UNDERGRADUATE THESIS

WATER AVAILABILITY ANALYSIS OF KETRO DAM FOR PRESENT AND FUTURE CONDITION

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PERNYATAAN

Yang bertandatangan di bawah ini, saya dengan data diri sebagai berikut:

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Menyatakan bahwa skripsi dengan judul:

"WATER AVAILIBILITY ANALYSIS OF KETRO DAM FOR PRESENT AND FUTURE CONDITION "

adalah benar-benar karya saya sendiri di bawah bimbingan dosen pembimbing dan dosen ko-pembimbing. Saya tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika keilmuan yang berlaku dalam masyarakat keilmuan. Apabila di kemudian hari ditemukan adanya pelanggaran terhadap etika keilmuan dalam karya saya, atau jika ada tuntutan formal atau non formal dari pihak lain berkaitan dengan keaslian karya saya ini, saya siap menanggung segala resiko, akibat, dan/atau sanksi yang dijatuhkan kepada saya, termasuk pembatalan gelar akademik yang saya peroleh dari Universitas Katolik Parahyangan.

Dinyatakan: di Bandung

Tanggal: 21 Juli 2020

Farrell Wiguna

WATER AVAILABILITY ANALYSIS OF KETRO DAM FOR PRESENT AND FUTURE CONDITION

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ABSTRACT

Ketro Dam is one of several dams in Sragen District, East Java. The dam is located on Bengawan Solo river network and acts as a fulfillment of irrigation water demand for 400 hectares of irrigation area. It has been running since 1984 and considered one of the oldest dams in Indonesia. This research aims to determine the reliability of Ketro Dam in meeting the fulfillment of irrigation water demand for present and future conditions. To determine the reliability of the Ketro Dam in the present term, a reservoir simulation model was carried out with four inputs, using HEC-HMS software to perceive the historical rainfall transformation, estimating the needs for irrigated water each half month, surface evaporation rate, and bathymetry data on the reservoir. The outcome of reservoir simulations throughout nine years showing that Ketro Dam was able to fulfill the demand for irrigation water approximately 82.1%. Therefore, the Ketro Dam is capable to fulfill the current water demand considering the standard which was set by the government is as low as 80%. This research is also using reservoir simulation to project and determine the capability of Ketro Dam when facing the same irrigation needs in the future. As a result, the input data of the historical rainfall transformation should be replaced with the projected rainfall transformation discharge. The projected rainfall data which also considers the effect of climate change is obtained from one of RCM called REMO Model with RCP 2.6 Scenario. The Comparison between RCM monthly rainfall and rain station produces an error value of 19.7% and 154.86 mm for the RMSE value. Reservoir simulation results shows that from 2021-2045 Ketro Dam failed to meet the constant irrigation needs of 400 hectares. This statement based on the fulfillment irrigation rate is only at 38.72% in 2021-2025, 36.09% in 2026-2030, 53.4% in 2031-2035, 13.5% in 2036-2040, and 38.8% in 2041-2045 which is still far below the government standard (80%). However, if we compare the rate of success from the current scenario (82.1%) and future scenario, the value from the future scenario is far below the current conditions. It is suspected that the analysis used in this thesis (future scenario analysis) has not accurately projected the future reliability of Ketro Dam.

Keywords: Reservoir Simulation, Water Availability, Climate Change, RCM, RCP 2.6, Ketro Dam

ANALISIS KETERSEDIAN AIR BENDUNGAN KETRO UNTUK KONDISI SAAT INI DAN YANG AKAN DATANG

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Juli 2019

ABSTRAK

Bendungan Ketro merupakan salah satu bendungan yang berada di Kabupaten Sragen, Jawa Timur. Bendungan yang berada pada jaringan Sungai Bengawan Solo ini difungsikan sebagai pemenuhan kebutuhan air irigasi untuk 400 hektar daerah irigasi. Bendungan ini merupakan salah satu bendungan tua di Indonesia yang telah berfungsi sejak tahun 1984. Studi ini bertujuan untuk mengetahui keterandalan Bendungan Ketro dalam pemenuhan kebutuhan air irigasi untuk kondisi saat ini dan kondisi yang akan datang. Untuk mengetahui keterandalan Bendungan Ketro untuk kondisi saat ini, dilakukan pemodelan simulasi waduk dengan empat buah *input*, debit hasil transformasi hujan historis menggunakan perangkat lunak HEC-HMS, estimasi kebutuhan air irigasi per setengah bulan, laju evaporasi permukaan, dan data batimetri waduk. Hasil simulasi waduk selama sembilan tahun menunjukan bahwa Bendungan Ketro dapat memenuhi kebutuhan air irigasi sebanyak 82.1%. Dapat disimpulkan bahwa Bendungan Ketro dapat memenuhi kebutuhan air saat ini dikarenakan berada di atas standar yang ditetapkan oleh pemerintah yaitu 80 %. Studi ini juga menggunakan simulasi waduk untuk mengetahui keterandalan Bendungan Ketro dalam menghadapi kebutuhan irigasi yang sama di masa yang akan datang. Oleh karena itu, *input* data debit hasil transformasi hujan historis harus diganti dengan debit hasil transformasi curah hujan proyeksi. Data curah hujan proyeksi yang juga memperhitungkan efek perubahan iklim didapatkan dari salah satu RCM bernama *REMO Model* dengan scenario RCP 2.6. Perbandingan antara curah hujan bulanan RCM dan stasiun hujan menghasilkan nilai *error value* sebesar 19.7 % dan 154.86 mm untuk nilai RMSE. Hasil simulasi waduk menunjukan bahwa Bendungan Ketro dapat memenuhi kebutuhan air sebesar 38.72% pada 2021-2025, 36.09% pada 2026-2030, 53.4% pada 2031-2035, 13.5% pada 2036-2040 dan 38.8% pada 2041-2045. Oleh karena itu, dari tahun 2021-2045 Bendungan Ketro dianggap gagal memenuhi kebutuhan air irigasi karena berada di bawah standar yang telah ditetapkan pemerintah yaitu sebesar 80 %. Namun jika kita membandingkan tingkat keberhasilan skenario masa kini (82.1%) dan masa depan, nilai skenario masa depan berada jauh dibawah nilai skenario masa kini. Hal ini menyebabkan dugaan bahwa analisis untuk skenario masa yang akan datang belum dapat secara akurat atau tepat memproyeksikan keterandalan Bendungan Ketro dalam memenuhi kebutuhan air di masa depan.

Kata Kunci: Simulasi Waduk, Ketersediaan Air, Perubahan Iklim, RCM, RCP 2.6, Waduk Ketro

PREFACE

This thesis is made as a requirement to complete a bachelor's degree in Civil Engineering from the Faculty of Engineering at Parahyangan Catholic University. There are a lot of people around the writer that gave the writer technically guidance and mental support in the making of this thesis. Therefore, this page is specially dedicated to thanks to those people who always be on the writer's side while making on this thesis. The writer would like to express the gratitude to:

1. My supervisor, Doddi Yudianto, Ph.D., who has provided a lot of knowledge, suggestions, and constructive comments during the entire process of this thesis.
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5. Civil Engineering 2016 for the moment and memory during the writer study in Parahyangan Catholic University.
6. All the writer friends and colleagues who cannot be mentioned one by one who has given their support

The writer realizes that this thesis may contain many limitations and there is still a lot of room for improvement. Therefore, the writer would greatly appreciate any suggestions and critiques to improve this thesis. Nonetheless, the writer wish that this thesis can be useful for any reader.

Bandung, July 2020

Farrell Wiguna

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CHAPTER 1
INTRODUCTION

1.1 Background

Dam is one of vital infrastructures that aims for: water preservation, river diversion, and flood control (Direktorat Jenderal Sumber Daya Air, 2003). In Indonesia, there was a considerable number of dams that were built in the colonization era. According to Samketo (2016), since 1970, a lot of reservoirs especially in Java Island have shown a degradation of performance. This issue puts into question whether the performance of the older dams is still able to cope with the current or future condition. That being said, having a sustainable water infrastructure is one of the most favorable solution to create a sustainable water resources (Bocchini, Frangopol, Ummenhofer, & Zinke, 2014).

The performance of a dam is subjected to many factors, one of which is climate. Climate has become a major direct and subtle influence in human survival since the beginning of civilization (McLeman, 2011). The uncertain behavior of climate brings many problems to the society, even to vital infrastructures. The most impacted sector is agriculture because many farmers depend their livelihood alone on the precipitation (Jones, Hansen, Royce, & Messina, 2000). Furthermore, the impacts of climate change can be seen in many aspects including the intensity of weather-related disaster and the changing of precipitation pattern (IPCC, 2001). For example, a very intense unpredictable rainfall which leads to flood disaster, or a long and dry period which leads to drought catastrophe. Several studies have been performed to study the impacts of climate change by projecting the precipitation rate induced with climate change effect using Global Climate Models (GCMs) and Regional Climate Models (Hewitson & Crane, 2006). Thus, in civil engineering point of view, this dataset can be good scenario to understand the resilience of water infrastructures.

This study will be carried out in one of the old dams in Indonesia, Ketro Dam, which is located in Sragen District, Central Java Province, and was built in 1984. It is one of the key roles in maintaining water supply in the Sragen District, especially for irrigating the 400 hectares area. With regard to the impacts of climate change and the fact that Ketro Dam was designed 36 years ago, the water supply capacity of the reservoir needs to be evaluated.

Hence, this study is carried out to analyse the current and future condition of Ketro Dam in fulfilling the constant irrigation demand by performing a reservoir simulation.

1.2 Aim and Objective

This thesis aims to study and evaluate the Ketro Dam's water availability in the present and future condition.

The objectives are formulated as follows:

1. To estimate the water demand required for irrigation
2. To perform a reservoir simulation using historical precipitation data
3. To generate rule curve as the basis for the dam's operation
4. To perform RCM data comparison
5. To perform a reservoir simulation using RCM projected precipitation data
6. To analyse and compare the result of the simulations for all scenarios

1.3 Scope of Study

This study focusses on a reservoir simulation for the present and future scenarios. Future scenarios simulation will be carried out by solely changing the historical precipitation dataset to projected RCM-precipitation dataset. The other factors such as changes in irrigation demand, climatology and river topography for future scenario will be assumed unchanged.

1.4 Research Methodology

The research methodology for this thesis consists of:

1. Literature Study

   This step is carried out to understand the basic principles of the studied topic and previous study that has been done.

2. Data Analysis

   This step is carried out to process the raw data as input for mathematical modeling such as historical precipitation data, climate data, topography data, projected precipitation data.

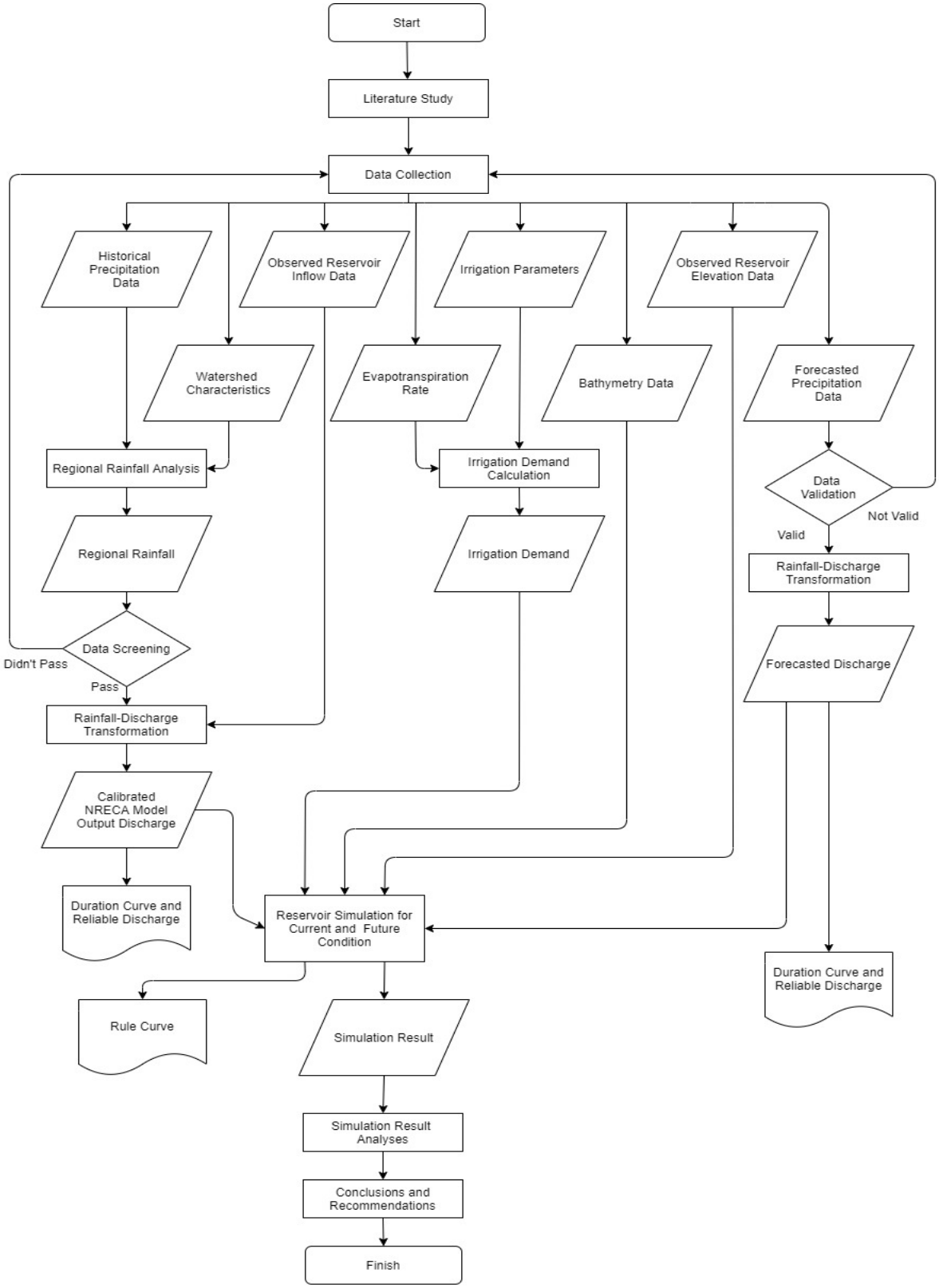
3. Mathematical Modeling

   This step is carried out to calculate rainfall-runoff transformation using HEC-HMS mathematical model and NRECA conceptual model. Reservoir simulation is also carried using spreadsheet

4. Result Analysis

   This step is carried out to discuss the results of the analysis that has been done.

The research methodology's diagram is presented in Figure 1.1


Start
Literature Study
Data Collection
Historical Precipitation Data
Observed Reservoir Inflow Data
Irrigation Parameters
Observed Reservoir Elevation Data
Watershed Characteristics
Evapotranspiration Rate
Bathymetry Data
Forecasted Precipitation Data
Regional Rainfall Analysis
Irrigation Demand Calculation
Data Validation
Not Valid
Valid
Regional Rainfall
Irrigation Demand
Rainfall-Discharge Transformation
Data Screening
Didn't Pass
Pass
Forecasted Discharge
Rainfall-Discharge Transformation
Calibrated NRECA Model Output Discharge
Duration Curve and Reliable Discharge
Reservoir Simulation for Current and Future Condition
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