In conclusion, the alternative [B2-1] (Complete Dike) and the alternative [B2-3] (Submerged Dike H = MSL + 6 meter) at the upstream of Tortola channel can be confirmed as the appropriate technically possible alternatives. In the following sections, these two alternatives will be discussed for facility planning together with necessary bank protection measures, environmental, economic and financial studies.

For all alternatives, except the alternative [B2-8] the discharge at Ya - Ya section, which is the downstream section of the Tortola channel confluence to the Rio Grande channel, is almost same as the present discharge. This result assures that the present deep section in the Ya – Ya section would be maintained naturally even with the constructed dike.

7.3.4 Facility Planning

(1) Structure Type

The structural types for the complete closing dike and the submerged dike are studied taking into consideration of hydraulic aspects, construction cost as well as environmental effects. In case of the submerged dike, the scouring associated with flow disturbance due to overflowing the dike top may be expected at the downstream side of the dike. This aspect is also taken into account in the dike design. Typical sections of the dikes and plan view are shown respectively in Fig. 7-3-9 and Fig. 7-3-10.

[Design of Main Body]

For the closing dike, a rock fill mount type is selected from the viewpoint of utilizing local materials of low cost and easiness of maintenance. The crown width of 10 m and side slopes of 1:1.5 at both upstream and downstream is selected considering past experiences of these types of works.

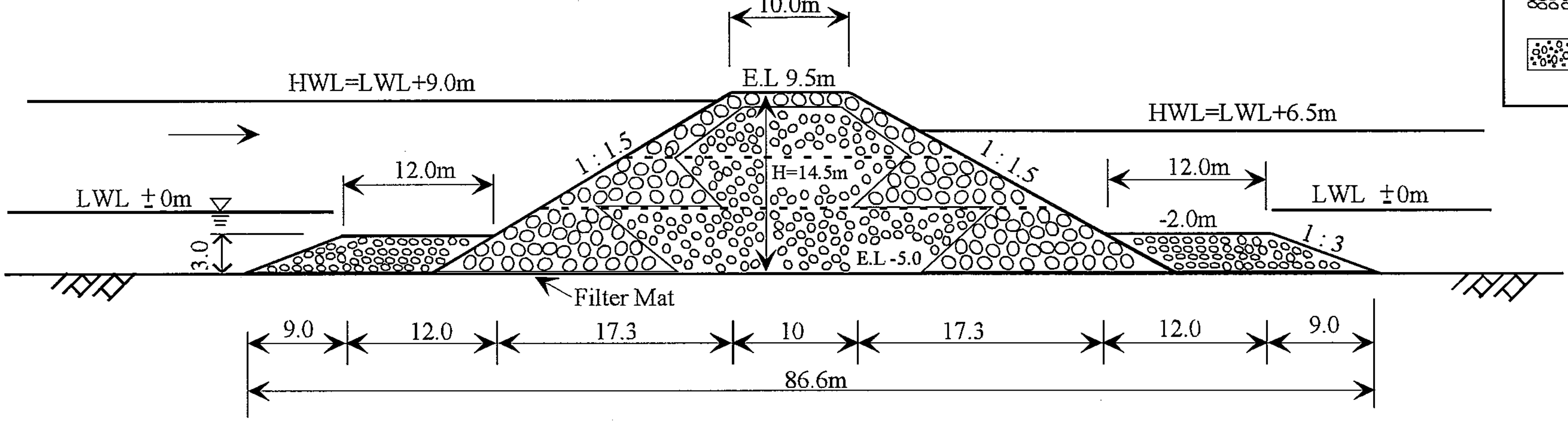
In case of the submerged dike, a mound type closing dike with a crown width of 12m is designed with a gabion mat for the safety against the overflow velocity of about 3 m/s over the crown. The dike slopes of 1:1.8 and 1:3 at the upstream and downstream sides are applied respectively, considering the stability of gabion materials of the works.

In both cases, foot protection dike is also designed at both upstream and downstream sides to enhance the stability of the dike. In case of the submerged dike, the length at downstream side is designed two times longer to that of complete closing dike in order to prevent the damage to the riverbed due to the disturbances of the flow. The dimensions of the dikes are shown in Table 7.3.5.

Legend

- Large Stone
- Core Stone
- Gabion work

Alt.[B2-1]:Typical Section of Complete Closing Dike (Rubble Stone Works)



Alt.[B2-3]:Typical Section of Submerged Dike (Rubble Stone and Gabion works)

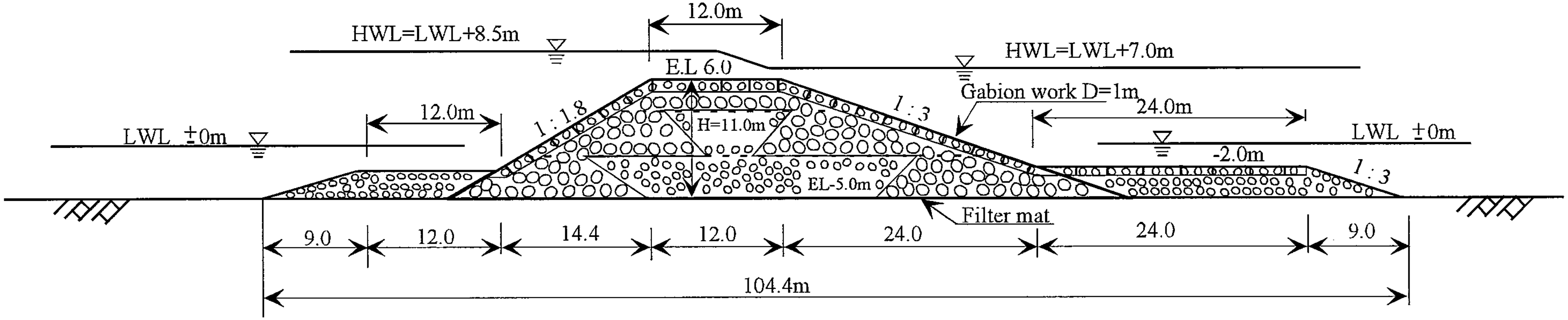


Fig. 7-3-9 **Typical Section of Dike**

THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA

Dimensions of Closing Dikes

	Complete Closing Dike (m)	Submerged Closing Dike (m)
Crown width (B0)	10	12
Revetment upstream (B1)	200	350
Downstream (B2)	200	400
Waterway (L)	600	800

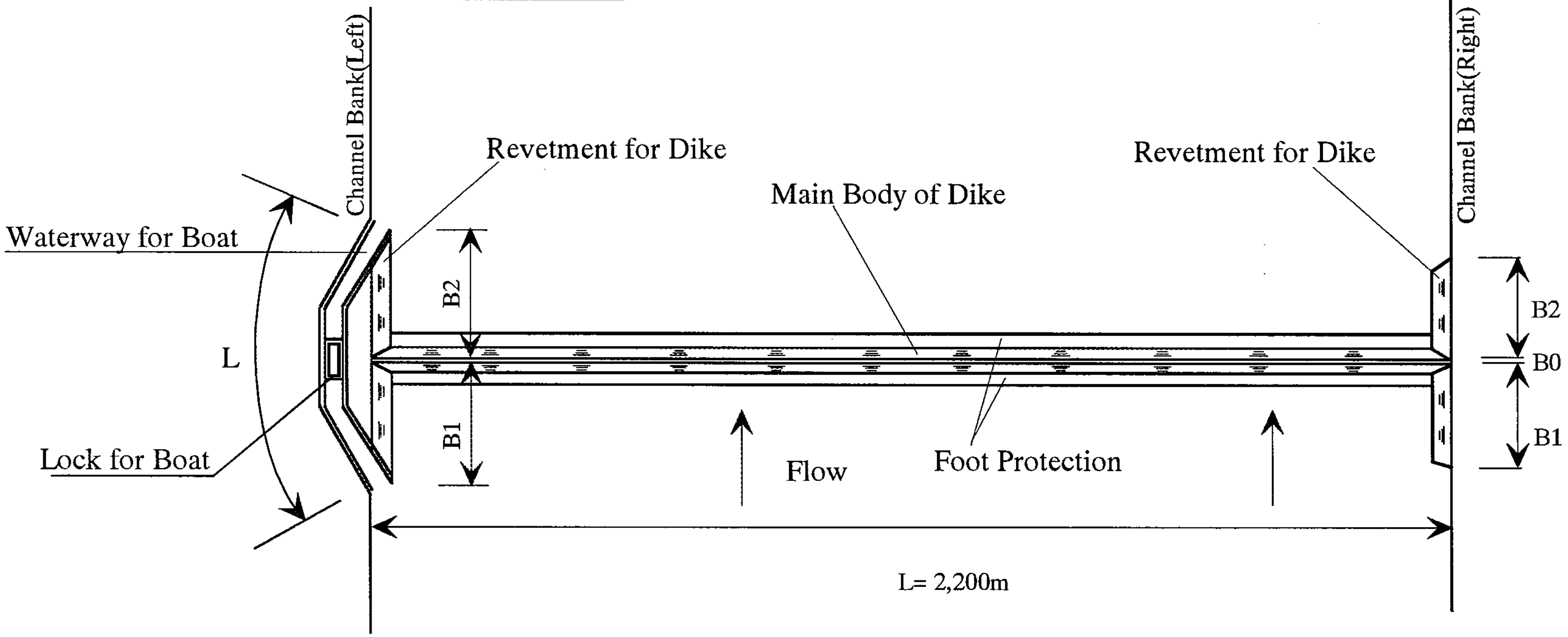


Fig.7-3-10 **PLAN VIEW OF CLOSING DIKE**

THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA

Table 7.3.5 Dimensions of the Dikes

	Complete closing dike	Submerged dike
Type	Mount type	Mount type with gabion mat
Construction material	Stone	Stone
Width of crown	10m	12m
Slope of dike		
Upstream side	1 / 1.5	1 / 1.8
Downstream side	1 / 1.5	1/ 3.0
Foot protection		
Upstream side	12m	12m
Downstream side	12m	24m
Base work	Filter mat	Filter mat

[Revetment for Dike]

Revetment for dike is designed at both upstream and downstream of left and right banks to prevent the bank erosion and to protect the main body. The gabion type structure is selected from viewpoints of low construction cost and easiness of maintenance. For the complete closing dike, the length of each revetment is 200m and total number of revetments at both sides would be four (total length is 800m). However, for the submerged dike, the length is designed as 2 times longer of that complete closing type due to overflow condition. The plan view and typical section are shown respectively in Fig. 7-3-10 and Fig. 7-3-11.

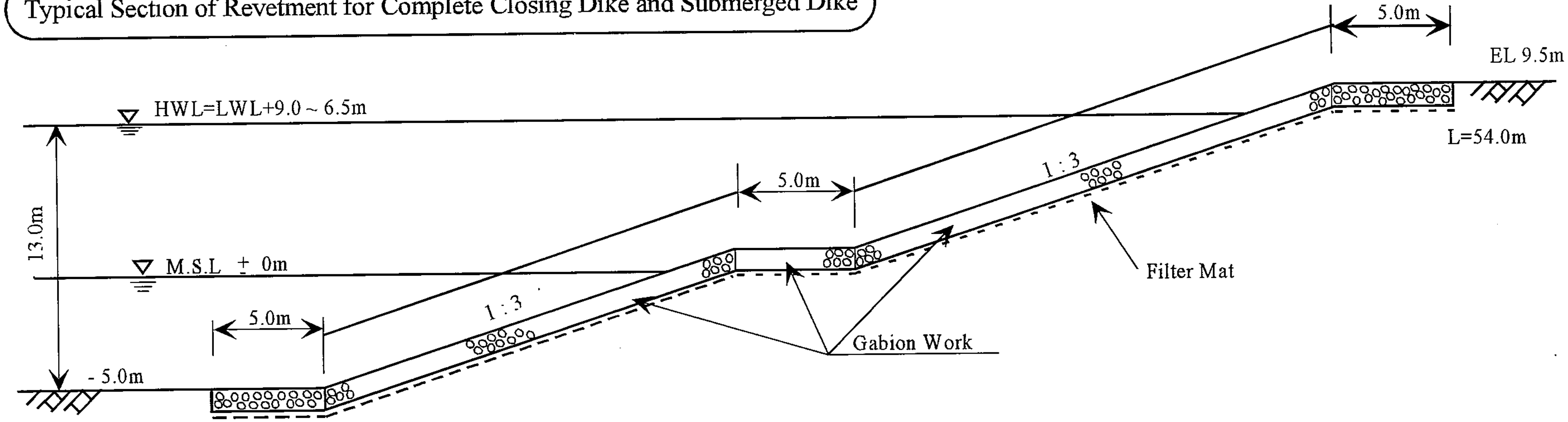
[Waterway for fishing boats]

As a result of construction of complete closing dike, the transportation of fishing boats would be totally disturbed. To solve this problem, waterway with navigation lock gates is designed. The width of waterway would be determined based on two-way traffic of fishing boats. For submerged dike, the length is designed as 2 times longer compared to complete closing type taking into consideration of the extent of disturbance flow due to overflow condition. The typical cross section is shown in Fig. 7-3-12.

(2) Bank Protection (Revetment at Barrancas Section)

The extent of revetment of about 4,000m (1,500m + 2,500m) long is determined based on the hydraulic aspects considering the velocity change between before and after the dike construction. A revetment is built along the bank where velocity after construction of the dike would be greater than the present maximum velocity of 1.4 m/s. The revetment of total 4 km length was proposed as a minimum requirement of erosion protective measures. It is recommended that in the future it is necessary to monitor the hydraulic condition along the banks such as flow velocity and the process of the bank erosion during the construction of the revetment, and in case if it is necessary, additional revetments should be constructed. Fig. 7-3-13 shows the longitudinal velocity profiles along the left bank of Guarguapo - Barrancas - Ya Ya sections along with the reach to be protected in the Barrancas town.

Typical Section of Revetment for Complete Closing Dike and Submerged Dike



Typical Section of Revetment at Barrancas

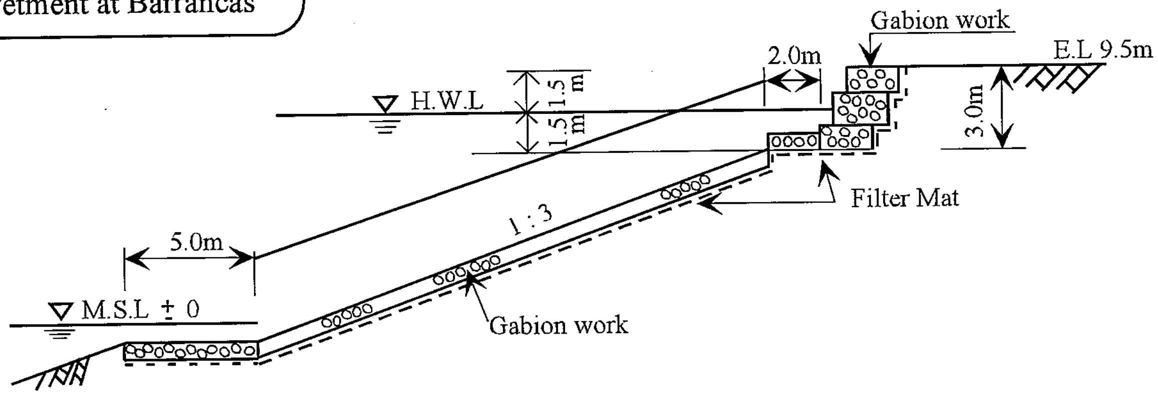


Fig.7-3-11	Typical Section of Revetment
THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA	

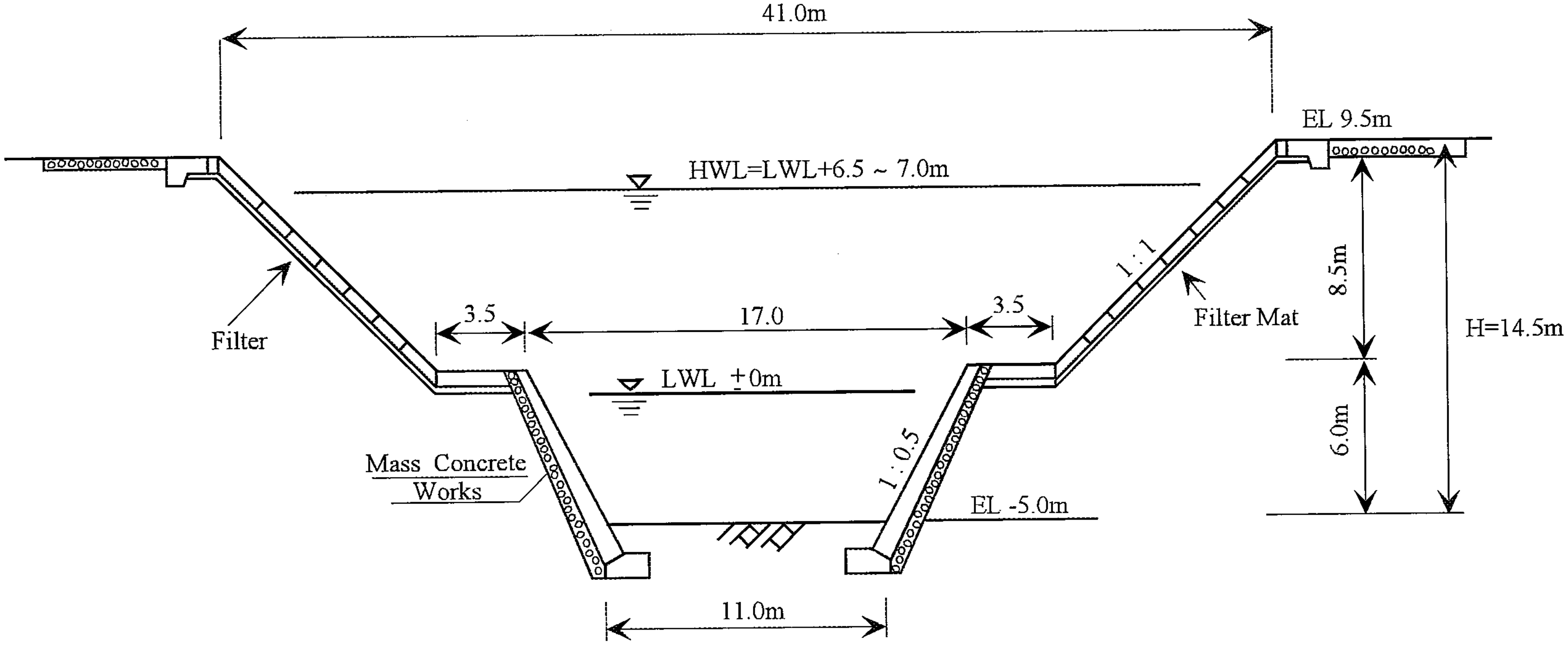


Fig.7-3-12	Typical Section of Waterway for Boats

THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA

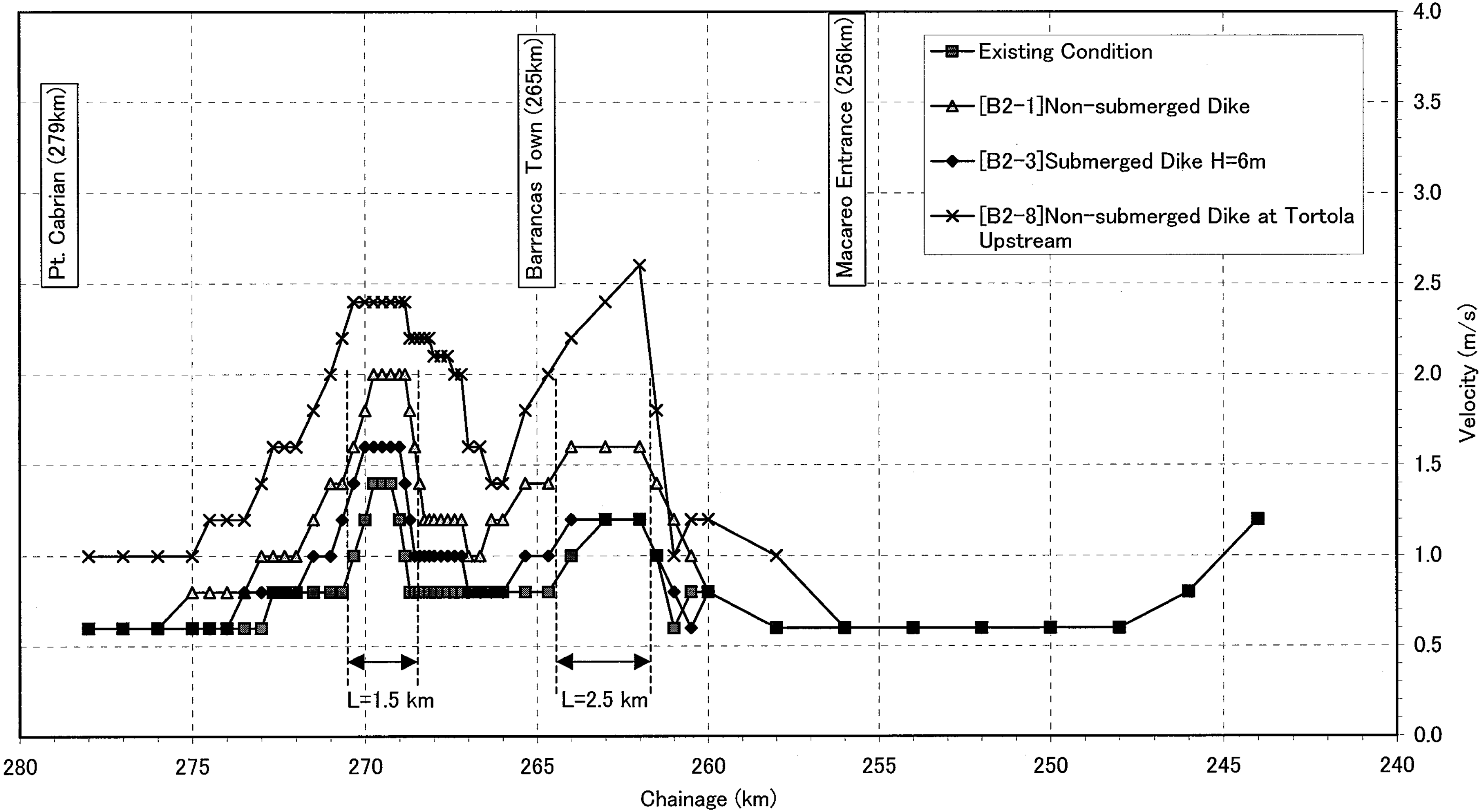


Fig. 7-3-13 Velocity Along the Left Bank of Guarguapo-Barrancas-Ya Ya Sections

A gabion type structure is designed in view of the low cost and ease of maintenance. The gabion is planned according to the bank profile measured at site investigation and survey works. The typical section is shown in Fig. 7-3-11.

By either of the alternatives [B2-1] or [B2-3], the peak discharges in the Piacoa channel and the Guarguapo - Barrancas sections in the Rio Grande channel would increase substantially as shown in Fig. 7-3-5. As exposed rocks exist along the narrow sections of the Piacoa channel, the bank erosion may be regarded minor. Although velocities close to the right bank of the Rio Grande channel and the banks of the channel between Varadero island and Chivera island would increase to some extent, still velocity close to the left bank of the Rio Grande channel would be the highest. Therefore, considering importance of the area along with environmental and economic factors, bank protection is focused only on the left bank of the Rio Grande channel.

The details of alternatives [B2-1] and [B2-3] are shown in Fig. 7-3-14, Fig. 7-3-15 and Fig.7-3-16.

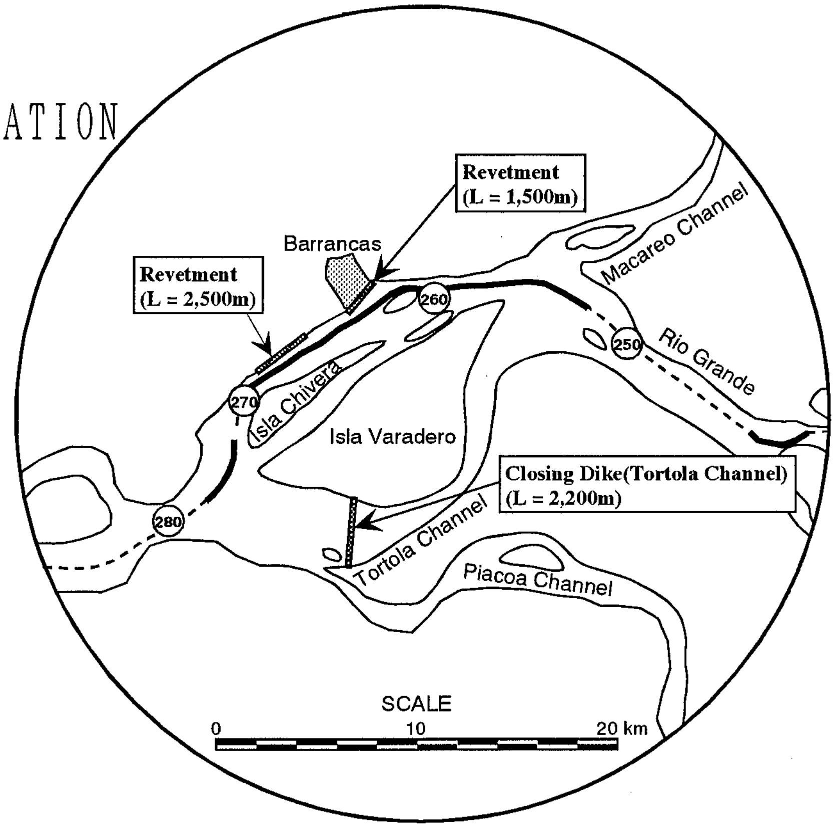
7.3.5 Non-Structural Measures

Seasonally deep-water path in the Rio Grande channel is subject to changes in elevation of riverbed according to flow variation, although it is recognized no remarkable changes in riverbank alignment and reaches required for dredging. By conducting regular bathymetric survey, the deeper area in the channel has to be defined and revised as the navigation route from the viewpoint of reduction of dredging activities and safe navigation, after careful evaluation of vessel maneuvering.

In the section of Barrancas from 260 km to 270 km, navigation route is located in the left sub-branch of flow divided by the long sandbar lying in the main stream of the Rio Orinoco. In the comparison of the navigation charts in 40 years between 1959 and 1998, the sandbar has been divided into two by a new diversion channel formed at 262 km, and the water path tends to flow from left to right sub-branch through the diversion break as shown in Fig 7-3-17. Since it can be seen also from the results of the 2-dimensional analysis, there is a possibility that the present deep-water path would shift, in the near future, to the right flow side depending on the flow variation. Through the regular bathymetric survey, therefore, it is important to analyze the trend of the riverbed changes and review the navigation route for the reduction of dredging activities.

At present, the patrol survey, which is the longitudinal sounding survey for three lines: the right, center and left side of navigation canal, has been conducted each month by INC to detect the shallower channel bed. The extensive sounding survey from bank to bank in the dredging sections has been conducted once in several years at certain sections of the channel. However, it could be said that the bathymetrical information close to both banks in navigation chart has not been updated for a long time. In order to minimize dredging activities by specifying the best route for navigation through the deepest area of channel, the conduct of periodical bathymetric surveys in the navigation channel would be required.

LOCATION



Dimensions of Closing Dikes

	Complete Closing Dike (m)	Submerged Closing Dike (m)
Crown width (B0)	10	12
Revetment upstream (B1)	200	350
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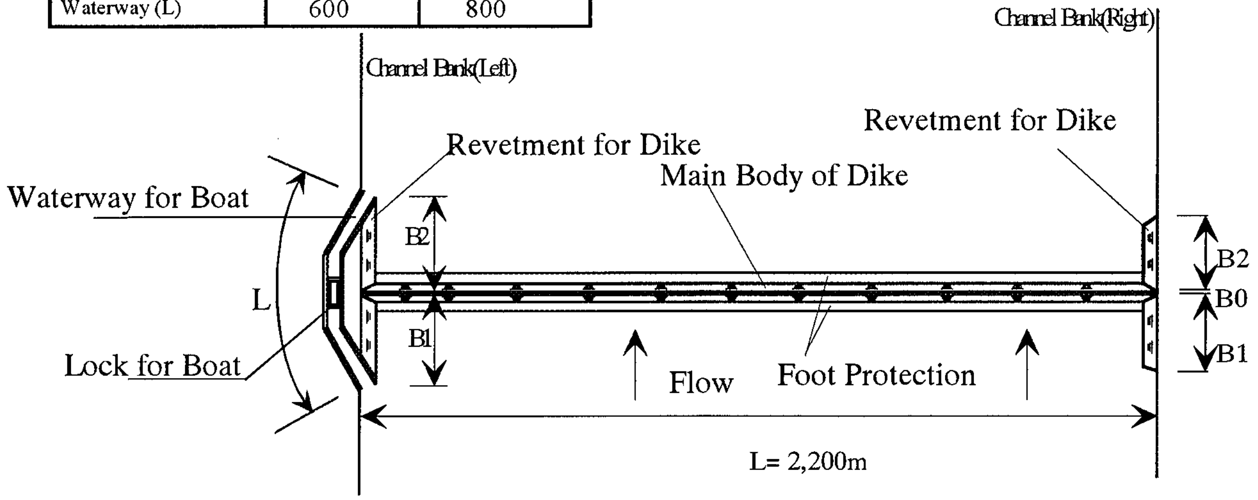
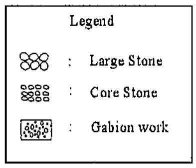
Waterway (L)	600	800

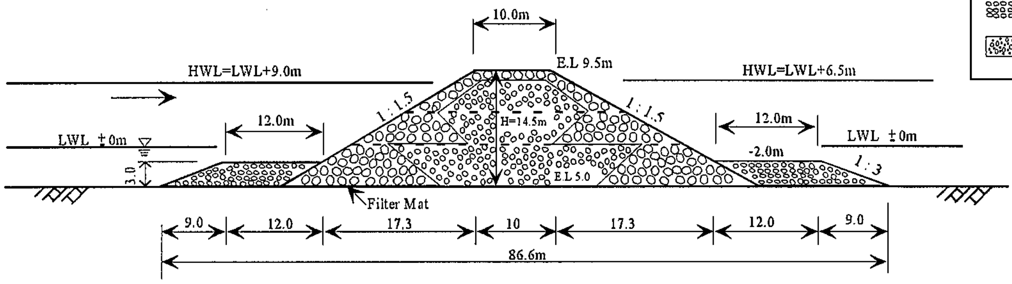


PLAN VIEW OF CLOSING DIKE

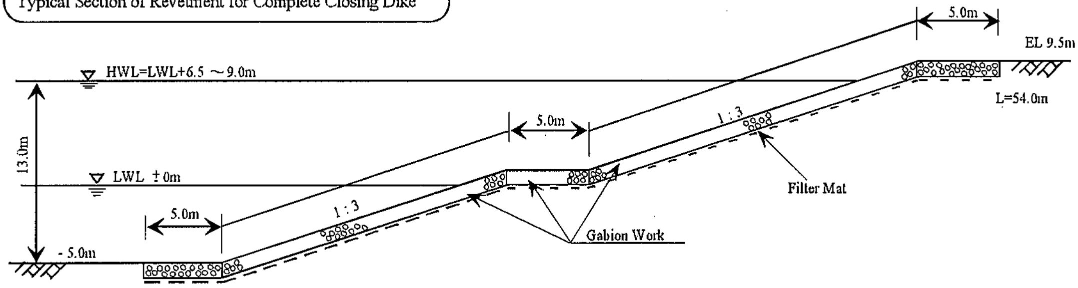
Fig.7-3-14	LOCATION AND PLAN VIEW OF THE CHANNEL IMPROVEMENT STRUCTURES



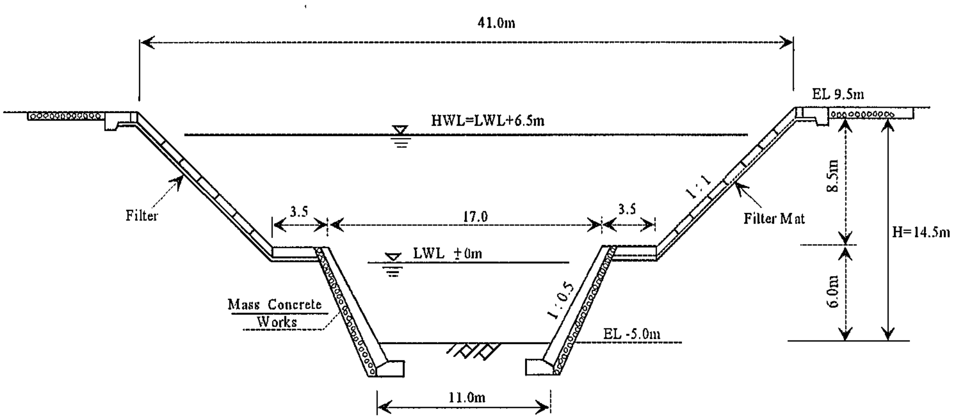
Typical Section of Complete Closing Dike (Rubble Stone Works)



Typical Section of Revetment for Complete Closing Dike



Typical Section of Waterway for Boat



Typical Section of Revetment for Waterway at Barrancas

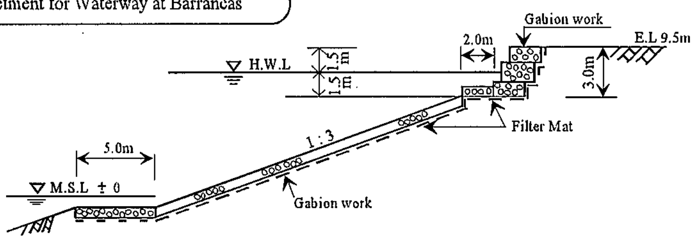
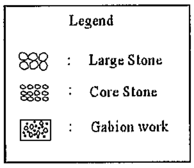
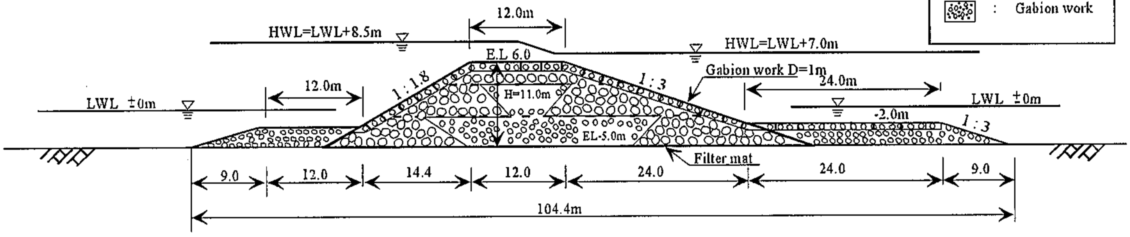


Fig.7-3-15	**TYPICAL SECTIONS OF ALTERNATIVE [B2-1] (NON-SUBMERGED DIKE)**

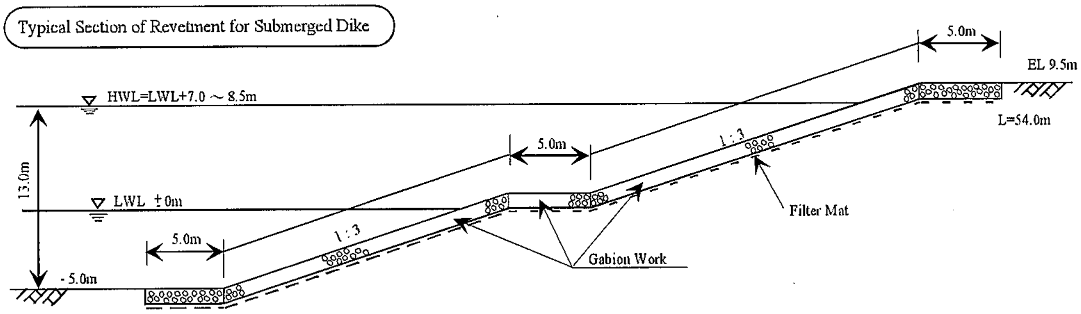
THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA



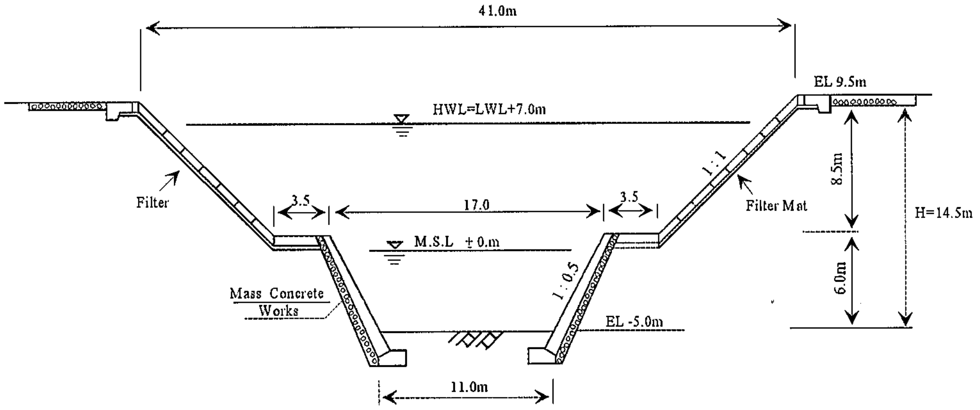
Typical Section of Submerged Dike (Rubble Stone and Gabion works)



Typical Section of Revetment for Submerged Dike



Typical Section of Waterway for Boat



Typical Section of Revetment at Barrancas

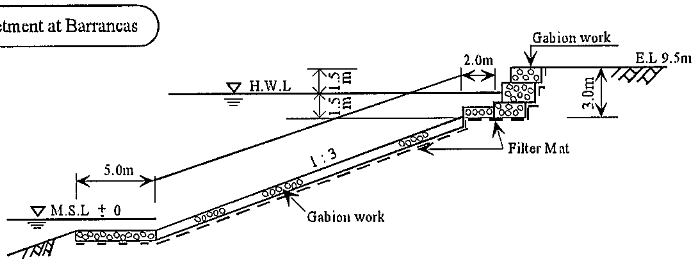
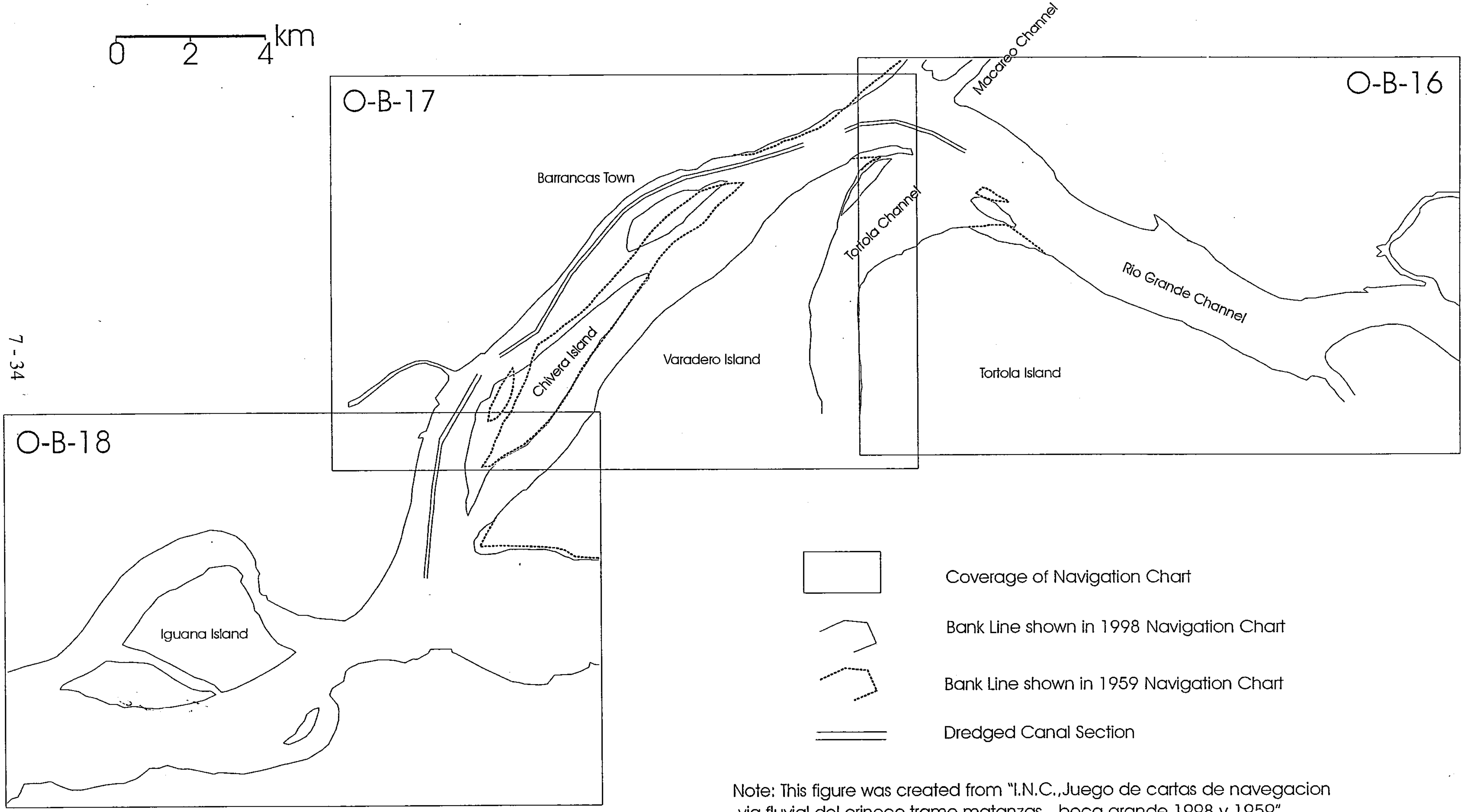


Fig.7-3-16	**TYPICAL SECTIONS OF ALTERNATIVE [B2-3] (SUBMERGED DIKE H=MSL+6 m)**

THE STUDY ON INTEGRATED RIVER IMPROVEMENT OF THE ORINOCO RIVER IN THE REPUBLIC OF VENEZUELA



Note: This figure was created from "I.N.C.,Juego de cartas de navegacion via fluvial del orinoco tramo matanzas - boca grande 1998 y 1959"

Fig. 7-3-17 Recent Bank Line Changes in the Rio Grande Channel