7.4.3 Estimated Cost for Dredging Improvement

(1) Basic assumptions for calculation of tangible benefits as follows:

- Revision of track recorder for Orinoco and Guayana
- Disposal of dredged spoils to designated sites outside the Channel by bottom dumping barges.

(2) Cost

Track recorder to Orinoco and Guayana

- Display and computer software	US$4,500 x 2	US$	9,000
- Software	US$62,000 x 2		124,000
- Installation Cost incl. Training			57,500
SUB-TOTAL		**US$**	**190,500**
Monthly Consumables and Misc. Expenses		**US$**	**500**

Disposal of dredged spoils to designated sites outside the Channel by bottom dumping barges.

- Installation of discharge piping for Orinoco	US$	2,900,000
- Bottom dumping barge (3,500 m^3 x 2)		9,500,000
- Pusher barge (4000 PS x 2)		9,500,000
SUB-TOTAL	**US$**	**21,900,000**

- Monthly Operation and Maintenance Cost (Fuel Oil, Lubrications, Seamen's Salary, Supply and etc.)	US$	318,000
- Monthly Administration Charge		25,000
SUB-TOTAL	**US$**	**343,000**

The above cost are used in calculating the economic and financial internal rates of return.

Note:

1) The Channel as well as the dredge are provided with GPS receiver and D-GPS transmitter/receiver, hence, are excluded from the above costs.
2) Location of intake will be determined by GPS and Gyro.
   Survey data will be displayed before and after dredging.

7.4.4 Further Study Required for Fluff Deposition and Appropriate Dredging Activities

The maintenance dredging volume of 10 million m^3/year in the outer channel in Boca Grande amounts a significant portion of the total dredging volume of 18 million m^3/year in the Rio Grande navigation channel. In case of inner channel, sediment deposits as the form of sand while in the outer channel, it takes the form of fluff (flocculated fine sediment) and sand both. Fluff characteristics vary along the outer channel due to the various conditions such as salinity, density currents etc. Moreover, the process of fluff deposition, consolidation and its time scale are not known and dredging methods should be properly selected taking them into the account too.

In order to maintain the required depth of the channel by means of efficient and effective dredging methods, study on fluff deposition is essentially important. However, due to lack of previous studies and limited data, detailed site surveys and site testing are needed to analyze and understand the quite complex sediment transport behavior in Boca Grande.

Major important items required to be investigated for the analysis of fluff deposition are as follows.

(1) It is necessary to identify the reaches of navigation channel according to the sediment deposition rate and its pattern such as sediment in suspension with fluff layer or with consolidated layer etc, for planning the appropriate dredging methods.

Following types of sounding instruments with acoustic waves different to each other can be used simultaneously to detect the sediment layers.

1) SC-3 salt water wedge detector : able to detect very tiny difference in density and use to differentiate the water layer and watery sediment layer.

2) SH-20 watery sediment detector : able to detect thickness of the watery sediment layer by emitting two waves of different frequencies.

3) CAP-6000 Chirp sooner : able to detect the top of the clayey sediment layer which underlies the watery sediment layer.

(2) Orinoco delta can be considered as a stratified estuary due to the interaction of saline water with river water and small tidal variations specially the reach close to the river mouth. Hence salinity intrusion profile should be checked and included in flow analysis in Boca Grande.

(3) In order to determine the appropriate dredging method by analyzing the physical properties of sediment, detailed site surveys and site/laboratory testing should be carried out.

1) Items to be investigated:

No. of sampling	:	one (1) every 10 km, total 7 locations
Location of sampling	:	At the edge of the channel
Depth of Sampling	:	Up to –17 meters LWL
Laboratory Test	:	Moisture content, unit weight, particle size distribution, liquid and plastic limit, consolidation, consolidation by settlement, cohesion, chemical properties.
Depth of Bed	:	By echo sounder (24 kHz and 200 kHz)

2) Based on the investigation the following will be determined:

- Unit weight of the fluffs at different levels
- Based on the result of the consolidation analysis, the frequency of agitation will be formulated.
- Similarly, based on the result of the consolidated analysis, the most appropriate method of dredging will be evaluated such as agitation or removal or a combination of both.
- The appropriate drag head will be studied and recommended.

(4) With availability of sufficient data including properties of sediment, salinity profile and flow characteristics, numerical model can be applied to predict the sediment discharge and distribution in the Boca Grande.

In addition to above, following items are also to be considered.

(5) Examination of Dredging Method

In order to attain maximum dredging performance, the following items should be checked:

1) Discharge velocity to attain maximum output.

2) Size and revolution of impeller to attain maximum output.

3) Appropriate depth of drag head to attain maximum output.

(6) Checklist Items for Orinoco Dredge

The Orinoco dredge was constructed in August 1978 about twenty years ago. In order to improve its performance; the following items should be checked:

1) During the span of twenty (20) years, based on maintenance record, the spare parts with frequent replacements must be listed up.

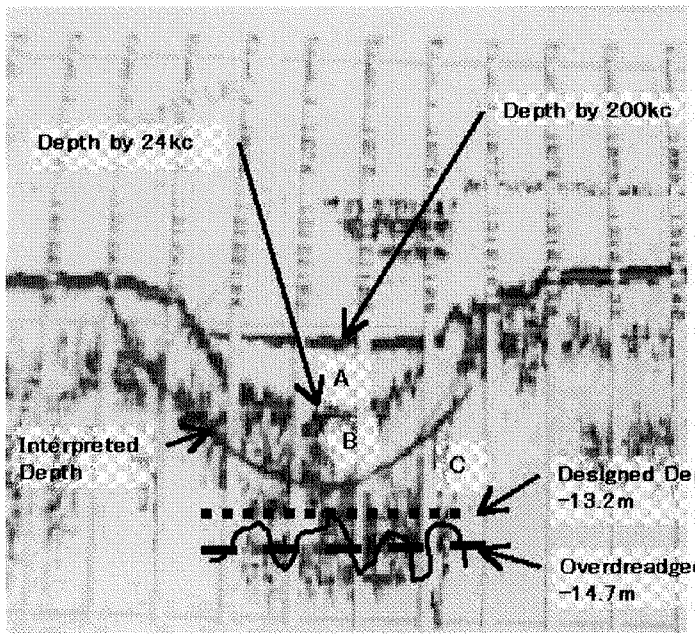
2) The structural integrity of the dredge such as the steel frames, sheets and others should be investigated and replaced where required.

3) System check of the dredge should be conducted particularly on the engine, power supply, pumps hydraulic systems and pipes and related equipment.

4) The drag arm, ladder and winch etc. must investigated and improved as necessary.

Note: Change of Unit Weight of Fluff due to Consolidation

The Fig. 7-4-15 is a sounding chart recorded by INC by means of the Eco-Sounder of 24 kHz and 200 kHz frequencies. It shows the different layers of fluff along the channel depending on the progress of consolidation. It is assumed that Layer A shows the fluff which has been agitated after 30 days. Layer B shows the fluff which has been agitated after 30 to 120 days. Layer C shows the fluff which has been agitated after 120 days. The navigable depth of the channel according to the INC is marked as "Interpreted Depth". The unit weight for each layer is assumed as shown in the Table 7.4.3.



Layer	Unit Weight
A	1.15 to 1.25 t/m^3
B	1.30 t/m^3
C	> 1.32 t/m^3

Table 7.4.3
Unit Weight of Fluff in Layers

Fig 7-4-15 Layers of Fluff

The deposited fluff in the outer channel consolidates with time and it results to increase the unit weight. As a result, fluff layers are formed vertically with different unit weights. In the Rio Grande channel, sounding frequencies of 24 kHz and 200 kHz are used for the bathymetrical survey. As frequency of 200 kHz can detect only the shallow interface between seawater and the unconsolidated fluff, in the Rio Grande channel the frequency of 24 kHz is used in order to detect denser layer, which is not appropriate for the navigation. However, there are locations where it is possible to navigate in the consolidated layer detected by frequency of 24 kHz. Hence, depth termed as interpreted depth is used by experience.

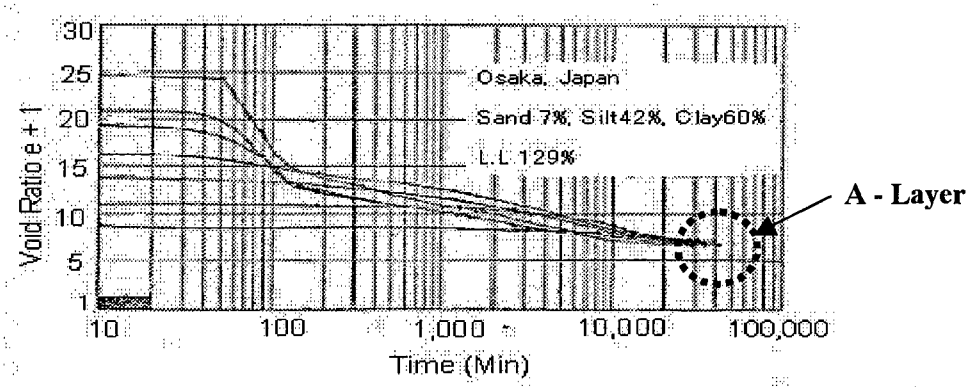


Fig 7-4-16 Settlement time

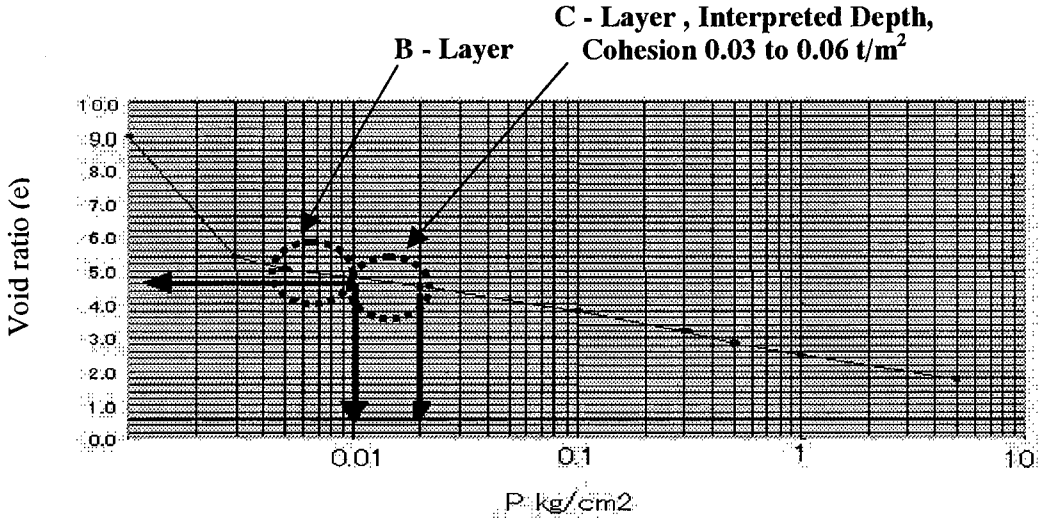


Fig. 7-4-17 Consolidation, e-log(p) curve

Table 7.4.4 Relation among Void Ratio, Unit Weight & Moisture Content

Void Ratio	Unit Weight	Moisture Content	
10.0	1.18	389%	
9.0	1.19	350%	
8.0	1.21	311%	
7.0	1.23	272%	
6.0	1.26	233%	
5.0	1.30	194%	
4.5	1.32	175%	
4.0	1.35	155%	
3.5	1.39	136%	
3.0	1.44	117%	Liquid Limit
2.5	1.49	97%	

Specific Gravity:

Sea Water	1.03
Soil	2.65

The density of fluff layer increases with time in the progress of consolidation. As the density of the layer A is assumed as 1.15 to 1.25 t/m3, the void ratio would be about 8. According to the Fig. 7-4-16, it takes about 30 days to form the layer A. Fig. 7-4-17 shows the variation of void ratio with the pressure (Force over a unit area) and the corresponding locations of layer B and layer C. The pressure increases rapidly due to the increment of weight and void ratio decreases with the consolidation.

The resistance caused by the fluff on vessel navigation increases with the increase of cohesion due to the consolidation. As an example for a given engine power, allowable speed of vessel depends on the cohesion of the fluff and deceleration of Panamax size Vessel due to fluff resistance can be calculated as follows:

Power = Force x Velocity

$$Hp = \frac{1000\ (W \times L \times S) \times C}{75 \times e \times f}$$

Where:

W = Width of the ship

L = Length of the ship

S = Speed (3 m/s, 1.5 m/s)

C = Cohesion

Hp = Horse power (12,000 PS)

e = Mechanical efficiency

f = Shape factor

When:

S = 3 m/s, C = 0.03 t/m^2

S = 1.5 m/s, C = 0.06 t/m^2