ACP
AUTORIDAD DEL CANAL DE PANAMA

PRELIMINARY ENGINEERING STUDY
PRE-FEASIBILITY OF PANAMA CANAL ATLANTIC CROSSING

AUTORIDAD DEL CANAL DE PANAMÁ

DEPARTAMENTO DE INGENIERÍA Y PROYECTOS
DIVISIÓN DE INGENIERÍA
SECCIÓN DE INGENIERÍA CIVIL

JULY, 2004

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AUTORIDAD DEL CANAL DE PANAMA

ESTUDIOS PRELIMINARES DE INGENIERÍA PARA LA PRE-FACTIBILIDAD DE UN CRUCE SOBRE EL CANAL DE PANAMÁ EN EL LADO ATLÁNTICO

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ABBREVIATIONS AND ACRONYMS

ACP	Autoridad del Canal de Panamá / Panama Canal Authority
HHW	Highest high water.
MLW	Mean Low Water (Atlantic side)
MLWS	Mean Low water springs (Pacific side)
MOP	Ministerio de Obras Públicas / Public Works Ministry
MTC	Marine Traffic Control
n.m.	Nautical Miles
NPV	Net Present Value
P.I	Point of intersection
PLD	Precise Level Datum. Elevation reference system for the Panama Canal
VPD	Vehicles per day
VPH	Vehicles per hour

EXECUTIVE SUMMARY

Construction of new locks on the Atlantic side of the Panama Canal will interfere with the existing road network connecting the east and west sides of Colon Province. As a result, it will become imperative to include a crossing alternative that provides uninterrupted traffic during and after construction of the future Panama Canal Atlantic locks.

Different crossing alternatives were analyzed for the Panama Canal Atlantic Crossing. Table R-1 shows a list of the considered crossing alternatives and their associated costs. Initial construction costs and life cycle costs for a 25 year planning horizon are presented. Initial costs for the life cycle cost analysis also include project development costs which include design, contract management and contingencies.

	Alternative B-1 2 lane bridge	Alternative B-1 4 lane bridge	Alternative B-2 2 lane bridge	Alternative B-2 4 lane bridge	Alternative T-1 2 lane tunnel	Alternative F1-A Ferry System	Alternative F1-B Ferry System
Construction Cost ($)	142.92M	178.6M	152.8M	191.1M	244.7M	3.6M+8M (Terminal + Boats)	3.5M+8M (Terminal + Boats)
NPV ($)	155.2M	193.5M	164.3M	205.1M	274.1M	17.6M	17.6M

Table R-1. Crossing alternatives and Costs

Alternatives B-1 and B-2 involve crossing the canal with high level bridges. Both consist of cable-stayed bridges located to the north of the existing canal. Bridge vertical clearance is selected at 80m above mean low water to proved passage for ACP floating

equipment and future Post-Panamax vessels. Horizontal clearances are selected as required for dry construction of piers. Bridge alignments were selected based on the two probable alignments for the future Atlantic Locks. Both alternatives allow a crossing capacity of at least 700 vph per lane, assuming a traffic composition including 15% heavy vehicles and 12% buses.

Alternative B-1 provides a 500m horizontal clearance while spanning the existing and new navigation channels for future lock in alignment A2 under its main span.

Alternative B-2 provides a 550m horizontal clearance spanning the new navigation channel on alignment A1 under its main span, and 266 horizontal clearance spanning the existing channel under the west sidespan.

Two bridge widths are presented for each alignment, 2 lane and 4 lane. No projection of future traffic demand exists to date, therefore, both alternatives are left open for future reference when a complete traffic study is undertaken.

Only one tunnel alignment (T1) with two lanes of traffic was considered. Tunnel alternatives provide similar crossing capacities as bridge alternatives. The tunnel on this alignment has the shortest portal-to-portal length, passing below the future locks on alignment A2. Alignment A1 will require a longer tunnel, or with steeper grades. Cost analyses for alternative T-1 indicate that it is not the best alternative from an engineering and cost point of view, therefore, no additional effort was spent on tunnel alternatives for other lock alignments.

Ferry alternatives provide the lowest initial investment and the lowest life cycle cost. For actual traffic levels, a ferry service can provide an efficient transportation link between both sides of the canal. However, as population grows, a ferry crossing may have to grow proportionally to such an extent as to interfere with canal operations. As shipping traffic through the Panama Canal is also expected to increase in the future, a hard link crossing may prove to be a more viable alternative.

Future actions required as a result of this study include:

- Definition of the final crossing alternative based on the alignment of the future locks on the Atlantic side.

- Definition of the final crossing corridor, based on the alternative decided, and determination of right-of-way requirements.
- Development of a complete socioeconomic analysis of the area, including growth projections based on the different crossing modes. This will provide economic insight as to the most favorable crossing alternative, which up to this point has only been suggested on the basis of financial and engineering criteria.
- Determine future traffic projections for the area under study, taking into account the development of all modes of crossing, in order to permit final dimensioning of the selected crossing mode.
- Include the crossing costs as a part of the mitigation costs associated with construction of new locks on the Atlantic side. Even though this project is an infrastructure project, it should be regarded as a mitigation measure for negative effects caused by expansion of the Panama Canal.
- As soon as the final alignment and location of the future Atlantic locks is decided, Panamanian government authorities should be involved in the decision making process leading to the final crossing alternative, as it will become part of the national transportation network.

1 INTRODUCTION

The Panama Canal Authority (ACP) undertook a study to evaluate the pre feasibility of the construction of a new crossing over the Atlantic side of the Canal. This study is part of the Master Plan for increasing the capacity of the Canal. It was devised as a measure to provide mitigation for the possible effects that the construction of new locks can have on the development of the western coast of Colon Province (also referred to as Costa Abajo de Colón).

This study is divided into several parts and becomes a multidisciplinary effort, carried forward by the ACP and a Contractor retained for specific areas of work. This report presents the results of the engineering evaluations of the Panama Canal Atlantic Crossing conducted to date. Environmental evaluations that are a part of this study will be conducted under contract.

1.1 PROJECT BACKGROUND

The only crossing over the Atlantic side of the Canal is located on the north end of Gatun Locks. It communicates the east coast of the Canal and the towns located at the western side of Colon Province. It also provides access to some reverted areas, including Fort Sherman and the potential tourist area of Fort San Lorenzo. There is no actual communication for vehicular traffic between the western coast of Colon and other parts of the country other than the eastern part of Colon province. Consequently, the only roadway access to this part of the country is by means of this crossing, making it a vital artery in the transportation network of the country. Figure 1 shows the general location of the existing crossing.

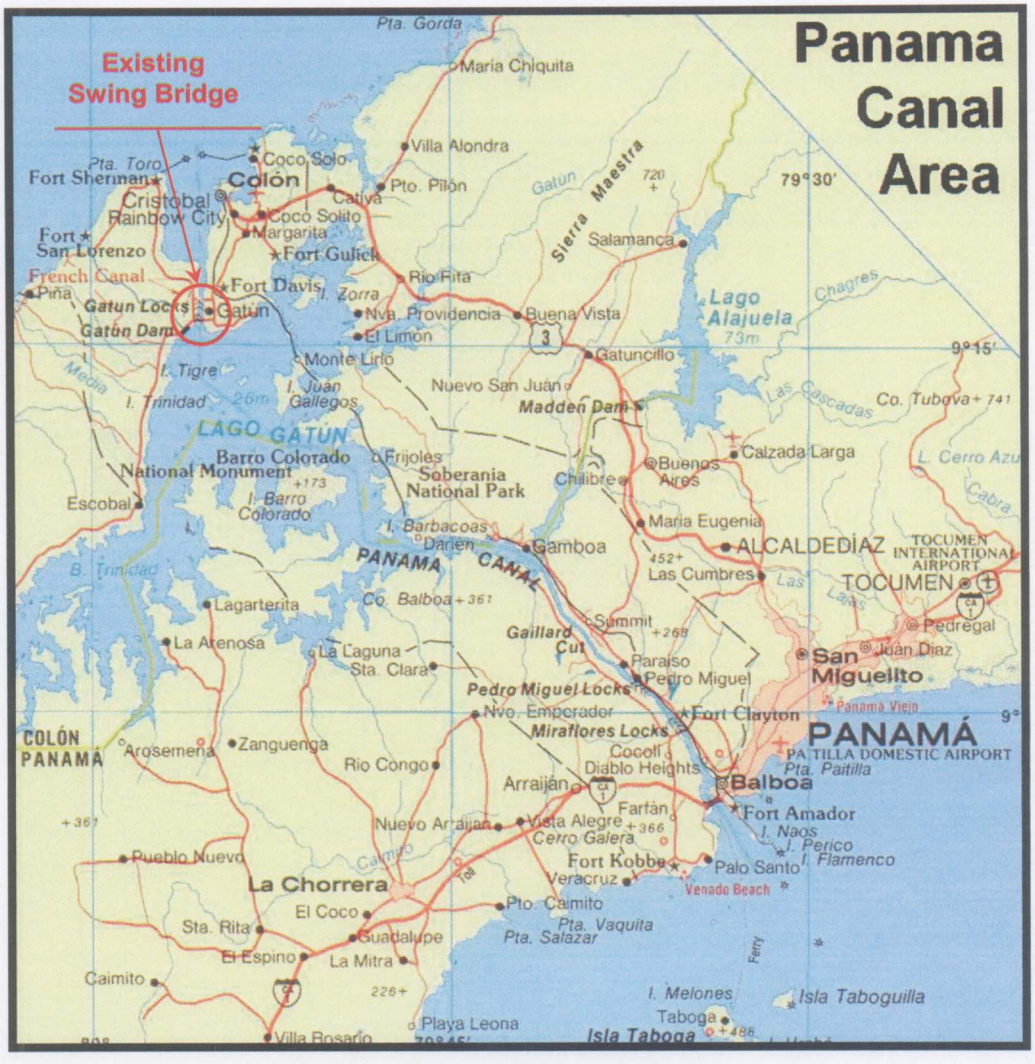


Figure 1. Regional location of existing crossing

The crossing consists of two low-level, one-way swing bridges spanning each lock chamber at the forebay of the locks. The bridges are limited in capacity to 20 tons and have sharp turning radii at the access and exits. The maximum vertical clearance in the crossing is 4.25m. These characteristics make the crossing unsuitable for some kinds of traffic and very limited in traffic capacity. Figure 2 shows the layout of the existing crossing.

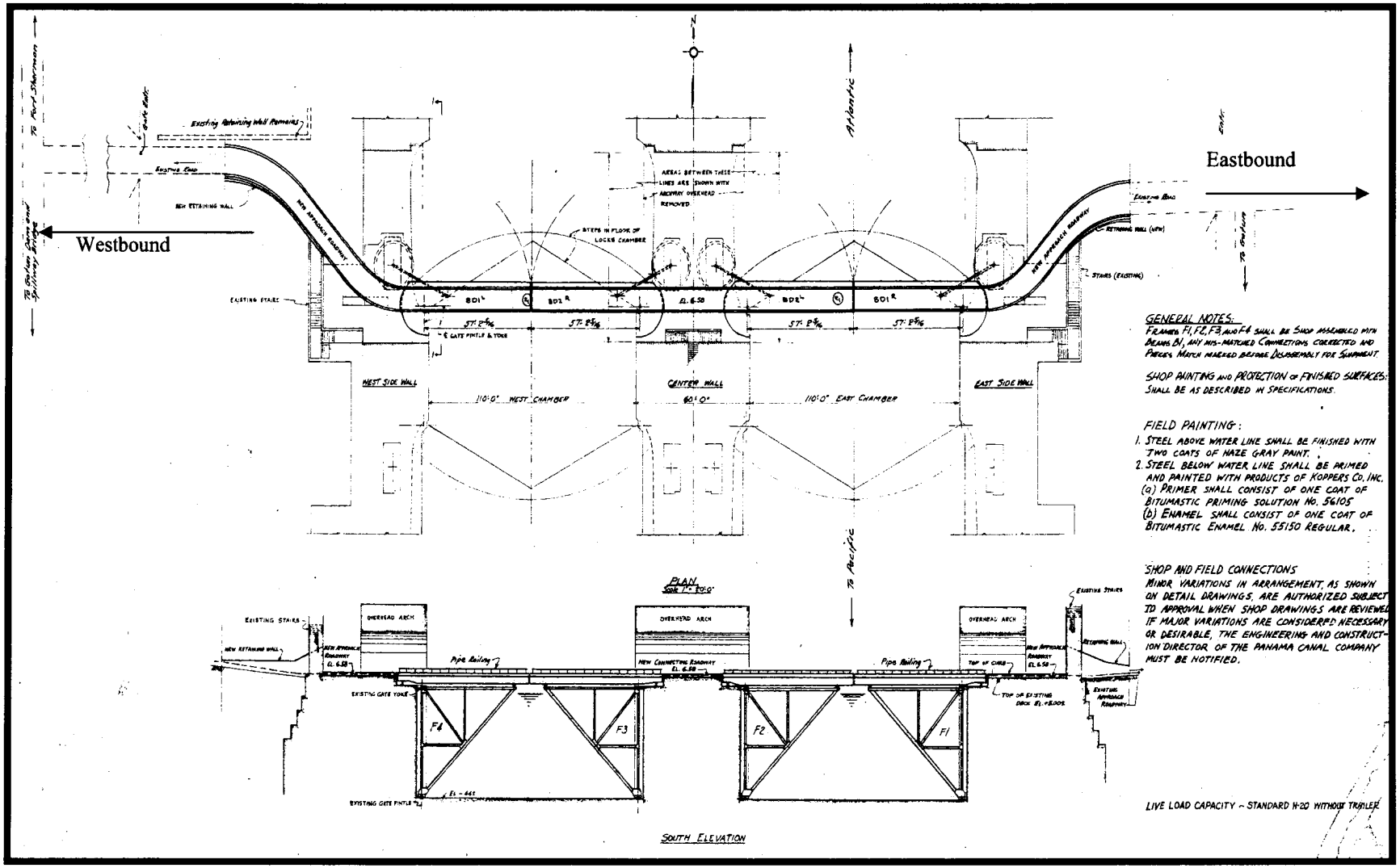


Figure 2. Existing crossing over Gatun Locks

Ship transit is given priority at the locks, therefore, the bridge has to remain closed during entrance and exit of locking ships. While the ships are in the chamber with the downstream gates closed, the bridge remains open to communicate the east and west coasts. Due to the increasing number of ship transits and the presence of larger ships, users of the bridge often have to wait in line at both sides of the bridge in order to go across. Moreover, regular bridge maintenance operations require closing the bridge for varying periods of time, which may be as long as 12 hours.

In 1993 a tri-party commission formed by Panama, Japan and the United States presented a final report on the alternatives to the Panama Canal. The commission recommended the construction of a two-lane bridge over the Atlantic side of the Panama Canal and replacement of the bridge on the Pacific side before the year 2020[1]. If the general conditions of the capacity increase project and its impact on the transportation segment are not very different from the ones used in this study, it is acceptable to conclude that a new crossing will be required in the event of increasing the capacity of the Canal in the near future.

As part of its Master Plan, the Panama Canal Authority is evaluating the construction of a new set of high-draft locks on the Atlantic side, located to the east of the existing locks. The exact alignment and footprint of these locks is still being decided. However, it is a known that the construction of these new locks will affect vehicular traffic between the east and west coasts of the Canal. The ACP is analyzing crossing alternatives as a mitigation measure for the negative impacts that the construction may have on regional development and user perception. The goal is to provide a means of crossing that will permit vehicular traffic to move between both sides at equal or better conditions than currently exist.

1.2 PROJECT PURPOSE AND STUDY OBJECTIVES

The purpose of the Panama Canal Atlantic Crossing is to provide efficient surface transportation between the east and west coasts of the Panama Canal. Improved road

[1] Final Report of the Commission for the Study of Alternatives to the Panama Canal, Volumes I, IV & VIII. Yachiyo Engineering Co., LTD. 1993

transportation between the two coasts will be required as a solution for the vehicular traffic interruption created by the construction of new locks. The project shall be regarded as a mitigation measure for the impact of the construction of new locks, as opposed to the development of a new crossing based on required growth of the transportation network, or solution to existing crossing capacity deficiencies.
The objectives of the study are two-fold:

- To evaluate different crossing alternatives and select the most promising for a future feasibility analysis, which shall be an integral part of the feasibility analysis of new Atlantic locks.
- To determine the impacts that each alternative may have on the social and natural environment, and provide mitigation measures for these impacts. This part of the study is pending award of a contract.

This report presents the primary findings of the assessment of the 7 build alternatives and a no-build alternative.

1.3 PROJECT JUSTIFICATION

From the aforementioned information, the need for the project may be justified. The justification is based primarily on the Canal expansion, but other considerations shall be mentioned:

- Assuming that the Panama Canal Expansion program calls for the construction of new locks on the Atlantic side of the Canal, the road network will have to be interrupted at Road 836. This is the only road leading to the existing bridge, and interconnecting the east and west sides of the Canal Atlantic entrance. Interruption of this road network will force the need for a new crossing to permit roadway access to the Western coast of Colon.
- Even though the capacity of the existing bridge is sufficient to carry the actual daily traffic loads, maintenance work and longer closure time due to ship traffic

limit the capacity of the bridge at certain hours of the day. Added to the fact that there are no alternate routes from any other part of the country, this limitation of the present bridge has constrained the development of the western coast of Colon. There is also a perception of lack of reliance on the crossing, which restrains the economies of scale of businesses that operate on this part of the country. On the other hand, the no build alternative for the new locks may produce a debate over the ACP's responsibility for future improvements or replacement of the crossing. This becomes a state affair, out of the scope of the present work.

2 DESCRIPTION OF ALTERNATIVES

7 build alternatives were selected for evaluation for the Panama Canal Atlantic Crossing study. All the routes were located adjacent to the existing Gatun Locks. The selection of alternatives was based on four principles:

- To obtain the shortest crossing
- To keep the users time of travel as close as possible to the existing.
- To avoid having to transit over highly populated areas to gain access to the crossing.
- To avoid construction on the Gatun Dam earth embankment.

The alternatives utilize different alignments and crossing modes. Alignment selection was based mainly on information from topographic maps, aerial photographs, and engineering judgment. Field inspections and walk-through of the routes were conducted for some of the alignments. Some alternatives were selected for study because they had been proposed in earlier evaluations.

Three crossing modes were evaluated: Two hard link modes consisting of high level bridges or tunnels, and a ferry system. Each mode was coupled with different alignments to produce the build alternatives.

An initial evaluation was performed on some of the alternatives in order to discard those that may not be worthy of additional evaluation. This screening process was based on engineering judgment. No elaborate analysis or calculations were performed on these initially discarded alternatives.

The description of all alternatives is shown in the Table 1. Figure 3 depicts the locations of the seven build alternatives selected for the Panama Canal Atlantic Crossing study. The figure shows a general location of the crossing and the roads required to integrate it to the existing transportation network.

To date, there is no definition of the final location of the future locks in the Atlantic side, therefore, two possible bridge alignments were provided in order to provide crossing alternatives for future lock alignments A1 and A2, as defined in the Panama Canal Master Plan. The bridge alternative over lock alignment A1 takes into account construction of a fourth lane of locks adjacent to the future third lane. It was considered that this construction will take place before the design life of the bridge is finished, so it will be desirable to dimension the bridge in such a way that supports have sufficient horizontal clearance to accommodate future navigation channel expansion.

The tunnel alignment with the shortest portal-to-portal distance was analyzed. Depending on the cost of this alignment, it will be decided if additional effort is required for analyzing other possible tunnel alternatives.

The ferry alternative uses existing facilities on the east side. These facilities will have to be demolished if the new locks are placed in the A1 Atlantic Locks alignment, which follows the 1939 excavation. If this is done, the east side terminal will have to be moved eastward, and its construction costs will be similar to the terminal on the west side. The costs of demolition of the existing facilities will not be added to the cost of the terminal. These will have to be included in the overall cost of the lock project.

Alternative	General location and alignment of principal structure or route	Features
No-Build	Existing	One-way swing bridges at north end of Gatun Locks
B-1	Main span located approx. 3.2 km north of existing crossing on west-east alignment. Proposed for lock alignment A-2	High level bridge over north approach channel to Gatun Locks. Proposed cable-stayed bridge with 80m vertical clearance and 500m main span.
B-2	Main span located approx. 2.0 km north of existing crossing on east-west alignment. Proposed for lock alignment A-1	High level bridge over north approach channel to Gatun Locks. Proposed cable-stayed bridge with 80m vertical clearance and 550m main span.
B-3	Main span located approx. 2.6 km south of existing crossing on west-east alignment	High level bridge over Gatun Lake south of Gatun Locks. Proposed 350m clear bridge with 80m vertical clearance on main span crossing navigation channel of new locks and 200m clear bridge with 67m vertical clearance on existing navigation channel.
T-1	Approx. 3.3 km north of existing crossing on west-east alignment	Subaqueous tunnel under approach channel to Gatun Locks. Proposed tunnel with a 2585m portal-to-portal length .
F-1	Approx. 2.9 km north of existing crossing	Ferry system from existing Mindi Dock on east side to west side near entrance to French Canal.
F-2	Approx. 8.0 km north of existing crossing	Ferry system from Pier 16 on Cristobal to west side near Fort Sherman.
F-3	Approx. 1.8 km south of existing crossing	Ferry system from Aguas Claras on east side to west side near Gatun Dam.

Table 1. Description of project alternatives

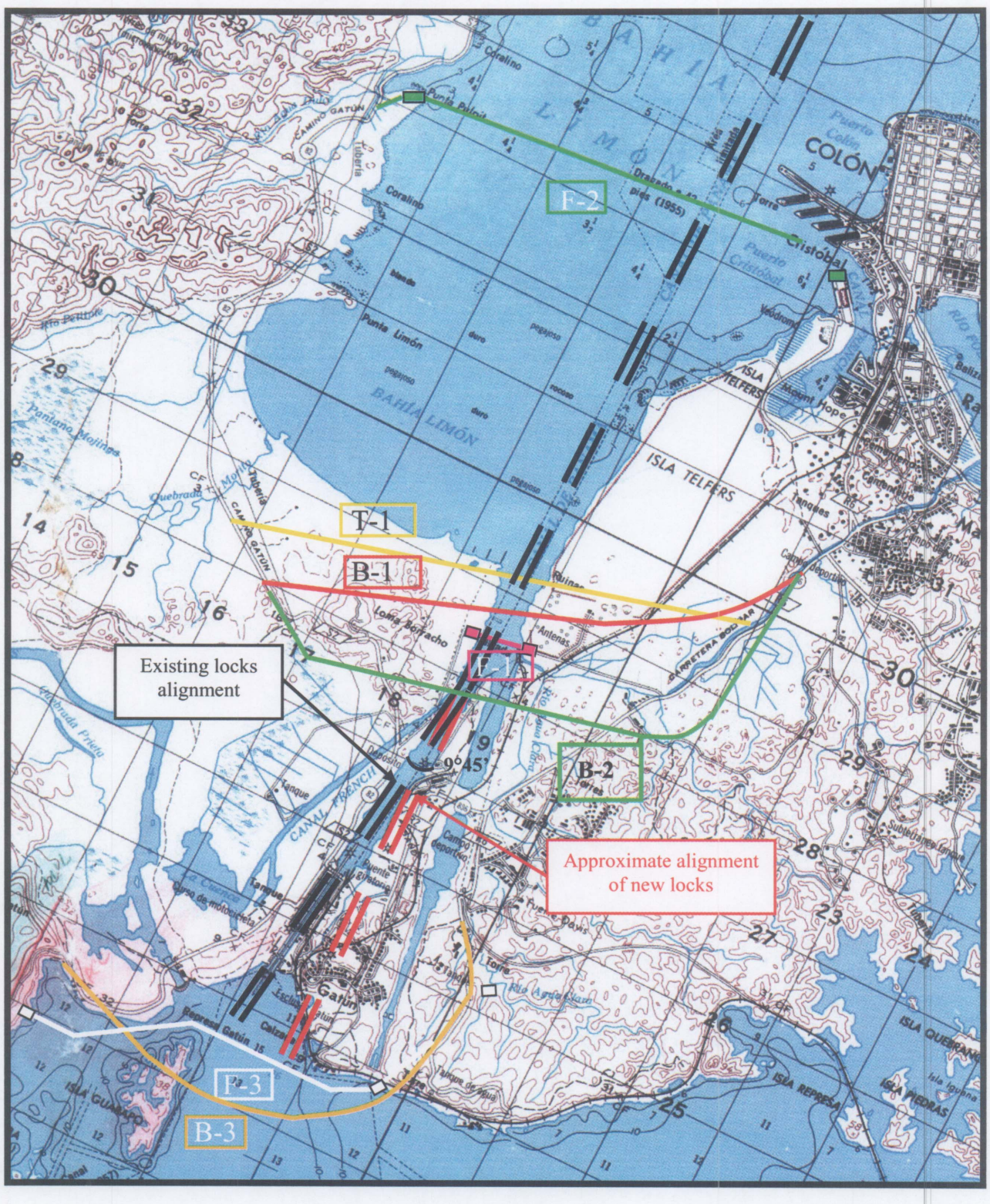


Figure 3. Panama Canal Atlantic Crossing alternatives

2.1 PRELIMINARY SCREENING OF ALTERNATIVES

An initial screening analysis of some of the alternatives was performed. This analysis was based on engineering judgment and focused on the alternatives with the longer water crossings. Alternatives B-3, F-2 and F-3 were discarded based on the following:

- Alternative B-3: This alternative crosses over Gatun Lake, south of the existing Gatun Locks. It requires a long bridge structure, with a main span permitting an 80m vertical clearance and at least 350m horizontal clearance on the navigation channel of the proposed new locks. It will be assumed that the floating crane "Titan" will navigate under this span when in route to the Atlantic Ocean or to the existing Gatun Locks. Therefore, the bridge over the navigation channel of the existing locks will require a vertical clearance of 67m (Bridge of the Americas) and a horizontal clearance of 200m. This alternative requires that most of the bridge structure be built over water, having to build supports "in the wet". Soundings indicate water depths in the order of 11m to 15m in the locations of required supports, making their construction more expensive than in dry land. Also, these supports will be located in the vicinity of the ship anchorage south of Gatun Locks. This area is highly congested with marine traffic and will require extensive measures to protect bridge supports against damage from ship collisions.

- Alternative F-2: This alternative was selected for study because it was previously mentioned as a possible route for a ferry crossing. It used the vacant infrastructure of Pier 16 as the east terminus, therefore, it was considered a viable alternative. It requires westbound traffic to be diverted to Cristobal using the already crowded roads that connect Colon City with the Trans-Isthmian highway. Otherwise, new roads could be built to connect Bolivar Highway with the East Terminal. The one-way water crossing distance from pier 16 to the possible west terminus is approximately 2.5 nautical miles. This alternative would require users

of the system to travel around 10km by road from the west terminus to the actual crossing point west of Gatun Locks. As most of the actual westbound traffic has destinations on the Western Coast of Colon, this alternative proves to be detrimental to the users and to the transportation system. It will require extensive work on existing roads or the construction of new access roads from Bolivar Highway to provide acceptable levels of service. The travel times will also be extended due to a longer water crossing and road portion.

- Alternative F-3: This alternative involves a ferry system with termini on Aguas Claras on the east side and a point on the west coast outside of the limits of the earth embankment of Gatun Dam. Aguas Claras was chosen as the terminal point on the east side because it has en existing road and won't require addition of long new road segments. It was assumed that construction of a ferry terminal on the earth embankment of Gatun Dam on the west side is not permitted. This alternative involves a one-way water crossing distance of approximately 2.6 nautical miles. A short road (about 300m) will be required on the west side to provide communication with Gatun Road. On the east side, the location of the ferry terminal will have interference with the Panama Railroad tracks. Railroad traffic is expected to grow considerably in the next years, therefore, this location may present logistic problems with the operation of the ferry. Also, the water crossing will take place in the area of the ship anchorage south of Gatun Locks. With the construction of new locks, ship congestion and traffic in this vicinity will increase and traffic will take place simultaneously in the approach channels to both locks. This will make ferry operations difficult, requiring very close coordination with canal operations.

The no-build alternative was also not carried forward as a part of this study, as it was decided that a new crossing will be required when construction of the new locks begin. Also, construction of a similar swing span over the new locks was not considered as it involved two consecutive waiting lines for users going across the Panama Canal. Due to

the discomfort that such a measure may cause on users, this alternative was not considered as part of the analysis.

3 ENGINEERING EVALUATION OF ALTERNATIVES

After the screening process for identifying viable alternatives, a more detailed evaluation of the remaining candidates was performed. This part of the work is summarized in the sections below. All the sketches referred to in this section of the study are located in Appendix A.

3.1 PRELIMINARY ENGINEERING AND GENERAL CRITERIA

The preliminary engineering studies for alternative evaluation involve refining the design information, including right of way requirements, alignments, clearances, earthworks, definition of structure and highway cross sections, terminal layouts, bridge types, tunnel types and others. This process is carried out in accordance to the specified design criteria for each alternative. All the geometrical information was developed based on large scale topographic maps of the Gatun area. Topographic information of the preliminary alignments for the bridge and tunnel alternatives was obtained in the field during the alternative definition process. This helped verify existing data and re-evaluate the proposed alignments.

The design criteria for this project will be divided in two groups: General criteria and technical criteria. General criteria include those parameters inherent to the particular conditions of the Panama Canal Atlantic Crossing. The most important include:

- Maintain travel time as close as possible to the existing conditions on the most traveled routes. This will involve locating the access and egress roads in close proximity to the existing most probable origins and destinations. The specific conditions of the project imply that all the alternatives will have direct

connections or connecting roadways to Gatun Road on the west and Bolivar Highway in the east.

- Minimize interference with Panama Canal operations and future expansion. Where possible avoid construction adjacent to the navigation channel of the Canal. To avoid interference with future expansion and excavations, the horizontal P.I that defines the approach channel to the existing and new Gatun locks in alignment A-2 shall be taken as a point of reference. All hard link alternatives will be located to the north of this intersection, except where bridges have the possibility of spanning both navigation channels. Clearances and navigational aspects will be defined latter in this document.
- Avoid construction on the earth embankment of Gatun Dam.
- Apply AASHTO standards[2] in the design of roadways and crossing structure. Specify general guidelines from MOP[3] for the construction of the project.
- Maintain a minimum Level of Service C on all fixed link highways. For two-way traffic on two lanes, and accounting for the heavy vehicle and bus traffic of the area, the minimum capacity of the crossing will be roughly 700 vph per lane.
- Base ferry design on existing literature on the subject and past experience with ferry crossings in the Panama Canal.
- Establish cost estimates based on quantity calculations and unit prices obtained from recent projects with similar characteristics and adjusted as required for this particular project, accounting for the preliminary nature of the work.
- Establish life cycle costs based on estimates of initial cost, operation and maintenance costs and future refurbishing costs.
- Base conceptual design of all structures on factors such as ease of construction, use of locally available materials, low first cost and low maintenance costs.
- Consider interference with actual Panama Canal Railway operations in the area, as well as their future expansion. New lock construction may require relocation

[2] Policy on Geometric Design of Highways and Streets. American Association of State Highway and Transportation Officials.
[3] Manual de Construcción de Carreteras y Puentes. Ministerio de Obras Públicas de Panamá.

of tracks and construction of new spur tracks. All track crossings shall be properly accounted for in the final design.

3.2 TECHNICAL DESIGN CRITERIA

This section covers the technical criteria used for development of the alternatives for the Panama Canal Atlantic Crossing. It is considered a preliminary set of criteria, to be changed as additional data is collected and a more in-depth feasibility analysis is performed. However, it is deemed sufficient in the evaluation of alternatives for a pre-feasibility analysis.

3.2.1 ROADWAY DESIGN CRITERIA

• Design year:	2030 (assuming construction ends in 2005)	
• Current average daily traffic:	1000 VPD	
• Minimum Level of Service	C	
• Design vehicle:	AASHTO WB-15 (WB-50)	
• Design speed:	80 Kph	
• Maximum allowable grade:	On roadway	8.0%
	On Bridge	4%
	On Tunnel	2%
• Maximum superelevation:	6%	
• Minimum radius:	300m	
• Number of lanes:	2 or 4	
• Widths:	Lanes:	3.65m
	Shoulders	1.85m
• Surface treatment:	Asphalt/concrete	
• Assumed embankment slopes:	See document	

3.2.2 BRIDGE DESIGN CRITERIA

- Loads and geometry: Per AASHTO Standard Specifications for Highway bridges.
- Earthquake loads: Should be based on site-specific conditions. For purpose of a preliminary feasibility study, values of A_v=0.20 and Aa=0.15 could be used.
- Vertical clearance: A minimum clearance of 80m from HHW will be used to allow transit of floating crane TITAN underneath the main span of bridge, in transit towards ACP facilities or the Atlantic anchorage. This clearance was deemed sufficient for future Post-Panamax traffic. Vertical clearance of 5.50m will be provided at all roadway crossings and 7.05m at railroad crossings.
- Horizontal clearance: The minimum horizontal clearance will be selected based on the possibility of in the-dry-pier construction.

3.2.3 FERRY DESIGN CRITERIA

• General design	Double-ended, open-deck
• Capacity:	10 trucks or buses and 40 cars
• One way crossing distance:	0.25 n.m. to 0.50 n.m. approx.
• General route:	Protected water navigation in the navigation channel north of Gatun Locks
• Operating profile:	Up to 48 one-way crossings per day per boat
• Endurance or autonomy:	Dependent on operator
• Terminal holding area size	One entire ferry load
• Terminal surge area size	One entire ferry load
• Terminal facilities	Passenger shelter Security guard shelter Office Public Rest Room Crew Parking

Adequate area lighting

3.2.4 TUNNEL DESIGN CRITERIA

- Cross Sectional Geometry: Standards for lane and shoulder width and vertical clearance for highways have been established by AASHTO. For truck highways, the vertical clearance shall be at least 16 feet (4.88m) over the entire width of roadway plus an allowance for resurfacing. For curved alignments with superelevations, clearances shall be increased to provide for overhang.
- Alignment: Alignment should be straight, if possible. If curves are required, the minimum radius is determined by stopping sight distances and acceptable superelevation in relation to design speed. Passing distances do not apply, since passing in tunnels is not permitted.
- Tunnel on highways: Tunnel should be designed for the speed governing on the approach highways according to local regulations. The minimum radius of curvature preferably should not be less than 460 meters.
- Curvature and superelevation: In accordance with "Policy on Geometric Design of Rural Highways" by AASHTO. Superelevations should not exceed 0.10 to 0.12 mt./mt.
- Grades: Upgrade in tunnels carrying heavy traffic are generally limited to 3.5% to reduce ventilation requirement. For long two-lane tunnels with two-way traffic, a maximum grade of 3% is desirable to maintain reasonable truck speed. For downgrade traffic, 4% or more is desirable. Grades between channel lines controlling navigation depth are at a minimum adequate for drainage to a low point, preferably not less than 1%. Lengths of vertical curves at grade changes are governed by design speed and stopping sight distance.

3.2.5 NAVIGATIONAL ISSUES PERTAINING TO ALL ALTERNATIVES

There is one important navigation channel in the vicinity of the proposed crossing locations. It encompasses shipping lanes and leads to the approach channels to both the existing Gatun Locks and future Atlantic side Locks. By virtue of being located across the main channel of the Panama Canal, navigation must be maintained at all stages of construction of the crossing.

The navigational channel north of Gatun locks is a sea-level channel formed by the excavation of the portion of land connecting Limon Bay with Gatun Locks. Water levels in the channel are controlled by the Atlantic Ocean tides, with a small tidal variation ranging from -0.38m PLD to +0.56m PLD. The mean sea level is +0.06m PLD. There is negligible influence from the waters upstream of the channel in the navigation conditions of the area. The regulation works of Gatun Lake consist of a spillway whose discharge flows on a different channel leading to the Caribbean Sea, flowing on the original bed of the Chagres River. Therefore, there is negligible impact of regulation water on navigation and currents.

Future expansion of the navigational channel due to the construction of new locks may require a prism approximately 270m wide. This expansion is expected to take place to the east of the existing sailing line, as the new lock will be located in that direction. The west bank of the channel is in very close proximity to the west prism line, constraining the ability of using water based construction equipment on this side. Future expansion of the channel to the east may present the same problems. It is safe to consider that all alternatives be developed assuming land based construction methods, with minimal interference to navigation operations.

Vertical and horizontal clearances will be based on the controlling clearances of existing canal crossings. References for clearances will be the Bridge of the Americas, the Second Bridge over the Panama Canal (Puente del Centenario) and the prism lines of the proposed Culebra Cut expansion. For the bridge and tunnel alternatives, additional consideration will be given to the fact that most of the construction of piers, portals and other important features be made in the dry. For the ferry alternative, it will be assumed that terminals will be located distant from the sailing line, protected from wakes of passing ships or in areas where navigation takes place at very reduced speeds.

Table 2 shows the different navigational aspects that influence the design of the different alternatives.

Reference	Maximum future Prism widths	Main span between CL piers	Vertical clearance	Observations
Bridge of the Americas	800' = 244m[4]	343.8m	67 m from MLWS	Through-truss steel arch bridge. Built 1962
Second Bridge over Panama Canal (Puente Centenario)	900' = 275m	420m[5]	80 m from HHW	Concrete cable stayed bridge. Exp. 2004
Proposed future Culebra Cut widening	260m	N/A	N/A	One-way Post-Panamax Traffic

Table 2. Reference parameters for navigational aspects

3.3 ENGINEERING COMPARISON

Following is a description of the different crossing alternatives selected at this stage of the study. All the alternatives were selected to the north of the existing Gatun Locks. Assumptions made during the process are documented for each alternative, in order to provide insight to the activities which require more in-depth analysis at further stages. All drawings and sketches are located in Appendix E.

[4] Balboa Bridge, General Plan and Elevation (Dwg. 3601-3011). Sverdrup & Parcel Engineering Co. 1959
[5] Segundo Puente sobre el Canal de Panamá, Vista General. Leonhardt, Andrä und Partner. 2002

3.3.1 ALTERNATIVE B-1. HIGH LEVEL BRIDGE OVER FUTURE LOCK ALIGNMENT A-2

The high-level bridge alternative proposed for the crossing involves the use of a cable-stayed bridge, located approximately 3.2 km north of the existing crossing at the knuckle of Gatun Locks. Due to the vertical clearance limitation required by the canal, a site was chosen which minimizes the length of the elevated approach roadways to the main bridge. This bridge location was chosen because of the existing topography on the west side of the canal. The east side of the canal in this area is relatively flat and low, which makes the use of elevated approach roadways unavoidable.

The bridge geometry is governed by the required horizontal and vertical navigational clearance in the Canal. The bridge lies on the west-east alignment.

The road bridge across the Canal has a total length of 3470 meters, of which 950 meters is a cable-stayed bridge. The west superstructure consists of seven typical three span continuous segmental concrete bridges of 210 meters. The east superstructure consists of five typical three span continuous segmental concrete bridges of 210 meters.

The cable-stayed bridge is the three span type and it has a main span of 500 meters flanked by two side spans of 225 meters. The cable system is of the modified fan configuration with two vertical cables plan along the edges of the bridge deck. Thus, a high efficiency of the cable support for both vertical and torsional loading is achieved. The pylons are of the portal type supporting the two vertical cable systems arranged in each side of the bridge deck.

Both, the west and east approaches are constructed on fill. The approach on the west side includes a 45 meters bridge over Gatun road and the approach on the east side includes a 45 meters bridge over Bolivar highway.

Two bridge layouts were developed for this alternative. One is a two-lane bridge, and the other, a four-lane bridge. The final layout shall be decided based on a capacity analysis that takes into account future demand on the transportation network. The general layout for two-lane bridge and four-lane bridge are shown on drawing SK-35-1. The superstructure and substructure will be made of concrete.

As mentioned before, the general design considerations used in developing the bridge layouts are as follows:

- Design speed: Design speed for urban arterials generally range from 65 Kph to 100 Kph. The lower speeds apply in the central business and higher speeds are more applicable to the outlying business and developing areas. For the bridge over the Atlantic side of the Panama Canal, a design speed of 80 Kph was chosen.
- Grades: The grades selected may have a significant effect on its operational characteristics. Steep grades affect truck speeds and overall capacity. However, maximum grade in itself is not a complete design control. It is necessary also to consider the length of particular grade in relation to desirable vehicle operation. The term "critical length of grade" is used to indicate the maximum length of a designated upgrade on which a loaded truck can operate without an unreasonable reduction in speed. Maximum grade of 4% is considered appropriate for a design speed of 100 Kph.
- Widths: The two-lane bridge consists of two 3.65 meters traffic lanes and have usable shoulders 1.85 meters wide in each side of pavement. The four-lane bridge consists of four 3.65 meters traffic lanes. Both, a two-lane bridge and a four-lane bridge have a 1.20 meter pedestrian walkway in each side. A capacity analysis shall be used to determine the proper number of lanes.
- Pavement crown: A 2 percent crown is constructed to provide cross-slope drainage for the pavement.

3.3.2 ALTERNATIVE B-2. HIGH LEVEL BRIDGE OVER FUTURE LOCK ALIGNMENT A-1

The high-level bridge alternative proposed for the crossing involves the use of a cable-stayed bridge, located approximately 2.0 km north of the existing crossing at the knuckle of Gatun Locks. Due to the vertical clearance limitation required by the canal, a site was chosen which minimizes the length of the elevated approach roadways to the main bridge. This bridge location was also chosen because it allows an optimal span arrangement distribution for a concrete cable stayed bridge. At the same time, it permits

spanning both navigation channels with only one principal bridge structure. The east side of the canal in this area is relatively flat and low, which makes the use of elevated approach roadways unavoidable.

The bridge geometry is governed by the required channel width leading to the future Atlantic Locks. The bridge lies on the west-east alignment.

The road bridge across the Canal has a total length of 3782 meters, of which 1202 meters is a cable-stayed bridge. The west superstructure consists of six typical three span continuous segmental concrete bridges of 215 meters. The east superstructure consists of six typical three span continuous segmental concrete bridges of 215 meters.

The cable-stayed bridge is the three span type and it has a main span of 550 meters flanked by two side spans of 266 meters, each with a 60 meter anchor span. The cable system is of the modified fan configuration with two vertical cables plan along the edges of the bridge deck. Thus, a high efficiency of the cable support for both vertical and torsional loading is achieved. The pylons are of the portal type supporting the two vertical cable systems arranged in each side of the bridge deck. The main span of the bridge is located across the navigation channel leading to the new Atlantic Locks. The existing navigation channel, leading to Gatun locks will be spanned by the west sidespan. The approach on the west side includes a 45 meters bridge over Gatun Road.

Two bridge layouts were developed for this alternative. One is a two-lane bridge, and the other, a four-lane bridge. The final layout shall be decided based on a capacity analysis that takes into account future demand on the transportation network. The general layout for two-lane bridge and four-lane bridge are shown on drawing SK-35-2. The superstructure and substructure will be made of concrete.

As mentioned before, the general design considerations used in developing the bridge layouts are as follows:

- Design speed: Design speed for urban arterials generally range from 65 Kph to 100 Kph. The lower speeds apply in the central business and higher speeds are more applicable to the outlying business and developing areas. For the bridge over the Atlantic side of the Panama Canal, a design speed of 80 Kph was chosen.

- Grades: The grades selected may have a significant effect on its operational characteristics. Steep grades affect truck speeds and overall capacity. However, maximum grade in itself is not a complete design control. It is necessary also to consider the length of particular grade in relation to desirable vehicle operation. The term "critical length of grade" is used to indicate the maximum length of a designated upgrade on which a loaded truck can operate without an unreasonable reduction in speed. Maximum grade of 4% is considered appropriate for a design speed of 100 Kph.
- Widths: The two-lane bridge consists of two 3.65 meters traffic lanes and have usable shoulders 1.85 meters wide in each side of pavement. The four-lane bridge consists of four 3.65 meters traffic lanes. Both, a two-lane bridge and a four-lane bridge have a 1.20 meter pedestrian walkway in each side. A capacity analysis shall be used to determine the proper number of lanes.
- Pavement crown: A 2 percent crown is constructed to provide cross-slope drainage for the pavement.

3.3.3 ALTERNATIVE T-1. TUNNEL UNDER NAVIGATION CHANNEL

The tunnel alternative proposed for the crossing involves the use of a two-lane tunnel, located approximately 3.3 km north of the existing crossing at the knuckle of Gatun Locks. Existing traffic conditions at the crossing do not justify the need for additional lanes at present time. As opposed to a bridge, tunnel capacity is easier to increase in the future by adding parallel tubes. In the case of bridge construction, it is generally not desirable to build parallel bridges, but instead to plan for the widest bridge that may be required to accommodate future traffic projections.

The proposed tunnel has a cylindrical cross section, with an internal diameter of 13.50m. The roadway features two 3.65m lanes with 1.85m shoulders on each side. There is one emergency walkway, and exhaust and supply air shafts on top and bottom. Vertical clearance to the ceiling is limited to 5.00m.

The tunnel lies on the west-east alignment. Total project length is estimated at 5140 meters. Portal-to-portal length of the tunnel is 2585m, of which nearly 400m are under water. On the east side, there is a 570 meter approach ramp and adjusting area, with retaining wall on both sides. On the west side there is a 260 meter approach ramp and adjusting area with retaining walls on both sides. The rest of the approach and connections with the existing roads on both sides will be provided by means of roadway segments. The approach on the west side includes a 45 meter bridge over Gatun road and the approach on the east side includes a 45 meter bridge over Bolivar highway.

At the lowest point, the top of the tunnel is 4.00m under the maximum proposed channel depth. This depth is kept constant under the navigation lanes to allow deepening the channel as required for 50 foot draft vessels. The general layout for the tunnel is shown on drawing SK-35-3.

Upgrades and downgrades on the tunnel sections were limited to 2% maximum, for maintaining adequate truck speeds on the upgrades. This is an important factor in two-lane bridges without passing lanes. Lower grades are also beneficial for ventilation purposes. Longitudinal grades were also kept over a minimum slope of 1%, in order to maintain adequate drainage.

No attempt was made to ascertain the construction method for the proposed tunnel, as no complete geological exploration exists. However, recent trends for subaqueous tunnel construction on soft soils indicate a preference for trench and sunken tube construction for the underwater part of the crossing. This kind of construction, in combination with traditional tunneling methods, has proven to be economical for short tunnel crossings. As opposed to TBM or other types of construction, close coordination with navigation should be established as most of the work takes place from floating equipment.

3.3.4 ALTERNATIVE F-1. FERRY SYSTEM NORTH OF GATUN LOCKS

Ferry systems are not new to the Panama Canal. Since the beginning of Canal operations, ferry systems were used to cross vehicular traffic and equipment across Canal

waters. The best known was the Thatcher Ferry, which crossed the Pacific entrance of the Canal. The only route had termini in La Boca on the east side, and near Farfan Road on the west side. It was put out of service in 1962, when the Thatcher Ferry Bridge (better known as the Bridge of the Americas) was opened. The two diesel powered boats were of open-deck, double-ended construction. See figure 4. Car capacity was in the order of 20 vehicles. In 1941, a conceptual study to cross the Canal with a tunnel showed a car count in the order of 850,000 cars per year[6]. Due to the limited capacity of the ferry system and the projected demographic growth on the west side of Panama City, the initiative to develop a new crossing led to the construction of the bridge.

Figure 4. Old Thatcher Ferry (Ferry Boat Porras) departing from La Boca Terminal

Preliminary car counts in the Gatun Bridge show an actual traffic volume in the order of 350,000 vehicles per year[7]. Using simple calculations, it is determined that the actual volume may be handled by a ferry system with one route and two relatively small boats. Peak hour traffic is in the order of 100 vehicles each way. Due to the actual traffic conditions and car counts, it is estimated that two 40 car/10 truck ferry boats can handle

[6] Vehicular traffic carried by Thatcher Ferry. Special Engineering Division, The Panama Canal Co. SK 1770-3 and SK 1770-4. 1941.

[7] Vehicular car counts carried out in the bridge access roads by the ACP Canal Protection Division. April 2 thru April 21, 2003.

current traffic. More information on the future growth of the area with the development of the crossing will be required for a better estimate of the required boat capacity, number of boats and their scheduling to better suit peak hour traffic.

Due to the short distance over water, one-way travel time will be in the order of 30 minutes. This time includes the loading and unloading times. This will allow a capacity of 4 one-way crossings per hour with two boats.

The ferry boats are assumed to be of the self propelled, open deck, double ended type, similar to the old Thatcher Ferry. These are the most suitable type for short small capacity, short crossings and navigation in protected waters. Being shallow draft vessels, they require less deep mooring facilities at the terminals. Because of the short crossing distance considered in this location, the double ended type of boat requires less maneuvering in order to attain the correct mooring position at the terminal and are easier to load and unload. The limited maneuvering consideration becomes important as ferry operations take place near the canal prism lines.

The preliminary selection of the terminal locations was carried out considering several factors, outlined in Table 3, along with their respective benefits. See sketch SK-36-4 for a general layout of the ferry crossing alternative.

Consideration	Benefits
Use of existing facilities in ACP possession	Initial cost, reduction of land acquisition, small increases in disturbance to the environment
Proximity to existing roads	Construction of shorter access roads, cost, reduced disturbance to the environment
Reduced crossing distance	Reduced crossing time, lower operating costs
Reduction of interference with canal operations	

Table 3. Ferry terminal selection considerations

Access roads for the new terminals were chosen as two-lane asphalt roads. As stated in the design criteria, the typical lane width for these roads is 3.65m, with 1.80m shoulders on each side of the road, yielding a 10.9m wide total roadway cross section. Side slopes of 1 : 1.5 were selected for the purposes of earthwork calculations. The cross section of the road consists of a 0.35m compacted base course and 0.10m thick asphalt pavement on the road lanes with asphalt primer on the shoulders. Because of the low levels of traffic expected for the ferry alternatives, regular intersections at grade were used for connections with existing roads. These intersections will be controlled by the use of traffic signs on the new access roads.

The east side terminal was located on the existing facilities of Mindi Dock, 1.6 miles north of the existing Gatun Locks. This dock was built the Panama Canal Company and served various purposes along its history. Originally it was used to unload coal that was then transported by rail to other locations in the Atlantic side of the Panama Canal Zone. It was latter refurbished with a truck loading platform for the same purposes. Because of this latter use, the structural capacity of the dock is adequate for the intended use of ferry terminal. Despite remaining basically unused for several years, a preliminary inspection shows that it is still in good condition. Slight modifications of the dock structure will be required in order to adequate it for Ferry terminal use. These modifications include demolition of a part of the raised superstructure, construction of a pontoon supported transfer bridge with a mechanical apron, construction of a system of dolphins for guide racks and moorings and construction of supporting facilities for personnel and users. Because the tidal variation at the Atlantic coast is small, a short transfer bridge is required. This bridge was chosen to be built with a steel plate girder structure hinged to the dock on one side and supported to the pontoon on the other. Draft variations during loading of the vessel will be controlled by means of the pontoon and a mechanical apron located at the end of the bridge. This apron will be lifted to allow departure and arrival of the vessels.

Supporting facilities that will be provided at each terminal location include a guard booth, office areas for the crew and public restrooms.

The existing road that connects Mindi Dock with Cristobal road consists of a two-lane dirt road, presently in good condition. This road will have to be leveled and provided with asphalt pavement and longitudinal drainage. There is a one-lane steel bridge that crosses a rainfall detention channel at the intersection with Cristobal Road. This bridge will have to be rebuilt in order to provide two lanes of traffic. Installation of railroad barriers will be required as access to Mindi Dock requires crossing the tracks of the Panama Canal Railway Co. See sketch SK-36-5 for a general layout of the proposed east side terminal.

Two configurations were analyzed for the west side terminal of alternative F-1. These were named alternatives F-1a and F-1b. See sketch SK-36-4. Both alternatives connect with Gatun Road on the west side of the Panama Canal.

Figure 5. Bird's eye view from Mindi Dock, looking west.

Alternative F-1a (see sketch SK-36-6) consists of an excavated basin located 2.7 kilometers north of the existing Gatun Locks. This basin is located practically parallel to the east side terminal and provides the shortest crossing. Construction of this terminal will require the excavation of the basin on the west coast of the canal, dredging to a depth that provides adequate draft for the chosen boat, construction of the pontoon supported transfer bridge with a mechanical apron and land side abutment, construction of a system of dolphins for guides racks and construction of supporting facilities for personnel and

users. For estimation purposes, the basin was chosen to be approximately 60m wide, 100m long, with 2:1 side slopes and dredged to –5.0m PLD.

Access to location of terminal F-1a (see sketch SK-36-7) will be provided by means of a 940m access road.

Alternative F-1b (see sketch SK-36-8) consists of a sheet pile formed quay wall located at the entrance to the old French Canal excavation, 2 kilometers north of the existing Gatun Locks. The berthing area for the Ferry will consist of a system of dolphins for guide racks on the water side and fenders located on the quay wall on the land side. The abutment for the pontoon supported transfer bridge with a mechanical apron will be built at the south end of the wall. After construction of the wall, the water side will be excavated and dredged to a depth that provides adequate draft for the chosen boat. For estimation purposes, the length of the wall along the berthing area was chosen as 100m, which provides enough berthing length for a 75m LOA vessel. Additional wall will be built to provide seat for the abutment and erosion control. The total height of the sheet piles was taken as 9.50m, assuming a total embedment equal to 1/3 of the exposed length. Dredging of a channel to –5.0mPLD will be required along the navigation channel of the ferry.

Access to location of terminal F-1b will be provided by means of a 600m access road, as shown on sketch SK-36-9.

It is worth mentioning that at present time, the Panama Canal Authority is developing a ferry crossing at the Atlantic side, north of Gatun Locks. This ferry crossing is located adjacent to the Davis launch landing, and will connect Jaowin Road on the east side with Gatun Road on the west side.. Due to space constraints and geologic conditions, the layout of the terminal differs from what is shown for the proposed Mindi ferry crossing. Is should be noted that this crossing will not be readily accessible after construction of a new set of Atlantic locks is undertaken, thus requiring relocation of the terminals. However, the operation of this ferry will provide good insight as to the operational characteristics of the vessels and service levels for the users.

3.4 COST CONSIDERATIONS

Preliminary cost calculations for the proposed build alternatives were obtained based on the developed conceptual designs. The costs obtained those associated with the development and construction of the project, and costs over the service life of the alternative.

3.4.1 CONSTRUCTION COST ESTIMATES

In the development of costs for each alternative, only the major items were quantified. Unit prices were obtained from available information for similar construction. Other items were added as lump sums. Preliminary cost estimates are found in Appendix A.

As there is great latitude in cost differences between projects, contingency factors were applied. The different contingency factors were decided based on the amount of site-specific information for each item of the work, and the degree of uncertainty that existed at the time of developing the conceptual designs. Items with higher uncertainty were assigned a larger contingency factor.

Tunnel costs for subaqueous construction present enormous variability, mainly in part by construction method, location, equipment availability, length of total tunnel construction, etc. For sunken tube and combined construction methods, prices range from $22,000 to $88,000 per lane meter of tunnel with a total length of about 2500m. Project in the upper bound costs involve significant difficulty due to existing constraints. For the Atlantic Crossing, a unit cost of $42,500.00 per lane meter was used, in order to reflect the difficulties involved in working in the navigation channel of the Panama Canal. Appendix B shows additional information regarding tunnel construction costs.

3.4.2 PROGRAM DEVELOPMENT COSTS AND TOTAL COSTS

Program development costs were applied as a percentage of the initial construction costs. They are added to the construction costs in order to represent the initial investment

required for the project, and are spread over the construction and implementation time of each alternative. The percentages used for development costs in this project were:

- Engineering 6.0%
- Contract Management 10%
- Overall Contingency 10%
- Mitigation Depending on EIS

Right of way costs, if applicable, should be taken as project development costs and added to the total, based on the specific requirements of each alternative.

A summary of all initial construction costs associated with the alternatives is shown in Table 4. The costs tabulated do not include boat acquisition costs for the ferry alternatives.

Ferry boat acquisition costs where estimated based on existing public information. Relationships of cost as a function vehicle capacity and ferry deck square footage were obtained in order to be able to provide a reasonable estimate of first cost of the ships. These relationships are shown in Appendix C. Based on the size of ship considered, acquisition costs are in the order of $4,000,000.00 for each boat. This value is considered acceptable, as the ship does not require a large number of amenities or accommodations as do the boats in the upper bound cost ranges, due in part to the short navigation time.

	Alternative B-1 2 lane bridge	Alternative B-1 4 lane bridge	Alternative B-2 2 lane bridge	Alternative B-2 4 lane bridge	Alternative T-1 2 lane tunnel	Alternative F1-A Ferry System	Alternative F1-B Ferry System
Construction Cost	$142,924,450.00	$178,596,850	$152,734,000.00	$191,071,750.00	$244,687,400	$3,554,003.44	$3,484,162.67
Design	$8,575,467.00	$10,715,811.00	$9,164,040.00	$11,464,305.00	$14,681,244.000	$213,240.206	$209,049.76
Contract Management	$14,292,445.00	$17,859,685.00	$15,273,400.00	$19,107,175.00	$24,468,740.000	$355,400.344	$348,416.27
Overall Contingency	$14,292,445.00	$17,859,685.00	$15,273,400.00	$19,107,175.00	$24,468,740.000	$355,400.344	$348,416.27
Right of Way							
TOTAL COST	**$180,084,808.00**	**$225,032,035.00**	**$192,444,840.00**	**$240,749,405.00**	**$308,306,123.00**	**$4,478,044.33**	**$4,390,044.97**

Table 4. Initial Cost of Crossing Alternative Infrastructure

3.4.3 LIFE CYCLE COSTS

Each alternative will incur in varying costs over its useful life. Included are costs associated with maintenance, refurbishment, rehabilitation and general operation of the alternative. These costs are divided in annual costs and periodic costs.

The source for these costs was taken from the available information for similar projects and reasonable assumptions based on the nature of each alternative. No attempt was made to derive specific costs for each alternative, as the designs used are on a conceptual stage.

In order to develop the life cycle costs and include them in the cash flow of the project, some assumptions were made regarding their distribution over time. These assumptions are:

- Construction and acquisition costs were lumped at the beginning of the project.
- Annual maintenance and operation costs are lumped at the end of each year, starting the year construction ends.
- Useful life of bridge and tunnel alternatives is 75 years, after which their value is zero.
- Useful life of ferry boats is 50 years, after which their value is zero. Major electrical and mechanical work will be required every 25 years.
- Ferry terminals require maintenance every 5 years.
- Pavements will have to be overlaid at 15 year intervals.
- Long term inflation is taken as 2%.
- Long term interest rate is taken as 6.2%.
- Straight-line depreciation is used to calculate the salvage value of the project.

The present value method was used to determine life cycle costs. Constant year 2005 dollar values were used in the cash flow to determine the net present worth value, using a project horizon of 25 years after construction ends. Table 5 presents the net present value of each of the crossing alternatives, using the parameters described above. As a reference, initial construction cost is given for each alternative.

	Alternative B-1 2 lane bridge	Alternative B-1 4 lane bridge	Alternative B-2 2 lane bridge	Alternative B-2 4 lane bridge	Alternative T-1 2 lane tunnel	Alternative F1-A Ferry System	Alternative F1-B Ferry System
Construction Cost ($)	142.92M	178.6M	152.8M	191.1M	244.7M	3.6M+8M (Terminal + Boats)	3.5M+8M (Terminal + Boats)
NPV ($)	155.2M	193.5M	164.3M	205.1M	274.1M	17.6M	17.6M

Table 5. Construction Cost and Net Present Value of Crossing Alternatives

Appendix D contains the life cycle costs analysis for each of the alternatives considered for the Atlantic Crossing.

3.5 CONCLUSIONS ON PRELIMINARY ENGINEERING AND COST

Preliminary engineering for selected alternatives for the Panama Canal Atlantic crossing was performed. Cost estimates for each of the alternatives were obtained in order to evaluate initial construction and project development costs, as well as information required for preliminary life cycle cost analyses.

From the information presented in the text, it can be concluded that:

- Ferry crossing alternatives require the lowest initial investment, and have the lowest life cycle cost when compared to "hard link" alternatives. However, they have limited capacity and may impair economic growth of the western part of Colon Province. There is a limit up to which additional ferries can be added to the route in order to maintain an adequate level of service. It is worth reminding that ferries will be operating in the navigation channels of the Panama Canal,

which are actually congested with shipping traffic. Future expansion of the Panama Canal will increase congestion, therefore limiting ferry activity. Therefore, hard link crossings may be a more viable alternative for heavily congested waterways.

- Bridge crossings have the lowest initial and life cycle costs for the hard link alternatives. The final location of the bridge will depend on the alignment chosen for the new Atlantic locks. The number of lanes required should be obtained from a complete traffic analysis in conjunction with a socioeconomic analysis that can project future traffic growth once a hard link crossing is established. Final layout of the bridge crossing should be decided once channel alignment and width are decided.
- Tunnel crossings are costlier to build and operate than bridge alternatives. They require continuous monitoring, as well as ancillary equipment not required for bridges. There is little experience in Panama with tunnel construction and maintenance. They do have more flexibility in case capacity increases are required, because of the possibility of building parallel tubes. However, the cost of building an initial and future tube is easily overridden by the initial cost of building one wider bridge.

4 ENVIRONMENTAL ANALYSIS OF ALTERNATIVES

4.1 SOCIAL ENVIRONMENT

4.2 NATURAL ENVIRONMENT

4.3 EFFECTS ON SOCIOECONOMIC ENVIRONMENT

4.4 EFFECTS ON HISTORIC AND CULTURAL RESOURCES

APPENDIX A: PRELIMINARY COST ESTIMATES

The following pages show a preliminary cost estimate for each of the alternatives considered for the Atlantic Crossing. Only major items were quantified, and only construction costs are reflected. Program Development costs are given in the main text.

PANAMA CANAL ATLANTIC CROSSING

Alternative F-1A
Ferry System

ITEM	UNIT	QUANTITY	UNIT COST	CONTINGENCY	TOTAL COST
EAST SIDE - MINDI TERMINAL					
Roadways					
Base course	m3	4905	$19.49	10.0%	$105,167.24
Primed Shoulders	m2	5400	$4.25	10.0%	$25,240.14
Asphalt pavement	ton	2737.5	$109.15	10.0%	$328,687.82
Terminal					
Demolition of existing structure	m2	145.08	$23.78	20.0%	$4,139.97
Refurbishing existing structure	Global	1	$16,528.93	20.0%	$19,834.71
Pontoon with guides	Global	1	$210,509.90	20.0%	$252,611.88
Dolphin slip (8 dolphins)	Global	1	$317,558.09	20.0%	$381,069.70
Transfer bridge	Global	1	$26,976.45	10.0%	$29,674.10
Apron with machinery	Global	1	$19,491.66	20.0%	$23,389.99
Bollards	Unit	2	$2,455.95	10.0%	$5,403.09
Guard Booth	m2	8	$233.90	10.0%	$2,058.32
Office	m2	20	$272.88	10.0%	$6,003.43
Restrooms (M/F)	m2	8	$545.77	10.0%	$4,802.74
Electrical Infrastructure	Global	1	$0.00		$0.00
Drainage Structures					
Replace existing bridge at Bolivar Road	ml	30	$10,447.53	10.0%	$344,768.44
TOTAL EAST SIDE TERMINAL - ALT F-1					$1,532,851.57

ITEM	UNIT	QUANTITY	UNIT COST	CONTINGENCY	TOTAL COST
WEST SIDE TERMINAL - ALT. F-1A					
Roadways					
Cut	m3	39020	$5.22	25.0%	$254,789.10
Fill	m3	35600	$5.36	25.0%	$238,702.64
Base course	m3	3073.8	$19.49	10.0%	$65,904.80
Primed Shoulders	m2	3384	$4.25	10.0%	$15,817.15
Asphalt pavement	ton	1715.5	$109.15	10.0%	$205,977.70
Terminal					
Initial clearing and grubbing	m2	9500	$3.20	10.0%	$33,404.80
Dry excavation (Nat. Soil @ 5.00PLD)	m3	39785	$5.22	20.0%	$249,392.95
Wet Excavation from land	m3	22457.5	$7.24	10.0%	$178,735.51
Dredging to El. -5.00 PLD	m3	2275	$13.57	20.0%	$37,035.71
Base course	m3	199.5	$19.49	10.0%	$4,277.44
Asphalt pavement	ton	166.25	$109.15	10.0%	$19,961.41
Pontoon with guides	Global	1	$210,509.90	20.0%	$252,611.88
Dolphin slip (8 dolphins)	Global	1	$317,558.09	20.0%	$381,069.70
Transfer bridge with abutment	Global	1	$33,759.55	10.0%	$37,135.51
Apron with machinery	Global	1	$19,491.66	20.0%	$23,389.99
Bollards	Unit	2	$2,455.95	10.0%	$5,403.09
Guard Booth	m2	8	$233.90	10.0%	$2,058.32
Office	m2	20	$272.88	10.0%	$6,003.43
Restrooms (M/F)	m2	8	$545.77	10.0%	$4,802.74
Electrical Infrastructure	Global	1	$0.00		$0.00
Drainage Structures					
Culverts	ea	1	$3,898.33	20.0%	$4,678.00
TOTAL WEST SIDE TERMINAL - ALT F-1A					$2,021,151.87

TOTAL COST ALTERNATIVE F-1A	**$3,554,003.44**

PANAMA CANAL ATLANTIC CROSSING

Alternative F-1B
Ferry System

ITEM	UNIT	QUANTITY	UNIT COST	CONTINGENCY	TOTAL COST
EAST SIDE - MINDI TERMINAL					
Roadways					
Base course	m3	4905	$19.49	10.0%	$105,167.24
Primed Shoulders	m2	5400	$4.25	10.0%	$25,240.14
Asphalt pavement	ton	2737.5	$109.15	10.0%	$328,687.82
Terminal					
Demolition of existing structure	m2	145.08	$23.78	20.0%	$4,139.97
Refurbishing existing structure	Global	1	$16,528.93	20.0%	$19,834.71
Pontoon with guides	Global	1	$210,509.90	20.0%	$252,611.88
Dolphin slip (8 dolphins)	Global	1	$317,558.09	20.0%	$381,069.70
Transfer bridge	Global	1	$26,976.45	10.0%	$29,674.10
Apron with machinery	Global	1	$19,491.66	20.0%	$23,389.99
Bollards	Unit	2	$2,455.95	10.0%	$5,403.09
Guard Booth	m2	8	$233.90	10.0%	$2,058.32
Office	m2	20	$272.88	10.0%	$6,003.43
Restrooms (M/F)	m2	8	$545.77	10.0%	$4,802.74
Electrical Infrastructure	Global	1	$0.00		$0.00
Drainage Structures					
Replace existing bridge at Bolivar Road	ml	30	$10,447.53	10.0%	$344,768.44
TOTAL EAST SIDE TERMINAL - ALT F-1					$1,532,851.57

ITEM	UNIT	QUANTITY	UNIT COST	CONTINGENCY	TOTAL COST
WEST SIDE TERMINAL - ALT. F-1B					
Roadways					
Cut	m3	5300	$5.22	25.0%	$34,607.44
Fill	m3	3410	$5.36	25.0%	$22,864.49
Base course	m3	1962	$19.49	5.0%	$40,154.76
Primed Shoulders	m2	2160	$4.25	5.0%	$9,637.14
Asphalt pavement	ton	1095	$109.15	5.0%	$125,498.99
Terminal					
Initial clearing and grubbing	m2	2800	$3.20	5.0%	$9,398.10
Dry excavation (Nat. Soil @ 5.00PLD)	m3	7488	$5.22	20.0%	$46,938.66
Dredging to El. -5.00 PLD (3.00 ave dredge)	m3	27000	$13.57	20.0%	$439,544.67
Steel Sheet Piles (Length aprox. 7.00m)	m2	1627.5	$233.90	10.0%	$418,739.28
Base course	m3	90	$19.49	5.0%	$1,841.96
Asphalt pavement	ton	750	$109.15	5.0%	$85,958.21
Pontoon with guides	Global	1	$210,509.90	20.0%	$252,611.88
Dolphin slip (4 dolphins)	Global	1	$317,558.09	20.0%	$381,069.70
Transfer bridge with abutment	Global	1	$33,759.55	10.0%	$37,135.51
Apron with machinery	Global	1	$19,491.66	20.0%	$23,389.99
Bollards	Unit	2	$2,455.95	5.0%	$5,157.49
Guard Booth	m2	8	$233.90	10.0%	$2,058.32
Office	m2	20	$272.88	10.0%	$6,003.43
Restrooms (M/F)	m2	8	$545.77	10.0%	$4,802.74
Electrical Infrastructure	Global	1	$0.00		$0.00
Drainage Structures					
Culverts	ea	1	$3,898.33		$3,898.33
TOTAL WEST SIDE TERMINAL - ALT F-1B					$1,951,311.10

TOTAL COST ALTERNATIVE F-1B	**$3,484,162.68**

PANAMA CANAL ATLANTIC CROSSING

Alternative B-1

Two (2) lane bridge

Summary of cost

Item	Unit	Total	Unit price(B./)	Total cost (B/.)
Cable stayed bridge	ml	950	60,000.00	57,000,000.00
West approach viaduct	ml	1470	30,000.00	44,100,000.00
East approach viaduct	ml	1050	25,000.00	26,250,000.00
Embankment material (west side)	m3	1041650	5.00	5,208,250.00
Embankment material (east side)	m3	919650	4.00	3,678,600.00
Bridge over Gatun road	ml	45	17,500.00	787,500.00
Bridge over Bolivar highway	ml	45	17,500.00	787,500.00
Hot asphalt concrete pavement (west)	metric ton	8900	55.00	489,500.00
Hot asphalt concrete pavement (east)	metric ton	7100	50.00	355,000.00
Hot asphalt on bridges	metric ton	14800	50.00	740,000.00
Base course (west side)	m3	16100	40.00	644,000.00
Base course (east side)	m3	12760	35.00	446,600.00
Realignment of existing channel	ml	1500	1,500.00	2,250,000.00
Box Culverts	ml	75	2,500.00	187,500.00
			Total	**$142,924,450.00**

PANAMA CANAL ATLANTIC CROSSING

Alternative B-1

Four (4) lane bridge

Summary of cost

Item	Unit	Total	Unit price(B./)	Total cost (B/.)
Cable stayed bridge	ml	950	75,000.00	71,250,000.00
West approach viaduct	ml	1470	37,500.00	55,125,000.00
East approach viaduct	ml	1050	31,000.00	32,550,000.00
Embankment material (west side)	m3	1272600	5.00	6,363,000.00
Embankment material (east side)	m3	1105100	4.00	4,420,400.00
Bridge over Gatun road	ml	45	22,000.00	990,000.00
Bridge over Bolivar highway	ml	45	22,000.00	990,000.00
Hot asphalt concrete pavement (west)	metric ton	17630	55.00	969,650.00
Hot asphalt concrete pavement (east)	metric ton	14200	50.00	710,000.00
Hot asphalt on bridges	metric ton	19700	50.00	985,000.00
Base course (west side)	m3	26520	40.00	1,060,800.00
Base course (east side)	m3	21300	35.00	745,500.00
Realignment of existing channel	ml	1500	1,500.00	2,250,000.00
Box Culverts	ml	75	2,500.00	187,500.00
			Total	**$178,596,850.00**

PANAMA CANAL ATLANTIC CROSSING

Alternative B-2

Two (2) lane bridge

Summary of cost

Item	Unit	Total	Unit price(B./)	Total cost (B/.)
Cable stayed bridge	ml	1082	64,500.00	69,789,000.00
West approach viaduct	ml	1350	30,000.00	40,500,000.00
East approach viaduct	ml	1350	25,000.00	33,750,000.00
Embankment material (west side)	m3	205000	5.00	1,025,000.00
Embankment material (east side)	m3	205000	4.00	820,000.00
Bridge over Gatun road	ml	45	17,500.00	787,500.00
Hot asphalt concrete pavement (west)	metric ton	8800	55.00	484,000.00
Hot asphalt concrete pavement (east)	metric ton	10600	50.00	530,000.00
Hot asphalt on bridges	metric ton	16200	50.00	810,000.00
Base course (west side)	m3	15900	40.00	636,000.00
Base course (east side)	m3	19000	35.00	665,000.00
Realignment of existing channel	ml	1500	1,500.00	2,250,000.00
Realignment of Gatun Road	ml	500	500.00	250,000.00
Realignment of Bolivar Highway	ml	500	500.00	250,000.00
Box Culverts	ml	75	2,500.00	187,500.00
			Total	**$152,734,000.00**

PANAMA CANAL ATLANTIC CROSSING

Alternative B-2

Four (4) lane bridge

Summary of cost

Item	Unit	Total	Unit price(B./)	Total cost (B/.)
Cable stayed bridge	ml	1082	80,625.00	87,236,250.00
West approach viaduct	ml	1350	37,500.00	50,625,000.00
East approach viaduct	ml	1350	31,000.00	41,850,000.00
Embankment material (west side)	m3	242000	5.00	1,210,000.00
Embankment material (east side)	m3	242000	4.00	968,000.00
Bridge over Gatun road	ml	45	22,000.00	990,000.00
Hot asphalt concrete pavement (west)	metric ton	17600	55.00	968,000.00
Hot asphalt concrete pavement (east)	metric ton	21100	50.00	1,055,000.00
Hot asphalt on bridges	metric ton	21400	50.00	1,070,000.00
Base course (west side)	m3	26400	40.00	1,056,000.00
Base course (east side)	m3	31600	35.00	1,106,000.00
Realignment of existing channel	ml	1500	1,500.00	2,250,000.00
Realignment of Gatun Road	ml	500	500.00	250,000.00
Realignment of Bolivar Highway	ml	500	500.00	250,000.00
Box Culverts	ml	75	2,500.00	187,500.00
			Total	**$191,071,750.00**

PANAMA CANAL ATLANTIC CROSSING

Alternative T-1

Two (2) lane tunnel

Summary of cost

Item	Unit	Total	Unit price(B./)	Total cost (B/.)
Tunnel	ml	2585	85,000.00	219,725,000.00
West concrete retaining wall	ml	520	4,000.00	2,080,000.00
East concrete retaining wall	ml	1140	4,000.00	4,560,000.00
Waste material (west side)	m3	117300	5.00	586,500.00
Waste material (east side)	m3	81600	4.00	326,400.00
Bridge over Gatun road	ml	45	17,500.00	787,500.00
Bridge over Bolivar highway	ml	45	17,500.00	787,500.00
Mechanically stabilized earth wall (west side)	m2	8200	400.00	3,280,000.00
Mechanically stabilized earth wall(east side)	m2	15600	350.00	5,460,000.00
Hot asphalt concrete pavement (west)	metric ton	8150	55.00	448,250.00
Hot asphalt concrete pavement (east)	metric ton	6100	50.00	305,000.00
Concrete pavement (west side)	m2	9350	150.00	1,402,500.00
Concrete pavement (east side)	m2	10175	150.00	1,526,250.00
Base course (west side)	m3	14750	40.00	590,000.00
Base course (east side)	m3	11000	35.00	385,000.00
Realignment of existing channel	ml	1500	1,500.00	2,250,000.00
Culverts	ml	75	2,500.00	187,500.00
			Total	**$244,687,400.00**

APPENDIX B: TUNNEL COST ESTIMATES

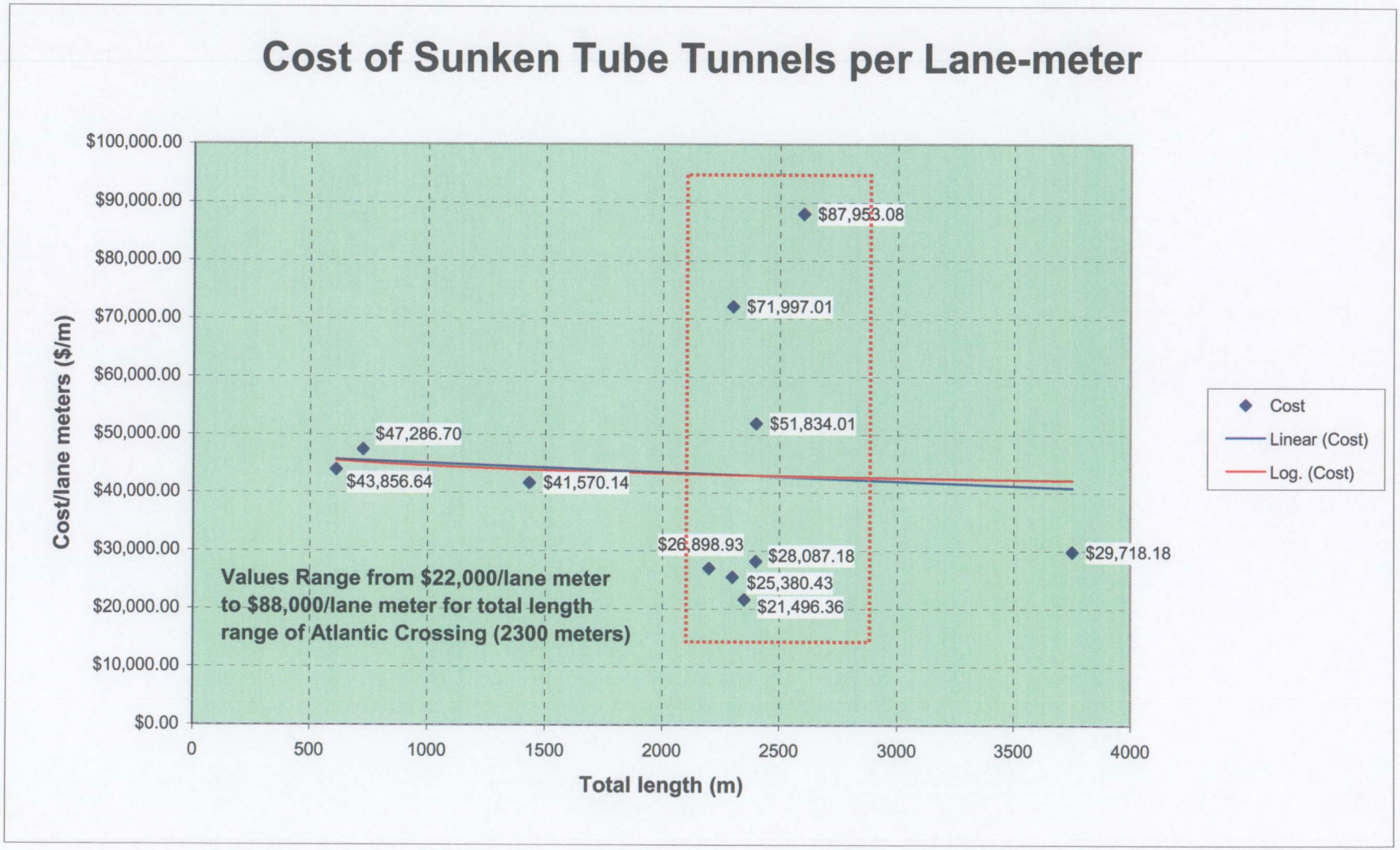
Information given in this appendix shows construction costs of different tunnel projects per meter of roadway lane. The table shows construction costs of tunnels, regardless of construction method. The plot only shows construction costs of tunnels built with sunken tube/combined construction methods.

This information was obtained from public sources.

TUNNEL CONSTRUCTION COSTS

Actual Year	2004	
Inflation Rate	1.5	%

Country	Name	Construction Method	Length (m)	Lanes (No.)	Lane length (m)	Year Built	Initial Cost ($)	Years in service	Inflated cost ($)	Cost/lane meter ($/m)
Panama	Clair Murdock Estimate Pacific Crossing	Combined - C/C, NATM, Sunken Tube	2300	6	13800	2000	$330,000,000.00	4	$350,249,971.71	$25,380.43
Netherlands	Westerschelde	TBM	6600	4	26400	1997	$912,000,000.00	7	$1,012,178,560.57	$38,340.10
USA	Holland Tunnel		2600	4	10400	1927	$48,000,000.00	77	$151,052,003.71	$14,524.23
USA - Boston	Ted Williams Tunnel	Sunken tube	2600	8	20800	1995	$1,600,000,000.00	9	$1,829,423,960.63	$87,953.08
USA - Maryland	Fort McHenry Tunnel	Sunken tube	2400	8	19200	1985	$750,000,000.00	19	$995,213,059.03	$51,834.01
USA - Maryland	Baltimore Harbor Tunnel	Sunken tube	2400	4	9600	1955	$130,000,000.00	49	$269,636,960.27	$28,087.18
Spain - Madrid	Metrosur	TBM	40850	2	81700	2000	$935,000,000.00	4	$992,374,919.83	$12,146.57
Norway	Laerdal Tunnel	Drill/blast - drilling jumbos	24500	2	49000	2000	$158,000,000.00	4	$167,695,441.00	$3,422.36
Australia	Sidney Harbour Tunnel	Sunken Tube / combined	2300	4	9200	1992	$554,000,000.00	12	$662,372,466.99	$71,997.01
U.K.	Medway Tunnel (2 tubos)	Sunken Tube	725	4	2900	1991	$113,000,000.00	13	$137,131,426.18	$47,286.70
U.K.	Hernandarias	Sunken Tube	2350	2	4700	1969	$60,000,000.00	35	$101,032,879.10	$21,496.36
U.K.	Kingsway Tunnel		2485	8	19880	1971		33	$0.00	$0.00
Netherlands	Tunnel Groene Hart	TBM	8620	2	17240	1999	$461,000,000.00	5	$496,627,925.79	$28,806.72
U.K.	Dartford Tunnel 1st	Shield	1435	2	2870	1963	$24,200,000.00	41	$44,557,734.17	$15,525.34
U.K.	Dartford Tunnel 2nd	Sunken Tube	1435	2	2870	1980	$83,460,000.00	24	$119,306,304.68	$41,570.14
Australia	Cross City Tunnel		2100	4	8400	2004	$680,000,000.00	0	$680,000,000.00	$80,952.38
Hong Kong	Eastern Harbour Tunnel	Sunken Tube	2200	6	13200	1989	$284,000,000.00	15	$355,065,906.93	$26,898.93
Ireland	Jack Lynch Tunnel	Sunken Tube	610	6	3660	1999	$149,000,000.00	5	$160,515,316.58	$43,856.64
Denmark	Oresund Tunnel	Sunken Tube	3750	6	22500	2000	$630,000,000.00	4	$668,659,036.89	$29,718.18

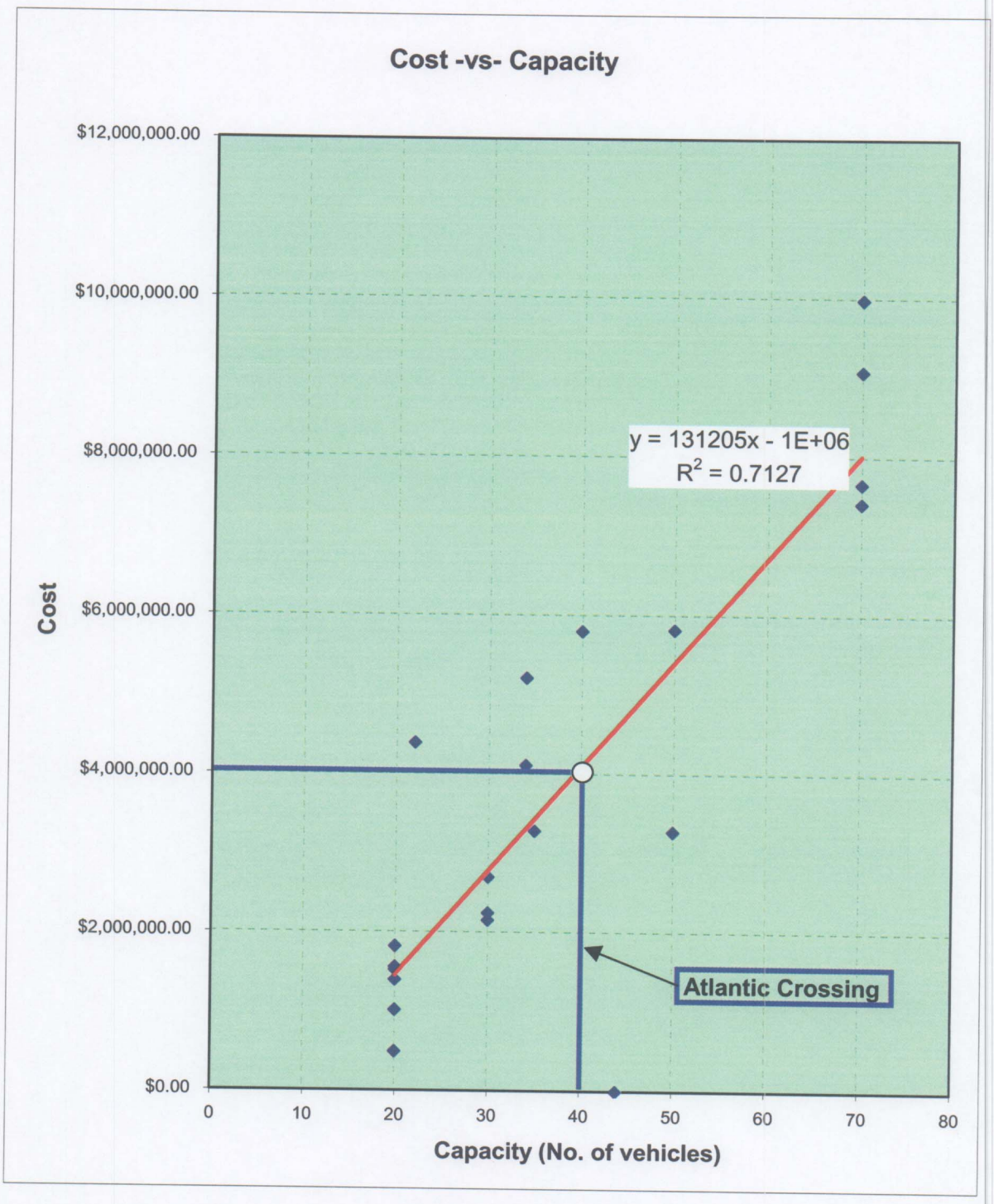

Cost of Sunken Tube Tunnels per Lane-meter
Cost/lane meters ($/m)
$100,000.00
$90,000.00
$80,000.00
$70,000.00
$60,000.00
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$0.00
0
500
1000
1500
2000
2500
3000
3500
4000
Total length (m)
$87,953.08
$71,997.01
$51,834.01
$47,286.70
$43,856.64
$41,570.14
$26,898.93
$28,087.18
$25,380.43
$21,496.36
$29,718.18
Values Range from $22,000/lane meter to $88,000/lane meter for total length range of Atlantic Crossing (2300 meters)
Cost
Linear (Cost)
Log. (Cost)

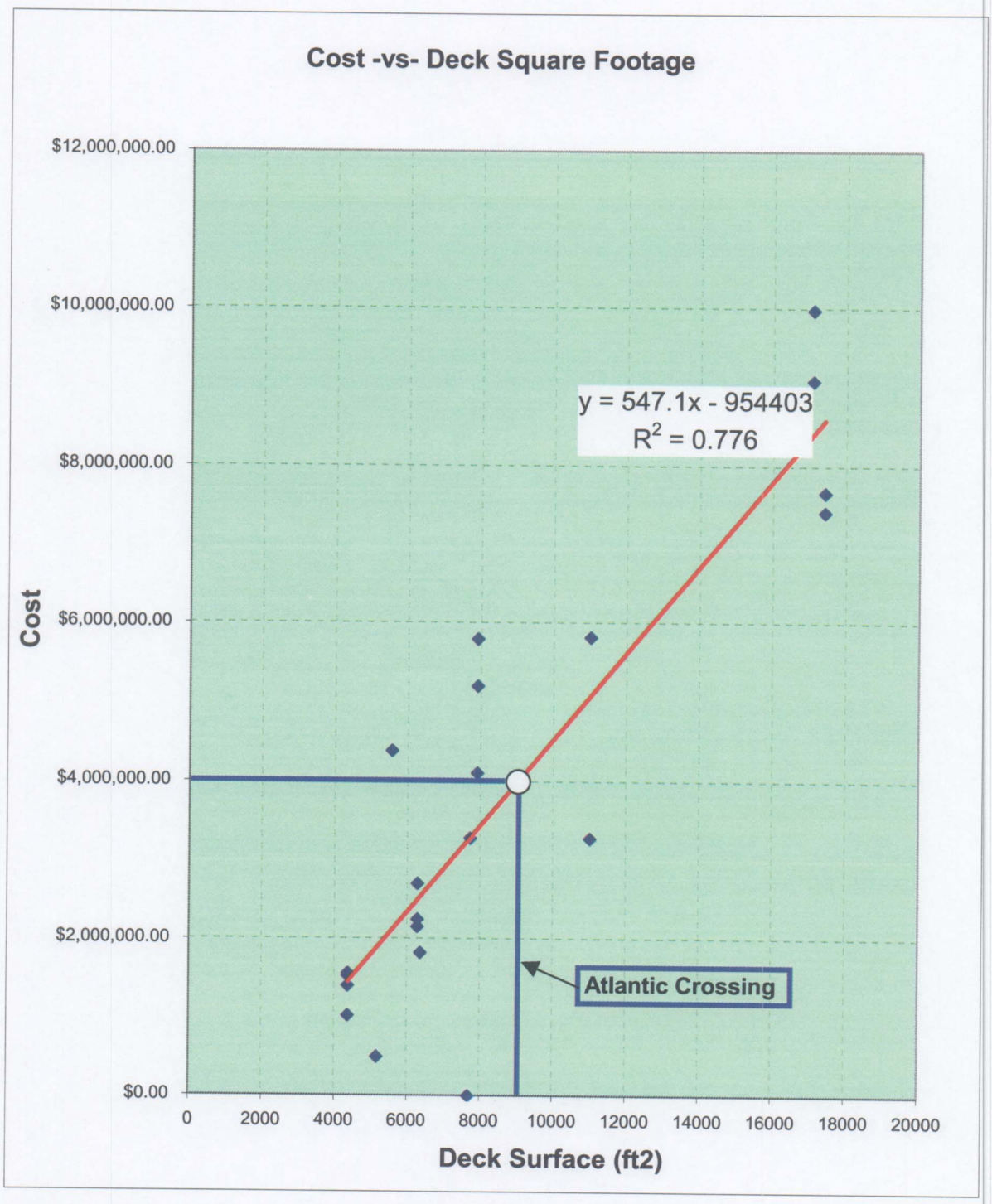
APPENDIX C: FERRY BOAT COST ESTIMATES

The plots shown in the following pages show the relationship of ferry boat acquisition costs as a function of two parameters:

- Vehicle capacity
- Deck square footage

This information was obtained from public sources.


Cost -vs- Capacity
$12,000,000.00
$10,000,000.00
$8,000,000.00
$6,000,000.00
$4,000,000.00
$2,000,000.00
$0.00
Cost
y = 131205x - 1E+06
R2 = 0.7127
Atlantic Crossing
0
10
20
30
40
50
60
70
80
Capacity (No. of vehicles)


Cost -vs- Deck Square Footage
$12,000,000.00
$10,000,000.00
$8,000,000.00
$6,000,000.00
$4,000,000.00
$2,000,000.00
$0.00
Cost
y = 547.1x - 954403
R2 = 0.776
Atlantic Crossing
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Deck Surface (ft2)

APPENDIX D: LIFE CYCLE COSTS OF CROSSING ALTERNATIVES

The following pages contain life cycle cost analyses for each of the crossing alternatives considered.

General considerations for these costs:

- Initial cost includes all project development costs, and for analysis purposes are lumped at the beginning of construction.
- Annual operation and maintenance costs include regular inspection costs, spread out annually within their recurrence intervals.
- Pavement overlay costs include a 25% increase factor. This accounts for partial removal of existing overlay and ancillary costs incurred for maintaining traffic while working in alternate lanes.
- Straight-line depreciation is used to calculate the salvage value of the alternatives. Salvage value is calculated for major construction items and overlays in all alternatives. Machinery salvage value is included in ferry alternatives.
- Only one life cycle cost analysis was performed for the ferry alternative F-1. As both possible alternatives (F-1a and F-1b) have similar construction, operation and maintenance and other costs, only the one providing the highest life cycle cost was used.

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			B-1 (2 lane)
Construction Begins (All alternatives)	2005		
Construction Ends			2008
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	3
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$180,084,808.00
Ferry Boat Acquisition			$0.00
Annual O & M costs			$150,000.00
Periodic costs			
Pavement Overlay			$925,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$0.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$0.00
Frequency of maintenance (in years)			12.5
Number of maintenances in useful life			1
IN			
Salvage Value			
Bridge and Roadways			$85,950,000.00
Structure construction cost			$128,925,000.00
Bridge useful life			75
Tunnels and Roadways			$0.00
Structure construction cost			$0.00
Tunnel useful life			75
Ferry Boats			$0.00
Ferry useful life (in years)			50
Overlays			$616,666.67
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS			
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$180,084,808.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$0.00
Annual O & M costs			$2,028,124.94
Periodic costs			
Pavement Overlay			$441,085.51
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH OUTFLOWS			$182,554,018.45
IN			
Salvage Value			
Bridge and Roadways			$27,161,249.82
Tunnels and Roadways			$0.00
Ferry Boats			$0.00
Overlays			$194,874.20
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$27,356,124.02
NET PRESENT VALUE OF ALTERNATIVE			($155,197,894.43)

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			B-1 (4 lane)
Construction Begins (All alternatives)	2005		
Construction Ends			2008
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	3
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$225,032,035.00
Ferry Boat Acquisition			$0.00
Annual O & M costs			$150,000.00
Periodic costs			
Pavement Overlay			$1,250,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$0.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$0.00
Frequency of maintenance (in years)			12.5
Number of maintenances in useful life			1
IN			
Salvage Value			
Bridge and Roadways			$107,270,000.00
Structure construction cost			$160,905,000.00
Bridge useful life			75
Tunnels and Roadways			$0.00
Structure construction cost			$0.00
Tunnel useful life			75
Ferry Boats			$0.00
Ferry useful life (in years)			50
Overlays			$833,333.33
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS

OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$225,032,035.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$0.00
Annual O & M costs			$2,028,124.94
Periodic costs			
Pavement Overlay			$596,061.50
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH OUTFLOWS			$227,656,221.44

IN			
Salvage Value			
Bridge and Roadways			$33,898,630.23
Tunnels and Roadways			$0.00
Ferry Boats			$0.00
Overlays			$263,343.51
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$34,161,973.74

NET PRESENT VALUE OF ALTERNATIVE	($193,494,247.70)

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			B-2 (2 lane)
Construction Begins (All alternatives)	2005		
Construction Ends			2008
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	3
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$192,444,840.00
Ferry Boat Acquisition			$0.00
Annual O & M costs			$150,000.00
Periodic costs			
Pavement Overlay			$1,000,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$0.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$0.00
Frequency of maintenance (in years)			12.5
Number of maintenances in useful life			1
IN			
Salvage Value			
Bridge and Roadways			$96,551,000.00
Structure construction cost			$144,826,500.00
Bridge useful life			75
Tunnels and Roadways			$0.00
Structure construction cost			$0.00
Tunnel useful life			75
Ferry Boats			$0.00
Ferry useful life (in years)			50
Overlays			$666,666.67
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS

OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$192,444,840.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$0.00
Annual O & M costs			$2,028,124.94
Periodic costs			
Pavement Overlay			$476,849.20
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH OUTFLOWS			$194,949,814.14
IN			
Salvage Value			
Bridge and Roadways			$30,511,295.30
Tunnels and Roadways			$0.00
Ferry Boats			$0.00
Overlays			$210,674.81
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$30,721,970.11

NET PRESENT VALUE OF ALTERNATIVE	($164,227,844.02)

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			B-2 (4 lane)
Construction Begins (All alternatives)	2005		
Construction Ends			2008
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	3
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$240,749,405.00
Ferry Boat Acquisition			$0.00
Annual O & M costs			$150,000.00
Periodic costs			
Pavement Overlay			$1,400,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$0.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$0.00
Frequency of maintenance (in years)			12.5
Number of maintenances in useful life			1
IN			
Salvage Value			
Bridge and Roadways			$120,467,500.00
Structure construction cost			$180,701,250.00
Bridge useful life			75
Tunnels and Roadways			$0.00
Structure construction cost			$0.00
Tunnel useful life			75
Ferry Boats			$0.00
Ferry useful life (in years)			50
Overlays			$933,333.33
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS

OUT

Initial Construction Cost (Lumped at the beginning of construction)			$240,749,405.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$0.00
Annual O & M costs			$2,028,124.94
Periodic costs			
Pavement Overlay			$667,588.88
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH OUTFLOWS			$243,445,118.82

IN

Salvage Value			
Bridge and Roadways			$38,069,201.43
Tunnels and Roadways			$0.00
Ferry Boats			$0.00
Overlays			$294,944.73
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$38,364,146.16

NET PRESENT VALUE OF ALTERNATIVE	($205,080,972.66)

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			T-1
Construction Begins (All alternatives)	2005		
Construction Ends			2008
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	3
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$308,306,123.00
Ferry Boat Acquisition			$0.00
Annual O & M costs			$1,000,000.00
Periodic costs			
Pavement Overlay			$800,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$0.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$0.00
Frequency of maintenance (in years)			12.5
Number of maintenances in useful life			1
IN			
Salvage Value			
Bridge and Roadways			$1,050,000.00
Structure construction cost			$1,575,000.00
Bridge useful life			75
Tunnels and Roadways			$150,910,000.00
Structure construction cost			$226,365,000.00
Tunnel useful life			75
Ferry Boats			$0.00
Ferry useful life (in years)			50
Overlays			$533,333.33
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS

OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$308,306,123.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$0.00
Annual O & M costs			$13,520,832.91
Periodic costs			
Pavement Overlay			$381,479.36
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH OUTFLOWS			$322,208,435.28

IN			
Salvage Value			
Bridge and Roadways			$331,812.83
Tunnels and Roadways			$47,689,403.26
Ferry Boats			$0.00
Overlays			$168,539.85
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$48,189,755.93

NET PRESENT VALUE OF ALTERNATIVE	($274,018,679.34)

PANAMA CANAL ATLANTIC CROSSING

NET PRESENT VALUE ANALYSIS OF ALTERNATIVES

			CROSSING ALTERNATIVE
			F-1
Construction Begins (All alternatives)	2005		
Construction Ends			2007
Planning Horizon (after end of construction)	25	yrs	
Contruction period		yrs	2
Discount Rate	6.20	%	
Inflation Rate	2.00	%	
Effective Rate	4.20	%	

CASH FLOW IN YEAR	2005 CONSTANT $		
OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$4,500,000.00
Ferry Boat Acquisition			$8,000,000.00
Annual O & M costs			$500,000.00
Periodic costs			
Pavement Overlay			$250,000.00
Frequency of overlay (in years)			15
Number of overlays in useful life			1
Replace mechanical/electrical equipment			$25,000.00
Frequency of replacement (in years)			25
Number of replacements in useful life			0
Terminal Maintenance			$10,000.00
Frequency of maintenance (in years)			5
Number of maintenances in useful life			4
IN			
Salvage Value			
Bridge and Roadways			$2,370,000.00
Structure construction cost			$3,555,000.00
Bridge useful life			75
Tunnels and Roadways			$0.00
Structure construction cost			$0.00
Tunnel useful life			75
Ferry Boats			$4,000,000.00
Ferry useful life (in years)			50
Overlays			$166,666.67
Equipment replacement			$0.00
Terminal Maintenance			$0.00

LIFE CYCLE COSTS

OUT			
Initial Construction Cost (Lumped at the beginning of construction)			$4,500,000.00
Ferry Boat Acquisition (Lumped at the beginning of construction)			$8,000,000.00
Annual O & M costs			$7,044,353.95
Periodic costs			
Pavement Overlay			$124,219.22
Replace mechanical/electrical equipment			$0.00
Terminal Maintenance			$22,614.97
NET PRESENT VALUE OF CASH OUTFLOWS			$19,691,188.14

IN			
Salvage Value			
Bridge and Roadways			$780,404.80
Tunnels and Roadways			$0.00
Ferry Boats			$1,317,138.91
Overlays			$54,880.79
Equipment replacement			$0.00
Terminal Maintenance			$0.00
NET PRESENT VALUE OF CASH INFLOWS			$2,152,424.50

NET PRESENT VALUE OF ALTERNATIVE	($17,538,763.64)

APPENDIX E: DRAWINGS AND SKETCHES

SK-35-1	ALTERNATIVE B-1
	GENERAL LAYOUT
SK-35-2	ALTERNATIVE B-2
	GENERAL LAYOUT
SK-35-3	ALTERNATIVE T-1
	GENERAL LAYOUT
SK-35-4	ALTERNATIVE F-1
	GENERAL LAYOUT
SK-35-5	ALTERNATIVE F-1 (A & B)
	EAST SIDE TERMINAL
SK-35-6	ALTERNATIVE F-1A
	WEST SIDE TERMINAL F-1A
SK-35-7	ALTERNATIVE F-1A
	WEST SIDE ACCESS ROAD F-1A
SK-35-8	ALTERNATIVE F-1B
	WEST SIDE TERMINAL F-1B
SK-35-9	ALTERNATIVE F-1B
	WEST SIDE ACCESS ROAD F-1B