Sodus Point Lighthouse. Crashing waves break over barriers protecting Sodus Point on eastern Lake Ontario.

Photo courtesy of Wayne County Office of Tourism

Sea Grant New York

Coastlines

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BREAKING THE WAVES

Even before the Colossus stood guarding the port of Rhodes in ancient Greece, people have erected barriers along shorelines to protect harbors, ports and beaches from the ravages of storms and breaking waves. In 19th century New York State, a lattice work of timber boxes filled with sand protected the city of Plattsburgh from swells on Lake Champlain. Lighthouses were erected along barriers to protect the Great Lakes ports of Buffalo, Sodus and Oswego. Whether wood or rock, concrete or mounded earth, these structures generally built parallel to the shoreline are known as breakwaters. When needs call for a low-tech barrier made of recycled materials in an upstate NY lake or a high-tech perforated concrete structure built to withstand a Japanese tsunami, Dr. Phil Liu wrote the book...

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... for more on breakwaters ancient and modern

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA U.S. DEPARTMENT OF COMMERCE

BREAKING THE WAVES

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A leading expert world wide on structures for protecting coastlines and harbors, **Dr. Philip L.-F. Liu** of Cornell University's School of Civil Engineering knows about breakwaters. For a recent NYSG-funded project, Dr. Liu developed a mathematical model to aid in the design of breakwaters to fit the needs of individual locations. According to Liu, traditional laboratory development of breakwater design has its limitations. Says Liu, "Out in the field, there are so many factors in play that it is difficult to assess all the parameters. But using a numerical approach avoids these limitations and gives you a much more robust model."

There are many factors that affect the efficiency of a breakwater. Three primary ones are: the nature of the material that makes up its foundation, the characteristics of the waves it will be subject to, and the slope and sediment of the harbor bottom. A hard structure may be rocked by wave action whereas a porous structure may let waves pass through with a diminished force. A muddy versus a sandy bottom will alter the wavelength of the incoming waves. Adequate mathematical models take all these variables into account.

Dr. Liu and his group at Cornell are looking at innovative breakwater designs for the global community. He is currently working with colleagues in Europe and Asia, helping researchers and engineers find the most effective and efficient breakwater design at each unique location using local materials. For example, in Japan where designers of coastal protection structures are most concerned with tsunami damage, the preferred design is of poured concrete and not rocks or gravel as these resources are not readily available.

One of the trends in modern breakwater design is making them more environmentally friendly. According to Dr. Liu, "Using a perforated structure improves water quality. By allowing water to flow in and out of the structure, water does not become stagnant."

Another global trend is using breakwaters for multiple purposes. In some locations in Europe and North America, breakwaters create areas for recreational use such as swimming or fishing. In Portugal, resource managers are using breakwaters for wave energy conversion and generating electricity. Each of these kinds of designs can benefit from Liu's numerical model.

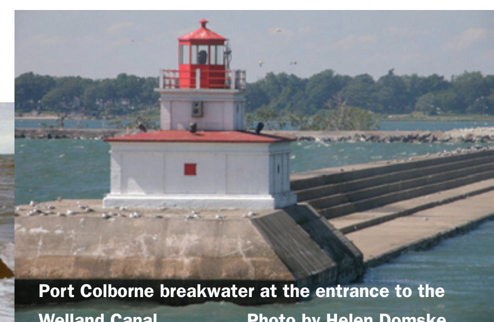
With all of his international work, Dr. Liu warns that with global climate change and the danger of storm surge, breakwater designers and engineers must be more innovative.

Dr. Lui has spent some time in Louisiana, post-Katrina. His recommendation is that designers use a multi-layered system of a submerged breakwater and the natural environment of the wetlands. "These multi-layered systems don't have just one levee," he observes, "The design must consider the effects of wetlands and forests on wave heights before waves come into contact with the manmade structures."

Considered a world expert on the subject, Dr. Liu was called to Sri Lanka after the devastating December 2004 tsunami where he helped to calculate the wave forces that brought about unparalleled destruction and loss of human life. This sobering experience led Dr. Liu to feel even more strongly about developing early warning systems especially in the Pacific regions where earthquakes occur almost daily and the potential for tsunamis is great.

Dr. Liu's NYSG-funded project is culminating in a practical user's manual for the numerical model. His colleagues at the Universidad de Cantabria in Santander, Spain are already using this manual to calculate wave forces on the northern coast of Spain. Warning systems coupled with efficient breakwater design using the numerical model have the potential for keeping coasts and their inhabitants protected world wide.

— Barbara A. Branca



Port Colborne breakwater at the entrance to the Welland Canal . Photo by Helen Domske

LI Sound breakwater photo by Jay Tanski

Dr. Liu's numerical model includes complex equations that help designers calculate wave action above a breakwater. Whether made of natural materials like this one on LI Sound, heavy construction to support this Lake Erie lighthouse, or perforated concrete like this Japanese design, numerical models translate into proper design for local needs.

$$\frac{\partial \langle \bar{u}_i \rangle}{\partial x_i} = 0$$

$$\frac{\partial \langle \bar{u}_i \rangle}{\partial t} + \frac{\partial \langle \bar{u}_i \rangle \langle \bar{u}_j \rangle}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \langle \bar{p} \rangle}{\partial x_i} + g_i - \frac{\partial \langle \overline{u_i' u_j'} \rangle}{\partial x_j} + \frac{1}{\rho}\frac{\partial \langle \bar{\tau}_{ij} \rangle}{\partial x_j}$$

Photo courtesy of Dr. Philip L.-F. Liu