Estuarine Mixing – Tutorial Script

Let's move inside San Francisco Bay estuary and observe some of the processes at work in this embayment where salt water and fresh water mix – our definition of an estuary. These simplified cross-sections provide some basic guidelines for various mixing models. In all these images, the fresh river water is shown on the right as a shallower area of the estuary, with the saltwater, average salinity 34 ppt, and deeper depths on the left. In the top image, we have a high volume river that overpowers the local tidal system. The freshwater pushes out and over the much denser saltwater and creates a freshwater wedge on top of a saltwater wedge below. We call this a **salt wedge estuary**, and as you can see it has a strong halocline, as the surface water and deep water don't mix. The opposite of that is a **well-mixed estuary**, where weak, low-volume rivers enter the ocean and the tides overwhelm and simply absorb that water in increasing amounts. The surface water and deep water are the same, so there is no halocline. In between the two, we have **a partially mixed estuary**. This happens when the river's volume is moderate and more matched by tidal currents. There is a bit of a wedge and bit of mixing. Surface waters are fresher than deep waters but not by the same amount as a salt-wedge estuary. A halocline exists, but it's weaker. What happens when the tides move into a river that dries up in the summer and leaves behind evaporite minerals? The waters pick up and dissolve the salts and get saltier as they move inland. These are called **reverse estuaries**.

Pause now.

Let's review some examples. Starting with San Francisco's North Bay, we have a medium-volume river, the Sacramento River which mixes with moderate tides. The result is a partially mixed estuary. We have a weak halocline here, and the deep water is always a bit saltier than the surface water. In the South Bay we have two things going on. The freshwater input here is extremely low, so it's primarily a well-mixed estuary. In fact, the salinity of the South Bay is typically around 30 ppt, very close to that of seawater, which is why whales are occasionally spotted here during Spring and Fall plankton blooms. As the seawater migrates into the mouths of the small rivers in these areas, the salinity will decrease over a short area with no haloclines and a well-mixed profile. However, these colored ponds were developed to increase evaporation and produce a variety of salts. Some of these ponds are still active – others are not. As waters mix around these ponds, salinity actually increases, and we have a reverse estuary. In addition, there is a seasonal change that happens to the mixing in the South San Francisco Bay estuary. During Spring, after months of rain and at the height of snow melt in the mountains, the rivers in this area will be at their highest. The increased river volume leads to a partially mixed estuary, with a weak halocline. This type of mixing is short lived, however, and disappears as the river volume shrinks again during Summer.

This image of Laguna Madre behind barrier islands in the Gulf of Mexico shows another reverse estuary. Evaporation rates in this lagoon are so high that seawater gets progressively saltier and saltier as it moves in and mixes with the lagoon waters. This image of the mouth of the Columbia River – a high-volume river – demonstrates a salt-wedge estuary.. Imagine being in a boat in these waters and not even being able to see land, but having freshwater at the surface, and on the seafloor beneath, you are fishing for saltwater fish.

Pause now.
For more information and more detail, continue on to the next video in this series.

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Coastal Video Series:
Part I: Coastlines
Part II: Beaches and Sand Migration
Part III: Estuarine Mixing
Part IV: San Francisco Bay

Estuarine Mixing
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