THE TECHNICAL STUDY

ON

THE DREDGING PROJECT

OF

THE STRAIT OF SINGAPORE

(Preliminary Report)

January 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

Introduction

This report is concerned with the technical study and cost estimation of the dredging work for the removal of four shoals located in the Strait of Singapore.

In order to obtain the basic data for the study the following field surveys were conducted at the site. These surveys were conducted during the period of October and November 1978 by the survey team of the Government of Japan with cooperation of the Government of Singapore.

(1) Sounding survey.

(2) Geophysical exploration

(3) Boring.

(4) Submarine observation.

(5) Test dredging

Cost estimation of the dredging work was made for the case of a Japanese agency ordering to a Japanese contractor as a contract work. Therefore, should there be changes in the conditions, the contract work cost and work administration cost would have to be corrected. It is also necessary to add the price contingency when the time of commencement of the work is made clear.

1. Winds and Waves

1-1. Winds

Now looking the winds in the vicinity of the Strait of Singapore from the records of observation at the Raffles Lighthouse (Apr. 1976 - Mar. 1977), the predominant direction throughout the year is easterly, north-eastern wind being predominant during the period of from December to March and south-eastern wind in April to September. But, in October and November, the wind direction is not constant, and even a westerly wind is noted.

With respect to the wind speed, the characteristic breeze in the tropical zone is prevailing, with the winds of 5.5 m/s or higher emerging at a rate of about 30 percent and those of 10.7 m/s only at a rate of 1 percent.

In this water area, however, a squall often accompanies a gust before and after it takes place with wind waves of about 50 cm generated so that for operation of smaller boats this point should be noted.

1-2. Waves

The Strait of Singapore connects, at its east end, to the South China Sea so that greater swells and wind waves are apt to emerge towards the east.

Where the four shoals are located is the water area in the west of the Sakijang Pelepah Island. It is the narrowest water area in the Strait of Singapore and provides a great sheltering effect with a number of islands spotted here and there, and the sea is relatively calm.

Observation of the wave heights in this strait was conducted by PSA for a period of about one month from January 23 to February 21, 1976, in the vicinity of the Johore Shoal off in the east of Singapore in use of buoy type pressure wave recorders of Holland made.

According to the result of the observation, waves of 5 feet or less in the significant wave height accounted for 95 percent, or those of 7 feet or less in the maximum wave height for 91 percent, in the winter when the waves were largest throughout the year. The water area where the shoals are located is considered to be more calm as stated above so that there will be no particular hazards caused to execution of the dredging work.

However, as stated later, the shoals are located near the boundary of the traffic zone in the strait and the inshore traffic zone so that the dredging work will normally subject to the waves in the wake of large ships navigating nearby.

Such ship waves will be as high as 1.0 - 1.5m so that care should be exercised in the work.

2. Tidal Currents

The tidal currents in the vicinity of Singapore are subject to the influence of the tropic tide and are diurnal generally. In the port area and the strait traffic zone, the west-bound current is predominant, and its duration is 14∿16 hours a day.

Now seeing the currents in the strait from the current tables at two points, or Gusong Tower and Batu Berhanti, in the Main Strait which are relatively close to the shoals, a considerable difference is noted between these two points.

Taking the occurrence of the daily maximum current speed, the days of a maximum speed less than 3 kn is about 170 days at Batu Berhanti against 350 days at Gusong Tower, and when the annual maximum current speed is taken, it is given as 4.3 kn at Batu Berhanti, while it is given as low a value as 3.4 kn at Gusong Tower.

Such is, of course, conceivable from the topographic configuration of the area in the vicinity of the strait, the line connecting the St. John Island and Batu Berhanti representing the narrowest part of the strait and being thus considered to be the place where the current is fastest.

The measurement of the current speed was conducted in use of an automatic propeller current meter borrowed from PSA for short hours on the occasion of test dredging at Shoal A on November 2∿4 against the current table of Gusong Tower. It will be noted that the tidal current at Shoal A has a delay of about 1 hour from that at Gusong Tower and also a speed about two times or more greater. Consequently, the tidal currents at Shoals A and B seem to be close to the forecasted value at Batu Berhanti rather than that at Gusong Tower.

According to the visual observation at the time of test dredging at Shoal A, the westerly current flowed nearly parallel to the traffic zone, while the easterly current seemed to flow in the direction E rather than NE, and at the slack water, the sea was not completely still but seemed to the S-current remaining.

Thus, in mooring and fixing the dredgers at the site, if it is positioned parallel to the traffic zone, it will receive a strong current on its side from the norhth, making it difficult to fix the position, so that it will be required to prepare for such current with sufficiently strong anchors and anchor chains.

Next, seeing the annual current distribution by speed and by month from the forecasted values at Gusong Tower, the period of December to March when the northeastern monsoon is prevailing seems to correspond to the worst period of tidal condition in the strait.

According to the current table of Gusong Tower, the hours of a current speed less than 1.5 kn constitute about 75 percent throughout the year. Thus, from the foregoing consideration, the hours of a current speed less than 3 kn in the vicinity of Shoals A and B seem to be of the same percentage.

3. Topographic Features and Soil Conditions of Singapore

3-1. General

The Singapore Island takes a rhombic form extending for about 20 km south and north and about 40 km east and west and presents different topographic features on the east and west sides about the railway running south and north slightly on the western side of the center of the island.

The west side of the railway comprises a number of undulations with small hills, while the central part consists of a succession of gentle hills.

The east side is of a height of about 20 m above the sea and presents a gentler topography than the central part.

The highest height of the island is the Bukit Timah Hill at 166 m.

Such topographic features reflect the soil conditions clearly. That is, the area showing a topography of relatively large undulations on the west side consists of ancient sedimentary rocks, while the central part consists of granite.

The area on the east side consists of diluvial deposits of a relatively low degree of solidification. Additionally, there is a relatively extensive distribution of alluvial low land zones in the Jurong area and along the Kallang River.

Shoals A and B are located at the tip end of a succession of islands, or Sentosa Island, Tekukor Island and Sakijang Island, lying in the SE-direction from the north, and looking south from the shoals, shoals are lying successively in this direction to the Sambo Island of Indonesia.

Obviously, such topographic elevation may be taken as to be reflecting the structure of Jurong Formation of ancient sedimentary rocks.

For Shoals C and D, they may be taken similarly as those in line with the islands of Jurong-Bukom-Sebarok extending in the SE-direction.

Thus, in the area of the Strait of Singapore from Sakijang Island to Senang Island, it seems that the bottom configuration is a reflection of the soil structure on land.

As the result of the survey, it was found that the shoals had all the Paleozoic Jurong Formation distributed.

3-2 Topographic Configurations of Shoals

To grasp the topographic configurations of the shoals and adjoining bottoms, a sounding survey was conducted with a precision echo-sounder designed for shallow water used at a measuring line interval of 25m average. The resulting topographic configuration of the respective shoals will be described in the following.

(1) Shoal A

This shoal is situated at about 2.0km in the south off the Sakijang Bendera Island in the west-bound lane of the traffic zone in the Strait of Singapore close to the boundary on the inshore traffic zone.

The shoal shallower than the depth of -21.0m lies SW-NE nearly parallel to the traffic zone in the Strait in the form of an oval of a length of about 100m, width at the central part of about 40m and area of 3,000m^2.

The shallowest place is located in the northern part of the shoal, and its water depth is -17.0m. With the net volume of shoal over the depth -21.0m at 5,000m^3, this shoal is the smallest except Shoal D among the four shoals.

The water depth in the peripheral area of the shoal is generally greater than -23m. But, there is a shallow place of -22.0∿23.0m present in the southern part of the shoal so that there is a possibility of a shallow place less than -21.0m being present in the range which was not covered by the survey of this time.

(2) Shoal B

This shoal is situated in the inshore traffic zone about 1.5km in the south off the Sakijang Bendera Island and is contiguous upon Shoal A.

This shoal comprises six large shallows and several smaller shallows spotted around the large shallows and, being constrained by the soil condition and the direction of current, presents a complex form. Further, with greater undulations of the bottom than those of Shoal A, there is a possibility of a shallow place less than -21.0m being present in the area outside the range of the present survey so that care should be exercised.

The shallowest place is located at the west end of the group of shallows, and with a depth of -11.7m, it is the shallowest place throughout the Shoals A∿D.

The net volume of shoal over the depth -21.0m is 88,000m^3 with area of 34,300m^2.

(3) Shoal C

This shoal is situated in the inshore traffic zone about 2.5km in the south east off the Sebarok Island.

The shoal of a depth shallower than -21.0m has an extended oval form with a length of about 750m, width of about 250m at the central part and area of 126,300m^2.

Lying in the direction of NW-SE, it represents the soil structure.

The shallowest place is located at the central part of the shoal, and its depth is -13.3m.

This shoal is the largest among the four shoals with a net volume of shoal over the depth -21.0m at 389,000m^3.

(4) Shoal D

This shoal is situated in the inshore traffic zone close to the border line to the traffic zone in the Strait at about 3.0km in the south off the Sebarok Island.

The shoal over the depth -21.0m takes a square form with a length of the side at about 50m. The shallowest place is located at the center of the shoal. With a depth of -18.3m, it is the deepest place throughout these four shoals.

The Shoal has an area of 1,700m^2 and a net volume of shoal at 2,100m^3 and is thus the smallest among the four shoals.

3-3 Soil Conditions of Shoals

3-3-1 Submarine Observation

In order to confirm the topographic configurations of the bottoms and the surface deposits of the Shoals A∿D, a submarine observatory investigation was conducted.

The investigation included visual observation and photographing of the bottom configurations and sampling of the deposits.

(1) Shoal A

As the result of the submarine observation, it was found that the surface was a zone of bare rocks with undulations of about 0.5m in height.

On the surface of the Shoal, there was noted a level surface which had a width of only 10∿15m, and this level surface also included undulations of about 0.3∿0.5m, and there was no completely flat surface present.

The rocks forming the shoal were of alternate layers of sandstone, conglomerate and mudstone, and cracks were noted at an interval of 20∿50cm. Large boulder of conglomerates of 0.1∿1.0m diameter were seen here and there on the surface but in a very small quantity.

(2) Shoal B

This shoal has a bottom configuration of many undulations with no flat surface observed as in the case of Shoal A.

According to the result of the sounding survey, a flat surface of a width of about 10m was noted at about -24m, but no flat surface having a width of 10m or more was noted at a depth of -20m or less.

Slopes from one flat surface to another were generally of sharp angle and have a head of 0.5∿1.0m.

Considering from the result of observation of the soil structure on land, this head seems to reflect the feature of the soil structure in this area. The Jurong Formation constituting this area is of a relatively sharp angle of dip, while it is composed of alternate layers of sandstone, conglomerate and mudstone, so that it is presumed that it underwent a differential erosion.

For the deposit on the bottom, gravels are distributed in the dents, but the other part has the rocks exposed as in the case of Shoal A.

Sampled rocks from the surface were sandstone and conglomerate.

Judging from the foregoing result of bottom observation and the soil structure on land, both Shoals A and B are considered to have similar soil conditions.

(3) Shoal C

Seeing from the result of the sounding survey, this shoal has a bottom configuration unlike to those of Shoals A and B, presenting little undulation and a relatively smooth topography.

From the result of the submarine observation, the undulations have a height of only about 0.3m, forming a gentle slope of $2\sim5°$, and the topography is scarecely changing sharply.

As the deposit on the bottom, coarse sand consisting mainly of shells was noted in small dents.

The projected parts have rocks exposed, and the soil is composed mainly of sandstone and conglomerate.

(4) Shoal D

The bottom configuration of this shoal features in that a number of round sandstone boulders are deposited on the surface.

The round boulders had as large a diameter as 1m maximum, and there was a deposit of sand and silt noted between the boulders, while no bare rock was observed.

The collected samples were of reddish brown sandstone.

3-3-2 Results of Borings

To see the soil composition and the extent of weathering in the direction of depth of the shoal, three rotary borings were carried out in Shoal C where it was possible to erect a boring frame.

(1) Boring C-1

In this boring, a hole was drilled for about 10 m from the bottom surface (A.C.D. -17.19 m) to A.C.D. -27.54 m.

The soil was comprised of tuffaceous sandstone and tuff, the former being from A.C.D. -17.99 m to -21.69 m and the latter from -21.69 m to -25.79 m.

The soil was generally weathered strongly, and the value of standard penetration test into the tuff was 50 blows/ 16cm.

(2) Boring C-2

In this boring, a hole was drilled for about 10 m from the bottom surface (A.C.D. -15.65 m) to A.C.D. -25.85 m.

From A.C.D. -16.45 m to -19.45 m was a layer of reddish brown stiff clay including gravels of a size of 2∿3 mm spotted here and there.

From A.C.D. -19.45 m to -25.85 m was a layer of alternation of tuffaceous sandstone, mudstone and conglomerate.

In this boring, it was noted that the soil was weathered strongly throughout the layers to argillization except gravels in conglomerate.

(3) Boring C-3

In this boring, a hole was drilled for 3 m from the bottom surface (A.C.D. -15.60 m) to A.C.D. -18.60 m.

The boring gave conglomerate throughout the layer, with the matrix composed of sandstone and mudstone.

The gravels were smaller than 20 mm diameter and were scattered in the mudstone.

Judging from the foregoing result of boring, the soil of Shoal C seems to correspond to Jong Faces in Jurong Formation.

3-3-3 Geophysical Exploration

For Shoals A∿D, geophysical exploration was conducted at a measuring line interval of 25m average.

Consequently, it was found that the shoals had invari ably the rock bed present from the bottom surface without any deposit covering the rock.

It is reported, as the result of an investigation of submarine observation, that in Shoal A~D, the bottom surface is comprised of the rock bed or boulders and that Shoal C has the rock bed exposed with deposits noted from place to place in the dents of the rock bed. The result of geophysical exploration is in agreement with the foregoing result.

3-3-4 Result of Test Dredging

Test dredging was performed on Shoal A in use of a grab dredger with a $7m^3$ grab bucket (60 tons).

The dredging was made by excavating flat the vicinity of the peak of the shoal for about 20m by 20m and pit dredging a point in such area, and the total volume of soil of test dredging was about $700m^3$ in a loosened state after excavation.

(1) Observation of collected samples

The samples collected from Shoal A by grab dredging were sedimentary rocks called Jurong Formation in Singapore comprising sandstone, mudstone and conglomerate deposited in the Mesozoic.

The collected rocks were generally in the form of lumps of several to several tens centimeters, and those taken from the bottom surface had sea weeds and coral attached and the surface oxidized into a brownish color.

The largest block of rock among those collected in the test dredging was a conglomerate of about 150cmx150cmx100cm.

Lithologically, the rocks are weathered and soft generally and, when hammered, are fractured readily along the bedding plane, with dull sound. The composition of the rocks collected in the test dredging is considered generally to be conglomerate: sandstone: mudstone = 5:3:2, and the result of observation of the respective typical samples is given below.

-Conglomerate

Presenting a bluish gray or brownish color. The gravels are, for the greater part, subpebbles or pebbles of about 2∿3mm diameter, the largest size being about 20mm.

The gravel itself is hard, but the rock itself is of loose solidification and, when hammered, is crushed relatively easily with dull sound.

Partially, there were observed relatively hard milky white to bluish gray conglomerates containing a quartz vein of about 1∿2mm thick.

-Sandstone

Presenting a bluish or greenish gray or brownish color, and including partially granules of 2∿3mm diameter.

The rock is brittle in quality and can be crushed readily by a hammer and partially by hand. In the rock blocks are developed bedding planes at an interval of several to several tens centimeters.

-Mudstone

Presenting a bluish or greenish gray or brownish color.

The rock is brittle in quality and, when hammered, crushed readily with a dull sound. In the rock blocks are seen bedding planes at an interval of several to several tens centimeters, and the blocks are parted readily along such bedding plane.

As described in the foregoing, the pit dredging at the same point by means of grab bucket was made to a depth of -23m in order to examine the extent of weathering in the direction of depth, but little change was noted in the extent of weathering of the rock.

The hardness of the respective rocks obtained by a Mohs scale of hardness as a measure of the extent of weathering is given below:

Conglomerate	3∿5;
Sandstone	3∿6; and
Mudstone	2∿4.

The foregoing agrees well with the results of field observations. The sandstone shows a relatively high value of hardness at 6, but it had bedding planes developed well and is thus brittle.

(2) Grab efficiency of grab bucket

Now calculating the mean grab per operation of grab bucket from the total volume of soil excavated in the test dredging and the total number of grab operations, there was obtained, upon the volume of soil measured in the barge at $690m^3$ and the total number of grab operations at 235 (except void grabbing due to overturn, etc. of the grab),

Mean grab per operation = 690/235 = 2.94 (m^3), or

Grab efficiency = 2.94/7.0 = 0.42.

4. Survey of Dangerous Objects

The shoals being exposed in the deep waters with fast currents, it was prospected that there would be little possibility of bombs and shells being present. But, in the present survey at the site, there were discovered ten 500 lbs bombs and a number of anti-aircraft shells and machine gun shells near the peak of the Shoal A.

Discovery of the 500 lbs bombs was immediately notified to the government authorities concerned, and they were disposed by blasting at the site by the hand of the Navy. Of these ten bombs, nine exploded completely with considerable power.

Fortunately, no mine was discovered in the area of the present field survey. But, in view of the past discovery of dangerous objects in the offshore water area of Singapore, possibility of the presence of mines in the dredging area is by no means negated, while the bombs and shells stated above involve a great danger to the work. Thus, it is considered to be indispensable to conduct a complete sweeping survey of the dredging area before the work is commenced.

Shoals A, B and C have no deposit at all respectively, while Shoal C has sand deposited only in a thin layer so that burial of dangerous objects is not conceivable. Thereofore, no magnetic survey is required, but the direct observation of the bottom by divers will be an effective method.

Where skin diving is employed for submarine works, there will be only a work time of 1 hour available at the time of slack water (tide turn) on account of the depth and current. In the strait area, the diurnal tide is governing, and one of two slack waters a day often occurs in night so that the daily working hours will be very short. Thus, it will be required to use a number of divers simultaneously.

Where an explosive object is found, the disposition team of the Navy of Singapore will come, upon request, to the site on the same or next day. But, the diving hours are limited, while the blasting work may not always be finished in one day. Thus, it is important to allocate a sufficient time of work for the sweeping survey prior to the work.

5. Transit Ships

According to the result of a survey conducted jointly by PSA and Marine Department of the ships passing through the Strait of Singapore, the monthly traffic of ships as of October 1976 is about 4,500 ships. By the type of ship, the cargo boats account for 59.4%, tankers for 27.9%, other bulk carriers for 1.4% and passenger ships for 1.4%. Particularly noteworthy is the number of large tankers passing through the Strait of Singapore.

Of these four shoals, the Shoal A is located in the west-bound traffic zone, while the other Shoals B, C and D in the inshore traffic zone. Shoals as they are, there is a sufficient water depth so that they pose little hazard to the traffic except the fully loaded large tankers. Thus, there are many ships passing over the shoals presently.

Accordingly, when a dredger is fixed on any of the shaols, it is important to take measures for safety with, for example, lighted buoys properly installed to prevent ships from entering into the work water area and causing accidents.

What is considered to be particularly important from the experience of the field survey conducted this time, is the countermeasures to the west-bound large ships in the case of dredging of the Shoals A and B.

Presently, the west-bound ships are navigating with the lighted buoy on the Hambat Shoal seen on the right side. Here, in order to clearly indicate the survey area, the Shoals A and B were surrounded by three lighted buoys, when the west-bound large ships ran often into the area by mistake, and it was very dangerous. It will then be required to give consideration to the period of circulation of the work and for increasing the number of radio warnings by PSA.

Additionally, it is important to take care of the ship waves of large vessels or high speed boats navigating in the proximity.

The ship waves are distinguished in the wake of a container ship or war vessel navigating at a high speed rather than a large tanker and are sometimes as high as $1.0 \sim 1.5$ m.

Such waves are hazardous not only to the work boat itself but to the safety of the smaller ancillary boats such as anchor boat, passenger boat, etc., inducing unexpected accidents so that for such smaller boats, adequate types and capacities must be chosen with, of course, due consideration given to the fast current.

Presently, where a large grab dredger is operated, use of a tug/anchor boat of 1,000∿1,500 PS class is noted, and such will insure safety.

6. Dredging of Shoals

6-1 Examination of Dredging Method

From the result of investigation of the rock quality stated above, the rocks belong to the so-called soft to medium rock so that in dredging, no special method such as blasting or rock crashing by means of rock breaker will be required (if used, it may result in higher cost) but that direct dredging by means of dredger will be practicable.

When the rock quality only is taken into considerations, a grab, dipper or pump dredger is usable. But, when the field conditions are taken into account such as that the dredging is to be made deep at -21m, that the current is fast as about 5kn maximum and that the bottom including the shoals and their vicinities are of undulating rocks, the dipper dredger is not usable in that the maximum dredging depth of the dipper dredger available in our country is -16.0m while the tide level at the site is about 3m.

From the depth of dredging, the pump dredger is usable. But, since the bottom material is the sloping and undulating rock, it will be impossible to fix the dreger with spuds. A Christmas tree method not in use of the spuds may be used. But, in the fast current up to 5kn and against the relatively small areas of dredging of Shoals A, B and D, there will be great difficulties involved in obtaining accuracy in fixing the stern and for swinging. Thus, in the present case, the pump dredger is considered to be inadequate.

From the foregoing examination, the optimum dredger from the technical as well as economical point of view is the grab dredger. Thus, from the result of the test dredging at the site, a method of using a heavy or ultraheavy grab bucket having a capacity of $7m^3$ (60t) or more was taken as an object for estimation of the work cost.

In this case, whether a $7m^3$ (60t) class grab bucket or a larger one ($13m^3$ (120t)) should be used is dependent on the total volume of soil to be dredged and the specified work period. Thus, comparative estimations were made for the respective cases of dredging. In the case where a large grab type dredger is used, this class dredger is not available in the vicinity of Singapore presently so that it is contemplated to bring the dredger from Japan.

6-2 Work Programme

6-2-1 Dredging Quantity

Table Dredging quantity by shoal

Shoal \ Quantity	Dredging area (m2)	Net dredging (m3)	Extra dredging (m3)	Total* Quantity (m3)
A	2,972	4,938	2,378	7,320
B	34,332	88,038	27,466	115,500
C	126,345	389,146	101,076	490,220
D	1,669	2,149	1,335	3,480
Total	165,318	484,271	132,255	616,520

* The total quantity is the sum of net dredging and extra dredging and is represented with the figure in the unit's place rounded.

6-2-2 Work Hours and Monthly Quantity of Solids Dredged

Work hours a day: 24 hours

Operation hours a day: 18 hours

Work days a month: 24 days

Monthly quantity of solids dredged:

$7m^3$ Grab dredger	Shoals A, B and D	$8,035m^3$
	Shoal C	$14,430m^3$
$13m^3$ Grab dredger	Shoals A, B and D	$18,403m^3$
	Shoal C	$34,690m^3$

6-2-3 Fleet Composition

The following two kinds of fleets will be used in combination, as required.

	Heavy type grab fleet	Ultraheavy type grab fleet
Grab dredger	DE-1600PS, $7m^3$ grab, 1	DE-3200PS, $13m^3$ grab, 1
Tugboat	D-1100PS	D-2000PS
Anchor boat	D-120PS	D-360PS
Hopper barge	2 ($500m^3$, bottom door type)	2 ($800m^3$, bottom door type)
Passenger boat	4 (Wooden, D-100PS)	4 (Wooden, D-100PS)

The boat position is to be secured constantly by a radio range finder.

6-2-4 Dumping Area

The dumping area will be chosen in the south of the Semakau Island as shown in the attached chartlet.

6-3 Cost Estimation

Before looking into the attached table, the following points should be noted.

(1) This estimation was made in December 1978 with the rate of conversion of Singapore dollar to Japanese yen at 1 S$ = 90.9 yen.

(2) With respect to the availability of the working craft at the site, a $7m^3$ class dredger is presently working in Singapore water area, and a $13m^3$ class dredger will be brought from Japan. Therefore, should the time of commencement of the work be delayed, this must be reexamined.

(3) The following items are not included in this estimation:

a. Where documentary procedures are required for entry or exit of the boats and personnel into or out of the port area for the sake of the work, cost elevation due to degradation of the efficiency on account of the resulting standby, etc.
b. Custom duties for the vessels, equipment and materials brought into Singapore for the sake of the work, and port dues to the vessels as foreign vessels;
c. Fees for use of basins and public jetty;
d. Expense of demolishing dangerous objects when those are discovered at the site; and
e. Cost for price increase of commodities.

(4) In the miscellaneous work are included the following:

a. Expense of diver survey of dangerous objects;
b. Expense of installation, movement and maintenance of marker buoys;
c. Expense of warning system for navigating vessels;
d. Survey expense for completion inspection; and
e. Sampling and testing expense of dredged soil.

(5) As supervising boats, a launch and a speed boat are to be provided when these are requested.

(6) The physical contingency is applied where an extra cost is required for removal of rock which is different from that initially forecasted when such is encountered.

Table - Work Cost by Case

Cost in Singapore Dollars

Case		I	II	III	IV
Names of shoals demolished		A	A and D	A, B and D	A,B,C, and D
Net volume of shoals	m^3	4,938	7,087	95,125	484,271
Quantity of dredging	"	7,320	10,800	126,300	616,520
Term of works	Month	4	5	27	27
Size of grab backet	m^3	7	7	7	7 and 13
I. Contractor' cost					
1. Dredging cost		754,000	1,113,000	13,014,000	37,413,000
2. Mobilization and Demobilization cost		-	-	-	5,621,000
3. Miscellaneous work		171,000	242,000	1,627,000	4,233,000
Total		925,000	1,355,000	14,641,000	47,267,000
II. Contingency					
Physical		171,000	252,000	2,952,000	5,857,000
Price					
III. Employer's cost		159,000	171,000	741,000	741,000
Grand Total		1,255,000	1,778,000	18,334,000	53,865,000