

Overall Goal of the IS-STM

Develop a standard that provides a very high degree of life-safety protection from extreme storm events for Residential and Community Shelters

Question: What is your performance expectation of a storm shelter?

Presentation Agenda

- The Purpose and Scope of IS-STM Storm Shelter Standard (ICC-500)
- Highlights of the Design Provisions
 - Structural Systems
 - Building Envelope
 - Operational & Human Features
- Schedule / Status of the Standard
- Questions / Additional Discussions

ICC/NSSA Storm Shelter Standard

- Collaborative effort
 - International Code Council
 - National Storm Shelter Association
 - Federal Emergency Management Agency
- Begun in spring 2003
- Standard anticipated in January 2008



FEMA

Purpose of the ICC-500

Establish minimum requirements to safeguard the public health, safety, and general welfare relative to the design, construction, installation, repair, operation and maintenance of storm shelters constructed for refuge from high winds associated with tornadoes and hurricanes. This standard is intended for adoption by government agencies and organizations setting model codes to achieve uniformity in the technical design criteria in building codes and other regulations.

Briefing for the 2007 Florida Governor's Hurricane Conference

ICC/NSSA – Standard for the Design and Construction of Storm Shelters (ICC-500)

To protect occupants during high wind events



- Enterprise, AL
- March 2007
- 8 killed while taking refuge from a tornado
- No shelter in the school



To protect occupants during high wind events



- Arcadia, FL
- Hurricane Charley, 2004
- 1,000+ people evacuated during storm



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To protect occupants during high wind events



- Patterson, LA
- Hurricane Andrew, 1992
- Designated shelter, luckily not used



Scope of the ICC-500

This standard applies to design, construction, installation, inspection, and operation of storm shelters constructed independently or constructed as safe rooms within a building for the purpose of providing safe refuge from storms that provide high winds, such as tornados or hurricanes.

- Residential and Commercial
- Includes Considerations for
 - Architectural
 - Structural
 - Mechanical
 - Electrical
 - Plumbing
 - Other

Chapters of the ICC-500

- Chapter 1 – Application and Administration
- Chapter 2 – Definitions
- Chapter 3 – Structural Design Criteria
- Chapter 4 – Siting
- Chapter 5 – Occupancy, Means of Egress, and Accessibility
- Chapter 6 – Fire Safety
- Chapter 7 – Shelter Essential Features and Accessories
- Chapter 8 – Test Methods for Impact and Pressure Testing
- Commentary

Highlights of the Design Provisions

Structural and Envelope

Wind Speeds & Structural Loads

- Apply to all shelter types
 - Community or Residential
 - Large or Small
- Wind Speed Maps and Shelter Design
 - Wind Speeds / Wind Loads
 - Design methods
 - Design Parameters
- Windborne Debris
- Other Loads and Considerations

Application of Pressures and Debris Requirements

- Wind Pressure Criteria
 - Apply to all MWFRS per ASCE 7
 - Enclosure classification has different requirements
 - Apply to all C&C per ASCE 7
 - Including all doors and protection devices
- Debris Impact Criteria
 - Apply to all exterior surfaces providing protection for shelter occupants

Shelter Design Wind Speeds

- Considered probabilistic maps
- Considered historical data and maps
- Proposing separate maps and design criteria (including debris) for
 - Tornado shelters
 - Hurricane shelters

Theme throughout IS-STM Standard

Peak Gusts over Land by Hurricane Category

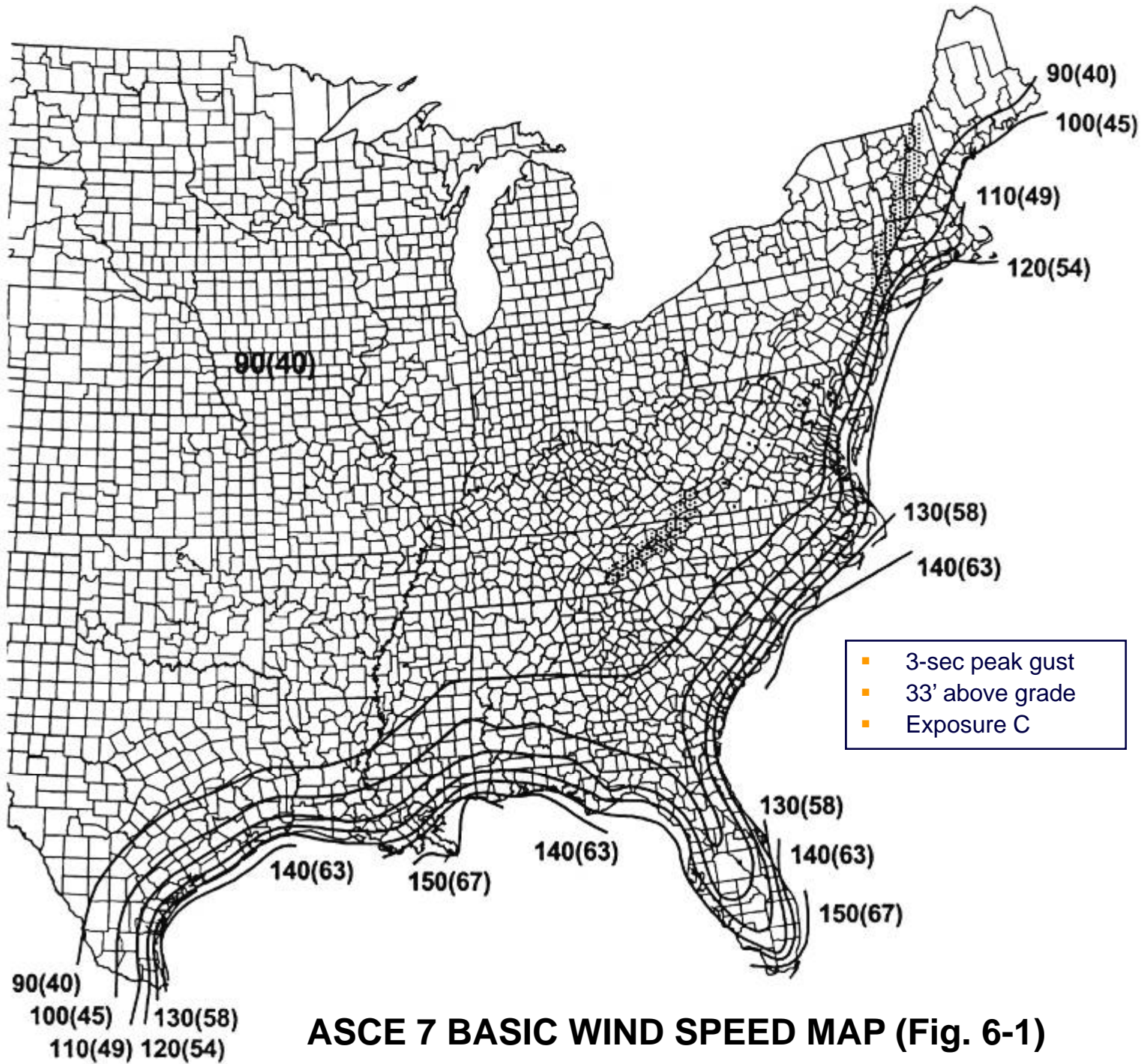
(after Vickery et al, 2000), and

Enhanced Fujita Scale

(Wind Science and Engineering Center, 2006)

| Saffir-Simpson category | Max (1 min) sustained wind speed over water (mph) | Max (3 sec) gust speed over land (mph) | Enhanced Fujita Scale | Fastest 1/4 mile wind speed over land (mph)* | Calculated Max (3 sec) gust speed over land (mph) |
|-------------------------|---|--|-----------------------|--|---|
| TS | <74 | <82 | EF0 | 40-72 | 65-85 |
| CAT 1 | 74-95 | 82-108 | EF1 | 73-112 | 86-110 |
| CAT 2 | 96-110 | 109-130 | EF2 | 113-157 | 111-135 |
| CAT 3 | 111-130 | 131-156 | EF3 | 158-207 | 136-165 |
| CAT 4 | 131-155 | 157-191 | EF4 | 208-260 | 166-200 |
| CAT 5 | >155) | >191 | EF5 | >261 | >200 |

* Original Fastest 1/4 mph wind speeds proposed for Fujita Scale



ASCE 7 BASIC WIND SPEED MAP (Fig. 6-1)

ICC-500 Hurricane Shelter Design Wind Speeds

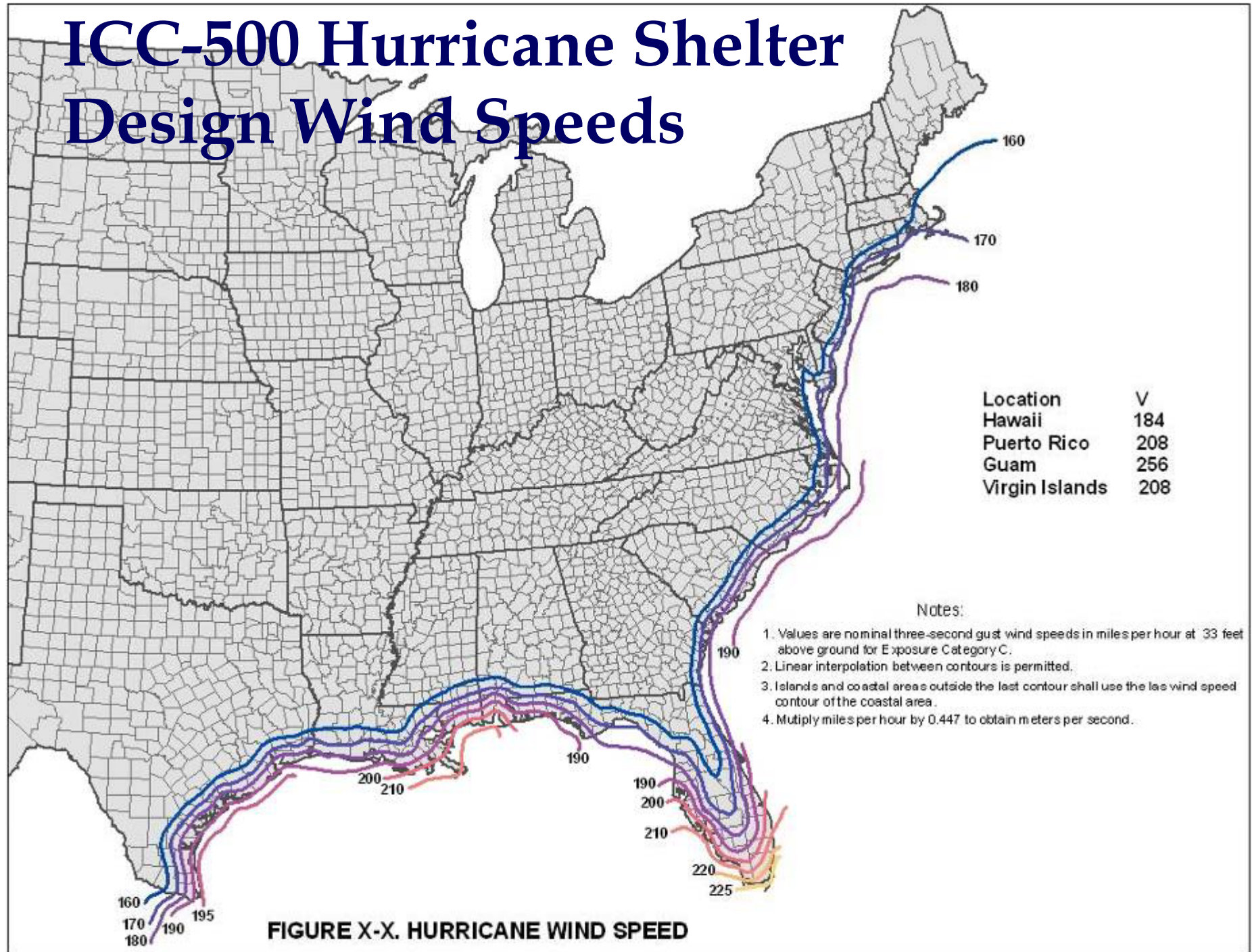


FIGURE X-X. HURRICANE WIND SPEED

Hurricane Shelter Design Wind Speeds

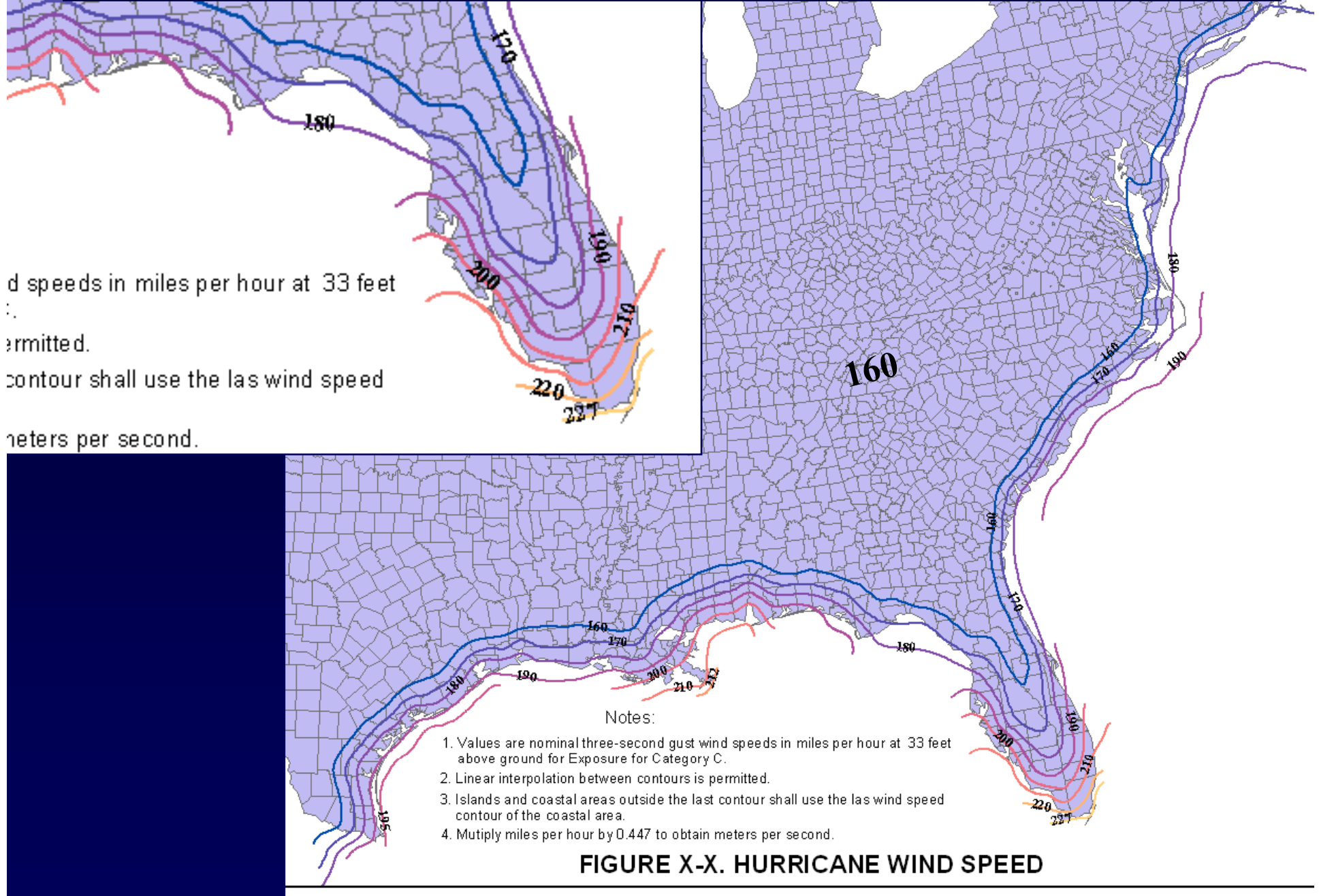
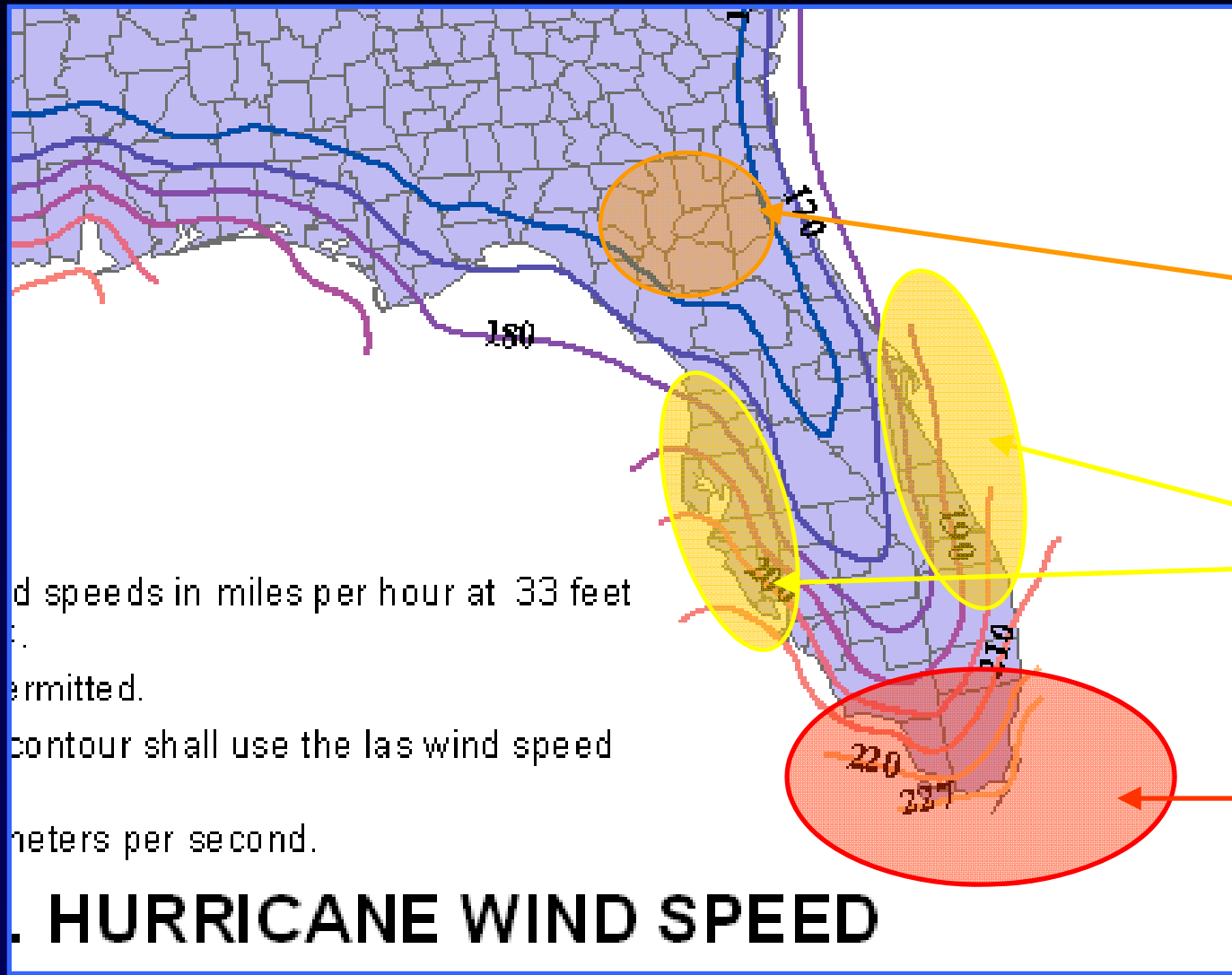


FIGURE X-X. HURRICANE WIND SPEED

Briefing for the 2007 Florida Governor's Hurricane Conference

ICC/NSSA – Standard for the Design and Construction of Storm Shelters (ICC-500)



Weak Cat 4
Hurricane Charley
F3 tornado

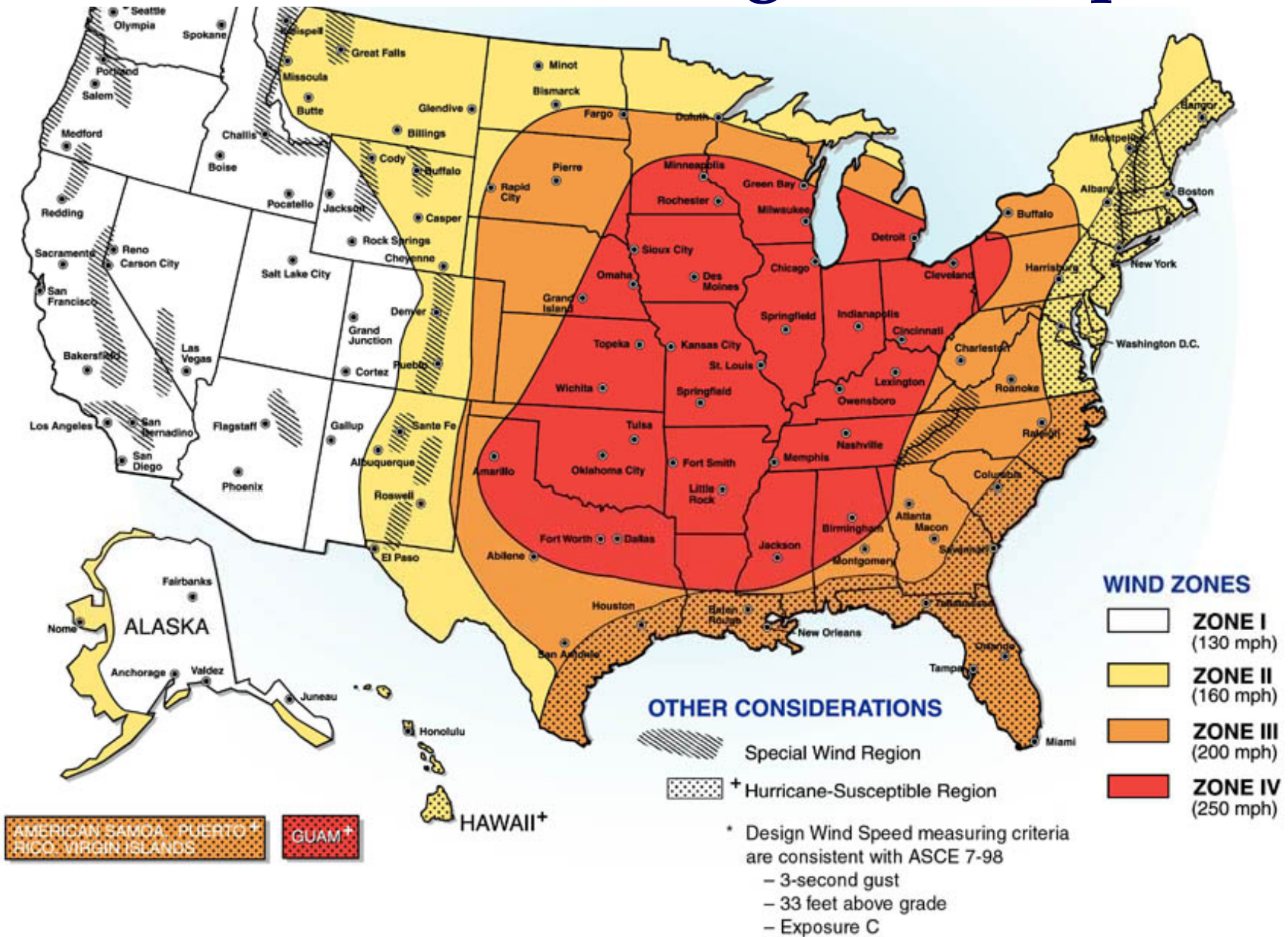
Strong Cat 4 –
Hurricane Andrew

Cat 5 –
Hurricane Camille

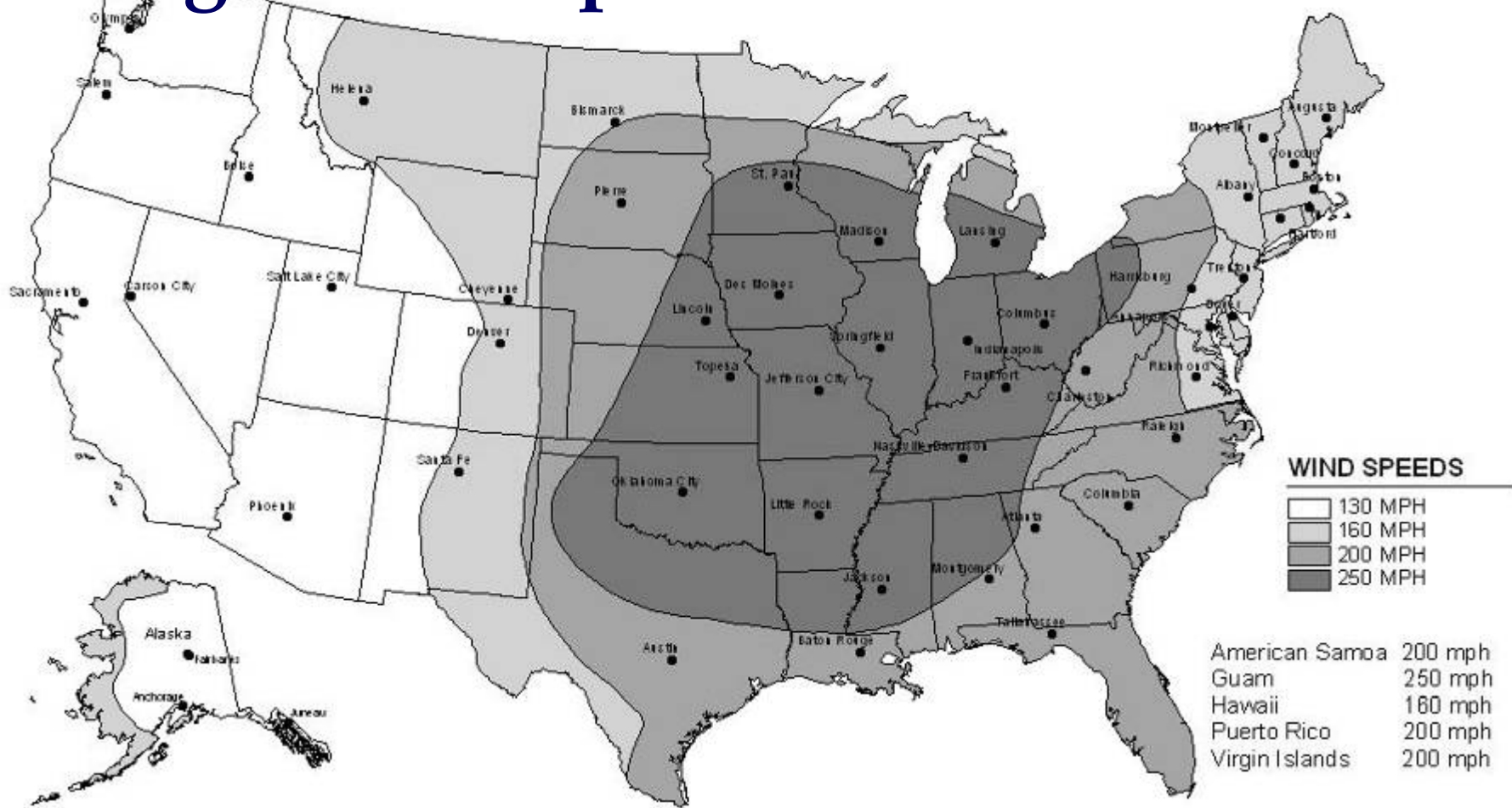
Wind speeds in miles per hour at 33 feet
permitted.
contour shall use the last wind speed
meters per second.

HURRICANE WIND SPEED

FEMA 361 Shelter Design Wind Speeds



ICC-500 Tornado Shelter Design Wind Speeds



- Notes:
1. Values are nominal three-second gust wind speeds in miles per hour at 33 feet above ground for Exposure Category C.
 2. Multiply miles per hour by 0.447 to obtain meters per second.

FIGURE Y.Y TORNADO WIND SPEED MAP

Calculation of Wind Loads

(Use ASCE 7, and adjust as proposed)

- Velocity Pressure (psf):

$$q = 0.00256 K_z K_{zt} K_d V^2 I$$

- K_z = Velocity Pressure Exposure Coefficient
- K_{zt} = Topographic Factor
- K_d = Wind Directionality Factor
- V = Design Wind Speed
- I = Importance Factor

K_z Velocity Pressure Coefficient and Site Exposure

- Velocity profiles remain unchanged, but selection of exposure categories is modified
- Use Exposure C for Tornado Shelters – MWFRS and C&C
- Use Exposure C Hurricane Shelters – MWFRS and C&C
 - Exception: Exposure B is permitted in cases where this roughness will very clearly remain in place even after an intense hurricane (MWFRS only)

Summary of Design Coefficients Differences

ASCE 7-02

- K_z based on exp B or C
- $K_d = 0.85$
- $V = 2\%$ annual prob
(64% chance in 50 years)
- $I = 1.15$

Draft ICC-500 Standard

- K_z exp C, w/ limited B
- $K_d = 1.0$
- $V = 0.01\%$ annual prob
(0.5% chance in 50 years)
- $I = 1.0$

Internal Pressure

- For Tornado shelters – APC must be considered
 - Use $GC_{pi} = +/- 0.18 + \text{APC contribution}$
 - Use $GC_{pi} = +/- 0.18 + \text{design for venting}$
 - Use $GC_{pi} = +/- 0.55$
- For Hurricane shelters – no APC
 - Use $GC_{pi} = +/- 0.18$ or $+/- 0.55$ per ASCE and largest opening requirement
- In FEMA 361, must use $GC_{pi} = +/- 0.55$

Load Factor

- Strength design. Use the ASCE 7 load combinations with the following modifications:
 - In load combination 3, replace $0.8W$ with $0.5W$
 - In load combinations 4 and 6, replace $1.6W$ with $1.0W$
 - Exception 1 shall not apply
 - In FEMA 361, a $1.2W$ was used in load combination 6
- Allowable stress design. Use the ASCE 7 load combinations with the following modifications:
 - In load combinations 5, 6, and 7 replace W with $0.6W$
 - In FEMA 361, a W was used – there was no reduction

Design Pressure Comparison

Example - Ft. Lauderdale

- Proposed Design Pressures are 44% larger than ASCE 7
- Proposed Design Pressures are 13% lower than EHPA (using recommended wind speed of ASCE 7 + 40 mph)
- Percentages will vary with location along the coast

Windborne Debris

- Much new research recently published and underway
- Aerodynamics – wind tunnel and analytical and numerical models indicate that missiles travel at higher wind speeds than previously assumed
- Post-disaster debris information gathered to help develop/validate new debris flight/trajectory models

ICC-500 Tornado Missile

- Representative missile = 15 lb 2x4
- Horizontal missile speeds (see table)
- **Current FEMA 361 missile for all zones:**
 - 15 lb 2x4
 - Horizontal speed = 100 mph
 - Vertical speed = 67 mph

| Zone - Design Wind Speed (V) | Horizontal Missile Speed - Tornado | Vertical Missile Speed - Tornado |
|------------------------------|------------------------------------|----------------------------------|
| Zone IV – 250 mph | 100 mph | 67 mph |
| Zone III – 200 mph | 90 mph | 60 mph |
| Zone II – 160 mph | 85 mph | 56 mph |
| Zone I – 130 mph | 80 mph | 53 mph |

ICC-500 Hurricane Missile

- Representative missile = 9 lb 2x4
- Horizontal missile speed
 - $0.4 \times V$
 - V = peak gust wind speed
 - See table
- Vertical missile speed
 - $0.1 \times V$
- Current FBC large missile:
 - 9 lb 2x4
 - Horizontal speed = 34 mph

| Hurricane Design Wind Speed (V) | Horizontal Missile Speed - Hurricane | Vertical Missile Speed - Hurricane |
|---------------------------------|--------------------------------------|------------------------------------|
| 255 mph | 102 mph | 26 mph |
| 250 mph | 100 mph | 25 mph |
| 240 mph | 96 mph | 24 mph |
| 230 mph | 92 mph | 23 mph |
| 220 mph | 88 mph | 22 mph |
| 210 mph | 84 mph | 21 mph |
| 200 mph | 80 mph | 20 mph |
| 190 mph | 76 mph | 19 mph |
| 180 mph | 72 mph | 18 mph |
| 170 mph | 68 mph | 17 mph |
| 160 mph | 64 mph | 16 mph |

Protection of Building Envelope

- Walls and roof systems must be impact resistant
 - Roofs cannot have loose-laid roof coverings
- Openings required to be debris impact resistant or have impact resistant coverings (opening protectives)
- These requirements are consistent with FEMA 361

Doors and opening protectives

- Must resist design wind pressures
- Must resist design forces from representative windborne debris
- No minimum requirements for hinges or latches – must pass tests
- FEMA 320 and 361 – must have 3 latches and 3 hinges

Door Systems

Shelter doors will be opened during the storm, for numerous reasons including

- late arrivals
- investigating damage
- moving between shelter areas
- people wanting to smoke
- etc. - human nature

Opening Protectives (ie., Window Protection Systems)

Will systems requiring operation or installation work as planned?

Do Shelter operators have the

knowledge

time

materials, tools, keys

to install/operate hurricane protection systems?

Opening Protectives

- Tornado Shelters
 - Readily available
 - Readily installed / closed
 - All components attached to protection
- Hurricane Shelters
 - Allowed to be stored and installed over time
 - Must resist pressures and debris impact

Complete Testing Protocol for Pressure and Debris Impacts

- Complete protocol for pressure testing of walls, roofs, and opening protectives
- Complete protocol for debris impact testing of walls, roofs, and opening protectives

Design Provisions

Flood Considerations

Flood Hazards - Community Shelters

- The shelter floor shall be elevated above the highest elevation determined from:
 - Local floodplain management requirements
 - 100 year flood elevation + 2 ft (BFE+2)
 - 500 year flood elevation, when determined
 - Maximum inundation elevation from a Category 5 hurricane in areas subject to storm surge

Note: Appropriate rainfall flooding should also be considered

Flood Hazards – Residential Shelters

- The shelter floor shall be elevated above the highest elevation determined from:
 - Local floodplain management requirements
 - One foot above the flood elevation corresponding to the highest recorded elevation if the area is not in a mapped special flood hazard area or in a non-participating community (with respect to the NFIP).

Note: Appropriate rainfall flooding should also be considered

Rain Loads for Hurricane Shelters

- Special Precautions should be taken:
 - Heavy rains can last several days
 - Pay special attention to design of secondary drainage
 - Drains may become clogged by debris or wind-induced movement of roof gravel
 - Must carefully consider ponding phenomena
- This was not addressed in FEMA 361

Identification of Design Parameters

- Specified in Section 106 and 107
 - Addresses the need for special inspections
 - Requirements for signage and labeling
 - Requirements for the identification of design parameters on building plans
 - Provides minimum square footage requirements for occupants

Design Provisions

Operational and Human Factors

Use and Occupancy

- Normal use occupancy code requirements apply, unless otherwise noted
 - Dedicated single-use shelters are “assembly” occupancy
- Shelter definition:
 - A building, structure, or portion(s) thereof, constructed in accordance with this standard, designated for use during a severe storm event.

Use and Occupancy

- Shelter requirements separated into two types:
 - Tornado
 - Hurricane
- Shelter Types subdivided:
 - Large, 51 or more occupants
 - Small, 50 or less occupants
 - Exception: Residential and One & Two Family Dwellings (16 or less occupants)

Use and Occupancy

- Number of Egress Doors
 - Determined by normal use as required by applicable code
 - “Assembly” use shall apply to single-use shelters
 - Doors must swing in direction of egress
- An emergency escape opening is required where two or fewer doors (direction of swing is inward to shelter space) egress to the outside of the shelter
 - Exception for doorways protected from accumulation of debris

Use and Occupancy

- Occupant density based upon “net usable floor area”
 - Net usable is space that can actually be occupied by a person
- Number of standing, seated, wheelchair and bedridden spaces to be determined by applicable authority
- Shelters shall be sized for at least one wheelchair space per 200 occupants
- Design occupancy period:
 - Tornado @ 2 hours
 - Hurricane @ 24 hours

Use and Occupancy

- Minimum net usable floor area per occupant, Community Shelters:
 - Tornado
 - Standing or seated = 5 sq.ft.
 - Wheelchair = 10 sq.ft.
 - Bedridden = 30 sq.ft.
 - Hurricane
 - Standing or seated = 20 sq.ft.
 - Wheel Chair = 20 sq.ft.
 - Bedridden = 40 sq.ft.
- Generally consistent with FEMA 361

Use and Occupancy

- Minimum net usable floor area per occupant, Residential Shelters:
 - Tornado
 - 1&2 Family Dwellings = 3 sq.ft.
 - All other residential - Standing or seated = 5 sq.ft.
 - Wheelchair = 10 sq.ft.
 - Bedridden = 30 sq.ft.
 - Hurricane
 - 1&2 Family Dwellings = 7 sq.ft.
 - All other residential - Standing or seated = 10 sq.ft.
 - Wheel Chair = 10 sq.ft.
 - Bedridden = 40 sq.ft.
- Generally consistent with FEMA 320, but more detailed

Operational and Functional Considerations

- IS-STM sets requirements for:
 - Ventilation
 - Back-up/emergency power
 - Emergency lighting
 - ADA compliance
 - Fire barrier ratings
 - Toilets and handwashing fixtures
 - On-site potable water
 - Supplies (such as first-aid kits)
- Generally codifies the criteria from FEMA 361
- Does not address operations and management plans

Essential Features & Accessories

- Hurricane Shelters
 - Natural Ventilation required
 - Two options; above- and below-ground
 - Outside air intakes to be located 10 ft from noxious contaminant sources
 - Exhaust or intake openings to be protected
 - Mechanical ventilation required consistent with emergency power system

Essential Features & Accessories

- Hurricane Shelters
 - Emergency power system required; system to support occupied spaces, critical support areas & systems:
 - Life safety systems
 - Standby lighting; avg=10 f.c.
 - Standby branch wall circuits
 - Mechanical ventilation circuits
 - Permanent-installed standby gen-sets not required
 - Standby gen-set(s) to be independent of off-site utilities
 - All components of emergency power system to be protected from design event; including temporary gen-set

Essential Features & Accessories

- Hurricane Shelters
 - Standby gen-set to operate continuously for 24 Hours
 - Standby & emergency power system's access route to be protected from design event
 - Emergency lighting req'd; avg=1 f.c.
 - Exceptions for small shelters and 1&2 family dwellings; one flashlight per 10 occupants

Essential Features & Accessories

- Hurricane Shelters
 - Standby gen-set to operate continuously for 24 Hours
 - Standby & emergency power system's access route to be protected from design event
 - Emergency lighting req'd; avg=1 f.c.
 - Exceptions for small shelters and 1&2 family dwellings; one flashlight per 10 occupants

Use and Occupancy

- Shelters shall be provided with an accessible route (ANSI A117.1)
- Fire Extinguisher req'd within shelter areas
 - Exception for 1&2 Family Dwellings

Use and Occupancy

- Two-hour *fire barrier* separation req'd between shelter space and other building areas
 - Includes penetrations and openings
 - Exception for 1&2 Family Dwellings
- Exterior walls of storm shelters to be constructed with fire-resistance req'd by applicable code

Essential Features & Accessories

- Hurricane Shelters
 - Plumbing/Water
 - Small shelter: No reqm'ts for potable or waste water
 - Large Shelter: One gallon potable water/occupant
 - Large Shelter: 1 1/2 gallons waste water/occupant
 - Temporary or on-demand resources acceptable

Essential Features & Accessories

- Hurricane Shelters
 - Plumbing/Sanitation
 - Small shelter: One toilet
 - Large Shelter: One toilet/50 occupants
 - Small Shelter: Handwashing facilities not req'd
 - Large Shelter: One Handwashing facility/100 occupants
 - Temporary fixtures acceptable
 - Exceptions for 1&2 Family Dwellings

Essential Features & Accessories

- Hurricane Shelters
 - First-aid kit req'd for small and large shelters
 - Exception for 1&2 Family Dwellings

Essential Features & Accessories

- Signage req'd for both Tornado and Hurricane Shelters, Large & Small
 - Interior signage must direct occupants to shelter areas
 - Signage req'd on inside of shelter area(s)
 - Floor Plan sign req'd in facility manager's office, inside shelter area & at exits
 - Exception for 1&2 Family Dwellings

Public Comment Phase for ICC-500

- 1st Public Comment Draft
 - Posted for public comment - November 10, 2006
 - Public comment closed – December 26, 2006
 - Public comment review meeting – January 15-17, 2007
- 2nd Public Comment Draft
 - Posted for public comment – February 27, 2007
 - Public comment closed – March 26, 2006
 - Posting to ANSI Standards Action Public Posting – April 2007
 - Public comment review meeting – August 2007 (TBD)
- All public drafts, meeting notices (open to public), agendas and minutes posted on ICC web site
- Anticipated release date of January 2008 for ICC-500

www.iccsafe.org/cs/standards/is-stm

Questions for ICC

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Next Meeting – August 2007 !!!!

Additional Discussion Points and Supplemental Information

Storm Shelter Committee Members

- Building Code Officials
- Emergency Planning Managers
 - Federal (FEMA) and State Officials
- Industry
 - NAHB, NSSA, PCA, NCMA, AISI, Ingersoll Rand
- University faculty members:
 - LSU, Texas Tech, Clemson
- Consultants
 - URS, ARA, PBA, DuPont

Status

- First committee meeting (May 2003)
- Gather input from scientific, technical, and user communities (ongoing)
- Develop draft standard and publish draft standard for public comment (November 15, 2006 through December 26, 2006)
- **Formal, public committee meeting to address all comments January 15-18, 2007**
- Publish standard (est. mid 2007)

'Type' of Exposure B Important



Example of pre-storm Exposure B, becoming Exposure C during storm



K_{zt} Topographic Factor

Accounts for speedup in wind near top of hills, ridges and escarpments

- Tornado Shelter
 - $K_{zt} = 1.0$
Effects of topography on tornado windspeeds are unknown
- Hurricane Shelter
 - Per ASCE 7-05

K_d Directionality Factor

- Accounts for reduced probability of maximum wind speed occurring simultaneously with most vulnerable wind direction
- ASCE 7-05
 - $K_d = 0.85$
- IS-STM Hurricane and Tornado Shelter
 - $K_d = 1.0$
Changing wind direction may bring maximum or near maximum wind speeds over a wide range of wind directions

I Importance Factor

Accounts for change in MRI based on relative level of hazard to human life

- ASCE 7-05
 - $I = 1.15$ for shelters
- IS-STM Hurricane and Tornado Shelter
 - $I = 1.0$
Already using an 'ultimate' wind speed with long mean recurrence interval

Other Debris Hazards

- Rollover hazards
- Laydown hazards
- Collapse hazards

- Siting requirements to minimize these hazards
- If they are present, must design for impacts

Essential Features & Accessories

- Tornado Shelters
 - Natural Ventilation req'd
 - Ventilation and internal pressure relief may be designed concurrently
 - Two options based on NSSA standard; above ground and below ground cases
 - Outside air intakes to be located 10 ft from noxious contaminant sources
 - Exhaust or intake openings to be protected
- More detailed than FEMA 361

Essential Features & Accessories

- Tornado Shelters
 - Back-up or emergency gen-sets not required
 - Emergency lighting req'd; avg=1 f.c.
 - Exceptions for small shelters and 1&2 family dwellings; one flashlight per 10 occupants
 - Plumbing/Sanitation
 - Toilet fixtures: up to 50=1; 51-500=2; then 1 add'l:500
 - Temporary fixtures acceptable
 - Exception for 1&2 Family Dwellings
 - Handwashing facilities not req'd for small; 1:1000 for large
- Codifying FEMA 361 criteria

Essential Features & Accessories

- Tornado Shelters
 - Plumbing/Water
 - No potable or waste water reqm'ts for either large or small shelters
 - First-aid kit req'd for small and large shelters
 - Exception for 1&2 Family Dwellings

References Documents

- NSSA Industry Standard: *Standard for the Design, Construction, and Performance of Storm Shelters*
- FEMA 320: *Taking Shelter from the Storm*
- FEMA 361: *Design and Construction Guidance for Community Shelters*
- ARC 4496: *Guidelines for Hurricane Evacuation Shelter Selection*
- Florida Building Code - Enhanced Hurricane Protection Areas (EHPA), Section 423.25
- FL DCA Statewide Emergency Shelter Plan

Information Sources

- *Design & Construction Guidance for Community Shelters (FEMA 361)*
- *Taking Shelter from the Storm: Building a Safe Room inside your House (FEMA 320)*
- National Storm Shelter Association Standard (NSSA 4000-02)
- Florida's Public Shelter Design Criteria (section 423.25, Florida Building Code)

Information Sources

- *MASS CARE—Management and Operations (ARC 3041)*
- International Code Council (ICC) Codes
- Various FEMA, ARC and FBC publications and provisions