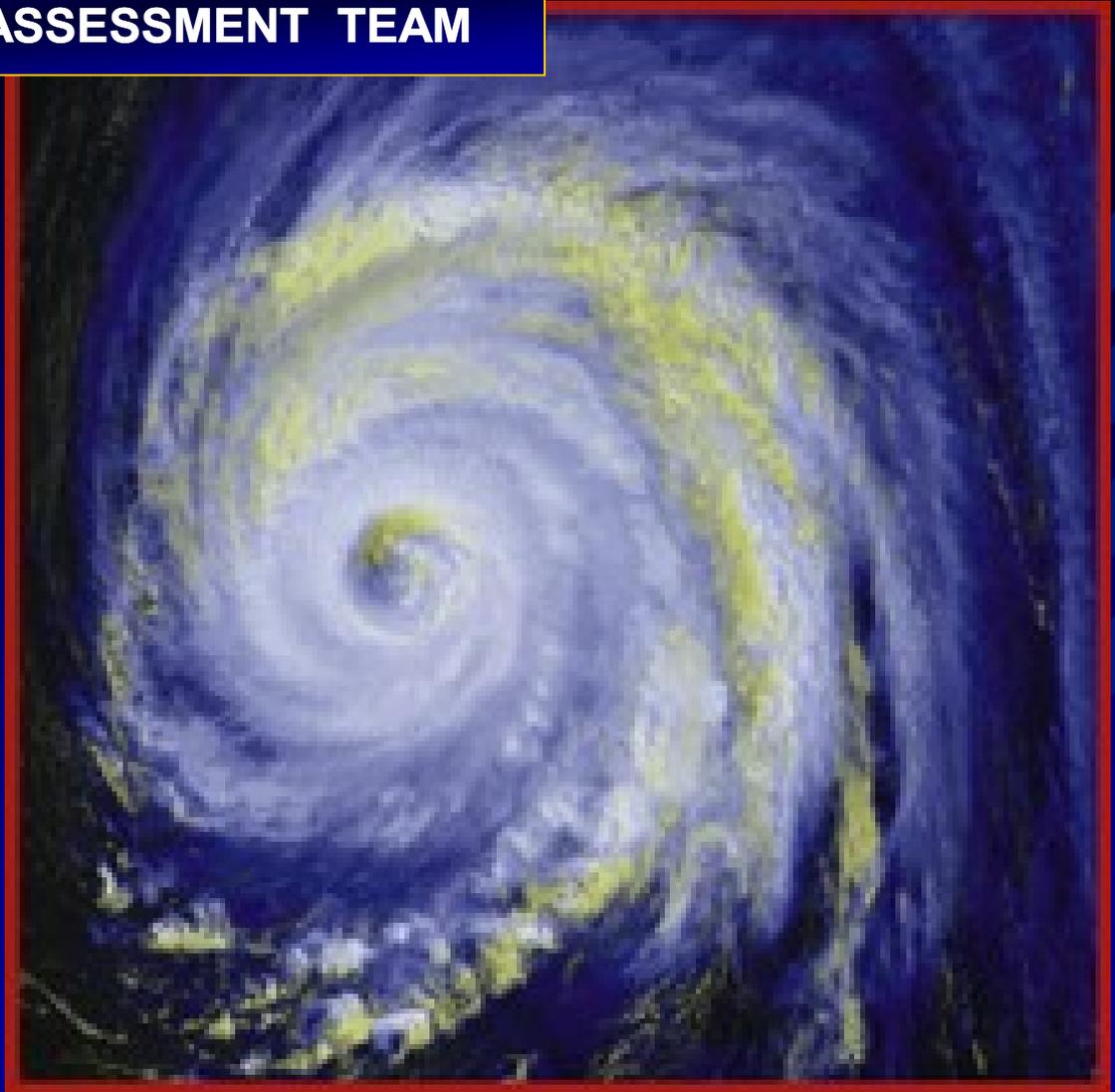


**BUILDING PERFORMANCE ASSESSMENT TEAM**

# Hurricane Opal in Florida

**OBSERVATIONS,  
RECOMMENDATIONS, AND  
TECHNICAL GUIDANCE**



**FEDERAL EMERGENCY MANAGEMENT AGENCY**

**MITIGATION DIRECTORATE**



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Building Performance Assessment Team

- Team Objectives
  - Inspect damage to buildings
  - Assess performance to buildings
  - Evaluate design and construction practices
  - Evaluate code requirements and enforcement
  - Make recommendations as necessary

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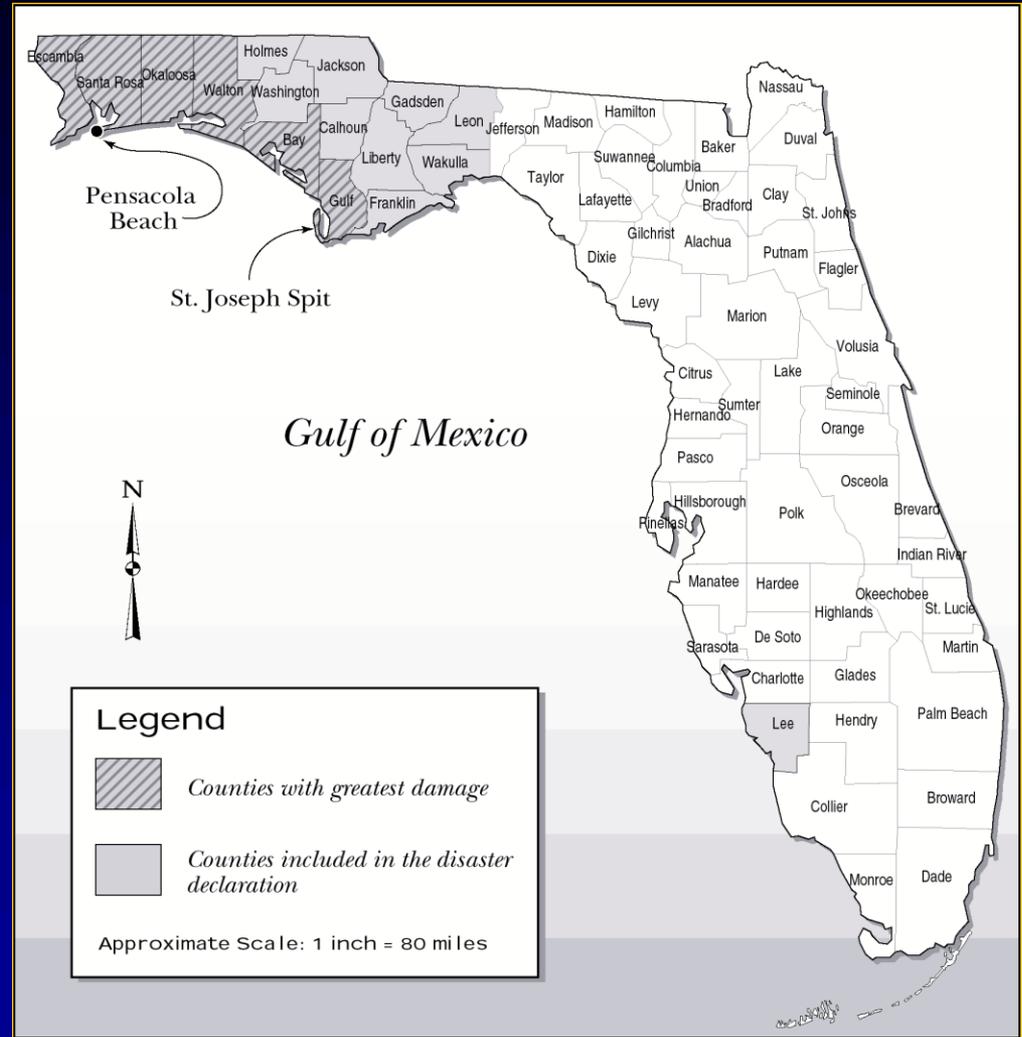
# FEMA Building Performance Assessment Teams

- Team Members
  - Representatives of public and private sectors with expertise in:
    - structural and civil engineering
    - building design and construction
    - code development and enforcement

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## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Florida counties included in the Hurricane Opal Federal disaster declaration.*



# Observations

- Building Types
  - Pre-FIRM
    - 1-3 story on slab-on-grade
    - 1-3 story on timber piles
  - Post-FIRM
    - 1-3 story wood-frame structures elevated on timber or concrete pile foundations



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# Observations

- Applicable Codes and Requirements
  - State of Florida construction requirements
  - Standard Building Code
  - NFIP requirements



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# Observations

- Wind Damage
  - Observed limited damage
    - roofing shingles and tiles
    - exterior sheathing
    - unsecured air conditioning compressors
    - power poles and lines
    - signs

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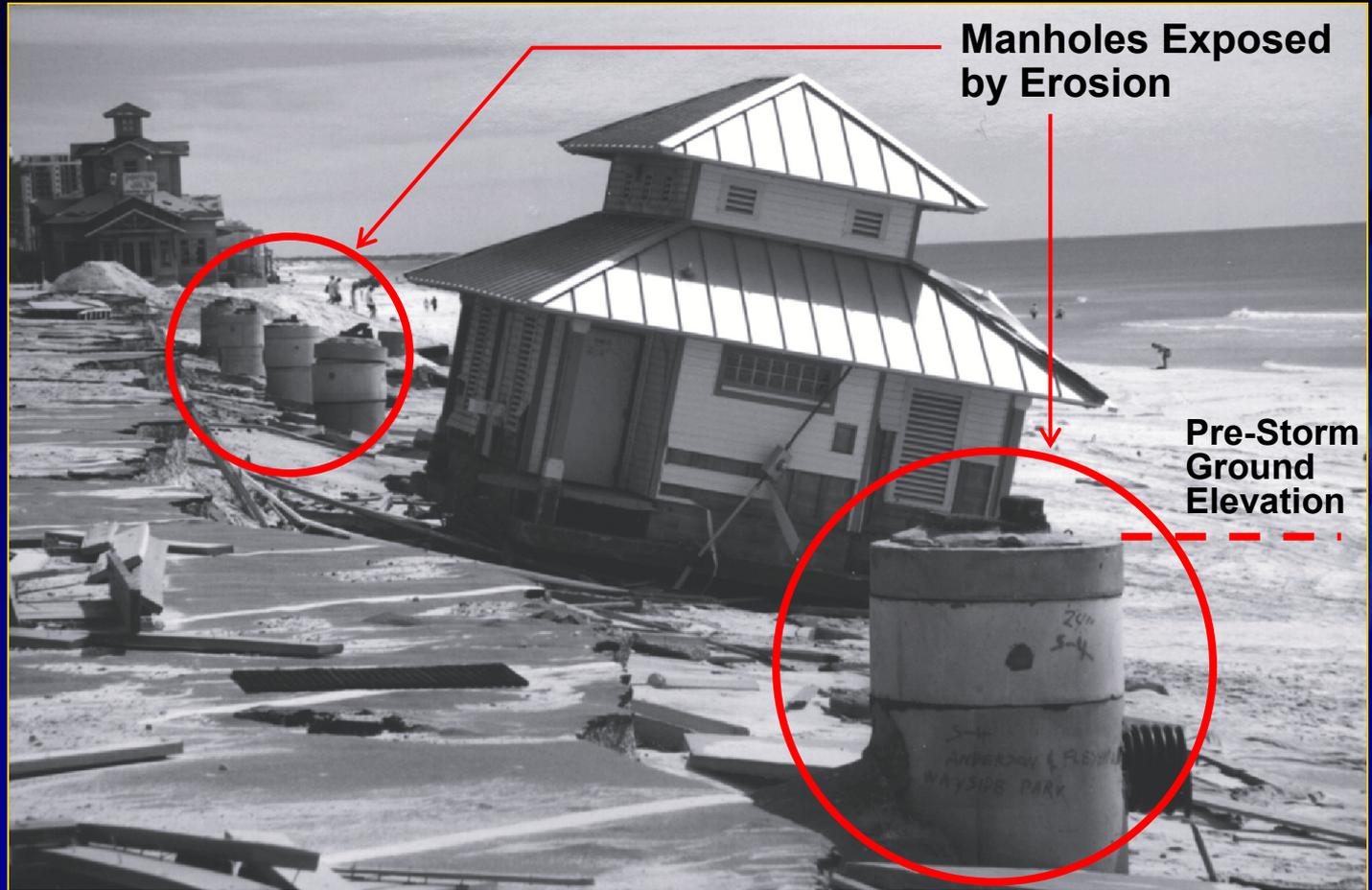


# Observations

- Flood Damage
  - Extensive along the study area
    - pre-FIRM structures in V-Zones
    - post-FIRM structures in all Zones that were exposed to high-velocity flows
    - post-FIRM structures not properly constructed or elevated
    - pre-and post-FIRM structures dependant on failed seawalls or bulkheads for protection



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Beach erosion caused major damage to structures, as well as roads and utilities.*

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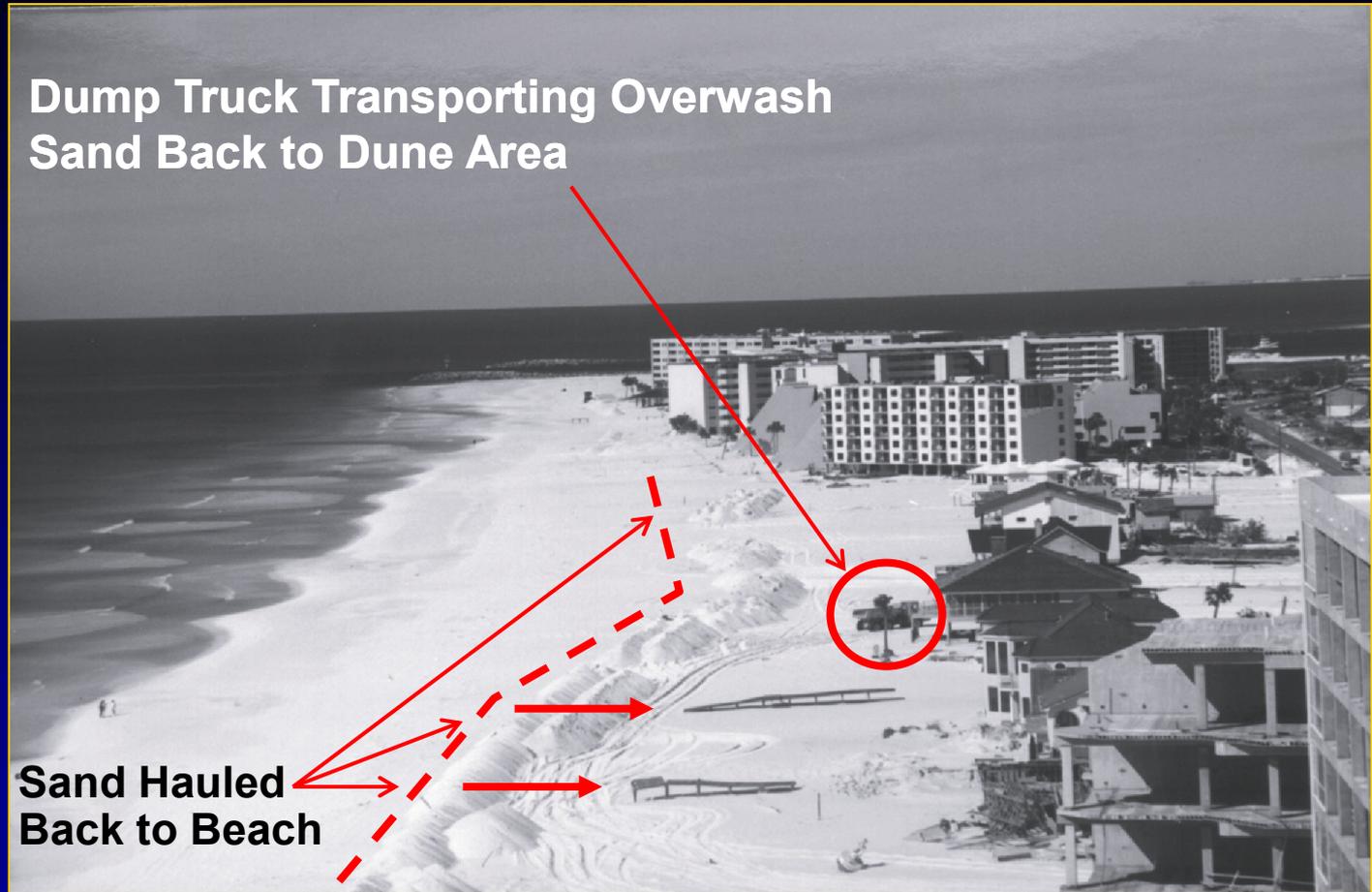
# Observations

- Erosion
  - Significant loss of dunes
  - Overwash caused burial of roads 500 feet inland
  - Dune retreat of 75-100 feet



## FEDERAL EMERGENCY MANAGEMENT AGENCY

### Dump Truck Transporting Overwash Sand Back to Dune Area



*Beach erosion eliminated protection for structures. It is important that the beach and dunes be rebuilt as soon as possible. Arrows point to walkways used to traverse dune that has been washed away.*



# Observations

- Scour
  - Ground levels from front-row structures reduced by 3-7 feet
  - Seaward edge of high dunes lost 10-20 feet
  - Localized scour depressions of 6-12 inches in depth near bases of piles



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Erosion such as this took place along the gulf coast, causing structures to be undermined and resulting in damage.*

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## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Undermining of concrete decks and floor slabs caused the failure of many unreinforced concrete structures.*

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FEDERAL EMERGENCY MANAGEMENT AGENCY

# Observations

- Debris
  - Small debris
    - household items
  - Large debris
    - pier piles and braces
    - dumpsters
    - boats



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Debris, consisting of broken concrete and wood framing systems, generated by surge action.*

**BUILDING PERFORMANCE ASSESSMENT TEAM**

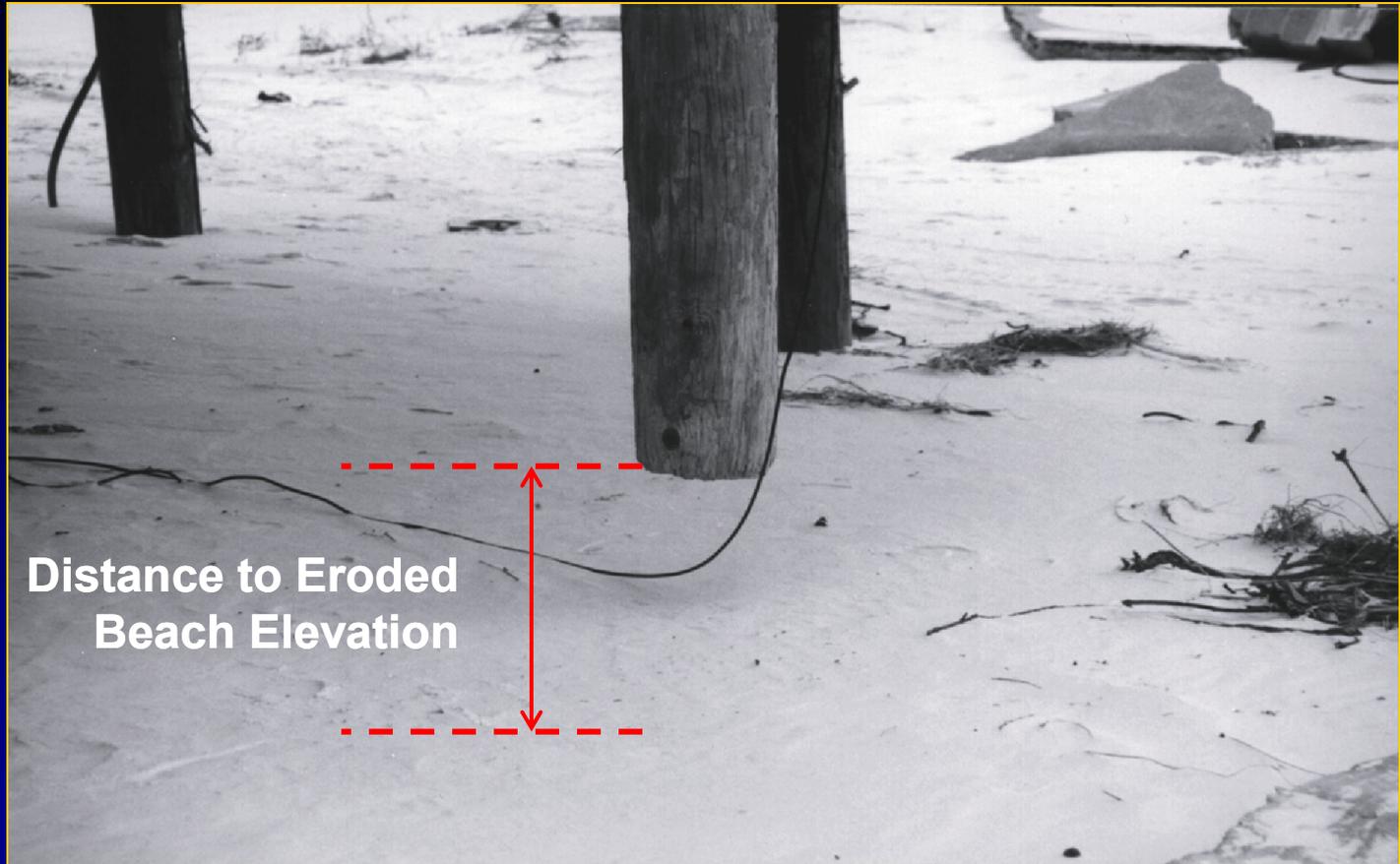


# Observations

- Pile and Pier Foundations
  - Well designed and constructed piles survived the storm
  - 3-7 feet vertical erosion was common
  - Insufficient penetration of piles led to collapse
  - Many undersized piles failed



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*These piles were not embedded deep enough to survive the erosion of the sand. As a result, there is now a large gap between the bottoms of the pilings and the ground surface.*



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*These piles were not long enough and were spliced to add depth. The splicing was exposed by storm-induced erosion.*

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# Observations

- Framing Systems
  - Poor beam-to-beam and joist-to-beam connections were common
  - Typical problems
    - pile notching greater than 50% of pile cross-section
    - poor alignment of piles
    - use of wooden shims to support beams
    - over-dependence on nails / metal straps

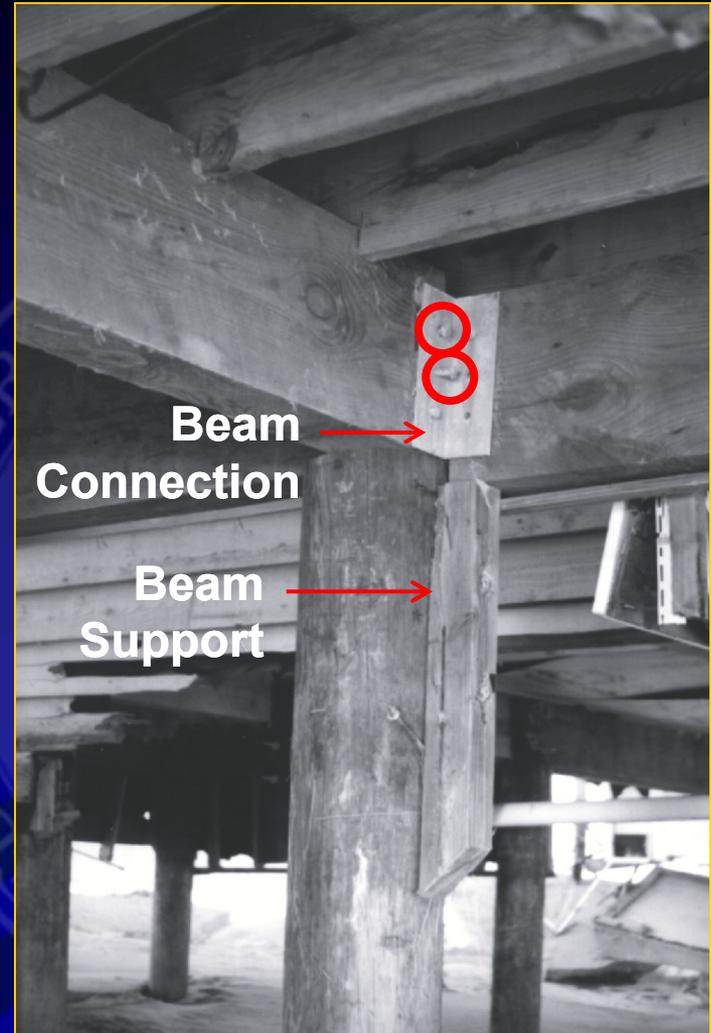


# Observations

- Connections
  - Many were deficient
    - corrosion of galvanized straps, hangers, and joist-to-beam ties
  - Failure due to insufficient nailing and storm forces exceeding design forces



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*The floor beam connection and beam support shown here illustrate the lack of design and proper construction observed on many damaged structures. Note the bolt pullouts (circled). Also, the beam support is attached to the pile with lag bolts rather than bolts that extend through the pile.*



# Observations

- Bracing
  - Some failures were caused by horizontal loading from water, debris or both
  - Knee bracing common - no failures were observed
  - Notches for bearing seats in the piles can weaken the structural integrity
  - No failures from threaded galvanized rods and turnbuckles

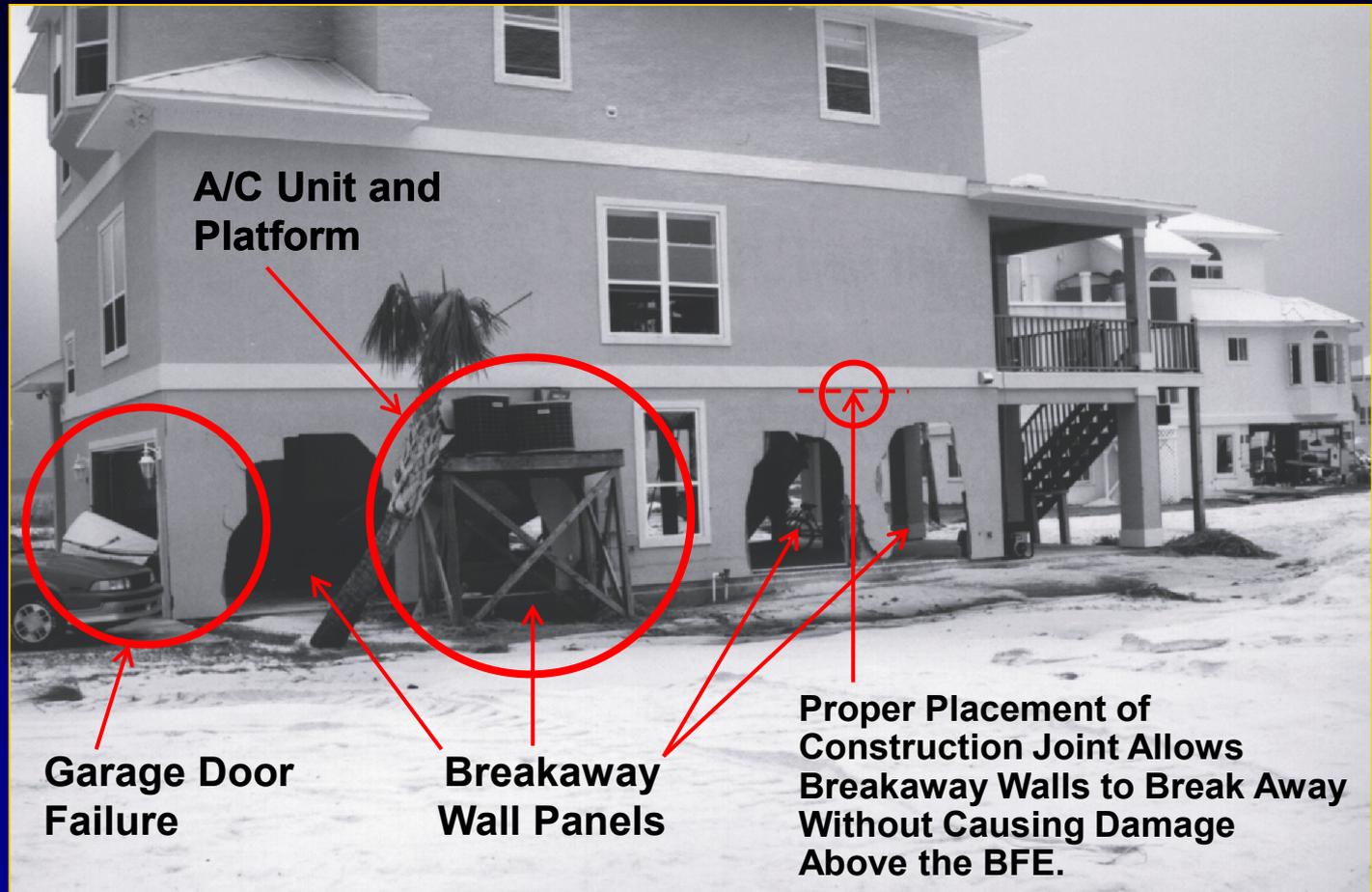


# Observations

- Breakaway Construction and Enclosures
  - Many damaged or destroyed enclosures below elevated structures
  - Some post-FIRM breakaway walls broke as intended, but damaged exterior sheathing and wall finishes
  - This minor damage could have been prevented through better design and construction



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*These breakaway walls functioned as designed, lessening the pressures of water, sand, and debris on the structure.*

**BUILDING PERFORMANCE ASSESSMENT TEAM**



# Observations

- Utilities
  - The BPAT observed many problems:
    - location of equipment (meters, panels, boxes and wiring) below the lowest habitable floor
    - attachment of utilities to breakaway walls
    - failure to support and fasten air conditioners
    - placement of utility lines and connections on the seaward side of buildings



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*These breakaway panels functioned as designed. Note the loss of the air conditioning unit platform.*

**BUILDING PERFORMANCE ASSESSMENT TEAM**



# Observations

- Seawalls
  - Widespread failure of seawalls and bulkheads
  - Wing walls failed due to flanking by erosion and scour
  - Failed seawalls contributed to other structural and non-structural damage



# Observations

- Seawalls (cont.)
  - Characteristics of walls that survived:
    - reinforced concrete slab or sheetpile
    - sufficient wall height or backfill protection
    - sufficient anchorage and embedment
    - wing walls that extend landward of the effects of erosion and scour



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Fractured seawall, damaged by storm forces. Not the erosion of the bank behind the wall.*

**BUILDING PERFORMANCE ASSESSMENT TEAM**



# Observations

- Drainage and Drainage Structures
  - Many remains of new stormwater structures were observed
  - It appears that erosion beneath structures was exacerbated by upland stormwater runoff



# Observations

- Design, Construction and Workmanship
  - Many structures built without detailed plans
  - Structures were not built in accordance with the plans that were available
  - Numerous examples of poor workmanship were noted



# Observations

- Siting
  - No significant damage of State-permitted structures seaward of the Coastal Construction Control Line
  - One-half of the pre-existing structures seaward of the Coastal Construction Control Line sustained structural damage



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- V-Zone Mapping
  - Restudies / revisions to FIRMS should be completed
  - Pre-storm V-Zone were too narrow which underestimated the actual risk



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Reconstruction
  - Study local flooding conditions during Opal to determine post-storm reconstruction guidance
  - Identify coastal A-Zones that are subject to V-Zone forces and regulate reconstruction to V-Zone standards



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Coastal A-Zones
  - Stricter new construction standards should be adopted
  - The City of Pensacola Beach provided a good example of a success story



# Recommendations

- Foundation Design Requirements
  - Communities should adopt a multi-hazard approach to reexamine designs
  - Slabs used solely for parking
    - should not be attached to structural members
    - should be designed to break in the event of undermining



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Permitting, Plan Review and Inspection
  - Quality of workmanship, permitting, and plan review should be improved
  - Contractors should be required to strictly adhere to design plans
  - Enhanced training / certification of reviews and inspectors
  - Greater use of licensed design professionals

**BUILDING PERFORMANCE ASSESSMENT TEAM**



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Construction Materials
  - Materials should meet or exceed requirements in the Standard Building Code
  - Materials subject to flooding should resist damage, deterioration, corrosion and decay



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Construction Materials (cont.)
  - Guidance given in FEMA's Technical Bulletin 8-96 and 2-93
  - Examples include discussion of hurricane straps and hangers, composite beams and asphalt roofing shingles



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Repair and Retrofit of Damaged Structures
  - structures should be inspected to ensure compliance with applicable codes
  - 50 % rule may dictate compliance with different regulation
  - Opportunities to retrofit should be pursued



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- New Construction and Substantial Improvements
  - Construction plans should be sealed by a registered design professional
  - Communities should consider setbacks and first floor elevations exceeding the minimum requirements

**BUILDING PERFORMANCE ASSESSMENT TEAM**



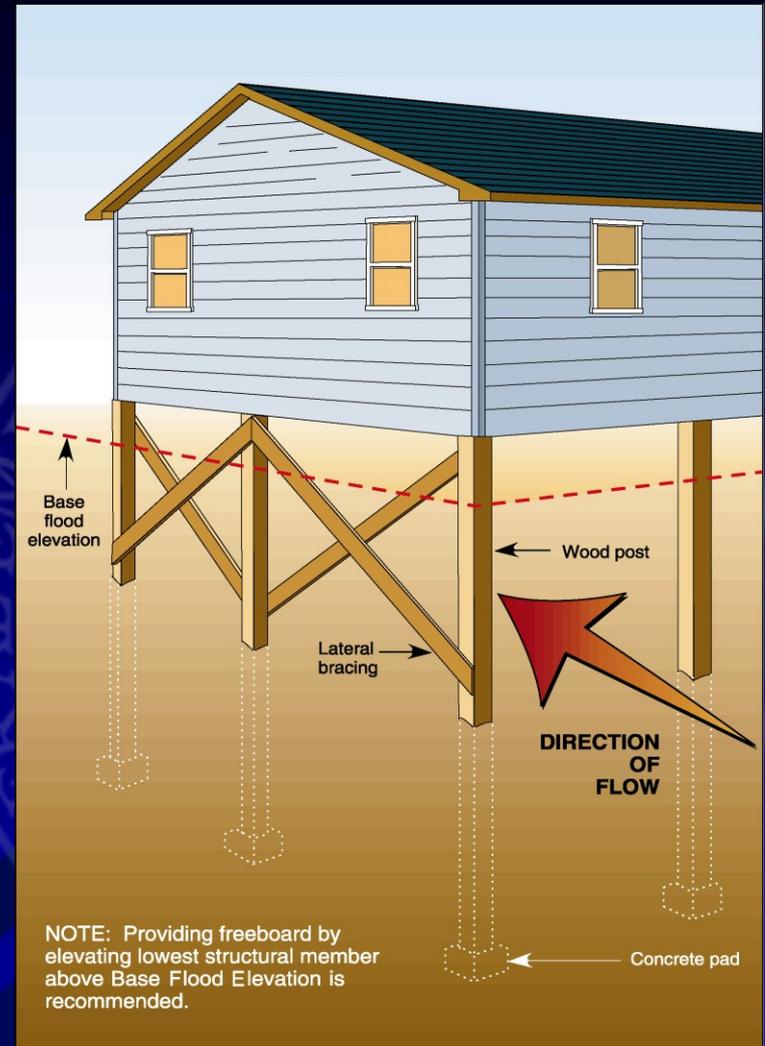
FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Pile, Post, Column and Pier Foundations
  - Should be designed in accordance with ASCE code
  - Use documented erosion and scour values in the design of the foundation embedment
  - BPAT recommended designs



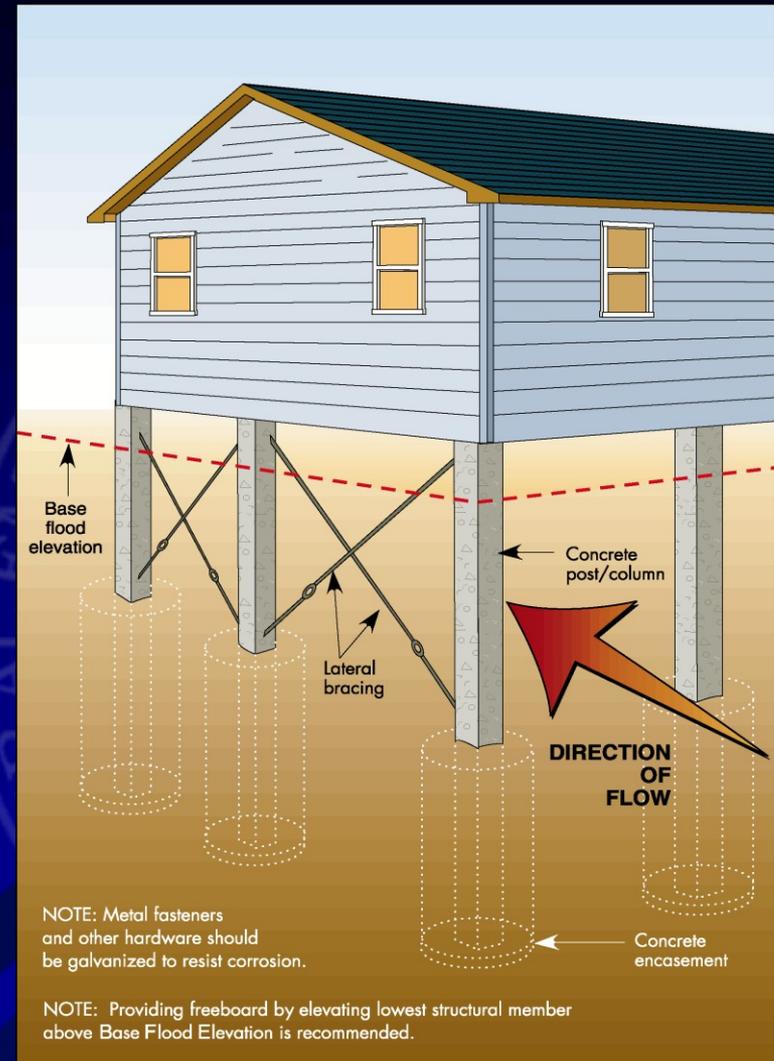
## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Posts are placed in excavated holes and may be anchored in a concrete pad at the bottom of the hole. Where possible, lateral bracing should be parallel to the anticipated flow path (FEMA 1993a).*



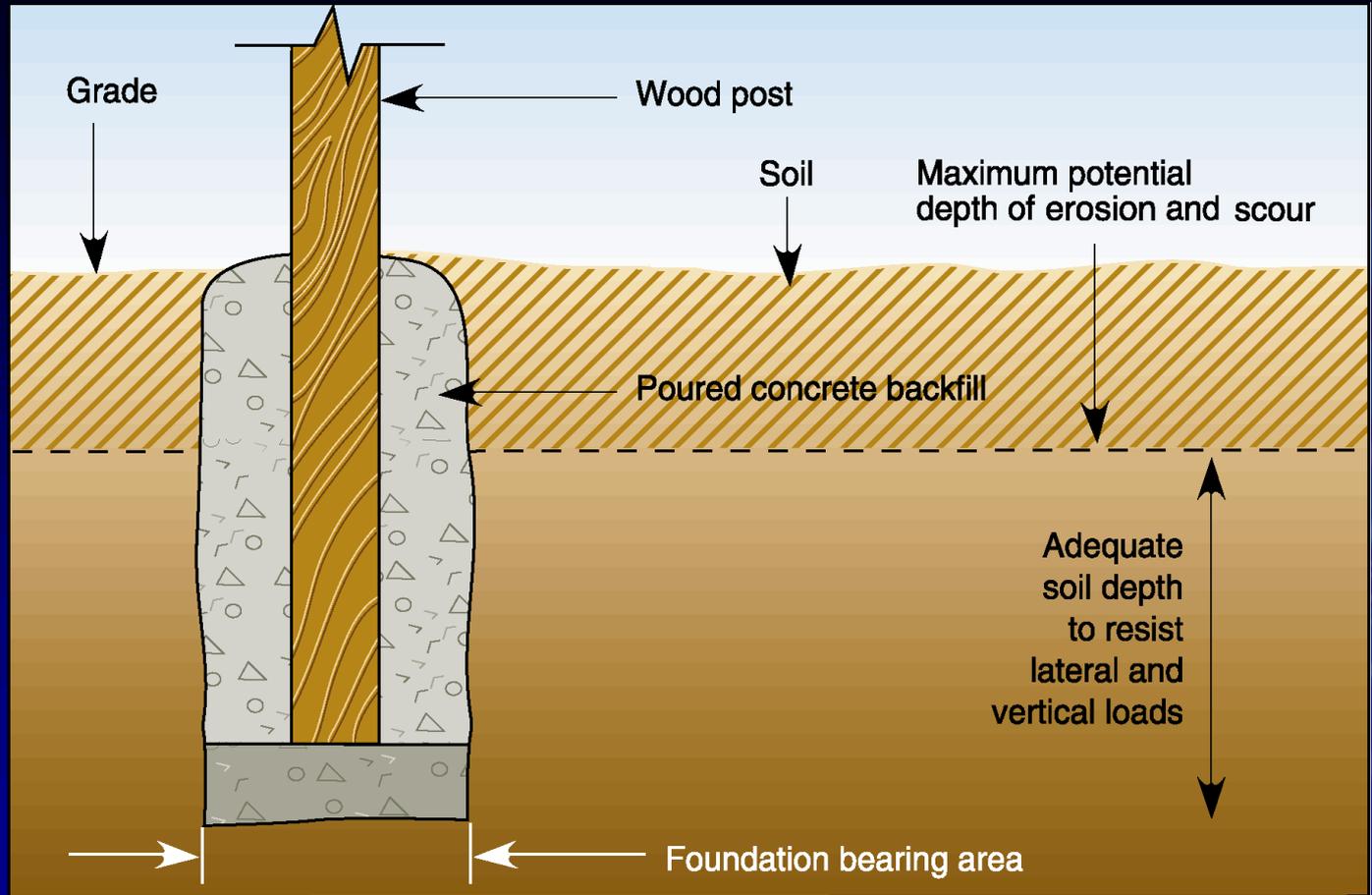
## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Posts can also be anchored in concrete encasements. Where possible, lateral bracing should be oriented parallel to the anticipated flow path (FEMA 1993a).*



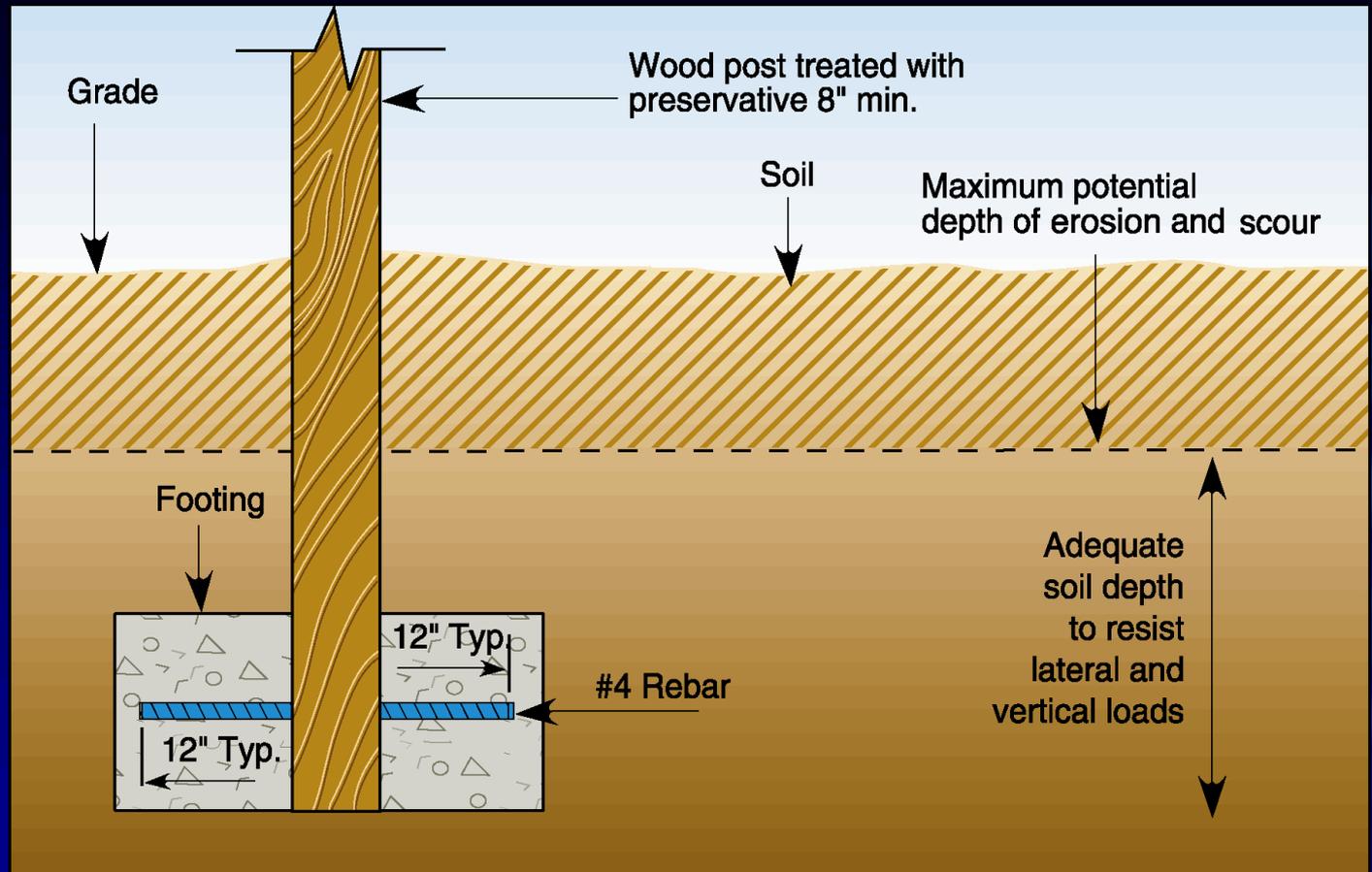
## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Post on concrete bearing pad. Soil depth below maximum potential depth of scour is adequate to withstand lateral and vertical loads during the base flood (after FEMA 1993a).*



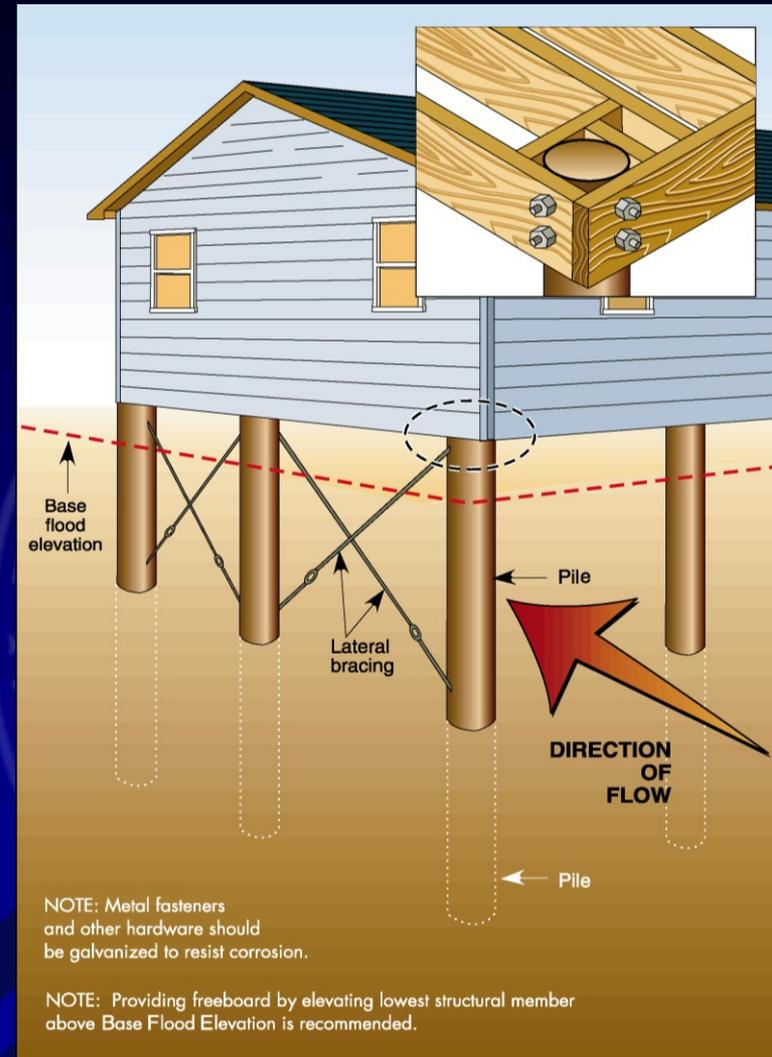
## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Anchorage of post. Soil depth below maximum potential depth of scour is adequate to withstand lateral and vertical loads during the base flood (after FEMA 1993a).*



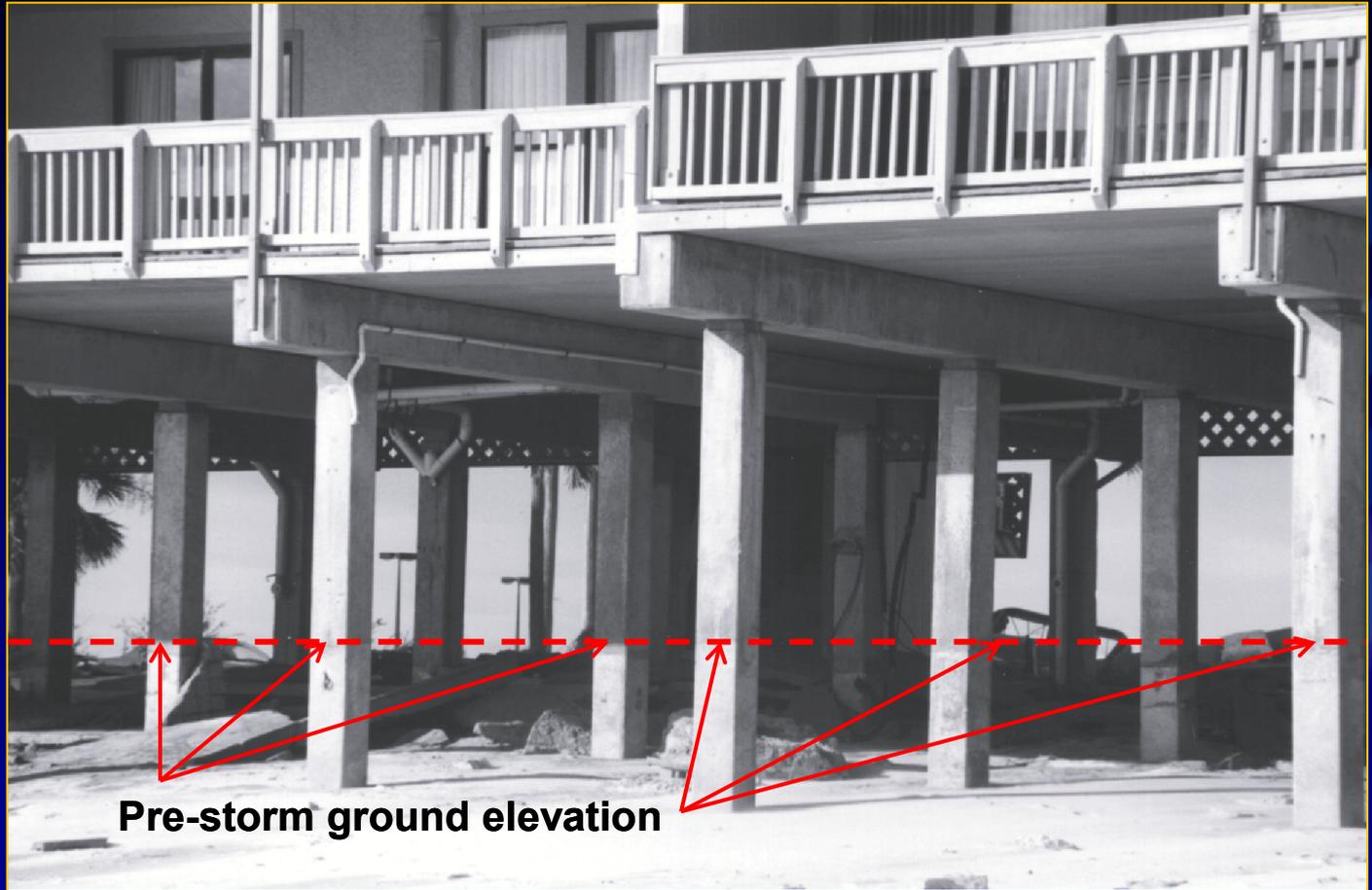
## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Piles are mechanically driven into the ground and are therefore less susceptible to high-velocity flooding, erosion, conical scour, and pullout. Where possible, lateral bracing should be oriented parallel to the anticipated flow path (FEMA 1993a).*



## FEDERAL EMERGENCY MANAGEMENT AGENCY



**Pre-storm ground elevation**

*This well-constructed concrete structure survived the storm with little or no damage, even with 5 feet of erosion*

**BUILDING PERFORMANCE ASSESSMENT TEAM**



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Framing Systems
  - Designed to support anticipated loads
  - Any deviation should be in accordance with code requirements



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Connections
  - Minimum standards for connectors
    - hot-dip galvanized steel
    - comply with Standard Building Code specs
    - comply with FEMA TB 8-96
  - Wood should not be used as a shim material

**BUILDING PERFORMANCE ASSESSMENT TEAM**



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Bracing
  - Hot-dip galvanized steel rods - threaded on both ends with a turnbuckle in the center
  - Wood bracing is acceptable if designed properly

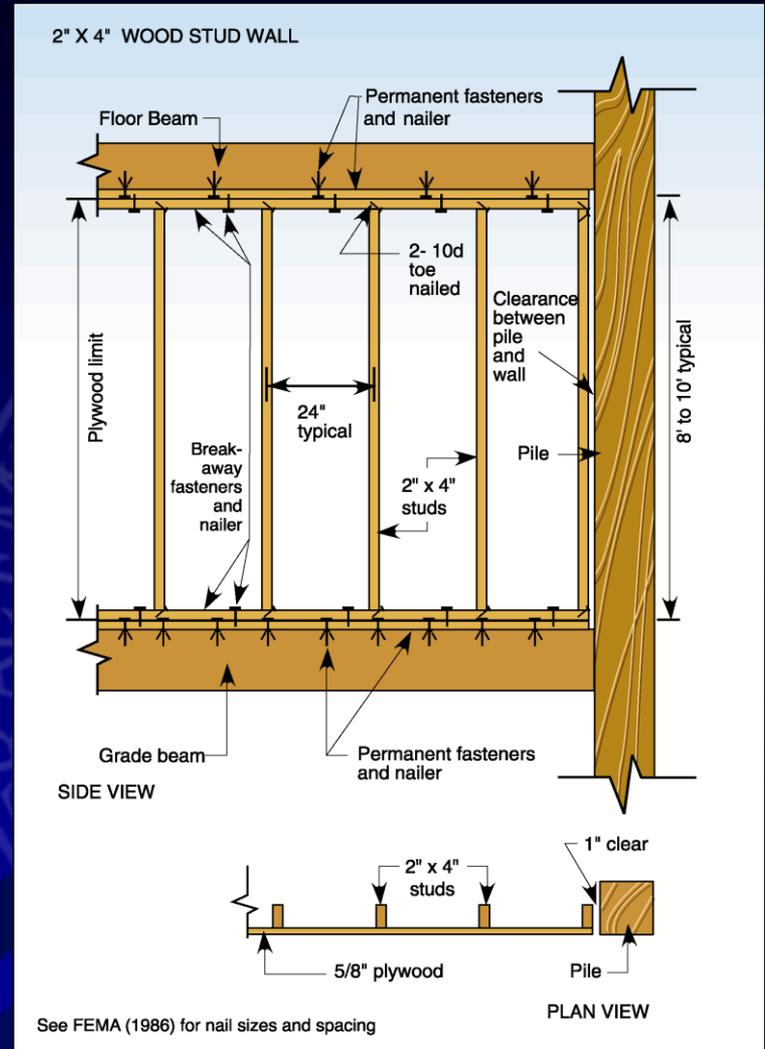


# Recommendations

- Breakaway Walls
  - Recently constructed walls in V-Zones performed well
  - Address problems with breakaway walls
    - attached to other structure elements above the lowest floor
    - attached to utility lines



# FEDERAL EMERGENCY MANAGEMENT AGENCY



*Wood stud breakaway wall (after FEMA 1986).*



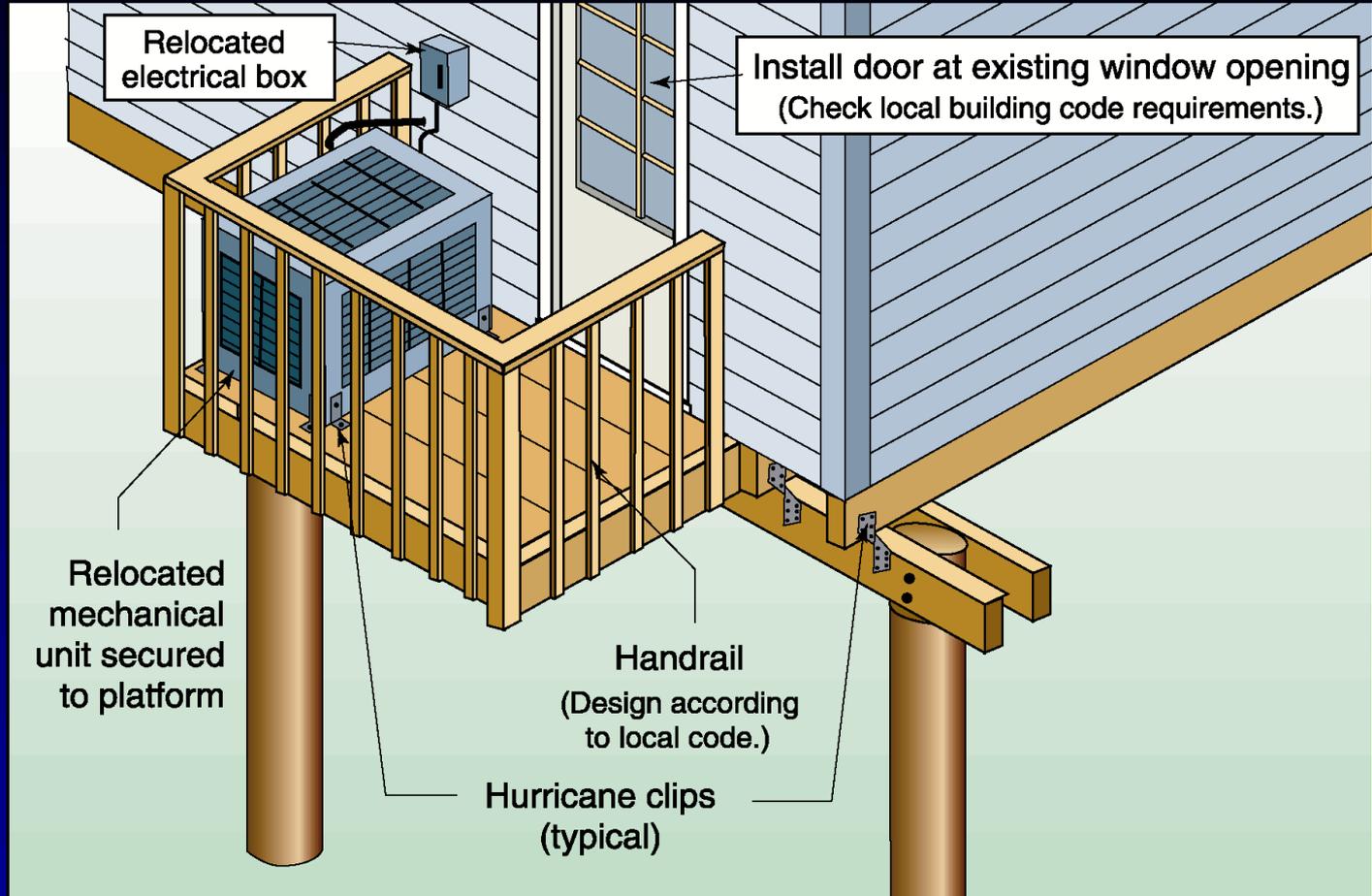
FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Utilities
  - Recommended placement
    - Landward side of structure for V-Zones
    - Elevated at or above the BFE
    - If below the BFE, utilities should be in floodproof enclosures



## FEDERAL EMERGENCY MANAGEMENT AGENCY



*Installation of a mechanical balcony as a retrofit for an elevated home.*



FEDERAL EMERGENCY MANAGEMENT AGENCY

# Recommendations

- Seawalls and Erosion Control Structures
  - Should not be relied upon to contain soil for habitable structures
  - Wing walls should extend beyond storm-induced erosion