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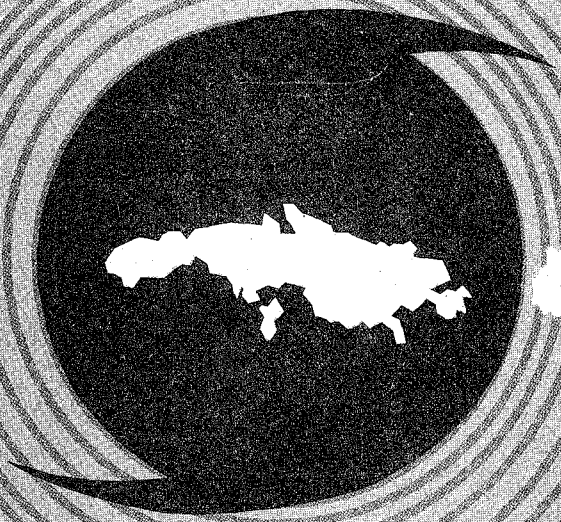
HURRICANES IN PARADISE



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Island Resources Foundation

HURRICANE IN PARADISE:

PERCEPTION AND REALITY OF THE HURRICANE HAZARD IN THE VIRGIN ISLANDS

By

MARTYN J. BOWDEN

with the
assistance of
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Cartography: Clark University Cartographic Laboratory
Report based on data collected and processed during
Clark University January Study Periods, 1969, 1970, 1972

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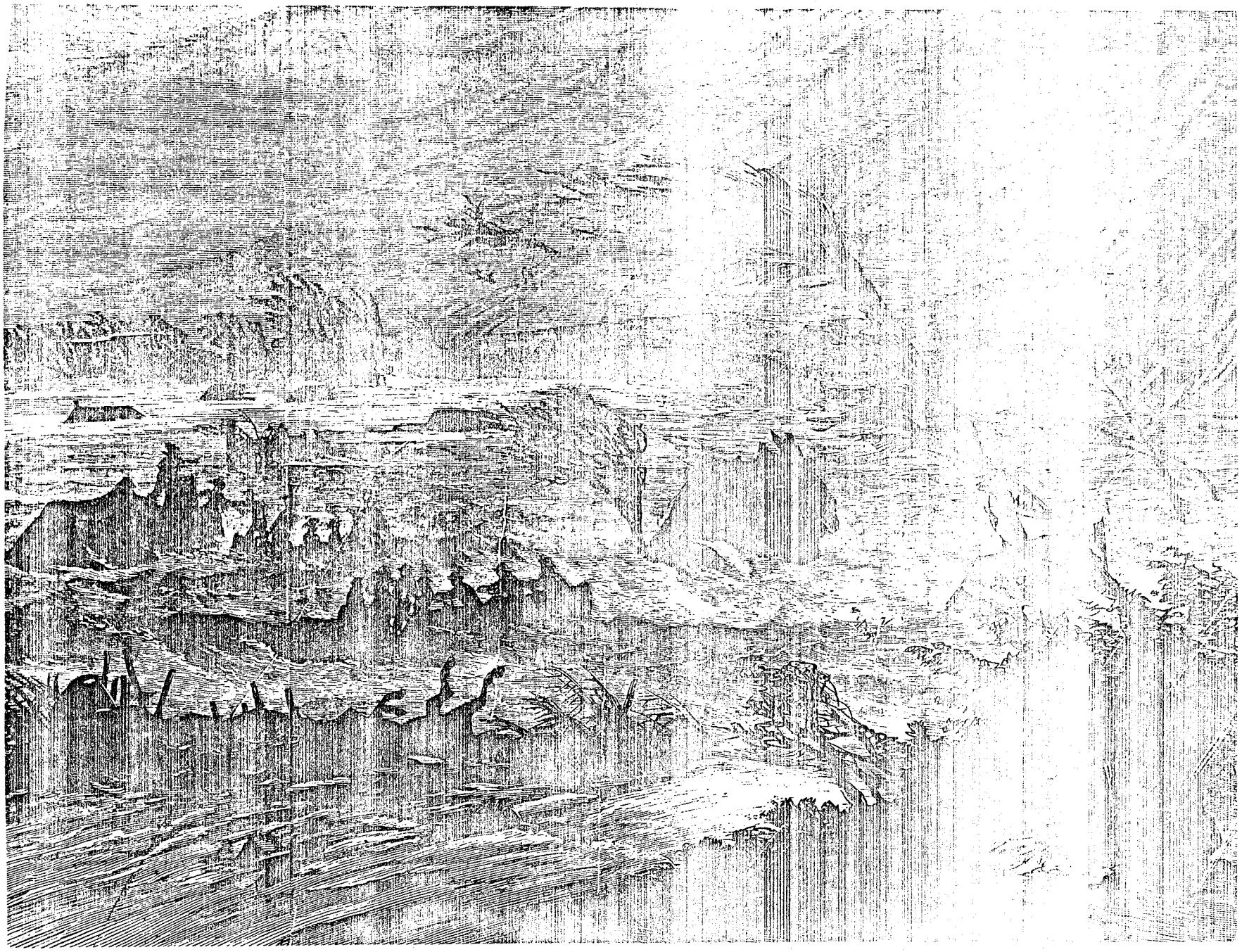

THE FLOODS IN THE WEST INDIES—INUNDATION OF THE ISLAND OF TORTOLA.

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Foreword

Many people from Clark University helped in bringing this monograph to completion. Six students worked with me in presenting the first questionnaires concerned with hurricanes in four Virgin Islands in January 1969. The results of this preliminary survey were pulled together in a mimeographed report "Luck, Prayer, and Cycle", written by the senior author, and incorporated in Parts 3 and 4 of this monograph. This early report benefitted from the hard, constructive criticism of R. W. Kates and his 'hazard seminar' in the spring of 1969, and it was Bob Kates who encouraged us to test the I. G. U. Hazard questionnaire in St. Thomas in January 1970. Gilbert White of the Institute of Behavioral Sciences, University of Colorado provided funds to defray our transportation costs and subsequently arranged for the processing of the data analyzed in Parts 3 and 4.

The nine students who accompanied me in testing the I. G. U. questionnaire experienced much frustration and encountered much hostility in many areas of St. Thomas. They pursued their tasks in most cases with commendable resolve, particularly Henry Aay, W. Banning, John Sorenson, Bob Simpson and Marc Eichen.

In 1972 our task was to pull together and analyse data on the hurricane as reality. Much spadework was done by the group in the fall of 1971, many hours of reading and copying newspaper reports were expended at the New York Public Library and the Public Library, Charlotte Amalie. We also spent much time in the office of Robert Calvesbert, Commonwalth Climatologist, Puerto Rico. The group then worked closely on the materials that constitute Parts 1 and 2 of the report. Only in the last week were the tasks of writing the separate sections apportioned to the individuals named as authors in the Table of Contents. Successive drafts of the 'sections' were discussed in seminar by the group as a whole and then subjected to the editorial pen of the senior author. The whole was a fine and commendable group effort by some excellent people: Diana Fainberg, Stephen Barnhart, Melvin Norris, Bernard Greenspan, Richard Martin, Geoffrey Weiner, John Shapiro and Richard Kollmar.

The staff at the Peace Corps Training Center, St. Thomas in 1969, 1970, and 1972 always made us welcome and by providing accommodation at reasonable cost made our research possible; Mr. Stephen Johnson of Mary's Fancy in 1969 and 1970 helped us greatly with transport expenses; Dr. Edward Towle of the Island Resources Foundation and the late director of the Caribbean Research Institute and Robert vanEepoel of Insular Environments, Inc. were truly 'our men in St. Thomas' providing us at times with financial, and at all times with moral, support in our endeavors. Miss Enid Baa always seemed to realize the potential value of our studies and has gone out of her way to make our work on the microfilm readers as pleasant and productive as such tedious work can be. And Robert Calvesbert answered many of our questions while spending time with us on St. Thomas in 1972, made available his hurricane library, and established many contacts for us in Puerto Rico. Without our Caribbean friends this monograph would not have been possible.

In a very real sense our presence in the Caribbean was due in all three years to those in charge of the January Study Project at Clark University who found our projects worthy and provided us with basic funds for equipment and supplied on-island and inter-island transportation, etc. For my own support in the islands in 1969, 1970, and 1972 I am also greatly indebted to Dr. Saul Cohen and the Graduate School of Geography, Clark University; and to Margaret, Marc. and Jonathan I owe a peace of mind that has come with them whenever we've been together in the islands.

What follows - the research design and interpretation in Parts 1 and 2, and the writing in Parts 3 and 4 - is my responsibility.

Twelfth Night, 1973
Lindbergh Bay, St. Thomas

Martyn J. Bowden

(News clipping) (V.I. Times)

"VIRGIN ISLANDS' CATASTROPHE"

Charlotte Amalie, Oct. 10. Linda, the most damaging hurricane in the island's history struck St. Thomas and apparently St. John in the early hours of yesterday morning. Chaos reigns, and only the wildest rumors are circulating. Telephone and electricity wires are down, and main roads are blocked or washed out in the center of St. Thomas at least. The island is no longer one but rather many isolated communities, and it may well remain so for a week. Thirty are already known to be dead, and a conservative estimate places loss of property at $50 million. Clearly this hurricane of 1980 will go down as the Islands' worst.

The infamous Linda passed south of St. Maarten on October 7th and 8th, and was reported with winds of 100 mph before hitting St. Thomas. It must have intensified substantially and extended its diameter by 15 miles, for from the evidence of damage to warehouses, docks and hangers winds must have gusted to 144 miles in the passage over the island. The calm eye has been reported from Frenchman's Bay, Charlotte Amalie, and Brewer's Bay - it must therefore have been at least 4 miles wide. The hurricane appears to have moved at a very slow 8mph.

The barometer dropped to 27.96 at Frenchman's Bay and Charlotte Amalie and 27.99 at Truman Field.

Looking at a report published 7 years ago in 1973 we see that only 3 hurricanes in the last 120 years had pressures lower than Linda's eye, and only 2 had stronger winds. It is hard as yet to say how high the tidal surge was, but the record of mud, rock, wood, boats, sand, and trees at Lindbergh, Crown and Long Bays in particular suggests that it was about 10 feet - again slightly less severe than those of the hurricanes of 1867 and 1916. Linda brought a near-record 12 inches of rain (in 36 hours) to Fort Mylner; 10.3 inches to Charlotte Amalie, and 8.1 inches (in 24 hours) to Truman Field. From our vantage point alone, the worst prophesies of the Office of Civil Defense have been fulfilled. Many houses built with projecting eaves in the last 50 years have had their roofs ripped clean off, slightly loose corrugated iron was ripped off homes and made lethal missiles, and there are very few of the newer homes whose plate glass and jalousied windows were apparently able to withstand winds that were steady for long periods at more than 115 mph.

Iron roofs, coconuts, large branches, even trees, signs, shingles, buckets etc. hurtled through the air. From Wintberg through Mafolie to Crown Mountain the story of wind damage is the same, and the situation is rumored to be worse on the North Side and at Mandahl which are cut off by road blockages. From the waterfront with binoculars we can see that some landslip and collapse of structures has occurred in the Mafolie area, and the Mafolie road is blocked by some massive slides of rock, soil and shrubs - something that was to be expected after such heavy soaking rains (8 inches in 10 hours?) accompanied by such high winds that loosened broad sheets of protective soil and vegetation.

Rumors telling of disastrous landslip attended by loss of life continue to dribble in from Fortuna - Bordeaux where most residents elected to stay despite the absence of a local medical center. On the East End by contrast tidal surge caused much damage, inundating and largely destroying three beach resorts and causing heavy damage at Vessup and Benner Bays. Fortunately most of the housing at Frydendal appears to be saved. The surge in the east was apparently less than at Charlotte Amalie, and there was no 'calm' on the north, suggesting that the eastern limit of the eye may have been Nadir, Donoe and Wintberg (and missing Tutu?).

Whether for this reason or because of the soundness of the structures, roof anchoring and steel-louvred windows, the general damage levels in the Tutu area appear relatively low. Flooding is the serious problem here. The Mylner Shopping Center is under 4 feet of water and all of the three guts that join at Fort Mylner backed up and flooded the houses near them to as much as two feet deep. But the providence that spared Tutu was apparently the death-dealing blow that struck Nadir and Bovoni. The millions of gallons that rushed past Fort Mylner down narrow Turpentine Run met the tidal surge head-on and led to a flood back-up of between 10 and 15 feet, and possibly more, at Nadir. Some houses may have been completely inundated, and reliably verified loss of life here already insures that Linda will be the worst killer-hurricane in Virgin Islands' history.

We know little about St. John except that the planned evacuation of campers and of the exposed residents of Cruz Bay to the Nazareth School at Redhook was only partially completed when Linda hit, although it appears that the worst section of the storm probably affected the southern portions of the island only.

Most of the readers of this limited edition will be city residents and will know the scale of the devastation here in Charlotte Amalie. The compact stone building of the Danish period with their strong wooden and metal shutters were models of resilience as they were in 1916, 1871, and 1867, and although the tidal surge passed over Main Street in many places there are some business buildings whose merchandise is largely undamaged. But such buildings are a minority in the area between Main Street and the waterfront where tidal surge and floodwater back-up together with the high level of window and door breakage have insured that most first-floor merchandise has been written off. The worst damage to the commercial area is concentrated between the Center cinema and the Post Office and between St. Peter's and the market (where back-up was particularly bad). In the district behind St. Peter's hundreds are homeless as a result of high wind damage combined with an extraordinary and unexpected flood back-up. It appears also that the dead center of the eye was here for upwards of 45 minutes in an area with many wooden houses. Some of the shouses imploded and collapsed. The scale of damage here and at Nadir and Fortuna may turn out to be the surprises and the real tragedies of the storm.

Equally disastrous yet expected were the disasters at Pearson Gardens, Altona-Contant, Frenchtown, and Nisky. From the Antilles Airboat dock through Honduras, Demerara and Frenchtown is a wasteland from which all residents were fortunately evacuated, and similar disaster befell the warehouses and homes tretching back from Crown Bay between Wayne Aspinall School and the Sub-Base. Fortunately disaster here was foreseen and loss of life averted by evacuation.

Some relief supplies are already coming in by helicopter and this may well be our only link with the outside world for some days. Word from Truman Field is that the airport is a tangled mass of bushes, wire, trees, mud, metalwork, sand, stones and water, and that households in the area had water and mud up to 2 and 3 feet in their homes. Most people were evacuated to the College. Electric lines are down throughout the island and it is estimated that the earliest that electricity will be restored, with the help of linemen from Puerto Rico and the mainland, will be 2 weeks. Only now do we realize that so many of the supermarkets, mini-marts and food wholesale warehouses were liable to flooding from either tidal surge or overland torrents or both. We can only hope that Sub-Base and the West India Dock will be cleared rapidly enough to get relief supplies in. Emergency food supplies are available for the moment at St. Peter's, Lincoln, and Nazareth schools. The Office of the Director of Civil Defense and the Office of the Governor have issued the following proclamations and warnings.....

A journalist with crisper English will very probably report a hurricane at least as disastrous as this before 2000. Such storms have come on average once every 33 years in the last 150 years, and there is no scientific reason to believe that such a storm will not come in the next 25 years, even though it has been 57 years since the last storm of this type hit St. Thomas directly. What is clear is that these future hurricanes of the magnitude of 1867, 1871, and 1916 will cause an unprecedented amount of damage on St. Thomas and St. Croix since, in these 57 years, the U.S. Virgin Islands have been transformed from the 'poor men' to the 'rich men' of the Caribbean. There is now a vast amount of loss (in dollar value) such that hurricanes of secondary force, e.g., that of 1932, were they to pass over St. Thomas now, would cause far more dollar damage than the disastrous whirls of 1867, 1871 and 1916 did.

The amount that will undoubtedly be lost when the hypothetical Linda and her awesome sisters hit the 'American Paradise' has been compounded and is being compounded every day; for every day there are new immigrants to the Virgin Islands--mainly continentals--who are told, and may want to believe, that the hurricane danger is minimal or non-existent. There is at least one generation of Virgin Islanders, and perhaps two, who share the 'hurricane myth'. It is for the education of these people (primarily) that the first part of this report was written, but it will also provide information for any group, government agency etc. that wishes to place the recent past in perspective. This section of the report sets out a chronology and classification of all the tropical cyclones that have

passed within 200 miles of St. Thomas since 1866 and indicates the potential damage-producing characteristics of these storms. It predicts the chances of future occurrence of such storms on a yearly basis and on a weekly basis during the hurricane season.

Attempts are made in part two to assess the nature and extent of damage produced by these storms--by wind, tidal surge, flood, pressure changes etc. -- and to suggest thereby the potential damage-producing characteristics of the storms that will inevitably hit St. Thomas in the next 100 years. These estimates are crude, particularly those used to predict probable precipitation levels and flood damage potential. They are also as accurate as is possible without a heavily-funded research endeavor, and as accurate as is necessary to convince homemaker and businessman of the danger of hurricanes.

When the hurricane reality (parts 1 & 2) is compared with hurricane conceptions and views of the hurricane hazard (part 3) the rationale of this report is transparent: a vast and dangerous discrepancy between the two is documented, and this must needs be made part of the Virgin Islander's consciousness by government agencies, educational establishments, citizens' groups, communications media, etc., if a future catastrophe is to be averted or at least mitigated. Part three should aid these groups in pinpointing the inaccuracies, misinformation, and mis-

leading analogs of the populace, and provide an initial basis for a hurricane preparedness 'talk-in' at the community and, ideally, at house-to-house levels. (Talk-ins of the latter type would of course be dependent on costly and complex simulations of the passage of future probable hurricanes--what was to be the final part of this report). In the absence of such detailed and intensive studies and subsequent talk-ins it will be necessary to focus hurricane education programs upon certain groups, and it is the major purpose of part four to show which groups--by age, sex, housing status, provenance, religious affiliation, former hurricane experience etc. -- are most in need of hurricane education. Part four identifies those who are unaware of, and make few if any of the necessary preparations for, a hurricane when one is forecast. No more than the crudest indications of the scale of preparedness for a severe hurricane are documented, but these suffice to portend a great future disaster.

PART I: TROPICAL CYCLONES

(1.)

CHARACTER AND FREQUENCIES IN ST. THOMAS

Definitions

Tropical cyclones and their damaging effects are known in and throughout the West Indies. They are of three types: tropical depressions, tropical storms, and hurricanes. The basis for differentiation among the several types is the maximum wind speed, and the standard definitions adopted here follow Dunn and Miller,[1] and Cry,[2] and Cry, Haggard, and White.[3]

Tropical depressions have wind speeds up to 38 miles per hour, while tropical storms have wind speeds ranging from 38 to 73 miles per hour. Hurricanes have wind speeds of at least 74 and as much as 200 miles per hour. All three have certain characteristics in common.

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[1]Gordon E. Dunn and Banner I. Miller, Atlantic Hurricanes, Baton Rouge: Louisiana State University, 1960, pp. 9-10.

[2]George W. Cry, "Tropical Cyclones of the North Atlantic: Tracks and Frequencies of Hurricanes and Tropical Storms, 1871-1963," U.S. Weather Bureau, Technical Paper No. 55, Washington, D.C., 1965, pp. 2-3.

[3]George W. Cry, William H. Haggard, and Hugh S. White, "North Atlantic Tropical Cyclones: Tracks and Frequencies of Hurricanes and Tropical Storms 1886-1958," U.S. Weather Bureau, Technical Paper No. 36, Washington, D. C., 1959, pp. 1-2.

For instance, north of the Equator they are counter-clockwise swirls of wind. As the wind speeds increase, eye formation becomes more distinct until in hurricanes, the eye may have a radius of five to ten miles.[4]

The tropical cyclones that passed through and close to the Virgin Islands, and in particular St. Thomas, between 1867 and 1967 were all classified on the basis of these definitions. Emphasis was on those tropical cyclones that were of some consequence to the islands, either beneficial (as in drought-breaking rains) or destructive (as in flooding, tidal surge, and dangerous winds). The classification that follows is therefore unique to St. Thomas (and to a large extent St. Croix), although the method can be applied elsewhere.

The area of investigation focussed on St. Thomas and a region of 200 miles in radius. One hundred hurricanes and tropical storms passed through this region between 1867 and 1967, if the monographs of Garriott,[5] Mitchell,[6] and Stone[7] are taken as authoritative. The data

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[4]Tropical depressions were excluded from our study because of the minimal damage they effect.

[5]E. B. Garriott, West Indian Hurricanes, U. S. Weather Bureau, Washington, D. C., 1900, p. 69.

[6]Charles Mitchell, "West Indian Hurricanes and other Tropical Cyclones of the North Atlantic Ocean," Monthly Weather Review, Supplement No. 24, 1924, W. B. Publ. #840, Washington, Government Printing Office, pp. 3-47.

[7]Robert G. Stone, "Meteorology of the Virgin Islands," Scientific Survey of Puerto Rico and the Virgin Islands, New York Academy of Sciences, 19, Part 1, 1942, pp. 1-138.

drawn from these sources were checked against studies made by Cry,[8] and Cry, Haggard, and White.[9] Finally, many local newspapers were examined.[10] It was found, on the basis of newspaper accounts, that of the 100 tropical cyclones 48 had affected St. Thomas in some way. These were the storms of the 'revised chronology' (Table 1) subjected to detailed analysis in the pages that follow.

Pattern of Hurricanes 1867-1967

When reduced by means of ten-year moving averages, the data in the chronology reveal two peaks of cyclonic activity: 1890 to 1914, and 1928 to 1938 (Figure 1). A random rather than a cyclical pattern of hurricane occurrence is revealed, as might be expected. It should be stressed, however, that the 100-year time-period and the paucity of early accounts conspire against establishment of long-range trends.[11] Reports of

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[8]Cry, op. cit.

[9]Cry, Haggard, and White, op. cit.

[10]Newspapers consulted in the Library, Charlotte Amalie were The (St. Thomas) Daily News, 1933-1971; St. Thomas Tidende, 1867-1908; St. Croix Avis, 1871-1971; St. Thomas Mail Notes, 1928; and The Bulletin (St. Thomas), 1917-1932.

[11]This statement remains true despite the excellent work of Jose Carlos Millas, Hurricanes of the Caribbean and Adjacent Regions, 1492-1800, Academy of the Arts and Sciences of the Americas, Miami, Florida, 1968.

endemic droughts in the 1870's and 1880's[12] and since 1910 (excluding the 1930's) confirm our findings, inasmuch as the relative wetness of the 'hurricane season' (July to October) is positively related to the number of tropical storms passing. An interesting paradox is also revealed in Figure 1, in that the three major hurricanes to have hit St. Thomas in the last 100 years--those of October 1867, August 1871, and October 1916-- occurred outside of these peak periods of hurricane frequency.

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[12]Martyn J. Bowden et al., Climate, Water Balance, and Climatic Change in the Northwest Virgin Islands, St. Thomas: Caribbean Research Institute, 1970.

Date of tropical cyclone	Classification St. Thomas	Relative [illegible] St. Thomas	St. Croix	Lowest pressure (in inches) Unknown	St. Thomas	St. Croix	[illegible] Unknown	[illegible] St. Thomas	St. Croix	[illegible] (surface)	[illegible]	[illegible]
Aug 2-3 1837	1A	A	Bn	27.8	27.8		S 1[illegible]	S 1[illegible]				
Oct 29 1867	1A	A	Bn	27.95	27.95		S 13[illegible]	G 170 13[illegible]		20	ESE	
Aug 23 1871	2A	A	Bn	[illegible]	2[illegible].40		G 143 S 115	G 143 S 11[illegible]	G 120 S [illegible]63		[illegible]L	
Sept 10-11 1872	(3C)	Ce						(<[illegible])				
Sept 14 1876	3Bs	Bs	A	2[illegible].1[illegible]		27.1[illegible]	S 157	[illegible] S [illegible]	S 157	21.6	ESE	
Nov 27-29 1878	3	Cs				29.75		G 65 S 45-50	S 45-[illegible]			
Aug 21-22 1881	3Bs	A			29.[illegible]			G 75 S 4[illegible]-[illegible]0		3[illegible]		ma[illegible] sur[illegible]
Sept 3-4 1889	3Bn	Dn			29.32	29.5[illegible]		G 91 S 65-70			ESE	min. wind
Aug 19-20 1891	(3C)	Cs	Bs			29.81		(<60)			SE	heavy rains
Sept 2-3 1891	(3C)	Dn	Dn					(<60)				heavy rains
Aug 17 1892	(3C)	Dn	Dn			29.69		(<60)				
Aug 16-17 1893	2Bs	Bs	Bs		29.63	29.55		G 105 S 75-80	G 111 S 80-85			heavy rain min wind mod surge
Sept 20 1894	(3C)	Cs			Slight Depr.			(<60)				
Aug 31 Sept 1 1896	(3C)	Cs	Cs					(<60)			SE	
Sept 11-13 1898	(3C)	Ce						(<60)				
Aug 7-9 1899	2Bs	Bs	Bs	P.R. 27.75	29.30	29.02	P.R. 137	G 117 S 85-90	G 130 S 95-100			major flood surge min wind
Aug 30-31 1899	(3A)	A	Bn					(<60)			ESE	
July 6-8 1901	3C	Cs	Cs		29.86			G 85 S 60-65	G 85 S 60-65		ESE	min wind surge
Sept 11-12 1901	(TS) 3Bn	Bn	Cn		29.78	29.82		G 78 S 55-60	G 78 S 55-60	12	ESE	
Oct 9 1901	(TS) (3Bs)	Bs	A			29.82		(<60)	55-60		SE	
Sept 2-3 1906	3Bn	Bn	Cn		29.72	29.82		G 50 S 39				
Sept 26 1908	(TS) (3C)	Cs			29.81			(<60)			E	
Aug 22 1909	(TS) 3C	Ds			29.72			<60			W	major flood
Nov 13-14 1909	(TS) 3C	Cn			29.71	29.30		<60				
Aug 24-25 1910	(TS) 3C	Cs	Cs					<60			E	
Sept 6-7 1910	3Bs	Bs				29.74		<60	G 70 S 54	18-20		min. wind
Aug 10-11 1915	(3C)	Ds		J 29.34				(<50)		12.5	ESE	
Aug 21-22 1916	2Bs	Bs		29.20	29.65		150+	G 120 S 92			E	mod. flood + wind
Aug 30 1916	3C	Ds		J 29.20				G 65 S 40-50				min. wind
Oct 9-10 1916	1A	A	Bn	28.10	28.10	28.65		G 160 S 125			SE	mod. flood surge major wind
Aug 28-29 1924	2Bn	Bn			28.56			G 143 S 110			SE	mod. wind
Sept 12-14 1928	2Bs	Bs	A	27.50	29.30	(C) 28.90	165	G 130 S 90-100				min. wind major surge
Sept 2 1930	3C	Cs			29.76							
Sept 10-11 1931	3Bs	Bs			29.52							
Sept 26-27 1932	2Bs	Bs	Bn		29.20	29.55	F.R. S 120	G 117 S 85-90	G 91 S 60-70			mod. wind
July 25-26 1933	(TS) 3C	Cs	Bs		29.89	29.65		G 78 S 60	G 91 S 60-70	12	SE	
Aug 29 1933	(TS) 3Bn	Bn			29.86			S<50		10	E	min. flood
Aug 25 1937	(TS) 3C	Cn			29.90			S<50		8	SE	
Oct 13 1939	(TS) 3C	Cn		29.40	29.74			G 91 S 65-70				
Aug 5 1940	(TS) 3Bn	Bn			29.91			G 26 S 20		14	SE	
Sept 12-13 1945	3C	Cn						G 31 S 24		16		
Aug 23-24 1949	(TS) 3C	Cn			29.32		70	S<60				
Aug 21-22 1950	3C	Cs			29.84		92	G 50 S 35-40	G 78 S 60		ESE	
Sept 8 1953	3Bn	Bn						G 45 S 35			SE	
Aug 6-7 1955	3Bn	Bn				29.52		G 71 S 50-55				mod. floods
[illegible] 11-12 [illegible]	2C	Cs			28.65		10[illegible]	G 104 S 80		15	SE	min. mod. surge mod. flood
Sept 4-5 [illegible]	2Bn	Bn			28.05		128	G 104 S 75-80				min.- mod. flood
Sept 26 [illegible]	3C	Ds		28.26			120	G 58 S 40-45		16		min. surge
Sept 4 [illegible]	3C	Ds		27.76			137	G 85 S 55-65				min. surge

10-Year Moving Average for Frequency of
Tropical Storms and Hurricanes (St. Thomas) 1867-1967

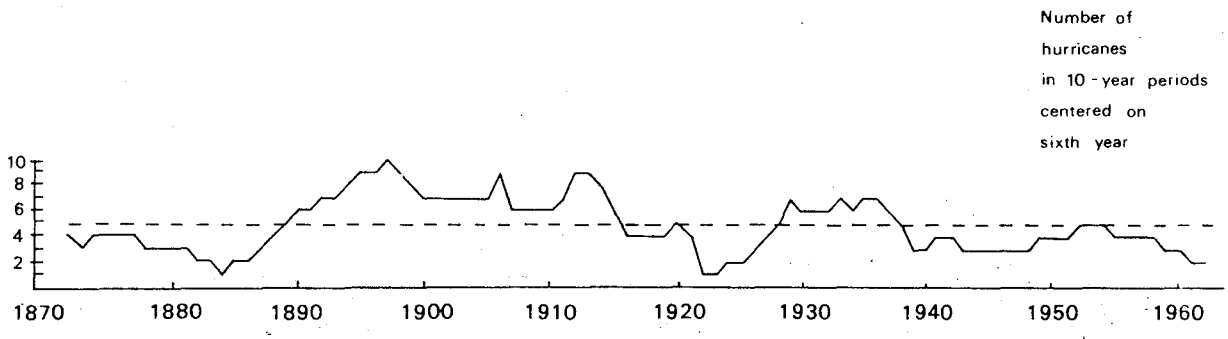
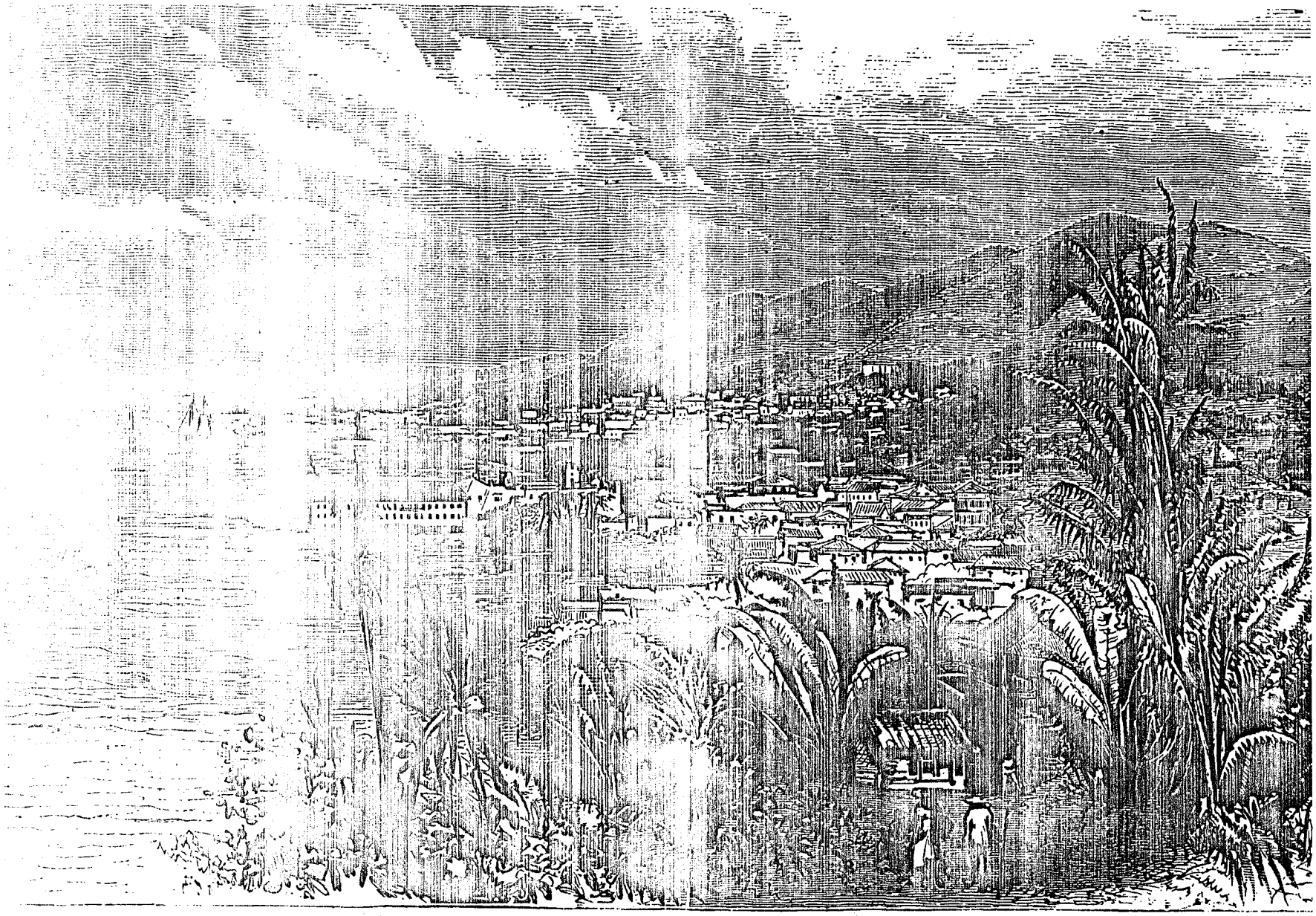
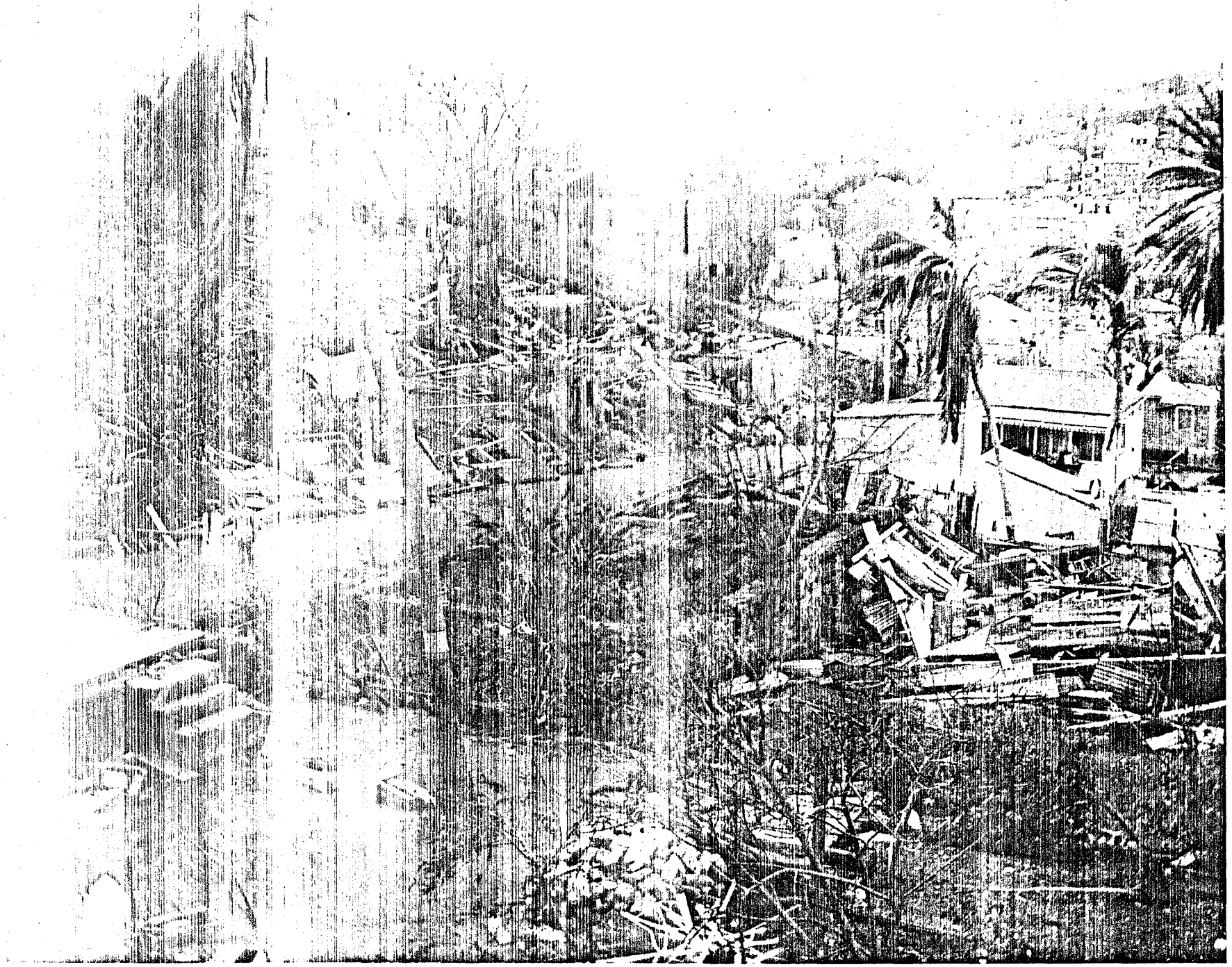


Figure 1



THE TOWN OF ST. THOMAS, NEARLY DESTROYED BY A HURRICANE, AUGUST 21, 1871.—[SEE PAGE 869.]



The Town of Charlotte Amalie, August 28, 1974

Probabilities of Tropical Cyclones in St. Thomas

The probabilities of tropical cyclones affecting the Virgin Islands are presented in Table 2, which compares our calculations with those of Hope and Neumann[13] and those of vanEepoel, Owen, and Dammann of the Caribbean Research Institute (column 4).[14] A probability is taken here to mean a percentage chance of occurrence. In this case, it is the most likely pattern of occurrence if 48 tropical cyclones were generated in 100 years. A frequency is taken to mean the actual pattern of occurrence of these 48 tropical cyclones between 1867 and 1967. Hope and Neumann's probabilities (column 3) are based on tropical cyclone occurrences from 1886 to 1968. The probabilities calculated by the Clark group (column 1) are based on the revised chronology of 48 hurricanes and tropical storms occurring between 1867 and 1967. The second column summarizes the actual frequency pattern of these 48 storms.

At least one tropical cyclone affected St. Thomas in 39 of the last 100 years (frequency), and the probabilities of such an occurrence predicted by the Clark group and by Hope and Neumann are similar: 42 and 47 years in 100, respectively. Probability of occurrence of at least two hurricanes per year is .06 (one year in 16) as calculated by

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[13]John R. Hope and Charles J. Neumann, Climatology of Atlantic Tropical Cyclones by Two and One-Half Degree Latitude-Longitude Boxes, E.S.S.A. Technical Memorandum WBTM SR-44, Weather Bureau, Southern Region, Fort Worth, Texas, February, 1969.

[14]Robert P. vanEepoel, Wadsworth Owen, and Arthur E. Dammann, Notes on Some Oceanographic and Marine Factors in the U.S. Virgin Islands, St. Thomas: Caribbean Research Institute, Special Publication No. 2, March, 1971.

TABLE 2

PROBABILITY AND FREQUENCY OF TROPICAL CYCLONES ON ST. THOMAS

Number of tropical cyclones per year	Probabilities based on the occurrence of 48 cyclones 1867-1967.	Frequencies-based on the timing of the 48 cyclones that affected the V. I. 1867-1967.	Hope and Neumann: Probabilities based on storms passing through the grid block bounded by lat. 17° 30'-20° 0'N long. 70° 0'-72° 30'N 1886-1968.	Caribbean Research Institute (1971) Probabilies based on hurricane occurrences in St. Thomas, 1680-1963.
0 per year	.58	.61	.53	.94
at least 1 per year	.42	.39	.47	.05
at least 2 per year	.06	.07*	.13	.00

*There were two years in which three hurricanes affected the Virgin Islands between 1867 and 1967: 1901 and 1916.

the Clark group and .13 (one year in 8) according to Hope and Neumann. The actual frequency of occurrence of at least two tropical cyclones per year in the last 100 years is .07 (one year in 14).

Understandably, Hope and Neumann present probabilities of tropical storm occurrence that are somewhat larger than ours. They included in their calculations all tropical storms and hurricanes that passed through an arbitrarily defined study area: the two and one-half degree latitude-longitude box containing the Virgin Islands (lat. 17° 30' - 20° 0'N, long. 70° 0' - 72° 30'W). The U. S. Virgin Islands are southwest of the center in this grid block. By contrast, the Clark group chose an area centered on the island of St. Thomas and counted only hurricanes and tropical storms that had a noticeable effect on the Virgin Islands. Consequently our results are more directly applicable to the Virgin Islands than are those of Hope and Neumann.

Despite differences in time-period, area, and focus, however, the similarities of the probabilities calculated by Hope and Neumann and by the Clark group are striking.

Both results contrast sharply with probabilities recently presented in a publication of the Caribbean Research Institute (1971).[15] How these probabilities were derived is not explained, but it may be that the authors were concerned only with the largest hurricanes. Apparently

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[15] Ibid.

all hurricanes from earliest recorded dates to 1963 were considered. As many of these early hurricanes went unrecorded, or were associated in records only with the Caribbean island that suffered the worst impact of the hurricane, any calculations based on hurricanes of record in the last 283 years are bound to underestimate the frequency of their occurrence. In addition, the probability of occurrence of hurricanes as presented by the C. R. I. monograph appears to be related positively to the size of land mass.[16] Whatever the methods used, the probabilities derived are misleading.

Tropical Cyclone Characteristics and Classifications

To this point no distinctions have been made among the 48 tropical cyclones, although obviously they varied in many ways. Our ultimate concern was with estimating the potential damage that might be inflicted by tropical cyclones of various types. Thus, in accumulating data particular attention was paid to those elements of tropical cyclones that were measurable predictors of damage (Table 1). Occasionally, informa-

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[16] In the table of probability given in the C. R. I. monograph, Cuba, Hispaniola, and Puerto Rico have very high probabilities compared with the Virgin Islands. In the probabilities given by Hope and Neumann, most of the grid blocks covering Hispaniola and Cuba have a lesser probability of tropical storms and hurricanes than the Virgin Islands, and Puerto Rico has approximately the same probability of occurrence as the Virgin Islands. Presumably the number of hurricanes affecting the large land masses was compared to the number of hurricanes affecting the small land masses, without any weighting for size.

tion was limited or contradictory. In such cases, attempts were made to reconstruct the storm using the most reliable information available.

For 37 of these 48 tropical storms and hurricanes, data drawn from Mitchell, Stone, Garriott and the local newspapers proved satisfactory. For the remainder, classifications were interpolated from known trajectories and hurricane data for Puerto Rico, Tortola, St. Kitts, etc. These eleven storms--essentially weak--are indicated in parentheses in Table 1, column 1.

In determining the key characteristics in hurricane classification special attention was paid initially to the three major effects of hurricanes: rains (either beneficial or destructive), winds, and tidal surge. As regards the winds, it was important to establish pressure readings or actual wind speeds or both at the center of the storm. Similarly, angle of approach, central pressure, highest wind speeds, and speed of the forward movement were needed in computing the level of tidal surge. Rainfall computation, however, depended heavily on non-tropical cyclone variables. Nevertheless, for rainfall as with the other two elements, it was necessary to know the position of the storm relative to St. Thomas; its line of passage (directly over, north, south, and east of the island); and distance from St. Thomas.

From this list of characteristics, three facts were seen as critical: 1. wind speeds at St. Thomas; 2. the line of the tropical cyclone's passage (north or south); and 3. the distance in miles of the storm center from St. Thomas. Three ranges of wind speed at St. Thomas were recognized: less than 74 miles per hour (storm type 3 in Table 1); 74 to 120 miles per hour (storm type 2); and over 120 miles per hour (storm type 1). Increased damage levels were related to winds of the three types, as is seen in Part 2. Tropical storms that passed directly over St. Thomas were designated as type 'A'; those that passed within 50 miles as type 'B'; and those that passed 50 to 200 miles from St. Thomas as type 'C'. In addition, uncapitalized 'n' (north) and 's' (south) are used. Thus, a 2Bs storm is one that passes within 50 miles to the south of St. Thomas, but not directly over it. In such a storm (hurricane) St. Thomas would experience windspeeds of 74 to 120 miles per hour.

Theoretically, there are 18 possible types of tropical cyclones in the classification. But as applied to St. Thomas, certain types were combined or excluded. For example, St. Thomas is so small that an 'A' type hurricane would completely cover the island. In this case, the appending of an 'n' or 's' would be meaningless. Similarly, 'C' type storms pass so far away that their passages to the north or south, 50

or 200 miles away, have only minor effects on wind speeds, tidal surge, and rainfall. Rather, the most important characteristic is the strength of the storm, which is best shown by the wind speeds in St. Thomas. Similarly, because of the distance of the eye from St. Thomas, there were no winds over 120 miles per hour (type 1) recorded over the island in either 'B' or 'C' type tropical cyclones. In total, nine types of tropical cyclones that affected St. Thomas are recognized in Table 3.

The Occurrence of Tropical Cyclones of Various Types

In the past one-hundred years, four hurricanes of A-type have passed directly over the Virgin Islands. The hurricanes of 1867 (October 29) and 1916 (August 21 and 22) are considered the most memorable examples of this most severe hurricane experienced in the northern Caribbean. In the 100 years preceding 1867 at least two storms of this magnitude affected the Virgin Islands,[17] and this suggests that the probability of occurrence of such storms is 3 to 4 percent or one in every 25 to 33 years (Table 4). Five out of the six A-type hurricanes of the last 200 years occurred between Supplication Day (July 25) and the local Thanksgiving Day (October 25). The one exception, the hurricane of October 29, 1867, was probably the most severe A-type hurricane experienced in the Virgin Islands. A-type hurricanes have occurred either early or late in the season. No hurricanes of this type have occurred during the month of September.

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[17]These were the storms of August 31, 1772 and August 2 and 3, 1837.

TABLE 3

Frequency of Nine Types of Tropical Cyclones

Experienced in St. Thomas, 1867-1967

Wind Speeds at St. Thomas	Distance of storm center from St. Thomas				Total
	Directly over St. Thomas	Within 50 miles and to the north Bn	Within 50 miles and to the south Bs	More than 50 miles away C*[1]	
over 120 mph (type 1)	2	0	0	0	2
74 - 120 mph (type 2)	1	2	4	1	8
less than 74 mph (type 3)	1	8	5	24	38
Total	4	10	9	25	48

*[1] The D-type storms of Table 1 were combined with C-type storms.

TABLE 4

Occurrence of Tropical Cyclones of Various Types

Type	Total Number	Frequency of Type	Cumulative Frequency	Probability of Type	Cumulative Probability of Types
A	4	.04	.04	.04	.04
Bs	9	.09	.13	.07	.11
Bn	10	.10	.23	.07	.18
C*	25	.24	.47	.22	.40

*The D-type storms of Table 1 were combined with C-storms.

A majority of hurricanes that have affected the Virgin Islands have been of the C-type (Table 4). Of the storms that have come outside of the official hurricane season, all but one have been of this less destructive type (Table 5). They make up a large portion of the storms in the early part of the hurricane season (August 10 - September 2) and in the late season (September 17 - October 27), and are outnumbered by A- and B-type storms at the height of the hurricane season (August 26 - September 18). Only one B-type has been recorded outside of August

and September, and most (11 to 19) occurred in the three weeks at the height of the hurricane season. There is a clear tendency for the less damaging 'Bn' variant to occur early in the season whereas the 'Bs' type tends to occur later.

TABLE 5

Frequency of Tropical Cyclones During Selected Periods

Type	Jan. 1 July16	July17 July24	July25 Aug.1	Aug.2 Aug.9	Aug.10 Aug.17	Aug.18 Aug.25	Aug.26 Sept.2	Sept.3 Sept.10	Cont. Below
A	.00	.00	.00	.00*1	.00	.01	.01*2	.00	
Bs	.00	.00	.00	.01	.01	.01	.00	.02	
Bn	.00	.00	.00	.02	.00	.01	.03	.03	
C	.01	.00	.01	.00	.03	.06	.04	.02	
Total	.01	.00	.01	.03	.04	.09	.08	.07	

Type	Sept.11 Sept.18	Sept.19 Sept.26	Sept.27 Oct.3	Oct.4 Oct.11	Oct.12 Oct.19	Oct.20 Oct.27	Oct.28 Nov. 4	Nov.5 Dec.31
A	.00	.00	.00	.01	.00	.00	.01	.00
Bs	.02	.01	.00	.01	.00	.00	.00	.00
Bn	.01	.00	.00	.00	.00	.00	.00	.00
C*3	.02	.02	.01	.00	.01	.00	.00	.02
Total	.05	.03	.01	.02	.01	.00	.01	.02

*1 Hurricane of 1837 occurred at this time.
*2 Hurricane of 1772 also occurred in this period.
*3 D-type storms of Table 1 were combined with C-storms.

PART II: THE DESTRUCTIVE FORCE OF TROPICAL CYCLONES ON ST. THOMAS

Wind Damage

When a hurricane strikes a populated area, much of the damage will be caused directly by the intense winds. In this study, therefore, an attempt has been made to reconstruct the character of the winds associated with each hurricane in the chronology. For most of the tropical cyclones affecting the Virgin Islands, however, the available information from newspapers and climatological data is very limited. In many cases the only references to winds were reports of damage, as in 1916:

> The fall of the coal cranes afford the best idea of the force of the wind. These huge machines were made to withstand a wind velocity of 100 miles an hour, but their collapse during the second part of the storm proves the speed of the wind to have been greater.
>
> The sight of coal cranes lying in a heap of bent and twisted ruins is an extraordinary one, a part of each hanging in the sea. Who among us saw those monster machines put up, each taking months to erect and each having no less than 35,000 rivets, ever imagined they could be wrecked by wind![18]

Reports such as this indicated extremely strong winds producing heavy damage, and it became clear from numerous newspaper accounts that such damage was produced by winds that exceeded 120 mph (type-1 winds). Other accounts suggested more moderate wind speeds:

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[18] St. Thomas Tidende, October 14, 1916

> Some houses were entirely gutted of their contents: others had a wing carried away, others the roof, whilst such loose objects as windows and doors were nowhere to be found except scattered abroad in fragments.[19]

Damage levels such as these appeared to result from winds ranging from 74 to 120 mph (type-2). Winds of lower speeds produced negigible damage:

> Accounts from the country rural districts tell of no damage beyond the breaking and uprooting of trees and the destruction of fences.[20]

This level of damage was caused by winds below 74 mph (type-3).

In lieu of specific accounts of wind damage or actual wind speeds, the maximum sustained wind speeds for a majority of the hurricanes on the chronology were derived from the central pressure readings. The basis for this interpolation was Kraft's equation,[21]

$$V_{max} = 14 \sqrt{1013 - P_c}$$

where V_{max} represents the maximum sustained winds at the surface (30 ft. and lower) in knots, and P_c is the central pressure of the hurricane in millibars.

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[20] Ibid, August 19, 1893.

[21] Charles Holliday, On the Maximum Sustained Winds Occurring in Atlantic Hurricanes, E.S.S.A. Technical Memorandum WBTM-SR-45, Weather Bureau Southern Region, Fort Worth, Texas, May 1969. Kraft's formula is used by the National Hurricane Research Center. However, other formulas have been developed.

Based on these figures for maximum sustained winds, it proved possible to compute the peak gusts associated with several storms by multiplying by a gust factor of 1.3 as suggested by Haddock.[22]

Wind speeds associated with storms that did not pass directly over the island were found by using a modification of a graph by Friedmann[23] relating the winds on either side of the storm to the central pressure reading. In checking our interpolations against newspaper accounts, they were found to be reliable in nearly every instance.

On October 9th and 10th of 1916, a hurricane passed directly over the island of St. Thomas. The central pressure was approximately 28.10 inches. Applying our working model, the maximum sustained wind speed is found to be 125 mph with gusts upward to 160 mph. (This is supported by the newspaper inference concerning the coal cranes).[24] This hurricane caused extensive damage to St. Thomas, but because it passed

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[22]Gerald Haddock, "Hurricane Load Criteria", Puerto Rico Water Resources Authority, Electrical Planning and Research Division, EPR2-072, San Juan, Puerto Rico, n.d., p. 9.

[23]D. G. Friedman, "The Hurricane Hazard in Louisiana", Unpublished Report, Research Department, Travelers Insurance Companies, May 20, 1966, pp. 1-5. Applying firm data from our chronology to Friedman's graph (page 4a of his articel) we obtained an empirical relation for the Virgin Islands which, when checked against the remaining data, gave favorable results.

[24]St. Thomas Tidende, October 14, 1916.

45 miles to the north of St. Croix it is estimated that the sustained winds on St. Croix did not exceed 90 mph. This hurricane was classified as type-A for St. Thomas while it was a type-Bn for St. Croix.

Wind speeds were computed in the same manner for the hurricane of September 14, 1876, (which passed over St. Croix and caused only minor damage to St. Thomas) and for many other hurricanes on the chronology.

With these wind velocities it is possible to estimate resultant damage. James Power[25] cites from the American Standards Association factors to be used when determining the velocity pressure of winds on structures of various types (Table 6). Using the formula for velocity presure,[26] where V is the

$$q_o = .00256\ V^2$$

maximum wind velocity in mph and q_o is the pressure in pounds per square foot, it can be determined whether or not a particular structure will be able to withstand the winds of a given hurricane.

For example, the velocity pressure of the winds from the hurricane in October of 1916 was 40 pounds per square foot and 65.5 pounds per

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[25] James Power, "Building Construction and Precautionary Maintenance in Hurrican Areas", from Final Report of the Caribbean Hurricane Seminar, held at Ciudad Trujillo D.N., Dominican Republic, February, 1956, p. 295.

[26] Ibid, p. 293

square foot for the gusts. The subsequent force applied to the average roof is 1.625 times greater than the gust velocity pressure, or 107 pounds per square foot. Obviously very few roofs can withstand pressures of this magnitude and consequently they were blown off.

In the past 100 years in St. Thomas two storms were in the type-1 wind speed group (1867 and 1916). Nine of them or 19 percent had wind speeds between 74 and 120 mph winds (type-2). The remaining 37 hurricanes were capable of causing only minor damage, with small shacks and fences being destroyed.

TABLE 6

Factors for Determining Velocity Pressures

Roofs	1.625 times the velocity pressure (q_o)
Mainframe	1.3 times the velocity pressure (q_o)
Exterior Walls	1.3 times the velocity pressure (q_o)
Overhanging Eves and Cornices	2.6 times the velocity pressure (q_o)

Tidal Surge for St. Thomas

The St. Thomas Tidende, the St. Croix Avis, and The Virgin Islands Daily News have reported higher than normal tides associated with hurricanes twelve times since 1867. The reports list damage, but not high water marks, and consequently estimates of tidal surge are qualitative. The newspaper reports of tidal surge fall into three groups based on the character and locale of destruction. The first group is based on newspaper reports of heavy damage extending inland from the waterfront. They are epitomized in reports of the storm of 1867, an example of which follows:

> The buildings at Honduras wharf broken up... The jetties at the coaling wharf of the Royal Mail Steam Packet Company, totally destroyed... Hazzell's new wharf...the jetties destroyed. The premises on the other side... jetties broken up...the houses a little higher up the hill...all broken up. The dwellings and the coal shed at the wharf of the Compagnie Generale Transatlantique destroyed. The barracks in the rear of Fort Christian, capable of accommodating a thousand men destroyed.[27]

In sum, waterfront facilities were damaged heavily, and there are obvious indications of heavy damage from the surge further inland. Six storms of this type affected St. Thomas 1867-1967, and these are classified as having produced tidal surges of type one (Table 7).

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[27] St. Thomas Tidende, November 13. 1867

The second group of reports describes heavy damage only in the waterfront area. The storm of 1893 provides a good example:

> THE SEA from morn till eve was much agitated and in its rage lashed the shore with such tremendous force that not even the most substantial wharves could resist the impact, many of the wood as well as stone receiving very extensive injuries, some being totally destroyed... our GREAT FLOATING DOCK stood majestically by her cables.[28]

This, and other reports, indicate extensive damage only on the waterfront. Tidal surges of this type were described in association with two hurricanes that affected St. Thomas 1867-1967. These were classified as type-two tidal surges (Table 7).

The third group of newspaper reports describe slight damage to the waterfront or to ships in the harbor or to both. The papers report heavy seas or limited waterfront damage. An example is the storm that passed St. Thomas in April of 1956 in which "Shops and establishments along the shore were flooded".[29] There is no mention of widespread destruction associated with tidal surges of this type (Table 7).

This three-fold classification of tidal surges derived from newspaper accounts was compared with quantitative estimates of surge heights.

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[28] St. Thomas Tidende, August 19, 1893.

[29] The (St. Thomas) Daily News, August 14, 1956

These estimates were obtained by using a profile for a standard hurricane developed by Jelesnianski.[30] There are four curves in this profile. Two give surge heights for hurricanes with radii of maximum winds of thirty nautical miles. The larger curve is for a storm with a crossing angle of 90 degrees, the smaller is for a storm with a crossing angle of 140 degrees. The two smaller curves are for hurricanes with radii of maximum winds of fifteen nautical miles. As with the first set, the larger of these curves is for a hurricane with a crossing angle of 90 degrees and the smaller has a crossing angle of 140 degrees.

Three problems arise when using this profile to predict surge in the Virgin Islands. The first is that the data for these profiles were obtained from hurricanes that made landfall on the U. S. Gulf and Atlantic coasts. These are open coasts with long continental shelves and as such would tend to generate a higher surge. The other problems are that seven of the fourteen hurricanes for which surge was predicted in the Virgin Islands had winds of one hundred and twenty miles per hour or over, and the crossing angle of all storms was less than 90 degrees. These last two factors would tend to increase the surge. However, even if they were

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[30] A standard hurricane has winds of one hundred miles per hour and a forward speed of fifteen miles per hour. See Arnold L. Sugg, A Mean Storm Surge Profile, E. S. S. A. Technical Memorandum WBTM-SR-49, Weather Bureau, Southern Region, Fort Worth, Texas, December, 1969.

taken together they would not counter-balance the first factor. Therefore, the surge for the Virgin Islands will be lower than that suggested by Jelesnianski's profile.[31] To take account of these problems twenty-five percent is subtracted from the tidal-surge heights yielded by Jelesnianski's profile, and a minimum-maximum range of tidal surge is given (Table 7).

The profile predicted high surge for fifteen hurricanes, and the newspapers reported surge damage for twelve of these. For the three cases unreported in the newspapers the profile predicted very low surge levels (two feet or less). And such a small level is unlikely to produce newsworthy damage.

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[31] "Empirical Relationships of the Central Pressures in Hurricanes to the Maximum Surge and Storm Tide", Monthly Weather Review, 85, pp. 168-172. Discussion with Robert Calvesbert, E.S.S.A. Commonwealth Climatologist, San Juan, Puerto Rico, on 1-23-1972.

TABLE 7

Tidal Surge Chronology

Date	Type of newspaper-reported surges. Estimates in ( )	Tidal surge in feet* Min.	Max.	Type of tropical cyclone classification	Winds over 120mph
Oct 1867	1	7	12	1A	x
Aug 1871	1	6	8	2A	x
Sept 1876	3	3	5	3Bs	
Aug 1893	2	4	5	2Bs	
Aug 1899	1	6	8	2Bs	x
July 1901	3	0	2	3Cs	
Aug 1910	(3)	0	2	3Bs	
Aug 1916	2	4	6	2Bs	
Oct 1916	1	6	10	1A	x
Sept 1928	1	6	8	2Bs	x
Sept 1931	(3)	0	2	3Bs	
Sept 1932	1	5	8	2B	x
Aug 1950	(3)	0	2	3Cs	
Aug 1956	3	1	3	2Cs	
Sept 1960	3	0	2	2Bn	x

*Plus or minus six inches due to height of tide.

In Table 8, the typology of damage as reported in newspapers is related to surge-ranges predicted by the profile, and to various groups of tropical cyclones. It is readily seen that 2Bs storms with five feet of surge or more produce type two reported damage at the least. Storms of type 2A and stronger produce at least five feet of surge, and type one damage. Storms of 3Bs type and weaker generate under five feet

of surge, and a reported damage of type three.[32]

TABLE 8

Interrelationship of Chronological Classification and Tidal Surge

Groups of storms based on classification in the chronology (Table 1)	Tidal surge in feet Min.	Max.	Type of surge (1, 2, 3) reported by newspaper
1A	6	12	1
2A	6	8	1
2B	5	8	1
2Bs	4	8	1 & 2
3Bs	3	5	3
2Cs	1	3	3
3Cs	0	2	3
2Bñ	0	2	3

Flooding and Hurricanes

Inland flooding resulting from the heavy rains of a tropical cyclone is often a major cause of damage. Unlike wind and storm surge, however, there is no definitive measure of the extent of inland flooding. In addi-

[32]This surge section is primarily concerned with Charlotte Amalie because it is one of the most affected areas on St. Thomas. This is because it is on the south side of the island, and hurricanes passing to the south, going from east to west will generate the most surge there. Hurricanes passing to the north generate very little surge on St. Thomas.

tion, the scarcity of records and of specific references to hurricane-induced flooding render accurate reconstruction of past floods impossible. One major source of hurricane accounts, old newspapers, were notably deficient in their mentioning of inland flooding. Descriptive accounts can be misleading and provide no empirical basis for a close examination of tropical flooding. Where no detailed descriptions or damage estimates exist, the closest approximation of an indicator of flood severity is rainfall records.

Actual rainfall totals on St. Thomas were available for only 21 of our 48 tropical cyclones. Almost all of these rainfall totals came from Charlotte Amalie. Amounts were interpolated for 13 additional tropical cyclones from monthly precipitation records for Charlotte Amalie given in Stone.[33] These 34 storms formed the basis of our tropical cyclone rainfall analysis. However, rainfall alone does not indicate the extent of flooding that takes place.

Soil Moisture Storage Levels and Hurricane Flooding

The amount of moisture in the soil prior to the passage of a tropical cyclone is of great importance in determining the extent of inland flooding caused by heavy rainfall. The ability of the soil to absorb quantities

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[33]Stone, op. cit. Appendix Table 4A, p. 86 contains monthly rainfall totals for Charlotte Amalie from 1877 to 1917, as well as the long-term monthly averages computed from these. Rainfall amounts for thirteen tropical cyclones were interpolated by subtracting the average monthly rainfall from the actual amount which fell during the month the tropical cyclone occurred.

of rainwater diminishes the amount of runoff and thus the potential for severe flooding.

To understand more fully the nature of flooding during past hurricanes, and the potential for flood damage during future heavy rainfall events, an attempt was made to estimate the levels of soil moisture in Charlotte Amalie on the eve of those hurricanes which deposited over 3 inches of rainfall on St. Thomas. To generate these levels, daily precipitation records for the 40 days preceding the storm were needed. These records were available only from 1921 to the present, and only 6 hurricanes which produced heavy rainfall occurred during this period.

Using a computer print-out for daily soil moisture storage in Charlotte Amalie for 1958 to 1968,[34] and the rainfall figures preceding the storm, it was possible to estimate both the soil moisture storage level which existed on the eve of each hurricane, and the probable runoff in inches caused by the storm's passage. As a further aid in interpolation, Thornthwaite and Mather's soil moisture retention table number 16[35] was utilized. For the calculations, a 5-inch soil water holding capacity was assumed.

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[34]Martyn J. Bowden et. al., Climate, Water Balance, and Climatic Change in the Northwest Virgin Islands, Caribbean Research Institute, 1970, fig. 6, p. 46.

[35]C. W. Thornthwaite and J. R. Mather, Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance, Drexel Institute of Technology, Laboratory of Climatology, Publications in Climatology, Vol. 10, No. 3, Centerton, New Jersey, 1957.

After six soil-moisture computations were made, it was obvious that three of the six heavy-rain producing hurricanes 1921-1970 brought rain to soils with soil moisture levels of less than 1 inch. These low amounts are typical of this relatively dry island. The greatest estimated soil moisture level was 2.60 inches, or slightly more than 50 percent of the soil's water holding capacity. This was also the only amount over 2 inches. The other soil moisture storage levels exceeding 1 inch on the eve of the hurricane were 1.50 and 1.90 inches. Continuous records indicate that the soil is even drier on average than is apparent from these figures.

Probabilities of different daily levels of water-holding capacity have been computed for Alexander Hamilton Airport, St. Croix. These generalized probabilities are transferable to parts of St. Thomas including Charlotte Amalie. They are based on the number of days in which the soil was at six different levels of field capacity from 1958 to 1968.[36] Here again, a 5-inch soil moisture storage capacity is assumed. Thus, there is a probability of .71 that the soil will contain less than 20 percent (1 inch) of its field capacity. This figure indicates the extreme aridity of the soil which exists on average for more than 70 percent of the days in a year.

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[36] Bowden et. al., op. cit., table 8, p. 48. Of course the depth of soil in many places is negligible. Bare rock surfaces are common on the hill slopes behind Charlotte Amalie, Truman Field, and Soto, for example. Little or no soil moisture storage capacity exists here and thus run-off will be rapid.

More relevant probabilities are those depicting soil moisture storage levels during the slightly wetter months of the hurricane season (August, September and October). These figures still indicate only a 32 percent chance of having a soil moisture level of 1 inch or more. A soil moisture level of more than 5 inches (indicating run-off) did not occur at all during the hurricane season for the years of record at Alexander Hamilton Airport. Such a level was attained only once at Charlotte Amalie during the same period.

Due to the limited nature of our hurricane sample with soil moisture storage figures, therefore, the base of estimation was extended by examining 20 very recent non-troipical cyclone rainfall events with more widely varied levels of soil moisture storage, precipitation, and damage.

TABLE 9

The Probability that Soils were at Six Different Levels of Water Holding Capacity, Aug. - Oct.

Alexander Hamilton Airport, St. Croix 1958-68

Percentage Water Holding Capacity	Probability of Occurrence	Water-Holding Levels (in inches)
<20%	.68	<1"
20-38%	.16	1.0-1.9"
40-58%	.11	2.0-2.9"
60-78%	.05	3.0-3.9"
80-98%	.01	4.0-4.9"
100%(run-off)	.00	>5"

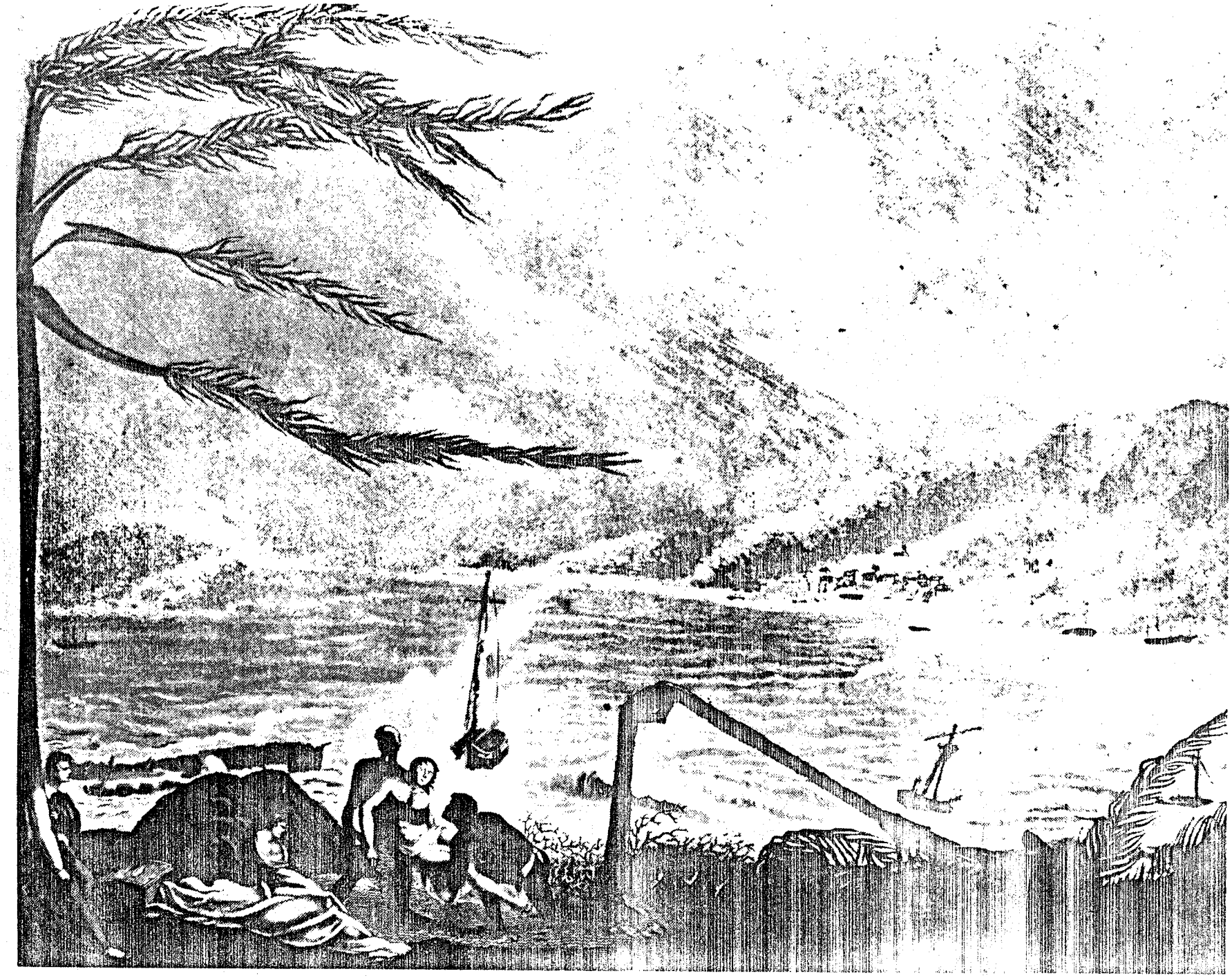
Extension of the Base for Estimating Hurricane-Related Flood Damage

Damages from high winds and tidal surges in the Caribbean are generally associated with hurricanes, but this is not true of flooding which is more likely to occur and cause extensive damage in non-hurricane situations. This is particularly true in the Virgin Islands where recent hurricanes have been of moderate intensity and have not always produced large amounts of rainfall, whereas the long-period rainstorms of May and the Autumn months often deposit five or six inches of rain in a three- or four-day period. In developing a prediction of probable flood damage resulting from hurricanes, therefore, our

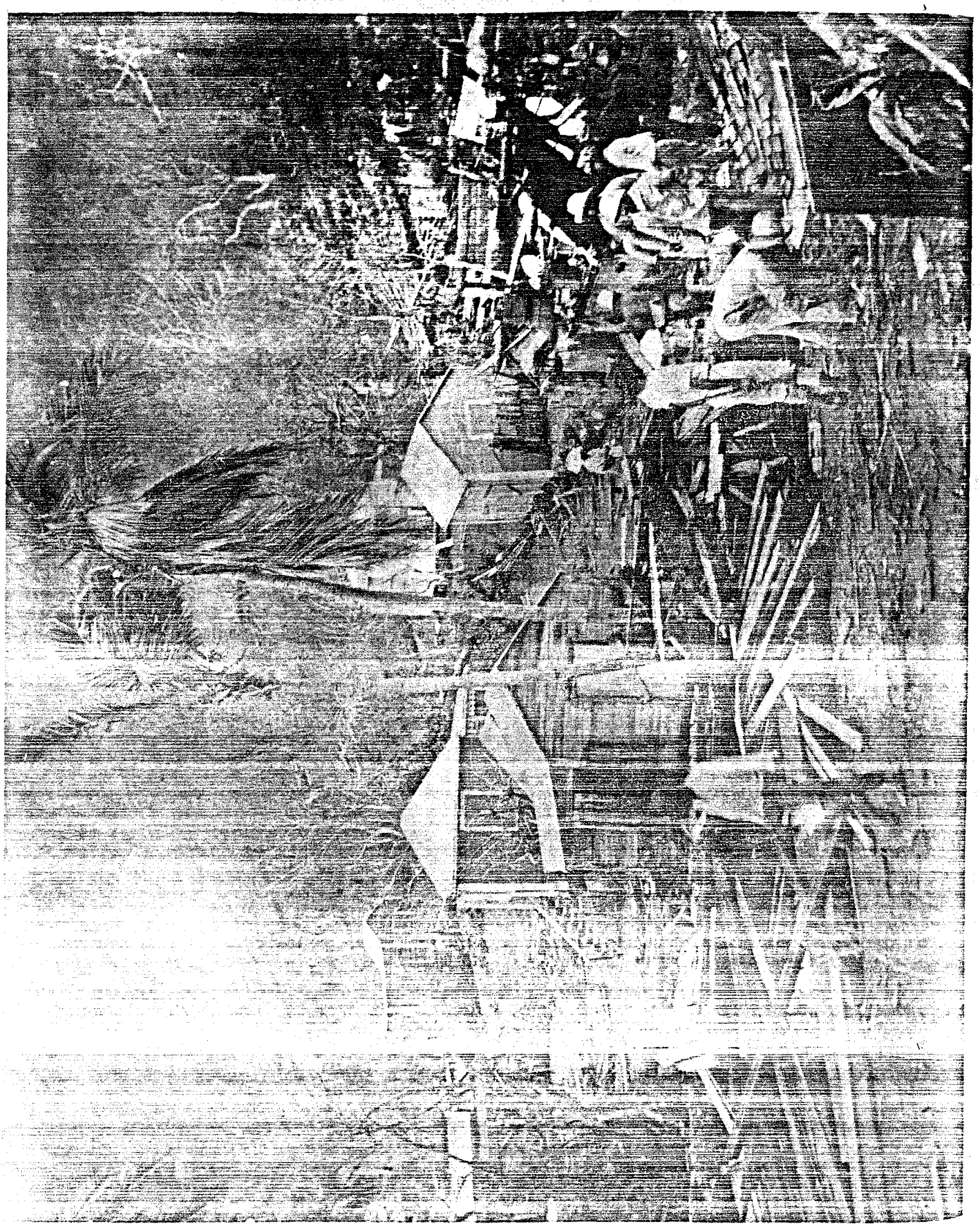
limited information was extended by an analysis of flood estimations that followed rainfall instances not associated with tropical cyclones. These floods that result from non-hurricane situations are considered here to be similar in practically all respects to floods produced by hurricanes. Each flood circumstance can also be related to the types of hurricanes discussed in the previous section in terms of damage. In such a way this process of model reconstruction is one of interchangeability between hurricanes and storms.

The large amount of flooding data available for the period 1955-1971 as found in The (St. Thomas) Daily News and the U.S. Department of Commerce Climatological Data: Puerto Rico and Virgin Islands, dictated the period of extensive study. A total of twenty-three instances of sizeable rainstorms producing flood conditions were identified and analyzed in detail (Table 10). These rainstorms range from torrential downpours lasting a few hours and depositing about two inches of rain to the severe storms of May 1960 and October 1970 which deposited from ten to fifteen inches of rain on St. Thomas in about three days.

Using past damage figures from newspaper sources it proved possible to get some damage data for floods since 1955. Unlike information on the physical phenomenon itself, however, such damage figures were hard to find and were often limited in monetary figures to damage con-



"St. Thomas after the Hurricane of 1819" - Aquatint by T. L. Busly 1820



cerning single establishments only. The highest damage figures (also some of the newest) are those of the storm of October, 1970, in which the island suffered about six million dollars of damage and was declared a disaster area. The (St. Thomas) Daily News of October 8 gives accounts from the citizenry describing Main Street as a "river", Mafolie Hill as "Niagara Falls", and low-lying areas of the islands as the "Mississippi Delta during a flood".[37] This flood brought about damage in dollars far exceeding that of the greatest hurricane of record in St. Thomas.[38]

Using these storm data we developed a number of crude graphs relating different characteristics of these storms. Precipitation data for three St. Thomas stations (Charlotte Amalie, Truman Field, and Fort Mylner) for 24-hour, 48-hour, and whole-storm time-periods were plotted against six damage categories. As would be expected, damage was shown to increase as precipitation increased, but there also appears a marked difference in the slopes of the graphs depending on the time period (Table 11). Runoff for Charlotte Amalie, stream discharge rates

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[37] The (St. Thomas) Daily News, Oct. 8, 1970, pp. 3, 6.

[38] This is due mainly to the fact that the last major destructive hurricane occurred in 1916 when population and property values were low as was the value of the dollar.

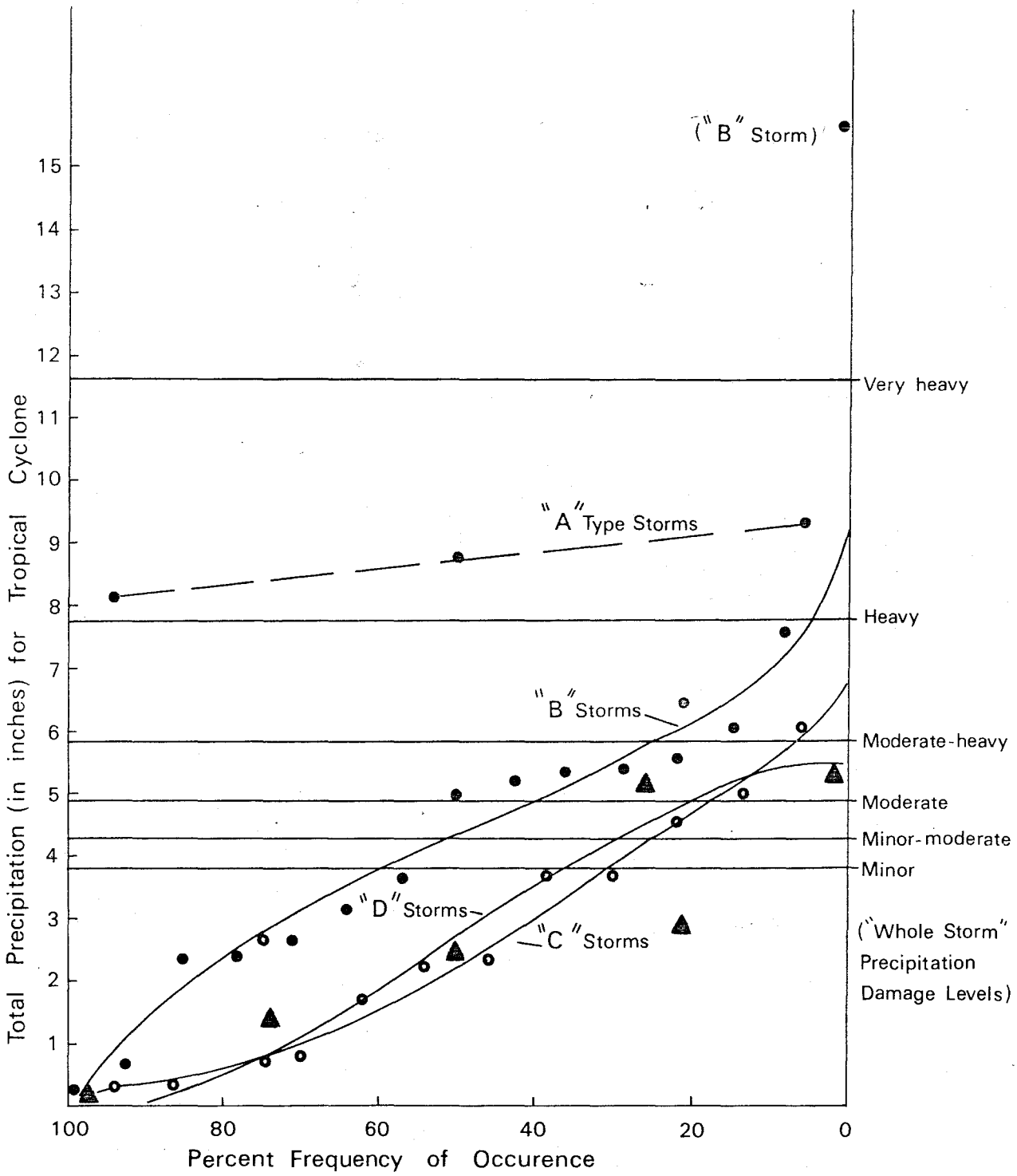

Figure 2
(Triangles = "D" storms; open circles = "C" storms)

for Turpentine Run for 1963-1969,[39] and soil saturation[40] are other flood-related characteristics which were correlated with each other, (and with rainfall totals for the storms and with the damage categories). The crude curves in Table 11 reveal that damage increases as precipitation, runoff, and stream discharge increase, and that stream discharge increases as runoff and precipitation increase. The threshold levels for damage are appreciably higher for "whole-storms" and "47-hour precipitation periods" than for 24-hour precipitation periods. This is particularly true for the "heavy" and "very heavy" damage categories. More damage occurs under saturated soil conditions than when the soil is comparatively dry (rows 4 and 5 in Table 11).

It also proved possible to relate these flood-producing storms directly to the hurricane damage potential models (figure 2). It was found in some cases that a non-hurricane storm that produced flooding could be as potentially damaging as a type 1A hurricane, even though it is not accompanied by high winds or tidal surge. A set of precipitation-frequency of occurrence graphs was formulated from which it proved possible to estimate, using certain precipitation amounts occurring in

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[39] U. S. Geological Survey, "Daily Gage Height and Discharge Data for Turpentine Run, St. Thomas", 1963-1969.

[40] Bowden et. al., op. cit., Figure 6, p. 46 and Table 8, p. 48, and C. W. Thornthwaite and J. R. Mather, op. cit.

hurricanes since 1921, the damage that could be expected from a hurricane that deposited a certain amount of rain on St. Thomas. Using the precipitation-damage graph for the whole storm (row 3 in Table 11), damage estimates for certain rainfall amounts can be derived and they can be related readily to ranges of precipitation characteristic of certain types of hurricanes. Thus probably flood damage estimates can be made for hurricanes of four types (A, B, C, D) as well as the percentage frequency of occurrence of varying amounts of precipitation which fell during these storms (figure 2).

In such a way it was determined that there is a fifty to sixty percent chance that a "B" type storm will deposit at least four inches of rain and hence produce minor or minor-moderate flood damage. A "B" type hurricane has a forty percent chance of producing five inches of precipitation which in turn would cause moderate damage. There is a twenty-five percent chance of such a storm producing about six inches of rainfall and causing moderate-heavy damage, and a five percent chance of a "B" storm depositing eight inches of precipitation and causing heavy damage. Very heavy damage as a rule is unlikely to occur from a "B" type storm (Table 12). Only one such tropical storm brought very heavy damage during the fifty-year period, that of the storm of September 1928.

"C" type storms (those passing fifty to one hundred miles away from St. Thomas) are more likely to produce smaller amounts of precipitation and less damage. In thirty percent of the cases of tropical storm occurrences of type "C" only one inch or less of rain resulted. In only thirty

Table 11

Crude Relationships Between Damage Levels and Precipitation, Run-off, and Stream Discharge, St. Thomas

	Average Damage Levels					
	Minor	Min.-Mod.	Mod.	Mod.-Heavy	Heavy	V. Heavy
24-hour precipn. (in inches)	2.5	3.0	3.5	4.2	4.8	5.2
48-hour precipn. (in inches)	3.2	3.7	4.2	4.8	5.6	6.0
Whole-storm precipn. (in inches)	3.8	4.4	4.8	6.0	7.8	11.6
Whole-storm precipn. Soil Moisture Storage < 1.5"	4.3	4.4	5.0	7.2	i.d.	i.d.
Soil Moisture Storage > 1.5"	3.0	3.8	4.7	5.8	i.d.	i.d.
Run-off (in inches) *1	0.5	1.0	2.3	4.0	7.0	10.0
Stream Discharge in thousand gallons on heaviest day *2	1,500	5,000	12,000	30,000	50,000+	i.d.

*1 Charlotte Amalie.
*2 Turpentine Run.
i.d. Insufficient data.

Table 12

Probabilities of Damage Levels in Hurricanes of Various Types.

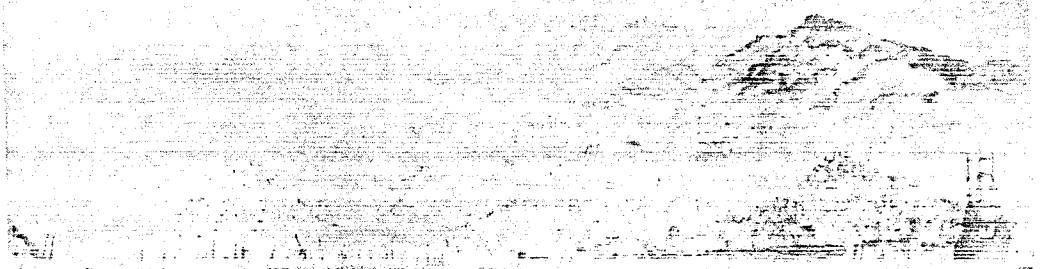
	Damage Levels (in dollars)					
Types of Hurricanes	Minor (50-500)	Min.-Mod. (500-5,000)	Mod. (5,000-50,000)	Mod.-Heavy (50,000-500,000)	Heavy (500,000-5 million)	V. Heavy (5 million + over)
A	100	100	100	100	100	i.d.
B	60	52	42	36	6	i.d.
C	34	26	18	6	0	0
D	36	28	18	0	0	0
s	33	28	23	16	5	0
n	52	50	46	20	0	0

percent of the storms did minor flood damage occur. Moderate damage is even less likely to occur having done so less than twenty percent of the time. Only one "C" type storm produced moderate to heavy flood damage during the study period.

It was decided that the graphs of "A" type storms and "D" type storms were based on three and six cases respectively and thus sufficient only for crude estimations. However, it can be fairly safely assumed that an "A" type tropical storm (that which passes directly over the island) on the average will produce about eight to ten inches of rain and will cause heavy or very heavy flood damage. "D" type storms seem to share closely the characteristics of "C" type storms but it is unlikely that such a storm would cause more than moderate damage (Table 12).

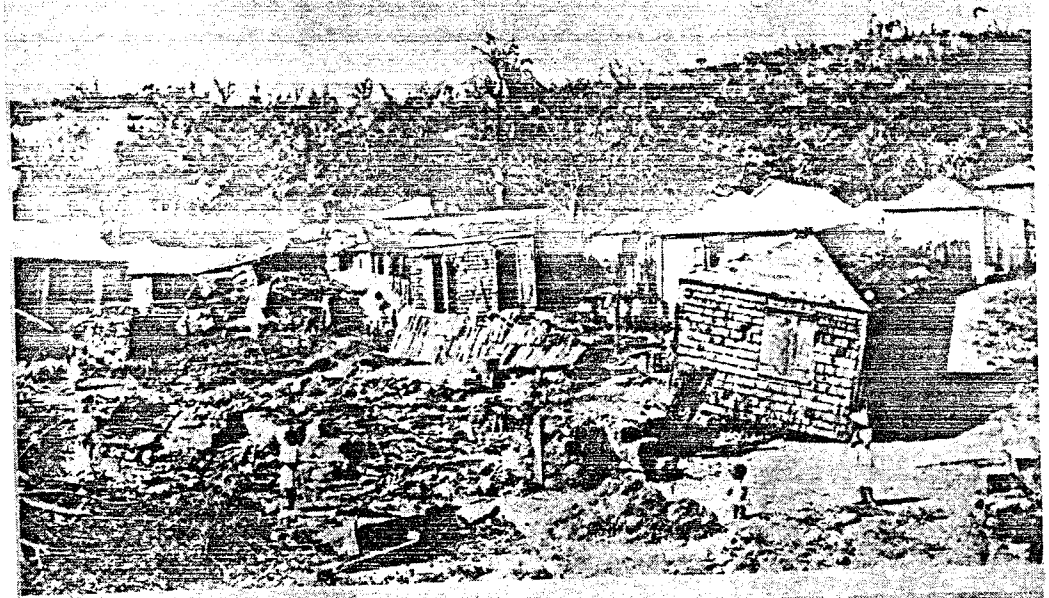
Storms passing north of the island seemed to produce either slight amounts of precipitation (one-half to two inches) or fairly large amounts (five or six inches). Southerly hurricanes tended to be much more regular in their progression with numerous hurricanes producing variable amounts of precipitation (Table 12). The only super-hurricane (1928 in terms of precipitation) which occurred during the period 1921 to 1971 passed south of St. Thomas and deposited sixteen inches of rain on the island. This extremely wet hurricane, however, barely produced the rainfall amounts that occurred during the May 1960 and October 1970 storms of non-hurricane origin.

Thus in order to obtain a good definition of hurricane flooding capabilities it has been necessary to extend our estimation base to non-hurricane flooding occurrences. Future flood damage levels are made more readily estimable for St. Thomas but the problem of estimating damage will be made more difficult by the constantly increasing urbanization, population, inflation, and property values of St. Thomas.



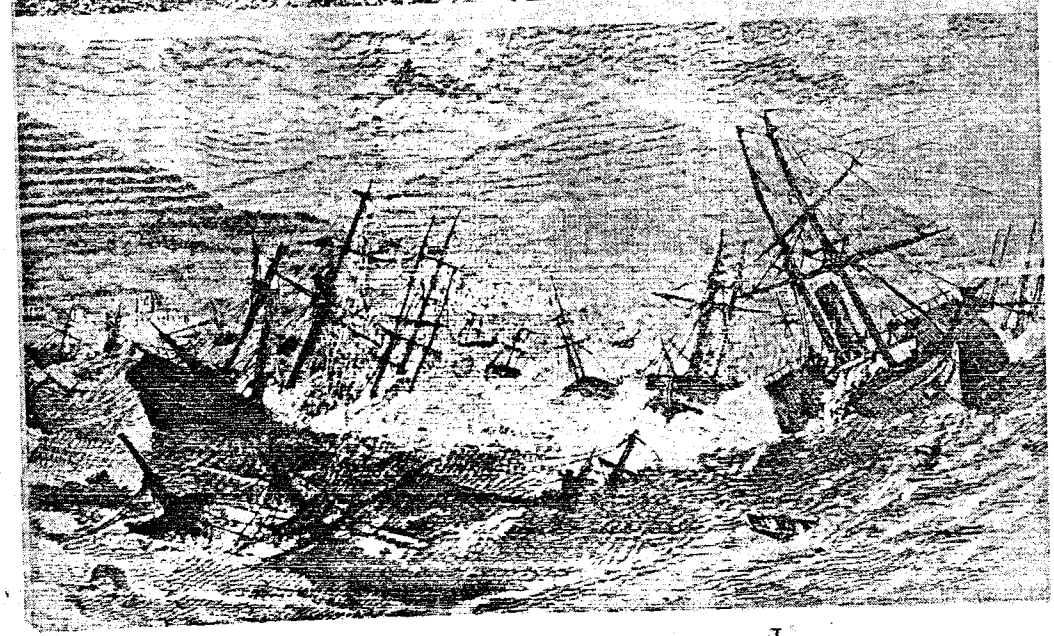
St. Thomas after the earthquake on 18th November 186-
Woodcut from Ill. Tidende. KB.

St. Thomas efter jordskælvet 18. nov. 1867.
Træsnit i Ill. Tidende.



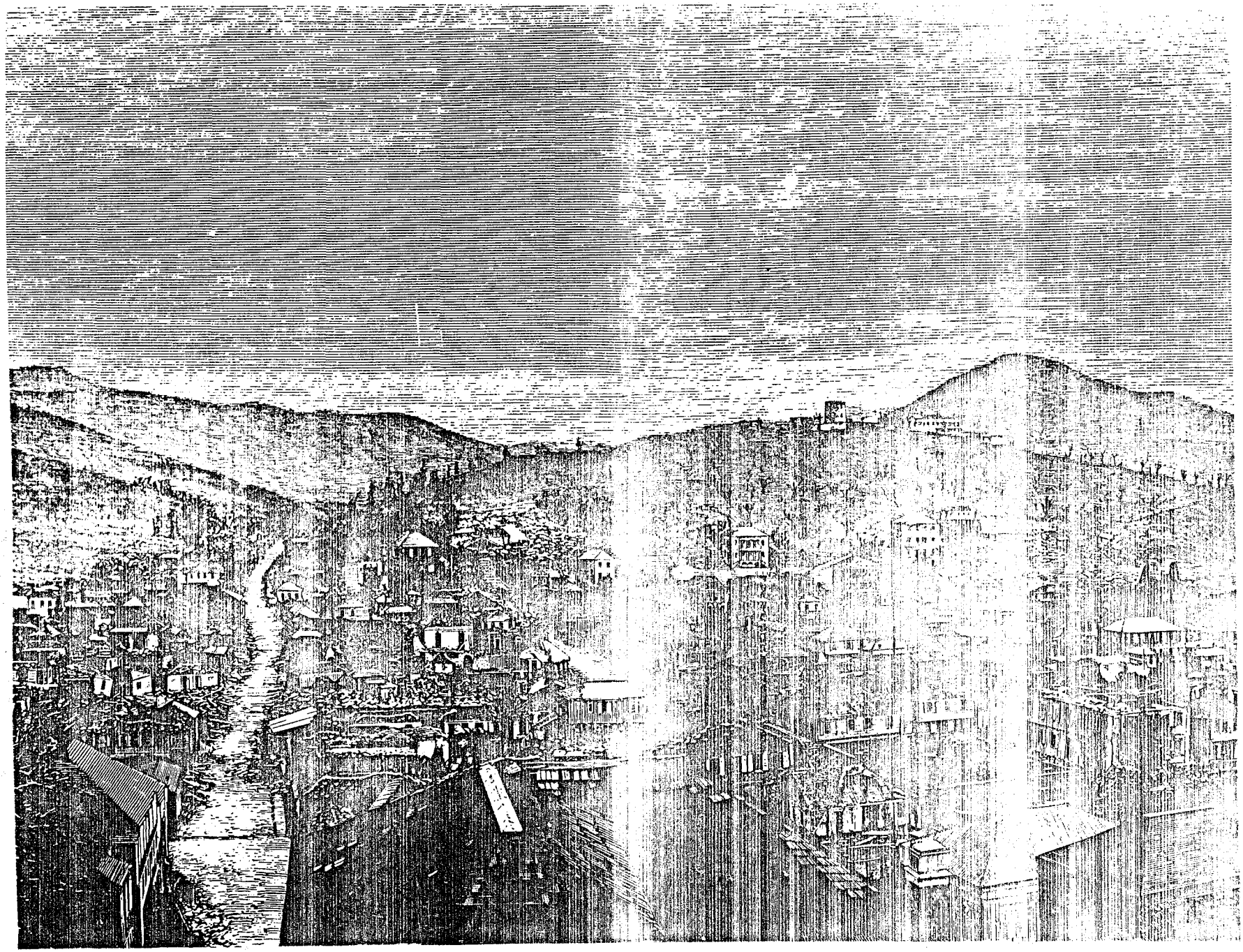
In the trail of the hur
St. Croix 1916. KB.

Orkanens hærgen på St. Croix 1916. KB.



The harbour of St. Th
during the hurricane
of 29th October 1867.
Woodcut
from Ill. Tidende. KB.

St. Thomas havn under
29. oktober 1867.
Træsnit i Ill. Tidende.



II. St Thomas efter Orkanen den 21de August 1871. Efter et Fotograph

IV. Town of Charlotte Amalie, August 28, 1924

PART III: CONCEPTIONS OF HURRICANES AND OF THE HURRICANE HAZARD

Hurricanes of Scientist and Islander

The hurricane known to the scientist is not that of the islander. In the last half century, the islands have had few tropical cyclones that were called "hurricane" locally: only two of the 19 tropical cyclones experienced since 1920 were real hurricanes to long-time island residents interviewed in 1969 (Table 13): those of 1928 (St. Croix) and 1932 (St. Thomas). And similar conclusions were drawn from the extensive hazard survey in St. Thomas in 1970. Almost half of those who shared island hurricane lore identified the period 1928-1932 as the last time the Virgin Islands "had trouble with hurricanes" (Table 14). And when asked to identify the "worst year for hurricanes in the Virgin Islands", more than half of those with some knowledge of hurricanes in the islands pinpointed the years 1916, 1928, and 1932 (Table 15). Apparently the tropical cyclones of the scientist become true hurricanes if they cause a great amount of damage to property and distress to people. These things happen in the extreme form of the hazard--when the center of a well-developed tropical cyclone (classified as A-type,or occasionally B, in the first part of this report) passes directly over or very close to a locale.

Table 13

Dates of Last Hurricanes to Hit the Virgin Islands, as Perceived by Residents (Jan. 1969).

Respondents (Elite)	Precise and correct identifications by year. 1867	1916	1924	1928 SC	1931 ST	1932 ST	1933 ST	1956 SC	1960 ST	Imprecise or incorrect identifications by decade. 19C	10s	20s	30s	40s	50s	60s	DNK	NoHs
S.C. Educated				5		1		1(+1) *1								1		
S.C. Dec-M.				4			1											
S.T. Educated		(1)		(2)		3				(1)			(2)		(1)	sc*2		
S.T. Dec-M.		(1)		(2)		4									(1)	sc*		
T. Educated		(2)	2(+1)			(1)	1		(1)	(1)								
Sub Total		4	3	13		9	2	2	1	2	0	0	2	0	2	1		
T. Popul. Res >10			(1)								(1)					(1)		
T. Popul. Res ≤10												2						
T. Folk		(1)	2(+1)			1			1	(1)						1		
S.T. Popul Res >10	(1)	1(+1)			3 1	8					1	(1)	(2)	1 sc*			5	
S.T. Popul Res <10				1 sj*		2			1			2	3(+1)	1				1
S.T. Folk				1		3			1		1	(1)		1				1
Sub Total	1	3	4	2	1	14			3	1	3	6	6	3	0	2	5	2
Total	1	7	7	15	1	23	2	2	4	3	3	6	8	3	2	3	5	2

*1 Figures in brackets are 'hurricanes' mentioned as additions to the original answer.

*2 (s.c.) indicates that the 'hurricane' was identified by a Thomian as occurring on St. Croix.

*3 (s.j.) indicates that the interviewee was on St. John.

Hurricanes of 1867, 1916, and 1924 affected both St. Thomas and St. Croix.

Those of 1928 and 1956 affected St. Croix; while those of 1931, 1932, 1933, and 1960 affected St. Thomas.

Hurricanes that affect St. Thomas generally affect Tortola and St. John.

Three hurricanes affected the Islands in 1916 and 2 in 1924.

DNK-did not know

NoHs-No hurricanes

Res-resident

T-Tortola

S.C.-St. Croix

S.T.-St. Thomas

Popul.-Populace

Table 14

When Was The Last Year There Was Trouble With Hurricanes? (1970, St. Thomas)

	1916	18	24	26	27	28	29	30	32	34	35	37	38	55	56	58	60	64	66	67	68	69	30's	40's	50's	60's
Those with hurricane experience (48)	1					6			13				1		1	1	4	3	2			5	2	1	½	½
Those without hurricane experience (41)		1	1	1	1	4	2	2	4	1	2	1		1			1	2		2	2					
Total 89	1	1	1	1	1	10	2	2	17	1	2	1	1	1	1	1	5	5	2	2	2	5	2	1	½	

Table 15

When Was The Worst Year For Hurricanes? (1970, St. Thomas)

	1778	1915	1916	1918	1920	24	26	28	29	30	32	35	50	52	53	54	56	58	60	65	66	DNK	NA
Experience (48)	1		17½	2	1	½		6	1		3		1		1	1	1	1	2	1	1	7	
Without Experience (41)		1	5	2		2	1	2½	2	1	1½	1		1				1	1			17	2
Total	1	1	22½	4	1	2½	1	8½	3	1	4½	1	1	1	1	1	1	2	3	1	1	24	2

Sharers of Island Hurricane Lore: The Nature of Island Hurricanes

The true hurricane is 'recalled' in the islands by many who did not experience it. The big hurricane, in effect, becomes part of island lore transmitted eventually to inexperienced newcomers. But this transmission process takes time, and the information transmitted is rarely precise (something that becomes immediately obvious in tables 14 and 15). As might be expected in an island with so many recent immigrants, a large proportion of them do not as yet share island lore.

In fact the island population can be divided into four groups based on knowledge of hurricane lore. One group, constituting a little less than one-third of the population, know practically nothing of the history of hurricanes in the Virgin Islands. Another well-informed third of the population recognizes three types of hurricanes. They realize that the 1916 hurricane was very severe (and the worst this century). This group also recognizes hurricanes of moderate severity--those of 1928 and 1932 (called troublesome); as well as a third set of basically inconsequential tropical storms, not called 'hurricanes':[41] those of the 'sixties that "grazed" these lands . These 3 types are essentially the A, B. and C-type hurricanes recognized in the first part of the study.

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[41]Four persons, residents for more than 45 years on the three major islands were asked in 1969: when was the last hurricane on their respective islands?: On St. Thomas all four answered 1932; on St. Croix 3 of 4 answered 1928; and on Tortola 3 of 4 answered 1924. The fourth respondents on both Tortola and St. Croix identified 1933. To these 12 people there had been no hurricanes since 1933.

The remaining one-third of the population is in various stages of acquiring this hurricane lore. Half of this group differentiate two types of hurricanes. They think of the B-type hurricanes of 1928 and 1932 as the 'worst' experienced on the islands, and of the C-type hurricanes of the 'sixties as "troublesome." For the remainder of the group (one-sixth of the population) there is only one type of hurricane on St. Thomas: the C-type hurricanes of the 'sixties' which are considered to be the worst experienced in the islands.

Interestingly the seven hurricanes and tropical storms of the period 1934 - 1954 are erased from memory in St. Thomas (Tables 14 and 15). To the experienced, these storms were inconsequential--like those of the 'sixties. Long-term residents experience great difficulty in identifying one hurricane from this 20-year period. Thus to those in the process of acquiring island hurricane lore, these "lesser" storms are effectively outside living and recounted memory. And for the majority of the island's many recent immigrants these hurricanes are outside their period of experience in the Virgin Islands. It is easy to see why the island population consistently underestimates the frequency of visitation of tropical cyclones.

Experience of the Damaging Hurricane

What is perhaps remarkable is that so much information has been imparted to recent arrivals and to many of the younger islanders, to the

point where half of the population is aware of either a two- or three-fold differentiation of hurricanes in the islands. For as far as could be established in 1969, less than 5 percent of the population had suffered through the last big hurricane of 1916, and less than one in ten of the present population experienced the moderately severe hurricanes of 1928 and 1932.

There are, of course, many immigrants who have experienced hurricanes elsewhere. And in 1970 an attempt was made to estimate the portions of heads of households who had experienced hurricanes somewhere (Table 14). Approximately half of the respondents felt that they had experienced hurricanes.

But among many of these the hurricane experience was of inconsequential tropical storms at best. It was concluded that 37 out of 93 had experienced damaging hurricanes (C-type hurricanes or worse). And some of these had experienced as many as 5 hurricanes. Based on another question concerning potential damage that hurricanes could effect on a household, it was inferred that one-quarter of the respondents had experienced at least moderately severe (B-type) hurricanes, and that at least one-tenth of the heads of household had experienced severe (A-type) hurricanes. This was confirmed obliquely in answers to another question concerning major damages effected by hurricanes in the experience of respondents. Most people thought of hurricanes as

producing less than wholesale destruction, and they associated with the hurricane one type of damage only (household usually). One in ten mentioned three or four types of damage, and we infer from this that these persons at least believe that hurricanes in the Virgin Islands could bring wholesale destruction to home, people, community, and work (Table 16).

There are, of course, some people who have experienced severe hurricanes in Florida, Santa Domingo, and Puerto Rico and typhoons in the Pacific, who feel that similarly severe hurricanes will not occur in the Virgin Islands. And there are others who have experienced severe and moderately severe hurricanes in the Virgin Islands who believe that such storms will never strike again (i. e. they assume that the storm of 1916 was a 500-year or 1,000-year hurricane).

TABLE 16

Types of Damage if a Hurricane Strikes St. Thomas (1970, St. Thomas)

Number of Elements Identified	Damaged Elements				Total
	Workplace	House	Community	People	
One	2	25	5	3	35
Two	2	3	6	1	12
Three	2	2	0	2	6
Four	2	2	2	2	8
Total	8	32	13	8	61

In sum a sizeable proportion (as much as one-third) of the population of the Virgin Islands know practically nothing about past experience with hurricanes in the Virgin Islands, and has no experience with hurricanes in general. Another one-third which is relatively well informed of either hurricane experience in the V.I. or elsewhere inherits, from those with extensive experience, the tendency to underestimate the frequency of past hurricanes.

Taken in this light it is easy to explain some rather remarkable answers to a question posed in 1970; "Do the people of the Virgin Islands have trouble with hurricanes?" Almost half of the responsdents felt that the islands did not have 'trouble' with hurricanes and another large group (20 percent) said they were not sure (Table 17).

TABLE 17

Do the People of the Virgin Islands have trouble with Huuricanes?

(1970, St. Thomas)

	Responses				
Persons:	Don't Know	Yes	No	Doubtful	Total
Numbers	11	29	43	9	92
Percentages	11.9	31.5	46.7	9.7	100

The term 'trouble' was used later in the questionnaire and apparently meant different things to different people. Some with hurricane experience know that one troublesome hurricane (defined as severe) has occurred this century, and were tempted to conclude that the islands are essentially untroubled by such hurricanes. Others not aware of the severe hurricanes of 1916 and 1928-32, yet aware of the lesser storms of the last 10-15 years, take these as the standard "hurricanes" and conclude that these (and future storms) were not troublesome. Thus many use false standards in judging the 'hurricanes' likely to hit the islands.

Given varying personal definitions of hurricanes and the general tendency to forget many less memorable storms, it is difficult to establish popular estimations of long-term trends of hurricane frequency. Clearly, however, the probability of hurricane occurrence in the Virgin Islands is grossly underestimated by most islanders, simply because the definition of "hurricane" for a majority of them is stricter than that adopted by the scientific community. Furthermore, there is an optimistic streak in most people when faced with predicting the likelihood of natural disaster likely to affect them,[42] as well as the tendency in experiential chronologies to eliminate less memorable disasters from the record and to calculate the incidence of future catstrophe based on memorable past

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[42]Ian Burton, R. W. Kates, and R. Snead, The Human Ecology of Coastal Flood Hazard in Megalopolis, Univ. of Chicago, Dept. of Geography Research Paper No. 115, 1969, pp. 154-160.

events.[43]

Even among long-term island residents and among those with extensive hurricane experience there is a tendency to underestimate the frequency of the tropical cyclones that have affected the islands. And this tendency is more marked among recent migrants and among the inexperienced. This error in estimation is being further compounded by many, for when asked to project these widespread underestimations of tropical cyclone frequency into the future ten of 27 people classed as folk and populace [44] felt that the chance of the islands' receiving a hurricane in the near future was less than in the past, and three of these felt there would be no more hurricanes on the islands (surprisingly one had experienced a hurricane in 1932). The same proportion of the folk and populace thought the chance of receiving a hurricane in the near future to be greater than in the past, and seven of 27 thought the chance to be unchanged.

Among the elite the predictions were quite different. None of the elite interviewed in 1969 felt that the chance of getting a hurricane in the near future was less than in the past, and most of the decision-making elite thought the chance was greater (Table 18).

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[43] T. F. Saarinen, Perception of the Drought Hazard of the Great Plains, Univ. of Chicago, Dept. of Geography, Research Paper No. 106, 1966, pp. 61-76.

What was clear in 1969 (in terms of the question posed) was that the frequency of hurricanes (already underestimated) was seen to be changing by a large proportion of elite, populace, and folk. What were the reasons for these changes in the estimated future frequency of hurricanes compared to the past?

In many cases 'optimistic' beliefs have grown as a result of a long hurricane-free period and a simple projection of this into the future. 'Pessimistic' beliefs are more common among the well educated who know that the last 40 years have been unrepresentative. Others of the optimists felt the absence of hurricanes to be a result of a local Caribbean climatic change: the shift of the path or paths of hurricanes relative to the small Virgin Islands group. Most of these people felt that the chances of receiving hurricanes in the near future was either unchanged or less than in the past.

TABLE 18

Predictions of the Chance of Receiving a Hurricane in the Near Future Relative to the Past - Numbers of Persons by Groups (1969)

Group	Chance of Hurricane in the Near Future Relative to the Past:			Sample
	Greater	Unchanged	Less	
Educated Elite	4	5	0	9
Decision-Making Elite	6	1	0	7
Populace (resident >10 years)	4	5	4	13
Populace (resident <10 years)	3	2	2	7
Folk	3	0	4	7
All Groups	20	13	10	43

Reasons for Changing Hurricane Frequencies: Changing Tracks

To some there is a "hurricane belt", "chain", or "zone" in the Caribbean and according to four of five who mentioned the belt, the Virgin Islands are no longer in it. "If they (hurricanes) veer from the natural path St. Thomas gets them." A variant of this view is that there used to be three Caribbean hurricane tracks passing over Barbuda; Guadeloupe; and Martinique, with the middle track (Guadeloupe) over the Virgin Islands. For some reason tropical cyclones have not been on this track for about 40 years, and one long-term resident felt that this change was therefore permanent.

More widespread were views that there are only two major hurricane tracks in the Caribbean area - one to the north and east of the Virgins, and one to the south and west - and that the Virgin Islands rarely receive more than the side-effects of the storms on these two tracks.

The idea of there being two major hurricane tracks (to the northeast and to the southwest of the Virgin Islands) has also been fed by a publication widely circulated in the islands: Hurricanes and Holidays.[45]

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[45] Hurricanes and Holidays--Supplication Day (July 25) Local Thanksgiving Day (Oct. 25). Mimeographed pamphlet, ESEA Title III staff. n.d., (St. Thomas, ?) 26 pp.

The pamphlet paraphrases scientific information in describing the nature and tracks of hurricanes in the Caribbean area, and combines these with selected newspaper accounts of past disasters. The publication mentions a Cape Verde hurricane track which is shown passing to the north of the Virgin Islands. Another compound track, called the "Caribbean", is sketched in far to the south-west, and is apparently of no consequence to the Virgin Islands. Both tracks have basis in fact (as represented), but the manner of their graphic presentation--two heavy black lines and arrows--tends to suggest absolute rather than relative presence.

Related beliefs are that the storms have been tending to pass either far to the north, hitting Florida ("they all go east of here, I come from St. Martin and that gets hurricanes"; "they start 1000 miles east and usually shift northwest and miss St. Croix. They usually hit Florida rather than us") or "farther in the south"("the changing wind pattern has carried them south of St. Thomas"). These hurricanes on the southern track either "spin themselves out" before reaching the Virgins or "go over Puerto Rico's East End." This view of the Virgin Islands' meat being the poison of Puerto Rico and Florida may stem from the coverage in the Island press and radio of the storms that hit these 2 places with disastrous consequences (and might have hit the islands).

Some who feel that there is a decreasing chance of hurricanes 'explained' this by pointing to either the small size of the storms or the

small size of the islands or both. In one case we were told that hurricanes were too youthful to be damaging: "the hurricanes spawn near here and therefore they are not of high velocity", and in another case the hurricanes were dying out before reaching the Virgins and therefore not damaging: "they come to here from 500 to 600 miles south and break their force on the lower islands". These quotations are from prominent officials who have lived 10 years or less on the islands, but there were native residents who expressed similar, if less genetic ideas (Table 19). Were these people taking for granted the widespread lore of a major shift of the two tracks along which hurricanes (with winds of more than 60 miles per hour) moved or had they forgotten both the past record of hurricanes and that the islands had been the same size when they were hit by damaging hurricanes in 1867, 1916, 1924, 1928, and 1932?

The Changing Atmosphere

Many people felt that the absence of hurricanes in the last 40 years was associated with large-scale changes in atmospheric circulation or pressure or temperature (Table 19). "Stronger winds recently have blown the storms away"; "the changing wind pattern has carried them south"; and there are no hurricanes "because of the trade winds". Four of the ten in this group who felt that "atmospheric conditions and wind had prevented one (hurricane) from hitting" had earlier in the interview

Table 19

Reasons for the Prolonged Absence of Hurricanes from the Virgin Islands: Numbers of Persons by Groups.

Group	God & Prayers	Luck & Chance	Law of Averages & Statistics	Small Size of Storm & Islands	Hurricane Cycle "OFF"	Changes in Hurricane Tracks	Atmospheric change Wind Temp.
Educated Elite	1	1	1	1	2	0	2
Decision-Making Elite	1	1	0	2	1	2	0
Populace resident >10 years	5	4	3	0	0	3	3
Populace resident <10 years	0	1	1	3	0	4	3
Folk	0	3	0	1	0	2	3
Total	7	10	5	7	3	11	11

(43) individuals

blamed atomic testing for the climatic change on the island. Three others blamed man for meddling with the atmosphere and thereby changing hurricane frequency through his cloud-seeding operations, increasing flow of air traffic, and increased use of "electrical appliances...(that) attract hurricanes and draw them".

"Atmospheric pressure is less, so less hurricanes and we're not likely to get one, the chances don't increase", one school teacher informed us. Some, like this school teacher, convinced of a long-term climatic change thought of it as nearly permanent. But the majority of this group thought of hurricane absence as a temporary consequence of atmospheric changes. And in January, 1969 many saw signs that a major atmospheric change was under way, as epitomized in the colder and recently wetter winters and the increased windiness of January 1969. The floods of May 1969 following a monthly rainfall of between 15 and 25 inches apparently convinced even more people that there was a high chance of the islands' having a hurricane in 1969 or in the near future.[46]

The Imminent Hurricane

For everyone in 1969 who felt that the chance of an imminent hurricane was declining there were two who believed that the chance was greater, and Table 19 reveals that the elite and particularly the decision-

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[46] Communication with Robert vanEepoel, mid July, 1969.

makers form a large proportion of this pessimist group. Some explained their view on the basis of an incipient reversal of the atmospheric conditions or a prospective change in the direction of hurricanes from the pattern of the last 40 years. But the majority of the pessimists stressed luck (and the law of averages), prayers, and cycles as the reasons for the recent absence of hurricanes.

Hurricane Cycles

Those who believe that hurricane frequency follows a cyclical pattern feel that the "on-cycle" has either begun or is imminent. Two decision-makers on St. Croix indicated that Senator Lawaetz of St. Croix "who is a farmer, feels that there is a cycle of hurricanes and that one was due in 1968". One agreed, the other did not, adding that there were others besides Lawaetz who "think there is a 40-year cycle." Three others among the educated elite recognized hurricane cycles. A Tortolan thought that "hurricanes go in cycles of 10 or 20 years" and equated them with the wet phase in the wet and dry cycle. He felt that the "island should get one soon". In St. Thomas we were told that "climatic change goes in cycles--wet and dry as with hurricanes". ("Since we haven't been hit the chances that we will be increase every year"). As with drought, so with hurricanes, the cycle theorists are found, almost exclusively in the elite group(s). Could it be that 'cycles' are an elite idea rarely transmitted to the folk and populace?

Religion

Religion and superstition are both deeply involved in beliefs about hurricanes particularly among native residents. Yet in the open-ended questionnaire of 1969 God and prayers were mentioned as being effective against hurricanes only by old natives. Non-natives simply commented on the native belief in the efficacy of prayer. The "people are very suspicious...(and) very religious and say a prayer if the hurricane doesn't strike". This suggests, perhaps, a strong carry-over among the older natives of the great fear of hurricanes that existed among the islanders when Earl Shaw did his field research in the Virgin Islands in the late '20s.[47] Stone (1942), paraphrasing Shaw, wrote that among Cruzians "these storms (hurricanes)... are regarded with such dread by the people that special prayers for deliverance are made at the beginning of the hurricane season, and a thanksgiving service is held when the period of danger is past."[48]

The open response of the old native was epitomized in 1969 by a 78-year old native school teacher who had lived all her life on St. Thomas. She identified (quite correctly) three severe hurricanes: those of 1867;

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[47]Earl B. Shaw, Geographic Studies on the Virgin Islands of the United States, Unpublished Ph. D. in Geography, Clark University, 1932, pp. 36-58.

[48]Stone, op. cit., p. 50

1932 - "the last one" and 1916 "the worst one", that "blew the house in" with "very strong winds". She prays to God "on July 25th in the churches to spare them from hurricanes", and "on October 25th", she prays "thanking God they have been spared... Hurricanes haven't hit the island (since 1932) because of luck and God." An old native policeman used similar words: "hurricanes...haven't hit because we pray that they won't hit".

We were told on two separate occasions on St. Thomas in 1969 that "A catholic priest said that if a church was built facing east on the hillside, the island would be spared from hurricanes. The church was built shortly after the 1932 hurricane. There has not been a hurricane for 30 years". And we were told on both St. Croix and St. Thomas that the Governor (Paiewonsky) had recently stated, following a hurricane scare, that "good people had been spared by God".

While the old natives may be frank about their belief in the efficacy of God and prayer, a large proportion of the islanders place more faith in prayer than they profess openly. For while only 2 in 89 volunteered "prayer" as a "perceived adjustment" to the hurricane hazard in the 1970 questionnaire, 62 of the 69 who responded knew of friends and neighbors who prayed when hurricanes were forecast and imminent. Fifty-six of 62 viewed prayer as a 'good' rather than a 'bad' response to the hurri-

cane danger (27 answered neither negatively nor positively), and a large number of people mentioned going to the church (or fort) as another good response to the hurricane danger (Table 24).[49] However, not even the older islanders believe that divine absolution from hurricanes will go on indefinitely; on the contrary most implied in 1969 that a hurricane was imminent (Table 18): "God is on our side (but) we're in for a big one soon though," a 55-year old native school teacher told us.

Superstition

No one was willing to admit belief in magic and superstition in relation to hurricanes but many assured us such beliefs exist, while others were at pains to deny their own belief in superstition when asked about hurricanes. According to a school principal, "often the kids would talk of spirits--jumbies--that would tell (that) it - a hurricane - was coming". This presumably reflects adult talk at home.

Luck and the Lore of Averages

Belief that an increase in hurricane frequency is imminent is more commonly associated with the view that the "luck", "statistics", and "sheer chance", that have kept hurricanes away for the last forty years, cannot go on forever. One optimist (a continental hotel owner) felt that good luck would continue indefinitely and two thought the chance of a

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[49] On the strength of the religious beliefs mentioned in 1969 we included a special question in the 1970 survey, and the answers to this question turned out to be the most effective correlate with a great number of variables and perhaps the best predicter of behavior before and during hurricanes.

hurricane striking to be unchanged, but for others the lore (or law) of averages is now operating against the Virgins. "The law of averages determines what areas will be hit and what won't be, (the hurricane is) just a phenomenon of nature", (Thomian woman), and "the law of averages says there will be one (hurricane) soon", (male Tortolan). "We can attribute it (the absence of hurricanes) to luck and statistics", said a Thomian member of the educated elite, "and since we haven't been hit, the chances that we will be increase every year." Elsewhere, on two different occasions we were told that statistics had recently been foiled - "statistics said we were to get one (hurricane) this year (1968)" and "the odds were against us last year".

Those who combine the notion that the islands have been "just lucky" in missing hurricanes with the belief that a hurricane is imminent, are predominantly long-term, mainly native, residents on each island during this century, i.e., one every twenty-five years.[50] Their view is epitomized, perhaps, by the statement of an articulate native decision-maker who had spent all his 50 years on the Virgin Islands and experienced the 1928 hurricane on St. Croix: "Hurricanes come at least twice in a lifetime...(and so)... I feel one is overdue".

In fact island leaders seem to be convinced of the imminence of a major hurricane. In a behavioral context this pessimistic view shared by the decision-makers and many long-term (native) residents will have

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[50] J.S. Beard, The Natural Vegetation of the Windward and Leeward Islands, Oxford: Clarendon Press, 1949, p. 175.

a salutary effect on hurricane preparedness in the immediate future or until a hurricane hits (with the one qualification that preparedness be extended beyond the official limits of the hurricane season). But, by the same token, once a hurricane has hit, those "pessimists" who believe in the law of averages and cycles may feel that the likelihood of another hurricane hitting the islands in the same year or immediately afterwards is negligible. Both the theory of probability and the recorded hurricane experience of the islands reveals the falsity of this response.

Probability theory suggests that there is, in fact, no greater chance of a hurricane next year than in any other year in the past or future and therefore that people should be well prepared every year. For this reason and others, a majority of the educated elite (1969) held the view of an unchanged probability of a visitation by a hurricane. This view was also found among a sizeable number of the populace who had lived on the islands more than 10 years (1969). Interestingly (yet in a small sample) it was not found among the folk who believed either that there was less chance of hurricanes in the future because the atmosphere and hurricane tracks had changed markedly or that there was more chance of hurricanes because the islands had too long defied the "law of averages."

Four Stories and the Pattern of Hurricane Occurrence

The Hazard-Group questionnaire in 1970 asked a direct question on patterns of hurricane frequency. After a hurricane four men told different stories about a hurricane coming again. The first suggested that hurricanes come in clusters (suggesting that another hurricane would come soon); the second stressed the randomness of hurricanes (suggesting that hurricanes would come again "in any year"); the third stressed the cyclic nature of hurricanes (suggesting that there was a regular time for hurricanes and "that time must pass before it comes again"); the fourth thought that hurricanes would not come again (Table 20).

Only six of 93 respondents thought the pattern of hurricane occurrence to be cyclical in the long-term (third story), while another four of 93 felt that a clustering tendency--a form of cyclical pattern--described hurricane frequency. This goes some way to confirm our finding of 1969 that 'cycle' theorists are a small (probably elite) group and that cycle theory is rarely found among the populace, for only 11 percent saw a recognizable pattern in hurricane occurrence, and half of these (5 of 10) respondents were young (18-30 years). The vast majority of Thomians (4 out of 5 persons) believed that hurricanes "would come again, but did not know when, because hurricanes can happen in any year" (second story). The remaining six of 93 persons either felt that hurricanes would not come again (fourth story) or could not identify with any of the four stories as

Table 20

Percentage Proportions of Persons' Answers to the Story Question

	First Story (Clustering)	Second Story (Random Series)	Third Story (Cyclical)	Fourth Story (No More)	Don't Know	Total
Young (18-30 yrs)(22)	9.0	72.7	13.6	4.5	0.0	100.0
Middle Aged (30-50 yrs) (40)	2.5	85.0	5.0	2.5	5.0	100.0
Old (50-90 yrs) (31)	3.2	87.0	3.2	0.0	6.4	100.0
Total (93)	4.3	82.7	6.4	2.1	4.3	100.0

Table 21

Hurricane Expectancy (Will a Hurricane Come Again in Your Lifetime?)

	Don't Know	Yes	No	Total
Number of People (Respondents)	36	51	6	93
	38.7	54.8	6.5	100.0

		Those Who Answered Yes (54.8)			
	Don't Know	Can't Say When	A Few Years	Soon	Many Years	No
Percentages	38.7	29	10	15	1	6

presented.

Unfortunately missing was a story suggesting that the longer the time since the hurricane the greater the chance of occurrence of a second (the law of averages). People who believed this were clearly included under the rubric of the second story. Two similar yet distinctive viewpoints on hurricane incidence were subsumed in the responses of the great majority who opted for the second story. But it was not possible from the story-question (1970) to check the inference to be drawn from Table 18 (1969) that among the populace respondents divided equally over the two views (i.e., seven of 20 thought the chance to be unchanged, and seven of 20 thought the chance to be greater). This roughly equal division was, however, confirmed by the answers to another question: Do you think the hurricane will come again in your lifetime? Of the 51 respondents who said 'yes' (Table 21), 46 percent thought the hurricane would come "soon" or "in a few years", (believers in the law of averages), while 52 percent "couldn't say" when the hurricane would come (believers in random series).

The Beneficent Hurricane

We have assumed to this point that respondents felt that hurricanes were essentially destructive. However, two long-time natives pointed out that hurricanes brought welcome rain to the islands, and one of these men, from the educated elite group, saw hurricanes as more beneficial than detrimental to the islands in that they brought much needed rain

that could end a drought. (It was implied in fact that the passage of a hurricane was one of the few ways that a drought such as the one recently experienced, could be broken.)[51] "I think men are seeding the hurricanes and breaking them up. They are robbing us of moisture from them".

This conception of the beneficent hurricane, is surprising, at first glance. But it must be remembered (1) that the cautious scholar R. B. Stone wrote in 1942 "that it is not minimizing the danger from these storms to say that they rarely strike with great severity", and (2) that many if not a majority of the hurricanes that have come within 100 miles of the islands in the last 100 years have brought copious rains, frequently to parched agricultural lands, usually at a time when soil moisture storage levels were very low. Furthermore our Cruzian informant is not old enough to have experienced the last major hurrican of 1928 on St. Croix.

Thus there is no need to make any apology for this minority view, for there is a strong possibility that the 48 known hurricanes that have passed over or close to these dry islands in the last 100 years may, on balance, have been more beneficial than detrimental. The majority were C and D

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[51]To my knowledge seeding operations have been under way for the last 3 years and possibly more on St. Croix. The drought--the worst drought in V. I. history--has been synchronous with these operations and a hurricane is long overdue according to this man and many others. It is an easy step to relate the three, particularly if one believes that hurricanes are beneficent, in that they can break protracted dry spells.

type storms passing at more than 50 miles distance of Bn storms passing north. These storms have brought rain usually without severe flooding, and without tidal surge. And certainly in recent decades with better warning systems, stricter building codes, more protection for people and animals, the decline of crop agriculture and the great need for full cisterns and catchments for a growing population, all but the most serious hurricanes might well be a boon in this special situation where drought is practically endemic.[52]

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[52]See "Tropical Storms that are Beneficial", in Ivan R. Tannehill, Hurricanes, Princeton: Princeton University Press, 1950, pp. 130-131. Fassig, as paraphrased by Tannehill "found that 60 percent of the storms that affected Puerto Rico from 1899 to 1928, inclusive, were beneficial."

PART IV: ADMUSTMENTS TO THE HURRICANE HAZARD

Awareness of the Hurricane Season: Official and Unofficial

> "June too soon, July stand by, August come if it must, September remember, October all over." Virgin Island saying--School teacher, St. Thomas, January, 1969.

There is an official hurricane season in the Virgin Islands. It runs from Supplication Day (July 25th) -- a holiday -- to Thanksgiving Day (October 25th). More than 75 percent of the people interviewed (1969) included this period in their hurricane season. Nine people equated the hurricane season with the official season -- giving the exact dates of the latter. Not surprisingly four out of the five decision-makers and four of the long-term residents in the populace mentioned these exact dates (Table 22). If nothing else, there is a great deal of consistency in the islanders' views about the hurricane season.

This is not surprising when it is noted that all the 48 hurricanes experienced in the American islands since 1867 have occurred in July, August, September and October, with by far the majority passing in August and September (Table 1). The islanders assume this record in their responses. More than 90 percent of the people consider September as a hurricane month, and more than 80 percent include August, the last week in July and the first three weeks in October -- the official hurricane season (Table 22). No hurricanes have occurred in 1738 and none

Table 22

Periods in which Hurricanes can be expected in the U.S. Virgin Islands (29 interviews)

Group	May	June	July	July 25-31	Aug.	Sept.	Oct. 1-25	Oct.	Nov.	Dec.	Jan.
Educated Elite (4)	0	1	3	(3)	4	2	(2)	2	0	0	0
Decision-Making Elite (5)	0	0	1	5	5	5	5	1	0	0	0
Populace, resident more than 10 years (11)	1	1	3	7	7	11	9	5	2	1	1
Populace, resident less than 10 years (6)	1	1	4	5	6	6	6	5	2	0	0
Folk (3)	1	1	2	2	3	3	3	3	0	0	0
Total (29)	3	4	13	22	25	27	25	16	4	1	1

are expected, except perhaps by the few who included May, June and November in the hurricane season, and by the four people (out of twenty-nine) who warned us that hurricanes can occur in any month.[53]

Yet there is one danger in too ready an acceptance by officials and others of these precise dates for the beginning and end of the hurricane season; the acceptance of the idea that hurricanes only occur between these dates and the consequent danger that preparedness would be restricted to that period. This danger is more real when it is recalled that it is the decision-makers and long-time residents who think of a rigidly-defined hurricane season. That preparedness over a longer season in the Virgin Islands is perhaps more imperative than on the coasts of the continental United States is obvious, for the northeast Caribbean is closer to the major hurricane source area, and it is possible that tropical cyclones can be formed in the vicinity of the Virgin Islands and burst upon them without much warning even in the

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[53]One person called a recent gale in January in St. Croix a "hurricane", and another mentioned a hurricane that affected Anegada, British Virgin Islands, on Christmas Day. John P. Knox noted that "Sir R. H. Schomburgk has found recorded from the year 1494 to 1846, or in a period of 352 years, 127 hurricanes and severe gales, which committed more or less injury in the West Indies. Of this number occurred in March, 1; June, 4; July, 11; August, 40; September, 28; December, 2. Of 13 no date or month recorded."

(Historical Account of St. Thomas, West Indies, New York: Charles Scribner, 1852). Ivan R. Tannehill (op. cit., p. 113) has published the following figures of the number of tropical storms in each month, 1887 to 1944, and the number of known hurricane intensity are given in brackets (hurricanes of the Gulf, Caribbean and North Atlantic): May 5 (0); June 25 (10); July 30 (16); August 87 (59); September 134 (76); October 107 (40); November 27 (7); December 2 (0); Total 416 (208).

days of the U.S. Weather Bureau warning system.[54]

Out of the 48 tropical cyclones that have affected St. Thomas and St. Croix since 1866, two (both severe) have occurred outside the official hurricane season--on July 14, 1916 and October 29, 1867, presumably after the establishment of the period July 25 to October 25 as the official hurricane season. The records of hurricanes in the Caribbean as a whole show that at least one in every 10 hurricanes hit the area outside this period.[55] Another worrying point is that six hurricanes have occurred in the last week of July since 1737, which suggests that the official hurricane season (and hurricane preparedness) might with great safety be brought forward to mid July or earlier, and to include late October in which the worst hurricane ever measured (1867)moved over St. Thomas.

Signs of the Imminent Hurricane

Before the U.S. Weather Bureau hurricane warning system was well developed, the islanders relied on many signs to forewarn them of hurricanes and there are still many who rely on natural 'signs'.[56] Informants

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[54]Tannehill, op. cit., pp. 55-69, and particularly p. 57.

[55]Ibid., p. 113.

[56]Knox, op. cit., pp. 214-216.

told us in 1969 that: "Farmers could tell by a heavy crop of avocado pears. This would mean no hurricane." Another told us that "Birds, certain kinds, indicate the presence of hurricanes." A recurrent theme was the brightness and calmness before the hurricane: "A completely clear and bright sky" (St. Croix), a marked "lightening" of the sky (St. Thomas), "a calmness the day or two before" (Tortola). There are obviously many other harbingers of the hurricane. "Old timers would notice it by the yellow color of the sky" a 55-year old native told us, and an agricultural expert told us that "I look for very high rain clouds (and) the roll and roaring of the tides." A Tortolan agriculturalist still looks for "tide rises" and a native Thomian has a feeling" when a hurricane is due and finds 3 indications: the "birds move inland, sea gets calm and winds shift"

This line of questioning was pursued in 1970. Respondents were asked: "are there any signs or ways of knowing when a hurricane will come again?" Unfortunately the last word troubled some, who answered the question literally, concluding that the question referred to long-term patterns and prediction. Many of those who answered "no" were of this type (Table 23). Others apparently answered the intended question: "what signs, if any, warn you of an imminent hurricane?" Fifty-five respondents were aware of such warnings, and 51 specified the warning signs.

TABLE 23

The Existence of Signs Predictive of Hurricanes

No Signs	Don't Know	Signs Not Specified	Signs Identified: Human Phenomena	Natural Phenomena	Human & Natural Phenomena	
29	9	4	25	21	5	51
			49%	41.1%	9.8%	100%

Most of the "human phenomena" identified referred to agencies: the Weather Bureau, and the Civil Defense, etc. Other replies of this type included man-made instruments and institutions: the radio, the barometer, "the red flag up", the hurricane season, etc. Surprisingly only half of the respondents mentioned these signs or warnings exclusively; ten percent use both human and natural phenomena, and a remarkable 2 in 5 say they use natural phenomena exclusively, e.g. "ring around the moon", "the roosters stop crowing", "birds fly away", in addition to the signs mentioned in 1969.

Obviously there are many who have never paid much attention to Weather Bureau warnings, and others who distrust the Weather Bureau[57]

[57] A tornado study made by Duane D. Baumann and John H. Sims in Illinois and Alabama found a remarkable difference in the reliance on the U.S. Weather Bureau in the two states. There was heavy reliance on natural phenomena and a relative distrust of the Weather Bureau in Alabama (unpublished paper, mimeographed, Analysis of the Tornado Hazard Data).

(and the Civil Defense), perhaps because of the "false alarms" of hurricanes that have not affected the islands in any way. "The Weather Bureau many times thought we'd get it, but we fooled them", a Thomian told us half-seriously. "I rely on atmospheric signs when a hurricane is going to strike regardless of the Weather Bureau", said another in St. Croix (1969). It is clear that for some the U. S. Weather Bureau and meteorologist at San Juan are replacing the "jumbies" as prophets and bad men of the hurricane.

There is, of course, some danger in being totally reliant on one source of hurricane information--the U. S. Weather Bureau, and some value remains in watching for the "natural" folk signs of hurricanes as a secondary warning system. In certain circumstances, radios may be unavailable or out of commission, and it is still possible for youthful tropical cyclones to develop to the southeast and south of the Virgin Islands and burst on the islands before warnings could be widely transmitted from San Juan.

There is another quite different potential danger associated with the U. S. Weather Bureau warning system and publicity of the Chief of Civil Defense--that a new series of hurricane beliefs, true and false, may develop as a result of the apparent excess of hurricane information now being provided. There is already a great deal of evidence that such reactions have set in. A little knowledge, where nothing but (folk) lore

existed before, may be a dangerous thing. For instance, some who have lived on the islands for 40 years or more belive that hurricane frequency in the Caribbean has increased of late (whereas this apparent increase is simply the result of the better and farther-ranging information on hurricanes provided in the last 20 years by the U.S.W.B.). These persons also know from personal experience that the Virgin Islands have had no hurricanes since 1932. From the comparison of these 2 'facts' they draw support fot the notion that the Virgin Islands can no longer be in the hurricane belt, for they have been made aware of a large number of hurricanes that have no more than "grazed" the outer islands.

Perceived and Actual Adjustments to the Hurricane Hazard

Even the best of questionnaires, processed subsequently with the most advanced techniques leave many questions unanswered and remarkable gaps in our knowledge. In the Virgin Islands in 1970 we were testing the standard questionnaire to be used in cross-cultural studies of all types of hazards by the I.G.U. Commission on Man and Environment and, as a consequence, many of the sections used in the trials were later discarded and other sections were substantially modified while we were in the process of collecting data. Furthermore the processing of the data by the Institute of Behavioral Sciences, University of Colorado Graduate School Computing Center went through different stages, and, as might be expected of an experimental phase in the questionnairing procedure, the

data were sometimes processed in a sub-optimal fashion.

Most of the problems noted above affected the all-important section of the questionnaire (1970) devoted to perceived and actual adjustments to the hurricane hazard. Consequently what follows is a summary of our findings that is at times simply a presentation of raw data.

To the question: "When a hurricane comes, what do other people (friends and neighbors) do?" respondents were encouraged to volunteer responses (unprompted). The replies are indicated in Table 24. Follow-up questions mentioned six adjustments to hurricanes identified in the trial-run of the questionnaire and respondents were asked if "other people" made specified adjustments and whether these were considered "good or bad". (Table 24). These "perceived adjustments" made by others were then compared to the "actual adjustments" of the respondent: "do you do any of these things?"

Analysis of the perceived adjustments to the hurricane hazard proved far from simple, and a number of the writer's hypotheses were directly controverted. A surprisingly weak positive relationship (significant only at the 11% level) was shown between the number of perceived adjustments to hurricanes identified by respondents and the number of actual adjustments made by each. And the number of perceived adjustments was not found to be related in any way either to 1) expectations of hurricane fre-

quency in the future, or to 2) estimations of hurricane frequencies in the Virgin Islands in the past, or to 3) judgements as to whether the Virgin Islands had "trouble" with hurricanes.) This surprising lack of relationship between perceptions of adjustments and perceptions of past and future incidence and character of Virgin Islands hurricanes was compounded by even more surprising negative correlations. Our study found that the higher the levels of literacy, the higher the income levels,[58] and the higher the hurricane damage levels experienced by respondents in previous hurricanes, the fewer the number of adjustments volunteered by respondents. These relationships were significant at the .15, .015, and .01 levels of significance respectively. Furthermore and perhaps consistent with the last findings, no relationship was recognized between the number of adjustments identified and the number of hurricanes actually experienced (per year of age).

Owners did tend to recognize more potential adjustments than did tenants, and the same was true of the long-time residents as compared to recent arrivals. But in both cases the relationships were quite weak (at the 17% level of significance). Whereas interpretation of the number of perceived adjustments to hurricanes proved difficult, that pertaining to actual adjustments was relatively straightforward. As might have been

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[58] The strong positive relationship between income and literacy was significant at better than the .001 level of significance.

TABLE 24

Array of responses--what do your friends and neighbors do?

		Responses when asked:			Perception of Value of Adjustments		
	Mentioned (open ended)	Yes	No.	NA	Good	Bad	No Answer
Nothing	5	33	27	24	2	46	41
Pray	2	60	7	20	56	6	27
Bar House	54	30	1	4	66	7	16
Cut Trees	3	30	41	14	34	20	35
Leave	8	37	37	7	31	34	24
Go to Church, Fort	17	60	8	4	60	10	17
Get Food, Water	31						
Other Provisions	15						
Prepare Boat	3						
Other	14						
Total	152	250					

expected strong positive relationships existed (significant at the .001 level) between the number of adjustments actually made and 1) the number of hurricanes experienced (per 100 years of age) by respondents and 2) the housing (tenant or owner) status of respondents. Owners and those with extensive hurricane experience made (or stated that they made) far more (and different types of) adjustments than renters and those with little former experience with hurricanes. Estimations of past hurricane frequencies, and the number of years lived in the Virgin Islands were not positively related to the number of actual adjustments.

The Adjustments Made in the Virgin Islands (1970)

Most people were aware of a range of adjustments made by others (neighbors and friends). These ranged from evacuation, preparation, and protection to relatively passive prayer. Protection by barring the house is the most common response of neighbors and friends. Only one person of those interviewed was unaware of persons who failed to bar houses. The majority of respondents saw purpose to this--but there were some (9 percent) who felt that the battening of doors and windows was dangerous. The flow of wind through the house afforded better protection than barring, they felt.

Few people (4 percent) mentioned the cutting of trees close to the house, in our introductory (open-ended) discussion. But it became clear that tree-cutting before the onset of the hurricane was common in St.

Thomas: approximately 42 percent of the people were aware of this practice. The majority of islanders were, however, unaware of the practice, and this would account in large measure for the many who had "no answer" about the value of this response when asked whether tree-cutting was good (Table 24). A majority of those who had thought about it felt that cutting of trees was valuable. Others were ambivalent (as in East Pakistan).[59] Trees provided protection against the wind (particularly in moderately severe hurricanes) but there was also the danger of trees or large branches falling on and against the houses. Furthermore, in the Virgin Islands many of the trees near houses are coconut trees with numerous compact projectiles. On the whole in the Virgin Islands it was felt to be beneficial to cut trees before a major hurricane although there were many who saw this as more dangerous than effective, and a very large proportion who were unaware of the tree-cutting as a protective measure or of the debate concerning its effectiveness.

Preparation for a hurricane is also common--food, canned goods, and water are laid in by many although by fewer than might have been expected (31 of 89), and a sizeable proportion of islanders know of friends

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[59]M. Aminul Islam, Human Adjustment to Cyclone Hazards: A Case Study of Char Jabbar, Natural Hazard Research, Working Paper No. 18, 1971, p. 13.

who get in "other provisions"--candles, matches, oil, gasoline, etc. (17 of 89). Unfortunately procedural problems in the questionnaire curbed further pursuit of information on 'preparation', although it did appear that 3 of the 89 at least prepared their sailboats for the storm.

Evacuation from home or office building etc. is a widespread response and takes two forms on the island--one, movement to large, ostensibly strong buildings, notably the fort and churches--is viewed generally with approval by the majority of the island's inhabitants; approximately 10 percent of the island's inhabitants were unaware of at least one friend or neighbor who availed him- or herself of this opportunity. One in eight thought this response was bad.

The other form of evacuation--leaving St. Thomas--is an option open to a smaller proportion of the population. Surprisingly, half of the respondents were aware of this form of evacuation. An owner of a large hotel complex on St. Thomas told me that if a hurricane was near, he took the opportunity to visit his family and friends on the mainland: "after all it is the off-season and the hotels empty with the first threat of hurricane." This adjustment, while obviously effective, is nevertheless resented (and thought to be selfish) by at least half the islanders. Those who leave in this way are thought to be fair-weather friends of St. Thomas, letting those who stay face the storm and the aftermath of destruction.

Those who find this response 'good' clearly see it from the viewpoint of the individual concerned. Those who find the response 'bad' base their judgement on the feeling for loyalty to place and upon the need for the rallying together of the island community in the storm's wake.

Few mentioned 'prayer' as an adjustment in the open-ended questioning, yet when asked directly most respondents indicated a knowledge of friends and neighbors who prayed before the onset of a hurricane. Less than 10 percent of the respondents were unaware of this 'adjustment'. Belief in the effectiveness of prayer was widespread, although there were many who felt simply that prayer "wouldn't hurt". The few who thought prayer to be 'bad' did not specify why.

Remarkable, yet highly consistent with the findings on the awareness of the incidence and character of the potential hurricane hazard, was the high proportion of respondents who were aware of friends and neighbors who did "nothing" when a hurricane was forecast or imminent. Of those who responded almost 60 percent knew of people who did nothing. This failure to take any precautions before the onset of a hurricane was deplored by practically all our respondents.

Religion, Prayer, and Hurricane Hazard Adjustment

Encouraged by the Hazard Group to add one question to the standard questionnaire being tested, we followed tantalizing leads from the 1969 study, and attempted to relate religious behavior and hurricane hazard

perception. The question inserted was: What did you do last Supplication Day--the official and traditional beginning (July25) of the hurricane season in the Virgin Islands? Three responses, along a continuum, were common: "go to church", "pray", and "do nothing".

We found that the more aware people were that the Virgin Islands had 'trouble' with hurricanes (question 18 and Table 18), the greater was the chance of their going to church and praying (relationship significant at the 1 percent level). Quite consistent with this was the finding that the higher a person's estimate of the past frequency of hurricanes in the Virgin Islands, the greater the tendency to pray and go to church on Supplication Day (relationship significant at the 1.5 percent level, Table 25). Those who go to church on Supplication Day have a greater fear of, and a much more accurate knowledge of the hurricanes that have affected and will affect the Virgin Islands. Conversely, those who do nothing on Supplication Day are either doubtful whether the islands are troubled by hurricanes or feel that the islands are not troubled by hurricanes or underestimate the character and frequency of the major tropical cyclones.

Religious behavior on Supplication Day was not shown to be related significantly to the four stories (question 20 and Table 20) chosen by respondents. Nevertheless most of those who failed to choose the second story which presented hurricane incidence correctly as a random series

were also people who did nothing on Supplication Day. Therefore, many who do nothing on Supplication Day do so because their information on hurricanes is deficient.

Not surprisingly, disproportionately large numbers of the church-goers on July 25 are over 50 years of age and owners of houses (Tables 26 and 27). They have accumulated a great deal of hurricane knowledge and have much to lose. They tend to expect prospective aid to come from the government after a damaging hurricane (Table 28). Those who do nothing, or simply pray, on Supplication Day tend to be young and middle-aged tenants with less experience of hurricanes and (presumably) less to lose in a troublesome hurricane. These people tend to expect either no aid after hurricanes or help from the Red Cross, church, or other special groups (rather than from the government).

The relationships between religious behavior and the respondent's age (question 6) and housing status (question 10) were significant at the 5 and 1 percent levels respectively, and the relationship between religious behavior and the source of prospective aid in the hurricane's aftermath was significant at the 2 percent level.

Table 25

Religious Behavior and Estimated Past Frequency of V.I. Hurricanes in Respondent's Lifetime (Percentages)

Religious Behavior on S.D.	No. of Hurricanes Estimated						
		1	2	3	4	5	Total
	Cases	(14)	(12)	(8)	(7)	(1)	
Go to Church	(18)	28.5	50.0	50.0	42.8	100.0	42.8
Pray	(9)	14.2	8.3	25.0	57.1	0.0	21.4
Nothing	(15)	57.1	41.6	25.0	0.0	0.0	35.7
Total	42	100.0	100.0	100.0	100.0	100.0	100.0

Table 26

Religious Behavior on Supplication Day and Age (Percentages)

Behavior on S.D.	Age Group of Respondents (in years)				
		10-30	30-50	>50	Total
	Cases	(21)	(40)	(30)	(91)
Don't Know	(4)	14.2	2.5	0.0	4.3
Go to Church	(30)	23.8	29.9	43.3	32.9
Pray	(21)	19.0	17.5	33.3	23.0
Nothing	(36)	42.8	50.0	23.3	39.5
Total	(91)	100.0	100.0	100.0	100.0

Relationship significant at the .045 level of significance

Table 27

Religious Behavior and Housing (Percentages)

Behavior on S.D.	Housing Status		
	Owners	Renters	Total
Cases	(58)	(32)	(90)
Don't Know	1.7	9.3	4.4
Go to Church	36.2	28.1	33.3
Pray	31.0	6.2	22.2
Do Nothing	31.0	56.2	40.0
Total	100.0	100.0	100.0

Relationship significant at the .008 level of significance

Table 28

Religious Behavior and Prospective Source of Aid After Hurricane

Behavior	Source of Aid					
	Don't Know	Friend	Gov't	Spec. Group	No One	Total
Cases	(1)	(2)	(50)	(34)	(4)	(91)
Don't Know	1	0	2	1	0	4
Go to Church	0	0	20	9	1	30
Pray	0	1	9	11	0	21
Do Nothing	0	1	19	13	3	36

Relationship significant at the .017 level of significance

Neither the number of hurricanes actually experienced by respondents (question 15) nor the worst damage levels experienced in the hurricanes (question 16) were related to religious behavior on Supplication Day. And it will be recalled, these variables were not related in any obvious way to the number of perceived adjustments to the hurricane hazard.

Adjustment levels among the populace appear to cut across lines of literacy, income, actual hurricane experience, previous hurricane damage experience, and years of residence in the Virgin Islands. Only in the area of religious behavior are relationships strong and consistent.

The absence of relationships where they might have been expected simply points up both the remarkable diversity of perceptions of the hurricane hazard held by the people of the Virgin Islands and the highly varied experiential and educational backgrounds of the peoples who have migrated to the Virgin Islands in the last 25 years.

The people who are really sensitive to the hurricane danger are those from all walks of life who have sunk much of their life's capital into a home and property. Whether these people are 50-years old Virgin Islanders with experience of only one major hurricane or continental retirees resident five years on St. Thomas and with no hurricane experience, they fear the hurricane, make numerous adjustments when a hurricane is imminent, and pray to God in church on Supplication Day that they will be spared in the coming hurricane season. They see

hurricanes as a random series (probability theory), are relatively pessimistic in reading the record of past hurricane occurrences in St. Thomas, and are essentially realistic in their view of the likelihood of a visitation of damaging hurricanes in the future. As a group they place little faith in 'natural' predictive signs of imminent hurricanes, some relying exclusively on U.S. Weather Bureau hurricane forecasts, and others believing that hurricanes are the will of a whimsical and arbitrary God whose signs are not made obvious to man.

As a group these persons present little problem to those concerned with educating Virgin Islanders to hurricane preparedness. By contrast, another group--those who "do nothing" on Supplication Day, present a major problem. Many of these people, having little knowledge of the hurricane history of St. Thomas think of Supplication Day as unnecessary; others think of the observance as outdated, given modern building strengths and technology and the 'fact' that hurricane tracks have changed. Others, a sizeable number, have never heard of Supplication Day--a situation symptomatic of a dangerous lack of awareness of the Virgin Islands hurricane hazard; still others have so little to lose that their only concern is personal safety.

Whether or not church-going and prayers are effective on Supplication Day or any other day in mitigating the hurricane hazard is immaterial. What is important is that religious behavior, particularly on

Supplication Day, is the single best indicator available for identifying those who have a limited awareness of the hurricane hazard and sometimes related unpreparedness.

There would be little need for a report on hurricane hazard perception if a severe hurricane (A-type) had struck the Virgin Islands in the last 30 years, or if a damaging hurricane (B-type) had come in the last 15 years. This is the average time-interval separating hurricanes of these types in the V.I. in the last 100 years. As it happens, however, the last A-type and B-type hurricanes visited upon St. Thomas 56 years and 40 years ago respectively. Thus a number of myths have grown up about the past and future hurricanes and their patterns, character and frequencies in the islands. Half-truths and distortions are commonplace, and many of them are fueled by often well-intentioned but frequently misguided publications available on the islands. What is surprising is that in an island with large numbers of recent immigrants, so many are aware of the hurricane hazard and of the many possible adjustments that can be made. Clearly many people make adequate adjustments when a hurricane is forecast.

Nevertheless there are also many who do little or nothing when a hurricane is forecast. These people make up anywhere between 8 and 20 percent of the population of St. Thomas, and perhaps as much as one-fifth. Another estimated 25 to 35 percent of the population either make

inadequate preparation for impending hurricanes or have imperfect information about the possible intensity, frequency, and future probabilities of hurricanes and of associated tidal surges and floods.

Furthermore, of those who are generally prepared, there are many in coastal areas, in flood plains in steep-sided vallyes, and at the bases of recently cut-over steep hill-slopes etc. who are unaware of, and make inadequate preparation for the unforeseen localized dangers that will some day face them.

Conclusion: Increasing Preparedness

The loss of life and some of the property damage that the imaginary Linda causes in the futuristic scenario that prefaces this report can be averted if the Virgin Islands adopt the "Homeport" plan, the model of how "an imaginary city gets ready for a hurricane."[60] The Hurricane Preparedness Plan devised by N.O.A.A. for the imaginary city of Homeport is much more than St. Thomas has at the moment. It demands a Hurricane Preparedness Committee with seven major responsibilities, the elaboration of special communication links, selection of shelter areas, development of evacuation plans and maps (three - for storm tides of different projected levels are prepared for Homeport), and, above all,

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[60] The Homeport Story, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1971.

a large scale program to acquaint the public with the plans and with the committee's role in hurricane preparedness.[61]

A start in the Virgin Islands might be made by distributing The Homeport Story to prospective members of the Preparedness Committee and their institutions and offices. A follow-up at the public level might distribute the brief N.O.A.A. circular "Hurricane Safety Rules" to all households on the island.

Two handbooks have apparently been widely circulated on the island by the office of Civil Defense. It is significant,however, that in our interviews (with over 170 people) no one mentioned any of these publications or brought them out to show us. There are good reasons for this. Two-thirds of the 90-page booklet entitled In Time of Emergency: A Citizen's Handbook on Nuclear Attack, Natural Disasters concerns nuclear attack. The four pages (75-78) devoted to "Floods and Hurricanes", are hidden in the remainder of the booklet which concerns natural disasters that are potentially of little consequence to the Virgin Islands.[62]

The 100-page Survival Handbook issued by the government of the Virgin Islands does abstract the relevant sections concerning hurricanes

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[61] Ibid., pp. 5-16

[62] In Time of Emergency, U.S. Department of Defense, Office of Civil Defense, H-14, 1968.

from In Time of Emergency but this follows 50 pages of administrative and legislative memoranda of little concern to the public and another 20 pages of minutiae.[63] The information useful in time of and before hurricanes is simply lost and the public (average citizen) cannot be bothered to find it. Some of the booklets will undoubtedly be taken off the shelf, dusted off, and studied after a disaster, but most will have been misplaced or thrown out simply because they are too big, too disparate, and irrelevant to the average citizen. The booklets (reflecting the interest of the issuer - the O. C. D.) are concerned more with nuclear attack than with hurricanes, and with aftermath rather than with preparation for disaster.

Shorter more precise statements are needed if people are to be better prepared: something that can be stuck on the wall in the home and business that can be found or referred to immediately or something carried around by the individual. The Miami Herald's 27 instructions on "What To Do If A Hurricane Threatens" set around a map showing the tracks of the 15 major hurricanes since 1900 is good. It is backed by a useful Hurricane Tracking Map. It is large (23 x 15 inches) but it can be affixed to kitchen-cupboard doors. The wallet-size "Tips for

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[63] Survival Handbook, Government of the Virgin Islands, Office of the Governor, Office of Civil Defense, n. d.

Hurricane Safety" cards published by N.O.A.A.[64] are more succinct and handy and could be carried in the hurricane season by practically everyone on the islands. A minimum improvement upon present procedures could be effected in the Virgin Islands if these materials were mailed to each householder accompanied by suggestions as to where to post the materials mailed. If these and similar pamphlets could be delivered to each householder by hand by members of the O.C.D. community-disaster teams in late June-early July this would ensure a more effective distribution and use. It would at the same time identify to citizens the important local-disaster workers to whom they should turn for leadership. This delivery might occur at each house once every 3 to 5 years, and an effort could be made to identify new householders, and visit each of these before the onset of the hurricane season. The teams might well receive current N.O.A.A. publications such as Hurricane[65] and The Homeport Story.[66]

If such a policy could be implemented, it might double the effectiveness of present preparations. Thus for a severe hurricane such as that described in the scenario $2-3 million of damage and inestimable lives

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[65] Hurricane, U.S. Department of Commerce, Environmental Science Services Administration, 1968.

[66] The Homeport Story, op. cit.

might be saved with a rough outlay of $300,000 over the next 30 years.[67]

Distribution of generally applicable printed materials, however personal, will not ensure maximum preparedness in the Virgin Islands. A re-education program at the individual level is necessary. This report is a preliminary source for such re-education at say the school and community levels. But it is not enough. Thirty years of myth-making about the weak and disappearing hurricane combined with the natural feeling that the disaster will befall others have combined to make the O.C.D.'s task difficult. To counterbalance this effectively can only in my opinion be done if teams of responsible and respected community householders approach the householders in the community and draw up a large-scale personalized "master contingency plan" for each house or group of houses, or, failing that, pinpoint the individual's house in relation to the various evacuation and contingency plans drawn up. Trained physical geographers familiar with the islands' stream, drainage, soil, and coastal characteristics could work out such large scale local 'plans' intuitively, but community volunteers would have more difficulty particularly in envisioning the workings of the hydrologic system at say the "basin-wide" scale (e.g. in the Turpentine Run basin in a 100-year hurricane). It would help immeasurably if physical geographers could

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[67]The crude estimates are extensions of estimates made by Arnold L. Sugg, "Economic Aspects of Hurricanes," Monthly Weather Review, 95, No. 3, 1967, pp. 143-146.

run simulations of hurricanes of various types, magnitudes, and probabilities of occurrence, estimate and map the areal expression of each of these at the micro-level, and ensure that this information is translated comprehensively to those whose task is to set up personalized "master plans" at the community, street, and individual level.

When all is said and done what could be saved by such a procedure (if preparedness were thus increased) is say 5 to 8 million dollars once every 33 years (15 million dollars each century). How much would the procedure cost? Is it worth the annual outlay? The simulation and explanation over 33 years would cost at most $3/4 million and the distribution of the two "publications" would cost $1/2 million through conventional channels. Thus $4 to 7 million in property and lives of inestimable value would be saved if such procedure were instituted. (The calculation does not put any value on the time of the community volunteers, however).

Clearly maximum preparedness will save many lives but will only cut down a small proportion of the costs of hurricane damage. Four fifths of all hurricane damage will be unaffected by even maximum preparedness. Research workers and planners having done all they can to ensure maximum preparedness are thus faced with a second problem that of foreseeing and predicting the sum total of island-wide problems at the level of micro-events that will face them in the aftermath of hurricanes of various characteristics and magnitudes.

The relationship between the Red Cross, the Office of Civil Defense, and other government agencies have been specified; enabling legislation

has been enacted, and procedures for the employees of government agencies, etc. have been specified.[68] But as far as I have been able to determine no projections of the possible and probably spatial and environmental impact of a future hurricane have been made, at any scale.

> Linda, the most damaging hurricane in the island's history struck St. Thomas and apparently St. John in the early hours of yesterday morning. Chaos reigns and.....

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[68] Survival Handbook, op. cit., pp. 5-50

Appendix 1

The Hurricane Section of the Questionnaire (1969)

The hurricane section of the interview was added after interviewing had been under way for almost a week. I became interested in some of the hurricane lore and decided to add a series of further questions. These questions were separate from the interview sheets, and as the interviewers were going through the whole questionnaire from memory after a week in the field, the hurricane section was missed by a few. Consequently our sample is smaller than for other climatic data. Something needs to be said about the sample. We made no attempt to get a random sample for we needed people who had lived on the islands at least 2 years for most of the questions, and in some cases answers were not processed unless the interviewee had lived 5 years or more in the islands.

Appendix 2

Definitions

The educated elite are defined as people with little or no political power but who are 1) in prominent positions in agencies concerned with climate and water resources, 2) in an information-providing position (to both the folk and populace, and the decision makers), and 3) who might be expected to be appraised of the basic 'scientific' knowledge of the island's physical environment. The decision-making elite are prominent people with political power in the islands. The populace were separated from the folk group by their level of education, associations, and occupations. They were presumed to have received some high school education, and to have the newspapers and radio as their main source of "scientific" information about the physical environment. The group included twelve school teachers, twelve hotel, business and store owners and managers (including two wives of business men), three real estate agents, ten bank, store, and office assistants in positions of some authority, one head librarian, two senior policemen, and the vice-president of the student body in the local high school. We eliminated four questionnaires from this group because the interviewees had been on the island less than three years.

The folk group included five taxi drivers, three native sales clerks and typists, two farm workers, one construction worker and one wife of a farm worker. The people in this group had less than a high school education, and their main sources of information were presumed to be family, local groups and hearsay. Perception of the environment was presumed to have been little changed by the reading of elite (educated)

sources. Three interviews from this group were of necessity removed because of the summariness of the answers and the general hostility of the interviewee. We experienced a great deal of difficulty with others in this group and four questionnaires might well have been rejected because of the excessive succinctness of the answers. A separate series of questions was set up for the folk group but the simplification of the wording of the questions is obviously not enough. We found the young native island folk the most hostile, but the British West Indians who had been in the Virgins less than 10 years were also uncommunicative when approached by our group.

Appendix 3 Characteristics of the Sampled Population (1970)

Cases

	Sample		18-30 yrs.	30.1-50 yrs.	50.1 + yrs.	Total
Age (Q. 6)	(93)	No:	22	40	31	93
		%	23.6	43.0	33.3	100.0

			0-10 yrs.	10.1-20.00 yrs.	20.1 & more	Total
Years lived in the V.I. (Q.21)	(89)	No:	29	16	44	89
		%	32.5	17.9	49.4	100.0

			Don't Know	Yes	No	Doubtful	Total
Expectancy to live in V.I. many more yrs. (Q.22)	(93)	No:	10	73	6	4	93
		%	10.8	78.5	6.5	4.3	100.0

			Low	Moderate	High	Total
Literacy (Q.8)	(91)	No:	9	29	53	91
		%	9.8	31.8	58.2	100.0

			Owner	Tenant	Seasonal	Total
Housing (Q.10)	(93)	No:	59	33	1	93
		%	63.4	35.5	1.1	100.0

			High	Medium	Low	Total
Income (Q.38)	(90)	No:	27	43	20	90
		%	30.0	47.8	22.2	100.0

			Protestant	Catholic	None	Atheist	Jewish	Total
Religion (Q.12)	(90)	No:	56	25	7	1	1	90
		%	62.2	27.8	7.8	1.1	1.1	100.0

Advantages of Living on V.I.

Emphasis on:

			Advantages	Disadvantages	Neither	Total
Pros & Cons. of V.I. (Q.13)	(91)	No:	50	7	34	91
		%	54.9	7.7	37.4	100.0

			Don't Know	Family	Friend	Special Group	Gov't	No-One	Total
Adviser in Community Problems	(93)	No:	1	12	10	19	35	16	93
		%	1.1	12.9	10.8	20.4	37.6	17.2	100.0

Appendix 4

I.G.U. Commission on Man and Envrionment

Test of Hazard Group Questionnaire (1970)

1. Date

2. Country

3. Place

4. Number of interviewer

5. Number of respondent

IS THE HEAD OF THE HOUSE AT HOME?

6. Age in years

7. Number, age and sex of persons in household:

Age	Male	Female
over 21		
16 - 21		
0 - 15		
Total		

8. Literacy

Cannot read Read but less than 6 years formal schooling
Formal schooling of 6 years or more

9. Occupation

Artisan Tradesman Laborer Government
Education Manufacturer Professional Unemployed
Retired Other specify

10. Housing

Owner Tenant Seasonal Communal

11. Predominant language spoken in household

12. Religion

13. What are the principal advantages and disadvantages in living in this place? a. Emphasis on: Advantages Disadvantages Neither b. List any hazards (social or natural) noted by respondent

14. Do the people of the Virgin Islands have any trouble with hurricanes?

Yes Doubtful No Don't know
(At this point, introduce the sentence completion test.)

15. In the years since you were born, how many times have there been hurricanes in the Virgin Islands?

15a. Have you experienced any yourself? Yes No Number
If no, skip to question 19.
If yes, where

16. What happens to your household if a hurricane strikes?
a. List any effects volunteered by respondent

b. Are the damages considered to be:
Total (80 - 100%) Substantial (21 - 79%)
Slight (1 - 20%) Non-existent (%)

c. What are the major damages?
Workplace House Community People

17. When was the worst year for hurricanes?

18. When was the last year when there was trouble with hurricanes?

19. Do you think the hurricane will come again in your lifetime?

Yes Don't know No If yes, soon? in a few years? in many years? can't say?

20. Here is a story on which we would like your comments.
Once after a hurricane four men spoke about a hurricane coming again. The first said that the hurricane would come again soon because when hurricanes happen, more will soon follow.
The second thought that hurricanes would come again, but did not know when, because hurricanes can happen in any year.
The third said that he knew when the hurricanes would come, for there is a regular time, and that time must pass before it comes again. The fourth thought that the hurricanes would not come again.
Which man had the best idea about the coming of hurricanes?

21. How many years have you lived in the Virgin Islands?

22. Do you think you will live in the Virgin Islands many more years?

    Yes Doubtful No Don't know

23. During the years you have lived here, how many years would you say have been for you? Good Regular Bad

24. When you want to talk over an important community problem to whom do you speak?

    Family Friend Special group or person specify
    Government No one

25. If you have problems after a hurricane occurs who can you go to for help in recovering from your losses?

    Family Friend Special group or person

    specify Government No one

26. How successful have such people been in helping you recover your losses? (If No in 15a: How successful do you think such people would be in helping you to recover your losses?)

    Completely Somewhat successful Somewhat unsuccessful
    Don't Know

27. Do you know anyone who has been helped by the government because of a hurricane?
    a. Yes No
    b. If Yes, explain

28. Are there any signs or ways of knowing when a hurricane will come again?
    a. Yes No Don't know
    b. If yes, explain

29. When a hurricane comes, what do other people do?

Adjustments	Mentioned by respondent	when asked yes	no	good	bad	why
Nothing						
Pray						
Bar House						
Leave the V. I.						
Go to Fort						
Church						
Cut Trees						

30. Do you do any of these things? Why?

31. What did you do when the Weather Bureau last forecast a hurricane warning?

32. Will you do anything different next time? Yes No
If yes, what?

33. What do you do on Supplication Day? July 25

If answer to 15a was No, skip to question 36.

34. Next time there is a hurricane, would you do anything any different than you did last time?
Yes No If Yes, what?

35. If a warning were to be given that a hurricane is coming this year, would you do anything different? Yes No
If yes, what?

36. Do you try to carry any money over from one year to the next year?
Yes No Don't know
a. If yes, about what proportion do you carry over from year to year?
b. If yes, but respondent cannot say
c. If yes, but respondent would not say

37. Is there anything that the people, your friends and neighbors, can do to prevent damage from a hurricane?
Yes Don't know No If yes, specify

Interviewer's comments:

38. Estimated income in relation to mean for group — High / Medium / Low

Interview situation: Alone / Group

Respondent's attitude: Hostile / Neutral / Helpful

Reliable / Unreliable

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Typographical ERRORS in HURRICANES IN PARADISE

Title page - 1st line: "Hurricanes" for "Hurricane"

Table of Contents, line 14, "Destructive" for "Distinctive"

Page v, line 17, "houses" for "shouses"

Page v, line 24, "stretching" for"tretching"

Page 20, Footnote 19 missing

Page 20, line 6, "negligible" for "negigible"

Page 21, Footnote 23, line 4 "article" for"articel"

Page 22, Footnote 25, line 2 "Hurricane" for "Hurrican"

Page 33, line 11, "tropical" for "troipical"

Page 41, Footnote 40, op.cit.

Page 42, line 6, "probable" for "probably"

Page 51, line 9, "proportions" for "portions"

Page 53, line 10, "respondents" for "responsdents"

" " line 14, "Hurricanes" for "Huuricanes"

Page 54, line 20, "catastrophe" for "catstrophe"

Page 67, line 14, after "residents" insert "who have a good idea of the frequency of big hurricanes."

Page 70, lower part of Table 21, Title "when will the hurricane come?"

Page 72, line 13, "Hurricane" for"Hurrican"

Page 73, line 1, "or" for "of"

Page 74, line 1, (heading) "Adjustments" for"Admustments"

Page 74, last line, after "in" insert "the other months since records were first collected in" 1738.

Page 76, Footnote 53, op.cit.

Page 81, line 2, "Believe for "belive"

" " line 8, "for" for "fot"

Page 111, line 29, "Meteorological" for Meterorological" and Bull. of Am. Met.Soc.

Typographical ERRORS in HURRICANES IN PARADISE - (cont'd)

Page 112, line 21, "Meteorological"

Page 113, line 14, "New York"

Page 113, line 15, insert "1924"

Page 114, line 16, "Southern"

ADDENDUM

Page 11, line 9, "long. 62° 30' - 65°0' W)."
for "long. 70°0' - 72°30' W)."

Col. 1 Rainstorm Date	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
		Rainfall Station in Inches						Dis-charge[3]	Damage Estimate[4]
	Station	24 hr.	48 hr.	4 day	7 day	SMS[1] (CA)	R-O[2] (CA)		Mod.
8/6-7/55	CA	7.04	7.04			1.50	4.50		
	TF	4.16	4.16						
6/14-17/56	CA	3.96	4.50			1.80	1.30		Minor
	TF	2.41	4.04						
	Donoe	3.88	4.48						
8/12/56	CA	3.80				0.50			Mod.
	TF	2.34							
1/10-13/58	CA	4.00	4.05			0.60			Minor
	TF	1.67	2.41						
	EFM	3.35	3.41						
5/4-5/58	CA	3.28	3.68			1.00	minimal		Mod.-Min.
	TF	3.49	4.02						
	EFM	3.87	4.30						
10/15/58	CA	1.57	2.69			.50			Min. (blackout
	TF	4.52	5.35						
	EFM	1.88	2.65						
5/7-9/60	CA	8.60	13.25	16.51		1.70	13.20		Heavy
	TF	10.62	10.73	14.81					
	Donoe	10.05	10.23	10.23					
	EFM	5.61	7.05	9.29					
9/4-6/60	CA	4.25	4.57			0.50			Min.-Mod.
	TF	5.48	5.58						
11/29-12/4/ 1960	CA	5.55	6.86	8.53	10.09	0.70	5.8		Mod.
	TF	4.96	5.62	7.58	9.93				
	EFM	5.29	6.55	8.60	10.71				
10/2-3/61	CA	4.04	4.45			0.50	minimal		Minor
	TF	4.45	5.19						
10/8-10/61	CA	2.11	3.38			2.60	1.0		
	TF	4.78	5.19						
10/30-31/61	CA	6.35	6.99			1.50	3.50		Mod.
	TF	5.84	7.69						
11/13-14/61	CA	1.50	2.02			2.80			
	TF	2.97	3.19						
	EFM	1.56	2.33						
11/27-29/61	CA	1.84	3.42			4.00	2.42		Mod.
	TF	1.27	2.11						
	EFM	1.73	2.59						
8/28-29/63	CA	3.35	4.60			0.60	0.20	80	Minor
	TF	2.63	3.95					(28) 4880[5]	
	EFM	2.90	5.07					3830	
5/4-10/65	CA	2.15	3.10	4.39	5.56	0.50	1.06	4	Termed beneficial by breaking long drought
	TF		MISSING					(9) 266	
	EFM	.75	1.10	2.18	3.10			30	
11/4-5/65	CA	3.15	4.90					(5) 4155	
	TF	1.71	2.67					843	CA hit hard
	EFM	1.83	3.16						
11/25-27/65	CA	1.65	1.80			4.80	1.60	10	
	TF	.83	.91					(26) 902	
	EFM	1.91	2.03					301	
12/10-13/65	CA	2.40	3.75	5.09		4.40	4.50	(11) 8303	Min.-Mod.
	TF	1.34	2.40	2.75				5071	
	EFM	1.61	3.19	4.83				3461	
1/13-14/66	CA	1.34	1.51			3.80	.31	(14) 1102	Minor; Frenchtown flooded brief but heavy rain
	TF		MISSING					413	
	EFM	1.52	1.68					105	
3/1/69	CA	6.30				0.40	1.7+	538	Brief, but heavy rain caused moderate heavy damage
	TF	.13						(1) 11,691	
	EFM	4.15						764	
5/18-25/69	CA	5.76	5.99	7.93	11.00	0.40	6.40	1,581	Mod.-Heavy
	TF	3.92	4.79	6.67	8.59			(23) 108,467	
	EFM	5.70	5.97	9.36	10.88			8,836	
9/18-19/69	CA	.73	1.06			0.80		149	Minor
	TF	.55	.97					(18) 850	Tutu, Fort Mylner
	EFM	.99	1.52					423	
11/22-23/69	CA	3.43	4.78			0.90	0.68	241	Min.-Mod.
	TF	1.59	2.18					(22) 41,807	
	EFM	3.95	5.00					3,900	
5/8-13/70	CA	4.20	4.90	6.20	6.65	0.90	2.55		Heavy CA mainly
	TF	3.22	5.18	6.14	6.52				
	EFM	1.98	3.61	4.87	6.48				
10/5-11/70	CA	6.70	7.54	10.53	14.05	1.10	10.15		$6,220,000
	TF	3.67	4.61	6.12	8.25				V. Heavy
	EFM	4.75	6.98	10.82	14.74				

CA = Charlotte Amalie
TF = Truman Field
EFM = Estate Fort Mylner

1 SMS (Col. 7) = Soil Moisture Storage CA. (in inches)
2 R-O (Col. 8) = Run-off at CA. (in inches)
3 The three highest-day levels of discharge in the storm at Turpentine Run (in 1,000 gallons per day).
4 For definition of damage levels see Table 12.
5 Figure underlined (Col. 9) is highest-day level.