FINAL REPORT

OMAN EXPEDITION
December 1995—January 1996

Western Australian Maritime Museum Report No. 116

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- Sur Beach Resort Motel
- Budget (Salalah)
- Thrifty Car Rental

TABLE OF CONTENTS

PERSONNEL

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Essa Habshi Juma Al Kendi	Diver
Abdulla Hadid Khalfan Al Ma'ashri	Diver
Mohammed Habshi Juma Al Kendi	Diver
Mansoor Ali Abda'razaq Al Baluchi	Diver
Rashid Humaid Salem Al Azoobi	Diver
Said Mubarek Juma	Cook
Taib Rashid Hamed A'Shuhi (Army)	Transport driver

EARTHWATCH VOLUNTEERS
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Marilyn Scowcroft

The Project wishes to thank all the staff and volunteers for their valuable input and hard work.

LIST OF ILLUSTRATIONS

FIELD REPORT
1995-96 OMAN EXPEDITION

The expedition was divided into two portions, 7-22 December, 1995 (Team I); and 28 December-11 January, 1996 (Team II), with each team having very different aims.

Three primary goals were set for the expedition:

1. To complete the documentation of the existing traditional craft, specifically the following:
   A. The sewn vessel in Raysut port belonging to His Excellency Yousef bin Alawi bin Abdallah, and said to be either a *ghanjah* or 'Salalah *sambuk*'. The vessel is significant primarily for its mode of construction (sewn) but also because nothing quite like it has been seen during this investigation either in the literature or in previous field research.
   B. The *ghanjah* on display in Sur. This vessel, the *Fatah Al Khair*, is believed to be the last remaining one of its type in the Arabian Gulf. The purchase and display of the vessel has been paid for primarily by a consortium of citizens of Sur.
2. To continue the documentation by notes and photographs the maritime graffiti in Oman.
3. To initiate, in collaboration with terrestrial archaeological teams from the CNRS (France) and IsMEO (Italy), underwater searches and surveys in the hope of discovering ancient wrecksites or artefacts.

Since these goals are dissimilar, requiring different methodologies, they will be treated separately.

DOCUMENTATION OF TRADITIONAL CRAFT

The documentation of traditional craft is important for three reasons:

A. Most traditional craft are no longer used and are rapidly disappearing. Few records of them have been made in the past. Collectively, they comprise an important historical body of vessels, with significance within the Indian Ocean region. As such, they form an important part of global maritime technology.

B. Typological characteristics of the vessels can place them chronologically and geographically within the general maritime technological development of the region. The design features they retain, the construction configurations and methods employed, their decorations, and the materials from which they are made can all indicate links and relationships with other regional cultures.

C. To date, no wrecksites of indigenous craft have been discovered, and the information on shipbuilding technologies of the western Indian Ocean is therefore sparse. Properly catalogued, these same characteristics may help identify or classify any future archaeological discoveries of shipwrecks in the region.

As the vessels themselves form a part of the historical record, so do the representations of them in the maritime graffiti found in the forts and homes as well as in the petroglyphs on cliff faces. The project seeks to continue the photographic documentation of this aspect of the historical record. Already a large number of engraved and painted images, since lost during fort renovations, have been recorded photographically.

TEAM I
7-22 December, 1995
Team I was concerned with recording the sewn vessel *Marjan Al Bahr* (Coral of the Sea) at Raysut and the *ghanjah* named *Fatah Al Khair* (Beginning of Goodness) at Sur.

Marjan Al Bahr
After flying to Salalah in the south of Oman, we were met at the airport by Muqaddam (Commander) Said Khamis Rajibon, Commanding Officer of the naval base at Raysut, and went immediately to Raysut port to inspect the vessel. *Marjan Al Bahr* is a sewn vessel, built five or six years ago (reports of building date varied) for His Excellency Yousef bin Alawi bin Abdallah, Minister of State for Foreign Affairs. Though of recent vintage, it was produced using traditional sewn boat techniques. His Excellency has generously offered the vessel to the collection of traditional boats being assembled for inclusion in the proposed National Maritime Museum of Oman.

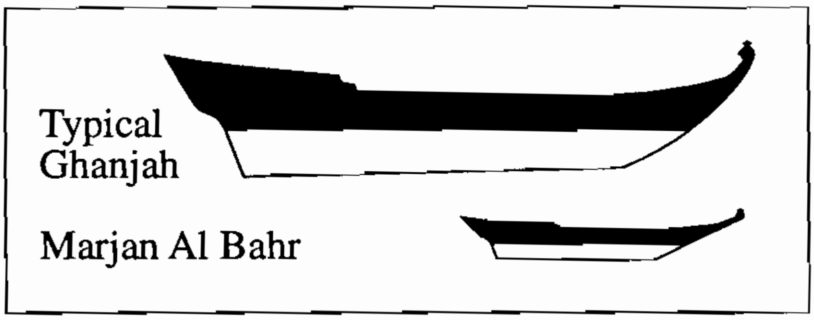

Figure 1. Comparison of hull shapes, typical *ghanjah* and *Marjan*

General Description
Marjan has been identified by Omani informants as a *ghanjah* or a 'Salalah *sambuk*'. The term *ghanjah* is firmly established in the literature on Arab seafaring as referring to large transom-stern round-bilged vessels of 23 metres (75 feet) to perhaps 36 metres (120 feet) in length with a distinctive stem head and quarter galleries (Figure 1). The straight raking stem of *Marjan* surmounted by a disk is similar to the extinct battil, while the tri-foil crest motif fixed to the top of the disk is a feature of the *ghanjah*. The transom and false quarter galleries also echo the design of a *ghanjah* but on a smaller and much less elaborate scale. Although Marjan has some features similar to a *ghanjah*, its hard chine and much smaller size of 14.2 metres (47 feet) probably preclude its inclusion within the *ghanjah* classification. The term sambuk is at least as nebulous, being variously applied to the double-ended sewn *sambuk*, or *kambari*, of the Dhofar coast, a type of open boat (now extinct) used for lightering and sardine fishing; a transom-sterned cargo vessel once common in the Red Sea and Omani coasts, having a curved prow with scimitar-shaped end; and as a generic term for 'boat'.

Basic specifications

LOA	14.200
Max Beam	3.505
Displacement	4.13 tonnes (on draught of 0.65m)

General Condition
The vessel stands on the hard at Raysut Port, unprotected from the weather and not properly supported under the bilges. Supports comprise four timbers laid athwartships under the keel, and four toms on each side, fitted under the sponson rail. The vessel has suffered from exposure and drying in the sun. The rows of holes drilled for the stitching have generated numerous cracks in the planks, parallel to the plank edges. The traditional antifouling made of rendered mutton fat and

lime is flaking off, and the coating of fish oil on the upper works is significantly weathered.

The hull is slightly twisted. It is not known whether it was built with a twist or if the twist is due to the vessel being improperly supported, but probably the latter.

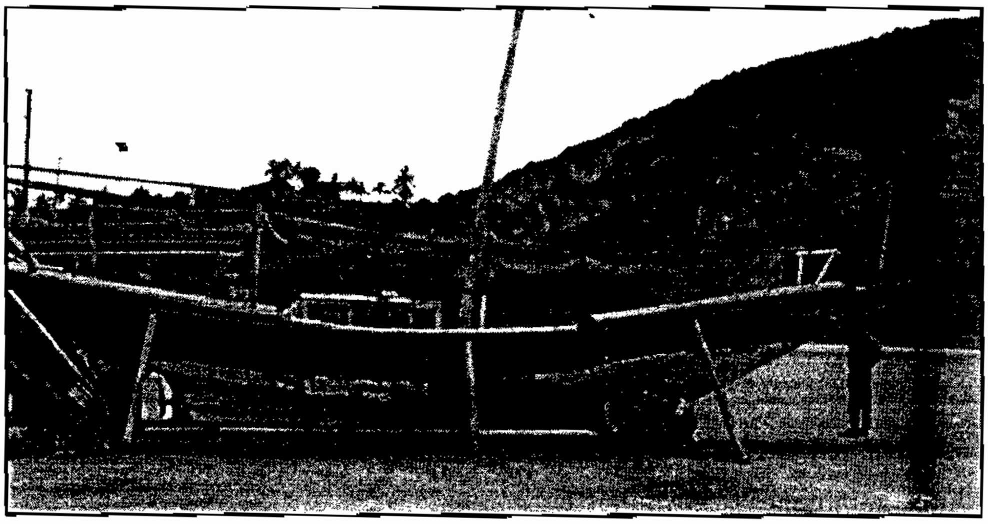

Figure 2. *Marjan Al Bahr*

Viewed from the bow, the hull is markedly asymmetric (Figure 2), the port chine being lower than the starboard. This is definitely a built feature, not a result of the vessel having been improperly supported. The lower planking (to the chine) on both sides is arranged in a complex pattern, employing drop strakes and stealers (Figure 3). From the planking pattern it is evident that emphasis was put on building the mid-sections first. Whether this was a purely technical consideration, or owes something to cultural influences is equivocal. The order of assembling plank strakes is clear from the planking pattern. Plank scarfs often create hard angles within the length of a strake, rendering the run of the bottom planking unfair. The upper strakes are continuous, fair strakes composed of planks joined with simple straight scarfs. Like all sewn boats, this vessel is shell-built, that is, the planks were assembled before frames were fitted.

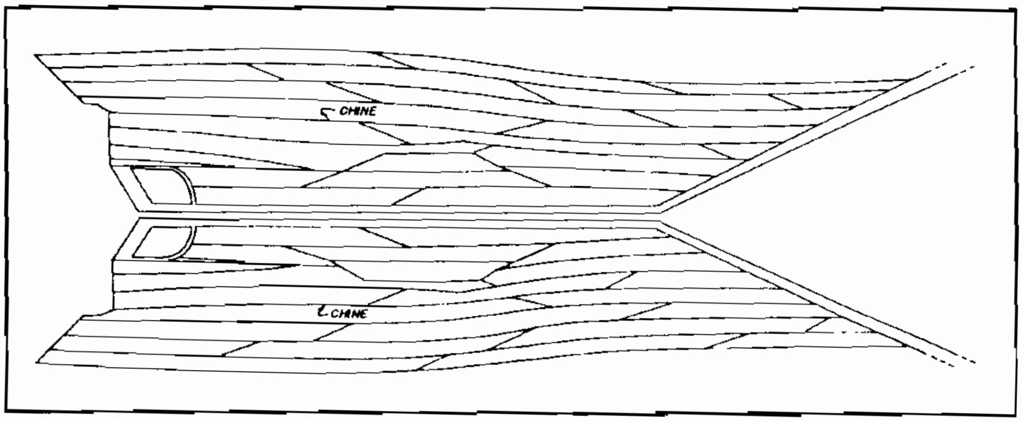

Figure 3. Planking pattern of *Marjan Al Bahr*

The hull planking is fastened by continuous sewing using coir or date palm fibre rope. We were told by one of the builders, Sbait Fail Hamus, that the rope was date palm, but coir is more commonly used in this region. Hull framing is also fastened with the same rope, lashed through holes drilled in each strake of the planking. The cap rail, inwales, inside bulwark planking and sponson (rub rail) are fastened with modern steel nails and screws, or bolts. The building of the vessel was commenced by Amal Salim Najam, and took three men four months to build. Although Sbait stated that many of these had been made, our research, both archival and in the field has never discovered another. It could be that all have disappeared, though this is unlikely to have happened without any reference or graphic representation in the literature, or that Sbait meant that many hard-chine sewn boats had been made locally, which is certainly true.

Examination of the macro features of the hull planking suggests it is mango wood (*Mangifera indica*) but no samples were taken to enable positive identification. This species would be consistent with the hull planking material normally used in this region. However, Sbait stated that the planking timber was *faini*, from Dubai. As no timber originates in Dubai, it would clearly be a species imported through Dubai. The name *faini* may be a corruption of *aini* (*Artocarpus hirsuta*), an Indian timber commonly used in boat building.

Propulsion

The vessel is fitted with a large diesel engine, one mast and one sail. The engine occupies a great deal of space under the deck. A propeller shaft fitted with a three-blade propeller is fitted through the horn timber, within an aperture ahead of the sternpost.

The sail has been grossly effected by exposure and is in very poor condition. The rigging, of polypropylene, has been damaged by extended exposure to the ultraviolet radiation in sunlight and has also perished.

Hull Measurement

A measurement grid was laid off in chalk lines on the hard surface under the vessel. The grid comprised a datum line (directly under and parallel to the lower arris of the keel, port side) and perpendicular stations set at one-metre intervals. The forward extremity of the stem was designated as the "0" point of the grid for station measurements.

The hull was measured on its starboard side using two methods:
1. Direct offset and height measurement by tape measure, using the baseline as "0" for offsets and the hard surface as a "0" for height measurements.
2. Electronic measurement by EDM (Electronic Distance Measuring), the EDM device being mounted on a theodolite to measure horizontal and vertical angles. A prismatic reflector fixed to a conical mount with the optical centre 150 mm from its apex was used as a target for the infrared EDM beam. The apex of the target was held at selected positions (the gunwale and each plank seam at each station, as well as extremities and key profile points) and the distance, vertical and horizontal angles recorded for each position. Two reference points, one at each end of the baseline were also recorded.

The data gathered from the two surveys was then read into a Power Mac 7200 computer, using the Maxsurf naval architecture software. The software allowed the creation of a lines plan for the vessel (see Appendix A).

Calculations of stability and hydrostatic data were then done, based on the computer-generated hull surface. These calculations appear in Appendix A.

As the vessel is not symmetrical, the under body of the port side was also measured, from the keel rebate to the chine, using the tape measure to log the offsets and heights of plank seams at each of the stations 6 through 11.

Construction

Marjan was shell-built, that is, the planks were assembled before the frame timbers were fitted. For sewn construction there is no other way, as it is impossible to sew plank seams which are hidden behind frames. This method of hull construction, in which the shape of the individual planks dictates the shape of the vessel, was employed almost universally worldwide for centuries. In some regions (such as the western Indian Ocean, south-east Asia and northern Europe) it is still widely used. This hull-first system was used in Mediterranean boat construction during the Bronze Age and classical times, as well as in ancient Egypt and Mesopotamia. Thus, the system used for building *Marjan* has an ancient lineage.

Recommendations

Hull support. Of primary importance is the proper support of the hull. A cradle designed to support the keel, bilges, and topsides is required. Due to the complex pattern of planking, the lack of fairness in the strakes, and the asymmetry of the hull, the drawings give only an approximation of the hull shape. Some adjustment to the cradle will be required to fit the hull for safe transport and display.

Ali Ahmed Mahash Al Shahri

One of the highlights of our time in the Dhofar region was an evening spent with Mr Ali Ahmed Al Shahri, who for the past eight years has been conducting independent and self-funded research into the ancient rock art of the region. We visited Mr Ali at his home, and found rooms packed with artefacts, photographs of the rock art, computer equipment, and on-going experiments aimed at discovering the ancient formulae used to make the paints and pigments used in the rock art. Among the innumerable examples he displayed for us several representations of ships which are dated to the Iron Age. In addition to documenting the rock art and attempting to analyse its chemistry, Mr Ali is striving to decipher the ancient script.

Fatah Al Khair

Background

Built in Sur in 1949, the *Fatah Al Khair* (Figure 4) is possibly the last remaining *ghanjah* in the Gulf. For nearly half a century this vessel traded in the Gulf and western Indian Ocean, sailing to Aden, Mombasa, Dar As Salaam, Zanzibar, Malindi, Mogadishu, as far south as Mozambique, and to the north through Hormuz to Kuwait, Doha, Bahrain, Basra, and other Gulf ports, across the Indian Ocean to Karachi, Bombay, Goa, Calicut, Trivandrum, and to Sri Lanka, as well as a number of other ports in the region.

The trading season started from August and lasted for nine months, with three months reserved for maintenance during the south-west monsoon season. The cargoes were generally foodstuffs or timber: Iraqi dates from Basra to India, Omani dates, salted shark, kingfish, tuna from Sur to Africa, returning with mangrove poles, sesame oil, coconut oil and coffee beans. Of the fish, kingfish was the most important. On one passage to Africa, 22,000 kingfish were taken. They were loaded on the Al Jazir coast, then taken to Sadh or Mirbat to dry (as there is the best climate for this) before shipping to East Africa.

Initially rigged as a two- masted sailing vessel, four years after launching *Fatah Al Khair* was fitted with a 400 horsepower diesel engine.

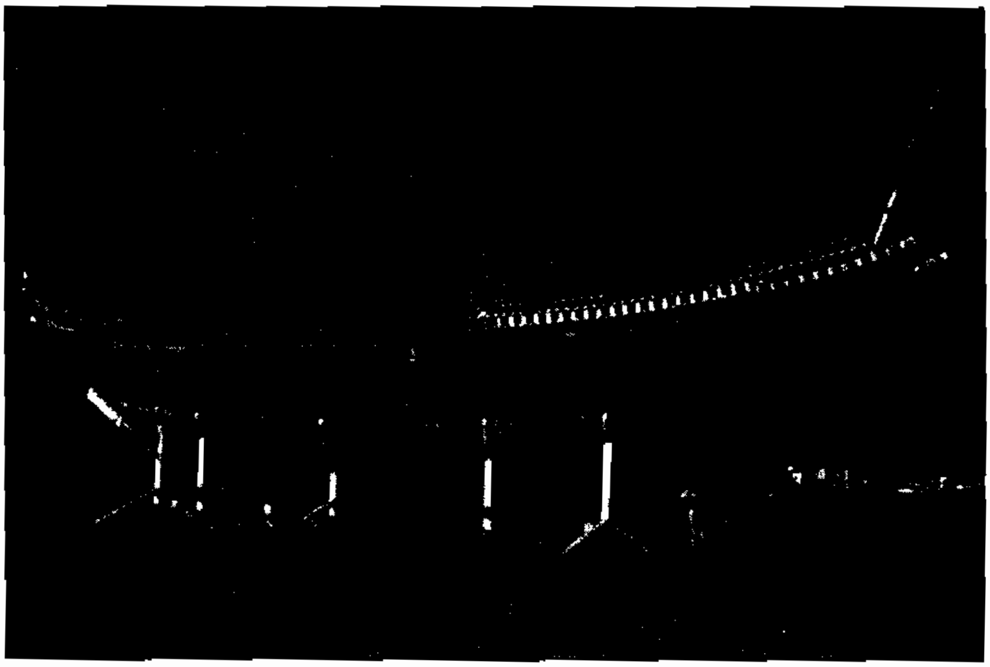

Figure 4. *Fatah Al Khair* on display in Sur

In 1993 a consortium of citizens of Sur had been formed to raise capital, which, combined with funds form the government, enabled the purchase, restoration and display of the ghanjah. It now stands on reclaimed land extending into the inlet at Sur.

During the 1994 season our Earthwatch team had attempted to completely document the ghanjah, However, at that time, workers were swarming all over the vessel, building a cradle around it and preparing it to be moved from the water to the reclaimed land where it now stands. After three days of competing with the local workers, we abandoned the effort until this year.

Hull Measurement

A base line (a level, taut string) was set up 29.535 metres from the hull, parallel with the keel. The distance from the hull was somewhat arbitrary, but was chosen because it provided a good view of the entire hull and enabled the stringline to be easily set up over the hard surface of the walkway surrounding the hull. A 50 metre tape measure was laid along this baseline. The EDM was then set up at successive intervals along the baseline. At each position, a plumb bob suspended from the EDM made certain that the height of the EDM remained constant in relation to the level string line, and that the exact longitudinal position of the EDM along the baseline could be noted. No attempt was made to keep the intervals along the baseline identical, rather the EDM was set up and each position accurately recorded. Enough measurement stations to adequately record the vessel were all that were necessary. At each measurement station, an angle sight was taken along the baseline, then the instrument swung 90° toward the vessel, so that the line of sight to the vessel was always perpendicular to the baseline and thus to the longitudinal centre-line of the vessel.

TEAM II
28 December, 1995-11 January, 1996

Objectives:
The primary aim of Team II was to conduct underwater surveys of Khawr Al Jaramah, Khawr Al Hajar, and the nearby coast. The two khawrs are situated near Ra's Al Hadd, the easternmost point on the Arabian peninsula. Numerous archaeological sites, dating from Neolithic through recent times, have been discovered in this region, with sites from the fourth, third and second millennia BCE being common. It was hoped that, with the plethora of sites on land, the sea might also yield some discoveries. We intended to search for evidence of sunken vessels, artefacts, or any clues to human maritime activity.

By mutual agreement, Team II was to work closely with elements of the Diving Unit of the Royal Navy of Oman, and with a team of French and Italian terrestrial archaeologists from the Joint Hadd Project. The RNO Diving Unit had set up camp at the designated base, the turtle sanctuary at Ra's Al Junayz, a day ahead of our arrival (Figures 5 and 6). They had provided eight divers, a compressor, two rubber boats, air tanks and various other diving equipment, a large mess tent and—very important—a cook. The Omanis had also come armed with musical instruments (drums and an *oud*) and a great deal of enthusiasm. In addition to their excellent diving skills, their nightly musical performances contributed a welcome ethnicity to the camp routine.

The Surveys:
Maritime archaeology faces a number of problems, not the least of which is actually locating a significant site. In the Mediterranean Sea this is not too much a problem, as seafaring activity has been intense for thousands of years, and many of the wreck sites are marked by their cargoes of amphorae or metal ingots. Though certainly numerous, indigenous wrecksites in the Arabian Gulf offer few advantages for being discovered. The cargoes of the vessels were often perishable—horses, agricultural products, wood, incense, for example. Rarely were goods shipped in large amphora-like ceramic containers, which might survive and mark a wreck site.

The warm waters of the Gulf promote biological and chemical activity, which accelerate the destruction of organic and metallic remains. The generally high rate of sedimentation near the mouths of wadis where ancient harbours, villages and anchorages might logically be situated, means that early remains are likely to be deeply buried. While the deposition of silt would tend to preserve artefacts, it also makes finding them difficult. Faced with these problems, the discovery and identification of sites are formidable undertakings.

Camped at Ra's Al Junayz, the first problem we encountered was the weather. Unusual heavy rain flooded the wadis and coastal plains, bogging vehicles, cutting some roads, making driving difficult and challenging. Worst of all, the sedimentary runoff from the flooding rendered the visibility in the water of the inlets virtually nil. We lost two entire days of diving due to zero visibility.

When diving did commence, keeping all the non-divers engaged was somewhat problematical. It had been hoped that the discovery of artefacts underwater might keep the non-divers well occupied with cataloguing and on-site conservation duties. However, as the divers were finding nothing but modern artefacts, this was not the case. We were able to employ non-divers in the roles of navigat-

Figure 9. The stone anchor shank from Shiya

channel clean of anything of interest. The bottom comprised barren sand, with occasional small rocks.

For the second survey, it was decided to examine the shores just inside the entrance to the khawr. On the eastern side of the entrance is a twin-headed bay, divided by a rocky outcrop (Figure 6). The northern head is very shallow, while the southern part drops off more quickly. Much of that southern shore is a cliff face, which joins the cliff of the main channel. A 300-metre jackstay was dropped in six metres depth inside the southern half of the bay, and run out toward the main channel. On reaching the main channel, the jackstay turned south, to run parallel with the eastern shore of the channel. Each 100-metre section of the jackstay was marked with a float attached to a riser. The jackstay depth in the main channel was approximately sixteen metres. Currents flowing at differing rates played havoc with our attempts to keep the swimline perpendicular to the coast and jackstay. Again, nothing of interest was found.

In a cove on the Indian Ocean shore, about five miles north of Ra's Al Jinns (Figure 6), a stone anchor (Figure 7) had been discovered in 1994, and recovered by the Earthwatch team in December that year. Believing the anchor might be an indicator for a wrecksite, we decided to survey the cove. But again, nothing of interest was found during a sweep of the shore to approximately 100 metres offshore (Figure 6).

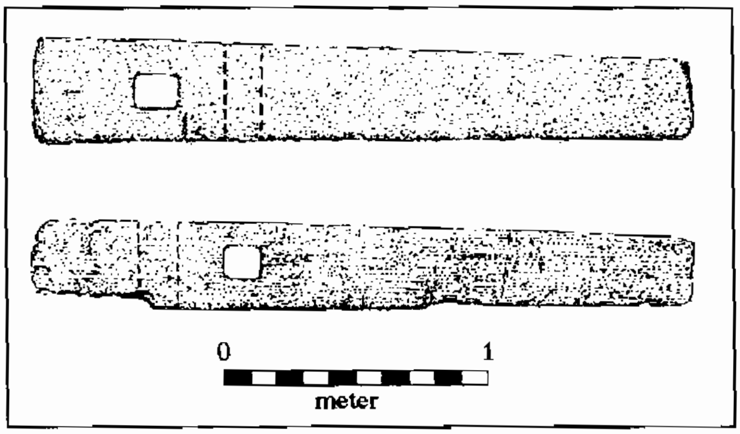

Figure 10. Limestone anchor shank from Shiya

On the bluff above the western shore of the entrance to Khawr Al Jaramah, a fourth millennium BCE site was noted. During its occupation, this site would have been visible from far out at sea, and may have acted as a beacon or landmark for ships returning to the khawr. From a base established on the beach below this site the waters of the western shore were then surveyed (Figure 6), but without any significant discoveries.

Surveys were undertaken along the coast between Khawr Al Jaramah and Khawr Al Hajar. For the first of these a 300-metre jackstay was laid off the western headland of Khawr Al Hajar. Depths ranged from six to twelve metres. Visibility was about four metres. Six divers covered a path some

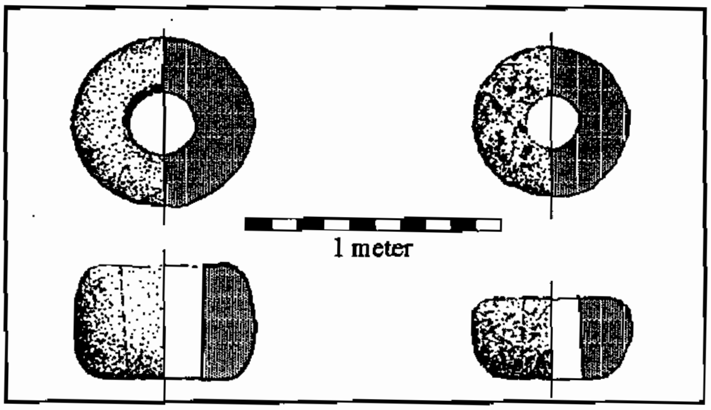

Figure 11. Ringstones from A'Sulayb (left) and Shiya

20-22 metres wide along the jackstay, about 40 metres from the shore. Meanwhile, one person snorkelling carefully examined the shallows along the rocky shore. On the following day a second survey was done, commencing where the previous one had ended and extending to the entrance of Khawr Al Jaramah.

January 5 was used for rest and recreation, the teams driving south to the Wahiba Sands. We had intended to drive as far as the giant dunes, but with the expedition leader insisting on a little 'recon' work on the way, we ran out of time. During reconnaissance, we were shown a tall 'ringstone' (Figures 8 and 11) which had been recovered from the sea by the local people at A'Sulayb. The stone was located at A'Seelah, a few kilometres from A'Sulayb, having been spirited away from A'Sulayb by villagers. A number of theories of what it might be were put forward by locals and team members. These suggestions included a mast step, counterweight, part of an anchor, and 'collar' for a well. None of these conclusions offered a satisfactory answer. See below for further discussion.

Badan at Al Ashkharah

During the reconnaissance it was also discovered that the four cargo *badan* on the beach at Al Ashkharah had been burned. There now remains in Oman only one well-preserved example of this type of vessel (the *Al Khammam* on Masirah island).

Stone anchor shank and ringstone

Three days before the end of Team II's time, we were shown a large stone anchor (Figures 9 and 10) on the beach at Shiya, near Sur. This anchor had been dragged up the beach by the local people, from just below the low water mark. It had been discovered about three years ago after a storm, which had stripped away the sand that buried it. Its original position (taken by GPS and averaged from two readings) was:

7-68-912 E
24-97-313 N

About a kilometre and a half north-west of the anchor site, another ringstone (Figure 11) was located in the inter-tidal zone. The GPS Position (averaged from two readings) was:

7-67-582 E
24-97-464 N

The object was made from a red-orange stone, as yet unidentified. With the reluctant permission of the villagers, the stone anchor was recovered for transport to Muscat. At the same time the team recovered the ringstone, to transport to Muscat for further study. It is hoped both objects will eventually be displayed in the proposed maritime museum.

The stone anchor, technically the shank of an anchor, is of the standard Indian Ocean type—a monolith rectangular in section, with rectangular holes (thought to have held wooden arms) cut through the lower end, perpendicular to each other. The sedimentary rock bore chisel marks on all six faces, and inside the perpendicular holes. A major difference with others of its type, however, was the absence of a round hole at the upper, narrow end. Clearly, this was either not a finished anchor shank and had never functioned as such, or had been broken. Others without the hole at their upper end have been reported in the past, but on this one the chisel marks on all faces were identical, probably indicating all the shaping had been done at the same time. Perhaps it had been used as ballast, not as an anchor. But its proportions, when compared to other complete ones of similar size, seem to indicate that it may have been broken. At an estimated 640 kg, it was considerably larger than the one recovered in 1994, which weighed approximately 260 kg.

When they are not discovered in archaeological context, it is difficult to date this type of anchor, as its use has a very long history. There are two fragmentary specimens which have been excavated in Siraf (Whitehouse, 1970:140), one of which is stratigraphically dated to no later than the 8th century and the other to the 11th century. Another shank has been discovered near a Red Sea wrecksite (Lone Mushroom site) in association with medieval pottery (Raban, 1990:302-303). Although the use of large stone anchors in the region is attested until recent times and small ones (of different design) are still in use today, most of the stone anchor shanks discovered in the western Indian Ocean (there are approximately twenty-five known) probably are of great antiquity.

The purpose of the ringstone remains a mystery. It is similar to the one found at A'sulayb (now at A'Seelah), and to another reported in 17 metres of water off Qalhat, and to several excavated at the Indus Valley civilisation site of Mohenjo-daro. As at least one at Mohenjo-daro was inscribed, archaeologists have speculated that these stones could be calendar stones, or perhaps anchors (Cleuziou, personal communication). It is curious that both the ringstones the team inspected have slightly tapered axial holes. The taper has not been reported in the ringstones from Mohenjo-daro; but whether this is from its being overlooked or actually not present is not known. It might be logical to assume that the ringstone was intended to fit over or onto a tapered shaft of some sort. In view of the fact that all three known in Oman were in a maritime context when discovered, the anchor hypothesis seems reasonable, though they may have equally been cargo or some unknown piece of equipment. Further research is needed.

Conservation Support:

In the event of the discovery of historical maritime archaeological material, preservation procedures were to be carried out by an appropriately experienced conservator. This role also included observation-based assessments of the underwater environment in the region where wreck or other sources of material may be found. The presence of any man-made or worked materials, historic or recent, would be assessed in terms of condition as a guide to corrosion and bio-deterioration in the coastal waters of Oman.

As this report has already mentioned, and despite a considerable amount of searching, no underwater sites, wrecks or otherwise were found. The only man-made objects discovered underwater were small multi-pronged anchors of modern manufacture and fishing nets. The ferrous construction material of these anchors exhibited moderate corrosion with little concretion formation suggesting recent loss, and indicating current-driven sand and water blasting. Modern fishing net materials were discovered in good condition and will persist for many years. No wood was seen underwater. Unless sunken vessels are rapidly buried then the traditional fastening techniques used in the region are likely to result in a relatively quick break-up. The accelerated biodegradation of wood in the warm waters off the coast of Oman and the relatively strong currents experienced in the area of investigation result in rapid breakdown and dispersal of wood. In searching for evidence of man-made or worked materials underwater the divers were briefed to look for mainly ceramics and objects made of stone, in particular stone anchors, and advised to look for regular shapes which would contrast quite markedly with the general underwater terrain.

Much of the underwater area investigated was aligned along low cliffs which resulted in a consequent steep underwater slope. As the incline of the slope decreased towards the seabed it was transformed into a series of sand and marine debris-filled pockets defined by rock formations and boulders. Rock substrates were frequently covered in masses of soft corals which disguised all small-scale features. This type of seabed was very difficult to search with any consistency despite the use of several divers on a swim-line. Close to the cliff-line pockets of water-worn stones were discovered which without other evidence provided no clue as to whether some stones were derived from the ballast of wrecked vessels.

The locations where underwater searches took place were selected on the potential for finding traditional watercraft of the Indian Ocean nations trading with Oman. The perishable cargoes of these vessels and non-metal construction methods used would leave little evidence unless rapid burial and preservation occurred after sinking. If European vessels were lost in the area investigated the chance of discovery would improve markedly.

Ring Stones and a Stone Anchor

The earlier recovered ringstone (at A'Seelah) and anchor (Shiya) appeared to be in good condition despite the anticipated potential for exfoliation should salts have permeated the stone. In addition the alternating wet and dry environment of the inter-tidal zone would be expected to promote disintegration. At this stage accurate identification and determination of the permeability of the stone used to make the objects has not been made. Perhaps long standing traditional use of specific types of stone for these purposes has led to the discovery of stones tolerant and/or impervious to salt damage.

As a precaution desalination of the second ringstone (recovered from the inter-tidal zone at Shiya) was advised before allowing prolonged drying.

Future Conservation work in Oman

The discovery of underwater sites in Oman will allow a more thorough and scientific interpretation of the effects on materials subjected to the prevailing environmental conditions. In this event an environmental assessment will be carried out on-site in conjunction with the acquisition of corrosion data and bio-deterioration studies.

The Forts

At the end of the expedition the forts of Bayt Al Na'aman, Jabrin and Hazm were visited. Visits to the forts were primarily aimed to discover and record ancient graffiti, specifically relating to maritime themes (see below under Photographic Support). In conservation terms it was noted that the graffiti is vulnerable to some aspects of tourism, deliberate/accidental touching and defacing by modern graffiti. Repair and restoration of the forts does frequently result in covering and/or obliteration of ancient graffiti. The structure of some forts is at risk as exfoliation of building fabric is occurring from rising ground water.

It was noted that Hazm Fort has been completely restored and the graffiti recorded by the expedition during 1994 no longer exists. It was inevitable that the graffiti would be destroyed during the restoration and it is fortunate that the documentation of a large portion of the maritime graffiti had been done by this project in 1994 prior to the completion of the restoration program.

Photographic Support:
Colour photographs taken in January 1996 by Patrick Baker and Jon Carpenter have been filed in the W. A. Maritime Museum Photographic Archive under the following numbers:-

Colour transparency collection - OM/1321-2029

Video recording (Hi8 format) was undertaken by Jon Carpenter, and also filed in the W. A. Maritime Museum Photographic Archive under the following numbers:-

MA (Hi8) 139 - 142.

Graffiti Photography
During the 1993-4 expedition ship illustration graffiti was recorded at a number of locations. In 1996 two of these (Bayt al Na'aman and Jabrin) were revisited to enable Patrick Baker to experiment with more refined photographic techniques.

At Bayt al Na'aman the incised ship illustrations were illuminated by a powerful (500 watt) wide angle beam floodlight, which enabled the viewer to see the effect and then photograph it. Light was introduced from a variety of directions, usually at a strongly oblique angle, to gain the maximum visible detail. 35mm photography, with fine grain black & white and colour slide films, was carried out, using wide angle and macro lenses. Direct TTL metering gave accurate exposure.

The technique was very effective. However the lamp used was mains-powered and the power supply at the forts erratic or non-existent. It would have been preferable to use a battery-powered cine light ("Sun gun").

At Jabrin the painted graffiti was often obscured by overlayers of paint or soot. It was hoped that the use of Infra-Red film would give a clearer differentiation of the illustrations. On the occasion that the experiments were undertaken it was only possible to use fairly low levels of existing natural light. A Tungsten Halogen floodlight, being rich in Infra-Red, would have been preferable and possibly more effective.

Konica IR 750nM film with Red (Wratten #25) and Infra Red (Wratten #87) filters was used, the film being rated at 25, 50 and 100 ISO, and developed in Kodak Tmax Developer for twelve minutes @ 20°C,1:9 dilution.

Prior experimentation was necessary to determine camera exposure. Despite the visual opacity of the Infra-Red transmission filter the built-in TTL metering (Auto setting) of the Nikon FE2 and Olympus OM2 cameras used was able to be used, with a x2 factor (e.g. 25 ISO instead of 50 ISO), plus "bracketing" of +1 and -1 stops.

There was some increase in definition when the Infra-Red photographs were compared with conventional monochrome and colour photographs of the same subjects although no "hidden" graffiti was detected. However, it is difficult if not impossible to anticipate the infra red reflectance of materials and surfaces by visual inspection. It is therefore recommended that Infra Red photography is undertaken in addition to conventional photography whenever it might be of benefit.

Publications:

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Other Accomplishments and Benefits:

The project is pleased to note that work done over the past four years has raised the public awareness within Oman of traditional craft, and contributed significantly to a revival of interest in preserving and using the craft. Corporate donations have enabled the project to purchase three vessels for and on behalf of the Omani people. A fourth, the *Marjan Al Bahr* mentioned above, has been donated to the project by its owner, His Excellency Yousef Al Alawi, Minister of State for Foreign Affairs.

Acknowledgments:
The Royal Navy of Oman provided invaluable assistance in the form of technical and logistical support. We are most grateful to His Highness Shihab bin Tarek bin Taimur Al Said, Commander of the Royal Navy, to Mqm Tom Hammon, to the members of the Diving Unit, and its commander, Raa'id Bob Nankivell, and to Raa'id Rukn Bahry Khamis bin Humaid Al Araimi.

Funding for the expedition was provided by Earthwatch and its EarthCorps of volunteers, Omani companies and individual staff contributions. Our thanks also to all the people who helped in so many ways in the planning, running and support of the project, including Raa'id E M Roles, Mqm Steve Bennett, Mqm Said Khamis Rajibon, Wakeel Richard Honeychurch, Mr Ahmed Bahwan, Sheikh Nasser bin Hamed bin Khalfan Al Mukheini, Mr Tariq Ahmed Al Sutohy, Ms Marcia Dorr, Mr Neil Richardson, Ms Antonia Goddard and Ms Amanda Morwood.

Bibliography:
Raban, A., 1990, Medieval anchors from the Red Sea, *International Journal of Nautical Archaeology,* **19**.4.
Whitehouse, D., 1970, Excavations at Siraf, second interim report, *IRAN* **8.**
Whitehouse, D., 1970, Siraf: a medieval port of the Persian Gulf, *World Archaeology,* Vol 2.

APPENDIX A

Marjan Al Bahr
Lines Plan
Calculations
Curve of Areas
Hydrostatics
Hull Resistance/Speed

The **Lines Plan**, shown in three views, describes the general hull shape of the vessel. The hull has been 'sliced' by imaginary planes which intersect with the surface of the hull, the edges of which show in the three views, much like contour lines on a map. The horizontal planes are called Waterlines, and appear as curved lines in the Plan View. The vertical planes are called Buttock Lines, and appear as curved lines in the Profile View. The Waterlines (planes) and the Buttock Lines (planes) are equally spaced, 0.5 meter apart. The Section Lines, in the athwartships plane, are spaced 2 meters apart, and they appear as curved lines in the Body Plan View. The spacing of Waterlines, Buttock Lines and Section Lines are represented by the grid of straight lines encompassing the vessel in each view.

The plan was drawn from the measurements recorded during the EDM survey of the vessel.

The **Calculations** are determined by a number of formulae, in reference to the hull form and the designated waterline. These calculations give indications of the stability, cargo capacity, speed potential, powering requirements and general characteristics of the hull. The results we are primarily interested in are the length waterline, hull draught, displacement, wetted surface, prismatic coefficient, and GM transverse.

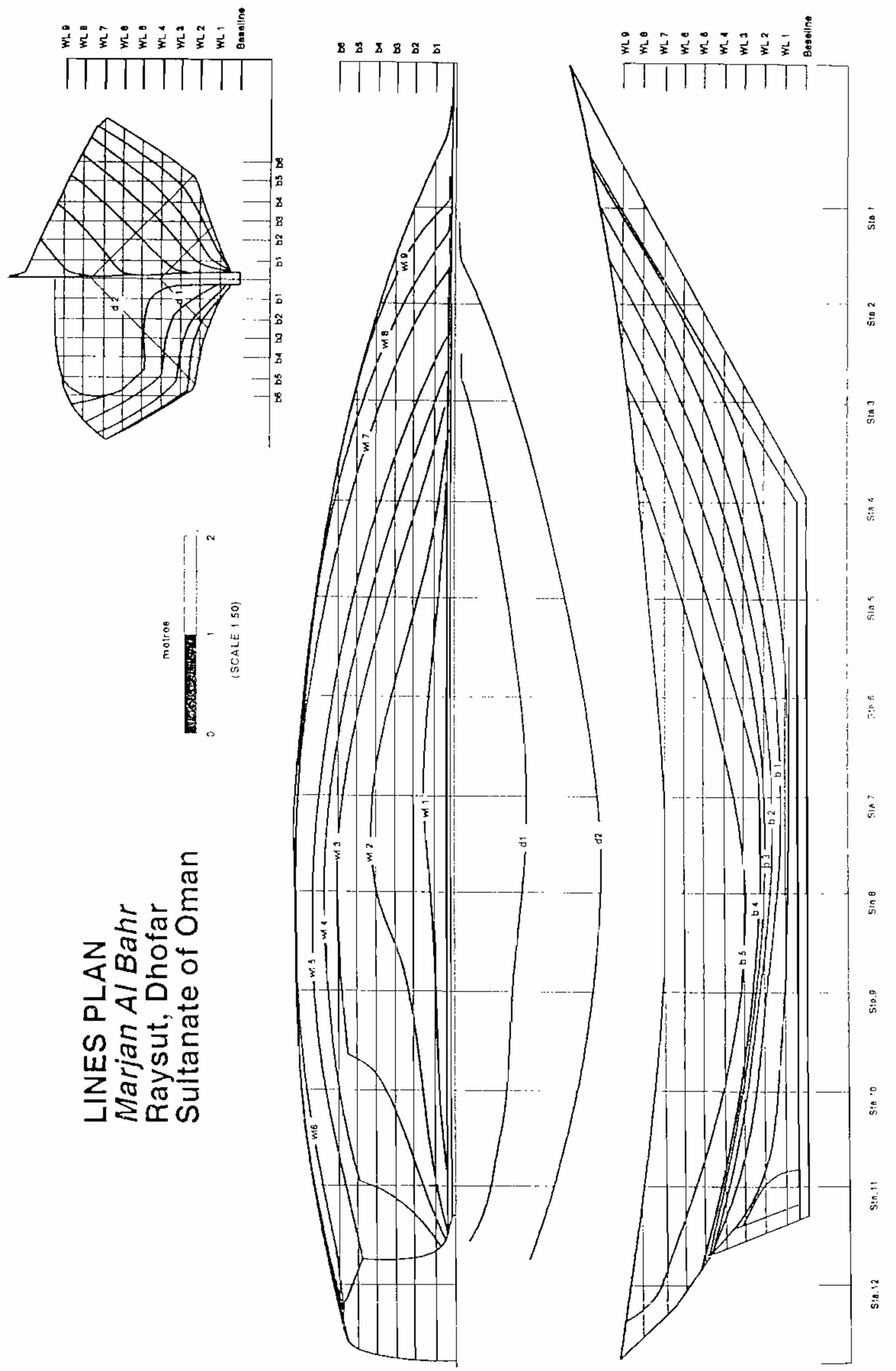
1. Length waterline: helps to predict speed potential. Roughly speaking, with displacement hulls (like *Marjan Al Bahr*) the longer the waterline, the faster the boat.
2. Hull draught: indicates the depth of the hull below the designated waterline.
3. Displacement: indicates powering requirements, and when combined with calculations of the weight of hull and rig, provides information on the cargo capacity (dead weight tonnage).
4. The wetted surface is the total immersed surface area for the given waterline. Because the surface area creates friction (and therefore drag) the power required to move the vessel is directly related to the immersed surface area.
5. Prismatic coefficient (C_p) is an indication of the fineness or bluntness of the hull shape. *Marjan Al Bahr* has a C_p indicating a fine hull that would probably be easily driven, but provide little space for cargo.
6. GM transverse is the metacentric height, which provides an indication of the stiffness and stability of the hull. At over a metre, the GM indicates a rather stiff hull, one that would carry sail well and provide good stability.

The **Curve of Areas** is a graphic representation of one of the calculations, that is, the distribution of the volume of displacement along the length of the hull. The Curve of Areas can be a useful indication of the handling characteristics of the hull. In the case of *Marjan Al Bahr* the distribution appears largely symmetrical, but with a sharp bulge just aft of amidships.

Under the heading of **Hydrostatics**, is shown a **Stability Curve**, which gives a general indication of the stability of the vessel. The Stability Curve is very steep, peaking at about 56°. This indicates a very stiff vessel, likely to have a lively motion. The **Downflooding Angle**, at 78°, means the vessel begins taking on water through the main hatch at this angle. In reality, the probable shifting of cargo or ballast would likely occur much earlier. Free surface water inside the vessel would also introduce an instability factor, which would make the vessel less stable than indicated by the shape of the curve beyond 78°.

The **Hull Resistance/Speed** graph is calculated on a set of parameters called 'Delft 3', which are suited to displacement-type sailing hulls. The graph provides a guide to maximum hull speed and probable average cruising speed of the vessel. This graph shows a hull easily driven to about six knots. After this speed is reached, the resistance (and therefore power required to drive the vessel) increases rapidly. It is clear that about twice the power is needed to drive the vessel at eight knots as at seven.

The theoretical 'maximum hull speed' of a displacement (non-planing) vessel is given by the formula Hull Speed (knots) = $2.5\sqrt{\text{Waterline Length (metres)}}$. For *Marjan*, this theoretical maximum hull speed is $2.5\sqrt{8.865} = 7.44$ knots, a figure that agrees fairly well with the graph. *Marjan Al Bahr* would probably sail easily at five-six knots.

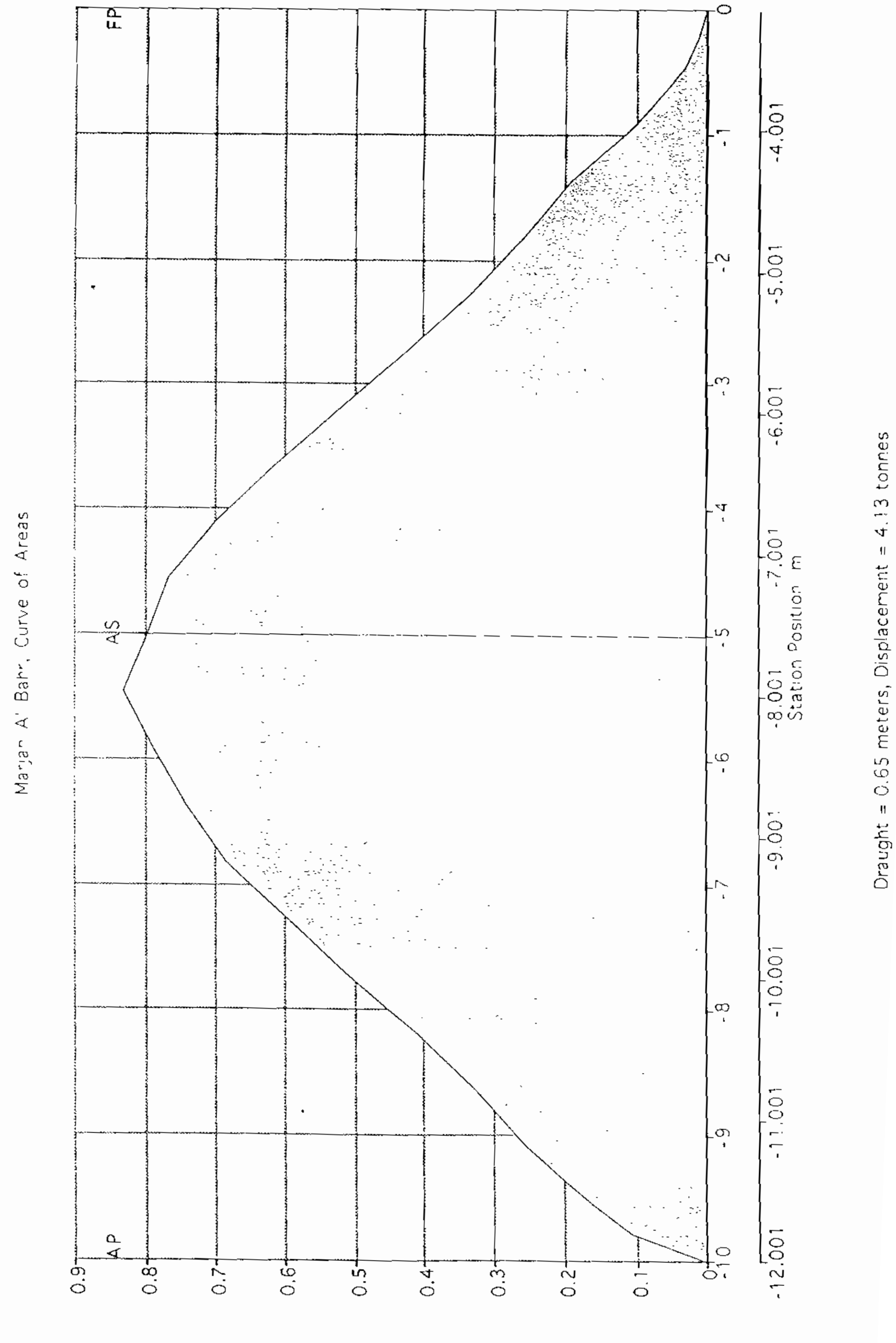

LINES PLAN
Marjan Al Bahr
Raysut, Dhofar
Sultanate of Oman
metres
0 1 2
(SCALE 1:50)

Marjan Al Bahr, Calculations

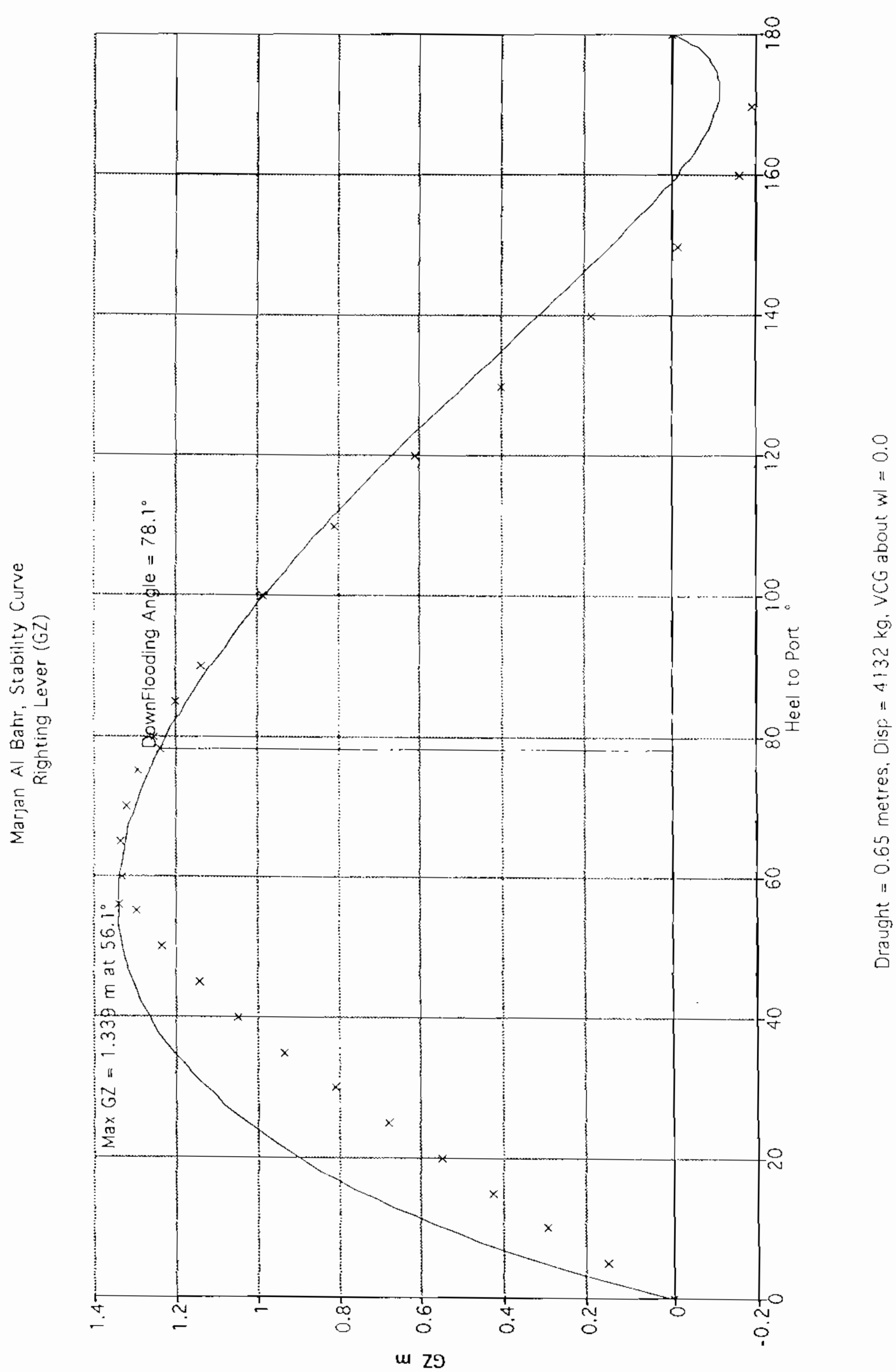
```
$*******************************************
$*
$*
$*
$*
$*
$*      THESE CALCULATIONS REQUIRE UNITS TO BE SET TO METRES
$*          ***************************************
$*
$*******************************************

$ CALCULATE INTERMEDIATE RESULTS HYDROSTATICS
$************************************
v1=((sa0+sa10)*0.5)+((sa1+sa9)*1.5)+((sa0.5+sa3+sa5+sa7+sa      13.642
v2=(v1*Spacing)/3                                                 4.031
Lb=sa0.5+(sa1*1.5)+(sa2*8)+(sa3*6)+(sa4*16)+(sa5*10)+(sa6        73.407
b1=((wlb0+wlb10)*0.5)+((wlb1+wlb9)*1.5)+((wlb0.5+wlb3+wlb!       48.086
Vb=(((sa0*cav0)+(sa10*cav10))*0.5)+(((sa1*cav1)+(sa9*cav9        -2.697
ws=((igir0+igir10)*0.5)+((igir1+igir9)*1.5)+((igir0.5+igir3+igir 65.611
ts=((tgir0+tgir10)*0.5)+((tgir1+tgir9)*1.5)+((tgir0.5+tgir3+tgi 129.259
Lm=dr0.5+(dr1*1.5)+(dr2*8)+(dr3*6)+(dr4*16)+(dr5*10)+(dr(        94.908
Lp=((dr0+dr10)*0.5)+((dr1+dr9)*1.5)+((dr0.5+dr3+dr5+dr7+dr       17.873
Lf=wlb0.5+(wlb1*1.5)+(wlb2*8)+(wlb3*6)+(wlb4*16)+(wlb5*1(       265.187
L  =spacing*10                                                    8.865


$ CALCULATE FINAL VALUES HYDROSTATICS
$*****************************
Length water line               m = L                             8.865
Max cross section            sq m = maxa                          0.798
Hull draught                    m = maxd                          0.669
Beam waterline                  m = maxb                          2.454
Displacement                   kg =  v2 * 1025                 4131.980

LCB aft of st0                  m = (Lb/v1)*Spacing               4.770
LCB  as percentage                = 10* (Lb/v1)                  53.810
VCB   below dwl                 m = Vb/v1                        -0.198

Waterplane area              sq m = b1*Spacing/3                 14.209
LCF aft of st0                       m = (Lf/b1)*Spacing          4.889
LCF as percentage                 = 10*(Lf/b1)                   55.149

Lateral plane area           sq m = Lp*Spacing/3                  5.281
Centre Lateral area aft st0 m = (Lm/Lp)*Spacing                   4.708


Wetted surface area          sq m =  ws* Spacing/3               19.388
Total surface area           sq m =  Ts* Spacing/3               38.196
Sinkage               kg per cm = (b1*Spacing/3)*10.25          145.647
Prismatic coefficient             =  v2/ (MaXa*L)                 0.570
Block coefficient                  =  v2/(L*maxb*maxd)            0.277
Water plane coefficient           =  b1/(30*maxb)                 0.653
Midship area coefficient          =  maxa/(maxb*maxd)             0.486
Lateral plane coefficient         = Lp/(30*maxd)                  0.890
```

Marjan Al Bahr, Calculations

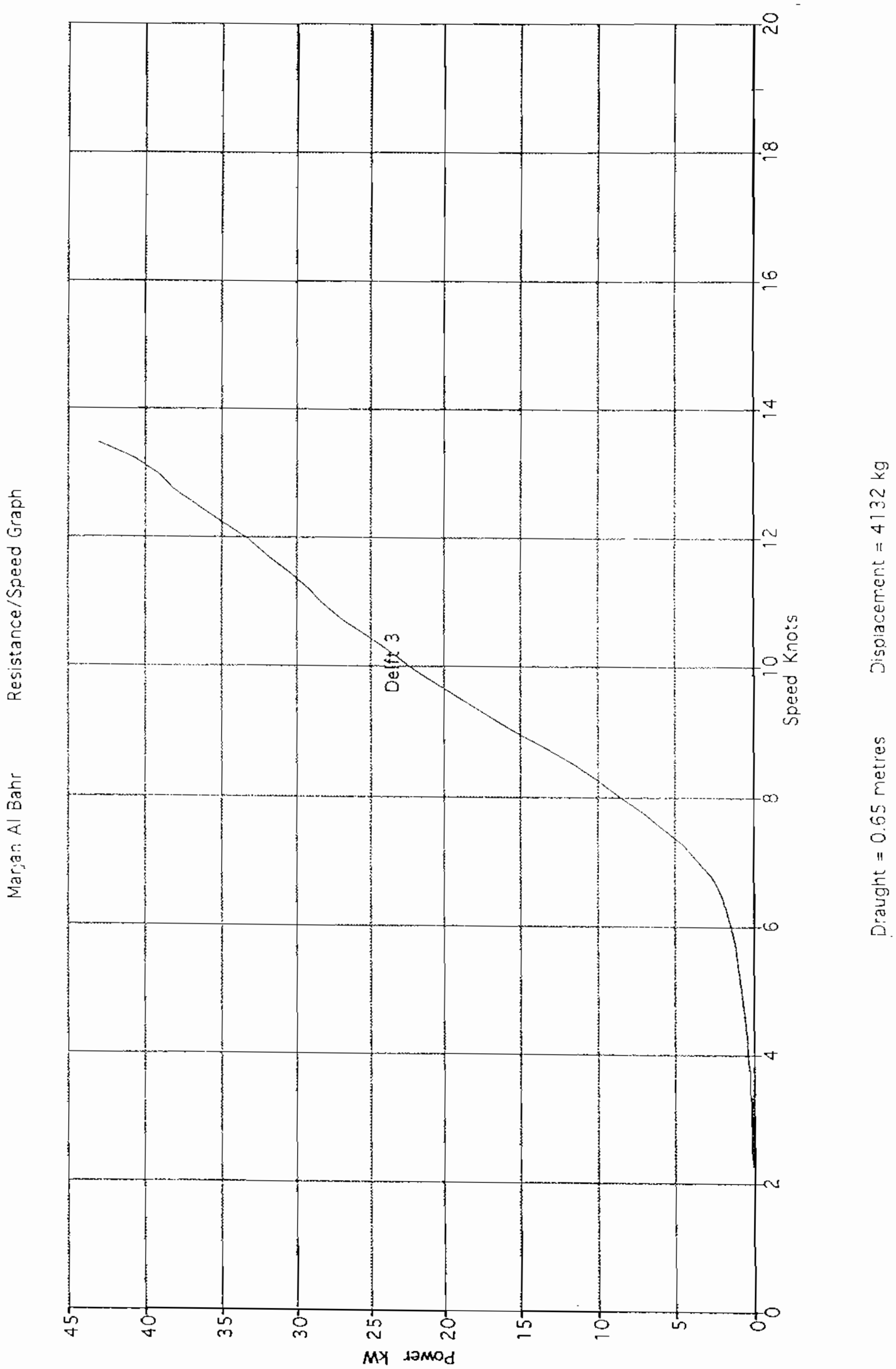
```
$*********************************
$ CALCULATE INTERMEDIATE RESULTS STABILITY
$ ENTER V.C.G. about DWL
VCG=0                                                                  0.000
$*********************************

Ilf=((wlb0+wlb10)*12.5)+((wlb0.5+wlb9.5)*40.5)+((wlb1+wlb9)          245.025
Il5=(Ilf*(spacing^3))/3                                               56.903
WPA=b1*spacing/3                                                      14.209
LCF=((Lf/b1)*spacing)-(spacing*5)                                      0.456
It1=((((wlb0*0.5)^3)+((wlb10*0.5)^3))*0.5)+((((wlb0.5*0.5)^3)         25.712
Il=Il5-(WPA*(LCF^2))                                                  53.943
It=It1*spacing*2/9                                                     5.065
BMl=Il/v2                                                             13.381
BMt=It/v2                                                              1.257
KB=maxd+(vb/v1)                                                        0.472
KG=maxd+VCG                                                            0.669
GMl=KB+BMl-KG                                                         13.184
GMt=KB+BMt-KG                                                          1.059

$ CALCULATE RESULTS STABILITY DATA
$***************************
Longitudinal Inertia  about LCF        m4 =Il5-(WPA*(LCF^2))          53.943
Transverse Inertia about centreline    m4 =(It1*spacing*2)/9           5.065
BM longitudinal                         m =Il/v2                      13.381
BM transverse                           m =It/v2                       1.257
GM longitudinal                         m =KB+BMl-KG                  13.184
GM transverse                           m =KB+BMt-KG                   1.059
Moments to change trim 1 cm        kgm cm =((v2*1025)*GMl)/           61.448
Righting Moment at 1 degree           kgm =v2*1025*GMt*0.0            76.566
Vertical Centre of Gravity above DWL    m =VCG                         0.000
```



Marjan A' Bahr, Curve of Areas
AP
AS
FP
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
-12.001
-11.001
-10.001
-9.001
-8.001
-7.001
-6.001
-5.001
-4.001
Station Position m
Draught = 0.65 meters, Displacement = 4.13 tonnes



Marjan Al Bahr, Stability Curve
Righting Lever (GZ)
Max GZ = 1.339 m at 56.1°
DownFlooding Angle = 78.1°
GZ m
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
20
40
60
80
100
120
140
160
180
Heel to Port °
Draught = 0.65 metres, Disp = 4132 kg, VCG about wl = 0.0


Marjan Al Bahr
Resistance/Speed Graph
Delft 3
Power kW
45
40
35
30
25
20
15
10
5
0
Speed Knots
0
2
4
6
8
10
12
14
16
18
20
Draught = 0.65 metres
Displacement = 4132 kg

APPENDIX B

Fatah Al Khair

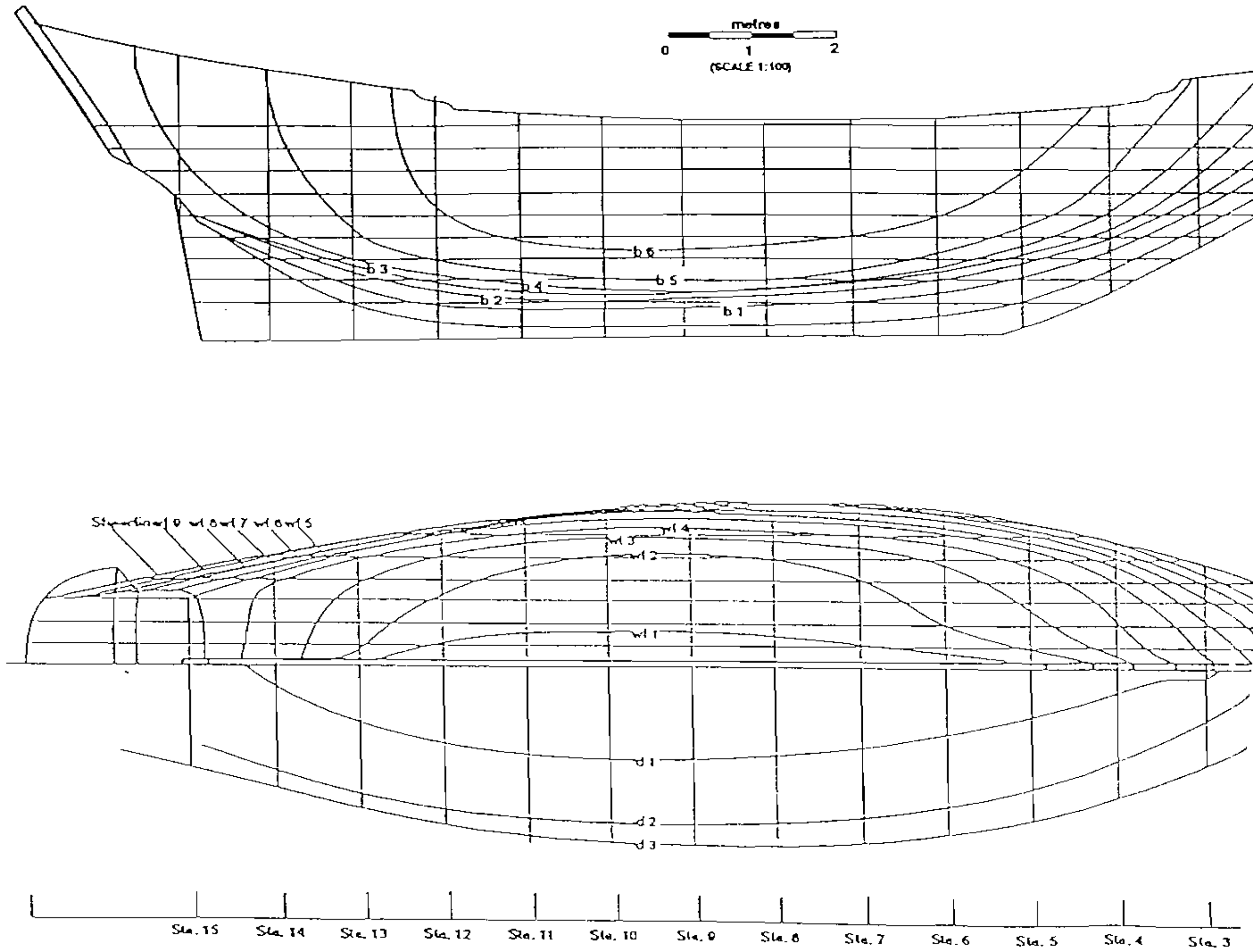
Lines Plan

Calculations

Curve of Areas

Hydrostatics

Hull Resistance/Speed

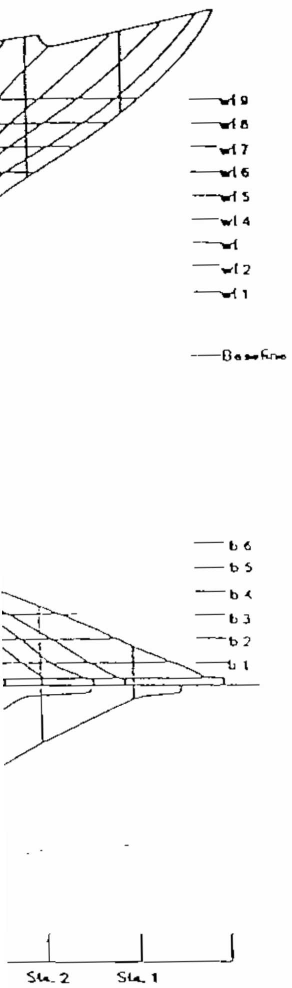

metres
0
1
2
(SCALE 1:100)
b 6
b 3
b 5
b 4
b 2
b 1
wl 4
wl 3
wl 2
wl 1
d 1
d 2
d 3
Sta. 15
Sta. 14
Sta. 13
Sta. 12
Sta. 11
Sta. 10
Sta. 9
Sta. 8
Sta. 7
Sta. 6
Sta. 5
Sta. 4
Sta. 3

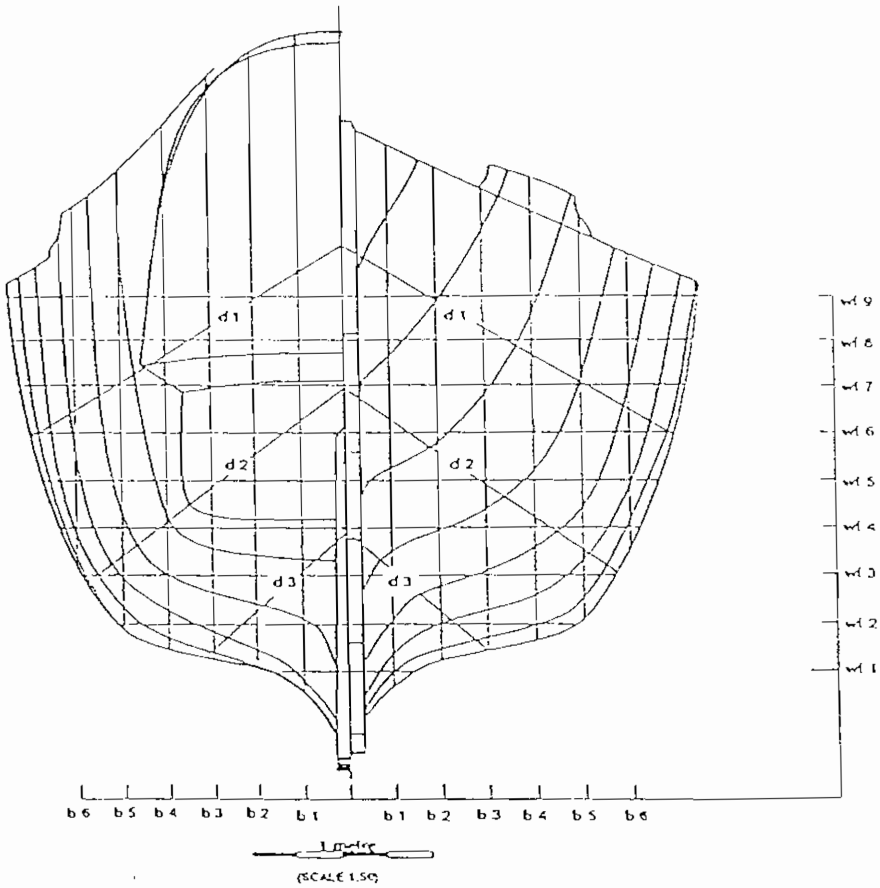
LINES PLAN

Fatah AL Khair

Sur

Sultanate of Oman





See Appendix A for explanation of a **Lines Plan**, the **Calculations**, the **Curve of Areas**, **Hydrostatics**, and the **Hull Resistance/Speed** graph.

The plan was drawn from the measurements recorded during the EDM survey of the vessel.

The **Calculations** comprise a great number of data, of which a few of the more important are considered here.

1. Length waterline: helps to predict speed potential. Roughly speaking, with displacement hulls (like *Fatah Al Khair*) the longer the waterline, the faster the boat. With its waterline length of nearly three times that of *Marjan Al Bahr*, the potential difference in speed in significant.
2. Hull draught: indicates the depth of the hull below the designated waterline.
3. Displacement: provides an indication of the powering requirements, and when combined with calculations of the weight of hull and rig, provides information on the cargo capacity (dead weight tonnage).
4. The wetted surface is the total immersed surface area for the given waterline. Because the surface area creates friction (and therefore drag) the power required to move the vessel is directly related to the immersed surface area.
5. Prismatic coefficient (C_p) is an indication of the fineness or bluntness of the hull shape. *Fatah Al Khair* has a C_p well suited to a displacement sailing hull.
6. GM transverse is the metacentric height, which provides an indication of the stiffness and stability of the hull.

The **Curve of Areas** is a graphic representation of one of the calculations, that is, the distribution of the volume of underwater displacement along the length of the hull. The Curve of Areas can be a useful indication of the handling characteristics of the hull. In the case of *Fatah Al Khair* the distribution appears very symmetrical, which usually indicates easy handling of the vessel in regard to steering and manoeuvrability.

Under the heading of **Hydrostatics**, is shown a **Stability Curve**, which gives a general indication of the stability of the vessel. The Stability Curve is rather steep, peaking at 78°. The **Downflooding Angle**, nearly 119°, means the vessel theoretically retains the integrity of its stability well into the curve. In reality, the probable shifting of cargo or ballast would likely occur much earlier. Free surface water inside the vessel would also introduce an instability factor, which would make the vessel less stable than indicated by the shape of the curve beyond 119°.

As with the *Marjan Al Bahr*, the **Hull Resistance/Speed** graph is calculated on a 'Delft 3' set of parameters. It shows that the hull is easily driven to about 10 or 12 knots (nautical miles per hour) hull speed, after which the power required to increase speed rises rapidly. The theoretical 'maximum hull speed' of this boat (according to the waterline length) is about 12.5 knots. The Resistance Curve shows that the power input required is already rising significantly before this speed is reached. According to the curve the vessel would probably best be sailed at a maximum of about 10 knots, still a very good turn of speed for any sailing vessel.

Fatah Al Khair, Calculations

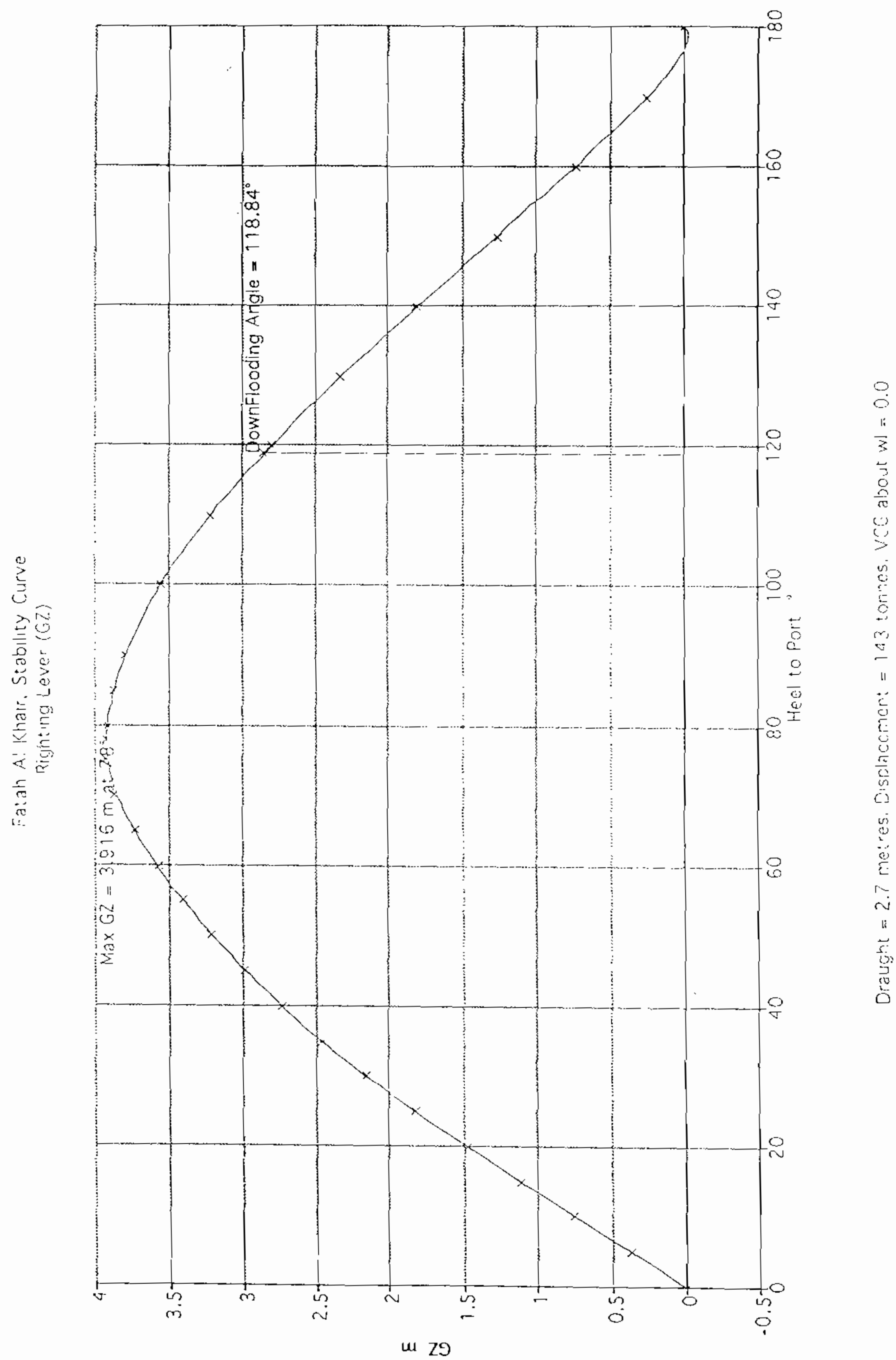
```
$ * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
$*
$*
$*
$*
$*
$*      THESE CALCULATIONS REQUIRE UNITS TO BE SET TO METRES
$*             ***************************************
$*
$ * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

$ CALCULATE INTERMEDIATE RESULTS HYDROSTATICS
$ * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
v1=((sa0+sa10)*0.5)+((sa1+sa9)*1.5)+((sa0.5+sa3+sa5+sa7+sa        169.244
v2=(v1*Spacing)/3                                                  139.866
Lb=sa0.5+(sa1*1.5)+(sa2*8)+(sa3*6)+(sa4*16)+(sa5*10)+(sa6          898.081
b1=((wlb0+wlb10)*0.5)+((wlb1+wlb9)*1.5)+((wlb0.5+wlb3+wlb!         146.649
Vb=(((sa0*cav0)+(sa10*cav10))*0.5)+(((sa1*cav1)+(sa9*cav9         -126.588
ws=((igir0+igir10)*0.5)+((igir1+igir9)*1.5)+((igir0.5+igir3+igir   237.543
ts=((tgir0+tgir10)*0.5)+((tgir1+tgir9)*1.5)+((tgir0.5+tgir3+tgi    426.918
Lm=dr0.5+(dr1*1.5)+(dr2*8)+(dr3*6)+(dr4*16)+(dr5*10)+(dr(          373.374
Lp=((dr0+dr10)*0.5)+((dr1+dr9)*1.5)+((dr0.5+dr3+dr5+dr7+dr          68.487
Lf=wlb0.5+(wlb1*1.5)+(wlb2*8)+(wlb3*6)+(wlb4*16)+(wlb5*1(          775.322
L  =spacing*10                                                      24.793


$ CALCULATE FINAL VALUES HYDROSTATICS
$ * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
Length water line          m = L                                    24.793
Max cross section       sq m = maxa                                  9.246
Hull draught               m = maxd                                  2.693
Beam waterline             m = maxb                                  6.431
Displacement              kg = v2 * 1025                        143363.024

LCB aft of st0             m = (Lb/v1)*Spacing                      13.156
LCB  as percentage           = 10* (Lb/v1)                          53.064
VCB   below dwl            m = Vb/v1                                -0.748

Waterplane area         sq m = b1*Spacing/3                        121.194
LCF aft of st0                m = (Lf/b1)*Spacing                   13.108
LCF as percentage            = 10*(Lf/b1)                           52.869

Lateral plane area      sq m = Lp*Spacing/3                         56.599
Centre Lateral area aft st0 m = (Lm/Lp)*Spacing                     13.516


Wetted surface area     sq m =  ws* Spacing/3                      196.311
Total surface area      sq m =  Ts* Spacing/3                      352.814
Sinkage            kg per cm = (b1*Spacing/3)*10.25               1242.238
Prismatic coefficient        =  v2/ (MaXa*L)                         0.610
Block coefficient            =  v2/(L*maxb*maxd)                     0.326
Water plane coefficient      =  b1/(30*maxb)                         0.760
Midship area coefficient     =  maxa/(maxb*maxd)                     0.534
Lateral plane coefficient    =  Lp/(30*maxd)                         0.848
```

Fatah Al Khair, Calculations

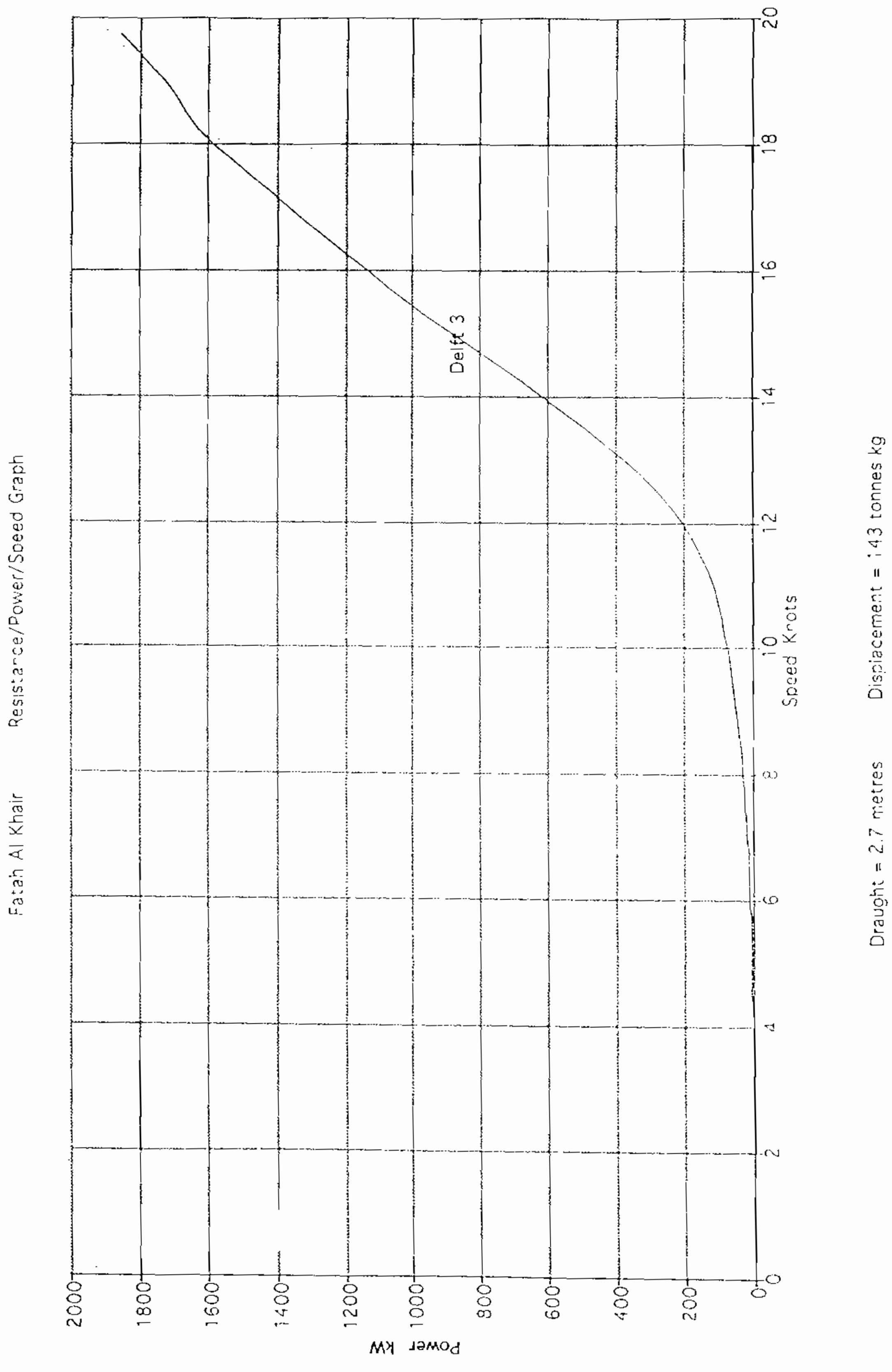
$ *	
$ CALCULATE INTERMEDIATE RESULTS STABILITY	
$ ENTER V.C.G. about DWL	
VCG=0	0.000
$ *	
llf=((wlb0+wlb10)*12.5)+((wlb0.5+wlb9.5)*40.5)+((wlb1+wlb9)	833.174
ll5=(llf*(spacing^3))/3	4232.352
WPA=b1*spacing/3	121.194
LCF=((Lf/b1)*spacing)-(spacing*5)	0.711
It1=((((wlb0*0.5)^3)+((wlb10*0.5)^3))*0.5)+((((wlb0.5*0.5)^3)	596.211
Il=Il5-(WPA*(LCF^2))	4171.027
It=It1*spacing*2/9	328.481
BMl=Il/v2	29.822
BMt=It/v2	2.349
KB=maxd+(vb/v1)	1.945
KG=maxd+VCG	2.693
GMl=KB+BMl-KG	29.074
GMt=KB+BMt-KG	1.601

$ CALCULATE RESULTS STABILITY DATA
$ *

Longitudinal Inertia about LCF	m4 =Il5-(WPA*(LCF^2))	4171.027
Transverse Inertia about centreline	m4 =(It1*spacing*2)/9	328.481
BM longitudinal	m =Il/v2	29.822
BM transverse	m =It/v2	2.349
GM longitudinal	m =KB+BMl-KG	29.074
GM transverse	m =KB+BMt-KG	1.601
Moments to change trim 1 cm	kgm cm =((v2*1025)*GMl)/	1681.175
Righting Moment at 1 degree	kgm =v2*1025*GMt*0.0	4015.597
Vertical Centre of Gravity above DWL	m =VCG	0.000



Fatah Al Khair, Stability Curve
Righting Lever (GZ)
Max GZ = 3.916 m at 78°
DownFlooding Angle = 118.84°
Heel to Port °
GZ m
Draught = 2.7 metres. Displacement = 143 tonnes. VCG about wl = 0.0


Fatah Al Khair
Resistance/Power/Speed Graph
Delft 3
Speed Knots
0 2 4 6 8 10 12 14 16 18 20
Power kW
0 200 400 600 800 1000 1200 1400 1600 1800 2000
Draught = 2.7 metres
Displacement = 143 tonnes kg