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# Planning and Design for Hurricane Protection with Sea Level Rise

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Bob Ivarson, PE, D.WRE

Hampton Roads Sea Level Rise/ Flooding Adaptation Forum
22 May 2015

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# Introduction

- My perspective and the need for an area-wide planning approach
- Design Criteria
- Planning / feasibility studies
- Design and the various delivery methods for implementation

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# Perspective

- 42 years of professional practice in heavy civil works planning, design and construction management (dams, hydropower, flood control, environmental restoration, inland marine navigation, and coastal protection and restoration)
- Practice has included civil, structural, H&H, mechanical, and geotechnical engineering
- Have utilized Design-Bid-Build, Design-Build, & Early Contractor Involvement
- Without developing an area-wide plan and following it to completion during design and construction, unintended consequences will be costly. The plan should include rezoning areas to as a minimum prevent continued development in at risk areas.

# Design Criteria

- It is extremely important to establish the design criteria prior to the planning phase in order to evaluate the most economic alternatives.
- I will address the following criteria:
  - Hydraulics including sea level rise and design storm
  - Geotechnical including subsidence and long term settlement
  - O&M
  - Structures
  - Mechanical / Gates and pump stations
  - Electrical / Power and standby power

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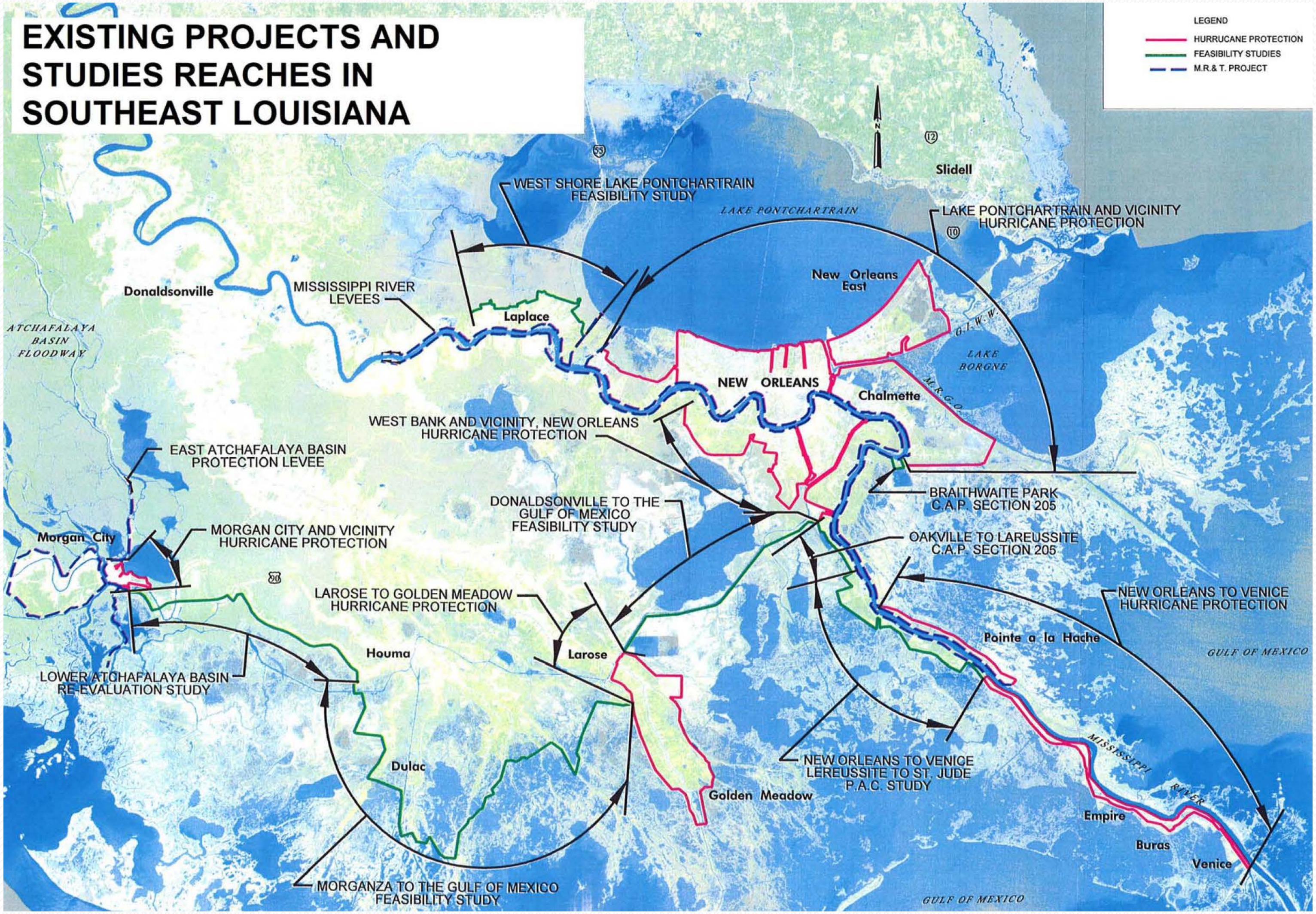
# The New Orleans System

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# The New Orleans System

- 280 Miles of Levees (with I-Walls) or Floodwalls
- 222 Miles of Levees
- 163 Drainage Openings
- 159 Access Openings
- 143 Railroad Openings
- 69 Miles of Interior Levees/Floodwalls
- 32 Interior Pump Stations (to interior canals)
- 23 Pump Stations (interior canals to outside protection)
- 12 Navigation Floodgates
- 3 Navigation Locks

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# Hydraulics
# Sea Level Rise

- Accepted practice and that adopted by the USACE is IPCC 2007.
- They provide 3 scenarios for forecasting future rise.

EC 1165-2-212
1 Oct 11

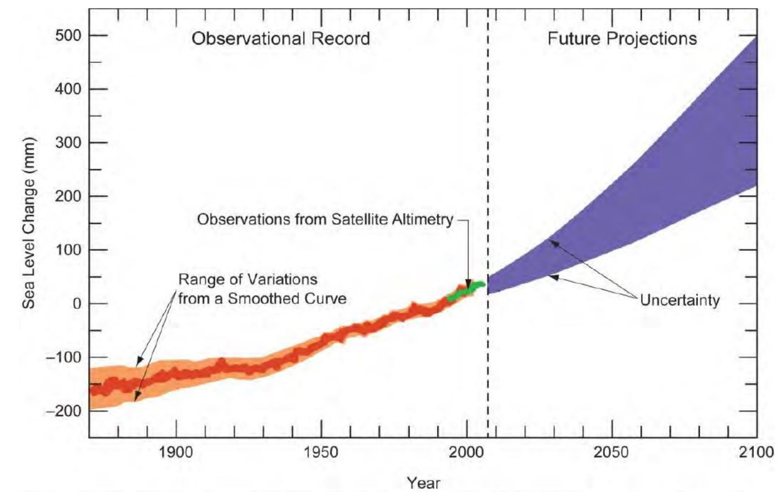



Figure B-12. Illustration of GMSL (deviation from the 1980-1999 mean) as observed since 1870 and projected for the future. The future projections have been calculated independently from the observations (after IPCC 2007a, FAQ 5.1, Figure 1).

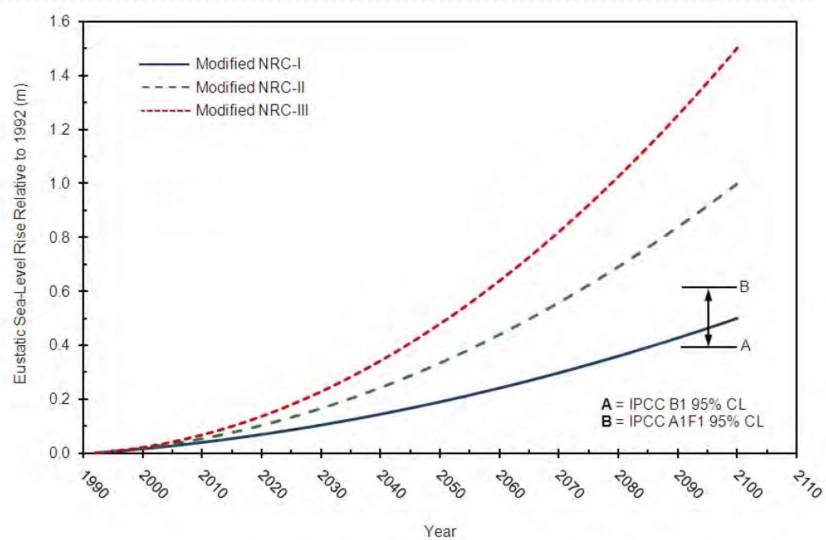



Figure B-13. Modified NRC (1987) GMSL rise scenarios and the IPCC (2007) scenario estimates for use in predicting future sea-level change.

# Hydraulics
# Sea Level Rise

- I urge caution about being too conservative with the forecast as the support data is highly variable.

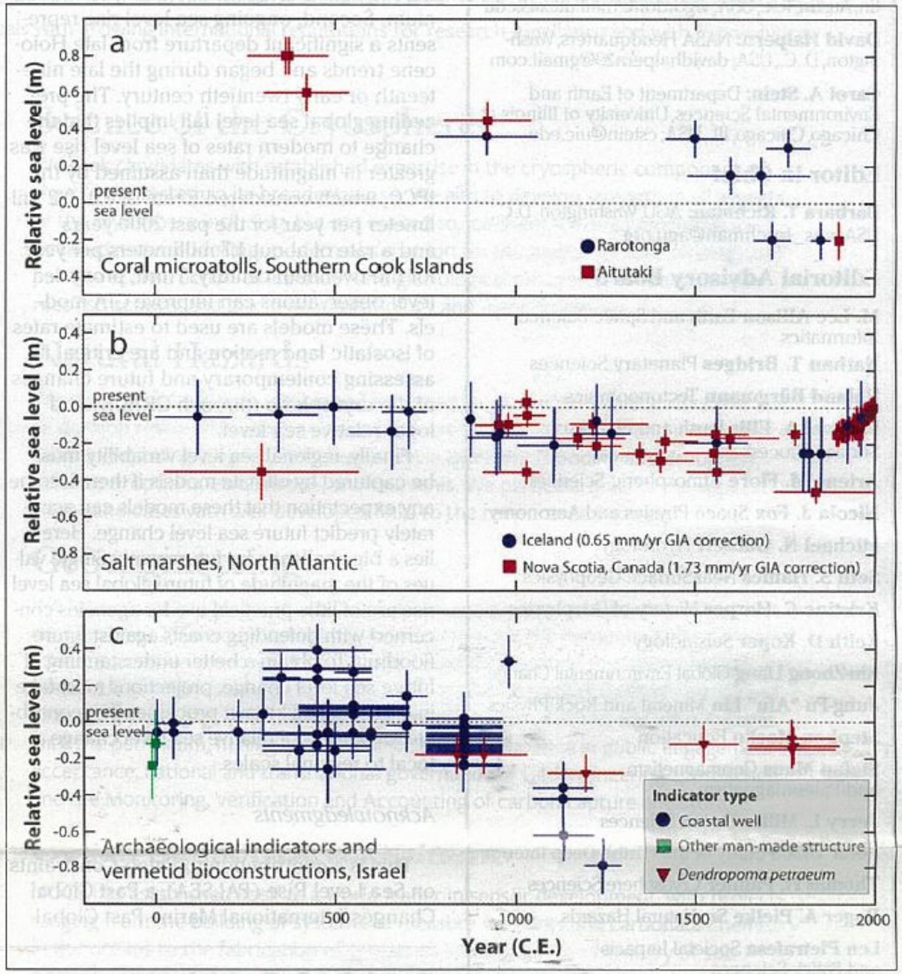
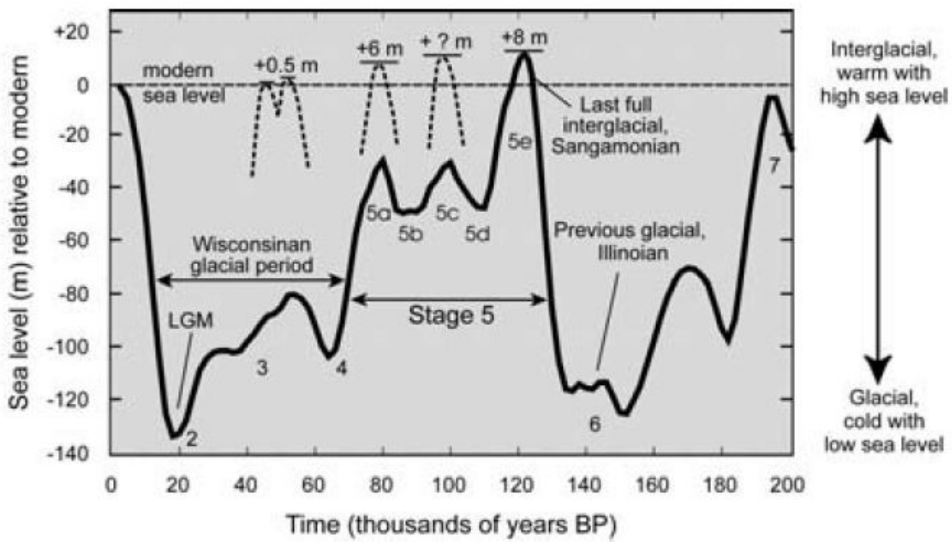
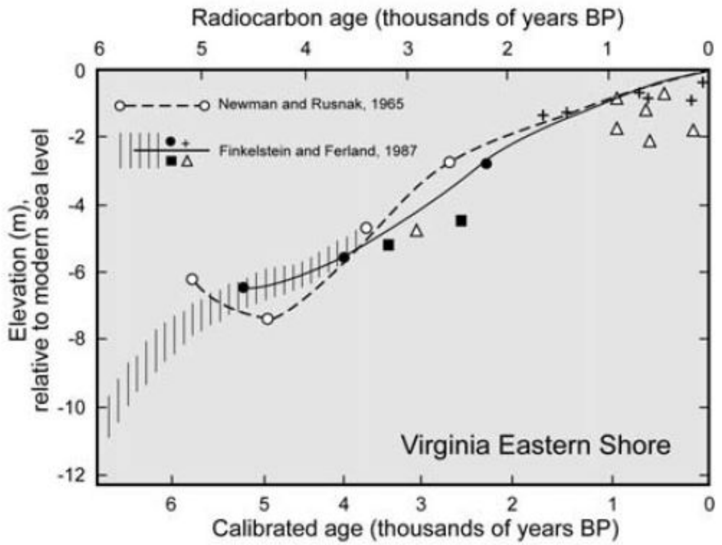
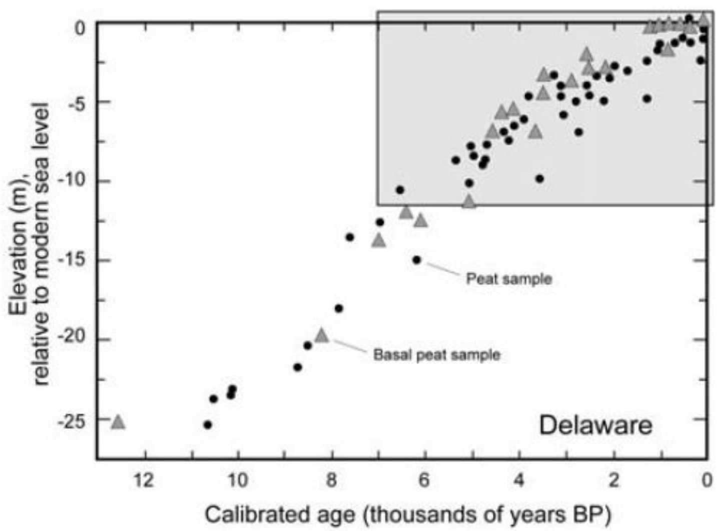



*Fig. 1. Examples of proxy sea level reconstructions spanning the past two millennia. (a) Coral microatoll records from the South Pacific [*Goodwin and Harvey*, 2008]. (b) Salt marsh records from Iceland [*Gehrels et al.*, 2006] and Nova Scotia, Canada [*Gehrels et al.*, 2005]. The effects of glacial isostatic adjustment (GIA) have been removed from these records. (c) Sea level record from the Mediterranean coast of Israel [*Sivan et al.*, 2004, 2010; *Anzidei et al.*, 2011; *Toker et al.*, 2011] based on archaeological structures and analysis of vermetid (*Dendropoma petraeum*, a mollusk) colonies.*

# Hydraulics
# Sea Level History

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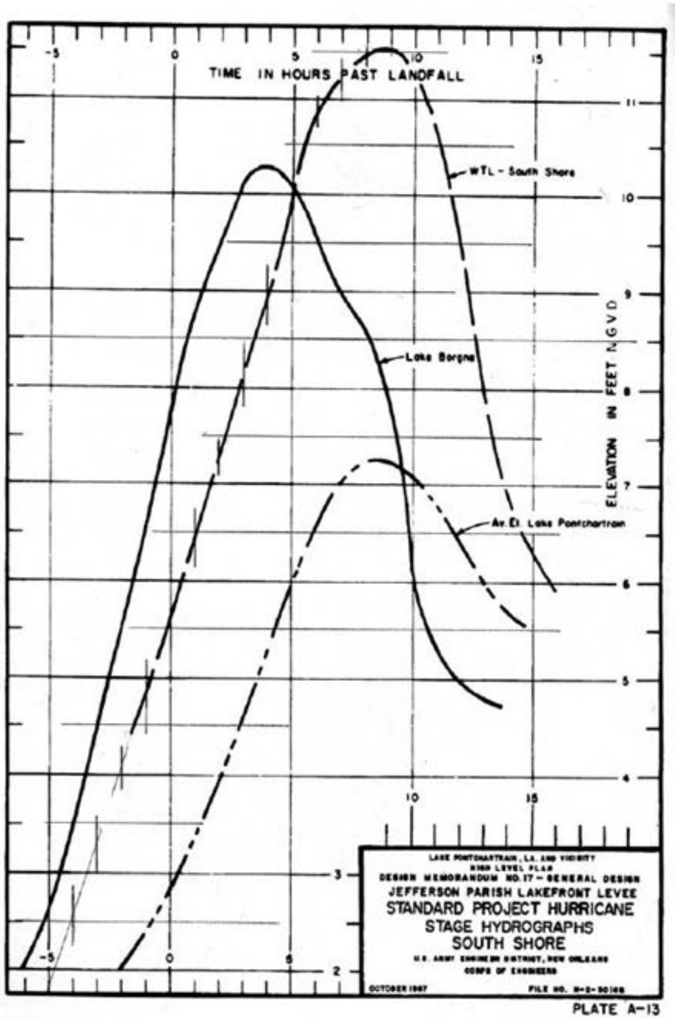
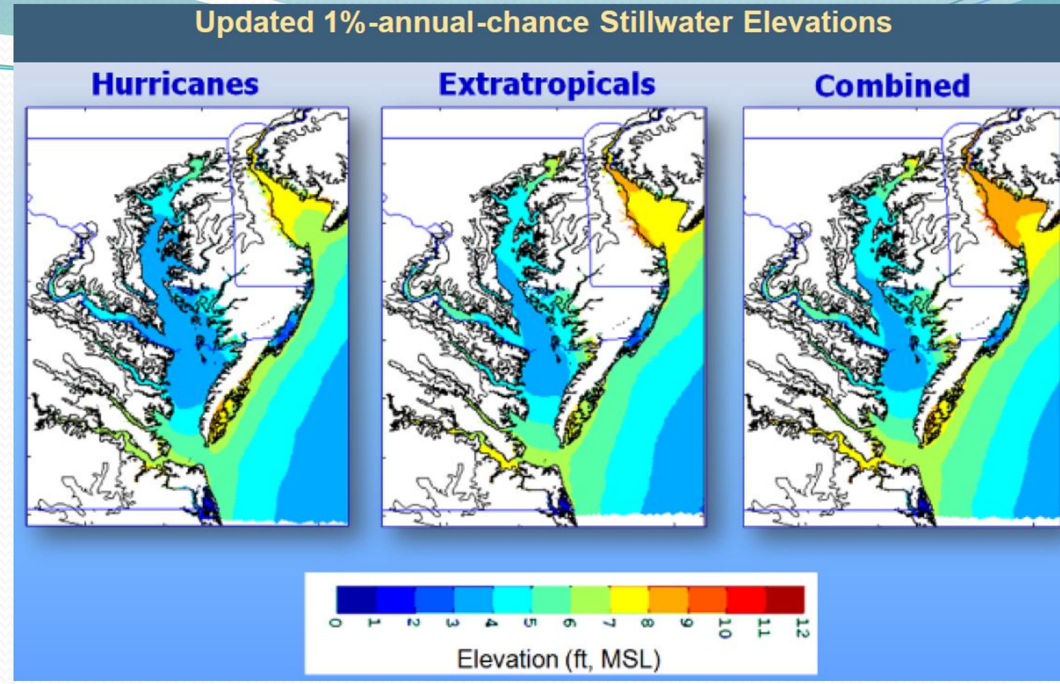
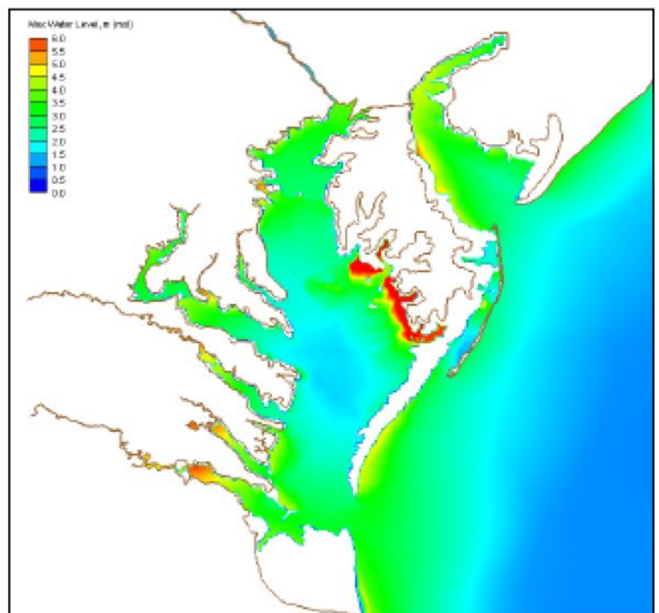
# Hydraulics Hurricane Surge

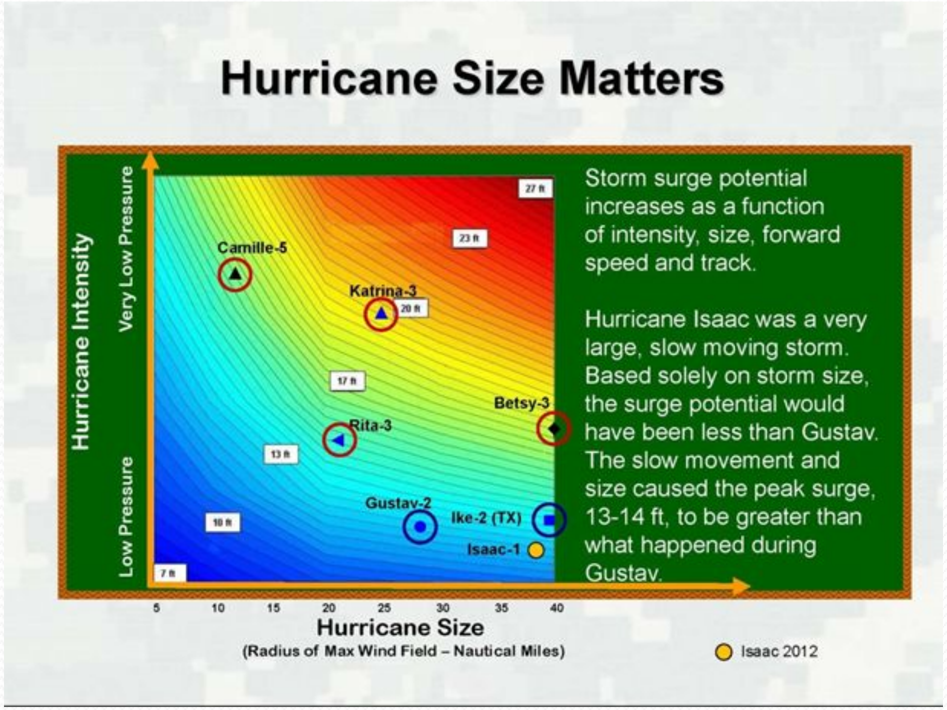


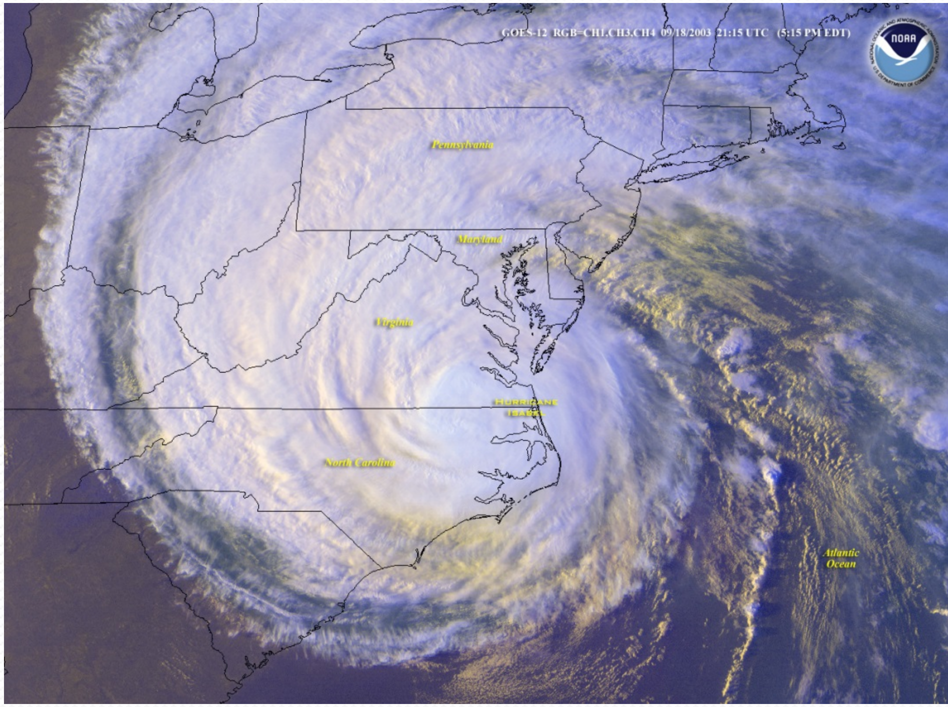



Calculated maximum water levels for all simulated hurricanes (1895-2004).

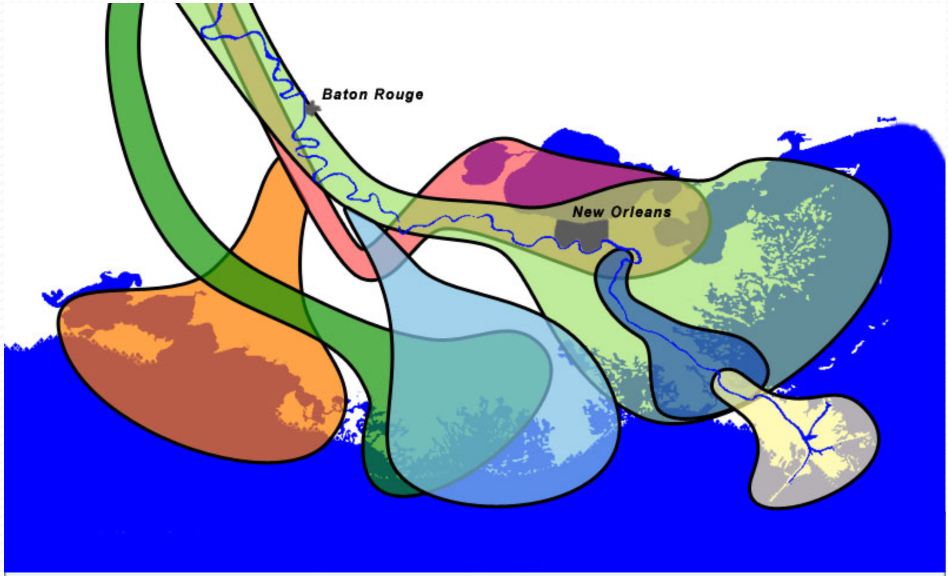
# Hydraulics
# Hurricane Surge

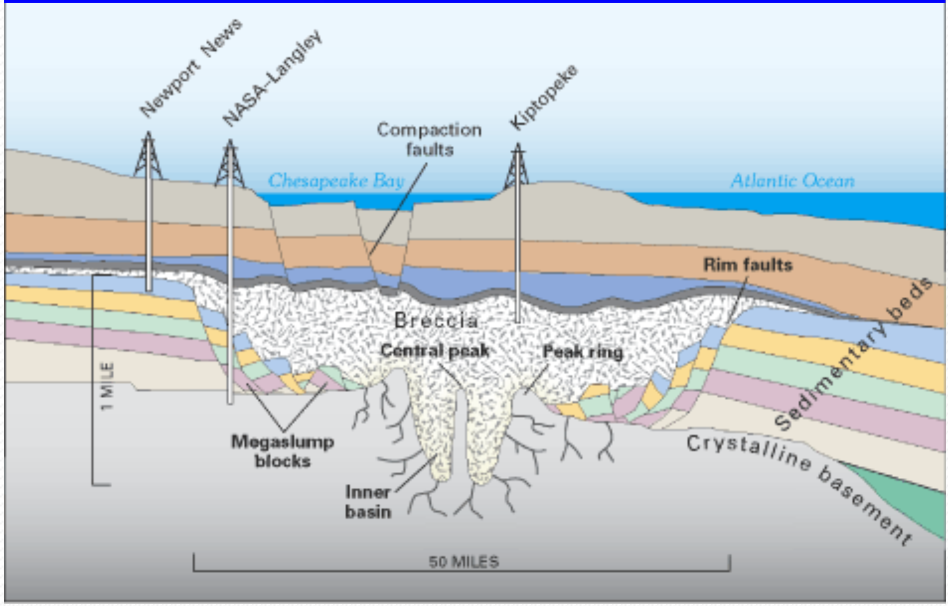


# Geotechnical Foundation Strengths

- Foundation strengths greatly affected the cost of hurricane protection.
- They are affected by fluvial geomorphology of the site.
    - In New Orleans sediment transport - 600,000,000 T/yr and 10+ times the depth of unconsolidated sediments as the Chesapeake.
    - Significant effect on required FOS for design.

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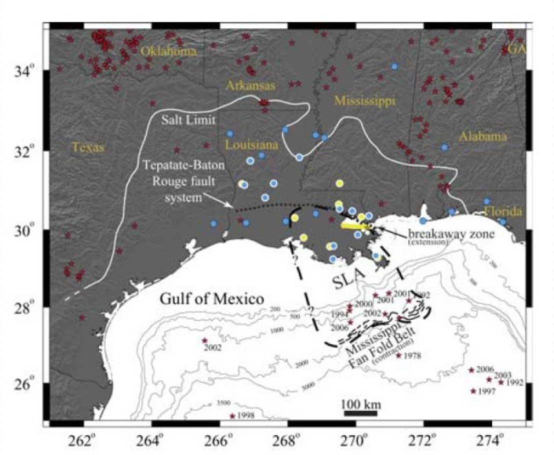
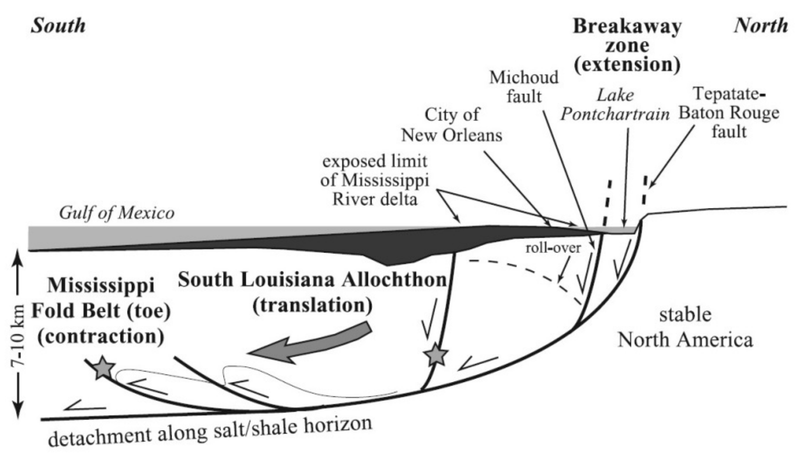
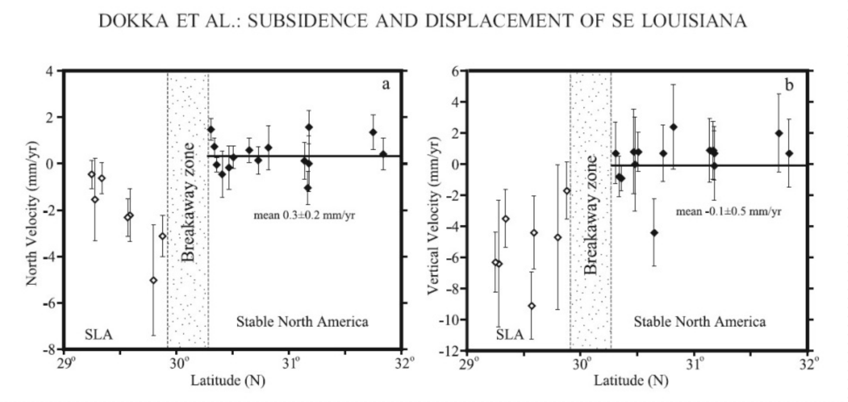
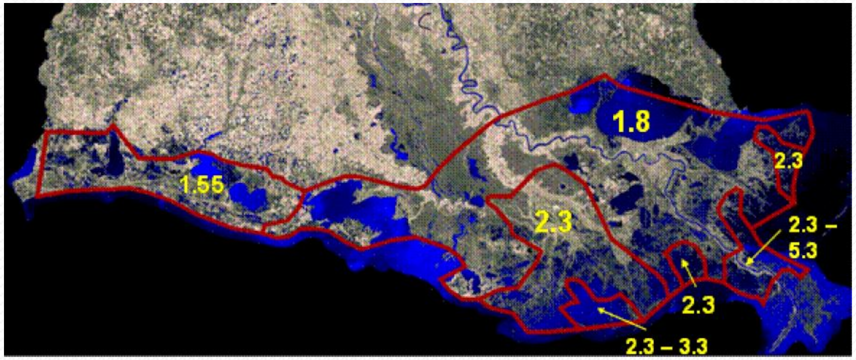
# Geotechnical Subsidence – New Orleans

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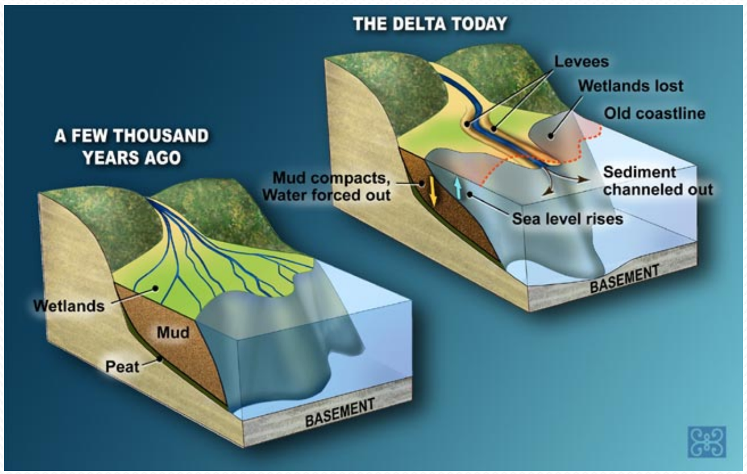
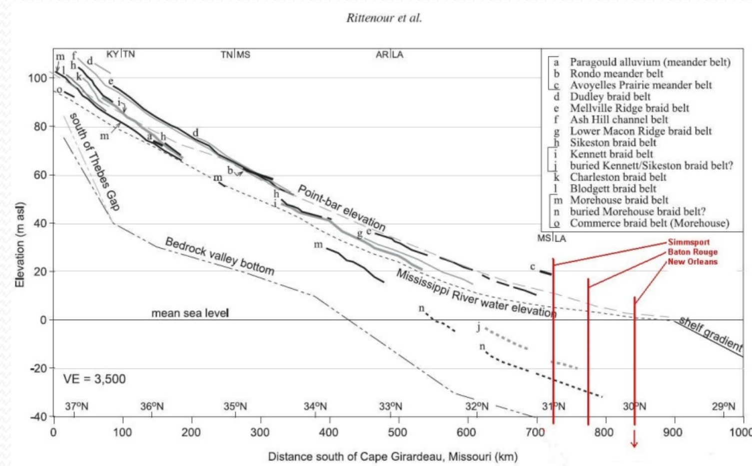
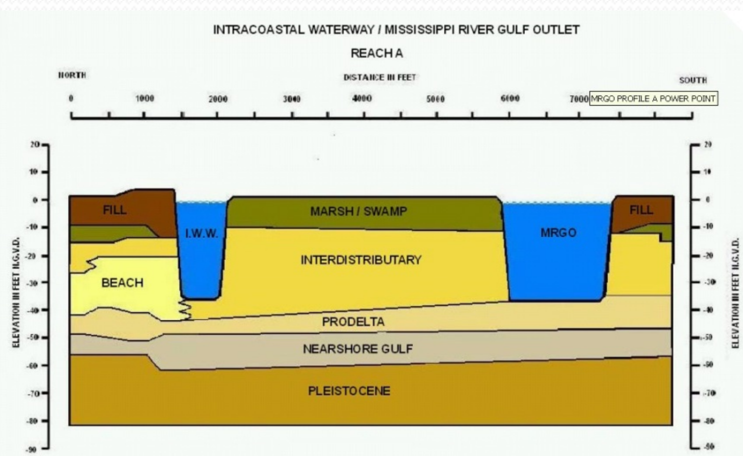
# Geotechnical Foundation Strengths – New Orleans




## Generalized Stratigraphy
## Soil Properties

Ground surface El. 0

Peat, γ = 85 pcf, c = 150 psf, w = 300%,

Swamp: γ = 95 pcf, c = 200 psf, w = 100%

Soft organic clay: γ = 100 pcf, c = 200-400 psf, w = 160%

Interdistributary and Prodelta clay: γ = 105 pcf, c = 400-800 psf, w = 40 to 60 %, PL=20, LL =70

-50 to -70

Nearshore Gulf sand overlying Pleistocene Clay: γ = 115 pcf, c > 1,000 psf

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# O&M

- Who will own, operate and maintain the facilities is extremely important. Adequately resourced?
- Reducing requirements for an active flood fight is highly desirable.
  - 465 openings to close.
  - 55 pump stations to operate.
- Maintenance cannot be ignored.

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# Structures

- Design guides and criteria should be agreed to in the planning phase for accurate cost estimating.
- Requirements should be prescriptive:
  - FOS
  - Concrete reinforcement at about 50% of balanced design
  - Minimum steel thickness – 3/8”
  - Corrosion control

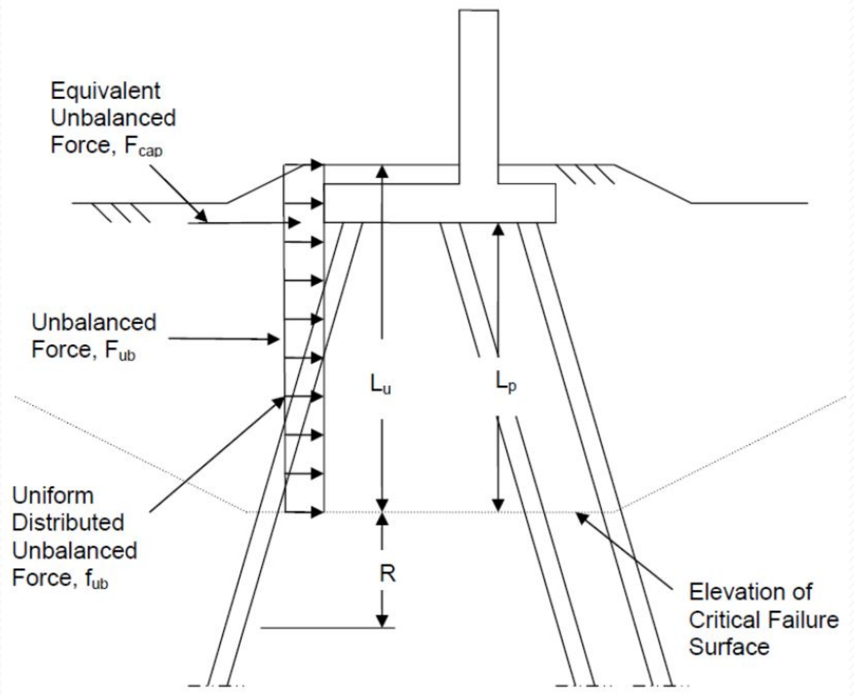


**Figure 3.10 Unbalanced Forces.**

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# Electrical and Mechanical

- This primarily revolves around how reliable is the grid?
- Will the facilities only be used for hurricane protection or more often?
  - Stand-by power and electric motor drives for small loads
  - Possibly direct diesel engine drives for large pumps.
  - Fuel storage and maintenance can be problematic if the grid can be down long.

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# Planning / Feasibility Studies

- Effective planning must consider:
  - Geologic and hydrologic conditions,
  - Design criteria, and
  - Flood Operations and regular maintenance.
  - Most of the New Orleans planning evaluate parallel protection versus perimeter protection.
- Features to be considered and planned:
  - Levees
  - Floodwalls
  - Closure structures and gates
  - Interior drainage pump stations
  - Electrical power and standby power

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# Levees

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# Floodwalls


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# Gates and Closure Structures


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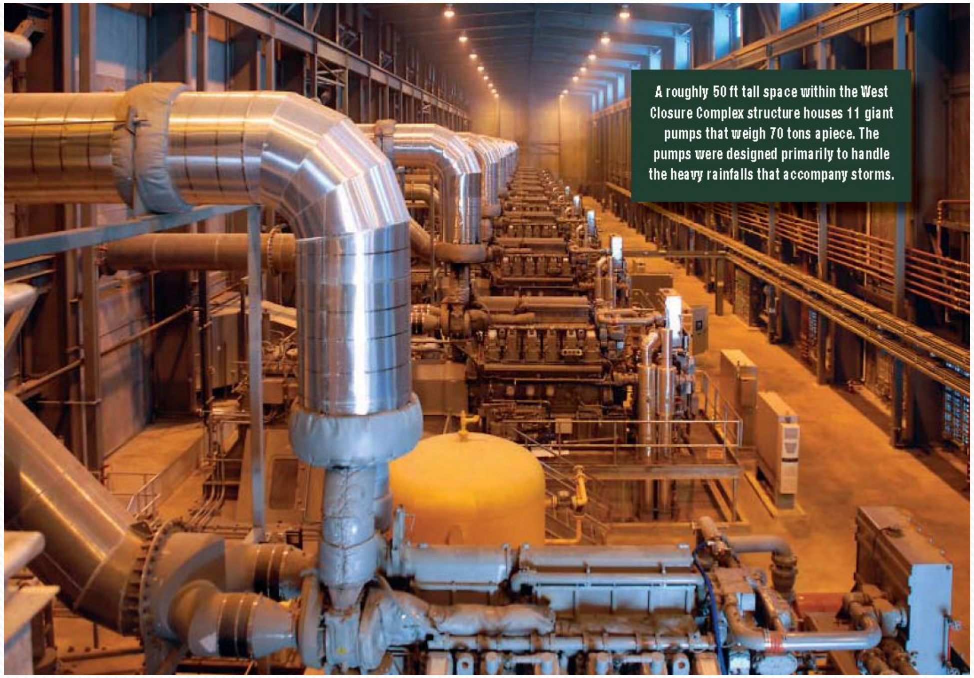
# Interior Drainage Pump Stations




# Electrical Power and Stand-by Power

- Power requirements for pumping is quite large and due to the unreliability of the electrical grid during a hurricane most pumps are diesel driven.
- Emergency or stand-by power is provided for the auxiliaries to start and run the diesel drives (about 3 to 5% of pumping power requirements.
- The exception to this is the City of New Orleans, which insists on electric motor driven pumps and complete power stations supplying the pump stations.

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# Post Hurricane Katrina Planning

- Evaluated how to most economically repair and enhance the New Orleans Hurricane Protection System:
  - Provide 1% probability storm protection
  - Parallel protection
  - Or Perimeter protection
- Perimeter protection was 30% cheaper.

# Design and Construction

- Three types of delivery methods were used in New Orleans
  - Traditional Design-Bid-Build – Primarily used for the smaller projects.
  - Early Contractor Involvement – Used for the GIWW  WCC.
  - Design-Build – Used for both the Lake Borgne Barrier and the Outfall Canals Closures and Pump Stations.
- Because of the need for rapid rebuilding and enhancement of the New Orleans HPS following Katrina and Rita all 3 types of delivery systems were employed by the New Orleans District USACE.
- I'll briefly discuss the types of projects implemented with each of the delivery systems and how each work.

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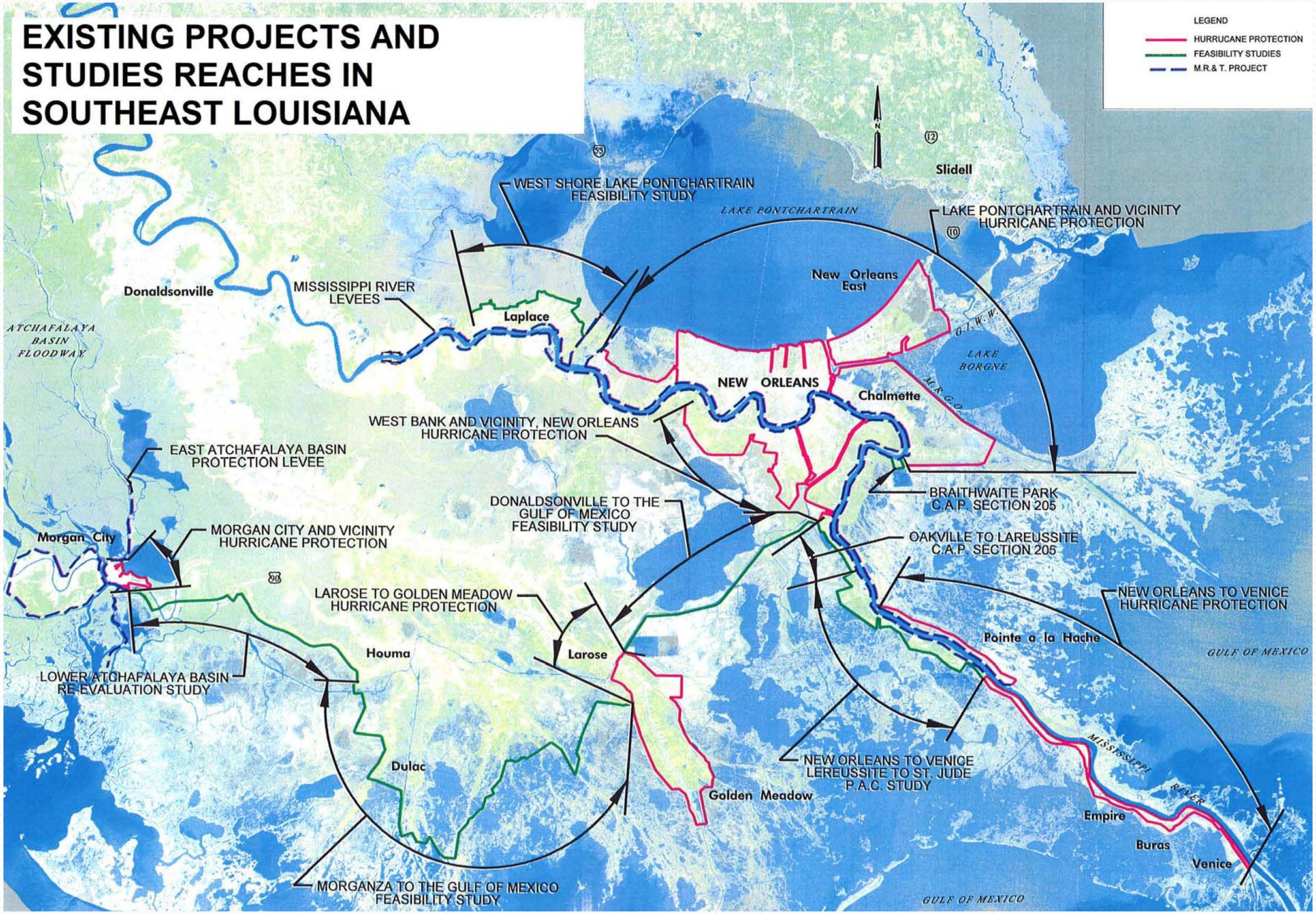
# The New Orleans System

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# Design-Bid-Build (D-B-B)

- Design-Bid-Build is the traditional delivery method for civil works type projects.
- Design is completed before bidding and construction.
- Usually longest schedule but most owner control and least direct cost.
- In New Orleans this method was used for:
  - Levee raises
  - Replacing I-walls with T-walls
  - Pump station improvements to fronting protection

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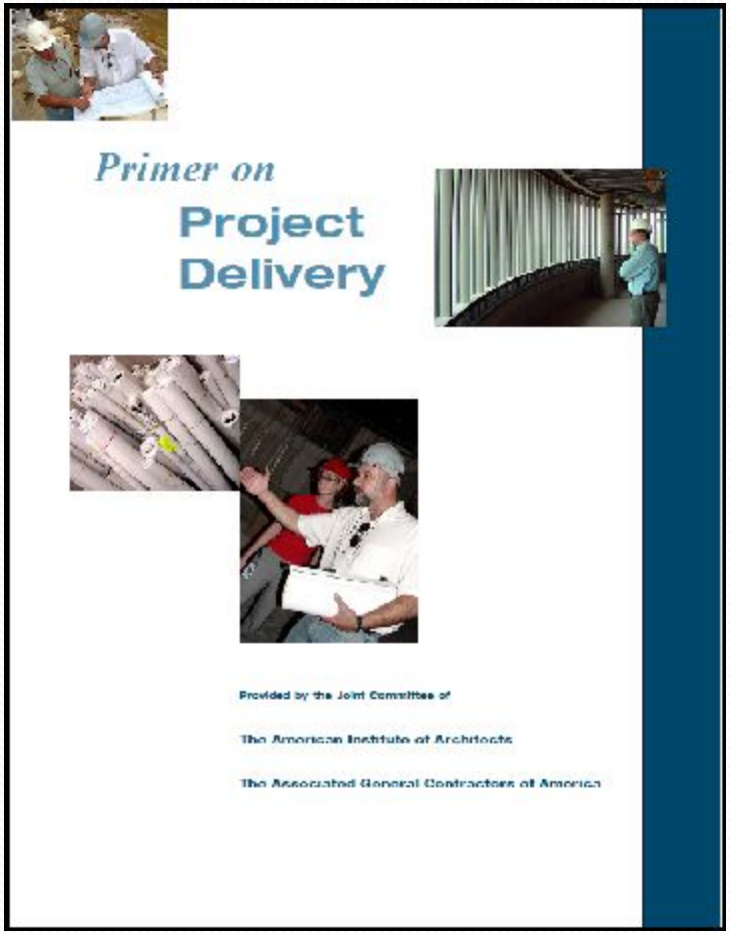
# Early Contractor Involvement (ECI)




- What is ECI?

  *Hiring the Contractor before the design is complete.*

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# ECI is…

- A project delivery method where the Owner engages the services of a general contractor to provide “preconstruction services” concurrent with design effort
- The contract includes the Owner’s ability to exercise an option for the construction
- Contract includes terms and conditions to allocate risk among the parties
- For federally funded projects, a Fixed Price Incentive contract IAW FAR 16.403

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# Greater New Orleans HSDRRS
# West Bank and Vicinity


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# The Gulf Intracoastal Waterway West Closure Complex was Delivered by this Method


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# PS Major Design Milestones

| Design Milestone | Completion Date |
|---|---|
| Notice to Proceed | 12-17-08 |
| 50% Excavation and Cofferdam Package* | 03-18-09 |
| 35% Plans and Specifications | 04-01-09 |
| Geotechnical Report | 05-08-09 |
| Pump Procurement Bid Package | 05-15-09 |
| 50% Plans and Specifications | 05-29-09 |
| Pile Load Test Inspection and Report | 05-08-09 |
| Foundation & Piles Package | 07-27-09 |
| Placement of Piles Begins | 08-06-09 |
| 95% Plans and Specifications | 09-18-09 |
| *Design Summit* | 10-26-09 thru 10-28-09 |
| Original 100% Plans and Specifications | 11-09-09 |

*Construction Cost Estimates and Schedule updates provided with pump procurement package, pile & foundation package, and each general construction package

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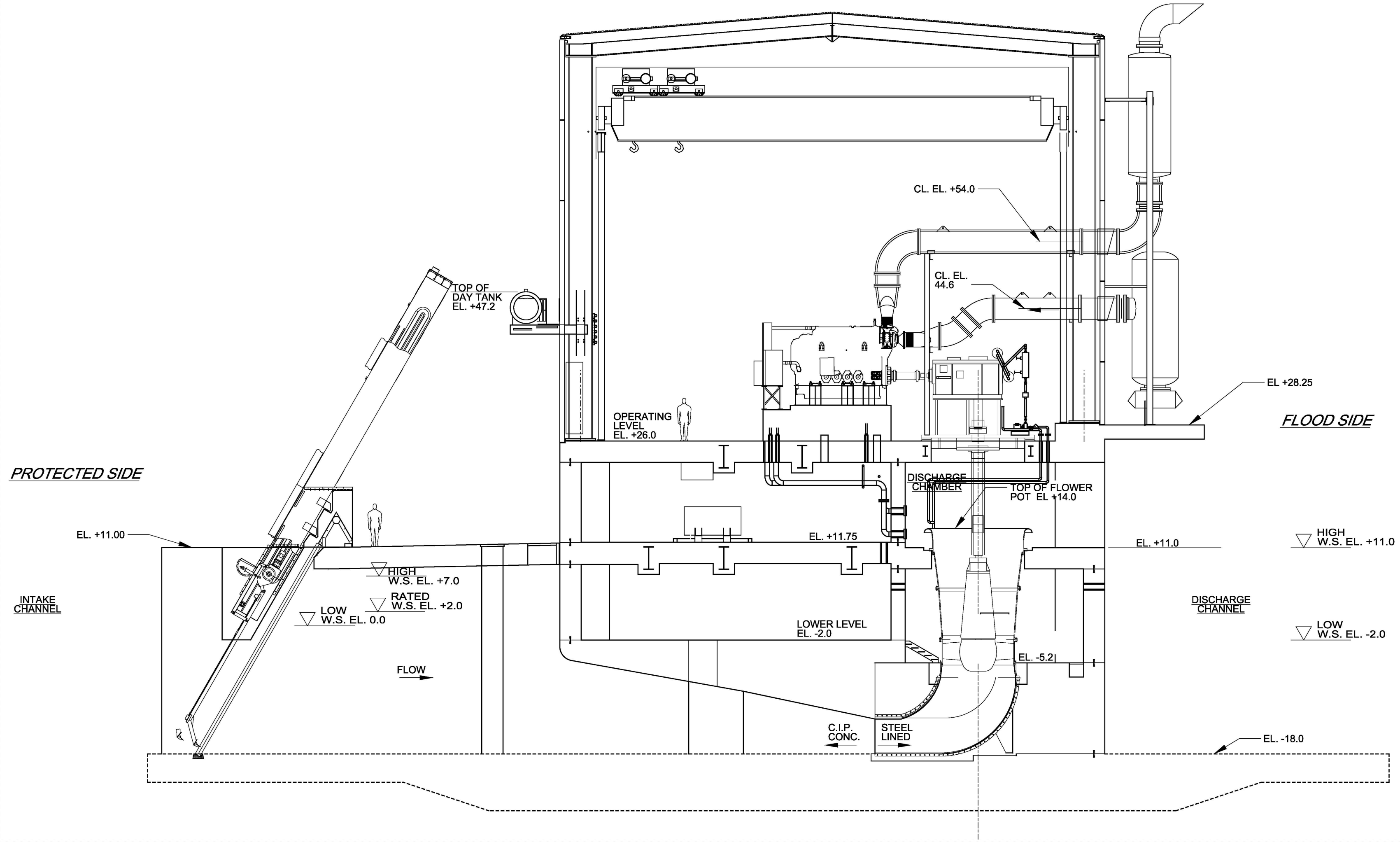
# PS Major Design Milestones

| Design Milestone | Completion Date |
|---|---|
| Redesign Begins | 11-01-09 |
| *Revised General Construction Package* | |
| 100% REV 1 Gen Const Package | 04-15-10 |

# GIWW PS Cross Section

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# Superstructure


- Steel frame structure (473 feet x 77 feet x 60 feet in height)
- Eight-inch precast concrete panels
- Metal roof with four expansion/contraction joints

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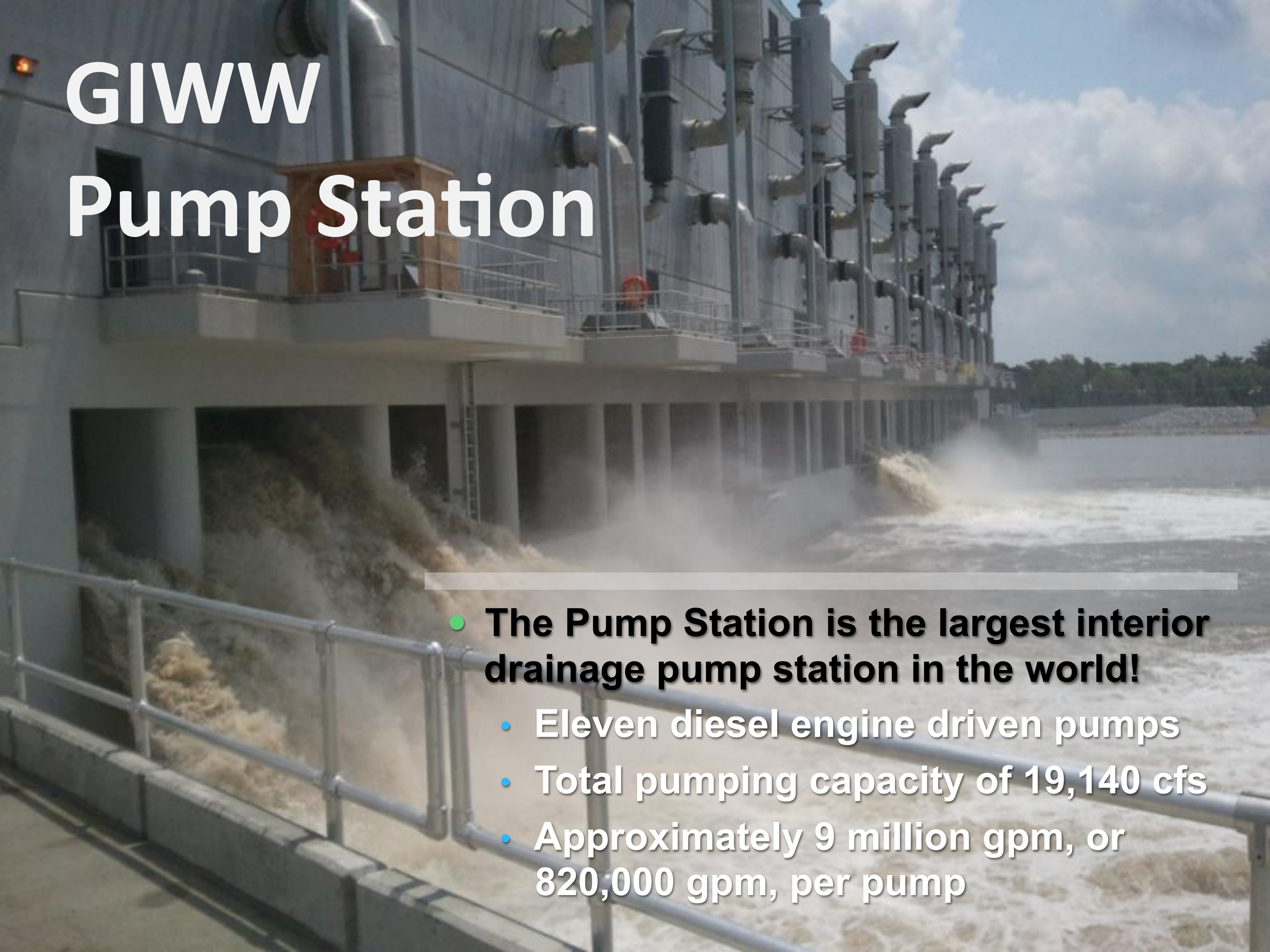

# GIWW Pump Station

- **The Pump Station is the largest interior drainage pump station in the world!**
  - Eleven diesel engine driven pumps
  - Total pumping capacity of 19,140 cfs
  - Approximately 9 million gpm, or 820,000 gpm, per pump


20
TON
JLG LIFT
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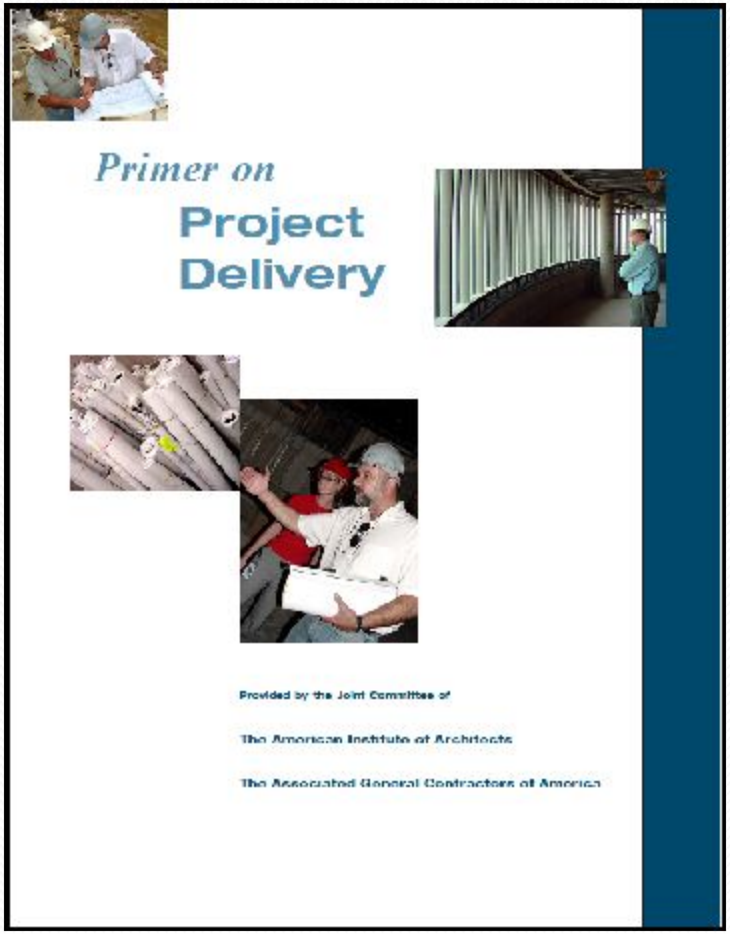
# Design-Build (D-B)




- What is D-B?

  *The Contractor is hired after 30% design and completes the design and constructs mostly at the same time.*

# The IHNC Lake Borgne Barrier was Delivered by this Method

- Largest D-B in USACE history
  - Construction cost $1.35 billion
  - 2 miles long / 26 feet high
  - Construction completed in 2yrs
  - Won the 2014 ASCE Opal Award
- Gerwick/COWI lead designer for:
  - Surge Barrier
  - GIWW Sector Gate Monolith
  - GIWW Concrete Barge Gate
  - GIWW Approach Walls

# IHNC Lake Borgne Barrier
# Hurricane Isaac Aug 2012

- +14 ft surge (Katrina +15.5ft)
- Prevented Lower 9th Ward from flooding

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# The delivery method saves time
# A repetitive structure saves money

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# The Permanent Canal Closures and Pump Stations is also being delivered by D-B

- 17th Street Station
  - 12,600 cfs discharge cap.
- London Avenue Station
  - 9,000 cfs discharge cap.
- Orleans Station
  - 3,000 cfs discharge cap.
- All three stations have electric motor driven pumps and an adjacent diesel electric power station.

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# QUESTIONS

**GIWW WCC Pump Station**
**19,140 CFS**
**11 Pumps**