CHAPTER 7 PRIORITY PROJECT FOR CHANNEL IMPROVEMENT

7.1 Priority Reaches for Structural Measure

At the apex of the Orinoco delta, discharge of the Orinoco river starts to spread as a consequent of flat elevation of the delta. The sediment transported from the upstream deposits due to low flow velocity forming sand bars/islands resulting in several irregular and distributed channels with complicated river configurations. The annual maintenance dredging volume is huge in the navigation channel. In the Guarguapo – Barrancas – Ya-Ya reach alone, it amounts to 3.8 million m^3 in average.

In the master plan study, results of 1 dimensional numerical study explain the prominent depth-width inverse relationship of the channels in the delta owing to the mild slope, uniform fine sand in the channel bed and simple annual discharge pattern etc. The structural improvement measures to increase the navigable depth should be envisaged considering this peculiar phenomenon of the river flow regime. Moreover, as Orinoco river is one of the largest rivers in terms of scale and discharge, large scale improvement measures along the longitudinal direction of the channel would not be economically feasible. Hence, appropriate structural measures should be considered as point measures targeting specific places. Therefore, the alternative B2, to regulate the flow in Tortola channel by a dike, is selected as a possible structural measure to deepen the Barrancas section. However, in other sections, structural measures are not proposed due to high construction and maintenance cost. Accordingly it is required to continue with the maintenance dredging efficiently with effective methods to optimize the quantity of dredging works.

7.2 Structural Measure

7.2.1 Environmental Considerations

The closure of Tortola channel directly influences the social environment and the ecosystem as a result of stagnation of water body and sediment deposition in both upstream and downstream of the dike. In order to reduce the adverse effects of alternative B2 scheme, several modifications are considered as countermeasures. Instead of complete closing dike, submerged closing dike or dike with culvert/slit openings that allows certain water flow over the dike is considered. A bypass channel with navigation lock to allow for the passage of boats is considered to mitigate the adverse effects on the waterway transportation of local people. The protection measures such as revetment along the bank, are essential to prevent bank erosion in the Barrancas reach due to the significant increase of discharge in the Rio Grande channel.

7.2.2 Alternatives for B2 Scheme

(1) Determination of Alternatives

Taking into the consideration the environmental issues and economic factors, eight modified alternatives for B2 scheme, referred to as [B2-1] to [B2-8], were studied as shown in Table S.7.1.

The alternatives [B2-1] and [B2-2] are considered to analyze hydraulically appropriate location for the closing dike along the Tortola channel. For simplification, among the alternatives allowing water flow over/through the dike, submerged dike case is selected only for hydraulic analysis, since the dike with culvert/slit openings would also have similar hydraulic analysis results to that of submerged dike, once it is designed for same flow discharge. The alternatives [B2-3], [B2-4] and [B2-5] will be utilized to determine the suitable height and allowable discharge for the submerged dike.

Table S.7.1 Alternatives for B2 Scheme

Type	Alternative	Main Facilities	Remarks
Closing Dike	B2-1	Closing dike at Tortola upstream	To determine the appropriate location
	B2-2	Closing dike at Tortola downstream	
Submerged Dike	B2-3	Submerged dike at Tortola upstream; H = MSL+6m	To select the suitable dike height
	B2-4	Submerged dike at Tortola upstream; H = MSL+3m	
	B2-5	Submerged dike at Tortola upstream; H = MSL+0m	
Referential Dike	B2-6	Groins at Tortola entrance	To check the applicability of Groins
	B2-7	Groins at Tortola entrance and midstream	
	B2-8	Closing dike at Tortola and Piacoa entrance	To evaluate the substantial increase of discharge

The structural measures such as Groin type or huge scale closing dikes are not suitable measures according to the previous studies. However, the alternatives [B2-6], [B2-7] and [B2-8] are selected as referential alternatives to study and confirm their inapplicability as appropriate measures.

(2) Hydraulic Analysis Using Mathematical Models

In this feasibility study, 2-dimensional numerical analysis was applied to analyze the hydraulic effects in detail and evaluate the appropriate dyke system. The applied 2-dimensional numerical model is widely used and composed of 3 modules; hydrodynamic module, sediment transport module and bed change module. At a certain time step, flow is calculated for the gridded priority reaches in the orthogonal curvilinear co-ordinate system in hydrodynamic module based on the current channel bed elevations solving the continuity equation and momentum equation for incompressible fluid by implicit solution method. Using the calculated flow condition, sediment transport and the bed change are calculated using Engelund Hansen formula in sediment transport module and bed change module, respectively. At the next time step, flow is calculated based on the updated bed elevation.

Taking into the consideration of the vast extent of objective area and the complicated river networks, the river improvement study is conducted through two steps applying one dimensional and two dimensional hydraulic simulation analyses.

In first step analysis described in the previous chapters, one-dimensional hydraulic analysis is applied to reproduce the channel bed profile in the whole objective area, placing attention to the prevailing relationship between the discharge, bed height, channel width, etc. In addition, according to the analysis of the characteristics of changes in channel course, it was identified the "longitudinal variation of channel bed elevation due to bed shear force as a consequent of channel width and/or discharge variation" as a key point aiming at river improvement. Accordingly, practical alternatives of channel improvement were discussed in macro viewpoint. As for analyzing characteristics of changes in river course for the vast and complicated river areas, at least, it is required a period of several decade or more for the long term analysis. This long term analysis was conducted and obtained satisfactory results, by using one-dimensional analysis, because of the present specific channel conditions, uniform medium fine sand of riverbed material through the whole stretches, and the prevailing simple and regular discharge pattern with seasonal changes.

For the second step, two-dimensional analysis that considers secondary flow phenomena, is conducted to evaluate the hydraulic effects such as eroding the side banks and the changes in deepest channel bed at complicated meandering sections as well as the effects of lowering the navigation channel bed, by the structural measures in the selected river sections. The time scale for this analysis should be carefully selected taking into the consideration the requirement of reproduction of the effects of sediment load discharge in the downstream section in the objective areas and the heavy computational burden of 2 dimensional calculations.

7.2.3 Results of Analysis

Based on flow analysis, the alternatives [B2-1], [B2-3] and no alternative case (without project) were selected for sediment transport and bed change simulations. The lowest bed elevation profiles along the reach of Guarguapo – Barrancas - Ya Ya for alternatives [B2-1] and [B2-3] are lowered by 3.9 m and 2.6 m, respectively. Both alternatives were confirmed to be effective to eliminate the current maintenance dredging requirement. Result of hydraulic analysis for the alternatives are described below. (see Fig. S-7-1)

(1) Complete Closing Dike

The location at upstream of the Tortola channel (Alternative [B2-1]) would be appropriate for the closing dike, since alternative [B2-2] would raise the water level in the Tortola channel by about 2 m than that of alternative [B2-1] which might cause unfavorable conditions. In addition to the hydraulic effects, the structural volume of dike in the Tortola channel is lower.

In the alternatives [B2-1] and [B2-2] for complete closing dikes, nearly zero velocity indicates water stagnation in the Tortola channel. Under this condition, sedimentation would occur at both upstream and downstream of the dike. Consequently, the Tortola channel will be filled with sediments.

(2) Submerged Closing Dike:

Only the alternative [B2-3], the dike height is MSL+6 m, would provide the required discharge increase of 3,000 m^3/s compared to the existing condition in the Barrancas section. The submerged dike of height less than MSL+3 m is not effective to increase the discharge of the Rio Grande channel to meet navigation requirement. However even with the submerged dike of height higher than MSL+6 m, the overflow would last only 3 months a year. Under this condition, sedimentation would occur at both upstream and downstream of the dike. Consequently, the Tortola channel will be filled with sediments.

(3) Groins

According to the results of Alternative [B2-6] and [B2-7], installation of groins is not an effective means to increase the discharge of the Rio Grande channel. The velocities at the cross sections where the groins are installed, are comparatively high due to the reduced effective flow areas.