Public-Private Coastal Resilience Innovating

Topic Solution Summary

Civil Engineers can form public-private partnerships to innovate coastal infrastructure that is cost-effective, resilient, and increases species diversity on coastal land and in coastal water.

As an example of private action, the citizens of Broad Beach, Malibu, California have formed a district to recover their beach. The Broad Beach Geologic Hazard Abatement District (Broad Beach) is funding a $31 million project through their property taxes. As of December 2015, the $31m will move 43,000 truckloads of sand (0.6 km^3) 65 miles one-way from an inland sand and gravel mine. (For the purpose of this innovation, I will define this action of a group of wealthy people as a "private" action.)

A hypothetical example of public-private partnerships would recover Broad Beach with steps including:

1. Broad Beach would obtain cost quotes for more options including: a) dredge-barge supply of the same amount of sand from offshore deposits; and b) offshore structures which cause sand accretion.
2. Item 1 quotes are likely to cost more than trucking inland sand.
3. Broad Beach works with regional governments to establish a Coastal Sustaining Fund (Fund). The Fund develops tools (programs, structures, managed ecosystems, etc.) in concert with coastal permitting agencies to ensure new coastal infrastructure adapts to climate change while being cost-effective, resilient, and increasing species diversity.
4. The Fund members assist Broad Beach in obtaining permits to widen their beach as part of more resilient and ocean restoring infrastructure including: previously untried adaptation tools and regionally shared sand supply infrastructure.

Submission and Supporting Evidence

Coasts have many stakeholders making it difficult to agree on what action to take in response to their present and future situations. The stakeholders' might be oversimplified into two opposing viewpoints: x) leave it to nature (don't touch it, don't build on it); or y) protect or increase human return on investment.

The first order of business for our public-private coastal resilience partnerships is to bring both parties together with the realizations:

x) It is too late to leave it to nature. Climate change impacts are accelerating and already causing habitat damage and species extinctions.
y) Building species diversity-increasing habitat into our coastal investments can provide more protection at less cost.

We have rapid and unavoidable changes in coastal water:

1. Increasing acidification due to dissolved CO_2 (already adverse to Seattle area oyster industry)
2. Warmer water which holds less dissolved oxygen
3. Warmer water caused migration of mobile sea life
4. An excess of plant nutrients from urban and agriculture runoff
5. Yet to be discovered issues, like the extreme toxic algae bloom delaying the start of the 2015 Dungeness crab season off Northern California

We have rapid and unavoidable changes on coastal land:

1. Higher sea level, probably a meter by 2100, almost certainly 10 meters by 2200
2. Higher and more frequent storm surge
3. More frequent large waves
4. More intense precipitation adding backwater curves to the storm surge
5. Longer and more intense droughts

Possible tools for the public-private coastal resilience teams

<u>Managed seaweed ecosystems, virtual desalting</u>

Seaweed forests raise local pH by consuming CO_2, increase local dissolved oxygen, and uptake excess nutrients[1]. Large managed seaweed forests might prevent toxic microalgae blooms. Growing and harvesting seaweed is a form of virtual desalting. Virtual desalting involves coastal communities increasing the amount of food they grow in salt water for food production to compensate for globally decreased fresh water food production. Also see page 3 of Big Picture Resilience via Ocean Forests.

[1] The Paul G. Allen Family Foundation is funding the initiative Cultivating Seaweed in Puget Sound to Protect Shellfish and other sensitive species from Ocean Acidification. University of Virginia, U.S. and the University of New South Wales, Australia are planting seagrass to improve habitat, store carbon, and anchor sand.

Whatever offshore structure is installed, it can be designed to also include anchors for seaweed forests, marine agronomy, and integrated multi-trophic aquaculture. It might also incorporate means to distribute nutrients, and flex to improve harvesting efficiencies. For example the anchors of an invisible breakwater, shown in Figure 1 can also anchor long-line seaweed farms. If the long-line of Figure 1 were attached to the shore-side anchor, the long-line would be "in the calm" during storms.

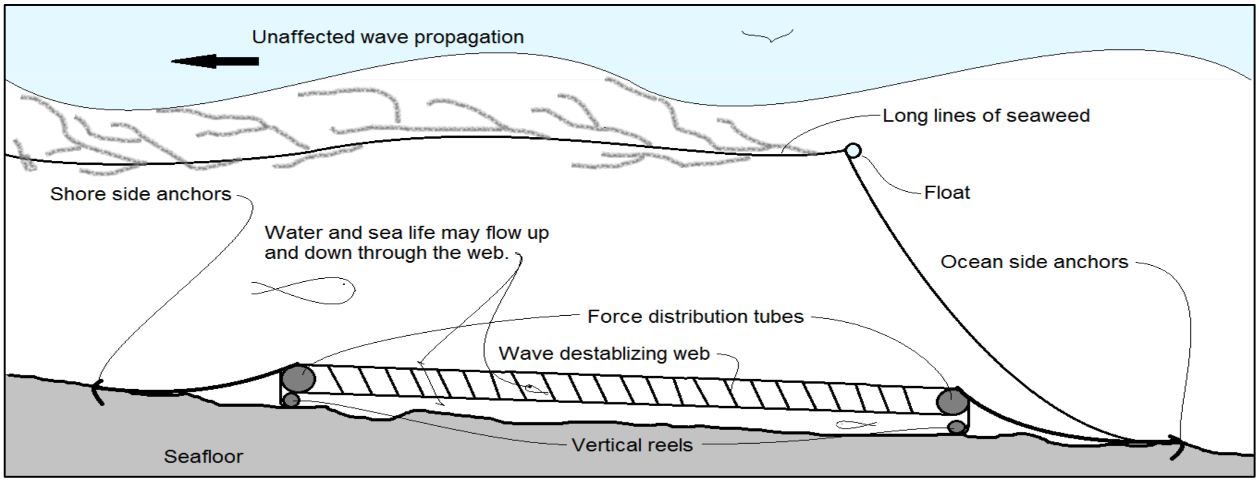

Fig. 1 – Profile showing long-line seaweed farming above an adjustable invisible breakwater

The web of the invisible breakwater can double as a flexible surface for an oyster[2] or abalone farm. The entire farm could be raised to "snorkeler depths" for "harvest your own" days. The structure can include real-time maintenance and scientific information gathering via power and instrumentation cables extended to shore. The reef breakwaters could be managed and fished with autonomous vehicles[3].

Off shore flood capture

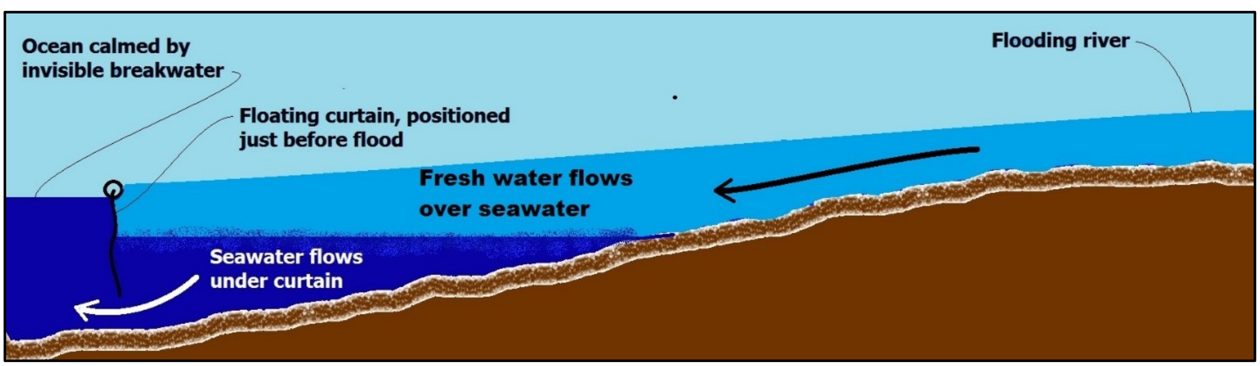

Fig. 2– Elevation section of floating curtain during a flood

[2] Tottenville, New York is building a breakwater which will employ oysters to increase breakwater height over time.

[3] "The Starfish Assassin", Scientific American, January 2016 finds and kills crown-of-thorns-starfish. "It's now so good it even ignores our 3-D-printed decoys and targets only live starfish," Matthew Dunbabin, Queensland University of Technology in Australia

Fresh water floats over salt water because fresh water is less dense. We can use this fact to capture flood waters and store them for later use. Figure 2 shows a river of fresh water, density near 1,000 kg/m^3, flowing into the ocean, density near 1030 kg/m^3. The vertical scale in Figures 2-3 is exaggerated relative to the horizontal scale. A drinkable layer of fresh water can extend miles out to sea, depending on factors such as the volume of the river flow and the mixing energy of waves and tides.

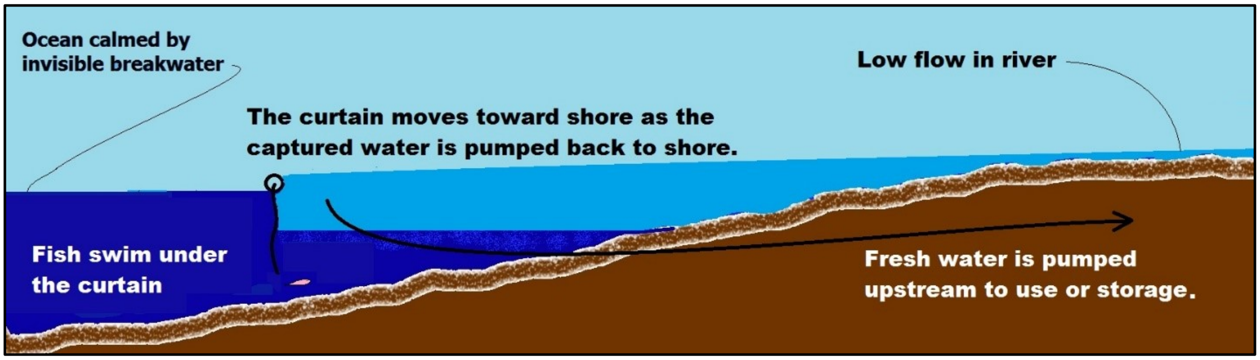

Fig. 3 – Elevation section of floating curtain contracting during fresh water storage

When river flows are low, the natural system prevails, the curtain is not deployed. When river flows are high, The curtain of Figures 2 and 3 is deployed to capture fresh water and floating plastic debris. The invisible breakwater is raised per Figure 4 whenever waves would otherwise increase fresh and salt water mixing. (One possible invisible breakwater system is shown in Figures 1 and 4.) The curtain will also capture any floating debris (plastics).

Invisible (sometimes natural) breakwaters

Coral and oyster reefs are natural breakwaters, generally invisible from shore. Both can rise with sea level. Both coral and oysters will become extinct from warming and acidification. We might keep coral and oyster reefs healthy and growing with occasional doses of deep cool ocean water. Biological research has intensively studied the role of heat and acid variability in conditioning water quality to enable coral growth. Experiments indicate that providing a safe temperature oscillation range will promote resilience, and can switch on rapid adaptation pathways in the coral to reduce the risk of bleaching. That is, by stressing and resting the coral, the coral will adapt more quickly to survive in warming oceans. Major coral bleaching and death can be prevented with water temperature as little as 1°C below ambient for a month. Deep ocean water is 10°C to 25°C cooler than surface water. Raising deep water to condition coastal water (raise the pH, increase dissolved oxygen) offers possibly the best way to prevent coral extinction[4].

Invisible flexible breakwaters can be artificial structures which move up or down in the water column. They can be invisible to waves when surfers want good waves, then adjusted to provide

[4] Raising deep cool ocean water to de-stress coral reefs is an important component of Haven Atolls. Haven Atolls is a concept for preserving islander and coastal homes and coral reef ecosystems through a millennium of Climate Change.

sand accreting waves at night or complete calm during storms. Figures 1 and 4 show such an invisible breakwater which uses energy-dissipating turbulence.

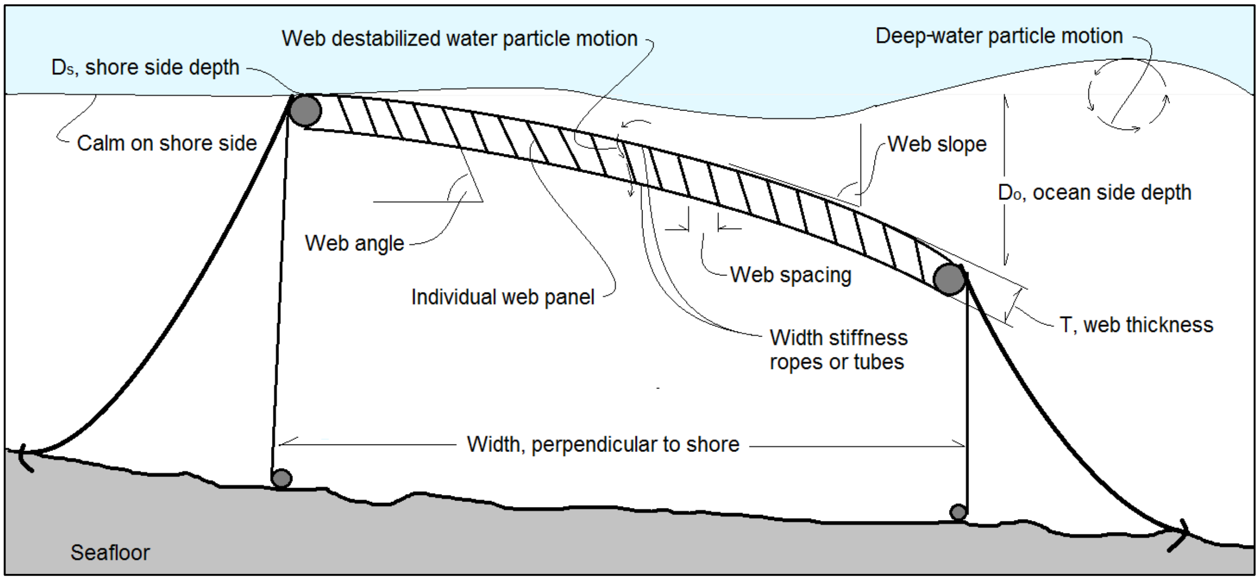

Fig. 4 – Profile of adjustable invisible breakwater in wave destabilizing position

Coastal ocean surface storm waves would be 100 to 300 meters long over 10 to 20 seconds. That means the water particle velocity and associated forces are in opposite directions on the flexible breakwater at any one time. Waves are an oscillating traveling force, which means Civil Engineers can design flexible structures with just the right mass and stiffness to neutralize or extract the wave energy with relatively little net force. The principal could be compared to a self-anchoring arch bridge. The oscillating motions also allow application of the principle of "added mass" as well as the ability to increase mass inexpensively by filling geosynthetic containers with seawater.

Flexible breakwaters would not prevent temporary storm surge or tsunami. However, the calm water would be agreeable to structures on stilts or which float to stay above the flood.

Invisible, but solid, breakwaters could reduce tsunami damage. This is because a subsea "wall" will reflect the tsunami. Picture a barrier in 70 m water depth, 100 m thick, the top of the wall is 20 m below sea level. Such a wall may be built relatively inexpensively with geosynthetic materials and hydrostatic sand. Hydrostatic sand structures are described by Dowse, "New Developments in the Use of Sand for Construction of Deep Water Offshore Structures," Oceanology International 1975. They work because the active earth pressure of dry sand inside an impermeable membrane is less than the confining hydrostatic pressure. A vertical sided SANDISLE column has a bearing capacity equal to 3.4 times the hydrostatic pressure. This assumes a wet sand density of 1800 kg/m^3 (110 lbs/cuft) and an angle of internal friction of 33°.

A coral or oyster reef and seaweed grow-harvest systems would be included on and around the tsunami barrier to continually increase its height while locally reducing ocean acidification and increasing dissolved oxygen content.