Database model for inventory and condition assessment of hydraulics infrastructure in Indonesia

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Abstract. Indonesia is a country that has a reasonably large area with quite a lot of water resources such as rivers, reservoirs, lakes, and so on. To manage these water resources, quite a lot of physical infrastructure is needed from upstream to downstream. A well-documented physical infrastructure will assist the government in maintaining and repairing the building if there is damage/disruption. This research aims to develop a database model for the inventory of existing hydraulic structures in the Cengklik reservoir area and an evaluation sheet for their condition. The database model for inventory and evaluation sheets is structured within the MYSQL Relational Database Management Systems (RDBMS) framework based on attributes of a dam studied and expert judgments, and the user interface is developed using the PHP framework for managing the database. The research results are a water/hydraulics structures inventory database model and an evaluation sheet for one type of hydraulics structure in the form of a dam. The built model is expected to help supervisors in the field record the condition of hydraulic structures in their area of responsibility and assist the government in managing the hydraulic infrastructure.

1 Introduction

Water is a source of life for living things on earth. Its existence in various forms will significantly support the life of humans, animals, and plants and the environment around it [1]. Indonesia is an archipelago with abundant water resources such as rivers, lakes, and groundwater. Thousands of waterways flow throughout Indonesia [2]. Communities use water resources for clean water sources, agricultural irrigation, fisheries, etc.

Management of rivers and river basins[3] is essential to maintain their benefits and sustainability [4]. Indonesia has established river basin offices to manage all water resources, including rivers. The River Region Office (RRO) has the task of implementing water resource management, which includes planning, construction, operation, and maintenance in the context of water resource conservation, resource utilization, and control of the destructive power of water in river areas.

Water resource management activities often involve a lot of data and stakeholders [5] besides the RRO. They are local governments through which the river flows or other official

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agencies. This requires a structured data storage and access system. A well-developed data storage system [6] helps officers prepare construction activity plans, implement them, and evaluate hydraulics structures in a river area. Now, it has been found that data storage for hydraulics infrastructure is managed separately from condition assessment data. Data management is sometimes run by many stakeholders, causing redundancy among them. Well-connected data management between agencies and system integration for inventory and condition assessment of hydraulic infrastructure will help data integrity and management.

Today is the era of information and communication technology [7]. Almost everything on earth is captured/recorded and stored electronically, and various platforms/applications are available. Government organizations have data that is often needed by others. The data should be easily accessible/shared so that it is more advantageous for the community's needs. This situation requires an effort to provide an information system platform to bridge stakeholder data exchange. The system will increase the benefit to stakeholders in utilizing the shared data optimally.

The geographic information system (GIS) [8], is a system that processes data stored in a database and displays it as a map. Currently, many technologies are equipped with this facility. The OpenStreetMap [9] is a free map provider that Leaflet.js accompanies [10], a library with JavaScript language utilized for web Geographical information systems (GIS) [11]. The GIS requires MySQL [12] as software for rational database management systems (RDBMS). Several open software required for web-based application development are PHP [13] and JavaScript [14].

As mentioned above, this research aims to develop a web application for inventory and condition assessment of hydraulics structures in Indonesia utilizing GIS support. The software developed is expected to simplify the inventory and assessment process for hydraulic infrastructure in Indonesia.

2 Research Method

2.1 Locations

This research was primarily conducted in the hydraulics laboratory and computing laboratory. Cengklik reservoir in Boyolali Regency, Central Java, is used as a case study. The database model of hydraulics structures and web application was developed in the computing laboratory. Figure 1 shows the location of Cengklik reservoir on Google Maps.

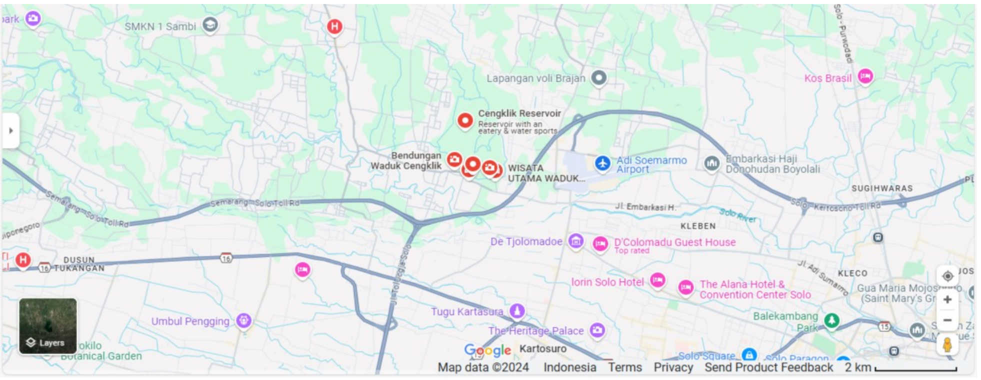

Fig. 1. The location of Waduk Cengklik on Google Maps.

2.2 Tools

Database models and web-based application development utilize several software and libraries. Several open-source software and libraries include MySQL, Visual Studio Code, CodeIgniter framework, Leaflet, Bootstrap, JavaScript, and OpenStreetMap. MySQL is utilized to develop a database model in RDBMS schema. Visual Studio Code [15,16] is an IDE (Integrated Development Environment) that is used to code the algorithm of a web-based application with CodeIgniter PHP framework V.3[17]. The Leaflet.js [10] is a library in JavaScript language that allows access to map provider OpenStreetMap [9].

2.3 Procedure

The research begins with data collection on hydraulics-building attributes from several kinds of literature. The database model is built based on attribute data by creating tables in a MySQL database server. The PHP script of CodeIgniter is coded to construct a model, visual, and controller (MVC) for accessing the database in Microsoft Visual Studio. In this stage, the application's user interface is also developed. The map provider (the OpenStreetMap) is accessed using the library Leaflet.js to build the map on several pages. The result will show the map on a page with the coordinates of the hydraulics building.

3 Result and Discussion

3.1 Database Model

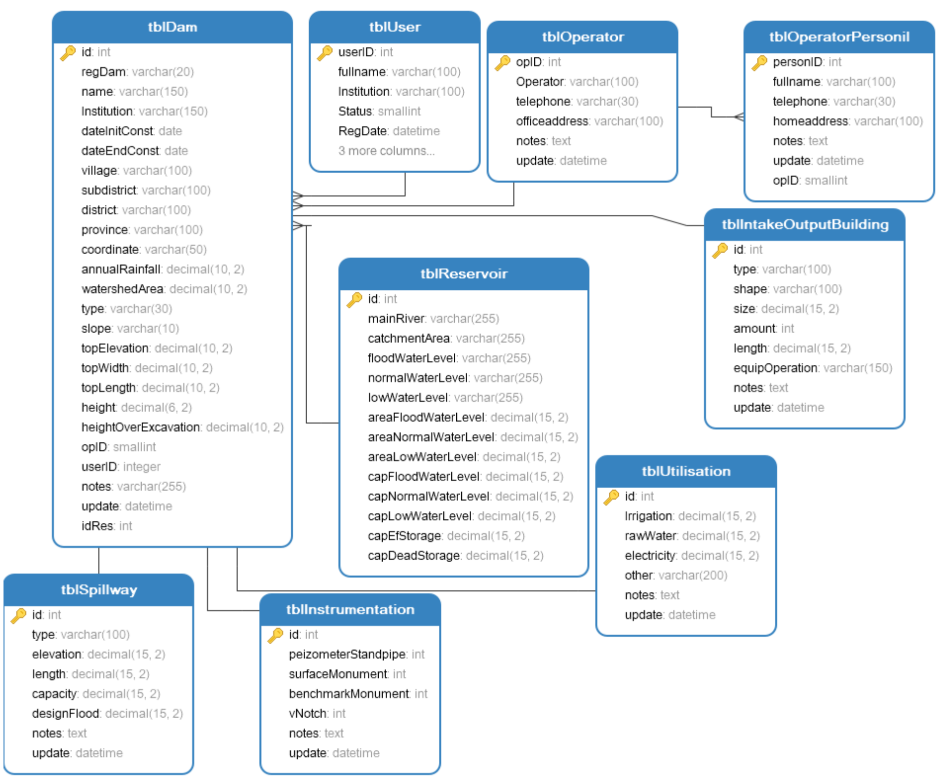

Fig. 2. Entity Relationship (ER) model for dam data inventory.

The research finds that there are types of hydraulics buildings i.e. waterway diversion, levee, revetment, gabion, sea dike, jetty, crib, side spillway, flood gate, flood pump, weir, rubber weir, dam or reservoir, flood retention reservoir, check dam, Sabo dam, intrusion control gate, groundwater irrigation, surface irrigation, etc. As this paper focuses on a dam or reservoir, Figure 2 shows the database structure in the form of the ER diagram for the inventory data model for the dam as part of the hydraulics infrastructure.

The inventory model comprises eight tables i.e. *tblUser*, *tblDam*, *tblReservoir*, *tblSpillway*, *tblInstrumentation*, *tblIntakeOutputBuilding*, *tblUtilisation, and tblOperator*, *tblPersonil Operator*. The relationships among tables are one-to-one (-) and one-to-many (⋞). An example of a one-to-one relationship is that one dam has one spillway, which shares a similar primary key (*tblDam* and *tblSpillway*). The one-to-many relationship is that one reservoir can have many dams (*tblReservoir* and *tblDam*). IdRes in *tblDam* preserves data integrity as a foreign key for the primary key id in *tblReservoir.*

The assessment model includes physical, operational, safety, and institutional performances. Figure 2 shows a dam performance assessment schema with its component and sub-component for each performance assessed.

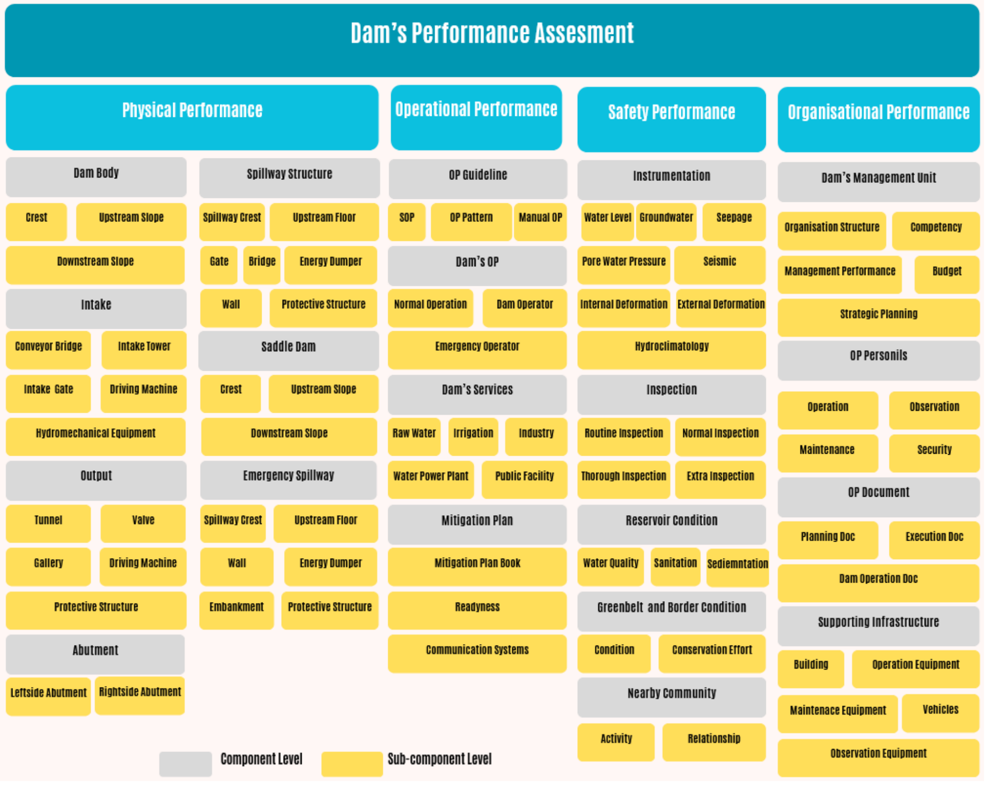

Fig. 3. The dam's performance assessment components and sub-component's structure.

The physical performance contains seven components, i.e., dam body, intake, output, spillway, saddle dam, emergency spillway, and abutment structures, as seen in Figure 3. Each component is decomposed into several sub-components, each with several criteria for assessment scoring. For example, the dam body has sub-components, i.e., crest, upstream, and downstream slopes. Figure 4 shows the ER diagram for physical assessment with the component dam body and its sub-components.

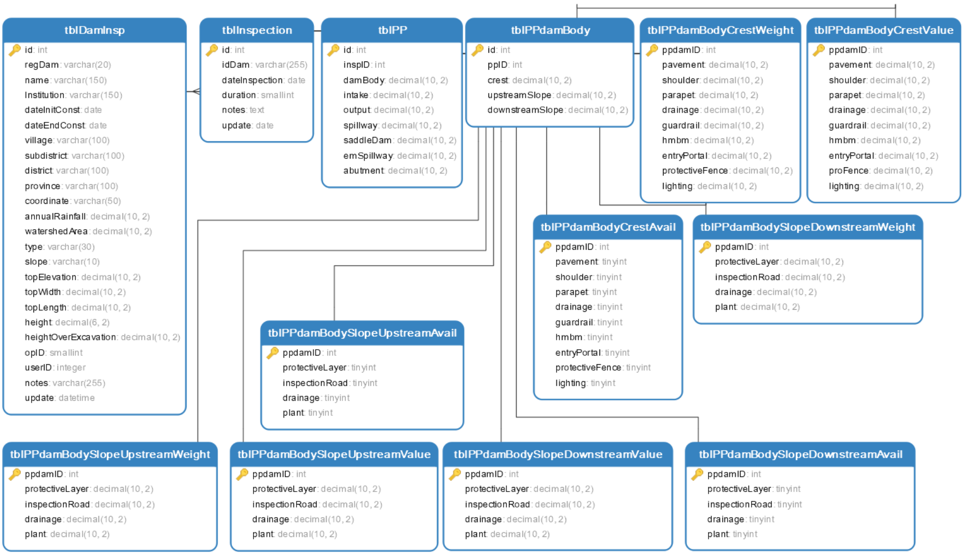

Fig. 4. Entity Relationship (ER) model for a dam body assessment database at physical performance.

The ER model developed is further to be converted into database format in the MySQL platform. The rest of the evaluation, such as operational, safety, and organizational performances, are also transferred into the MySQL database based on the structures in Figure 3.

3.2 Application User Interface

Figure 5 below shows an example of several images captured from the application's user interface, including the front page, login form, main menu, and input menu for dam attributes. The rest of the forms are for the assessment process and output.

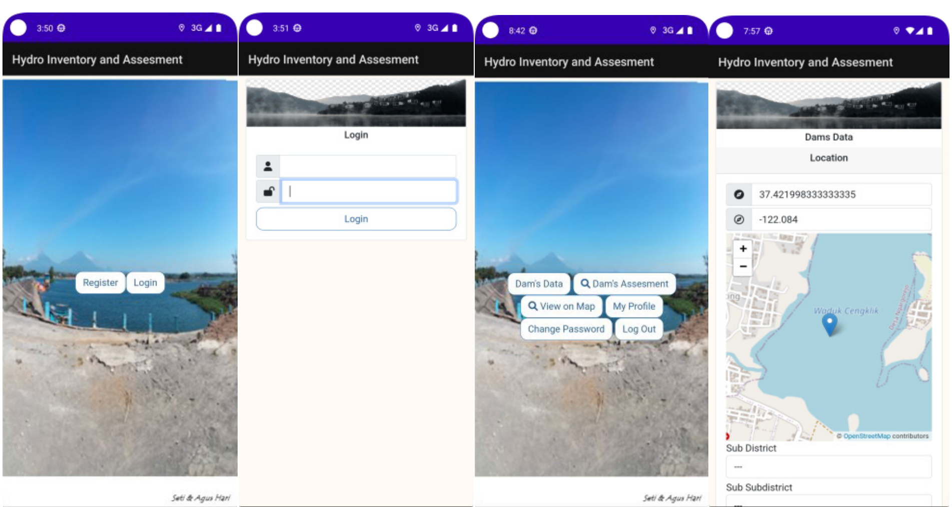

Fig. 5. The user interface of *Hydro Inventory and Assesment* developed at research.

3.3 Assessment of Cengklik Dam

Figure 6 shows the dam body at Cengklik reservoir. The assessment is categorized into physical, operational, safety, and organizational. This paper focuses on the physical performance assessment of the dam.

Fig. 6. The dam body comprises the crest, upstream slope, and downstream slope of Cengklik dam.

The assessment process is separated into four categories, i.e., physical, operational, safety, and organizational. Each category is decomposed into several components. The components are further distributed into several sub-components with their criteria/indicators. The proportion/percentage of each component/sub-component/indicator is determined by an expert based on his experience. If the proportion of them is zero (0%), it is indicated that the component/sub-component/indicator does not exist in the dam's structure.

The results of the physical assessment are presented in Table 1 and Table 2. Table 1 describes the detailed score of each indicator where several indicators will contribute to a sub-component, and several sub-components will generate a component score accordingly.

Table 1. Physical assessment of Cengklik Dam.

Components	Sub-components	Indicators	Status	Score	Total
Dam Body (35%)	Crest (40%)	Pavement (65%)	√	69	69
		Shoulder (0%)	–	–	
		Parapet (0%)	–	–	
		Drainage channel (0%)	–	–	
		Guard rail (0%)	–	–	
		BM stake (17%)	√	73	
		Entry portal (17%)	√	63	
		Protective fence (0%)	–	–	
		Lighting (0%)	–	–	
	Upstream slope (30%)	Protective layer (67%)	√	69	72
		Inspection road (33%)	√	79	
		Drainage (0%)	–	–	
		Plants (0%)	–	–	
	Downstream slope (30%)	Protective layer (50%)	√	76	74
		Inspection road (25%)	√	73	
		Drainage (25%)	√	71	
		Protective fence (0%)	–	–	
Intake Structures (24%)	Conveyor bridge (19%)	Abutment (19%)	√	65	68
		Bridge slab (19%)	√	61	
		Girder (25%)	√	70	
		Handrail (13%)	√	72	
		Column (25%)	√	71	
		Cable Stay (0%)	–	–	
	Intake tower (19%)	Wall (25%)	√	69	70

Components	Sub-components	Indicators	Status	Score	Total
		Slab (25%)	√	68	
		Protection roof (25%)	√	63	
		Inspection ladder (25%)	√	79	
		Lift (0%)	–	–	
	Intake gate (25%)	Stoplog (0%)	–	–	81
		Trash rack (0%)	–	81	
		Trash Bom (0%)	–	–	
	Hydromechanical equipment (38%)	Automatic panel (0%)	–	–	70
		manual drive (100%)	√	70	
	Drive machine (0%)	Motor Crane (0%)	–	–	–
		Sling cable (0%)	–	–	
		Panel (0%)	–	–	
		Genset (0%)	–	–	
		Backup genset (0%)	–	–	
Output Structures (24%)	Tunnel (75%)	Penstock (70%)	√	68	69
		Connection (30%)	√	71	
	Valve (0%)	Operation panel (0%)	–	–	-
		Butterfly valve (0%)	–	–	
		Cone Valve (0%)	–	–	
		Needle Valve (0%)	–	–	
	Drive machine 0%	Panel (0%)	–	–	-
		Generator (0%)	–	–	
		Backup Generator (0%)	–	–	
	Protection structures (25%)	wall (33%)	√	70	71
		Floor (33%)	√	70	
		Inspection ladder (0%)	–	–	
		Protection Roof (33%)	√	73	
	Gallery (0%)	Concrete wall (0%)	–	–	-
		Inspection ladder (0%)	–	–	
		Lighting (0%)	–	–	
Spillway (18%)	Upstream floor (13%)	Concrete layer (100%)	√	78	78
	Top Spillway (27%)	Concrete layer (100%)	√	79	79
	Slide channel (13%)	Concrete slab (70%)	√	78	76
		Drain hole (30%)	√	72	
	Wall/ wing (13%)	Concrete wall (70%)	√	70	70
		Concrete joint (30%)	√	70	
	Energy dissipation (27%)	stilling basin (50%)	√	70	71
		Plunge basin (50%)	√	72	
		Jump basin (0%)	–	–	
	Spillway gate (0%)	Spillway gate (0%)	–	–	-
		Lift equipment (0%)	–	–	
		Drive equipment (0%)	–	–	
	Bridge (7%)	Abutment (19%)	√	76	74
		Bridge slab (19%)	√	73	
		Girder (25%)	√	75	
		Handrail (13%)	√	75	
		Column/pole (25%)	√	72	
		Cable Stay (0%)	–	–	
	Protection structures (0%)	Wall (0%)	–	–	-
		floor (0%)	–	–	
		Protection roof (0%)	–	–	
		Inspection ladder (0%)	–	–	

Table 2 shows the summary of the assessment at Cengklik Dam. The dam only has four physical components, i.e., dam body, intake structure, output structure, and spillway; the result score is 72, which means the dam is in good physical condition.

Table 2. Summary of Physical Assessment of Cengklik Dam.

Component	Weight	Value	Score	Explanation
Dam Body (35%)	35%	71	**72**	**Good**
Intake Structures (24%)	24%	72		
Output Structures (24%)	24%	69		
Spillway	18%	75		
Saddle dam	0%	-		
Emergency spillway	0%	-		
Abutment	0%	-		

4 Conclusions

The research concludes that a database model for inventory and assessment of hydraulics structures/buildings has been developed. The application's user interface has also been developed and made possible to be accessed via the Internet. This helps the River Region Office make decisions regarding hydraulic infrastructure maintenance and rehabilitation. The implementation of the application at Cengklik Dam resulted in the performance of the physical assessment reached a score of 72 (good), indicating the physical infrastructure of the dam is in good condition.

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