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Article

Flood monitoring and early-warning system based on the Internet of Things (IoT)

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***Abstract*—Flood disasters are a recurring problem in Sragen Regency, primarily caused by the overflow of the Bengawan Solo River during the rainy season with high rainfall intensity and duration exceeding 4 hours. According to data from the Sragen Regency Disaster Management Agency (BPBD), over the past seven years, 46 floods have occurred in 16 villages across 20 sub-districts in Sragen Regency. The impacts of these disasters include infrastructure damage, material losses, and threats to human safety, further aggravated by the limited availability of early warning tools. To mitigate these impacts, an effective monitoring and early warning system is needed. The objective of this research is to develop an Internet of Things (IoT)-based system capable of monitoring water conditions and providing early warnings through Telegram notifications using the Blynk application. This system is designed to provide accurate and timely information regarding water levels and early flood warnings to the community in Sragen Regency. In its development, the system utilizes an HC-SR04 ultrasonic sensor to measure water surface height, an ESP32 microcontroller for data processing, and Blynk IoT and a Telegram bot as remote notification media. Additionally, visual indicators such as LED lights and a buzzer are used to provide local early warning signals regarding potential floods. The innovation offered by this IoT-based flood monitoring system focuses on real-time detection and anticipation of flood threats. This research also developed a system integrating Blynk with Telegram, enabling rapid notification delivery. Test results show that the system is capable of detecting water levels with an accuracy reaching 95%, providing early notifications with an average latency of 1.2 seconds, and maintaining connection stability up to 99%. Through this research, it is hoped to provide a significant contribution to the development of IoT-based disaster mitigation technology. Compared to conventional systems, this innovation offers high accuracy, more affordable costs, and ease of use, which is expected to assist disaster management officials and the community in mitigating flood risks and enhancing disaster preparedness in Sragen Regency.**

***Keywords*—blynk; iot; monitoring; early warning; telegram.**

1. Introduction

Sragen Regency, through which the Bengawan Solo River flows (Sragen, 2024), often encounters annual flooding issues caused by the river overflowing during the rainy season. This leads to damage to infrastructure, material losses, and risks to human safety (Ilmuddin & Putra, 2022; Nofrialdi & Ikhsan, 2023; Pratama, 2024). Although early warning tools are available, their effectiveness remains limited, which prevents the necessary information from reaching the community

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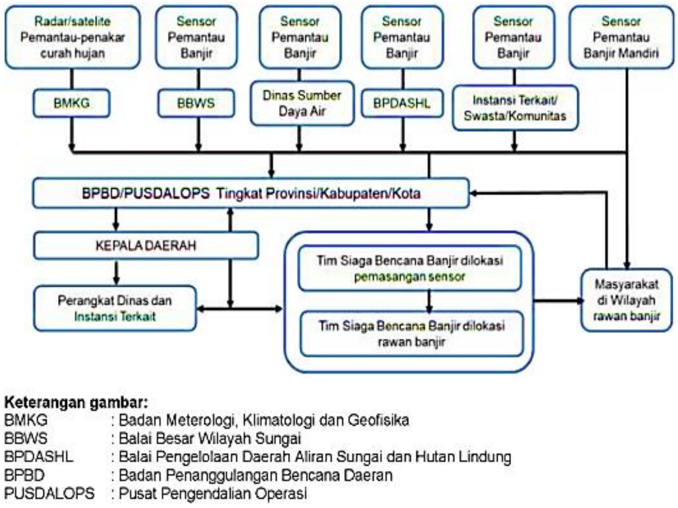

Fig. 1. Flood early warning flow

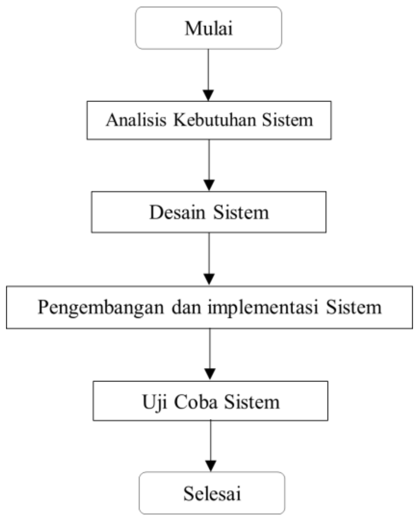

Fig. 2. Flowchart of system development method

effectively.

Based on the Sragen Regency Disaster Risk Assessment document 2023-2027 (Sragen, 2024), it is evident that the size of the area facing potential flood hazards is influenced by regional conditions. In the last seven years, the occurrence of flooding in Sragen Regency has varied from two to twenty-two times each year. With a high susceptibility to flooding, the total area at risk in Sragen Regency covers 31,763.52 Ha (Sragen, 2024).

For managing risk, Internet of Things (IoT) technology can be a useful approach (Tenda et al., 2021). Using an IoT-based water level monitoring system with the Blynk application, data can be collected instantly, and early warnings can be sent directly to the public through the Telegram platform (Dasril et al., 2024). This system uses an ESP32 microcontroller and an HC-SR04 ultrasonic sensor, equipped with LED lights and a buzzer to act as visual and sound indicators for flood warnings (Razor, 2024; Setiawan et al., 2022). The ESP32 DEV KIT is a microcontroller connected via Wi-Fi used in this research, and the system's programming is done using the Arduino IDE (Prastyo, 2022).

In a previous study, a design for an Internet of Things (IoT)-based flood monitoring and early warning system was put into practice at the Pusdalops PB BPBD West Sumatra (Nofrialdi & Ikhsan, 2023). This research employed ultrasonic sensors and an ESP8266 module to gather data from the sensors, which was then processed by NodeMCU before being sent to IoT Telegram. The water level was shown with three status levels: "safe", "alert", and "danger". The findings of that study successfully produced a water level monitoring system.

In this research, the system is further improved using the NodeMCU ESP32, offering more than 520 KB of memory, advantages in GPIO (General Purpose Input/Output) capability, faster Wi-Fi connection, and full Bluetooth support. Flood warning signals are shown through a red LED light for alert, yellow for caution, and green for standby status, and a buzzer is also included as a warning sign. Real-time river water level data is shared only for the "caution" status via a Telegram bot.

Additionally, the monitoring system in this study makes use of the Blynk Platform, which is a fitting choice for checking water levels before flooding happens, because it is easy to use and works with various IoT devices. Blynk provides a simple interface that can be reached using mobile devices, allowing users to observe river water levels instantly through a smartphone application. Blynk has the capacity to work with different IoT modules, like ESP8266 and ESP32, thereby simplifying the process of building IoT-based monitoring and early flood warning systems in a more effective and straightforward way (Alfaridzi et al., 2020).

This research is intended to plan, build, and test an Internet of Things (IoT)-based flood monitoring and early warning system capable of providing real-time information about water surface height and giving accurate and timely early warnings to the community in Sragen Regency.

2. Method

In this research on an IoT-based flood monitoring and early warning system (Tamam & Sakti, 2024), the data collection method included field observations to understand flood conditions and risks firsthand, and document study from related government agencies, such as disaster risk documents. Information identified with related agencies can be seen in Fig. 1 (Nasional, 2022).

In the early flood warning flow shown in Fig. 1, this research aims to support the duties and functions of the Sragen Regency BPBD, particularly at the stage of evacuation recommendations by leaders and independent evacuation appeals to communities in areas with potentially high flood risk. By designing an IoT-based monitoring and early warning system, readiness is expected to improve before deploying local government officers or rapid response teams.

Building the system in this research uses the prototype method (Meisak et al., 2022), which can be seen in Fig. 2.

2.1. System requirements analysis

First, the researchers identified system requirements to understand the overall system goal. For this, direct field observation is necessary (Husnah et al., 2024). In designing this system, several required hardware components can be seen in Table 1.

Furthermore, to operate the flood early warning system in this research, in addition to the hardware components already

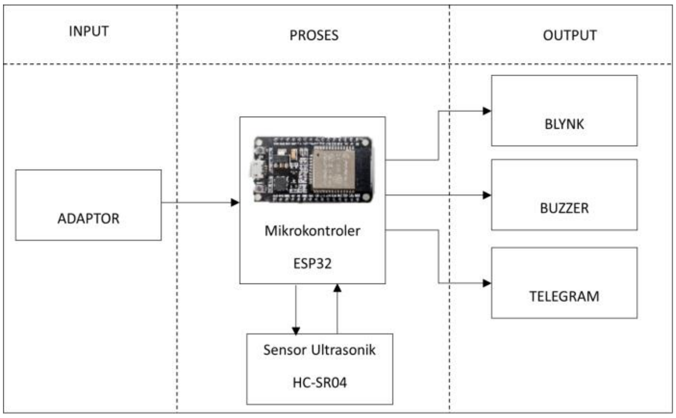

Fig. 3. System block diagram

mentioned, several software components are also needed, including:

a. Windows OS
b. Arduino IDE for microcontroller programming
c. Telegram Bot as a notification medium
d. Blynk Application as a data visualization platform

Besides these hardware and software components, a Wi-Fi communication network is also necessary as a connecting medium.

2.2. System design

Based on the previous system requirements analysis, the system design process leads to a framework model for water level monitoring and the early warning mechanism to be built. In this design, a system block diagram was created to show the interaction among all components, including the adaptor, sensor, microcontroller, LED, buzzer, Blynk IoT, and Telegram bot (Setiawan et al., 2022).

The system block diagram in Fig. 3 explains the system input and output process stages as follows:

a. Input block: describes the adaptor as the electronic medium for the entire system circuit
b. Process block: consists of an ultrasonic sensor that measures the water surface height distance and ESP32 as a microcontroller that produces LED output to send information to the IoT platform application
c. Output block: The resulting information from the IoT platform will be displayed on Blynk as a visualization of the water height distance, while the buzzer serves as a sound visualization, and Telegram acts as a medium for sending flood early warning notifications at the "Danger" status.

Furthermore, hardware development was carried out by assembling physical components such as ESP32, ultrasonic sensor, LED, and buzzer according to the initial design that was created (Waluyo & Putra, 2024). The system design resulting from the previous requirements analysis and block diagram visualization can be seen in Fig. 4.

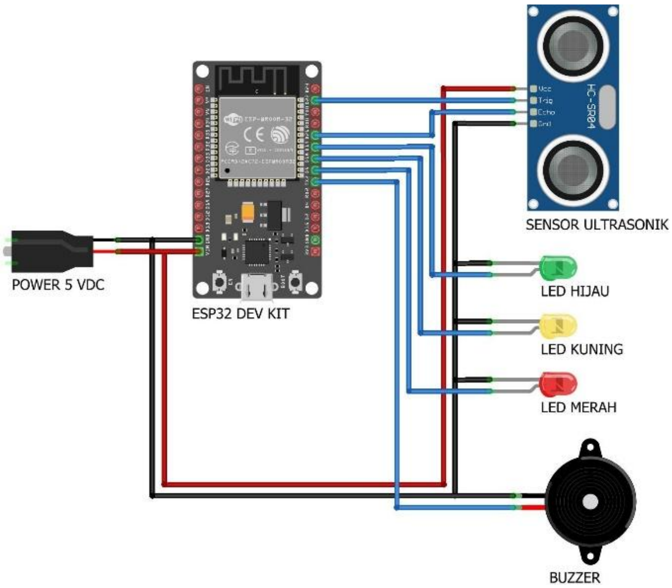

Fig. 4. System circuit

Table 1. Hardware components

Components	Quantity	Unit
ESP32 DEV KIT	1	set
HC-SR04 Sensor	1	set
Green LED	1	set
Yellow LED	1	set
Red LED	1	set
Buzzer	1	set
Smartphone	1	set
Red AWG26 Cable	1	set
Black AWG26 Cable	1	set
Green AWG26 Cable	1	set
Jumper Cable	1	set
Adapter	1	set
Box Cover	1	set

2.3. System development and implementation

Based on the system design that was created, the next stage is system development through prototype creation, which includes sensor setup for data monitoring, integration with the Blynk IoT platform, and logic arrangement for sending notifications via Telegram.

The system flowchart in Fig. 5 explains the process flow for developing and implementing the IoT-based monitoring and early warning system to be built using NodeMCU ESP32, Blynk IoT Application, and Telegram Bot. This flowchart can be used to present manual activities, processing, or a combination of both.

The flowchart provides a visual overview of the system with the following details:

a. Start: The process begins with input-output initiation in the system.
b. The ultrasonic sensor reads the water distance to determine the water height level.
c. ESP32 receives distance data and processes information

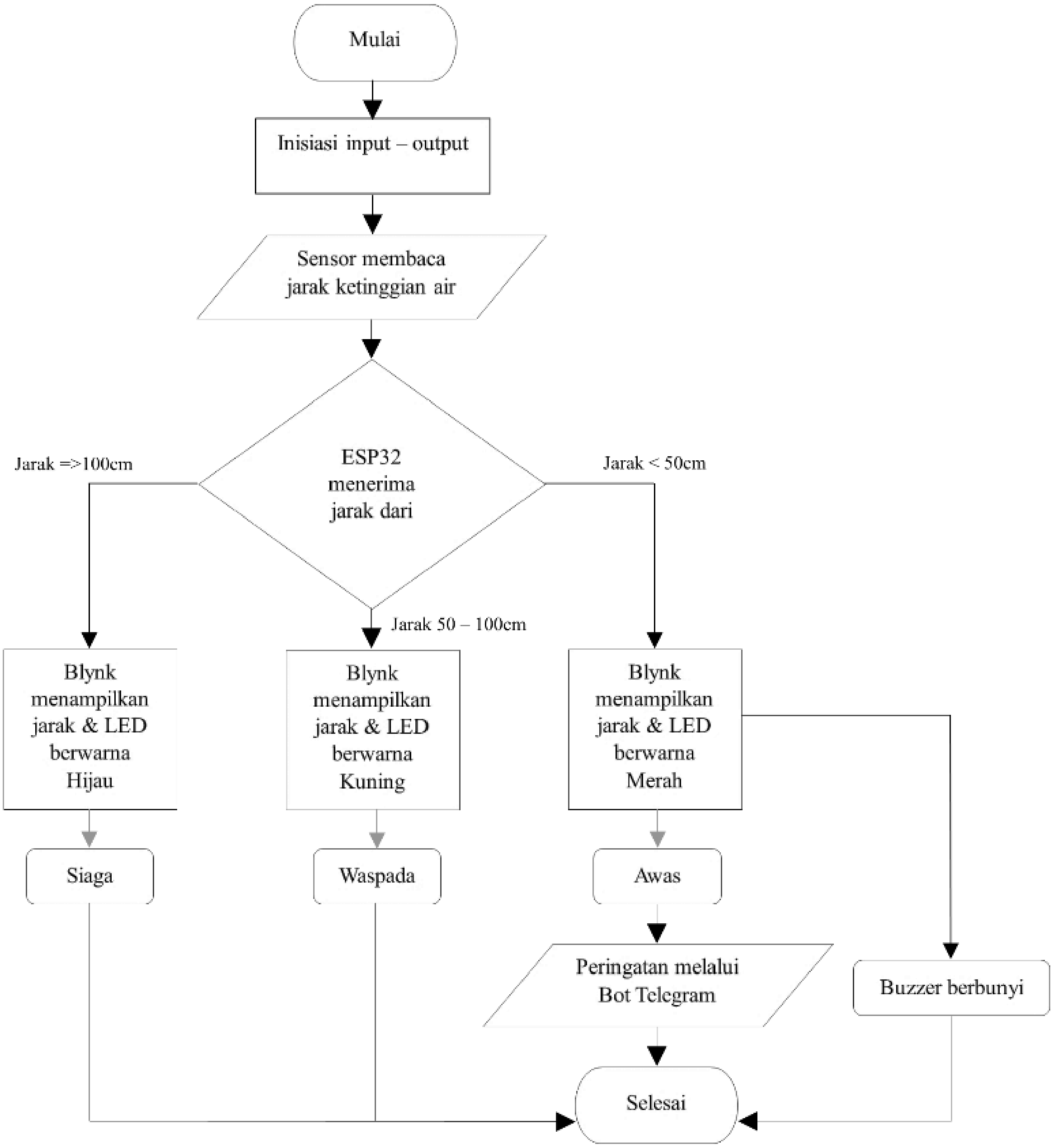

Fig. 5. System flowchart

from the sensor to determine the status based on the measured distance.

d. The measurement status is divided into three: standby (green LED lights up), caution (yellow LED lights up), and alert (red LED lights up). Measurement values are shown on the Blynk platform, and when the danger condition occurs, the system sends a warning via the Telegram bot and activates the buzzer as an additional alarm.
e. End: The process concludes after appropriate actions are carried out.

3. Results and discussion

3.1. Implementation results

Based on the system requirements analysis, design, and development and implementation carried out in the previous stages, this section will present the results and discussion regarding system testing during the construction of the system in this study. In this stage, sensors were installed and IoT devices were configured to gather real-time data, software was developed to process sensor data, flood risk was analyzed, and alerts were sent to users.

Regarding the system employed by the Regional Disaster Management Agency (BPBD) of Sragen Regency, an illustration of the process for installing sensors and sirens can be seen in Fig. 6 (Nasional, 2022). Furthermore, the implementation of hardware testing for the IoT-based flood monitoring and early warning system (Setyawan et al., 2023), specifically the NodeMCU ESP32 connection, is shown in Fig. 7.

Programming was carried out using Arduino to configure the ESP32 so it could read data from the ultrasonic sensor. Additionally, logic implementation was done to activate LEDs and a buzzer based on the detected water level, and Telegram API integration was used to send warning messages to users.

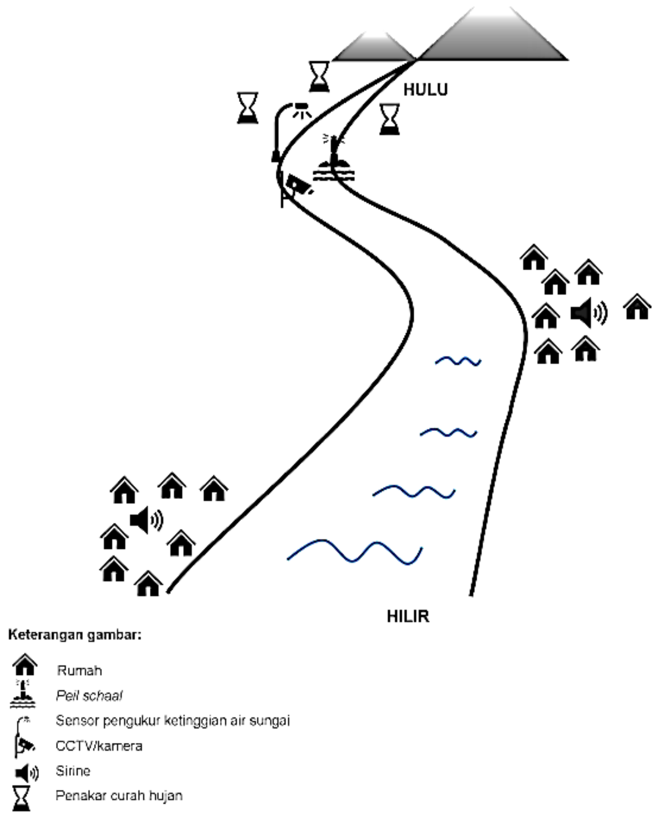

Fig. 6. Illustration of sensor and siren installation

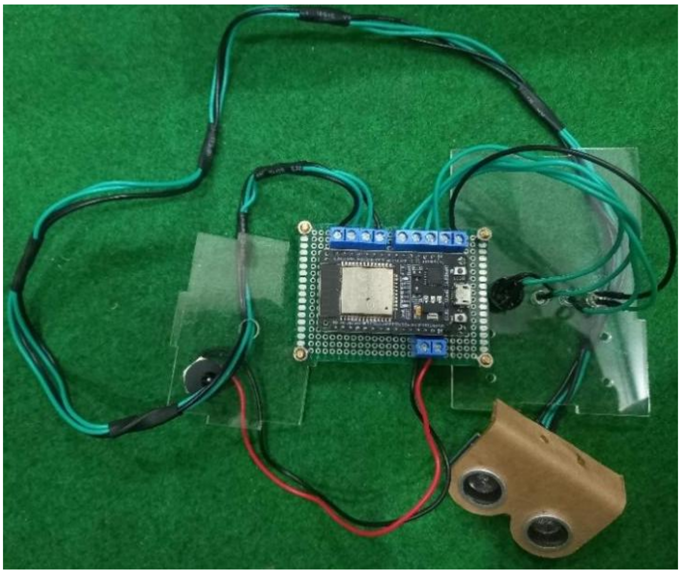

Fig. 7. Connection circuit on ESP32

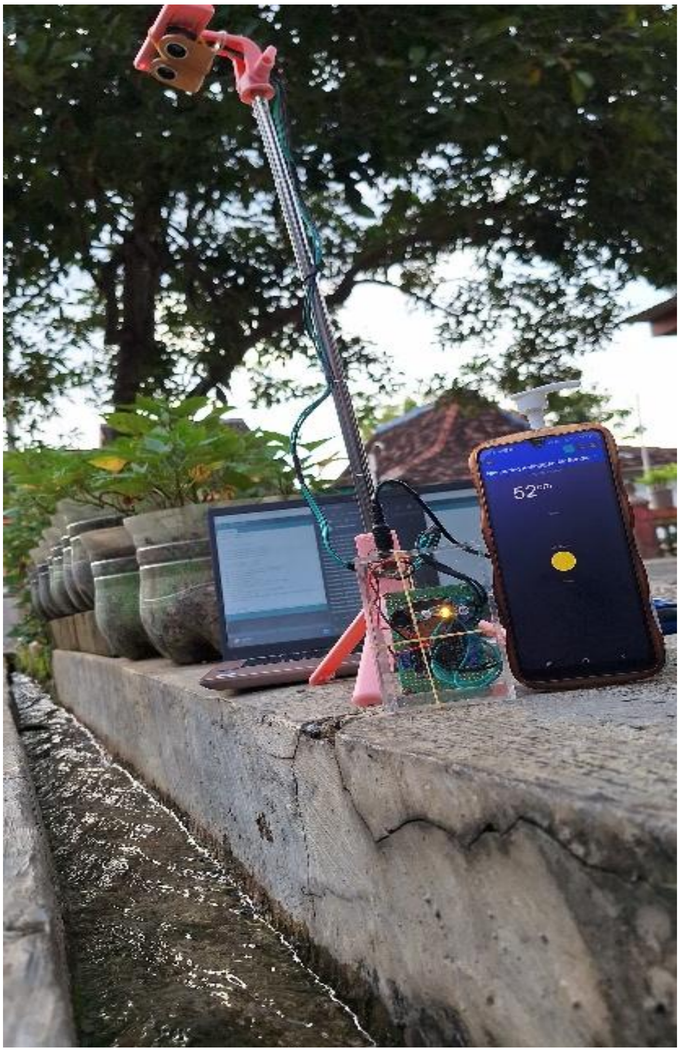

Fig. 8. Flood early warning system circuit

The programming steps included writing, compiling, and uploading the program (Prastyo, 2022; Razor, 2024).

3.2. System testing

The next stage involved conducting functional testing of the system to ensure all components could operate correctly and that data was collected and processed accurately. This testing also aimed to confirm the system could work under actual conditions and provide suitable warnings (Tenda et al., 2021; Waluyo & Putra, 2024). The complete sequence for testing the flood monitoring and early warning system can be seen in Fig. 8.

In Fig. 8, the results of measuring the distance from the water surface to the sensor during the testing phase are visible. The algorithm that was put into practice is as follows:

a. If the distance from the river water surface to the sensor is below 50 cm, the measurement will be sent through the Blynk application, the red LED will turn on indicating an "Alert" flood status, followed by a warning notification via the Telegram bot and the buzzer sounding.
b. If the distance from the river water surface to the sensor is between 50 cm and 100 cm, the measurement will be sent through the Blynk application, the yellow LED will turn on indicating a "Watch" flood status, and the buzzer will not sound.
c. If the distance from the river water surface to the sensor is above 100 cm, the green LED will turn on indicating a "Standby" flood status, and the buzzer will not sound.

The monitoring of the distance from the water surface to the sensor as sent through the Blynk application is shown in Fig. 9, while the view on the Telegram Bot can be seen in Fig. 10.

Table 2. Device testing results

Distance (Blynk)	Telegram	LED	Buzzer	Status
=>101 cm	Inactive	Green	Inactive	Standby
51 – 100 cm	Inactive	Yellow	Inactive	Caution
<=50 cm	Active	Red	Active	Alert

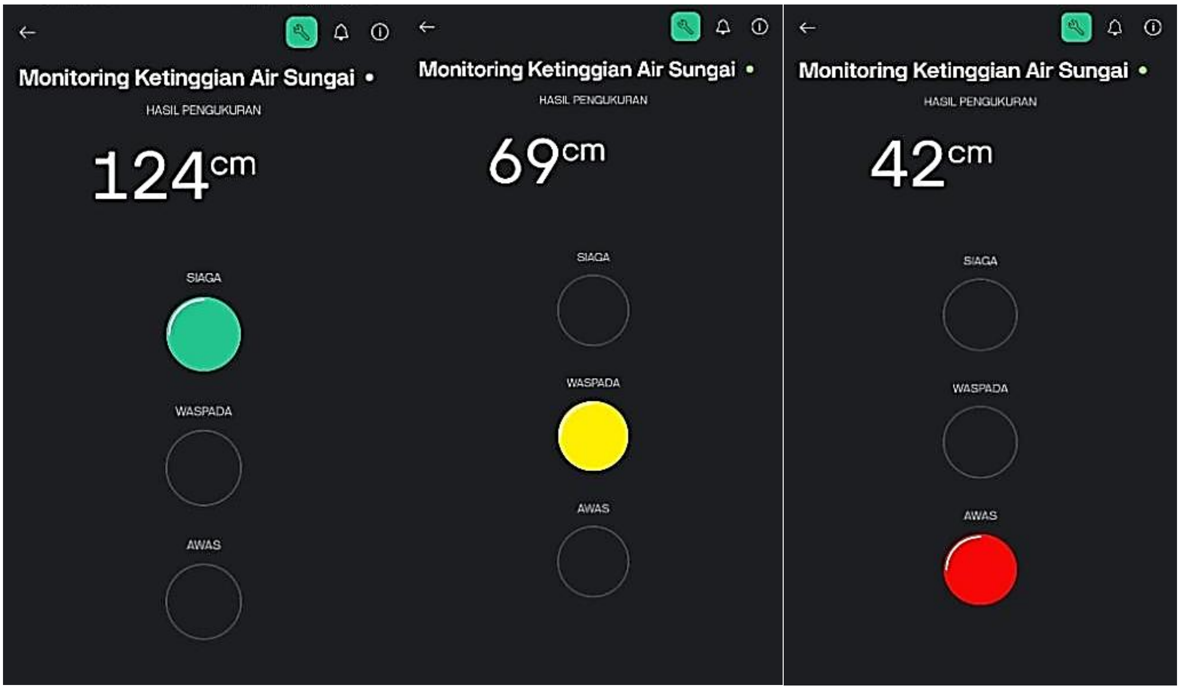

Fig. 9. Monitoring the water surface distance in the Blynk application

The testing results for the IoT-based flood monitoring and early warning system are presented in Table 2. The test results show that this system is capable of detecting changes in water level accurately and providing an appropriate response corresponding to each condition. The visual indicators (LEDs), audio indicator (buzzer), and real-time communication through the Blynk and Telegram applications functioned effectively.

4. Conclusion

This research has successfully developed an Internet of Things (IoT)-based flood monitoring and early warning system prototype with quite high levels of effectiveness and efficiency, and ease of implementation. This system uses an ESP32 microcontroller, an HC-SR04 ultrasonic sensor, LED indicators, a buzzer, the Blynk application, and a Telegram bot to monitor and provide real-time flood warning information. The results of the system tests in this study indicate that the system is capable of detecting water levels and providing appropriate warning responses based on flood status, namely Standby, Alert, and Danger. Water level data is shown in real-time through the Blynk application, and warnings for the "Danger" status are sent through the Telegram bot, along with a buzzer sound as an additional signal to ensure information is quickly received by the community.

Applying this technology shows great potential in supporting efforts to reduce flood risk, particularly in areas prone to flooding such as Sragen Regency. Therefore, this system is expected to be a suitable technology solution for increasing community preparedness and decreasing the impact of flood disasters (Ghazi et al., 2024).

However, there are some limitations in this research, and the need for a strong Wi-Fi signal to maintain connection stability is one of them. Making this aspect work better will be a focus for further research so the system can operate more reliably under different network conditions.

To improve the system's dependability, integrating alternative communication modules, such as GSM or LoRa networks, is suggested so that the system continues to function in areas with weak or unstable Wi-Fi connections. Further development could include adding prediction features using artificial intelligence to make detection and response to flood threats more accurate. For large-scale application support, testing power efficiency and hardware durability in the field is very important so the system can be used continuously over a long time.

Data availability

All data produced or examined during this study are present in this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have

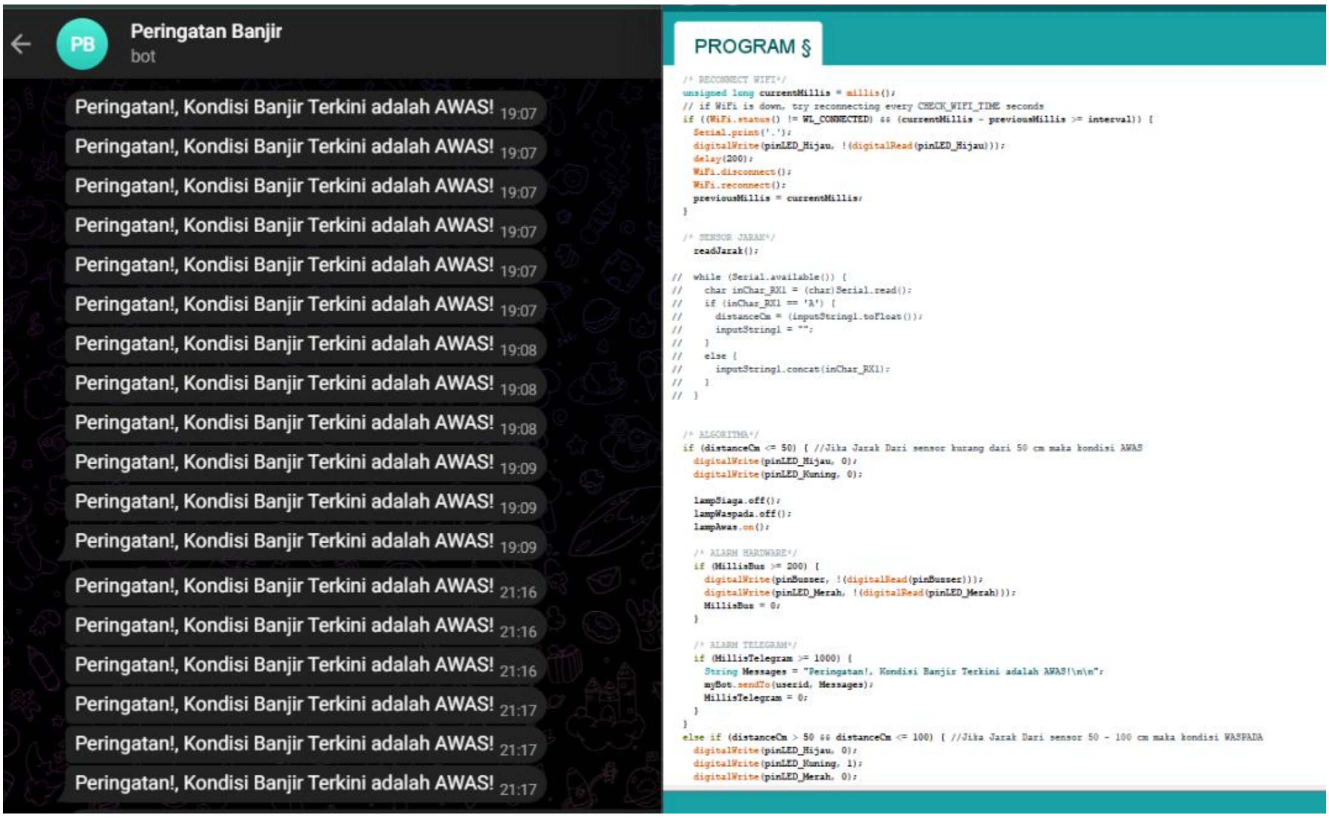

Fig. 10. Telegram bot display

appeared to influence the work reported in this paper.

Authors' contributions

All authors participated in the study design, writing, and manuscript revision. YR drafted the initial manuscript, VA revised the manuscript, and EP supervised the study. All authors have reviewed and approved the final manuscript.

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Photograph and biography of the authors (Yuli Ratmini, Vihi Atina, and Eko Purwanto) were not available at the time of publication.