Coastal Hydraulics

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D. M. McDowell and B. A. O'Connor

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E. M. Wilson

Coastal Hydraulics

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Second Edition

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Preface to the Second Edition

The date of publication of the first edition of this book (by the first author) approximately coincided with the beginning of a period of 'mighty ferment' in the development of understanding of the physics of the sea, its motions, its forces and its capacity for erosion, sediment transport and deposition.

Whereas twelve years ago many of the phenomena of morphological change could only be developed in a qualitative sense from simple basic physical formulae, subsequent research, model testing and fullscale monitoring present many new quantitative design methods with reasonable assurance of reproducing nature, having regard to the inherent uncertainties of the sea and its energy transfers.

We need to recognise many reasons for adopting a probabilistic approach to the behaviour of the sea. Questions of uncertainty in energy transfer largely concern variations in solar radiation, directly as air/sea temperatures and indirectly as winds over the face of the sea. Additionally, wave patterns, turbulence and sea levels need to be expressed in statistical terms of magnitude and frequencies. The behaviour of a water particle at an instant of time represents the consequences of innumerable events at innumerable points in space. Hence, extreme effects are bound to be expressed in terms of exceedance.

When, however, we are concerned with the measurement of change over a long period of months or years, we may reasonably consider an estimate related to mean conditions and, if we wish, representing uncertainty in terms of a standard deviation. Even so the uncertainty may still extend to an unpredictable event causing an irreversible change.

Perhaps the single most important feature responsible for technical advance has been the increased activity offshore, particularly in relation to gas and oil. Structures of a size and cost never previously built at sea demand much data on winds, currents and waves for economic design. The availability of such data makes it possible to tackle many more maritime problems with assurance. Ever greater investigation and analysis, essential to reliable prediction, can be justified by the increasing capacity and reduced costs of computers, with associated advances in programming, and the process snowballs as monitoring of the out-turn permits comparison with hindcasting.

Whereas, in consequence, the first edition was conceived much as an introduction to the marine environment, at a time of only slight sea tang in a first-degree course in civil engineering, the second edition is more ambitious in

attempting to combine a reasonable coverage of the basic physics with an adequate handbook for tackling simpler problems and a book of reference for the more complex ones. The ubiquity of the programmable pocket calculator, even for the most isolated engineer, implies that the complexity of a recommended method of analysis may be considered primarily in relation to the economic benefit that this allows. In the first edition, the isolated engineer was assumed to rely on observation, slide rule and power of logic only.

This has been a difficult book to write, particularly in relation to selection of material in order to combine immediately useful advice with introductions to developments still at a stage of major growth. The authors wish to acknowledge the help, advice and criticism from many of their colleagues in and around Sir William Halcrow & Partners including particularly W.L. Wood, L. Summers, C.J. Antonakis, J.E. Clifford, P.S. Godfrey, R.J. Maddrell and M. O'Leary. The authors will welcome criticism towards, perhaps, an improved third edition. Finally, we would like to thank Mrs Iris Golding for her valuable work in typing the drafts and Mrs Margaret Powers for preparation of the figures.

Notation

Symbol	Brief Definition	Dimensions
A	Amplitude of tidal constituent	—
A	Highest wave crest	L
B	Height of tidal bore	L
b	Distance between wave orthogonals	L
b	Breakwater gap width	L
b_0	Distance between wave orthogonals in deep water	L
C_c	Contraction coefficient	—
C_v	Velocity coefficient	—
C	Wave celerity	LT^{-1}
C_D	Drag coefficient	—
C_L	Lift coefficient	—
Ch	Chezy coefficient	—
C	Friction coefficient	—
C_g	Wave group velocity	LT^{-1}
C	Lowest wave trough	L
$C_{D_{90}}$	Chezy coefficient with D_{90} roughness length	—
C_M	Mass coefficient	—
C_n	Ratio of wave group velocity to celerity	—
C_0	Wave celerity in deep water	LT^{-1}
C_s	Wave celerity in shallow water	LT^{-1}
c	Concentration of sediment	—
c	Bottom energy coefficient	—
$\hat{c}$	Maximum volumetric concentration	—
c_0	Reference concentration	—
$\bar{c}_b$	Average concentration in bed load	—
cn	Jacobian elliptic function	—
D_{35}	Grain diameter (35% finer than)	L
D_{50}	Grain diameter (50% finer than)	L
D_{90}	Grain diameter (90% finer than)	L
D_{gr}	Dimensionless grain size	—
d	Diameter	L
d	North declination	—
$\hat{d}_0$	Maximum water particle orbit at bed	L

Symbol	Brief Definition	Dimensions
E	Earth's mass	M
E_k	Kinetic energy of wave per unit width	MLT^{-2}
E_p	Potential energy of wave per unit width	MLT^{-2}
E_t	Total energy of wave per unit width	MLT^{-2}
E	Phase of tide rising force	—
E	Total energy of wave per unit area	MT^{-2}
E_f	Dissipation of energy per unit area of bed	MT^{-2}
e	Radius of the Earth	L
e	Void ratio	—
F_r	Froude number	—
F	Fetch	L
F_e	Effective fetch	L
F	Force	MLT^{-2}
F_{wc}	Dimensionless coefficient	—
f	Frequency	T^{-1}
f	Friction parameter	—
f_c	Current friction factor	—
f_e	Wave energy factor	—
f_p	Peak energy frequency	T^{-1}
f_w	Wave friction factor	—
g	Acceleration due to Earth's gravitational force at surface level	LT^{-2}
g	Phase lag constant	—
H	Wave height	L
$\bar{H}$	Mean wave height	L
H_{max}	Maximum wave height	L
H_{rms}	Equivalent root-mean-square wave height	L
H_s	Significant wave height (average height of highest one-third waves)	L
$H_{1/10}$	Average height of highest 10% waves	L
$H_{1/100}$	Average height of highest 1% waves	L
H_I	Incident wave height	L
H_R	Reflected wave height	L
H_T	Transmitted wave height	L
H_b	Wave height at breaking	L
H_{des}	Design wave height	L
H_0	Deep water wave height	L
h	Sea depth	L
h	Beach height	L
h_0	Height of median sea level, between wave crest and trough, above mean sea level	L
$\bar{h}$	Mean depth	L
h_b	Breaker depth	L
h_s	Depth at toe of structure	L
I_{wc}	Dimensionless coefficient	—
I_1	Immersed sediment transport rate	MLT^{-3}

Symbol	Brief Definition	Dimensions
K_D	Coefficient for breakwater armouring	—
k	Tidal phase lag	—
k	$2\pi/L$	L^{-1}
k_N	Roughness length	L
K_R	Wave height refraction coefficient	—
K_s	Wave height shoaling coefficient	—
K_f	Wave height friction coefficient	—
K	Dimensionless coefficient for bulk sediment transport	—
K', K''	Coefficients for bulk sediment transport	$M^{-1}L^2T^2$
L	Wave length	L
L_0	Wave length in deep water	L
L_{sol}	'Length' of solitary wave	L
l	North latitude	—
l	Mixing length	L
l	Length of basin	L
M	Solitary wave factor ($2\pi/L_{sol}$)	L^{-1}
M	Moon's mass	M
M_2	Tidal constituent (principal lunar)	—
N_s	Stability number for breakwater armouring	—
N	Dimensionless constant in longshore	—
N_z	Number of zero crossings	—
N_K	Keulegan-Carpenter number	—
n	Tidal speed number	T^{-1}
n	Empirical exponent	—
P	Wave power per unit width	MLT^{-3}
P_n	Normal tidal tractive force	LT^{-2}
P_t	Tangential tidal tractive force	LT^{-2}
P_s	Static component of wave pressure	L
P_v	Dynamic component of water pressure	L
P	Dimensionless parameter in longshore current model	—
P	Cumulative probability	—
P	Empirical constant	—
P_j	Empirical coefficient	—
p	Water pressure	$ML^{-1}T^{-2}$
p_0	Atmospheric pressure	$ML^{-1}T^{-2}$
p	Power per unit area	MT^{-3}
p	Normal dispersive stress	$ML^{-1}T^{-2}$
p	Porosity of sediment	—
Q	Volumetric sediment transport rate	L^3T^{-1}
Q	Overtopping rate	L^3T^{-1}
Q_g	Longshore transport rate (with groynes)	L^3T^{-1}
Q_o	Longshore transport rate (without groynes)	L^3T^{-1}
Q_p	Transport rate passing a breakwater	L^3T^{-1}
Q_x	Longshore transport rate upstream of a groyne	L^3T^{-1}
q_b	Volumetric rate of bed transport per unit width	L^2T^{-1}

Symbol	Brief Definition	Dimensions
q_s	Volumetric rate of suspended transport per unit width	L^2T^{-1}
R	Wave run-up	L
R	Hydraulic radius	L
R	Overfill ratio	—
Re	Reynolds number	—
r	Distance between Earth and Moon	L
r	Coefficient of wave run-up	—
S	Strouhal number	—
S	Wind slope of sea surface	—
S	Length of cylinder	L
S	Distance from wall	L
S_{ij}	Momentum flux tensor	—
S^{nn}	Spectral density of surface elevation	—
S^{mm}	Spectral density of mud line bending moment	—
S_2	Tidal constituent (principal solar)	—
s	Distance along wave orthogonal	—
s	Bed slope	—
s_f	Friction slope	—
T	Wave period	T
T	Fundamental mode of oscillation	T
T_p	Corresponding to peak energy of spectrum	T
T_{sol}	'Period' of solitary wave	T
t	Time	T
U	Wind velocity	LT^{-1}
U	Group velocity of waves	LT^{-1}
U_0	Group velocity of waves in deep water	LT^{-1}
U_g	Gradient wind	LT^{-1}
$\bar{U}$	Mass transport velocity under waves	LT^{-1}
Ur	Ursell number	—
u	Tidal current	LT^{-1}
u	Orbital velocity of waves (horizontal)	LT^{-1}
$\hat{u}$	Maximum orbital velocity	LT^{-1}
$\hat{u}_0$	Maximum orbital velocity at the bed	LT^{-1}
u	Velocity in x -coordinate direction	LT^{-1}
$\bar{u}$	Depth mean velocity	LT^{-1}
u'	Velocity fluctuation	LT^{-1}
V	Dimensionless longshore current velocity	LT^{-1}
V	Velocity normal to member	LT^{-1}
V_s	Speed of vessel	LT^{-1}
v	Velocity in y -coordinate direction or general current velocity	LT^{-1}
v'	Velocity fluctuation	LT^{-1}
v_0	Maximum longshore current velocity with no mixing	LT^{-1}
v_*	Shear velocity	LT^{-1}

Symbol	Brief Definition	Dimensions
v_{*c}	Shear velocity due to current alone	LT^{-1}
v_{*wc}	Shear velocity due to wave and current	LT^{-1}
$\hat{v}$	Maximum velocity at the free surface	LT^{-1}
$\bar{v}$	Depth mean velocity	LT^{-1}
v_n	Velocity normal to wave direction	LT^{-1}
v_p	Velocity parallel to wave direction	LT^{-1}
v_b	Mean velocity of sediment in bed load	LT^{-1}
W	Weight of breakwater armour	M
W	Width of fetch	L
w	Velocity in z -coordinate direction	LT^{-1}
w_s	Particle fall velocity	LT^{-1}
w	Orbital velocity of waves (vertical)	LT^{-1}
$\hat{w}$	Maximum orbital velocity	LT^{-1}
X	Body force in x -direction	MLT^{-2}
X	Horizontal water particle displacement	L
X	Non-dimensional x -coordinate	—
X	Non-dimensional horizontal length for solitary wave	—
x	Distance to centre of the Moon	L
Y	Body force in y -direction	MLT^{-2}
Y	Non-dimensional y -coordinate	—
Y	Non-dimensional vertical length for solitary wave	—
Z	Longitude of point on Earth's surface relative to Moon	—
Z'	Dimensionless bed load thickness	—
z	Vertical distance with origin at water surface	L
z'	Vertical distance with origin at the bed	L
z_0	Bed load thickness or reference level	L
α	Friction angle (angle of repose)	—
α	Angle between wave crest and contour	—
α	Angle of inclination of face of seawall	—
α	Phase lag angle	—
α_b	Angle of wave incidence at breaker line	—
β	Angle of inclination of bed to horizontal	—
β	Ray separation factor	—
β	Angle of shoreline at breakwater	—
γ	Non-dimensional height of solitary wave crest	—
γ	Wave breaking index	—
γ_s	Density ratio	—
Δ	Damage parameter for rubble mound	—
Δ	Volume of non-dimensional solitary wave/unit width	L^2
Δ_r	Bed form height	L
Δ_s	Relative density ratio	—
δ	Phi mean difference	—

Symbol	Brief Definition	Dimensions
ϵ	Dimensionless block factor	—
ϵ	Spectral width parameter	—
ϵ	Coefficient of eddy viscosity	L^2T^{-1}
ϵ_s	Sediment diffusion coefficient	L^2T^{-1}
ϵ_0	Reference eddy viscosity (at z_0)	L^2T^{-1}
ϵ'	Normalised diffusion coefficient	—
ζ	Vertical water particle excursion	L
η	Water surface elevation	L
η	Efficiency	—
θ	Latitude	—
θ	Angle of wave crest relative to x -axis	—
θ	Shield's relative stress parameter	—
θ_0	Angle between shadow line and breakwater	—
θ_b	Angle between wave orthogonal and beach normal at breaking	—
κ	Von Kármán's constant	—
λ_r	Bed form wavelength	L
μ	Non-dimensional surface elevation for solitary wave	—
μ	Molecular viscosity	L^2T^{-1}
μ_e	Pseudo-horizontal eddy viscosity	L^2T^{-1}
μ	Ripple factor	—
μ	Phi mean	—
ν	Coefficient of dynamic viscosity	$ML^{-1}T^{-1}$
ξ	Horizontal water particle excursion	L
ξ	Horizontal water particle excursion at the bed	L
ξ	Exponent in sediment concentration distribution	—
ρ	Water density	ML^{-3}
ρ_a	Air density	ML^{-3}
ρ_r	Rock density	ML^{-3}
ρ_s	Sediment grain density	ML^{-3}
σ	$2\pi/T$ where T is wave period	T^{-1}
σ	Standard deviation	—
σ	Phi sorting or phi standard deviation	—
σ_r	Phi sorting ratio	—
τ	Shear stress	$ML^{-1}T^{-2}$
τ_d	Dispersed shear stress	$ML^{-1}T^{-2}$
τ_t	Critical threshold stress	$ML^{-1}T^{-2}$
τ_0	Shear stress at the bed	$ML^{-1}T^{-2}$
τ_s	Shear stress at the surface	$ML^{-1}T^{-2}$
τ_{wc}	Shear stress due to waves and currents	$ML^{-1}T^{-2}$
τ_c	Shear stress due to currents alone	$ML^{-1}T^{-2}$
ϕ	Angle of friction	—
ϕ	Velocity potential	L^2T^{-1}
ϕ_0	Phase lead of maximum shear stress	—
ψ	Stream function	L^2T^{-1}

NOTATION

XV

Symbol	Brief Definition	Dimensions
ψ	Wind stress and atmospheric pressure term	$ML^{-1}T^{-2}$
Ω	Earth's angular spin velocity	T^{-1}
Ω	Force potential	$\bar{}$
ω	Vorticity	T^{-1}