# Technical Papers

## Applying Mathematics to the Surf

Neville de Mestre*

A lot can happen in the boundary layer of the world's oceans. I am referring to that thin strip adjacent to the coastline where the surf occurs due to the breaking of the waves to form a moving surf front, sometimes called 'breakers'. I was introduced to this recreational playground by my father, who had joined Wollongong Surf Club in 1925. My maternal grandfather had joined North Wollongong Surf Club in 1911 as a foundation member. It therefore was quite natural that I became a proficient surfer very early in my life and eventually someone with a leaning towards fluid mechanics after graduating in applied mathematics from Sydney University in 1959.

The fluid mechanics of the surfing region is quite complicated. The water movement is extremely turbulent, the interface between the water and the air is constantly moving, and the bathymetry of the bottom is frequently changing as the sand is moved by the pounding waves. To date, most research efforts to understand the surf have been carried out experimentally in simplified wave tanks or using coastal observations from cameras. As you will see shortly, a surfing fluid scientist can contribute extra information from first-hand experiences.

My initial foray into understanding the surf was to begin an investigation of bodysurfing. An early model recognised that a human body can be propelled forward on a broken surf front if it can get up to wave speed in deep water just as the wave is about to break. This skill requires some practice with correct timing of the launch because breaking waves are usually travelling with speeds greater than 4 m/s, whereas the swimming speed of the best human swimmers is a little more than 2 m/s. However one can also catch a broken surf front if one can launch oneself from a standing position on a sandbank just as the front arrives. My first model of bodysurfing used Sir Isaac Newton's acceleration law with a simple approximation for the forward forces exerted by the water particles inside the crest of a breaking wave to provide the forward momentum. Unless you have bodysurfed you will not be aware of the strength of these forces, but it is observable when porpoises ride ocean waves near the shore or ships' bow waves out at sea. There is still work needed to improve this model.

Recently I have used my seventy years of experience as a surfer, lifeguard and surfing competitor to undertake the development of a hazard rating system for the surf at any position on any part of the coastline at any time. This seemed necessary after three deaths by drowning in big seas at the Australian Surf Life Saving Championships in 1996, 2010 and 2012. In each of these cases, it became obvious through hindsight that the events should have been moved to safer venues.

*Emeritus Professor, Bond University. Email: margnev2@bigpond.com

Immediately after the 2012 accident, my colleague Gary McCoy and I began working on a quantitative Surf Hazard Rating (SHR) system. This was to emulate the MacArthur Fire Danger Rating system which I was familiar with through my research into wildfire behaviour in the 1980s.

The SHR system is based mainly on seven factors within the surf zone. These are: breaking wave height, breaking wave period, breaking wave type, surf zone width, surface turbulence, littoral drift and outward rip current movement. Integer rating values have been assigned to each of these surf characteristics with the SHR being the total of these seven values. Less frequently occurring hazards such as low water temperature, visibility problems due to sun glare, bluebottles, floating storm debris and the presence of sharks can be accounted for in an 'Others' category.

The difficulties in developing a surf hazard rating system are twofold. First of all, a consistent weighting has to be used across the surf characteristics to emphasise the relative importance of each one. This has taken us five years of observation and discussions with many surfing experts at numerous beaches.

The second difficulty arises through trying to measure the two main contributing characteristics, namely wave height and surf zone width. The maximum wave height in any set of waves can be estimated using a lightweight vertical pole positioned at the water's edge. An observer notes the position on the pole where his or her eye is aligned with the wave crest and the horizon. Our rating system only requires this to be accurate to 0.5 m.

The maximum surf zone width is obtained using the time taken for the front to travel from breaking point until it peters out. Numerous experiments were conducted by me using a bodyboard to catch small, medium and large waves and ride their associated surf fronts directly towards the shore. The data obtained from a waterproof Global Positioning watch attached to my wrist established that all surf fronts travel with uniform retardation. One of the basic kinematical formulae for uniformly accelerated motion is

$$s = \tfrac{1}{2}(u+v)t,$$

where $s$ denotes the distance travelled, $t$ the time taken, with $u$ and $v$ the initial and final velocities. From the GPS data it is seen that the final velocity is near 2 m/s while the initial breaking wave speeds range from 4 to 8 m/s as the wave heights increase from small to large waves. This suggested that a suitable heuristic for estimating zone width in metres with a watch is to multiply the time taken in seconds by 3, 4 and 5 respectively for small, medium and large waves. The agreement with the distance data from the experiments is accurate enough for our purposes, since the rating system only increases by one for each 20 m of surf zone width.

At this stage SHR values have been measured in conjunction with more than 2000 surf boat races in various Australian states. These were correlated against dangerous incidents such as overturning, back-shooting, collisions and slewing involving the boats in these races. The statistical analysis yielded a likelihood of an incident during a race when the SHR was equal to or greater than 13. Consequently all surf boat rowers and sweeps must now wear helmets during races or training when this threshold is reached.

However the main purpose of developing the SHR is to help surf carnival officials decide to move, postpone or cancel events when the surf becomes too hazardous for the competitors. Not enough data has been collected yet to determine a cut-off threshold for this.

Further possible uses of the SHR include

(i) the setting of safe surf swimming areas for the public by professional life-guards and voluntary surf club patrol members,

(ii) a Surf Safety Index for all surfing competitors balancing the SHR against their personal competence,

(iii) the measure of hazards for recreational surf and rock fisherpersons,

(iv) a measure of the surf hazards at the bars of coastal rivers.