THESIS

WATER QUALITY MODELLING OF CITEPUS RIVER

KELVIN GOSTALIN
NPM: 2016410013

SUPERVISOR

Doddi Yudianto, Ph.D. **Prof. Seo YongChan**

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Nama lengkap	: Kelvin Gostalin
NPM	: 2016410013

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Bandung, 16th Desember 2019

Kelvin Gostalin

2016410013

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Kelvin Gostalin
Student Number: 2016410013

Supervisor: Doddi Yudianto, Ph.D. and Prof. Seo YongChan

PARAHYANGAN CATHOLIC UNIVERSITY
FACULTY OF ENGINEERING, CIVIL ENGINEERING DEPARTMENT
(Accredited by SK BAN-PT No. 1788/SK/BAN-PT/Akred/S/VII/2018)
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ABSTRACT

In this research study, HEC RAS 5.0.3 is used to simulate the hydrodynamic modelling and make a well-calibrated water quality model to simulate the pollutant transport in Citepus River. The well-calibrated water quality model is used to simulate several case scenarios to restore the Citepus River water quality into water quality Class III based on the Indonesia Government Regulation No.82 of 2001. The simulated water quality parameters are Temperature, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5). Those water quality parameters are obtained by field measurement and water sampling at several locations along Citepus River. This research study provides three series data of hydraulic data and water quality data. In hydrodynamic modelling, the measured hydraulic depth and the simulated hydraulic depth are analyzed by using RMSE and correlation coefficient evaluation criterion. Based on the data analysis, it is found that the RMSE value for three series data are 0.91, 0.69 and 0.89 while the correlation coefficient are 0.17, 0.34, and 0.15. After the hydrodynamic modelling, the water quality model calibration is done by determining the Decay Rate Coefficient (k1), and Reaeration Coefficient (k2). The water quality model simulation is conducted for each data series in order to get the proper water quality model. The value of Decay Rate Coefficient (k1) and the Reaeration Coefficient (k2) that give a good model calibration are 1.4/day and 12/day. Based on the validated water quality model, two kinds of case scenarios are conducted in order to control the Citepus River pollution and restore its water quality into water quality Class III. The first case scenario assumes that the pollution from Citepus River is controlled into water quality standard for domestic wastewater while the wastewater from Ciroyom River remains the same with the actual condition. The second case scenario assumes that both of the wastewater from Citepus River and the wastewater from Ciroyom River are controlled into water quality standard for domestic wastewater. However, based on the simulation result for both case scenarios, it is found that Citepus River water quality still doesn’t meet the criteria for water quality Class III.

Keywords: DO, BOD_5, Hydrodynamic Modelling, Water Quality Model Calibration, RMSE, Correlation Coefficient, Decay Rate Coefficient, Reaeration Coefficient, Water Quality Class III.

PEMODELAN KUALITAS AIR SUNGAI CITEPUS

Kelvin Gostalin
NPM: 2016410013

Pembimbing: Doddi Yudianto, Ph.D. dan Prof. Seo YongChan

UNIVERSITAS KATOLIK PARAHYANGAN
FAKULTAS TEKNIK JURUSAN TEKNIK SIPIL
(Teakreditasi Berdasarkan SK BAN-PT Nomor: 1788/SK/BAN-PT/Akred/S/VII/2018)
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ABSTRAK

Pada studi penelitian ini, program HEC-RAS 5.0.3 digunakan untuk mensimulasikan model hidrolik and membuat model kualitas air yang terkalibrasi untuk mensimulasikan transport polusi di Sungai Citepus. Model kualitas air yang terkalibrasi dengan baik kemudian akan digunakan untuk mensimulasikan beberapa kasus skenario untuk memulihkan kualitas air Sungai Citepus ke kualitas air Kelas III berdasarkan PP RI No.82 Tahun 2001. Parameter kualitas air yang disimulasikan di dalam model kualitas air antara lain Temperature, Dissolved Oxygen (DO) dan Biochemical Oxygen Demand (BOD_5). Parameter kualitas air tersebut diperoleh dari pengukuran lapangan dan sampling air limbah pada beberapa lokasi di sepanjang Sungai Citepus. Studi penelitian ini menyediakan tiga seri data untuk masing-masing data hidrolik dan data kualitas air. Dalam pemodelan hidrodinamik, kedalaman hidrolik yang terukur dan kedalaman hidrolik hasil simulasi model akan dianalisis menggunakan RMSE and koefisien korelasi. Berdasarkan hasil analisis data, diperoleh nilai RMSE untuk tiga seri data antara lain 0.91, 0.69, dan 0.89. Sementara itu, nilai koefisien korelasi untuk ketiga seri data antara lain 0.17, 0.34 dan 0.15. Simulasi model kualitas air dilakukan setelah simulasi model hidrodinamik. Kalibrasi model kualitas air dilakukan dengan cara menentukan koefisien k1 (Decay Rate Coefficient) dan koefisien k2 (Reaeration Coefficient). Model kualitas air disimulasikan untuk setiap seri data untuk memperoleh model kualitas air yang baik. Nilai koefisien k1 (Decay Rate Coefficient) dan koefisien k2 (Reaeration Coefficient) yang memberikan model kalibrasi yang baik adalah 1.4/hari dan 12/hari. Berdasarkan model kualitas air yang telah tervalidasi, dua kasus scenario disimulasikan untuk mengendalikan polusi Sungai Citepus dan memulihkan kualitas airnya ke kualitas air Kelas III. Pada kasus scenario pertama, diasumsikan air limbah yang berasal dari Sungai Citepus telah memenuhi standar baku air limbah untuk limbah domestik sementara kualitas air limbah yang berasal dari Sungai Ciroyom dibiarkan tetap sama sesuai dengan kondisi aktualnya. Pada scenario kedua, diasumsikan baik air limbah yang berasal dari Sungai Citepus maupun air limbah yang berasal dari Sungai Ciroyom telah memenuhi standar baku air limbah untuk limbah domestik. Namun, berdasarkan hasil simulasi kedua scenario, diketahui bahwa kualitas air pada Sungai Citepus tetap tidak memenuhi standar untuk kualitas air Kelas III.

Keywords: DO, BOD_5, Pemodelan Hidrodinamik, Kalibrasi Model Kualitas Air, RMSE, Koefisien Korelasi, Koefisien Decay Rate, Koefisien Reaerasi, Kualitas Air Kelas III.

PREFACE

Praise and thanks to God Almighty for His Grace and His Blessings so the author can finish his research study entitled “Water Quality Modelling of Citepus River”. With the completion of this research study, the author wants to convey gratitude profusely to his supervisors; Doddi Yudianto, Ph.D. and Prof. Seo YongChan for their guidance during the making of this research study. Beside that, the author also wants to express his gratitude and appreciation to his family. Even though the author faces lot of difficulties in this research study, his family never stop in motivating the author to keep up the good work. Words can’t express how grateful the author to them for their love, care, support and most importantly their prayers so that the author can finish this research study well. Finally, in this opportunity, the author also wants to say thank you to:

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Finally, for all the author’s friends, thank you for your endless understanding and encouragement during the making of this research study. The author realizes that this research study may still contain many limitations. Therefore the author hopes there will be any suggestions in order to enhance the usefulness of this research study. In the end, the author hopes this research study can also give benefits for the future research studies.

Bandung, 16th December 2019

Kelvin Gostalin

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LIST OF NOTATION AND ABBREVIATION

DO : Dissolved Oxygen Concentration (mg/L)

BOD : Biochemical Oxygen Demand Concentration (mg/L)

COD : Chemical Oxygen Demand Concentration (mg/L)

CBOD : Carbonaceous Oxygen Demand Concentration (mg/L)

NBOD : Nitrogenous Oxygen Demand Concentration (mg/L)

D : Dissolved Oxygen Deficit (mg/L)

D0 : Dissolved Oxygen Concentration (mg/L)

k_d : Decay Rate Coefficient (/day)

k_1 : Decay Rate Coefficient (/day)

k_a : Reaeration Coefficient (/day)

k_2 : Reaeration Coefficient (/day)

L0 : Ultimate BOD Concentration (mg/L)

$\bar{u}$: Mean Velocity

x : Length (m)

$DO_{initial}$: Dissolved Oxygen Concentration before 5 days incubation (mg/L)

DO_{final} : Dissolved Oxygen Concentration before 5 days incubation (mg/L)

Dilution : Ratio between the volume of sample and the volume of dilution water

t : Time (day)

Z1, Z2 : Elevation of the main channel inverts (m)

Y1,Y2 : Depth of water at cross-section (m)

V1, V2 : Average Velocity (m/s)

$\alpha 1, \alpha 2$: Velocity Weighting Coefficients

h_e : Energy Head Loss (m)

L : Discharge weighted reach length (m)

$\bar{S}_f$: Representative Friction Slope Between Two Cross-Section (m)

C : Expansion – Contraction Loss Coefficients

C_{us} : Local Courant Number (dimensionless)

U_{us} : Velocity of Water Quality Cell Face (m/s)

Δx : Length of Water Quality Cell (m)

Δt : Time Step (second)

α_{us} : Local Peclet Number (dimensionless)

Γ_{us} : Dispersion Coefficients at water quality cell face (m^2/s)

V : Volume of Water Quality Cell (m^3)

Q : Flow Discharge (m^3/s)

A : Cross Sectional Area (m^2)

S : Sources and Sinks (kg/s)

k_T : Rate Constant at Temperature T

k_{20} : Rate Constant at Temperature 20'C

θ : Temperature Correction Coefficient

v : Average Velocity of Water's Flow (m/s)

B : Average Channel Width (m)

H : Average Channel Depth (m)

v^* : Friction Slope Between Two Cross-Section

n : Number of observation data

x_i : Observation Value (mg/L or ‘C)

$\hat{x}_i$: Simulation Result Value (mg/L or ‘C)

RMSE : Root Mean Square Method

r : Correlation Coefficient

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CHAPTER 1

INTRODUCTION

1.1 Background

The availability of an adequate water supply in terms of both quantity and quality is essential to human existence. Human may live for many days without food but the absence of water for only a few days may cause fatal concequences. Human uses large amounts of water everyday since water serves different purposes such as domestic purposes, industrial purposes and agricultural purposes. According to article from Indonesia Minister of Public Works and Human Settlements, each person consumes water up to 150 Litres per day. The wastewater from those water uses will eventually be disposed into a water body. But, important to note that every water body can only accept a limited amount of physical, chemical and biological substances without a significant deterioration. (Water Quality Handbook Second Edition, 2007)

As populations and economies grow significantly these days, more pollutants are generated. As a result, water bodies can be polluted by a wide variety of substances such as toxic chemical, petroleum (oil), plant nutrients, organic waste and even pathogenic microorganism. The wastewater that comes from urban or residential areas is known as Domestic Wastewater. Domestic wastewater contains high of organic substances and pathogens. Beside that domestic sewage is also a major source of plants nutrients such as nitrates and phosphates. Both of these nutrients cause the growth of algae in the water (eutrophication).

The observed river in this research study is Citepus River that located in Bandung City, West Java. As we can see in **Figure 1. 1**, this river is located in the middle of Bandung City. The recent situation of Citepus River is shown in **Figure 1. 2.**

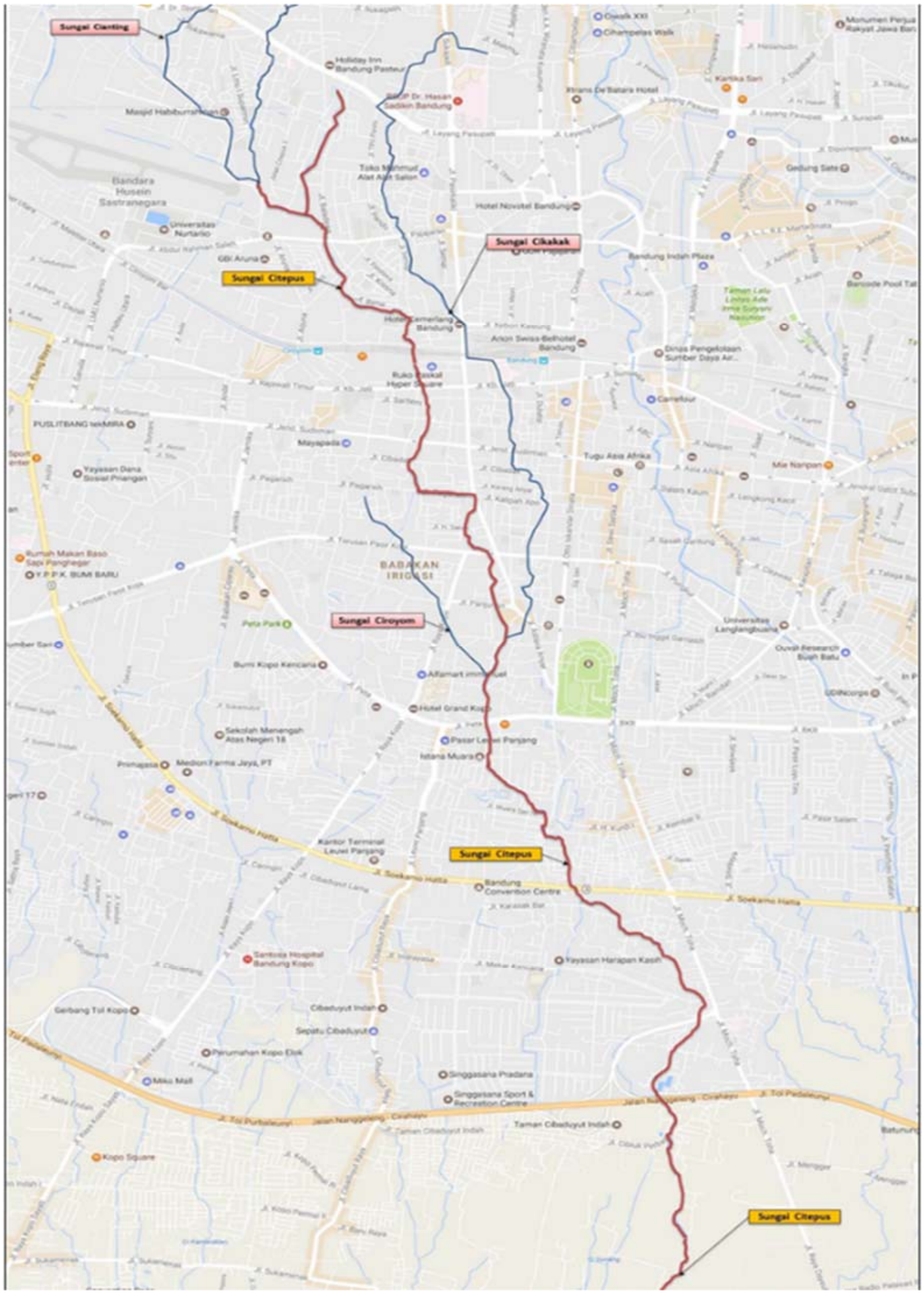

Figure 1. 1 Citepus River Location

Figure 1. 2 Citepus River Recent Condition

According to MERDEKA's Article, most of rivers in Bandung City are badly polluted by human feces including Citepus River. The article mentioned that tons of human feces are disposed into Citepus River every day. The poor sanitation system is the reason why Citepus River can be polluted by pathogens bacteria (*E Coli*) that is excreted in feces. Ideally, each house must has a septic tank to treat the wastewater from toilet before disposing it into river. But in reality, the people's residences along Citepus River discharge the wastewater from toilet directly into river. As a result, Citepus River emits a bad odor and the color of the water turns into black especially during the dry season.

The problem of badly polluted Citepus River must be undertaken seriously since the downstream of this river is Citarum River. According to TRIBUNJABAR's Article, Citarum River is used to supply water to the home for 25 million people in Jakarta (Indonesia Capital City), and to irrigate 5% of the nation's rice field. As Citarum River plays this vital function, the quality of domestic wastewater that comes from Citepus River must be controlled based on a certain level or parameter.

Based on the condition of Citepus River that has been described before, this research study aims to make a well calibrated water quality model and simulate several case scenarios to restore Citepus River's water quality into water quality Class III based on Indonesia Government Regulation No.82 of 2001.

1.2 Key Problems

Every water body must has its total effluent allowed to be discharged or water environmental capacity. As long as the pollutant discharged does not exceed the water's environmental capacity, the water body won't badly polluted. The situation in Citepus River shows that the river is already badly polluted especially during the dry season. During the dry season, the watercolor from this river is black and sometimes the water emits a bad odor that can be dangerous for human health. In response to this problem, this research study proposes to make a well-calibrated water quality model and then simulates several case scenarios to restore Citepus River water quality.

1.3 Research Objectives

The main objective of this research study is to utilize a simple reliable water quality model with its hydrodynamic model set, as a basis for decision making in river water quality assessment project. Some other specific objectives are given as follow:

1. To obtain the water quality parameters such as Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5) by water sampling at different locations along Citepus River.
2. To assess the water quality condition in Citepus River based on the level of pollution and its characteristic.
3. To simulate several case scenarios to restore Citepus River's water quality into water quality Class III based on Indonesia Government Regulation No.82 of 2001.

1.4 Scope of Study

1. Only Temperature, DO and BOD_5 water quality indicators are going to be modeled inside the water quality model for Citepus River.
2. The Segmentation of Citepus River that will be modelled is start from Padjajaran street to Soekarno Hatta street.
3. HEC-RAS 5.0.3 is used in performing hydrodynamic modelling and water quality calibration for Citepus River. Important to note, this software can only simulate one-dimensional water quality model.

1.5 Research Methodology

Like any other research study, problem identification is addressed first in order to conduct a research study. Problem identification aims to clearly identifying the root cause of a problem and developing a detailed problem statement. Beside that, a good literature study is also needed while conducting a research study. Literature study enables the researcher to fully understand the theories that the research might rest upon and also immerse the researcher in the language of the discipline. The good literature study will help the researcher to determine their scope of study and the need for their research. The literature study for this research study includes the study about water hydrodynamic modelling, water quality modelling, the previous studies that have been done, and sufficient understanding about the assumption and limitations for representing the actual condition inside the model. This literature studies are used to enhance the insight of the researcher to better conceptualize the problems.

This research study basically consists of hydrodynamic modelling and water quality model calibration. Water quality calibration involves a comparison between the simulation result and the field measurement so that data collection is needed and it has to be done properly since it will determine the model validity.

Two kind of data that are collected in this research study are water quality data and hydraulic properties data. The water quality data is collected manually by the researcher within different locations along the

Citepus River. Three kind of data that are measured from the water sample are water temperature, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5). In hydraulic properties data, there are three kind of data that are used for the modelling such as Channel Geometry, Average Flow Discharge and Average Flow Velocity. The Channel Geometry data is obtained from Bandung Water Research Center (Puslitbang Air Bandung) but the average flow discharge and average flow velocity data are measured manually within different locations along Citepus River to obtain the actual representative data.

When all the hydraulics properties data have been collected then those data are inputed into HEC RAS 5.0.3 to performing a hydrodynamic modelling. Two kind of data that are inputed to HEC RAS 5.0.3 to performing a hydrodynamic modelling are geometry data and steady flow data or unsteady flow data. In this research study, only a steady flow condition that is simulated therefore the steady flow data is inputed into HEC RAS. The reason behind the selection of steady flow condition is because the water level from the different observation stations do not change significantly with time so that it is assumed that the river has a constant flow or steady flow. The geometry data consist of the river cross section data, river long section data, and roughness coefficient (manning's coefficient) to represent the energy loss due to the friction forces between the river bed and the water. Once the geometry data and the steady flow data have been inputed into HEC-RAS 5.0.3 then the program is ran to performing a hydrodynamic analysis. Important to note, a good hydrodynamic model is a model that will shown a reasonable flow profile along the river.

The second model simulation that also need to be properly done is water quality simulation. Similar with hydrodynamic modelling, the water quality modelling is also performed by HEC-RAS 5.0.3. In water quality modelling, there are five parameters that are inputted into HEC-RAS 5.0.3 such as Decay rate coefficient (k1), Reaeration coefficient (k2), water quality boundary condition, water quality initial condition, and longitudinal dispersion coefficient. The water quality model calibration is done by determining the value of Decay rate coefficient (k1) and Reaeration coefficient (k2) that give a good water quality model. The good water quality model is the model that shows a good agreement with the measured data.

Once the water quality model has been well-calibrated, two kind of case scenarios are conducted by the researcher in order to restore Citepus River's water quality into water quality Class III. Finally, some conclusions and recommendations are given according to the result of this research study. The flow chart for this research study is shown in **Figure 1. 3.**

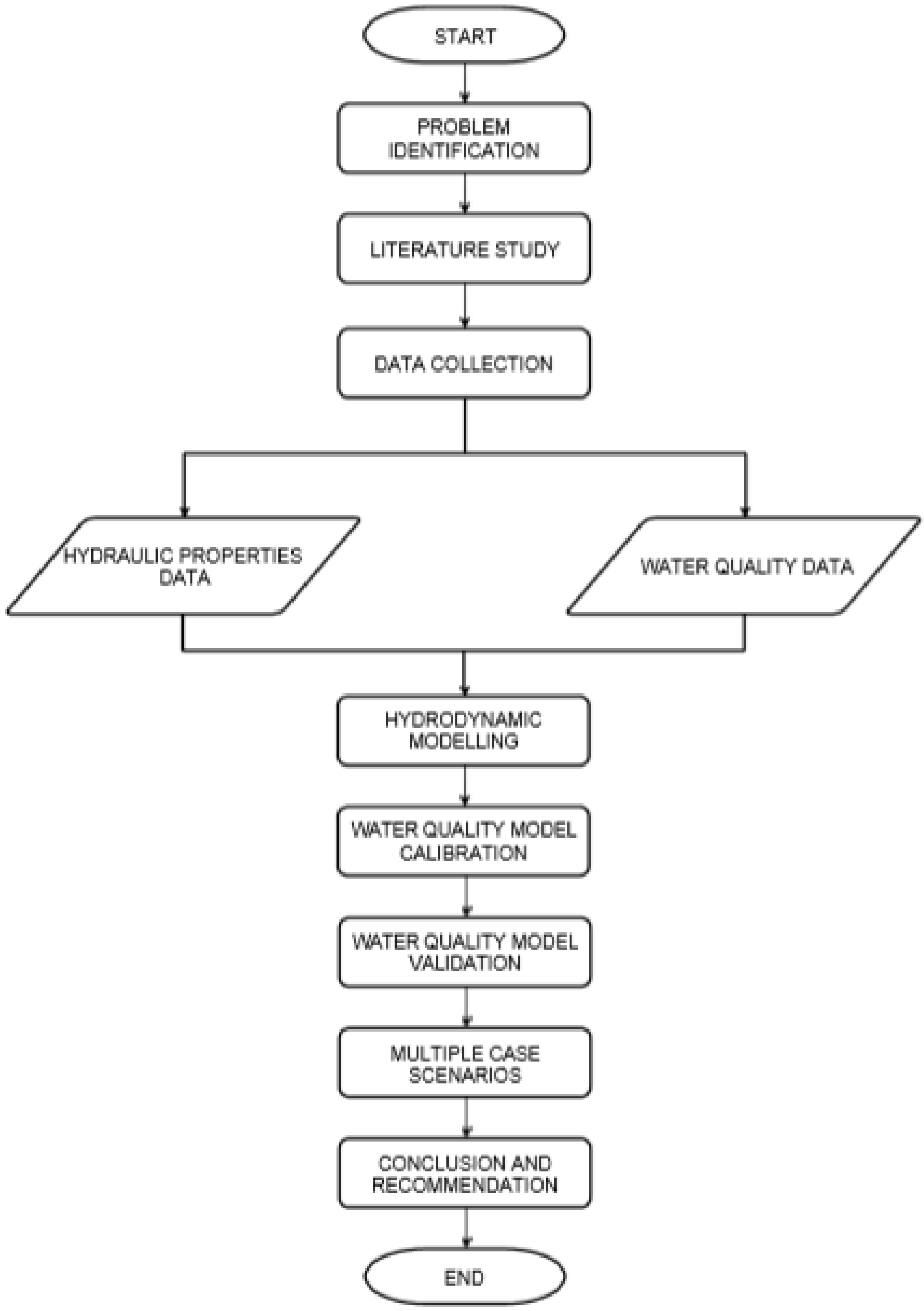

Figure 1. 3 Research Flow Chart