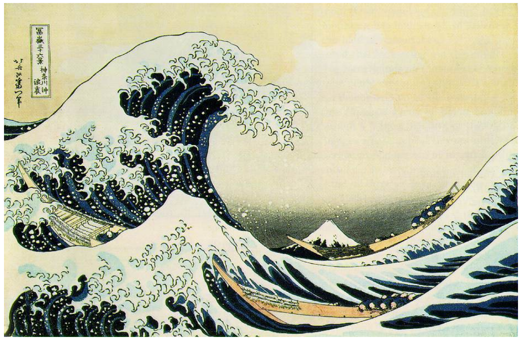


Waves in water …

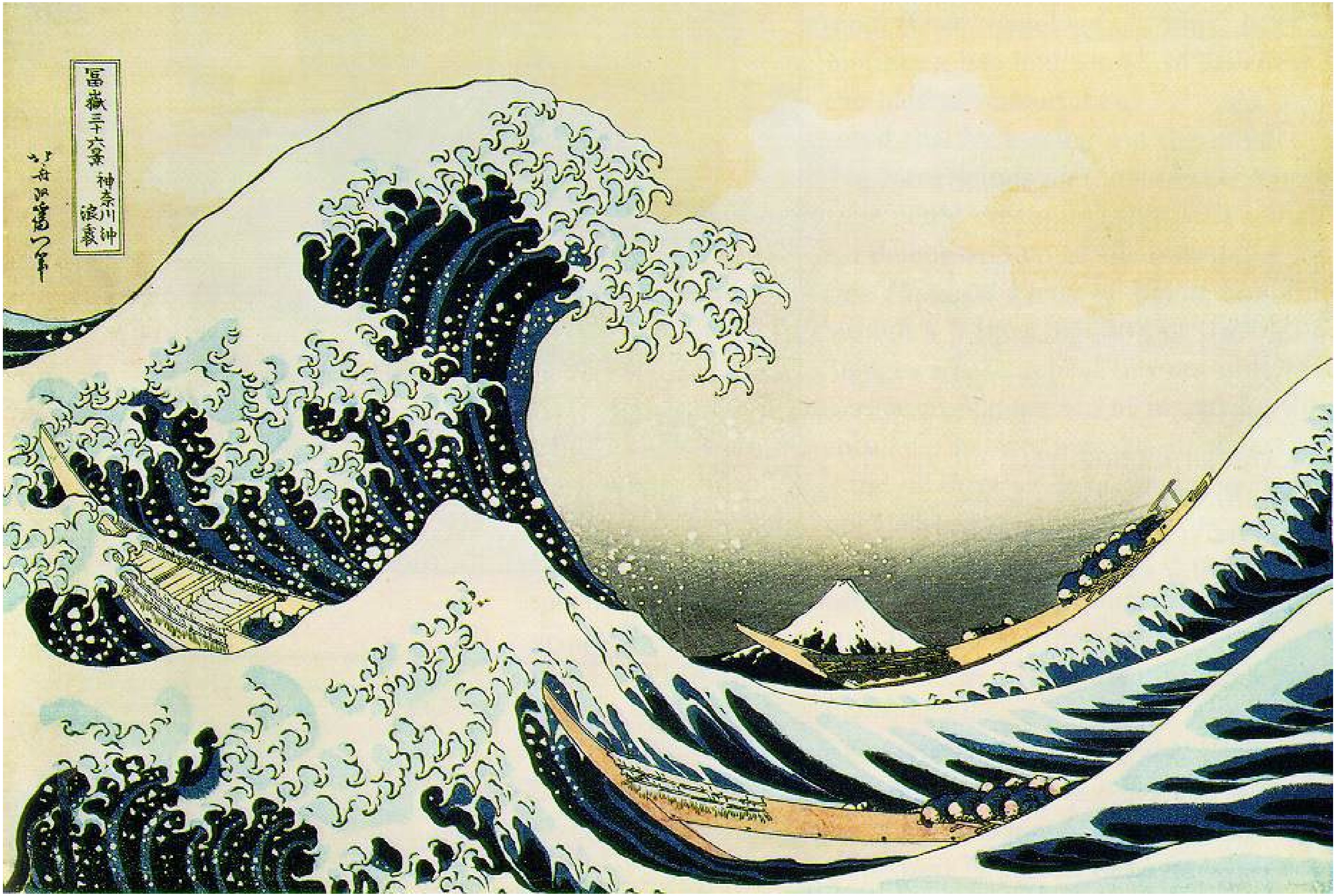
… where there is nothing quite so practical as a good theory

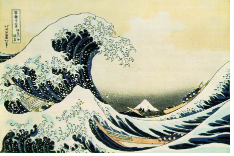
A presentation of the many aspects of wave motion and the theories used to describe them

John Fenton

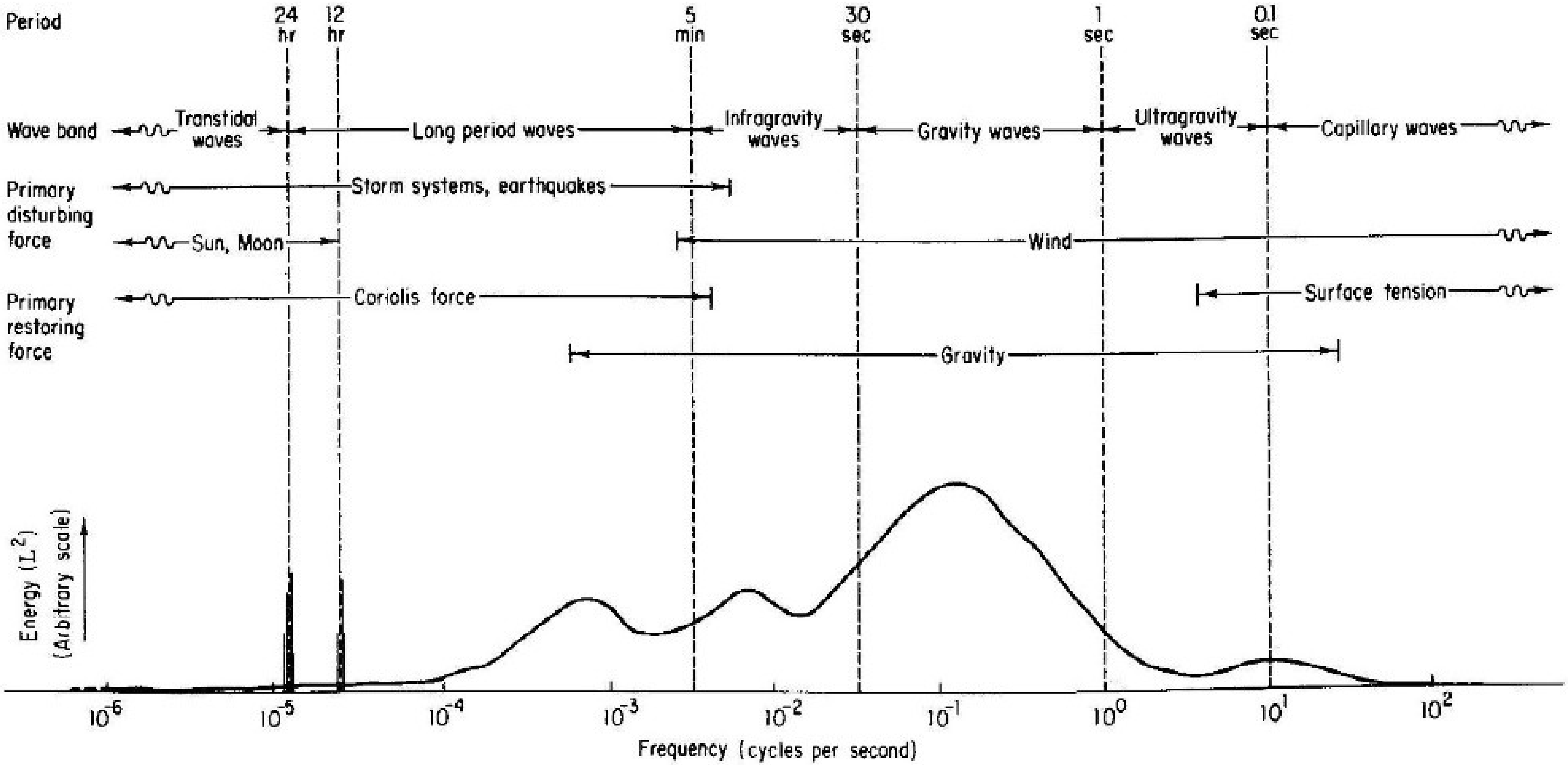
http://johndfenton.com/Lectures/Coastal-and-Ocean-Engineering/

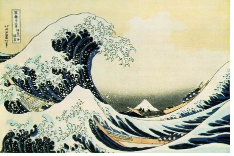
Sometimes, there is nothing quite as useless as any theory …





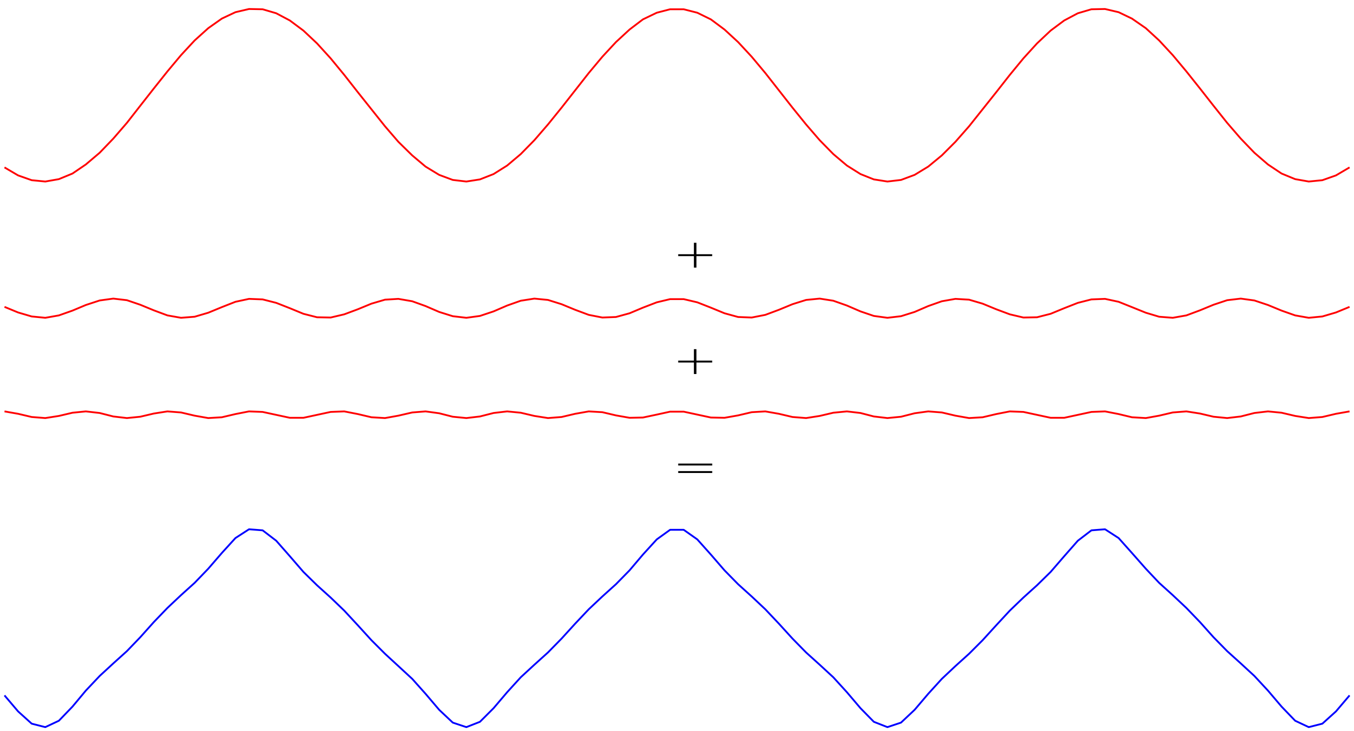
The spectrum of water waves

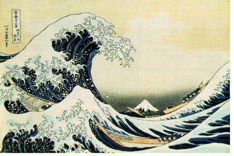




Spectral representation – *Fourier* series

- Any periodic function can be represented by a sum of sine waves of periods 1, ½, 1/3, ¼ *etc.*
- Just perfect for water waves!

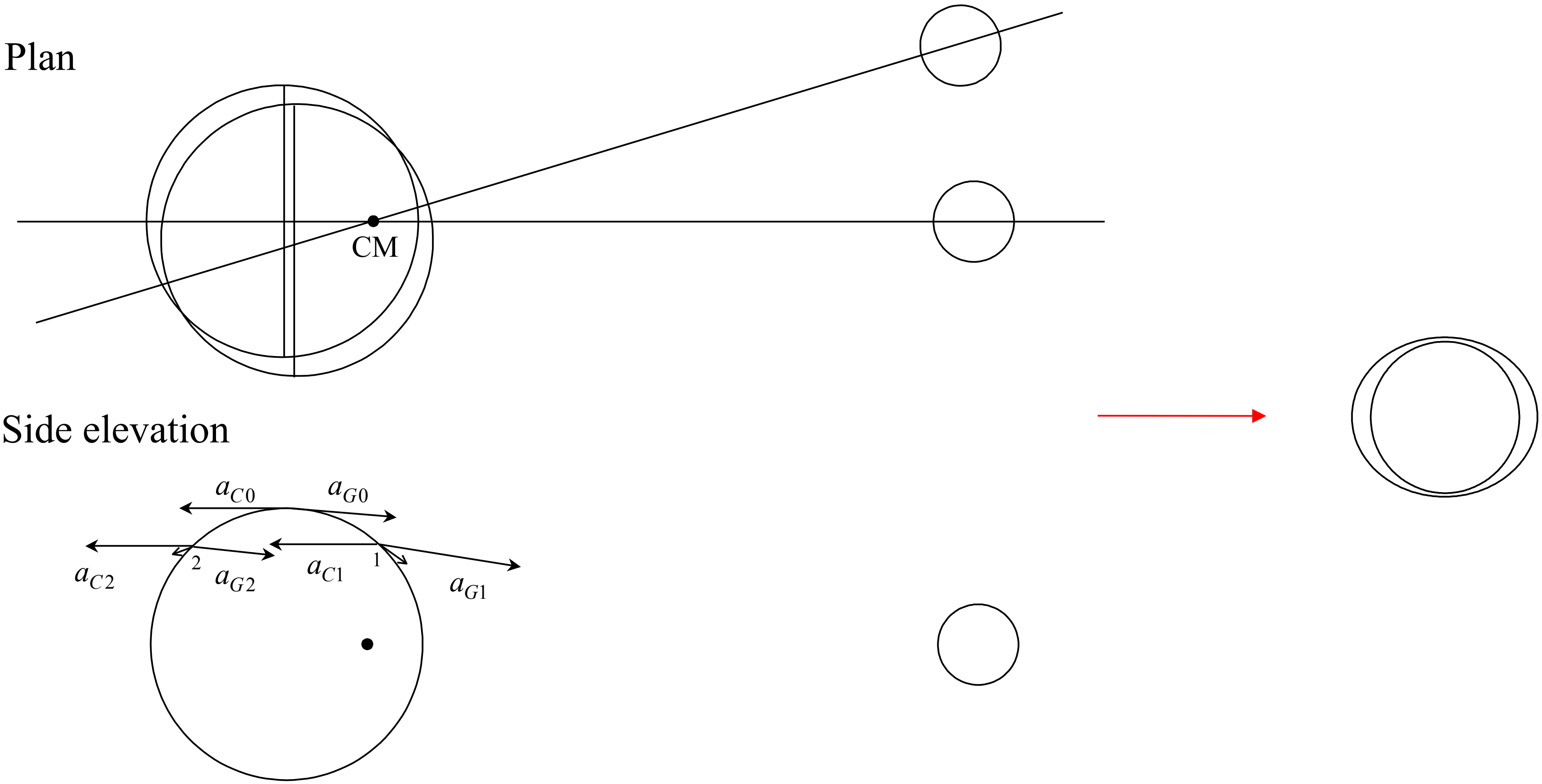


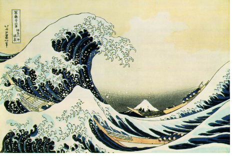


Newton’s equilibrium theory of the tides …

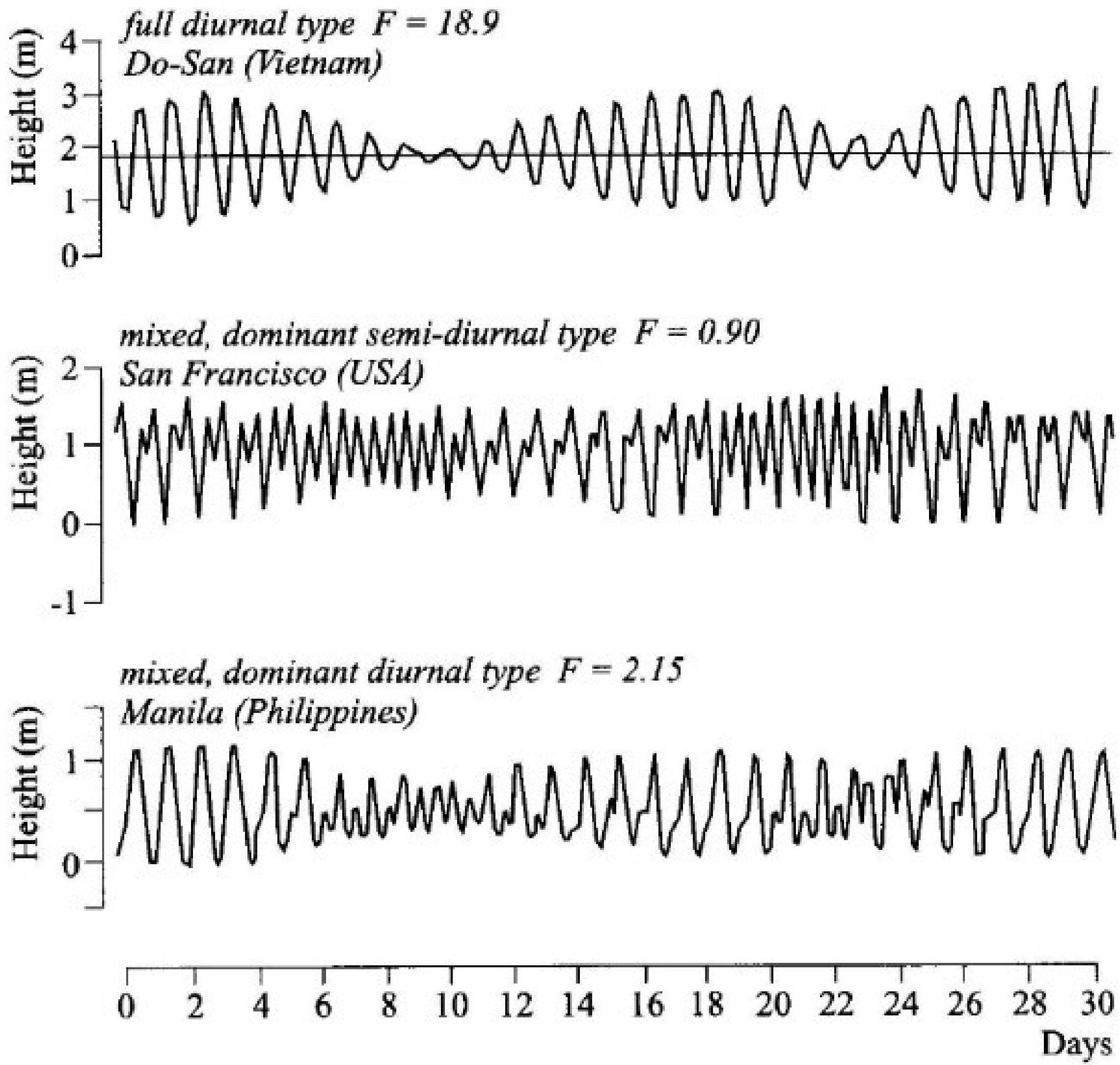
(a) Plan

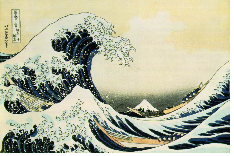
(b) Side elevation





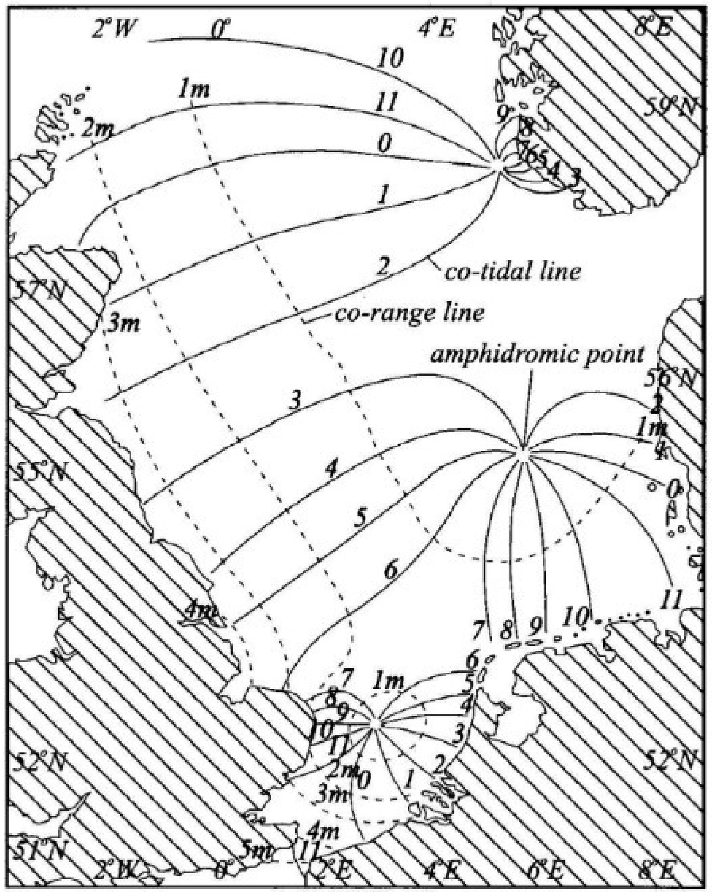
… explains why in most places on earth there are 2 tides per day



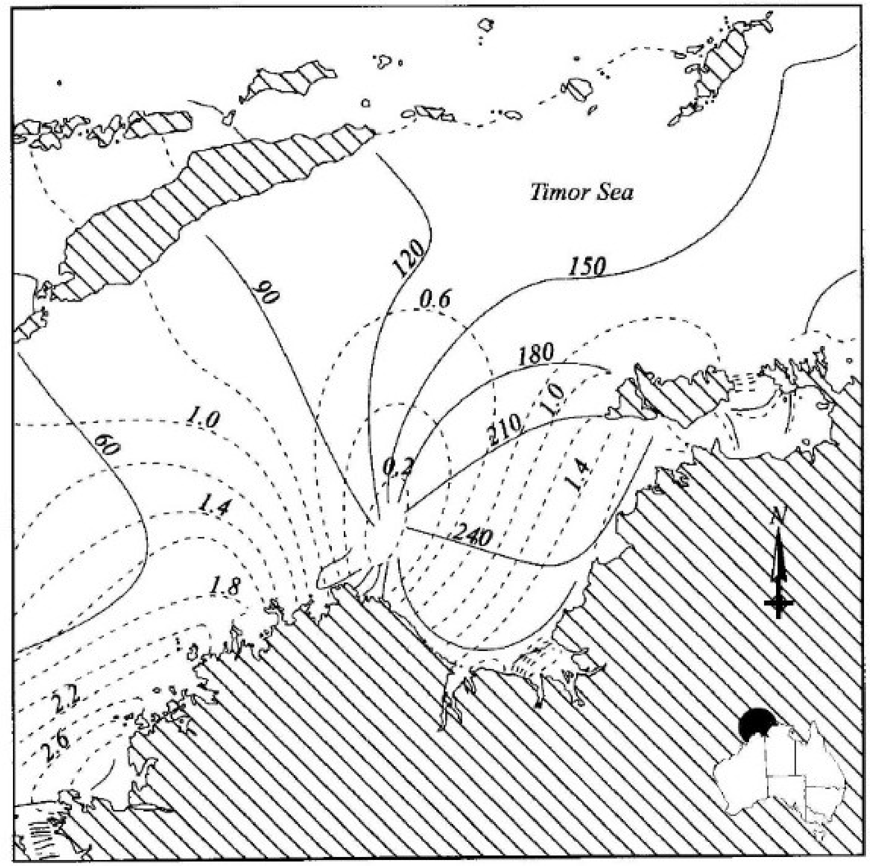


However, near coasts the tidal wave is a *Kelvin* wave

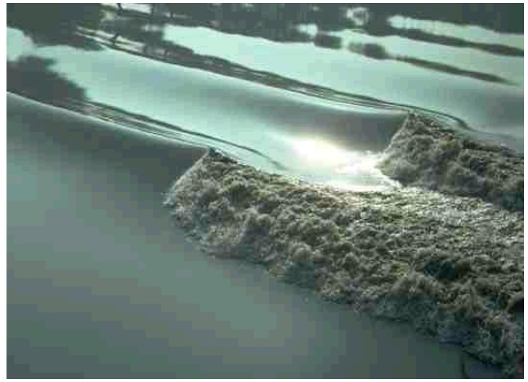
The North Sea



The Timor Sea



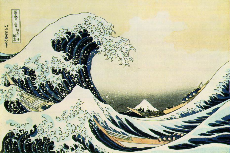
Tidal bores – the Mascaret – here on the Severn, Seine & Dordogne



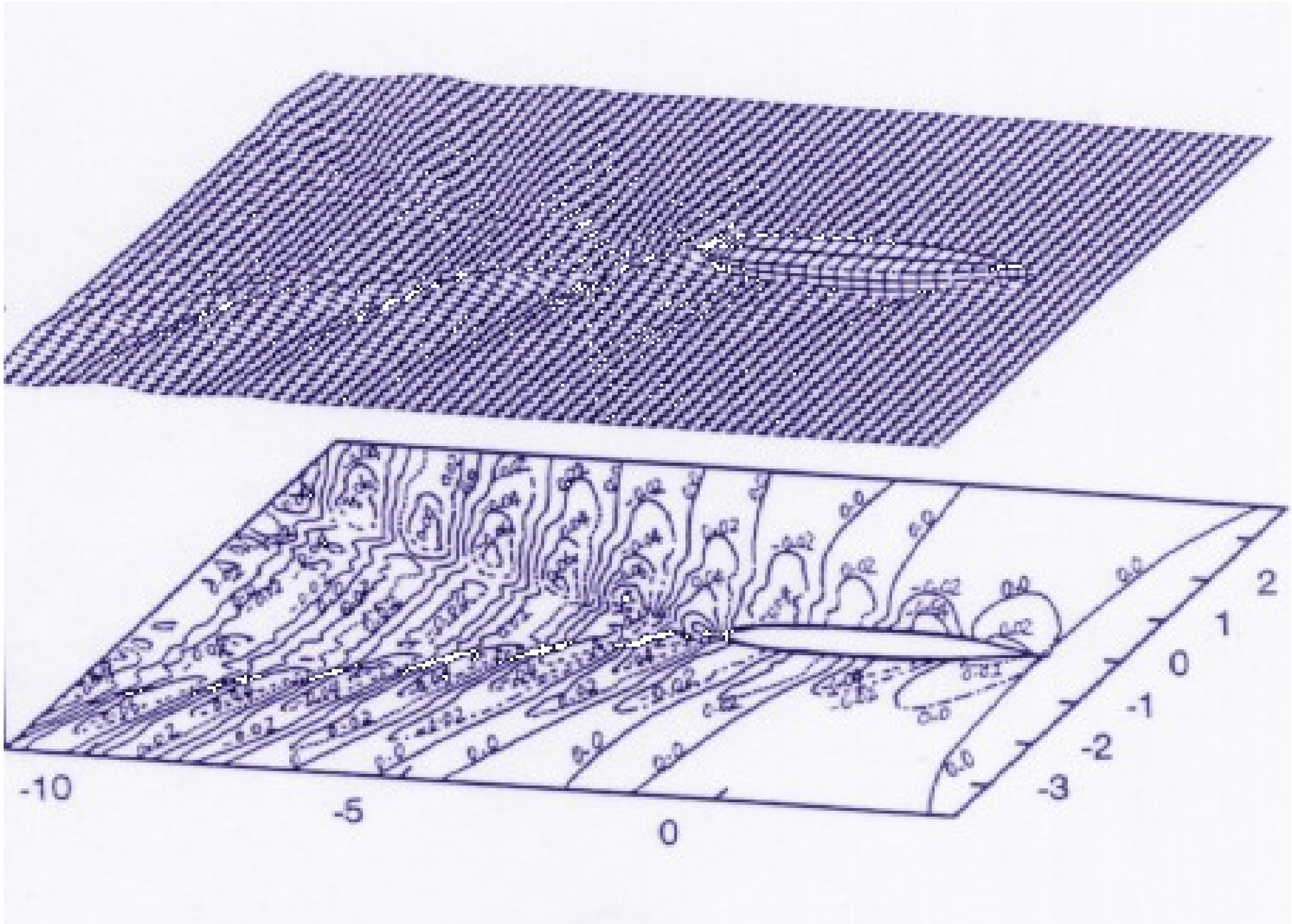
The River Severn

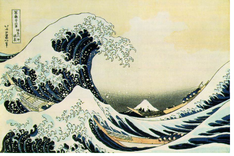
The Dordogne

The Seine



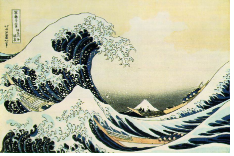
Ship waves



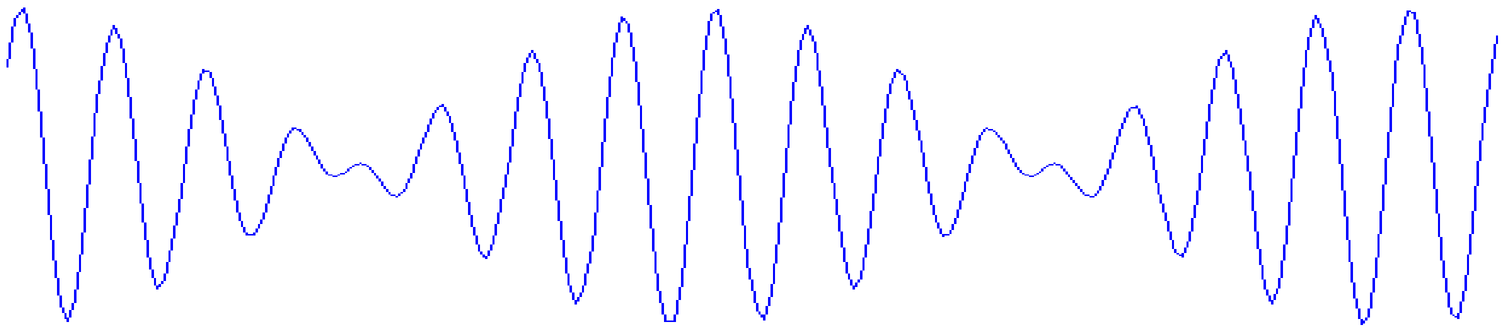


What are some of the properties of water waves?

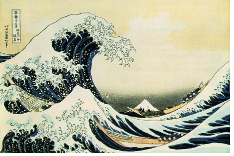
- Waves occur at all length and time scales, due to many physical processes
- Waves refract – the velocity depends on the water depth
- Waves can pass through each other – some do, but some don't
- Waves are dispersive – they propagate at different velocities depending on wavelength
- Waves diffract – they are scattered by solid objects, thereby causing forces on them (oil rigs *etc*.)
- Waves are nonlinear – higher waves travel faster, waves coalesce, once coalesced they show a remarkable stability. When they reach the coast, many different behaviours are possible
- Waves provide the mechanism for sand removal and transport – and hence much coastal geomorphology



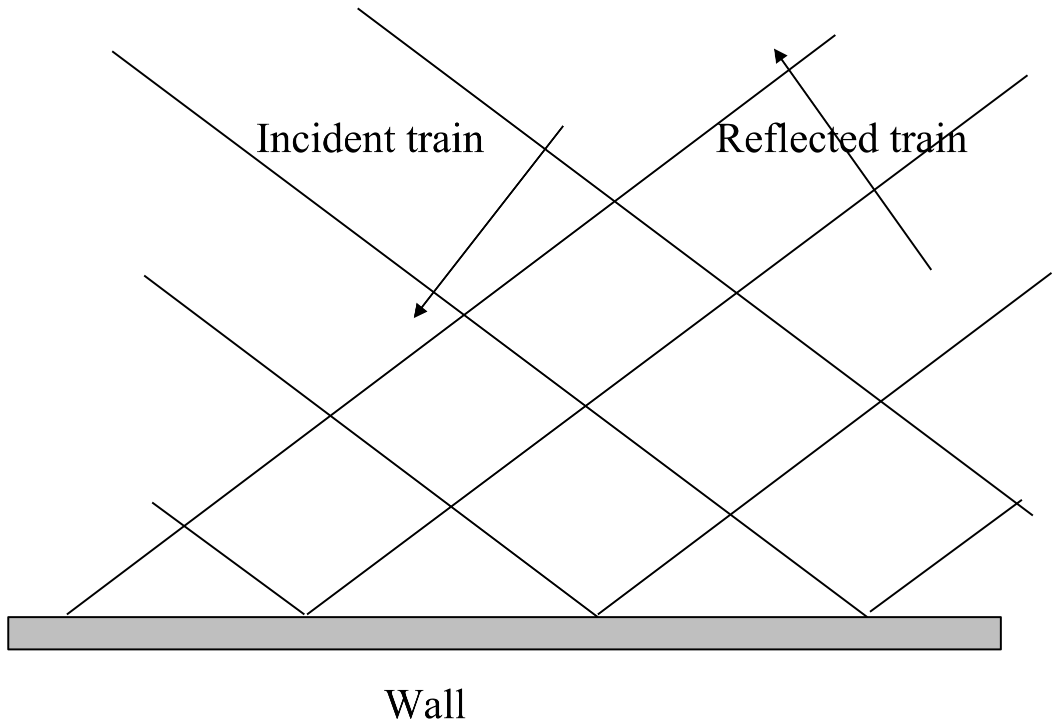
Beats – two wave trains with different wavelengths



- If there are two wave trains present with different wavelengths, we get the phenomenon of *beats*
- The length of the group is inversely proportional to the difference in wavelengths
- Hence, if the difference in length (or period) is 1/7, there will be 7 waves in a group
- And so the surfer's adage, that every 7   wave is large, can be explained
- Now let's see how they propagate …

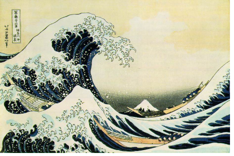


Waves propagating in different directions – *short-crested* waves



Let's see what this looks like ...

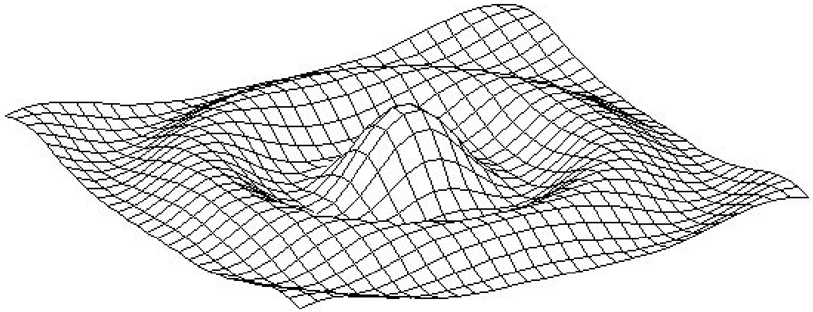
New Zealand: Rangitoto (“Bloody Heavens”) Island – intersecting waves

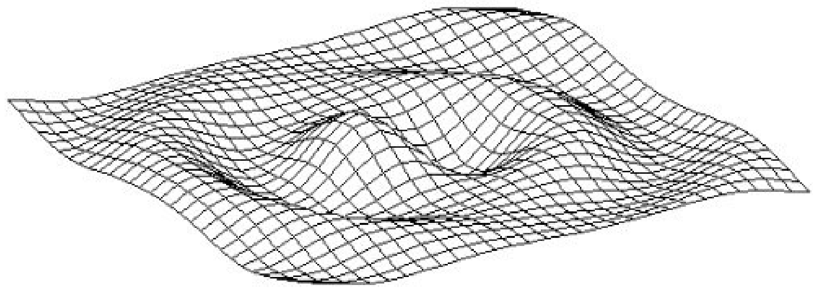


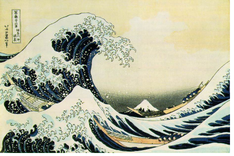
More complicated geometry: resonance in harbours, lakes, *etc.*

- Finite masses of water can support wave motion
- A circular harbour can be shown to be described by *Bessel functions*
- Each type of oscillation has a characteristic period of oscillation
- If there is a stimulus (*e.g.* waves or wave groups) with a period close to that, the oscillation can be induced
- Can create problems in harbours
- Now let’s see how they behave …

Axisymmetric

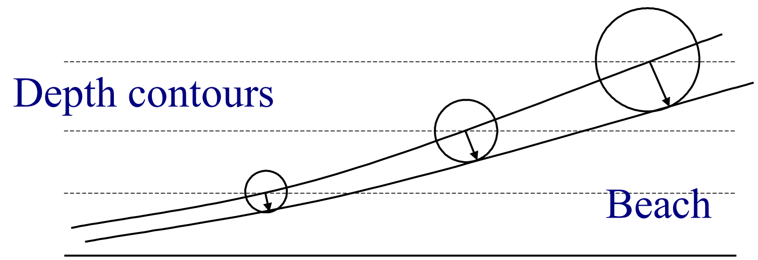


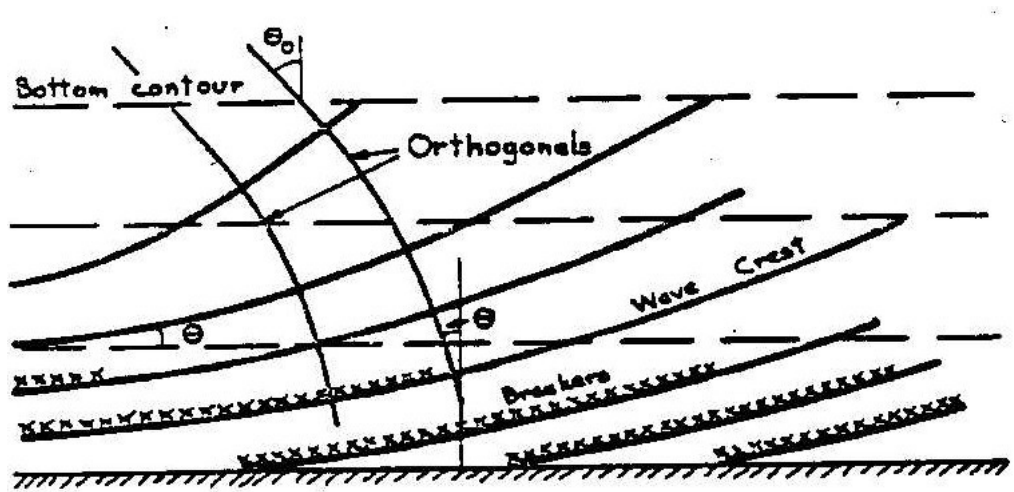




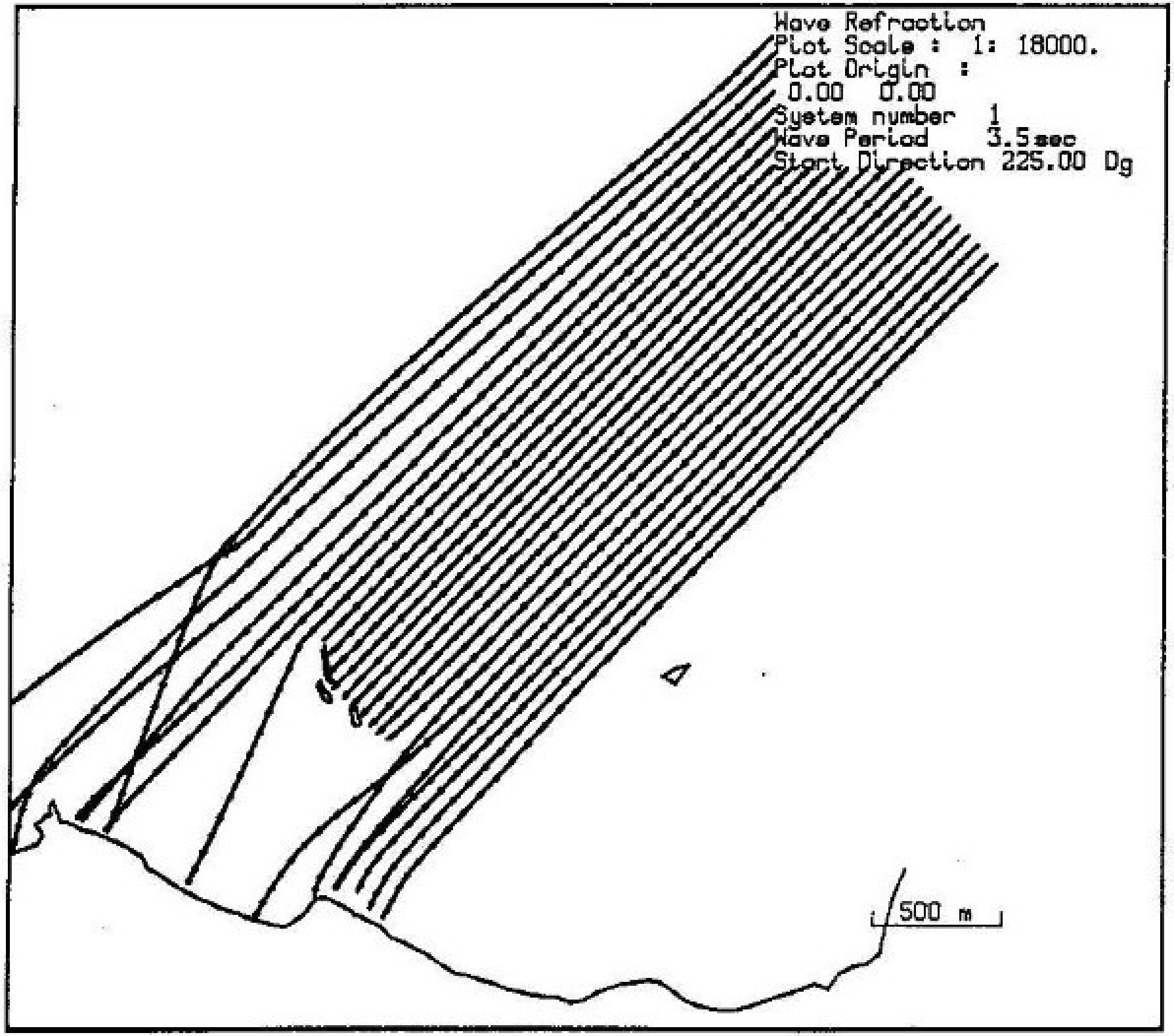
Refraction of waves

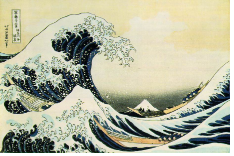
- The basic rule for long waves is that $c = \sqrt{gh}$
- Waves are faster in deeper water and slower in shallower water
- Leads to refraction, or the bending of waves as they enter shallow water
- Often they are still not exactly parallel to the coast
- Leads to littoral drift – sand moving along the beach



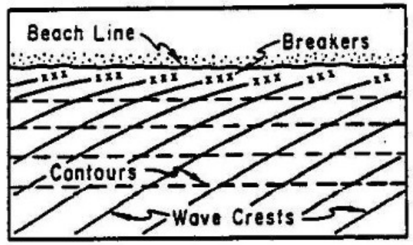


A typical calculation of wave refraction

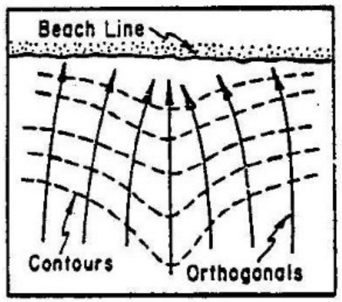


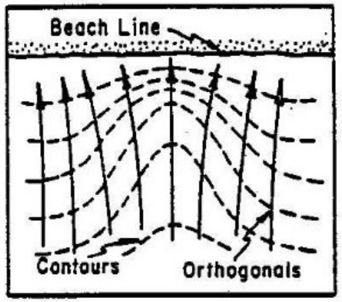


Some more realistic coastlines …



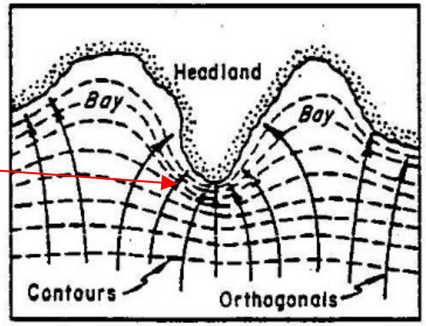
(a) Refraction Along a Straight Beach with Parallel Bottom Conours





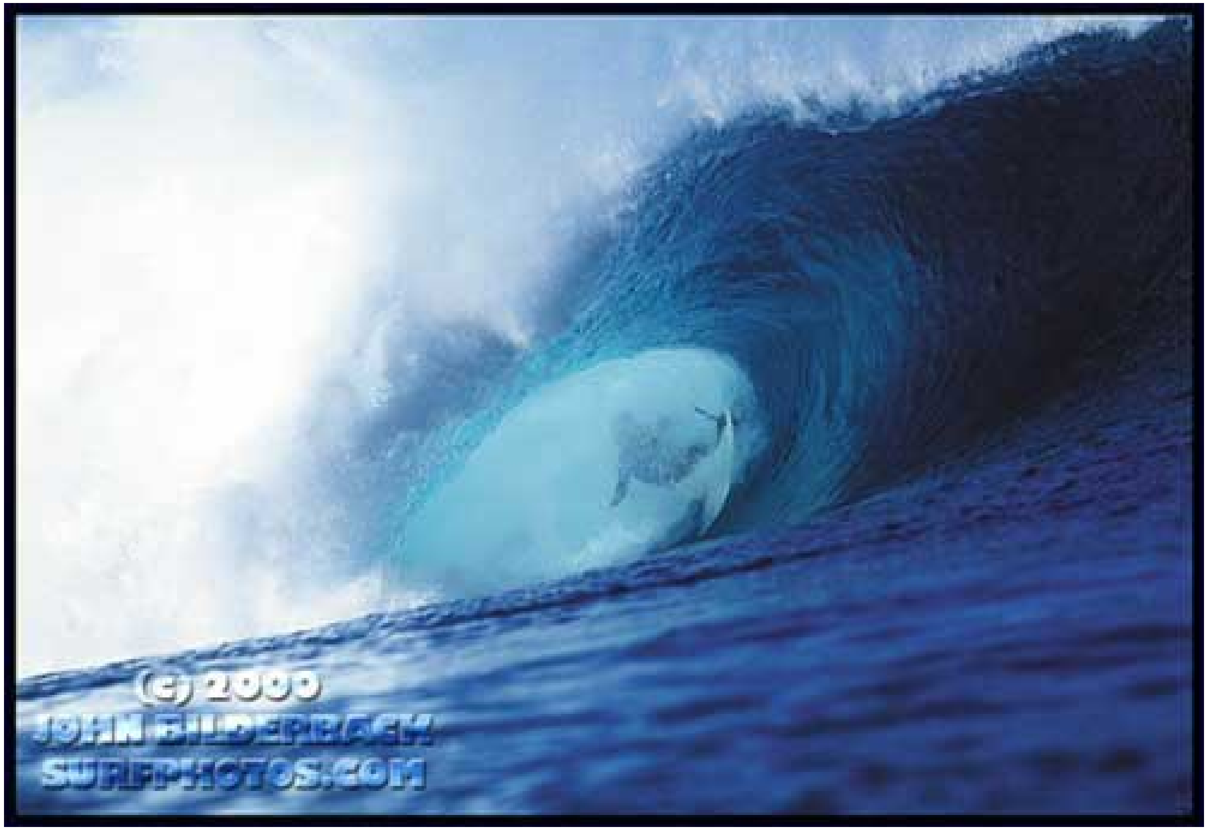
(b) Refraction by a Submarine Ridge (c) Refraction by a Submarine Canyon

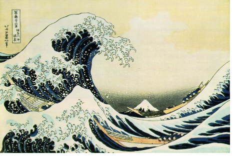
Here are the surfers



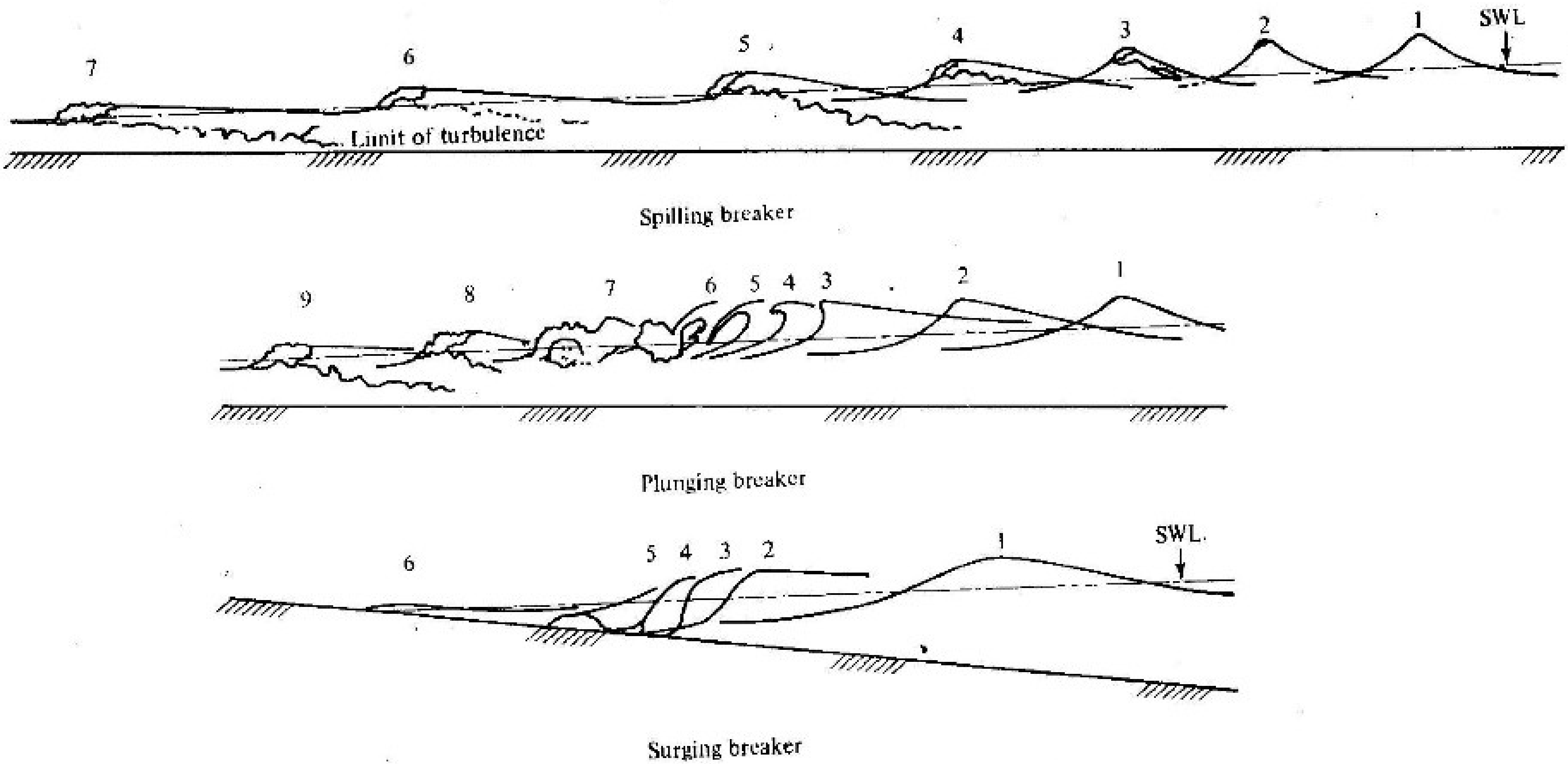
(d) Refraction Along an Irregular Shoreline

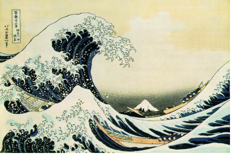
A plunging breaker





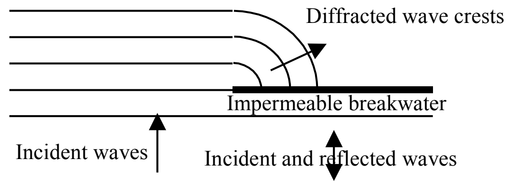
Some different types of breaking waves – depend on beach slope



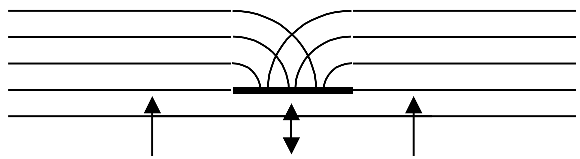


Waves show *diffraction* too …

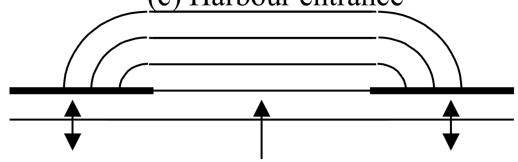
(a) Semi-infinite breakwater



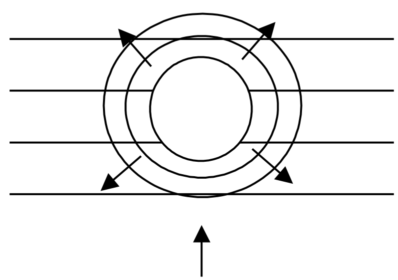
(b) Finite breakwater

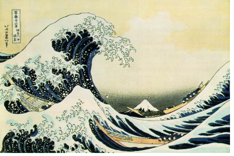


(c) Harbour entrance

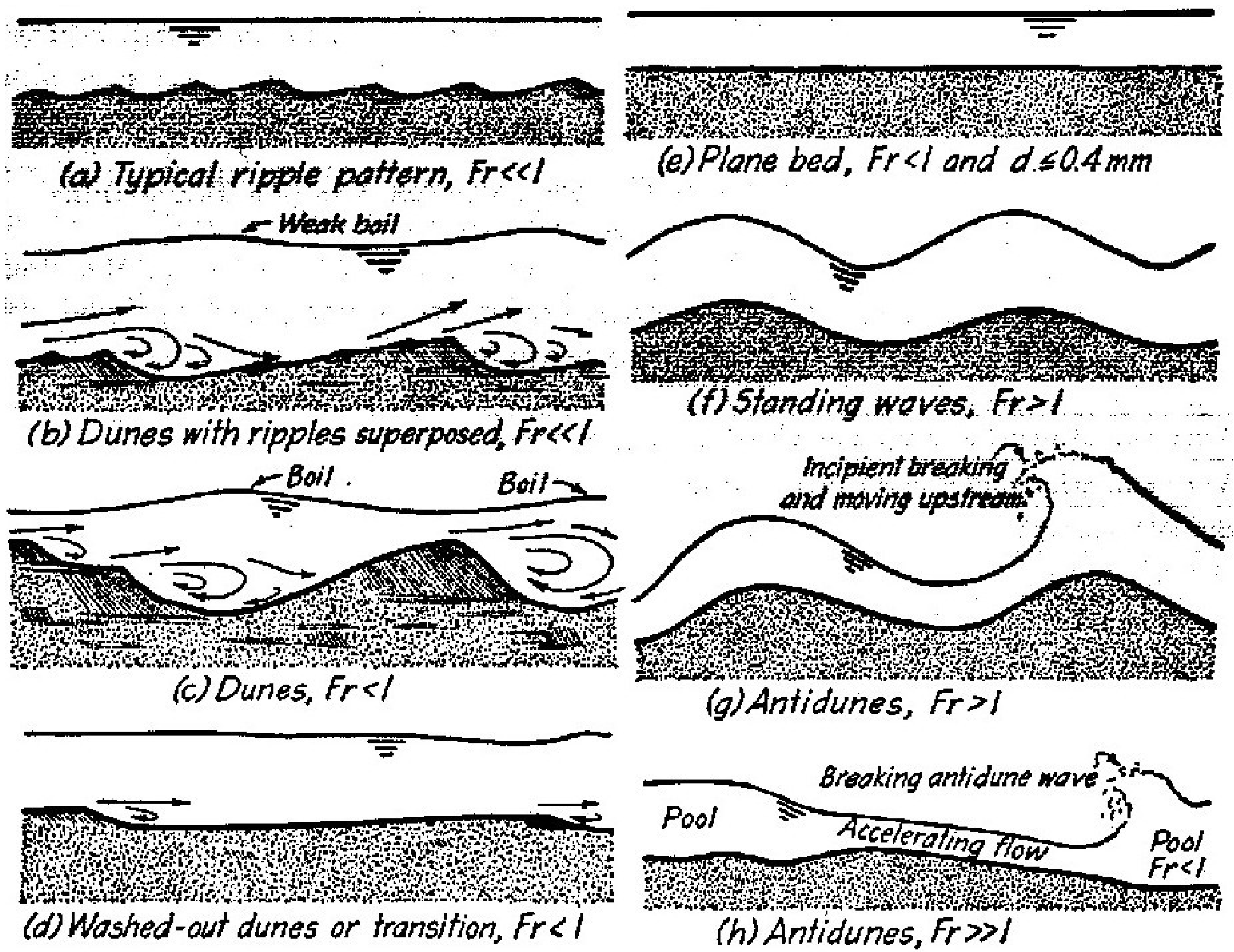


(d) Vertical cylinder – oil tank *etc*.

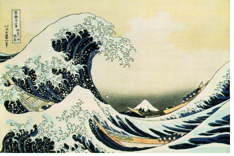




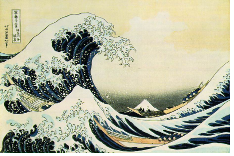
Waves where the bed is mobile



A stationary wave in a stream entering the sea



What waves can do over many years …



And now something very different – long waves in rivers

- Long waves in rivers are often dominated by friction
- This means that they do not propagate as a wave without change
- Instead, they show the phenomenon of *diffusion*, whereby disturbances become damped and spread out in space and time
- As an example, consider the effects of the tide on a river …

Flood waves in rivers

Dresden on the River Elbe in August 2002

Flood waves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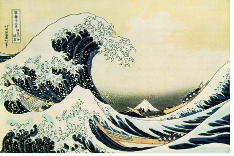
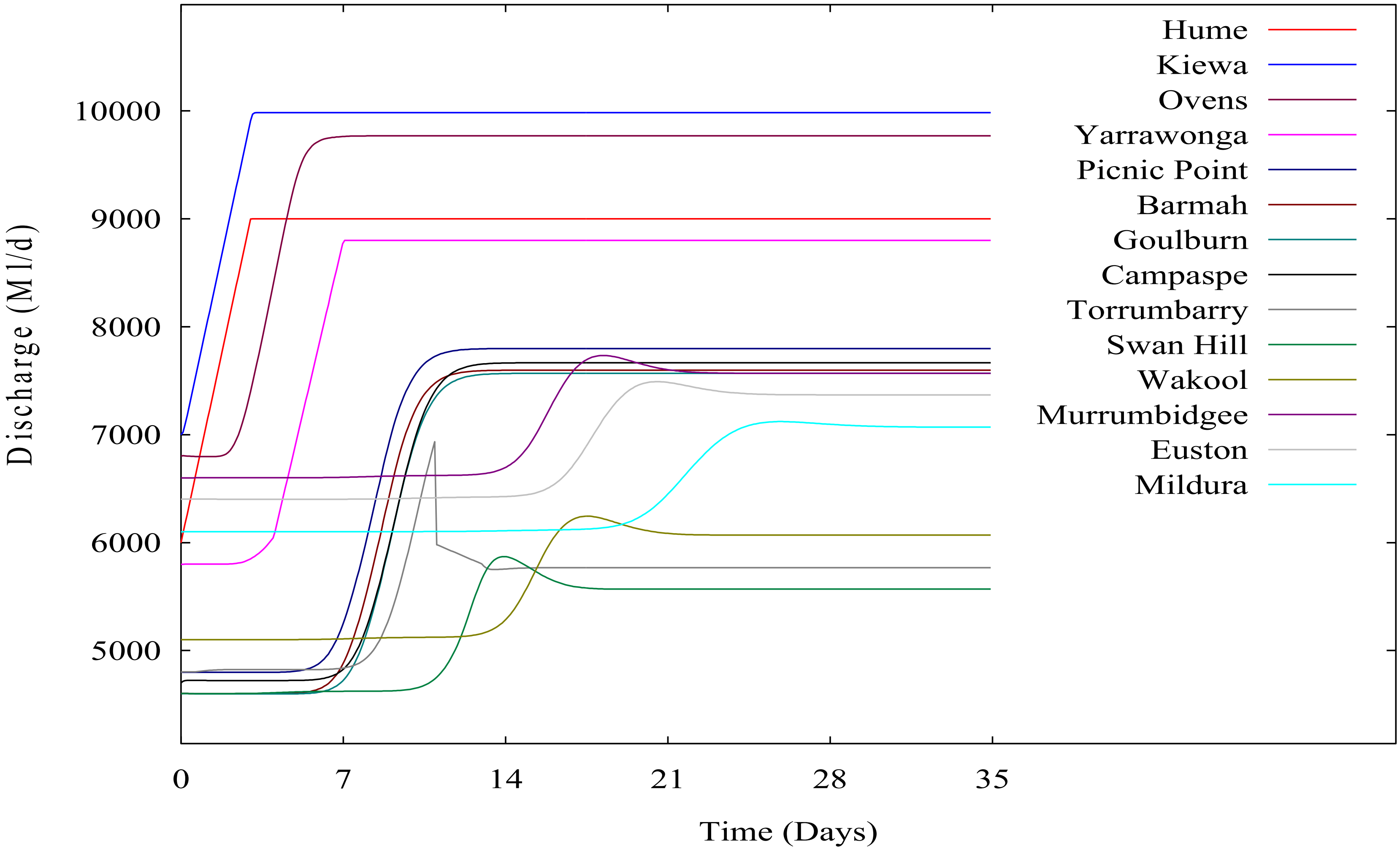
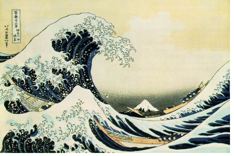
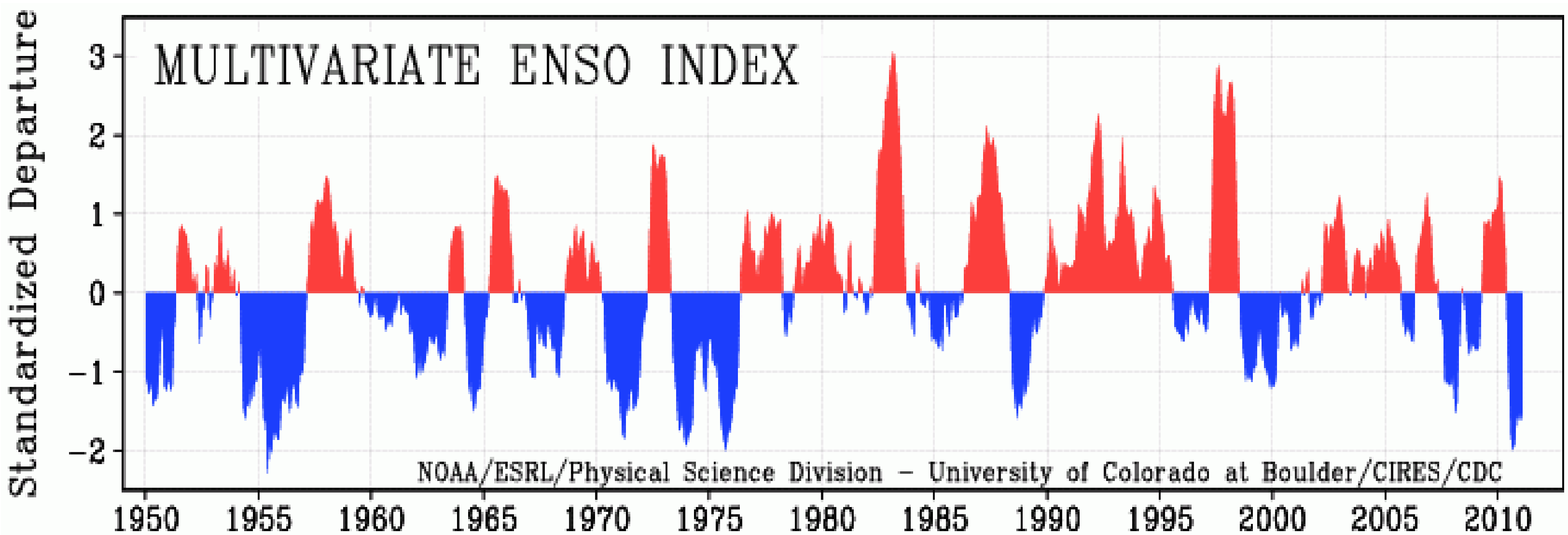


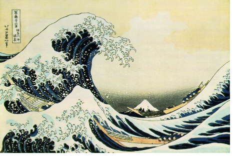
The movement of a flood wave in the Murray River, Australia





Another wave, the El Niño – Southern Oscillation





And finally, waves and wave phenomena we have not mentioned …

- The generation of micro-seisms by reflection of waves from cliffs
- Rossby waves – where the earth's rotation is the restoring force
- The recently-discovered waves in the Indian/Southern Oceans
- Forces on bodies due to diffraction
- Waves where the water is density-stratified
- Capillary waves (due to surface tension)
- Dynamic waves in rivers and canals
- And so on …
- We live on a watery sphere which contains a remarkably complex system of disturbing and restoring forces and interacting waves and resonances, all of which are important to the natural environment and are fascinating to study.

And some beings just want to have fun …