

THE REQUIREMENT FOR HYDROGRAPHIC SURVEYS IN PORTS AND ANCHORAGES

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ABSTRACT

The advent of larger, special-purpose ships in the last two decades has made big demands on a number of ports in the world since such vessels require deeper and wider channels than heretofore, as well as modern facilities to ensure their quick turn-around. Port Authorities have therefore had to undertake major projects requiring heavy investment for fear that shipowners would "by-pass" their port.

This paper points out that accurate and comprehensive hydrographic data is a pre-requisite for any marine development scheme in a port. It cautions those unaware of this need by providing examples of cases where industry has incurred heavy losses and where there have been delays in commissioning new facilities precisely on account of this lack, or this insufficiency, of reliable hydrographic data.

To avoid such pitfalls the paper recommends that Port Authorities should create their own hydrographic services to meet their conservancy requirements and also to undertake improvement of their existing facilities. Two existing port hydrographic services are briefly described to provide an idea of the diversity of requirements, their resources and manpower, and also how these ports in widely differing environments have dealt with their problems.

Finally a suggestion is made as to how a modest organization can be set up to meet a port's hydrographic requirements, and the sources for obtaining expert advice in this sphere are indicated.

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The management of most ports is vested in a Port Authority. The duties and powers of Port Authorities are generally regulated by national

legislation and whilst responsibilities and powers vary from one administration to another they do have certain common features. These are to provide, maintain and operate the port and harbour facilities under their jurisdiction and to take such action as is necessary to improve the port. There is also legislation to empower the Port Authority to engage in activities which appear to it to be advantageous or necessary in the discharge of its functions.

A modern port is a complex organization which has to provide numerous facilities and services in order to satisfy its major customer—the shipowner. The need to co-ordinate and improve overall planning of port operations has encouraged port authorities to assume increasing responsibility for some functions which have traditionally been the preserve of other government departments.

Apart from providing the static facilities i.e. piers, quays, locks, etc., most ports are usually responsible both for conservancy and for the provision and maintenance of aids to navigation. Where a body other than the Port Authority has assumed this duty, it has often led to ill-defined boundaries of responsibility and duplication of effort.

The technological progress in ship construction in the last two decades has enabled shipowners to operate bigger ships with deeper draughts and, due to their greater cargo-carrying capacity, freight rates have, as a result, been kept down. One consequence is that shipowners have demanded better facilities in ports to service the new generation of special-purpose vessels. Deeper draft ships naturally require deeper and wider channels. To maximise load-carrying capacity there has been a tendency on the part of shipowners to persuade port authorities to accept less under-keel clearance; port authorities have acceded to this request because their revenue depends on the volume of cargo handled. These factors, and keen competition amongst ports to attract a bigger share of the seaborne traffic, have compelled most authorities to review critically their conservancy functions.

There is no gainsaying the fact that adequate hydrographic surveying is a pre-requisite for all port development projects, be it for deepening the navigable channels, for the construction of new facilities for servicing modern ships, or for the establishment of a deep-water oil-terminal to serve the mammoth tankers of today.

Port managements should view hydrographic surveying, both to fulfil the conservancy responsibilities and for charting, as an essential but non-commercial activity. There are indirect benefits to be gained by the proper discharge of a port's conservancy responsibilities, and the possibility always exists that there might be penalties to be paid for failure to do so.

Within the limits of a port, the Port Authority provides a public service, and it has a statutory responsibility for the safety of navigation. In common law an invitor/invitee relationship exists, whereby it would be held that the Authority has responsibility to ensure that those navigating within its area of responsibility might do so without danger to life or property. The obligations incumbent upon an Authority include : a) surveying and demarcation of the best navigable channels; b) provision

of correctly placed aids to navigation; c) monitoring changes in the channel regime by frequent resurveys; d) maintenance of aids to navigation in good order, and e) dissemination of pertinent information to the public. Under national legislation the Port Authority has no liability for damage caused when it is not held to be at fault. Such protection does not, however, extend to cases where the Port Authority does not exert its responsibility in the matter of conservancy or is wilfully negligent.

The extent of hydrographic surveying in a port is governed by the relationship between the largest and deepest-draught vessels using the port and the prevailing depths of the channels and their degree of stability. All port users need to know the exact depths of water in the various berths, docks and channels. In ports with stable seabed conditions the task poses no problem; known seasonal changes can be calculated and allowed for, particularly if the port is exclusively used by mariners with local knowledge and by local pilots. On the other hand a port with a long approach through waters where the estuarine conditions are unstable is faced with several essential requirements : a) to survey berths, dock basins and entrances and approach channels at regular intervals in order to monitor changes, so that realistic safety margins may be determined; b) to analyse tidal conditions, both tidal heights and tidal streams; c) to investigate such other natural phenomena as wave heights and meteorological disturbances before, during and after the passage of cyclones, as these influence navigational safety and hence determine the limitations on the use of the port.

The advent of larger ships has made big demands on port managements, since these vessels require deeper and wider channels which, in order to reduce the vessel's "down time", must be accessible throughout the day and night irrespective of tidal conditions. Consequently, many ports have had to undertake capital dredging of areas critical to navigation. Dredging, new works, and major changes to existing facilities are all apt to change the channel regime; accordingly, the secondary effects of the changes have to be considered as seriously as the viability of the principal schemes themselves. Forecasts of the situation can be made more accurately and reliably if available hydrographic data is comprehensive and has been carefully maintained and analysed over a period of many years. The fine margins of safety now accepted in terms of under-keel-clearances demand a high standard of accuracy and reliability from the hydrographic surveyor; for example, improved tidal and surveying accuracy can make a valuable contribution to the determination of under-keel clearance and to the profits as well as the costs involved.

In ports, hydrographic surveying for dredging control can be subdivided as follows : a) routine surveys of all areas subject to siltation to determine re-dredging requirements; b) pre-dredging surveys to locate shoal depths as well as to estimate dredging quantities for assessing the cost and period of dredging work; and c) post-dredging surveys to confirm the newly-dredged depths.

The level of investment that a port should make in hydrographic surveying in order to satisfy its commercial needs is a management decision and one to be made in accordance with normal management criteria.

Whenever there is a requirement for dredging there is also a requirement for hydrographic surveying. Ports carrying out maintenance dredging on a round-the-year basis need to employ their own hydrographic surveyors, since the surveyors can play a valuable part in the dredging operation. Dredging and hydrographic surveying, properly integrated, can result in considerable economy, and such economy can well exceed (in some cases many times over) the cost of the hydrographic surveying element. In ports where the tidal regime is unstable, proper utilisation of good hydrographic information leads to economy and improvement in operating efficiency. Resultant benefits to the port could possibly outweigh the cost of acquiring the information. Concomitant with the dredging requirements in ports is the need to locate suitable spoil grounds in areas where the dumped material will not be carried back into the channels or anchorages. Routine surveys of spoil grounds are also required in order to monitor the accretion caused by dumping as well as to determine their continued use by loaded hopper barges which must have the necessary flotation for dumping.

The principal users of hydrographic information in ports are the Marine and Traffic Departments, respectively concerned with the safety of navigation and the efficient routing and allocation of vessels, and lastly the Department which has responsibility for dredging and harbour works.

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Having established that it is in the interests of ports to have adequate hydrographic coverage of their waters, let us now examine the various alternatives.

Ports can obtain the best service by employing their own hydrographic surveyors and the establishment of a hydrographic section or department to carry out all necessary hydrographic surveys and related studies. This is by far the most economical solution where surveys are required all the year round, as the resources are fully utilised. However, in a port where the requirement for hydrographic surveying is only occasional, it may perhaps be more economical to have the surveys carried out by the national Hydrographic Office, or by the hydrographic department of another port. If this is not possible, then the surveying work could be contracted out to a private firm of hydrographic surveyors.

It has been the experience in many countries that national hydrographic offices have not always been able to cater for the needs of ports, due to their own commitments which take precedence over port work. Similarly, ports which have their own hydrographic departments also find it difficult to help other ports because they themselves have only a modest organisation with little spare capacity.

Surveys under contract have been carried out in many ports but too often these have not been of the highest standard; however if the Port Authority employs a professional hydrographic surveyor to vet the results, this will have a tautening effect on the standard of work carried out by the contract surveyors. The rapid growth in the numbers of firms claiming competency to undertake hydrographic work has not been matched by any

increase in better training facilities. The number of professionally qualified sea surveyors is relatively small, and many are employed in managerial positions and not in the field. As a result, the standard of work supplied has not always been of the highest, due to the engagement of insufficiently experienced field staff and to inadequate supervision.

When complex or extensive hydrographic considerations are involved it is most important to have the services of an experienced qualified hydrographer as consultant. Engineering works in the marine environment are extremely costly and any failure to collect the correct or sufficient hydrographic data on which to base such work could well prove to have been a false economy.

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The following account of some of the author's experiences is given to alert new and developing ports to the shortcomings so commonly encountered in contracting work out to private organisations, particularly in the absence of the necessary "know-how" when checking the specifications for, and results of, such work.

Recently, a Port Authority awarded a contract for the construction of new berths on a "turn-key" basis to a reputed firm. After the construction had already begun the project was referred to a hydrographic expert for his critical review. It was found that the alignment of the berths was normal to the flow pattern and in the direct path of the sediment transport. Serious manoeuvring difficulties and recurring siltation were thus likely to occur; radio tracer studies carried out confirmed earlier fears. Similarly model tests confirmed that difficulties would occur in berthing/unberthing operations. Timely modification of the plans eliminated the risk of situation and greatly reduced manoeuvring difficulties.

In another case a large oil company awarded to one and the same firm a contract for both dredging and the post-dredging survey. The inevitable result was that it was claimed that the channel was indeed dredged to the projected depth. However, a check on the survey by the Ports Hydrographer showed that shoals 1 metre shallower than the projected depth still existed. The end result was considerable extra expenditure and delay in putting the berths into commission.

In its desire to accommodate larger vessels at new facilities under construction, one Port Authority, at the instance of the shipping community and on the advice of Consulting Engineers, decided to deepen a channel by dredging from 41 feet to 49 ft at a cost of 3.5 million U.S. dollars. However, before actually awarding the contract the matter was referred to the Hydrographer. After analysing the draughts of larger vessels (including their bunkering and water requirements and the consequent increase in draught), and the prevailing tidal conditions, he found that the channel would only require dredging to 42 ft (estimated cost 300,000 U.S. dollars) without hampering the navigation of larger vessels. Thus a considerable saving was effected.

In establishing a new oil terminal it is essential to collect comprehensive hydrographic, geologic and tidal data. In one case a Single Buoy

Mooring (SBM) was commissioned by a large oil company to unload Very Large Crude Carriers (VLCCs) with tonnages of up to 250,000 dwt. Unfortunately, sufficient data was not collected, and after the SBM was completed it was realised that the terminal was located in an area where the axes of the tidal streams varied widely. During following winds this caused the VLCCs to ride onto the buoy when discharging. In order to prevent damage to the SBM, the VLCCs thus have either to use their own auxiliary engines at "slow astern" or to resort to a tug. The economies originally envisaged by importing crude oil in mammoth tankers have suffered somewhat owing to the expense involved in the use of tugs for the tankers' entire stay at the terminal. Another case was that of a poorly investigated seabed where the oil pipe-line fractured under pressure owing to the presence of a soft strata on the seabed. Rectifying this major defect cost the company a great deal, whereas the cost of collecting comprehensive hydrographic data would have been minimal in comparison.

A six berth port was built in a developing country in the 1960s to export bulk commodities. Breakwaters were built to protect the harbour from strong prevailing winds and the wind-generated waves. The area within the harbour was dredged to cater for deep draught bulk carriers. Some time after the port became operational it was realised that a "bar", 3 metres shallower than the required depth formed seasonally at the harbour entrance during the south west monsoons, due to "littoral drift". Continual and intensive redredging was necessary in the area of this bar in order to maintain depths, and the port was obliged to acquire a dredger specially for this purpose.

Port Authorities are recommended to demand from the tendering firms the Curriculum Vitae of the personnel proposed in order to assure themselves that only duly qualified and experienced personnel are utilized.

On the other hand, Port Authorities with their own hydrographic service have benefited greatly by drawing upon this expertise when executing any marine developments. The Calcutta Port Trust has built a subsidiary port for deep draught ships at Haldia in the lower estuary of the Hooghly. From the conceptual to the operational stage the Hooghly River Survey played a very important part in providing accurate hydrographic information on which to base the design of the port. Similarly, the Port of Singapore Authority has completed major developments to improve their facilities, all of which were successful due largely to excellent data collected and to the feasibility studies carried out by its Hydrographic Department.

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Prior to the creation of its hydrographic department a Port Authority should first establish its hydrographic requirements, then examine the means available for conducting such hydrographic surveys, and the equipment required, and finally estimate the cost of such operations, and work out the benefits to be derived.

In any port the amount of hydrographic work required will depend upon : a) the size and resources of the port; b) its hydrographic morphology, in particular of the navigable channels; c) the prevailing depths

vis-a-vis the draught of vessels customarily navigating the waters; d) the degree of bed stability and e) the potential for development to accommodate larger vessels. In the final analysis, it must be ascertained whether there is concrete evidence that absence of hydrographic data puts a genuine constraint on either fulfilling conservancy tasks or undertaking new projects.

It is difficult to make specific recommendations as regards the organisation or the choice of equipment and craft ideally suited for a port's hydrographic service, owing to the diversity of requirements, resources and available man-power.

The approach to begin with should be a modest set-up, making maximum use of any existing capability and gradually expanding it, and its hierarchical responsibilities must be modified at each stage and estimates provided of the staff required, and the technical and administrative support needed, together with assessments of the craft, crews, equipment, accommodation and other facilities which must be provided.

In the formative stages the need for training is paramount and use should be made of the training facilities in a number of countries which are available under bilateral aid programmes, or the Colombo Plan Technical Assistance Scheme, the U.N. Development Programmes, and the Commonwealth Fund for Technical Cooperation Programme, for instance.

A most important consideration is the choice of the person to direct the project from the beginning. Some of the qualities to look for are :

- a) high professional qualifications in hydrography and experience in port conservancy functions;
- b) demonstrated drive, tact and management ability;
- c) a keen interest in the sea and maritime affairs;
- d) enthusiasm in training of subordinates, and
- e) sense of responsibility towards the organisation.

Given the right choice of individual, problems connected with training, equipment, infrastructure, etc., can largely be left to that individual within the larger framework of the Port Administration.

Hydrographic work in port waters largely consists of revision or repeat surveys of the area within the port's jurisdiction. Expeditious dissemination of hydrographic information in the best available manner is of great significance in day-to-day operations. Since the publication of charts is normally the task of the national hydrographic office, a port's hydrographic department could content itself with a modest cartographic office capable of producing 'plans' of the areas surveyed.

Permanent survey stations for visual horizontal control can be set up on existing prominent features, or on buildings, etc., and where necessary survey monuments can be erected. Field sheets showing such marks, the shoreline, etc., can be prepared in advance, and for large-scale surveys sextant lattice sheets can be used for expeditious plotting of the field work. A few automatic tide gauges judiciously located to give representative tidal phenomena will suffice.

Hydrographic information can be disseminated by radio on VHF or HF, or by WT. Use of semaphore, employing depth symbols, is also

common. Fluorescent tubes, assembled in appropriate signal forms, to convey information to pilots have proved advantageous.

For ease in promulgation of hydrographic information navigable channels can be defined by numbering the "tracks" which in turn can be physically marked by transits, leading lines, etc. This facilitates description of changes since depths available on the different tracks in each channel, bar or at crossings can be more clearly promulgated.

A modest beginning can be made by first employing an experienced surveyor as described earlier. Two persons for observing sextant angles simultaneously, a helmsman and a boatman will be required in due course. The equipment required initially include i) a 10-12 metre boat, preferably with an all round view to facilitate angle-observations; ii) a shallow-water echo-sounder; iii) two or three survey sextants; iv) a station pointer; and v) an automatic well-type tide gauge. Other equipment which will be required before any hydrographic surveying can be carried out consists of a theodolite; a level and its levelling staves; short-range electronic distance measuring equipment; a steel tape-line and a surveying chain; and standard drawing material. Most of this equipment could be borrowed from either the Engineering Department or the Land Survey Section.

It has been the author's experience that freshly-recruited High School graduates can be easily trained within 6-8 weeks to observe sextant angles. Within the same time, helmsman can be trained to keep a straight course with the aid of visual transits or by compass.

In the initial stages, a survey of a small area within the port can be effected by carrying out local triangulation with reference to two or three easily accessible and intervisible marks — for example the ends of a pier or a cargo transit shed. The survey can later be connected to the local geodetic datum. In most cases either the Public Works Department or the Land Survey Section is in a position to supply geodetic data and data on existing bench marks. In order to avoid possible duplication these departments should be consulted prior to commencing any work on setting up horizontal control. In the absence of an automatic tide gauge, a tide pole can be erected on the end of a pier to facilitate tidal observations.

Once the survey work is in progress and immediate survey needs are met, thought should be given to the phased expansion of the organisational structure to an optimum level of development in order to meet the long-term needs of the port. Consultations with the hydrographic services of other Port Authorities should prove useful, for their experience in recruitment from available manpower within the country, training of personnel and the choice of equipment would be invaluable.

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Hydrographic services of two ports in entirely different environments are described below to give an idea of different types of organisations required to fulfil widely differing commitments.

The first of these services is the Hooghly River Survey (HRS), serving the Port of Calcutta (India) owing its origin to the East India Company,

which, in the late seventeenth century, sent a 60 ton pinnace "Diligence" to "take notice of the channels and depths of the River Ganges and the entrance thereto". After a brief account of the marine environment of Calcutta, the growth and the present status of the service are described.

The River Hooghly is formed by the confluence of the Rivers Bhagirathi and Jalengi, two offshoots of the Ganges. Some eighty miles downstream from this confluence is situated the Port of Calcutta which is accessible to ocean-going vessels through a 126 mile long approach channel from Sandheads at the head of the Bay of Bengal. The port's jurisdiction extends over 170 miles of the river proper, and another 40 miles into the Bay of Bengal. The river, which is only 1800 metres wide at Calcutta, fans out to some 13 nautical miles at Sagar where it discharges into the Bay of Bengal. Calm weather prevails only during the period of the north-east monsoons. i.e. November to February. The rest of the year, strong south west monsoons prevail, bringing in their wake depressions and cyclones of severe intensity between July and October. The river is tidal for its entire length, and tidal currents of 7 knots are experienced in "Springs" during both the ebb and flood periods.

Two distinct seasonal regimes govern the navigable depths over some 16 navigational 'bars' and 'crossings' over a distance of 120 miles downstream of Calcutta. The "Freshets" occur between July and October when the ebb current, augmented by the fresh water discharge due to monsoon rains, has preponderance over the flood currents, and all channels in the upper river align themselves in the axis of the ebb currents. The rest of the year is the dry season, when, due to the fall in river discharge, the flood currents gain preponderance over ebb currents, causing lateral shifting of the channels in the upper reaches of the river. During such transitory stages the depths deteriorate, and continual heavy dredging is required to maintain depths.

The Hooghly River Survey is headed by the River Surveyor who is assisted by two Deputy River Surveyors, 15 commanders and 40 other surveyors. The service operates a fleet of four sea-going survey vessels and sixteen survey launches which work from six survey bases ashore. A separate section carries out hydrological and oceanographic observations and collects the necessary data. A small electronic laboratory maintains all electronic equipment used. Two Decca Hi-Fix/6 chains are operated for position-fixing in the estuary. Surveys of the entrances to docks, berths and locks are carried out on a regular basis under the supervision of a Senior Commander. The sea-going ships are commanded and manned by HRS officers; these vessels also have aboard certified Marine Engineers, a Radio Officer, an electronic assistant, and a complement of between 20 and 35 ratings. The commanding officers of survey vessels and shore stations are entirely responsible for the area under their charge and daily disseminate local navigational warnings. A special research unit exists for feeding in the required information for hydraulic model studies. Six sea-going dredgers each carry aboard two surveyors who carry out the pre-dredging and post-dredging surveys and make a daily examination of the dredged areas to assist the dredger's master in planning the next day's work.

Fair drawings of the surveys are sent to the head office as soon as the surveys are completed and the cartographic department prints the survey plans and Notices to Mariners (known as "River Notices") within 24 hours, for distribution to pilots and shipping companies.

Typical patterns of navigation are established for inward and outward shipping. All inward ships commence their voyage at Sandheads at two hours before low water; they negotiate the estuarine "bars" on a rising tide and then pass all upper reach "bars" at or near high water to arrive off the Calcutta docks on the first moments of the ebb. However, deeper draught ships bound for Haldia, a new port established in the estuary, navigate at half flood in order to reach Haldia at high water. The outward-bound vessels are divided into two categories. Those with small draught (6 to 7 m) leave Calcutta a little before low water and meet the flood tide at a distance of 15 nautical miles downstream and then navigate the upper reaches on the flood so as to pass the controlling "bar" at high water. They continue their outward passage in the estuary on the ebb tide. Deep draught outward-bound ships are obliged to navigate the entire river on the flood tide and anchor two or three times on their way down to await the successive flood tides, thus taking as long as 36 hours to complete the passage.

Recruitment to the HRS is made from amongst candidates who have completed training aboard T.S. "Rajendra". The officers then undergo an intensive training programme lasting 5 to 6 years during which time they are posted to survey vessels and/or dredgers. After passing three professional examinations they take two examinations to qualify them for command and as pilots after which they are eligible for promotion to higher ranks. In addition to their surveying duties, commanding officers of ships are responsible for the maintenance of and repairs to their craft, as well as for the welfare of the ship's complement.

The second service, in an entirely different environment, is the Hydrographic Department of the Port of Singapore Authority (PSA), which was created as a Section in December 1965 under the supervision of an ex-naval hydrographic surveyor. Under the auspices of the Colombo Plan, the PSA obtained in 1970, from India, the services of the author with a view to developing this section into a fully-fledged national Hydrographic Department catering for the needs of the port, the Government and industry. The staff at that time was composed of two graduates in land surveying, three survey technicians, one cartographic assistant and a clerical assistant, none having had any formal training in hydrography or a marine background.

Singapore's territorial waters cover an area of about 225 sq. miles. Situated almost on the Equator, Singapore has the good fortune never to experience cyclones and their accompanying bad weather. These factors led to a decision to think in terms of shore-based survey parties using small, adequately-equipped survey craft. This obviated the necessity for personnel with a marine background and qualifications.

The survey craft acquired, therefore, comprised a 22 metre steel-hull twin-screw survey vessel and two 14-metre wooden-hull survey launches. Though the entire survey area is within sight of land, position fixing by

visual control is not possible in most areas due to continual poor visibility, industrial smog and, last but not least, to numerous ships at anchor which obscure the main shore-control points. To overcome this problem, a permanent Decca Sea-Fix chain was installed in 1972-73. For some areas not adequately covered by the Sea-Fix chain, a Motorola Mini-Ranger Mark III was acquired. However, conventional methods are still used, where possible, in close proximity to the land. Other equipment purchased included a Tellurometer CA-1000, a transit sonar and a coordinatograph.

The recruitment of personnel at a professional level posed problems. The non-availability of local specialist training facilities precluded the recruitment of personnel at a junior level and the subsequent offering of further training in all disciplines within the broad spectrum of hydrography. Thus, more as a matter of expediency, recruitment had to be made from amongst candidates with suitable backgrounds. For the grade of Assistant Hydrographer, officers with a marine background or graduates in land surveying, physics or mathematics were selected. For the newly-created grade of Technical Officer, those in possession of a diploma in Land Surveying from the local Polytechnic college were recruited, as well as twelve junior staff with a secondary education in English, Mathematics and Sciences who were employed as Survey Technicians; another twelve were recruited as Cartography Technicians. All recruitment was phased, which facilitated suitable training of staff and automatically brought about a hierarchical system within the Department.

It was obvious that personnel with different backgrounds and qualifications could not be trained in common further training courses. Neither was it practicable or essential to train the entire staff in all disciplines. Hence tailor-made courses were arranged in order to make the best use of training and available resources without causing an undue shortage in the manpower required for carrying out the day-to-day functions of the Department.

The majority of the staff have now completed a training course relevant to their duties. Most survey officers and technicians and all the cartographic staff underwent their training in India, at the Naval Hydrographic School and then at the Naval Hydrographic Office in Dehra Dun. Some officers went also to the UK, USA and Japan for further training in the different disciplines.

The major tasks completed by Singapore's Hydrographic Department were revision surveys of port waters where new developments have taken place, and joint hydrographic surveys of the Malacca and Singapore Straits. Also undertaken were several feasibility studies—for the establishment of a container port, the Pasir Panjang Wharves for vessels drawing up to 36 feet, and for tanker terminals including a Single Buoy Mooring. Radio-active and fluorescent tracer studies were undertaken to determine sediment movement in an attempt to arrest siltation.

The Department took over the maintenance of aids to navigation in 1973 and brought about some sorely-needed improvements. In 1975 the Department published its first nautical chart and since then has published four other charts of Singapore waters. Monthly Notices to

Mariners are published for the updating of these charts; in addition, ad hoc Notices to Mariners are also issued as necessary. Important changes concerning navigation are broadcast as Navigational Warnings via the Singapore Radio Station.

In addition to its own commitments, the Department has also carried out important hydrographic surveys of ports in West Malaysia, Brunei and the Philippines, and in two cases has recommended remedial measures to prevent recurring siltation.

Singapore's Hydrographic Department now has a fully competent staff of 160 working in the various branches of hydrography, cartography and maintenance of aids to navigation, and can thus undertake all types of work within its territorial waters.

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Port authorities wishing to set up their own hydrographic service or strengthen their existing service are recommended to seek the advice of an expert hydrographer in their country to review their requirements and suggest the necessary measures. In cases where such expert advice is not readily available within the country, assistance should be sought from another country, preferably one with similar conditions and problems, under the bi-lateral and/or other technical assistance programmes listed earlier. Expert advice can also be sought from the International Hydrographic Bureau, Monte-Carlo, Monaco.