Joint declaration, Vrijling, Kok, de Wit and Gautier dd Janaury 21st, 2009
concerning wave and flow modeling New Orleans - MRGO
for Hurricane Katrina, August 2005

We, Han Vrijling, Matthijs Kok, Lynyrd de Wit and Caroline Gautier, under penalty of perjury, state as follows:

1. This Declaration is submitted on behalf of the Plaintiffs in *Robinson v. United States*. This Declaration addresses our review over the past two weeks of relevant Defendant's Expert Reports (Westerink, Ebersole and Resio) received December 29, 2008. The purpose of this Declaration is review where defendants experts agree with our findings and to discuss those that still seem to be in question. This declarations content are constrained in that we have only had effectively two weeks to review the new analyses made by Defendant's experts. Furthermore, we restrict ourselves to the subjects we have studied, viz waves and surge.

2. We are part of the Plaintiffs' expert team that undertook an extensive interdisciplinary study of the extent to which the Mississippi River Gulf Outlet effected the flooding of New Orleans and St. Bernard Parish ("Greater New Orleans") during Hurricane Katrina. This analysis confirmed our conclusion that the MRGO was a substantial factor in causing increased surge levels and waves near the levees east of St. Bernard.

3. As scientists, Plaintiffs' experts wanted to test their understanding of the contribution of the MRGO on the flooding during Hurricane Katrina by conducting extensive modeling of different scenarios, each with an explicitly stated set of assumed conditions, using state-of-the art techniques similar to those used by other scientists in the field, including the Army Corps and its consultants. The results of this modeling are set forth in three expert reports (de Wit et al 2008. Flow Modeling New Orleans -Mississippi River Gulf Outlet, Hurricane Katrina August 2005 - FINAL REPORT Scenario 1, 2A, 2B, 2C, 2D, 3; Gautier et al 2008 a. Wave Modeling New Orleans - Mississippi River Gulf Outlet, Hurricane Katrina August 2005 - FINAL REPORT; Gautier et al 2008 b. Wave Modeling New Orleans - Mississippi River Gulf Outlet, Hurricane Katrina August 2005 – APPENDICES) . The results of this modeling added much depth to our understanding.

As reported in de Wit et al 2008, the scenarios tested the following conditions:

Scenario 1: "Katrina Real Run"—surge that engulfed the land and coastal areas, and man-made features as they actually existed on August , 2005, with no surge reduction/prevention safeguards; degraded wetlands

Scenario 2a: No MRGO channels or LPV flood protection works except at the 40 Arpent location; pristine wetlands

Scenario 2b: No MRGO channels or LPV flood protection works; pristine wetlands

Scenario 2c: "Neutral MRGO": No MRGO channels, full pre-Katrina complement of LPV flood protection works; pristine wetlands

Scenario 2d: No MRGO channels or LPV flood protection works; pristine wetlands except MRGO spoil piles;

Scenario 3: MRGO as authorized with 650'top width and full pre-Katrina complement of LPV flood protection works; pristine wetlands but no surge reduction/prevention safeguards

4. Scenario 2c is Plaintiffs' "no negligence" scenario, to use Defendant's terminology, because it assumes the MRGO is "hurricane neutral," *i.e*., the navigation channel has no effect, with surge buffering wetlands as they existed before 1958, and no surge conduit or funneling of water. Scenario 2c reflects the Plaintiffs' position that Government had a legal duty to design, construct, operate, and maintain the MRGO so that it did not create any added risk of flooding the neighborhood. As set forth in the three above-referenced and Dr. Bea and Kemp's separate reports, Scenario 2c—the Hurricane Neutral MRGO—did not result in catastrophic flooding of Plaintiffs' properties, thereby confirming our conclusion that it was the MRGO's very existence in its defective condition that was the determinative factor in causing the catastrophic flooding of New Orleans East, Lower 9th Ward, and St. Bernard Parish.

5. The combined ADCIRC surge, FINEL flow dynamics and SWAN wave modeling are very useful in explaining the complexities of the flooding of the St Bernard Polder.

6. **Observations on Defendant's Expert Report by Westerink**

This section contains a short review of the report "Department of Justice Expert Witness Report: ADCIRC Storm Surge Simulations" of 22 December 2008 prepared by Joannes J. Westerink. The report is about surge elevations in the New Orleans area during Katrina and the influence of the MRGO on this. He used ADCIRC to calculate a 'Katrina Real Run' and several scenarios taking into account the influence of MRGO. Although our report (De Wit 2008) is about the same subject, and some of his scenarios are chosen similar to our scenarios, he does not refer to our report in his text and he does not mention or question our results. Only Table 1 of his report, reproduced below, where his six scenarios are related to our scenarios, mentions our work.

Table 1: Description of the six scenarios simulated in this report.

United States' Scenario	Plaintiffs' Scenario	MRGO Reach 1/GIWW	MRGO Reach 2	Chalmette Levee	Marsh	Description
H1 *Katrina Real Run*	1	2005 pre-Katrina dimensions	2005 pre-Katrina dimensions	2005 pre-Katrina dimensions	2005 pre-Katrina conditions	Conditions at Hurricane Katrina landfall.
H2 *No MRGO with 2005 wetlands*		1958 pre-MRGO (existing GIWW dimensions)	None (channel eliminated and topography raised to surrounding area)	2005 pre-Katrina dimensions	2005 pre-Katrina conditions	Conditions at Katrina landfall, if MRGO had not been constructed.
H3 *No MRGO with 1956 wetlands*	2C	1958 pre-MRGO (existing GIWW dimensions)	None (channel eliminated and topography raised to surrounding area	2005 pre-Katrina dimensions	1956 pre-MRGO conditions	Conditions at Katrina landfall, if MRGO had not been constructed and marsh had remained in pre-MRGO condition.
H4 *No MRGO with 1956 wetlands and a relocated Chalmette Levee*	2A	1958 pre-MRGO (existing GIWW dimensions)	None (channel eliminated and topography raised to surrounding area)	Idealized levee (17.5 ft) at 40 Arpent location	1956 Pre-MRGO conditions	Conditions at Katrina landfall, if MRGO had not been constructed, marsh had been in 1956 pre-MRGO condition, and Chalmette levee had been constructed at 40 Arpent location.
H5 *MRGO as designed with 2005 wetlands*		Ideal MRGO (approximate design dimensions)	Ideal MRGO (approximate design dimensions)	2005 pre-Katrina dimensions	2005 Pre-Katrina conditions	Conditions at Katrina landfall, if MRGO had been at design dimensions.
H6 *MRGO as designed with 1956 wetlands*	3	Ideal MRGO (approximate design dimensions)	Ideal MRGO (approximate design dimensions)	2005 Pre-Katrina dimensions	1956 Pre-MRGO conditions	Conditions at Katrina landfall, if MRGO had been at design dimensions and marsh had been in 1956 pre-MRGO condition.

Table 6.1 Description of the scenarios used by the defendant's experts and correspondence with the Robbinson's experts scenarios (Westerink 2008, Table 1, p. 87)

Dr. Westerink (2008) uses the most recent version of the ADCIRC model (SL-15) for his simulations of 6 Scenarios. The Scenarios H1, H3, H4 and H6 are comparable to our Scenarios 1, 2c, 2a and 3, and ADCIRC and FINEL can be compared. Although Westerink's results are different from our results on details, his main findings about the storm surge and the influence of the MRGO are similar to ours. Therefore only a brief review is given. This section compares first the input, then the results of the ADCIRC model with the FINEL model.

The input used in ADCIRC for the "Katrina Real Run" and scenario H3, H4 and H6 (our scenario 2c, 2a and 3) is the same as the input in FINEL on most points. Some differences are:

In the input wind fields the Defense experts have shifted the Hurricane Katrina track some miles to the east of its actual track during the storm. But this does not significantly materially change any results other than the timing of the peak surge event.

ADCIRC uses the influence of wave radiation stresses on the water motion, FINEL does not. But the boundary conditions in FINEL are adapted by the Robinson experts in the USA to match the observed high-water marks. Implicitly also the influence of wave radiation stresses on the peak surge levels are taken into account in this way.

Bottom roughness of industrial areas next to the IHNC-north is in ADCIRC higher (Manning's n=0.12) as in FINEL (n=0.07). FINEL Manning values are on the low side (smooth), but even in FINEL the flow velocities inside the industrial areas stay very low around 1 fps, as in the IHNC channel itself flow velocities up to 10-13 fps are found. The low velocities together with the high elevation of the industrial area leads to negligible discharges over the industrial areas compared to the discharge in the IHNC itself. This small difference in input will not influence the results.

The most important difference in input bottom roughness comes into light when the two tables below from p. 88 and 89 of Westerink's report are compared.

Table 2: Manning n values for Louisiana Gap (LA-GAP) classificat

LA-GAP Class	Description	Manning-n
1	Fresh Marsh	0.055
2	Intermediate Marsh	0.050
3	Brackish Marsh	0.045
4	Saline Marsh	0.035
5	Wetland Forest – Deciduous	0.140
6	Wetland Forest – Evergreen	0.160
7	Wetland Forest – Mixed	0.150
8	Upland Forest – Deciduous	0.160
9	Upland Forest – Evergreen	0.180
10	Upland Forest – Mixed	0.170
11	Dense Pine Thicket	0.180
12	Wetland Scrub/Shrub – Deciduous	0.060
13	Wetland Scrub/Shrub – Evergreen	0.080
14	Wetland Scrub/Shrub – Mixed	0.070
15	Upland Scrub/Shrub – Deciduous	0.070
16	Upland Scrub/Shrub – Evergreen	0.090
17	Upland Scrub/Shrub – Mixed	0.080
18	Agriculture – Crops – Grass	0.040
19	Vegetated Urban	0.120
20	Non-Vegetated Urban	0.120
21	Wetland Barren	0.030
22	Upland Barren	0.030
23	Water	0.02-0.045

Table 3: Manning n values for 1956 Louisiana land use classification.

Type	Description	Equivalent GAP	Manning-n
3	Fresh Marsh	Type 1 – Fresh Marsh	0.055
4	Non Fresh Marsh	Type 3 /4 – Brackish and Saline Marsh	0.050
7	Forest	Type 5 – Wetland Forest	0.045
8	Swamp	Type 5 – Wetland Forest	0.035
11	Agriculture/Pasture	Type 18 - Agriculture	0.140
12	Developed	Type 19 - Urban	0.160
23	Water	Type 23 - Water	0.02-0.045

Table 6.2 Manning n values used in ADCIRC (Westerink 2008, Table 2&3, p. 88-89)

Table 2 is taken from standard sources and is in accord with what we used for the FINEL modeling (actually we use n=0.10-0.12 for forest, just to be sure not to exaggerate the influence of the forest on the surge), but notice that in Table 3, the two forest categories (Types 7 and 8) are given Manning's 'n' values (roughness or friction) that are lower than for fresh marsh (Type 3). They should be three times higher, in the 0.140 to 0.160 range given in Table 2. Our first thought was that this is a typo mistake, but it is not. As can be seen in all of Westerink's

scenarios where the 1956 landscape is invoked, the swamp is given a Manning's of 0.55, as if it were fresh marsh.

It is important to compare his Manning's use in the different Scenarios. Figure 2 below from p. 120 of Westerink's report displays the Defense experts expression of the 1956 swamp and upland forests as orange and green, respectively. The lighter orange is swamp with more scattered trees.

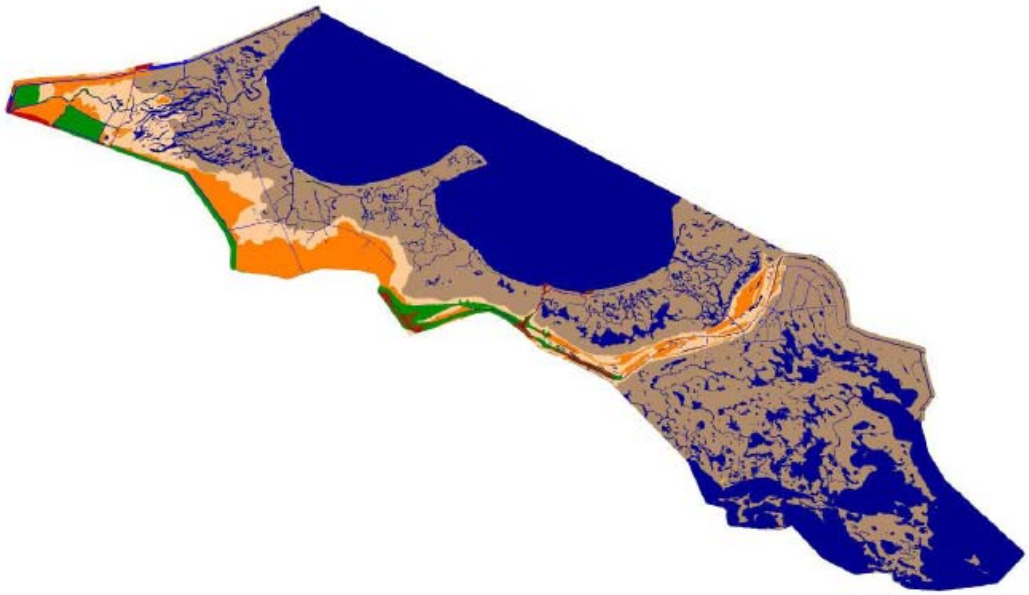


Figure 55: Land use within the MRGO region of influence in 1956 (Barras, 2008). Brown represents non-fresh marsh; tan represents fresh marsh; orange represents swamp; dark brown represents agricultural/pasture; red represents developed areas.

Figure 6.1. From Westerink page 120.

This habitat distribution is pretty well represented in the topography, which will have an effect even if the Manning's are not right, as is shown below in Figure 3 from the top of page 106 of Westerink's report.

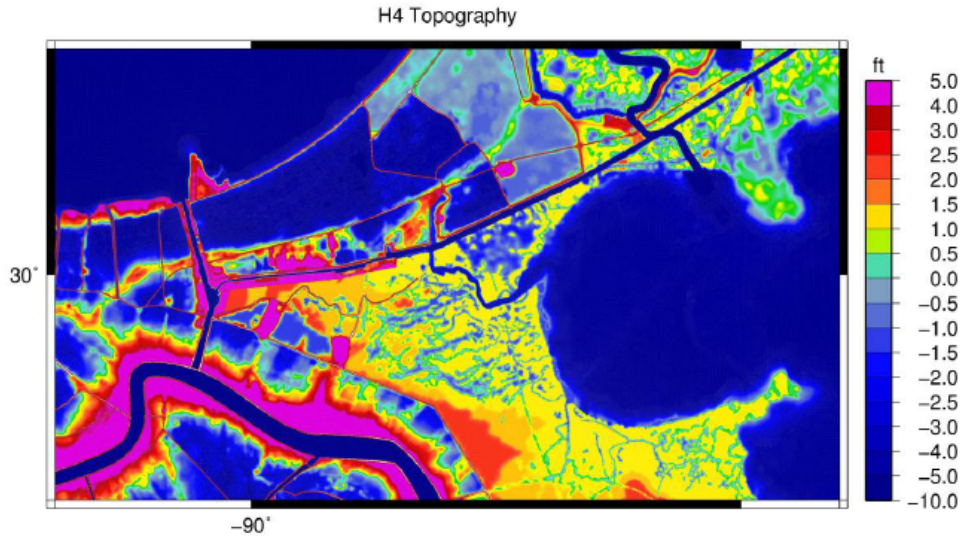


Figure 30: H4 model topography and bathymetry (ft relative to NAVD88 2004.65) in the vicinity of the IHNC to the Golden Triangle used in the *No MRGO with 1956 wetlands with relocated Chalmette Levee* simulation.

Figure 6.2 from page 106 of Westerink's Report

So, it is a surprise to see the Manning's mapped as shown below in Figure 4 from p. 107, where the swamp is given a Manning's n of 0.055, only slightly higher than the 0.045 of the brackish marsh that makes up most of the land in the funnel.

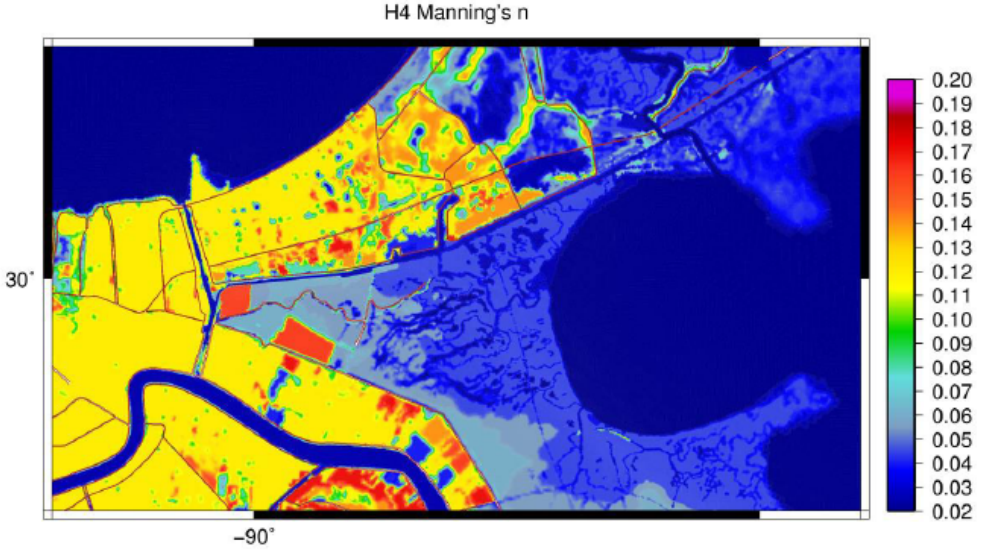


Figure 33: H4 model Manning n bottom friction values in the vicinity of the IHNC to the Golden Triangle used in the *No MRGO with 1956 wetlands with relocated Chalmette Levee* simulation.

Figure 6.3 from page 107 of Westerinks report.

Thus Westerink seems to have an error in his sue of Manning's coefficients for the case of his 1956 wetlands.

ADCIRC results

Figures 142-143 show that the peak surge levels in ADCIRC 'Katrina Real Run' are good on MRGO Reach 1 and the IHNC, but about 3 ft too low on Lake Borgne and at Lake Pontchartrain. That ADCIRC shows good correspondence to the high water marks inside the channel system of IHNC and MRGO Reach 1 is strange as in reality there was major flooding of the New Orleans Metro Bowl, New Orleans East and Chalmette/St. Bernard, which is not taken into account by ADCIRC (nor in FINEL). The boundary conditions used in FINEL on Lake Borgne and Lake Pontchartrain are adjusted by the USA Robinson experts to match the high water marks. Because the boundary conditions in FINEL are higher than the corresponding hydrographs in ADCIRC, the surge levels in FINEL Scenario 1 are also higher than ADCIRC Scenario H1. The surge levels in FINEL "Katrina Real Run" on Lake Borgne and Lake Pontchartrain are closer to the high water marks than ADCIRC, and the surge peaks along MRGO Reach 2 found in FINEL are closer to reality than in ADCIRC.

Maximum surge in ADCIRC Scenario H1 on the MRGO Reach 2 (Figure 138) is >16 ft, in FINEL those values are between 17 and 18 ft. Comparing the hydrographs on MRGO Reach 2 between ADCIRC and FINEL, the difference is about 2.5 ft. The reasons for this must lie in the improved raised boundary conditions used in FINEL.

The ADCIRC maximum water levels read from the hydrographs in the IHNC are about 3 ft lower than FINEL, but an exact comparison is hard as the location in the hydrographs are slightly different in both models and the surface elevation shows large gradients on the IHNC. The reasons for this must also lie in the improved boundary conditions used in FINEL.

Besides these absolute differences in maximum peak elevation between ADCIRC and FINEL, the comparison between the scenarios (and thus the influence of MRGO on peak surge) is similar for ADCIRC and FINEL:

- Comparing Scenario H1 and H6 (our Scenario 1 and 3) shows maximal 0.5ft difference on IHNC. Same conclusion from FINEL results.
- Comparing Scenario H1 and H3 (our Scenario 1 and 2c) shows maximal 3.5ft difference on IHNC south. FINEL 3 ft.
- Comparing Scenario H1 and H3 (our Scenario 1 and 2c) shows maximal 0-0.5 ft difference on MRGO. FINEL 0.5-1.5 ft.

Dr. Westerink is focusing on maximum surge levels, not on the time development of the surge or on the difference of time development between Scenarios. The time development of the surge is also important for the resulting flooding. Westerink also does not look at discharges or overtopping rates as we have assessed in our report. It is a pity that the filling of the wetlands of St. Bernard as shown for Scenario H1 in Figure 138, is hided in the results of the Scenario runs in Figures 146-181. It would have given an illustration of the difference between the Scenarios for the filling of the polder.

One final remark about the ADCIRC results is we did not understand fully the results presented in the report. Look at Figure 6.4, 6.5 and 6.6 below. Peak surge in Figure 184 for Scenario H1 is 8.5 ft, this is at Lake Pontchartrain north of Seabrook. The max. surge value at this location in Figure 138 is 9 ft. this is a difference of 0.5 ft. Comparing the hydrograph at the confluence of the IHNC and GIWW in Figure 192 with a peak surge of 13.6 ft with the close up of Figure 138 (max surge elevation between 13 and 14 ft) is consistent with each other. So on one location the hydrograph is consistent with the plotted surface elevation, on another it isn't. The difference is small however, but we don't understand the cause of it. Another difficulty is the time axis in the hydrographs. The timescale is not UTC time but also not Local Time, and it mentions September 2005, as Katrina was in August 2005.

But whatever reason may be for the differences between hydrographs and max surge elevation plots, maybe we didn't read carefully enough under the time constraint we had, we do not believe it does impact the conclusions of Westerink.

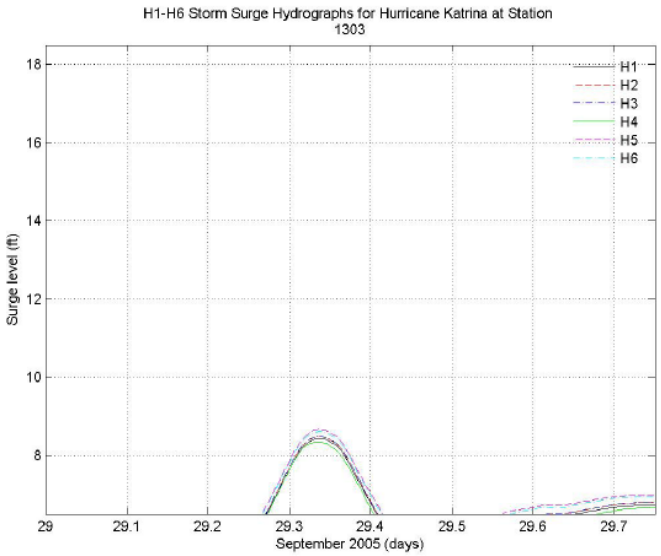


Figure 184: Time series of water surface elevation (ft) during the peak surge for Scenarios H1-H6 north of Seabrook.

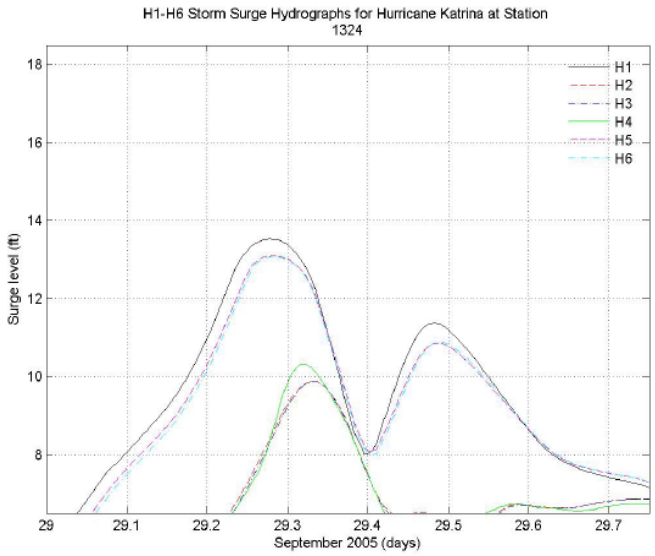


Figure 192: Time series of water surface elevation (ft) during the peak surge for Scenarios H1-H6 at the confluence of the GIWW and IHNC.

Figure 6.4 Two hydrographs from ADCIRC (Westerink Fig. 184 p. 194 & Fig. 192 p. 202)

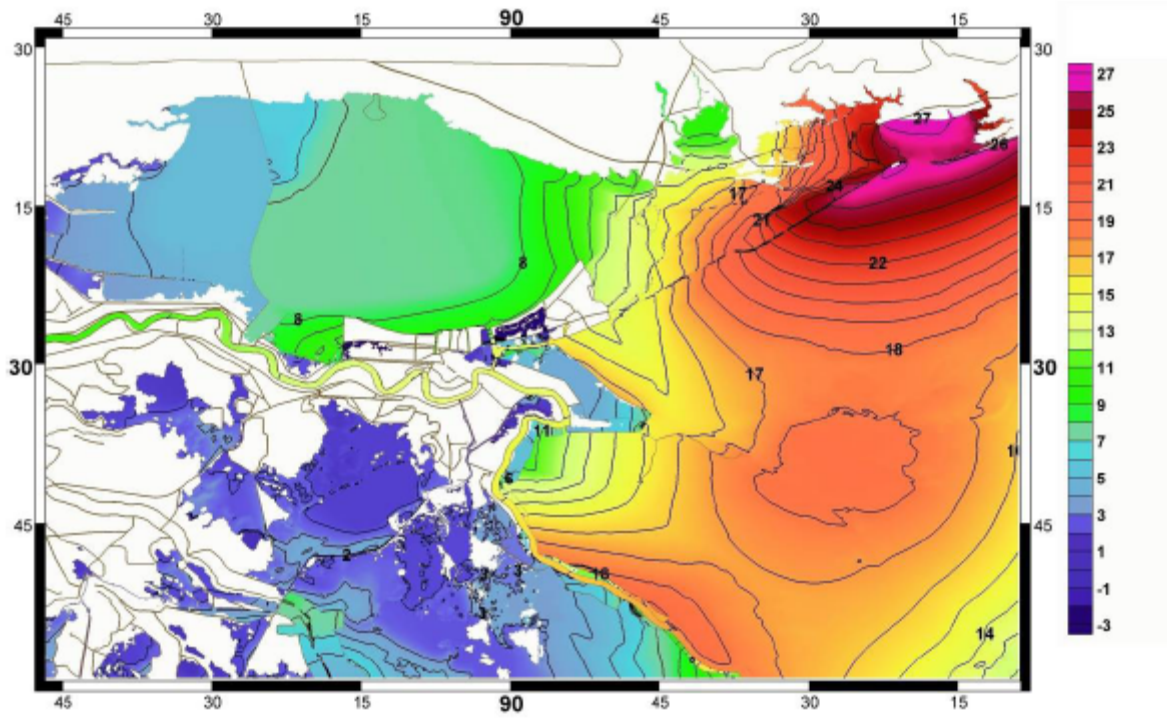


Figure 138: ADCIRC maximum elevation contours (ft) during Hurricane Katrina for the area around New Orleans and Lake Pontchartrain.

Figure 6.5 Maximum ADCIRC surge elevation scenario H1 (Westerink Fig. 138 p.167)

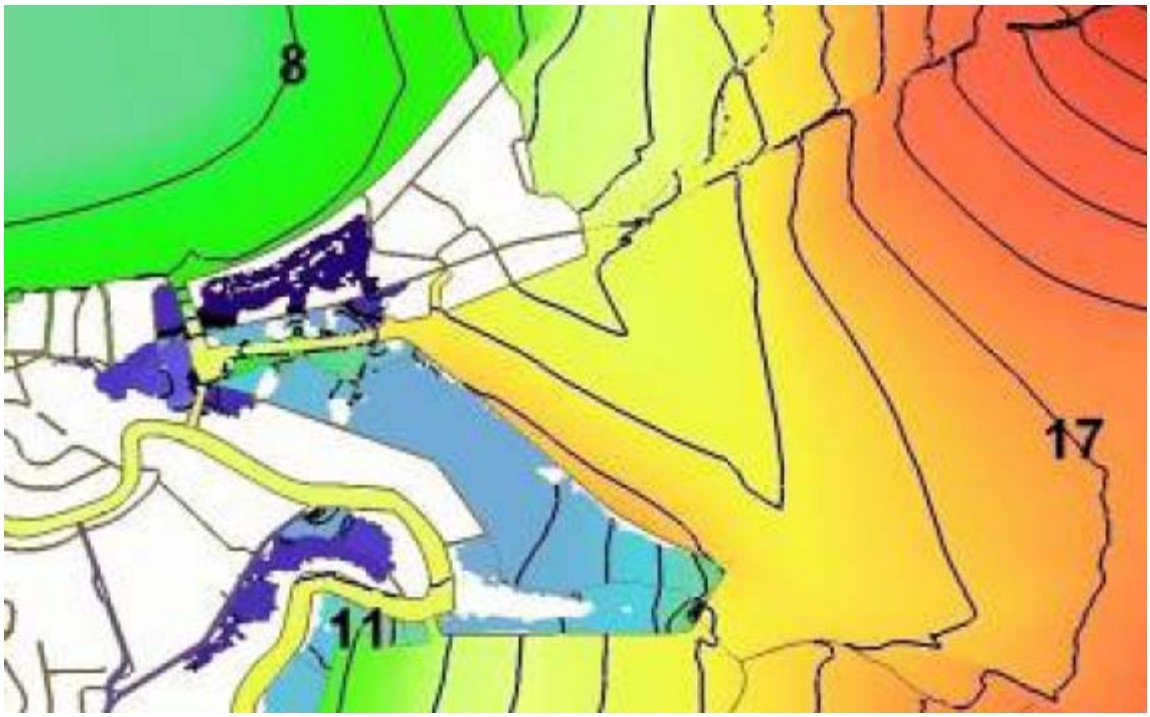


Figure 6.6 close up from Fig. 138 Westerink

Conclusion about Westerink's report

Dr. Westerink does not question any of our conclusions, and we do not question his conclusions either. ADCIRC is an outstanding model to give insight in the flow dynamics in an incredibly large area as the Louisiana coast with large detail. The results of ADCIRC and FINEL are comparable, giving confidence in the quality of both. The differences between the Scenarios, and thus the influence of the MRGO on the storm surge, are similar in ADCIRC and FINEL results. There are some differences though between the FINEL and ADCIRC model, most important one the adjusted raised boundary conditions used in FINEL on Lake Borgne and Lake Pontchartrain to better match the high water marks here, leading to surge levels in FINEL which are 2.5-3ft higher than ADCIRC. So although the main findings about the storm surge and the influence of the MRGO are similar, when the results are used for a flooding analysis then the results using FINEL water levels will be totally different from using ADCIRC water levels.

7. Observations on Defendant's Expert Report by Resio

The Resio-report ("Expert report", prepared by Dr. D.T.Resio dd December 21st, 2008) describes the specification of waves along reach 2 of the MRGO, using the STWAVE and the COULWAVE models. In the following discussion we will address the similarities and differences between the defence and our wave model data. Furthermore, in Appendix 7-A I will present some of the existing data and additional tests in such a way that the scenarios can be better compared with each other and clarify the results. In order to better manage the amount of data contained in the SWAN report we concentrate the discussion on three locations, Bayou Bienvenue (ray 1), Bayou Dupre (ray 6) and halfway in between (ray 3).

We focus on three scenarios:

Scenario 1: Katrina real run (situation just prior to hurricane Katrina's landfall)

Scenario 2C: Neutral MRGO (levees present, MRGO absent, original vegetation)

Scenario 3: MRGO-as-designed (levees present, MRGO with original dimensions, original vegetation)

First we acknowledge that the new STWAVE simulations have been carried out with the full plane version of the model. As also discussed by Dr Kemp (2009) the defence experts have realized that the half-plane version of STWAVE as used by IPET give erroneous data for the MRGO Reach 2 levees. So to address this deficiency the USACE experts now have a new grid, Louisiana Southeast, which they have run in full-plane mode. This grid roughly corresponds to the 'C' grid implemented by ourselves (Gautier et al., 2008) for SWAN.

But whereas we applied several nested grid runs in order to achieve high resolution simulations (66 ft x 66ft) in which characteristic features in bathymetry and bottom friction are included, the

resolution of the STWAVE simulations has a questionable value of 656 ft x 656 ft which is a factor 100 less. The width of the MRGO-as-designed is 500 ft which is less than the grid spacing of the STWAVE model. This is a major problem for the model that must represent the channel as a series of holes or beads rather than as a linear feature (See figure 7.1). Also the pre-Katrina dimensions of the MRGO are such that we doubt a proper representation of the channel in the STWAVE simulations. Their conclusion on page 53 that the maximum surges, waves and associated wave periods seem consistent for all of the scenarios simulated is not surprising with this relatively large grid spacing.

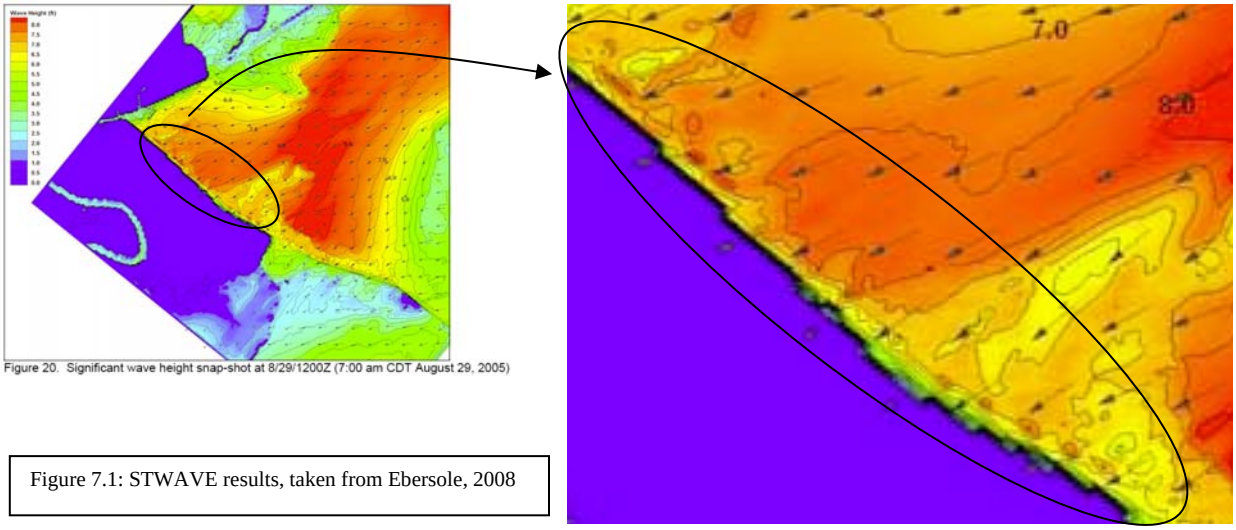


Figure 20. Significant wave height snap-shot at 8/29/1200Z (7:00 am CDT August 29, 2005)

Figure 7.1: STWAVE results, taken from Ebersole, 2008

The wave simulations on the Louisiana Southeast full-plane STWAVE grid are driven with boundary conditions that come from the Lousiana Southeast half-plane grid. STWAVE can be implemented as either a half-plane model, meaning that only waves propagating toward the coast are represented, or a full-plane model, allowing generation and propagation in all directions. The half-plane grid was applied in such a way that it was suitable for the ocean waves, but less for the local waves generated by the hurricane winds.

For the STWAVE modeling presented in December 2008 the US experts used the ADCIRC SL-15 grid and computed surge outputs as generated by Westerink. However, by using the ADCIRC computed surge surfaces they are about 3 feet too low along Reach 2 (see Paragraph 8 on the Ebersole report). That means that the STWAVE model underestimated the wave heights at the peak of the Katrina storm along Reach 2 by about 1 ft. His surge levels are therefore not consistent with the FINEL simulations (Wit, 2008). Furthermore, their waves are not really consistent with the surge level specified using the uncertain multiplicative factor of 1.12 on surges. In Figure 7.2.b&c the difference in wave height is shown as a result of differences in surge (Figure 7.2.a). The spatial extent of the larger waves expands within the MRGO and GIWW channels, more than that the peak waves goes up.

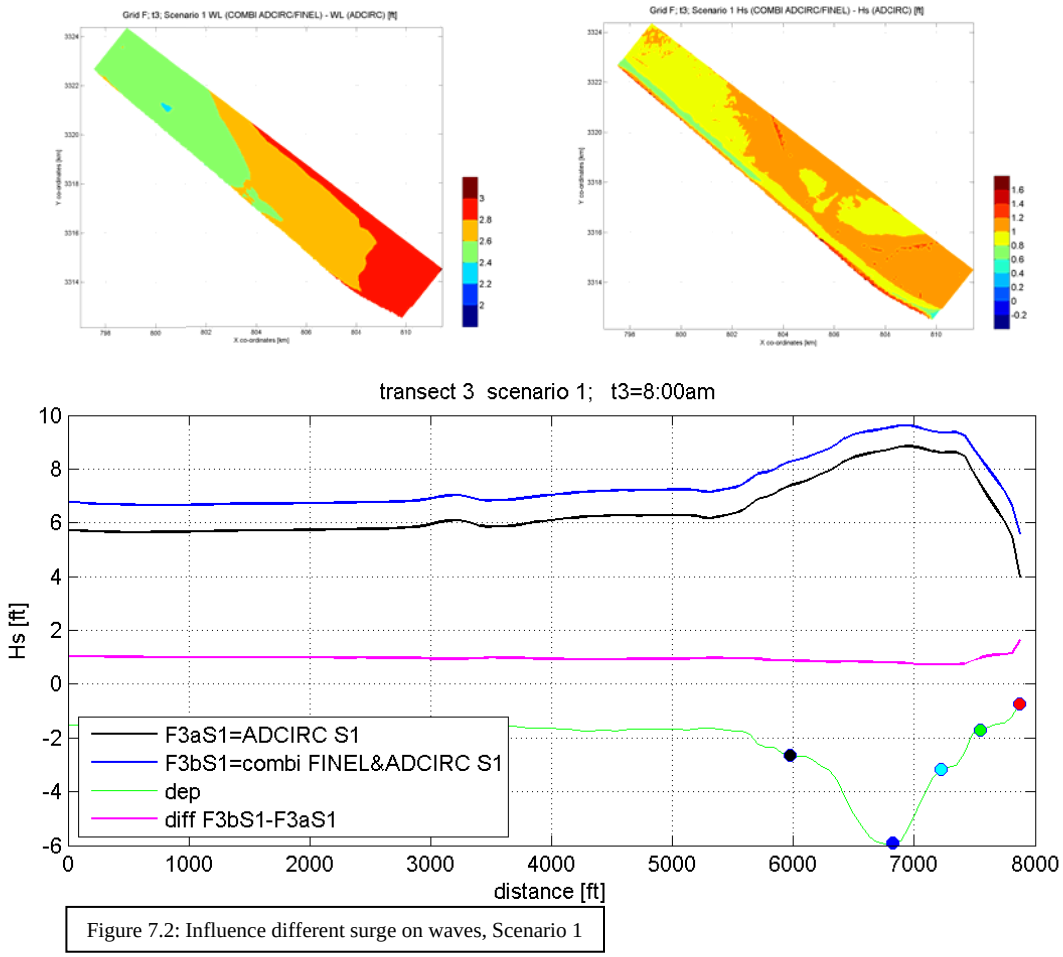


Figure 7.2: Influence different surge on waves, Scenario 1

For the remaining, there are many similarities between the STWAVE and the SWAN simulations. STWAVE is now producing results that are comparable to SWAN output for the Real Katrina run from the south-eastern lobe of Lake Borgne. SWAN indicates a maximum significant wave height for Scenario 1 of 8.7 to 9.9 feet, while STWAVE gives 7.5 to 8.2 feet (Resio 2008, figure 16 pg 39). These differences are within a range that can be explained by datum differences (NGVD29 for STWAVE, NAVD88 for SWAN) particularly if it is recognized that the surge surface for STWAVE is 1 to 3 feet lower in the area of interest than for SWAN (Kemp 2009). The influence of the lower water levels is about 1 foot in significant wave height. The peak wave period in southern Lake Borgne is 6 to 7 seconds for both SWAN and STWAVE, and closer to 5 seconds in the MRGO Reach 2 channel. Resio (2008, p. 48) states that STWAVE is producing mean periods, and that multiplication by a 1.15 factor is required to convert this output to the spectral peak wave periods provided by SWAN. There is thus no real difference to speak of.

Overall, we think the results of STWAVE and SWAN for the 'Katrina Real Run' are fairly close. However, the grid resolution of the STWAVE is too low to properly judge the influence of the various MRGO-scenarios.

Next, we will discuss the three points where Dr Resio questions our SWAN report.

A) Plaintiffs' Wave Report dubiously assumes that a segment of the Reach 2 levee would have been shielded from hurricane winds by cypress trees if the MRGO had not been constructed.

Dr Resio claims that the plaintiff's experts have erroneously described the vegetation in the wetland areas in the 'Golden Triangle' but presents no data to prove his point. We relied on other members of the Robinson expert team for the vegetation information. Plaintiff's experts Day and Shafer (2009) present data to prove that our representation of the vegetation in 1958 is correct. Part of their line of evidence is oblique aerial photographs recently obtained with the defence experts' reports (Day and Shafer, 2009). What Resio also fails to acknowledge is that we ran a series of sensitivity test to determine the impacts on the waves of different vegetation types (versions g, h and i) (Gautier et al, 2008, pg 22). Dr Bea in his analysis utilized the 2C (i) where the vegetation was presented as dense marsh. No tree cover was included. Plaintiff experts wanted to be as conservative as possible in their determinations of waves in their different scenarios. Resio does not seem to appreciate this point. Additionally, Dr Bea made allowances for the vegetation fringe between the MRGO channel and the levee itself, something not considered or acknowledged by the defence experts. Taking this vegetation fringe into account actually works to the benefit of the Defence team.

Resio claims that an 80 percent reduction in the wind field in areas of trees is problematic but he totally ignores defence expert Westerink (2008) who cites Reid and Whitaker (1976) in stating that:

> "it can be shown that very little wind momentum transfers through heavily forested canopies."

Additionally, Westerink was also part of a team that published a paper "Influence of Wetland Degradation on Surge" (http://www.waveworkshop.org/10thWaves/Papers/wamsleyetal_hawaiiconf.pdf) which stated

> "Wetlands can reduce surge potential .....by reducing surface winds due to higher sub-aerial surface roughness and by slowing surge propagation due to bottom friction in shallow flow at the inundation front." They went on to state "The winds input to the ADCIRC and STWAVE models are reduced to account for the higher surface roughness through a directional land masking procedure. In addition to reducing wind speeds, forested wetlands can also inhibit wind from penetrating through the tree canopy and shelter the water surface from wind stress. Features such as heavily forested canopies

> allow little momentum transfer from wind fields to the water column (Reid and Whitaker 1976) and thus the model does not apply a wind stress in wetlands or other areas classified as forest."

Based on these statements we could have reduced the winds by 100%. What is also important to note is that Resio, even though other users of STWAVE do, never incorporated the canopy effect even though Westerink did so for his ADCIRC modelling.

Numerous other authors reference wind reduction by vegetation including Schaffranek and Jenter (2001) show that the effects of the wind on flow in the vegetated wetlands are significantly damped relative to their effects in open water. Plaintiff experts went to great lengths to ensure their vegetation depictions were correct, undertook sensitivity analyses, and used conservative wave numbers (Bea 2008) in doing their erosion studies. The inescapable fact is that the construction, operation and maintenance of the MRGO exacerbated the wind wave field during Hurricane Katrina.

B) Plaintiffs'' Wave Report arbitrarily applies incompatible bottom friction formulae using one set of formulations to activate bottom friction in the "Katrina Real Run" base case and a second set to activate bottom friction in the "No MRGO" and "MRGO as Designed" scenarios.

Before changing the friction formulations in the SWAN settings we did sensitivity runs for various situations and we concluded that the two formulae we applied give similar results for their default settings (JONSWAP 0.067 and Collins 0.015). Since the marshes have reduced significantly since the construction of the MRGO, we focussed on the vegetation only in the scenarios where vegetation was thought to be important. For a proper comparison, the influence of the present vegetation must be taken into account for the "Katrina Real Run" as well. To find this influence we carried out additional SWAN simulations and came to the conclusion that the significant wave height in scenario 1 would be approximately one foot less in the MRGO if the present vegetation had been taken into account, see Figure 7.3.

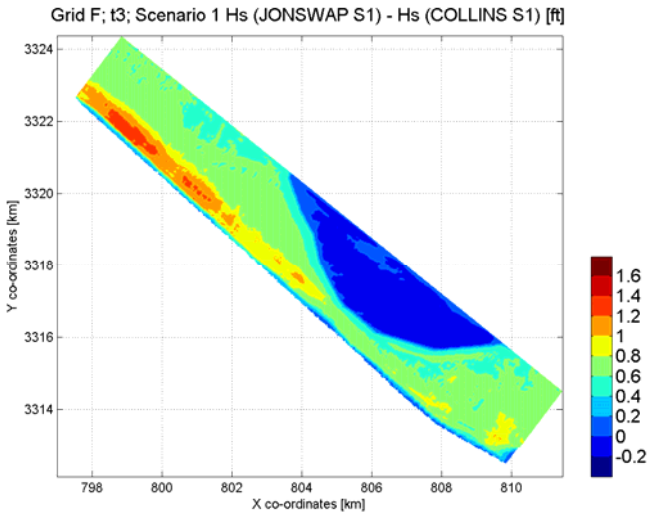


Figure 7.3: Scenario 1 differences Hs [ft] between uniform JONSWAP and Collins with present vegetation

C) Plaintiffs' Wave Report applies a wave growth source term that overestimates wave growth on short fetches like the MRGO fetch, making the reported conclusions as to the effect of the MRGO on waves suspect.

It is true that different wave growth source terms produce different results for significant wave height here. The wave growth source terms have been a point of debate among SWAN modelers before. However, according to the Shore Protection Manual prediction curves, the wave growth over 1500 ft, 40 ft deep with wind speeds of 100 mph (characteristic values for August 29th, 8:00 local time) is in the order of 2-3 ft. If we look at our SWAN results of the wave growth across the MRGO, we find reasonable values of 2.2 ft significant wave height for transect 1 and 3. Applying default SWAN settings would lead to circa 1.5 ft wave growth.

In general, the saturation-based wave growth model of Van der Westhuysen gives in most cases better results than the default settings [Westhuijsen, 2007]. Note that in our specific case the wave propagation and generation were computed on a considerable area and not only for the short fetches on the MRGO.

Conclusion

Overall, we think the results of STWAVE and SWAN for the 'Katrina Real Run' are fairly close. However, the grid resolution of the STWAVE is too low to properly judge the influence of the various MRGO-scenarios.

References

1 Coastal Engineering Research Center: "Shore Protection Manual", 1984

2 Westhuysen, Andre van der: "Advances in the spectral modelling of wind waves in the nearshore", 2007.

3. Schaffranek, R.W., and Jenter, H.L., 2001, Observations of daily temperature patterns in the southern Florida Everglades: American Society of Civil Engineers Wetlands Engineering and River Restoration Conference, Reno, Nevada, August 27-31, 2001, 4 p.

4. Ty V. Wamsley1; John Atkinson2; Mary A. Cialone1; Alison S. Grzegorzewski1; Kendra Dresback3; Randy Kolar3; Joannes Westerink, 2007. “Influence of Wetland Degradation on Surge” (http://www.waveworkshop.org/10thWaves/Papers/wamsleyetal_hawaiiconf.pdf

Appendix 7-A: Presentation results SWAN

In Figures 7A 1.1 - 1.3, the wave parameters at 8:00 am (the peak of the storm) on rays 1, 3 and 6 are given. These figures give much more information than the tables (7A-1.1 and 1.2) which only give the results on the blue ("deep"), green ("toe") and red ("levee") location. In each figure, all three scenarios are present. The green lines show the water depth, defined as the sum of surge and bottom level. The three scenarios can be easily recognized in the green lines.

Everywhere along the rays, the continuous lines representing wave parameters for scenario 1 is higher than the other scenarios. The exact difference between the scenarios depends strongly on the considered location. In scenario 1 the high wind speeds and the large water depth of the MRGO result in large wave heights up to almost 10 feet. At the toe of the levee (at the green dot) the wave height has reduced to circa 8 à 9 feet.

In scenario 2C the MRGO is absent and therefore the variation in wave parameters along the rays is almost zero. Significant wave height is about 5 feet, peak wave period about 3.5 seconds.

The dashed line of scenario 3 also indicates wave growth across the MRGO, but since its dimensions are smaller than in scenario 1, the wave growth is less. Furthermore, the vegetation in scenario 3 reduces the waves compared to scenario 1. If Katrina would have hit the area just after construction of the MRGO, so with its original channel dimensions and with the surrounding vegetation present, the significant deep water wave height would be about 25-50% less than what it was in the real Katrina situation.

After having taken notice of Dr Resio's suggestions, we did additional sensitivity tests, which were consistent with what Resio has shown. Figures 7A- 2.1, 2.2 and 2.3 are equivalent with 7A-1.1, 1.2 and 1.3 but represent the wave situation if the default KOMEN wave growth source term had been used and the present vegetation had been taken into account in Scenario 1 with the Collins friction formulation. It does not really affect any of our conclusions about the importance of the channel in amplifying waves or of the vegetation in diminishing them adjacent to the levees of the MRGO or GIWW, or in your ability to distinguish differences between the wave climate found in the MRGO for the three scenarios tested.

fig 7A-1.1

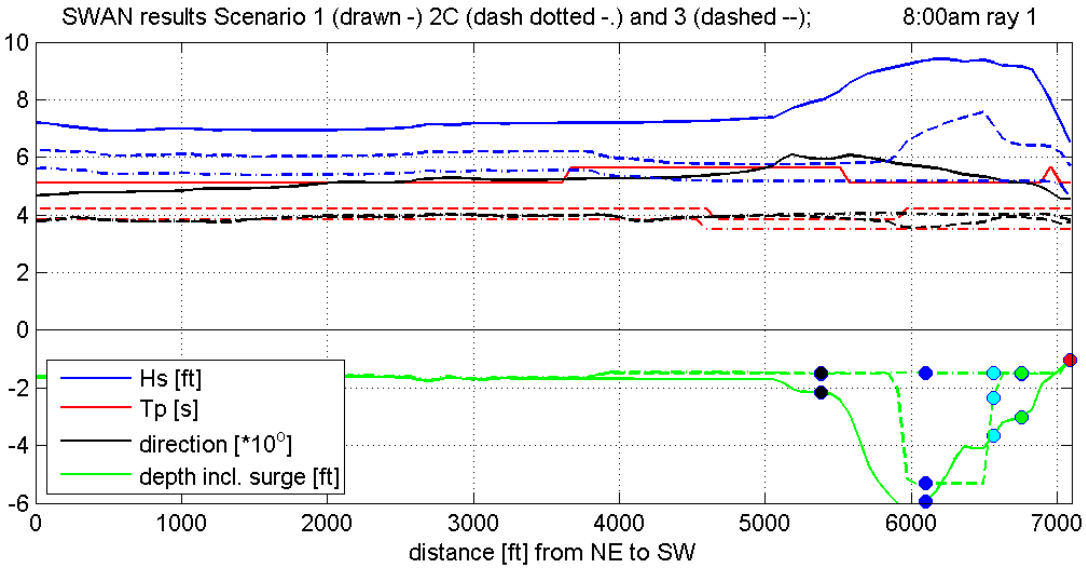


fig 7A-1.2

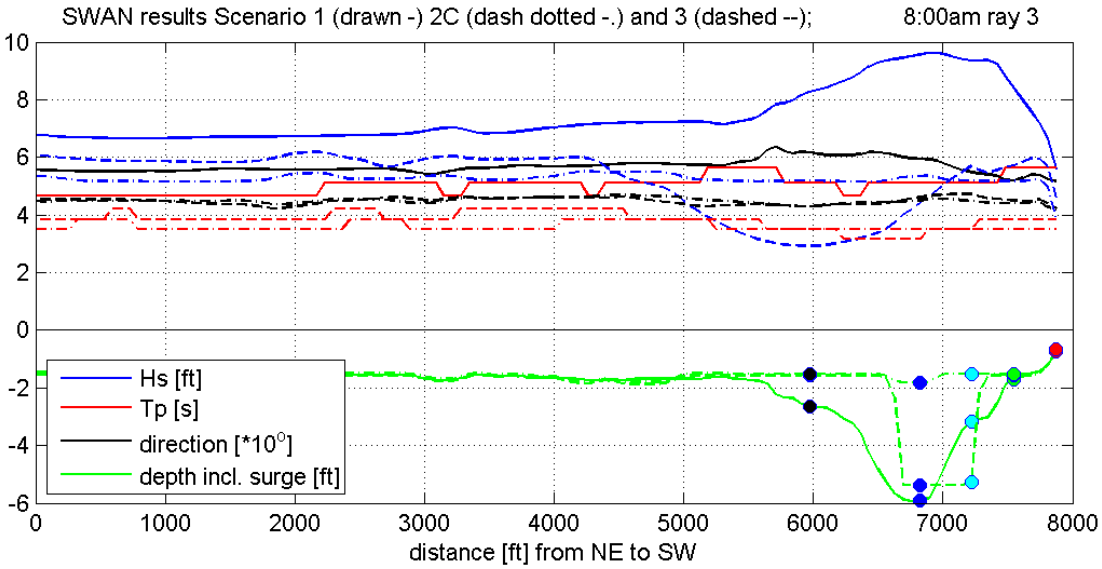
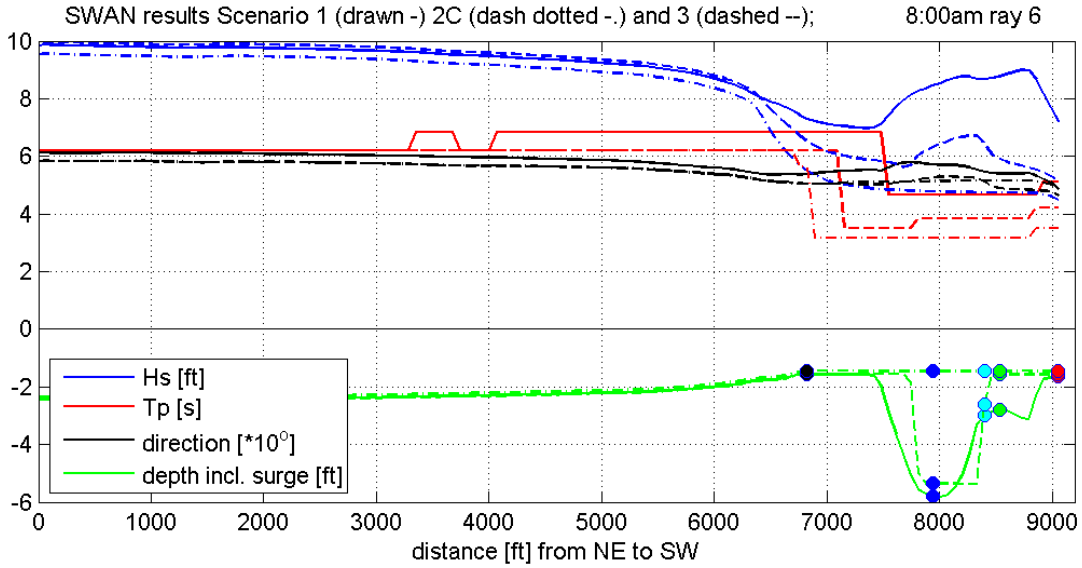


fig 7A-1.3



Hs [ft]	6 am						7 am						8 am						9 am					
	Levee		Toe		Deep		Levee		Toe		Deep		Levee		Toe		Deep		Levee		Toe		Deep	
	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3
ray 1	4.5	-	6.8	4.3	6.9	4.7	5.7	-	8.3	5.5	8.4	6.0	6.8	6.0	9.1	6.4	9.4	6.9	4.3	-	5.3	3.9	5.4	3.9
ray 3	3.3	2.9	6.0	4.0	7.1	3.1	4.9	4.1	7.4	5.0	8.6	3.9	6.0	5.0	8.4	5.7	9.6	4.4	3.6	2.6	4.7	2.7	5.1	2.2
ray 6	5.5	3.6	6.9	4.2	6.8	4.7	6.8	4.7	8.5	5.4	8.3	6.0	7.3	5.2	8.8	5.9	8.7	6.4	3.2	2.0	4.1	2.2	4.1	2.4

Table 7A-1.1: SWAN results Hs [ft]; S1=Scenario 1, S3=Scenario 3

Tp [s]	6 am						7 am						8 am						9 am					
	Levee		Toe		Deep		Levee		Toe		Deep		Levee		Toe		Deep		Levee		Toe		Deep	
	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3	S1	S3
ray 1	4.7	-	4.7	3.5	4.2	3.5	4.7	-	4.7	3.8	4.7	3.8	5.1	4.2	5.1	4.2	5.1	4.2	4.2	-	4.2	3.5	4.2	3.5
ray 3	4.7	3.2	4.7	3.2	4.2	2.6	5.1	3.5	5.1	3.5	4.7	3.2	5.6	3.8	5.6	3.8	5.1	3.2	4.7	3.2	4.7	3.2	4.7	2.9
ray 6	4.2	3.5	4.2	3.2	4.2	3.5	4.7	3.8	4.7	3.8	4.7	3.8	5.1	4.2	4.7	3.8	4.7	3.8	42	2.9	4.2	2.9	4.2	2.9

Table 7A-1.2: SWAN results Tp [s]; S1=Scenario 1, S3=Scenario 3

fig 7A-2.1

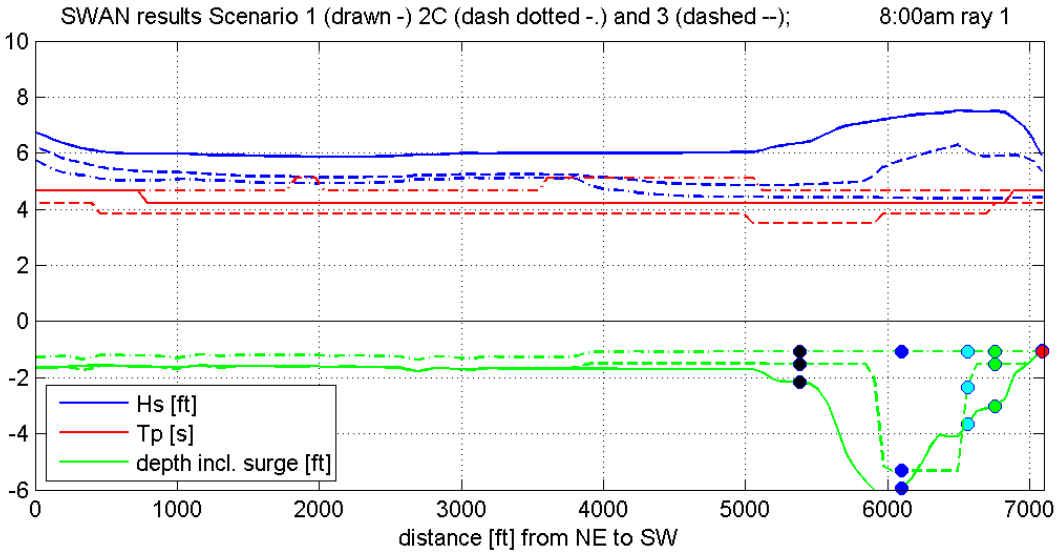


fig 7A-2.2

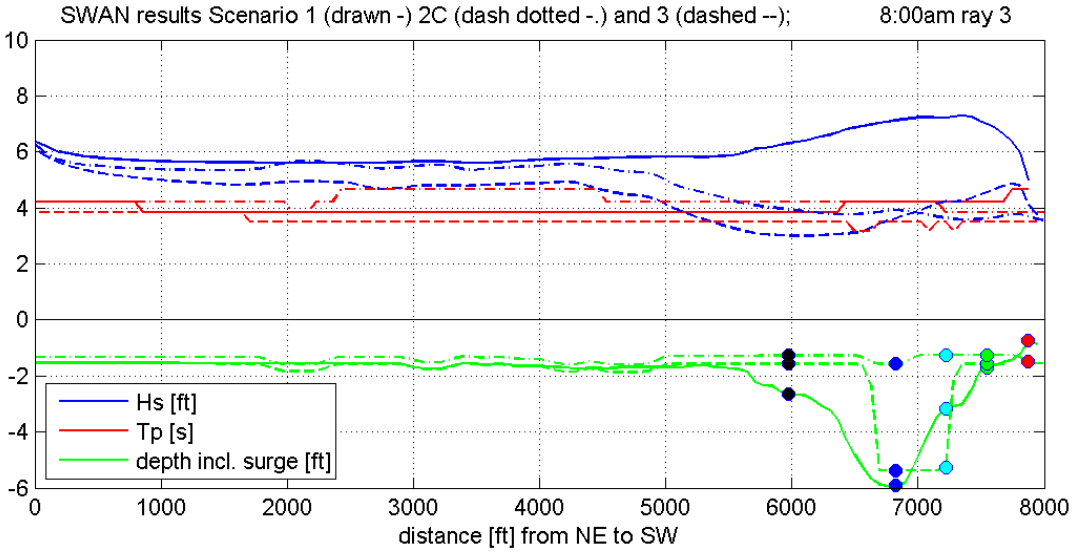
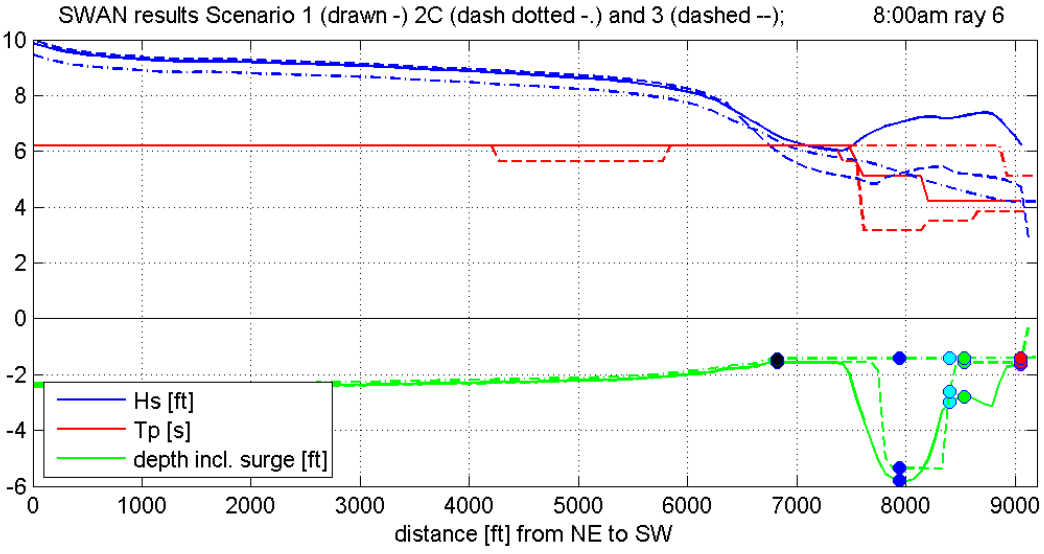


fig 7A-2.3



8. Observations on Defendant's Expert Report by Ebersole

As far as it concerns subjects that were studied by us, viz waves and surges, Mr Ebersole refers in his expert report to data described in Resio's and Wensinks expert reports. Therefore, our suggestions presented in Paragraph 6 and 7 hold for the Ebersole report too. Given our reservations about the waves in Paragraph 7 we are not sure that Ebersole could give valid conclusions on the various scenarios.

Apart from this, we have a remark on Ebersole's report, concerning the scaling factor of 1.12 for the water levels, see his Table 1 on page 27. First of all, it is not wise to use a uniform scaling factor generated for a location in the middle of a wetland to represent what is happening on a levee and vice versa. This single factor seems to have been used for various times and various scenarios. Furthermore, the way the factor is derived is not clearly described. This makes the quality of the presented surge and hence the waves computed with this surge rather doubtful.

9. Observations on Defendant's Expert Report by Fitzgerald

In the report "Interior Flooding Analysis – St Bernard and Lower Ninth Ward, Orleans Parish, Hurricane Katrina , August 2005, New Orleans area, Louisiana" by Stephen Fitzgerald a model has been developed, comparable with our interior Flooding model of the polders. Although some assumptions are different, the results are almost identical with our results.
Mr. Fitzgerald also compared the results of the Katrina Flooding with a scenario. In this scenario, the same conditions as with Katrina are used, except MRGO was assumed to be in the as designed condition and the wetland and marsh topography was pre-MRGO, or 1956 conditions. In our report, we also included a scenario, but in that scenario all negative influences of the MRGO on high water levels are compensated. In our analysis of this scenario we used the dike erosion results of Mr Bob Bea, and the results show that without the MRGO the Katrina flooding would have been less severe. This explains why our conclusions are different from the conclusions of Mr Fitzgerald.