



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES ENGINEERING

**EVALUATING THE POTENTIAL EFFECTIVENESS OF STRUCTURAL FLOOD
MITIGATION MEASURES ON RIVER NABUYONGA IN MBALE CITY.**

BY

EMURWON MARVIN JEREMIAH

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This final year project report submitted to the department of Mining Engineering as a partial fulfilment of the requirements of the award of Bachelor of Science degree in Water Resources Engineering.

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ABSTRACT

The Nabuyonga River in the northern division of Mbale City has been facing an alarming increase in flood frequency, with significant events occurring in 2019 and 2022. Heavy rainfall, rapid urbanization, poor agricultural practices, and climate change are the main contributors to these floods. The impacts have been severe causing tremendous effects such as displacement of residents, destruction of homes and property, and loss of lives. Public health hazards, such as cholera, dysentery, diarrhea, and typhoid, have also emerged as significant concerns due to flooding. Although measures, like planting bamboo trees along riverbanks, have been implemented, they are not sustainable long-term solutions due to deforestation and other man's related activities.

There is a critical need for long-term structural measures that prioritize sustainability to mitigate future floods. Flooding along the Nabuyonga River has caused not only property damage but also economic losses and increased exposure to water borne diseases. Without any intervention, the situation may severely impact the political, economic, and social aspects of Mbale City. Stakeholders are urged to devise effective solutions to mitigate the disastrous effects of flooding. The implementation of this research could profoundly impact Sustainable Development Goals 6, 11, and 13.

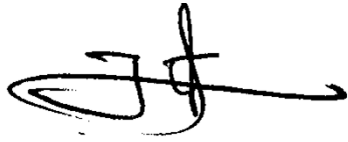
The main objective of the study is to evaluate the potential effectiveness of structural flood mitigation measures and suggest the most effective measure. The study will focus on the geographical area of the Nabuyonga River in Mbale City within the Namatala watershed. The research will be conducted over a four-month period and will not account for climate change impacts. The study seeks to reduce flood risk and vulnerability along the Nabuyonga River's floodplain through the integration of hydrological models using software such as HEC-HMS and hydraulic models using HEC-RAS. Levee, channel straightening, detention basin or floodwall design will be done using the HEC-RAS.

Keywords: Hydrological modelling, hydraulic modelling, statistical analysis, floodwalls

DECLARATION

I Emurwon Marvin Jeremiah declare that this proposal report is my own research and has neither been used nor submitted in any institution or university for any academic award.

Signature.....



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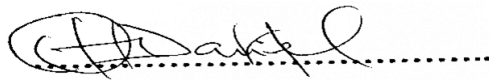
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APPROVAL

This final year research project proposal has been submitted to the Department of Water Resources Engineering under the supervision of

Mr. OLOGE HECTOR DANIEL

SIGNATURE



DATE

14/5/2025

DEDICATION

I dedicate this research to my dear parents, Mr. Obeelee Edward and Mrs. Bisanga Daisy Neddy, in honor of their unwavering love, support and encouragement throughout my academic journey. Their sacrifices and guidance have been the foundation of my success.

A special dedication goes to my university supervisor, Mr. Ologe Hector Daniel for the invaluable mentorship, expert guidance and constant encouragement throughout the course of this research.

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LIST OF ACRONYMS

1DCNN	One-Dimensional Convolutional Neural Network
ArcGIS	ArcGIS Geographical Information System
DEM	Digital Elevation Model
DWRM	Directorate of Water Resources Management
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modelling System
HEC-SSP	Hydrologic Engineering Center – Software Statistical Package
\MWE	Ministry Of Water And Environment
SLR	Sea Level Rise
STAAD Pro	Structural Analysis And Design Program

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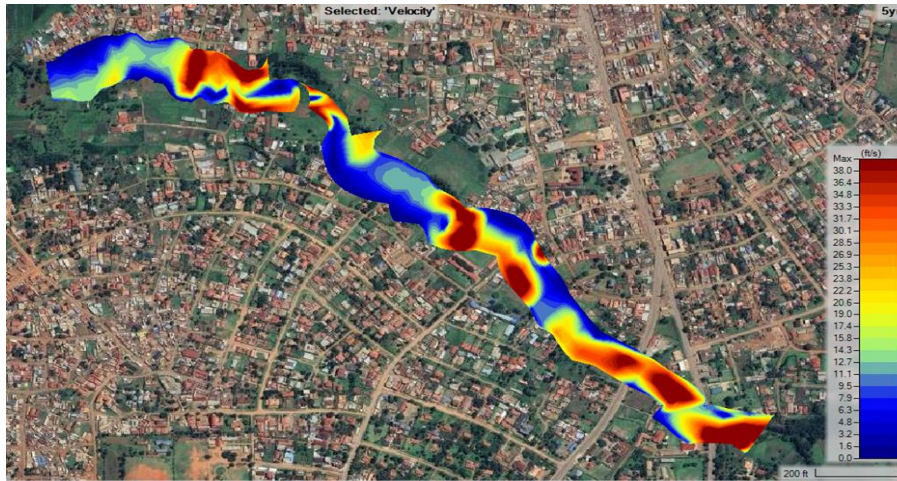


Figure 3:Flood velocity under levee

4.Conclusion

Hydrologic and hydraulic modeling of structural flood mitigation measures for River Nabuyonga indicates that levees are the most effective structural intervention. They offer balanced performance across all critical flood parameters. Their implementation can significantly reduce flood risk in Mbale City along River Nabuyonga, supporting sustainable urban resilience and disaster management.

5.Recommendations

The models are developed specifically for river Nabuyonga in Mbale.However the methodology can be adapted to provide similar results on other rivers provided the required datasets for that location are available.Access to high quality datasets.Use of AI and ML to reduce human error in data inputs.The levee height can act as a starting point for structural design and analysis.More flood parameters should be used to increase accuracy of the model

6.References

Albertini, C., Miglino, D., Bove, G., De Falco, M., De Paola, F., Dinuzzi, A. M., Petroselli, A., Pugliese, F., Samela, C., Santo, A., Speranza, G., Gioia, A., & Manfreda, S. (2022).

Integration of a Probabilistic and a Geomorphic Method for the Optimization of Flood Detention Basins Design. 9. <https://doi.org/10.3390/environsciproc2022021009>

Alice Gallazzi, Immacolata Tolone, Marina Credali, Francesco Ballio, & Daniela Molinari. (2023). *Flood risk assessment in support of the evaluation and selection of risk mitigation measures*. <https://doi.org/10.5194/egusphere-egu23-16311>

Ansari, A. H., Mejia, A., & Cibir, R. (2024). Flood teleconnections from levees undermine disaster resilience. *Npj Natural Hazards*, 1(1). <https://doi.org/10.1038/s44304-02400002-1>

Austin, J., Sharp, M., Sossenkina, E., Vroman, N., Simm, J., Hollingsworth, C., Bake, D. de, Labrujere, A., Tourment, R., & Hahn, M. (2021). *Risk Informed Decisions for Levees*. null-null. <https://doi.org/10.3311/floodrisk2020.24.7>

Bertrand, N., Liquet, M., Moiriat, D., Bardet, L., & Duluc, C.-M. (2019). Uncertainties of a 1D Hydraulic Model with Levee Breaches: The Benchmark Garonne. In P. Gourbesville, J. Cunge, & G. Caignaert (Eds.), *Advances in Hydroinformatics* (pp. 189–204). Springer Singapore.

Bhat, M. S., Alam, A., Ahmad, B., Kotlia, B. S., Farooq, H., Taloor, A. K., & Ahmad, S. (2019). Flood frequency analysis of river Jhelum in Kashmir basin. *Quaternary International*, 507, 288–294. <https://doi.org/10.1016/j.quaint.2018.09.039>

Eldin, H., & Elhanafy, M. (2014). *Engineering Applications of Computational Fluid Mechanics Vol.*

Environmental and Social Impact Assessment for Mbale & Small Towns Water Supply and Sanitation Project Final Report. (2018). www.awe-engineers.com

Gallazzi, A., Molinari, D., Ballio, F., Credali, M., Tolone, I., Muratori, S., & Asaridis, P. (2024). *A Multi-Criteria Analysis procedure for the evaluation and classification of flood risk mitigation strategies*. <https://doi.org/10.5194/egusphere-egu24-8205>

Ganguli, P., & Coulibaly, P. (2019). Assessment of future changes in intensity-durationfrequency curves for Southern Ontario using North American (NA)-CORDEX

- models with nonstationary methods. *Journal of Hydrology: Regional Studies*, 22. <https://doi.org/10.1016/j.ejrh.2018.12.007>
- Georgic, W., & Klaiber, H. A. (2022). A Flood of Construction: The Role of Levees in Urban Floodplain Development. *Land Economics*, 98(1), 78–97. <https://doi.org/10.3368/le.98.1.071520-0106R1>
- Goeury, C., Bacchi, V., Zaoui, F., Bacchi, S., Pavan, S., & El kadi Abderrezzak, K. (2022). Uncertainty Assessment of Flood Hazard Due to Levee Breaching. *Water (Switzerland)*, 14(23). <https://doi.org/10.3390/w14233815>
- Hamdan, A. N. A., Almuktar, S., & Scholz, M. (2021). Rainfall-runoff modeling using the hec-hms model for the al-adhaim river catchment, northern iraq. *Hydrology*, 8(2). <https://doi.org/10.3390/hydrology8020058>
- H.Wang. (2021). *Flood your neighbors: Spillover effects of levee building*.
- Indrawati, Di., Hadihardaja, I. K., Bagus Adityawan, M., Pahrizal, S. F., & Taufik, F. (2019). Diversion Canal to Decrease Flooding (Case Study: Kebon Jati-Kalibata Segment, Ciliwung River Basin). *MATEC Web of Conferences*, 147. <https://doi.org/10.1051/matecconf/201814703006>
- Javier Silas Omagor. (2022, August 20). *Revisiting Nabuyonga, the river of death and destruction*.
- John, A., Mbajiorgu, C. C., Awu, J. I., Mbajiorgu, C. C., Manta, H. I., & James, D. D. (2017). Flood Inundation Simulation using HEC-RAS Hydrologic Model: A Case Study of Oyun River, Nigeria. *International Journal of Basic and Applied Sciences Mbajiorgu et. Al*, 7(1), 62–68. www.crdeepjournal.org/ijbas
- Kazakis, N., Kougias, I., & Patsialis, T. (2015). Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope-Evros region, Greece. *Science of the Total Environment*, 538, 555–563. <https://doi.org/10.1016/j.scitotenv.2015.08.055>

- Kourtis, I. M., Tsihrintzis, V. A., & Baltas, E. (2020). A robust approach for comparing conventional and sustainable flood mitigation measures in urban basins. *Journal of Environmental Management*, 269. <https://doi.org/10.1016/j.jenvman.2020.110822>
- Kratzert, F., Herrnegger, M., Klotz, D., Hochreiter, S., & Klambauer, G. (2019). NeuralHydrology – Interpreting LSTMs in Hydrology. In W. Samek, G. Montavon, A. Vedaldi, L. K. Hansen, & K.-R. Müller (Eds.), *Explainable AI: Interpreting, Explaining and Visualizing Deep Learning* (pp. 347–362). Springer International Publishing. https://doi.org/10.1007/978-3-030-28954-6_19
- Kreibich, H., Piroth, K., Seifert, I., Maiwald, H., Kunert, U., Schwarz, J., Merz, B., & Thielen, A. H. (2019). Natural Hazards and Earth System Sciences Is flow velocity a significant parameter in flood damage modelling? In *Hazards Earth Syst. Sci* (Vol. 9). www.nat-hazards-earth-syst-sci.net/9/1679/2009/