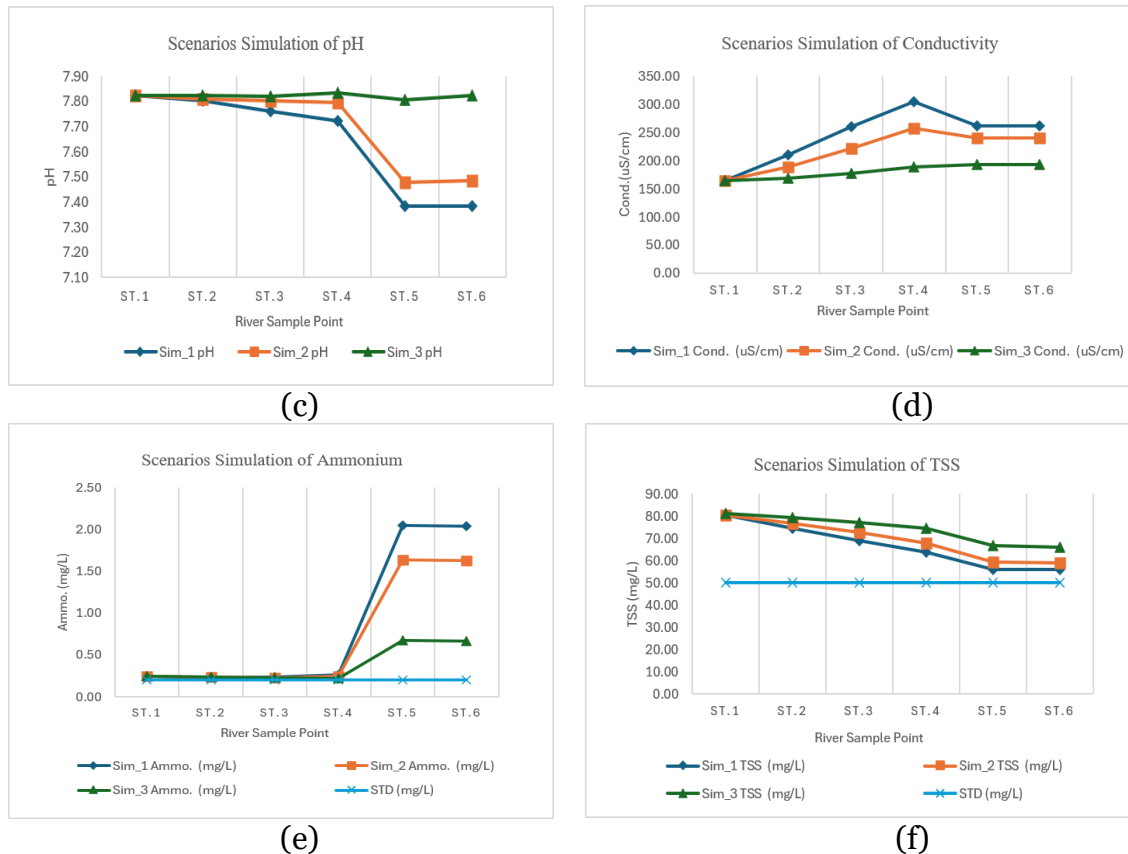


Figure 7. (a) Scenarios temperature ; (b) Scenarios DO ; (c) Scenarios pH; (d) Scenarios conductivity ; (e) Scenarios ammonium; (h) Scenarios TSS.

3.5 AHP Surface water management alternatives

Hierarchy Design goal is to improve river water quality by evaluating alternatives, and pairwise comparison done by experts using Saaty's 1–9 scale. The alternatives and composite weights score is detailed in Table 8 and Figure 8 below.

Table 8. Alternatives description and its weight

	Management Alternative	Description	Weight
1	Upgrading Wastewater Treatment Plants (WWTPs).	Improve municipal treatment before discharge.	30.9%
2	Riparian buffer and greenbelt restoration.	Creating vegetative zones to trap pollutants and stabilize riverbanks.	18.7%
3	Community-based monitoring and clean-up.	Local community participation in waste management and awareness.	25.3%
4	Strengthened Enforcement Penalties.	Strictly control of illegal discharges and fines for violators.	6.5%
5	Incentive-Based Pollution Control.	Rewards for individuals adopting cleaner production.	6.9%
6	River reaeration and ecological rehabilitation.	Mechanical/nature-based enhancement of dissolved oxygen.	11.6%

The calculated Consistency Ratio (CR) is 2.0%, which is significantly lower than the acceptable threshold of 10%. AHP tool ranked Upgrading Wastewater Treatment Plants with high weight of 0.31, Community-based monitoring and clean-up with score of 0.253.

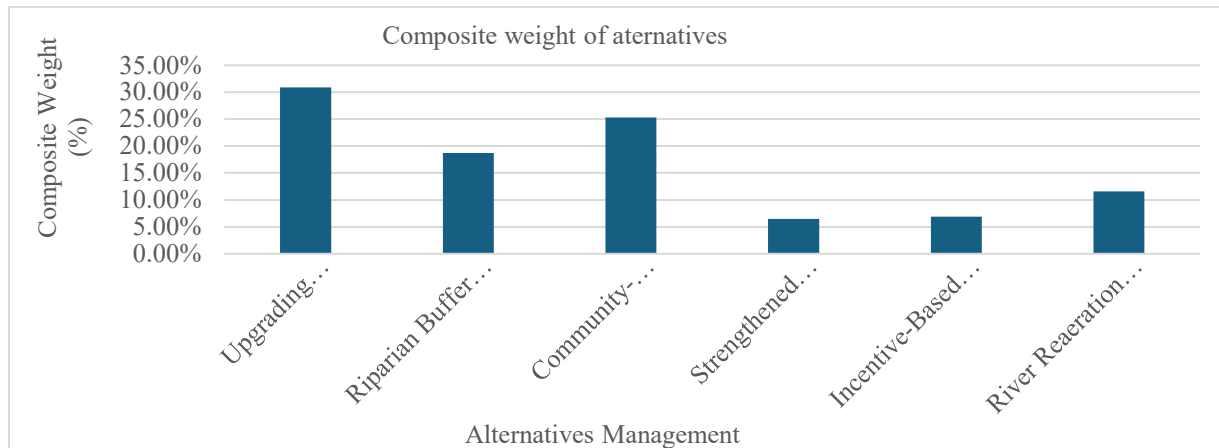


Figure 8. Graph of composite weight of alternatives management for surface water quality.

According to Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management, some of water quality parameters in Cikapundung river exceeded allowable standards.

The amount of error between the observed and simulated data using RMSPE showed nearly the same values for pH, temperature, DO, conductivity, nitrate, ammonia, and TSS (i.e., 4%, 8%, 9%, 24%, 26%, 45% and 58% respectively) while the error rate between RMSE and R^2 is very small and it is within the acceptable limits, which means that model can be applied to Cikapundung river. Some of the errors in the modelling were unavoidable due to the resource fund, time limits and field work involved collection of single samples at each station. Kannel et al. (2007) showed that the RMSPE values for measuring the accuracy of qualitative simulation of the river must be less than 52%.

The scenarios simulation results indicates that scenario 3 provides the most effective improvement in river water quality parameters. The result shows temperature, pH, DO, nitrate, Total P and conductivity comply with permissible standard under all scenarios. Simulation output provides that ammonium and TSS exceeding allowable standard and remains the most critical concern parameters and may require additional pollution control measures. For effective management of water quality (Hiralkumari B. Patel., et al. 2024) considered strategy of reductions in wastewater discharge quantity as 10%, 20%, and 30% of total discharge. Also (Waturu M., et al. 2022) indicated that different management strategies, such as amendments in pollution load, river inflow, wastewater flow, and improvement in treatment efficiency, can be simulated. Najamussahar H MULLA et al., (2024) during study showed that simulation by pollution load modification result to improvement of water quality parameters. Mohammad R. G et al., (2023) demonstrated that pollution load reduction by 10%, 40%, and 70% showed water quality parameters improvement after simulation.

The Analytical Hierarchy Process (AHP) tool ranked upgrading Wastewater Treatment Plants (WWTPs) with high composite weight of 0.31 as the first strategy while Community-based monitoring and clean-up activities with composite weight score of 0.253 as second alternative in Cikapundung river water quality management. The AHP analysis result by Y Ciawi et al., (2022) showed that pollution prevention with alternative number 2, "Improving monitoring and supervision of wastewater disposal" has the highest CW value of 0.317 among other strategies.

4. CONCLUSION

The most important conclusions drawn from this study are QUAL2Kw was successfully applied to simulate water quality conditions in the Cikapundung River. Scenario based analysis demonstrated significant improvements in dissolved oxygen and nutrient reduction under integrated management measures. Scenario 3 achieved the best overall water quality performance among the evaluated alternatives. AHP ranked upgrading wastewater treatment plant with score weight of 0.31 and Community-based monitoring and clean-up activities with composite weight of 0.253 as the most prioritized management alternatives. The integrated use of QUAL2KW and AHP tools provides an effective decision-making support tool for sustainable surface water management.

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REFERENCES

- F Fitriana, D Yudianto, and Y C Seo (2024): Application of QUAL2Kw for Water Quality Modeling in the Cibarani Irrigation Channel, Bandung City, Indonesia
- Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning implementation of Environmental Protection Management.
- Gregory J. Pelletier., Steven C. Chapra., Hua Tao (2005) QUAL2Kw-A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration.
- Jason Sauer & Heejun Chang (2025): Watershed management may overcome effects of climate change on stream water quality in the Portland metropolitan area.
- Klaus D. Goepel, (2013). Implementing the Analytic Hierarchy Process as a Standard Method for Multi-Criteria Decision Making in Corporate Enterprises.
- Peny Supriatno, Rizky Syaputra, Robertho Kadji, Lia Alfianita (2022). Water Quality and Hydrochemical Studies in Watersheds Cikapundung River Case Study.
- Saaty, T.L.1980. The Analytic Hierarchy Process. New York, McGraw-Hill.
- Saaty, T.L. (2008) 'Decision making with the analytic hierarchy process', *Int. J. Services Sciences*, Vol. 1, No. 1, pp.83–98.
- TK Nufutomo, BS Muntalif, HD Ariesyady, & A Sudradjat (2023): Water Quality Analysis Using QUAL2Kw Model During the Rainy Season and Dry Season in Upper Citarum Watershed, West Java, Indonesia.
- Xue Li, Kunxia Yu, Guoce Xu, Peng Li, Zhanbin Li, Peng Shi, Lu Jia, Zhi Yang, & Zihui Yue (2025): Quantifying thresholds of key drivers for ecosystem health in large-scale river basins: A case study of the upper and middle Yellow River.
- Y Ciawi, P M D Padilla, & M I Yekti (2022): The strategy of Tukad Badung pollution control using QUAL2Kw and AHP.