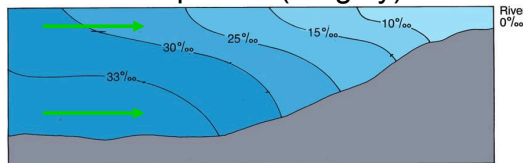


Circulation in Estuaries

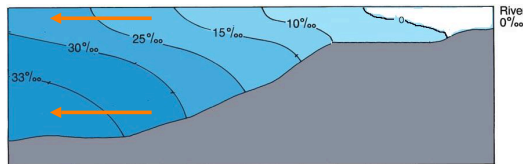


- Instantaneous tidal exchange (flood & ebb)
 - Tidal flood & ebb at all depths at (roughly) the same time

– Flood



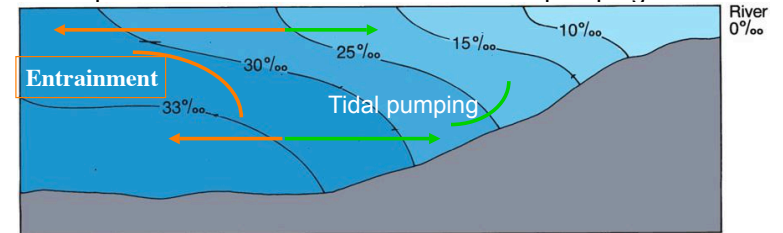
– Ebb



Circulation in Estuaries



- Net circulation (mean over many tidal cycles)
 - Tidal flood & ebb average *almost* to zero
 - Surface layer: ebb is stronger than flood (rivers)
 - Subsurface layer: flood is stronger than ebb
 - Replace water lost to entrainment & tidal pumping



Types of Estuaries



- 4 types of estuaries
 - Classified by pattern of vertical stratification
 - Salinity is the most important factor
 - Unlike temperature dominance in most oceans
 - Change in salinity between upper and lower layers
 - See table in lab manual p. 38.
 - Vertical salinity gradient is a balance
 - River flow creates the stable vertical stratification
 - Mixing due to tidal action disrupts stratification.

Salt wedge estuaries

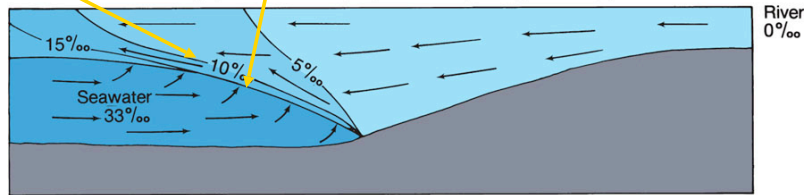


- Dominated by high river runoff
 - Large river mouths
 - Columbia & Mississippi
 - Smaller river mouths entering larger estuaries
 - Duwamish entering Puget Sound
 - Named for sharp boundary between river & sea water
 - Strong halocline moves back and forth with tides
 - Strong vertical stratification

Salt wedge estuaries



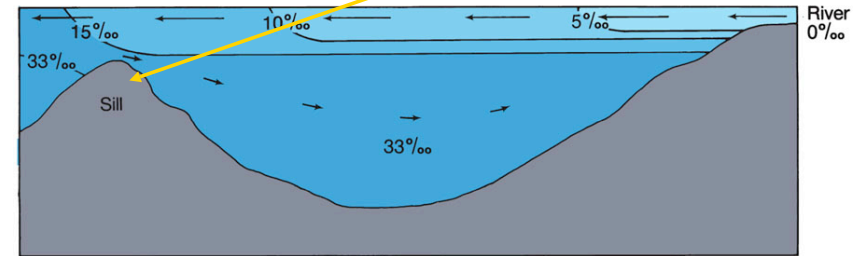
- Dominated by high river runoff
 - Weak vertical mixing, strong stratification
 - Strong halocline “wedge” moves with tide
 - Moves up river channel for some distance on flood
 - Moves out into open water on flood
 - Weak entrainment of higher-S water



Fjord estuaries



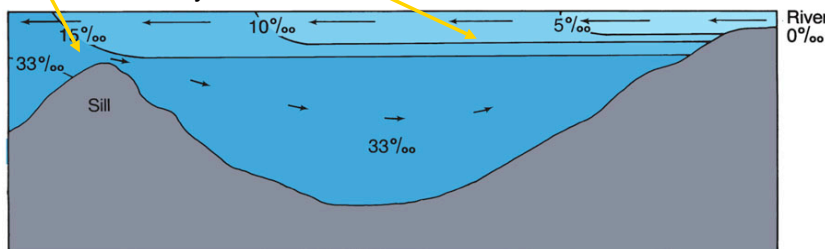
- Like a salt wedge but some special traits
 - Carved by glacier: Deep, narrow, straight
 - U-shaped cross section vs. V-shaped river valleys
 - Shallow area called a **sill** at the mouth



Fjord estuaries



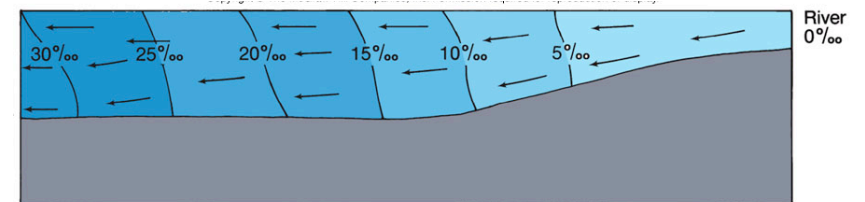
- **Sill** blocks exchange of deep water with ocean
 - Little water movement below sill depth
- Strong vertical stratification
 - River water runs off with little mixing
 - Nearly horizontal isohalines



Well-mixed estuaries



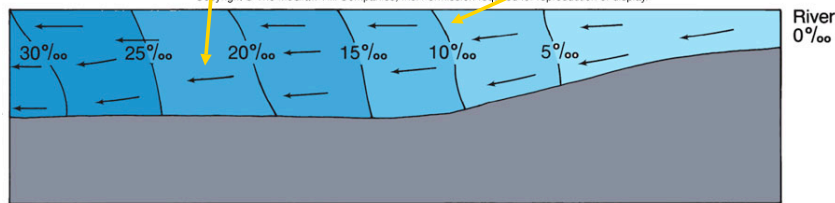
- Low river input & strong tidal mixing
 - Far from river mouth
 - In areas of large tidal exchange, fast tidal currents, and/or turbulence
 - Often shallow



Well-mixed estuaries



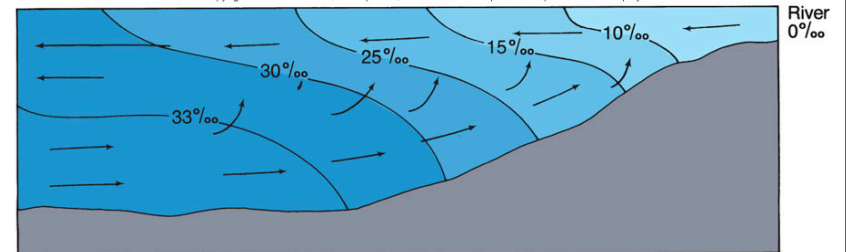
- Weak vertical stratification & halocline
 - Isohalines almost vertical
 - Move back & forth with tide
- **No** 2-layered net circulation
 - Net outflow at all depths



Partially-mixed estuaries



- **Rough balance between rivers & mixing**
 - 2 layers & 2-layered circulation
 - Halocline weaker & broader than salt wedge or fjord
 - Mixing, entrainment, tidal pumping stronger



Flushing in Estuaries



- Gradual replacement of water in estuary
 - Inflowing river & ocean waters flushed to sea
 - Removes pollutants, replaces nutrients & O₂

