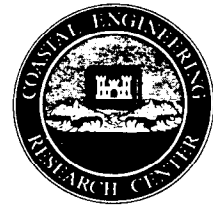# Coastal Engineering
Technical Note

NMLONG: NUMERICAL MODEL TO SIMULATE WAVE TRANSFORMATION
AND LONGSHORE CURRENT

<u>PURPOSE</u>: To describe the application of the numerical model NMLONG (<u>N</u>umerical <u>M</u>odel of the <u>LONG</u>shore current) for calculating regular and random wave transformation, mean water surface, and longshore current across a beach profile of arbitrary shape.

<u>BACKGROUND</u>: NMLONG is a PC-based model that calculates wave height, wave angle, mean water surface, and longshore current over an irregular bottom profile that can include longshore bars. The program includes features such as self-contained data entry, default values of model parameters, error trapping, on-line help, and graphics. The major assumptions in NMLONG are longshore homogeneity (straight and parallel bottom contours) and linear wave theory. Potential applications of NMLONG include estimating the distribution and magnitude of sediment or pollutant transport, estimating wave overtopping and wave forces, and preliminary structure design (e.g., length and placement of groins or breakwaters). The model parameters can be quickly changed for sensitivity analysis. NMLONG is useful for planning studies where funding and data limitations prevent use of two-dimensional models. The next sections describe the wave, water surface, and longshore current calculations. Details of the model physics are given by Kraus and Larson (1991).

Waves. Wave transformation in NMLONG includes shoaling, refraction, breaking with energy dissipation, and wave reformation. Wave shoaling and refraction are calculated using linear wave theory. Wave breaking, energy dissipation, and wave reformation are calculated with the Dally, Dean, and Dalrymple (1985) breaker decay model. Wave breaking is initiated if the wave-height-to-water-depth ratio exceeds an empirical incipient breaking coefficient, γ_{br} . Wave reformation occurs if the wave height decays to a "stable" value given by a wave-height-to-water-depth ratio less than an empirical coefficient, Γ_{stb} . The rate of energy dissipation in the surf zone is controlled by the empirical coefficient, κ , which is the percentage of the excess energy flux (local minus stable flux) that is dissipated. Dally, Dean, and Dalrymple showed that Γ_{stb} and κ are relatively constant for a variety of wave and beach conditions. Wave dissipation outside the surf zone, wave diffraction, and atmospheric (wind) input to waves are excluded.

Random wave transformation is simulated by assuming a Rayleigh distribution of wave heights offshore (waves are assumed to be narrow banded in frequency and direction, so randomness enters only in variability in wave height). NMLONG randomly selects wave heights from the Rayleigh distribution and transforms them as individual waves. The individual wave heights are used to calculate root-mean-square wave height, H_{rms} , at each point across the profile. On the

order of 100 waves must be simulated to accurately represent the wave height distribution. This approach neglects wave-wave interactions.

Mean Water Surface. The mean water surface elevation (setup and set-down) produced by waves and wind is calculated from the cross-shore momentum balance. Radiation stress (wave forcing) is calculated from linear wave theory. Wind stress is calculated with the drag coefficient formulation given by the WAMDI Group (1988). The set-down boundary condition at the most seaward point is given by the analytical expression of Longuet-Higgins and Stewart (1962). For random wave simulation, mean water surface elevation from the individual waves are averaged at each profile grid point.

Longshore Currents. Wave- and wind-driven longshore current is calculated from the longshore momentum balance. The model includes wave and wind forcing, lateral mixing, and bottom friction. Lateral mixing is modeled with an eddy viscosity approach. Eddy viscosity is defined as the product of an empirical coefficient (Λ_{mix}), maximum bottom orbital velocity, and wave height. Bottom friction is the most difficult term to calculate because it is nonlinear (in the unknown current velocity) and requires time averaging of nonlinear terms over wave period. NMLONG provides two solution options, one for linearized bottom friction and another for full nonlinear bottom friction. Bottom friction is linearized with the weak-current assumption which is applicable for cases where longshore current is weak compared to the orbital velocity. The weak current assumption does not require small incident wave angles (Liu and Dalrymple 1978, Kraus and Sasaki 1979). Nonlinear bottom friction is calculated using a square wave to represent the sinusoidal time variation in the wave orbital velocity (Nishimura 1982, 1988), so the time average is calculated analytically. The bottom friction is still nonlinear in the current velocity and is solved iteratively. The nonlinear bottom friction solution is computationally slightly slower, but more accurate for strong current. For both linear and nonlinear bottom friction, a constant bottom friction coefficient, C_f , must be specified. The current is solved with a double-sweep finite-difference scheme. The offshore boundary condition for the current is zero wave-driven velocity. For random wave simulation, longshore currents from individual waves are averaged at each profile point.

PROGRAM INPUT: Program input is entered interactively through menus. Input is broken into waves and wind, model setup, empirical parameters, and model options under the Model Parameter Menu; beach profile under the Beach Profile Data Menu; and wave and current data under the Data (Measurement) Menu.

Model Setup: number of computation points (M), spacing of points (Dx), and tide level (Dtide) relative to the datum used in specifying the beach profile depths. The computational grid starts at the most shoreward beach profile distance and extend offshore a distance of M times Dx . The term "grid" for this one-dimensional model represents equally spaced computational points along a shore-normal transect. The grid should extend well offshore of the surf zone because the wave-driven current is assumed to be zero at the offshore limit of the grid.

Waves and Wind: reference wave height (Href), reference wave angle (Zref), wave period (T), depth at the reference point (Dref), wind direction (Zwind), and wind speed (W) at the 10-m elevation. The reference point must be seaward

of the computational grid (wave height and direction are transformed by linear refraction and shoaling to the grid). Wave and wind angles are relative to shore normal with positive angles clockwise from shore normal.

Empirical Parameters: wave-height-to-water-depth ratio for incipient breaking (γ_{br} = 0.78), stable wave-height-to-water-depth ratio for wave reformation (Γ_{stb} = 0.40), energy flux dissipation rate (κ = 0.15), lateral mixing coefficient (Λ_{mix} = 0.30), and bottom friction coefficient (C_f = 0.01). The values in parentheses are defaults. These parameters are all nondimensional.

Model Options: regular or random wave simulation (REG or RAND) (for random waves, the number of waves to be simulated and H_{rms} at Dref must be specified), linear or nonlinear bottom friction (LIN or NONLIN), and the length unit labels (m or ft). The program interprets all length units based on the length unit labels. Length units are not converted by changing the length unit labels.

Beach Profile: The beach profile is specified by interactively entering an array of distances and depths in an editor provided as part of the model. Distances are measured as positive traversing offshore, generally starting shoreward of the still-water line. Distances do not need to start at zero, but must be positive. Depth is measured relative to a datum such as mean-water level. Elevations above the datum are entered as negative depths. The depth for calculations can be altered by adjusting "Dtide," so the profile data do not need to be re-entered (positive DTIDE increases water depth). The spacing of profile data does not need to match the computational grid. For computations, the depths will be linearly interpolated to the grid. The number of profile points entered should be sufficient to define the features on the profile (e.g., a plane beach requires only two points).

Data: Wave and current measurements from laboratory or prototype beaches can be entered in arrays of wave height and longshore current versus distance. Distances must be referenced to the same baseline as the beach profile distances. Data are plotted with the calculation results for comparison.

PROGRAM OUTPUT: Graphical and printed output are produced by NMLONG. After model calculations are made, a plot of the wave height, longshore current, and beach profile is displayed on the monitor. The plot can be copied on a laser printer. Printed output of the beach profile data, calculation results (wave height, wave angle, mean water surface, and longshore current at each grid point), and model parameters is controlled from the File Printout Menu.

EXAMPLE: NMLONG menus direct user input. On-line help is activated with < F1 > key to display parameter defaults and limits. Although error trapping is built into NMLONG, to avoid violating model assumptions, engineering judgement is essential in interpreting model results. This section guides you through an example application of NMLONG.

NMLONG is initiated by typing NMLONG followed by a carriage return. The first NMLONG screen gives identification information, including the release date and version of the model you are using. Press any key to continue.

The second screen is the Project Options menu (Fig. 1). This menu controls file management. It allows you to list, select, create, copy, delete, name, and save "projects." A project is six files, created by NMLONG, which contain input and output information. The files share the project name with file extensions that differentiate their contents. Menu options are accessed by typing a single letter (e.g., < C > to create a project) without a carriage return. For this example, enter < P > to select an existing directory to store project files. We have selected a directory by typing \nmlong\data\ followed by a carriage return. Next, type < C > to create a project. Type the project name EXAMPLE (no file extension) and a carriage return. Existing projects can be selected with < S >, renamed with < N >, written to a file with < W >, reloaded with < R > (to restore saved values), deleted with < D >, or copied with < 1 >. If < L > is selected, a small menu pops up that lists projects in the current directory. The project "DEFAULT" contains values used to create a new project. Values in DEFAULT can be changed, but these files must be present in the current directory to create a project. To move to the Main Menu enter < M > or exit the program with < X >.

```
|                                                                    |
|          N M L O N G :   P R O J E C T     O P T I O N S           |
|      _____          |
|                                                                    |
|          < C > reate New Project                                   |
|          < D > elete Current Project                               |
|          < L > ist Projects                                        |
|          < N > ame Current Project (Rename)                        |
|          < P > roject Directory              \nmlong\data\         |
|          < R > eload Existing Project Data                         |
|          < S > elect Project                 EXAMPLE               |
|          < W > rite Data Changes to File                           |
|          < 1 > Copy Current Project                                |
|                                                                    |
|          < M > ain Menu                                            |
|          < X > Exit Program                                        |
|      _____          |
|                                                                    |
|              Enter choice -                                        |
|                                                                    |
```

Fig. 1. Project Options Menu

NMLONG takes you directly to the Model Parameter Menu (Fig. 2) after creating a new project. Model parameters are entered by selecting the menu number of the parameter you want to change, then entering a new parameter value followed by a carriage return. Enter menu number 18 to enter all parameters for the new project. Use the backspace or delete key to delete existing parameters and enter new values followed by a carriage return. When the random wave option is selected, a small window appears which asks for the number of random waves and H_{mo} . Enter menu number zero to return to the Main Menu. NMLONG

asks "Would you like to save the values in the data file? (y/n)." Enter y
to save the parameters. Note that you can temporarily change parameters on
any menu and calculate results without saving the parameters in project files.

```
|                                                                              |
|    N M L O N G :   M O D E L   P A R A M E T E R   M E N U                    |
|    _____          |
|                                                                              |
|    Waves and Wind                    Model Setup                             |
|     1)  Href           2.0   m        6)  M             100                   |
|     2)  Zref          10.0  deg        7)  Dx            2.0 m                 |
|     3)  T              8.5  sec        8)  Dref          2.0 m                 |
|     4)  Zwind         10.0  deg        9)  Dtide         0.0 m                 |
|     5)  W              0.0  m/sec                                             |
|                                                                              |
|    Empirical Parameters              Model Options                           |
|    10)  Gambr          0.78          15)  REGular/RANDom Waves REG            |
|    11)  Gamstb         0.40          16)  LINear/NONLINear Friction LIN       |
|    12)  Kappa          0.15          17)  Length unit labels   m              |
|    13)  Lammix         0.30               (m - meters, ft - feet)            |
|    14)  Cf             0.0100                                                 |
|                                                                              |
|    18)  Change all values                                                    |
|     0)  All values correct... Go to Main Menu                                |
|    _____          |
|              To modify a value enter menu number                             |
|                      and press return -                                      |
|                                              Project: EXAMPLE                 |
|                                                                              |
```

Fig. 2. Model Parameter Menu

```
|                                                                              |
|              N M L O N G :   M A I N   M E N U                                |
|    _____          |
|                                                                              |
|              < B > each Profile Data Menu                                     |
|              < D > ata (Measurement) Menu                                     |
|              < F > ile Printout Menu                                          |
|              < M > odel Parameter Menu                                        |
|              < P > roject Options Menu                                        |
|                                                                              |
|              < C > alculate                                                   |
|              < G > raph Previous Results                                      |
|              < S > hell                                                       |
|              < X > Exit                                                       |
|    _____          |
|                                                                              |
|              Enter choice -                                                   |
|                                              Project: EXAMPLE                 |
|                                                                              |
```

Fig. 3. Main Menu

The Main Menu (Fig. 3) directs input, output, and calculations. The input menus may be accessed in any order. Select < B > to go to the Beach Profile Menu.

Beach profile data are entered from the Beach Profile Menu (Fig. 4). For project EXAMPLE, a barred profile with 15 points has been entered. The profile begins at 100 m from some baseline and extends to a distance 340 m. To enter or edit profile data, enter < E > and use the function keys and cursers to move through the array. After editing the data, remove any profile points at the end of the list with zero distance and zero depth (added by carriage returns at the end of the list) using < F4 >. Use < ESC > to return to the command line. NMLONG automatically checks that the distances are increasing offshore, and alerts you of errors. You can locate these errors with < F5 >. From the command line, return to the Main Menu with < M >. NMLONG will again ask if you wish to save the data, enter y for yes.

```
|                                                                              |
|         N M L O N G :   B E A C H   P R O F I L E   M E N U                   |
|         _____         |
|                                                                              |
|           Distance                                                           |
|           Offshore        Depth                                              |
|  No.         m              m                                                |
|         _____                                         |
|                                                                              |
|   1        100.0          -0.60                                              |
|   2        111.0           0.10                                              |
|   3        132.0           1.00            Editor Commands                   |
|   4        145.0           1.50                                              |
|   5        156.0           1.70       ESC - Command Line                     |
|   6        169.0           1.90       F3  - Insert Line                      |
|   7        173.0           1.95       F4  - Delete Line                      |
|   8        186.0           1.85       F5  - Locate Error                     |
|   9        190.0           1.80       F6  - Increment Decimal                |
|  10        195.0           1.70       F7  - Decrement Decimal                |
|  11        199.0           1.75       PGUP/PGDN                              |
|  12        207.0           1.81       HOME/END                               |
|  13        214.0           2.00                                              |
|  14        246.0           3.10                                              |
|  15        340.0           4.00                                              |
|         _____                                         |
|                                                                              |
|  E - Edit          M - Main Menu                                             |
|                                                         Project: EXAMPLE     |
|                                                                              |
```

Fig. 4. Beach Profile Menu

The model parameter and beach profile data are the essential information to calculate the wave transformation, mean water surface, and longshore current. Start calculations by selecting < C > at the Main Menu. After the calculations are complete, a plot of the wave height, longshore current, and

bottom profile will appear (Fig. 5). A carriage return will bring up the option of printing the plot on a laser printer, then returns you to the Main Menu.
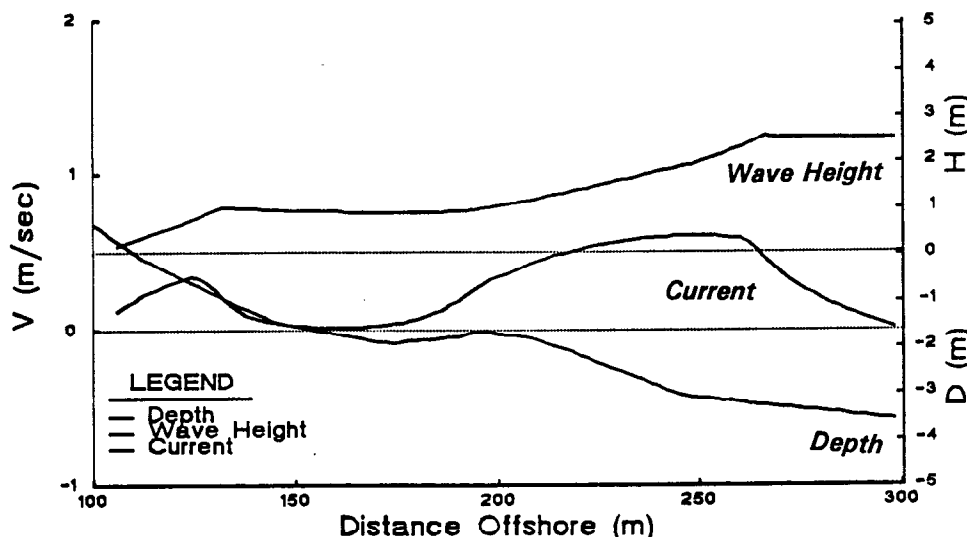
EXAMPLE

Fig. 5. NMLONG output plot

Printed copies of the results are controlled by the File Printout Menu (< F > on the Main Menu). The File Printout Menu (Fig. 6) selects the information to be printed. Calculation results (option < C >) includes wave height, wave direction, mean water surface, and longshore current. After printing files, return to the Main Menu with < G >. Exit NMLONG with < X >, or return to other menus to change parameters.

```
NMLONG:   FILE   PRINTOUT   MENU


        < B > each Profile Data
        < C > alculation Results
        < D > ata (Measurement)
        < M > odel Parameter Data
        < A > ll Data Files for this Project

        < G > oto Main Menu


              Enter choice -

                              Project: EXAMPLE
```

Fig. 6. File Printout Menu

This example demonstrates only a few of NMLONG's capabilities. Model features

are easy to access through the menus, aided by on-line help. Additional user information is given by Williford, Tanner, and Kraus (in preparation).

AVAILABILITY: NMLONG was developed under the Dredging Research Program by Dr. Nicholas C. Kraus. An executable copy of NMLONG is available from Dr. Kraus, USAE Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. For additional guidance on applying NMLONG, please contact the author, Ms. Jane McKee Smith, at (601) 634-2079 or Dr. Kraus at (601) 634-2018. NMLONG is also available as part of the Shoreline Modeling System (SMS); for more information on the SMS contact Mr. Mark Gravens at (601) 634-3809.

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