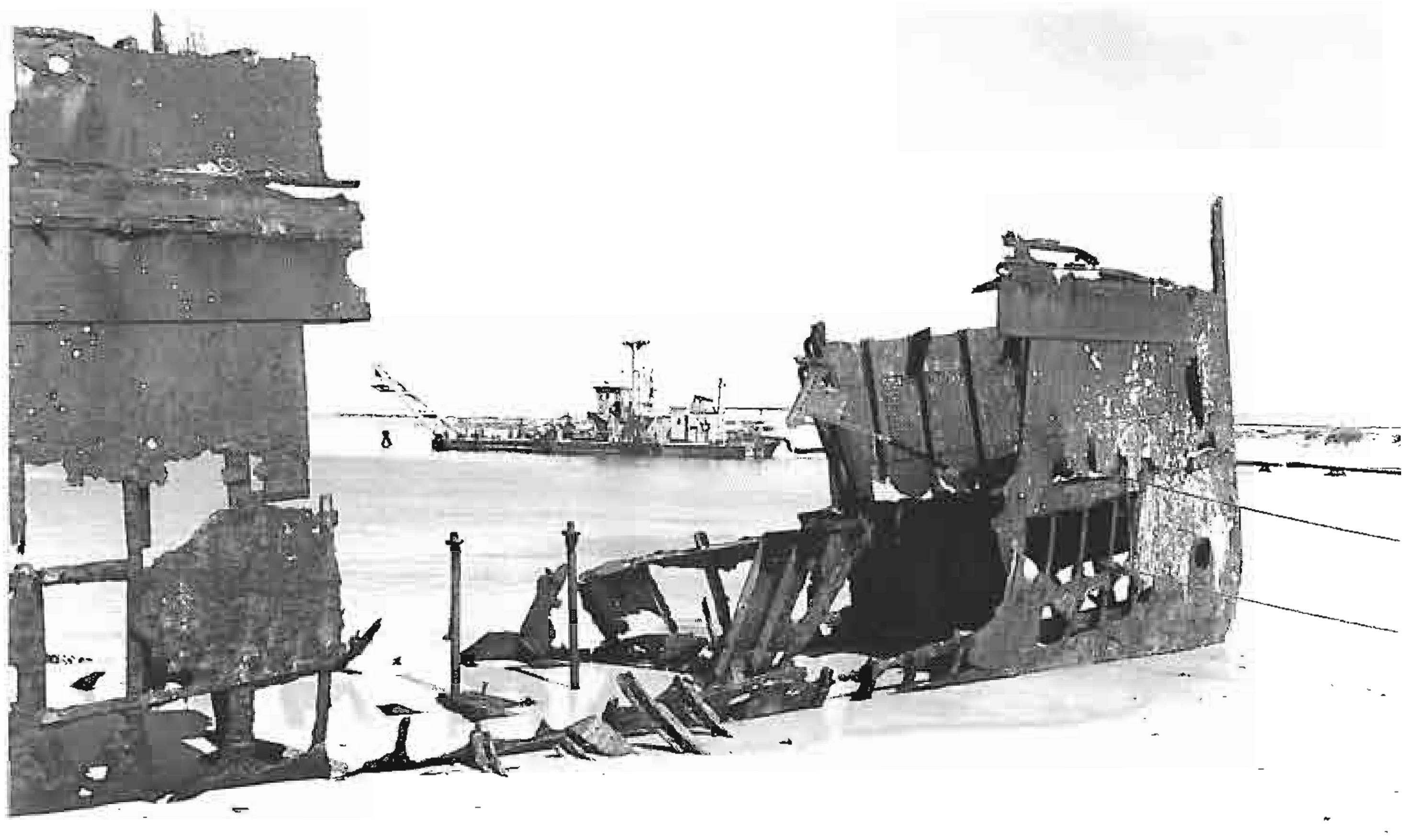
JERVOISE BAY PROJECT REPORT

A survey of the shipwrecks *Abemama* and SS *Alacrity*



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Report - Department of Maritime Archaeology, Western Australian Maritime Museum, No. 127.

JERVOISE BAY PROJECT REPORT

A survey of the shipwrecks *Abemama* and SS *Alacrity*

Prepared for Halpern Glick Maunsell
by

D. Garratt and C. Souter

With contributions from
P. Baker, J. Carpenter, J. Green, M. McCarthy and V. Richards

June 1997

Cover: The SS *Alacrity* on the original shoreline, 1975. Note the dredge in the background.
Photo: J. Carpenter, WA Maritime Museum, 1975.

ABSTRACT

This document has been prepared for Halpern Glick Maunsell by the authors on behalf Department of Maritime Archaeology of the Western Australian Maritime Museum.
The Department of Materials Conservation of the WA Museum has also assisted.
The commissioning brief required the consultants to provide a detailed survey of two shipwrecks lying in Jervoise Bay, the iron-hulled SS *Alacrity* and the 3-masted American schooner *Abemama;* to report on the structural condition and stability of each wreck and to record the location and depth of the wrecks to Australian Map Grid co-ordinates, chart datum AUS 66.
Time constraints allowed only a very brief period of ten days to complete the task.
Part A. of this report includes a brief account of the history of the vessels and a statement of their cultural significance. In Part B, a description of the wreck sites is provided and previous archaeological excavations are reviewed.
The aims and methods utilised in conducting the survey of the wrecks appears in Part C. The results are presented in Part D. Three options for the preservation of the wreck sites are discussed and recommendations for ensuring an optimum state of preservation follows.

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ACKNOWLEDGMENTS

The authors acknowledge the assistance of staff of the Western Australian Maritime Museum especially Project Supervisor, Dr Michael McCarthy. Adjunct Associate Professor, Jeremy Green, Head of Department of Maritime Archaeology conducted the DGPS survey. Technical assistance and diving supervision was provided by Maritime Museum Technical Officer, Geoff Kimpton. Museum photographer, Patrick Baker recorded all aspects of the survey.

The underwater conservation survey assessment was carried out by diving conservator, Jon Carpenter and a detailed analysis of the survey data was conducted by research scientist, Vicki Richards from the Department of Materials Conservation.

Tidal information for Jervoise Bay was provided by Mr Jeff Tomlinson of International Shipyards, Henderson.

The production of this report was funded by LandCorp.

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

DGPS	Differential Global Positioning System
PWDWA	Pubic Works Department, Western Australia
WAM	Western Australian Museum
WAMM	Western Australian Maritime Museum

EXECUTIVE SUMMARY

The wrecks of the iron steam-tug SS *Alacrity* (1902–1931) and the wooden-hulled three-masted schooner *Abemama* (1919–1927) have long been a feature of the shores of Jervoise Bay, a noted ship's graveyard since the nineteenth century. The vessels there range from the remains of a WWII Dutch submarine through to wooden-hulled sailing ships and iron steamers.

Many of these wrecks have been protected for the future despite the burgeoning shipbuilding industry that has been developing rapidly on the shores of the Bay over the past two decades. This, in itself, has proved an interesting mix of site management strategies alongside rapid shoreline development. Some sites have had jetties and other structures built nearby and others have been incorporated into land-fill, all with a view to their preservation in areas long-since rendered inaccessible to the general public due to the activities and demands of industry.

Earmarked in 1978 as sites of educational and recreational significance, two wrecks, the *Abemama* and *Alacrity* were considered especially worthy of preservation and presentation as two of Western Australia's most accessible shipwreck sites. Lying only a few metres offshore adjacent a very popular beach and recreational facilities, these sites were then managed and presented to the snorkelling public who regularly accessed the beach adjacent.

Jervoise Bay's pre-eminence as an Australian centre for shipbuilding and the associated need for more land on which to develop further will lead to these beaches being closed to the public for safety reasons and will see the area in which the *Abemama* and *Alacrity* lie enclosed in groynes and breakwaters. This will also see an end to recreational visits to both the beaches and the two wrecks.

Preservation for the future then is the issue in the face of the need to develop slipways and wharves in the vicinity of these two sites.

Utilising a grant provided by LandCorp, the Department of Maritime Archaeology at the Western Australian Museum has commissioned the authors to conduct a series of studies designed to identify the management options available for these two sites in the light of their impending inaccessibility to the public and to recommend those most beneficial with respect to their preservation for the future.

Dr M McCarthy
Project Supervisor
Curator of Maritime Archaeology
Department of Maritime Archaeology
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JERVOISE BAY PROJECT REPORT

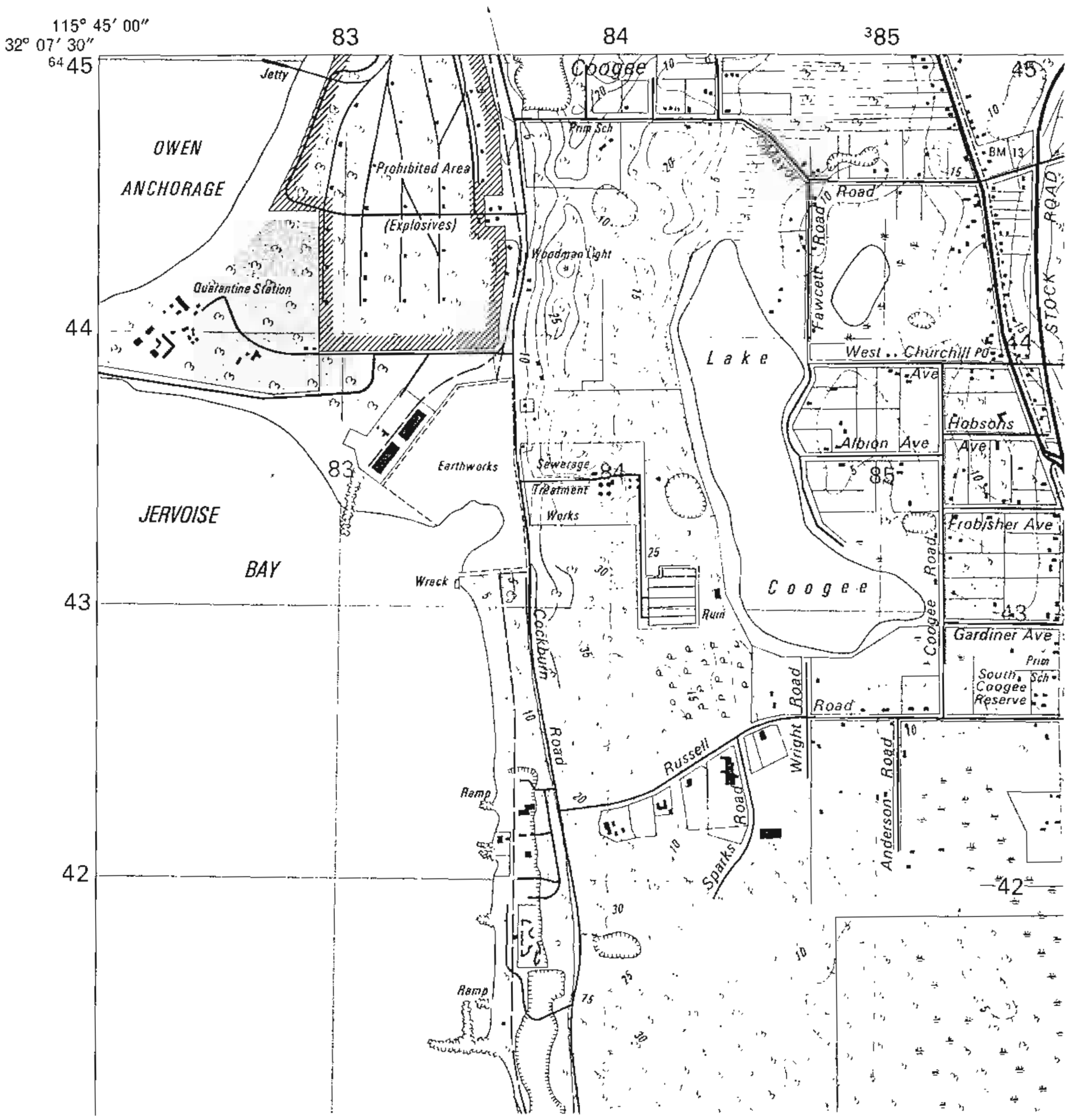


Figure 1. Australia 1: 25 000 Topographic Survey. Fremantle SW, Sheet 2033-1 SW (Edition 1), Series R 811, 1976. The wreck of the *Alacrity* is shown above. The *Abemama* lies under the beach to the east. Note the date.

PART A HISTORICAL BACKGROUND AND CULTURAL SIGNIFICANCE

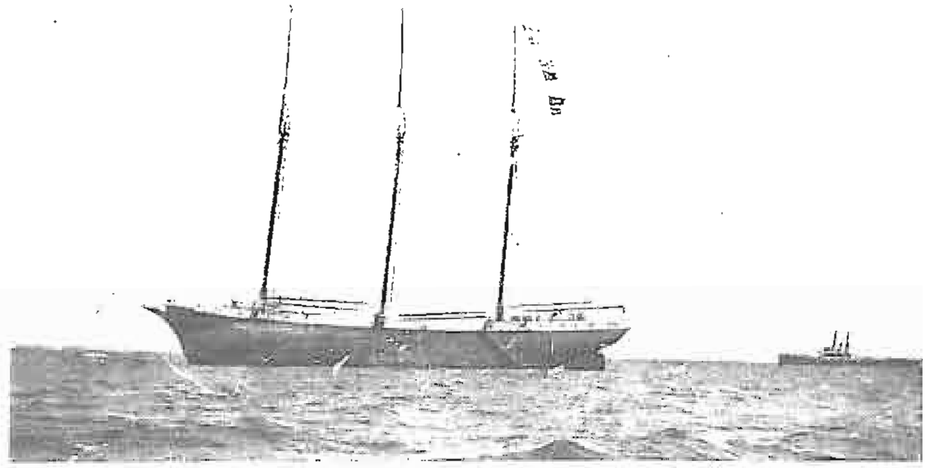


Figure 2. The *Abemama* at anchor – the vessel in the background is the *Alacrity*. Photo: Mrs A. McGhie.

Figure 3. The *Alacrity* during dredging activity. Photo: Jon Carpenter.

From Western Australian Museum information pamphlet, (McCarthy, 1993).

1.0 The Alacrity/Abemama Wrecksites

These two wrecksites are valuable educational and recreational assets as they are easily accessible and safe for study in calm conditions with an offshore breeze.

THE *ALACRITY*

Construction	:	Steel, twin-screws, two decks, tug
Dimensions	:	Length 145.6 ft (44.4 m), beam 27.1 ft (8.3 m), depth 13.5 ft (4.1 m)
Tonnage	:	353 tons gross, 349 tons underdeck, 32 tons net
Rig	:	Rigged as a ketch. Top speed 12 knots
Built	:	1893 by the Societe Anonyme des Forges et Chartiers de la Mediterranee, at Havre, France
Engines	:	Two triple expansion engines each with cylinders of 15 in. (32.1 cm), 23 in. (58.4 cm) and 35½ in. (90.17 cm) diameter with a stroke of 23½ in. (59.7 cm) developing 122 hp.

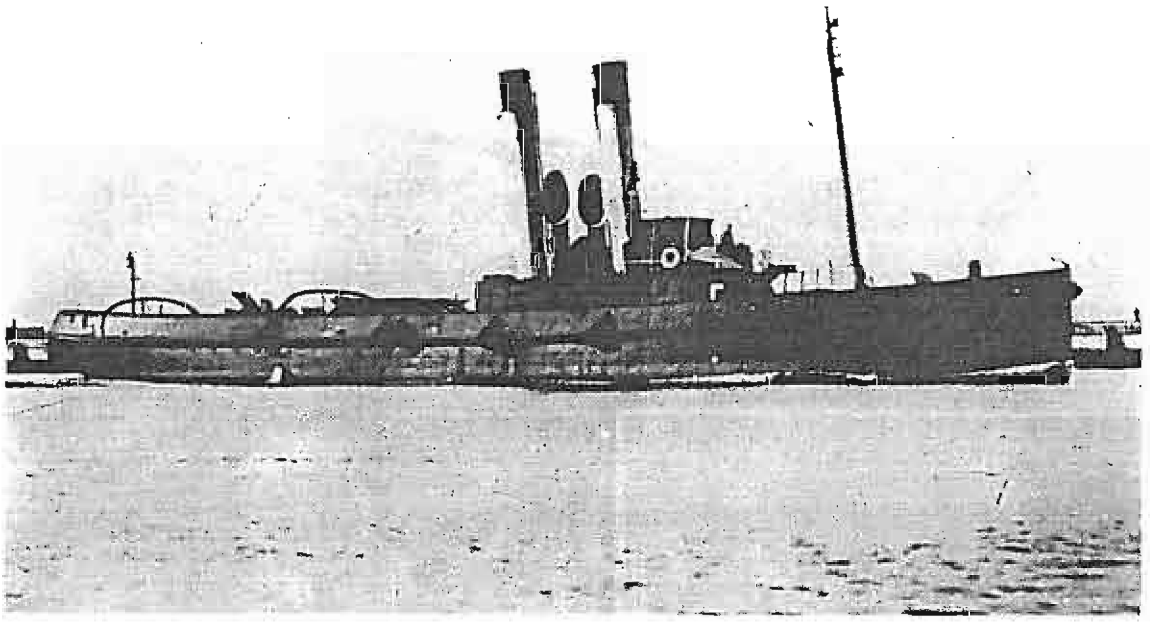


Figure 4.

The *Alacrity* first appeared in the Fremantle Shipping Register in 1902. She was used during World War I as an unarmed patrol vessel in the Indian Ocean, and as a tug in Fremantle Harbour.

She remained with the Navy and in 1919 was used by Admiral Lord Jellico in his inspection of Cockburn Sound as a potential naval base. She was later involved in the preparation of Henderson Naval Base in Jervoise Bay and was bought by A.E. Tilley & Co in 1925, being sold to a wrecking company in 1931. In April or May of that year she broke her mooring and drifted ashore where she now lies.

In earlier years the wrecksite was a favourite haunt for children until dredging operations undermined the site and caused the shoreline changes that have left the wreck 50 metres out to sea.

museum

1.1

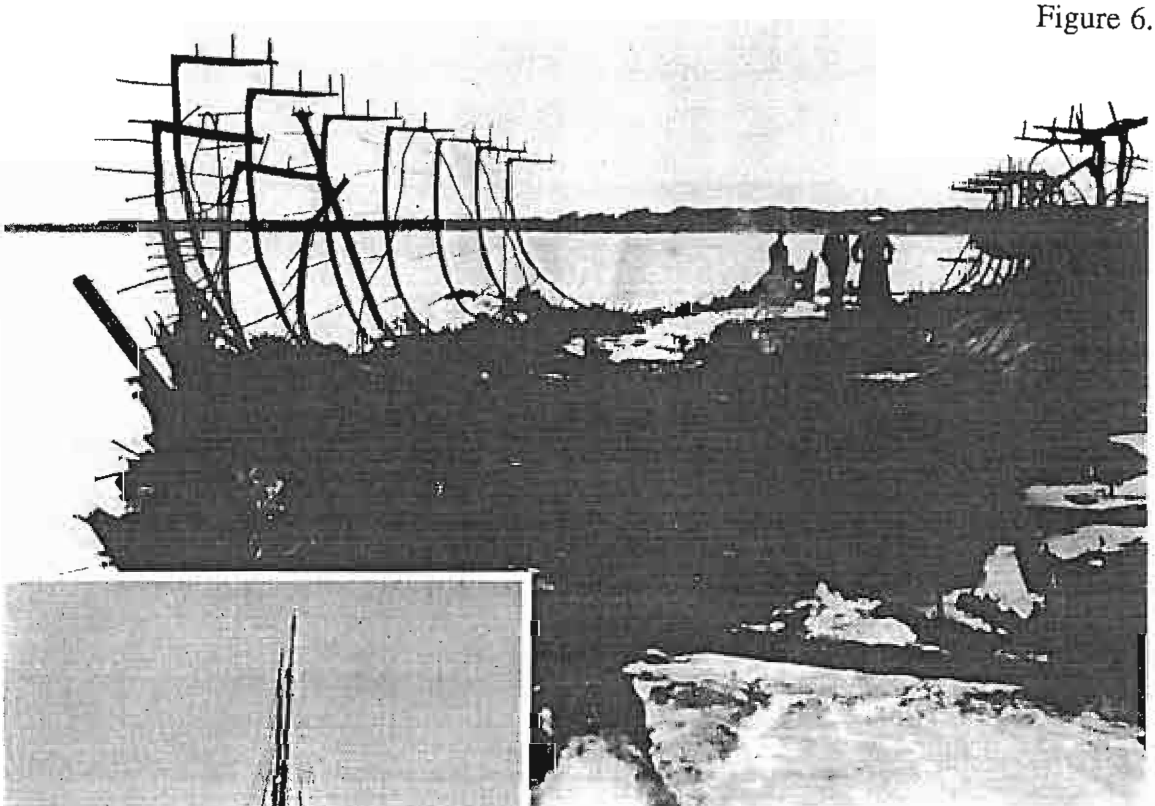
THE *ABEMAMA*

Construction	:	Wood. Iron fastened. Single deck. Poop and deck houses, eliptical stern, carvel plank
Dimensions	:	Length 133.6 ft (40.7 m) x beam 32.6 ft (9.9 m) x depth 12.2 ft (3.7 m)
Tonnage	:	395 tons (gross), 317 tons (under deck), 337 tons (nett)
Rig	:	Three-masted schooner
Built	:	Liverpool, Novia Scotia by the S.B. and Transportation Company in 1918

The schooner *Abemama* was registered in Liverpool, Nova Scotia in 1919. She worked the Eastern States trade routes until 1923 by which time she had deteriorated badly. After repairs she sailed for Fremantle and plied between Port Cloates and Fremantle until 1926. She was involved in the construction of the Beadon Point Jetty, and in 1927 was moved to an anchorage in Jervoise Bay near the *Alacrity* where she was placed in the care of Mr and Mrs Arnold McGhie. In June of that year the *Abemama* was wrecked during a severe storm which has been documented by Mrs McGhie. She and her husband managed to reach the safety of the shore due to the seamanship of Arnold McGhie, who returned to the vessel for several months while dismantling the wreck. It was later reported that vandals had set fire to the wreck and completely destroyed the vessel.

The wrecksite is quite extensive and was well preserved for many years by a layer of sand which disappeared during the shoreline changes which resulted in the collapse of the *Alacrity*.

Figure 6.



(Above) The burnt-out remains of the *Abemama* showing exposed deck supports (Photo Mrs A. McGhie)

(Left) The *Abemama* ashore (Sawday Collection)

Figure 5.

1.2 STATEMENT OF SIGNIFICANCE

ALACRITY

Historical
SS *Alacrity* was used during WWI as an unarmed patrol vessel in the Indian Ocean. Whilst still in the service of the Navy the vessel was involved in the transport of Admiral Lord Jellicoe in his inspection of the Cockburn Sound area as a potential Naval Base. *Alacrity* was involved in the preparation of the Jervoise Bay area for the proposed Henderson Naval Base until the plans were scrapped under the terms of the Washington Treaty.

Educational
The wreck's shallow water accessibility makes it an excellent training area for recreational divers and marine archaeologists, as the visible remains display the classic features of an iron wreck.

Recreational
The wreck is an ideal protected dive or snorkel site accessible to the public.

Archaeological
Although the hull remains and some ship's fittings are still present, there is little artefactual material left on the site due to it's accessibility.

ABEMAMA

Historical
The *Abemama* is one of the last sailing ships to be wrecked on this coast and represents a late stage in North American sailing ship construction. It was also involved in the construction of the Beadon Point Jetty at Onslow, c. 1926.

Technological
The constructional techniques of the period are well documented and the vessel is representative of North American sailing ship construction, a well known method. However, the deck of the *Abemama* was supported by iron knee riders and other less common iron work.

Educational
As with the *Alacrity*, this vessel's accessibility allows the site to be used as a training ground for maritime archaeology students and recreational divers.

Recreational
The wreck is an ideal protected dive or snorkel site accessible to the public.

Archaeological
The only wooden sailing shipwreck available for study in the metropolitan area. The vessel's floor timbers are the most distinguishing feature on the site. The wreck has been surveyed in detail and there remains little archaeological information to be gained from this site.

PART B SITE DESCRIPTION

2.0 GENERAL SITE DESCRIPTION

The *Alacrity* and *Abemama* lie on a sandy sea-bed 200 metres south-east of the navigation light marking the entrance to the Jervoise Bay Boat Harbour. The wrecks lie approximately 50 metres out to sea from a gently sloping beach. The depth of water in the imediate proximity of the wreck sites does not exceed 3.5 metres. A low limestone reef lies between the wrecks and the shoreline. Originally, *Alacrity* rested on the beach in the intertidal zone and *Abemama* lay under the sand. Land reclamation for shipbuilding, oil rig and groyne construction have contributed to the dramatic shoreline changes and the subsequent submergence of the wrecks.

The seabed surrounding the wrecks gradually slopes seaward. At the stern the *Alacrity* lies on an exposed limestone substrate which gradually disappears beneath sand towards the bow. Sand build-up has occurred along the shoreward side of *Abemama* and there is some evidence of sand scour at the stern of the *Alacrity*. The *Alacrity* may act as a breakwater for the *Abemama*.

Extensive marine growth covers much of the wrecks.

2.1 *Alacrity*

The vessel dimensions are approximately 44 x 10 metres, lying on a north south axis, bow to the north. The wreckage is heavily concreted and densely covered with sessile marine organisms. The sternpost(?) of the *Alacrity* is visible from the shore with a section of the stern breaking the surface at low tide. Most of the hull around the turn of the bilge has collapsed. Hull structure at the stern and midships projects approximately two metres above the sea bed. The average height of the adjoining hull structure is approximately one metre. Due to the dredging operations for the construction of the oil rig *Ocean Endeavour,* and subsequent cyclonic activity, the shoreline has undergone some comprehensive changes. The wreck which was originally beached now lies 50 metres from the shore in a maximum depth of 3.5 metres for example. The bow and stern remain in an upright position and several major bulkheads are in place supporting the frames and other parts of the vessel's structure.

Figure 7. *Alacrity*, port counter at the stern showing corroded hull plates and exposed frames. Visible on the starboard side is the propeller shaft "A" frame and starboard propeller shaft. Photo No. 5151/31: P. Baker, WAMM.

2.2 *Abemama*

The *Abemama* lies on her port side on a north south axis with the bow to the south. The wreck lies parallel to the shore in a depth of 3.2 metres of water. The timbers are exposed due to recent shoreline changes, and the height of the wreckage above the seabed does not exceed one metre. Planking, frames and some iron fittings extend approximately 3 metres outwards from the keel, giving an overall breadth of six metres. The identifiable features around midships consist of iron knee riders, deck supports, mast rings and constructional fittings. The frames and planking on the starboard side have broken off near the keel and there is minimal hull structure remaining on this side. The wreck was stabilised under a layer of sand until the shoreline changes in 1975. The more exposed hardwood timbers of the *Abemama* were covered with sessile marine organisms while the exposed ends of the hardwood frames also exhibited damage caused by marine borers.

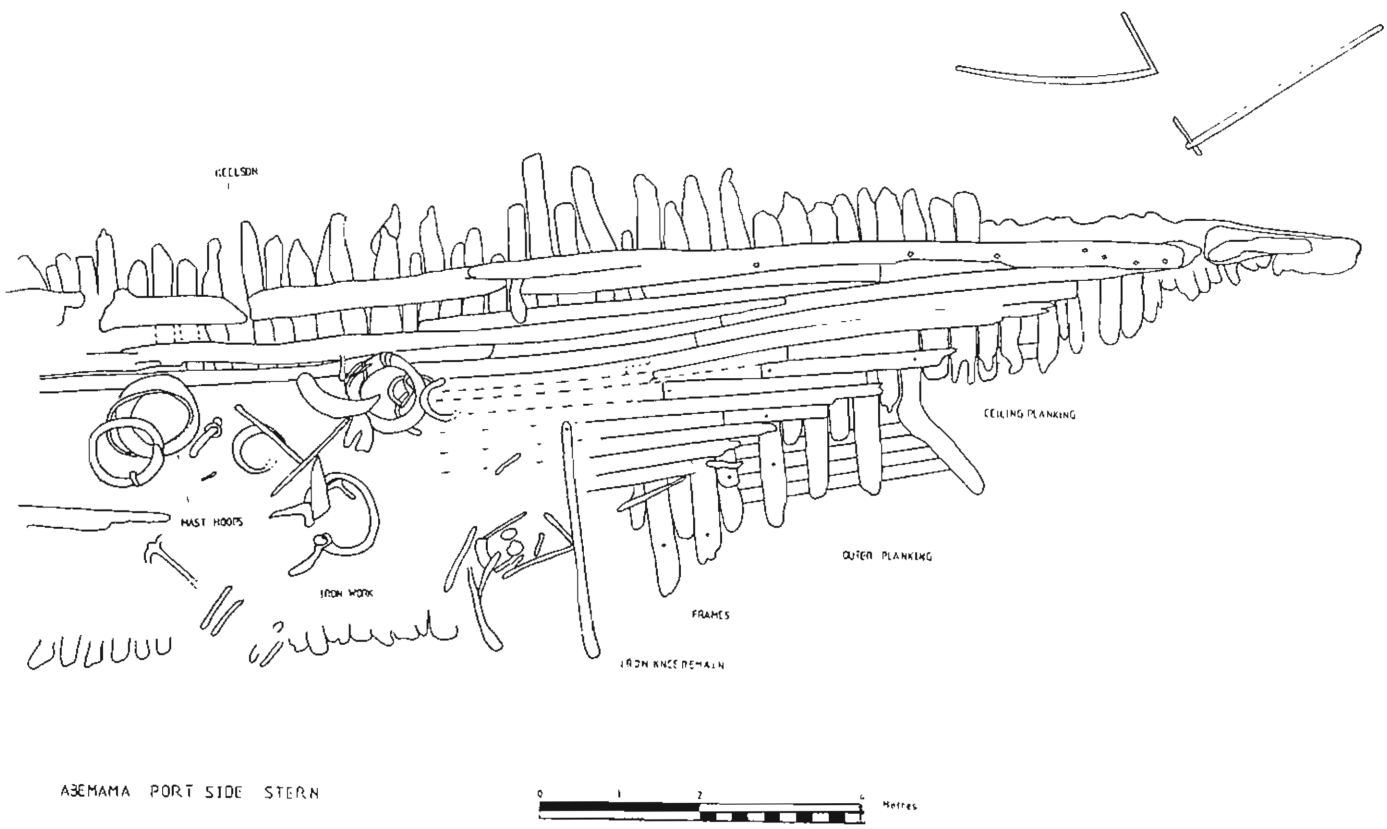


Figure 8. Site plan, *Abemama*. S Lester, WA Maritime Museum, 1981.

PART C 1997 SITE SURVEY

3.0 AIMS

3.1 To fix the position of both wrecks,their debris field and to relate sites to the coastline using a Differential Global Positioning System, (DGPS).
3.2 To fix the position of both wrecks in relation to one another using the least squares adjustment DOS program.
3.3 To procuce a predisturbance survey by the Department of Materials Conservation, Western Australian Museum.
3.4 Excavation of test trenches and site survey.
3.5 Depth soundings.
3.6 Produce a photographic record of the sites.

Method

3.1 DGPS position fixing was obtained using a Trible ScoutMaster-OmniSTAR Differential GPS and PowerBook 170 data logging system. Six points on each wreck were buoyed; bow, stern and four parallel points midships. The positions were fixed from the Museum work boat, *Seaspray*. The location of the shoreline was plotted by taking DGPS positions in the minimal navigation depth of 0.75 metres. The results were plotted using AUS 84 Datum and AUS 66 Datum.

3.2 The wrecks were surveyed and the information analysed using a "least squares adjustment" computer program. This process uses the measurements from each buoyed point to the remaining five points to plot each of the wreck remains. Measurements were taken between buoyed points on both wreck sites in order to plot the relationship of the vessels to each other as they lie on the sea bed. The report records the X and Y coordinates, datum points and direct distances between particular points. The residuals indicate how much each distance has been changed in order to create a plan of best fit.

3.3 A predisturbance survey (conducted by conservator Jon Carpenter, on behalf of the Department of Materials Conservation), was undertaken to acquire chemical data and samples of sediment and wreck material. The purpose of a predisturbance survey is to assess the physical, chemical and biological environment of a site in order to determine the extent and rate of degradation. The report and analysis is in preparation.

3.4 Two test trenches were excavated at the *Alacrity* site to determine the depth of burial and the status of the hull structure under the sediment. These factors aid in understanding the stability of the site and the feasibility of certain recommended protection measures such as relocation of the site. Trench 1 was dredged adjacent to the bow area and measured approximately 1m x 0.5m.
Trench 2, located one metre from bow on the starboard side, was dredged to determine depth of burial of vessel remains and to locate the turn of the bilge. The *Abemama* wreck site was not excavated as adequate data exists from previous excavations.

3.5 Depth over the site were determined by means of an LOWRANCE LMS 200 echo sounder mounted aboard the Maritime Museum work boat, *Seaspray*. Soundings were corrected for transponder height below the sea surface, (45 cm). The area to be surveyed was buoyed and five runs were made over the wreck sites on an East - West axis, between Latitude 3208.75 and 3208.70. The tidal information derived from the Australian National Tide Tables, 1997, for Fremantle was considered to be inconsistent with the true tidal dynamic in Jervoise Bay and for this reason, the tide gauge at the International Shipyards at Henderson was selected as a more accurate datum point. Date of survey: 29 May 1997
Survey commenced at 1138 hours - depth at datum point - 1.90 metres.
Survey concluded at 1.92 hours - depth at datum point - 1.92 metres.

3.6 Patrick Baker, WA Museum photographer, recorded the site using still and video photography to aid in the task of site assessment. The photography also serves as the most recent record of the site prior to the proposed development of the area.

Figure 9. A diver conducting the predistubance survey. Photo: P. Baker, WA Maritime Museum, 1997.

PART D RESULTS

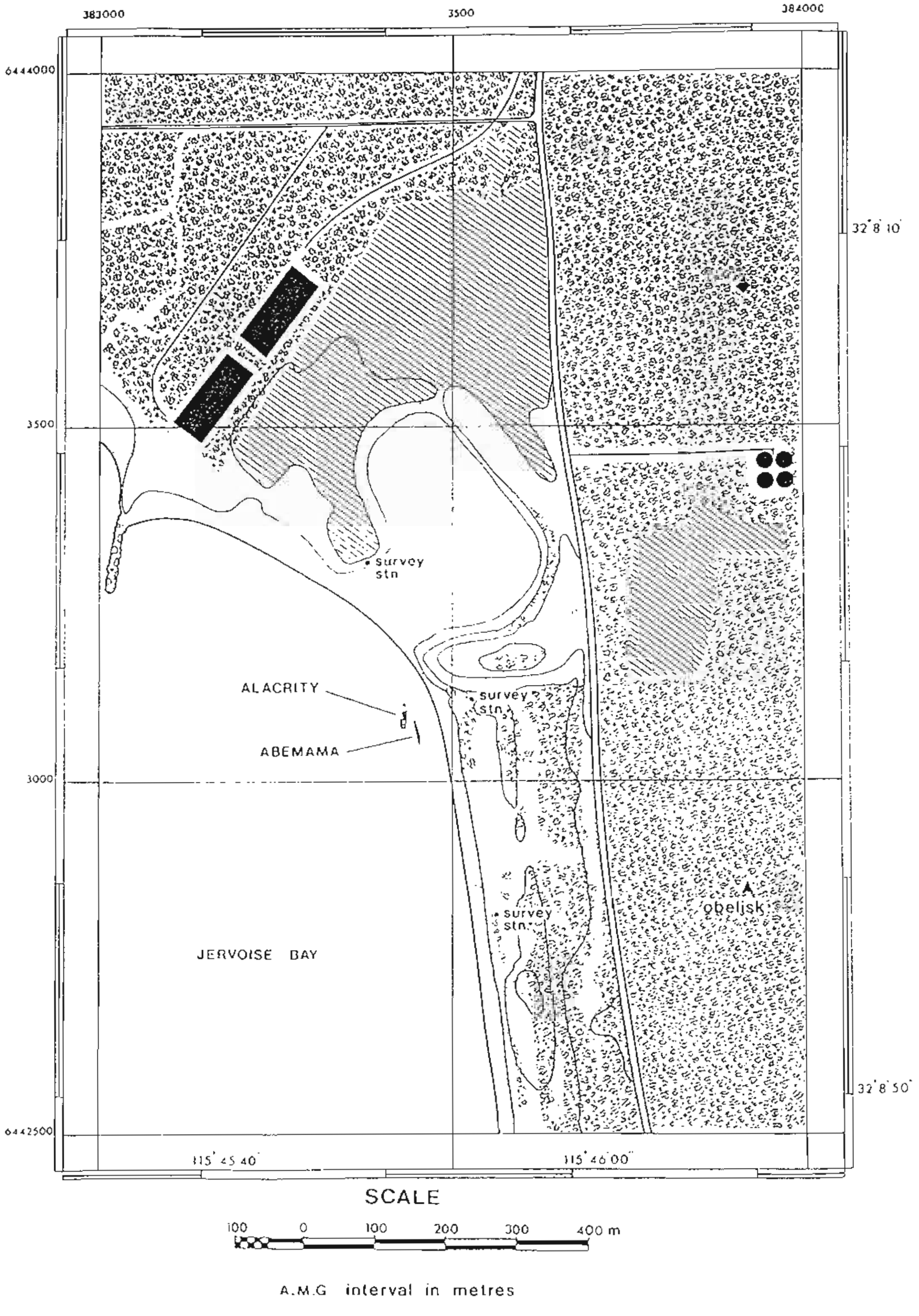


Figure 10. Jervoise Bay showing the location of the *Abemama* and SS *Alacrity*. P. Clark, WAMM, 1981.

4.0 POSITION FIXING

4.0 Position Fixing

DATUM AUS 66

TAG	FIX	UTM	UTM	LAT	LONG
A	1	50-3-834-29	H-64-430-64	3208.563	11545.839
B	2	50-3-834-27	H-64-430-89	3208.549	11545.838
C	3	50-3-834-29	H-64-430-98	3208.545	11545.840
D	4	50-3-834-29	H-64-431-08	3208.539	11545.840
E	5	50-3-834-37	H-64-430-97	3208.545	11545.845
F	6	50-3-834-37	H-64-430-85	3208.552	11545.844
G	7	50-3-834-48	H-64-430-44	3208.574	11545.852
H	8	50-3-834-44	H-64-430-56	3208.567	11545.849
I	9	50-3-834-44	H-64-430-69	3208.560	11545.849
J	10	50-3-834-39	H-64-430-82	3208.553	11545.846
K	11	50-3-834-45	H-64-430-80	3208.554	11545.849
L	12	50-3-834-49	H-64-430-69	3208.560	11545.852

DATUM AUS 84

TAG	FIX	UTM	UTM	LAT	LONG
A	1	50-3-836-33	H-64-429-59	3208.729	11545.968
B	2	50-3-836-31	H-64-429-84	3208.716	11545.967
C	3	50-3-836-34	H-64-429-93	3208.711	11545.969
D	4	50-3-836-33	H-64-430-03	3208.706	11545.969
E	5	50-3-836-41	H-64-429-92	3208.712	11545.974
F	6	50-3-836-41	H-64-429-80	3208.718	11545.974
G	7	50-3-836-53	H-64-429-39	3208.741	11545.981
H	8	50-3-836-49	H-64-429-51	3208.734	11545.978
I	9	50-3-836-49	H-64-429-64	3208.727	11545.978
J	10	50-3-836-43	H-64-429-77	3208.720	11545.975
K	11	50-3-836-49	H-64-429-75	3208.721	11545.979
L	12	50-3-836-53	H-64-429-64	3208.727	11545.981

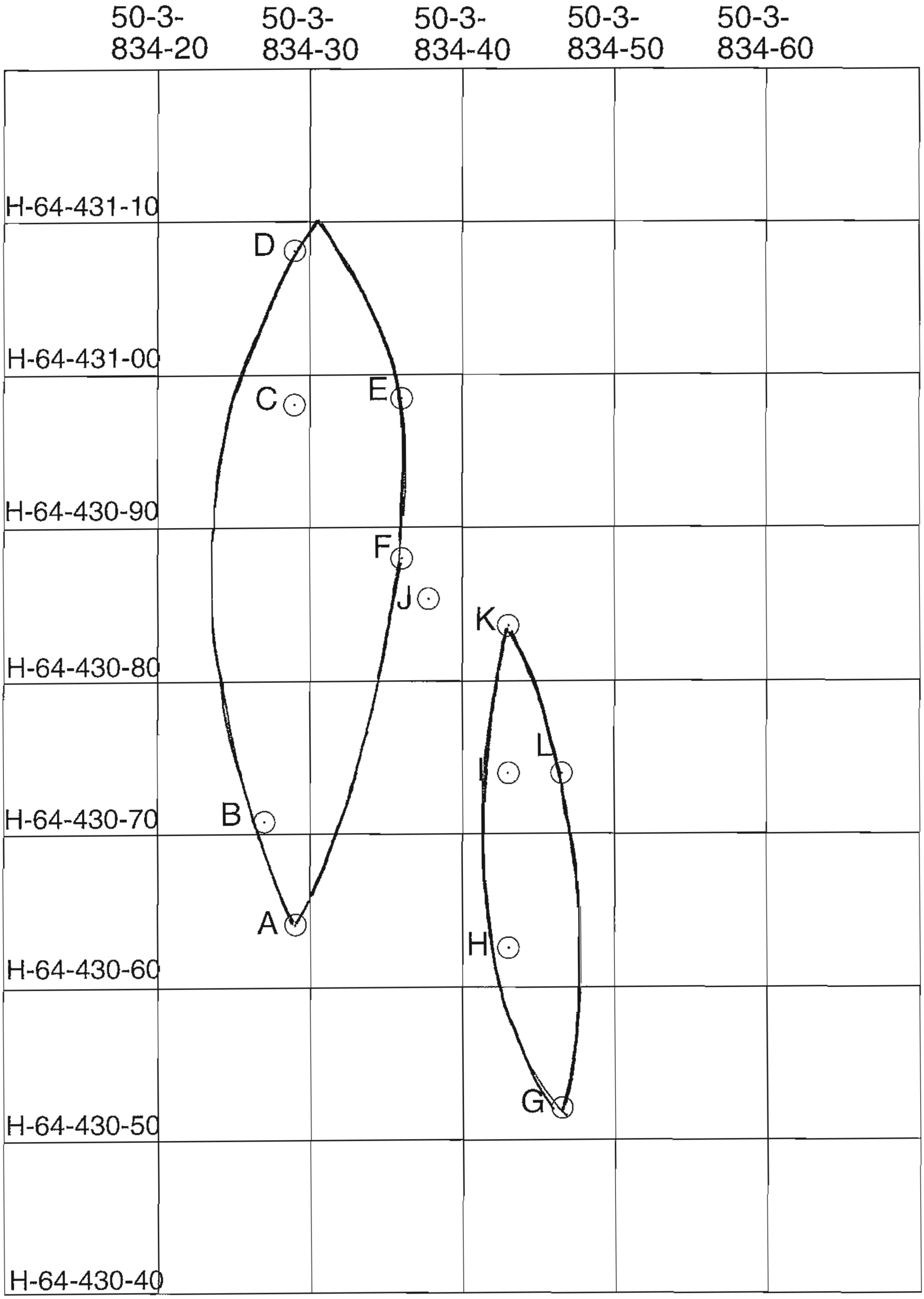


Figure 11. GPS POSITIONS DATUM AUS 66

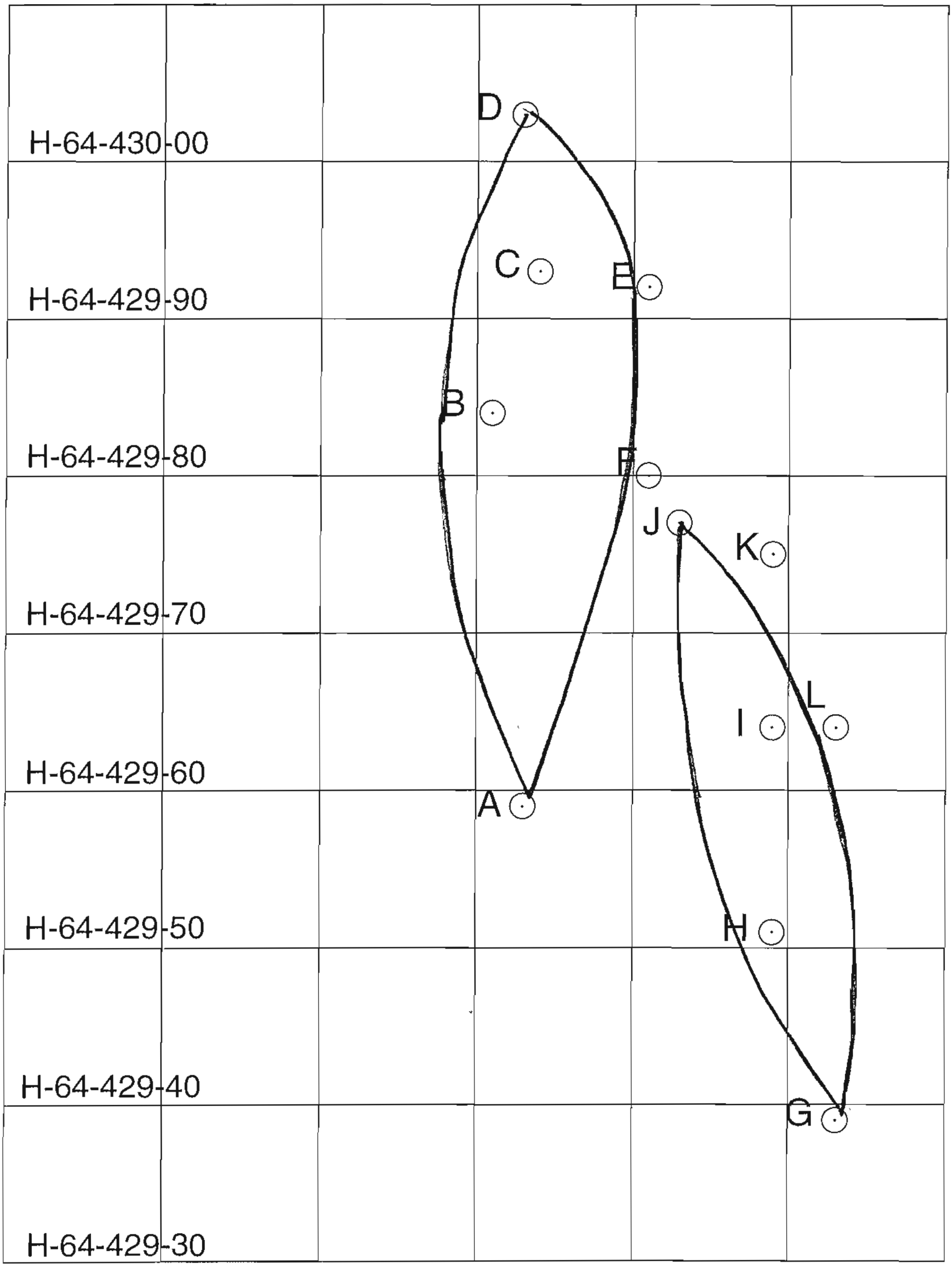


Figure 12. GPS POSITIONS

DATUM AUS 84

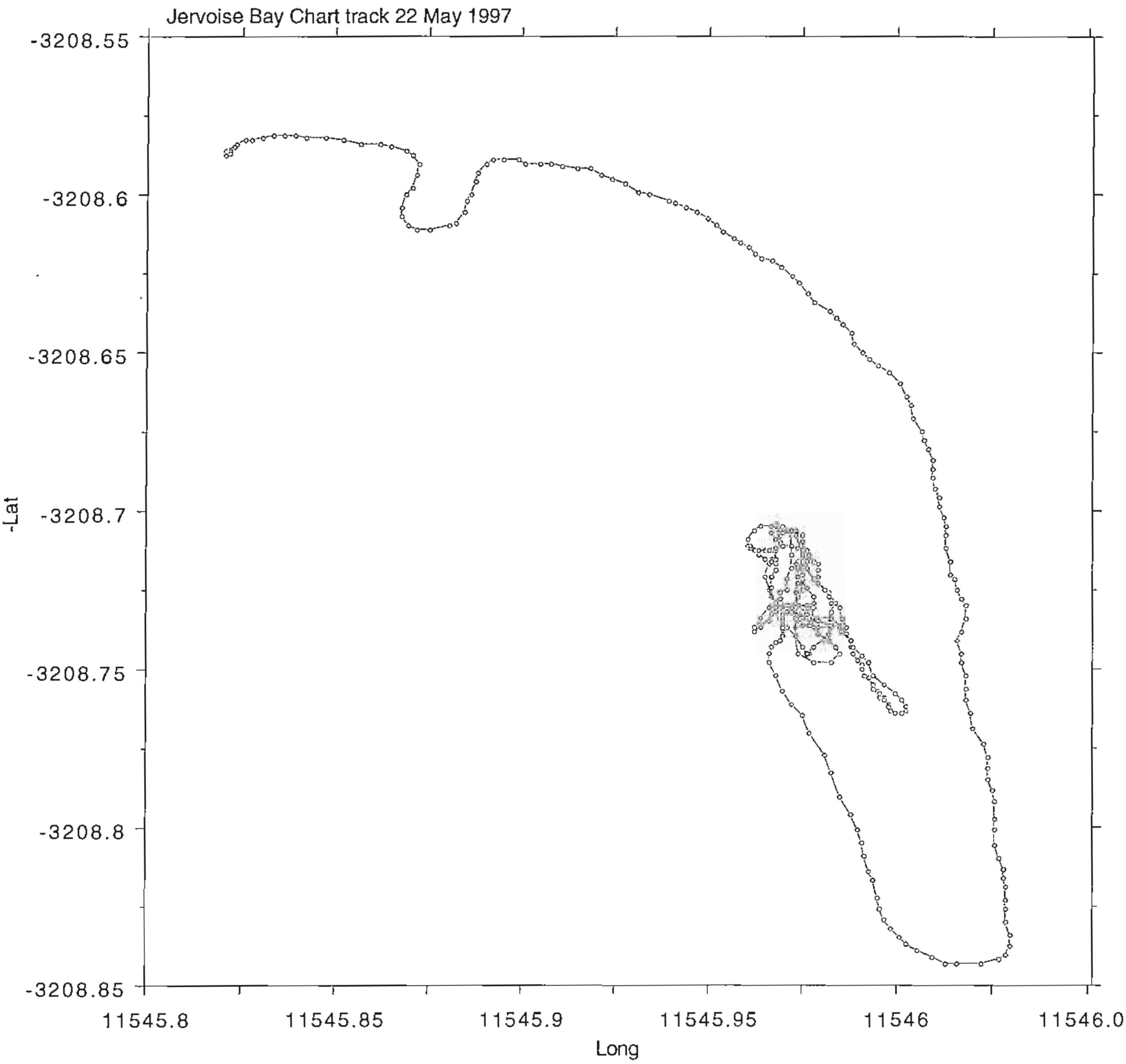


Figure 13. GPS Shoreline plot, May 1997.

4.1 Least Squares Data Report

Report on file E:\WEB\JERVFIN.RPT at time Fri May 23 18:36:59 1997

Datum Points
============

Name	Comments	X	Y	Z	Weight	N Meas	Residual
A	(Var.)	7.097	-7.479	0	1	5	0.138
B	(Var.)	17.337	-0.002	0	1	4	0.419
C	(Var.)	32.541	3.045	0	1	5	0.335
D	(Var.)	45.494	2.666	0	1	4	0.47
E	(Var.)	33.85	-0.569	0	1	7	0.488
F	(Var.)	19.188	-5.945	0	1	8	0.257
G	(Var.)	-2.773	-31.709	0	1	7	0.09
H	(Var.)	10.842	-22.884	0	1	6	0.097
I	(Var.)	18.245	-17.178	0	1	6	0.366
J	(Var.)	25.852	-12.26	0	1	7	0.267
K	(Var.)	21.511	-21.026	0	1	5	0.104
L	(Var.)	14.857	-26.192	0	1	4	0.027

Direct Distances
================

From	To	Dist.	Weight	Residual	Comments
A	B	12.55	1	0.129	
A	C	27.8	1	-0.265	
A	D	41.4	1	*-1.685	(Ignored)
A	E	27.7	1	-0.069	
A	F	12	1	0.188	
B	C	14.7	1	0.806	
B	D	29	1	-0.716	
B	E	16.5	1	0.023	
C	D	12.6	1	0.359	
C	E	3.8	1	0.044	
C	F	16.3	1	-0.203	
D	E	11.5	1	0.586	
D	F	27.9	1	-0.22	
E	F	14.7	1	0.917	
E	J	13.4	1	0.765	
G	H	16.2	1	0.025	
G	I	25.8	1	-0.248	
G	J	34.5	1	0.106	
G	K	26.5	1	0.03	
G	L	18.5	1	-0.027	
G	A	26.2	1	-0.037	
G	F	33.7	1	0.153	
H	I	9.6	1	-0.253	
H	J	18.3	1	0.089	
H	K	10.7	1	0.13	
H	L	5.2	1	0.003	
H	F	18.8	1	0.083	
I	J	8.6	1	0.458	
I	K	5.2	1	-0.153	
I	L	5.2	1	*** 4.43	(Ignored)
I	E	23.8	1	-1.011	
I	F	11.2	1	0.072	
J	K	9.6	1	0.181	
J	L	17.8	1	-0.052	
J	F	9.4	1	-0.219	
K	L	8.4	1	0.025	

Relative Depths
===============

Most Z	Least Z	(M-L)	Weight	Residual	Comments

Offsets
=======

From	To	Off	Along	Off	Weight	Res	Cmts

Name		X	Y	Z	Weight	N Meas	Residual	Comments
A	(Var.)	7.097	-7.479	0	1	5	0.138	
B	(Var.)	17.337	-0.002	0	1	4	0.419	
C	(Var.)	32.541	3.045	0	1	5	0.335	
D	(Var.)	45.494	2.666	0	1	4	0.47	
E	(Var.)	33.85	-0.569	0	1	7	0.488	
F	(Var.)	19.188	-5.945	0	1	8	0.257	
G	(Var.)	-2.773	-31.709	0	1	7	0.09	
H	(Var.)	10.842	-22.884	0	1	6	0.097	
I	(Var.)	18.245	-17.178	0	1	6	0.366	
J	(Var.)	25.852	-12.26	0	1	7	0.267	
K	(Var.)	21.511	-21.026	0	1	5	0.104	
L	(Var.)	14.857	-26.192	0	1	4	0.027	

Slopes
==============

From	To	Slope	Weight	Resid	Comments

Bearings
==============

From	To	Bearing	Weight	Resid	Comments

Statistics
==========

12 datums, (0 ignored)
36 direct distances, (2 ignored)
0 relative depths, (0 ignored)
0 offsets, (0 ignored)
0 slopes, (0 ignored)
0 bearings, (0 ignored)
Datums: Average absolute residual 0.255; Max average residual 0.488
Direct Distances: Max negative residual -1.011; Average absolute residual 0.254; Max positive residual 0.917

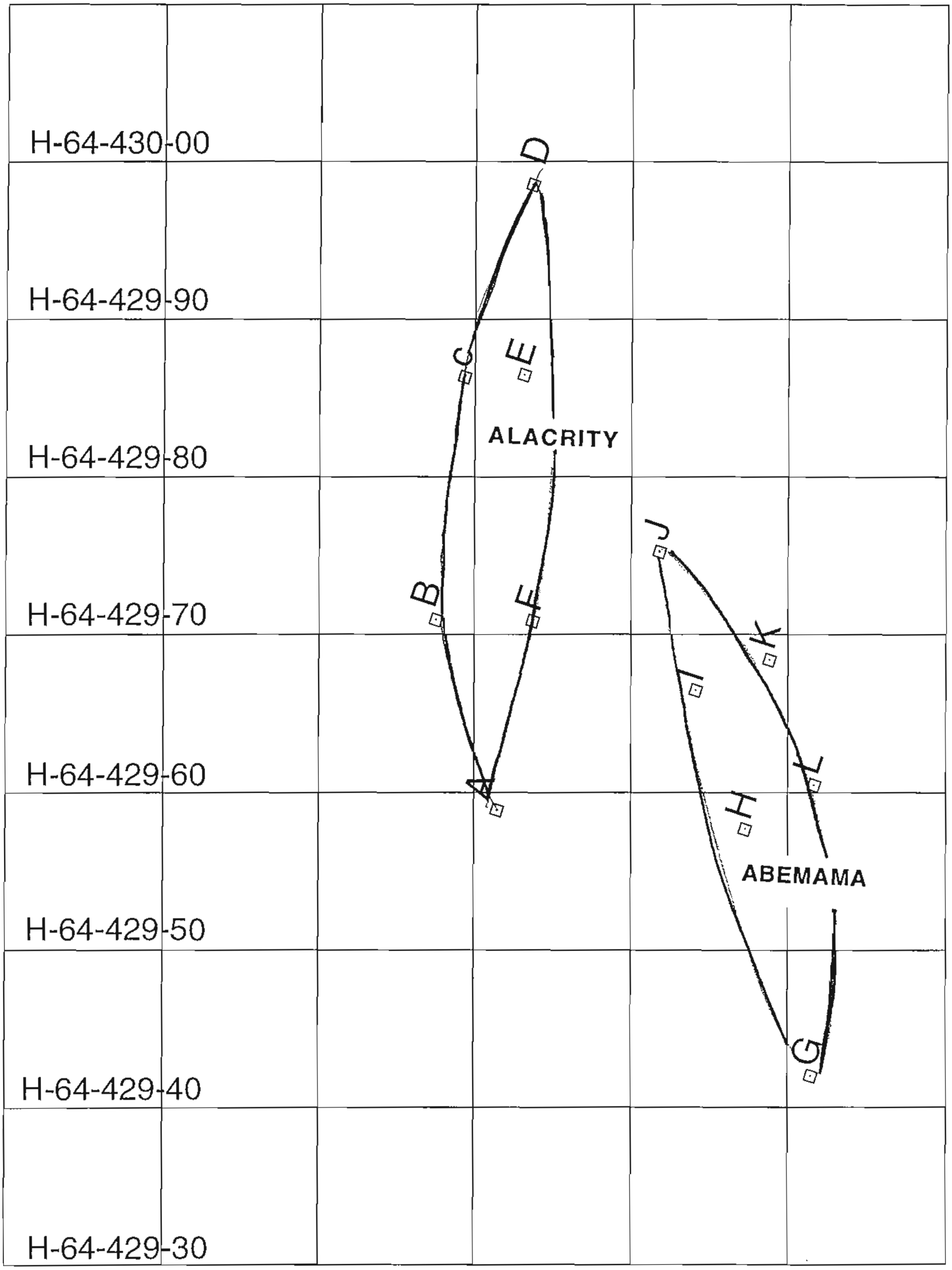


Figure 14. TAPE MEASURE SURVEY

DATUM AUS 84

4.2 Predisturbance Survey Data

Figure 15. Conservator taking corrosion measurements on the *Alacrity* hull plates. Photo: P. Baker, WAMM 1997.

Abemama Wrecksite - pH Profiles Jon Carpenter & Dena Garratt 22/5/97

After an over-swim of the wreck, timbers approximately midsite were selected for pH profiles and sampling. Five sets of readings were aquired, four from the seaward facing side of the vessel and one from the opposite side which faces the shore. Prior to recording the wood surface was gently cleaned to remove a light covering of sediment and marine growth. After the initial surface reading drilling was carried out progressing in 5 to 10 mm increments (approx). Actual drilled depths were accurately recorded using a micrometer. The depth to which the drill bit penetrated was determined by the hardness of the wood and the power of the drill (torque) in relation to the relatively large diameter drill bit (15 mm). It was found that the drill bit would tend to bind in the hole and stop the drill at a depth of 100 mm (approx). Following the aquisition of pH profiles a 40 mm diameter core sample of the wood was cut out alongside each of the drilled holes. Three larger wood samples were collected, one each from drilled sites on opposite sides of the wreck (drill sites 1 and 5) and from a baulk of timber (sample 6) located in the centre of the wreck which included a treenail. See diagram for location and position of recording/sampling.

General Information Seawater pH 8.10
Water Temperature 19-20 C

Drill Position 1 (Seaward)

pH	Drill Depth (mm)	Water Depth	Wood Core	Large Wood Sample
8.3	wood surface	2.7 m	Bag No 7	Bag No 4
7.34	2 mm			
8.00	3 mm			
6.39	5 mm			
6.79	10 mm			
6.20	20 mm			
6.26	25 mm			
6.94	27 mm			

wood too hard to drill

Drill Position 2 (Seaward)

pH	Drill Depth (mm)	Water Depth	Wood Core	Large Wood Sample
8.8	wood surface	3 m	Bag No 9	Non taken
7.41	9 mm (wood soft)			
7.33	13 mm			
7.14	20 mm			
6.47	34 mm			
6.30	45 mm			
6.15	52 mm			
5.77	57 mm			
5.40	65 mm			
5.41	68 mm			

Wood too hard to drill

Drill Position 3 (Seaward)

pH	Drill Depth (mm)	Water Depth	Wood Core	Large Wood Sample
8.7	wood surface	3.2 m	Bag No 8	Non taken
8.7	2 mm			
7.63	9 mm (pale wood colour)			
7.36	25 mm (dark wood colour)			
7.42	32 mm			
7.15	42 mm			
7.06	51 mm			
7.20	62 mm			
8.06	115 mm (wood thickness)			

Drill Position 4 (Seaward)

pH	Drill Depth (mm)	Water Depth	Wood Core	Large Wood Sample
8.11	wood surface	2.8 m	Bag No 10	Non taken
7.60	6 mm			
6.53	8 mm			
6.35	20 mm			
6.39	31 mm			
6.44	42 mm			
6.31	53 mm			
6.44	67 mm			
6.40	80 mm			
6.27	88 mm (Drill Binding)			

Drill Position 5 (Shoreward)

pH	Drill Depth (mm)	Water Depth	Wood Core	Large Wood Sample
8.11	wood surface	2.5 m	Bag No 5	Bag No 6
7.92	5 mm			
6.78	5 mm			
6.82	6 mm			
6.72	15 mm			
6.59	25 mm			
6.63	34 mm			
6.61	48 mm			
6.64	58 mm			
6.70	65 mm			
6.73	72 mm			
6.76	83 mm			
6.77	94 mm (Drill Binding)			

Alacrity Wrecksite - pH and Corrosion Potential Measurements
Jon Carpenter & Dena Garratt 21/5/97

Eight pH and corrosion potential measurements were aquired. Four from the iron hull plates, near the stern post, which were drilled in upper and lower positions on the seaward and shoreward facing sides of the vessel. Two measurements one from either side of the hull mid site (approx). One measurement on a large iron shaft (prop shaft?)in the middle of the vessel lying (approx) between the latter two measurements positions. The final measurement was aquired from collapsed hull plating lying across the bow end of the vessel. Prior to drilling marine growth was stripped away from the concreted iron surface with a knife blade. In hindsight a smaller masonary drill bit should have been used to drill the relatively thin concretion layer (max 8 mm) as the optimum measurable closed volume of seawater was not attained for recording pH. The variance in the pH readings may reflect this.

General Information

Seawater pH 8.05
Water Temperature 19-20 C

Location	pH	Ecorr	Concretion mm	Water Depth
Shoreward Lower Stern	7.35	-564	8 mm	2.6 m
Shoreward Upper Stern	7.02	-565	8 mm	0.9 m
Seaward Lower Stern	5.77	-566	8 mm	2.5 m
Seaward Upper Stern	6.83	-567	6 mm	1.3 m
Seaward Mid Site	7.83	-573	2 mm	2.3 m
Middle Site	7.38	-568	4 mm	2 m
Shoreward Mid Site	5.45	-568	6 mm	2 m
Bow	5.24	-570	8 mm	3.6

A:\ALACABEM.DOC

Sediment Samples

Location	Bag No	pH	Ecorr	Water Depth
Alacrity				
Bow	23,25,32,48	7.80	-257	3.7 m
Bow (dredged)	8,9,10,11	Not aquired		3.7 m (low tide)
Midships	21,26,41	Not aquired		2.2 m
Stern	4,33,38,41	8.08	-210	3.3 m
Abemama				
Bow	18,30,34,37	7.99	-210	3.1 m
Stern	27,27,35,46	7.78	-224	3 m
Between Alacrity/Abemama				
	22,29,45,50	8.19	-231	2.9 m
Off Site				
	1,2,3,7	Not aquired		

5.0 EXCAVATION TEST TRENCHES AND SURVEY

Figure 16. Diver recording excavation data. Photo: P. Baker, WAMM 1997.

5.1 Excavation Results

Test trenches were excavated at the *Alacrity* site to determine the depth and type of wreckage beneath the sand. *Abemama* had been adequately investigated on previous occasion and the depth of the remains had been established, for example, the Class of 1981, *Abemama* excavation report, WA Maritime Museum, WA Maritime Museum file No. MA 4.81.

The depth of excavation of Trench 1 at the *Alacrity* was approximately 0.5 metres. The excavation revealed that wreckage lies buried for a distance of approximately one metre from the northernmost extremity of the bow and consists of iron ribs and hull plating. Dredging midships was not considered necessary as only a thin layer of sediment, approximately two centimetres deep, lay over the hull remains, consisting of iron frames and hull plating. The excavation at the bow revealed an intrusion of lighter coloured sand into the darker sediment which suggests some mobility of sand at this location in the recent past. This may be attributed to sand scouring which occurs in medium to heavy seas.

The wreckage in Trench 2 was buried 1.5m below the seabed. The detritus primarily consists of small pieces of ironwork, ranging in size from 2 cm to 20 cm in diameter, possibly corroded bulkheads or hull plating. In this area of the wreck most of the hull beyond the turn of the bilge has collapsed.

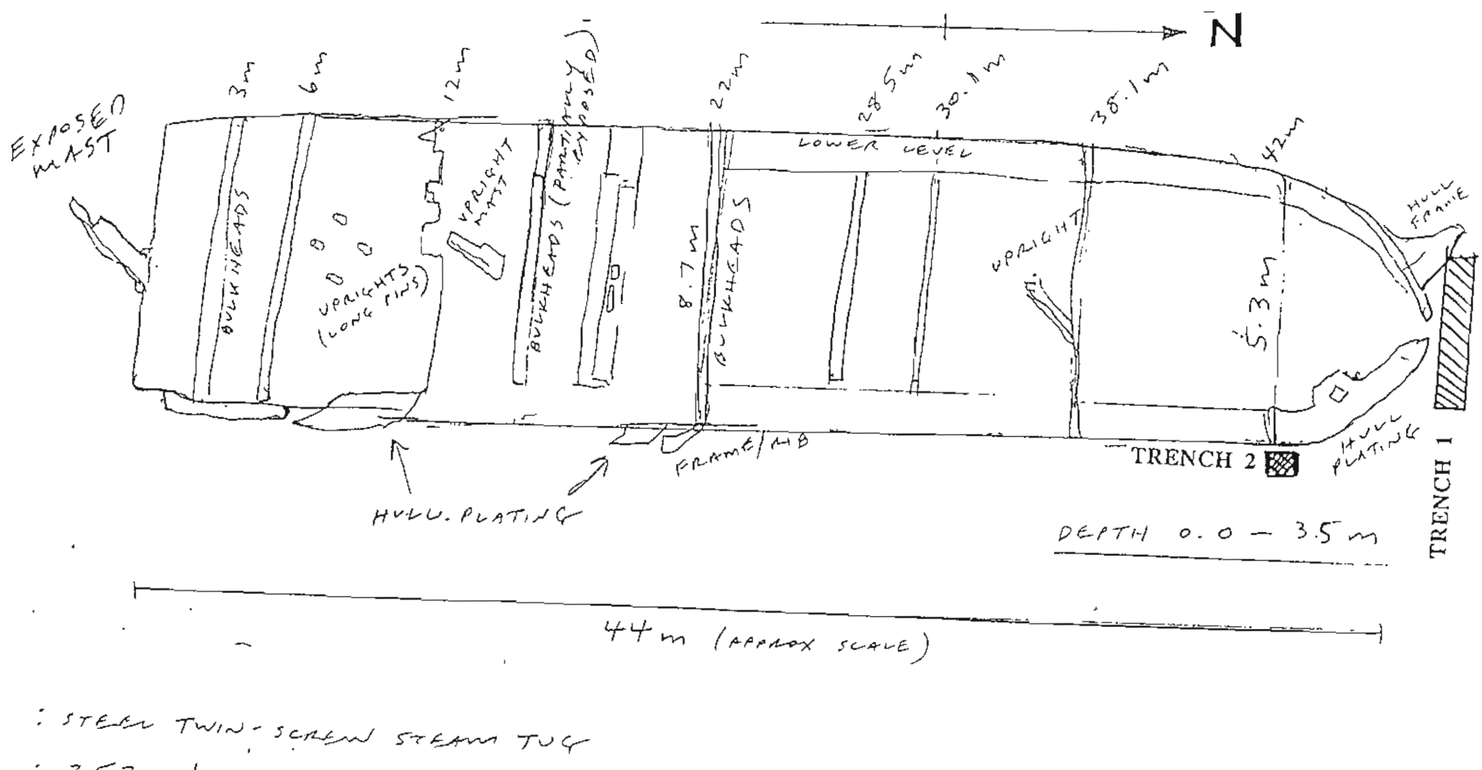


Figure 17. Field sketch plan of SS *Alacrity* showing the position of the test trenches. S. Souter, WAMM 1997.

6.0 DEPTH SOUNDINGS

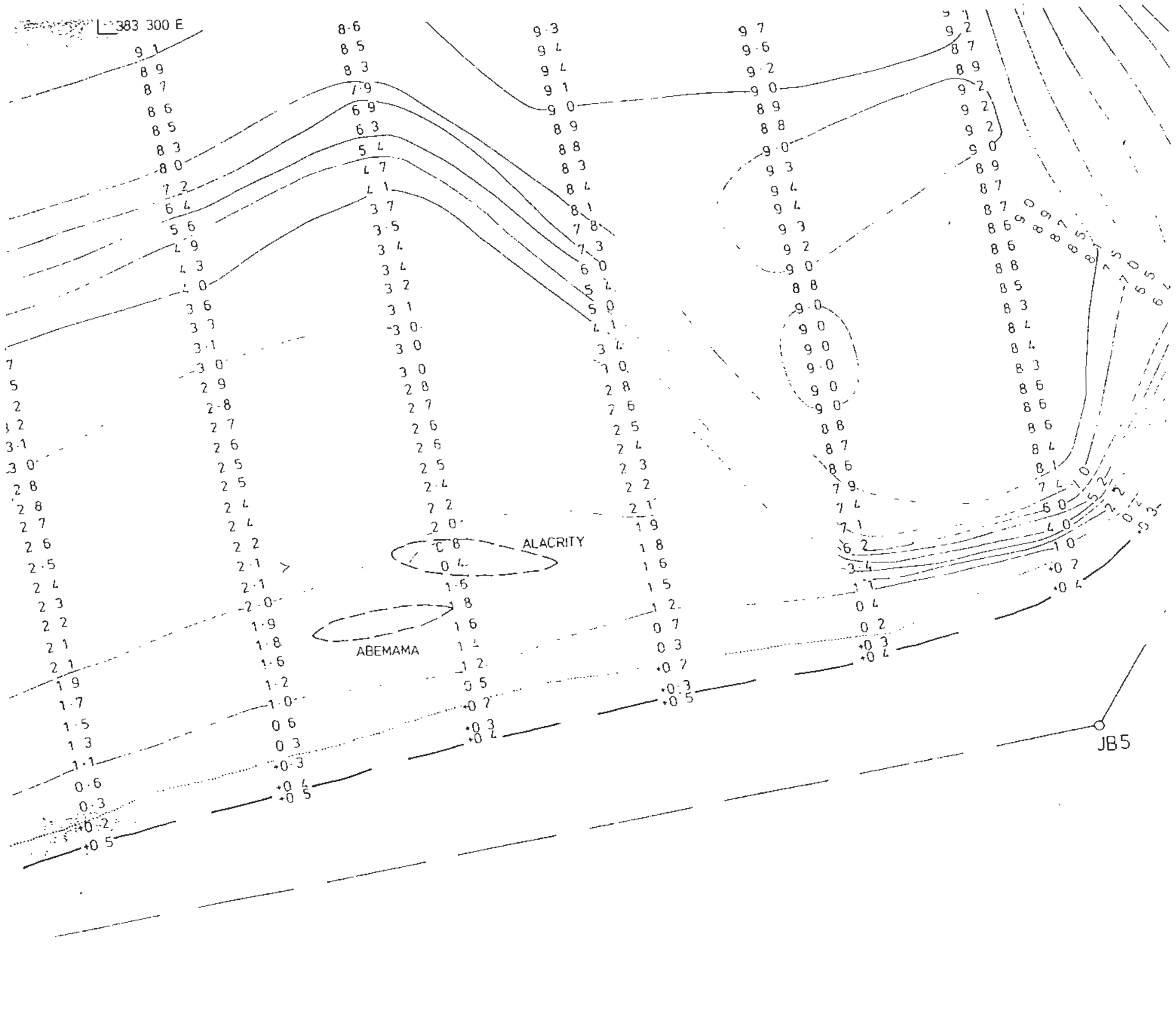


Figure 18. Public Works Department. Depth Soundings, Jervoise Bay, 1980, showing the depths after the dredging.
See results for 1997 over.

JERVOISE BAY DEPTH SOUNDINGS. 22 May 1997

Datum: International Shipyards, Jervoise Bay.
Survey run commenced 1138 1.90m
Survey run completed 1208 1.92m

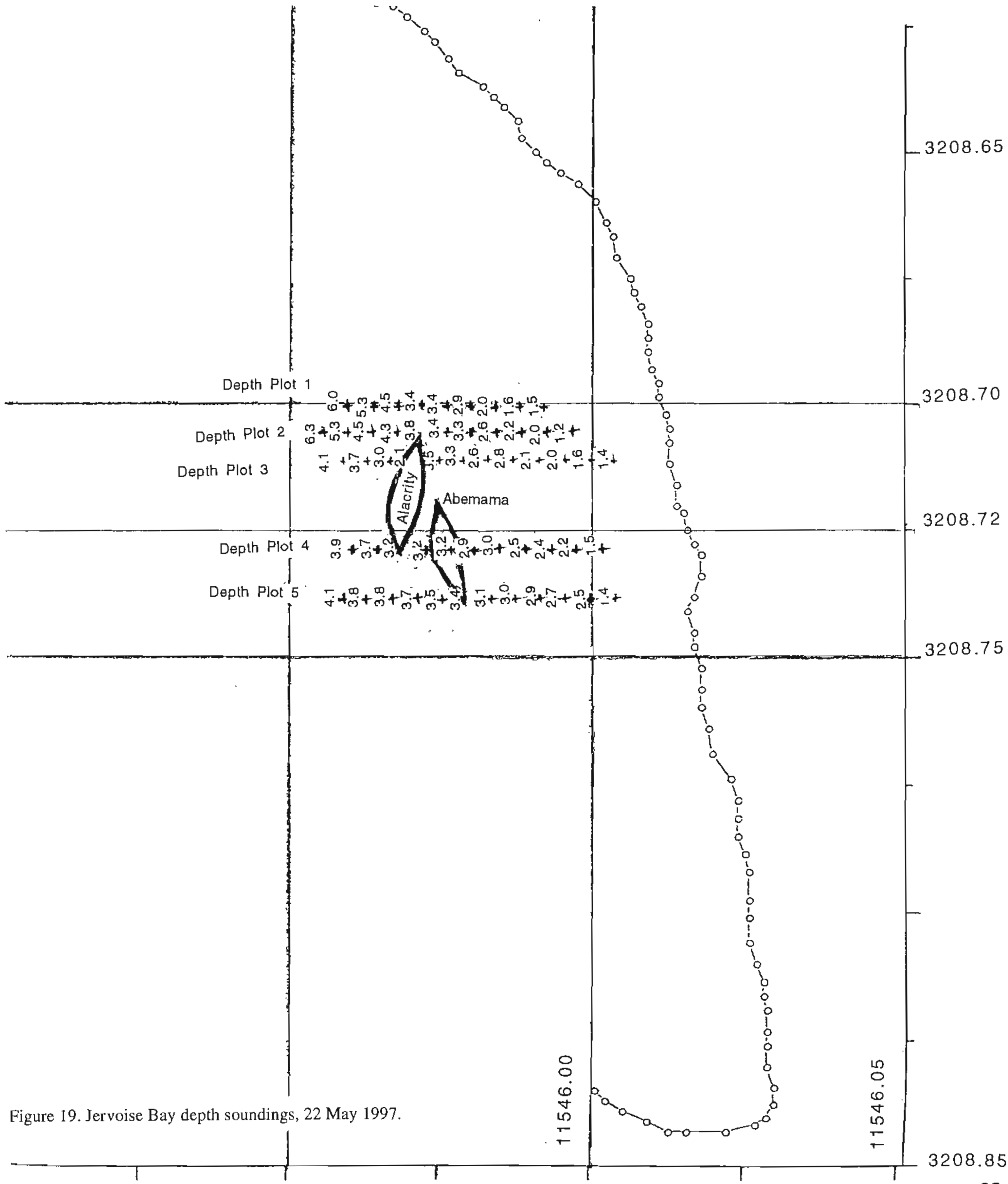


Figure 19. Jervoise Bay depth soundings, 22 May 1997.

7.0 SHORELINE MODIFICATIONS AFFECTING THE POSITIONS OF THE *ABEMAMA* AND *ALACRITY*

The natural coastal processes and the shoreline modifications which have influenced the positioning of the *Alacrity* and *Abemama* on the sea bed can be understood using several techniques.

- analysis of aerial photographs
- review of published charts and surveys
- review of Public Works Department shoreline movement plans
- review of wreck inspections
- sediment movement modelling

7.1 Analysis of Aerial Photographs

The series of aerial photographs dating from 1959 to 1980 demonstrate clearly, the profound effect of the dredging undertaken for the launching of the oil rig *Ocean Endeavour*. The shoreline has receded significantly and this is demonstrated in the aerial photographs compared in the following illustration, (Figure 20) which shows the outline of the shore in 1959, 1975 and 1980 respectively. Photos reviewed; WA 578, WA 604, WA 673, WA 1593.

7.2 Review of Published Charts and Surveys

Charts referred to include; Department of Transport, WA 001; AUS. 117, PWD WA Charts; Orthophoto Map Perth 5000 BG 34/03.0ZE; Australia 1: 25 000 Topographic Survey. Fremantle SW, Sheet 2033-1 SW (Edition 1), Series R 811, 1976. The comments in 7.1. are reflected in this data.

7.3 Coastline Movements

The Public Works Department have prepared shoreline movement plans based on historical aerial photographs and periodic depth soundings. Chart Nos. are; PWDWA 51173-5-1, PWDWA 51173-4-1, PWDWA 5248-2-2. These measure shoreline erosion/accretion patterns along the coastline from Fremantle to Cape Peron taking in Jervoise Bay from 1942 to 1976. They include impact such as dredging of the channel for the launching of the *Ocean Endeavour.*

7.4 Review of Wreck Inspections

There have been four major maritime archaeological inspections of the *Abemama* and *Alacrity* wreck site undertaken by the Department of Maritime Archaeology, WA Maritime Museum,
1978, M. McCarthy
1980, Class of 1980, P. Clarke
1982, Class of 1982, S. Cushnahan
1990, Class of 1990, Post Graduate Diploma in Maritime Archaeology
1996, Class of 1996, Post Graduate Diploma in Maritime Archaeology

From a review of the reports above, it has been established that in the intervening sixteen years the wrecks have remained in the same position, relative to one another, ie. the angles and distance between the wrecks have remained constant, while the shoreline and depths have changed markedly.

7.5 Sediment Movement

A survey involving the numerical modelling of swell waves was undertaken by Lawson and Treloar (1987) in Owen Anchorage to investigate how waves affect sediment movement. Numerical modelling estimates the weighted mean average of the swell wave height and direction at the shoreline. The results indicated that swell waves tend to move sediment form north to south.

The direction of locally generated seas vary throughout the year however, their dominant direction is from the southwest resulting in a south to north sediment movement. (Port Catherine Harbour Development, WA Maritime Museum file: MA 10.80)

Jervoise Bay is well protected from northwest storm conditions but is subject to strong seasonal south westerly conditions.

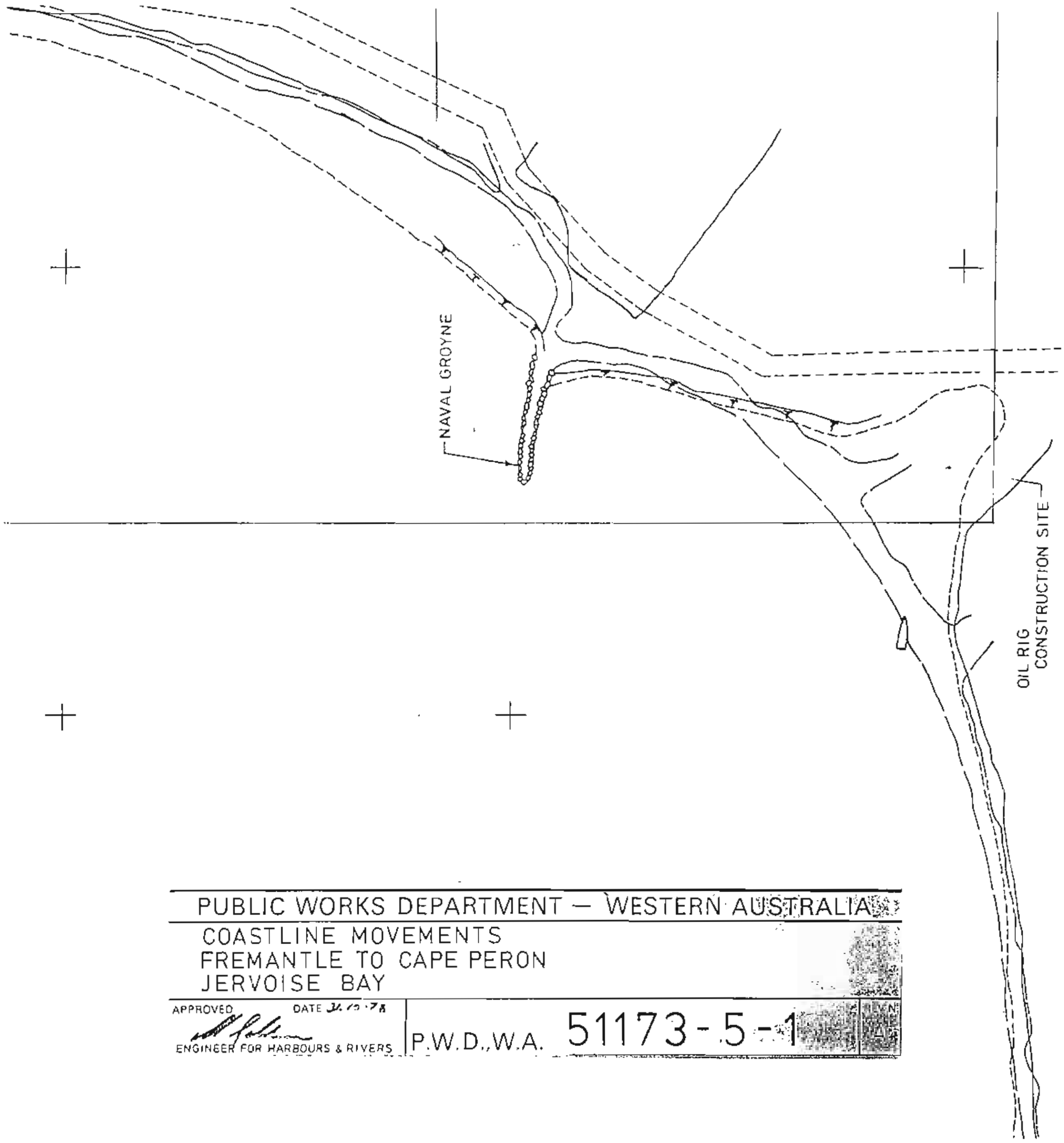
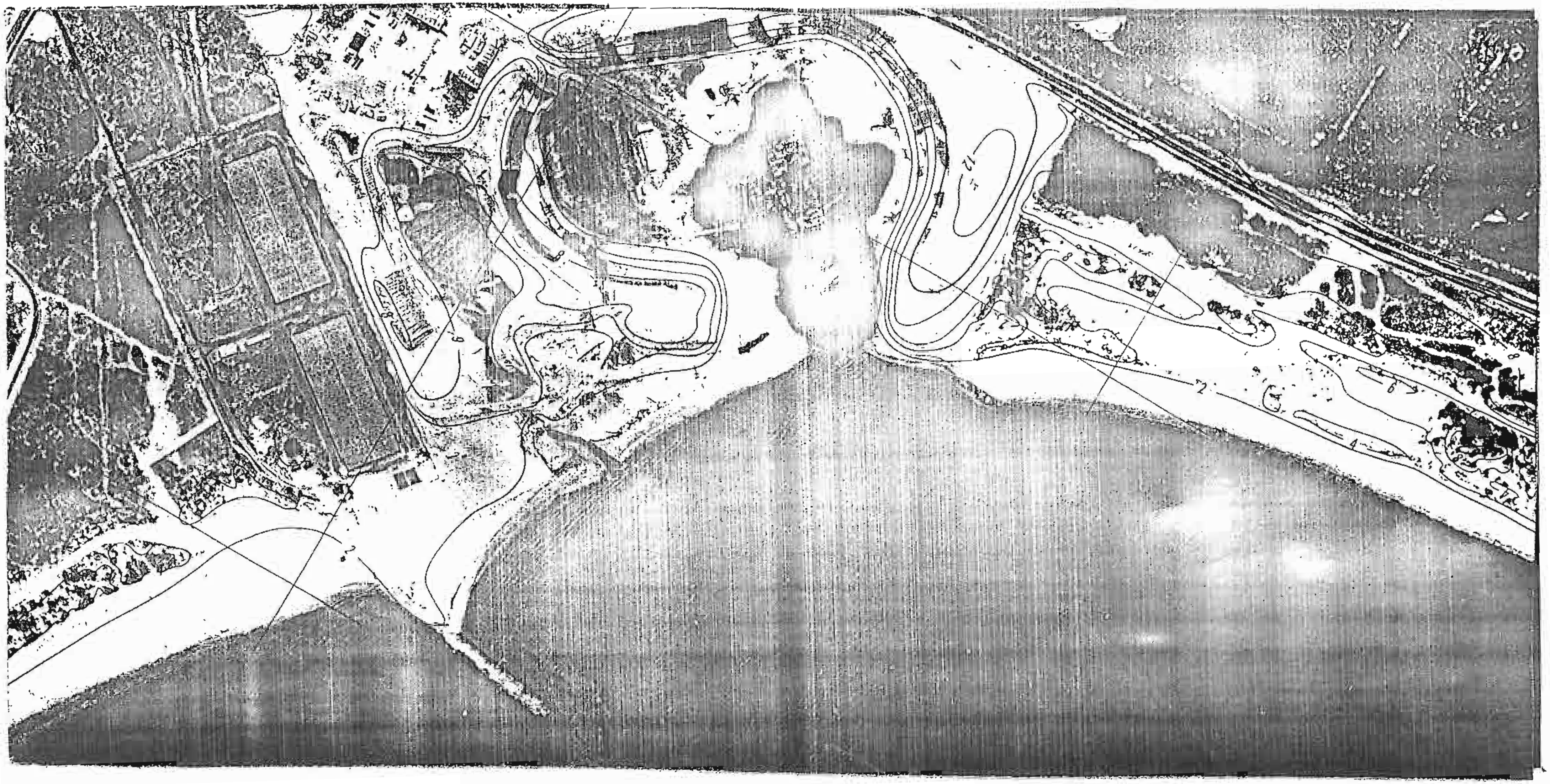


Figure 20. Public Works Department, Coastline Movements. Fremantle to Cape Peron, Jervoise Bay, 1976.

Explanation of Overlays

Figures 21, Jervoise Bay, 1975, showing the shore line immediately before and after the opening of the Ocean Endeavour pond. Note the erosion of sand on the port side of the *Alacrity*.
22

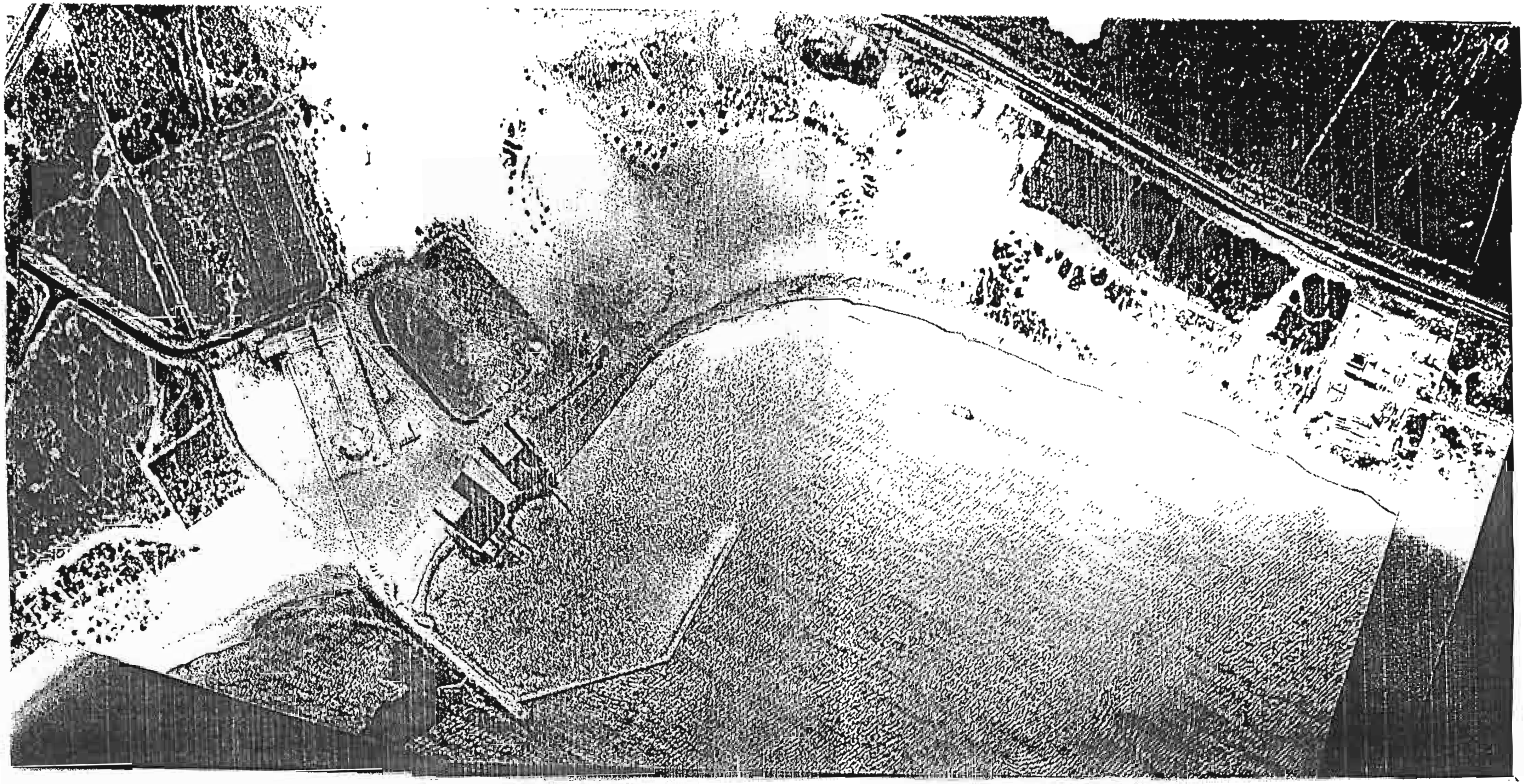


JERVOISE BAY 1975

Figure 21. Jervoise Bay, 1959 and 1975, showing the shore line immediately before and after the opening of the *Ocean Endeavour* pond.

JERVOISE BAY 1959

JERVOISE BAY 1975

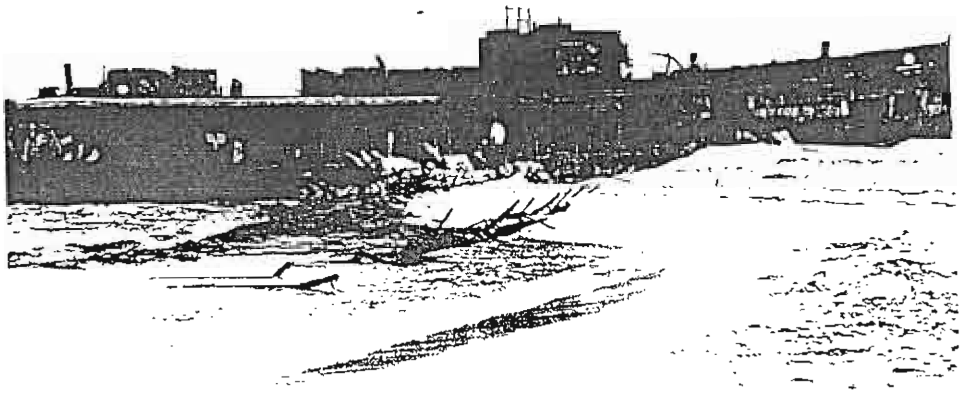


JERVOISE BAY 1980

Figure 22. Jervoise Bay, 1959 and 1980, showing the extent of beach erosion around the *Alacrity* and *Abemama*. Note that the *Ocean Endeavour* pond has completely silted up.

JERVOISE BAY 1959

JERVOISE BAY 1980



[1]It is useful to note at this juncture that wrecks can move, even after many years. The evidence appears above in the case of the *Abemama*.

Figure 23. The iron-hulled SS *Alacrity* in the process of disintergration over a period of about twenty years up to around 1975. The *Abemama* can be seen inshore on the aft quarter of *Alacrity*. The uncovering of the two sites is due to dredging nearby. Note the varying angles of the *Abemama* hull to the *Alacrity*.
Photos: D. Gilroy and D. Robinson, (from M. McCarthy, 1996.)

8.0 SITE STABILITY

Archival information and the survey by McCarthy (1978), clearly indicate that at some time before the 1978 study, the *Abemama* changed its orientation to the shoreline and to the *Alacrity*. This phenomenon has been recorded on many occasions. In the case of the *Alex T Brown*, a four-masted schooner beached at Yanchep in 1917, for example, Museum records indicate that the wreck moved after storm surges have caused extensive beach erosion, (WAMM File No. 215.80).

The wrecks have however, remained stable in relation to the shore and each other since the WA Maritime Museum survey in 1978. From the analysis of aerial photographs it appears that they have not changed position since the launch of the oil rig *Ocean Endeavour* in 1975 and the ensuing shoreline modifications. The site is however, subject to constant wave and surge action which contributes to the gradual deterioration of both wrecks. The wrecks are stable in terms of their position on the seabed.

8.1 *Alacrity*

The structural integrity of the *Alacrity* appears to have remained constant over periodic inspections since 1978, although in this inspection it was noted that the hull remains have generally weakened. Visual inspection indicates that the upright sections of the wreck that are subject to the forces of wave action and surge are structurally unsound. In particular, the stanchions, frames, bulkheads and hull plates appear severely corroded.

8.2 *Abemama*

The *Abemama* site is a low profile site with the majority of the wreckage standing a metre or less above the seabed. The site is periodically covered with weed which offers some protection form wave action. The structural integrity of the site appears to have not markedly changed over the series of inspections since 1978.

9.0 WRECK PRESERVATION OPTIONS

In the analysis of instances of wreck preservation there are several options available;

Option 1: Burial in a land-backed facility
Option 2: Re-position
Option 3: Incorporation into a Jetty

Two of these options i.e. burial and relocation have been used in specific case examples such as the *Day Dawn* which was sunk below the harbour datum at Careening Bay (HMAS Stirling) and then later relocated (McCarthy, 1980 ; Erskine *et al.*, 1996). Burial has also occurred in the case of the American whalers which were wrecked at Koombana Bay, Bunbury (McCarthy, 1982). The *August Tellefson* (1898) is an instance where the jetty on which it was impaled was reconstructed to pass completely through the vessel, (Henderson 1995:287).

9.1 Option 1: Burial

The most effective means of assuring the long term protection of the *Alacrity* and *Abemama* is entombment in a mechanically and biologically stable, dry, anaerobic environment.
In this case, infilling the wrecks and forming a land-backed wharf is the preferred course of action. There is one noted precedent for this, a Marina development in Coogee that was proposed in 1991 for example. Among the options discussed in this case, was infilling the wreck of the *Omeo* (1894) as part of the land reclamation works. It presented the same location problems as that of the *Alacrity* and *Abemama*.
Conservation research scientist, Ms Vicki Richards (1990) reported on the Conservation Ramifications of the *Omeo* Site Development. This paper investigated the effects of infilling this composite wreck site and the expected type of degradation that may occur. These factors can also be applied to the infill consideration of the *Alacrity* and *Abemama* wrecks. The landfill option would reduce the availability of oxygen and halt water movement. These are two of the main factors which influence the rate and mechanism of corrosion on the *Alacrity* site. Wood structural remains of the *Abemama* would be protected from continued physical and biological degradation. For example, the site would be protected from wood borers as they are restricted to the intertidal zones, above the sediment line and require oxygen.
It must be noted that taking the wrecks out of their present context by infilling with sand and sediment will not decrease the deterioration and it will change the mechanism of degradation. Under these anoxic conditions anaerobic bacteria will be dominant. In terms of deterioration sulphate reducing bacteria are the most important component of anaerobic biota. Normally the absence of oxygen would slow the corrosion process. However the catalysing action of the sulphate reducing bacteria and formation of acids will increase the corrosion of the metal in its buried state. The resulting corrosion rates can be significantly higher than those in similar environments with minimal bacteria. Richards argues that bio-deterioration of the metal components in land fill areas may be enhanced by anoxic bacteria but if the biological activity is lowered by reducing the availability of a food source, such as the timbers, the rate of degradation could be dramatically decreased. There are however, other variables that must also be considered.
Factors influencing the stability of proposed burial of the site include, particle size, degree of compaction and water content of the landfill material. The burial of the site will eventually create a state where, in chemical terms, the wrecks reach a dynamic equilibrium with the surrounding micro-environment and corrosion essentially ceases. It also provides protection against destruction by physical processes, such as water movement, biological attack and human interference.

Wrecks of the American whalers lost at Bunbury in the early 1840's demonstrate the effects of burial in sand. The extension of a breakwater at Casuarina Point and harbour works undertaken around the turn of the century, caused beachfront accretion in the head of the bay and the erosion of the beach to the north. The main result of these shoreline changes has been to leave those vessels previously wrecked on the beach near the estuary mouth, now quite some distance inland and under several metres of sand. These American whalers were rediscovered in the course of mining activity in the 1960's. Three vessels lie within a short distance of each other and are in an good state of preservation.

In another example, the wreck of the *Twilight* (1869) lies partly buried in sand some distance inland from the shoreline at Twilight cove near Eucla. It was also found to be well preserved when investigated by former Museum Conservator, Neil North in 1977, (Henderson 1988:226).

9.2 Option 2: Re-position

From past experience, it is clear that the task of re-positioning or moving shipwrecks can prove difficult, both logistically and financially and can alter or damage the vessel's structural remains. The wooden barque, *Day Dawn* (1886) was moved in Careening Bay for example (McCarthy 1980). Approximately 20% of the hull structure was lost after relocation. The wreck's new position did not offer the same environmental conditions and work had to be carried out in later years to stabilise the wreck site. The North Mole barge was successfully relocated in Fremantle, using the but this was only made possible due to the intact form of the vessel's iron hull (Class of 1996).

9.3 Option 3: Incorporation into Jetty

Another option is to incorporate both wrecks into a jetty structure.

This alternative would leave the wrecks of the *Abemama* and *Alacrity* accessible and afford them some protection with the construction of a jetty around them. The effects of propeller wash on both sites from vessels berthing at this new jetty may accelerate the rate of degradation of both wrecks, however. In the case of the Albany Town Jetty, the propellers from nineteenth century steamships and later modern vessels caused a mixing of both artefactual and biological material in the sediment on either side of the jetty, (Garratt, McCarthy, *et al.* 1995). Scour pits not only disturb but can destroy a shipwreck and in artefactual assemblage on the seafloor. Also, the sites, although visible, would not be accessible to the public as they will be unsuitable for recreation. Therefore, there is little to be gained from an educational or recreational stand point by pursuing this option.

10.0 RECOMMENDATIONS

The incorporation the *Abemama* and *Alacrity* wreck sites into a landbacked wharf would ensure the preservation of these sites for the future, providing that the process did not cause damage to the fabric of the wrecks and that nothing of a permanent nature is built over the site. There is potential for physical damage to occur during the burial process, therefore careful choice and even distribution of fill material is advised. Once buried, the location of the shipwrecks should be accurately recorded and properly marked with an interpretive plaque. Monitoring of the sites could be facilitated by the installation of sand filled well liners. These would give access to a portion of the site and provide an inspection ports for future research.

CATALOGUE OF PICTORIAL MATERIALS

ABEMAMA

Black and white photographs (Listed in Department of Maritime Archaeology PINDEX)

Title	Film Nos.
Illustrations	891-896
Photomosaic	891-895
Plans & drawings	899, 1321, 1329, 1675-1681
Student UW photos	1329-1331

Transparencies (64 listed in Department of Maritime Archaeology SLIDE PHOTO INDEX)

Title	Slide Nos.
Underwater	AB/ 1-36, 38 & 39, 42-55 (1981)
Historical	AB/ 37, 40
Drawings	AB/ 56 & 57
Location Map	AB/ 58 (Showing *Abemama* and *Alacrity*)
Site Plans	AB/ 59-64

See also; *Alacrity* Slide Nos. 36-38 (Duplicates from D. Robinson, 1972, 1975, 1977 respectively).

Photomosaic
Abemama bow section. M. Staniforth, S. Cushnahan, N. Clarke, 198

Site plans
Abemama Site Plan. Mid-section. (Scale 1:10). K. Moon, J. Worsley.
Abemama Plan 0 to 12 metre section.
Abemama Plan 12 to 35 metre section.
Abemama Port Side Stern. (Scale 1:20). S. Lester.

Ship's Plans
Abemama Bow and Formast
Abemama Broadside (Scale 1": 114.77")

SS *ALACRITY*

Black and white photographs (Listed in Department of Maritime Archaeology PINDEX)

Title	Film Nos.
	696, 868, 897, 967, 906, 986, 4263, 5151

Transparencies (42 listed in Department of Maritime Archaeology SLIDE PHOTO INDEX)

Title	Slide Nos.
Underwater	ACY/ 5 & 6, 8-34
Historical	ACY/ 41, 42, (Duplicate of AB/ 37)
Drawings	ACY/ 39 & 40
Above water	ACY/ 4, 7, 36-38 (Duplicates from D. Robinson, 1972, 1975, 1977 respectively).

Artefact Drawings
Alacrity fittings

JERVOISE BAY

Transparencies (8 listed in Department of Maritime Archaeology SLIDE PHOTO INDEX)

Title	Slide Nos.
Location Maps	JB/A/ 11, 12
	JB/D/ 1 (Duplicate of JB/A/ 11)
	JB/D/ 2 (Duplicate of AB/ 58)
Drawings	JB/D/ 5 (Duplicate of ACY/ 40)
Site Plans	JB/D/ 11 (Duplicate of AB/ 59)
	JB/D/ 12 (Duplicate of AB/ 62)
	JB/D/ 13 (Duplicate of AB/ 63)

Aerial Photographs

WA 578 Trigg to Bunbury. Scale 1: 15840, 8.11.1959.
WA 604 Trigg to Bunbury. Scale 1: 15840, 4.3.1960.
WA 673 Trigg to Bunbury. Scale 1: 15840, 26.10.1960.
WA 1593 Coast Run - Kalbarri to Israelite Bay. Scale 1: 15000, 6.11.1975.
Photo Nos. 5080, 5081, 5097, 5098.
Photo Nos. 5018, 5026, 5027, 5028, 5039, 5041, 5167, 5178, 5186, 5202, 5205, 5269, 5351, 5486.

Video

Video Film No. MA 192. Copied from original 8mm film shot between 1945 and 1947 and donated to the Maritime Museum by Mr M. Edgar. Shows the relative states of preservation of the *Abemama* and *Alacrity* and the proximity and orientation of the wrecks to one another. Also includes the submarine *K VIII*.

Video Film No MA 144. Above water, Jervoise Bay and *Abemama* and *Alacrity*. 21 May 1997. 1:00:30–1:12:20.

Video Film No. MA 251. Underwater, Jervoise Bay and *Abemama* and *Alacrity*. 21 May 1997. 29.48 – 47.46.

Maps and Charts

Abemama wreck site location map.
Scale 1:40. A.M.G. interval in metres. Compiled from field survey and aerial photography by P. Clark, May 1981.

AUS 117 Australia - West Coast, Gage Roads and Cockburn Sound, 1997. (Scale 1: 25000).

Australia 1: 25 000 Topographic Survey. Fremantle SW, Sheet 2033-1 SW (Edition 1), Series R 811 1976.

Lands and Surveys (Dept. of) *Orthophoto Map*. Perth 5000 BG 34/03.0ZE. (Scale 1:5000).
Australian Map Grid Interval 500 metres. Contour Interval 2 metres from Australian Height Datum. February 11, 1975.

PWDWA 51173 - 4 - 1 *Coastline Movements. Fremantle to Cape Peron, Woodman Point,* October 1978. Scale 1:5000.
Photography used in plots: Coast run WA 1648 (Scale 1:15000) November 1976. Fremantle runs 6 & 7. (Scale 1:14550) January 1942.

PWDWA 51173 - 5 - 1 *Coastline Movements. Fremantle to Cape Peron, Woodman Point,* October 1978. Scale 1:5000.
Photography used in plots: *Coast Run* WA 1648 (Scale 1:15000) November 1976.
Fremantle runs 7 & 8. (Scale 1:14550) January 1942.

PWDWA 5248 - 2 - 2 Jervoise Bay/Woodman Point Planning Study. Soundings, February 1980. Scale 1:1000.

WA 001 Australia - West Coast. Ocean Reef to Cape Peron. 1995. (Edition No. 8),
(Scale 1: 75000).

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Day Book Jervoise Bay Project - *Abemama/Alacrity*. May 1997
MA 4.81 (Wreck) *Abemama*
MA 215.80 (Wreck(*Alex T Brown*
MA 8.87 (Wreck) *August Telefson*
MA 9.86 (Area) Cockburn Sound Wrecks
MA 10.78 (Area) Jervoise Bay
MA 121.84 (Wreck) North Mole wreck
MA 10.80 (Wreck) *Omeo*

APPENDIX A

CONSERVATION MANAGEMENT INTERIM REPORT

ABEMAMA

CONSERVATION MANAGEMENT INTERIM REPORT

ABEMAMA

Jon Carpenter
Conservator

Vicki Richards
Conservation Research Scientist

Department of Materials Conservation
Western Australian Museum
June 1997

CONSERVATION MANAGEMENT REPORT

ABEMAMA

DATE WRECKED 27 June 1927

DATE OF INSPECTION 21 - 22 May 1997

WEATHER AND SEA CONDITIONS

Fine to overcast with light winds. Swell present on the 21 May 1997 created water disturbances and strong underwater motion. Tides are diurnal and the tidal range during the period of inspection was 0.2m to 0.6m, the mean variation being 0.4m [Department of Defence 1996]. The water temperature varied slightly between 20°C on the surface to 19°C at depth. The pH of the sea water was 8.05 and the redox potential was 416mV relative to the normal hydrogen electrode. The dissolved oxygen content was 7.5ppm (84% of air saturated water).

SITE

a) Location

The *Abemama* lies in the northern end of Jervoise Bay, Cockburn Sound, Western Australia (Figure 1, Figure 2, wreck no. 3). The partial isolation from the prevailing longshore current and ocean swell combined with a narrow tidal range has greatly reduced ocean flushing and sediment interchange between the open ocean and Cockburn Sound. The wind is the most important force driving the water circulation within the Sound. The wind pattern during a typical winter high pressure system causes a slow, poorly developed anticlockwise gyre of approximately 5-10cms^{-1}. In Cockburn Sound the sublittoral profile is characteristically a wide, gently shelving fringing platform plunging steeply to a flat basin floor consisting of fine carbonate muds. The shoreline from Fremantle to Cape Peron is now largely stable, with its stable forms generally controlled by structures erected at the shore [Department of Conservation and Environment 1979].

b) Description

i) General

The seabed around the wreck gradually slopes away to seaward. The seabed surface comprises of loose calcareous sand. These materials overlay a denser calcareous sandy gravel derived from the weathered lithified Tamala limestone [Environmental Management Services 1994]. The vessel lies almost level with little variation in depth between bow and stern (approx. 0.5m) on a calcareous sandy seabed. There are areas of exposed limestone on the seabed shoreward of the vessel. Some mounding of sand has occurred along the shoreward side of the *Abemama*. There are no reefs in close proximity.

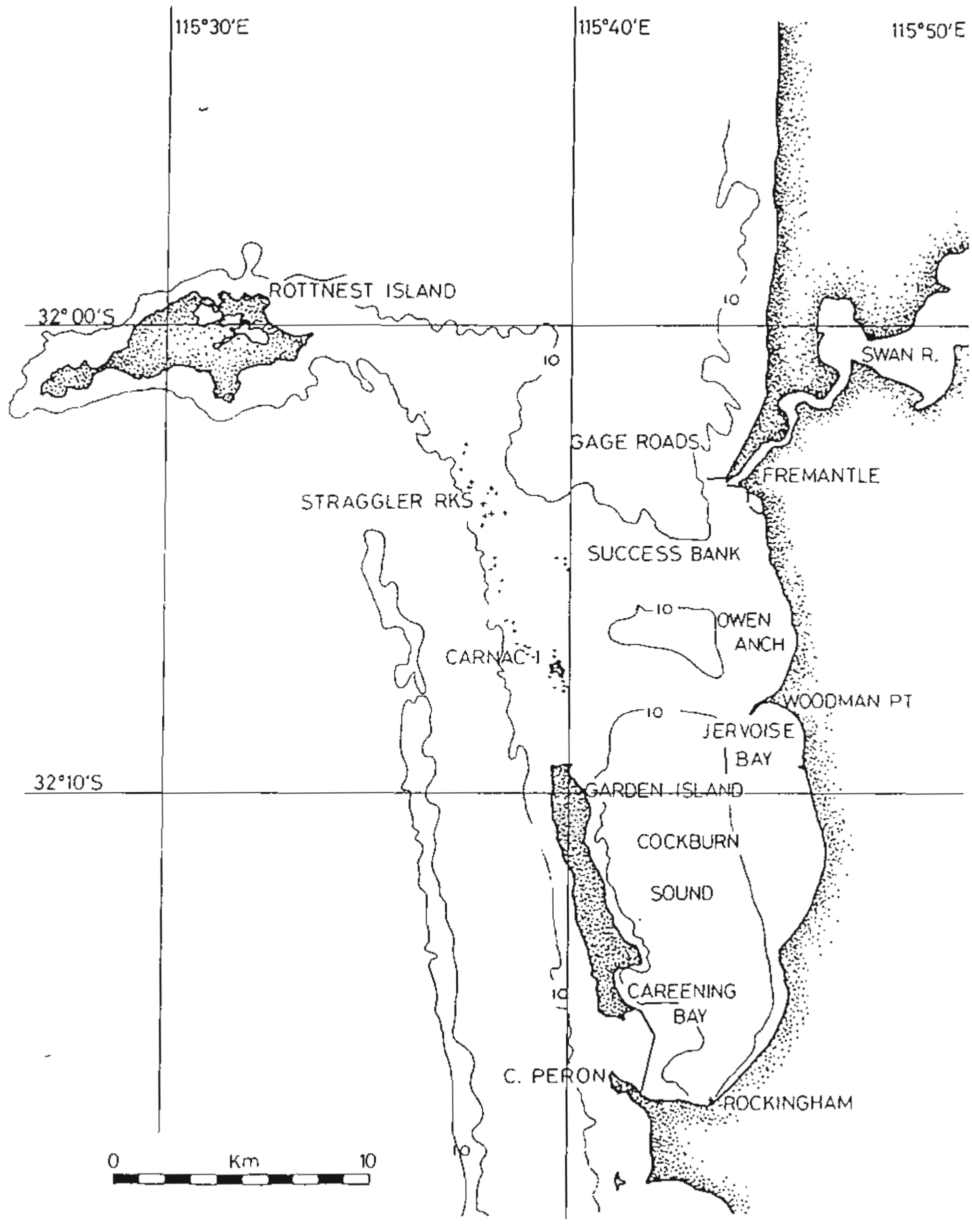

Figure 1. A map of the Fremantle area showing Jervoise Bay [McCarthy 1983].

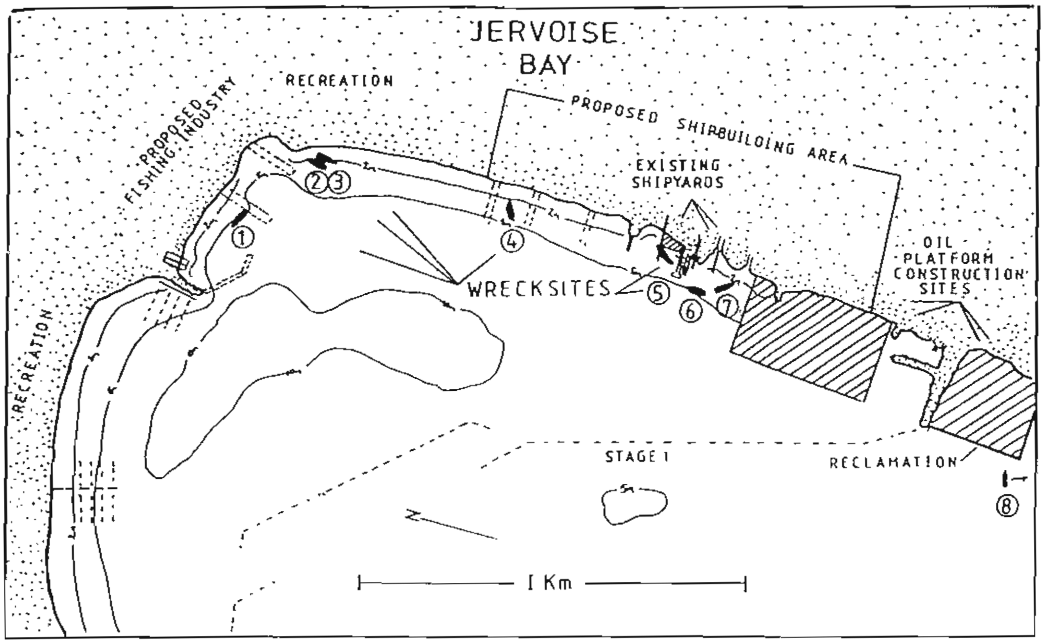

Figure 2. Jervoise Bay showing the positions of the *Alacrity* (2) and the *Abemama* (3) [McCarthy 1981].

ii) Flora and Fauna Assemblages

The concreted surfaces of the *Alacrity* were quite densely covered with sessile marine organisms, including. In less concentrated areas of growth small algal forms were present. The more exposed hardwood timbers of the *Abemama* were quite densely covered with marine organisms, such as mussels, sponges, ascidians, tunicates and barnacles. Barnacle colonisation appeared to be more prominent on this wreck than on the *Alacrity*. Outer hull planking was generally free of marine growth. The exposed ends of the frames exhibited damage caused by marine borers. No live examples were observed. During timber sampling procedures, bristle worms were noticeably present. Common blowfish were present in considerable numbers and one octopus was seen..

iii) Freshwater Influence

There is no apparent fresh water influence. No rivers discharge into Jervoise Bay and the only source of fresh water is local run-off from the mainland and direct precipitation. The effect would be minimal.

iv) Human Disturbance

Cockburn Sound has extensive industrial and urban developments on its coastline. During the last thirty years, it has been used as a disposal site for municipal sewage and industrial wastes. Due to these effluents, Cockburn Sound basin sediments are moderately polluted with lead, mercury and zinc which has caused some deterioration of the water quality and contamination of some of the marine biota with these heavy metals. These effluents have also been associated with eutrophication and damage to the seagrass meadows that are an integral part of the protective sand banks of Cockburn Sound and provide sheltered habitats for marine fauna [Monk & Murray 1990].

The major inputs of heavy metals to Cockburn Sound were associated with the gypsum effluent from the CSBP fertiliser factory situated towards the southern end of the Kwinana industrial area and sewage effluent from the Woodman Point sewage treatment plant (WPTP) located at the northern edge of the

Kwinana industrial area, adjacent to Jervoise Bay. Over a five year period, between 1979 and 1984, the heavy metal input into Cockburn Sound was greatly reduced by the diversion of sewage effluent and changes in industrial practices at Kwinana. However, heavy metals are not biodegradable and they must be removed from the sediment by dilution or dispersal. As Cockburn Sound is partially isolated from longshore sediment and water movements, both dilution and dispersal are likely to be occurring extremely slowly. Therefore, large areas of the Cockburn Sound basin remain contaminated with significant quantities of anthropogenic heavy metals [Monk & Murray 1990; Murphy 1979].

The WPTP, prior to 1979, was also a major contributor of total nitrogen and ammonia, phosphorus and sulphides to Cockburn Sound. Excessive nitrogen and phosphorus levels cause eutrophication of water bodies and the effects are varied but are always associated with extensive changes in water quality. Sulphides are rapidly oxidised in sea water but unless sufficient mixing with seawater takes place then depletions in dissolved oxygen concentrations can occur. However, this situation produces a local, rather than regional effect [Department of Conservation and Environment 1979].

Jervoise Bay was one of several well known ships' graveyards and was utilised from 1890 to 1910. The *Abemama* broke away from her mooring in Jervoise Bay during a severe storm on the 27 June 1927 and was blown on to the shore where she lay for a few weeks before vandals burnt and totally destroyed the vessel. The wreck site was quite extensive and well preserved for many years by layers of sediment in approximately 2m of water and about 30m from the shoreline. The overall disturbance of this site is attributable to changes brought about by activities along and development of the foreshore. Most importantly, in 1975 dredging occurred to enable the newly completed construction of the oil rig, *Ocean Endeavour*, access to the open water of Jervoise Bay. As a consequence of this dredging, shoreline changes occurred and the *Abemama* was completely exposed (Figure 3) [McCarthy 1981; 1983].

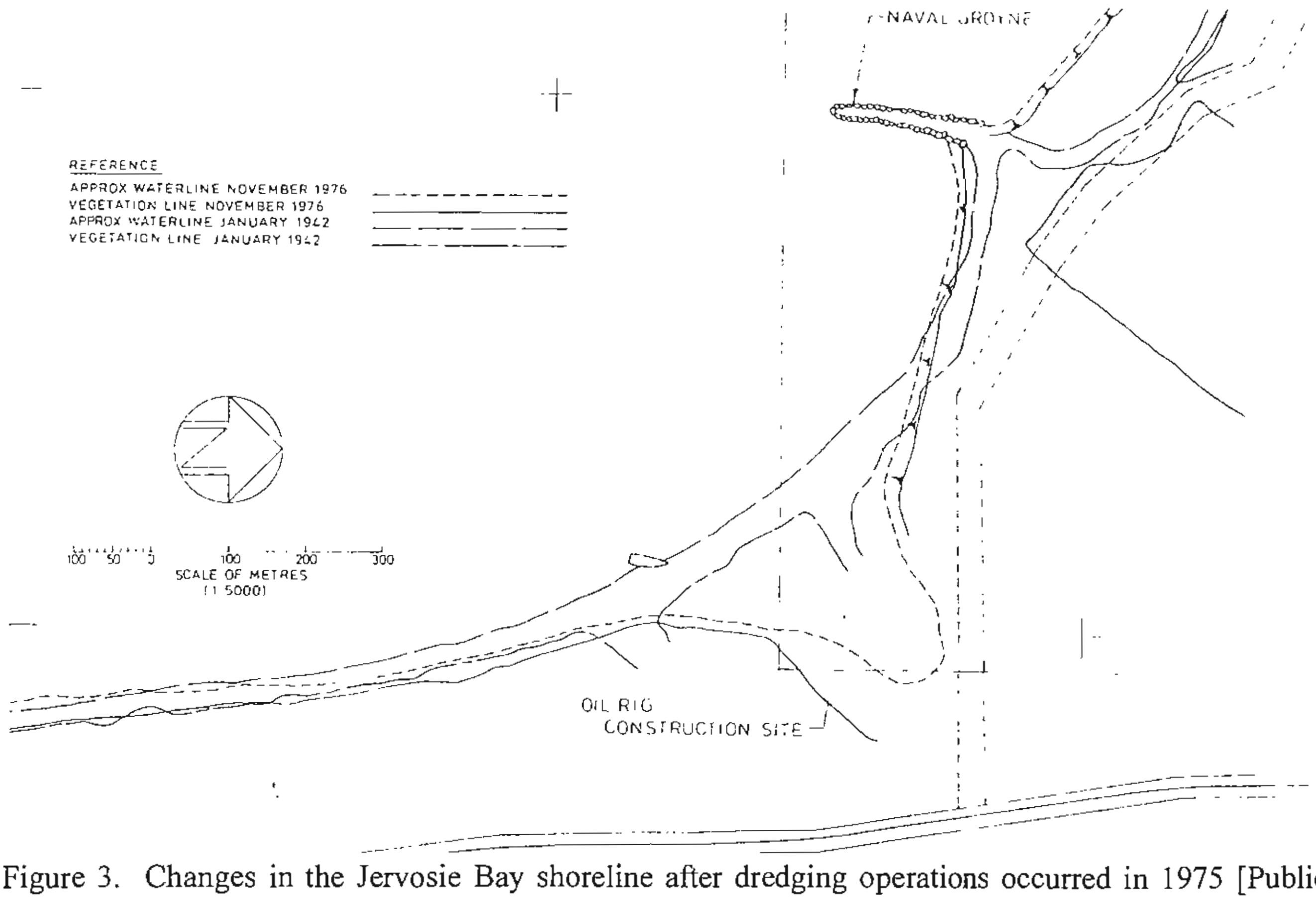

Figure 3. Changes in the Jervosie Bay shoreline after dredging operations occurred in 1975 [Public Works Department Map 1978]

WRECK

a) General Observations

The *Abemama* was a Canadian built, iron fastened wooden vessel [McCarthy 1981; 1983]. The wreck lies on a north-south axis at a depth of approximately 2m, covering an area about 35m long and 10m wide (Figure 4). The stern lies towards the north and the stern in a southerly direction. The remains of the *Abemama* lie almost parallel but slightly converging to the *Alacrity*. The *Abemama* is offset approximately 20m to the south and 10m to the east on a similar north-south axis. There is about 9m separating the two wrecks at the closest point. It is evident that the wreck lies on the port side and has been preserved to about the turn of the bilge by the sand cover. Some iron knees and rigging lies west of the bow. In profile, the wreck rises approximately 0.5m above the surrounding seabed.

b) Degree of Site Exposure

Exposure of the *Abemama* was quite extensive revealing a considerable number of frames and the inner surfaces of outer hull planking. The inner surfaces of these hull timbers were generally free of marine growth which may suggest only recent exposure. Despite the evidence of sand mounding against the shoreward face of the hull some scouring has occurred. The extent of marine life colonisation, particularly towards the bow end of the vessel, suggests this section is likely to be exposed to the marine environment for a longer period of time. There is a proportion of the wreck buried in the sediment, however, the extent of this burial was not ascertained (Figure 4).

c) Evidence of Seasonal Exposure

Sediment sampling procedures revealed dark, anaerobic sediment approximately 150 mm beneath the seabed surface suggesting stability of the sediment beneath this depth. At other times of the year seasonal differences may increase the depth of mobile sands above this stable layer.

d) Evidence of Human Disturbance

General evidence of human presence was confirmed by the visit of a fisherman to the site during museum investigations. This would suggest the possibility of potential contamination of the site by fishing tackle and refuse. The close proximity of this wreck to the shore obviates the need for a boat and this situation may have encouraged visits by recreational divers. There is no evidence, or suggestion that the wreck would have been damaged as a result of diver visitation.

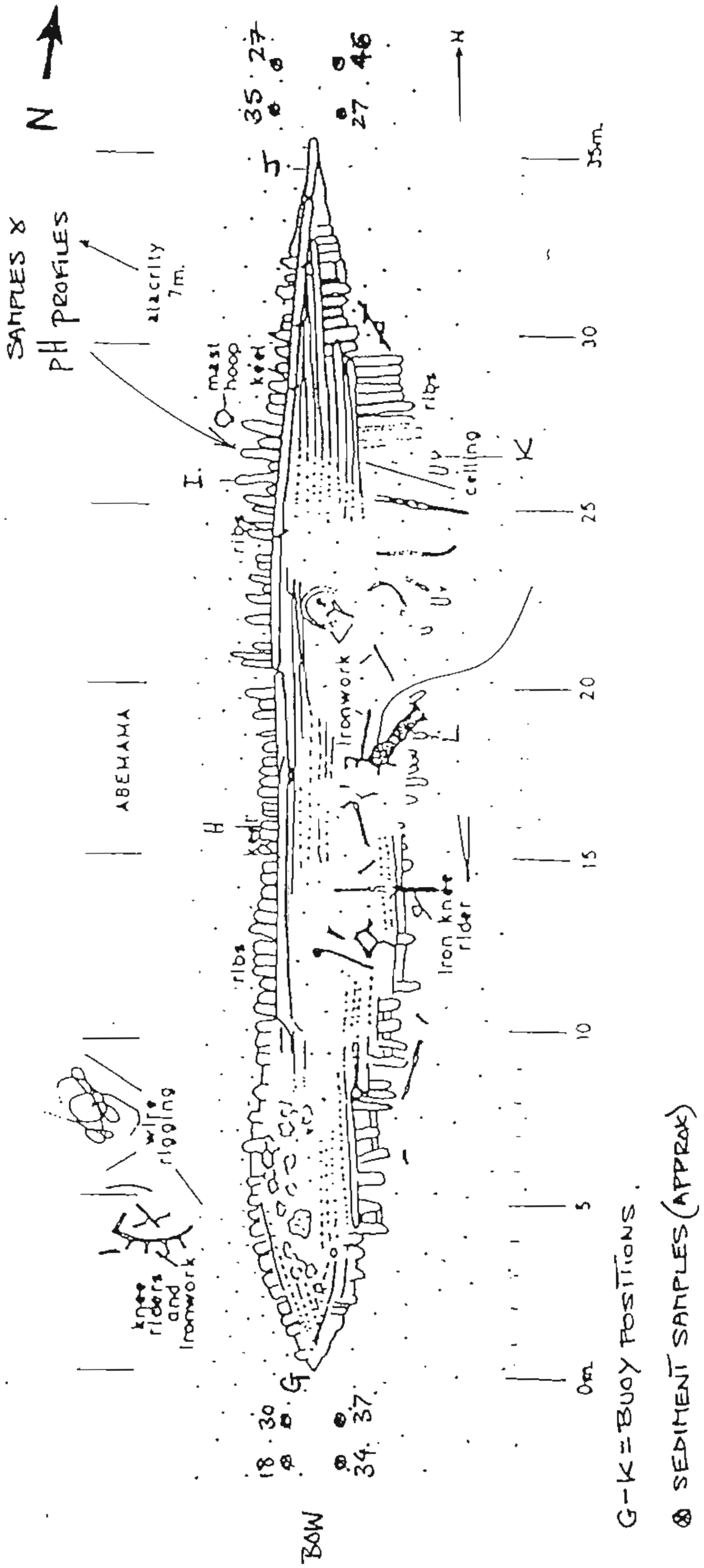

Figure 4. Site plan of the *Abemama* wreck site [McCarthy 1981; 1983].

e) Exposed Structure and Artefacts

i) Iron

No shipboard artefacts were observed only collapsed hull structure was present around the site. Iron knees and riders lay on either side of the wreck, however, no corrosion potentials of these structural fittings were measured.

f) Organic Survey

i) Wood

Generally, the exposed structural timbers of the *Abemama* appeared to be in relatively good condition, however, some exposed hull timbers had suffered the depredation of marine borers. The interior surfaces of the outer hull planks had suffered considerably less deterioration than the frames suggesting that these timbers had been extensively buried in the past and only recently exposed. In-situ pH profiles of selected aerobic structural timbers were obtained (Figure 4 & 5). Samples of the measured timbers were collected for wood identification and maximum water content (U_{max}) analyses (Figure 4 & 5).

ii) Sediment

Samples of sediments were collected at different positions on the wreck site (Figure 4). Some redox potentials and pHs were measured at the sample collection point. The results are shown in Table 1. The sediment samples are currently being analysed for inorganic elements, size fractionation and organic materials. Samples of sea water from Jervoise Bay and pore water samples extracted from the sediment samples will also be analysed for basic and major ions and nutrient levels. These analyses are being performed and supervised by Mr Steve Fisher of Geotech and paid for by the Materials Conservation Department of Western Australian Museum. The results are not available as yet.

Table 1. Sampling information and chemical measurements of sediment samples collected from the *Abemama* site.

Sample No.	Collection Site	pH	Redox Potentials (rel. NHE) (V)	Water Depth (m)
5	mid section between wrecks	8.19	+0.009	2.9
6	off site (background)	-	-	-
7	bow	7.99	+0.030	3.1
8	stern	7.78	+0.016	3.0

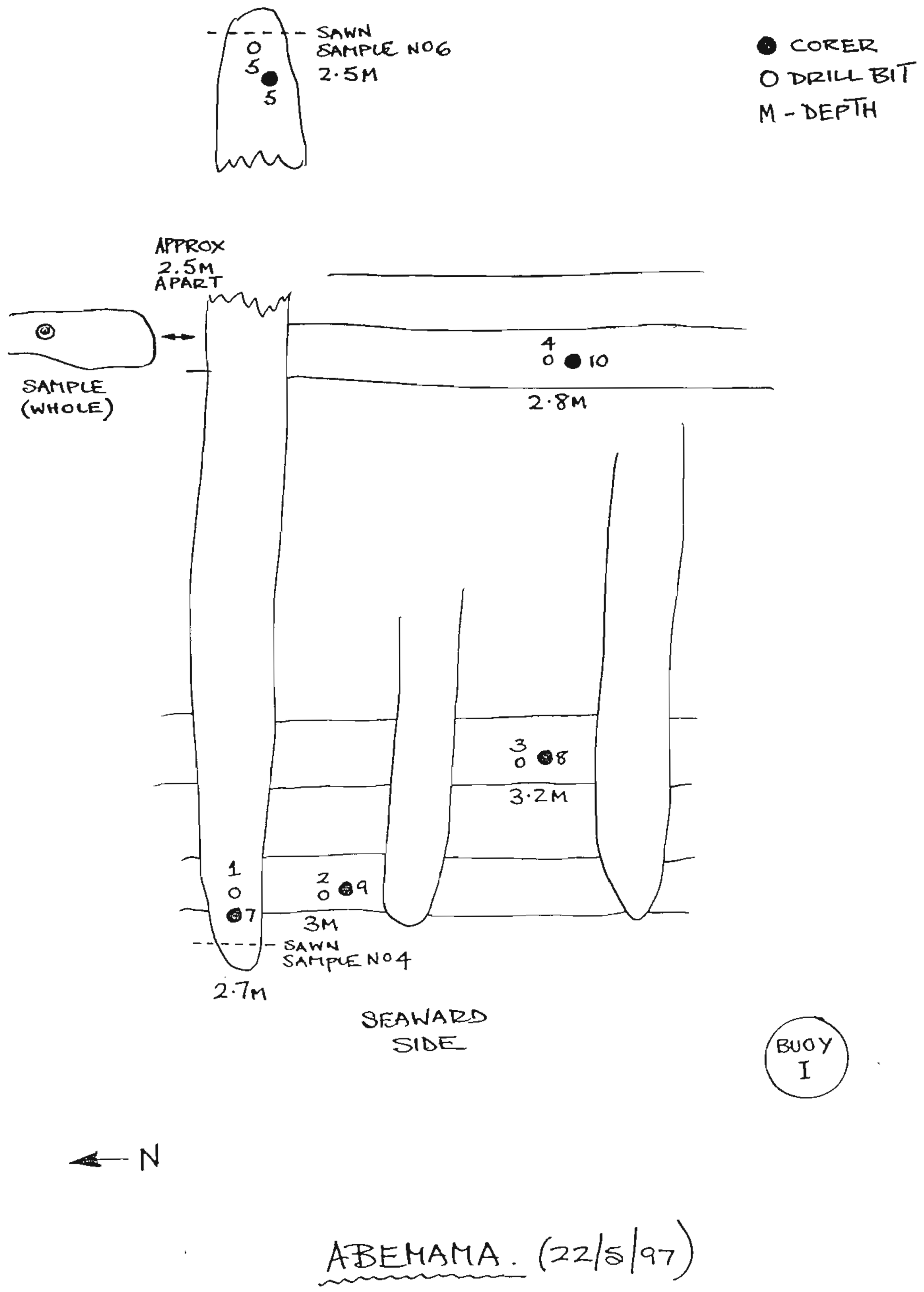

Figure 5. Position of pH profiles and wood sampling on the *Abemama* site [Carpenter 1997].

g) Interpretation of Results

i) Wood

The site positions and pH profiles of some structural members (i.e. frames, keel/keelson and outer planking) of the *Abemama* are shown in Figures 5 and 6, respectively. Some of the measured main structural timbers of the *Abemama* have been identified [Godfrey, I.M. 1997, pers. comm., 4 June]. The frame was identified as beech and would be more likely to be an American beech due to the origin of the vessel. The outer hull planking and a tree nail was tentatively identified as Douglas fir. All timbers measured were exposed to the aerobic marine environment.

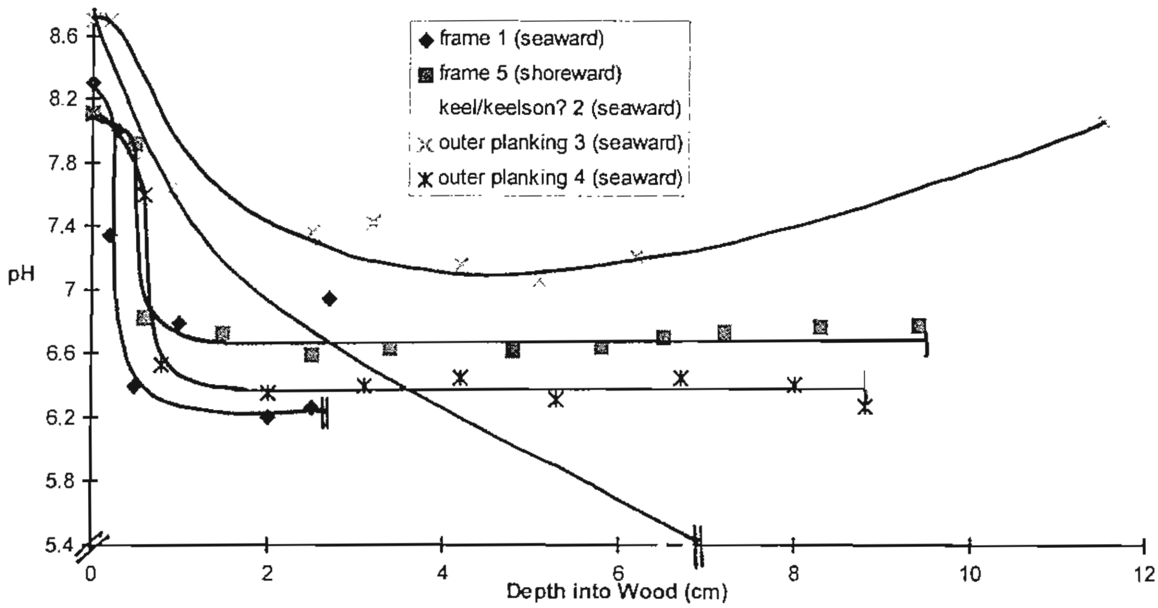

Figure 6. pH profiles of selected timbers measured on the *Abemama* site.

From observing the pH profiles of these aerobic timbers, in general, the pH of the surface wood is high then as the depth into the timbers increases there is a sharp and rapid decrease in pH. The higher pH measured on the wood surface, slightly more acidic than sea water, is indicative of the pH being controlled by the buffering capacity of the sea water. More importantly, this maximum pH denotes the area of greatest deterioration. As wood degrades in a marine environment by physical and biological means, its polysaccharide content is reduced and spaces created within the wood structure are then filled with alkaline sea water. This initially occurs in the outer more exposed areas of the timber. Hence, the normally acidic nature of the wood becomes progressively more alkaline with increasing degradation due to the inward diffusion of sea water. The pH then rapidly decreases as the depth increases into the wood core indicating a gradual decrease in the extent of degradation. The pH will reach a minimum denoting the area of least deterioration where the wood is less waterlogged. The overall decrease in the pH of the wood core is an indication of the inherent acidity of the wood. The innermost wood is still waterlogged, albeit to a lesser extent than the outer surfaces, therefore the pH will be more alkaline than the standard pH of seasoned, modern, undegraded wood of the same species.

The outer hull planking measured in position 3 (Figure 5) was the most degraded of the timbers measured. The pH values of the outer planking (3) were higher than those measured for other timbers and the pH decreased only slightly as the core depth increased. The minimum pH value measured for outer planking (3) at a depth of 5cm was 7.06. This indicates that this timber is generally more degraded than the other measured timbers. After this minimum, the depth into the wood continued to increase and there was a turning point and the pH began to increase again, indicating a gradual increase in the extent of wood degradation as the opposite side of the timber is approached. However, the lower pH of 8.06 at a depth of 12cm indicates that the lower, more protected side of the timber is not as degraded as the more exposed, upper surface. The pH profile of the other outer planking (4), seems to indicate a lesser extent of deterioration due to the more rapid decrease in pH as the core depth increases. The pH then began to plateau at a core depth of about 2cm and the average minimum pH was 6.37 ± 0.06. No measurements were taken after about 9cm as the drill was binding.

In addition, plots of pH versus core depth may also be used to approximate the width of structural timbers that are difficult to measure physically. From the pH profiles, the outer planking on the *Abemama* site would be about 12cm wide.

The seaward side of an exposed frame (1) was relatively well preserved and less degraded than the shoreward side of frame (5). The drill could not penetrate the frame at position 1 after 3cm as the wood was too hard, however, the minimum pH at a core depth of 2cm was 6.20. The maximum pH occurred on the outer wood surface on the shoreward side of the frame (5) indicating the area of greatest degradation. As the depth into the timber increased there was a gradual decrease in pH which plateaued at a core depth of 0.6cm and the average minimum pH was 6.70 ± 0.08 denoting the area of least degradation. Measurements ceased after 9.5cm as the drill was binding. The fact that the seaward frame (1) was less degraded than the shoreward frame (5) is easily explained by the fact that the shoreward timber would be exposed to greater physical deterioration by wave action and sand and water impingement due to the shore break. Another influencing factor would be the breakwater effect of the *Alacrity* effectively protecting the seaward side of the *Abemama,* near the stern, as the iron wreck would take the brunt of any rough sea conditions.

The supposed keel or keelson is the least degraded of the measured structural timbers. The pH of the wood surface was high then as the core depth into the timber increases there is a sharp and rapid decrease in pH indicating a gradual decrease in the extent of degradation. The pH reached a minimum of 5.40 at 6.5cm denoting the area of least deterioration where the wood is less waterlogged. After this depth, the drill could not penetrate the timber as the wood was too hard.

ii) Sediment

The sediment, to a depth of approximately 15cm, was essentially sterile with respect to artefact material. The average pH and redox potential of the surface sediment on the *Abemama* site (Table 1) was 7.88 ± 0.15 and 0.023 ± 0.010V, respectively. These measurements indicate that the sediment is a slightly basic, slightly oxidising micro-environment. However, these results suggest that the zero redox level coincides with the depositional interface (sea water/sediment interface). This means that on the sediment surface, aerobic bacteria have removed all the free oxygen from the interstitial water and CO_2 accumulates and the pH will increase accordingly. Conversely, aerobic oxidation of organic material in the surface sediment will produce acidic metabolites and by-products and the pH will subsequently decrease. Therefore, the average pH of the surface sediment is a compromise between opposing biological equilibria.

CONCLUSIONS

The *Abemama* site is a typical aerobic, open circulation, oxidising marine environment. The condition of the exposed structure on-site was as expected as the water column is an open circulation, aerobic marine environment. Generally, the pH profiles indicate that these aerobic timbers possess a degraded outer core, approximately 1cm thick, with a relatively undegraded, solid wood core. Therefore, overall the exposed wooden hull structure is in relatively good condition, however, there is no doubt that the degradation of this site has been significantly increased due to the changes in the shoreline causing the almost total exposure of the site. Physical, chemical and biological degradation of the exposed hull structure would have increased due to this exposure and deterioration will continue to occur on this site. Aerobic biodeterioration and physical degradation due to water and sand impingement are the major causes of the degradation of the exposed wood components. Aerobic bacteria and biota, such as marine worms, can not survive under anaerobic conditions which would form under sediment layers, hence, with the removal of the sediment, biological colonisation and subsequently, deterioration would increase dramatically. In this shallow depth (2m) there is greater total water movement, increasing the dissolved oxygen flux to the wreck material and the more exposed the wreck, the greater the turbulence, causing increased deterioration of the exposed wood and metal. This localised turbulence would be increased by periods of rough weather and the movement of vessels in Jervoise Bay.

The sediment largely consists of a mixture of calcareous sand and is relatively dynamic, slightly basic and slightly oxidising in nature. With greater total water movement which would occur periodically on this site, the sand may be mobilised and physical degradation of wreck material by sand and water impingement will increase.

In conclusion, the results of this pre-disturbance survey indicate that the exposed hull remains of the *Abemama* are in relatively good condition however, the rate of degradation would have increased dramatically after the changes to the coastline in 1975. Therefore, for 22 years, the *Abemama* has been almost totally exposed to the ravages of an aerobic, open circulation, oxidising marine environment. It is the synergistic effect of biological, chemical and physical degradation mechanisms which is causing the degradation of this wreck site. The total exposure of the *Abemama* would have accelerated its breakdown and contributed to its progressive collapse due to increased corrosion and biodeterioration and physical deterioration caused by sea generated forces, such as swell, wave action and currents. However, at times, the seasonal deposition of sediments may provide some short term protection to these structural remains.

FUTURE RECOMMENDATIONS

There were a number of options discussed for the protection of this shipwreck with respect to future shoreline development in Jervoise Bay. Three options were discussed: 1) relocation of the shipwreck, 2) incorporation into the jetty structure and 3) burial in land fill. Option three is the most appropriate method of preserving this historical shipwreck with respect to the conservation priorities. However, the proposed burial of the *Abemama* in the land fill area to be undertaken as part of the land reclamation operations will again, alter the environmental conditions affecting this site.

Including this wreck in the land fill area will reduce the availability of oxygen, halt water movement and decrease biological deterioration which are the main factors influencing the rate and mechanism of corrosion on this site. Hence, the burial of this wreck should decrease the degradation rate markedly. However, by incorporating this shipwreck in land fill, the main effect on the vessel will be a significant decrease in water content of the wooden structure. Care must be taken to ensure that the wreck is not permitted to dry rapidly as this will cause irreversible shrinkage, cracking and distortion of the wooden hull structure. However, if the drying is slow, gradual and controlled, which should occur under land burial conditions, the aforementioned structural damage may be minimalised.

Another point to consider is that anoxic conditions would develop in land fill and in terms of deterioration, sulphate reducing bacteria are the most important component of anaerobic biota. However, the growth of anaerobic sulphate reducing bacteria not only require anoxic conditions but sulphate and essential organic food sources. The wood would provide a supplementary food source and the biodeterioration of the organic components in this land fill area could continue. However, it is common knowledge that the rate of degradation of organic materials decreases dramatically under anaerobic conditions.

The particle size, degree of compaction and water content of the land fill will determine the physical characteristics and influence the chemical reactions that occur in the sediment. The sediment may physically support the weakened structure but problems may arise with settling and compaction of the particles. Corrosion of the iron fittings will continue if sea water is in contact with the wreck as ground water. Depending on the burial material used and its compaction around the site, oxygen availability will be reduced thus inhibiting the corrosion process. There is potential for physical damage to occur during the burial process and careful and even distribution of the fill is advisable.

Access to part of the wreck should be available, for example through a sand filled well, as environmental, pH and corrosion monitoring will assist in determining if this method of protection is suitable for the preservation of composite shipwrecks.

ACKNOWLEDGEMENTS

The authors would like to thank Ms Corioli Souter and Mr Geoff Kimpton for their assistance during the course of the fieldwork. Ms Dena Garratt deserves special mention for assisting in collecting the on-site pre-disturbance data and samples.

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APPENDIX B

CONSERVATION MANAGEMENT INTERIM REPORT

ALACRITY

Jon Carpenter
Conservator

Vicki Richards
Conservation Research Scientist

Department of Materials Conservation
Western Australian Museum
June 1997

CONSERVATION MANAGEMENT REPORT

ALACRITY

DATE WRECKED April/May 1931

DATE OF INSPECTION 21 - 22 May 1997

WEATHER AND SEA CONDITIONS

Fine to overcast with light winds. Swell present on the 21 May 1997 created water disturbances and strong underwater motion around the periphery of the wreck. Tides are diurnal and the tidal range during the period of inspection was 0.2m to 0.6m, the mean variation being 0.4m [Department of Defence 1996]. The water temperature varied slightly between 20°C on the surface to 19°C at depth. The pH of the sea water was 8.05 and the redox potential was 416mV relative to the normal hydrogen electrode. The dissolved oxygen content was 7.5ppm (84% of air saturated water).

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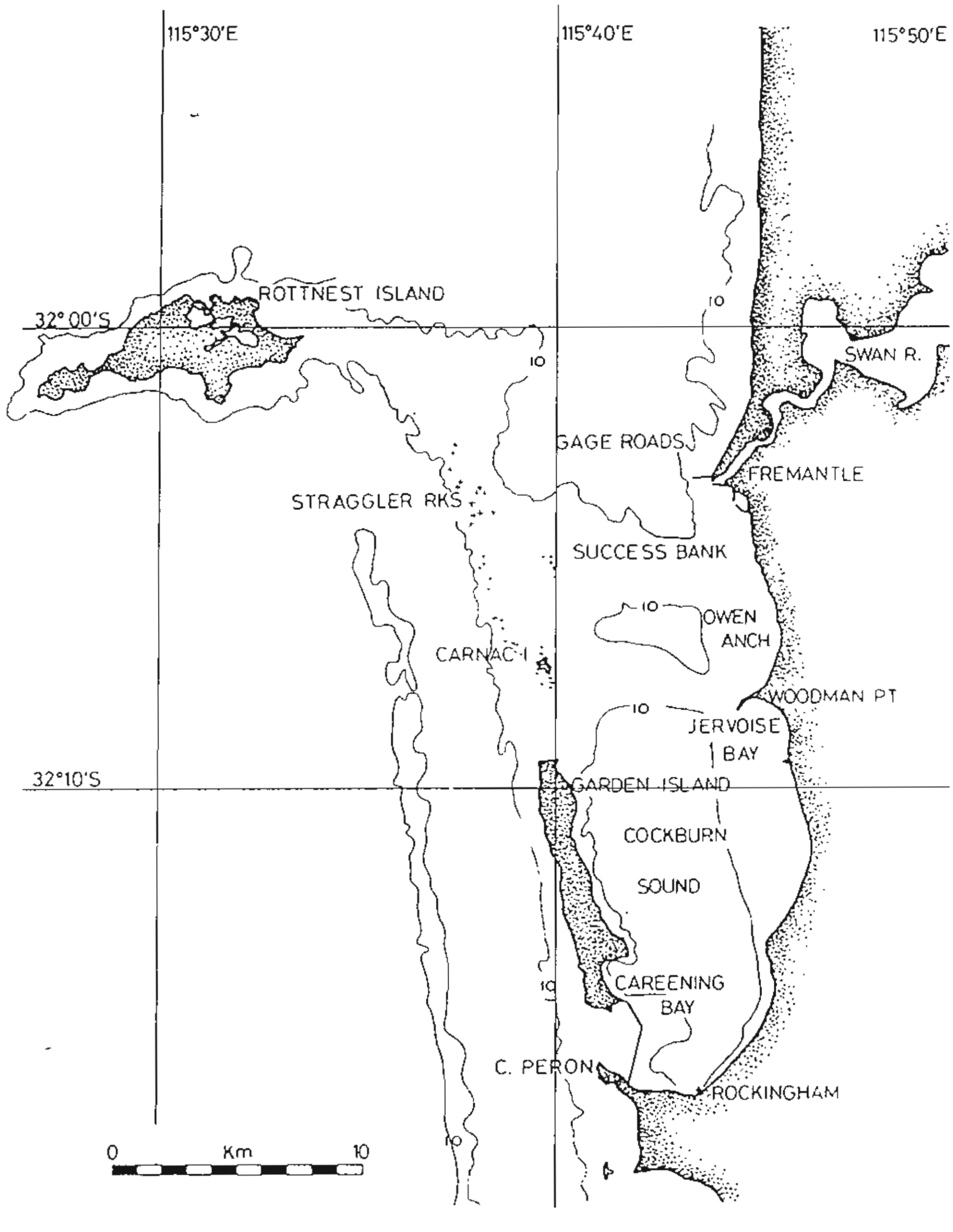
i) General

The seabed around the wreck gradually slopes away to seaward. The seabed surface comprises of loose calcareous sand. These materials overlay a denser calcareous sandy gravel derived from the weathered lithified Tamala limestone [Environmental Management Services 1994]. The vessel lies almost level with little variation in depth between bow and stern (approx. 0.5m). At the stern, the *Alacrity* rests on an exposed limestone substrate which gradually disappears beneath sand towards the bow. A trench (1.5m deep) excavated by water dredge at the bow did not expose rock. There are areas of exposed limestone on the seabed shoreward of the vessel. There is some evidence of sand scour at the stern of the *Alacrity*. There are no reefs in close proximity.



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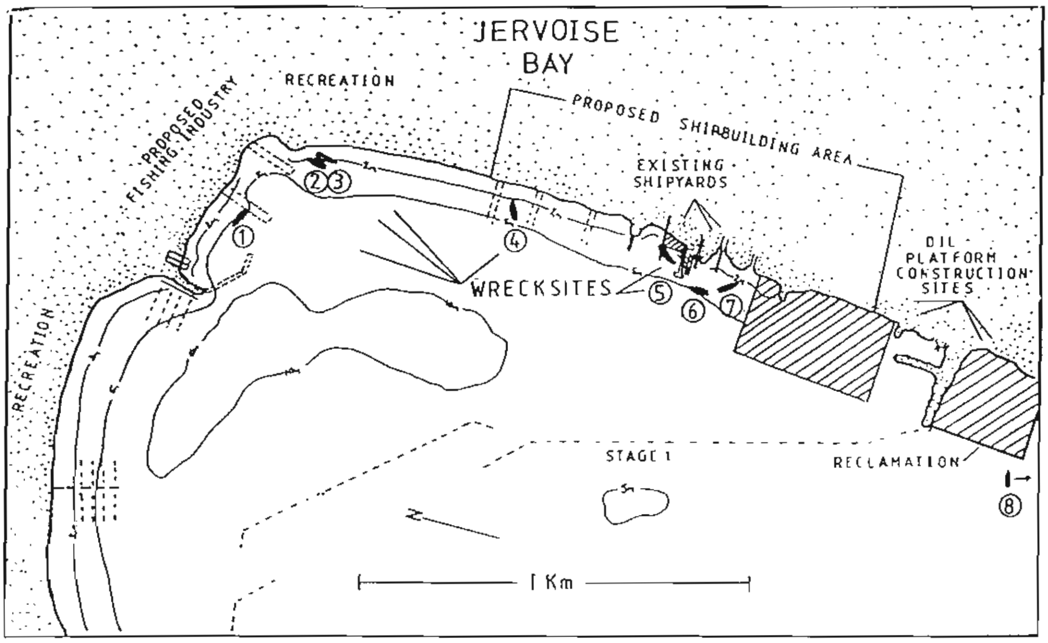

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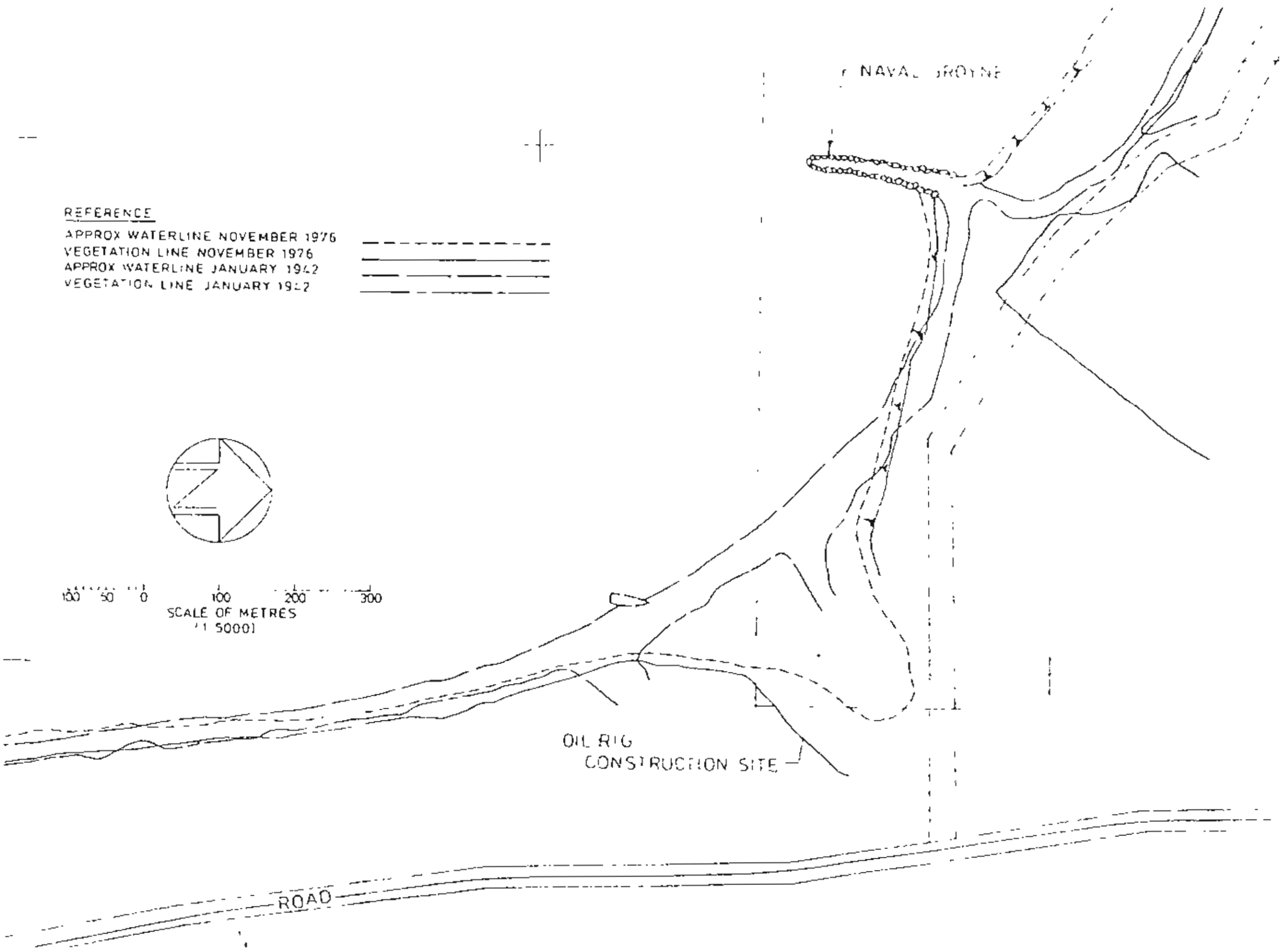

Figure 3. Changes in the Jervosie Bay shoreline after dredging operations occurred in 1975 [Public Works Department Map 1978]

WRECK

a) General Observations

The *Alacrity* was a French built steel tug [McCarthy 1981; 1983]. The wreck lies on a north-south axis at a depth of approximately 3m, covering an area about 40m long and 10m wide (Figure 4). The bow lies towards the north and the stern in a southerly direction. The wooden wreck of the *Abemama* lies almost parallel to the *Alacrity* but it is offset approximately 20m to the south and 10m to the east on a similar north-south axis. The bow end of the *Alacrity* and the majority of the hull above the bilge has collapsed and some hull-side structure lies on the sand seabed. In profile, the wreck rises approximately 1m above the surrounding seabed.

b) Degree of Site Exposure

The highest part of the *Alacrity* is the stern post which extends approximately 1.5m above the sea water surface. In profile, hull structure at the stern and mid section rises approximately 2m above the surrounding seabed. The average height of the adjoining structure is about 1m above the sediment. There is a proportion of the wreck buried in the sediment up to about the turn of the bilge, however, the extent of this burial was not ascertained as the bottom of the vessel was not located during dredging operations (Figure 4).

c) Evidence of Seasonal Exposure

Sediment sampling procedures revealed dark, anaerobic sediment approximately 150 mm beneath the seabed surface suggesting stability of the sediment beneath this depth. At other times of the year seasonal differences may increase the depth of mobile sands above this apparently stable layer. Excavations at the bow revealed an intrusion of lighter coloured sand into the darker zone which suggests some mobility of sand at this end of the vessel in the recent past, possibly due to scouring and wave action.

d) Evidence of Human Disturbance

General evidence of human presence was confirmed by the visit of a fisherman to the site during museum investigations. This would suggest the possibility of potential contamination of the site by fishing tackle, rubbish, and more importantly the use of the exposed stern post as a boat mooring. Ropes secured around the stern post indicated this had taken place without any apparent damage, but such actions could eventually contribute to the partial destruction of the site. The close proximity of this wreck to the shore obviates the need for a boat and this situation may have encouraged visits by recreational divers. There is no evidence, or suggestion that the wreck would have been damaged as a result of diver visitation.

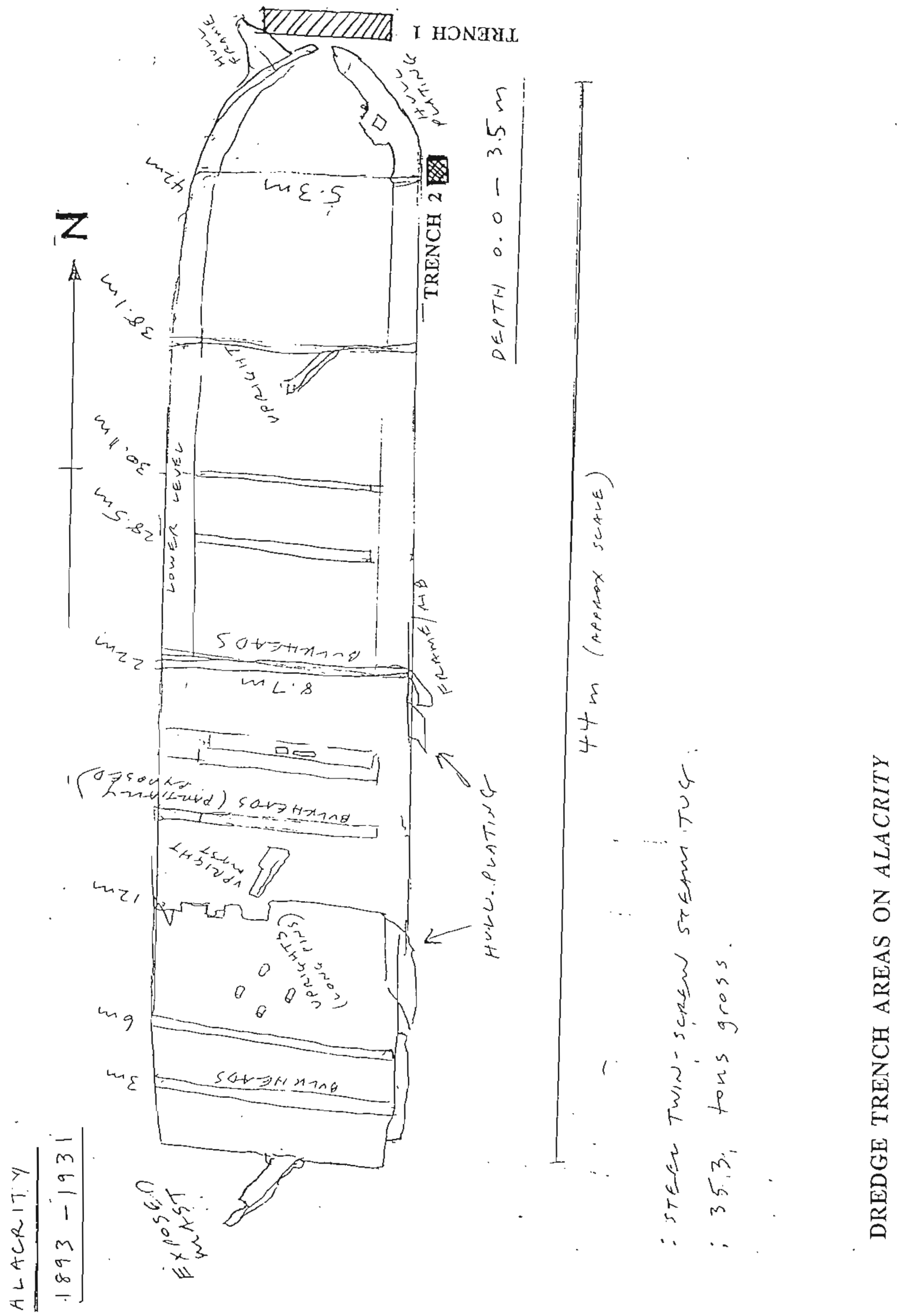

Figure 4. Location of the dredged trench areas on the *Alacrity* site [Souter 1997].

e) Exposed Structure and Artefacts

i) Iron

No shipboard artefacts were observed only collapsed hull structure was present around the site. Eight sets of corrosion potential and surface pH measurements were acquired and the results are presented in Table 1. The iron hull plates near the stern post, in upper and lower positions on the seaward and shoreward facing sides of the vessel, either side of the hull mid section, a large iron shaft, possibly a prop shaft located mid site and collapsed hull plating lying across the bow end of the vessel were measured (Figure 5). Marine growth was stripped away from the concreted iron surface with a knife blade prior to drilling. In hindsight a smaller masonry drill bit should have been used to drill the relatively thin concretion layer (maximum depth 8 mm) as the minimum closed volume of sea water was not attained for recording the surface pH. The variance in the pH readings may reflect this.

Table 1. Corrosion and redox potentials of metal fittings measured on the *Alacrity* site.

Measurement Position	pH	Corrosion Potential (rel. NHE) (V)	Depth of Concretion (mm)	Water Depth (m)
stern, lower, shoreward	7.35	-0.324	8	2.6
stern, upper, shoreward	7.02	-0.325	8	0.9
stern, lower, seaward	5.77	-0.326	8	2.5
stern, upper, seaward	6.83	-0.327	6	1.3
mid section, shoreward	5.45	-0.328	6	2.0
mid section, seaward	7.83	-0.333	2	2.3
large iron shaft	7.38	-0.328	4	2.0
bow	5.24	-0.330	8	3.6

f) Organic Survey

i) Sediment

Samples of sediments were collected at different positions on the wreck site (Figure 5). Some redox potentials and pHs were measured at the sample collection point. The results are shown in Table 2. The sediment samples are currently being analysed for inorganic elements, size fractionation and organic materials. Samples of sea water from Jervoise Bay and pore water samples extracted from the sediment samples will also be analysed for basic and major ions and nutrient levels. These analyses are being performed and supervised by Mr Steve Fisher of Geotech and paid for by the Materials Conservation Department of Western Australian Museum. The results are not available as yet.

Table 2. Sampling information and chemical measurements of sediment samples collected from the *Alacrity* site.

Sample No.	Collection Site	pH	Redox Potentials (rel. NHE) (V)	Water Depth (m)
1	bow	7.80	-0.017	3.7
2	bow at depth 1.5m	-	-	5.0
3	midships	-	-	2.2
4	stern	8.08	+0.030	3.3
5	mid section between wrecks	8.19	+0.009	2.9
6	off site (background)	-	-	-

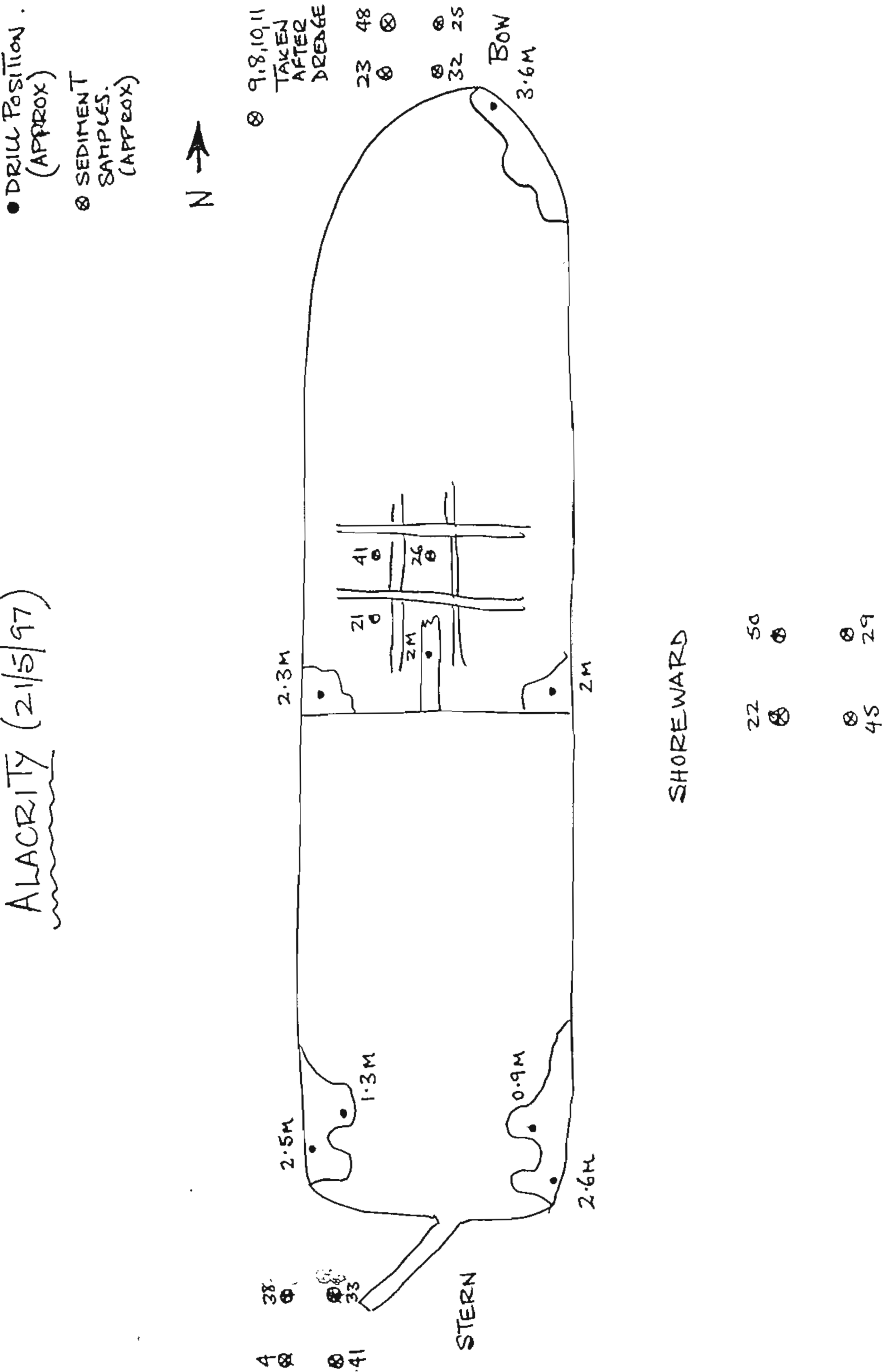

Figure 5. Position of corrosion potential and surface pH measurements and sediment sampling on the *Alacrity* site [Carpenter 1997].

g) Interpretation of Results

i) Iron

The iron structure exposed to this oxidising marine environment was covered with aerobic concretion and secondary marine growth. The depth of concretion on the wrought iron hull plates was approximately 6 ± 2mm. Iron is not biologically toxic and assists in increasing the growth rate of encrusting organisms. The concretion acts as a semi-permeable layer on the surface of the iron, effectively separating the anodic and cathodic sites and produces an acidic, iron and chloride-rich micro-environment at the residual iron surface. The average surface pH and corrosion potential of the residual wrought iron was 6.61 ± 0.98 and -0.328 ± 0.003V, respectively. In comparison, the pH of the sea water was 8.05 which is about 26 times more alkaline than the average surface pH of the residual wrought iron measured under the concretion. The individual measured voltages and corresponding surface pHs were plotted on the Pourbaix diagram for iron in aerobic sea water (Figure 6).

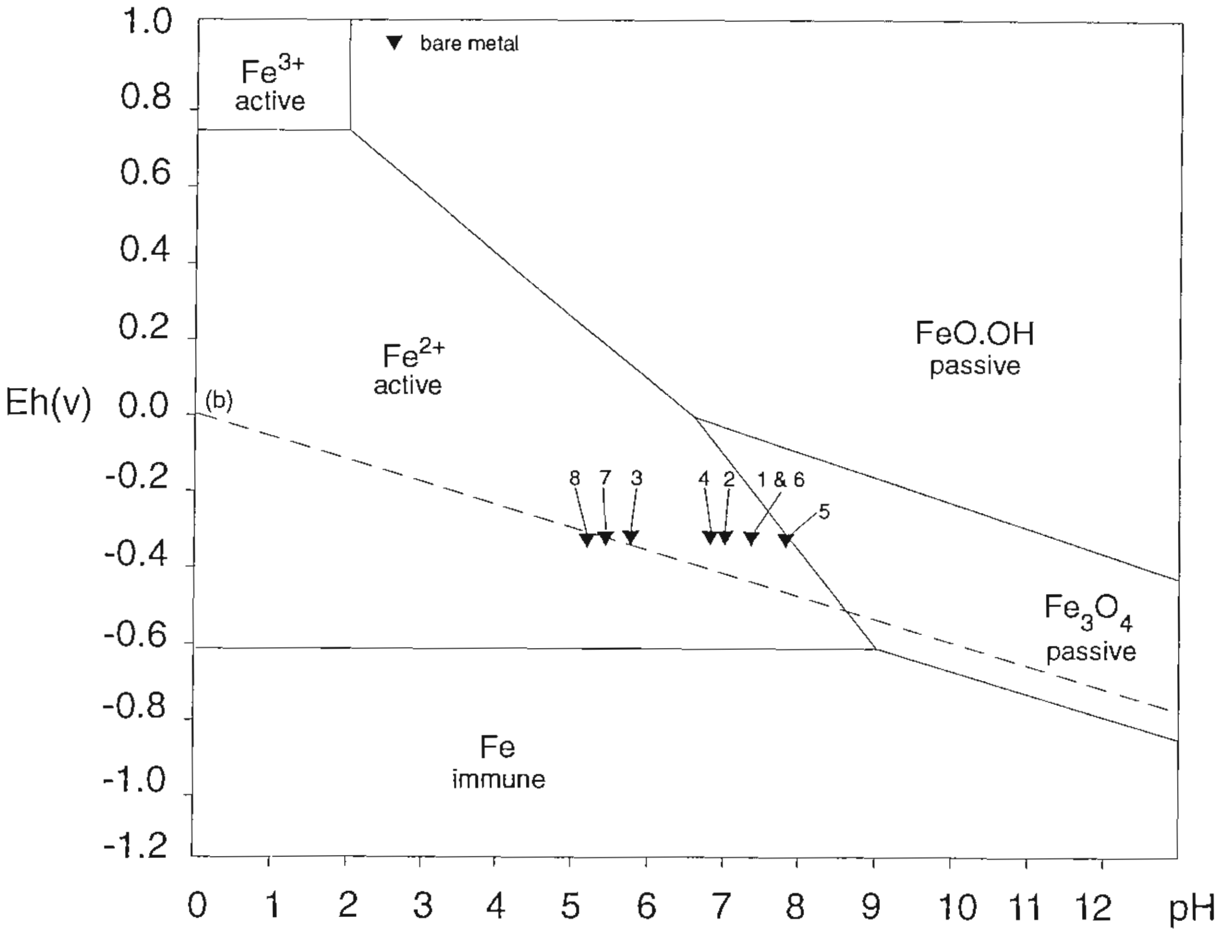

Figure 6. Pourbaix diagram for iron (10^{-6}M) in aerobic sea water at 25°C indicating the state of iron objects on the *Alacrity* site.

These points on the Pourbaix diagram for iron in aerobic sea water indicate that these iron fittings are actively corroding. The major phase in wrought iron is ferrite with strips of slag incorporated into the structure during the manufacturing process. The corrosion of wrought iron does not leave a coherent residue beneath the concretion layer only a void, but iron minerals such as FeO.OH, Fe_3O_4 and FeOCl are present in the corrosion product layers.

ii) Sediment

The sediment, to a depth of approximately 15cm, was essentially sterile with respect to artefact material. The average pH and redox potential of the surface sediment on the *Alacrity* site (Table 2) was 8.02 ± 0.20 and 0.007 ± 0.024V, respectively. These measurements indicate that the sediment is a slightly basic, neither oxidising nor reducing micro-environment. However, these results suggest that the zero redox level coincides with the depositional interface (sea water/sediment interface). This means that on the sediment surface, aerobic bacteria have removed all the free oxygen from the interstitial water and CO_2 accumulates and the pH will increase accordingly. Conversely, aerobic oxidation of organic material in the surface sediment will produce acidic metabolites and by-products and the pH will subsequently decrease. Therefore, the average pH of the surface sediment is a compromise between opposing biological equilibria.

CONCLUSIONS

The *Alacrity* site is a typical aerobic, open circulation, oxidising marine environment. The condition of the exposed structure on-site was as expected as the water column is an open circulation, aerobic marine environment. The iron hull structure is actively corroding and is progressively collapsing due to extensive *in-situ* corrosion. Physical, chemical and biological degradation of the exposed iron structure will continue to occur on this site. In this shallow depth (3m) there is greater total water movement and the higher the object profile above the sea bed, the greater the turbulence, increasing the dissolved oxygen flux to the wreck material causing increased deterioration of the exposed metal. This localised turbulence would be increased by periods of rough weather and the movement of vessels in Jervoise Bay.

The sediment largely consists of a mixture of calcareous sand and is relatively dynamic, slightly basic and neither oxidising or reducing in nature. With greater total water movement which would occur periodically on this site, the sand may be mobilised and physical degradation of wreck material by sand and water impingement will increase.

In conclusion, the results of this pre-disturbance survey indicate that the exposed hull remains of the *Alacrity* are being destroyed at a relatively rapid rate. It is the synergistic effect of biological, chemical and physical degradation mechanisms which is causing the degradation of this wreck site. Following changes to the coastline in 1975, the wreck has been totally immersed in an oxidising marine environment for about 22 years. This total submergence of the *Alacrity* has accelerated its breakdown and contributed to its progressive collapse due to increased corrosion and physical deterioration caused by sea generated forces, such as swell, wave action and currents. However, the gradual build-up of a concretion layer on the metal surface may provide some reinforcement to the structural remains.

FUTURE RECOMMENDATIONS

There were a number of options discussed for the protection of this shipwreck with respect to future shoreline development in Jervoise Bay. Three options were discussed: 1) relocation of the shipwreck, 2) incorporation into the jetty structure and 3) burial in land fill. Option three is the most appropriate method of preserving this historical shipwreck with respect to the conservation priorities. However, the proposed burial of the *Alacrity* in the land fill area to be undertaken as part of the land reclamation operations will again, alter the environmental conditions affecting this site.

Including this wreck in the land fill area will reduce the availability of oxygen, decrease the variations in temperature and halt water movement which are the main factors influencing the rate and mechanism of corrosion on this site. Hence, the burial of this wreck should decrease the degradation rate markedly. However, care must be taken as the action of this artificial diagenesis may not decrease the degradation but merely change the mechanisms of deterioration.

Anoxic conditions would develop in land fill and in terms of deterioration, sulphate reducing bacteria are the most important component of anaerobic biota. If the oxygen content of the water or moisture immediately in contact with the metal becomes very low then the redox potential of this water can fall below the hydrogen evolution potential and the main cathodic reaction in the metal corrosion process is not the reduction of oxygen but the formation of hydrogen. In the absence of catalysts this reaction is generally slow on most metals and consequently their corrosion rate is low. The action of sulphate reducing bacteria speeds up this reaction. The enzyme hydrogenase produced by the bacteria catalyses the reaction and formation of acids will also increase the corrosion rate. The resulting corrosion rates are much higher than those in similar environments with low bacteria population. However, the growth of anaerobic sulphate reducing bacteria not only require anoxic conditions but sulphate and essential organic food sources. The biodeterioration of the metal components in this land fill area may be enhanced by anoxic bacteria but if the biological activity is lowered by reducing the availability of suitable food sources and sulphate then the overall rate of degradation will decrease dramatically.

The particle size, degree of compaction and water content of the land fill will determine the physical characteristics and influence the chemical reactions that occur in the sediment. The sediment may physically support the weakened structure but problems may arise with settling and compaction of the particles. Corrosion will continue if sea water is in contact with the wreck as ground water. Depending on the burial material used and its compaction around the site, oxygen availability will be reduced thus inhibiting the corrosion process. There is potential for physical damage to occur during the burial process and careful and even distribution of the fill is advisable.

Access to part of the wreck should be available, for example through a sand filled well, as environmental and corrosion monitoring will assist in determining if this method of protection is suitable for the preservation of iron hulled shipwrecks.

ACKNOWLEDGEMENTS

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APPENDIX C

JERVOISE BAY WRECKS PROJECT –DIVE LOG

Key: LS&S = Low Seas & Swell

Date: 21.05.97	Location: Jervoise Bay	Site: Abemama/Alacrity	
Vessel:	Seaspray	Diving Equipment: Hookah/Scuba/Snorkle	
Depth: 5m	Conditions: LS&S	Wind: NE 5 kts	Water Temp: 20°
Personnel:	Corioli Souter, Dena Garratt (Joint OIC), Geoff Kimpton, (Technical Officer), Jon Carpenter, (Conservation), Patrick Baker (Photography).		

Diver	Time In	Out	Total	Task
Dena	1030	1130	60	Predisturbance survey, Alacrity
Jon	1030	1135	65	Predisturbance survey, Alacrity
Patrick	1040	1135	55	Photography

Corioli Standby Diver
Total dive time: 3 hours 0 mins (180 mins)

Diver	Time In	Out	Total	Task
Dena	1220	1240	80	Sediment sampling, Alacrity/Abemama
Jon	1220	1240	80	Sediment sampling, Alacrity/Abemama

Corioli Standby Diver
Total dive time: 2 hours 4 0 mins (160 mins)
Cumulative dive time: 5 hrs 40 mins (340 mins)

Diver	Time In	Out	Total	Task
Corioli	1307	1437	90	Test trench, port side, midships, Alacrity
Geoff	1307	1447	100	Test trench, port side, midships, Alacrity
Patrick	1334	1410	27	Photography

Dena Standby Diver
Total dive time: 3 hours 37 mins (217 mins)
Cumulative dive time: 9 hrs 17 mins (557 mins)

Date: 22.05.97	Location: Jervoise Bay	Site: Abemama/Alacrity	
Vessel:	Seaspray	Diving Equipment: Hookah/Scuba/Snorkle	
Depth: 5m	Conditions: LS&S	Wind: NE 5 kts	Water Temp: 20°

Personnel: Corioli Souter, Patrick Baker, Jon Carpenter, Dena Garratt, Geoff Kimpton

Diver	Time In	Out	Total	Task
Jon	1015	1225	130	ph sampling, Abemama timbers
Dena	1015	1225	130	ph sampling, Abemama timbers
Geoff	1045	1145	60	Buoyed both wreck sites in prep. for DGPS
Corioli	1045	1145	60	Buoyed both wreck sites in prep. for DGPS
Jon	1230	1300	30	Timber sampling, Abemama
Patrick	Standby diver			

Total dive time: 6 hours 50 mins (410 mins)
Cumulative dive time: 16 hrs 07 mins (967 mins)

Diver	Time In	Out	Total	Task
Dena	1400	1605	125	Least squares measurements
Corioli	1400	1605	125	Least squares measurements
Jon	1415	1500	45	ph Abemama timbers. Cut timber sample
Patrick	Standby diver			

Total dive time: 4 hours 55 mins (295 mins)
Cumulative dive time: 21 hrs 02 mins (1262 mins)