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Automated flood water level sensor and alarm system using Arduino Uno

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Abstract

This study focuses on developing and evaluating an Automated Flood Water Level Sensor and Alarm System using Arduino Uno to bolster flood monitoring and early warning capabilities. The system integrates water level sensors with Arduino Uno to detect rising water levels and trigger alarms for timely alerts. By investigating the system's effectiveness across various parameters like accuracy, effectiveness, maximum distance detection, and water level measurement, the research aimed to provide insights into its performance and potential impact on flood resilience efforts. Key components such as ultrasonic, capacitive, and sound sensors are incorporated into the system to provide real-time data on water levels. The study underscores the importance of automated flood detection systems in mitigating the devastating consequences of floods, especially in flood-prone regions. By harnessing Arduino technology and sensor capabilities, the research seeks to empower communities to respond promptly and effectively to flood events, safeguarding lives and property. The significant findings indicate that the system demonstrates high accuracy, effectiveness, reliability, and responsiveness in detecting floods and monitoring water levels. Integrating the water sensor, LEDs, and buzzer proved highly effective, and there was no significant difference in performance compared to existing flood monitoring methods. This contributes to advancing flood monitoring technology and enhancing disaster preparedness strategies, offering valuable insights for future research. Future researchers may incorporate technology like apps, messages, or QR codes that can effectively disseminate critical information to those in affected areas, helping them stay safe and take necessary precautions.

Keywords: automated flood water level sensor, Arduino Uno, flood monitoring, early warning system, disaster preparedness

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1. Introduction

Floods are the most prevalent natural disasters, and floods' growing frequency and intensity have been widely recorded over the previous decades. Flood risk reduction is a top issue for many Asian cities, particularly those in low-elevation coastal locations. According to the World Disasters Report (McClean, 2010), Asia is the most disaster-prone continent, with many locations particularly vulnerable to the combined impacts of subsidence and rising sea levels, which have already resulted in severe flooding. Asia continues to be the most disaster-prone continent, with many locations particularly vulnerable to the combined impacts of subsidence and increasing sea levels, which have already resulted in severe flooding. A succession of unexpected disasters, such as the catastrophic floods in the Philippines caused by super typhoon Yolanda, also known as "*Haiyan*" in the Philippines, highlighted the significant effect of disasters on people and economic growth (Aitsi-Selmi et al., 2016). These patterns highlight the importance of community- and government-based catastrophe preparedness and responses in mitigating disaster-related damages. Decision-makers have acknowledged the region's vulnerability to seismic shocks. That is why having a device that can measure the water level of a specific location is essential so that people may be prepared.

Flooding is the most common natural catastrophe that produces widespread destruction, resulting in loss of life, property damage, and key public health infrastructure (World Health Organization, n.d.). It has a substantial impact, with around 40% of the road network being waterlogged or inaccessible, and circulation is strongly impacted by considerable vehicle speed declines, longer travel times, and greater distances driven in and around the affected area (Diakakis et al., 2020). Heavy rain pours down, streets turn into rivers, and the fear of floods rising is a common scenario in the Philippines during typhoons and monsoons. During the rainy season, the total volume has abundant water, which causes river water to overflow and cannot accommodate the excess volume of water. When a typhoon hits, it brings intense rainfall, leading to overflowing rivers, saturated soil, and landslides in hilly areas. The consequences are far-reaching and severe, ranging from the loss of lives and displacement of communities to damage to infrastructure and agriculture. Flooding in the Philippines has become a recurrent challenge, making it crucial for us to develop innovative solutions like flood water level sensors to reduce the impact of these calamities and safeguard our people and resources. It is essential to have an efficient flood response operation system to manage all activities during a flood. It is impossible to exaggerate the significance of flood water level sensors. They allow for the timely distribution of resources and monitoring of water levels in urban drainage systems, rivers, lakes, reservoirs, and lakes. These sensors also assist communities in preparing for flood disasters and lessen their effects by helping to create precise flood models and forecasts (Wan Hassan et al., 2019).

Climate change has intensified the frequency and severity of flooding worldwide, making early warning systems and flood monitoring technologies crucial for disaster preparedness and response. One innovative approach to addressing this challenge is the integration of flood water level sensors with Arduino microcontrollers (Wan Hassan et al., 2019). Arduino, an open-source electronics platform, has gained remarkable popularity among hobbyists, researchers, and engineers due to its versatility, accessibility, and affordability. When combined with flood water level sensors, Arduino offers a cost-effective and customizable solution for monitoring water levels in rivers, lakes, reservoirs, and urban drainage systems. This integration empowers individuals and communities to build their flood monitoring systems and opens the door to research, innovation, and the development of localized flood resilience strategies (Saida et al., 2024). Flood water level sensors using Arduino present a compelling avenue for investigation due to their potential to democratize flood monitoring technology. These sensors, typically equipped with ultrasonic, pressure, or capacitive measurement mechanisms, offer real-time data on water levels, helping predict and respond to flood events efficiently.

Furthermore, Arduino's user-friendly programming environment simplifies the creation of data logging, alerting, and visualization systems, making it accessible even to those with limited technical expertise.

In addition, the Arduino Uno is like a small brain that can make things happen. It is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (6 can be used as PWM outputs), six analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. Imagine you want to know if your street will flood when it rains a lot, and this project will come in handy. The researchers used an Arduino Uno to create a smart gadget that measured the water level. When the water gets too high, the light will tell us if it has flooded. This helps us stay safe and prepared during heavy rains and typhoons in the Philippines. This project is all about keeping our communities safe from flooding disasters. This comprehensive investigation seeks to elucidate the potential of Arduino-based flood water level sensors as a scalable and adaptable flood monitoring and management tool. By examining the technical aspects, environmental impact, and socio-economic implications of such systems, this research aims to contribute to the ongoing efforts to mitigate the devastating effects of floods in the Philippines. Through the fusion of Arduino technology and flood water level sensors, the researchers endeavor to empower individuals, communities, and organizations to pursue flood resilience, ultimately saving lives and safeguarding property.

Today, the standard method often alerts the relevant controlled registered individuals, causing saving citizens to take longer since most of their possessions cannot be stored. Given the situation, it is vital to construct an accurate, innovative flood monitoring system that uses sensors. Arduino may be implemented as a real-time monitoring system, increasing system efficiency. The primary goals of this study are to develop a system that uses both ATmega328P-based technology and sensors, web apps, Arduino, and network components to detect floods and warn the company and to develop an automated water level sensor and alarm system using Arduino Uno.

Statement of the Problem - This study aimed to develop an automated flood water level sensor and alarm system using an Arduino Uno. Specifically, it seeks to answer the following questions: (1) What is the status of the Automated Flood Water Level Sensor and Alarm system using Arduino Uno in terms of accuracy, effectiveness, detecting distance, and changes in water level? (2) Is it effective to use the water sensor, LEDs, and buzzer in developing the Automated Flood Water Level Sensor and Alarm System using Arduino Uno? (3) Is it effective to use the Automated Flood Water Level Sensor and Alarm System in terms of detecting rising water levels and alerting people? (4) Is there a significant difference between the existing flood monitoring method and the Automated Flood Water Level Sensor and Alarm System using Arduino Uno in terms of detecting the flood?

Significance of the Study - This study addresses the critical need for an affordable and accessible flood detection system tailored to San Jose Occidental Mindoro, where heavy rains and typhoons often lead to devastating floods. Utilizing an Arduino Uno, this system aims to provide accurate and timely flood warnings that are measurable in terms of effectiveness. Achieving this goal is relevant and essential, as it directly impacts the safety and well-being of communities in flood-prone areas. Furthermore, this study's completion within a defined time frame ensures that its outcomes can improve disaster response and mitigation efforts, ultimately helping safeguard lives and property during extreme weather events. The researchers aim to bridge the gap in current flood monitoring methods, making it achievable to provide timely flood warnings even in remote areas. This solution addresses the pressing need and aligns to enhance disaster preparedness and safeguard vulnerable communities during heavy rains and typhoons, ultimately contributing to more effective disaster management in San Jose, Occidental Mindoro. For the students of DWCSJ, the machine might benefit the students at Divine Word College of San Jose as a safety device that will alert them of the flood, which can speed up their reaction time and signal them to prepare for stormy weather. For citizens and consumers, the device can benefit individuals by providing efficient and timely flood warnings that can enhance their disaster preparedness. For the community, developing this device could considerably bridge the gap even in remote areas, safeguarding vulnerable communities during heavy rains and typhoons, especially in flood-prone areas. And finally, for future researchers. The development of the device and the information acquired in the study can be valuable and utilized as a reference for future research.

This study will help citizens become aware of their surroundings during an upcoming storm. This study provides an overview of the use and effectiveness of automated water level sensors and alarm systems. It educates and serves as a guide for future research on similar and related topics.

Scope and Delimitation of the Study - The general intent of the study is to develop an early flood detector using Arduino to keep our communities safe from flooding disasters. In the Philippines, a school in the province of Occidental Mindoro, the Divine Word College of San Jose, will be the focus of this study because it is known for its- flood-prone area. A road flood is the flood that this device intends to detect. This study uses water level, flow, and sound sensors to detect floods. They allow for the timely distribution of resources and monitoring of water levels in urban drainage systems, rivers, lakes, reservoirs, and lakes. These sensors also help communities prepare for flood disasters and lessen their effects by helping to create precise flood models and forecasts. This study did not cover other aspects regarding the early flood detector, such as public access to warnings because of data privacy and the conciseness of sound alarms. Scalability is also not covered in this study. Other enhancements in the device's features might broaden the field being studied. However, in conducting the study, the level of flood water was detected.

2. Methodology

Research Design - A developmental evaluative research design was used in this study. This study employs an experimental design with a significant relationship between independent and dependent variables. The influence of independent variables on dependent variables is often observed and recorded over time to assist researchers in reaching a plausible conclusion about the link between these two variable types. Various experiments were performed to determine the efficacy of the flood water level sensor. It aims to know the potential use of water level sensors in detecting early floods. With the help of the Arduino Uno, it would give power to the automated water level sensor.

Data Gathering Procedure - The automated flood water level sensor system interfaces an Arduino Uno with an ultrasonic sensor for precise measurements. The sensor is placed in a flood-prone location to detect the flood's water level. This study is automated, meaning users don't need to touch or press any buttons on the Automated Flood Water Sensor to activate it. It benefits all, whether a child, an adult, or even a senior citizen. The device was finished in 2 weeks. The researchers made sure to gather all the parts they needed before starting. Then, they put everything together, wrote the code, and ensured it was correctly calibrated. They worked step by step, making improvements as they went along. This helped them finish quickly and make sure everything worked well. After the researchers experimented with their work, they presented the evaluation checklist to the 20 volunteer participants inside the Divine Word College of San Jose campus. They were randomly chosen since the researchers aimed to determine if the device was working correctly. The evaluation checklist was evaluated using expert validity.

Research Process: Stage 1 Preparation and Gathering of Materials - The production of the Automatic Flood Water Level Sensor uses the following materials to work appropriately: Arduino Uno R3, 330 Ohm Resistor, Water Level Sensor, Battery, Jumper wires, Breadboard, LED Lights, Plastic Casing, Buzzer, Plastic casing, SB Cable and Power supply. The researchers used familiar materials such as the Arduino Uno R3, the sensors, batteries, wires, and resistors, as those materials are like the ones used during the 2 Sumo Robot competitions in which the school had previously participated. The materials mentioned previously were bought online. The casing was made of plastic and was either 3D printed or purchased at a local hardware store. The researchers' materials cost around 500 pesos in all. The researchers used the "starter kit Uno R3 mini, mini-breadboard, LED, jumper wire, and button for Arduino compatibility at around 390 pesos. In comparison, the plastic casings are 75 pesos, and the battery costs 64 pesos. The total cost of materials is Php 1,029.00.

Stage 2: Building and Development of the Project - Creating an automated flood water sensor using Arduino Uno provides a cost-effective and accessible solution for monitoring water levels, enabling timely responses to potential flood events. The Arduino Uno's versatility and ease of programming make it an ideal platform for developing customizable flood-sensing systems, empowering communities to enhance their resilience against water-related disasters. It took the researchers 2 to 3 weeks to build the device. You'll need key components to create an automated floodwater sensor using an Arduino Uno. Connect an ultrasonic or capacitive water level sensor to the Arduino Uno board. These sensors can measure the distance between the sensor and the water surface, providing data on the water level. Ensure the sensor is securely placed in a waterproof housing to protect it from the elements. Next, program the Arduino Uno to read data from the water level sensor. Write code that interprets the sensor data, establishes a baseline for normal water levels, and sets a threshold for triggering flood alerts. Implement conditional statements to initiate actions when the water level surpasses the predefined threshold, such as activating an alarm, sending notifications, or even interfacing with external devices. If desired, integrate a display unit to provide real-time visual feedback on the water level. Additionally, consider incorporating communication modules like Wi-Fi or GSM for remote monitoring capabilities. Finally, assemble the components into a compact and weather-resistant enclosure. Ensure the power supply, whether from batteries or an AC adapter, is protected from water. Test the system thoroughly to validate its functionality and reliability. With these steps, you'll have created a primary yet effective automated flood water sensor using Arduino Uno, capable of providing early warnings and facilitating timely responses to potential flood events.

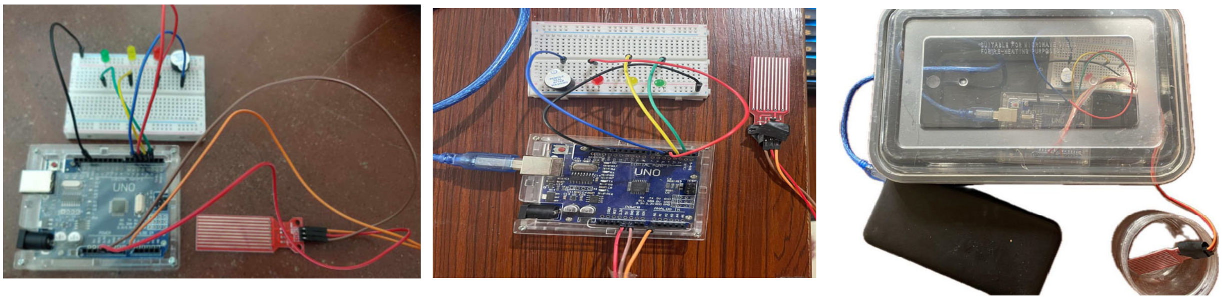

Figure 1. Actual Product of Automated flood water level sensor and alarm system using Arduino Uno

Stage 3: Experimental Stage, Observation and Data Recording - The proposed invention was to be tested to see if it was a more practical and necessary tool for sensing floods. The device was first easily tested in flood-prone areas until the flood motion sensor picked them up. The accuracy of this product was assessed by the researchers using a variety of techniques. In 2 weeks, the researchers have already finished their product. The testing took two days to ensure the system functioned properly and adjust calibration. Alertness from the researchers during testing was needed for the study. In addition, they document the observations and results from these actual tests. Moreover, the primary data is gathered before and after the researchers finish the sensor. The researchers documented each stage of the process, preparing the necessary tools and building the sensor. All of the images and videos captured throughout the sensor's assembly were done accordingly to demonstrate that the researchers were the ones who built it. While the sensor was completed, the researchers tested it to see if the final result worked. Additionally, they documented all of the information and guaranteed the honesty and integrity of the data collected.

Statistical Treatment of the Data - Statistical analysis of an automated water level sensor and alarm using Arduino Uno involves examining the collected data to draw meaningful insights. Initially, the researchers calculate descriptive statistics, such as the weighted mean, to determine the level of effectiveness of the device and the range of values. These metrics provide a quick overview of the data, telling us how the water levels vary and the typical values. Visualizing the data through graphs or charts helps us see trends or patterns over time or under different conditions. In addition, the researchers used correlation analysis to determine the effectiveness of the materials used in developing the device. In contrast, a t-test was used to determine if there is a significant difference between the existing flood monitoring method and the automated flood water level sensor and alarm system using Arduino Uno to detect floods.

3. Results and Discussions

Table 1

Status of the Automated Flood Water Level Sensor and Alarm system using Arduino Uno in terms of Accuracy, Effectiveness, Detecting Distance and Changes in Water

Indicators	4 (SA)	3 (A)	2 (DA)	1 (SDA)	Weighted Mean	Descriptive Indicator
The device is accurate in detecting floodwater.	14	6	0	0	3.70	Strongly Agree
The system is effective in performing its intended function.	13	5	2	0	3.55	Strongly Agree
The system can reliably detect the distance of the floodwater.	11	7	2	0	3.45	Strongly Agree
The system accurately measures and responds to changes in water level.	13	6	1	0	3.60	Strongly Agree
Overall Mean					3.57	Strongly Agree

Legend: 3.26 - 4.00 Strongly Agree, 2.51 - 3.25 Agree, 1.76 - 2.50 Disagree, 1.00 - 1.75 Strongly Disagree

Table 1 shows that the Automated Flood Water Level Sensor and Alarm System using Arduino Uno excels across all evaluated parameters. It accurately detects floods (3.70) and effectively performs its function (3.55). Additionally, it reliably detects the maximum distance of floodwater (3.45) and accurately measures changes in water level (3.60). Based on the survey, the 20 participants who tested the device all strongly agreed that the device is accurate, effective, and can reliably detect the distance of the floodwater. As evidenced by the Flood Water Level Sensor and Alarm System, the Arduino-based system demonstrates exceptional accuracy and effectiveness in monitoring flood situations. This aligns with Kondaveeti et al.'s (2021) findings regarding Arduino's superior performance in sensing applications, underscoring Arduino's proficiency in sensing and detecting tasks. They also support the notion that Arduino is highly capable of sensing various environmental factors.

Table 2

Correlation Analysis on the Effectiveness of Using Water Sensor, LEDs, and Buzzer in Developing the Automated Flood Water Level Sensor and Alarm System using Arduino Uno

Independent Variable	Dependent Variable	R-value	R^2(Effect Size)	t-value	P value	Interpretation
Water Sensor	Automated Flood Water Level Sensor	0.889	0.790	6.134	0.000	Highly Significant
Green, Yellow, and Red LED	Automated Flood Water Level Sensor	0.823	0.677	4.579	0.001	Highly Significant
Buzzer	Automated Flood Water Level Sensor	0.889	0.790	6.134	0.000	Highly Significant

Legend: *Highly Significant at $p \leq 0.01$ *Significant at $p \leq 0.05$

The researchers conducted ten trials to determine if the device was working. Each trial indicates whether the components were working or not. This setup ensures timely detection and alerting of flood conditions, leveraging the water sensor's precise measurement capabilities to trigger appropriate responses through the LED indicators and buzzer, as demonstrated by the consistent functionality observed by the researchers. The water sensor, chosen for its ease of use and accuracy in measuring water level distances, as highlighted by Darwis et al. (2023), plays a critical role in detecting the distance of the water surface. When the detected distance exceeds the programmed threshold, the buzzer alarms and LED indicators.

Table 3 shows that the correlation analysis on the effectiveness of using a Water Sensor, LEDs, and Buzzer in developing the Automated Flood Water Level Sensor and Alarm System using Arduino Uno is highly significant, as indicated by the low p-values of 0.000 for water sensor, 0.001 for LEDs and 0.000 for the buzzer, means that the null hypothesis is rejected, suggesting a significant relationship between the independent variables (Water Sensor, LEDs, and Buzzer) and the dependent variable (Automated Flood Water Level Sensor). This proved that the materials used during the device's construction are effective in developing automated flood water level sensors and alarm systems using Arduino Uno. This finding aligns with the study by Rachel et al. (2019), which highlights how Arduino-based systems integrate various components to function together seamlessly. The Water Sensor, LEDs, and Buzzer work with Arduino, controlling their operations based on programmed instructions. Therefore, the high significance observed in the correlation analysis underscores the interconnectedness and effectiveness of these components in the automated flood water level sensor and alarm system.

Table 3

Correlation Analysis on the Performance Level of Automated Flood Water Level in terms of Detecting Rising Water Levels and Alerting People

Independent Variable	Dependent Variable	R-value	R^2(Effect Size)	t-value	P value	Interpretation
Automated Flood Water Level Sensor	Detecting water levels and Alerting people	0.673	0.453	2.219	0.051	Significant

Legend: *Highly Significant at p≤0.01 *Significant at p≤0.05

The researchers conducted five trials to determine the device's performance. The experiments consist of 5 rising water levels: 40 cm, 50 cm, and 60 cm. Each trial indicates whether the rising water level was detected or not and whether the system alert was triggered. The results demonstrate that the system reliably detects rising water levels and promptly triggers alerts, indicating its capability to address flood-related challenges in affected areas. This finding aligns with the study conducted by Noar et al. (2019), which revealed that the system functions effectively when the Arduino Uno accurately senses the sensor data. Both the buzzer and LED indicators are functioning correctly.

In addition, Table 3 shows the results of the correlation analysis on the performance level of the Automated Flood Water Level Sensor in terms of detecting rising water levels and alerting people. The study revealed a significant relationship between the Automated Flood Water Level Sensor and its ability to detect water levels and alert people, with a p-value of 0.051. While this significance is just above the conventional threshold of $p \leq 0.05$, it still suggests a meaningful relationship. The significant correlation observed in Table 5 underscores the effectiveness of the Automated Flood Water Level Sensor in detecting rising water levels and issuing timely alerts to mitigate flood-related risks. This finding echoes the study by Odli et al. (2019), which emphasizes the importance of issuing alerts based on the increase in water height and setting up warning levels proportional to the fixed monitoring point.

Table 4

t-Test Results in the Difference between the Existing Flood Monitoring Method and Automated Flood Water Level Sensor and Alarm System Using Arduino Uno

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	1	3.6
Variance	0	0.01125
Observations	5	5
Hypothesized Mean Difference	0	
Df	4	
t Stat	-54.81281278	
P(T<=t) one-tail	3.31612E-01	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	6.63223E-01	
t Critical two-tail	2.776445105	

Legend: *Highly Significant at p≤0.01 *Significant at p≤0.05

Table 4 presents the results of a t-test to analyze the difference between the existing flood monitoring method and the Automated Flood Water Level Sensor and Alarm System using Arduino Uno. The t-test was performed, assuming unequal variances between the two methods. The null hypothesis is accepted with a t-statistic value of -54.81281278, which is significantly smaller than the t-critical value of 2.776445105. Therefore, the existing flood monitoring method and the automated flood water level sensor and alarm system using Arduino Uno are similar. This implies that both methods perform similarly in terms of their effectiveness in detecting floods; both the existing method and the Arduino-based systems are equally effective in detecting rising water levels during floods, as evidenced by the consistent detection observed across all trials for both methods. This finding contradicts the results of the study by Naik and Bhavani (2023), which suggests that the results of their experiment showed that, when compared to the microcontroller, the Arduino was far more accurate in its monitoring of the water's quality than the microcontroller was. This was proved by the microcontroller's results needing to be more precise. This discrepancy may stem from differences in experimental setups or methodologies between the studies.

4. Conclusions

Based on the summary of findings, the following conclusions concerning the research problems were made: It demonstrated high accuracy, effectiveness, reliability, and responsiveness in detecting floods and monitoring water levels, making it a valuable tool for enhancing flood risk management efforts. Integrating the water sensor, LEDs, and buzzer has proven highly effective in reliably detecting and alerting individuals to flood events. The Automated Flood Water Level Sensor and Alarm System detects rising water levels and alerts people, ensuring timely responses to potential flood events. There is no significant difference between the existing flood monitoring method and the Automated Flood Water Level Sensor and Alarm System in detecting floods.

Recommendation - The researchers recommend the following: To improve accuracy further, the consumers or users may calibrate the water sensor to ensure precise measurements regularly. Implementing a calibration routine at predetermined intervals will help maintain consistency and reliability in detecting flood levels. To enhance flood risk management efforts, the Local Government Unit (LGU) may consider expanding the deployment of automated flood water level sensors and alarm systems to more locations prone to flooding. The LGU may integrate remote monitoring features into the system to enable real-time monitoring of water levels from a centralized location. This will facilitate swift response actions and coordination during flood events, improving overall responsiveness and managing flood risks. It is recommended that future researchers continue assessing the usability and cost-effectiveness of the Arduino-based system for widespread deployment in flood-prone regions. National Disaster Risk Reduction and Management Council (NDRRMC) may add a device to inform people affected by floods, which sounds like a proactive approach to disaster management. Incorporating technology like apps, messages, or QR codes can effectively disseminate critical information to those in affected areas, helping them stay safe and take necessary precautions.

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