ESTIMATING LINE-LIKE RISK FOR TROPICAL CYCLONES
PART I - SIMULATION APPROACH

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Introduction

Simulation methods have emerged as reliable, and in some cases, the only means available for predicting extreme winds, storm surges and other impacts in tropical cyclone regions of the world. Information on cyclone impacts and their relative risk is critical to the assessment of those areas most exposed to the cyclone hazard and to the design of structures to resist their effects.

The author has been involved over the last decade in applying the simulation approach to predicting cyclone risk in a number of regions of the world. For example ...

- **Design wind speeds** found in the **current Caribbean Uniform Building Code** have been based on the tropical cyclone simulation of wind speeds using a method developed and refined by the author at the University of Western Ontario.

- **Design storm surge heights** for the **proposed Darwin South Seawall** and **new East Arm Port** in Darwin Harbour, are being based on the results of a study using the simulation approach just completed by Vipac, the Bureau of Meteorology's Special Services Unit (SSU) and GEMS (Global Environmental Modelling Services).

- A major study of **insurance risk** for commercial and residential dwellings in cyclone-prone areas of Queensland has just been completed by the SSU and the author using the simulation approach on a regional scale.

Line-Like Risk for United States Locations

The work carried out at the University of Western Ontario, and referred to above, was initially funded by the Electric Power Research Institute (EPRI), which at the time was keenly interested in establishing line-like risk for transmission lines following several major "cascade failures" involving the loss of tens of kilometres of line.

To assist in assessing this line-like risk, the simulation procedure which had been developed by the author to predict extreme wind speeds along the U.S. Gulf and Atlantic Coastlines was extended to examine the increased risk sustained by line-like structures such as transmission lines. This paper details some of the results from this study and draws general conclusions related to the exposure of transmission lines in tropical cyclone-prone areas.

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An example of the extreme wind speed estimates previously determined by the author for the U.S. Gulf and Atlantic Coasts is shown below in Figure 1. The wind speed estimates are applicable to point structures, i.e. indicating the risk that an isolated building would experience.

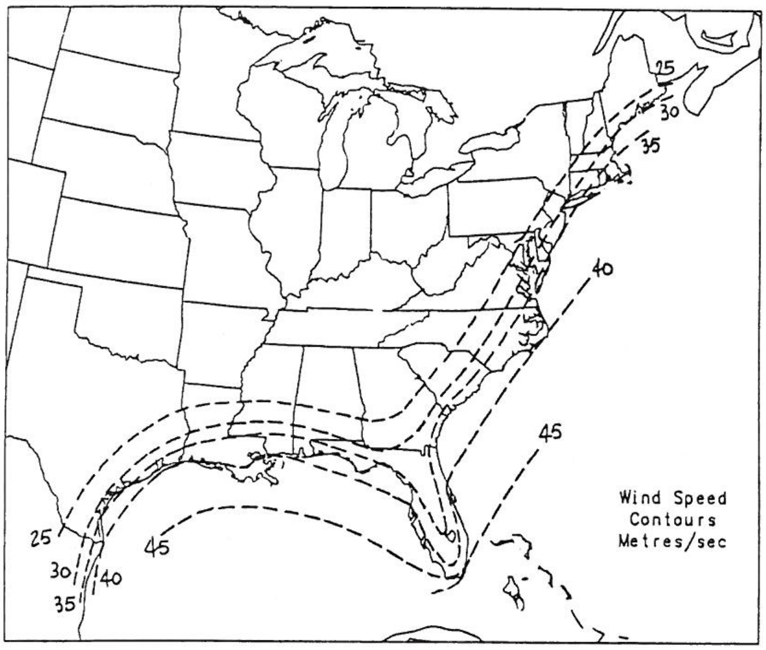

Figure 1

Simulation Approach
100–Year Return Period
(10–metre Height)
Mean Hourly Winds

To examine the expected increase in line–like risk, three representative locations have been chosen, shown in Figure 2, close to **Galveston, Miami and Charleston**. At each of these locations two lines are defined, one running **parallel to the coastline**, the other running inland **perpendicular to the coastline**. Also shown is the mean tropical cyclone approach angle at each of the three sites. The three sites allow different relationships to be examined between the lines and the predominant direction of storm motion.

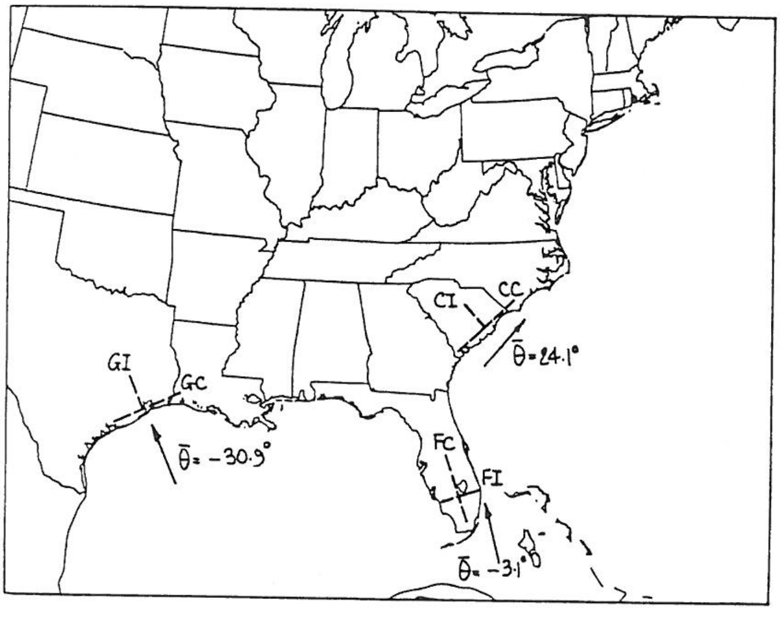

Figure 2

Location Map
for Line–Like Risk
Simulation Examples

The Galveston coastal line ("GC") and inland line ("GI") run perpendicular and parallel to the average track angle of tropical cyclones in the area respectively. The opposite occurs for the two Charleston lines, with the coastal line ("CC") aligned almost parallel with the predominant storm direction and the inland line ("CI") perpendicular. The two lines located within the lower Florida peninsula are both inland.

For each of the above examples, the simulation procedure was run over time periods resulting in the generation of approximately 2500 tropical cyclones. As each storm was created within the simulation, wind speeds were concurrently recorded at fixed intervals along the line and the **maximum value at any point** recorded. This resulted in the compilation of a separate set of **"line" extremes**, representing the maximum wind speeds seen by the line, regardless of where along the line the particular speed was sustained.

The results for the two Galveston lines are shown in Figure 3. Extreme-value distributions were computed for two "GC" lines of length 100 km and 200 km running along the coast, for a single "GI" line of length 100 km running inland from the coast and finally, for a point on the coastline at the junction of "GC" and "GI" lines. There is a clear increase in the risk (higher wind speeds for the same return period) for the two coastal lines, as compared with the inland line which exhibits only a modest increase.

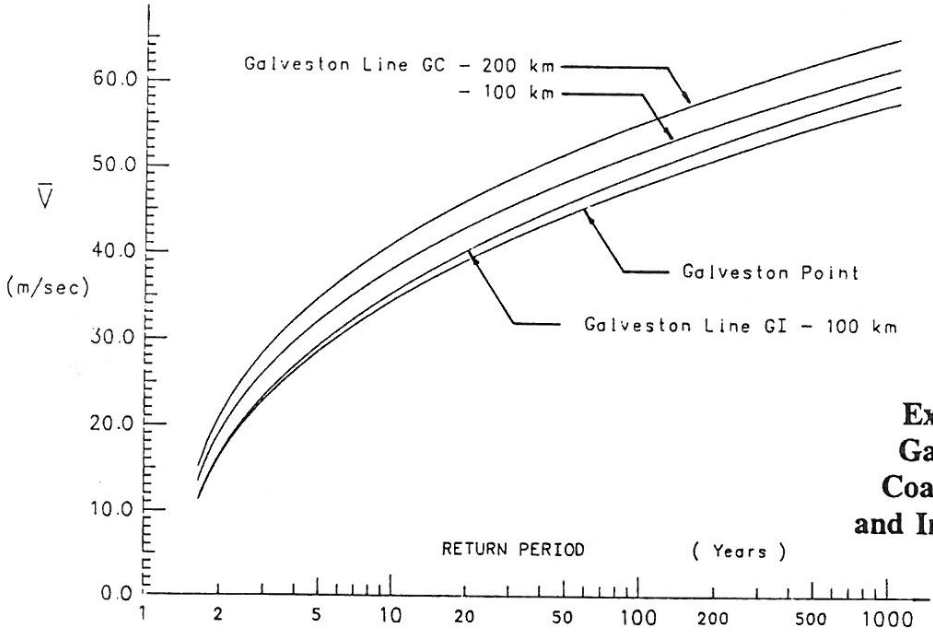

Figure 3

Extreme Estimates Galveston "Point", Coastal Lines "GC" and Inland Line "GI"

The increases are significant. For example, the 100-year extreme estimate is 48.0 m/sec for the single point distribution. The same speed has return periods of 50 and 25 years for the 100 km and 200 km "GC" coastal lines respectively. Alternatively, the 100-year extreme estimate for the 200 km "GC" coastal line (55.0 m/sec) has a return period of approximately 500 years for the single point distribution.

The extreme-value distributions for the Charleston point, coastal ("CC") and inland ("CI") line extremes are shown in Figure 4. The increase in risk is almost the same for the coastal and inland lines (note the coastal line is 200 km long, double the inland line length). The risk magnitudes do not change as much as indicated for the Galveston lines. The 100-year estimate for the 200 km "CI" coast line (54.0 m/sec) corresponds to a 200-year return period for the single point distribution.

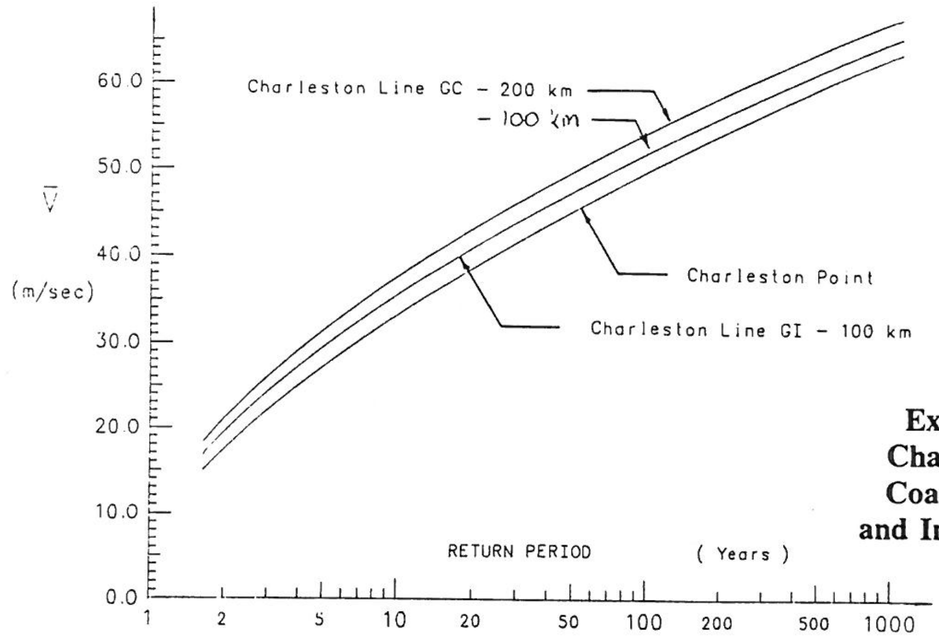

Figure 4

Extreme Estimates Charleston "Point", Coastal Lines "CC" and Inland Line "CI"

The results of the two simulations performed for the Florida Peninsula lines were almost identical to the Charleston runs with similar increases in risk for the two lines running along and across the axis of the peninsula.

General Conclusions

The differences in line-like risk at the three locations examined can be related to cyclone track characteristics in the immediate area. Lines running perpendicular to the main storm track direction will experience higher wind speeds over their total length. This effect coupled with the decrease in wind speeds for landfalling storms accounts for the lower risk in lines of equal length running inland in the Galveston area compared to the coastal lines. Along the Atlantic coast two opposing influences tend to balance out the risk for lines located along the coast and perpendicular to the coast. Although wind speeds are generally weaker for inland locations, lines located perpendicular to the coast are also perpendicular to the mean storm direction and hence experience a greater range of storm maxima than lines located along the coast whose points will typically be at the same distance from the storm path as it moves parallel to the coast.

The three examples chosen indicate that line-like risk behaviour may be conveniently described by considering regions along the Gulf Coast separately to the Florida peninsula and Atlantic Coast. For Gulf Coast locations, a useful rule of thumb for estimating the increased risk for line-like structures is to reduce the return period associated with a given wind speed for a point structure by approximately 50% for every 100 km length for coastal lines, and 15% for every 100 km length for lines perpendicular to the coast. For Florida peninsula and Atlantic Coast regions a single reduction may be used for all lines regardless of orientation, equal to approximately 25% for every 100 km length of line.

The author is currently examining line-like risk using the simulation approach for Australian cyclone-prone regions and the development of useful approximations for quantitative line-like risk factors in different regions.