CARIWIG Case Study Report 7

Scenarios of discharge for the Hope River Watershed in response to variable tropical cyclone characteristics

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Summary

- Inland and coastal flooding in relation to the passage of tropical storms or cyclones is prevalent in the Caribbean. The more intense flood events have led to the loss of lives and infrastructure, for example the collapse of two important bridges in Kingston, Jamaica's capital in relation to Tropical Storm Gustav in 2008. Knowledge of how storms of varying strengths along different paths and moving at various speeds may impact flood potential at a location is vital to persons with assets in the location of interest or whose livelihoods may be impacted or for those who design the interventions to respond to impacts or reduce future risks.
- Scenarios of discharge from the Hope River Watershed are investigated in relation to a range of tracks and speeds for a hurricane with similar rainfall and wind profile as Hurricane Ivan at category 5.
- When the speed of a hurricane with characteristics similar to Ivan is increased, there is a slightly lower peak discharge from the watershed and less time to flood. With an examination of more storm scenarios these are likely useful inputs in disaster plans at the community or parish level.
- Of the scenarios investigated, the discharge is a maximum for the track south of Jamaica and implies that the elevated flood risks that have traditionally been attributed to hurricanes passing directly over an area may not be as representative as previously thought.

Aim and objectives

The study examines six scenarios of watershed runoff in response to a range of tracks and speeds for an intense hurricane. The study allows a look at flood risks for the Hope River Watershed that has been the site of intense flood events in the last decade. This is important in light of the communities sited near the watershed and the valuable infrastructure located there. The information obtained from this study is a first step towards providing communities, planners, disaster response agencies and non-governmental organizations with possible flood potential and conditions (paths, strengths, speeds) for which these could likely occur.

Which tools were used? How and why?

The SMASH model is to used to define track, name of tropical cyclone/hurricane, category of storm and forward speed for investigation. After the model run is executed, rainfall amounts and wind speeds are available at 15 minute intervals for an area of interest around the chosen storm path. The model provides a single output file of rainfall intensity (in mm/hr) or wind speed (knots) for each grid box chosen over the region of interest. It should be noted that rainfall derived from SMASH is the value for each grid box at a 25 km by 25 km resolution.

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No method is applied to extract station level data from the grid box (otherwise known as downscaling). For each path Hurricane Ivan was chosen at category 5 and speeds of 17 (minimum) and 25km/hr (maximum) were selected for the paths shown in Figure 1. The SMASH tool is used because it allows users to obtain rainfall intensities and wind speeds in relation to a scenario of their choosing. The data obtained can be fed into an impacts model to investigate what this scenario may mean for a particular sector. This study highlights water but is reproducible for agriculture, coastal interests, urban drainage and other applications.

Runoff simulations are undertaken for the Hope River watershed using the HEC HMS model developed by the US Army Corps of Engineers (http://www.hec.usace.army.mil/software/hec-hms/). HEC-HMS is a physically based, semi-distributed hydrologic model that simulates the hydrologic response of a watershed subject to a given hydro-meteorological input herein rainfall. Runoff at selected vulnerable sections of the watersheds (e.g. Kintyre, Harbour View) can thereafter be analyzed. HEC – HMS uses a pre-processor called HEC GEOHMS, which uses a GIS based interface to develop the basin model comprising of catchments, drainage lines, slope using the Digital Elevation Model for the watershed as the base layer. Processing was done using a DEM of 6m horizontal and 1m vertical resolution.

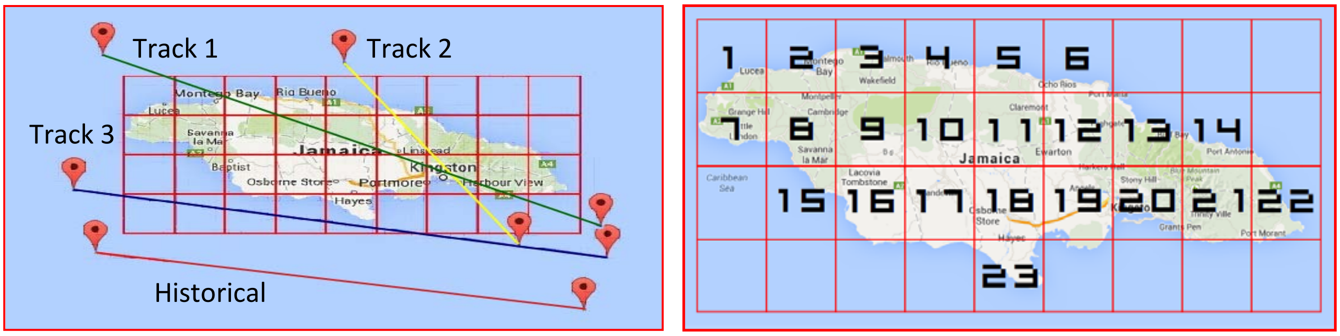

Figure 1. Three tracks defined across Jamaica and the grid boxes for which rainfall series may be viewed or downloaded. The Historical Ivan track is also shown. Hope River is located in grid box 20.

The findings

Hurricane Ivan traversing Track 1 at 17 km/hr (Figure 2a) shows dual peak rainfall intensity of 10 and 12mm. The first peak is found to occur around 3:45 hrs after initiation of storm and the second peak occurs at 11:15 hrs. For the same track but with speed of 25km/hr (Figure 2b) the first peak intensity appears at 2:30 hrs and the second at 6:30 hrs after onset of storm. Therefore as expected the peak rainfall occurs over a given location earlier for a faster moving storm. This is seen for tracks 2 and 3 as well.

Interestingly the rainfall profile associated with Track 3 at 17 km/hr tends towards a normal rainfall distribution (Figure 2e) with a peak rainfall intensity of 12mm. Track 3 at a speed of 17km/hr shows peak rainfall between 7:30 to 10:00 hrs after initiation while the same track at a speed of 25km/hr shows a similar wide peak rainfall between 5:00 to 7:00 hrs after initiation. This suggests that at maximum speed of 25km/hr the watershed gets impacted by severe rain for a shorter duration from the onset of storm with a shorter basin lag. The results also confirm that different tracks yield different rainfall intensities and distributions at a given location.

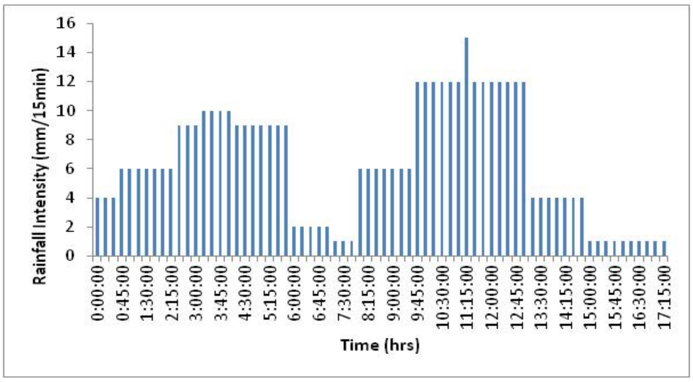

Fig 2a Rainfall Intensity for Track1 at 17km/hr

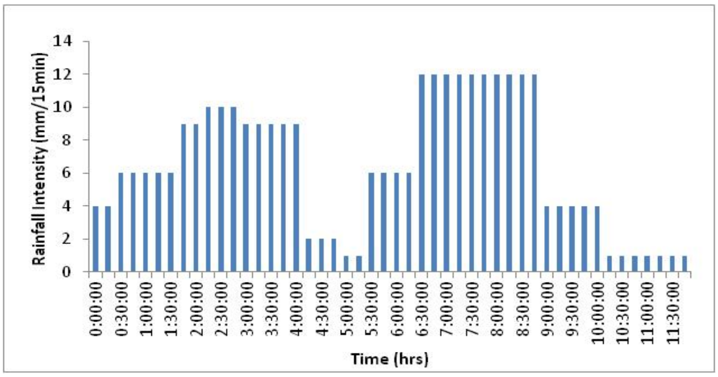

Fig 2b Rainfall Intensity for Track 1 at 25km/hr

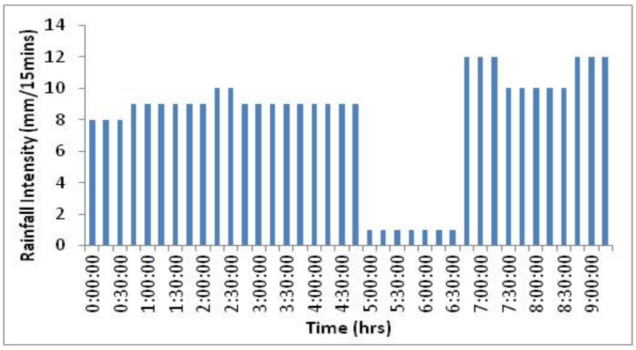

Fig 2c Rainfall Intensity for Track 2 at 17km/hr

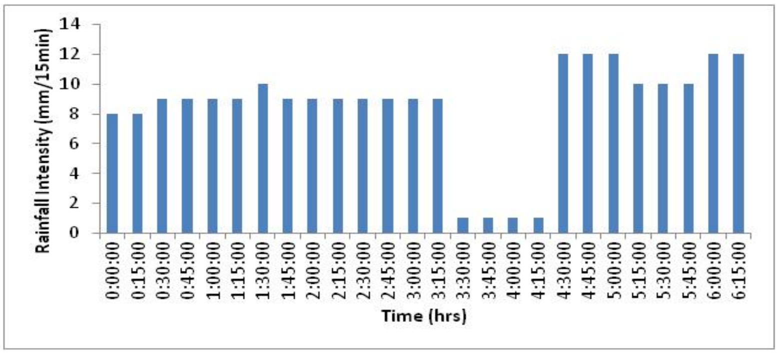

Fig 2d Rainfall Intensity for Track 2 at 25km/hr

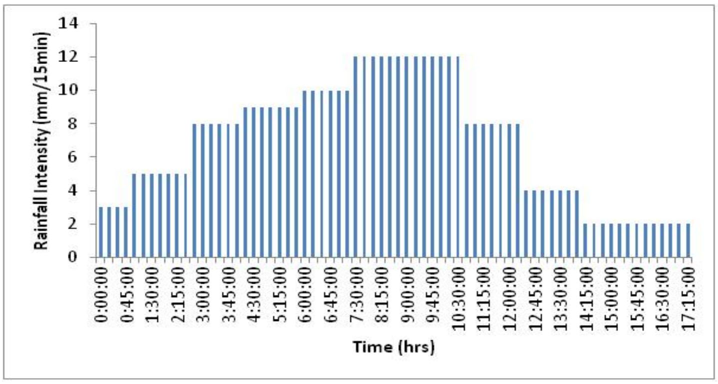

Fig 2e Rainfall Intensity for Track 3 at 17km/hr

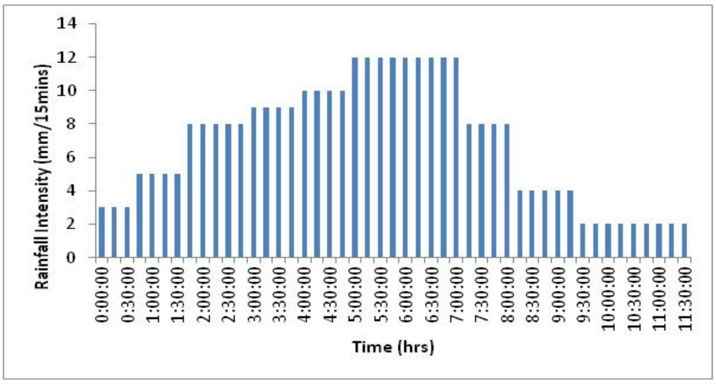

Fig 2f Rainfall Intensity for Track 3 at 25km/hr

Model runs from HEC HMS for Track 1 at speed of 17km/hr shows a peak discharge of ~ 310 cumecs corresponding to approximately 14 hours after onset of storm for Junction A (Figure 3 and Table 1). Junction A corresponds to location of the fording Kintrye which has suffered repeated flooding. The HEC HMS runs in relation to Track 1 at a speed of 25km/hr show similar peak discharge and shorter basin lag time (time taken by water to move from extreme end of the watershed to the river). In other words when the speed of the hurricane is increased, there is a decrease in peak discharge though not significant and the basin takes a shorter time to flood. Similar results are noted in relation to Tracks 2 and 3. However it is interesting to note that Track 3, which has a track similar to the Hurricane Ivan that impacted Jamaica September 10-12, 2004 shows the maximum discharge of 335 cumecs for junction near the fording at Kintyre as well as in the sub-basin K when compared to the corresponding discharges in relation to Tracks 1 and 2. Hence the suggestion is that the CARIWIG SMASH model is able to yield rainfall amounts which when used in a hydrological model yields discharge similar to past extreme events. This speaks to the validity of the SMASH output. The results also show that maximum discharge was not obtained from the "direct hit" scenarios but the offshore passing storm.

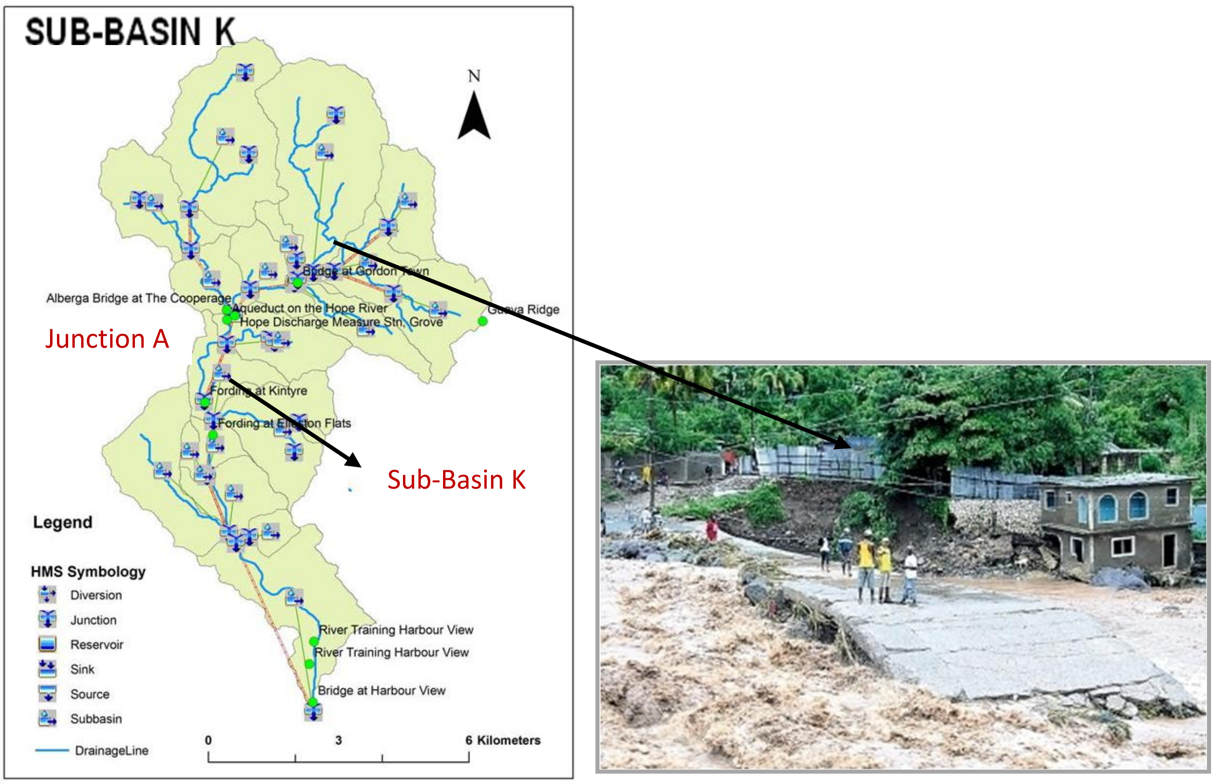

Figure 3 Basin model for the Hope River watershed.

Table 1. Peak discharge and lag time for various tracks and speeds at Junction A

	Forward Speed (km/hr)	Peak discharge (cumecs)	Lag time to peak discharge (hours)
Track 1	17	310	14
	25	250	12
Track 2	17	280	12
	25	200	8
Track 3	17	335	14
	25	280	8

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Implications for policy and planning

The study demonstrates that peak discharge and therefore flood potential for a particular watershed maybe analyzed in relation to any number of storm scenarios. The magnitude of the peak discharge and the time for flooding of watershed to occur could be useful inputs to community and parish level disaster plans and in identifying worst case scenarios for which communities or response teams should be prepared, particularly as more storms are incorporated in SMASH. This information is also useful in design and location of critical infrastructure.

The study also demonstrates that the higher inland flood risks often attributed to storms passing directly over the island versus those storms traversing offshore may not be accurate. If further studies confirms this, this may have implications to the level of preparedness and the amount of resources set aside for response to an impending storm system. This also has implications for access to external financing to support recovery as some insurance and financial instruments do not "kick in" outside of a direct storm "hit".

Feedback on the tools

The SMASH tool is indeed an innovative approach to assessing the possible influence of different strengths, tracks and speeds of a hurricane on rainfall intensity at a location and ultimately discharge from a watershed. It has a very useful application in conjunction with hydrological models to estimate the runoff from rainfall intensity observed over a grid box.

The model in its current form generates rainfall over 25 km grid boxes. This presents a limitation as for a number of applications including some hydrological investigations higher resolution is necessary.

What more could be done?

The incorporation of more storms in SMASH would allow the investigation of more scenarios. Coupling this with a look at a number of other tracks, strengths and speeds could be useful in creating a flood potential database for a number of key locations across Jamaica that at a minimum allows the identification of some worst case scenarios. It may be possible that the output of these investigations could also be useful in the creation of flood maps in relation to various peak discharges.

Using SMASH with other sector models would also be useful. Other modelled systems such as urban drainage and coastal areas for which rainfall or wind is an important input may be examined with the view of identifying impact of different storm scenarios on the systems and how these may feed into disaster preparedness or reducing adverse risks associated with each scenario.

Incorporation of topographical effects would also be a useful addition to the SMASH.

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