DEVELOPMENT OF COASTAL SCIENCE AND ENGINEERING: PART 2 - FROM ORDER TO CHAOS

ABSTRACT/RESUME

This paper describes the possible functioning of coastal science and engineering in a postmodern era. It was preceded by a companion paper "From Choas to Order" that describes the rise of modern coastal science and engineering.

Cette communication décrit comment la science et le génie côtier pourraient fonctionner dans un ère postmoderne. Elle est précédée d'une présentation intitulée "From Chaos to Order", qui décrit l'évolution de la science et du génie côtier durant l'ère moderne.

INTRODUCTION

In the previous paper we discussed the rise of *modern* science in general and coastal engineering in particular, and found that this rise had peaked. The peak occurred at different times for different disciplines. For coastal engineering the *denouement* began in the 1970s and continues today, introducing the *postmodern* era of coastal engineering in which we are awash with criticism of science and scientific procedures, engineering and engineering methods, and teaching techniques and contents.

We are also very aware of the limitations of our trade and the uncertainties contained in our methods and solutions. Post-modern influences on our 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 lateral spreading of beach fills. It then continues to discuss uncertainties of the model results, caused by our inadequate knowledge of even these basic things. The conclusions are rife with "may" and "could". The third article discusses the design data obtained world-wide, using physical models (large wave flumes). It presents a very long concluding discussion, which says essentially that hydrodynamic data 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 summarise 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. Does this sound postmodern?

Engineers also do not have the confidence of the general public that existed even thirty years ago. All our engineering societies are now moaning about this (lack of) image. They feel they must do things to enhance (read rightfully restore) the image of engineers and engineering. Unfortunately, this is only modern thinking in a postmodern society. We can only regain the public's confidence if we find new ways of doing engineering in a new society. In sociological jargon, we need a *paradigm shift*.

To illustrate the concept of paradigm shift, we draw a comparison between engineers and loggers. The logger, a Canadian icon for close to 200 years, has undergone the type of shift in paradigm that is needed for engineers, but there were several false starts. The first loggers were employed harvesting oak. The supply was virtually unlimited and new settlers wanted land cleared for farming. The demand was almost unlimited - the virtually insatiable market of Europe. Whole industries arose around logging. Some people became very wealthy. But the supply dried up since the oak was *mined* (oaks were not replaced).

This forced a fundamental change in the logging industry. Fortunately, around the time when the supply of oak was depleted, a demand for newsprint arose and an "unlimited" supply of softwood that could be turned into pulp was found practically all over Canada. A further increase in softwood demand resulted from the need for lumber by a burgeoning construction industry. Was this major change in logging practice a paradigm shift in the logging industry? I think not. The so-called unlimited supply of good softwood also ran out eventually. A paradigm shift from modern logger to postmodern logger would have been to replace the trees with seedlings. A paradigm shift would have been to stop the mining of trees and to make the industry sustainable. Such a shift occurred in Canada only relatively recently. It happened earlier elsewhere and has not yet been introduced in some societies. And this is a simplistic description. The paradigm shift would also need to include environmental issues, consultation with the public, etc.

The parallel with coastal engineering is rather striking. As society, we have mined and with few exceptions continue to mine the coastal area. We have extracted whatever is of value – constructed harbours, used and abused beaches, built developments too close to the shore, used water and replaced it with polluted effluent, over-fished, etc. Most of our projects were designed without proper regard for sustainability, and technical and social impacts.

THE NEXT STEP

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. This is the paradigm shift 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.

But first let us look at the meaning of the concept *postmodern*. Table 1 lists some of its attributes.

The question is: How do we adjust to this new reality? Some new ideas (possibly new paradigms) are presented in Table 2.

WHERE TO IN EDUCATION ?

In the area of post-secondary education there is definite change in emphasis as shown in Table 3. The lengthy era of modern education concentrated on knowledge generation and knowledge transmission through a strict hierarchical system – "recognised" university hires professors of repute who pass theory and examples on to students. This was accomplished through highly structured lectures, possibly enhanced with tutorials. But now there is a need to introduce more a flexible education. In the past, an employer expected a new engineer to know basic principles and the employer provided on-the-job training (a form of apprenticeship). Now, a new engineer is expected to be well rounded and able to earn money for the employer from day one. Hence, teaching of theoretical concepts must be enhanced by skills education (problem solving, management techniques, etc.) and education in relationships (to be able to interact with colleagues from different disciplines and with the public). That requires greater emphasis on design courses, teamwork, interdisciplinarity, communication, problem solving and self-directed learning. Thus seminars, workshops and projects replace many of the more theoretical lectures supported by tutorials. Of course the theoretical knowledge suffers through this shift in emphasis, but perhaps engineering education had become too theoretical as a result of *modern* thinking.

Fortunately these changes fit with the times. Students who have been raised on "show and tell", Sesame Street clips, radio and TV sound bites, and television images that move or flash every 4 seconds (this is broadcast policy now) simply are not capable of sitting through a one-hour lecture on the Navier Stokes Equations. Students whose activities, as they grew up, such as music, ballet and sports were all coached (in which improvement occurs by action, guided by coaching) thrive on project work guided by "resource persons". Students who can navigate the internet, which is a most tangled, uncoordinated, unsupervised, unstructured mass of information of which 99% may be irrelevant and/or incorrect can sort through masses of input from various sources, determine what is germane to a problem and apply the information correctly (with proper coaching). So from that perspective there is a need for major change in the strategy for transmission of knowledge at the university level.

Table 1: Some Aspects of Postmodernity

The failure of "System" and "Progress" introduced a type of Nihilism	
Societal benchmarks	**Technical parallels**
Cynicism: Democracy does not work - Vietnam war, watergate; politics and its leaders are mistrusted	Cynicism: Engineers have messed up and therefore cannot be trusted to produce correct and viable solutions.
Uncertainty: We cannot tell what will happen next.	Uncertainty: The best engineering efforts and formulations cannot provide certain answers.
Breakdown of recognised large, general systems into smaller, more specific subsystems (e.g. "music" becomes classical, jazz, rock, rap, grunge).	Breakdown of Coastal Engineering into fundamental, theoretical, academic, applied, computer related, design, etc. aspects.
Each new subsystem develops its own rules and language. Compare an orchestra with a rap group.	Design, research, computing, etc. have become separate games, with 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). Practicing engineers do not read the latest papers, nor attend technical conferences, because the bulk of the research results are not relevant to practice. Similarly, many researchers are not much interested in solving "practical" problems – perhaps because these are 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.)	Unfortunately, the holistic tool *par excellence* in engineering is the "bottom line". Chief engineers are replaced by business graduates, accountants or lawyers.
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 do not attend university to learn so much, as to be empowered to become consumers. Many 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. Government programs are replaced by stakeholder discussions.
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 appear to represent reality

Table 2: Some New 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 still have very local emphasis.
Sustainability.	We need to consider the whole system and audit all projects (e.g. consumption of water and energy) to determine true sustainability.
Learn to live with uncertainty.	Our formulations cannot give certain answers. 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 automatically provide insight in long term coastal processes.

Table 3: 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" along the way.
Learning environment	Classroom, professor lectures.	Seminars and project presentations as well as 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 is an irrelevant interference to theoretical development and thinking. But PowerPoint and the Internet are ideal to present and browse project information, case studies and examples. Once again, this fits in with the needed change.

There is a danger that the media becomes the message that actual transmission of knowledge suffers at the hands of the "experience" movement and the multi-media glitz. We saw that teaching less theory is not necessarily bad, but an engineering student still needs to graduate with a solid theoretical background. Engineering education after all is different from hockey. There probably is such a thing as hockey theory, but its impact on the game is not comparable in any way to the impact theoretical knowledge in fluid mechanics has on the solution of even simple hydraulics problems.

RESEARCH

What about research? There are some disturbing trends. First, there are many research papers that show an appalling lack of literature review. This is understandable, because of the very large quantities of information that need to be read and analysed, but the result is much re-invention of wheels. Second, much of what parades as new discovery in research is simply improvement of results already discovered earlier, using better measurement techniques, or more sophisticated modelling. Third, there is a trend toward research factories and highly structured research programs. Research has become both a business and a game.

As a business, research must produce products. These are highly qualified people and publications. To accomplish this, research should not be too novel; otherwise money might be spent on non-productive results (dead ends). This is like a business that cannot only follow up new ideas, but must have a line of product. It is also like a game because researchers and their employers keep strict score of the number of publications and graduates. The highest score wins with the funding agencies, which generally do not look at paper content, just numbers. To obtain the high scores, the game 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 net outcome of the business/game approach to research is not innovation, the striking out in totally new and promising directions, but it is mostly a refinement of what is already known. I am 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, but the argument goes that the new wrinkles should be introduced because they give higher order of (theoretical) accuracy or because better measurements were used. The question should be asked: What do these "improvements", which are essentially study results (analysis), do for design (synthesis)?

At a time of rapid change, such as we are experiencing now, at the beginning of the postmodern era, we need real innovation. Periodically we need research that really helps to move boundaries. Such innovation can come out of research factories, but it can also come out of independent thinkers working alone or in small groups. The initial improvements need not be gigantic, but they should provide new directions. These can then be filled out by subsequent detailed research by the many other researchers, waiting for a new topic to show up. Some historical examples of the change of thinking needed are:

- Terps (mounds of earth) permitted people to survive flooding (two millennia ago). No longer was life left in the hands of the gods of wind and water, but someone did something about the large and regularly occurring loss of life. This was a major invention. Imagine someone getting this idea, while there was no equipment to move such large volumes of earth. Also in delta areas where such flooding occurred there was no rock, so the concept of armour protection did not come from experience; it needed to be invented.
- Artificial shore nourishment. This was a radically new design concept. Eroding shores are protected with "soft" sand deposits, instead of with "hard" shore protection structures.
- Berm breakwaters made it possible to build breakwaters of materials traditionally thought to be unsuitable.
- The mild slope equations and their parabolic approximation 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 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 innovation, there is a need for more application of research. Research results need to be developed into engineering tools. There should be less emphasis on diagnosis (analysis, science), and more on cure (synthesis, application to solve problems).

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 of knowing who the authorities were and how they worked and reacted. A summary of the aspects of coastal engineering/management is given in Table 4.

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

Table 4: 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

QUO VADIS?

Do I dare to conclude? Here are some ideas. We need to accept that we live in a postmodern culture (also in coastal engineering and management). What we thought was carved in stone is no longer certain. Uncertainty has become a key word; uncertainty in authority, in direction and in results and solutions. We need to accept uncertainty. We also need to be able to communicate both postmodernity and uncertainly, particularly to clients, who do not want to deal with them.

We must recognise 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. In a litigious society we also need to heed all legal implications.

We need to become more aware of the global village we live in. In the past, if regulations were too stringent at home, there was always some other less developed country with less stringent laws about polluting or development. Today, we can no longer export our problems, because everyone realises that we share the same atmosphere, hydrosphere and monetary sphere. Hence, sustainability must be on a world scale and auditing (for energy, water, etc.) needs to become standard practice.

Education and research needs to reflect this change to postmodern engineering, but so must our designs and the management principles. The problems that need to be solved are very large. As a general incentive, 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 this problem.

In the coastal field, 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.
- Rising water levels increase the vulnerability of our coasts through both higher water levels and larger waves.
- Global warming may cause very large changes in water levels, waves, and the incidence and severity of storms.
- Periodic flooding still kills many people living near shorelines mainly in low-lying delta areas, particularly in developing countries.
- Although research and modelling permit insight in coastal processes, these are on very local and temporal scales. We must learn to understand how coastal processes behave on larger scales (decades to centuries – 10 to 1000 km). This cannot be simply extrapolated from the smaller scale process knowledge. Remote sensing now permits snap-shot measurements of large scale processes, but development over a larger the time scale is still not understood. This is a matter of the highest priority.

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

At this time of upheaval in our thinking and acting, we remain hopeful and confident. We can do, but that it must be done differently. And times of *great change* are times of *great opportunity*!

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