JERICHO TECHNICAL REPORT - 21

APPLICATION OF STORMS IN THE HOLDERNESS REGION

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1 INTRODUCTION

The JERICHO project aims to analyse measured buoy data and compare it with wave heights and periods derived from satellite data. The analysis is intended to describe the wave climate and identify any long-term trends.

Halcrow's role in the project, in combination with Proudman Oceanographic Laboratories (POL), is to use numerical models to transfer the deep water wave climate to the shore to determine whether changes in deep water wave climate will have any effect on the wave climate experienced at the coast.

We are considering three sites Holderness, Lyme Bay (West Bexington) and Cardigan Bay.

To date we have only considered the one site at Holderness, the wave modelling has involved the following:

- Setup of Halcrow's refraction model (REFPRO);
- Setup Halcrow's Shoreline And Nearshore Data System (SANDS);
- Transformation and comparison of wave data.

The subsections below follow aim to explain in detail the tasks described above. A final subsection provides figures showing our findings and summarises the results.

2 DATA

2.1 Wave data

POL have supplied Halcrow with measured timeseries wave data and in return Halcrow have supplied POL with bathymetry data they will require to transform the deep ocean waves to within 10km of the coast.

The data supplied from POL is recorded from their wave rider buoys and is to Ordnance datum.

Satellite timeseries wave data has been provided by Satellite Observing Systems, due to the nature of the satellite the data is very sparse, approximately one record every ten days.

Details of the time series wave data provided by are shown in Tables 2.1 to 2.2.

Table 2.1 Holderness wave and depth time series data.

Location	Mean recorded depth (m)	Type of buoy	Start of data	End of data
N1	12.5	Wave Rider (WR)	09/10/94	16/01/96
N1b	12.5	POL Monitoring Platform (PMP)	09/10/94	29/12/95
N2	18.3	Directional Wave Rider (DWR)	08/11/94	16/01/96
N3	29.9	Directional Wave Rider (DWR)	14/10/94	28/02/95
N3	N/A Satellite data	N/A Satellite data	07/10/92	24/12/97

Note: Location 'N1b' is bottom-mounted device measuring Pressure and current data.

Table 2.2 Positions of Holderness study locations.

Location	Latitude (N)	Longitude (E)	Easting	Northing
N1	053,45.84	000,00.77	532661	431630
N1b	053,45.83	000,00.49	532350	431622
N2	053,47.51	000,03.34	535390	434832
N3	053,50.57	000,09.11	541566	440674

2.2 Bathymetric data

The Holderness study area is covered by admiralty charts 107 and 121. These charts have been previously digitised by Halcrow, and were therefore retrieved from Halcrow's data archive system. The data is held as Eastings, Northings and depth values on a Geographical Information System (GIS) system, Microstation.

3 WAVE MODELLING

3.1 REFPRO model

The program calculates the paths of wave rays (lines orthogonal to the wave crests) as the wave propagates from element to element across the bathymetric model, using a circular arc technique. This may be done for specific tide levels and ranges of wave periods, tracking to or from a number of study points. For this study we have used backward tracking, this provides an accurate and detailed study of the wave climate and is the basis of wave height and energy determination. The waves are tracked in a range of directions form a study point.

Our objective was to transform both recorded and satellite waves from location 'N3' to positions 'N1' and 'N2' then compare the actual recorded waves at 'N1' and 'N2' with the transformed waves.

The REFPRO grids were set up over the Holderness bathymetry using Halcrow's program GRIDMKR (Gridmaker). The grid system starts with a 50m grid over the study location area, then gradually increasing offshore from 100m to 200m and finally 500m. The refraction grid structure can been seen in Figure 1. Halcrow's program GRIDMKR was then run in order to produce the refraction grids. GRIDMKR interpolates data points and converts them into a bathymetric grid, suitable for use with the REFPRO model.

REFPRO was setup and ran for locations ‘N1’ and ‘N2’. The model was ran for three water levels namely 1.1m (MLWS), 3.55m (mean of all tide levels) and 6.1m, (MHWS), these were derived from the Bridlington tide gauge, shown in Table 3.1. The wave periods used for REFPRO are a standard set of fifteen, the scan range for the rays start from 330 degrees and go clockwise around to 150 degrees, shown in Table 3.2.

Table 3.1 Tidal Levels at Bridlington referred to Chart Datum.

Place	Heights in metres above datum				Datum
	MHWS	MHWN	MLWN	MLWS	
Bridlington	6.1	4.7	2.3	1.1	3.35 below ODN

Table 3.2 REFPRO conditions for locations ‘N1’ and ‘N2’.

Wave period (s)	Scan range from (deg)	Scan range to (deg)
2.0	330	150
2.3	330	150
2.7	330	150
3.2	330	150
3.7	330	150
4.4	330	150
5.1	330	150
6.0	330	150
7.0	330	150
8.2	330	150
9.6	330	150
11.2	330	150
13.1	330	150
15.5	330	150
18.0	330	150

After running REFPRO the results are checked by using REFPLT this program enables the backtracking rays to be plotted, examples of this are shown in Figure 2.

The refraction coefficients calculated by REFPRO were then imported into SANDS where the wave transformations were to take place.

3.2 SANDS database

Halcrow's Shoreline and Nearshore Data System, SANDS, is a software package for the storage, retrieval and analysis of coastal and environmental data. It has been developed over a period of some years, based upon the experience of coastal scientists and working engineers, to provide a tool specific to the needs of coastal monitoring.

The system combines mapping and graphing with various data entry and analysis functions, including some sophisticated modelling.

Its purpose is to provide a means by which the data collected during a monitoring programme can be stored in a consistent way and analysed readily. These analyses are a valuable tool in establishing links between measured processes which affect the coast (winds, waves, water levels etc.) and data from inspections or surveys of the coast's response.

SANDS includes a number of mathematical models which can be used to derive time-series data from other data in the system. A wave transformation model calculates the wave climate at an inshore point, given water levels and offshore wave data. Thus, a single offshore data source can provide inshore data at any number of locations around the coast. Water level surges can be assessed by comparison of measured water levels with the astronomical tide level predicted from 61 tidal constituents within SANDS.

SANDS has facilities for storing, displaying and analysing time series data such as waves, winds and water levels. These measured or modelled data are loaded into the SANDS database using customised data import routines. Graphs may be used to examine the relationships between different climatic variables or to view conditions during significant time periods. Wave data can be analysed with respect to an energy threshold in order to identify storms in the data set. Thus it possible to assess the 'typicality' of a storm in terms of its energy and orientation to the coastline. This and other analyses can be used in conjunction with inspection records to establish cause and effect patterns for the coastline.

A SANDS database was setup specifically for the ‘JERICHO’ project.
The locations provided from POL (shown in Table 2.2) were entered into SANDS along with the relevant converted time series wave data.
The depths of the study locations were corrected from Chart datum to Ordnance datum by a conversion of –3.35 metres, before importing into SANDS.
The refraction coefficients calculated by REFPRO were also imported into SANDS to the relevant locations, ‘N1’ and ‘N2’.
An extra location was added into the SANDS database, namely a tide point at Spurn Head. A tide point is required to do wave transformations within SANDS and Spurn Head was chosen because it was nearest to the study locations, the tidal constituents from the 1998 Admiralty tide tables were entered into SANDS, therefore providing a predicted tide.

Both recorded and satellite time series wave data was then transformed from location ‘N3’ to ‘N1’ and ‘N2’.
SANDS was then used to graph the recorded wave data at locations ‘N1’ and ‘N2’.
Periods of interest were then printed out together with the corresponding periods from the transformed data, for comparison.
Note only location ‘N2’ has directional data provided.
These comparisons are best shown as a series of line graphs, Figures 3 to 10

This method of comparison via graphing is not suitable for displaying the recorded and transformed satellite data. The satellite only passes over the site ‘N3’ every ten days therefore the data is very sparse, this means that there are only fourteen common records that can be compared directly between the recorded and satellite data sets.
The recorded and transformed satellite data is therefore best compared by means of an extremes analysis.

4 EXTREME WAVE CONDITION ANALYSIS

Extremes analysis is used to provide a series of extreme wave heights for various storm return periods. Halcrow's advanced wave modelling package MWAVE incorporates the routines to calculate extremes.

In order to investigate extreme wave conditions, wave data from all directions were fitted to a Weibull and a Gumbel distribution, respectively. Historical records show that the Weibull distribution provides good predictions of extreme wave height data. For this study the results reveal that the relationships between both recorded and satellite data are accurate within 0.5m, which are illustrated in Figures 14, 15 and 16. The predicted results from the Weibull distribution for extreme wave conditions are shown in Table 1.1 to Table 1.6.

Table 1.1 Extreme Wave Conditions at location 'N3' (Recorded data)

Return Period (years)	Wave height (m)
1	4.562
5	5.076
10	5.283
20	5.482
50	5.736
100	5.921
150	6.027
200	6.101
300	6.204
1000	6.501

Table 1.2 Extreme Wave Conditions at location 'N3' (Satellite data)

Return Period (years)	Wave height (m)

1	4.35
5	4.791
10	4.967
20	5.136
50	5.35
100	5.506
150	5.595
200	5.657
300	5.743
1000	5.991

Table 1.3 Extreme Wave Conditions at location ‘N2’ (Recorded data)

Return Period (years)	Wave height (m)
1	3.648
5	4.007
10	4.15
20	4.287
50	4.461
100	4.587
150	4.659
200	4.709
300	4.779
1000	4.979

Table 1.4 Extreme Wave Conditions at location ‘N2’

(Transformed from satellite data at location ‘N3’)

Return Period (years)	Wave height (m)
1	3.089

5	3.449
10	3.595
20	3.736
50	3.915
100	4.046
150	4.121
200	4.173
300	4.246
1000	4.456

Table 1.5 Extreme Wave Conditions at location ‘N1’ (Recorded data)

Return Period (years)	Wave height (m)
1	3.464
5	3.895
10	4.069
20	4.239
50	4.455
100	4.613
150	4.703
200	4.767
300	4.855
1000	5.111

Table 1.6 Extreme Wave Conditions at location ‘N1’

(Transformed from satellite data at location ‘N3’)

Return Period (years)	Wave height (m)
1	2.92

5	3.344
10	3.518
20	3.687
50	3.905
100	4.066
150	4.158
200	4.223
300	4.314
1000	4.577

5 CONCLUSIONS

RECORDED DATA

The correlation between the recorded wave data and transformed wave data is quite accurate.

The results are best represented as a series of line graphs comparing like locations and periods as shown in Figures 3 to 10.

Further confirmation is provided by comparing the differences between recorded wave data and transformed wave data, examples of this are shown in Figures 12 and 13.

It can be seen that Figure 12 shows that the difference in transformed wave heights and measured wave heights at location ‘N1’ to be on average within 0.3 of a metre, stormy periods in this timeseries produce waves of 5.5 metres. Similarly Figure 13 shows that the difference in transformed wave periods and measured wave periods at location ‘N2’ to be on average within 2 seconds, periods in this timeseries can reach 11.5 seconds.

We can therefore conclude that the recorded wave data transformed from ‘N3’ to ‘N1’ and ‘N2’ is a realistic representation of the actual recorded wave data at locations ‘N1’ and ‘N2’.

SATELLITE DATA

This study reveals that the relationship of the extreme wave heights of both recorded and satellite derived data, position ‘N3’, are accurate to within 0.5m. The extremes calculated from the transformed waves at ‘N2’ and ‘N1’ were also within 0.5m of the extremes calculated from the recorded waves at these locations.

This is best shown in Figures 14 to 16.

FIGURES - NOT INCLUDED

Figure 1 The REFPRO Grid System

Figure 2 Ray Plots, Results from REFPRO

Figure 3 Recorded and Transformed Wave Heights for location ‘N1’ for the period 14/10/94 to 01/03/95

Figure 4 Recorded and Transformed Wave Periods for location ‘N1’ for the period 14/10/94 to 01/03/95

Figure 5 Recorded and Transformed Wave Heights for location ‘N2’ for the period 08/11/94 to 28/02/95

Figure 6 Recorded and Transformed Wave Periods for location ‘N2’ for the period 14/10/94 to 01/03/95

Figure 7 Recorded and Transformed Wave Heights for location ‘N1’ for the period 31/12/94 to 07/01/95 (Storm Period)

Figure 8 Recorded and Transformed Wave Heights for location ‘N1’ for the period 07/02/95 to 14/02/95 (Storm Period)

Figure 9 Recorded and Transformed Wave Periods for location ‘N2’ for the period 31/12/94 to 07/01/95

Figure 10 Recorded and Transformed Wave Periods for location 'N2' for the period 07/02/95 to 14/02/95

Figure 11 Recorded and Transformed Wave Directions for location 'N2' for the period 08/11/94 to 28/02/95

Figure 12 Difference in Wave Heights, Position 'N1' (Transformed minus Measured) for the period 14/10/94 to 28/02/95

Figure 13 Difference in Wave Periods, Position 'N2' (Transformed minus Measured) for the period 14/10/94 to 28/02/95

Figure 14 Recorded and Satellite Derived Extreme Wave Heights at Location 'N3'

Figure15 Recorded and Transformed Satellite Extreme Wave Heights at Location 'N2'

Figure16 Recorded and Transformed Satellite Extreme Wave Heights at Location 'N1'