DEVELOPMENT of a Water Level Data Logging System with Web-Based Data Visualization for Remote Monitoring STATIONS

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ABSTRACT

The disastrous effects of floods have caused devastating destruction to residential infrastructure, displaced individuals, and even loss of lives in low-lying communities. Over the years, the aftermath of floods has profoundly impacted agricultural sectors, leading to significant damage to crops and livestock, disrupting food supply chains and agricultural productivity. This study underscores the importance of implementing effective disaster preparedness and mitigation measures to enhance community resilience during natural disasters, thereby reducing the increase in water levels in primary river systems in a local community. To support the collective efforts of local authorities in flood disaster preparedness, this study incorporates a water-monitoring device and a time-series web-based monitoring platform as primary tools for river water-level monitoring. This web monitoring platform allows users to visualize water level trends in a web chart with views ranging from daily to custom time frames. The web visualization is designed to be compatible and accessible on various devices, including desktops, tablets, and smartphones, enabling users to monitor river conditions from anywhere and make informed decisions. Moreover, water levels were classified according to the Philippine standard water level alert categories: green, yellow, orange, and red. On the other hand, displaying the measurement of water level increase or decrease in a web section has effectively conveyed a river's matching water level category. This implementation empowers barangay authorities to augment conventional practices for assessing river conditions within their jurisdictions during periods of intense rainfall and tropical storms.

KEYWORDS: *Water Level Monitoring, Web-based Data Visualization, SDLC*

INTRODUCTION

Flooding from heavy rainfall, tropical storms, typhoons, and other related factors has caused destructive effects due to the climate crisis (Ray, 2023). leading to the overflowing of dams, rivers, lakes, and other bodies of water (Loc, et al. 2020). Saddi et. al, (2017) stated that these natural disasters have damaged property and crops, caused economic losses, and even resulted in fatalities in several communities across the Philippines. According to the annual report on Philippine tropical cyclones of DOST-PAG ASA on 2024, about 20 tropical cyclones enter the Philippine Area of Responsibility (PAR) each year, with about 8 to 9 crossing the Philippines. The peak of the typhoon season usually occurs from July to November, during which seventy percent of typhoons develop.

One significant reason the Philippines strengthened disaster risk reduction and management is its geographic location and its need to adapt to climate change (OECD, 2020). As mentioned in the Philippines: National Climate Change Action Plan 2011-2028, published in 2024, the climate forecasts conducted by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) for 2020 and 2050 suggested rising temperatures across the Philippines. Temperature changes contributed to intensified rainfall associated with typhoons (Kawasaki et al., 2022) Cabrera et al., (2020) described flooding as a result of various factors. The limited capacity of river systems and the rapid expansion of human settlements in low-lying areas were primary factors in the floods that affected the communities. While typhoons significantly contributed to flooding, they also had more devastating effects (Kurata et al., 2022).

The National Disaster Risk Reduction and Management Plan (NDRRMP) provided a structured framework for implementation from 2011 to 2018. Based on the outlined plan, NDRRMP maintained four priority areas: Prevention and Mitigation, Disaster Preparedness, Disaster Response, and Rehabilitation and Recovery. Prevention and Mitigation were the most essential among the four priority areas, as successfully managing these two stages can alleviate the challenges in subsequent phases. As stated in the National Climate Change Action Plan 2011-2028, these include highlighting strategic actions to mitigate the potential impacts of hazards or risks by reducing vulnerability. The NDRRMP also included hazard mapping and assessment at the local and barangay levels to monitor and disseminate data on critical hazards and vulnerabilities.

The study of Dela Santos (2021) showed that among the most disastrous typhoons in Philippine history was typhoon Haiphong on September 27, 1881, which caused 20,000 deaths; typhoon Yolanda on November 7-8, 2012, resulting in 6,300 deaths and more missing; typhoon Uring with 5,101 deaths from November 4-7, 1991; typhoon Pablo with 1,901 casualties between December 2-9, 2012; and the typhoon Angela that caused over 1,800 Filipinos to lose their lives on September 22, 1867. Moreover, some of the most expensive typhoons include Yolanda in 2013, which cost the Philippine economy 95.5 billion pesos, followed by Pablo in 2013 with 43.2 billion, Glenda in 2014 with 38.6 billion, Ompong in 2018, and Peping in 2009, which resulted in P27.3 billion pesos lost in the destruction of crops and properties.

In response to the late President Benigno S. Aquino III's request to develop a proactive system for prevention and Mitigation, the DOST and PAGASA collaborated to establish Project NOAH. The project involved placing ARG and WLMS in the country's major river basins (RBs) (Cadiz, 2018). The 2022 NOAH-Google Analytics Review showed that Project NOAH also aimed to generate more accurate 3D flood hazard maps using a modeled hydrometeorological inundation map to identify areas prone to flooding.

In connection with flood disaster management, the LGUs and other partnered agencies coordinated evacuation efforts in local communities, identified safe evacuation routes, and managed shelters for displaced individuals [13]. Moreover, assigned Disaster Risk Reduction Management agencies, such as the CDRRMO and BDRRMO, focused on water-level markings or concrete indicators to identify flood risk categories along a river (Balderama, 2022).

METHODS

The methodology used in this study is the Systems Development Life Cycle (SDLC), which provides a systematic, structured approach to conducting the inquiry. SDLC methods provide a step-by-step process to guide research effectively from project initiation to deployment. This approach not only enhances the overall organization of the study but also contributes to a more thorough investigation, allowing for a comprehensive understanding of the subject matter.

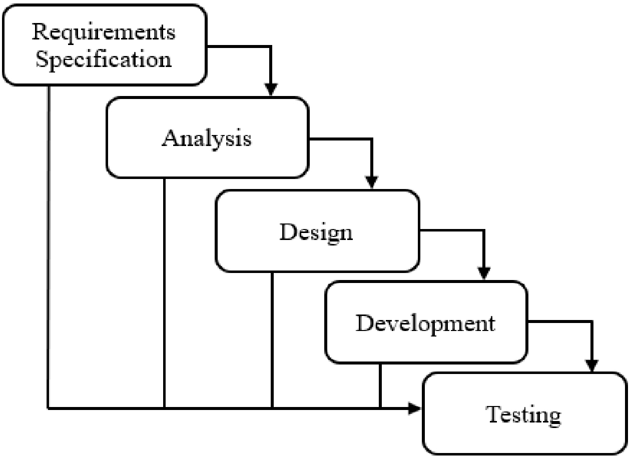


Figure 1. Systems Development Life Cycle (SDLC)

Requirements Specification

The process starts by collecting requirements and gathering stakeholder feedback. At first, the researcher conducted interviews at the Barangay Disaster Risk Reduction Management Office (BDRRMO) and the City Disaster Risk Reduction Management Office (CDRRMO) to gather valuable insights into the existing infrastructure, protocols, and strategies for flood disaster response for affected communities. The collected data and feedback now served as the basis for defining the system's functional and non-functional requirements.

Analysis

In this context, the information collected from stakeholders is thoroughly examined and understood to identify needs and opportunities to improve current practices. The tasks performed in this phase include analyzing the existing protocols of the LGU and other partner government agencies for flood disaster response and management, and outlining the possible system requirements aligned with the targeted stakeholders' needs.

Design

To design the system's user interface (UI), the web-based design tool Figma was used to create an interactive simulation of its flows and transitions. This approach helps streamline the system's design and user interactions, enabling rapid prototyping and user feedback to improve its features. Moreover, the designed prototypes served as the basis for the actual system development.

Development

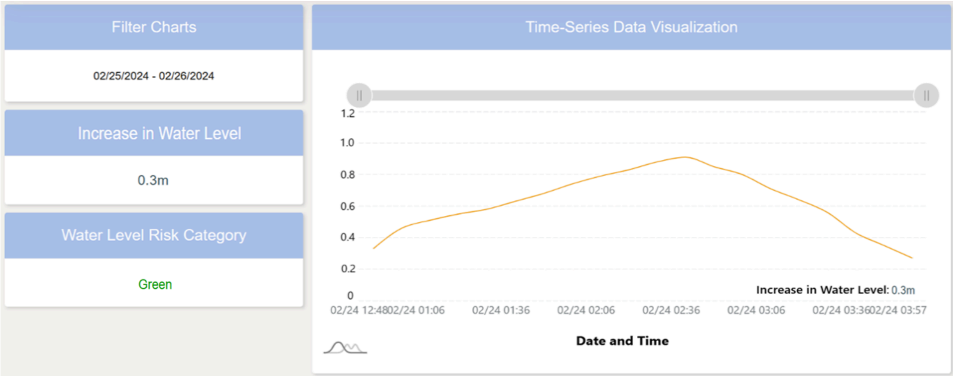
The web-based monitoring was programmed in plain JavaScript. At the same time, HTML and CSS define the system's front end, while PHP is the server-side scripting language applied for dynamic functionality and database interactions. Finally, the AmCharts JavaScript library was used to create a time-series line chart of the water levels.

Testing

The web-based platform is hosted by a provider, enabling remote monitoring via online access. With this, stakeholders assess the system's accuracy and suggest potential enhancements for better implementation. Moreover, conducting system testing provides real-world experience with how the system works and enables evaluation of its effectiveness during deployment.

RESULTS

Understanding how the system measures water volume in an enclosed environment is pivotal for determining water-level variations (Horno, 2023). On the first test, water level categories were marked on the water tank. The green water level category ranges from 0.80 – 0.99 meters, the yellow category at 0.60 to 0.79 meters, the orange category at 0.40 – 0.59 meters, and the red category at 0.20 – 0.39 meters, respectively. The water tank was filled with water at the start of testing. As a result, water levels gradually increased, surpassing the other water level variations. On the other hand, the water was released from the tank, and the findings show a downward trend in water levels. The figure below shows the line chart visualization of the data.



Filter Charts: 02/25/2024 - 02/26/2024

Increase in Water Level: 0.3m

Water Level Risk Category: Green

Figure 2. Water tank testing result

High tides have significantly affected coastal communities by raising water levels (Cao et al., 2024). High and low tides are natural phenomena driven by sea-level fluctuations (Akhtar et al., 2020). To assess the system's effectiveness in measuring water-level variations, the second test was conducted on the seawall. This test aimed to observe changes in water level during high and low tides. During the test, water level categories were set to 3 meters for green, 2.5 meters for yellow, 2 meters for orange, and 1.5 meters for red. Findings showed that the web monitoring displayed an increase in water level during high tide and a decrease during low tide, which maintains the green water level category and a 1.5-meter rise in water level.

Moreover, Chen et al., (2022) stated that monitoring river water levels is essential for effectively facilitating community response during flood events, as main river basins often contribute significantly to flooding in low-lying communities (Sholihah et al., 2020). During the third test, water levels were remotely monitored at the riverside, with green, yellow, orange, and red categories set at 4 meters, 3.5 meters, 3 meters, and 2.5 meters, respectively. The weather was serene throughout testing, and there was no significant increase in water levels in the area. As a result, a consistent increase of 0.48 meters in water level was monitored on the web platform, which was categorized as green.

CONCLUSION

Implementing technology-based solutions at times of natural calamities, such as flooding, helps improve conventional practices and offers alternative means to execute interventions that will help elevate community resilience effectively. This approach helps minimize the adverse impacts of floods on affected populations, especially in low-lying communities.

The web-based data visualization of time-series water-level data enabled remote monitoring of river conditions. Given these patterns, water level data in a web chart illustrates the historical and latest trends. Historical data present the previous trends in water-level conditions in the testing area; these trends are interpreted based on increases or decreases in water-level measurements.

On the other hand, incorporating a web platform feature that identifies the corresponding water level category facilitated easy recognition of the current water level status. Among the three identified testing areas in this study, water level changes were observed at the water tank and seaside locations, while steady conditions were observed at the riverside. The web-based monitoring also reflected these changes, which conform to the testing areas' environmental conditions.

REFERENCES

Akhtar, M. N., Anees, M. T., & Bakar, E. A. (2020). Assessment of the effect of high tide and low tide condition on stream flow velocity at Sungai Rompin's mouth. *IOP Conference Series: Materials Science and Engineering, 920*(1), Article 012014. https://doi.org/10.1088/1757-899x/920/1/012014

Balderama, O. F. (2022). Climate change adaptation practices towards sustainable watershed management: The case of Abuan watershed in Ilagan City, Philippines. In *Interlocal adaptations to climate change in East and Southeast Asia* (pp. 33–44). Springer. https://doi.org/10.1007/978-3-030-81207-2_3

Cabrera, J. S., & Lee, H. S. (2020). Flood risk assessment for Davao Oriental in the Philippines using geographic information system-based multi-criteria analysis and the maximum entropy model. *Journal of Flood Risk Management, 13*(2). https://doi.org/10.1111/jfr3.12607

Cadiz, N. R. (2018). UP NOAH in building resilient Philippines: Multi-hazard and risk mapping for the future. *Procedia Engineering, 212*, 1018–1025. https://doi.org/10.1016/j.proeng.2018.01.131

Cao, X., Shi, J., Zhang, C., & Zheng, J. (2024). The combined effects of tide and storm waves on beach profile evolution. *Ocean Engineering, 299*, Article 117416. https://doi.org/10.1016/j.oceaneng.2024.117416

Chen, C., Fu, R., Ai, X., et al. (2022). An integrated method for river water level recognition from surveillance images using convolution neural networks. *Remote Sensing, 14*(23), Article 6023. https://doi.org/10.3390/rs14236023

Del Horno, L., Segura, E., Somolinos, J. A., & Morales, R. (2023). A new methodology-based sensorial system with which to determine the volume of liquid contained in a cylindrical tank subjected to full variations in its orientation. *Journal of Marine Science and Engineering, 11*(12), Article 2316. https://doi.org/10.3390/jmse11122316

Department of Science and Technology–Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2018). *Annual report on Philippine tropical cyclones*. https://pubfiles.pagasa.dost.gov.ph/pagasaweb/files/tamss/weather/tcsummary/PAGASA_ARTC_2018.pdf

Ho, H. L., Park, E., Chitwatkulsiri, D., et al. (2020). Local rainfall or river overflow? Re-evaluating the cause of the Great 2011 Thailand flood. *Journal of Hydrology, 589*, Article 125368. https://doi.org/10.1016/j.jhydrol.2020.125368

Kamiohkawa, S., Maruyama, A., Buot, I., & Buot, M. (2021). Index assessment of household social vulnerability to climate change: A case study of Laguna Province, Philippines. *Journal of Environmental Science and Management, 24*(1), 68–76. https://doi.org/10.47125/jesam/2021_1/07

Kurata, Y. B., Prasetyo, Y. T., Ong, A. K., Nadlifatin, R., & Chuenyindee, T. (2022). Factors affecting perceived effectiveness of Typhoon Vamco (Ulysses) flood disaster response among Filipinos in Luzon, Philippines: An integration of protection motivation theory and extended theory of planned behavior. *International Journal of Disaster Risk Reduction, 67*, Article 102670. https://doi.org/10.1016/j.ijdrr.2021.102670

Lagmay, A. M. A., Racoma, B. A., Aracan, K. A., Alconis-Ayco, J., & Saddi, I. L. (2017). Disseminating near-real-time hazards information and flood maps in the Philippines through web-GIS. *Journal of Environmental Sciences, 59*, 13–23. https://doi.org/10.1016/j.jes.2017.03.014

Lau, Y.-Y., Yip, T.-L., Dulebenets, M. A., Tang, Y.-M., & Kawasaki, T. (2022). A review of historical changes of tropical and extra-tropical cyclones: A comparative analysis of the United States, Europe, and Asia. *International Journal of Environmental Research and Public Health, 19*(8), Article 4499. https://doi.org/10.3390/ijerph19084499

National Climate Change Commission. (2011). *National Climate Change Action Plan 2011–2028*. https://climate.emb.gov.ph/wp-content/uploads/2016/06/NCCAP-1.pdf

NOAH Center. (2022). *The 2022 NOAH-Google Analytics review*. https://noahcenter.up.edu.ph/the-2022-noah-google-analytics-review/

Organisation for Economic Co-operation and Development. (2020). Approaches in the Philippines to increased coherence in climate change adaptation and disaster risk reduction. *Climate Change Adaptation and Disaster Risk Reduction*. https://doi.org/10.1787/4ec0f8bc-en

Ray, A. (2023). *Machine learning-based flood risk modeling using features from satellite, socioeconomic, geographic, and building data* [Master’s thesis, Massachusetts Institute of Technology].

Santos, G. D. (2021). 2020 tropical cyclones in the Philippines: A review. *Tropical Cyclone Research and Review, 10*(3), 191–199. https://doi.org/10.1016/j.tcrr.2021.09.003

Sholihah, Q., Kuncoro, W., Wahyuni, S., Suwandi, S. P., & Feditasari, E. D. (2020). The analysis of the causes of flood disasters and their impacts in the perspective of environmental law. *IOP Conference Series: Earth and Environmental Science, 437*(1), Article 012056. https://doi.org/10.1088/1755-1315/437/1/012056