Hurricane Katrina’s Impact on Louisiana’s Transportation Infrastructure

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Glenn J. Rix
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Outline

• Overview of Hurricane Katrina
• Damage to Highway and Rail Bridges and Roads
  - Rerouting of traffic
  - Impact on new design
• Damage to Ports
  - Physical damage
  - Operational impacts
• Related initiatives at Georgia Tech
Hurricane Katrina

- August 25, 2005, 6:30 pm EDT - Landfall near Fort Lauderdale, FL as a Category 1 hurricane with maximum sustained winds of 75 mph.
- August 28, 2005 - Category 5 hurricane with maximum sustained winds of 175 mph and a pressure of 902 mbar (fourth lowest on record).
- August 29, 2005, 7:10 am EDT - Landfall near Buras, LA (Plaquemines Parish) as a Category 4 hurricane with maximum sustained winds of 140 mph.
- August 29, 2005, 11:00 am EDT - Landfall near Louisiana-Mississippi border as a Category 3 hurricane with maximum sustained winds of 125 mph.
Maximum Sustained Winds

Legend

- Hurricane Katrina Track
- Maximum Sustained Winds (MPH)
  - < 40
  - 41 - 60
  - 61 - 80
  - 81 - 100
  - 101 - 122

Scale:

0 15 30 60 90 120 Miles
## Storm Surge in MS Gulf Coast

*Surveyor’s have begun documenting and refining the data from Hurricane Katrina’s storm surge. Here are some of their preliminary findings.*

<table>
<thead>
<tr>
<th>Preliminary elevation</th>
<th>Location</th>
<th>Hurricane Camille</th>
<th>Rough difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 feet</td>
<td>East Pearl River at I-10 east bridge end</td>
<td>6.9 feet</td>
<td>±8 feet</td>
</tr>
<tr>
<td>15 feet</td>
<td>Devils Swamp at box culvert at I-10</td>
<td>10.4 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>24 feet</td>
<td>Gulf side of I-10 overpass of Mississippi 43</td>
<td>14.6 feet</td>
<td>±0 feet</td>
</tr>
<tr>
<td>23 feet</td>
<td>Inland side of I-10 overpass of Mississippi 43</td>
<td>13.8 feet</td>
<td>±9 feet</td>
</tr>
<tr>
<td>21 feet</td>
<td>Jourdan River at I-10 west bridge end</td>
<td>14.2 feet</td>
<td>±7 feet</td>
</tr>
<tr>
<td>25 feet</td>
<td>Jourdan River at inland side of I-10 east bridge end</td>
<td>15.1 feet</td>
<td>±10 feet</td>
</tr>
<tr>
<td>28 feet</td>
<td>Jourdan River at Gulf side of I-10 east bridge end</td>
<td>16.9 feet</td>
<td>±11 feet</td>
</tr>
<tr>
<td>19.8 feet</td>
<td>Jourdan River at Mississippi 43 gage</td>
<td>12.2 feet</td>
<td>±8 feet</td>
</tr>
<tr>
<td>19 feet</td>
<td>Wolf River at I-10 west bridge end</td>
<td>13.5 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>19 feet</td>
<td>Wolf River at I-10 east bridge end</td>
<td>13.5 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>19 feet</td>
<td>Bernard Bayou at I-10</td>
<td>14.3 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>20 feet</td>
<td>Fritz Creek at Cowan-Lorraine Road Extension</td>
<td>13.5 feet</td>
<td>±7 feet</td>
</tr>
<tr>
<td>19 feet</td>
<td>Tchoutacabouffa River at I-10</td>
<td>13.3 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>16 feet</td>
<td>Old Fort Bayou at I-10</td>
<td>11.4 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>18 feet</td>
<td>West Pascagoula River Inland side of I-10 west bridge end</td>
<td>9.1 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>10.6 feet</td>
<td>Escatawpa River at I-10 gauge</td>
<td>4.9 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>20 feet</td>
<td>House on Kennedy Lane near Damphman Point, Biloxi</td>
<td>14.2 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>24 feet</td>
<td>Isle of Capri Casino, Biloxi</td>
<td>15.6 feet</td>
<td>±8 feet</td>
</tr>
<tr>
<td>18.6 feet</td>
<td>Communications building on Whites Bayou, near Pearl</td>
<td>8.8 feet</td>
<td>±10 feet</td>
</tr>
<tr>
<td>19 feet</td>
<td>Popp’s Ferry Bridge, south abutment</td>
<td>13.9 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>17.7 feet</td>
<td>Tchoutacabouffa River at Mississippi 15 and 67, D’Iberville</td>
<td>12.6 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>20.8 feet</td>
<td>Old Fort Bayou at Mississippi 609</td>
<td>14.8 feet</td>
<td>±6 feet</td>
</tr>
<tr>
<td>20 feet</td>
<td>Biloxi Bay/Beach Mini Mart near east end of U.S. 90 bridge</td>
<td>15.5 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>27 feet</td>
<td>1310 Scenic Drive, Pass Christian</td>
<td>23.4 feet</td>
<td>±4 feet</td>
</tr>
<tr>
<td>26 feet</td>
<td>1310 Scenic Drive, Pass Christian</td>
<td>23.4 feet</td>
<td>±3 feet</td>
</tr>
<tr>
<td>28 feet</td>
<td>1320 Scenic Drive, Pass Christian</td>
<td>23.4 feet</td>
<td>±5 feet</td>
</tr>
<tr>
<td>12.7 feet</td>
<td>Pascagoula River at I-10 east bridge end</td>
<td>8.6 feet</td>
<td>±4 feet</td>
</tr>
<tr>
<td>13 feet</td>
<td>Pascagoula River at I-10 west bridge end</td>
<td>8.6 feet</td>
<td>±4 feet</td>
</tr>
</tbody>
</table>
Storm Surge in MS Gulf Coast

Katrina’s surge: The storm surge from Hurricane Katrina inundated South Mississippi’s coastline.

6 a.m.

9 a.m.
All the barrier islands were under water.

11 a.m.

Height of the storm:
- In the Kiln area, the storm surge was as high or higher than a regulation high school football goal post at 30 feet tall.
- In Gulfport, Bay St. Louis, and Waveland, the storm surge was 25-30 feet.
- In Biloxi, the storm surge was between 20-25 feet.

SOURCE: Mississippi State University GeoResources Institute

Rudy Sova / THE SUN HERALD
Storm Surge in MS Gulf Coast
Overview of Damage

• Over 45 bridges sustained damage in AL, LA, and MS.
• Most damaged bridges were adjacent to water.
• Substructures were rarely damaged.
• Damage on superstructure typically consisted of unseating of decks and damage to guardrails.
• Significant damage to bridges due to loose barges and boats.
• Significant damage to roads in storm surge areas
• Debris on roads and bridges caused major disruption
• Damage depended on the connection between decks and bents
Performance and Repair of Bridges
Overview of Bridge Damage in AL
Overview of Damage - AL

In Alabama, 2 bridges received moderate to major damage, and two bridges received minor damage.

<table>
<thead>
<tr>
<th>Bridge name</th>
<th>Carrier</th>
<th>Status as of 7 Nov</th>
<th>Repair cost</th>
<th>Expected downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochrane Africatown USA Bridge</td>
<td>Alabama DOT</td>
<td>Currently being repaired</td>
<td>$1.75 million</td>
<td>none</td>
</tr>
<tr>
<td>I-10 On-Ramp at Mid-Bay Crossing of US-90/98</td>
<td>Alabama DOT</td>
<td>Repairs begin in January 2006</td>
<td>$1 million</td>
<td>6 months</td>
</tr>
<tr>
<td>Bayou La Batre</td>
<td>Alabama DOT</td>
<td>Repairs completed</td>
<td>&lt;$100,000</td>
<td>none</td>
</tr>
<tr>
<td>Dauphin Island Bridge</td>
<td>Alabama DOT</td>
<td>Repairs completed</td>
<td>&lt;$100,000</td>
<td>none</td>
</tr>
</tbody>
</table>
The hurricane picked up an oil drilling rig and smashed it into the Cochrane-Africatown Cable Stayed Bridge. Amazingly, the cables escaped major damage and the bridge is still carrying traffic (photo courtesy of Cochrane-Africatown Cable Stayed Bridge).
Overview of Bridge Damage in LA

- Conventional Bridge - Katrina
- Movable Bridge - Katrina
- Movable Bridge - Rita

[Map showing locations such as Pontchartrain Causeway, Bayou Bayou, Pearl River, Belle Chase, Yscloskey, and others with markers for bridge damage during Katrina and Rita.]
I-10 Twin Spans

- 5.4 Miles
- 12–15 Feet Above Water
- Prestressed spans
I-10 Twin Spans – Damage

- 170 Eastbound spans shifted alignment
- 303 Westbound spans shifted alignment

- 38 Eastbound spans fell in water
- 26 Westbound spans fell in water
I-10 Twin Spans – Damage

Spalling at girder seats

Spalling at bent caps

14,000 ft barrier railing

Fossier
1. The Lifting

Storm surge rose to 14 to 16 feet above sea level beneath the bridge decks, where beams captured air beneath them, increasing the upward force to 900,000 pounds.
2. The Pounding

At the same time, waves of 13 feet atop the surge hit the sides of the bridge decks with 700,000 pounds of force every 6.5 seconds at the height of the storm.
3. The Breaking

The water’s lifting and pounding broke the connections between 150-foot-deep pilings and piers supporting the bridge decks, allowing the decks to slide sideways or fall into the water.
I-10 Twin Spans – Repair

Span realignment

- Consult FDOT
- Hire construction manager (Volkert)
- 1 span open October 10
- Repair bid at $31,000,000 w/ additional incentives

Span replacement – Acrow Bridge
I-10 Twin Spans – Repair

- Replacement bridge in 3-4 years. Potentially bid in early 2006.
- Estimated cost of ~$600 M
Overview of Bridge Damage in MS
Overview of Damage - MS

- In Mississippi, bridges in three counties (Hacock, Harrison, and Jackson) were damaged

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<tr>
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<th>Status as of 7 Nov</th>
<th>Repair cost</th>
<th>Expected downtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacagoula River</td>
<td>I-10</td>
<td>Open</td>
<td>N/A</td>
<td>Partial close for 20 days</td>
</tr>
<tr>
<td>Bay St. Louis</td>
<td>US-90</td>
<td>Closed (Complete collapse)</td>
<td>$150,000,000</td>
<td>670 days</td>
</tr>
<tr>
<td>Henderson Point</td>
<td>US-90</td>
<td>Closed (Six spans drifted)</td>
<td>$2,100,000</td>
<td>172 days</td>
</tr>
<tr>
<td>Biloxi Ocean Springs</td>
<td>US-90</td>
<td>Closed (Complete collapse)</td>
<td>$150,000,000</td>
<td>550 days</td>
</tr>
<tr>
<td>I-110 Biloxi Back Bay</td>
<td>I-110</td>
<td>Open</td>
<td>$2,400,000</td>
<td>Partial close until repair</td>
</tr>
<tr>
<td>David V. LaRosa</td>
<td>Wittman Road</td>
<td>Open</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Popps Ferry</td>
<td>Popps Ferry Road</td>
<td>Closed</td>
<td>N/A</td>
<td>176 days</td>
</tr>
</tbody>
</table>
US90 Biloxi-Ocean Springs Bridge Damage

(Chapman)
US90 Biloxi-Ocean Springs Bridge Damage

Steel-Bronze Bearing Damage

Abutment Damage and Loss of Backfill
US90 Biloxi-Ocean Springs Bridge Repair

- Complete Replacement with new 6-lane high-rise bridge
  - Avoid storm surge issues
  - Increased capacity
- Contracting
  - Design-build
  - Estimated at $150 million
  - Completion in May, 2007 (1.5 yrs)
I-10 Pascagoula River Bridge

Damage

Damage to 6-span East-bound section due to Barge Impact
Typical Damage to Movable Bridges
Typical Damage to Movable Bridges

• Deck/pier damage from debris collision
• Water damage to mechanical and electrical systems from prolonged submersion:
  - Drive motors and their limit switches
  - Bridge control rooms
  - Bearings, sheaves and cables
  - Navigation lights
  - Electronic traffic gates
• Soil scour and slope failures
Performance and Repair of Roads
Extensive debris and 4 ft of sand covered the road after Katrina.

Damage to the pavement, sliding of asphalt, and damage to culverts and stormwater systems also inhibited traffic.
Road US90 (Biloxi to Bay St. Louis) Repair

- 1 week to clear debris
- 2 months to allow 2 of 4 lanes open to traffic
- Expected repair completion by mid-December
Performance and Repair of Railroad Bridges
Location of railroads and railroad bridge damage due to Katrina
Railroad Performance: Norfolk Southern Railroad’s five mile long Lake Pontchartrain bridge, lost its track due to the storm surge.
East of Saint Louis Bay, the CSX track was littered with debris, including barges, carried by the storm.
US90 – Biloxi-Ocean Springs

Note: No Damage to Railroad Bridge Adjacent to US90
US90 — Biloxi–Ocean Springs

Note: No Damage to Railroad Bridge Adjacent to US90
Re-Routing & Traffic Demands - MS

Increased Traffic Count and Demands on I-10 *Post Katrina*

2005 Estimated ADT = 76000
2004 AADT = 62000

2005 Estimated ADT = 76000
2004 AADT = 59000

2005 Estimated ADT = 52000
2004 AADT = 37000

2004 AADT = 46000

2004 AADT = 47000

2004 AADT = 46000
2004 AADT = 34000
2004 AADT = 35000

2004 AADT = 17000
Impact on New Design - AL

Because of the many broken anchor bolts and damaged angle clips on the US90 to I-10 Ramp, Fred Conway (the Chief Bridge Engineer for the Alabama DOT) said they will switch from anchor bolts to through rods on the connections to the precast I-girders on new construction. A better connection to the bent caps will also likely be required.
Impact on New Design - LA

For segments of the bridge which must be below surge levels, provide vertical tie downs and air vents for each span.

Take measures to protect rebar from corrosion

- Coated rebar
- High performance concrete
Impact on New Design - LA, MS

Build bridges well above the projected storm surge levels.
Summary and Conclusions

• Over 45 bridges had moderate to significant damage (estimated cost – $1 billion)

• Significant debris on roads

• Major disruption to rail traffic

• Appears that simple measures (shear keys, air vents) may be effective in limiting damage
Ports Visited

- River ports
  - Port of New Orleans
  - Port of South Louisiana
  - St. Bernard Port, Harbor, and Terminal District
  - Plaquemines Port, Harbor, and Terminal

- Coastal ports
  - Port Fourchon
  - Port of Terrebonne
  - Port of Morgan City
Ports Visited

Legend
- Hurricane Katrina Track
- Maximum Sustained Winds (MPH)
  - 21 – 40
  - 41 – 60
  - 61 – 80
  - 81 – 100
  - 101 – 122

- Ports

- Morgan City
- South Louisiana
- New Orleans
- St. Bernard
- Plaquemines
- Terrebonne
- Pourchon
Port of South Louisiana

• 54 river miles in length
• 249 million tons of cargo in 2004
• Largest tonnage port in the Western Hemisphere and 4th largest in the world
• More than 50% of all U.S. grain exports
• Primary import is crude oil
• 23rd largest U.S. port by cargo value in 2003
Port of South Louisiana

- Minor wind damage to grain conveyors and
Port of South Louisiana

- Operational impacts from closure of Mississippi River downstream due to navigation hazards, loss of communications and electrical power, and displacement of work force.
- Normal operations restored within one week.
Port of New Orleans
Port of New Orleans

- Diverse general cargo and passenger port
- 12th largest U.S. port by cargo value in 2003
- Principal imports include steel, petroleum products, rubber, plywood, coffee, machinery, and foodstuffs
- Principal exports include wood and paper products, foodstuffs, steel, chemical products, cotton, and rubber
Port of New Orleans

- Minor wind damage
Port of New Orleans

- Fire at Mandeville Wharf caused by exploding propane gas cylinders
Port of New Orleans

- Damage to container cranes at the France Road Terminal
Port of New Orleans

- Primary operational impacts due to displaced labor force including stevedores, longshoremen, and truck drivers

<table>
<thead>
<tr>
<th>Date</th>
<th>Estimated Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 20, 2005</td>
<td>40%</td>
</tr>
<tr>
<td>December 2005</td>
<td>60%</td>
</tr>
<tr>
<td>February 2006</td>
<td>80%</td>
</tr>
</tbody>
</table>
St. Bernard District
St. Bernard District

- Significant wind and flooding damage
Plaquemines District
Plaquemines District

- Distributed facilities composed of cargo transfer terminals for coal, grain, oil, and other raw materials
- Operational center for the offshore oil and gas industry
- Thin “ribbon” of land protected by Mississippi River levees and “back levees”
Plaquemines District

- 17 failures of back levees
Plaquemines District

- Catastrophic flooding
Plaquemines District

- Runaway barges and boats
Plaquemines District

• Long-term impacts of displaced workforce
  - CHS Grain Terminal
  - As of October 20, 2006, an estimated 40% of the workforce was unaccounted for and 10% to 20% were frequently absent
Port Fourchon
Port Fourchon
Port Fourchon

- Service port for offshore oil and gas production
  - Supports production of 16% - 18% of U.S. energy supply
- Land base of the Louisiana Offshore Oil Port (LOOP), which handles 13% - 15%
Port Fourchon

- Minor wind damage
Port Fourchon

- Maintenance and replenishment of surrounding marsh areas
Port Fourchon

- Debris fences
Port Fourchon

- Elevated telecommunications infrastructure
## Preliminary Damage Estimates

<table>
<thead>
<tr>
<th>Port</th>
<th>Estimated Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of New Orleans</td>
<td>$730 million</td>
</tr>
<tr>
<td></td>
<td>(private) $270 million</td>
</tr>
<tr>
<td>St. Bernard Port, Harbor, and Terminal</td>
<td>$20.1 million</td>
</tr>
<tr>
<td>District</td>
<td>(public)</td>
</tr>
<tr>
<td>Port Fourchon</td>
<td>$6.3 million</td>
</tr>
<tr>
<td>Plaquemines Port, Harbor, and Terminal</td>
<td>?</td>
</tr>
<tr>
<td>District</td>
<td></td>
</tr>
</tbody>
</table>
Transportation Networks
Value of U.S. Waterborne Trade

2003 Modal Share

Source: Bureau of Transportation Statistics (2004)
2003 Container Trade (TEU)

Source: Port Import/Export Reporting Service (PIERS)
Seismic and Hurricane Hazards
Component Performance

Crane response

Pile-deck connection

Liquefiable soil
System Performance

Berth allocation

Crane scheduling

Container location

Container Storage and Stacking

Transfer to/from Truck and Rail
Acknowledgements

- National Science Foundation
- American Society of Civil Engineers
- Nicholas Pansic
- Jeff Hellstrom
- Joe Acardo
- Brian Adams
- Davie Breaux
- Duane Gapinski
- Deborah Keller
- Denny Lundberg

- Robert Scafidel
- Mitch Smith
- Karen St. Cyr
- Henry Sullivan
- Tim Tregle
- Urban Treuil
- Ed Watson
- Paul Zimmerman
- People of South Louisiana