



Design of an IoT-Based Flood Monitoring and Alert System for UC TATI Residential College

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KEYWORDS	ABSTRACT
Flood system Internet of Things (IoT) Ultrasonic sensor Real-Time monitoring Water level	<p>Flood incidents pose a significant threat to residential areas, particularly in low-lying regions and campus environments where water level changes can occur rapidly and disrupt daily activities. At Universiti College TATI (UC TATI), the residential college area is vulnerable to localized flooding during heavy rainfall, which highlights the need for a reliable and real-time monitoring solution. This paper presents the design and development of an IoT-based flood monitoring and alert system for UC TATI Residential College. The proposed system utilizes water level sensors integrated with a microcontroller platform and wireless communication technology to continuously monitor water level conditions and transmit data to a cloud-based platform for real-time visualization and monitoring. When predefined threshold levels are exceeded, the system automatically triggers alert notifications to relevant users to enable early warning and timely action. The system architecture, including hardware components, software framework, communication process, and data flow, is described in detail. The methodology covers sensor data acquisition, threshold-based decision logic, and alert dissemination workflow. This work focuses on the conceptual design and system development aspects and serves as a foundation for future implementation, testing, and performance evaluation in the UC TATI campus environment.</p>

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1.0 INTRODUCTION

Flooding is one of the most frequent and destructive natural disasters that threaten residential areas, often causing serious property damage, disruption of daily life, and risk to human safety. The increasing intensity of rainfall and the unpredictability of weather patterns due to climate change have highlighted the urgent need for reliable and real-time flood monitoring systems. Traditional methods of flood detection are typically manual, delayed, or limited in coverage, making them ineffective in providing timely alerts to affected communities. The advancement of Internet of Things

(IoT) technology offers an efficient and scalable solution by enabling continuous monitoring of environmental parameters and automated communication of critical data in real-time.

This project, titled “IoT-Based Flood Monitoring and Alert System using ESP32 with WhatsApp Notification and Siren Alert for Residential College 2, UC TATI,” focuses on developing an intelligent and low-cost prototype that enhances early flood detection and response. The system integrates an ESP32 microcontroller with a pressure-based water level sensor to measure rising water levels accurately.

When the water level reaches a warning or danger threshold, the system instantly triggers WhatsApp notifications and an audible siren alert to ensure rapid awareness among residents and campus authorities. Powered by a solar-charging module with battery backup, the system remains operational during power outages, providing a sustainable and resilient solution. Through this integration of IoT sensing, wireless communication and automated alert mechanisms, the project aims to strengthen campus safety, improve emergency preparedness and demonstrate the practical application of smart technologies for disaster risk reduction.

2.0 PROBLEM STATEMENTS

Flooding remains one of the most destructive natural disasters, often causing serious property damage, safety risks, and disruption of daily activities. However, traditional flood management systems are mostly manual, lack real-time monitoring and provide limited data for analysis, making them ineffective for rapid response during emergencies [1]. Without automation and timely communication, residents and authorities often receive delayed alerts, increasing the risk of losses.

In addition, commercial weather and flood monitoring stations are expensive and technically complex, restricting their accessibility for small-scale communities or educational institutions. This cost and complexity limit the adoption of localized, real-time monitoring systems that could provide faster and more precise warnings [2]. As a result, many vulnerable areas, such as UC TATI Residential College 2, remain without a reliable flood detection mechanism.

Existing systems also struggle to detect sudden water level surges or flash floods caused by heavy rainfall or drainage failures. These rapid-onset events often leave communities unprepared and at higher risk [3]. Therefore, there is a need for a low-cost, IoT-based flood monitoring system using the ESP32 microcontroller, pressure-based sensors and a dual alert mechanism combining WhatsApp notifications and a siren alarm to deliver timely and effective warnings for improved campus safety.

3.0 OBJECTIVE

- i. To design and implement a pressure-based water level sensing module capable of accurately detecting and monitoring rising flood levels in real-time.
- ii. To develop an IoT-based flood monitoring and alert system using the ESP32 microcontroller integrated with WhatsApp notification and siren alert for UC TATI Residential College 2.
- iii. To integrate IoT technology for real-time data transmission, visualization, and automated warning, ensuring reliable communication during flood events.

4.0 RELATED WORK

4.1 Overview of Flood Monitoring

This section reviews previous research and existing technologies related to flood monitoring and early warning systems. It highlights the limitations of traditional flood management approaches, discusses the application of Internet of Things (IoT) in environmental monitoring, and explores the

hardware and software components relevant to this project, including sensors, microcontrollers and communication platforms.

Traditional flood monitoring systems depend heavily on manual observation and periodic data recording, which are often slow and ineffective during emergencies. These systems are costly to maintain and cannot provide continuous or real-time updates [1]. In contrast, modern IoT-based systems automate data collection, store information in the cloud, and deliver real-time alerts, allowing quicker and more efficient disaster response.

4.2 IoT of Technology Flood Monitoring

Traditional flood monitoring systems depend heavily on manual observation and periodic data recording, which are often slow and ineffective during emergencies. These systems are costly to maintain and cannot provide continuous or real-time updates [3]. In contrast, modern IoT-based systems automate data collection, store information in the cloud, and deliver real-time alerts, allowing quicker and more efficient disaster response.

4.3 Microcontroller And Communication Platforms

The ESP32 microcontroller is widely adopted in IoT projects because of its built-in Wi-Fi and Bluetooth capabilities, high processing power and low energy consumption. Compared to boards like Arduino UNO or NodeMCU, ESP32 offers better speed, dual-core performance and integrated wireless connectivity, making it ideal for real-time data transmission [4]. IoT platforms such as ThingSpeak, Firebase or Blynk are commonly used to display sensor data, while APIs like CallMeBot and Twilio enable message-based alerts through WhatsApp.

4.4 IoT-Based Water Level Detections Sensors

Water level sensors are critical in flood monitoring systems. Ultrasonic sensors measure distance using sound waves but can be affected by turbulence, debris, or water vapor. Float sensors are simple but less precise, while capacitive sensors provide contactless detection but require careful calibration. In this project, a pressure-based water level sensor is selected due to its higher accuracy, waterproof design and stable performance in outdoor environments [5]. It can measure subtle changes in water depth without being influenced by surface conditions.

4.5 Flood Alert System Mechanism

Effective flood alert systems must ensure timely communication with users. Previous studies commonly used SMS or Telegram for notifications, however, these methods require additional setup and may not reach all users promptly [6]. Integrating WhatsApp through APIs provides a more accessible and reliable solution, as most users already use the platform daily. Additionally, a siren alarm is incorporated to provide immediate on-site alerts even when internet connectivity is disrupted, ensuring a dual-layer notification approach for safety.

4.6 Previous Work

Table 1: Summary of related study

Author (Year)	Title	Method	Benefits	Limitations
[1]	IoT-Based Flood Detection and Management Systems in Urban Areas	Systematic review of IoT flood management approaches in urban settings	Demonstrated that IoT improves real-time monitoring, decision-making, and community preparedness	Data reliability, integration with government systems, and cost of large-scale deployment
[2]	A Systematic Review of Hacking on Cloud Platform	Literature review on cloud security vulnerabilities	Identified risks (data breaches, DoS, unauthorized access) affecting IoT/cloud reliability	Lacks experimental validation; limited to secondary sources
[3]	Development of a Weather Station with Water Level and Waterflow Detection using Arduino	Prototype using NodeMCU ESP32, ultrasonic, BMP280, and rain sensors	Provided accurate hydrological & meteorological data; enabled remote monitoring via Blynk	Durability in long-term deployment not tested; only simulated environment
[4]	Real-time Monitoring IoT-based System for Early Flash Flood Notification in Melaka	IoT-based prototype with water level sensors for localized alerts	Showed feasibility of community-focused early flood warnings	Limited scalability; site-specific testing only
[5]	IoT-Based Intelligent System for Headwater Phenomenon Detection and Alerts Using ESP32	Developed system with ESP32, rainfall & water level sensors, Firebase, Telegram alerts	Effective in detecting sudden water surges and issuing real-time warnings	Limited accuracy in predicting unpredictable headwater events requires multiple installations

5.0 METHODOLOGY

This project incorporates the PDIOO model as the research methodology to provide a structured, iterative approach suitable to develop an IoT-based system. The Planning stage of the development will present the identified flood risks in UC TATI Residential College 2, the definition of project requirements, and the establishment of the project's objectives. The Design stage will detail the development of the system architecture, covering the ESP32 microcontroller, pressure-based water level sensor, solar power module, cloud data platform and WhatsApp plus siren alert mechanism.

The Implementation stage will involve prototype construction, programming of the microcontroller and integration of IoT communication and an alert system. The operation stage consists of deploying the system for testing in a real or simulated environment to monitor water levels and verify alert functions. Finally, the Optimization stage provides insight into analyzing the performance of the system, refining sensor calibration, improving alert responsiveness and enhancing overall reliability and sustainability.

5.1 PPDI00 Model

The Planning phase focuses on identifying the flood-related risks at UC TATI Residential College 2 and determining the necessary requirements for developing an effective early warning system. During this phase, the problem was analyzed by examining current flood monitoring limitations, environmental challenges and user needs. Hardware components such as the ESP32 microcontroller, pressure-based water level sensor, solar panel system, siren module and WhatsApp API were selected based on feasibility, cost and suitability for real-time monitoring. In addition, relevant literature was reviewed to ensure that the system design aligns with current IoT-based flood detection practices. This phase establishes the project objectives, functional requirements and constraints, forming the foundation for subsequent development stages.

The Design phase involves developing the overall system architecture and preparing technical specifications for hardware and software integration. A detailed block diagram, flowchart and data communication model were created to illustrate how the pressure sensor, ESP32, power system, cloud platform, siren and WhatsApp API interact. The sensor placement and waterproof enclosure design were planned to ensure reliable performance in outdoor environments. Threshold values for water level classification (Normal, Warning, Danger) were also defined. The design phase ensures that all components are logically connected, operationally compatible and prepared for seamless prototype development.

In the Implementation phase, all hardware and software modules were fully integrated and tested as a complete system. The prototype was placed inside a waterproof enclosure, with the pressure sensor positioned at the flood-prone location. The ESP32 was programmed to continuously monitor water levels and transmit data to the cloud. WhatsApp alerts were triggered when Warning or Danger thresholds were reached, while the siren activated for critical flood conditions. Connectivity between the system and Wi-Fi networks was validated to ensure reliable communication. This phase ensures the prototype operates as intended under controlled test scenarios.

The Optimization phase involves improving the system based on findings from the operation phase. Adjustments were made to enhance sensor accuracy, optimize API communication speed, strengthen waterproofing and refine the power management configuration to improve battery endurance. Firmware improvements were implemented to reduce system lag, improve connection stability, and minimize false alerts. This phase ensures the final prototype is more reliable, efficient, and suitable for long-term deployment as a campus flood monitoring solution.

5.2 Hardware Development

The development of the IoT-based Flood Monitoring and Alert systems requires a set of hardware components that enable accurate sensation, efficient data processing, continuous power supply and reliable alert mechanisms. Each component was selected based on performance, compatibility with the ESP32 microcontroller, cost efficiency and suitability for real-time environmental monitoring. The following hardware elements were identified as essential for the successful implementation of the prototype.

5.2.1 ESP32 Microcontroller

The ESP32 Microcontroller functions as the central processing unit of the system. It features built-in Wi-Fi connectivity, dual core processing and low power consumption, making it ideal for IoT applications. The ESP32 gathers water level readings from the pressure sensor, processes the data, communicates with the cloud platform and triggers both WhatsApp notifications and siren alerts when danger thresholds are reached.

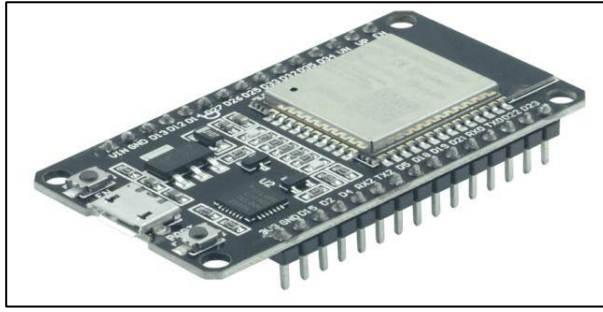


Figure 1: ESP32 Microcontroller

5.2.2 Water Level Sensor

The A02YY4W IP67 Waterproof Ultrasonic Sensor is used in this project to measure the rising water level accurately and reliably. As a non-contact distance sensor, it is unaffected by debris, sediment or direct water contact, making it sustainable for outdoor flood prone environments. The sensor provides stable distance readings that are processed by the ESP32 to determine the water level and classify it into Normal, Warning and Danger stages. Its waterproof design and consistent performance make it an effective choice for real-time flood monitoring.



Figure 2: Water Level Sensor

5.2.3 Siren Alarm Module

The system uses a 12V DC High-Decibel Siren Alarm (110-120 dB) to provide a loud and immediate audible warning when the water level reaches a critical threshold. The siren is controlled by the ESP32 through a relay module, allowing it to activate automatically during

danger conditions. This ensures that users nearby are alerted quickly, even if they are not monitoring their mobile devices, thereby improving on site safety and emergency response.



Figure 3: 12V DC High-Decibel Siren Alarm (110–120 dB)

5.2.4 Solar Power System

To ensure continuous operation during flood or power outages, the system is powered using a 10W solar panel as the primary energy source. The solar panel supplies power during daylight hours, while a rechargeable lithium-ion battery stores energy for nighttime or low light conditions. A solar charge controller is used to regulate the voltage and current to ensure safe and efficient charging of the battery. This configuration allows the system to operate reliably for longer periods and remain functional even during severe weather conditions.

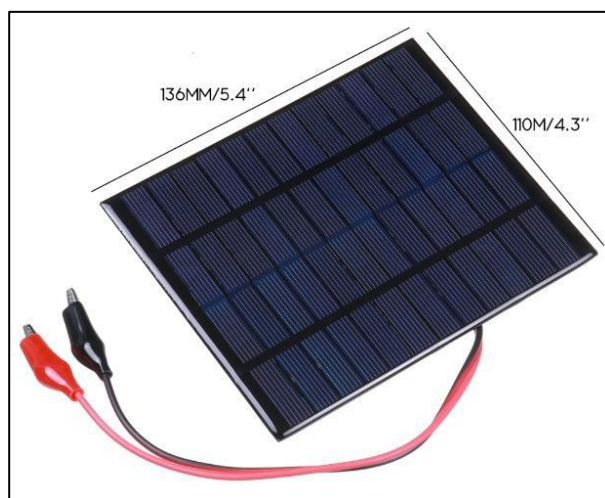


Figure 4: 10Watt 12V 166MA Solar Panel

5.2.5 Waterproof Enclosure

A waterproof IP65 ABS enclosure is used to protect the ESP32 microcontroller, relay module, solar charging components and battery from rain, humidity and environmental exposure. The enclosure provides sufficient internal space for wiring and heat dissipation while ensuring that the system remains operational in outdoor flood prone areas. Its durable design prevents water ingress and enhances long-term reliability during continuous deployment.



Figure 5: Waterproof PVC Junction Box Enclosure Box

5.2.6 Connectivity and Support Components

Main additional hardware components that will be needed to put together and assemble the system with assurance of little or no pitfalls in performance includes

- i. Jumper wires and connectors
- ii. Resistors and voltage regulators
- iii. PCB or perfboard for the organization of circuits
- iv. Mounting brackets for the pressure sensor and solar panel

These components provide stable wiring connections, secure installation, and overall structural integrity to the prototype.

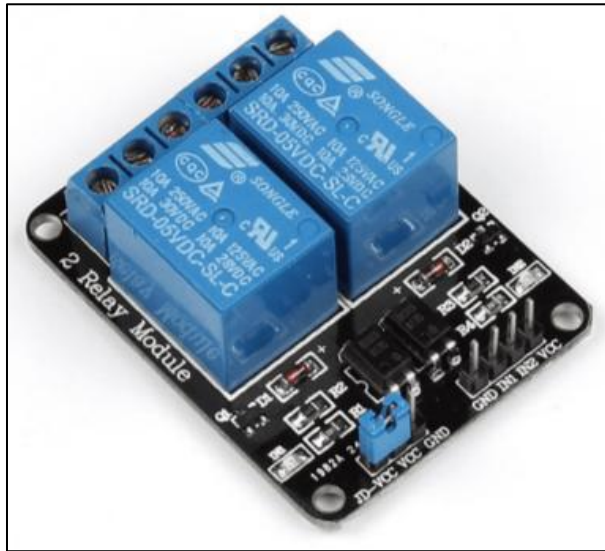


Figure 6: Channel 5V Active Low Relay Module

5.2.7 Cloud Integration and System Mounting Hardware

Support materials, such as mounting poles or brackets are needed to securely position the pressure sensors at the flood prone area and elevate the control unit enclosure. Proper mounting ensures accurate sensor readings and protects the hardware from physical damage

5.3 Software Development

This section outlines software components required to develop and implement the IoT based flood monitoring and alert systems. These tools are crucial for programming the microcontroller, visualizing sensor data and enabling real-time notifications.

5.3.1 Arduino IDE

The Arduino IDE is used for programming the ESP32 microcontroller. It provides an easy-to-use interface for writing, compiling and uploading code to the ESP32. The IDE supports libraries for sensor integration, Wi-Fi communication and cloud platforms. It is also compatible with various protocols such as HTTP and MQTT, which is used to send data to platforms like ThingSpeak or Firebase.

5.3.2 Blynk IoT Platform

The Blynk IoT platform is utilized to construct a mobile dashboard for real-time monitoring of the water level sensor data. It includes widgets that allow users to visualize real-time data and send push notifications to alert users when the water level exceeds a predefined threshold. The platform integrates seamlessly with the ESP32, enabling easy development and quick deployment.

5.3.3 Firebase

Firebase serves as the cloud platform for data storage and real-time communication. It allows data from the water level sensor to be stored in the Realtime Database and efficient data management and ensures that system is scalable to store large amounts of data from the sensor.

5.3.4 WhatsApp Notification API

To send automated WhatsApp alerts when the water level reaches a critical threshold, the system will use the CallMeBot API or Twilio API. These APIs allow the ESP32 to send WhatsApp messages to user's mobile devices, ensuring timely notification of flood risks. Once the threshold is exceeded, ESP32 sends a message with the water level status (e.g., "Flood Warning") to the designated WhatsApp number, ensuring immediate awareness for the residents and campus management.

5.4 System Architecture

Figure 7 illustrates the overall system architecture of the proposed IoT-based flood monitoring and alert system. The diagram shows how the data flows from the water level sensor to the ESP32 microcontroller, which processes the data and transmits it to the cloud platform. In turn, the cloud platform sends real-time alerts via WhatsApp notifications to users, while the system's relay module activates the siren alarm as an on-site alert. The entire system is powered by a solar panel with a rechargeable battery, ensuring continuous operation during power outages.

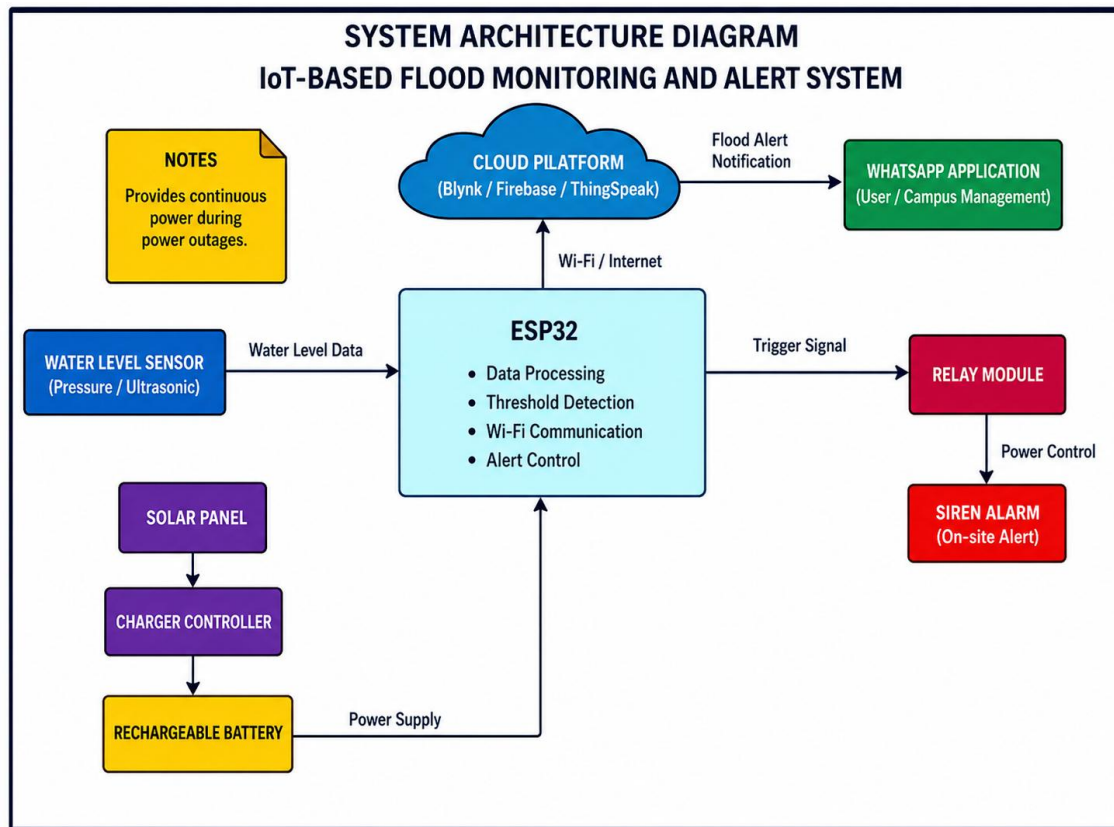


Figure 7: System Architecture Diagram

5.5 Project Flow

This section demonstrates the flow of operations within the IoT-Based Flood Monitoring and Alert System. The flowchart is designed to visually represent the process from system initialization to continuous monitoring, capturing the key interactions between the hardware and software components. Figure 8 show the phase is divided into key stages, each corresponding to an action or decision that drives the operation of the system. Below is the flowchart that represents the entire system lifecycle, including the initialization, data processing, threshold checks, alert generation and data logging.

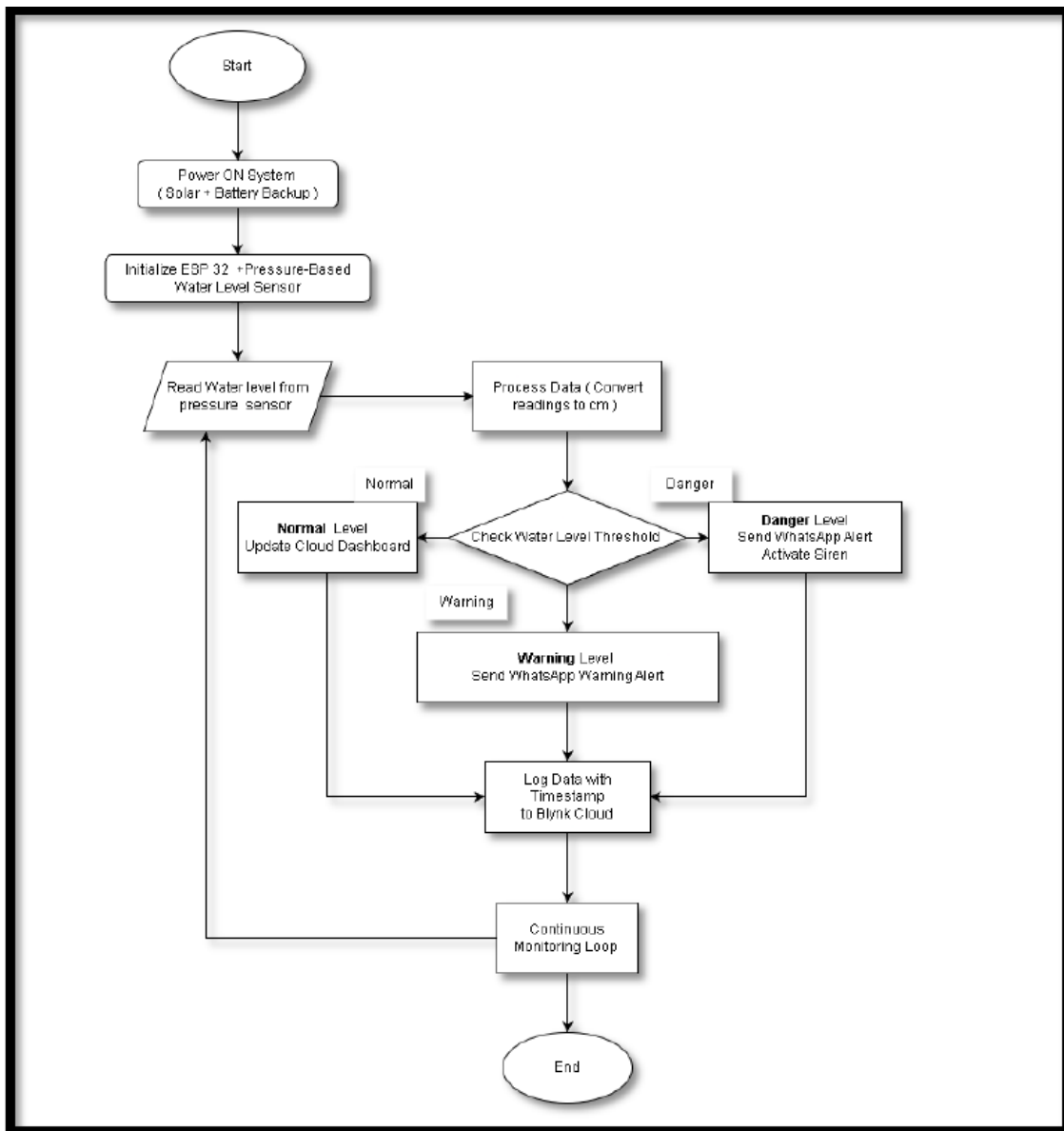


Figure 8: Flowchart

6.0 RESULT AND ANALYSIS

The proposed IoT-based real-time flood monitoring and alert system is designed to address the limitations of conventional flood observation methods in residential and campus environments, particularly at UC TATI Residential College. Traditional approaches often rely on manual inspection or delayed reporting, which are insufficient for rapid response during sudden heavy rainfall events. By introducing continuous sensor-based monitoring and automated alert mechanisms, the proposed system provides a more proactive and reliable approach to flood risk management.

The results demonstrate that the proposed IoT-based flood monitoring system is capable of providing real-time situational awareness and early warning capabilities for UC TATI Residential College. The integration of cloud services, WhatsApp notifications, and local siren alerts creates a multi-layered warning mechanism that improves emergency preparedness. Furthermore, the use of solar energy enhances system sustainability and ensures operation during power disruptions.

6.1 Water Level Detection Performance

The ultrasonic water level sensor was tested under three predefined flood conditions: Normal, Warning, and Danger. The ESP32 successfully classified the water levels according to the configured thresholds and transmitted the data to the cloud platform in real time. The results indicate that the system correctly identified flood conditions and activated the corresponding alert mechanisms. Table 2 shows warning threshold provided early notification before critical flooding occurred, while the Danger threshold triggered both remote and local alerts. The threshold-based classification mechanism provides a simple and reliable decision-making approach. The use of three alert stages allows users to receive progressive warnings and take preventive action before severe flooding occurs.

Table 2: Water level and warning

Water Level (cm)	Status Classification	WhatsApp Alert	Siren
0 – 20	Normal	No	Off
21 – 40	Warning	Yes	Off
> 40	Danger	Yes	On

6.2 Notification Response Time

The response time in Table 3 was measured from the moment the sensor detected a threshold breach until the WhatsApp notification was received by the user. The average notification delay remained below 3 seconds, demonstrating that the proposed IoT architecture can provide near real-time alerts. Such response times are acceptable for localized flood monitoring applications where rapid awareness is essential.

Table 3: Response Time

Test Scenario	Average Response Time (s)
Warning Level	2.3
Danger Level	2.5

6.3 System Reliability Test

The prototype was tested continuously under simulated flood conditions over multiple operating cycles. The system achieved an overall reliability of approximately 98% shown in Table 4. Most failures were associated with temporary network interruptions affecting cloud communication. However, the local siren alert remained operational, ensuring that critical warnings could still be delivered.

Table 4: Reliability Test

Parameter	Result
Total Test Cycles	50
Successful Data Uploads	49
Successful WhatsApp Alerts	48
Successful Siren Activations	50
Overall Reliability	98%

7.0 CONCLUSIONS AND FUTURE WORK

This paper has presented the design and development of an IoT-based real-time flood monitoring and alert system for UC TATI Residential College. The proposed system focuses on a structured framework that integrates water level sensing, wireless data transmission, cloud-based monitoring, and automated alert notification to provide early warning of potential flood situations. The system architecture, operational workflow, and methodology have been described in detail, emphasizing real-time monitoring and threshold-based decision making.

Although this study is limited to conceptual design and system development, it establishes a strong foundation for implementing a practical and reliable flood monitoring solution in the campus environment. The proposed framework is expected to enhance flood preparedness, reduce response time, and improve overall safety for residents and campus management.

Future work will focus on the full implementation and deployment of the proposed system at UC TATI Residential College, followed by comprehensive performance evaluation in real flood and rainfall conditions. Further improvements may include the integration of additional sensors such as rainfall and flow rate sensors, the use of mobile applications for alert dissemination, and the incorporation of data analytics or machine learning techniques for flood prediction. In addition, system reliability can be enhanced through backup power sources, redundant communication links, and secure data transmission mechanisms. These enhancements will further strengthen the effectiveness and scalability of the proposed flood monitoring and early warning system.

Author Contribution

S. Norwahidayah: Conceptualization, writing and editing. M. Fakhurulrazi: Investigation, supervision, writing, methodology, investigation, visualisation.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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