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Rapid Flood Warning System in Recreational Areas Using LoRa-Based Sensor Network

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ABSTRACT

Rapid floods usually occur in an uncertain and unpredictable time, and it will cause major disaster to environment and humanity especially at recreational areas. An IoT early warning system using Arduino technology is proposed to cater this problem. The system includes sensors for temperature, humidity, water flow, and ultrasonic measurements used for further analysis. This research aims to develop a system to monitor and detect water flow activity, such as water level and velocity, and notify of potential rapid floods earlier than estimated occurring time. The current temperature and humidity of the areas also can be recorded with the proposed device The System Development Life Cycle (SDLC) methodology was adapted for implementation of the project. Field testing at Puncak Janing Waterfall in Kedah State was chosen as test site for sensor functionality evaluation. Data is stored in a Firebase database, with an ESP32 Lo-Ra used for connectivity suitable for remote area and coding was done in Arduino IDE tool. The project successfully monitors and stores water level and velocity data and the data can be use as benchmarking the time rapid flood will occur.

1. INTRODUCTION

Natural disasters occur everywhere in the world, and they have an impact on the nation's economy and quality of life for its citizens (Hameed et al., 2020). Flood is one of the major disasters that affects many people each year in numerous places throughout the world. It endangers people, natural resources, and the environment, as well as creating economic losses. This flood disaster can occur anywhere, but the recreation area is the most dangerous.

In recent years, Malaysia's Kedah state has witnessed rapid and severe floods, notably in its recreational rivers. The floods in 2021, 2022, 2023 and 2024 caused considerable disruptions, affecting both local communities and tourists. These occurrences have been attributed to a mix of high rainfall and insufficient drainage systems, exacerbated by climate change (Malaysian Red Crescent Society, 2021). The severity and regularity of these floods have prompted worries about the region's readiness and resilience to similar natural disasters.

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The 2022 and 2023 floods were especially destructive, with multiple rivers in Kedah overflowing their banks, causing widespread damage to infrastructure and property. Many recreational sites, popular with both locals and tourists, were inundated, resulting in significant economic losses (Mukhtar, 2023). The state administration has since been encouraged to develop stronger flood protection measures, including as strengthening drainage systems and building flood barriers (Bernama, 2022).

In 2024, the situation the situation has become worse when early and severe monsoon rains caused another round of flooding in the region. The frequency of severe floods highlights the critical need for effective flood management techniques. To further prepare communities for such emergencies, local administrations have started developing emergency response plans and community awareness initiatives. The frequent flooding in Kedah highlights the greater issues posed by climate change, as well as the importance of proactive and long-term responses. (Ibrahim M.S. N. et. al, 2023)

Rapid flooding in Yan, Kedah, has become a severe issue, exemplified by recent events in 2023-2024. The area has been severely impacted by heavy monsoon rains, which have swamped local drainage systems and caused rapid river overflowing. These floods have caused enormous damage to houses, infrastructure, and agricultural grounds, severely affecting the livelihoods of locals. The recurring frequency of these floods highlights the critical need for enhanced flood management methods and infrastructure in the region to reduce future risks and strengthen community resilience (The Star, 2024).

All the occurrence mentioned above is due to the possibility of a water velocity that appears unexpectedly and can cause rapid flood. Therefore, technology plays a critical role in detecting and avoiding floods in a timely way. We can detect and prepare for an impending crisis with the assistance of present technological capabilities (Roy et al., 2020). One of the technologies that may be employed to reduce flood-related fatalities is the flood monitoring system, particularly in places along the rural areas and near the waterfalls. The purpose of this article is to demonstrate the usefulness of Internet of Things technology in the context of smart cities, with the end goal of enhancing disaster response and early warning systems.

Flood monitoring systems serve an important role in disaster management and mitigation, especially in flood-prone areas. These systems collect real-time data on water levels, rainfall, and other hydrological variables, allowing for early warnings and informed decision-making. The growing frequency and severity of flood occurrences around the world, caused by climate change and urbanization, highlight the relevance of such systems (Smith & Ward, 2018).

One of the key advantages of flood monitoring systems is their capacity to issue early warnings. These systems use advanced technologies including remote sensing, satellite images, and ground-based sensors to detect changes in water levels and weather patterns. By sending out timely alerts, communities may take preventive measures like evacuating vulnerable areas and safeguarding property. This early warning capability is critical for decreasing fatalities and lowering the economic effect of floods (Pappenberger et al. 2015).

Additionally, flood monitoring systems help with long-term flood risk management and urban development. The data obtained by these systems can be used to detect flood-prone locations and inform the design and deployment of flood defenses such as levees and drainage networks. Furthermore, this knowledge helps planners design long-term land-use plans that take flooding hazards into account. Cities and regions can increase their resilience to future floods by incorporating flood monitoring data into planning procedures (Jongman et al., 2014).

The use of Internet of Things (IoT) technology in flood warning systems has greatly improved the ability to monitor and respond to sudden flood events. IoT devices, like as sensors and smart cameras, give real-time data on water levels, rainfall, and environmental factors, allowing early warning systems to notify communities and authorities quickly. This real-time data collecting, and analysis enables speedier decision-

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making and more effective emergency response procedures, reducing potential damage and saving lives. Furthermore, IoT-based flood monitoring systems can be combined with predictive analytics to more accurately forecast flood episodes, increasing preparedness and resilience to such natural catastrophes (Liu et al., 2019; Zanella et al., 2014).

Because of the issue and possible solution mentioned, this study has addressed the design, implementation, and test outcomes of a LoRa-based early flood related parameter monitoring and detection system and its avoidance utilizing the Arduino project are presented as solutions to the described problem. The proposed system will offer a straightforward monitoring interface, enough flood data, and short-term water level and water velocity forecasting in the future. The system's functionality and network performance utilizing an ultrasonic sensor, LoRa technology, and Arduino board are tested in a real-world setting. The positive results obtained from the on-site testing validate the effectiveness of the proposed sensor and network system. It indicates that the system is capable of accurately detecting and monitoring flood conditions, providing timely and reliable data or early warning purposes.

2. LITERATURE REVIEW

The literature review for the study mentioned above on flood detecting devices is provided below. Many studies have been conducted to monitor floods using different methods.

2.1 Development of Advanced Flood Detection System with IoT

Advanced flood detection system with IoT offers communities near bodies of water, mainly waterfalls, early warning when dams release their water. This system consists of a sensor module, microprocessor, and output module. The output module is installed in the homes of the residents. It has an ultrasonic sensor to measure water level and IoT, and the data is transmitted to the microprocessor. The microprocessor will take the data, process it, and send the desired output to the output module. The implementation of IoT technology distinguishes this flood detector from others. The alerts component of the output module consists of an app alert from the IoT feature. In the event of a water level rise or a warning from a nearby dam through IoT, users will first receive an alert or notification from the app. The siren will sound, and the user will receive an app warning if the dam opens the water gates. The hardware required in this project are Arduino Uno, Ultrasonic Sensor, Voltage Sensor, and Wi-Fi Serial Transceiver Module (ESP8266). The software that is being used for this project is Proteus ISIS 7 and the Blynk Application. As a data owner, teachers have an obligation to protect the privacy of their students and their own personal information. This includes ensuring that unauthorised parties cannot view, utilise, or spread the information in any way. It is also necessary to understand local laws and regulations pertaining to the gathering, archiving, and distribution of student records (Subeesh et al., 2019).

2.2 Flood Monitoring and Warning System with IoT

A study done by Haslina (2019) recognize the need of a robust solution that will help to mitigate the effects of flood. The paper has focused on the development of a Flood Monitoring and Warning System utilizing Internet of Things technologies. The study focusing on the finding of real-time water level for indicating the possibility of flood occurrence and noticing the water level to the user by using ultrasonic sensor.

From the literature review, this study is proposing a similar study with several enhancement by adding a water velocity reading in this study to create a more accurate estimation of potential rapid flood occurrence.

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3. METHODOLOGY

The methodology may be characterized as a set of phases that were utilized to explain and discuss the project development process. More detail was included in the methodology section on the actions taken to carry out the project's objectives, one of it is developing an early warning system with the assistance of IoT technology. Multiple phases of the project, including information collecting, project analysis requirements, project planning, system development, and project documentation, were employed as a System Development Life Cycle (SDLC) as illustrated in Fig. 1.

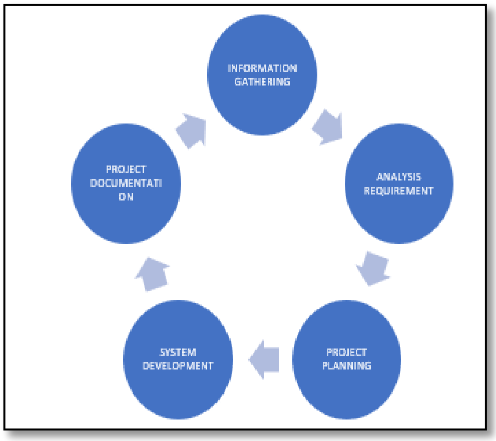

Fig. 1: SDLC Model

Source: Yadav (2021)

3.1 Hardware requirements

The component listed in Table 1 has been used for building the sensing device proposed in this project. LoRa E32 and ESP32 modules allow for wireless communication over long distances, which could be critical for transmitting real-time data from remote parts of a recreational area. The Waterproof Ultrasonic Sensor and Water Flow Sensor could monitor water levels and flow in rivers or lakes, providing early warnings of floods or rising water levels. The DHT22 sensor can be used to measure temperature and humidity, offering valuable environmental data that could signal weather changes or heat-related dangers. The LCD12C display and ESP32 Expansion Board allow for local data visualization and control of multiple sensors, while jumper sets ensure reliable connections between components. Such a system could proactively alert park rangers or visitors to potential hazards, enhancing safety in natural recreational areas where environmental conditions can change rapidly.

No.	Item	Quantity
1	LoRa E32	2
2	ESP32	2
3	Waterproof Ultrsonic	1

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Table 1. Hardware requirements

4	LCD12C	1
5	Jumper Set	8
6	RP SMA Antenna	2
7	DHT22	1
8	ESP32 Expansion Board	2
9	Water Flow Sensor	1

3.2 Software requirements

The project involves the use of a variety of software tools to increase productivity and design accuracy. Microsoft Office Word was used to record the project's progress and results. Diagram.net was instrumental in the creation of diagrams, such as flowcharts and SDLC models. For programming operations, the Arduino IDE was used to write code, interact with Arduino hardware, and upload programs to the microcontroller board. Schematic layouts were developed using Proteus 8, which ensured precise circuit representations. Finally, PowerPoint assisted in developing proposal slides that presented crucial features of the project.

3.3 Device process flowchart

This system consists of two flowcharts which are flowchart for transmitter and flowchart for receiver. This model has been proposed to cater for one of the objectives of this project which is enhancing the parameter used to indicate the potential of rapid flood occurrence. The proposed system also incorporates LoRa technology which will allow long-range, low-power communication in distant and remote places such as recreational areas with minimal infrastructure.

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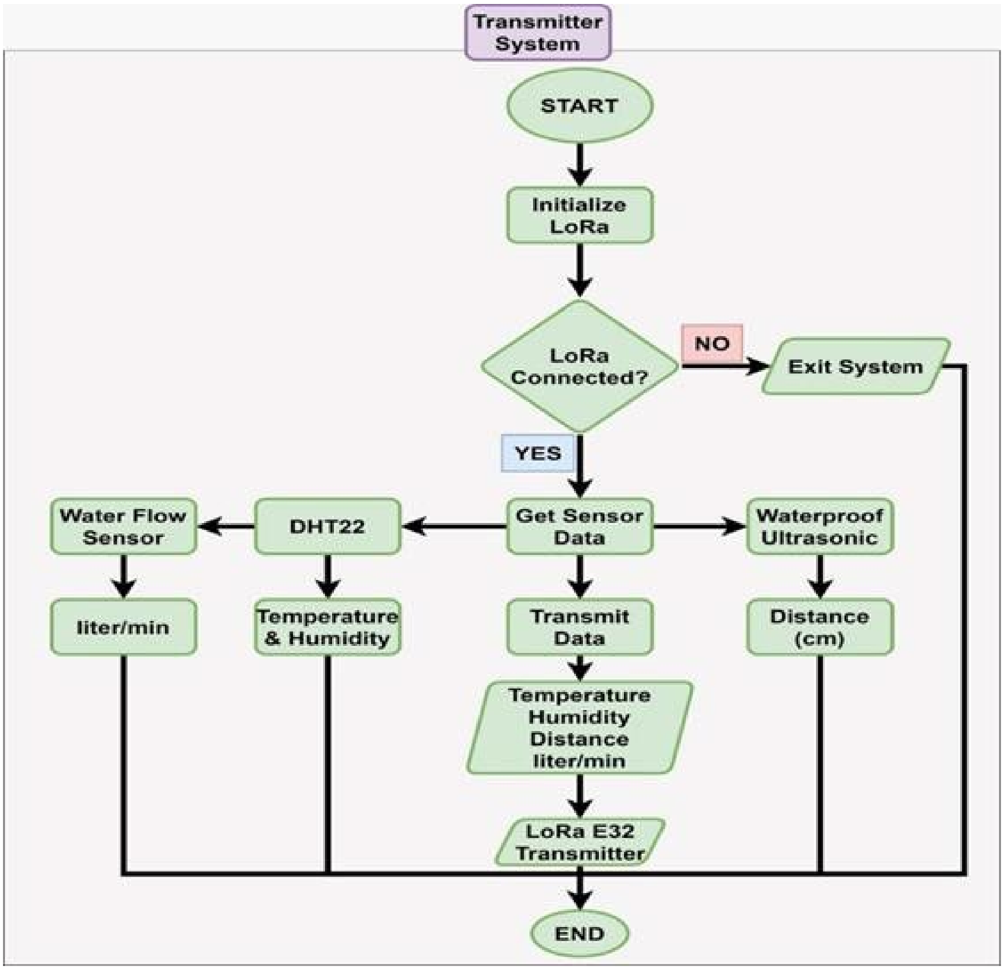

Fig. 2. Flowchart transmitter

According to Fig. 2, after initializing and confirming the LoRa connection, the system transmits a real-time environmental data to a remote receiver, to ensure a constant monitoring. The inclusion of LoRa radio network to the proposed device will also significantly enhances the system's range and reliability, allowing data to be transmitted across several kilometres, even in difficult terrains, without the need for traditional connectivity like cellular or Wi-Fi. This makes the proposed model is highly effective for flood detection, enabling a timely alerts and responses, particularly in areas like recreational rivers, which are currently susceptible to sudden water level changes.

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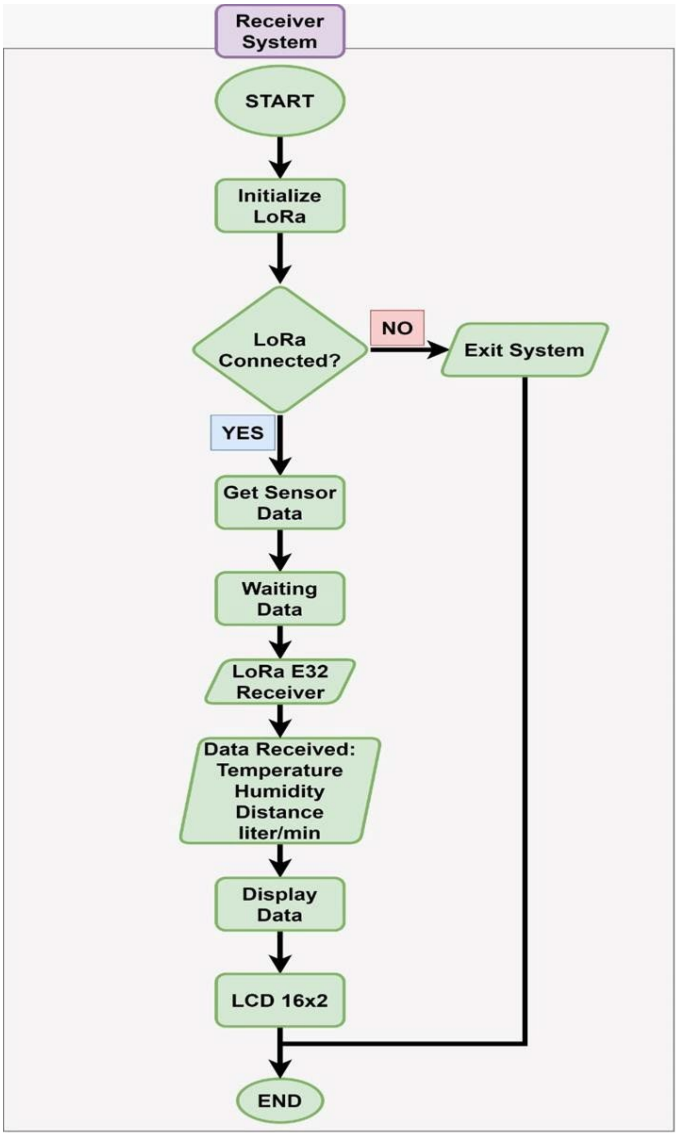

Fig. 3. Flowchart receiver

Fig. 3 above demonstrates the procedure of a Receiver System built to receive sensor data via LoRa (Long Range) communication technology. The system begins by initializing LoRa, then checks to see if the LoRa module is successfully connected. If the link is not established, the system will not begin the sensing process; otherwise, the process will continue to gather sensor data. The system then enters a waiting mode, anticipating data reception from the LoRa E32 Receiver. When data is received, it includes important information such as temperature, humidity, distance, and flow rate (liters per minute) of the river velocity.

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4. DESIGN AND DEVELOPMENT

This section will clarify how the system could operate regarding this system's design process and database. In making the system, all components must link to each other. The design includes system architecture to show the details about this project.

4.1 Prototype Development

The architecture of the system includes three different layers: the physical layer, the network layer, and the application layer as shown in Fig. 4. In the physical layer, some sensors are connected to the network layer that has LoRa and Wi-Fi which is from ESP32. All sensor readings from each post are displayed on the App, and an alert will be sent via Web and App from Firebase. Other than water level that has been sensed by ultrasonic sensor, the temperature sensor, humidity sensor and water velocity sensor also has been added in this project in order to increase the parameter measurement for predicting the possibility of rapid flood occurrence.

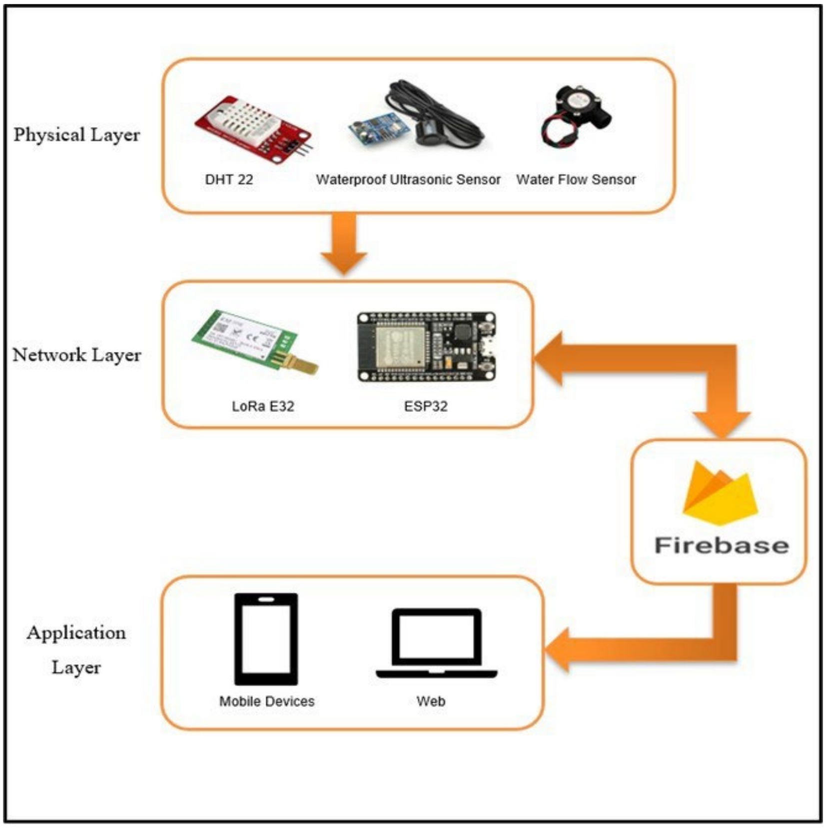

Fig. 4. System architecture

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5. RESULT AND ANALYSIS

The research used a field-testing technique. The experiments' goal is to analyse the system's efficacy and explore user involvement and device reactions to fulfil the project's main purpose, which is to determine whether the project can work in an isolated location.

Condition	Range (cm)	Status
	Below 200 cm	Safe
	200 - 290	Caution
	300 – 390	Caution
	400 cm and above	Relocate

Fig. 5. Water level benchmark

Source: Department of Irrigation and Drainage Malaysia (2023)

Fig. 5 above shows the indicator of water level status taken from Department of Irrigation and Drainage Malaysia (2023) used to estimate of flood occurrence. The referred water level has been used in the field testing to measure the reading of the IoT device proposed. By referring to the table, it shows that each level of water corresponds to a certain condition. Ranging from normal level to high water level. The column underlines the severity of each range, with normal levels offering no hazard and level exceeding 400 cm indicating a catastrophic flood risk will happen and evacuation procedure must be notified.

5.1 Field Testing Results

In order to testify the accuracy of the data provided by the proposed device, a field testing was done at Puncak Janing Waterfall in Kedah state. Data of water level and water velocity has been collected manuallty by using manual water level gauge and proposed IoT device and comparative study has been done.

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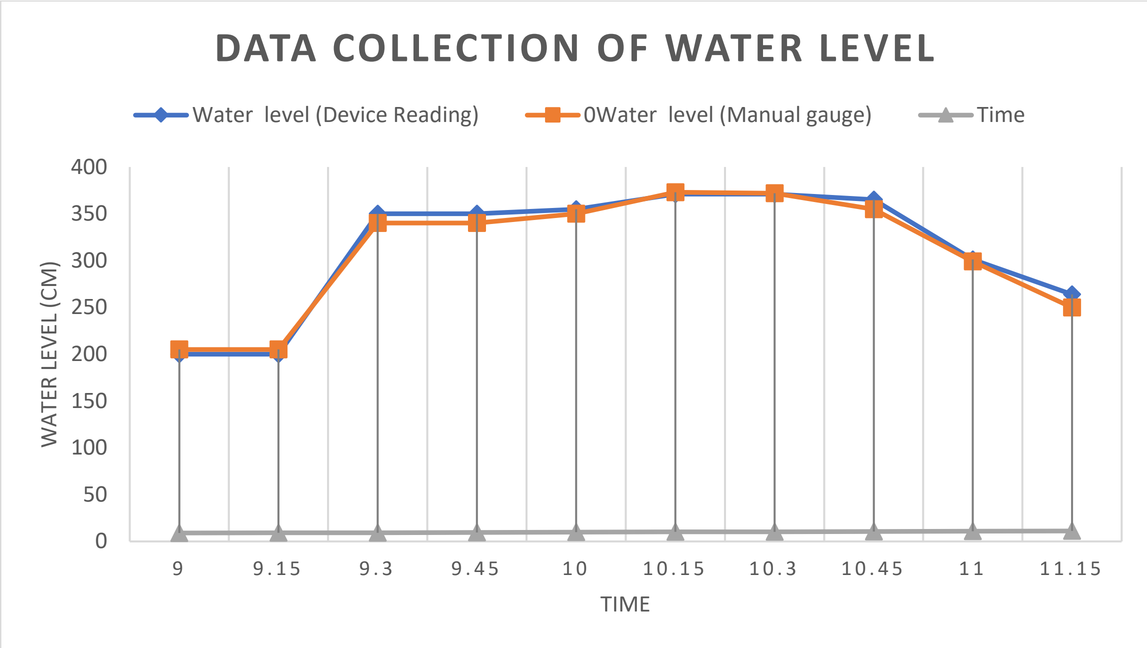

Fig. 6. Water level reading

Fig. 6 above shows the comparison results between water level readings over time using two methods where blue line indicates the proposed device reading while the red lines shows the water level readings from the manual gauge. Both are measured in cm and plotted on the vertical axis against time starting from 9 a.m. until 11.15a.m. The water level during the field testing begins at approximately 200 cm and gradually rising at 9.45 and 10.42 around 350 cm. Both methods of measurement show similar trends, indicating that the proposed device and manual readings are consistent with each other, Water level reads below 200 cm as seen between 9 a.m and 9.30 a.m has fall within the safe zone for recreational activities. However, from 9.30 a.m. onwards the water levels increases to the cautionary level (200-290 cm) and continues to rise to dangerous level near 400 cm where it is unsafe for recreation.

The observation can be concluded as a close agreement between both devices confirming a realiabe water level tracking but it is much safer of using the proposed device since it can track remotely from afar since it is using a wireless communiation to tranfer the data.

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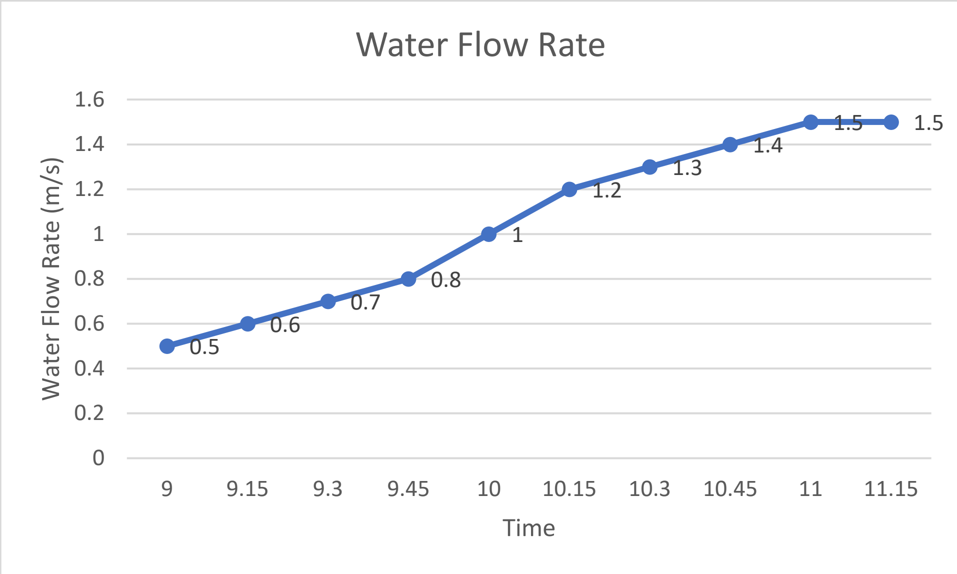

Fig. 7. Chart of water flow rate

In the Fig. 7, the water flow rate is represented by the "Water Flow Rate (m/s)" data. The water velocity is a measure of how fast the water is moving at a specific point in the system. It indicates the speed at which the water is flowing through the waterfall or channel. This is the additional measurement added in this project in order to create a much accurate of estimating the happening of rapid floods.

By observing the chart, it can see that the water flow rate increases gradually from 0.5 m/s at 9:00 AM to 1.4 m/s at 11:15 AM. The values show a consistent upward trend, indicating an increasing flow rate over time. The flow rate is directly proportional to the water velocity, meaning that the velocity increases. A much faster reading of the water velocity indicates a potential of rapid flood potential occurrence.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Limitations

There are several limitations and problems in the system that needs to be improved.

a. LoRa nodes typically operate on battery power, which can pose limitations in terms of battery life and maintenance. Researchers should carefully design power management systems to optimize energy consumption and consider alternative power sources, such as solar energy, to extend the system's operational lifespan.

b. Due to limited funds, this project currently only able to develop one transmitter for the early warning system, which may have an impact on the accuracy of the data collected. With only one transmitter, the system's coverage area will be limited, and it may not capture a comprehensive picture of the flood conditions across the entire targeted area. This could result in potential blind

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spots or gaps in the data, hindering the system's ability to provide a complete and accurate early warning.

6.2 Recommendations

Based on the results of the findings and conclusion gathered, the researchers would like to recommend some recommendations and ideas suggested to improve this project in future work:

a. Consider integrating solar power into the system. By incorporating solar panels and associated components, the system can harness renewable energy from the sun, reducing reliance on traditional power sources and increasing its reliability in remote areas. The solar power integration would ensure continuous operation of the system, even during power outages or in areas with limited access to electricity.

b. In the future, many transmitters to one receiver should be available so that the user may obtain more accurate data if one transmitter failures and the other transmitters serve as a backup. Having multiple transmitters strategically placed throughout the area would allow for a more robust and comprehensive data collection, providing a more accurate representation of the flood conditions in real-time.

6.3 Conclusion

The on-site findings played a crucial role in evaluating the performance and effectiveness of the proposed sensor and network system. By conducting tests and observations in the actual deployment environment, researchers were able to assess the system's functionality, reliability, and ability to meet the desired objectives. The positive results obtained from the on-site testing validate the effectiveness of the proposed sensor and network system. It indicates that the system is capable of accurately detecting and monitoring flood conditions, providing timely and reliable data for early warning purposes. The positive outcomes also imply that the system is robust, stable, and capable of withstanding the challenges and environmental factors present in real-world flood scenarios. Hopefully, this project can contribute to the research field by advancing knowledge, fostering collaboration, and inspiring further innovations in flood monitoring systems and public community.

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8. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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9. AUTHORS' CONTRIBUTIONS

Iman Hazwan bin Abd Halim, Muhammad Nabil Fikri bin Jamaluddin, and Ros Syamsul bin Hamid are all the authors and editors of this paper, equally.

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