ABSTRACT

1. INTRODUCTION

This report presents the results of the Development Study on the Improvement of Sewerage and Drainage system for Havana Bay in the Republic of Cuba. The Study has been conducted in three phases of 1) Basic Study, 2) Formulation of Sewerage Master Plan up to the target year of 2020 and 3) Feasibility Study on the Priority Projects identified in the Master Plan.

2. PRESENT SITUATION

Havana Bay and its bay basin contribute to the Cuban economy greatly as a commercial and industrial seaport. The bay basin has an area of 68 km^2 and a population of about 800,000 as of 2000, which represents 37% of the population of Ciudad de La Habana Province. Havana Bay has an area of 5.0 km^2, an average water depth of 9 meters, and a capacity of 47 million m^3. Because of the characteristics of Havana Bay as a closed water environment, the water of the bay is not exchanged easily with seawater. The pollutants originated from domestic and industrial wastewaters are being discharged into the bay through rivers, sanitary sewer mains and urban drains, and also directly discharged from pollution sources located along the shore of the bay.

3. SEWERAGE SYSTEM MASTER PLAN

The Sewerage Master Plan has been formulated in the following steps:

First, a strategy of water pollution control for the bay was formulated, in which how and how much the bay water environment will be improved by the rehabilitation and improvement of the existing sewerage system and by the development of new sewerage systems were studied. Considering present and future water uses in Havana Bay, water quality goals were proposed based on the draft of Cuban environmental quality standards for the water bodies and the results of a series of water quality simulations. The required level of wastewater treatment was also identified for the case of treated water discharge to the Havana Bay.

Second, rehabilitation and improvement plans for the existing sewerage system were proposed to solve identified problems and increase the system reliability, based on a series of studies concerning identified problems. A new sewerage system development plan was also proposed to reduce the pollution loads effectively and efficiently through a series of studies on alternative sewerage system that discharges treated wastewater into Havana Bay or the Caribbean Sea.

Third, the sewerage plans to be implemented by the target year of 2020 were selected as the sewerage system components of the Sewerage Master Plan. The costs required for the construction and operation of the proposed sewerage components were estimated. The implementation schedule of the Master Plan and necessary institutional strengthening were also proposed. The effects of the proposed projects on the water quality improvement of the bay were demonstrated with a simulation model of the bay water. Moreover the financial and economical viabilities of the project were examined and evaluated by the Discounted Cash Flow analysis and Sensitivity Analysis. The results of these studies were used to formulate the Sewerage Master Plan. Finally, some priority projects were selected for the next study phase of Feasibility Study.

(1) Water quality objectives and required wastewater treatment level

Water quality goals necessary to maintain the existing bay uses for tourism, recreation, industry, commerce and transportation are: Dissolved Oxygen concentration of above 3 mg/L (Goal 1), and Oil/Grease concentration of below 5 mg/L (Goal 2). Goal 1 requires that the organic

pollution of the bay should be reduced by the sectors of sewerage, drainage and industry, while goal 2 requires the actions of industry sectors, industry and workshops along the coast of the bay.

To achieve the minimum DO level of 3 mg/L in Atares where DO level is lowest in the bay, the new sewerage system need to have secondary treatment for all the wastewater collected.

(2) Sewerage System Plans

For the existing sewerage system, an improvement plan was prepared to solve the problems identified such as cross connections of sewers to drainage channels, inadequate capacities of sewer mains, malfunctioning screen equipment and pumps. Improvement of reliability of the existing sewerage system was also planned by the construction of a new Colector system that increases the capacity of the existing system and makes the rehabilitation of Colector Sur possible, rehabilitation of Colector Sur, and construction of a re-pumping station to facilitate the rehabilitation of transmission tunnel and Sea outfall.

The development plan of new sewerage systems were prepared to manage the wastewater discharged in the basin through a comparative study on six alternatives, including one alternative of Sea discharge. The alternative plan comprising four zonal sewerage systems was selected, in which the development of Luyanó-Martín Pérez Sewer District up to the year of 2020 could reduce the pollutant loads to the bay most effectively and efficiently. Finally, the development plan of Luyanó-Martín Pérez Sewer District was selected for a part of the Sewerage Master Plan.

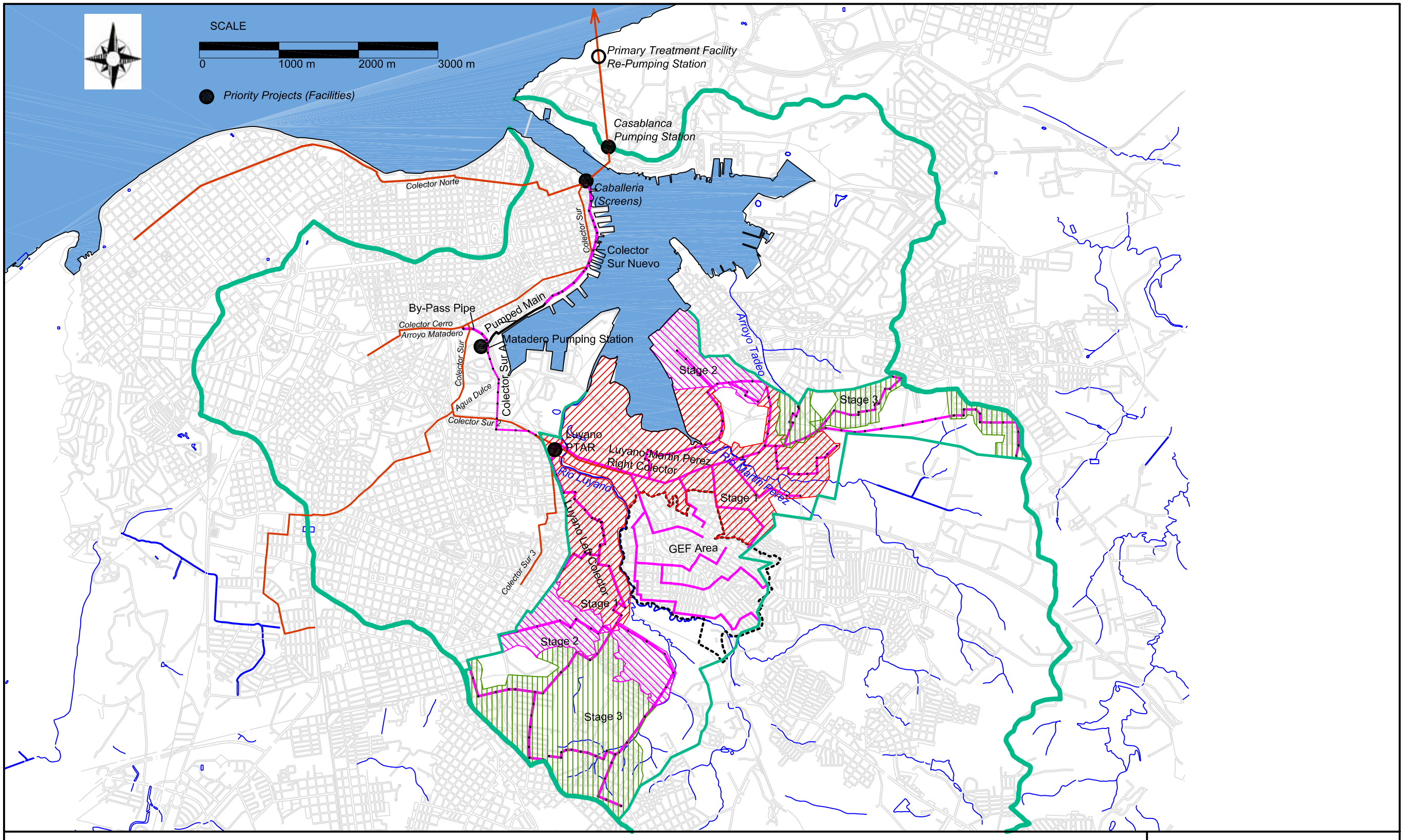
In the process of formulating the Sewerage Master Plan, many alternatives and options on the sewerage plans have been prepared and studied. Some of them would help to modify the Sewerage Master Plan when the conditions and assumptions are changed in the future.

(3) Sewerage Master Plan

The implementation of the proposed Sewerage Master Plan as shown in Figure 1, will accomplish the followings by 2020: 1) Sewer service populations will be 591,500 within the basin and 750,600 in total including 159,100 outside the basin. Within the basin, about 74% of the inhabitants will be covered. 2) About 80% (204,600 m^3/d out of 256,900 m^3/d) of the wastewater generated within the basin will be covered. 3) About 55% of the total organic pollution load in terms of BOD generated within the basin including pollutants from refinery, will be treated by the sewerage. Table 1 shows the estimated pollution loads reduction by the proposed new sewerage system developments when the secondary biological wastewater treatment processes are introduced. The proposed M/P and GEF projects cover 51% of the possible load reduction; (D+E)/B.

Table 1 Pollution Load Reduction with the M/P of New Sewerage Development

Item	Load			
	BOD_5	T-N	T-P	SS
New Sewerage System-All Sewer Districts				
Estimated load generation (A), kg/d	22,794	3,481	892	22,794
Estimated load reduction (B), kg/d	20,515	522	134	20,515
New Sewerage System-M/P Area				
Estimated load generation (C), kg/d	11,723	1,779	460	11,723
Estimated load reduction by GEF/UNDP (D), kg/d	2,546	64	17	2,546
Estimated load reduction by M/P (E), kg/d	8,005	203	52	8,005
Total estimated load reduction by GEF and M/P (D+E), kg/d	10,551	267	69	10,551
Pollution load reduction ratio of E/A	35 %	6 %	6 %	35 %
Pollution load reduction ratio of (D+E)/A	46 %	8 %	8 %	46 %



THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

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Figure 1
General Map of the Master Plan for Havana Bay Basin

Table 2 System Components of the Sewerage Master Plan

Stage	Improvement of the Existing Sewerage System	Development of the New Sewerage System
First Stage 2008 to 2010	To conduct the detailed cross connection surveys in the drainage area of Dren Matadero and prepare design work for the installation of connection pipes to solve the identified problems.	To install the proposed Luyanó-Martín Pérez Right Colector.
	To conduct detailed surveys on physical conditions of the siphon structure and prepare a rehabilitation plan including installation of additional siphon structure, if necessary.	To install the proposed Luyanó Left Colector.
	To take measures to solve the cross connections in the drainage area of Dren Matadero.	To construct the biological secondary wastewater treatment facilities at Luyanó WWTP, which have a treatment capacity of 207 L/s, making the total treatment capacity of 407 L/s or 35,200 m^3/d including the capacity of 200 L/s developed by the GEF/UNDP Project.
	To rehabilitate the two malfunctioning units of screen facilities at Caballeria.	
	To rehabilitate the Casablanca Pumping Station including replacement of the existing pump equipment with new four (4) units, (Q=1.75 m^3/s, H=8 m) including one standby unit.	To construct sewer networks and house connections in Luyanó-Martín Pérez Abajo Sewer District.
	To construct the proposed Matadero Pumping Station.	
	To install the proposed interconnection pipe between the Colector Cerro and the Matadero Pumping Station.	
	To install the proposed Pumped Main and Colector Sur Nuevo between Matadero Pumping Station and Screen Facilities at Caballeria.	
Second Stage 2011 to 2015	To conduct the detailed cross connection surveys in the drainage area of Dren Agua Dulce and prepare design work for installation of connection pipes to solve the identified problems.	To extend Luyanó-Martín Pérez Right Colector.
	To take measures to solve the cross connections in the drainage area of Dren Agua Dulce.	To extend Luyanó Left Colector.
	To rehabilitate Colector Sur.	To expand the treatment capacity of Luyanó WWTP by 207 L/s, which makes the total treatment capacity of 614 L/s or 53,100 m^3/d.
	To construct Colector Sur A. To construct a pumping station (Re-pumping Station) after the transmission tunnel, which have four (4) units of pumping equipment (Q =1.75 m^3/s, H=5 m) including one standby unit.	
	To conduct a minor repair work for the existing transmission tunnel. To replace the Sea outfall sewer.	To install sewer networks and house connections in Luyanó-Martín Pérez Abajo Sewer District.
Third Stage 2016 to 2020	To take measures to solve the cross connections in the area related to the Dren Agua Dulce.	To extend Luyanó-Martín Pérez Right Colector.
		To extend Luyanó Left Colector.
		To expand the treatment capacity of the Luyanó WWTP by 207 L/s, which makes the total treatment capacity of 821 L/s or 71,000 m^3/d.
		To construct sewer networks and house connections in the Luyanó-Martín Pérez Abajo sewer district.

The results of water quality simulation show that the implementation of M/P will improve DO level in Atares to meet the Class F (above 2 mg/L) of the draft Cuban Water Quality Standard from the existing water quality level which is below Class F. Therefore, secondary wastewater treatment in the New Sewerage District will be the first step in improving the water quality of the bay towards the water quality goal of 3 mg/L in DO.

The sewerage systems of the Master Plan were proposed to be constructed in three stages as presented in Table 2 and the required capital investment required was estimated as shown in Table 3. The costs of the Master Plan were estimated in terms of its Foreign Currency (FC) portion and Local Currency (LC) portion. The O/M costs such as personnel, power and chemical costs are estimated as follows: FC and LC are 17,000 US$ and 1,142,000 pesos, respectively in 2011 when the systems start their operation then FC and LC will increase 249,000 US$ and 1,658,000 pesos until 2030 as the wastewater volumes to the sewerage systems increases.

Table 3 Total Capital Investment required for the Sewerage M/P

Item	Improvement of Existing Sewerage		Development of New Sewerage		Total	
	FC	LC	FC	LC	FC	LC
Capital Investment for M/P						
Direct Cost	27,406	16,484	80,826	49,717	108,232	66,201
Indirect Cost	5,759	3,973	16,166	11,435	21,925	15,409
Total	33,165	20,457	96,992	61,152	130,157	81,610
Staged Capital Investment						
First Stage	14,869	9,111	37,027	23,676	51,895	32,788
Second Stage	14,116	8,491	26,968	16,553	41,086	25,043
Third Stage	4,180	2,855	32,997	20,923	37,176	23,779

Unit: FC: Thousand US$, LC: Thousand Cuban Pesos

The Financial Internal Rate of Return (FIRR) of the Sewerage M/P was estimated for the four different cases of counting only the US$ portion of the project costs, only the Cuban Pesos portion, counting both currency portions at the exchange rates ofUS$1:Peso1 and US$1:Peso 26. The FIRR was calculated under the conditions that service charges of the sewerage will be increased (six times for pesos payers and 2.3 times for US$ payers) and a contribution of US$2 from each foreign tourists who visits the Havana City will be introduced for cleaning up Havana Bay. The Economic Internal Rate of Return (EIRR) for the four cases were also estimated based the Willingness to Pay (WTP) of inhabitants and industries for the environmental improvement of the bay to evaluate the economic benefits of the M/P. The monthly WTP of inhabitants was set at 11 Pesos per household. The monthly WTP of industries was set based on the current sewerage service charges and the foreign tourist's contribution of 2 US$. Table 4 shows financial and economic indicators for the two cases in which both currency portions are counted.

Table 4 Financial and Economic Indicators for Sewerage M/P

Indicator	US$ + Peso(1US$=1Ps)	US$ + Peso(1US$=26Ps)	Remarks
Financial Analysis			Discount rate
FIRR	21.0%	1.8%	US$ 6%
B/C	2.1	0.6	Pesos 8%
NPV	(Ps) 135,728	(Ps) -877,044	
Economic Analysis			Discount rate
EIRR	54.6%	7.6%	US$ 10%
B/C	4.9	0.8	Pesos 10%
NPV	(Ps) 309,814	(Ps) -210,707	

4. FEASIBILITY STUDY ON THE PRIORITY PROJECT

(1) Priority Projects

The sewerage components proposed for the first stage project, presented in Table 2 and Figure 2, were selected as Priority Projects. The capital investment required for the Priority Projects is also presented in Table 3. The O/M costs were estimated at 17,000 US$ of FC and 1,142,000 pesos of LC in 2011 when the system starts its operation and will increase to 83,000 US$ of FC and 1,209,000 pesos of LC until 2020 as the wastewater volume to the sewerage system increases.

The Priority Projects are planned to maximize the use of the existing and new sewerage systems to reduce the pollution loads discharged into Havana Bay efficiently. The Priority Projects will provide the cost-effective wastewater collection and treatment facilities to serve the most densely developed and severely degraded urban areas within the bay basin. Each of the sewerage components was evaluated and their appropriateness and soundness were confirmed for their implementation.

The Priority Projects will improve the DO levels in Atares and in Guasabacoa will be up to the range of 1.5 to 2.0 mg/L. The improvement may looks relatively small compared to the improvement of 2.0 to 2.5 mg/L caused by the implementation of the M/P. However, comparing to the present DO level in Atares which is below 1.0 mg/L and almost anaerobic condtion, the improvement to the range of 1.5 to 2.0 mg/L resulted from the implementation of the Priority Projects will be a significant step to achieve the long-term water quality goal of 3.0 mg/L especially in terms of the elimination of pollution load discharging into Atares.

(2) Financial and Economic Evaluation

Table 5 shows the financial and economic indicators of the Priority Projects which were analyzed at the different exchange rates.

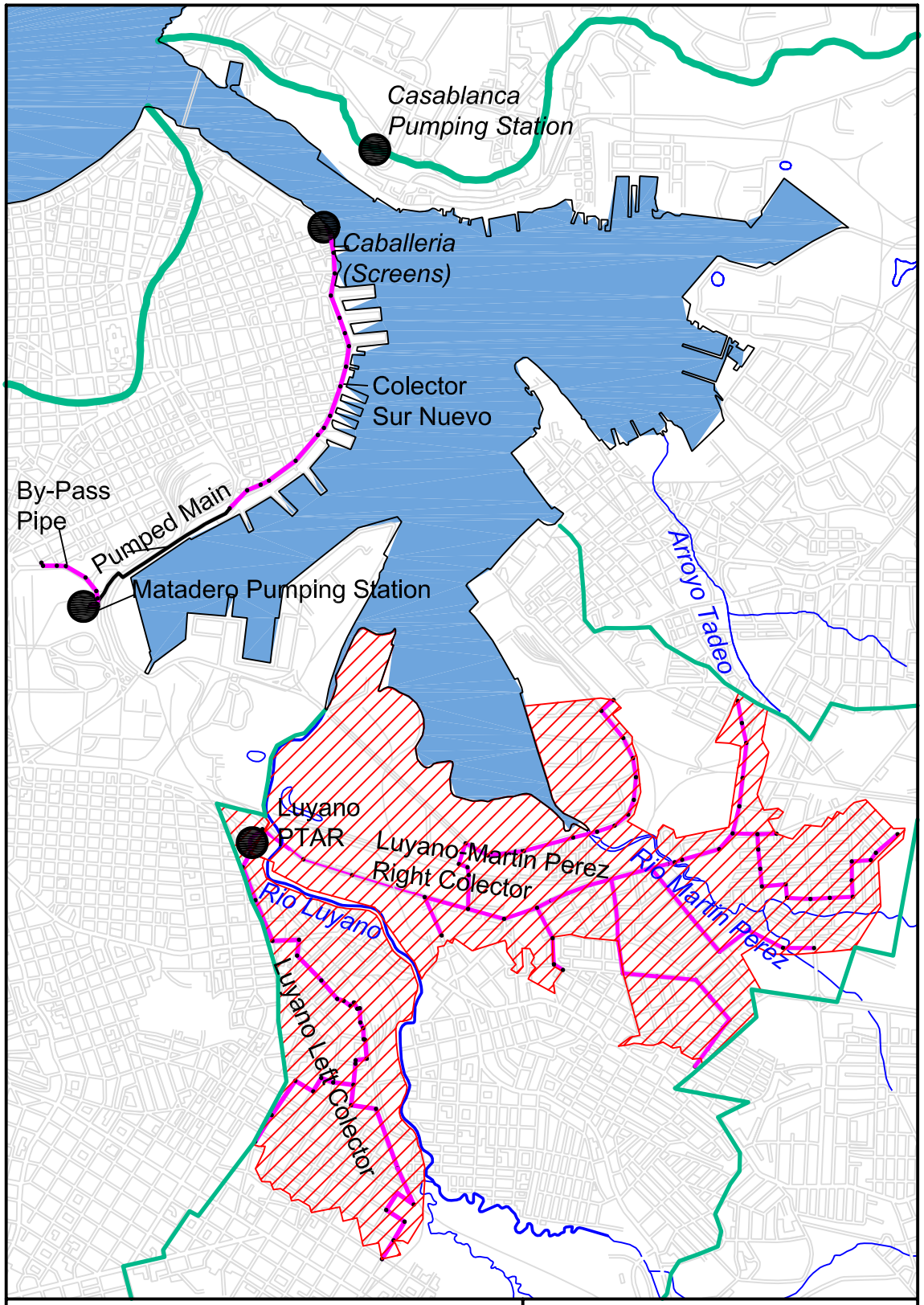
Table 5 Financial and Economic Indicators for Priority Projects

Indicator	US$ + Peso(1US$=1Ps)	US$ + Peso(1US$=26Ps)	Remarks
Financial Analysis			Discount rate
FIRR	28.1%	7.3%	US$ 6%
B/C	3.6	1.1	Pesos 8%
NPV	(Ps) 172,020	(Ps) 87,185	
Economic Analysis			Discount rate
EIRR	55.3%	13.4%	US$ 10%
B/C	7.1	1.3	Pesos 10%
NPV	(Ps) 292,477	(Ps) 226,272	

1) Financial Evaluation

The FIRRs, NPVs and B/Cs of the Priority Projects show high and positive values. These results indicate that the revenues from customers and the contribution from tourists will be large enough to pay for the construction and O/M costs of the project. Thus the Priority Projects are considered to be financially viable under the assumed conditions. However a financing source during the construction period which is preferably a soft loan should be sought. The FIRRs are sensitive both to construction cost and revenue. Under the conditions of a 20 percent increase in construction cost and a 20 percent decrease in revenue, the FIRRs are still maintained over 5 percent, which is considered to be robust.

The key assumptions for the financial analysis have been evaluated as follow:



THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 2 Priority Project Components
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Exchange rate: Under the uncertainties of the foreign exchange market, if, the financial situation is regarded the most favorable for the implementation agency of the Cuban side when the exchange rate of US$1:Ps1 is applied to the financial analysis. In other words the situation becomes the most unfavorable when the exchange rate of US$1:Ps26 is applied. We expect that the actual exchange rate will fall somewhere in-between the two situations.

Sewerage rate for domestic customers: Although a six-fold multiplication in seven years may seem unrealistic, it is justifiable. The current annual sewerage bill of Ps6 per person per year can be approximately converted to a Ps2 per household per month. Considering the Ps760 is the average monthly household income, the Ps2 accounts for merely 0.26 percent. Even after the six-fold increase, the sewerage bill of Ps12 will account for 1.58 percent of household income, which still stays around empirical ceilings. Incidentally a real increase of household income, that is likely to happen during the project period, is not considered.

Sewerage rate for state entities and institutional customers: The proposed sewerage rate turns out to be a five-hold multiplication in seven years. Compared with the tariff increase for domestic customers, which is six fold in seven years, this rise is still smaller.

Sewerage rate for hard currency (US$) earners: An 83 percent increase in seven years is small, compared with the tariff increase for domestic customers (500% increase) and that for state entities (400% increase).

Contribution from foreign tourists: Based on a survey conducted by the Study Team, the amount of US$2 per tourist can be applied to as contribution from foreign tourists to the sewerage projects. The US$2 is a 0.2 percent of the average tourist spending in Cuba, which is regarded inexpensive compared with most of entertainment costs paid by tourists.

2) Economic Evaluation

Both EIRRs estimated considering the US$ and Cuban Peso portions of the costs at the two different exchange rates are above 10 percent. The B/Cs and NPVs in these cases are also considerably high. This means that the project is economically sound and its implementation is justifiable. The sensitivity analysis of EIRR shows that under the conditions of a 20 percent increase in construction cost and a 20 percent decrease in revenue, the EIRRs are still maintained over 10 percent, which is considered to be robust.

The Priority Project also has various economic benefits that are difficult to be quantified. Some of those benefits are summarized in Table 6.

Table 6 Unquantifiable Economic Benefits

Item	Benefit
Reduction of diseases	Morbidities of water-born diseases and intestinal disease will decrease. Savings of medical costs are expected. Production sacrificed will decrease.
Replacement of old systems	Savings are expected by eliminating old septic tanks and cesspits that have shorter usable life and higher OM costs.
Increase of recreational and tour activities	A cleaner bay environment will bring more tourists and tour activities as well as recreational activities by inhabitants.
Increase of land values	Land values in sewerage service area and surrounding area of the bay will increase.
Protection of flora and fauna	Fish and other living things dependent on the bay will be saved.
Income from by-products	Sludge from WWTP can be used for agriculture and industrial production.
Improved quality of life	Esthetic value of the improved bay environment will enrich the quality of life of inhabitants.

(3) Environmental Impact Assessment (EIA)

The EIA carried out shows that the proposed Priority Projects are environmentally sound. However, localized impacts can be caused unless appropriate measures are taken to deal with the odor and sludge generated at the sewerage facilities. Other negative impacts are also expected to occur during construction. Therefore, it is recommended that the several prevention/mitigation measures proposed in the EIA should be carried out during the implementation of the Priority Projects.