Study of breaking waves helps stabilize lake shorelines

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Professor Frances Ting studying the motion of breaking waves.

In spring 2011, waves more than 5 feet high driven by 45 mph winds crashed through sandbag and concrete barricades along Lake Poinsett and Lake Thompson in eastern South Dakota. Spring flooding that leads to this level of destruction has occurred three times in the last 15 years.

"Waves a couple of feet high can produce tremendous forces," says professor Frances Ting of the civil engineering department. For nearly 25 years, he has been studying the motion of breaking waves that shape the shorelines of lakes, rivers and oceans. In February, Ting was recognized as the Distinguished Researcher and Scholar for the J. Lohr College of Engineering in recognition of his work with breaking waves.

Ting began analyzing waves as a postdoctoral research fellow at the University of Delaware Center for Applied Coastal Research in 1989. After coming to SDSU in 1995, he has continued that collaboration through funding from the Office of Naval Research and the National Science Foundation. Since 2000, Ting has received more than $1 million to support his work.

"Federal agencies are willing to put resources into protecting the coastline," Ting explains.

Devastating lake shorelines

A strong south or west wind is especially dangerous for Lake Thompson, according to Kingsbury County Emergency Management Director Cindy Bau. In 2011, people along the lakeshore sandbagged to break the waves and mitigate damage. "We did what we were advised to do, but it didn't work," she says.

Some parts of Lake Poinsett lost 20 to 30 feet of shoreline, according to David Schaefer, emergency management director for Hamlin County. "Waves just ate it up."

Lake Poinsett Watershed Project Coordinator Richard Smith estimated damage there was in excess of $1.5 million. "And this was after nearly $750,000 had been spent in the years prior to protect the shorelines from flood waves," he explains. Smith plans to visit Ting's lab to see how his research connects to what Smith is trying to accomplish at Lake Poinsett. "After 15 years of seeing the destruction that can happen to shorelines and the mistakes people have made in the past, we are finally getting others to appreciate the complexity of water waves," says Smith.

Understanding a wave's impact

According to Ting, the issue is not merely the occurrence of waves, but the nature of the waves themselves and how they work.

Predicting the behavior of breaking waves is difficult. "The surface of the water is constantly changing and folding in on itself, which makes understanding exactly what's going on challenging experimentally and computationally," Ting says. "A flow pattern of a breaking wave has swirling motions like those in a tornado" His research seeks to answer fundamental questions about the form and changing flow of waves, how they interact with the bottom and transport sediment.

"The idea is eventually to predict what might happen, for instance, when a storm or weather system hits a coastline or lake shoreline," Ting explains.

Ting and his team do the experimental work, while researchers at the Delaware research center perform the computer simulations. His current National Science Foundation project can support two graduate and two undergraduate students.

Making waves in the lab

The challenge for the team is to get good quality data, Ting explains. "Waves breaking incorporate air into the water, which then reflects light and obscures the motion of the tracers."

To create waves in the fluid mechanics laboratory, Ting uses a Plexiglas flume the length of two school buses that holds 4,500 gallons of water. The flume has a sloped bottom and a computer-controlled wave maker. As the mechanism moves, a laser illuminates tiny tracer particles in the water and a camera captures the motion of the waves.

After running the experiments, the researchers examine the wave's size, speed, rotation and other properties of fluid motion, Ting explains. "We study the data to gain insight into the detailed flow structures."

Scientists at the University of Delaware then compare the experimental data with their computer simulations. The researchers must fully understand the action of the waves before they can begin considering issues such as erosion. "Sediment brings it to a new level of complexity," Ting adds.

The information will help engineers predict the impact of water waves on bridges, dams and highways. Community planners can determine how to use resources effectively to protect these structures and to stabilize the shorelines.

Moving to three dimensions

For two decades, Ting has studied wave movement in two dimensions. This summer, he and graduate student Jedidiah Reimnitz are using glass beads that have the same density and size as sand particles with a new laser and camera system to capture 3-D images of wave flow patterns.

By achieving a greater understanding of how turbulence picks up bottom sediment in a specific setting, Ting says, "we can apply the basic physical mechanisms to other scenarios."

The simulations and modeling will help predict how waves will affect a shoreline or coastline, which will then allow zoning officers and emergency management directors to plan ahead to minimize future damage from these destructive waves.

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