The Louisiana Coastal Erosion Lawsuit: Bad Science and Bad Policy

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Abstract

A New Orleans area levee board and two parishes have sued the offshore oil industry members who have operated in Louisiana over the past 80 years. Plaintiffs claim that industry destroyed coastal wetlands during this period and that this destruction makes it more expensive for the levee board and parishes to do their jobs of protecting their jurisdictions from hurricane storm tides. They further allege that extraction of oil and gas has caused coastal subsidence, which also increases the impact of hurricane storm tides. Assuming, without deciding, that this lawsuit survives challenges to standing, prescription, and jurisdiction and is heard on the merits, the plaintiffs' claims are not scientifically sound. This article argues that the coastal marsh wetlands at issue in this lawsuit have little effect on storm tides. These wetlands waxed and waned over the past millennia without the intervention of man as the delta lobes have built and reabsorbed. Most importantly, relative sea level rise, driven by climate change and geologic subsidence, is the primary determinate of future hurricane storm tide risk in Louisiana. Past damage to wetlands does not affect this future risk, nor can it be abated by the proposed strategies of coastal restoration. This lawsuit denies the reality of climate change and geologic history. This denial, if encouraged by the courts, will make it harder to implement the retreat from the coast that is necessary to save the remaining wetlands and to protect human life and property in the long run.

Introduction

> "We live in the shadow of a danger over which we have no control: the Gulf, like a provoked and angry giant, can awake from its seeming lethargy, overstep its conventional boundaries, invade our land and spread chaos and disaster." Prayer for Hurricane Season.[2]

Hurricanes shape human life on the Louisiana coast. Subsidence and climate change driven sea level rise are inundating the coast, but it is hurricanes that will eventually wash away New Orleans and all other coastal Louisiana communities. On average, Louisiana is hit by a hurricane slightly more than once in every three years.[3] Many of these are deadly. Hurricane Katrina killed between 1500 and 1600 people in Louisiana. At least 1500 are estimated to have been killed in

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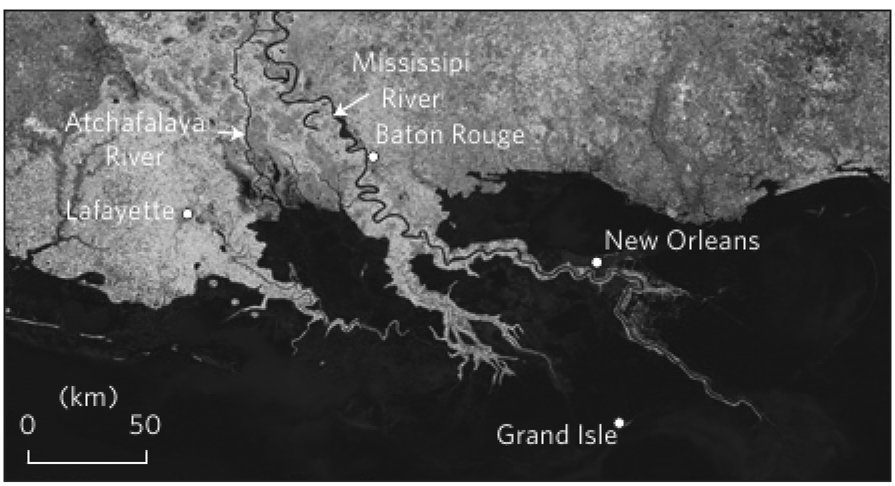
[2] Gomez, Gay M. *A Wetland Biography: Seasons on Louisiana's Chenier Plain*. P66 Austin: University of Texas Press (1998)

[3] "On average, since 1851, 0.7 tropical cyclones of tropical storm strength (2 tropical storms every 3 years), of which 0.3 are hurricanes (or one hurricane per 3 year period) should be expected somewhere within the state. A hurricane should make a landfall every 2.8 years." Roth D. Louisiana Hurricane History. p. 7 National Weather Service (2010).

the 1831 hurricane. The most deadly storm was Hurricane Number 10, in 1893, which killed an estimated 2000 people.[4]

The heart of this lawsuit, and of the Louisiana coastal restoration plan, is the belief that wetlands in the intertidal zone reduce hurricane storm tide. To put this claim in perspective, the hurricanes that killed the most people in Louisiana as a percentage of the population were before 1900. When you control for increase in population since that time, the 2000 people killed by Hurricane Number 10 numbers dwarf the toll of Hurricane Katrina as a percentage of the population.[5] These deaths, and the massive destruction that accompanied them, occurred despite the much larger extent of coastal wetlands, including huge old growth cypress forests. Thus the basic mythology that there is a hugely increased risk of hurricane damage due to the loss of wetlands is not supported by the historical record.

While fishermen and environmentalists lament the loss of Louisiana's coastal wetlands, the loss of the wetlands is only a symptom, not a cause, of hurricane risk. The core problem is the bad land use decisions that lead to development on land with a high rate of relative sea level rise. New Orleans is one of the least sustainable cities in the United States, with nearly 50% of the city already below sea level. Even on a calm summer day, a breach in the city's massive levee system could put 15 feet of water in some areas of the city and destroy tens of thousands of homes and businesses. All of the coastal areas, including cities such as Morgan City, Houma, and Lake Charles are subject to flooding from moderate sized hurricanes. NOAA models show that a slow moving category 3 hurricane could flood New Orleans despite the new federally funded levees. As will be detailed later, the future is grim. By 2100, conservative estimates of sea level rise and subsidence of the Mississippi Delta show that this is what the coast of Louisiana will look like:[6]



[4] Roth D. Louisiana Hurricane History. p. 8-9 National Weather Service (2010).

[5] Pielke Jr, Roger A, Joel Gratz, Christopher W Landsea, Douglas Collins, Mark A Saunders, and Rade Musulin. "Normalized hurricane damage in the United States: 1900-2005." 9 Natural Hazards Review 29, 38 (2008).

[6] Blum, Michael D, and Harry H Roberts. "Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise." *Nature Geoscience* 2, no. 7 (2009): 488–491.

Is this a realistic picture of the future? Is it overly optimistic since it assumes that no hurricanes will breach the deltas that preserve New Orleans and that the Mississippi will keep flowing along its current path, despite the hydraulic resistance posed by the increased sea level? Can coastal restoration change this picture in a positive way? Most critically, is this, the fault of the oil and gas industry as the plaintiffs claim?

The Coastal Erosion Lawsuit

> Coastal lands have for centuries provided a crucial buffer zone between south Louisiana's communities and the violent wave action and storm surge that tropical storms and hurricanes transmit from the Gulf of Mexico. Coastal lands are a natural protective buffer, without which the levees that protect the cities and towns of south Louisiana are left exposed to unabated destructive forces.
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> This natural protective buffer took 6,000 years to form. Yet, as described below, it has been brought to the brink of destruction over the course of a single human lifetime. Hundreds of thousands of acres of the coastal lands that once protected south Louisiana are now gone as a result of oil and gas industry activities - all as specifically noted by the United States Geological Survey. Unless immediate action is taken to reverse these losses and restore the region's natural defense, many of Louisiana's coastal communities will vanish into the sea. Meanwhile, inland cities and towns that once were well insulated from the sea will be left to face the ever-rising tide at their doorsteps.[7]

This introduction and related claims in the petition can be deconstructed into these assertions:

> **The Steady State Hypothesis.** There was a natural protective buffer around the coast that took 6000 years to build. This implies a steady state world with a gradually building buffer.
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> **What Happened in the 1930s?** Everything was fine until the 1930s – one lifetime - when the coastal lands started to disappear because of oil exploration and production.
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> **The Oil Industry Destroyed the Coastal Lands.** Cutting canals and cuts for pipelines destroyed coastal lands.
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> **Coastal Lands Protect Against Storm Tides.** The gravamen of this case is that the damage the oil companies did to coastal lands increased the risk of flooding, which is why the levee board should have standing. The flooding that matters most on the Louisiana coast is due to hurricane storm tides, so the claim is that the coastal lands destroyed by the oil company actions must protect against storm tides.
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> **Oil Extraction Causes Subsidence.** The plaintiffs also claim that extracting oil from the ground causes subsidence which is a reason that the Mississippi delta has such a high

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[7] Bd. of Comm'rs of the S.E. La. Flood Prot. Auth. E. v. Tn. Gas Pipeline Co., LLC., et al., No. 13-6911 (D. Ct. Orleans Parish, La. Jul 24, 2013). Available at: http://biotech.law.lsu.edu/blog/petition-for-damages-and-injunctive-relief.pdf

subsidence rate.[8] This assumes that oil and gas production, which is generally from deep wells in Louisiana, is causing surface subsidence.

Coastal Restoration is Possible. The plaintiffs tie this case to coastal restoration, rather than just levee building. This is intended to bolster their support from the environmental community, which should generally oppose levee building because of the damage levees do to the coastal wetlands. Coastal restoration depends on the steady state world hypothesis: you cannot restore coastal lands if the sea level is rising – at best, you can slow the loss.

When these claims are taken together, it is clear that this lawsuit denies climate change and its impacts on the Louisiana coast. The measure of damages is the increase in hurricane damage risk. If restoration is not possible, or would not reduce hurricane risk even if it was possible, then the only remaining strategy for a levee board is to use the money to support levees. That makes sense as a claim by a levee board. It does not have the money to pay its share of the construction of new levees by the Corps of Engineers, nor can it afford to maintain levees once they are constructed. Since the people of Louisiana are not interest in increasing taxes to pay for their own protection, the levee board and parishes are desperate to find someone else to pay for their projects.

Understanding the Mississippi Delta

The plaintiffs use the commonly understood idea of the delta as the bit of land that we are now living on that lies at the intersection of the land and the Gulf of Mexico. This is a very limited view of the delta. The Mississippi has been draining the interior of North American for hundreds of millions of years. It has continuously deposited sediment the entire time. The amount and location has varied with the climate and delta cycles, but the relentless deposition of sediment has never stopped. The geologic delta is an inverted mountain of sediment up to 65,000 feet thick extending from northern Louisiana out to the edge of the continental shelf. What is commonly thought of as "the delta" is really just the intertidal zone and the land adjacent to it. This is a thin veneer of recent sediment layered over the mountain that is the real delta.

As the delta was laid down, it deformed the earth's crust downward so that it subsided as more sediment was laid down. As the delta sank, it created room for more sediment – the accommodation space.[9] This process has been going on for so long that the delta has a constant downward velocity and sufficient inertia that it continues to sink even if less or no sediment is being added. The thin layer at the land-water interface that is the visible delta waxes and wanes through the climate and river deposition cycles. The core delta beneath the green veneer we call the delta just keeps growing and sinking.

The Steady State Hypothesis

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[8] "Indeed, the removal of fluid from beneath coastal lands is causing subsidence of those lands, contributing to a rate of relative sea level rise in coastal Louisiana that is staggeringly higher than other places in the country." Paragraph 6.9, page 10.

[9] Morton, R.A., Bernier, J.C. & Buster, N.A. Simple methods for evaluating accommodation space formation in coastal wetlands. 29 Wetlands 997, 1002 (2009).

The plaintiffs base their complaint on the idea of a delta slowly building a buffer of coastal lands through time. This steady progression is then interrupted in the 1930s and the coastal lands begin to disappear. The problem with this hypothesis is that there has never been a steady state on the Mississippi Delta.[10] Over the very long term, tens to hundreds of thousands of years, the delta is subject to the earth's climate cycles. These cycles are driven by eccentricities in the earth's orbit and by changes in greenhouse gasses driven by natural processes.[11] During the glacial maximums, enough water is tied up in glaciers and ice caps to drop the sea level four hundred feet from today's levels. During glacial minimums, glaciers and ice caps can nearly disappear and the sea level can rise by a hundred feet from current levels.

When sea level is dropping, the intertidal zone moves out into the Gulf of Mexico, and the river cuts a canyon through the delta so that the river mouth stays at sea level. At the glacial maximum, the intertidal zone delta is at the edge of the continental shelf. As the climate warms and water is freed up by melting glaciers and ice caps, sea level rises, and the river back steps up the delta. The intertidal zone delta moves inland and uphill as sea level rises. The river fills in the canyon as it back-steps.

The exact position of the intertidal zone will be determined primarily by sea level and secondarily by sediment. If there is a limited amount of sediment, say during a prolonged drought, the intertidal zone will be a little farther inland because subsidence will lower the delta faster than the river can fill the accommodation space caused by subsidence. If there is more sediment than is necessary to fill the accommodation space caused by subsidence, then the intertidal zone will be a little farther out into the ocean. This effect will only be significant when sea level is very stable. However, even small changes in sea level make dramatic changes in the accommodation space. A small rise in sea level pushes the intertidal zone far inland because the delta is so flat. To stay in the same place, the sediment would have to build out over the submerged slope of the delta, which would take a huge increase in sediment. The process works the same way in reverse: a small fall in sea level will pull the intertidal zone far into the Gulf, again because the delta is so flat.

The current interglacial cycle is very unusual in geologic terms. Sea level appears to have been fairly constant for the last 5,000 or so years. This has allowed the intertidal zone to stay in relatively the same place - but only relatively. During this period the river itself has moved over the delta like a snake. The river can only stay in a given channel for a certain period of time before so much sediment piles up in the channel and at its mouth that the river begins to back up. At this point the river begins the process of avulsing to a new course. The key is subsidence. Over the past 6000 years referred to by the plaintiffs, the river has recorded a very clear pattern of building out a finger of land into the gulf at the site of the active delta, as soon as that delta is abandoned by the avulsion of the river to a new channel, the abandoned delta begins to subside below the surface of the water and the new channel seeks out an area of open water created by

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[10] Blum, Michael D, Jonathan H Tomkin, Anthony Purcell, and Robin R Lancaster. "Ups and downs of the Mississippi Delta." *Geology* 36, no. 9 (2008): 675–678.

[11] Rial, J.A. Abrupt climate change: chaos and order at orbital and millennial scales. *Global and Planetary Change* **41**, 95–109 (2004).

the subsidence of a previous delta that will be capable of accommodating its sedimentary load allowing it to build out a new finger of land.

Over the period of stable sea level, the river has built several lobes, and several lobes have then been abandoned and subsided to open water. At no time was the entire area we think of as the current delta stable and supplied with sediment. The delta lobe on the south and east of New Orleans, where St. Bernard Parish is located, had already been abandoned long before the first dam or levee had been built on the river. The Chandeleur Islands are not barrier islands. They are the old edge of that lobe and the only part that is still above water. There are shoals beyond them that were above water and have now subsided well below the surface. The land between the St. Bernard coast and the Chandeleur Islands was "lost" without any human intervention, long before any current lifetime.

The succession of the multiple deltas that built the coast requires that abandoned lobes subside below the surface to create accommodation space into which new lobes would build in the future. The plaintiff's lawsuit covers the areas of the coast that were created by lobes that have been abandoned by the natural process of avulsion. In its natural state, the Mississippi would have finished abandoning its current lobe and channel in the 1970s, hastening the transformation of the St. Bernard and south New Orleans areas to open water.[12] This was prevented by the construction of the Old River Control Structure, which limits the amount of flow that can go through the prefer channel, the Atchafalaya River. Over the past 5,000 plus years, the delta has built and abandoned thousands of square miles of coastal lands, including some 14 different delta lobes.[13] The land change we are misnaming as "land loss" today is actually just the normal operation of the same natural delta cycle which has been in progress through the ages.

What Happened in the 1930s?

There many references to "land loss" since the 1930s. The plaintiffs imply that everything was fine up until then, with the idea that oil and gas development since then has caused the coastal land loss. Several different things happened around this time that impacted the Mississippi Delta. One is technological: this is when aerial photography was first used to map the Louisiana coast. NOAA has been surveying waterways in Louisiana for 200 years, and doing the best job possible at surveying the marsh land. But traditional surveying is very difficult and expensive on unstable ground. While waterways and shipping channels had to be accurately surveyed for navigation, there was no need for accurate measures of the wetlands.

Aerial photography, and mapping based on the photographs, allowed accurate, cost-effective mapping of the Louisiana coast for the first time. It also allowed the coast to be remapped at regular intervals. These maps are precise enough that it is easy to digitize them and overlay them with modern maps, enabling quick calculations of "land loss." The main reason that the 1930s seems to be an inflection point for land loss is that it was when good data because available for large areas of the Louisiana coast.

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[12] Fisk, Harold Norman. Geological investigation of the Atchafalaya Basin and the problem of Mississippi River diversion. Waterways Experiment Station, 1952.

[13] Frazier, David E. "Recent deltaic deposits of the Mississippi River: their development and chronology." *TRANSACTIONS—GULF COAST ASSOCIATION OF GEOLOGICAL SOCIETIES* 17 (1967): 287–325.

A second change during the 1930s was the sediment load in the river. The delta cycles tell us that sediment and sea level determine the location of the intertidal zone on the delta, with sea level being the dominate variable. For the first several thousand years of melting after the last glacial maximum (the Late Wisconsin, which peaked about 18,000 years ago), there was an enormous amount of sediment coming down the Mississippi, along with huge floods.[14] But sea level was rising, so even with all the sediment, the intertidal zone was pushed inland. During the long, stable period after the end of the last glacial period about 8,000 years ago, both sediment and sea level were relatively stable. As the American prairie was opened for agriculture, the sod busters destroyed the stable vegetation throughout the Mississippi Valley. This caused a massive loss of top soil, much of which ended up in the Mississippi River. Since sea level was fairly stable during the sod busting era, there may have been more net land building than in the past periods.

These wasteful agricultural practices were ended during the Dust Bowl in the 1930s, which reduced the sediment going into the river. At the same, dams and locks were being built on the upper Mississippi and Ohio Rivers to stabilize water flow for shipping. These structures trap sediment, further reducing the sediment that will ultimately be available for offsetting the natural subsidence of the delta.

The third change, and the most important in the long term, is that sea level rise started accelerating. Sea level is not uniform around the world. It varies with currents and local gravity, so that it is impossible to pin point the exact moment when sea level rise started accelerating. Researchers have found that acceleration over the long term rate during the latter part of the Holocene occurred in different places over a 40 year window centered on 1925.[15] Since sea level is the dominate variable on the location of the intertidal zone on the Mississippi Delta, accelerating sea level rise will cause relative rescission of the delta lobes – there will be relative land loss (or reduced land building) as compared to steady state sea level.

Over the past 100 years, sea level on the Louisiana Coast has risen by 8 inches. This rise, combined with the reduction in sediment, is enough to explain most of the actual land loss - or rather what should be properly understood as *land change* - on the Louisiana coast. It is important to be precise about land loss in Louisiana. In some cases, land loss is not the same as areas moving from vegetation to open water. For example, Hurricane Katrina was said to have caused a large amount of land loss on the Louisiana Coast. In most cases, however, the land had already subsided and left the vegetation floating. This floating vegetation looks like land on satellite and from an airplane. The hurricane tears it loose and suddenly there are huge expanses of open water. The hurricane did not destroy the land, it was lost to relative ocean rise and the weakening of the marsh before the hurricane. What the hurricane destroyed was the illusion that the combination of subsidence and sea level rise – relative sea level rise (RSLR) – had not affected the Louisiana coast. This occurred over years but was masked by the floating vegetation.

The Oil Industry Destroyed the Coastal Lands

[14] Dyke, Arthur S, and Victor K Prest. "Late Wisconsinan and Holocene history of the Laurentide ice sheet." *Géographie physique et Quaternaire* 41, no. 2 (1987): 237–263.

[15] Gehrels, W Roland, and Philip L Woodworth. "When did modern rates of sea-level rise start?" 100 *Global and Planetary Change* 263 (2013).

Since this lawsuit is about the destruction of a hurricane buffer zone by the oil and gas industry, the coastal lands that are at issue are the coastal marshes, salt and fresh, that were cut up with canals for petroleum exploration, production, and for pipelines.

The canals and the spoil berms formed from the dredged material from the canals interfere with the flow of the tide through the marsh. [16] The Louisiana coast has very little tidal action in the absence of storms. This is due to the peculiar nature of the Gulf of Mexico and the shallow reach of the Louisiana coast.[17] This makes the salt marsh especially sensitive to injuries that further reduce the tidal interchange. It is not salt water intrusion; they are already in salt water. It is the relative stasis of the water that harms the marsh by limiting the removal of toxic materials that accumulate from biological activity on the sulfate in sea water. As the marsh weakens and dies, the canal can widen and eventually the marsh can fail, giving way to open water. Thus a canal can cause progressive damage longer after its construction.

Fresh water marsh does not require tidal exchange. Canals directly destroy fresh water marsh to the extent that the marsh is dredged to form the canal and that marsh is buried under the spoil bank. But canals in fresh water marsh do not cause the same severe progressive damage as they do in in salt marshes unless the orientation of the canal is such that allows high tides to push salt water into the fresh water marsh.

There is no question that the canals cause significant harm to the salt water marsh and more limited damage to fresh water marsh. If this were a class action lawsuit where the land owners themselves were demanding that the land be restored or that a compensation payment for damages be made, it would fit into established legal precedent and it would be relatively simple to resolve the case, subject to the usual legal defenses. But this is not a lawsuit by land owners filing legacy lawsuit over restoration and compensation claims.

Coastal Lands Protect Against Storm Tides.

This is a lawsuit claiming that third parties, the levee board and the parishes, have been injured because the damage to the salt marsh increases the risk of storm tide damage. This is a claim for risk at the present time, and a claim that this risk will increase in the future if the coastal salt marsh is not restored. This raises two issues: what does the future look like; and does salt marsh actually protect against storm tides?

The first complicating factor in the simple “canals destroy wetlands” story is the problem of relative sea level rise. The rate of relative sea level rise is already higher than the historical rates when the marsh developed. While marsh can add elevation through the accumulation of organic material in the soil, it can only do that at a limited rate. If RSLR is higher than that accumulation rate, the marsh will eventually drown. RSLR is high enough to be stressing the marsh, making the effects of the canals more severe. There are areas where the marsh is changing to open water without any canals to damage it. As RSLR accelerates, even at the most conservative rates

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[16] Swenson, Erick M, and RE Turner. “Spoil banks: Effects on a coastal marsh water-level regime.” 24 Estuarine, Coastal and Shelf Science 599, 607 (1987).

[17] Platzman, George W. “Two-dimensional free oscillations in natural basins.” 2 *Journal of Physical Oceanography* 117, 129 (1972).

predicted, it is likely that the marsh in deeper water will drown and the marsh closer to shore will only survive it is free to migrate inland as the water deepens. This will be impossible if levees are built near the coast. So at some point in the future, any previous canal damage will not be relevant because those marshes would have drowned anyway. At that point, the levee boards themselves will be the biggest killers of salt marsh because their levees will prevent the natural inland migration of the marshes.

The value of wetlands in hurricane protection is usually stated in terms of some level of storm tide reduction per mile of wetlands. What limits the inland reach of storm tide (absent increases in land elevation) is the friction that the water must overcome as it covers the land and the amount of time it has to overcome the friction. One of the best studied systems is storm tide through coastal mangrove forests. Mangroves are an ideal vegetation to resist storm tide. They grow in wide bands from well into the ocean to a mile or more inland. They have a very high density of stems and above ground roots that resist the water. The roots and stems catch debris that is washing inland and that increases the resistance to the storm tide. Most critically, they are tall enough to be higher than all but the most extreme storm tide.

The dense thicket of mangroves slows the water that the storm is trying to push onshore. If the storm moves quickly, the water piles up in front of the mangroves and is lower behind them because the storm moves on before the water has time to get through the mangroves and reach its full depth.[18] Thus the height of the storm tide behind the mangroves is lower than in areas without a mangrove buffer, and higher in front of the mangroves. The shorter the time that the water is moving, the more effective the mangroves are at reducing the surge. When the tsunami hit Indonesia, mangroves provided protection. A tsunami wave is very fast moving, but it does not last very long. (There may be a train of the waves, but they are spaced far enough apart in time to act as single waves.) The tsunami wave runs out of water and power before it can equilibrate through the mangroves.

In contrast, a slow moving hurricane has plenty of time to push through mangroves and other wetlands. Just as the tide itself has no trouble passing through wetlands, a slow moving hurricane keeps pushing its wall of water through the wetlands until it gets so far inland that the elevation of the land stops it. Thus a storm with a 20 foot storm tide, could, in theory, flood 50 to 100 miles inland across the flat coastal land in Louisiana. In Hurricane Rita, a storm tide of no more than 15 feet went 50 miles inland, aided by flow up an estuary.[19] Even minor storms now flood large areas of the coast because the elevation is so low due to subsidence and sea level rise.

The salt marsh damaged by the canals (and the same for fresh water marsh, which is more resistant to damage by canals) is relatively short and does not provide as much friction as mangroves. The same hydrology of the Gulf of Mexico that is responsible for the low rise and fall of the daily tides has the opposite effect for storm tides. When a hurricane is within two hundred miles of the Louisiana coast, a 3-4 foot storm tide will flood the entire Louisiana coast.

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[18] Liu, Huiqing, Keqi Zhang, Yuepeng Li, and Lian Xie. "Numerical study of the sensitivity of mangroves in reducing storm surge and flooding to hurricane characteristics in southern Florida." 64 *Continental Shelf Research* 51 (2013).

[19] Berenbrock, Charles, Robert R Mason Jr, and Stephen F Blanchard. "Mapping Hurricane Rita inland storm tide." 2 *Journal of Flood Risk Management* 76, (2009): 76–82.

For example, Hurricane Ike, which came ashore on the Bolivar Peninsula in Texas, caused massive flooding on the Louisiana coast.[20] 12 to 48 hours before a hurricane comes ashore on the Louisiana coast, storm tides raise sea level on the coast. The larger the diameter of the storm and the higher the wind speeds, the earlier before landfall the sea level rises.

Thus, well before a hurricane and its major storm tide comes ashore, the intertidal wetlands will be completely submerged by the forerunner storm surge. Since the ocean is effectively infinite for the purposes of storm tide, once the wetlands are flooded, they are just an extension of the ocean floor and provide little or no resistance to the storm tide. There are also claims that the marsh will reduce wave heights. This is true, but only in a very limited case. The maximum attenuation of wave height occurs when the marsh is higher than the wave. As the marsh drowns, the wave attenuation diminishes and becomes insignificant once the water level is higher than the marsh.

NOAA weather storm tide modeling confirms the limited effect of marsh land on storms tides. In the large storms that pose the greatest threat to the inhabited areas of the coast, the wetlands will have little or no effect on either waves or the ultimate storm tide height. There is no evidence that the potential storm tide attenuation by intertidal wetlands should be considered as a factor in either levee heights or calling evacuations. Thus the destruction of coastal marsh land, as lamentable as it might be from an environmental perspective, does not increase the risk of storm tide damage on the eastern Louisiana coast, when considered in the light of the special nature of storm tide in Louisiana.

Oil Extraction Causes Subsidence.

If one reviews the Louisiana Coastal Restoration Plan and myriad papers that have been funded to support it, you will not find any discussion of geologic faulting. This is also true of most of the wetlands research that is published about coastal Louisiana. The assumption seems to be that since the delta is just a big pile of silt and sand, it does not have faults and earthquakes. Even levee planning is done without much attention to potential fault lines.

The irony is that coastal Louisiana has one of the most complex and well-studied fault systems in the world. Unlike California, where faults are studied because of the risk of catastrophic earthquakes, Louisiana faults are studied to find oil. The delta is riven with faults and moving blocks of delta defined by the faults. A close look at a map of the wetlands will show knife edge divisions between a growing marsh and open water. That is a fault line, and the open water is on the downthrown block, meaning that it is subsiding faster than the area where the marsh is still growing. This is independent of canals or any other factors that influence the survival of the marsh.

A few researchers have tried to prove that oil extraction causes surface subsidence.[21] This is certainly possible with the right geology. There are fields in other places where the oil is found in

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[20] East, Jeffery W, Michael J Turco, and Robert R Mason. "Monitoring inland storm surge and flooding from Hurricane Ike in Texas and Louisiana, September 2008" pp 31-34. USGS, Open-File Report 2008–1365 (2008).

[21] Morton, Robert A, Julie C Bernier, and John A Barras. "Evidence of regional subsidence and associated interior wetland loss induced by hydrocarbon production, Gulf Coast region, USA." 50 *Environmental Geology* 261 (2006).

shallow sand formations that behave like aquifers: they collapse when the oil is withdrawn and they are close enough to the surface to cause surface subsidence. This is easily demonstrated with water pumping. The Entergy plant in New Orleans pumps water from the aquifer for pass through cooling and in the process has caused more than a meter of subsidence in the surrounding community.[22] (This may have increased flooding in that area during hurricane Katrina.)

Most of the oil production in coastal Louisiana is from deep wells in dense rock. There are no open pore spaces to collapse and the well is deep enough that it would be unlikely to cause surface effects even if there were deep porosity changes. But there are areas where there is both a subsidence hotspot and oil wells, so it is not unreasonable to question whether the oil wells cause subsidence. Careful examination shows that the correlation is between faults and subsidence. Most faults show a subsidence hotspot. Faults are also where you often drill for oil, because the fault structure traps oil and gas. Faults without oil wells have subsidence. Oil wells on faults have subsidence. Oil wells that are not associated with faults do not have subsidence. It is highly likely that carefully controlled research, using the most accurate available fault maps and elevation data, could clearly answer the question of whether oil production causes subsidence.

Coastal Restoration is Possible.

This is a distractor in this lawsuit. The primary causation fails because the destruction of the marsh land by canals does not increase the risk of storm surge. But assuming, for the sake of argument, that there is causation, is coastal restoration an appropriate remedy? Even the language is inappropriate. Just as coastal erosion makes no sense – the land is still there, just submerged by RSLR – restoration makes no sense. The best research shows that there is no way to return the sediment levels in the river to those of the days of when we had bad farming practices and no dams and levees. At the same time, regardless of what you believe is driving climate change and whether we have the ability to alter it, sea level is rising, and rate of rise is increasing. It is already rising fast enough to force the delta to recede even if there was enough sediment and by 2100, it will drown most of the current wetlands.

In the world of climate change and rising sea level, restoration is not possible. At best, it might be possible to slow the loss of land in a very small area, at the cost of increasing it in other areas. The Atchafalaya delta/Wax Lake delta area is building a little land, and is geologically more stable area than the old Mississippi channel. Gradually allowing the Atchafalaya to capture the majority of the flow of the Mississippi might allow the Atchafalaya delta to persist longer in the face of sea level rise. Navigation could be done down the Atchafalaya, which may be the only way to keep the river open in the long term. But this would be at the cost of cutting New Orleans off from the river, which is politically impossible. It will happen at some point, either through the failure of the Old River Control Structure, or because sea level has risen enough that the Mississippi will not flow to New Orleans.

Making the Oil and Gas Industry a Better Coastal Citizen

[22] Dokka, Roy K. "The role of deep processes in late 20th century subsidence of New Orleans and coastal areas of southern Louisiana and Mississippi."116 *Journal of Geophysical Research: Solid Earth* B06403 (1, 17) (2011).

Whether this lawsuit is well founded, it is clear that the oil and gas production industry has not been a good coastal citizen in the past. Many companies have also supported pro-coastal restoration groups such as America's Wetlands and the Louisiana Coastal Restoration Authority itself. While these groups might not directly support this lawsuit, it is their fantasy of coastal restoration that makes it possible.

The energy industry should become a leader in science-based coastal policy. The first priority is beginning the retreat from areas at highest risk from relative sea level rise and catastrophic hurricanes. Port Fourchon and the Grand Isle area, Morgan City, and Houma are areas whose primary reason for existence is the oil and gas industry. Moving facilities out of these regions – either farther inland to safer areas such as Lafayette or offshore entirely – makes good long term business sense. While New Orleans is less dependent on the oil and gas industry, moving from New Orleans to more secure locations such as Baton Rouge would send a powerful message that the industry supports rational land use planning based on geology and climate science. If suppliers and contractors were also encouraged to abandon high risk coastal areas, it would change the conversation from coastal restoration to environmental and societal protection through a managed retreat from the coast.

Conclusions

This lawsuit is based on the mythology that the Mississippi delta is in a steady state world and that, but for the actions of bad people – the oil industry, the Corps of Engineers – everything would be fine. The plaintiffs' claims deny climate change and the best coastal science. The defense of this case should be seen as an opportunity to bring the best science to bear on questions of the Louisiana coast and its future in a changing world.