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THE NATION

Fatal Flaws: Why the Walls Tumbled in New Orleans

Experts point to defects in design, construction and maintenance that left levees vulnerable.

January 17, 2006 | Ralph Vartabedian and Stephen Braun | Times Staff Writers

NEW ORLEANS — In the frantic days after Hurricane Katrina, the Army Corps of Engineers scrambled to plug a breach on the 17th Street levee, dropping massive sandbags from a fleet of helicopters.

But the engineers were baffled: The sandbags kept disappearing into the watery breach. The pit eventually swallowed 2,000 sandbags, each weighing between 3,000 and 20,000 pounds. It was an early sign that the hurricane had opened an extraordinarily deep hole in the foundation of the storm wall, pointing to a fundamental breakdown in the engineering of the city's levee system.

Investigators recently told The Times that the 17th Street levee failed because its engineers made a series of crucial mistakes, one of which was to base the levee design on the average strength of the soil rather than on the strength of its weakest layer. The errors may reflect a loss of expertise during the 1990s, when the corps sharply downsized its soil laboratories.

The faulty soil analysis is one of many defects or flaws in concept, design, construction and maintenance that left many of the levees in New Orleans especially vulnerable to Katrina. Environmental miscalculations, including the loss of natural protection from marshes, added to the problems.

The errors might have been offset had the corps required larger safety margins, and that raises questions about the corps' internal culture.

Although the levees' shortcomings became apparent shortly after the hurricane hit, experts are only now pinpointing the underlying causes of the collapses. What they find will determine who bears the political and legal responsibility for the flood and provide a technical basis for any future levee system to protect New Orleans from a monster storm.

The levee failures were among the most costly engineering errors in the United States, measured by lives lost, people displaced and property destroyed, said half a dozen historians and disaster experts.

Katrina flooded New Orleans with about 250 billion gallons of water and killed more than 1,000 people.

"I don't think there is anything comparable in recent American history," said retired engineering professor Edward Wenk Jr., a science advisor to three presidents and investigator of the Exxon Valdez accident.

Early blame for the levee failures has fallen largely on the Army Corps of Engineers, the principal architect of a 40-year project to protect New Orleans from hurricanes.

Corps officials say they will accept responsibility for the failures if investigations prove that their supervision of the system was deficient.

"What I don't think we understand yet is the forces that caused those failures," said Lt. Gen. Carl Strock, corps commander and its chief of engineers. "A failure is really where a design does not perform as intended. If forces we designed for were exceeded, there may not be a design failure."

However, a preliminary report funded by the National Science Foundation has found evidence of design flaws in the city's concrete storm walls, where at least six catastrophic failures caused half of the flooding.

A handful of technical, civil and criminal investigations are underway, including an effort by the Justice Department to look for possible criminal negligence.

The corps is conducting the federal government's official investigation, despite widespread concern that only an independent board of investigators is likely to be impartial.

The corps was slow to make public all of its engineering paperwork on the levees and has still not produced a full record of the internal correspondence that occurred during the last 15 years. Moreover, it is not examining what role its organization and culture played in technical lapses, which, Wenk said, typically are at the root of engineering disasters.

The corps says it has addressed those concerns by recruiting outside experts to participate in its investigation. The agency is expected to make its final report in June.

The corps is attempting to temporarily repair 50 miles of damaged levees before the hurricane season next June. The Bush administration announced last month it would spend $3.1 billion for temporary levee repairs and limited upgrades in the next several years.

However, many local leaders believe the levee system must be strengthened to withstand the strongest possible hurricane -- a Category 5 -- to restore full confidence in the city.

Katrina, a Category 5 storm over the Gulf of Mexico, weakened to a Category 3 by the time it hit New Orleans.

Making his ninth visit to New Orleans since Katrina struck, President Bush last week praised the $3.1-billion initiative but said nothing about Category 5-level protection. And, according to the corps, even the temporary repairs and limited upgrades will not protect the city from another Category 3 storm, which has winds up to 130 mph and storm surges as high as 12 feet above normal.

Meanwhile, more than four months after the hurricane, investigators are still coming to grips with the levee system's technical failures and shortcomings that paved the way for Katrina's destruction.

Weak, Slippery Soil

No levee failure was more dramatic than the breach at the 17th Street Canal, where a 465-foot section of concrete wall gave way Aug. 29, flooding the affluent Lakeview section of New Orleans.

Floodwaters were 3 to 5 feet below the top of the levee wall when it collapsed. The soil under the levee, composed of layers of loose clay and softer organic peat, was too weak to handle the weight of the water pushing against the levee walls.

The earthen base of the levee slid backward by about 45 feet, taking the concrete storm wall along for the ride. The whole system relied in part on heavy-gauge steel beams, called sheet piling, driven into the soil for reinforcement. But they only went to a depth of 17 feet below sea level, not deep enough to provide a strong foundation, National Science Foundation investigators say.

In rebuilding the damaged sections of the canal levees, the corps is sinking sheet piling 45 feet, and in some areas is using heavier gauge piling up to 70 feet deep. The corps says the deeper piles are needed because soil in the damaged areas is even weaker than before Katrina.

The levee design was overseen by the corps but assigned to two firms: Eustis Engineering, which analyzed the soil under the levee; and Modjeski and Masters Consulting Engineers, which did the structural design. (Neither firm returned phone calls seeking comment.)

The levee design depended on crucial soil measurements along the canal that began in 1981. Technicians drilled for soil samples 300 to 500 feet apart to measure the strength of the soil.

The soil tests provided accurate and complete data about the weak soils, but government and private design engineers made three crucial errors analyzing the information, said Bob Bea, a UC Berkeley engineering professor who is part of the National Science Foundation investigating team.

First, engineers determined the overall strength of the soil by averaging different layers and different sections along the banks of the canal. But it was the weakest layers of soil that would determine the overall strength, and using the average gave the engineers a false confidence, Bea said.

Second, the levee design failed to account for the fact that the soil would weaken significantly once the canals were full of water and the soil became saturated, Bea said. Soil tests conducted before the levees were built showed the soil's sheer strength was about four times greater than after Katrina. The engineers incorrectly believed that sediment in the canals would prevent water from intruding through foundations, but dredging and other activity disturbed that natural seal, he said.

Finally, the engineers miscalculated how the levee foundation could slide, if it did fail. They assumed the greatest risk of failure was in one of the stronger layers of soil, whereas it failed in a weaker layer.

Since Katrina, the corps has proposed installing storm gates that would seal off the 17th Street Canal, along with the city's two other major drainage canals. Once the canals were sealed off from Lake Pontchartrain, hurricane surges would no longer be able to travel through them into the heart of the city.

Not long after construction started on the levee, signs of trouble popped up.

The company that built the 17th Street storm wall, Pittman Construction, warned the corps in the early 1990s that the pilings were unstable and had caused problems during construction. The company filed a claim for more money but lost its case.

"Pittman told the corps he was concerned about the weak soils," said Herbert Roussel, a consulting engineer hired by the company's owner, A.E. Pittman. "The corps acted as though it was his problem."

Loss of Expertise

As questions about the soils were being raised, the corps shut down its soils lab in the New Orleans district and curtailed its geotechnical research lab in Vicksburg, Miss.

The labs had long performed crucial soil analysis and research for projects around the country, but the corps' leadership wanted staff engineers to oversee outside contractors, said Bill Marcuson, the former director of the New Orleans soils lab and president-elect of the American Society of Civil Engineers.

"That trend leads to less in-house capability and competence," Marcuson said. "If the corps is not physically doing research, it is hard to evaluate the quality of others' research."

Strock said the moves were part of a larger federal government trend to save money by turning over work to the private sector. He conceded that the practice "eroded our technical capability," but said the damage was limited.

But Bea countered that the agency lost significant technical capability, particularly in its large civilian workforce.

"They don't have the number of people or the quality of people that they used to," said Bea, who began his engineering career with the corps.

Levees Without Armor

Along many levee sections, particularly those on the waterway known as the Industrial Canal, water poured over the tops of storm walls and cascaded down the backside, scouring and weakening the foundations.

Eventually, the walls collapsed. If they had remained standing, they would have acted as a buffer and slowed the pace of flooding.

The levees could have survived the overtopping if the backs of the walls had had concrete or heavy stone pads at their base, a protection known as "armoring."

Some of the storm walls in New Orleans were built with armored foundations and significantly stronger sheet piling, known as T-walls. Those levees did not fail and incurred far less damage during Katrina.

The corps generally assumed that hurricane flood waters would not rise high enough to spill over the levees. But most outside experts say that assumption was a mistake.

"There are only two kinds of levees: those that have been overtopped and those that will be overtopped some day," said Gerald Galloway, a levee expert at the University of Maryland. He added that armoring "is not cheap or simple."

The corps is replacing some failed sections of levees with T-walls. Brig. Gen. Robert Crear, the corps' district engineer in New Orleans, said the agency was preparing to armor many levees under the $3.1-billion rebuilding program. The armoring will include placing beds of rock or concrete at the base of the walls to prevent erosion in future storms.

Thin Safety Margins

Doubts about the corps' oversight have also flared over the low margin for error designed into the canal floodwalls. Engineers design structures to withstand forces far greater than the maximum anticipated loads to compensate for uncertainties in their own understanding and for possible defects in construction.

According to Wenk, the engineering expert, public structures typically have safety margins as high as four, meaning they are four times as strong as it is anticipated they will need to be.

Corps documents indicate that engineers approved a margin of 1.3 for the floodwalls. That meant the walls were designed to be 30% stronger than the maximum stress expected from a hurricane flood surge.

Wenk said he was astounded by such a low factor, particularly for a system that protected such a large urban area.

Strock agreed that the issue needed close attention. "I was not aware before this event that the factor was 1.3," he said.

Critics have questioned whether the corps devoted sufficient attention to safety, and Strock acknowledged that the low safety margins "may get back to the cultural issue."

Overgrown Trees, Brush

Years of neglected maintenance in southern Louisiana may have contributed to the heavy flooding, engineering experts said.

The growth of large trees near the 17th Street Canal levee may have helped undermine the floodwall. Katrina's strong winds blew down a massive oak near the levee breach and investigators believe the roots of the tree pulled out a large plug of soil from the embankment.

The Orleans Levee District is responsible for maintenance and employs work crews to trim grass along the levee slope. But trees and bushes sprouted from the yards of private homes near the breach site and were left untrimmed for years because of opposition from homeowners and the failure of levee officials to move aggressively.

The Orleans Levee District could have taken action, critics say. Just across the 17th Street Canal, the levee wall owned by the neighboring East Jefferson Levee District is regularly shorn of trees and heavy brush.

"It is a major concern," said Jim Baker, superintendent of operations for the East Jefferson Levee District. "If you have a tree blow over, it can open up a good size hole. I don't like trees growing on our levees."

Lost Wetlands Barrier

Closer to the Gulf of Mexico, a different kind of environmental miscalculation also contributed to the disaster.

Environmentalists, political leaders and engineers warn that decades of neglect and corps-sponsored dredging led to the disappearance of vital wetlands, allowing hurricane storm surges to threaten New Orleans.

When Hurricane Katrina roared up the Gulf of Mexico, it spawned a storm surge toward New Orleans through a navigation channel known as the Mississippi River Gulf Outlet, or MRGO.

The outlet was built from marsh and wetlands by the corps in the early 1960s to allow large ships quicker access to the Port of New Orleans. Originally designed as a 300-foot-wide channel, the outlet has widened to more than 3,000 feet, the result of repeated dredging by the corps and of ships' wakes.

"You can put more surge through a wider body," said Thomas Sands, a retired corps general who headed the New Orleans district. "When I was district engineer, the erosion along the MRGO was horrible."

The project also allowed salt water to penetrate and destroy hundreds of square miles of wetlands that acted as a natural flood barrier.

Henry "Junior" Rodriguez, president of St. Bernard Parish, said that the heavy flooding that topped his community's levees during Katrina was far worse than during Hurricane Betsy in 1965.

"Listen, we didn't even have levees during Hurricane Betsy and the flooding wasn't as bad," Rodriguez said.

After Katrina, the corps has pledged to halt dredging of the MRGO for at least a year and is considering proposals to scale it back.

The agency is also proposing to channel sediments and freshwater into the marshes to reduce future wetlands losses, though the National Research Council recently termed the current proposals inadequate.

"We will never be able to rebuild the coast we had 50 years ago, but the wetlands still out there can be preserved," said Carlton Dufrechou, executive director of the Lake Pontchartrain Basin Foundation, a leading environmental group in the region.

"If we do nothing, the gulf will be lapping at the edges of New Orleans in future decades," Dufrechou said. "And if the MRGO stays open, you might as well put a bull's-eye on the city and tell everybody to clear out on June 1 when the hurricane season starts."
