Rise Of The Drones: *How Unmanned Surveying Can Help Make Our Coasts Resilient*

Jason Magalen's winning proposal in ASCE's Innovation Contest

OBJECTIVE

According to the National Oceanic and Atmospheric Administration (NOAA), in 2010, 39% of the United States' population (123.3 million people) lived in counties adjacent to the shoreline. By 2020, this amount is projected to increase by 8%, amounting to an additional 10 million people living near the coast[1]. As of 2012, LiveScience estimated an even larger number of people living in coastal counties: 52% of the U.S. population[2]. The numbers are even more staggering when viewed from a worldly perspective: The UN Atlas of the Oceans estimated that in 2001, over half of the world's population lived within 200 km (124 miles) of a coastline; and that present day data suggest that 44% of the population lives within 150 km (93 miles) of the coast[3]. Regardless of the data source or method of interpretation, it is evident that more and more global citizens are choosing to live near the coasts.

While at first glance this may not seem too concerning, engineers, planners and managers must now begin considering the future potential impacts of global climate change, sea level rise and increased storm intensities when designing near the shore. Each of these mechanisms will make our coastlines more vulnerable to erosion and flood inundation, and the potentially damaging effects of each. The ultimate impact of shoreline failure is the destruction of our coastal infrastructure and disruption of life.

While it is feasible to design and build resilient coastal infrastructure at present, without first addressing the resiliency of our shorelines, we may be over-designing our coastal infrastructure. We must first understand how best to protect the infrastructure from the destructive processes of the oceans and water bodies. Only then will we be able to cost-effectively design resilient infrastructure inland of the shorelines.

STATE OF THE SCIENCE

Our coastlines are our first line of defense from the relentless attack of the sea. They protect our infrastructure and allow a majority of the world's population to enjoy living so close to such a powerful force. Along any individual beach, for example, sediment grain sizes vary, beach slopes change, and sandbars form in response to the incident hydrodynamics impacting a shoreline. While beach morphology is a result of the incident hydrodynamics (i.e., wave and current climate), it also is a response that protects the beach and shoreline from continued erosion. Sand bars are a great example of this feedback mechanism: as larger waves break at a beach, the resultant near-shore forces will erode sand from the foreshore and transport it offshore to form a sandbar. The newly formed bar will cause waves to break farther offshore thereby decreasing the propagating wave energy dissipation that attacks onshore, and mitigating the additional loss of shoreline sediment. Unfortunately, this feedback mechanism ultimately results in a net loss of sediment, beaches and shoreline, as eventually, the sediment is transported out of the littoral system.

Mankind has constructed protective barriers at shorelines for centuries to try and stem the loss of land. Traditional coastal shore protection techniques to protect the infrastructure have included "hard" structure protection in the form of seawalls (e.g., concrete) and revetments (e.g., rock slope protection). Though these often are successful at halting erosion of the immediate lee shoreline, they oftentimes cause unintended consequences elsewhere (e.g., they may terminate along-shore sediment transport which leaves downstream land starved of sediment to protect from wave attack, resulting in downstream erosion).

As a result, there has been increased interest in "soft" engineering efforts that mimic natural shoreline protection techniques. Examples of these projects include "living shorelines", beach nourishment, dynamic revetments (cobble beaches) and foliage planting (e.g., mangroves and beach grass). As with the "harder" coastal protection structures, there are advantages and disadvantages to these techniques. Beach nourishment, for example, is a technique that has been implemented for decades in which sand is mined from a site (upland or in-water) and placed on a beach, artificially increasing the volume of sand at the beach, and, thus, the beach width. Though the sand will eventually erode from the system, it provides a temporary protective and economic (i.e. tourism) benefit to the community during its lifespan. Techniques like this, though, and those that are still in the inventive stage, are generally considered more environmentally friendly, and, as a result, are gaining increased support by coastal communities and agencies.

[1] http://oceanservice.noaa.gov/facts/population.html

[2] http://www.livescience.com/18997-population-coastal-areas-infographic.html

[3] http://www.oceansatlas.org/subtopic/en/c/114/

Though the potential of these softer coastal protection techniques are gaining attention, the number of sites that employ one of these solutions in the U.S. is low. One reason is that their short- and long-term performance is not well understood or quantified. A second reason is that coastal protection is often constructed on an emergency basis: When a coastal landowner's property becomes jeopardized as a result of shoreline loss and erosion, the emergency fix may be to place a sufficient volume of large stones at the shoreline to curb the erosive forces of the waves. This "hard" solution, however, typically has other, detrimental effects, as described above.

What's the answer?

The simple answer is that "there may be many answers." However, the solution proposed here is to become proactive. Assess the shoreline vulnerability before there is an emergency. Know what the potential environmentally-friendly, and effective, solutions are to protect the shorelines before they are damaged by future climate change. When the shorelines have been effectively protected from the onslaught of destructive forces, then, the focus can shift to building resilient infrastructure in our communities. By fortifying our first line of defense, engineers will be able to design more cost-effective and resilient communities.

How do we become proactive?

We (the coastal engineering and geology communities) need to understand how these shore protection alternatives perform! To work toward a solution, the coastal communities (engineers, planners, managers, users, and residents) must better understand what soft shore protection options exist, and what their advantages and disadvantages are. Though beach nourishment performance is, generally, well-understood, other techniques such as cobble berms and beach grass are not implemented as frequently; therefore the quantifiable performance data is lacking.

Cobble berms comprise a gradation of larger sized stone (e.g., pebbles through cobble) placed on a beach. This type of beach shifts and morphs based on the dynamic incident wave energy. It can withstand more powerful wave environments because their larger stone sizes prevent mass erosion from occurring, thereby providing for long-term protection of the beach and bluffs.

Beach grass acts to protect beach backshores, dunes and bluffs. The grass foliage dissipates erosive current or wave energy and the plant roots help anchor sediment, preventing mass erosion. Moreover, beach grass also mitigates for Aeolian sand transport (transport by wind) on the beach dunes and backshores, actively trapping sand that is being transported, and building larger, protective dunes.

Along the Oregon coast, cobble berms have been constructed along particularly vulnerable stretches of the shoreline. They have been monitored periodically for their performance, which is generally regarded as being satisfactory. Moreover, the benefit of beach grass is commonly agreed upon, for the reasons described above. In order to garner increased support for these types of shore protection, though, an abundance of performance data is needed.

The morphology of cobble berms needs to be assessed more frequently, though, so that the dynamic nature of these protection systems can be correlated with specific incident wave conditions. Put simply, we need to understand how they respond to specific storm events over the short- and long-term. For example, following a storm event, questions to be addressed may include:

- What was the impact on the cobble beach berm material volume?
- How did the slope of the revetment change?
- Is the berm dynamically re-positioning itself to protect from climate change?
- Did it protect the lee-side infrastructure effectively?

The same assessment can be made for beach grass. We need to understand how beaches protected with foliage react to specific storm events:

- Did the beach grass trap sediment?
- Did the spatial extent of the beach grass change?
- Would a larger extent of beach grass have been more effective?
- Has the volume of sand increased/decreased as a result of the beach grass presence?

Answering these questions quantitatively is imperative to assessing performance and designing future enhancements. However, collecting the data to answer these questions will require a significant effort (i.e. cost a lot of money) and may not pencil out under a cost-benefit analysis.

We need to shift our approach

METHODS

The advancement of technology has allowed for more rapid data collection and an increase in amount of data available to make decisions, with fewer personnel required. This trend is no more visible than in the vast growth of small unmanned aerial vehicles (SUAVs), which are being used today for a variety of reasons, from recreational use to commercial surveys (and some are even being proposed to replace delivery drivers[4]).

Today, SUAVs (also known as "drones") are capable of flying prescribed flight paths, taking photographs, and recording precise SUAV orientation and positioning. The results of these aerial surveys include high-resolution orthophotographs, three-dimensional digital elevation model (DEM) creation (i.e., photogrammetry), agricultural health surveys (using near infrared and multi-spectral cameras), and thermal imaging (e.g., for search and rescue or animal reconnaissance surveys). Advanced positioning and orientation instruments yield imagery and 3D point clouds that are accurate to centimeters (i.e., as accurate as RTK GPS surveying).

At present, the Sensefly Ebee is the author-recommended device with which to complete the shore protection surveys[5]. These SUAVs are the perfect tool with which to rapidly survey shoreline protection performance. They are simple, efficient, and effective. The flight plan is created on a desktop or laptop computer and downloaded to the SUAV. The drone is then activated and launched. It spirals up to its prescribed altitude and begins taking pictures along its path. When complete, the drone returns to a predetermined location and lands autonomously. Data are downloaded from the SUAV and processed with the Sensefly production software.

The 3D point cloud DEMs can be easily and rapidly compared with historical DEMs of a project site to calculate, e.g., beach volume change. In this manner, very rapid and simple performance evaluations of the coastal shore protection are completed and quantified, yielding information about the loss and accretion of sediment volume, beach slope and orientation changes, and/or beach grass spatial extent variations. At present, this approach is not being used along the Oregon coast in abundance, to the knowledge of the author. Therefore, an example project is proposed:

In 2013, a cobble beach berm was built by the U.S. Army Corps of Engineers (USACE). The location is at the root of the South Jetty at the Mouth of the Columbia River. This location was susceptible to large wave events and was vulnerable to a potential breach of the sand spit that ties the jetty to land.

Though the Oregon Department of Geology and Mineral Industries (DOGAMI) has been monitoring this site for morphologic changes, elevation measurements were collected along distinct linear transects. This is a labor-intensive manner in which to survey and results in data gaps between each survey line.

Application of a SUAV such as the Sensefly Ebee at this site would increase the data density and decrease the amount of man-hours necessary to complete the survey. A high-resolution DEM would be created in a fraction of the time needed to complete the survey along discrete transects, and would be immediately comparable to previous surveys. Further, since historical morphology data already exists at this site, application here presents a prime opportunity from which to compare the SUAV technology to the previous survey methods. Moreover, surveying with a SUAV is a much less expensive and intensive operation than airborne LiDAR (Light Detection And Ranging), which yields the same data (i.e. a 3D point cloud), but at a coarser resolution. To its further detriment, airborne LiDAR data collection requires an airplane and pilot, which significantly increases the costs required to collect the data.

Collection of shoreline change data with a SUAV will proactively allow us to ascertain the performance of this cobble beach berm at more frequent intervals to quantify its performance. It will allow for the improvement of design parameters for these types of shoreline protection methods, thereby enhancing the field of coastal engineering. The survey technique opens the doors to an entirely new business model which focuses on efficiency and cost-effectiveness to improve our coastal defense mechanisms. It allows for innovation to transform the way we collect and utilize data from our coastlines. It will allow us to correlate the performance of our shore protection systems to the physical processes that attack them (i.e., the waves). And, finally, it will facilitate resilient design at our coasts, and, resultantly, of our inland coastal infrastructure.

[4] http://www.amazon.com/b?node=8037720011
[5] https://www.sensefly.com/drones/ebee.html

About the Author and Contest

Portland Coastal Engineer Jason Magalen *proved to be the top-honored participant in the American Society of Civil Engineers' inaugural Innovation Contest.*

ASCE launched the Innovation Contest in December 2015 to help unearth new ideas for reducing infrastructure life-cycle costs. Magalen's proposal received three awards: the Overall Winner award for Greatest Impact in Achieving the ASCE Grand Challenge, the Best Value Award in the contest's Resilience category, and the Most Efficient Award in the Internet of Things category.