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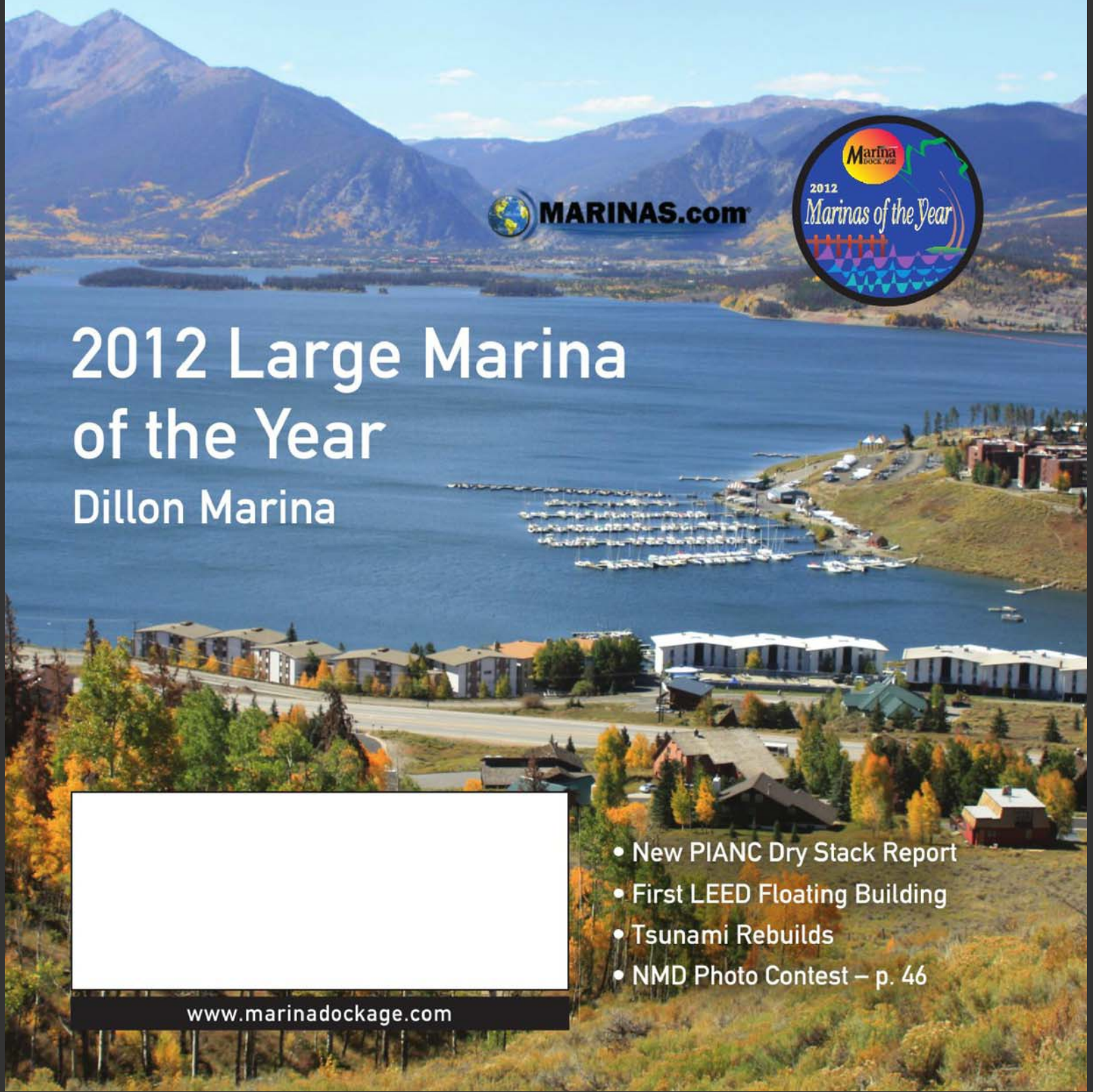

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In the Aftermath of a Tsunami: Two Marinas, Two Rebuilding Approaches

by Robert Wilkes

At 2:46 p.m. on March 11, 2011, a tectonic shift off the coast of Japan set in motion a 9.0 magnitude "100-year" earthquake, the most powerful in Japanese history. Japan is the best-prepared place on earth for a tsunami, but nothing could have prepared the Japanese for what followed. Floodwalls built to protect coastal towns were easily overtopped; 16,000 people killed and 217 square miles inundated. Many are still missing. Bits of lumber were found on the hillsides of Iwate Prefecture 124 feet above sea level. Children's soccer balls are now washing ashore in Alaska.

The tsunami raced across the ocean at the speed of an airliner. As the underwater shock wave reached the Mendocino Escarpment, a two-mile rise in the ocean floor extending 1,200 miles westward from Cape Mendocino, its energy was funneled toward the coast of Northern California. At about 7:45 a.m. PST, ten hours after the quake, Crescent City, Calif., was in the grip of a 2.5-meter tsunami. The town of Santa Cruz, south of San Francisco, was also struck but with lesser force. The tsunami devastated the harbors of all two communities and threatened further damage to the local economies.

This is the story of two harbors and the two paths they took to rebuild their marinas. Each had to jury-rig temporary moorage and get operating again. Each chose a different solution to dock replacement. All three benefited from inspired leadership from their harbor and port executives.

Crescent City

"Crescent City is tsunami central," said Richard Young, harbormaster and CEO. This charming city near the California Redwoods has suffered eleven tsunamis greater than one meter since 1933. Virtually any tsunami that originates in the Pacific "Ring of Fire" will make its way to Crescent City.

The marina was severely damaged by a November 2006 tsunami that originated from an 8.3 magnitude earthquake in the Kuril Islands. In the aftermath, a local firm, Stover Engineering, was assigned to lead a team of engineering consultants with the firm Ben C. Gerwick of Oakland, Calif., assigned responsibility for the structural engineering of the replacement marina. At the time of the 2011 tsunami, the port had just completed a lengthy planning and permitting process and was set to begin the project.

Tsunami-Resistant Marina

Between the 2006 and 2011 tsunamis, Gerwick engineers had developed a computer simulation that modeled the actions of a tsunami in the harbor. No one expected the model to be tested so quickly. Ted Trenkwalder, a Gerwick structural engineer, said, "The 2011 event fit the model very well. The flow patterns and velocities were very close to what we predicted."

Made wiser by two tsunamis in four and a half years, Young and the Crescent City Harbor Commission decided to do more than just rebuild the old marina. "If we had built the marina we had planned on an aggressive schedule, it would have been destroyed," Young said. They told Gerwick to think about a marina that could survive future tsunamis.

The engineers first considered changes to the harbor, such as a "tidal gate" (too complicated and expensive) or simply a wider harbor entrance to reduce powerful currents (too much exposure to winter storms). After rejecting these ideas, they turned their attention to a tsunami-resistant marina.

"We were in uncharted waters," Young said. "There were no standards, codes or guidelines. No one had done it before."

Costs and Benefits

FEMA typically pays 75 percent of the cost of rebuilding after a disaster, but only for in-kind replacement. The agency, however, will fund those additional costs necessary to meet codes and building standards that have changed or been enacted since the original marina was built. Young and his team reasoned that any new marina should be built to standards that will ensure survival in all but the most severe tsunamis.

Gerwick told the California Coastal Commission, the primary permitting agency, that if national and state codes require structures to survive earthquakes and floods, a marina in Crescent City should be required to survive a tsunami. The Commission agreed, and FEMA and Cal EMA supported the plan.

To design the first tsunami-resistant marina, the engineers developed parameters and studied the costs to design for 10-, 25- and 50-year events. "The 50-year marina was easily the best value," Young said. The higher initial cost was clearly less than the cost of rebuilding the marina several times over. "The rugged marina we chose was a radical leap in design, but it was fiscally conservative," added Young.

Strength and Flexibility

The pivotal factor in achieving a robust

The Dock that Crossed the Pacific

Massive amounts of debris from the tsunami are migrating on winds and currents to the far corners of the world. Nir Barnea, northwest regional coordinator for National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program, is tracking Japanese tsunami debris, including three large commercial docks. One of the docks beached on the coast of Washington State in December. NOAA, state agencies and some universities are monitoring invasive species and other debris on the dock and are removing them when possible. "The good news," Barnea said, "is that radiation levels from the debris are nil." The location of the other two docks is unknown. For more information go to *www.marinedebris.noaa.gov*.

marina is the strength, size and number of piling. The 140 original steel piling were 14 inches in diameter and set 10 feet into the bedrock. The new steel piling are 30 inches in diameter, 70 feet long and are socketed approximately 35 feet deep into the rock. The new piling have an HDPE sleeve for corrosion resistance.

"The piling are the last line of defense," Trenkwalder said. "We designed them with a 25 percent reserve. In an extreme event, we may lose some docks but the piling should survive. If that happens, rebuilding will be far less costly and take less time."

Bellingham Marine is manufacturing the concrete floating docks. "We just completed the heavy-duty modules for the outer dock," said Jesse Ellenz, Bellingham's Northwest Division general manager. He said the outer dock is a wave attenuator designed to calm the harbor. "It is not a tsunami attenuator. The impressive thing about the design of this system is that every dock is designed to survive a tsunami on its own without the benefit of protection," Ellenz said.

This module for the outer dock at Crescent City shows pre-installed pockets in the dock for the piling.

The bulk of the marina consists of custom-built Unibolt docks. Craig Funston of Redpoint Structures, who engineered the docks, said Unibolt is based on Bellingham Marine's Unifloat design. "It connects the modules using a heavy-duty hinged steel connection. The hinging mechanism allows the system to be flexible without sacrificing strength," Funston said.

Derrick Ames, Bellingham's on-site project manager, said "The modules are among the largest and strongest in the world for this type of application." Ames added, "They have a huge number

The replacement piling at Crescent City are massive and numerous. They are socketed 35 ft. into the bedrock.

of steel reinforcing rods, six inches on center." Because of their size and weight, Bellingham Marine cast them on-site on a synchro lift platform (similar to those used in shipbuilding and dry dock operations).

Each module measures 16 feet wide, 40 feet long and up to seven feet high. The modules weigh up to 160,000 pounds, and the pile hoops weigh 600 to 800 pounds. The in-water work at the marina should be completed in November and is projected to be fully completed February 15, 2014.

Santa Cruz Harbor

"Our U-Dock was completely destroyed," said Lisa Ekers, port director. She added that most of the rest of the docks had hidden damage. "It can take a long time to get a project like this done," Ekers said. "We didn't have the time."

Ekers challenged engineers and manufacturers to meet her design requirements and get the marina in the water in 90 days. The port specified a custom-designed system of plastic-lumber docks built to withstand a two-foot tsunami wave. Ekers had a preference for the plastic lumber system for its flexibility and thought it was a good fit with the Clean Marina program.

"We presented a plan that allowed them to maintain operations throughout the rebuild process," said Steve Canaday, Bellingham's regional manager of project development.

The new marina uses HDPE plastic lumber and composite decking, and corrosion-resistant steel bracketing holds the system together. The project also included updated mechanical and electrical systems, and the installation of upland vaults for future expansion of electrical services.

"Our story is plastic and speed," Ekers said. "The timeline was dependent on FEMA, Cal EMA, the Coastal Commission and all the regulatory agencies. We got FEMA approval in two months, and Bellingham Marine built and installed the marina in 90 days, reusing most of the existing pilings. We powered through and made it happen on time. From the tsunami to the ribbon cutting was five months." ⚓

Robert Wilkes writes about the marina industry from Bellevue, Wash.