Preface for Special Issue of the Journal of Engineering Mathematics

A Commemoration of Howell Peregrine, 30 Dec. 1938 – 20 Mar. 2007

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Introduction:
Howell Peregrine was a one-off scientist. He was a highly creative British applied mathematician whose intellectual integrity was an example to his students and colleagues. It was his imaginative courage that made him such a widely admired supervisor, thinker and advocate of engineering mathematics. He also attracted criticism due to the audacity of his ideas. Much of his research was inspired by engineering problems from the field of fluid dynamics, especially waves on the surface of water. He was happiest when observing nature, working with engineers, and on seeing his mathematical ideas either tested or put to good use.

Howell had a very energetic enthusiasm for his work as a researcher and teacher. He had a boyish sense of fun. I worked with him for over six years at the formative start of my own research career. I cannot write here about all of Howell's many interests, so in this preface I take a personal view. This special issue of the Journal of Engineering Mathematics contains articles on some of the topics that Howell cared about, and most of the authors had close personal and professional links with him. Individual authors mark their inspiration from Howell with citations to his work and acknowledgments to him of their intellectual debts. Howell's own papers will go on inspiring fluid dynamicists far into the future.

First Impressions:
I first met Howell in July 1986 when I visited the Mathematics Department at Bristol University for an interview to become another of his many PhD students. He was not made a professor until 1987, but he had been lecturing and researching at Bristol since 1964. When he died he was still working within the department.

In July 1986 his fourth-floor office was like one of the caves of Aladdin. On the back of the door was a poster of his most famous photograph, of the Severn Bore, partly smooth flow and partly breaking near the river bank. (The image was one of twelve used in a London Underground poster campaign celebrating the Year of Mathematics 2000.) There were several two-metre high bookcases and filing cabinets against three walls, and one bookcase, that you could almost walk around, was devoted to volumes of the Journal of Fluid Mechanics (JFM), of which he was an associate editor. The bare wooden floor sagged under the weight of stacks of books and papers. On the window shelf were mathematical toys and fan coral collected on his many trips to beaches overseas. Amongst the toys was a vortex-maker that he had constructed from two drinks bottles sealed together at their necks: the green liquid inside made a vivid lecture demonstration of vorticity and free surfaces in action. From his office there was a view of the other university buildings, especially Physics in its mock medieval castle.

Sitting with Howell, he made a strong first impression: he had clear blue eyes, neglected hair, a lean wiry frame and an electrically driven enthusiasm for talk and ideas. Here was a man with knowledge and, more interestingly, a generous supply of ideas about how to use and explore further the science and mathematics of water waves. The subject of water waves (in all their aspects) was Howell's passion. As I got to know him, the odd combinations of jacket, shirt and tie that he wore from day to day showed that he paid little attention to colour matching or personal appearance, which is odd in a man who was such a keen observer of nature. The most important side of working with Howell was his conversation.

Ideas and Howell:

Years after great thinkers die, we are left with the books and papers that they wrote, but we rarely get a glimpse of *how* new science was discussed before it was written down. How do ideas grow, become formulated in mathematics and get transmitted? What happens to ideas as they change from rumours or news, through correspondence or declared beliefs asserted in papers, to become improved or overturned by new ideas or possibly decisive experiments? Early on in my career as a PhD student, a Bristol lecturer told me that Howell talked through a hundred ideas a day, but only one might be worthwhile. I suppose he meant his warning kindly, but what the lecturer did not know was that I liked Howell's generosity of ideas, especially as I think I grew better at noticing the gold flecks in the torrent of his speculations. Howell struggled out loud with many concepts at their earliest stage of conception; before equations, before even symbols or names for the relevant quantities. To help him he loved making sketches when trying to interpret photographs or experimental results. What are the significant length scales? Are there differing velocities or a preferred frame of reference? What are the important forces at work? Is there a dimensionless number, such as an aspect ratio, whose smallness can be exploited?

To me it is worth highlighting the difficulty that scientists, engineers and mathematicians have in the early stages of making a new mathematical model. Before one has the notion of a balance of processes, a researcher struggles to express the right question, clumsily sketches a diagram, or talks speculatively with colleagues to try to interpret a photograph. In the field of water waves, Howell energetically worked to get to the point where he could apply mathematics to some new facet of free-surface flow: interactions between waves and the bed; wave-wave interactions; wave steepening, breaking and overturning; the processes happening in a spilling breaker; sloshing in lakes and containers; and the forces due to waves meeting structures. Once he had ideas nailed down he was swift to work out the mathematical consequences and publish, usually in collaboration. Then he went to work again translating ideas for different professional communities, especially among engineers, and publicising work through talks.

Working with Howell:

From the year after my MSc, when I worked in industry, I had learnt computer programming. Howell set me to work on a computer code called CHY, written by John Dold (then a postdoc at Bristol and now a professor at Manchester University), and two PhD students, Mark Lewy and Fernando Teles daSilva (now a lecturer in Rio de Janeiro). The program CHY computed the irrotational flow beneath a moving liquid surface on which the exact nonlinear boundary conditions were satisfied to a high degree of approximation. With this it was possible to solve numerically initial value problems, and follow very accurately the motion of solitary waves steadily propagating in water of constant depth. This solitary-wave work was done by M. Tanaka at Bristol. The joy of CHY was that it was based on a complex variable formulation of the water wave problem, and employed symmetry of the domain by reflection in the flat sea bed. (This followed different earlier work by Michael Longuet-Higgins and E.D. Cokelet.) The use of complex variables meant that conformal mappings could be used to solve flows in more complicated fluid domains, by transforming the physical plane to another complex domain possessing a flat bed, and back again at every time step. Howell set me this task and the first shape we treated was a submerged semi-circular bump, which the conformal mapping laid flat on the bed. We sent a solitary wave over the top. The surprise was that if the radius of the bump exceeds 70% of the still water depth then, after the main wave has passed, a secondary wave forms over the bump and breaks *backwards* away from the departing solitary wave. (Why do waves usually break *forwards*?) Here the backwards breaking was a qualitative feature of the computations which we could check against experiments. Howell's world-wide connections helped set up my first visit in 1987 to Santander, in Spain, where Miguel Losada and Cesar Vidale's group worked in their long wave-tank facility. They made a concrete semi-circular bump to put on the floor of the wave channel and the very first wave sent over it showed a line of perfectly *backwards* breaking water near the obstacle.

I followed this up with a second visit in 1988 and the results were presented at Torremolinos for the International Coastal Engineering Conference. I remember the meeting because Howell was there and we shared a hotel room. I observed Howell's spartan habits at close quarters. I never saw Howell touch alcohol and he was a life-long teetotaler. That said, he was always sociable and good at looking after party-goers.

Some of his Students and Co-Workers:

From 1986, when I joined Bristol, until the end of my employment with him in November 1992, Howell had (as he had throughout his career) many postgraduates and postdocs simultaneously under his care. His first PhD student was Ron Smith, now a professor at Loughborough University. To judge just a six year spell, my contemporaries, also working with Howell included Nick Dodd, Nilesh Popat, Marcus Naraidoo, Adam Anderson, Robert Tong, Rhys Gwynlliw, Fernando Teles daSilva and Mark Lewy. I also helped Howell supervise Maggie Topliss, at the start of her successful thesis work. For shorter periods while I was there John Dold, Jane Lawrie, Gary Watson and Declan Diver were postdocs with Howell, and soon after I left other postdocs who collaborated with him were Karen Henderson, Laurent Thais, and Serafim Kalliadasis. Also there were many overseas visitors who came to talk with Howell about research. Notable was A.A. Korobkin, a world authority on fluid impacts. We postgrads were all decidedly different characters and I now have the experience to know that this put stresses on Howell's time. He kept up a round of at least weekly meetings with all his co-workers. He certainly set high standards of evidence-based research. I slowly got used to Howell's multiple redrafting – his capacity for writing comments on others' drafts of chapters and papers was inexhaustible. I had to be careful not to ask for *final* comments! His last postdoc was Dr Henrik Bredmose. Over his career he collaborated with 29 postdocs and supervised 26 PhD students who successfully completed.

Peregrine International:

Howell hosted several important workshops at Bristol, including *Floods due to High Winds and Tides* in 1978. One which I helped organise, in 1991, was *Nonlinear Wave Propagation*. It was notable for the large proportion of Russian and east European researchers who were then only just becoming free to visit the West, and who beat a way to Howell's door. The grandfather of 20th century water waves, V.I. Zakharov, came to preside as the official Chair of the Workshop.

Across the world there seemed to be engineers, oceanographers and scientists who knew Howell's papers or happily remembered his visits. To introduce myself I would say "I am from Bristol", and so often the reply was "Ah, so you must know Professor Peregrine!". For me to admit that I actually worked with Howell usually brought wide smiles and opened doors.

When travelling abroad he was a celebrity: I often saw Howell approached by conference delegates who wanted to be photographed next to the great man. He took this in typically dignified Englishman fashion, but I could tell he was delighted with the real admiration with which he was held overseas. He had many friends in America where he had travelled extensively, including Ib Svendsen and Jurjen Battjes.

I'm grateful to Professor Mitsuhiro Tanaka of Gifu University for the following account of a trip that Howell made to Japan in August 1987. This was in the year following a collaborative visit that Mitsuhiro made in Bristol, which involved wave-breaking computations of the fully nonlinear equations of free-surface flow, and which were reported in JFM by Tanaka, Dold, Lewy and Peregrine, 1987 as *The instability and breaking of a solitary wave*. Howell was at a symposium in Tokyo, to present this work, and afterwards they both travelled to Fukuoka, after a plane journey to Kagoshima, because there are many wonderful tourist attactions between these two cities. Mount Aso and Takachiho are among them: Mount Aso is a large active volcano with a huge caldera, and Takachiho is a hilly area known as the place where it is believed that thousands of years ago the descendants of the gods who created the Japan Islands descended to the ground from the sky for the first time. They rented a car to drive the nearly 600km (with two overnight stops), to their destination. On the way they took in the sea coast, and while walking on the beach Howell whipped out a hand lens to examine the flora and insects. Howell knew the Latin names for the local trees and flowers. Mitsuhiro was impressed by Howell during a train journey: instead of just relaxing and watching the scenery go by in a foreign country, Howell noticed that there is a *classification* of three distinct Japanese roof styles. He was not just seeing the scenery from the train window like some tourist, but *observing* it. Howell also had a chance to experience unusual fluid mechanics: sharp-crested waves and splashes on a boat trip on the fast flowing Kiso River, being photographed leaning far back into a strong wind on Mt. Aso, and observing the froth on the surface of tea stirred with bamboo, served by Mitsuhiro's sister.

Summing up, Mitsuhiro told me, "I feel that he was a natural philosopher who possessed a keen sense of practical significance."

Howell and the Birth of a Research Idea:

This story is about just one of Howell's ideas: I make a survey of his published findings in the next section.

In the last months of 1989, just as the map of European borders was being redrawn, I was trying to finish my PhD thesis, and Howell was getting increasingly interested in violently breaking waves. Some CHY computations had shown that if a steepening water wave meets a vertical wall the free surface can move much more violently than in the absence of the wall. If the initial conditions are just right then the wave does not have enough room to overturn. Instead the wave can either trap a small space of air against the wall or, more interestingly, make a violently accelerating jet that shoots upward. We were able to compute surface-particle speeds of tens of $\sqrt{gh}$, (where $\sqrt{gh}$ is the characteristic wave speed in water of depth h). And the accelerations were phenomenal: thousands of times greater than g, the gravitational acceleration. Together we talked often with the help of blackboards about how to *model* this mathematically, teasing out questions such as "How can we characterise such big velocity changes over such short time intervals?", and "If the pressure is zero at the free surface, which are the significant terms in Bernoulli's equation?", and so on..... With Howell, there were always questions.

In the early spring of 1990 we had another late afternoon conversation, and he left my office saying, "I'm sure there's something in Lamb about this". Whatever he had in mind I couldn't find it in my copy of the great work *Hydrodynamics* by Horace Lamb, but some synapses must have snapped and reconnected overnight in Howell's head (it was rumoured, plausibly, that he took the latest volume of JFM to bed). The following day he returned with the relevant article on page 11 – a theory for the instantaneous pressure field which brings about a change in the fluid velocity! And, even better, the idea connected with his work on the initial wavemaker problem sketched out in 1973, on an overhead projector slide, now lost. We found that we could turn around the ideas in Lamb and treat the change in momentum during impact as the cause of the impulsive pressure field. An impulse was created by the forces of reaction exerted by the boundaries on the fluid. This was all very good for my thesis. But Howell's excitement and the redrafting, delayed my thesis submission. I had every reason to be grateful though, as I continued to be employed as his research assistant. Howell coined the term "flip-through" for the whipping action of the free surface near the wall during impact. I didn't like the term at first, but when I found other people using it I realised that the idea was propagating!

Here's a demonstration of a violent flow that you can try, and which Howell loved to show visitors. Put a few cubic centimetres of water in a plastic drinking cup and throw it up and away out the window of a building at least three storeys high. If you can manage to get the water to start its fall as a single blob then, by about the third storey downward you should see the blob explode into a pretty shower of droplets. Howell used to argue about what forces between the air and the water blob could cause the *suddenness* and *violence* of this explosion. What do you think?

Research Ideas:

Howell's Cambridge PhD thesis includes pioneering computations (on the University Mathematical Laboratory EDSAC II Computer) of the Boussinesq equations of wave propagation from constant depth onto a plane beach; work which later appeared in JFM as his first two papers: *Calculations of the development of an undular bore*, of 1966, and *Long waves on a beach*, of 1967. These papers are set in two spatial dimensions but he went on to treat the moderate influence of changing channel width and three-dimensional motion, in two further JFM papers *Long waves in a uniform channel of arbitrary cross-section* and *Solitary waves in trapezoidal channels*, published before 1970. In the book *Waves on Beaches* (1972) edited by R.E.Meyer, Howell brought together much material that is scattered in the literature, in a paper entitled *Equations for water waves and the approximations behind them*, (pages 95–121). Two later papers relate to his computational work on runup: in 1979 Stephen Hibberd and he wrote *Surf and runup on a beach.* Howell followed up this theory with a 2001 JFM paper, with PhD student Steven Williams, entitled *Swash overtopping a truncated beach.*

Howell also wrote on waves and currents. His first paper on this, in 1971, is about the waves in a ship's wake. Then he published papers on river currents and trains of waves, in 1972 and 1975, with Ron Smith. In 1976 he wrote a review article for the journal Advances in Applied Mechanics: *Interaction of water waves and currents.* When a wave crest is bent by refraction (due to a change of depth or a current) the local convergence of wave fronts can force the free surface steepness to become locally too high for linear or shallow water theories to describe the subsequent motion adequately. The focussing of waves at a caustic was discussed with Miky Stiassnie in their 1979 Philosophical Transactions of the Royal Society of London paper *Nonlinear effects upon waves near caustics.* In 1981 they continued their collaboration with two JFM publications, one on the shoaling of, and a second paper on the refraction of, finite amplitude surface waves in water of slowly varying depth. Also in 1981 Susan Ryrie wrote, with Howell, on the refraction of waves of finite amplitude which are obliquely incident on a beach. Other work on surf zone currents appears in a review in his 1998 contribution to Theoretical and Computational Fluid Dynamics. He also contributed to a joint JFM paper in 1999 to an understanding of how internal waves (and hence their associated currents) can bring about the focussing of surface waves.

Howell's interest in Schrödinger's equation led to a 1983 article in the Journal of the Australian Mathematical Society. Here he derived 'breather' solutions of the Schrödinger equation and discussed their relevance to water waves. Subsequent writers have shown how important this work is to help us understand the so-called freak or rogue waves that appear without warning to mariners. With J.R. Stocker, in 1999 he derived a Schrödinger equation that included the influence of currents. Other computational work with the nonlinear Schrödinger equation in 1999 was published with Karen Henderson and John Dold which appeared in Wave Motion.

The dynamics of strong turbulence at free surfaces is shown clearly in Howell's famous photograph of the Severn Bore. In the image the water surface is partly smooth, and partly rough, bubbly and turbulent (where the wave is breaking by the riverbank). For the 1978 International Conference on Coastal Engineering he presented experimental and theoretical work that he'd done in collaboration with Ib Svendsen in their joint paper *Spilling breakers bores and hydraulic jumps.* Years later, in 2001, Maurizio Brocchini and Howell investigated this topic again in two JFM papers. One of the driving forces behind this work was Howell's long obsession with trying to understand the flow in the frothing forward face of a spilling breaker. This topic came up in his conversation so often that it became *the* problem of *the* spilling breaker.

In 1985 Howell wrote a paper in JFM (volume 157), stimulated by work of Frank T. Smith and B. Fornberg, that contains eleven lines of displayed mathematics, only three of which are equations, the other eight are order-of-magnitude expressions accounting for the distinct regions of flow behind a circular cylinder in flow whose Reynolds number exceeds 100. The work concentrates on what can happen downstream to the vorticity generated by the boundary layers that separate from the cylinder.

Late in his career Howell derived a new approach to vorticity, this time in the surf zone. This work with Onno Bokhove, should be better known. It first appeared in the Proceedings of the 26th International Conference on Coastal Engineering, 745–758, in 1998. Further consequences appeared as *Large-scale vorticity generation by breakers in shallow and deep water*, in the European Journal of Mechanics B/Fluids **18**, 403–408, 1999. The essence of these papers is the proof of a theorem, and just a few of its consequences. Suppose a breaking wave has a finite length of crest and that there is a discontinuity in surface elevation along the length of the crest, such that the difference in water depths and the changes in the horizontal velocity component normal to the crest line are governed by the classical theory of the hydraulic jump. Then if you consider a geometrical loop L which encircles one end of the crest line and which terminates at adjacent points on the two sides of the crest line, then the circulation Γ in the fluid around L is changing at a rate $d\Gamma/dt$ that Howell proved is given by an expression that is directly proportional to the rate of energy loss (as predicted by the classical hydraulic jump theory). One consequence of this generation of circulation is that vorticity (with a vertical axis) must be being generated by breaking waves, especially so at the two endpoints of any length of breaking-wave crest. Other consequences of this theorem are still being worked out (see the 2008 PhD thesis of L.Solorzano Sanchez, UEA) but they suggest the possible presence of high concentrations of vorticity and local currents very close to the shoreline. The influence of vorticity currents on subsequent wave breaking, sediment movement, pollutant dispersal and swimmers' safety are all worthy of more attention.

On another topic, Howell published photographs (taken by two Bristol University undergraduates) of the bifurcation of a liquid bridge, in which a water droplet was falling and separating from the rest of the fluid exiting a tap, published in JFM in 1990. The images show a remarkable asymmetry: just before the instant of separation the top of the spherical drop is attached to a cone of water above it. He also wrote on the low-Reynolds-number flow of a liquid flowing downhill with a free surface, in collaboration with Rhys Gwynlliw.

There are also his papers on wave impact, including overtopping, the influence of air entrainment, the cleaning of containers and the majestic phenomenon of wave spray plumes next to structures. All this is linked with him trying to understand the mechanics of flip-through. He spent a lot of time on the engineering problems of interpreting, fluid mechanically, the presence of cracks and cavities made by wave action on sea walls. New cracks are often found after a storm has passed, leaving few clues as to what the waves were doing while the damage was being created. The increasing speed and resolving power of experimental photography and on-site video pictures have given ever more tantalising glimpses of the violent flows of wave impact. With each step, more is revealed, and more questions can be asked. With others, Howell computed, modelled, experimented and wrote many papers on these topics. One of his last papers was in 2007, which appeared in volume 54 of *Coastal Engineering*, (pages 602–617). It was the fruit of a long collaboration with the Plymouth engineering experimentalist Geoff Bullock, C. Obhrai, and his last postdoc Henrik Bredmose. They reported detailed computations of wave impact against a vertical seawall, with an account of the trapped air content and the forces generated by the violent collision. The paper also reports peak pressures of many atmospheres measured in-situ during full-scale wave impacts against Alderney breakwater in the Channel Islands. Engineers Gerald Müller (Southampton) and Tom Bruce (Edinburgh) collaborated with Howell to interpret measurements of wave impact pressures in an artificial crack placed in situ. Theoretical and numerical work on high-pressure aerated flow in cracks led to a PhD in 2003 for Ann McCabe (née Porter) under Howell's supervision.

His Other Work:

While Howell had many simultaneous research projects, he was also doing a full load of teaching and administration, ultimately becoming head of the Applied Mathematics Group at Bristol. He was also an associate editor for the Journal of Fluid Mechanics, processing 1200 papers over 28 years of service. Every paper had at least three referees' reports. In the first two pages of volume 580 of JFM, Keith Moffatt paid tribute to Howell for this "massive contribution to the continuing success of the Journal." One of Howell's research training exercises was to get extra opinions on submitted work from his postdocs. He once gave me something typed on flimsy airmail paper with the parting comment: "The references look a bit old; tell me what you think, with some more recent references." The paper looked rather good, so I went to the library and found some related papers. By pure chance I found an obscure one that was identical to the submitted paper! I took the evidence to Howell, and he and I giggled nervously, because we had both come so close to being badly duped.

Howell's own comments to authors sometimes provoked them to do new work. Someone told me of a paper that the referees were satisfied with, but in which there was an unevaluated constant, about which Howell nagged the authors. Eventually the researchers did some interesting new work and wrote an appendix to explain how to evaluate the constant. They then resubmitted the paper. When Howell read and understood the appendix he asked for it to be removed, as it was now superfluous!

Other administrative work that Howell did very well was winning grants. His colleague David Evans at Bristol estimated that Howell was awarded over £1.3 million (then about two million US dollars) in research grants over his career, and this was for *mathematics* during the 1980s and 1990s, an era of cuts in UK academic funding. And all the time he was writing journal articles and conference papers: around 200 refereed items in all, on every aspect of water waves: waves and currents, breaking, waves over topography, wind-wave interactions, caustics, the nonlinear Shrödinger equation, computations, experiments and nearly always in fruitful collaboration with experimenters, students (including undergraduates) and other theorists.

The Society for Underwater Technology gave Howell their 2001 Oceanography Award, in recognition of his outstanding research into all aspects of waves and currents.

Howell as a Public Speaker:

Howell's public speaking style was energetic but amorphous. He would start excitingly and then find himself wanting to talk about six different things. With his experienced command of the subject, Howell could talk well about all six things, but he struggled to find the right order in which to take matters. He got better at giving seminars and he quickly embraced the power of visual display software and data projectors. His chairmanship could be a show-stopper: I once saw him halt a Royal Society discussion meeting to interrogate a speaker about his first line of mathematics; a form of the mass continuity equation.

He was not an easy lecturer for his audience to follow, particularly for beginners. A former Bristol undergraduate (who is now a fluid dynamicist) told me Howell was "not particularly good at giving lecture notes, but he was very enthusiastic." In research talks, I enjoyed the excitement and passion that Howell radiated when he was showing vivid photographs of waves and talking about the physical processes at work.

Writing, Reading and Observing:

Howell took his writing style and discipline very seriously, (as you would expect for a JFM associate editor). He disliked certain over-used or misused words, among which were "used" (lazy), "interaction" (reserve for when A influences B *and* B influences A) and "computer simulation" (cartoons and movie special effects, not science). He knew and admired great scientific prose, and yet his boyish exuberance in talk sometimes broke through into his writing. His essay *The fascination of fluid mechanics* is positively playful (and includes his famous Severn Bore picture). It appeared in the 25th anniversary issue of JFM, in 1981. (It appears along with a marvelous article that Howell strongly recommended, by George Batchelor entitled *Preoccupations of a journal editor*.) On another occasion Howell broadened my reading when we were talking about sand dunes on the shore: Brigadier Ralph A. Bagnold's *The Physics of Blown Sand and Desert Dunes* is a fine book. (Bagnold also did pioneering work on water-wave impact forces.)

I could never match Howell's observational powers, and to help me he suggested M. Minnaert's book *Light and Colour in the Open Air*. Here are six examples of Howell's observing skills: (i) In a talk he once showed a picture of waves breaking on Bondi Beach. The crest had a swept-back mane of spray. I asked, was the wind offshore? He explained, no, the air was still; it was the forward motion of the wave which caused the air to comb back its summit. (ii) Don't vertically exaggerate a plot of a wave's profile because it changes the slope of the surface. (iii) Howell said "It can be the *difference* between the theory and the experimental data that shows the science missing from the model." (iv) A white china tea cup outdoors: the rays of sunlight reflect inside the cup and come together in a bright pattern called a caustic; this is an example of geometric optics (Howell was interested in caustics because they occur in water waves in wakes and currents). (v) To photograph waves, first point your camera *towards* the sun's reflection on the water, and then a little away from that to find the maximum contrasts in light intensity on the surface (and an overcast sky can be helpful). (vi) To become expert in observation, "Never lose a chance to watch waves!"

Howell was an accomplished photographer. He often arose early on trips to "catch the best light" (he also reckoned the weather was best soon after dawn, whatever it turned out to be later in the day). David Griffel told me that Howell sometimes took stereoscopic pictures of landscape scenes: his technique was to use an ordinary camera loaded with colour slide film: take one picture and then move a pace or two to the side and take another picture of the same scene. After processing, the two small slides may be lined up side-by-side so that your eyes can juxtapose the pictures, and so create a stereo view.

His waves pictures were famous, but he had a less well known interest in geology, wildlife, flowers and fungi, and he kept an allotment. During 1974-5 he was President of the Bristol Naturalists' Society. He once told me that he had been surprised the day before at his home, to see on the ground just outside his back door, a falcon clutching a pigeon that it had only just killed. The falcon was in a stand-off with a cat that also wanted the pigeon!

Howell's Upbringing, Academic Career and So-Called Retirement

I left Bristol in November 1992. Howell continued to supervise PhD students and postdocs beyond his so-called retirement in 2004. (He disliked the word retirement, with reference to himself.) The meeting that celebrated his fortieth year at Bristol, his sixty-fifth birthday year and his twenty-fifth anniversary as a JFM associate editor, was entitled *The fascination of fluid mechanics*, after his famous essay.

The two-day meeting was well attended by Howell's many former co-workers, and the event included a dinner at which Howell gave a speech in which he reminisced about his happy childhood. Howell was born in Prenton, Birkenhead, near Liverpool. He showed pictures of his fascination with beaches and waves from the time he could walk. His mother, who was present, confirmed that he was a scientist from the start. Howell's father, 'Peri', was a great influence: he was an engineer who, among other things, worked on the Whittle jet engine during the Second World War, and he became a consulting engineer. Peri kept a huge library of technical works (that I once saw); he did original work on gear design and he was a member of both the Institute of Mechanical Engineers and the Institute of Electrical Engineers.

After moves to North Wales (to avoid wartime bombing), to Yorkshire in 1941 and Tynemouth in Northumberland in 1945, Howell's family settled in Kelshall, near Royston, in Hertfordshire, in 1950. Howell had two younger brothers, David and Roger. From pre-school age Howell was fascinated by maps and atlases (a delight that expanded for him into the age of internet access to relief maps of the Earth's surface). Howell's teenage education was at the Hitchin Boys Grammar School, founded in 1639. As a very able student, especially in maths, he used the time going to school by bus each day by talking with other students and helping them with their last-minute homework. In this way he began very young to teach and supervise.

While still only 16, Howell won a state scholarship for entry to Oxford University. With this to look forward to, he took a year out, between school and starting university, during 1956-7 to travel in the USA, and he sailed home on an Irish freighter. Although Howell described himself as an engineer, he studied for his first degree in mathematics at Jesus College, Oxford University and he worked in mathematics departments from then on. During his first degree, he had a summer internship at the Royal Astronomical Observatory at Herstmonceux, Sussex. In 1960 he became a PhD student in the newly established Churchill College at Cambridge University, supervised by the eminent applied mathematician T. Brooke Benjamin. He already rowed at Oxford, (a hobby that he kept up in later years) and at Cambridge he used this viewpoint to watch waves in the wakes of boats, and wave reflections at the river banks, topics about which he wrote papers later. His doctoral thesis includes pioneering computations of the Boussinesq equations, for the propagation of waves onto a beach; work which later appeared in JFM. Howell held a research fellowship at the Institute of Oceanography of the University of British Columbia, in Vancouver in 1964. His lectureship at Bristol was his first academic post, from 1964.

In the early 1970s Howell married Gill, a school mathematics teacher who had been a mathematics student at Bristol University. Together they had three children: Lucy, Tim (who is a trained engineer) and David.

In 1987 he became Professor Peregrine and gave his inaugural lecture *Waves on Beaches: the fascination of fluid mechanics.*

After 'retirement' in 2004, Howell kept working at Bristol as an Emeritus Professor. He hardly slackened his daily schedule in the department of 0845 start and 1730 finish (taking work home with him). Except when he entertained visitors to lunch, he ate frugally from a tiny lunch-box, and drank coffee from a sludge-green mug. He cycled three miles to work, and three miles home each day, and when it rained he wore a mud-yellow cape, wellington boots and a sou'wester. He moved out of his fourth-floor office into the nearby Royal Fort Annex, and then into another annex on St Michael's Hill still close to the Mathematics main building. I last saw Howell at the April 2006 British Applied Mathematics Colloquium, in Keele. He was thinner I thought (he was always very healthily slim) and his talk was as sharp as ever. His conversation had even broadened, and we were able to talk about art – he had become fascinated by Salvador Dali. This was a late blossoming of a less well known interest he had in mountain landscapes, landscape painting and visiting art galleries when on trips abroad.

Near the End:

At the start of 2007 Howell was suffering back pain. He was diagnosed with an inoperable cancer which had already advanced onto his spine. He continued to help supervise PhD students and do work for JFM. One colleague who visited Howell in Bristol's Southmead Hospital saw that, despite lying in his sickbed, Howell took as much interest in books, toys, gadgets and the conversation of his visitors as he had ever done while at work, and during his last days he was still trying to supervise PhD students.

Towards the end of March 2007 Howell died in his sixty-ninth year. His funeral was a public event for all his family and friends. During the funeral service people spoke warmly of Howell's influences on their lives. At the reception afterwards there was plenty of conversation about the many sides of Howell's life and work. Howell's son, Tim, summed up his devotion to his family: "As a father he was perfect". He was buried, in a whicker casket, in the Memorial Woodlands at Earthcott Green, a few miles north of Bristol.

Soon after the funeral I visited Howell's last office. I sat in his chair and looked at his beloved books on the shelves. Under the desk was a pair of his sandals. It reminded me vividly of Howell cycling vigorously in those sandals, his white plastic panniers loaded with papers, and his gaze far off, thinking about some problem on a distant shore.

Acknowledgments: I thank the Chief Editor, Henk Kuiken for asking me to be guest editor for this issue commemorating Howell Peregrine. I am also grateful to Associate Editor Alexander Korobkin for his editorial help. I thank Tim Peregrine, Mitsuhiro Tanaka, David Griffel, Henrik Bredmose and Jurjen Battjes for their detailed and illuminating stories about Howell. I thank also all those who knew Howell and who encouraged me to take on this project, especially Hubert Chanson, Alison Hooper, Onno Bokhove and Maurizio Brocchini. Although I cannot name them, I thank the many referees who skilfully scrutinized the draft papers submitted for this special issue.