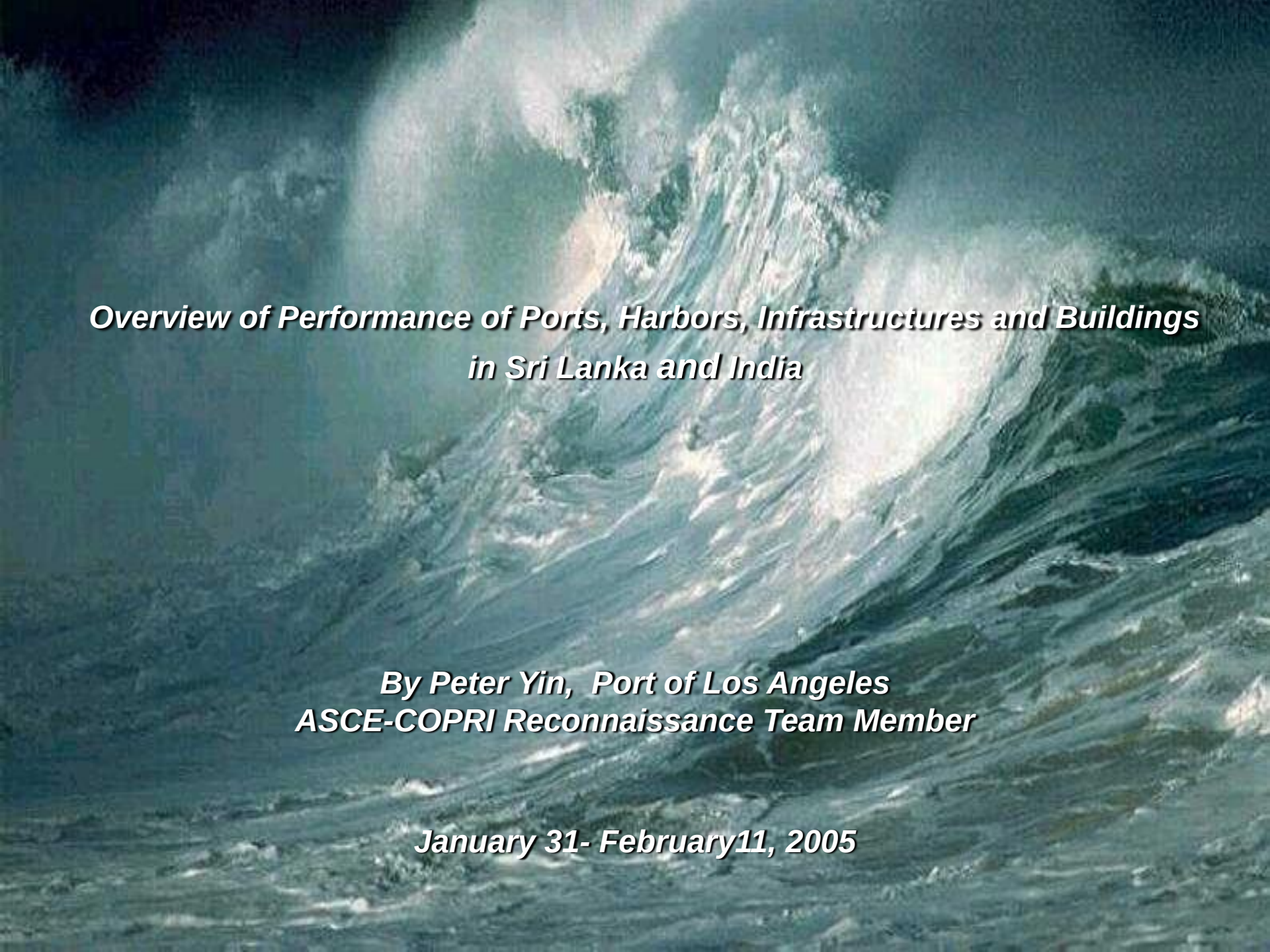
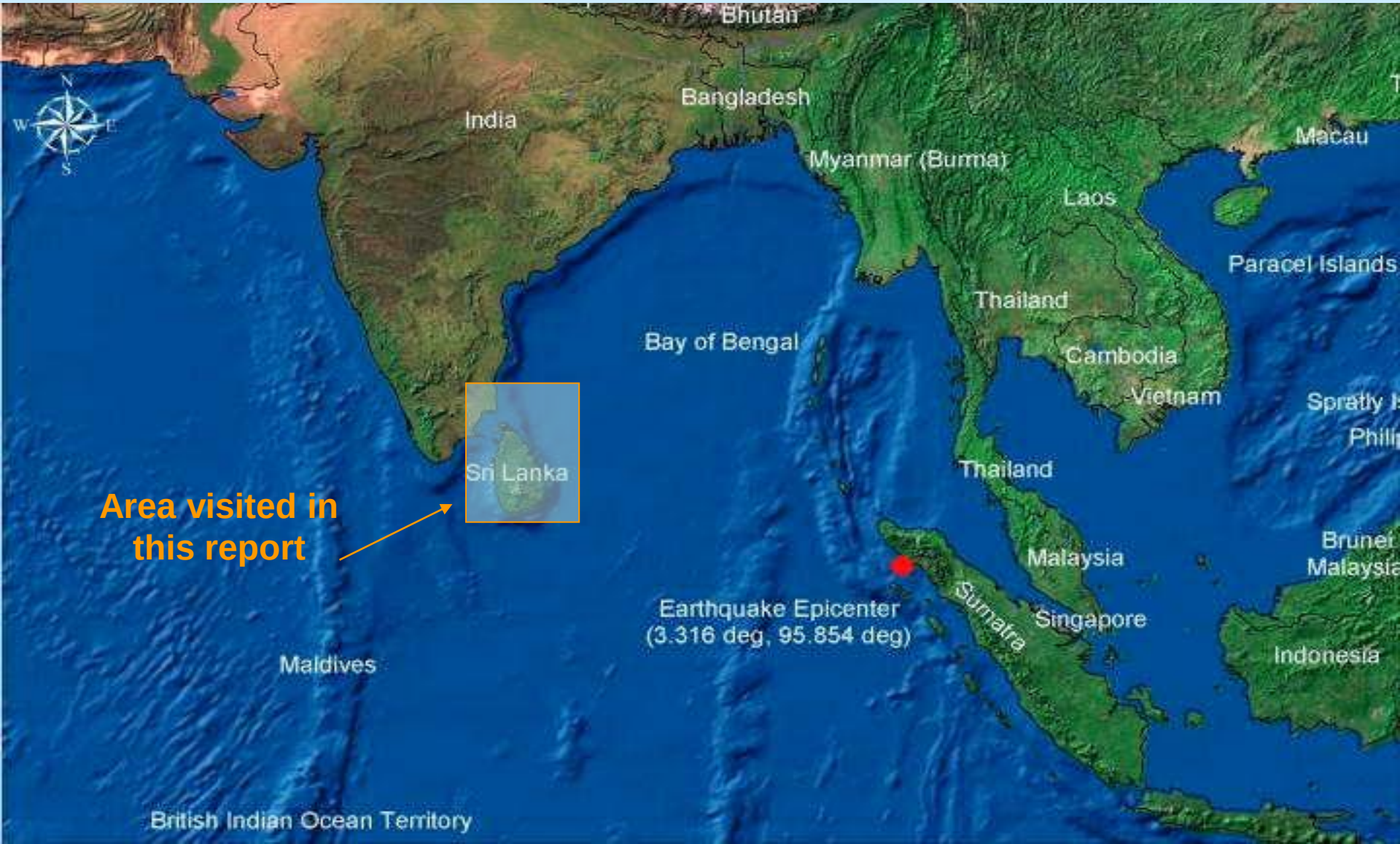


Overview of Performance of Ports, Harbors, Infrastructures and Buildings in Sri Lanka and India

By Peter Yin, Port of Los Angeles
ASCE-COPRI Reconnaissance Team Member

January 31- February11, 2005

Following the Sumatra Earthquake and Tsunami ASCE sent Reconnaissance Teams to Thailand, India and Sri Lanka.



ASCE Sri Lanka Reconnaissance Team visited the island from <u>1/31/05 to 2/4/05</u>

Major ports visited:

- **Trincomalee**
- **Colombo**
- **Galle**

Buildings, bridges, Ports, and fishing harbors were observed and evaluated

Part I : Building Performance

Heavy losses occurred at west coastline of Sri Lanka, area does not face the origin of tsunami.

Panadura, 25 km South of Colombo

Nearly all houses along this west coast line were destroyed.

Hambantota, S.E. Lanka:

11 m (33 ft) water level was the highest.

Hambantota:
4,500 people perished at this fishing town.

East Sri Lanka (AP Photo):
Raging water at beach front properties.

East Sri Lanka:

From Kalmunai to Batticaloa, many houses ended up like this one at the coast line.

East Sri Lanka:

Another ocean front community. Un-reinforced brick and/or masonry construction were typical in the region.

Common damages: Un-reinforced masonry structures were no match for the wave, but reinforced concrete members survived.

Another comparison between un-reinforced and reinforced members.

In the same region, properly designed and constructed buildings suffered minimum damages.

Inside the same ocean front building. Only glass windows were broken.

South of Kalutara:

Railroad bridge was destroyed, highway bridge next to it was not.

River connect to the ocean collected most of the flow. Bridge and abutment at upper stream were washed away by receding water. The highway bridge facing in-coming surge survived.

Arugam Bay:Bridge at southeast coastline
Water over-flowed the superstructure.

South abutment and approach road were washed away.

Expansion joint still there, high above the water.

Approach road and abutments connecting the two bridges were gone.

Doomed morning ride at Bentota, 60 km south of Colombo:
Railroad track was several thousand feet from the ocean, but the water level reached 20 ft or more above the ground at this location.

People jumped on the train in the attempt to escape, but the train was toppled and battered by the flood. 1500 lives perished.

Hambantota: Thousands feet away from shoreline, this transmission tower was stuck down by the current with a floated bus. Noted all the houses nearby were destroyed.

**Along east coastline, from Arugam Bay to Trincomalee Bay,
many roads adjacent or connect to lake or lagoon need major repair.**

Contrary to the east coast roads, the service roads at the west region suffered minimum damages.


Part III: Ports and Harbors

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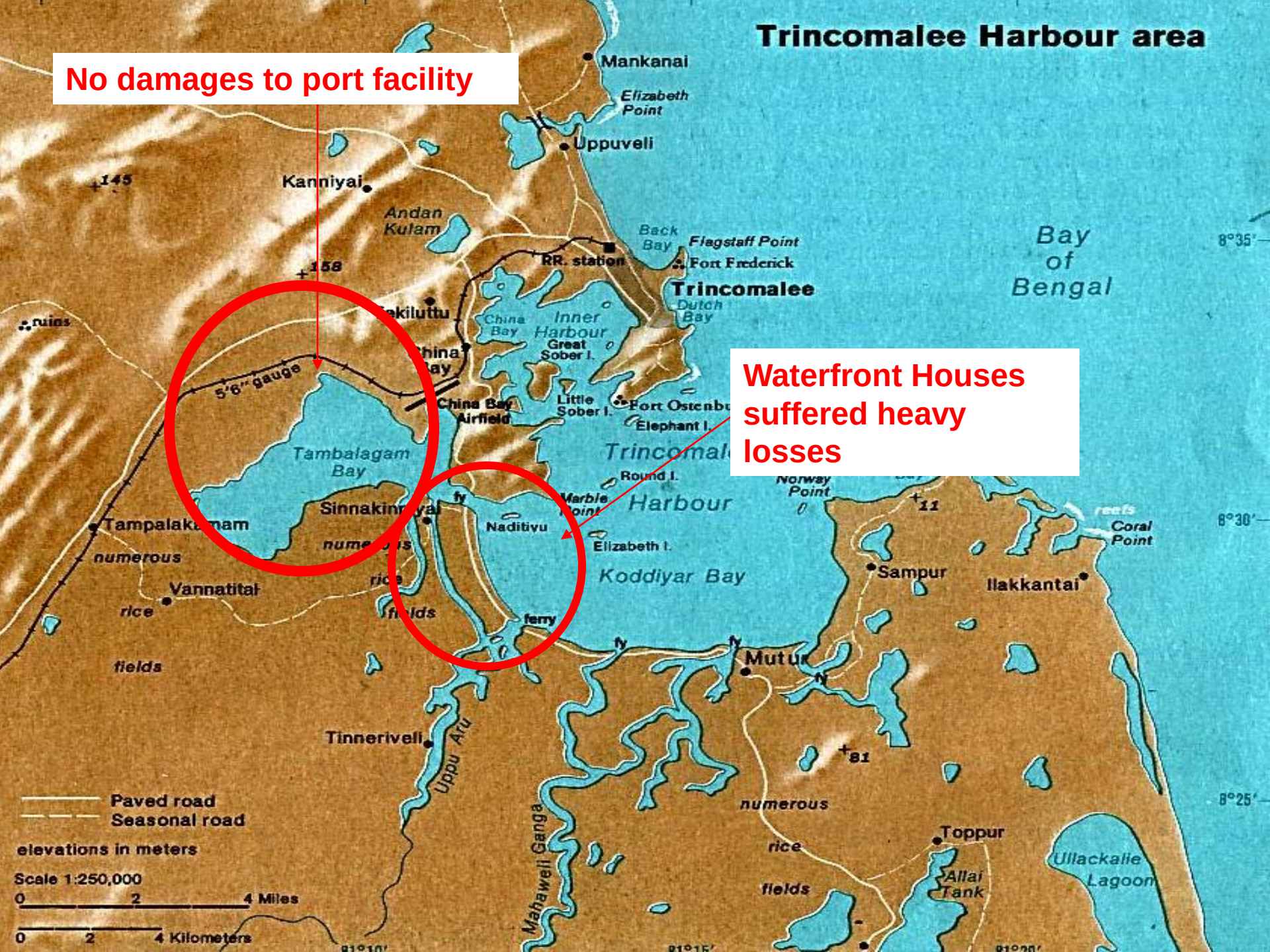

Trincomalee Harbour area
No damages to port facility
Waterfront Houses suffered heavy losses
Mankanai
Elizabeth Point
Uppuveli
Kanniyai
145
158
Andan Kulam
Back Bay
Flagstaff Point
Fort Frederick
RR. station
Trincomalee
Dutch Bay
Bay of Bengal
8°35'
ruins
China Bay
Inner Harbour
Great Sober I.
5'6" gauge
China Bay Airfield
Little Sober I.
Fort Ostenbu
Elephant I.
Tambalagam Bay
Round I.
Norway Point
Marble Point
Harbour
Sinnakinniyai
Naditivu
Elizabeth I.
Koddiyar Bay
Tampalakamam
numerous
rice
fields
Vannatital
ferry
Sampur
Ilakkantai
reefs
Coral Point
8°30'
Mutur
Tinneriveli
Uppu Aru
81
numerous
rice
fields
Toppur
Allai Tank
Ullackalie Lagoon
Mahaweli Ganga
8°25'
Paved road
Seasonal road
elevations in meters
Scale 1:250,000
0 2 4 Miles
0 2 4 Kilometers
81°10'
81°15'
81°20'

Tricomalee Inner Harbor:
Even though fierce surge attacked outer harbor, narrow entrance minimized the damages to the inner harbor facilities.

Tricomalee Outer Harbor:

Almost all the houses at coast line were destroyed.

The Port of Galle, Southwest Sri Lanka:
Water was 10 ft above the deck and port buildings.

No major damage was reported, even though 2 m (6’) of silt filled the inner harbor and a 650 ton ship was tossed to on top of the deck.

Port of Colombo

- General cargo terminal and 2 container terminals
- 12-15 m draft (Jaya) and 9-11 m draft (SAGT)
- 2 million T.E.U in 2004
- Reinforced concrete deck on piles
- 200 Ha water area, 130 Ha land area

Tsunami brought no surging waves, but fast rising water.

Three feet of water covered the wharfs before receding.

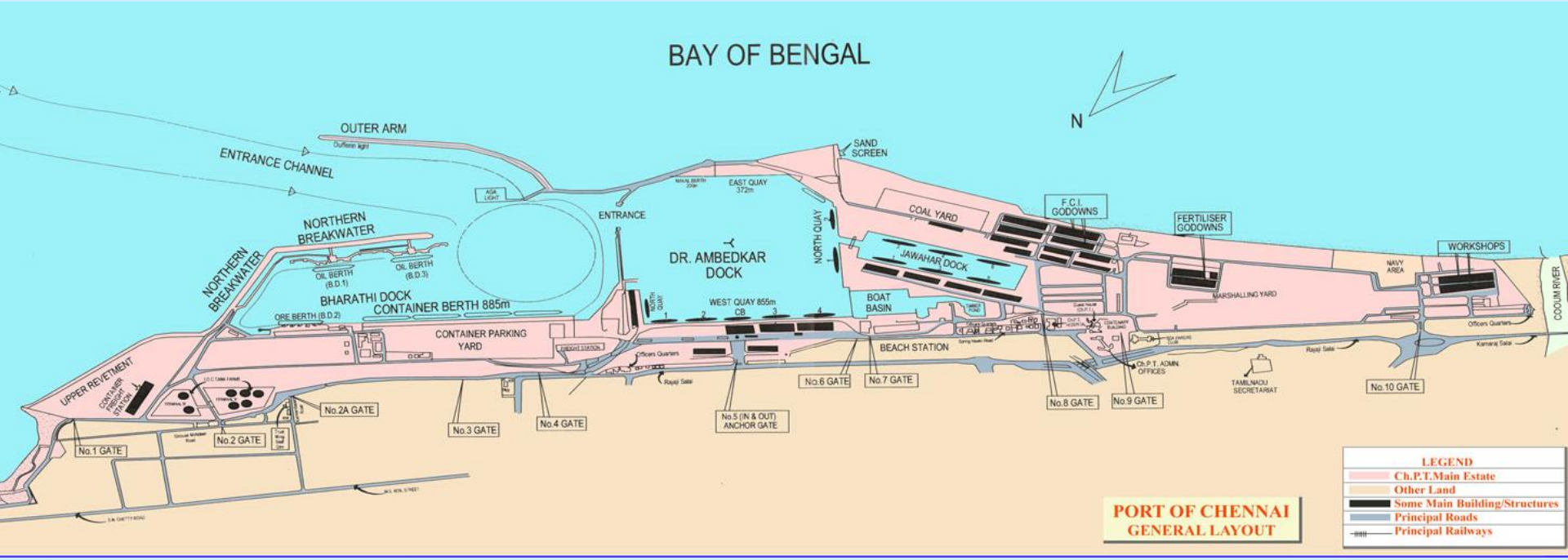
Minor damages occurred near light house when a ship hit the breakwater (slipped away from the wharf by receding water).

Observation in Southeast India:

2/7/05-2/11/05

Ports visited:
Chennai
Ennore
& Fishing harbors

Chennai Port, India



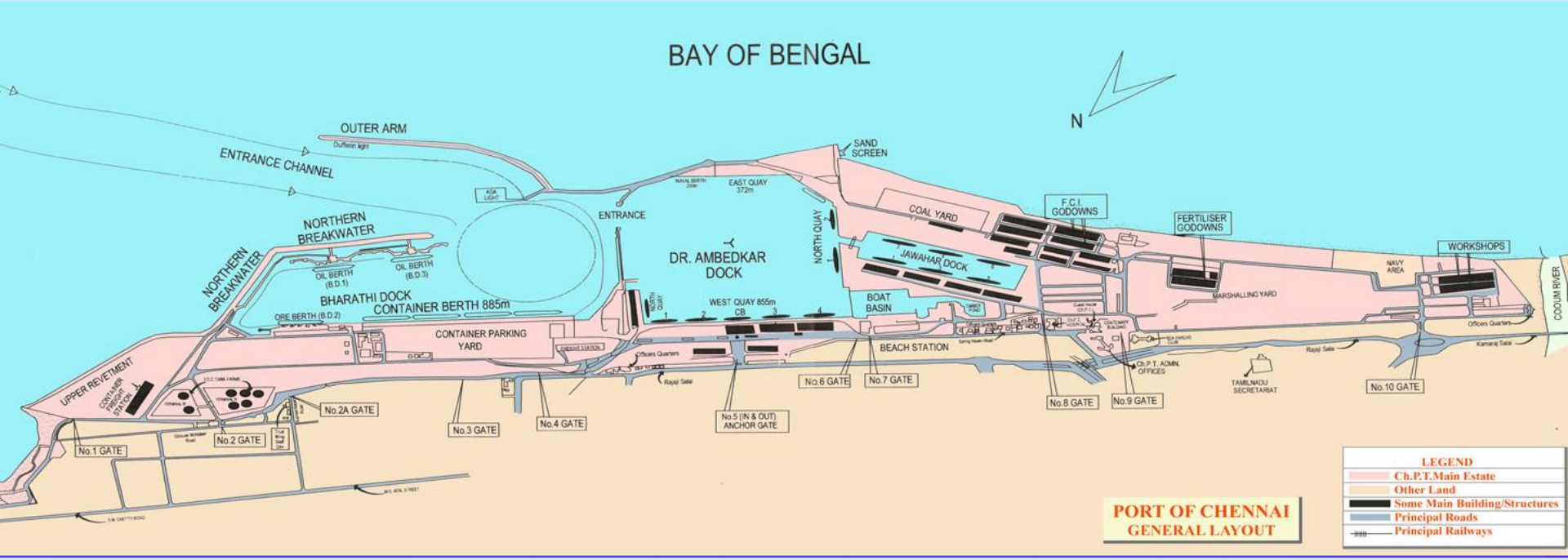
Chennai Port: 5 m (16 ft) or higher waves hit the port and fish harbor. (Deck is 4 m above MLLW level)

Water receded from the backland.

Despite the broken mooring line and high water level, wharf structures suffered no damage.

Strong current is clearly visible inside the harbor.

Chennai Port, India



Water current circled and swirled around these vessels inside the harbor.

Damages caused by collision of floating ship.

Ship floating with the receding water. Broken mooring line is visible.

Receding water scoured the foundation, and deepened the channel by several feet.

Pier settlement due to scouring.

Catwalk and dolphin were knocked out by floating vessel.

Most damages on breakwater occurred at the inner side.

Ennore, the Port for energy, located 24 km north of Chennai.

Breakwater shows no damage.

Port staff was well prepared when Tsunami threat was noticed.

Tug boats were used effectively to keep the ship from floating around the harbor.

Sound judgment and timely response averted potential damages at this port.

General Findings:

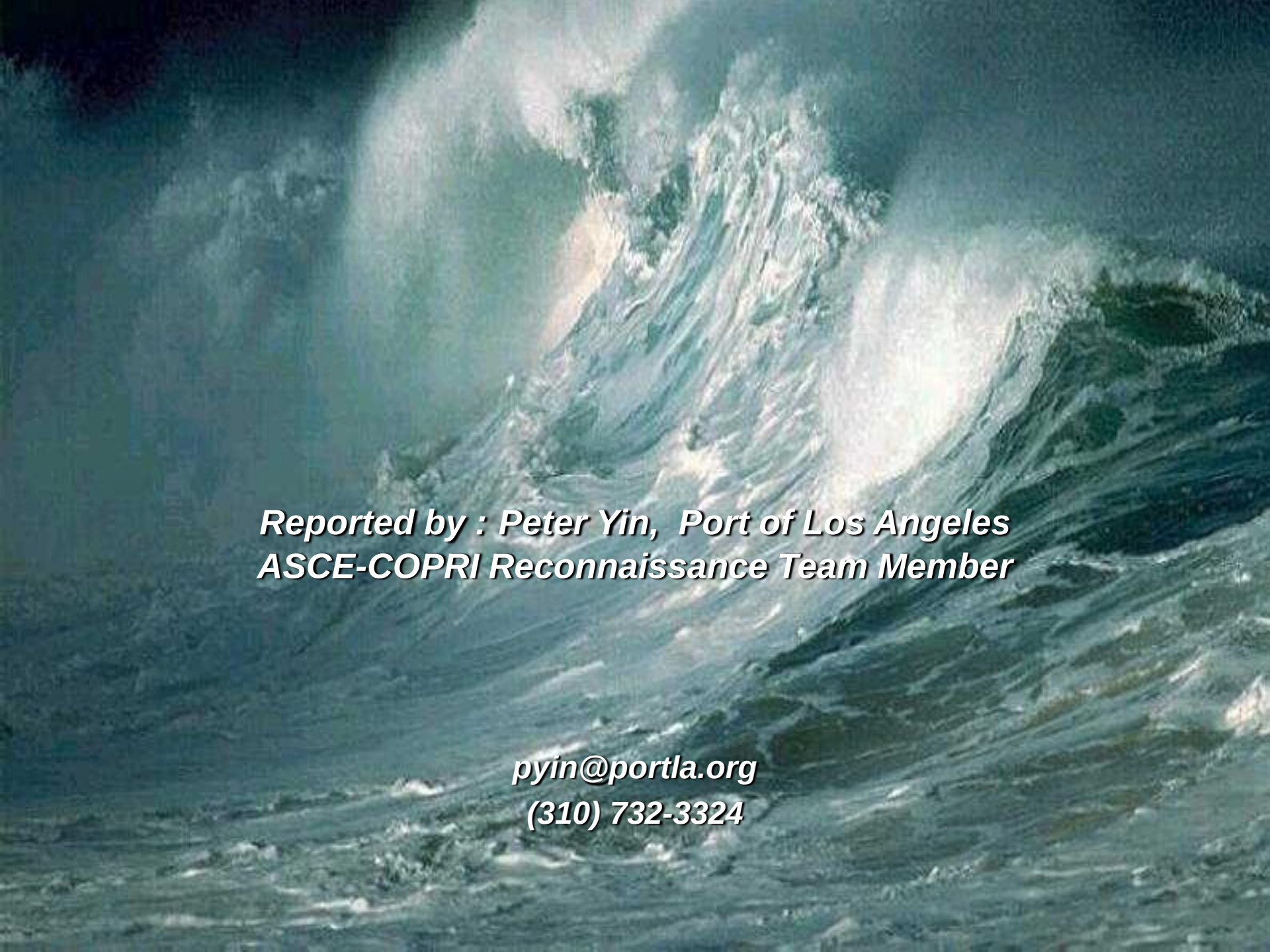
- **Early Warning System:** Many lives could have been spared had such system existed.
- **Education:** Common sense and traditional wisdom could have reduced the loss. Education should pass through generations.
- **Disaster Management System:** Well planned, well executed emergency response plan is essential.
- **Impacted Area:** Reflecting waves may cause damages just as severe as direct surge.

Observations on Infrastructures and Buildings:

- Site specific: Similar to a seismic event, the magnitude of damage is subject to many factors. Similar buildings next to each other may have different outcomes.
- Receding water caused more bridge and abutment damages at the river and lake areas that drained the flooded water.
- Damages were not limited to immediate costal area. High water level, strong surge and/or receding flow destroyed structures several thousand feet to the inland.
- Building code enforcement is essential. Almost all property that was lost, was not properly engineered.
- Planning and zoning: Low lands or coastal regions subject to monsoons and floods may need special zoning regulations and building height requirements.

Observations on Port Facilities

- Most modern port structures are capable to resisting tsunami waves.
- Depends on layout, geometry, location, water depth, and other hydraulic, structural and geotechnical features, some ports may have strong current and scouring problems, while others may be filled with silt.
- Rising water may break mooring lines. In the ports that have strong current and fast receding water, floating vessels should be a concerned issue. Scouring should be investigated.
- Hydraulic modeling and laboratory test could be considered at major ports.
- Breakwater damages generally occurred at inner side of the structure.



Reported by : Peter Yin, Port of Los Angeles
ASCE-COPRI Reconnaissance Team Member

pyin@portla.org
(310) 732-3324