Analysis and Response to 10/23/14 SLFPA-E Letter Regarding the Monte Carlo Analysis

1/15/2015

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▪ *Purpose*

Provide response to the 10/23/2014 SLFPA-E letter concerning Monte Carlo Overtopping Calculations

▪ *Summary*

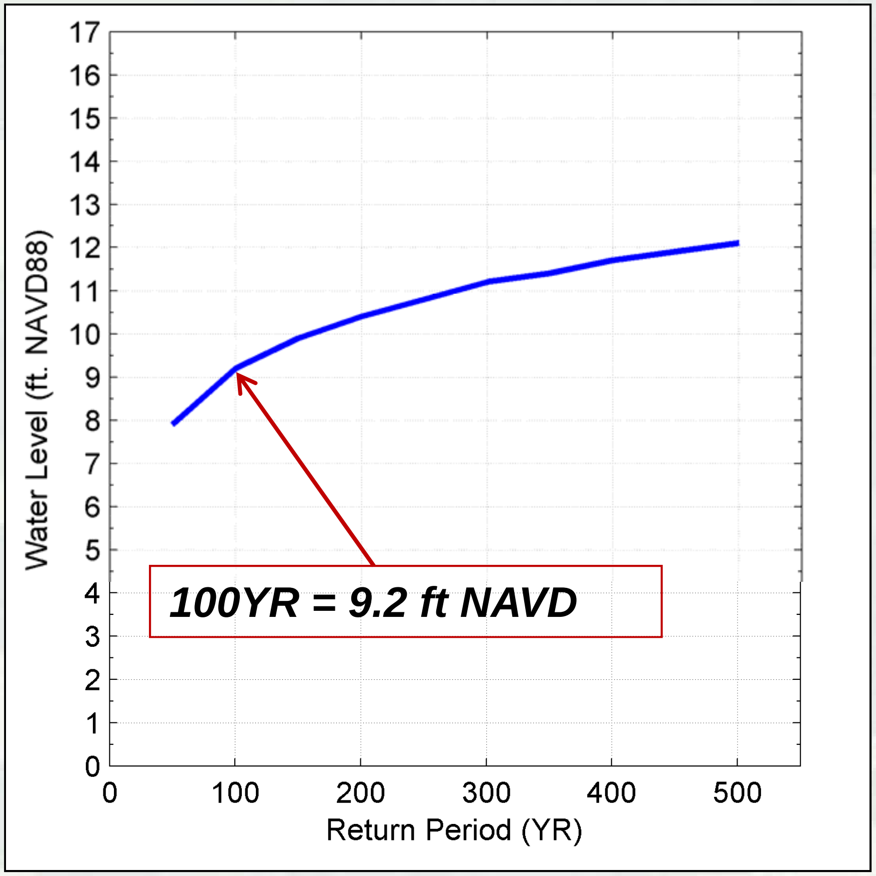
- SLFPA-E Letter

- Response including comments from Dr. Resio and Dr. Mathijs Van Ledden.

- Monte Carlo Analysis with increased uncertainty

- Conclusions, including recommendation for reoccurring surge hazard analysis

Stage-Frequency Without Uncertainty



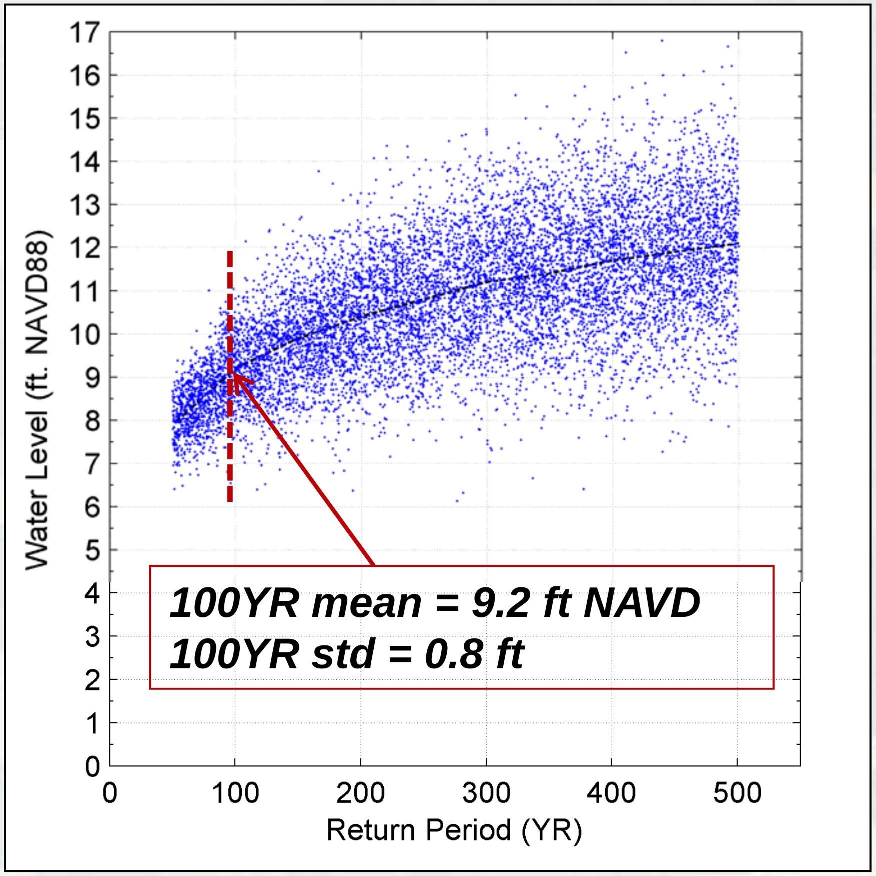
Neglecting uncertainty is a dated approach.

In the past, freeboard would be arbitrarily added to levee design elevations to address uncertainty.

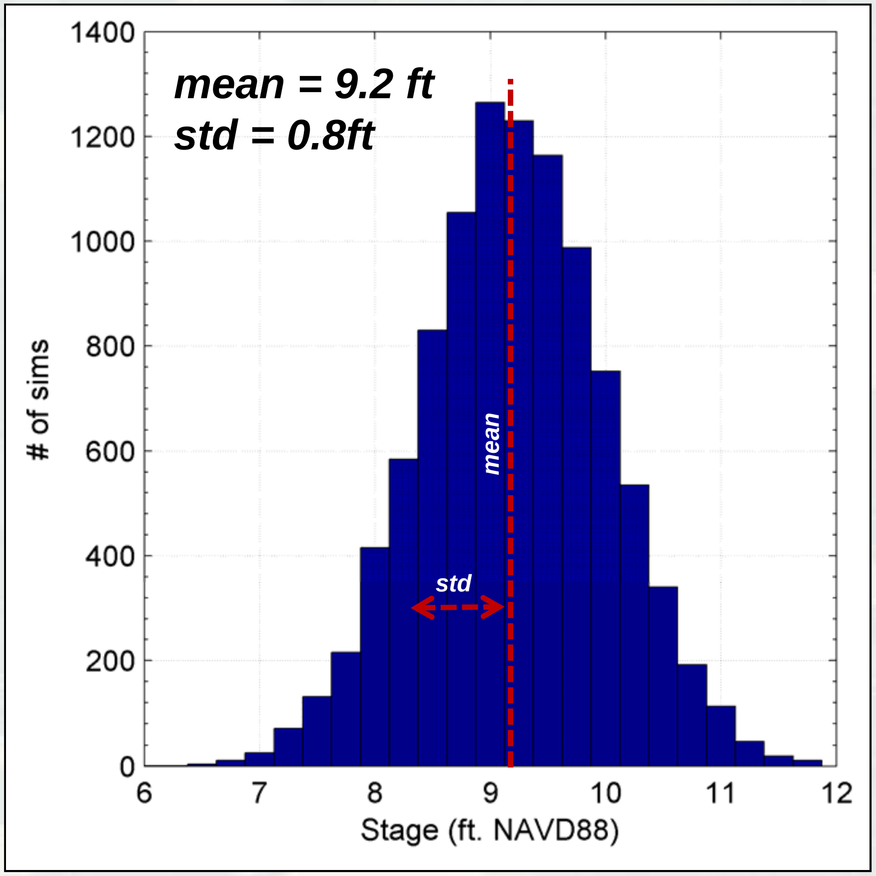
Hydraulic calculations are inherently uncertain. (Manning's equation, weir equation, ADCIRC, etc)

Lack of long term climate record, water level records adds to uncertainty of stage-frequency data.

Stage-Frequency With Uncertainty



100 Year Surge as a Random Variable:



In Monte Carlo Analysis, 100YR Surge Elevation, Significant Wave Height, Wave Period are treated as random variables with mean and standard deviation.

▪ SLFPA-E Letter 10/23/2014

- The letter describes an issue concerning the Monte Carlo overtopping analysis used to determine 100YR HSDRRS design elevations.

- The letter suggests that the standard deviations of the 100YR surge elevation are too low, resulting in inadequate estimates of Q90 overtopping rates, and possibly the need for higher levees.

- The author describes sources of uncertainty in stage frequency data:

  Modeling Uncertainty σM (ADCIRC model validation, neglect of tides, errors in wind fields, etc)

  Sampling Uncertainty σS (lack of climate record)

"If values of both σM and σS are combined, we would estimate a full swl σ value for JL01 on the order of 3.0ft (33%) or more. Furthermore, given the nature of surge SWL uncertainty, a SWL uncertainty σ value of the order of 3.0ft is clearly much more reasonable than a value of 0.6 ft. Importantly, a five-fold increase in the value of SWL will produce a much greater estimate of Q90"

▪ USACE Response

- **SUMMARY: The Corps did not identify any concerns or issues with the design methodology used in the hydraulic surge modeling and overtopping analysis for the Greater New Orleans HSDRRS 1% (100-year) event.**

- USACE provided SLFPA-E letter to experts involved with hydraulic design of HSDRRS and asked for comment and clarification.

  Dr. Donald Resio (former ERDC senior scientist)

  Headed a team that conducted the 2007/2008 Surge Hazard Analysis. Outputs of the JPM-OS analysis include stage-frequency and uncertainty estimates.

  Dr. Mathijs Van Ledden (Royal Haskoning)

  Member of design team at MVN-H&H responsible for development of MATLAB based Monte Carlo Overtopping Tool. This tool takes JPM-OS output and determines 1% design elevations.

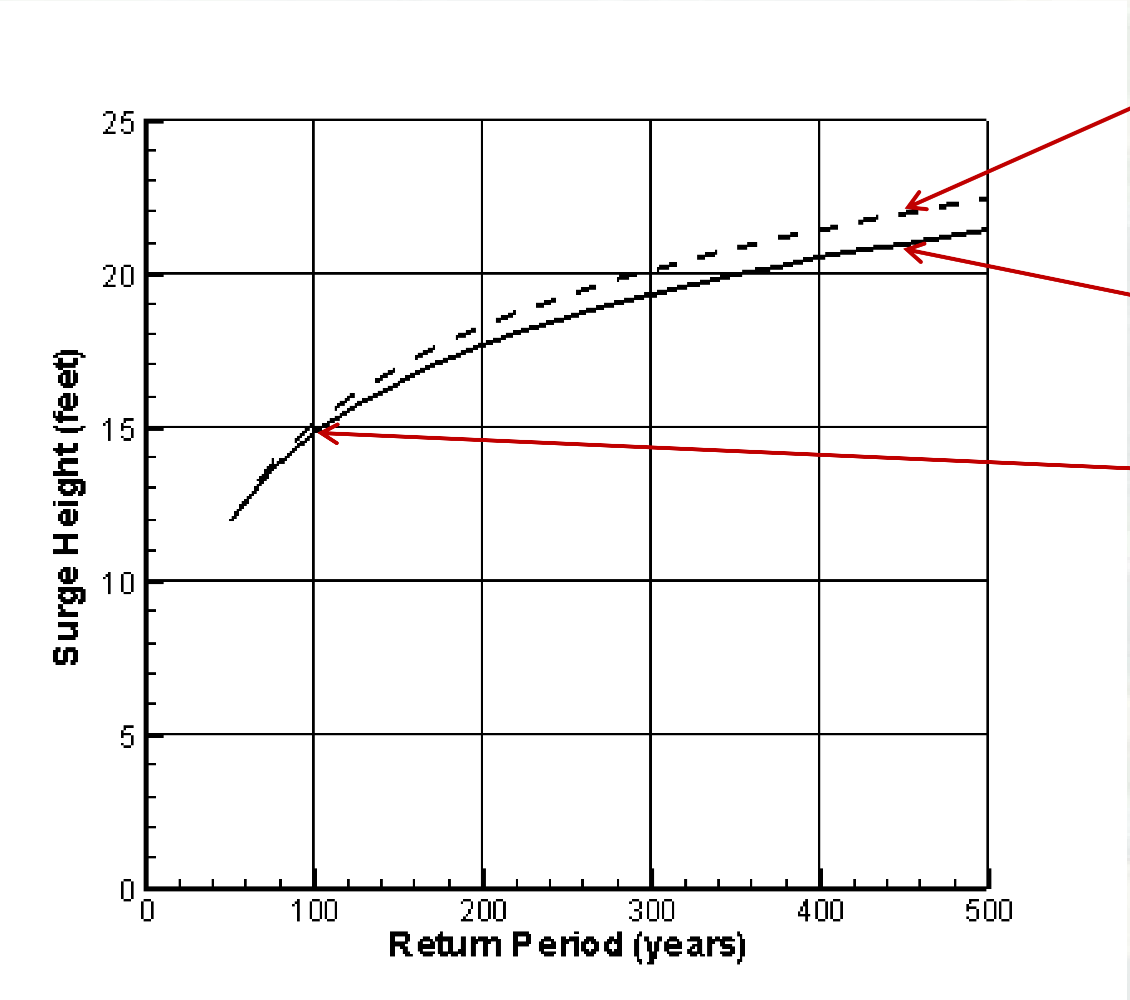
- USACE MVN H&H conducted re-analysis of overtopping rates using larger standard deviations

▪ Dr. Resio's comments:

- ► In the 2007/2008 timeframe, at the request of the New Orleans District H&H Branch, Dr. Resio provided estimates of aleatory uncertainty for use by the MVN H&H Branch in the Monte Carlo analysis. Dr. Resio was well aware that only the aleatory uncertainties were used for the standard deviations of surge values in the Monte Carlo analysis. Thus there is no "disconnect" between what the team intended and what was ultimately carried through in the Monte Carlo analysis.

- ► If the larger standard deviations (std=~3.0' as described in SLFPA-E letter) were to be applied in the Monte Carlo analysis, the mean water levels actually used in the HSDRRS design would have to be adjusted downward by approximately 0.3 ft (varies) to remove the effect of the epsilon term; otherwise the epistemic uncertainty would be accounted for twice.

Example of Stage-Frequency Curve with and without Epsilon Term



With Epsilon term

Without Epsilon Term

About 0.3 ft difference at 100YR Return Period

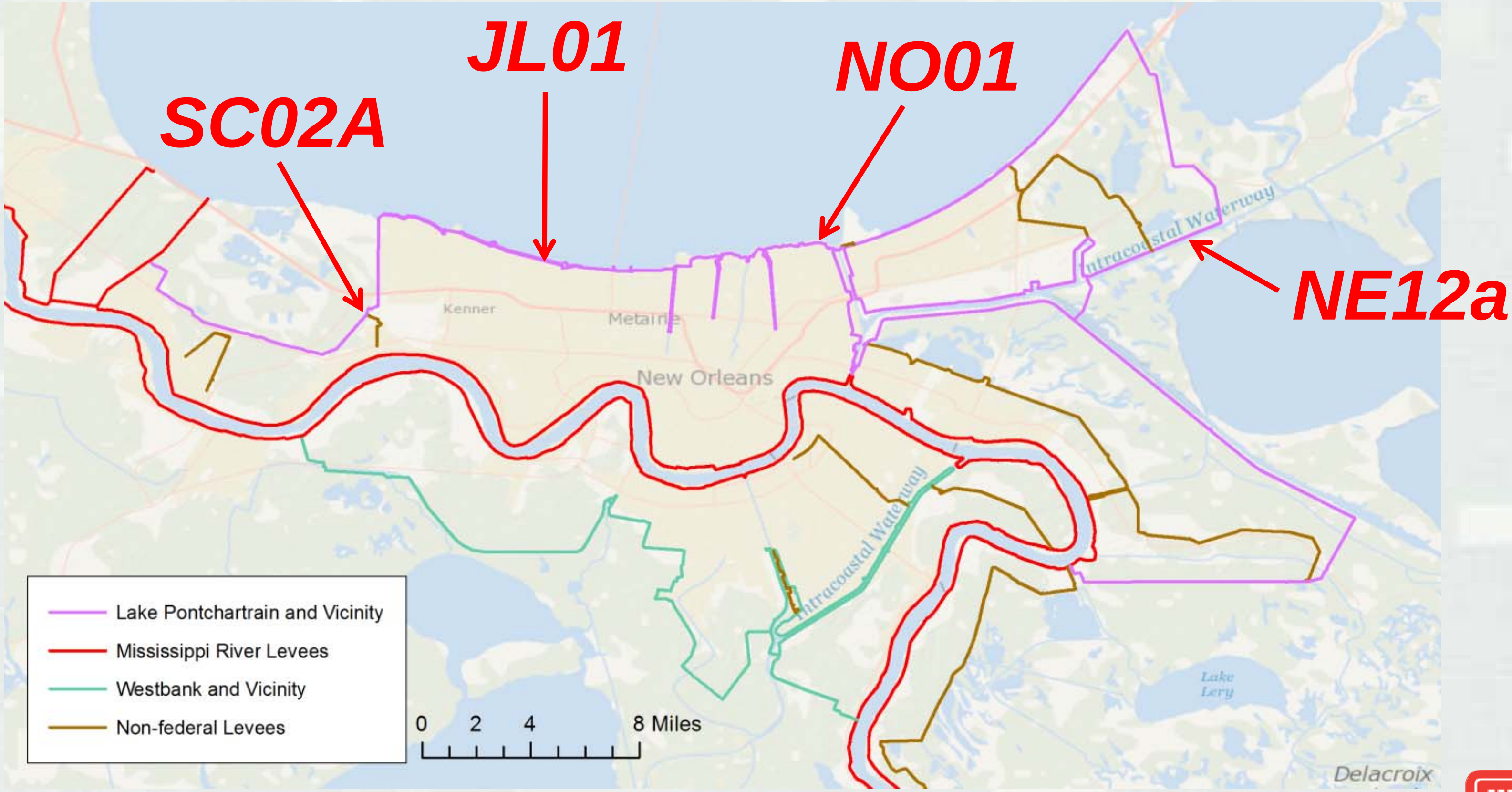
Example:
1% mean swl = 9.0 with 0.6ft std
Would become:
1% mean swl = 8.7ft with 3.0ft std

Source: Resio Presentation at 8/2013 Surge Hazard Workshop

▪ Dr. Van Ledden's comments:

- At the time of the HSDRRS design, a team consisting of engineers from private and public sector under guidance of MVN was responsible for developing the Monte Carlo design approach. The Monte Carlo approach was externally peer reviewed and vetted through ASCE.
- At that time, a decision was made to use only the aleatory-based standard deviations from the JPM-OS method in the Monte Carlo analysis. The general opinion was that this decision was a prudent way forward viewing the entire modeling/design approach and all assumptions made in the entire chain.
- One cannot isolate the choice of standard deviations in the surge levels from the rest of the design approach without review of the entire design process to see what the impacts are from other, often conservative, decisions.
- The design approach used to determine elevations of HSDRRS should be periodically re-assessed to determine the current level of risk reduction using the most advanced science and engineering available. Improvements to the surge hazard analysis might include updating the climatological record (adding recent storms such as Gustav, Ike, and Isaac to the JPM-OS analysis), adding model resolution to the ADCIRC grid, using a refined wind drag formulation, updating the design criteria, and many more potential issues discussed at the August 2013 surge hazard workshop.

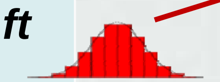
Reanalysis of Monte Carlo Overtopping Calculations using larger standard deviations.
MVN-H&H 10/2014



Monte Carlo Overtopping Calculations: Example

1% mean surge = 11.2 ft NAVD
1% std = 1.1 ft

1% mean Hs = 5.0 ft
1% std = 0.5 ft



1% mean Tp = 9.0 sec
1% std = 1.8 sec

Non-random variables:
Crest elevation = 15.5 ft
Slope = 1:4
Roughness factor = 1
Berm factor = 0.6
Wave angle factor = 1
Wall factor = 1
Toe Elevation = -1.3 ft

Van der Meer Overtopping equations:

$$\frac{q}{\sqrt{g H_{m0}^3}} = \frac{0.067}{\sqrt{\tan\alpha}} \gamma_b \cdot \xi_0 \cdot \exp\left(-4.3 \frac{R_c}{H_{m0}} \frac{1}{\xi_0 \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v}\right)$$

and a maximum of:

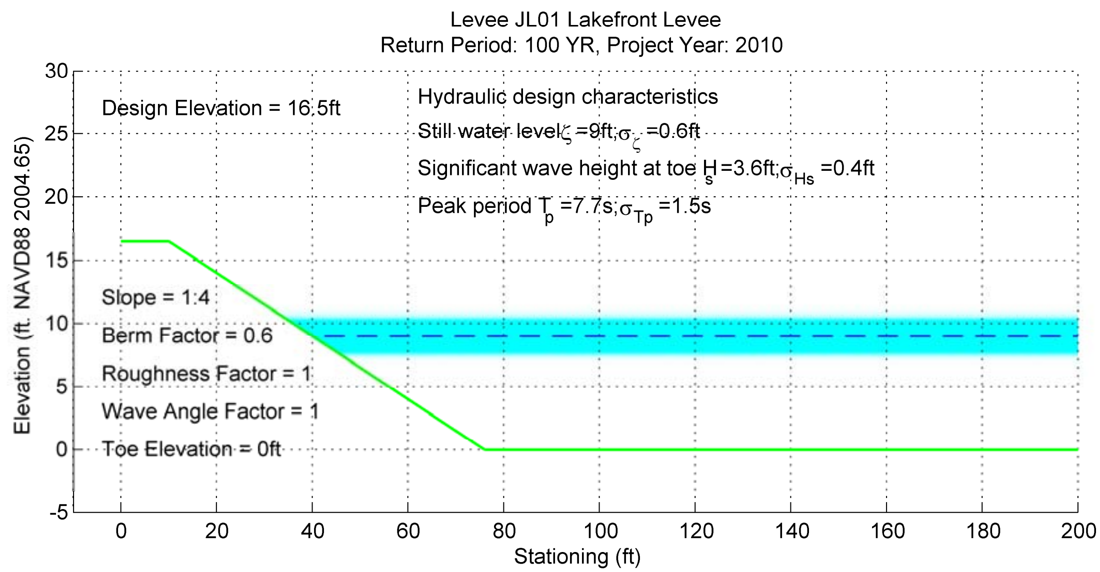
$$\frac{q}{\sqrt{g H_{m0}^3}} = 0.2 \cdot \exp\left(-2.3 \frac{R_c}{H_{m0}} \frac{1}{\gamma_f \cdot \gamma_\beta}\right)$$

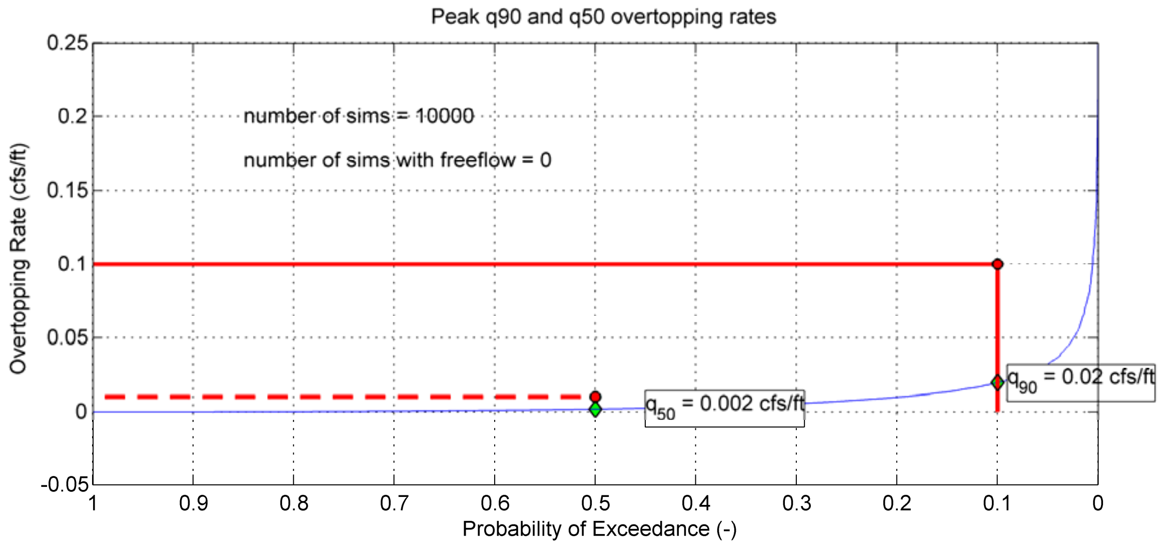
for n = 1:10,000

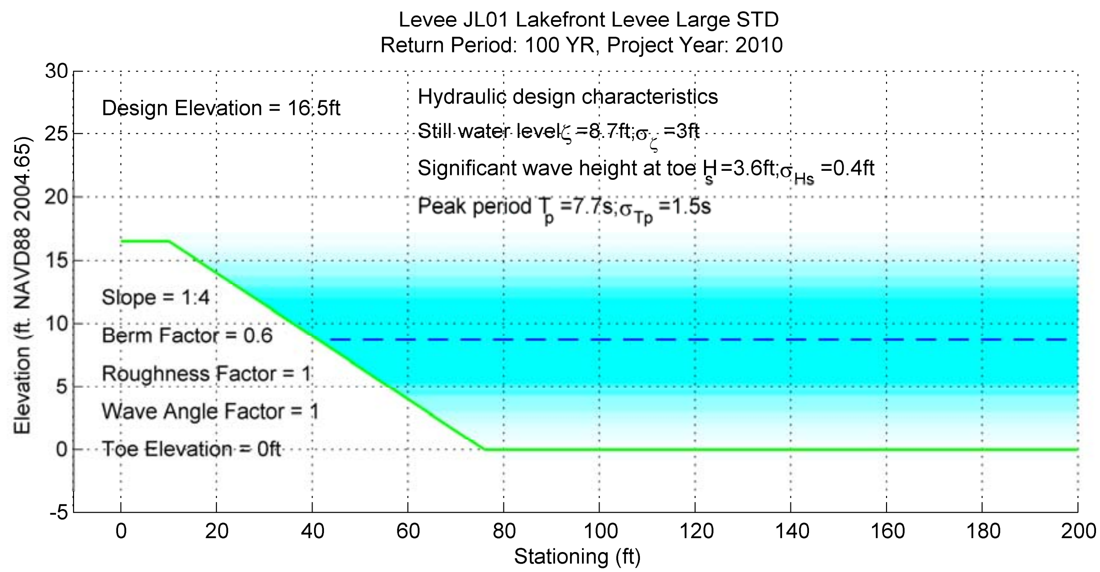
Sample surge level based on mean 1% surge and std
Sample a wave height and period based mean and std
Sample coefficients of the overtopping formulae
OT(n)=overtopping rate

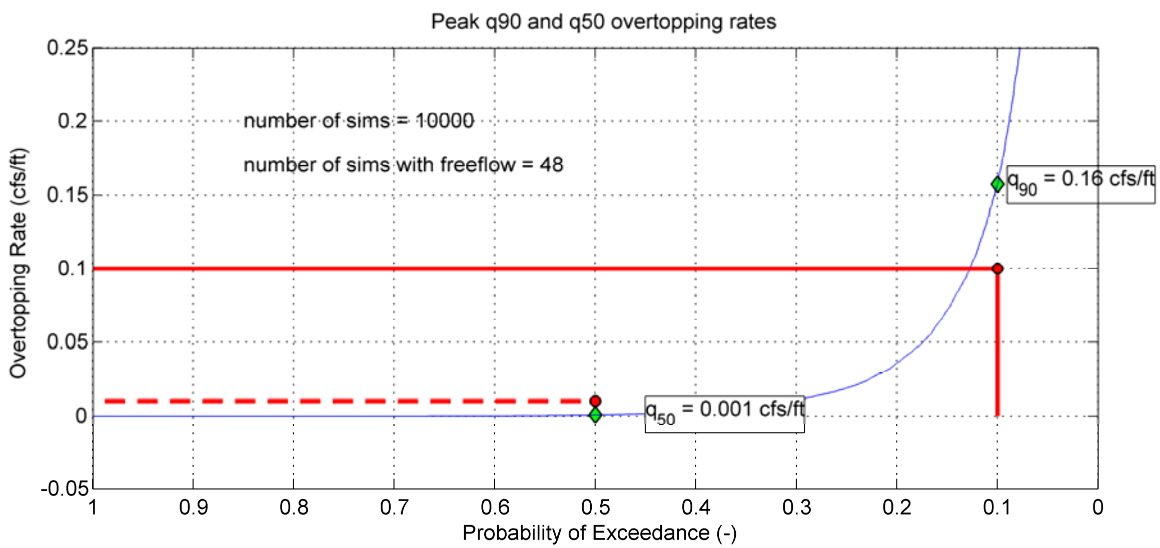
end

90% of the 10,000 overtopping rates are less than Q90
50% of the 10,000 overtopping rates are less than Q50


Levee JL01 Lakefront Levee
Return Period: 100 YR, Project Year: 2010
Design Elevation = 16.5ft
Hydraulic design characteristics
Still water level ζ =9ft; σ ζ =0.6ft
Significant wave height at toe H s =3.6ft; σ Hs =0.4ft
Peak period T p =7.7s; σ Tp =1.5s
Slope = 1:4
Berm Factor = 0.6
Roughness Factor = 1
Wave Angle Factor = 1
Toe Elevation = 0ft
Elevation (ft. NAVD88 2004.65)
Stationing (ft)

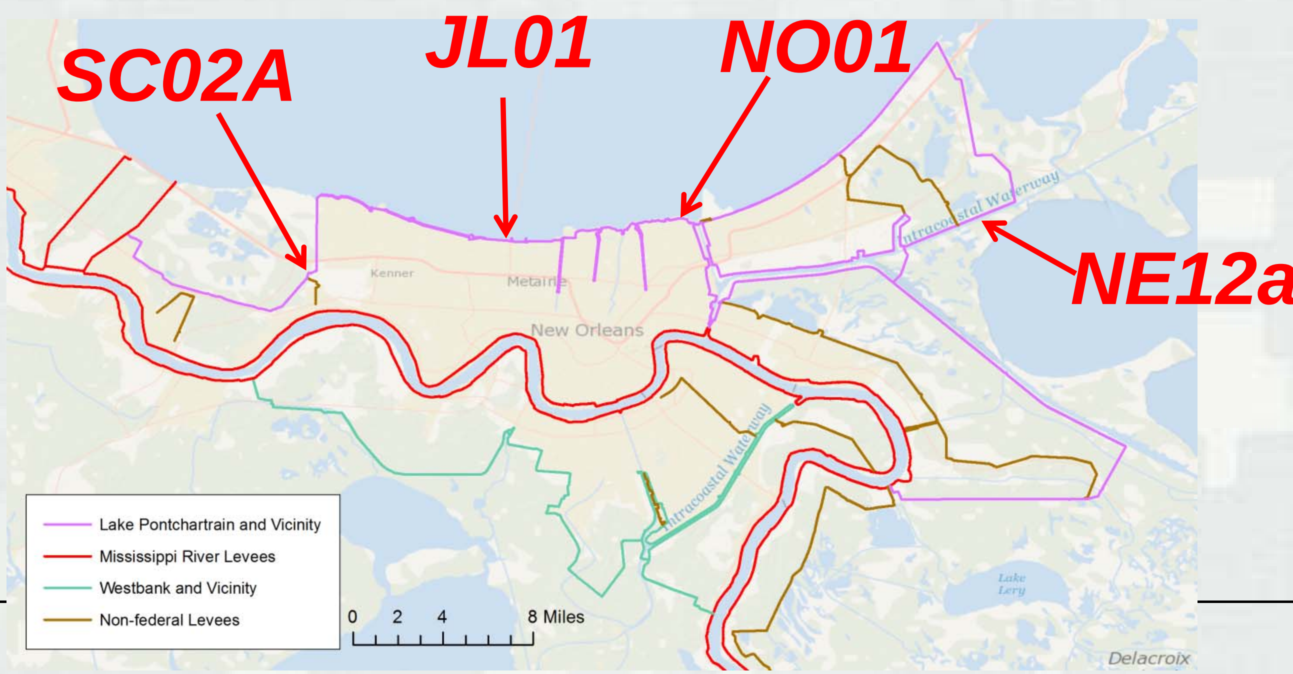

Peak q90 and q50 overtopping rates
number of sims = 10000
number of sims with freeflow = 0
q 50 = 0.002 cfs/ft
q 90 = 0.02 cfs/ft
Overtopping Rate (cfs/ft)
Probability of Exceedance (-)


Levee JL01 Lakefront Levee Large STD
Return Period: 100 YR, Project Year: 2010
Design Elevation = 16.5ft
Hydraulic design characteristics
Still water level ζ =8.7ft; σ ζ =3ft
Significant wave height at toe H s =3.6ft; σ Hs =0.4ft
Peak period T p =7.7s; σ Tp =1.5s
Slope = 1:4
Berm Factor = 0.6
Roughness Factor = 1
Wave Angle Factor = 1
Toe Elevation = 0ft
Elevation (ft. NAVD88 2004.65)
Stationing (ft)


Peak q90 and q50 overtopping rates
number of sims = 10000
number of sims with freeflow = 48
q90 = 0.16 cfs/ft
q50 = 0.001 cfs/ft
Overtopping Rate (cfs/ft)
Probability of Exceedance (-)

Impacts to Q-90 using larger standard deviations

Segment	Original Q90 (cfs/ft)	Q90 with larger 2.6’ standard deviations (cfs/ft)	Q90 with larger 3.0’ standard deviations (cfs/ft)
NE12a	0.09	0.14	0.20
NO01	0.03	0.23	0.38
JL01	0.02	0.10	0.16
SC02A	0.04	0.53	1.17



- **Must review all decisions in design process**

JPM-OS

•Update probability distributions functions with recent data (Gustav, Ike, Isaac)
•JPMOS Method – Resio Surge Response vs Toro
•Standard Deviations from JPM-OS code
•JPMOS code issues

ADCIRC+STWAVE Modeling

•Powell vs Garret wind drag formulations
•Wind adjustment factor 1.09 vs 1.0, storm decay rates
•Levees set to non-overtopping for with-project scenarios
•Starting water surface elevation
•Mesh resolution, survey accuracy, datum issues
•Friction in STWAVE modeling
•Future conditions modeling, SLR rates

Levee Design Monte Carlo Analysis

•Co-incident peak waves and surge, perpendicular approach
•Levee slope/roughness
•Breaker parameter of 0.4
•TAW Equations vs Bousinesq Modeling
•Overtopping Criteria (Q90< 0.1cfs/ft), Q50< 0.01 cfs/ft)
•Rounding final designs up to nearest 0.5 ft

Construction and Other Issues

•Structural Superiority
•Overbuild
•Subsidence rates

Conclusions

• ***SUMMARY: The Corps did not identify any concerns or issues with the design methodology used in the hydraulic surge modeling and overtopping analysis for the Greater New Orleans HSDRRS 1% (100-year) event.***

• **The smaller standard deviations in HSDRRS design report were used in conjunction with very conservative overtopping criteria:**
Q90< 0.1cfs/ft   Q50<0.01cfs/ft

• **Larger standard deviations can be used, but do not appear to increase overtopping rates (Q90) beyond critical levels according to CSU tests.**

• **The Corps recommends complete reanalysis of the Greater New Orleans HSDRRS on a re-occurring interval of at least 10yrs.**

• **The next surge hazard analysis would include lessons learned from the previous analysis, and include the latest science and technology.**

• **Given the previous analysis was conduction 2007/2008, the re-evaluation would be due in 2017/2018.**

Questions?