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Ph.D. in Meteorology

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Characterizing flood response to intense rainfall using observational and model data: Case studies on riverine floodings in Pampanga, Matina and Cagayan River basins

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ABSTRACT

This dissertation is a collection of independent research studies in stand-alone chapters that covers various investigations of flood hydrological responses of selected river basins in the Philippines due to intense rainfall. Particularly, this dissertation is divided into six chapters. Chapter I contains the motivation and objectives of the entire collection which highlights the need for understanding the flood responses of river basins for effective disaster risk management as limited studies have been undertaken on the hydrometeorological behavior of the country's catchments. Chapter II discusses the research framework encompassing all individual research and its principles. It also highlights several kinds of research related to the present studies. Chapter III discusses the Pampanga River Basin (PRB), a large river system equipped with gauging stations for monitoring and flood forecasting. Hydrological responses in terms of flood onset and lag time being affected by TCs directly or indirectly using the observational data from 2013-2018 were analyzed. Flood events were selected based on the assessed threshold levels (alert, alarm, critical) established by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) in the Arayat station as a forecast point. Results show that TCs induced all flood events in the PRB during the study period. All intense TCs that directly traversed the PRB resulted in critical-level river floods. These TCs also had the shortest onset of 7 – 27 h from alert to the critical level. On the other hand, floods from distant landfalling TCs are dependent on the season. TCs traversing north (south) of the basin induced flooding only during the southwest (northeast) monsoon season. These TCs can raise water levels from alert to critical in 11 – 48 hr. As large uncertainties remain in TC rain forecasting, a simple checklist method for flood forecasting that depends on the general TC track, season, and accumulated rainfall was proposed for groups with limited forecasting resources. Chapter IV focuses on the Matina River Basin (MRB), a small ungauged river basin in highly urbanized Davao City. The hydrological response

of this data-scarce river to intense rainfall brought by localized thunderstorms was studied by simulating two flash flood events using the Physically Based Distributed Hydrological Model (PBDHM). Meanwhile, the PBDHM simulation showed good correspondence between the simulated time difference from peak rainfall to flood peak with the reports on the ground, which is equal or less than 80 min. This result can serve as a basis for developing a flood forecasting system in the rivers of Davao City and elsewhere. Chapter V investigates the flood hydrological response of the Cagayan River basin due to the influence of historical warming on the rainfall characteristics of TY Vamco. The characteristics of rainfall was investigated using the Weather Research and Forecasting (WRF) model by applying the pseudo - global warming method with a 40-year regression of sea surface temperature (SST), environmental temperature, and relative humidity (RH) profiles from JRA-55 reanalysis data. Three model runs are done to produce: (1) control run (CTR), (2) regressed SST (SST) run, and (3) regressed SST, T, and RH profile run, or the Historical Warming (HW) run. Simulation results show that cooler SSTs in the past produced less intense TY Vamco. However, the higher mid-tropospheric RH in the historical run induced more precipitation along the external rainbands which happen to fall on the Cagayan basin. Subsequently, the river discharge was simulated using modeled rainfall utilizing the Rainfall-Runoff and Inundation (RRI) model. The SST run had 20% relative difference river discharge compared to the control run, attributed to the less intense simulated TC, while the HW run only had 1.7% discharge reduction relative to the control, attributed to the changes in rainfall distribution. In terms of inundation area, the SST and HW run had lower 1-6 m flood area coverage of 24.3% and 2.81%, respectively. Results show that historical warming of the environment yields more intense present-day TY Vamco and higher rainfall. Still, variations in rainfall distribution led to comparable historical rainfall to the present. Lastly, Chapter VI discusses the summary, conclusion, and recommendations for future investigations relative to the three studies presented. The result of this study can be beneficial not only for flood

forecasters but also for policymakers in guiding them in implementing projects concerning river basin improvement for disaster preparedness.

Keywords: river basin, flood, physically based distributed hydrological model, rainfall-runoff and inundation model, historical warming