NTSB National Transportation Safety Board

*Office of Research and Engineering*

# Bridge Description and Collapse

Jim Wildey

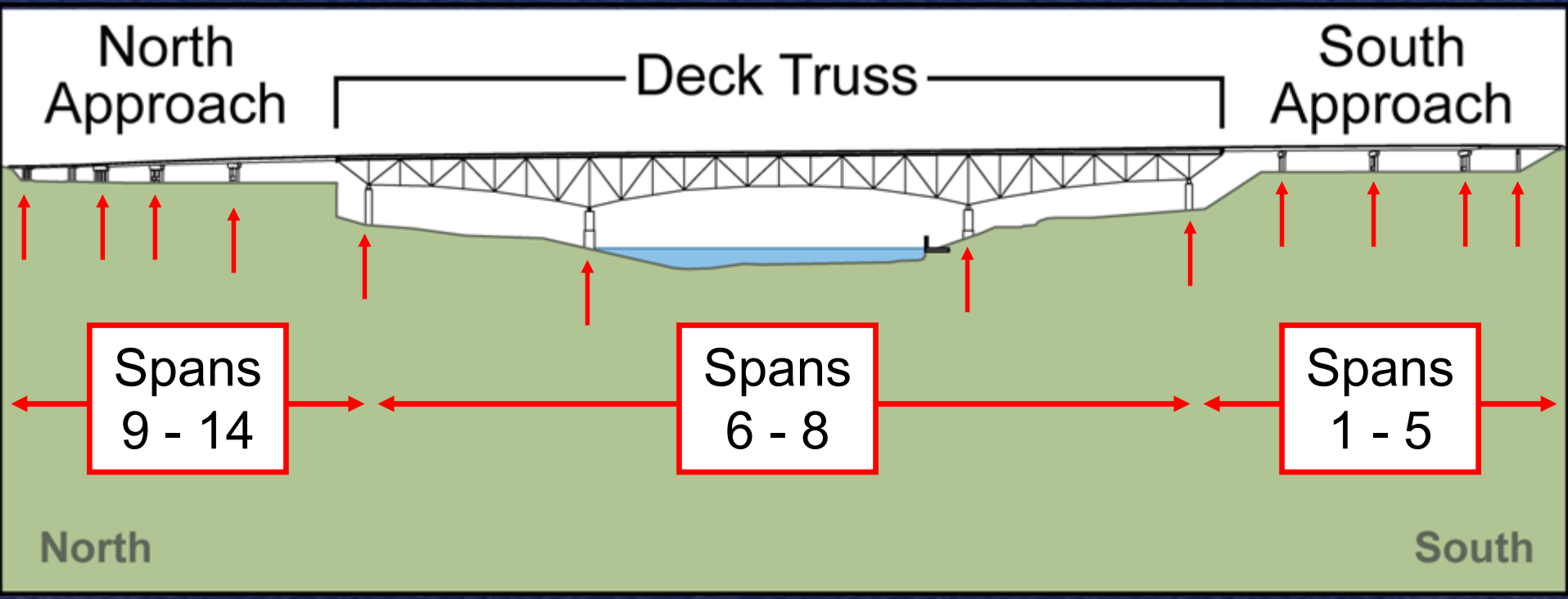
# Presentations

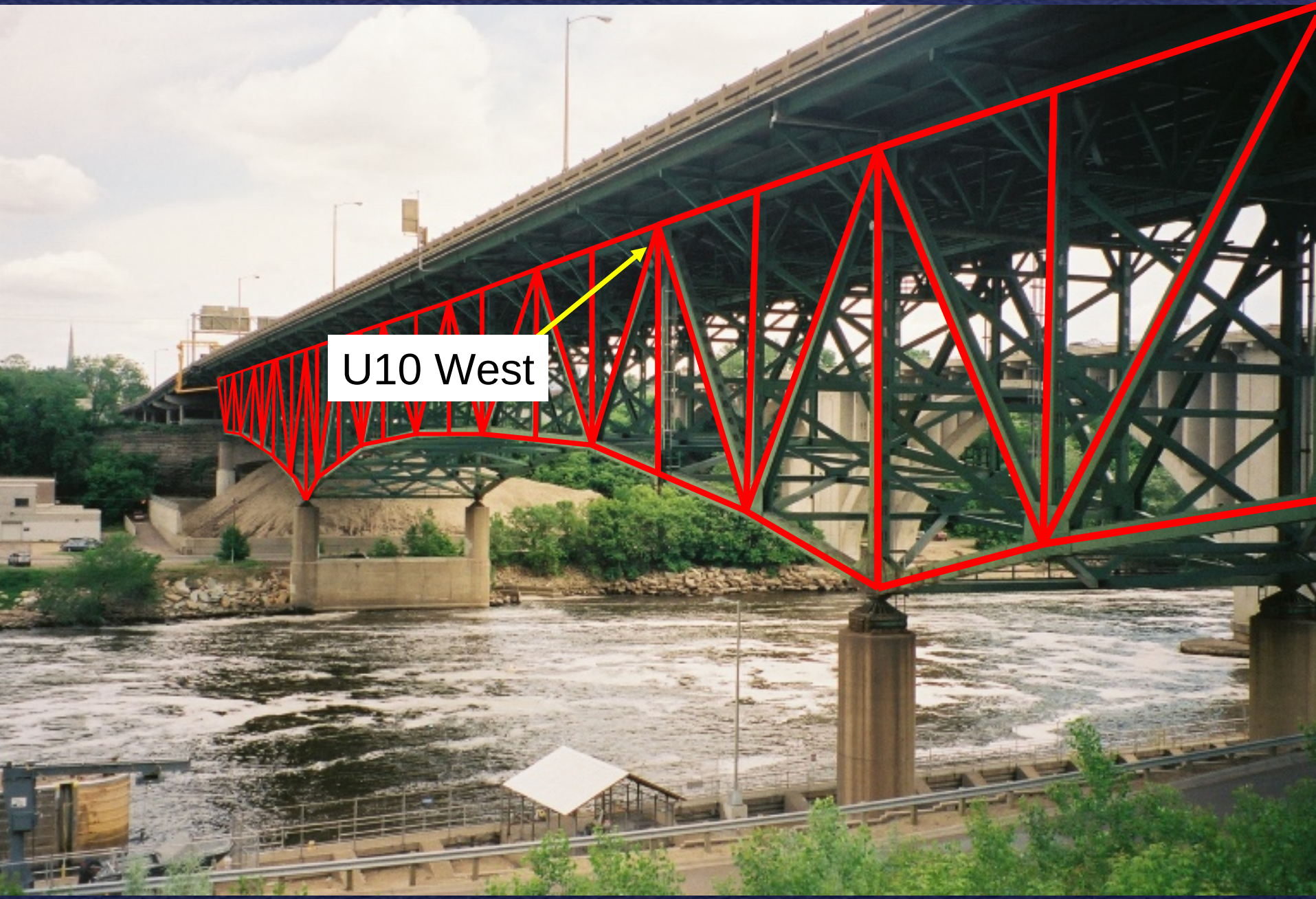
1. Bridge description and collapse
2. Construction activities on bridge at time of collapse
3. Gusset plate inadequacy
4. Finite element modeling analysis
5. Design and review process
6. Bridge load rating and bridge load analysis
7. Bridge inspections
8. Gusset plate inspections

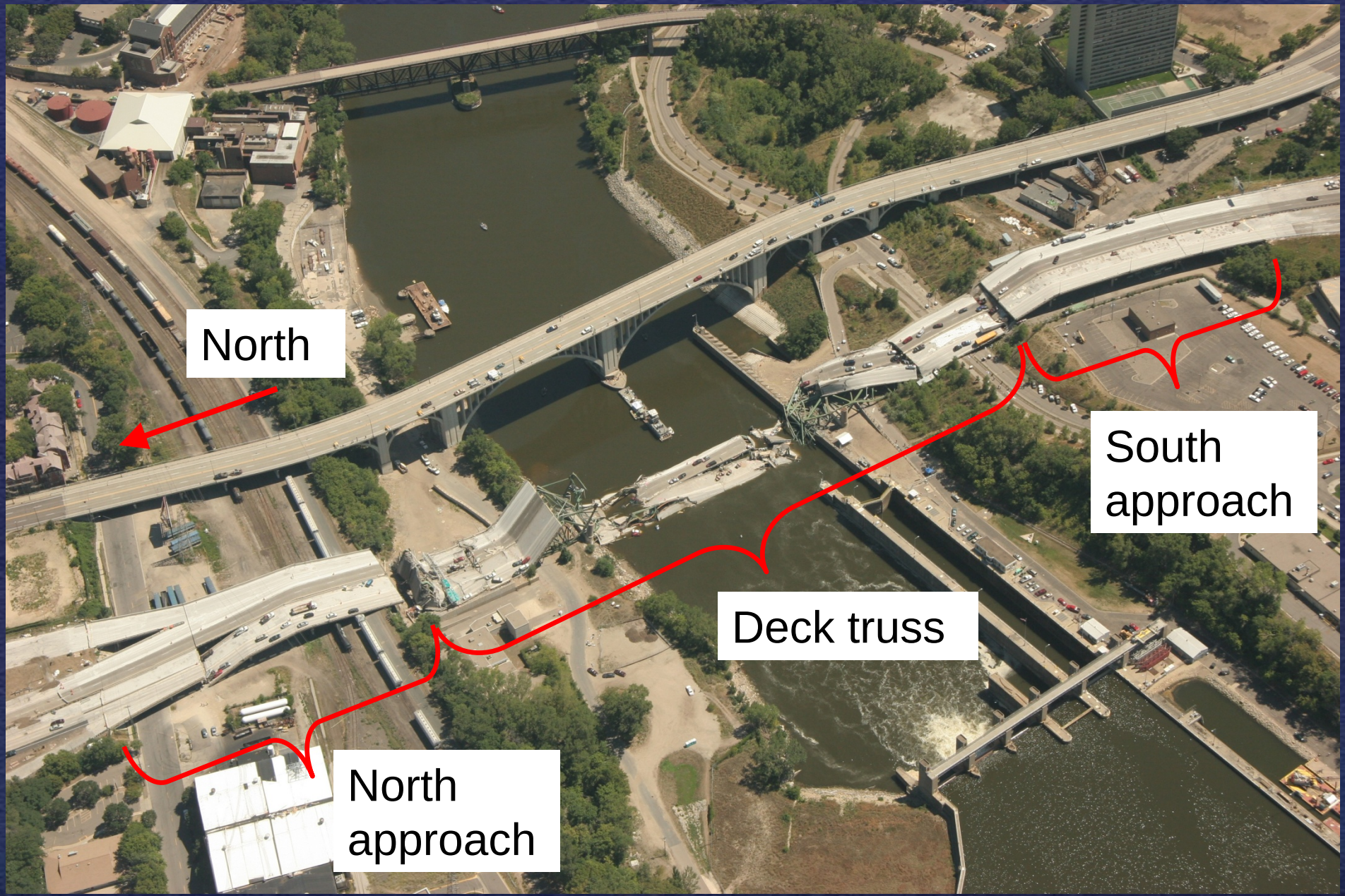
# Bridge Description and Collapse

1. General description of bridge
   - Structural elements
   - Bridge modifications
2. Sequence of collapse
   - Initiation location
   - Secondary damage and fractures
3. Factors excluded

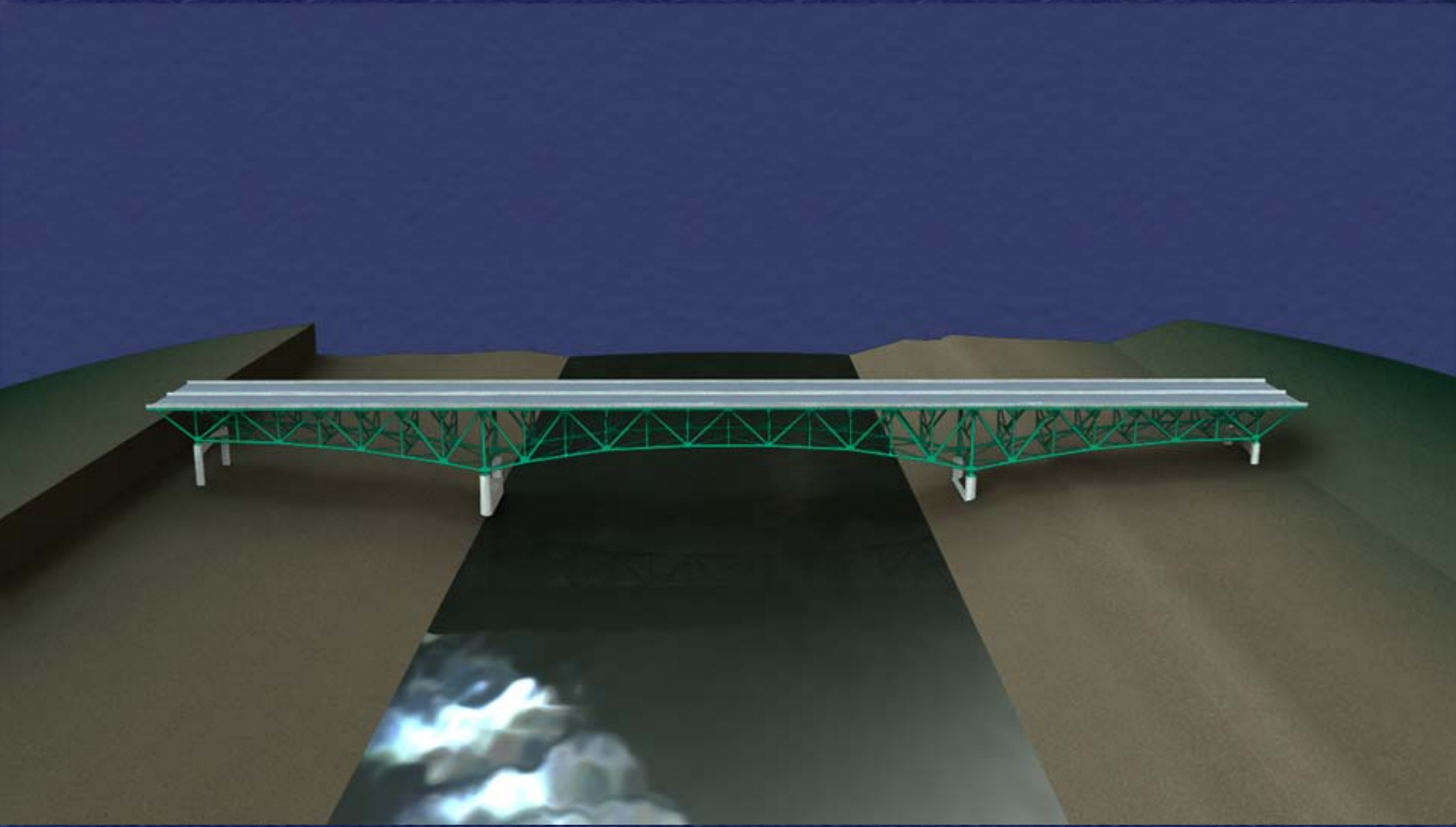
# Bridge Description and Collapse

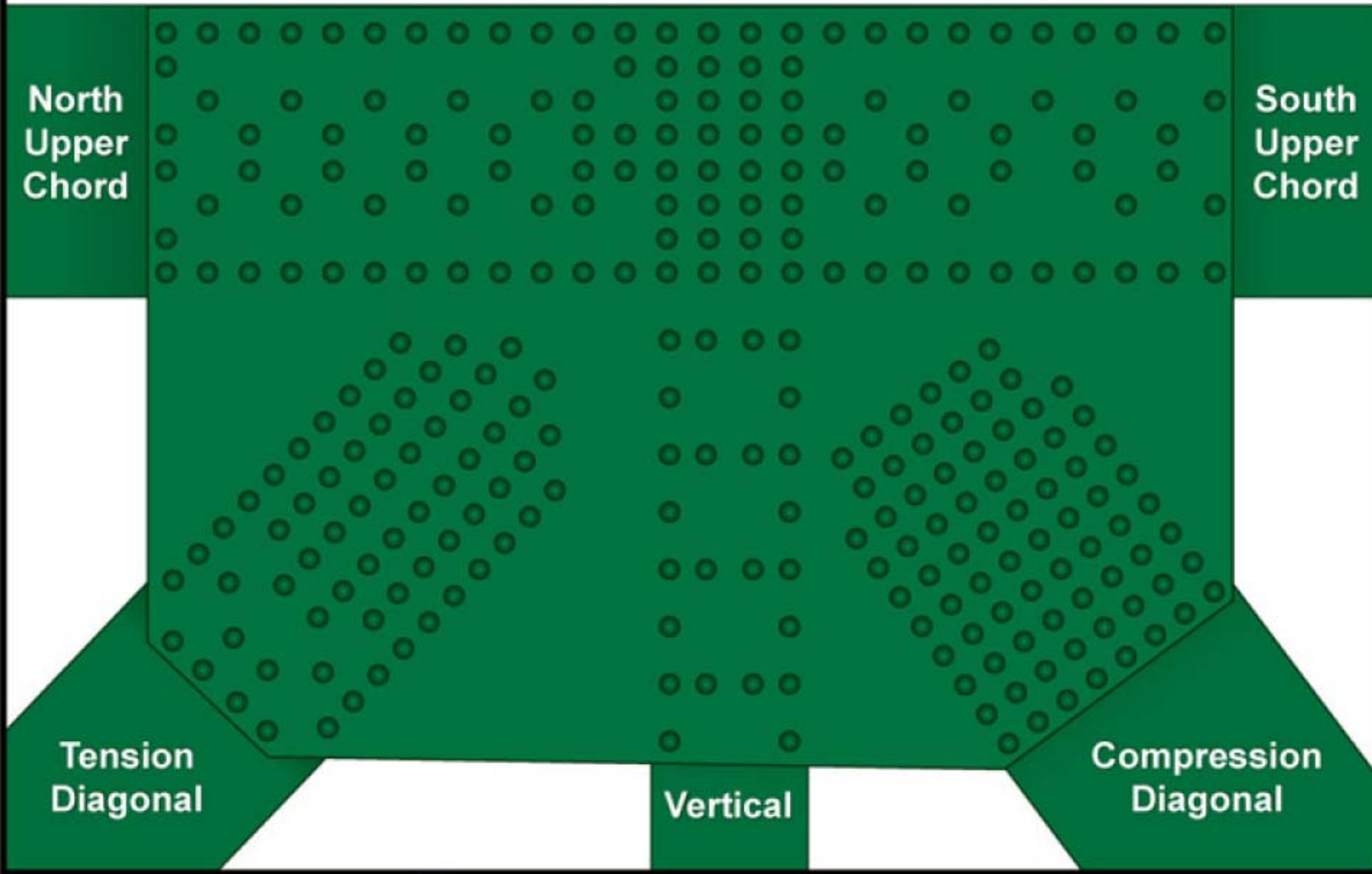



U10 West


North
South approach
Deck truss
North approach

# General Description of the Bridge

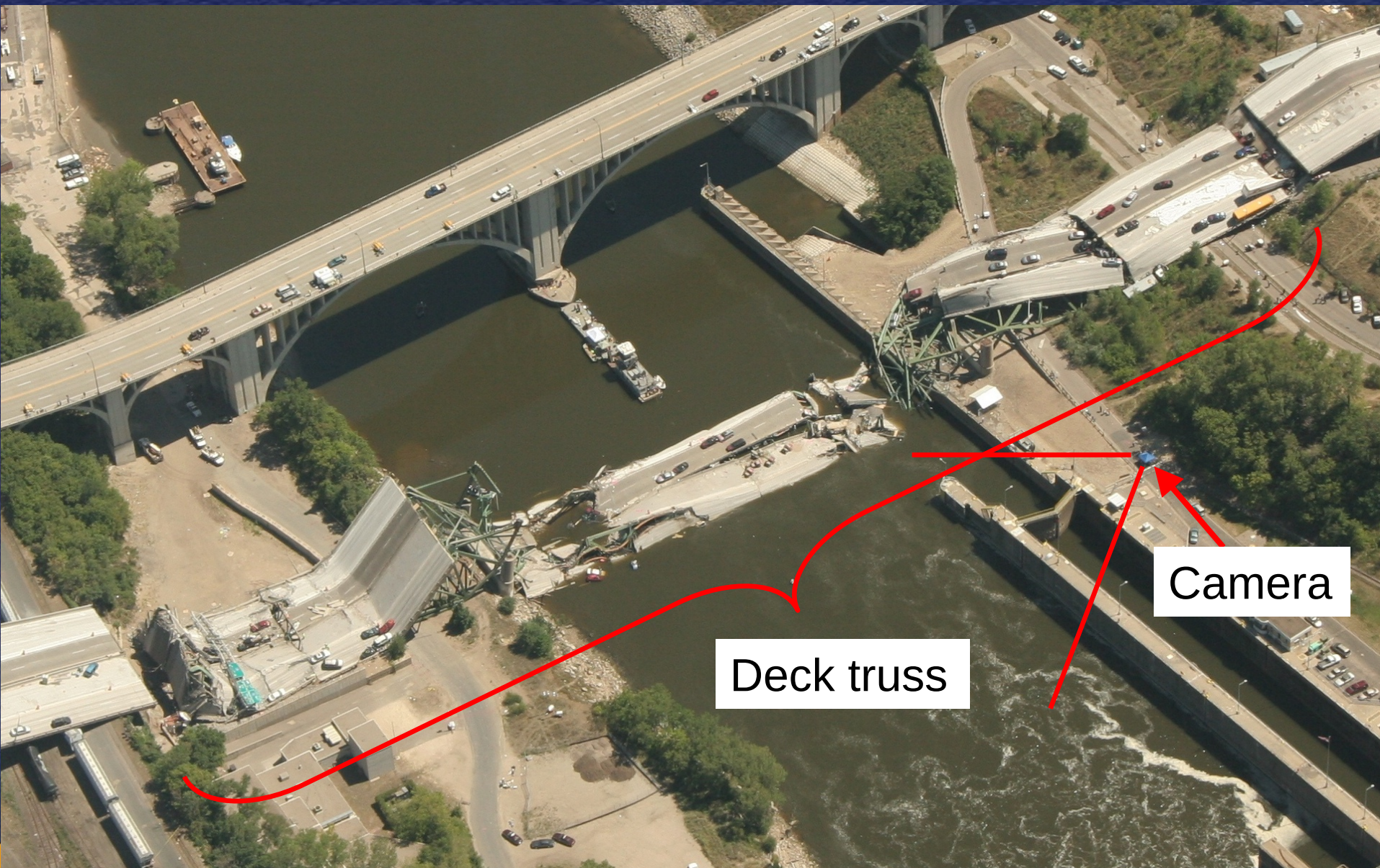



North Upper Chord
South Upper Chord
Tension Diagonal
Vertical
Compression Diagonal
National Transportation Safety Board

# General Description of Bridge

- Deck truss original weight: 18.3 million pounds
- 1977 Modification
  - Deck thickness increased
  - Added over 3 million pounds
- 1998 Modification
  - Barriers / deicing system
  - Added 1.2 million pounds

# Sequence of Collapse



# Video Evidence

# Video Evidence

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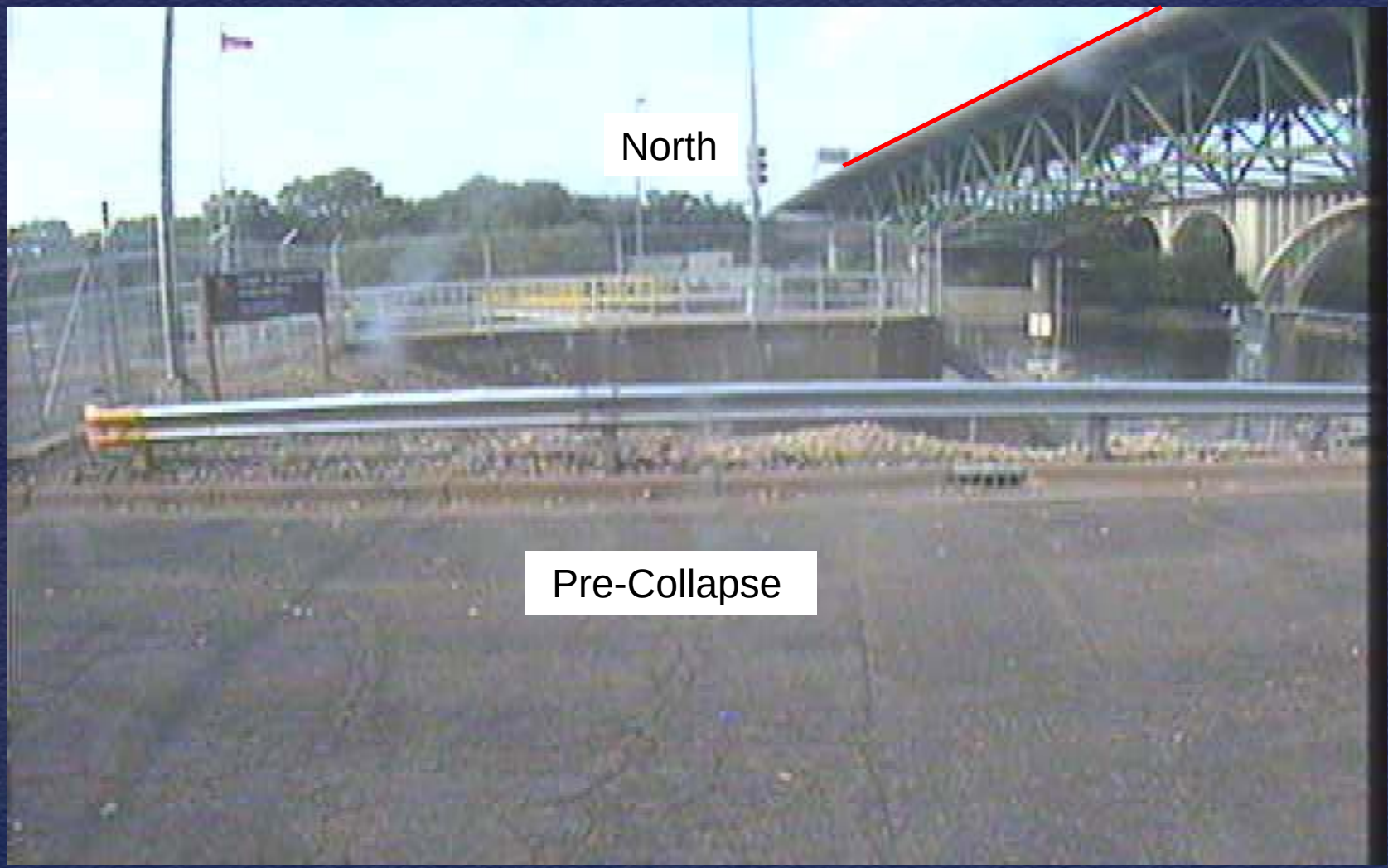

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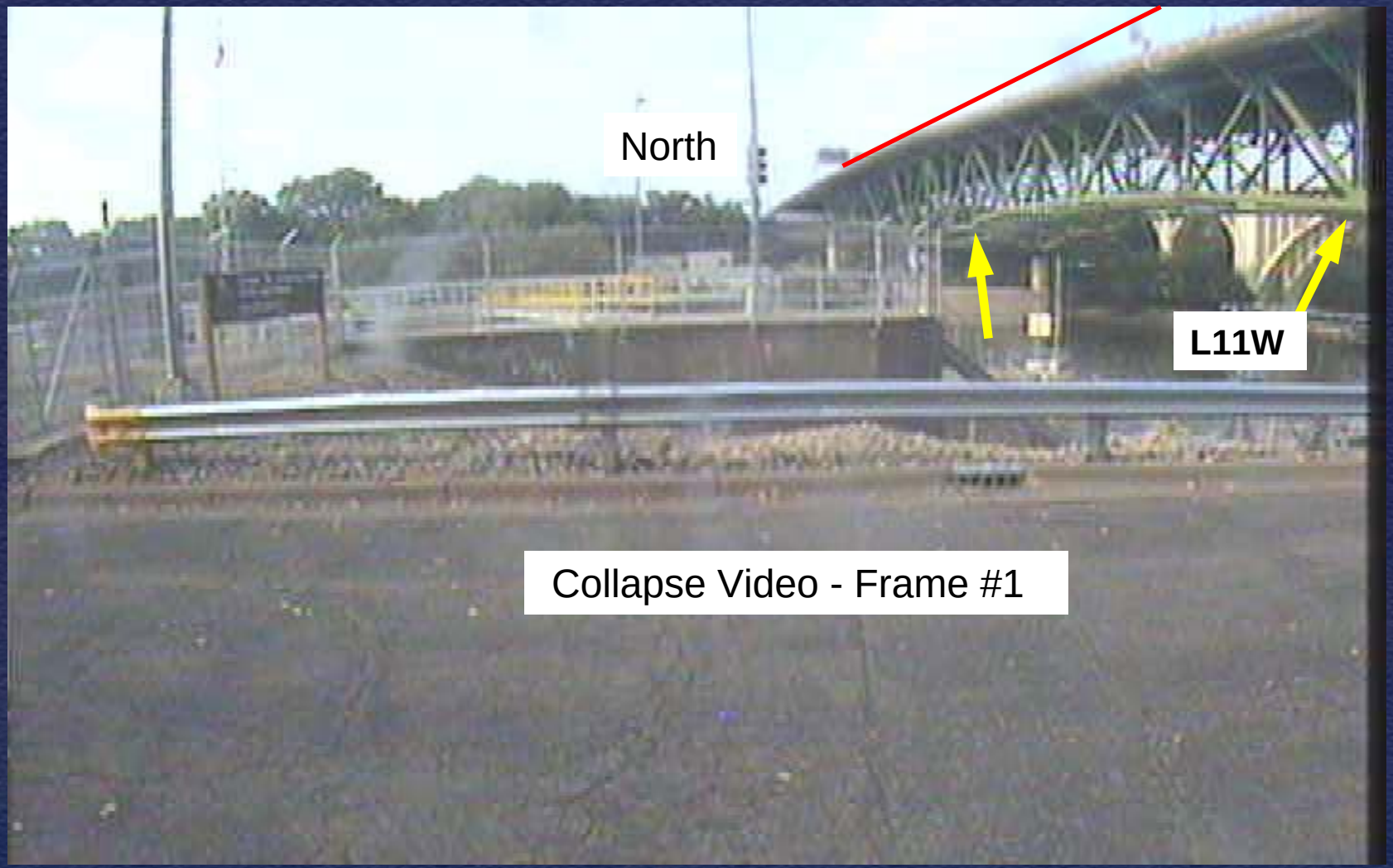

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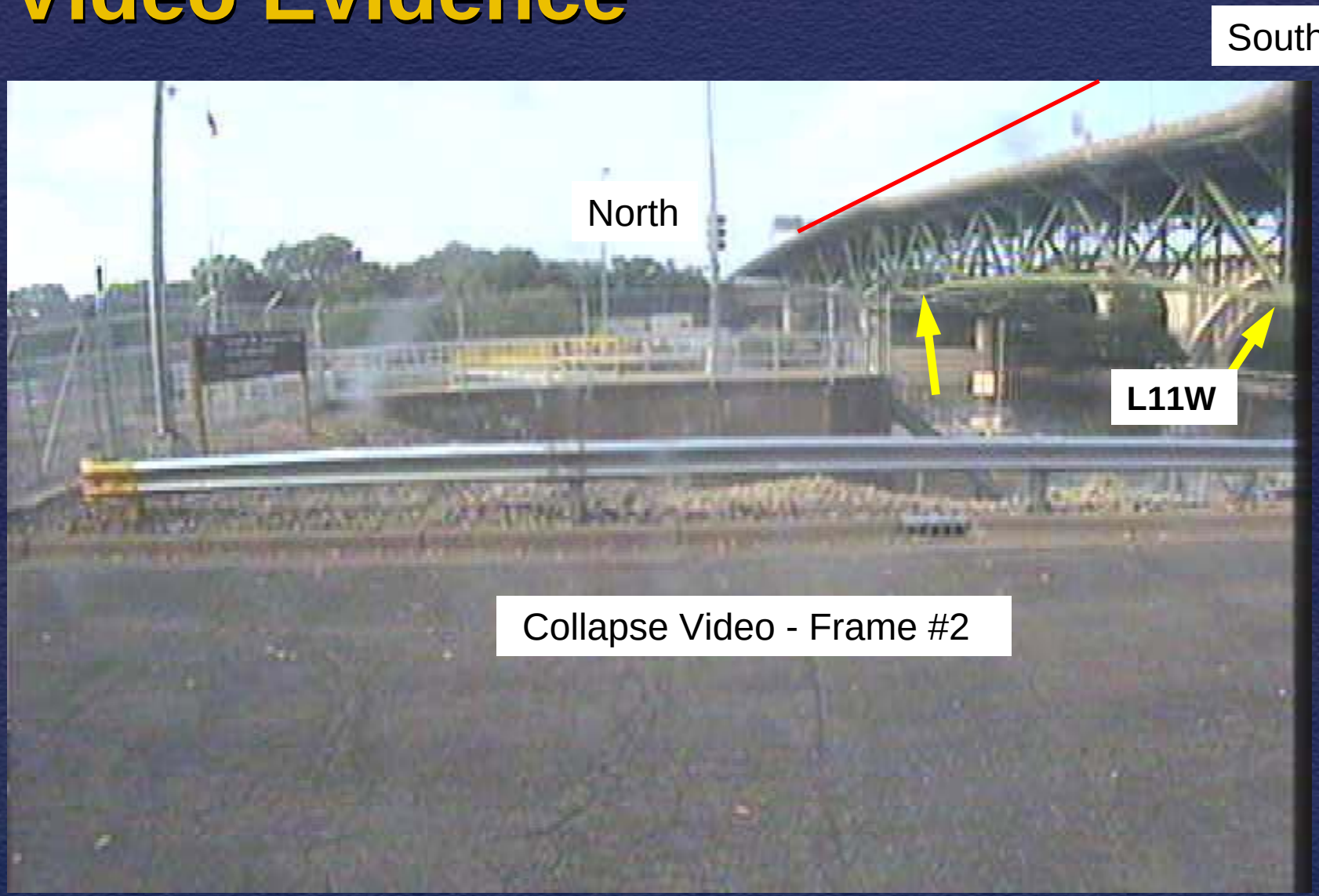

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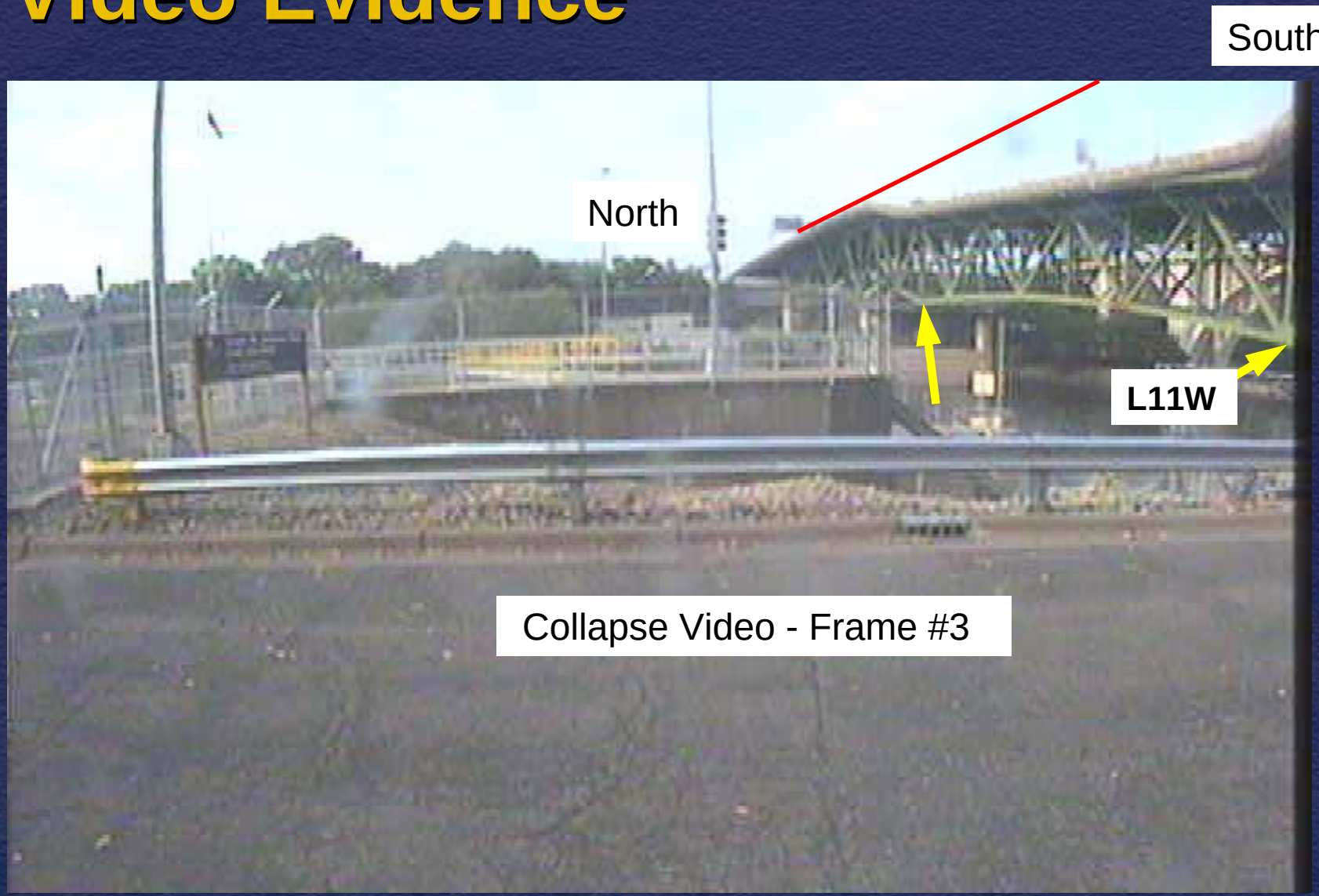

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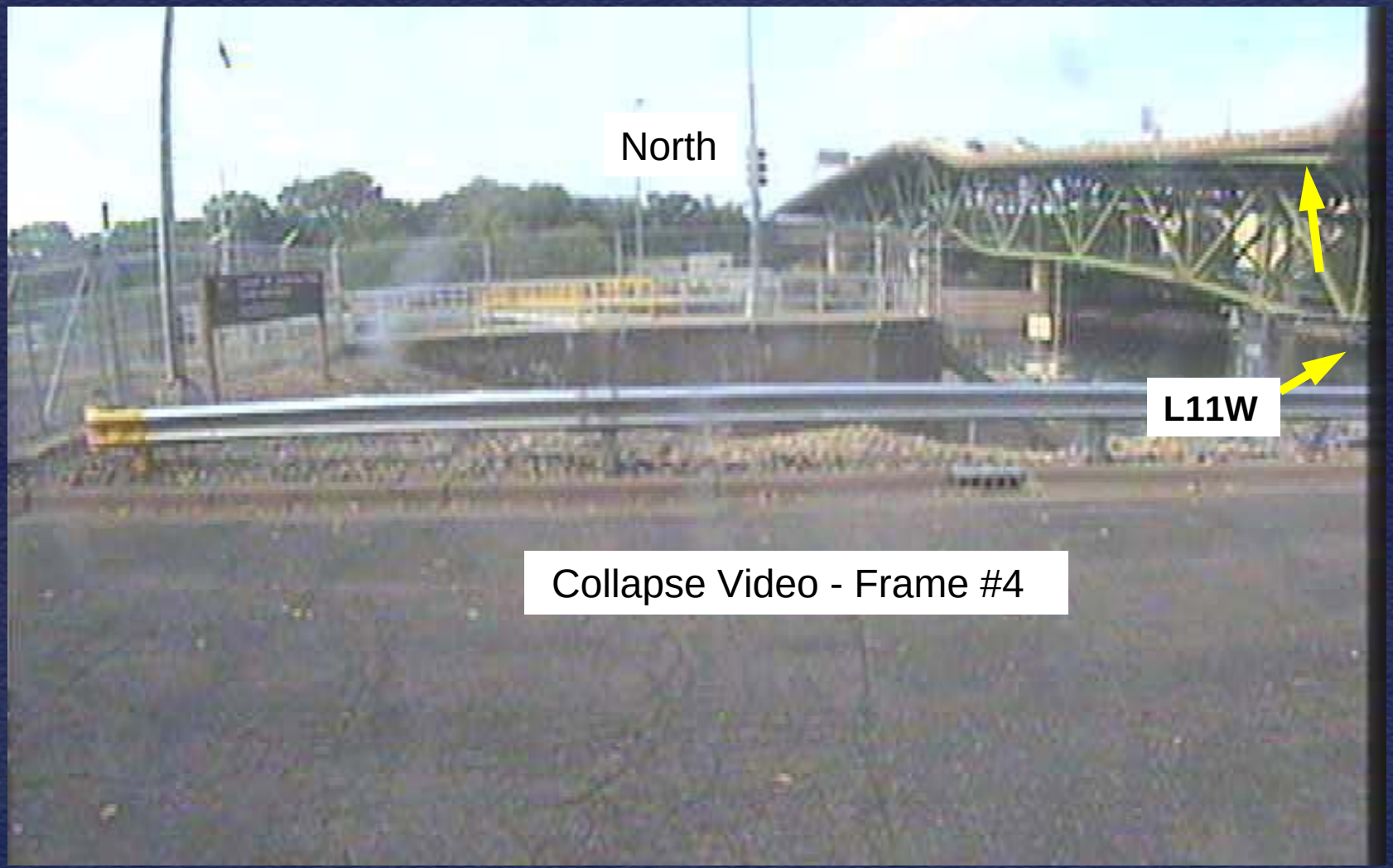

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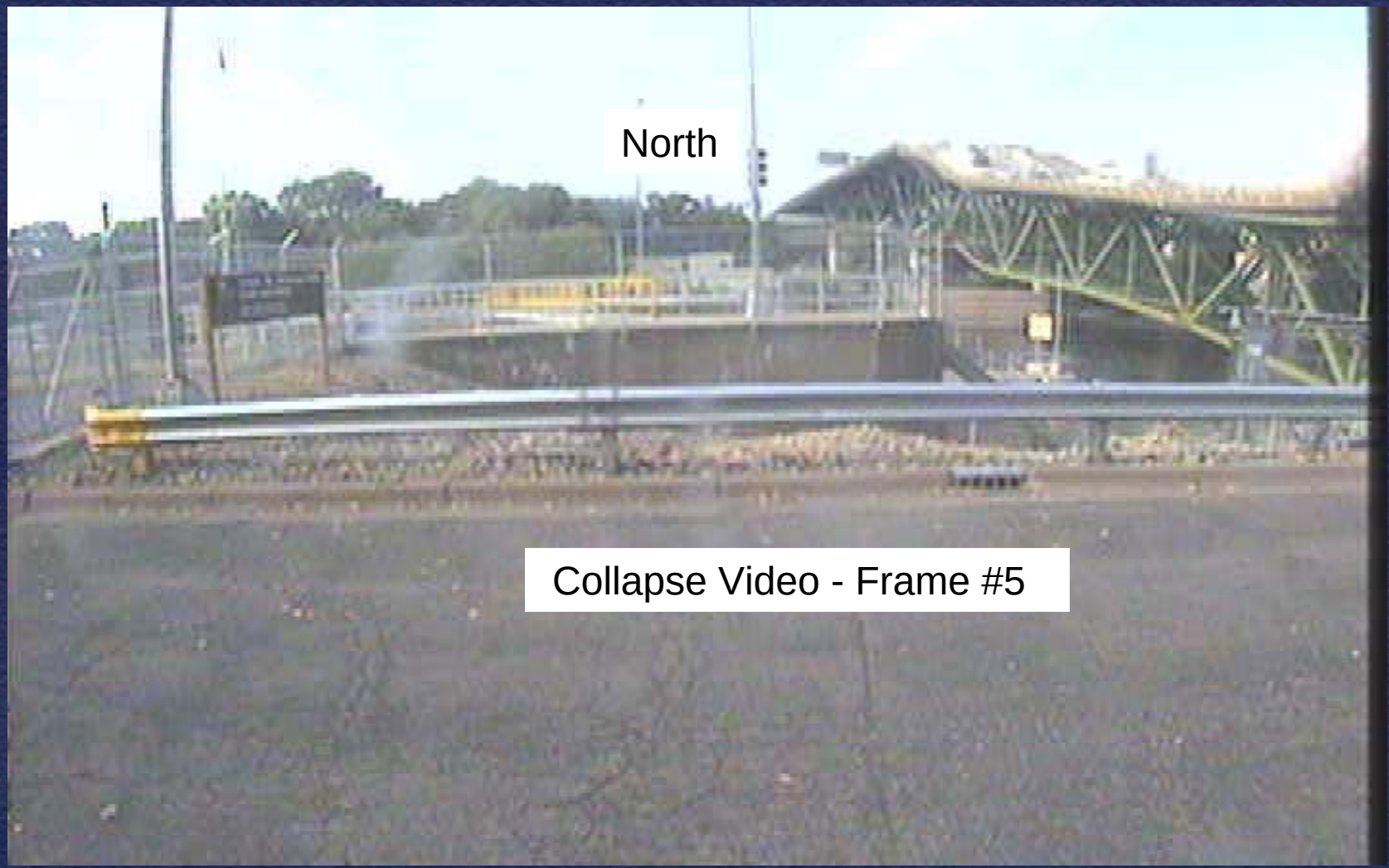

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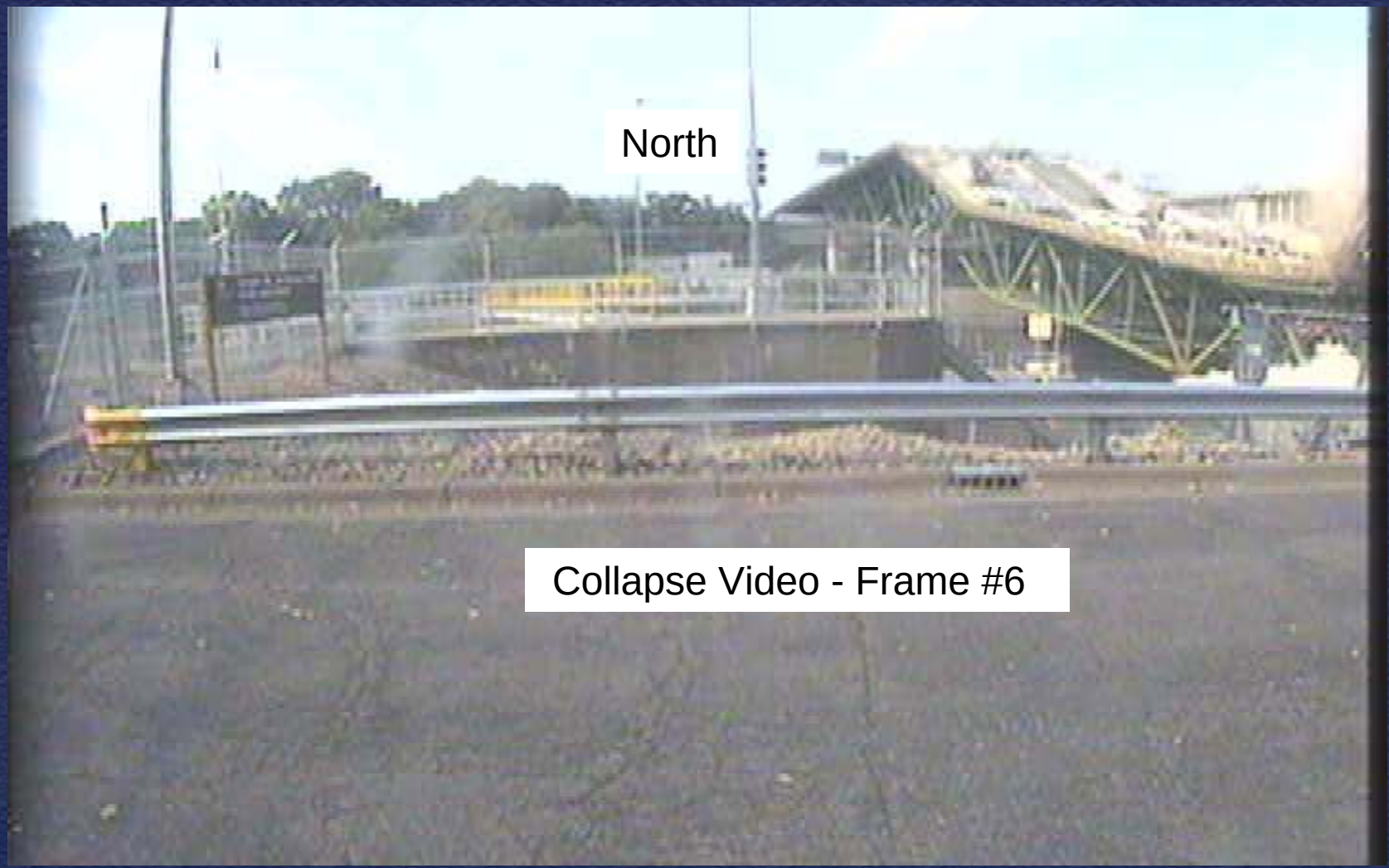

# Video Evidence

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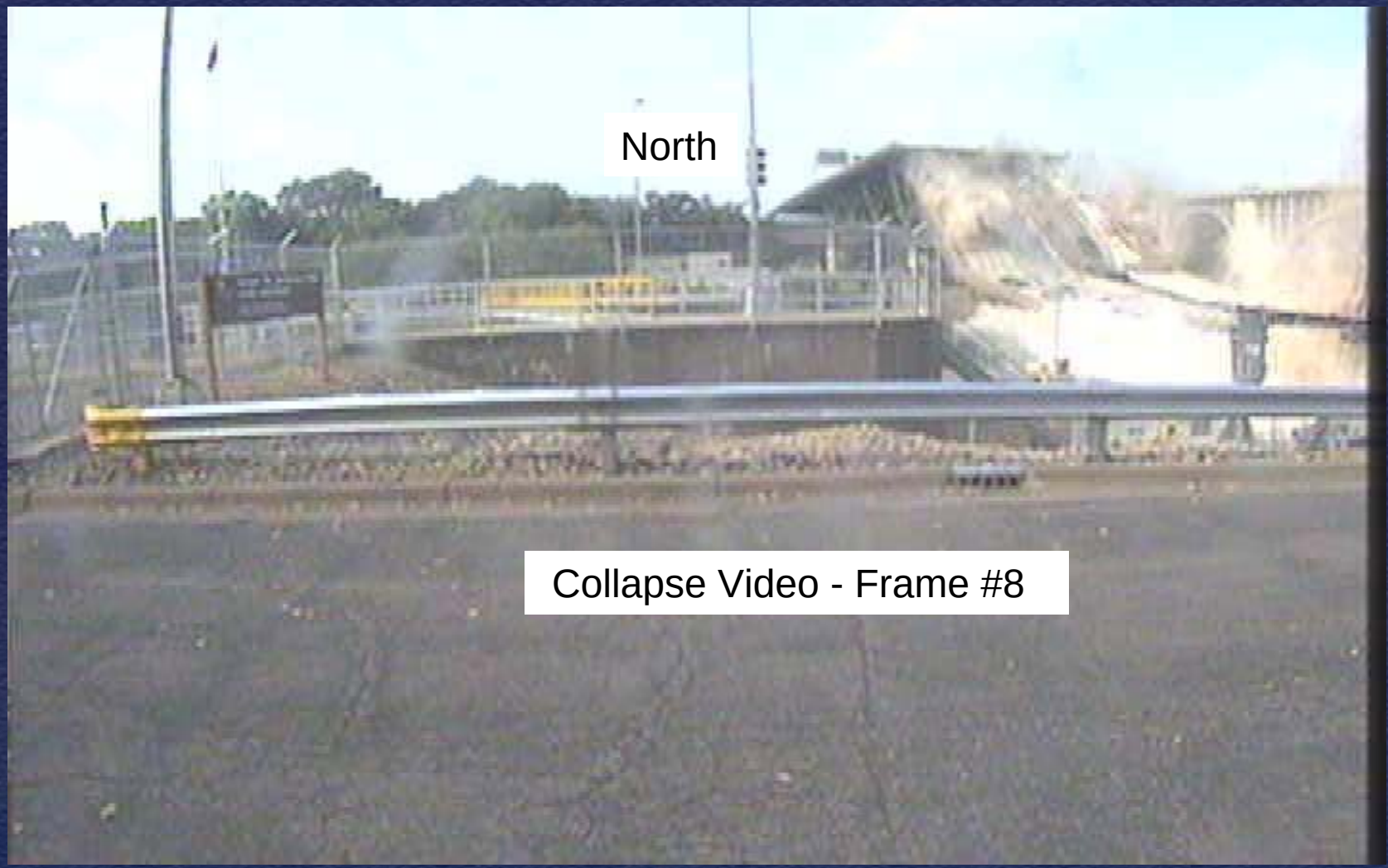

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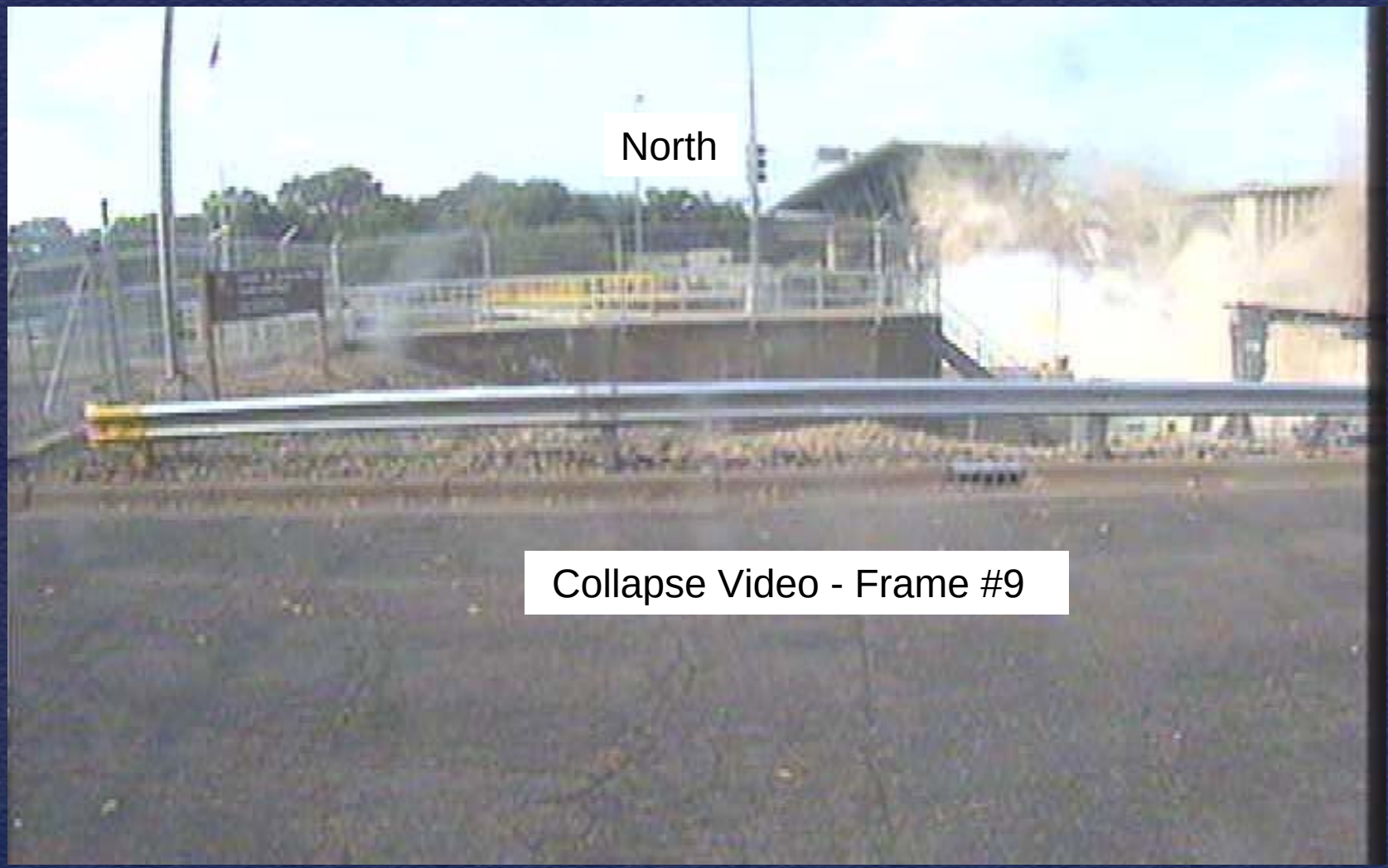

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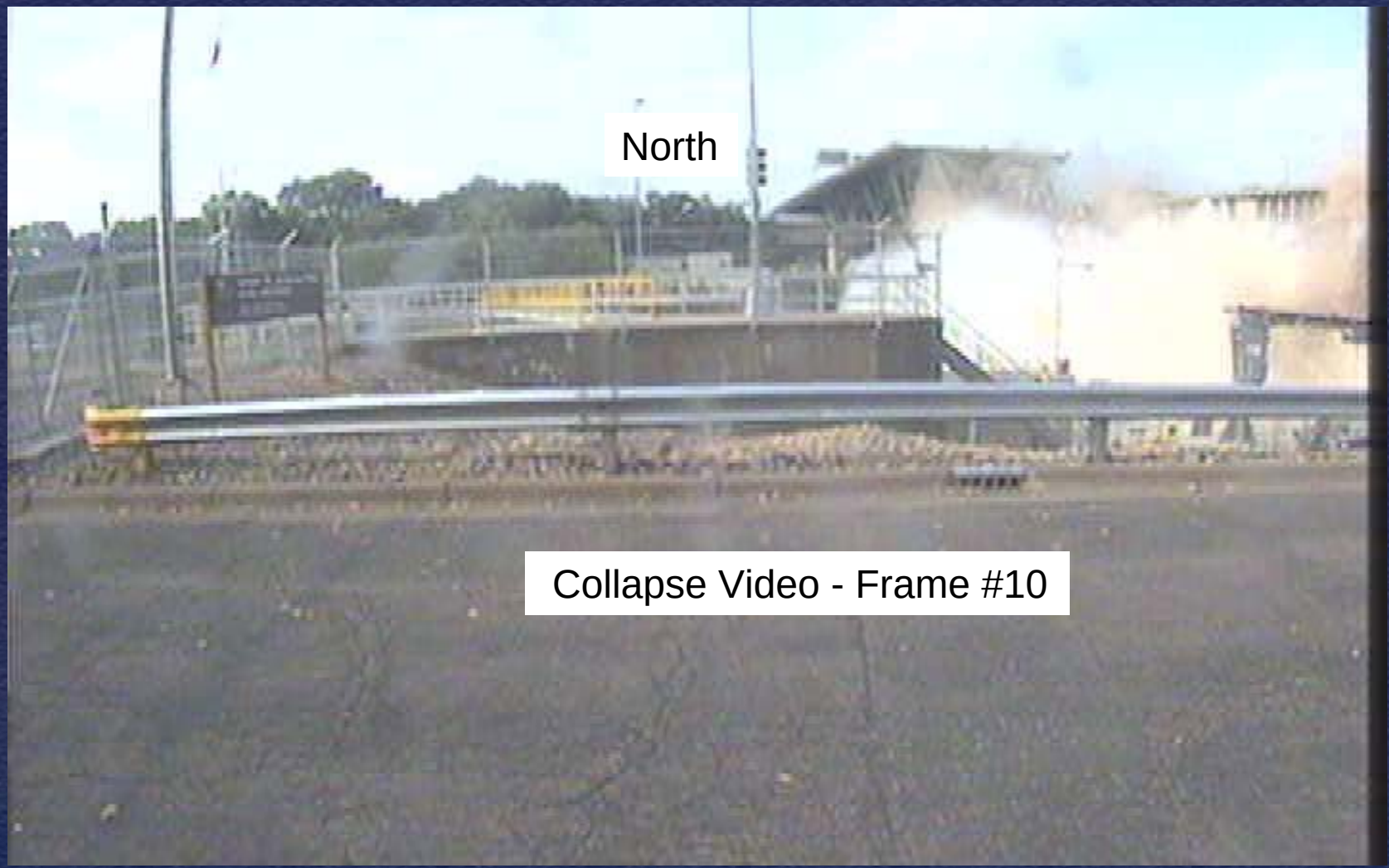
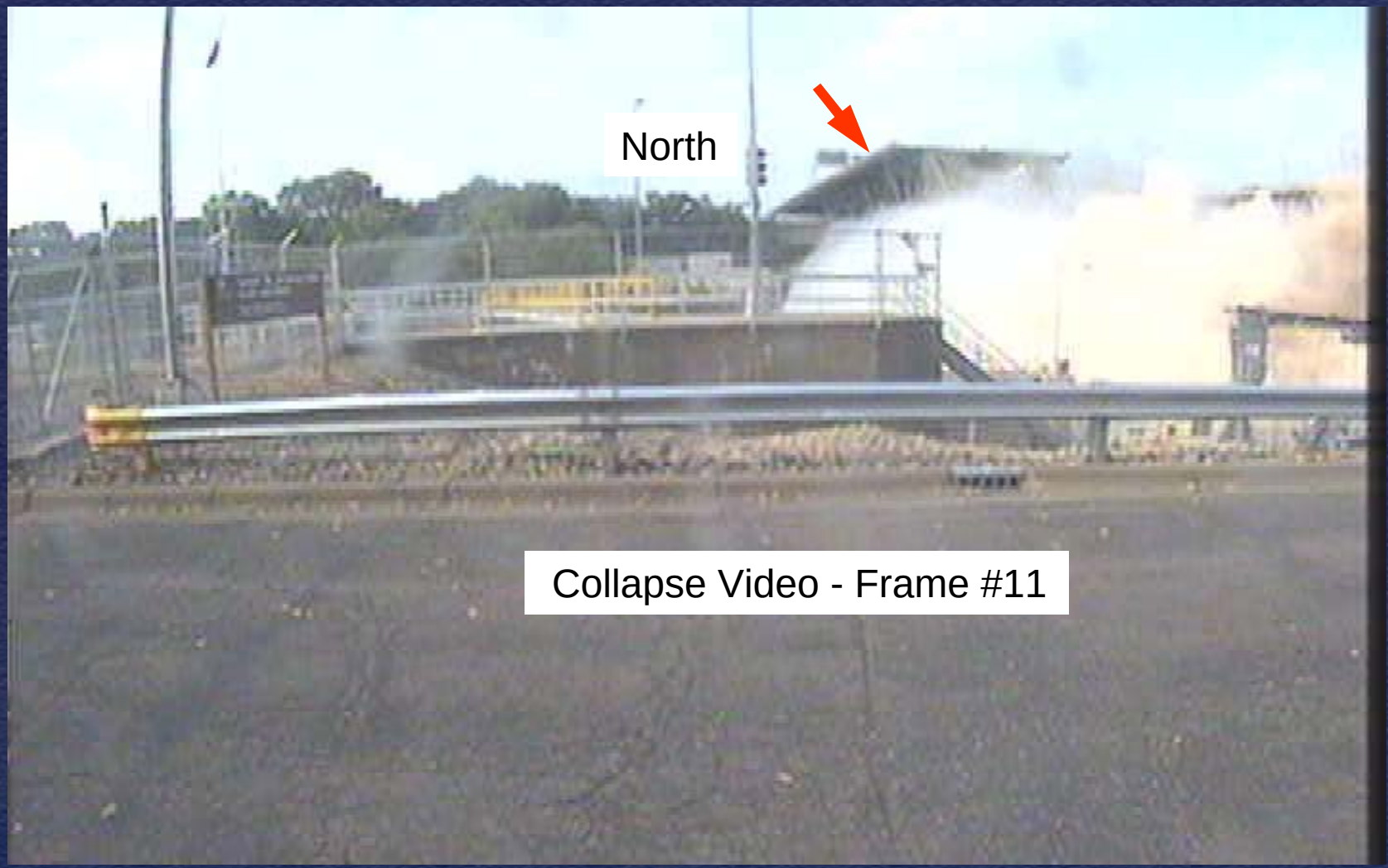


# Video Evidence

South



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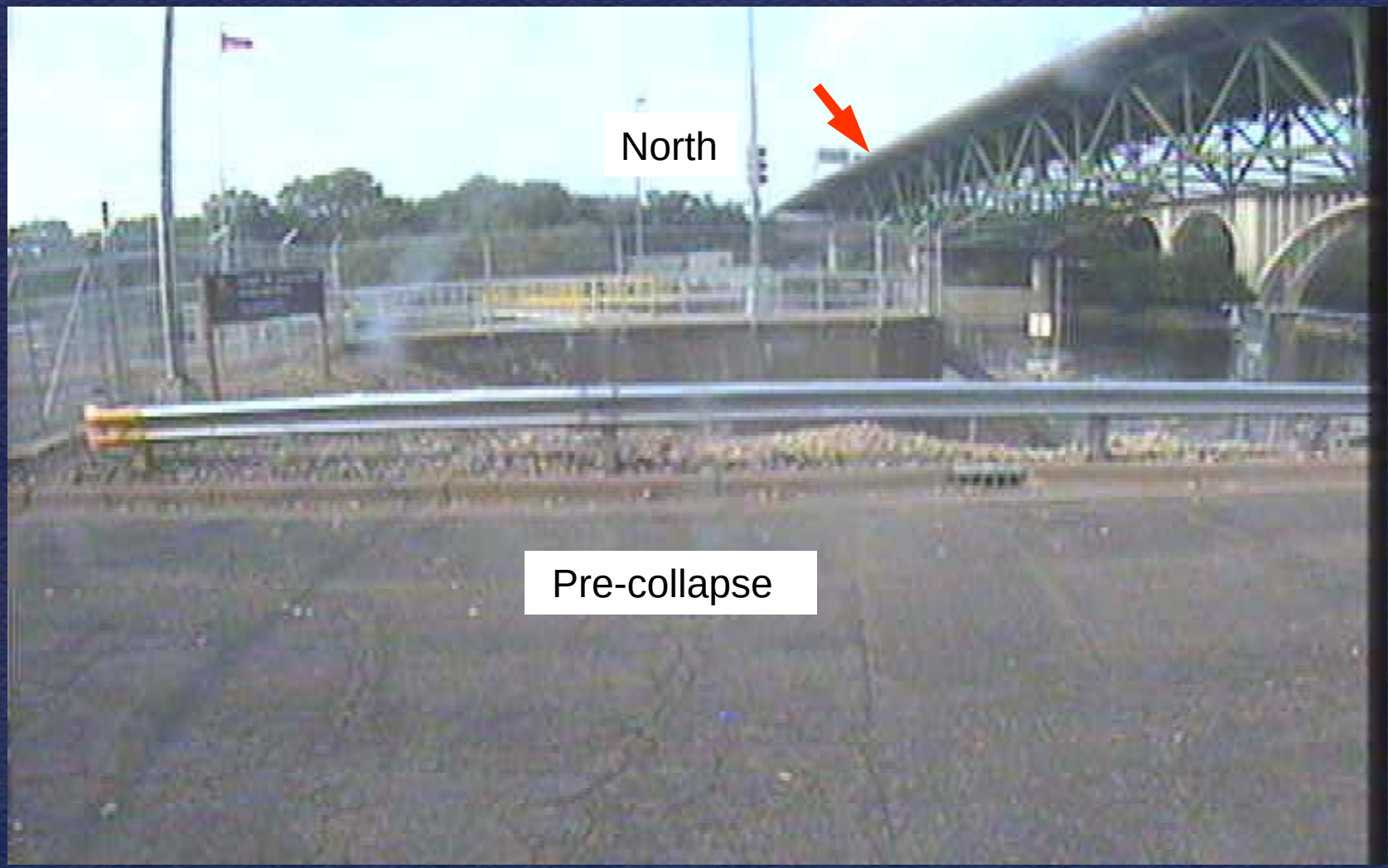


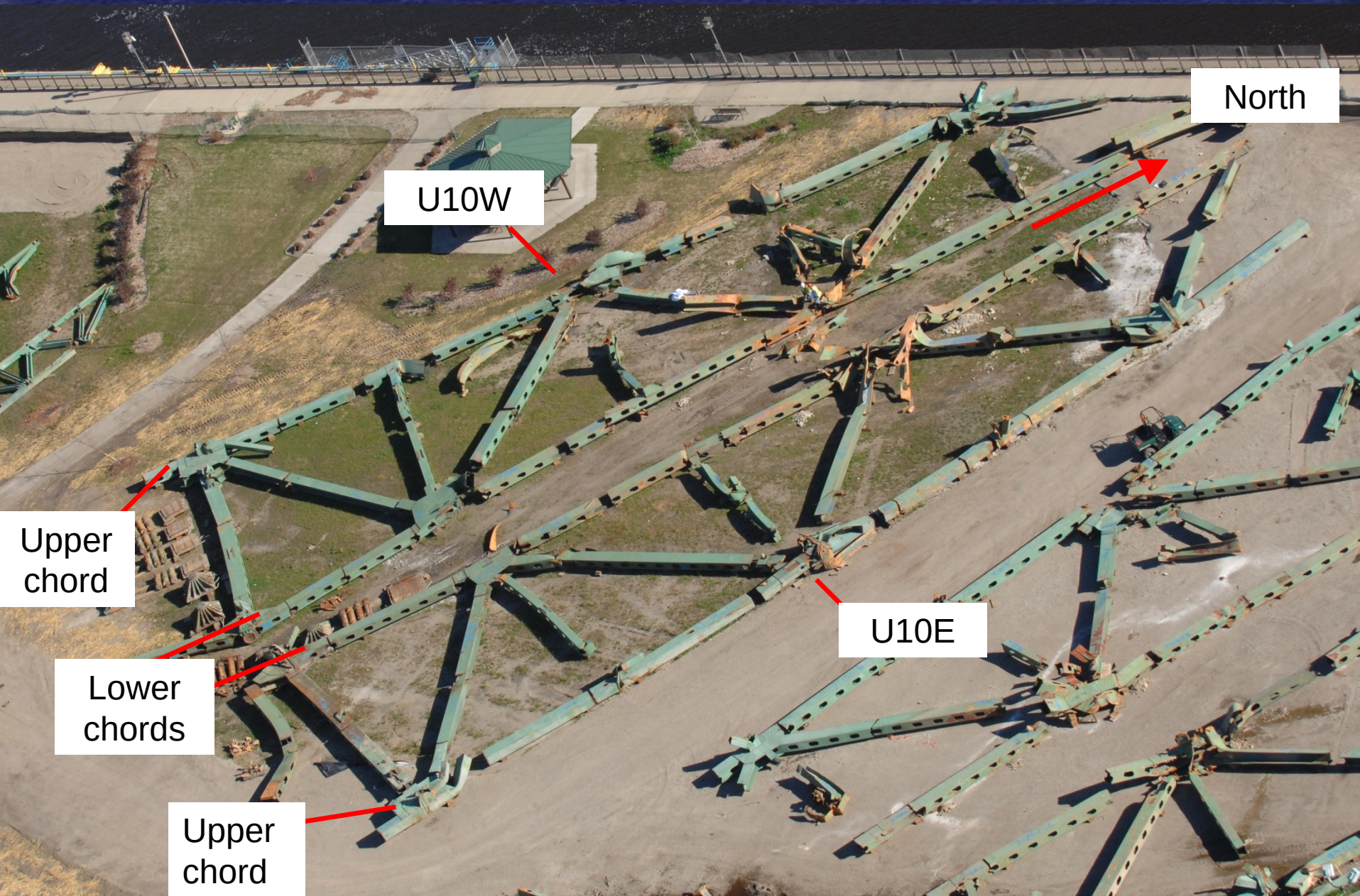
# Video Evidence

- No initiation in center section or north section
- Collapse initiated south of node L11
- Node L11W remained intact after collapse initiated
- Deck lifted from stringers above node L11 and further to the south

# Basis of Collapse Sequence

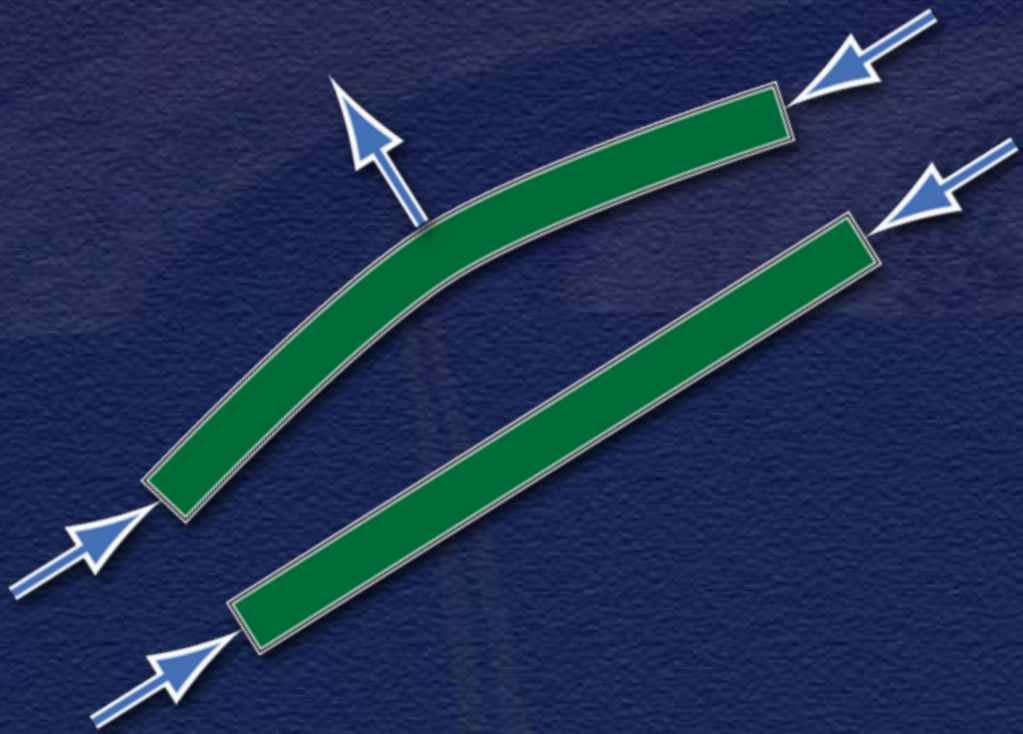
- Video evidence
- Fracture and damage patterns
- Finite element analysis

# Fracture and Deformation



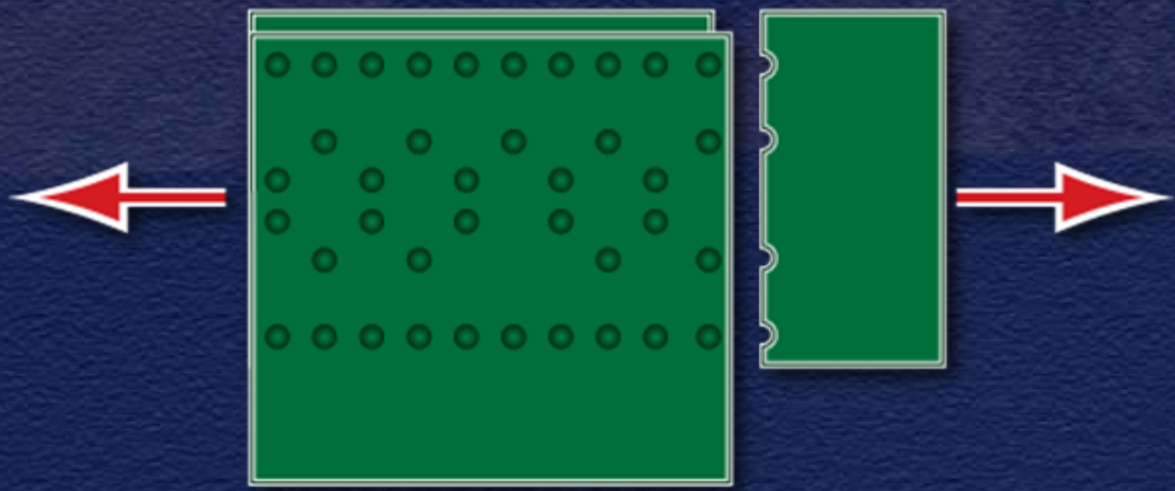
# Sequence of Collapse Methodology

- Initiating event occurs from forces acting along the members
  - Buckling under compression



# Sequence of Collapse Methodology

- Initiating event occurs from forces acting along the members
  - Buckling under compression
  - Tension fracture without bending



# Sequence of Collapse Methodology

- Deformation adjacent to fracture
  - Occurs during fracture process
  - Not from subsequent collision or ground impact

# Sequence of Collapse Methodology

- Documentation
  - Fractures
  - Deformation patterns
  - Impact marks
- Damage evaluation
  - Early in collapse process?
  - From subsequent ground or riverbed impact?

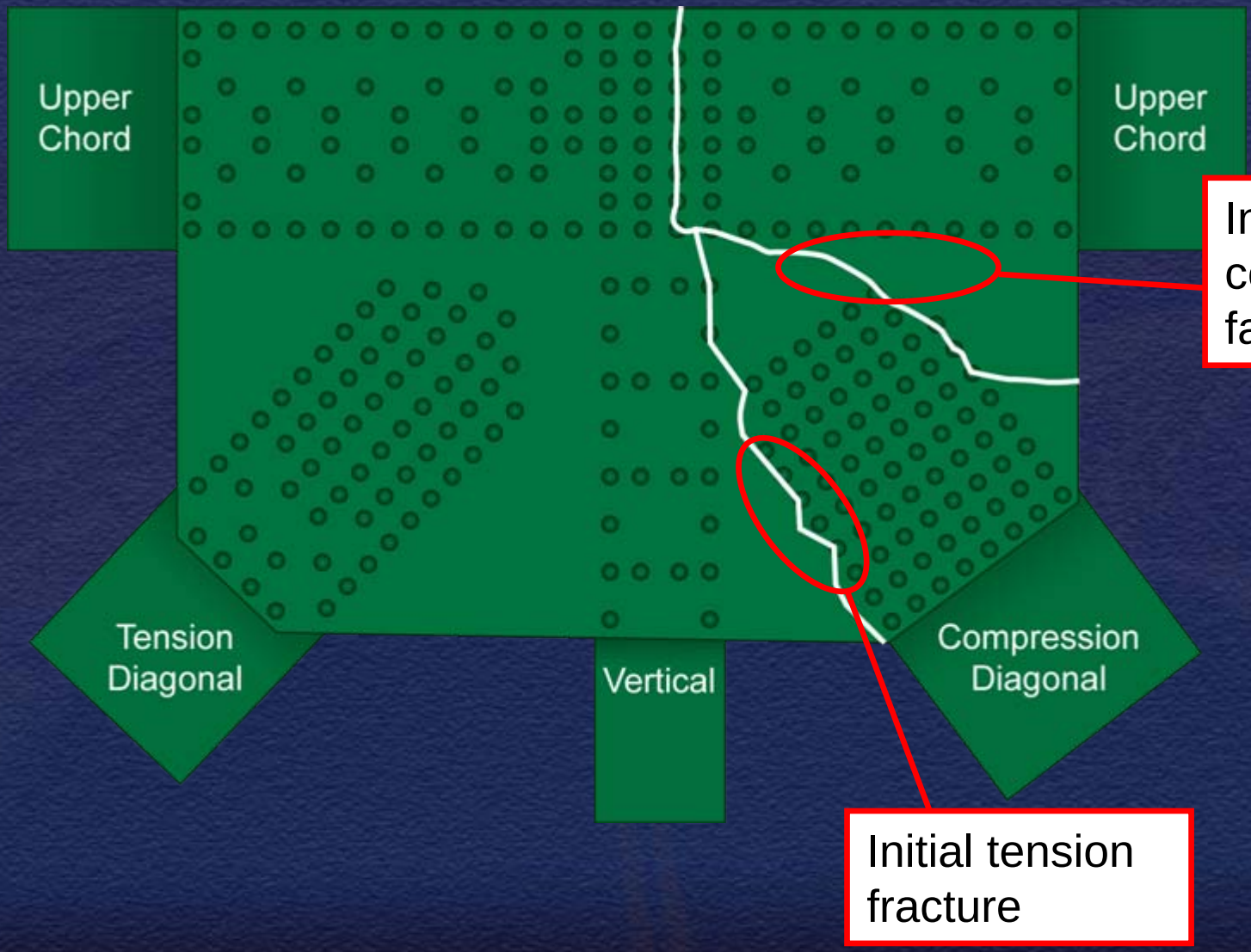
# Sequence of Collapse Methodology

- Methodology used in other investigations
  - TWA Flight 800
  - Rail from Baltimore railroad tunnel fire

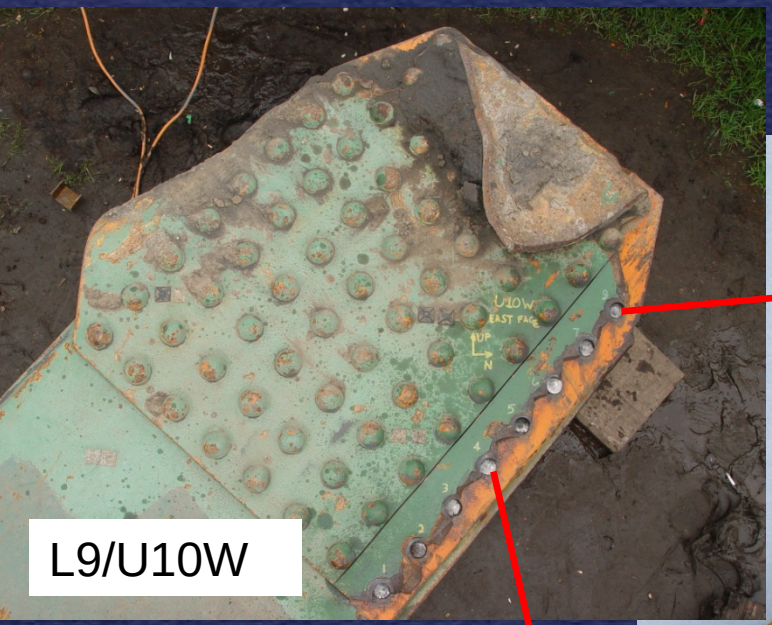
# Sequence of Collapse Results

- Main trusses fractured between nodes 9 and 10
- Fractures in node U10 gusset plates met initial event criteria

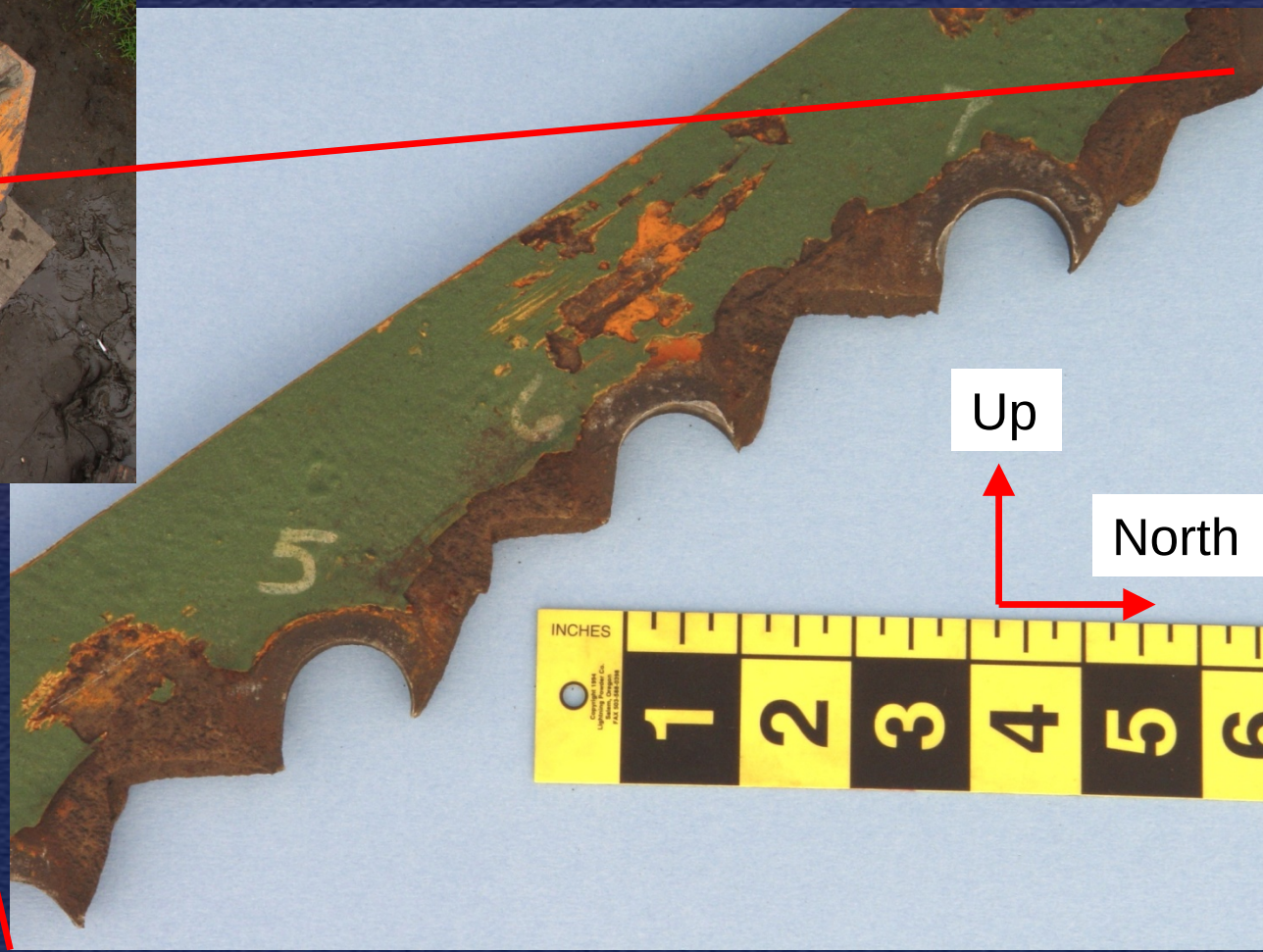
# Drawing of Fractures in Node U10E West Gusset Plate

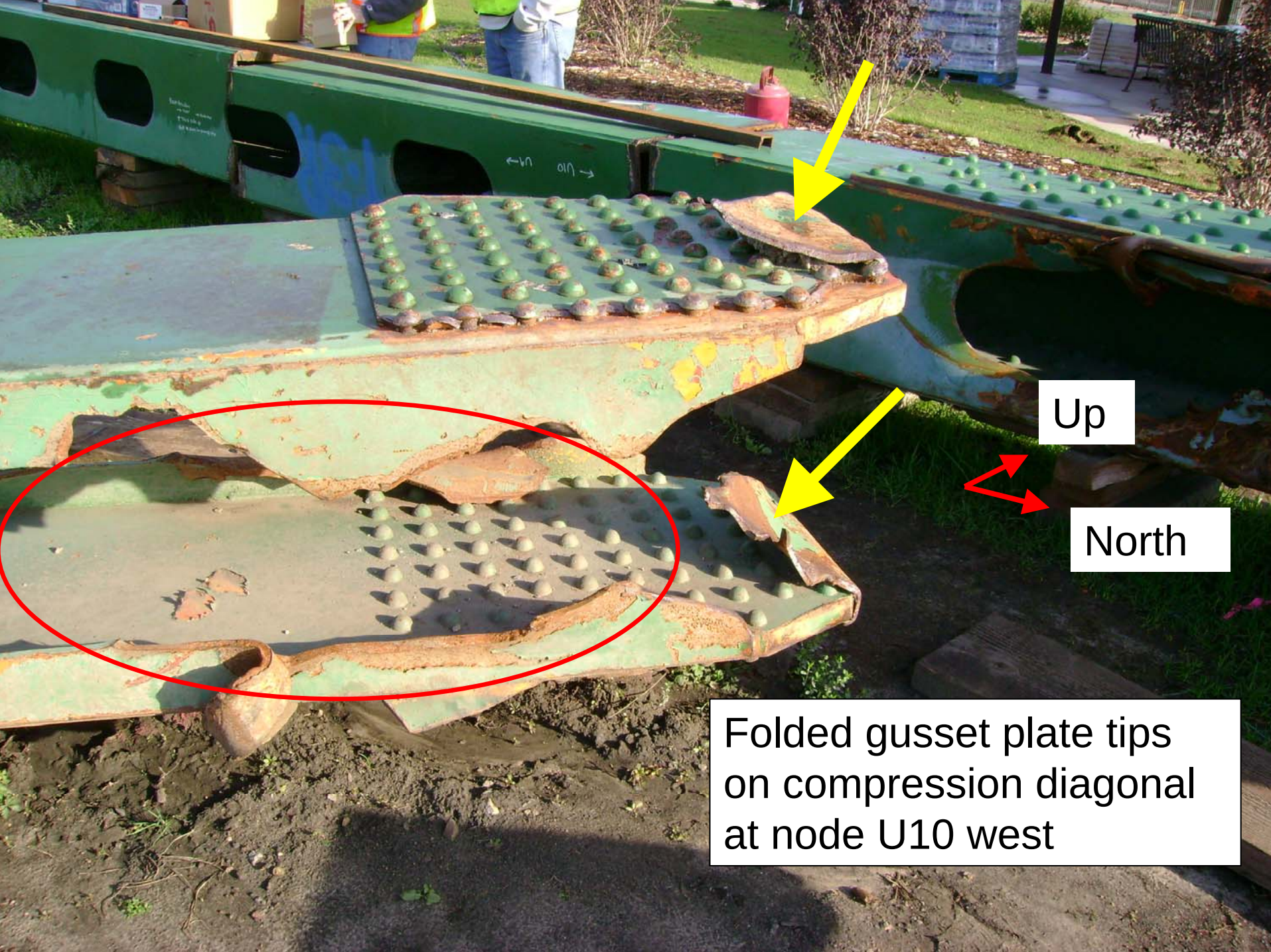


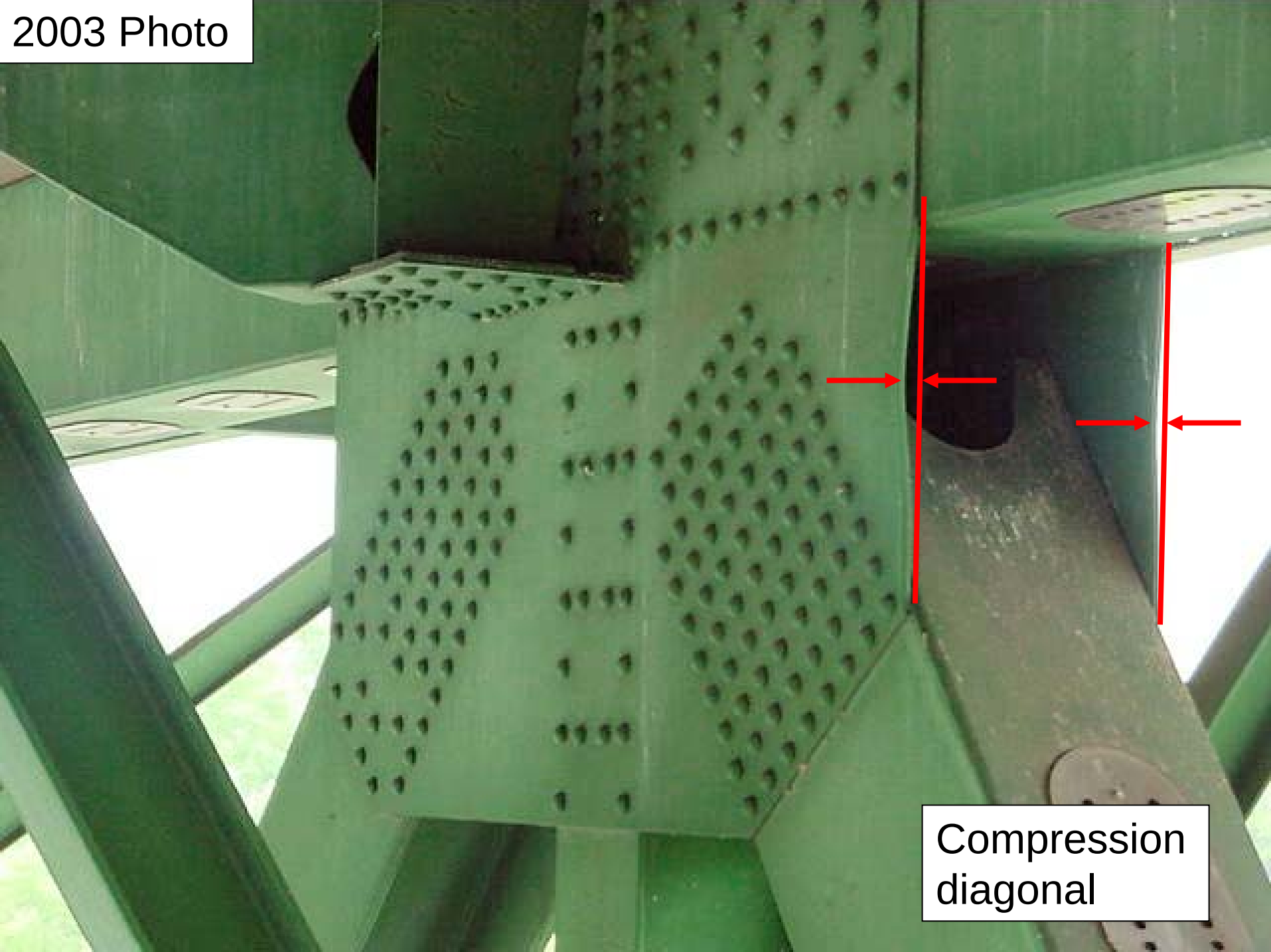
# Initial Tension Fracture U10 West




L9/U10W

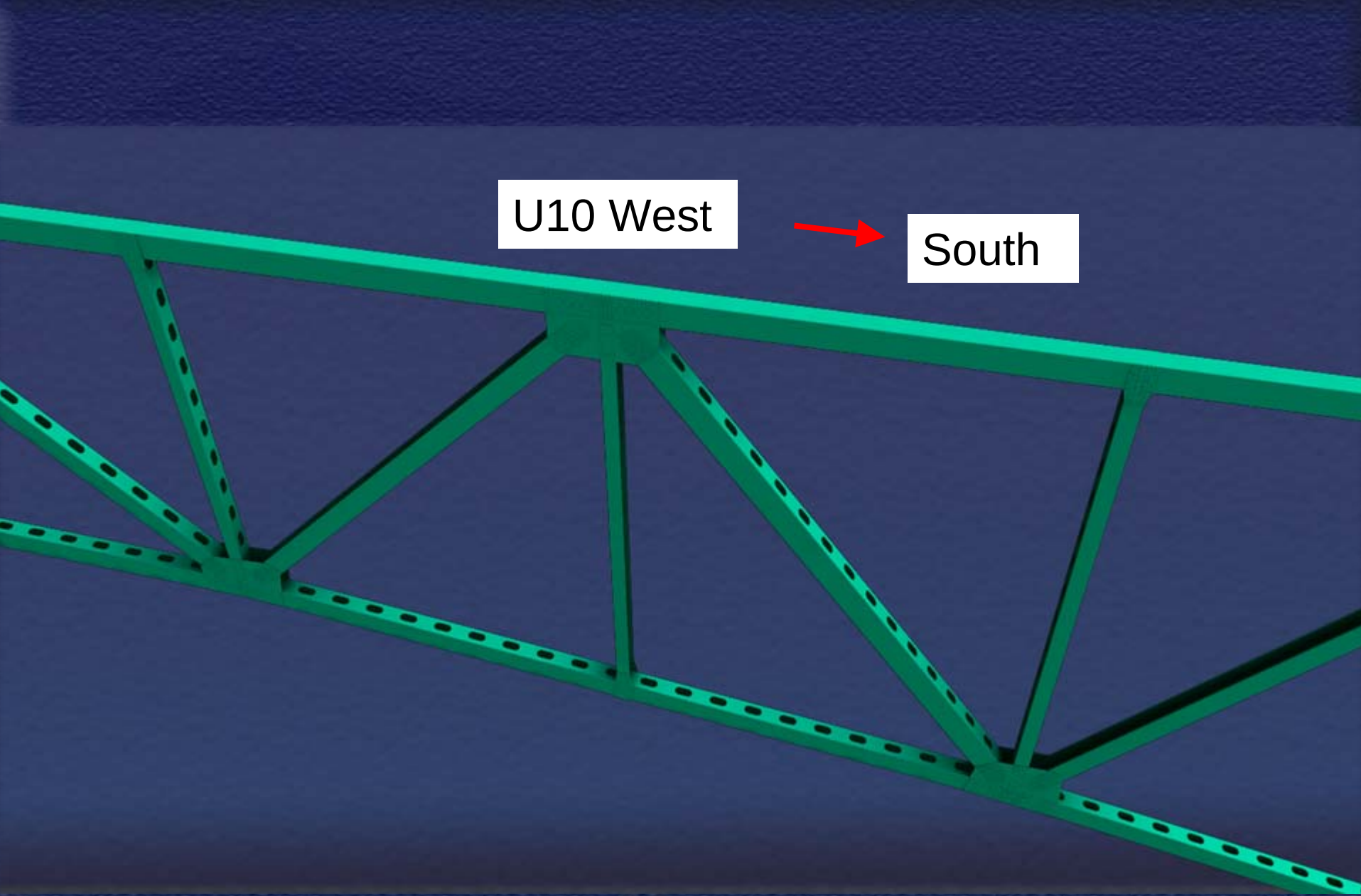


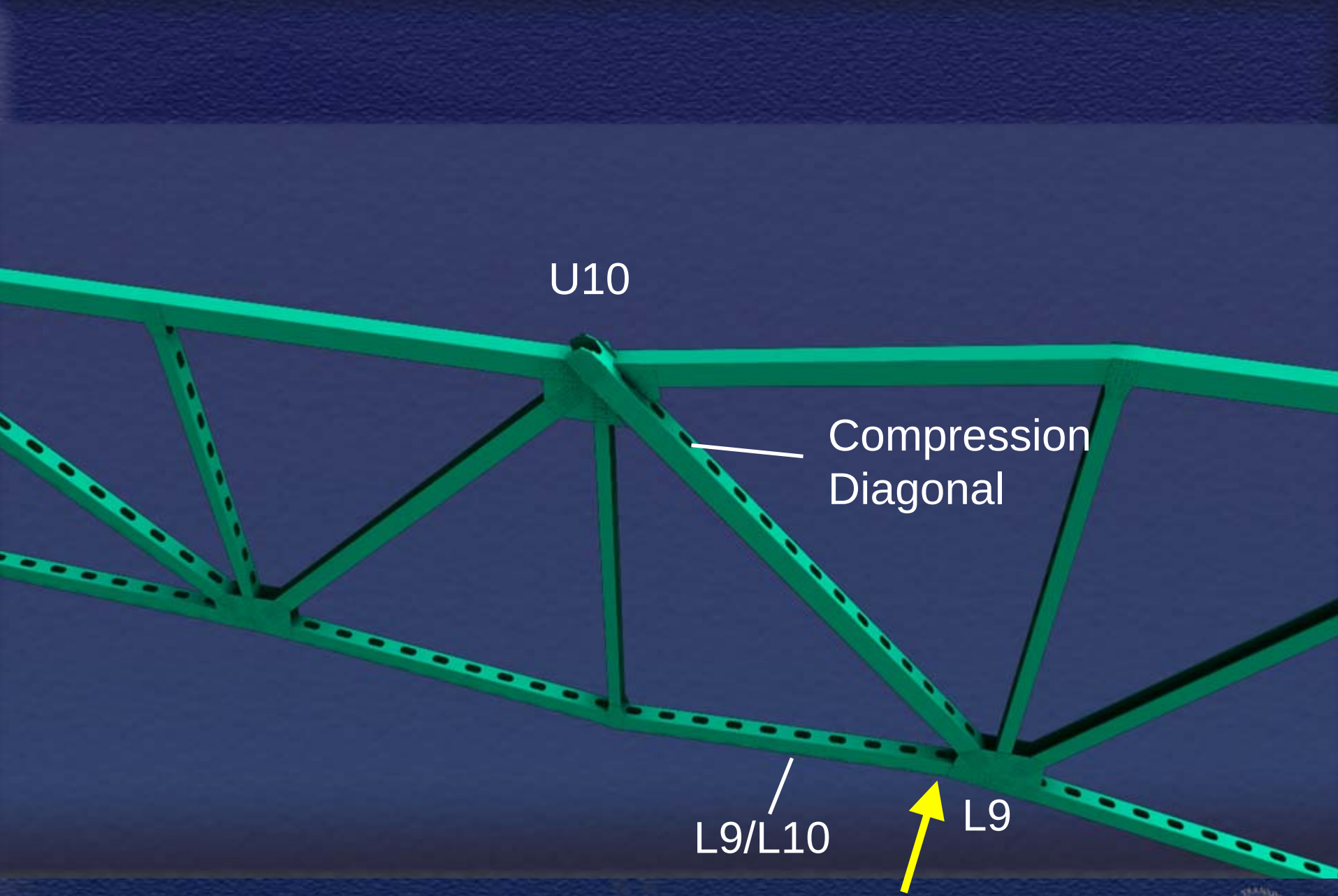

Up
North
Folded gusset plate tips
on compression diagonal
at node U10 west


2003 Photo
Compression diagonal

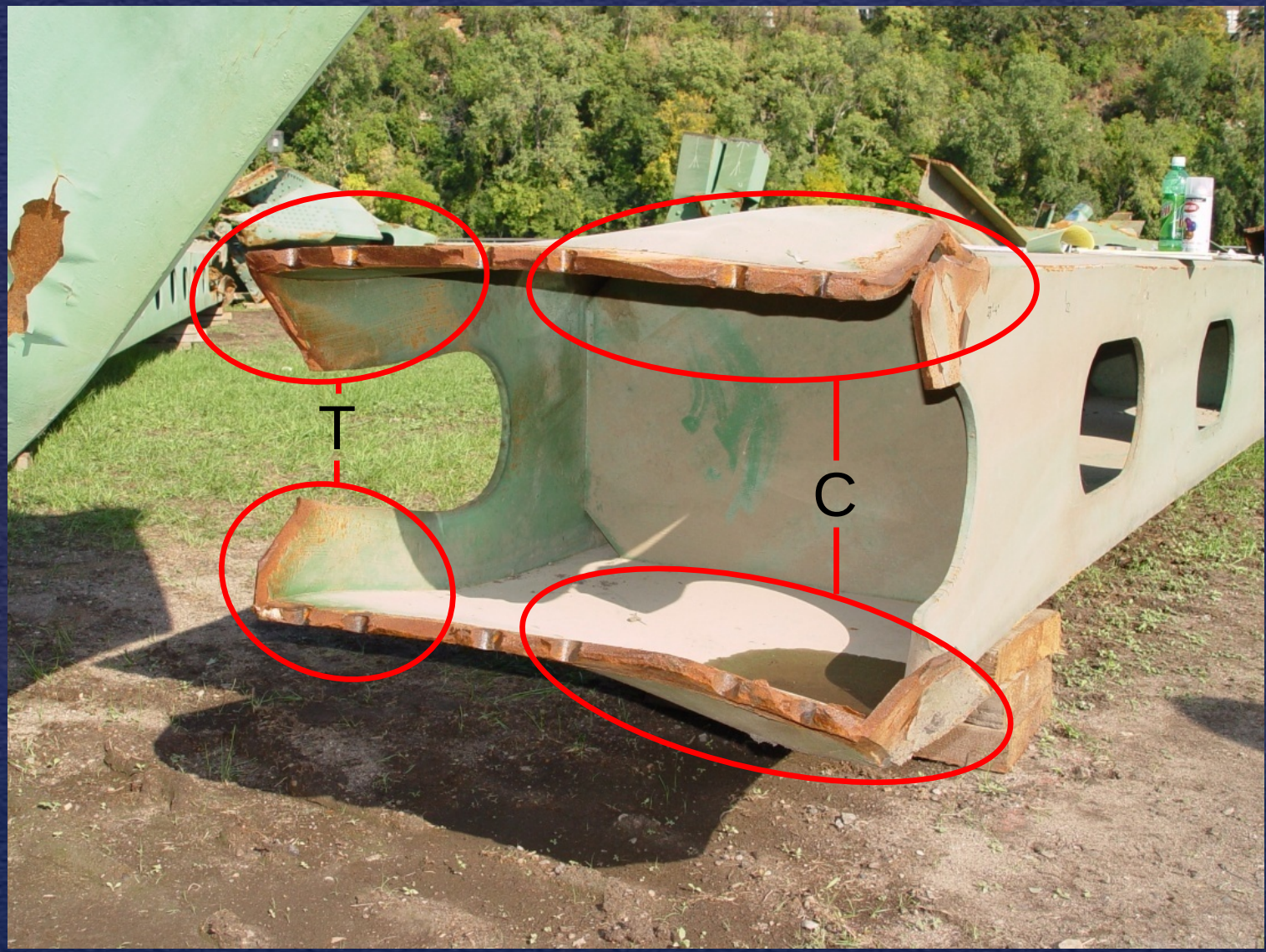
# Collapse Initiation

- Initial failure in U10 gusset plates
  - Compression failure above compression diagonal
  - Tension fracture
- Collapse was unavoidable once gusset plates failed at node U10


U10 West
South

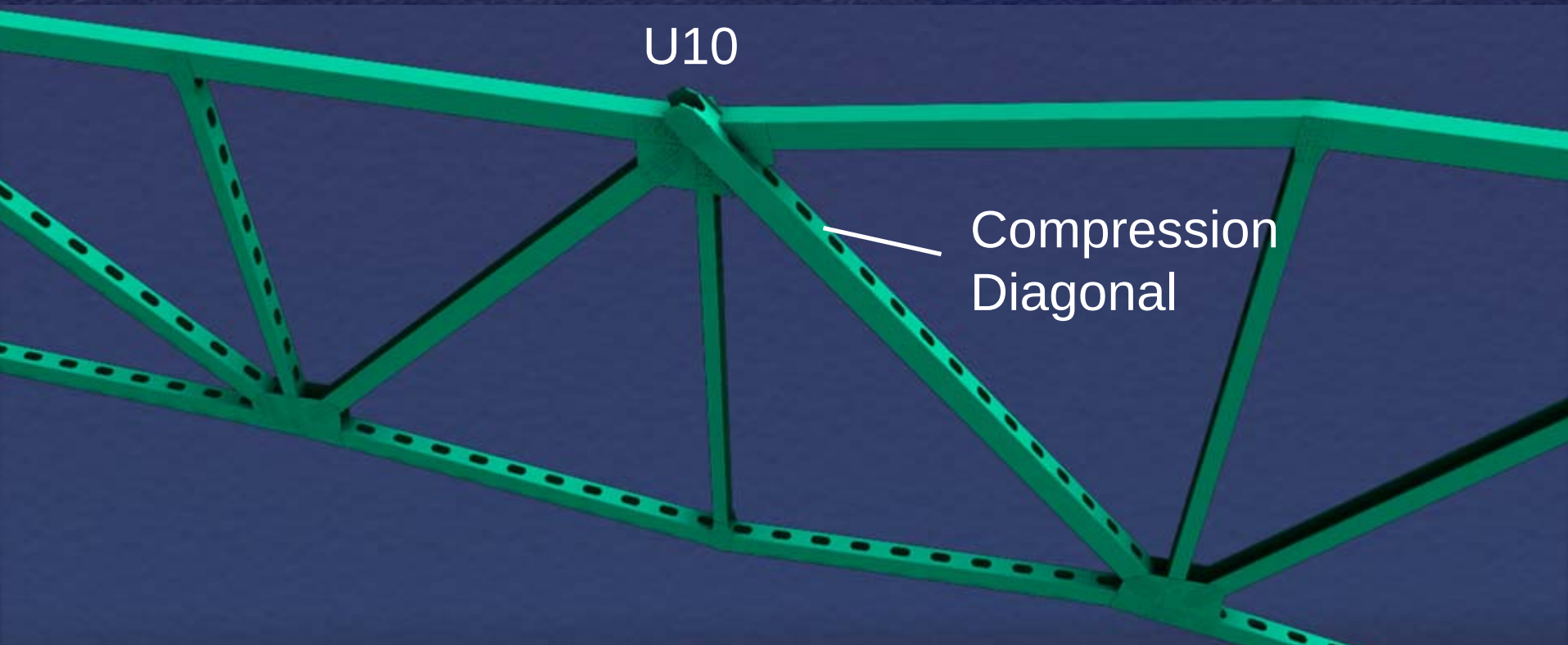

U10
Compression
Diagonal
L9/L10
L9

# Secondary Damage - Bent and Fractured Member



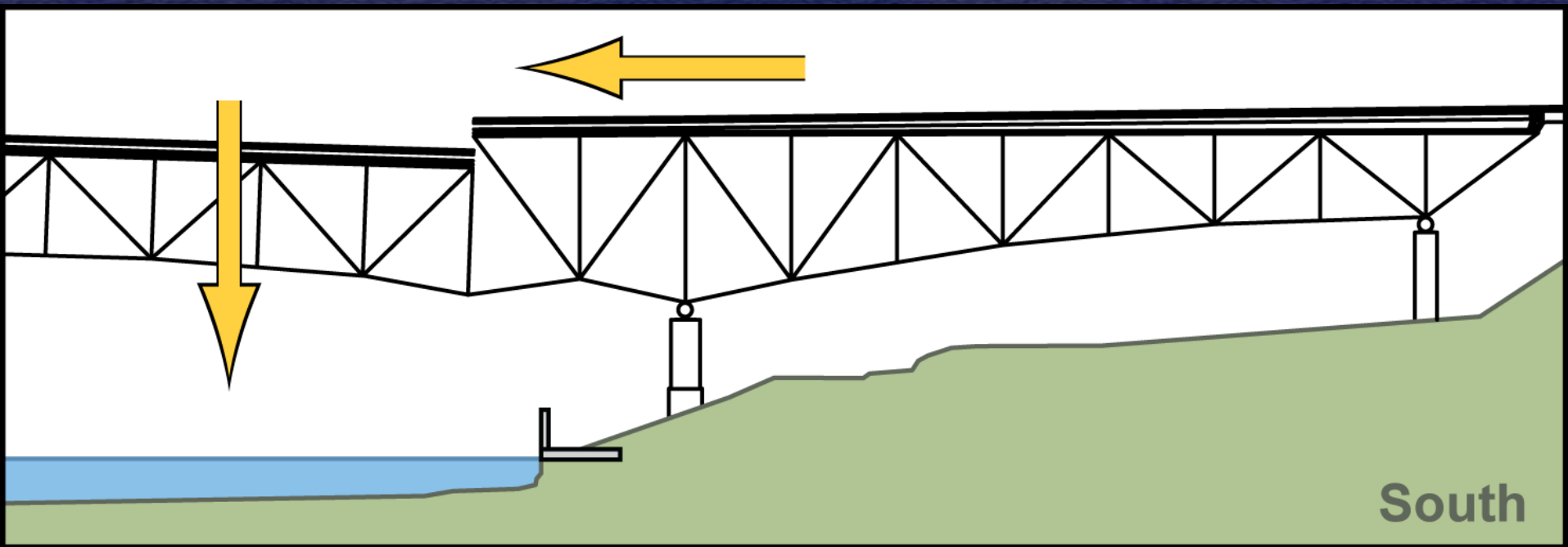
# Sequence of Collapse

1. Gusset plates at nodes U10 failed, compression diagonals translated to the west, and remaining portions of nodes U10 were pulled down and through diagonals



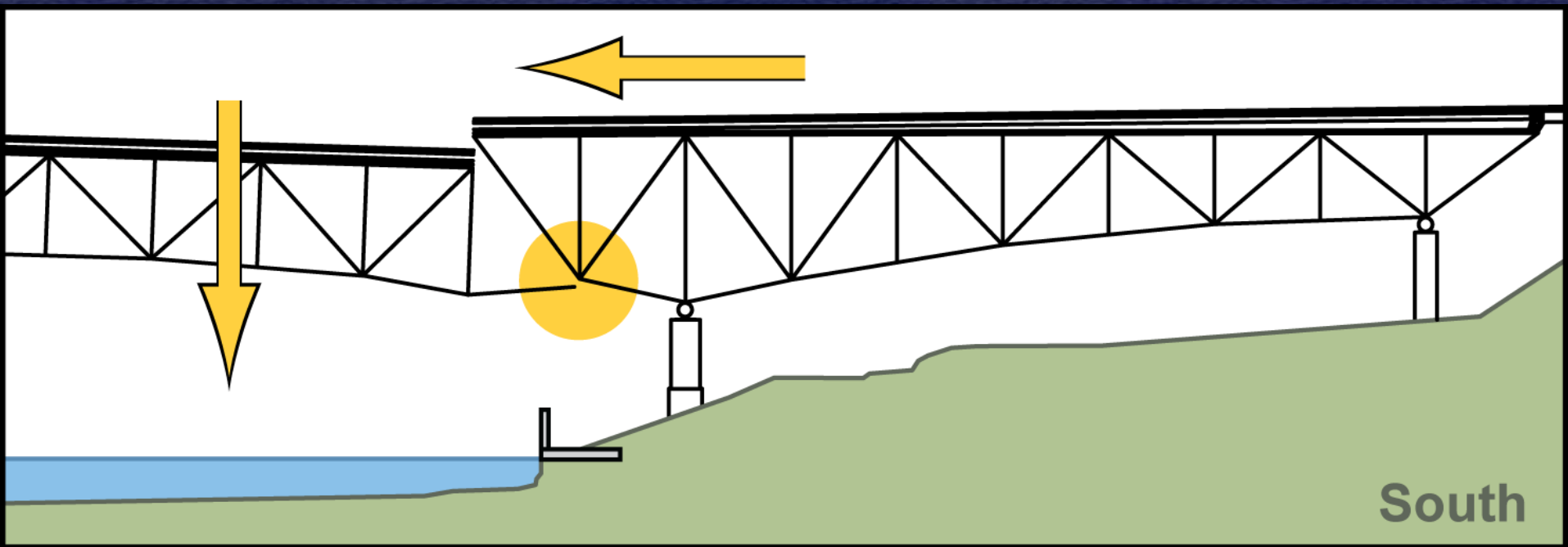
# Sequence of Collapse

2. Dropping of center span created tension loading in main truss lower chords and secondary structural members. This loading pulled south portion of deck truss to the north, off pier 5, causing loss of support for south approach spans



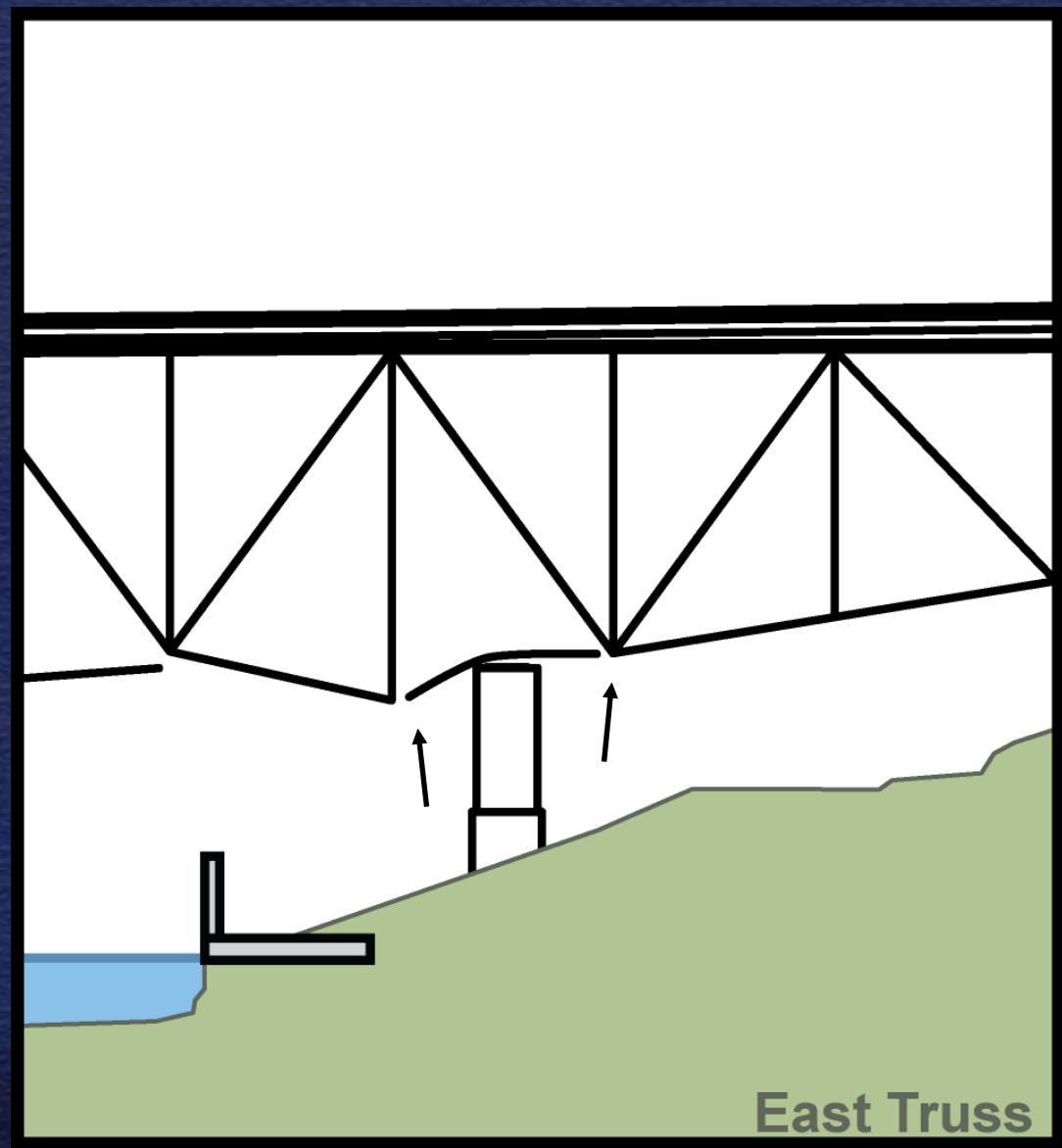
# Sequence of Collapse

3. Other main truss members fractured in bending

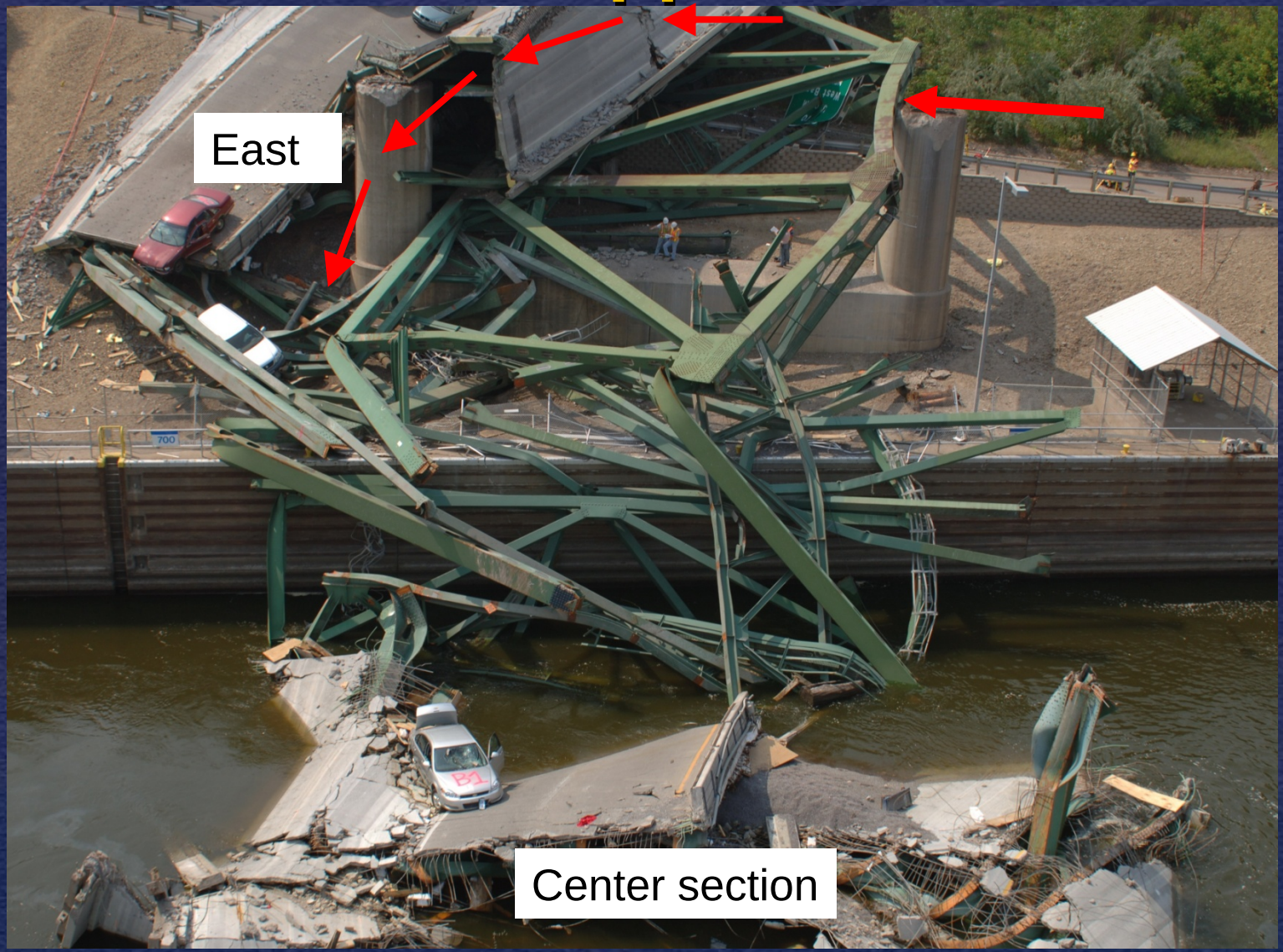


# Sequence of Collapse

4. Lower chord L7/L8 east fractured from its nodes, allowing south portion of truss to topple to the east

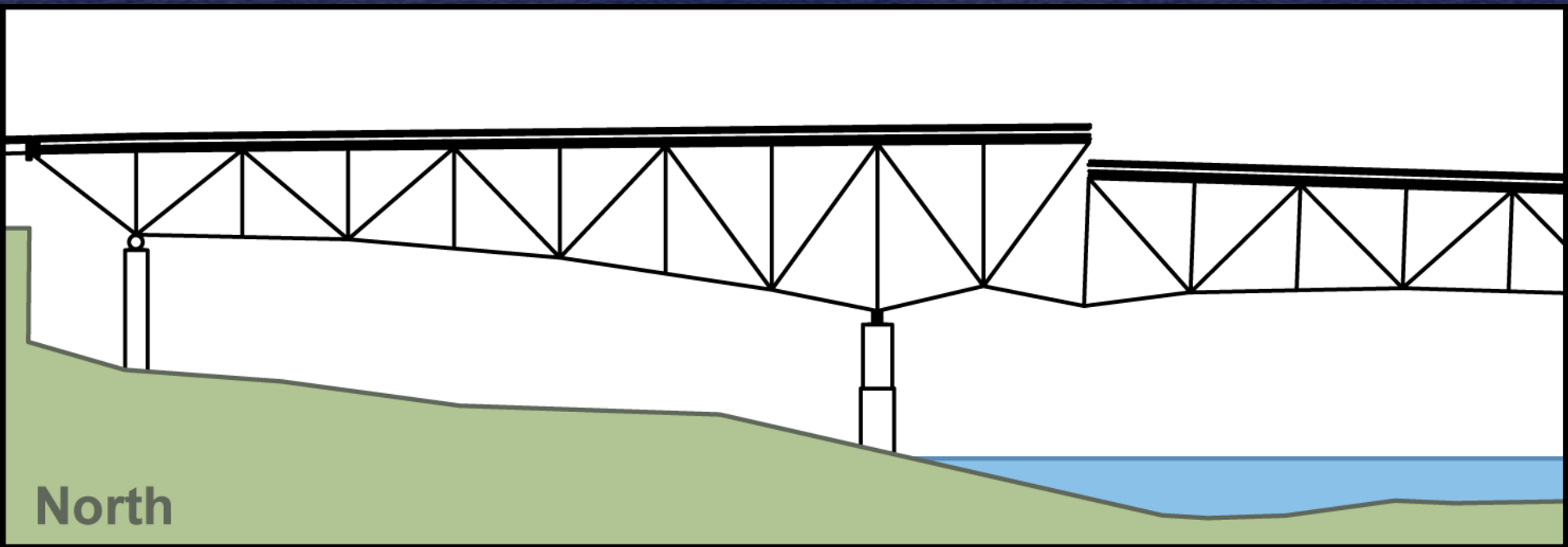


# South Portion Toppled to the East



# Sequence of Collapse

5. Gusset plates at node U10′ failed, and additional secondary failures in this portion of the truss completely separated the center section of the center span from remainder of deck truss



# Sequence of Collapse

6. Deck truss collapsed above pier 8, causing loss of support for north approach spans, and this collapse spread southward toward pier 7

# Factors That Did Not Contribute

- Corrosion damage
- Fracture of a floor truss
- Pre-existing cracking
- Bearings and piers

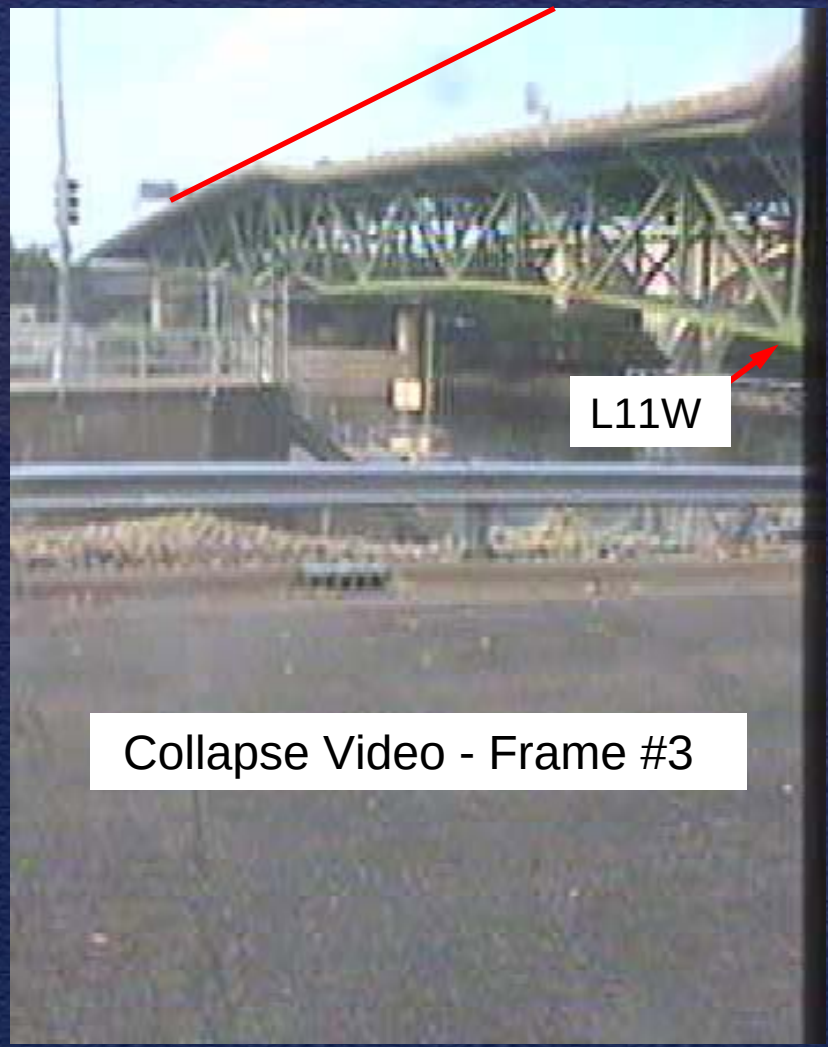
# Corrosion Damage

- Some corrosion present
  - Secondary members
  - Lower chord gusset plates
- Inspection records documented corrosion

# Corrosion Did Not Contribute

L11 gusset plates failure eliminated as factor as shown by:

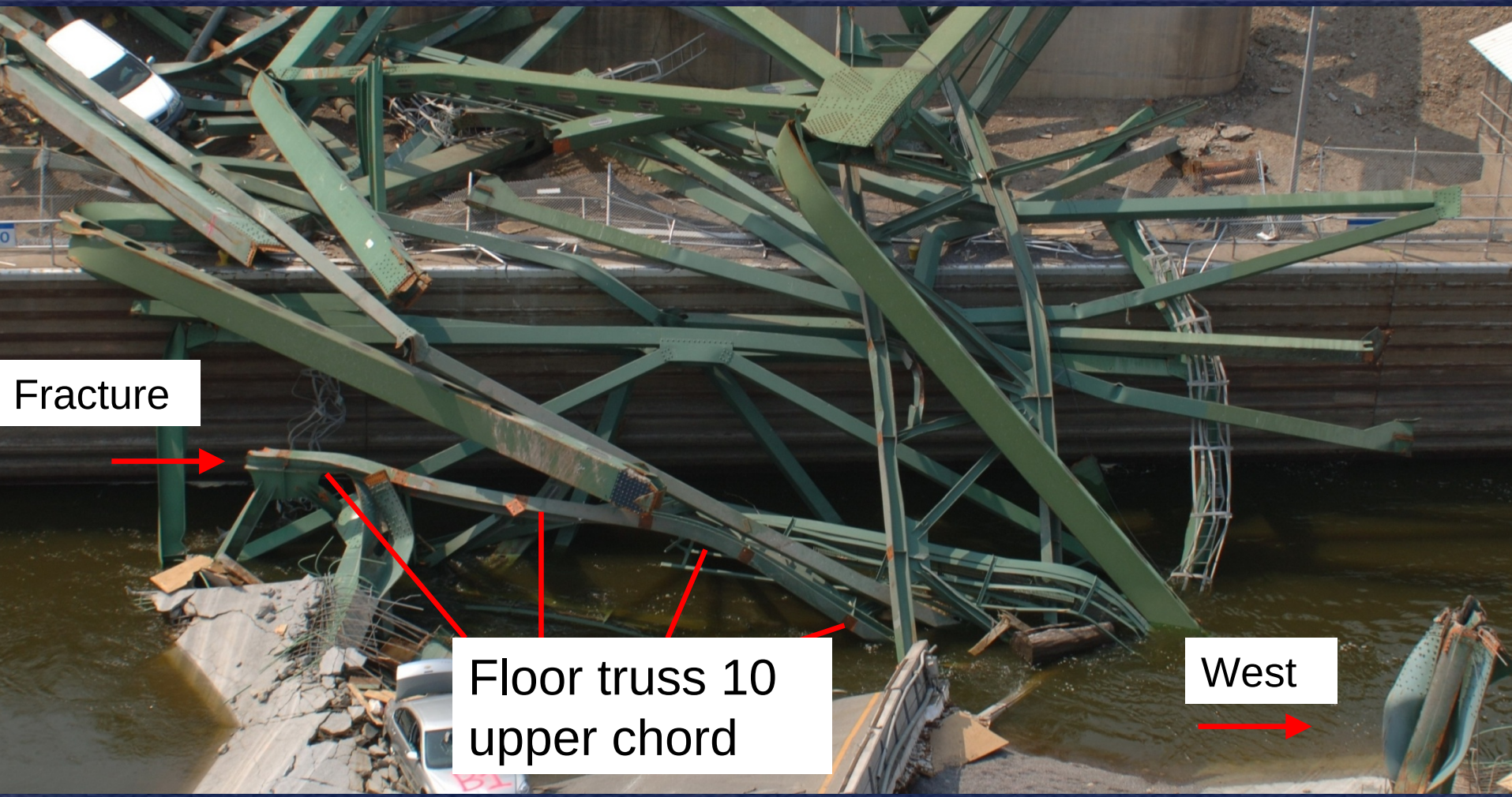
- Fracture and deformation patterns
- Video recording
- Finite element analysis



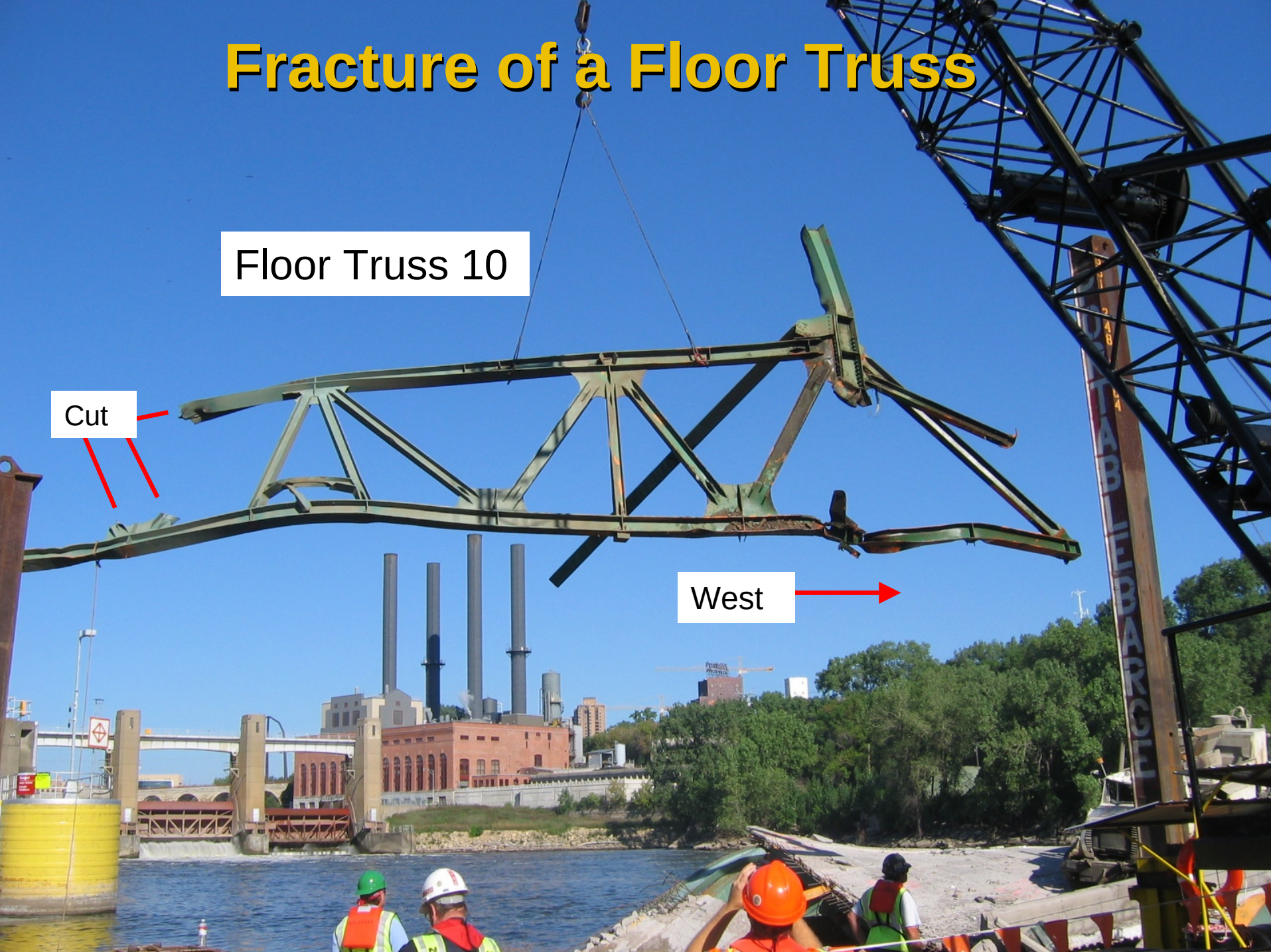



NTSB

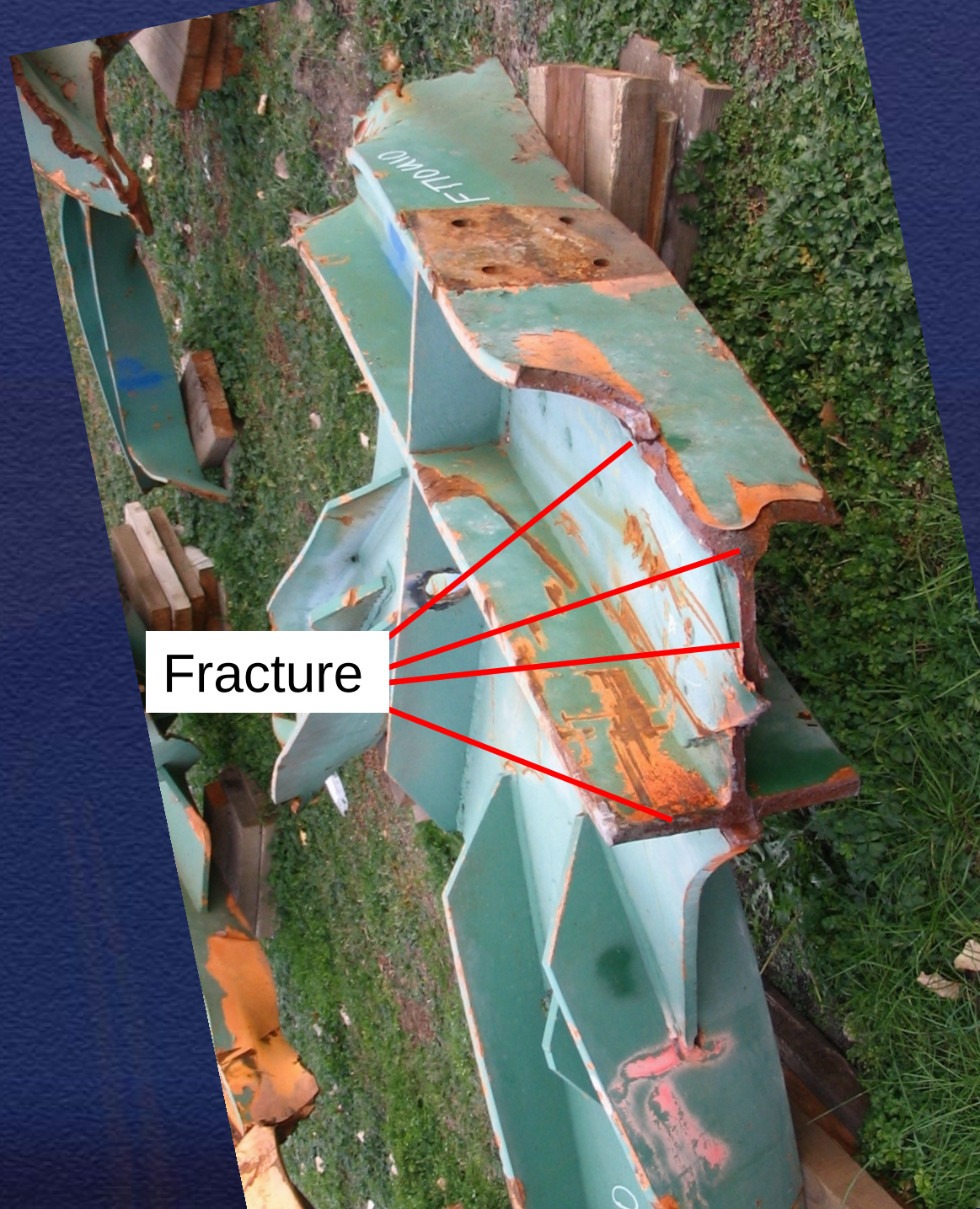
# Fracture of a Floor Truss



# Fracture of a Floor Truss



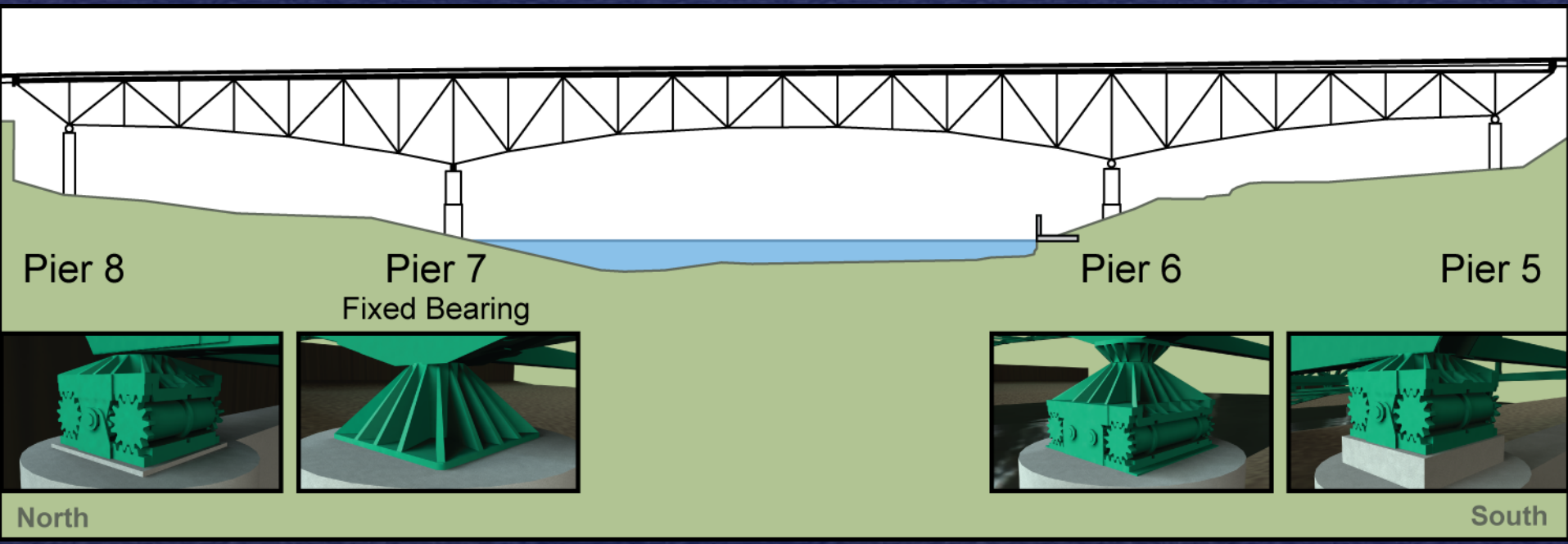
# Floor truss 10 – secondary damage



# Preexisting Cracking

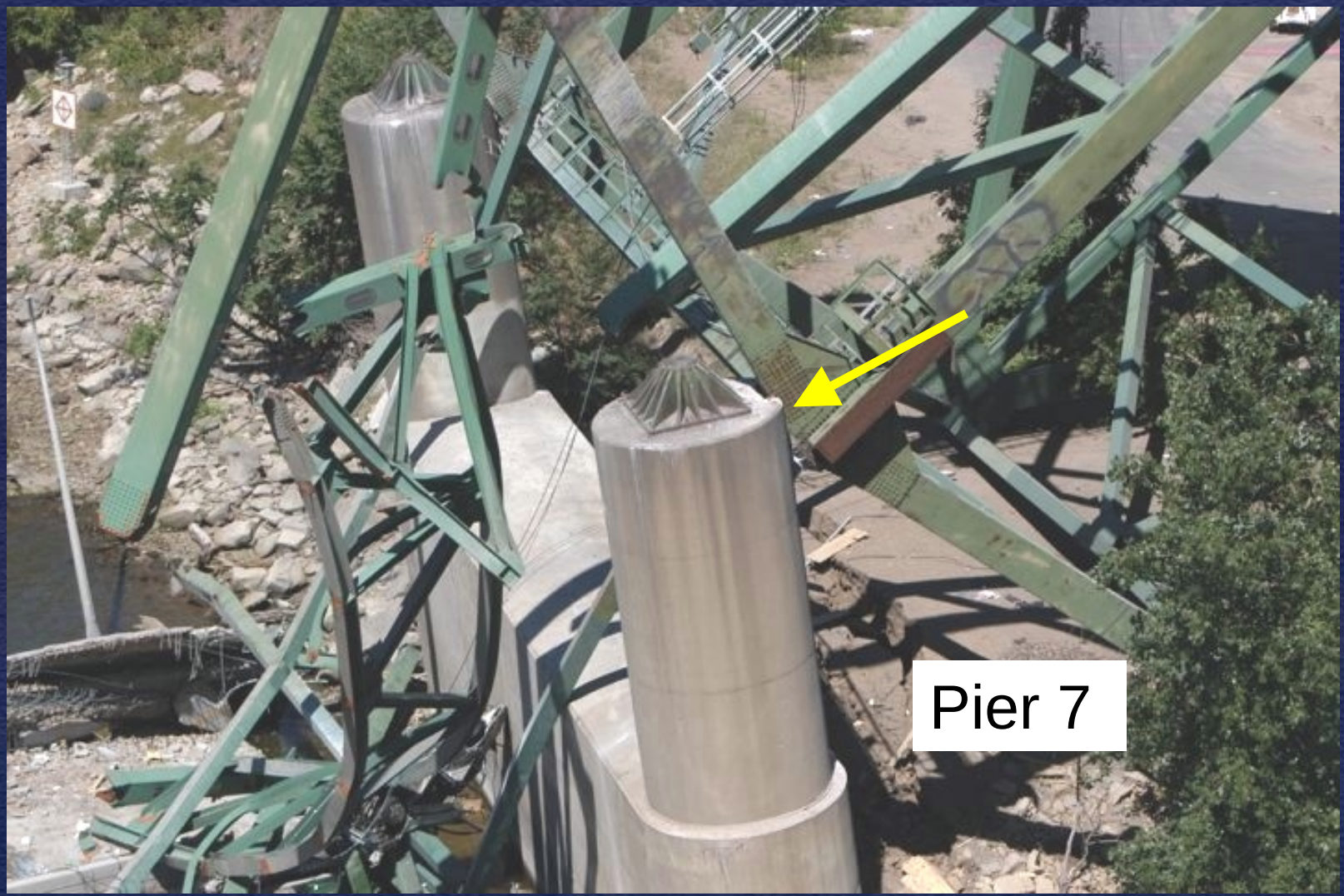
- Primarily in approach spans
- Main truss welds
  - Near node U14
  - Near node U7′
- No fatigue cracking in fractured pieces
- U10 gusset plates
  - Ductile overstress tension, shear, and bending fractures

# Bearings and Piers




- Rollers were moving
- Wear in center of contact plates
- No horizontal shifting of piers

# Pier Movement



# Overall Summary

- Collapse initiated with failure of gusset plates at nodes U10
- Complete collapse was unavoidable once these gusset plates failed
- Other possible initiation locations and factors were ruled out
- All findings were supported by
  - Fracture and deformation patterns
  - Video evidence
  - Finite element analysis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