Hampton Harbor, New Hampshire

PART I. WAVE THEORY, MEASUREMENTS, AND ANALYSES

Webhannet River, Maine

CHAPTER 1

THE CANADIAN WAVE CLIMATE STUDY - THE FORMATIVE YEAR

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ABSTRACT

This paper describes the need for, and the factors involved in, the establishment of a Wave Climate Study, illustrated with particular reference to the Canadian Wave Climate Study

INTRODUCTION

The shortage of sea wave information is world-wide, and that which does exist has usually been obtained for specific purposes and is of value only in a very limited area Of the existing information, a large part in incomplete in comparison with the desirable minimum of a year's continuously-sampled conditions, and much of that which has been collected systematically has been analyzed in ways which are difficult to interpret Canadian waters were no better, and no worse, documented than most others, but the Canadian Department of Public Works, probably the major potential user of wave data, became concerned at the lack of information The engineering design division had the foresight to see that techniques had advanced sufficiently to justify the setting up of an organization to devote itself solely to the collection of wave data to meet future needs Because of the size of the country, the project envisaged was probably larger than any similar project which had previously been undertaken anywhere else in the world Treasury approval was obtained for an exploratory phase, with a nominal budget of $183,000, and the author was privileged in being asked by the Chief Engineer of the Design Directorate, Mr G Millar, to direct the study in its formative year from October, 1968

GENERAL JUSTIFICATION FOR A WAVE CLIMATE STUDY

The first part of any such study is largely an administrative exercise Although the need to spend money is more than obvious to anyone who has ever had to dream up design wave characteristics, it has to be justified in some detail to the controller of the purse strings Part of the justification

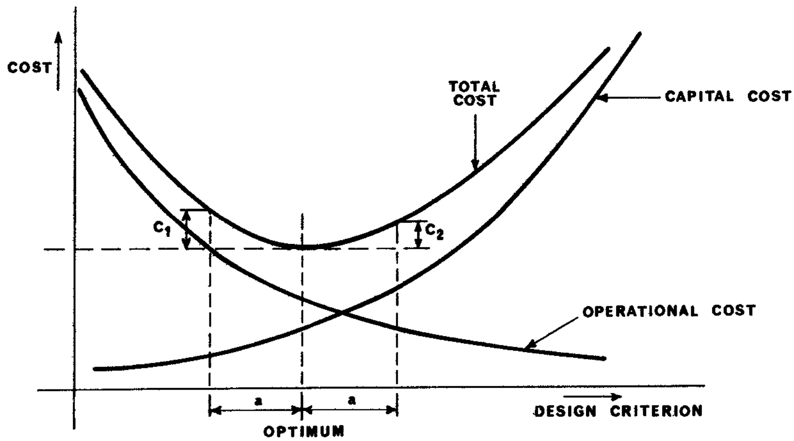

Figure 1 Schematic Relationship between Cost and Design Criteria

is not difficult to find, wherever structures have been built in exposed locations there must have been failures which have been expensive to remedy, and it is likely that it would be easy to find major repair bills totalling far in excess of the likely cost of any wave climate study It is just conceivable that no major repair works have been necessary, in which case this is again a forceful argument in the minds of the Treasury Officials as it is most likely that the structures have been overdesigned, and that the initial capital outlay has been excessive. Figure 1, based on a diagram in a paper by J. Ploeg[1], suggests that there is a fairly sharp optimum cost of design for coastal structures, so that without a fairly good estimate of wave conditions, which are major parameters, it would be nearly impossible to come close to the optimum, and the cost would necessarily increase As a consequence of this, it is reasonable to infer that the structure which is ultimately the cheapest will require occasional expenditure on maintenance and repair of storm damage Wave conditions are only one, albeit major, of a number of parameters affecting the ultimate cost of a structure The cost of failure is very much more than the actual rebuilding cost, for example, if a breakwater fails, in addition to the basic repair cost there will be the cost of overloading alternative ports and transport systems, and also the social costs, the latter may well have been completely neglected in many assessments and include the disruption of normal patterns of life and true unemployment costs (not just those of unemployment benefit), and possibly the costs of loss of life

It cannot be pretended that good wave information alone will enable a designer to define the optimum precisely, but it should appreciably reduce deviations from the optima and make important savings in expenditure

STANDARDS FOR DESIGN

In the development of standards and criteria for the design of marine structures it is necessary to have reliable information, in some detail, on wave conditions which do, and are liable to, occur The only way to ensure that criteria for waves are realistic is to study them, instrumentally and theoretically, in all geographical areas

Uses for wave information are legion Apart from the obvious ones of design parameters for specific projects, and design standards in general, the results of a comprehensive wave climate study can be used for the assessment of utilization of all kinds of surface vehicles, ships, hydrofoils and hovercraft, drilling, pile-driving and pipe-laying vessels, and for many other civil, as well as military, purposes

PERSONNEL AND ORGANIZATION

The minimum personnel requirements of such a study, apart from a study Director, are for one or more Civil Engineers with marine experience, and preferably with a mathematical aptitude, a Hydrodynamicist with oceanographic experience to be responsible for data collection, for each field team a competent electronic engineer able to plan his own programme and work on his own, often in remote situations, and a technician able to work with him and on small boats Diving experience in the field team would also be a useful attribute

The field team should preferably be supervised by the oceanographer, and the analysis of results would be undertaken jointly by him and the civil engineers, who would then be responsible for treatment of data and its interpretation for engineering purposes Apart from technical prowess, enthusiasm for and appreciation of the value of the whole project are essential in every member of the whole study The field team must have the ability to meet and win the confidence of all persons whose cooperation is required for the success of an installation

The engineers in the project must also be involved in the field work to help them appreciate the problems and difficulties involved, but their main task will be in the interpretation and application of data to real engineering problems They will find themselves called upon to advise and pronounce on all manner of problems connected with waves The study Director will probably have some difficulty in keeping a balance such that the group continues its research, and also helps those needing advice and often more substantial assistance, especially as they may well be the people on whom his field staff rely rather heavily for support in installing, running and maintaining equipment

The study must maintain close links with two groups who are generally regarded as distinct entities - at one end is the construction organization which may not be research oriented, and at the other end is the oceanographic research organization which might not be too interested in detailed practical applications of its work The study should, if at all possible, house all its staff in close proximity to each other within one building, and also have its own laboratory and at least some workshop facilities. Only in this way can full discussion, essential in such a project, take place and all members of the staff be able to appreciate the problems and needs of the other parts of the project.

TASKS OF THE STUDY

Existing Data

One of the first tasks will be the tracking down and collection of all documents purporting to give wave information The data in each one will have to be assessed, and listed according to its geographical location, so that when future needs arise it can be retrieved quickly. It is quite probable that very little data achieving the required standards will be found

Known future needs

Many projects can be foreseen in general, if not in detail, several years in advance, so that a picture can be built up showing where requirements for wave information are likely to be concentrated This information can often be obtained from area Public Works Authorities, Port and Harbour Authorities and major resource exploiters such as oil and mineral companies

DEVELOPMENT OF A PLAN OF OPERATION

When all the existing data has been collected and opinions on future needs have been assembled (previous attempts at wave recording are indications that there may be more interest in those areas), it will be possible to propose areas in which general coverage stations should be placed. Usually these should be in open waters, placed so that each station samples wave conditions which are likely to be significantly different from those at any adjacent station. Possible specific locations can usually be determined from hydrographic charts of the area, in conjunction with land maps to give an indication of shore conditions, accessibility and density of habitation. The locations must be as exposed as possible and not suffer significantly from refractive effects, be shielded by reefs or sand bars, or be sheltered by long stretches of shallow water If an underwater cable is to be used, a 'safe' landing zone must be available fairly conveniently, tidal currents should be as small as possible. Possible locations for housing the recording equipment, such as lighthouses or other officially-owned buildings on a coast, may be found from charts and land maps, the authorities concerned are often only too pleased to help by giving introductory letters for project personnel to present to lighthouse staff and others, asking them to give assistance during site surveys.

When specific locations have been decided it is then necessary to make site surveys. The actual visit to each site at which a cable may be brought ashore entails inspection on foot, preferably at low tide, to determine an actual route for the cable The route must be as protected as possible to avoid sharp rocks and areas where boulders are liable to be moved by high waves A major hazard for surface instruments is that they may be in collision with shipping, be stolen, or even used as targets for shooting practice, submerged instruments are less vulnerable, but can easily be trawled up, or the cable may be wrecked by a dragging anchor, in either case all local marine authorities and opinions must be sounded to determine the liklihood of misadventure These will usually range from black despair to high optimism, the real answer usually lies between the two, and a crystal ball may well be needed before the final decision is taken

Loss of information can, and will, occur through many different causes, in fact, wave recording is a highly hazardous operation, at least from the point of view of the resulting data In planning the Canadian Study, it is intended to leave each recorder in operation for two years so that gaps in the first year's records can be patched with data from the second In the relatively rare cases when the first year's records have insignificant gaps, the instrument can be withdrawn and moved elsewhere In ice-free waters a year means twelve calender months, but where the water is frozen over for part of the time, the "year" is taken to be the mean duration of time when substantial ice-cover is absent

ASSESSMENT OF INSTRUMENTS

There is no universal wave recorder, but for most studies it may well be possible to standardize on one sub-surface pressure recorder, one surface buoy and one through-surface recorder From the technical points of view of expertise in servicing and costs of spares, the virtues of having as few different types of instrument as possible are self evident. In the Canadian Study, it was initially intended to standardize on three types

(1) N.I O Shipborne wave recorder This can only be used for routine data collection where a vessel is stationary at one place for long periods - for example, on Light Vessels or Weather Ships, or where a vessel often revisits a station or small area for routine sampling purposes In our case the two Canadian Ocean Weather Ships which operate on station P in the North Pacific were each already fitted with a Shipborne wave recorder The only remaining Light Vessel in Canadian waters, the LURCHER, was scrapped as an economy measure less than a month before the equipment was due to be installed One instrument was installed on the PORTE DAUPHINE, a Great Lakes Institute vessel, the one destined for LURCHER should be installed on a vessel belonging to the Canadian Centre for Inland Waters

(2) Pressure recorder If at all possible the recorder should be capable of being monitored, so that a fault can be recognised at a very early stage To achieve this it is necessary to use an underwater cable, but cables suffer badly from the vagaries of the sea, and may be damaged in a variety of ways which can reduce the insulation For long-term installations it is essential that any damage which impairs the signal should be recognised at once In a recorder which transmits back a voltage or a current, diminution of the insulation can result in an attenuated signal reaching the shore unit, and the presence of the trouble may not be recognised for a long time Even when it is known that the record is in error, it may not be possible to determine with any certainty the time of onset of the trouble, and many perfectly good records may have to be scrapped Possibly the most elegant alternative is the use of the frequency modulation system in which a pressure signal is converted in the transducer into a frequency signal, so that a frequency is transmitted up the cable. As long as the frequency can be discriminiated from background noise, regardless of the state of the cable, a shore unit will record the correct pressure Failure, when it comes, will be catastrophic, and will be immediately recognisable

At the time when the Study was looking into the problem, only two types of F M wave recorders were commercially available After testing one of each it was decided to standardize on the instrument designed and built by the National Research Council in Ottawa

(3) Surface buoy These instruments are intended for use where the water is deep and a pressure unit cannot be used, or where the distance to shore makes the cable cost prohibitive They transmit by radio to a shore station, which may be twenty or thirty miles away One of each of two different types were tested, and it was decided to standardize on the Waverider buoy built by Datawell of Holland

Through-surface recorder In the first stages where only general area data was sought, there was no need for a through-surface recorder (they generally need to be fixed to an existing structure)

DATA HANDLING

In the Canadian Study it was intended initially to record by pen on paper charts, there were several reasons for this The assessment of instruments was not due to be completed until the autumn of 1969, and until decisions had been made it was not possible to decide the type of digital equipment needed to match the outputs In remote outstations the use of sophisticated equipment, especially if it is untried, can waste a great deal of time Even if all the equipment had been well proven and was likely to give no trouble, the shortage of skilled technical staff would have reduced the number of installations which could be made in a given time. The philosophy at present is that if good chart records can be obtained they can be analyzed cheaply at headquarters by people other than technicians

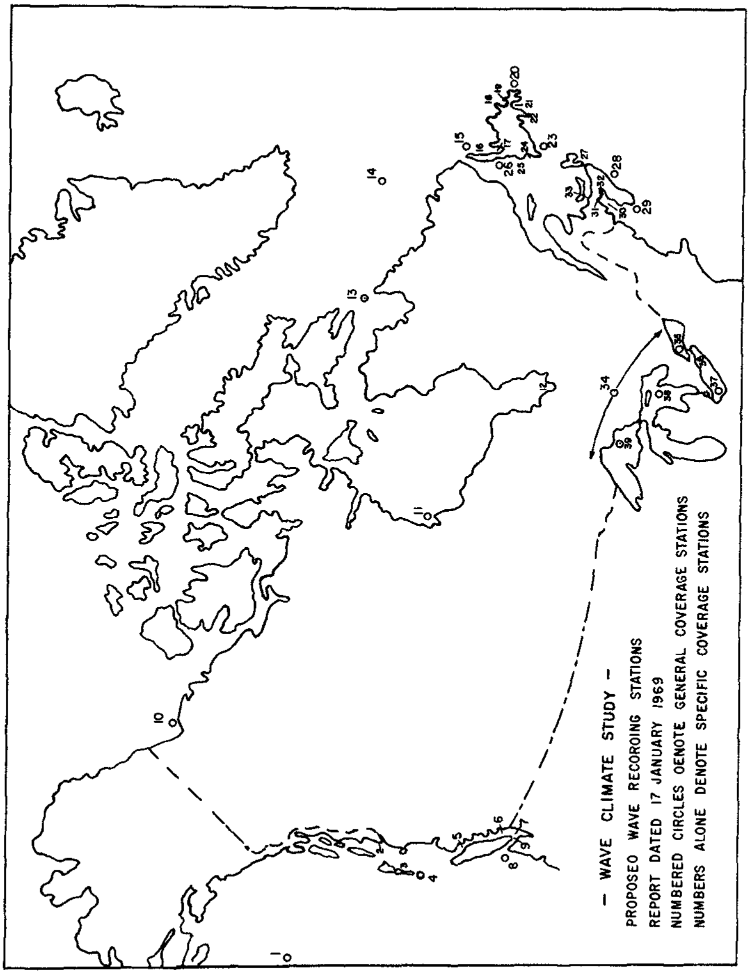

Figure 2 First proposal for Wave Recording Stations

One technique which needs to be investigated is the transmission of data over existing telephone lines back to headquarters This would reduce the amount of data logging equipment needed, and have the great advantages that only one data logger would be required and could therefore be of high quality, and also that servicing staff would be easily available It would have the disadvantage that spurious signals might be injected into the records by parts of the system out of our control and that recording might not always be possible at the required time due to conjested lines

The intention is to process the data, whether on charts or tape, following the recommendations given by the author[2] at the 1966 conference

WIND DATA

A very important source of information from which wave data can be calculated is wind data Measured or even observed wave data is sparse, but measured wind data is much more common and in many places is available for half a century or more For calculations of extreme wave conditions the wind data may not be in the most useful form, the information needed is the most probable value of the highest mean wind, over durations up to 24 hours, likely to be exceeded once in some long period of time such as 20, 50 or even 100 years If the basic measurements of mean hourly wind speed have been consistently made for at least ten years, an extrapolation can be made from them. The author is at present aware of only two countries where wind data is available in the required form, these being the United Kingdom[3] and Canada[4], where the data has recently been obtained by this Study If this mean-hourly data is available, a further requirement for wave forecasting is information on the ratios of the mean wind speed over periods of from six to twenty four hours to the highest mean hourly speed in each storm For Canada this was done for the 20 most severe storms at 21 typical stations, the mean speed over 24 hours was between 60% and 80% of the greatest mean hourly value,and the mean speed over six hours was between 80% and 90% of the greatest mean hourly value For the U.K some ratios have been calculated by Shellard (private communication) and the percentages were a little higher

REFRACTION STUDIES

Any study group established to provide wave information will rapidly find itself being called upon to produce refraction diagrams Several methods of doing this have been published, and one must be chosen and adapted to suit the computational facilities available, ideally the output should be drawn by a plotter In the Canadian Study, the method devised by the U S Coastal Engineering Research Center was adapted[5], with the output presented on a Benson Lehner plotter

THE PROPOSALS AND ESTIMATED COSTS FOR THE CANADIAN STUDY

To achieve reasonable coverage of Canadian waters, 39 stations were designated (Fig 2), 9 being on the Pacific coast, 5 in northern waters, 19 on the Atlantic coast and 6 on the Great Lakes Details of the specific proposals are not given here, as they are of local value only The estimated total cost is just over one million dollars, spread over five years

The staff requirements are for five persons in the first year building up to ten in the fourth year, the total number of man-years amounting to 40   At the end of the five years the study ought to achieve reasonable coverage of Canadian wave conditions, with data processed and presented in a standardized manner

CONCLUSIONS

The needs for wave information are many, but the cost of a major comprehensive study is more than justified by the probable economies in construction and repair costs alone

In the running of a Wave Climate Study, a lot will depend on the recruitment of staff with not only the appropriate abilities but with the sort of pioneer enthusiasm which is necessary in a small new project, in which there are few precedents and where improvisation is needed in isolated locations   Such a group must not only collect and analyse data, but it must be capable of acting as a consultant to interpret its findings and advise those who need the data and who will, in all probability, flock to it in increasing numbers   Indeed, maybe its major problem will be that of finding a way to limit the time spent in solving particular localized problems, as this can easily interfere with the task of making and interpreting field measurements - the first priorities of the study   At this stage it is hard to estimate what will happen after five years, but the author's feelings are that the group will be so involved in many projects that its continuation will be essential to the proper design of marine works in Canada, and that its usefulness in many other spheres as well will ensure its survival both as a data collecting and an engineering consultant agency

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