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Coastal engineering—quo vadis?

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Abstract

This paper traces the development of coastal engineering, drawing parallels with history of civilization and development of society in general. It recognizes three distinct ages—those of providence, progress and nihilism. It recalls the impact of the enlightenment and describes the rise of the modern era, in which coastal engineering has its roots; the time with the underlying motto "yes we can!" Next, we follow the move to postmodernism where we find that our models have practical limits, that there are no single, correct answers and that good coastal engineering is not necessarily good. We explore the concepts of uncertainty, pluralism and sustainability. Finally, we attempt to find some direction to proceed with coastal education, research and management within the postmodern environment.

1. Preface

This is not a finished story. It is merely a discussion. It is incomplete and waits for all of us to complete it. This essay is also written from a western perspective. There are many other, parallel developments that are not discussed here.

2. Introduction

To understand the history of coastal science and engineering requires an understanding of the history of civilization and development of technology. I am greatly indebted to Lyon (1999) for the basic ideas.

The development of western society over the past few millennia can realistically be divided into three ages, as summarized in Table 1. In the first age, a very short time ago (on a geological time scale) or a long time ago (on our cultural time scale), the operative word was providence. Every civilization believed in God (or gods) and his (her) laws were the rule of life. Life was simple—please the gods and they will protect you and provide for you. But a few hundred years ago,[1] this lifestyle became too simple for some. They thought that human beings, who could reason, should be less dependent on fickle gods. They proposed that we take our lives into our own hands and become responsible for our own fate.[2] The inscrutable laws of the gods were replaced by the one aspect of life that appeared constant—the laws of nature. These laws were perceived not to be inscrutable; they could be subjected to study. It was expected that we should in time be able to understand these laws of nature and then steer our own course into the future. Definite progress along the line from relative chaos to relative order was expected.[3]

[1] The recorded notable exception was the Sumerian culture (4000 BPE). Their civilization was the first to move away from a simple agrarian survival routine and think independently of their gods. They invented writing to record their thoughts and the Gilgamesh epic (2700 BPE) describes their relationships to their gods. They also invented ownership of property, the wheel (3700 BPE), the plow, and a math system (base 60, which is still in use in our time keeping). Hammurabi (1700 BPE) who re-united the Sumerian civilization as Babylonians is known for his vast irrigation and construction projects as well as his codification of the Babylonian laws (from which many of our legal tenets are derived). Greek thinkers formed the next exception of total dependence on their gods (400 BPE).

[2] This involved moving away from an agricultural society, as it did for the Sumerians.

[3] This so-called enlightenment was the general change in thinking that brought us into the modern world. It was not the first such major shift as we already noted for the Sumerians and Greeks in footnote 1.

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Table 1
Simplified view of development of western society

Age	1	2	3
Keyword	Providence	Progress	Nihilism
Time	400–1600	1600–1800	1800+
Philosophy	Hippo	Enlightenment	Nietzsche, Heidegger
Laws	Laws of the gods	Laws of nature	None
Crux	History is linear (not cyclical as believed earlier). Hope is future-oriented (other-worldly).	Secular version of providence. Hope is in a future here on earth.	Futility of any system. Progress is an aberration.

As "scientific" work began, the laws of nature became better understood and it appeared that this understanding would ever increase to a point where we clearly knew what they were, how we had to deal with them and even how we could make improvements. The *modern*[4,5] era had begun. Scientific method and discovery was the new paradigm. Anything was considered possible, given the right environment. After that we began to discover that perhaps life will remain inscrutable. Why, in the light of the enlightenment and all that rigorous scientific follow-up were we not able to provide neatly closed solutions? What about violence and war? Why can we not prevent the common cold?

A new era began with thinkers such as Nietzsche (1844–1900), Heidegger (1889–1976) and others. In sociological jargon, this is called the *postmodern*[6] era. Although these new ideas required some time to take hold, it is now generally perceived that mainstream thinking today is postmodern. Some individuals and whole areas of life still subscribe to modernity. (Yes, we can!—given enough funding, effort, education and research.) Much of such antiquated thinking is actually still found in the areas of science and technology, which are the direct descendants of the modern age.

In this paper, the journey of coastal engineering will be traced through examples of societal changes with a focus on science, technology, hydraulics, fluid mechanics, and finally coastal engineering.

3. Modernity

The rise of modernity can be traced through some societal benchmarks, as in Table 2. Also included in Table 2 are names and benchmarks from the fields of hydraulics, fluid mechanics. Coastal science and engineering[7] prior to 1950 was mainly concerned with large issues of national interest, such as national defence, transportation and safety from flooding. The keyword for the modern era was progress and the tools to achieve this may be characterized by system and organization. The rise of the great research institutions began in this modern era—every country needed (a) national research organization(s).

Coastal engineering and science were born and grew up in this buoyant atmosphere of modernity. The pioneering work of wave forecasting and maritime construction to support the effort of World War II from 1940 to 1945 was followed by a large expansion of funding and facilities related to coastal engineering. Fishing ports needed to be built and improved. Harbours needed to be built and expanded to accommodate both larger and more cargo-specific vessels. New transportation systems needed to be developed. Shorelines were improved and shore protection was built to provide safety against flooding and shore erosion (Kamphuis, 1996). The International Conferences on Coastal Engineering began in 1950.

In this modern era, every bit of research was indeed expected to add to the general body of knowledge and, given time and funding, the solution of coastal problems could be improved and accurate answers for questions that had been there since antiquity could be provided. These were halcyon times and in the midst of all this optimism, the computer arrived, spurring even greater euphoria. These exciting times continued into the 1980s.

Table 2
Modernity

Modern is defined by its system, organization and progress	
Societal benchmarks	Fluids parallels
Age of enlightenment (1600–1800)	Galileo, Descartes, Pascal, Hooke, Newton, Leibnitz
Industrial, French and American revolutions (1750–1850)	Bernoulli, Euler, d'Alembert, Lagrange, Laplace, Gerstner, Chezy, Navier, Coriolis
Victorian era of optimism (1850–1910)	Saint-Venant, Airy, Russell, Froude, Francis, Stokes, Helmholz, Kelvin, Dupuis, Vernon-Harcourt, Pelton, Boussinesq, Reynolds, Rayleigh, Lamb. Work on waves and wave theory. Some coastal modelling
Chicago world's fair "A century of progress" (1933)	Physical modelling—the large laboratories start. Much of the work related to transportation and national safety. Engels, Rehbock, Freeman
Rise of National Socialism (1933–1945), and "World War II"	Waves and coastal research takes place in support of the war effort (Sverdrup, Munk)
Post-war optimism (1948–1968)	Prandtl, Blasius, von Karman, Taylor, Bakhmetev. Large research institutions flourish
Science and technology boom (1948–)	Explosion of hydraulics facilities and papers in all areas of hydraulics and fluid mechanics
Rise of consumer society (1948–). Demand for industrial products (houses, automobiles, infrastructure) increased rapidly	Real beginning of coastal engineering in support of transportation (shipping and ports), safety against flooding and erosion, and tourism

[4] We will use some sociological jargon, in particular the terms *modern*, *postmodern* and *paradigm shift*, because they are flags that identify rather complex societal developments and have become generally adopted into our lexicon.

[5] *Modern*: Belonging to the era when we thought everything was possible, the era when society was certain it made progress.

[6] *Postmodern*: Belonging to the era after we woke up to the fact the premises of the modern era are false.

[7] Coastal management is a very recent discipline. Historically, it was synonymous with coastal engineering. Managing the coasts (essentially to maximize their economic value) was expressed completely in design and construction related to personal safety, military defense and transportation (Kamphuis, 2000, Ch 10).

4. Towards the end of coastal modernity

However, clouds appeared on the horizon of this bright future. At the 1970 International Conference on Coastal Engineering in Washington, an impromptu discussion took place about the real value of hydraulic model studies—the backbone of coastal research and design. Although the clients trusted the model results, the modellers themselves had difficulty believing them. They saw that physical modelling, upon which much of coastal engineering knowledge was based, had reached practical limits. Because of limitations such as scale and laboratory effects, models could only provide answers up to certain levels of accuracy. To improve the results, larger models were used, however, the cost of such models was exorbitant and clients were no longer willing to pay for them. This *malaise* increased as time progressed. This was essentially our manifestation of the coming to an end of the modern era. Table 3 describes some of the symptoms in more detail.

The *malaise* appears at different times in different disciplines. Whereas some philosophers began to feel uneasy about progress and the directions of modernity already in the 19th century, some scientists and engineers are still not aware of the limitations of modern science and technology in the 21st century.

The recognition of limitations in a particular field is related to where the discipline is on the learning curve. Electronics, communications and data transmission, for example, are still on the steeper part of their learning curves. A level of optimism that larger, faster computers, smaller chips and more sophisticated software will help solve some of the world's problems appears to be justified. The same is true for health care research. Nevertheless, an overall recognition that the modern era has come to an end even in those fields would help to place this research in a postmodern context.

In the coastal field, there may still be some who believe that more sophisticated numerical modelling will provide ever better answers, but most scientists and engineers now recognize the uncertainties of our methods and results. They are also aware that it is unlikely that we will be able to produce much better answers in the future. Many of us no longer believe that knowledge in our particular discipline will improve rapidly and indefinitely. At the same time, clients are beginning to ask the same questions about numerical modelling, as they did in the 1970s about physical modelling.

As we approached the end of the modern era of coastal engineering, two new words gradually crept into the vocabulary of the coastal engineers and scientists. These were "sustainability" and "uncertainty". They reflect the realization that solutions need to be found with the future (of the world) in mind and that these solutions have limitations, which will probably not become much more certain in the future.

5. Postmodern coastal engineering

Postmodern influences on our technical discussions are evident everywhere in coastal engineering and management. As an example, let us look at Hamm and Stive (2002), an excellent special issue of Coastal Engineering (the journal). Its Vol. 47, No. 2 of Dec. 2002 is entitled "Shore Nourishment in Europe". This volume contains 6 papers, reviewing shore nourishment practices in Europe. The authors are top European designers and academics; well-respected scientists, engineers and modellers. The first article simply presents data and draws no conclusions. The second article discusses the use of (numerical) modelling. It questions basic concepts such as beach profile, depth of closure, influence of granulometry, determination of a basic state of the shore, and rate of lateral spreading of beach fills. It then continues to discuss uncertainties of the model results, caused by our inadequate knowledge

Table 3
The end of modernity

Societal benchmarks	Technical parallels
There seems to be an end (limit) to "Progress"	Theoretical frameworks, physical and numerical models cannot describe completely what happens in practice
Extrapolation of existing political and societal systems no longer works	Larger groins and higher seawalls, larger models and higher order equations are not the answer. (What good is a higher order equation when the coefficients that need to be introduced can vary over two orders of magnitude, without adequate explanation?)
Existing political systems, such as colonialism and finally communism disintegrated	Position of leadership and authority of some universities and national laboratories gradually eroded
Large agglomerations (e.g. "Africa", USSR, Canada?) were replaced by many small nation states	The few recognized centres of presumed excellence were replaced by many small centres of excellent thought and application
At the same time a few super states have remained or become important (e.g. China, US and the European Union)	Some of the large research and engineering centres re-emerged as (physical and numerical) superpowers
Some participants continue the modern course of development and progress	Most technical research and publication continues unabatedly along modern lines—systematic research is presumed to lead to progress
Negative impacts of modernity such as environmental degradation and depletion of natural resources lead to a questioning of status quo	Negative impacts of modern engineering such as environmental degradation and depletion of natural resources lead to a questioning of status quo
There seems to be too much emphasis on specialization and too little integration of the various disciplines	Communication between theory and academia on the one hand, and design and engineering practice on the other has broken down

Table 4
Some aspects of postmodernity

Societal benchmarks	Technical parallels
Cynicism: Democracy does not work—Vietnam war, watergate; mistrust of politics	Cynicism: Engineers have messed up and therefore cannot be trusted
Uncertainty: We cannot tell what will happen next	Uncertainty: The best engineering efforts and formulations cannot provide certain answers
Breakdown of recognized large, general systems into smaller, more specific subsystems (e.g. "music" becomes classical, jazz, rock, rap)	Breakdown of coastal engineering into separate fundamental, theoretical, academic, applied, computer-related and design aspects
Each new subsystem develops its own rules and language. Just compare a symphony orchestra with a rap group	Design, research, computing, etc. have their own goals, rules and languages
Communication between the subsystems virtually disappears	Much of coastal research is science (analysis) that has little in common with design (synthesis). Hence, practicing engineers do not read the latest papers, nor attend technical conferences (perceived to be too theoretical). Similarly, many researchers are not interested in solving "practical" problems (perceived to be unscientific)
All sub-systems speak simultaneously (All types of music emanate from same radio station)	Projects must still combine the separate worlds of design ideas, theoretical thought, research, computer simulation and ingenuity
Fragmentation prompts "holistic" approaches (interdisciplinary, trans-national, etc., and pop artists become soloists with symphony orchestras)	Unfortunately, the holistic tool *par excellence* in engineering has been the "bottom line". Hence, chief engineers are replaced by business graduates, accountants or lawyers who simply "plug in" the engineering
Work and its cultural implications have been replaced by consumerism. One is not judged by one's work, but by one's clothes, house, automobile	Many students attend university not so much to learn, as to be empowered to become consumers. Employees work, not to solve problems, but to earn money to buy consumer products
Authority is replaced by discussion	Theoretical instruction is replaced by case studies and extensive discussion. Lectures become seminars and workshops. Theory is replaced by databases and computer simulations. Extensive stakeholder discussions replace government directives
Knowledge is not sufficient. Relationships are important	Theoretical and empirical knowledge are de-emphasised. Discussions with stakeholders and relationship to the environment are emphasised
Reality is replaced by a mix of virtual and real	Numerical models with heavy graphics are thought to represent reality

of even these basic things. The conclusions are rife with "may" and "could". The third article discusses the design data obtained world-wide, using a type of physical model (large wave flumes). It presents a very long concluding discussion, which says essentially that hydrodynamic results are not bad, but sediment response and bathymetry change vary so much between various tests that it is difficult to draw general conclusions. The fourth article states that grain size distribution is important, but it needs much more work. The next article looks at large scales (distance and time) and concludes that we know little about these. The final article tries to summarize the European experience with shore nourishment. After 282 pages, the final statement is: "The facts and views presented in this paper are based on information available to the authors and on their personal interpretations that do not necessarily correspond with the opinions of their institutes and governments, nor with those of the European Union". Now, does this sound postmodern?

Not only do the engineers themselves lack the confidence of the past, but engineering also does not enjoy the public confidence that existed in earlier times, even thirty years ago. All our engineering societies now decry this (lack of) image and feel they must enhance (read "rightfully restore") the status of engineering. Unfortunately, this is only modern thinking in a postmodern society.

Atkins (2003) compares the Quantum hypothesis to a virus that "destroyed classical physics completely in just a few decades". "Not only did the virus eliminate some of the most cherished concepts of classical physics, such as particle, wave, and trajectory, but it also tore to shreds our established understanding of the fabric of reality." Then Atkins goes on to describe the uncertainty principle, Schrodinger's Equation, wave functions and probability distributions. Such is the *paradigm shift*[8] of physics. A similar paradigm shift is needed in our field. Perhaps not of the same order of magnitude, but a true paradigm shift nonetheless. A shift that clearly takes into account the aspects of postmodernity, as listed in Table 4 and encompasses some of its paradigms shown in Table 5.

6. About learning

Wolterstorff (2003) makes some very astute observations on learning. He defines modern "properly conducted" learning as a communal activity that is based on common human convictions (rational consensus) of the players. The shared human capacities of perception, introspection and reason are then used to move knowledge to a higher plane that eventually also enjoys rational consensus. Thus, modern learning moves single-mindedly from one rational consensus to the next rational consensus.

In postmodern times, Wolterstorff says that consensus was recognized as white, heterosexual, male, colonialist, whatever. There are other different viewpoints (pluralism). Wolterstorff also states that many now say that all learning is "particularist and perspectival". In any case, the modern concept of properly conducted learning has collapsed and Wolterstorff proposes

[8] *Paradigm shift*: A genuine shift from one model or standard to another—a profound change in thinking.

Table 5
Some paradigms of post-modernity

Societal benchmarks	Technical parallels
Bigger is not better: the United Nations now has many very small member states	Many small universities and research units are entering the field and are producing good work
Extrapolation must be replaced by change	Research focus needs to shift from mainly "safe" research, producing many papers (extrapolation) to more innovation. Real innovative research may only have a small chance of success, but the successes produce quantum leaps that, in turn, can be followed by many years of "safe" research. Similar comments could also be made about engineering practice and engineering education
Global and yet: The global village exists, but local concerns remain the focus of attention	Electronic communication has put engineers and researchers around the globe in immediate and constant touch. Knowledge has become a worldwide commodity. Yet most problems are still local
Sustainability	We need to consider the whole system and audit all projects (e.g. for the consumption of water and energy) to determine true sustainability
Learn to live with uncertainty	Our formulations cannot give answers with certainty. We need to learn to quantify this uncertainty, take it into account in design, and communicate it to the public
Increase in knowledge does not necessarily mean better solutions to problems	Better equations do not result in better drinking water. Being able to understand or model detailed sediment movement does not provide insight in long term coastal processes

that it be replaced by a "dialogic pluralism" (speaking to each other, listening to each other and being aware that there is no single voice of truth).

7. Where to in education?

Table 6 shows that in the area of post-secondary education a definite change in emphasis is needed. The lengthy modern era of education concentrated on knowledge generation and transmission of this knowledge through a strict hierarchical system—"recognized" universities hire professors of "repute" who pass theory and perhaps some examples on to students, who then go out to "improve" the world. All this was accomplished through highly structured lectures, possibly enhanced with tutorials. In the postmodern environment there is a need to introduce a more flexible education. In the past, an employer expected a new engineer to be "educated" (to know basic principles, to be able to apply them in a general manner, and to have some needed skills, such as surveying and drawing). Then the employer provided on-the-job training about particular applications of the knowledge attained at university (a form of apprenticeship). Now, a new engineering graduate is expected to be sufficiently well rounded and able to earn money for the employer from Day 1.

As a result, teaching theoretical concepts must be enhanced by extensive skills education (problem solving, management techniques, etc.) and education in relationships (with colleagues from different disciplines, with the public and with the environment). If design is the synthesis of varying concepts into a related whole, the task of engineering education has broadened substantially and integrated learning becomes an important part of the curriculum. There is a need for greater emphasis on design courses, teamwork, interdisciplinarity, communication, problem solving and self-directed learning. Seminars, workshops and projects will replace many of the more theoretical lectures supported by tutorials.

Fortunately, the needed changes fit within other developments of the times. First, students who have been raised on "show and tell", Sesame Street clips, 5-s TV sound bites, and constantly moving and flashing video images simply are not capable to sit through a 1-h chalk talk on the Navier Stokes Equations. Second, as the students grew up, their activities, such as music, ballet and sports were coached (in which improvement occurs by action, guided by coaching). Such students will thrive on project work guided by "resource persons". Third, students who have grown up with the computer can successfully navigate the internet, which is a most tangled, uncoordinated, unsupervised, unstructured mass of information of which 99% may be irrelevant and/or incorrect. Such students will also be able to sort through masses of input from various sources, determine what is germane to a problem and apply the information with proper coaching.

So there are really two perspectives that force major changes in strategy of the transfer of knowledge at university level: the employers' need to fit new graduates into a very complex world, driven by tight economic considerations, and the students' prior development.

Table 6
Emphases of education

	Modern	Postmodern
Knowledge	Generation	Transfer, communication, management
Teachers	Professor	Teams of professor(s), tutors, mentor(s) and peers
Professor	Researcher	Communicator, coach, cheer leader
Material	Sound theoretical development, illustrated by examples	Problem solving from experience provided by examples. Learning any necessary principles occurs along the way
Learning environment	Classroom, professor lectures	Seminars, project presentations, work terms and practicum in addition to lectures
Presentation	Chalk talk, overheads	Power point, TV, video, multimedia

What about the curriculum? What is taught? How is it taught? Multi-media instruction is not necessary to teach a basic concept or theory. A PowerPoint presentation of a theoretical development is a contradiction in terms. Development of theory is utterly boring in a PowerPoint presentation, and the glitz of PowerPoint or a multi-media presentation is an irrelevant interference to theoretical development and thinking. But PowerPoint and the Internet are ideal to collect, collate, browse and present project information, case studies and examples. Once again, these developments fit with the needed changes.

Of course, there is a danger that the media become the message and that actual transmission of knowledge suffers. However, teaching less theory is not necessarily bad. It is possible that engineering education had become too theoretically oriented, as a result of modern thinking and the influence of science-based criteria. Yet, an engineering student still needs to graduate with a solid theoretical background. Engineering education is different from football or hockey. There probably is such a thing as hockey theory, but its impact on the game is by no means comparable to the impact of theoretical knowledge of fluid mechanics on the solution of even simple hydraulics problems. Teaching engineering must walk a fine line between new and old. The new requirement could be compared to teaching music. Theory is important but becoming a musician requires much practice.

8. Where to in research?

What about research? At the outset we must understand that technical research, almost by definition, is still fully grounded in the modern concept that research is consensus building to a higher level of understanding. Thus, research is expected to contribute directly to advancement of knowledge and improvement in standard of living. Is research then an anachronism in a postmodern society? Definitely not, but the concepts that research is able to solve all coastal problems by digging deeper into narrow pits of knowledge and that research moves smoothly from consensus to a higher level consensus are. Research must be viewed as one (valuable) link in a complex problem solving network, involving many varying players and viewpoints.

There are some disturbing recent trends in research. First, many research papers show a lack of understanding of the literature. There are two reasons for this. There are vast quantities of information to be read and much of this material is quite useless, because it is the result of a “publish or perish” syndrome (see below) rather than true inquiry with a desire to advance existing knowledge and move technical boundaries. This lack of reading has, however, resulted in much re-invention of wheels.

There is also a trend to form research factories with highly structured research programs. Research has become both a business and a sport. As a business, research must produce product–highly qualified people and publications–in order to generate income (research grants). To accomplish this, research should not be too novel; otherwise money might be spent on non-productive results (dead ends). Like a business, research cannot only follow up on new exciting ideas, it must also provide consistent product.

Research has also become a sport. The researchers and their employers keep strict score of the number of publications and graduates, and the highest score wins. The funding agencies generally do not have the ability to look at the quality of papers and graduates, just their numbers—and the environment is truly one of publish or perish. To obtain the high scores, the sport is to publish (almost) the same material as often as possible, a bit like high jumpers. Each paper and each post graduate or post-doctoral student clears a slightly higher bar. The result of this practice is a barrage of published pages in as many varied reputable journals as possible for each research project. One or two seminal papers every decade or so, succinctly listing the goals of the research and the advances made would waste less time and be certainly be more productive.

The net outcome of this business/sport approach to research is often not innovation, the striking out in totally new and promising directions, but mostly a refinement of what is already known. Much of what parades as new discovery is simply improvement of earlier results through better measurement techniques, or more sophisticated modelling. One is struck, for example, by the number of papers on (presently) hot topics such as the application of Boussinesq theory or wave impact on vertical breakwaters. Many of the added twists only result in minute improvements or sometimes no improvement at all. The argument given for doing this research is that the new wrinkles should be introduced because they give a (theoretically) higher order of accuracy or because better measurements were used. The question that is not asked is: What do these “improvements”, which are essentially study results (analysis), do for design (synthesis)? We need to be clear as engineers that the ultimate goal of our research is improved design (synthesis). If it is not, we have become scientists (analysts).

At a time of rapid change, at the beginning of the postmodern era, we need a paradigm shift. We need some real innovation that addresses the new realities. Periodically we need research that really moves boundaries. Such innovation can come out of research factories, but it can also come out of independent thinkers working alone or in small groups. Such innovation can result not only from large research grants, but it can also result from clear thinking on a shoestring. The improvements need not be gigantic, but they should provide new directions and truly move boundaries. These real innovations will then be filled in by subsequent detailed research by the many other researchers, shopping for research topics. Some historical examples the types of change needed are:

– Terps: These are large mounds of earth that permitted people to survive flooding over two millennia ago (in the age of providence). No longer was life left in the hands of the gods of wind and water, but someone did something

about the regularly occurring loss of life. Imagine someone coming up with this idea, while there was no equipment to move such large volumes of earth. Further, in delta areas where such flooding occurred there was no rock, so the concept of shore protection did not come from experience; it needed to be invented. The terp was indeed a major invention. It was a paradigm shift instigated by simple, ordinary people, two millennia ahead of western philosophers.
– Artificial shore nourishment: This was a radically new design concept. Eroding shores are protected with "soft" sand deposits, instead of with traditional "hard" shore protection structures.
– Berm breakwaters: They made it possible to build breakwaters of materials traditionally thought to be unsuitable and in areas previously thought to be unserviceable.
– The mild slope equations and their parabolic approximation: They opened the way to modern wave-averaged numerical modelling methodology.
– Boussinesq theory and its extension to deep water permitted numerical modelling of very detailed within-wave processes.
– Remote sensing: It permits data collection on large distance scales and will be of tremendous help in developing models of large-scale processes.

Apart from the fact that we need more innovation, there is also a need for more and better application of research. Research results need to be further developed into engineering tools, moving the emphasis from diagnosis (analysis, science) to synthesis (application to solve problems). Finally, research needs to become more interdisciplinary, truly integrating various disciplines and pluralistic viewpoints.

9. Note on authority

Historically, coastal engineering and coastal management were synonymous (Kamphuis, 2000, Ch. 10). Maximizing the economic value of the coast was the modern goal. Personal safety, military defence and transportation were the concerns. Government, as the ruling authority, set the bounds. Government money was the fuel for the engine. There was a comfortable feeling in knowing who the authorities were, how they worked and reacted, and what was expected. A summary of some of the aspects of coastal engineering/management is given in Table 7.

The post-modern goal of coastal engineering and management is very much concentrated on quality of life. Besides the consumerist aspects, such as vacation opportunities and private and public ownership, there is focus on sustainable development, involving environmental and social impacts, and water quality. Designing for all of these is much more difficult than combining water, rocks and sand. Who sets the expectations? Who is the authority? Certainly it is no longer only the government and its bureaucrats. It is the various "stakeholders", the property owners, environmental groups, tourism industry as well as government. Both the authority and the instructions to the engineer are much more vague, making the task of engineers and managers much more difficult.

Table 7
Coastal engineering/management

	Modern	Post-modern
Management	Coastal Engineers	Coastal Management
Main goal	Maximizing economic value	Quality of life
Main concerns	Safety, defence, transportation	Plus sustainable development, environment, water quality
Authority	Government	Discussion, advocacy, stakeholder groups, including government

10. Quo vadis?

What do we dare to conclude? Here are some ideas. We need to accept that we live in a postmodern culture. What we thought was carved in stone is no longer stable and the changes were rapid. Uncertainty has become a keyword; uncertainty in authority, in direction and in results and solutions. We need to accept this uncertainty. We also need to be able to communicate both postmodernity and uncertainty, particularly to clients, who want clarity and certainty.

We must recognize that there is no ultimate solution. All we can do is to strive for an optimum solution. And the process of optimization needs to include many more factors than simply economics or keeping the client happy. The additional considerations are primarily concerned with sustainability. We need to address biological and sociological impacts.

We need to become more aware of the global village we live in. In the past, if regulations were too strict at home, there was always some other less developed country with less stringent laws about pollution or development. Today, we can no longer export problems, because everyone realizes that we share the same atmosphere, hydrosphere and monetary sphere. Hence, sustainability must be on a world scale and complete auditing (for energy, raw materials, water, etc.) needs to become standard practice. Education and research need to reflect the change to postmodern science and engineering, and so must our designs and the management principles.

The problems that need to be solved are very large. From a general perspective: this world has 1 Billion (out of 9 Billion) people without adequate drinking water supply and 2 Billion without an adequate sewerage system. A higher order equation or a more sophisticated design procedure does not solve these problems.

From a coastal perspective, we also face substantial problems. Some challenges are:

– Practically all of our coasts are eroding, because the beaches were placed at an earlier geological time with larger supplies of sediment.
– Coastal areas will be subject to ever more intensive development, increasing the magnitude and complexity of coastal problems and making their solution more urgent.

- Climate change causes large changes in water levels, waves, and the incidence and severity of storms.
- Rising water levels will increase the vulnerability of our coasts through both higher water levels and larger waves.
- Periodic flooding still kills many people living near shorelines mainly in low-lying delta areas, particularly in developing countries.
- How do coastal processes behave on larger scales (decades to centuries—10 to 1000 km) and how do we model at those scales?
- How do we interact with the biological and ecological systems?
- As I write an unspeakable disaster unfolds itself. Tsunamis generated by a massive earthquake off Sumatra have directly killed tens of thousands of people over an area of thousands of kilometers. No doubt many more will die because infrastructure and livelihood are destroyed. All of this concerns coastal engineering at its most practical levels.

Coastal teaching, research and engineering need to address these challenges. Coastal scientists, engineers and managers must be suitably equipped to carry out their formidable tasks. Teaching, research and engineering must all change with the times and in the process large communication gaps must be bridged—gaps between various disciplines, but also between coastal science, coastal management, coastal engineering and coastal education.

This is a time of upheaval in our thinking and acting. But we can remain hopeful and confident throughout this transition. We can do and indeed we must do. But things must be done differently. And times of great change are also times of great opportunity!

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