DISCRIMINATING EF4 AND EF5 TORNADO DAMAGE

Jim LaDue, NOAA/NWS/OCWWS/TD/**WDTB**

Tim Marshall, Haag Engineering

Kevin Scharfenberg, NOAA/NWS/OCWWS

Corresponding author contact: James.G.LaDue@noaa.gov

F4 to F5 determination prior to 2002

F4	207 – 260 mph	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	>260 mph	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.

Note, terms like well "constructed" and "strong" are used but what do they mean?

Enter the EF-scale: EF4/5 candidates

Red: expected wind speed ≥ 200 mph

blue: max wind speed ≥ 200 mph

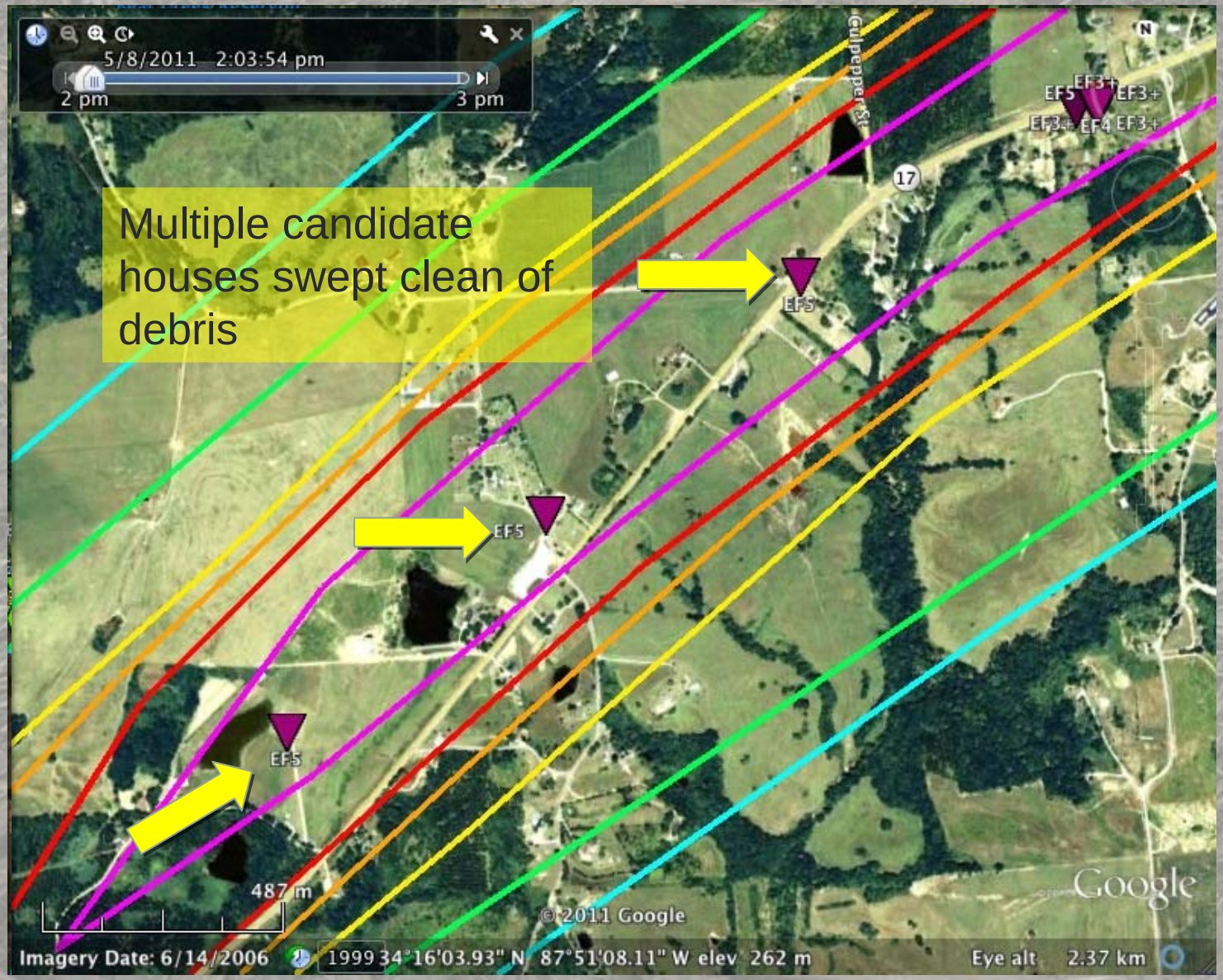
Green: max wind ≥ 167 ≤ 199 mph

Black, max wind speed < 167 mph

			Vegetation
			Towers/Poles
	23	Warehouse Building [Tilt-up Walls or Heavy-Timber Construction] (WHB)	Metal Building/Canopies
	21	Metal Building System (MBS)	
	20	Institutional Building [Hospital, Government or University Building] (IB)	Professional Buildings
	19	High-Rise Building [More than 20 Stories] (HRB)	
	18	Mid-Rise Building [5-20 Stories] (MRB)	
221 mph	17	Low-Rise Building [1-4 Stories] (LRB)	
224 mph	16	Junior or Senior High School (JHSH)	Schools
203 mph	15	Elementary School [Single Story; Interior or Exterior Hallways] (ES)	
201 mph	12	Large, Isolated Retail Building [K-Mart, Wal-Mart] (LIRB)	Commercial/Retail Buildings
	11	Large Shopping Mall (LSM)	
	10	Strip Mall (SM)	
200 mph	9	Small Professional Building [Doctor's Office, Branch Banks] (SPB)	
	8	Small Retail Building [Fast Food Restaurants] (SRB)	
205 mph	7	Masonry Apartment or Motel Building (MAM)	
217 mph	6	Motel (M)	
205 mph	5	Apartments, Condos, Townhouses [3 stories or less] (ACT)	Houses: The only DI with a debris blown away DOD can be EF5
	2	One- or Two-Family Residences (FR12)	

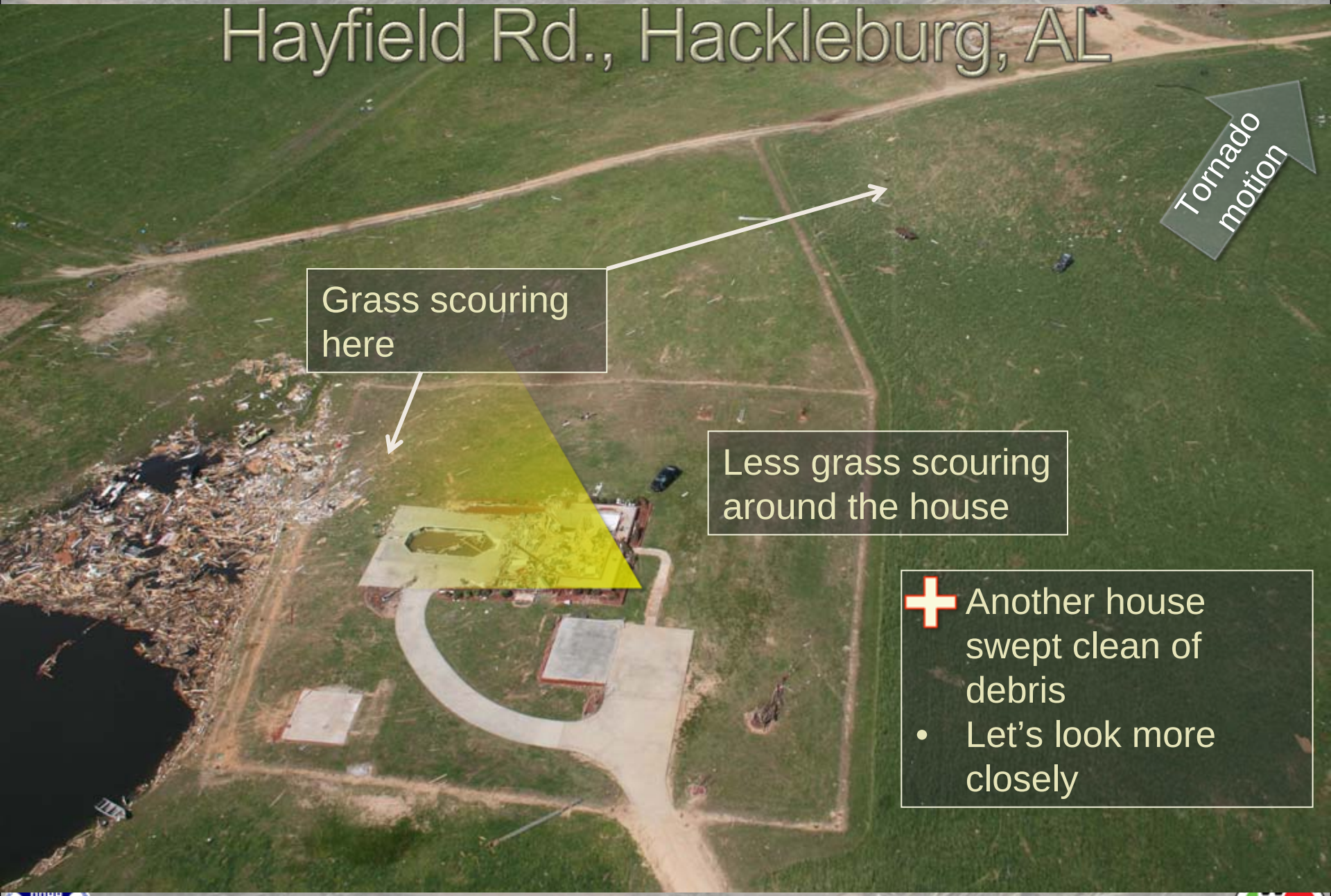
What does it take to get EF5 rated tornadoes?

Hackleburg, AL



Multiple candidate houses swept clean of debris

Hayfield Rd., Hackleburg, AL



- Another house swept clean of debris
- Let's look more closely

Photo by Tim Marshall

Hayfield Rd., Hackleburg, AL

+ Any debris above basement swept away from the house
− CMU foundation unreinforced

Verdict:

- Weakness in foundation
- Most scouring located away from the house
- EF4

Simplest way for an upgrade?

- Rebar in the CMU foundation
- A solid concrete stemwall, inc the back

Photo by Tim Marshall

Tuscaloosa, AL

Damage imagery provided by National Ocean Service

Chastain Manor Apartments, Tuscaloosa

Photo by Tim Marshall

Chastain Manor Apartments, Tuscaloosa

Photo by Jim LaDue

Chastain Manor Apartments, Tuscaloosa

Apartments, Condos, Townhouses

Almost complete destruction of top two stories

Expected wind speed = 180 mph

To go EF5, we would have to see compelling evidence of superior construction

2nd floor resting on fill. Bottom plates straight nailed into floor diaphragm

1st floor down a hill

What about the Chastain Manor Clubhouse?

What is needed to be EF5?
- Metal straps anchoring studs
- And/or more debris removal inc. sill plates
- And/or more scouring

\+ Proper anchor bolts but typical washers

\- Sill plates straight nailed into studs from below.

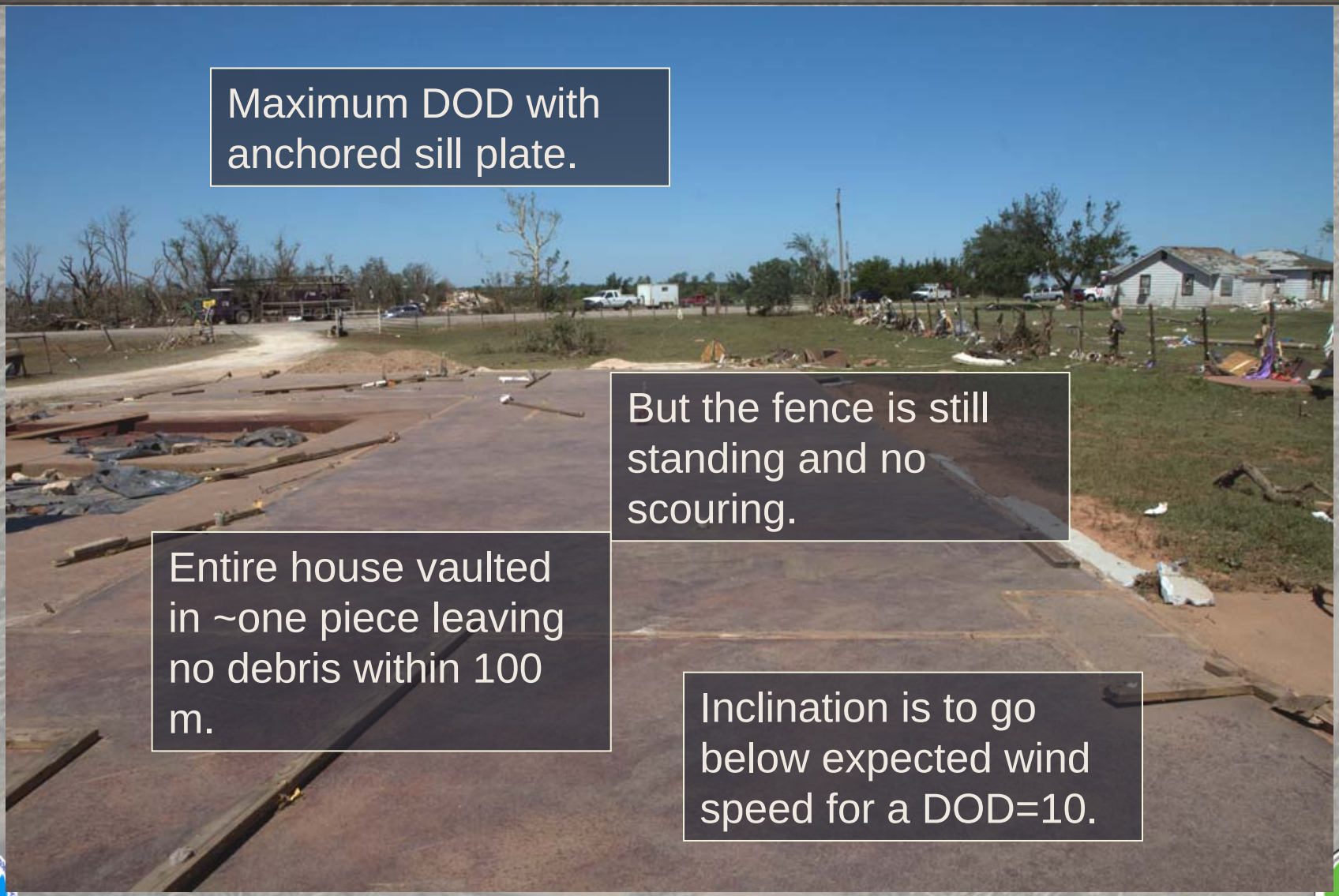
\- Too much debris around considering weakness.

2011 Apr 30 Photo by Jim LaDue

Lot's of discussion about Chastain Manor

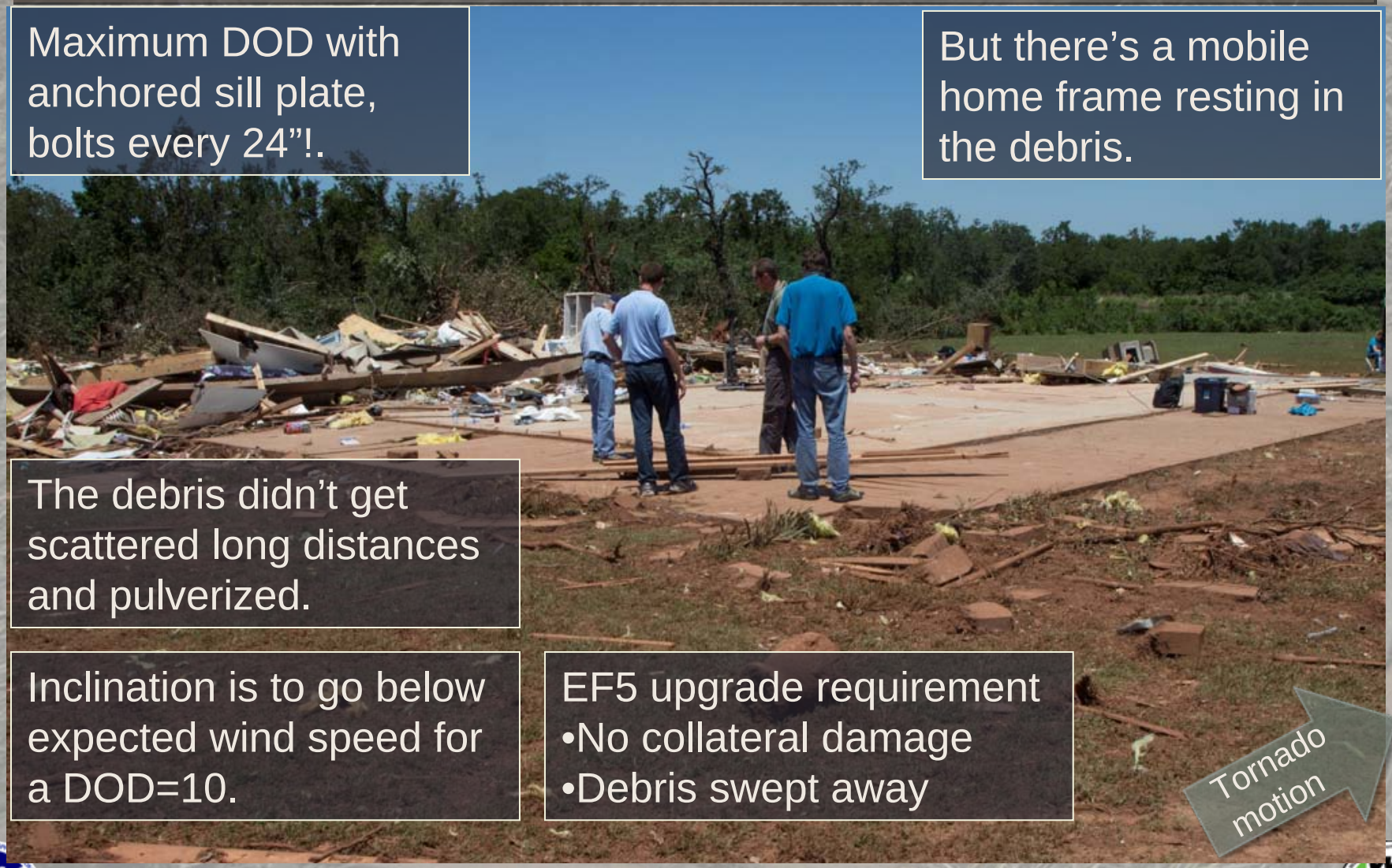
Surveyors	rating	Estimated wind	Reasoning
Authors	EF4	190 mph	•max DOD matches observations, •Current code means pick expected wind, •Needed more than straight nailed studs •context of surroundings
URS Corp for FEMA	EF4		•Lack of hurricane clips on long span roof trusses
NSF team	EF5 (3 team members in favor)	> 199 mph	•Slab swept clean indicates greater than DOD=6. •Nail spacing to code (6" OC) •Quality Southern Pine, large shearwalls •Similar construction to houses where a higher DOD is available
	EF4 (3 team members in favor inc. team leader)	~180 mph	•Lack of clips on girders or top plates to rafters •Lack of roof deck panel staggering •Anchor spacing, no square plate washers •Seems to be built closer to 90 mph code

That's why context is so important



South of Dibble, OK 2011 May 24 Photo by Jim LaDue

Did the wind alone take the house down?



Maximum DOD with anchored sill plate, bolts every 24”!.

But there’s a mobile home frame resting in the debris.

The debris didn’t get scattered long distances and pulverized.

Inclination is to go below expected wind speed for a DOD=10.

EF5 upgrade requirement
- No collateral damage
- Debris swept away

East of Dibble, OK 2011 May 24 Photo by Jim LaDue

Context: What is remaining at the house?

- All walls down but debris remained
- Jacuzzi remains in usable condition
- DOD=9, 170 mph wind

Piedmont, OK 2011 May 27 Photo by Jim LaDue

Context: Conditions surrounding the house

Shrubs look in good condition.

Grass unscoured.

Houses left in center of path had walls standing.

Nail penetrated only ¼" into stem wall.

Used lower bound wind threshold 165 mph.

Tornado motion

East of Holt, AL 2011 May 1 Photo by Jim LaDue

Context: Landscaping and vehicles

Violent tornadoes shred exposed vehicles, some more so than others and we don't know why for sure.

Shrubs stripped and debarked are typical around houses with true EF5 damage.

Piedmont, OK 2011 May 27 Photo by Jim LaDue

Context: Ground scouring: Use in context with established DIs

This magnitude of scouring near a slabbed house would add confidence to go with > 200 mph

Dependent on exposure. Don't expect as much in a residential setting or small clearings.

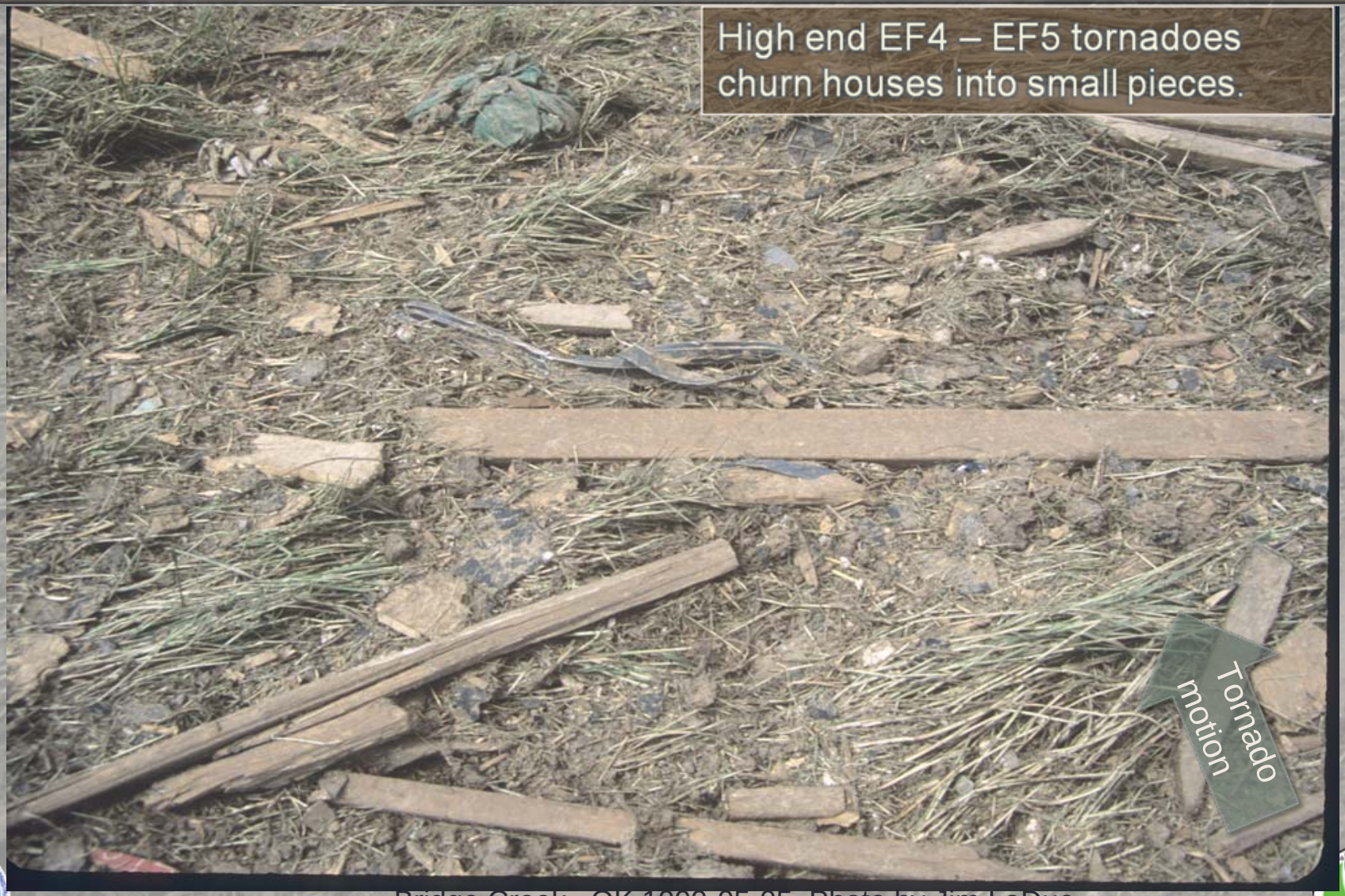
Philadelphia, MS 2011 Apr 27 Photo by NWS JAN

Stripped pavement

- Adds confidence of an EF5 to a DI but is typically not as reliable as ground scouring.
- Poor asphalt is susceptible to stripping.

Blanchard, OK 2011 May 26 Photo by Jim LaDue

Debris patterns



Bridge Creek, OK 1999-05-05 Photo by Jim LaDue
Piedmont, OK 2011 May 27 Photo by Jim LaDue

Some straddle the line

Blanchard, OK 2011 May 26 Photo by Jim LaDue

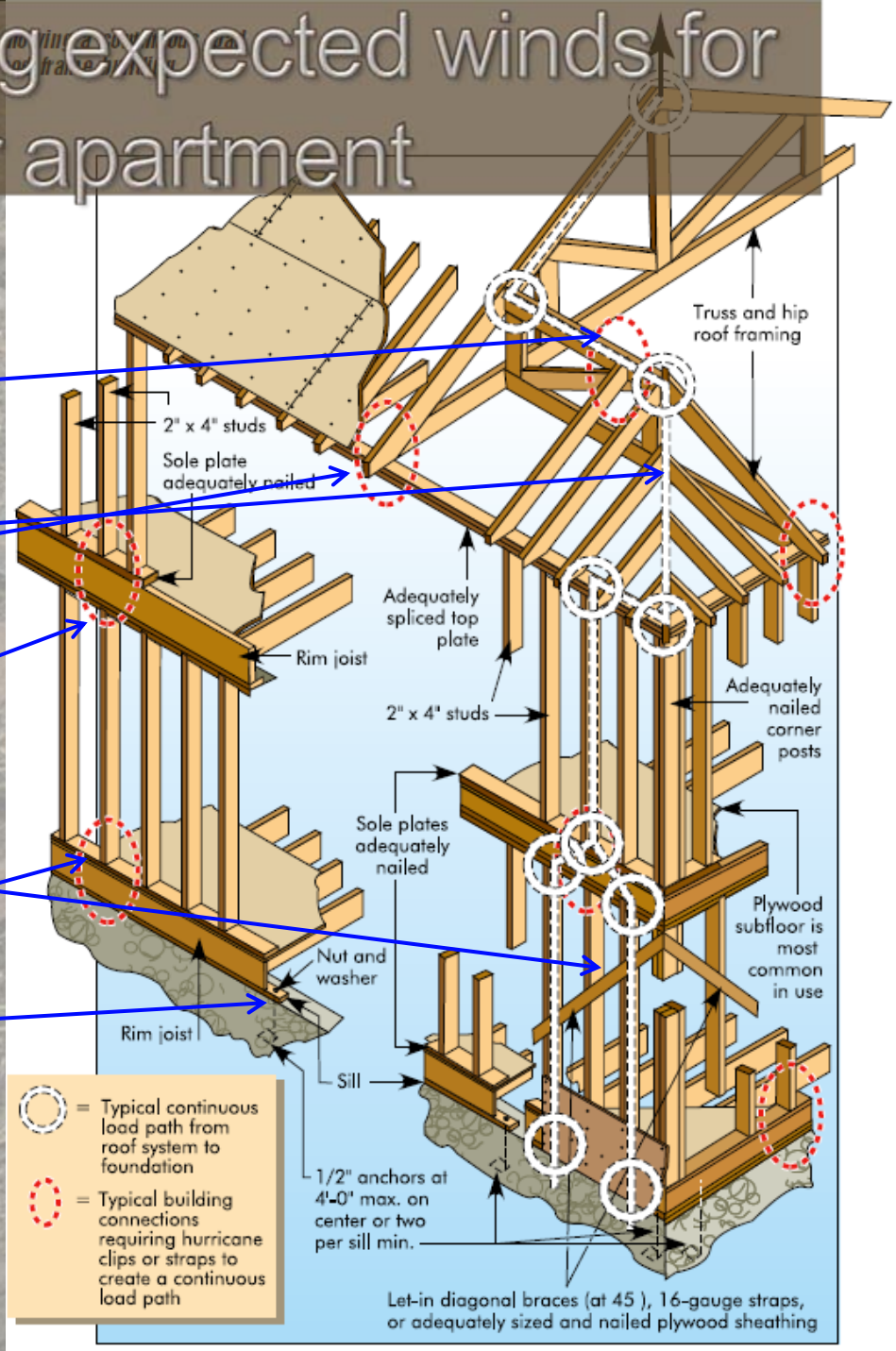
Solid EF5

1999-05-04 Bridge Creek, OK Jim LaDue

Criteria for exceeding expected winds for a house or apartment

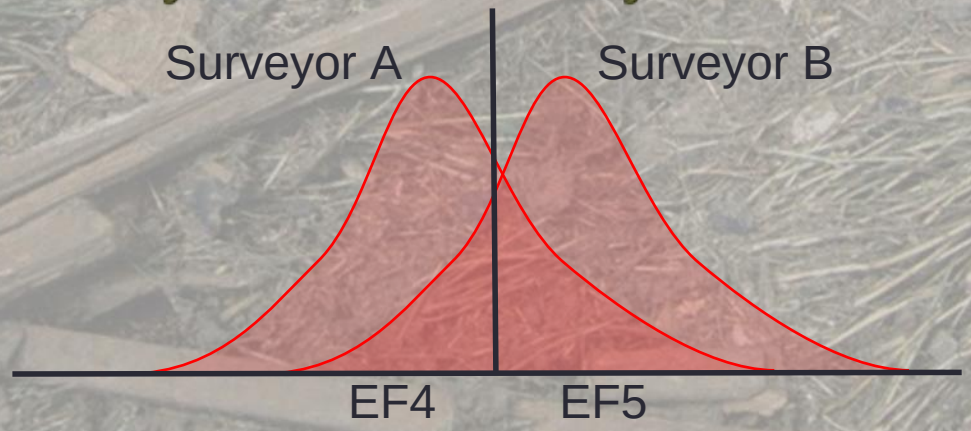
- Roof sheathing to rafters or trusses
  - 3/8" plywood/OSB
  - Fastened at six inch intervals to underlying trusses or rafters by 8d nails or better
  - OSB or plywood in good condition
  - Ridge straps
- Roof framing
  - Adequate nailing of rafters to ridges
  - Cross bracing of rafters or trusses
- Roof connection to walls
  - Rafter clips
- Walls
  - OSB or plywood sheathing overhanging the sill plate and 2nd floor joist
  - Or straps connecting 1st to 2nd floors
  - Diagonal braces at corners
  - No excessive windows.
- Studs/Floor joist to sill plate
  - 2 16d 3.5" nails, preference for serrated nails
  - A real connector would be metal clips
- Sill plate to foundation wall
  - J-bolts placed 3-6 ft, within 12" of corners nuts and washers on all, no weaknesses in wood
- Foundation
  - Concrete or reinforced CMU, or pile and column

Not all of these components may exist



Discriminating EF4 from EF5?

- Look for signs of continuous load path
- If house debris gone,
  - Check for evidence of good construction by what's left
  - Do the surroundings support a violent tornado?
  - Talk to the owner if possible
- Consensus with other surveyors
- There's always uncertainty



A house with this continuous load path would exceed expected wind speeds

Blanchard, OK 2011 May 26 Photo by Jim LaDue