EXECUTIVE SUMMARY

Introduction

1) The Orinoco river basin of 1,015,000 km^2 that is rich in mineral resources such as iron ore, bauxite, etc is the third largest catchment area in South America. The development of the basin is one of the highest priorities of the Government of Venezuela to slough off present economic structure highly dependent on petroleum exportation. In the development plan, as artery of the transportation in Orinoco basin, strengthening and maintenance of the navigation system in the Orinoco river is proposed as a high priority task in order to secure effective and reliable waterway navigation channel. Under these circumstances, the Government of Venezuela requested the Government of Japan to conduct the study on the comprehensive river improvement in the delta at the downstream of Ciudad Guayana City, and formulate a Master Plan and to carry out the feasibility study for the priority project selected in the Master Plan in close cooperation with the prime agency, the General Direction of Orinoco-Apure Program (PROA) of Ministry of Environment and Natural Resources (MARN) and other related agencies, National Institute of Canalization (INC), National Hydraulics Laboratory (LNH) and enterprises of Venezuelan Corporation of Guyana (CVG).

2) Navigable spans of the Orinoco catchment within Venezuela consist of three channels: Orinoco, Apure and Portuguesa with a total length of 2,100 km. The downstream of Ciudad Guayana city, 339 km length of Rio Grande channel, is placed as the most important reach in the Orinoco-Apure Navigation Axis. The Rio Grande channel is required to be maintained for the navigation of 65,000 dwt Panamax type vessel with a minimum water depth of 44 ft in the rainy season and 34 ft in the dry season. However, due to heavy sediment discharge from the Orinoco river basin, the navigation channel in the delta requires more than 18.5 million m^3 continuous dredging annually. This huge amount of maintenance dredging brings to weaken the sales competence of export materials in the international market due to the high navigation cost. Moreover, it has been difficult to ensure sufficient draft for vessel navigation because of low dredging effectiveness due to the return of the dredged materials into canal and less dredging time due to the frequently occurring technical troubles in dredges. Consequently the vessels are obliged to adjust the cargo loading at present.

3) It is required to formulate an effective and reliable waterway transportation system among the major channels of Rio Grande, Macareo, Manamo, to cope with the transportation of future cargo demand. To this end an integrated river improvement plan in the Orinoco Delta need to be conceived. The improvement plan should be technically feasible and economically viable with minimum environmental impacts.

Forecast of Cargo Transportation

4) The cargo traffic flow in the region is almost exclusively concentrated in the Rio Grande Channel of the Orinoco River, although a small portion of cargo generated by the various industrial activities located in Ciudad Guayana is transported by roads to and from northern coastal ports. The scale of the total recent annual cargo flow is reported to be in the order of 20 million tons per year according to the statistics in 1997. The largest cargo is the 9 million tons of iron ore annually exported by Ferrominera. Almost all cargo handled in Puerto Ordaz is industrial cargo of 10 enterprises such as iron ore, direct reduced iron, steel products, bauxite, alumina, aluminum, clinker, petroleum.The cargo throughput share of above enterprises accounts for more than 95% of the total amount.

5) Due to Venezuelan policy of encouraging export oriented steel industries and the introduction of value added industries, steel product and direct reduced iron have been increasing and total cargo throughput will be forecasted to reach 28 million tons in 2020 in the high growth case. In contrary, the exported iron ore in the region has been declining in the past two decades, and is forecasted to decline further. In fact, according to the plan of Ferrominera, the forecasted volume of exported iron ore would decline gradually to 4 million tons until 2003 but would remain the same thereafter.

Waterway Transportation System

6) With emphasizing the iron ore transportation since it is the most critical factor in deciding capacity of the navigation channel, future waterway transportation system coping with cargo shipping demands is projected as shown in the Table below taking into consideration of navigation route, iron ore export with or without a transfer port along with their location and vessel types.

Future Waterway Transportation System in Orinoco Delta (Target Year 2020)

Transport Cargo	Period	Navigation System	Remarks
Iron Ore	① Period: Present-2003	The navigation route should be along Rio Grande. While existing Transfer Vessel (TV) and two shuttle vessels are still in operation, the existing transportation system with TV should be maintained.	Same as the present transportation system
	② Period: 2003-2007	The navigation route should be along Rio Grande. With retirement of the Transfer Vessel, two existing Shuttle Vessels will be in operation.	The decision has to be made whether to maintain the existing transfer system or not, on the basis of both final destinations and their imported volumes.

	③ Period: 2007-2013	The navigation route should be along Rio Grande. With retirement of one shuttle vessel, remaining shuttle vessel will be in operation.	Exporting to the destinations in Europe, one option is that a Panamax size carrier, loading at Puerto Ordaz within the allowance of the depth of the channel, making a direct trip to the final destination. Another is that a Panamax size carrier, partially loading at Puerto Ordaz, and additionally loaded from the Shuttle Vessels at Boca de la Serpiente to full capacity.
	④ Period: After 2013	The navigation route should be along Rio Grande. After 2013, in the time after the retirement of both existing Transfer Vessel and two existing Shuttle Vessels.	It would be desirable that a Panamax size carrier, fully loaded at Puerto Ordaz, makes a direct trip to the final destination. It should be noted that the use of Panamax size carriers makes competitive sense in the world freight market if appropriate final destinations are chosen.
Other Cargo (Non-Iron Ore)	Present-2020	Cargoes other than iron ore are forecasted to increase to 22 million tons per year in 2020 compared to the present 11 million tons per year. The sizes of ships are almost all Small Handy class at present and this will likely remain unchanged up to 2020 according to the investigations on kind of cargoes. Even if ship sizes are larger than Small Handy, they would probably be no more than Handymax class because most Panamax size carriers are not equipped with self-loading/unloading systems.	

7) In the course of the decentralization and privatization by the Venezuelan government, the CVG owned enterprises were privatized and allowed to have their own port facilities. Hence, there is no single entity in Puerto Ordaz for comprehensive port management as a port authority. Therefore, it is required to establish a port authority to cover a wide range of port activities related to development, maintenance, administration and management of port facilities as well as the enhancement of port use in order to achieve sustainable economic growth of the region and consequently for accomplishing the country's development strategy.

8) According to the MTC report in 1991, the traffic capacity in the Rio Grande channel was estimated to be about 1,100 vessels per year. However even now when the traffic is 900 vessels per year congestion takes place, which leads vessels to wait for 6 hours. In addition the traffic tends to increase and the total annual traffic in each direction in the channel is estimated at more than 1,100 vessels in 2010 and around 1,300 vessels in 2020 in case of high growth case in demand forecast. Therefore the shortage of channel capacity for traffic volume will be more serious in near future. Furthermore, in the Rio Grande Channel some navigational traffic accidents occur due to the existence of flood flow and narrow reaches enough only for one way traffic. Under these circumstances, in order to increase the traffic capacity and ensure the traffic safety in the canal it is desired to introduce VTMS and conduct development study the convoy system. Especially the investment to the VTMS is highly recommended because in the long run these efforts and costs will be compensated by the possible reduction of maritime insurance costs.

9) In order to get a clear view of barge navigation along the Macareo channel, a case study was conducted using barge train transport system for iron ore from Puerto Ordaz to the sea, instead of Shuttle Vessels system (Panamax Size) through the Rio Grande channel, based on the future exportation demand of iron ore according to the reduced Cargo Throughput Forecast of 4 million tons in year 2003. As for iron ore transportation by barge trains in Macareo channel, two possible alternatives are envisaged for transferring iron ore from barge to oceangoing vessel through either existing transfer vessel or in a new port to be constructed at the channel estuary. It is judged that the barge train scheme lacks economic/financial viability and its implementation is not justifiable under the present conditions. The examination of the possible implementation of the barge train scheme shall be studied in the future when the timing is deemed to be appropriate from the viewpoint of not only iron ore transportation but also the progress and maturity of the development of the Orinoco-Apure Axis.

River Channel Improvement

10) The channel improvement in this study is focused to Rio Grande route (total length 339 km), which was selected as the most suitable navigation route among all, such as Manamo and Macareo routes, taking into consideration of present and future cargo demands and efficient shipping systems as well as prevailing channel characteristics, improvement and maintenance costs for navigation. As for the sufficient channel improvement to minimize the dredging activities and to guarantee the navigation safety as well, a combination of ① structural and ② non-structural measures must be employed along with ③ an efficient method for dredging activity.

Concept of Channel Improvement

Subjective Channel	Rio Grande Channel (L=339 km)		
Present Problems	Difficulty in huge amount of dredging work required and in provision of target depth for navigation		
Concept for the Improvement	① Structural	② Non-structural	③ Improvement of Dredging methods
	Navigation channel improvement		Operation and Maintenance
	Reduction of dredging volume with river structure	Reduction of dredging volume without river structure	Provision of required depth
	- River structures to confine the flow to a narrow width and increase the discharge in the navigation channel. - River structures to close the river branches	- Usage of deeper route for navigation	- Increase of dredging time - Acquire a flat bed leveling the uneven channel bottom - Prevent the return of disposed dredged materials into the channel

11) **[①Structural Measures]:** Specific characteristic of the Rio Grande channel, which is of prime importance prior to undertake the improvement measures, is the longitudinal variation of channel bed elevation due to bed shear force as a consequent of channel width and/or discharge variations. Based on these characteristics of the river flow channels, improvement measures are determined to acquire a larger water depth either by confining the flow to a narrow width or increasing flow discharge in the navigation channel. Two types of measures, a) "point structural measures" targeting specific places and b) "longitudinal structural measures" along the channel can be envisaged. As the Orinoco river is a huge river in terms of scale and discharge, large scale improvement measures along the longitudinal direction of the channel would not be both economically feasible and practical due to the lengthy dredging reaches. Hence, appropriate improvement measures should be focused as point measures targeting specific places.

Applicability of Structural Measures

Measures		Applicability
a) Point measures	Closing dike for secondary channels	A point structure is quite effective to control the discharge or increase the flow intensity along the main channel, which is technically applicable to the Rio Grande Channel.
b) Longitudinal measures	Groins	They are economically not feasible as well as unpractical for the Rio Grande Channel, which has long dredging sections and a mild slope.
	Training dikes	They are economically not feasible as well as unpractical for the Rio Grande Channel, which has long dredging sections.

12) **[Alternatives for Structural Measures]:** The dredging section of Guarguapo - Barrancas - Ya-Ya is confirmed as only one possible section, for applying channel improvement by means of possible point measures to lower the bed elevation of navigation channel, by closing the Tortola channel currently carrying 40 % of the main stream discharge, by 2.2 km long dike. Consequently, the discharge of navigation channel could be increased and the annual maintenance dredging of 3.80 million would be eliminated. In this study, the submerged dike scheme, in addition to the complete closing dike, is also considered to mitigate the environmental impact. The construction costs for the both complete closing dike and submerged dike are US$ 101 million and US$ 129 million respectively.

Technically Possible Measures

Channel	Dredging Section	Dredging Length km (Annual Dredging Volume in million m^3)	Applicability of point measures (Results of M/P)	Measures studied in F/S
Rio Grande	(1) San-Felix	8 (1.61)	×	-
	(2) Aramaya	4 (1.04)	×	-
	(3) Guarguapo-Barrancas-Ya-Ya	19 (3.82)	○	The measure to increase discharge in the navigation channel by closing Tortola Channel
	(4) Araguaito	1 (0.10)	×	-
	(5) Sacupana-Guasina	16 (1.51)	×	-
	(6) Curiapo	2 (0.40)	×	-
	(7) Boca Grande	78 (10.00)	×	-
Total		128 (18.48)		

13) **[Environmental Impacts due to Structural Measures]:** Consequent to the closing of Tortola channel by implementation of structural measures, even by a submerged dike as an adverse environmental effect mitigation measure, stagnation and the fill-up of the water body in the whole stretch of the Tortola channel could not be avoided in the long term. Therefore, the closure of the channel would affect the people heavily dependent on fishery. Consequently resettlement of riverbank population would be required.

14) **[②Non Structural Measures]:** In order to reduce the maintenance dredging volume, the non-structural measures as less expensive measures, can also be applied for channel improvement by specifying the best route for navigation through the deepest area of the channel. Seasonally the deep water path in the channel would move according to the change in river flow. Therefore, not only conducting bathymetric surveys in the navigation channel for pre and post dredging but also conducting regular bathymetric surveys, the deeper area in the channel has to be defined and the navigation route realigned in viewpoint of reduction of the dredging volume, after careful evaluation.

Regarding ③ Dredging Improvement in the above Table, it is described as follows,

Dredging Improvement

15) At present, the Channel is maintained by three (3) dredges including two INC's owns dredges, namely: Rio Orinoco and Guayana, and Hang Jun 6001 Dredge contracted with China Harbor. All dredges are of trailing suction side discharge type except for Guayana of Hopper type.

16) The following dredging improvement measures are recommended in technical viewpoints.

(a) **[Introduction of Track Recording System]:** Generally, the Channel dredged section by a trailing suction dredge shows that the dredged channel bottom is extremely irregular with many peaks and valleys. In order to obtain the maximum depth with minimum dredging, it is required to locate accurate position and depth of previously dredged area or remaining high spots by introducing recording and storing devices. Presently, the channel is provided with transmittal stations by INC from which data are received through GPS satellite to identify the location of the dredge. An integrated system equipped with track display recorder and drag head positioning system is recommended as improvement to track the depths and locations of shallow spots precisely during dredging operation. The cost for the improvement of two dredges operated by INC is estimated in the amount of US$ 191,000.

(b) **[Introduction of Barge System]:** Because of the short length of discharge pipe, the side casting method would only permit the disposal of the dredged spoils either adjacent to the Channel or into the Channel, the return of disposed material into the channel, especially at Boca Grande, is remarkably

high. In order to eliminate a possible return of disposed material into the channel by the present method of side casting, the use of dumping barge is recommended to dispose outside of the channel. For the Rio Orinoco dredge, two conveyors each comprised of a barge of 3,500 cubic meter capacity and a 4,000PS pusher boat will be needed. The cost is estimated in the amount of US$ 21,900,000.

(c) **[Increase of Dredging Hour]:** According to the annual operation dredging record of the three (3) dredges in recent years, the total annual dredging hours of Rio Orinoco and Guayana is less than 3,000 hours, which is less than 50 % of 6,000 dredging hours of earlier operated dredge Icoa. Thus, resultant dredging volume has not satisfied with the designed volume and it has been difficult to ensure the required navigation depth. Since the reason of low operating time involves various factors, in order to overcome the problems, it is required to take a comprehensive dredging study including executing methods, system and institutional management.

17) **[Fluff Study]:** To date, detailed study on properties of fluff deposits has not been conducted in Boca Grande. Echo sounding survey is not a tool to evaluate the physical properties of fluff in order to determine effective method and program of dredging operation. Hence, sufficient number of fluff samples from the channel should be tested in a laboratory for physical properties such as natural water content, unit weight, grain size distribution, cohesion, etc. In particular, unit weights at different depths and time elapse for consolidation should be determined based on the result of consolidation analysis so that appropriate frequency of agitation could be formulated for dredging operation. Similarly, based on the result of the consolidation analysis, the most appropriate mode of dredging such as agitation method or removal or the combination thereof should be investigated.

18) **[Institution for Maintenance Dredging]:** In order to increase the efficiency of dredging works, it is recommended to establish a task force within a few years to discuss the required institutional reforms. A scheme for carrying out the dredging works by private companies under the planning, management and supervision of INC is recommended to be considered to follow the government policy of decentralization. Under this system, INC will be planning and regulating body, leaving the actual execution role to third parties in the form of "outsourcing".

Economic Evaluation

19) **[Structural Measures]:** The economic analysis was conducted for the cost comparison between periodic dredging and structural measures of channel improvement, which is envisaged as only one possible alternative of structural measures at the section of Guarguapo-Barrancas-Yaya. Both the Complete Closing Dyke Project and the Submerged Closing Dyke Projects indicate that the benefit arising from the investment cost fails to show viability from the viewpoint of the national economy. Needless to say, the financial viability of both projects is also difficult. Therefore, even though they are technically feasible, implementation of these projects should be suspended.

Results of Economic Evaluation for Channel Improvement

	Complete Closing Dike	Submerged Closing Dike
B/C	0.95	0.74
EIRR	-	-
Economical Feasibility	Not Feasible (X)	Not Feasible (X)

20) **[Dredging Improvement Measures]:** Both the Additional GPS Project and the dumping barge Procurement Project clearly indicate viability from the viewpoint of the national economy. The positive impact of improving the dredging efficiency, which is currently said to be about 25% at the Boca Grande channel, can be anticipated in addition to other benefits such as lower shipping cost due to the navigability of large vessels, reduction of required dredging time etc. The introduction of dumping barge system in particular should result in a significant improvement of the efficiency and this result is expected to contribute to improving the financial balance of the INC.

Results of Economic Evaluation for Dredging Improvement

	Additional Installations for Present GPS System	GPS + Dumping Barge Procurement
B/C	43.76	4.36
EIRR	493 %	53 %
Economical Feasibility	Feasible (O)	Feasible (O)

Conclusions

Results of the study on the comprehensive river improvement, in order to implement effective maintenance dredging for vessel navigation coping with the future cargo transportation along Orinoco river, are as follows:

21) **[Navigation Route and Vessel Size]:** It is recommended that the Rio Grande channel is the most suitable navigation route among all the alternative routes in the Orinoco delta. The channel should be maintained to accommodate Panamax size carriers (65,000DWT) in terms of its depth and width, according to the present and foreseeable future requirements.

22) **[Structural Measures]:** It is technically feasible to minimize the periodic dredging requirement in the Rio Grande channel with the provision of structural measures; closing dikes, as evaluated by the 2-dimensional hydraulic simulation analysis. However, these structural measures are evaluated as economically and financially not viable due to the high construction and maintenance cost. Moreover, as a result of the closure of channel, potential adverse environmental effects on the social environment and ecosystem due to stagnation of water body, sediment deposition, disturbances on the waterway transportation and fisheries industry are also evaluated as significant. Furthermore, unforeseen phenomena in long-term view such as river course changes and morphological variations due to the large-scale improvement measures could not be analyzed by presently available tools of hydraulic analysis and remained as unsolved problems (risks). Therefore, it is risky to propose any structural measures without having considerably high benefit compared to the cost. Consequently, in

an overall sense, structural measures to deepen the navigation channel in the Rio Grande are justified as not feasible.

[Numerical Simulation for Hydraulic Analysis]: The two-steps approach of one-dimensional and two-dimensional hydraulic simulation applications are conducted in the river improvement study as the objective area is vast in extent and consists of complicated river networks. In first step analysis, one-dimensional hydraulic analysis is applied to reproduce the channel bed profile in the whole objective area and the characteristics of changes in channel course are identified as the key points aiming at the river improvement. Accordingly, practical alternatives of channel improvement could be discussed in macro viewpoint. For the second step, two-dimensional analysis which considers the secondary flow phenomena, is conducted to evaluate the hydraulic effects by the implementation of structural measures, 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. This two-steps approach of one-dimensional and two-dimensional numerical model applications can be used as a reference for the other similar future river improvement studies dealing with a complicated channel network with confluence and bifurcation.

23) **[Dredging Improvement Measures]:** The periodic maintenance dredging is evaluated as the only viable means to meet the navigation requirement from the overall viewpoints of technical, economic, financial and environmental aspects. In order to realize effective dredging, as the results of the analysis for present dredging activities within the scope of work for this study, the following dredging improvements are evaluated as feasible in technical and economical viewpoints.
    - Provision of RTK/GPS with precision location recording system and drag head positioning system to locate precisely shallow reaches and high spots.
    - Minimize return of disposed materials to navigation channel by introducing barge system.
    - Reduction of non-operation time of dredges by means of proper employment system, spare parts management system and orderly maintenance works etc.

Recommendations

In order to continue the maintenance dredging in the future and to ensure the safe, effective and reliable Orinoco navigation canal, MARN-PROA should promote to carry out the following recommendations with coordination of relevant implementation agencies.

24) **[Comprehensive Dredging Study]:** Implement an integrated dredging study including the executing methods, dredging system, dredging constituent etc., together with following items.
    - Review of institutional structure for maintenance dredging (Administrative Measures)
    - Dredging system including dredging methods and techniques, dredge types etc. (Technical Measures)

25) **[Fluff Characteristics Investigation]:** Execute an integrated study to examine the physical properties of fluff to determine the most appropriate method of dredging operation at the outer channel (Boca Grande section).

26) **[Establishment of Committees for Institutional Restructure]:** To overcome the present institutional and management deficiencies, establish a committee to study the effectiveness of assigning the maintenance dredging activities to private companies under the planning, management and supervision of INC. Moreover, to expedite the overall port management in Puerto Ordaz coping with the future cargo throughput and vessel traffic, establish a single entity called Port Authority, for a wide range of port activities related to development, maintenance, administration and management of port facilities as well as the enhancement of port use.

27) **[Introduction of Vessel Traffic Management System]:** In order to cope with the increase of future traffic volume as well as to ensure the safe and effective navigation in the Rio Grande navigation channel, in which there are several narrow reaches enough only for one way traffic, introduce a vessel traffic management system (VTMS) to identify the positions of all the vessels at any instance and to co-ordinate and control the vessel movements.

28) **[Periodical Review for Channel Alignment]:** As a non-structural measure, conduct regular bathymetric surveys by INC and realign the navigation route through the deepest area of the channel to reduce the maintenance dredging requirement.