INTEGRATION AND COMPUTATION IN AN ENVIRONMENTAL STUDY

by

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ABSTRACT

A high level of integration of disciplines and use of a centralised computer data base and programming system were seen to offer advantages in a study of the marine and coastal environment of the Port Melbourne Authority. These goals were only partially attained but the effort was well worthwhile.

1. INTRODUCTION

For an environmental study to achieve an overview of the wide range of variables, processes and interactions in a given region, the results of work in many disciplines must be integrated. The integration of the different disciplines depends critically upon flows of information. These in turn depend upon the use of the computer to store, process and display information.

This paper describes the integration of disciplines and the centralised computer data base and programming system used in the Port of Melbourne Environmental Study. The purpose and results of the study are outlined first to provide the context.

2. THE PORT OF MELBOURNE ENVIRONMENTAL STUDY

2.1 Purpose

The Port of Melbourne Environmental Study was divided into firstly a study of the sociological implications of the possible expansion of Webb Dock with some emphasis on land transport serving the dock and secondly the Marine Study of 6 Webb Dock. The Marine Study was aimed at assessing the effects on the marine and coastal environment of reclamation and dredging activities associated with the construction of Berth 6 Webb Dock. The site of the proposed construction is in Hobsons Bay, close to the mouth of the Yarra River. The study involved investigations of water movement, water quality, coastal processes and the ecology of the Bay.

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The Port of Melbourne has been developed over the last 150 years along the lower Yarra River and around its mouth, in an indentation of Port Phillip Bay known as Hobsons Bay. The Webb Dock container terminal is in Hobsons Bay immediately to the east of the mouth of the Yarra River (Fig. 1). Hobsons Bay forms the southern boundary to Melbourne, and hence is of importance to the city as a recreational area for boating, fishing, for swimming, and for the aesthetic enjoyment of water and its shoreline. The value of Hobsons Bay would be lowered if the water quality were to be reduced, if the ecosystem of the bay were to be disturbed or if the beaches were severely eroded. Severe changes in the regime of the bay could adversely affect commercial fishing within Port Phillip or could conceivably interfere with port operations. Proper management can avoid these problems, but management requires reliable baseline information on the present state of the bay, an understanding of the processes which are important and, based upon both of these, strategies for predicting changes to the ecosystem of the bay following construction or other activities. The study provided the baseline data on water circulation, water quality, beaches and sediments and marine ecology, an understanding of the important processes and specific predictions for the changes which would result following construction of Berth 6 Webb Dock.

2.2 Method

The Port of Melbourne Authority commissioned the Centre for Environmental Studies, University of Melbourne, to carry out a study to provide baseline information and to assess the consequences of construction of a new berth —— No.6 —— in Webb Dock. This study was commenced in 1977 and the final report was presented in August 1979. Following a three months planning period, twelve months of measurement were carried out within Hobsons Bay and the lower Yarra River. In addition to the data obtained specifically by the study, historical data and data collected on a continuing basis by government authorities were used.

Water movement was determined by direct current metering, continuous current metering, drogue tracking and from temperature and salinity data (Mills et al 1978, Dandy et al 1980). Wave records, tidal data, long-term meteorological data for the Melbourne Regional Station and wind data for periods of interest at Breakwater Pier were obtained from government departments. Water quality parameters measured were temperature, salinity, dissolved oxygen, light transmission, turbidity, nitrogen, phosphorus, *E. coli* and *Salmonella* bacteria and inflows from minor drains.

For the study of the beaches and sediments, beach profiling and lead-lining were carried out, sediment samples were collected and analysed, a sand tracer test was conducted and waves, winds and currents were measured. Other data used were air photos, records of construction, dredging and shipping movements.

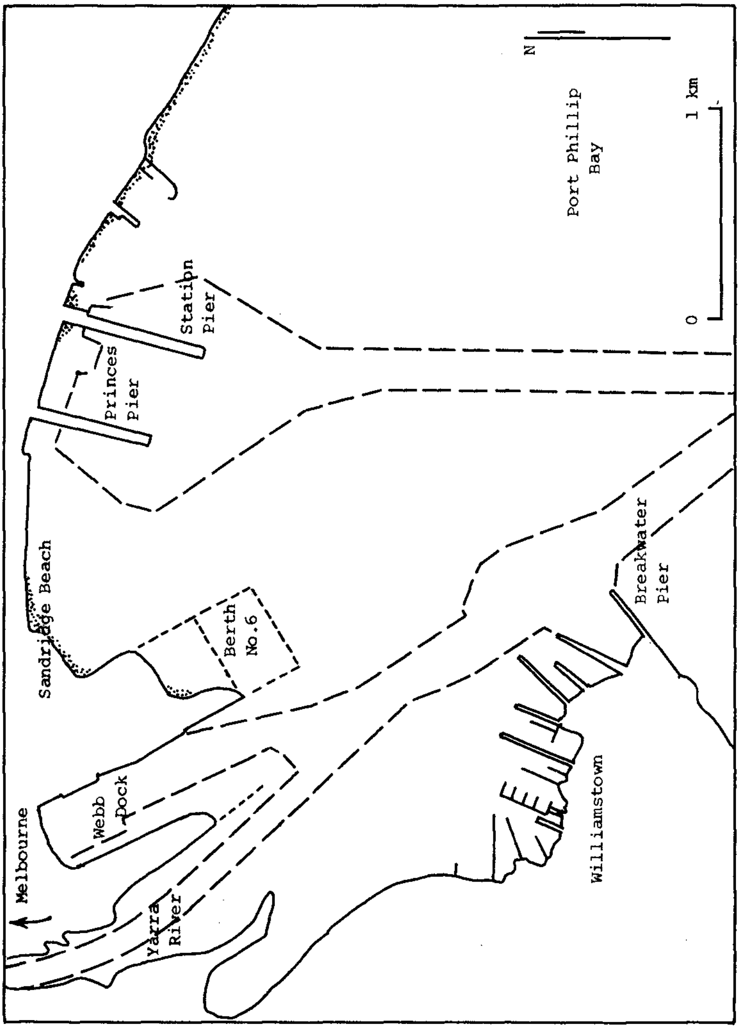

Fig. 1 Hobsons Bay, Melbourne

The ecological studies concentrated on sampling the intertidal and subtidal epibiota (algae and fauna) on port structures, and the benthic infauna of the bed and intertidal margins of the bay. Fish populations were sampled by seining in shallow water. A survey of recreational fishing in Hobsons Bay was conducted.

2.3 Results

The principal findings were:

- The water circulation in Hobsons Bay is primarily wind driven, but the effects of Yarra River flow and stratification must be taken into account and tides may be important in some circumstances.
- Except in the surface plume of water from the Yarra River, the water of Hobsons Bay is predominantly derived from Port Phillip Bay. Within the Yarra River and river plume, bacterial and nutrient levels are high and dissolved oxygen concentrations are below desirable levels. Elsewhere the water quality meets EPA objectives.
- Sand is found on and just offshore of the beaches. Sediment movement on Sandridge Beach, to the east of Webb Dock, is highly variable but is predominantly to the west. The silt bed of Hobsons Bay may be resuspended by wave action but is not undergoing significant net movement.
- Both the hard and soft substrates of Hobsons Bay and Webb Dock support a diverse and productive biota, and there are significant populations of fish. Productivity is lower in Webb Dock than in Hobsons Bay, but it is still high by general standards. The biological communities are well adapted to the existing environmental conditions and can withstand the disturbances imposed by shipping and the natural stresses of variable temperature and salinity.

All variables were related to water movement and water quality, hence predicted changes in flow patterns enabled the changes following construction of Berth 6 to be predicted.

3. COMPUTATION

3.1 Purpose

The extensive use of a computer data base and centralised programming system was anticipated to provide economical and fast data reduction and presentation and ready access to all data by all participants in the study. The advantages of centralisation are that by examining the needs of all groups together, uniformity of recording is obtained where possible, the number of data handling programs and the computational effort are reduced and ease of access and ease of inter-comparison of different types of variables are increased.

3.2 Method

The e.d.p. work was placed under the control of one staff member possessing both a broad knowledge of disciplines involved in environmental studies plus expert knowledge of computing, assisted by junior programmers and data entry personnel. The use of a purely computer oriented specialist was not seen to provide the proper liaison which this position required, but we recognise that we were very fortunate in obtaining the services of a man expert in both areas.

The e.d.p. specialist developed a general strategy for data entry and error checking, data file structure, frequently used data manipulation and reduction programs, and frequently used tabular and graphical presentations of data. He collaborated with other senior staff in development of these and specialised analysis programs required, supervised junior staff in preparing programs and using them, and trained all staff in the use of the system as it was developed.

Available funds permitted minor improvements to be made to the existing computer hardware. The existing system, shown schematically in Fig. 2, consisted of a Hewlett Packard model 9830 programmable calculator, with 8-K words memory, programmable in BASIC, with extended string and matrix handling capabilities. An internal cassette drive permitted storage of data with the capacity of 32-K words per cassette. The calculator was usable as stand-alone machine or as an intelligent terminal for data transmission to and from the University's Central Computer — a CDC Cyber. A small plotter was connected to the 9830 and other plotters were available at the University Computer Centre. This system serviced the Centre for Environmental Studies, and could not be wholly dedicated to this study, hence the decision was taken to provide an additional direct line to the University Computer and to provide an auxiliary cassette drive for the 9830.

The software required may be divided into four groups. Data entry and error checking routines were specially prepared for the study. Data manipulation, reformating and editing routines were also specially written, to enable correction of data files, combination of files for use in calculations and to enable stranger tapes written in other computer installations to be read by the Cyber. Data preparation routines, including those used in smoothing raw data, for changing time base intervals, resolving vectors and so on, were again specially written although they utilised well known algorithms. Finally, the more substantial programs for tasks such as time series analysis or statistical analysis were obtained from other installations wherever possible. Because of its great convenience the SPSS package was utilised for all basic statistics operations, despite its inefficiency for some types of calculations.

3.3 Results

Approximately 300,000 data values were entered to form the main

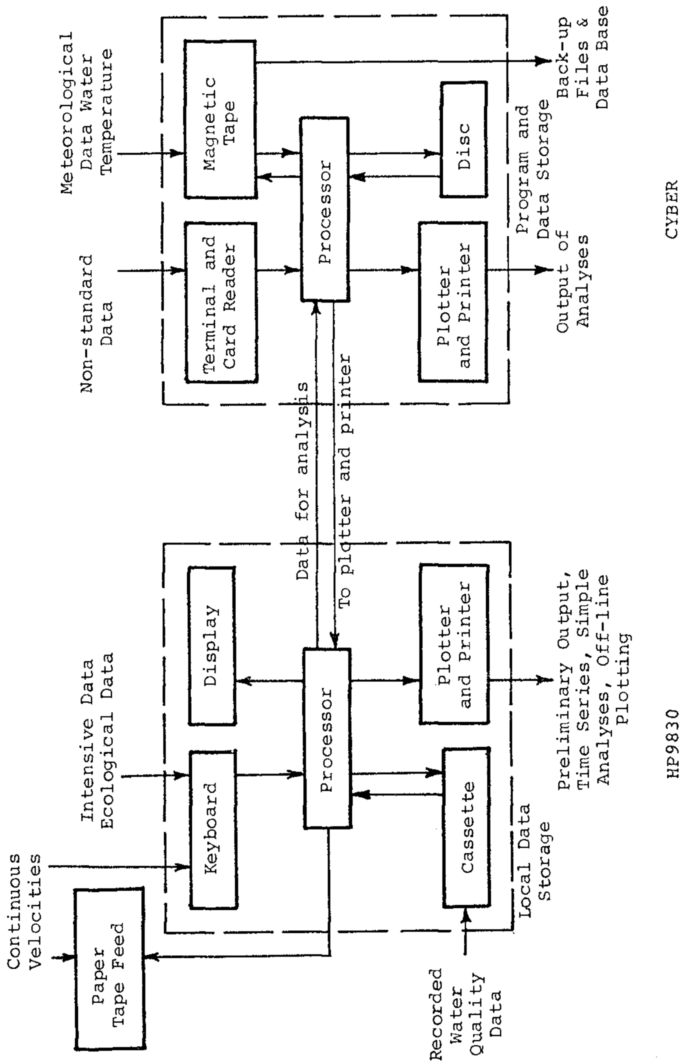

Fig. 2 Computer configuration used for data entry archiving and processing

data base, while tapes obtained from government agencies contributed a further 200,000 data values, primarily meteorological data. The centralised programming facility provided approximately 80 programs, most of them in the area of data manipulation, reformating and editing. Approximately 80 additional programs or variations of programs were prepared outside the central system, mostly in the areas of data analysis and presentation. Averaged over the course of the study, the computer specialist devoted between one and two days of each week to the job. Junior programmers contributed approximately one man year of work and data entry personnel approximately three man years. Other project staff contributed approximately half a man year to the programming and about the same to the data entry.

The forms of data input, principal computer files created and the source of the principal computer programs used are shown in Table 1 for the water quality and water movement data; the first six columns represent over 98% of the data. The table shows that a wide variety of input forms were used, most data were put onto local cassette for limited local computations and onto the central data base, and processed on the central computer programs. The similar tables for the sediment data again showed the same features with nearly all computation done centrally. The tables for the ecological and human activity data showed that most data were keyed in and entered into local cassette files and the central data base, but most computation was done locally or on programmable calculators.

The use of this system resulted in an excellent data base, achieved economically.

The anticipated benefits of rapidly available data and rapid presentation of simple analyses were not realised for three reasons. Firstly, at the conclusion of the year of data collection a bottleneck developed because of the excessive amount of data entry simultaneously with development and utilisation of the analysis programs. Computer specialists and hardware were both overloaded for several months and remained under pressure for a considerable time. Secondly, some members of the team possessed programming skills and chose to exercise them rather than await the development of programs by the hard-pressed computer specialist. This practical but necessary decision resulted in some duplication of efforts and reduced the future utility of the sets of programs developed, through use of different formats and less complete documentation.

Finally, the proper development of the analysis programs had to await the development of an understanding of the Hobsons Bay systems. For example, the spatial and temporal variability of currents in Hobsons Bay was greater than anticipated, so that the drogue movements — with their built in averaging — provided a better picture of water movements than did the current metering. The unexpectedly large populations of subtidal epibiota also lead to changes in methods of analysis.

TABLE 1 Use of Computer System for Water Quality Data

Date Type	Melb. Wind, Rain	Break-water Wind	River Flow	Cts. Current	Temp. Record	Intensive Data[3]	Drain Data[4]	Salinity Record	Drogue Tracks	Bacteria Data[5]
Input Form	T	K	K	KR	T (P,K,C)	K	P	K(C)	P	K
Local Cassette File	–[2]	X	X	X	–	X	–	X	–	X
Central File (Data Box)	X	X	X	X	X	X	–	–	–	X
Local Computation	–[2]	X	–[2]	(X)	–	–	–	X	–	X
Central Computer Individual Programs	–	–	–	–	–	X	–	–	–	–
Central Computer Central Programs	X	X	X	X	X	(X)	–	–	–	–

T = Externally written tape
K = Keyed in
KR = Keyed in from record on paper tape
P = Paper copy only
C = Internally written cassette
( ) = Limited use only
X = Principal facility used

[1] Calibration corrections only.
[2] Limited data set used with bacteria data.
[3] Current, temp., salinity, nutrients.
[4] Discharge, temp., salinity, nutrients.
[5] E. coli, temp., salinity, tide.

The appendix contains a description of one of the data entry programs and illustrates the passage of data from input to analysis.

4. INTEGRATION OF DISCIPLINES

4.1 Purposes of Integration of Disciplines

Direct collaboration between specialists in different disciplines is required for two principal reasons: firstly because of the need to utilise information obtained by one discipline to explain and extend the results obtained within another. For example, biomass and populations of the biota were found to depend upon the physical and chemical variables of temperature, salinity, turbidity, water velocity and location with respect to the river plume. Analysis and interpretation of these data required collaboration of sedimentologists, marine chemists, engineers and biologists.

Secondly, unless all factors are favourable, the making of a recommendation on proposed works requires that unlike quantities be compared or unlike measures be combined —— for example a loss of water suitable for swimming might be offset by an increase in waters available for fish nursery areas.

4.2 Methods of Integration of Disciplines

Integration of the different disciplines required that the individuals perceive the benefits of close cooperation and that the facility for this cooperation be provided. As has been pointed out by many others, it is necessary to put effort into such collaborative work for it to succeed. Even the gaining of working knowledge of the jargon of the other disciplines requires effort, but is an essential pre-requisite to collaboration.

In the planning of this environmental study, as with most others, the tasks were distributed according to the specialised backgrounds of the different workers, so that one of the team was responsible for the ecological studies, another for the sediment studies, and so on. Such a division of labour seems to be unavoidable if high technical standards within each area of the study are to be achieved. The initial division then had to be overcome by conscious effort, by planning for the different parts of the study to interlock and by arranging for the offices of the different specialists to be in close proximity and for them to work together as much as possible.

Total integration was clearly not essential or even desirable. Determination of the hydrodynamic patterns required hour by hour measurements while determination of the typical populations of barnacles at a site required seasonal measurements and even the actual days of measurement did not have to coincide for the one series to provide support to the other. By not striving for needless synchronisation, better use was made of boats, instruments and support personnel.

The flows of information are illustrated in Figs. 3, 4 and 5. Each figure shows the flows — from left to right — of raw data, reduced data and basic statistics, combined and correlated results of several types of data, culminating in the predicted change in a selected variable following construction. The flows of all levels of data to the data base have not been shown for clarity. Similar figures could be presented for other variables such as turbidity, epibiota, bacteria, algae, etc.

Both the correlated results, which describe the present regime of the bay, and the predictions are useful outputs from the study as are the raw data and basic statistics which provide a baseline against which future states may be compared.

4.3 Results of Integration of Disciplines

Despite an appreciation of the need for integration, the different specialist tasks diverged very early and some of the field measurements were carried out with inadequate regard to integration of the disciplines.

However, at the stage of analysis and reporting of results, a high degree of integration was achieved, in large measure by the channelling of all data through the e.d.p. specialist and by one of the senior staff making some contribution to the writing of all of the component parts of the report. The pressures of meeting deadlines within the specific tasks discouraged the other members of the team to become involved outside their own speciality except upon direct request. This is a very common experience with inter-group cooperation, where the willingness of the various individuals is not a sufficient stimulus in the face of the more clearly perceived pressures within their own specialist task, and since the collaboration between groups frequently depends on one or two individuals it may break down completely under such stress.

5. CONCLUSIONS

The interdependence of all parts of the study, at the level of interpretation and prediction has been shown. The water movement investigation and the water quality investigation proved so interdependent that they were completely merged early in the study. All parts of the study depended on the results of the water quality and water movement investigations with the latter playing the major role in the prediction of changes following construction. In this study, the predicted changes in all variables were very small and so application of multi-objective planning techniques was not necessary.

Integration was encouraged by joint planning, by working in close proximity, and by joint writing of each major section of the report.

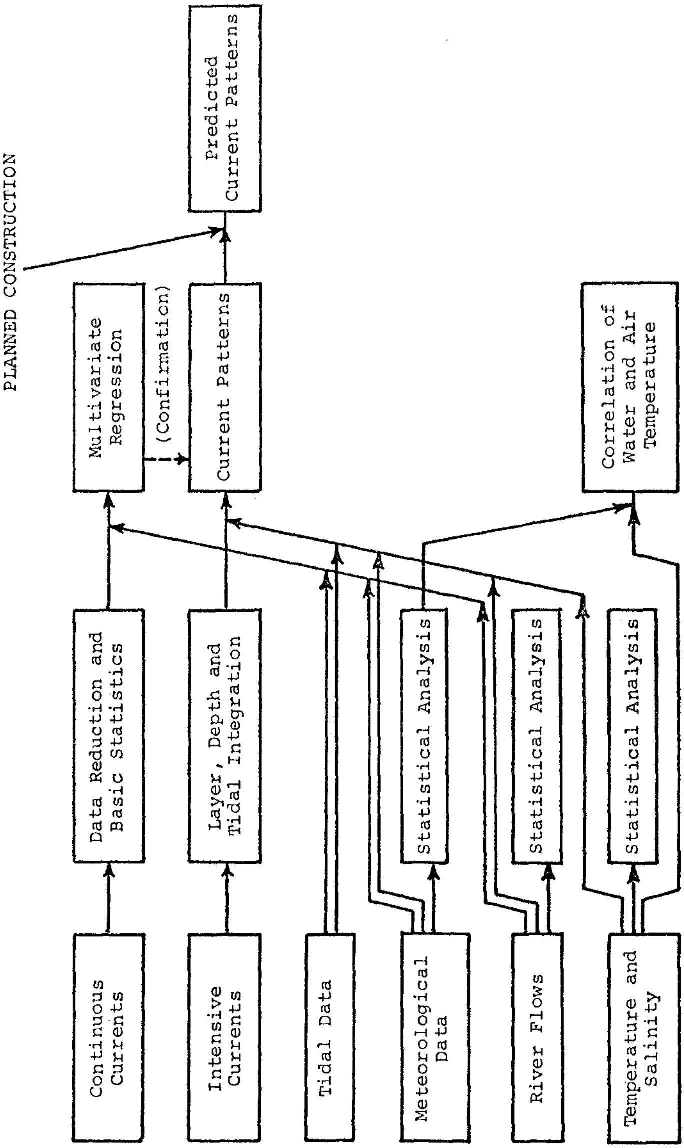

Fig. 3 Flows of information used to analyse currents and water temperatures

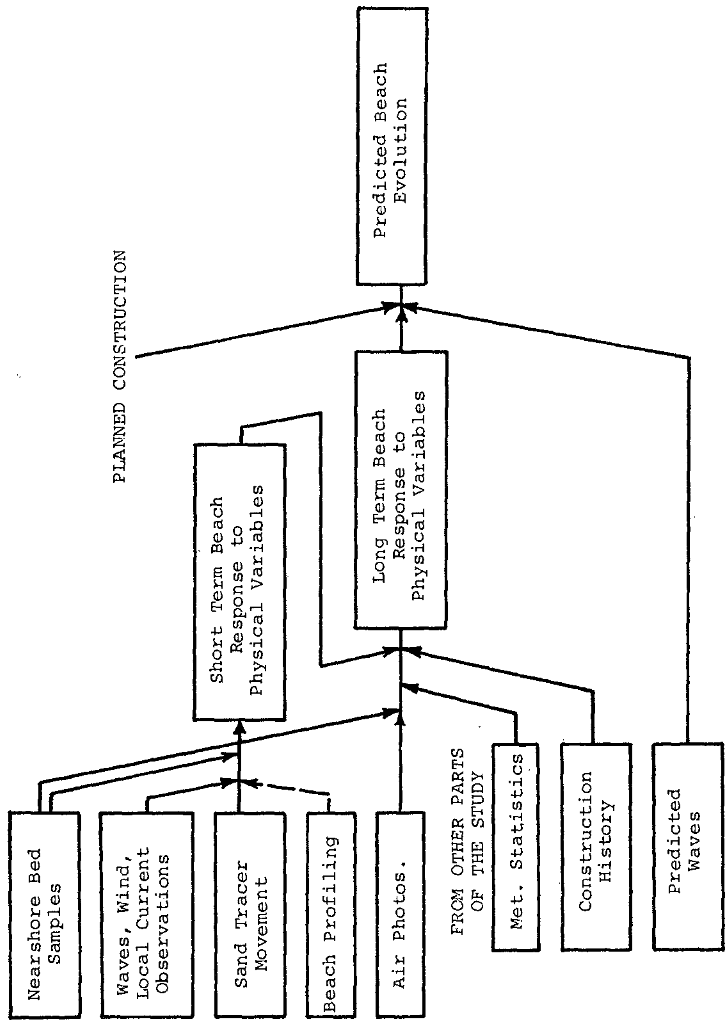

Fig. 4 Flows of information used to analyse beach dynamics

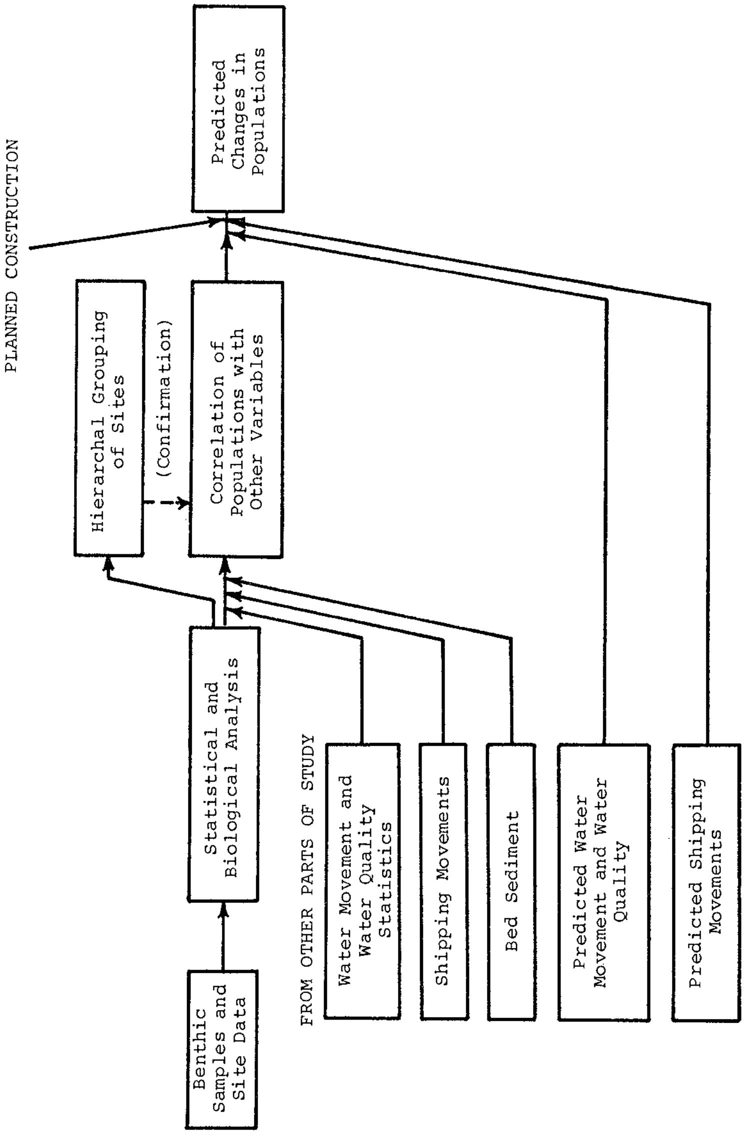

Fig. 5 Flows of information used to analyse benthic biota

However, full integration was not obtained because of the need to meet deadlines and the need to utilise specialists in each area to ensure high technical standards

The objective of a centralised computing service for the study was not wholly successful but was worthwhile by making available documented programs and data files, with common formats. The success achieved was largely due to having a person skilled in both computing and the disciplines involved in the study. Periods of high demand lead to delays, and to individually written programs which met the study objectives but are not of general use.

6. ACKNOWLEDGEMENT

The study was funded by the Port of Melbourne Authority, whose staff were of great assistance.

7. APPENDIX: DATA ENTRY, EDITING AND STORAGE

A suite of programs for use on the Hewlett Packard Model 9830 calculator was developed to facilitate data entry, error checking and transfer for the purposes of the study. Data collected during the intensive field exercise were recorded on special field sheets. These were hand edited in the office to correct for calibration and instrument errors prior to entry on the computer. Data were entered from the edited field sheets, or from printed paper tapes produced by the current meters, by specially trained operators, through the keyboard of the 9830, were stored on cassettes and were later transferred to the Cyber computer. Once stored in the Cyber, the data files could be corrected, data could be transformed, files could be joined or merged and listings or plots of data prepared.

As an example the sequence of steps for the continuously recording current meters will be described. These instruments printed the speed and direction on a paper tape at pre-determined intervals, normally five or fifteen minutes. For data entry the tapes were mounted in a specially constructed transport, mounted on the 9830. The operator, after mounting the tape and cassette, generated a header file on the cassette, specifying the maximum record length, number of data fields per record and the number of characters in each field. He then entered specifications of the parameters, comprising parameter name, measuring unit, alphanumeric or numeric, scalar or vector, precision, maximum and minimum expected values, time or position sequence of data, coordinate location of data point and time index.

The operator then commenced the actual entry of data entering a number for current speed and one for current direction. The following tests were automatically performed and if any succeeded, an error condition was signalled:

- Incorrect field length (number of characters).
- Illegal alpha characters.
- Number of decimal places does not correspond to specified precision.
- Decimal place omission.
- Presence of more than one decimal point.
- Presence of decimal point in integer field.
- Data out of range specified.

These errors had to be corrected by the operators before the data were stored on cassette. They could arise due to discrepancy between the raw data and the value entered or as a result of an anomalous value appearing in the data field resulting from instrumental or recording errors. Other errors were usually detected using basic statistical and time series functions, following data entry. The simplest check was to prepare a time series plot of the velocity magnitude and direction, or of the orthogonal components and to examine this plot for anomalous values. Basic statistics were obtained at the same time and gave an indication if the nature of the record differed from previous records.

The cassette prepared on the 9830 was then batched with various others to the Cyber as a raw data file. Errors detected through the time series plot and other means were then corrected using the file editing capability of the Cyber. Missing data were indicated by an asterisk or a sequence of 9s, but were not replaced. The raw data files thus prepared form part of the data base.

Before the continuously recorded velocities could be used for analysis, files of 30 days of data had to be prepared. First the data were manipulated, to obtain values at constant time intervals throughout the files to be combined. This step was necessary as the starting time of one file might not be at an integral number of time steps after the end of the previous file, the time steps might not be equal in the two files, or the time step might be shorter than that needed for the analysis so that alternate data only might be required in the combined file. The two files were then combined, with the gap between them treated as any other missing data. If the sequences of missing data were short, they were filled by interpolation but if long they were filled manually utilising the best estimates after considering all of the available data. The resultant 30 day files were then stored as part of the data base and were utilised in data analysis.

Analyses performed using the 30 day files of current data included the preparation of velocity scattergrams, analysis of tidal harmonics, correlation of velocity data with wind and with atmospheric pressure, and correlation with velocity data obtained at other sites. From these analyses the physical factors responsible for the currents were ascertained, the likely velocities under particular sets of physical circumstances were predicted for periods of interest, and annual averages were estimated. In addition to time series plots and scattergrams, hodographs, cumulative vector plots and other pictorial representations were used to display the information on the velocity field. This work is presented by Dandy, Mills and Hinwood (1980). Tapes from the instruments which were recorded in a computer compatible form were handled in the same fashion as 9830 raw data cassettes.

8. REFERENCES

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