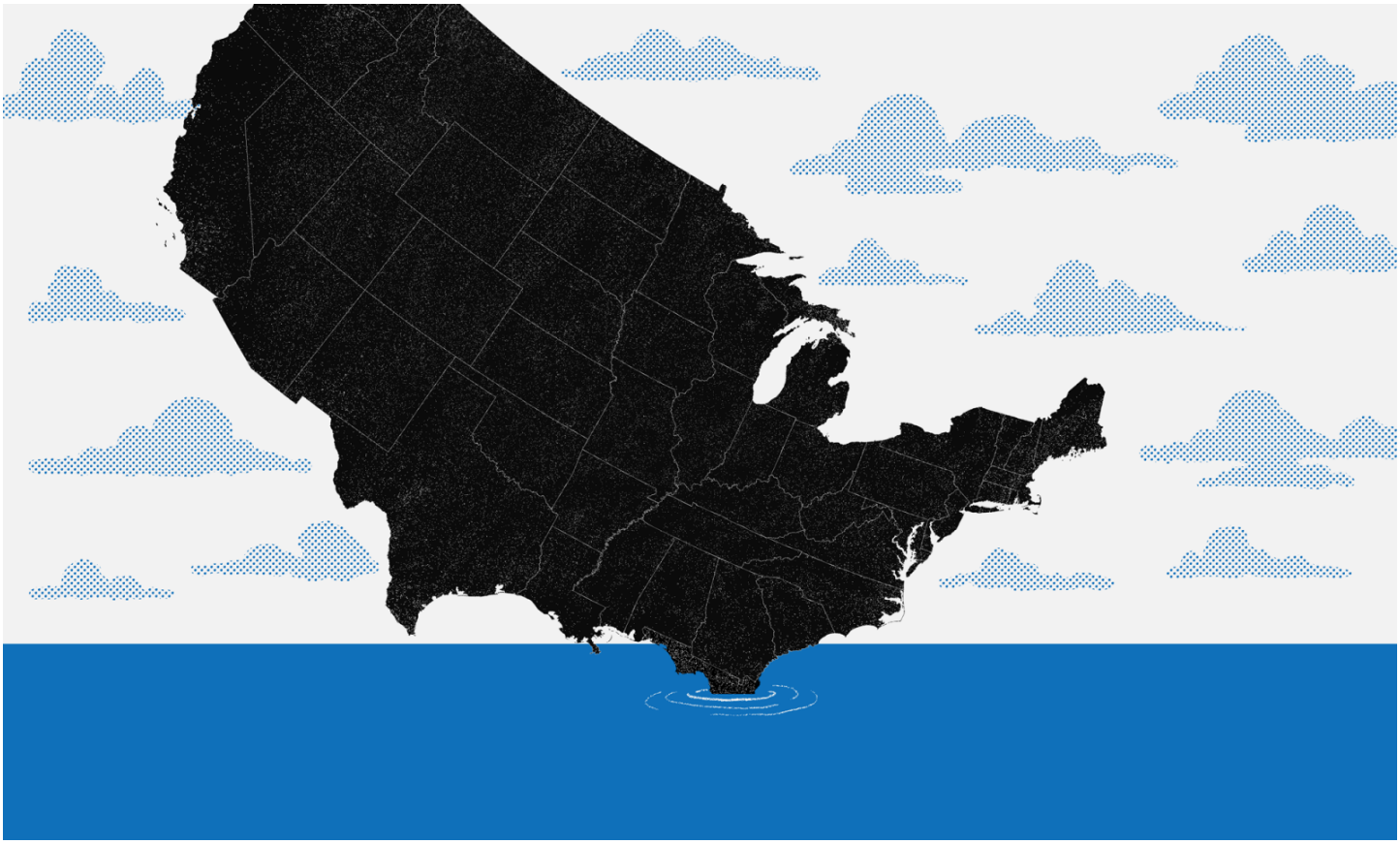
This is How South Florida Ends



Maddie Stone
gizmodo.com

It’s a scorching midsummer day, and the sawgrass is still under a pale blue sky. Waist-deep in water and sinking slowly into the muck, I fend off mosquitos as a man from South Florida’s Water Management District mixes a bag of salt into a hot tub-sized bucket on the side of the road. Thirty feet away in the marsh, another city official wearing waders and a bug hat stands on a narrow steel walkway, dangling the end of a long hose over a plexiglass chamber.

The experiment seems innocuous enough. Seawater is being added to a freshwater wetland, and scientists are observing what happens. The grim subtext is that this same experiment is about to play out in real life and on an enormous scale, from here in the southern Everglades, to Miami forty miles east, to the Florida Keys due south. If scientists are correct, much of South Florida will be underwater by the end of the century. A sawgrass marsh in southern Everglades National Park. (All images by Maddie Stone)

Standing next to me, pulling strands of what looks like a moss-covered scarf out of the water, is Viviana Mazzei, an ecology PhD student at Florida International University. It's a periphyton mat,

she explains, a unique symbiosis of algae, bacteria, and other microorganisms that forms the base of the Everglades' food chain. When the saltwater comes, it's expected to die, with profound ecological consequences.

Flat, low, and on a porous bedrock, South Florida is extremely vulnerable to the impacts of sea level rise.

"The urgency for doing this work has never been greater," Tiffany Troxler, the FIU ecologist leading the experiment, told me later that week over the phone. "The Everglades is a world treasure, and we'd like for people to continue coming here to enjoy it for a long time."

Today, the Everglades is fighting a war. Its adversary—rising sea levels brought on by man-made climate change—is relentless and merciless. It's coming faster than we think. And unlike an earlier war between man and the so-called river of grass, this fight will have no winners.

The first war on the Everglades began over a century ago, when European colonists arrived in South Florida intending to grow crops and build cities, and instead found themselves wading through a mosquito-infested swamp. It was a dreary, dismal, abominable place, "suitable only for the haunt of noxious vermin, or the resort of pestilential reptiles" according to an early government report.

In other words, it was America's last frontier, and man's God-given right to conquer it. And so, men conquered, or at least they tried. For decades, efforts to tame the wetlands proved futile. The tides turned in 1928, when a devastating hurricane flooded Lake Okeechobee—the enormous freshwater reservoir that fed wetlands to south—sending nearly three thousand Everglades pioneers to a watery grave. That disaster prompted the US Army Corps of Engineers to erect an enormous dike around the lake, cutting off the Everglades' lifeblood and draining hundreds of thousands of

acres for agriculture. East, west, and south of Lake Okeechobee, the Army Corps dug thousands of miles of levees and canals to move water around in a more orderly fashion.

An example of an artificial canal dug to divert water in South Florida.

Fast forward to 2016. The Miami metropolitan area is home to nearly six million people and hundreds of billions of dollars' worth of real estate. It's a popular travel destination, a gateway to Latin America, and headquarters to major multinational corporations including Burger King and Office Depot. The gentle creep of freshwater down a hundred-mile-long, sixty-mile-wide river of grass is no more—it's been replaced by the largest flood control structure in America.

A quick drive inland reveals what subjugation of the Everglades has wrought: an ecosystem in shambles. Reduced to less than half of their former extent and receiving only a third of the freshwater that they used to, most of the remaining wetlands are far too dry. Populations of native birds, fish, and reptiles have declined precipitously; invasive species are rampant. Toxic algae blooms are now a summertime tradition. So-called "white zones"—vast expanses of dead vegetation—speckle America's largest wetland like canker sores.

Still, all of the ecological problems triggered by development and artifical drainage pale in comparison to the existential threat now posed by too much carbon in the atmosphere: sea level rise.

"The important thing we have learned from studying the past is that sea level rises in pulses."

Since 1930, sea levels in South Florida have risen nearly a foot. The Intergovernmental Panel on Climate Change conservatively predicts another three feet of global sea level rise this century, as

polar ice caps melt and warming seawater expands. The National Oceanic and Atmospheric Administration, meanwhile, projects up to six and a half feet of rise.

A freshwater sawgrass marsh in Everglades National Park.

Hal Wanless, a geologist at the University of Miami who's spent 50 years documenting the past 18,000 years of sea level changes in South Florida, thinks the highest government projections are too low. "The important thing we have learned from studying the past is that sea level rises in pulses," he told me when I met him in his office on campus. These pulses, which have caused as much as thirty feet of sea level rise per century in the recent geologic past, are tied to periods of "rapid ice sheet disintegration" on Greenland and Antarctica.

Wanless believes we're entering another such period now. And the evidence is certainly mounting. In the late 1980s, scientists were talking about how Greenland might start to melt due to global warming; by the mid 1990s it was already happening. Now, that melt is accelerating. A recent study in *Geophysical Research Letters* estimates that Greenland lost a trillion tons of ice between 2011 and 2014, contributing twice as much to global sea level rise as it did during the prior two decades.

All of this is just the beginning. A recent study in *Nature Climate Change* concludes that if every nation aggressively reduced its carbon emissions now, we'd still be locked into nearly 100 feet of sea level rise over the long term.

And when it comes to vulnerable coastlines, South Florida is at the top of the list. Not only is the region very flat and very low, it sits on a porous limestone bedrock built of ancient reef structures. "

A sawgrass marsh in southern Everglades National Park. (All images by Maddie Stone)

“The analogy most commonly used is Swiss cheese,” Doug Yoder, deputy director of Miami Dade’s Water and Sewer Department, told me. Over thousands of years, acidic rainwater has eaten holes through the limestone, allowing the ocean to bubble up from below.

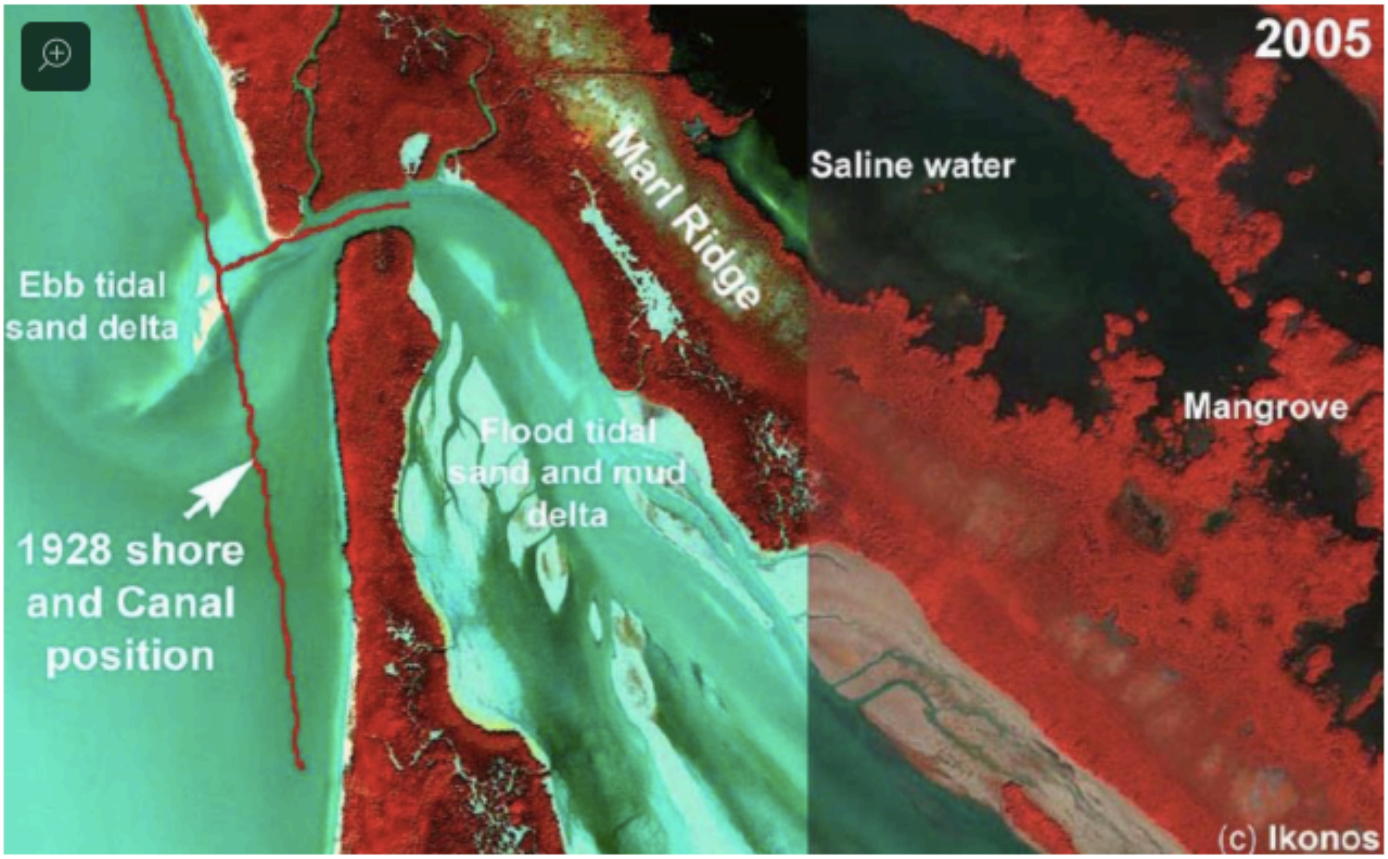
“You can’t build dikes or sandbars to keep it out,” Coral Gables’ mayor Jim Cason said. As mayor of a city that would have been underwater just a few million years ago, Cason is acutely aware of his community’s tenuous relationship with the sea. He has a saying about South Florida: “Our future is what happens to ice.”

“Many people still don’t get it,” Wanless said, describing an instance when he was called out to Miami Beach’s Public Works Department in 2009. At the time, the city’s now-infamous tidal flooding was just starting to garner attention. Wanless recalled a group of men in suits and ties saying, “Dr. Wanless, we’re having a problem. We need to know where to put the water.”

“I said, you can put it anywhere you want,” he told me. “It’s the ocean. It’s arrived.”

The battle against rising sea levels is conspicuous at Miami Beach, which is already spending hundreds of millions of dollars raising its roads and building pumps to divert the invading saltwater into Biscayne Bay. But along South Florida’s wilder coastlines, a more dramatic siege has garnered comparably little attention.

Take Cape Sable, a lonely expanse of marsh, mangrove swamp, and white sand beach at the southwest toe of Everglades National Park. Wanless has been trekking out here for decades, and he's watched the shoreline fall back hundreds of feet. "This is a very dynamic area, and it gives us an inkling of the kinds of changes we're going to see," he said.



Google Earth image of Cape Sable with historic shoreline position overlain, via Erik Stabenau

Cape Sable's troubles began in the early 20th century, when settlers cut canals to the ocean to drain the inland swamp and gain access for cattle pasture. The land was eventually abandoned, but the canals remained and broadened over time, channeling saltwater into the sawgrass marsh, a freshwater ecosystem. Today, this is causing the marshes' thick peat soils to collapse.

"You have to understand that these highly organic peat soils we have in the Everglades are a balance between the production of plant matter and the forces breaking that plant matter down," Steve Davis, an ecologist at the Everglades Foundation, told me. "As these soils become exposed to salt, you strongly tip the balance toward a more rapid breakdown."

Peat collapse is now being observed at freshwater-starved inland marshes, too, and as seawater continues to invade, the problem will get worse. "The more we look, the more evidence we see," Davis said. "The rate of elevation loss we could be looking at is potentially dramatic."

According to Erik Stabenau, an oceanographer with the National Park Service, the issue of whether or not to restore Cape Sable's collapsed marshes—now open lakes of seawater—is complicated by sea level rise. "We can shut down the flow through the canals so you don't get saltwater in there,"

he said. “And we might be able to manage it for a generation or two. But we’re in the forever business.”

The sawgrass-mangrove transition zone near the southern edge of Everglades National Park.

Further east, the ecosystems of Florida Bay are also suffering, thanks to historic drainage problems and modern climate change. Covering 800 square miles between the southern coastline and the Florida Keys, the bay is home to a stunning variety of plants, fish, and birds, endangered manatees, bottlenose dolphins, loggerhead sea turtles, and American crocodiles. Like a thirstier version of parklands to the north, it receives far less freshwater than it used to.

“The rate of elevation loss we could be looking at is potentially dramatic.”

If there are too many hot days and not enough rain, salinity levels in Florida Bay skyrocket—which is exactly what happened last fall following a severe drought. The consequence? Tens of thousands of acres of seagrass wilted and died, blanketing the estuary in a plume of yellow sulfide.

For now, the die-off appears to have ended. But as miles upon miles of dead seagrass stews in the summer heat, it’s being gobbled up by jellyfish, which excrete nitrogen and phosphorus-rich waste. This, ecologists fear, could trigger an enormous algae bloom, choking out sunlight and sucking the remaining oxygen out of the bay. “It’s sort of a chain reaction that causes the die-off to persist over a long time,” Davis said.

One way or another, it’ll take the seagrass years to recover. In the meantime, Florida Bay will continue to fight storm surges and rising sea levels at half-health. Whether this means the ocean will plow further inland faster is unclear.

Eventually, the seawater *will* push inland, and if Wanless is right, eventually is coming soon. This adds urgency to the research of Troxler and her students. After watching a freshwater wetland get hosed down with brine, Mazzei and I drive south to a brackish site, where the same treatment is being applied. Here, the dearth of freshwater caused by recent drought and so many dikes up north has taken a toll. In some places, tufts of sawgrass stand nearly a foot above the peat; their long white roots exposed like teeth with receding gum lines.

A Florida International University-led saltwater addition experiment is taking place in the Everglades to explore the effects of rising sea levels.

Ben Wilson, an ecology PhD student from Alabama, is out in the muck taking measurements of carbon dioxide, methane, and other invisible gases from the saltwater addition plots. These chemical fingerprints, he explains, will help scientists understand how important ecological processes like carbon sequestration will be impacted by rising sea levels.

I ask Wilson if studying a doomed ecosystem gets him down at all. Not really, he says. “If we can learn anything that helps us preserve these ecosystems a little longer, to me that’s worth it.”

One could dismiss the plight of the swamp as trivial compared with the annihilation of entire cities along South Florida’s coastline, but the two are inextricably linked. The millions of people living in the Miami metro area drink from the Biscayne aquifer, a vast freshwater lens underlying much of South Florida. If the Everglades becomes too salty, so will Miami’s water supply. “The extent that these wetlands can hold together is the extent that we get water quality protection,” Troxler said.

Freshwater flows through the Biscayne aquifer in a southeasterly direction, mixing with seawater when it arrives at the coast. But as sea levels rise, the saltwater front is advancing. Already, this has caused a handful of drinking wells at Hallandale Beach to become contaminated. With another eight inches of rise, more than half of the flood control structures built to keep the seawater at bay could become useless. “Gravity is just not going to work as well as it used to,” Yoder said.

There is, however, a way to buy the communities of South Florida time: by restoring the flow of freshwater from the north to push back against the rising seas. And that’s exactly what Everglades conservationists have been fighting to do for decades.

A dozen miles east of Miami, the strip malls peter out and give way to expansive meadows of sawgrass, marking the edge of Everglades National Park. If you want to cross the park to catch a boat tour out of Everglades City, there’s only one direct route—the Tamiami trail.

Cutting straight across the park like a pencil line etched into a pastel landscape of muted greens and browns, the Tamiami trail was considered a feat of engineering when it was laid down in the 1920s. Now, as with many other legacies of South Florida’s development boom, it’s clear the highway has inflicted untold harm on the Everglades.

A section of the Tamiami Trail.

A canal roughly the width of the highway itself rims the Tamiami’s north-facing side, catching freshwater and diverting it east, to aquifers along the coast. “The Tamiami trail has become an obstruction to north-south water flow—it basically acts as a dam,” Julie Hill Gabriel, director of

Everglades policy for Audubon Florida, told me. “One of our big challenges is, how do you get that obstruction out of the way?”

For now, the solution lies in raising parts of the road so that water can flow underneath. A one-mile section of the so-called Tamiami bridge was completed in 2013, and construction of another 2.6 mile segment could begin this fall. Eventually, federal government plans to extend the bridge up to 6.5 miles.

A dirt road just north of the Tamiami Trail.

It’s a major symbolic victory for conservationists, but in reality the Tamiami bridge is a small piece of what’s needed to solve the Everglades’ water problems. The fundamental issue is that not enough fresh water comes south from Lake Okeechobee anymore—and that problem calls for more complex and costly engineering solutions.

“Putting that water back certainly buys us time. It certainly buys us environmental resilience.”

That’s where the Comprehensive Everglades Restoration Plan (CERP) comes in. Formally launched in 2000, this multi-decade, Army Corps-led effort to restore the Everglades by putting the water back where it needs to be was initially pegged as a $10.5 billion project. Nearly twenty years in, it’s been plagued by delays and budget cuts, fought by agricultural lobbies, and remains nowhere near completion. Meanwhile, the estimated cost of CERP has soared.

One of the biggest challenges facing Everglades restoration is simply acquiring land south of Lake Okeechobee, in what’s known as the Everglades Agricultural Area (EAA). “We need big, engineered wetlands,” Zac Jud of the Florida Oceanographic Society told me. “Instead of flowing billions of gallons of water [from Lake Okeechobee] to the coast, we need to send it through

filtration marshes, so that by the time it gets to the south, it's clean enough to give to the Everglades."

Algae blooms, such as the one pictured here in Stuart, Florida from July, 2016, are one ecological side effect of agriculture and artificial drainage in South Florida.

But most of the land that could store water to send into these wetlands is owned by several politically powerful sugar companies, who like South Florida's plumbing the way it is.

In 2014, after a large parcel of land south of the lake went on the market, Floridians voted overwhelmingly in support of Amendment 1, which earmarked hundreds of millions of taxpayer dollars for its purchase. Instead, the state took that money and used it to purchase anything and everything else in the name of conservation. They even gave some of it directly to farmers. Environmentalists place the blame squarely on the sugar lobby.

"Amendment 1 was misappropriated, and we did not get the opportunity to buy land south of the lake," Jud said. "The governor sided with the sugar industry."

Despite recent setbacks, proponents of Everglades restoration are encouraged by the public support their cause has garnered. It's now widely agreed that moving more freshwater south is our best (and perhaps only) shot at revitalizing the Everglades—stopping peat collapse, preventing seagrass die-offs, and allowing more natural ecological transitions to occur as climate change progresses.

What's more, with rising sea levels threatening to wipe South Florida off the map, a healthy Everglades could be the last line of defense. "You could say Everglades restoration is a waste of money because it's all going to be drowned anyhow," Wanless said. "But if you can have a more reliable, higher level of freshwater running through the Everglades, and the wetlands can build up

peat again, you can keep the saltwater encroachment at bay better. And that's worth it's weight in gold."

"Putting that water back certainly buys us time," Stabenau said. "It certainly buys us environmental resilience. Does it solve the problem forever? I don't think sea level is going to come up just a few inches and stop. But if it turns out down the road that we have engineering solutions to climate issues and water problems, we're buying ourselves time to figure that out."

On my last day in the Everglades, I took a tour of Ten Thousand Islands, a swampy archipelago rimming Florida's southwest coast. For thousands of years, Native Americans lived here like kings, feasting off oysters, crabs, lobsters, and fish. Peregrine falcons soared overhead as our airboat navigated tufts of land held together by twisted mangrove roots. The silhouettes of sausage-shaped manatees appeared and faded again. A bottlenose dolphin caught our boat's wake and followed it, leaping in and out of the water as my tour guide made sharp turns to kick up surf.

Tiny islands held together by mangroves are a ubiquitous feature of Ten Thousand Islands.

In this tattered mosaic of water and land, the Everglades is still wild. The existential threats I'd spent the last week learning about seemed to fade into irrelevance. It was difficult to imagine how humans could destroy something so vast.

My guide seemed to share this view. The rise and fall of the sea, he said, was something that city folk in Miami worried about. Out here, the will of the ocean was inevitable, as much a part of the fabric of life as the rise and fall of the sun.

Florida will be underwater again someday, probably no matter what we do. But right now, on timescales that matter to people, it is people who will decide its fate.

As black-bottomed storm clouds rolled in, we hurried back to the shore.