El Sadat STEM School

وزارة التربية والتعليم والتعليم الفني

MINISTRY OF EDUCATION AND TECHNICAL EDUCATION

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Present and Justify a Problem and Solution Requirements.

- Egypt Grand Challenge(s)
- Problem to be solved
- Research
- Other Solutions Already Tried

CHAPTER 1

1. Present and Justify a Problem and solution requirements

1.1 Egypt Grand Challenges

In Egypt, there are a lot of grand challenges that face Egyptians. These problems can be categorized into two categories. There are **Environmental** and **economic** problems.

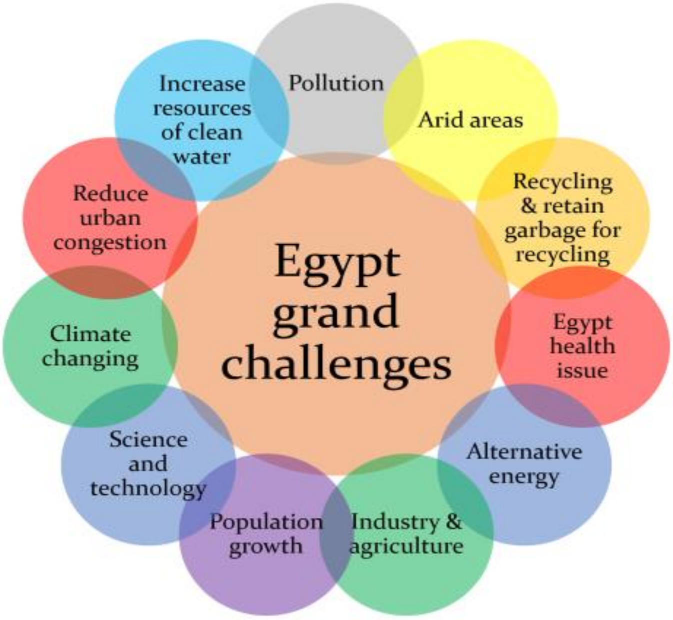


FIG. (1)

Environmental problems as:

1. Improve the use of alternative Energies
2. Global health
3. Improve sources of clean Water
4. Climate Variability
5. Pollution
6. Recycling & retaining garbage for recycling
7. Improve use of arid areas

Economic problems as:

1. Science and technology
2. Transportation
3. Percentage of population
4. Increase the industrial base of Egypt.
5. Reduce urban congestion.

A) Adapted climate change

Flooding can come from a variety of sources, including river overflows, heavy rains, snowmelts, and storm surges, falling into different types of floods:

Figure (2)

Fluvial flooding: Flooding occurs when rivers or streams overflow their banks, mainly due to heavy rainfall or snowmelt. Approximately 40 million people in the United States are at risk of river flooding that has the potential to devastate urban and agricultural areas, such as during the 2019 floods along the Arkansas, Mississippi, and Missouri rivers.

Coastal Flooding: This is driven by storm surges during coastal storms, such as hurricanes, and is exacerbated by sea level rise. Less severe but disruptive, high tide flooding occurs due to a daily tides overtopping storm drains and reaching into coastal communities.

Flash Floods: These are rapid and sometimes unpredictable floods, normally caused by heavy rain in a short time, and they usually occur in low-lying areas or areas with poor drainage. The flash floods that happened in California at the beginning of 2023 showed just how deadly such rapid water rises could be.

Urban Flooding: This is unique to areas with dense populations, when rainfall overwhelms stormwater systems. Events like Hurricane Ida in New York City in 2021 showed how heavy rains turn city streets into rivers, affecting residents in below-ground dwellings and straining infrastructure.

Within Egypt, the River Nile is controlled by two dams at Aswan and a series of seven barrages, among the most important hydraulic structures in the Egyptian water control system. They regulate the Nile flow discharge and water levels. In addition to the Aswan High Dam, some of these barrages produce hydropower. The Nile in Egypt consists of two parts, the Nile Valley and the Nile Delta. The delta barrages Barrage which was constructed in 1939 at Km 953.5 from Aswan Old Dam. Recent economic activities especially agriculture and industry activities and populations around delta lands have increased the need for risk management and assessment of damage due to dam failure which can lead to enormous loss of life and property. Flood inundation due to dam failure happens occasionally in the world. Such an event may cause serious loss of life, property, environmental damage, and economic repercussions. This study was put on track with the objective of analysis the hydraulic hazards of inundation of delta lands due to the failure of the Aswan High Dam. This study aims to assess the impact of such a catastrophic event on the inhabited areas downstream of the delta barrage to the Mediterranean Sea, or any

Figure (3). (The High dam)

urban area which might be in the path of the flood surge waves.

Climate change results in more intense rainfall. This increases the chances of flooding. This is because warming means the air can hold more moisture (for every 1℃ of warming, the atmosphere can hold 7% more moisture). Climate change also makes connecting extreme weather events more likely. For example, stronger heat and dry conditions result in parched soils. Parched soil increases the risk of flash flooding when it rains.
Climate change responses include adaptation (risk reduction, like building flood defenses) and anticipatory action (risk aversion, like evacuating people). These are critical parts of reducing devastation.
Not only does the warming wetter world create greater rainfall, it also sets in motion such seasonal fluctuations that there would be more flooding. Warmer temperatures mean more snow and ice melts faster, which in turn promotes an early start to the next year's "rain-on-snow" season that leads to river overflows all at once. Stronger and more frequent hurricanes are also associated with climate change--think Hurricane Harvey or the devastation wrought by Hurricane Maria. These hurricanes generate heavy rainfall and increased wind speeds which exacerbates storm surges, as rising sea levels allow the surge to go further inland.

Climate Justice and Adaptation
As the probability of flooding increases, there is believed to be a greater call toward a climate justice approach in deciding inequity in funding and adaptation measures. The community on the very front lines in this climate crisis has called for a "loss and damage fund" to support recovery from climate-induced disasters. COP27 climate talks in Sharm El-Sheikh recognize such a need with an agreement to create such a fund. This would, however, require that the funds reach those most affected by climate change, and it calls for political will and an urgent massing of forces from wealthier nations with larger historical responsibility for the emissions.

Figure (4).

The desire is there to curb flooding through structural adjustments and policy reviews. A good example includes the fact that most of the current FEMA flood maps across the United States are out of date, with nearly 60% being behind current climate realities. Moving these maps with real projections considering recent climate change would go a long way towards better community preparation. Adaptation through building resilience- such as stormwater infrastructure improvement, wetlands restoration, and other green infrastructure-is highly vital.

conclusion

Flooding has become an environmental, social, and economic problem-one increasingly driven by climate change-that requires immediate action and long-term adaptation strategies. Both point to the recognition of the nexus between climate change and socioeconomic vulnerability with flooding, for which fair solutions should be fully achieved through holistic flood mapping, robust infrastructure, and financial remunerations among the worst-hit. Flood disasters striking more frequently and with greater ferocity around the world underscore the urgent need for climate action to both limit warming and support adaptation on the front lines.

B) Improve the scientific and technological environment for all.

Through the Egyptian Grand Challenge, which will foster innovation in areas of water resources management and flood prevention technology, it can offer real solutions to one of Egypt's number one environmental challenges: floods. Flooding is a major danger in Egypt; already, one of the populations and infrastructure are especially at risk from a threat in the Nile Delta. Although the Aswan High Dam maintains positive control over water flow, receding dams or natural disasters may materialize in deadly floods. An equipment-based flood detection project, aiming at this problem, performs online monitoring of the water level, flow velocity, and rainfall data in real-time. This system provides early warnings for disaster prevention. Sensors coupled with Internet of Things (IoT) technologies and geographic information system (GIS) mapping support effective flood prediction and timely response, thereby attenuating the negative impact on the communities.

The project strengthens Egypt's Grand Challenge through the context of utilizing technological solutions to the problems associated with environmental risks. By placing wireless sensors to detect the water level behind the dam and to comprehend the pattern of unusual water flows. Early warnings produced
through such a process will be truly empowering to the decision-makers. Coupled with IoT devices, GIS mapping improves the detection of flood risk and helps in evacuation planning and estimating damages.

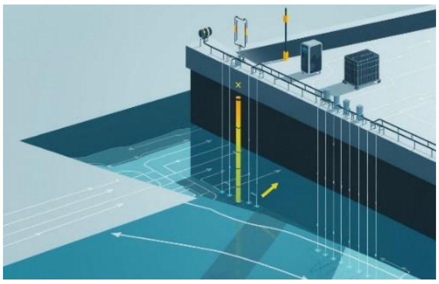


Figure (5).

And it may not rain here, but climate change is still increasing the spillover and intensity of extreme weather elsewhere, which means an increased chance of some flooding (with all that destroyed forest hey) round here. As temperature increases, and more extreme rainfall events occur globally and ice melts within the climate system, they have also made flooding-related threshold exceedances likely. It thus improves Egypt's ability to monitor and respond to floods in the context of climate adaptation. Though there are more challenges to go, this is a landmark initiative.

Figure (6).

It will enable Egypt to avoid the efficient loss of life, limb, and property while at the same time making an original contribution to the science and technology program as a practical solution for controlling flood waters, disaster risk reduction, and climate-resilient development. Nevertheless, this is an important undertaking for enabling sustainable advancement down the line to take place; it will not be easy.

1.2 Problem to be solved

What happen if our project succeeded

If our project succeeded, we will be able to predict the expected coming floods with our easily constructed system that can detect the coming floods by easily measured parameters that are: pressure, humidity, water flow rate, and water level. This will increase the feel of safety in urban areas and also increase the value of the new cities, and decrease the damages that is caused by a surprise flood.

What happen if we our project failed.

If our project failed, we would be prevented from the feel of the safety from a surprise flood that may cause much deaths and economic losses. This will decrease the quality of life and the safety rate of the country between the world countries.

1.3 Research

Topics Researched About deepen understanding the problem

1. Long-term trends in rainfall and weather variability
2. Effects of rising temperatures on flood frequency.
3. Factors affecting sensor reliability in extreme weather
4. Methods for calibrating water level and flow sensors Use of GPS for location tracking in flood monitoring systems.
5. Use of historical flood data to predict future events.
6. Statistical modelling of flood risk based on hydrological data.
7. Role of urban planning in flood prevention
8. disaster management systems.
9. Causes of floods, including heavy rainfall
10. Influence of topography and geography on flood occurrence
11. Limitations of current flood detection methods

Further Topics Related to Solutions

1. Multi-Sensor Flood Monitoring Systems.
2. Energy-Efficient, Low-Cost Design.
3. Data Processing and Real-Time Alerting.
4. Human-Centered Design for Accessibility.
5. Remote Monitoring and Cloud-Based Data Storage.
6. Algorithms for predicting flood likelihood based on multiple parameters
7. Data Fusion Techniques for Multi-Sensor Systems.
8. Solar Power Integration for Sustainable Operation.
9. User-Centered Design for Diverse Communities.
10. Wireless Communication for Remote Deployment.

1.4 Other Solutions Already Tried

1-An early warning system for flash floods in hyper-arid Egypt

Flash floods in arid mountainous regions are destructive natural disasters. A flash flood can be generated instantly during or shortly after a rainfall event, especially when high-intensity rain falls on steep hill slopes with exposed rocks and a lack of vegetation (Lin, 1999; Wheather, 2002). Flash floods are usually characterized by raging torrents resulting in flood waves that sweep everything before them. As a consequence, the debris load is mostly high, which further magnifies the destructive power of a flash flood.

The most important processes in arid catchments are: infiltration, routing, and transmission losses. Runoff generation is dominated by infiltration excess rather than saturation excess. Many arid catchments have impermeable hill slopes and highly permeable alluvial channel beds through which floodwater infiltrates. It is not uncommon that no flood is observed at a gauging station, when further upstream a flood has been generated and lost to bed infiltration. The process of transmission losses and channel routing over a dry river bed also needs to be explicitly represented in arid watershed modelling tools. For arid areas. This evidence is in contradiction with the common understanding in temperate or humid areas that complex high-resolution models can represent localized rainfall-events and small-scale processes better. One effective way to reduce the risk of flash floods lies in the implementation of an early warning system, abbreviated as EWS. When warnings are issued before a flash flood event,

additional time is created to take action and save lives and property. The unexpected arrival of a flash flood in combination with its force, limited understanding of the risks, and small space-time scales provide explicit challenges for the development and implementation of an early warning system for flash floods, even in the most advanced regions of the world. For data-poor areas, the challenges are exacerbated.

Firstly, the lack of available data is a prime cause of the limited understanding of the flash flood dynamics, which in turn inhibits the calibration and validation of hydrological and hydraulic models. In addition, many of the hydrological models are built for more humid conditions and do not represent arid conditions well. Conventional densities of rain gauge networks furthermore often do not represent the intensity and spatial distribution of rainfall over the catchment well.

Secondly, due to the destructive force of a flash flood, flow measurements are lacking or uncertain. In addition, the remoteness, harsh climate, and destroyed roads inside wadis make it difficult to measure and collect field data. The latter makes flash flood events particularly difficult to observe and to predict and prompts the development of alternative data collection strategies. An increasingly popular trend to counteract the lack of data is the use of remote sensing and rainfall forecasting.

An operational EWS is a system that issues forecasts upon which is acted. Warnings can be issued based on pre-defined thresholds of meteorological observations and/or forecasts, runoff, flow, flood depth or flood extent. In the US, the flash flood guidance (FFG) system operates as part of the much broader National Weather Service River Forecast System (NWSRFS). It takes a different approach as described above as the FFG system tries to estimate the amount of rainfall required to exceed a threshold, given initial states of soil moisture conditions from a hydrological model,

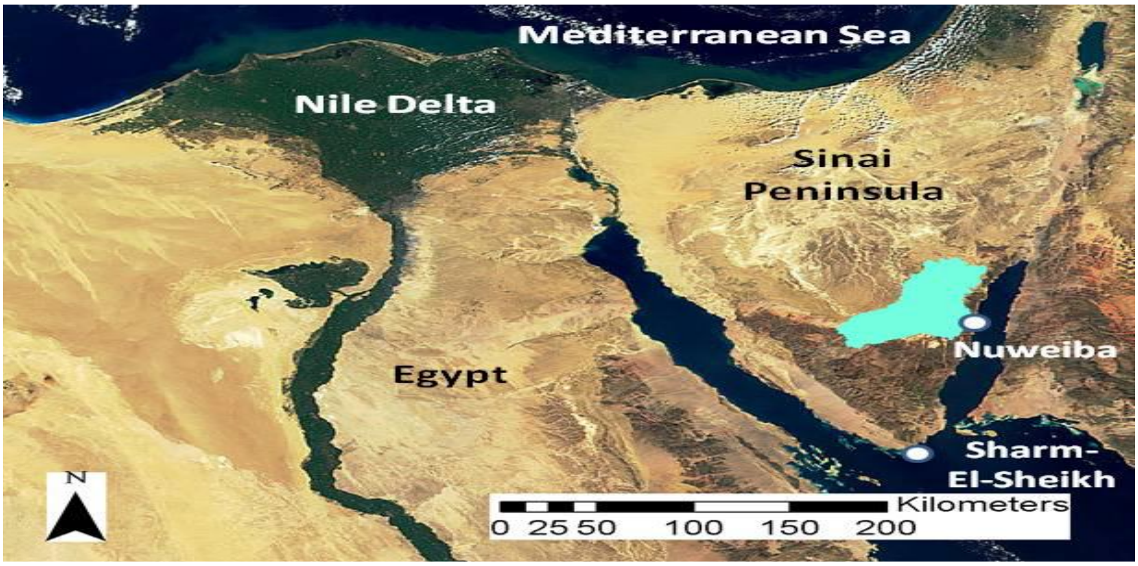


Figure (7). (Location of case study Wadi Watir in the Sinai peninsula of Egypt.)

Nuweiba is located at the outlet of Wadi Watir. The well-known tourist city Sharm El-Sheikh is located in the southernmost point of the Sinai peninsula.-

and then evaluates the probability of receiving such rainfall. Other systems are operational but are mostly unpublished, in grey literature or not specifically designed for flash floods. The EWS presented in this paper follows the first method. To the best of the authors' knowledge, it is one of the first operational EWS for flash floods in the hyper-arid areas of the Arab world and Nile Basin countries.

Early warning system: a chain of components

The EWS consists of a number of components, linked and activated through an automatic platform. Figure 5 shows the different components. Rainfall forecasting is the first and most essential component. The rainfall data are consequently transformed and aggregated into spatially averaged catchment rainfall for each sub-catchment in the study area. The sub-catchment rainfall forecast serves as input for the rainfall-runoff model. Runoff volumes and discharges are routed through the main channel until the outlet at Nuweiba.

The routing can be performed by either using the rainfall runoff model or a more detailed hydraulic model. Finally, the EWS sends alerts according to user-defined thresholds of danger. The alert can range from a simple message to a map showing the zones at risk and even a full (automatically prepared) report. A warning will first be handled by an operator to exclude false warnings through rapid desktop screening of simulation anomalies and communication

with experts on-the-field (e.g. based on cloud patterns and Bedouin traditional weather knowledge). If positive, the warning is submitted as an external warning to decisionmakers. This gives decision-makers lead time to respond and take actions to avoid (or minimize) damages. All components are developed, but they are still in an operational testing phase. Forecasted rainfall is currently used for issuing warnings. Due to the limited potential for calibration of the hydrological models, the forecasts on runoff, discharge, and flood depth are done only on a qualitative basis. The effectiveness of communication and decisionmaking procedures for actions is currently under evaluation.

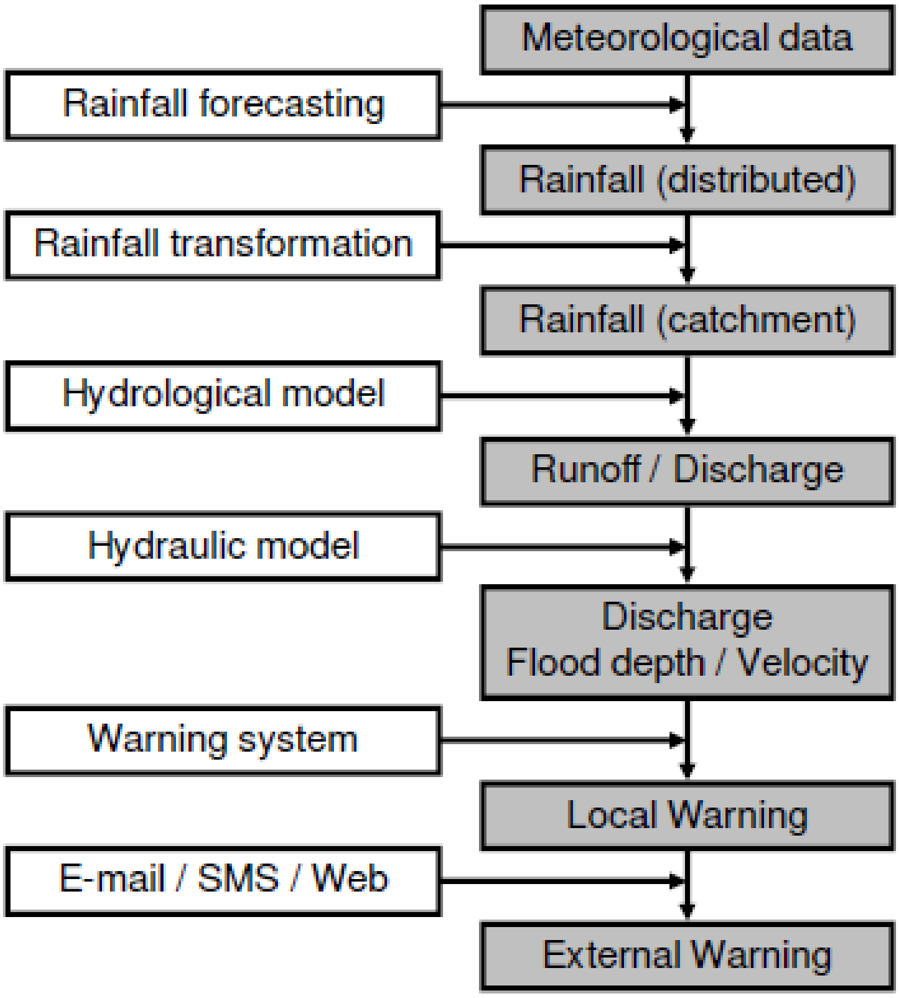


Figure (8). The chain of components that forms the early warning system.

Advantages of the project:
Data-Driven approach.
Focus on relevant parameters.
Improved infrastructure.

Disadvantages of the solution:
Data Scarcity.
Institutional Dependence.
False alarms.

2-Flood early warning system at Jakarta dam using internet of things (IoT)-based real-time fishbone method to support industrial revolution 4.0

This researcher set out to develop an efficient flood early warning system designed to keep the public informed and aid the government in managing disasters. At the heart of their system is a Raspberry Pi mini-computer, which they chose as the central control. This device gathers data from a range of sensors: a Water Level Sensor to measure water height, an Ultrasonic Sensor for additional monitoring, a DHT11 Sensor for temperature and humidity, and a Buzzer to sound audible alerts.

To build this system, the researcher reviewed extensive literature and gathered data from relevant studies to design an IoT-based flood detection tool. They integrated the Raspberry Pi as the main controller, collecting and processing real-time data from all sensors to ensure the system's accuracy. The setup is intended for flood-prone areas like reservoirs, sluice gates, and rivers, supporting Smart City and Smart Environment concepts.

In their tests, the researcher found that this early warning system performed exceptionally well, delivering near-perfect results. They enabled the system to send updates through Twitter, making it more effective than manual alerts. With its ability to provide timely and accurate warnings, this system could reduce flood-related damages significantly, contributing to both prevention and disaster management. The researcher hopes their work will improve preparedness for future floods, benefitting both communities and government efforts.

Methodology

Key Components of the Fishbone Method:

1. Tools and Devices: Essential devices include laptops, webcams, Raspberry Pi, and sensors like DHT11 (for temperature and humidity) and water level sensors.

2. Information & Data: Critical data includes water level, temperature, humidity, and wind speed. This data is acquired, processed, and analyzed using tools like webcams and sensors.

3. Design System: Involves creating use-case, activity, and sequence diagrams to establish how the system will operate and respond in real time.

4. Testing (Pengujian): Testing processes ensure that the system's collected data is accurate, and the IoT-based framework functions reliably before full implementation.

5. Goal: The ultimate aim is to create a flood warning system that supports Industry 4.0 by utilizing real-time data for effective disaster prevention at critical locations, like Jakarta Dam.

In summary, this Fishbone method organizes the requirements and procedures for developing a comprehensive flood early warning system using IoT technology, ensuring a structured approach to collecting, processing, and testing data in real time.

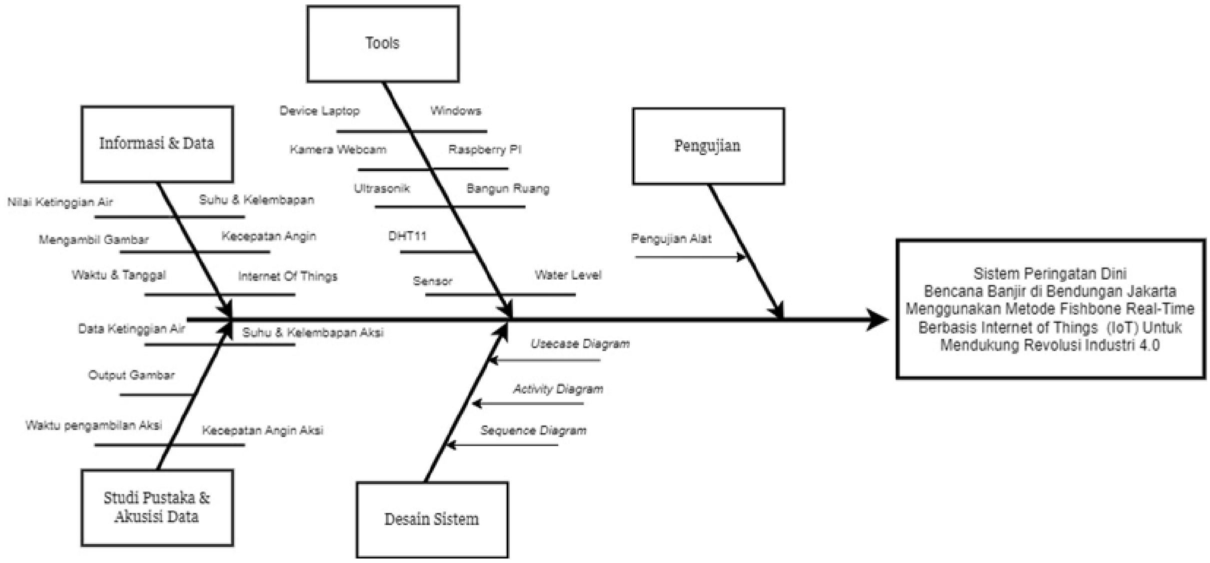


Figure (9). Fishbone method.

Planning Phase

System planning

The system design stage in this phase is very crucial and important because it will be the main foundation for this tool to run properly so that the problems faced can be resolved properly, in this case by using several UML models, namely use case diagrams and Activity Diagrams.

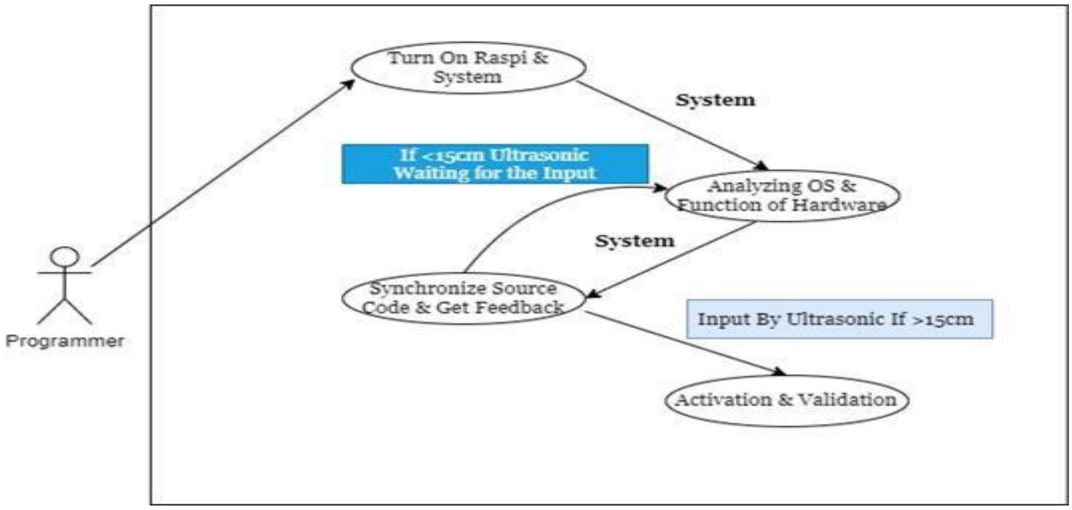


Figure (10). Use case diagram.

Initially, the programmer powers on the Raspberry Pi and the system. If the ultrasonic sensor detects an object within a distance of less than 15 centimeters, the system awaits further input. Subsequently, the system performs an analysis of the Operating System (OS) and the functions of the associated hardware. Should the ultrasonic sensor detect an object at a distance greater than 15 centimeters, input is then provided to the system, which proceeds to the source code and

gather feedback. Following this, the system undergoes an activation and validation phase to ensure that all processes synchronize are running correctly. This diagram likely represents a segment of prototype development or functional testing in a hardware project that involves a proximity sensor.

Use case diagrams are used to illustrate the interaction between a system and an actor (be it a human or another system) in the context of system functionality.

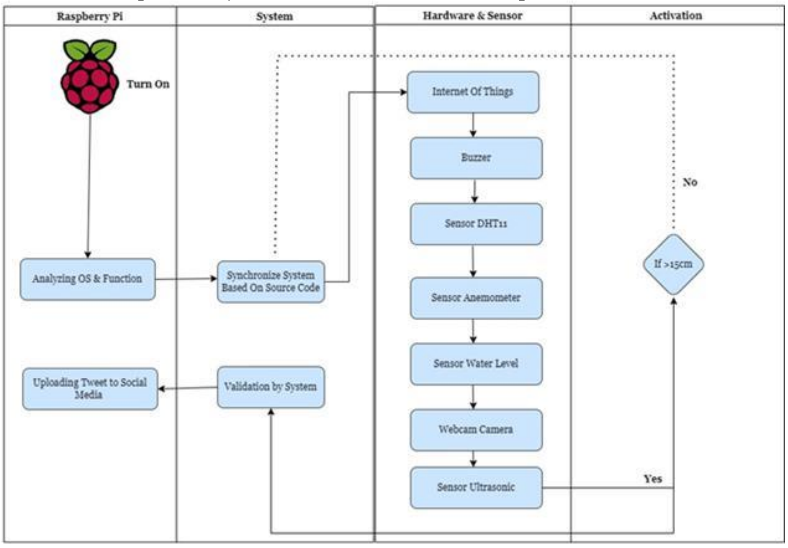


Figure (11). Activity Diagram.

Advantages of the project:
IoT Integration for Real-Time Monitoring.
Structured Problem-Solving Approach.
Multi-Sensor Data Collection.
Enhanced Communication.
Scalable and Modifiable Design.

Disadvantages of the project:
Dependency on Internet and Power Supply.
Sensor Accuracy and Placement Issues.
Complexity of Fishbone Method Implementation.
Limited Warning Time for Downstream Areas.
High Initial Investment.

3-Previous Design of early warning flood detection systems for developing countries

Natural disasters are a worldwide phenomenon and require significant cooperation to address. Recent hurricanes, floods, and other events have illustrated this along with the differences of the effects of disasters on developed compared to developing countries.

Figure (12). The path of Hurricane Mitch (1998).

In the recent US flooding due to storms in the Midwest, loss of life and property damage were minimized due to emergency systems available in the highly developed US, while a storm that ravaged approximately seven states caused twenty deaths and $30 million dollars in damage with only a few left homeless or hungry. On the opposite side, over a much smaller geographic area, North Korea struggled to deal with the displacement of over 300,000 people, approximately 221 deaths, and a cost of $6 million, most to feed those made homeless by the disaster that resulted in part from the lack of development of warning systems and information at the community level of the impending flooding. From this perspective, the struggle with flooding that faces developing countries presents a pressing issue that we cannot ignore while promising a solution that is globally applicable. Warning communities of the incoming flood, however, is an expensive proposal given the limited resources of the countries. Current methods add to the difficulty with the need for expensive equipment and centralized, computationally difficult flood detection schemes. This presents an opportunity to use the latest work in information communication technology and sensor networks to solve this problem in a way that balances the minimal cost requirement and limited computational power with the need for high reliability of both the system and computation. The problem of early warning rapidly grows in complexity upon close inspection and the addition of work within a developing country only increases that complexity. In our work, we examine the problem of flooding on the Aguan River in north-eastern Honduras. This river basin covers a geographic area of 10,000 km2 and contains at least 25 highly threatened communities of approximately 35,000 people total. The project began after the devastation caused by Hurricane Mitch in 1998 where a wall of water passing down the river during the night caused approximately 5,000 deaths with an additional 8,000 missing, and 12,000 injured. While considering Mitch a significant disaster in the region, people do not view it as an isolated event. The river experiences annual flooding due to both heavy rain and hurricanes, and, within the intense hurricane period of 2005, the government declared Hurricanes Beta, Gamma, and Stan national disasters. Many lives and property could be saved if people knew the flood was coming and, after flooding occurred, could monitor the river to understand how to best focus relief efforts. With saving Honduran lives through flood warnings as our goal, this paper proposes a high-level solution to the early warning system problem. We have been working on this problem since January 2004 and have performed several prototype experiments toward our solution. This paper discusses some of those experiments and extracts a set of lessons learned from them that can aid others working on this issue along with similar large-scale technology for developing regions

Methodology

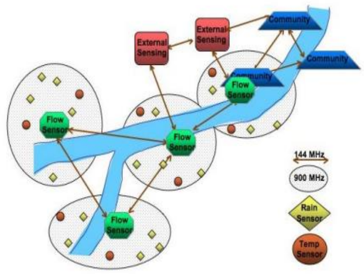


Figure (13). Flood warning sensor network with flow, rain, and temperature sensors using 144 MHz and 900 MHz communication.

The four major tasks for the project are event prediction, authority alerting, community warning, and evacuation, allocated to the project group and CTSAR, respectively. The team of project members works on technology for forecasting and warning of events and the provision of notifications, while CTSAR is responsible for policies, community relations, and evacuation practices. The sensing capability is further limited by the remote, and weather-dependent nature of the area, making volunteer-based monitoring infeasible and an autonomous sensor network required. The system design includes monitoring a large 10,000 km² area, predicting flood events, and enduring environmental challenges while minimizing costs.

This autonomous network requires long-range (25 km) communication for distant nodes and short-range (8 km) communication within local networks. For long-range communication, 144 MHz radios are chosen, adaptable for data with a custom modem to avoid recurring costs. Short-range communication uses the 900 MHz band. The system has four operational areas: sensing, computation, government interface, and community interface. Sensors measure river levels, rainfall, and air temperature, powered by solar panels. Larger microprocessors are used in nodes with 144 MHz radios for redundant computation. Government interfaces provide technical data storage, while community nodes alert local residents via elected members using radios and visual signals.

Flood prediction relies on statistical methods to anticipate river levels up to 48 hours in advance, correlated with hazard maps developed from community input. Each community's hazard map informs which areas flood at specific river levels, creating a localized flood prediction system.

Lesson learned

The technology shows great promise to aid the people of Honduras. Our early experiments confirm the feasibility of a sensor network for use in a developing country and for use in providing disaster warnings, thereby yielding an easily deployable and scalable system. We created two communication solutions and verified that both function, finalizing that portion of the system. Similarly, all three sensors work in a node structure that meets the computational requirements of current microprocessors, along with successful packaging and installation procedures. Finally, we have infrastructure needs such as power and antenna towers solved, placing us in the position where all components are functional and only connecting everything into a complete system remains. Performing these experiments, in addition to component verification, gained us constructive insights due to some unexpected issues, which, while not technical barriers to the system, furnish general lessons valuable for projects of this size within a developing country. Redundancy: While most agree that technology systems need redundancy, an early warning system notifying people of disasters needs significant redundancy at all levels. On the technical side, a node could fail at any time due to element exposure destroying some part of the system, people stealing or damaging some part, or the more standard death of some part. All of this can reduce or ruin the ability of the system to accurately predict flooding. Therefore, every key level of the technology needs redundancy: sensor, communication paths, Fig. 5. 5 Meter Antenna Tower with Security Fig. 6. Camouflaged Rainfall Sensor data storage, batteries, computational units, and so on. Additionally, the policies need redundancy.

Advantages of the project:
Comprehensive and Scalable Design.
Community-Centric Approach.
Sustainable Power Solution.

Disadvantages of the project:
Infrastructure Challenges.
Dependency on Local Engagement.
Exposure to Environmental and Human Risks.

Generating and defending a Solution.

- **Solution and Design Requirements**
- **Selection of Solution**
- **Selection Prototype**

CHAPTER 2

2. Generating and defining a solution

2.1 Design requirements

To make any project you must put some design requirements to yourself and after making the project and testing it you have to see if it achieved the design requirements or not if it achieved the design requirements so, your project is successful and if it didn’t achieve just one of the design requirements, so it didn’t success.

Our project has its own design requirements which are:

Real-Time Monitoring: Continuously track environmental data for immediate flood detection.

Multi-Sensor Integration: Combine flow rate, Soil moisture, barometric pressure, and humidity sensors for comprehensive and accumulative monitoring.

Threshold-Based Alerts: Trigger alerts when any sensor data exceeds predefined safety levels.

Energy Efficiency: Ensure at least six months of operation on battery power, with optional solar power integration.

Data Processing & Visualization: Provide real-time data visualization through an easy-to-use dashboard.

Testability: Allow for sensor calibration and testing to maintain accuracy.

Scalability: Design the system to allow for future expansion and integration of additional features or sensors.

Remote Data Access: Enable remote access to data through cloud or mobile platforms, allowing users to monitor flood conditions from any location.

So, these were the design requirements that we achieved by making our project and testing it by using a testable prototype and these were a very useful achievement for Egypt, and it will help Egypt a lot in the future in making more smart, safe, and sustainable building for the people that can use them.

And there are other design requirements that cannot be achieved by this small-scale prototype, but they will be achieved in the future on large-scale smart buildings, and we will put these design requirements in our recommendations for the people who will work on our project in the future on the large scale.

2.2 Solution Selected for the Prototype

Since real-time detection of the flood is a quite complex challenge, our approach will be to establish a multi-sensor monitoring system that would be effective in tracking crucial environmental factors related to flood conditions. The sensors include a flow rate sensor, ultrasonic water level sensor, atmospheric pressure sensor, and humidity sensor for data acquisition in real-time. The data is treated and presented on a dashboard whose output warns users against risks of flooding at dangerous levels. The solution works in the direction of being energy-efficient and low-cost to enable communities with floods, especially in faraway areas or low-resource areas, to be supported at an affordable level.

Why We Chose This Solution?

We have implemented this multi-sensor solution to enhance the detection accuracy by collecting data from more environmental factors than just one parameter. This will therefore serve to provide a more reliable and comprehensive picture of the flood conditions and therefore enhance the prediction accuracy of our system and allow for timely alerts. Each sensor was chosen to be cost-effective, durable, and good at monitoring conditions relevant to detecting flooding.

Prototype Concept

The prototype will be integrated:

1. (Flow Rate and Soil moisture) to measure water flow speed and levels of rising water.
2. (Atmospheric - Barometric Pressure and Humidity Sensors) for monitoring weather conditions that usually precede floods.

Acquisition and processing of data from the sensors will then be done by an (ESP32 microcontroller), which in turn will send that data to a communication dashboard for real-time condition display and alarm in case flood thresholds are reached. The system shall be driven by a battery, with an option for solar integration toward long-term operations, even in remote areas. This solution would provide an accurate, low-cost, accessible flood warning system that meets the needs of the most vulnerable communities.

2.3 Selection of prototype

The prototype flood detection system is a compact, multi-sensor unit able to realize the real-time monitoring of flood risks with data processing and alerting. Key components include a flow rate sensor, soil moisture sensor, atmospheric pressure sensor, wind speed sensor, and humidity sensor. It uses an ESP32 microcontroller as a central processing unit to integrate all sensor data, run the detection algorithms, and communicate with the user dashboard for monitoring and alerting.

Each component has been chosen based on ensuring specific aspects of flood detection, as shown below:

- Flow Rate Sensor: This measures the water flow rate and can therefore show increased runoff during heavy rainfall or when river levels are about to rise.
- Soil moisture Sensor: Changes in water level, as determined by the height of the water, can give direct data on imminent flooding.
- Atmospheric/Barometric Pressure Sensor: Supplies signals regarding low air pressure that is usually associated with storms. This helps in forecasting conditions that are favorable for flooding.
- Humidity Sensor: Detects moisture in the air, which is part of the early signs associated with the development of a storm.

These sensors would be encapsulated in a waterproof casing for strength in rough weather. Each sensor would be connected individually to the ESP32 microcontroller, which is programmed to collect, process, and send the data to an Android application. The system is powered with a lithium-ion battery; it is also designed with the option to

integrate solar power to energize the system with very low maintenance.
Prototype includes:
Data Processing Module: This module processes the sensor readings via an ESP32 microcontroller and compares them with predefined thresholds for the generation of alerts. Dashboard and Alert System: The data is transmitted to a user dashboard that visually represents the sensor readings and issues real-time alerts when any of the parameters cross flood risk thresholds.
Power System: It will be powered by a 5V lithium-ion battery; this allows six months of operation and, with the installation of solar panels, enhances the sustainability of energy supply.
Meeting the Design Requirements
The proposed prototype meets the design requirements in the following way:
- Real-Time Monitoring: There is always data gathering from multiple sensors to detect flooding in real-time.
- Multi-Sensor Integration: Utilizing four sensors, the analysis of environmental conditions related to flooding will be most comprehensive.
- Threshold-Based Alerts: Thresholds programmed on the ESP32 lead to real-time alerts for actionable information.
- Weather Resistance: The system operates in all sorts of weather conditions, thanks to the waterproof casing and robust design.
- Cost-Effectiveness: The use of affordable, off-the-shelf components minimizes total cost.
- Data Visualization: Data visualization is presented in an easy-to-read format on a dashboard.
Scalability: Because of its modular design, if needed in the future, there is ease of integration for more sensors or cloud-based enhancements.
So far, this prototype is practically viable, durable, and affordable, which meets all the identified design requirements, hence allowing for the correct and timely detection of floods with notifications to residents suited for communities prone to flooding.

Constructing and Testing
a Prototype.

- Materials and Methods
- Test plan
- Data collection

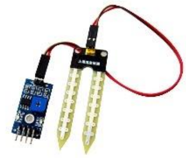
CHAPTER
3

3. Constructing and Testing a Prototype.

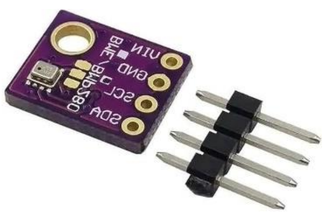
3.1 Materials

ESP32-WROOM-32U
420 L.E

Water flow sensor
transparent YF-S201C
300 L.E



Water level Sensor
45 L.E



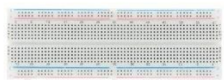
BMP 280
70 L.E
‘

DHT 11
55 L.E

DC/DC conversion
110 L.E

Magnetic buzzer
7.5 L.E

Jumper wires
50 L.E



Breadboard
40 L.E

DC jack female
7 L.E

12 Rechargeable battery
300 L.E

Adapter 12.6V
170 L.E

Methods

<u>Connection</u>

The construction of the prototype started with gathering the compartments together: The sensors were connected to the microcontroller (ESP32) by jumpers connected to the breadboard, where the microcontroller is fixed and receives data. Other modules, such as the soil moisture module and the BMP 280 sensor module, were also fixed in the breadboard. We used many jumpers to make a long wire to connect the soil moisture sensor and the water flow rate sensor to isolate them from the rest of the compartments and the water.

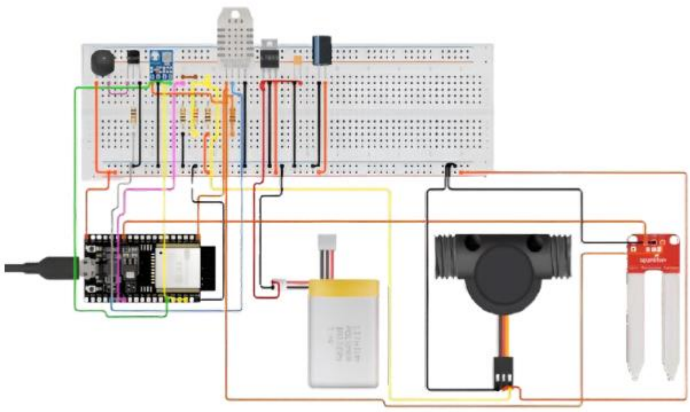


Figure (14). A design for the circuit.

<u>Designing</u>

After the completion of the connection stage, the subsequent step involves the creation of the ultimate product, with a primary emphasis on two key aspects. Firstly, Fix the sensors in their proper position even placed on the box or the other free parts. Secondly, Adjust the codes of every sensor to work properly with the other sensors, and give correct readings in their new fixed position.

The network connection for the ESP32 and the mobile phone is the same Wi-Fi network to send data for the dashboard in the app and give alert notifications.
The application development leveraged Node-RED, a visual programming tool ideal for IoT and real-time data applications, by integrated process involved:
Establishing MQTT communication to transmit real-time data.
Creating flows to interpret the data and identify the flood risk based on the chosen parameters that we measure and give reading according to defined functions.
Configuring notifications to alert the users of impending flood risks if the sensors' readings have reached dangerous conditions.

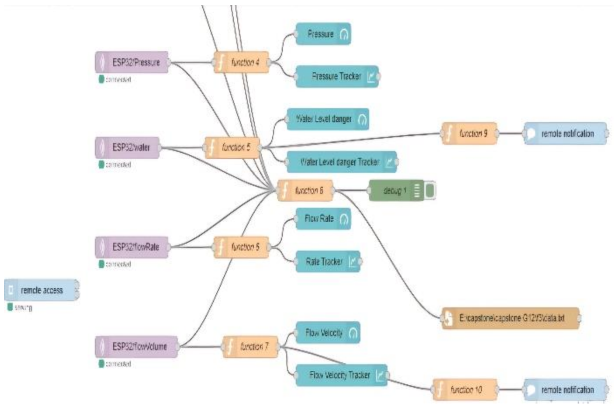


Figure (12). (node-red programming)

3.2 Test plan

In our project, the test plan mainly focuses on testing the functionality of each sensor and its ability to detect different factors. The test plan is divided into two branches:

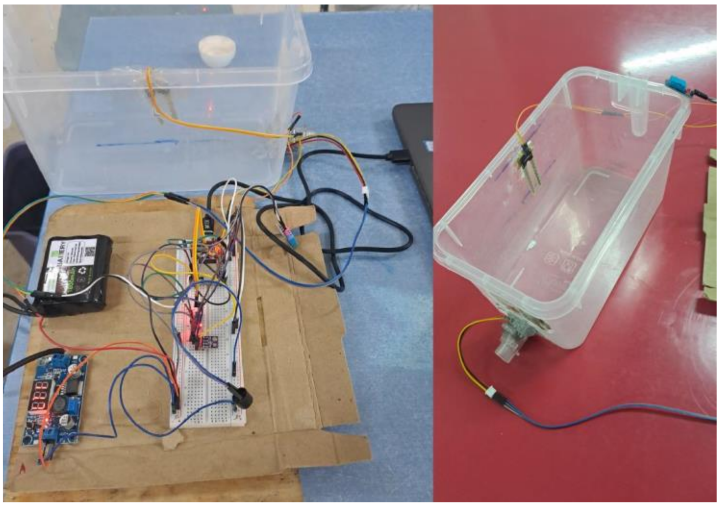


Figure (13). (Real made prototype)

1-Testing the ability of sensors to detect surrounding factors.

BMP280 Barometric Pressure: Tested by blowing on the sensor to create higher external pressure, then checking for increased pressure readings.

DHT11: Exposed to hot water vapor to measure both temperature and humidity. The sensor was left in the vapor until it recorded high readings for both parameters.

Flow Rate and Water Level Sensors:

Tested by pouring water to reach the maximum height, observing the response of the water level sensors, and calculating the danger level percentage. The changes in flow rate and velocity were monitored using the Water Flow Sensor Transparent YF-S201C.

2-Testing the mobile application's ability to visualize data. While exposing each sensor to its respective testing conditions, a team member monitored the values displayed on the application dashboard. These values were then compared to those shown in the serial monitor to ensure accuracy.

3.3 Data collection

Tool	Usage	Picture
Welding wire machine	**Melt the tin with the pins of the sensors**	
Cutting and measuring tools	**Precision tools like calipers, rulers, and cutting mates for accuracy in design**	
Super glue	**To fix the compartments on their positions**	
Circuit simulators	**Software apps as Fritzing and Tinkercad circuits for Electronics designing**	
	Personal protective Equipment (PPV	
Lab apron & Gloves	**Important for protection against electrical connections while connecting circuit wires**	 
Mask & Goggles	**protecting from bad contaminants emitted from welding machine**	

Table 3.1. (Used tools)

We aim to increase the technological environment for Egypt and reduce the effect of flash floods by a project can expect the coming flood, its mechanism is monitoring several parameters, which are noticed before happing of the flood, then give alert if the input data to the sensors reach the threshold. After completing the circuit connections, finalizing the ESP code, and adjusting the application, the desired test plan was ready to undergo the test. Eventually, the following results were attained.

<u>Positive results</u>

- The system was fully operational and integrated, with all sensors performing optimally. The flow rate, water level, temperature, humidity, and pressure sensors provided reliable data, offering accurate readings with high precision and approximately accurate results.

- The readings are correlated, and the efficiency of the project is considerably good.

- The sensors respond effectively to changing conditions, providing quick reactions and adaptations to any shifts. This shows that the system could be relied upon and trusted.
- The data is displayed in an easily interpretable way, not complex, and indicates

danger levels using different specific colors. All of this provides a smooth understanding for any regular user, and the data is correctly stored, allowing the user to review the reading history.

- The system demonstrates its capability in providing alerts, either through a warning buzzer tone or by sending notifications in abnormal conditions.

Negative results

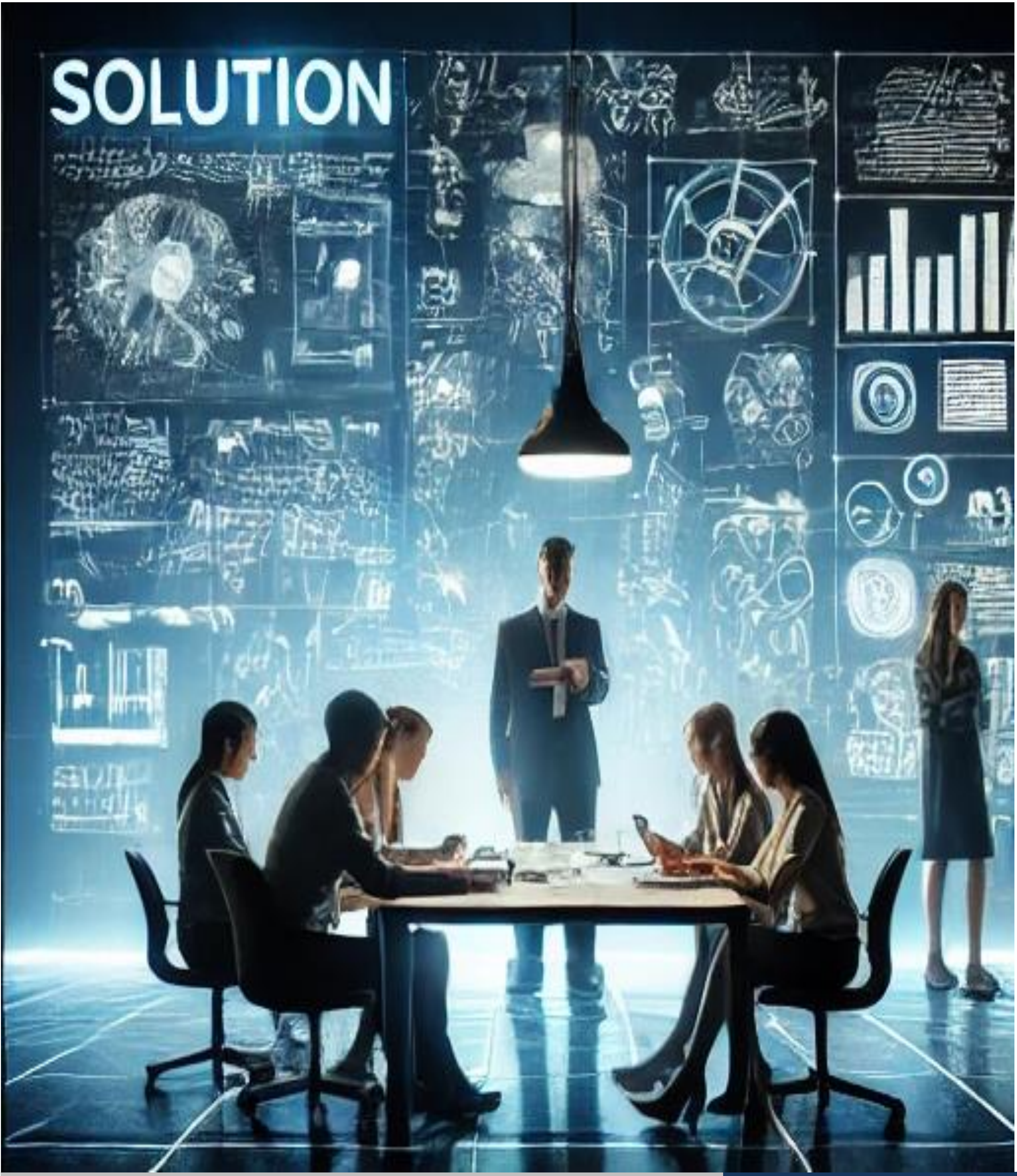
- The readings from the system aren't perfect due to some environmental factors and power instability. Another reason is that the sensors don't have high accuracy, as they're not original sensors but are samples provided for small projects, so each sensor has some reasonable error.

- The project readings sometimes have a delay before they appear on the dashboard in the mobile app, and there are two main reasons for this. First, the internet connection can be unstable, since Wi-Fi is used for communication. Any slowdown in the connection can cause delays in showing the readings on the dashboard. The second reason is that the Node-RED server is usually under a heavy load, which slows down the process of receiving and sending data.

The reading of sensors are shown on the table below:

Reading	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**
Temperature (C)	19.4	19.4	20.6	22.6	25.1	28.4	32.8	31.2	31
Humidity(%)	63	63	74	80	88	98	98	86	77
Pressure (hPa)	1015.71	1015.71	1016.54	1016.39	1016.26	1015.16	1016.09	1016.02	1015.97
Velocity cm/s	151	144	131	118	105	91	---	---	---

Table 3.2 (Sensors' readings)



Evaluation, Reflection, Recommendations.

- Analysis and discussion
- Recommendation
- Learning outcome
- List of sources in APA format

CHAPTER 4

4. Evaluation, Reflection, Recommendations.

4.1 Analysis and Discussion

Flooding in Egypt become devastating, especially for those living near the Nile. Heavy rainfall or storms upstream can cause flash floods, overwhelming drainage systems and damaging homes, roads, and crops. Climate change has a main role in flooding occurrences, so we try to adapt to these conditions and make a system to overcome this issue. The system will monitor the possibility of flood occurrence according to specific environmental parameters. These parameters are temperature, humidity, and pressure. These parameters have a standard value for achieving the safety of the region. The system measures temperature, humidity, pressure, water level and discharge velocity, which must stay within specific safety thresholds.

Scientific base

According to **Torricelli's law As shown in Figure (6)**, also known as **Torricelli's theorem**, is a theorem in dynamics relating the speed of fluid flowing from a hole to the height of fluid above the hole. The law states that the speed v of efflux of a fluid through a sharp-edged hole in the wall of the tank filled to a height above the hole is the same as the speed that a body would acquire in falling freely from a height.

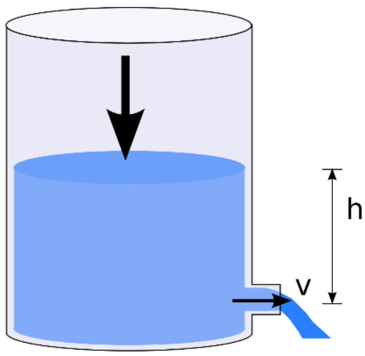
Torricelli's Law is considered a special case of Bernoulli's equation with some Assumptions:

1. The fluid at the surface of the reservoir is nearly stationary, so its velocity (v_1) is approximately zero.
2. The pressure at both the surface and the orifice is atmospheric ($P_1 = P_2$).
3. The potential energy at the orifice is negligible, as the height at the orifice (h_2) is taken as zero.

Torricelli's Law

$$v = \sqrt{2gh}$$

Where:
- v: Speed of the fluid (m/s)
- g: Acceleration due to gravity (9.81 m/s²)
- h: Height of the fluid column (m)



Fig(6): Torricelli's Principle

We use Torricelli's Law to understand the relationship between the water velocity measured by the **YF-S201C Water Flow Sensor** and the water height that are detected manually. In our experiment, we poured water into a container and recorded the velocity readings at different heights. According to the equation, we can rewrite **Torricelli's Law as $v^2 = 2gh$** which shows a direct relationship between the square of the velocity and the height of the water column. By squaring the velocity values at each height reading, we can represent this relationship graphically. Additionally, we can calculate the correlation between our readings by statistics concepts by using

Pearson correlation formula:

H(m)	V²(m²/S²)
0.13	2.2801
0.112	2.0736
0.095	1.7161
0.078	1.3924
0.066	1.1025
0.05	0.82181

Table(4): Reading

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \cdot \sum(Y_i - \bar{Y})^2}}$$

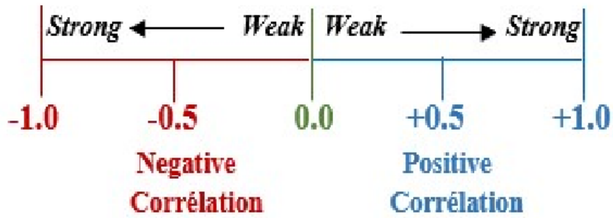
Where:

-X represents *height* and Y the *velocity* ^{2}

-X_i and Y_i are the individual data points.

- $\bar{X}$ and $\bar{Y}$ are the means of the X and Y variables, respectively.

- r is the Pearson correlation coefficient.



Fig(8): scattered pattern and regression line

By substituting in the law the correlation (r)= 0.9961

In statistical concepts, this correlation is classified as very strong. The strength of the correlation, as illustrated in the in Figure(7). , serves as a positive indicator of the accuracy of our calculations and the reliability of our data collection.

It is critically important to create a regression line to effectively visualize the trend or relationship between velocity squared and height by a single line. The equation of the regression line is calculated using the following formula: $v^2 = mH + c$

Where :

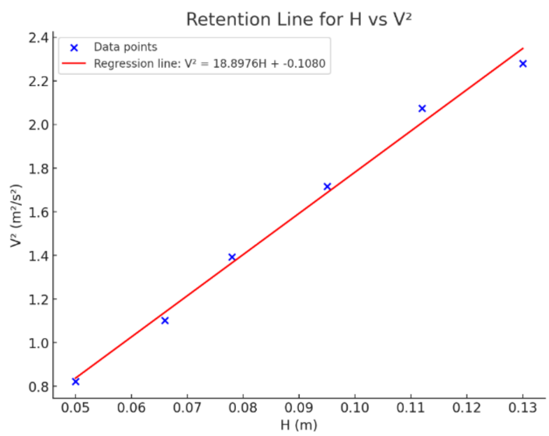
$$m = \frac{\sum(H_i - \bar{H})(V_i^2 - \bar{V}^2)}{\sum(H_i - \bar{H})^2} \quad \& \quad c = \overline{v^2} - m\bar{H}$$

m =18.8976 & c =-0.108

According to the original equation $v^2 = 2gh$, the slope of the line $\frac{dv^2}{dh}$ should equal (2g) which is constant .

By comparing the slope of our regression line to (2g),

we can validate the accuracy and efficiency of



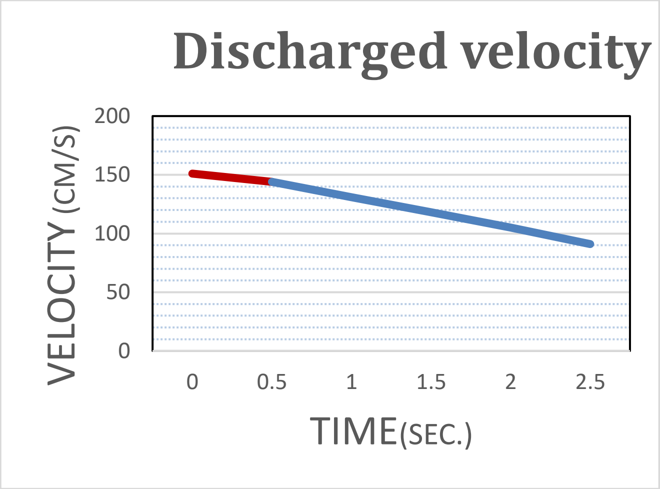
Fig(7):Correlation strength level

our calculations. In our case the slope represented by (m)then we can represent the accuracy by $=\frac{m}{2g}=\frac{18.8976}{2\times 9.8}=96.35\%$

The high accuracy of our reading show that our data and calculation could be reliable and trusted

The Water Flow Sensor YF-S201C contains an internal fan that rotates as water flows through it. This rotation generates pulses, which are translated into the water flow rate, typically measured in L/min.

The resulting number will be divided by 60000 to get the flow rate in m³/s. Then if we need to get the velocity of the water, we use the continuity equation, which states that (Q=Area/velocity), where the area = 0.000127 m²/s.

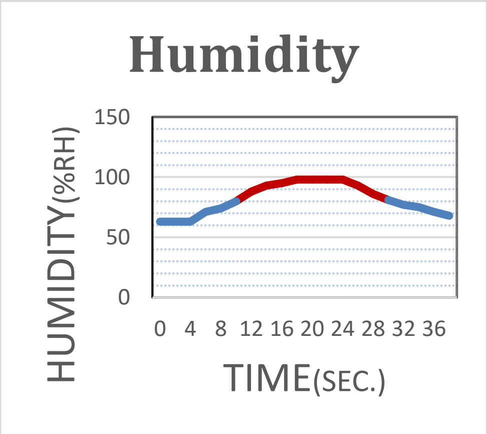


Fig(9): Velocity test

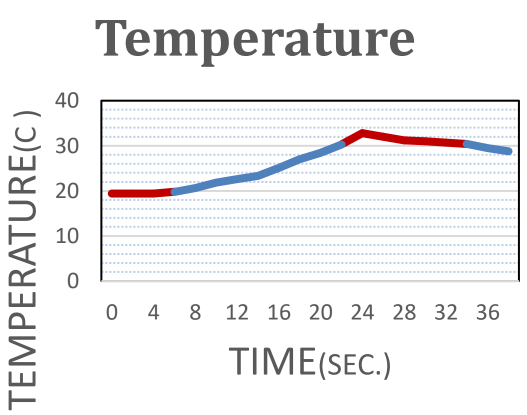
for testing ,We poured water to fill the container and recorded the velocity over time. The threshold for our system is set at a water velocity of 150 cm/s, which is considered the approximate maximum velocity that indicates a danger level.

- The DHT 11 is used to measure the temperature and humidity. The temperature should stay between 20°C and 30°C. If it drops below 20°C, condensation increases and this leads to heavy rainfall and potential flash floods, especially in poorly drained areas. On the other hand, when temperatures rise above 30°C, the atmosphere becomes unstable, which can also trigger heavy rain.in terms of humidity, it should remain below 80%. When it exceeds this threshold, the air holds more moisture which increases the possibility of making heavy rain quickly

- We boiled water in a glass and placed it beside the system. The sensor demonstrated its ability to adapt to environmental changes and the readings clearly indicated whether the conditions were normal or not, proving the sensors are reliable and effective.

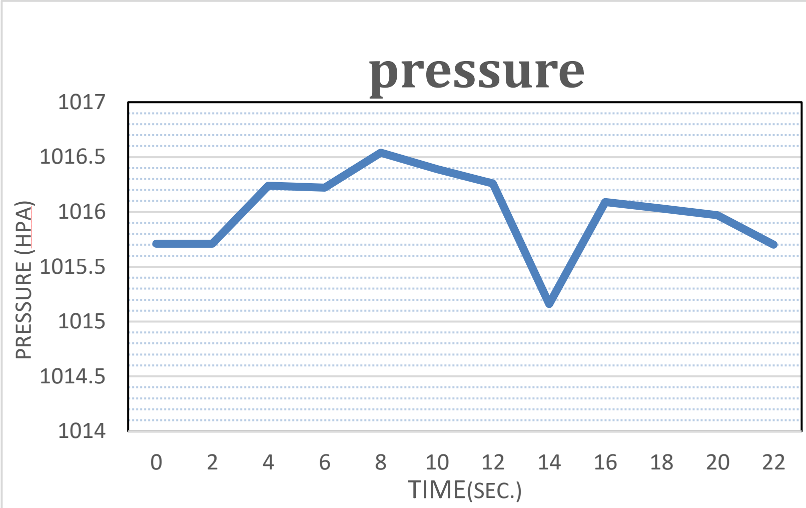


Fig(10): Humidity test



Fig(11):Temperature test

- We're using the BMP280 Barometric Pressure Sensor to monitor external pressure. the normal pressure should stay above 1010 hPa because anything lower can encourage cloud formation and increase humidity, which often leads to heavy rain. To test the sensor, we tried blowing on it to simulate a sudden increase in pressure. The sensor responded perfectly, as shown in the graph. This test proves that it's accurate and reliable for detecting changes in pressure in real life.



Fig(12) Pressure test

Power and Memory Calculation

Power and Memory Calculations DHT11 :2 values (temp and humidity) × 2 bytes each = 4 bytes, Soil Moisture: 1 value × 2 bytes = 2 bytes, Flow Rate: 1 value × 4 bytes (float) = 4 bytes, BMP280 :2 values (pressure and temperature) × 4 bytes each = 8 bytes, Timestamp:1 value × 4 bytes = 4 bytes. Pre- record size =22 bytes/record Total records in one year: 2 records/minute×525,600 minutes/year=1,051,200 records Total storage=22 bytes/record×1,051,200 records/year=23,126,400 bytes/year≈22.05 MB First, total sensors power= ∑ (I x V) = 1.6846 Watt. Second, E battery=V battery×C battery, to calculate it Runtime(hours)= E battery / P total, E battery = 4380 hours x 1.6846 Watt= 7378.548 W. h, the battery desired must be 12V, 614.879 ampere-hours.

4.2 Recommendation

The project faces challenges due to limited time and budget, and we propose recommendations for teams to adopt and continue developing our work:

1-Using real-time data to create models that simulate how floods might spread, helping to predict their impact and provide more accurate early warnings.

2-Using of better sensors and modules to collect more fast and accurate data for more precise calculations and outputs such as GFS131-WC2 as a Flow Sensor or SHT35 (Sensirion) as a temperature and humidity sensor.

3-Using GIS tools to generate detailed flood maps, to make it easier for authorities to plan and coordinate their responses effectively.

4-Using the high discharged velocity to move turbine for generating clean renewable energy.

4.3 Learning outcomes

The learning outcome	The Usage in the project
PH.1.01	Identifying the types of errors and calculating them for each sensor using its datasheet or through manual experiments ensured documenting the errors in the results, making them more accurate and reliable.
PH.1.08	We learned the basics of pressure, like the different units and how they relate to each other. We also measured the current atmospheric pressure and compared it to the standard to check for any abnormalities. Additionally, we explored how pressure changes with water depth, which helped us understand fluid dynamics better and apply it to our project.
PH.1.09	We studied the equation of continuity to calculate the water flow rate and applied Bernoulli's equation to understand the relationship between the height of water in the dam and the velocity of discharged water. This analysis was crucial for accurately modeling the dynamics of our project.
ES.2.02	modeling water reservoirs by tracking water levels and flow, helping manage water use for needs like irrigation and drinking, and ensuring better resource planning.
ES.2.05	understanding river systems and drainage basins by showing how water interacts with landforms and the hydrologic cycle. The flood early warning system you created helps monitor river systems, predict flooding, and manage drainage basins more effectively.
PH.3.04	understanding the basic elements of communication and knowing the ways of transmission between the esp32 (transmitter) and the user's phone (receiver).
PH.3.05	using Wi-Fi to wireless data transfer for real-time

	communication. Analog signals are continuous, while digital signals are discrete. Converting between them involves sampling and quantization to process and transmit data efficiently.
CH.3.01	applying scientific methodology by identifying flood risks, designing and testing a solution, collecting data, and analyzing results to confirm the system works. It's a practical way to solve real-world problems using science. And applying the conservation of energy law to calculate power usage, helping estimate battery life and optimize efficiency.
E.N.W.2.2.2	Compose three-paragraph essays with an introduction, body, and conclusion with guidance and for self-initiated and assigned writing.
CS.2.05	We learned about programming languages that are used for esp. coding.
ST.3.02	We used to calculate the correlation between velocity squared, draw the regression line, and determine its equation.
PH.2.03	We measured the voltage of our battery and calculated the power requirements of our project. Using this information, we estimated how long the battery would last and evaluated the efficiency of the power supply.

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