New Orleans Levees in Hurricane Katrina

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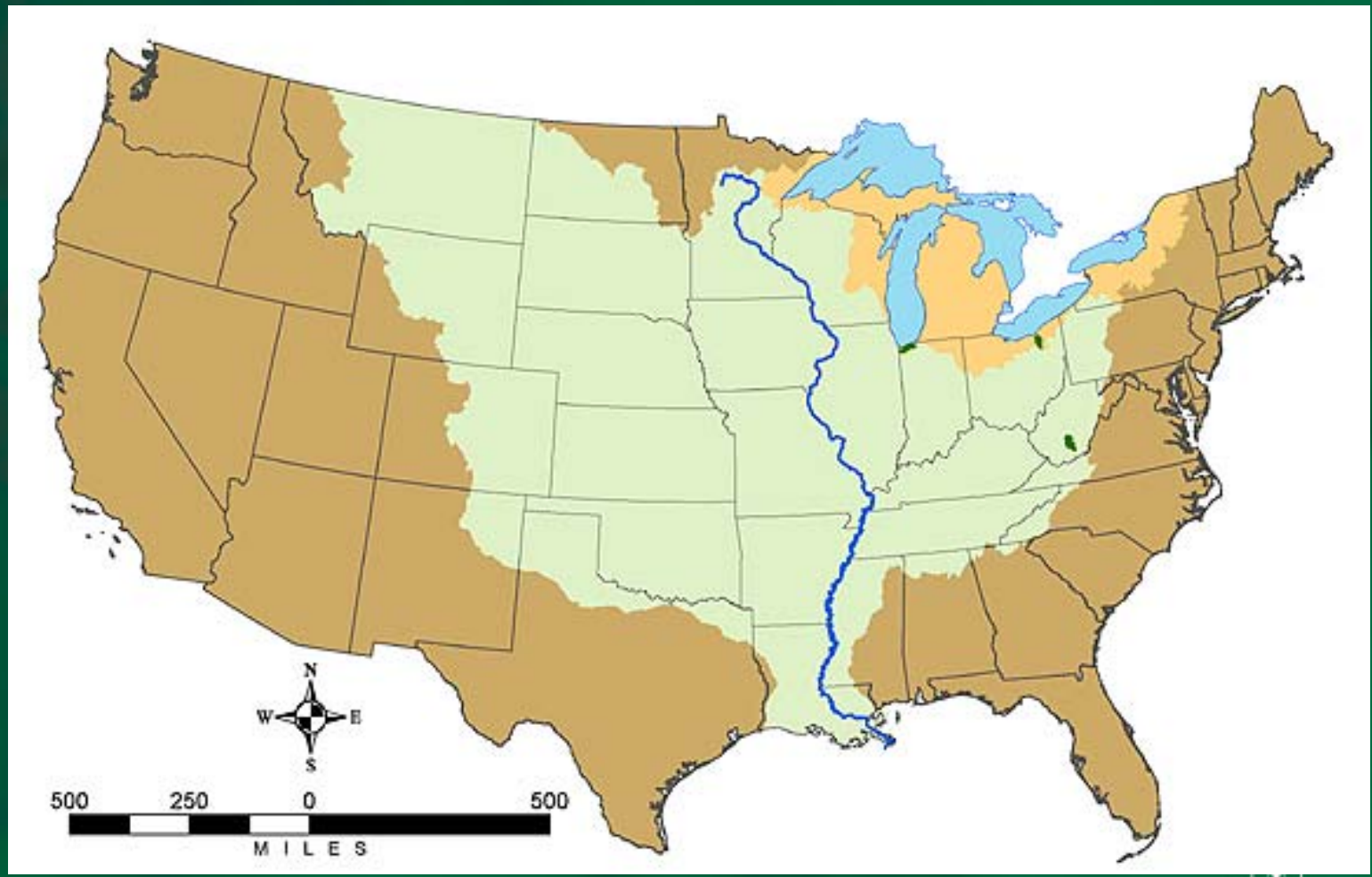
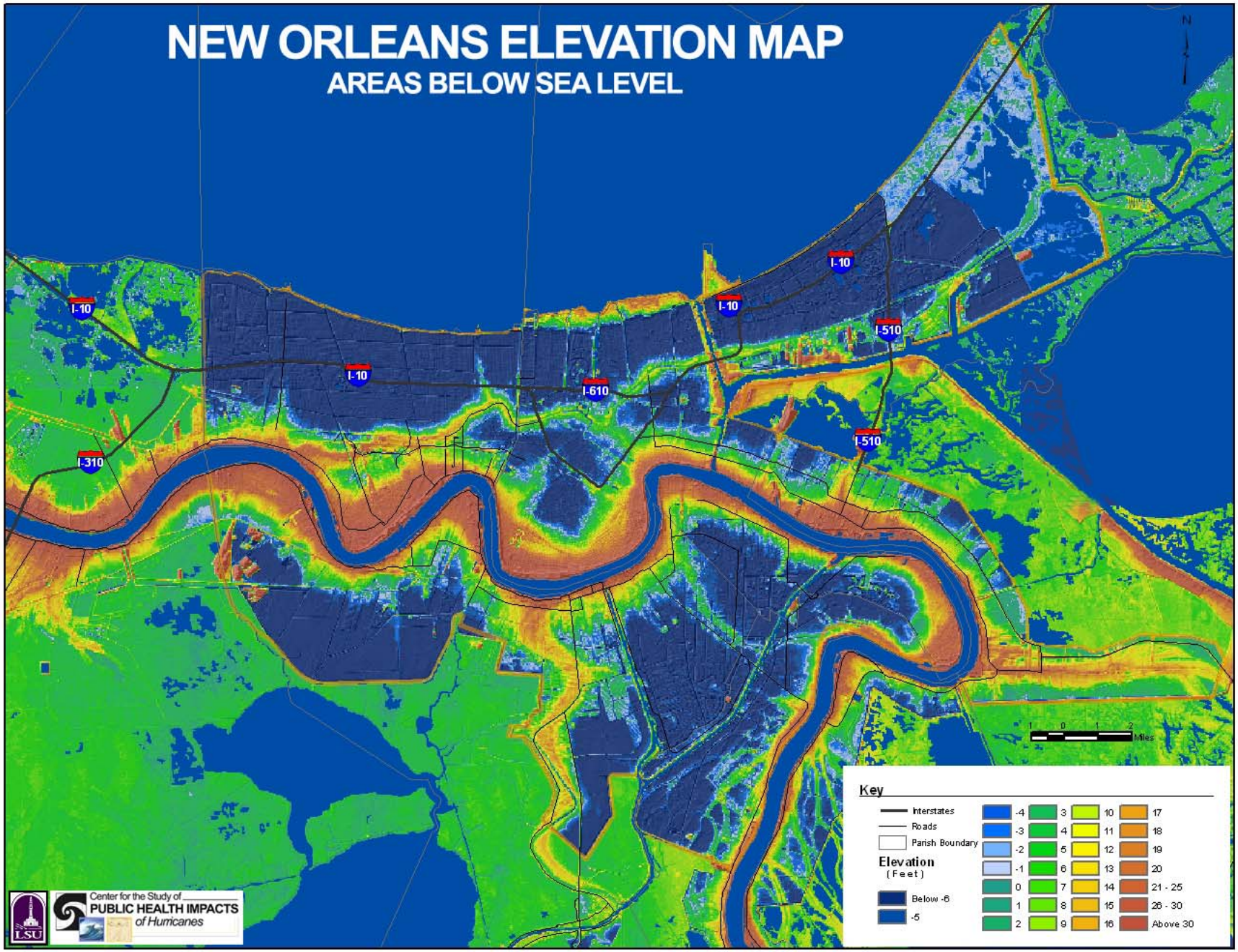
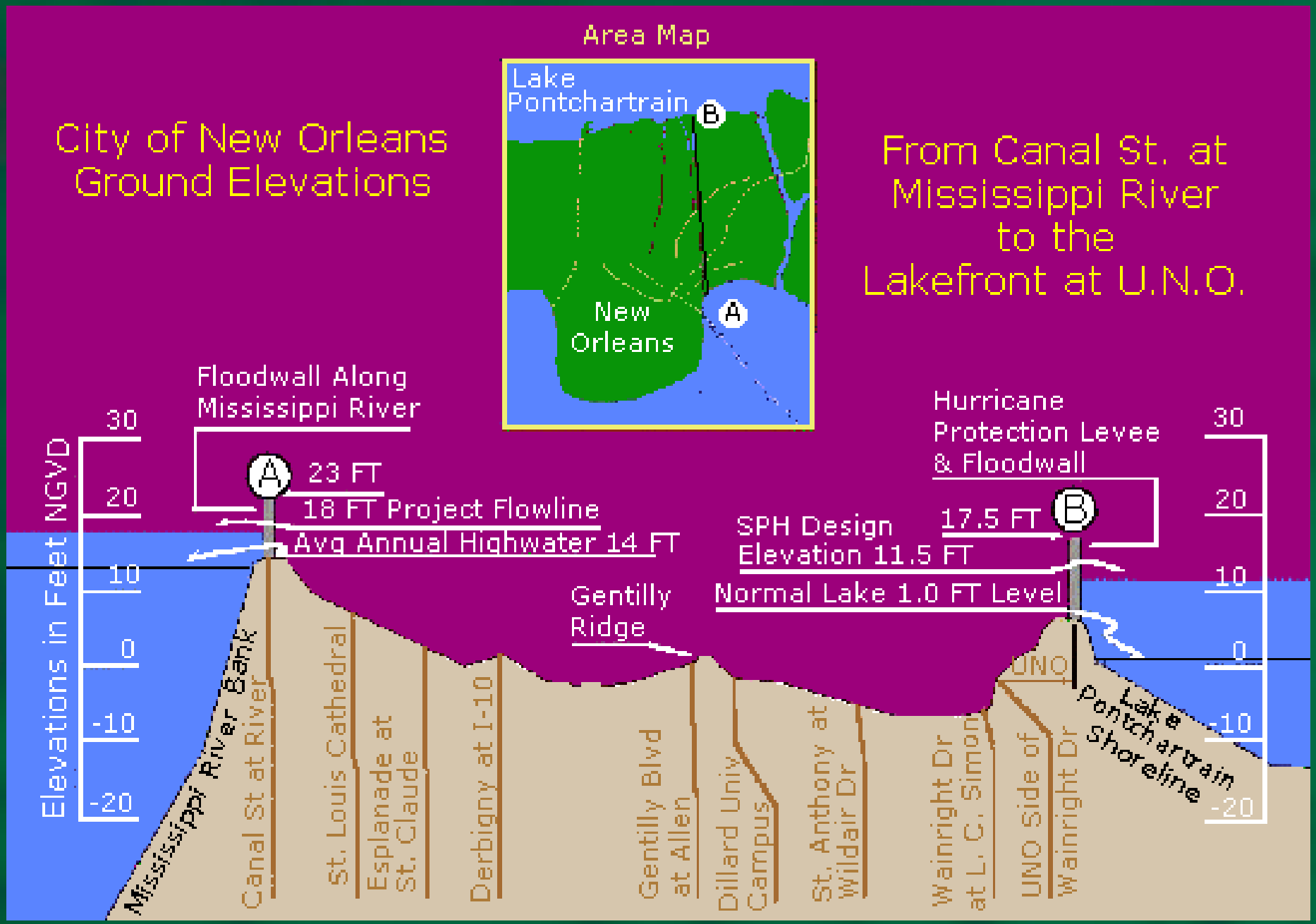
The Mississippi River Valley




NEW ORLEANS ELEVATION MAP
AREAS BELOW SEA LEVEL
I-10
I-10
I-10
I-10
I-510
I-610
I-510
I-310
1 0 1 2 Miles
Key
Interstates
Roads
Parish Boundary
Elevation
(Feet)
Below -6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21 - 25
26 - 30
Above 30
Center for the Study of
PUBLIC HEALTH IMPACTS
of Hurricanes
LSU


City of New Orleans
Ground Elevations
Area Map
Lake
Pontchartrain
B
New
Orleans
A
From Canal St. at
Mississippi River
to the
Lakefront at U.N.O.
Floodwall Along
Mississippi River
A
23 FT
18 FT Project Flowline
Avg Annual Highwater 14 FT
Hurricane
Protection Levee
& Floodwall
B
17.5 FT
SPH Design
Elevation 11.5 FT
Normal Lake 1.0 FT Level
Gentilly
Ridge
Elevations in Feet NGVD
30
20
10
0
-10
-20
Mississippi River Bank
Canal St at River
St. Louis Cathedral
Esplanade at
St. Claude
Derbigny at I-10
Gentilly Blvd
at Allen
Dillard Univ
Campus
St. Anthony at
Wildair Dr
Wainright Dr
at L. C. Simon
UNO
UNO Side of
Wainright Dr
Lake
Pontchartrain
Shoreline

History

- **1727** – Four foot levee, one mile long
- **1735** – Levee collapsed in **flood**
- **1763** – 50 miles of levees
- **1785** – Massive river **flooding**
- **1816** – Levee break **inundates** New Orleans for a month
- **1849** – Sauvee Crevasse inundates New Orleans from behind; **flooded** from April to June

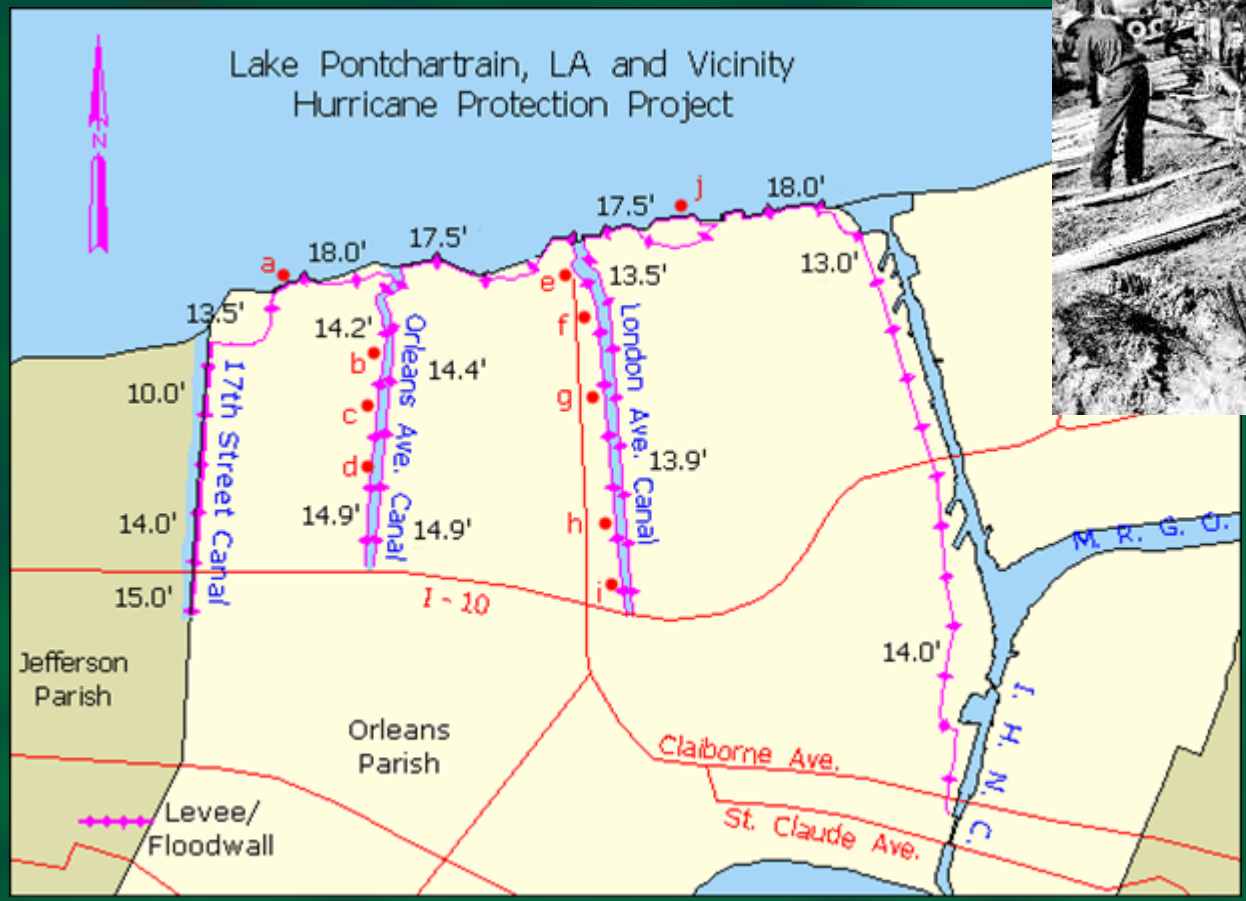
History

- **1879** Mississippi River Commission
- **1900 to 1920** Levees, drainage canals and pumps. 3.2 billion gal/day
- **1912** – Interior **flooding** from heavy rains
- **1917** – Wood screw pumps; 7 billion gal/day

History

- **1922** – Ponchartrain levees raised to el. 9.6. "Made land" built landside.
- **1927** – Major Mississippi River **flooding**
- **1947** – Hurricane overtops levees, **flooding** Orleans and Jefferson parishes
- **1956** – Hurricane Flossie **floods** along Industrial Canal
- **1964** – Hilda does same
- **1965** – **Betsy** hits New Orleans with 100 mph winds. 8 ft of **flooding**, 7000 homes damaged
- **1969** – Camille **floods** Industrial Canal area

Hurricane Protection



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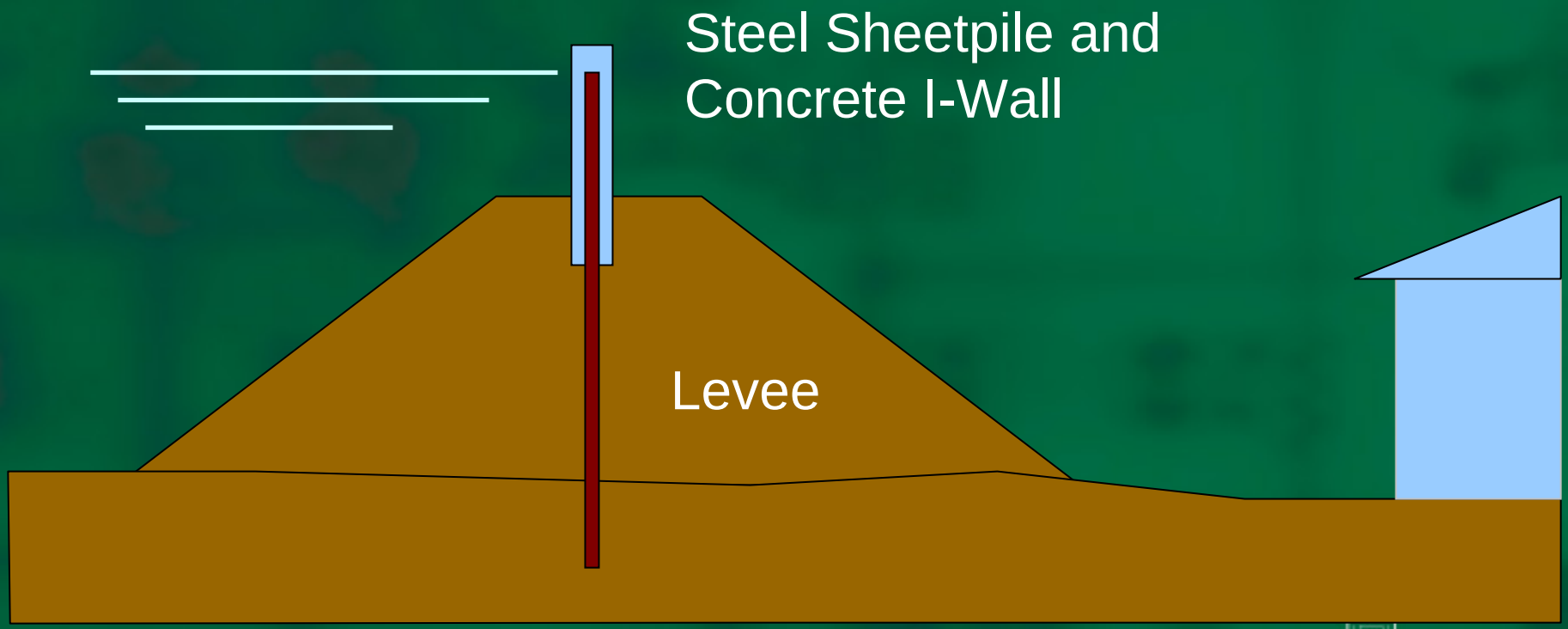
Hurricane Protection

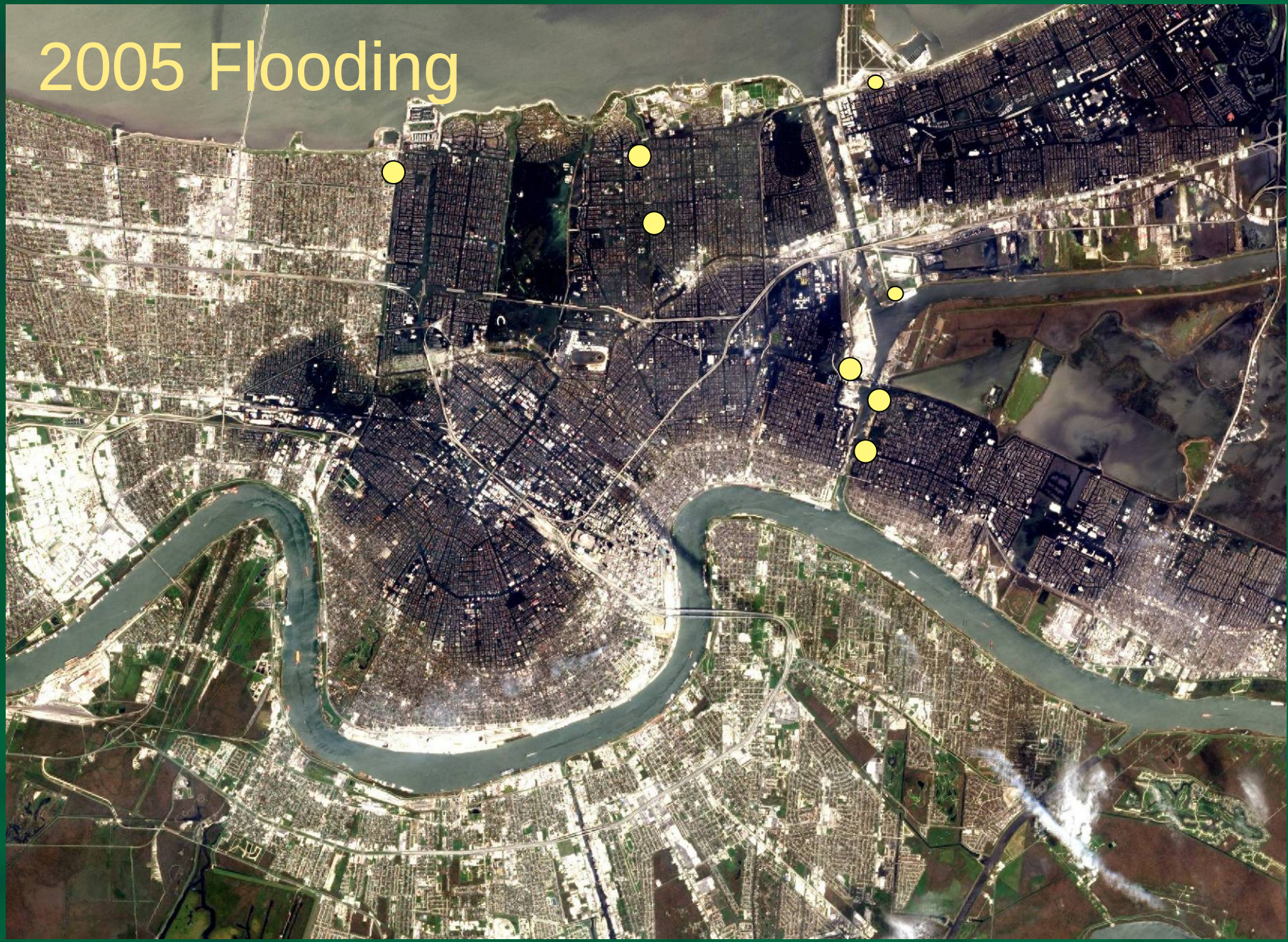


Hurricane Protection

Hurricane Protection

- Designed for **Standard Project Hurricane** – Presently considered to be water levels due to a fast moving Category 3
- Corps stated this is equivalent to **200 – 300 year protection.”**
- Others said **100 year protection**

2005 Flooding

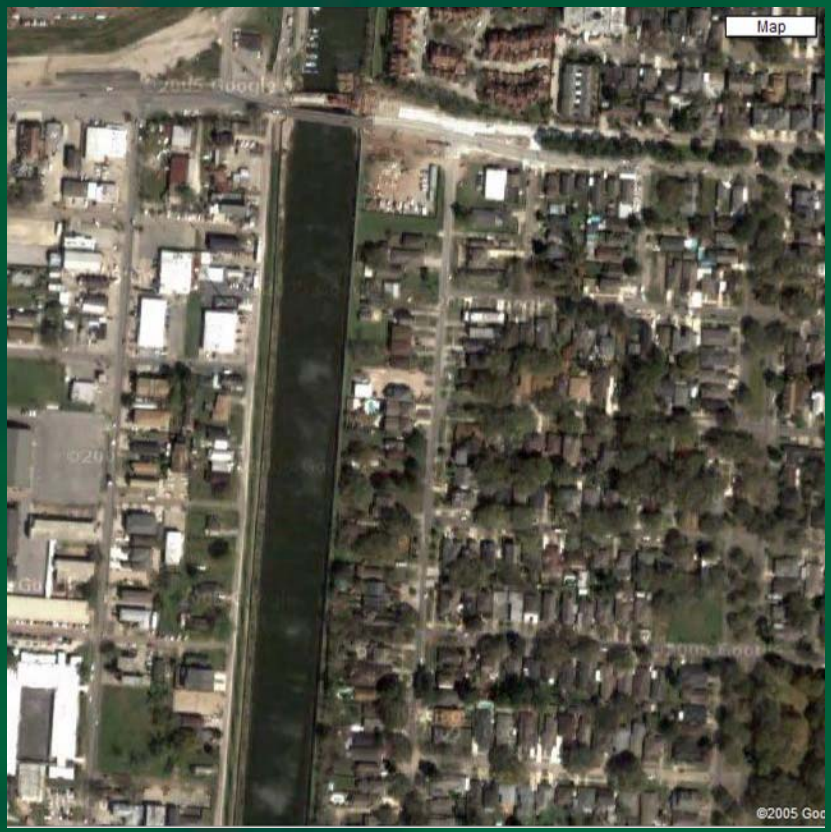


Investigations

- October 2005
  - Corps' ERDC Team
  - *** ASCE Levee Assessment Team**
  - * California Team, sponsored by NSF
  - * Joint report to U.S. Senate in November 2005

- Ongoing
  - Interagency Project Evaluation Team (IPET)
  - ASCE Review Team
  - NRC Team

17th Street Canal – Before and After



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17th Street Canal

ASCE Team, October 2005
- Levee and floodwall displaced 35 ft landward due to apparent sliding on peat or soft clay in foundation

IPET Report
- Sliding was in the clay layer

17th Street Canal

17th Street Canal

17th Street Canal

17th Street Canal

17th Street Canal

House foundation

Intact waterstop

17th Street Canal

Peaty foundation material

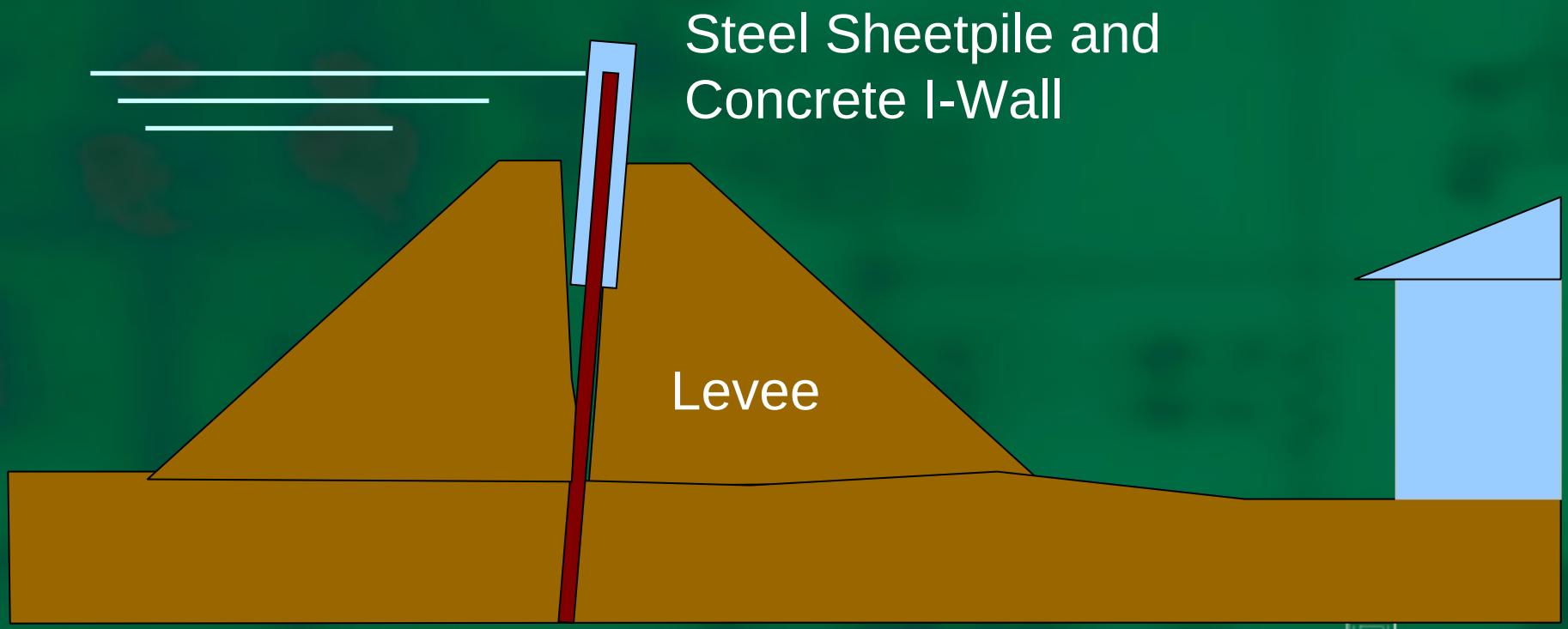
Repaired section

17th Street Canal

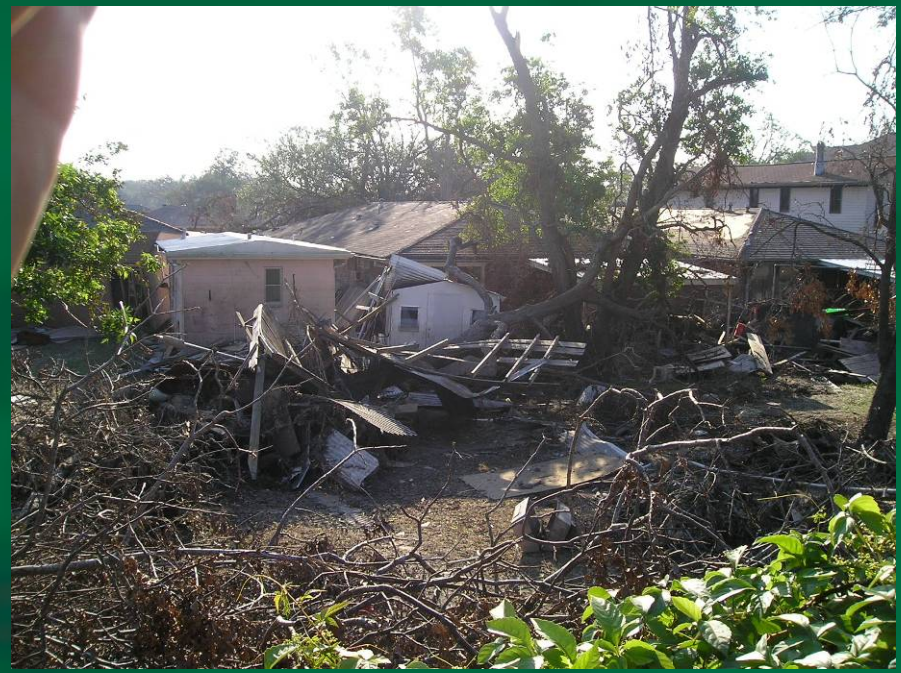
17th Street Canal – IPET Report

- One foot thick clay layer under the peat
- LL = 95%
- s_u / p′ = 0.24
- Strength increases 11 psf / ft of depth
- Strength weaker at toe than under levee, not considered in design
- Floodwall deformation creates crack and full canal side water pressure

17th Street Canal – IPET Report



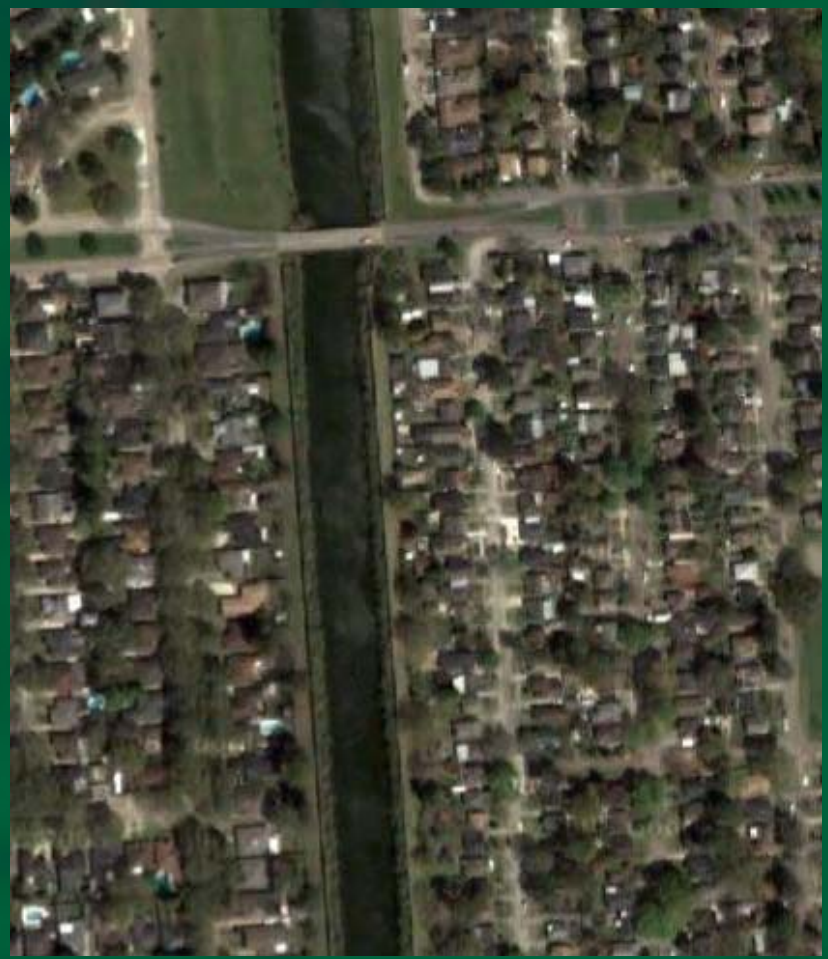
17th Street Canal



Neighborhood damage

2005 Flooding

London Ave. canal north



London Ave. canal north

London Ave. canal north

London Ave. canal north

London Ave. canal north

London Ave. canal north

London Ave. north – east side

London Ave. north – east side

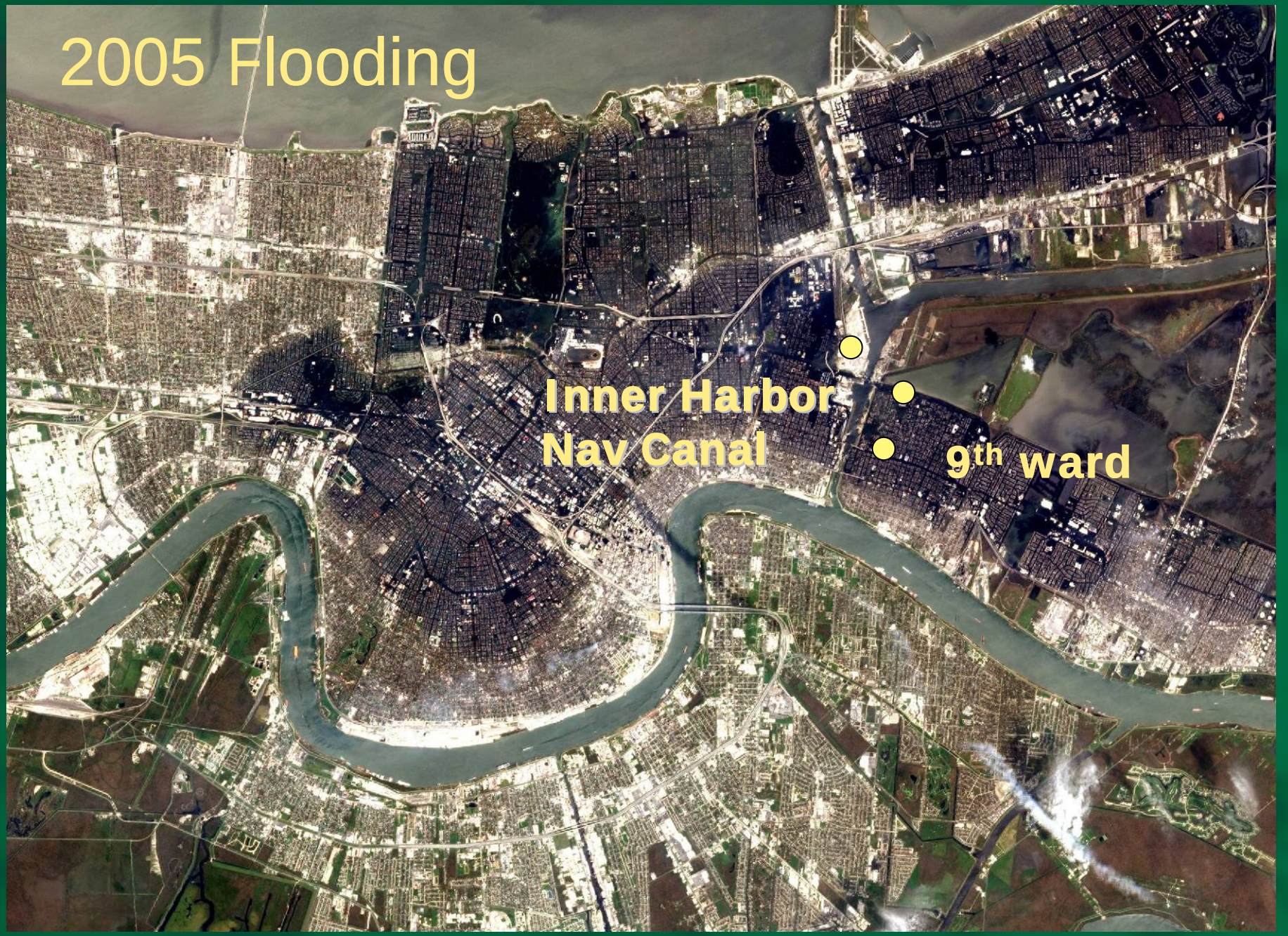
London Ave. canal south

London Ave. canal south

London Ave. canal south

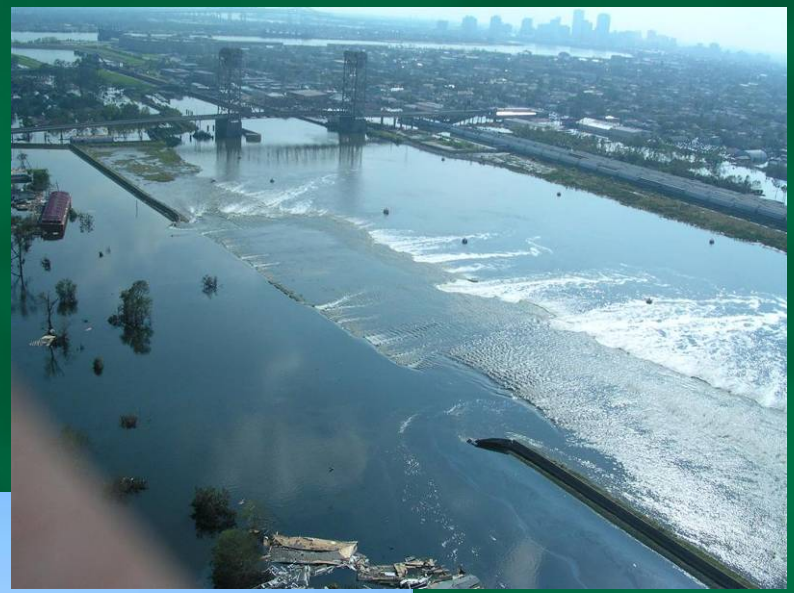
London Ave. canal south

2005 Flooding



Industrial Canal – Ninth Ward

Industrial Canal – Ninth Ward



Industrial Canal – Ninth Ward

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Industrial Canal – Ninth Ward

Industrial Canal – Ninth Ward

Industrial Canal – Ninth Ward

Industrial Canal – West

Bayou Bienvenue

Mississippi River Gulf Outlet

Entergy Plant

Entergy Plant

Entergy Plant

Point a la Hache

Point a la Hache

Point a la Hache

Observations

- Six major breaks in New Orleans
  - Three failures at levels lower than top of wall
    - 17th St. Canal – sliding on soft clay or peat
    - London Ave. Canal – underseepage through thick sand (2)
  - Three failure due to overtopping
    - Industrial canal – Ninth ward (2)
    - Industrial canal – West
- Dozens of breaks east and south of New Orleans

Observations

- Engineers and the public cannot easily perceive low probability, high risk events
- Event larger than the design event was not imagined – **No provision for overtopping**
- Levees are a series system with **little or no redundancy**
- I-Walls in levee crown **restricted access** for emergency closure, and violated Corps' own policy
- **Transitions** built by different jurisdictions at different elevations

Transitions

Observations

- ASCE Levee Assessment Team, Nov 17, 2005
  - "...three weakest links failed, fourth weakest link experienced a near failure...Next weakest link has not been tested. ... warrants an overall review." (inserted by Wolff)
- IPET Report No. 2, Mar 10, 2006
  - "...significant system-wide implications because gap formation and lateral variation of shear strength beneath the levee must be considered for other I-wall sections
- ASCE letter to Corps, Mar 23, 2006
  - "We conclude that a determination of the overall safety of the hurricane protection system cannot be made until such time as the remainder of the system can be evaluated with the benefit of this new information."

In closing...

Mechanical Engineering Design Philosophy:

Design > Build > Test > Redesign

Civil Engineering Design Reality

Review past failures > Design > Build > Hope