An Holistic Approach

to ensuring that hospitals function
to maximum efficiency
following severe hurricanes in the Caribbean

Tony Gibbs FREng

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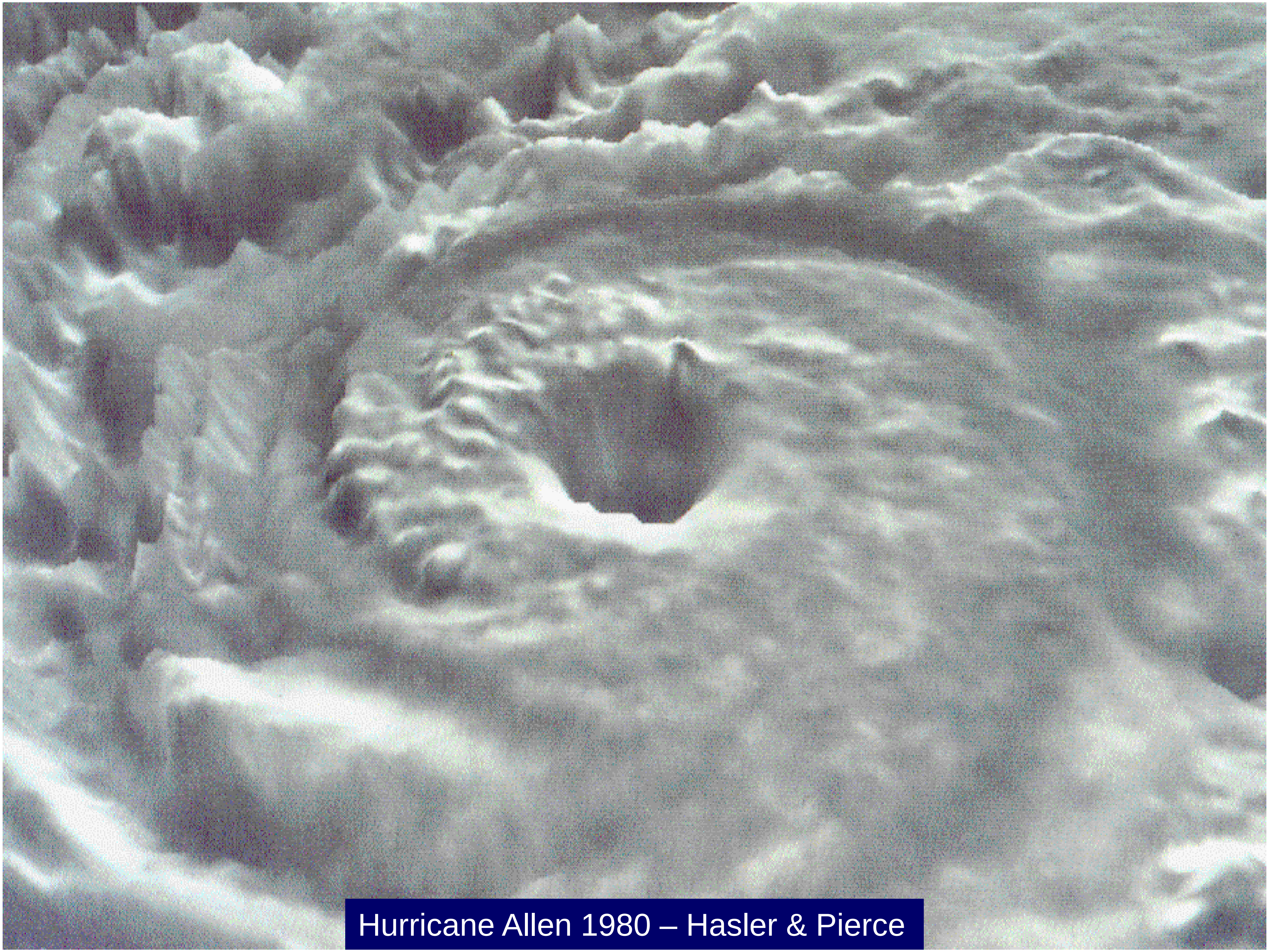

Hurricane Allen 1980 – Hasler & Pierce


The Caribbean
an area of multiple hazards
Florida [USA]
Atlantic Ocean
The Bahamas
Nassau
Miami
Gulf of Mexico
Turks and
Caicos Islands
St Kitts/Nevis
Anguila
Virgin
Islands
Havana
Cuba
Barbuda
San Juan
Antigua
Dominican
Republic
Puerto
Rico
Leeward
Islands
Guadeloupe
Haiti
St Croix
Santo
Domingo
Dominica
Port-au-Prince
Martinique
Cayman Islands
St Lucia
Jamaica
Greater Antilles
Barbados
Kingston
Mexico
St Vincent
Windward Islands
Grenada
Lesser Antilles
Tobago
Belize
Belize
Islas Los
Roques
Trinidad
Caribbean Sea
Curacao
Aruba
Bonaire
Guatemala
Honduras
Caracas
San
Salvador
Tegucigalpa
Venezuela
El Salvador
Nicaragua
Colombia

Hurricanes routinely cause the loss of functionality of referral hospitals in the Caribbean, North and Central America.

This is unacceptable and an avoidable inconvenience for the affected communities.

Princess Margaret Hospital, Jamaica
Hurricane Gilbert (1988)

Central Medical Stores, Grand Turk
(Hurricane Ike, 2008)

Cornwall Regional Hospital, Jamaica (Hurricane Gilbert, 1988)

Impact of natural hazards on hospitals (1981 - 1996)

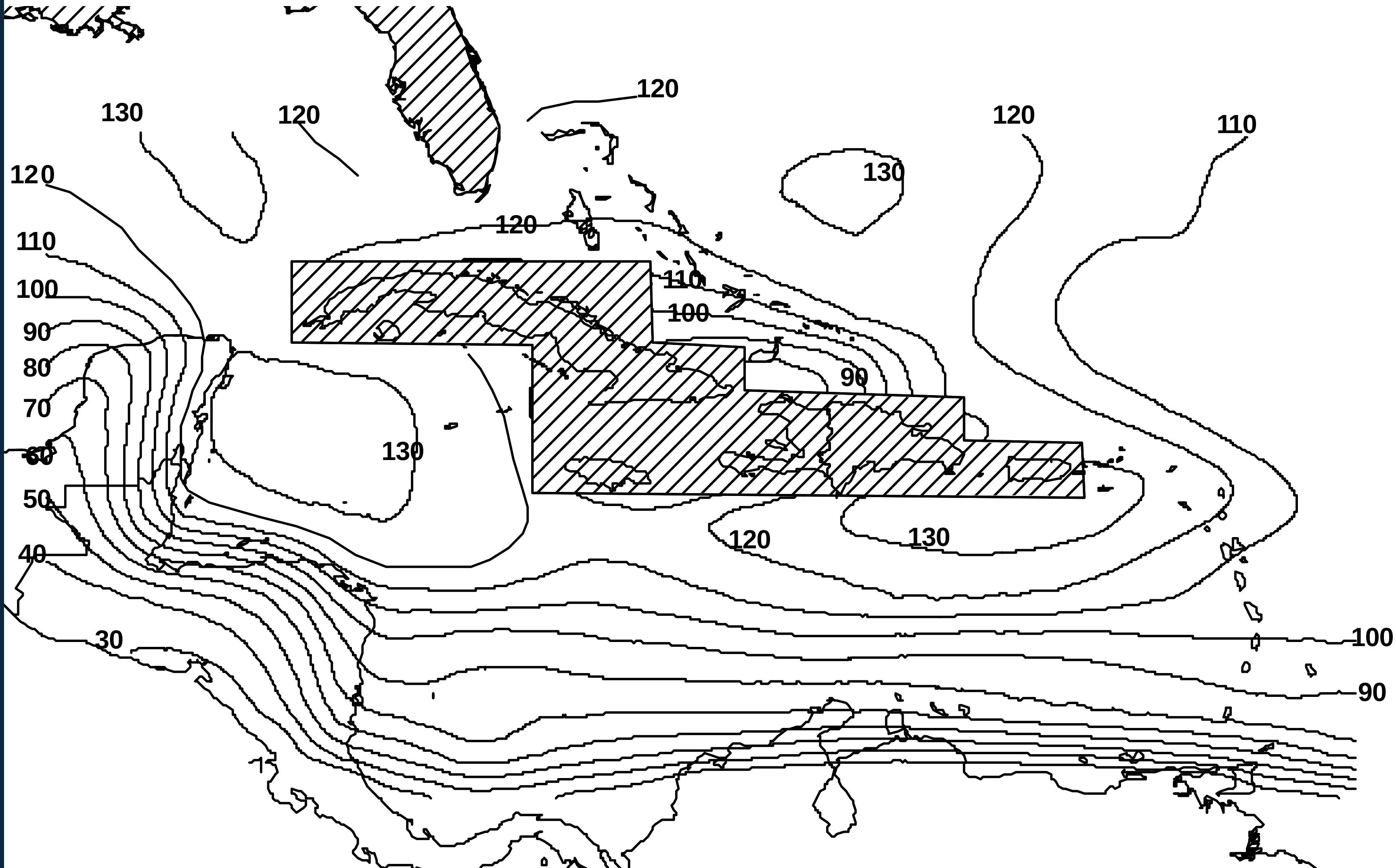
- According to the Economic Commission for Latin America and the Caribbean (ECLAC), between 1981 and 1996:
  - 93 hospitals and 538 health centers were damaged as a result of natural hazards.
  - Losses amounted to US$3.1 billion.
- This could be compared to an extreme situation in which 20 countries in the region had each suffered the loss of 5 major hospitals and 27 health centers.

Hospitals are especially vulnerable to natural hazards

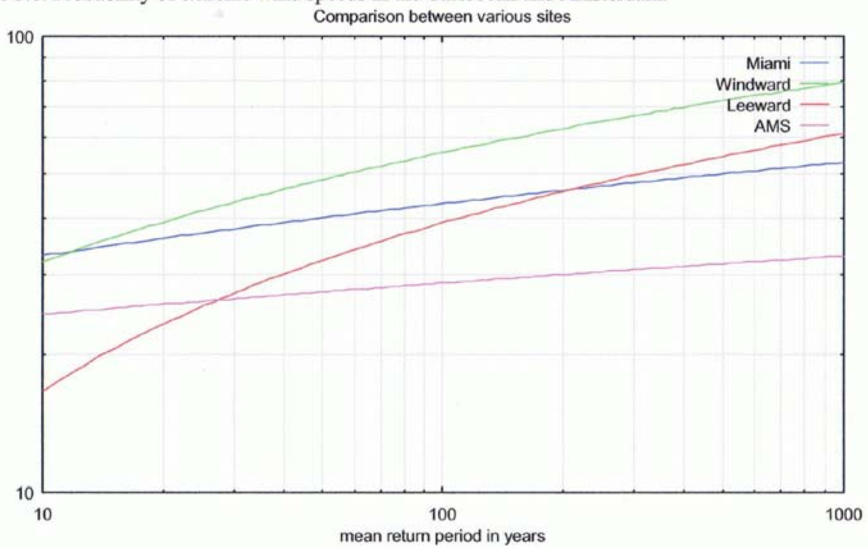
- The occupancy rate is constant, 24 hours a day, year-round.
- It is almost impossible to evacuate a hospital in the event of an emergency.
- The survival of some patients depends on the proper operation of the equipment and the continuity of basic services.
- In emergencies and disasters, medical facilities are essential and must continue to function after the event has taken place.
- Hospitals are highly dependent on public utilities (water, electricity, communications, etc.) which are often interrupted in the event of a disaster.

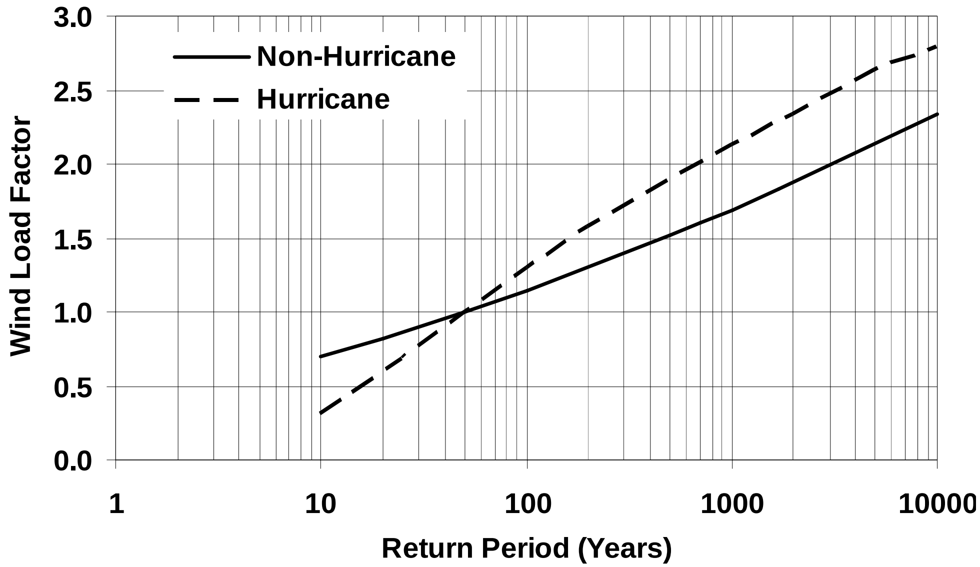
The Hurricane Hazard

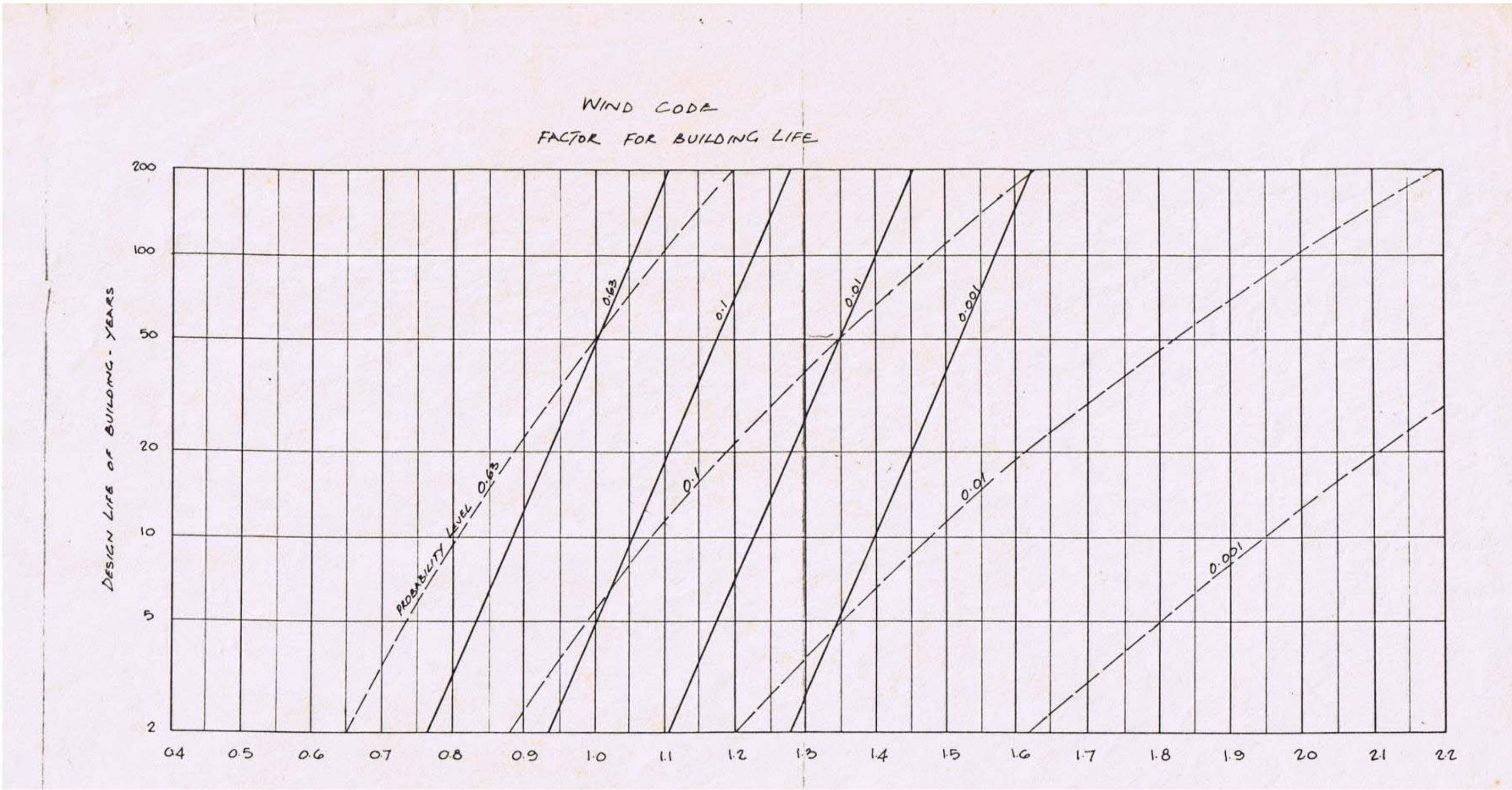
50-Year, 3-sec Wind Speeds for Caribbean

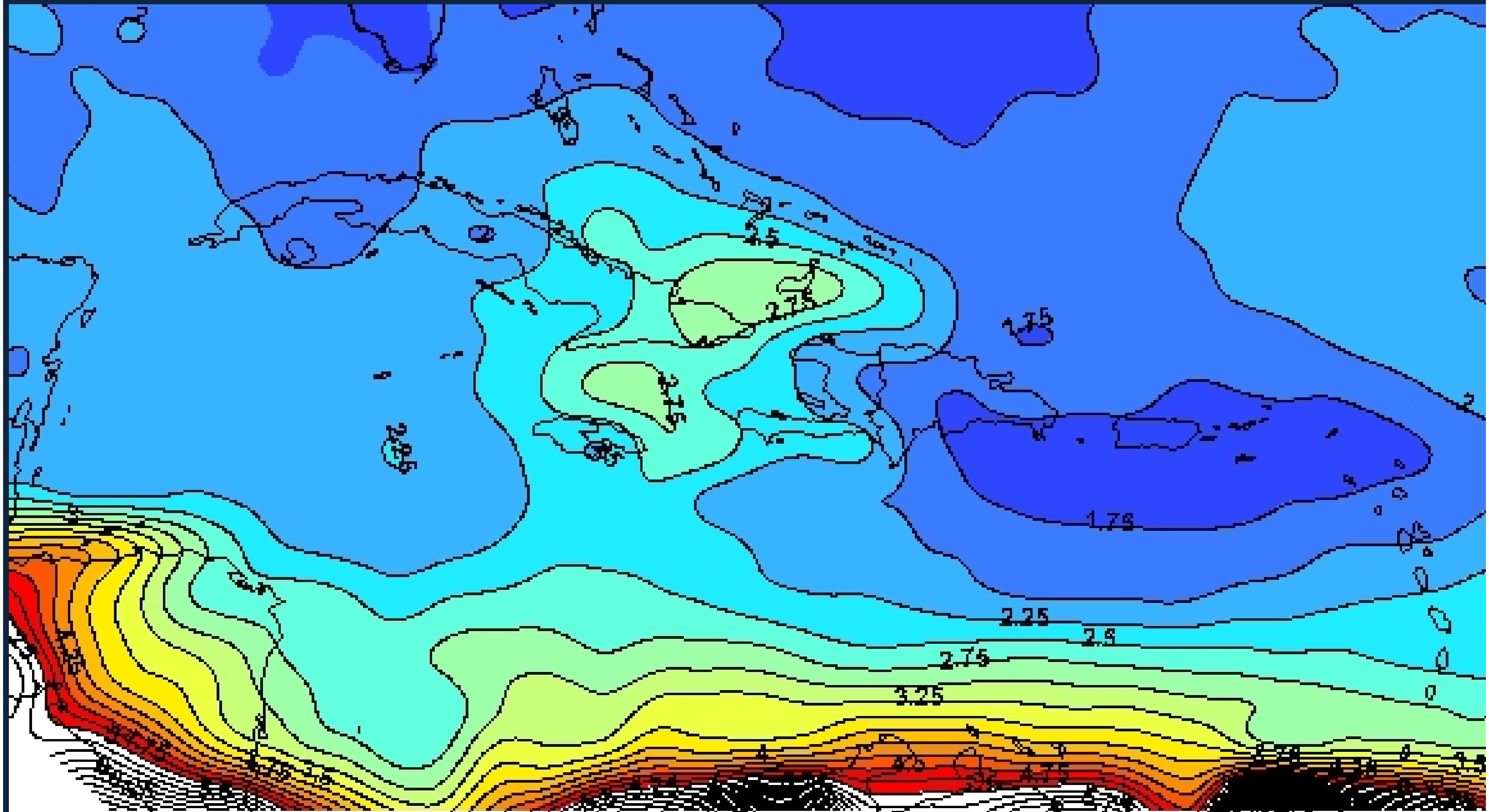


ure 3.6: Probability of extreme wind speeds in the Caribbean and Amsterdam.

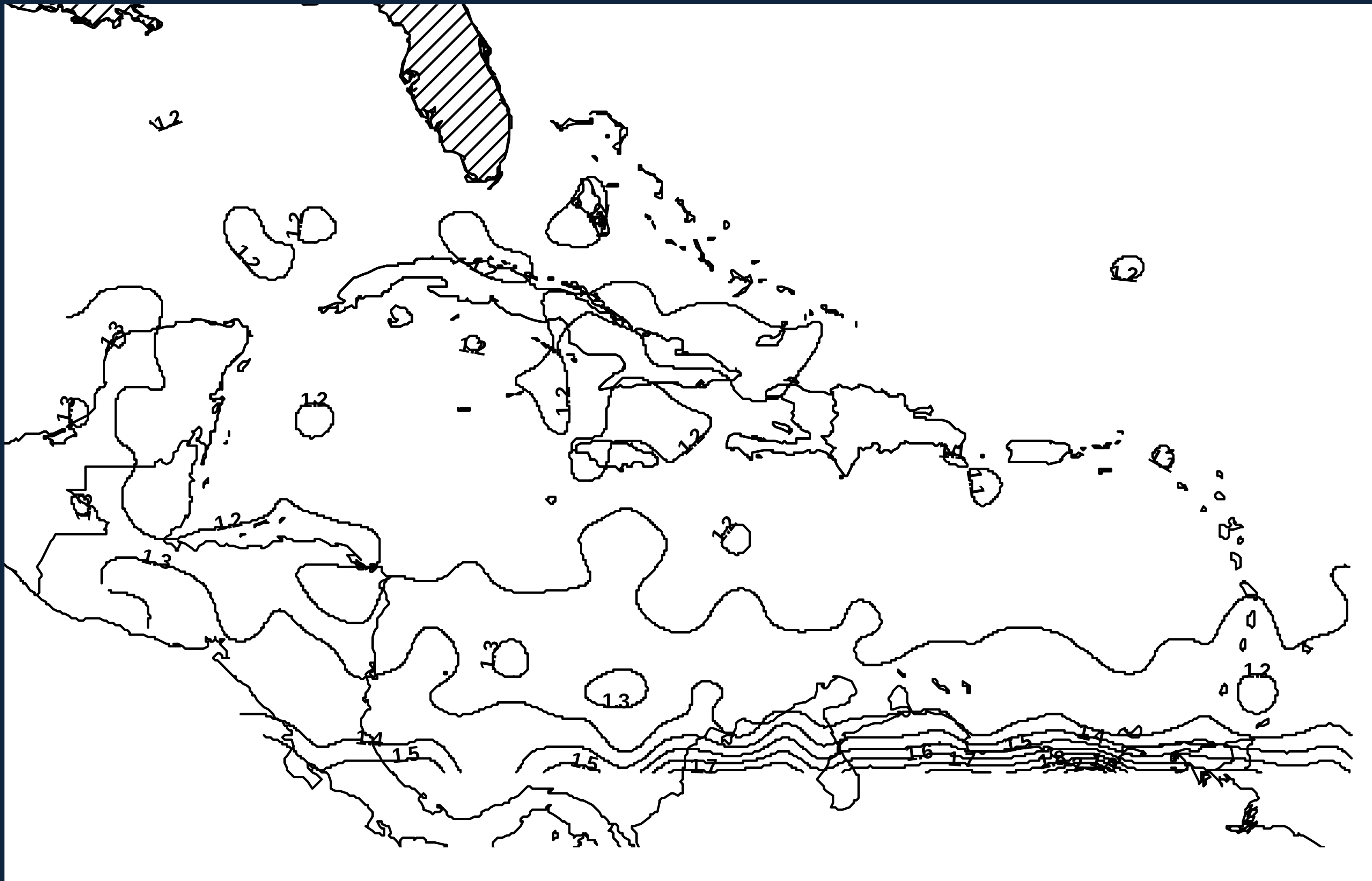






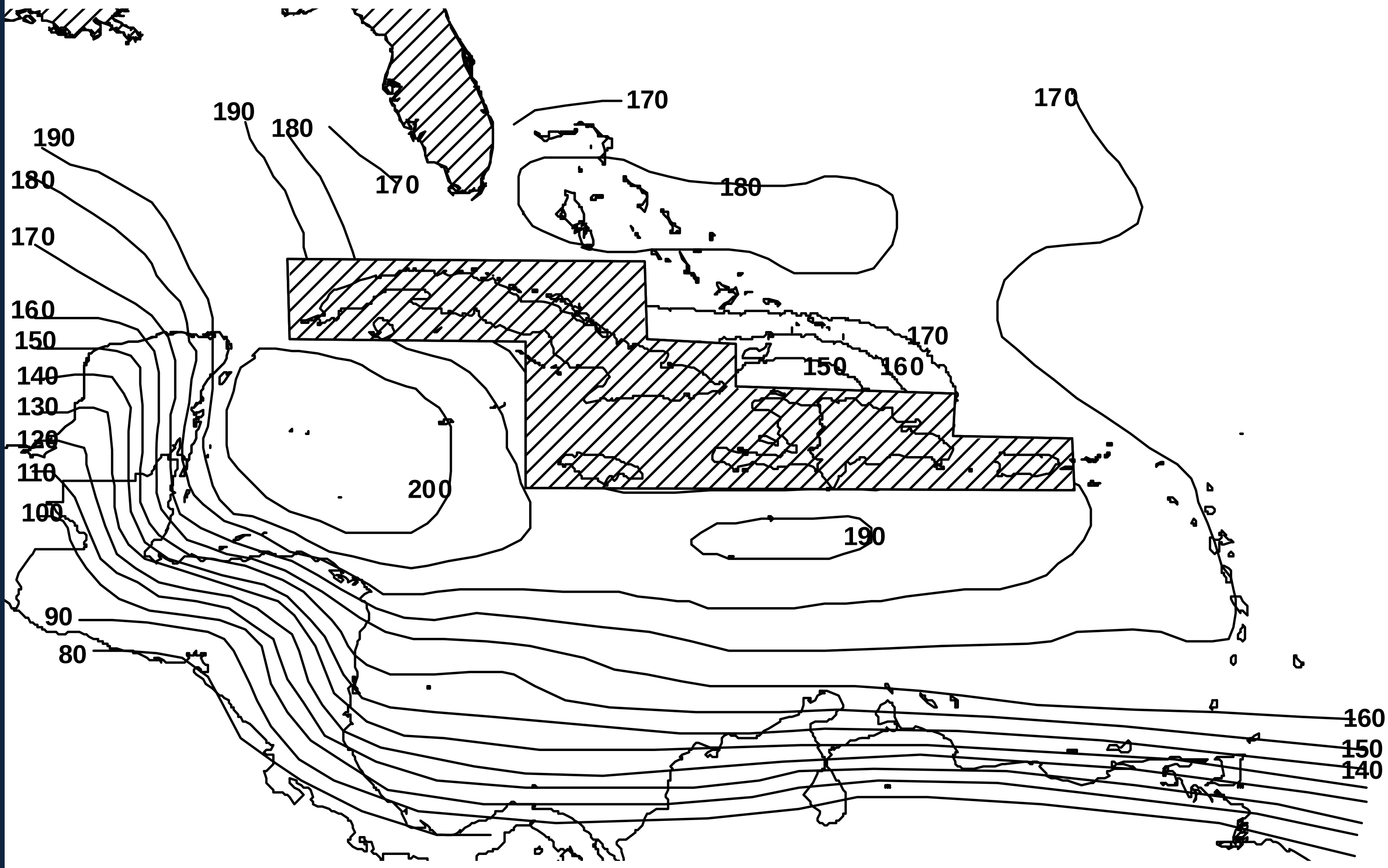


Load Factor – Contour plots of $(V_{700}/V_{50})^2$

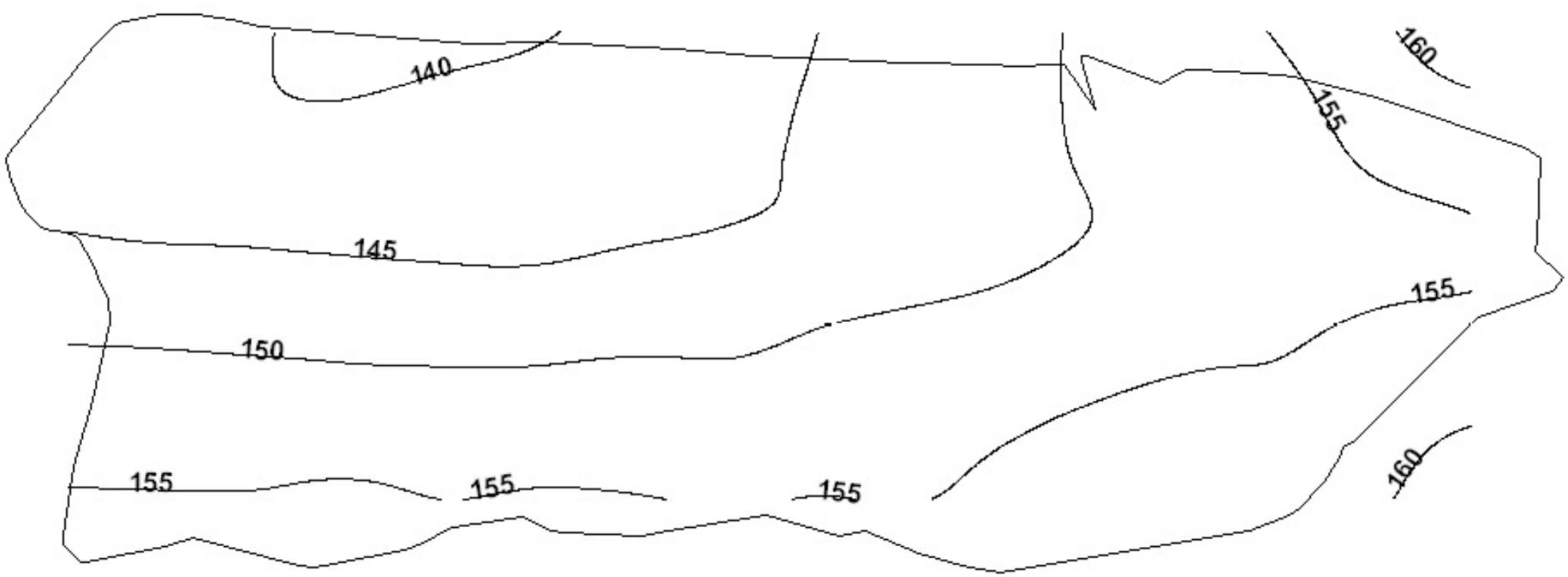


Importance Factor for ASCE category III and IV structures defined by $I=(V_{1700}/V_{700})^2$

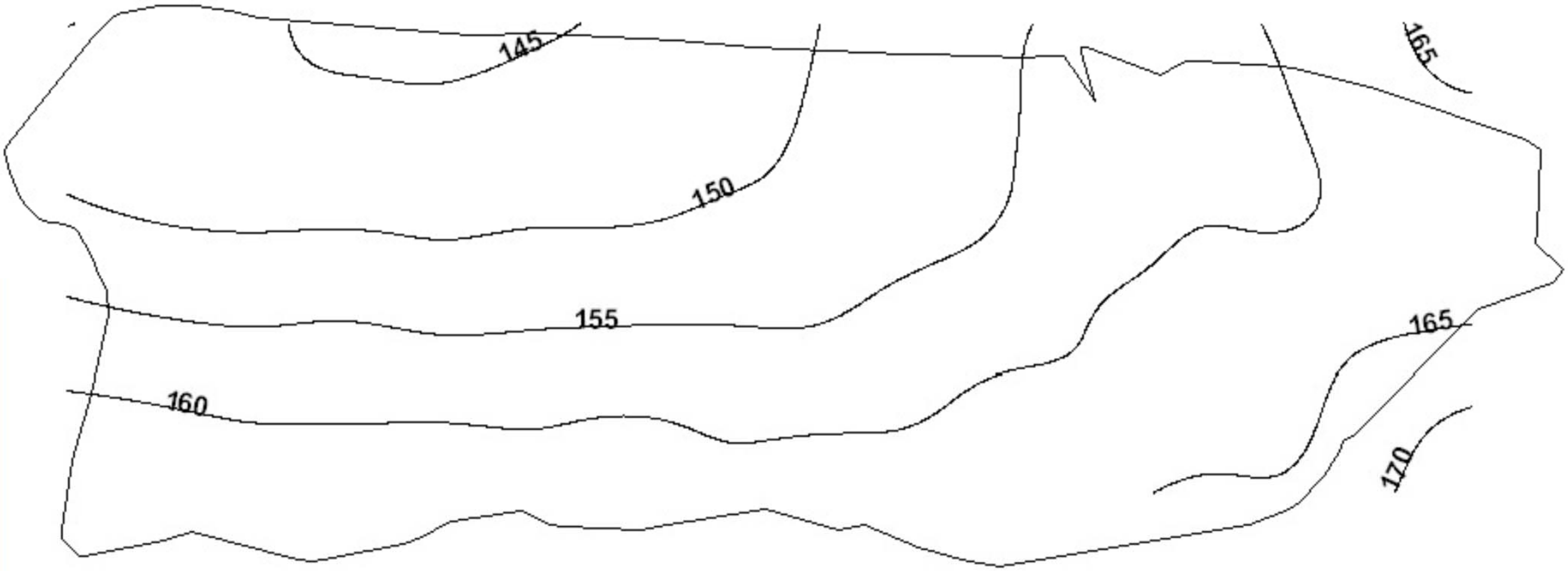
1700-Year 3-sec Wind Speeds for Caribbean



700 year Return Period Wind Speeds for Puerto Rico



1700 year Return Period Wind Speeds for Puerto Rico



- ASCE 7 Basic Wind Speed, V – 3-sec, 33 ft height, Exposure C, 50 years

- For same level of safety in the Caribbean a pseudo-50-year wind speed = $V_{700}/\sqrt{1.6}$ must be used instead of the real V_{50}.

- Alternatively the real V_{50} could be used with an upward adjustments to the Load Factors and Importance Factors.

- **Alternatively, the Basic Wind Speed could be taken as V_{700} for Category II buildings and V_{1700} for Categories III and IV buildings, with the Load Factor and Importance Factor both = 1. This last approach will be simpler in a regional context.**

Load Combinations
(factored loads using strength design)

1: $1.4(D + F)$

2: $1.2(D + F + T) + 1.6(L + H) + 0.5(Lr \text{ or } R)$

~~3: 1.2D + 1.6(Lr or R) + (L or 0.8W)~~

3a: $1.2D + 1.6(Lr \text{ or } R) + (L \text{ or } 0.8W_{700}/1.6)$

~~4: 1.2D + 1.6W + L + 0.5(Lr or R)~~

4a: $1.2D + 1.0W_{700} + L + 0.5(Lr \text{ or } R)$

5: $1.2D + 1.0E + L$

~~6: 0.9D + 1.6W + 1.6H~~

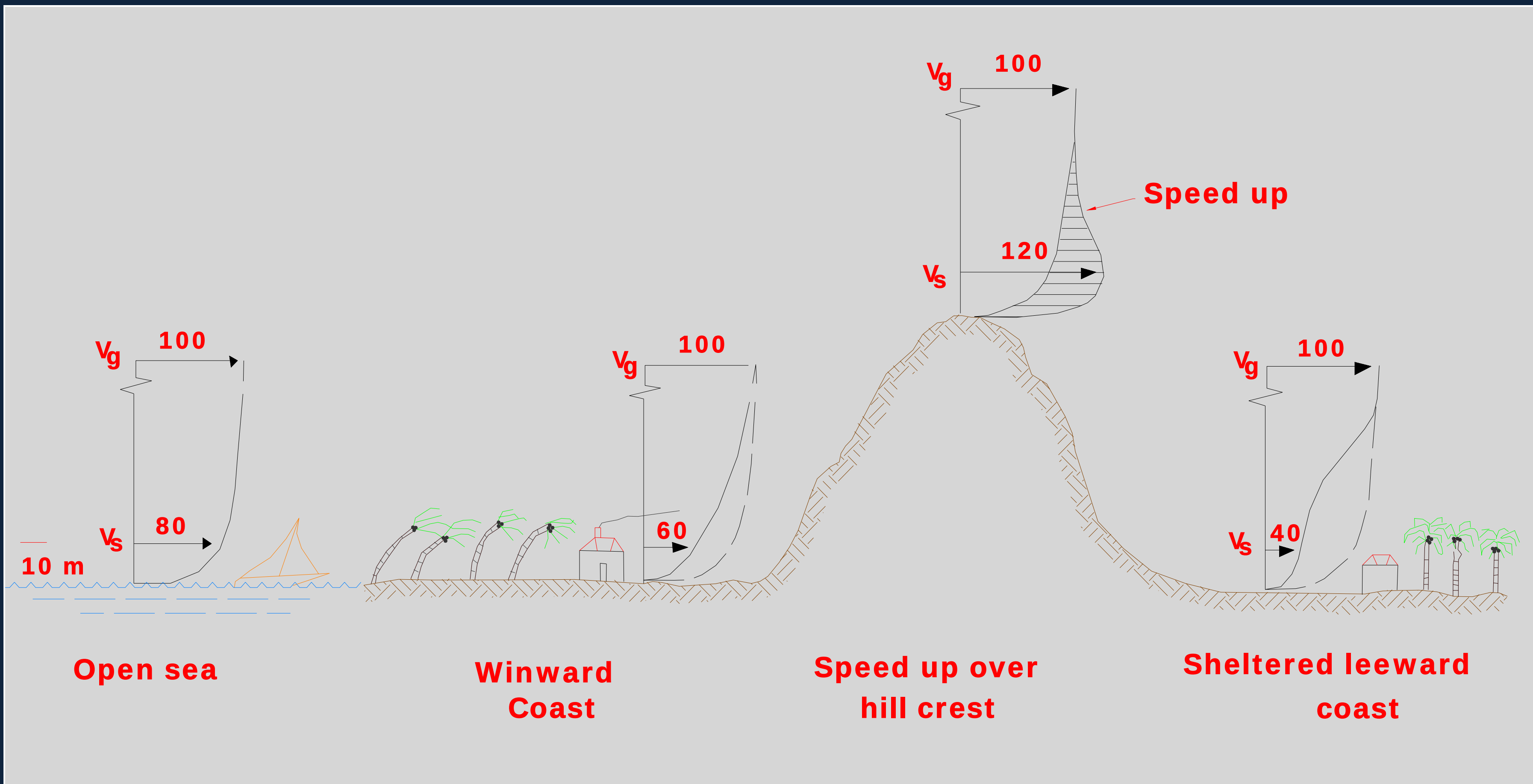
6a: $0.9D + 1.0W_{700} + 1.6H$

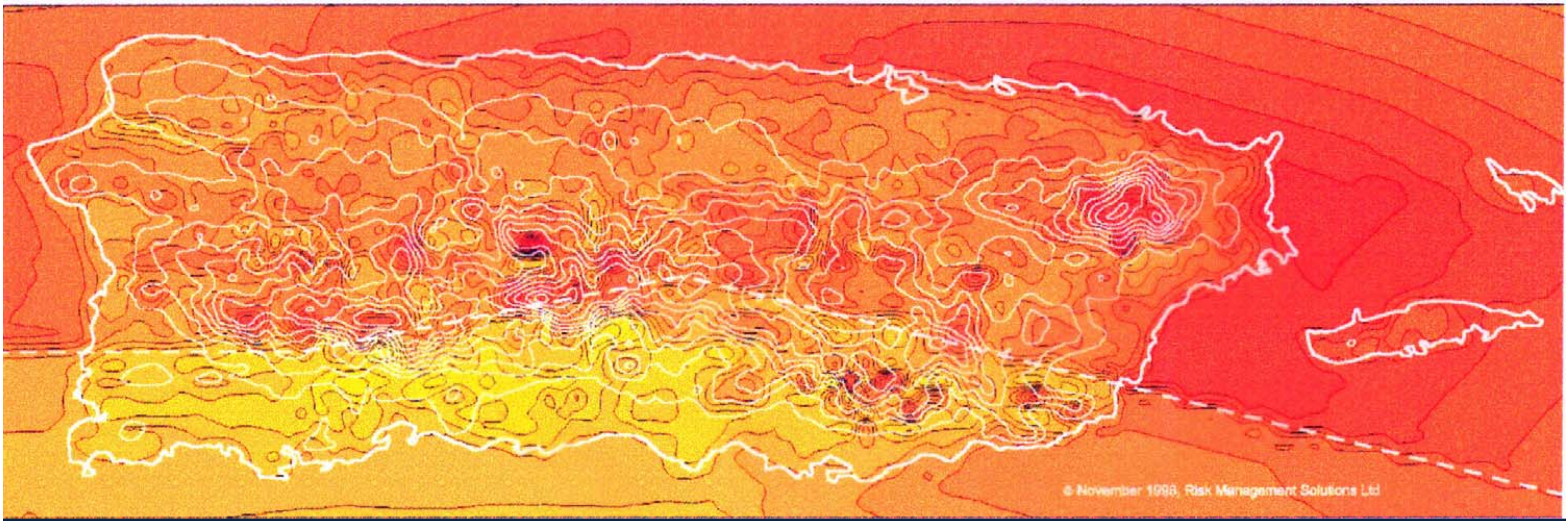
7: $0.9D + 1.0E + 1.6H$

Topographic Effects

Photo: UWO-BLWTL

Sketch showing effects of topography on wind velocity on a hilly island



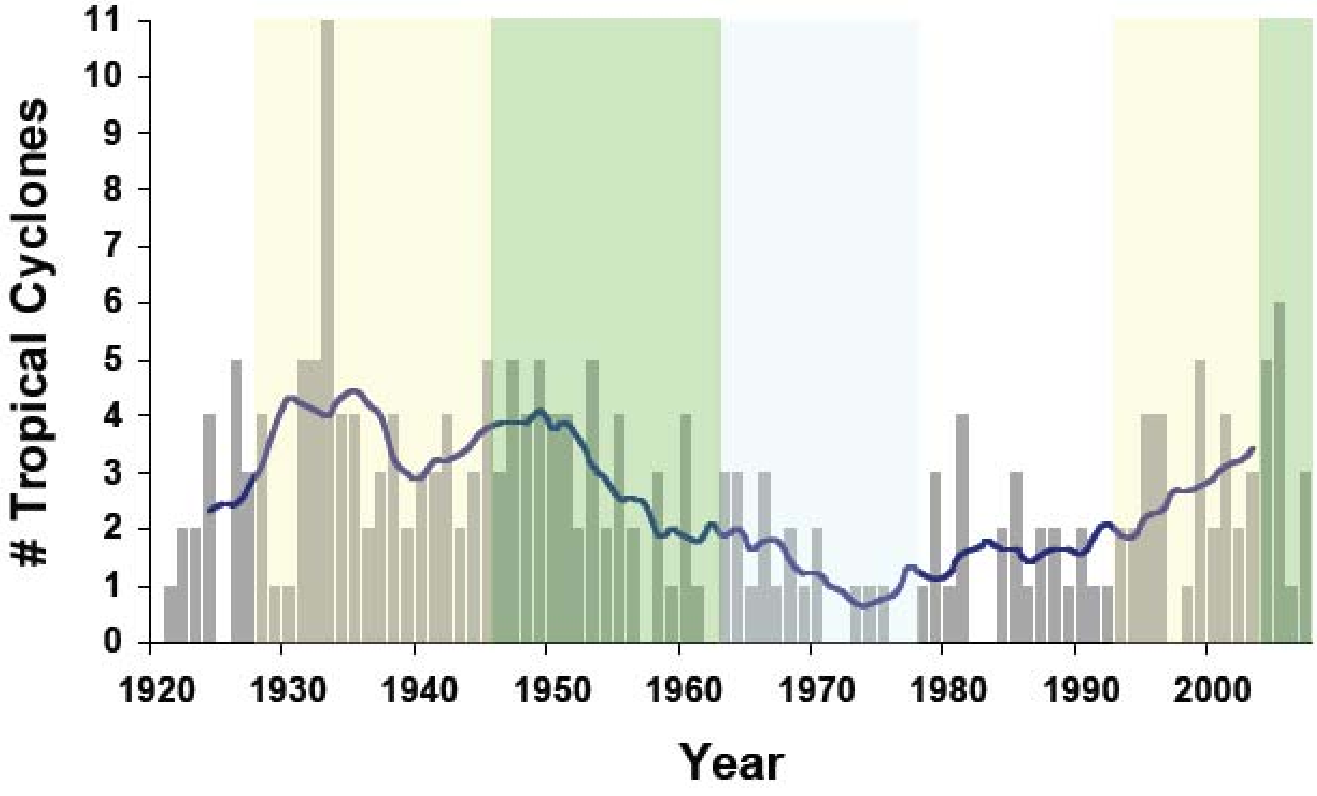


Puerto Rico – Hurricane Georges, 1998

Risk Management Solutions

Climate Change

Caribbean Landfalling TCs



More landfalls during warm phase of AMO

Figure Courtesy: M. Jelinek

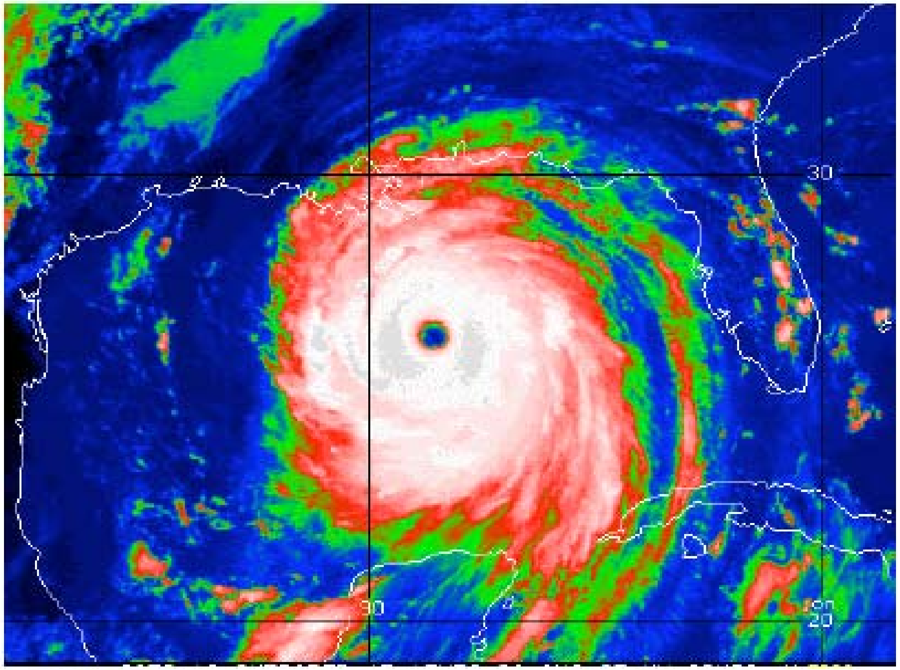
AMO = Atlantic multi-decadal oscillations

Projections for the average number of NATL tropical cyclones for 2025

(1^{o}F warming)

# of Tropical Cyclones:

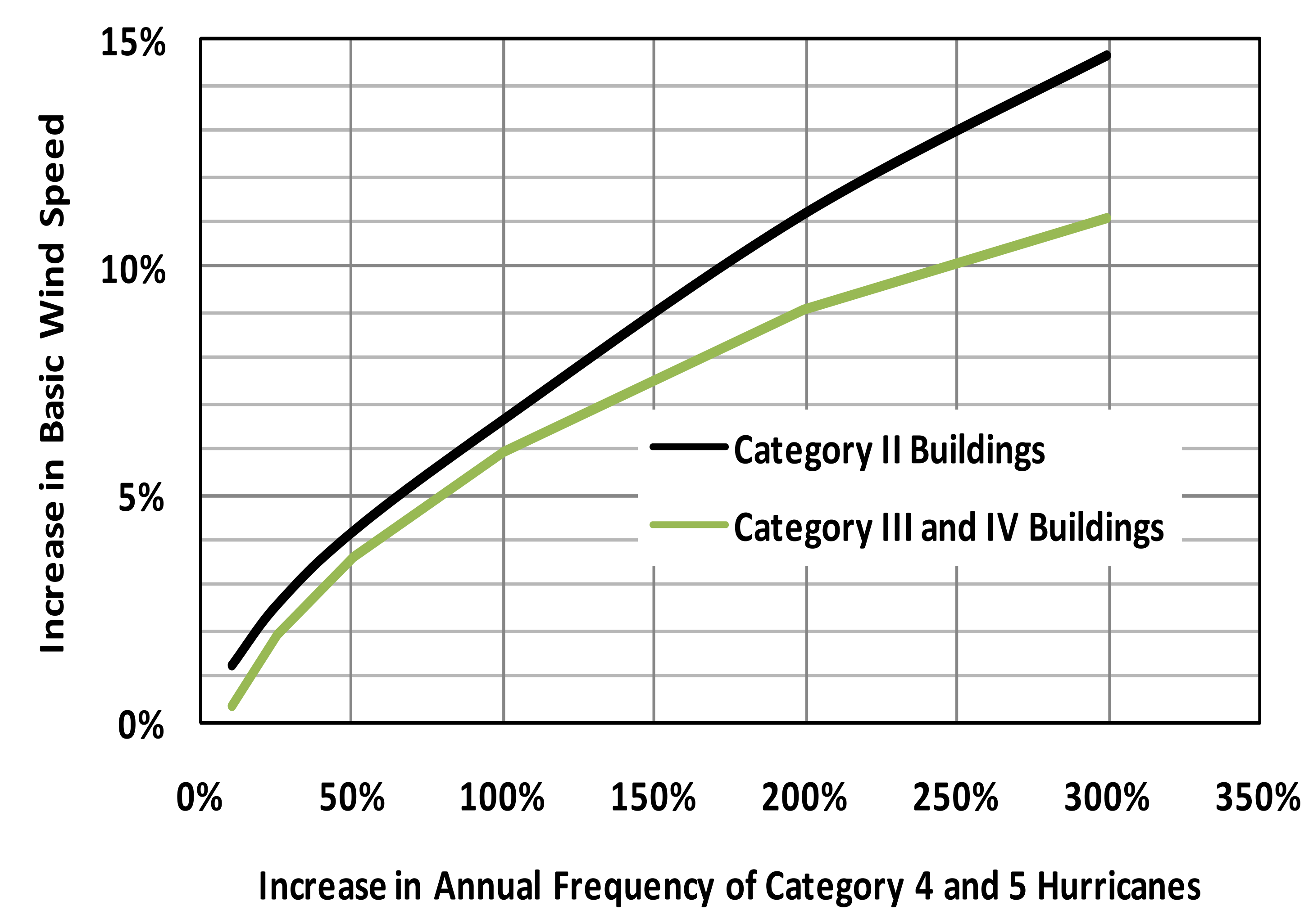
- Avg for last 50 yrs: 10
- Avg last decade: 14
- **Avg ca. 2025: 15-20**
  category 4+5 3-4



The combination of greenhouse warming and natural variability will produce unprecedented tropical cyclone activity in the coming decades

NAtl = North Atlantic

Percentage Increase in Basic Wind Speed in Lucia
vs
Percentage Increase in Annual Rates of Category 4 and 5 Hurricanes



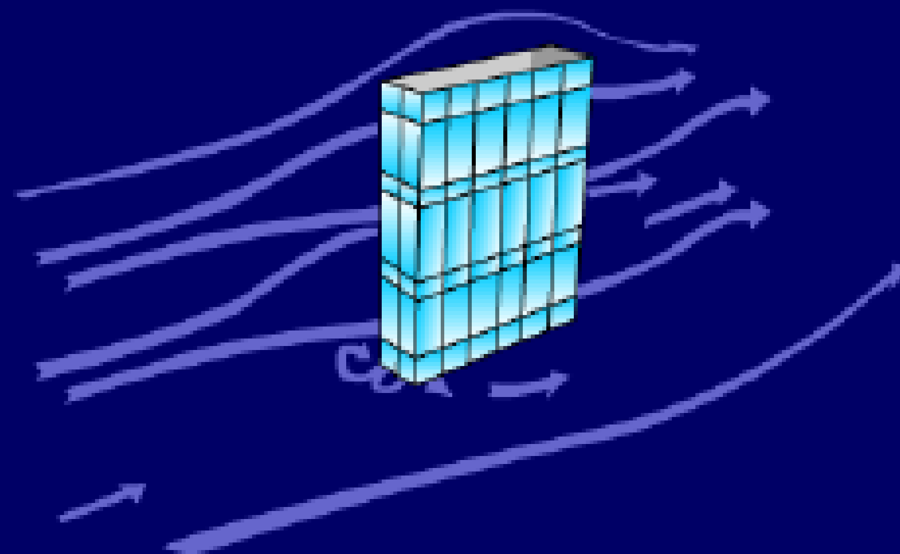
ARA

Holistic Approach – the programmes include:

- education of engineers and architects;
- post graduation training of engineers and architects;
- development of building standards;
- development of code "overlay" documents dealing specifically with referral hospitals;
- implementation of independent reviews of designs and of quality assurance during construction;
- attention to the non structural components;
- vulnerability assessments of existing hospitals;
- retrofitting actions for vulnerable, existing hospitals;
- maintenance programmes.

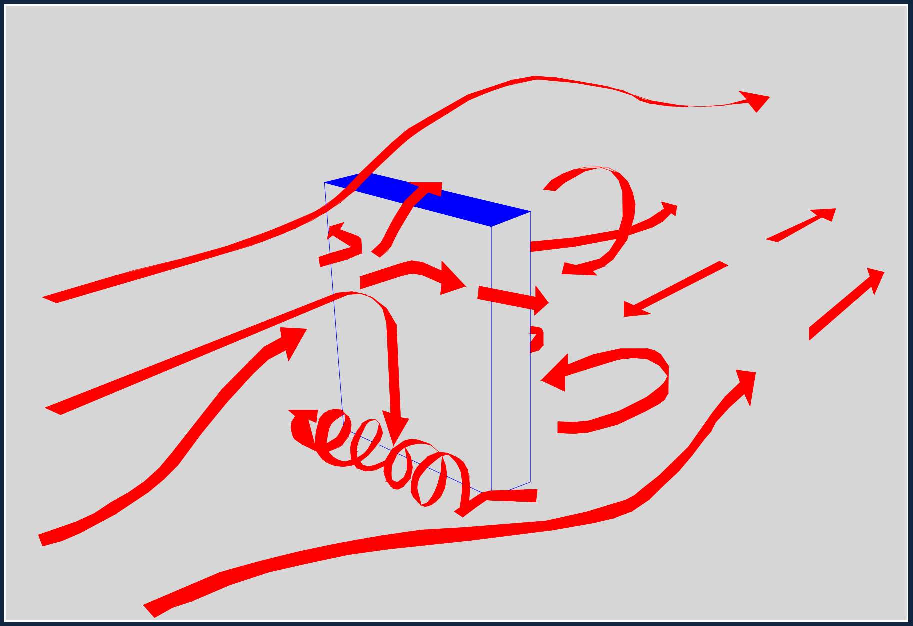
Education of Engineers and Architects

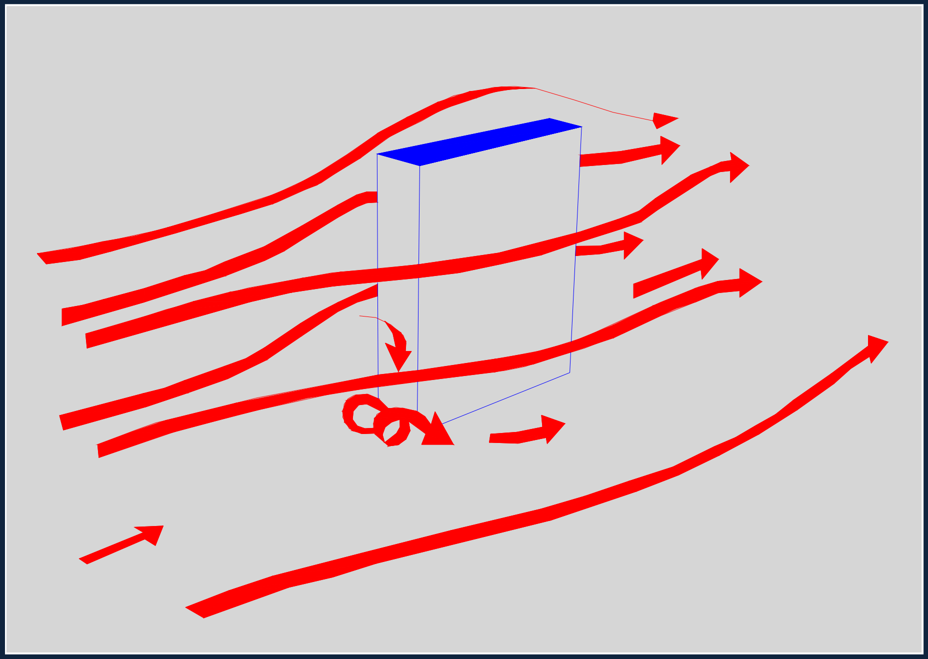
Wind patterns around buildings



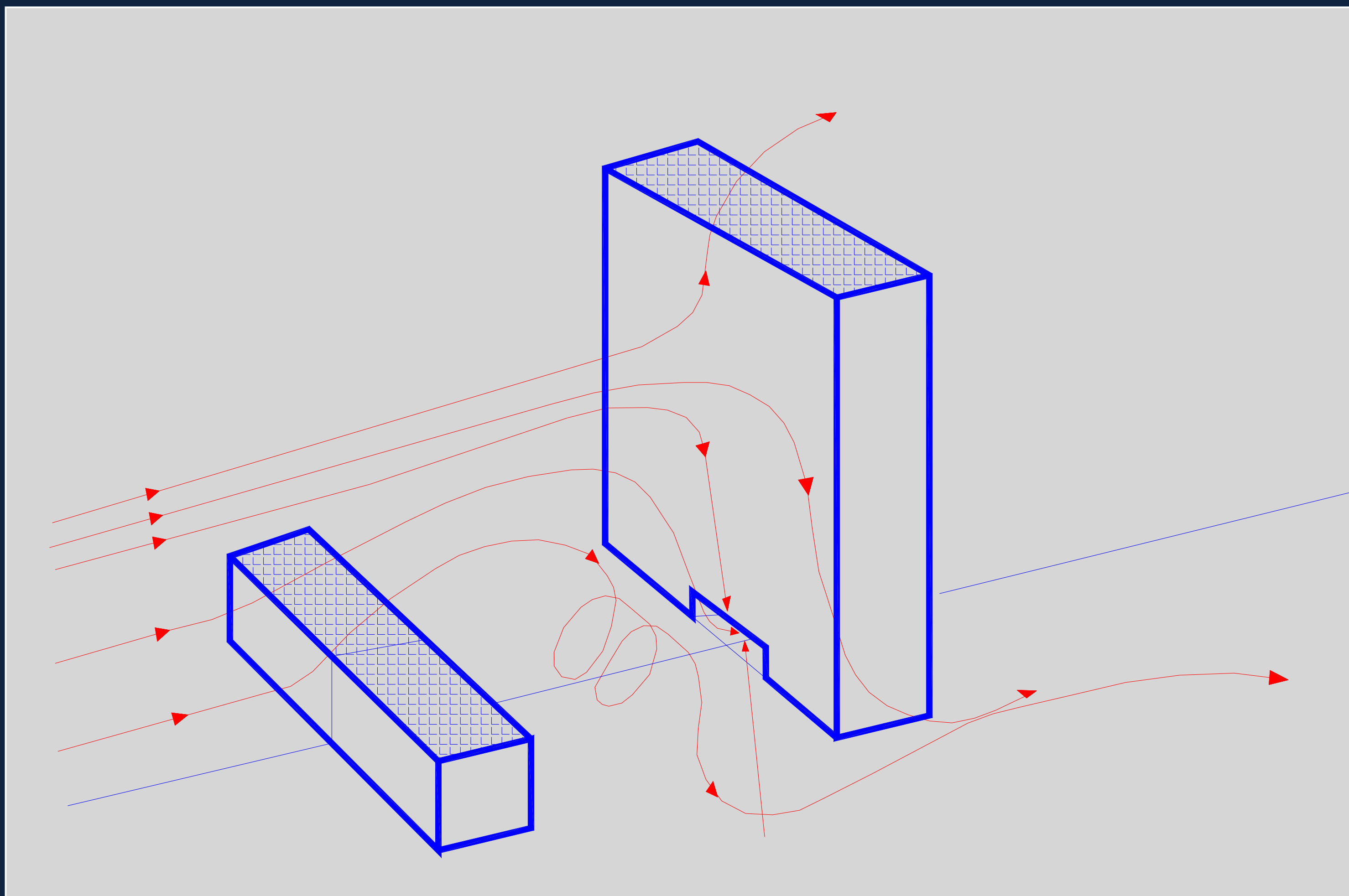
Outward pressure on four of the five surfaces
Inward pressure on the windward face only

Turbulent flow of wind on longitudinal and transverse sides of high rise buildings

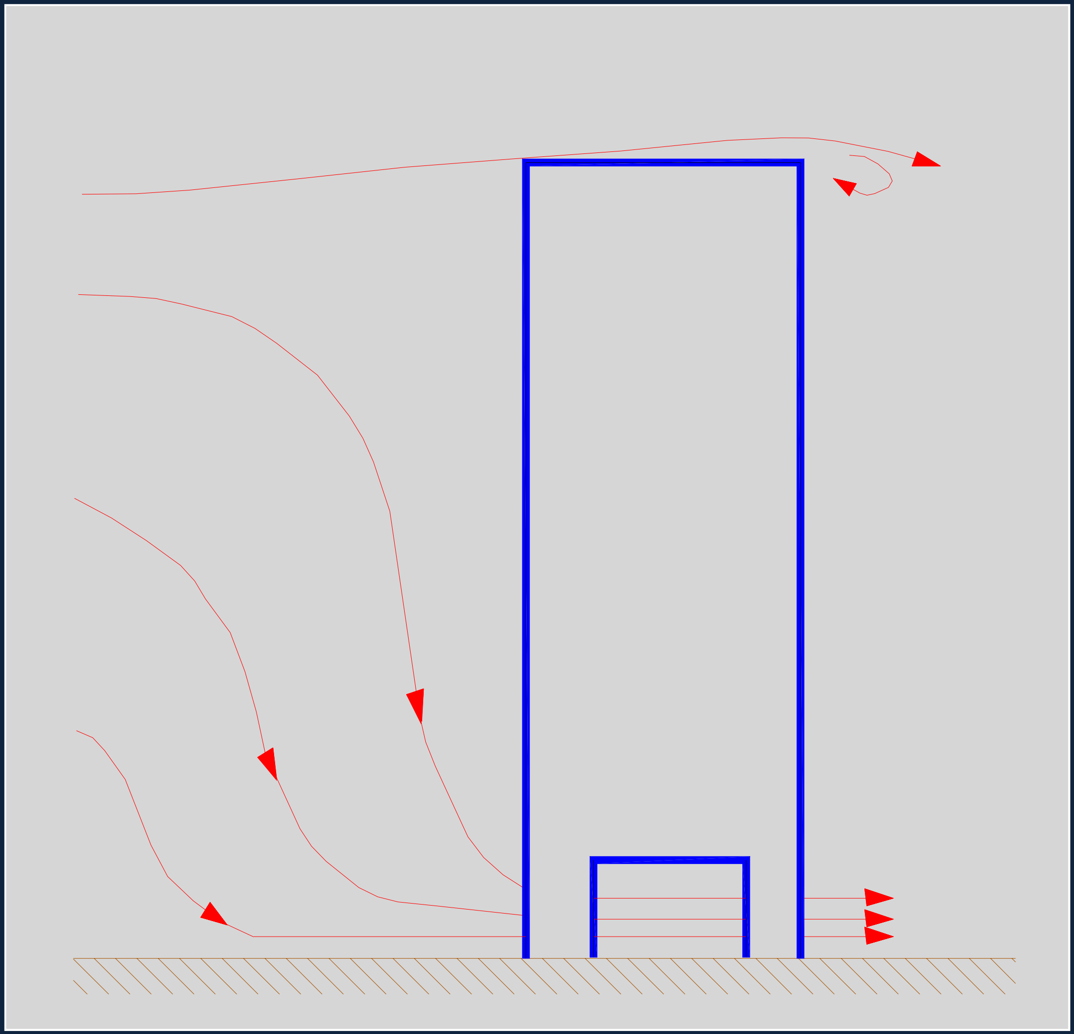




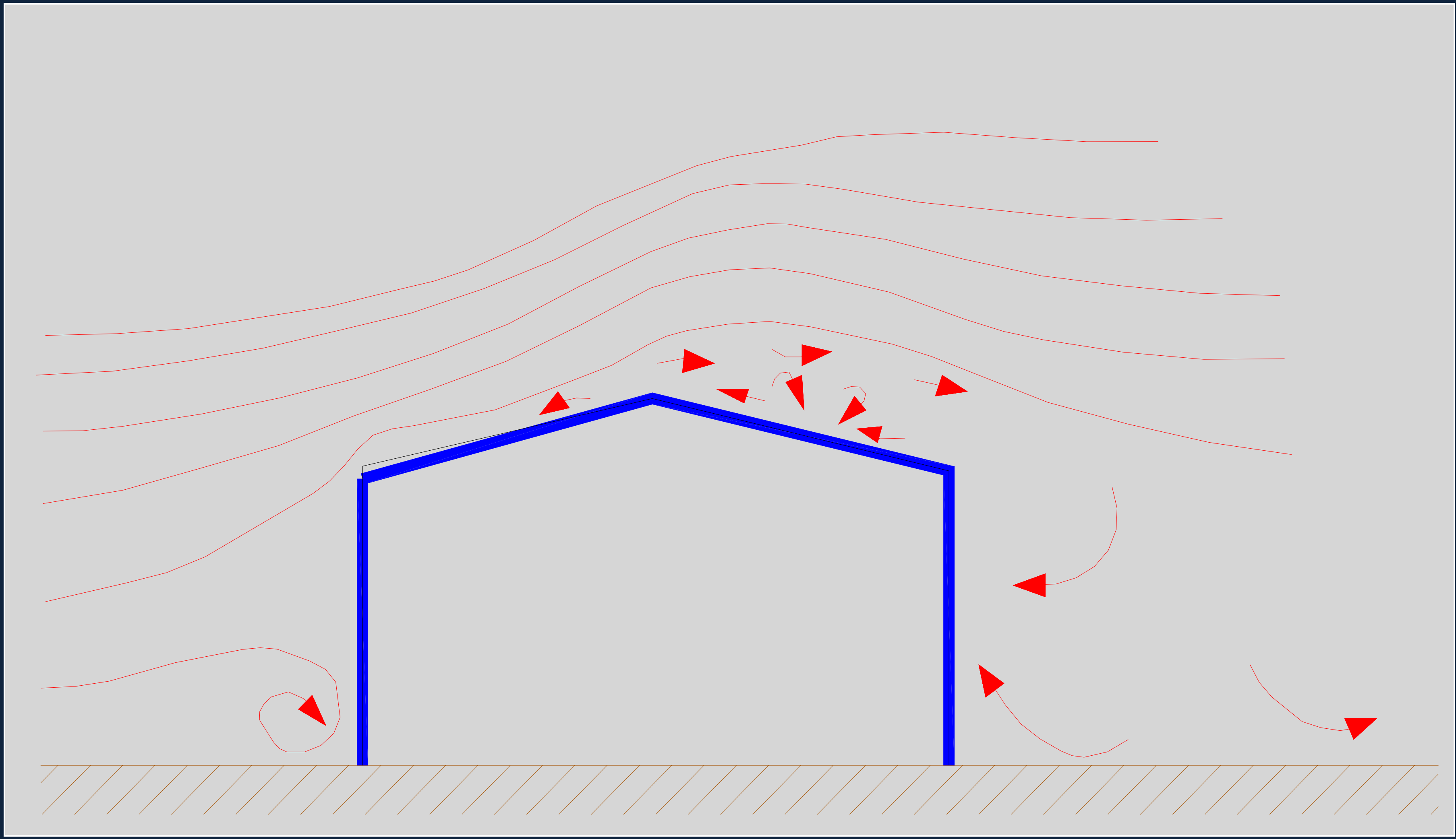
Turbulent flow on high rise buildings due to upwind obstructions



Wind velocity increase due to large openings at lower floors

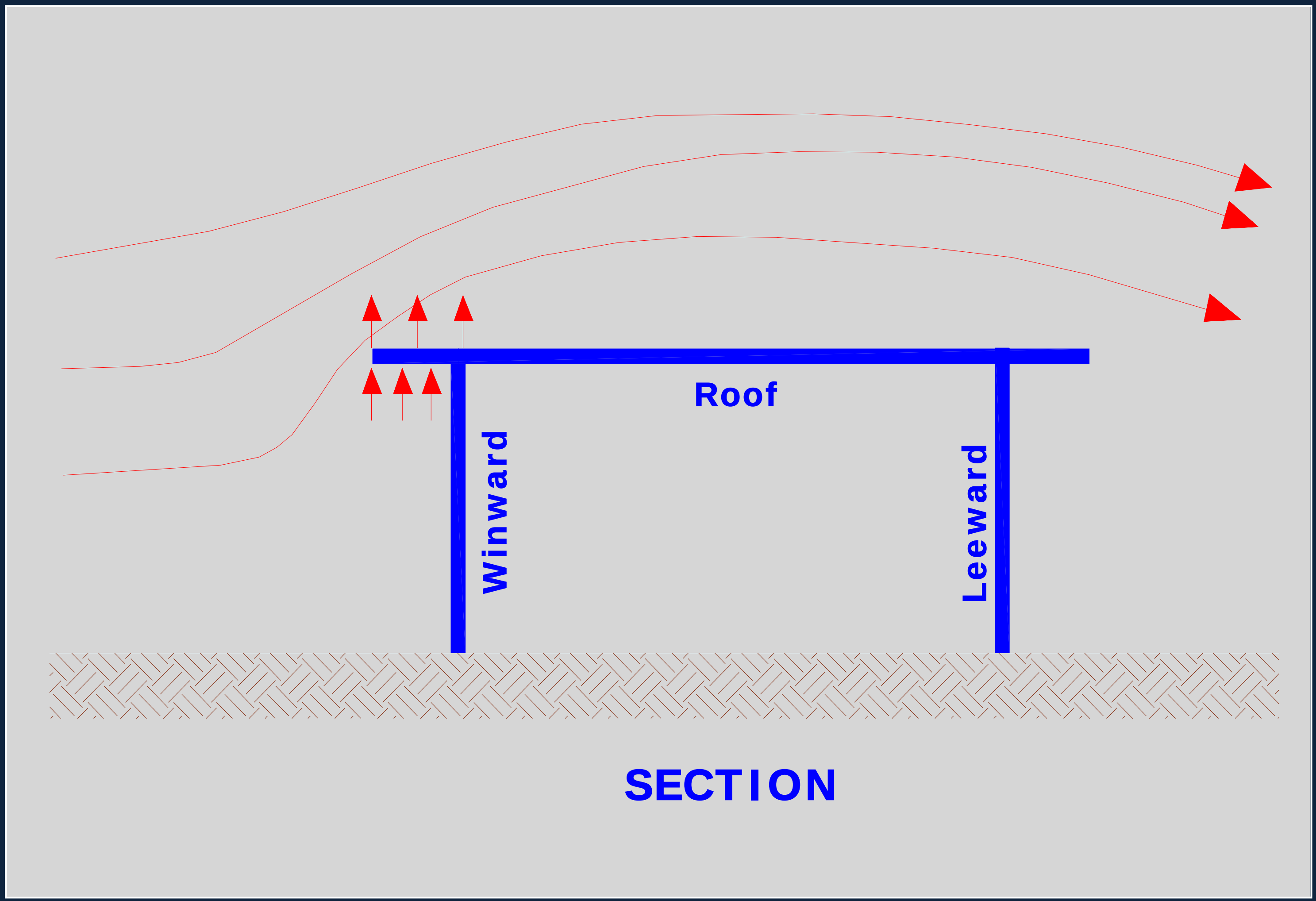


Wind flow over gabled-roof buildings showing turbulence on leeward roof and walls



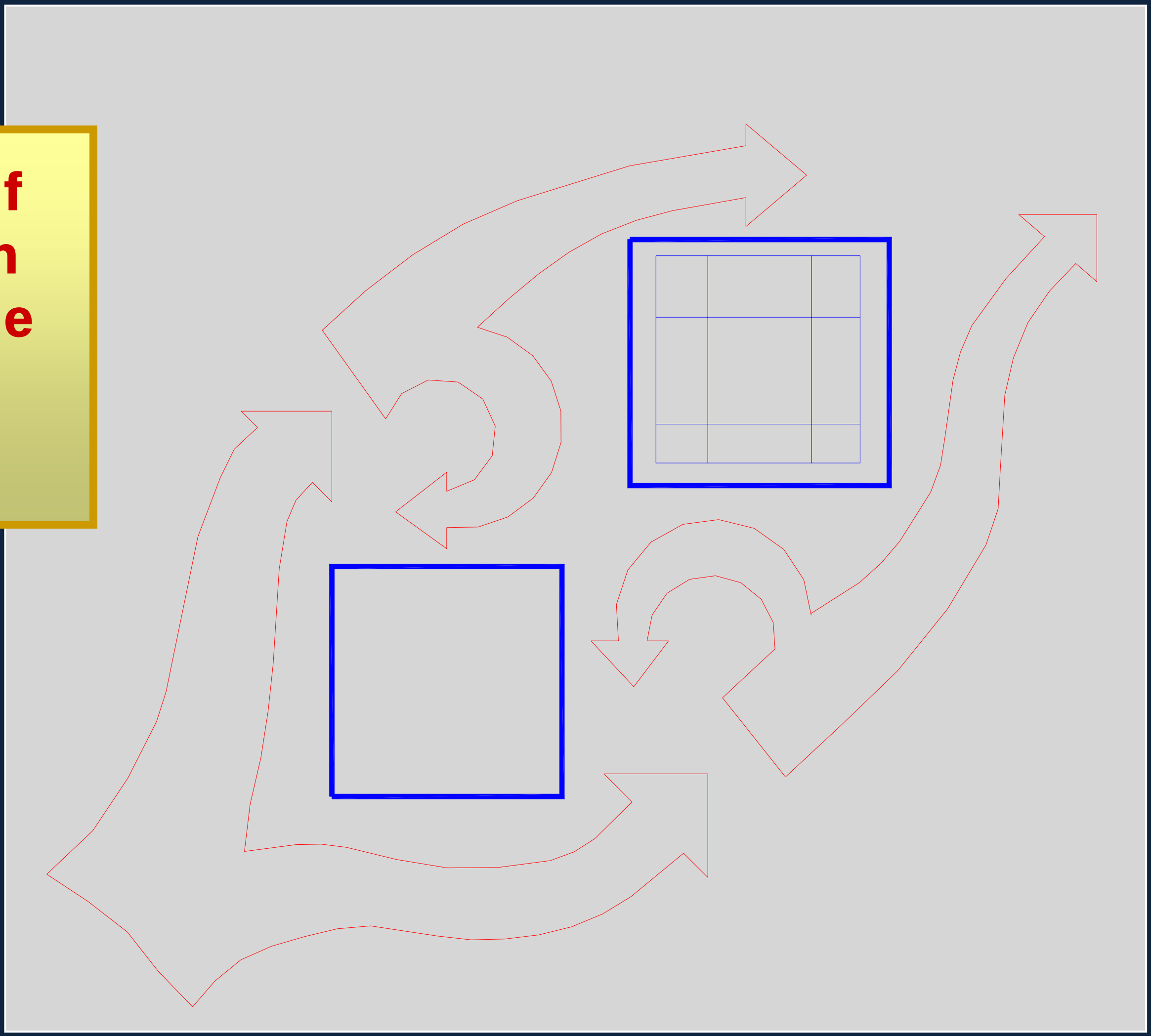
Pressure increase

due to wind on overhanging roofs



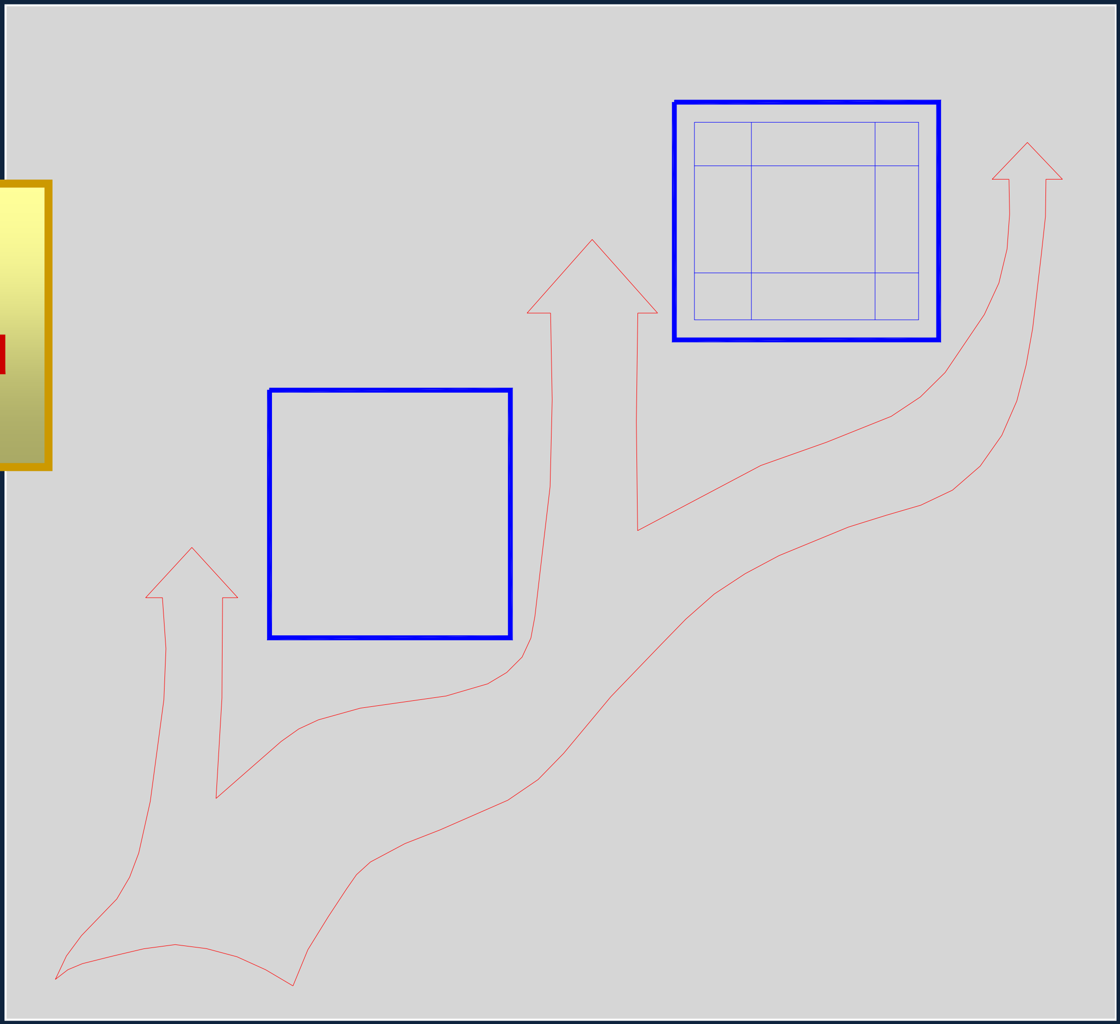
Protection effect of upstream building

A favorable location of adjacent buildings can decrease the hurricane effects reducing the wind loads

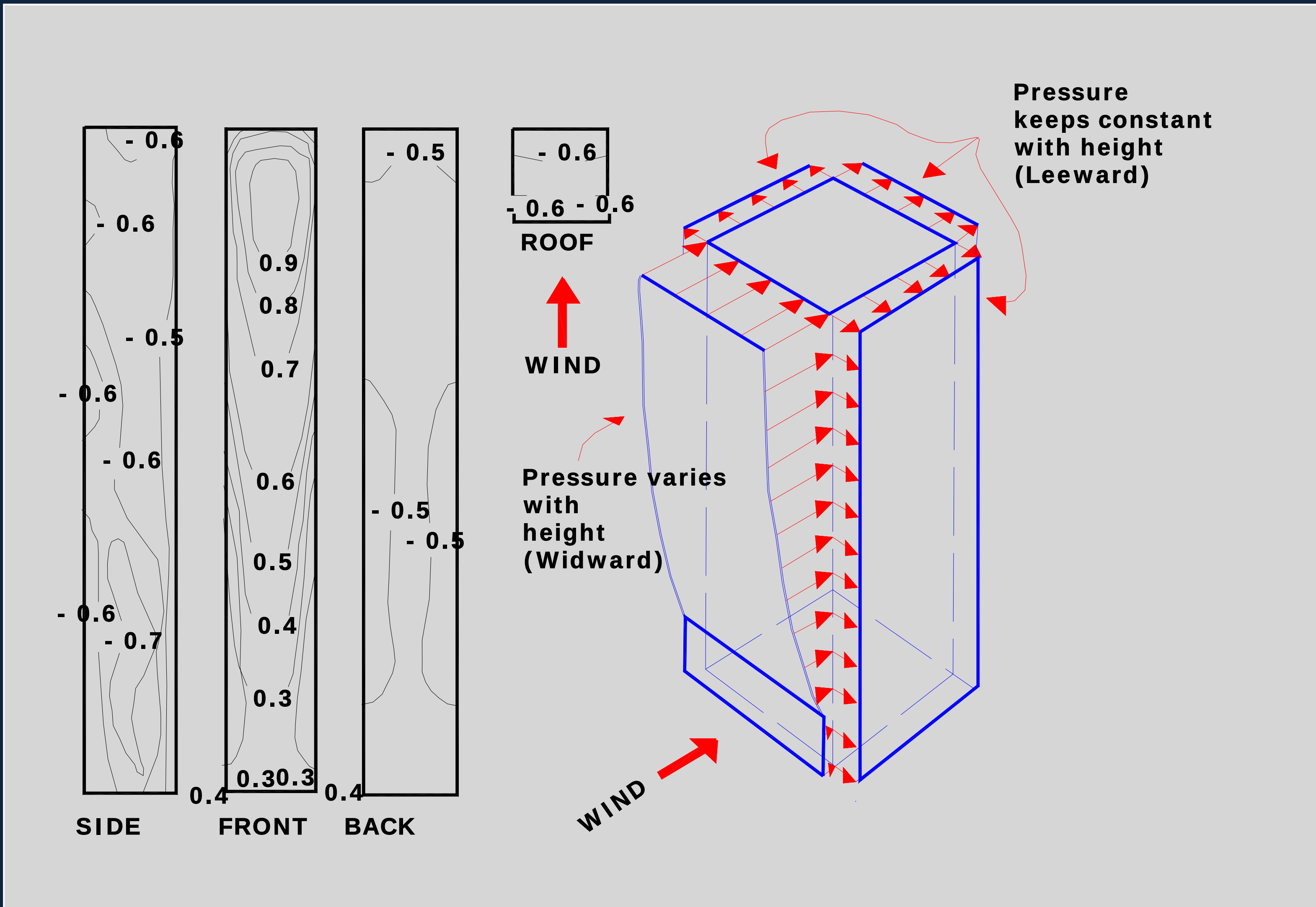


Unfavorable location of an adjacent building

A bad location of nearby buildings might induce increase of wind loads

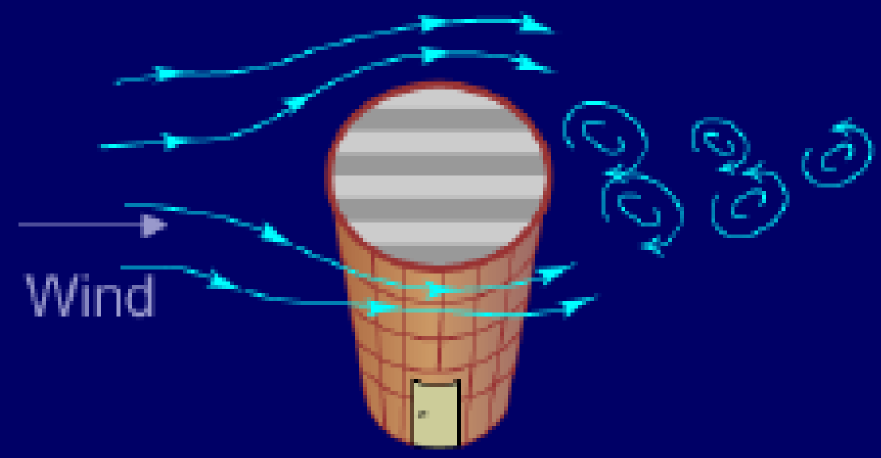


Pressure coefficients on high rise buildings



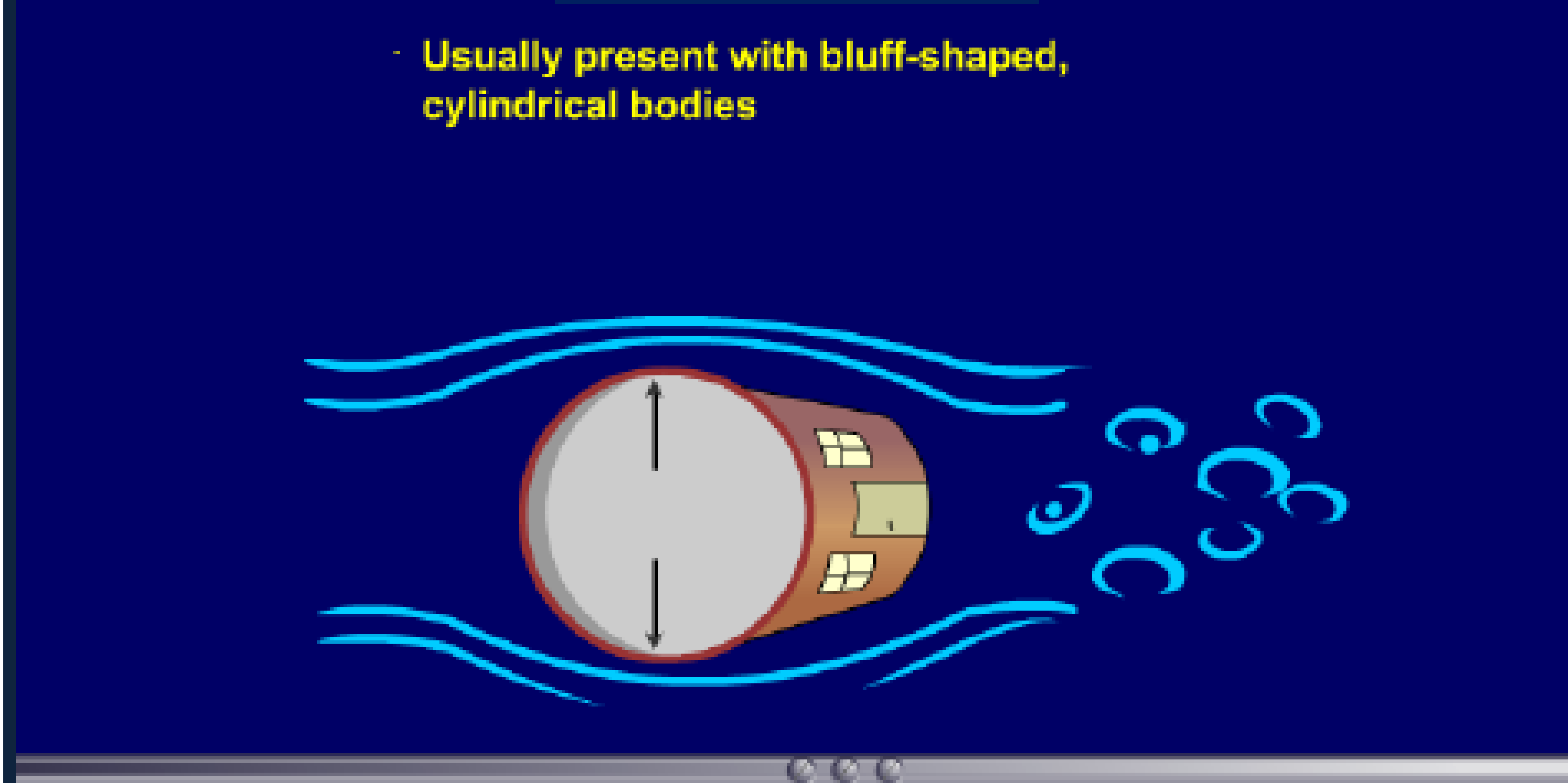
Dynamic Response

- Along-wind vibration (buffeting)
- Cross-wind vibration (vortex shedding)
  - Most common with cylindrical structures.



Wind flowing around bluff bodies
Vortices shed behind the structure

Vortex Shedding



almost always present with bluff-shaped cylindrical bodies

development of code "overlay" documents dealing specifically with referral hospitals

Safe Hospitals Initiative

Definition:

“ A health facility whose services remain accessible and functioning at maximum capacity and in the same infrastructure, during and immediately following the impact of a natural hazard.”

The Life Cycle of a Building:

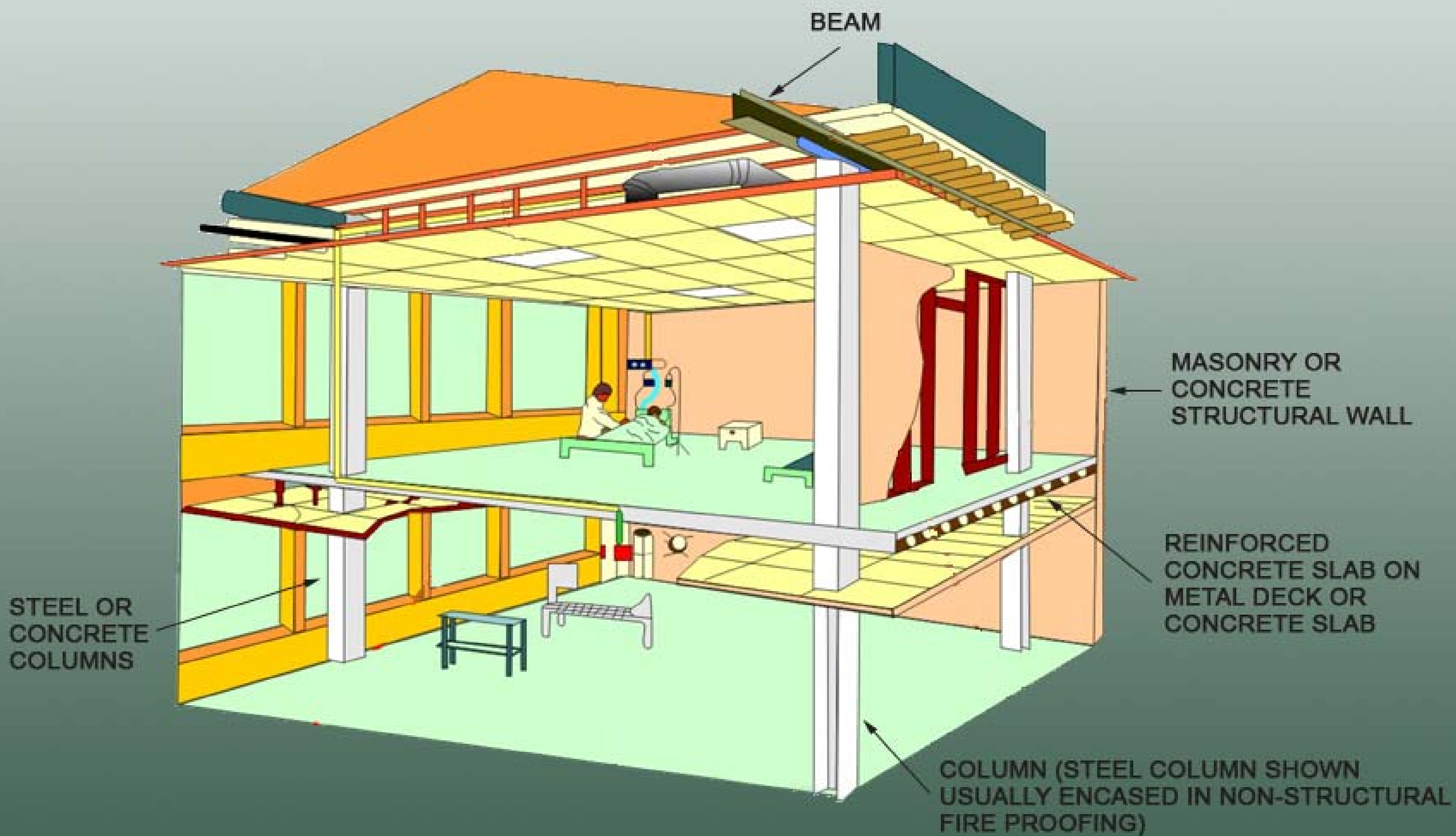
(1) Design (*ie* conceptual design)
(2) Analysis
(3) Detailing
(4) Construction
(5) Maintenance
(6) Demolition

Conceptual design involves a series of decisions among which are:

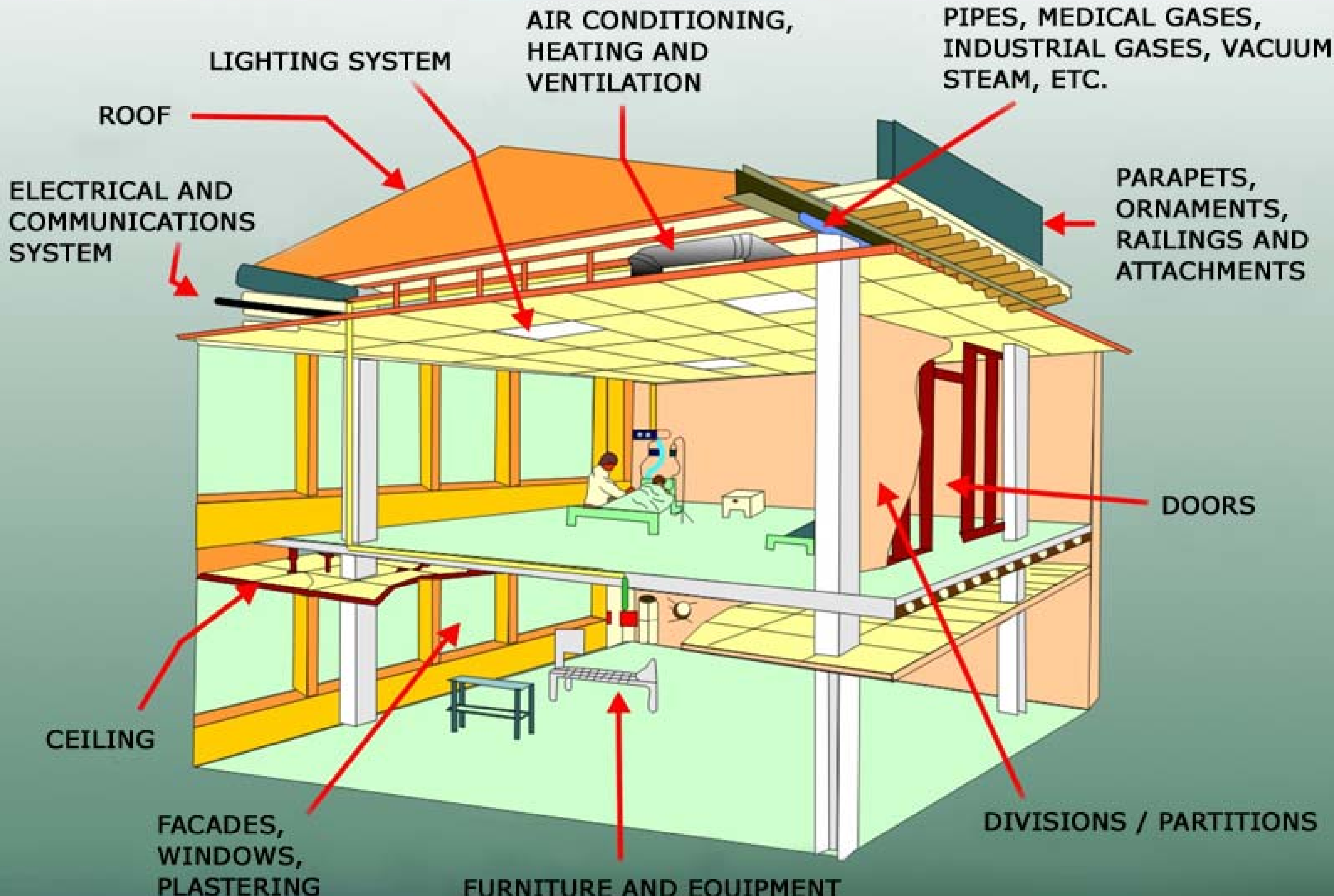
(1) the geometry or shape or configuration of the building;
(2) the siting of the building;
(3) the materials of construction;
(4) the structural system.

attention to the
non-structural components

Structural Components



Nonstructural Components



vulnerability assessments of existing hospitals

Vulnerability assessments

Qualitative methods

They assess quickly and simply the structural safety conditions of the building. The structure is rated, among other characteristics, according to the following:

- The age of the building
- The state of conservation
- The characteristics of the materials used
- The number of stories
- The architectural plan
- Estimation of base shear strength

Vulnerability assessments

Quantitative methods

The goal is to determine the levels of resistance, flexibility and ductility demands of the structure by means of an analysis similar to that used in new buildings, incorporating nonstructural elements.

Assessment methods

- Previous experience
- Analysis - mathematical simulation
- Laboratory tests
- Expert opinions

Nonstructural components to consider when assessing vulnerability

ARCHITECTURAL	EQUIPMENT (floods)	BASIC INSTALLATIONS
• Facades • Roofs or decks • Parapets • Chimneys • External plaster • Glass windows • Attachments (signs, antennae,etc) • Ornaments • Canopies • Lighting system • Railings • Doors and exit routes • Expansion joints	• Medical equipment • Laboratory equipment • Industrial equipment • Supplies	• Industrial gas piping • Steam • Air-conditioning systems • Heating • Ventilation • Electrical distribution • Back-up power • Communications • Drinking water • Industrial water • Sewerage

Waterproof membrane removed

Photo: Tony Gibbs


Photo: Tony Gibbs

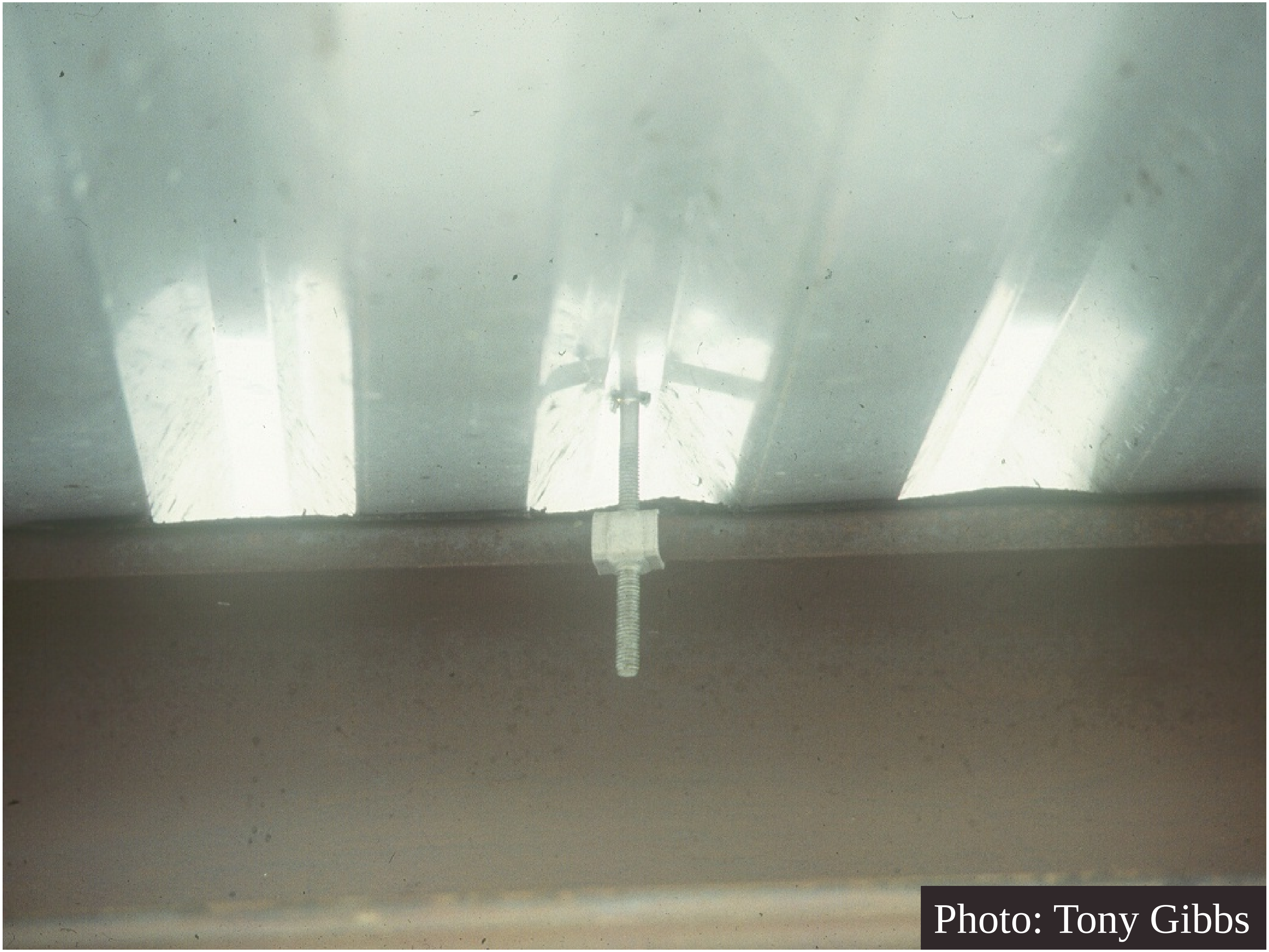
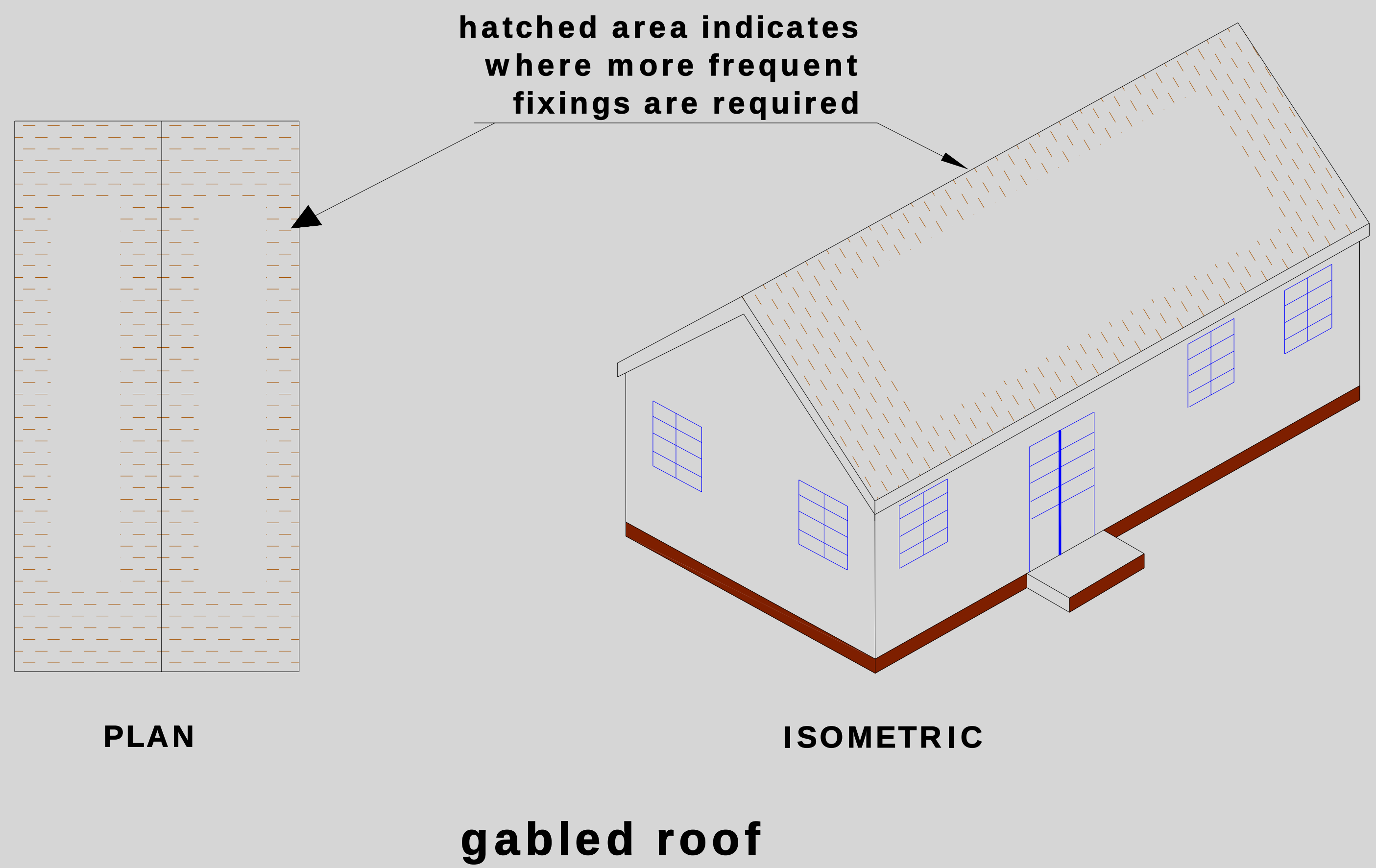


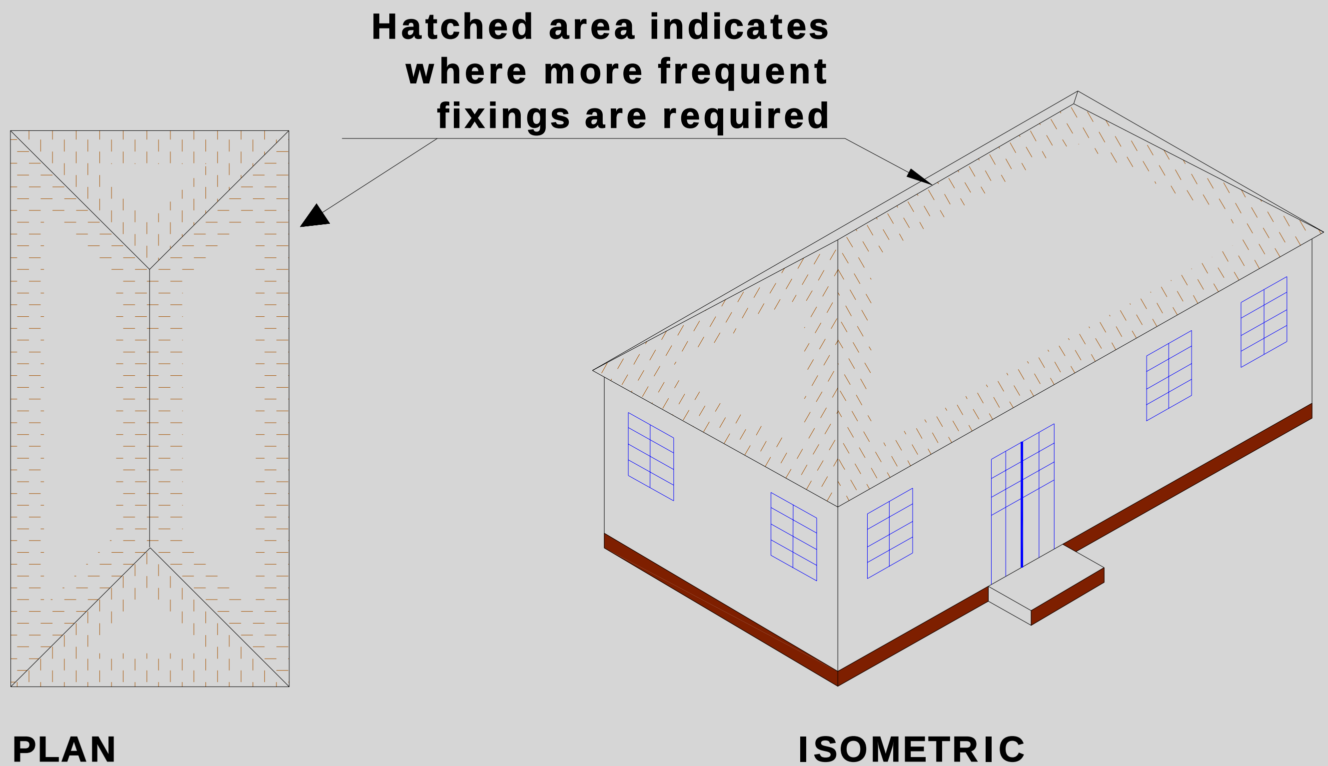
Photo: Tony Gibbs


Photo: Tony Gibbs

Gabled roof with slopes of 20 to 30 degrees are second best against hurricanes

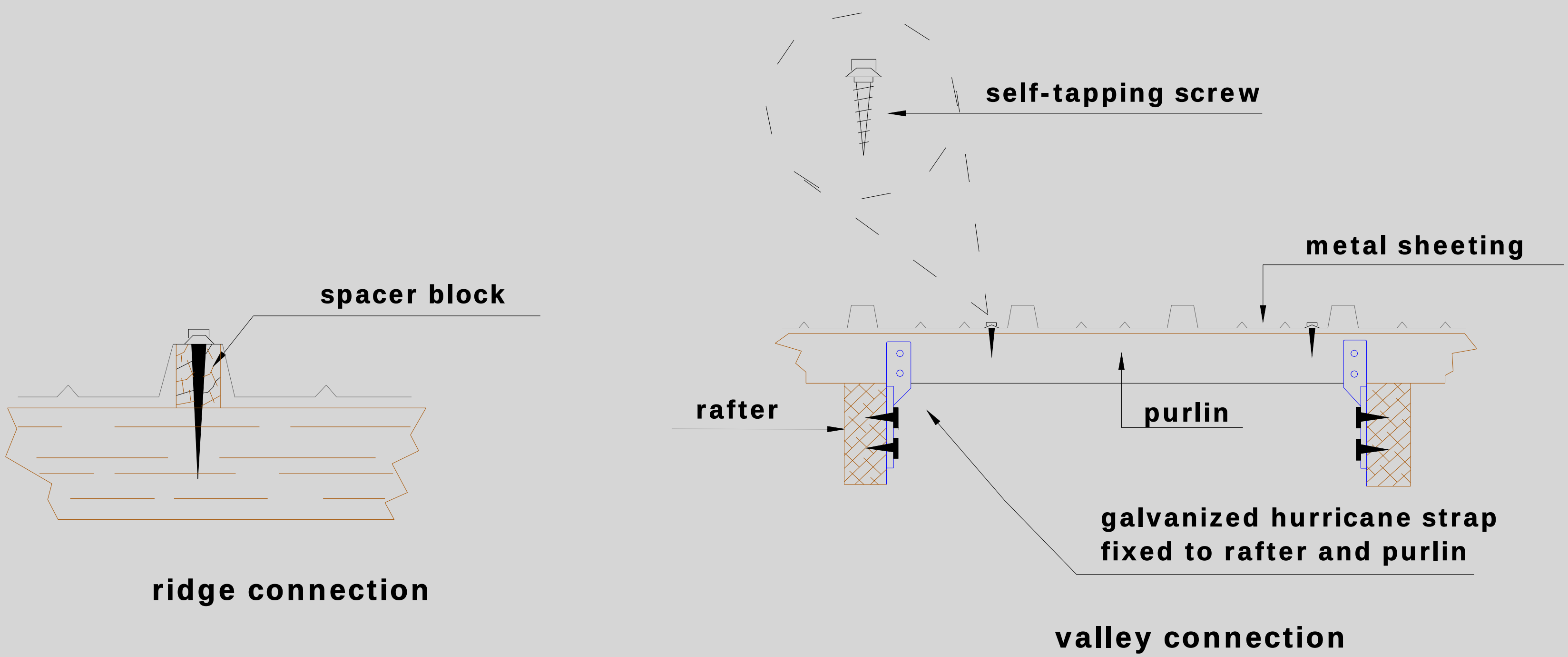


Hipped roof recommended over flat roof

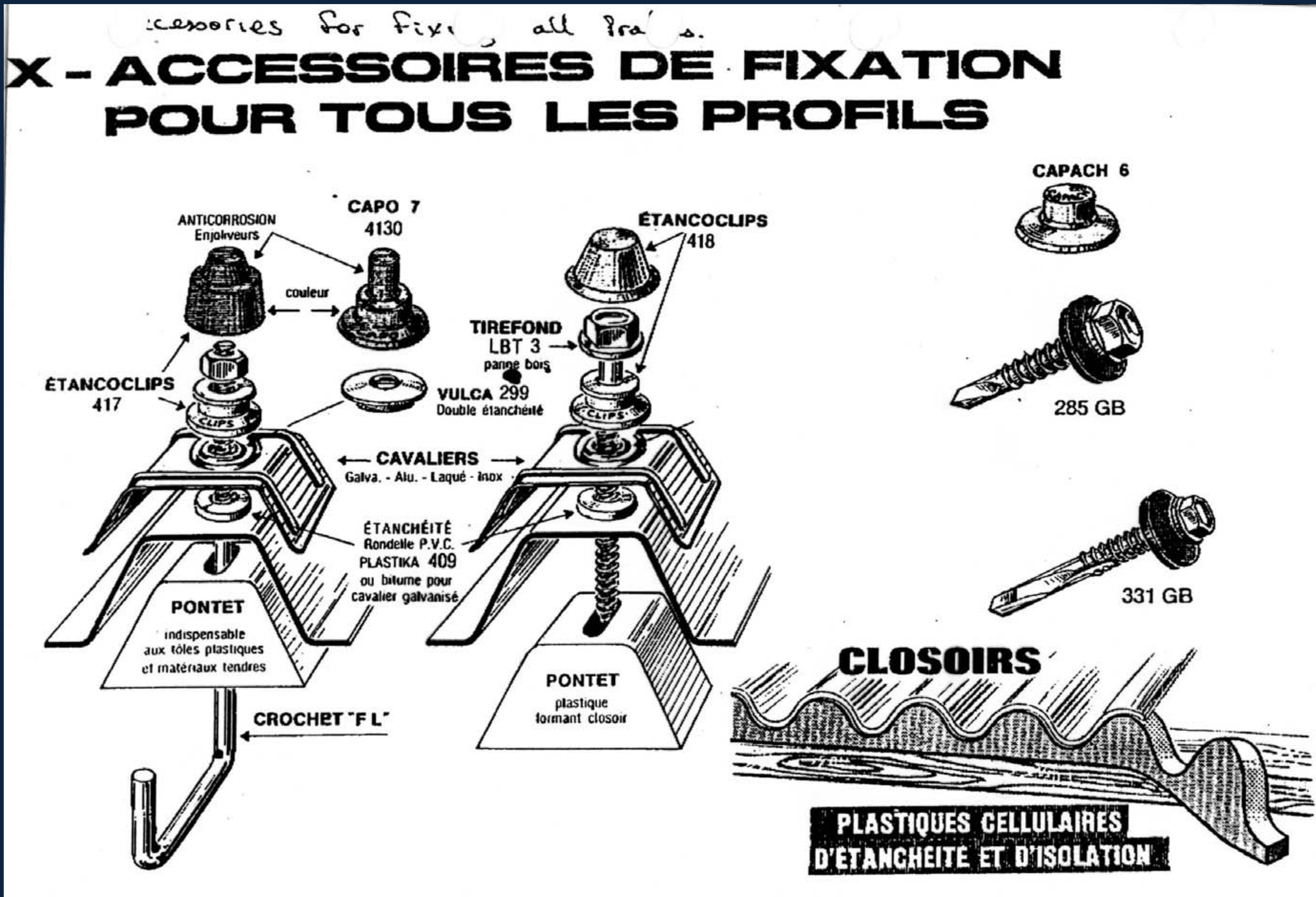


Hipped roof

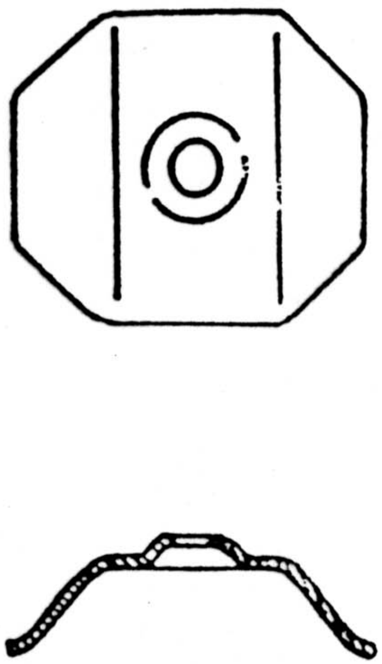
Connection details between metal sheet roof and purlins



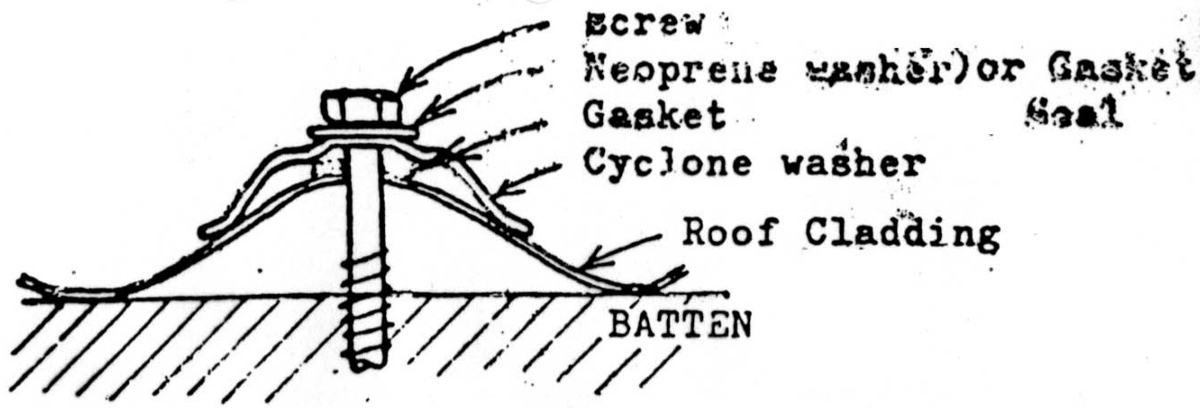
Metal sheet fixings and purlin-to-rafter connection



Accessories for fixing all profiles



Cyclone Washer : Example of One Type Specified by Manufacturers



Screw Fixing : Example of use of One Type of Cladding Fixing Specified by a Manufacturer for use of a Particular Product in Cyclonic Areas

ALSO SPECIFIED :

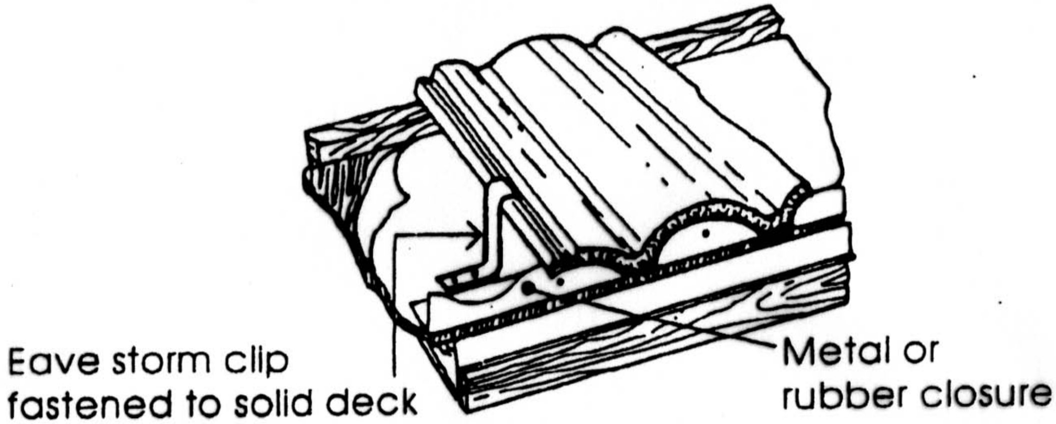
* Spacing of fixings
* Increased fixing at roof edges and changes in slope
* Special requirements (eg holes through sheet to be
  predrilled
  screws not to be overtightened
  etcetera)

EXAMPLE OF FIXING FOR SHEET METAL PRODUCT

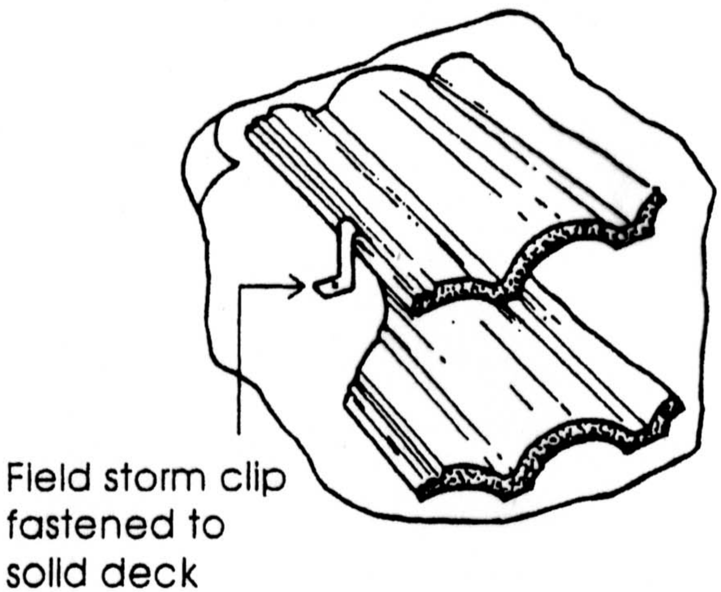
(Exact Requirements Given by Manufacturer)

Loss of Spanish tiles – Miami, Hurricane Andrew, 1992

EAVE STORM CLIP FASTENED TO SOLID DECK



FIELD STORM CLIP FASTENED TO SOLID DECK



FIELD STORM CLIP FASTENED TO BATTEN

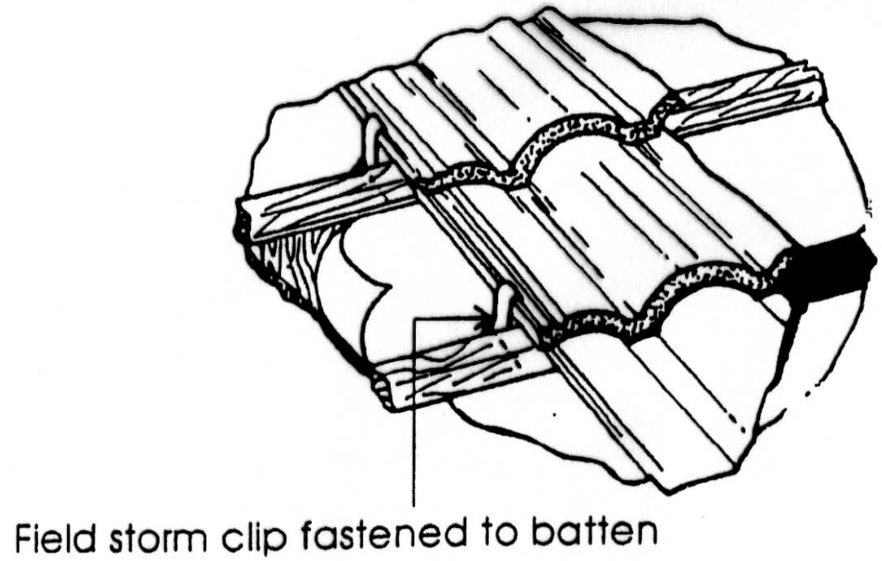
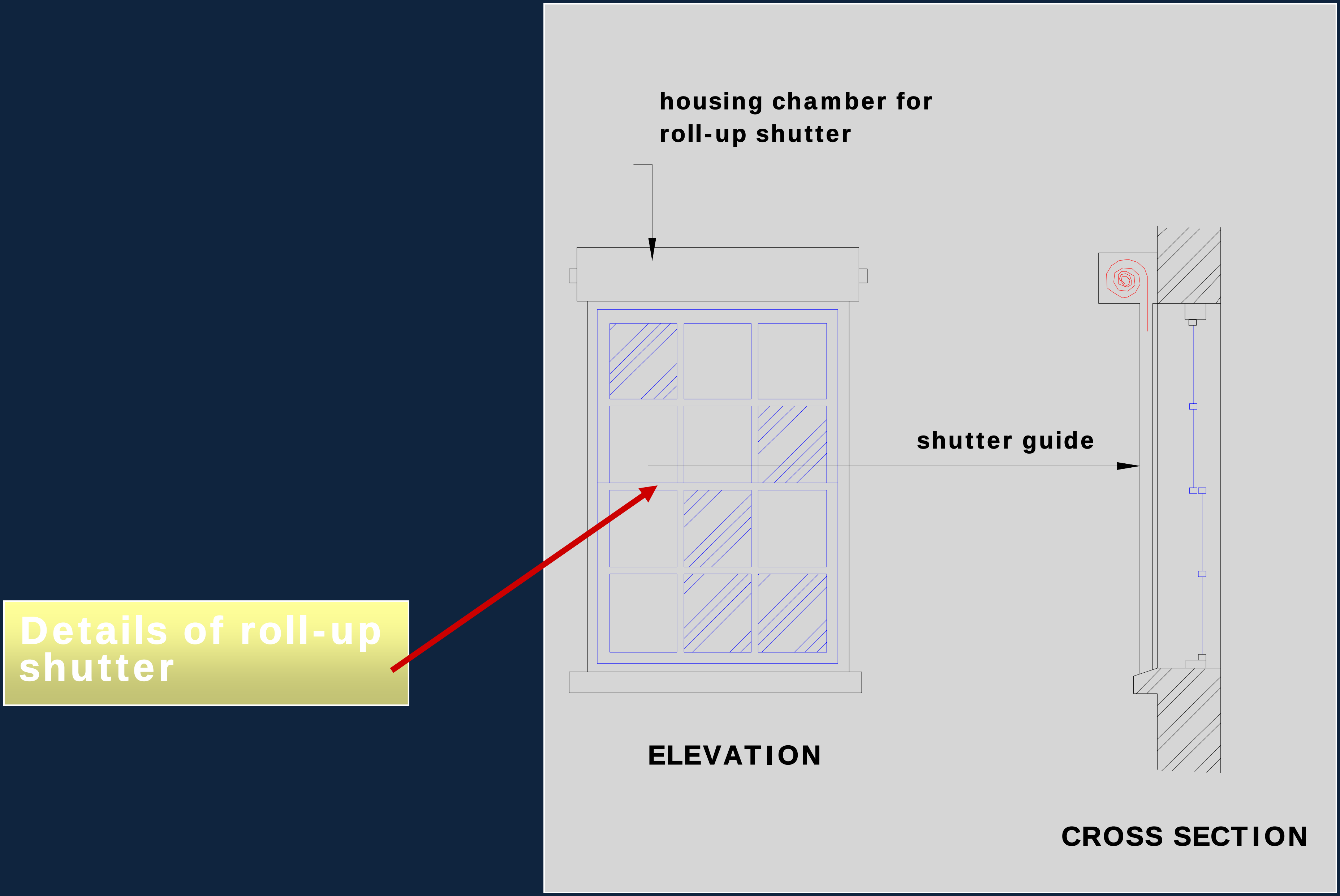
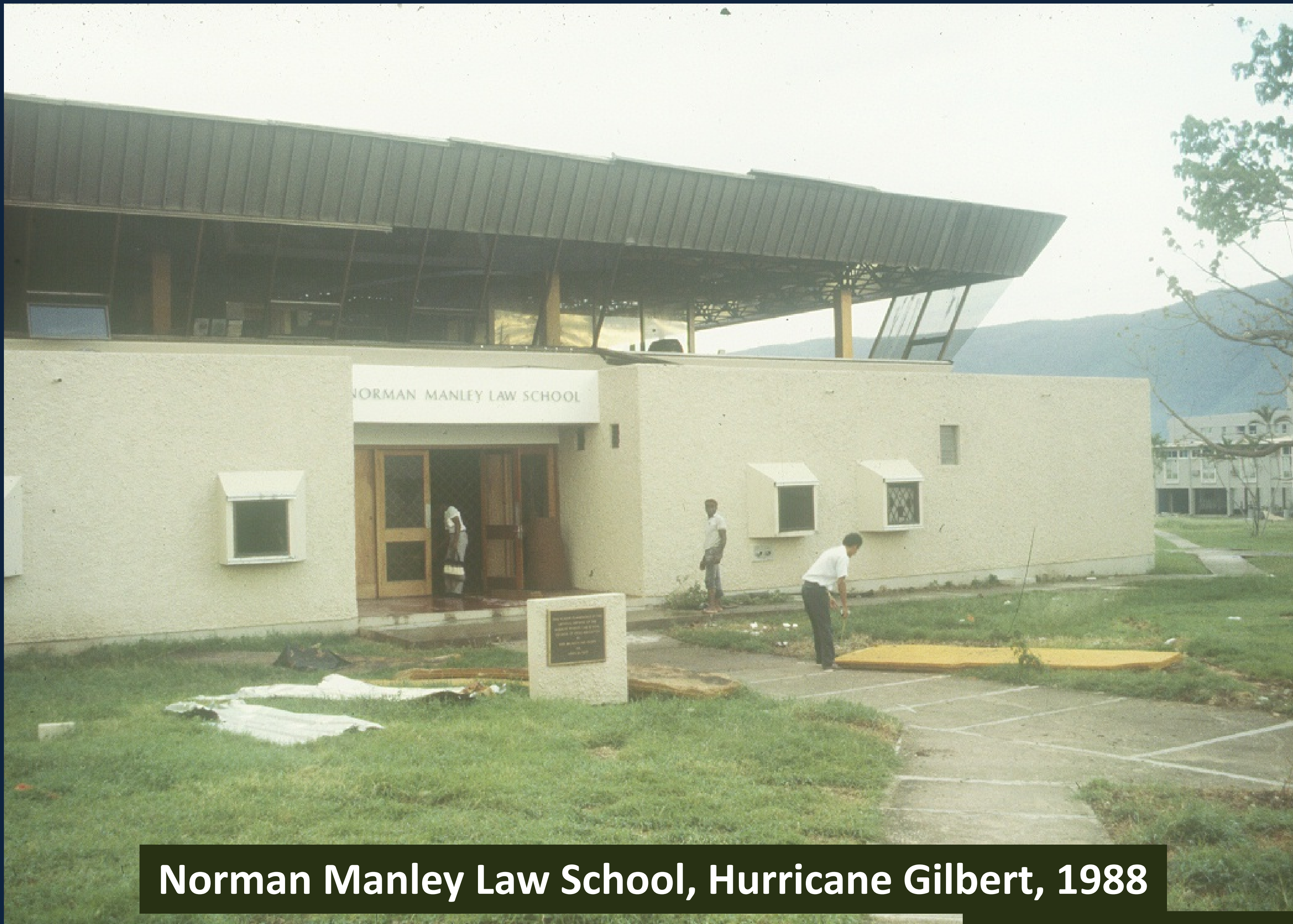



Photo: Tony Gibbs

Polycarbonate, impact-resistant windows

Photo: Tony Gibbs


housing chamber for
roll-up shutter
shutter guide
ELEVATION
CROSS SECTION
Details of roll-up shutter



Norman Manley Law School, Hurricane Gilbert, 1988

Photo: Tony Gibbs

Antigua, Hurricane Luis, 1995

Photo: Tony Gibbs

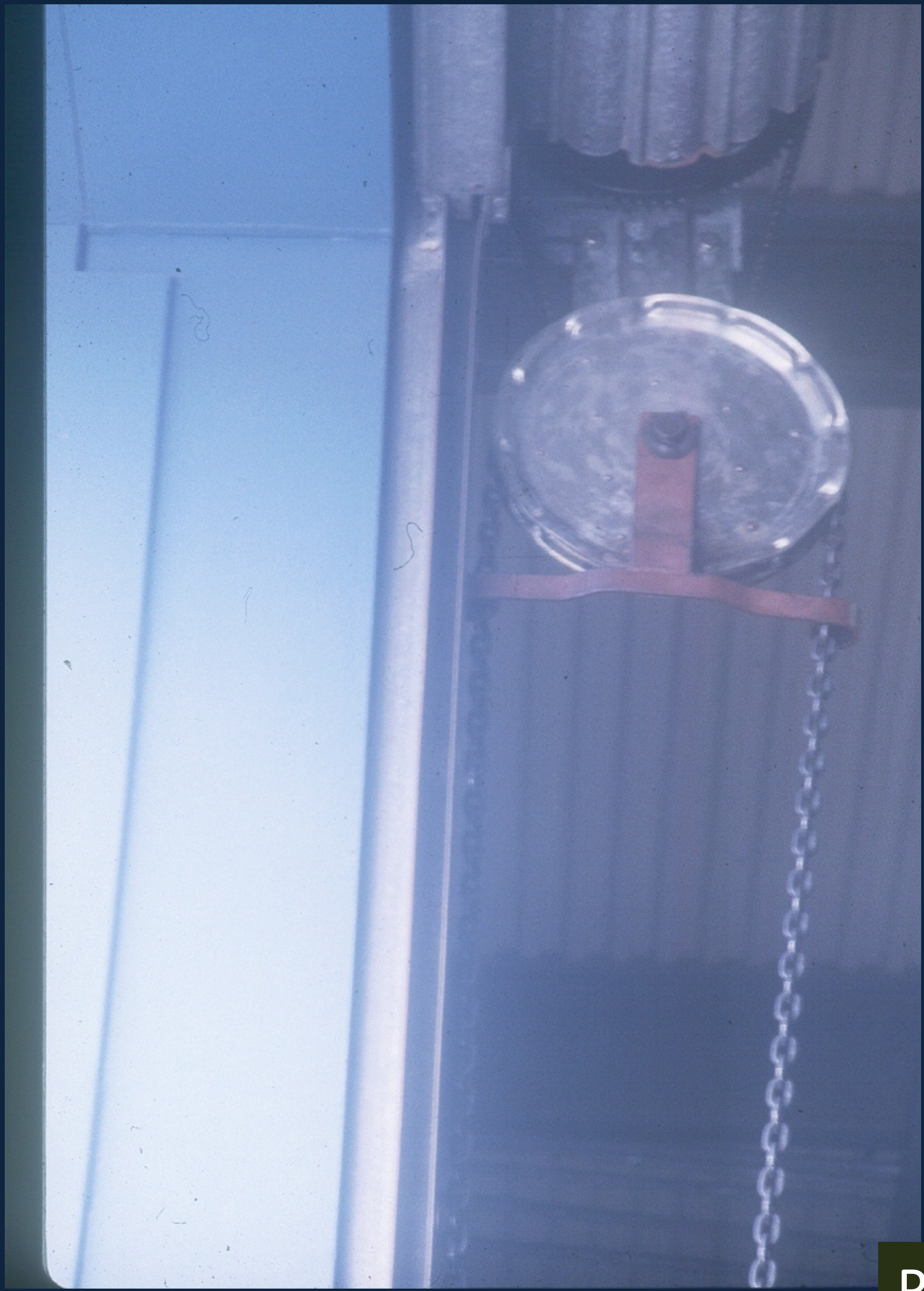
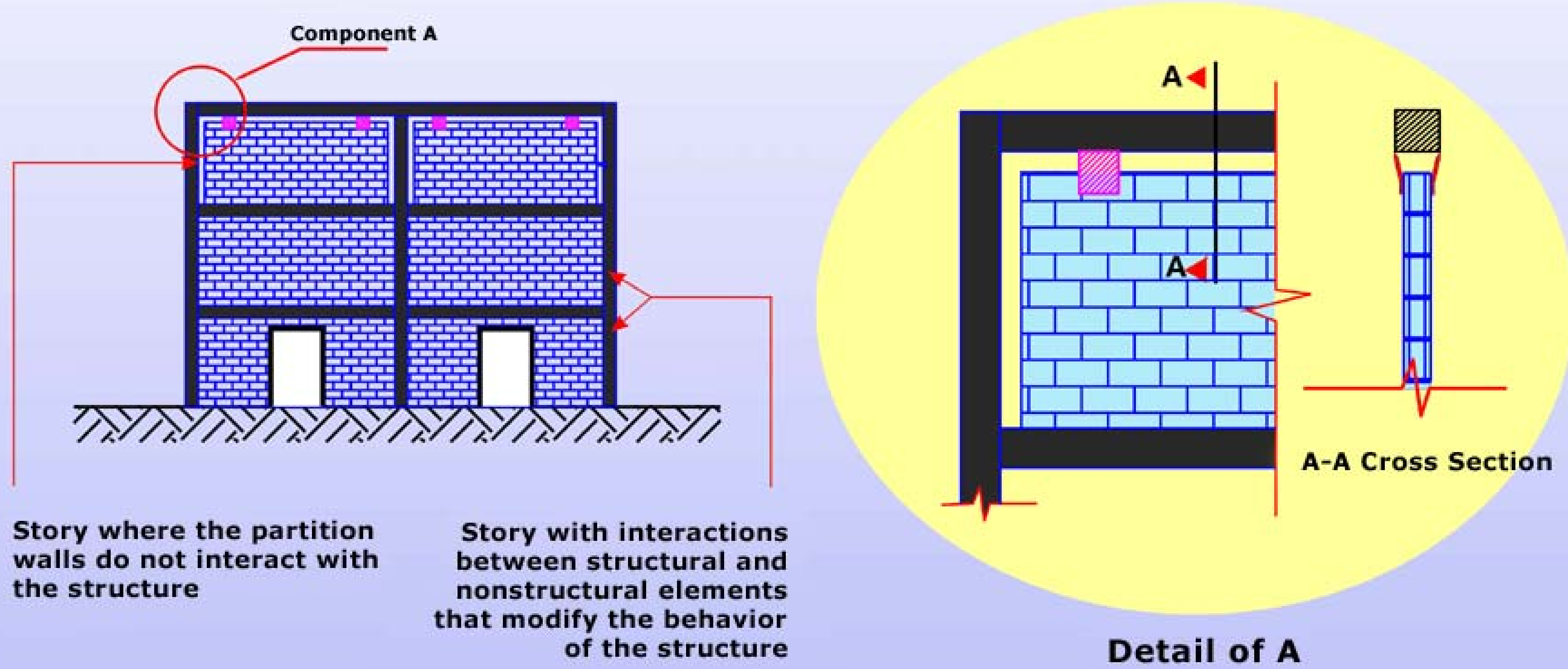
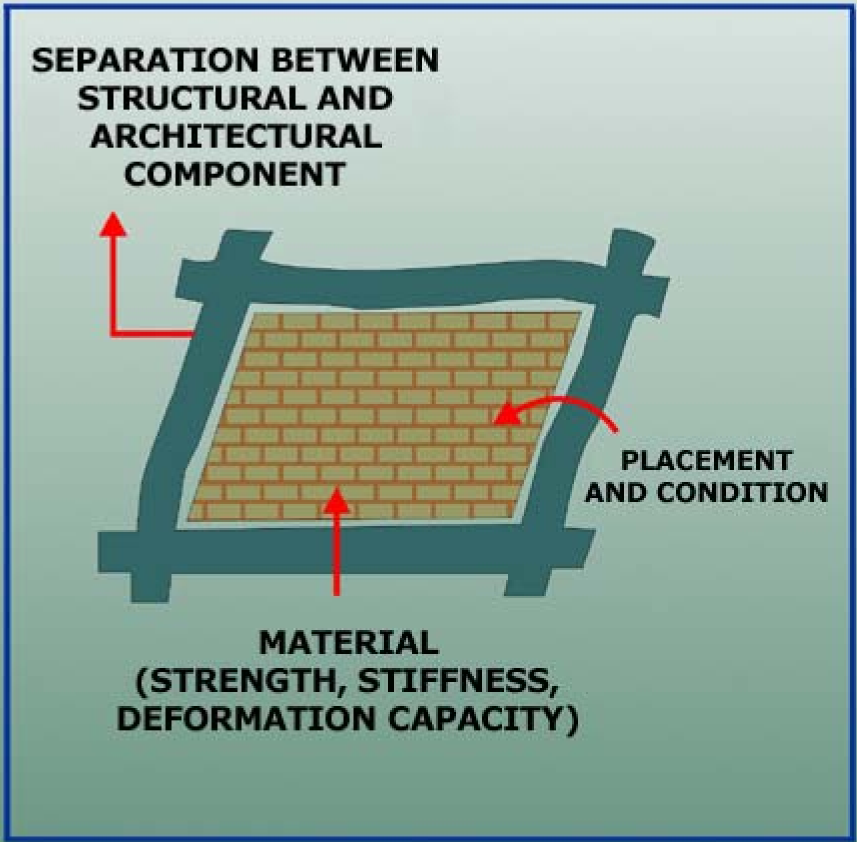


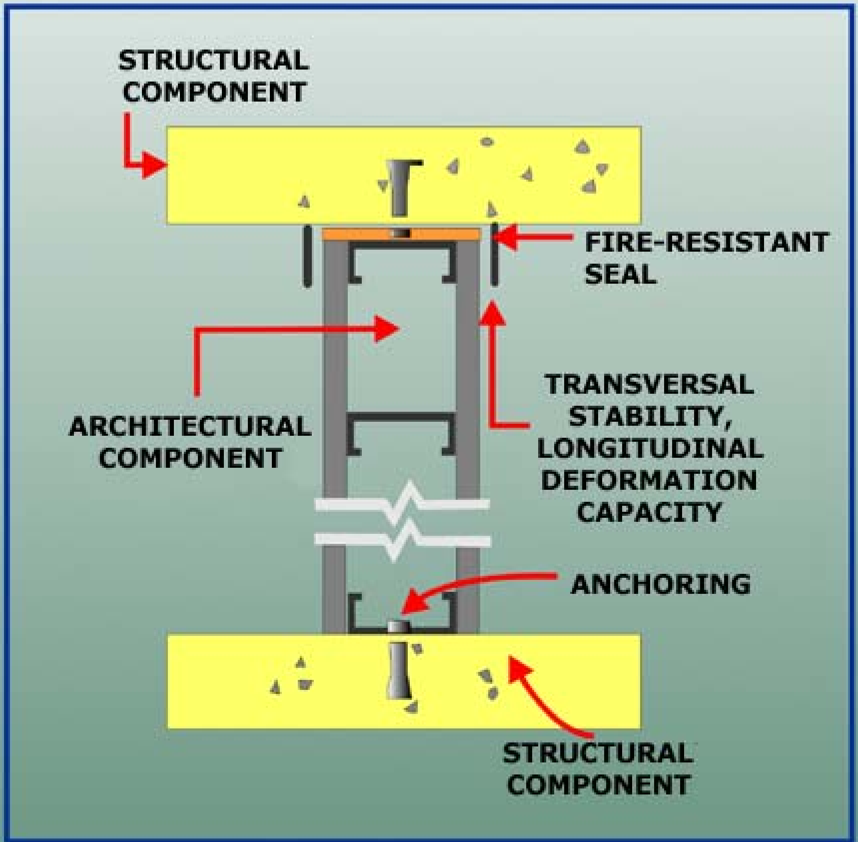
Photo: Tony Gibbs

Interaction between structural and non-structural elements

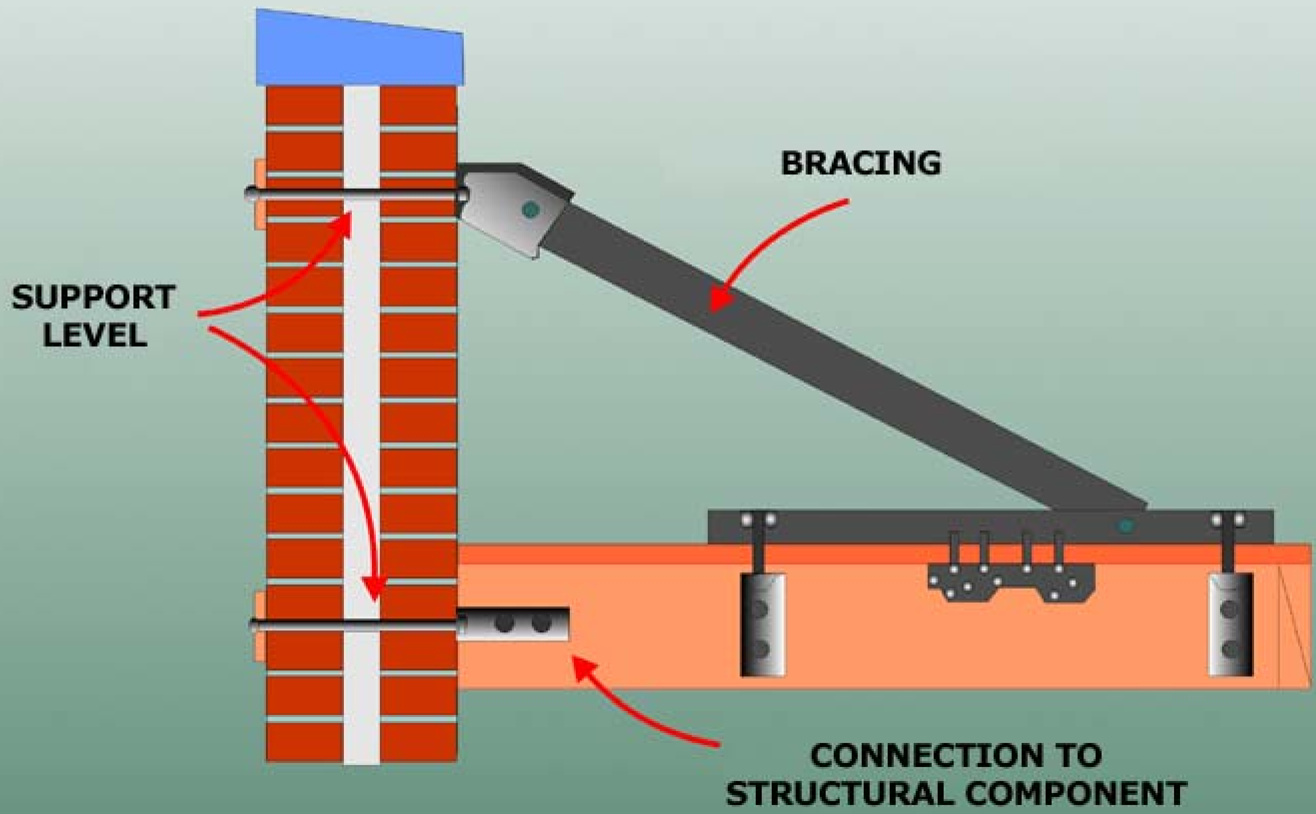


Considerations regarding partitions, façades, and windows





Restraints for parapets, signs and ornaments



Criteria for equipment classification

Indispensable: Equipment that can not easily be replaced and is essential for the provision of health services

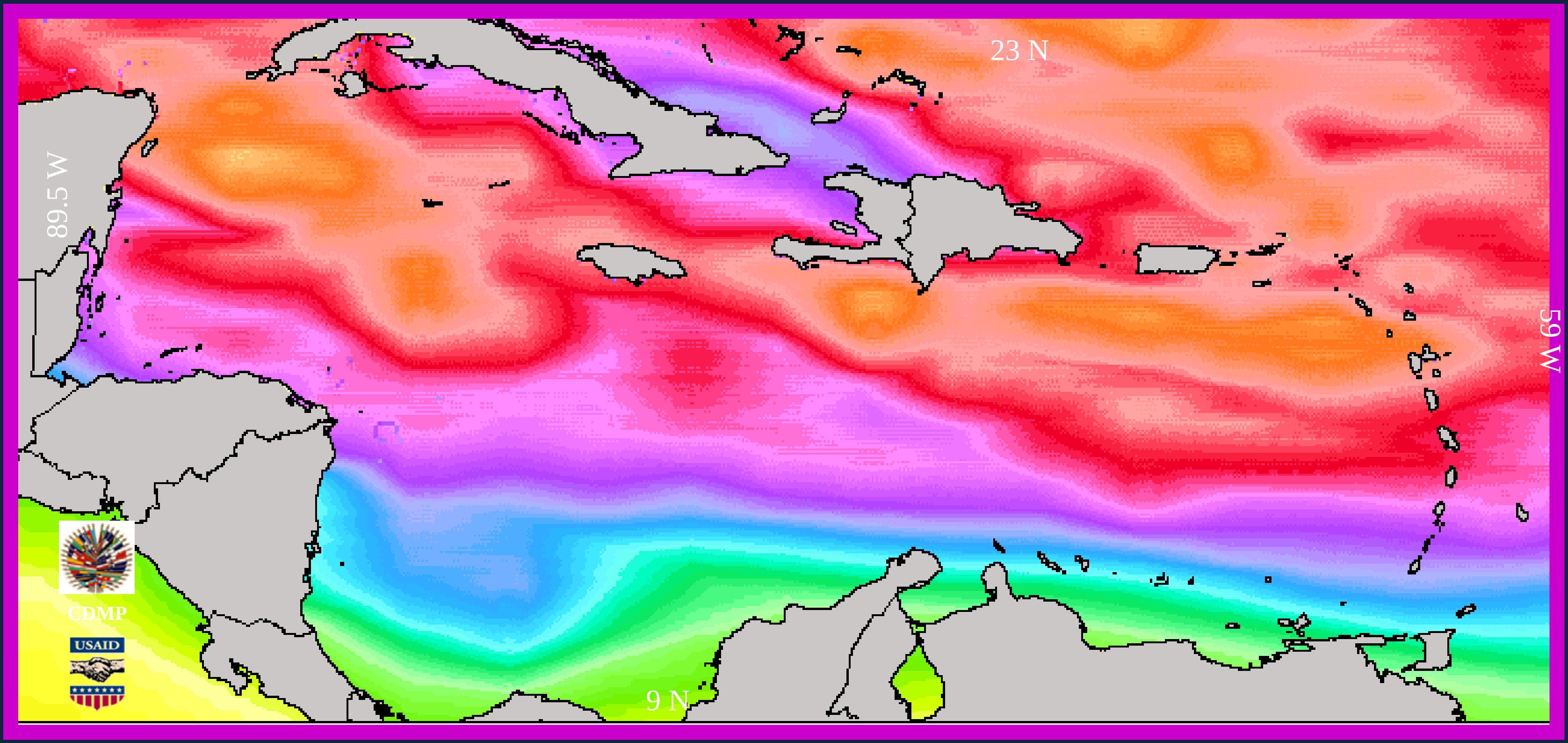
Essential: Similar to indispensable equipment, except that it can be replaced promptly

Hazardous: Equipment that can injure people and damage objects

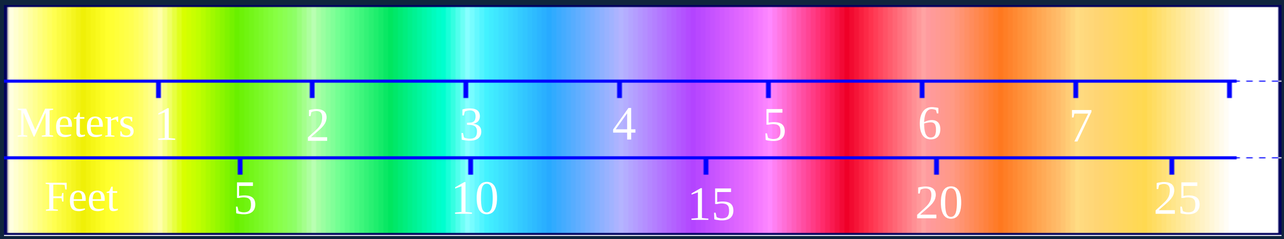
Chaotic: Equipment whose failure may cause disruption to its environs

Functional: Equipment that is not used for emergency health care

Maximum Wave Heights (50-year return)

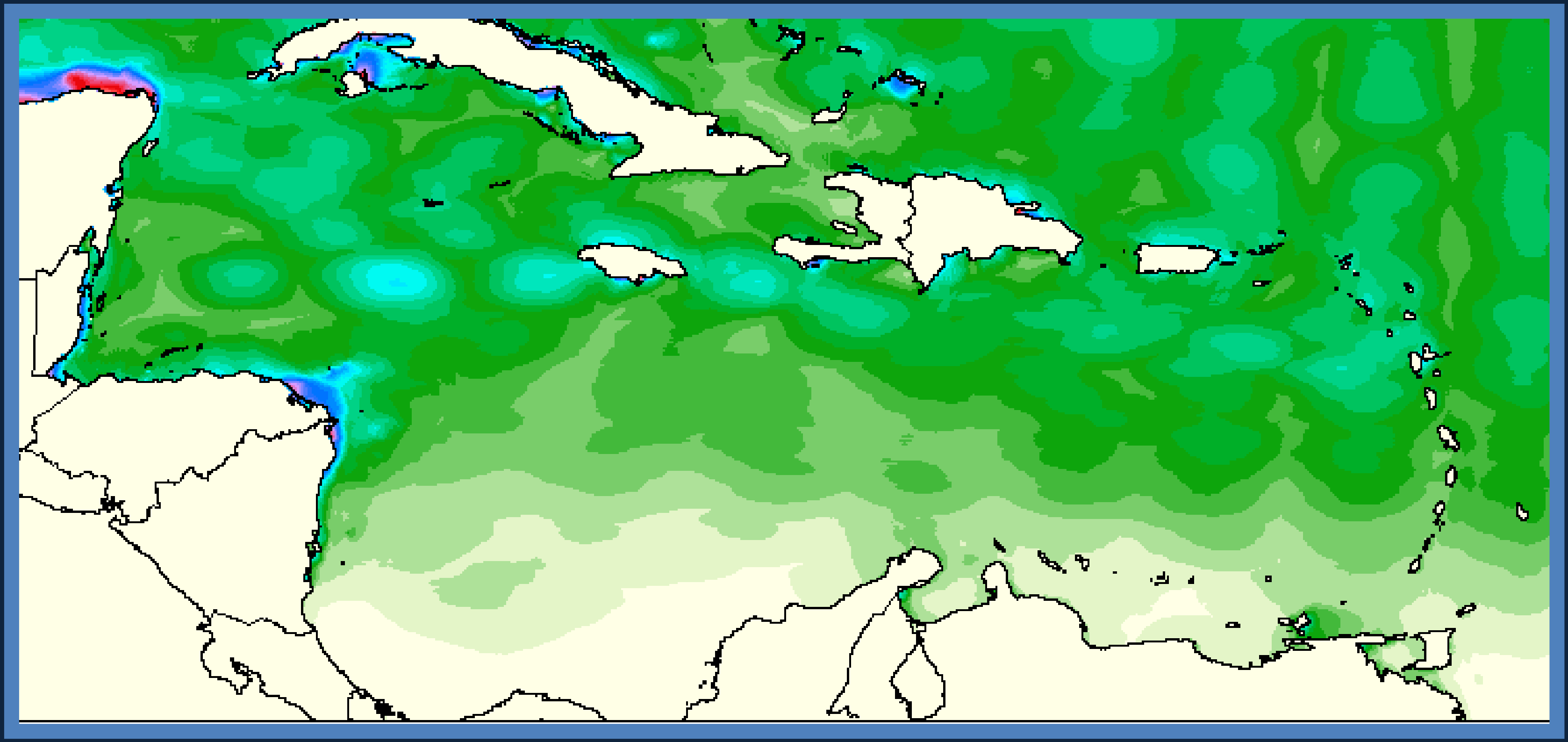


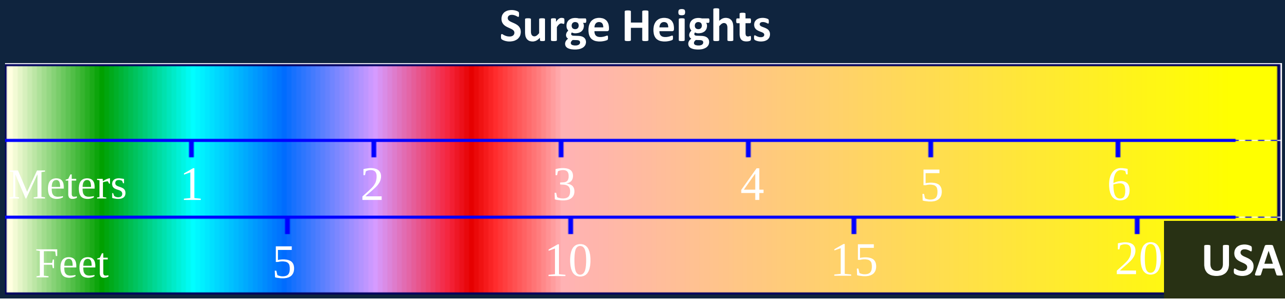
Wave Heights



Hurricane Wilma, Havana, 2005

Maximum Storm Surge (50-year return)



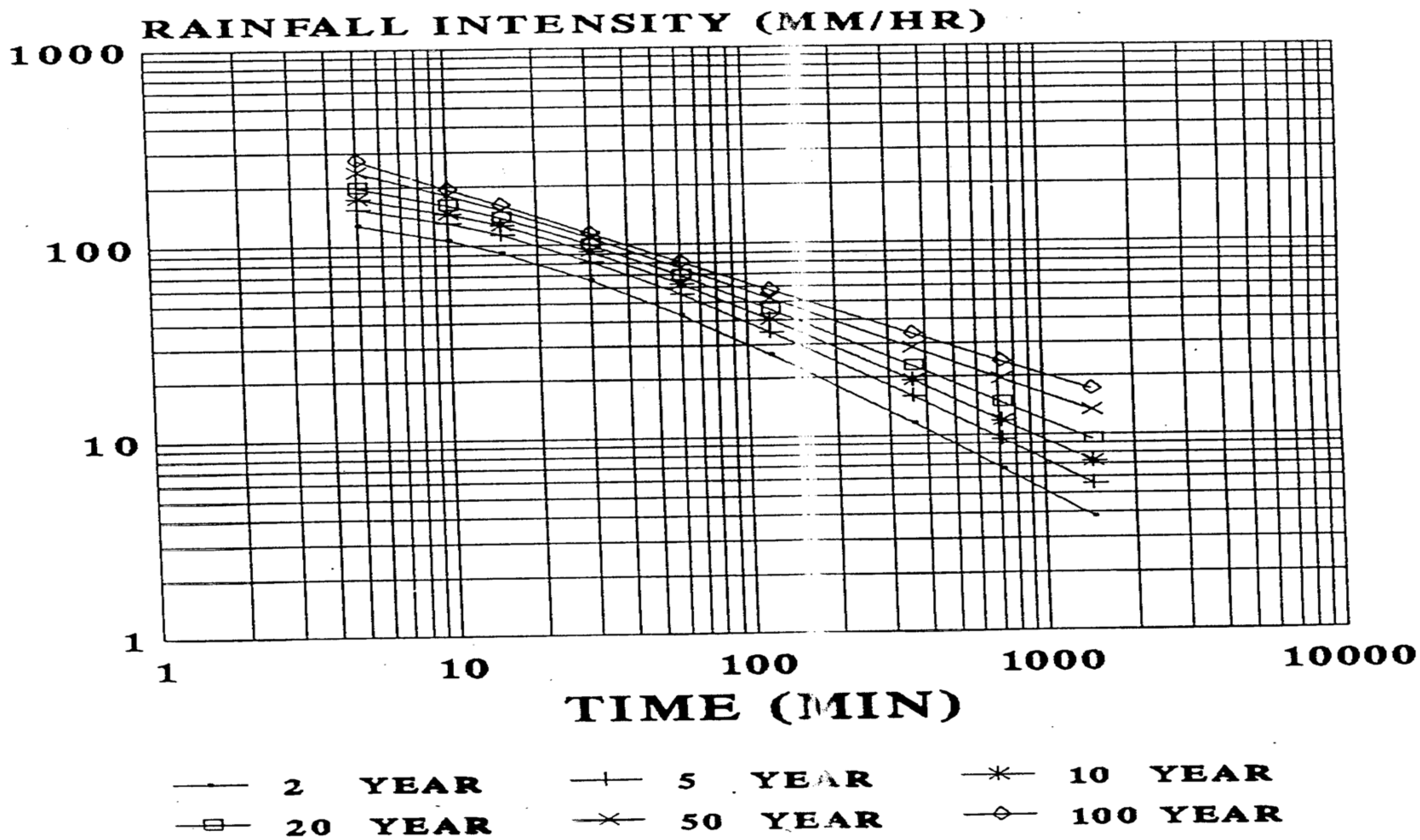


USAID-OAS CDMP

Hurricane Wilma, Havana, 2005

Grand Cayman Hospital – Hurricane Ike, 2004

Photo: Tony Gibbs



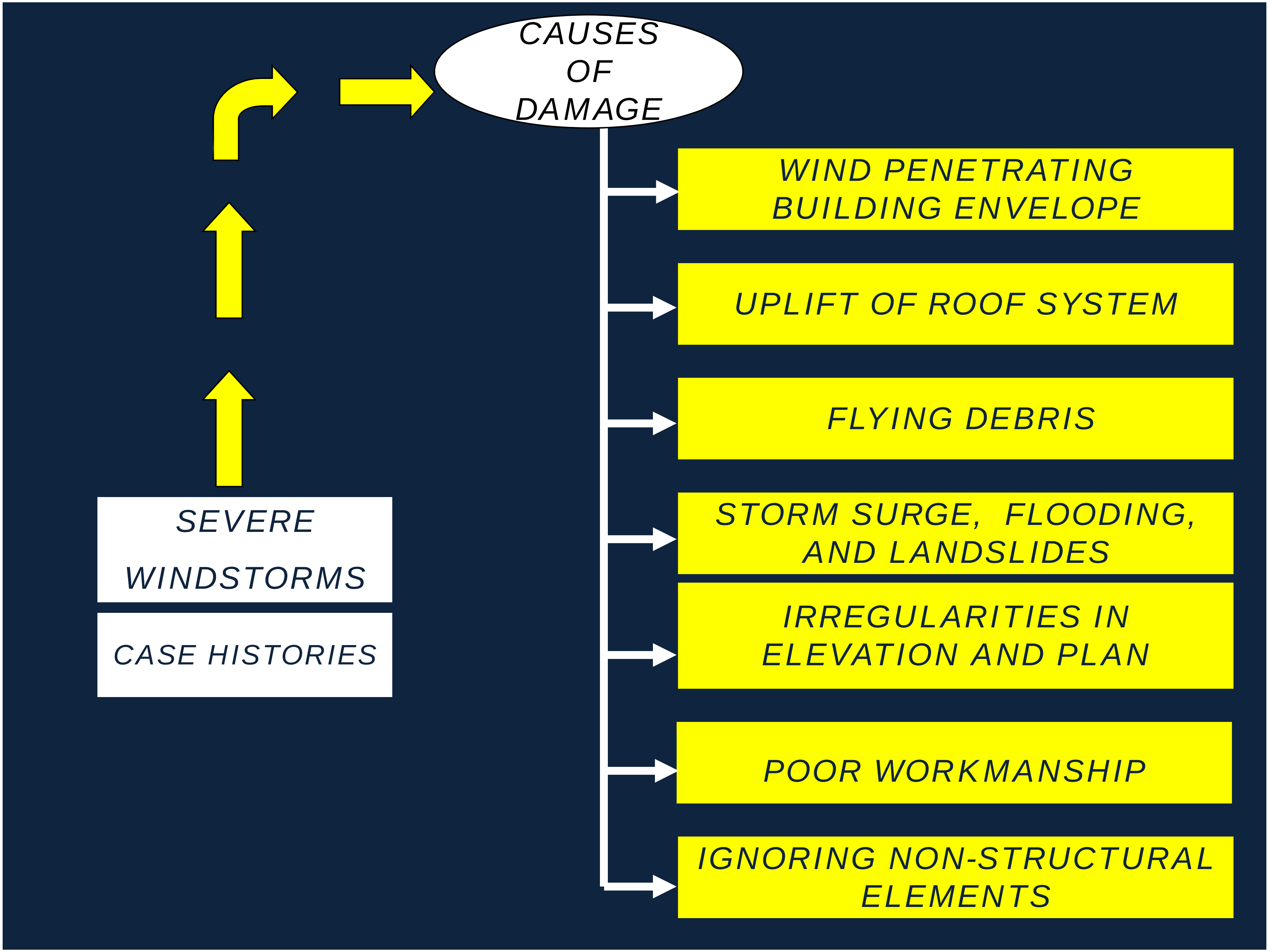
Intensity-Duration-Frequency Curves

Cumming Cockburn Limited
Errol Clarke Associates Limited
Franklin and Franklin (1983) Limited
Charlesworth & Associates

Government of Barbados
Stormwater Drainage Study

Storm Rainfall
IDF Curves - Husbands

Figure D.3.2


CAUSES OF DAMAGE
WIND PENETRATING BUILDING ENVELOPE
UPLIFT OF ROOF SYSTEM
FLYING DEBRIS
STORM SURGE, FLOODING, AND LANDSLIDES
IRREGULARITIES IN ELEVATION AND PLAN
POOR WORKMANSHIP
IGNORING NON-STRUCTURAL ELEMENTS
SEVERE WINDSTORMS
CASE HISTORIES

implementation of
independent reviews of designs
and of
quality assurance during construction

Hurricane Luis in
Sint Maarten and Saint Martin

Dutch side (Netherlands Antilles Meteorological Service):
Highest gust 99 knots or 51 ms^{-1}

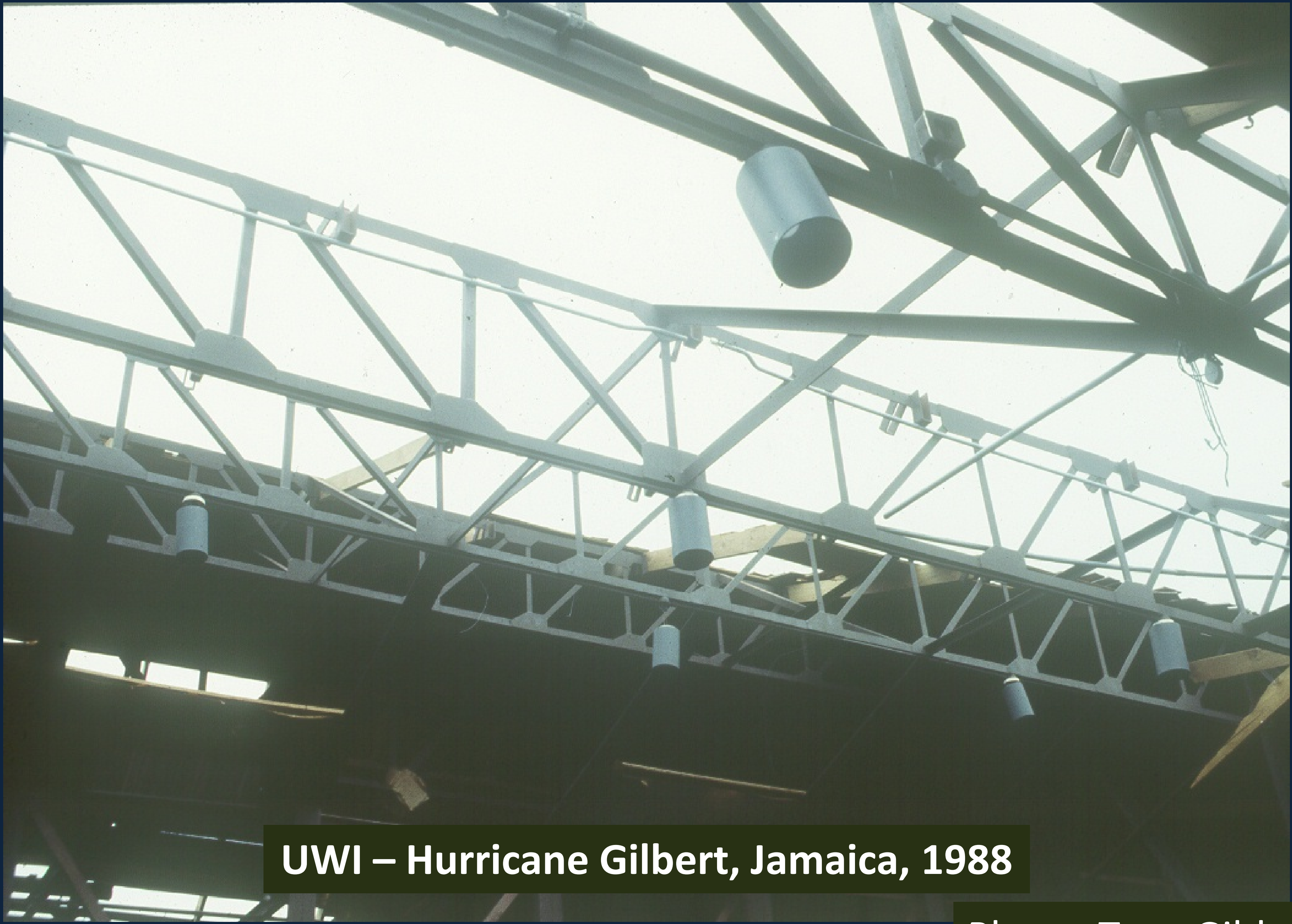
French side:
No anemometer measurements available

Dutch side:
Catastrophic damage
- 100% GDP direct
- 100% GDP indirect

French side:
Not much damage

UWI – Hurricane Gilbert, Jamaica, 1988

Photo: Tony Gibbs



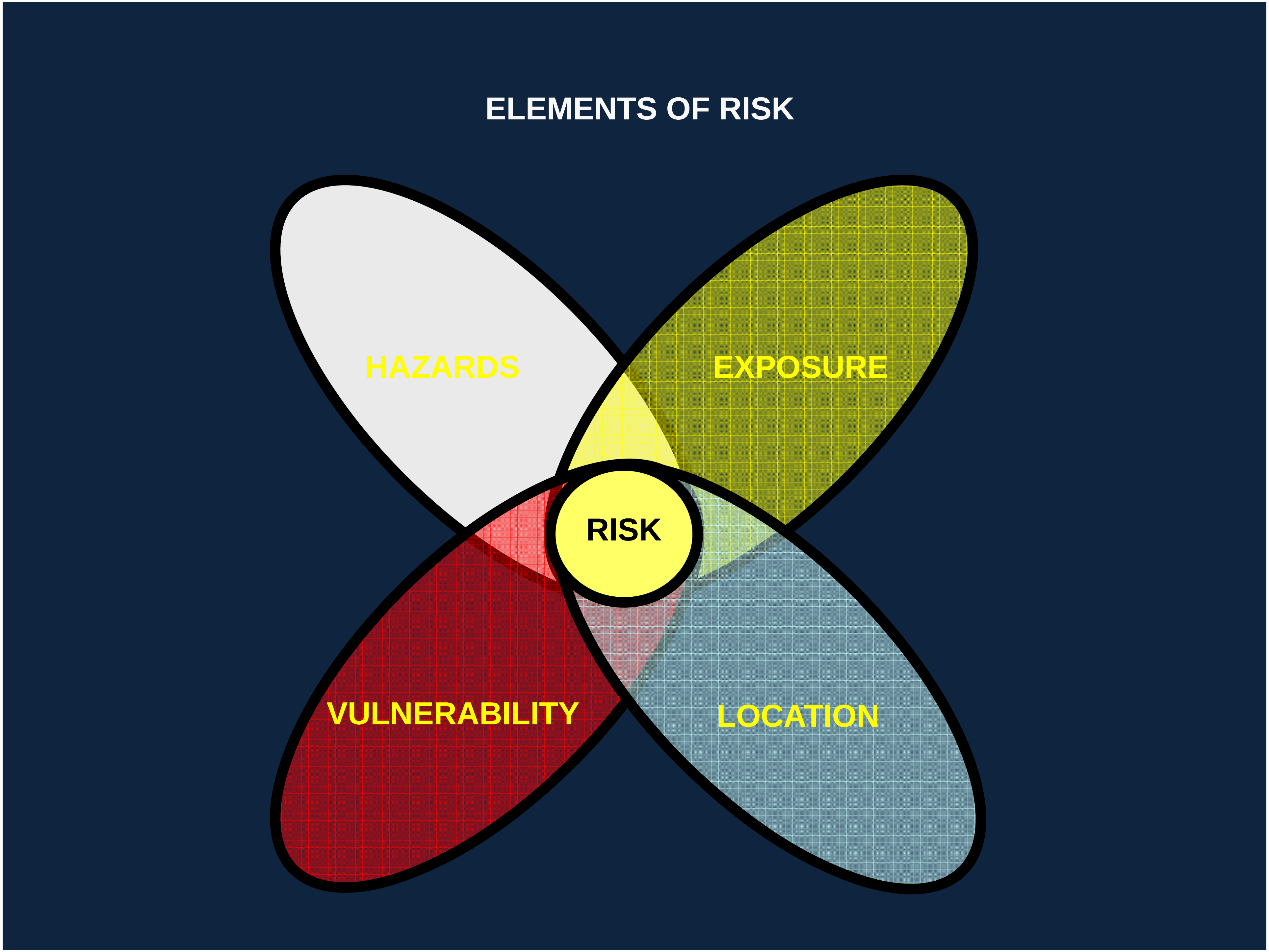
UWI – Hurricane Gilbert, Jamaica, 1988

Photo: Tony Gibbs

UWI – Hurricane Gilbert, Jamaica, 1988

Photo: Tony Gibbs

Atlantic LNG Train-4 Jetty-2


ELEMENTS OF RISK
HAZARDS
EXPOSURE
RISK
VULNERABILITY
LOCATION

THE CHAIN OF SUCCESS

- o selecting consultants
- o terms of reference for design consultants
- o the role of the design team leader
- o agreeing the performance expectations of the facility
- o agreeing the design criteria for wind, torrential rain and storm surge
- o focussing on the non-structural components
- o independent reviews of designs
- o vulnerability audits of existing facilities
- o setting priorities for retrofitting and implementation of recommended actions
- o maintenance of existing facilities

Numbers of hospitals were in ruins, including the important Real Hospital de San Lázaro. At the moment of greatest medical need, La Habana de San Cristóbal found itself with limited capacity to care for the thousands of injured habaneros. ‘All my work has been lost...’ despaired Alfredo Saurulle, director of the Real Hospital de San Lázaro. ‘The principal entrance has collapsed......Various wards and the new infirmary building have suffered much damage; all the roofs are ruined.’ – from *Diario de la Marina* (San Francisco de Borja Hurricane of 10-11 October 1846.)

Plus ça change, plus c’est la même chose.