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# Coastal Engineering Technical Note

## Evaluation and Application of the Wave Information Study for the Northern Pacific Ocean

### INTRODUCTION

The Wave Information Study (WIS) for the Northern Pacific Ocean (WIS Reports 14 and 16) provides a wave climate for the U.S. shorelines of the Northern Pacific based on simulation of 20 years of weather data from the period 1956-1975. During these years few wave data exist with which to evaluate the adequacy of the total hindcast procedure which includes derivation of pressure charts, translation of these into wind estimates, and then calculation of wave conditions. In 1991 CERC conducted a one-year hindcast of the Northern Pacific Ocean for the year 1988 and evaluated the model results against extensive wind and wave measurements now available in order to provide guidance on the quality of the previous hindcast work. This CETN provides a brief summary of that hindcast and guidance on the use of the earlier WIS study.

### 1988 HINDCAST STUDY

Since almost no wave data exist in the Northern Pacific Ocean for the 1956-1975 period, CERC decided to hindcast a recent year, 1988, in which extensive wave and wind data were available using data and procedures as close to those used for the 1956-1975 hindcast as possible. Wind data for the Northern Pacific Ocean were obtained from the Fleet Numerical Oceanographic Center (FNOC) and interpolated onto the Northern Pacific Ocean grid used in the original study. These winds were used to drive the original wave model used for the 1956-1975 study, and wave conditions were estimated and compared to six offshore National Data Buoy Center wave buoys.

The differences between the 1988 and 1956-1975 studies are in the use of FNOC winds rather than those derived by the WIS wind model used for 1956-1975 and in the inherent difference between the year 1988 and the period 1956-1975. WIS experience is that the FNOC- and WIS-produced winds are not strongly different and that 1988 was not an atypical year. Hence, the differences seen between the measured and modelled results are likely to be typical of the differences between the statistics hindcast for 1956-1975 and what would have been measured.

### RESULTS

The six buoys are located as shown in Figure 1. Other measurement sites and WIS stations are also shown and referred to in WIS Report 29 (Hubertz, et. al., in publication) which discusses the comparisons in more detail. The buoys are distributed along the Washington, Oregon, and California coasts, the

Gulf of Alaska, and off Hawaii. The bias and RMS errors in wind speed are given in Table 1, and those for wave height and period are given in Tables 2 and 3 respectively.

Table 1 indicates that the magnitude of the bias between the predicted and measured wind speeds ranges on a monthly basis from -0.8 to -5.6 knots with the overall bias typically about -3.0 knots with the model underpredicting the winds. The RMS error in wind speeds ranges from 3.8 to 8.8 knots on a monthly basis with a typical value of 5.5 knots. Detailed analysis of the distribution of wind speeds indicates that the FNOC winds overpredict at low values and underpredict at high values. Comparison to WIS winds for 14 station months indicates that these statistics are typical of the WIS-produced winds.

Table 2 indicates that the wave predictions have a bias of -0.3 to 2.8 m on a monthly basis relative to the measurements with the predictions biased usually high. Overall, the bias is about 1.0 to 1.5 m high. The RMS error in wave height on a monthly basis ranged from 0.4 to 3.3 m with a typical value of about 1.5 m. The wave periods predicted tended to be biased high by from -1.6 to 7.5 sec on a monthly basis, with the overall bias about 1.5 sec high (predicted greater than measured). The RMS error in wave period ranged monthly from 0.5 to 10.2 sec with the typical value about 3.5 sec.

Although the periods predicted are, on average, longer than the measured, analysis of the period distribution shows a clear tendency for the hindcast not to produce as many long period waves (15 sec or greater) as observed.

Analysis of individual buoy records indicates that the wave predictions follow general details of the observed record but shifted high. Storms seem well represented, but the swell between events is consistently overestimated. The predicted periods are slightly high, but very long swell periods are underestimated.

RECOMMENDATIONS

Based on the 1988 hindcast, users of the WIS Northern Pacific Ocean data set for the period 1956-1975 should interpret the data to have the following range of accuracies:

a. Wind speed: low in the mean by 3.0 knots, RMS error 5.5 knots.

b. Significant wave height: high in the mean by 1.0 m, RMS error 1.5 m.

c. Peak period: high in the mean by 1 sec, RMS error 3.5 sec.

Additionally, when designs involve long period swell, consideration should be given to lengthening the period to account for the underestimate. Adjustment of the WIS 14 and 16 data to account for these biases is a difficult problem, but it is believed that the tendency to overpredict exists in the basic hindcast. Procedures to correct should be considered on a site by site basis. WIS staff may be contacted for assistance at 601-634-2028.

REFERENCES

Corson, W. D., Abel, C. E., Brooks, R. M., Farrar, P. D., Groves, B. J., Jensen, R. E., Payne, J. B., Ragsdale, D. S., and Tracy, B. A. 1986. "Pacific Coast Hindcast Deepwater Wave Information," WIS Report 14, US Waterways Experiment Station, Vicksburg, MS.

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Jensen,R. E., Hubertz, J. M., Thompson, E. F., Reinhard, R. D., Groves, B. J., Brown, W. A., Payne, J. B., Brooks, R. M.,McAneny, D. S. in publication. "Southern California Hindcast Wave Information", WIS Report 20, USAE, WES, Vicksburg, MS.

Table 1

Bias (kts) of FNOC Wind Speeds to Measured at Buoy Locations

1988

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | -5.1 | | -3.9 | -3.1 | -4.6 | | | | | -4.6 | -3.3 | -2.7 |
| 46022 | -5.6 | -4.1 | | -3.4 | -3.8 | -3.5 | | | -3.5 | | | -1.7 |
| 46028 | -2.5 | -2.5 | -5.4 | | -5.3 | -4.1 | | | -3.8 | -2.6 | | -3.3 |
| 46003 | -2.2 | -3.0 | -2.2 | -2.8 | -3.0 | -1.5 | -3.2 | | -2.8 | -2.9 | -2.4 | -2.4 |
| 46006 | -0.8 | -0.8 | -1.0 | | | | | | -1.7 | -1.1 | -1.0 | -1.2 |
| 51001 | | | -4.3 | -4.6 | -4.0 | -4.5 | -4.5 | | -2.7 | -3.3 | -4.1 | -3.8 |

Bias = Calculated Monthly Average - Measured Monthly Average

Root Mean Square Difference (kts) of FNOC Wind Speeds from Buoy

1988

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 7.2 | | 6.3 | 5.8 | 6.8 | | | | | 6.3 | 6.1 | 6.3 |
| 46022 | 7.7 | 5.9 | | 5.8 | 6.8 | 6.5 | | | 6.8 | | | 6.1 |
| 46028 | 4.8 | 5.4 | 6.3 | | 6.6 | 6.9 | | | 5.7 | 4.1 | | 5.5 |
| 46003 | 5.4 | 7.9 | 8.8 | 5.0 | 4.9 | 4.0 | 4.6 | | 6.2 | 6.1 | 6.3 | 5.9 |
| 46006 | 5.4 | 4.7 | 3.8 | | | | | | 3.8 | 3.9 | 4.4 | 3.9 |
| 51001 | | | 5.0 | 5.1 | 4.7 | 4.9 | 5.0 | | 4.3 | 4.2 | 4.8 | 5.0 |

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Number of Cases Compared

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 119 | | 71 | 120 | 78 | | | | | 124 | 120 | 123 |
| 46022 | 124 | 116 | | 120 | 123 | 120 | | | 100 | | | 124 |
| 46028 | 123 | 116 | 124 | | 123 | 120 | | | 119 | 124 | | 123 |
| 46003 | 124 | 116 | 124 | 119 | 124 | 120 | 124 | | 120 | 124 | 119 | 123 |
| 46006 | 123 | 116 | 60 | | | | | | 120 | 123 | 119 | 122 |
| 51001 | | | 86 | 120 | 124 | 120 | 123 | | 119 | 117 | 120 | 124 |

Table 2

Bias (m) of Wave Height from Measurements

1988

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 1.2 | | 1.2 | 1.3 | 1.5 | | | | | 0.7 | 1.6 | 2.8 |
| 46022 | 0.9 | 1.1 | | 0.9 | 1.0 | 0.7 | | | -0.1 | | | 2.0 |
| 46028 | 0.8 | 1.0 | 1.1 | | 0.7 | 0.6 | | | 0.2 | 1.6 | | 1.8 |
| 46003 | 1.1 | 1.3 | 1.4 | 1.2 | 1.4 | 0.8 | 0.4 | | 0.8 | 0.7 | 1.1 | 1.1 |
| 46006 | 0.8 | 1.2 | 2.0 | | | | | | 0.5 | 1.0 | 1.8 | 1.2 |
| 51001 | | | 0.6 | 0.2 | 0.1 | 0.1 | -0.3 | | 0.3 | 0.3 | 0.2 | 0.6 |

Bias = Calculated monthly average minus measured monthly average

Root Mean Square Difference (m) of Wave Height

1988

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 1.6 | | 1.5 | 1.5 | 1.6 | | | | | 0.8 | 2.0 | 3.3 |
| 46022 | 1.5 | 1.4 | | 1.1 | 1.1 | 0.8 | | | 0.7 | | | 2.7 |
| 46028 | 1.3 | 1.2 | 1.5 | | 0.9 | 0.8 | | | 0.5 | 1.8 | | 2.4 |
| 46003 | 1.8 | 1.7 | 1.8 | 1.5 | 1.6 | 0.9 | 0.5 | | 1.4 | 1.2 | 1.6 | 1.6 |
| 46006 | 1.5 | 1.5 | 2.3 | | | | | | 0.6 | 1.3 | 2.3 | 1.5 |
| 51001 | | | 1.3 | 0.7 | 0.4 | 0.6 | 0.4 | | 0.6 | 0.5 | 0.8 | 1.0 |

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Number of Cases

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 119 | | 71 | 120 | 78 | | | | | 124 | 120 | 74 |
| 46022 | 124 | 116 | | 119 | 123 | 120 | | | 100 | | | 52 |
| 46028 | 119 | 113 | 123 | | 119 | 118 | | | 112 | 51 | | 45 |
| 46003 | 124 | 116 | 124 | 118 | 124 | 120 | 124 | | 120 | 124 | 119 | 122 |
| 46006 | 122 | 114 | 55 | | | | | | 120 | 120 | 115 | 121 |
| 51001 | | | 85 | 118 | 124 | 119 | 123 | | 119 | 117 | 120 | 124 |

Table 3

Bias (s) of Wave Peak Period from Measurements

| | 1988 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
| 46010 | -0.3 | | 1.9 | 1.0 | 2.2 | | | | | 0.2 | 1.3 | 5.6 |
| 46022 | -1.3 | -0.6 | | 0.6 | 1.1 | 0.9 | | | -0.2 | | | 7.5 |
| 46028 | -1.6 | -0.8 | -0.4 | | -0.4 | -0.2 | | | -0.7 | 6.6 | | 7.2 |
| 46003 | -0.2 | 0.5 | 1.5 | 0.4 | 1.4 | 0.3 | 0.1 | | 0.3 | 0.4 | 0.8 | 0.3 |
| 46006 | -0.8 | -0.9 | 1.2 | | | | | | -0.5 | 1.0 | 0.7 | 0.3 |
| 51001 | | | -0.8 | 0.2 | 0.2 | -1.3 | -1.6 | | -0.2 | -0.9 | 0.2 | -0.4 |

Bias = Calculated monthly average minus measured monthly average

Root Mean Square Difference (s) of Peak Period

| | 1988 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
| 46010 | 3.6 | | 3.9 | 2.7 | 3.2 | | | | | 1.6 | 3.0 | 8.7 |
| 46022 | 4.4 | 2.5 | | 2.6 | 2.7 | 2.6 | | | 2.2 | | | 10.2 |
| 46028 | 4.7 | 4.0 | 3.4 | | 3.8 | 3.2 | | | 3.7 | 8.3 | | 10.1 |
| 46003 | 3.2 | 2.1 | 3.1 | 2.2 | 2.4 | 2.5 | 0.5 | | 2.2 | 2.2 | 2.7 | 2.4 |
| 46006 | 3.3 | 3.6 | 4.1 | | | | | | 2.4 | 2.8 | 3.1 | 2.6 |
| 51001 | | | 3.7 | 2.9 | 2.8 | 4.1 | 2.3 | | 2.7 | 2.6 | 2.7 | 2.3 |

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Number of Cases

| Buoy | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46010 | 119 | | 71 | 120 | 78 | | | | | 124 | 120 | 74 |
| 46022 | 124 | 116 | | 119 | 123 | 120 | | | 100 | | | 52 |
| 46028 | 119 | 113 | 123 | | 119 | 118 | | | 112 | 51 | | 45 |
| 46003 | 124 | 116 | 124 | 118 | 124 | 120 | 124 | | 120 | 124 | 119 | 122 |
| 46006 | 122 | 114 | 55 | | | | | | 120 | 120 | 115 | 121 |
| 51001 | | | 85 | 118 | 124 | 119 | 123 | | 119 | 117 | 120 | 124 |

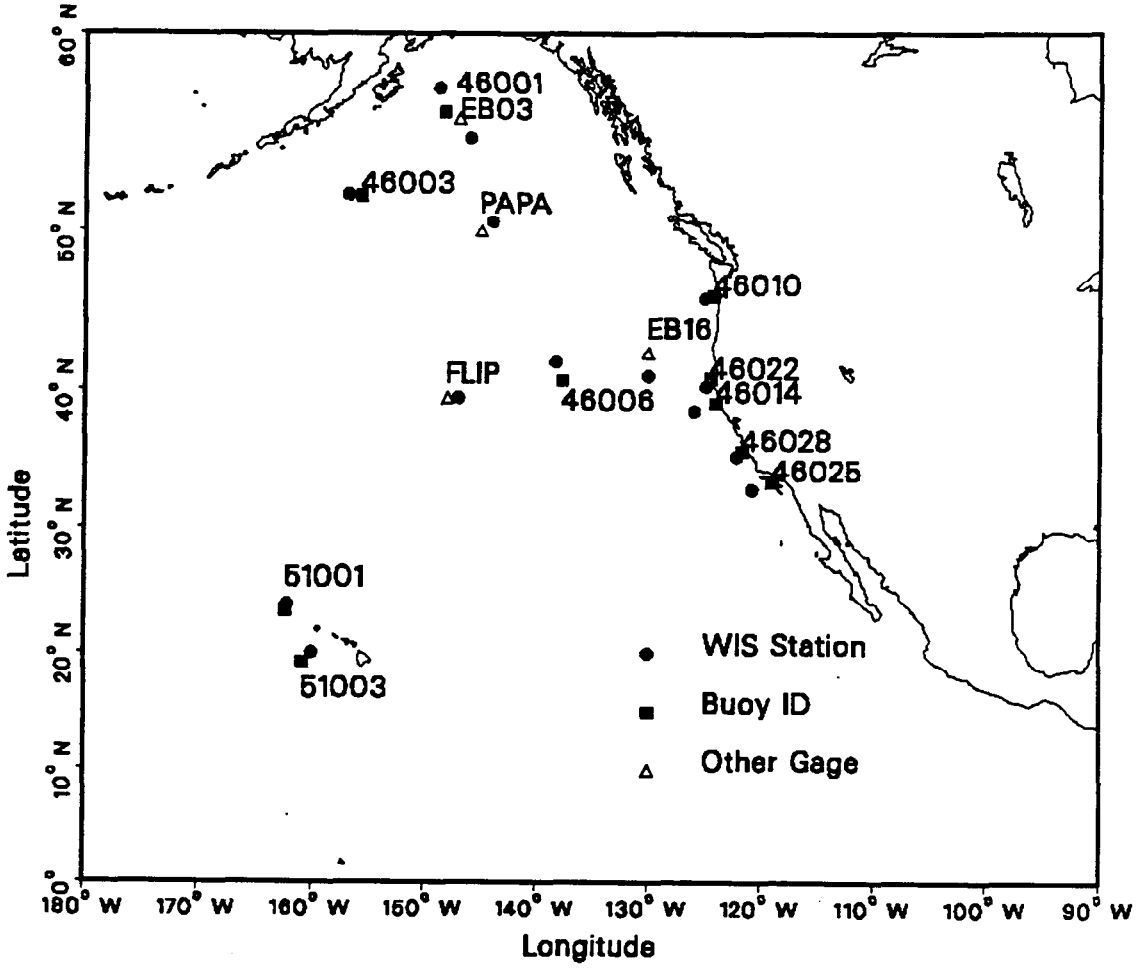


**Figure 1** Location Map for Hindcast and Measurement Stations