CHAPTER 5 DESIGN OF ACCESS CHANNEL

CHAPTER 5 DESIGN OF ACCESS CHANNEL

5.1 Existing Access Channel and Ship Handling

5.1.1 Existing Access Channel and Basin

No light buoys mark the access channel for deep draft ships and also ship is not leaded by leading lights. Lighthouses at Punta Chiquirín and at a position of NW extremity of Isla Zacatillo are the only navigation aids in the access channel. Both lighthouses are aluminum tower with concrete base. Berth lights are installed on the both end of Port of Punta Gorda to illuminate the berth at night.

5.1.2 Existing Ship Handling

Pilotage is not compulsory for any ship but is available on request.

The channel navigation has no restriction but it is preferable on flood tide with draft over 24 feet to keep enough under keel clearance and it is recommended to carry out during daytime. Berthing operation is usually carried out on slack tides due to cross currents, up to 3-4 knots. Max size of ship accepted is 22,000 DWT type (LOA:190 m)

5.2 Design Criteria for Access Channel and Turning Basin

5.2.1 Ship Characteristics

The characteristics of planned ships for the study of access channel and turning basin are tabulated as follows:

Table 5.2.1 Characteristics of Planned Ships to call La Unión Port

(Unit: m)

Cargo Item	Type	DWT	LOA	Breadth	Sailing Draught
Cereals	Panamax Bulker	50,000	185	32.2	11.8
Fertilizer	Handysize Bulker	43,000	183	30.5	12.0
Iron/Steel Products	Handysize Bulker	30,000	177	27.0	11.0
Raw Sugar	Handysize Bulker	26,000	173	25.2	10.0
Containers	Panamax Container Ship Capacity of 4,800 TEUs	55,000	294	32.2	13.1

5.2.2 Ship Passage Pattern

Because of law ship traffic, an oncoming ship is likely not happen. And the traffice would be controlled by Vessel Traffic Service System which will be equip with the port. Also considering the initial construction cost is huge, the access channels is configulated as one way navigation.

5.2.3 Natural Conditions

The natural conditions related to ship navigation are as follows:

(1) Wind

According to the information of monthly average wind velocity and dominant wind direction at La Unión-City from 1970 to 1985, the average wind velocity is about 2 m/sec –3 m/sec through the year. As to the predominant wind direction, NE prevails from November to February and SW from March to October.

It shows the wind velocity observed during the period between 1996 and 2000 are 1.3 to 2.6 m/s.

(2) Tidal Current

According to the current measurements carried out in September 2001 under the study, the maximum current at a speed of 1.79 m/s was observed at the inner channel area and 0.8 to 1.60 m/s current speed at the outer channel area was observed.

(3) Waves

According to US Naval Oceanographic Data, the wave height at Punta El Chiquirín (the narrowest point of the channel) is from 0.0 to 3.0 m and the frequency over 1.5 m heights is 3.6%.

(4) Visibility

According to the pilot of the Cutuco Port, no fog and mist has been observed at La Unión area.

5.2.4 Design Base

For the purpose of defining the various channels dimensions, Guidance for Design "Publication PTC II-30 by PIANC, June 1997" is applied for a preliminary consideration. And in order to verify the first time ship maneuvering simulation is carried out.

Table 5.2.2 Determination of Channel Configuration

Channel Configuration		Depends on	Requirements estimated by	Verified by
Alignment		- Bathymetry, topography - Capital and maintenance dredging volumes - Ease of Navigation	- Volumes calculation - Sediment	Fast time ship maneuvering Simulation
Width	Straights	- Vessel size: Ship length, Beam	PIANC Code	Fast time ship maneuvering Simulation
	Bends	- Vessel size: length, beam and change in heading	Geometry	Fast time ship maneuvering Simulation
Underkeel Clearance	Squat	- Vessel size: length, beam, draught and forward speed	Under keel Clearance Model	
	Pitch/roll	- Vessel size: length, beam, draught and wave height	Under keel Clearance Model	
Channel depth		- Underkeel clearance - Maintenance dredging		
Side slopes		Bed material and exposure to waves and currents	Empirical formula	

5.3 Preliminary Design of Access Channel and Turning Basin

5.3.1 Horizontal Alignment

(1) Straight Division

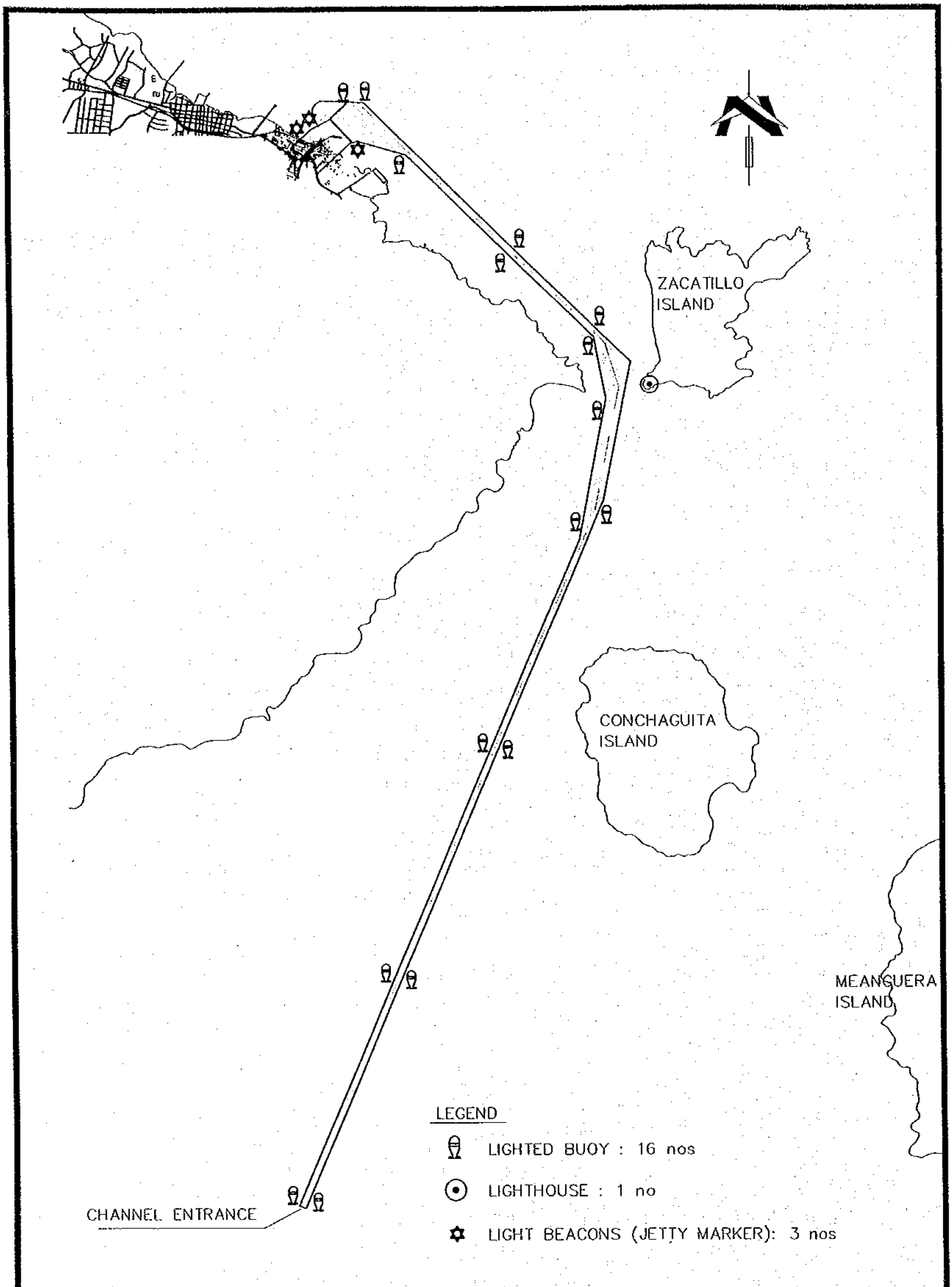
The Cutuco Port is situated in the inner area of Fonseca Gulf. In order to approach to the port, the ships have to pass through the strait between the Punta Chiquirín Cape and Zacatillo Island and turns to the westward changing about 80 degree direction. In the open sea of Fonseca Gulf the existing approach channel is aligned parallel to the coast with about 1 km offshore.

The unobstructed view can be seen from both the open sea and from the Cutuco Port to Peninsula Los Negritos of Zacatillo Island. Hence the straight division of channel shall be aligned targeted at the southwest nose, Peninsula Los Negritos. And at this intersection point, a lighthouse shall be established to aid ship navigations. In these straight division the current direction is almost parallel to the channel and ship can navigate in parallel to the current direction.

(2) Bend Division

In the strait at the Cape Chiquirín, the ships have to turn by about 80-degree direction northwestward. In the strait the water depth is naturally deep enough and more than 20 m depth with more than 400 m width that will provide enough additional width at the bending division as shown in Figure 5.3.1.

The alignment in the bend division shall be determined in the deeper area and in parallel to current flow direction.



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	5.3.1	ALINGMENT OF ACCESS CHANNEL

(3) Channel Width

Channel width is related to the breadth of the largest vessel to be called and the relationship depends on a number of factors affecting the navigation including ship speed, cross winds, cross currents, longitudinal currents, waves, bottom surface, waterway depth, cargo hazard level and bank clearance.

(4) Widths on Straight

The widths on straight division are estimated from PIANC standard and the ship-handling simulation as shown in Table 5.3.1. The first time ship maneuvering simulation is carried out under various sea and weather conditions to verify those estimations. The detail of the simulation is described in the Section 5.4.

Table 5.3.1 Layout of Navigation Channel

Ship Type	Container		Bulker	
Channel	Outer	Inner	Outer	Inner
PIANC Standard	142 m	132 m	148 m	151 m

(5) Widths on Bends

Bend division in navigational channels need to be carefully designed to allow for the dynamic behavior of ships when turning. Width on bend between outer and inner channels is 350-500 m and those widths are checked and examined in the ship maneuvering simulation.

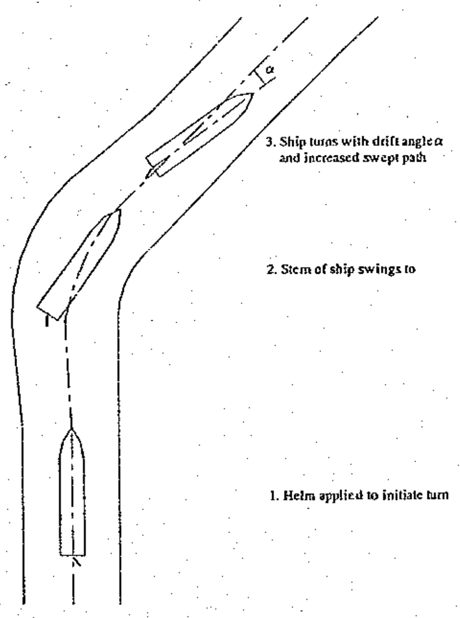


Figure 5.3.2 Turning Behavior of Ships

As a ship enters a turn, the rudder is applied which moves the stern of the vessel toward the outer side of the bend, as indicated in Figure 5.3.2. The ship then moves around the bend with a drift angle, which has the effect of increasing the swept path of the ship.

To allow for this increase in swept path, each bend of over 5 degrees change in channel direction needs to be widened. The increase in width is usually applied to the outside of the bend to accommodate the stern of the ship.

To allow for this increase in swept path, each bend of over 5 degrees change in channel direction needs to be widened. The increase in width is usually applied to the outside of the bend to accommodate the stern of the ship.

(6) Turning Basin

The area of basin for turning in front of the berths is determined in considering the conditions such as the size of ships, sea and weather condition and number of tug boats to be used for assistance.

A turning basin is designed for both ships at container and multi-purpose berths because two ships do not sail at the same time by limited number of tugboats.

In the fast time ship-handling simulation radius of 2 times the overall length of the largest container ship is applied.

5.3.2 Vertical Alignment

(1) Underkeel Clearance and Required Dredged Level

Adequate provision is needed for clearance beneath vessels to ensure that ships do not ground during navigation of the channel. The depth of water needed by a vessel is determined by its sailing draught and sufficient additional clearance (underkeel clearance).

The required clearance varies depending on the size of vessel, its speed, extent of the channel, wave conditions, and wind conditions.

These requirements are summarized in Table 5.3.2 and Table 5.3.3. These show that more clearance is required in the outer channel section than in the inner channel. The underkeel clearance requirements are built into the assessment of channel utilization.

The design vessels are Panamax type having the characteristics acquired as the Panama Canal Limitation as follows.

Panama Canal Requirement for passing

1) Depth: 12.04 m vessel draught in fresh water
11.80 m vessel draught in seawater

2) Length: 294 m

Therefore, the design sailing draught is adapted as 11.8 m in seawater conditions in the east coast. In the case of bulker, the major cargo flow is from American Gulf to the West coast. Hence the vessels draught is limited by the limitation of the Panama Canal. However in the case of container vessels, the cargo moving is mainly in the west coast, the vessels will operate without the draught limitation. The full draught of Panamax container vessels is adapted as 13.1 m as shown on Figure 5.3.3.

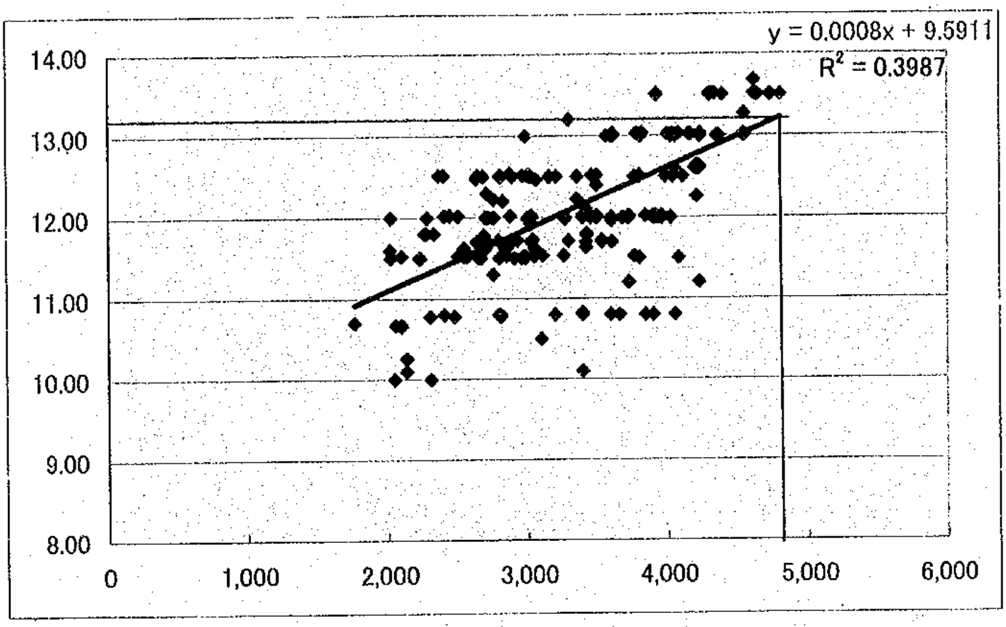


Figure 5.3.3 Panamax Container Vessels Draught

Underkeel clearance has been calculated in consideration of a relatively large offshore wave condition of 1.5 m. The channel depth and allowance is required to allow for vessel squat of the order of 0.7 m (at 9 knots relative ship speed) and wave-induced motion of the order of 0.4 m. Therefore the recommended underkeel clearance is 0.7 + 0.4 + 0.3 = 1.4 m, considering a disastrous net underkeel clearance as 0.3 m. In the case with wave height 2.0 m, the vessels will navigate with low speed, and then the required underkeel clearance is not necessary to increase.

In inner channel, underkeel clearance was calculated in consideration of a relatively small offshore wave condition of 1.0 m. The channel depth and allowance is required to allow for vessel squat of the order of 0.45 m (at 7 knots relative ship speed) and wave-induced motion of the order of 0.15 m. Therefore the recommended underkeel clearance is 0.45 + 0.15 + 0.3 = 0.90 m.

Therefore, the required water depths are:

Outer Channel :	-14.5 m
Inner Channel :	-14.0 m
Turning Basin :	-14.0 m

Table 5.3.2 Underkeel Clearance Related to Vessel Size, Speed and Wave Conditions in Outer Channel

Wave height 1.5 (m) Sailing in					
Design Ship, Draught and speed	Wave-induced vertical motion	Computed squat	Disastrous net underkeel clearance	Total underkeel clearance	Required Depth of water
Container **13.1 m** 9 knots	**0.40 m**	**0.70m**	**0.30 m**	**1.40 m**	**14.50 m**
Bulker 11.8 m 9 knots	1.00 m	0.90 m	0.30 m	2.20 m	14.00 m

Source: Consultants Research

Table 5.3.3 Underkeel Clearance Related to Vessel Size, Speed and Wave Conditions in Inner Channel

Wave height 1.0 (m) Sailing in					
Design Ship, Draught and Speed	Wave-induced vertical motion	Computed squat	Disastrous net underkeel clearance	Total underkeel clearance	Required Depth of water
Container **13.1 m** 7 knots	**0.15 m**	**0.45 m**	**0.30 m**	**0.90 m**	**14.00 m**
Bulker 11.8 m 7 knots	0.15 m	0.60 m	0.30 m	1.05 m	12.85 m

Source: Consultants Research

(2) Side Slopes

It is not usual to employ theoretical analytical methods to determine the most appropriate side slopes for navigation channels in estuarial waters. This is because standard soil mechanics solutions cannot account for disturbing forces due to tidal and fluvial currents, wave action, or ship wash. Slope design is therefore usually based upon experience of slope behavior under similar soil and hydrodynamic conditions.

An analysis of the design slopes adopted in 12 different channels around the British Isles shows a range from 1 in 4 to 1 in 10 with an average slope of 1 in 6.7.

British Standard 6349: Part 5, Code of Practice for dredging and land reclamation, at Table provides the following guidance:

Table 5.3.4 Slopes for Various Soil Type

Soil Type	Slopes	
	Still Water	Active Water
Rock	Nearly vertical	Nearly vertical
Stiff clay	45°	45°
Firm clay	40°	35°
Sandy clay	25°	15°
Coarse sand	20°	10°
Fine sand	15°	5°
Mud and silt	10° to 1°	5° or less

Typical soils illustrated in Figure 5.3.4 throughout the navigation channel are classified as sandy and gravely silt. The environment is generally active, due to wind generated waves, or ship wash. If guided by the above, an appropriate slope will be in the range less 10°~15°, or between 1 in 5.6 and 1 in 3.7.

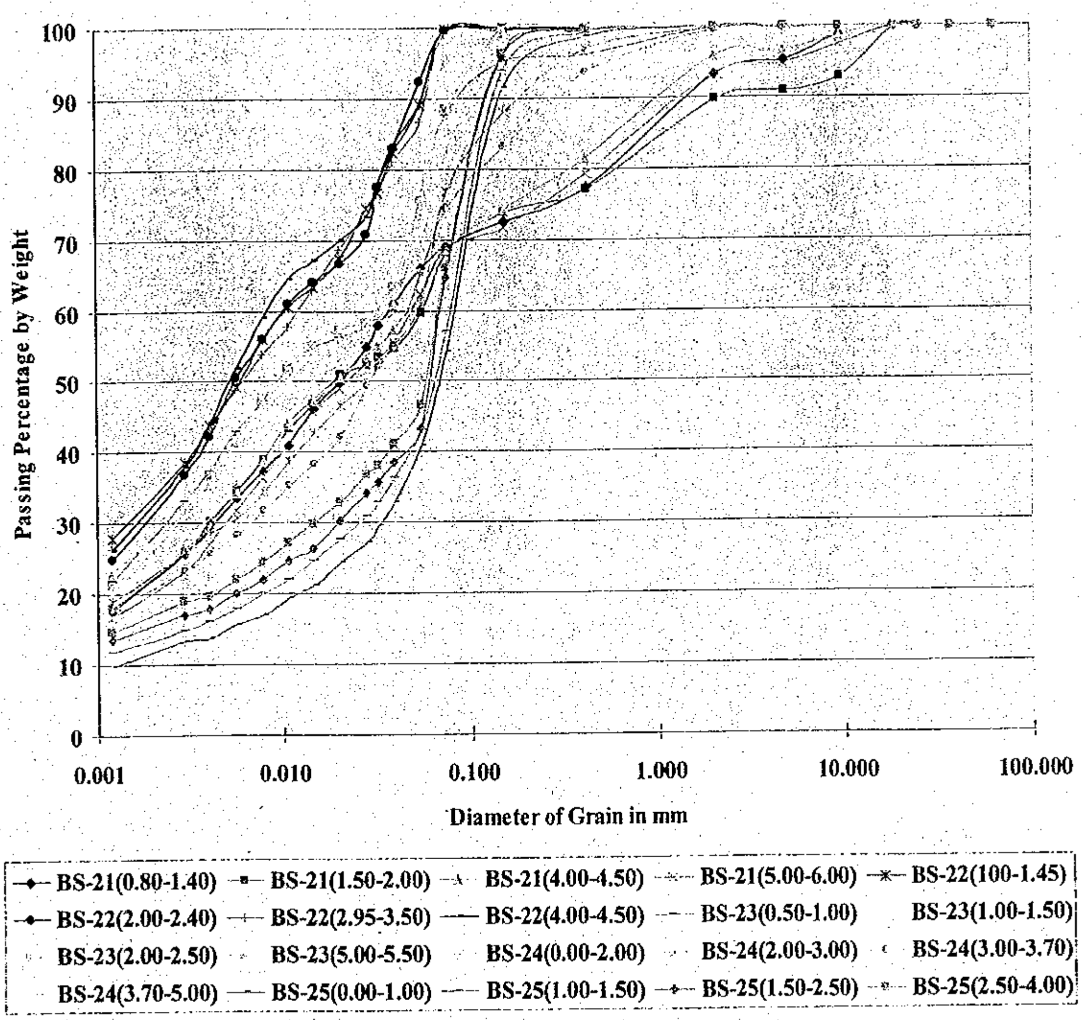


Figure 5.3.4 Grain Size Distribution in Channel Area

Besides, the moisture contents and unit weight of materials to be dredged are indicated in Figures 5.3.5 and 5.3.6. The average moisture contents are ranged from 50% to 150% and the unit weight is 13 to 14 kN/m^3. Based on the site condition that proposed channel area would be classified as more firm clay, despite the value of the standard penetration test is lower than 2 to 4, the design side slope is finally determined at 1:3 or 1:5 (in the middle of 10°~ 20°).

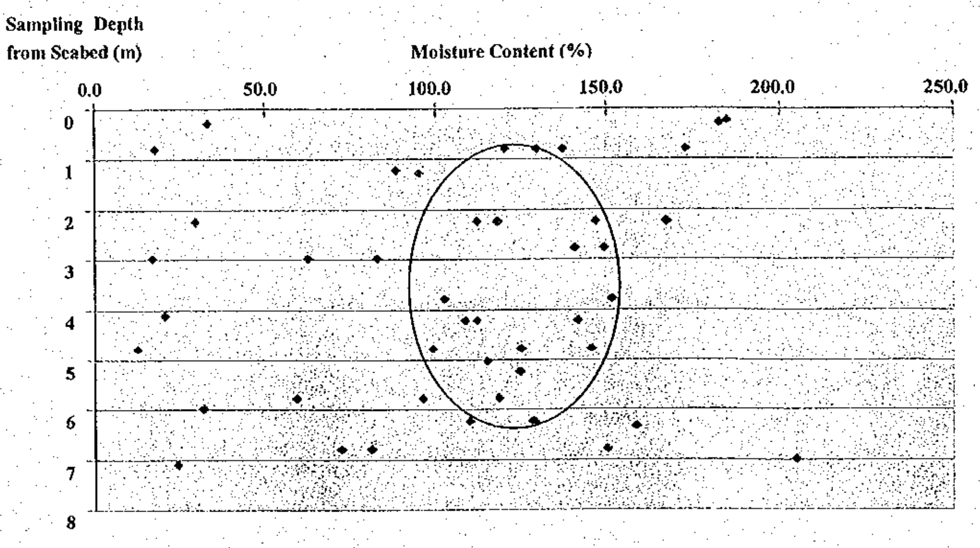


Figure 5.3.5 Moisture Content of Materials to be Dredged

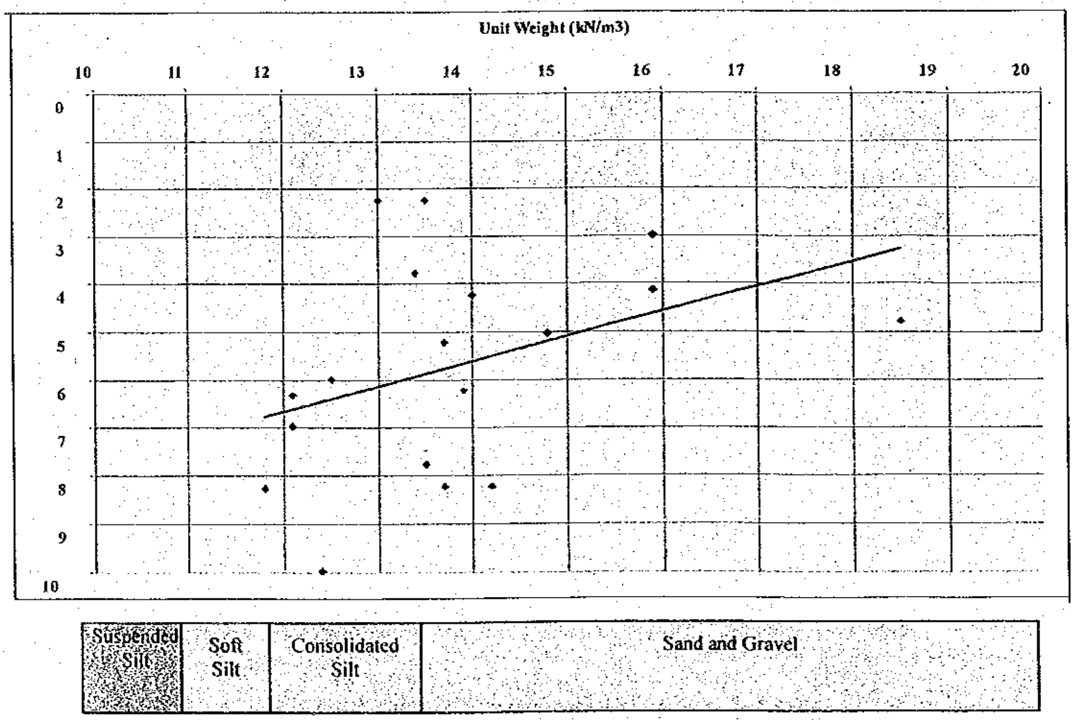


Figure 5.3.6 Unit Weight of Materials to be Dredged

It is therefore recommended that the design channel slopes be as follows:

[Recommended design slopes]

Berth and turning area:	1 in 3 ~ 5
Inner channel:	1 in 3 ~ 5
Outer channel:	1 in 5

5.4 First Time Ship Maneuvering Simulation

5.4.1 Construction of Simulation Model

(1) Purpose of the Ship Maneuvering Simulation Study

Usually the channel is designed according to PIANC standard, but in case of the port surrounded by strong current such as La Unión Port the special study should be applied. With reference to the new access channel, it is most important to study very carefully and to prepare in advance for smooth navigation in the channel and berthing/unberthing operation without hindrance for the future operation. Particular consideration should be given to the oceanic climate, because the outer channel is designed facing the open sea.

The principal purpose of the study is to examine the pla nned channel and turning basin design thoroughly and deeply, and to suggest appropriate recommendations.

Computer simulations support the study extensively.

(2) Flow of the Ship Maneuvering Simulation

The flow of the study is shown in Figure 5.4.1

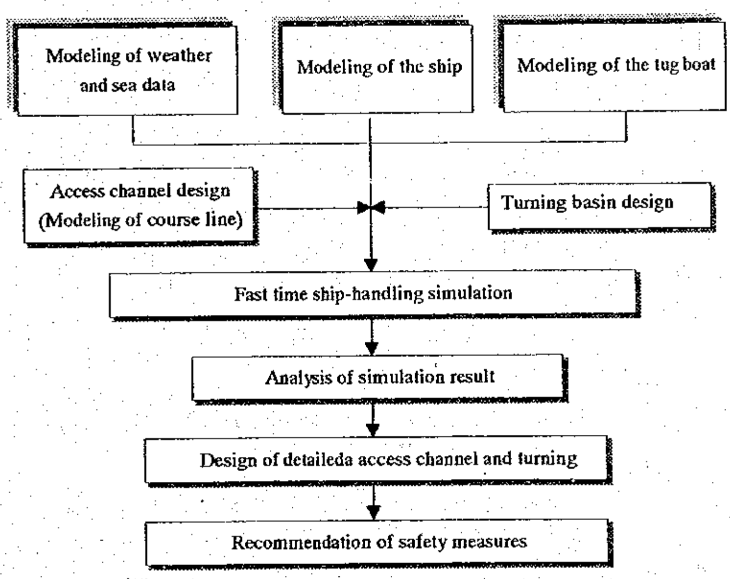


Figure 5.4.1 Flow of Study

(3) Ship Maneuvering Simulation

1) Simulation System

The fast time ship handling simulation is a numerical ship handling simulation conducted with an automatic controller replacing the human navigator. It is to provide the data about limited in scope behavior of the man-machine-environment system under designed conditions and constraints.

The simulation system used for the fast time ship -handling simulation consists of the following components.

a) Motion computing system, which is a system implementing the mathematical models of the simulation system.
b) Automatic controller, which is a system that realizes some control strategy.
c) Simulated control input system, which is a system that connects the automatic controller and the motion computing system.
d) Output system, which is a system that records the simulation state.

The mathematical model of the ship maneuvering that is employed within the simulation system can be classified as a modular type one. The modular means the total force acting on the ship is expressed as a sum of components forces acting on the parts of the ship. The model is based on the published results of researches conducted in Japan within the MMG (Mathematical Modeling Grouped) and the MSS (Model for Slow and Shallow Motions) projects.

The following forces are modeled in the system:

- Hull force, propeller force, rudder force, tugboat force (Side thruster force)
- Wind force, wave force, tidal current force

The effects of restricted water depth are included into the models of hydrodynamic forces. The power of ships engine, rudder position and tugboats Z-propeller are also modeled using specific dynamic equations.

2) Model of Wind and Tidal Current Condition

Wind and tidal current condition are determined according to the survey data. Their predominant directions are taken into consideration.

3) Ship Used for the Fast Time Ship-handling Simulation

Table 5.4.1 shows the principal particulars of the ship which is used for the ship - handling simulation model.

Table 5.4.1 Ship's Principal Particulars

LOA		292.15 m	
LPP		273.00 m	
Breadth		32.26 m	
Depth		21.20 m	
DWT		59,418 MT	
Condition		Full load	Half load
Draft		13.00 m	11.00 m
Displacement Tonnage		78,722 MT	63,350 MT
Project area	Front	1,000 m^2	1,060 m^2
	Side	5,300 m^2	5,870 m^2
Speed	Full	11.9 knots	12.1 knots
	Half	9.3 knots	9.5 knots
	Slow	7.5 knots	7.7 knots
	D.Slow	6.5 knots	6.7 knots

4) Simulation Cases

Simulation cases are shown in Table 5.4.2.

Table 5.4.2 Simulation Cases of Fast Time Ship-handling Simulation

Parameter	Unberthing	Channel navigation	
	Turning	Course keeping	Course change at bent
Wind direction	8 directions	8 directions	8 directions
Wind velocity	12 & 15 m/s	12 & 15 m/s	12 & 15 m/s
Current set	Follow and against	Follow and against	Follow and against
Current velocity	1,2 & 3 knots	1,2 & 3 knots	1,2 & 3 knots
Water elevation	LWL	LWL	LWL
Ship's condition	Full and half load	Full and half load	Full and half load
Ship's speed	-	Slow and half	Slow and half
Total cases	192 cases	384 cases	

5) Depth of Water

Depth of water is set to 14.5 m for the outer channel and 14.0 m for the inner channel and turning basin in the simulation.

6) Model of Tugboat

Two tugboats will be used for turning operations but no tugboat will be applied for channel navigation. Tug powering used for the simulations is shown in Table 5.4.3

The powering is derived from the manufacturer bollard pull data considering a reduction of the operational efficiency due to wave height. Those tug boat will be in service in the future.

The bollard pull is estimated by the following formula.

Tug Bollard Pull
= PS/100 x (factor of bollard pull) x (working condition efficiency)

Where,

Factor of Bollard Pull : 1.67 per 100 PS

Working Condition Efficiency : 0.75 under the normal working condition with 1m waves

Thus, the bollard pull for 3,600 PS tugboats is,

(3,600 / 100) x 1.67 x 0.75 = 45.0 ton

Table 5.4.3 Tug Powering (Full out-put)

Tug boat	3,600 PS Class
Wave Height	Under 1.0m
Bollard Pull	45.0 tonf

5.4.2 Simulation Results

Simulations are performed on the basis of the natural environment of the water area in order to investigate the effects of the natural environment on channel navigation and unberthing operation off the berth.

The method used for the evaluation of the results depends on the purpose of simulation. Generally, simulations designed for the answering the question of the objective limits. The system controllability is evaluated from the following viewpoints.

1) Attaining the control objectives at the given natural condition such as wind and current.
2) An amount of the control energy such as rudder angle or a tugboat thrust required attaining the control objectives at the given natural conditions.
3) A tendency of the change of system behavior that occurs due to modification of the simulation conditions.

The results of the simulations are described as follows.

1) Following current of 3 knots effects very much for ship maneuvering especially at the bend.
2) Current of 3 knots effects very much for turning of a ship. The ship is drifted downstream during swinging her round.
3) Basic maneuvering lane and additional widths depending on natural condition for objected container ship are examined under limitation of 2 knots current as

shown below. Those figures are decided considering the output of ship's tracks on simulation.

Outer channel : 3.0 B
Inner channel : 3.7 B

The total width of the channel is determined by adding additional width for bank clearance and for some factors such as bottom surface configuration and navigation aids to the above widths.

Basic turning area is examined as 2 times length over all of objected ship under 2 knots current limitation. The ship should be located at proper position in the turning basin by tug assistance considering current set when it begins to swing round.

Two sets of 3,600 Hp class tugboats are required to assist for berthing/unberthing operation of container ship and bulker under the operational criteria.

5.5 Proposed Alignment and Operation Criteria

According to the result of simulation, alignment of access channel is designed as shown in Figure 5.5.1 and Table 5.5.1.

The required wideth for Bulker is indicated by the dostted line with the sailing water depth.

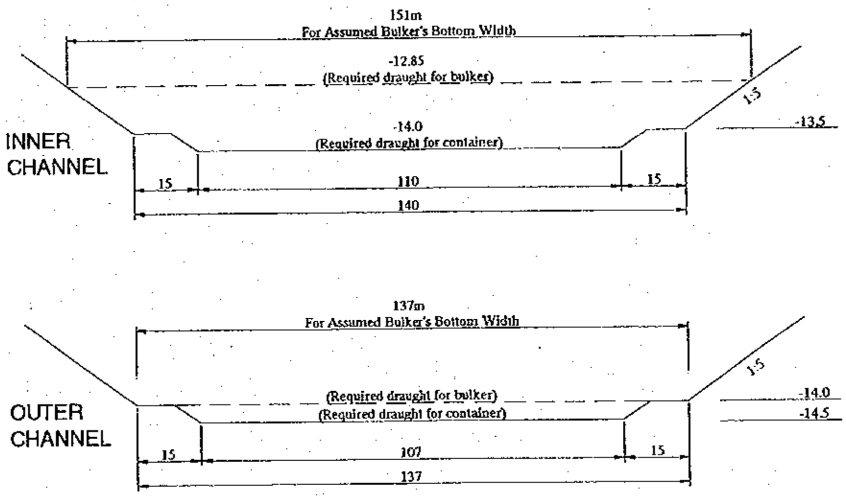


Figure 5.5.1 Width on Straight Division

Table 5.5.1 Layout of Access Channel

Ship Type	Container		Bulker	
Channel	Outer	Inner	Outer	Inner
PIANC Standard	142 m	132 m	148 m	151 m
Fast Time Simulation	130 m	140 m	137 m	151 m

According to the results of simulat ion, current and wind velocity should be taken into consideration to maintain safe navigation.

The following operational criteria for natural condition are recommended for ships calling the port.

Table 5.5.2 Operational Criteria

Natural condition	Outer channel	Inner channel
Wind velocity (Average)	12 m/s	12m/s
Current velocity (Follow)	2 knots	2 knots
Wave height (H1/3)	1.5 m	1.0 m
Visibility	3 miles	3 miles

It is calculated based on the tide table data of the La Unión Port (2001). Over 2 knots current velocity appears in the inner channel is as follows.

1) Hours over than 2 knots in flood tide: 5.2 h/day
2) Hours over than 2 knots in ebb tide: 5.2 h/day
3) When in negative, over than 2 knots velocity does not appear and those days are about 10 days/month. (120 days/year)

With a current velocity limitation of following current over 2 knots, the availability of channel for entering and leaving ship is computed at about 85% per year.

$$120^{d} * 24^{h} + 245^{d} * (24-5.2)^{h} = 7{,}486^{h}$$

$$7{,}486^{h} / (24^{h} * 365^{d}) = 0.854\ (85.4\%)$$

5.6 Sedimentation Analysis

5.6.1 Methodology

(1) Hydrodynamic Modeling

In order to undertake an assessment of the potential for sedimentation in the deepened channel, and the dispersion of material arising from the dredging operations, a tidal flow model of the Fonseca Gulf is set up. Detailed bathymetric in the vicinity of the port and any other information relating to bathymetric in the area of the approach channel is also used to set up a digital terrain model of the Gulf. The model covers the entire Gulf, with a boundary Farallones de Consiguina on the Nicaraguan side, and offshore to allow inclusion of the proposed disposal area.

The TELEMAC flow model is used to simulate the tidal currents. The grid used have a resolution of 20 – 30 m in the basin and inner channel, while the outer channel have a resolution of 20 m across the width. Elsewhere the resolution is reduced to up to 1 km. The numerous rivers in the Gulf are represented in as much detail as they are presented on available charts.

Current measurements undertaken by the JICA Study Team during the current measurement survey is used to calibrate the flow model. Thereafter, spring and neap tidal currents is simulated in the model, for exiting conditions and for the case including the channel deepened to –11 m and also –14 m.

Tidal currents is simulated for dry season conditions assuming negligible fluvial discharge down the rivers that feed into the Gulf, and also for wet season conditions using measured data obtained for the rivers local to the Port. All cases of the channel simulations use a single channel alignment.

Wave activity is also give rise to the potential for infill, particularly in the more exposed outer channel. The offshore wave climate is be defined in terms of an average annual climate, and using the wave model. TELURAY, nearshore average annual wave climates is determined at three locations of the outer channel for use as input to the sedimentation studies. These annual wave climates take into account stormy or abnormal conditions. Swell waves do not penetrate into the inner channel area and is not simulated in this region.

(2) Sedimentation Analysis

Sediment data for the site indicates that the region is characterised by mainly muddy sediments, with high levels of suspended sediment concentrations, particularly in the outer channel where wave action is significant.

Sedimentation in the channel occurs due to three main mechanisms:

Degradation of the channel side slopes. This is a geotechnical issue of side slope stability, though wave and tidal conditions are a controlling influence.

Infill due to direct sedimentation as a consequence of reduced bed shear stress in the deepened channel, and cross currents that transport sediment-laden water into it.

Potential fluidisation of the bed due to wave effects, the transport of fluid mud into the channel under gravity. This process is only likely to occur in the outer channel where wave action is relatively high.

Infill due to direct sedimentation was assessed using the HR Wallingford mud transport model, SUBIEF, that simulates the erosion, transportation, and deposition of cohesive sediment. SUBIEF is part of the TELEMAC modelling suite and run on the same mesh as the TELEMAC flow model.

A total of four channel tests were performed comprising the two channel depth configuration and wet and dry season spring and mean tide current fields.

Data from the site indicates that in the outer channel there is an abundance of muddy deposits on the bed, and that wave and tidal action gives rise to high levels of suspended sediment concentrations. Because the existing dredged channel does not extend into this more exposed area, the occurrence of fluid mud is not known, and therefore, estimates of the magnitude of infill is not possib le. The risk of infill of fluid mud in the channel is assessed by analysing the wave climate information and the tidal current information at the three nearshore wave locations and calculating their combined effect on the bed. Using this information an estimate of the potential for infill due to this mechanism is made.

(3) Result of Analysis

Simulations have been performed with a channel of 11 m depth and 14 m depth, for spring and mean tide conditions. Simulation were carried out separately for mud infi ll and sand infill under the tidal conditions of mean tide and spring tide. Analysis of the flow model results indicated that for the 11 m channel there is a tendency for the streamlines to be attracted to the channel, which has the advantage of maintaining a high bed shear stress, thereby reducing the potential for deposition.

For the 14 m depth the attraction of the flow is not sufficient to overcome the reduction in depth, and the bed shear stress reduces, giving rise to the potential for deposition. Figure 5.6.1 shows the annual rate of infill of mud along the length of the channel. It is observed an erosion near the end of the turning basin, but deposit near the berth. In the inner channel, the bulk of the infill between 2,360 m to 5,360 m from the end of turning basin in the average rates of 0.25 – 0.50 m/year.

For the sand transport simulations the reduced tidal currents for the mean tide has the effect of reducing the transport rate and thereby reducing the rate of infill. Figure 5. 6.2 shows the annual rate of infill of sand along the length of the 14 m channel. The erosion near the end of the turning basin is quite significant, but the deposit is concentrated near the distance of 5,360 m from the end of the turning basin.

Infill of mud and sand per tide for spring and mean tide conditions were summed up based on the annual tide movement. The predicted rates of infill for both 11 m channel and 14 m channel are as shown in Table 5.6.1.

Table 5.6.1 Predicted Infill Volume of Channel (unit : 1,000 m^3/yr)

	Turning Basin	Inner Channel	Outer Channel	Total
[Case of 11m Channel]				
Sand Infill	67.4	69.1	13.9	150.3
Mud Infill	0.0	0.0	31.1	31.1
Total Infill	67.4	69.1	45.0	181.4
[Case of 14m Channel]				
Sand Infill	248.9	89.6	64.9	403.4
Mud Infill	229.2	363.6	247.2	840.0
Total Infill	478.1	453.2	312.1	1,243.4

Total infill for the 11m channel is 181,000 m^3/year.

For 14 m channel annual rate of infill 1,243,000 m^3 comprising 403,000 m^3 of mud and 840,000 m^3 of sand.

Though the simulation results revealed that significant maintenance dredging is required, there is a lack of substantial information on the degree of potential sedimentation. Accordingly, the estimates of infill are based on the available data and using program of high technology, but it shoulld be noted that prediction of sediment transport are subject to wide variations. Therefore, rates of infill shall be considered as an approximate and frequent monitoring of dredged channel is prerequisite.

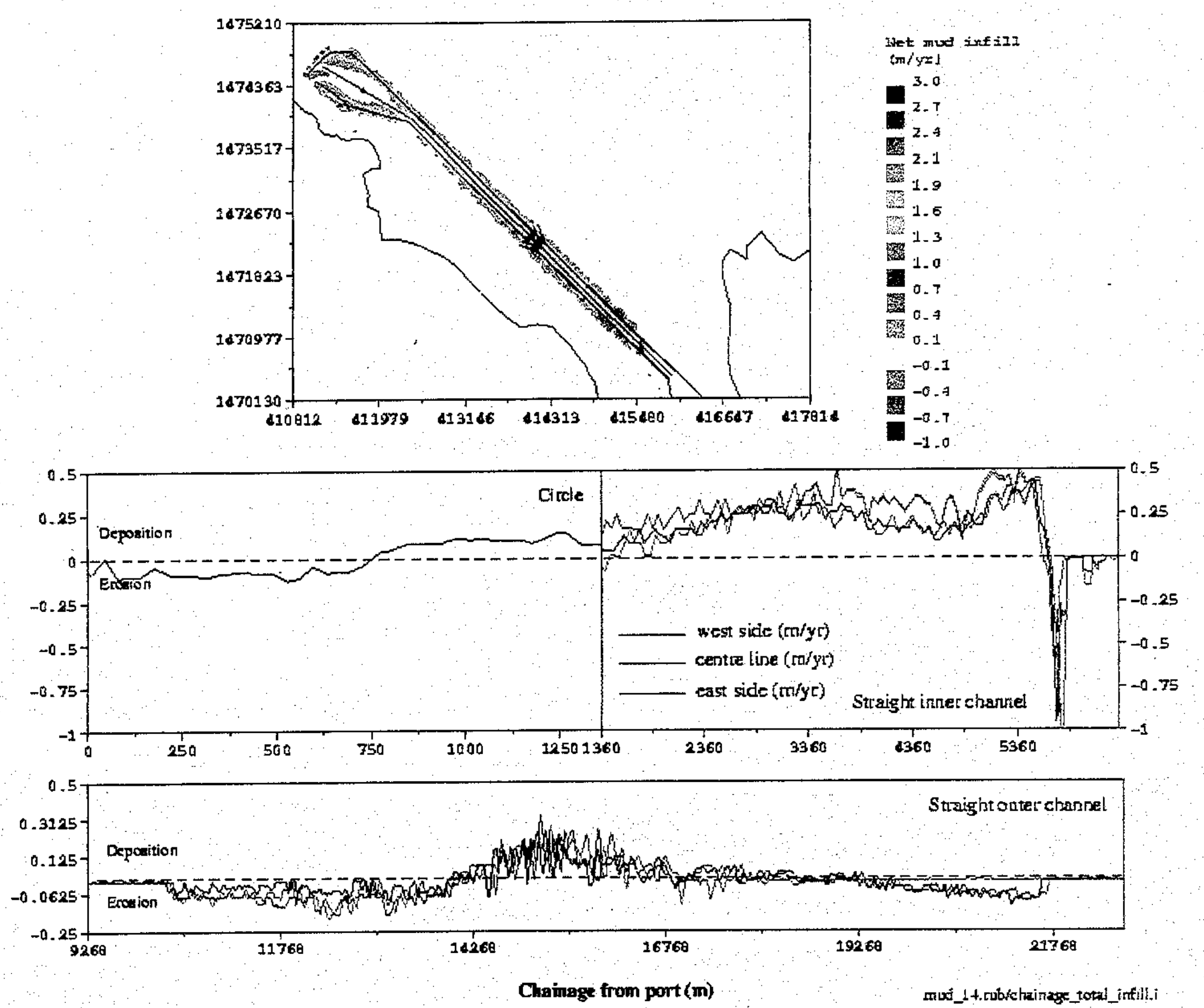


Figure 5.6.1 14 m Channel Infill of Mud

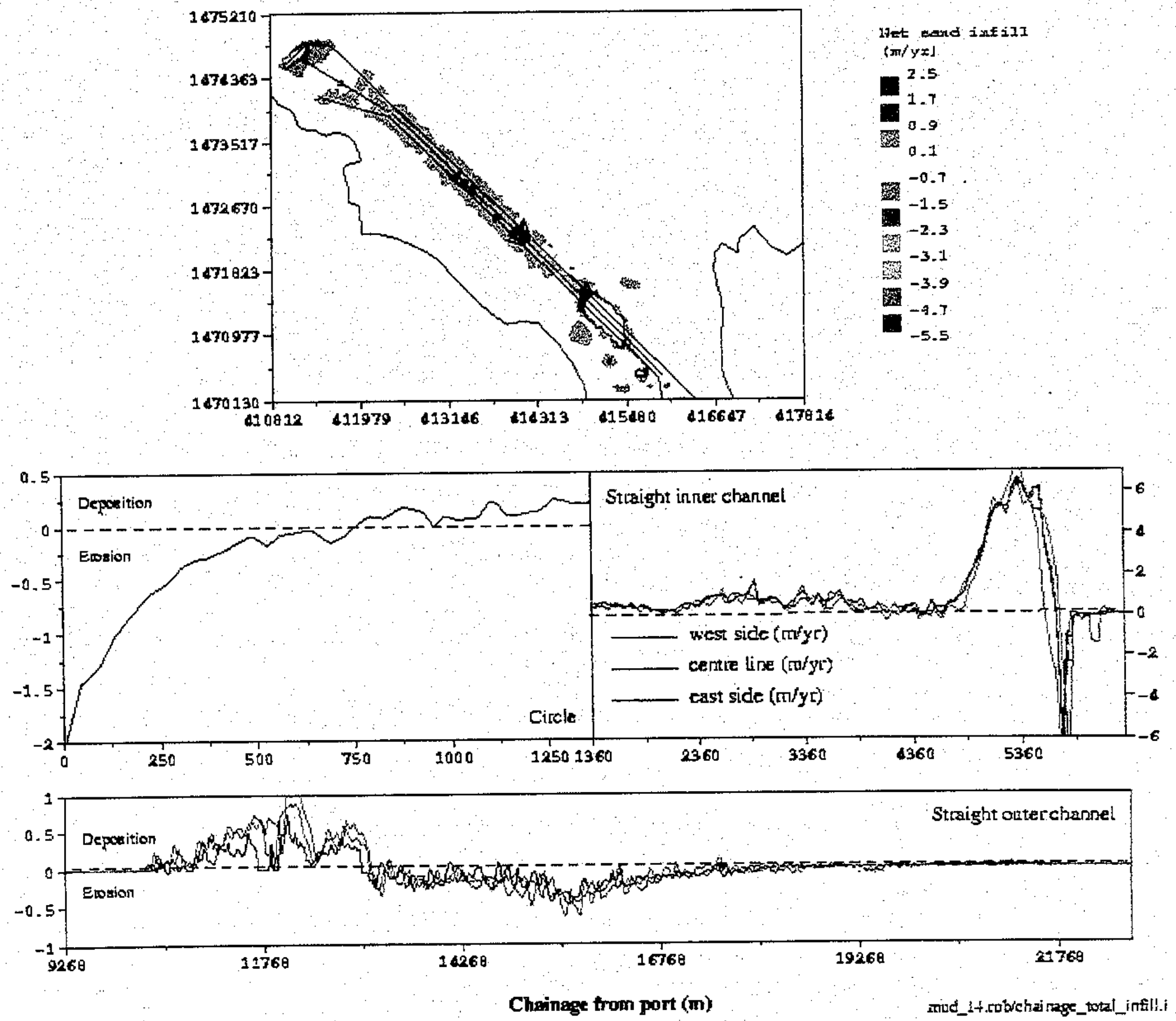


Figure 5.6.2 14 m Channel Infill of Sand

5.7 Navigation Aids and Vessel Traffic Services

5.7.1 Navigation Aids

Navigation Aids along the access channel and turning basin were studied by site investigation and fast time ship maneuvering simulation.

Ships navigating through the channel are not allowed to go outside of the channel limit, therefore, the navigation aids pointing the location of the channel through day and night are prerequisite for safe navigation. Light house and light buoys will be introduced to support the pilot and captain of the ships.

The light from Lighthouse at southwest nose, Peninsula Los Negritos of the Zacatillo Island indicates the alignment of the both outer and inner channel.

Light buoys indicate the width of the channel and area of the turning basin.

Some buoys located in near Cape Chiquirín indicate the shallow water areas to avoid the ship aground on them.

Large size light buoys at the entrance of the outer channel are set for captains to catch the entrance of the channel easily.

A recommended system for the navigation aids is indicated in Table 5.7.1 (also see Figure 5.3.1 for its location).

Table 5.7.1 Recommended Navigation Aids System

Description	Specification	Unit	Number
Lighthouse	10 m Height Aluminum ally made	set	1
Channel Entrance Mark	Lighted Buoy	sets	2
Channel Marker	Lighted Buoy	sets	11
Basin Marker	Lighted Buoy	sets	3
Light Beacon	Jetty Marker	sets	3

5.7.2 VTS (Vessel Traffic Service)

VTS is introduced to maintain a safe and effective channel navigation and port operation. The traffic control center in the port shall be equipped with a VHF radio communication system to receive timing of ETA and ETD from ships. Such information will be transmitted to the ships in the port and approaching to the port. Also it includes the clearance for entering/leaving the channel and any other information concerning pilot and tug assistance.

VTS is basically consisted of VHF radio, AIS (Automatic identification system) receiver and PC displaying the ships under way on the graphic map of the channel and port. Figure 5.7.1 shows the block diagram of system.

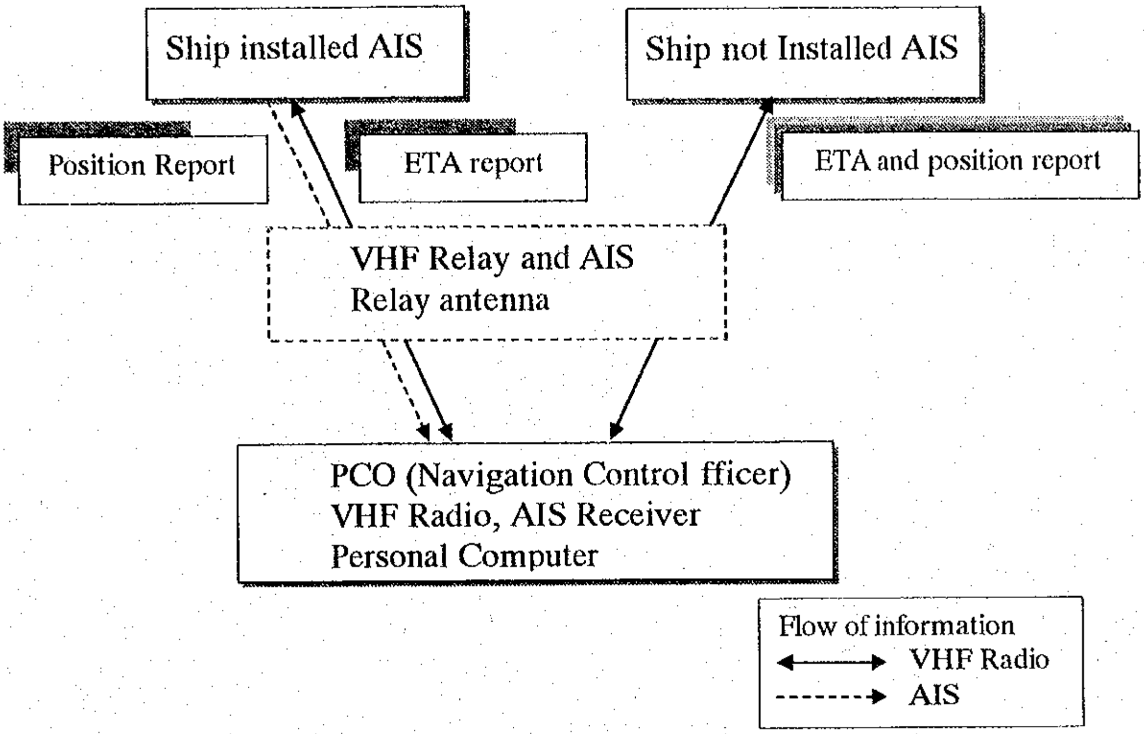


Figure 5.7.1 Block Diagram of System