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Long-Term Analysis of Trends in Shore Protection Based on Papers Appearing in the *Journal of Coastal Research*, 1984–2000

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ABSTRACT

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The *Journal of Coastal Research* (JCR), an international coastal/marine science journal, deals with all aspects of coastal research. Shore protection is an applied discipline that is mainly conducted by coastal engineers, but which receives background support in the geological and oceanographic sciences. When seen from the purview of coastal engineering *per se* (51 papers) and ancillary environmental (empirical) studies of natural process (113 papers), related numerical and quantitative (modeling) studies (49 papers), biophysical impacts of coastal structures (39 papers), and economics and policy (3 papers), there were about 255 papers in the JCR fitting these broad categories. These specializations averaged about 21% of all papers in any particular volume over the period of study. The percentage of shore protection papers by volume for 16 volumes (1984–2000), four issues each per year, ranged from 11.5% (1985) to 29% (1991).

Prominent trends include increasing numbers of studies that analyze shoreline position, more numerous studies of coastal environmental impacts from shore protection structures, and steady flow of papers dealing with shore protection. These decadal trends reflect increasing awareness of natural erosion trends as well as those exacerbated by engineering works, including structures that are designed to mitigate erosion but which have unwanted effects. Somewhat surprising are trends that evaluate the performance of shore protection efforts, such as beach replenishment, as well as introspection of cost-benefit analyses used to justify beach projects. Accountability became a controversial issue that was associated with predictions of design life and durability of beach projects. The great beach nourishment debates raged through the 1990s and continue today after curtailment of federal participation in most new beach restorations. A recent minor trend focuses attention on controversial aspects of coastal modeling in the service of shore protection. Different schools of thought surfaced as debaters considered application of numerical models under a variety of shore conditions. Another important trend features overarching and increasing concerns to better understand basic coastal biophysical processes, as they are incorporated into the practice of shore protection, within the context of rapidly changing political and socioeconomic regimes around the world. This emerging insight conditions policy that steers research directives in the coastal zone. Rationalization of shore protection measures is a new and productive trend that fosters research and technology transfer to the management sector.

ADDITIONAL INDEX WORDS: *Beach erosion, beach nourishment, coastal erosion, coastal engineering, environmental management, shore erosion.*

INTRODUCTION

As a major research journal in the coastal-marine sciences, the *Journal of Coastal Research* (JCR) receives contributions on a wide range of topics related to the general theme of coastal research. The JCR specifically solicits a wide range of contributions that deal with or emphasize multidisciplinary approaches to problem solving in the coastal zone. Many papers consider theoretical aspects of coastal research as well as practical approaches to management of shores while numerous professional papers and technical communications deal with the general theme of shore protection. This topical area is interpreted in the broadest sense to include not only engineering efforts to mitigate shore erosion through protection efforts, but also those researches that provide background or backup studies that must be considered by engineers in their conceptual approach to shore protection. Backup studies, thus, include investigation of coastal biophysical processes and phenomena, for example, studies of erosion trends via shoreline movement (*e.g.* advance and retreat), causes of shore erosion (*e.g.* atmospheric, terrestrial, and oceanographic factors that induce shoreline movement or result in instability), and environmental, socio-economic or political implications of shore erosion. Erosion protection efforts themselves have environmental impacts, some good and some adverse, because they are designed to interact with natural processes. Prior to protection, quantification of coastal processes is often attempted in an effort to deduce potential changes to the shore under different scenarios of "do nothing," a policy of non-interference, or to estimate impacts that

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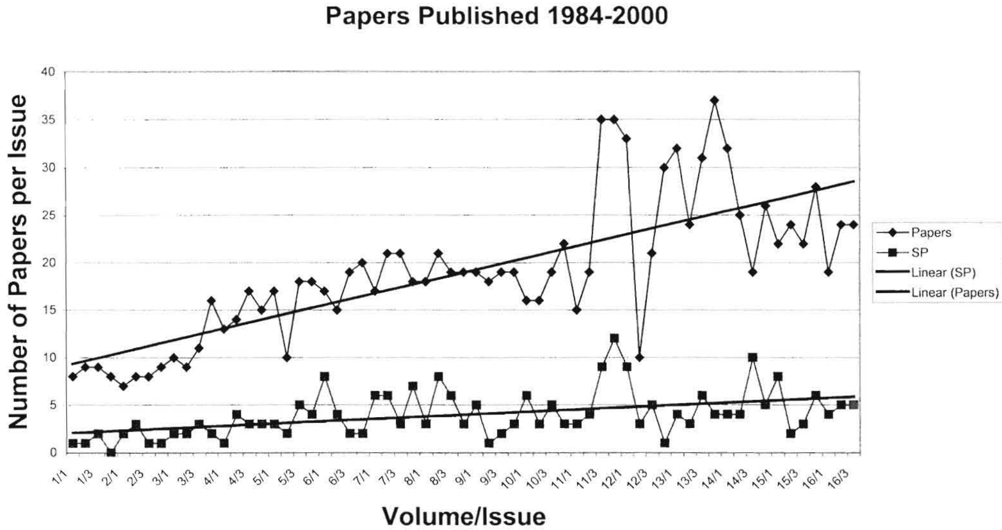

Figure 1. Trends of papers published in the *Journal of Coastal Research* by total number of papers in each issue, four issues to one volume year. The upper graph shows the total number of papers published, regardless of the subject matter. The lower graph shows the number of papers published in each issue for the category of shore protection. Straight lines in each data set are regression lines. Papers = all papers published, SP = papers published in the thematic area of shore protection.

are induced by engineering structures. The economic viability of shore protection is an important consideration but few fiscal studies are reported in the JCR. Such studies are also used in design considerations where alternative approaches are considered. The focus here, however, is on the following main areas: (1) coastal engineering research and technology transfer (scientific and geotechnical background studies), (2) quantitative studies of natural coastal phenomena, (3) environmental impacts of shore erosion, (4) shore erosion trends, and (5) shore protection efforts. These five broad subject areas define the context of shore protection papers that have been submitted to the regular issues of the JCR over the last two decades; topics extant in the special issues are not considered in this analysis.

Review of publishing trends, which in turn reflect research thrusts, show an overall increase in the total number of papers submitted to the JCR. Compared to the 34 papers published in 1984 (Volume 1), there were 89 papers for Volume 16 in 2000. Figure 1 illustrates linear growth trends for all papers increasing at a faster rate than papers dealing with shore protection. Volumes 11 through 13 contained substantially more papers than previous or subsequent issues (*c.f.* Figure 1) in terms of both overall papers and those dealing with shore protection. It is not known whether the number of papers published from 1995 through 1998 reflects a short-lived national or international trend or was just coincidental. Nonetheless, the large numbers of papers in those volumes does reflect an overall trend toward increasing numbers of papers per issue. The increased contribution of shore protection papers was modest during this same period. The total number of published papers for the study period was 1206 with shore protection papers averaging about 21% for the nearly bidecadal period (Table 1).

Table 1. *Coastal protection papers published in the JCR by topical category for the period 1984–2000.*

	Research	Quantitative	Impacts	Erosion	Economics	Structures
No. Papers	78	49	39	35	3	51
% of Total	6.5	4.1	3.2	2.9	0.25	4.2
% of SP	31.2	19.6	15.6	14.0	1.2	20.4

Total number of papers published is 1206; the number of shore protection (SP) papers totals 255. Categorization of shore protection themes is as follows: Research = costal engineering research and technology transfer; Quantitative = numerical and quantitative studies (incl. modeling); Impacts = environmental impacts of shore protection works; Erosion = studies of sediment transport, longshore drift, and shoreline change analysis; Economics = cost of shore protection; Structures = coastal protection works (including artificial beaches and dunes).

Compared to the total number of papers published, those dealing with subfields of shore protection always accounted for less than 10% with the specialized discipline of basic research accounting for the highest number of papers (6.5% of the total of total number published) (Table 1). Other subfields contributed smaller percentages of the total for basic research (6.5%), numerical and quantitative studies (4.1%), environmental impacts of shore protection works (3.2%), studies of erosional trends (2.9%), studies of coastal structures *per se* (4.2%), and investigations of shore protection costs (0.25%). As shown in Table 1, the percentage of papers published in the subfields of shore protection is highest in research (31.2%), structures (20.4%), and quantitative studies (19.6%). As far as the JCR is concerned, shore-protection papers focus on coastal engineering research and technology transfer for structures (51.6% of all papers published in the overall category of shore protection: research plus structures). Most of the papers in this group deal with aspects of coastal oceanography and environmental studies, particularly as they relate to beach state and morphodynamics. Key issues here are oceanographic (hydrodynamic) processes, geologic processes and materials, combinations of process and form via morphodynamics, and coastal environmental process-response conditions.

A summary of shore protection papers appearing in the JCR (from 1984 to 2000) is tabulated in Table 2. In this table, papers in various categories are listed by first author, and in some cases by first and second author names if there are two authors, in alphabetical order to show authorship and occurrence of publication by volume and issue. Perusal of Table 2 identifies the major players in the field as surnames are repeated viz. BRUUN (four times for the categories of research and technology transfer) while CHANDRAMOHAN, HALL, HEMSLEY, HOUSTON, HUBERTZ, KOBAYASHI, KUMAR, MORANG, and PILKEY appear at least twice. In the numerical and quantitative studies category, the following researchers turn up two or more times in the list: DUBOIS, WANG, and ZHANG. The environmental impacts category shows HESP, HILTON, and LOUTERS showing up at least twice. Repeat authorship occurs in the shore protection category for BRUUN, FISCHER, PILKEY, and KOBAYASHI. In summary, of the total number of papers cited in this study (1206), only about 4% are by repeat authors. Of the 255 papers in the overall shore protection category (*cf* Table 1), about 19% are comprised by repeat authorships. Thus, about 80% of the shore protection papers are not by repeat authorship, suggesting a diversity of contributors.

COASTAL ENGINEERING RESEARCH AND TECHNOLOGY TRANSFER

Making up about one-third of all papers in the shore protection category, these kinds of studies are crucial to advancement of shore protection efforts. Because these reports tend to have an orientation toward basic research rather than a focus on engineering applications (*e.g.* ALLEN, 1985; BRUUN, 1986; PLANT and GRIGGS, 1992; ANTHONY, 1994; REED and WELLS, 2000), there is a time lag for assimilation by the coastal engineering research community. The new findings must be tested and verified before eventually becoming incorporated into structure design or placement considerations. Even though these kinds of papers are wide ranging, they may differ from similar papers in engineering journals (*e.g. Coastal Engineering*) in that they tend to more generally incorporate an awareness or cognizance of natural environmental parameters rather than rely on purely mathematical approaches to problem solving. The more general and applied approach in the JCR may make these kinds of papers somewhat more interesting to read and thus more comprehensible to a wider audience. These are not papers for coastal engineers *sensu stricto* because the JCR requires a broad approach that includes coastal zone managers as part of the readership and coastal research community. Table 3 is a bibliographic citation of the complete reference for authors listed in Table 1, in the research and technology transfer category.

Examples of the wide-ranging scope of the JCR are legion within this group of papers. Papers dealing specifically with coastal engineering research and technology transfer include reviews of research activities in the U.S. Army Corps of Engineers (*e.g.* HOUSTON, 1988; CAMFIELD, 1988; HALES, 1995) and reviews of procedures for collecting data and surveying in the coastal zone (*e.g.* HEMSLEY, 1990; MCANENY, 1994; MORANG *et al.*, 1997; LARSON, 1997). Other types of background research dealt, for example, with sand sampling on beaches and classification of beach profiles (*e.g.* PHILLIPS, 1985; ARAYA-VERGARA, 1986; DEAN, 1991) and with basic research associated with the transport of sediments alongshore (*e.g.* ALLEN, 1985; KRAUS, 1987; BODGE, 1989; STONE and STAPOR, 1996; BADR and LOTFY, 1999). Interest in water-level fluctuations and causes of water movement up or down as well as measurement techniques, as from tide gauges, for example (*e.g.* DINNEL and SCHROEDER, 1989; BAUER, 1990; DIAS and ABORDO, 1992). Increase in water level (*i.e.* eustatic sea-level rise) is related to shore erosion and consequently to shore protection, giving this line of inquiry an immediate applied aspect. Waves are important parameters in the shoreline stability equation as they affect, for example, bed stability, setup, currents, and sediment transport. Wave steepness, height, and angle of incidence additionally have safety considerations in the approaches to inlets and in navigation channels. Wave transformation and shore-breaker classification (*e.g.* BALSILLIE, 1985; KOBAYASHI, 1988; OKAZAKI and SUNAMURA, 1991; BRIGGS, 1993) as well as wave measurement (*e.g.* VIGGOSSON *et al.*, 1988; HSU *et al.*, 2000) represent an increasingly important line of inquiry in coastal research. Studies dealing with beach materials (grain-size parameters), the dynamics and classification of cross-sectional shapes and erosion (transport) of eroded beach sediments was a frequent focus of research in the last two decades. Papers dealing with water movement (including tidal fluctuations, super-elevations of water level, setup and setdown, and para/diabathic currents) and waves were prominent among those published in the category of research and technology transfer.

QUANTITATIVE STUDIES OF COASTAL PHENOMENA

Although only about 4% of the total number of papers published in the JCR, this thematic group accounts for about 20% of the papers dealing with shore protection topics (Table 1). Complete bibliographic citations for the papers listed in the category of quantitative studies are given in Table 4.

The debates about numerical modeling started in Volume 7, issue 3 (1991), and continued through Volume 16, number 1 (2000). The main issues here focused on concerns related to the use of mathematical models to predict beach behavior (*e.g.* PILKEY *et al.*, 1990, 1993; YOUNG *et al.*, 1995, 1997; THIELER *et al.*, 2000). Criticisms, from a geologic perspective, dealt with many different issues, one of which is the critical concept that underlies all models used to predict beach behavior, the shoreface profile of equilibrium (including the concept of closure depth). There were many other issues of concern, especially the assumptions that go into quantitative models that attempt to approximate natural conditions. It has been argued (*e.g.* YOUNG *et al.*, 1995) that some of the initial assumptions of the models are not realistic and in

Table 2. *List of coastal protection papers, listed in alpha order, appearing in the Journal of Coastal Research, from 1984 to 2000, and summarized by topical category.*

Research and Technology Transfer	Numerical & Quantitative Studies[1]	Environmental Impacts[2]	Erosion Trends	Shore Protection
Allen 1(3)85[3]	Arcilla 5(3)89	Bruun 2(2)86	Amin & Davidson-Arnott 13(4)97	Ahrendt & Köster 12(1)96
Antony 10(1)94	Arnoux-Chiavassa et al. 15(1)99	Chasten 9(4)93	Ashley 3(3)87	Bottin 7(1)91
Araya-Vergara 2(2)86	Balsillie 1(3)85	Cialone & Stauble 14(2)98	Aubie & Tastet 16(3)00	Bruun & Willekes 8(4)92
Badr & Lofty 15(1)99	Basco et al. 15(1)99	Drapeau et al. 15(1)99	Bruun 11(4)95	Bruun 3(3)87
Barua & Kana 11(3)95	Bauer 6(4)90	Eitner & Ragutzki 10(3)94	DeVries 8(2)92	Bruun 4(1)88
Black 8(2)91	Bodge 8(1)92	Fanos 11(3)95	Dolan et al. 6(2)90	Bruun 6(2)90
Bodge 5(2)89	Bray et al. 11(2)95	Fenster & Dolan 12(1)96	Douglas et al. 14(3)98	Bruun & Adams 4(4)88
Bottin 6(1)90	Bruun 4(4)88	Fletcher et al. 13(1)97	Fenster & Dolan 9(1)93	Bull et al. 14(1)98
Braband 7(1)91	Daviglia et al. 7(2)91	French & Livesey 16(3)00	Finkl 12(1)96	Burnett & Whiteside 8(1)92
Brander 15(3)99	Cialone 10(3)94	Frihy et al. 16(3)00	Jones et al. 9(1)93	Butler & McAllister 16(2)00
Briggs 9(2)93	Cin & Simeoni 10(1)94	Gaillot & Piegay 15(3)99	Hackney & Cleary 3(1)87	Carter et al. 2(1)86
Bruun 14(3)98	Cooper 14(1)98	Hall & Pilkey 7(3)91	Hall et al. 2(2)86	Carver & Bottin 13(4)97
Bruun 16(2)00	Crowell et al. 13(4)97	Hesp & Hilton 12(3)96	Kahn 2(3)86	Charlier & de Meyer 11(4)95
Bruun 4(2)88	Cummings 14(4)98	Hilton & Hesp 12(2)96	Koster & Hillen 11(4)95	Clayton 5(3)89
Bruun 6(4)90	De Lange & Healy 10(4)94	Kraus & McDougal 12(3)96	Lacey & Peck 14(4)98	Davison et al. 8(4)92
Butt & Russell 16(2)00	Dean 13(3)97	Louters et al. 7(3)91	Leatherman et al. 13(4)97	Davis & Wang 16(2)00
Camfield 4(3)88	Desa et al. 4(3)88	Louters et al. 14(3)98	Psuty & Moreira 8(3)92	Dixon & Pilkey 7(1)91
Caruso & Pousa 8(2)92	Doering 13(4)97	Mass & Hobbs 14(2)98	Rongning & Hualiang 11(4)95	Fanos et al. 11(2)95
Chandramohan & Nayak 8(4)92	Douglas & Cowell 16(1)00	Milton et al. 13(3)97	Samsuddin & Suchindan 3(1)87	Fischer 2(1)86
Chandramohan et al. 5(4)89	Dubois 8(3)92	Moon et al. 10(3)94	Smith & Abdel-Kader 4(2)88	Fischer et al. 11(3)95
Chapalain & Boczar-Karakiewicz 8(2)92	Dubois 15(1)99	Peterson et al. 16(2)99	Smith & Jakson 6(1)90	FSBPA 11(2)95
Dean 7(1)91	Eliasson 12(1)96	Pilkey 11(3)95	Terich & Levenseller 2(4)86	Granja & Carvalho 11(4)95
DeKimpe et al. 7(2)91	Friedrichs 11(4)95	Plant & Griggs 8(1)92	Walton 5(3)89	Hemsley 6(2)90
Dias & Taborda 8(3)92	Gibeaut et al. 14(3)98	Pope 13(3)97		Idorn 7(4)91
Dinnel & Schroder 5(3)89	Gibson et al. 13(3)97	Steinitz et al. 14(3)98		Kelletat 8(3)92
Eitner 12(2)96	Guan et al. 15(4)99	Suandar et al. 10(4)94		King et al. 16(1)00
Finkl 14(3)98	Hanson 5(1)89	Truitt 4(3)88		Laustrup 4(4)88
FitzGerald et al. 10(1)94	Hobbs et al. 8(2)92	Vd Wal 14(2)98		Leonard et al. 6(1)90
Foster et al. 10(3)94	Hsu & Wang 13(4)97	Walton 5(4)89		Louisse & vd Meulen 7(4)94
Shoshany et al. 12(1)96	Hubbert & McInnes 15(1)99	Wu & Yuan 11(3)95		Mimura & Nunn 14(1)98
Haddad & Pilkey 14(4)98	Hughes 11(4)95			Moller 8(3)92
Hales 11(1)95	Hyllier et al. 13(1)97			Pilkey & Clayton 5(1)89
Hall et al. 6(1)90	Irish & Lillycrop 13(4)97			Pilkey 6(1)90
Hall et al. 3(4)87	Jayakumar & Mahadevan 9(4)93			Pilkey 9(1)93
Healy et al. 15(4)99	Johnson 14(3)98			Pirazzoli 7(1)91
Heerden & DeRouen 13(3)97	Karambas 15(1)99			Saffir 8(2)92
Hemsley & Brooks 5(4)89	Krauss et al. 12(3)96			Sawaragi 4(4)88
Hemsley 6(2)90	Komar & McDougal 10(1)94			Shore Protection
Hemsley et al. 7(2)91	Lee 10(1)94			Simeonova 8(3)92
Houston 4(2)88	Leeknecht et al. 11(4)94			Tait 11(2)95
Houston 7(2)91	Mani et al. 10(4)94			Thyme 6(1)90
Hsu et al. 16(3)00	Markle 5(3)89			Turner & Leatherman 13(4)97
Hubertz et al. 10(1)94	Marsh et al. 15(3)99			Twu et al. 15(4)99
Hubertz et al. 7(4)91	Mathew et al. 12(1)96			Vasco Costa 7(4)91
Hume & Herdendrof 8(2)92				Verhagen 12(1)96
Inman & Dolan 5(2)89	Morton et al. 9(3)93			Verhagen 6(1)90
Jackson & Jensen 11(1)95	Muñoz-Perez et al. 15(4)99			Visser & Bruun 13(4)97

Table 2. *Continued.*

Research and Technology Transfer	Numerical & Quantitative Studies[1]	Environmental Impacts[2]	Erosion Trends	Shore Protection
Kobayashi 4(3)88	Muraca & Rossi 11(4)95			Ward et al. 14(4)98
Kobayashi et al. 7(1)91	Okazaki 7(2)91			Watson & Finkl 6(3)90
Kraus 3(2)87	Parson et al. 13(4)97			Wilson 11(4)95
Kroon & Hoekstra 6(2)90	Rey et al. 11(4)95			Yazdani & Kadnar 9(4)93
Kumar 3(3)87	Russel & Huntley 15(1)99			Yazdani & Ycaza 11(3)95
Kumar et al. 16(3)00	Sheall 7(2)91			Yazdani et al. 13(1)97
Larson et al. 13(2)97	Signell et al. 16(3)00			Zenkovich & Schwartz 3(2)87
Lauters 7(3)91	Skyum et al. 12(4)96			Zunica 6(3)90
Lawrence & Davidson-Arnott 13(4)97	Smith & Zarillo 6(1)90			
Lee et al. 11(4)95	Sobey & Barker 13(2)97			
Lin & Metha 5(3)89	Suhayda 13(3)97			
Liu & Mei 5(4)89	Sundar et al. 9(3)93			
Maa & Wang 11(4)95	Thieler et al. 16(1)00			
Mallayachari & Sundar 12(2)96	Thompson & Hadley 11(3)95			
May & Stapor 12(3)96	Walton 14(4)98			
McAneny 10(2)94	Wang et al. 11(3)95			
Morange 8(2)92	Wang & Davis 14(3)98			
Morang et al. 13(1)97	Williams et al. 16(3)00			
Morang et al. 13(4)97	Xu & Wright 14(2)98			
Naffaa 11(1)95	Xu et al. 10(2)94			
Nielsen & Hanslow 7(4)91	Zarillo & Park 3(4)87			
Nikolov et al.10(3)94	Zhang & Edge 14(2)98			
Nnaji et al. 12(1)96	Zhang et al. 15(2)99			
O'Brien et al. 15(1)99	Young et al. 11(3)95			
Osborne & Rooker 15(1)99	Yuksel et al. 14(3)98			
Phillips 1(2)85				
Pilkey & Leonard 7(3)91				
Pilkey et al. 9(1)93				
Reed & Wells 16(1)00				
Ruig & Louisse 7(4)91				
Simeoni et al. 15(2)99				
Smith 10(2)94				
Soland et al. 12(1)96				
Stone & Stapor 12(3)96				
Trembanis & Pilkey 14(2)98				
Tillotson & Komar 13(2)97				
Valverde et al. 15(4)99				
Viggosson et al. 4(2)88				
Visser & Brunn 13(4)97				
Walker et al. 7(4)91				
Wilcock et al. 14(1)98				
Xue 15(4)99				
Xu & Wright 14(2)98				

[1] This category includes beach, coastal oceanographic and environmental studies in the broadest context of research activities commonly associated with these endeavors.
[2] Instrumentation and survey is included in this category.
[3] The format for bibliographic citation in the JCR follows volume, issue, and year of publication viz Volume 1, Issue 1, 1985 = 1(1)85.

some cases simply do not agree with natural conditions in the field. Assumptions regarding initial conditions for input into computer programs such as GENESIS (HANSON, 1989), for example, centered on quantification of certain parameters without taking into consideration measurement errors that were associated with (1) shoreline position, initial and for all calibration and verification runs, (2) bathymetry, (3) berm height, (4) closure depth (often estimated rather than measured), (5) location and volume of beach fill, and (6) line source or sink of sand. Difficulties also pointed to perceived model imperfections, particularly those associated with the longshore transport equations and shoreline change (YOUNG *et al.*, 1995, 1997). Still other issues, raised by THIELER *et al.* (2000), dealt with concerns arising from geologic and oceanographic considerations of about fifty assumptions, oversights, and oversimplified or averaged data.

The dialogue that ensued was beneficial and useful to the research community at large because the issues that were brought up for discussion focused attention on important processes of natural conditions where the present state of knowledge appeared to be insufficient to make broad sweeping statements concerning the way things should be in nature, compared to the way things may actually be. It was often shown or pointed out that conditions that are perceived as

Table 3. *List of bibliographic citations for papers occurring in the category of 'research and technology transfer.'*

Author(s), Date. Bibliographic Citation
Allen, J.R., 1985. Field measurement of long shore sediment transport: Sandy Hook, NJ, USA. *JCR*, 1(3), 231–240.
Anthony, E.J., 1994. Natural and artificial shore of the French Riviera: An analysis of their interrelationship. *JCR*, 10(1), 48–58.
Araya-Vergara, J., 1986. Towards a classification of beach profiles. *JCR*, 2(2), 159–166.
Badr, A.A. and Lofty, M.F., 1999. Tracing beach sand movement using fluorescent quartz along the Nile delta promontories, Egypt. *JCR*, 15(1), 261–165.
Barua, D.K. and Kana, T.W., 1995. Deep water wave hindcasting, wave refraction modeling, and wind and wave induced motions in the east Ganges-Brahmaputra delta coast. *JCR*, 11 (3), 834–848.
Black, K.P. and Rosenberg, M.A., 1992. Natural stability of beaches around a large bay. *JCR*, 8(2), 385–397.
Bodge, K., 1989. A literature review of the distribution of longshore sediment transport across the surf zone. *JCR*, 5(2) 307–328.
Bottin, R.R., Jr., 1990. Case study of a successful beach restoration project. *JCR*, 6(1), 1–14.
Brabrand, T., 1991. The Vicking port, Trondhein, Norway. *JCR*, 7(1), 85–107.
Brander, R.W., 1999. Sediment transport in low-energy rip-current systems. *JCR*, 15(3) 839–849.
Briggs, M.J., 1993, Making waves at CERC. *JCR*, 9(2), 448–461.
Brunn, P., 1990. Gravel on beaches on Hilton Head Island, South Carolina—Relation between "specific surfaces" (surface area divided by the weight of the gravel) and the location of the gravel pieces in the uprush zone. *JCR*, 6(4), 1021–1022.
Brunn, P., 1998. Port engineering and its relation to coastal engineering. *JCR*, 14(3), 1152–1157.
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Butt, T. and Russel, P., 2000. Hydrodynamics and cross-shore sediment transport in the swash-zone of natural beaches: A review. *JCR*, 16(2), 255–268.
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Caruso, H.A. and Pousa, J.L., 1992. Length of wave records: A numerical model to simulate its influence upon frequency distribution of wave heights and periods. *JCR*, 8(2), 340–347.
Chandramohan, P. and Nayak, B.U., 1992. Longshore sediment transport model for the Indian west coast. *JCR*, 8(4), 775–787.
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Chapalain, G. and Boczar-Karakiewicz, B., 1992. Modeling of hydrodynamics and sedimentary processes related to unbroken progressive shallow water waves. *JCR*, 8(2), 419–441.
Dean, R.G., 1991. Equilibrium beach profiles: Characteristics and applications. *JCR*, 7(1), 1–10.
DeKimpe, N.M.; Dolan, R., and Hayden, B.P., 1991. Predicted dune recession on the outer banks of North Carolina, USA. *JCR*, 7(2), 451–464.
Dias, J.A. and Taborda, R., 1992. Tidal gauge data in deducticing secular trends of relative sea-level and crustal movements in Portugal. *JCR*, 8(3), 655–659.
Dinnel, S.P. and Schroeder, W.W., 1989. Coastal water level measurements, northeast Gulf of Mexico. *JCR*, 5(3), 553–562.
Eitner, V., 1996. The effect of sedimentary texture on beach fill longevity. *JCR*, 12(2), 447–461.
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Hubertz, J.M.; Driver, D.B., and Teinhard, R.D., 1991. Wind waves on the great lakes: A 32 year hindcast. *JCR*, 7(4), 945–968.
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Kraus, N.C., 1987. Application of portable traps for obtaining point measurements of sediment transport rates in the surfzone. *JCR*, 3(2), 139–152.
Kroon, A. and Hoekstra, P., 1990. Aeolian sediment transport on a natural beach. *JCR*, 6(2), 367–380.
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Kumar, V.S.; Kumar, K.A., and Anand, N.M., 2000. Characteristics of waves off Goa, west coast of India. *JCR*, 16(3), 782–789.
Larson, R.; Morang, A., and Gorman, L., 1997. Monitoring the coastal environment; Part: sediment sampling. *JCR*, 13(2), 308–330.
Lawrence, P.L. and Davidson-Arnott, R.G..D., 1997. Alongshore wave energy and sediment transport on southeastern lake Huron, Ontario, Canada. *JCR*, 13(4), 1004–1015.
Lee, Guoan-hong; Nicholls, R.J.; Birkemeier, W.A., and Leatherman, S.P., 1995. A conceptual fairweather-storm model of beach nearshore profile evolution at Duck, North Carolina, U.S.A. *JCR*, 11(4), 1157–1166.
Lin, C-P. and Mehta, A. J., 1989. Turbidity-induced sedimentation in closed-end channels. *JCR*, 5(3), 391–402.
Liu, K. and Mei, C.C., 1989. Effects of wave induced friction on a muddy seabed modeled as a Bingham-plastic fluid. *JCR*, 5(4), 777–790.

Table 3. *Continued.*

Author(s), Date. Bibliographic Citation
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Mallayachari V. and Sundar, V., 1996. Wave transformation over submerged obstacles in finite water depths. *JCR*, 12(2), 477–483.
May, J.P. and Stapor, F.W., Jr., 1996. Beach erosion and sand transport in Hunting Island, South Carolina, USA. *JCR*, 12(3), 714–724.
McAneny, D.S., 1994. Regional coastal databases for corps of engineers districts. *JCR*, 10(2), 270–277.
Morang, A., 1992. Inlet migration and hydraulic processes at East Pass, Florida. *JCR*, 8(2), 457–481.
Morang, A.; Larson, R., and Gorman, L., 1997. Monitoring the coastal environment. Part I: Waves and currents. *JCR*, 13(1), 8–22.
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Naffa, M.G., 1995. Wave climate along the Nile delta coast. *JCR*, 11(1), 219–229.
Nielsen, P. and Hanslow, D.J., 1991. Wave runup distributions on natural beaches. *JCR*, 7(4), 1139–1152.
Nikolov, K.; Revilla, J.A.; Alvarez, C., and Luceno, A., 1994. A design for combined sewer system elements with overflows in coastal zones. *JCR*, 10(3), 531–539.
Nnaji, S.; Yazdani, N., and Rambo-Rodenberry, M., 1996. Scour impacts of coastal swimming pools on beach systems. *JCR*, 12(1), 186–191.
O'Brien, M.K.; Valverde, H.R.; Trembais, A.C., and Haddad, T.C., 1999. Summary of beach nourishment activity along the Grate Lake's shoreline 1955–1966. *JCR*, 15(1), 206–219.
Osborne, P.D. and Rooker, G.A., 1999. Sand re-suspension events in a high energy infragravity swash zone. *JCR*, 15(1), 74–86.
Philips, J D., 1985. Estimation of optional beach profile sample intervals. *JCR*, 1(2), 187-
Pilkey, O.H. and Leonard, L.A., 1991. Reply to: Houston (1991) [Journal of Coastal Research, 7(1), 565–577], Re: Discussion of Pilkey and Leonard (1990) [Journal of Coastal Research, 6(4), 1023 *et seq.*] and Houston [Journal of Coastal Research, 6(4), 1047 *et seq.*]. *JCR*, 7(3), 879–875.
Pilkey, O.H.; Young, R.S.; Stanley, R.R.; Smith, A.W.; Wu, W., and Pilkey, W.D., 1993. The concept of shoreface profile equilibrium: A critical review. *JCR*, 9(1), 255–278.
Reed, A.J. and Wells, J.T., 2000. Sedimentation distribution patterns offshore of a renourished beach: Atlantic beach and Fort Macon, North Carolina. *JCR*, 16(1), 88–98.
Ruig de, J.H.M. and Louisse, C.J., 1991. Sand budget trends and changes along the Holland coast. *JCR*, 7(4), 1013–1026.
Simeoni, U.; Calderoni, G.; Tessari, U., and Mazzini, E., 1999. A new application of system theory to foredunes intervention strategies. *JCR*, 15(2), 457–470.
Smith, A.W., 1994. The coastal engineering literature and the field engineer. *JCR*, 10(2), iii-250.
Shoshany, M.; Golik, A.; Degani, A.; Lavee, H., and Gvirtzman, G., 1996. New evidence of sand transport direction along the coastline of Israel. *JCR*, 12(1), 311–325.
Stone, G.W. and Stapor, F.W., Jr., 1996. A nearshore sediment transport model for the northeast Gulf of Mexico coast, U.S.A. *JCR*, 12(3), 786–793.
Tilloston, K. and Komar, P.D., 1997. The wave climate of the Pacific Northwest (Oregon and Washington): A comparison of data sources. *JCR*, 13(2), 440–452.
Trembais, A.C. and Pilkey, O.H., 1998. Summary of beach nourishment schemes along the U.S. Gulf of Mexico shoreline. *JCR*, 14(2), 407–417.
Valverde, H.R.; Trembais, A.C., and Pilkey, O.H., 1999. Summary of beach nourishment episodes on the U.S. east coast barrier islands. *JCR*, 15(4), 1100–1118.
Viggósson, G.; Sigurdarson, S., and Tryggvason, G.S., 1988. Wave measurements in Iceland. *JCR*, 4(2), 207–218.
Visser, K. and Brunn, P., 1997. The Punaise underwater dredger. *JCR*, 13(4), 1329–1334.
Walker, D.J.; Dong, P., and Anastasiou, K., 1991. Sediment transport nears groins in the nearshore zone. *JCR*, 7(4), 1003–1012.
Wilcock, P.R.; Miller, D.S., and Shea, R.H., 1998. Frequency of effective wave activity and the recession os coastal bluffs: Calvert Cliffs, Maryland. *JCR*, 14(1), 256–268.
Xue, C., 1999. Coastal sedimentation, erosion and management on the north coast of Kosrae, Federated States of Micronesia. *JCR*, 15(4), 927–935.
Xu, J.P. and Wright, L.D., 1998. Observations of wind-generated shoreface currents off Duck, North Carolina. *JCR*, 14(2), 610–619.

representing reality may sometimes be rather different from actual conditions. Reviews of the use of deterministic numerical models in applied coastal studies (*e.g.* YOUNG *et al.*, 1995; THIELER, *et al.*, 2000) encouraged useful examination and discussion of the terms 'calibration,' 'validation,' and 'verification' in the context of coastal engineering models.

SHORE EROSION TRENDS AND ENVIRONMENTAL IMPACTS

Studies of shore erosion and its impact on coastal environments accounted for about one quarter (29.6%) of the shore protection papers (Table 1). Bibliographic citations for papers dealing with erosion trends and environmental impacts are compiled in Tables 5 and 6, respectively. Elucidation of erosion trends is essential to successful shore protection for justification of protective efforts and determination of the most appropriate means of protection in the form of hard or soft shoreline stabilization. Most efforts described in the JCR feature beach renourishment (replenishment, restoration) schemes, including pre-project justification and post-project performance evaluations. Adverse environmental impacts were detailed in most papers in an effort to establish the need for shore protection. The degree of impact was often related to the severity of trends where rapid rates of shoreline retreat were seen as the most dangerous to maintenance of shoreline integrity, but slower rates over longer periods of time were also viewed as threat to environmental stability. Many different approaches were deployed in efforts to best evaluate true or actual rates of shoreline retreat. These different approaches to data analysis stemmed from problems with the data sets and difficulty in approximating shoreline movement, as either transgressive or regressive motions, or determination of dynamically stable shorelines. Trend analysis was in some cases almost problematic but most observations showed that erosion threatened natural environments and was most commonly mitigated along developed shorelines.

SHORE PROTECTION EFFORTS

Papers here focused on many topics within this thematic grouping. It is not possible to indicate all of the different types of shore protection works or programs, but several different approaches to shore protection works are notable. The development, application and effectiveness of large hard structures, for example, are described for mound structures

Table 4. *List of bibliographic citations for papers occurring in the category 'numerical and quantitative studies.'*

Author(s), Date. Bibliographic Citation
Arcilla, A.S., 1989. An integrated numerical approach for coastal engineering problems. *JCR*, 5(3), 603–616.
Arnoux-Chiavassa, S.; Rey, V., and Fraunie, P., 1999. Modeling of suspended sediments fluxes off the Rhone river mouth. *JCR*, 15(1), 61–73.
Balsillie, J., 1985. Redefinition of shore breaker classification as a numerical continuum and a design shore-breaker. *JCR*, 1(3), 247–254.
Basco, D.R. and Shin, C.S., 1999. A one-dimensional numerical model for storm-breaching of barrier islands. *JCR*, 15(1), 241–260.
Bauer, B.O., 1990. Assessing the relative energetics of "infragravity" motions in lakes and bays. *JCR*, 6(4), 853–866.
Bodge, K.R., 1992. Representing equilibrium beach profiles with an exponential expression. *JCR*, 8(1), 47–55.
Bray, M.J.; David, J.C., and Hooke, J.M., 1995. Littoral cell definition and budgets for central southern England. *JCR*, 11(2), 381–400.
Brunn, P., 1988. The Brunn rule of erosion by sea-level rise: A discussion on large-scale two three-dimension usages. *JCR*, 4(4), 627–648.
Caviglia, F.J.; Pousa, J.L., and Lanfredi, N.W., 1991. A determination of the energy flux constant from dredge records. *JCR*, 7(2), 543–550.
Cialone, M.A., 1994. The coastal modeling system (CMS): A coastal processes software package. *JCR*, 10(3), 576–587.
Cin, R.D. and Simeoni, U., 1994. A model for determining the classification, vulnerability, and risk in the southern coastal zone of Marche (Italy). *JCR*, 10(1), 18–29.
Cooper, N.J., 1998. Assessment and prediction of Poole Bay (UK) sand replenishment schemes: Application of data to Fuhrboter and Verhagen Models. *JCR*, 14(1), 353–359.
Crowell, M.; Douglas, B.C., and Leatherman, S.P., 1997. On the forecasting future U.S. shoreline positions: A test of algorithms. *JCR*, 13(4), 1245–1255.
Cummings, P.D., 1998. The growth of wind waves estimated using a new irrotational finite amplitude water wave model. *JCR*, 14(4), 1354–1352.
De Lange, W. and Healy, T., 1994. Assessing the stability of inner shelf dredge spoil mounds using spreadsheet applications on personal computers. *JCR*, 10(4), 946–958.
Dean, R.G., 1997. Models for barrier island restoration. *JCR*, 13(3), 694–703.
Desa, E.; Nayak, M.R., and Prabhu Desai, R.G., 1988. Microprocessors design aspects for coastal oceanographic instruments. *JCR*, 4(3), 499–506.
Doering, J.R.C., 1997. Predicting shoaling wave heights. *JCR*, 13(4), 1213–1220
Douglas, B.C. and Crowell, M., 2000. Long-term shoreline position prediction and error propagation. *JCR*, 16(1), 145–152.
Dubois, R.N., 1992. A re-evaluation of the Brunn's rule and supporting evidence. *JCR*, 8(3), 618–629.
Dubois, R.N., 1999. An inverse relationship between the A and m coefficients in the Brunn/Dean equilibrium profile equation. *JCR*, 15(1), 186–197.
Eliasson, J., 1996. Probability of tidal surge levels in Reykjavik, Iceland. *JCR*, 12(1), 368–374.
Friedrichs, C.T., 1995. Stability shear stress and equilibrium cross-sectional geometry of sheltered tidal channels. *JCR*, 11(4), 1062–1074.
Gibeaut, J.C.; Gutierrez, R., and Kyser, J.A., 1998. Increasing the accuracy and resolution of coastal bathymetric surveys. *JCR*, 14(3), 1082–1098.
Gibson, D.J.; Ely, J.S., and Looney, P.B., 1997. A Markovian approach to modeling succession on a coastal barrier island following beach nourishment. *JCR*, 13(3), 831–841.
Guan, C.; Rey, V., and Forget, P., 1999. Improvement of the WAM wave model and its application to the Rhone river mouth area. *JCR*, 15(4), 966–973.
Hanson, H., 1988. Genesis—A generalized shoreline change numerical model. *JCR*, 5(1), 1–28.
Hobbs, C.H., III, Halka, J.P., Kerhin, R.J., and Carron, M.J., 1992. Chesapeake Bay sediment budget. *JCR*, 8(2), 292–300.
Hsu, Tai-Wen and Wang, H., 1997. Geometric characteristics of storm beach profiles. *JCR*, 13(4), 1102–1110.
Hubbert, G.D. and McInnes, K.L., 1999. A storm surge inundation model for coastal planning and impact studies. *JCR*, 15(1), 168–185.
Hughes, M.G., 1995. Friction factors for wave uprush. *JCR*, 11(4), 1089–1099.
Hyllier, T.M.; Stakhiv, E.Z., and Sundar, R.A., 1997. An evolution of the economic performance of the U.S. Army Corp of Engineers Shore Protection Program. *JCR*, 13(1), 8–22.
Irish, J.L. and Lillicrop, W.J., 1997. Monitoring New Pass, Florida, with high density Lidar bathymetry. *JCR*, 13(4), 1130–1140.
Jayakumar and Mahadevan, R., 1993. Numerical simulation of shoreline evolution using a one line model. *JCR*, 9(4), 915–923.
Jonhson, H.K., 1998. On modeling wind-waves in shallow and fetch limited areas using the method of Holthuijsen, Booij and Herbers. *JCR*, 14(3), 917–932.
Karambas, T.V., 1999. A unified model for periodic non-linear dispersive waves in intermediate and shallow water. *JCR*, 15(1), 128–139.
Krauss, N.C.; McDougal, W.G., and Ajiwibowo, H., 1996. The effects of seaways on the beach: Part II, Numerical modeling of SUPERTANK seawall tests. *JCR*, 12(3), 702–713.
Komar, P.D. and McDougal, W.G., 1994. The analysis of exponential beach profiles. *JCR*, 10(1), 59–69.
Lee, P. Zi-Fang, 1994. The submarine equilibrium profile: A physical model. *JCR*, 10(1), 1–18.
Leenknecht, D.A., Sherlock, A.R., and Szuwalski, A. 1995. Automated tools for coastal engineering. *JCR*, 11(4), 1108–1124.
Mani, J.S.; Oumeraci, H., and Muttray, M., 1994. Rundown velocity along the slope of a breakwater with accropode cover layer. *JCR*, 10(4), 789–802.
Markle, D.G., 1989. Physical models of coastal structures as designed and used by the U.S. Army Corps of Engineers. *JCR*, 5(3), 573–592.
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Mathew, J.P.; Mahadevan, R.; Bharatkumar, B.H., and Subramanian, V. 1996. Numerical simulation of open coast surges. Part I: Experiments on offshore boundary conditions.JCR, 12(1), 112–122.
Mathew, J.P. and Mahadevan, R., 1996. Numerical simulation of open coast surges. Part II: Experiments with storm parameters and shelf geometry. *JCR*, 12(1), 123–132.
Morton, R.A.; Leach, M.P.; Paine, J.G., and Cardoza, M.A., 1993. Monitoring beach changes using GPS surveying techniques. *JCR*, 9(3), 702–720.
Muños-Perez, J.J.; Tejedor, L., and Medina, R., 1999. Equilibrium beach profile model for reef protected beaches. *JCR*, 15(4), 950–957.
Muraca, A. and Rossi, V., 1995. Field analysis of wave action on breakwaters. *JCR*, 11(4), 1025–1034.
Okazaki, S-i. and Sunamura, T., 1991. Re-examination of breaker-type classification on uniformly inclined laboratory beaches. *JCR*, 7(2), 559–564.
Parson, L.E.; Lillicrop, W.J.; Klein, C.J.; Ives, R.C.P., and Orlando, S.P., 1997. Use of Lidar technology for collecting shallow water bathymetry of Florida Bay. *JCR*, 13(4), 1173–1181.
Rey, V.; Davies, A.G., and Belzons, M., 1995. On the formation of bars by the action of waves on an erodible bed: A laboratory study. *JCR*, 11(4), 1180–1194.
Russel, P.E. and Huntley, D.A., 1999. A cross-shore transport "shape-function" for high energy beaches. *JCR*, 15(1), 198–205.
Sheall, I.L., 1991. Reducing costs and improving the industry: Goals of the dredging research program of the United States. *JCR*, 7(2), 535–542.
Signell, R.P.; List, J.H., and Farris, A.S., 2000. Botton currents and sediment transport in Long Island Sound: A modeling study. *JCR*, 16(3), 551–566.
Skyum, P.; Christiansen, C., and Blaesild, P., 1996. Hyperbolic distributed wind, sea-level, and wave data. *JCR*, 12(3), 883–889.

Table 4. *Continued.*

Author(s), Date. Bibliographic Citation
Smith, G.L. and Zarillo, G.A., 1990. Calculating long term shoreline recession rates using aerial photographic and beach profiling techniques. *JCR*, 6(1), 111–120.
Sobey, R.J. and Barker, C.H., 1997. Wave-driven transport of surface oil. *JCR*, 13(2), 490–496.
Suhayda, J.N., 1997. Modeling impacts of Louisiana barrier islands on wetland hydrology. *JCR*, 13(3), 686–693.
Sundar, V .; Noethel, N., and Holz, K.P., 1993. Wave kinematics in a groin field-time domain analysis. *JCR*, 9(3), 831–846.
Thieler, E.R.; Pilkey, O.H., Jr.; Young, R.S.; Bush, D.M., and Chai, F., 2000. The use of mathematical models to predict beach behavior for U.S. coastal engineering: A critical review. *JCR*, 16(1), 48–70.
Thompson, E.F. and Hadley, L.L., 1995. Numerical modeling of harbor response to waves. *JCR*, 11(3), 744–753.
Walton, T.L., Jr., 1998. Least squares filtering to assess shoreline changes signatures. *JCR*, 14(4), 1225–1230.
Wang, F.C.; Ransibrahmanakul, V.; Tuen, K.L.; Wang, M.L., and Zhang, F., 1995. Hydrodynamics of a tidal inlet in Fourleague Bay/Atchafalaya Bay, Louisiana. *JCR*, 11(3), 733–743
Wang, P. and Davis, R.A., Jr., 1998. A beach profile model for a barred coast—Case Study from Sand Key, West-Central Florida. *JCR*, 14(3), 981–991.
Williams, J.J.; Bell, P.S.; Thorne, P.D.; Trouw, K.; Hardcastle, P.J., and Humphery, J.D., 2000. Observed and predicted vertical suspended sediment concentration profiles and bedforms in oscillatory-only flow. *JCR*, 16(3), 698–709.
Xu, J.P. and Wright, L.D., 1998. Observations of wind-generated shoreface currents off Duck, North Carolina. *JCR*, 14(2), 610–619.
Xu, J.P.; Wright, L.D., and Boon, J.D., 1994. Estimation of bottom stress and roughness in lower Chesapeake Bay by the intertidal dissipation method. *JCR*, 10(2),329–8.
Young, R.S.; Pilkey, O.H.; Bush, D.M., and Thieler, E.R., 1995. A discussion of the generalized model for simulating shoreline change (GENESIS). *JCR*, 11(3), 875–886.
Yuksel, Y.; Cevik, E.O., and Kapdasli, S., 1998. Bed shear stress distribution over beach profiles. *JCR*, 14(3), 1044–1053.
Zarillo, G.A. and Park, M-J., 1987. Sediment transport prediction in a tidal inlet using a numerical model: Application to Stony Brook Harbor, Long Island, New York, USA. *JCR*, 3(4), 429–444.
Zhang, L. and Edge, B.L., 1998. A note on applications of the mild-slope equation for random waves. *JCR*, 14(2), 604–609.
Zhang, L.; Kim, M.H.; Zhang, L., and Edge, B.L., 1999. Hybrid model for Bragg scattering of water waves by steep multiple-sinusoidal bars. *JCR*, 15(2), 486–195.

and (*e.g.* BRUUN, 1987; KING*et al.*, 2000; SAWARAGI, 1988; ZENKOVICH and SCHWARTZ, 1987) and breakwaters (*e.g.* KING *et al.*, 2000; LAUSTRUP, 1988; CHARLIER and DE MEYER, 2000) whereas smaller hard structures such as groins are additionally considered (*e.g.* BULL *et al.*, 1998; FRENCH and LIVESEY, 2000). Types of engineering structures to protect estuaries and semi-enclosed bays from the effects of storm surges are summarized by WATSON and FINKL (1990), for the Thames Estuary and coastal Netherlands, and from flooding due to relative sea-level rise as discussed by PIRAZZOLI (1991). Drainage works were considered in terms of large coastal zone projects such as sewage system design for overflow and for test sites on single beaches in the case of beach dewatering (*e.g.* TURNER and LEATHERMAN, 1997). Soft engineering works mainly focused on beach replenishment and construction of artificial beaches (see subsequent discussion) and dune management for shore protection (*e.g.* VERHAGEN, 1990). These examples are by no means comprehensive, as the scope of shore protection efforts reported in the JCR is wide. A bibliographic reference list of papers occurring in this category is provided in Table 7.

Table 5. *List of bibliographic citations for papers occurring in the category 'erosion trends—studies of sediment transport, longshore drift, and shoreline change' category.*

Author(s), Date. Bibliographic Citation
Amin, S.M.N. and Davidson-Arnott, R.G.D., 1997. A statistical analysis of the controls on shoreline erosion rates, Lake Ontario. *JCR*, 13(4), 1093–101.
Ashley, G.M., 1987. Assessment of hydraulics and longevity of Wood End Cut (inlet), Cape Cod, Massachusetts, USA. *JCR*, 3(3), 281–296.
Aubie, S. and Tastet, Jean-Pierre, 2000. Coastal erosion processes and rates: An historical study of the Gironde coastaline, Southwestern France. *JCR*, 16(3), 756–767.
Brunn, P., 1995. The development of downdrift erosion. *JCR*, 11(4), 1242–1257.
De Vries, J.W., 1992. Field measurements of the erosion of cohesive sediments. *JCR*, 8(2), 312–318.
Dolan, R.; Trossbach, S., and Buckley, M., 1990. New shoreline erosion data for the mid-Atlantic coast. *JCR*, 6(2), 471–478.
Douglas, B.C.; Crowell, M., and Leatherman, S.P., 1998. Consideration for shoreline position prediction. *JCR*, 14(3), 1025–1033.
Fenster, M.S. and Dolan, R., 1993. Historical shoreline trends along the Outer Banks, North Carolina: Processes and responses. *JCR*, 9(1), 172–188.
Finkl, C.W., Jnr., 1996. What might happen to America's shorelines if artificial beach replenishment is curtailed: A prognosis for southeastern Florida and other sandy regions along regressive coasts. *JCR*, 12(1), iii.
Jones, J.R.; Cameron, B., and Fischer, J.J., 1993. Analysis of cliff retreat and shoreline erosion: Thompson Island, Massachusetts, U.S.A., *JCR*, 9(1), 87–96.
Hackney, C.T. and Clearly, W.J., 1987. Saltmarsh lost in southeastern North Carolina lagoons: Importance of sea level rise and inlet dredging. *JCR*, 3(1), 93–98.
Hall, S.L.; Wilder, W.R., and Fischer, F.M., 1986. An analysis of shoreline erosion along the northern coast of East Galveston Bay, Texas. *JCR*, 2(2), 173–180.
Kahn, J.N., 1986. Geomorphic recovery of the Chandeleur Islands, Louisiana, after a major hurricane. *JCR*, 2(3), 337–344.
Koster, M.J. and Hillen, R., 1995. Combat erosion by law coastal defense policy for the Netherlands. *JCR*, 11(4), 1121–1128.
Lacey, E.M. and Peck, J.A., 1998. Long-term beach profile variations along the south shore of Rhode Island, U.S.A. *JCR*, 14(4), 1255–1264.
Leatherman, S.P.; Douglas, B.C., and Crowell, M., 1997. Beach erosion trends and shoreline forecasting. *JCR*, 13(4), iii.
Psuty, N.P. and Moreira, M.E.S.A., 1992. Characteristics and longevity of beach nourishment at Praia da Rocha, Portugal. *JCR*, 8(3), 660–676.
Rongning, L. and Hualing, X., 1995. A channel erosion and accretion analysis of One Port in Beibu bay, China. *JCR*, 11(4), 1037–1041.
Samsuddin, M . and Suchindan, G.K., 1987. Beach erosion and accretion in relation to seasonal longshore current variation in the Northern Kerala coast, India. *JCR*, 3(1), 55–62.
Smith, S.E. and Abdel-Kader, A., 1988. Coastal erosion along the Egyptian delta. *JCR*, 4(2), 245–256.
Smith, A.W. and Jackson, L.A., 1990. Assessment of past extend of cyclone beach erosion. *JCR*, 6(1), 73–86.
Terich, T. and Levenseller, T., 1986. The severe erosion of Cape Shoalwater, Washington. *JCR*, 2(4), 465–478.
Walton, Jr., T.L., 1989. Simulating Great Lakes water level for erosion prediction. *JCR*, 5(3), 377–390.

Papers featuring design considerations and anticipated environmental impacts, but which did not consider construction *per se*, were grouped in the section dealing with environmen-

Table 6. *List of bibliographic citations for papers occurring in the category 'environmental impacts.'*

Author(s), Date. Bibliographic Citation
Brunn, P., 1986. Morphological and navigation aspects of tidal inlets on littoral drift shores. *JCR*, 2(2), 123–146.
Chasten, M.A. and Seabergh, W.C., 1993. Beach responses and channel dynamics at little river inlet, North and South Carolina. *JCR*, 9(4), 973–985.
Cialone, M.A. and Stauble, D.K., 1998. Historical findings on web shoal mining. *JCR*, 14(2), 537–563.
Drapeau, G.; Gauthier, D., and Lavallee, D., 1999. In situ deposition versus transport by density currents of dredged sediments dumped in coastal waters. *JCR*, 15(1), 87–96.
Eitner, V. and Ragutzki, G., 1994. Effects of artificial beach nourishment on nearshore sediment distribution (Island of Norderney, Southern North Sea). *JCR*, 10(3), 637–650.
Fanos, A.M., 1995. The impact of human activities on the erosion and accretion of the Nile delta coast. *JCR*, 11(3), 821–833.
Fenster, M. and Dolan, R., 1996. Assessing the impact of tidal inlets on adjacent barrier island shorelines. *JCR*, 12(1), 294–310.
Fletcher, C.H.; Mullane, R.A., and Richmond, B.M., 1997. Beach loss along armored shorelines on Oahu, Hawaiian Islands. *JCR*, 13(1), 209–215.
French, P.W. and Livesey, J.S., 2000. The impact of fish-tail groynes on sediment deposition at Morecambe, North-West England. *JCR*, 16(3), 724–734.
Frihy, O.E.; Dewidar, K.M., and El Banna, M.M., 1998. Natural and human impact on the northeastern Nile delta coast of Egypt. *JCR*, 14(3), 1109–1118.
Gaillot, S. and Piegay, H., 1999. Impact of gravel mining on stream channel and coastal sediment supply example of the Calvi Bay in Corsiga (France). *JCR*, 15(3), 774-
Hall, M.J. and Pilkey, O.H., 1991. Effects of hard stabilization on dry beach width for New Jersey. *JCR*, 7(3), 771–786.
Hesp, P., and Hilton, M.J., 1996. Nearshore-surfzone limits and the impacts of sand extraction. . *JCR*, 12(3), 726–747.
Hilton, M.J. and Hesp, P., 1996. Determining the limits of beach-nearshore sand systems and the impact of offshore coastal sand mining. *JCR*, 12(2), 496–519.
Krauss, N.C. and McDougal, W.G., 1996. The effects of seaways on the beach: Part I, an updated literature review. *JCR*, 12(3), 691–701.
Louters, T.; Mulder, J.P.M.; Postma, R., and Hallie, P.F., 1991. Changes in coastal morphological processes, due to the closure of tidal inlets in the SW Netherlands. *JCR*, 7(3), 635–652.
Louters, T.; van der Berg, J.H., and Mulder, J.P.M., 1998. Geomorphological changes of the Oosterschelde tidal system during and after the implementation of the Delta Project. JCR, 14(3), 1134–1151.
Maa, J.P.-Y. and Hobbs, C.H., III, 1998. Physical impact of waves on adjacent coasts resulting from dredging at Sandbridge shoal, Virginia. *JCR*, 14(2), 525–536.
Milton, S.L.; Schuman, A.A., and Lutz, P.L., 1997. The effect of beach nourishment with aragonite versus silicate sand on beach temperature and loggerhead sea turtle nesting sites. *JCR*, 13(3), 904–915.
Moon, V.; de Lange, W.; Warren, S., and Heady, T., 1994. Post-disposal behavior of sandy dredged material at an open-water, inner shelf disposal site. *JCR*, 10(3), 651–662.
Peterson, C.H.; Hickerson, D.H.M., and Johnson, G.G., 1999. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. *JCR*, 16(2), 368–378.
Pilkey, O.H., 1995. The Fox guarding the Hen House. *JCR*, 11(3), iii.
Plant, N.G., and Griggs, G.B., 1992. Interactions between nearshore processes and beach morphology near a seawall. *JCR*, 8(1), 183–200.
Pope, J. 1997. Responding to coastal erosion and flooding damages. *JCR*, 13(3), 704
Steinitz, M.J., Salmon, M., and Wyneken, J., 1998. Beach renourishment and loggerhead turtle reproduction: A seven year study at Jupiter Island, Florida. *JCR*, 14(3), 1000–1013.
Sundar, V., Noethel, H., and Holz, Klaus-Peter, 1994. Wave direction in a groin field. *JCR*, 10(4), 839–849.
Truitt, C., 1988. Dredged material behavior during open-water disposal. *JCR*, 4(3), 489–498.
Van der Wall, D., 1998. The impact of the grain-size distribution of nourishment sand on aeolian sand transport. *JCR*, 14(2), 620–631.
Walton Jr., T.L. and Bruno, R.O., 1989. Longshore transport at a detached breakwater, phase II. *JCR*, 5(4), 679–692.
Wu, C. and Yuan, S., 1995. Dynamic structures and their sedimentation effects in Huangmaohai Estuary, China. *JCR*, 11(3), 808–820.

tal impacts of engineering works. Evaluations of structure performance perhaps provided the most useful information for JCR readers who are interested in overall structural reliability, shoreline stability fronting engineering works, and development or reduction of downdrift erosion (summaries are provided in BRUUN, 1995).

BEACH NOURISHMENT, REPLENISHMENT, RESTORATION

Perhaps the most interesting and informative developments of the last two decades were the "great shore protection debates." These debates, which took the form of professional papers and an extended series of discussions and replies, as well as letters to the editor, clarified differences in approach among the disciplines of geoscience and engineering. The debates were wide ranging and covered many different topics related to aspects of shore protection. Salient among the debate topics were themes that focused on beach erosion control and public issues, rationalization of shore protection measures, and evaluations of beach replenishment. The debates were especially instructive and illuminating because they brought to the fore some aspects of shore protection that were previously not well known by the coastal research community and apparently not fully appreciated by coastal managers.

Consideration of beach renourishment, for example, led to spirited discussions because the technique is the protective measure of choice for shorelines fronted by sandy beaches. A series of papers initiated by Professor Orrin Pilkey and his graduate students and colleagues at Duke University (Durham, North Carolina), seemed innocuous enough, at least at first. The papers first considered the beach replenishment experience in the United States in a series of analyses for the Atlantic coast (PILKEY and CLAYTON, 1989; LEONARD *et al.*, 1990a), Gulf of Mexico (DIXON and PILKEY, 1991), and Pacific Coast (LEONARD *et al.*, 1990b). The early papers were mostly tabulations of data related to replenishment episodes along US shores. These reports featured information that was related to length of shore (*i.e.* sandy beach) that was renourished, date of renourishment, funding type, volume of sand deposited along specified lengths of shore, documented costs, and sources of information. Cursory inspection of the tables revealed glaring gaps in data where volumes, lengths of shore, types of funding, or documented costs could not be determined from published reports or from mostly unpublished federal or local government records. Inaccurate record keeping by the authorities overseeing replenishment efforts thus hindered nonpartisan attempts to evaluate the performance

Table 7. *List of bibliographic citations for papers occurring in the category 'coastal protection.'*

Author(s), Date, Bibliographic Citation
Ahrendt, K. and Kostner, R., 1996. An artificial longhsore bar at the west coast of the island of Sylt/German Bight—First experience. *JCR*, 12(1), 354–368.
Bottin, R.R., Jr., 1991. Fisherman's wharf: Hydraulic design of a successful harbor project. *JCR*, 7(1), 1–10.
Brunn, P. and Willekes, G., 1992. Bypassing and backpassing at harbors, navigation channels, and tidal entrances: Use of shallow-water draft Hooper dredges with pump-out capabilities. *JCR*, 8(4), 972–977.
Bruun, P., 1988. Rationalities of coastal erosion and protection: An example from Hilton Head Island, South Carolina. *JCR*, 4(1), 129–138.
Brunn, P., 1990. Beach nourishment—Improved economy through better profiling and backpassing from offshore sources. *JCR*, 6(2), 265–278.
Brunn, P. and Adams, J., 1988. Stability of tidal inlets: Use of hydraulic pressure for channel stability 4(4), 687–702.
Bull, C.F.J.; Davis, A.M.; Jones, R., and Kamel, A.M., 1998. The influence of fish-tail groynes (or breakwaters) on the characteristics of the adjacent beach at Llandudno, North Wales. *JCR*, 14(1), 93–105.
Burnett, A.D. and Whiteside, P.G.D., 1992. Dredged sand and gravel for construction purposes—an assessment procedure and Hong Kong case study. *JCR*, 8(1), 105–124.
Butler, D.F. and McAllister, R., 2000. Hillsboro inlet and the lighthouse: One hundred and fifteen years of change. *JCR*, 16(2), 336–345.
Carter, C.H.; Monroe, C.B., and Guy D.E., Jr., 1986. Lake Erie shore erosion: The effect of beach width and shore protection structures. *JCR*, 2(1), 17–24.
Carver, R.D. and Bottin, R.R., Jr., 1997. Reef breakwater design for Burns Waterway Harbor, Indiana, U.S.A. *JCR*, 13(4), 1267–1281.
Charlier, R.H. and de Meyer, C.P., 1995. New developments on coastal protection along the Belgian coast. *JCR*, 11(4), 1287–1293.
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Clayton, K.M., 1989. Sediment input from the Norfolk cliffs, Eastern New England—A century of coastal protection and its effects. *JCR*, 5(3), 433–443.
Davidson, A.T.; Nicholls, R.J., and Leatherman, S.P., 1992. Beach nourishment as a coastal management tool: An annotated bibliography on developments associated with the artificial nourishment beaches. *JCR*, 8(4), 984–957.
Davis, R.A., Jr.; Wang, P., and Silverman, B.R., 2000. Comparison of the performance of three adjacent and differently constructed beach nourishment projects on the gulf peninsula of Florida. *JCR*, 16(2), 396–407.
Dixon, K.L. and Pilkey, O.H., Jr., 1991. Summary of beach replenishment on the U.S. Gulf of Mexico shoreline. *JCR*, 7(1), 249–256.
Fanos, A.M. and Khafagy, A.A., and Dean, R.G., 1995. Protective works on the Nile delta coast. *JCR*, 11(2), 516–528.
Fischer, D.W., 1986. Beach erosion control: public issues on beach stabilization decisions, Florida. *JCR*, 2(1), 51–60.
Fischer, D.W.; Rivas, V., and Cendrero, A., 1995. Local government planning for coastal protection: A case study of Cantabrian municipalities. *JCR*, 11(3), 858–874.
FSBPA, 1995. Why Floridians oppose president Clinton's proposal to drop federal matching funds to preserve America's beaches. *JCR*, 11(2), 568–569.
Granja, H.M. and de Carvalho, G.S., 1995. Is the coastline "protection" of Portugal by hard engineering structures effective?. *JCR*, 11(4), 1229–1241.
Hemsley, J.M., 1990. Monitoring completed coastal projects: Status of a program. *JCR* 6(2), 253–264.
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Kelletat, D., 1992. Coastal erosion and protection measures at the German North Sea coast. *JCR*, 8(3), 699–711.
King, D.M., Cooper, N.J., Morfett, J.C., and Pope, D.J., 2000. Application of offshore breakwaters to the UK: A case study at Elmer beach. *JCR*, 16(1), 172–187.
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Leonard, L.; Clayton, T., and Pilkey, O.H., 1990. An analysis of replenished beach design parameters on U.S. east coast. *JCR*, 6(1), 15–36.
Louisse, C.J. and van der Meulen, F., 1991. Future coastal defense in the Netherlands: Strategies for protection and sustainable development. *JCR*, 7(4), 1027–1042.
Mimura, N. and Nunn, P.D., 1998. Trends of beach erosion and shoreline protection in the rural Fiji. *JCR*, 14(1), 37–46.
Moller, J.T., 1992. Balanced coastal protection on a Danish North Sea coast. *JCR*, 8(3), 712–718.
Pilkey, O.H. and Clayton, T. D., 1989. Summary of beach replenishment experience on the U.S. east coast barrier islands. *JCR*, 5(1), 147–160.
Pilkey, O. H., 1990. A time to look back at beach replenishment. *JCR*, 6(1), iii.
Pilkey, O.H., 1993. Can we predict the behavior of sand: in a time and volume framework of use to mankind?. *JCR*, *9(1)*, iii–v.
Pirazzoli, P.A., 1991. Possible defenses against a sea-level rise in the Venice area, Italy. *JCR*, 7(1), 231–248.
Saffir, H.S., 1992. An evaluation of present-day hurricane resistant building codes. *JCR*, 8(2), 492–495.
Sawaragi, T., 1988. Current shore protection works in Japan. *JCR*, 4(4), 531–542.
Simeonova, G.A., 1992. Coastal protection against erosion along the Bulgarian black sea. *JCR*, 8(3), 745–751.
Tait, S., 1995. Organization plan for "Save America's Beaches". *JCR*, 11(2), 566–567.
Thyme, F., 1990. Beach nourishment on west coast of Jutland. *JCR*, 6(1), 201–210.
Turner, I.L. and Leatherman, S.P., 1997. Beach dewatering as a 'soft' engineering solution to coastal erosion—A history and critical review. *JCR*, 13(4), 1050–1063.
Twu, Sheng-Wen and Liao, Wei-Miu, 1999. Effects of seawall slopes on scour depth. *JCR*, 15(4), 985–990.
Costa, F.V., 1991. Coastal structures design taking into consideration the consequences of possible failures. *JCR*, 7(4), 1175–1180.
Verhaguen, H.J., 1996. Analysis of beach nourishment schemes. *JCR*, 12(1), 179–185.
Verhaguen, H.J., 1990. Coastal protection and dune management in the Netherlands. *JCR*, 6(1), 169–180.
Ward, D.L.; Wibner, C.G., and Zhang, J., 1998. Runup on coastal revetments under the influence of onshore wind. *JCR*, 14(4), 1325–1333.
Watson, I. and Finkl, C.W., Jnr., 1990. State of the art in storm-surge protection: The Netherlands Delta Project. *JCR*, 6(3), 739–767.
Wilson, K.C., 1995. Suction design consideration for sand bypassing/backpassing*systems*. *JCR*, 11(4), 1329–1336.
Yazdani, N. and Kadnar, J.O., 1993. Effect of wind on coastal construction on Florida. *JCR*, 9(4), 1054–1064.
Yazdany, N. and Yeaza, I.D., 1995. Multy-Agency integrated code for coastal construction. *JCR*, 11(3), 899–903.
Yazdani, N., Nnanji, S., and Rambo-Rodembery, M., 1997. Concept breakwater swimming pool design for coastal areas. *JCR*, 13(1), 61–66.
Zencovich, V.P. and Schwartz, M.L., 1987. Protecting the Black Sea—Georgian S.S.R. gravel coast. *JCR*, 3(2), 201–210.
Zunica, M., 1990. Beach behavior and defenses along the Lido de Jesolo, Gulf of Venice, Italy. *JCR*, 6(3), 709–720.

of beach replenishment efforts in the USA. Nevertheless, results of the Duke University studies showed that there were many problems associated with beach replenishment and, in particular, that the method often does not perform as anticipated or as projected by the U.S. Army Corps of Engineers in feasibility studies.

Arising from these reviews of replenishment activities in the US, a new terminology was developed to describe the ruggedness or persistence of sand placed along the shore to form artificial beaches. *Beach durability* defined how well the beach performed under a variety of conditions. The definition of beach durability by LEONARD *et al.* (1990a,b) seems forthright as stated "... the time between placement and loss of at least 50% of the original fill volume." HOUSTON (1991) suggests, however, that the initial adjustment of the fill to an equilibrium profile should not be interpreted as a "loss" of volume because the material remains offshore. SMITH (1990) questions whether the profile of equilibrium really exists and suggests that the beach has a continuing cascade of temporary regime profiles. Applications of the concept of equilibrium profiles to problems of coastal engineering are discussed by DEAN (1991) in relation to sediment redistribution and grain sizes. The identification of profile evolution is an important consideration in the analysis of the performance of placed material and its longevity. Disagreement and opposing points of view regarding the overall beach fill budget emphasized that many fills have short lives. A related concept was the *beach half-life,* referring to the time elapsed before half of the subaerial beach was eroded. These terms proved to be useful and they have remained in the literature as part of the scientific jargon associated with beach replenishment activities.

The Duke University studies (*e.g.* PILKEY and CLAYTON, 1989; LEONARD *et al.*, 1990a,b; DIXON and PILKEY, 1991) discovered that replenished beaches rarely persisted for the design life, which was usually projected ten years or more into the future. The percentage of replenished beaches lasting more than five years along Atlantic barrier islands averaged about 65% while those on Gulf and Pacific coasts respectively averaged about 75% and 55%. Other considerations coming out of the beach renourishment debates focused on erosion rates. HOUSTON (1991), for example, took issue with LEONARD *et al.* (1990) who concluded that renourished beaches erode at rates greater than natural beaches, an observation that SMITH (1990) found not surprising. Recognition of the role played by grain size in beach stability confirmed previous observations and reinforced recognition that coarser grain sizes produced steeper, more stable, and longer lived fills (*e.g.* BRUUN, 1990; PILKEY, 1990; SMITH, 1990; DEAN, 1991). Controversy surrounded the kinds of methods that are used to estimate erosion rates, with HOUSTON (1990) emphasizing that extrapolations are not advisable because erosion is seasonal or cyclical. As emphasized by SMITH (1990), designer prediction of replenished beach life of one to several decades is not advisable because beach conditions are too variable and especially vulnerable to cycles of storminess. Results of various discussions seemed to indicate that methods to establish beach fill loss rates need to be standardized to reduce widely differing results stemming from different interpretations of the same data.

Aside from the durability issue, it was found that the longevity of the subaerial beach was shorter than anticipated. It became an important issue because the subaerial beach is that part of the beach that is visible and usable by the public. Although part of the beach still existed as a submerged feature along the shore, via conservation of sand in the nourishment project area, it was of little direct use by the public. The *effective* or *usable beach* width was thus often much less than the whole beach, part of which was under water. From the point of view of the coastal engineer, the project was successful although part of the beach was submerged. The public, however, perceived the situation quite differently and this led to diverging opinions as to the success of a project. The new terminology concerning beach durability and effective or usable width was a step forward in that it brought into focus issues that were heretofore not fully recognized.

Methods of data analysis was a recurring discussion in the decade of the 90s (*e.g.* HOUSTON, 1990, 1991; LEONARD *et al.*, 1990a,b, 1995; PILKEY, 1990, 1995; PILKEY and LEONARD, 1990a,b,c; SMITH, 1990). It is interesting to note that it is not only the methods of analysis that are discussed, but also the acquisition of data itself. Information that is accurate and reliable apparently is not always readily available from federal and local governmental sources. Often, when it is available, the data are surrounded by questions of validity. The age-old caveats surrounding data seem especially pertinent to beach replenishment studies because it is essential to know whether the data is adequate, accurate, appropriate, and relevant. When these concerns are not met for each bit of data, analysis of that data becomes suspect at best and meaningless at worst. The discussions of data quality, or lack of it, highlighted the need for better record keeping. These debates appear to have had the salubrious effect of stimulating more comprehensive documentation and reporting of beach nourishment projects.

CONCLUSIONS

In the near first twenty years of publication in coastal research, the *Journal of Coastal Research* has become a major player in the arena of marine and environmental science. Over the sixteen-year period of study, the JCR produced 1206 professional papers with an average of about 75 papers per volume year. In the first decade, the average number of papers per volume year was about 60 whereas in the second decade the number of published papers increased to about 81 per volume year. Debates arising from papers critical of projections for the life spans of renourished beaches and some quantification of coastal processes, especially coastal modeling efforts, created renewed interest in technical and engineering aspects of coastal management. Numerical studies (including quantitative models) and investigations of shore protection works each accounted for about one-quarter of the shore-protection papers published. Coastal engineering research and technology transfer comprised about one-third of the papers while studies of environmental impacts and shore erosion combined accounted for about 15%. Increasing interest is associated with numerical studies, supported by backup studies in basic research, and environmental impacts of shore protection works.

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BULL, C.F.J.; DAVIS, A.M., and JONES, R., 1998. The influence of fish-tail groynes (or breakwaters) on the characteristics of the adjacent beach at Llandudno, North Wales. *Journal of Coastal Research*, 14(1), 93–105.

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