Feasibility Study of the Construction of an Artificial Island at the Pacific Entrance to the Panama Canal

Estudio de Factibilidad de la Construcción de una Isla Artificial en la Entrada del Pacífico al Canal de Panamá

JETRO

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Resumen

SUMMARY

1. Backgrounds of the Feasibility Study

Autoridad del Canal de Panama (ACP) is evaluating the possibility to expand the Canal to accommodate ships larger than Panamax vessels. The proposed construction of new locks and the related work for the expansion of the Panama Canal are expected to generate significant quantities of excavated materials, amounting to some 50-70 million m^3. As part of its activities, the Panama Canal Master Plan for the expansion of the waterway is considering land reclamation at the Pacific entrance to the Panama Canal, as an alternative to give excavated material a beneficial use.

In order to assess the technical and environmental aspects of the land reclamation alternatives, JETRO's Preliminary Study on "Land Reclamation Alternatives for the Pacific Entrance to the Panama Canal" was carried out in cooperation with ACP from December 2002 to March 2003. In this preliminary study, with a view to the beneficial usage of excavated materials coming from Panama Canal Expansion Plan activities, land reclamation alternatives were proposed in consideration of Japanese technologies and experiences. Due to time constraints and lack of data, some bold assumptions were adopted in evaluating land reclamation alternatives.

In response to the request for a subsequent study from ACP, Japan External Trade Organization (JETRO) has decided to carry out the "Feasibility study for the Construction of Artificial Island at the Pacific Entrance to the Panama Canal" in 2003. The Feasibility Study is executed by the study team organized by Nippon Steel Corporation, in cooperation with Nippon Koei Co., Ltd.

2. Objectives of the Feasibility Study

This Feasibility Study of JETRO (hereinafter called as JETRO F/S) aims to propose constructing an artificial island using the excavated materials resulting from the proposed construction of new Pacific locks and analyze the feasibility of the project.

3. Executing Agency of the Project

The executing agency is Autoridad del Canal de Panama (ACP).

4. Study Area

The Study area is at the Pacific entrance to the Panama Canal (see **Figure 4.1**).

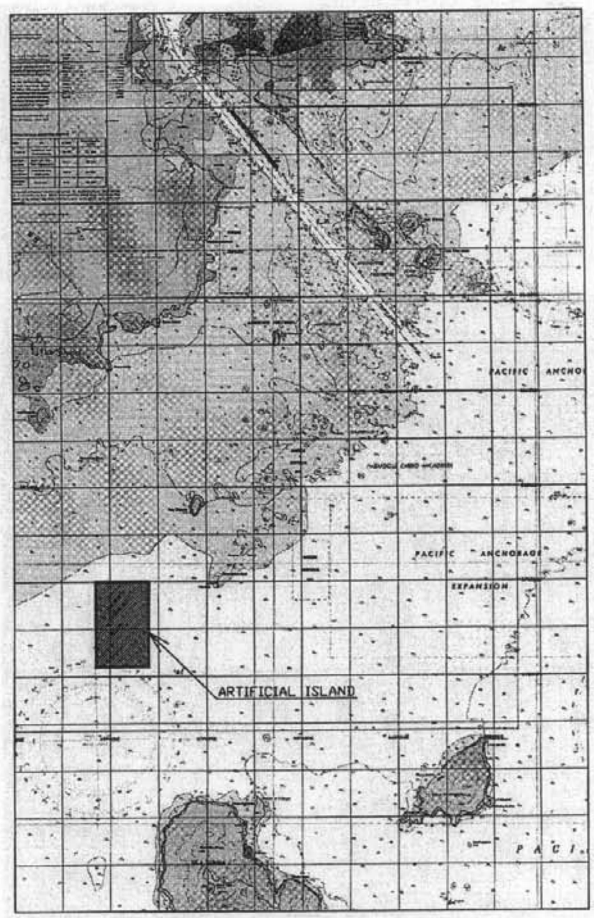
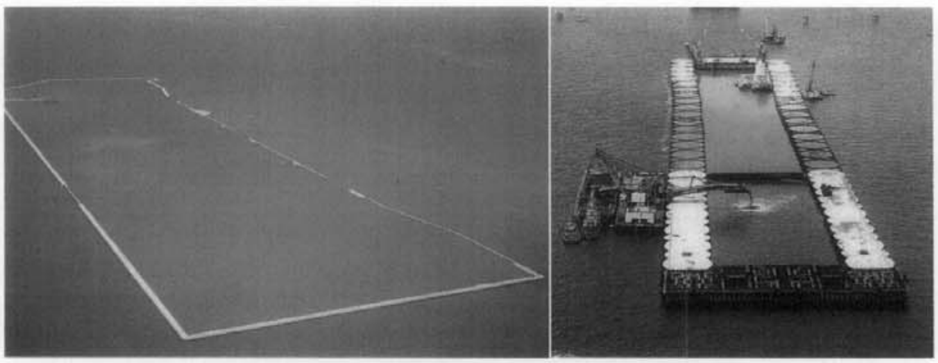


Figure 4.1 Location Map

5. Artificial Island Construction Method

During and after construction of Artificial Island, one of the most principal concerns is to achieve the minimum impact on environment. Particularly, the seawater pollution must be avoided carefully.

As shown in **Figure 5.1**, when constructing an artificial island in Japan, the reclamation is implemented after all construction of surrounding revetment. Therefore, environmental impact can be minimized because the reclamation area is separately enclosed perfectly in the sea.



(a) Kansai International Airport

(b) Tokyo-wan Aqua Line (Umihotaru Island)

Figure 5.1 Construction Examples of Reclaimed Islands in Japan

Among popular structural types in Japan is steel sheet pile cellular-bulkhead quaywall or concrete caisson. In this situation, there are two differences between them, in terms of installation site environment and construction period. In the construction (installation) of sheet pile cellular-bulkhead quaywall, driving sheet piles and then inside filling can keep the seawater clean from contamination. On the other hand, in the construction of concrete caisson, rubble replacing may cause seawater pollution. Furthermore, casting, hauling and emplacement of concrete caisson need generally longer time than driving sheet piles. Additionally, it needs wide area for casting work and setting of concrete plant near the construction site. Consequently, steel sheet pile cellular-bulkhead quaywall is recommended in this Study.

6. Container Terminal Planning for Artificial Island Size

There is a plan to use the artificial island for a container terminal in the future. Artificial island size is studied based on container port operation activities.

6.1 Target Vessel

In this Feasibility Study, the dimensions of the target vessel are in accordance with those of the Third Locks Project as mentioned below.

Length Overall (LOA)	:	385.7m
Breadth	:	54.9m
Draft	:	15.2m
DWT	:	105,000
TEU	:	10,500

Considering above dimensions, it can be assumed that target vessels are able to carry 21 rows of containers on the deck.

6.2 Container Demand Forecast

Balboa Port is at present playing an important role as the transshipment port in the Pacific Ocean side of Panama and Panama Port Company has a vision to expand Balboa Port to receive a growing number of containers in the future although the available onshore area seems narrow to handle staking containers. The number of containers to be handled in Panama at the year 2025 has been projected to be approximately 5,690,000 TEUs as a medium transshipment scenario by the ACP

Study. Under such circumstance, it can be assumed that the Artificial Island will receive approximately 1,000,000 TEUs for the year 2025 in consideration of the allocation each other.

6.3 Berth Dimensions

The container terminal should be designed to accommodate the target vessel, with a draft of 15.2m fully loaded. The length of the container berth is determined from the design vessel length and bow and stern mooring space. Suppose the mooring angle of vessels is 45 degrees considering that the berth line is continuous and straight, the length of the berth can be calculated to be 450m by the following formula.

Length of Container Berth = 385.7 m + 2 x (54.9/2 + 2.0) = 444.6 m → 450 m

6.4 Number of Container Berths Required

Using the container traffic forecast by ACP, the number of container berths required at the year 2025 should be determined by the following formula.

Nb = My / (Ec x Nc x (1+Rf) / (Dy x Hd) / Br

Where;

Nb	:	Required number of container berths	
My	:	Container throughput (in TEUs) at the year 2025	1,000,000 TEUs
Rf	:	Ratio of 40 foot containers	80%
Ec	:	Container handling productivity per hour	25 Boxes
Nc	:	Number of gantry crane to be allocated	2 Nos.
Dy	:	Annual operational days	356 Days
Hd	:	Working hours per day	20 Hours
Br	:	Berth occupancy rate	0.40

Nb = 1,000,000 / (25 x 2 x 1.8) / (20 x 356) / 0.40 = 3.90 → 4 berths in 2025

The required number of container berths (Nb) has been calculated to be 3.90. Therefore, four (4) container berths, each of which is equipped with two (2) gantry cranes should be planned to accommodate the prospected number of containers at the year 2025. Two (2) berths are to be planned additionally at the year 2035 provided that the container cargoes increase with a growth rate of five (5) percent.

6.5 Depth of Container Terminal

The depth of a container terminal should be sufficient to cope with a growing number of container cargoes taking into account the stacking method in the yard and necessary facilities in the container terminal. Considering the future increase of container cargoes to be triggered by the increase of containerization ratio and future deployment of larger size container vessels, a depth of 500 m for the container terminal should be planned.

6.6 Phase-wise Development

(1) Phase I

As the transshipment study by ACP is targeted the year 2025, the Phase I development of the Artificial Island Project can be set as the same year as well. Based on the required number of container berths, the Phase I development has been formulated. Also, dredging plan has been determined phase-wisely to achieve cost-effective development.

(2) Phase II

The Phase II development is targeted at the year 2035, which is 10 years later of the Phase I. Two (2) additional container berths would be provided to meet the container demand in 2035 and additional work for dredging and the construction of onshore facilities is required.

6.7 Reserved Area for Future Commercial Activity

Two (2) liquid cargo berths are provided to receive bunker oil for container vessels.

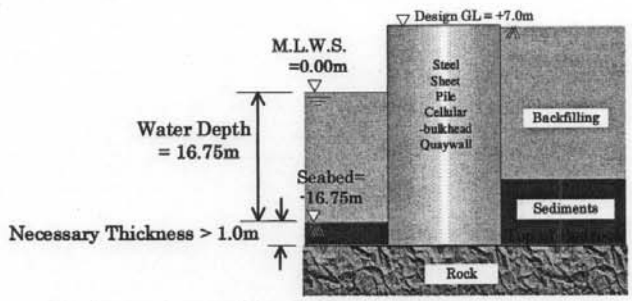
The existing water depth at the liquid cargo berths is sufficient to accommodate 30,000 class tankers and it is possible to apply tidal operation. Some tank storages are also to be provided on land to stock oil. Bunker oil can be transported from the storages to the container berth through pipeline connection.

Once the Artificial Island is constructed using the material generated from the Third Locks Project, various distribution facilities would be located near the container terminal. Also, various commercial activities on the Island are expected to generate.

7. Artificial Island Location

7.1 Location on North-South Direction

Necessary depth for the berth facility is planned as MLWS –16.75m. Roughly estimating the unevenness of existing seabed level at 1 m, the shallowest level of installment of steel sheet pile cellular-bulkhead quaywall should be set to MLWS –18m. This minimum depth is illustrated in **Figure 7.1.1**.



Minimum depth of bedrock
< M.L.W.S. –16.75m - 1.0m = -17.75m ⇒ -18.0m

Figure 7.1.1 Minimum Depth for Installment of Cellular-bulkhead Quaywall

If Artificial Island is constructed on the shallower rock layer than MLWS –18 m, the construction cost can increase considerably due to huge excavation volume of stiff rock layer.

On the other hand, the farther away from landside to offshore (southbound) the construction site is located, the larger the infrastructures becomes, such as the sectional size of cellular-bulkhead quaywall and the total length of Accessway. Consequently, the construction cost will be much more expensive.

In this study, the following alternative cases are compared in terms of construction cost to decide the best location of Artificial Island on north-south direction.

a) Location I (see **Figure 7.1.2**)

Artificial Island is located to correspond the north edge of Island with the contour line of rock layer level of MLWS -18 m. There is no need to excavate stiff rock layer in this case. The length of accessway is 5,525m, and the distance between the coast and south edge of the island is 7,325m (= 5,525m + 1,800m).

b) Location Alternative II -a (see **Figure 7.1.3**)

Artificial Island is located to correspond the south edge of Island with the south edge of Location P1 defined in ACP Report "Preliminary Study of Island Development at the Pacific Entrance of the Panama Canal". The length of accessway is 4,645m. The distance between the coast and south edge of the island is 6,445m (= 4,645m + 1,800m), which is almost equivalent to P1. In this case, rock excavation is needed to construct two berths in north side of island, but not in the construction of four berths in south side.

c) Location Alternative III (see **Figure 7.1.4**)

Artificial Island is located to correspond the north edge of Island with the north edge of Location P1 defined in ACP Report as well. The length of accessway is 3,820m, which is almost equivalent to P1. The distance between the coast and south edge of the island is 5,620m (= 3,820m + 1,800m). Though there is merit in this case of reducing the total length of Accessway, huge quantities of stiff rock have to be excavated for all six berths unfortunately.

d) Location Alternative II -b

The location of Artificial Island is the same as Location Alternative II -a. However, the necessary depth of berth is changed to MLWS -13.5 m for the first northern berth and MLWS -14.5 m for the second northern berth. This case allows intentionally the

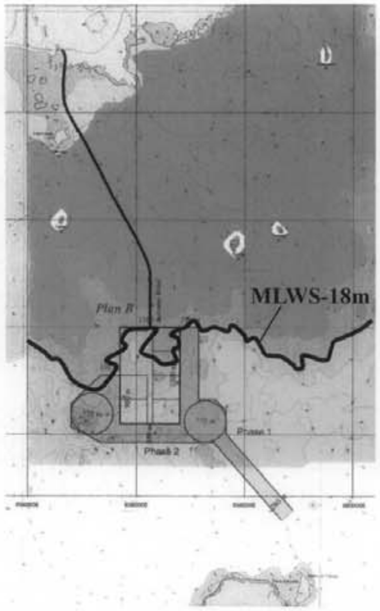


Figure 7.1.2 Location I

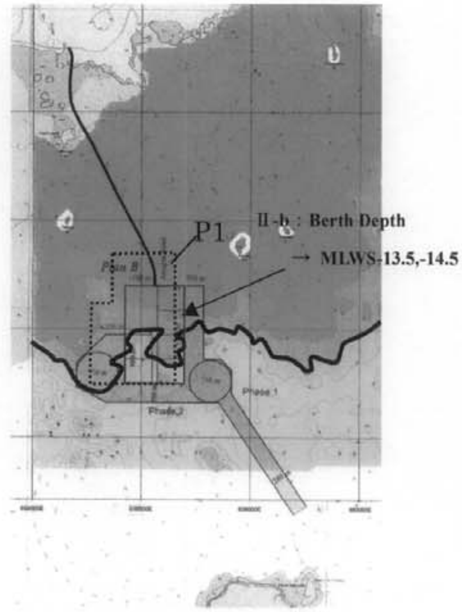


Figure 7.1.3 Location II-a and II-b

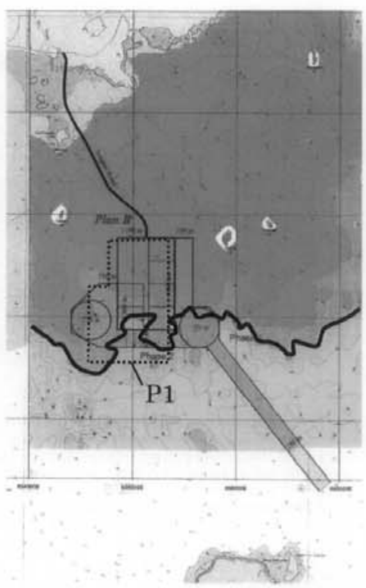


Figure 7.1.4 Location III

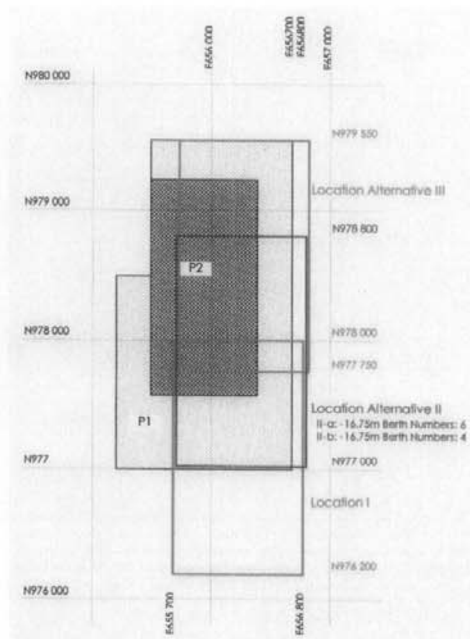


Figure 7.1.5 Comparison of Location

Table 7.1.1 Comparison of Location Alternatives

	Location I	Location Alternative II-a	Location Alternative III	Location Alternative II-b
1. POV				
1.1 Artificial Island Location	On the northern limit without rock dredging [Latitude] North end: N978 000 South end: N976 200	South end latitude is equal to the one of ACP-P1 [Latitude] North end: N978 800 South end: N977 000	North end latitude is equal to the one of ACP-P1 [Latitude] North end: N979 550 South end: N977 750	= Location Alternative II-a [Latitude] North end: N978 800 South end: N977 000
1.2 Number of -16.75m berth	-16.75m berth: 4+2 = 6			-16.75m berth: 4 -14.5m berth: 1 -13.5m berth: 1
2. Features				
2.1 Length of accessway	5,525m [Base]	4,645m [-880m]	3,820m (same as ACP-P1) [-1,705m]	= Location Alternative II-a
2.2 Reclamation Volume	39 Mm3	37 Mm3	34 Mm3	37 Mm3
2.3 Dredging volume	Soil: 9.0 Mm3 Total: 9.0 Mm3	Soil: 11.0 Mm3 Rock: 0.4 Mm3 Total: 11.4 Mm3	Soil: 12.3 Mm3 Rock: 2.0 Mm3 Total: 14.3 Mm3	Soil: 10.6 Mm3 Total: 10.6 Mm3
3.Construction Cost				
(1) Quaywall/Revetment	269 M US$	263 M US$	262 M US$	262 M US$
(2) Reclamation	96 M US$	93 M US$	88 M US$	93 M US$
(3) Accessway	99 M US$	85 M US$	72 M US$	85 M US$
(4) Dredging	65 M US$	139 M US$	371 M US$	76 M US$
Total Cost	529 M US$	580 M US$	793 M US$	516 M US$
4. Evaluation	AA	A	B	A

reduction of berthing ability of two northern berths, in which the berth depth should have been, MLWS -16.75 m originally. Other four (southern) berths can keep the sufficient depth of MLWS -16.75 m.

The result of comparison of these four Location Alternatives is shown in **Table 7.1.1** and **Figure 7.1.5**. The construction cost in **Table 7.1.1** includes that of Accessway.

In comparison of Location Alternatives Ⅰ, Ⅱ-a and Ⅲ, it is obviously proved that the construction sites in northern side from the line of rock layer level of MLWS -18 m lead to be more expensive. This is because the cost-push for rock excavation is larger than the cost-down by shortening the total length of Accessway. Meanwhile, the construction cost becomes higher when the construction site is set farther to offshore in southern direction, as mentioned previously. Consequently, the cost can be minimized when the Artificial Island is located to correspond the north edge of Island with the contour line of rock layer level of MLWS -18 m.

Actually, Location Alternative Ⅱ-b can be constructed with cheaper cost than Location Ⅰ due to no rock excavation. However, Location Alternative Ⅱ-b cannot maintain satisfactory berthing ability.

In this study, it is concluded that Location Ⅰ is the best location for construction of Artificial Island on the north-south direction.

7.2 Recommended Location for Artificial Island

As a result of the above comparison study, the recommended location of Artificial Island is set to the followings (see **Figure 7.2.1**):

North Edge of Artificial Island: N978000
East Edge of Artificial Island: N656800

Figure 7.2.1 Best Location of Artificial Island

8. Analysis of Wharf Operation Efficiency

Based on the location of the artificial island recommended above, the effect of wave transformation and calmness of the existing basin condition due to the placement of the proposed artificial island were investigated. And then, wharf operation efficiency for cargo handling at each container berth was calculated.

The model results have concluded the following matters.

- The typical wave climate in the area of the proposed artificial island is relatively mild with the geometry of the Gulf of Panama and South America limiting the directions of waves entering the region. Additionally, the near-shore islands of ISLA TABOGA and TABOGUILLA will provide a relatively tranquil area behind, which in turn, a better position and suitable place for the proposed artificial island.
- If container berths are located on the east side and the west side of the artificial island, the standard level of wharf operation efficiency for cargo handling, 97.5%, can be achieved without a breakwater.
- The ratio of wave height is relatively large at the south of artificial island, because wave directions are almost southwardly at the project site. And the standard level of wharf operation efficiency for cargo handling, 97.5%, can not be achieved at the southern berths. Consequently, a breakwater is needed if the container berths are located on the south side of the artificial island.

9. CURRENT ANALYSIS

The current simulation was implemented to evaluate the potential impacts of the construction of the artificial island and the access way.

The following was concluded based on the mathematical modelling of the effects of the construction of the artificial island and the proposed accessway:

- The construction of the island will change current directions and speeds in some degrees, however such change does not significantly affect the natural current conditions of the bay as a whole.
- The impact of increase in the current velocities from the natural condition is mostly significant in the northern part of Taboga Island, however, such increase remains within around 10cm/s from the natural condition.
- The accessway design shall incorporate a bridge or intermittent trestle sections to avoid any impact on the shore area and to prevent negative effects especially due to the social and environmental value of Veracruz Beach.

10. Container Terminal Layout

Table 10.1 shows the comprehensive evaluation results of container terminal alternatives.

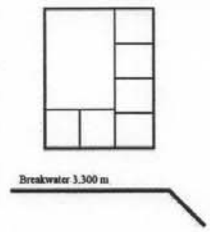
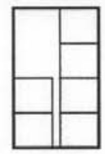
In view of the calmness, Plan-B and C will achieve the standard level of wharf operation efficiency for cargo handling, 97.5%, while Plan-A needs a breakwater to secure designated calmness in the port.
In terms of terminal operation, Plan-C is the best plan since quayside gantry cranes can be utilized to all the berths.

According to the results of current simulations, Plan-C will have a biggest influence on the speed of the current among the three alternatives. However, such change in the current is not so significant

The island construction cost for Plan-B is a base case and cost difference from the base case for Plan-A and Plan-C is shown in **Table 10.1**. Plan-A is most costly because a breakwater is needed to secure calmness in the port.
Hence, according to the overall evaluation, the recommended container terminal

layout is Plan-B.

Table 10.1 Evaluation of Container Terminal Layout

	Plan-A	Plan-B	Plan-C
Container Terminal Layout			
Island Area	1,400m * 1,800m = 252 ha	1,100m * 1,800m = 198ha	733m * 2,700m = 198ha
Reclamation Volume	49 M m^3	39 M m^3	40 M m^3
Evaluation Item 1. Port Operation			
1) Calmness (Chap 4 & 6)	AA (100% > 97.5%) (Breakwater is necessary)	A (98.4% > 97.5%)	A (98.0% > 97.5%)
2) Terminal Operation	A	A	AA (Gantry cranes can be utilized to all other berths)
2. Influence to Current	A	A	B
3. Island Construction Cost	B (US$ +135 M)	AA (Base)	A (US$ +54 M)
Comprehensive Evaluation	B	AA	A

11. Cost Estimate

11.1 Overall Project Cost Estimation (Plan B)

Estimated construction cost of the Panama Artificial Island and container terminal is summarized in **Table 11.1**.

Table 11.1 Summary of Construction Cost - Plan-B

(Million $)

Component	Phase 1	Phase 2	Total
Island Construction			
Quaywall / Revetment	269		269
Reclamation	96		96
Breakwater	0		0
Sub Total	**365**		365
Accessway	99	0	99
Infrastructures	74	39	113
Container Terminal Module	217	103	320
Total	755	142	**897**

11.2 Comparison of Construction Volume and Cost

Table 11.2 shows the comparison of construction volume and cost between two alternatives. As the proposed artificial island in this JETRO F/S is also advantageous to the total construction cost as the revetment can be used for the quaywall of the container terminal.

Table 11.2 Comparison of Construction Volume and Cost

Items	JETRO F/S Plan-B	ACP-P2-A*)
Size of Artificial Island	1,100m*1,800m = 198 ha (1.29)	900m*1,700m =153 ha
Reclamation Volume	39 M. m^3 (1.26)	31 M. m^3
Island Construction	$ 365 M.	$ 248 M.
Accessway	$ 99 M.	$ 103 M.
Infrastructures	$ 113 M.	$ 138 M.
Container Terminal Module (Marine Structures for Container Terminal)	$ 320 M. ($ 75 M.)	$ 447 M. ($ 183 M.)
Total Cost	$ 897 M. ($ 453/m2)	$ 936 M. ($ 612/m2)

*) ACP: PRELIMINARY STUDY OF ISLAND DEVELOPMENT AT THE PACIFIC ENTRANCE OF THE PANAMA CANAL, Final Report, Volume 1 of 2 Main Report, December 2001.

12. Environmental Evaluation

Environmentally, the proposed project location does not pose a significant threat to the environment for many reasons, such as:

1. No loss of inter-tidal habitat (depending on the structure of Accessway) and no loss of vegetative protected species;
2. Dumping of excavated materials will be done in a contained environment thus greatly minimizing environmental impact, which is normally associated with open sea dumping;
3. Location is nearby island formations, therefore environment is thus adapted to the existing velocity variations of the currents; and
4. Recommended access way structure provides a feasible and suitable solution since it minimizes the barrier effect.

It was identified that one of the few irreversible impacts of the implementation of the project, nevertheless mitigable, is the location of the access point of the access way. This point falls in the border of a naturally protected area, such area lost would have to be compensated by a re-vegetation measure as proposed in the Draft Environmental Management and Monitoring Plan.

It is implied that all other conditions regarding the operations, local regulations and international agreements would be fully complied with, therefore having a negligible impact as long as the regulation are met.

It is expected that a full fledge Environmental Impact Assessment will be carried out to obtain approval by the Autoridad Nacional de Ambiente (ANAM) once a decision is reach on the detail design of the infrastructure.

It was learned from an interview by a member of the JETRO Study Team that the project area is not visited by artisanal fishermen; therefore, little impact is expected by the project construction in such industry.

The alternative to dump the material from the works of the excavation of the third set of locks in a contained environment is definitely a better environmental option than reclamation near the shore since it implies loss of inter tidal habitat and the need for a larger area to accommodate the same volume of material.

The greatest impact of the proposed island construction comes from the construction of the access way and not the island construction itself. The proposed use of the island as a container terminal is the cleanest potential use of the development as manageable levels of waste a generated and can be treated as proposed in the EMMP.

13. Project Evaluation

13.1 Economic Evaluation

The economic internal rate of return (EIRR) of the Project based on a cost-benefit analysis is 12.4%.

13.2 Financial Evaluation

The financial internal rate of return (FIRR) of the Project is 9.6%, which is much higher than JBIC's interest rate (1.2 %) for preferential terms loan..

14. Conclusion

JETRO Feasibility Study for the Construction of an Artificial Island at the Pacific Entrance to the Panama Canal was carried out in cooperation with Autoridad del Canal de Panama (ACP) from August 2003 to January 2004. In this feasibility study, an artificial island construction plan was proposed with a view to the beneficial usage of excavated materials coming from Panama Canal Expansion Plan activities, and this proposed artificial island construction project was ascertained to be feasible from technical, economic, financial and environmental point of views.