A sensor system (right) can register levee damage and warn of an impending break — for example, by comparing data with measurements from actual tests (center). Left: A dam near St. Petersburg, Russia.

Bulwarks with Brains

When a levee breaks, it endangers not only human life but also the infrastructure of entire regions. As part of the international UrbanFlood project, Siemens in Russia is researching a detection system that monitors levee condition and issues a warning before danger develops.

Every year, we see images from around the world of huge stretches of land submerged under water. Many of these floods — whether in New Orleans, China's Jiangxi Province, or on the Oder River at the German-Polish border — have something in common: the breach of a levee or dam. Today, infrastructures in 136 coastal cities with populations of more than one million rely on the protection offered by dikes and levees. The danger here is steadily increasing, as climate change is resulting in rising sea levels.

Up until now, a relatively simple technique has been used to ensure that levees remain intact, despite the abrasion and wear they are exposed to: their walls are built higher and reinforced. "Simply reinforcing levees that are often hundreds of kilometers long is not an effective solution," warns Prof. Robert Meijer, a levee protection expert and information technology specialist at the University of Amsterdam and the Netherlands Organization for Applied Scientific Research (TNO). "First of all, this involves an upgrade of the entire levee. That costs a lot of money— €2,000 and up per meter, in fact. The second problem is that this method only buys time, and even after that you still won't have any idea when a specific section of the levee is in danger of breaking apart," says Meijer.

That's one of the reasons why Meijer launched UrbanFlood with TNO. The idea behind the project, which is being funded by the European Commission, is to make bulwarks so "intelligent" that they present a better alternative, both economically and physically, to huge dike expansions and upgrades. To this end, Meijer went looking around the world for technologies that could monitor levee stability down to the last meter in order to predict fractures or the damage that would result from flooding, thereby allowing measures to be taken in advance.

Synergies with Industrial Solutions. Meijer found what he was looking for in 2009 — at Siemens Corporate Technology (CT) in Russia and the State Polytechnical University in St. Petersburg. The CT team, which is headed by Bernhard Lang, has made a name for itself, among other things with a self-controlling software system that uses measurement sensors to monitor the operation of production facilities. This adaptive system is fed with all available production data. Using this input, the system then independently monitors manufacturing activities by comparing the information with data obtained from sensors mounted on machines. It is thus able to recognize errors in the making, and issue an alarm before they occur (see *Pictures of the Future*, Spring 2010, p. 96).

"Monitoring a levee is similar to monitoring a production process," says Lang. "It's only the definition of the problem to be solved that's different. The challenge with the UrbanFlood project was to generate the data we needed to program our sensor system. In this case, we needed empirical data. These parameters provide us with information on when specific factors will result in levee damage."

Lang and his team constructed several test levees and dikes along the Dutch-German border in Emsland, fitted these inside and out with sensors, and then intentionally destroyed them using different methods. "We eroded the back of one dike by deluging it with water, for example, which is exactly what happened during the great North Sea flood of 1953," Meijer explains. "In another test, we simulated piping — one of the main causes of levee damage and failure. Piping occurs when water persistently penetrates a levee, creating a small tunnel. Huge forces are released during this process, and eventually, within just a few minutes, the barrier falls apart like a house of cards." Piping was in fact one of the reasons why New Orleans suffered such severe flooding during Hurricane Katrina.

Team members calibrate their software in line with the parameters measured during tests, such as water and air pressure, levee widening, and humidity and temperature differences between the dike interior and exterior. "Destroying the levees provided us with data that's indispensable for reliable monitoring," says Lang, whose work recently won him first prize in the Sustainable Portfolio Ideas category of a Siemens-wide sustainability competition. "When we program our software with these parameters, it will be able to recognize and forecast dangerous situations before anything serious happens."

Once the software has been updated, it will be tested at Livedijk, near the Dutch port of Eemshaven. The two-year trial will teach the intelligent software from CT Russia how to correctly interpret dike-sensor data under real-life wind and weather conditions. This will also involve incorporating into the analysis seasonal and daily influences, such as precipitation levels and winds from various directions. The goal of the research is to ensure that the system can automatically provide information in a timely fashion on whether and when a levee or dike section is becoming porous and beginning to shift, thereby indicating that it may be at risk of breaking.

Cell Phone Alarm. Researchers are also working on alarm notification options. Sensor positioning technology, for instance, would make it possible to inform authorities of the precise location of a damaged levee section, which would allow them to repair it as quickly as possible. If a levee breach could no longer be prevented, residents of the surrounding area could be informed via cell phone and then evacuated. Such a system would notify all cell phones operating in the affected area. It would even be possible to instruct vehicle navigation systems to guide vehicles around and away from area deemed to be at risk.

For the next project phase, Lang and his team plan to equip levee and dike sections in London, Amsterdam, and St. Petersburg with the monitoring system and then use a distributed Internet-based software platform to monitor and evaluate the levee and dike sections. "Effective levee protection is not a local issue but a global task," says Lang. "That's why the long-term goal of UrbanFlood is to achieve redundant Internet-based levee monitoring worldwide." Lang therefore hopes that in the not-too-distant future, the project might help reduce the severity of the flood disasters that occur each year. ■ *Sebastian Webel*