Change in the Precipitation Parameter Source and its Effect in Previously Designed Structures

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Abstract

The impact of any development brings with it a series of changes to the environment that must be mitigated; thus, a Hydrologic and Hydraulic Studies become necessary to bring solution at the design process. The precipitation-frequency is an important factor to be used in of this Study. The National Weather Service periodically publishes reports that include the occurrence of precipitation in Puerto Rico. Until 2006, the most recent report was Technical Paper TP-42, published in 1961 until it was reviewed, and the new calculation incorporated in the Volume 3 of the NOAA Atlas 14. Owing to this change, we have carried out a comparative study of the TP-42 versus NOAA Atlas 14 and its effect on structures such as bridges that were designed under Technical Paper T-42. This study has proven that there is a significative change in the design parameters obtained from HH Studies based on the use of TP-42 versus NOAA Atlas 14.

Introduction

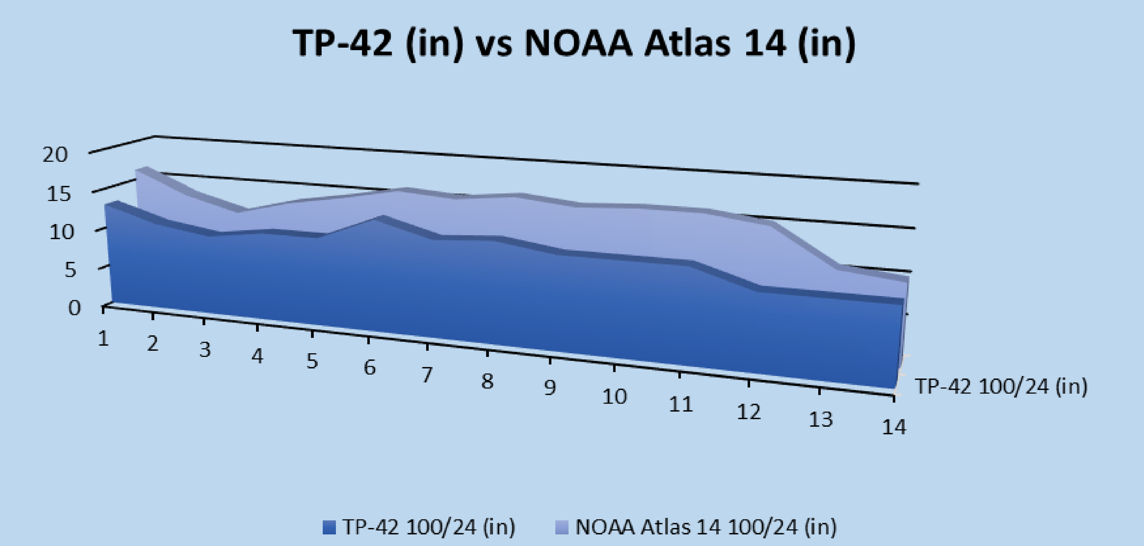
Evidence indicates both observational and from model projections, that changes to the climate are taking place. Although the magnitudes of these changes rely on innumerable uncertainties, the fact that our climate is changing is unquestionable. To ensure a functionality of our daily life, it is therefore important to study the potential climate change impacts on infrastructure. Considering that bridges have a considerably long service life, it is of direct significance to find out their reliable operation against climate change risks.

Background

On 2006, the NWS release the NOAA Atlas 14 Volume 3 substituting the TP-42 as the precipitation-frequency estimate source to conduct a hydrologic study. The primary difference between Atlas 14 and TP-42 is: the inclusion of 54 years of daily precipitation data, and the number of stations included in the analysis.

Problem

The change in the precipitation source from TP-42 to NOAA Atlas 14 Volume 3 and the climatic change observation and prediction, induced to review the change in the precipitation parameter source and the amount in precipitation depth, resulting that all storm precipitation has increased in depth compared to those on the TP-42. This fact create an issue that conduct a research to evaluate the real effect that this changes have on structures such as bridges.



Methodology

Hydrologic and Hydraulic Studies are an essential study to establish the flood hazards and mitigate against flood loss in the future. For this research, the hydrologic modeling where performed using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). Using a Type 2 hypothetical storm, Curve Number as a loss method, a Unit Hydrograph and the area, each basin was modeled to obtain the peak discharge (Q). This data was obtained from HH Studies provided by the ACT. The results were used to perform a hydraulics analysis.

Replacment Bridge at PR 102	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	W.S. Elev (m)	W.S. Elev Design (m)	Vel Chnl (ft/s)	Vel Chnl Design (ft/s)
	Before Bridge	TP-42 HMS	15817.45	0.71	15.41	4.70	4.02	6.99	5.58
		Atlas 14 HMS	23268.86	0.71	18.68	5.69		8.1	
	Bridge								
	After Bridge	TP-42 HMS	15817.45	0.69	9.65	2.94	3.16	14.4	12.04
		Atlas 14 HMS	23268.86	0.69	12.36	3.77		14.92	

For this research, the hydraulics modeling was performed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS). The modeling provided information about the water surface elevation and channel velocities for the study area, which were used to compare both precipitation frequency in terms of water surface elevation and velocities for two study cases. The design elevation and velocity obtain using the TP-42 precipitation were compare to the NOAA Atlas 14 Volume 3 precipitation.

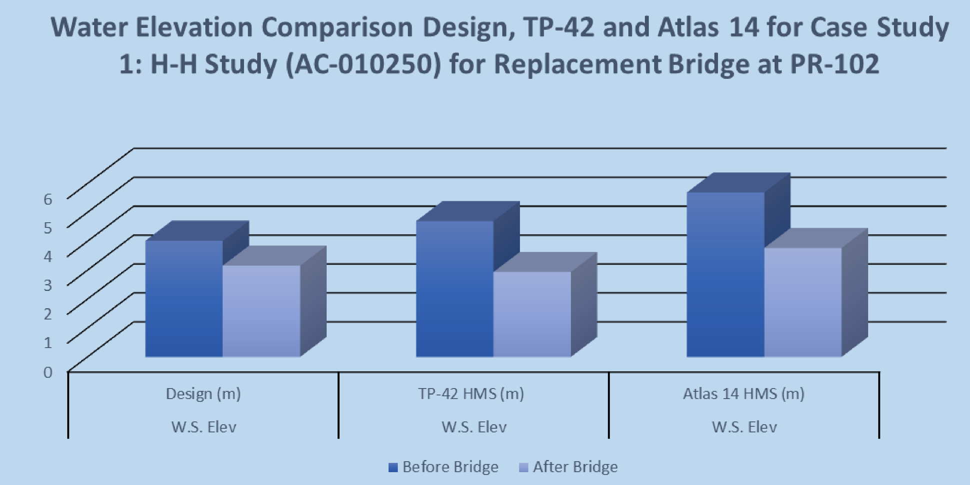
New Bridge PR 1 La Muda	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	W.S. Elev (m)	W.S. Elev Design (m)	Vel Chnl (ft/s)	Vel Chnl Design (ft/s)
	Before Bridge	TP-42 HMS	19719.73	222.95	245.52	74.83	74.75	9.72	8.99
		Atlas 14 HMS	28396.55	222.95	249.86	76.16		10.72	
	Bridge								
	After Bridge	TP-42 HMS	19719.73	221.26	244.71	74.59	74.66	9.29	7.45
		Atlas 14 HMS	28396.55	221.26	249.07	75.92		10.09	

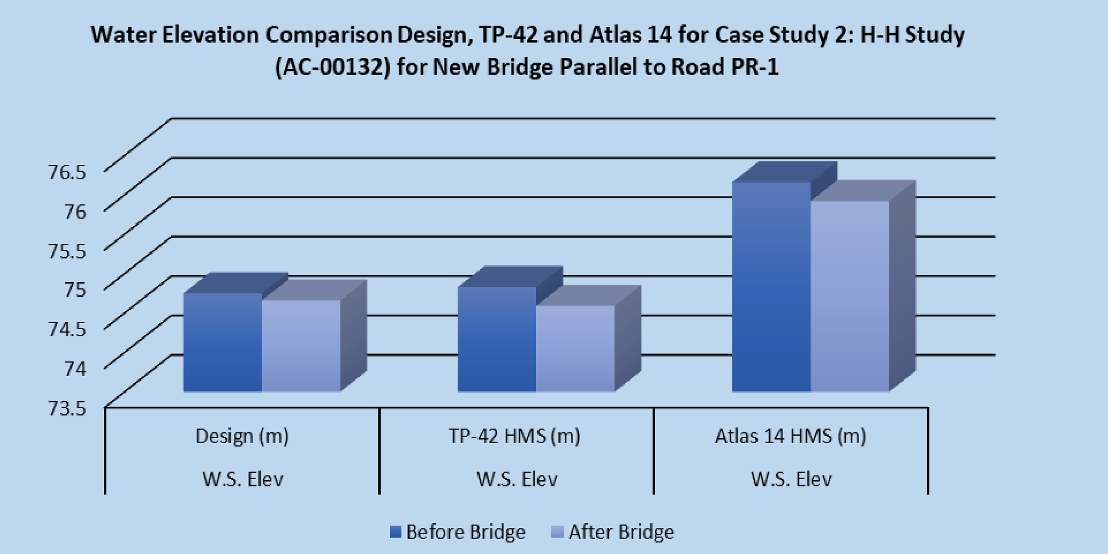
Results and Discussion

Ten Hydrologic and Hydraulic Studies were selected in order to compare the peak flow generated using the TP-42 precipitation-frequency and NOAA Atlas 14 Volume 3 precipitation-frequency. The basins considered on each study where analyzed by HEC-HMS. For each study the area, curve number and time of concentration were gathered, and input into the HEC-HMS modeling software. For each case, the modeling was run using both, the 100 years 24 hours TP-42 precipitation depth and the 100 years 24 hours Atlas 14 precipitation depth. The results from this series of modeling are precis on the table below.

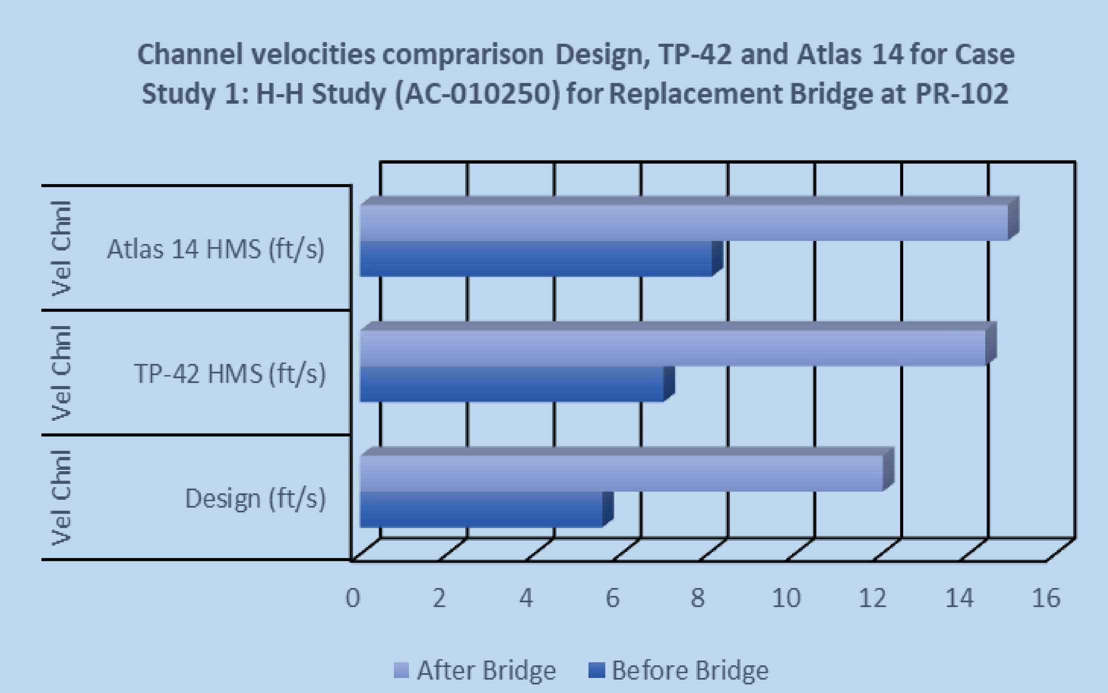
HH Study ATC	TP-42 100/24 (in)	NOAA Atlas 14 100/24 (in)	Basin	Q HH (CMS)	Q TP-42 HMS (CMS)	Q Atlas HMS (CMS)	Dif %
AC-012201	13	16.3	1	841.973	771.7	973.3	26.12%
AC-086112	11	13.4	1	130.00	146.10	191.40	31.01%
AC-000019	10	11.6	1	1174.1	1199	1360.8	13.49%
Ac-000093	11	13.4	1	87.00	90.00	115.00	27.78%
AC-00132	11	14.6	1	636	558.4	804.1	44.00%
AC-00661	13.88	16	1	12.12	35.60	41.80	17.42%
AC-003069	12	15.5	1	453	443.5	598.1	34.86%
AC-005319	12.5	16.3	1	325.22	718.20	978.30	36.22%
AC-010250	11.5	15.6	1	144.642	134.9	192.9	42.99%
	11.5	16	2	182.445	172.6	265.2	53.65%
	11.5	16	3	155.346	140.4	200.8	43.02%
AC-010925	9.3	15.1	1	137.34	110.60	203.50	84.00%
	9.3	10.7	2	99.22	100.70	119.60	18.77%
	9.3	9.95	3	58.47	56.10	60.90	8.56%

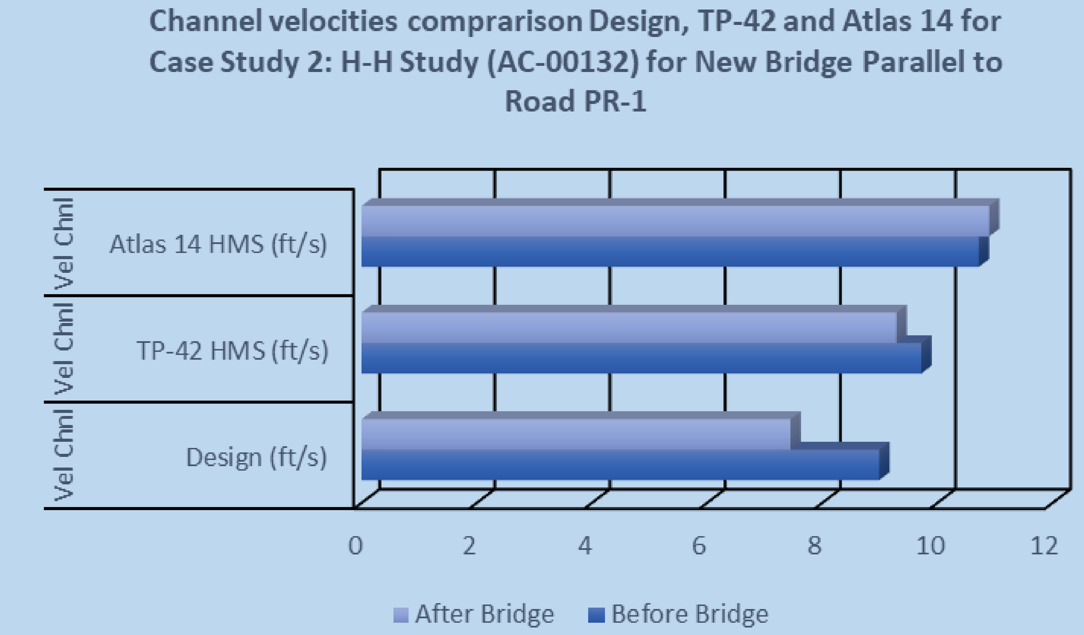
As it can be seeing the difference in peak flow, goes from 8.56% to 84%. Clearly, the precipitation on Atlas 14, for all storm event's definitions have increased in depth, consequently, the peak discharge has increased too. The H-H Study (AC-010250) for Replacement Bridge at PR-102 at Mayaguez, and the H-H Study (AC00132) for New Bridge Parallel to Road PR-1 at Guaynabo, were selected for the hydraulics modeling. Using the new peak discharge generated by the HEC-HMS both the TP-42 and the Atlas 14, were modeled on HEC-RAS providing us with the new elevations. The elevation was significative increased compared to the design parameter used. The next two graphs shows the change on elevation.





Channel velocities as it was expected, increased too, both before and after the bridge. The next two graphs shows the change on velocities for both cases.



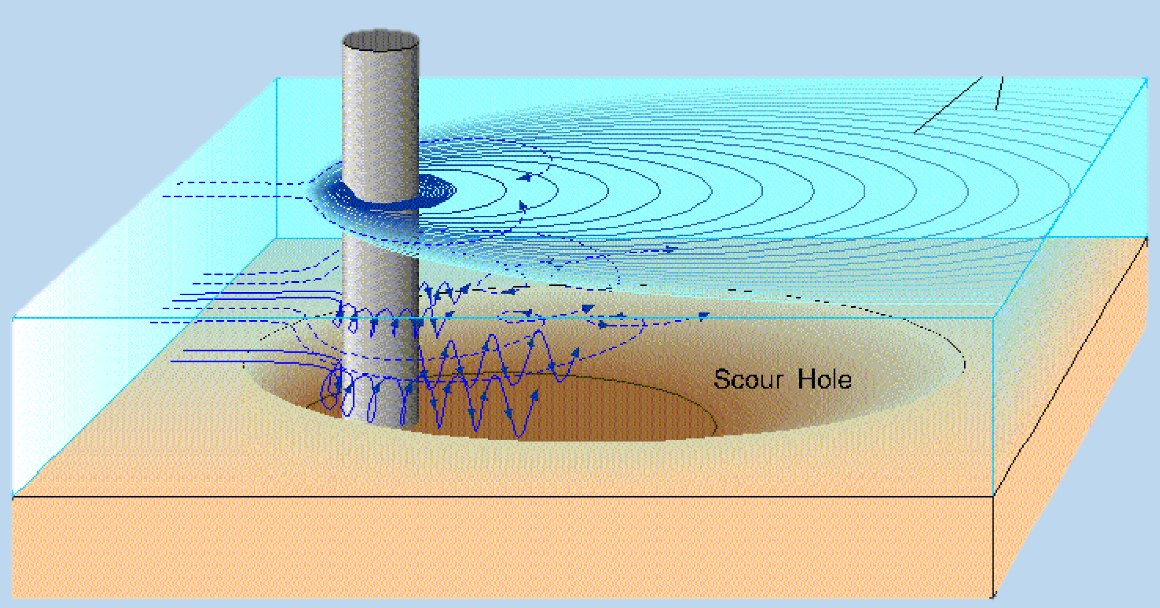


Conclusions

The National Weather Services (NWS) NOAA Atlas 3 Volume 14 replacing the Technical Paper 42 on 2006, was without doubt a change hydrology speaking. Including the most recent 54 years of precipitation data and incrementing the numbers of stations included in the analysis bring with it a most precise precipitation depth data easily to obtain from a website. Structure such as bridges and culvert are design for a long period of service and this research have proven that the lifespan has been reduced or in the worst case it not complied with the code, even for the time that they were design. Bridges and culverts have been designed assuming stationarity in rainfall records, meaning that there will be no significant changes in rainfall intensities. The evidence that the climate is changing, and the fact that this issue will result in different rainfall intensities and patterns, suggested that is time to incorporate and dynamic precipitation analysis on the hydrologic studies and structure design or at least use our engineering judgment into designs to balance risk across a structure's lifespan. These meaning a more resilient study and design.

Future Work

The fact that all storm events definitions have increased in depth, open the window to an imperative need for the creation of a system to review the public structures designed under the Technical Paper 42. Despite the fact that this study has shown that there is a change in the water surface flow and elevation, affecting the safety and lifespan of structures, it is essential to review other parameters such as scour and other studies on structures, which combined to change in flow and elevation of the surface water, can derive on a reduce lifespan of structures.



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References

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