WRP Technical Note HY-CP-5.3
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Program for Comparison of Wave Theories for Waves Over Cohesive Sediments

PURPOSE: The need to protect, restore, and create wetlands in places such as coastal Louisiana has forced wetland scientists to reevaluate the standard models used for predicting waves, currents, shear forces, and soil behavior based on adaptability to the shallow, complexly connected and muddy marshes, ponds, waterways, and embayments. A program to compare various theoretical models for predicting surface wave propagation over cohesive bottom sediments is presented here. The program provides a tool for coastal scientists and engineers to better understand the interaction of waves and muddy bottom sediments.

BACKGROUND: Wetland scientists and engineers at Louisiana State University are developing new ways of measuring and parameterizing hydrodynamic processes that lead to marsh loss and conversion of land to open water or, conversely, to wetland building and enhancement through increased sedimentation or reduced wave/current forces. The work is a response to the need to understand not only the naturally occurring processes but also the various effects of proposed coastal wetland restoration measures. Coastal researchers need theoretical models that can predict waves, currents, and rheological forces in and on the marsh, and that can be tested using instrument arrays designed for wetland environments. An interactive computerized wave theory guide is discussed below.

WAVE THEORIES: An interactive program was developed that calculates and compares wave characteristics computed from wave theories for propagation over seabeds assumed to be rigid, elastic, viscous, or visco-elastic. The rigid bottom theories include linear wave theory and Stoke's second-order wave theory.

The elastic bottom wave theory is based on Mallard and Dalrymple (1977). These researchers presented a linear analytic solution for periodic water waves passing over a deformable bottom. The solution assumes a constant water depth underlain by a perfectly elastic soil of infinite depth with a shear modulus that represents a soft marine sediment. Soil stresses, displacements, and related water wave kinematics are obtained.

The viscous bottom wave theory is based on Dalrymple and Liu (1978), who presented theories developed for a linear water wave propagating over a two-layer viscous fluid system. The height of the surface wave is specified, and the forced interfacial wave characteristics and wave attenuation rate are determined. A complete model is presented for an upper layer of any depth and a lower layer that can be both deep and shallow. A simplified model is also presented which gives explicit solutions for wave damping when the thickness of the lower layer is greater than the boundary layer thickness developed by the fluid motion.

The visco-elastic wave theory is based on MacPherson (1980). He presented an analysis based on small-amplitude wave theory of the coupled interaction between the bed (which responds in both an elastic and viscous manner) and an overlying layer of inviscid fluid. A dispersion relation is derived from which wave attenuation rates and seabed deflections are calculated.

WBI PROGRAM: The theories mentioned above are included in a program called Wave Bottom Interaction or WBI program (coded in BASIC). Input data for the program are wave height and period, water density, viscosity and depth, and thickness, density, viscosity, and elasticity of the bottom sediments. The program is designed for shallow-water calculations.

Model output is shown in Table 1. The first lines of output echo the input data (Table 2). The next lines give computed values from each of the wave theories for wavelength, celerity, relative water depth, horizontal velocity profile, bottom pressure amplitude, distance for a wave height attenuation of 1/e, wave height amplitude after propagating a distance of 10 wavelengths, bottom wave amplitude, and the phase difference between the surface wave and the bottom wave.

Table 1
Output of the WBI Model

Program WBI
Wave Height (ft) = 20 — **Wave Period (s) = 10**
Water Depth (ft) = 100 — **Sediment Thickness (ft) = 500**
Sediment Shear Modulus (psf) = 10,000 — **Sediment Viscosity (ft2/s) = 1**

	Wave Theory				
Parameter	**Linear**	**Stokes**	**Elastic**	**Viscous**	**Viscoelastic**
Wavelength (ft)	452.1	452.1	435.5	512.0	497.9
Celerity (ft/s)	45.2	45.2	43.6	51.2	49.8
Relative water depth	0.2212	0.2212	0.2296	0.1953	0.2008
Horizontal velocity (ft/s)					
0.0	7.12	7.54	7.39	6.29	6.47
-25.0	5.33	5.54	5.56	4.63	5.02
-50.0	4.18	4.29	4.46	3.41	4.09
-75.0	3.55	3.61	3.95	2.51	3.56
-100.0	3.34	3.39	3.95	1.85	3.39
Bottom pressure amplitude (psf)	290.1	289.3	330.6	2,108.3	618.2
Decay distance (ft, thousand)	0	0	0	4,176.0	21,555.7
Decay/wavelength	0	0	0	0.9923	0.999
Amplitude mud wave (in.)	0	0	13.75	35.00	33.50
Mud wave phase shift (deg)	0	0	180	0	179.99
End of program					

Note: Conversion factors for non-SI to SI units of measurement are as follows: multiply degrees (angle) by 0.01745329 to obtain radians; multiply feet by 0.3048 to obtain meters; multiply inches by 2.54 to obtain centimeters; and multiply pounds (force) per square foot by 47.88026 to obtain pascals.

The program must be run from a BASIC language system such as GWBASIC on IBM-compatible personal computers. Lines 200 to 300 contain the program input data. These data must be modified for each set of desired computations. That is, the values for wave height (H), period (T), etc., must be changed to the values desired. The program will display the output with an option to save it to a file. The program's output is saved to a file called OUT.WBI.

Table 2
Input Data Lines for WBI Program

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200 REM  INPUT OF WAVE/BOTTOM PARAMETERS
210 REM  THE WATER IS LAYER 1 AND THE HALF SPACE OF SEDIMENTS IS LAYER 2

220 H=20            : REM INPUT "WAVE HEIGHT (FT) =";H
230 T=10            : REM INPUT "WAVE PERIOD (S) =";T
240 D1=100          : REM INPUT "WATER DEPTH (FT) =";D1
250 RHO1=1.92       : REM INPUT "DENSITY OF WATER (SLUGS/CF) =";RHO1
260 MU1=.00001      : REM INPUT "VISCOSITY OF WATER (FT2/S) =";MU1
270 D2=500          : REM INPUT "THICKNESS OF SOFT BOTTOM SEDIMENTS (FT) =";D2
280 RHO2=3          : REM INPUT "DENSITY OF BOTTOM SEDIMENTS (SLUGS/CF) =";RHO2
290 G2=10000        : REM INPUT "SHEAR MODULUS OF BOTTOM SEDIMENTS (PSF) =";G2
300 MU2=1           : REM INPUT "VISCOSITY OF BOTTOM SEDIMENTS (FT2/S) =";MU2
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