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LOW-COST SYSTEM OF AUTOMATIC WATER LEVEL RECORDER TOOLS BASED ON MICROCONTROLLER ARDUINO

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Abstract: Technological innovation in agriculture has recently been changed to the newest technology, such as innovation in irrigation systems widely used for the dry season. High cost of the tools for developing the system for automatic water level recorded being the main problem in integrating the system in irrigation. Previous research stated that the main problem was difficulty detecting water flow integrated into the irrigation system. This research aims to develop innovative technology in the reservoir using microcontrollers in real-time observation in Ponjong's reservoir. This research discovered that the most significant discharge from the outlet was 0.0867 m3/second. In addition, the microcontroller Atmega-328 and the ultrasonic-HCSR04 have been successfully installed and working correctly and functionally as a sender and receiver of data that could be applied as an automatic water level record used to measure the water level.

Keywords: agricultural technology; Arduino; automatic water level recorder; reservoir.

2020 AMS Subject Classification: 92C60.

1. INTRODUCTION

Water is a natural resource that contributes significantly to the growth and development of human

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life [1]. The drought season usually hits areas with low water conservation [2]. This disaster is a vital threat to an area because it disturbs the basic needs of human life [3]. The development of dry land agriculture faces many obstacles, including water shortages during the dry season and soil conditions sensitive to erosion [4]. On flat dry land, the low cropping index is low because the availability of water for irrigation only comes from rainwater [2]. Furthermore, in the agriculture sector, one of the critical success factors for obtaining satisfactory agricultural output is the availability of sufficient water [1]. At the turn of the month every year, the seasons constantly change. Sometimes is the rainy season, and sometimes is the dry season. To meet the water needs of crops other than water from rain, it is better to find other water sources through rainwater harvesting technology by building reservoirs [5]. However, during the dry season or periods of little rainfall, the water discharge from irrigation water sources tends to decrease, making the available water insufficient to meet the water needs for irrigation of farmers' crops [5]. One alternative solution to this problem is the construction of a reservoir [6].

Generally, the reservoir is a basin that regulates and accommodates rainwater supply and improves water quality in related water bodies [1], [4]. Furthermore, it could function as storage of groundwater and rainwater and also works to recharge groundwater to conserve water resources [7]. Besides, the reservoir accommodates surface runoff when it rains and for farming during the dry season. A basin that can store water is determined by several factors, including the location and design of the waters [4]. Based on the observation location in Ponjong's reservoir, Gunung Kidul, Yogyakarta, Indonesia, we evaluated that the location was suitable for the research to test the Automatic Water Level Recorder (AWLR) tool.

2. PREVIOUS STUDIES

Referring to the research from [8], [9] stated that implementing water level monitoring in the aquaponic system requires high cost and attention to developing the system. The problem of the high cost and complexity of the tools was the gap of this research to developing a low-cost system for designing and developing AWLR. Moreover, this research proposed and evaluated the AWLR system in Ponjong village, particularly for long-term measurements ($\geq$ 15 days), which are relatively low-cost compared to manual reservoir measurements. This comparison could watch from the operational cost component used and spent of the cost compared to the automatic AWLR [10]. Besides, with this system's development this research, we hope that tide measurements for research and practical purposes in remote areas where tide stations are not available would be possible at a lower cost and with better results [8].

The recent research on the AWLR system was a tool to replace conventional height measurement systems used to measure the water level in irrigation canals [2], [3], [11], [12]. The AWRL was widely used to measure parameters in watershed hydrological activities, monitoring wells, and mining, and also be an early warning system for flooding in a watershed [11], [13]. Therefore, to sum up, this chapter, the research objectives are to design and develop the innovation in the AWLR system and evaluate the performance of the AWLR as a low-cost system.

3. MATERIALS AND METHODS

3.1. Automatic Water Level Recorded (AWLR). The AWLR is a tool to determine the water level in rivers, lakes, or irrigation canal segments, including reservoirs [14]. The AWLR determines the amount of discharge in irrigation canal segments [4], [15], [16]. Besides, the AWLR's operating principle is to connect the chain with the float and the load placed on the pulley [14]. The float is placed on the water's surface, and any float movement will cause a change in the pulley system. The pulley rotates the potentiometer to change the incoming voltage. The amount of incoming voltage is inputted in the mechanical sensor output. The output that is issued is an analog signal that is used as input data. Moreover, the microcontroller digitizes the analog input into digital data. After that, the output from the Arduino is inputted for the General Pocket Radio Service (GPRS) shield. Before becoming input for the GPRS shield, the digital input has characterized by the American Standard Code for Information Interchange (ASCII). Furthermore, it is sent to the monitoring officer's cellphone via a short message service [16]–[19].

Several of the research in the AWLR system has been studied in different pathways. The first research was conducted by [2], who designed a water information management system in a palm oil plantation. The research has designed a drainage management information system in palm oil plantations, including the water level data. Other research on water level monitoring was also proposed by [3], [4]. Both researchers used microcontrollers Atmega-328 and Ultrasonic-HCSR04, and the smartphone and the system also monitored the research. Moreover, the water level detection research was also proposed using telegram and buzzer communication media ultrasonic sensors HCSR04 and ESP8266-12 modules proposed by [18]. The result of the research could detect the water's surface level. In addition, the usefulness of the microcontroller of Atmega is also widely used in water level monitoring and detection research. The implementation has been done in several pathways, such as in gallon cleaner, flood evaluation, flood detection, and others [20],

[21].

Furthermore, the design of the AWLR system used an ultrasonic distance sensor which was then converted into output data for water level change in cm per unit time of 10 minutes conveyed by an SD-card. The resource used was two batteries with a type of 18650 with an output voltage of 4.2V and a capacity of 3000 milliampere-hour (mAh). Each battery was arranged in parallel, so the total capacity was 6000 mAh. Furthermore, the specifications and functions of each component used in this research are described in Table 1 and Figure 1.

TABLE 1. AWLR Components

Components	**Functions**	**Price/Unit (in USD)**
Arduino Uno	Based on the Atmega-328 microcontroller as the control center for electronic components	11.93
Sensor ultrasonic-HCSR04	As an ultrasonic-based distance meter that measures the speed of sound propagation between the object and the sensor	0.78
Real-time clock (RTC) DS3231	As a digital timing module in real time	2.02
Liquid crystal display (LCD) 16x2 i2c	As a media display of data read by the sensor	2.09
Modul SD-card	Access to the SD Card to read and write data using the Serial, parallel interface (SPI) system	5.21
18650 lithium battery	As a power source for the operation of the tool	1.63

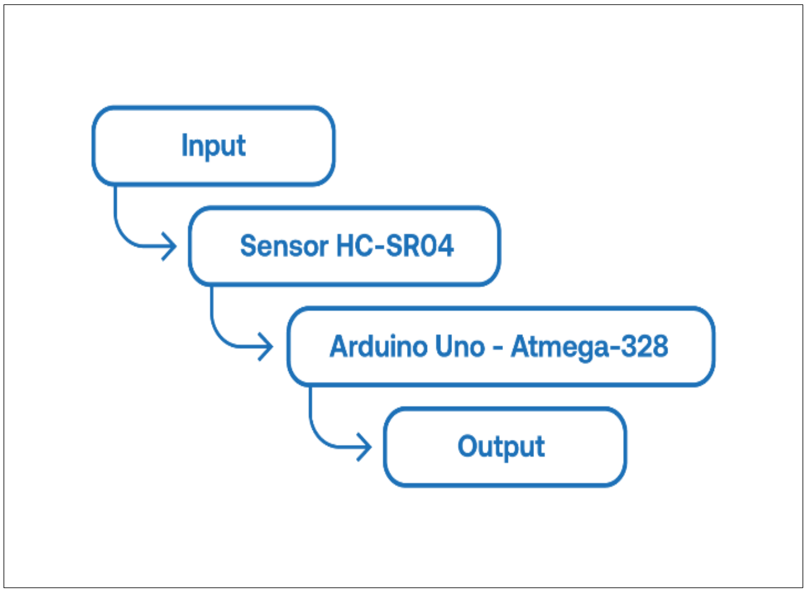

FIGURE 1. AWLR Data Processing Flow

Referring to the AWLR of data processing, every electronic device has a process flow which generally includes input, process, and output. At the process step itself, each electronic device will depend on the program installed for Arduino Uno using the C programming language through the Arduino IDE application. Furthermore, the AWLR has the following processing flow: the program will be executed after the microcontroller receives a source voltage of 5-12 volts, ultrasonic distance sensor will be initialized to detect the presence or absence of the object being measured, the ultrasonic distance sensor will measure the length of sound reflection on an object. It will be converted into distance units which the microcontroller will then process into numbers and letters on the liquid crystal display (LCD). Moreover, the LCD displays sensor data in real-time, and the microcontroller communicates with visual basics to display the data continuously. The data are also be stored on the micro-SD attached to the SD-card module in the .txt format.

3.2. Arduino Uno. Referring to the concept that Arduino is a physical programmable board [22]. The Arduino also can be used as a standard tool for study and research because Arduino could be a quick tool for developing small projects involving sensors [23]. Besides, the Arduino microcontroller is simple to learn and programmable [22], [23]. According to [3], Arduino Uno is a microcontroller board based on Atmega-328 that has 14 input/output pins, of which six pins can be used as PWM outputs, six analog inputs, a 16 MHz crystal oscillator, a USB port, a power jack, ICSP header, and a reset button. That could be concluded that Arduino Uno was a single board with an Atmega-328 microcontroller.

Moreover, the usefulness of Arduino in the research field has been validated in several works. Mainly to make a sophisticated and valuable product in everyday life, such as making tools that could work automatically, monitoring, and controlling [17], [24]-[27]. This statement was stated in the research from [28], who studied integrating Internet of Things (IoT) sensors to analyze water samples. A conceptual design that combines several water sensors, such as temperature, turbidity, hydrogen (pH) potential, and the Total dissolved solids (TDS), has been realized using the Arduino microcontroller.

3.3. Research Tools and Location. This research was implemented in Ponjong's reservoir in Ponjong village, Gunung Kidul, Yogyakarta, Indonesia, with a specific coordinate is 7^{o} 54' 33" S 110^{o} 46' 11" E. The specifications of the tools and materials and prices of each unit for the installation are shown in Table 2.

TABLE 2. Material of Research Experiment

Tools	**Materials**	**Price/Unit (in USD)**
ASUS - Processor: Intel® Core™ i3-10110U Processor 2.1 GHz (4 MB Cache, up to 4.1 GHz)	Arduino Uno Atmega-328 microcontroller	7.28
VPR Tape Measure 5m/16ft 19mm	LCD 16x2 i2C	2.84
	Sensor Ultrasonic-HCSR04	25.00
	SD Card	25.00
	SD Card Module	7.99
	DS3231 Real Time Clock	18.79
	Jumper Cables	13.40
	Battery with type 18650	14.99

3.4. Hardware Assembly. The AWLR assembly combines the components to form a functional circuit system. The steps to be carried out in the assembly until installed the AWLR system at Ponjong's reservoir are shown in Figure 3. Moreover, in Figure 3, the AWLR was installed above the flow of the reservoir at a height appropriate for the reservoir's conditions. The tools installation must be above the water level and not obstructed by any objects. In Ponjong village, we installed the tool at a height of about 62 cm with a water depth of 92 cm with measurements just below the AWLR.

3.5. Research Flow. The flow of research has generally been described through the following flowchart testing research. The flow of the research started from the preparation, function test, lab accuracy test, and tools test diagram are shown in Figure 2.

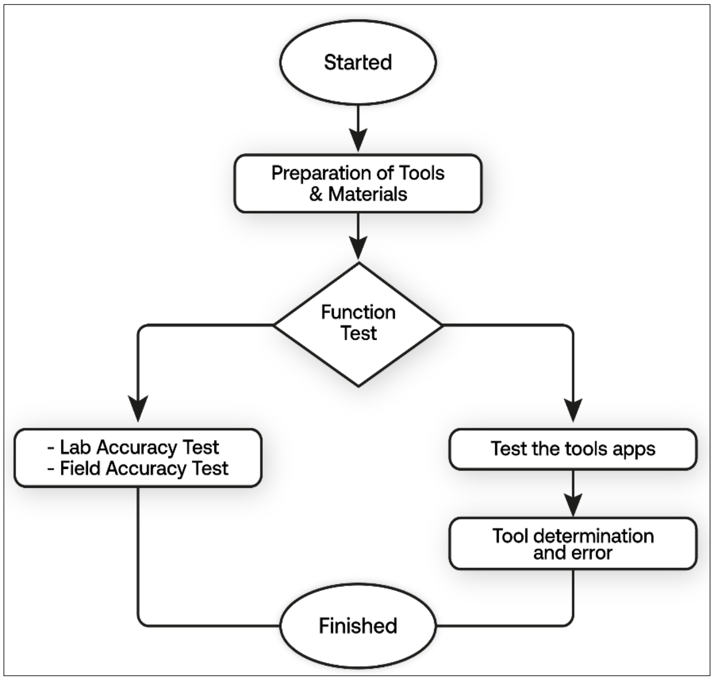

FIGURE 2. AWLR Testing Research Flow

FIGURE 3. The Installation of AWLR

3.6. Research Procedures. The procedure of this research was divided into several steps. The first step was the preparation of tools and materials. At the same time, the second step was a functional test of the tool to ensure that the tool used in research could perform functionally. There wre several testing steps with the following parameters: the sensor can work to measure the distance, the data can be stored, and the power source using a battery type 18650 could supply the power needs of the tool. Furthermore, the third step was the tool application test, which is carried out, such as accuracy testing and volume calculations, comparing tool measurements with actual measurements. Moreover, test the application to see the ability of the tool to measure the water level at the monitoring location.

3.7. Tool Function and Test. Before the tool was tested in Ponjong's reservoir, it was necessary to carry out the functional testing phase in the lab to see if the components of this tool could work properly and produce the desired data output. The test was carried out by conducting experiments on several distance variants. The distance variant used has a minimum distance of 10 cm and a maximum of 130 cm.

3.8. Tool Application Test. After the tool has been confirmed to function, it will be tested for accuracy and performance in the field. Testing is carried out by conducting accuracy tests and application tests. The accuracy test compared the measurement results with the distance measured using a meter tool.

4. RESULT AND DISCUSSION

4.1. Tool Accuracy Test. The test was carried out by measuring AWLR with 13 distance variations. The closest distance was 10 cm, and the farthest was 130 cm. These measurements were compared the distance measured manually using a meter and the distance measured by AWLR. The result of the measurement is described in Table 3.

TABLE 3. Sensor Measurement Test Results

No.	Actual Measurement (cm)	Sensor Measurement (cm)	|Δ|	Error (%)	Accuracy (%)
1	10	10	0	0.00	100.00
2	20	20	0	0.00	100.00
3	30	29	1	3.25	96.75
4	40	38	2	1.33	98.67
5	50	50	0	0.00	100.00

6	60	59	1	1.25	98.75
7	70	70	0	0.00	100.00
8	80	80	0	0.00	100.00
9	90	88	2	3.33	96.67
10	100	100	0	0.00	100.00
11	110	109	1	0.92	99.08
12	120	119	1	0.77	99.23
13	130	129	1	1.00	99.00
$\bar{X}$	***10***	***69.30***	***0.69***	***1.00***	***99.00***

4.2. Tool Application Test and Field Accuracy Test. The water level measurement was carried out to test the application of the AWLR tool. After installing the device a few hours later, we checked the data taken by AWLR. Data collected from the AWLR tool were stored in the SD-card. The next step was to reset Arduino Uno by pressing the red button on the Arduino Uno board so the tool could return to reread, and the last was to close the box and tighten the bolts. After the data was retrieved, it was then seen whether the file contained the results of the AWLR reading. If the reading can be displayed, then AWLR can work functionally, and the data stored on the SD card was the distance data between the sensor and the water surface. Furthermore, to obtain data on the water level, the data must be processed again using the formula in Equation 1.

$$\text{WL (Water Level)} = (\text{Lwater} + \text{Ds}) - \text{R} \qquad (1)$$

Where:

L_{water} = High water depth at the time of installation

D_s = distance between sensor and water level at installation

R = Measurement results by sensors

Moreover, after the data from AWLR were processed, water level data were obtained. Table 5 is data on the water level in Ponjong village with a measurement with a depth of 92 cm at the time of installation. Table 4 shows that the tool's average accuracy was 98.45%, with an average error of 1.55%. There were different levels of accuracy in experiments in the lab. The differences in accuracy were due to measurements in the field observation. The object being measured was flowing water with a high enough turbidity level, so the sensor had difficulty reading the reservoir's water surface in Ponjong's reservoir.

TABLE 4. Results of AWLR Measurement Tests

No.	**Readout time (cm)**	**Actual measurement (cm)**	**|Δ|**	**Error (%)**	**Accuracy (%)**
1	62	63	1	1.23	98.77
2	62	64	2	2.47	97.53
3	62	64	2	2.47	97.53
4	63	64	1	1.21	98.79
5	63	64	1	1.21	98.79
6	65	66	1	1.47	98.53
7	65	66	1	1.47	98.53
8	65	67	2	2.44	97.56
9	65	67	2	2.44	97.56
10	66	67	1	1.34	98.66
11	65	66	1	1.47	98.53
12	65	67	2	2.44	97.56
13	64	66	2	2.12	97.88
14	64	66	2	2.12	97.88
15	65	67	2	2.44	97.56
16	66	68	2	2.47	97.53
17	67	68	1	1.52	98.48
18	67	69	2	2.12	97.88
19	67	68	1	1.52	98.48
20	67	69	2	2.12	97.88
$\bar{X}$	***64.75***	***66.30***	***1***	***1.55***	***98.45***

4.3. Channel Discharge Measurement Method. The discharge or amount of river flow is the volume of flow flowing through a cross-section of the river per unit of time. The formulation is usually expressed in cubic meters per second (m^3/second) or liters per second (liter/second). The discharge measurement carried out at a water surveying post mainly aimed to make a discharge curve from the water estimating post concerned [16]. The measurement of discharge was a measurement of wet cross-sectional area, velocity of flow, and water level. The general formula was commonly used in Equation 1 [29].

$$\mathbf{Q = A.V} \quad (1)$$

Where:

Q = Discharge (m^3/second)

A = Wet cross-sectional area (m^2)

V = Flow rate (m/second)

4.4. Flow Discharge Calculation. Calculating data flows discharged in the Ponjong's reservoir measured directly or indirectly is the result of multiplying the cross-sectional area of the channel by the flow velocity according to the following equation 1. Before calculating the discharge, we must know A and V, which can be seen from the calculation means: T1 = 10 seconds; T2 = 8 seconds; T3 = 12 seconds; P = 1.20 m.

A = width (b) x surface height (h)

= 1.10 m x 0.43 m

= 0.4730 m^2

V = distance between cross-section I and II (p)/time (t)

= 1.20 m/10 second

= 0.12 m/second

TABLE 5. Results of Discharge Calculations

No.	**Observation Phase**	**Wide (m)**	**Water Level (m)**	**Wet Cross-sectional area (m2)**	**Velocity (m/second)**	**Water Discharge (m3/second)**
1	Phase I	1.10	0.43	0.4730	0.12	0.0567
2	Phase II	1.10	0.46	0.5060	0.15	0.0759
3	Phase III	1.10	0.38	0.4180	0.10	0.0418
	Average			***0.4656***	***0.12***	***0.0581***

Moreover, Table 5 shows the result of the discharge calculation at Ponjong's reservoir, measured within three phases, each observation phase spaced within five days. In this research, we only made three observations of water levels: August 10, 15, and 20, 2022. From the calculation and results, the most significant discharge that came out of the outlet was 0.0759

m^3/second, and the minor discharge that came out of the outlet was 0.0418 m^3/second, with an average discharge that can be 0.0581 m^3/second. More details of the relationship between Ponjong's reservoir discharge and water level are shown in Table 6 and Figure 4.

TABLE 6. Relationship Between AWLR Data and Estimated Reservoir Discharge

No.	**Sensor measurement (m)**	**Estimated water discharge (m3/second)**
1	0.62	0.1349
2	0.62	0.1394
3	0.62	0.1394
4	0.63	0.1435
5	0.63	0.1435
6	0.65	0.1518
7	0.65	0.1518
8	0.65	0.1518
9	0.65	0.1518
10	0.66	0.2727
11	0.65	0.1518
12	0.65	0.1518
13	0.64	0.1476
14	0.64	0.1476
15	0.65	0.1518
16	0.66	0.2727
17	0.67	0.1600
18	0.67	0.1600
19	0.67	0.1600
20	0.67	0.1600

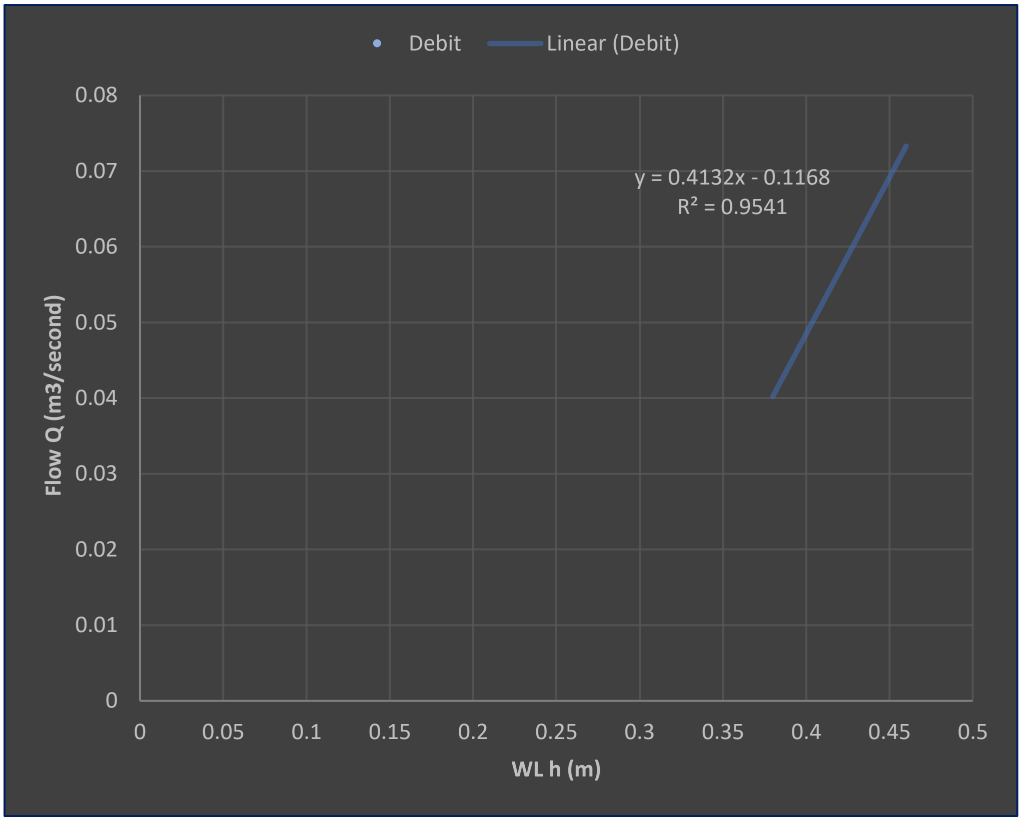

FIGURE 4. Relationship Between Reservoir Discharge and Water Level

Based on Figure 4, we could evaluate the relationship between Ponjong's reservoir discharge and the water level. A linear line relationship was made based on flow measurement data at Ponjong's reservoir. The equation of Y = a + bX, where the value a = -0.1168, and the value b = 0.4132 with a determinant coefficient value (R^2) = 0.9541. This equation could relate to the data taken using AWLR to predict discharge for crop irrigation needs. In addition, Table 6 shows the data estimated reservoir discharge. Besides, referring to Table 6, we could estimate the discharge using the equation Y = 0.4132x – 0.1168, with a determinant coefficient value (R^2) = 0.9541, where the value of y was the estimated discharge. X was the water level taken using AWLR, and the average estimated discharge for crop irrigation was 3.2484 m^3/second. If converted to liters, the available discharge at the Ponjong's reservoir for irrigation purposes was 3,248.4 L. Furthermore, the same research methods have been conducted by [30], [31]. The research stated that the water requirements in the dry season achieved 5.6355 mm/day or 0.6537 liter/second. In addition, referring to the rice water demand data, the reservoir was capable of irrigating 248,0351 hectare areas (ha) of rice.

5. CONCLUSION

There are several conclusions to this research. First, this tool's percentage level of accuracy is measured by sequential testing to measure objects from the closest distance of 10 cm to the farthest distance of 130 cm. The tool's accuracy is 99.00%, with an average error percentage of 1.00%. The second one is the microcontroller Atmega-328 Arduino Uno. This ultrasonic sensor controller functions as a sender and receiver of data and can be applied as an AWLR to measure the water level. The last one is based on calculating the discharge at Ponjong's reservoir outlet; the most significant discharge was 0.0867 m3/second. In addition, future suggestions for this research was needed to improve the accuracy and precision of the tool. Besides, this can be done using a different type of sensor than this research. Furthermore, improvements and modifications can be made to the tool to increase efficiency and effectiveness in the water level data collection. This research work is available for improvement by utilizing the Internet of Things (IoT) concepts and embedding the other tools and sensors related to the AWLR, so the monitoring of the AWLR could be maintained directly in the monitoring system and possibly developed in the mobile android-based system.

CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

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