Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

Volume XX

**Comments and Observations
of the Member Governments on
"A Feasibility Report"
Submitted by SINBOL**

Official Edition

1993

Comments and Observations

of the Member Governments on

"A Feasibility Report"

Submitted by

SINBOL

October 15, 1993

Comisión de Estudio de las Alternativas al Canal de Panamá
Commission for the Study of Alternatives to the Panama Canal
パナマ運河代替案調査委員会

15 de octubre de 1993

Licenciado
Rubén Elías Rodríguez Avila
Gerente del Centro de
Información y Miembro del
Comité Coordinador
Comisión de Estudio de las
alternativas al Canal de Panamá
Ciudad

Estimado Licdo. Rodríguez:

En cumplimiento de lo acordado en la reunión de la Junta de Comisionados celebrada en la República de Panamá el 17 de septiembre de 1993, tengo a bien someter a usted, los comentarios del gobierno de la República de Panamá, al documento presentado por el Consorcio SINBOL denominado "Un Informe de factibilidad".

Según lo acordado, los comentarios de los tres países participantes, esto es; los Estados Unidos, Japón y Panamá, serán incorporados en la parte frontal del antes referido informe, para que en este orden se integre el volumen XX del Informe General del Estudio.

De usted muy atentamente,

Guillermo Elías Quijano Jr.
Comisionado de la República de Panamá

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Comisión de Estudio de las Alternativas al Canal de Panamá
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COMENTARIOS DE LA REPUBLICA DE PANAMA AL DOCUMENTO DENOMINADO "UN INFORME DE FACTIBILIDAD" PRESENTADO POR EL CONSORCIO SINBOL

El informe de factibilidad presentado por el Consorcio SINBOL, refleja la posición y/o criterio profesional del consultor, y sigue, a juicio del gobierno panameño, los lineamientos consignados en el Plan Detallado del Estudio (PDE) y los términos de Referencia (TDR) aprobados. Lo anterior fue también expresado por el coordinador del Estudio designado por SINBOL, y consta en las actas de la reunión de clausura de la Junta de Comisionados.

Debemos anotar, sin embargo, que las posiciones de la Secretaría Ejecutiva y SINBOL, con respecto a ciertos aspectos del Estudio, no siempre fueron coincidentes. Particularmente, en lo relativo a la metodología de la preselección de las alternativas y la apreciación de los resultados presentados por el contratista del componente de proyecciones de mercadería y tráfico, tales diferencias son más notorias. No obstante, se considera que estas diferencias de criterio, tomadas en su conjunto, no habrían variado el resultado de la preselección y menos aún, el resultado final del estudio de factibilidad.

Observamos también, que el informe de factibilidad no discute con la consideración que se merece, ni refleja en su grado de importancia, los costos de las últimas opciones, tanto de canal a

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nivel como de canal de esclusas. Estas últimas opciones optimizan y muestran las fases en que pueden ser construidas las alternativas seleccionadas. Ejemplo de lo anterior, es la opción de una sola vía por el Corte Gaillard, en la alternativa de esclusas de nivel alto, y; la opción de una sóla vía de acceso en el atlántico en la alternativa de canal a nivel. Si bien es cierto que por falta de tiempo, no se consideraron estas opciones dentro de los componentes económicos y financieros, no dejan de constituir posibilidades potenciales que mejoran sensiblemente la relación costo/beneficio y las posibilidades financieras.

Adicionalmente, el informe incluye en su parte preliminar un compendio (abstract), en el que se formulan criterios que no son compartidos por la Secretaría Ejecutiva, ya que se basan en presunciones que no tienen fundamento en los resultados sometidos por los contratistas de los componentes. Esta sección, al igual que el prefacio, no fueron sometidos a la consideración de la Secretaría dentro del borrador del informe final, por lo que no se tuvo la oportunidad de formular las observaciones oportunamente.

El gobierno de la República de Panamá, basado en los informes y conclusiones presentados por los contratistas de los componentes del Estudio y el informe de factibilidad del consultor general SINBOL, tiene el firme convencimiento de que cualquier alternativa de mejora al actual canal, debe estar basada en la alternativa de

un tercer juego de esclusas de nivel alto, con capacidad para barcos de hasta 150,000 toneladas de peso muerto. Esta alternativa, con los ajustes y detalles que sean requeridos, deberá ser emprendida con la anticipación que permita estar preparados para prestar servicio en el año 2,020, que es cuando el actual canal no estará en condiciones de satisfacer adecuadamente la demanda.

La República de Panamá debe también expresar su decidida disposición de trabajar en la implementación de una entidad que garantice el manejo eficiente y contínuo de la vía interoceánica, a partir del mediodía hora de Panamá, del 31 de diciembre de 1999. Asimismo, hace un llamado a nuestros históricos asociados, a la comunidad marítima internacional y en fin, a todos los hermanos países cuyas economías están vinculadas en cualquier grado al servicio que ofrece nuestro canal, a unirse a nuestro país, y brindar todo el apoyo que sea requerido, para enfrentar el reto económico y financiero que significa para esta pequeña nación, ejecutar mejoras de gran magnitud a la vía interoceánica, para beneficio del comercio marítimo mundial y lógicamente, teniendo en cuenta la justa compensación que debe recibir la República de Panamá por el hecho de su contribución extraordinaria al progreso y desarrollo económico mundial.

Guillermo Quijano Jr.
Comisionado de la República de Panamá

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TRANSLATION

October 15, 1993

Licenciado
Rubén Elías Rodríguez Avila
Information Center Manager
and Coordinating Committee Member
Comission for the Study of Alternatives
to the Panama Canal
City

Dear Mr. Rodríguez:

In compliance to which was agreed upon in the Commissioners Board Meeting held in Panama on September 17, 1993, enclosed please find the comments of the government of the Republic of Panama, regarding the Report submitted by SINBOL named "A Feasibility Report".

As agreed upon, the comments of the three participating countries, that is the United States of America, Japan and Panama would be incorporated on top of the SINBOL Feasibility Report, and in said order, Volume XX of the General Report should be integrated.

Yours very truly,

Guillermo Elías Quijano
Commissionner of the Republic of Panama

TRANSLATION

COMMENTS OF THE REPUBLIC OF PANAMA ON "A FEASIBILITY REPORT" SUBMITTED BY SINBOL

The feasibility report submitted by the SINBOL Consortium reflects the position and/or professional opinion of the consultant, and follows, in the eyes of the panamanian government, the guidelines set forth in the previously approved Detailed Plan of the Study (PDE) and the Terms of Reference. The above was also stated by the Study coordinator appointed by SINBOL and it has been included in the minutes of the closing meeting of the Board of Commissioners.

We must note, however, that the Secretariat and SINBOL, were not always in agreement concerning certain aspects of the Study. This is true especially as it pertains to the methodology of the pre-screening of alternatives and the appreciation of the results submitted by the contractor of the Commodity and Traffic Projection Study Component. Nevertheless, it is felt that these differences of opinion, taken as a whole, would not have changed the results of the prescreening and much less the final result of the feasibility study.

We note also that the Feasibility Report does not give due consideration, nor does it reflect the importance of the costs of the last options, both of the sea level canal and of the locks canal. These last options optimize and show the phases in which the selected alternatives can be constructed. An example is the option of a single lane through the Gaillard Cut, in the High-Rise lock canal alternative, and the option of a single access lane on the Atlantic in the sea level canal alternative. Even though it is true that due to the time limitation these two options were not taken into consideration within the economic and financial components, they are still

potential options which improve significantly the cost/benefit relationship and the financial possibilities.

In addition, the report includes in its preliminary section an abstract in which opinions are stated which are not shared by the Secretariat because they are based on assumptions which have no basis on the results submitted by the component contractors. This section, as well as the preface, were not submitted to the consideration of the Secretariat within the draft of the final report, therefore it was not possible to make observations at that time.

The Government of the Republic of Panama, based on the reports and conclusions submitted by the Study Component Contractors and the Feasibility Report submitted by SINBOL, is firmly convinced that any alternative to improve the existing canal must be based on the alternative of a third set of High-Rise Locks, with capacity of up to 150,000 DWT. This alternative, together with the adjustments and details that may be necessary, must be started with enough anticipation to be ready to operate by the year 2020, which is the date when the existing canal will no longer be adequate to satisfy the demand.

The Republic of Panama must also express its decided willingness to work in the implementation of an entity which guarantees the efficient and continuous functioning of the interoceanic waterway, as of noon, Panama time, 31 December 1999. In addition, it calls upon our historical partners, the international maritime community and all the sister countries whose economies are linked in any degree to the services rendered by our canal, to join our country and give all the support that may be required, to confront the economic and financial challenge

posed by the need to effect large scope improvements in the interoceanic canal, for the benefit of world maritime commerce and logically, taking into consideration the just retribution that must be received by the Republic of Panama by virtue of its extraordinary contribution to progress and global economic development.

Guillermo Quijano Jr.

Panama Commissioner

EMBAJADA DEL JAPON
EN PANAMA

15 de octubre de 1993

Lic. Rubén E. Rodríguez
Gerente
Centro de Información
Amador, Edif. No.1
Ciudad de Panamá

Estimado Lic. Rodríguez:

Me es grato dirigirme a usted para enviarle, adjunto a la presente, el texto de los comentarios del Gobierno del Japón sobre "A Feasibility Report", tal como se acordó en la 18a. reunión de Comisionados de la Comisión de Estudio de las Alternativas al Canal de Panamá.

Agradeciendo de antemano su amable atención a la presente, me despido de usted,

Atentamente,

T. Asawa

Takamitsu Asawa
Segundo Secretario

cc: Sr. Carlos Stagg
Sr. Vandoster L. Tabb, Primer Secretario,
Embajada de Estados Unidos de América

TRANSLATION

EMBASSY OF JAPAN
PANAMA

15 of october of 1993

Licenciado
Rubén Elías Rodríguez
Manager
Information Center
Amador, Bldg No.1
Panama City

Dear Mr. Rodríguez:

I am pleased to attach herewith the text of the comments of the Government of Japan regarding "A Feasibility Report", as agreed upon in the 18th meeting of the Board of Commissioners of the Commission for the study of alternatives to the Panama Canal.

Thanking you in advance for your kind attention, I remain,

Yours very truly,

Takamilsu Asawa
Second Secretary

cc: Mr. Carlos Stagg
Mr. Vandoster L. Tabb- First Secretary
Embassy of the United States of America

Comments on A Feasibility Report

A Feasibility Report was submitted to the Commission for the Study of Alternatives to the Panama Canal on September 15, 1993 by SINBOL. At the 18th Board Meeting on September 17, 1993, it was decided that the three countries could submit the comments on "A Feasibility Report" to the Information Center in Panama by October 15, 1993 and these comments, if any, would be attached in front of "A Feasibility Report" in the Vol. XX of the Final Report of the Commission.

After reviewing "A Feasibility Report" of The Study of Alternatives to the Panama Canal, the Government of Japan is of the firm view that it should be commended that "A Feasibility Report" is highly comprehensive and well organized in spite of time constraint imposed on SINBOL in the final stage. In particular, it should be noted that "A Feasibility Report" is the essence of the most current and complete study regarding transisthmian canals across Panama, which is this present Canal Alternatives Study during 1985-1993, by the Trinational Study Commission.

Comisión de Estudio de las Alternativas al Canal de Panamá
Commission for the Study of Alternatives to the Panama Canal
パナマ運河代替案調査委員会

October 13, 1993

Mr. Ruben Elias Rodriguez Avila
Executive Director
Panama Canal Information Center

Dear Mr. Rodriguez:

During the September 17 meeting of the Board of the Commission for the Study of Alternatives to the Panama Canal, we Commissioners agreed to provide, by October 15, comments on behalf of our governments regarding SINBOL's "A Feasibility Report." It was further agreed that these comments will be published as part of Volume XX of the Study, with and on top of the SINBOL text. Finally, it was agreed that "A Feasibility Report" would be "received" by the Commissioners, rather than "accepted."

I attach hereto my government's comments and some further observations of my own, both of which should be published to give perspective to "A Feasibility Report." Please note that the United States Government also requests that the text of the Joint Commissioners Statement, with which we began Volume I, also be attached along with these comments and observations at the front of Volume XX.

Thank you for acting as recipient of these comments and observations on behalf of all three Commissioners and their governments, and for ensuring that Volume XX of our Study is published and distributed in the proper, agreed-upon form.

Sincerely,

J. Michael Farrell
U.S. Commissioner
Commission for the Study of Alternatives to the Panama Canal

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Comments of the United States Government
on "A Feasibility Report" by SINBOL

The Government of the United States of America accepts as authoritative the results of the expert component contractors as contained in the Joint Commissioners Statement appended hereto. Specifically, we subscribe to the conclusion of this report that "the high rise lock alternative with a single lane portion in the Galliard Cut, operating in conjunction with the present Panama Canal and capable of handling ships of a design of 150,000 DWT (deadweight tons) would be the most effective enhancement." Such an enhancement would provide all the services which a user country legitimately could ask of Panama, at the most reasonable cost. Increases in demand would merely increase a lock's utility.

We also accept as authoritative the finding reflected in the Joint Commissioners Statement that "the one lane sea level canal, operating in conjunction with the present Panama Canal...would not be feasible to consider as a viable enhancement to the Panama Canal." We accept this statement not only because of the excessive cost of constructing such a facility (which is less efficient than additional new locks, rendering a sea level canal unnecessary), but also because of the extensive and critical problems connected with any attempted construction of a sea level enhancement to the present canal.

We note that in the final version of "A Feasibility Report," found in this volume, SINBOL states in chapter 8 that because of environmental and other problems related to Route 10, a change in the proposed route might be appropriate. This suggestion fails to remind the reader that both this study and recent predecessors had identified Route 10 as the best route available for a sea level canal. We believe, based on the component contract research, that the previous version of that paragraph, in the penultimate version of "A Feasability Report," was correct when it candidly and simply confessed that a sea level canal was "infeasible on an ecological basis." In this and other changes, most notably in the insertion of nonstandard and unproven methodologies, in less than accurate characterization of work by component contractors, and in the use of unsubstantiated assumptions and speculation straining to make a sea level canal look less infeasible, the final draft of SINBOL's "A Feasibility Report" decreased in quality as it departed from the component contractors' results. We thus recognize as appropriate the Panamanian, Japanese and U.S. Commissioners' decision merely to "receive" rather than to "accept" "A Feasibility Report."

The United States Government firmly believes that any further consideration of an enhancement to the Panama Canal should relate exclusively to a new set of locks. We believe that the United States and Panama, working together, will resolve issues related to the best form of canal management entity in time to ensure the smooth and uneventful transfer of the Canal to full Panamanian operation by the end of 1999. We accept the high rise lock as the best expansion project, and we are willing to work with the GOP to keep that eventual expansion project in mind as the model for all future planning.

In addition, I have the following observations on why it is necessary to be very cautious in reading "A Feasibility Report:"

The SINBOL admission that billions of dollars in outright donations would have to be made in order for sufficient funds to be available for building a sea level canal was yet a further reason for canal users and user governments alike to discard any further consideration of a sea level canal.

The true costs of a sea level canal have not fully been established. The continued paucity of geologic information along the route of a sea level canal caused SINBOL to estimate that an adequate program of test hole drilling could cost $12 million. Without such a program to establish basic soil characteristics along the route, it would be impossible to make a fair estimate of to what extent the occurrence of landslides during construction would drive up the cost, as they did for the present canal. Without this added information on probable costs, the mention by SINBOL of "possible cost reduction measures" in recalculating the cost of a sea level canal is an empty and misleading promise.

SINBOL, moreover, fails adequately to reflect the issues which lead to a finding of ecological infeasibility for a sea level canal. For example, they fail to discuss the substantial negative impact of a sea level canal on the ground water supply of nearby areas along the canal route. They also do not take seriously enough the impact which the trans-Panama migration of marine biota would have on such things as fisheries, nor do they appropriately reflect that the impact of such migration is relevant beyond Panama's immediate seacoasts. Such issues cannot be avoided by simply suggesting to shift the canal route.

The SINBOL product is not the disinterested "Feasibility Report" which it should have been. Rather, it is an internally-negotiated document which still bears the imprint of at least one SINBOL member's predetermined but unsubstantiated views. The negative effects of that influence appear for example in chapter 5 of "A Feasibility Report," in the form of a non-standard prescreening methodology which was rejected by the Study. Although in that instance the professional engineering judgement provided by SINBOL matched the alternatives chosen, their methodology remains suspect and unaccepted.

Likewise, chapters 8 and 9 of "A Feasibility Report" are a disappointment. SINBOL was supposed to draw useful inferences for future action based on the findings of the expert component contractors, not depart from those contractors' authoritative findings into flights of speculation. Chapters 8 and 9 show SINBOL engaging in deliberate attempts to portray the sea level canal as somehow not so infeasible, not so problematic, in spite of the facts. In this attempt, SINBOL used premises and speculations which are both beyond SINBOL's authority and beyond the evidence from the component contractors' expert results. For the data behind the findings and conclusions of this Study, therefore, we must suggest that the interested reader go to the reports of the component contractors themselves, rather than trusting themselves to SINBOL's unproven musings.

J. Michael Farrell
U.S. Commissioner

THE FINAL REPORT OF THE COMMISSION FOR THE STUDY OF ALTERNATIVES TO THE PANAMA CANAL

JOINT COMMISSIONERS STATEMENT

SEPTEMBER 20, 1993

Establishment and Purpose of the Commission

In 1985, the governments of Panama, Japan and the United States formed the Commission for the Study of Alternatives to the Panama Canal (the Commission) as an international organization, charged with responsibility for determining what, if any, marine or land based alternatives or enhancements to the present Panama Canal might have to be put in place to meet the demands of world trade in the Twenty-First Century. This grew out of a commitment made in Article XII of the Panama Canal Treaty of 1977 to conduct a joint study of the feasibility of a sea-level canal in Panama.

As constituted by the member governments, the Commission functioned with a Board of Commissioners, as the Canal Alternatives Study (CAS) policy making body, and a Secretariat, as its expert, technical implementing arm. Each member government was represented on the Board by a Commissioner and up to three Deputy Commissioners; each government also maintained a permanent delegation to the Secretariat of up to four delegates.

Implementation of the Study of the Commission

For the first five years, the Commission's effort was directed toward the formalization of rules of procedure and other regulations, selection of the Feasibility Analysis/Final Report

(FA/FR) contractor, and the formalization of the overall study plan. On the 24th of September, 1990, the Detailed Plan of Study (DPS), which indicated the plan and schedule of the whole study, was completed. On the basis of the DPS, (See Detailed Plan of Study of Alternatives to the Panama Canal, Volume II.) the study was implemented through the following phases:

- Phase I — The Background Studies, prescreening and selection of alternatives (for the Feasibility Analysis);
- Phase II — Commodity and traffic projection, determination of cost and capacity of the selected alternatives;
- Phase III — Feasibility analysis of the alternatives; and,
- Phase IV — Preparation of the Final Report.

These Phases of the Study have been conducted for the latter three years. In February, 1991, the Commission entered into a contract under which SINBOL, a consortium of contractors from the Republic of Panama, the United States, and Japan, would assist the Secretariat in the implementation of the Study and oversight of the CAS component contracts, as principal consultant. The first stage of the Study Plan was then inaugurated.

Phase I

The first phase, which was also called prescreening, was designed to identify the Canal Alternatives for the Feasibility Study within two basic conceptual categories of alternatives or enhancements, to wit:

- Improvements to the present Canal,

  High Rise Lock alternatives with Lake Gatun mean water level at 85 to 90 feet,

  Low Rise Lock alternatives with Lake Gatun mean water level at 30 to 55 feet, and,

- Sea-level canal alternatives,

  A Sea-level canal to replace the existing Canal (Route 14S),

  A Sea-level canal approximately 16 kilometers to the west of the existing Canal (Route 10).

During this phase, consideration was made to identify the key elements which characterize the engineering concept of the alternatives. SINBOL performed preliminary background studies. A literature survey and review to identify the key elements to be employed for Phase I Studies was carried out. Elements identified, called principal concepts of the canal alternatives, were Gatun Lake water level, Design Ship size, Improvement of channel route and number of lanes management. The prescreening phase was a sort of sensitivity analysis with respect to these principal concepts and, to the extent they initially could be defined, to the benefits and costs of each.

The Study was divided into specific areas of inquiry called study components. The responsibility for performing these study components was assigned by competitive bidding to private contractors, non-profit organizations, universities, and professional organizations and approved by the Board.

The Phase I component studies provided necessary information to carry out the prescreening analysis. The three Phase I components were: the Operating Characteristics and Capacity Evaluation (OCCE), Engineering and cost Estimates (ECE) and the Commodity and Traffic Projection (CTP).

To mobilize these component studies, consistent parameters were proposed and introduced on the basis of available sources. When sufficient information or data were not available, assumptions were made to accommodate comparison of alternatives within an acceptable level of analysis.

The non-water related alternatives (transisthmian pipeline, rail, road, transshipment centers, etc.), were to be treated as complementary to the water related alternatives and to be studied only in those instances where such a system is required or desirable, and in connection with whatever marine oriented alternative was selected as the preferred enhancement.

During this stage, as a part of the collection of background information, a contract for the compilation of a Biological Inventory (BB/BI) in certain designated areas of Panama (awarded in April, 1992) continued to be performed throughout this post-prescreening stage. This component was designed to obtain baseline information to evaluate environmental impacts in the project area which, at the time of contract negotiation, was limited to the present Panama Canal and surrounding areas. Because of time and budget constraints, the BB/BI did not cover all Route 10 areas proposed for a sea level alternative. As its results became available, they were used by the Environmental Analysis (EA) and Impact upon Panama (IOP) component studies to be carried out during Phase III.

To conclude the prescreening in July 1992, SINBOL made a presentation of the results of their work and the three Delegations to the Secretariat provided their comments on the pre-screening to the Board regarding the results of the prescreening process. Thereafter, on July 24, 1992, the Board selected two enhancements for feasibility study as follows:

- a one or two lane high rise lock canal alternative capable of handling ships of a design of 150,000 or 200,000 DWT; and

- a one lane sea level canal alternative capable of accommodating a design ship size of 250,000 DWT .

Both of these would be operated in conjunction with the existing Canal with the widened Gaillard Cut. With the Board's decision in selecting the above two enhancements for further study, the remaining variations were eliminated from further consideration and CAS moved into the next stage.

Phase II

In the second phase of the Study, the following component studies were carried out to examine in depth the above two alternatives:

- Operating Characteristics and Capacity Evaluation (OCCE),

- Preliminary Engineering and Cost Estimates (ECE).

- Commodity and Traffic Projections (CTP),

The CTP refined the earlier Phase I preliminary traffic forecasts, cargo volumes, transportation cost data, trends and projections of ship size and distribution. The base year for the study was 1990 and the forecast periods were for the years 2020 and 2060. The results of the study are incorporated as Table - 1 (Attachment I).

The OCCE component focused on the refinement of the model used in prescreening in order to accommodate operations, among other things, such as the parallel sea level canal operated simultaneously with the present Canal and the single lane Gaillard Cut operation.

The ECE provided descriptions of the main features of each prescreened enhancement; general engineering conditions; schematic layouts; water and tidal management plans; construction excavation and dredging needs; the nature, location and type of structures; mechanical and other equipment and incidental facilities needed for the alternatives; and, construction schedules and cost estimates for each.

These three studies were intended to provide as precise information of projection, capacity and cost as possible, and provide the basic data for cost benefit analysis for the Feasibility Study (Phase III). All possible efforts were made for interface among the three component studies. In addition, whatever and whenever new information from one component could be fed into others, timely interaction was performed.

During the course of Phase II studies, it was proposed and agreed upon that High Rise lock alternatives with a single lane in Gaillard Cut for 150,000 DWT and 200,000 DWT, and a single lane approach channel for the sea level alternative, be studied in the OCCE and the ECE studies. The results of these studies, which have been prepared by the Commission, are incorporated into Table - 2 (See Attachment II).

The work of the component contractors was substantially completed by July 7, 1993. At that time, the results of the component contracts were certified to SINBOL, for use in the preparation of a Feasibility Report.

Phase III

As the first step of Phase III, and, based upon the decision of the Board as well as reflecting the newly attained information by the Phase II component studies, the Secretariat with the assistance of SINBOL, revised and finalized the Terms of Reference (TOR) for the remaining component studies:

- Financing Schemes, Financial Analysis and Management Arrangements (FS/FA/MA);
- Biological Background and Biological Inventory (a refinement of scope for this already contracted study);
- Economic Analysis and Analysis of Impact on Users (EAIU);
- Environmental Analysis (EA); and,
- Analysis of Impact upon Panama.

Based upon the data supplied by the CTP and ECE studies, in conjunction with that of the OCCE, the FS/FA/MA and the EAIU component contractors conducted financial and economic analyses respectively. Close interface among the contractors was maintained during document reviews as the contractors prepared their studies.

The FS/FA/MA component study was to assess the feasibility of the alternatives based on various financial arrangement and toll structures and to recommend the formulation of the most appropriate management arrangement and toll structure for the two enhancements. The EAIU also analyzed the impact of the operation of alternative canal enhancements on the world users of the canal.

In the FS/FA/MA and EAIU studies, optimization was made for the High Rise Lock Canal and Sea level canal alternatives to maximize the benefits flowing to each. Both studies also were designed to provide a recommendation on feasibility. These are incorporated into Table - 2 (See Attachment II).

The EA component study provided an evaluation of the potential environmental effects associated with each of the enhancements. The purpose of the analysis was to review the available biological information, evaluate the environmental impacts anticipated from each of the alternatives, identify data gaps, and recommend mitigation measures and additional environmental studies, if deemed necessary. This component study also identified impacts common to both the High Rise Lock and Sea Level alternatives, as well as impacts associated solely with either alternative.

The IOP qualified and quantified probable effects and impacts of the prescreened surviving alternatives on Panama and the project region. The IOP was designed to complement data from the EAIU component study. The IOP identified and analyzed the most important discriminating impacts on Panama presented by the surviving two alternatives.

The Feasibility Analysis, based on the data provided by the study component contractors reports, was completed by SINBOL on September 15, 1993. (See A Feasibility Report.) The report traces the study from inception to final analysis and provides recommendations for further study prior to the inception of any enhancement project. The final findings and recommendations of this Commission are drawn in part upon that report to the extent that it characterizes the overall activities, findings and conclusions of the component contractors.

Phase IV

This report constitutes Phase IV of the Study of the Alternatives to the Panama Canal.

As a result of this effort, all documents and papers have been maintained in an Information Center, which should be continued in order to provide ready access for the public at large, the business community and for any future studies. Requests for copies of the reports of the Commission for the Study of Alternatives to the Panama Canal should be directed to the Information Center (Edif. Fuerte Amador, Aptdo. 3403, Panama 4, Rep. of Panama, Tel. 28-2665, Fax 28-0974)

Recommendations

Based upon the findings discussed below, and recognizing the importance of the Panama Canal to world trade and its increasing importance to Central and South America, the Commissioners for the Study of Alternatives to the Panama Canal conclude and recommend by consensus as follows:

(1) The present Panama Canal, with the widened Gaillard Cut, appears capable of handling the demand of international oceanborne commerce to the end of the second decade of the 21st century. However, some action should be taken before 2020 to prepare for the time when the projected traffic cannot be accommodated by the present Panama Canal.

(2) Future study should be carried out to firmly establish when an enhancement would be needed to presage the additional environmental studies required for final engineering and design and the start of construction.

(3) At a time when an enhancement to the present Panama Canal, with the widened Gaillard Cut, would be required, consideration should be given to the high rise third lock capable of handling 150,000 DWT vessels.

(4) In addition to the findings and conclusions below, each Commissioner may submit corresponding recommendations to his respective government.

(5) The Republic of Panama should maintain, at an appropriate location sponsored by an appropriate agency, the Information Center of the Study.

Findings and Conclusions

Based upon the results of the component contracts and taking into consideration the contents of the Feasibility Report of the principal consultant SINBOL, the following findings are made:

- Study results indicate that the high rise lock alternative, with a single lane portion in the Gaillard Cut, operating in conjunction with the present Canal and capable of handling 200,000 DWT vessels, would be marginally feasible;

- Study results indicate that the one lane sea level canal, operating in conjunction with the present Panama Canal and capable of handling ships of a design of 250,000 DWT, would not be feasible to consider as a viable enhancement to the Panama Canal;

- Study results indicate that no enhancement is required before the end of the second decade of the 21st century as the present Panama Canal, with the Gaillard Cut widening project, is capable of accommodating demand at least to that time;

- Study results indicate that the high rise lock alternative with a single lane portion in the Gaillard Cut, operating in conjunction with the present Panama Canal and capable of handling ships of a design of 150,000 DWT would be the most effective enhancement;

- before implementation of any project, additional investigation will be required, especially in the areas of impacts on the environment and of geomorphological and natural conditions and toll structure with more user-friendly scenario as there was not sufficient time to do so during the term of the Commission; and,

- because of the time lapse between this Study and the need for an enhancement, most of the feasibility studies would have to be updated to take into account the then world trade financial and economic picture.

This Study is the final outcome of years of assiduous effort and study by all the participants concerned, from both public and private sectors, based on international cooperation among three governments.

We Commissioners are very grateful to all participants for their utmost endeavors and firmly believe that this Study is a highly comprehensive, solid and valuable one. It is of great importance to, and represents a significant asset for, the Republic of Panama as well as the whole world as the most current and complete study regarding transisthmian canals across Panama.

J. Michael Farrell

Chairman

Commissioner of the United States of America

Guillermo Quijano, Jr.

Commissioner of the Republic of Panama

Yoji Sugiyama

Commissioner of Japan

Attachment I

The results of the CTP study projected annual transits through the canal for various vessel sizes as follows:

Table-1 Traffic projections under the conditions of various maximum ship sizes

Maximum Ship Size	Year 1990	Year 2020	Year 2060
65,000 DWT	11,162	17,359	18,078
150,000 DWT		17,796	23,934
200,000 DWT		17,844	24,074
250,000 DWT		17,356	24,053

Unit: Number of Ships

Since the projected annual transit capacity of the canal with the widened Gaillard Cut is 17,000 transits, an enhancement may be expected to be needed by 2020.

Attachment II

Table - 2 Study Results and Evaluation

Option *1	Transit Capacity (1,000)	Cost Billion Dollars	Economic Internal Rate of Return	*2	Financial Internal Rate of Return	*2	Result *2
1-a	34.6	7.4	7.1%	△	10.1%	△	△
1-b	34.4	5.4	8.5%	○	15.8%	●	●
2-a	35.3	8.5	6.5%	△	8.4%	×	×
2-b	34.6	6.4	7.6%	○	12.3%	△	○
3-a	41.7	13.5	4.8%	×	4.5%	×	×
3-b	44.0	12.7	5.0%	×	N.A.	×	×
S.Q.	17.0	-					
Source of Data	OCCE Phase II	ECE Phase II	EAIU		FS/FA/MA		

Note:

*1

1-a; High Rise Lock Canal with **Double** lane Gaillard Cut and Design Ship size 150,000 DWT,

1-b; High Rise Lock Canal with **Single** lane Gaillard Cut and Design Ship size 150,000 DWT,

2-a; High Rise Lock Canal with **Double** lane Gaillard Cut and Design Ship Size 200,000 DWT,

2-b; High Rise Lock Canal with **Single** lane Gaillard Cut and Design Ship Size 200,000 DWT,

3-a; Sea-level Canal with single lane channel, 3 lane tidal locks and Design Ship size 250,000 DWT,

3-b; Sea-level Canal with single lane Channel, a pair of tidal gates and design ship size 250,000 DWT.

S.Q.; Existing Panama Canal with widened Gaillard Cut

*2

● Very feasible

○ Feasible

△ Marginally feasible

× Not Feasible

N.A. Not Examined (obviously not Feasible)

Attachment III

CONTENTS OF THE FINAL REPORT

OF

THE COMMISSION FOR THE STUDY

OF

ALTERNATIVES TO THE PANAMA CANAL

SEPTEMBER 20, 1993

The Final Report of the Commission consists of the following documents:

Vol. I — The Final Report of the Commissioners for the Study of Alternatives to the Panama Canal, Commissioners Joint Statement

Executive Summaries of the Following (in order):

- Detailed Plan of Study
- Operating Characteristics and Capacity Evaluation, Phase I
- Engineering Cost Estimates Study, Phase I
- Commodity and Traffic Projection Study, Phase I
- Operating Characteristics and Capacity Evaluation, Phase II
- Engineering Cost Estimates Study, Phase II
- Commodity and Traffic Projection Study, Phase II
- Environmental Analysis
- Biological Data Background and Biological Inventory
- Economic Analysis and Impact on Users
- Financing Scheme, Financial Analysis and Management Arrangements Study
- Impact Upon Panama Study
- A Feasibility Report (Chapter 1.0 entitled "Executive Summary")

Vol. II — Detailed Plan of Study

Vol. III — Operating Characteristics and Capacity Evaluation (OCCE) Study, Phase I

Vol. IV — Engineering and Cost Estimates (ECE) Study, Phase I

Vol. V	Commodity and Traffic Projection (CTP) Study, Phase I
Vol. VI	OCCE Study, Phase II
Vol. VII	ECE Study Phase II (1)
Vol. VIII	ECE Study Phase II (2)
Vol. IX	ECE Study Phase II (3)
Vol. X	CTP Study, Phase II (1)
Vol. XI	CTP Study, Phase II (2)
Vol. XII	Environmental Analysis
Vol. XIII	Biological Inventory and Biological Analysis
Vol. XIV	Economic Analysis and Impact on Users (1)
Vol. XV	Economic Analysis and Impact on Users (2)
Vol. XVI	Financing Scheme, Financial Analysis and Management Arrangements (1)
Vol. XVII	Financing Scheme, Financial Analysis and Management Arrangements (2)
Vol. XVIII	Financing Scheme, Financial Analysis and Management Arrangements (3)
Vol. XIX	Impact upon Panama Analysis
Vol. XX	A Feasibility Report

A Feasibility Report
Preface

The Study of Alternatives to the Panama Canal was carried out under a Commission representing the Republic of Panama, the United States of America, and Japan. The Study was managed by a Secretariat composed of technical staff from the member nations.

As indicated in the Detailed Plan of Study (DPS), the FA/FR Contractor (SINBOL) performed, under the direction of the Secretariat, the prescreening and selection of alternatives, the feasibility analysis, the tasks asociated with A Feasibility Report, and the provision of advice and assistance to the Secretariat throughout the course of the Study.

In preparation for the preliminary analysis and prescreening of alternatives, SINBOL conducted the following tasks:

- Analysis of the Present Situation in Panama
- Status of the Present Panama Canal
- Historical Trade Analysis
- Future Transportation Systems and the Significance of the Isthmus in World Trade

The results of these tasks and preliminary results from Phase I Component Studies were used by SINBOL in the Prescreening and Selection of Alternatives effort. Phase I Component Studies which provided preliminary information included the following:

- Preliminary Engineering and Cost Estimates
- Preliminary Operating Characteristics and Capacity Evaluation
- Commodity and Traffic Projection

General information dealing with the environmental impacts was also considered in the Prescreening and Selection effort. Detailed information became available later with the completion of the Background Biological Data and Biological Inventory Component Studies and was used is subsequent analyses.

Upon completion of the Prescreening and Selection effort, the Commission selected two alternatives; namely, the High Rise Lock Canal and the Sea Level Canal - Route 10 for further studies. Phase II component studies provided additional information on the Phase I topics. In addition, Phase III component studies including Financing Scheme, Financial Analysis and Management Arrangement, Environmental Analysis, Economic Analysis and Analysis of Impact Upon Panama were undertaken and depended substantially on the results of Phase II component studies.

SINBOL provided advice and assistance to the Secretariat in the prequalification and selection of Component Contractors, and in the development and review of the component studies.

A Summary of the project background, component studies, feasibility analysis, overall evaluation and recomendations for further studies are included in this report.

SINBOL is a consortium of engineering and financial firms representing the countries of Panama, The United States of America and Japan whose governments sponsored this study. The SINBOL consortium consisted of the following companies:

S	STONE & WEBSTER ENGINEERING CORPORATION 245 Summer Street, P.O. Box 2325 Boston, Massachussetts 02107
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The many contributions, made by professional staff from SINBOL who participated in this Study as well as the preparation of this report are acknowledged below.

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The opportunity to have worked together with all of the participants in this Study of Alternatives to the Panama Canal including the Commissioners, Delegates, component contractors, many government officials concerned, and personnel of the Panama Canal Commission is sincerely appreciated.

A Feasibility Report
Abstract

Summary

The study concept was initiated under the 1977 Panama Canal Treaties to determine if a previously identified route through Panama for a sea-level canal will really be needed. Appropriately, the scope of the study was expanded by the Preparatory Committee to include consideration of all alternatives to the Panama Canal within Panama . The need for a sea-level canal route can only be evaluated in terms of the adequacy of the existing canal and the feasibility of various alternatives.

Historical alternatives were grouped into four conceptual alternatives namely, High Rise Lock Canal, Low Rise Lock Canal, Sea Level Canal Route 10, and Sea Level Canal Route 14S. Each conceptual alternative was sub-divided by 9 cases including three different configurations and design ship classes, then a total of 36 cases was examined by a preliminary cost/benefit analysis.

Two surviving canal concepts for feasibility studies were: a High Rise Lock Alternative and a Sea-Level Route 10 Alternative, with design ships of 150,000 DWT, 200,000 DWT, and 250,000 DWT respectively. Both of these alternatives would operate in combination with the present canal, referred to as the Status Quo case which includes the approved widening of the Culebra Cut.

In the course of the study preliminary engineering and cost estimates were produced for many different canal configurations. These numbers provided a basis for consistent comparison among the configurations.

Some specific products of the study that will be of lasting value and useful in determining the ultimate optimal project include the following:

- Data for estimating and comparing costs by size and type canal,
- Identification of capacity limitations of canals, and
- Identification of site-specific impacts and problems.

The engineering analysis report established that many types of canal improvement schemes can be constructed. The purpose of commodity, traffic, economic, and financial analyses was to determine a most suitable canal that can be built, based on a best estimate of future demand.

In this feasibility study the following eight alternatives are examined:

1:	150,000 DWT High Rise Lock Alternative
1-a:	150,000 DWT High Rise Lock Alternative with Single Lane Culebra Cut
2:	200,000 DWT High Rise Lock Alternative
2-a:	200,000 DWT High Rise Lock Alternative with Single Lane Culebra Cut
3:	250,000 DWT Sea Level Alternative with (3 plus 1) Pacific Tidal Locks
3-a:	250,000 DWT Sea Level Alternative with (1 plus 1) Pacific Tidal Locks
4:	250,000 DWT Sea Level Alternative with Tidal Gates
4-a:	250,000 DWT Sea Level Alternative with Tidal Gates and Single Lane Atlantic Approach

An overall evluation of the above eight alternatives was made using criteria based upon engineering, economic, financial and cost effectiveness. The results of this overall evaluation can be summarized as follows:

Alternative	Overall Evaluation
1	Marginal
1-a	Good
2	Poor
2-a	Acceptable
3	Not acceptable
3-a	Not acceptable
4	Not acceptable
4-a	Not acceptable

Based on financial analysis, three High Rise Lock Alernatives (alternatives 1, 1a, and 2a) would be feasible provided canal tolls are raised to the "Optimal level" used in the financial analysis and provided Panama would apply part of the canal tolls to future construction instead of using them for other national needs. Among the alternatives which are feasible, the 150,000 DWT High Rise Alternative with a Culebra Cut single lane (1a) is the most feasible.

Conclusions

Based on the study results, the following conclusions can be drawn:

- There is a need for a canal to accommodate vessels larger than 65,000 dwt. size. Improvement of the existing canal with larger locks is the indicated solution.

- A High Rise lock canal with a single lane Culebra Cut sized to accommodate ships in size range of 150,000 to 200,000 deadweight tons is feasible from an engineering,

economic and financial viewpoint.

- The feasibility of a sea-level canal could not be established under the framework used in this study .

- Should traffic demand increase by approximately 15 percent above the presently adopted forecast, there is a good chance some of the variations of the Sea Level Route 10 Alternatives could become feasible. The improved feasibility of a Sea Level Alternative still could not be any better than the High Rise Alternatives.

- Before a major canal project can go forward, the following three critical issues need resolution:

  - Acceptance of impacts upon Panama's economy and internal needs.

  - Acceptance of an environmental mitigation and remediation plan to satisfy valid concerns related to the enviroment.

  - Assessment of the impacts of increased canal tolls on users of the canal.

- Before a major canal project can go forward, a permanent canal entity is needed with the power to levy and raise tolls, borrow money, plan long-range, and provide continuity of canal operation and management.

- Panama's legislation and the conditions of international treaties must be investigated and adjusted as required before a permenant canal entity is established.

Recommendations

Listed in priority order, they are as follows:

- Establish a new concept for a permanent canal entity as soon as possible. A new entity is needed to succeed the Panama Canal Commission which expires at the end of 1999. An entity that can provide continuity of planning, and that can implement major improvement projects is needed. A canal authority form of entity is recommended.

- A Panamanian Government initiative to undertake the following additional studies is recommended:

  - Evaluation of the impacts of building a major canal alternative upon the Panamanian economy including the ability of Panama to dedicate part of the tolls prior to construction to help for the future cost of the canal alternative.

- Assessment of the changes occurring within the entire watershed area available as a water source for the future operation of canal alternatives. The preservation of future hydrologic conditions will be vital to the development of either a High Rise Lock or a Sea-Level Canal alternative.

- Assessment of the Environmental Impacts of building a major canal alternative and development of an Environmental Mitigation and Remediation Plan to alleviate the impacts.

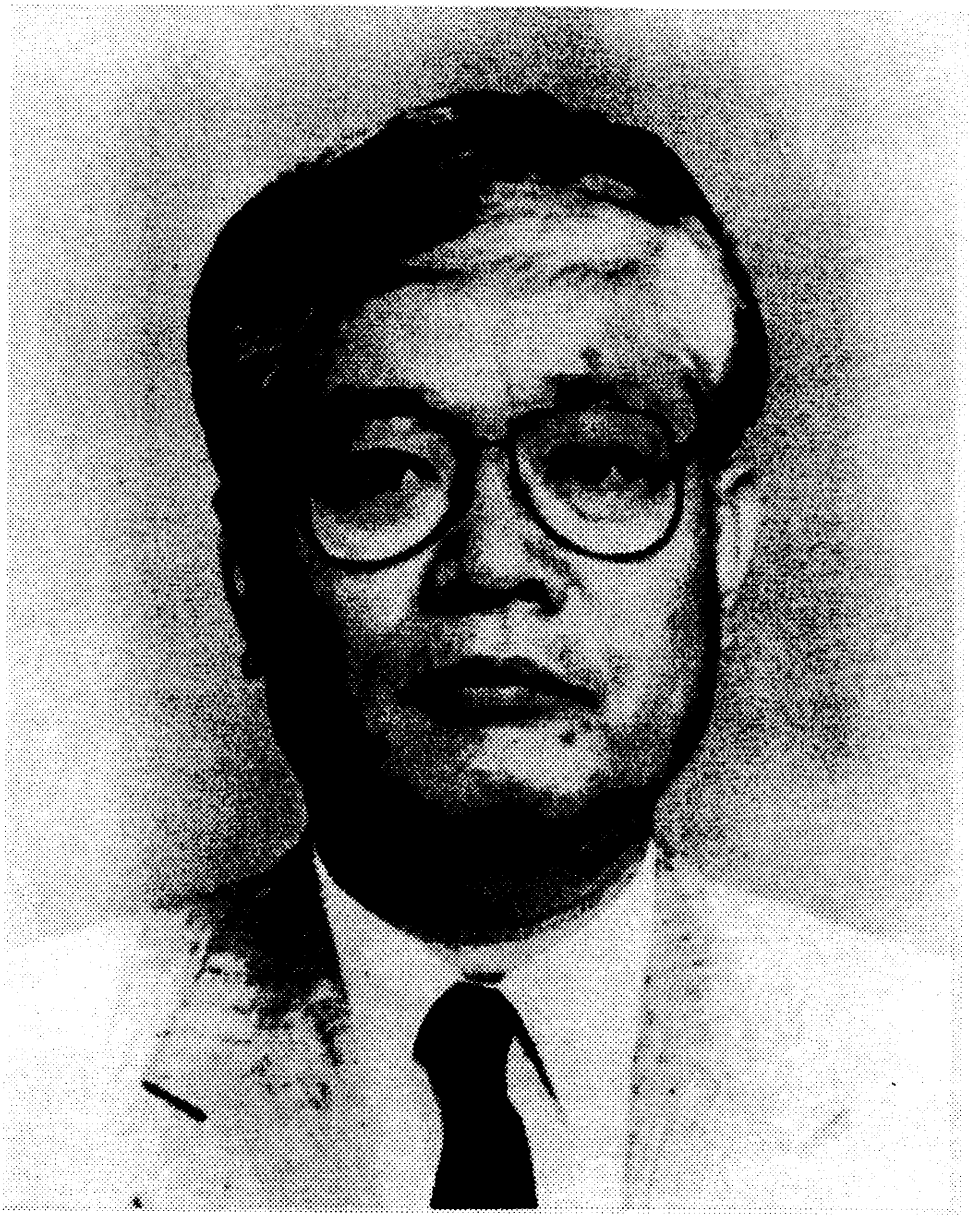
- Assessment of the impacts of increasing canal tolls upon the shipping industry and its level of use of the canal.

- Further study is appropriate for the most promising alternatives, High Rise Lock Alternative with 150,000 DWT design vessel and Single Lane Culebra Cut and a High Rise Lock Alternative with 200,000 DWT design vessel and Single Lane Culebra Cut.

- Considering the importance of the Panama Canal to international trade, further studies need to include investigating a more user-oriented toll scenario than the optimum toll scenario used in this study.

- Careful monitoring of actual canal transits, as well as by-pass cargo movement, is recommended to form a basis for deciding the optimal timing of a new canal operation. The best estimate at present is sometime between 2015 and 2020.

In memory of



Seiichi Omura

A Feasibility Report
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A Feasibility Report
List of Acronyms

ANCON	National Association for Natural Conservation
B/C	Ratio of Benefit to Cost
B-C	Net Benefit (Benefit minus Cost)
BEACHES	Computer Model to Estimate Shoreline Changes
CAS	Commission for the Study of Alternatives to the Panama Canal
CIA	Classification and Identification of Alternatives
CTP	Commodity and Traffic Projection
DPS	Detailed Plan of Study
DRT	Differential Ready Time
DUT	Differential Underway Time
DWT	Dead Weight Tons also as dwt.
EAIU	Economic Analysis and Impact on Users
ECE	Engineering and Cost Estimates
EIRR	Economic Internal Rate of Return
EL.	Elevation
FA/FR Contractor	Feasibility Analysis/Final Report Contractor
FFMS	Financing Scheme, Financial Analysis, and Management Arrangements Study
FIDIC	International Federation of Consulting Engineers
FIRR	Financial Internal Rate of Return
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
HRLC	High Rise Lock Canal
HWL	High Water Level
IDB	Inter-American Development Bank

List of Acronyms

INRENARE	National Institute of Natural Renewable Resources
IOCS	Inter Oceanic Canal Study also called Anderson Report
IRR	Internal Rate of Return
JAX	List of Memorandum to the IOCS (1970) Report
JICA	Japan International Cooperation Agency
LATIS	Name of Computer Program to Simulate tidal current in Open Channel with control measures
MCM	Million Cubic Meters.
MIS	Management Information System
NB	North Bound
NIEs	Newly Industrialized Economies
NPV	Net Present Value
O & M	Operating and Maintenance
OA	Office Automation
OCCE	Operating Characteristic and Capacity Evaluation
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
OECF	Overseas Economic Cooperation Fund of Japan
OMR	Operating, Maintenance and Replacement
P.L.D.	Plane Level Datum
PCC	Panama Canal Commission
PCNT	Panama Canal Net Ton
ROUTES	Computer Model to Estimate Sedimentation Depths
SDB	Ship Data Bank
SDR	Social Discount Rate

List of Acronyms

SEP	Self Elevating Platform
SINBOL	Consortium Conducting FA/FR Study
SLC	Sea Level Canal
SLC 10	Sea Level Canal on Route 10, also SLC
SB	South Bound
SPC	Special Purpose Corporation
SQ	Status Quo
TAMS	TAMS Consultants of New York, N.Y.
TICW	Time in Canal Water
TOR	Terms of Reference
U.N.	United Nations
U.S.	United States
UK	United Kingdom (Britain)
WAM	Waterway Analysis Model
WEFA	WEFA Group of Philadelphia, PA., U.S.A.
YEC	Yachiyo Engineering Company, Limited.

A Feasibility Report
1.0 Executive Summary

1.1 Study Background

The Study of Alternatives to the Panama Canal was authorized initially as part of the 1977 Panama Canal Treaties. The treaties principally deal with termination of United States rights in Panama related to the present Panama Canal. Article XII, Paragraph 1 of the treaty signed in Washington on September 7, 1977, states that "during the duration of this treaty, both parties commit themselves to study jointly the feasibility of a sea-level canal in the Republic of Panama...". Described herein is the evolution of the study authority, and the evolution of the study into a tri-national undertaking of broad scope and complexity.

This study of Alternatives to the Panama Canal is the latest in a long series of isthmian canal studies. It was originally conceived for a very specific purpose, in treaty negotiations between Panama and the United States, to determine if a previously identified route through Panama for a sea-level canal was really needed. To determine the need for the identified canal route, it was necessary to study all alternatives to the Panama Canal. The study was undertaken with Japan as the third co-equal sponsor. The scope of the study and tri-national participation made it an extremely complex undertaking. This study did build upon numerous prior study accomplishments. It advanced the state of the art in analyzing the capacity of canal alternatives. It went beyond all prior studies in examining the economic justification and financial feasibility of potential projects, and is a valuable addition to the body of knowledge on isthmian canals.

This is the first study entirely based upon meeting the needs and objectives of maritime trade among nations. No consideration was given to ship transits resulting from other than commercial maritime trade.

1.1.1 Study Origin

Over time, a large number of studies have examined the feasibility of trans-isthmian canals, in Panama and elsewhere in Central America. Primarily, the studies examined physical feasibility and technical aspects of canal construction, and there has been lengthy debate over the merits of a sea-level canal versus a lock-type canal. The sea-level canal historically was envisioned to have significant operational advantages. The present Panama Canal was started by Ferdinand De Lesseps as a sea-level canal in 1881, and was beyond the capability of existing technology and construction equipment available in the early 1900s. It was finally completed as a lock canal by the United States in 1914. After World War II, canal studies predominantly identified a sea-level canal as the solution to anticipated capacity constraints of the existing canal.

The construction started by De Lesseps was based on a concession from Colombia, and completed by the United States based on the Hay-Bunau Varilla Treaty of 1903 with Panama. As a result, there is a symbiotic relationship between Panama Canal studies and the U.S. treaties with Panama. The more recent U.S. canal studies recognized the need to modify the 1903 Treaty to provide the necessary territorial rights for a sea-level canal if one were built, and a 1970 study was intended to provide the basis for treaties to replace the 1903 Treaty.

1.1.2 Study Sponsorship and Participation

To implement the study called for in the 1977 Treaty, the governments of the United States and the Republic of Panama used exchanges of diplomatic notes. In the initial exchange of notes on September 30, 1982, the two countries agreed to establish a Preparatory Committee to consider how to conduct the canal feasibility study. Based upon the agreement reached by exchange of notes and an earlier expression of interest by Japan, the two countries simultaneously invited the government of Japan to participate in the Preparatory Committee's work. The tri-national Preparatory Committee held a series of meetings between 1982 and 1985, and produced a Final Report that defined the study scope and objectives as well as how the study was to be performed. The fundamental concept in the Committee's recommendations was that the study would be a joint effort of the three nations. A study based on that concept was agreed to by the United States, Panama, and Japan, in a three-way exchange of diplomatic notes on September 26, 1985.

The tri-national Preparatory Committee set the pattern for how the study was to be performed by its recommendations. The Committee started with a clean slate because of the brevity of the treaty provision, and its members started deliberations with diverse views of what was to be studied and how it should be studied. The 1982 exchange of diplomatic notes simply directed the Committee to prepare and agree upon the terms of reference for the study, to specify the objectives of the study, the organizational structure of the study, and the study budget, funding sources, and schedule. The Preparatory Committee was able to reconcile diverse views and produce its report by mutual agreement. Its recommendations specified equality in study funding and study work, with mutual agreement required for virtually all decisions. With three sovereign nations involved, and a large number of individuals and study contractors, mutual agreement was sometimes hard to achieve.

1.1.3 Study Objectives and Organization

The Final Report of the Preparatory Committee stated the study objectives as follows:

- to identify potential transportation alternatives to the Panama Canal within the Republic of Panama;
- to study these alternatives in accordance with the terms of reference contained in the Final Report... in order to develop the information necessary to evaluate the feasibility of each alternative;

- to select the best alternative and study it in detail; and

- having studied in detail the best alternative, to develop conceptual plans for said alternative for the consideration of the Member Governments of the Study Commission.

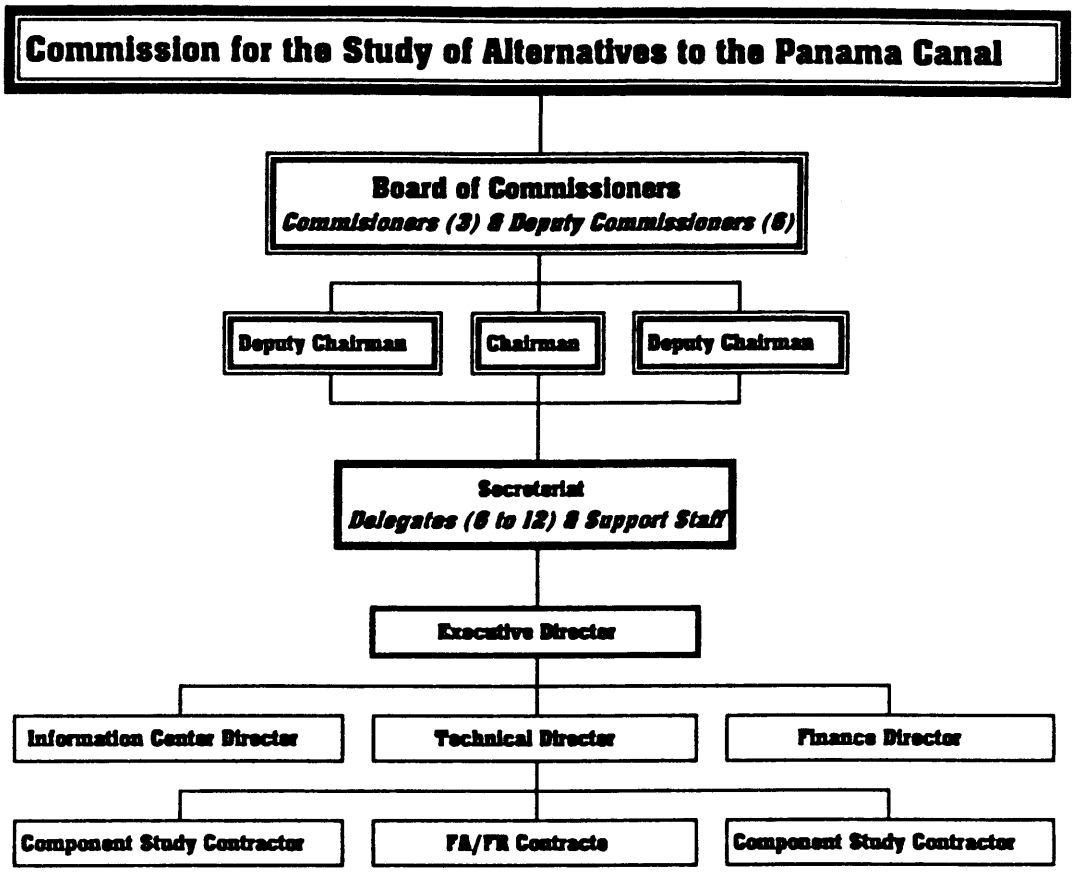
To provide a definitive answer to the question of the need for another canal and the related territorial requirements in Panama, the study envisioned by the Preparatory Committee was expanded by an exchange of notes in 1982 establishing the study commission to be much broader and comprehensive than the sea-level canal study called for in the 1977 Treaty. To carry out the study, the Committee recommended creation of an international/tri-national study commission, and specified an organization structure appropriate for a major study effort. The organization structure incorporated requirements to assure equal participation in study direction, management, and distribution of work.

The basic organization elements were (1) an executive body, the Board of Commissioners, (2) a staff of technical experts to provide day-by-day administration and management of the study, the Secretariat, and (3) a large number of individuals and organizations collectively called Study Contractors (Technical Advisors) who were employed individually or through consortia to perform the work in study components. The Commission board members were Commissioners and Deputy Commissioners appointed by the three nations who participated in the study. The board members were the official representatives of their respective governments in an otherwise independent international study commission. As such, they had direct and sole responsibility for direction and performance of the study. Board chairmanship was rotated annually among the three Commissioners representing the sponsorship countries, and the Board was required to make decisions by unanimous agreement.

The Secretariat members were Delegates and Principal Delegates appointed by the participating governments. Within the Secretariat, there were three officers, an Executive Director charged with overall responsibility for carrying out the study, a Technical Director charged with supervision of contract management, and a Financial Director responsible for financial controls and budgets. The three directorships were allocated to delegates from each of the sponsoring governments, and similar to Board offices, directorships rotated annually. Directors could act independently in most matters but were required to have mutual agreement in certain specified areas. Provision was also made for an Information Center Director.

The Study Contractors employed to perform study work were predominantly but not exclusively nationals of three participating countries. A unique special contract called the Feasibility Analysis/Final Report (FA/FR) contract provided a specialized technical body to advise and assist the Secretariat for the duration of the study. The FA/FR Contractor was under the direct supervision of the technical directors but had no supervisory authority over other study contractors. The assistance included initiating the study, support in contracting for and integrating the results of component studies, and production of a feasibility report.

Figure 1.1.3-1
Canal Alternatives Study Organization Chart



Because of the special nature of this contract, substantial equality in effort and cost was required, among the tri-national participants. Several specialized contractors were engaged to make detailed studies of special specific topics. These studies were components of the overall study, herein referred to as component studies, and the contractors as component study contractors. Most of the component studies were performed by one firm from a sponsorship country, but some studies involved multiple firms and nationalities. As part of quality control, contractor supervision by the Secretariat and contract monitoring by the FA/FR Consortium were performed by individuals not of the same nationality as the study contractor. The organization structure of the Study Commission is shown in Figure 1.1.3-1.

1.2 Study Framework

The Final Report of the Preparatory Committee provided a very specific description of the study envisioned by the Committee. This initial study plan and budget included three iterations of feasibility analysis in increasing detail, four phases for the sequence of component studies and integration of results, a timetable for performing the studies with an estimated duration of five years, and a study budget totalling $20 million. The study budget was shared equally among Japan, Panama and the United States. The contribution from Japan was made through the Japan International Cooperation Agency (JICA). Participation by Panama was made possible through a loan from the Inter American Development Bank (IDB). The United States contribution was administered through the Department of State.

Subsequent events changed the duration of the study although the basic study framework produced by the Committee has survived largely intact. The modifications to the initial plan of study were needed to compress study activities into the remaining time available.

Development of a Detailed Plan of Study (DPS) was the first step in the actual work of the study. The Detailed Plan of Study (DPS) was prepared by the FA/FR Contractor, a tri-national consortium known as SINBOL, under contract to the Commission. The DPS was approved by the Board of Commissioners on September 24, 1990.

A summary of the four phases in this plan is as follows:

- Phase I. Preliminary Studies, Pre-screening and Selection of Alternatives
- Phase II. Refinement of Commodity and Traffic Projections, Engineering Evaluation, Determination of Cost and Capacity of Selected Alternatives
- Phase III. Feasibility Analysis of the Selected Alternatives
- Phase IV. Selection and Description of the Alternative

The DPS itself identified many of the historic alternatives, and relied on a prescreening process to reduce the number of alternatives to be further evaluated. The identification of all historical alternatives was based on an extensive literature search.

The historical alternatives were broadly classified into three categories: improvements to the existing canal; construction of a sea-level canal; and, non-canal alternative transportation systems.

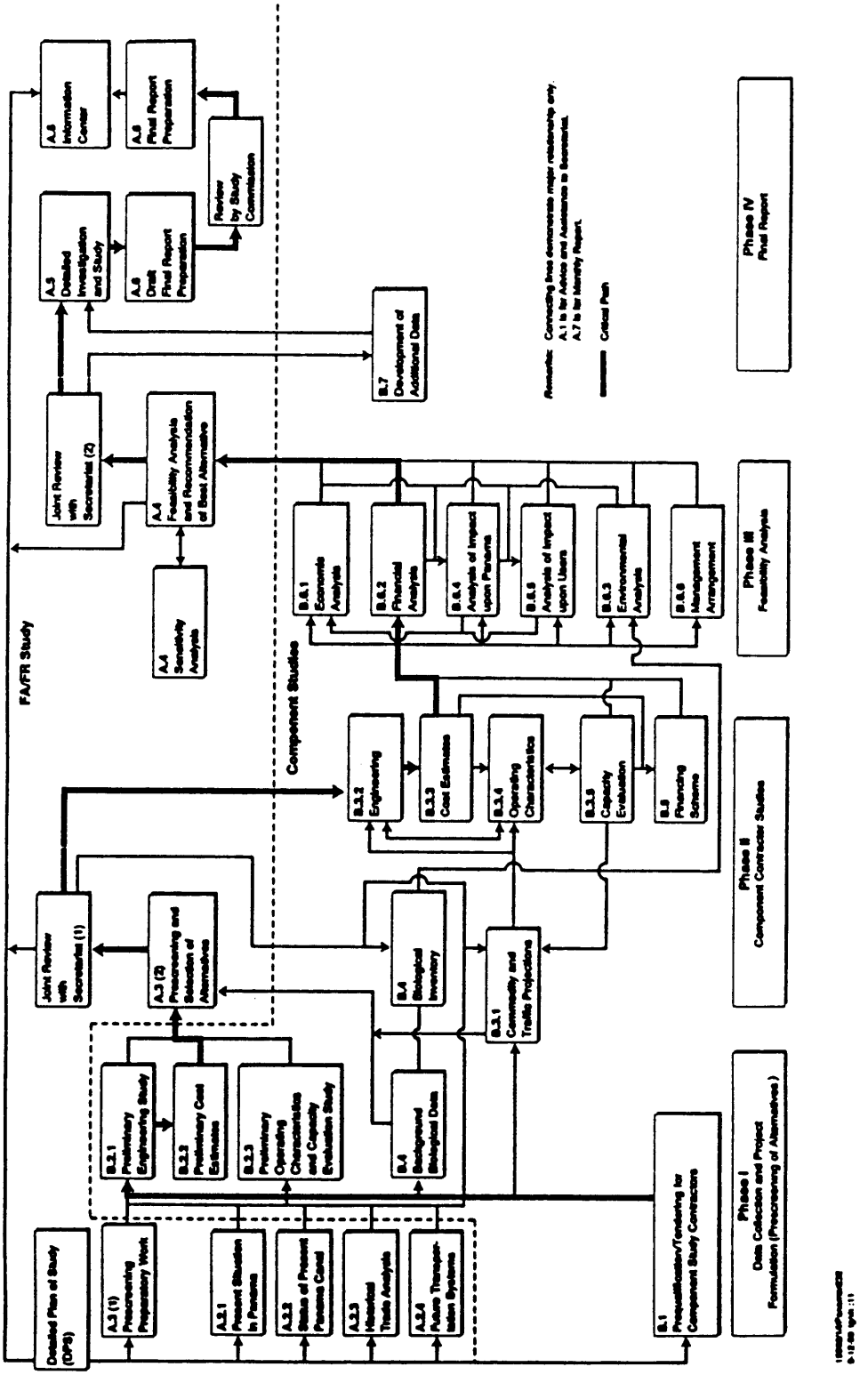
These are listed below:

- Improvements or enlargements to the existing canal
    - Status Quo alternative (includes Gaillard Cut widening)
    - Non-lock improvements
    - Third Locks Plan
    - Terminal Lake Plan and variations
    - Deep Draft Lock Canal Plan
    - Lopez-Moreno Plan
- Sea-level canal
    - 1970 Interoceanic Canal Studies, Route 10
    - 1970 Interoceanic Canal Studies, Route 14S
    - Vergara Plan
    - Nagano Plan
- Non-canal complementary transportation systems
    - Oil pipeline
    - Land bridge systems (railway and highway)
    - Appropriate parts of the Centerport Concept
    - Other

Because of the time required for extension of the study duration and agreement to proceed with the study, the work schedule was compressed by having the FA/FR contractor consortium assist the Secretariat by doing the four initial background studies. Board approval to proceed became effective on February 25, 1991. The overall sequence and type of work in the four phases is shown in Figure 1.2-1.

Figure 1.2-1

Canal Alternatives Study Work Flow Chart



1.2.1 Preliminary Studies, Prescreening and Selection of Alternatives

After completion of the Phase II component studies and commencement of the Phase III component studies, both The Commission and SINBOL recognized that the Agreement for Services cannot be implemented fully in accordance with its original terms and conditions by September 25, 1993.

As a result SINBOL was released from any obligation to carry out "Detailed Investigation and Study". Instead, SINBOL conducted Feasibility Evaluation of the two conceptual alternative which survived the prescreening and selection. In addition, SINBOL's evaluation will be documented in "A Feasibility Report" instead of "Final Report" as required by the original agreement.

Phase I work consisted of obtaining information needed to scope specific component studies, initiation of component studies, and the development and use of a prescreening process to select alternatives to be studied in subsequent phases.

As mentioned, the consortium assisted the Secretariat by performing four preliminary background studies. These studies and the purpose of each were as follows:

- Present Situation in Panama, used to scope biological inventory and studies of environmental and social economic impacts on Panama.

- Status of Present Panama Canal, provided information for engineering studies.

- Historical Trade Analysis, provided information for traffic and capacity evaluation and screening of alternatives.

- Future Transportation Systems, provided information for vessel size analysis and screening of alternatives.

Based on the preliminary studies, terms of reference were prepared for the Background Biological Data and Biological Inventory studies, and the three other component studies; Engineering and Cost Estimates, Operating Characteristics and Capacity Evaluation, and Commodity and Traffic Projections. These three basic component studies were initiated promptly and were completed in Phase II.

Concurrent with the initial contract awards, the consortium developed the process to reduce the previously identified historic alternatives to four basic concepts: a High Rise Lock Canal, a Low Rise Lock Canal, a Sea Level Canal on Route 14S, and a Sea Level Canal on Route 10. Each of these alternatives was compared with the existing Panama Canal modified to include the Culebra (Gaillard) Cut widening announced by the Panama Canal Commission in 1992, which hereinafter is known as the Status Quo (SQ) Case.

The alternatives in Panama that did not involve canal construction such as pipelines and overland transportation systems, were, in effect, set aside and treated as "complementary alternatives". Criteria developed to evaluate the canal alternatives were based on Engineering Soundness, Approximate Benefit/cost Evaluation, Adaptability for Future Expansion, Impact on Existing Canal, and Environmental/Socioeconomic Aspects. Preliminary results of Phase I Component Studies were supplemented with information from preliminary studies, and a prescreening process was used to select the alternatives for feasibility analysis. This effort resulted in a sea level canal located west of the existing canal (Route 10) and improvements of the existing canal (a High-Rise Lock Canal).

1.2.2 Commodity and Traffic Projections, Determination of Cost and Capacity of Selected Alternatives

Phase II was a continuation of the traffic, engineering, and capacity analyses of Phase I, and was focused on the prescreened alternatives. The design vessel sizes and related canal dimensions and features became the basis for cost, capacity, and traffic estimates in Phase II.

- Commodity and Traffic Projections (CTP) were based on bilateral trade forecasts to year 2060 desegregated to trade routes. The potential canal traffic was based on trade routes where the canal offered the shortest distance, and the projected canal traffic was based on the selected design vessel sizes accommodated by the canal alternatives. These studies are reported by the WEFA Group, Richardson Laurie Associates and BST Associates.

- Engineering and Cost Estimates (ECE) were based on comprehensive conceptual designs for the two selected canal alternatives. These design concepts were based on consideration of all site conditions, design and construction requirements. The development of these concepts and their associated costs are reported on by Yachiyo Engineering Company, Limited.

- Operating Characteristics and Capacity Evaluation (OCCE) interacted with the other studies. It used a simulation model, developed to measure the capacity of the existing canal and canal alternatives on a consistent basis, to estimate the ability of individual canals and combinations of canals to accommodate projected canal transits. Another part of the component was modelling of tidal currents in the sea-level alternative and use of alternate traffic lane configurations. The identification of canal and vessel operating characteristics provided information that is useful for canal design purposes. The development of these studies is contained in reports by TAMS Consultants, Inc., Oak Ridge National Laboratory, and American Bureau of Shipping.

1.2.3 Feasibility Analysis of Selected Alternatives

Phase III consisted of a series of feasibility and impact analyses. With the exception of the analysis of environmental impacts, the feasibility and impact analyses could not commence until substantial completion of the Phase II traffic/engineering/capacity analyses. In the case of environmental impacts, it was desirable to continue the biological inventory as long as necessary. As a result, the time available for feasibility and impact analyses was very limited. In an effort to shorten study time, some of these studies were merged so they could be performed by a single contractor. The ultimate set of component studies was as follows:

- Economic Analysis and Impacts on Users (EAIU). These analyses were based on the transportation cost savings indicated by traffic projections, and the engineering cost estimates. The analysis brought the economic benefits of cost savings and the economic cost of canal alternatives together to apply standard measures of economic feasibility. It also estimated the economic impacts of canal construction and operation on Panama and on canal users. These analyses are reported by Mitsubishi Research Institute, Inc. and YACHIYO Engineering Co, Ltd.

- Financing Scheme, Financial Analysis, and Management Arrangements (FFMS). These analyses were based on the estimated degree to which benefits could be converted to canal revenues under alternate toll schemes. The estimated revenues and costs of canal alternatives were brought together in a cash flow analysis to identify financial feasibility. This also included an analysis of the types of management arrangements appropriate for the canal. These analysis are contained in reports by Nathan Associates Inc. et. al.

- Background Biological Data and Biological Inventory, Environmental Analysis. The biological data and inventory components and the environmental analysis were performed by separate contractors. They are linked for description purposes because the analysis was founded on the results of the data and literature search as well as physical inventory. The purpose of the biological data base and inventory was to identify the populations of aquatic and terrestrial flora and fauna that might be impacted by canal construction and operation. The purpose of the analysis was to quantify the ecological, principally non-human, impacts, and to identify measures to minimize or mitigate impacts. The biological data and inventory components are developed by ANCON/University of Panama et.al. The environmental analyses study is reported on by Dames and Moore Inc.
- Impacts on Panama. The final component study was an addition to the DPS designed to provide complete identification, and to the extent possible quantification, of all impacts attributable to construction and operation of canal alternatives. The analysis integrates and supplements the information on social, economic, financial, political, geographical, and ecological impacts contained in the background and other component studies. The Impacts on Panama analysis was prepared by Booz Allen and Hamilton, Inc.

Table 1.3-1

Study Cases for Optimization

Conceptual Alternative	Sub Group	Study Case	Ship Size	Summit Lake	Route
Alternative 1 High Rise	1 - a	L - 1	100	90	Existing Canal Alignment
		L - 4	150		
		L - 7	250		
	1 - b	L - 2	100	85	Existing Canal Alignment
		L - 5	150		
		L - 8	250		
	1-c	L - 10	100	85	New Canal Alignment in Gatun Lake
		L - 13	150		
		L - 16	250		
Alternative 2 Low Rise	2 - a	L - 3	100	55	Existing Canal Alignment
		L - 6	150		
		L - 9	250		
	2 - b	L - 11	100	55	New Canal Alignment in Gatun Lake
		L - 14	150		
		L - 17	250		
	2 - c	L - 12	100	30	New Canal Alignment in Gatun Lake
		L - 15	150		
		L - 18	250		
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	Nos.of lanes	Route 14S
		S - 10	250	2	
		S - 12	300		
	3 - b	S - 16	150	Combination 2+1	
		S - 17	250		
		S - 18	300		
	3 - c	S - 7	150	1	
		S - 9	250		
		S - 11	300		
Alternative 4 Sea Level Route 10	4 - a	S - 2	150	2	Route 10
		S - 4	250		
		S - 6	300		
	4 - b	S - 13	150	Combination 2+1	
		S - 14	250		
		S - 15	300		
	4 - c	S - 1	150	1	
		S - 3	250		
		S - 5	300		

1.3 Prescreening of Alternatives

In the important step of prescreening of the historical alternatives, the objectives were two-fold:

(1) preliminary optimization of canal size within a conceptual alternative; and,

(2) the relative evaluation of all conceptual alternatives.

In the process of prescreening, historical alternatives were simplified and grouped into four conceptual alternatives having basic similarities; namely a High Rise Lock Canal, Low Rise Lock Canal, Sea Level Canal on Route 14S and Sea Level Canal on Route 10. Each conceptual alternative was evaluated using a series of study cases shown in Table 1.3-1.

Each conceptual alternative included nine cases with each case representing different: routes, sizes of design ship, elevation rise in lake level (where appropriate), number of lifts, or number of canal ship lanes.

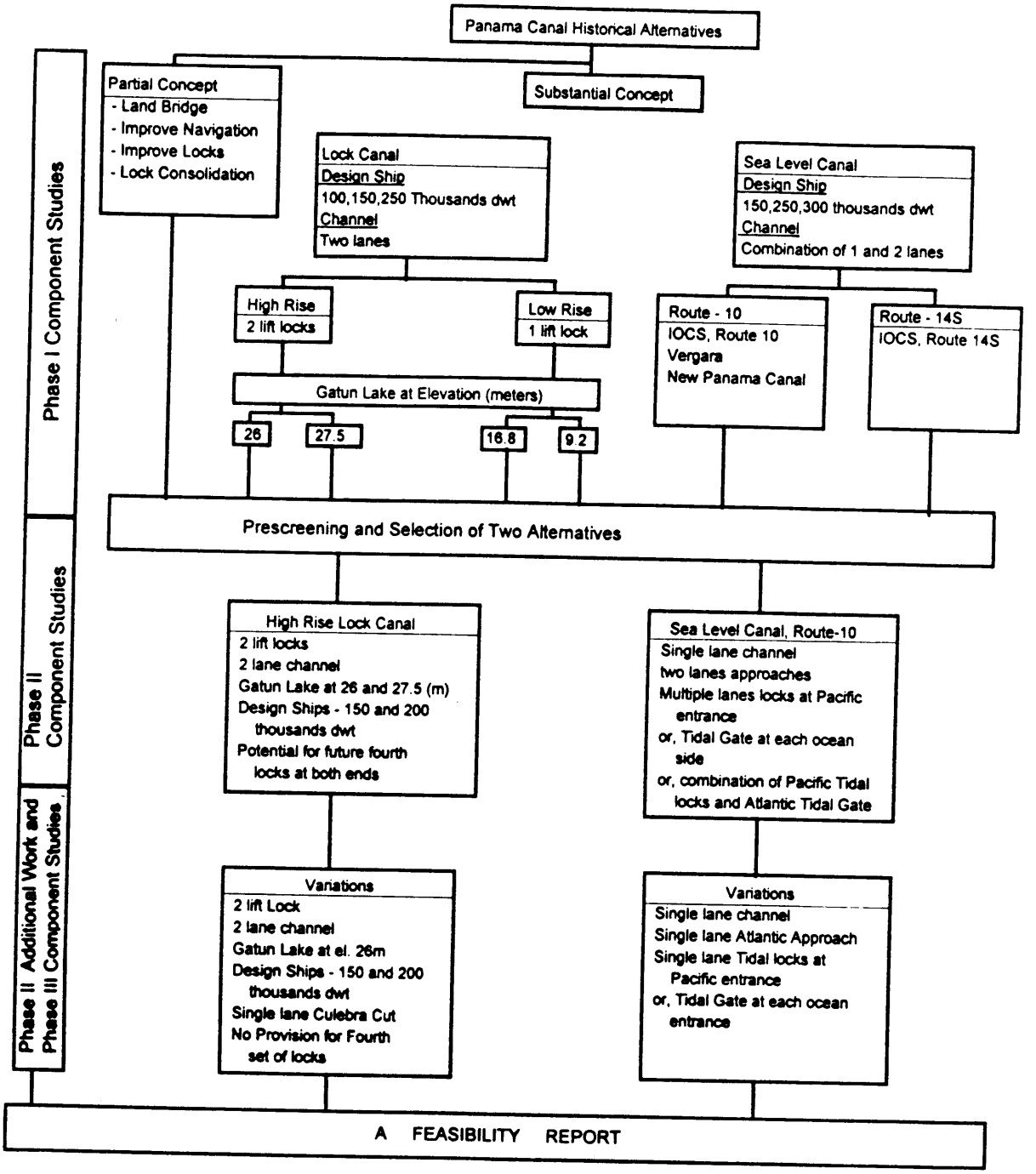
The route for the High Rise and Low Rise Lock Canal alternatives was the existing Panama Canal route with minor alignment changes to improve navigation. The number of lifts were one and two lifts. Two canal ship lanes were included in the evaluation. Different elevations for the canal Summit Lake were Elev. 85 and 90 feet for the high rise options and Elev. 30 and 55 feet for the low rise options. The design ships considered were 100,000 dwt, 150,000 dwt and 250,000 dwt.

The routes of the two sea level canal alternatives were those defined in the IOCS (1970) study as 14S, which approximates the present Panama Canal at sea level, and Route-10 which is about 18 km west of the existing Panama Canal. The design ships considered were 150,000 dwt, 250,000 dwt, and 300,000 dwt. Canal ship lanes considered one, two, and a combination of one and two lanes. The actual methodology and criteria for the prescreening of alternatives involved an assessment utilizing information obtained from each study case tabulated in Table 1.3-1.

The process included an assessment of the following key factors:

- Engineering Soundness,
- Approximate Benefit/Cost Evaluation,
- Adaptability for future expansion,
- Impact of construction upon the existing canal facility, and
- Environmental and Socioeconomic Impacts.

Figure 1.3-1
Process Used in Selecting Alternatives



The process was described in a submittal to CAS SC-100/92 dated June 24, 1992 entitled "Methodology and Criteria for Prescreening of Alternatives".

An approximate cost/benefit analysis and prescreening process were conducted by SINBOL. The results of this process are illustrated diagrammatically in Figure 1.3-1. The SINBOL prescreening recommended design ship sizes of 200,000 dwt for the High Rise Lock Canal, and 250,000 dwt for the Sea Level Canal - Route 10 for further studies.

SINBOL and the Secretariat conducted parallel prescreening exercises, which were presented to the Commission on July 14, 1992. Based on those presentations, the Board chose to proceed with the Phase II Component Studies for two alternatives, a High Rise Lock Canal and a Sea-Level Canal on Route-10 as illustrated in Figure 1.3-2.

1.4 Results of Component Studies

Through the Prescreening of Alternatives, two canal concepts with dissimilar sizes were selected for detailed investigation in Phase II and III - namely a design ship size of 150,000 and 200,000 dwt High Rise Lock Canal, and a design ship size of 250,000 dwt Sea-Level Canal-Route 10. These two canal concepts would provide additional transit capacity while allowing for continued operation of the Status Quo Canal.

1.4.1 Commodity and Traffic Projections

The three basic efforts involved in this component study were: (1) trade analysis and forecasts; (2) vessel fleet analysis and forecasts; and, (3) projection of canal traffic in terms of cargo tonnage and number of vessel transits. Two substantial associated efforts were: (1) analysis of U.S. overland transportation costs to determine potential shift in port and coastal routings for grain and container traffic; and, (2) analysis of ocean transportation cost for certain commodities (coal, iron ore, crude oil, and containerized cargo) to determine potential shift in vessel routings through use of a larger canal.

Trade Analysis

The foundation for the analysis was a proprietary world trade database and trade model. Worldwide trade in 1990 was approximately 4.1 billion tons. The model and database incorporated a large portion of worldwide trade involving bilateral trade between 60 individual countries, or combinations of countries, with 1990 maritime commerce of 2.6 billion tons. As described hereinafter, this total trade was winnowed to the canal related bilateral trade, relevant to the Panama Canal, and desegregated on a trade route basis to the trades for which canal routings are shorter (potential trade) and those which are not (non potential trade). The results are shown in the following Table 1.4.1-1 with actual and projected tonnages:

Figure 1.3-2
Location Map for Canal Alternatives

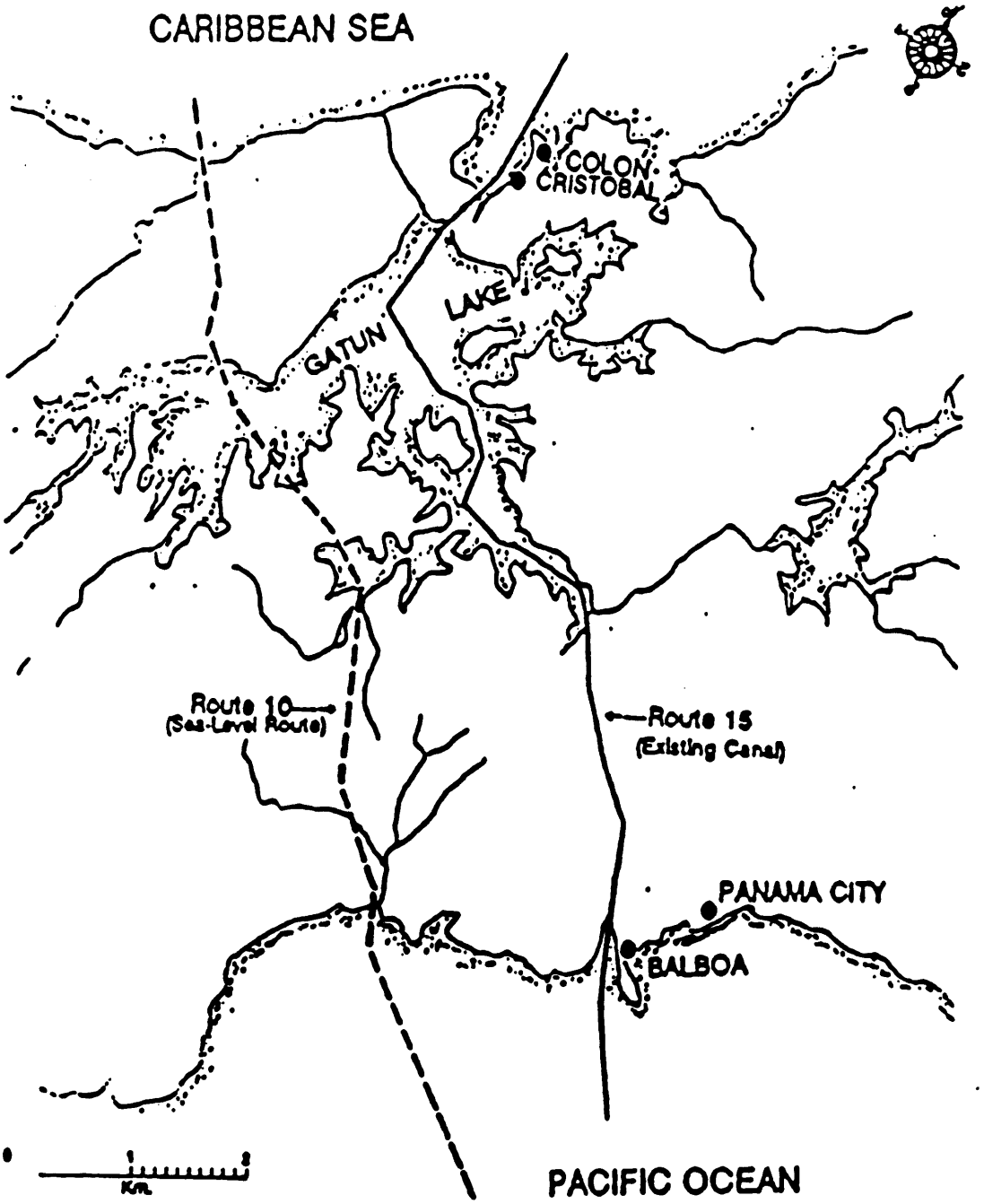


Table 1.4.1-1

Maritime Trade, Actual 1990 and Projections

(millions of metric tons)

Trade	Periods of Analysis		
	1990	2020	2060
Worldwide	4,060	NA	NA
Canal Bilateral	401	830	1,140
Potential	196	377	514
Non-Potential	205	447	625
Panama Canal	158	266	277

The "canal bilateral" trade (69 Trade Routes) includes most transoceanic trade but is significantly smaller than global trade because it excludes intra-regional trade. Intra-Europe maritime trade alone is about 1.5 billion tons. The identity of the specific countries involved was carried through most of the analysis to allow reexamination of potential versus non-potential splits, but was consolidated into 69 trade routes for traffic projections.

Commodities were consolidated into 14 categories, and mileage as a proxy for transportation cost was used to split potential from non-potential trade. Transportation costs via the canal and alternate routes were calculated later for other purposes. Actual and projected Panama Canal trade differs from potential canal trade principally because canal constraints make it more economical to use larger ships on more circuitous routes. Panama Canal trades, known as the Status Quo commodity flow, was projected by taking into account the capacity constraint of the SQ Canal.

Vessel Fleet Analysis

The potential traffic of canal alternatives will depend upon potential canal trade, the distribution of vessel sizes serving that trade, and the vessel size limits of the canal alternatives. Because vessels in world trade are subject to redeployment, the forecast of vessel sizes involved a series of vessel fleets:

(1) the world fleet, actual 1990 and estimated 2020 and 2060 size distributions for eleven vessel type categories;

(2) adjusted world fleets based on anticipated changes due to larger canal sizes (only expected to affect containerships and dry bulk carriers);

(3) the canal trade route vessel fleets, desegregated by canal direction (northbound, southbound) from the adjusted world fleets; and,

(4) the distribution of vessel sizes expected to use canal alternatives after excluding oversize vessels. Tabular summaries in the study do not show the distribution of trade route vessel sizes before the exclusion of oversize vessels.

Table 1.4.1-2 gives a summary based on the forecast for global fleet sizes. The canal-specific fleet forecasts gave percentage distributions for deadweight size ranges, and the average vessel deadweight within each range. Records of the Panama Canal Commission were used to identify the vessel types associated with specific commodities (some commodities move on more than one type vessel), the degree to which canal vessels are loaded (vessels do not always operate fully loaded), and the ratio of empty to loaded vessels on specific trade routes.

Table 1.4.1-2

Projection of World Fleet Composition by Vessel Size and Type

(percent cumulative capacity by vessel size increments in years 2020, 2060)

Vessel Type (excludes passenger)	Vessel Deadweight Size Increments					
	<65,000(1)		<150,000		<250,000	
	2020	2060	2020	2060	2020	2060
Container/Breakbulk	100.0	100.0	-	-	-	-
Full Container (2)	91.3	81.6	100.0	100.0	-	-
Full Container (3)	73.6	65.7	100.0	100.0	-	-
Breakbulk General	100.0	100.0	-	-	-	-
Refrigerated	100.0	100.0	-	-	-	-
Roll-on Roll-off	100.0	100.0	-	-	-	-
Vehicles Carrier	100.0	100.0	-	-	-	-
Dry Bulk (2)	61.9	65.7	81.5	78.3	95.3	95.5
Dry Bulk (3)	60.7	64.2	81.8	79.7	95.2	95.2
Dry Bulk (4)	60.6	64.2	81.6	76.0	95.2	95.2
Chemical Tanker	100.0	100.0	-	-	-	-
LPG Tanker	72.6	72.6	100.0	100.0	-	-
Oil tanker	17.6	21.2	45.9	52.2	54.7	66.3

Notes: (1) Dry Bulk <65,000 includes Panamax vessels to 90,000 dwt
(2) Global fleet with no size changes due to enlarged Canal
(3) Global fleet with size changes attributed to 150,000 dwt. Canal
(4) Global fleet with size changes attributed to 250,000 dwt. Canal

Projection of Canal Traffic

The trade and vessel forecasts were integrated by assigning commodity tonnages to the type vessels identified from PCC records, then consolidated by vessel type and trade route, and converted into vessel cargos based on the forecasted ship mix and average loads per PCC records. Vessel transportation costs were developed as part of the fleet forecast, and comparative transportation costs via the canal-route and the least cost alternative route were used to project specific bypass commodities coming to the canal route.

Since canal records show some non-potential trade moving via the canal for reasons such as liner vessel itinerary, total traffic projections include that additional traffic. It represents about ten percent of Present Canal traffic.

The final results are shown in the following table.

Table 1.4.1-3

Panama Canal Traffic, Actual 1990 and Projections

(thousands of metric tons, total number of vessels loaded and empty)

Design Vessel Size	Cargo Tonnage			Vessel Transits		
	1990	2020	2060	1990	2020	2060
Present Canal	157,472	265,962	276,529	11,162	17,359	18,078
150,000 dwt	NA	360,990	490,647	NA	17,796	23,934
200,000 dwt	NA	363,312	494,726	NA	17,844	24,074
250,000 dwt	NA	369,833	508527	NA	17,856	24,053

Supplemental Analyses

The vessels and their associated cargos now transiting the Canal are not expected to be affected by canal size constraints except for dry bulkers, oil tankers and container ships. For the unaffected vessel types, the conversion of trade forecasts to cargo projections was a straightforward arithmetic exercise, as described above. Transportation costs for the vessels subject to size constraints were scrutinized to identify movements "at the margin" and these were given detailed supplemental analysis. The affected vessel types and the specific cargo movements examined were as follows: (Some LPG tankers exceed the present canal's limits, but they do not operate on Canal routes.)

•	Dry Bulkers	Coal, U.S. East Coast to Far East Coal, U.S. Gulf Coast to Far East Coal, Colombia East Coast to Far East Coal, Canada West Coast to Europe Coal, Canada West Coast to Brazil Iron Ore, North Brazil to Far East Iron Ore, Venezuela to Far East Iron Ore, Canada East Coast to Far East Iron Ore, Chile to Europe
•	Oil Tankers	Crude Oil, Venezuela to Far East
•	Containerships	Containers, U.S. East Coast to/from Far East Containers, U.S. West Coast to/from Europe

Based upon detailed voyage costing and consideration of vessel alternatives (sizes, routing, and backhauls), projected canal traffic was split out of the potential dry bulk cargo movements according to canal size. The dry bulk analysis did not consider grain because it was assumed that U.S. port depth constraints would limit the size of grain vessels in canal grain traffic.

The Venezuelan oil movement is a heavy crude in water emulsion. It was assumed that it would be unsuitable for the trans-isthmian pipeline, and could be a canal movement for the alternative sizes of canals. The containership analysis focuses on the comparative cost and apparent time-value advantage of U.S. overland transportation. Comparative costs and the capacity to transport containers was investigated. The findings indicate that some containerized cargos would become part of potential commodity flows.

1.4.2 Engineering and Cost Estimates

The engineering basis for cost estimates involved three critical design assumptions: (1) design vessel sizes, (2) clearances between vessels and channel and lock geometry, and (3) the resulting channel and lock dimensions. Because of the importance of these assumptions, they were fixed by agreement or direction of the Secretariat. The purpose in so fixing the assumptions was to make competing lock canal and sea level canal designs as comparable as possible.

Design Vessels

During the course of the study, the Secretariat specified the dimensions for design vessels of 100,000, 150,000, 200,000, 250,000 and 300,000 deadweight tons. The dimensions for design purposes were based on the envelope of actual vessel dimensions in those sizes so that all vessels of the specific deadweight ton displacement could transit the canals. Average vessel dimensions in most sizes are significantly less. The dimensions of design vessels for the final canal sizes are shown in Table 1.4.2-1.

Figure 1.4.2-1

Construction Cost Estimates

Canal Type	High Rise Lock Canal (HRLC)				Sea Level Canal Route-10 (SLC-10)				
	150 dwt		200 dwt		Pacific Lock		Pacific/Atlantic Gates		Gate/Lock
	Two lane	One lane	Two lane	One lane	Two lane	One lane	Two lane	One lane	Two lane
Total Excavation[1]	3,100.0	1,680.7	3,565.0	1,980.8	6,433.0	6,432.9	7,562.0	6,088.4	6,433.0
Lock and/or Gate[2]	1,880.0	1,744.1	2,138.0	1,981.9	2,987.0	820.5	1,167.0	1,166.9	3,545.0
Hydraulic Structures[3]	0.0	0.0	237.0	237.0	971.0	971.0	971.0	971.0	971.0
Transportation[4]	459.0	459.0	510.0	510.0	241.0	207.0	328.0	241.0	241.0
Navigation System	414.0	414.0	414.0	414.0	546.0	546.0	477.0	477.0	546.0
Construction Support	425.0	291.2	425.0	291.2	574.0	481.4	574.0	481.4	574.0
Others[5]	1,095.0	829.4	1,256.0	959.7	1,175.0	1,429.7	1,668.0	1,424.8	1,848.0
Total (2020)	7,373.0	5,418.5	8,546.0	6,374.8	13,519	10,888.7	12,747.0	10,850.7	14,159.0
Additional (2060)	1,407.0	1,407.0	1,350.0	1,350.0	1,717.0	1,717.0	775.0	775.0	1,717.0
Total (2020 + 2060)	8,780.0	6,825.5	9,896.0	7,724.8	15,236	12,605.7	13,522.0	11,625.7	15,876.0
Operating and Maintenance - Annual Costs in Million Dollars									
Year 2020	493.6		501.4		541.2		531.5		546.0
Year 2060	595.0		602.8		634.4		624.4		639.2

Notes: Source: YEC, Phase II Final Report and Additional Work

1 Total Excavation includes dry, wet, and excavation spoil placement.

2 Lock and/or Gate includes fabrication, transportation, construction of related facilities.

3 Hydraulic Structures includes construction of dams, breakwaters, diversion, recycling, etc.

4 Transportation includes construction roads and permanent roads and bridges.

5 Others include all indirect construction costs.

6 One lane means, in the case of High Rise with one lane Culebra Cut and in Sea Level, single lane approaches.

Table 1.4.2-1
Design Vessel Dimensions
(dimensions shown in feet/meters)

Vessel Size	Length	Beam	Draft
150,000 dwt.	1003.9'/306 m.	150.9'/46 m.	59.1'/18 m.
200,000 dwt.	1092.5'/333 m.	164.0'/50 m.	62.3'/19 m.
250,000 dwt.	1168.0'/356 m.	177.2'/54 m.	68.9'/21 m.

Design Clearances

Channel and lock dimensions are derived from the design vessel dimensions after allowance for clearances to minimize potential vessel contact with fixed objects and other vessels. Since vessel movements reflect individual vessel characteristics and the effects of wind, waves, currents and human error, (and in confined channels, the effects of water compression called bank suction and vessel squat), there is no way to design an absolutely safe canal.

Prevailing practice worldwide is to base clearances on historical experience, and increasingly, physical modelling and computer simulations are used to refine dimensions. Although there has been some modelling of the existing and previously considered canals in Panama, time did not permit such refinement for this canal alternatives study. Instead, generic allowances for the various clearances were used that favored safe navigation.

Clearance allowances are commonly accounted for in a ratio of channel dimension to vessel beam or draft, where the channel dimension includes the combination of vessel or vessels and clearances. Alternately, the allowance can be calculated as a series of clearances for specific factors such as vessel roll, heave, squat, and weather conditions. Although worldwide the practices differ, the end results are remarkably similar.

The Canal Alternatives Study provided for safe clearances by using ratios based on design vessel dimensions, at the upper end of ranges for expected operating conditions.

The design clearance ratios used for study purposes are shown in Table 1.4.2-2. Additional widths at channel bends were calculated based on formulas.

Table 1.4.2-2

Channel and Lock Design Parameters

(ratio of critical dimension to design vessel dimension)

Critical Dimension	Vessel Dimension	Design Ratio Used
Channel Width, one-way	Beam	3.5
Channel Width, two-way	Beam	7.0
Channel Depth	Draft	1.15
Lock Width, one lane	Beam	1.1 ±
Lock Depth	Draft	1.1 ±

Channel and Lock Dimensions

Vertical and horizontal dimensions were largely the product of the two preceding assumptions, but were fixed for study purposes by the Secretariat. Lock length clearances are usually site-specific, there are no generic criteria, and a judgement call is required. Lock lengths provide for assisting tugboats in the lock canal alternatives. The tidal lock length does not. The resulting dimensions are shown in Table 1.4.2-3.

Table 1.4.2-3

Channel and Lock Chamber Dimensions

(dimensions shown in feet/meters)

Vessel	Channel		Lock Chamber		
Size	Width	Depth	Length*	Width	Depth
150,000 dwt.	1049.9'/320.0 m	68.9'/21.0 m	1279.5'/390.0 m	164.0'/50.0 m	65.6'/20.0 m
200,000 dwt.	1148.3'/350.0 m	72.2'/22.0 m	1378.0'/420.0 m	180.4'/55.0 m	70.5'/21.5 m
250,000 dwt.	1246.7'/380m[1]	78.7'/24.0 m	1410.8'/430.0 m	196.9'/60.0 m	75.5'/23.0 m

Notes: * Determined by the ECE Contractor considering emergency space.
(1) one-way channel width is 623.4'/190.0 m.

Lock Canal (HRLC) Features

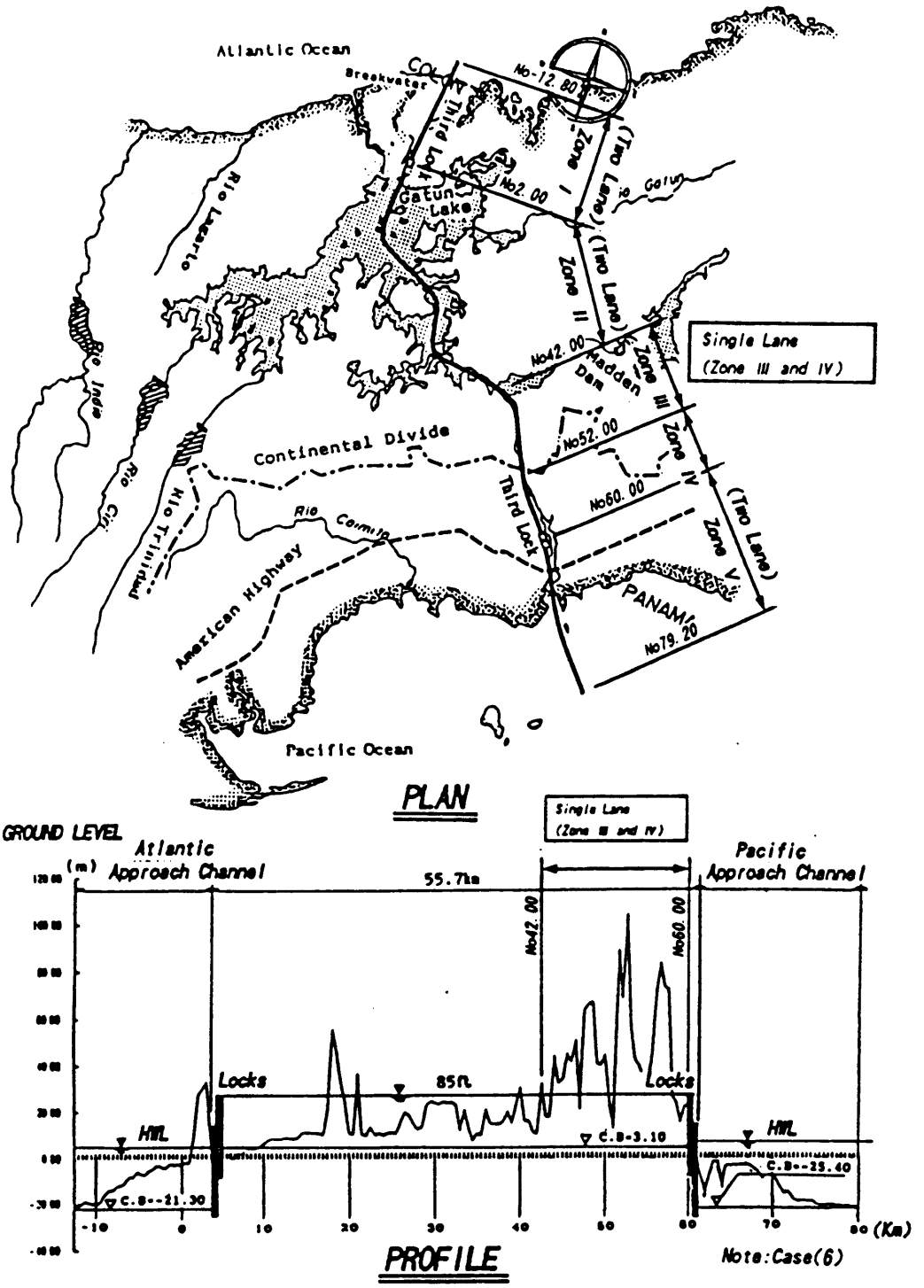
The location, route, and profile of the lock canal alternatives are shown in Figure 1.4.2-1. Both alternatives, for either 150,000 or 200,000 dwt. vessels, would use the route of the present canal except for new channels that would by-pass the existing locks at both Gatun and Miraflores Lakes. At each lock site a single lane of lock chambers would raise vessels to lake level, or lower vessels to sea level, in two lifts. Along with accommodating larger vessels, the new locks would facilitate vessel transits by using fewer lock chambers or lifts, and by consolidating lockage operations on the Pacific side at one location. The existing locks, which require three lifts to and from lake level would remain in operation. On the Atlantic side, the new channel would utilize the third locks excavation and lock site east of Gatun Locks. The new Pacific locks and bypass channel are proposed to be at about 2 km west of the 1942 excavation to improve navigation.

Overall, the lock canal alternatives incorporate desirable features from previous canal studies including the new channel alignment on the Pacific side, avoid the disruption of canal traffic in the Terminal Lake Plan, and add improvements such as two-lift rather than three-lift locks. Costs are dominated by excavation and lock construction. Although a full array of canal infrastructure is already in place, substantial investment would still be required for navigation aids and equipment to assist vessels through the new locks. Estimated costs also include up to $0.5 billion for new or replacement bridges. As shown in Section 1.4.2.6, $337 to $971 million is for lock water supply. Because the timing of that investment is subject to some key assumptions, an explanation follows.

The supply of lockage water for the present Panama Canal has been a matter of concern over time because of occasional dry years and the anticipation of increasing numbers of lockages. The amount of water from rainfall and existing or proposed reservoirs can be calculated with reasonable precision. Alternately, lockage water can be recycled by use of holding ponds and pumping. That is a more expensive solution. As a result, finding a workable solution is not the major problem; the challenge is to estimate the amount of water needed, based on vessel transits, and lock cycles and flushes. The analysis of canal alternatives introduced a new dimension into estimating water consumption because larger locks will use more water, and consumption will depend on how vessels are routed through the two canals. With the lock canal alternatives or with dual canal operation, vessels can be routed to minimize water consumption <u>or</u> to maximize vessel transits. The engineering analysis favored water conservation and the capacity analysis optimized vessel transits, hence they produced differing estimates of water consumption.

Ultimately, the determination of water consumption for design purposes involved a judgement call, provided by the Secretariat. This affected when the water supply dams would be needed for lock canal alternatives, not their size or cost. Under all assumptions, the 200,000 dwt. canal would require a new water source dam (Indio) as part of initial construction.

Figure 1.4.2-1
Lock Canal Alternatives



Depending on assumptions, the 150,000 dwt. canal would require the same new source either initially or early in the 2020-2060 period. Each canal alternative would require an additional dam during the period for water regulation (different sources). As insurance, both lock canals have provisions for the recycling of lock water. The present canal would not need additional water supply or recycling for operation in conjunction with the sea-level canal.

The sea-level canal would include one water storage dam to supply a proposed freshwater barrier.

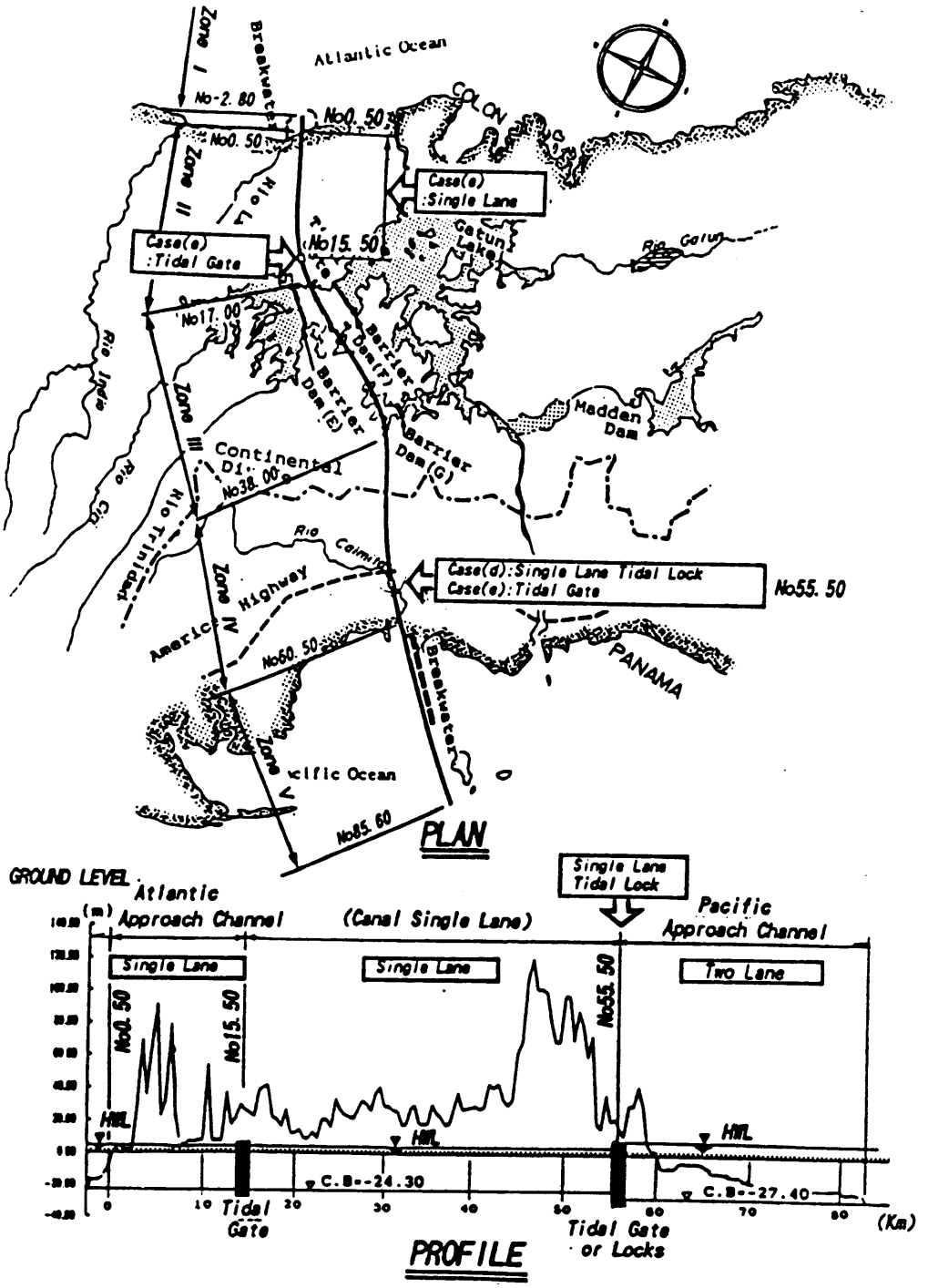
Sea-level Canal Features

The location, route, and profile of the sea-level alternative are shown in Figure 1.4.2-2. The canal route utilizes the Chorrera Gap to cut through the continental divide about 15 kilometers west of the present Panama Canal. Total length of the new canal, coastline to coastline, would be about 60 kilometers, and length deepwater to deepwater (- 20 m.), would be about 90 kilometers. Comparable lengths for the Panama Canal and lock canal alternatives are about 65 and 95 kilometers. Although the sea level route is somewhat shorter, its average and peak ground elevations are higher. The Pacific entrance of the sea level canal would be at the town of Puerto Caimito at the mouth of the Caimito river. North of the continental divide the route crosses two arms of the present Gatun Lake, and barrier dams would be required to maintain the lake and separate lake and canal water levels. The route also intersects a number of rivers, and diversion channels and structures would be required. At the north end, the Atlantic entrance would be at the town of Nuevo Chagres near the mouth of the Rio Lagarto. The Pacific and Atlantic entrance channels would require dredging for a total length of 27.3 kilometers, and breakwater protection.

As shown in the cost section, excavation cost dominates total canal cost. Although there are no navigation facilities and only a limited amount of other transportation infrastructure in place along the sea-level route, the estimated costs for those categories approximates those for lock canal alternatives. Similar to the lock canals, four bridges would be required, but the lower population density permits simpler structures. Since water supply costs are also substantially smaller, tide locks and/or tide gates are the second largest cost category. The amount of these costs, and the variation in costs of alternate solutions to control tide height and currents deserves explanation, and can be summarized as follows.

Conceptually, a sea-level canal operates at mean or average sea level. In practice, sea level depends on the stage of the tide. In the case of a Panama Canal, Atlantic tides rotate around mean sea level by about nine inches, those on the Pacific by about nine feet. Without tidal control structures, there will be a lot of water flowing in one direction or the other, on balance from Pacific to Atlantic. The resulting currents have been determined unacceptable for vessel navigation. The alternate control structures are tide locks or tide gates. Most lock gates are built for water pressure from one direction, and they are expensive.

Figure 1.4.2-2
Sea Level Canal Alternative



Lock gates can be built to handle water pressure from alternate directions, and they are even more expensive. Tide gates are routinely built to withstand pressure from alternate sides. Unlike lock gates that function in pairs with a vessel chamber in between, tide gates function alone to hold the water within the canal at mean sea level when the tide is low. Above mid-tide, the gate can be opened for the passage of vessels. Tide gates are a lower cost solution for canal operation. They also have some significant implications. Since they open only above mid tide, they are open to vessel traffic only half of each day. If vessels traveling in opposite directions have to share use of the same gate, as contemplated for the sea-level alternative, vessels in any one direction can use it about half of a half of a day. Since the flow of water through the gate is tidewater, biota migration through the canal is a distinct possibility. Use of a lock with a freshwater head or pumped freshwater filling could minimize the migration. The design of such features need further detailed investigations, modeling and refinements, which would be necessary in order to establish a basis for the implementation of this very sensitive project.

In the "low cost" solution with tide gates, a Pacific tide gate five kilometers inland from the coast would operate in conjunction with an Atlantic tide gate 15 kilometers inland from the Atlantic coast. Due to different timing of tide heights, one gate would be open when the other was closed. The gate openings would be 190 meters wide, and vessels could move through unassisted. Although there would be a peak head of tidewater of about nine feet at Pacific high tide, the confined channel between tide gates would moderate tide currents. The high head of Pacific tidewater also means that there would be a persistent flow from Pacific to Atlantic.

The next lowest cost solution would use tide locks at the Pacific location only. They could be filled with tidewater to eliminate the free flow of ocean tide water and most currents. The tidal lock chambers investigated consisted of a multi-lane lock to provide reasonable capacity during the tide window. Costs for this sub-alternative are based on three lanes initially, with addition of a fourth lane before 2060. The tidal lock chamber was reduced in the Phase II additional study of a single lane. The high cost solution would combine the Pacific tide lock with an Atlantic tide gate. The combination would effectively eliminate tidal currents, and with provision for filling the lock with freshwater, could provide a freshwater barrier to biota migration. The development of such a scheme may provide an acceptable freshwater barrier; however additional investigation and development would be required to confirm this proposed solution.

Cost Estimates

The final engineering analysis determined costs for seven canal configurations. They include two sizes of lock canals with alternate Gatun Lake levels of 85 and 90 feet, and one size of sea-level canal with three alternate solutions for structures to handle tide height differences. Prior to final feasibility analyses, the 90-foot lake level was eliminated as not a cost effective tradeoff for decreased channel excavation. The trade offs for tide control structures were unresolved, and this produced the array of cost estimates shown in Table 1.4.2-4 and Figure 1.4.2-3. The engineering cost estimates were the basis for economic and financial feasibility analyses that are described hereinafter.

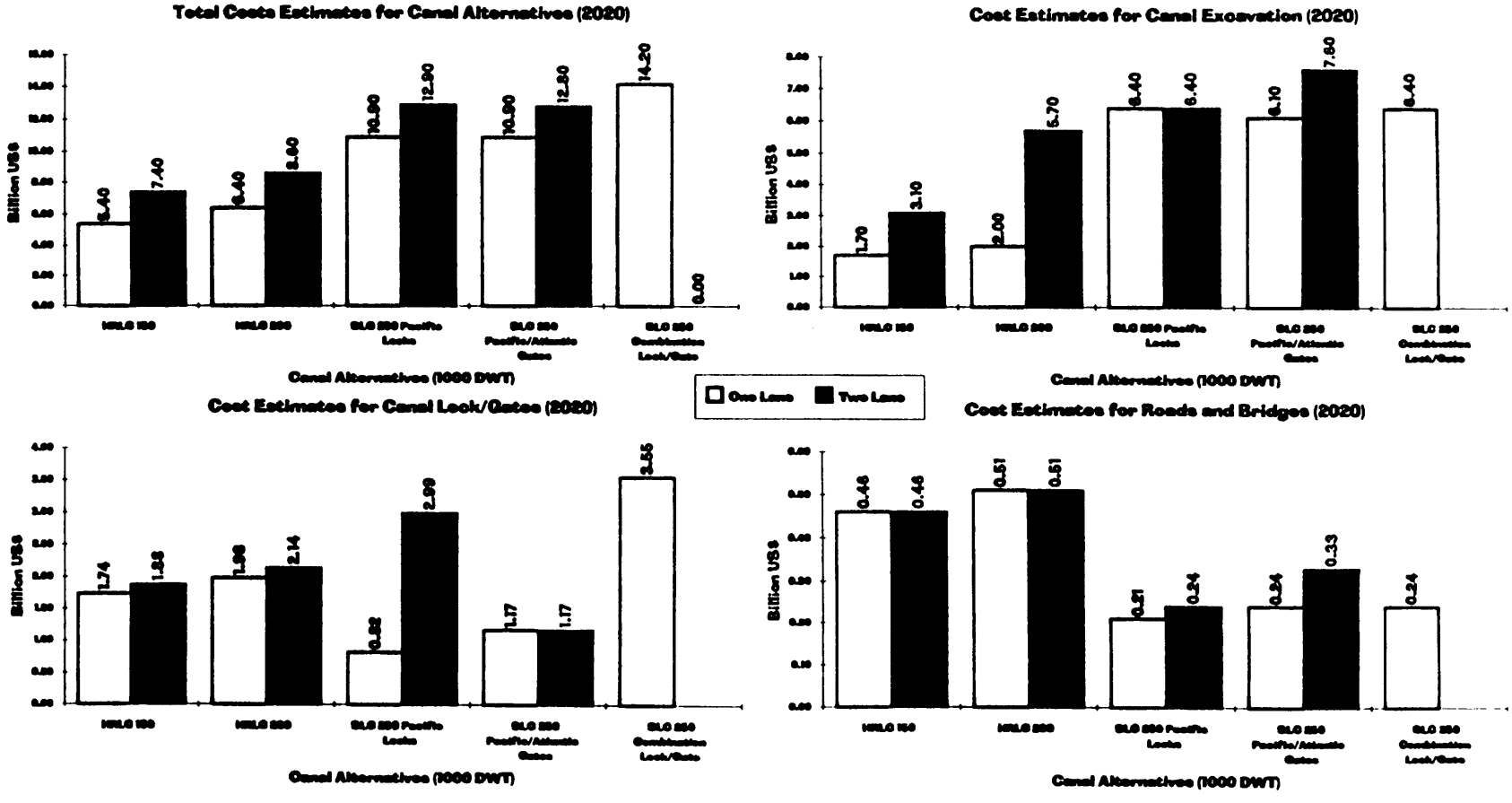
Table 1.4.2-4
Construction Cost Estimates (million US$)

Canal Type	High Rise Lock Canal (HRLC)				Sea Level Canal Route-10 (SLC-10)				
	150 dwt		200 dwt		Pacific Lock		Pacific/Atlantic Gates		Gate/Lock
	Two lane	One lane	Two lane	One lane	Two lane	One lane	Two lane	One lane	Two lane
Total Excavation[1]	3,100.0	1,680.7	3,565.0	1,980.8	6,433.0	6,432.9	7,562.0	6,088.4	6,433.0
Lock and/or Gate[2]	1,880.0	1,744.1	2,138.0	1,981.9	2,987.0	820.5	1,167.0	1,166.9	3,545.0
Hydraulic Structures[3]	0.0	0.0	237.0	237.0	971.0	971.0	971.0	971.0	971.0
Transportation[4]	459.0	459.0	510.0	510.0	241.0	207.0	328.0	241.0	241.0
Navigation System	414.0	414.0	414.0	414.0	546.0	546.0	477.0	477.0	546.0
Construction Support	425.0	291.2	425.0	291.2	574.0	481.4	574.0	481.4	574.0
Others[5]	1,095.0	829.4	1,256.0	959.7	1,175.0	1,429.7	1,668.0	1,424.8	1,848.0
Total (2020)	7,374.0	5,418.5	8,546.0	6,374.8	13,519	10,888.7	12,747.0	10,850.7	14,159.0
Additional (2060)	1,407.0	1,407.0	1,350.0	1,350.0	1,717.0	1,717.0	775.0	775.0	1,717.0
Total (2020 + 2060)	8,781.0	6,825.5	9,896.0	7,724.8	15,236	12,605.7	13,522.0	11,625.7	15,876.0
Operating and Maintenance - Annual Costs in Million Dollars									
Year 2020	493.6		501.4		541.2		531.5		546.0
Year 2060	595.0		602.8		634.4		624.4		639.2

Notes: Source: YEC, Phase II Final Report and Additional Work
1 Total Excavation includes dry, wet, and excavation spoil placement.
2 Lock and/or Gate includes fabrication, transportation, construction of related facilities.
3 Hydraulic Structures includes construction of dams, breakwaters, diversion, recycling, etc.
4 Transportation includes construction roads and permanent roads and bridges.
5 Others include all indirect construction costs.
6 One lane means, in the case of High Rise with one lane Culebra Cut and in Sea Level, single lane approaches.

Figure 1.4.2-3

Construction Cost Estimates



In all of the canal alternatives shown in Table 1.4.2-4, operation and maintenance costs reflect combined operation of the existing Panama Canal and the canal alternative. The estimated operation and maintenance (O & M) costs for the existing canal that are included in the annual O&M shown are $421.2 and $469.2 million for 2020 and 2060, respectively.

For comparison with Table 1.4.2-4, initial excavation for the present Panama Canal was 177 million cubic meters. Cost was $387 million.

1.4.3 Capacity Estimates

The three basic efforts involved in this component study were: (1) estimation of tidal currents in the proposed sea level canal; (2) identification of relevant vessel and canal operating practices and parameters; and (3) based on the results of those investigations, simulation modeling of vessels using the Panama Canal and canal alternatives. Two associated efforts were estimation of sedimentation in the sea-level canal from intersecting rivers and at ocean entrances, and identification of the type and costs of navigation aids and vessel assistance for all canal alternatives.

Estimation of Tidal Currents

Table 1.4.3-1

Estimated Tidal Currents in Sea Level Canal

(specific locations of maximum speeds generalized for display purposes)

Canal Configuration	Maximum Water Speed in Knots		
	North End	Mid-Canal	South End
No Gates, 425 m.wide channel	5.5	4.7	4.2
No Gates, 180 m.wide channel	5.2	4.2	4.0
Two Gates, 60 km. & 180 m. channel	0.2	1.3	2.2
Two Gates, 40 km. & 150 m. channel	0.0	1.0	1.0
Vergara, 210 km^2 Basin	4.3	3.3	3.1
Vergara, 100 km^2 Basin	4.7	3.9	3.4

The foundation for this analysis was a proprietary mathematical model (LATIS). The results for open channel flow and for flow control by tide gates agreed generally with the results of mathematical modelling for the 1970 canal study by the U.S. Army Corps of Engineers. In addition, the largest effort modelled currents for an alternative to tide gates to control Pacific tide heights, an artificial embayment as proposed in the "Vergara Plan". The results are summarized in Table 1.4.3-1. As shown in Table 1.4.3-1, there is an inverse correlation between canal size and current speed. Smaller currents are better. The Vergara basins did not reduce currents significantly, and resulted in unacceptable (9 to 17 knot) currents at the ocean entrance to the basins.

Identification of Operating Practices and Parameters

The investigation was useful for identifying equipment to facilitate lock and canal transits. The most significant finding for capacity analysis was that current speeds for safe vessel navigation should not exceed two knots for vessels headed into the current, one knot for vessels traveling with the current. This fixed the need for tide current control structures in the sea-level alternative. It also identified the desirable pattern for vessel transits in the sea-level canal. For the best vessel control, it is desirable to have the vessel headed into the current at all times.

It is possible to schedule transits of the sea-level canal so that vessels are always headed into the current, because of the timing of Atlantic and Pacific tides and the length of the canal. However, that requires the vessel or vessel convoys to enter the canal on a falling tide. The result is that vessels or convoys headed in any one direction have just two windows of opportunity each day, three hours each, to start a canal transit.

Simulation of Canal Transits

Computer simulations of canal transits were performed using a modification of a model developed for lock canal system analysis. Since all canal alternatives eventually incorporated some combination of locks or tide gates, it was an appropriate model to use. The principal findings were;

(1) the capacity of the present Panama Canal will be inadequate to accommodate the number of vessels projected to use that canal in 2020 and subsequent years;

(2) the capacity of both lock canal sizes would be more than adequate to accommodate their projected traffic throughout the analysis period ending 2060;

(3) a sea-level canal with two lanes throughout would have more than adequate capacity for all projections, but a single lane canal or a canal with a single lane central section would have a capacity approximating that of the present canal, hence the selected sea-level alternative, with a one-way central section, would have to operate in conjunction with the present canal; and,

(4) the combined capacity of the single lane sea level alternative and the present canal would be more than adequate.

In the capacity analysis, a critical assumption was the amount of delay associated with canal use that vessel operators would accept. Some amount of delay is routine in canal use for various reasons, and vessel operators usually allow a day for canal transits although actual travel through the canal may take about nine hours. Two estimates of capacity were produced, based on average delay times of six and ten hours. Capacity estimates were derived from delay curves produced by multiple runs of the model using incremental numbers of transits. The higher estimated capacity (at ten hours delay) is at the point where the delay curve becomes almost vertical, hence very little additional capacity would accrue with extraordinary delay times.

All variations of the selected sea-level alternative are tide dependent, hence an average tide delay of 4.5 hours can be expected, plus additional delay due to peaking because of random vessel arrivals. The simulations produced a large number of capacity estimates that are shown in the component study report. Vessel transit capacity estimates for the Status Quo Panama Canal and selected canal alternatives are shown in Table 1.4.3-2, along with vessel transit projections.

Table 1.4.3-2

Canal Capacity Estimates and Projected Vessel Transits

(sea level canal capacities are combined capacity, sea-level and present canal)

Canal Size & Type	Transit Capacity		Transit Projection	
	6 Hr. Delay	10 Hr. Delay	Year 2020	Year 2060
Present Canal, Status Quo	16,100	17,000	17,359	18,078
150,000 dwt Single Lane Lock, Double Lane Canal	32,500	34,600	17,796	23,934
150,000 dwt Single Lane Lock, Culebra Cut Single-Lane	31,200	34,400	17,796	23,934
200,000 dwt Single Lane Lock, Double Lane Canal	33,200	35,300	17,844	24,074
200,000 dwt Single Lane Lock, Culebra Cut Single-Lane	31,600	34,600	17,844	24,074
250,000 dwt Sea Level (with tidal gates)	42,500	44,000	17,856	24,053
250,000 dwt Sea Level (with 3 Pacific tidal locks)	33,300	41,700	17,856	24,053
250,000 dwt Sea Level (with/ Pacific tidal lock)	20,800	24,000	17,856	24,053
250,000 dwt Sea Level (tidal gates & Atlantic single lane approach)	—	35,800	17,856	24,053

One of the important results of the computer simulations as shown above, was to produce more total capacity for the combined sea-level/Panama Canal operation, as well as the existing canal modified by adding new locks, than the total for either combined new canal system operating as separate individual canals. This happened because the computer model assigned vessels to the two canals based on least delay time, vessel size permitting.

Other findings from the capacity analysis were that single lane traffic in Culebra Cut reduced capacity of the lock canal alternatives by only a small amount, about five percent. Single lane traffic in the sea-level canal north of the central section would reduce capacity a substantial amount, about 20 percent, but remaining capacity would be fully adequate for all traffic projections shown in Table 1.4.3-2. The results of sedimentation analysis and identification of vessel navigation assistance requirements were incorporated in the engineering effort.

1.4.4 Impact Assessment Studies

Two separate component studies addressed different aspects of impact identification. The Environmental Analysis Component Study focused on ecological issues whereas the Impacts Upon Panama study considered a broad array of impacts that could affect the human inhabitants of Panama. The results of the baseline studies, Background Biological Data and Biological Inventory, were the foundation for findings of the environmental analysis. The Impact Upon Panama study relied on independent analysis using information from background and other component studies.

Background and Baseline Information

Impact identification depends on a through understanding of existing conditions, and the ability to predict future change. Within the time limits available for performing this study, sufficient information was developed to produce initial estimate of impacts of construction and operation of canal alternatives. The environmental analysis recognize that additional information will be needed prior to actual project construction, for a more precise determination of impacts of the selected alternatives.

A background study, Present Situation in Panama, provided a relevant history of Panama and descriptions of physical conditions and human activities. It was and is a useful reference. The biological baseline studies, Background Data and Inventory, are described more fully below.

Background Biological Data

A literature search and a field inventory were distinct but related efforts to produce baseline information identifying the aquatic and terrestrial flora and fauna that might be impacted by project construction and operation. Both efforts were performed by the same contractor consortium and were confined to a study area defined in the terms of reference for the component studies.

This study area was designed to provide information for assessment of a lock canal. The study area is shown in Figure 1.4.4-1.

The literature search identified all existing ecological information about the study area. It then identified the representative and important habitats for further study. The habitats were delineated on maps, with a preliminary classification system based on physical characteristics. The literature search included examination of aerial photographs, and these were used to identify and classify land use, also the extent of deforestation due to urbanization, farming and logging, and the extent and type of remaining forest cover.

Biological Inventory

The literature search identified the species and habitats reported in the study area. The purpose of the field inventory was to verify or identify the population density of the species in their respective habitats, and to identify the factors now affecting population size such as water quality and deforestation.

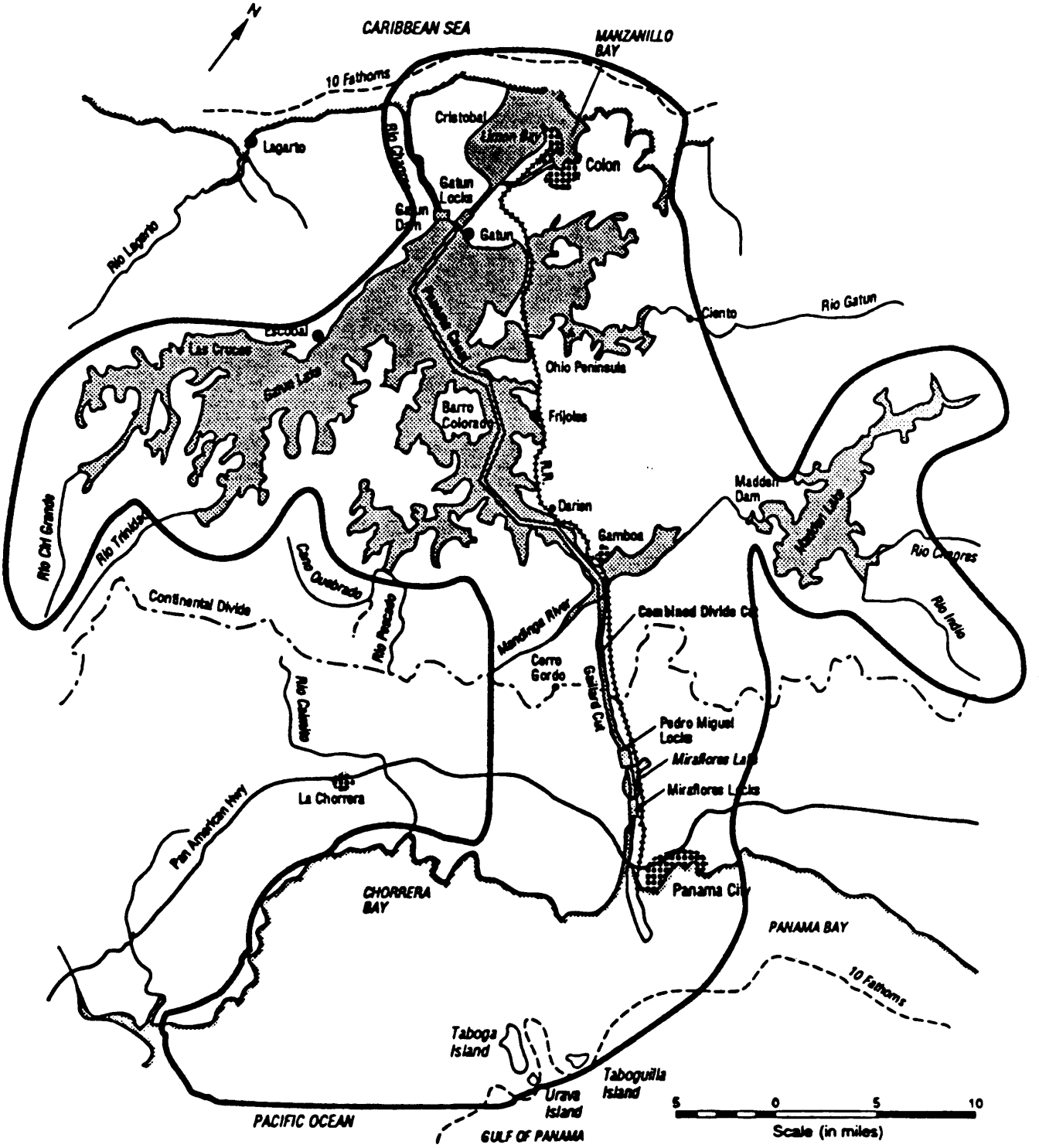
Because the study area defined in the terms of reference for the study did not include all of the sea-level canal route, the inventory results are directly relevant for lock canal alternatives and impacts for the sea level canal must be inferred. Because the duration of the inventory was 14 months, it provided some indication of seasonal variation in habitat population, but it does not identify longer-term variation and trends.

Habitat locations within the study area were determined by habitat importance or as specified in the terms of reference. Within specific habitat locations, sites for observations, surveying, and sampling, were fixed by map coordinates (transects). The inventory of terrestrial flora was based on surveys that identified size, abundance, mixture of species, and importance.

Terrestrial vegetation, insects, reptiles and amphibians, birds, and mammals were identified and inventoried in different locations throughout the Study Area. Freshwater physical and chemical parameters were measured throughout the Study Area. Freshwater physical and chemical parameters were measured throughout the Canal basin, and macrophytes, benthic organisms, and fish were collected and inventoried.

Chemical and physical parameters were also measured in the marine environment in the Pacific and Caribbean portions of the Study Area, along with the collection of benthic organisms and fish, and the study of mangrove estuaries, sea grass beds, and coral reefs. Overall the inventory effort consisted of about 500 sampling sites and over 2000 data collection trips.

Figure 1.4.4-1
Study Area



Environmental Analysis Study Results

The Environmental Analysis study evaluated the different ecological effects of the activities with the construction, operation, and maintenance of the two canal alternatives, recommended mitigation measures, and identified additional environmental studies that would be required. This evaluation emphasized important species, as well as significant ecological habitats and communities. Among the issues considered were biological, physical, and water quality changes in fresh and marine waters, effects on terrestrial flora and fauna, effects on protected and unique habitats, and potential for effects on protected and unique habitats, and potential for interoceanic transport of marine organisms. The impacts resulting from construction, operation, and maintenance of a canal vary according to the environmental resources in each of the areas effected.

Impacts common to both Alternatives include:

- Destruction of forested areas and damage and destruction to terrestrial habitats, species, biological and genetic diversity of the flora and fauna.

- Changes to freshwater and marine habitats and organisms caused by aquatic excavation and disposal of excavated material.

- Adverse impacts on adjacent wetland and movement of water in the area, caused by construction of new roads.

- Impacts on river flow, aquatic biota and sedimentation patterns, loss of fish spawning areas and creation of barriers to fish movement from the creation of dams and impoundments.

- Impacts to mangrove swamps, salt marshes, estuaries, seagrass beds, and coral reefs, resulting from various marine development activities.

- Creation of habitats for various insect disease vectors.

In general, the High Rise Lock canal has a greater potential for impacts to terrestrial rather than aquatic resources. Specific impacts include:

- Large areas will be impacted by the development of water supply reservoirs, including loss of significant tropical forest resources. Construction in the Trinidad basin will also affect wetlands at the mouth of the river. Additional significant forested areas impacted are to the west of Culebra Cut.

- Potential adverse impacts to the commercial fisheries in the area through the disposal of excavated material in the Bay of Panama.

- Major changes to the species composition in Rio Indio resulting from the connection with Gatun Lake by a drainage canal.

- Potential reduction in the effectiveness of this freshwater barrier to the trans-isthmian movement of marine species caused by recycling of lockage water.

The sea level canal, being a much more extensive project, has a greater overall potential for impact, with impacts to aquatic resources being greater than terrestrial impacts. Impacts include the following:

- Impeding the movement of terrestrial organisms along the isthmus through the introduction of a separate, wider aquatic barrier than the existing Canal.

- A major increase in the potential for inter-oceanic movement of marine organisms, with resultant major impacts to important components of the marine ecosystem in both oceans.

- Major changes to the species composition in the Lagarto River, caused by the drainage canal from the isolated portion of Gatun Lake.

- Severe impacts to fifteen important rivers and streams. In addition, construction in the Caimito River would severely impact the mangrove swamps at the mouth of the river, and the new dam on the Gatun River will inundate additional diverse terrestrial habitats.

- Removal of large areas of Gatun Lake and related wetlands through the construction of barrier dams dividing Gatun Lake.

- Potential impacts to water supply aquifers in the area.

Standardized impact reduction practices would be instituted for all construction activities. Further site-specific field studies would be conducted to determine the presence of sensitive ecological resources within specific impact areas. Where on-site mitigation is judged to be possible, appropriate measures would be instituted, such as avoidance, establishment of buffer zones, proper scheduling of construction, and encouragement of natural revegetation.

If avoidance is not possible, other measures would be instituted, such as relocation of the sensitive resource combined with habitat compensation, to ensure that there is no net loss of habitat and regional biodiversity.

Specific mitigation recommendations were made for each of the two Alternatives. The Environmental Analysis Component Contractor did not believe that the proposed freshwater barrier would be effective in preventing trans-isthmian movement of marine organisms. In addition, recommendations were made for future supplemental studies, directly related to the impacts and mitigation for the Canal Alternative chosen.

Impacts Upon Panama

The objective of this component study was to provide a basis for evaluating canal alternatives in terms of overall impacts. The study identified, and quantified where possible, the direct and indirect impacts of canal construction and operation, beneficial and otherwise. Canal construction, operation, and financing costs from other component studies were some of the sources used to estimate direct impacts. An econometric model was used to estimate some of the indirect impacts, and the impact on Panama's Gross Domestic Product. The study's findings were presented in six categories:

- Economic Impacts;

Construction and operation of any canal alternative will have a long-term beneficial impact on Panama by providing a sustainable income source through the next century. Although no alternative is expected to change the economic structure of the country during construction or operation, the greatest direct economic impacts will result from construction and operation of the sea-level alternative because of higher cost, larger expenditures in Panama, and greater employment opportunities for Panamanian workers. The value of economic benefits is shown in Table 1.4.4-1.

Table 1.4.4-1

Estimated Impact of Canal Alternatives on The Panamanian Economy

(millions of 1990 U.S. dollars, percent average annual increase in Gross Domestic Product)

Impacts	150,000 dwt	200,000 dwt	250,000 dwt
During Construction			
Construction Period	10 years	10 years	15 years
Value Added	$ 708.1	$ 792.9	$ 911.1
Intermediate Purchase	$ 809.3	$ 906.3	$ 1,041.3
Increase in GDP	0.95%	1.06%	0.81%
During Operation (at 6% discount rate)			
Value Added	$ 3,819.8	$ 3,635.6	$ 4,174.6
Intermediate Purchase	$ 2,030.7	$ 1,932.4	$ 2,219.3
Increase in GDP	1.30%	1.20%	1.40%

The study estimated that the number of jobs created during peak construction would be 9,600 and 10,700 for the two sizes of lock canal, 9,400 for the sea level canal. A potential negative impact of the canal construction would be the absorption of workers from their present employment in Panamanian construction or other employment sectors, particularly if desirable skills were diverted for the extended duration of the canal construction.

- Financial Impacts

Beneficial impacts on Panama were identified as increased import duties during construction, and increased personal and business taxes during construction and operation. Similar to economic benefits, these were expected to be greatest for the sea-level canal.

Potential negative impacts were reduced government income from canal operations, to the extent revenues would be applied to canal construction costs. Also, a reduced government borrowing power for other needs, to the extent the credit of Panama would be needed to guarantee construction financing.

- Political Impacts

Although Panama will own the present Panama Canal after 1999, construction of any of the canal alternatives is likely to revive the issue of foreign presence because any external borrowing will likely involve some degree of external oversight of canal construction and operation. There were no identifiable political benefits to canal construction.

All of the alternatives involve some disruption of present conditions, and the way in which changes are handled will affect the political consequence. Construction of any alternative will accelerate the present population inmigration from the rural areas into the Panama-Colon metropolitan area, and may induce immigration from other countries. This will increase competition for housing, and the need for infrastructure expansion.

Without commensurate increase in housing and infrastructure, the increased income from canal construction could create housing shortages and overburden the infrastructure.

Because the sea-level canal project is largest in size and cost, its economic and financial impacts would be greatest. For the same reasons, it has the greatest potential for undesirable political consequences. More residents will have to be relocated because of construction. It will require a larger increase in security forces for canal protection than the lock canals. At this time, it involves a number of environmental issues that have not been resolved.

Because of growing environmental awareness within Panama and elsewhere in the world, the study anticipated extended political debate before canal construction is started.

- Socio-Cultural Impacts

Similar to political impacts, the identifiable impacts are negative, and center on migration and relocation of residents, and competition for housing and public services in the metropolitan area. Unlike political impacts, the study found no significant difference in socio-cultural impacts attributable to different canal concepts.

The report noted that the problems associated with migration to the Panama-Colon metropolitan area are pervasive, and development of social infrastructure and public services to overcome the problems associated with rapid population growth are likely to be expensive to the entire country and will be required regardless of whether or not canal improvements take place.

The study anticipated that a majority of the project induced immigrants will be unskilled laborers who will not be absorbed by the canal construction activities or by the existing Panamanian employment sectors. While some of this labor may be absorbed into some of the jobs vacated by individuals moving from existing jobs into employment on the canal construction project, it is likely that a large portion of this group will be unemployed.

The additional metropolitan area population resulting from project induced immigration could cause an increase in spontaneous settlement within and outside metropolitan area. Without proper forethought and planning, poverty and accompanying social pathologies such as substance abuse, prostitution, and an increase in criminal activities are likely to increase to critical levels.

The health care system may also be taxed beyond its capacity by the increased demand placed on it from the growing population. The report noted that the provision of on-site housing and services for workers involved in canal construction would free up some existing housing within the metropolitan area for use by others. However, care would be needed to avoid creation of the negative images of workers camps associated with construction of the existing canal. Also, care would be needed to assure equitable and productive disposition of the housing following completion of construction.

- Geographic and Environmental Impacts

The study found that geographically, the value of the country will increase with any of the canal alternatives. This will come from planned financial development, enhanced tourism, and increased economic activities. It will also include strengthening of the banking system, the insurance sector, the ports, airports, and communications facilities.

The identified environmental impacts were basically those identified in the ecological assessment: loss of forest cover and habitats, potential loss of species, and potential interoceanic migration of species via the sea-level canal. Specific concerns for the human inhabitants of Panama with the sea-level canal, were degradation of surface water supplies from Gatun and Miraflores lakes due to lock canal water recycling and saltwater intrusion into ground water supplies.

- Infrastructure Impacts

The study found a combination of positive and negative impacts. All canal alternatives were expected to result in improved roads, utility extensions, and additional bridges. These would be positive benefits. In addition, under the sea-level alternative, a new transisthmian road will be added alongside the canal as well as several new roads serving remote towns.

Negative impacts included the loss of existing structures due to canal construction, an estimated 1000 structures in the case of the sea-level alternative, and a much smaller number of structures for the lock-canal alternatives. It would include the elimination of the existing port facilities at Rodman, on the present canal channel opposite Balboa port facilities. The government of Panama is planning to redevelop the Rodman facilities as an extension of the Balboa complex, and channel widening for the lock canal alternatives would require a much more expensive solution for port expansion.

A significant negative impact of the sea-level canal could be the potential intrusion of seawater into aquifers. In areas where groundwater supplies are being exploited, additional infrastructure may be needed to carry water from more distant sources, or existing wells may require deepening in order to reach adequate water sources.

The Impacts Upon Panama Study concluded that "In every sense, the High Rise Lock Canal Alternative is the least intrusive". It further states that the High Rise Lock Canal will have the least impact on current or planned infrastructure, on financial and economic flexibility of the Government in terms of guarantees and revenue, on the population and socio-cultural infrastructure in terms of relocation of people and government areas of control and protection, and on the environment and geography.

1.4.5 Economic Analysis

Two separate analyses called for in the plan of study were merged into one component study to expedite feasibility analysis. This component study was the Economic Analysis and Impacts on Users (EAUI) Study. The economic analysis provides a common basis for evaluating multiple alternatives to compare net benefits and identify priorities.

Estimation of Benefits and Economic Costs

Variations of both the High Rise Lock Canal (HRLC) and Sea Level Canal (SLC) were taken into account for economic analysis. They include options of a single lane trough the Culebra Cut section for both cases of 150,000 dwt and 200,000 dwt for the HRLC. In the case of the SLC two options were considered for additional studies. These Alternatives are shown in Table 1.4.5-1.

Table 1.4.5-1
Alternatives

Case	Conceptual Alternative	Ship Size	Nos. of New Lanes		Remarks
			Canal	Lock/Gate	
1	HRLC	150,000 dwt	2	1	
1-a	HRLC	150,000 dwt	2	1	Culebra Cut Single Lane
2	HRLC	200,000 dwt	2	1	
2-a	HRLC	200,000 dwt	2	1	Culebra Cut Single Lane
3	SLC	250,000 dwt	1	3 + 1*	Pacific Tidal Locks
3-a	SLC	250,000 dwt	1	1 +1**	Variation of Case 3
4	SLC	250,000 dwt	1	1	Tidal Gates
4-a	SLC	250,000 dwt	1	1	Tidal Gates Single Lane Atlantic Approach
5	SLC	250,000 dwt	1	3 + 1	3 Locks plus 1 Tidal Gate

Notes: * 3 Pacific Tidal Locks + 1 lane for future expansion.
** 1 Pacific Tidal Lock + 1 lane for future expansion.

Direct benefits were defined as the transportation cost saving measured by the cost difference between via the canal route (with project condition) and via the least-cost alternative route (without project condition).

Types of benefits defined in the EAIU study are:

1) Route-shifting benefits by over-Panamax (Panamax is a term used to describe vessels size to fit in the canal) vessels: Benefits of cargos on over-panamax vessel which can transit the canal alternatives.

2) Route-shifting benefits by under-panamax vessels: Benefits of cargos on under-panamax vessels which transit canal alternatives due to the capacity (17,000 ships per year) of the Status Quo (SQ) Canal.

3) Size shifting benefits: Benefits of cargos on under-panamax vessels to be carried by larger vessels due to enlargement of the Canal.

Based on transit cargos and unit transportation cost per cargo ton in each trade route by ship type and ship size from the CTP, Phase II, direct benefits were estimated for case design ship size: 150,000 dwt, 200,000 dwt and 250,000 dwt for the years 2020 and 2060. The direct benefits are summarized in Table 1.4.5-2.

Table 1.4.5-2
Direct Benefits
(Millions of 1990 US$)

	Route-Shift Over - Panamax	Size-Shift	Route-Shift Under - Panamax	Total
2020				
150,000 dwt	217	334	0	551
200,000 dwt	240	334	0	574
250,000 dwt	260	334	0	594
2060				
150,000 dwt	445	649	324	1,418
200,000 dwt	471	651	324	1,446
250,000 dwt	499	651	324	1,474

Transit vessels projected by CTP Phase II Study is given in Table 1.4.5-3

Table 1.4.5-3
Transits Projection

	1990	2020	2060
SQ	11,162	17,359	18,078
150,000 dwt	-	17,796	23,934
200,000 dwt	-	17,844	24,074
250,000 dwt	-	17,856	24,053

The capacity of the SQ plus each canal alternative projected by Phase II OCCE study is given in Table 1.4.5-4

Table 1.4.5-4
Capacity of Alternatives

Study Case Ph. II & III	Alternatives	Capacity (Transits per year) (10 hour delay)
	Status Quo	17,000
1	HRLC 150,000 dwt	34,600
1-a	HRLC 150,000 dwt Culebra Cut Single Lane	34,400
2	HRLC 200,000 dwt	35,300
2-a	HRLC 200,000 dwt Culebra Cut Single Lane	34,600
3	SLC 250,000 dwt 3 Lanes of Pacific Tidal Locks	41,700
3-a	SLC 250,000 dwt 1 Lanes of Pacific Tidal Locks	34,000
4	SLC 250,000 dwt Tidal Gates (TG)	44,000
4-a	SLC 250,000 dwt TG Single Lane Atlantic Approach	35,800
5	SLC 250,000 dwt 3 Tidal Lock plus TG	----

Transits projected by the CTP Phase II Study were assumed to continue at a constant growth rate after 2060. The benefit after the year when the numbers of transits estimated reach the capacity of each alternative remains constant.

Economic costs of each canal alternative were estimated based on capital cost and operation and maintenance costs estimated in the ECE Phase II Study. Dams and pumping stations to provide sufficient water for lock operations were planned to be developed timely in order to assure Lock operation in dry years. The base for estimation of economic costs is international prices (border prices). No adjustment was made for costs of capital equipment since prices of this equipment are to be supplied from major industrial countries, and are regarded as international prices. The Local portion of project costs was converted to economic costs by using various conversion factors.

Economic costs of alternatives are shown in Table 1.4.5-5.

Table 1.4.5-5
Economic Capital Costs

Case	Alternatives	Economic Costs (10^6 US$)
1	HRLC 150,000 dwt	8,807
1-a	HRLC 150,000 dwt Culebra Cut Single Lane	6,865
2	HRLC 200,000 dwt	9,916
2-a	HRLC 200,000 dwt Culebra Cut Single Lane	7,759
3	SLC 250,000 dwt 4 Lanes of Pacific Tidal Locks	15,113
3-a	SLC 250,000 dwt 2 Lanes of Pacific Tidal Locks	12,004
4	SLC 250,000 dwt Tidal Gates (TG)	14,000
4-a	SLC 250,000 dwt TG Single Lane Atlantic Approach	11,551
5	SLC 250,000 dwt 3 Tidal Lock Plus TG	15,747

Evaluation

The conditions and assumptions for economic analysis proposed by the component contractor or requested by the Secretariat were as follows:

1) Base year is 2010;

2) Economic life of the project is 101 years between 2020 and 2120;

3) Commencement year of operation is 2020; and,

4) Social discount rate recommended is 5 percent per annum.

The summary of benefit-cost (B/C) ratio and the Internal Rate of Return (IRR), as seen in Table 1.4.5-6, shows that the 150,000 dwt lock canal, Culebra Cut Single Lane attained the highest IRR of (8.3%) and a B/C ratio of 1.99.

The sea level alternative which attained the best score is the 250,000 dwt, tidal gates and Single Lane Atlantic Approach.

Table 1.4.5-6

Economic Evaluation

(Benefits, Costs and B/C Ratio based on 5% Social Discount Rate)

Case	Benefit	Cost	B/C	IRR
1	12,507	7,595	1.60	7.0
1a	12,507	6,288	1.99	8.3
2	12,806	9,026	1.42	6.4
2a	12,806	7,297	1.75	7.5
3	13,146	13,975	0.94	4.8
3a	13.140	11,805	1.11	5.4
4	13,146	13,022	1.01	5.0
4a	13,146	11,374	1.16	5.5
5	13,146	14,648	0.90	4.7

Other Benefits/Impacts

For the people of Panama, there clearly will be benefits in terms of construction payrolls and purchases of goods and materials. Appropriately, these induced benefits are excluded from direct benefits. Because they may be significant considerations in how canal alternatives are viewed by the affected parties, they were quantified as impacts in the economic analysis.

Impacts on canal users were quantified two ways, as induced trade, and as induced or saved income. The former used net transportation cost reduction with an optimal toll structure, converted to the value of the economic activity and cargo tons based on price elasticity of demand by canal user region. The latter used total transportation cost savings converted to the value of the economic activity based on the economic multiplier effect and marginal propensity to consume and import in canal user regions. Impacts on users were calculated as of year 2020.

The results are shown in Table 1.4.5-7.

Table 1.4.5-7

Economic Impacts on Users by Canal Alternatives in 2020

(millions of 1990 U.S. dollars, other amounts as shown)

Type of Impacts	Canal Size		
	150,000 dwt.	200,000 dwt.	250,000 dwt.
Induced Trade	$68	$80	$90
Trade in (000) tons	563	668	749
Multiplier Effect	$920	$973	$1,005

1.4.6 Financing Scheme, Financial Analysis and Management Arrangements

The basic premise for financial analysis was that construction of any of the canal alternatives would rely on financing for the project. This would require canal revenues adequate to pay the cost of canal operation (as at present) and canal construction (either through contributions to construction cost, or repayment of borrowed funds and interest).

Accordingly, the separate but related efforts required were to:

(1) Develop a recommended toll policy and system for each of the canal alternatives;

(2) Formulate the most appropriate management arrangement and structure for each of the Canal Alternatives;

(3) Define an appropriate financing configuration or scheme for each of the canal alternatives;

(4) Measure the financial viability of each alternative; and,

(5) Identify Canal alternatives which are Financially Feasible.

The following six alternatives including the variations of the prescreened alternatives that were analyzed are shown in Table 1.4.6-1.

Table 1.4.6-1
Alternatives for the FFMS Study

Case	Description
1 1-a	150,000 dwt High Rise Lock Alternative 150,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut
2 2-a	200,000 dwt High Rise Lock Alternative 200,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut
3	250,000 dwt Sea Level Alternative with (3 plus 1) Pacific Tidal Locks*
4-a	250,000 dwt Sea Level Alternative with Tidal gates and Single Lane Atlantic Approach **

Notes: * This case is referred to as CASE A in the FFMS component contractor report
** This case is referred to as CASE E in the FFMS component contractor report

Canal Toll Schedule

The toll analysis was based on all revenue of a Panama Canal attributable to canal alternatives as well as the Status Quo Canal. The practical reasons for doing so were to generate enough additional revenue to make a meaningful contribution to construction costs, and the fact that all canal alternatives operate in conjunction with the Status Quo canal. A limit of a 100 percent increase for any vessel type was imposed in the toll analysis. This is based on a consensus estimate of the toll level above which the shipping community would poorly receive and view with alarm. In addition to this limit, toll optimization was constrained to minimize traffic diversions, and disruption of existing trade patterns and by traffic diversity. Within those limits, the toll analysis was to maximize revenues and promote traffic growth and canal utilization, with a toll schedule related to user's ability to pay. As a practical matter, whether and when such a toll schedule can be implemented will depend on the legal authority of the canal entity.

The present canal toll structure has been in place for almost 80 years. Infrequent and relatively small increases in toll levels are based on cost of service, as required by current law. All vessels are basically charged the same toll rates based on Panama Canal net ton (PCNT). To fully maximize canal revenues, the toll schedule would have to differentiate among ship type and, within ship type, by size. After review of tariffs with multiple rates by vessel size and type (Suez Canal) and cargo type (St. Lawrence Seaway), the analysis focused on adding a minimum number of specific rates for certain vessel types and sizes in order to retain most of the simplicity of the present canal tariff. The analysis then determined the general and vessel-specific rates for Panama Canal that maximized revenues within the given set of constraints using transportation cost comparisons to identify traffic diversions.

The optimal schedule produced by the analysis has a general level of rates 100% higher than the present canal tolls, $4.02 per PCNT laden, $3.20 per PCNT in ballast. The vessel specific rates are limited to tankers of 40,000 PCNT or larger, $3.30 and $2.63 per PCNT laden and in ballast, and dry bulk carriers of 70,000 PCNT or larger, (applicable to 200,000 dwt. canal only) $1.51 and $1.20 per PCNT laden and in ballast for the year of 2020. As of 2060, the discount rates for large tankers and dry bulk carriers would no longer apply.

Alternate toll levels tested included the current level, that level increased 50 and 100 percent, and numerous variations. Traffic diversion estimates were based on analysis of laden vessels, and ballast vessel traffic was assumed to be affected proportionately. The analysis was limited to transportation costs; the net canal traffic after diversions that was used to estimate canal revenues did not include the non-potential trade traffic included in traffic projections. Table 1.4.6-2 summarizes estimated laden and ballast transits and toll revenues, as determined for financial analysis.

Table 1.4.6-2

Estimated Laden and Ballast Transits And Revenue with Alternate Tolls

(vessel transits, with toll basis, and revenues in millions of 1990 US $)

	Canal Sizes							
	Present		150,000 dwt		200,000 dwt.		250,000 dwt.	
	2020	2060	2020	2060	2020	2060	2020	2060
Current Toll Level								
Transits	14,458	17,135	15,533	21,451	15,612	21,374	15,624	21,404
Revenues	$482	$591	$612	$869	$630	$895	$637	$908
Toll Level Increased 50%								
Transits	14,117	16,803	15,307	21,097	15,237	21,040	15,384	21,058
Revenues	$702	$861	$904	$1,279	$904	$1,319	$938	$1,335
Toll Level Increased 100%								
Transits	14,112	16,570	14,752	20,660	14,954	20,815	15,097	20,835
Revenues	$934	$1,110	$1,123	$1,638	$1,169	$1,732	$1,215	$1,754
Optimal Toll Level								
Transits	14,112	16,735	15,160	20,660	15,223	20,815	15,238	20,835
Revenues	$934	$1,110	$1,175	$1,638	$1,186	1,732	$1,221	$1,754

Source: FFMS Final Report, Volume 1, Section 3

Canal Expenditure and Funding Sources

The cost of constructing alternative canal projects requires the use of every possible source of funds. To analyze all potential sources, it was necessary to restate construction costs to identify the cost of construction equipment, other equipment, other construction costs, and indirect costs.

For subsequent cash flow analysis it was necessary to determine the amount and timing of construction costs by cost category, and to make assumptions as to contractor progress payments and withholdings. Subsequent cash flow analysis also required determination of canal operating costs. A group of experts identified the following as a list of potential construction funding sources and assumed a financing configuration or scheme:

- Japan Ex-Im Bank
- U.S. Ex-Im Bank
- Equip. Suppliers
- Commercial Banks
- Development Banks
- Japan ODA Program
- U.S. Bond Issues
- Japan Bond Issues
- Outside Equity
- Government Grants

The assumed distribution of funding sources was the same for all canal alternatives. Table 1.4.6-3 shows the percentage distribution by source and assumed terms and interest rates. Because of the differing repayment terms and contribution of toll revenues, no overall blended interest rate applies.

One of the most important features of the financing scheme is the establishment and the preservation of a toll reserve trust fund that would be endowed with net income generated from Canal tolls after Panama acquires control of the Canal in 2000. It is assumed that Canal tolls could be increased from the years 2000 through 2019 to generate resources for the trust fund since the toll increase will be associated with capital improvement.

The group of experts deemed funding by outside equity and government grants to be too speculative for a financing plan.

Table 1.4.6-3

Assumed Sources of Funding for Canal Construction

(percent distribution of funding by source, assumed loan interest & terms)

Funding Source	Interest Rate (%)	Grace Period (year)	Total Term (year)	Project Component				
				Const. Equip. (%)	Other Const. (%)	Other Cost (%)	Other Share (%)	Proj. Share[1] (%)
Japan Ex-Im Bank	6.70	0	10	40	40	0	0	12.7
U.S. Ex-Im Bank	7.00	3	12	40	40	0	0	12.7
Equip. Suppliers	6.75	3	5	5	5	0	0	1.6
Commercial Banks	6.75	5	10	0	0	5	5	3.4
Development Banks	7.50	5	20	0	0	27	27	18.4
Japan ODA Program	4.50	7	20	0	0	4	4	2.7
U.S. Bond Issues	8.25	5	15	0	0	17	17	11.6
Japan Bond Issues	7.35	0	20	0	0	17	17	11.6
Outside Equity	NA	NA	NA	0	0	0	0	0
Government Grants	NA	NA	NA	0	0	0	0	0
Toll Reserve Trust Fund	NA	NA	NA	15	15	30	30	25.2

Note: (1) The share of total project cost varies with project size. These % are for a High Rise 150,000 dwt Alternative

Source: FFMS Final Report, Volume 1, Section 6.

Canal Management Arrangements

In order to form a basis for the development of a financial analysis, a study of management arrangements was undertaken at the direction of CAS. This was accomplished as part of the scope undertaken by the FFMS component contractor.

Consideration of the type of entity that will manage a Panama canal in the future is relevant for two reasons:

(1) the life of the present Panama Canal Commission will expire at the end of 1999; and,

(2) the financing available for constructing canal alternatives will depend on the type of successor organization.

The analysis examined a number of canal, port, and related organizations and identified their attributes. The Suez Canal Authority was specifically examined because of important similarities.

A set of evaluation criteria was developed to determine, for study purposes, the form of organization that would best serve Panama, suit potential funding sources, and provide unified management for all canal alternatives.

The evaluation criteria were as follows:

- Compatibility with Panamanian sovereignty;
- Compatibility with existing international law and treaties;
- Insulation from local politics;
- Financial integrity and stability;
- Capacity for long-term planning;
- Customer responsiveness;
- Management autonomy and flexibility;
- Labor productivity;
- Ability to evolve and absorb or spin off functions;
- Compatibility with evolution of existing Panama Canal entity; and,
- Ability to consolidate Panama's other interoceanic transportation initiatives.

The models for management arrangements evaluated were:

- Panamanian Government Department;

- Panama Canal Authority;
- International Public Entity;
- Special Purpose Corporation; and,
- Private Company.

The management models recommended in the FFMS Study for the canal alternatives assume that a single entity will be established to manage and operate the existing Canal and any future alternative Canal.

After evaluation, a Panama Canal Authority has been identified as the preferred management arrangement suitable to handle the financial management, and operating efficiency requirements of the Canal Alternative. From a Panamanian point of view it is probably a more easily comprehensible and thus acceptable formula for organizing Panama's relationship to the Canal Alternative.

The Panama Canal Authority model has the additional advantage of an ability to evolve toward being a special purpose corporation (SPC). If over time the ownership and operating characteristics of SPC presented clear benefits for the development and management of the Canal alternative, the authority could easily establish and even invest in an SPC and contract out day-to-day operation and management of the Canal alternative to the entity.

Hence the Panama Canal Authority model was used as the basis for financial feasibility analysis.

Financial Feasibility Analysis

Various financial analyses were made for measuring the financial viability of each Panama Canal alternative. For each of the Canal alternatives, the following three scenarios of alternative toll structures and rates were prepared:

- Existing Panama Canal toll structure and rates;
- Existing Panama Canal toll structure and rates increased by 50 percent; and,
- The optimal toll system that differentiates toll rates on the basis of ship type and ship size.

Because financial analyses require an estimate of annual project financial cash flows to calculate various financial evaluation ratios such as the financial internal rate of return (FIRR), the following assumptions were made:

- Toll Revenues

For the years 2000 through the 2019 period, toll revenues under the existing toll scenario were estimated on the basis of the average annual growth rate of toll revenues between actual 1991 and projected 2020 toll revenues. For the 50 percent increase toll and optimal toll scenarios, toll revenues in 2000 through 2019 were estimated based upon the average annual growth of toll revenues calculated between 1999 Status Quo existing tolls and the projection for 2020 Status Quo toll revenue for each corresponding toll scenario.

As for the intervening years between 2020 and 2060, annual revenues were assumed by the same interpolation method based on estimated revenues of 2020 and 2060 in each Alternative.

- Other Revenues

Other canal operating revenues were calculated on the basis of the FY 1991 revenues and increased according to the annual average growth in the Canal transits projected for the 1991 through 2020 and 2020 through 2060 periods.

- Construction and Operating & Maintenance Costs

The construction costs provided by the ECE contractor were used, with timing of expenditures appropriately allocated for financial analysis. Operating & Maintenance costs were adjusted to reflect Panama Canal Commission expenses that would no longer apply after 2000. Annual costs were assumed by interpolation.

- Payment to the Republic of Panama

It is unlikely that the government treasury would be willing to part entirely with the flow of funds generated by Canal operation. To the contrary, in order for the Canal alternative to be able to attract the proposed financing, limits need to be established on the amount of funds that will be paid to the national treasury. Because of these reasons, it was assumed that annual payment to the Republic of Panama would be 10 percent of total Canal revenues.

- Trust Fund and Dividend Policy

Funds that are maintained in the toll reserve trust fund are assumed to earn 4 percent interest on the prior year's balance.

Dividend distributions are assumed to be released only when a current year's net income after debt service and payment to Panama is positive and when the trust fund balance always exceeds $500 million.

All of the financial analyses and results were conducted on the basis of constant 1990 U.S. dollars.

The financing scheme and financial analysis of each Canal alternative under each toll scenario were evaluated using the following criteria.

- Is the toll reserve trust fund balance always positive?
- Is the minimum debt service coverage ratio sufficient?
- Is the financial internal rate of return (FIRR) of the incremental cash flow before financing adequate to encourage international development institutions and agencies to participate in the project?
- Is the FIRR of the incremental cash flow after financing adequate to encourage private investors and commercial banks to participate in the project?
- Are the net present values of the incremental cash flow before and after financing positive values?
- Is the debt to equity ratio appropriate?
- Does the alternative remain financially viable under the various sensitivity analyses that include interest rates increased, capital cost increased, operation and maintenance costs increased?

The result of calculating and analyzing these evaluation criteria by each Canal alternative under existing toll scenario demonstrates that none of the Canal alternatives turn out to be feasible.

With a 50 percent increase in tolls, the trust fund balance can be kept always positive for the two High Rise Culebra Cut Single Lane Alternatives.

None of the six alternatives examined in the FFMS are feasible since they cannot satisfy other criteria. In the 150,000 dwt case, the FIRR before financing (6.7%), for example, is less than the target result (8%).

Table 1.4.6-4 shows a summary of the results of financial analyses for each Canal alternative under the optimal toll system scenario.

Table 1.4.6-4

Summary of Financial Results by Canal Alternative Under Optimal Toll System Scenario

Evaluation Criteria	Target Result	High Rise 150,00 dwt	High Rise 200,000 dwt	High Rise 150,000 dwt Culebra Cut Single Lane	High Rise 200,000 dwt Culebra Cut Single Lane	Sea Level Case A	Sea Level Case E
Trust Fund balance always positive	Yes	O	O	O	O	X	X
Financial internal rate of return before financing (%)	8-10	O (10.1)	O (8.4)	O (15.8)	O (12.3)	X (4.5)	X (6.0)
Financial internal rate of return after financing (%)	12-15	O (18.0)	X (9.8)	O (28.0)	O (21.2)	X (3.3)	X (5.3)
Net present value before financing (US$MM)*	Positive Value	O (951)	O (193)	O (2,086)	O (1,521)	X (-2,608)	X (-1,223)
Net present value after financing (US$MM)*	Positive Value	O (1,069)	O (391)	O (2,073)	O (1,566)	X (-2,130)	X (-9.02)
Minimum debt service coverage ratio-current	1.3	X	X	X	X	X	X
Minimum debt service coverage ratio-overall	1.5-2.0	O	O	O	O	X	X
Debt/equity ratio	Below 4.0	O	O	O	O	O	O
Is the alternative financially with:							
a. Interest rates increased 25 percent	Yes	O	X	O	O	X	X
b. Capital costs increased 25 percent	Yes	X	X	O	O	X	X
c. Operation and Maintenance costs increased 25 percent	Yes	O	X	O	O	X	X
Conclusion Is project financially feasible?		O	X	O	O	X	X

* Based upon an interest rate of 8 percent

Note: O represents meeting the target.
X represents not meeting the target.
The results of sensitivity analysis with Status Quo Canal tolls increased 50 percent are excluded.
Source: Tables 6-7 through 6-24 and Appendix J in FR.
Tables 11 through 28 and Table 30 in Annex to DFR.

Table 1.4.6-4 shows the following three High Rise Canal Alternatives are feasible under optimal toll scenario and rates, because they reach almost all targets of criteria.

- High Rise 150,000 dwt Alternative
- High Rise 150,000 dwt Culebra Cut Single Lane Alternative
- High Rise 200,000 dwt Culebra Cut Single Lane Alternative

It also shows that High Rise 150,000 dwt Culebra Cut Single Lane Alternative is the most attractive among three from a financial viewpoint.

The Sea Level Canal alternatives and High Rise 200,000 dwt Alternative are not found to be financially feasible under any of the scenarios analyzed.

1.5 Conclusions and Recommendations

1.5.1 Conclusions

Based on the study results, the following conclusions can be drawn:

- There is a need for a canal to accommodate vessels larger than 65,000 dwt. size. Improvement of the existing canal with larger locks is the indicated solution.
- A High Rise lock canal with a single lane Culebra Cut sized to accommodate ships in size range of 150 to 200 thousand deadweight tons is feasible from an engineering, economic and financial viewpoint.
- The feasibility of a sea-level canal could not be established under the framework of this study.
- Should traffic demand increase by approximately 15 percent above the presently adopted forecast, there is a good chance some of the variations of Sea Level Route 10 Alternatives could become feasible.

  The improved feasibility of a Sea Level Alternative could not be any better than the High Rise Alternatives.
- Before a major canal project can go forward, the following three critical issues need resolution:

- Acceptance of financial impacts upon Panama's economy and internal needs;
- Acceptance of an environmental mitigation and remediation plan to satisfy valid concerns related to the environment; and,
- Assessment of the impacts of increased canal tolls on users of the canal.

- Before a major canal project can go forward, a permanent canal entity is needed with the power to levy and raise tolls, borrow money, plan long-range, and provide continuity of canal operation and management.

- Panama's legislation and the conditions of international treaties must be investigated and adjusted as required before a permanent canal entity is established.

1.5.2 Recommendations

Listed in priority order, they are as follows:

- Establish a new concept for a permanent canal entity as soon as possible. A new entity is needed to succeed the Panama Canal Commission which expires at the end of 1999. An entity that can provide continuity of planning, and that can implement major improvement projects is needed. A canal authority form of entity is recommended.

- A Panamanian Government initiative to undertake the following additional studies is recommended:
  - Evaluation of the financial impacts of building a major canal alternative upon the Panamanian economy including the ability of Panama to dedicate part of the tolls prior to construction to help for the future cost of the canal alternative.
  - Assessment of the changes occurring within the entire watershed area available as a water source for the future operation of canal alternatives. The preservation of future hydrologic conditions will be vital to the development of either a High Rise or a sea-level alternative.
  - Assessment of the Environmental Impacts of building a major canal alternative and development of an Environmental Mitigation and Remediation plan to alleviate the impacts.
  - Assessment of the impacts of increasing canal tolls upon the shipping industry and its level of use of the canal.

- Further study is appropriate for the most promising alternatives, High Rise Lock Alternative with 150,000 dwt design vessel and Single Lane Culebra Cut and a High Rise Lock Alternative with 200,000 dwt design vessel and Single Lane Culebra Cut.

- Considering the importance of the Panama Canal to international trade, further studies need to include investigating a more user oriented toll scenario than the optimum toll scenario contained in this study.

- Careful monitoring of actual canal transits as well as by-pass cargo movement is recommended to form a basis for deciding the optimal timing of a new canal operation. The best estimate at present is sometime between 2015 and 2020.

List of Tables and Sources

Table N°.	#Title & Source
1.3-1	Study Cases for Optimization Source: SINBOL
1.4.1-1	Maritime Trade, Actual 1990 and Projections Sources: Commodity and Traffic Projections Study, Final Report Volume I, Table 2 and page 1-19.
1.4.1-2	Percent Vessel Fleet Deadweight Capacity by Vessel Size Sources: Commodity and Traffic Projections Study, Final Report Volume I, Tables 3.1 through 3.21.
1.4.1-3	Panama Canal Traffic, Actual 1990 and Projections Sources: Commodity and Traffic Projections Study, Final Report Volume I, Tables 3 and 4.
1.4.2-1	Design Vessel Dimensions Source: Preliminary Engineering and Cost Estimates Study, Phase II Final Report, Volume 1, Table II.1.1-1.
1.4.2-2	Channel and Lock Design Parameters Sources: Preliminary Engineering and Cost Estimates Study, Phase II Final Report, Volume 1, Pages II.1.1-2,3,and 4, and U.S. Army Corps of Engineers Manual EM 1110-2-1613, "Hydraulic Design of Deep-Draft Navigation Projects".
1.4.2-3	Channel and Lock Chamber Dimensions Sources: Preliminary Engineering and Cost Estimates Study, Phase II Final Report, Volume 1, Tables II.1.1-2 and II.1.1-3.
1.4.2-4	Construction Cost Estimates Sources: Preliminary Engineering and Cost Estimates Study, Phase II Final Report, Volume 1, Executive Summary Summation Table, and Part II Tables 3.3-4 and 3.3-5.
1.4.3-1	Estimated Tidal Currents in Sea Level Canal Source: Operating Characteristics and Capacity Evaluation Study, Phase II Final Report, Figure 4-6.
1.4.3-2	Canal Capacity Estimates and Projected Vessel Transits Sources: Operating Characteristics and Capacity Evaluation Study, Phase II Final Report, Table 7-4, and Commodity and Traffic Projections Study, Final Report Volume I, Table 4.

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1.4.4-1	Estimated Impact on Canal Alternative on the Panamanian Economy Source: Economic Analysis and Impacts on Users Study, Draft Final Report, Chapter V.
1.4.5-1	Alternatives Source: SINBOL based on the component studies
1.4.5-2	Direct Benefits Source: Economic Analysis and Impacts on Users Study, Final Report and Additional Study
1.4.5-3	Transit Projection Source: Commodity and Traffic Projections, Phase II Final Report Volume I
1.4.5-4	Capacity of Alternatives Source: Operating Characteristics and Capacity Evaluation, Phase II Final Report
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1.4.5-7	Economic Impacts on Users by Canal Alternatives in 2020 Source: Economic Analysis and Impacts on Users Study, Final Report
1.4.6-1	Alternatives for the FFMS Study Source: SINBOL based on the component studies
1.4.6-2	Estimated Laden and Ballast Transits and Revenues with Alternate Tolls Sources: Financing Scheme, Financial Analysis, and Management Arrangements Study, Final Report Volume 1, Tables 3-4 through 3-27, and Tables 3-29 through 3-36
1.4.6-3	Assumed Sources of Funds for Canal Construction Sources: Financing Scheme, Financial Analysis, and Management Arrangements Study, Final Report Volume 1, Tables 6-1 through 6-4.

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1.4.6-4 Summary of Financial Feasibility Analysis by Canal and Toll Alternative
Sources: Financing Scheme, Financial Analysis, and Management Arrangements Study, Final Report Volume 1, Table 6-25 and Annex to Draft Final Report, Table 29

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1.1.3-1 Canal Alternatives Study Organization Chart
Source: Final Report of the Preparatory Committee, Figures 1A and 1B

1.2-1 Canal Alternatives Study Work Flow Chart
Source: Detailed Plan of the Study of Alternatives to the Panama Canal, Volume I, Figure 1-1

1.3-1 Process Used in Selecting Alternatives
Source: SINBOL

1.3-2 Location Map for Canal Alternatives
Source: Operating Characteristics and Capacity Evaluation Study, Phase II Final Report, Figure 1-1

1.4.2-1 Construction Cost Estimates by Category
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1.4.2-2 Route and Profile of Lock Canal Alternatives
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1.4.4-1 Study Area
Sources: Detailed Plan of the Study of Study to the Panama canal, Volume II Terms of Reference for Environmental Analysis, Figure 6.

A Feasibility Report
2.0 Introduction

The purpose of this section is to explain how this study originated, how its scope and form were established, and the factors that determined how the study was conducted.

2.1 Study Authority

Article XII (1) of the Panama Canal Treaty between the Republic of Panama and the United States, signed in Washington on September 7, 1977, states that "... during the duration of this Treaty, both parties commit themselves to study jointly the feasibility of a sea-level canal in the Republic of Panama, and in the event they determine that such a waterway is necessary, they shall negotiate terms, agreeable to both Parties, for its construction".[1]

The issues and events that produced the 1977 Treaty centered on the operation of the existing canal, and the origin and importance of the sea-level canal study is not widely acknowledged. The commitment to a canal study was a deliberate choice, with a distinct history described hereinafter. Earlier studies of sea-level canals had recognized the need to modify or replace the then-existing canal treaties, because of new and different territorial requirements. The new Treaty was the proximate cause of this study.

2.1.1 The 1977 Panama Canal Treaty.

The Torrijos-Carter Treaties were signed in Washington on September 7, 1977. The treaties basically "acknowledges that the Republic of Panama's sovereignty over its territory" and that on December 31, 1999, "Panama shall assume total responsibility for the management, operation and maintenance of the Panama Canal".

The treaty also certifies that "The United States of America transfers, without charge, to the Republic of Panama all right, title and interest the United States of America may have with respect to all real property, including non-removable improvements thereon".

The 1977 Treaty provided for an orderly termination of United States rights in Panama during a transition period that is to end December 31, 1999.

[1] "Panama Canal Treaty", signed 7 Sept. 1977, (TIAS 10030), United States Treaties and Other International Agreements Volume 33 Part 1 (1987) p. 39.

- Article I of the Treaty abrogated all prior treaties granting the United States territorial rights in Panama.

- Article III, Canal Operation and Management, provided for transfer of Canal properties and management to Panama, pursuant to a specific implementation agreement that accompanied the Treaty.[2]

- Article IV, Protection and Defense, provided for withdrawal of the U.S. military presence in Panama, also pursuant to a specific implementation agreement accompanying the Treaty.[3]

- Article XII, in addition to the commitment to the sea-level canal study, the United States was granted conditional rights to construct a third lane of locks for the existing canal during the duration of the 1977 Treaty.

A companion 1977 treaty[4] relating to the Permanent Neutrality and Operation of the Panama Canal was signed at the same time and place. This treaty set forth principles for the operation of the canal after 1999. They included efficient operation, just and reasonable tolls, and a military presence for canal protection only by Panama. Other governments were invited to endorse those principles, and a large number of them have done so.

2.1.2 Prior Treaties and Agreements

The Hay-Bunau Varilla Treaty of 1903, between the United States and Panama, gave the United States the exclusive right in perpetuity to build and operate a canal across Panamanian Territory, and with all the rights in a distinct area, the "Canal Zone". Treaties with Panama in 1936 and 1955 relinquished some U.S. rights and provided additional benefits for Panama, but did not fundamentally change the 1903 Treaty relationship. To improve that relationship, a draft treaty package was developed by United States and Panamanian negotiators between 1964 and 1967, but was never signed or ratified.[5]

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[2] "Agreement in implementation of Article III of the Panama Canal Treaty", signed 7 Sept. 1977, (TIAS 10031), United States Treaties and Other International Agreements Volume 33 Part 1 (1987) p. 141.

[3] "Agreement in implementation of Article IV of the Panama Canal Treaty", signed 7 Sept. 1977, (TIAS 10032), United States Treaties and Other International Agreements Volume 33 Part 1 (1987) p. 307.

[4] "Treaty Concerning the Permanent Neutrality and Operation of the Panama Canal", signed 7 Sept. 1977, (TIAS 10029), United States Treaties and Other International Agreements Volume 33 Part 1 (1987) p.1.

[5] Final Report of the Atlantic-Pacific Interoceanic Canal Study Commission, Washington, 1 Dec. 1970.

The treaty package would have replaced the 1903 Treaty with three separate treaties. One recognized Panamanian sovereignty, and provided for shared jurisdiction and management of the Canal and would have terminated in 1999 or no later than 2009.

A second treaty would have granted the United States rights to build a sea-level canal, and operate it for 60 years or until 2067. The third treaty provided for continued use of military bases by the U.S., with termination dates related to the other proposed treaties. The extent to which the draft treaties are reflected in the 1977 and 1979 treaties is discernable. Respectively, the 1977 and 1979 treaties address the proposed arrangements for the existing canal and the military bases. The notable exception is the provision in the 1977 Treaty for a sea-level canal study in lieu of a more specific commitment. Historically there has been a need for a contractual agreement, treaty or concession, to define the rights of canal sponsors or proponents. The absence of a specific commitment was undoubtedly deliberate, thus this canal study remains as a significant effort.

2.1.3 Prior Studies

The history of trans-isthmian canal studies goes back to shortly after the arrival of Europeans. The debate about whether the canal should be sea-level or lock-type has been almost as long. In the 1800's, canal studies generally favored lock-type canals, as a consequence of available technologies and construction capabilities.

The present Panama Canal was started by Ferdinand De Lesseps as a sea-level canal in 1881, and completed as a lock canal by the United States in 1914. That and the fact that the Canal's capacity was more than adequate, quieted the debate for the next 30 years. It was revived after World War II in a series of studies precipitated by a strong growth in Canal traffic.

A number of capacity augmentation studies examined incremental improvement of the existing Canal, by widening Culebra Cut, by completion of the "Third Locks" project and/or replacement of existing locks, and by consolidation of lock locations (the "Terminal Lake Plan"). An innovative 1981 proposal by a Panamanian engineering firm, would have effectively rebuilt the lock canal with a lower Gatun Lake level, channel deepening, and new locks. However, several major studies recommended a new sea-level canal on or near the present Canal route as the ultimate solution for obtaining an adequate capacity. These included U.S. studies in 1947, 1960, and 1970, a 1981 Japanese study (the "Nagano Plan), and a Panamanian proposal in 1982 (the "Vergara Plan).[6]

Predominantly, these studies examined few issues beyond physical feasibility and technical aspects of Canal construction.

[6]Bastian, David F., The Transisthmian Alternatives for Increasing the Throughput Across Panama, Commission for the Study of Alternatives to the Panama Canal, Panama, R. de P., May 1990.

The 1947 U.S. study identified 30 potential routes that ranged from Mexico to Colombia, investigated the use of nuclear explosives for excavation and it was very comprehensive in examining financial feasibility. The study intended to support the Draft treaties previously described, and specifically addressed the feasibility of a sea-level canal. The end product of the various studies produced a wide variety of alternatives that would improve, supplement, or replace the existing Canal, but no specific solution prevailed over the others.

The one area where alternatives have been narrowed down, involves the sea-level canal, where there is general agreement that it should be located on or near the present Canal route (routes designated 14 and 10 in the 1947 study), and that its construction is physically feasible. This latest canal study reflects the interaction of prior study findings and related international agreements. The main challenge was to identify the best project for Panama, for the international community and that could be financially feasible and implementable.

2.2 Study Implementation

By an exchange of diplomatic notes on September 30, 1982, the governments of the Republic of Panama and the United States of America agreed to establish a Preparatory Committee to consider how to conduct a canal feasibility study in accordance with Paragraph 1 of Article XII of the Panama Canal Treaty of 1977 plus all alternatives, including lock canals.[7] Based upon the agreement reached by the exchange of notes, and to an earlier expression of interest by Japan, the two countries simultaneously invited the Government of Japan to participate in the Preparatory Committee as a full member. Japan accepted the invitation.

2.2.1 Study Implementing Agreements

As a joint undertaking of sovereign governments, the canal study involved a unique combination of diplomacy and technical expertise. The study was performed by technical experts, but diplomats representing the governments were responsible for starting the study, monitoring its progress, and accepting its report. To initiate study implementation, the U.S. State Department and Panama's Ministry of Foreign Affairs used diplomatic notes to form a preparatory committee, a common practice in intergovernmental affairs.

The 1982 exchange of notes set forth an agreement that the Preparatory Committee would make recommendations to the member governments regarding a feasibility study, and specifically directed the Preparatory Committee to prepare and agree upon the terms of reference for the feasibility study, and to specify the objectives of the study, its administrative and organizational structure, its budget and funding sources, and a study schedule.

[7] "Agreement concerning creation of a preparatory committee to study alternatives to the Panama Canal", Exchange of notes at Washington, signed 30 Sept. 1982, (no TIAS number), U.S. Department of State pamphlet.

Subsequently in a September 1985 exchange of diplomatic notes, the United states, Japan and Panama agreed to share equally, one-third each, a study at a budgeted cost of $20 Million.[8]

2.2.2 Tri-National Sponsorship

The effect of the 1985 exchange of diplomatic notes was the acceptance of the Preparatory Committee's report and its recommended study, study schedule, and budget. The agreement to equitable cost sharing established equality as the fundamental relationship for all study activities. Japan, Panama, and the United States were thus equal partners. Decision making was guided by the study organization's structure and a comprehensive set of regulations and procedures. The study budget was shared equally among Japan, Panama and the United States. Participation by Panama was through a loan from the Inter American Development Bank (IDB). The contribution from Japan was made through the Japan International Cooperation Agency (JICA). The United States contribution was administered through the Department of State.

2.2.3 Tri-National Participation

In its Final Report, the Preparatory Committee recommended participation in the study by all three countries "... in a meaningful way in all aspects of the Study".[9] It also stated that "The distribution of contracts will be consistent with the source and proportion of each Government's contribution to the Study Budget". These principles were subsequently incorporated in procedures to produce a combination of multiple component contracts, a prime contract (the Feasibility Analysis/Final Report contract), direct participation by the Secretariat in contracting and contract management, and a requirement that all work be distributed equally by value among contractors from the three sponsoring countries.

The intent by the Preparatory Committee was to assure tri-national participation in the study, and in fact it did so. It produced equal participation, within the Secretariat and among contractors. Although the concept is consistent with the equal sharing of study costs, it drastically increased the complexity of the study.

2.3 Study Scope and Objectives

The Final Report of the Preparatory Committee stated the objectives of this study as follows:

- To identify potential transportation alternatives to the Panama Canal within the Republic of Panama;

[8] "Agreement concerning establishment of the commission for the study of alternatives to the Panama Canal," Exchange of notes at New York, signed 26 Sept. 1985, (no TIAS number), International Legal Materials (periodical) Volume 25 Part 1, p.63.

[9] Final Report of the Preparatory Committee for the Panama Canal Alternatives Study, Washington, 28 June 1985.

- To study these alternatives in accordance with the terms of reference contained in the Final Report of the Preparatory Committee for the Study of Alternatives to the Panama Canal in order to develop the information necessary to evaluate the feasibility of each alternative;

- To select the best alternative and study it in detail; and,

- Having studied in detail the best alternative, to develop conceptual plans for said alternative for the consideration by the Member Governments of the Study Commission.

2.3.1 Preparatory Committee Recommendations

From 1982 to 1985 the Preparatory Committee held seven formal meetings in Japan, Panama, and the United States. It reached agreement on a series of recommendations covering study objectives, study organization structure, study scope, study budget and schedule, and study cost sharing and financing.

As a vehicle to reconcile different visions of the study called for in the 1977 Treaty, the Committee established basic principles with respect to equal participation that became imbedded in the conduct of the study. The Committee also produced a study outline that greatly expanded the scope of the study. The 1977 Treaty specified a study of a sea-level canal. The study described by the Committee included consideration of all alternatives to the existing Panama Canal. The study scope recommended by the Preparatory Committee was a key turning point in the history of this study. It is also the key to understanding the evolution of a relatively focused and parochial study into one with near-global scope and complexity. The four study objectives stated by the Committee are deceptively simple. Collectively they describe a distinct series of analyses, and they set the pattern of the study.

2.3.2 Initial Study Plan and Budget

The Final Report of the Preparatory Committee was very specific in describing the study content and component studies (three levels of detail), the procedures for performing the studies and integrating results (four phases), the study duration (expected to be five years), and the study budget ($20 million). All of the recommendations have survived in the actual study to some extent, some intact and some modified by circumstances.

The concept of four study phases and a total study cost of $20 million are parts of the study that did not change. The study cost was a compromise amount, close to the estimates of Japan and the United States but substantially less than Panama's. It was fixed by the agreement to equal cost sharing; and the different fund sources of the study sponsors and the need for a new agreement inhibited incremental increases in funding. Hence there was no change in the study budget to cover cost increases due to price inflation or for other reasons.

The original four study phases can be described as follows (number of component studies to be contracted shown in parenthesis):

I. Background Studies and Identification of All Alternatives (5).

II. Commodity and Traffic Projections, Determination of Cost and Capacity of All Alternatives, and Identification of Acceptable Alternatives (6)

III. Feasibility Analysis of Each Accepted Alternative (6)

IV. Selection of Best Alternative (1)

To meet time and cost constraints, certain component studies were merged or modified in the Detailed Plan of Study and its modifications. The ultimate actual contents of the four phases in this study are fully described in a subsequent chapter.

A summary description of the contents of those phases is as follows (number of component studies/study contracts shown in parenthesis).[10]

I. Background Studies, Prescreening and Selection of Best Alternatives (8 component studies, 5 separate contracts)

II. Commodity and Traffic Projections, Determination of Cost and Capacity of the Selected Alternatives (5 component studies, 3 separate contracts)

III. Feasibility Analysis of the Selected Alternatives (6 component studies, 3 separate contracts)

IV. Selection of Best Alternative (1 component, 1 contract)

The most visible deviation from the initial study plan has been the study duration. Although there is not a complete agreement on the date from which to count time, the study duration clearly exceeded the original schedule of five years. It did so for a number of reasons, some of which are inherent in performing a study where participants speak three different languages, where there is difficulty in communicating and understanding, and difficulty in reaching agreement among representatives of three sovereign nations.

Spanish, English, and Japanese were all official languages for the study; English was the working language. Some of the reasons for delays were truly extraordinary: Civil unrest in Panama as well as an intervention by the United States.

[10]SINBOL Consortium, Detailed Plan of the Study of Alternatives to the Panama Canal, Volumes I and II, September 1990.

In perspective, the significant accomplishment has been a successful study that has been in close accordance with the original plan but not to its timetable.

2.3.3 Study Milestones

The following milestones are a chronological listing of significant events during the course of this study. As such, they are not limited to the specific milestones in the plan of study, nor do they include all elements in the plan. The purpose of these milestones is to provide a brief history of the study that conveys the unique flavor of the study effort.[11] [12]

- September 29, 1985 — Agreement to Tri - National Panama Canal Study (Tri - National exchange of diplomatic notes)
- June 2, 1986 — First Meeting of Board of Commissioners adoption of study scope, schedule and budget
- October 15, 1986 — First Invitation to Feasibility Analysis / Final Report (FA/FR) Study Contractors for submittal of pre-qualification credentials
- December 15, 1986 — Board Approval of Pre-qualified FA/FR Contractors
- April 17, 1987 — First Invitation for Contractor's Proposals for the FA/FR contract
- January 14, 1988 — Selection of FA/FR Study Contractor
- January 29, 1990 — Contract Award and Start of First Study Task Detailed Plan of Study by FA/FR Contractor
- September 24, 1990 — Board Approval of Detailed Plan of Study
- September 25, 1990 — Agreement to Extend Study Duration to September 24, 1993 (Tri - National exchange of diplomatic notes)
- February 25, 1991 — Board Agreement to Proceed with Study
    - Start of background studies,

[11] SINBOL Consortium, "Summary Schedule of Panama Canal Alternatives Study", 22 April 1991.

[12] Commission for the Study of Alternatives to the Panama Canal (Secretariat), "Summary Schedule of Phase 2 and Phase 3 Component Studies, 7 May 1993.

		○ Biological Inventory, ○ pre-qualification of component contractors
●	June, 1991	First Award of Component Study Contracts
●	June-July, 1991	Completion of Background Studies: ○ Present Situation in Panama ○ Status of Present Panama Canal ○ Historical Trade Analysis ○ Future Transportation System
●	August, 1991	Commencement of Phase I Component Studies ○ Commodity and Traffic Projections ○ Engineering and Cost Estimates ○ Operating Characteristics & Capacity Evaluation
●	July 10, 1992	SINBOL presents Prescreening of Canal Alternatives
●	July 14, 1992	Commissioners Approve Alternatives for Further Study.
●	July-August, 1992	Completion of Phase I Studies
●	Aug.-Sept. 1992	Commencement of Phase II Studies
●	November, 1992	Commencement of Feasibility Analyses ○ Economic Analysis & User Impacts, November 15 ○ Financial Analysis & Management, November 23
●	February 26, 1993	Start of Feasibility Report
●	March 19, 1993	Commencement of Impact Analyses ○ Analysis of Impact on Panama ○ Environmental Analysis
●	April-May, 1993	Completion of Phase II Studies ○ Engineering & Cost Estimates, April 23 ○ Commodity & Traffic Projections, May 7 ○ Operating Characteristics & Capacity, May 15

- June-July, 1993 — Completion of Phase III Studies
  - Completion of Feasibility and Impact Analyses
  - Completion of Biological Inventory Component
- September 15, 1993 — Completion of Feasibility Report

2.4 Study Direction and Management

The official form of the organization that produced this study was an independent international commission. Board members of the Commission for the Study of Alternatives to the Panama Canal represented their respective governments, but the execution of the study and management of the commission were the sole responsibility of the Board of Commissioners. The organization structure of the commission was prescribed in the Final Report of the Preparatory Committee.

Similar to the organization structure of other major studies, the basic organization elements were:

(1) an executive body, the Board of Commissioners;

(2) a staff to provide day-by-day administration and management of the study, the Secretariat; and,

(3) a large number of individuals and organizations with special expertise, acting through a consortia employed to perform the work in study components, collectively called "Study Contractors".

The specific responsibilities and functions of the Board of Commissioners, the Secretariat, and Technical Experts, were enumerated in the Preparatory Committee Report. They are consistent with the organization and practice in other major studies. Because of the tri-national nature of the study, the Preparatory Committee Report set forth unique requirements covering composition of the organization elements and selection of the individuals and firms involved. These requirements had a major impact on the way the study was conducted. The selection procedures, composition requirements, and key features of the organization elements, are described in following sections.

2.4.1 Board of Commissioners

Each of the three nations sponsoring the study was obligated to appoint one Commissioner, and entitled to appoint up to three Deputy Commissioners. The appointments were made by the respective governments at the cabinet level, hence Commission members held status as diplomats.

The report of the Preparatory Committee required the office of Board Chairman to rotate annually among the three Commissioners, with the two other Commissioners designated as Deputy Chairmen. Attendance of a Commissioner or authorized substitute from each nation was required to hold Board meetings. Voting power resided in the Commissioners or authorized substitutes, and the Board was required to make its decisions by unanimous agreement.

2.4.2 Secretariat Delegates

Each of the three nations sponsoring the study was obligated to appoint two Delegates, and entitled to appoint up to four Delegates to serve contemporaneously in the Secretariat. The report of the Preparatory Committee called for the Secretariat to be a body of experts, and Delegates were selected from the private sector as well as from a variety of government entities within the three governments. The credentials of the individuals represented a wide range of expertise. Appointments were made by the respective governments administratively, but Delegates also held status as diplomats. Within each nation's delegation, one of the appointees was designated Principal Delegate. The Republic of Panama was the designated location for the Secretariat's office, and for meetings of the Board. Delegates were authorized to contract for administrative support, and the individuals hired locally were designated support personnel.

The Report of the Preparatory Committee specified three offices within the Secretariat. These were Executive Director, Technical Director, and Finance Director. Respectively, the three Directors were charged with overall responsibility for implementing the study, supervision of contract management, and responsibility for financial controls and budgets. One Directorship was allocated to each country's delegation, with a requirement that the three directorships rotate annually among the three countries. Directors could act independently in most matters, but were required to have mutual agreement in certain specified areas.

2.4.3 Study Contractors

The report of the preparatory Committee contemplated use of multiple contractors to perform specific study components. In addition, its organization structure provided for a advisory and integrating contractor (the Feasibility Analysis/Final Report contract) to assist the Secretariat throughout the duration of the study. The assistance included implementing the study, integrating component studies, and production of the feasibility and final report. This contractor was under the direct supervision of the Technical Director and his Deputies, but had no supervisory authority over other study contractors.

One of the first activities of the Secretariat was to devise procedures to select and employ study contractors, consistent with the principles and requirements set out in the Preparatory Committee's Final Report. The intent was to open participation to a wide spectrum of technical experts -- academic, professional, and governmental -- and assure equal participation by nationality. A pre-qualification process was used, with evaluation based on mutually agreed upon criteria.

To assure substantially equal participation in study effort by nationality, the selection criteria required equal distribution by cost. Thus the principle of equality flowed through to contractor consortia, imposing a need for mutual agreement throughout the organization structure.

2.5 Status of the Canal

2.5.1 Physical Characteristics and Constraints

The present Panama Canal is a 80.4 kilometer (50 mile) long waterway that runs across the Isthmus of Panama in a northeast to southwest direction. It is a complex engineering facility consisting of artificially created lakes, dams, locks, power stations, anchoring facilities, breakwaters, roads, bridges, operational and management buildings, operational equipment and a highly skilled workforce.

The journey starting on the Atlantic side is as follows: from Limon Bay to the Gatun locks a vessel will travel approximately 12 km. (7.5 miles) at sea level. At the Gatun locks, the vessel will be raised to 26.0 m. (85 ft.) in three lifts (three consecutive chambers) where it will continue its travel on the Gatun Lake and through Culebra Cut for another 52.3 km. (32.5 miles) until it reaches the Pedro Miguel Locks. At this point the vessel will be lowered 9.4 m. (31 ft.) in one lift in order to enter Miraflores Lake where it will travel for another 3.2 km. (2 miles) before it reaches the Miraflores Locks. At the Miraflores Locks the vessel will be lowered 16.5 m. (54 ft.) in two lifts reaching sea level where it will travel for 12.9 km. (8 miles) to the end of the waterway. In this journey the vessel will have gone through three sets of locks, two artificial lakes and also through Culebra Cut.

The maximum width of the Canal is 305 m. (1,000 ft.) and the minimum is 152.5 m. (500 ft.) at Culebra Cut. There is an ongoing construction program whereby the Cut will be widened to 192 m. (630 ft.). For this report it is assumed that the widening program will be completed before construction of any alternative is implemented. The water depth in the Canal ranges from 13.7 m. (45 ft.) to 25.9 m. (85 ft.), being 13.7 m. (45 ft.) at the Cut.

The Gatun Lake is one of the two man made lakes used for canal navigation. It has a storage capacity of 659,000,000 cubic meters. It is also the main source of lockage water for canal operations. The Miraflores Lake is the other artificial lake that serves canal navigation. The Madden Lake is not used for navigational purposes but rather as a reservoir to satisfy potential needs of lockage water and also for municipal and hydroelectric uses. It has a storage capacity of 539,000,000 m^3.

The major constraints to the present Canal are related to accepting vessels larger than a certain size, operating capacity and passage restrictions at the Culebra Cut. The largest vessel size allowed to transit the Canal are called Panamax, having a nominal weight of 65,000 dwt.

The operating performance of the Canal in 1989 was 11,989 transits which is well under maximum capacity. Studies conducted by the OCCE Contractor and others have estimated present canal operating capacity to be higher than 16,000 transits per year for the projected traffic mix.

Culebra Cut restrictions are basically related to safety considerations, hence large ships as well as those carrying hazardous cargo are not allowed to navigate through the cut at night and during periods of dense fog, nor are they allowed to pass or overtake each other in the cut.

Water for lockage operations is not, nor will be, a constraint up until well after the year 2020 when additional dams and pump stations should be considered.

2.5.2 Ability to Serve World Commerce

The Panama Canal is a very efficiently run operation. It has a well structured organization in which the Chairman is the highest ranking executive officer. The highest management officer is the Administrator. Its operational organization is broken down in divisions which handle every need for the effective operation of the canal. Its workforce is highly trained and experienced. The maintenance programs carried out by the Panama Canal Commission are recognized as excellent. As a result of these maintenance and refurbishing programs routinely executed by the Panama Canal Commission, most of the present Canal structures, buildings and equipment are in good conditions and their life expectancy is far from coming to an end if these same programs are carried out by the successor organization that will administer the Canal.

Capacity projections have disclosed the fact that the Canal may serve a significant portion of world commerce using the canal route in its present condition.

2.5.3 Technological Changes in Transportation

Global economics, changes in world geopolitical parameters and greater awareness for earth conservation are and will continue affecting transportation modes and requirements. The present pattern of integrated large economic blocks will make each one of the new market regions more self sufficient. Under this scenario, it could be argued that trade between distant places would decrease. The same could be argued regarding the new geopolitical order in which distant allies are no longer required to provide aid to the weaker partner. As an aftermath of the end of the cold war, former enemies are becoming trade partners. These factors tend to inhibit the need for Canal improvements.

On the other hand, the ever increasing world population will bring an increase in vessel traffic from all parts of the world, derived not only from the larger population itself but also due to the loss of farmland being used by developers to accommodate this larger population. Countries that are self sufficient or partly self sufficient in some areas will become more dependent on others.

During the next few decades a significant shift on the extent and intensity of food production will occur from the temperate zones, where agricultural production has until now flourished in previously unoccupied lands and under a seasonal regimen, to the tropical zone where land is still abundant and energy for growth is available year round. This will increase international trade and thus vessel traffic.

The trend of the last decade towards larger vessels came to an end and is now being reversed for most vessel types. The reason is that ports in most of the industrialized countries are having enormous difficulties in improving their existing facilities. Larger vessels require deeper harboring areas. However, due to adverse environmental impacts, deepening of ports is encountering stiff resistance from local governments and the population nearby. New environmental protection regulations tend to make port improvements too expensive and economically unfeasible and unattractive. As a consequence of all these conditions, the world fleet will be more inclined towards the vessels that have been in fashion during the last decades and that can be accommodated in present port facilities.

The dynamic nature of changes affecting transportation on vessels limits the accuracy of forecasts, hence further studies must be undertaken periodically.

A Feasibility Report
3.0 Canal Alternatives Study

The Canal Alternatives Study is a large and complex undertaking which, conceptually is simply a feasibility study that concerns vessel navigation. The basic analyses in the study are those that are commonly used in navigation improvement studies and its findings are based on analyses that are widely accepted as well as commonly used. Innovation and imagination were needed to perform the study. For maximum credibility it uses analyses that are conventional and realistic measures of feasibility.

Similar to the study itself, the plan of study is large and complex. It is large because of the prescribed study scope and the amount of effort involved. It is complicated because there are many parts to the study.

3.1 Detailed Plan of Study

On January 14, 1988, The Board of Commissioners, Selected the SINBOL Consortium Technical Proposal as the highest ranked in technical merit among those considered for the FA/FR Study Component Contractor.

On January 29, 1990, The Commission and the Consortium entered into an agreement to prepare a Detailed Plan of Study (DPS). On September 24, 1990, the Final DPS produced by the Consortium was accepted and approved by the Commission.

The DPS was prepared in accordance with the guidelines established in the Final Report of the Preparatory Committee on the Panama Canal Alternatives Study and according to guidance provided by the Commission and its Secretariat.

The DPS included a detailed scope of work for the FA/FR contractor, Terms of Reference (TOR) for Component Studies, and Detailed Work Plan (DWP) for selected prescreening tasks to be carried out by the FA/FR Contractor.

Details on the DPS including the responsibilities of the Commission and its Secretariat, FA/FR Contractor, and Component Contractors can be found in the DPS.

As detailed in the DPS, the Detailed Work Plan (DWP) included four study phases and are briefly described below.

3.1.1 Phase I Study Plan - Prescreening and Selection of Alternatives

Phase I Study Plan included data collection, project formulation, and prescreening of alternatives. The FA/FR Contractor prescreened the alternatives under consideration based on, among others, four preliminary studies covering the Present Situation in Panama, the Status of Panama Canal, Historical Trade Analysis, and Future Transportation Systems, which had been completed earlier by member companies of SINBOL.

The purpose of Present Situation in Panama Component Study was to provide both general and specific scientific data and information as a basis for performing environmental and socioeconomic impact analysis. The study covered natural and physical conditions, economic, cultural, and political environment in Panama.

The Status of the Panama Canal Component Study examined the present configuration of the waterway including organization, composition of the work force, financial situation, the toll system, the operating and maintenance characteristics, and the Canal cargo and transit vessels. The study results were useful to other component studies, particularly engineering studies, and the prescreening and selection of alternatives.

The Historical Trade Analysis Component Study provided data and analysis of export and imports of major commodity groups, cargo movement, major trade routes for maritime and maritime related transportation systems in relation to the Isthmian route, and the origin-destination relationships for major commodity groups. These data were used to support the Commodity and Traffic Projection and the Analysis of Impact Upon Canal Users Component Studies.

The purpose of Future Transportation Systems was to identify the present status of the maritime transportation system, assess its future prospects,and to classify the significance of the Panamanian Isthmus in World Trade. The study results were used to support the Commodity and Traffic Projections and the Analysis of Impact Upon Panama Users Component Studies.

As part of preliminary analysis, the FA/FR contractor assembled available engineering data and criteria, cost, environmental and socioeconomic, operation and maintenance, and operating characteristics and capacity data for all historic Canal Alternatives included in the Study. The above data and document, titled *"Classification and Identification of Alternatives" (CIA)* was submitted to the Commission on July 18, 1991, via letter SC-079/91. In addition, the FA/FR Contractor provided the following services to the Commission as part of this phase:

- Advice in selecting viable alternatives
- Advice and assist in pre-qualification and tendering of component contractors and selecting and overseeing the work of component study contractors.

- Advice in recommending the best alternatives and prepare a detailed investigation of the recommended alternatives.

- Advice and assist in scheduling and managing the study program.

During this phase, four component Studies were awarded. The contract negotiation and awards were based on the Terms of Reference (TOR) included in the DPS. The DPS also provided basis for the Technical scope of work for the Component Contractors which was used to monitor and control these component studies.

These studies were;

- Preliminary Engineering and Cost Estimate,

- Commodity and Traffic Projection,

- Preliminary Operating Characteristics and Capacity Evaluation, and

- Background Biological Data.

The Preliminary Engineering and Costs Estimate Component Study developed capital improvements and costs for all historical alternatives applying principal of consistent assumptions and criteria so as not to bias the study in favor of any of the historic alternatives. The results were of great importance in the process of prescreening and selection of alternatives.

The Commodity and Traffic Projection Component Study projected the demand of the commodity and traffic transiting through the Panamanian Isthmus. Commodity and Traffic Projections were made for both the short-term (year 2020) and the long-term (2060). The purpose of this study was to provide a quantified definition of the demand for the future uses of the canal for the prescreening and selection of alternatives, and also provide key information and data to the Operating Characteristic Component Study.

The Operating Characteristic Study evaluated performance, in terms of transit time and minimum interval between ships, of vessels transiting through each of the alternatives. The Capacity Evaluation Study analyzed and estimated the transit capacity of each of the alternatives and determined the flexibility and feasibility for the future expansion. These studies also provided input to the prescreening and selection of alternatives.

The Background Biological Inventory Component Study determined the ecological baseline in areas of Panama which could potentially be affected by construction and operation of any lock canal alternatives. This study provided input to the Environmental Analysis Component Study. Preliminary Background Biological Data from this study provided input to the Prescreening and Selection of Alternatives.

The FA/FR Contractor prepared methodology and criteria for Prescreening of Alternatives which was presented and submitted to the Commission in its draft final form during the Informal Meeting of the Board of Commissioners on September 23, 1991. The introduction to the final "Methodology and Criteria for Prescreening of Alternatives" was submitted to the Secretariat on April 23, 1992 after several meetings and extensive discussions with the Secretariat. The prescreening of Alternatives results was submitted to the Secretariat on July 13, 1992 via letter No. SC-103/92 dated July 13, 1992, and was verbally presented to the Commissioners during a meeting in Panama on July 14, 1992.

It should be noted that preliminary results from all component studies except the Background Biological Data were completed and used in the prescreening of alternatives. The Biological Data Component Study was only partially completed at that time.

At the conclusion of the meeting of the Commissioners of July 14, 1992, the Secretariat with the advice of SINBOL was instructed to prepare detailed TORs for phase II component studies to include Canal Alternatives which survived the prescreening. These Alternatives were; high rise lock canal, and sea level canal (Route 10).

3.1.2 Phase II Study Plan-Demand Analysis and Engineering

The two conceptual alternatives which survived the prescreening and were recommended by the Commission for further studies in Phases II and III were:

- High Rise Lock Canal
- Sea Level Canal Route 10

The optimization studies conducted during the prescreening and selection of alternatives indicated that a High Rise Lock Canal with a design ship between 150,000 and 200,000 dwt was the optimal conceptual alternative and these two cases were recommended for Phase II studies. The same optimization studies also revealed that a single lane sea level canal along route 10 (IOCS Route 10) with a design ship of 250,000 dwt ship operating in conjunction with the existing canal was the other optimal conceptual alternative which was recommended for further development in Phase II.

The High Rise Lock Canal was to have two lanes, two rise locks, and a Gatun Lake at El 85 or El 90 feet. The Sea Level Canal was to be predominantly a single lane canal with two lane approaches from both the Atlantic and Pacific oceans and consideration of tidal gates, tidal locks, and combination of tidal locks and gates. The two conceptual alternatives were to be fully developed to accommodate projected transit for years 2020 and 2060.

Phase II Study required modification of the DPS to include:

- Reference to specific alternatives which survived the prescreening of alternatives in Phase I;

- Specific criteria and details related to those alternatives which survived the prescreening;

- Incorporate lessons learned from Phase I studies; and,

- Provide specific TORs, related to requirements for Phase II study. These TORs included specific engineering data, design criteria, environmental and socioeconomic sensitive areas, and cost savings and benefit methodology.

The same component contractors involved in Phase I were authorized to carry on Phase II studies. The Phase II studies included; commodity and traffic projection, operating characteristic and capacity evaluation, engineering and cost estimates, and biological inventory; the later is the continuation of background biological data in Phase I. It should be noted that for Phase II, neither the Biological Inventory Study nor the Background Biological Study was expanded to consider a sea level canal.

Phase II Commodity and Traffic Projection Study was an extension to the Phase I study with modification to include data obtained from the Panama Canal Commission (PCC), the Organization for Economic Cooperation and Development, and the United States Commerce Department. The purpose of this Phase II study remained to forecast cargo and flows in total by commodity and route in relation to the Panamanian Isthmus and number of vessels by design ship size for years of 1990, 2020, and 2060. An important parameter obtained and used by others from this study is the potential benefits derived from each canal alternative.

The Phase II Operating Characteristics and Capacity Evaluation Component Study was an extension to Phase I study providing transit time and minimum intervals between specified design ships and transit capacity of each specified alternative (150,000 and 200,000 dwt for High Rise Lock Canal, and 250,000 dwt for the Sea Level Canal. In addition, this study provided estimated data for sedimentation and littoral drift in the Canal and approach channels. Results of this study were used by other component contractors to estimate the potential revenues that could be derived from each of the two conceptual alternatives studied in this phase.

The Phase II Engineering and Costs Estimate Study developed capital improvements and costs for high rise lock canal with the design ships of 150,000 dwt and 200,000 dwt, and for Sea Level Canal (Route 10) for the design ship of 250,000 dwt.

During Phase II studies, assumptions were replaced with real data and design criteria specific to each alternative which survived the prescreening. Whereas consistent basic parameters were important criteria guiding Phase I studies and prescreening, specific data and design criteria guided Phase II studies. However, consistency was incorporated into Phase II by adopting Phase I approach and methodology especially in regard to water management and costs.

Since the study was more focused during the Phase II Component Studies, it became necessary and important to intensify the coordination among selected component contractors. Several objectives were accomplished by this coordination, including:

- To better describe technical scope and responsibilities of each contractor to avoid duplication of effort and disagreement in approach and methodology in overlap areas,
- To provide a list of information and requirements each contractor will need from others to complete their scope of work within schedule.
- To exchange information on lessons learned from phase I studies,
- To identify needs for information and results from other contractors, and
- To agree to communicate at reasonable intervals, and whenever needed in order to expedite the progress, and meet the study schedule.

The coordination began with meetings during the presentation of inception reports by the component contractors, and continued for the duration of each study. With the exception of Biological Inventory, all other component studies required developing detailed and specific TORs. The biological inventory component study TOR was joined with the background biological data during contract negotiation with this winning Component Contractor. All newly generated TORs other than those included in the DPS are included with the respective final study reports.

3.1.3 Phase III Study Plan - Feasibility Analysis

Phase III component studies consisted of Financing Scheme, Economic Analysis, Financial Analysis, Environmental Analysis, Impacts Upon Panama, Impacts Upon Users, and Management Arrangement.

A brief description of the purpose and use of these component studies is provided below.

- The Financing Scheme study provided the optimum funding source together with terms and conditions for each screened alternative.
- The Economic Analysis study provided important quantifiable primary effects (users capacity to pay) and benefits (in terms of benefits to Panama and user countries).
- The Financial Analysis Study provided judgement as to which alternative are financially viable and feasible. Financial projections provided as a result of this study depended very much on the costs and traffic demand forecast provided by other component studies.

- The Environmental Analysis Component Study provided characterization, to the extent possible, of anticipated effects on the environment imposed by each viable canal alternative. The analysis was restricted to an ecological assessment with remaining environmental elements considered in the Impact Upon Panama. Recommendations for additional ecological studies were also provided.

- The Analysis of Impacts Upon Panama provided the impacts of alternatives during construction and operation. The impacts could be direct effects (quantifiable by economic analysis) and indirect effects in terms of long-lasting influence as a result of regional development.

- The Analysis of Impact Upon Users provided short-term direct (during construction both positive and negative) and short-term indirect (increase or decrease of canal cargo and traffic benefits during construction upon canal users). In addition, long term direct (transit of larger Panama's ships and commodity) and long-term indirect (lower transportation and commodity prices and higher employment and income) was forecasted.

- The Management Arrangement Study provided the optimum functional arrangement for each canal alternative.

Phase III component studies overlap with Phase II component studies for several reasons, these include; requirements of input data, especially those dealing with the costs and benefits; identification of project impacts; coordination of impact mitigation schemes; innovative financing schemes; and the most cost effective management arrangements.

3.1.4 Phase IV Study Plan - Final Report

In the original DPS dated September 18, 1990, this phase was to be conducted in its entirety in the FA/FR contractor. The only exceptions were additional data to be developed by various component contractors. Due to the fixed September 25, 1993 diplomatic completion deadline for this project, the numerous delays experienced in awarding some of the component studies, and also delays experienced in meeting schedules by few component contractors; it became necessary for the commission to redefine a reduced scope work for Phase IV work so that a report could be issued prior to the termination of this study. Therefore, Phase IV consist of only the Feasibility Report effort mandated by the Commissioners. The redefined scope of work of Phase IV specified the following deletions and changes:

- Delete detailed investigation and study;

- Delete development of additional data; and,

- Replace The Draft and Final Report by a Draft and Final Feasibility Report.

It should be noted that as originally scheduled, Phase III would have ended with the feasibility analysis and recommendations of the best alternative; however, due to reasons indicated above it ended with component study reports detailing only the feasibility of those alternatives which survived the prescreening. The resulting Feasibility Report provides a summary of all the studies which were conducted to determine feasibility of all the alternatives to the Panama Canal. The report contains conclusions and recommendations regarding methodology to secure the necessary additional data and outlines the detailed investigation that needs to be conducted to select the most viable alternative.

3.2 Modifications to the Detailed Plan of Study

The notes exchanged among the governments of Japan, Panama and the United States of America on September 25, 1990, directed that the work of the Commission must be completed by September 25, 1993.

For this reason and others indicated above, both the Commission and SINBOL recognized that the Agreement for Services can not be implemented fully in accordance with its original terms and conditions before September 25, 1993. Therefore, the agreement was amended to permit the commission to conclude its activities by September 25, 1993.

The Amendment included;

1. Releasing SINBOL from any obligation to recommend a Best Alternative.

2. Releasing SINBOL from any obligation to carry out the "Detailed Investigation and Study" as outlined in the original Agreement for Services.

3. SINBOL will evaluate the High Rise Lock Canal and the Sea Level Canal alternatives as recommended by the Commissions Board of Commissioners meeting in Panama held on July 24, 1992. This evaluation will be based on the results of Phases II and III component studies provided the results of these studies are made available to SINBOL on or before June 15, 1993.

4. SINBOL's feasibility evaluation of alternatives will be documented in "A Feasibility Report" instead of the "Feasibility Analysis" required in the Original contract.

For schedule of dates and further details regarding the amendment to the agreement for Services, see "Memorandum of Agreement For Services Between The Commission For The Study Of Alternatives To The Panama Canal and the SINBOL Consortium".

3.3 Analytical Requirements for the Study

This section identifies the special requirements of this study, and describes their purpose and significance in the study effort.

3.3.1 Identification and Screening of Alternatives

The canal alternatives study is unique in many respects, not the least of which is the requirement in the scope of study produced by the Preparatory Committee to consider all alternatives to the Panama Canal in Panama. Most navigation studies routinely identify alternatives during the formulation of a plan for a specific improvement. Typically that improvement is a project that can be implemented by the study sponsor - subject to physical and financial feasibility. It is usually called the "structural solution."

Other solutions to the navigation problem that could be implemented by others, or at least are not implementable by the study sponsor, are usually called "non-structural solutions". They include the type of vessels used and the way they are operated, and/or use of other transportation modes. Traditionally they have been handled as alternatives to use of the project, or as alternative ways to use the project, and the requirements to analyze their feasibility are minimal.

The requirement to consider "all" alternatives to the Panama Canal imposed a new dimension on the determination of what is feasible. For that reason, the Canal study incorporates a number of analyses that are not normally a part of a navigation improvement study. These center on the screening of potential projects to provide an orderly way to reduce the number of projects considered in the final feasibility analysis. In addition to the screening that is a regular part of navigation studies, the canal study used a unique preliminary or "pre-screen" screening process. In it, 36 specific cases were designed and costs estimated in order to provide a basis for four conceptual alternatives. The evaluation of the conceptual alternatives was similar to project evaluation, and involved engineering and economic analyses, and assessment of impacts and implementability. Overall, this resulted in three iterations of design and screening in the study, and there is a notable repetition of analyses in the study plan. In large part, the complexity of the study is attributable to the requirement to consider all alternatives.

Over time, many alternatives have been proposed, and some have been implemented. These were identified as part of the preparation of the Plan of Study.

To provide the various study contractors with a finite number of alternatives, there was an initial determination of representative projects, and these were categorized as follows:

- Improvements or Enlargements to the Existing Canal
    - Status quo alternative (includes Culebra Cut widening)

- Non-lock improvements
- Third Locks Plan
- Terminal Lake Plan and variations
- Deep Draft Lock Canal Plan
- Lopez-Moreno Plan

- Sea-level Canal

  - 1970 Interoceanic Canal Studies, Route 10
  - 1970 Interoceanic Canal Studies, Route 14S
  - Vergara Plan
  - Nagano Plan

- Non-Canal Complementary Transportation Systems

  - Oil pipeline
  - Land bridge systems (railway and highway)
  - Appropriate parts of the Centerport Concept
  - Other

The non-canal complementary transportation systems identified in the plan of study are alternate transportation modes in Panama. As such, they are part of the "all alternatives in Panama" to be considered pursuant to the study scope by the Preparatory Committee. Similar to the Canal itself, these are alternatives to utilize the inherent advantages of the Panamanian Isthmus for interoceanic transportation. Therefore, they are considered as canal alternatives that provide supplementary capacity rather than "non-structural alternatives" in lieu of a canal. Because the complementary systems are in various stages of development, determinations of feasibility were deemed inappropriate, and for analytical purposes they have been treated as alternate transportation routes. The actual or estimated cost of transportation has been used to allocate cargo flows.

The various structural alternatives identified in the plan of study were initially categorized according to specific improvement plan or proposal. To provide a useful basis for developing comparative designs and costs, the individual concepts were reduced to four basic concepts; two lock-type canals--high lake level and low lake level, and two sea-level canals based on alternate routes.

To provide a basis for designing and costing specific projects, two sets of three different design ship sizes were agreed upon, along with general design criteria incorporating the salient features of each conceptual alternatives. This resulted in a total of 36 cases, 18 lock canal and 18 sea level. To distinguish the level of detail in their plans, these alternatives have been called study cases.

The lock canal study cases were based on three design vessels (100,000, 150,000 and 250,000 dwt sizes, four lake water levels (90', 85', 55' and 30'), four modifications of the existing Canal route, all two-lane, and two lock alternatives (1 and 2 lifts).

The sea level canal study cases were based on three design vessels (150,000, 250,000 and 300,000 dwt sizes), three lane alternatives (one-way, two-way, and mixed one-way/two-way), and two routes (Route 10 and Route 14S).

In the pre-screening process, the cost and benefit analysis was used to consolidate the 36 study cases into the promising conceptual alternatives. Four conceptual alternatives were evaluated for acceptability based on engineering considerations, impact assessment and implementability. They were evaluated for economic efficiency based on preliminary estimates of traffic and the resulting B/C ratios. All four conceptual alternatives passed the test of acceptability, hence the B/C ratios became the controlling selection factor. Two of the four canal concepts had positive B/C ratios implying economic justification, and these became the basis for the final alternatives. They were the High Rise Lock Canal, and the Sea Level Canal on Route 10.

To provide a basis for final design of the canal alternatives, revised design vessels and design criteria were agreed upon. This resulted in several alternatives of the two surviving concepts. The lock canals used design vessels of 150,000 dwt and 200,000 dwt, the sea level canals used design vessels of 250,000 dwt.

3.3.2 Canal Capacity Analysis

Concern about the capacity of the Panama Canal was the fundamental reason for this study, hence there was a special need to define it as precisely as possible. Because two basic types of capacity limits apply to all waterways, it is essential to distinguish between them, and to describe how they apply to the Panama Canal and how they are treated in this study.

- Vessel size limits are determined by the dimensions of vessels in relation to the dimensions of channels and locks, and constraints are readily apparent although the exact size limits are subject to interpretation. Due to economies of scale, vessel sizes tend to grow over time, and this was the proximate cause of Canal studies after World War II.

- Vessel transit limits -- or the ability of a waterway to accommodate a specific number of vessels during a given time period -- are the result of the interaction of a number of factors including the size, speed, and maneuverability of vessels in constricted waters, and the cycle time of locks where they are involved. Transit limits are remarkably difficult to define with precision because of the many variables involved including assumptions as to operating practices and alternatives. As a result, the various Canal studies performed after World War II have produced a variety of estimates of vessel transit limits and cargo throughput capacity.

In the canal alternatives study, the two types of capacity limits have been treated separately, with some linkage between the two analyses. Vessel size limits were treated as part of the estimation of project benefits, as is customary in navigation studies involving harbors. That part of a navigation study normally identifies future vessel fleet composition and the potential beneficiaries of channel or lock improvements based on vessel size versus lock or channel size, with transportation cost reduction benefits attributed to use of larger vessels after the improvement. Based on the design criteria for the improvement, the comparison of sizes is uncomplicated except to the extent use of alternate channel depths and partially loaded vessels is considered. Vessel transit limits required a special analysis in this study because of the lack of agreement in prior study results, and because it was necessary to devise a measurement system that produced comparable results for the existing Canal and the potential canal alternatives. This analysis incorporates procedures that are customary in canal system studies along with a number of unique features. This capacity analysis is described explicitly in a subsequent chapter, and is summarized below.

The transit capacity analysis was a major effort because it involved two distinct types of canals - lock type and sea level - and multiple variations of each including two-way and one-way traffic. A major challenge was to devise a measurement system that produced comparable capacity estimates for the disparate alternatives. In lock canals, the cycle time of the lock for filling and emptying is a key factor in transit capacity, but actual capacity is greatly influenced by the arrival patterns of vessels and the speed with which they can enter and clear lock chambers. In sea level canals, vessel maneuverability is a key factor, and actual capacity is greatly influenced by the type, size, and speeds of the vessels involved.

A sea level canal in Panama is also affected by differential tide heights in the Atlantic and Pacific, resulting in a potential for tidal currents that could affect vessel maneuverability. The net effect is that the two basic types of canals and their variants have offsetting advantages and disadvantages, and the capacity analysis was an essential device for considering them.

The way in which the canal is operated is part of the set of alternatives incorporated into the assumptions as to with and without project conditions. The capacity analysis included a comprehensive investigation of present canal practices to facilitate vessel transits, and examination of records of weather delays and downtime for maintenance. These past practices and experience were reflected in capacity estimates, and were the basis for recommendations for vessel navigation aids and assistance to be provided as part of improvement plans.

Similar to canal operating characteristics, the way in which vessels are operated is also part of the set of alternatives incorporated into the assumed future project conditions. Based on past experience with the Panama Canal, it was assumed that vessel arrivals would continue to be random (except for scheduled passenger ships), and that vessel operators would continue to accept queuing. Those practices were deemed equally applicable to both types of canals. However, the consideration of sea level canals required extensive additional analysis of ship navigation in tidal currents.

As a result of the above analysis, it was determined that an acceptable level of vessel safety required tidal locks or gates to control currents. In fact, they are now part of the Sea Level Canal plans for that reason as well as environmental protection, and are reflected in capacity estimate assumptions as to operating practices.

Except for passenger ships, the arrival of ships at the Canal is, and is expected to be, random. When they arrive, vessels may be able to move into a queue immediately, or they may be delayed for various reasons. Once in the queue, they may be delayed waiting for a clear channel. Once the queue is underway, it may be delayed by individual vessels having problems, or weather or lock or channel conditions. Because of the number of factors involved, delays can grow exponentially. Since delays account for most of the difference between theoretical and actual capacity, delay analysis is a central effort in capacity analysis. Mathematical models using probability distributions to account for randomness have been developed for queuing problems such as this.

The contractor performing the capacity analysis used a proprietary mathematical model to estimate tidal currents for the sea level canals.

The contractor used a modification of a lock system capacity model developed by the U.S. Army Corps of Engineers to derive capacity estimates based on delay curves. In effect, the model computes the exponential growth in delay time due to interaction of the various system components. Since canal throughput continues to grow as delays build -- up to the point of theoretical maximum capacity -- practical capacity depends on the amount of delays that are acceptable. That amount of delay involves a judgement call, and the analysis provided alternate estimates. The capacity analysis produced a number of recommendations for specific design considerations.

The two areas of investigation that produced the most significant recommendations were the analysis of sea level canal tidal currents and currents and sedimentation from intersecting streams and rivers, and the capacity analysis that identified the most effective locations for two way traffic. The capacity analysis produced estimates of transit capacity related to delay time for the present Canal and its alternatives. The results of the analysis therefore do not identify one finite limit to transit capacity, but provide a basis for arriving at practical capacity using comparative transportation costs. Accordingly, the analysis did not set a limit on project benefits and potential revenues directly, but it is meaningful when related to potential future traffic and comparative transportation costs.

A Feasibility Report
4.0 Background and Baseline Studies

4.1 Historical Background

Soon after the foundation of the city of Panama in 1519, Emperor Carlos V ordered studies for the potential construction of a pathway that would join the Pacific and the Atlantic oceans. Licenciado Espinoza, who explored the region in 1534 recommended that the Crown open a canal using the course of the Chagres River. However, the project was abandoned and during the next three centuries Camino Real, and overland trade route that joined the two oceans, was used for transportation of goods. Camino de Cruces was another route also available at the time which used part of the Chagres river for navigation.

Between 1850 and 1855, the 80 Km. Panama Transisthmian Railway was built joining the terminal cities of Panama and Colon. The alignment of this railway was later used as reference for future canal alternatives.

In 1866, Vice Admiral Davis identified nineteen potential routes through Central America, and in 1867 the United States was granted a concession from the Colombian Government to explore routes in the Isthmus of Panama. In 1870, the Colombian Senate refused to ratify the Arosemena-Sanchez-Hulburt Treaty whereby the United States would have been granted authorization to excavate an interoceanic canal through the Isthmus of Panama.

In 1880, the French began construction of the Panama Canal. The French intended to build an interoceanic sea level canal. The effort undertaken by the French was unsuccessful due to financial and engineering difficulties and in 1888 the Universal Company for the Interoceanic Canal declared bankruptcy.

In 1902 Mr. Bunau-Varilla on behalf of the French, proposed to Vice Admiral Walker the transfer of the Canal Company assets to the United States for the sum of forty million dollars. This offer changed the Vice Admiral's decision to recommend the Nicaraguan route over the Panama Route. In that same year, the Spooner Law was enacted by which the President of the United States could start negotiations to construct an interoceanic canal through the Central American Area.

In 1903 the Herran-Hay Treaty was rejected by the Colombian Senate. This action provoked strong reactions in Panama that eventually led to its independence from Colombia. After independence, Panama and the United States executed a treaty for the construction of the Panama Canal. The French also proceeded to sell their canal rights to the United States.

In 1904 canal construction activities started and two years later, in 1906 the U.S. Congress approved a plan to modify the original design from a sea level concept to a system of locks. The Panama Canal was successfully completed in 1914.

Due to the continuous increase in canal traffic, the U.S. Government delegated to the Army Corps of Engineers the responsibility to perform studies to enhance canal capacity. In 1931 the Corps of Engineers proposed three alternatives: to add a third set of locks, to convert the existing canal into a sea level canal or to build a new lock canal in Nicaragua.

In 1936 the U.S. Government requested the Governor of the Canal Zone to make recommendations for the improvement of canal capacity. The Governor presented a plan which was based on the previous Corps of Engineers recommendation to add a third set of lock on the existing canal. During the next years, design of the new structures was completed and excavation work was started; however in 1942, as a result of the United States commitment into World War II, the project was halted and was never again restarted.

In 1945, the U.S. Government directed the Canal Zone Governor to develop means to increase canal capacity. The study was to include the possibility of other canal routes that would offer better defensive position. As a result of this study, 30 alternative routes were proposed. The "Study of the Isthmus Canal" dated 1947 concluded that the most desirable and viable alternative was a sea level canal.

In 1957, the U.S. Congress appointed a Board of Consultants of the Isthmian Canal Studies to investigate both short and long range plans for improvements to the Panama Canal, specially in light of projected needs by 1999. The report stated that no sea level canal project in the Canal Zone should be undertaken in the near future. It also recommended further studies with respect to the use of nuclear excavation in the future.

In 1960 the Panama Canal Company appointed a Committee that would review and improve the 1947 report. This new study was performed in conjunction with the Atomic Energy Commission.

In 1964 a report entitled "Studies of the Isthmus Canal" proposed three alternatives to improve traffic capacity across Panama:

1) Third Set of Locks at Miraflores and Gatun;

2) Terminal Lake Plan; and,

3) Sea Level Canal following in general terms the alignment of the existing canal.

Further studies were later conducted and in 1970 the "Report of the Interoceanic Canal Study Commission" (IOCS), also known as the Anderson Report concluded that the most feasible alternative was the then Route 10 (west of the existing canal). This report also concluded that a new conventionally excavated sea level canal would have the capacity of up to 35,000 transits with ship sizes of up to 250,000 dwt and that design and construction would take about 14 years at a total project cost of approximately 2.9 billion dollars.

In 1977 the United States and the Republic of Panama signed a treaty which included a mandatory provision for the performance of a study on the viability of a sea level canal across Panama. It required that the study be completed by the year 2000.

In 1978 the United States authorized a study commission to update the findings of the 1970 Interoceanic Canal Study. In 1981 the Republic of Panama informed the United States of its interest in participating in the forthcoming study. Japan had also demonstrated interest in the interoceanic study to be conducted. As a result, in 1982 Japan was invited to participate in these endeavors. Hence the Tripartite Preparatory Committee was formed by the three countries and was assigned the responsibility to produce the terms of reference for the Study of Alternatives to the Panama Canal and in 1985, the terms of reference for the studies were formally accepted.

On July 10, 1990 a meeting was held to discuss the potential extension of the Commission for the Study of Alternatives to the Panama Canal beyond September 1990. It was decided to extend the Commission charter through the end of September, 1993.

On February 25, 1991 the SINBOL Consortium was authorized to proceed with the Feasibility Analysis/Feasibility Report Study as part of the Study of Alternatives to the Panama Canal.

4.2 Background Studies to Identify and Screen Canal Alternatives

4.2.1 Present Situation in Panama

A detailed study entitled Present Situation in Panama was carried out with the objective of providing information to analyze the overall situation on the physical, economic, cultural and political environment of the Republic of Panama. Different factors relating to the present situation in Panama were studied and analyzed such as terrestrial and marine environment and ecology, geographical aspects, economic and financial aspects, socio-cultural and political factors affecting Panama. The following section provide some of the findings of this study.

The country has a total area of 77,082 sq. kms. and a population of 2,315,047 according to the 1990 census. The average annual rainfall is close to 3,500 mm. The rainy season spans from mid-april to mid-november.

In terms of seismology, it has been determined that according to the distribution of epicenters, two zones of intense seismic activity are identified: at the south west of the Providence of Chiriqui and at the south east of the Providence of Darien.

The tides on the Pacific side have variations as large as five meters and with a very regular pattern of behavior. On the Atlantic side, tide variations scarcely reach one meter and are more affected by meteorological conditions, thence their behavior is less regular.

The largest ethnic group in the country is the so called mestizo, which is the breed of the native indians and the spaniards. This group is scattered alongside the whole country with smaller representation in the terminal cities of Panama and Colon.

Although Spanish is the language spoken by the vast majority of the population, English is also widely spoken as a second language by some.

Politically the country is a democracy headed by the President as the chief of the executive branch. The legislative branch is represented by the National Assembly and the judicial branch is represented by the Supreme Court together with the rest of the judicial system.

Panama is divided in nine provinces. The Governor is the highest executive authority in the provincial government. Provinces are subdivided in districts. Altogether there are 67 districts in the country. The highest district authority is the mayor.

4.2.2 Status of Present Panama Canal

Principal Features

Canal Characteristics and Constraints

A description of the physical characteristics and constraints of the present Panama Canal appears in Section 2.5.1 of this report.

Locks and Lock Gates

There are three sets of locks located at Gatun, Pedro Miguel and Miraflores. These locks were all constructed following basically the same engineering concepts with dimensional variations in accordance with the location of the locks and the geographical constraints of each site which determined the height of each lift and the number of them.

The locks were made of massive concrete of the gravity type, the sidewalls ranging in thickness from 13.7 m. (45 ft.) to 15.2 m. (50 ft.) at the bottom to 2.43 m. (8 ft.) at the top, the centerwall being 18.3 m. (60 ft.) thick solid concrete from top to bottom.

The floor is also a massive concrete slab ranging from 4.0 m. (13 ft.) to 6.1 m. (20 ft.) in thickness. This massive concrete construction has been one of the leading factors in the preservation and high performance of the lock structures.

The minimum chamber width at any one point of the locks is 33.2 m. (109 ft.). The length of each chamber varies from 320.3 m. (1,051 ft.) to 326.4 m. (1,071 ft.) and the depth also varies from 12.1 m. (39.7 ft.) to 12.5 m. (42.0 ft.).

The lock gates are of the miter gate type closing at an angle of 65 degree. Each leaf measures 19.8 m. (65 ft.) in length, 2.1 m. (7 ft.) wide and 14.3 m. (47 ft.) to 25.0 m. (82 ft.) in height. The gates were fabricated of steel members forming a framework onto which sheeting plates were placed. The gates have a hollow core (Details of locks and lock gates are available in the component study "Status of Present Panama Canal" sections IV A and IV B).

An evaluation of the present condition of these structures was hampered due to measures enforced by the Panama Canal Commission which made access to most areas and documents of concern very difficult if not impossible. However, from performance assessments provided verbally by PCC personnel as well as from the well known maintenance programs carried out by PCC it may be concluded that the present physical condition of these structures is good.

Dams

The Canal includes three dams, the Madden, the Miraflores and the Gatun dam. The Madden dam has drum type gates, the Gatun dam has the Stoney type gates, and the Miraflores dam is of the Stoney type gates.

Power Stations

The Panama Canal has three main power stations which supply all the necessary electric power for the operation of the Canal.

The Madden power station is located at Madden Dam. It is a hydroelectric type power station consisting of 3 turbines with a capacity of each turbine of 12 megawatts with a total output of 36 megawatts.

The Miraflores power station is located nearby the site of Miraflores dam towards the Pacific end of the Canal. It is a thermoelectric type station that includes 5 turbines for a total output of 94 megawatts.

The Gatun power station is located at the site of the Gatun dam towards the Atlantic end of the Canal. It is a hydroelectric type power station of 6 turbines with capacities ranging from 3.5 to 4.5 megawatts for each turbine for a total output capacity of 24 megawatts.

As in the case of most other structures of the Canal, adequate routine maintenance programs have contributed to the preservation and good conditions of most of the Canal structures. Hence, it is reasonable to conclude that if proper maintenance programs are carried out in the years to come, these facilities will serve for many more years.

Anchoring Facilities

On the Atlantic side there are several anchorage areas located within the breakwater. These anchorage areas have minimum water depths ranging from 9.8 m. (32 ft.) to 12.8 m. (42 ft.). There is also an area assigned for anchorage of ships carrying explosives. Beyond the breakwater there is the Atlantic anchorage expansion area with a minimum water depth of 21.3 m. (70 ft.).

On the Pacific side there are also several anchorage areas thus; the merchant vessels anchorage area with a water depth of 16.8 m. (55 ft.), the explosives anchorage, and the Pacific anchorage expansion with a minimum depth of 19.8 m. (65 ft.).

Anchoring facilities are also located also at Gatun, Balboa, Miraflores and Gamboa. The Gamboa anchoring facility is mostly for PCC"s Dredging Division barges that provide maintenance for the Panama Canal waterway. There is a tie-up station completed in 1986 which is located at the Paraiso area in front of the Paraiso township on the west bank of the Canal. This tie-up station has four breasting dolphins that serve two ships at a time. Ships may dock on this tie-up station for repairs or for other purpose without affecting the canal traffic since the tie-up station was designed and built outside the existing west prism line of the Canal.

Lockage Locomotives

Movement of vessels as they approach the locks and also inside the locks is assisted by the lockage locomotives specially designed and built for Canal operations. There are 82 units weighing 55 tons each with 170 Hp capacity, 14.5 kph maximum design speed and pulling capacity of 31,181 kg. These locomotives are used to maintain a ship position while within the locks; ships move through the locks under their own power.

Breakwaters

The Atlantic entrance of the Canal is protected with a breakwater extending from Toro island located on the west side of the Canal and from Coco Solo point on the east side of the Canal, leaving an opening between these two arms for ship access of approximately 610 m. (2,000 ft).

The Pacific entrance of the Canal is protected with a breakwater located on the east side of the Canal that runs from Amador joining the islands of Naos, Perico and Flamenco with the mainland.

Roads and Bridges

There are three bridges that presently cross the existing Canal. The Bridge of the Americas, the crossing path for the Pan American Highway is located on the Pacific end of the Canal. This structure is an arch truss steed bridge with a total length of 1,654 m. (5,425 ft.), a main span of 344 m. (1,128 ft.) and a vertical clearance at high water level of 63.7 m. (209 ft.). The maximum canal bottom width with full vertical clearance is approximately 243.9 m. (800 ft.).

The Miraflores Bridge is located immediately downstream of the Miraflores locks. It is a swing type bridge with a total length of 3,300 m. (10,827 ft.). This bridge has 4 traffic lanes with concrete roadway. The bridge as well as the approaches are normally closed to the public. When open, it provides access from Gaillard Highway near Ft. Clayton on the east side of the Canal, to Borinquen Highway near the Miraflores Locks on the west side of the Canal.

The Gatun Bridge is a movable bridge adjacent to lower Gatun locks. It is closed up to one hour per each passing ship. This bridge has one lane only, a maximum vehicle capacity of 20 tons, and a maximum width of 4.3 m. (14 feet.).

The main road that provides support to Canal operations is the Transisthmian highway that links the terminal cities of Panama and Colon and serves most towns and villages on the east side of the Canal. It is 79.8 km. (56 miles) long and is mostly two lanes except at the approaches to the terminal cities where it becomes four lanes. The Gaillard Road is located on the east side of the Canal. It is a two lane concrete pavement road between Panama City and Gamboa, where the Panama Canal Commission's Dredging Division main facilities are located. This highway provides access to the Miraflores and Pedro Miguel locks from the east side of the Canal.

The Borinquen Highway is located on the west side of the Canal originating in the town of Cocoli. It is a two lane asphalt paved road providing access to areas past the hills of the Gaillard Cut on the west bank. This roadway also provides access to the Paraiso Tie-up Station and to the Miraflores Locks from the west side of the Canal.

Utilities

In order to provide support services to Canal operations there exist a wide variety of supporting facilities scattered alongside the Canal. There are two dry docks for ship repairs (one in Balboa and the other in Coco Solo), three fuel oil tank farms, two water treatment plants, and three sewage treatment plants.

Operation and Maintenance Buildings

The Panama Canal Commission has numerous buildings for its operation and maintenance personnel.

The Administration Building located in Balboa houses most of the main administrative staff. Each administrative and operational division within the Panama Canal organization has its own main building in addition to shops, yards and operation areas distributed over the Canal route to provide quick response.

Spoil Areas

The PCC has established dredge disposal on the Pacific side at Farfan, Rodman and alongside the Pacific breakwater near the Naos Island. On the Atlantic side, four spoil areas exist at the breakwater, Limon Bay, Telfers and Gatun.

Operational Characteristics

Operational Criteria

Operational criteria are dictated in accordance with four basic considerations namely: safety, capacity, operating cost, and water consumption. Safety is the foremost concern of all Canal operations and the basis for most of the rules and regulations. Capacity provides support to keep ship's time in canal waters to less than 24 hours. Operating Costs require that the Canal be operated as economically as possible unless there is a congestion due to the arrival of a larger number of ships that could dictate costlier operations. Canal water consumptions is not normally a problem during average years, but may presents problem in dry years wherein restrictions are required.

Lock Operation

Locks are huge structures engineered to control the flow of water by gravity from lake level to sea level. The lockage water is introduced to the east and west lanes by means of three sets of culverts, 2.4 m. (8 ft.) by 4.6 m. (15 ft.) each, located on both sides of the centerwall, which are used for both filling and spilling each chamber. These huge gates allow water to pour into enormous tunnels which run the length of the locks, one in each sidewall and one in the centerwall. Each is eighteen feet in diameter and can deliver 1.5 million gallons per minute. This raises or lowers the level in the chamber almost two feet each minute until the water level has been equalized between chambers. If both sidewall and centerwall culverts are used, the entire chamber can be filled or emptied in just over eight minutes.

A control room located on the centerwall of the uppermost chamber provides the necessary controls over closing and opening of gates. This location provides an unobstructed view to the control room operator of the whole lock operation upon which the locks are displayed in miniature, a working reproduction that duplicates the working of the machinery. The operator can see at a glance the position of valves, gates and the water level in the chamber itself as the model responds instantaneously to what is occurring in the locks; all these controls are

mechanically interlocked. This system has withstood the test of time, for the original controls are still in use for over 75 years.

Navigation System

Panama Canal pilots are assigned to a vessel while in transit through the Canal. These pilots have control of the navigation and movement of such vessels. The control pilot is responsible for compliance with navigation rules and directives as applicable. All vessels that transit through the Canal are assisted by the tug boats at the entrance of each set of locks and as required in their journey through the Canal. The vessels use their own engines to cross Gatun and Miraflores Lakes, and to navigate the Gaillard Cut area. Once in the locks, movement of the vessel will be assisted by the towing locomotives.

4.2.3 Historical Trade Analysis

The report on "Historical Trade Analysis" prepared by SINBOL in June 1991, consists of macro economic and foreign trade data of major countries and regions, and trade routes and commodities movement data relating to the Panamanian Isthmus. This report was used as data source for other component studies that followed.

The contents of the report are:

1. Macro economy of major countries and the world;

2. Economic activities of major countries and the world;

3. Foreign trade activities of major countries and regions;

4. Major trade routes in relation to the Panamanian Isthmus;

5. Origin and destination of major commodities in relation to the Isthmian trade routes; and,

6. Major historical events of the world and regional economy and trade

Most of macroeconomic and foreign trade data were based on statistical data from international organizations. Some of trade data including ocean trade were collected from the National Library, semi-government and private institutes in Japan. The data on commodity movement through the Panama Canal was based on statistics issued by PCC. The information of shifted cargoes comes primarily from US sources.

The feature of the report is a large collection of various data. Items of data presented in the report shown below:

1. Macroeconomic data on major countries

    1) Population
    2) GDP/GNP
    3) Per capita GDP/GNP

2. Macroeconomic activities of major countries

    1) Employment by industrial sector
    2) Composition of GDP by sector
    3) Import and export

3. Foreign trade data on major commodities by country/ region

    1) Consumption and production
    2) Export and import
    3) Ocean cargo movement
    4) Ocean cargo movement through the Panama Canal

4. Major trade routes relating to Panamanian Isthmus

    1) Inter-port distance (nautical miles) between major ports

5. Isthmian trade from PCC

    1) Historical data on ocean movement of commodities through the canal by a pair of origin and destination

All information except for inter-port distance are a series of historical data. A supplemental description regarding historical events of the world and trade is also presented.

4.2.4 Future Transportation Systems

The report on "Future Transportation Systems" consists of various data on maritime transportation and was performed by SINBOL in June 1991. This report was intended to be used as data source for the component studies and FA/FR study that followed.

The contents of the report are:

1. Overview of present situation and future prospects of maritime, land and air transportation system;

2. Present status and future prospects of maritime transportation system;

3. Trends in cost and tariff of maritime transportation;

4. Trends in design and ships; and,

5. Complementary transportation system to Panama.

Data and information were collected from publication on statistics obtained in Japan, Panama, USA and UK. The data and information concerning items 1, 4 and 5 above were mostly derived from existing statistics and National Library, government, semi-government and private institutions. Those of items 2 and 3 were based on a report prepared by a UK consultant firm.

The item 1 above presents qualitative analyses of the current transportation situation and prospects for future maritime, land and air transportation systems. The contents of maritime transportation system focuses on development of large bulk carrier ships and trends for increasing containerization. The land transportation systems are primarily discussing on existing conditions and prospect for land bridge and pipeline systems focusing on the Trans-Panama Pipeline and prospect of coal slurry system. The air transportation systems discussed aircraft design, airport development and air cargo distribution.

The items 2, 3 and 4 above present both quantitative and qualitative analyses of more detailed aspects regarding maritime transportation. The items contained are;

- Fleet development by type of ship.
- Transits of vessels through the Panama Canal.
- Future seaport development.
- Technical innovations of oceangoing vessels.
- Maritime transport cost and freight rates.

Analysis of relation between ship size and ship dimension in terms of length, beam and draft in general and Panama Canal transit vessels.

The item 5 above discusses prospects for complementary transportation systems (railway, highways and pipeline systems) to the existing Panama Canal. In particular, pipeline systems outlines the future prospect of the Trans-Panama Pipeline by discussing potential production of Alaskan crude oil and growing demand of the west coast market for Alaskan oil.

4.3 *Background Biological Data and Biological Inventory*

The evaluation of ecological impacts of constructing and operating a canal Alternative provides important data to the decision-making process. In order to assess the ecological impact, it is necessary to describe the baseline conditions in the area to be impacted.

A two-part program was utilized to describe the ecology of the area potentially impacted by a lock canal. The first part was essentially a literature survey which obtained and summarized the existing ecological data relevant to the study area. The second part consisted of actual biological field data collection and analysis of terrestrial, freshwater, and marine flora and fauna within the study area, Figure 4.3-1.

4.3.1 Background Biological Data Study

Approach

The Background Biological Data Study is a comprehensive literature survey to provide background information on the terrestrial, marine, and freshwater flora and fauna in the vicinity of the study area. It was originally intended that one of the uses of this information would be to provide input to the prescreening of alternatives. Because of changes in component contract schedules, this was not possible. It did however provide information for the refinement of the Biological Inventory methodology, as well as for the Environmental Analysis component and the overall analysis of the prescreened alternatives.

Methodology

A consortium integrated by the University of Panama and the ANCON Organization implemented this work over a two-month period using the "Natural Heritage Methodology", developed by the Nature Conservancy, which involved four stages of data compilation:

- Identification of available information sources
- Collection of available data
- Review of information
- Summarization

Figure 4.3-1
Study Area

Summary of Results and Conclusions

Environmental Studies

Numerous studies dealing with various environmental issues have been conducted in Panama. Many of these have been directly related to the Canal itself, while others deal with the general ecological descriptions, and issues of development, exploitation, and pollution.

The construction of the original Canal and the impoundment of the Chagres River to form Gatun Lake, and the construction of Madden Dam to form Alajuela (Madden) Lake, inundated ecologically diverse habitat. The ecological resources of the Panama Canal basin have been under rapidly increasing stress, primarily due to rapid rural and urban growth, and the resultant pressures of migration, colonization, and subsistence agriculture. This has lead to major deforestation in many parts of the Study Area, Figure 4.3.1-1.

In addition to the losses of ecological resources, this deforestation has increased erosion within the watershed, and resulted in high rates of sedimentation within Gatun and Madden Lakes, thus limiting the storage capacity of the lakes and effecting the operation of the Canal.

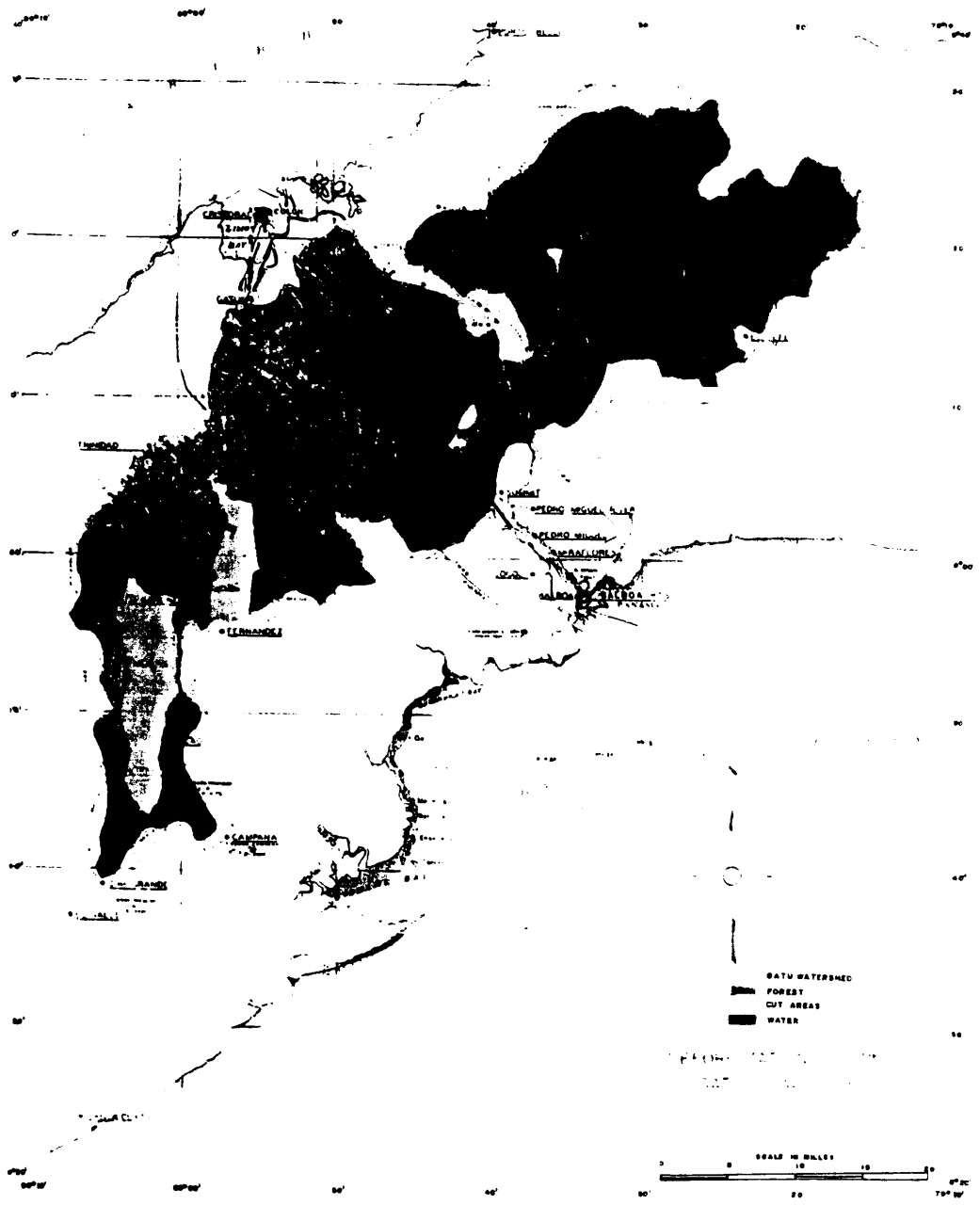
Terrestrial Studies

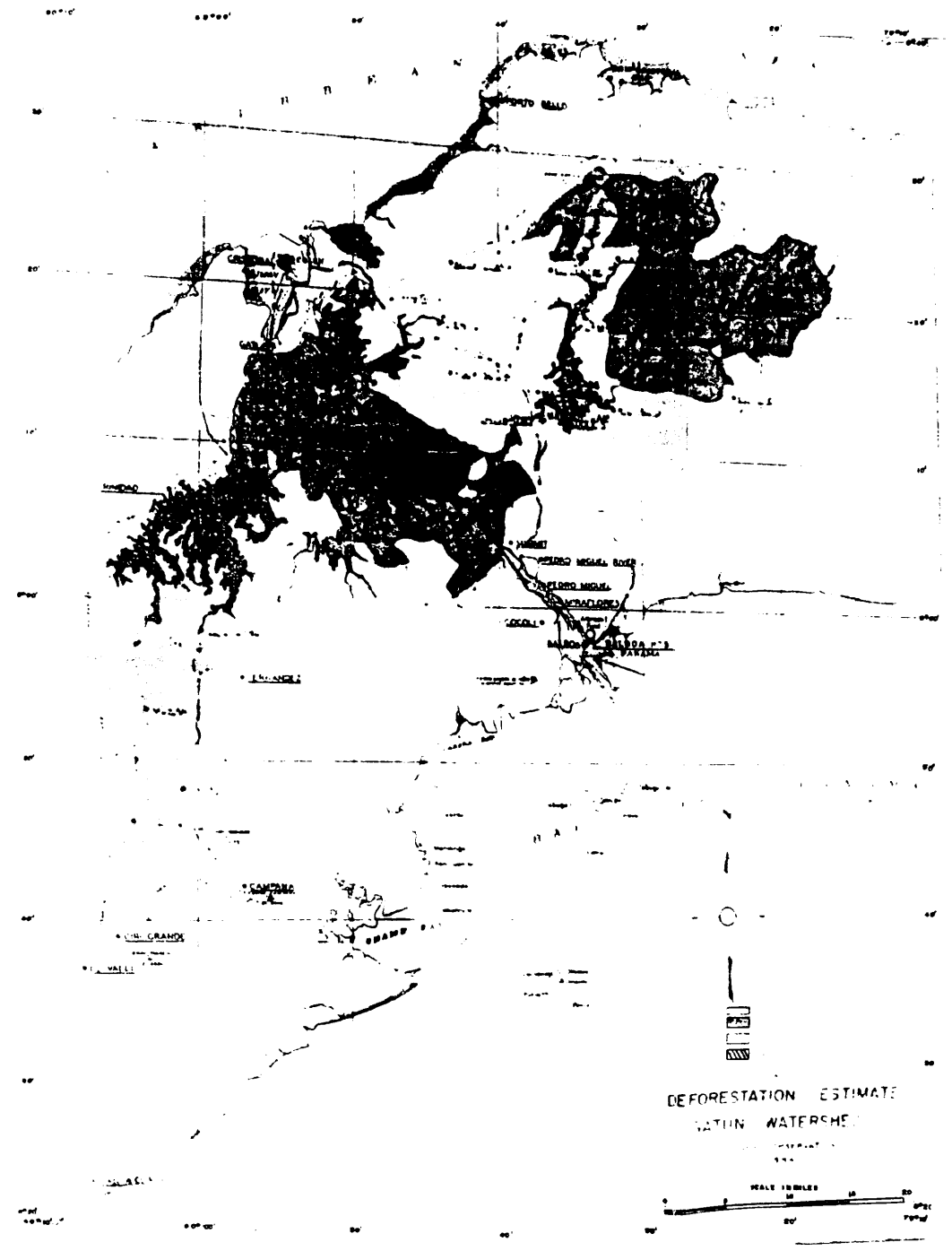
The Study Area, contained within the provinces of Panama and Colon, occupies the central part of the Isthmus, and contains approximately 2,900 km^2. The topography of this area is made up of formations presenting a gentle hill-like mountain range. About 85 % of the Study Area consists of variable soils in sloping terrain. They are made up of clays with a fine superficial layer of rich organic material. Mountains, hills, and slopes make up about 5% of the Study Area. These soils are of a clay-like texture and vary from moderately fertile to infertile.

The study area contains three climatic subtypes: Tropical Rainforest in the extreme northwestern portion, characterized by high temperatures and heavy rainfall year-round; Tropical Monsoon from the northern to the central part of the study area, characterized by high temperatures and seasonally excessive rainfall; and Tropical Savanna located in the southern portion, characterized by high temperatures with a dry season. Only about 12 % of the Study Area contains arable land which will support cultivation with proper soil conservation procedures. Another 18% of the area consists of non-arable land which can support limited agricultural use.

The main rivers that drain into the Study Area are the Chagres, Gatun, Boqueron, Pequeni, Ciri Grande, and Trinidad. The Chagres is the largest, with a length of 125 km., including the Lake Alajuela basin. This lake provides about 40% of the water for the Panama Canal, as well as drinking water for Panama City and Colon. According to the Holdridge system the Study Area consists of four Life Zones (Based on potential rather than existing habitat types). Approximately 90% of the study area is classified as Tropical Moist Forest.

Figure 4.3.1-1
Deforestation Area





The insects of Panama have been extensively studied since the early 1900s. Panama's moist tropical climate, as well as its rich flora and fauna, have contributed to an extremely numerous and diverse insect community. They form a vital link in the functioning of the ecosystem. Many insects also have played an important role in human activities, mainly through their role as disease vectors. There is not enough information to determine or discuss the status of insect species, but their widely varied and important roles in the functioning of the ecosystem must be recognized.

Studies to date have identified 220 mammalian species in Panama, 11 of which are endemic to the country. It is estimated that 159 species (including 3 found only in Panama) inhabit the Study Area. Detailed information about the mammals in the Study Area has been limited to intensively studied sites such as Barro Colorado. Most species are closely tied to the forest habitat, which has been also reduced in recent years. Under INRENARE Directive, 33 mammal species are protected by law, 29 of which have been reported from the Study Area. Panama has an extremely high diversity of reptiles and amphibians. It is estimated that less than 10% of these species have been studied to determine their population, distribution, reproduction, behavior, or life history. Some species are of reptiles and amphibians are known to be registered and/or qualified for consideration as endangered; two turtles, the hawksbill and baula, are in danger of extinction, and are protected in Panama by executive decree.

The bird population of Panama is very diverse and has been extensively studied in certain areas. There have been a total of 929 species identified and registered in Panama. Of this total, 52 species are direct importance to humans (hunting, commercial, etc.), 30 are from the Study Area. Twenty-five species from the Canal area are protected by the laws of Panama. Although Panama's diverse bird population is located mainly within protected areas, it is quite vulnerable to loss of habitat through deforestation, road construction, and other development, as well as illegal and/or uncontrolled hunting.

Panama, because of its geographic location, has a rich and diverse flora, which combines elements of Central and South America as well as the Caribbean. More than 8,500 species of higher plants have been identified, including 900 species of fern. Analysis of available aerial photographs enabled the University of Panama and ANCON to prepare a mosaic map of vegetative cover types in the Study Area (Map 15 - Mosaic of Study Area Forest Coverage, in the Biological Data Background report) (U.Panama/ANCON, 1993). The majority of forested habitats occur in the central portion of the Study Area. These are all in the Tropical Moist Forest life zone. Barro Colorado Island contains more than 1,400 species of higher plants, while Soberania National Park contains probably between 1,500 and 2,000 species. There are only few remaining relatively virgin areas of diverse floral composition within the study area. Those forested areas that do exist are found within protected parks such as Soberania and Chagres National Parks, Barro Colorado National Monument, and Taboga Wildlife Refuge, as well as certain areas under U.S. Military and Panama Canal Commission Control.

A large number of plants found within the Study Area are considered endangered or threatened, mainly because of excess commercial harvesting of some of the valuable trees, and destruction of habitat by deforestation and colonization. It is estimated that within the last 30 years, over 60% of the forests in the Canal basin were destroyed.

Fresh Water Environment

There have been extensive limnological studies done in the Panama Canal Basin. The results of this study are presented in the Biological Data Background Report and are briefly described below.

Gatun Lake has a surface area of 167 mi^2 and a watershed of 1,300 mi^2. The main water source is the Chagres River with headwaters to the east. Gatun Lake is considered to be mesotrophic, with nutrient levels generally low, but with higher concentrations noted near areas of human settlement. Sediments contain a high amount of decomposing organic material, related to the original inundation of the forested area in 1912. There are sediment deposits located at the mouths of the largest tributaries.

Lake Alajuela was formed by the construction of Madden Dam in 1930. The lake has a surface area of 19 mi^2 and a drainage area of 396 mi^2. It provides increased water capacity for the Canal system, as well as hydroelectric power and drinking water. There has been extensive deforestation in the watershed, which has accelerated erosion, sedimentation, and flooding. The lake is considered to be between mesotrophic and mesoeutrophic, with higher levels of phosphorus appearing in the inflow rivers than at the dam. Lake Alajuela sediment also have high levels of decomposing organic materials.

The Chagres-Gamboa-Gaillard (Culebra) Cut Region has extremely complex hydrography. Many streams and rivers drain into the area, but the principal water input is from the Chagres via the Madden Dam releases. This flow is extremely variable, and is probably the major influence on the water quality in the area.

There is also considerable effect of surges from lock operations at Pedro Miguel, as well as from maintenance dredging operations and ship traffic. Sediments contain large amounts of decomposing organic material. Copper levels are unusually high, perhaps due to deposit of copper-rich sediments from tributaries and copper sulfate used for weed control.

Miraflores Lake is a water body formed by the flow of water from the Pedro Miguel locks. It also receives flow from the Rio Caimitillo, run-off from the Tanque Rojo landfill, and sewage from Paraiso-Pedro Miguel. There is some salinization of the lake waters due to boat passage. The lake is considered to be mesotrophic.

There are 28 species of aquatic macrophytes reported from the Canal area. The most abundant species is Hydrilla, which is found in waters up to 20 feet deep. This species is difficult to control, and is a problem in many of the shallower areas of Gatun Lake. Also a problem is the water hyacinth and water lettuce. The benthic community in the study area is composed mainly of mollusks, annelids, and arthropods. Mollusk densities in Gatun Lake near Barro Colorado Island have been reported to be high. More than 80% of the benthic community in the Gaillard Cut is made up by the oriental clam. More than 130 species of fish have been reported. The fish community is dominated by the peacock bass, an exotic species introduced to the Lake in 1965 as a sport fish. It has been responsible for the elimination of six of the eight most common native fish, and has had major impact on the food chain and other communities of the lake, including the plankton.

4.3.2 Biological Inventory Component Study

Approach

The Biological Inventory Component Study was a 14-month ecological field study, covering five sampling periods. This study was intended to gather baseline data for a wide range of biota within a Study Area which would most likely be impacted by construction and operation of a high-rise lock canal. It was not intended to provide information relevant to a sea-level canal alternative, and did not collect data for many areas affected by a sea-level canal at Route 10.

Methodology

The five sampling periods occurring at approximately 3 month intervals were designed to provide some indication of seasonal changes, as well as year-to-year variability. The study was limited in scope due to schedule and budgetary constraints of the overall program. The need to conduct many studies in parallel, and the schedule requirements of the overall program limited the amount of information from the study that could be included in this report. This summary is based on the initial fourth sampling.

Summary of Results and Conclusions

Terrestrial Environment

The Study Area is covered with an intricate mosaic of remaining Primary Forest, secondary forests in varying stages of development, grasslands, and small temporary agricultural plots. Pequeni and Trinidad are under considerable deforestation pressures, and consequently contain relative few trees, with herbaceous species tending to predominate. Cruces, Mandinga, Jefe and Chagres are isolated and/or protected and are developing toward mature secondary forest habitat. None of the sites have any potential for commercial timber harvesting, but they have considerable importance for wildlife habitat, soil protection, and Canal watershed maintenance.

Results of the entomological collections have been compiled for each type of sampling equipment used. Seasonal and locational variation has been noted for various insect species and families, often related to differences seasonal changes in vegetation. Marked reductions in abundance in many collections were noted between the wet and dry seasons. Sweepnetting through grasses collected numerous spiders as well as insects which are beneficial for biological control. Pitfall traps collected many ground-dwelling insects, with ants and rove beetles being most important. Mites and ticks were important components. Combined sampling with the aquatic net and dipnet produced many insects of medical importance, including the mosquitoes Aedomyia sp., Aedes sp., and Mansonia sp. Berlese funnel sampling also collected many ground-dwelling ants and mites. The most important components of the carcass trap collection were beetles and various flies. Oviposition traps collected principally dipterans.

A total of 57 species of amphibians and 52 reptile species have been collected and/or identified at the study sites during the first four quarterly sampling periods. The sampling location at San Juan de Pequeni has the highest diversity of species, while Ciri is the least diverse. This is probably related to the higher habitat diversity at San Juan de Pequeni, than at Ciri which is generally pastureland. The most common species at all sites are small tree frogs at the margins of forest streams and at the edges of ponds in open areas, the other frogs and the lizards in the forest understory. Two previously undescribed species were found during the sampling.

During the four quarterly samplings from May 1992 through March 1993, a total of 386 bird species, distributed among 19 orders and 52 families, have been identified. Of these, 22 are considered to be threatened and 9 endangered. Eighty-two species are migratory, either wintering in Panama or transient, the most abundant species are the turkey vulture, followed by the black vulture, the neotropic cormorant, the gray-breasted martin and the cattle egret. The study of mammals did not begin until the fourth quarter of 1992, and only preliminary data are available. To date, eighty three out of a list of 163 species of terrestrial mammals have been identified within the Study Area.

Fresh Water Environment

Measurements through four quarterly samplings allow some general observations about the limnological conditions in the Panama Canal watershed. In almost all cases, there has been very uniform temperature distribution in the water column at each sampling station. In the Alajuela at the station nearest Madden Dam a thermocline persisted throughout the rainy season, but was less pronounced during the dry season. Dissolved oxygen followed a similar pattern. The waters of Gatun Lake were determined to contain generally well oxygenated waters, low concentrations of nutrients, suspended solids, and low turbidity, as well as absence of coliform bacteria. There is no thermal stratification. Alkalinity appears to decrease from east to west in the lake. The station in the Chagres River between Gatun Lake and the Caribbean shows a typical estuarine situation, with freshwater at the surface and salt water at the bottom. Both layers are well oxygenated, and there is no indication of contamination.

Some observations of seasonal variation in the watershed include increases in chlorophyll concentrations from July to November, as well as a decrease in turbidity and suspended solids. Coliform bacteria also decreased during this period.

Analysis of the sediments showed a general increase in lime and clay over what had been reported from previous studies. This could be attributed to increased sediment loads in the basin. There were some locations however where this was not observed. Organic matter and nutrients in the sediments are generally comparable to previous studies. There appears to be a concentration of sediment nutrients at the station in the western branch of Gatun Lake. Metals in the sediments are generally low and within the range of previous studies. Contamination with hydrocarbons was noted in the sediments near the Gatun anchorage, and at other locations in the southern portion of Gatun Lake.

In the northeastern portion of Gatun Lake, the most frequently enumerated macrophyte was Panicum grande. The south-central portion of the Lake contain many stands of Hydrilla verticillata, thriving on the shallow waters created by dredge spoil disposal. The Culebra Cut contains isolated colonies of floating vegetation and exogenous plant debris.

In the southwestern part of the Study Area, the Ciri Grande River is dominated by Eichhornia azura. Polygonum sp. and Panicum sp. are also abundant in some upstream sectors. The Trinidad River contains principally Paspalum repens and Polygonium Hispidium, along with many masses of Sesbania sp., Salvinia sp., and fern and grass debris.

A log boom is placed in the Chagres River at Gamboa to control downstream movement of macrophytes and debris. The most frequent macrophytes in this area are Salvinia sp., Eichhornia crassipes, Lemna sp., Ceratophyllum sp., Hydrilla sp., and Pistia sp. Upstream of the boom, to the Madden Dam, the principal macrophytes in the Chagres are Pistia stratiotes, Salvinia sp. E. crassipes, and Ludwigia sp. The Chagres River, downstream of the Gatun Dam, is dominated by Hydrilla sp. and Phragmites sp.

In Lake Alajuela and its tributaries, the most abundant submerged species is Hydrilla verticillata, with areas of Lemna minor, Azolla sp., and Lyngbia sp. During low water, Ambrosia cumanensis and Polygonium sp. are frequently encountered, but are very infrequent during periods of high water.

The benthic community of Gatun Lake is dominated by snails (Gastropoda), clams (Pelecypoda), and aquatic worms (Annelida: Oligochaeta). Gastropods were found at 6 of the 7 sampling stations, where they comprised approximately half of the entire benthic population. Pelecypods are the second most abundant benthic class in Gatun Lake, and were present in greatest densities near the entrance of Rio Gatun. Sphaerid clams (Musculium sp. and Sphaerium sp.) and Corbicula sp. were the dominant clam genera.

Tubificidae (principally Brachiura sowerbyi) made up approximately two-thirds, and Naididae made up one-third of the annelid worms. Hirudinea (leech) adults and cocoons were found in the southern part of the lake, as were bryozoan colonies. Dipteran (fly) larvae were present at various stations. About three-quarters of the dipteran larvae collected were of the family Tendipediae, while the balance were Culicidae (mosquitoes and phantom midges). Nematodes (roundworms) were collected in relatively low densities. A few crustaceans were collected, represented by the Ostracoda ("seed shrimp") and Decopoda (juvenile shrimp).

A total of 14 fish species representing 11 families have been collected to date. The most abundant species, Brycon chagrensis, Hoplias microlepis, Cichla ocellaris, and Cichlasoma maculicaudia, generally accounted for over half the entire catch. Marine and brackish water species have also been captured in areas of the watershed, particularly Miraflores Lake, Culebra Cut, and the mouth of the Ciri Grande River. These include Eugerres plumeieri, Diapterus sp., Elops affinis, Mugil curema, and Lutjanus sp. Five crustacean species have also been captured. These include the freshwater Macrobrachium (three species), Penaeus sp., and the brackish water Callinectes toxotes.

Marine Study

In the Pacific, data from the temperature and salinity measurements in the Bay of Panama for the first three sampling periods indicated that the water column is not stratified and is well mixed from surface to bottom. Salinity also was fairly uniform, with the exception of near the discharge of the Canal system, as well as near some river discharges, where low surface water salinity was recorded. Dissolved oxygen levels were also quite uniform throughout the water column, with surface waters containing oxygen at about saturation concentrations. Nutrient concentrations were generally low, with higher concentrations of nitrates being related to freshwater discharges from the Canal. A considerable difference was noted however, during the fourth quarterly sampling, which took place in March. The seasonal upwelling was noted, with decreased surface water temperatures, decreased dissolved oxygen, and increased salinity, chlorophyll a, and nutrients throughout the water column. A thermocline was noted at a depth of between 5 and 10 m.

In the Caribbean, there is generally uniform distribution of parameters within the water column, and no detectable stratification. Overall conditions were similar throughout all four quarterly samplings. There is a relatively thin layer of surface water of low salinity within Limon Bay. Dissolved oxygen, even in the deepest waters, rarely goes below 78% saturation. Nutrients and chlorophyll a concentrations were generally low and relatively uniform throughout the water column. A slight increase in nutrients and chlorophyll a in Limon Bay in November is probably related to freshwater input from Gatun Lake via the Canal locks. Biochemical oxygen demand (BOD) was highest in August and lowest in November, parallelling a similar pattern of coliform bacteria counts. Concentration of metals was similar to those shown in other studies, and were lower than those of the Pacific.

Sediments in the Pacific Study Area were generally muddy, with a high silt/clay fraction. Organic nitrogen ranged from 0.1% to 0.36% of the sediments. Organic carbon ranged from 8.7 to 22.9 mg/g, with no discernable temporal or spatial pattern. Metal concentrations are generally uniform. The sediments at most of the Caribbean stations were also muddy (silt/clay), but with a higher content of sand. Organic nitrogen content was somewhat lower (with a range of 0.1% to 0.19%) than the Pacific sediments. Likewise, the organic carbon was also lower, with mean concentrations between 12 and 14 mg/g. Metal concentrations were relatively uniform. Hydrocarbon analysis of the sediments showed slight or no contamination at most locations. The exceptions were three stations with heavy ship activity: near the Balboa piers and in the area where ships moor awaiting Canal transit. These sediments were considered to be contaminated with petroleum. Hydrocarbon contamination was noted at the station near the Cristobal pier, with slightly elevated levels near the Gatun locks and near the mouth of the Chagres River.

In the benthic community, 146 taxa have been identified to the species level, with polychaetes, nematodes, and some bivalves still being enumerated. Based on three sampling periods, Polychaeta, Bryozoa, Crustacea, and Mollusca are the most important benthic groups. The Crustacea are dominated by isopods, gammarideans, and amphipods, while bivalves of the Nuculanidae, Solecurtidae, and Tellinidae families are the dominant mollusks. During the first three sampling periods, mean abundance of benthos was higher in the Caribbean than in the Pacific samples. There was however a steady reduction in abundance per station noted over the three sampling periods. During the fourth sampling (dry season), mean abundance was greater in the Pacific. Diversity of organisms was also greater in the Caribbean during the first three samplings, but lower in the fourth. Distribution and composition of taxa is generally similar at all water depths. Abundance and diversity in the Caribbean however is greater at the offshore stations than for those located within Limon Bay.

All coral communities on the islands within the Pacific Study Area small (less than 100 m^2 reefs), with the exception of Uraba Island. As of the completion of the third quarterly report, eleven scleratinian species have been identified, including the genus Siderastrea - the first record for the eastern Pacific. Eleven coral reefs in the Caribbean have been sampled. As of the third sampling, 47 species have been identified, including some that are not common in the Caribbean. Overall, less than 10% of the reef coverage are living corals. The data collected and on-site observations appear to show that most of the reefs are declining in diversity, when compared with other reefs on the Caribbean coast.

The structure of the mangrove communities on both coasts is heavily influenced by salinity gradients in estuarine areas. Differences have been observed between the Caribbean and Pacific. In the Caribbean, exposed fringes of the mangrove community are dominated by Rhizophora spp., while in the Pacific, this species did not dominate these areas, and occasionally was absent entirely. The impacts of human activity are generally more evident in mangroves on the Pacific coast.

There are no seagrass beds on the Pacific coast of the study area, due to the extreme tidal range and poor water clarity. The Caribbean coast within the Study Area is a high energy area, subject to surf from the open sea. It also receives loads of suspended sediments during the rainy season. This tends to limit seagrasses to shallow water and protected areas. The seagrass beds provide important fish habitat.

The greatest abundance of invertebrate larvae were recorded in the Pacific, with crustacean zoea, "other organisms", bivalves, and shrimp postlarvae predominant. A total amount of 3,378 benthic organisms were collected of which 55% (1,848 organisms) were found in six (6) Caribbean stations. Identification of the benthic community (1.00 mm mesh size) yield 171 taxa including one new isopod species of *Cyathura* found offshore from the Limon Bay stations on the Caribbean side. Mean abundance of benthic organisms was greater in the Caribbean area with 227 org./m^2 than that of the Pacific with 160 org./m^2 for the mean case.

Mean abundance and number of species was 1.6 times greater for the offshore stations than those located within Limon Bay in the Caribbean. Those stations closest to the Panama Canal entrance in both oceans (Pacific: M-01 and Caribbean: M-09 and M-10) exhibited a reduction in relative abundance and diversity.

In general, mean abundance of benthic organisms in the Pacific follows a typical bimodal pattern through time, with peaks of abundance during March and July. Mean abundance of benthic organisms in the Caribbean followed a typical unimodal pattern with a peak abundance in July.

Collections of meroplankton showed a peak of abundance during November 1992, especially at stations located at the entrances to the Panama Canal. The highest abundance of eggs of engraulid and clupeid fish was observed in the Caribbean area (17,569 and 9,091 eggs/100 m^2), whereas in the Pacific the counts revealed densities of 3,503 and 2,861 eggs/100 m3 for clupeid and edngraulid fish.

The most common larvae on invertebrates at both sides were the Zoca, postlarvae of penaeid shrimps, and petropod, gastropod, and bivalve larvae. In the pacific area, the postlarvae of penaeids were particularly abaundant between the November 1992, and February 1993 samplings. These postlarvae are believed to belong to the species *Penaeus occidentalis, P. stylirostris,* and *P. vannamei* which have been previously reported to be highly abundant in the area during this part of the year. Also, a high abundance of bivalve larvae was observed in the Pacific side and this might be related to the seasonal upwelling which enhances the phytoplankton productivity in the area.

In general, the overall abundance of meroplankton is higher in the Caribbean than the Pacific. This might be related to the role of coral reefs, seagrass meadows, mangrove forests and estuaries as spawning and breeding areas for many marine species.

In all, 197 species of marine fish were collected during this inventory, 113 species from the Pacific and 84 in the Caribbean. Among these, only 9 identical species were found in both oceans. The highest diversity of sublittoral fish was related to the proximity to estuarine areas that are nursery grounds for fish larvae and postlarvae. A high diversity was recorded in the sampling stations located near the estuary of Chame, whereas the lowest diversity was observed in the shores along the Pacific entrance to the Canal. In the Caribbean, most of the diversity of species was gathered from the collections of fish in the station located in front of Bahia las Minas, another estuarine area.

Fish were observed to be particularly abundant in the Pacific at the beginning of the rainy season (June 1992 and May 1993). To some extent this is believed to be related to the period that follows the dry season upwelling. Low sea temperature related to this upwelling move many fish and invertebrate species to the warmer shallow waters. The increase means the abundance observed a few weeks after the upwelling might suggest a intense recruitment of juveniles from the neighboring estuaries and mangrove bordered coast.

In general, the abundance of fish in the Caribbean remained fairly uniform through this inventory, although a slight increase in the abundance was recorded during February 1993.

A total of 105 species of marine invertebrates were collected during this inventory, 56 species collected in the Pacific and 49 in the Caribbean.

The total collected biomass for the collections at both oceans was 239.08 kg (171.10 kg in the Pacific, and 67.98 kg in the Caribbean). The highest biomass in the Pacific was provided by the swimming crab *Callinectes arcuatus* in the rainy season collections, but during the upwelling, the squid *Lolliguncula panamensis* proved to be the dominant taxa. In the Caribbean, the biomass was mostly provided by the shrimp *Penaeus braziliensis* and another swimming crab, *Portunus anceps*.

The species dominance in the Pacific occurred as follow: the swimming crab *Callinectes arcuatus* during the rainy season collections (July, August and December 1992); the sea pansy *Renilla amethystina* in December 1992, and February 1993; and the seabob shrimp *Xiphopenaeus riveti* in May 1993.

In the Caribbean, another swimming crab, *Arenaeus cribarius* dominated during sampling from the rainy season (July, August, December 1992, and May 1993), this was followed by the shrimp *Penaeus braziliensis* during the dry season (February 1993).

The composition of the samples revealed that both in the Pacific and the Caribbean crustaceans made up to 50% of the macroinvertebrates collected.

List of Tables and Sources

Figure N°.	Title & Source
4.3-1	Study Area (Biological) Source: University of Panama Consortium and ANCON Consortium, Biological Data Background, April 15, 1993, Maps No. 9.1 and 9.3
4.3.1-1	Deforestation Area Source: Same as 4.3.1-1, Map No. 22

A Feasibility Report

5.0 Phase I - Prescreening and Selection of Alternatives

5.1 Preliminary Study of Alternatives

5.1.1 Introduction

The existing Panama Canal was completed in August 1914. As traffic steadily increased, it became apparent that the capacity of the canal would eventually become inadequate. Since 1929, several studies have been commissioned and conducted to deal with the long term need to increase canal capacity. In May 1982, the Preparatory Committee on Panama Canal Alternatives Study was established between the United States and Panama. Japan joined the committee soon thereafter. Between 1929 and the establishment of the Preparatory Committee, several studies were conducted and became part of the so called "Historical Alternatives".

5.1.2 Historical Alternatives

As indicated in the Detailed Plan of the Study (DPS), these alternatives to the Status Quo were broadly classified into three basic categories as follows:

Improvements to the Existing Canal

- Non-locks improvement
- Third Locks Plan
- Terminal Lake Plan and Variations
- Deep Draft Lock Canal Plan
- Lopez-Moreno Plan
- Culebra Cut Widening Plan

Sea-Level Canal Alternatives

- 1970 Interoceanic Canal Studies, Route 10
- 1970 Interoceanic Canal Studies, Route 14S

- 1982 Route Plan
- Vergara Plan
- Nagano Plan

Non-Canal Alternative Transportation Systems

- Oil Pipeline
- Slurry pipeline
- Conveyors
- Land bridge systems (railway and highway)

5.1.3 Conceptual Alternatives

In order to conduct this study, historic alternatives that were presented in the DPS, were simplified and initially grouped as described below. The thought process, beginning with the historical alternatives, developing four Conceptual Alternatives, and using these in combination with other complementary systems to arrive at a feasibility report of selected alternatives, is depicted in Figure 5.1.3-1.

Substantial concepts

Substantial concepts were considered to be major works to convey large ships across the isthmus, such as widening and deepening the canal, raising the canal water level, varying the method of lock water controls, and devising methods of tidal control for a sea level canal.

The application of substantial concepts to the various historical alternatives resulted in the formulation of four conceptual alternatives that are the basis of all studies conducted in the Phase I. Based on this criteria, all alternatives have been classified into one of the following four categories:

- High Rise Lock Canal

Maintains the present Gatun Lake level of 85' to 90' above sea level with small variations. New sets of larger locks and the widening and deepening of the channel will be undertaken to accommodate larger ships.

- Low Rise Lock Canal

Contemplates a lower lake level of 30' to 55' above mean sea level plus a new set of larger locks and the widening and deepening of the channel to accommodate larger vessels.

- Sea Level Canal on Route 10

Follows a path approximately 16 km west of, and generally parallel to, the present canal.

- Sea Level Canal on Route 14S

Follows the general alignment of the present canal.

- Status Quo

Present Canal including approved widening of Culebra Cut.

Details concerning each of the above conceptual alternatives expressed in terms of their historic alternative/plan, proposed route, size of design ship, elevation rise in water level, number of lifts, and number of ship lanes are summarized in Table 5.1.3-1

Partial concepts

Consist of both supplementary and complementary systems to the major canal. Supplementary systems include: improving ship navigation, improving navigation aids, and improving lock structures, including consolidation of the Pacific locks.

The non-canal complementary systems include other methods of transporting cargo across the Isthmus of Panama, such as a landbridge (highway and railway) and pipelines. Although their costs and benefits are approximated for use in Phase 1, complementary systems, if needed, will be studied in greater detail in Phase 2. The non-canal complementary systems component of the "partial concepts" idea were made a part of the Engineering and Cost Component Study (ECE).

Details of the capabilities and design considerations of these complementary systems are summarized in Table 5.1.3-2.

Figure 5.1.3-1
Alternatives Evaluation Process

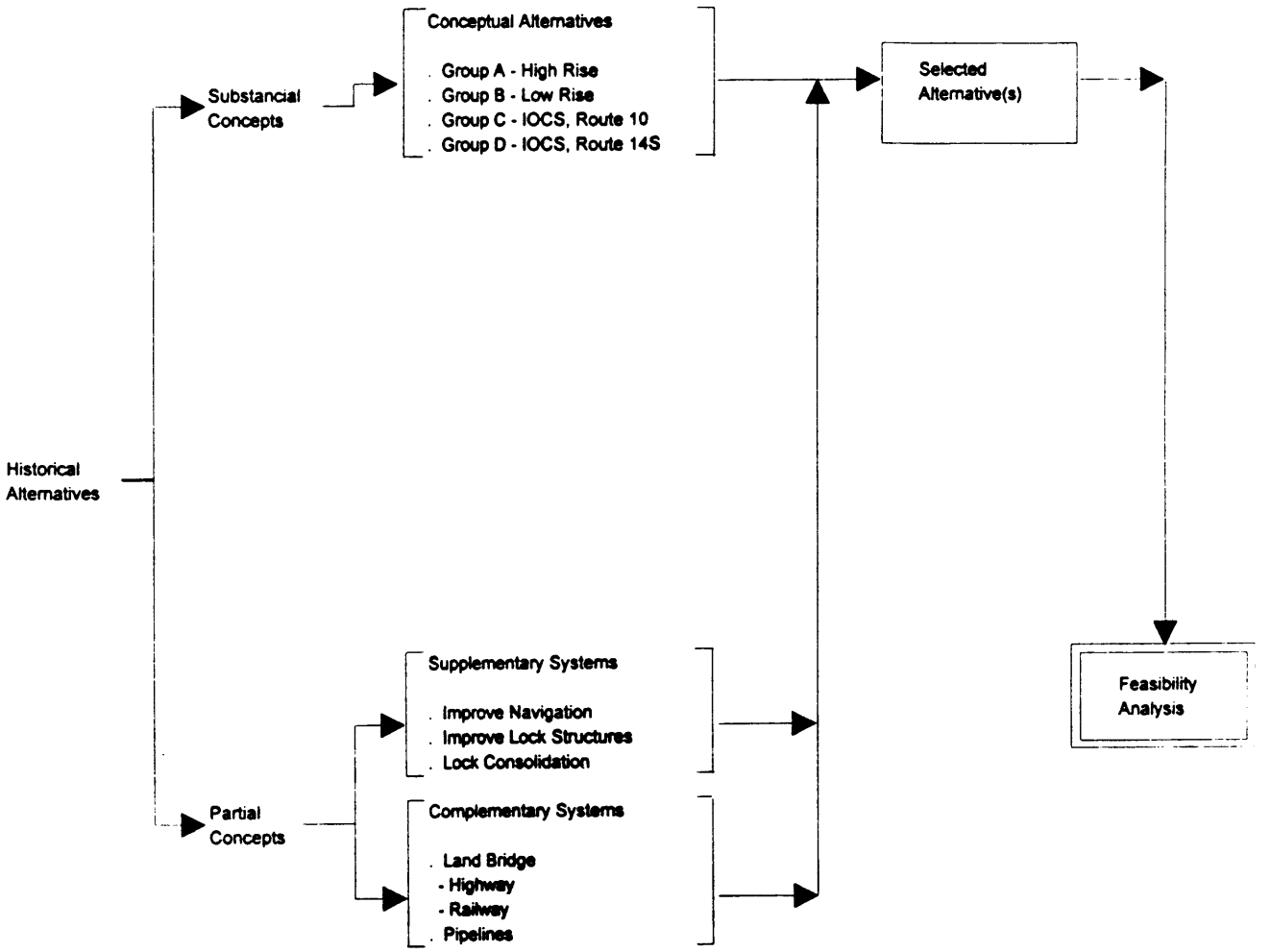


Table 5.1.3-1
Summary of Substantial Concepts

Conceptual Alternatives	*Corresponding Alternative/Plan* *	*Route*	*Ship Size (10^3 dwt)*	*Lake Rise (WL-ft)*	*No. of lifts*	*No. of lanes*
A. High Rise Lock Canal	*I-d Third Locks* *I-e Terminal Lake Plan* *I-f Deep Draft*	*15+Third Locks Route and 15 (part) + Gatun Lake Modified Route + Third Locks Route*	*100* *150* *250*	*90* *85*	*2*	*2*
B. Low Rise Lock Canal	*I-g Panamanian Alternative*	*15+Third Locks Route and 15 (part) Gatun Lake Modified Route + Third Locks Route*	*100* *150* *250*	*55* *30*	*1*	*2*
C. Route 10 Sea Level Canal	*II-a IOCS Route 10* *II-c Vergara* *II-d New Panama Canal*	*10*	*150* *250* *300*	*0*	*0*	*1* *2* *50%-1* *50%-2*
D. Route 14S Sea Level Canal	*II-b IOCS Route 14S*	*14S*	*150* *250* *300*	*0*	*0*	*1* *2* *50%-1* *50%-2*
E. Status Quo (Baseline)	*I-a Status Quo* *I-b Cut widening*	*15*	*65*	*85*	*3*	*1 and 2*

* *I-C are all partial concepts as indicated in Figure 5.1.3-1*

Table 5.1.3-2
Summary of Complementary Systems

Complementary Systems	Route	Capacity
F. Oil Pipeline & Associated Mooring Facilities	Western Panama Near Existing Petroterminales Location	(mil. b./day) 0.5 1.0 1.5 2.0
G. Landbridge, Railway & Associated Port and Terminal Facilities using Centerport Concepts	Central Panama: Panama City to Colon	(mil. ton/yr) 10 20 30 40
H. Landbridge, Road & Associated Port and Terminal Facilities using Centerport Concepts	Central Panama	(mil. ton/yr) 10 20 30 40

mil. b/day = million barrels / day

5.2 Commodity and Traffic Projection

5.2.1 Introduction

The Phase 1 Commodity and Traffic Projection (CTP) study was conducted by the WEFA Group, with subcontract support from Richardson Lawrie Associates and BST Associates. The work was divided into five tasks in order to project the Panama Canal commodity flow and the number of transit vessels by ship type and size. The contents of the Phase I CTP Final Report are summarized in Table 5.2.1-1.

- Task 1 - WEFA reviewed all the available data and established the methodology of commodity and traffic projections.

- Task 2 - WEFA constructed four databases for the CTP study, (1) Panama Canal Vessel Database, (2) World Commodity Flow Database, (3) Panama Canal Commodity Flow Database, and (4) other database developed within the WEFA Group.

- Task 3 - The global bilateral trade was projected by trade route and commodity in detail. The projection of commodity flows (22 commodity groups) between origin and destination in trade routes in 1990, 2020, and 2060 was presented in the Interim Report published in September, 1991. The PCC commodity flows in 2020 and 2060 by trade route were estimated by assuming that the Panama Canal trade routes in the future will receive the same constant share of commodity flows as that in 1990.

- Task 4 - The world vessel fleet development (ship mix and average dwt) for 2020 and 2060 was projected by type of vessel. The projection of transit mix for the Panama Canal was made based in the world fleet development. The Panama Canal commodity flows were then converted into number of laden and ballast transits for both south and northbound transits by ship type and size.

- Task 5 - WEFA presented vessel transportation costs in terms of hourly cost by ship and size, maritime transportation cost of selected ship types via the Panama Canal by trade route and size and annual closure costs of the Status Quo Canal comprising transportation diversion cost and toll revenue losses for the year 2020.

Table 5.2.1-1
Contents of Phase I CTP Final Report

Task	Chapters	Contents
1	3 and 4	Review of Data and Approach
2	5	Database Construction
3	6 and 7	Forecast of Commodity Flow
4	8 and 9	Vessel Mix and Projections
5	10	Additional Vessel Economics

5.2.2 Review of Data and Approach

The work of review was basically divided into two components.

One component was the review of various data consisting of Gross Domestic Product (GDP) and population for world economic forecasts, world commodity flow including landbridge bypass and vessel fleet, and Panama Canal commodity flow and transits.

The other component was the review of previous demand study (Panama Canal commodity and traffic projection) by Manalytics and TBS which contributed to the establishment of a methodology for the CTP study. This methodology consists of three work steps.

The first step was commodity projection in both the short-term (up to 2010) and long-term (2010 onward, up to 2060) basis. The second step was the projection of world fleet development (global vessel supply and mix) based on world commodity projection. The third step was the analysis of vessel economics which determined the number of Panama Canal transits for each ship design size (65,000, 100,000, 150,000, 250,000 and 300,000 dwt).

5.2.3 Database Construction

The database which WEFA worked to construct included (1) a Synthetic Panama Canal Transit Database for 1990, and (2) a Panama Canal Commodity Flow Database. Due to the lack of available data published by PCC, the first Database covering transits by vessel type and size, laden and ballast on route basis was extensively supplemented by other sources including Lloyds data, primarily to meet the requirements of the capacity analysis studies conducted by TAMS.

The second Database, Panama Canal Commodity Flow, was developed from the annual PCC reports. WEFA judged that the classification of commodity groups presented in the annual PCC reports was not useful to them for vessel transit forecasting purposes. As a result, WEFA aggregated all commodities into a final set of commodity groups (10 commodity groups) to be directly used to forecast vessel transits.

5.2.4 Forecast of Commodity Flow

The outputs of this task were (1) a bilateral commodity flow projection (22 commodity groups) for 2020 and 2060 between origin and destination (trade routes), and (2) Panama Canal commodity flows (10 commodity groups) for 2020 and 2060.

Bilateral commodity flows

The classification of commodity groups employed for projection of bilateral commodity flows in Phase I was as follows:

1) Bulk grain
2) Iron ore & concentrates
3) Bauxite & Alumina
4) Coal & Coke
5) Sugar& Molasses
6) Logs & Lumber
7) Minor bulks
8) Refrigerated foods
9) Vehicles
10) General cargo, foods
11) General cargo, crude material
12) General cargo, chemical products
13) General cargo, manufactures
14) General cargo, mechanical equipments
15) General cargo, electrical equipments
16) General cargo, others
17) General cargo, containerized
18) General cargo, non-containerized
19) Gas, natural/manufactured
20) Bulk chemicals
21) Oils & fats
22) Crude oil

A series of data on bilateral commodity flows (21 commodity groups) was first presented in the Interim Report in September, 1991. The second edition of a bilateral commodity flows was submitted to CAS in May 1992 which included crude oil and the split of Canada into east-west coast from some commodity groups.

The projection of bilateral commodity flows for 2020 and 2060 was based on various economic forecasts in regions relating to trade routes. The study items for quantitative analyses were population and labor force, per capita GDP (productivity), terms of trade, and transportation costs containing wage and fuel costs. WEFA also made a qualitative assessment of regions from the viewpoint of environment and technical development.

WEFA used their own econometric model called the World Model System (30 models) consisting of 24 industrial countries and 6 regions. Each Model, consisting of 215 variables, was mainly used for the short-term projection. The log-term projection of bilateral commodity flows for 2020 and 2060 was carried out on the assumption that the ratio of imports to GDP for each country and commodity will continue to be the same in real terms. Then, these imports were distributed for exporting countries. The total of these exports was also compared to GDP of exporting countries.

Panama Canal commodity flows

The Panama Canal commodity flows were first presented in the Phase I CTP Draft Final Report in April 1992. The classification of commodity groups for Panama Canal commodity flows was as follows:

1)	Bulk chemicals	6)	Minor bulks
2)	Containerized	7)	Oils & Fats
3)	Crude oil	8)	Petroleum products
4)	General cargo	9)	Reefer cargoes
5)	Major dry bulks	10)	Vehicles

The Panama Canal commodity flows for 2020 and 2060 was first estimated with an assumption of constant market share. In order to accomplish this task, WEFA put the Panama Canal and world trade commodity flows on the same commodity and trade route basis. It was reported that growth rates of commodities by a pair of origin and destination were applied to the FY 1990 PCC Canal cargo data to project Panama Canal commodity flows.

WEFA analyzed the bypass cargo by landbridge and water-routes. The bypass cargoes studied were confined to specific bulky commodities and container cargoes on the particular trade routes. Such bypass cargoes were evaluated by comparing freight costs via the Isthmian route and those via other waterborne or landbridge routes.

A comparison of freight costs was conducted by design ship size (100,000, 150,000, 250,000 and 300,000 dwt) and estimation of the Panama Canal commodity flows for the Status Quo and each design ship were estimated as shown in Table 5.2.4-1

Table 5.2.4-1
WEFA's Estimated Panama Canal Commodity Flows
units: Million tons

	1990	2020	2060
Status Quo	156.4	265.1	411.7
100,000 dwt	156.4	267.9	417.2
150,000 dwt	156.4	319.5	487.5
250,000 dwt	156.4	335.0	504.3
300,000 dwt	156.4	335.0	504.3

5.2.5 Vessel Mix and Projection

Prior to the projection of transit mix of the Panama Canal, the WEFA group forecast world vessel fleet development (ship mix and average dwt) by ship type. First they discussed the prospect of ship technology development, and then estimated ship mix and average dwt of 10 types of ships for 2020 and 2060.

The forecast of the Panama Canal transit mix for 2020 and 2060 was based on the 1990 synthesized Panama Canal Vessel transit database together with their projected development of the estimate of transit mix. WEFA used two sets of parameters:

- average dwt by size range and ship type on each route
- percentage distribution of tonnage (dwt) by size for each type of ship and route

The Panama commodity forecasts were converted into numbers of laden and ballast transits by ship type and size based on projection of transit mix of the Panama Canal.

The results are given in Table 5.2.5-1.

Table 5.2.5-1
Projected Total Panama Canal Transits

Maximum Ship Size	No. of Annual Ship Transits		
	Year 1990	Year 2020	Year 2060
65,000 (S.Q.)	11,520	18,350	24,710
100,000	-	17,620	23,880
150,000	-	18,140	24,500
250,000	-	18,220	24,420
300,000	-	18,210	24,410

Note: Totals are rounded.
Source: Commodity and Traffic Projections Study, The WEFA Group

5.3 Canal Operation and Capacity Evaluation, Phase I

5.3.1 Approach

The purpose of the Phase I Operating Characteristics and Capacity Evaluation Study (OCCE) was to identify and assess major operating characteristics of alternative plans, which may have decisive roles in the selection of each alternative plan, and then evaluate approximate vessel transit capacity of each alternative in relation with transit time and delay.

Due to the complexity of the system to be evaluated, Monte Carlo simulation was selected as the main study tool and time and cost consideration resulted in the use of existing model with necessary adaptation to the project situation. TAMS Consultants Inc., in association with Oak Ridge National Laboratory and the American Bureau of Shipping, proposed the use of the Waterway Analysis Model (WAM) which had been developed and used by the U.S. Army Corps of Engineers to simulate shallow draft barge traffic on the U.S. inland waterways for more than 10 years.

WAM by its flexible programming nature, proved to be the most adequate simulation model for this component study. For the sea level alternatives, however, an additional analysis was necessary for representing the hydraulics of this group of alternatives such as tide cycle, magnitude of tide level, induced tidal current, and canal operating cycle.

To this aim, a mathematical model LATIS which is one of the TAMS's service program was utilized.

5.3.2 Models Adopted

Description of WAM

An overview of the structure of WAM is presented in Figure 5.3.2-1. The following is a brief description of the four major components of WAM.

a. System Description Input Data

This is a set of input records which describes the waterway network (ports, locks and interconnecting channels), the vessel fleet, and commodity data for which area assigned in original WAM has been modified to accommodate input data for twenty-two different classes. Schematic presentations of typical canal system are shown in Figures 5.3.2-2 and 5.3.2-3. For high rise alternatives, following system descriptions are made: The system consists of a port at each end, locks at Gatun, Pedro Miguel, and Miraflores, six bends including a bend to represent Culebra Cut, and intervening reaches between these elements. Some intermediate ports are added to represent junctions where new channels for the third locks plan would join the existing system. Configurations with a third lane of locks are represented as a branch in the network, with the new locks located in this branch. The WAM at phase I requires pre-assigning vessels to use new locks, but this feature will be modified to so-called dynamic assignment system.

b. External Event Input Data

These input records are read into the model during the simulation process and trigger occurrence of events. There were three types of external events inputs:

i) shipment data;

ii) run control data; and,

iii) lock downtime events.

While items ii) and iii) basically remain as they are, item i) shipment data has been largely modified to accommodate new project requirements. Since the forecast of traffic and induced vessel transit requirements to the canal has been assigned to a component study contractor other than TAMS, the simulation process has to start with the generation of vessel arrival at each end port conforming with the requirements set up earlier by the.traffic and vessel transit study. This function, generating of arrival vessels, therefore, replaces most of the original functions of shipment data in WAM. In phase I, vessel arrivals are assumed to be random occurrences, in other words, assumed vessel arrival patterns to each end port are Poission type ones.

Figure 5.3.2-1
Structure of Waterway Analysis Model

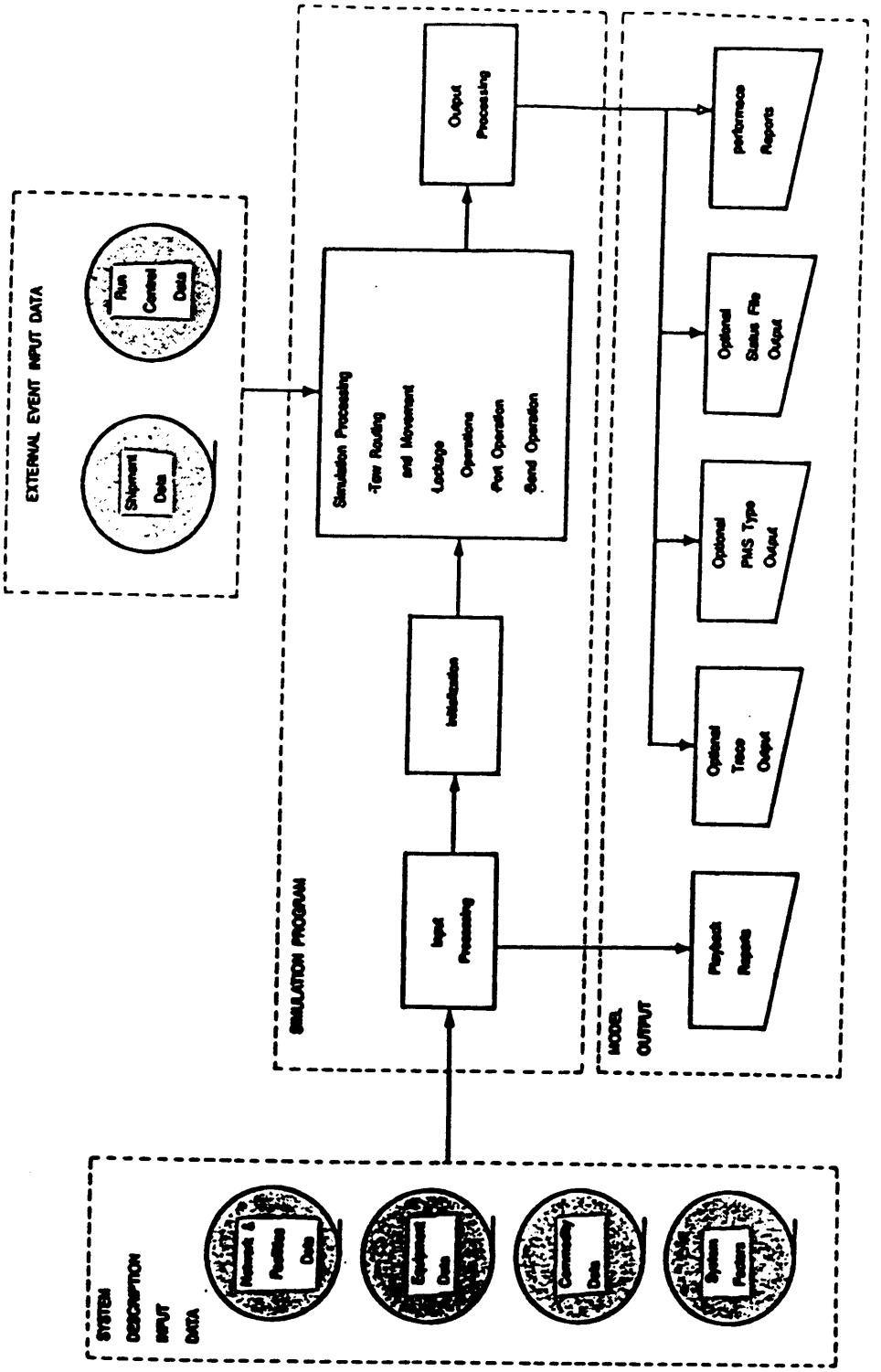
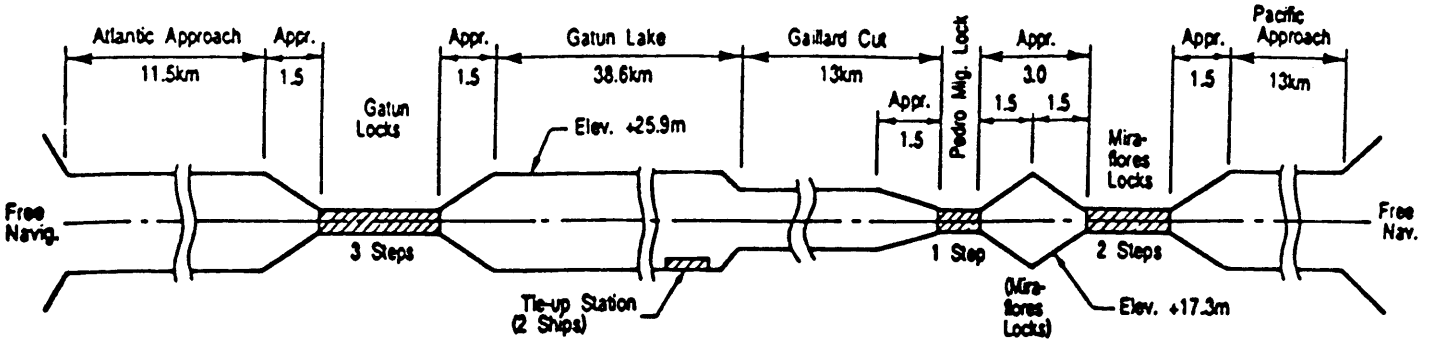
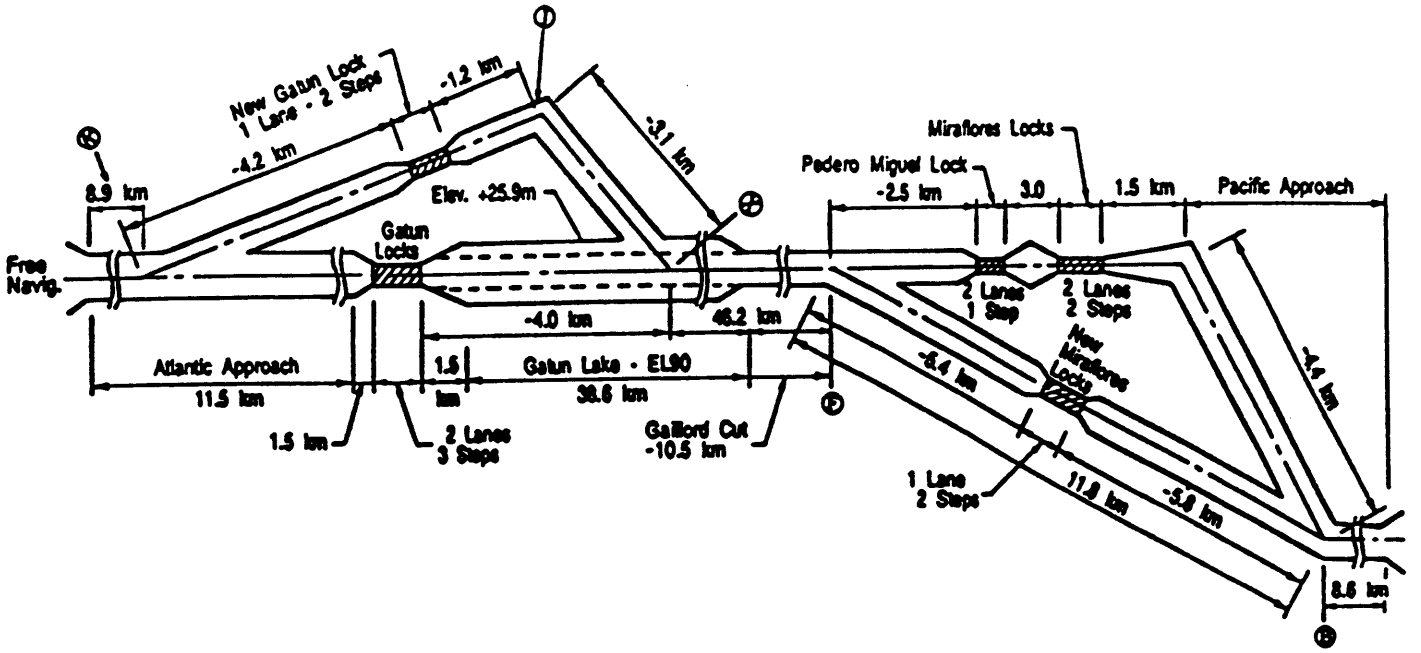


Figure 5.3.2-2
Schematics of Alternative Lock Plans



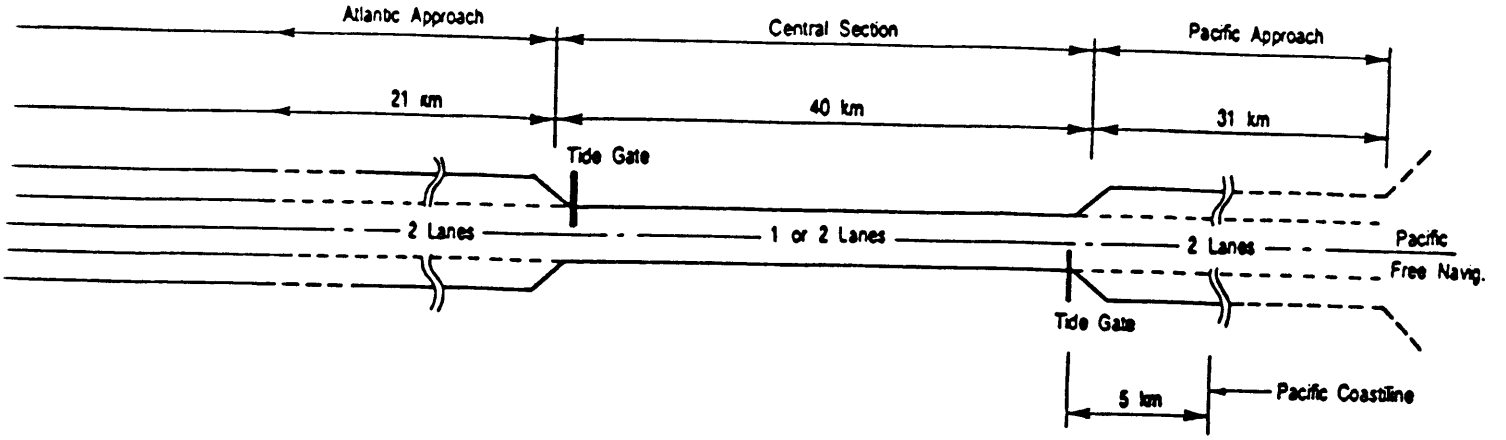
EXISTING PANAMA CANAL (ROUTE 15)



HIGH RISE LOCK CANAL

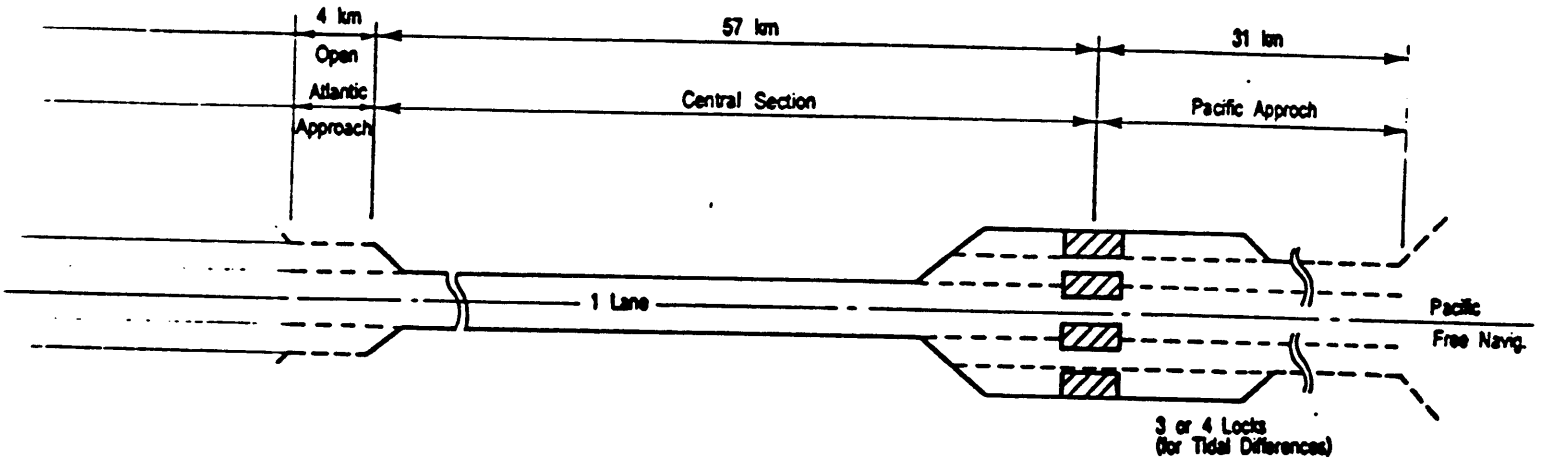
Route 15 and Third Locks Route

Figure 5.3.2-3
Schematics of Alternative Sea Level Plans



ROUTE 10

TIDE GATES



ROUTE 10

LOCKS AT PACIFIC END

The run control records cause such events as the resetting of accumulated statistics, the printing of intermediate output records, the saving of optional data and the end of simulation. The lock downtime records cause a specified lock chamber to go out of service, to simulate equipment malfunctions accidents, weather delay, and so on.

c. Simulation Program

The simulation program is the operational heart of the model. It processes the input data, produces playback reports, initializes the waterway system, processes each transit from one end to the other end, records statistics for generation of performance output reports, and creates files for post-processing by other programs.

d. Output Reports

Playback reports are preceded by the input processing routines of the simulation program. These reports echo the system description input data in a convenient format for user data checking. The output processing routines of the program use statistics gathered during the simulation to generate performance reports on lock utilization and delay, vessel utilization, port activity, detailed traffic summaries, and other optional reports specified by the user.

Lockage Time and Passage Time in Channel

There are two other main features of WAM to be specifically mentioned in this section, which are directly related to the transit time of vessels; one is the lockage time and the other is vessels passage time in channels.

Lockage time of vessel in the model is decided by the built-in table function which has been made on data obtained from SDB and supplemental field observations. Adopted probability distribution function is a type of Gamma distribution for which means and standard distributions are decided by the following function.

$$\begin{pmatrix}\text{mean and standard} \\ \text{div. of Gamma Dist.}\end{pmatrix} = f \begin{pmatrix}\text{type of lockage operation*, vessel class, transit} \\ \text{direction, type of towing locomotive operation**}\end{pmatrix}$$

where, lockage types are classified by:

i) fly/exchange: consecutive opposite direction operation in the same lane

ii) turnback: consecutive same direction operation in the same lane; and,

iii) tandem lockage: multiple vessel lockage for smaller vessel.

Types of towing locomotive operation** are:

i) normal operation; and,

ii) relay operation which is a faster and a little bit costlier operation.

For phase I, the approach was to conduct most model runs with continuous relaying so as to estimate maximum capacity. For phase II, the model can be modified to permit switching into and out of relay operations on demand driven basis. After detailed examination, it has been decided to treat the dual chamber /locks as a single chamber lock.

The main reasons are; i) the level of detail available in the SDB for lock passage time does not support more detailed modeling of each level at Gatun and Miraflores, which could be represented as successive locks, and ii) the field observations made at those locations indicate that a greater level of detail is not needed.

Contrary to the lockage operation, vessel passage time in channel sections has been decided based on the internally generated vessel speed and the sectional distance of each channel configuration data. WAM is equipped with a vessel speed function to generate vessel speed, acceleration/deceleration for each vessel class from the corresponding standard vessel characteristics such as block coefficient, horsepower, and ship length which were collected and analyzed for each vessel class by utilizing SDB and other supplementary information.

Description of LATIS (Tidal Hydraulic Study)

Model studies were made to analyze the tide level and induced current speed in the sea-level canal alternatives due to changes in the tides in the two oceans. TAMS' program LATIS was used to formulate a mathematical model for the above mentioned tidal hydraulics of sea-level canal alternatives. LATIS's standard programming resolves the vertically integrated equations of motion in an open channel, the Saint Venant equations in an explicit finite difference scheme.

In this model, each canal system is decomposed to a set of links and nodes. Node characteristics or volumes are introduced with tables of volumes versus water surface elevations while link characteristics are introduced with tables of top widths, areas and conveyance also versus water surface elevations. Then the computation phase is conducted for each time interval first calculating the elevations for all nodes and second the discharges for all links, subject to various possible boundary conditions.

The time interval for calculation is set at 50 seconds for all cases except for Vergara plan for which 25 seconds time interval is applied. Manning's Number, a measure of channel roughness, is selected at 0.025, and sensitivity calculations with 0.035 are also made for some cases.

- Cases Analyzed

Tidal currents for various sea-level alternatives studied with the aid of this model are:

i) 180 m wide canal, single lane traffic, 58 km long;

ii) 425 m wide canal, two lane traffic, 58 km long;

iii) Gates at both ends of 58 km, 180 m wide canal;

iv) Gates flanking 40 km, single lane section Pacific end at 16 km.;

v) Gates flanking 40 km. single lane section with Pacific end at 6.0 km.;

vi) Vergara Alternative with confined water area of 210 sq. km at the Pacific end of the model; and,

vii) Vergara Alternative with Confined water area of 100 sq.km at the Pacific end of the model.

Schematic representations of i) through vii) cases are summarized and shown in Table 5.3.2-1.

- Boundary Tides and Bottom Elevation

Boundary Tides were selected from the US National Oceanic and Atmospheric Administrations publication for Balboa, at the Pacific end of the canal and for Cristobal, at its Atlantic end. A pair of spring and neap tides for the month of January 1992 was chosen from the above mentioned publication.

The canal cross section was assumed to be trapezoidal with 1:2.5 side slopes, and bottom elevation was assumed to change linearly from -29 m Precise Level Datum (PLD) at the Pacific end to -26 m at the Atlantic end for 180 m wide canal as the base case.

- Major findings of the analysis are:

i) Vergara alternatives are considered very difficult, if not impossible, to implement because of the associated high current speeds both in the canal and at the entrance. Maximum current speeds in the canal recorded 5.2 knots for 100 Sq.km case and 4.3 knots for 210 Sq.km case. Moreover, the maximum computed current speed at the entrance was 17 knots for 210 Sq.km case, and 75 percent of the time the current speed would be higher than 6 knots. In case of 100 sq.km alternative, corresponding figures were reduced to 9 knots, 80 percent, and 4 knots respectively;

ii) Positive tidal current control schemes, either by tide gates or tide locks, need to be implemented to central tidal current within the practical level. Without the control scheme, maximum tidal current at the Atlantic end will exceed 5 knots; and,

iii) For the single lane sea-level alternatives vessels must form convoys for transit, therefore, tide characteristics, tide cycle in particular, becomes a critical factor in the operating characteristics and capacity of the canal.

In this relation, two types of cyclic operation namely, 12.5 hour cycle (full tide operation), and 6.25 hour cycle (half tide operation) are recommended for further study.

Results of tidal hydraulic analysis by LATIS are summarized and shown in Table 5.3.2-1.

5.3.3 Input Data to the Model

It is widely recognized that the reliability of simulated results largely depends on the accuracy and adequacy of input data to the model. In this respect, WAM is not an exception, but in fact, WAMs' flexible programming nature requires much more careful examination of input data than usual simulation programs.

The main sources for providing input data were:

i) General information on existing canal including Status Quo alternative was provided by Panama Canal Commission (PCC);

ii) Dimensions and configurations on conceptual alternative plans was provided by Engineering and Costs Study (ECS);

iii) Traffic projections and associated ship mixes for years 2020 and 2060 was provided by Commodity and Traffic Projection Study (CTP) for the five different maximum design vessels which specifies the size of alternative canals;

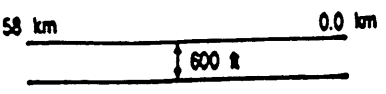
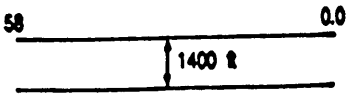
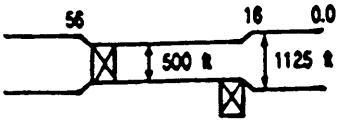
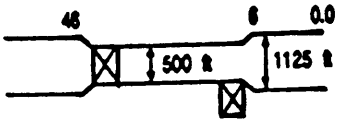
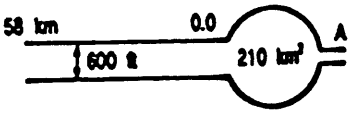
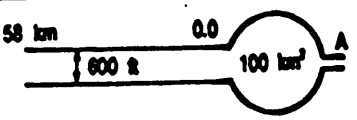
iv) Details of operating characteristics such as lockage time and channel passage time by vessel class are extracted from the 1990's Ship Data Bank of PCC; and,

v) Supplementary field observations and other investigations have been made by TAMS (OCCE contractor) as necessary.

Summarizing information collected and analyzed from the above, input data finalized at this stage of the study are presented hereunder.

Table 5.3.2-1

Results of LATIS Analysis

CASE TESTED	CONFIGURATION OF CANAL (Atlantic End / Pacific End)	ELEVATION OF BOTTOM AT PACIFIC END	MAX. WATER SPEED (Knots)			
			58 km	36 km	0.0 km	A
1 WITHOUT GATES		-94.2	5.2	4.2	4.0	•
2 WITHOUT GATES		-94.2	5.5	4.7	4.2	•
3 GATES AT 58 & 0.0 Km		-94.2	0.2	1.3	2.2	•
4 GATES AT 56 & 16 Km		-80.2	0.4	1.0	1.5	•
5 GATES AT 46 & 6 Km		-80.2	0.0	•• 1.0	1.0	•
6 VERGARA ALTER. I		-94.2	4.3	3.3	3.1	17
7 VERGARA ALTER. II		-94.2	4.7	3.9	3.4	9

All of the results refer to the spring tide situation.

Manning's Number = 0.025, which is a measure of channel roughness.

• Max. water speed refers to a location 56 km from the Pacific entrance.

•• Max. water speed refers to a location 27.0 km from the Pacific entrance.

- Vessel Classification

All SDB vessels were related to vessel types 1 through 14 (see Table 5.3.3-1) for analysis and for preparation of model inputs. In addition, vessel types 15 through 22, corresponding to ships from 100,000 to 300,000 dwt in size were added for analysis of lock and sea-level alternatives.

Table 5.3.3-1
Ship Type and Size

1	Up to 60' beam	12	100+' beam, >38' draft
2	61-69' beam	13	commercial passenger
3	70-79' beam	14	recreational vessels
4	80-89' beam, <36' draft	15	100,000 dwt ship ballast
5	80-89' beam, >36' draft	16	100,000 dwt ship laden
6	90-99" beam, <30 draft	17	150,000 dwt ship ballast
7	90-99" beam, 30-36' draft	18	150,000 dwt ship laden
8	90-99" beam, >36' draft	19	200,000 dwt ship ballast
9	100+' beam, <30 draft	20	200,000 dwt ship laden
10	100+ beam, 30-36' draft	21	300,000 dwt ship ballast
11	100+ beam, 30-38' draft	22	300,000 dwt ship laden

- Ship Transit Projections

A summary of the projections prepared by the WEFA Group of ship transits covering ship mix with five alternative maximum vessel sizes for years 2020 and 2060 appears in Table 5.2.5-1.

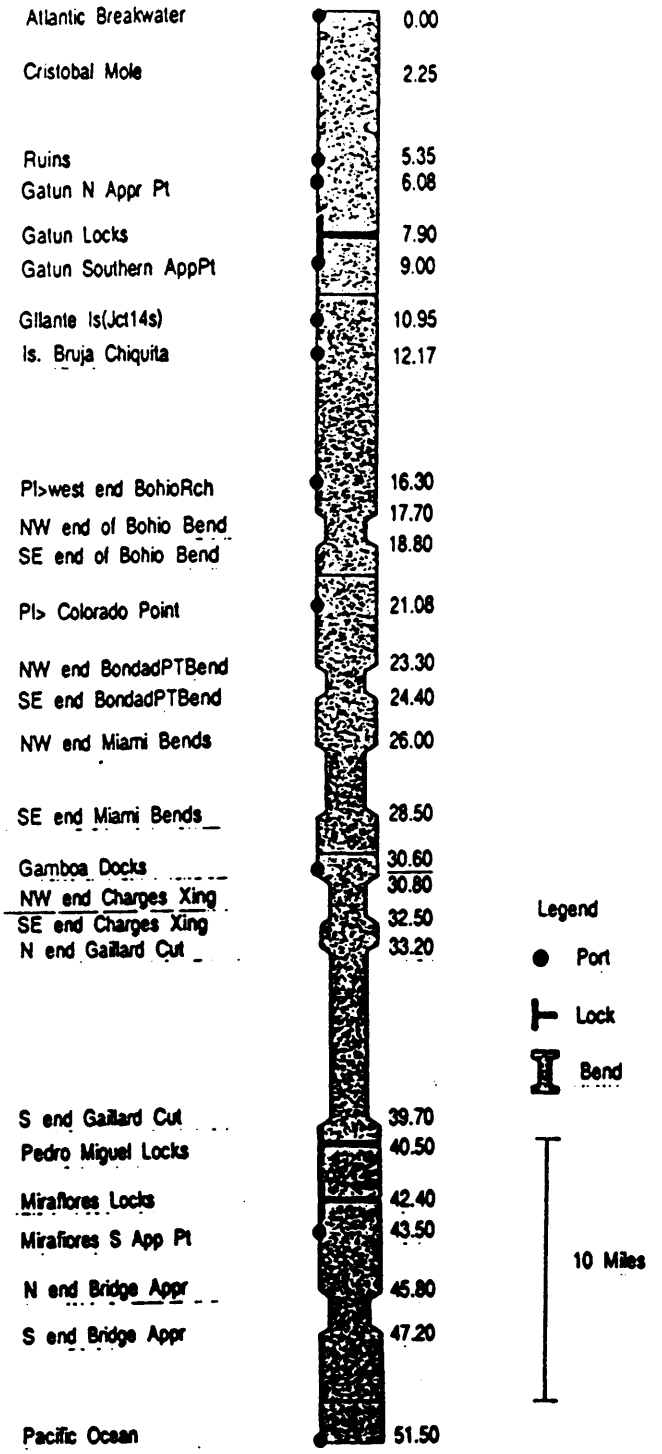
Table 5.3.3-2 is the break down and more precise input form of this table indicating the distribution in transits between laden and ballasted ship, northbound and southbound.

Network Structure

A basic node and link file describing the present layout of the Panama Canal transformed into a schematic diagram is shown in Fig. 5.3.3-1. The network structure is a general purpose one, so various input parameters were selected to tailor it to the precise purposes of the Phase I simulation runs. For example, the bends in Gatun Lake do not impose any appreciable restrictions on navigation, so their geometric and operational parameters were selected to permit unimpeded passage of vessels. Likewise, port operations are not of interest in this study, so all port variables were set so as to render the model's port loading, unloading, and dispatching logic inoperable.

Figure 5.3.3-1

Schematic of Basic Network for WAM



The bendway representing the Culebra Cut deserves special mention. It was input as a single straight segment, with a width of 500 ft. and with vessel clearance requirements such that two vessels with combined beam exceeding 140 ft. would not be allowed to pass. The basic effect for these WAM runs is that class 6 vessels and larger, which have beams greater than or equal to 95 feet, would require a clear cut. The more detailed geometry of the Cut was not represented, since it would have no added impact on vessel operations in the model.

Table 5.3.3-2

Distribution of Total Panama Canal Vessel Transits

Year: Case	Ballast		Laden		Total		
	North	South	North	South	North	South	ALL
1990:1	676	1,084	4,806	4,956	5,482	6,040	11,522
2020:1	1,043	1,790	7,684	7,833	8,727	9,623	18,350
2020:2	995	1,758	7,362	7,509	8,357	9,267	17,624
2020:3	1,075	1,757	7,353	7,958	8,428	9,715	18,143
2020:4	1,088	1,756	7,351	8,028	8,439	9,784	18,223
2020:5	1,087	1,756	7,351	8,021	8,438	9,777	18,215
2060:1	1,349	2,197	9,967	11,193	11,316	13,390	24,706
2060:2	1,282	2,169	9,690	10,740	10,972	12,909	23,881
2060:3	1,385	2,168	9,652	11,296	11,037	13,464	24,501
2060:4	1,397	2,167	9,650	11,231	11,024	13,378	24,422
2060:5	1,395	2,167	9,650	11,224	11,023	13,391	24,414

Notes: 1: Status Quo - 65,000 dwt Design Ship
2: 100,000 dwt Design Ship
3: 150,000 dwt Design Ship
4: 250,000 dwt Design Ship
5: 300,000 dwt Design Ship
Source: Commodity and Traffic Projections Study

Locking Time

This input data is shown in Table 5.3.5-1 in comparison with the results of calibration run.

5.3.4 Operating Policy and Procedures

The operating policy or principal criteria governing canal operations are:

Safety

Safety of operations is first and foremost, and is the basis for many of the key operating rules.

Capacity

The capacity requirement is considered satisfied if congestion is avoided, i.e. if ships' time in canal waters do not exceed 24 hours.

Operating Costs

If the capacity criteria is satisfied, the Canal is operated as economically as possible. However, there is impending congestion as a result of a greater than ordinary number of ship arrivals or a lock lane out-of-service, faster but more costly operations will be used such as 'relay' operations (described below) at Gatun and Miraflores Locks.

Water Use

The availability of water for lockages is not a problem generally and not at all during rainy seasons. During a recent dry season, however, it was necessary to restrict vessel drafts below normal. At such time, water conservation takes on more importance.

Other operating rules to be specifically mentioned are:

i) The general operating procedure is "first come, first served", and this is adopted as the general rule of simulation.

ii) For safety reasons, large ships are not permitted to navigate through Culebra Cut at night and are not permitted to pass or overtake in the Cut, however this aspect is not taken into consideration in Phase I analysis. The main reason is that the canal after the completion of Culebra Cut Widening has been chosen as the Status Quo alternative.

iii) Passage through the canal can be reserved with priority through a booking system paying additional fee. In this case, passage within 18 hours is guaranteed.

iv) Preference transits proceed through the Canal upon arrival - e.g. Passenger Ships.

v) During light traffic periods, such as for eight hours each night, one lane at Pedro Miguel locks is shut down.

vi) Ships handling hazardous cargoes are not permitted to pass in the Cut (these and large ships are referred to as 'clear cut vessels').

vii) Small ships can share a lock chamber when their combined lengths do not exceed 800 feet; this is called 'tandem lockage'.

viii) If only one lane of a lock is being used, both the side wall and center wall culverts are assigned to that lane.

ix) If an upbound and a downbound passage are proceeding simultaneously through a lock, the center wall culvert is assigned to the upbound lane.

x) A ship may tie up on either side or either end of the center wall of a lock if its passage is delayed.

xi) 2 Lock maintenance staff are also trained to serve as operations staff, which provides considerable flexibility in staff assignments and the ability to respond to fast developing situations.

5.3.5 Model Calibration

In accordance with the normal procedure for simulation analysis, calibration runs have been made to check the simulated result against base-line case. Table 5.3.5-1 shows the WAM average locking time outputs and the PCC locking time schedule. The overall level of agreement is within acceptable limits for Phase I analysis.

Table 5.3.5-2 displays the locking times outputs by WAM along with the values obtained from the SDB records. Though the latter include some delay time, the agreement is considered reasonable. The standard deviations in the WAM results tend to be smaller than the SDB standard deviations, indicating that the analytical intent to use somewhat more compact distributions than those of the raw data was achieved.

During the above calibration run, actual lock downtime data for 1990 provided by PCC, which also includes scheduled lane outage and outages for preventive maintenance has been fully incorporated.

Table 5.3.5-1

WAM Calibration Results Compared with PCC Locking Time Schedule

Vessel Class	Source*	Average Locking Time (minutes)				
		Gatun Locks		Pedro Miguel Locks	Miraflores Locks	
		Regular	Relay		Regular	Relay
1	PCC	60	30	30	40	30
	WAM	53	32	27	37	23
2	PCC	60	35	30	40	30
	WAM	53	32	30	37	24
3	PCC	60	35	30	45	35
	WAM	54	32	30	42	28
4	PCC	70	40	40	50	40
	WAM	69	47	37	50	37
5	PCC	70	45	40	50	40
	WAM	68	44	39	50	38
6	PCC	70	40	40	55	40
	WAM	75	52	42	54	39
7	PCC	75	45	45	65	45
	WAM	77	55	43	61	48
8	PCC	85	50	50	70	50
	WAM	94	72	52	70	57
9	PCC	70	45	40	60	45
	WAM	75	51	43	64	49
10	PCC	85	50	50	70	50
	WAM	97	73	53	74	59
11	PCC	105	60	60	80	60
	WAM	121	97	62	84	71
12	PCC	125	75	65	90	60
	WAM	151	128	68	95	83
Tandem	PCC	70	40	40	50	40
	WAM	67	43	39	50	33

Note: * PCC = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration

Table 5.3.5-2

WAM Calibration Results Compared with SDB Locking Times

Vessel Class	Source*	Northbound Locking Time (minutes)					
		Gatun Locks		Pedro Miguel Locks		Miraflores Locks	
		Average	SD	Average	SD	Average	SD
1	PCC	79	21	34	28	51	13
	WAM	54	15	26	6.8	36	8.3
2	PCC	76	17	33	9.7	50	11
	WAM	55	16	28	6.7	41	9.0
3	PCC	76	18	34	9.6	50	11
	WAM	54	17	29	7.1	41	9.0
4	PCC	81	21	34	9.6	52	9.5
	WAM	72	18	29	7.1	50	8.8
5	PCC	86	17	38	5.5	56	6.9
	WAM	74	16	38	7.1	50	8.9
6	PCC	86	21	41	18	55	10
	WAM	77	18	42	10	54	9.8
7	PCC	91	19	42	13	58	7.8
	WAM	79	20	44	9.2	60	10
8	PCC	95	18	48	22	63	9.1
	WAM	96	18	52	11	69	9.3
9	PCC	93	21	45	18	61	9.1
	WAM	76	19	44	10	65	9.3
10	PCC	101	21	49	16	67	10
	WAM	100	17	54	13	74	10
11	PCC	-	-	-	-	-	-
	WAM	130	22	62	13	86	11
12	PCC	118	23	61	13	85	11
	WAM	149	22	73	14	101	12

Note: * PCC = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration

Table 5.3.5-2 (Continued)

Vessel Class	Southbound Locking Time (minutes)						
	Source*	Gatun Locks		Pedro Miguel Locks		Miraflores Locks	
		Average	SD	Average	SD	Average	SD
1	PCC	70	13	36	13	51	14
	WAM	51	13	29	7.4	37	9.7
2	PCC	70	14	36	14	50	10
	WAM	51	13	32	7.3	42	9.3
3	PCC	71	14	36	14	50	10
	WAM	51	13	32	7.3	42	9.3
4	PCC	75	15	38	12	53	12
	WAM	66	14	39	7.7	51	10
5	PCC	77	14	44	16	51	9.2
	WAM	67	13	39	7.6	51	11
6	PCC	79	15	41	12	56	15
	WAM	71	17	40	9.6	55	12
7	PCC	86	19	42	10	60	16
	WAM	75	14	43	7.8	61	14
8	PCC	92	16	45	8.7	62	15
	WAM	92	17	51	10	70	13
9	PCC	87	11	42	11	62	15
	WAM	72	17	42	9.5	63	13
10	PCC	93	13	47	9.9	65	14
	WAM	94	19	52	11	73	15
11	PCC	102	17	49	7.4	69	15
	WAM	116	16	62	11	82	13
12	PCC	124	19	56	10	77	14
	WAM	152	20	66	10	93	16

Note: * PCC = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration

The average lock delays recorded in the calibration run (regular lockage) are as follows:

Locks	Average Delay (hr.)	Lock Utility (%)
Gatun	3.1	75
Pedro Miguel	0.3	43
Miraflores	0.2	58

The higher delay at Gatun is a reflection of both the higher service time and the two 11.5 day lane outages. The results appear to be reasonable. As noted earlier, the average vessel speeds in the WAM output also agree reasonably well with observed data.

The overall average ship transit times (hours) in this run are as follows:

	North	South	Average
Travel	7.51	7.71	7.61
Delay	4.55	3.67	4.10
Total	12.06	9.80	11.71
SDB Data	12.50	9.80	11.1

As indicated, the match with the transit time results from analysis of the SDB records is relatively good. Combining this with the average of 11.6 hours of schedule delay experienced in 1990 indicates that the simulated time in canal waters is about 22.7 hours, which is under the PCC standard of 24 hours by only a small margin. This matches the information obtained during the visits of the research team to Panama.

In summary, the model calibration was deemed to be good enough to proceed with the simulation of the alternative conceptual plans. In particular, the results are sufficiently accurate to permit a screening level comparison of the plans. In Phase II a tighter calibration will be attained in order to permit more confidence in the model's absolute results.

5.3.6 Simulation Results of Conceptual Alternatives

All the alternative plans proposed historically have been synthesized into four basic groups:

A. Low-Rise Lock Canal Alternatives;

B. High-Rise Lock Canal Alternatives;

C. Sea Level Canal Alternatives; and,

D. Status Quo Alternatives (Baseline Case).

Five alternative design ship sizes were considered, ranging from 65,000 dwt to 300,000 dwt. The 65,000 dwt design ship size was considered for only the Status Quo Alternative. The High Rise and Low-Rise Lock Canal Alternatives were analyzed for design ship sizes of 100,000 dwt, 150,000 dwt, and 250,000 dwt. Under the Sea Level Canal Alternatives, the design ship sizes considered were 150,000 dwt, 250,000 dwt and 300,000 dwt. Table 5.1.3-1 shows the summary of conceptual alternatives that were analyzed for prescreening purpose. Schematic presentation of canal configurations for the above four conceptual alternatives are shown in Figures 5.3.2-2, and 5.3.2-3. Main features of each conceptual alternatives have been briefly explained hereunder.

Status Quo

The bendway representing the Culebra Cut was modified to widen the channel to 630 feet, and to eliminate nearly all ship passing delays. (Overtaking was still prohibited.) Lock downtimes were modified to remove the nightly shutdown of one lane at Pedro Miguel, and to remove the special maintenance downtimes (eg., the Gatun gate replacement) that occurred in 1990.

High-Rise Lock Canal

New channels were defined for the third locks. All channels which would be traversed by the larger ships were modified and single lane third locks, with the dimensions indicated below ere added in the new channels.

	100,000 dwt	150,000 dwt	250,000 dwt
New Locks (ft.)	1,046 x 154	1,191 x 177	1,220 x 187
Channel Depth (ft.)	62	69	79

It was considered that the Culebra Cut channel dimensions would be consistent with those at other reaches, so that the existing night time and clear cut restrictions in transit of large ships would not apply. Locking times at the new facilities were based largely on the locking times estimated for the existing Miraflores Locks for most existing ship sizes, because the new locks have only two lifts, as does Miraflores, locking times for the design vessels were developed to provide a smooth progression from the class 12 ships (the largest that can navigate through the existing locks) through the larger classes. The downtimes for the existing Miraflores Locks were assumed to apply to the new locks.

Single Lift High-Rise Lock Canal

This system was modeled with a lake level of 85 feet and a single lift in the new locks, for only the 100,000 dwt design ship case. This is similar to the High-Rise Lock Canal system, except that locking times at the third locks were reduced to simulate a single lift operation and a five foot reduction in lake level.

Low-Rise Lock Canal

All channels were modified to reflect the lower lake level (55 feet). Pedro Miguel Locks which currently provide the lift from 55 feet to 85 feet, would no longer be needed and were removed from the system. Locking times were reduced to account for the single lift operations at the new locks and the elimination of one lift at existing Gatun.

Sea Level Canal

The sea level canal was modeled as a separate system, not connected to the existing canal.

The Route 10 case was assumed, to have a 58 km cut across the Isthmus and double lane approaches for a total length of channel ranging from 87 to 90 km. The 58 km cut was assumed to be, alternatively, either single lane, dual lane or partial single/partial dual lane. Positive tidal current control was assumed to be provided by tide gates spaced at either 58 km or 40 km, with one gate always at the Pacific end, or by tidal locks at the Pacific side of the cut.

The following cases were modeled:

- single lane, 58 km between tide gates, 12.5 hour cycle;
- single lane, 40 km between tide gates, 6.25 hour cycle;
- single lane, 58 km canal section, Pacific locks, 12.5 hour cycle; and,
- dual lane, 58 km canal section, Pacific locks, random operations.

In addition, results for a dual lane canal with 40 km between tide gates were derived from the comparable single lane case. When it became apparent during the early computer runs that a single lane canal would not suffice for the year 2060, and that the capacity with tide gates is not very sensitive to ship size, some runs for 250,000 dwt and 300,000 dwt ships were replaced by others involving the use of a single lane canal in combination with the Status Quo canal.

The canal section was modeled as a"bendway" as was the case with the Culebra Cut. Channel and bendway speed coefficients were modified to produce the desired average ship speed. For the cases with a single lane canal, cycle times were imposed through use of the lock downtime feature.

The Pacific locks were modeled with locking times selected to produce an average service rate of three ships per hour per canal lane (equivalent to three parallel locks per lane).

Subsequently, a two-lane canal with a total of four locks was modeled. Downtimes beyond those needed for single lane convoy operations were borrowed from the data for the existing Pedro Miguel and Miraflores locks.

Combined Systems

As noted above, some cases involving a single-lane sea level canal used in conjunction with the Status Quo Canal were also modeled.

Results of Simulation Analysis

As the general understanding of congestion analysis, the capacity of any facility under study and delay or waiting time associated with it are the trade-offs. For this reason, the overall characteristics of capacity for given facility can be best demonstrated by the so-called "capacity-delay curve", the OCCE Component Contractor proposed and worked out one capacity-delay curve from the two simulation results, in this case at years 2020 and 2060, assuming a hyperbolic curve. Though this approach could not provide the evaluation of accuracy for each simulated result, it greatly reduces the number of simulation runs needed to draw a capacity-delay curve. In this type of study, relative accuracy of each simulated result is not our primary concern, therefore, the approach adopted by the OCCE Component Contractor is acceptable. In this practice, if both points fall on either the very flat or steep portion of the curve, the results may not produce a reliable curve or specific number, although a judgement can be formed regarding the level of capacity.

In a number of cases modeled, the delay times increased relatively slightly between years 2020 and 2060, indicating that the case is well within capacity for year 2060, but also signaling that an actual capacity computation would not be accurate.

In those cases we have presented the delay times produced by the model and indicated that the system has more than adequate capacity for the expected levels of traffic in year 2060, without stating an actual number. In other cases, where capacity would be exceeded by the year 2060, it was necessary to model cases with a fraction of the 2020 traffic (or, in the case of the Status Quo Canal, the 1990 data) in order to achieve a second data point. The Sea level cases that are based on a cyclic rhythm, in fact, require three data points.

The Panama Canal Commission policy is that ships, on average, should be able to transit within 24 hours of arrival. This criterion appears reasonable and is assumed to be maintained in the future. Considering that unimpeded travel time is usually 8 hours or less, an average delay of 16 hours was assumed as one basis for capacity. To account for preparation time for canal transit, delay time was also calculated based on ten hours of delay.

Capacity delay curves grouped with similar characteristics have been shown in Figures 5.3.6-1 and 5.3.6-2. Summary of all the simulated results are summarized and shown in Table 5.3.6-1, and estimated capacities for all the alternatives are shown in Table 5.3.6-2.

Followings are the major findings and comments for the simulated results at this stage.

The Status Quo canal barely meets ship transit requirements at year 2020, and its capacity will be exceeded shortly thereafter;

- capacity of new canal alternatives is more sensitive to alternative basic canal configurations than to variations based on maximum ship size;
- all High-Rise and Low-Rise Lock Canal alternatives, for all ship mixes studied, have adequate capacity to year 2060 and beyond;
- a single-lane Sea level Canal Alternative across the complete Isthmus with either tide gates spaced at 58 km or three parallel locks at the Pacific end would not be able to accommodate the ship transits projected for year 2020;
- a 40 km single-lane Sea Level Canal flanked by tide gates would barely accommodate ship transit needs in year 2020, and its capacity would be exceeded shortly thereafter;
- a two-lane Sea Level Canal with tide gates spaced at 40 km or with four parallel locks at the Pacific side would be able to meet ship transit needs to year 2060 and beyond; and,
- all single-lane Sea Level Canal alternatives, with tide gates or locks, in combination with the Status Quo Canal, have adequate capacity to year 2060 and beyond.

Figure 5.3.6-1
Panama Canal Capacity Study (1)

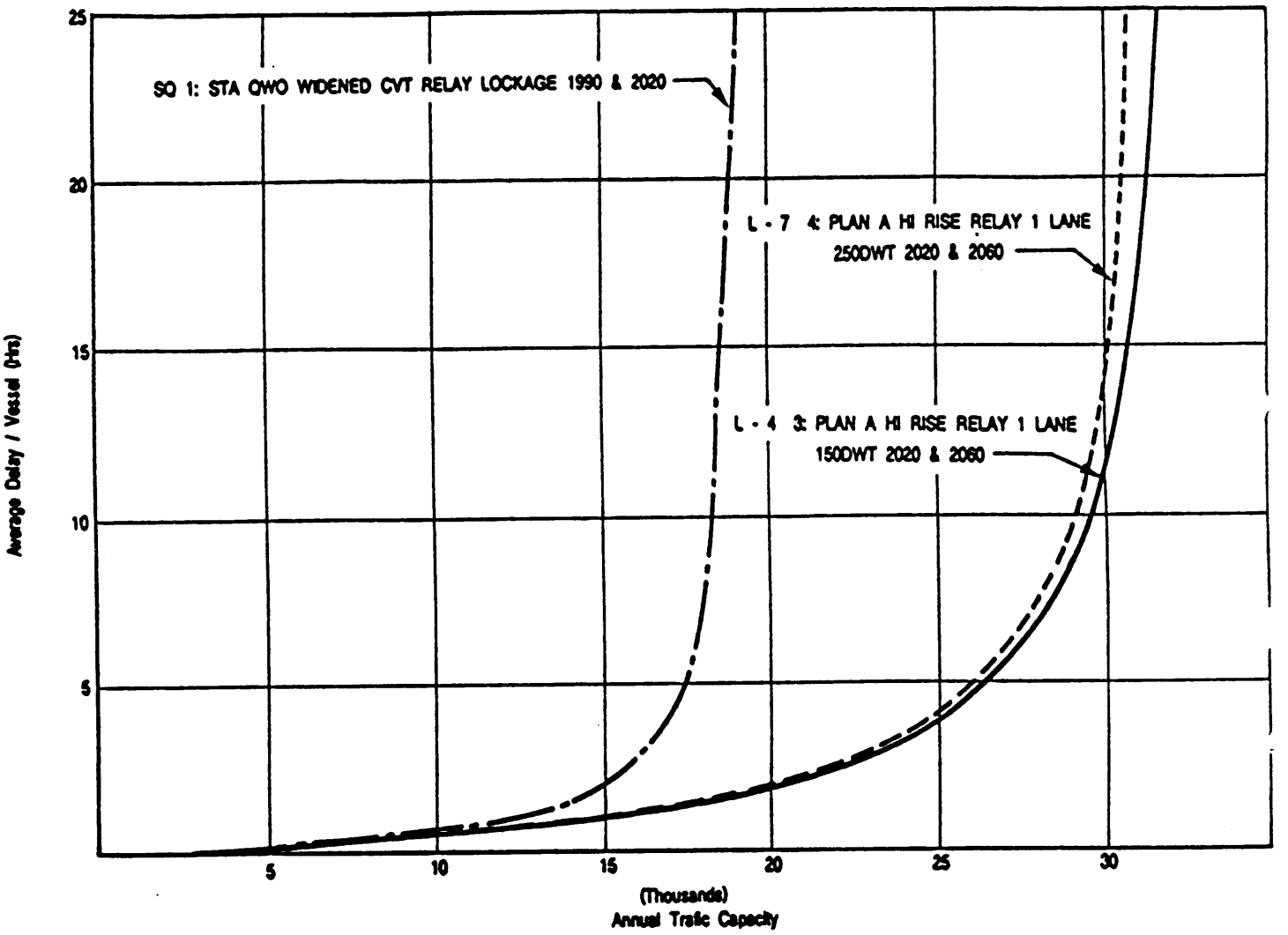


Figure 5.3.6-2
Panama Canal Capacity Study (2)

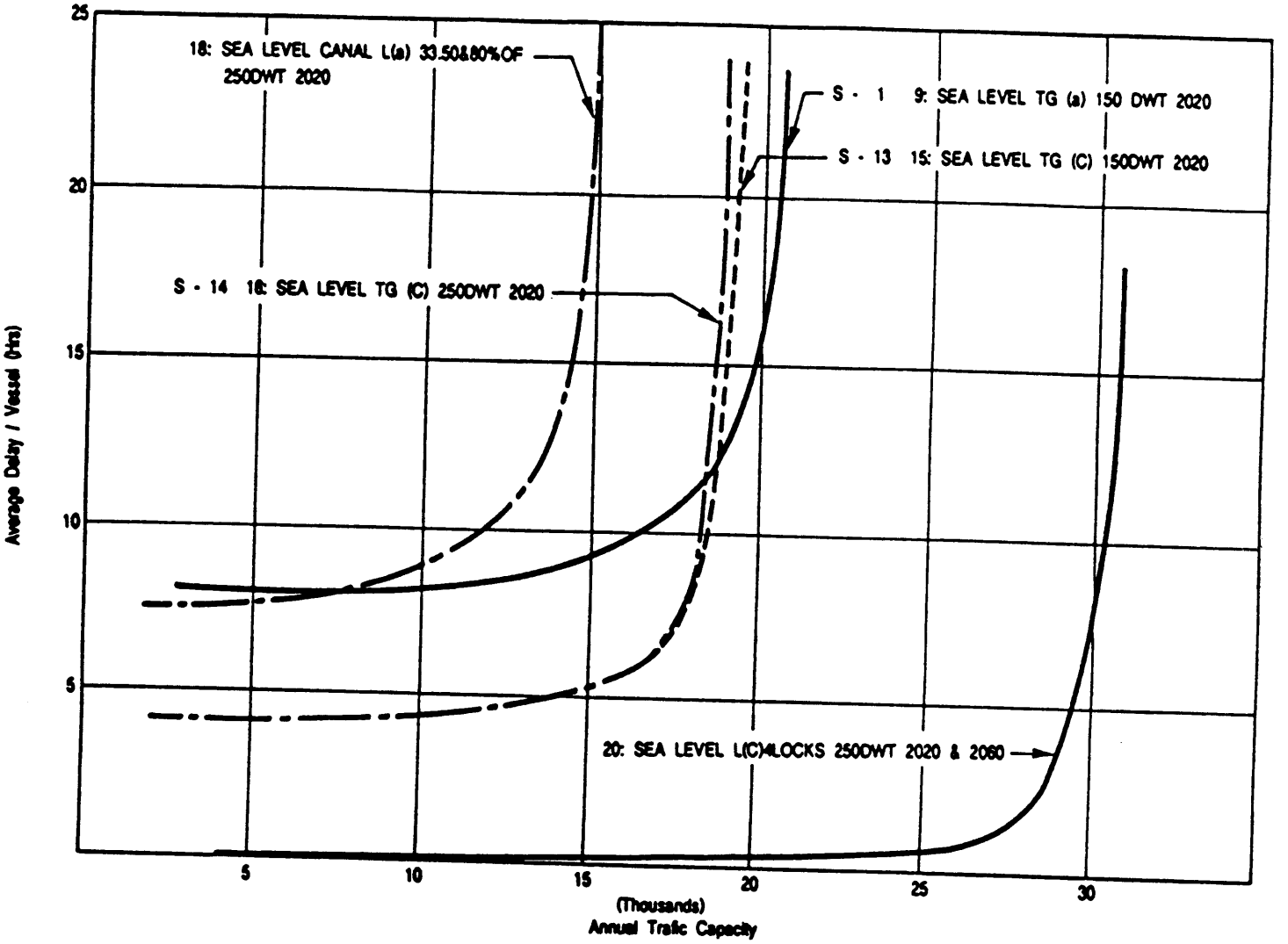


Table 5.3.6-1

Transit Delay and Estimated Capacity

Study Case[1]	No.	Conceptual Alternative	Maximum Ship (1000 dwt)	Average Delay per Ship (hr.)			Capacity Annual Transits (No. Ships)	
				Other	Year 2020	Year 2060	10 hr Delay	16 hr Delay
SQ	1	D Status Quo	65	0.79[2]	9.68	-	18,300	18,600
L-1	2	A High Rise Locks (90)[2]	100	-	1.50	2.53	[1]	[1]
L-4	3	A High Rise Locks (90)[2]	150	-	1.51	3.54	29,500	30,800
L-7	4	A High Rise Locks (90)[2]	250	-	1.46	3.65	28,900	30,100
L-2[7]	5	A High Rise Locks-85 It single Lane	100	-	1.50	1.98	[1]	[1]
L-3	6	B Low Rise Locks (55)[2]	100	-	0.76	1.03	[1]	[1]
L-6	7	B Low Rise Locks (55)[2]	150	-	0.76	1.16	[1]	[1]
L-9	8	B Low Rise Locks (55)[2]	250	-	0.76	1.17	[1]	[1]
S-1	9	C Sea Level, 58 km, Single Lane, Tide Gates	150	8.16&8.44[3]	11.4	-	16,300	19,800
S-3	10	C Sea Level ,58 Km, Single Lane, Tide Gates	250	-	-	-	16,300	19,500
S-5	11	C sea Level, 58 Km, Single Lane, Tide Gates	300	-	-	-	15,500	19,000
S-2	12	C Sea Level, 2 Lanes, Tide Gates, 40 Km	150	-	-	-	[1]	[1]
S-4	13	C Sea Level 2 Lanes, Tide Gates, 40 Km	250	-	-	-	[1]	[1]
S-6	14	C Sea Level, 2 Lanes, Tide Gates, 40 Km	300	-	-	-	[1]	[1]
S-13	15	C Sea Level, 1 Lane, 40 Km w/Tide Gates	150	4.18&4.32[4]	8.46	-	18,400	18900
S-14	16	C Sea Level, 1 Lane, 40 Km w/Tides Gates	250	[1]	[1]	-	18,200	18,600
S-15	17	C Sea Level, 1 Lane, 40 Km w/Tide Gates	300	-	-	-	18,000	18,500
-	18	- Sea Level, 1 Lane, 58 Km, 3 Locks	250	7.93&8.63 & 19.55[5]	-	-	11,700	14200
-	19	- Sea Level, 2 Lanes, 58 Km, 6 Locks	250	-	0.11	0.23	[1]	[1]
-	20	- Sea Level, 2 Lanes, 58 Km, 4 Locks	250	-	0.27	0.76	30,100	30,000
-	21	- No. 9	150	-	2.28	3.22	[1]	[1]
-	22	- No. 10	250	-	2.25	3.20	[1]	[1]
-	23	- No. 15	150	-	1.88	2.44	[1]	[1]
-	24	- No. 16	250	-	1.86	2.43	[1]	[1]
-	25	- No. 18	250	-	2..22	3.16	[1]	[1]

Notes: [1] The capacity is judged to be well in excess of the forecasted number of transits in Year 2060. [2] Year 1990 traffic.
[3] 33% and 50% of 2020 traffic [4] 33% and 80% of 2020 traffic. [5] 33%, 50% and 80% of 2020 traffic
[6] From List-Item 1, Appendix III, OCCE Agreement [7] Single Lift variant of Case L-2, Table XI-2

Table 5.3.6-2
Estimated Capacity

Study Case[1]	Conceptual Alternative	Maximum Ship Size (1000 dwt)	Capacity Annual Transits (No. Ships)	
			10 hr Delay	16 hr Delay
L-2	A High Rise Locks - 85 ft	100	[1]	[1]
L-5	A High Rise Locks - 85 ft	150	> 29,500	> 30,800
L-8	A High Rise Locks - 85 ft	250	> 28,900	> 30,100
L-10	A High Rise Locks - 85 ft	100	[1]	[1]
L-11	B Low Rise Lock - 55 ft	100	[1]	[1]
L-12	B Low Rise Lock - 30 ft	100	[1]	[1]
L-13	A High Rise Lock - 85 ft	150	> 29,500	> 30,800
L-14	B Low Rise Lock - 55 ft	150	[1]	[1]
L-15	B Low Rise Lock - 30 ft	150	[1]	[1]
L-16	A High Rise Lock - 85 ft	250	> 28,900	> 30,100
L-17	B Low Rise Lock - 55 ft	250	[1]	[1]
L-18	B Low Rise Lock - 30 ft	250	[1]	[1]
S-7	C Sea Level Route 14S, 1 lane	150	16,300	19,800
S-8	C Sea Level Route 14S 2 lanes	150	1	1
S-9	C Sea Level Route 14S, 1 lane	250	16,000	19,500
S-10	C Sea Level Route 14S, 2 lanes	250	[1]	[1]
S-11	C Sea Level Route 14S, 1 lane	300	15,500	19,000
S-12	C Sea Level Route 14S, 2 lanes	300	[1]	[1]
S-16	C Sea Level Route 14S, 40 Km, 1 lane	150	18,400	18,900
S-17	C Sea Level Route 14S, 40 Km, 1 lane	250	18,200	18,600
S-18	C Sea Level Route 14S, 40 Km, 1 lane	300	18,00	18,500

Notes: The capacities shown were estimated from similar cases in Table XI-1 and are approximate.
Study Cases L-2 through L-8 cover Route 15 + Third Lock.
Study Cases L-10 through L-18 cover Route 15 + Gatun + Third Lock.
[1] The capacity is judged to be well in excess of the forecasted number of transits in Year 2060
2 From List-Item 1, Appendix III, OCCE Agreement.

With the elimination of the constraint currently imposed by the Culebra Cut, it appears, in the case of the High-Rise and Low-Rise Lock alternatives, that delays encountered at the locks are the most critical factor influencing capacity. Consequently, plans that involve a reduction in locking time by means of a reduction of lift height (Low-Rise Locks) or in number of lifts (Single Lift Lock) achieve the highest capacities.

- In a Sea Level Canal, for any plan involving tide gates, the north gate should be placed not further than about 46 km from the Pacific in order to limit tidal currents to 1.0 knots.

With a 40 km spacing between gates, ships entering and exiting the canal from the Pacific, traveling at a speed of 13 km/hour, could be scheduled such that they would always confront a head current, not a following current. An additional benefit is that the canal will always be shielded from low tide; which would allow the Pacific approach channel to be dredged to a depth based on mean sea level, rather than mean low water.

- For safe navigation, 150,000 dwt ships and larger should be assisted throughout their transit with a 6,000 hp tug at the stern. Other tugs should be placed strategically along the canal to assist in the event the need develops to stop a convoy.

- If a two-lane Sea Level Canal is contemplated, it would be preferable to separate the lanes to improve navigation safety.

- The discharges of streams entering the canal along its length are relatively small and should not impede navigation.

5.4 Engineering Study and Cost Estimates, Phase I

Two of the important criteria for prescreening of alternatives are engineering soundness and capital cost. Engineering Soundness is expressed in terms of each alternative's, practicality and degree of risk involved in its engineering. A preliminary estimate of the capital cost of development of each alternative is an important parameter in the decision resulting from the prescreening of alternatives. The Phase I Study involved developing the conceptual design of each alternative to the point where major items was quantified, costed and impacts on present canal generally defined and identified. An order of magnitude of construction cost estimates was developed based on the overall schedule and construction plans prepared for each alternative. It was imperative to make reasonable assumptions to continue with the engineering and design studies for the following reasons:

(1) To provide assurance that consistency was established between all of the alternatives and there was no bias introduced in favor of any one alternative.

(2) Some of the historical alternatives were not developed beyond an idea by their authors and therefore required that assumptions be made to conceptualize these ideas.

(3) Some of the alternatives were studied extensively and developed by their authors, thus a reasonable design and documentation existed in reports; i.e., IOCS Study, therefore allowing this Phase I study to borrow from these to develop others.

(4) Phase I important cost data was defined and fixed in the early stages of this study again to assure consistency.

The Phase I Studies considered all four conceptual alternatives (substantial concepts) briefly described in Section 5.1. of this report. This Phase I Study also included the complementary components of the partial concepts. Results of the Phase I Engineering and Cost Estimates Component Study were extensively used in the prescreening and selection of alternatives.

5.4.1 Approach

Since all conceptual alternatives considered in Phase I Study were not developed to the same level of engineering knowledge and understanding, an important part of the approach for this phase was consistent and unbiased. A general framework of the technical scope of work was provided in the Terms of Reference (TOR) and included as part of the DPS (SINBOL, 1990). In addition, SINBOL gathered, developed, and assembled an extensive data and information base, as well as preliminary design criteria concerning all of the conceptual alternatives. Additional information important for this study were given to several component contractors specially to the contractors conducting this Phase I Study.

Included were lists of study cases for prescreening, generalized plans and profiles, description and traces of conceptual route alignments on topographic quadrangle maps, dimensions of design ships and lock chambers, typical canal cross-sections, generalized geologic information, slope stability considerations, suggested excavation slopes for different geologic formations, a conceptual plan for the sea level canal, a list of major feasibility check items, a cost estimate and schedule format, required capacity guidelines for complementary systems, the centerport executive summary, and suggested design standards. Several other items were identified and developed during contract negotiation and Inception Report stage which were given to the Component Contractor.

The principal items of engineering work identified in this component study included:

- Technology review
- Development of engineering criteria and standards

- Basic plans and preliminary conceptual design of each alternative
- Water balance study assuming no spilling and no hydroelectric generation
- Preliminary construction planning and scheduling

The cost estimate approach was to be prepared as an "order-of-magnitude" estimate with sufficient detail and consistency adequate for prescreening of alternatives. The following assumptions and guidelines were established as a basis for this component study:

- The cost to remedy or minimize the environmental and social impacts were not part of this study.
- The estimated cost will be quoted in constant 1990 dollars and no escalation for future inflation require consideration.
- The escalation rates for the past few decades were provided by SINBOL to this Component Contractor.
- Taxes and duties on equipment, material, and machinery would be waived by the Government of Panama.
- Panamanian Labor Laws, method of payment, and market rate were to be adopted and used in the cost estimates.

5.4.2 Engineering and Design Considerations - Basic Assumptions and Criteria

Major engineering and cost items studied are excavation, water resources, hydraulic structures, and items related to navigation and operation.

Engineering soundness of each of the alternatives studied was determined during Phase I and it was conducted independent of the cost estimates. Other attributes such as each alternatives' capacity to meet the forecasted demand, impacts on existing canal navigation and the environment, and each alternatives' cost competitiveness based on capital costs were also considered in the prescreening of alternatives. Determination as to adaptability of each alternative for potential future expansion was also attempted.

A summary of engineering attributes included in Phase I evaluation are provided below. (Refer to "The Study of Alternatives to the Panama Canal: Phase I Engineering and Cost Estimate, Yachiyo Engineering Company, February 1992", this report is herein called YEC - Phase I.)

Excavation

Excavation is an important engineering and construction attribute since it contributes more than 50 percent of the total cost of each alternative. Several items used to optimize excavation were given to this component contractors by CAS. Such items included: canal alternative routes (I through IV), geology and seismology of the study area including generalized geologic profiles based on IOCS and PCC studies, earthquake epicenter and tectonic map, stability of excavated slopes (classified into zones with recommended stable slopes for each zone), and the locations of spoil disposal areas (assumed for purpose of consistency in Phase I, to be at a specified distant from excavation of the canal).

Canal excavation, both wet and dry, would use present state-of-the-art excavation equipment, especially in marine excavation. About the only challenge that may exist is to optimize excavators with hauling equipment to eliminate bottlenecks during construction.

Water Resources

Discussions on rainfall, drainage area, watershed yield, storage capacity, current water use, and canal and management that are related to water restrictions are included in YEC-Phase I. Gatun Lake (approximately 430 square kilometers), formed by Gatun Dam built in 1912 on the lower Changes River, serves as a 53 kilometer long Canal waterway, in addition to being the source for canal lockage water. Additional water storage and flood control is provided by Madden Dam, that was built on the upper Chagres River in 1935 with an approximate area of 52 km^2.

This system provides an annual yield of about 6.6 billion cubic meters (average) of water. Currently 45% is used for lockage, 4 % for municipal water supply, 41% for power generation and spillage, and 10% for losses due to evaporation. Presently, there are no artificial water restrictions and the first priority is given to the navigational needs of the existing canal traffic. Water balance analysis using average discharges derived from 51 years of record, was conducted in order to determine if the present storage capacity is sufficient.

Where deficiencies were identified, priority was first given to developing storage that would be available by building new dams and then the balance would be obtained by pumping. No additional water savings such as tandem follow-up lockages and alternate direction lockages were considered in Phase I.

In the case of the low rise canal and sea level canals, a potential for flooding exists, and concepts for mitigation measures were included in the design (barrier dams, spillways, diversion channels, and water intake facilities). In cases where water shortages were identified, a new source was to be investigated and the potentials for development were identified.

Hydraulic Structures

In order to facilitate navigation across the Isthmus, hydraulic structures other than open channels are required. Such structures consist of dams, reservoirs, hydroelectric power, spillways, water conveying structures, etc. In the case of a sea level canal, the basic concept is to provide a waterway in the form of a man-made canal with navigation controls at the ocean entrances and exits, consisting of breakwaters, jetties or basins, anchorage and moorings, and means to regulate the effects of tides. In the case of a lock canal, almost all of the above basic requirements apply. Navigation is facilitated by lock gates which provide the means to lift the ships from sea level to the Gatun Lake level and to lower it back to sea level.

All of the historical lock canal alternatives incorporated a larger lock system and channel improvements (widening and deepening). For the sea level canal, tidal gates or other means to control tidal current were incorporated in the historical alternatives.

Gate and/or lock design parameters and specifications concerning water level requirements, freeboard, structural material, allowable stresses and failure mode, corrosion protection, transportation, fabrication and installation, and foundation preparation required analysis and recommendations. All gates and/or locks require optimization studies with special emphasize upon operating experience records.

A water conveying system for lockage is required for lock canal alternatives and hydraulic structures to control flooding are required for all sea level canal alternatives as well as for lock canal alternatives with Gatun Lake level at el 55 ft. (10.8 m) or lower.

Other hydraulic structures required are: anchorage at either end of the canal, and moorings/tieing stations in the canal.

Lock and Gate Structures

The design ships and lock chamber dimensions were given to the engineering component contractor and are provided in Table 5.4.2-1 and typical channel cross-sections for single and double lane are provided in Figure 5.4.2-1.

It was assumed that; (1) the filling and emptying system for the locks is to be a bottom longitudinal tunnel with a time cycle not to exceed 10 minutes per filling or emptying, (2) All approach walls including middle structural wall should be of the gravity type with adequate dimensions dictated by structural stability and enclosure of the tunneling system, and (3) all lock sill elevations are to accommodate high and low water elevations on the Pacific Ocean side and the high and low water lake elevations.

Table 5.4.2-1

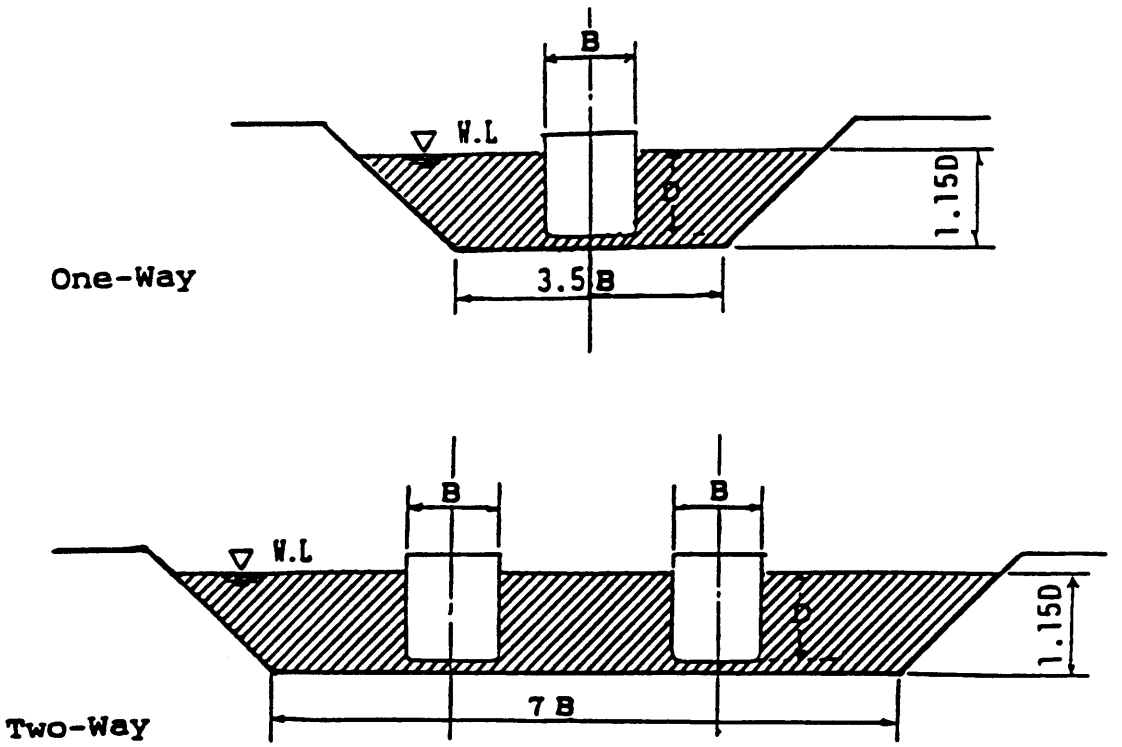
Design Ships and Lock Chamber Dimensions (Units: meters)

Ship Size	Design	Ship	Dimension	Dimensions	of Lock	Chamber
(dwt)	Length (L)	Beam (B)	Draft (D)	Length	Width	Depth
65,000	295 (1)	32 (1)	12 (1)	304.8 (2)	33.5 (2)	12.8 (2)
100,000	277	43	17	319	47	19
150,000	316	49	19	363	54	21
250,000	372	57	22	428	63	24
300,000	394	61	23	*	*	*

(1) Maximum passable size in the existing Panama Canal
(2) Existing Panama Canal lock dimensions
* Lock canal type is not considered for ships larger than 250,000 dwt

Figure 5.4.2-1

Typical Channel Cross Section



Other design parameters and criteria for locks considered in the Phase I study are:

- Emergency gate design for HWL plus 1.5 meter.
- Free board of 0.6 meter for both lock and maintenance gates and no free board for emergency gate.
- The gate material will be of low alloy carbon steel with high resistance to brittle fracture and fracture strength of up to 100 Kg/mm^2.
- The gates will have a corrosion protection system consisting of paint coatings and electric protection systems.
- Material failure modes, allowable stresses, corrosion protection system, unit weight, fabrication, transportation, and installation will be studied in detail during Phase II.

For the sea level canal, tidal gates will be provided at either end of a single or two-lane canals to be used at times when currents exceed acceptable limits. Tidal gates will be operated at either 6 or 12 hours cycle to coincide with the tides and when water level in the canal is almost equal.

Complimentary Systems

Complementary systems to be studied and developed in Phase I consisted of: (1) oil pipeline and port facilities at either coast with specified capacity ranging between 1.0 and 2.0 million barrels per day, and (2) landbridge consisting of either railway or highways, and associated ports and terminal facilities using the centerport concept with specified capacity ranging between 10 and 40 million tons per year.

5.4.3 Conceptual Designs for Lock Canal Alternatives

Canal Alignment/Route

There were four lock canal routes considered, these are summarized as follows:

- Route I makes maximum use of the existing canal and the abandoned 1942 third locks excavation, with the addition of a third set of locks, one new lock located west of the existing Miraflores Locks and the other east of the existing Gatun Locks.

  All existing locks at Gatun, Pedro Miguel and Miraflores will remain operational during and after construction. Gatun lake level will be at El. 26.0 m (85 ft) or 27.5 m (90 ft).

- Route II is basically the same as Route I with the exception of the Gatun lake channel, which is straighter than Route I, resulting in a Gatun Lake length shorter by about 6 kilometers. Gatun Lake level is at elevation (El.) 26.0 m (85 ft) or 27.5 m (90 ft).

- Route III is basically the same as Route I, with the exception of a new single lift lock at El. 16.8 m (55 ft) (the present level of Miraflores Lake).

  Several barrier dams will be required to hold the remaining section of Gatun Lake at the present elevation of 26.0 m (85 ft).

- Route IV is basically the same as Route II but at El. 9.2 m (30 ft) and a single lift locks

  Several barrier dams will be required to hold the remaining part of Gatun Lake at present El. 26.0 m (85 ft).

Geology and Seismology

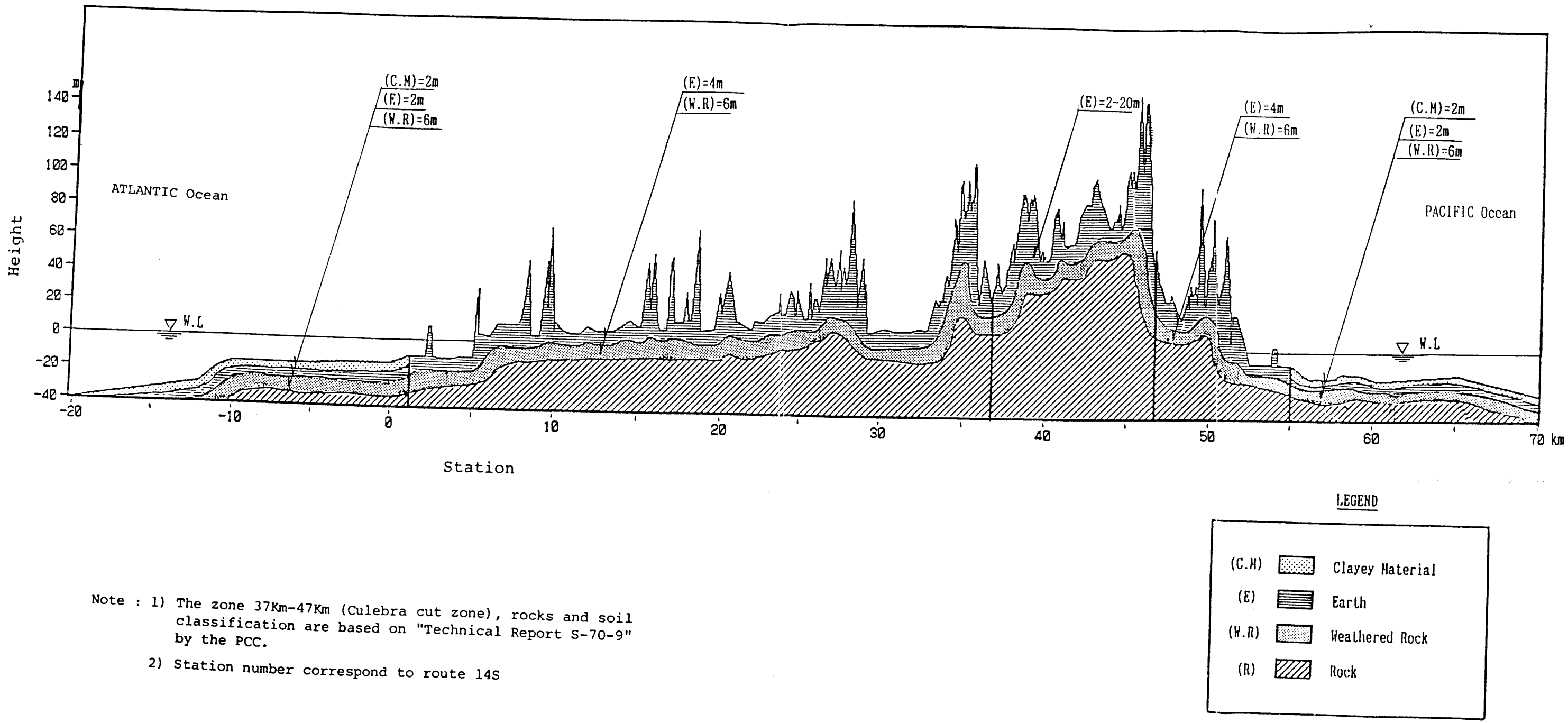
The geology of the area as detailed in the IOCS Report is complex and characterized by abrupt transitions from competent rock formation to materials of very low strength. The terrain on the Pacific side, including the continental divide, is dominated by conical hills, capped by basalt or agglomerate and surrounded and underlain by weak sedimentary and pyroclastic rocks. Materials in the central section of this area vary from weak clay shales to soft altered volcanics to relatively stronger sandstones and basalts. The ridges along the Atlantic Coast consist of medium hard limestones.

A typical geologic cross section along the existing canal, Routes I, II, III, IV, is presented in Figure 5.4.3-1 and Figure 5.4.3-2 is for Route 10 .

Seismically the area is not considered active although both historical and instrumental records show that between early 1900 and 1992, about eight strong motion earthquakes were felt in Panama with earthquake magnitude ranging between 6.3 to 7.7 on the Richter Scale.

It should be noted that the last damaging earthquake occurred on April 22, 1991 registering a magnitude of 7.4, with its epicenter about 126 kilometers southeast of San Jose, Costa Rica and near the Costa Rica and Panama border, where nearly 30 people lost their lives. This earthquake caused severe damage to villages on both sides of the border and it was also felt in Panama City, where fortunately no loss of life or property damage was experienced.

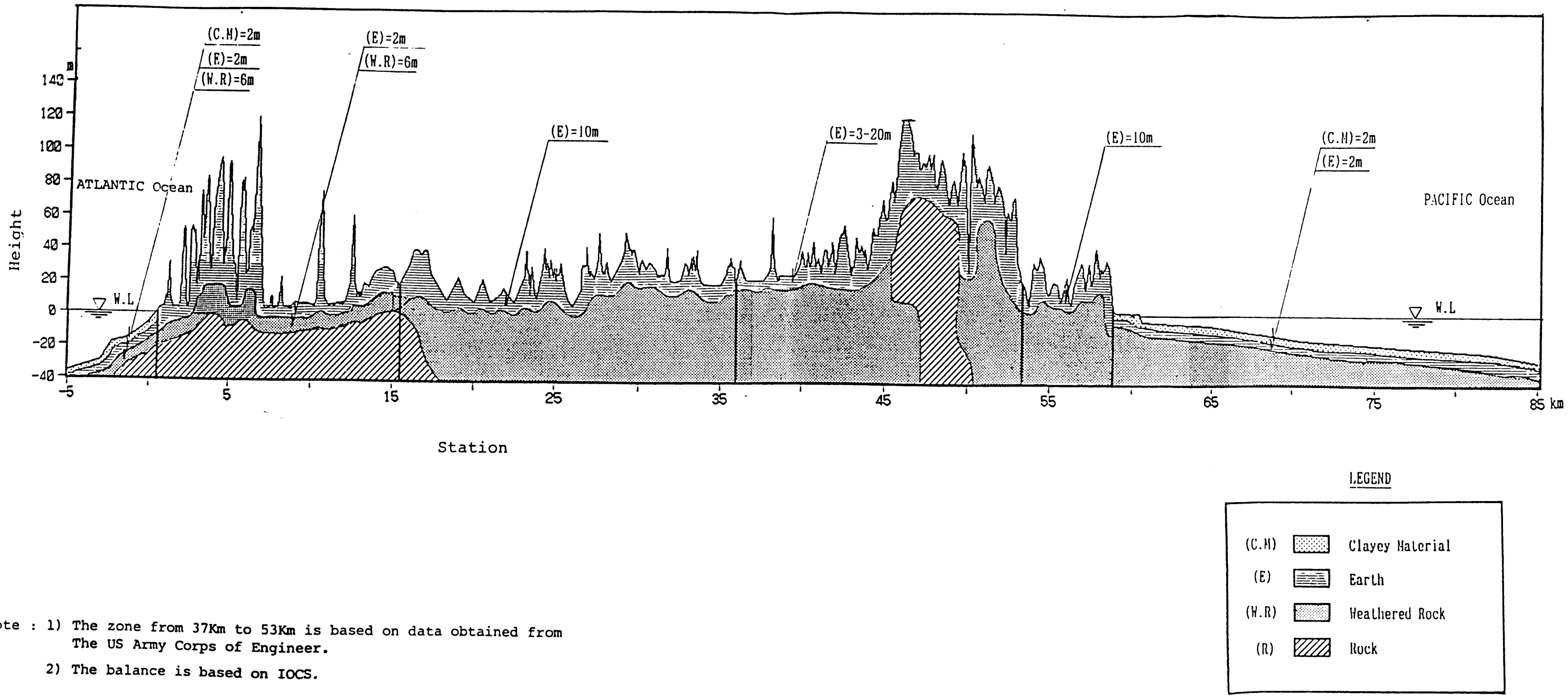
Figure 5.4.3-1
Geological Profile (Routes I, II, III, IV & 14S)



Note : 1) The zone 37Km-47Km (Culebra cut zone), rocks and soil classification are based on "Technical Report S-70-9" by the PCC.

2) Station number correspond to route 14S

Figure 5.4.3-2
Geological Profile (Routes 10)



Note : 1) The zone from 37Km to 53Km is based on data obtained from The US Army Corps of Engineer.

2) The balance is based on IOCS.

Excavation and Slope Stability

Basically geologic formations along the canal route were classified into zones for the purpose of excavation and slope stability. These zones are: Atlantic approach, Gatun lake, Culebra, Miraflores, and Pacific approach. Similarly, recommended criteria for excavated slopes were formulated for the five geologic zones identified above. The slope criteria were classified as Types 1 through 5 and geologically varying from hard rock to unconsolidated deposit. For more details on typical geologic profiles and slopes, see SINBOL letters SC-078/91 and SC-080/91 dated July 18, 1991 and July 22, 1991, respectively. In addition, YEC-Phase I provided a discussion of excavation and slope stability.

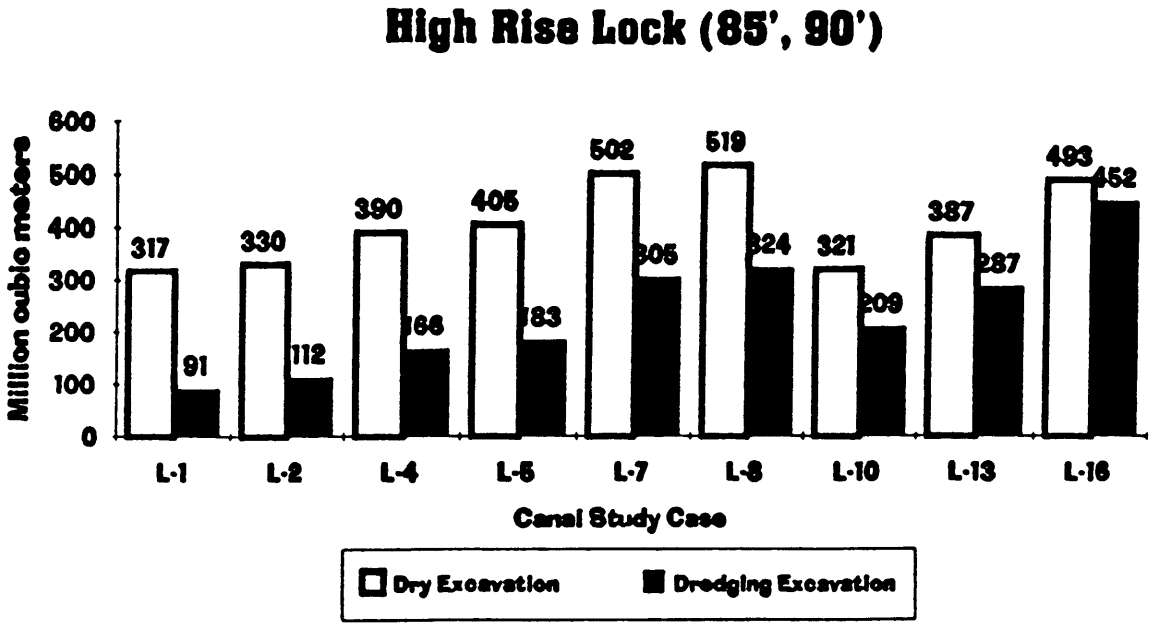
Based on data presented in YEC's Phase I Report, the total excavation (dry and wet) costs is a substantial portion of the total construction cost (between 45 and 59 percent for the high rise alternatives, and between 57 and 70 percent for the low rise canal alternatives). The wet excavation portion of the total excavation, is high and is reflected in the total excavation cost; therefore, optimizations of the route alignment and excavation equipment, especially hauling equipment, is recommended for careful review in Phase II. No optimization of either excavation equipment or hauling methods was made in this phase. YEC assumed that existing conventional excavation equipment was adequate for Phase I Study. Figure 5.4.3.3 represents a summary of excavation volumes for all study cases of the high and low rise lock canal alternatives and Figure 5.4.3.4 is for all sea level cases.

Hauling and disposal of excavation spoil can be very costly. Both hauling equipment and distances hauled will have a substantial effect on the total construction cost. A considerable portion of the excavated material will be used for construction of embankments, dikes, dams, flood control structures, and production of concrete aggregates. Select material consisting of gravel and rock fragments may be used for railroad ballasts, road bases, slope and embankment erosion protection, and breakwaters. The majority of the excavation spoil will require disposal in valleys along the canal alignment, in Gatun Lake, and in ocean areas. For consistency, YEC assumed that these disposal sites will be located no more than 3.5 kilometers away from the excavation areas. (The feasibility of excavation and construction is discussed in Section 8 of this report).

Water Resource Management

The main rivers contributing to Gatun and Madden Lakes are: Chagres, Pequeni, Boqueron and Gatun from the east side of the canal; and Ciri, and Trinidad, from the west side of the canal. Gauging stations and years of discharge records exist for all of these rivers. Rain gauges also exist to supplement discharge records, constituting good hydrologic records to estimate water yield from the contributing drainage area. Canal water requirements are drawn from these two lakes, and unstorable water, subject to flood control, is released over spillways. All water released from Madden Dam flows to Gatun Lake and is therefore available for use.

Figure 5.4.3-3
Excavation Volumes for Lock Canal Routes



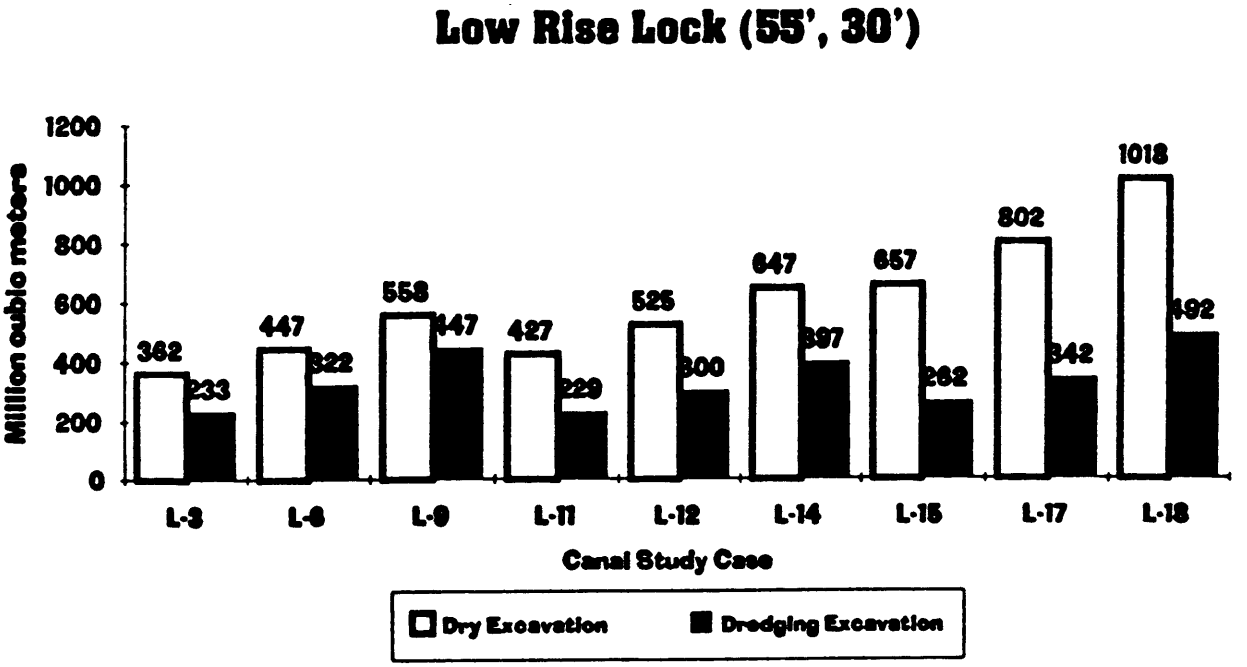
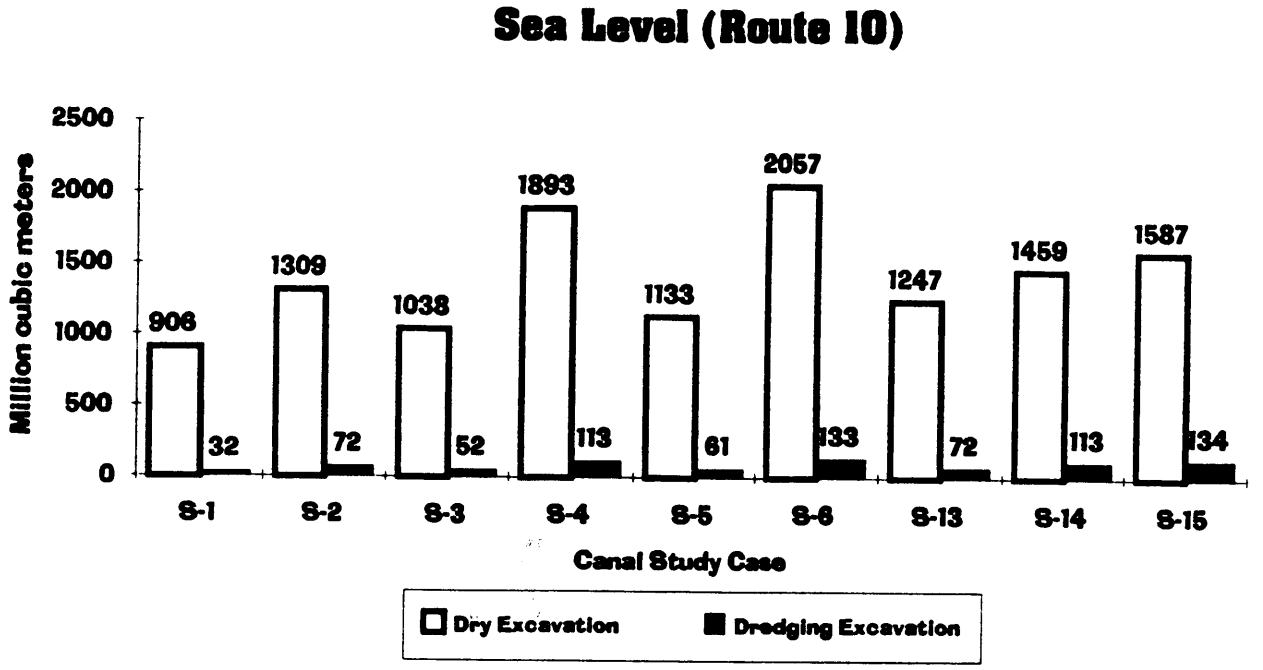
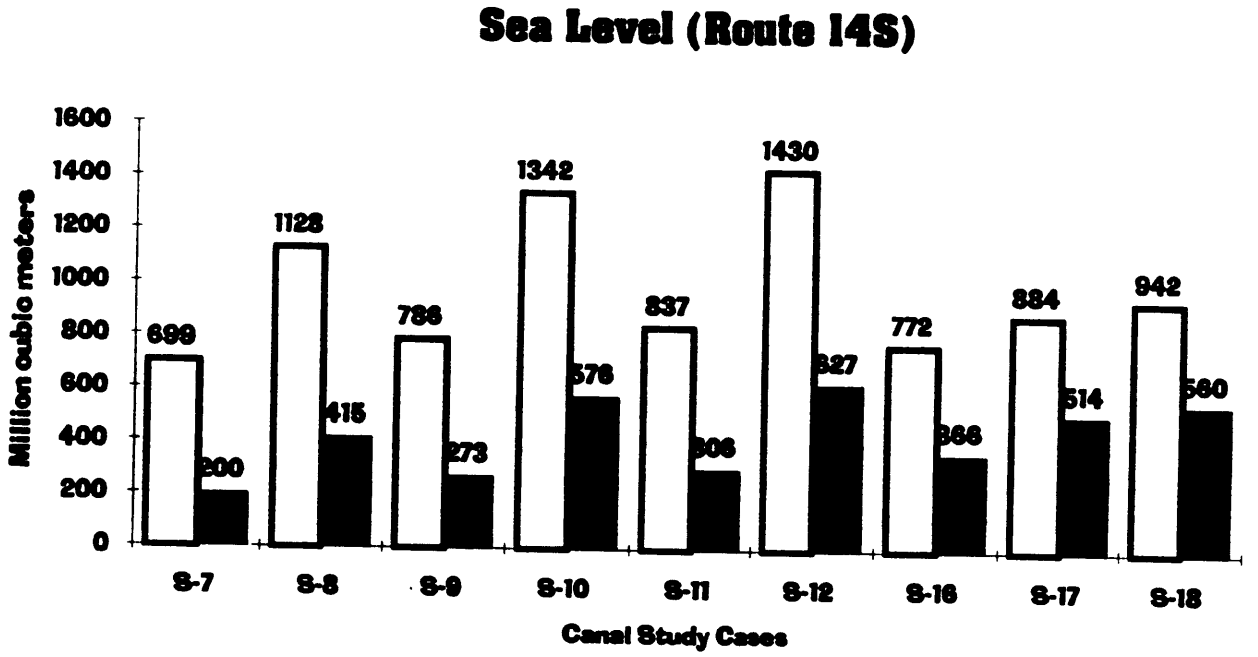


Figure 5.4.3-4
Excavation Volumes for Sea Level Routes





Available active storage at Madden Lake is between El. 76.81 m. and 60.96 m. Below El. 60.96 m. is normally dead storage and reserved for future municipal use in Panama. The usable capacity at Gatun Lake is between El. 26.53 m. and El. 24.99 m., and draft restrictions vary from 12.19 m. to 10.67 m. Available storage in Miraflores Lake is between the operating levels of elevations 16.76 m. and 16.15 m.

The annual yield recorded for over fifty years is about 6.6 billion m^3 (average) and the maximum and minimum yields are 10.7 billion m^3 and 3.6 billion m^3, respectively. The net average yield excluding evaporation losses is 5.9 billion m^3. The total combined available storage for Gatun (0.66 billion m^3) and Madden (0.54 billion m^3) is 1.2 billion m^3.

- Water Restriction and Competition

At the present time, there are no artificial water restrictions and the first priority in the use of water goes to the navigational needs of Canal traffic. Miscellaneous losses consist mostly of leakage from Gatun and Pedro Miguel locks; occasionally additional lockage is drawn at Pedro Miguel to raise Miraflores lake level to accommodate deeper draft vessels. Other losses are natural, such as evaporation and seepage, and are accounted for in the available lockage water capacity.

- Water Saving Alternatives

Since water management is the most important component of Canal operation, existing water sources, sources for increased capacity, and water saving measures were extensively studied.

The source of present water supply was summarized above and the source for increased capacity is summarized below.

- Water Saving Schemes include:

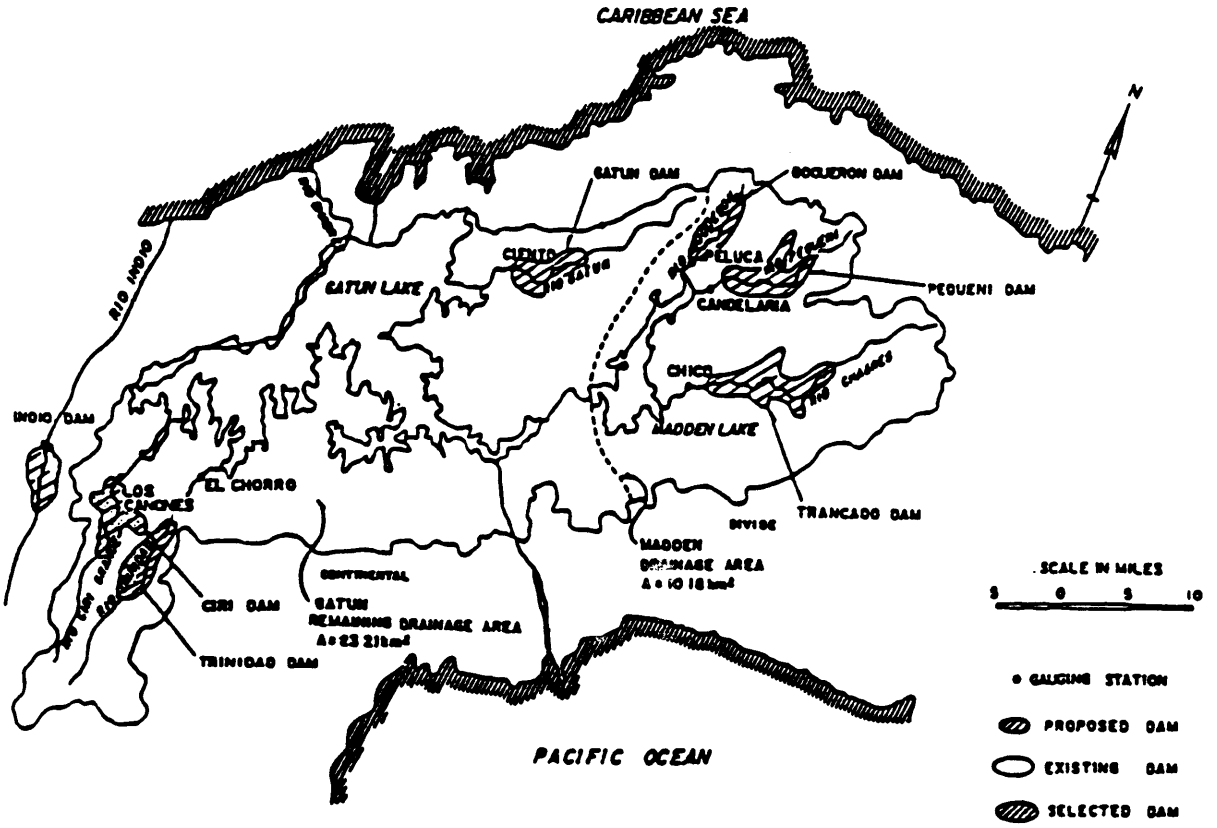
(1) Tandem follow-up lockages, are where two or more ships simultaneously occupy a lock chamber; and,

(2) Alternate direction lockages, made in the up direction at Gatun require three lock chambers of water and no additional water for reversal in the down direction because of its availability from the up direction. Alternate direction lockage at Miraflores Locks require two chambers in the up direction and none in down direction. This saving is true only for a certain vessel size.

None of the water saving schemes were used in the water balance simulation model in YEC-Phase I.

Figure 5.4.3-5

Proposed Dam Sites and Storage Capacity



Maximum Storage Capacities at Proposed Dam Sites

Dam Name	Tributary Name	Drainage Area(Km^2)	Capacity (mill.m^3)	Dam Height(m)	Note
Trancado	Chagres	425	---	---	
Pequeni	Pequeni	135	700	130	
Boqueron	Boqueron	95	800	110	
Gatun	Gatun	125	300	100	
Trinidad	Trinidad	185	700	90	Selected
Ciri	Ciri Grande	190	250	80	ditto
Indio	Indio	380	700	90	

Note : 1)Storage capacities (maximum) were estimated considering topographical condition only.
2)Storage capacity of Trancado dam was not estimated due to a lack of topographical maps.

BASED ON YEC FINAL REPORT

(PHASE I)

- Water Management Simulation Model

Considering additional water may be required to operate any of the lock canal alternatives, a mathematical simulation model was employed for all eighteen cases of the high and low rise lock canal alternatives. Figure 6.3.4-2 in Section 6.3, is a graphical depiction of the input and output of the mathematical model where required lockages control the simulation. Results of this simulation provide water deficiency which will require make-up from sources not presently available. This figure also shows input and output for a Gatun Lake level of El. 25.91 m., design vessel of 100,000 dwt and 20,000 transits in addition to the present transit capacity of 15,000 annually. For this particular case, a new source of water is to be provided by Trinidad and Ciri Dams, and a conservation measure provided by recycling ponds and pumping stations with a capacity of 150 cubic meters per second. Again, this model assumed no spilling and no hydroelectric generation. For details as to the assumptions, variables, logic, and results, see the YEC-Phase I Report.

Annual lockage water required for the status quo and all other conceptual alternatives is estimated and indicated in Table 5.4.3-1. As can be seen from this table, existing useable capacity is far less than that required for the added capacity by any of the lock canal alternatives studied. Therefore, investigations to locate a new source of lockage water were conducted. Figure 5.4.3-5 indicates all of the potential sources located east and west of the existing Canal. Adding dams in the Gatun watershed will increase storage capacity but will not be sufficient to meet the demands generated by some of the proposed canal alternatives. Spent lockage water will be stored in recycling ponds. One is proposed near Gatun Locks to the east of the Atlantic Approach Channel, and the other recycling pond is proposed at Miraflores Locks to the west of the Pacific Approach Channel. Both recycling ponds will require a pumping station to return the spent lockage water to the lakes. A surge basin near the new third Pacific Locks will be required to reduce the hydrodynamic impact causing pitching and rolling in ships as lockage water is discharge to the Canal. No such basin is required at the Atlantic Locks because lockage water is discharged to large bodies of water (lake or ocean) thereby acting as a surge basin.

- Potential for Flooding and Use of Excess Run off

Flood Control measures need to be taken into consideration for the Low Rise Lock at Summit Lake elevations of both 16.76 m (55 ft) and 9.14 m (30 ft.) Construction of barrier dams will be required to keep the unaffected Gatun Lake at its present elevation 25.91 m (85 ft.). These barrier dams will divide Gatun Lake into five separate reservoirs, will require modification of both Gatun and Pedro Miguel spillways, and flood control measures will require spillway capacity at four barrier dams in addition to a diversion culvert.

For location of barrier dams and spillways, see YEC-Phase I.

Table 5.4.3-1

Annual Lockage Water and Water Balance Table

(Based on YEC Final Report - Phase I)

Case N°.		L-12	L-15	L-18	L-3, 11	L-6, 14	L-9, 17	L-2, 10	L-2'	L-5, 13	L-8, 16	L-1	L-4	L-7
Design Water Level (Ft)		30	30	30	55	55	55	85	85	85	85	90	90	90
		100	150	250	100	150	250	100	100	150	250	100	150	250
		5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500
+ 10,000	Transin lockage water (MCM)	5.655	6.485	7.805	7.965	9.505	11.965	6.825	10.695	8.015	9.915	7.045	8.305	10.315
	Water shortage (MCM)	155	985	2,305	2,465	4,005	6,465	1,325	5,195	2,515	4,415	1,545	2,805	4,815
	Water release from new dam (MCM)	0	0	0	0	0	0	273	297	229	376	245	235	279
	Water pumping (MCM)	155	985	2,305	2,465	4,005	6,465	1,052	4,898	2,286	4,039	1,300	2,570	4,536
	Pump capacity (CU.M/SEC) without new dam	10	30	70	70	120	200	30	150	70	120	40	80	140
	Sets of pump stations	1	1	2	2	2	4	1	3	2	2	1	2	3
	Pump capacity (CU.M/SEC) without new dam	10	30	70	70	120	200	60	180	90	150	60	100	170
	Sets of pump stations	1	1	2	2	2	4	1	3	2	3	1	2	3
+ 20,000	Transin lockage water (MCM)	11,055	13,545	17,505	17,985	22,605	29,985	14,565	26,175	18,135	23,835	15,225	19,005	25,035
	Water shortage (MCM)	5,555	8,045	8,045	12,485	17,105	24,485	9,065	20,675	12,635	18,335	9,725	13,505	19,535
	Water release from new dam (MCM)	0	0	0	0	0	0	373	339	262	268	251	247	256
	Water pumping (MCM)	5,555	8,045	8,045	14,485	17,105	24,485	8,692	20,336	12,373	18,067	9,474	13,258	19,276
	Pump capacity (CU.M/SEC) without new dam	180	250	380	390	540	770	270	640	390	570	300	420	610
	Sets of pump stations	3	3	7	7	9	13	5	11	7	10	5	7	11
	Pump capacity (CU.M/SEC) without new dam	180	250	380	390	540	770	300	670	410	600	320	440	630
	Sets of pump stations	3	3	7	7	9	13	6	7	7	10	6	8	11
Actual pump head (meters)		(9.0)			(16.7)			(25.8)				(27.3)		

Note:
1) Lockage water includes the water for existing 15,000 transits.
2) Design water level 30' - 50' cases have barrier dams.
3) New dam capacity is shown in AP1-9 (Water balance simulation).
4) Pump capacity (1 set) = 60 cu.m/sec

Hydraulic Structures

- Third Lock Concept

Fundamentally, all lock canal alternatives, whether high rise or low rise, incorporate larger locks to accommodate ship sizes between 100,000 and 250,000 dwt. The site on the Atlantic side will be located approximately one kilometer east of the existing locks, at the third excavation executed in 1940. The area is low in elevation and irregular, and is underlain by sandstone and tuff of the Gatun formation which is approximately 400 m. thick. Gatun sandstone will provide a good foundation for the structures at this location. The lock site on the Pacific side will be located approximately one-half kilometer to the west of the existing locks, taking full advantage of the excavation executed in 1940. The topography consists of steep hills and narrow valleys ranging in elevation between 50 m. to 150 m. The foundation of the lock structures will be supported on basalt rock.

- Lock/Chamber Structure Conceptual Design

Lock chamber size was determined based on the design ship option considered. The Phase I study for lock canal alternatives included design ship sizes of 100,000 150,000 and 250,000 dwt. Lock chamber dimensions as well as the dimension of the design ships considered are shown Table 5.4.2-1. It was assumed for this study that the filling and emptying time for the lock chamber is nine minutes and that a bottom longitudinal square tunnel system 10 m x 10 m is conceptually adopted for this purpose. The lock structure, including approach walls, is assumed to be of the gravity type articulated to house the hydraulic tunnels. For additional conceptual design data including design elevations for chamber walls and lake levels for all of the study cases see YEC-Phase I. Because gates will be dewatered during scheduled maintenance, they will be designed and constructed as monolith structures.

- Gate Leaf

Existing gate structures from the U.S.A., Europe, India, Argentina, and Panama were surveyed in Phase I. Lock Gates provide control and means for ship lockage and transit, culvert gates provide the control mechanism for lockage water, emergency gates provide safe closure of the reservoir/lake water body and maintenance gates are used during planned outages of the operating gates for maintenance purposes. Navigational locks are the type of gates which will be required for any lock canal alternatives studied. There are other types such as entrance locks used for docks and tidal gates used in sea level canals. Different types of lock gates were considered during the Phase I study. It was found that the existing locks in the Saint Lawrence seaway in Canada, and those in the Panama Canal are rated high due to their capability to accommodate bigger ships with deep draft and the fact that they have very wide locks. Comparison of the existing navigational locks considered in this study indicated that more than 50% are miter type for both the upper and lower lock gates.

A conceptual study of available lock gates was conducted. Table 5.4.3-2 shows a summary of the locks surveyed. Technical and economical attributes were the primary basis of this study. It was decided that a miter type gate will be recommended, even though the torsional type rolling gate received favorable performance records. The performance of miter type gates has been established not only at the Panama Canal but at other locations in canal or river waterways maintained by the U.S. Corps of Engineers.

The selection of the miter gate type over the rolling gate was favored because of the lack of installation and maintenance records for the torsional rolling gate. The existing miter gates in the Panama Canal are in a very good condition and have an excellent record of performance since their installation.

Similar studies were performed for emergency, maintenance, and culvert gates. A drop type roller gate was selected for the emergency gate, a type that is not similar to the existing emergency gate. The selected emergency gate has at least two advantages over the existing gate: it is simple and has a shorter operating time. Caisson type gates are proposed for maintenance gates. A reversed radial gate is proposed for a culvert gate, which is different from the existing stoney sluice gate. The proposed reversed radial gates are technically superior to other fixed wheel gates because they provide reduced friction force during leaf operations.

- Requirements for New Dams

All lock canal alternatives will require additional lockage water capacity beyond present available storage capacity. Gatun and Madden Lakes provide the necessary lockage water to permit transit through the Status Quo Canal.

An investigation to identify new water storage capacity was conducted. Seven potential dam sites were investigated adjacent to the existing Canal and near Gatun Lake, as depicted in Figure 5.4.3-6. Topographic, geologic, and hydrologic factors determine the feasibility of dam construction. Availability of construction material from canal excavation provides favorable evaluation after the technical feasibility is confirmed.

Hydrological analysis was conducted to determine reservoir water surface levels, spillway, and dam crest elevations allowing for sedimentation and free board requirements. The results show that dams on the Trinidad and Ciri Rivers will provide the largest reservoir storage capacity.

A water balance simulation model conducted on all lock canal alternatives indicated that the present available water capacity for lockage is deficient by a range of 280 to 380 million cubic meters. Analysis of the proposed Trinidad and Ciri reservoirs indicates a combined storage capacity ranging between 280 to 380 million cubic meters.

Table 5.4.3-2

Comparison of Gate Types for Lock Gates

(Based on YEC Final Report - Phase I)

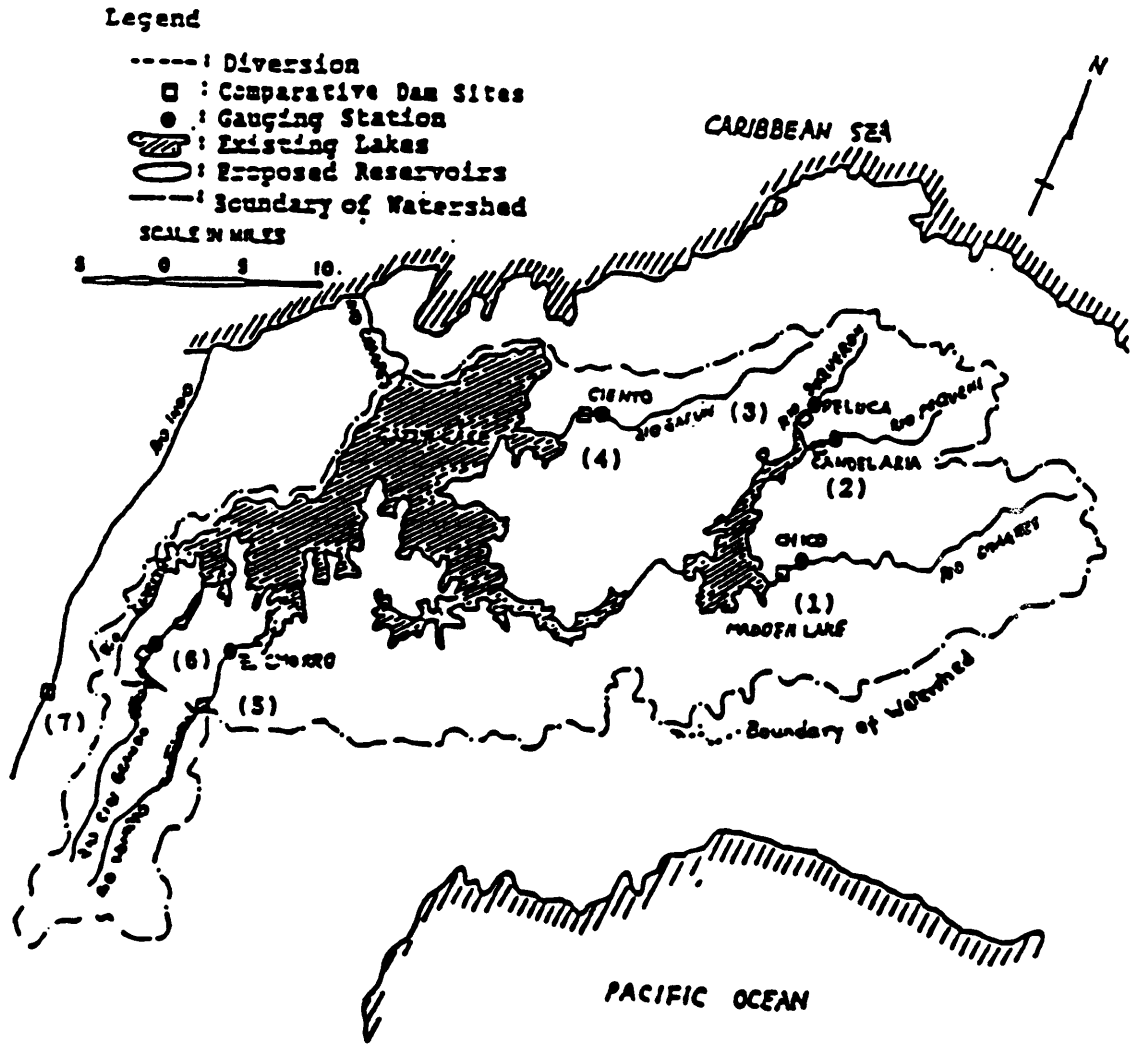
Movement	Direction of Movement	N°.	Structural Type	Function		Initial Cost	Maintenance Cost			Hoist Load		
				Chamber L^2 Efficiency	Stab. Against Propulsion		Sand & Silt	Removal & Reset	Mecha-nical Part	Friction	Grav. El. Change[4]	Hydr. Inert.[5]
Rotation	Vertical	2	Radial	O	O	●	O	X	▲	O	O	O
		3	Miter	O	▲	O	▲	O	O	O	O	▲
	Horizontal	4	Torsional	X								
		5	Bending	X								
		6	Radial	X								
Linear	Vertical	9+	Slide	O	O	●	▲	O	O	▲	X	O
		11	Torsional									
	Horizontal	10	Triangle	X								
		11	Torsional	O	O	●	●	O	O	▲	O	O

Note:
1. N°. corresponds to N°. of sketches on Fig 4.6.3 YEC Report
2. Chamber L Efficiency = Effective chamber length for lockage over actual chamber lengths. The effective chamber length = actual chamber length - the chamber length which cannot be used for lockage because of existence of a lock gate.
3. Stab. against propulsion = Stability of gate leaf supports against ship propulsion brows.
4. Grav. El. Change = Gravity center elevation change of a gate leaf. X means that there is the change during leaf operations.
5. Hydro. Inert. = Hydraulic inertia force. ▲ means that hydraulic inertia force will act on leaf skins during leaf operations.
6. Slide (drop) is a gate type corresponding to N°. 9 in YEC Report (Fig. 4.6.2), except that slide shoes replace rollers and the gate leaf is a torsional type instead of bending.
7. Elevation Marks: X = Not acceptable ▲ = Just acceptable level O = Acceptable without conditions ● = Strongly recommendable

Shows results of quantitative studies

Figure 5.4.3-6

Location of Rivers and Proposed New Dams



BASED ON YEC FINAL REPORT

(PHASE I)

- Barrier Dams

The high rise conceptual alternative would not require barrier dams or flood control structures. However, for the proposed lake elevations of 9.2 m (30 ft) and 26.0 m (55 ft), the so-called low-rise conceptual alternatives, barrier dams would be required to provide adequate storage and lockage capacity for all low-rise cases. Four barrier dams (A through D) would be required to separate proposed Gatun Lake levels of El. 85 ft, and either canal level El. 26.0 m (55 ft) or El. 9.2 m (30 ft.) The proposed location of the four barrier dams is shown in Table 5.4.3-3. Economics dictates that these barrier dams be constructed using excavated material from the canal area, and also that the construction of dam foundation and structure be performed underwater. Therefore, it is proposed that the dams be rockfill dams with sand and gravel filter material to minimize segregation when placed underwater. Other design details will be developed in Phase II.

Table 5.4.3-3
Location of Barrier Dams (low Rise Lock Canal System and Route 14S)

Dam	River	Drainage Area (km^2)	Reservoir		
			W. L. (m)	Area (km^2)	Capacity (mill. m^3)
A	Rio Chagres	1,320	26.1	2.7	14
B	Rio Gatun	370	26.1	67	820
C	Rio Trinidad	780	26.1	127	1192
D	Rio Pescado	300	26.1	16	58

- Other Structures

Other structures that may be required for lock canal alternatives consist of anchorage, mooring and breakwater. Anchorage at both the Atlantic and Pacific approaches is required for ships waiting their turns to enter the Canal. It is assumed that the majority of ships will not require anchorage, and also that none will require prolonged anchorage in or at the Canal.

The present anchorage available at the Atlantic/Limon Bay is approximately 26 square kilometers, which can accommodate 24 anchor positions; and the area on the Pacific side is about 58 square kilometers, which will accommodate more than 24 ships.

Moorings are needed for ships already in the Canal if passage is interrupted for any reason. The Culebra Cut between Gatun and Miraflores Lakes will govern mooring requirements. Ships in transit towards the Atlantic and in the cut area will have no mooring problems if transit through the Atlantic locks is interrupted, since they will be able to anchor in Gatun Lake. However, ships in the cut sailing south will be affected by interruptions in the Pacific locks and will require mooring. Mooring could take place near both Pedro Miguel and Miraflores Locks, but for safety reasons provision should be made for mooring near the Canal banks. Mooring within the Canal and especially in the cut area may consist of bollards located at reasonable intervals along the banks. Dolphin type mooring structures are recommended near lock structures.

Breakwaters are needed to shelter entrances to waterways from severe wave action which could affect safe navigation. Due to much more severe weather and deeper water on the Atlantic side, the present Canal includes a breakwater in Limon Bay to protect the Atlantic entrance to the Canal. There is no breakwater on the Pacific entrance side; only a dredged longer approach channel. It is not anticipated that new breakwaters will be required with any lock canal conceptual alternative; however, some upgrade may be required which will be determined in Phase II. For the purpose of prescreening and Phase I, it is assumed that existing breakwaters are adequate.

Bridges will be required across the canal to allow movement and minimize isolation of communities due to new canal construction. Location and type of the proposed bridges will be studied in detail during Phase II work.

5.4.4 Conceptual Design for Sea Level Canal Alternatives

There have been numerous sea level canal proposals dating back to long before the French attempt. Most sea level canal concepts considered recently are those included in the U.S. Army Corps of Engineers Study as detailed in their IOCS Report (1970).

Canal Alignment/Route

There are two sea level canal routes chosen in the IOCS (1970) Report, which are as follows:

- Route 14S in a sea level canal which basically follows the existing canal but has a straight section in Gatun Lake and about 13 kilometer bypass at the Pacific Locks and it will require the construction of several barrier dams; and,

- Route 10 is a sea level canal some 16 kilometers west and nearly parallel to the existing canal. This route will also require construction of several barrier dams to isolate Gatun Lake and impound the fresh water of the lake.

Alignment of a sea level canal along Route 10 and Route 14S are described and graphically shown in YEC-Phase I, pages S-18 through S-20, and in Section 5.1 of this report.

A special feature of the sea level canal is the tidal current generated by differences between the two ocean tides. Tidal current of 4.5 knots were measured from real physical model and also confirmed by mathematical modeling. To facilitate navigation, tidal current control is required.

Geology and Seismology

Although very limited studies were performed for the IOCS Study, a generalized geologic profile was constructed along Route 10 alignment and is presented in Figure 5.4.3-2.

In general, the geologic profile along Route 10 was found to be similar to that of the existing canal: however, it was suggested that more work was needed in the Continental Divide area to locate a more favorable geologic formation for the Route 10 alternative.

Geology of Route 14S is presented in Section 5.4.3 of this report and its geologic profile is similar to that presented in Figure 5.4.3-1.

Excavation and Slope Stability

Similar excavation zones and excavation slope types discussed in Section 5.4.3 of this report are applicable to the excavation and slope stability of the sea level canal. The only difference is in managing the excavation to its final grades since for Route 10 and part of Route 14S, the excavation start from virgin ground.

Based on data presented in YEC-Phase I, excavation cost accounted for 74 to 83 percent of the total construction cost of sea level canals and the wet excavation portion should range between 22 and 37 percent with an average of 30 percent. YEC-Phase I Report presented wet excavation for Route 10 varying from 3 to 8 percent of total excavation which is very low and recommendation were made to carefully review and correct these estimates for Phase II. Similar assumptions as to hauling and disposal was made for consistency. Use of excavated material for construction was assumed. Figure 5.4.3-4 is a graphical presentation of excavation volumes for all cases considered for Routes 10 and 14S of the sea level canal.

Feasibility of excavation and construction will be discussed in Section 8.3.1 of this report.

Water Resources Management

Water resource analyses and conclusions made for the lock canal alternatives remain valid for the sea level canal alternatives. A Route 10 sea level canal will divide Gatun Lake into two major parts and will require construction of several barrier dams and diversion channels.

The purpose of barrier dams is to allow construction of the sea level canal, separate lake freshwater from ocean salt water, and provide a means for flood control.

Operation of the existing Panama Canal will not be interrupted by construction and the requirements for lockage water will be assured by construction planning and management. Gatun Dam will continue to control runoff from the Chagres and Gatun River.

A sea level canal along Route 14S will also require barrier dams to isolate the new sea level canal from Gatun and Madden Lakes.

The design and construction of barrier dams present challenging foundation and embankment stability problems. Hydraulic heads exceeding 40 meters will exist during construction of the canal. Although failure of these dams is unlikely, it would have disastrous effects on the operation and safety of the existing Panama Canal. Because construction of these dams will be mostly accomplished underwater, rock fill dams are recommended. In addition, for all cases of conceptual alternative 14S, the upper Chagres River downstream from Madden Dam will require a barrier dam and a diversion plug to the Pacific Ocean at Gamboa.

Construction of diversion channels, spillways, culverts, and dams will have minimal impact on the operation of the present Panama Canal.

Environmental impacts of any of the sea level canal alternatives will be discussed in Sections 1, 7, and 8 in this report.

Hydraulic Structures

- Tides and Currents

Tides/tidal current and tidal check are important factors in determining the transit capacity of an Isthmian sea level canal. Tides will generate periodically reversing currents through a sea level canal, with a net flow from the Pacific to the Atlantic. Phase I OCCE studies used spring tides in the Pacific ranging from +3.15 m to -3.0 m (+10.3 ft to -9.8 ft), and the Atlantic range is from +0.37 m to -0.21 m (+1.2 ft to 0.7 ft). This difference in tide would produce currents in an open channel ranging from about 4 knots per hour at the Pacific end to more than 5 knots per hour at the Atlantic end.

The Vergara alternative employing a large embayment at the Pacific end of a sea level canal, Route 10 was eliminated from consideration by the OCCE component studies because; even though it reduced current in the canal, the reduction would not be sufficient for safe navigation. In addition, very fast currents would be generated at the entrance to the embayment area which would not be navigable for much of the tidal cycle and would create erosion, scour and embankment instability.

Cross currents and density currents caused by freshwater inflow are minimized by either diversion or by designing inlets to discharge into the Canal as nearly parallel to the centerline as possible.

- Tidal Control Structures

The Phase I, OCCE Component Studies concluded: a canal closure system consisting of two tide gates, or locks, at the Pacific side is needed to limit tidal currents to safe levels for navigation. Or, a single lane sea-level canal with tide gates or locks, in combination with the Status Quo (existing Panama Canal) Canal. There are many types of gate that can be used for tidal current checks. These are rotational, linear, and configured types. YEC presented in Table 4.6.1 of their Phase I Final Report a summary of gate selection study which was based on technical and economical factors. This study concluded that a torsion type rolling gate was overall preferred compared to all others; however, a triangular leaf rolling gate was selected because of its long term operating record and maintenance experiences.

A suitable corrosion protection system will be designed and installed during construction to protect and prolong the useful life of these gates. For optimization of other components of tidal gates, see YEC-Phase I Final Report, Section 4.3.

5.4.5 Construction Plans

The mix of construction equipment should be selected as a result of an economic analysis considering terrain, weather, and altitude. For example, a truck oriented system, rail oriented system, suction dredging, and conveyor system may all, individually or in combination, constitute an economic system.

For a predominantly earth moving project such as the Panama Canal, where over 50 percent of the total construction cost are estimated for earth moving, an efficient and profitable practice require balanced system for excavation, hauling, and disposal of spoil. Hauling is the critical link in this chain since, in general, the capacity of hauling equipment is less than that of large excavation equipment.

Wet excavation (dredging) systems are easier to design since a large dredge can operate alongside large hauling barges.

Past experience of excavation in the Continental Divide area indicated that soft altered volcanic rock at depth will have a major unfavorable effect on the stability of excavation slopes, a large landslide in the area of Culebra Cut east and west, and the continued monitoring of the stability of the Gold Hill area are examples. Therefore, detail geologic studies and a well defined geologic profile, especially for any sea level canal alternative along Route 10, will be required.

The design level earthquake will be determined in Phase II based on historical and instrumental seismicity, and will be included in the design criteria. Construction of locks, chambers, culvert, and approach walls, using concrete and rebars, will be accomplished, in general, without difficulties. Foundation preparations for these structures including barrier dams may be challenging. Dental work and/or grouting may be required prior to concrete placement for foundations. Foundation construction underwater will be difficult to control without good construction specifications. Although, most of this construction is conventional, specialty contractors may be required. Construction of all the conceptual alternatives studied in Phase I would require a minimum of 10 years and up to 20 years to complete. All high rise alternatives would require approximately 10 years to complete regardless of the design ship size with the exception of 250 thousands dwt requiring 16 years. For the low rise Canal at El. 16.5 m (55 ft.), construction was estimated to be completed between 10 and 14 years. The low rise Canal at El. 9.2 m (30 ft.), completion of construction was estimated between 14 and 18 years and construction completion time increase with increasing ship size. For a sea-level canal on Route-10, the estimated schedule ranged between 12 and 20 years, increasing both ship design and number of lanes. For a sea-level canal on Route 14S, results similar to the summary presented above for Route 10 are applicable.

Although, a project like this is very large in scope, it should not be difficult to construct since a high percentage of the construction is conventional. Therefore, the feasibility of constructing the most viable alternative is high and requires contractors demonstrating sensitivity to environmental and social impacts resulting during construction.

5.4.6 Preliminary Cost Estimates for Conceptual Alternatives

During the Phase I study, reasonable assumptions were made where historical alternatives were found to lack required information. Although, Yachiyo Engineering Company (YEC) cost estimates provided in Phase I Report lacked considerations for; economy of scale, balanced use of equipment, efficient material handling, and attention to impacts; it did provide consistent cost data adequate for screening of conceptual alternatives concluding all of Phase I Studies.

SINBOL provided further modifications to YEC cost data primarily correcting for Culebra Cut Construction, concrete, and transportation systems. YEC cost estimates as well as SINBOL, are presented in the summation Tables 5.4.6-1 to 5.4.6-4.

Table 5.4.6-1

Lock Canal Costs (YEC Final Report - Phase I)

UMMATION TABLES

LOCK TYPE STUDY CASES COMPARATIVE SUMMATION TABLE(1)

ITEMS	Unit	L-1	L-2	L-2'	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	L-11	L-12	L-13	L-14	L-15	L-16	L-17	L-18
A – FEATURES OF CANAL ALTERNATIVE																				
1) Design Ship	1000DWT	100	100	100	100	150	150	150	250	250	250	100	100	100	150	150	150	250	250	250
2) Route	I – IV	I	I	I	III	I	I	III	I	I	III	II	IV	II	II	IV	II	II	IV	II
3) Water level (El. ft.)	ft	90	85	85	55	90	85	55	90	85	55	85	55	30	85	55	30	85	55	30
4) Number of lifts	no.	2	2	1	1	2	2	1	2	2	1	2	1	1	2	1	1	2	1	1
5) Number of lanes	no.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
6) Route length; a. Atlantic Approach	km	11.8	11.8	11.8	11.8	12.1	12.1	12.1	12.5	12.5	12.5	11.8	11.8	11.8	12.1	12.1	12.1	21.9	12.5	12.5
b. Channel	km	60.8	60.8	60.8	61.0	60.8	60.8	61.0	60.8	60.8	61.0	54.8	55.0	54.8	54.8	55.0	54.8	52.6	55.0	54.8
c. Pacific Approach	km	14.3	14.3	14.3	14.3	17.5	17.5	17.5	21.9	21.9	21.9	14.3	14.3	14.3	17.5	17.5	17.5	14.5	21.9	21.9
Total Route Length	km	86.9	86.9	86.9	87.1	90.4	90.4	90.6	95.2	95.2	95.4	80.9	81.1	80.9	84.4	84.6	84.4	89.0	89.4	89.2
7) Channel cross-section (w x d)	m	301x18.7	301x18.7	301x18.7	301x18.7	343x20.9	343x20.9	343X20.9	399X24.2	399X24.2	399.24.2	301x18.7	301x18.7	301x18.7	343x20.9	343x20.9	343x20.9	399x24.2	399x24.2	399x24.2
B – WATER MANAGEMENT PLAN																				
1) Annual 15,000 transits in existing locks																				
a. Water volume required	bil.m3	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
b. Available water capacity	bil.m3	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.95	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
2) 20,000 transits/year in new locks																				
a. Water volume required	bil.m3	8.18	7.74	15.48	10.02	10.70	10.12		14.72	13.92	18.02	7.74	10.02	5.40	10.12	13.10	7.06	13.92	18.02	9.70
b. Total water required (1)a + (3)a)	bil.m3	11.13	10.69	18.43	12.97	13.65	13.07	13.10	17.67	16.87	20.97	10.69	12.97	8.35	13.07	16.05	10.01	16.87	20.97	12.65
c. Countermeasures to be taken								16.05												
– Water pumping with new dam	bil.m3	5.64	4.84	12.63	7.48	7.87	7.28		11.92	11.07	15.48	4.84	7.48	2.86	7.28	10.56	4.52	11.07	15.48	7.16
– Water pumping without new dam	bil.m3	5.35	5.20	12.94	7.48	8.16	7.58	10.56	12.18	11.38	15.48	5.20	7.48	2.86	7.58	10.56	4.52	11.38	15.48	7.16
d. – Sets of pump stations (with new dam)	set	3	3	7	4	5	4	10.56	7	6	9	3	4	2	4	6	3	8	9	4
– Sets of pump stations (without new dam)	set	4	3	8	4	5	5	6	7	7	9	3	4	2	5	6	3	7	9	5
C – MAIN ELEMENTS OF THE STUDY CASES																				
(1) Lock																				
a. Lock chamber dimensions ([LxWxD)& No.)	note*1	(A)-2	(A)-2	(A)-1	(A)-1	(B)-2	(B)-2	(B)-1	(C)-2	(C)-2	(C)-1	(A)-2	(A)-1	(A)-1	(B)-2	(B)-1	(B)-1	(C)-2	(C)-1	(C)-1
b. Gates																				
– Max lock gate dimensions (BxH)	m	47x36	47x35	47x48	47x39	54x37	54X37	54X41	63X41	63X40	63X44	47x35	47x39	47x32	54x37	54x41	54x34	63X40	63x44	63x37
– Lock gate total number (in pair)	no.	12	12	8	8	12	12	8	12	12	8	12	8	8	12	8	8	12	8	8
– Lock gates total weight	1000 ton	32.7	31.8	27.9	21.4	43.2	41.9	27.9	61.9	59.9	39.2	31.8	21.4	16.9	41.6	27.9	21.6	59.9	39.2	29.4
– Main culvert number	no.	32	32	24	24	32	32	24	32	32	24	32	24	24	32	24	24	32	24	24
– Main culvert dimensions (BxH)	m	7x8	7x8	8x9	8x8	8x9	8X9	9X9	9x10	9X10	10x11	7x8	8x8	8x7	8x9	8x9	7x8	9X10	10x11	9x9
– Emergency gate number	no.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
– Maintenance gate number	no.	1	1	1	2	1	1	2	2	2	2	1	2	2	1	2	2	2	2	2

OTES*1 Lock dimensions: (A) 319 x 47 x 19, (B) 363 x 54 x 21, (C) 428 x 63 x 24

BASED ON YEC FINAL REPORT (PHASE I)

Table 5.4.6-2

Lock Canal Total Costs (YEC Final Report - Phase I)

A. LOCK TYPE STUDY CASES COMPARATIVE SUMMATION TABLE(2)

ITEMS	Unit	L-1	L-2	L-2	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	L-11	L-12	L-13	L-14	L-15	L-16	L-17	L-18
C. Mule towing System																				
– Size	L,M,S	M	M	M	M	L	L	L	L	L	L	M	M	M	L	L	L	L	L	L
– Number	no.	72	72	48	48	72	72	48	72	72	48	72	48	48	72	48	48	72	48	48
(2) Barrier Dams																				
a. Site A,B,C,D :Total Volume	mill.m3	0	0	20.3	20.3	0	0	20.3	0	0	20.3	0	20.3	20.3	0	20.3	20.3	0	20.3	20.3
(3) New Dams																				
a. Site CM and Trinidad:Total Volume	mill.m3	4	5.5	5.5	–	4	4	–	4	5.5	–	5.5	–	–	4	–	–	5.5	–	–
(4) Excavation																				
a. Dry excavation	mill.m3	317	330	330	362	390	405	447	502	519	558	321	427	657	367	525	802	493	647	1,018
b. Dredging	mill.m3	97	112	112	233	166	183	322	305	324	447	209	229	262	287	300	342	452	397	492
Total excavation volume	mill.m3	414	442	442	595	556	588	769	807	843	1,005	530	656	919	674	825	1,144	945	1,044	1,510
(5) Concrete	mill.m3	8.3	8.3	8.3	7.8	11.8	11.8	9.0	16.8	16.8	11.2	8.3	7.8	7.8	11.8	8.0	8.8	16.8	11.2	10.8
(6) Power Requirement																				
a. Lock operation total requirement	1000 kW	57.7	56.5	51.8	37.0	93.4	88.9	58.7	113	108.4	88.7	56.2	37.0	25.5	89.4	58.7	38.7	108.4	71.4	48.2
– Lock gate operation	1000 kW	32.3	31.5	27.8	21.4	42.6	40.9	27.7	62.2	60.4	38.7	32.2	21.4	17.1	41.4	27.7	21.7	60.4	40.4	29.2
– Mule operation	1000 kW	25.4	24.0	24.0	15.6	50.8	48.0	31.0	50.8	48.0	31.0	24.0	15.6	8.4	48.0	31.0	17.0	48.0	31.0	17.0
b. Pump stations total requirement 20,000 transits (with dam)	1000 kW	55.2	56.2	129.0	73.6	92.0	73.6	110.0	129.0	110.0	166.0	55.2	73.6	36.8	73.6	110.0	55.2	110.0	166.0	73.6
c. Total power requirement Lock operation + pump station	1000 kW	113	111	181	111	185	163	169	242	218	236	111	111	62	163	169	94	218	237	120
D – CONSTRUCTION COSTS																				
(1) Channel excavation																				
a. Dry excavation	mill.US$	1,066	1,683	1,683	2,053	1,955	2,042	2,528	2,494	2,589	3,154	1,845	2,402	3,622	1,955	2,944	4,485	2,485	3,632	5,580
b. Dredging	mill.US$	1,555	1,209	1,209	2,778	1,731	1,984	4,024	4,042	4,423	6,069	2,978	3,134	4,097	4,010	4,181	5,380	7,044	5,712	6,189
Total channel excavation	mill.US$	2,610	2,892	2,892	4,829	3,686	4,038	6,552	6,536	7,012	9,223	4,823	5,536	7,719	5,965	7,105	8,875	9,509	9,344	13,769
(2) Lock concrete structure	mill.US$	692	692	692	575	875	875	658	1,212	1,212	822	692	575	560	875	658	631	1,212	822	789
(3) Gate leaves and related items	mill.US$	1,265	1,239	1,159	1,065	1,668	1,632	1,393	2,556	2,496	1,951	1,239	1,065	936	1,632	1,393	1,208	2,496	1,951	1,657
(4) New dams	mill.US$	68	85	85	–	68	68	–	68	85	–	85	–	–	68	–	–	85	–	–
(5) Barrier dams	mill.US$	–	–	–	348	–	–	348	–	–	348	–	348	348	–	348	348	–	348	348
(6) Pumping stations (20,000 transits)	mill.US$	255	255	595	340	425	340	510	595	510	765	255	340	170	340	510	255	510	765	340
(7) Indirect Cost	mill.US$	896	940	982	1,259	1,189	1,228	1,627	1,868	1,924	2,211	1,217	1,372	1,670	1,535	1,718	2,064	2,324	2,230	2,617
Total Project Cost (YEC Base Estimate)	mill.US$	5,786	6,103	6,405	8,414	7,911	8,177	11,066	12,835	13,239	15,318	8,111	9,234	11,401	10,415	11,728	14,399	16,136	15,456	19,716
Estimate Adjustments:																				
(8) Culebra (Gaillard) Cut Widening	mill.US$	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566	−566
(9) New bridges	mill.US$	681	681	681	681	786	786	786	964	964	964	681	681	681	786	786	786	964	964	964
(10) Concrete Cost Adjustment	mill.US$	−177	−177	−177	−149	−224	−224	−170	−319	−319	−213	−177	−149	−144	−224	−170	−164	−319	−213	−205
(11) Demolition of Lock Concrete	mill.US$				100			100			100		100	300		100	300		100	300
Total Revised Project Cost (2 Lane Design)		5,704	6,021	6,323	8,460	7,867	8,153	11,216	12,914	13,318	15,603	8,029	9,260	11,652	10,391	11,858	14,735	16,215	15,743	20,211
(12) Single Lane Lock Adjustment		−1094	−1079	−1033	−922	−1425	−1404	−1156	−2131	−2097	−1566	−1079	−922	−837	−1404	−1156	−1034	−2097	−1566	−1378
Total Revised Project Cost (1 Lane Design)		4,610	4,942	5,290	7,538	6,482	6,749	10,060	10,783	11,221	14,037	6,950	8,358	10,815	8,987	10,702	13,701	14,118	14,177	18,833
E – OPERATION AND MAINTENANCE COSTS																				
(1) Electrical power (energy)	mill.US$	40	40	84	40	84	58	58	86	77	85	40	40	22	58	58	33	77	85	42
(2) Manpower and other O&M costs	mill.US$	479	479	479	458	491	491	475	514	514	492	479	458	458	491	475	475	514	492	492
(3) Total O&M costs	mill.US$	519	519	543	498	555	549	533	600	591	577	519	498	480	549	533	508	591	577	534
F – CONSTRUCTION ASPECTS																				
(1) Comparative ease of construction	grade	B	B	B	B	B	B	B	B	B	B	A	A	C	A	A	C	A	A	C
(2) Technical soundness	grade	A	A	C	B	B	B	B	C	B	C	A	B	A	B	B	A	C	C	B
(3) Construction period	year	10	10	10	10	10	10	10	11	11	13	10	10	14	10	11	18	16	14	18
G – IMPACT AS REFLECTED IN COST ESTIMATES																				
(1) Impact on existing Panama Canal																				
a. Shutdown period during construction	month	0.5	0.5	0.5	2.0	0.5	0.5	2.0	0.5	0.5	2.0	0.5	2.0	2.0	0.5	2.0	2.0	0.5	2.0	2.0
b. Modification works to Panama Canal	grade	S	S	S	M	S	S	M	S	S	M	S	M	L	S	M	L	S	S	L
(2) Potential environmental impact																				
a. Disposal of dredged materials	grade	S	S	L	M	M	S	M	L	M	L		M	S	M	M	S	M	L	M
b. Placement of excavated materials	grade	S	S	S	S	S	S	M	M	M	M	S	M	M	M	M	L	M	L	L
(3) Socioeconomic impact																				
a. Relocation of residents	grade	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few	Few
b. Increase work opportunities	grade	M	M	M	M	M	M	L	L	L	L	M	L	L	L	L	L	L	L	L

NOTES:

1) Comparative ease of construction.
A=Dredging works will be easy.
B=Dredging works will be difficult.
C=Dredging works will be very difficult.

* Indicates lines added or revised by SINBOL

2) Technical soundness (Especially water recycling).
A=Pumping volume will be small.
B=Pumping volume will be medium.
C=Pumping volume will be large.

3) Impact
S=To be small.
M=To be medium.
L=To be large.

4) The project costs for the lock canal are estimated based on a 35,000 transits/year case. (15,000 transits at existing lock and 20,000 transits at new locks.)

5) Refer to Appendix 4 for Operation and Maintenance costs.

6) Electrical power cost is calculated as follows.
Cost = Total Power x 365 days x 24 hrs x (a) x 0.07US$
(where, (a):operating efficiency=60%, 1kw/hr=0.07US$)

BASED ON YEC FINAL REPORT
(PHASE I)

Table 5.4.6-3

Sea Level Canal Costs (YEC Final Report - Phase I)

B. SEA LEVEL CANALS COMPARATIVE SUMMATION TABLE (1)

ITEMS	Unit	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18
A – FEATURES OF ALTERNATIVES																			
(1) Design Ship	1000 DWT	150	150	250	250	300	300	150	150	250	250	300	300	150	250	300	150	250	300
(2) Route	10,14S	10	10	10	10	10	10	14S	14S	14S	14S	14S	14S	10	10	10	14S	14S	14S
(3) Number of lane	No.	1	2	1	2	1	2	1	2	1	2	1	2	50%-1.2	50%-1.2	50%-1.2	50%-1.2	50%-1.2	50%-1.2
(4) Route length; a. Atlantic Approach	km	3.5	3.5	3.85	3.85	3.9	3.9	12.1	12.1	12.5	12.5	12.6	12.6	3.5	3.85	3.9	12.1	12.5	12.6
b. Channel	km	57.0	57.0	57.0	57.0	57.0	57.0	53.0	53.0	53.0	53.0	53.0	53.0	57.0	57.0	57.0	53.0	53.0	53.0
c. Pacific Approach	km	25.7	25.7	27.7	27.7	28.7	28.7	17.5	17.5	21.9	21.9	23.2	23.2	25.7	27.7	28.7	17.5	21.9	23.2
Total Route Length	km	86.2	86.2	88.55	88.55	89.60	89.60	82.6	82.6	87.4	87.4	88.8	88.8	86.2	88.55	89.6	82.6	87.4	88.8
(5) Channel cross-section (W x D)	m	147X21	343X21	171X24.5	399X24.5	183X25.5	427X25.5	147X27	147X27	171X30.3	171X30.3	183X25.5	427X25.5	147X21	171X24.5	183X25.5	147X21	171X24.5	183X25.5
B – MAIN ELEMENTS OF THE STUDY CASES																			
(1) Tidal Gates Structure																			
a. Dimension	Note*1	A	A'	B	B'	C	C'	A	A'	B	B'	C	C'	A	B	C	A	B	C
b. Canal Partition Wall, length	km	–	26	–	26	–	27	–	27	–	27	–	27	–	–	–	–	–	–
(2) Tidal Gate																			
a. Tidal Gate dimension	m	147X27	147X27	171x30.3	171X30.3	181X31.4	181X31.4	147X27	147X27	171X30.3	171X30.3	183X31.4	183X31.4	147X27	171X30.3	183X31.4	147X27	171X30.3	183X31.4
b. Gate weight	ton	6,830	6,830	9,520	9,520	10,780	10,780	6,830	6,830	9,520	9,520	10,780	10,780	6,830	9,520	10,780	6,830	9,520	10,780
(3) Tidal Basin																			
a. Pacific; Basin area	Mil.m2	73	73	73	73	73	73	–	–	–	–	–	–	73	73	73	–	–	–
Embankment Volume	Mil.m3	18.5	18.5	18.5	18.5	18.5	18.5	–	–	–	–	–	–	18.5	18.5	18.5	–	–	–
b. Atlantic; Basin area	Mil.m2	62	62	62	62	62	62	–	–	–	–	–	–	62	62	62	–	–	–
Embankment Volume	Mil.m3	53.8	53.8	53.8	53.8	53.8	53.8	–	–	–	–	–	–	53.8	53.8	53.8	–	–	–
(4) Breakwater																			
a. Pacific : length	km	14.9	14.9	14.9	14.9	14.9	14.9	–	–	–	–	–	–	14.9	14.9	14.9	–	–	–
b. Atlantic: length	km	7.4	7.4	7.4	7.4	7.4	7.4	–	–	–	–	–	–	7.4	7.4	7.4	–	–	–
(5) Barrier Dams																			
a. Site A,B,C,D: Total Volume	Mil.m3	–	–	–	–	–	–	20.3	20.3	20.3	20.3	20.3	20.3	–	–	–	20.3	20.3	20.3
b. Site E,F,G : Total Volume	Mil.m3	10.7	10.7	10.7	10.7	10.7	10.7	–	–	–	–	–	–	10.7	10.7	10.7	–	–	–
(6) Flood Control																			
a. Diversion Culvert: Number	No.	2	2	2	2	2	2	–	–	–	–	–	–	2	2	2	–	–	–
b. Total length	km	18	18	18	18	18	18	–	–	–	–	–	–	18	18	18	–	–	–
(7) Excavation																			
a. Dry Excavation	Mil.m3	906	1,609	1,038	1,893	1,133	2,087	899	1,128	786	1,342	837	1,439	1,247	1,459	1,587	772	884	942
b. Dredging Excavation	Mil.m3	32	72	52	113	61	133	200	415	273	576	306	626	72	113	134	366	514	560
Total Excavation Volume	Mil.m3	938	1,681	1,090	2,006	1,194	2,190	899	1,543	1,059	1,918	1,143	2,065	1,319	1,572	1,721	1,138	1,398	1,502
* (8) Excavation (Revised Route 10 Excav Quantities)																			
* a. Dry Excavation	Mil.m3	713	1,143	828	1,383	907	1,489							950	1,112	1,239			
* b. Dredging Excavation	Mil.m3	225	538	262	643	287	701							369	440	482			
* Total Revised Excavation Volume	Mil.m3	938	1,681	1,090	2,006	1,194	2,190							1,319	1,572	1,721			
* (9) Concrete	Mil.m3	2.1	2.5	2.6	3.1	3.0	3.6	2.1	2.5	2.6	3.1	3.0	3.6	2.1	2.6	3.0	2.1	2.6	3.0

Note*1: A = 147(B) X 27.0(H), 1Lane
A' = 147(B) X 27.0(H), 2Lanes
B = 171(B) X 30.3(H), 1Lane
B' = 171(B) X 30.3(H), 2Lanes
C = 183(B) X 31.4(H), 1Lane
C' = 183(B) X 31.4(H), 2Lanes

* Indicates lines added or revised by SINBOL

BASED ON YEC FINAL REPORT
(PHASE I)

Table 5.4.6-4

Sea Level Canal Total Costs (YEC Final Report - Phase I)

8. SEA LEVEL CANALS COMPARATIVE SUMMATION TABLE (2)

ITEMS	Unit	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18
A - FEATURES OF ALTERNATIVES																			
(1) Design Ship	1000 DWT	150	150	250	250	300	300	150	150	250	250	300	300	150	250	300	150	250	300
(2) Route	10,14S	10	10	10	10	10	10	14S	14S	14S	14S	14S	14S	10	10	10	14S	14S	14S
(3) Number of lane	No.	1	2	1	2	1	2	1	2	1	2	1	2	50%-1,2	50%-1,2	50%-1,2	50%-1,2	50%-1,2	50%-1,2
(4) Route length: a. Atlantic Approach	km	3.5	3.5	3.85	3.85	3.9	3.9	12.1	12.1	12.5	12.5	12.6	12.6	3.5	3.85	3.9	12.1	12.5	12.6
b. Channel	km	57.0	57.0	57.0	57.0	57.0	57.0	53.0	53.0	53.0	53.0	53.0	53.0	57.0	57.0	57.0	53.0	53.0	53.0
c. Pacific Approach	km	25.7	25.7	27.7	27.7	28.7	28.7	17.5	17.5	21.9	21.9	23.2	23.2	25.7	27.7	28.7	17.5	21.9	23.2
Total Route Length	km	86.2	86.2	88.55	88.55	89.6	89.60	82.6	82.6	87.4	87.4	88.8	88.8	86.2	88.55	89.6	82.6	87.4	88.8
(5) Channel cross-section (W x D)	m	147X21	343X21	171X24.5	399X24.5	183X25.5	427X25.5	147X27	147X27	171X30.3	171X30.3	183X25.5	427X25.5	147X21	171X24.5	183X25.5	147X21	171X24.5	183X25.5
C - CONSTRUCTION COST																			
(1) Channel Excavation																			
a. Dry Excavation	Mil.US$	4,917	8,247	5,190	9,072	5,947	10,665	4,438	6,957	4,946	8,234	5,251	8,617	6,600	7,269	8,193	4,844	5,507	5,852
b. Dredging	Mil.US$	179	400	311	657	375	830	8,582	17,956	11,960	25,539	13,463	27,898	400	657	830	15,544	22,447	24,546
Total Channel Excavation	Mil.US$	5,096	8,647	5,501	9,729	6,322	11,495	13,020	24,913	16,906	33,773	18,714	36,715	7,000	7,926	9,023	20,388	27,954	30,398
(2) Tidal Gate Structure	Mil.US$	216	257	254	302	292	348	216	257	254	302	292	348	216	254	292	216	254	292
(3) Canal Partition Wall	Mil.US$	-	556	-	650	-	743	-	578	-	675	-	771	-	-	-	-	-	-
(4) Tidal Gate	Mil.US$	207	240	290	335	328	379	208	240	290	335	328	379	208	290	328	208	290	328
(5) Breakwater	Mil.US$	45	45	45	45	45	45	-	-	-	-	-	-	45	45	45	-	-	-
(6) Barrier Dam	Mil.US$	182	182	182	182	182	182	346	346	346	346	346	346	182	182	182	346	346	346
(7) Flood Control System	Mil.US$	13	13	13	13	13	13	-	-	-	-	-	-	13	13	13	-	-	-
(8) Indirect Costs	Mil.US$	1,044	1,713	1,128	1,923	1,271	2,235	2,320	4,327	2,863	5,783	3,263	6,263	1,346	1,516	1,703	3,499	4,729	5,132
Total Project Costs (YEC Base Estimate)	Mil.US$	6,803	11,653	7,413	13,179	8,453	15,440	16,110	30,661	20,659	41,214	22,943	44,642	9,012	10,226	11,586	24,657	33,573	36,498
Estimate Adjustments:																			
* (9) New bridges	Mil.US$	435	786	459	984	501	1062	435	786	459	984	501	1062	786	984	1062	786	984	1062
* (10) Concrete Cost Adjustment	Mil.US$	-40	-48	-49	-58	-57	-68	-40	-46	-49	-58	-57	-68	-40	-49	-57	-40	-49	-57
* (11) Revised Route 10 Excavation Adjustment	Mil.US$	1,180	2,836	1,436	3,496	1,471	3,231							1,906	2,313	2,384			
Total Revised Project Cost	Mil.US$	8,378	15,227	9,259	17,603	10,368	19,665	16,505	31,399	21,069	42,140	23,367	45,836	11,864	13,474	14,975	25,403	34,508	37,501
D - OPERATION AND MAINTENANCE COST																			
(1) Man Power and Others O&M Cost	Mil.US$	594	594	607	607	607	607	353	353	366	366	366	366	594	594	607	366	366	366
E - Construction Aspect																			
(1) Comparative Ease of Construction	Grade	A	A	A	A	A	A	B	B	B	B	B	B	A	A	A	B	B	B
(2) Technical Soundness	Grade	A	A	A	A	A	A	B	B	B	B	B	B	A	A	A	B	B	B
(3) Construction Period	Year	11	11	12	17	14	19	10	13	10	15	14	18	15	16	17	13	12	14
F - IMPACT AS REFLECTED IN COST ESTIMATES																			
(1) Impact on Existing Panama Canal																			
a. Shutdown Period During Construction	Month	-	-	-	-	-	-	6	6	6	6	6	6	-	-	-	6	6	6
b. Modification Works to Panama Canal	Grade	-	-	-	-	-	-	L	L	L	L	L	L	-	-	-	L	L	L
(2) Potential Environmental Impact																			
a. Gatun Lake Salinity Danger	Grade	S	S	S	S	S	S	L	L	L	L	L	L	S	S	S	L	L	L
b. Placement of Excavated Materials	Grade	M	L	M	L	M	L	S	M	S	M	S	M	L	L	L	S	S	M
(3) Socioeconomic Impact																			
a. Relocation of Residents	Grade	L	L	L	L	L	L	S	S	S	S	S	S	L	L	L	S	S	S
b. Increase Works Opportunities	Grade	M	M	M	M	M	M	M	L	M	L	M	L	M	M	M	M	L	L

NOTES:

1) Comparative ease of construction.
A=Excavation works will be easy.
B=Excavation works will be difficult.

2) Impact
S=To be small.
M=To be medium.
L=To be large.

* Indicates lines added or revised by SINBOL

BASED ON YEC FINAL REPORT (PHASE I)

5.5 Screening and Evaluation of Potential Alternatives

5.5.1 Introduction

Potential Alternatives to the Panama Canal which were considered to deserve further study and analysis were selected by two steps; the first step was to form groups of the alternatives named as conceptual alternatives from among thirteen historically proposed alternatives to the Panama Canal which include canal waterways and non-canal transportation systems, and the second step was to select at least more than one conceptual alternative for comparison through quantitative and qualitative evaluations. Comparison of the selected conceptual alternatives was proposed to be made after detailed study and analysis in order to make a recommendation of the best alternative to the Panama Canal.

The first step was discussed in the preceding Section 5.1, therefore in this section the study and analysis of the second step for screening and evaluation of the potential alternatives are described.

5.5.2 Engineering Feasibility of the Conceptual alternatives

Engineering soundness in each of the conceptual alternatives was reviewed from various viewpoints of design and construction, taking into account conventional and innovative techniques as well as those newly developed for this gigantic project. Based on the results of this study and analysis, all conceptual alternatives were sound and feasible from an engineering point of view.

The major items of design and construction of the conceptual alternatives, which were reviewed are summarized below:

- For High Rise Lock Canal
  - Foundation treatment of lock structure
  - Design of lock structure
  - Design of lock gate
  - Design of other hydromechanical elements
  - Deep water dredging and excavation
  - Slope stability treatment on banks of waterway
  - Construction operation in the existing Canal area especially in waterway widening and deepening
  - Ship maneuvering in lock chamber
  - Ship maneuvering in waterway
  - Water management including sea water pumping, water saving and new source development

- For Low Rise Lock Canal
  - Foundation treatment of lock structure
  - Design of lock structure
  - Design of lock gate
  - Design of other hydromechnical elements
  - Deep water dredging and excavation
  - Slope stability treatment on banks of waterway
  - Demolishing of existing locks
  - Construction operation in the existing Canal area especially in waterway widening and deepening
  - Ship maneuvering in lock chamber
  - Ship maneuvering in waterway
  - Water management including sea water pumping, water saving and new source development

- For Route 14S Sea Level Canal
  - Foundation treatment of tidal /lock gate
  - Design of tidal/lock gate structure
  - Design of tidal lock gate
  - Deep water dredging
  - Slope stability treatment on banks of waterway
  - Demolishing of existing structure
  - Construction operation in the existing Canal area
  - Tidal current analysis
  - Ship maneuvering in waterway under tidal current
  - Ship maneuvering through tidal gate or in lock chamber

- For Route 10 Sea Level Canal
  - Foundation treatment of tidal lock gate
  - Design of tidal/lock gate structure
  - Design of tidal lock gate
  - Deep water dredging
  - Slope stability treatment on banks of waterway
  - Tidal current analysis
  - Ship maneuvering in waterway under tidal current
  - Ship maneuvering through tidal gate or in lock chamber

In addition to the above major items, engineering soundness of design and operation of navigation aids, specially designed and manufactured construction machines and construction time schedule were examined in connection with the alternatives

Optimization

In order to select the more promising alternatives from among four conceptual alternatives The optimum scale of each of conceptual alternatives was first determined by comparing their project costs and project benefits. The four conceptual alternatives had nine study cases each as indicated below:

- For lock canal (High and Low Rise alternatives):
  - Design ship size
  - Summit lake water level
  - Waterway alignment
- For sea level canal (Route 14S and 10 alternatives)
  - Design ship size
  - Number of lanes of waterway
  - Waterway alignment

A total of 36 cases (nine study cases by four alternatives) as shown in Table 5.5.3-1 were studied to determine their respective project costs and benefits in order to optimize the scale of each conceptual alternative. In each case, the total benefit less cost was maximized against design ship size for the determination of the optimum scale of each conceptual alternative, thus accounting for all resources attributable to each. For the optimized scale of each alternative, the benefit cost ratio (B/C) was calculated in order to provide information for the quantitative evaluation of the conceptual alternatives and the selection of the alternatives which were worthy of further study and analysis.

Project Cost

The Final Report of the "Preliminary Engineering and Cost Estimates" provided "order of magnitude" cost data and information which was used for the quantitative evaluation of the conceptual alternatives. The costs for conceptual alternatives consist of capital investment cost (construction cost) and annual operation, maintenance and replacement (OMR) costs. The capital investment cost is broken down into direct construction cost and indirect cost as itemized below.

- Direct construction cost included:
  1) Excavation and dredging including disposal and/or reuse,
  2) Concrete for structures, etc.
  3) Hydromechanical works including lock and tidal gates, valves, pipes, pumps, etc,
  4) Electrical works including power station, pump station, substation, transmission and distribution lines, etc,
  5) Construction facilities including construction facilities, roads, bridges, utilities, motor pools, service and repair shops, temporary jetties, warehouses, laboratories, offices, quarters, etc., for construction use,

Table 5.5.3-1

Study Cases for Optimization

Conceptual Alternative	Sub-Group	Study Case	Ship Size	Summit Lake	Route
Alternative 1 High Rise	1 - a	L - 1	100	90	Existing Canal Alignment
		L - 4	150		
		L - 7	250		
	1 - b	L - 2	100	85	Existing Canal Alignment
		L - 5	150		
		L - 8	250		
	1-c	L - 10	100	85	New Canal Alignment in Gatun Lake
		L - 13	150		
		L - 16	250		
Alternative 2 Low Rise	2 - a	L - 3	100	55	Existing Canal Alignment
		L - 6	150		
		L - 9	250		
	2 - b	L - 11	100	55	New Canal Alignment in Gatun Lake
		L - 14	150		
		L - 17	250		
	2 - c	L - 12	100	30	New Canal Alignment in Gatun Lake
		L - 15	150		
		L - 18	250		
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	Nos.of lanes	Route 14S
		S - 10	250	2	
		S - 12	300		
	3 - b	S - 16	150	2 + 1	
		S - 17	250		
		S - 18	300		
	3 - c	S - 7	150	1	
		S - 9	250		
		S - 11	300		
Alternative 4 Sea Level Route 10	4 - a	S - 2	150	2	Route 10
		S - 4	250		
		S - 6	300		
	4 - b	S - 13	150	2 + 1	
		S - 14	250		
		S - 15	300		
	4 - c	S - 1	150	1	
		S - 3	250		
		S - 5	300		

6) Permanent infrastructure including permanent roads, bridges, offices, quarters, utilities, etc., required for operation and maintenance of the canal, and
7) Field and home offices expenses including overhead and profit.

- Indirect cost included:
  1) Administration,
  2) Design and construction supervision,
  3) Land acquisition and right-of-way,
  4) Compensation, and
  5) Contingency.

- OMR costs:

  OMR costs are the costs and expenses required for securing the canal under normal operation and maintenance conditions for whole period of the project life. They are itemized as below:

  1) Navigation service and control,
  2) Lock or tidal gate operation,
  3) Maintenance of waterways and harbors,
  4) General repairs and maintenance,
  5) Replacement of major parts of lock or tidal gates,
  6) Supply and logistics,
  7) Utilities, and
  8) Housing, general and administrative, and others.

All the costs are estimated in US dollars at constant 1990 price and presented in Table 5.5.3-2. All the costs (capital investment and OMR costs) are based on the information generated from the Engineering and Cost Estimate (ECE) Component Study estimates. The OMR costs shown in The Final Report of ECE Study are those for SQ and each alternative. The OMR costs shown in Table 5.5.3-2 are those attributing to each alternative. In the case of Route 14S, the SQ would be no larger operated. The OMR costs for Route 14S was calculated to be negative simply because the OMR cost for SQ and Route 14S are lower than those for SQ.

For the cost benefit comparison, the capital investment cost was discounted to the year 2011 and summed up to the year 2010 when the construction work was assumed to be completed. In this case, the construction costs were distributed based on the construction period for each study case, and the discounting was made using a 10 percent rate. Annual OMR costs were distributed for 50 years of the project life (the year 2011 to 2060) and discounted to the year 2011 when the project operation was assumed to commence, and summed up. The summary of the present worth of project costs for each study case in 2011 for both capital investment cost and OMR costs are shown in Table 5.5.3-3.

Table 5.5.3-2

Project Cost (unit: Million US$)

Conceptual Alternative	Sub-Group	Study Case	Ship Size	Capital Costs	OMR Costs
Alternative 1 High Rise	1 - a	L - 1	100	5,577	89
		L - 4	150	7,911	101
		L - 7	250	12,835	124
	1 - b	L - 2	100	6,103	89
		L - 5	150	8,177	101
		L - 8	250	13,239	124
	1-c	L - 10	100	8,111	89
		L - 13	150	10,415	101
		L - 16	250	16,136	124
Alternative 2 Low Rise	2 - a	L - 3	100	8,414	68
		L - 6	150	11,086	85
		L - 9	250	15,318	102
	2 - b	L - 11	100	9,234	68
		L - 14	150	11,728	85
		L - 17	250	15,458	102
	2 - c	L - 12	100	11,401	68
		L - 15	150	14,399	85
		L - 18	250	19,718	102
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	30,660	-37
		S - 10	250	41,214	-24
		S - 12	300	44,842	-24
	3 - b	S - 16	150	24,657	-24
		S - 17	250	33,573	-24
		S - 18	300	36,496	-24
	3 - c	S - 7	150	16,110	-37
		S - 9	250	20,659	-24
		S - 11	300	22,943	-24
Alternative 4 Sea Level Route 10	4 - a	S - 2	150	11,653	204
		S - 4	250	13,179	217
		S - 6	300	15,440	217
	4 - b	S - 13	150	9,012	204
		S - 14	250	10,226	204
		S - 15	300	11,586	217
	4 - c	S - 1	150	6,803	204
		S - 3	250	7,413	217
		S - 5	300	8,453	217

Table 5.5.3-3

Total Project Cost in 2011 Present Value (Discount Rate: 10%)

(Unit: million US$)

Conceptual alternatives	Case	Ship size (thousand DWT)	Summit lake W.L. (ft)	Route	No. of lanes	Capital investment cost in 2011	Annual OMR cost	Total present worth of OMR costs in 2011	Total project cost
Alternative 1 (E) High Rise	L- 1	100	90	Existing Canal alignment	2	8,868.2	89	1,051.7	9,919.9
	L- 4	150	90	ditto	2	12,114.8	101	1,202.5	13,317.3
	L- 7	250	90	ditto	2	20,604.4	124	1,476.3	22,080.7
	L- 2	100	85	ditto	2	9,356.3	89	1,051.7	10,408.0
	L- 5	150	85	ditto	2	12,533.2	101	1,202.5	13,735.7
	L- 8	250	85	ditto	2	21,253.1	124	1,476.3	22,729.4
Alternative 1 (N) High Rise	L-10	100	85	New alignment in Gatun	2	12,434.2	89	1,051.7	13,485.9
	L-13	150	85	ditto	2	15,963.7	101	1,202.5	17,166.2
	L-16	250	85	ditto	2	33,934.8	124	1,476.3	35,411.1
Alternative 2 (E) Low Rise	L- 3	100	55	Existing Canal alignment	2	13,038.5	68	809.6	13,848.1
	L- 6	150	55	ditto	2	17,224.9	85	1,012.0	18,236.9
	L- 9	250	55	ditto	2	29,192.7	102	1,214.4	30,407.1
	L-11	100	55	New alignment in Gatun	2	14,236.7	68	809.6	15,046.3
Alternative 2 (N) Low Rise	L-14	150	55	ditto	2	19,056.4	85	1,012.0	20,068.4
	L-17	250	55	ditto	2	28,685.9	102	1,214.4	29,900.3
	L-12	100	30	ditto	2	21,240.3	68	809.6	22,049.9
	L-15	150	30	ditto	2	30,252.7	85	1,012.0	31,264.7
	L-18	250	30	ditto	2	45,322.6	102	1,214.4	46,537.0
	S- 8	150	0	Route 14S	2	58,515.9	(37)	(403.5)	58,112.4
	S-10	250	0	ditto	2	81,048.6	(24)	(261.7)	80,786.9
	S-12	300	0	ditto	2	102,922.0	(24)	(261.7)	102,660.3
Alternative 3, Route 14S	S-16	150	0	ditto	2+1	46,990.5	(24)	(261.7)	46,728.8
	S-17	250	0	ditto	2+1	60,001.4	(24)	(261.7)	59,739.7
	S-18	300	0	ditto	2+1	67,286.1	(24)	(261.7)	67,024.4
	S- 7	150	0	ditto	1	24,667.3	(37)	(403.5)	24,263.8
	S- 9	250	0	ditto	1	31,799.9	(24)	(261.7)	31,538.2
	S-11	300	0	ditto	1	42,735.5	(24)	(261.7)	42,473.8
	S- 2	150	0	Route 10	2	18,911.1	204	2,224.8	21,135.9
	S- 4	250	0	ditto	2	29,376.6	217	2,366.6	31,743.2
	S- 6	300	0	ditto	2	35,945.5	217	2,366.6	38,312.1
Alternative 4, Route 10	S-13	150	0	ditto	2+1	17,015.3	204	2,224.8	19,240.1
	S-14	250	0	ditto	2+1	21,106.8	204	2,224.8	23,331.6
	S-15	300	0	ditto	2+1	24,602.3	217	2,366.6	26,968.9
	S- 1	150	0	ditto	1	10,884.8	204	2,224.8	13,109.6
	S- 3	250	0	ditto	1	13,526.9	217	2,366.6	15,893.5
	S- 5	300	0	ditto	1	14,778.9	217	2,366.6	17,145.5

Project Benefit

The benefits were estimated with a methodology proposed by SINBOL. The benefits used for cost benefit comparison for the purpose of selecting the promising conceptual alternatives was direct tangible benefit only. Direct intangible benefits, such as those accrued from improved navigation, etc., were not taken into consideration for benefit estimation, and neither were indirect tangible and intangible benefits such as those accrued from impacts upon Panama and users.

The nature of direct tangible benefits is defined as the resource cost saving (reduction of vessel operation costs) between "with project" and "without project" conditions. The cost reduction of ocean transportation, called "shipping cost reduction benefit", can be expressed in terms of shipping expenditure per day times the number of voyage days of the ship saved by using the Panamanian Isthmus route.

The estimation of direct tangible benefit or shipping cost reduction benefit was based on potential cargo flows in relation to the Panamanian Isthmus. The potential cargo flows are those for the existing Panama Canal (including its increasing cargo flows) plus shifted cargoes diverting from the Isthmian route due to size constraint. Those cargo flows are defined as those which have potential to pass through the Isthmus due only to shorter distance than any other alternative routes, if any physical and economic restrictions were removed completely. Accordingly, tolls which limits potential cargo flows through the Isthmian route were not taken into account for estimation of the benefit. Actually, maritime business and operation of vessels occur in a much more complicated way. However, it is extremely difficult to trace back the actual behavior and conditions of the maritime business and vessel operation and to reflect them in the estimation of the economic benefits. Therefore, simplified estimates of the potential cargo flows based on the difference in mileage, were adopted.

Selection of the promising alternatives was made by comparing benefit-cost ratio (B/C).

Cargo flows of the Panama Canal are multidirectional on over 80 trade routes involving many types and sizes of ships. Also, cargo flows need to be forecasted on a year by year basis spanning over 50 years of the project life including two specific target years of 2020 and 2060. Therefore, benefits for benefit cost comparison were treated in terms of a "Unit Benefit Method" to avoid complexity in calculations. In using the unit benefit method, the shipping cost reduction benefit is estimated on the basis of the "cargo flow in total" times and "established unit benefit".

The estimation of benefit is based upon data and information taken from the Panama Canal Alternatives Study Documents: WEFA's Interim Report, October 1991; Future Transportation Systems Report, CAS, 1991; WEFA's Final Draft Report, May 1992; PCC Annual Reports; and other related reports, data and information generated by WEFA, the Commodity and Traffic Projections (CTP), Study Contractor.

Cargo Flow

The potential cargo flow related to the Panamanian Isthmus provides the basis for estimation of the shipping cost reduction benefit. It was estimated based on bilateral cargo flows projected by WEFA in their October 1991 Interim Report and May 1992 Final Draft Report and its supplemental document.

The shifted cargoes currently transported via other waterborne routes or by other transportation modes such as the mini-landbridge and other land-bridges were defined as cargoes which may have potentiality to come back to the Panamanian Isthmus route.

The increasing Status Quo cargo is the cargo naturally increased without existing capacity constraints, such as insufficient handling capacity of locks and shortage of lockage water.

The shifted and increasing or incremental cargoes are calculated as a balance of potential cargo flows less those for the Status Quo canal with existing capacity constraints.

The potential cargo flow for the Panamanian Isthmus used for estimation of shipping cost reduction benefit were calculated as follows:

- Potential cargo flows by commodity type

Potential cargo flows were estimated for 1990, 2020 and 2060 by summarizing the results of "WEFA Trade Analysis" from their Interim Report, Oct. 1991 and May 1992 supplemental documents, after identifying trade routes one by one which have a geographically shorter distance than any other routes. The commodity type used for estimation are taken from the WEFA Trade Analysis. The results of potential cargo flow projection by commodity group is as shown in Table 5.5.3-4.

- The cargo flow projection for the Status Quo canal

Cargo flow of the Status Quo canal was made based on PCC Annual Reports and the report of Culebra Cut Widening Study (PCC). There are two kinds of demand forecast for the Status Quo canal; One is to forecast the demand by completely removing physical constraints which limit capacity of the canal, and the other is to forecast the demand under the existing physical constraints, such as insufficient capacity of locks, water shortage, etc. against increasing future demand. As a result of the analysis, the demand for the Status Quo canal under the existing physical constraints was considered to become a saturated condition around the years 2020-2030 due to insufficient capacity of the canal.

The projection of the cargo flow of the saturated Status Quo canal is as summarized in Table 5.5.3-5.

Table 5.5.3-4
Potential Cargo Flow (Unit: Million tons)

	Commodity	1990	2020	2060
1	Bulk grain	52	139	267
2	Iron ore & Concentrates	34	58	41
3	Bauxite/Alumina	4	13	21
4	Coal & Coke	52	112	143
5	Sugar and Molasses	6	5	8
6	Logs & Lumber	16	40	58
7	Minor Bulks	48	82	139
8	Banana	8	15	23
9	Refrigerated foods	5	11	17
10	Vehicles	5	8	8
11	General cargos	20	57	95
12	Petroleum products	36	41	57
13	Chemicals	18	53	83
14	Containerized	35	87	143
15	Oils and fats	1	1	2
16	Gas/Natural	1	4	5
17	Crude oil	11	5	7
	Total	352	731	1,117

Table 5.5.3-5
Status Quo Cargo Flow (Under Saturated Condition)
(Unit: Million tons)

Year	Cargo Flows
1990	157
2000	190
2010	220
2020	240
2030	250
2060	250

- Shifted and increasing (Incremental) cargo flows by commodity type and trade route

The projection of incremental cargo flows related to the Panamanian Isthmus is shown in Table 5.5.3-6. The parameters used to obtain shifted and increasing (incremental) cargo flows by commodity and trade route are:

- Incremental cargo flows are expressed in terms of a balance of potential cargo flows less those for the Status Quo canal.
- In order to calculate the balance, cargo flows for the Status Quo canal for the year 1990 were grouped by the same commodity classification as used for potential cargo flows.
- The incremental cargo flows for the year 2020 were estimated in the same manner.
- The cargo flows for the Status Quo canal for the year 2020 were estimated by constant market share based on those for 1990.
- The US mini land-bridge cargo was estimated to be about 40 million tons in 1990 and is expected to grow up to 100 million ton in 2060.
- The US mini land-bridge cargo was excluded from potential cargo flows because these cargos were assumed to remain carried by the US overland transportation mode.

Table 5.5.3-6
Incremental Cargo Flows Related to Panamanian Isthmus
(Unit: Million tons)

Year	Potential Cargo Flows	Cargo Flows Status Quo	Incremental Cargo Flows	Land Bridge Cargo Flows	Incremental Cargo Excl. Land Bridge
1990	359	157	202	40	162
2000	470	190	280	45	235
2010	580	220	360	50	310
2020	730	240	490	60	430
2030	810	250	560	70	490
2060	1,115	250	865	100	765

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- The incremental cargo flows for the year 2020 were estimated in the same manner.
- The cargo flows for the Status Quo canal for the year 2020 were estimated by constant market share based on those for 1990.
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2030	810	250	560	70	490
2060	1,115	250	865	100	765

- Unit Benefit Estimation

In order to estimate total benefit for each of the conceptual alternatives, the unit (per ton) benefit was first calculated for a series of factors listed below:

- Cargo flow;
- Trade route;
- Ship mix;
- Vessel operation cost; and,
- Transit cost through Panamanian Isthmus.

Vessel operation cost calculation for the Panamanian Isthmus route and its pair alternative route was made by using the computerized simulation method illustrated in Figure 5.5.3-1.

In the process of computing various "unit benefit" factors, the following steps are involved:

- Cargo Flow

The cargo flows used for the unit benefit estimation are based on the incremental cargo flows. They consist of the shifted cargo flows which have geographic potential to transit through the Panamanian Isthmus but are presently diverted from the Panamanian Isthmus mainly due to size of the canal structure against increased size of vessels in the world commercial fleet plus the Status Quo cargo flows which exceed the SQ capacity in the future.

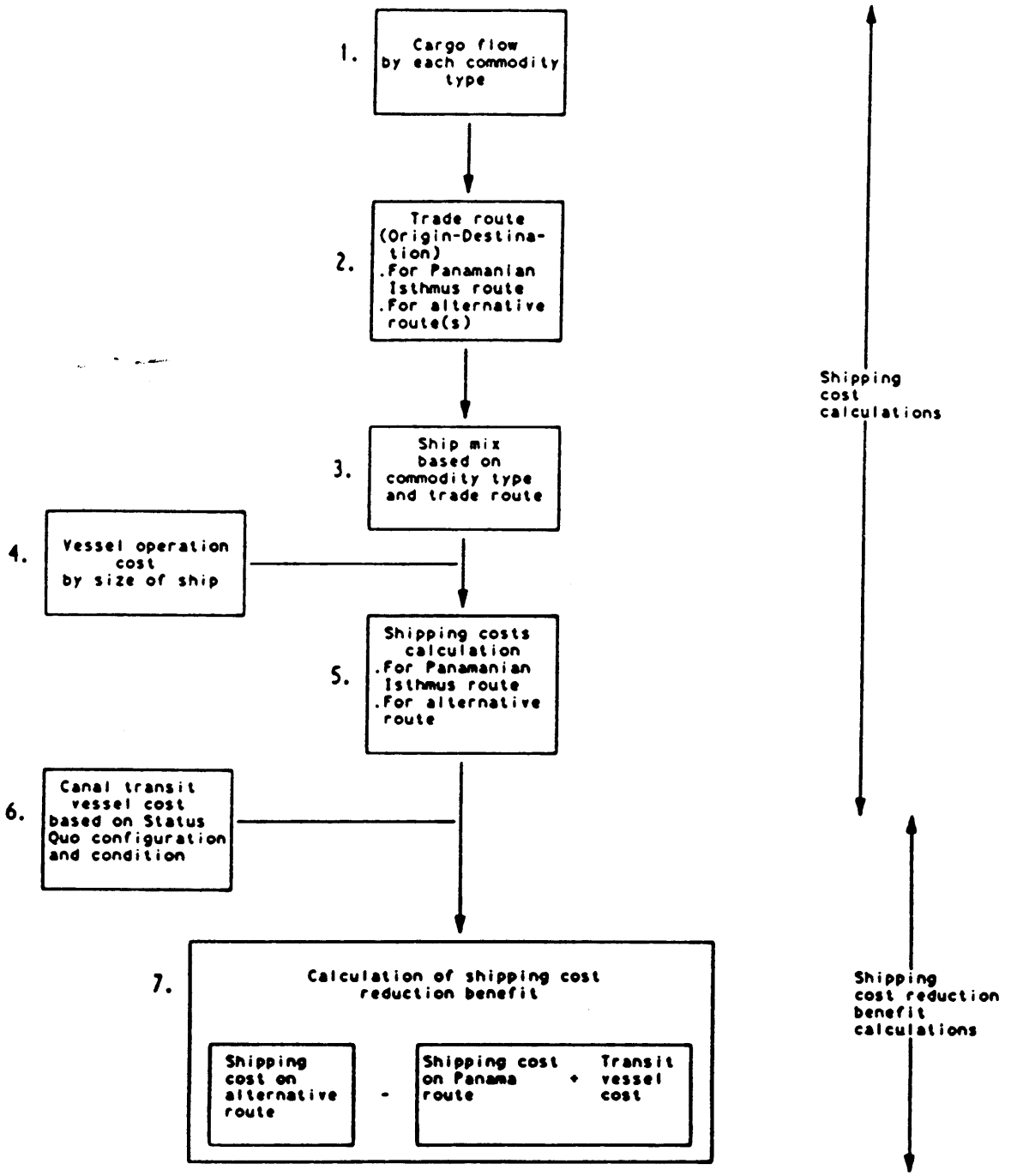
They are identified as major cargo flows by commodity type and by trade route for the years 1990 and 2020, referring to WEFA's World Trade Analysis. The incremental cargo flows used for unit benefit estimation are based on major trade routes only and cover almost 60% of the total cargo flows for 1990 and 75% for 2020, respectively.

- Trade Route

The trade routes used for the unit benefit estimation are the major trade routes only relevant to the major incremental cargo flows on which considerable tonnage of cargo is transported in relation to the Panamanian Isthmus. They were identified for commodity type taking into consideration only the geographical significance of port to port distance. Accordingly, in case a route through the Panamanian Isthmus is apparently shorter than any other alternative routes, it is identified as the trade route for the unit benefit estimation. Conversely, in case an alternative route is shorter or almost the same as the Panamanian Isthmus route, such route is not selected. The trade routes are expressed in terms of origin and destination, and then mileages are calculated based on representative loading and discharging ports on the routes. Port to port mileage is calculated based on the mileage table contained in the report, "Future Transportation Systems - CAS, 1991".

Figure 5.5.3-1

Computerized Simulation for Vessel Operation Cost Calculation



For each trade route, one route is taken via the Panamanian Isthmus and an alternative route is selected as via Cape of Good Hope, via Cape Horn or via Suez Canal. From among these alternative routes, the route providing the geographically shortest distance was identified as the alternative route to the Panamanian Isthmus route. The unit benefit was estimated based on the difference in mileage between the Panamanian Isthmus route and its alternative route.

- Ship Mix

The ship mix as well as the trade route are a key factor in calculation of the unit benefit. For the purpose of computing unit benefit, SINBOL projected the ship mix taking into account size distribution of vessels (dwt), by commodity type on each identified trade route and conditions at relevant ports.

Bulky and less-value cargoes such as coal and coke, grain, crude oil, etc. are apt to employ larger size vessels of 150,000 dwt to 300,000 dwt if a considerable volume of cargo could be collected to the ports. Conversely, specialized commodities are usually transported as a single item of commodity such as banana, vehicle, bauxite, alumina, sugar, molasses, petroleum products, chemicals, etc., and will generally employ smaller size vessels of less than Panamax size (65,000 dwt) mainly due to the difficulty in collecting a large volume of cargoes to the ports. To estimate the ship mix, these conditions are also taken into account.

The distribution of ship sizes was projected for each commodity type for the years of 1990 and 2020 based on the results of analysis of the WEFA's "Final Draft Report - CAS May 1992" and data and information regarding size distribution of vessels by type of vessel and size distribution of shipment of commodities contained in the report of "World Bulk Trade - Fearnleys, 1991" and "Future Transportation Systems - CAS, 1991".

- Vessel Operation Cost

Vessel operation cost used for the unit benefit was estimated for the standardized type of ship, which represents all types of ships, since for planning purposes shape and performance of almost all types of ships are considered to be similar except for full container type ship. Full container type ship usually has a streamlined shape and its speed is a little higher than that of other commercial ships. However, full container type ship represents about 1 % of world commercial fleet in number, and about 5% in tonnage. Its effect on the standardized type of ship is considered to be small.

Because of the nature of vessel operation cost that shows a non-linear shape with respect to the size of ship, vessel operation costs were estimated by sampling eleven sizes of the ship based on the data and information of the report, "Future Transportation Systems - CAS, 1991" and others such as "Lloyds Shipping Economist".

The cost items involved in the vessel operation cost estimation are:

- Capital Cost;
- Vessel cost;
- Preliminary cost; and,
- Managing cost
  - Capital cost
  - Insurance
  - Labor cost
  - Maintenance cost
  - Lubricant cost
  - Consumable cost
  - Overhead
  - Fuel cost
  - Operation fuel cost
  - Anchoring fuel cost
  - Port charges
  - Miscellaneous cost

Per day vessel operation cost with respect to the size of ship under normal voyage conditions was estimated in relation to the Panamanian Isthmus route.

It was estimated on the following assumptions and conditions.

Discount rate for capital recovery	:	10%
Repayment period	:	15 yrs
Speed of ship	:	14 kt/hr
Anchoring days/port	:	3 days

- Transit Cost through Panamanian Isthmus

The transit cost of a ship through the Panamanian Isthmus route was estimated independently from the vessel operation cost, since the transit condition of the ship is different from the operation of the ship traveling on the open sea.

The transit cost varies as a function of both size of the ship and transit time for each of the proposed 36 study cases of the conceptual alternatives. This variation is not so great, and the magnitude of the transit cost is small compared with total vessel operation cost.

The transit cost of ships through the Panamanian Isthmus route used in developing the unit benefit was estimated initially based on the Status Quo configuration and condition.

○ Travel speed of ship	:	7 kt/hr
○ Waiting and clearing time	:	15 hrs
○ Transit time through the Status Quo canal	:	9 hrs

- Unit Benefit Estimation

The "unit (per ton) benefit" was first estimated one by one for each cargo flow of each cargo type on the respective trade route by using an aforementioned computer simulation model. This was done by estimating vessel operation costs on both the Panamanian Isthmus route and the alternative route based upon the ship mix.

After adding the transit cost to the vessel operation cost for the Panamanian Isthmus route, both costs, one for the Panamanian Isthmus route and the other for the alternative route, were compared to compute the shipping cost reduction benefit.

Finally, each "shipping cost reduction benefit" for each cargo flow and trade route was summed up for all types of commodities, and then divided by total volume of shifted cargo flows. This was done in order to establish the "unit benefit" number to be used in estimating the benefits related to the cargo flows of the Panamanian Isthmus .

The unit benefit was calculated for the years of 1990 and 2020.

The unit (per ton) shipping cost reduction benefit was estimated at US$6.10 for 1990 and US$7.60 for 2020. Taking into account the uncertainty of the future world situation. The unit benefit was conservatively taken to be US$6.00 throughout the analysis..

Benefit Calculation

- Benefit from Shipping Cost Reduction

The shipping cost reduction benefit was calculated by multiplying the shifted cargo flows times the unit (per ton) benefit. The calculation was made for the specific target years of 2020 and 2060. Then, the computed benefit for 2020 and 2060 was distributed year by year for the 50 years project operation period commencing from the year 2011 (beginning of the year) to the year 2060.

In order to estimate proportions of cargo flows with respect to the sizes of design ship, the Panamanian Isthmus transit ship mix needed to be estimated.

The estimation of Panamanian Isthmus transit ship mix requires the basic projections of Status Quo transit ship mix and World fleet mix. Then, incremental cargo flows were distributed by sizes of ship. The ship size distribution of cargo for the sizes of design ship is summarized below:

Table 5.5.3-7
Incremental Cargo Flow Proportions

Size of Ships (dwt)	Rate of Cargo Flow Proportions
300,000 & over	1.000
Up to 300,000	0.941
Up to 250,000	0.830
Up to 150,000	0.451
Up to 100,000	0.200

Annual cargo flows up to the respective design ship size were calculated by multiplication of cargo flows with accumulated ship size distribution ratio. Annual benefit up to the respective design ship size was calculated by multiplying annual cargo flows with unit benefit. Capacity evaluation was conducted to assure canal capacity (number of transits) for each study case to meet with the demand projected (the number of transits associated with annual cargo flows). The transit number of ships through the Panamanian Isthmus route was projected at 4,400 transits in the year 2010 and 17,600 transits in 2060. The capacity of transit vessels was also estimated for each of the study cases in 5.3. As a result, 4 cases of the sea level canal, which have single waterway, S-1, S-3 and S-5, and double waterway, S-15, are deemed to be insufficient in capacity compared with the demand of transits to be expected in the final target year of 2060. Furthermore, six cases of S-16, S-17, S-18, S-7, S-9, and S-11 of Route 14S are deemed to have far smaller capacities.

The shipping cost reduction benefits were estimated by stopping the stream of benefit flow at the time when demand intersects the capacity. For cases S-16, S-17, S-18, S-7, S-9 and S-11, benefits were not calculated. Annual benefits were distributed for 50 years project life and were discounted by 10 percent. They were summed up to get the present worth of annual benefits. The present worth of annual benefits is summarized in Table 5.5.3-8.

Table 5.5.3-8
Project Benefit

Conceptual Alternative	Case	Ship Size	Shipping Cost Reduction Benefit
Alternative 1 High Rise	L - 1	100	10,261.8
	L - 4	150	18,430.4
	L - 7	250	26,004.1
	L - 2	100	10,261.8
	L - 5	150	18,430.4
	L - 8	250	26,004.1
	L - 10	100	10,261.8
	L - 13	150	18,430.4
	L - 16	250	26,004.1
Alternative 2 Low Rise	L - 3	100	10,261.8
	L - 6	150	18,430.4
	L - 9	250	26,004.1
	L - 11	100	10,261.8
	L - 14	150	18,430.4
	L - 17	250	26,004.1
	L - 12	100	10,261.8
	L - 15	150	18,430.4
	L - 18	250	26,004.1
Alternative 3 Sea Level Route 14S	S - 8	150	18,430.4
	S - 10	250	26,004.1
	S - 12	300	26,491.1
	S - 16	150	0
	S - 17	250	0
	S - 18	300	0
	S - 7	150	0
	S - 9	250	0
	S - 11	300	0
Alternative 4 Sea Level Route 10	S - 2	150	18,430.4
	S - 4	250	26,004.1
	S - 6	300	26,491.1
	S - 13	150	18,430.4
	S - 14	250	26,004.1
	S - 15	300	26,491.1
	S - 1	150	18,282.1
	S - 3	250	25,766.8
	S - 5	300	26,217.3

5.5.3.7 Optimization of Conceptual Alternatives

The optimization of four conceptual alternatives was made by comparing respective benefits and costs to obtain the optimum condition of each alternative. It was made by grouping 36 study cases into four groups of the alternatives (nine cases by four alternatives), containing three subgroups each, as summarized in Table 5.5.3-1.

The net benefit (B-C), and benefit-cost ratio (B/C) by study case were calculated and are shown in Table 5.5.3-9. The curves of net benefit and benefit-cost ratio with respect to the size of ship are depicted graphically by sub-group of each conceptual alternative.

In order to estimate the optimal size of ship by conceptual alternative, the highest net benefit was selected from each sub-group.

For the purpose of comparison of each conceptual alternative benefit-cost ratio curves of the selected sub-groups are depicted in Figures 5.5.3-2 to 5.5.3-5.

The results of optimum scale of the canal expressed in terms of ship size, and their respective B/C ratios were estimated and summarized as shown in Table 5.5.3-10 and depicted in Figure 5.5.3-6.

Table 5.5.3-10
Optimum Scale of Canal and B/C Ratio

Conceptual Alternative	Optimum Scale of Canal (dwt)	Benefit Cost Ratio (B/C)
High Rise Lock Canal	200,000	1.38
Low Rise Lock Canal	180,000	1.01
Route 14S Sea Level Canal	120,000	0.32
Route 10 Sea Level Canal	250,000	1.62

Table 5.5.3-9

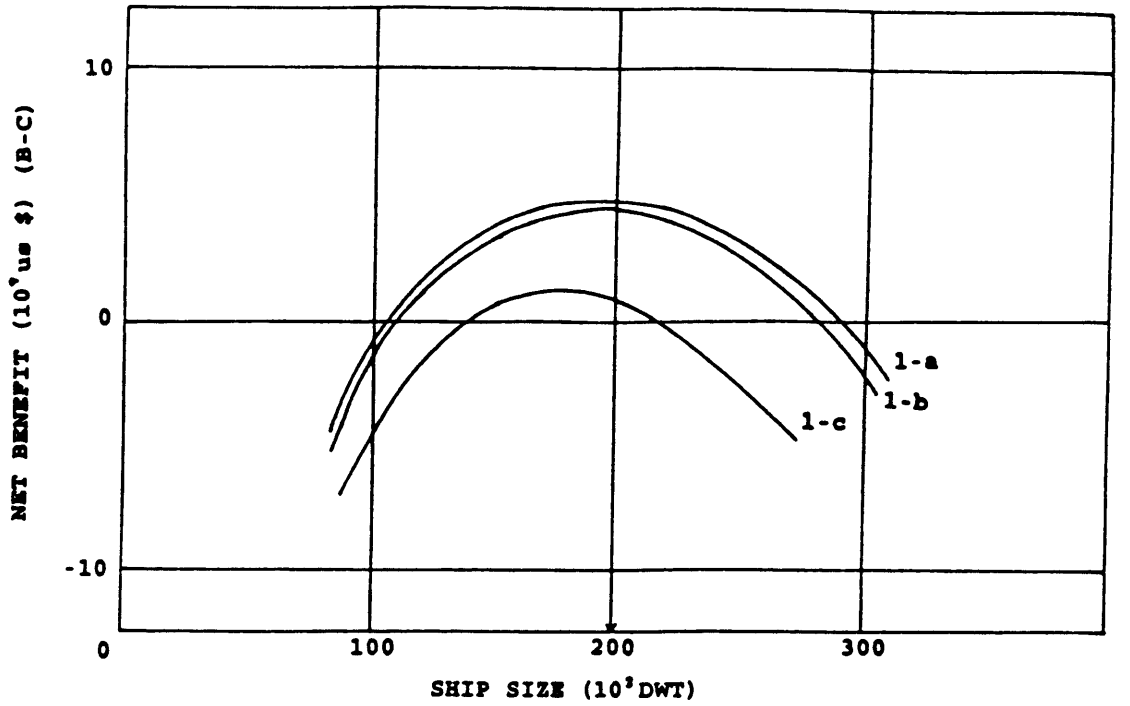
Net Benefits and Benefit Cost Ratios

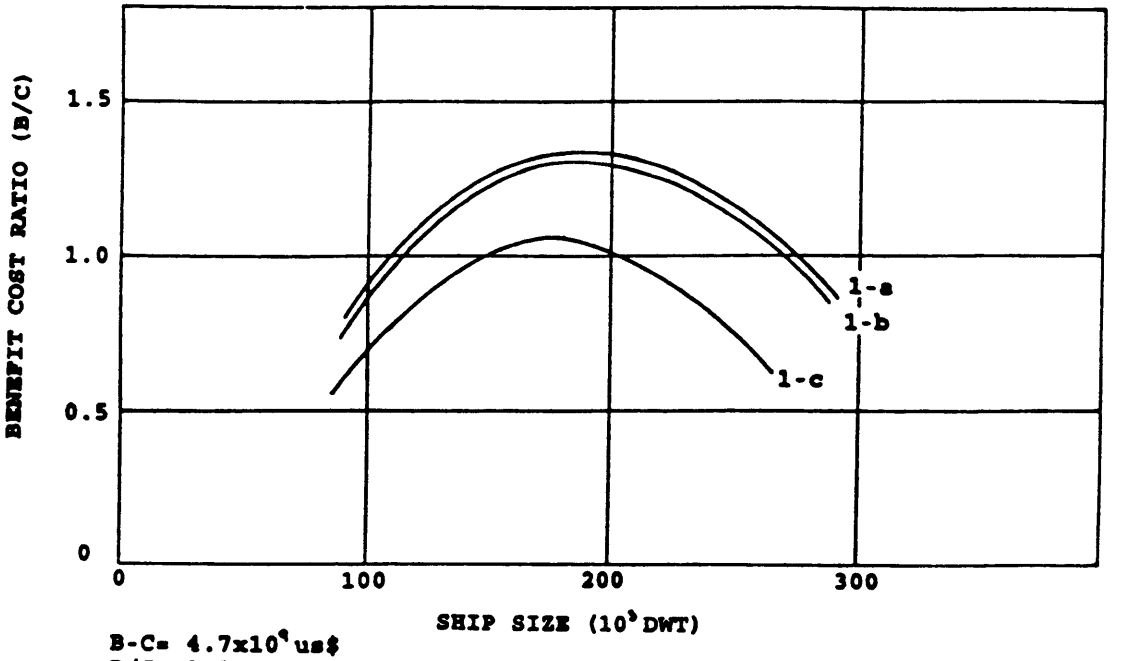
Conceptual Alternative	Sub-Group	Study Case	Ship Size	Benefit	Cost	Net-Benefit	B/C
Alternative 1 High Rise	1 - a	L - 1	100	10,261.80	9,919.90	341.90	1.03
		L - 4	150	18,430.40	13,317.30	5,113.10	1.38
		L - 7	250	26,004.10	22,080.70	3,923.40	1.18
	1 - b	L - 2	100	10,261.80	10,408.00	-146.20	0.99
		L - 5	150	18,430.40	13,735.70	4,694.70	1.34
		L - 8	250	26,004.10	22,729.40	3,274.70	1.14
	1-c	L - 10	100	10,261.80	13,485.90	-3,224.10	0.76
		L - 13	150	18,430.40	17,166.20	1,264.20	1.07
		L - 16	250	26,004.10	35,411.10	-9,407.00	0.73
Alternative 2 Low Rise	2 - a	L - 3	100	10,261.80	13,848.10	-3,586.30	0.74
		L - 6	150	18,430.40	18,236.90	193.50	1.01
		L - 9	250	26,004.80	30,407.10	-4,402.30	0.86
	2 - b	L - 11	100	10,261.80	15,046.30	-4,784.50	0.68
		L - 14	150	18,430.40	20,068.40	-1,638.00	0.92
		L - 17	250	26,004.10	29,900.30	-3,896.20	0.87
	2 - c	L - 12	100	10,261.80	22,049.90	-11,788.10	0.47
		L - 15	150	18,430.40	31,264.70	-12,834.30	0.59
		L - 18	250	26,004.10	46,537.00	-20,532.90	0.56
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	18,430.40	58,112.40	-39,682.00	0.32
		S - 10	250	26,004.10	80,786.90	-54,782.80	0.32
		S - 12	300	26,491.10	102,660.30	-76,169.20	0.26
	3 - b	S - 16	150	0.00	46,728.80	-46,728.80	0
		S - 17	250	0.00	59,739.70	-59,739.70	0
		S - 18	300	0.00	67,024.40	-67,024.40	0
	3 - c	S - 7	150	0.00	24,263.80	-24,263.80	0
		S - 9	250	0.00	31,538.20	-31,538.20	0
		S - 11	300	0.00	42,473.80	-42,473.80	0
Alternative 4 Sea Level Route 10	4 - a	S - 2	150	18,430.40	21,135.90	-2,705.50	0.87
		S - 4	250	26,004.10	31,743.20	-5,739.10	0.82
		S - 6	300	26,491.10	38,312.10	-11,821.00	0.69
	4 - b	S - 13	150	18,430.40	19,240.10	-809.70	0.96
		S - 14	250	26,004.10	23,331.60	2,672.50	1.11
		S - 15	300	26,491.10	26,968.90	-477.80	0.98
	4 - c	S - 1	150	18,282.10	13,109.60	5,172.50	1.39
		S - 3	250	25,766.80	15,893.50	9,873.30	1.62
		S - 5	300	26,217.30	17,145.50	9,071.80	1.53

Figure 5.5.3-2

Net Benefit and Benefit Cost Ratio

High Rise Alternative



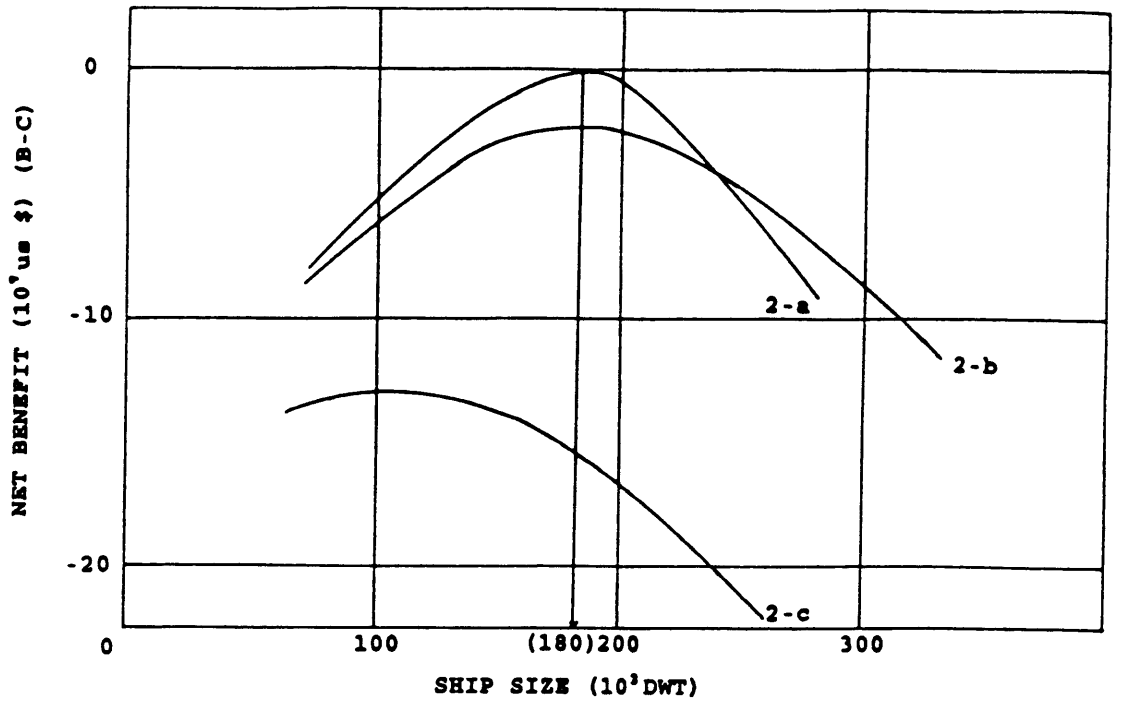


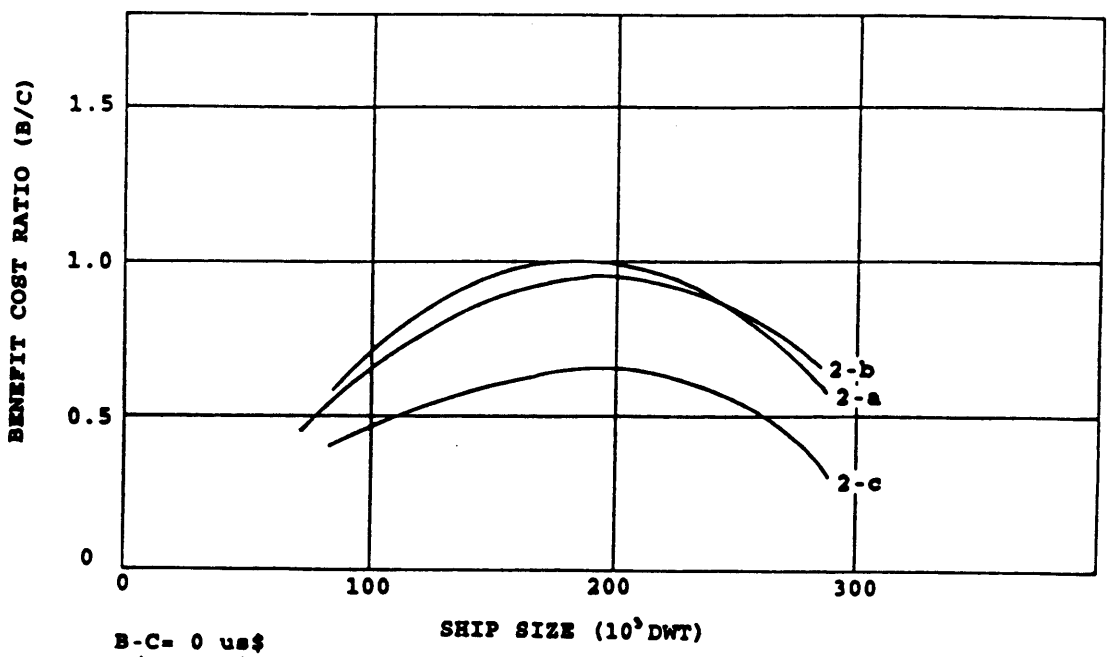
B-C= 4.7x10⁶us$
B/C= 1.38
OPTIMUM SHIP SIZE
= 200,000 DWT

Figure 5.5.3-3

Net Benefit and Benefit Cost Ratio

Low Rise Alternative



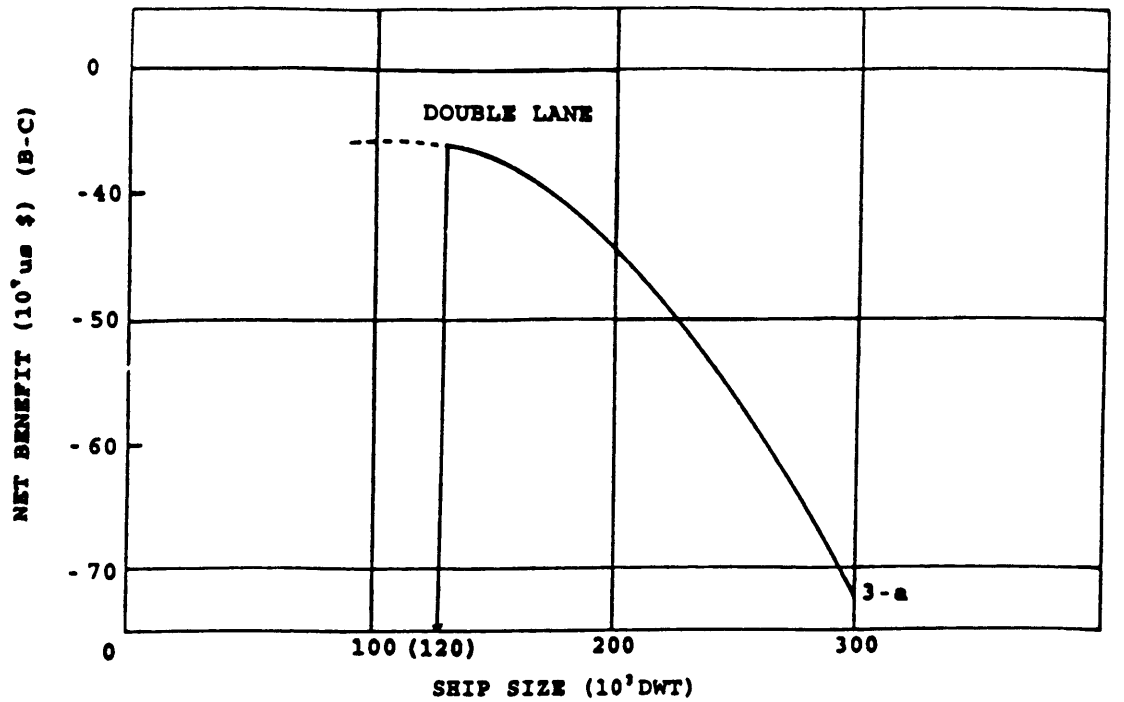


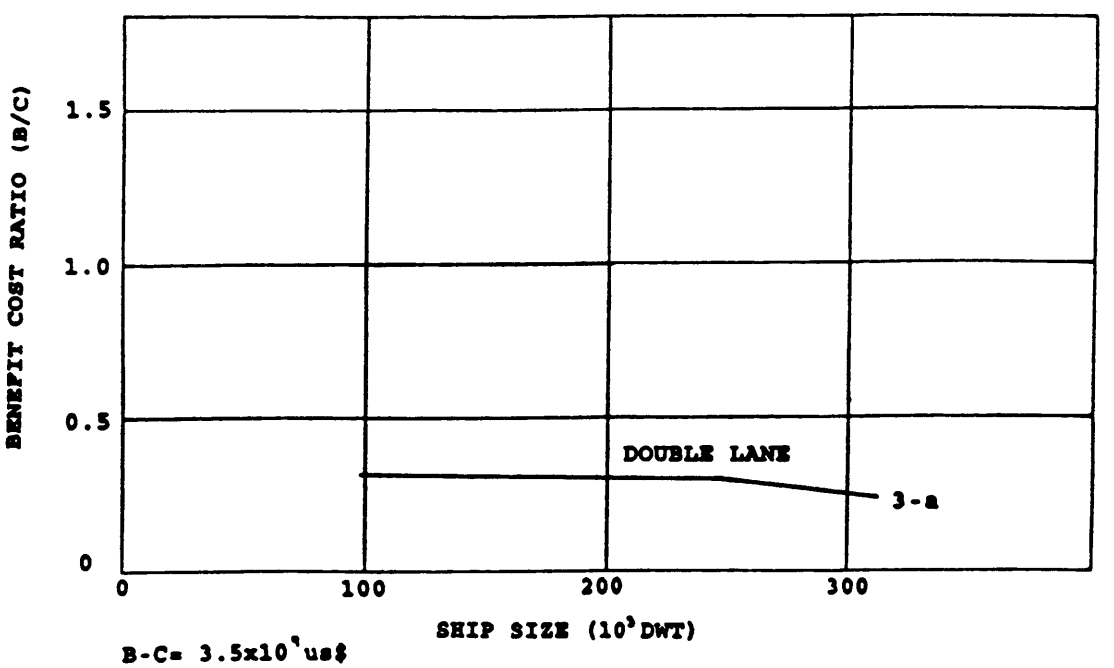
B-C= 0 us$
B/C= 1.01
OPTIMUM SHIP SIZE
= 180.000 DWT

Figure 5.5.3-4

Net Benefit and Benefit Cost Ratio

Route 14S Alternative



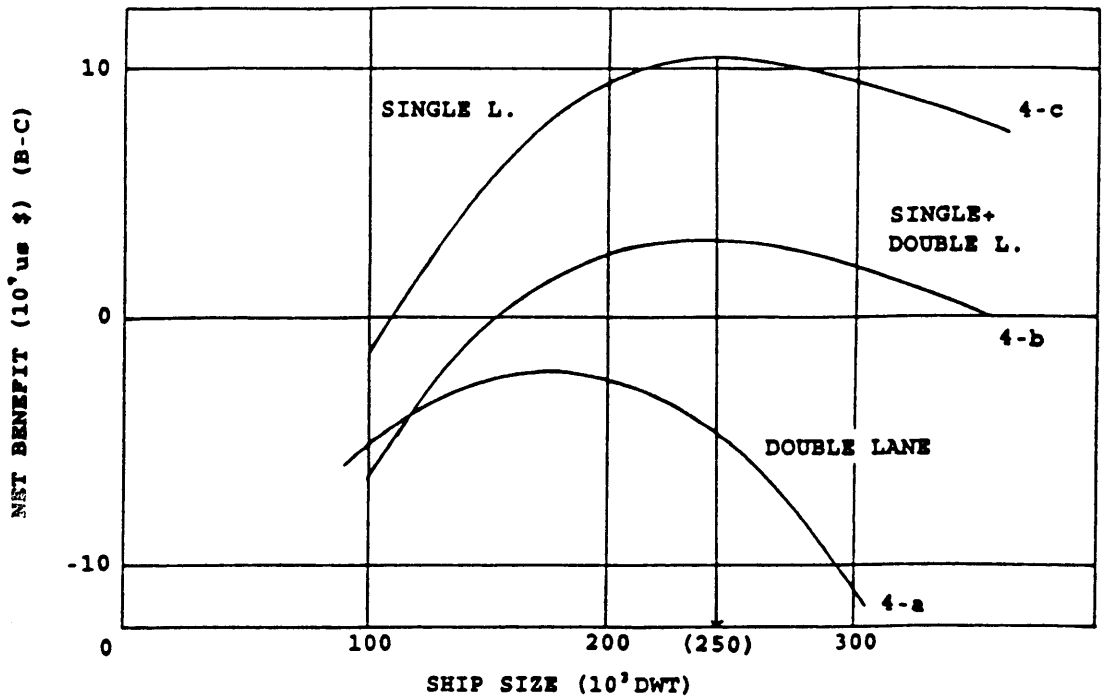


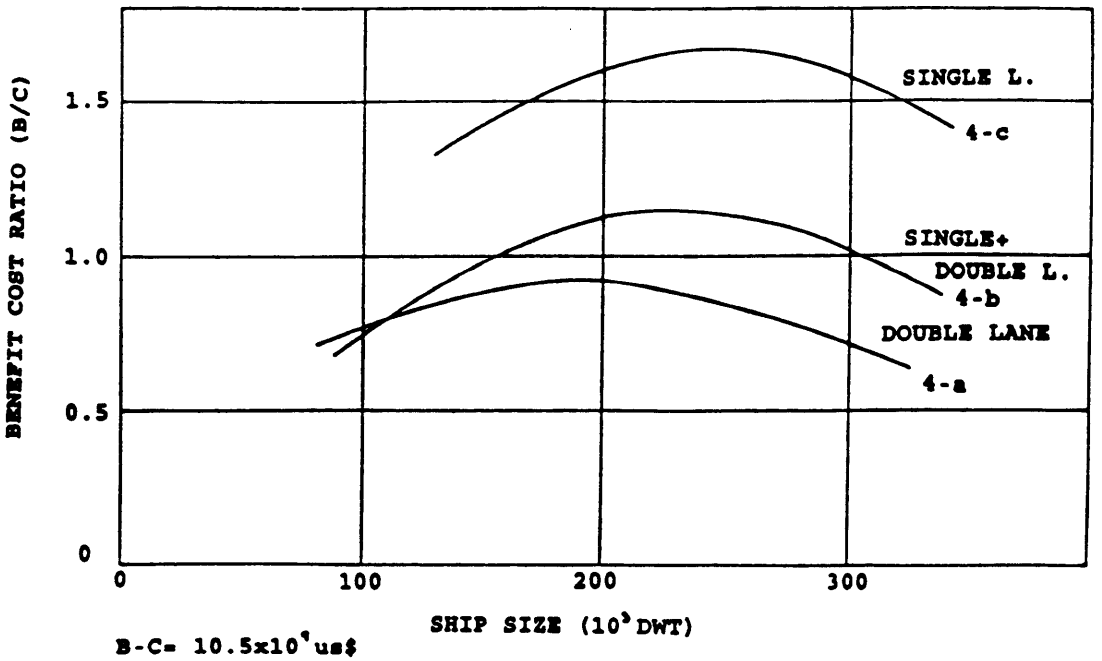
B-C= 3.5x10⁶us$
B/C= 0.32
OPTIMUM SHIP SIZE
= 120.000 DWT

Figure 5.5.3-5

Net Benefit and Benefit Cost Ratio

Route 10 Alternative

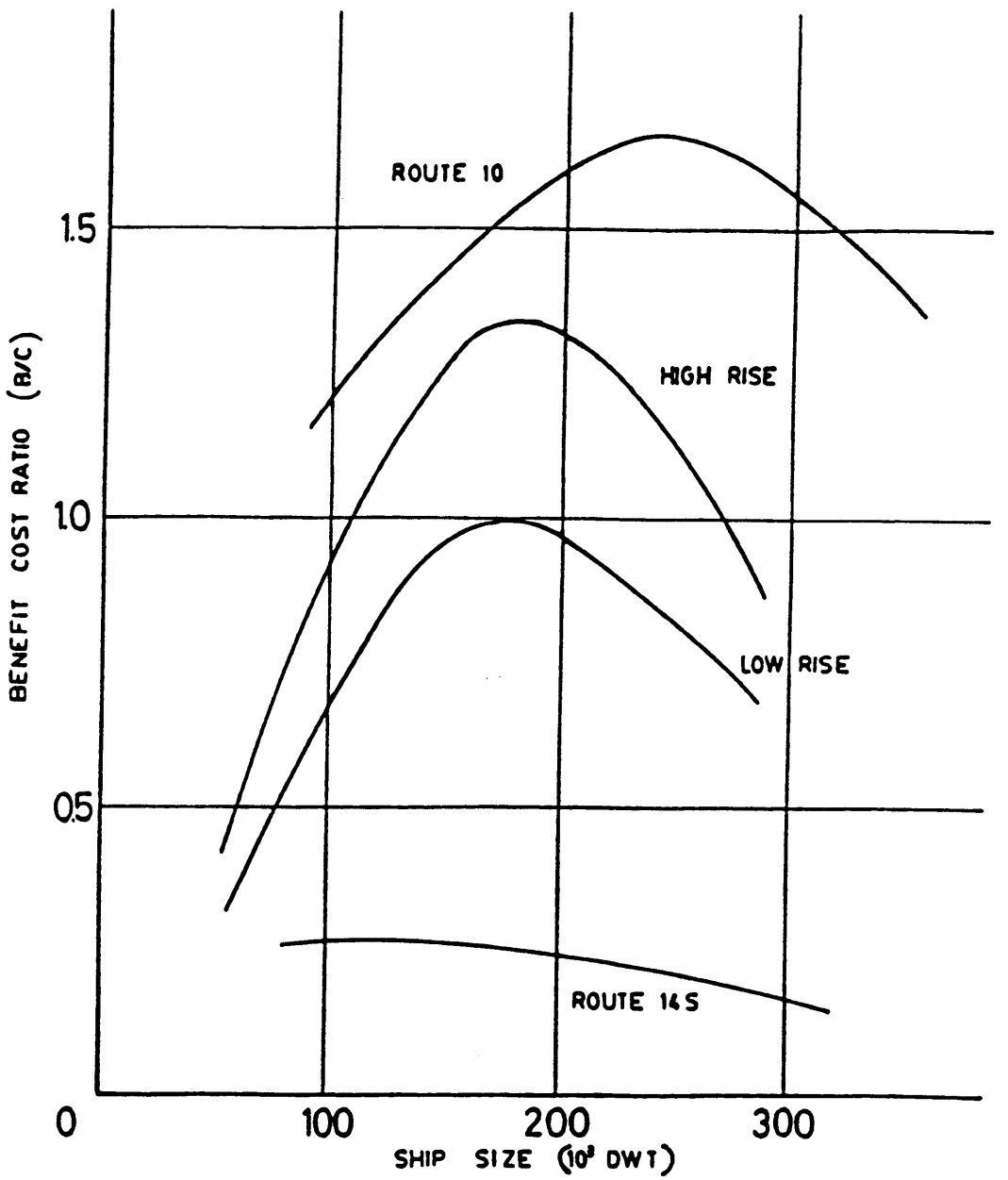




B-C= 10.5x10⁶us$
B/C= 1.62
OPTIMUM SHIP SIZE
= 250,000 DWT

Figure 5.5.3-6

Comparison of Benefit Cost Ratio for Each Conceptual Alternative



5.5.4 Qualitative Evaluation of Conceptual Alternatives

Introduction

In addition to the check of engineering feasibility and benefit-cost comparison or quantitative evaluation of the conceptual alternatives, the qualitative evaluation for the conceptual alternatives was made from various viewpoints.

The evaluation was made mostly by using a five point rating method, and the major items are:

1) Engineering soundness;

2) Adaptability for future expansion;

3) Impact on existing canal;

4) Potential for ecological/biological impact; and,

5) Potential for socioeconomic/cultural impact.

Engineering Soundness

After checking the substantial items of the engineering feasibility, engineering soundness of the conceptual alternatives was evaluated mostly from overall viewpoint of the construction and operation of the project including engineering, design, construction and cost evaluation. They are excavation and civil works, navigation and safety, and constructability and schedule.

The engineering soundness assessed the High Rise Lock Canal is the most desirable conceptual alternative and the Route 10 Sea Level Canal, would also have attractive qualities requiring further analysis in the following phase of the study.

Adaptability for Future Expansion

The adaptability of conceptual alternatives to future expansion was assessed primarily based on their constructability and operational requirements of the potential expansion. They are further evaluated from geological conditions for widening and deepening of the canal, proportion of dredging work in all excavation operation, number of locks, lockage water management, navigation control and tidal current control. As a result of the evaluation, future expansion is somewhat difficult for both lock canals (High Rise and Low Rise), and is adaptable for both sea level canals (Route 14S and Route 10). Accordingly, Route 10 Sea Level Canal got the highest score, followed by Route 14S Sea Level Canal.

Impact on Existing Canal

The existing Panama Canal is very important to the Republic of Panama and the world trade. Delays and interruptions caused by future construction of any of the four conceptual alternatives may have serious consequences upon the Republic's revenue source and the canal contribution to the world commerce.

Major attributes impacting on the canal operator and users were considered in the evaluation. Other impacts such as environmental, social and cultural are not included. The evaluation is made for impact of construction on navigation and vice versa, need of demolition of structures, change in Summit Lake water level, flooding, interruption of navigation, mitigation of potential shortage of lockage water as a result of barrier dam construction, need of massive barrier dams and spillways to preserve Gatun lake, loss of hydroelectric power generation, and impact due to long closure of the existing canal.

As a result of the evaluation, the High Rise lock canal and Route 10 sea level canal have only a slight impact on the existing canal and could be considered the desirable conceptual alternatives. The Low Rise Lock Canal and Route 14S Sea Level Canal will cause some to heavy impacts on the existing canal, which may be considered unacceptable by both the canal operator and users.

Potential for Ecological/Biological Impact

The evaluation of the conceptual alternatives was made on the basis of the established appropriate criteria and the areas potentially impacted by the construction and operation of the alternatives. Ecological factors used for the evaluation is negative terrestrial conservation, negative freshwater conservation, impact to marine species, wildlife barrier, impact to Gatun Lake and oceanographic impacts.

Based on judgements of the extent of potential impacts, relative importance of the criterion, ease of mitigation and reliability of data, each conceptual alternative was evaluated. As a result, Route 14S Sea Level Canal has a lower potential for adverse environmental impact than Route 10 Sea Level Canal. This is because Route 10 impacts new areas which are of known environmental importance; principally an extensive area of mangrove estuary at the north of Rio Caimito, and the valuable fishery resources of Chorrera Bay. The extensive nature of new excavation and construction activities along the length of Route 10 Sea Level Canal are contributes to this impact potential. Conversely, Route 14S Sea Level Canal utilizes mostly channels, cuts, and facilities of the existing canal. As such, it does not provide as great impact source as Route 10 Sea Level Canal. High Rise Lock Canal has a lower potential for adverse impact than Low Rise Lock Canal. The main reason for this difference involves the amount of changes that will be made to Gatun Lake, through the placement of massive barrier dams, and the potential for Gatun Lake salinization.

In conclusion, High Rise Lock Canal is the most acceptable conceptual alternative on the basis of ecological impact, and Low Rise Lock Canal the second acceptable alternative.

Potential for Socioeconomic/Cultural Impact

The evaluation of the conceptual alternatives from the socioeconomic/cultural viewpoint was made by comparing the potential socioeconomic and land use impacts which may arise from the construction of the new canal. The assessment of impacts was made for demographic issues, employment issues, land use issues and cultural resources issues. Based on a review of obvious socioeconomic, land use and cultural resources issues, Route 14S Sea Level Canal is the preferred alternative and Route 10 Sea Level Canal is the least preferred alternative. High Rise and Low Rise canals are in between. A weighing heavily in this conclusion is the demographic concerns related to relocation of population.

5.5.5 Potential Conceptual Alternatives Deserving Further Study and Analysis

As the result of the overall assessment of quantitative and qualitative evaluations, the following two potential conceptual alternatives for further study and analysis were selected by SINBOL and recommended to CAS.

Table 5.5.5-1
Selected Alternatives

Conceptual Alternative	Ship size (1,000 dwt)	No. of Lanes		Remarks
		Channel	Lock /Gates	
High Rise Lock Canal	150	2	1	Summit Lake at 85 and 90 feet Existing Canal Alignment
High Rise Lock Canal	200	2	1	Summit Lake at 85 and 90 feet Existing Canal Alignment
Sea Level Canal Route 10	250	1	1	Tidal gates, 2 lane approach channel
Sea Level Canal Route 10	250	1	3	Tidal gates, 2 lane approach channels
Sea Level Canal Route 10	250	1	1 + 3	Tidal gate (1) and tidal locks (3) 2 lane approach channel

(1) High Rise Lock Canal with design ship size between 150,000 dwt and 200,000 dwt

(2) Route 10 Sea Level Canal with design ship size of around 250,000 dwt

At the direction of the Board of Commissioners, CAS selected the following five cases to be evaluated in the subsequent Phase II and III Studies, as shown in Table 5.5.5-1.

5.5.6 Review of Prescreening Process with Data of Phase II and Phase III Studies

The prescreening process was executed with preliminary figures of traffic demand, cost estimates and benefit calculations which were made available at the completion of Phase I studies on CTP, OCCE and ECE. These Phase I studies have been upgraded in the subsequent Phase II studies. The prescreening process was a reviewed applying such upgraded figures of costs and benefits as worked out during Phase II and Phase III studies.

Adjustment of Costs

In Phase II ECE Study, the construction cost of the 150,000 dwt High Rise Lock Canal was estimated, which corresponds to the Study Case L-5 for the prescreening, and that of 250,000 dwt Sea Level Canal, Route 10, was also estimated which corresponds to the Study Case S-3 for the prescreening. The estimated costs are as follows (1990 US$ Million).

	Phase I	Phase II	Change (Phase II/ Phase I)
150,000 dwt HRLC, Single Lane Lock	6,773[1]	8,761[3]	1.29
250,000 dwt SLC, Route 10 Single Lane Channel	7,413[2]	11,551[4]	1.56

Notes: 1 Capital cost for L-5 is US$ 8,177 million from Table 5.5.3-2.
Cost reduction of single lane lock adjustment from double lane lock for L-5 is US$ 1,404 million as shown in Table 5.4.6-2.
Capital cost for L-5 with single lane lock is, therefore, US$ 6,773 million (8,177 - 1,404).

2 Capital cost for S-3 is US$ 7,413 million from Table 5.5.3-2.

3 Cost for High Rise Lock Canal of 150,000 dwt design ship size with 2-lanes channel and 1-lane lock is US$ 8,761 million as shown in Table 7.1.6-1.

4/ Cost for Sea Level Canal, Route 10, with Tidal Gates and Single Lane Channel is US$ 11,551 million as shown in Table 7.1.6-1.

From the above, the following cost adjustments are made to the costs presented in Table 5.5.3-2.

Conceptual Alternative	Cost Adjustments
High Rise Lock Canal	29% increase
Low Rise Lock Canal	29% increase
Sea Level Canal, Route 14S	no adjustment
Sea Level Canal, Route 10	56% increase

Benefit Adjustment

Total present values of benefit are compared in Phase I and Phase III as follows (1990 US$ Million):

Design Ship size	Phase I 1/	Phase III 2/
100,000 dwt	10,260 (56)	-
150,000 dwt	18,430 (100)	4,723 (100)
200,000 dwt	-	4,881 (103)
250,000 dwt	26,000 (141)	5,017 (106)
300,000 dwt	26,490 (144)	-

Notes: 1 Total benefit discounted to 2011 with a discount rate of 10% during the evaluation period of 50 years from 2011 to 2060. Refer to Table 5.5.3-8.

2 Total benefit discounted to 2020 with a discount rate of 8% during the evaluation period of 61 years from 2020 to 2080. Refer to Table 8.2.3-2 for 150,000 dwt, Table 8.2.3-3 for 200,000 dwt and Table 8.3.3.7-1 for 250,000 dwt.

Figures in parenthesis give index when 150,000 dwt value is 100.

The Phase III benefit study indicated that the benefit of 250,000 dwt is by only 6% larger than that of 150,000 dwt, while in the Phase I benefit study the benefit of 250,000 dwt was by more than 40% larger than that of 150,000 dwt. Therefore, the benefits in the prescreening are adjusted in the following manner:

Design Ship Size	Benefit Adjustment
100,000 dwt	No adjustment
150,000 dwt	No adjustment
250,000 dwt	6% more than the 150,000 dwt benefit
300,000 dwt	7% more than the 150,000 dwt benefit

Review of Prescreening

The benefit cost ratios shown in Table 5.5.3-9 are revised according to the proposed adjustment of costs and benefits in the previous sub-sections as shown in Table 5.5.6-1.

The revised benefit cost ratios shown in Table 5.5.6-1 confirmed the result of the prescreening based on the original benefit cost ratios shown in Table 5.5.3-9 that:

(1) High Rise Lock Canal is the most promising;

(2) The second best conceptual alternative is the Sea Level Canal, Route 10;

(3) The third best conceptual alternative is the Low Rise Lock Canal; and,

(4) The least promising conceptual alternative is the Sea Level Canal, Route 14S.

Table 5.5.6-1

Revised Net Benefits and Benefit Cost Ratios/Based on Phase II and III Data

Conceptual Alternative	Sub-Group	Study Case	Ship Size (10^3 dwt)	Benefit (B)	Cost (C)	B/C
Alternative 1 High Rise	1 - a	L - 1	100	10,261.80	9,919 x 1.29	0.80
		L - 4	150	18,430.40	13,317 x 1.29	1.07
		L - 7	250	19,536.20	22,081 x 1.29	0.69
	1 - b	L - 2	100	10,261.80	10,408 x 1.29	0.76
		L - 5	150	18,430.40	13,736 x 1.29	1.04
		L - 8	250	19,536.20	22,729 x 1.29	0.67
	1-c	L - 10	100	10,261.80	13,486 x 1.29	0.59
		L - 13	150	18,430.40	17,166 x 1.29	0.83
		L - 16	250	19,536.20	35,411 x 1.29	0.43
Alternative 2 Low Rise	2 - a	L - 3	100	10,261.80	13,848 x 1.29	0.57
		L - 6	150	18,430.40	18,237 x 1.29	0.78
		L - 9	250	19,536.20	30,407 x 1.29	0.50
	2 - b	L - 11	100	10,261.80	15,046 x 1.29	0.53
		L - 14	150	18,430.40	20,068 x 1.29	0.71
		L - 17	250	19,536.20	29,900 x 1.29	0.51
	2 - c	L - 12	100	10,261.80	22,050 x 1.29	0.36
		L - 15	150	18,430.40	31,265 x 1.29	0.46
		L - 18	250	19,536.20	46,537 x 1.29	0.33
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	18,430.40	58,112.40	0.32
		S - 10	250	19,536.20	80,786.90	0.24
		S - 12	300	19,720.50	2,660.30	0.19
	3 - b	S - 16	150	0.00	46,728.80	0
		S - 17	250	0.00	59,739.70	0
		S - 18	300	0.00	67,024.40	0
	3 - c	S - 7	150	0.00	24,263.80	0
		S - 9	250	0.00	31,538.20	0
		S - 11	300	0.00	42,473.80	0
Alternative 4 Sea Level Route 10	4 - a	S - 2	150	18,430.40	21,135.80 x 1.56	0.56
		S - 4	250	19,536.20	31,743.20 x 1.56	0.39
		S - 6	300	19,720.50	38,312.10 x 1.56	0.33
	4 - b	S - 13	150	18,430.40	19,240.10 x 1.56	0.61
		S - 14	250	19,536.20	23,331.60 x 1.56	0.54
		S - 15	300	19,720.50	26,968.90 x 1.56	0.47
	4 - c	S - 1	150	18,282.10	13,109.60 x 1.56	0.89
		S - 3	250	19,379.0	15,893.50 x 1.56	0.78
		S - 5	300	19,561.80	17,145.50 x 1.56	0.73

List of Tables and Sources

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5.1.3-1	Summary of Substantial Concepts Source: SINBOL
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5.2.4-1	WEFA's Estimated Panama Canal Commodity Flows Source: Final Report Phase I CTP Study
5.2.5-1	Projected Total Panama Canal Transits Source: Final Report Phase I CTP Study
5.3.2-1	Results of LATIS Analysis Source: Draft Final Report, Phase I OCCE Study
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5.3.6-1	Transit Delay and Estimated Capacity Source: Draft Final Report, Appendix III, Phase I OCCE Study
5.3.6-2	Estimated Capacity Source: Draft Final Report, Appendix III, Phase I OCCE Study
5.4.2-1	Design Ships and Lock Chamber Dimension Source: Phase 1, Preliminary Engineering and Cost Estimates, February 1992, CAS
5.4.3-1	Annual Lockage Water and Water Balance Table Source: Phase 1, Preliminary Engineering and Cost Estimates, February 1992, CAS
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5.4.6-1 and -2	Lock Canal Costs Source: Phase 1, Preliminary Engineering and Cost Estimates, February 1992, CAS
5.4.6-3 and -4	Sea Level Canal Costs Source: Phase 1, Preliminary Engineering and Cost Estimates, February 1992, CAS
5.5.3-1	Study Cases for Optimization Source: SINBOL

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A Feasibility Report

6.0 Phase II-Demand Analysis and Engineering

6.1 Commodity and Traffic Projections, Phase II

6.1.1 Introduction

The Phase I Commodity and Traffic Projections Study (Phase I CTP Study) was undertaken to provide basic data for preliminary benefit calculations for prescreening of canal alternatives. The Phase II CTP Study was prepared to provide inputs for subsequent Phase III Component Studies, i.e., the Economic Analysis and Impact on Users Study (EAIU Study) and the Financing Scheme, Financial Analysis, and Management Arrangements Study (FFMS Study).

The Phase II CTP Study was conducted based on the following conditions.

(1) As a result of prescreening of canal alternatives based on the Phase I CTP Study, the cases for the Phase II CTP Study were defined as follows in terms of maximum design ship size.

- 65,000 dwt (Status Quo)
- 150,000 dwt (High Rise Lock Canal Alternative)
- 200,000 dwt (High Rise Lock Canal Alternative)
- 250,000 dwt (Sea Level Canal Alternative)

(2) The Study did not take into account the following issues.

- The effect of the new canal on the world economy, global trade in aggregate and on patterns of world trade.
- The effects of projected improvements in infrastructure in Panama, such as the Centerport project.

(3) The base year for the Study was 1990 and the forecast periods were the years 2020 and 2060.

(4) The Study was based on "without toll" scenario and "with capacity constraint" condition through the Panamanian Isthmus.

The CTP Component Contractor first reviewed the available data and previous approaches. Then, the following steps were carried out:

(1) World trade for 2020 and 2060 was forecast in sufficient detail to project the world vessel fleet by ship type and size category for 2020 and 2060.

(2) The world vessel fleet was projected for each of the study cases.

(3) Comparative costs of shipping were estimated for each type of cargo by each type of ship in each ship size range through the Panama Canal and on bypass routes, including routes which include surface transport across the United States, the so-called "landbridge."

(4) Commodity and transit databases were developed from data provided via CAS by the Panama Canal Commission (PCC) for years 1986-1990.

(5) Part of the bilateral trade among nations on a route and commodity basis that represented the maximum "potential" commodity flows through the Isthmus, was determined in the absence of any physical, economic or other impediment.

(6) Potential Panama Canal trade was forecast for 2020 and 2060 from the world trade forecasts.

The fundamental approach of the Study was to develop forecasts of commodity and traffic flows by combining:

(1) the potential trade projections,

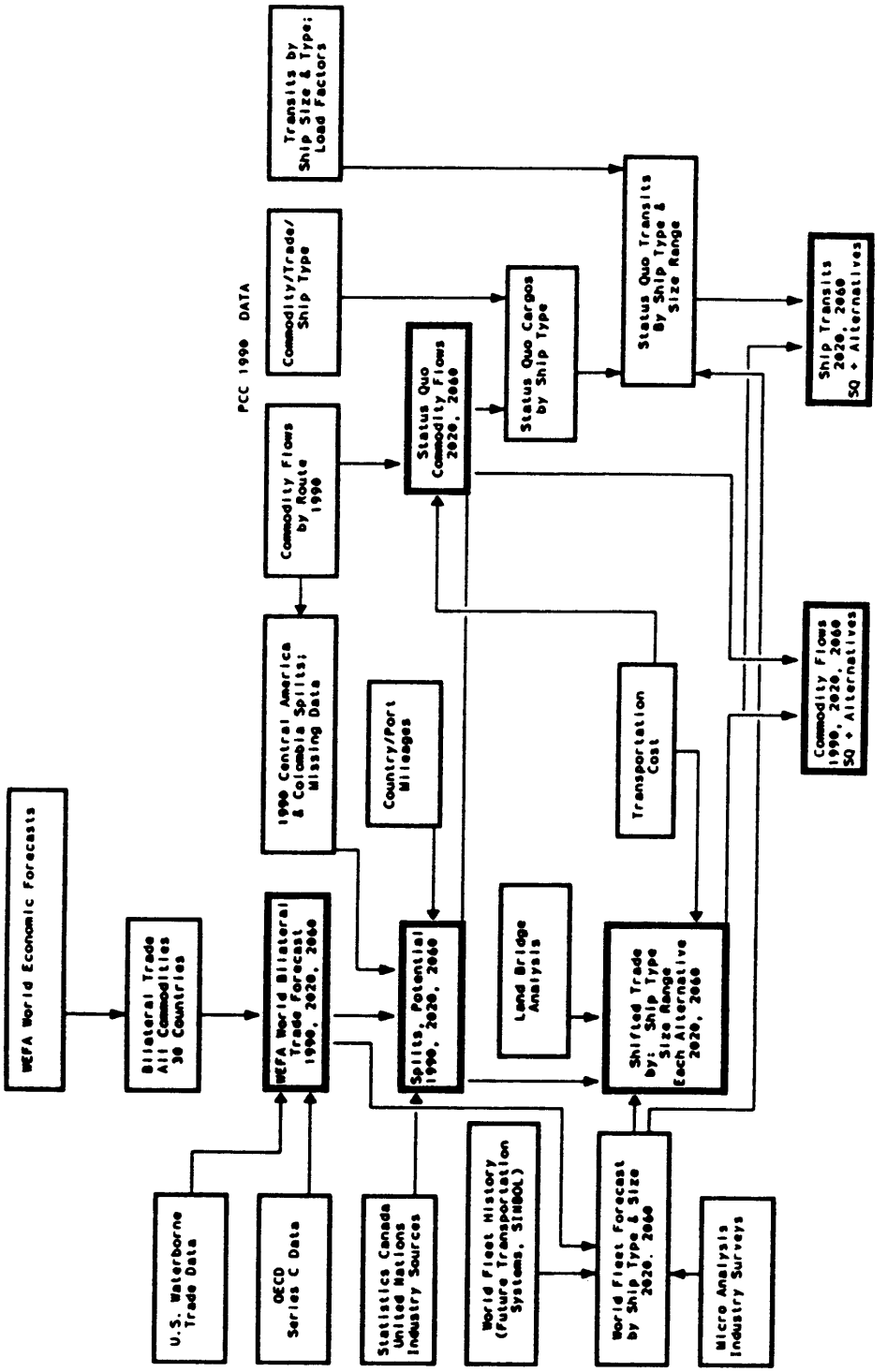
(2) the world fleet projections,

(3) the comparative shipping and landbridge economics, and

(4) the base year PCC data on the commodity composition of ship cargoes by ship type, the loading of cargoes by ship type and size range, and the size distribution by ship type of Canal shipping.

The major components of the Study and their interrelations are shown in Fig. 6.1.1-1. An important aspect of the flow chart of the Phase II CTP Study shown in Fig. 6.1.1-1 is that the bilateral and potential trade analysis was based on world trade flow data collected from OECD and U.N. and vessel transit projection was based on PCC commodity flow data which for many commodities did not agree with the bilateral trade data. Matching of these different sets of data was one of the most difficult tasks of the Phase II CTP Study.

Figure 6.1.1-1
Flow Chart of the CTP Study



6.1.2 Approach

Because of the very long term nature of this Study, several departures from and additions to the normal methods had to be incorporated. In the case of the world economic and trade forecasts, WEFA shifted from the stochastically based to a judgmental approach to the forecasts beyond the year 2010 of the key variables such as population, productivity, and the relation of trade to output. On the vessel side, extensive research was carried out as to the technical innovations planned or probable during the course of the Study. In light of this research, it was decided to adopt the following principles in developing a scenario of techno-economic changes likely to be achieved during the forecast period.

- Bearing in mind that some ships on order in 1991 would still be operational in the year 2020, the level of technology incorporated in the newest ships of 1991 was assumed to be the average level of technology in the year 2020.

- For a period from 2020 to 2060, the 2020 level of technology was assumed to persist except for some cases where it was apparent that change would be made. This included continuing trends in vessel propulsion and manning efficiencies. A particular conclusion in this regard was the requirement for skilled crew leading to the eventual disappearance of cheap labor from the global fleet.

Because only one world economics scenario was used for the Study, "conservative" assumptions were made. Global warming issue, however, was not assumed to become a serious policy issue.

6.1.3 World Economic and Trade Projections

In preparing the projections, considerations were given to the following factors.

- Geopolitical Factors
- Environmental Policy
- Population, Labor Force and Employment
- Technological Innovation
- Productivity by Region
- Transportation Costs
- Structural Change
- Terms of Trade

6.1.4 Bilateral Trade Relative to the Panamanian Isthmus

The term "bilateral trade" refers to the total trade between two countries on the Canal routes. In case of countries facing both Atlantic and Pacific Oceans, the countries were divided into two regions, West Coast and East Coast. The world bilateral or inter-regional trades were projected on a route and commodity basis.

Both the historical and forecast bilateral trades were estimated assuming the existing Panama Canal to be in place. In this Study possible changes were not estimated that would occur in bilateral trade if there were no impediments to maritime traffic across the Panamanian Isthmus. If these possible changes had been taken into account in the Bilateral Trade Analysis, the following effects would be conceivable.

(1) The reduced cost of the Isthmus route (no toll scenario) and its availability to larger ships than now allowed in the Panama Canal (no ship size limit) would shift patterns of bilateral trade. To name one example, the share of Colombian coal going to Asian markets would probably rise relative to the share going to European markets.

(2) The reduced overall costs of transportation would have the effect of increasing consumption and production in the world economy. This effect is briefly discussed in Section 7.5 Impacts upon Users.

The 66 bilateral trade routes, or inter-regional trade routes, were picked up for subsequent Potential Trade Analysis based on the PCC data on the trade routes.

6.1.5 Potential Commodity Flow through the Isthmus

Potential trade is that part of the bilateral trade that might have passed or may pass through the Isthmus in the absence of any impediment. The approach of this potential trade analysis was to determine potential trade on a mileage basis. Country-to-country and port-to-port mileages were compared between each Panama Canal route and the shortest alternative route.

Using the mileage basis alone ignores another factor in world trade. Most general cargo ships operate on regular routes, picking up cargo at any one port along the route and dropping it at another. The economics of this "liner trade" are such that shipping rates may not be a simple function of mileage. For this reason, a small amount of trade is observed on route whose mileage is longer through the canal.

The selected 66 routes of the bilateral or inter-regional trade were classified into the following four groups and potential trade was estimated from the bilateral or inter-regional trade for the same 66 trade routes.

- Routes for which all mileages through the Canal are greater.

- Routes for which most mileages through the Canal are greater.
- Routes for which some mileages through the Canal are greater.
- Routes for which no mileages through the Canal are greater.

Results of the bilateral and potential trade analysis for 1990 are shown in Table 6.1.5-1, which also shows the actual Panama Canal trade in 1990 for comparison. As shown in this table, the actual Panama Canal trade in some routes is larger than the potential trade and even larger than the bilateral trade estimated for 1990 based on the world bilateral trade data. This odd results are due to the following situation.

(1) There are routes on which Canal commodity flows are observed, but for which the Canal is not the shortest route.

(2) Bilateral trade is always reported on a country-to-country basis. To determine potential trade, bilateral trade for many countries had to be split between coasts or ports of individual countries.

In Table 6.1.5-2, projected trade volumes for 1990, 2020 and 2060 are given by commodity. Total bilateral trade in Table 6.1.5-2 refers to the trade on the Canal trade shown in Table 6.1.5-1, rather than the global total of bilateral trade.

For all of those commodities that travel in ships that can transit the present Canal, potential trade and Panama Canal trade should be identical except for the effects of liner trade. Unfortunately, this was not the case because of the following differences between the PCC data and the country, OECD and UN sources used for the bilateral trade analysis.

(1) The containerization of general cargo was estimated in the historical data based on surveys and other information. In general, containerization of internationally traded commodities is not given in the world trade data. On the other hand, the PCC provides data on total tonnes containerized, without indicating what specific goods are in the containers.

(2) The PCC has its own unique definitions of commodities. As the PCC has not shifted to an internationally accepted commodity coding basis, significant differences can be expected to arise for many of the commodities.

(3) Panama cargoes were assigned to major categories based on the type of ship in which the PCC shows the cargo being carried. In assigning the cargoes in the bilateral trade data, every effort was made to be consistent with the PCC, but differences inevitably arise.

Table 6.1.5-1

Bilateral and Potential Trade Analysis for 1990

Total Each Route (1,000 tons)

ORIGIN	DESTINATION	BILATERAL TRADE	PANAMA CANAL TRADE	POTENTIAL TRADE	NON-POTENTIAL TRADE	RATIO: POTENTIAL TO BILATERAL
Routes for which all mileages through the Canal are greater						
AFRICA	ASIA	18,330	1	0	18,330	0.0%
AFRICA	OCEANIA	835	127	0	835	0.0%
ASIA	EUROPE	43,767	368	0	43,767	0.0%
EUROPE	ASIA	51,865	494	0	51,865	0.0%
TOTAL		114,797	990	0	114,797	0.0%
PERCENT OF GRAND TOTAL		28.7%	0.6%	0.0%	56.0%	
TOTAL NON-POTENTIAL AS A PERCENT OF GRAND TOTAL BILATERAL					28.7%	
Routes for which most mileages through the Canal are greater						
OCEANIA	EUROPE	45,590	758	729	44,862	1.6%
S. AMERICA E.C.	OCEANIA	768	4	87	681	11.3%
MIDDLE EAST	U.S. W.C., HAWAII	574	73	73	501	12.8%
OCEANIA	S. AMERICA E.C.	2,302	534	561	1,741	24.4%
EUROPE	OCEANIA	3,023	1,045	942	2,081	31.2%
S. AMERICA E.C.	ASIA	49,440	1,954	20,657	28,782	41.8%
TOTAL		101,697	4,367	23,049	78,648	22.7%
PERCENT OF GRAND TOTAL		25.4%	2.8%	11.8%	38.4%	
TOTAL NON-POTENTIAL AS A PERCENT OF GRAND TOTAL BILATERAL					19.6%	
Routes for which some mileages through the Canal are greater						
OCEANIA	U.S. EAST COAST	4,899	3,704	3,940	959	80.4%
ASIA	U.S. EAST COAST	16,387	12,894	13,304	3,084	81.2%
ASIA	S. AMERICA E.C.	270	252	229	42	84.6%
AFRICA	U.S. W.C., HAWAII	162	124	144	17	89.4%
U.S. EAST COAST	ASIA	73,474	53,976	66,247	7,227	90.2%
S. AMERICA E.C.	U.S. W.C., HAWAII	1,872	2,238	1,808	64	96.6%
U.S. EAST COAST	OCEANIA	3,140	2,790	3,107	33	98.9%
S. AMERICA E.C.	CANADA WEST COAST	111	158	110	1	99.0%
U.S. W.C., HAWAII	AFRICA	1,669	1,452	1,663	6	99.6%
TOTAL		101,983	77,587	90,550	11,433	88.8%
PERCENT OF GRAND TOTAL		25.5%	49.2%	46.3%	5.6%	
TOTAL NON-POTENTIAL AS A PERCENT OF GRAND TOTAL BILATERAL					2.9%	
Routes for which no mileages through the Canal are greater						
U.S. W.C., HAWAII	S. AMERICA E.C.	350	344	350	0	100.0%
AFRICA	C. AMERICA W.C.	239	239	239	0	100.0%
AFRICA	CANADA WEST COAST	811	788	811	0	100.0%
AFRICA	S. AMERICA W.C.	81	81	81	0	100.0%
ASIA	CANADA EAST COAST	510	534	510	0	100.0%
ASIA	CENTRAL AMERICA E.C.,	1,548	1,642	1,548	0	100.0%
C. AMERICA W.C.	AFRICA	107	107	107	0	100.0%
C. AMERICA W.C.	CENTRAL AMERICA E.C.,	705	705	705	0	100.0%

Table 6.1.5-1 (continued)

ORIGIN	DESTINATION	BILATERAL TRADE	PANAMA CANAL TRADE	POTENTIAL TRADE	NON-POTENTIAL TRADE	RATIO: POTENTIAL TO BILATERAL
C. AMERICA W.C.	EUROPE	1,057	1,057	1,057	0	100.0%
C. AMERICA W.C.	S. AMERICA E.C.	160	160	160	0	100.0%
C. AMERICA W.C.	U.S. EAST COAST	3,716	1,669	3,716	0	100.0%
CANADA EAST COAST	ASIA	4,969	1,718	4,969	0	100.0%
CANADA EAST COAST	C. AMERICA W.C.	31	32	31	0	100.0%
CANADA EAST COAST	OCEANIA	175	140	175	0	100.0%
CANADA EAST COAST	S. AMERICA W.C.	334	236	334	0	100.0%
CANADA EAST COAST	U.S. W.C., HAWAII	10	52	10	0	100.0%
CANADA WEST COAST	AFRICA	1,292	1,716	1,292	0	100.0%
CANADA WEST COAST	CENTRAL AMERICA E.C.,	83	96	83	0	100.0%
CANADA WEST COAST	EUROPE	8,658	7,260	8,658	0	100.0%
CANADA WEST COAST	MIDDLE EAST	263	263	263	0	100.0%
CANADA WEST COAST	S. AMERICA E.C.	1,302	552	1,302	0	100.0%
CANADA WEST COAST	U.S. EAST COAST	1,052	1,054	1,052	0	100.0%
CENTRAL AMERICA E.C.,	ASIA	1,825	2,071	1,825	0	100.0%
CENTRAL AMERICA E.C.,	C. AMERICA W.C.	1,004	1,004	1,004	0	100.0%
CENTRAL AMERICA E.C.,	OCEANIA	24	24	24	0	100.0%
CENTRAL AMERICA E.C.,	S. AMERICA W.C.	804	804	804	0	100.0%
CENTRAL AMERICA E.C.,	U.S. W.C., HAWAII	1,232	1,232	1,232	0	100.0%
EUROPE	CANADA WEST COAST	250	463	250	0	100.0%
EUROPE	S. AMERICA W.C.	1,176	1,973	1,176	0	100.0%
EUROPE	U.S. W.C., HAWAII	3,393	3,500	3,393	0	100.0%
EUROPE	C. AMERICA W.C.	756	848	756	0	100.0%
OCEANIA	CANADA EAST COAST	158	521	158	0	100.0%
OCEANIA	CENTRAL AMERICA E.C.,	311	312	311	0	100.0%
S. AMERICA E.C.	C. AMERICA W.C.	1,868	1,868	1,868	0	100.0%
S. AMERICA E.C.	S. AMERICA W.C.	2,098	2,098	2,098	0	100.0%
S. AMERICA W.C.	AFRICA	137	137	137	0	100.0%
S. AMERICA W.C.	CANADA EAST COAST	481	41	481	0	100.0%
S. AMERICA W.C.	CENTRAL AMERICA E.C.,	5,627	5,627	5,627	0	100.0%
S. AMERICA W.C.	EUROPE	7,443	6,383	7,443	0	100.0%
S. AMERICA W.C.	S. AMERICA E.C.	485	229	485	0	100.0%
S. AMERICA W.C.	U.S. EAST COAST	8,250	7,993	8,250	0	100.0%
U.S. EAST COAST	C. AMERICA W.C.	4,170	4,332	4,170	0	100.0%
U.S. EAST COAST	CANADA WEST COAST	121	210	121	0	100.0%
U.S. EAST COAST	S. AMERICA W.C.	4,378	4,053	4,378	0	100.0%
U.S. EAST COAST	U.S. W.C., HAWAII	1,422	1,422	1,422	0	100.0%
U.S. W.C., HAWAII	CANADA EAST COAST	212	190	212	0	100.0%
U.S. W.C., HAWAII	CENTRAL AMERICA E.C.,	392	392	392	0	100.0%
U.S. W.C., HAWAII	EUROPE	5,475	5,626	5,475	0	100.0%
U.S. W.C., HAWAII	U.S. EAST COAST	996	996	996	0	100.0%
TOTAL		81,941	74,795	81,941	0	100.0%
PERCENT OF GRAND TOTAL		20.5%	47.4%	41.9%	0.0%	
GRAND TOTAL		400,418	157,739	195,541	204,878	48.8%

Table 6.1.5-2

Bypass Trade Analysis

	TOTAL BILATERAL TRADE			NON-POTENTIAL TRADE			POTENTIAL TRADE			PANAMA CANAL TRADE		
COMMODITY	1990	2020	2060	1990	2020	2060	1990	2020	2060	1990	2020	2060
IRON ORE	74,827	198,428	216,752	54,771	147,545	159,350	20,056	50,883	57,401	581	1,362	202
BAUXITE/ALUMINA	7,123	18,188	13,276	4,217	8,700	7,869	2,906	9,489	5,407	2,906	9,489	281
CRUDE PETROLEUM	12,540	25,244	24,692	2,918	6,236	8,144	9,621	19,008	16,548	9,621	5,008	459
COAL & COKE	66,990	144,336	190,271	40,233	80,539	107,527	26,757	63,796	82,743	10,978	5,507	3,419
BULK GRAINS	28,560	49,524	78,304	5,032	5,167	11,401	23,528	44,356	66,903	23,528	44,356	56,607
FERTILIZERS	19,801	20,431	41,906	6,360	12,734	23,172	13,440	7,697	18,735	13,009	8,229	8,595
BULK CHEMICALS	13,136	38,582	59,939	5,575	16,097	26,265	7,561	22,486	33,674	6,967	22,920	32,161
PETROLEUM PRODUCTS	24,122	32,429	30,023	7,980	15,109	20,808	16,142	17,320	9,215	12,490	16,995	4,140
OILS AND FATS	4,622	9,519	16,510	3,623	7,725	13,010	999	1,794	3,500	729	1,449	1,996
REFRIGERATED CARGO	7,805	18,607	29,674	2,091	4,753	7,477	5,713	13,854	22,197	5,389	13,614	18,496
VEHICLES	4,336	6,866	6,344	2,599	4,454	3,745	1,737	2,413	2,598	1,647	2,317	1,807
MINOR BULKS	77,341	120,147	199,917	33,712	50,442	85,243	43,628	69,705	114,674	36,806	57,404	49,802
CONTAINERIZED CARGO	56,795	134,673	218,295	35,201	86,401	148,981	21,594	48,272	69,314	20,840	46,835	54,313
GENERAL CARGO	3,084	7,351	13,742	564	1,364	2,315	2,520	5,987	11,426	11,980	30,477	44,251
TOTAL	401,080	829,520	1,139,644	204,877	447,267	625,307	196,203	377,060	514,337	157,472	265,962	276,529
MAJOR BULKS	190,039	435,720	523,295	107,171	248,187	294,289	82,868	187,533	229,003	47,615	65,722	60,968
CONTAINERS	56,795	134,673	218,295	35,201	86,401	148,981	21,594	48,272	69,314	20,840	46,835	54,313
OTHER	154,246	259,127	398,054	62,505	112,679	182,038	91,741	141,255	216,020	89,018	153,406	161,247

(4) The world trade data and PCC data never agree. The bilateral trade data are derived from customs data of the individual countries. The PCC is an entirely separate entity and cannot be expected to use the same definitions to make these two different data sources readily comparable.

As the base data for the commodity forecasts, the PCC data were used to be consistent with data on cargoes and ship transits, and growth rate were applied for projection rather than the levels of the potential trade forecasts for other than bulk trades, to which data from two different sources are almost the same. The detailed results of this analysis are presented in the Phase II CTP Study Final Report, Vol. III.

6.1.6 World Fleet Forecast

Table 6.1.6-1 gives a summary based on forecast for global fleet sizes.

Table 6.1.6-1

Percent of Cumulative Deadweight Distribution by Vessel Size and Type

(percent cumulative capacity by vessel size increments in years 2020, 2060)

Vessel Type (excludes passenger)	Vessel Deadweight Size Increments					
	<65,000(1)		<150,000		<250,000	
	2020	2060	2020	2060	2020	2060
Container/Breakbulk	100.0	100.0	-	-	-	-
Full Container (2)	91.3	81.6	100.0	100.0	-	-
Full Container (3)	73.6	65.7	100.0	100.0	-	-
Breakbulk General	100.0	100.0	-	-	-	-
Refrigerated	100.0	100.0	-	-	-	-
Roll-on Roll-off	100.0	100.0	-	-	-	-
Vehicles Carrier	100.0	100.0	-	-	-	-
Dry Bulk (2)	61.9	65.7	81.5	78.3	95.3	95.5
Dry Bulk (3)	60.7	64.2	81.8	79.7	95.2	95.2
Dry Bulk (4)	60.6	64.2	81.6	76.0	95.2	95.2
Chemical Tanker	100.0	100.0	-	-	-	-
LPG Tanker	72.6	72.6	100.0	100.0	-	-
Oil tanker	17.6	21.2	45.9	52.2	54.7	66.3

Notes: (1) Dry Bulk <65,000 includes Panamax vessels to 90,000 dwt
(2) Global fleet with no size changes due to enlarged Canal
(3) Global fleet with size changes attributed to 150,000 dwt. Canal
(4) Global fleet with size changes attributed to 250,000 dwt. Canal

Source: Final Report (Vol. I) of Phase II CTP Study

Based on the analyses on ship technology development, the potential development of the global fleet by ship type and size was examined for 2020 and 2060 as well as a ship mix for the Status Quo and other study cases. Considerations were given to possible influences of the development cases of the Panama Canal, i.e. under 150,000 dwt, 200,000 dwt and 250,000 dwt cases, on the size and composition of the world fleet. The details and analysis for Panama-specific and world fleet projections are presented in the CTP Study, Vol. I, Section 3.3 Global Fleet Forecast.

6.1.7 Transportation Cost Analysis

Transportation cost estimates were developed taking the capital costs, operating costs, voyage costs and system costs into account. The capital costs were based on values of ships and an interest rate of 9.0% for 2020 and 2060. The operating costs consisted of the following:

- Manning costs including wages, overtime, social security, leave, subsistence, training and catering costs
- Costs of repair and maintenance, stores and supplies
- Insurance costs
- Overheads of shipping companies

The voyage costs included fuel oil and diesel oil costs, port costs and cargo claims and commissions. The system costs were mostly container acquisition (purchase or leasing) and maintenance costs. The transportation cost study is given in the CTP Study Report, Vol. I, Section 3.4 Development of Ship Operating Costs and Seaborne Freight Costs, and the details are presented in the same report, Vol. II.

6.1.8 Commodity Flow Projections through Panama Canal

Commodity flows through the Canal are projected to 2020 and 2060 for each study case in the following manners.

(1) Potential commodity flows through the canal were distributed for various ship size categories in accordance with the forecast ship size distribution.

(2) The potential commodity flows by ship size categories up to the maximum allowable ship size of each study case were regarded as the effective commodity flows through the Canal.

(3) Transportation costs of the larger ship size categories through non-Panama route were compared with those of the largest ship size category within the maximum allowable ship size of each study case through Panama route, and if the former was more costly than

the latter, those commodity flows were assumed to be shifted to the Canal with a reduced ship size, formulating the second Panamax close to the maximum allowable ship size of each study case.

The commodity flow projections for a no-tolls scenario, taking into account capacity considerations for the Status Quo Canal, are summarized in Table 6.1.8-1 for each study case, and details are given in the CTP Study Report, Vol. I, Section 5 Panama Canal Commodity Flows and Vessel Transits and Vol. III, Section 2 Commodity Flow Projections through Panama Canal. The results shown in Table 6.1.8-1 are not significantly different in total from the Phase I CTP Study. However, there are significant differences in ship size distribution which arise from the following considerations.

(1) The ship size distribution in the actual PCC data used in the Phase II CTP Study is different in many respects from that in the synthetic ship transit distribution developed in the Phase I CTP Study.

(2) The conclusions of the analysis for the constrained 2060 Status Quo Canal are that the vessels re-routed are concentrated where alternative routes represent least additional miles and in the larger size ranges.

(3) As already noted, the exclusion of Panama Canal tolls from consideration in the Phase II CTP Study leads to greater switching of bypass traffic carried in very large vessels on to the Canal.

With the exception of three vessel types, the vessels and their associated cargos now transiting the canal are not expected to be affected by size constraints. Transportation costs for the vessels subject to size constraints were scrutinized to identify movements "at the margin" and those were given detailed supplemental analysis. The vessel types and the by-pass cargo movements were:

- Dry Bulkers
  - Coal, U.S. East Coast to Far East
  - Coal, U.S. Gulf Coast to Far East
  - Coal, Colombia East Coast to Far East
  - Coal, Canada West Coast to Europe
  - Coal, Canada West Coast to Brazil
  - Iron Ore, North Brazil to Far East
  - Iron Ore, Venezuela to Far East
  - Iron Ore, Canada East Coast to Far East
  - Iron Ore, Chile to Europe
- Oil Tankers
  - Crude Oil, Venezuela to Far East
- Containerships
  - Containers, U.S. East Coast to/from Far East
  - Containers, U.S. West Coast to/from Europe

Table 6.1.8-1

Annual Cargo Flows by Commodity and Route

Northbound and Southbound (1,000 tons)

COMMODITY	1990	2020	2060	ANNUAL GROWTH RATE 1990-2020	2020-2060	1990-2060
IRON ORE	581	1,362	202	2.88%	-4.66%	-1.50%
BAUXITE/ALUMINA	2,906	9,489	281	4.02%	-8.42%	-3.28%
CRUDE PETROLEUM	9,621	5,008	459	-2.15%	-5.80%	-4.25%
COAL & COKE	10,978	5,507	3,419	-2.27%	-1.18%	-1.65%
BULK GRAINS	23,528	44,356	56,607	2.14%	0.61%	1.26%
FERTILIZERS	13,009	8,229	8,595	-1.52%	0.11%	-0.59%
BULK CHEMICALS	6,967	22,920	32,161	4.05%	0.85%	2.21%
PETROLEUM PRODUCTS	12,490	16,995	4,140	1.03%	-3.47%	-1.56%
OILS AND FATS	729	1,449	1,996	2.32%	0.80%	1.45%
REFRIGERATED CARGO	5,389	13,614	18,496	3.14%	0.77%	1.78%
VEHICLES	1,647	2,317	1,807	1.14%	-0.62%	0.13%
MINOR BULKS	36,806	57,404	49,802	1.49%	-0.35%	0.43%
CONTAINERIZED CARGO	20,840	46,835	54,313	2.74%	0.37%	1.38%
GENERAL CARGO	11,980	30,477	44,251	3.16%	0.94%	1.88%
TOTAL	157,472	265,962	276,529	1.76%	0.10%	0.81%
150,000 DWT						
IRON ORE	581	20,302	11,071	12.57%	-1.50%	4.30%
BAUXITE/ALUMINA	2,906	9,489	5,407	4.02%	-1.40%	0.89%
CRUDE PETROLEUM	9,621	19,008	16,548	2.30%	-0.35%	0.78%
COAL & COKE	10,978	63,818	82,772	6.04%	0.65%	2.93%
BULK GRAINS	23,528	44,356	66,902	2.14%	1.03%	1.50%
FERTILIZERS	13,009	8,229	19,674	-1.52%	2.20%	0.59%
BULK CHEMICALS	6,967	22,920	33,857	4.05%	0.98%	2.28%
PETROLEUM PRODUCTS	12,490	16,995	8,311	1.03%	-1.77%	-0.58%
OILS AND FATS	729	1,449	2,549	2.32%	1.42%	1.80%
REFRIGERATED CARGO	5,389	13,614	21,223	3.14%	1.12%	1.98%
VEHICLES	1,647	2,317	1,829	1.14%	-0.59%	0.15%
MINOR BULKS	36,806	57,404	96,078	1.49%	1.30%	1.38%
CONTAINERIZED CARGO	20,840	50,611	67,180	3.00%	0.71%	1.69%
GENERAL CARGO	11,980	30,477	57,245	3.16%	1.59%	2.26%
TOTAL	157,472	360,990	490,647	2.80%	0.77%	1.64%
200,000 DWT						
IRON ORE	581	22,624	15,150	12.98%	-1.00%	4.77%
BAUXITE/ALUMINA	2,906	9,489	5,407	4.02%	-1.40%	0.89%
CRUDE PETROLEUM	9,621	19,008	16,548	2.30%	-0.35%	0.78%
COAL & COKE	10,978	63,818	82,772	6.04%	0.65%	2.93%
BULK GRAINS	23,528	44,356	66,902	2.14%	1.03%	1.50%
FERTILIZERS	13,009	8,229	19,674	-1.52%	2.20%	0.59%
BULK CHEMICALS	6,967	22,920	33,857	4.05%	0.98%	2.28%
PETROLEUM PRODUCTS	12,490	16,995	8,311	1.03%	-1.77%	-0.58%
OILS AND FATS	729	1,449	2,549	2.32%	1.42%	1.80%
REFRIGERATED CARGO	5,389	13,614	21,223	3.14%	1.12%	1.98%
VEHICLES	1,647	2,317	1,829	1.14%	-0.59%	0.15%
MINOR BULKS	36,806	57,404	96,078	1.49%	1.30%	1.38%
CONTAINERIZED CARGO	20,840	50,611	67,180	3.00%	0.71%	1.69%
GENERAL CARGO	11,980	30,477	57,245	3.16%	1.59%	2.26%
TOTAL	157,472	363,312	494,726	2.83%	0.77%	1.65%

Table 6.1.8-1 (continued)

COMMODITY	1990	2020	2060	ANNUAL GROWTH RATE 1990-2020	2020-2060	1990-2060
250,000 DWT						
IRON ORE	581	29,145	28,951	13.94%	-0.02%	5.74%
BAUXITE/ALUMINA	2,906	9,489	5,407	4.02%	-1.40%	0.89%
CRUDE PETROLEUM	9,621	19,008	16,548	2.30%	-0.35%	0.78%
COAL & COKE	10,978	63,818	82,772	6.04%	0.65%	2.93%
BULK GRAINS	23,528	44,356	66,902	2.14%	1.03%	1.50%
FERTILIZERS	13,009	8,229	19,674	-1.52%	2.20%	0.59%
BULK CHEMICALS	6,967	22,920	33,857	4.05%	0.98%	2.28%
PETROLEUM PRODUCTS	12,490	16,995	8,311	1.03%	-1.77%	-0.58%
OILS AND FATS	729	1,449	2,549	2.32%	1.42%	1.80%
REFRIGERATED CARGO	5,389	13,614	21,223	3.14%	1.12%	1.98%
VEHICLES	1,647	2,317	1,829	1.14%	-0.59%	0.15%
MINOR BULKS	36,806	57,404	96,078	1.49%	1.30%	1.38%
CONTAINERIZED CARGO	20,840	50,611	67,180	3.00%	0.71%	1.69%
GENERAL CARGO	11,980	30,477	57,245	3.16%	1.59%	2.26%
TOTAL	157,472	369,833	508,527	2.89%	0.80%	1.69%

Based upon detailed voyage cost comparison between via the canal route and the least-cost alternative route, projected canal traffic was split out of the potential dry bulk cargo movements according to canal size. The dry bulk analysis did not consider grain because it was assumed that U.S. port depth constraints would limit the size of grain vessels in canal grain traffic.

The Venezuelan oil movement is a heavy crude in water emulsion. It was assumed that it would be unsuitable for the trans-isthmian pipeline, and could be a canal movement for the alternative sizes of canals. The containership analysis focuses on the comparative cost and apparent time-value advantage of U.S. overland transportation, and comparative costs and the capacity to transport containers and grain were both investigated.

6.1.9 Ship Transit Projections

The effective commodity flow projections distributed to various ship size categories are converted to ship transit projections based on the estimated average dwt for each ship size category.

The ship transit projections are summarized below and presented in Table 6.1.9-1 for each study case, and details are presented in the CTP Study Report, Vol. I, Section 5 Panama Canal Commodity Flows and Vessel Transits and Vol. IV Transit Projections.

Study Case	Transits (No. of Ships)			Trade Volume (Million Tons)	Average Tons per Transit (1,000 Tons)
	Ballast	Laden	Total		
Status Quo					
1990	1,739	9,423	11,162	157.5	16.7
2020	2,464	14,858	17,322	266.0	17.9
2060	2,387	15,694	18,081	276.5	17.6
150,000 dwt					
2020	2,582	15,278	17,860	361.0	23.6
2060	3,662	20,278	23,940	490.6	24.2
200,000 dwt					
2020	2,566	15,242	17,808	363.3	23.8
2060	3,752	20,333	24,085	494.7	24.3
250,000 dwt					
2020	2,558	15,264	17,822	369.8	24.2
2060	3,675	20,385	24,060	508.5	24.9

Table 6.1.9-1

Summary of Ballast and Laden Transits for all Cases

STATUS QUO CANAL

1990	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL
Container-Breakbulk	14	13	552	554	566	567	1,133
Dry Bulk Carriers	316	28	1,136	1,612	1,452	1,640	3,092
Chemical Tankers	36	4	143	301	179	305	484
Full Container Ships	3	2	553	517	556	519	1,075
General Cargo Ships	72	54	364	419	436	473	909
Liquid Gas Carriers	68	1	8	102	76	103	179
Refrigerated Ships	24	498	1,119	598	1,143	1,096	2,239
Roll-on Roll-off	16	4	90	96	106	100	206
Oil Tankers	158	148	292	369	450	517	967
Vehicle Carriers	1	279	325	125	326	404	730
Passenger Ships	1	3	49	99	50	102	152
Total Ships	708	1,031	4,631	4,792	5,339	5,823	11,162

2020	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2020
Container-Breakbulk	29	12	794	826	823	841	1,664	1.29%
Dry Bulk Carriers	363	13	1642	1964	2,011	2,005	4,016	0.88%
Chemical Tankers	77	4	266	795	343	799	1,142	2.90%
Full Container Ships	5	4	1160	1,220	1,165	1,224	2,390	2.70%
General Cargo Ships	79	61	420	473	499	534	1,033	0.43%
Liquid Gas Carriers	126	2	10	211	136	213	349	2.25%
Refrigerated Ships	24	909	2,200	882	2,224	1,792	4,016	1.97%
Roll-on Roll-off	27	4	106	157	132	162	294	1.19%
Oil Tankers	234	97	185	568	419	666	1,085	0.39%
Vehicle Carriers	2	381	443	197	445	578	1,023	1.13%
Passenger Ships	2	9	154	183	155	192	348	2.80%
Total Ships	967	1497	7379	7479	8,352	9,007	17,359	1.48%

2060	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2060
Container-Breakbulk	37	21	1289	1039	1,326	1,060	2,386	1.07%
Dry Bulk Carriers	314	4	629	1976	944	1,977	2,920	-0.08%
Chemical Tankers	89	5	298	906	387	912	1,299	1.42%
Full Container Ships	1	4	1091	1181	1,092	1,185	2,277	1.08%
General Cargo Ships	126	97	681	713	807	810	1,616	0.83%
Liquid Gas Carriers	60	5	14	91	74	96	169	-0.08%
Refrigerated Ships	20	933	2500	1438	2,520	2,371	4,891	1.12%
Roll-on Roll-off	47	8	182	223	229	231	460	1.15%
Oil Tankers	96	29	62	205	158	233	391	-1.29%
Vehicle Carriers	2	438	510	233	512	671	1,183	0.69%
Passenger Ships	39	12	197	238	236	250	485	1.67%
Total Ships	831	1556	7451	8243	8,283	9,795	18,078	0.69%

Table 6.1.9-1 (continued)

150.000 DWT

1990	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL
Container-Breakbulk	14	13	552	554	566	567	1,133
Dry Bulk Carriers	316	28	1,136	1,612	1,452	1,640	3,092
Chemical Tankers	36	4	143	301	179	305	484
Full Container Ships	3	2	553	517	556	519	1,075
General Cargo Ships	72	54	364	419	436	473	909
Liquid Gas Carriers	68	1	8	102	76	103	179
Refrigerated Ships	24	498	1,119	598	1,143	1,096	2,239
Roll-on Roll-off	16	4	90	96	106	100	206
Oil Tankers	158	148	292	369	450	517	967
Vehicle Carriers	1	279	325	125	326	404	730
Passenger Ships	1	3	49	99	50	102	152
Total Ships	708	1,031	4,631	4,792	5,339	5,823	11,162

2020	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2020
Container-Breakbulk	29	12	794	826	823	841	1,664	1.29%
Dry Bulk Carriers	389	12	1536	2581	1,930	2,620	4,549	1.30%
Chemical Tankers	77	4	266	795	343	799	1,142	2.90%
Full Container Ships	5	4	1127	1115	1,132	1,119	2,251	2.49%
General Cargo Ships	79	61	420	473	499	534	1,033	0.43%
Liquid Gas Carriers	126	2	10	211	136	213	349	2.25%
Refrigerated Ships	24	909	2199	882	2,223	1,792	4,015	1.97%
Roll-on Roll-off	27	4	106	157	132	162	294	1.19%
Oil Tankers	329	98	181	521	510	619	1,128	0.52%
Vehicle Carriers	2	381	443	197	445	578	1,023	1.13%
Passenger Ships	2	9	154	183	155	192	348	2.80%
Total Ships	1087	1495	7235	8043	8,327	9,469	17,796	1.57%

2060	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2060
Container-Breakbulk	47	21	1429	1481	1,476	1,502	2,978	1.39%
Dry Bulk Carriers	317	26	2105	3168	2,421	3,188	5,610	0.85%
Chemical Tankers	117	10	366	946	483	956	1,439	1.57%
Full Container Ships	2	4	1259	1314	1,261	1,318	2,579	1.26%
General Cargo Ships	156	119	794	906	950	1,025	1,975	1.11%
Liquid Gas Carriers	952	5	14	124	966	129	1,095	2.62%
Refrigerated Ships	23	1046	2783	1493	2,806	2,539	5,345	1.25%
Roll-on Roll-off	49	9	187	299	236	308	544	1.40%
Oil Tankers	247	58	135	485	382	543	926	-0.06%
Vehicle Carriers	2	439	511	234	513	673	1,186	0.70%
Passenger Ships	0	12	9	238	9	250	259	0.76%
Total Ships	1913	1749	9592	10686	11,504	12,431	23,934	1.10%

Table 6.1.9-1 (continued)

200,000 DWT

1990	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL
Container-Breakbulk	14	13	552	554	566	567	1,133
Dry Bulk Carriers	316	28	1,136	1,612	1,452	1,640	3,092
Chemical Tankers	36	4	143	301	179	305	484
Full Container Ships	3	2	553	517	556	519	1,075
General Cargo Ships	72	54	364	419	436	473	909
Liquid Gas Carriers	68	1	8	102	76	103	179
Refrigerated Ships	24	498	1,119	598	1,143	1,096	2,239
Roll-on Roll-off	16	4	90	96	106	100	206
Oil Tankers	158	148	292	369	450	517	967
Vehicle Carriers	1	279	325	125	326	404	730
Passenger Ships	1	3	49	99	50	102	152
Total Ships	708	1,031	4,631	4,792	5,339	5,823	11,162

2020	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2020
Container-Breakbulk	29	12	794	826	823	841	1,664	1.29%
Dry Bulk Carriers	398	20	1545	2559	1,948	2,605	4,553	1.30%
Chemical Tankers	77	4	266	795	343	799	1,142	2.90%
Full Container Ships	5	4	1127	1115	1,132	1,119	2,251	2.49%
General Cargo Ships	79	61	420	473	499	534	1,033	0.43%
Liquid Gas Carriers	126	2	10	211	136	213	349	2.25%
Refrigerated Ships	24	909	2199	882	2,223	1,792	4,015	1.97%
Roll-on Roll-off	27	4	106	157	132	162	294	1.19%
Oil Tankers	303	89	181	599	484	688	1,172	0.64%
Vehicle Carriers	2	381	443	197	445	578	1,023	1.13%
Passenger Ships	2	9	154	183	155	192	348	2.80%
Total Ships	1071	1495	7244	7998	8,320	9,524	17,844	1.58%

2060	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2060
Container-Breakbulk	47	21	1429	1481	1,476	1,502	2,978	1.39%
Dry Bulk Carriers	384	26	2114	3044	2,497	3,064	5,562	0.84%
Chemical Tankers	117	10	366	946	483	956	1,439	1.57%
Full Container Ships	2	4	1259	1314	1,261	1,318	2,579	1.26%
General Cargo Ships	156	119	794	906	950	1,025	1,975	1.11%
Liquid Gas Carriers	952	5	14	124	966	129	1,095	2.62%
Refrigerated Ships	23	1,046	2783	1493	2,806	2,539	5,345	1.25%
Roll-on Roll-off	49	9	187	299	236	308	544	1.40%
Oil Tankers	231	58	135	462	366	520	886	-0.12%
Vehicle Carriers	2	439	511	234	513	673	1,186	0.70%
Passenger Ships	39	12	197	238	236	250	486	1.67%
Total Ships	2003	1749	9789	10544	11,791	12,283	24,074	1.10%

Table 6.1.9-1 (continued)

250,000 DWT

1990	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL
Container-Breakbulk	14	13	552	554	566	567	1,133
Dry Bulk Carriers	316	28	1,136	1,612	1,452	1,640	3,092
Chemical Tankers	36	4	143	301	179	305	484
Full Container Ships	3	2	553	517	556	519	1,075
General Cargo Ships	72	54	364	419	436	473	909
Liquid Gas Carriers	68	1	8	102	76	103	179
Refrigerated Ships	24	498	1,119	598	1,143	1,096	2,239
Roll-on Roll-off	16	4	90	96	106	100	206
Oil Tankers	158	148	292	369	450	517	967
Vehicle Carriers	1	279	325	125	326	404	730
Passenger Ships	1	3	49	99	50	102	152
Total Ships	708	1,031	4,631	4,792	5,339	5,823	11,162

2020	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2020
Container-Breakbulk	29	12	794	826	823	841	1,664	1.29%
Dry Bulk Carriers	400	20	1545	2594	1,950	2,640	4,590	1.33%
Chemical Tankers	77	4	266	795	343	799	1,142	2.90%
Full Container Ships	5	4	1127	1115	1,132	1,119	2,251	2.49%
General Cargo Ships	79	61	420	473	499	534	1,033	0.43%
Liquid Gas Carriers	126	2	10	211	136	213	349	2.25%
Refrigerated Ships	24	909	2199	882	2,223	1,792	4,015	1.97%
Roll-on Roll-off	27	4	106	157	132	162	294	1.19%
Oil Tankers	293	89	181	585	474	674	1,148	0.57%
Vehicle Carriers	2	381	443	197	445	578	1,023	1.13%
Passenger Ships	2	9	154	183	155	192	348	2.80%
Total Ships	1063	1495	7244	8020	8,312	9,545	17,856	1.58%

2060	Ballast North	Ballast South	Laden North	Laden South	Total North	Total South	TOTAL	Annual Average Growth Rat 1990-2060
Container-Breakbulk	47	21	1429	1481	1,476	1,502	2,978	1.39%
Dry Bulk Carriers	317	26	2124	3103	2,440	3,124	5,564	0.84%
Chemical Tankers	117	10	366	946	483	956	1,439	1.57%
Full Container Ships	2	4	1259	1314	1,261	1,318	2,579	1.26%
General Cargo Ships	156	119	794	906	950	1,025	1,975	1.11%
Liquid Gas Carriers	952	5	14	124	966	129	1,095	2.62%
Refrigerated Ships	23	1,046	2783	1493	2,806	2,539	5,345	1.25%
Roll-on Roll-off	49	9	186	299	235	308	543	1.39%
Oil Tankers	221	58	135	449	356	507	863	-0.16%
Vehicle Carriers	2	439	511	234	513	673	1,186	0.70%
Passenger Ships	39	12	197	238	236	250	486	1.67%
Total Ships	1926	1749	9798	10587	11,723	12,330	24,053	1.10%

6.2 Operating Characteristics and Capacity Evaluation, Phase II

6.2.1 Approach and Scope of Work

In the Phase II OCCE Study, firstly various modifications of WAM were made to give a better representation of the canal system in the simulation. Principal modifications were;

1) improvements on relay operation procedure, which may switch into and out of relay operation on a scheduled or demand driven basis,

2) an introduction of dynamic route assignment module which assigns the best route among the possible alternative routes to a ship to minimize her transit time by evaluating the status of alternative routes' expected transit time at the arrival of each ship, and

3) installation of modules for formation and operation of ship convoys in sea level alternatives. WAM, with these modifications, becomes capable of evaluating the single lane Culebra Cut operation which had not been made in the Phase I Study.

Secondly, detailed analyses were made on various input data to make simulated results more reliable. Among these efforts, the following two issues are to be specifically mentioned;

1) detailed analysis of SDB including vessel arrival patterns and vessel passage time in various canal segments,

2) refinement of vessel characteristics such as stopping distance, ship separation and vessel speed function, and

3) the scheduling of vessels underway.

Thirdly, two other important aspects directly relating to the canal operation were analyzed and assessed.

1) One is fresh water consumption associated with lock operation which had not been done in Phase I,

2) the other is requirements for the navigation support system, both for fixed installation and floating crafts.

Lastly, two hard engineering issues have been analyzed and assessed, which had originally been assigned for the ECE Study in the DPS and was shifted to the OCCE Study, namely:

1) examination of lock chamber size; as well as ,

2) sedimentation in a sea level canal and beach deformation which may be induced by the construction of new breakwaters.

Upon the completion of modifications, WAM has been calibrated with a refined set of data, then actual simulation runs are made for the pre-screened alternatives. At the final stage of the Phase II OCCE Study, two additional cases are added on the pre-screened alternatives for simulation runs, namely a High Rise 150,000 dwt Single Lane Culebra Cut and a High Rise 200,000 dwt Single Lane Culebra Cut alternative.

6.2.2 Modification of WAM

High Rise Lock Canal

The objective of this part of the study was to modify the WAM to provide for more realistic and accurate simulations and capacity determinations for the Status Quo and high-rise lock systems. The following sections describe the logic and program modifications that were implemented and tested in Phase II.

- Relay Lockages

Relay operations are now generated internally, based on queue size at the start and end of each eight-hour shift. Additionally, relay operations are started at one lane of dual-lane locks when the other lane is down.

This requires additional time distribution and queue size variables in the input data, and model logic to check the current queue size. It also requires a separate relay event generator to start and stop relay operations. Figures 6.2.2-1 and 6.2.2-2 indicate the logic used in the WAM. Modification of the output report displays, to provide information on the extent of relay utilization, was also accomplished. Items reported include percent utilization by relay and normal lockage time, percent of time in relay mode, and the number of relay shift operations by chamber. Additionally, the percent downtime and number of downtime events by chamber are reported. The WAM was modified to record the sum of queue lengths and the sum of the squares of queue lengths at each lock and bend, by direction and in total. Output tables on locks and bends were expanded to include the standard deviation and the actual average queue. Average and standard deviation of queue lengths are now recorded from the point of view of the ship, i.e., the queue length encountered upon arrival.

- Routing Dynamics

The WAM was modified to include internal decision rules for assigning a ship to the next sector of the network in cases where parallel routings are possible, e.g. the third lock plans. The model bases the routing choice on the minimum time to transit the next set of possible sectors divided by the number of available lockage lanes, as indicated in Figure 6.2.2-3.

A sector bias factor was added to adjust or calibrate the model and a routing switch, which can disable the dynamic routing option, was also added. The estimated minimum time to transit a sector uses the following equations;

- last transit time = transit time of last ship - sector bias;
- minimum time = (ships in sector X last transit time)/lanes;
- minimum time = maximum of minimum time or zero.
- Multi-Vessel Lockages

There was some concern that there were too many multi-vessel (tandem) lockages occurring in the preliminary simulation results, especially for the third lock alternatives which feature wider chambers. The model was modified to add a global clearance variable between vessel lengths. Also, the model was changed to prevent vessels from locking side-by-side. Test runs showed a significant reduction in the number of multi-vessel lockages as a result of these changes.

- Metric Conversion

This conversion was accomplished in two parts. First, the output reports were modified to display values in metric equivalents. Next, the model was changed to read input values in metric units.

- Expanded Output

The resource usage file output was expanded to show the route number. The route number is simply the sum of the sector numbers through which a shipment transits. In the OCCE Study, the network descriptions were configured in a way that this number is unique for all possible routes. For example, for the third lock alternatives, the route numbers have the following meaning:

- 19 Existing Locks;
- 22 New Gatun & Existing Miraflores;
- 21 Existing Gatun & New Miraflores;
- 24 New Gatun & New Miraflores.

The Foxpro program post-processor was modified to provide a summary of transit times and delays by route.

Figure 6.2.2-1

Logic for Relay Operations

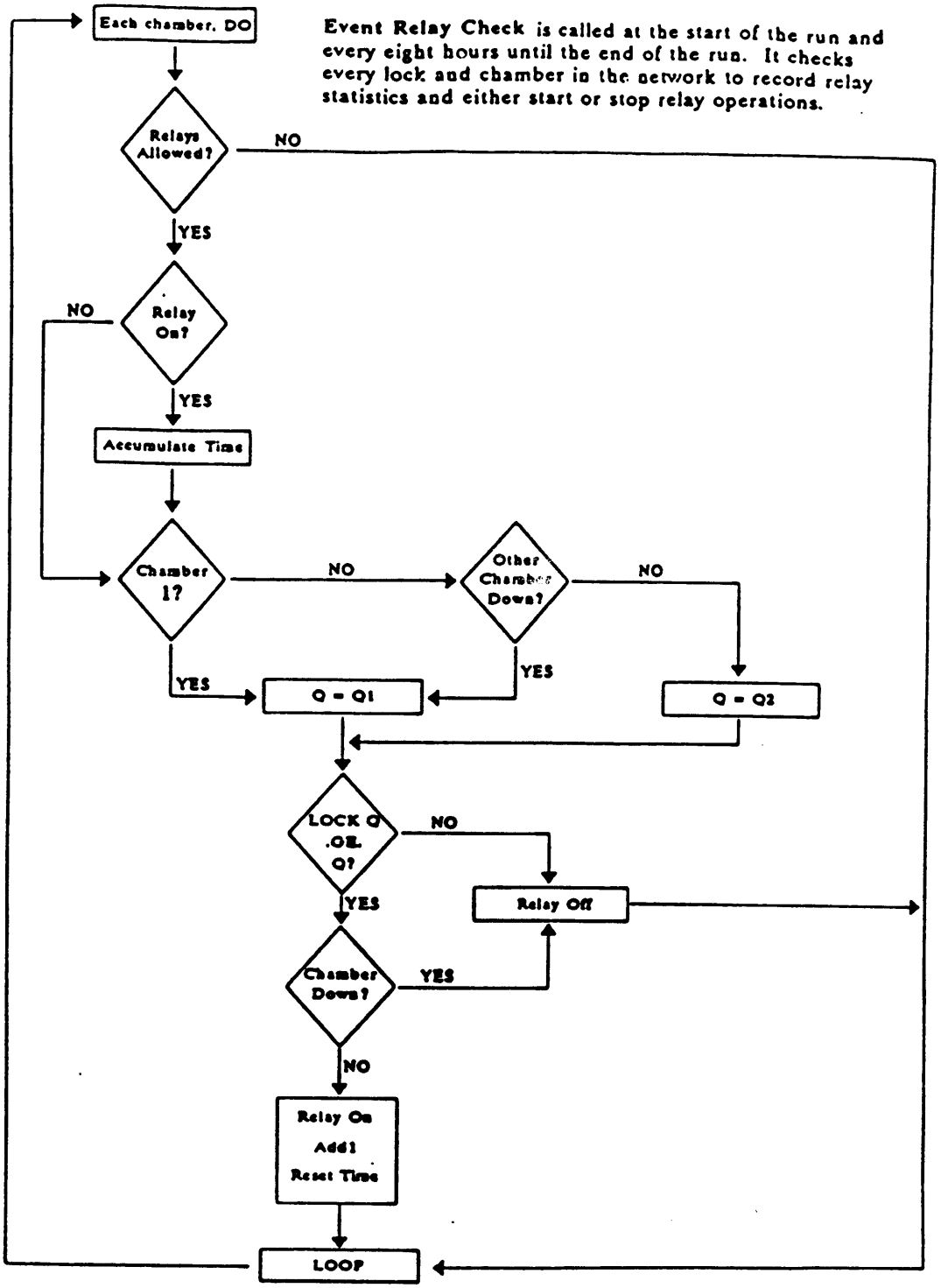


Figure 6.2.2-2

Logic for Relief During Lane Outages

Event Downtime was modified to check the relay status of this chamber and other chambers at the lock.

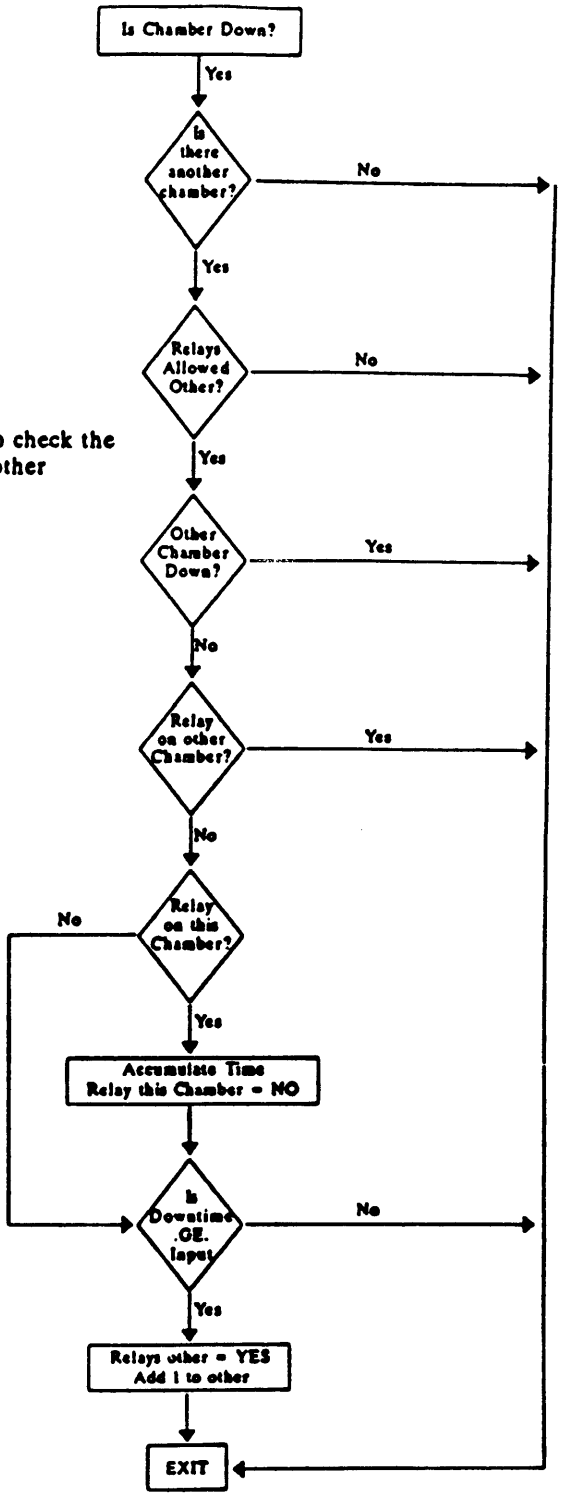
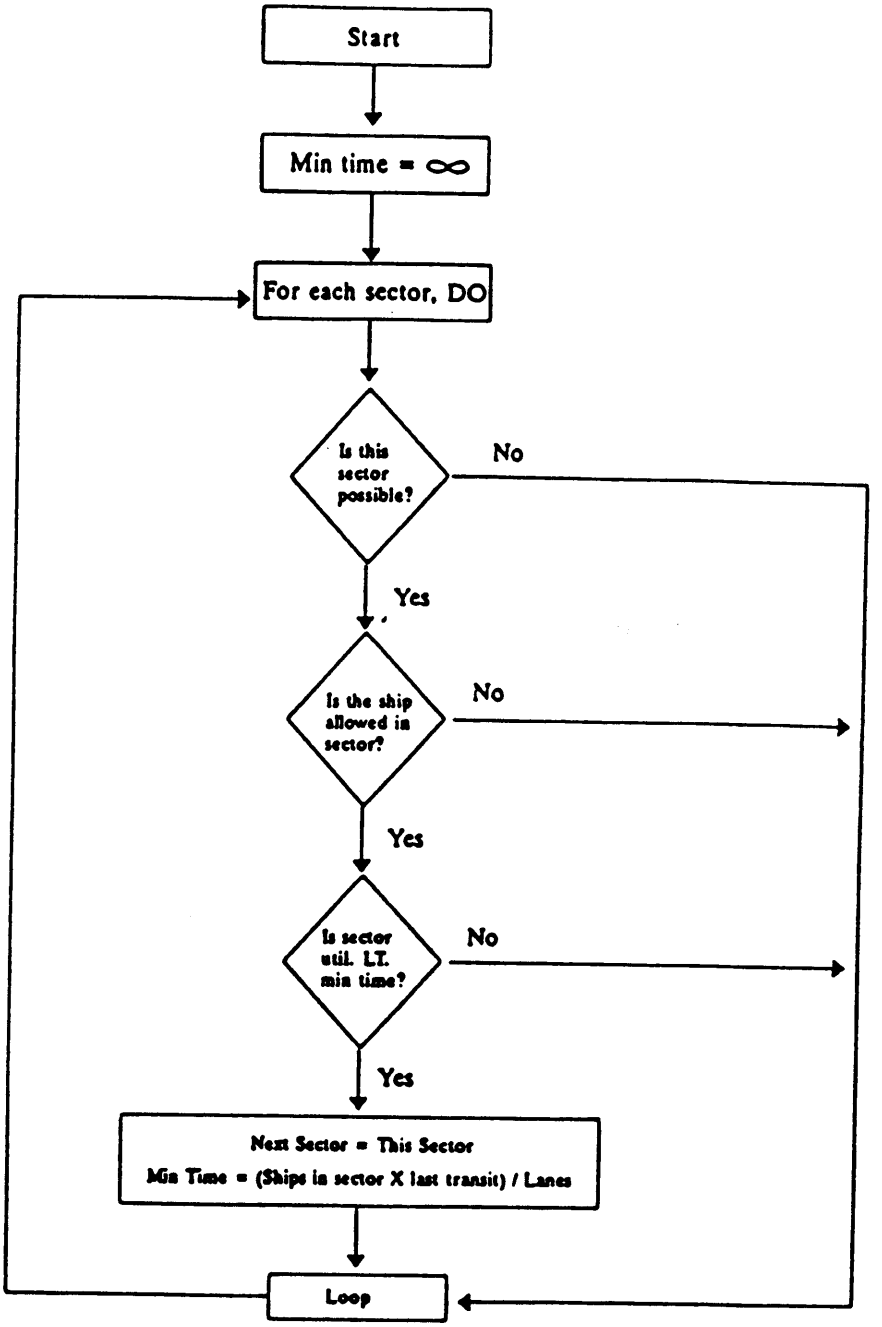


Figure 6.2.2-3
Dynamic Routing Logic



Sea-Level Canal

For Phase II of the study, the WAM was modified to incorporate new software modules to model the formation and operation of ship convoys through the proposed sea-level alternatives for the Panama Canal. This effort also included the development of algorithms to simulate dynamic ship assignments to alternative routes, including the sea-level and Status Quo options.

The convoy formation for the sea-level option is described by the model as follows:

1. After a ship route assignment for the sea-level route takes place, if a convoy is being formed and has not yet started its transit, the ship will travel to the anchorage to take its place in the convoy. The first ship of the convoy will time its arrival at the near tide gate at slack tide, a safe interval after the gate is scheduled to open.

   The new arrival will position itself behind the last ship ahead, at a distance equal to its "clearance". If there is no waiting queue, and the ship has been cleared for transit, the ship can proceed into the channel and travel at its allowable speed to join the convoy ahead, if any is present. During convoy travel each ship maintains its position relative to the ship ahead. This approach is structured to take into consideration the delays that might be experienced by the occurrence of unplanned interruptions.

   Before a ship "appears" at an open gate, it is determined whether there is enough time, before the tide gate closes, for the ship to enter the channel and completely clear the gate. If there is not enough time, this "last" ship becomes the "first" ship of the next convoy. This tide cycle delay, related to the gate position, would have been taken into consideration when making the dynamic route assignments.

2. The channel operation is simulated for convoys moving from the Pacific to the Atlantic ocean and conversely. The entering convoy waits until the exiting convoy clears by an appropriate time interval before entering the channel.

- Dynamic Ship Assignment

Dynamic ship assignment is based on the answer to the following question: How long will it take for a ship to traverse the canal using each of the alternative routes under their present conditions? At the dynamic assignment point, the model performs the following:

1. Given a ship type, the module determines whether it is a large ship which must use the sea-level canal route.

   If it is, this ship will proceed to join a convoy as described above.

   If it is not, then the following procedure is followed:

a. Calculate a base time for the ship to travel the sea-level channel, unimpeded. Calculate (update) the **impedance value**, defined as the delay due to the ships ahead in the convoy (number and type) but not yet in the channel. If the tide gate is closed, it takes into account the delay until the gate opens, as well as the waiting time imposed by other vessels awaiting the opening of the gate.

   The possibility that the waiting queues are so long that all the vessels cannot be serviced during the next or the remaining cycle time is also accounted for in these calculations. Add the impedance and the base time to obtain the ship's total travel time.

b. Estimate the delay that the ship would experience if it were to use the status quo canal. This estimate is based on the transit time of the last ship to use the status quo canal.

c. At the routing point and per each routing option, the assignment algorithm continuously updates the travel impedance due to the number and type of ships already present in the system.

d. The route selection is then based on the shortest estimated time to travel among the alternatives selected.

For the options with tidal locks, the single-lane channel requires convoy operations in alternating directions, hence, the same logic applies.

6.2.3 Refinements of Input Data

Analysis of SDB

- Data Structure and Definitions

As the preparatory work of detailed analysis on SDB, its terminology and structure are introduced briefly.

Table 6.2.3-1 is the definition of PCC vessel class where class 1 through 5 are classified as small vessels, 6 through 12 are classified as large vessels, and 13 and 14 classified as passenger and recreational vessels.

The number of vessels recorded for each class is also shown in Table 6.2.3-1.

Table 6.2.3-1

Vessel Classes and Observed Frequencies (1990)

Vessel Class	Beam (ft)	Draft (ft)	No. of Ships	
			Northbound	Southbound
1	< 60	-	1,371	1,604
2	60 - 69	-	588	596
3	70 - 79	-	1,455	4,493
4	80 - 89	< = 36	587	565
5	80 - 89	> 36	40	139
6	90 - 99	< = 30	298	233
7	90 - 99	30 - 36	262	295
8	90 - 99	> 36	149	152
9	> 99	< = 30	493	381
10	> 99	30 - 36	366	384
11	> 99	36 - 38	121	177
12	> 99	> 38	282	670
13	(Passenger)	-	46	97
14	(Recreational)	-	247	393

For each vessel that transited through the canal the following temporal events are recorded in SDB:

i) Arrival time,

ii) Ready time,

iii) Underway time,

iv) Arrival and departure times at the three sets of locks, and

v) Passing time at Gamboa.

Based on the above data, Differential Ready Time (DRT) and Differential Underway Time (DUT) are defined:

i) Differential Ready Time (DRT): difference in ready time and arrival time by direction and vessel class, and

ii) Differential Underway Time (DUT): difference in underway time and ready time by direction and vessel class.

Transit time through the Canal is divided into the following 5 different segments:

Segment 1: Transit time between Gatun Locks & End of Transit (NB);

Transit time between Transit Underway & Gatun Locks (SB);

Segment 2: Transit time between Gatun Locks & Gamboa Passing (NB & SB);

Segment 3: Transit time between Gamboa & Pedro Miguel Locks (NB & SB);

Segment 4: Transit time between Pedro Miguel Locks & Miraflores Locks (NB & SB);

Segment 5: Transit time between Miraflores Locks & End Transit (SB);

Transit time between Transit Underway & Miraflores Locks (NB).

- Screening the Data for Outliers

Data in SDB at present, include accidental delays, some errors, and do not specify vessel movements which have no direct concern with normal canal transit such as bunkering, repairing and accidental delay. Extreme figures of DRT, DUT, and transit time for each canal segment, induced by the above reasons, have to be screened out to produce a reasonable data base for further analysis. To this aim, DRT and DUT over 24 hours, and a segment passage time less than half and larger than twice the reasonably set expected mean value have been screened out as outlier. The results of this screening are summarized and shown in Table 6.2.3-2.

Analysis of DRT and DUT

Screened data of DRT and DUT have been tested statistically. Firstly, their probability distributions were tested against Normal Distribution and both have cleared this test with a satisfactory significance level. Secondly, difference in DRT and DUT between the small and large vessels was investigated. The results indicate that there is a statistically significant difference (α =0.05) in the DRT and DUT components for small and large vessels. (See Table 6.2.3-3)

Table 6.2.3-2
Summary of Screening for Eliminating Outliers

Variable	Assumed Average Value (hrs)	Minimum Value (hrs)	Maximum Value (hrs)	Northbound			Southbound		
				Before	After	% Outliers	Before	After	% Outliers
DRT	N/A	0.00	24.0	6,232	5,612	9.9	7,023	6,096	13.2
DRT	N/A	0.00	24.0	6,298	5,713	9.3	7,174	9,189	13.7
T.Seg1.	1.0	0.50	2.0	6,229	5,112	17.9	7,115	6,753	5.1
T.Seg2.	3.0	1.50	6.0	6,186	4,366	29.4	7,108	5,898	17.0
T.Seg3.	1.0 - 1.5	0.50	3.0	6,210	5,821	6.3	7,072	6,999	1.0
T.Seg4.	0.5	0.25	1.0	6,225	4,813	22.6	7,074	5,264	25.6
T.Seg5.	0.5 - 1.0	0.25	2.0	6,229	5,497	11.7	7,115	7,061	0.1

Note: T.SegX. represents Transit time through Segment X.

After arrival, small ships are readied, on the average, 0.816 and 0.8522 hours later than the large ships for northbound and southbound traffic, respectively.

On the other hand, smaller ships are underway for transit faster than the larger ships. The differences in DRT components for larger ships and smaller ships are 1.213 hrs and 1.356 hrs in the northbound and southbound directions, respectively.

Table 6.2.3-3
Differences in DRT and DUT between Large and Small Vessels

Time Component	Northbound Traffic		Southbound Traffic	
	Estimated Differences (hrs)	Standard Error of Estimate	Estimated Differences (hrs)	Standard Error of Estimate
DRT	-0.8164	0.0661	-0.8524	0.0687
DUT	1.2130	0.0887	1.3590	0.0885

Note: Negative sign indicates that Smaller Ships are delayed longer.

- Conclusions Concerning Preparation for Transit Time

In summary, based on review of SDB data and discussions with knowledgeable persons, the principal factor causing delay of ships preparing to transit appears to be the clear cut restriction in navigating the Culebra Cut. Once the Cut is widened and improved, and high mast lighting installed, delays prior to transit will decline significantly. No other measure to reduce preparation for transit time would have significant impact.

- Seasonal Fluctuation of Transit Demand

The percentages of ships arriving in each month in each direction were determined from the SDB data on day of arrival. Separate distributions were developed for small ships (vessel classes 1 through 5) and large ships (vessel classes 6 through 12). The results were shown in Figures 6.2.3-1 (Northbound), 6.2.3-2 (Southbound), and 6.2.3-3 (combined directions).

For Northbound transits, the large ships arrived at a higher than average rate in April of 1990, and small ships exhibited a similar peak in October. No significant departures from the mean are evident for Southbound ships.

Looking at both directions combined, there are no departures from the expected average of 8.33 percent per month that are significant enough to justify not using differential ship arrival rates by month or season. Consequently, ship arrival times were assumed to be distributed randomly (constant flow rate) throughout the year for all subsequent analyses.

- The Probability Distribution of Ship arrival

In general, the arrivals at a free-flowing section of a waterway can be expected to be random. When random arrivals are observed the counting distribution of arrivals at the section will follow a Poisson process with the following probability density function:

$$P(x) = \frac{(\lambda t)^x}{X!} \exp - (\lambda t)$$

where:

$P(x)$	=	probability that x ships will arrive during a counting interval t
λ	=	average rate of arrival, ships/day (flow rate)
t	=	duration of each counting interval, days
λt	=	average number of arrival ships during a period of duration t

Under these conditions, the ratio of mean and variance is approximately 1.0. In congested conditions, the flow is more uniform than random. The variance of the number of ships per interval is decreased.

Consequently, the ratio of mean and variance is expected to be greater than 1.0. For free-flow conditions, as the number of arrivals follows a Poisson process, the interarrival times (time headway between two successive ship arrivals) will follow a negative-exponential distribution. The probability density function of the negative exponential distribution is given by:

$$P(h \geq t) = \exp - (t / \bar{t})$$

where: $P(h \geq t)$ = probability of the headway h being greater than or equal to the indicated time interval t.

$\bar{t}$ = mean headway between two successive arrivals.

The frequency distribution of specified number of arrivals per day was computed from the ship data bank by transit direction. There are 6,305 northbound and 7,179 southbound ships, with mean headways of 1.388 hours and 1.219 hours in the Northbound and Southbound directions, respectively. The expected arrivals in each headway class (i.e. specified number of arrivals per day) were computed using the negative exponential probability density function. A goodness of fit test was performed to investigate the applicability of the negative exponential distribution to the interarrival time of ships. Table 6.2.3-4 summarizes the results of this analysis. The computed value of the fits indicate very high probabilities (nearly 100%) for Type 1 error in accepting the hypothesis that the interarrival time headways follow the negative exponential distribution.

Looking at the individual frequency values for the quarter hour increments used in the table, it appears that the directional distributions have the characteristic shape of the negative exponential distribution, but the initial height and rate of fall of the curve are not close enough to theory to survive a statistical test. Dividing the data into more or fewer groups produced similar results. It is likely that a Gamma or some other Erlang type distribution would produce an acceptable fit. It is also possible that the larger ships plan their arrivals to coincide with the current scheduling practices for transit of the Culebra Cut, which produces a departure from purely random arrivals. These findings notwithstanding, it still appears prudent to assume random arrivals as the appropriate basis for simulations of future systems. It is wellknown that random arrivals place the greatest stress on capacity constrained transportation systems. Consequently, assuming this condition will provide conservative estimates of system capacity.

- Lock Downtime Caused by Fog

To generate lock downtime data to represent the occurrence of fog, published summary data from The Panama Canal Pilot on the historical occurrence of fog at Pedro Miguel were used.

A spreadsheet graph of cumulative distribution of fog start times manually estimated for historical Pedro Miguel data are shown in Figure 6.2.3-4.

Figure 6.2.3-1

Percentage of Transits by Month (1990) (Northbound)

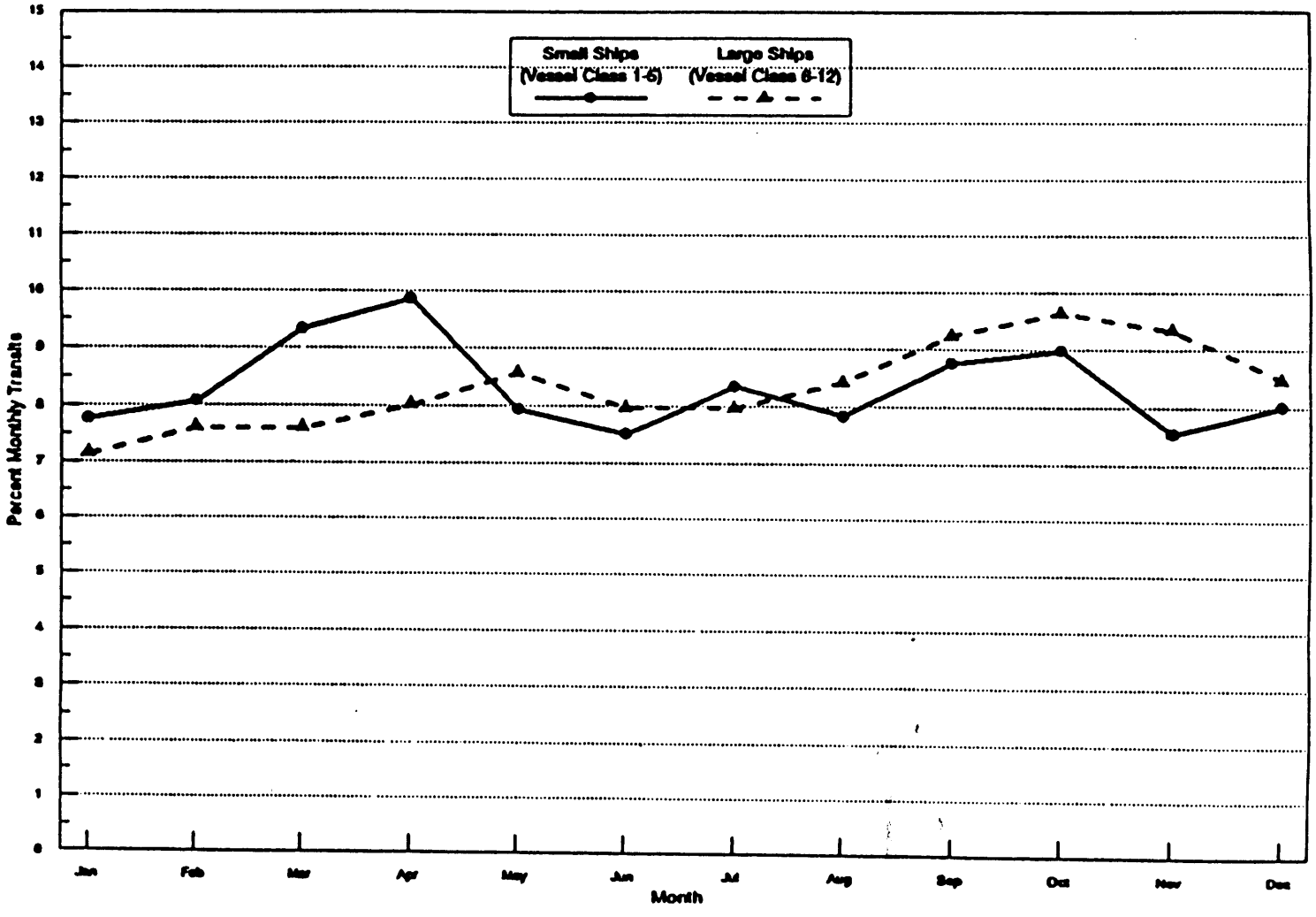


Figure 6.2.3-2

Percentage of Transits by Month (1990) (Southbound)

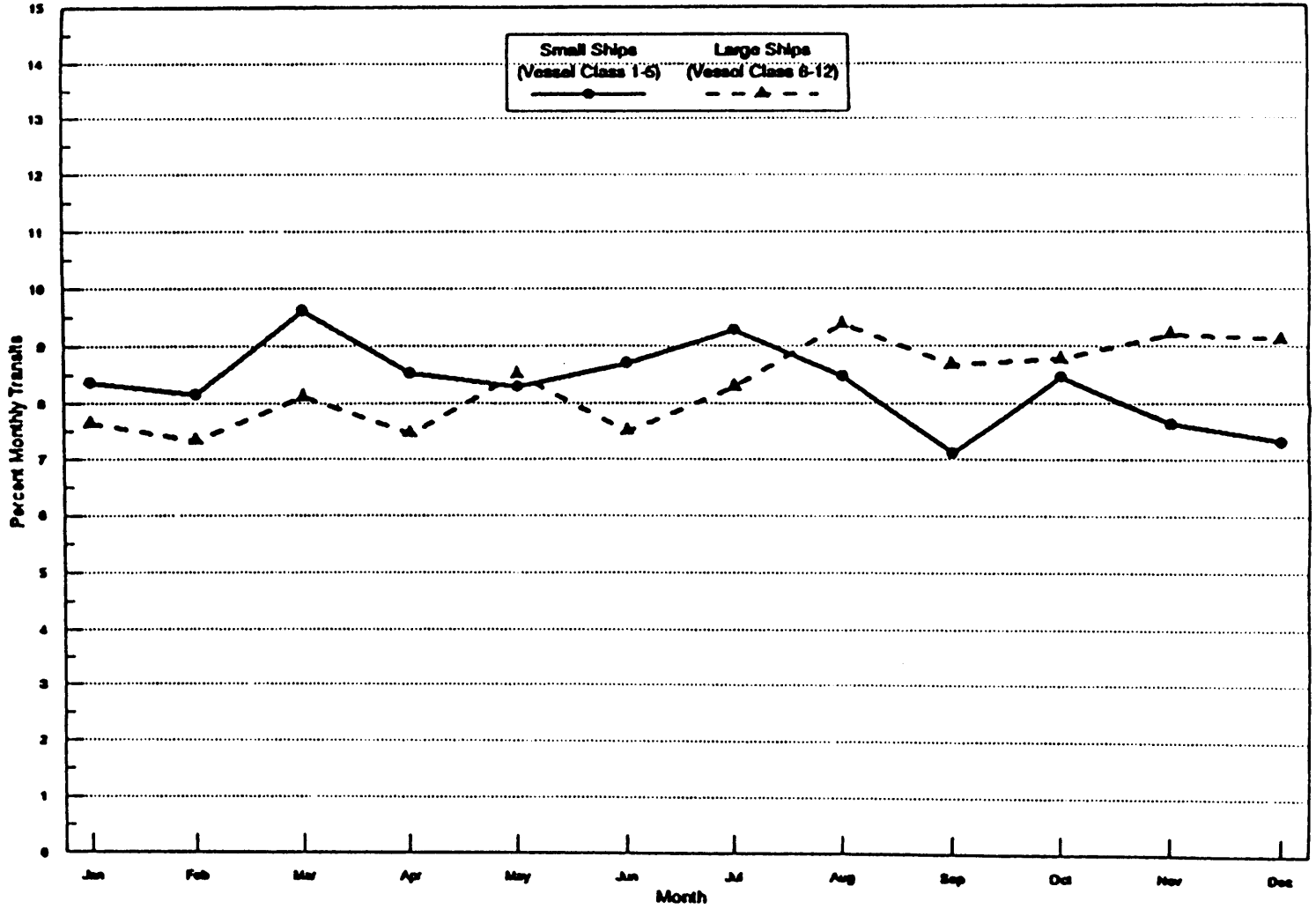


Figure 6.2.3-3

Percentage of Transits by Month (1990) (combined directions)

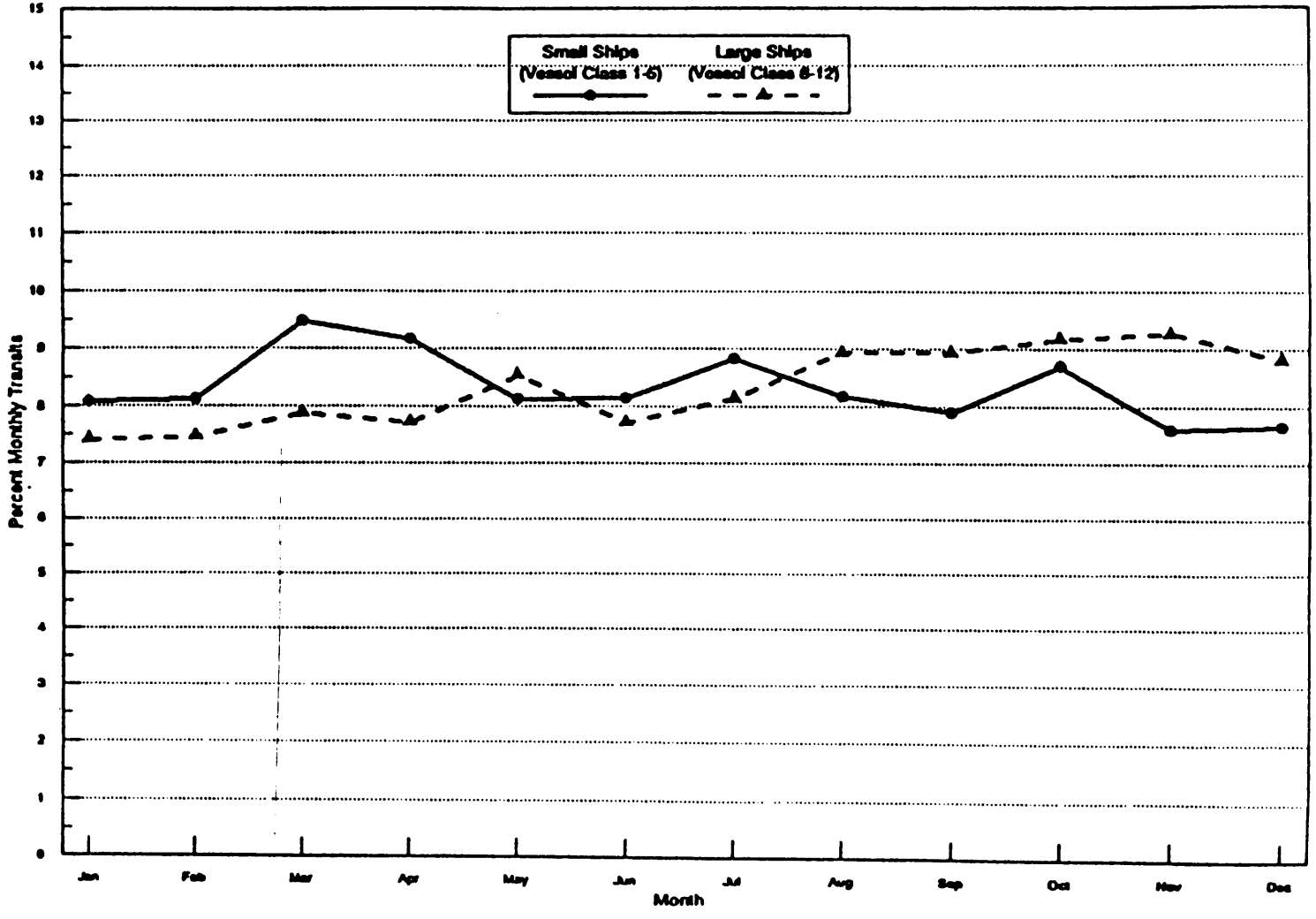
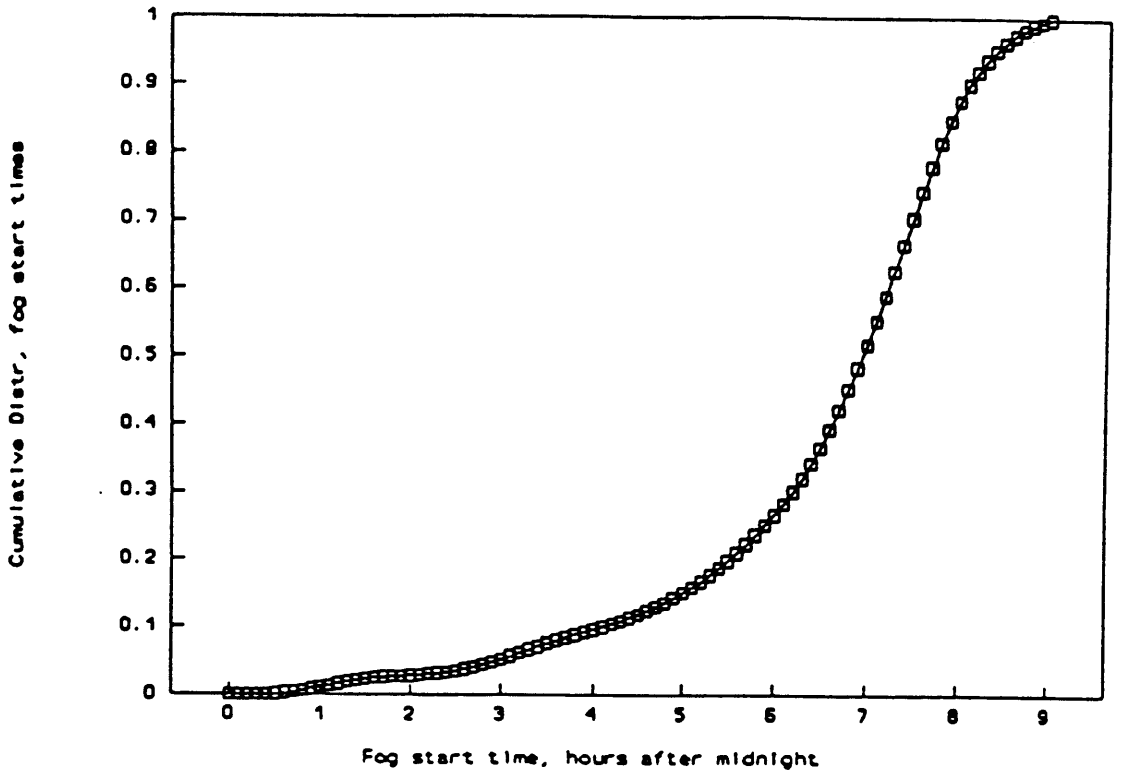


Table 6.2.3-4

Analysis of Inter-Arrival Times

Interval (hrs)	Northbound			Southbound		
	f_o	f_t	$(f_o-f_t)^2/f_t$	f_o	f_t	$(f_o-f_t)^2/f_t$
0.00-0.25	1,096	1,039.09	3.12	1,319	1,330.95	0.11
0.25-0.50	840	867.84	0.89	1,071	1,084.20	0.10
0.50-0.75	717	724.82	0.08	937	883.20	3.28
0.75-1.00	591	605.37	0.34	702	719.45	0.42
1.00-1.25	533	505.60	1.48	619	586.07	1.85
1.25-1.50	387	422.27	2.95	429	477.42	4.91
1.50-1.75	361	352.68	0.20	365	388.91	1.47
1.75-2.00	294	294.56	0.00	292	316.80	1.94
2.00-2.25	253	246.01	0.20	255	258.07	0.04
2.25-2.50	174	205.47	4.82	204	210.23	0.18
2.50-2.75	163	171.61	0.43	159	171.25	0.88
2.75-3.00	123	143.33	2.88	148	139.50	0.52
3.00-3.25	118	119.71	0.02	109	113.64	0.19
3.25-3.50	99	99.98	0.01	79	92.57	1.99
3.50-3.75	86	83.50	0.07	79	75.41	0.17
3.75-4.00	56	69.74	2.71	71	61.43	1.49
4.00-4.25	69	58.25	1.99	44	50.04	0.73
4.25-4.50	48	48.65	0.01	57	40.76	6.47
4.50-4.75	52	40.63	3.18	41	33.21	1.83
4.75-5.00	34	33.93	0.00	26	27.05	0.04
5.00-5.25	31	28.34	0.25	25	22.03	0.40
5.25-5.50	29	23.67	1.20	24	17.95	2.04
5.50-5.75	23	19.77	0.53	21	14.62	2.78
5.75-6.00	20	16.51	0.74	21	11.91	6.94
>=6.00	108	83.68	7.07	79	52.33	13.59
Mean Headway		1.388 hrs			1.219 hrs	
Standard Deviation		1.467 hrs			1.307 hrs	
Degrees of Freedom		24			24	
X^2		35.170			54.362	
Prob. of Type I Error		0.946			0.999	

Figure 6.2.3-4
Distribution of Fog Start Time



- Lock Chamber Size

Field observations in Panama in connection with the OCCE Study indicate that entry and exit times escalate sharply when the ships' beam is within 10% of the lock width and the draft is within 10% of the lock depth.

Accordingly, it is suggested that lock dimensions be 10% greater than each critical dimension for each of the Phase II design ships, with an additional allowance of 30 meters in lock length to allow a tugboat to accompany the ship; as follows:

	Design Ship (meters)			Lock Dimensions (meters)		
dwt	Length	Beam	Draft	Length*	Width	Depth
150 K	305.6	45.9	17.9	365	50	20.0
200 K	332.7	50.2	19.4	395	55	21.5
250 K	355.5	53.7	20.7	420	60	23.0

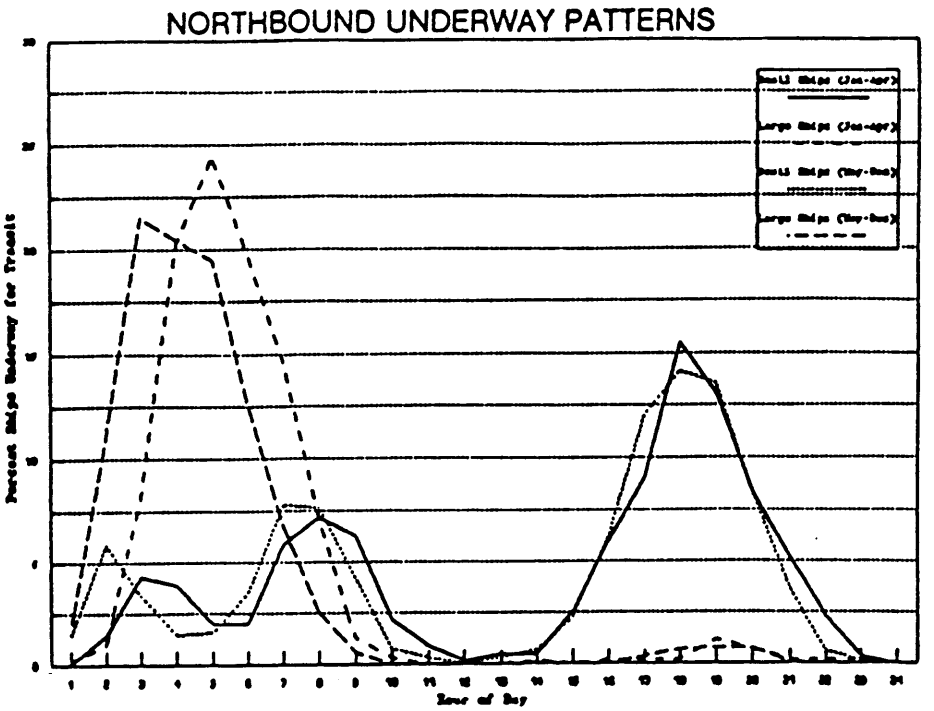
Note: * The Lock length (L) is measured from the tip to the pintail of miter gates.
Lengths were adjusted later to account for emergency as shown in Table 6.4.7-1 Footnote.

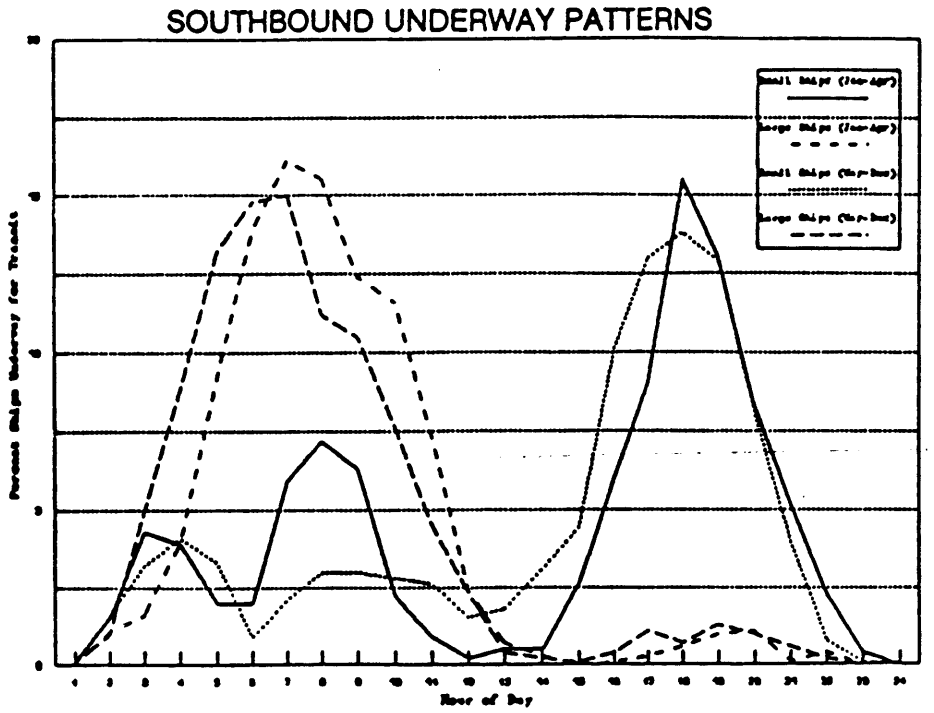
- Analysis of Ship Scheduling

The SDB records screening have been fully utilized for the model calibration, but the further analysis on the actual pattern of scheduled ship underway times in 1990 also carried out to make clear the effects of the *Clear Cut restriction* in navigating the Culebra Cut. The result of detailed analysis on the present ship scheduling process has been adopted to the computing logic for evaluating High Rise Canal Alternatives with single lane Culebra Cut.

The analysis of ship underway times in the SDB records indicated that the ship underway events are **not** random, that is, the time intervals between successive ships in one direction do **not** follow the negative exponential distribution. The scheduling practices used significantly influence the transit underway times of the ships. Another possibly important consideration for scheduling is the presence of fog. Large ships are normally not allowed to pass through the canal during night hours, and night traffic through the Culebra Cut is also sometimes restricted during the rainy (foggy) season. The SDB records were analyzed to test the influence of ship size and season on ship underway times. Figure 6.2.3-5 depict the patterns of underway times of small and large ships during different seasons for Northbound and Southbound ships.

Figure 6.2.3-5
Patterns of Underway Times





In these figures, large ships are those with beam exceeding 27.4 meters. It can be seen that the scheduling practices discussed above are reflected in these figures. The seasonal effect is also noticeable, particularly for the night hours, but it does not distort the basic pattern of ship underway times. Consequently, it was determined that there was not need to use different hourly ship underway time patterns for the different seasons. To incorporate both the random arrivals of ships and the scheduling practices in the simulated scenarios where channel widths in the Culebra Cut necessitate size-based ship scheduling, ship lists were generated in two stages for each such case. First, the specified number of ships were generated, assuming random (Poisson) arrivals. In the second stage these ships, each of which is treated as a separate arrival, were scheduled for transit through the Canal according to the logic described below.

- In general, all the ships in a given size category (large or small) are scheduled on a first-come-first-served basis. That is, no small ship can be scheduled ahead of other small ships that arrived earlier in a given direction of travel. The same logic applies to large ships also.

- Between hours 22:00 and 04:00 (Night Period), only small ships are scheduled and large ships are kept waiting.

- Between hours 04:00 and 10:00 (Morning Period) large ships are given preferential treatment. During this period, first large ships that arrived after hour 22:00 of the previous day are scheduled. These ships are followed by other large ships that arrived between hr 04:00 and the scheduled time of the last overnight large ship. After these two batches of large ships plus any other large ships waiting for transit are scheduled, the queue containing small ships is serviced.

- Between hours 10:00 and 14:00 (Day Period), small ships are given preferential treatment. Large ships are allowed only if there are no small ships waiting in the queue.

- Between hours 14:00 and 2:00 (Evening Period), large and small ships are serviced on first-come-first-served basis.

Vessel Configurations and Characteristics

In order to upgrade WAM vessel speed function, the recent trends of vessel configurations and characteristics in leading shipbuilders's records and those described in typical ship design books have been analyzed. Table 6.2.3-5 is a summary of the results of these investigations for vessel classes 1 through 12. In addition to the vessel configurations and characteristics study, stopping distances of various ships and their minimum separation distances in restricted water area have been analyzed by the aid of ship simulator. The results of Table 6.2.3-5 together with vessel configurations and characteristics for vessel classes over 13 are summarized and shown in Table 6.2.3-6.

Table 6.2.3-5

Vessel Configuration

No.	Type	Load	HP	DWT (summer)	Length (m)	Beam (m)	Draft Max. (m)	Block Coeffi-cient [Cb]	Sea Speed (kts) Max.	Sea Speed (kts) Avg.
1	Geo Survey Ship	Laden	7,200	3,100	89.00	15.54	5.49	0.56	17.1	16.8
		Ballast						0.55	17.6	17.4
2	Chemical Carrier	Laden	6,900	12,220	128.92	20.12	8.53	0.76	14.0	13.8
		Ballast						0.72	15.0	14.8
3	22K Bulk Carrier	Laden	7,000	22,000	152.09	22.86	9.75	0.79	13.9	13.7
		Ballast						0.77	14.9	14.7
4	34K Bulk Carrier	Laden	10,800	34,000	167.94	27.13	10.67	0.79	14.5	14.3
		Ballast						0.77	15.5	15.3
5	35K Bulk Carrier	Laden	11,300	36,000	168.24	27.13	11.28	0.80	14.5	14.3
		Ballast						0.78	15.5	15.3
6	Car Carrier	Laden	8,740	9,400	158.79	27.74	7.92	0.55	17.3	17.1
		Ballast						0.51	18.3	18.1
7	29K Bulk Carrier	Laden	7,500	29,000	170.07	27.43	10.06	0.79	14.1	13.9
		Ballast						0.76	15.1	14.9
8	45K Bulk Carrier	Laden	13,000	45,000	201.77	30.17	11.58	0.81	15.5	15.2
		Ballast						0.78	16.5	16.2
9	Car Carrier	Laden	14,700	15,396	199.94	32.31	8.84	0.58	18.0	17.8
		Ballast						0.52	19.0	18.8
10	44K Bulk Carrier	Laden	16,800	44,000	196.28	30.78	10.06	0.81	15.7	15.5
		Ballast						0.79	16.7	16.5
11	60K Tanker	Laden	14,000	60,000	218.84	32.31	11.58	0.81	15.7	15.5
		Ballast						0.79	16.5	16.2
12	66K Tanker	Laden	14,400	66,000	223.71	32.31	12.19	0.81	14.6	14.4
		Ballast						0.79	15.6	15.4

Table 6.2.3-6

Ship Speed, Stopping Distances, Ship Spacing and Tug Requirements

Ship	Type	Load	HP	DWT (summer)	Length (m)	Beam (m)	Draft Max. (m)	Block Coeffi-cient [Cb]	Sea Speed (kts) Max.	Sea Speed (kts) Avg.	Average Speed in Canal (Kts)	Minimum Spacing (m)	Stopping Distance at 7 Kts (m)	No. of Tugs Req'd.
20K	Tanker	Laden	12,000	27,000	186.53	24.99	9.75	0.75	16.4	16.2	6.5	776.29	517.53	0
		Ballast					5.48	0.73	17.4	17.2	6.5	570.56	380.37	0
35K	Tanker	Laden	12,000	38,000	181.96	27.43	11.5	0.82	16.0	15.7	6.5	791.53	527.58	0
		Ballast					6.40	0.79	17.0	16.7	6.5	582.14	387.99	0
45K	Bulk Carrier	Laden	13,000	45,000	201.77	30.17	11.5	0.81	15.5	15.2	6.5	897.90	598.60	0
		Ballast					6.40	0.78	16.5	16.2	6.5	660.16	440.11	0
65K	Tanker	Laden	14,500	61,000	206.95	32.31	13.7	0.81	15.5	15.2	6.5	961.90	641.27	0
		Ballast					7.61	0.79	16.5	16.2	6.5	706.80	471.20	0
100K	Bulk Carrier	Laden	15,000	120,000	249.92	45.11	16.1	0.81	14.0	13.7	6.5	1,290.16	860.10	0
		Ballast					8.83	0.79	15.0	14.7	6.5	948.19	632.12	0
150K	Tanker	Laden	15,650	146,270	274.31	43.28	16.7	0.81	14.0	13.7	6.5	1,463.58	975.62	1
		Ballast					9.14	0.79	15.0	14.7	6.5	1,075.89	717.16	0
200K	Bulk Carrier	Laden	15,600	201,200	298.69	49.98	18.5	0.82	12.0	11.7	6.5	1,684.85	1,123.13	2
		Ballast					10.3	0.80	13.2	13.0	6.5	1,238.65	825.66	1
250K	Tanker	Laden	23,640	258,000	330.08	60.04	19.5	0.82	14.0	13.7	6.5	1,948.49	1,298.99	2
		Ballast					10.6	0.80	15.0	14.7	6.5	1,431.88	954.59	1

The vessel data above were used to modify the Phase I values of the ship characteristics (length, beam, draft, horsepower, block coefficient) of the class 1 through class 14 vessels, derived from the SDB records. The vessel speeds computed by the WAM speed function required only minimal adjustment with the model's speed coefficients, so the revised vessel data were judged to be acceptable.

The estimates of the required ship separations in a sea-level canal, based on stopping distance simulations provided in the above table are based on emergency, full-astern stops. These separations, expressed in feet, were converted to minutes of travel time, then increased to reflect less severe stopping maneuvers and to provide a safety margin, and the resulting values were smoothed.

The minimum ship separations so derived are given in Table 6.2.3-7.

Table 6.2.3-6

Ship Spacing Data for Sea Level Canal

Ship Class	Minimum Spacing (minutes)	Ship Class	Minimum Spacing (minutes)
1	6.0	11	12.5
2	6.0	12	12.5
3	6.0	13	7.5
4	6.0	14	6.0
5	6.0	15	12.5
6	7.5	16	15.0
7	7.5	17	14.0
8	7.5	18	17.5
9	9.0	19	15.0
10	12.0	20	20.0

6.2.4 Model Calibration

In the Phase II OCCE Study, new data on ship characteristics were used (see Section 6.2.3), further analysis of SDB records was performed (see Section 6.2.3) and the other model inputs were successively refined to produce better agreement of the model outputs with the observed operations of the existing Panama Canal.

The improved WAM programming which was explained in Section 6.2.2 has been calibrated against the existing canal situation with the above explained refined input data. The main results of these calibration runs are summarized and discussed hereunder.

Table 6.2.4-1 shows the WAM average locking time outputs and the PCC lockage schedule times. (to produce this comparison, two WAM runs were made, with the model set to use regular lockage times and relay lockage times, respectively.) It is apparent that the scheduled times for relay lockage assume that ships are locking consecutively, and thus full credit for zero locomotive travel time is taken. In the model, the "turnback time" is not counted as part of a vessel's locking time.

Consequently, to obtain comparable figures, the average locking times output in the calibration run with relay lockage were reduced by 10 and 15 minutes at Miraflores and Gatun, respectively.

The overall level of agreement is quite good, especially for the regular lockage case. The relay lockage times are also in good agreement with the schedule times, with the possible exception of the times for vessel classes 10, 11, and 1 at Gatun. In general, where there are noticeable differences, the simulated average locking time exceeds the schedule time. This is in line with expectations, since the schedule excludes the long locking times that are observed to occur in practice, especially for the larger vessel classes.

Table 6.2.4-2 displays the locking times output by WAM along with the values obtained from the SDB records. Recognizing that the SDB values listed are taken from unsoothed data and include some delay time, the agreement is reasonable. The standard deviations in the WAM results tend to be smaller and more uniform than the SDB standard deviations, indicating that the analytical intent to use more compact distributions than those of the raw data was achieved.

A second major part of the calibration is estimating ship speeds in channels and in the Culebra Cut. Table 6.2.4-3 shows the five segments into which the canal system was divided for purposes of analyzing ship travel times and speeds, as explained earlier, and Table 6.2.4-4 gives the mean travel speeds for each segment, both from the SDB analysis and as computed by the model. As can be seen in the table, the agreement between the estimated and actual ship speeds is excellent. Some statistics concerning lock operations recorded in the calibration run are presented in Table 6.2.4-5. The lock utilization and delay levels look reasonable.

Table 6.2.4-1

WAM Calibration Results Compared with PCC Locking Time Schedule

Vessel Class	Source*	Average Locking Times (minutes)				
		Gatun Locks		Pedro Miguel Locks	Miraflores Locks	
		Regular	Relay		Regular	Relay
1	PCC	60	30	30	40	30
	WAM	57	33	28	39	31
2	PCC	60	35	30	40	30
	WAM	58	33	30	40	30
3	PCC	60	35	30	45	35
	WAM	59	32	31	45	35
4	PCC	70	40	40	50	40
	WAM	69	44	38	50	40
5	PCC	70	45	40	50	40
	WAM	69	46	39	51	39
6	PCC	70	40	40	55	40
	WAM	72	45	40	54	39
7	PCC	75	45	45	65	45
	WAM	75	46	44	62	45
8	PCC	85	50	50	70	50
	WAM	86	59	50	70	50
9	PCC	70	45	40	60	45
	WAM	73	48	44	61	45
10	PCC	85	50	50	70	50
	WAM	86	66	53	70	54
11	PCC	105	60	60	80	60
	WAM	106	77	61	82	59
12	PCC	125	75	65	90	60
	WAM	133	101	69	90	68
Tandem	PCC	70	40	40	50	40
	WAM	70	42	40	52	39

*PCC = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration (Phase 2)

Table 6.2.4-2 (1 of 2)

WAM Calibration Results Compared with SDB Locking Times

Vessel Class	Source*	Northbound Locking Times (minutes)					
		Gatun Locks		Pedro Miguel Locks		Miraflores Locks	
		Average	SD	Average	SD	Average	SD
1	SDB	79	21	34	28	51	13
	WAM	60	16	26	7.7	40	8.7
2	SDB	76	17	33	9.7	48	8.0
	WAM	61	17	29	7.5	40	9.0
3	SDB	76	18	34	9.6	50	11
	WAM	59	17	29	6.9	45	9.1
4	SDB	81	21	36	21	52	9.5
	WAM	70	17	36	6.6	50	8.8
5	SDB	86	17	38	5.5	56	6.9
	WAM	70	16	37	7.1	52	8.7
6	SDB	86	21	41	18	55	10
	WAM	71	19	41	9.1	53	9.9
7	SDB	91	19	42	13	58	7.8
	WAM	75	20	45	10	61	9.1
8	SDB	95	18	48	22	63	9.1
	WAM	87	20	50	9.3	70	9.8
9	SDB	93	21	45	18	61	9.1
	WAM	73	19	45	12	60	8.8
10	SDB	101	21	49	16	67	10
	WAM	88	18	54	12	71	11
11	SDB	-	-	-	-	-	-
	WAM	110	18	64	16	83	12
12	SDB	118	23	61	13	85	11
	WAM	127	22	73	14	94	11

*SDB = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration (Phase 2)

Table 6.2.4-2 (2 of 2)

WAM Calibration Results Compared with SDB Locking Times

Vessel Class	Source*	Southbound Locking Times (minutes)					
		Gatun Locks		Pedro Miguel Locks		Miraflores Locks	
		Average	SD	Average	SD	Average	SD
1	SDB	70	13	36	13	51	14
	WAM	54	14	29	7.8	39	9.3
2	SDB	70	14	36	13	49	9.9
	WAM	54	14	31	8.0	40	9.4
3	SDB	71	14	36	14	50	10
	WAM	54	14	32	7.5	44	9.3
4	SDB	75	15	38	12	53	12
	WAM	64	13	39	8.9	50	9.4
5	SDB	77	14	44	16	51	9.2
	WAM	63	11	39	7.6	50	11
6	SDB	79	15	41	12	56	15
	WAM	67	17	40	9.2	53	12
7	SDB	86	19	42	10	60	16
	WAM	68	15	43	10	60	12
8	SDB	92	16	45	8.7	62	15
	WAM	82	17	51	9.3	71	11
9	SDB	87	11	42	11	62	15
	WAM	67	17	42	9.0	58	13
10	SDB	93	13	47	9.9	65	14
	WAM	83	18	51	9.7	70	14
11	SDB	102	17	49	7.4	69	15
	WAM	101	20	60	9.0	78	14
12	SDB	124	19	56	10	77	14
	WAM	133	20	67	10	87	14

*SDB = Marine Bureau Scheduling Table
WAM = Waterway Analysis Model Output, 1990 Calibration (Phase 2)

Table 6.2.4-3
SDB Transit Time Segments

		Miles	Km
1	Atlantic Approach	9.3	14.9
2	Gatun Lake	21.9	35.3
3	Culebra Cut	10.9	17.5
4	Miraflores Lake	2.0	3.3
5	Pacific Approach	7.7	12.4
Total		51.8	83.4

Table 6.2.4-4
Ship Speeds: WAM Calibration vs. SDB Data

Segment		SDB Mean	WAM mean	WAM Std. Dev.
Atlantic Approach	NB	14.7	14.7	1.87
	SB	8.1	8.3	1.06
Gatun Lake	NB	7.0	6.9	0.92
	SB	9.8	9.9	1.33
Culebra Cut	NB	10.2	10.2	1.55
	SB	9.3	9.3	1.38
Miraflores Lake	NB	5.7	5.7	0.73
	SB	5.5	5.5	0.71
Pacific Approach	NB	6.1	6.1	0.79
	SB	9.3	9.3	1.20

Note: All speeds are expressed in units of statute miles per hour

Table 6.2.4-5
Calibration Run - SDB Ships

Lock	Ships	Average Lockage (hrs.)	Average Delay (hrs.)	Lock Utiliza-tion (%)	Relay Operation (hrs.)	Down Time (%)
Gatun	12,106	1.19	1.95	75	8.9	5.4
Pedro Miguel	12,110	0.66	0.28	44	0.0	11.6
Miraflores	12,108	0.89	0.28	59	1.7	1.4

In this run, relay operations were scheduled on demand at Gatun Locks about nine percent of the time during the year, but were needed only two percent of the time at Miraflores. It is recognized that the actual schedule of relay lockage periods at Miraflores would more closely resemble the schedule at Gatun; the model results merely reflect the lower service time at Miraflores. The high downtime at Pedro Miguel is due to the practice of shutting down one lane at night. The low delays experienced at this location confirm that this practice does not adversely affect the service capacity of the system.

Table 6.2.4-6
Calibration Run - SDB Ships (100% Relay Lockage)

Lock	Ships	Average Lockage (hrs.)	Average Delay (hrs.)	Lock Utiliza-tion (%)	Relay Operation (hrs.)	Down Time (%)
Gatun	12,106	1.03	1.03	65	92.7	5.1
Pedro Miguel	12,110	0.66	0.21	43	0.0	11.3
Miraflores	12,108	0.85	0.19	56	97.7	1.1

Table 6.2.4-6 provides the same statistics as in Table 6.2.4-5, but for the calibration run with 100% relay lockage. It is interesting to note that this extremely high usage of relay lockages produces an average delay savings of only about one hour per vessel. This result confirms the appropriateness of allowing the model to schedule relay lockage operations as needed in the runs to simulate the study cases.

6.2.5 Results of Simulation

The following is a summary of the conditions of simulation runs, for which explicit explanations have not been provided in the previous sections.

Status Quo

The status quo simulations for Phases I and II were carried out essentially in the same manner. The ship transits were generated for two different ship mixes, based oh the WEFA 2020 and 2060 forecasts. Separate runs were made for each ship mix at two different traffic levels, to provide the data points needed for the delay curves.

Study Case 1 is with ship mix in the CTP Component Study, and 1a with PCC ship mix.

High-Rise Canal

New channels were defined for the third locks. All channels which would be traversed by the larger ships were modified to provide minimum depths consistent with the drafts of the design vessels. The lock dimensions specified herein were used for the new locks. The level of Gatun Lake was set at 25.9 m (85-ft), vs the 27.4 m (90-ft) elevation used in Phase I. The restrictions on large ships transiting the Culebra Cut at night were removed, as was done in Phase I, except as necessary to reflect fog conditions.

Locking times at the new locks were derived from the input distributions for the existing Miraflores Locks. However, recognizing the greater clearances available between the vessel and the lock chambers, the maximum locking time used was that for a class 7 vessel, which has similar clearance in the existing locks. A smooth distribution of locking times from class 1 to class 7 was developed and applied to the range of ship sizes that would use the new locks. This is a significant departure from the Phase I procedure, where it was assumed that vessel clearances would be much smaller.

Study Case 2 is the 150,000 dwt one lock alternative, Study Case 3 is the 150,000 dwt two lock alternative, Study Case 4 is the 200,000 dwt one lock alternative, and Case 5 is the 200,000 dwt two lock alternative. Study Case 6 and 7 are the variations of Study Case 2 and 4, respectively, for which the Culebra Cut is designed as single lane operation for the vessels larger than 65,000 dwt.

The overall average ship transit times (hours) in this run are given in Table 6.2.5-1. As indicated, the match with the transit time results from analysis of the SDB records is relatively good. Combining the average travel time of 12 hours with the average of about 8 hours of schedule delay experienced in 1990 indicates that the simulated Time In Canal Waters (TICW) is about 20 hours, which is quite close to the 19 hours estimated from the SDB data.

Table 6.2.5-1

Calibration Run - SDB Ships

(Average Travel and Delay Times (hrs.))

	North	South	Average
Travel	6.56	5.69	6.10
Lockage	2.70	2.77	2.74
Lock Delay	2.57	2.46	2.51
Cut Delay	0.64	0.25	0.43
Total	12.47	11.17	11.78
SDB Data			
Travel	12.5	9.8	11.1
Udy - Ready	7.8	7.9	7.9
TICW	20.3	17.7	19.0

Both the simulated and actual TICW values are under the PCC standard of 24 hours by only a small margin. This matches the information obtained during the visits of the research team to Panama.

In summary, the model calibration was deemed to be good enough to proceed with the simulation of the alternative conceptual plans.

Sea-Level Canal

The sea-level canal was modeled as a separate channel in parallel with the status quo system. The Route 10 case was assumed, with a total length, including the lengths of the approach channels,of approximately 90 km. All cases featured dual lane approaches and a single lane canal section, and positive tidal current control with either tide gates or tidal locks. The following cases were modeled:

- 8 — single lane, 40 km between tide gates, 6.25 hour cycle, 13.0 km/hr ship speed;
- 9 & 10 — single lane, 51.5 km canal section, Pacific locks, three or four parallel chambers, 12.5-hour cycle, 13.0 km/hr ship speed.

Status Quo and High Rise Locks Cases

For the high-Rise Canal cases with a two-lane Culebra Cut, the model schedules vessels to begin transit immediately upon arrival. For the single-lane Culebra Cut cases, however, large ships arriving at night do not start their transit until early morning, using the logic outlined in Section 6.2.3.6. This waiting time, or ships' scheduled delay, was added to transit delay that results from congestion, to arrive at a total delay. A summary of the simulation results for the Status Quo and high-rise locks cases appears in Table 6.2.5-2.

Table 6.2.5-2
Summary of Simulation Results
Status Quo & High Rise Lock Canal

Case	Variable	Run 1	Run 2
1	Annual Transits	14,921	16,853
	Average Delay (hrs.)	3.84	9.22
1a	Annual Transits	9,885	15,680
	Average Delay (hrs.)	1.20	15.76
2	Annual Transits	23,626	34,060
	Average Delay (hrs.)	1.76	8.55
3	Annual Transits	30,182	53,382
	Average Delay (hrs.)	1.20	16.78
4	Annual Transits	24,662	36,238
	Average Delay (hrs.)	1.83	13.43
5	Annual Transits	30,179	55,574
	Average Delay (hrs.)	1.04	13.30
6	Annual Transits	23,622	34,538
	Average Delay (hrs.)	2.10	9.89
	Ships Scheduled Delay	0.38	0.44
	Total Average Delay (hrs.)	2.48	10.33
7	Annual Transits	23,622	36,248
	Average Delay (hrs.)	1.95	14.36
	Ships Scheduled Delay	0.39	0.41
	Total Average Delay (hrs.)	2.34	14.78

The capacity curves for the Status Quo and high-rise locks cases (1 through 7) appears as Figures 6.2.5-1 through 6.2.5-3. The summary outputs of average delay and transit times from the WAM resource files for cases 1 through 7, appear in Appendix 6-A.

WAM for Phase II Study, equipped with dynamic route assignment function, can provide utilization of each lock by transit vessels. Table 6.2.5-3 is an example of such output. This information is utilized as the basis of water usage analysis of High Rise canal alternatives.

Table 6.2.5-3
Dynamic Routing Results (High Rise Locks)

Case		Route			
		Status Quo	Gatun/ Pacific	Mirafl./ Atlantic	Atlantic/ Pacific
2	Percent Ships	30	23	21	26
	Avg. Transit (hrs.)	10.2	9.2	9.4	9.5
4	Percent Ships	29	23	21	27
	Avg. Transit (hrs.)	10.1	9.1	9.2	9.1

Sea-level Canal Alternatives

The Sea-Level Canal alternatives are based on a cyclical operation, which requires three data points to produce a capacity curve. For the combined sea-level and status quo alternatives (8, 8a, 9, 9a, 9b and 10), because actual travel times differ along the two routes, it was more appropriate to use transit time (travel plus delay) as a measure, rather than delay time alone. This is also compatible with the dynamic route assignment logic in the model, which attempts to equalize transit time on the two routes.

In all cases, except the status quo, the 2060 ship mix was used in the model. Alternative transit times of 15 hours and 19 hours were assumed as the basis of capacity for the combined sea-level/status quo cases. Since the travel (non-delay) portion of transit time through the status quo system is approximately 9 hours, these criteria are consistent with the delay criterion. Because of the different operating procedures for the sea-level canal, as compared with the status quo system, it was not possible to develop composite delay or transit time curves for these systems.

Figure 6.2.5-1

Capacity Curves for Status Quo (65,000 dwt)

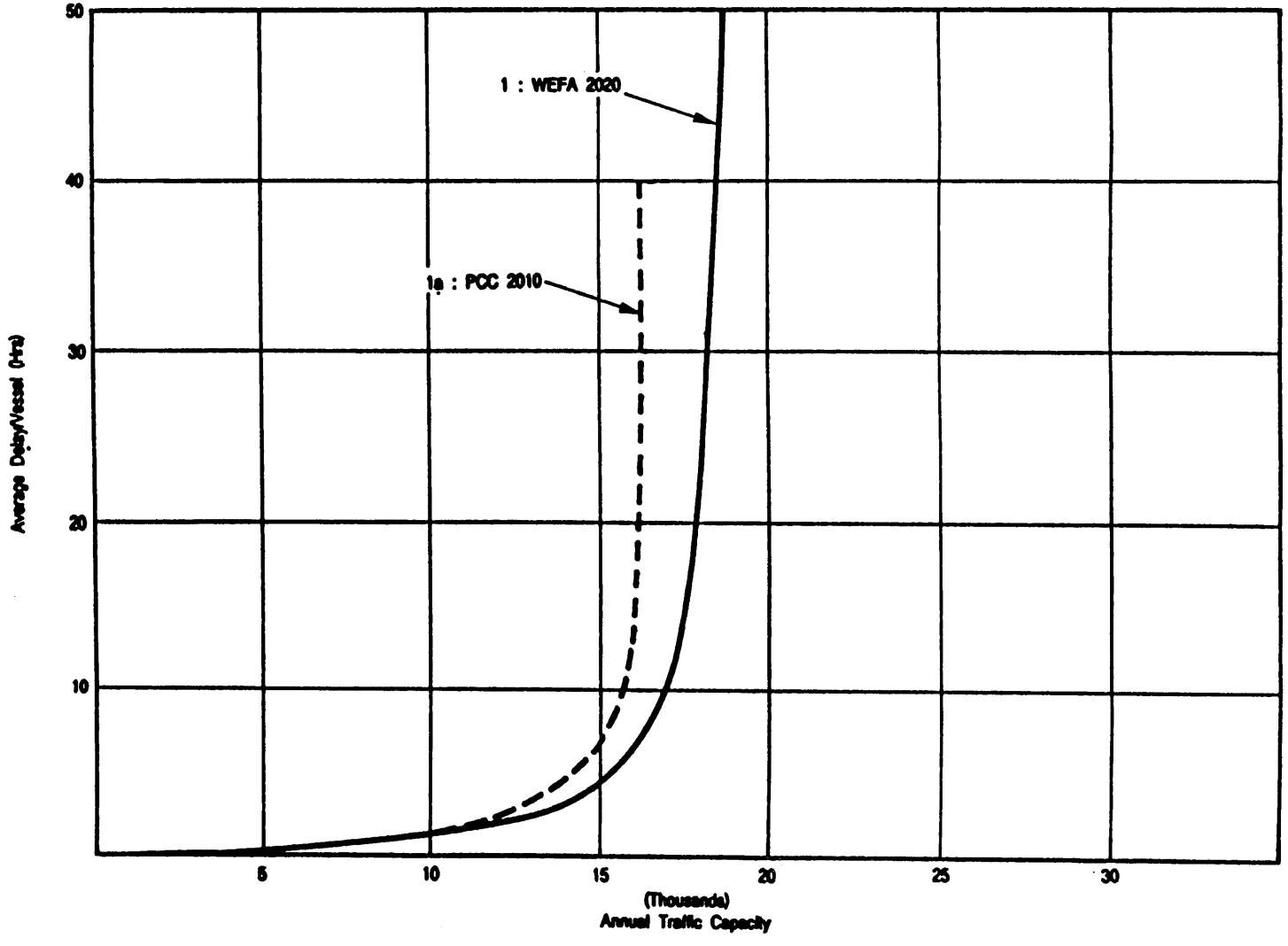


Figure 6.2.5-2

Capacity Curves for High-Rise Locks (150,000 dwt)

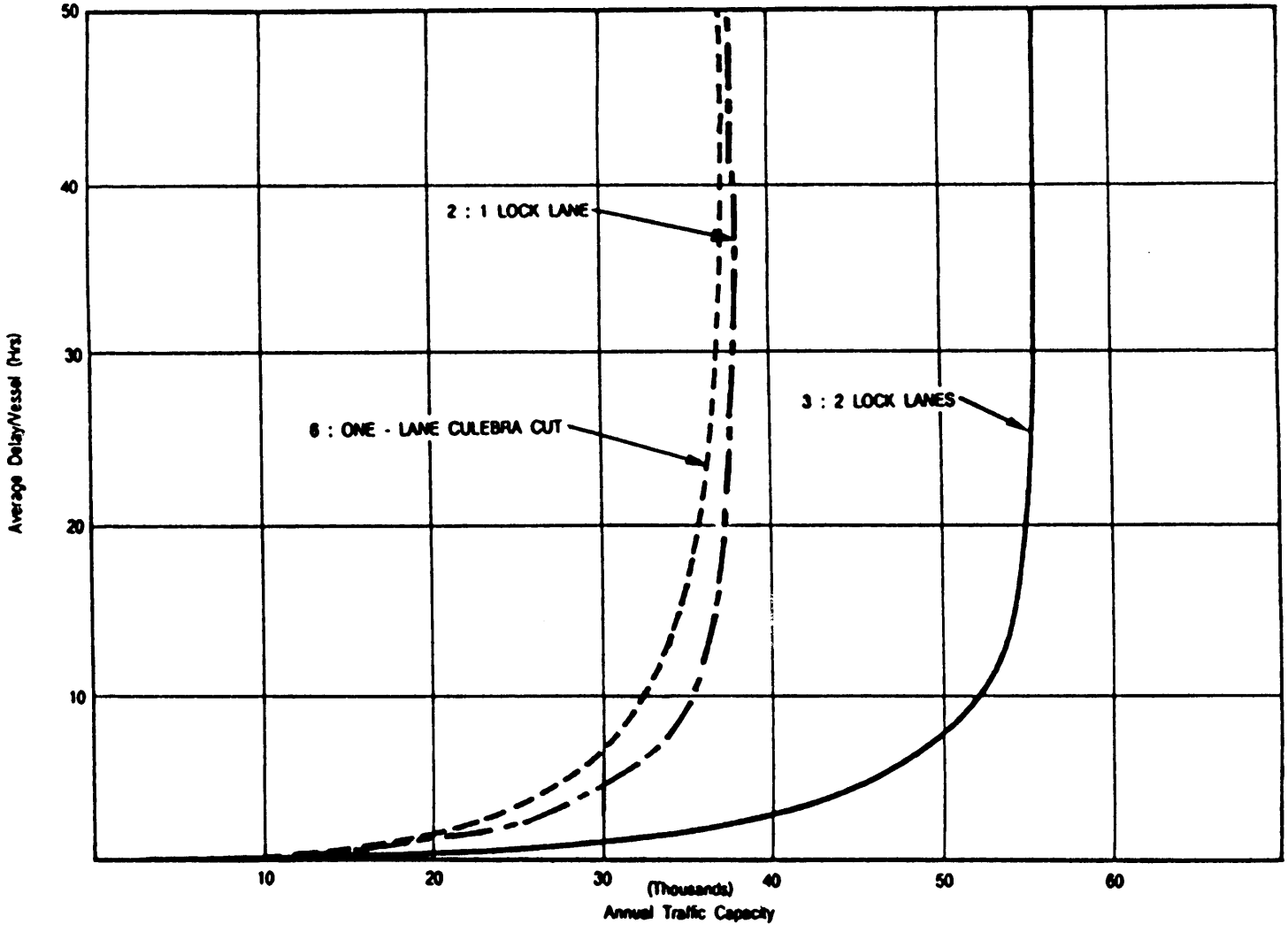
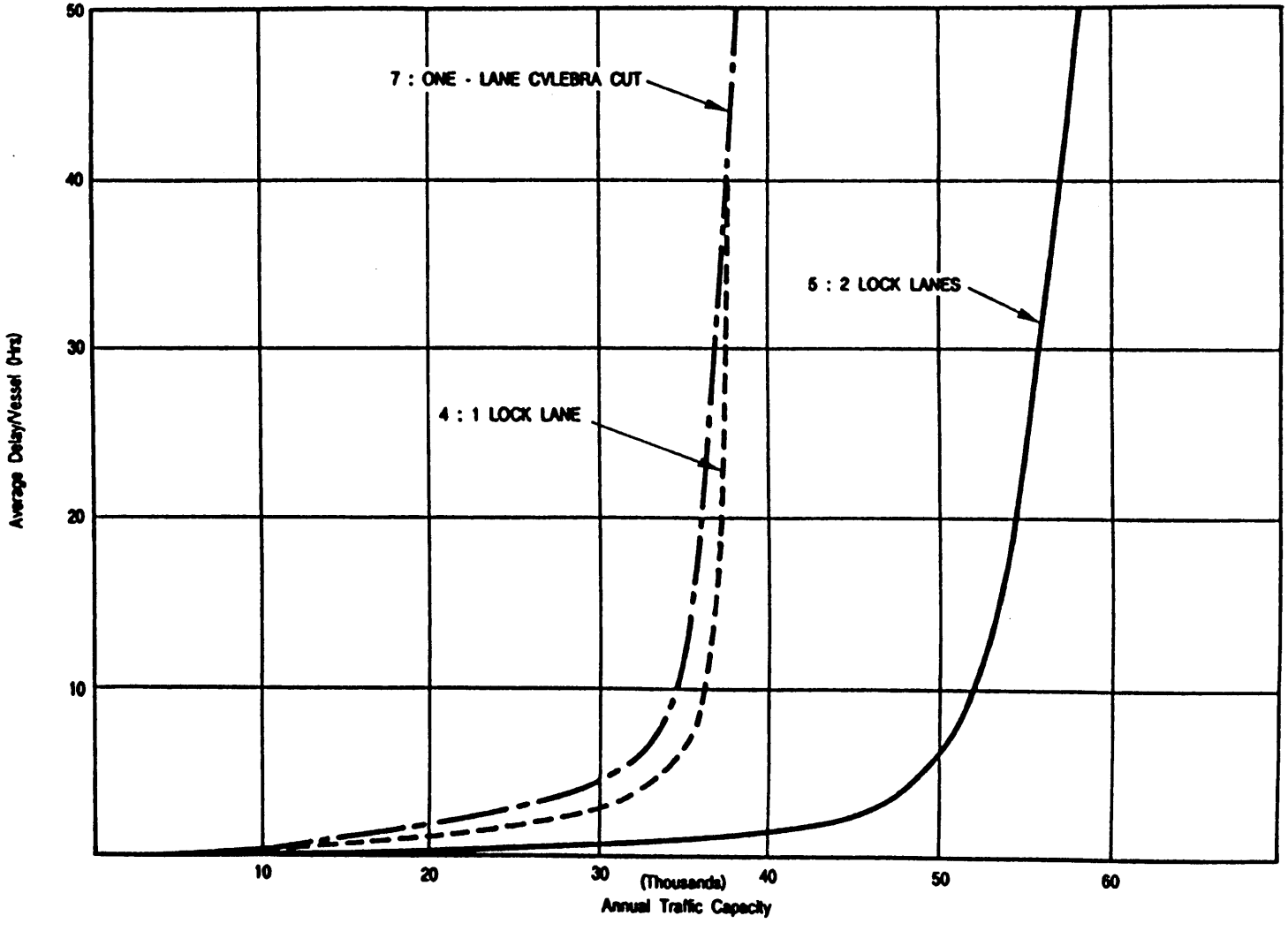


Figure 6.2.5-3

Capacity Curves for High-Rise Locks (200,000 dwt)



The principal reason is that the cyclic convoy operations of the single-lane sea-level channels impose a minimum average delay of several hours, even at very low traffic levels. Consequently, the following strategy was used to develop meaningful estimates of operational capacity for these cases:

1. The sea-level canal version of the WAM was used to simulate operation of the combined sea-level and status quo systems, including dynamic assignment of ships to the two channels. Runs were made at three traffic levels selected to span the knee of the capacity curve.

2. The simulation results for the sea-level portion of the system were used to develop a transit time vs. traffic level capacity curve for the sea-level canal only.

3. The capacity curve for case 1, the status quo system, was used to represent the operating characteristics of the status quo.

4. To estimate operational capacity at an average delay of 6 hours, the status quo traffic at 6 hours of delay was added to the sea-level traffic at a transit time of 15 hours.

5. To estimate operational capacity at an average delay of 10 hours, the status quo traffic at 10 hours of delay was added to the sea-level traffic at a transit time of 19 hours.

It was assumed that the ship mix of traffic in the status quo system in cases 8 through 10 will be approximately the same as the ship mix for case 1. This was verified by developing a representative delay curve for the status quo using the results from the case 8 simulations, and finding that this curve and the delay curve developed from the case 1 simulations were essentially the same. Table 6.2.5-4 contains the inputs to computation of the transit time curves for the sea-level route of the sea-level canal alternatives. In each case, the results were obtained from various elements of the WAM output or the Foxpro post-processing program, as indicated in the table. The number of ships per year and the corresponding average total transit time were input directly into the equations for estimating the function parameters. The actual capacity computation for the sea-level route for any transit time criterion was based on the formula:

$$q(t) = \frac{(t - t_o)\,Q}{(T - T_o) + (t - T_o)}$$

where: $q(t)$ = traffic level (number of ship transits) at transit time (t);
and, Q, T, T_o = canal capacity function parameters.

The capacities for the sea-level route component thus computed are shown in Table 6.2.5-4. The capacity curves are shown in Figure 6.2.5-4 and Figure 6.2.5-5.

Table 6.2.5-4

Summary of Simulation Results of Sea Level Canal

Case	Variable	Data Source[1]	Run 1	Run 2	Run 3
8	Ships/year	S	11,372	26,288	27,406
	Avg. Transit, hr.	S	8.90	14.13	29.90
9	Ships/year	S	2,622	21,424	29,100
	Avg. Transit Times, hr.				
	Single Lane Segment[2]	S	7.523	10.928	14.697
	Lock Delay	W/F	0.11	2.19	4.76
	Approach Channels[3]	W/F	3.768	3.768	3.768
	Total		11.40	16.89	23.22
10	Ships/year	S	2,564	21,358	29,098
	Avg. Transit Times, hr.				
	Single Lane Segment	S	7.620	10.490	13.050
	Lock Delay	W/F	0.06	1.05	1.61
	Approach Channels	W/F	3.581	3.581	3.581
	Total		11.26	15.12	18.24
9a	Ships/year	S	2,740	20,100	28,400
	Avg. Transit Times, hr.				
	Single Lane Segment	S	7.22	10.51	13.42
	Lock Delay	W/F	0.12	1.37	1.89
	Approach Channels	W/F	4.08	3.73	3.78
	Total		11.42	15.61	19.09
8a	Ships/year	S	10,976	17,756	19,504
Half-Cycle	Average Transit, hr.	S	9.14	13.53	39.77
9b	Ships/year	S	2,506	7.546	10.506
	Avg. Transit Times, hr.				
	Single Lane Segment	S	7.43	8.84	9.49
	Lock Delay	F	1.29	7.54	25.33
	Approach Channels	F	4.20	3.88	3.84
	Total		12.92	20.26	38.66

1 Key: S = WAM output file from sea-level canal module.
W = WAM print file.
F = Foxpro post processing of WAM resource usage file.

2 Sea-level channel between the tidal locks and the Atlantic end of the single-lane channel. Transit time includes delays due to convoy operations.

3 Transit time in channels outside of the single-lane segment, including lockage time but excluding lock delay, which is given in the preceding row.

Figure 6.2.5-4

Capacity Curves for Sea Level - Route 10 w/ Tidal Gates

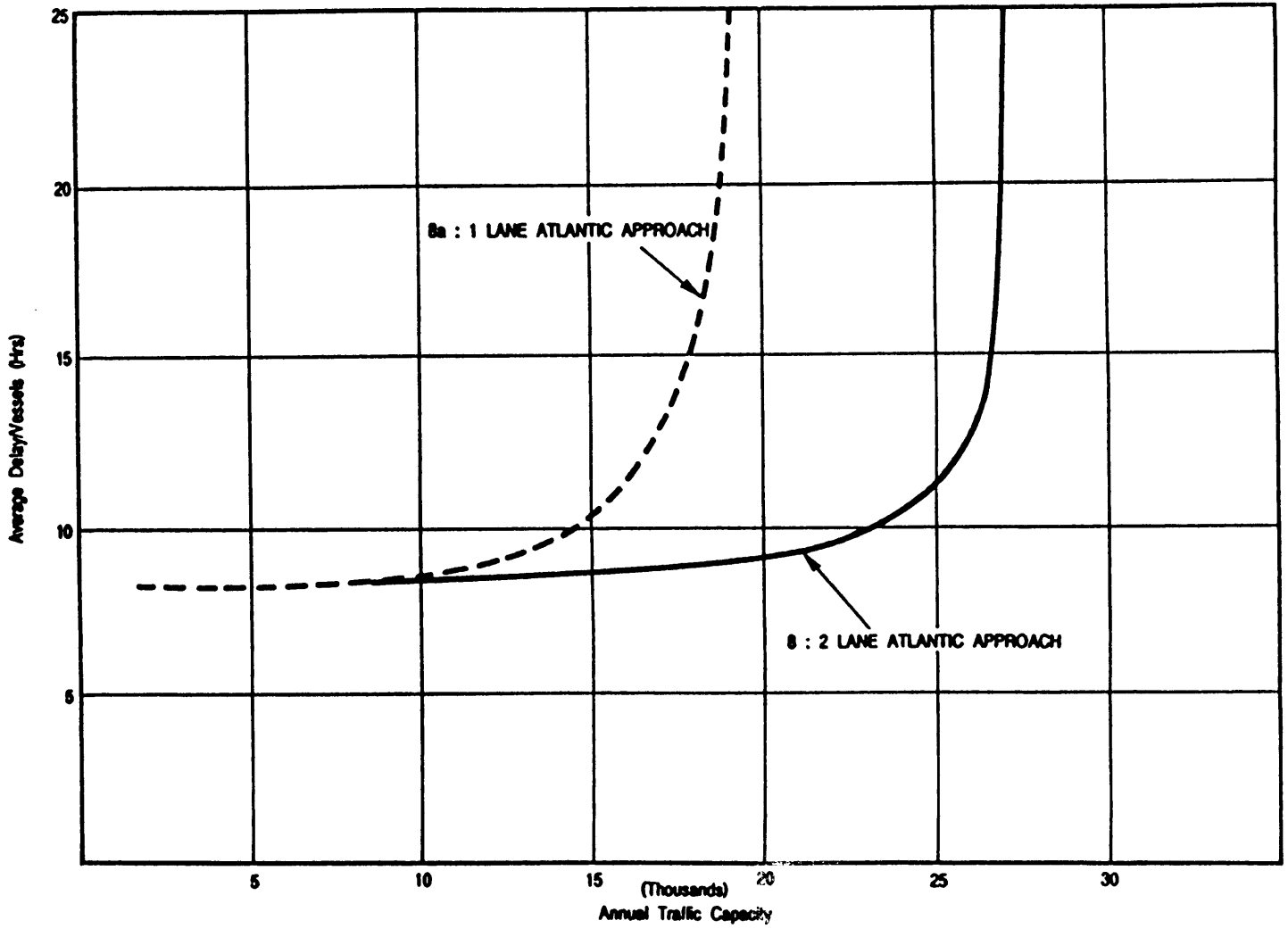


Figure 6.2.5-5

Capacity Curves for Sea Level - Route 10 - Pacific Locks

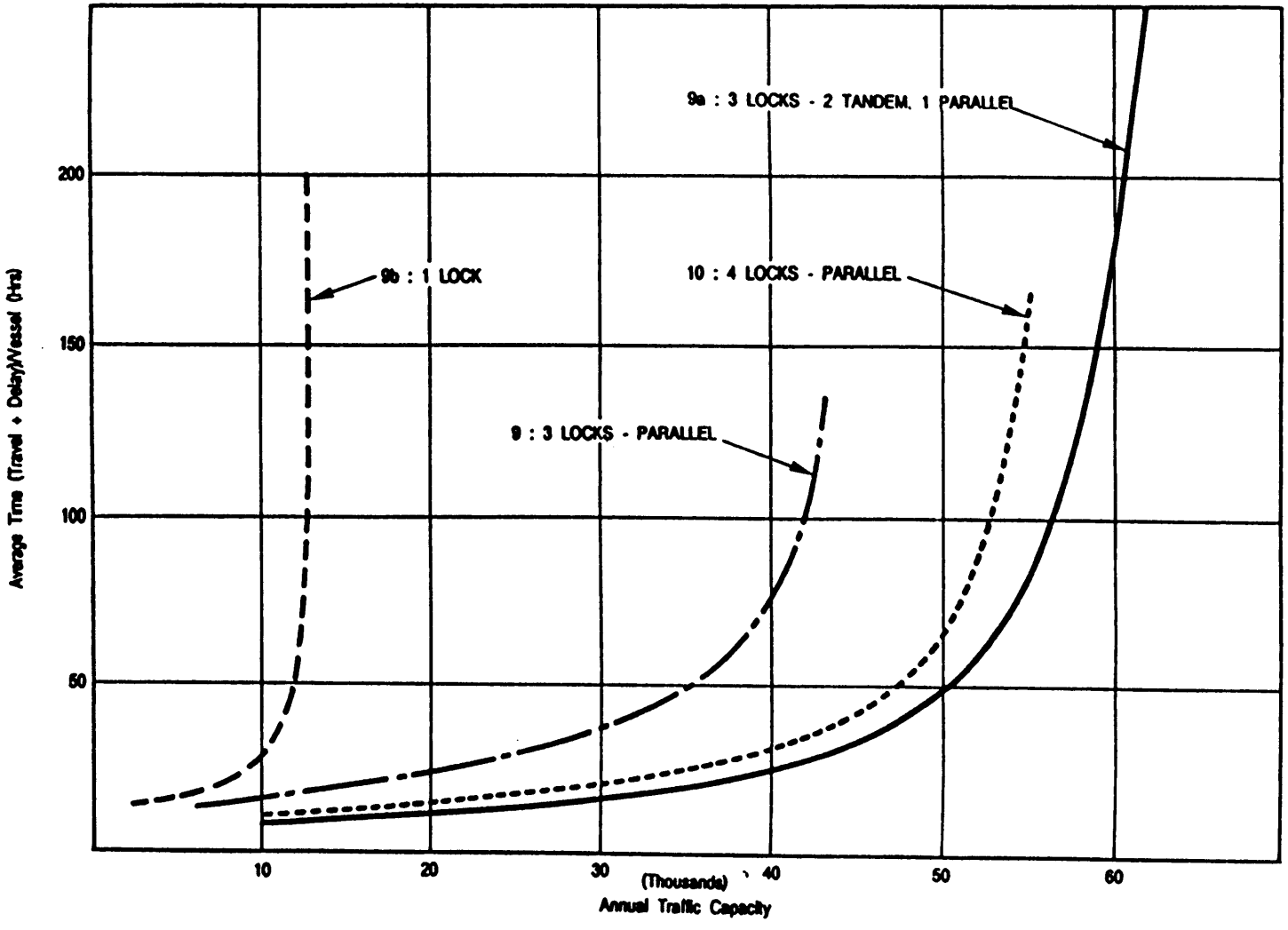


Table 6.2.5-5
Capacities of Sea Level Routes

Cases	Number of Vessel Transits	
	15 hr. Transit	19 hr. Transit
8	26,480	26,980
8a	18,190	18,790
9	17,270	24,750
9a	18,220	28,230
9b	4,690	7,060
10	20,980	30,500

The capacities from Table 6.2.5-5 were then added to the capacity of the Status Quo route to arrive at the total capacity of the system. In all cases, the capacity of the status quo system was computed as 16,060 vessel transits for the 15-hr. transit time criterion and 19,980 vessel transits with the 19-hr. criterion. Table 6.2.5-6 is the simulated results of Sea-Level Alternative with the dynamic route assignment and Table 6.2.5-7 is the summary table of the estimated capacity for each alternative studied in Phase II.

6.2.6 Navigation Support Systems

General Criteria

- Channel Range Lights

For the High-Rise Lock Canal, range lights for the new channels should be provided in the same manner as the present Panama Canal channels.

For the Sea-Level Canal the following lighting should be provided:

Leading Channel Range Lights should be provided throughout the canal channels. Excessively long stretches of straight channel should be avoided by having a small turn of 7 or 8 degrees every five miles or so to make possible these leading channel range lights.

In portions wide enough for two-way traffic, there should also be passing ranges.

Table 6.2.5-6

Dynamic Routing Results for Sea Level Canal

Case			Run 1	Run 2	Run 3
8A	Sea Level Half Cycle	Ships/Yr	10,976	17,756	19,504
		Transit (Hr)	9.14	13.53	39.77
	Status Quo	Ships/Yr	8,730	11,626	17,320
		Transit (Hr)	10.08	11.09	17.63
	Total Ships		19,706	29,382	33,548
	% to Sea Level		56	60	58
8A	Sea Level Full Cycle	Ships/Yr	7,426	17,772	24,584
		Transit (Hr)	12.05	13.61	18.17
	Status Quo	Ships/Yr	12,280	15,800	16,860
		Transit (Hr)	11.28	15.36	17.62
	Total Ships		19,706	33,572	41,444
	% to Sea Level		38	53	59
9B	Sea Level	Ships/Yr	2,506	7,546	10,506
		Transit (Hr)	17.20	20.26	38.66
	Status Quo	Ships/Yr	17,200	17,960	17,960
		Transit (Hr)	17.14	29.18	42.40
	Total Ships		19,706	25,506	28,466
	% to Sea Level		13	30	37
8	Sea Level	Ships/Yr	10,032	14,604	
		Transit (Hr)	8.67	9.09	
	Status Quo	Ships/Yr	8,156	9,650	
		Transit (Hr)	9.71	10.61	
	Total Ships		18,188	24,254	
	% to Sea Level		55	60	

Table 6.2.5-7

Estimated Capacity

Study Case	Conceptual Alternative	Maximum Ship Size 000s DWT	No. of New Lanes		Capacity-Annual Transits No. of Ships		Capacity M Tons	
			Channel	Locks	6 Hr. Delay*	10 Hr. Delay*	6 Hr. Delay	10 Hr. Delay
1	Status Quo	WEFA 65	-	-	16,100	17,000	374	395
1a	Status Quo	PCC 65	-	-	14,500	15,300	396	418
2	High-Rise Locks (85ft)	150	2	1	32,500	34,600	978	1,041
3	High-Rise Locks (85ft)	150	2	2	48,300	51,300	1,455	1,545
4	High-Rise Locks (85ft)	200	2	1	33,200	35,300	999	1,062
5	High-Rise Locks (85ft)	200	2	2	51,100	54,300	1,559	1,657
6	High-Rise Locks (85ft) Culebra Cut single-lane	150	2	1	31,200	34,400	941	1,038
7	High-Rise Locks (85ft) Culebra Cut single-lane	200	2	1	31,600	34,600	963	1,055
8	Route 10 Tide Gates & Status Quo	250	2/1	**	42,500	44,000	1,318	1,364
8a	Route 10 Tide Gates & Status Quo	250	1/1	**	34,300	35,800	1,063	1,110
9	Route 10, 3 Pacific Locks & Status Quo	250	1	3	33,300	41,700	1,032	1,293
9a	Route 10, 3 Pacific Locks & Status Quo	250	1	3***	34,300	45,200	1,063	1,401
9b	Route 10, 3 Pacific Locks & Status Quo	250	1	1	20,800	24,000	645	744
10	Route 10, 4 Pacific Locks & Status Quo	250	1	4	37,000	47,500	1,147	1,472

NOTE: Culebra Cut is two lanes, unless noted otherwise.

* The capacities of the sea-level canal cases (8 through 10) are based on transit times of 15 and, alternatively, 19 hours.

** Tide Gates

*** Two chambers in tandem and one in series.

The one-way portions of the canal should have, at about every 500 feet. (15 meters), fixed red lights on the west side and fixed green on the east side from the Atlantic entrance as far south as the Pacific tidal gates (or locks) with the lighting pattern reversed at that point. At the turns, the lights should be flashing.

In the two-way channels, there should be buoys or beacons on each side of the channel at least every half nautical mile (927 meters) lighted in the same manner as the bank lights. US Coast Guard specifications state that such buoys in the straight stretches should have occulting lights but fixed lighting is better for judging channel alignment from the bridge of a ship.

For both types of canal, state-of-the-art navigation aids should be supplied to aid the pilot during periods of poor visibility. Radar aboard transiting ships can not be counted on for this purpose.

Conceptual plans of the navigation aids for Sea-Level Canal alternatives appear in Appendix 6-B.

General Requirements for Tugs

Tug assistance should be provided on the bow of all vessels over 15,000 dwt as they approach locks or closed tidal gates. Additional tugs should be available to assist when special circumstances or emergencies require. Tugs scheduled to assist vessels over 75,000 dwt should be at least 6,000 hp and of the "tractor" type, which are capable of approximately equal thrust in all directions. All tugs should be equipped, and the crews trained, for fighting fires.

Vessels transiting narrow channels should be provided with a tug on the stern (Culebra Cut style) if they equal or exceed the following tonnages:

- Culebra Cut: one-way channel - 50,000 dwt;
- Culebra Cut: two-way channel - 100,000 dwt;
- Sea-Level Canal: one-way channel - 75,000 dwt.

It should be a transit requirement that such vessels be constructed with sterns that allow a tug to work there on the center line when deeply loaded. Detailed examinations for each alternative are appended as Appendix 6-B, but the two most promising cases are explained hereunder.

Ship tie-up facilities should be provided at the north end of the new Pacific locks for ships awaiting the passage of southbound clear-cut ships.

The safest and most rapid tie-up facility would be an approach wall on the north end of the locks long enough for two large ships to tie up after locking through. The wall should be at least 2,400 feet (732 meters) in length.

Locomotive tracks should extend to as near the end as practical. While this arrangement allows for rapid tie-up, it blocks one lane from being used for traffic in the opposite direction.

There should also be at least two additional tie-up berths close to the north end of the new Pacific locks. Using these additional berths will be time consuming due to the slow speed with which these ships have to be handled. Also, the mooring facilities must be sturdy enough to hold the ships in place while other very large displacement vessels pass near them in these confined spaces. To equip the canal to operate these locks at about capacity would require, at each of the two locks (Atlantic and Pacific ends), 10 locomotives for one-wall operation (allowing for two down for maintenance) and twice that number for two-wall operation.

Seven tugs should be able to handle the Pacific locks and the Cut and five tugs could handle the needs at the Atlantic locks. Allowing for three down for maintenance,a total of 15 tugs of 6,000 hp or greater would be required, building up to 19 tugs at capacity. This would be in addition to the fleet of tugs required to operate the original locks.

Equipment and Operating Costs

- Quantities Estimates

Based on the criteria set forth previously herein, Table 6.2.6-1 lists the type and quantities of navigation aids and equipment required in the alternative plans (designated as study cases 2 through 10) being compared in this study for transiting of large ships across the Isthmus. The items listed for the Alternatives are in addition to the quantities, also listed in this table, entailed in the Status-Quo Program (Scenario 1), of which are either already in place or will be before the year 2020. The status quo data are required for the preparation of annual maintenance and operating costs. The estimates are based on data on the existing canal furnished by PCC and the navigation support systems for the alternatives outlined in Chapter 9.

The number of tugboats listed in Table 6.2.6-1 for the levels of ship traffic projected in the year 2020. In subsequent years, when traffic is expected to increase, additional tugboats will have to be provided, and this should be considered in the financial analyses to be made by others. Of the quantities listed for tugboats in Table 6.2.6-1, 20 percent comprise spares for use in emergencies or are stand-by units to be used when other units are being overhauled or undergoing maintenance. For similar purposes, 15 percent of the towing locomotives listed in Table 6.2.6-1 consist of emergency or stand-by units. This distinction of operating and spare units is made for use in estimating subsequently the annual costs entailed in the scenarios.

- Estimated Values and Equipment Costs

The costs given in Table 6.2.6-2 are for both one-wall operations and separately for two-wall operations at the locks to be constructed in the alternative scenarios, the latter entailing a greater number of towing locomotives.

Table 6.2.6-1

Navigation Aids and Equipment Requirements

Item	Unit	Status Quo	Additional Quantities – Alternatives								
			2	3	4	5	6	7	8	9	10
1. Channel Navaids											
a. Range Lights	each	188 (a)	206 (b)	206 (b)	206 (b)	206 (b)	206 (b)	206 (b)	64	60	60
b. Bank Lights (1 lane)	each	–	–	–	–	–	–	–	530	694	694
c. Bank Lights (2 lanes)	each	164 (a)	174 (c)	174 (c)	174 (c)	174 (c)	174 (c)	174 (c)	52	20	20
d. Lighted Buoys	each	70 (a)	70 (a)	70 (a)	70 (a)	70 (a)	70 (a)	70 (a)	30	30	30
2. Tug Boats – HP											
a. 1,500	each	–	–	–	–	–	–	–	–	–	–
b. 2,000	each	2	–	–	–	–	–	–	–	–	–
c. 3,000–4,000	each	17	–	–	–	–	–	–	5	5	5
d. 6,000	each	–	15	17	12	17	15	15	9	15	15
3. Pilot Launches											
a. 175 HP	each	4	–	–	–	–	–	–	2	2	2
b. 200–211 HP	each	3	–	–	–	–	–	–	2	2	2
c. 260 HP	each	6	–	–	–	–	–	–	4	4	4
d. 300 HP	each	26	9	9	9	9	9	9	18	18	18
e. 565 HP	each	2	1	1	1	1	1	1	2	2	2
4. Misc. Craft	each	8	3	3	3	3	3	3	6	6	6
5. Towing Locomotives											
a. 25,000 lb.Cap.	each	–	–	–	–	–	–	–	–	–	–
b. 70,000 lb.Cap./1 Wall	each	82	20	38	20	38	20	20	–	40	60
c. 70,000 lb.Cap./2 Wall	each	–	40	76	40	70	40	40	–	80	100
6. Communication Eqpt.	set	–	–	–	–	–	–	–	–	–	–
7. Video & Computer Eqpt.	set	–	–	–	–	–	–	–	–	–	–
8. Traffic Mgmt. Center	each	1	–	–	–	–	–	–	1	1	1
9. Pilot Lodging Facilities	each	2	–	–	–	–	–	–	2	2	2
10.Vehicles	each	25	5	5	5	5	5	5	25	25	25
11.Tide Gates	each	–	–	–	–	–	–	–	2	–	–
12.Tug Boat Tie-up	each	–	–	–	–	–	–	–	2	2	2
13.Beaching Areas	each	–	–	–	–	–	–	–	2	–	–
14.Turning Basins	each	–	–	–	–	–	–	–	2	–	–

NOTES:
(a) To be relocated under the alternative development programs.
(b) 166 range targets to be relocated and 40 new targets to be installed.
(c) 124 bank lights to be relocated and 50 new bank lights to be installed.

Table 6.2.6-2

Navigation Aids and Equipment Values and Costs

Item	Cost/Unit	Relocation Cost/Unit	ESTIMATED COSTS – (Thousands of 1993 Dollars) Alternatives (Additional Costs) 2	3	4	5	6	7	8	9	10
1. Channel Navaids											
a. Range Lights	8,000	5,000	984	984	984	984	984	984	512	480	480
b. Bank Lights (1 lane)	10,000	2,000	–	–	–	–	–	–	5,300	6,940	6,940
c. Bank Lights (2 lanes)	25,000	2,000	1,498	1,498	1,498	1,498	1,498	1,498	1,300	500	500
d. Lighted Buoys	50,000	10,000	700	700	700	700	700	700	1,500	1,500	1,500
2. Tug Boats – HP											
a. 1,500	5,160,000	–	–	–	–	–	–	–	–	–	–
b. 2,000	6,140,000	–	–	–	–	–	–	–	–	–	–
c. 3,000–4,000	11,200,000	–	–	–	–	–	–	–	56,000	56,000	56,000
d. 6,000	19,000,000	–	285,000	323,000	228,000	325,000	285,000	285,000	171,000	285,000	285,000
3. Pilot Launches											
a. 175 HP	120,000	–	–	–	–	–	–	–	240	240	240
b. 200–211 HP	140,000	–	–	–	–	–	–	–	280	280	280
c. 260 HP	320,000	–	–	–	–	–	–	–	1,280	1,280	1,280
d. 300 HP	510,000	–	4,590	4,590	4,590	4,590	4,590	4,590	9,180	9,180	9,180
e. 565 HP	670,000	–	670	670	670	670	670	670	1,340	1,340	1,340
4. Misc. Craft	50,000	–	300	300	300	300	300	300	300	300	300
5. Towing Locomotives											
a. 70,000 lb.Cap/1 Wall	1,700,000	–	34,000	64,600	34,000	64,600	34,000	34,000	–	68,000	102,000
b. 70,000 lb.Cap/2 Wall	1,700,000	–	68,000	129,200	68,000	119,000	68,000	68,000	–	136,000	170,000
6. Communication Eqpt.	3,900,000	Exist.Facil.	1,000	1,000	1,000	1,000	1,000	1,000	4,000	4,000	4,000
7. Video & Computer Eqpt.	2,100,000	Exist.Facil.	200	200	200	200	200	200	2,500	2,500	2,500
8. Traffic Mgmt. Center	–	–	–	–	–	–	–	–	–	–	–
9. Pilot Lodging Facilities	–	–	–	–	–	–	–	–	–	–	–
10.Vehicles	15,000	–	75	75	75	75	75	75	375	375	375
11.Tide Gates	–	–	–	–	–	–	–	–	–	–	–
12.Tug Boat Tie-up	–	–	–	–	–	–	–	–	–	–	–
13.Beaching Areas	–	–	–	–	–	–	–	–	–	–	–
14.Turning Basins	–	–	–	–	–	–	–	–	–	–	–
Sub-Total – One Wall Operation			329,017	397,617	272,017	399,617	329,017	329,017	255,107	437,915	471,915
TOTAL One-Wall Operation -- Incl. 20% for Cont. & Eng.			394,820	477,140	326,420	479,540	394,820	394,820	306,128	525,498	566,298
TOTAL Two-Wall Operation -- Incl. 20% for Cont. & Eng.			435,620	554,660	367,220	544,820	435,620	435,620	306,128	607,098	647,898

Table 6.2.6-3

Annual Operating and Maintenance Costs Navigational Aids and Equipment

(Thousands of 1993 Dollars)

Item	Costs Per Unit Per Year: Payroll	Fuel or Power	Maint.	Total	ESTIMATED COSTS PER YEAR: Status Quo	Alternatives (Costs Additional to Status Quo): 2	3	4	5	6	7	8	9	10
1. Channel Navaids														
a. Range Lights)														
b. Bank Lights-1 Lane)- Total All Aids for Item 1					672	181	181	[illegible]	180	181	180	660	656	656
c. Bank Lights-2 Lanes)														
d. Lighted Buoys)														
2. Tug Boats - HP (Incl. 20% spares)														
a. 1,500	500	608	842	1,950	-	-	-	-	-	-	-	-	-	-
b. 2,000	500	900	1,246	2,646	2,646	-	-	-	-	-	-	-	-	-
c. 3,000-4,000	500	1,575	2,182	4,257	68,144	-	-	-	-	-	-	19,210	19,210	19,210
d. 6,000	500	2,700	3,740	6,940	-	94,500	108,380	76,860	108,380	94,500	94,500	52,860	94,500	94,500
3. Pilot Launches														
a. 175 HP	126	79	109	314	1,256	-	-	-	-	-	-	628	628	628
b. 200-211 HP	126	90	125	341	1,023	-	-	-	-	-	-	682	682	682
c. 260 HP	126	117	162	405	1,560	-	-	-	-	-	-	7,620	1,620	1,620
d. 300 HP % spares)	126	135	187	448	10,865	3,771	3,771	3,771	3,771	3,771	3,771	7,542	7,542	7,542
e. 565 HP	126	255	352	733	1,466	733	733	733	733	733	733	1,466	1,466	1,466
f. Pilots					5,900	625	625	625	625	625	625	5,000	5,000	5,000
4. Misc.Craft f. 1 spare)	120	50	30	200	1,700	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
5. Towing Locomotives (Incl.15% spares)														
a. 25,000 lb.Cap.														
b. 70,000 lb.Cap/1 Wall	195	340	215	750	-	12,880	25,290	12,880	25,290	12,880	12,880	-	27,880	41,790
c. 70,000 lb.Cap/2-Wal	195	340	215	750	55,080	25,720	50,580	25,720	50,580	25,720	25,720	-	55,720	69,650
6. Communication Eqpt.	(10% of Equip. Costs)				5	100	100	100	100	100	100	400	400	400
7. Video & Computer Eqpt.	(10% of Equip. Costs)				8	30	30	30	30	30	30	375	375	375
8. Traffic Mgmt. Center					1,670	385	385	385	385	385	385	836	836	836
9. Pilot Lodging Facilities					100	-	-	-	-	-	-	100	100	100
10.Vehicles	18	0.5	0.5	19	475	95	95	95	95	95	95	475	475	475
11.General Supervision					1,000	200	200	200	200	200	200	500	500	500
Sub-Total - One Wall Operation						114,500	140,810	96,879	140,809	114,500	114,499	99,374	162,870	176,800
TOTAL One-Wall Annual Cost — Incl. 15% Cont.						131,675	161,932	111,411	161,930	131,675	131,674	114,280	187,301	203,320
TOTAL Two-Wall Annual Cost — Incl. 15% Cont.					174,306	146,464	191,015	126,200	191,014	146,464	146,463	114,280	219,339	235,359

Note: The total annual cost for each alternative includes the cost of the status quo plus the additional cost listed for the alternative.

The figures presented in Table 6.2.6-2 is for a three-shift per day operation of the locks in all scenarios, and include an allowance of 20 percent for contingencies and engineering. The costs for facilities such as locks, tidal gates, tugboat tie-up stations, beaching areas, turning basins and other dredging works, buildings for traffic management operations and pilot lodging quarters are not included herein.

The costs are estimated as of 1993, so that adjustments will have to be made for inflation in the financial analyses to be undertaken by others. In those analyses, schedules will also have to be established for replacement of the navigation aids and equipment in the Status Quo Program not only for the year 2020 by which time that program is planned to be completed, but also in the subsequent time frames, as in the case of the alternative scenarios, which are to be established as the life of the project.

- Estimated Annual Operating and Maintenance Costs

Summarized in Table 6.2.6-3 are the operating and maintenance costs estimated to be incurred annually in each of study cases 2 through 10, in addition to such annual costs for the Status Quo Program.

The figures presented in Table 6.2.6-3 is for three-shift per day operations as of the year 1993, and include an allowance of 15 percent for contingencies. As in the case of capital costs, the figures presented in Tables 6.2.6-2 and 6.2.6-3 will have to be adjusted for inflation in the financial analysis to be made by others. In addition to costs for maintenance of navigation aids, the estimates include payroll, fuel and power costs for operation and for maintenance of the tugboats, launches and towing locomotives required to assist ships in their navigation through the Canal. Also included are payroll costs for supervisory and other personnel engaged in navigation-related activities, as well as for traffic management personnel. An allowance has also been included for the cost of power and other utilities for operations at the traffic management center, but not for maintenance of the office building, nor for the maintenance of lock structures, tidal gates and other facilities. Excluded from the estimates herein are amortization or depreciation and insurance costs for any equipment or facilities which it may be necessary to consider in the financial analyses to be made for the project.

  - Navaids

    Estimates for range targets includes targets for three lanes at the Culebra Cut reflecting its use as both a single-lane and double-lane channel.

    Capital costs for navaids were based on information provided by Tidelands Signal Company, a manufacturer familiar with the existing aids in the Canal.

    Costs for maintaining navaids are based on gross annual costs provided by the PCC, which were then proportioned according to the lengths of waterways.

- Tugboats and Launches

  The type, horsepower, purchase price and crew size of vessels are based on the PCC-supplied data. Capital costs for tugboats are based on an average cost of $3,200 per horsepower.

  Payroll costs were derived from a PCC supplied annual cost for 569 persons, or an average of $23,800 per person annually. Higher costs were assumed for pilots, and lower for crews.

  Based on PCC-supplied data, maintenance costs were estimated on the basis of $623 per horsepower. Costs for fuel, lubricants, etc. were based on a cost of $450 per horsepower annually.

- Towing Locomotives

  Payroll costs were derived from the average salary costs indicated above. Based on PCC supplied data, it is estimated that the average annual cost for maintaining each locomotive is $215,000. Power costs were estimated at $344,000 per locomotive, annually.

- Communications and Other

  Estimates were also made for the capital and operating costs of communications and traffic management equipment, supervisory costs and miscellaneous costs based on PCC furnished data.

6.2.7 Sedimentation and Deformation of Coastline - Sea-Level Alternatives

This study item was not originally included in OCCE defined in DPS, but added on OCCE after the CAS's approval of the proposal made by the consultant, TAMS. The main objectives of the study are to obtain first-hand approximation for i) the volume of expected annual maintenance dredging volume for sea-level alternatives, and ii) deformation of coastline by the construction of breakwaters.

The main tools for this study are TAM's library computer programs namely, LATIS, ROUTES and BEACHES. The main features are:

- LATIS — to determine hydraulic variables such as velocity, water depth, and create the necessary input data for ROUTES;
- ROUTES — to estimate sedimentation depths along the canal with the output from LATIS; and,

- BEACHES to estimate shoreline changes.

The models, which are idealizations of the physical process, give estimates which have to be interpreted with judgment. This is due to the underlying assumptions in the model, input data, boundary conditions, and the numerical scheme used in the algorithm. The values of several parameters were assumed, based on available literature and engineering judgment. For LATIS, brief explanations are made in Section 5.3.2.2. In this section, basic concepts of ROUTES and BEACHES are described.

Sedimentation in Sea-Level Canal

A sediment routing model, ROUTES, utilized as a main tool, assumes:

i) a uniform concentration for the entire water column; and,

ii) the suspended sediments travel at the same velocity as water.

An explicit finite difference solution is obtained for the mass conservation of each fraction diameter of sediment in suspension in a node during a computation time interval. The computation balances the flux of sediment entering or leaving the node with the increase or decrease of sediment mass in suspension in the node and the bottom deposits during the dame time interval. The mass in each node is converted to volume using a common deposit dry density.

The following finite difference expression of the sediment mass balance is written with the assumption of a deposit dry density of 1.0. A correction may be introduced in the final deposit depth if the deposit dry density is different.

$$V_i^{n+1} C_i^{n+1} - V_i^n C_i^n - \Sigma^m_{j=1} C_{ij}^n Q_{ij}^n \Delta t + V_j^n C_j^n \frac{W_d \Delta t}{Y_i^n} = 0$$

in which,

V_i	=	water volume in node i;
C_i	=	concrete in node i (dry weight of suspended material per unit volume);
C_{ij}	=	concentration in flux between nodes i and j;
Q_{ij}	=	water discharge between i and j;
t	=	time interval;
W_d	=	settling velocity of particle fraction with diameter d;
Y_i	=	water depth in node i;
m	=	number of nodes connected to node i; and
n	=	time increment superscript.

The flux concentration is weighted as follows:

$$C_{ij}^{n} = \alpha c_j^{n} + (1 - \alpha)\, c_j^{n} \quad 0 \leq \alpha \leq 1$$

The weighing coefficient alpha is selected so that the node supplying the flow has a higher weight.

The main sources of supplying of sediment materials are

i) river inflow to the canal,

ii) erosions of canal bed and side slopes due to tidal current, and

iii) scouring of canal side slopes by slip generating waves.

In this study, however, the last effect is not considered, because of the trade-off relation in scouring amount and cost for slope protection works which shall be examined in detailed engineering study.

As river inflow to the canal is concerned, the total catchment area of 1,700 sq. km and 15 rivers shall be covered. Characteristics of these rivers are summarized and shown in Table 6.2.7-1.

As an example of seasonal variation of river discharge in this area, Trinidad river's monthly discharge (1973 and 1974) at el Chorro is exhibited in Figure 6.2.7-1.

Reflecting the above characteristics, three flow conditions are chosen as one of the simulating conditions; Maximum flows, Mean flows, and Minimum flows.

For trial flow inputs, the following two cases are selected;

1) The tide gate at the Atlantic side, North gate, is closed, while the one at the Pacific side is open. Pacific tide controls the movement of sediment, and

2) The tide gate at the Pacific side, South gate, is closed while the one at the Atlantic side is open. Atlantic tide controls the transport of sediment.

Tides from January 3 to February 3, 1992 are chosen for simulation condition. Engineering judgments are required to decide sediment materials and sediment concentrations.

As the final inputs, the following combination is decided and shown in Table 6.2.7-2.

Table 6.2.7-1

Rivers Intercepting Route 10 - Data

No.	Name	Drainage Area (Sq.Mi.)	Invert EL (MSL)	Bank	Dist. in km from Atlantic	Max Flows (cfs)
1	Lagarto	45.0	0.0	W	1.54	270
2	Arrieros	34.0	0.0	E	1.54	204
3	Quebrada La Escoba	3.5	15.0	E	9.26	21
4	Quebrada Brazito	16.0	15.0	W	13.88	96
5	Trinidad & Ciri	288.0	30.0	W	20.05	1,728
6	Los Azules	32.1	70.0	W	32.39	193
7	Quebrada De Chico	4.2	70.0	W	34.71	25
8	Mendoza	3.7	60.0	W	36.25	22
9	Cano Quebrada	28.6	70.0	W	38.56	172
10	Pescado	8.5	70.0	E	39.33	51
11	Santa Cruz	2.2	95.0	W	44.73	12
12	Congo	2.8	250.0	E	49.05	17
13	Caimito I	115.5	30.0	W	54.00	693
14	Martin Sanchez	11.4	0.0	W	60.16	68
15	Caimito II	47.0	0.0	E	60.93	282

Table 6.2.7-2

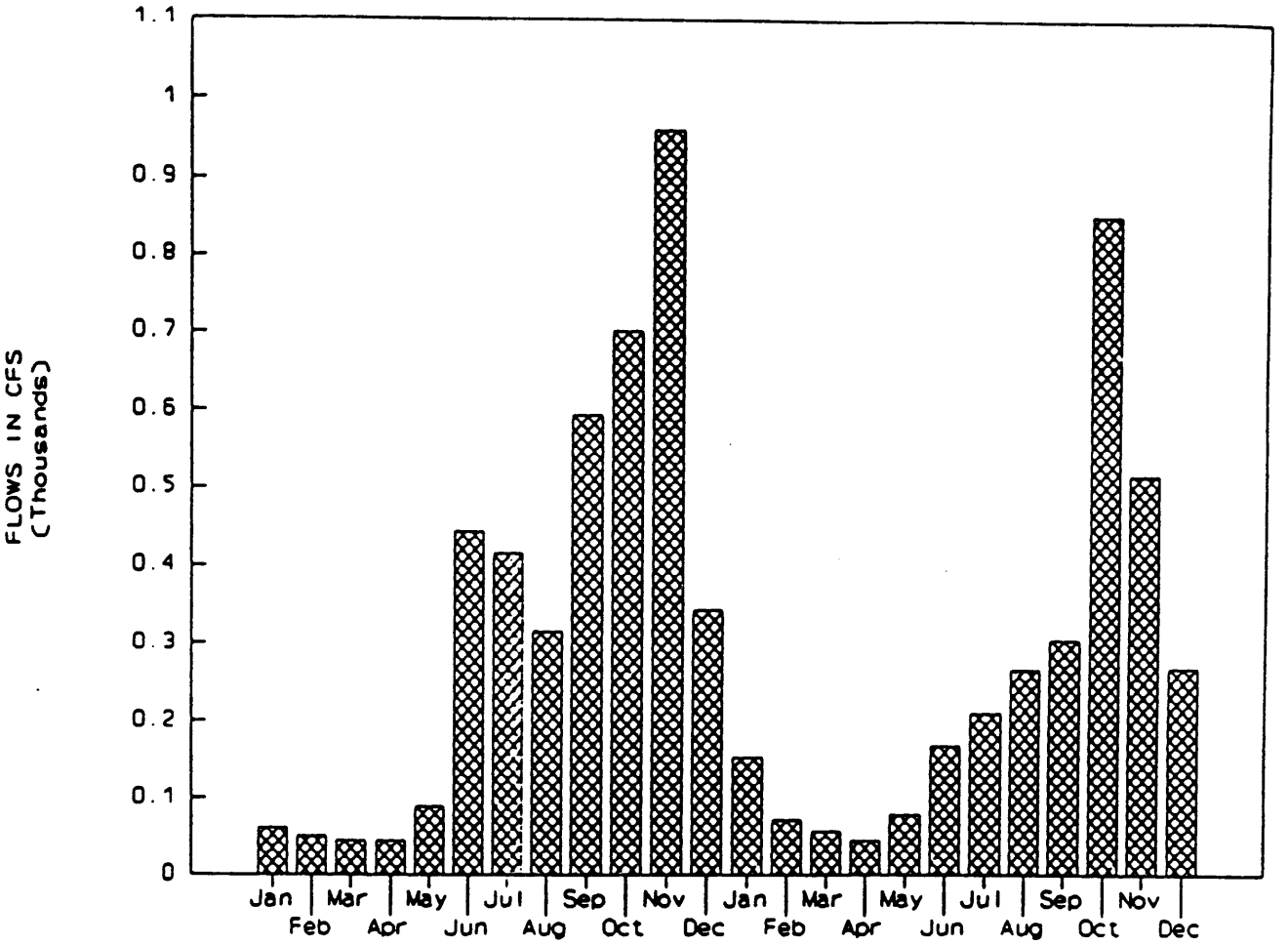
Sea-Level Canal Simulation Condition

Tide Condition	Flow Condition	Sediment Material	Sediment Concentration
Jan 3-13	Max Flow	Coarse Sand	5,000 (mg/l)
Jan 13-23	Mean Flow	Fine Sand	2,000 (mg/l)
Jan 23 - Feb 3	Min Flow	Clay	100 (mg/l)

Figure 6.2.7-1

Trinidad River at El Chorro

Monthly Mean Flows - 1973 & 1974



Based on the various simulations that were carried out, the following broad conclusions are made:

(a) When the South gate is closed and the sediment composition is sand, the depth of deposition varies from 0.5 cm to 16 cm per year along the canal for the different nodes.

(b) When the North gate is closed and the sediment composition is sand, the depth of deposition varies from 0.5 cm to 100 cm per year at the various nodes.

(c) When the South gate is closed and the sediment consists of clay, the annual deposition varies between zero to 5 cm along the canal.

(d) When the North gate is closed and the sediment consists of clay, the annual variation is from zero to 5 cm along the canal.

As far as the annual dredging is concerned, it can be in the range of 450,000 m^3/yr corresponding to an annual sedimentation of 2.5 cm in the entire stretch of the canal. According to the model results, the value reduces, to 270,000 m^3/yr corresponding to an annual sedimentation of 2 cm in the entire length, when rivers are diked. However, judgment has to be exercised in the use of these results due to the various approximations that have been used in the model. In order to check simulated results, bathymetric data were used firstly to estimate sedimentation rates for the existing canal.

The location of the reaches, the lengths, the survey dates, and the quantity of sediment deposited over a 150 m (500 ft) wide canal is tabulated as Table 6.2.7-3.

Table 6.2.7-3
Sedimentation Rate for Existing Canal

Location	Reach	Period	Quantity of Sediment (m^3)
Atlantic Entrance	1028+000 to 1030+500 m	6-85 to 1-88	46,985
Balboa Inner Harbor	2380+00 to 2400+00 ft	7-85 to 4-87	15,360
Pacific Entrance	2380+00 to 2570+00 ft 2740+00 to 2760+00 ft	6-84 to 3-87 7-85 to 1-87	23,920 4,760
Miraflores Lake	2140+00 to 2160+00 ft	1-87 to 10-91	20,659

The data were obtained from hydrographic surveys, conducted at the same location, at different periods of time. Care was taken to ensure that no dredging took place at the selected locations during the intervening period between the two surveys. To estimate the amount of sedimentation, reaches of specific lengths were selected. Numerical integration was used to estimate the volume of water below a datum. The change in the volume of water between the two survey periods gave the quantity of sediment either deposited or eroded.

Then the locations, the annual sedimentation rate per kilometer and the extrapolated values for a canal of 58 km long are summarized and shown in Table 6.2.7-4.

Table 6.2.7-4
Extrapolated Sedimentation Volumes for New Canal

	Sediment Deposition/Year	
	190 m Wide Canal (m^3/km)	58 km Stretch (m^3)
Atlantic Entrance	9,500	551,000
Balboa Inner Harbor	12,800	742,000
Pacific Entrance	11,850	687,300
Miraflores Lake	9,550	-

Summarizing all the discussions, the consultant, TAMS, concluded that for planning and estimation of annual dredging costs one could use a value of 550,000 m^3/year.

Coastline Deformation

The approach adopted in this study is basically the same as the Shore Protection Manual, US Army Corps of Engineers, therefore, further explanations are not considered necessary.

Wave and wind data were obtained from the National Climatic Data Center, Asheville, North Carolina. The five-year wave/wind data, each having 30,000 to 40,000 lines of record, were processed to isolate the wave data. These data covered most of the Caribbean Sea and some parts of the Pacific Ocean. For modeling the Atlantic side of the canal, waves were isolated between latitudes 9-15 degrees, and longitudes 75-84 degrees. For modeling the Pacific side, waves from latitudes 7-9 degrees and longitudes 77-81 degrees were isolated. Since these were deep water waves, and while approaching the shore these waves would lose strength, a coefficient of 0.1 was used to compute the effective waves along the shorelines.

For modeling, the shorelines have been assumed to be rectilinear. This assumption of shorelines in the Atlantic shores is reasonable. Lengths of the breakwaters on this side are 2.7 and 2.58 km. Therefore, a 2.6-km long structure length is assumed to represent the Atlantic jetties. An 8-km left shore and a 10-km right shore are taken for shoreline evolution modeling on the Atlantic side.

Although the right Pacific jetty is 7.5 km long, only 5.5 km is in water. The balance 2-km length near the shore is in mud. The left Pacific jetty is 2.5 km long, and is projected length with the 2.4 km hammer head is 4.5 km. Therefore, a structure length of 5.0 km is assumed to represent the Pacific jetties. A 14-km shoreline on the left side and a 14-km shoreline on the right side are taken for modeling. The shorelines have been assumed to be straight and the shoreline space increment has been taken as 1.0 km. A time increment of 15 days and an active beach depth of 5 m (15 ft) have been assumed.

The results of calculations are summarized and discussed hereunder, however, the model results must be considered as a qualitative indication of accretion and depletion. For a more quantitative estimate, the model parameters must be calibrated using historical measurements of an existing beach accretion and depletion case near the project location.

- Atlantic Jetties

Figure 6.2.7-2 shows results of the beach evolution model on the Atlantic side of the canal. Wave analysis showed stronger waves from the left side of the jetties and, therefore, accretion is predicted on the left side. As expected, depletion is predicted on the other side, the right hand side of the jetties.

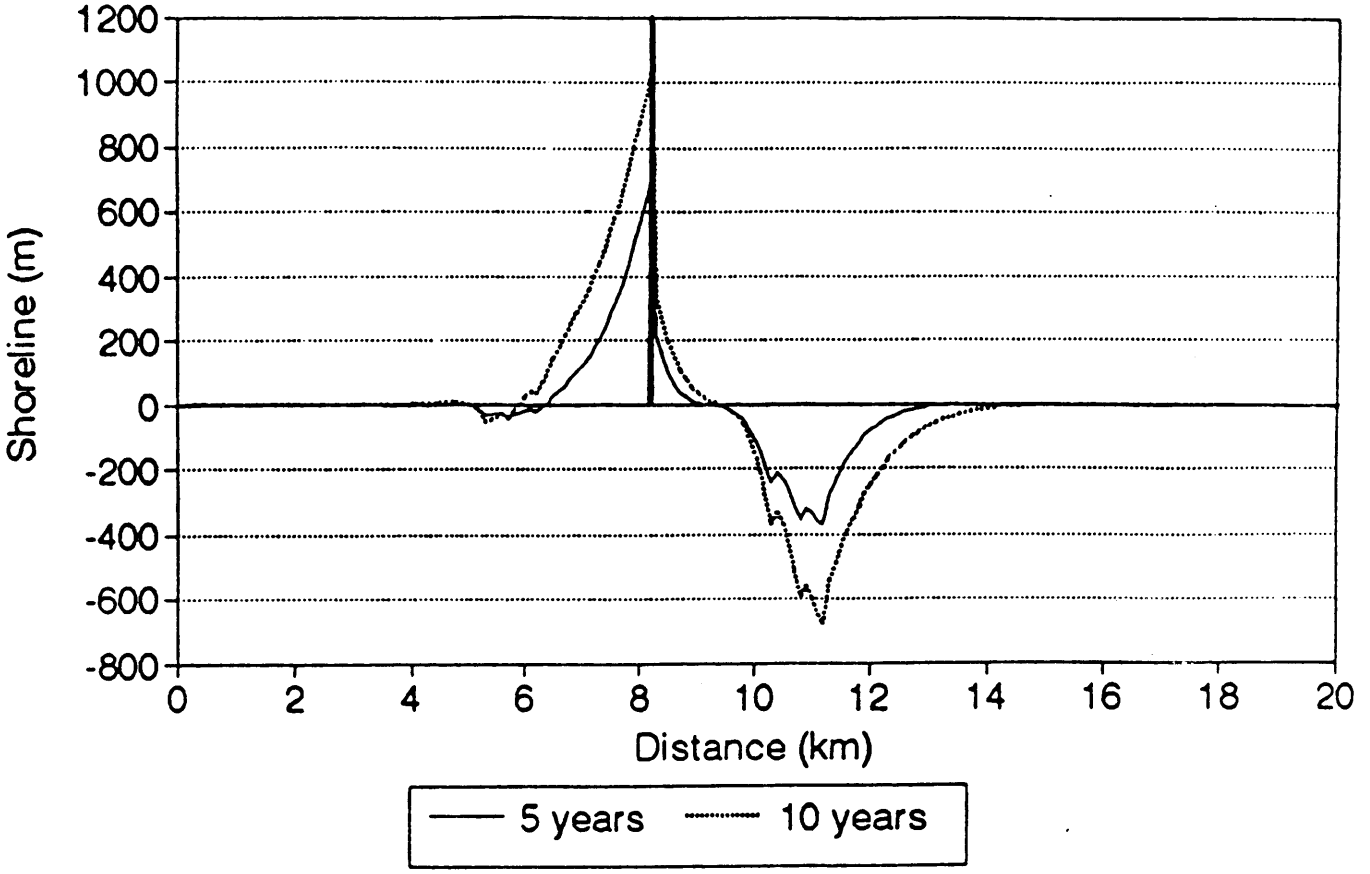
This indicates net littoral drift from left to right on the Atlantic shore of the canal. Onshore waves were found in 498 days in 5 years, and the model computed yearly representative (littoral drift producing) waves of 1.4 m (4.6 ft) for a period of 75 days from the left in comparison to 1.2 m (3.8 ft) of waves for a period of 15 days from the right. With all the assumptions and approximate parameters, the model predicted an accretion of 1 km on the left of the jetties and a depletion of 600 m on approximately 11 km from the right jetty in ten years.

- Pacific Jetties

With the same parameters, the model computed yearly representative (littoral drift producing) waves of 1.0 m (3.4 ft) for a period of 15 days from the left side of the Pacific Jetties and 1.2 m (3.8 ft) for the same period from the right side. Since the waves from both sides are approximately equal, the model computed zero net littoral drift, and thus, did not predict any accretion or depletion on either side. However since the waves from the right side are a little stronger, some accretion on this side and some depletion on the left side may be expected. Also, this side of the canal entrances is protected by peninsulas and shoals, and therefore, severe accretion and depletion are unlikely.

Figure 6.2.7-1

Beach Evolution Model Results - Atlantic



6.2.8 Water Management - High Rise Canal

With the dynamic route assignment process adopted in the Phase II WAM Model, the utilization of New Locks is expected to increase substantially (see Section 6.2.5) and accordingly, the water consumption associated with the newly introduced operating rule is also expected to increase rather drastically. To analyze the above feature of canal operation and reflect it into the engineering study, TOR for OCCE was expanded and this part of the Study was added on TAMS's original works. The total number of operations for each lock has been extracted from the simulated records for three cases, namely, 150,000 dwt High Rise Lock Alternative, 200,000 dwt High Rise Lock Alternative, and Status Quo. The annual water use for the existing Miraflores Locks and Gatun Locks, and New High Rise Locks (Atlantic and Pacific) are then estimated by following formulas;

Existing Miraflores:	$W = A \times H/3 \times L$;	$A \times H/3 = 95{,}000$ cubic meters
Existing Gatun:	$W = A \times H/3\ (2L - C/2)$;	$A \times H/3 = 95{,}000$ cubic meters
New High-Rise Locks	$W = A \times H/2 \times L$	
for	150,000 dwt:	$A \times H/2 = 252{,}500$ cubic meters
	200,000 dwt:	$A \times H/2 = 299{,}100$ cubic meters

where,
- C = no. of chamber operations per year
- L = no. of lockages per year
- W = annual water use cubic meters

In summary, the estimated total volumes of fresh water consumed as a result of lockages (in millions of cubic meters (M.c.m)) for the above three cases are as follows:

Total Fresh Water Use (M.c.m.)

Case		Year 2020	Year 2060
2	High Rise Locks (150,000 dwt)	6,381	8,029
4	High Rise Locks (200,000 dwt)	7,214	8,965
8	Status Quo Route (Used with Sea Level Canal, Tide Gates)	1,731	2,033

The details of simulated results and associated calculations are in Table 6.2.8-1.

Table 6.2.8-1

Fresh Water Consumption - High Rise Locks

	Gatun		Miraflores		New Atlantic		New Pacific	
	2020	2060	2020	2060	2020	2060	2020	2060
CASE 2								
A x H/3, cm	95,000		95,000					
A x H/2, cm					252,500		252,500	
Lockages	9,692	12,646	8,602	12,414	8,246	10,458	9,204	10,694
Chamber Operation	14,482	18,944						
Water Use, Mcm	1,156	1,506	819	1,182	2,082	2,641	2,324	2,700
CASE 4								
A x H/3, cm	95,000		95,000					
A x H/2, cm					299,100		299,100	
Lockages	9,540	12,320	8,400	12,020	8,350	10,460	9,288	10,784
Chamber Operation	14,230	18,464						
Water Use, Mcm	1,139	1,467	800	1,144	2,497	3,129	2,778	3,225
CASE 8								
A x H/3, cm	95,000		95,000					
Lockages	8,134	9,530	8,148	9,614				
Chamber Operation	12,464	14,634						
Water Use, Mcm	955	1,118	776	915				

6.3 Engineering and Cost Estimates, Phase II

6.3.1 Introduction

As described in Section 5.5 - Screening and Evaluation of Potential Projects, two conceptual alternatives survived the prescreening process and were selected by the Board of Commissioners for feasibility study. The two alternatives are: High Rise Lock Canal (HRLC), and Sea-Level Canal Route-10 (SLC 10). The general route layout and features of these two conceptual alternatives are presented in Figures 6.3.1-1 through 6.3.1-3 and Table 6.3.1-1.

A summary of canal construction cost estimates for all conceptual canal alternatives for years 2020 and 2060 are presented in Tables 6.3.1-2 and 6.3-1-3, and later modified and presented in Section 6.4.

The HRLC alternative is an improvement to the existing Panama Canal which will permit larger size ships ranging between 150 to 200 thousands dwt to transit. This includes, in addition to widening and deepening the canal, construction of a larger bypass lane using two-lift locks at both Gatun and Miraflores. Consideration was given for Gatun Lake to be raised to El. 90 ft. (27.5 m) in addition to present operating level of El. 85 ft. (26.0 m).

Table 6.3.1-1
Main Features of Alternatives

Alternatives		High Rise Lock Canal		Sea Level Canal		
Alignment		Along Existing Canal (see Figure 6.3.1-1)		Route 10 from IOCS Study (see Figure 6.3.1-2)		
Maximum Ship Size (dwt)		150,000	200,000	250,000		
Number of Ship Transits[1]	SQ (2020)	16,200	16,200	16,200		
	New Canal	2,000	2,000	2,100		
	Total	18,200	18,200	18,300		
	SQ (2060)	20,000	20,000	19,400		
	New Canal	4,600	4,600	5,100		
	Total	24,600	24,600	24,500		
Number of Lanes[2]		2		1 (approach 2)		
Number of Lifts		2		0		
Water Level		26.0 feet & 27.5 ft		Sea Level		
Tidal Lock & Gate[2]		n.a.		Case (a)	Case (b)	Case (c)
				parallel 4 locks	1 lane 2 gates	parallel 4 locks 1 gate
				(see Figure 6.3.1-3)		

Notes: 1 From TAMS - Phase I (see Sections 6.4 for changes)
2 See Section 6.4 for changes
n.a. Not applicable

Figure 6.3.1-1

Layout of High Rise Lock Canal (200,000 dwt)

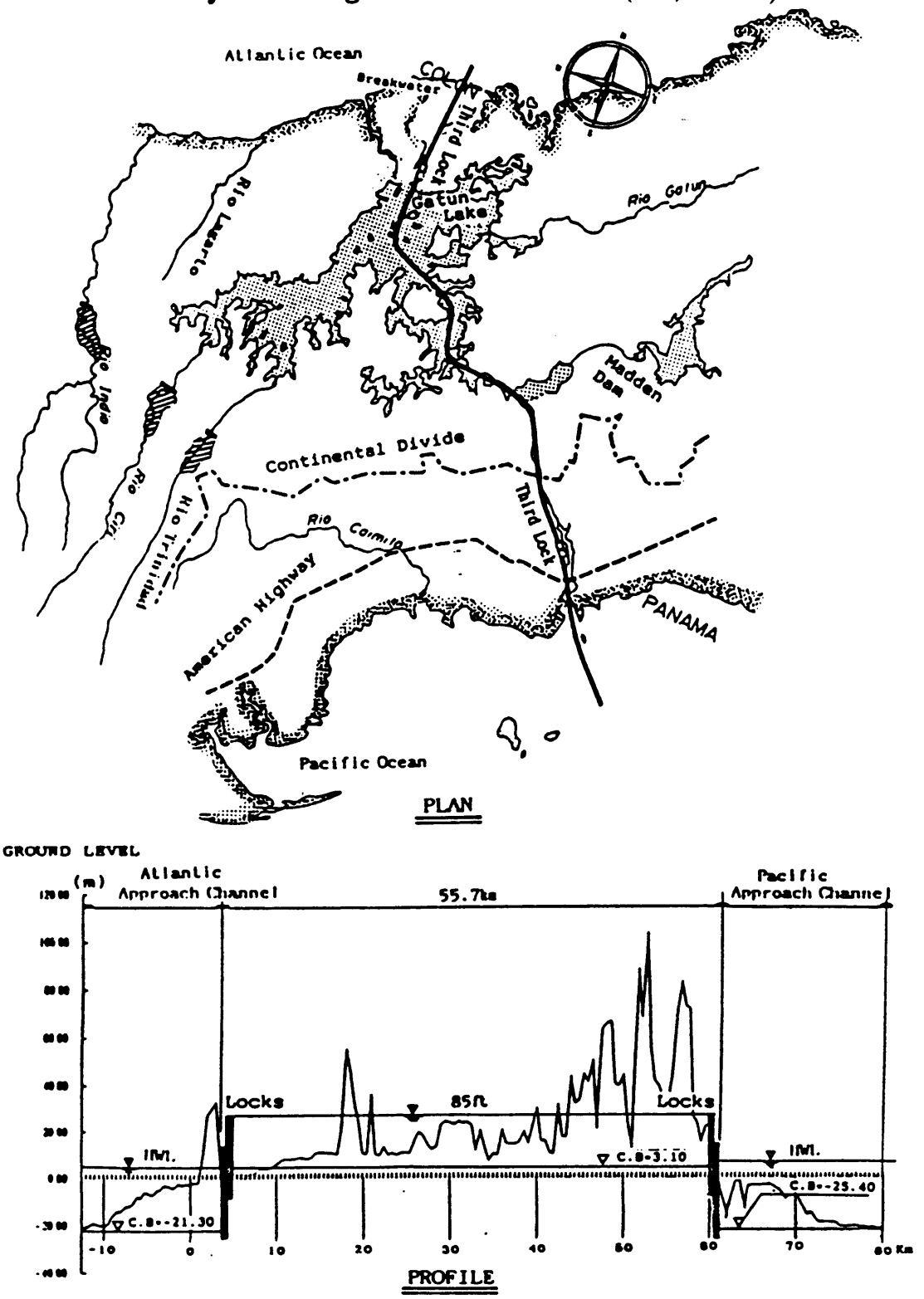
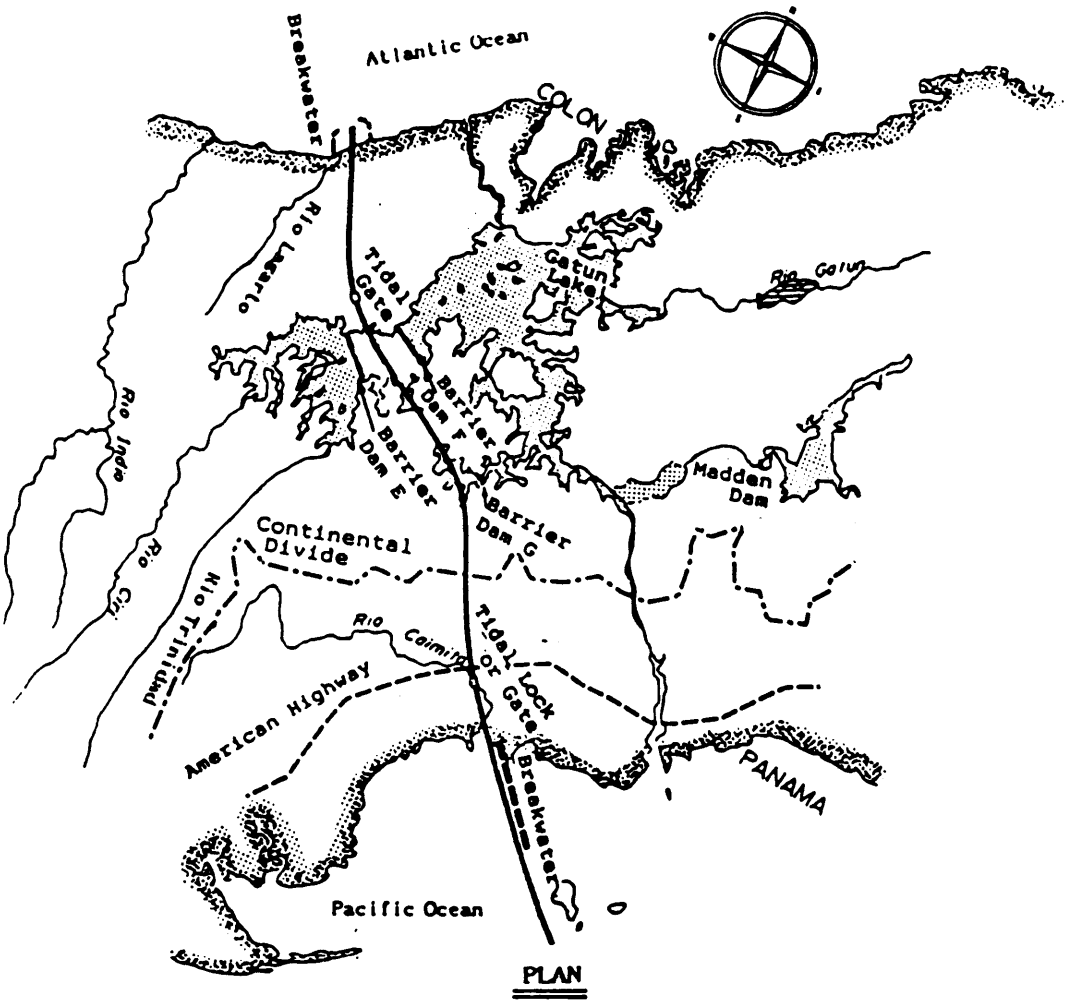


Figure 6.3.1-2
Layout of Sea Level Canal (Case (a) and (c))



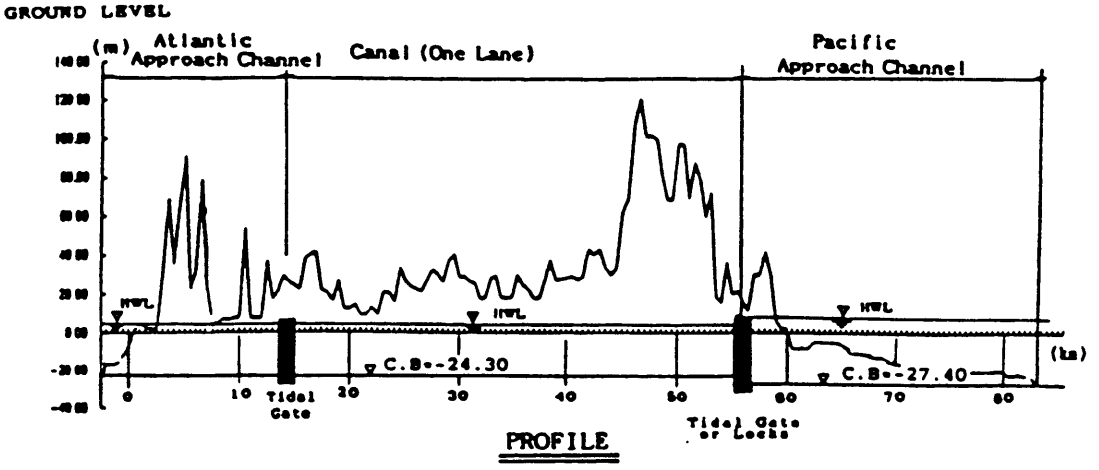
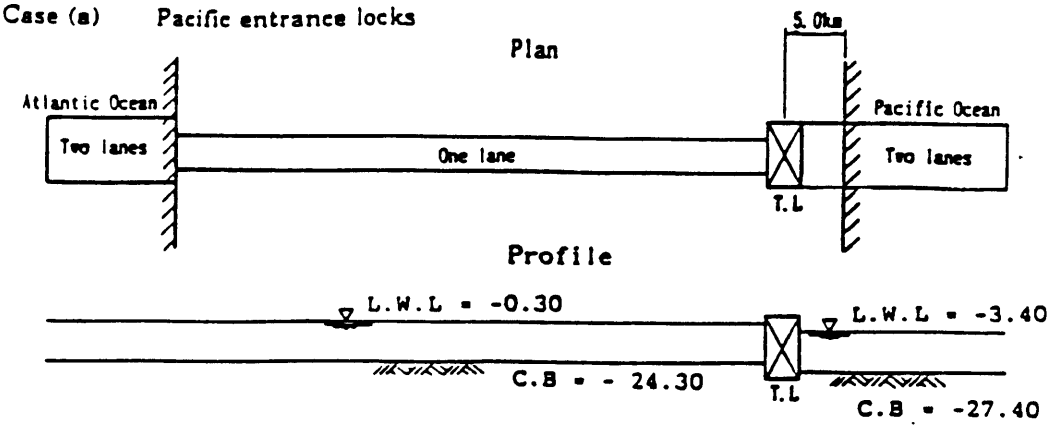


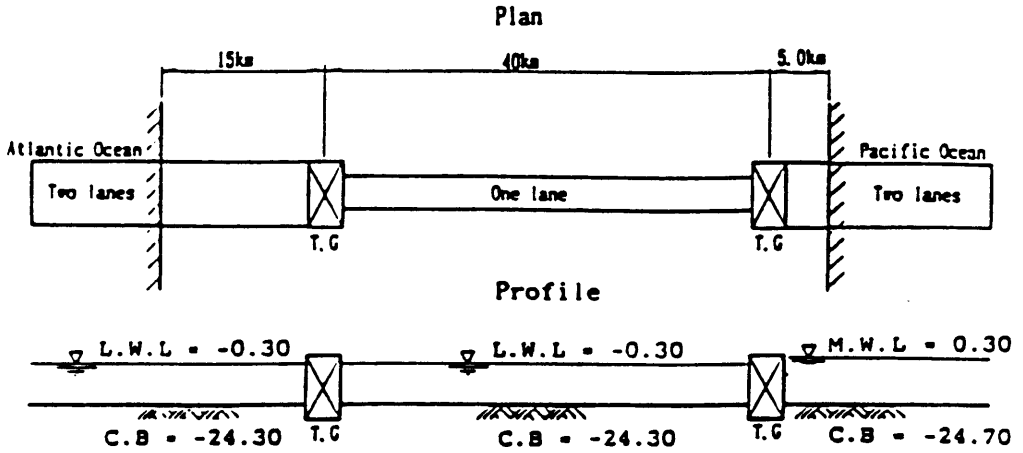
Figure 6.3.1-3

Cases of the Sea Level Canal

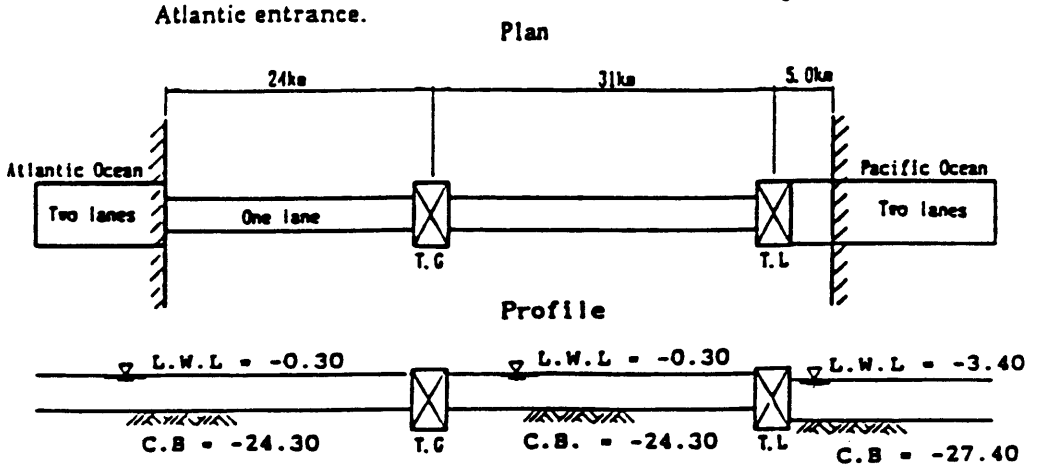
Case (a) Pacific entrance locks



Case (b) A pair of tidal gates



Case (c) A combination of Pacific entrance locks and tidal gate toward Atlantic entrance.



Note : T.L= Tidal Locks
T.G=Tidal Gates

Table 6.3.1-2
Summary of Features for Year 2020

Item	High Rise Lock (85 ft)		Sea Level Canal		
	150,00	200,000	case (a)	case (b)	case (c)
Total Cost (Mil. US$)	7,374	8,546	13,519	12,747	14,159
New Facilities Included:					
Canal	2 lane canal		1 lane canal & 2 lane approach		
Lock & Gate	third lane lock (1 lane of new locks)		parallel 3 lanes	1 lane 2 gates	parallel 3 locks 1 gate
Water Supply	n.a.	Indio	n.a.		
Pump Station (MCM)	n.a.				
Barrier Dam	n.a.		3		
Freshwater Dam	n.a.		considered		
Diversion Scheme	n.a.		considered		
Crossing Bridge	2 places		3 places		
Breakwater	existing available		additional new		

Table 6.3.1-3
Summary of Added Features for Year 2060

Item	High Rise Lock (85')		Sea Level Canal		
	150,00	200,000	case (a)	case (b)	case (c)
Total Cost (Mil. US$)	1,407	1,350	1,717	775	1,717
Lock & Gate	fourth lane lock (later tan 2060)		fourth lane lock	n.a.	fourth lane lock
Water Supply	2 dams Ciri, Indio	1 dam Trinidad	1 dam Upper Gatun		
Pump Station	2 places	2 places	n.a.		
Crossing Bridges	2 places		4 places		

It should be noted that the selection of 150 and 200 thousands dwt ships was a result of the prescreening study described in Section 5.5 since only the 150 thousands dwt was included in Phase I Engineering and Cost Estimates Study, the 200 thousands dwt ship for HRLC case was added to Phase II study scope in order to support optimization of the preferred HRLC alternative.

Construction of any HRLC alternative would not interrupt the operation and maintenance of the existing Panama Canal.

The SLC 10 conceptual alternative for the design ship of 250 thousand dwt was considered in Phase I study and was accepted by the Board for further development in Phase II. It follows the same alignment of Route 10 in IOCS (1970) Study and is mostly a one lane canal in the interior with two lane approach on the Atlantic and Pacific Coasts (Atlantic approach was later modified as described in Section 6.4). It will have tidal controls consisting of either tidal locks or tidal gates. Construction of SLC 10 will not interrupt the operation and maintenance of the existing Panama Canal.

The objective of Phase II is to provide preliminary engineering and conceptual design, construction cost estimate, operating and maintenance cost, and construction schedule and cash flow to allow for evaluation of the engineering feasibility of canal alternatives.

6.3.2 Approach

The general approach is described in details in the Terms of Reference (TOR) - Phase II Engineering and Cost Estimates and is included in YEC - Phase II Final Report. After completion of Phase II Study as outlined in the TOR, the Secretariat requested modifications and addition (Addendum to Phase II TOR) to the studies to be completed as described in Section 6.4:

- Implementation of phased construction for items related to infrastructures such as roads and bridges. Phased construction approach allowed scheduling these items after the year 2020 for completion by the year 2060 for both HRLC and SLC 10;

- Provide the cost of excavation for a single lane Culebra Cut instead of two lane;

- Eliminate the Western jetties of the Pacific entrance breakwater of the sea-level canal alternative; and,

- Provide cost estimates for a single lane Atlantic approach channel and a single lane tidal lock for the SLC 10 alternative.

Other assumptions and criteria are similar to Phase I and are described in Section 5.4.1.

6.3.3 Basic Assumptions and Design Criteria

Basic assumptions and design criteria were very critical elements of the Phase II Study and were mostly included in the TOR. Other assumptions and criteria were discussed and agreed upon during the Inception Report review meetings. A summary of important items is provided below:

- Conceptual alternative canal alignments presented in Figures 6.3.1-1 through 6.3.1-3.
- Gatun Lake design El. 85 ft. (26.0 m) and El. 90 ft. (27.5 m).
- The design ships and lock chamber dimensions given by CAS and presented in the Table 6.3.3-1 below. The length of the tidal locks for the sea-level canal should be based on the use of mules not tug boats. The rational supporting CAS' selection of the design criteria included in Table 6.3.3-1 is based on the following logic:
    - For design ship selection, it was based on the 90th percentile of bulk carriers in world fleet.
    - For the lock chamber selection, it was based on proposal by the OCCE component contractor to include:
        - Chamber width = 1.1 x the design ship beam (B);
        - Chamber depth = 1.1 x the design ship draft (D); and,
        - Chamber length = 1.1 x the design ship length (L) + 30 m.

Table 6.3.3-1
Design Ship and Lock Chamber Dimensions

Ship Size 1,000 dwt	Design Ship Dimensions (m)			Lock Chamber Dimensions (m)		
	Length(L)	Beam(B)	Draft(D)	Length(L)*	Width(W)	Depth(D)
65	295	32	12	304.8	33.5	12.8
150	306	46	18	365.0	50.0	20.0
200	333	50	19	395.0	55.0	21.5
250**	356	54	21	420.0	60.0	23.0

* Lock lengths were adjusted later to account for emergency as shown in Table 6.4.7-1 Footnote.
** Only sea-level canal

- The Channel Cross Section was given by CAS as presented in Figure 5.4.2-1 and was based on the following:

  - Suez Canal for Single Lane; and,
  - Existing Panama Canal for double lane.

- The geology of both canal alignments (HRLC and SLC 10) were investigated and discussed in IOCS (1970, Report - Annex V, Appendix 10 and JAX-46, 78, 79, 85, 92, 94, and 96). Other geologic reports covered part of the canal route such as Technical Report S-79-9, "Study of Clay Shale Slopes along the Panama Canal", Report 2, R. J. Lutton, U.S. Army Engineer Waterway Experiment Station, Vickslourg, Mississippi (1975). There are other reports published by the PCC covering detailed studies of specific landslides especially in the Culebra Cut area including the Gold Hill area. Summary of the geologic formations along the canal alignment for both the HRLC and SLC 10 are presented in the YEC - Phase II Final Report (April 1993), Parts III and IV.

- Excavation slope criteria was provided by SINBOL to the YEC for Phase I Study and was based on summary of information contained in The IOCS Reports (1970) and Memorandum, the Nagano Plan (1981), and technical reports published by the PCC. The slope criteria adopted by YEC used both the Nagano and IOCS Report generalized cross-section modified to incorporate information known from studies of past landslides and reports documenting the present monitoring program of a few slopes, especially the Gold Hill Area. YEC used a conservative approach to slope criteria which would increase excavation quantities and construction cost.

- The hydrology of the canal area is well documented by past water resource management studies and no change from criteria included in Section 5.4.2 was made for Phase II Studies. To summarize, the average annual yield recorded for 51 years is about 6,600 million cubic meters (m^3) and it ranges between a maximum of 9,950 million m^3 and a minimum of 4,900 million m^3. Average annual evaporation is estimated at 670 million m^3, and the net average yield is approximately 5,930 million m^3. The present yield is more than sufficient to support transit through the existing Panama Canal. The estimated total effective storage capacity of the two major lakes (Gatun and Madden) is about 1,200 million m^3. The design dry year controlled the quantity of water available for lockage and decided the need for other sources such as new dams and/or pumping stations.

- Geologic formations were classified into zones for the purpose of excavation as indicated in YEC-Phase II Final Report. No change from approach used in Phase I was made.

- For both the dry and wet excavation into hard rock, drilling and blasting techniques will be employed. Specially designed blast pattern will be used to produce rock fragments and aggregate sizes suitable for use in construction. Rock blasting guidelines were prepared and included in the YEC-Phase II Final Report (Part II, Section 2, Chapter 3).

A brief geologic characterization study indicate sufficient quantity of suitable formation exists to produce concrete aggregate required for construction.

- The Culebra Cut improvements project will be completed by the PCC prior to commencement of construction of any of the canal alternatives considered.

- Ecologically sensitive areas were identified on overlay map and given to YEC during the Phase II Inception Report. Identification of environmental impacts was required.

- A brief study of the feasibility of a freshwater barrier for the sea-level canal alternative was conducted.

- The Phase II Engineering Study included determination of a suitable transportation needs including roads, highways, and number of bridge crossings associated with the construction of any of the canal alternatives studied.

  CAS provided a suitable transportation plan and general guidelines as to the minimum number of canal crossing which should be included. The balance of a transportation plan was to be conceptualized by YEC and coordinated with various existing national transportation plans and was later modified by CAS; and is discussed in Section 6.4.

- The Phase II Study included conceptual design of a third set of lock designed for the HRLC to accommodate ship sizes of 150 and 200 thousands dwt. Excavation will be completed as a two lane channel and only one lock chamber will be constructed with a design provision to construct fourth set of locks for a potential future expansion. The two lane channel was changed to one lane as discussed in Section 6.4.

- In regards to the SLC 10, tidal locks or tidal gates were designed depending on the canal case considered. These gates or locks will accommodate 250 thousand dwt ships and will have single lane chambers. Optimization studies for locks and gates, including those used in hydraulic structures, and permanent corrosion protection were conducted in Phase I studies and the results of these studies were used for final selection, design, and costing for the Phase II Conceptual Alternatives. PCC valuable experience and practices are incorporated in this design.

- The design earthquake was based on historic and instrumental records of earthquakes which occurred in the Republic of Panama and the surrounding region. The appropriate seismic coefficient (horizontal acceleration) for the project surrounding was selected to be 0.1 g, and the horizontal acceleration coefficient is taken as (2/3) (0.1 g). Seismic design of important structures was based on the following general criteria:

  a. For all safety related structures and systems where failure may cause loss of life and navigation, the design earthquake full seismic coefficient should be used.

b. For important structures and systems where failure will cause temporary interruption in navigation but no loss of lives, one-half the design earthquake seismic coefficient may be used.

c. For all other structures where its failure will not cause danger to public safety nor unsafe navigation in the canal, no seismic design would be required.

- Itemized breakdown of operating and maintenance (O&M) was provided in the Phase II study fashioned after the PCC standard breakdown usually included in their annual report as a base. Additional O&M items specifically identified for any of the conceptual alternatives included in Phase II were added, example of such items included; surge basins, new dams, recycling ponds, pumping stations, tidal gates, ..., etc.

- Other navigational structures and systems included; mules, jetties, breakwater, moorings, anchorage, tie-up stations, ..., etc. were conceptually developed and costed in the Phase II studies and are discussed in Sections 6.3.4 through 6.3.7.

- Acquisition of real estate and population relocation for any of the conceptual alternatives were costed and are included in the Phase II study.

- Other construction related items such as; the effect of Panama climate, construction laydown areas, interference of construction with existing canal operations, availability of labor and equipment, infrastructure, housing, health facilities, camps, security, sanitary facilities, transportation allowance, gate leaf fabrication, etc. were considered and are included in the Phase II study.

- Panamanian labor laws governed the basis for labor rates, shifts, overtime, benefits, etc. and therefore provided the basis for construction schedules.

6.3.4 High Rise Lock Canal (HRLC), Project Description

Introduction

Phase I results indicated that an optimum HRLC case may be a canal with design ship between 150 and 200 thousand dwt and where Gatun Lake is at El 85 ft. (26 m) or El 90 ft. (27.5 m). Phase I included the 150 thousand dwt case but did not include the 200 thousand dwt case. The Phase II study added a new 200 thousands dwt and upgrading for the 150 thousands dwt.

Specific Criterias

- Basic Engineering Data

Basic engineering data and assumptions made and used are summarized in Table 6.3.4-1.

Table 6.3.4-1
Basic Engineering Data (Phase II)

Item	Description
1 Route	Reference High Rise Lock Canal (Fig. 6.3.1-1)
2 Lake Level	85 ft (26 m) and 90 ft (27.5 m)
3 Ship Size (Maximum)	150,000 dwt = 1,003.7 x 150.9 x 59.0 ft (306 x 46 x 18 m) 200,000 dwt = 1,092.2 x 164.0 x 62.3 ft (333 x 50 x 19 m)
4 Number of Lanes	Approach Channel 2 Lanes, Canal 2 lanes (Single lane in Culebra Cut)
5 Canal Width	150,000 dwt = 1,050 ft (320 m) 200,000 dwt = 1,148 ft (350 m)
6 Canal Depth	150,000 dwt = 69.9 ft (21.0 m) 200,000 dwt = 72.2 ft (22.0 m)
7 Lock Dimensions	150,000 dwt = 1,279.2 x 164.0 x 65.6 ft (390 x 50 x 20 m) 200,000 dwt = 1,373.6 x 180.4 x 70.5 ft (420 x 55 x 21.5 m)
8 Lock Data	1 lane & 2 lifts
9 N°. of Transits[1]	150,000 dwt in 2020 = 2,000 & in 2060 = 4,600 200,000 dwt in 2020 = 2,000 & in 2060 = 4,600 Existing Locks in 2020 = 16,200 & in 2060 = 20,000
10 Tidal Levels	High Water Level in Pacific = + 11.8 ft (3.6 m) Low Water Level in Pacific = - 11.2 ft (-3.4 m) High Water Level in Atlantic = + 1.6 ft (0.5 m) Low Water Level in Atlantic = - 1.0 ft (-0.3 m)
11 Earthquake[2]	Kh = 0.1 & Kv = Kh * 2/3

Notes: 1 Based on OCCE Phase I Studies (See Section 6.4)
2 Kh = horizontal acceleration coefficient
Kv = vertical acceleration coefficient

Figure 6.3.4-1
Simulation Model for Water Balance

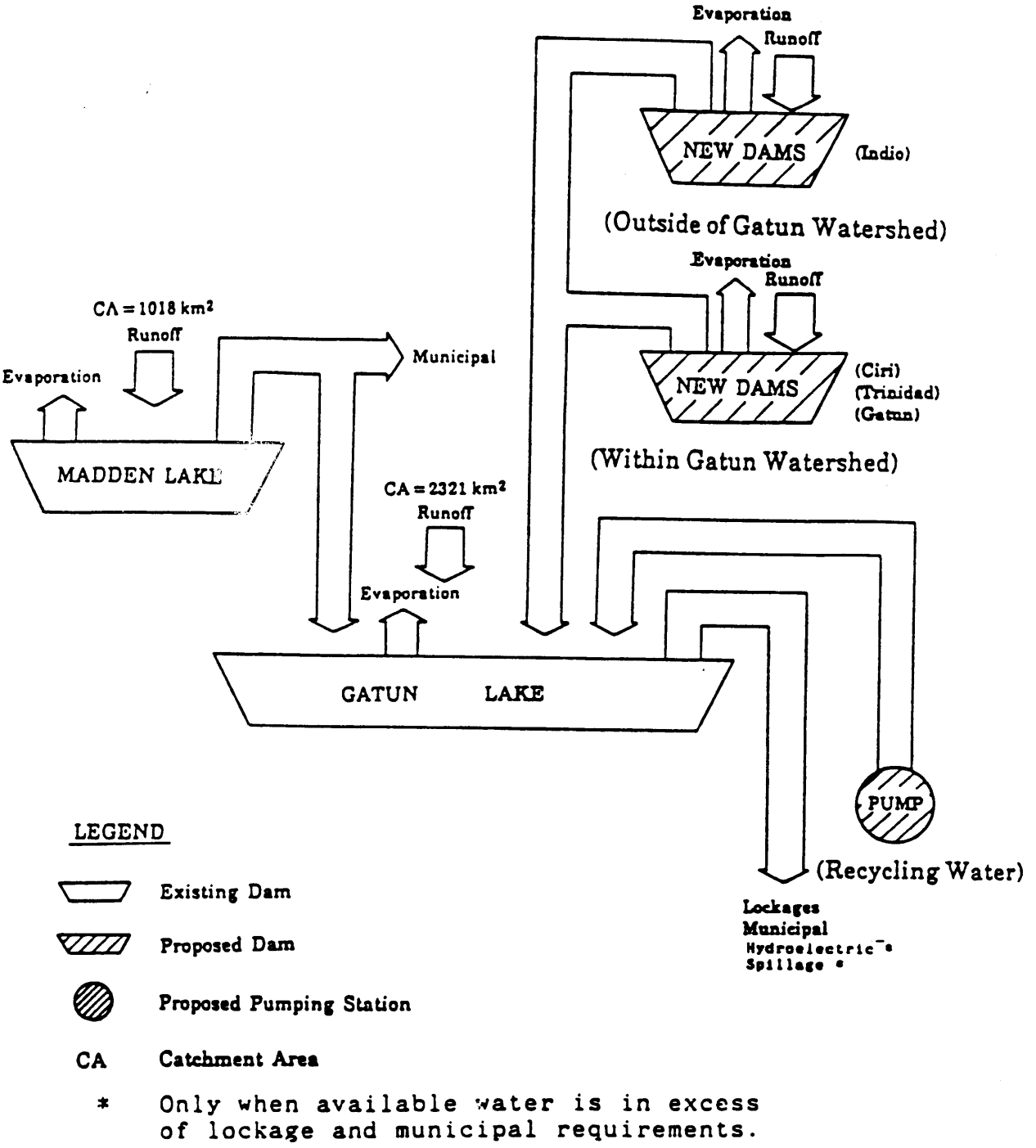
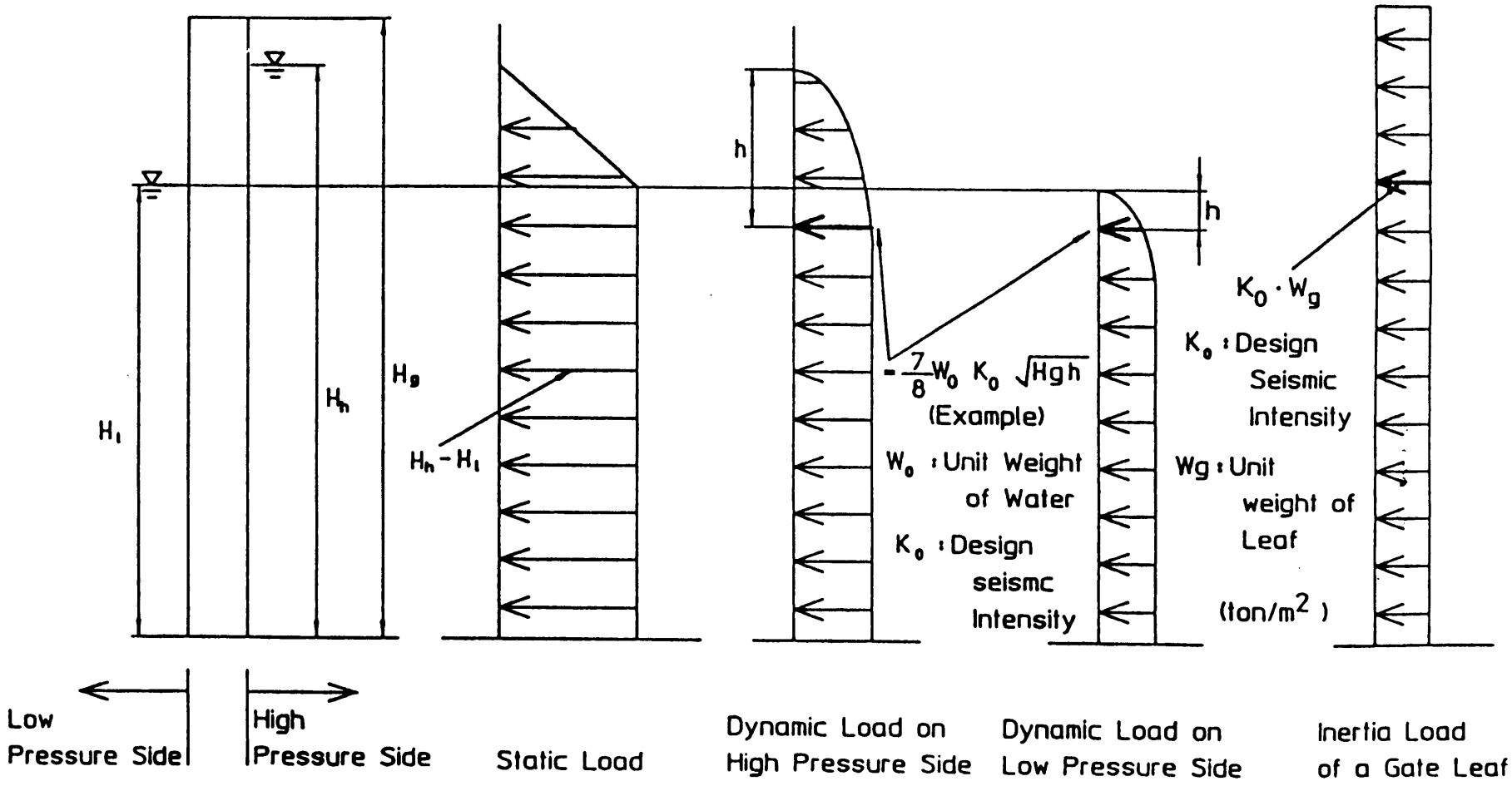


Figure 6.3.4-2

Load on Gate Leaf under Seismic Condition (ton/m²)



- Water Management

It was assumed that the entire yield from Gatun watershed will be available for lockage with the exception of a small portion devoted to municipal use. Mathematical Simulation Model was used to conduct water balance analysis. The lockage water required for one transit is as shown in Table 6.3.5-1. The following important guidelines and basic criteria were used:

- Monthly discharges were calculated based on over 50 years of records and the wet, average and dry year discharges were based on the last 10 years of record;
- Miraflores Lake was not included in the water balance model;
- Gatun Lake and Alajuela (Madden) Lake active storage is 659 million m^3 between El 25.1 and El 26.6 m and 539 million m^3 between El 61.0 and El 76.2 m, respectively.
- Total useable storage is the summation of both Gatun and Alajuela Lakes;
  - No provision is made to divert water for hydroelectric generation or for spillage; and,
  - Evaporation loss calculation is based on water levels and surfaces;
- Inputs and outputs of the water balance simulation model are presented graphically on Figure 6.3.4-1.

- Lock Structures

Specific design data and criteria related to the design of lock structures are provided in Table 6.3.4-1.

- Lock Gates

Common design data and criteria related to various gates are summarized below. All elevations are reference to P.L.D. (Plane Level Datum) in metric system.

The design water levels are provided in Table 6.3.4-2.

Table 6.3.4-2
Design Water Levels

Location	Water Level	H.W.L.	L.W.L.
Gatun Lake 85'	+26.0	+26.6	+25.1
Gatun Lake 90'	+27.5	+28.1	+26.6
Atlantic Side	+0.1 (M.S.L.)	+0.5	-0.3
Pacific Side	+0.3 (M.S.L.)	+3.6	-3.4

The water levels during operation are given in Tables 6.3.4-3 and 6.3.4-4.

- The design freeboard is 0.6 meters (2 ft.) for operating and maintenance gates and no allowance for freeboard was made for all other gates.

- The design pressure distribution both static and dynamic and the application of seismic design coefficient was as follows:

- Design seismic coefficient was taken as 0.1 g.

- Application of seismic coefficient used was:

  - for lock and maintenance gates 100% (0.1 g)
  - for culvert and emergency gates 50% (0.05 g)
  - for bulkhead gate 100% (0.1 g)

The external forces imposed by earthquake including water and inertia forces are shown in Figure 6.3.4-2. The recommended corrosion protection system included: paint coating, cathodic protection anodes, and incorporation of present PCC practice related to such system.

Table 6.3.4-3

Lock Gate Design Water Elevation During Operation (m) (Based upon P.L.D.)

Location	Given Elevation		After Raised		After Lowered	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Atlantic Side						
Gatun Approach	+26.6	+25.1				
Upper Chamber			+26.6	+25.1	+13.6*	+12.4
Lower Chamber			+13.6*	+12.4	+ 0.5	-0.3
Sea Side App.	+0.5	-0.3				
Pacific Side						
Gatun Approach	+26.6	-25.1				
Upper Chamber			+26.6	+25.1	+15.1*	+10.9
Lower Chamber			+15.1*	+10.9	+3.6	-3.4
Sea Side App.	+3.6	-3.4				

Notes: * El. +13.6 and 15.1 define the height of lower chambers on the Atlantic and Pacific respectively. Water consumption and economic optimization is possible and should be done in the detailed design stage.

Table 6.3.4-4

Design Heads of Operating Gate in Meter (200,000 dwt)

Gate Name	Operational Condition		Maintenance Condition	
	Lake Side	Ocean Side	Lake Side	Ocean Side
Atlantic Side				
Upper Operating Gate	23.0	8.8	23.0	0.0
Middle Operating Gate	35.7	8.8	22.7	0.0
Lower Operating Gate	35.4	21.5		
Pacific Side				
Upper Operating Gate	23.0	7.3	23.0	0.0
Middle Operating Gate	37.2	7.2	26.1	0.0
Lower Operating Gate	40.0	21.5		

6.3.5 High Rise Lock Canal Design Features

Preliminary engineering and design were conducted in Phase II for two ship sizes of 150 and 200 thousand dwt and two Gatun Lake elevations of 26.0 m and 27.5 m. The HRLC will follow basically the existing Panama Canal route with minor changes to improve navigation especially in Gatun Lake. The only substantial deviation is at the location of the third lock at both the Miraflores and Gatun Locks where a bypass channel will be excavated almost parallel to the existing locks to accommodate larger ship sizes.

The option of raising Gatun Lake to El 27.5 m was briefly studied and several problems were identified which will be discussed later. Rough cost estimates were provided and specific design features are briefly summarized below and a more detailed descriptions are provided in the YEC - Phase II Final Report.

Water Management

At present, lockage water required to transit ships through the existing Panama Canal is fully supplied by Gatun Lake storage and water balance analysis indicates more than sufficient water exists to satisfy capacity. The HRLC alternative will require additional lockage water that at some future time the demand will exceed Gatun Lake watershed and new storage capacity and new sources of water will be required outside of Gatun watershed.

Table 6.3.5-1 is a summary of the lockages required for cases studied and is based on the YEC-Phase II Final Report.

Table 6.3.5-1
Lockage Water for One Transit

Case		{1} Length (m)	{2} Width (m)	{3} Lift (step)	{4}Lockage (1,000 m^3)
Rise (ft)	Size (dwt)				
85'	65,000	304.8	33.5	3	177
85'	150,000	390.0	50.0	2	507
85'	200,000	420.0	55.0	2	601
90'	65,000	304.8	33.5	3	187
90'	150,000	390.0	50.0	2	536
90'	200,000	420.0	55.0	2	635

Note: (1,000 m^3) = (Rise(m)*{1}*{2}/{3}*2/1000

It should be noted that YEC based the water balance simulation analysis on canal transit capacity as presented by TAMS in the Operating Characteristics and Capacity Evaluation, OCCE Phase I which may underestimate lockage water requirement as discussed below.

The results of water balance simulation analysis for average, dry and wet years are graphically depicted in Figures 6.3.5-1 and 6.3.5-2.

Table 6.3.5-2 is a summary of annual transits as reported by TAMS-Phase I and lockage water required.

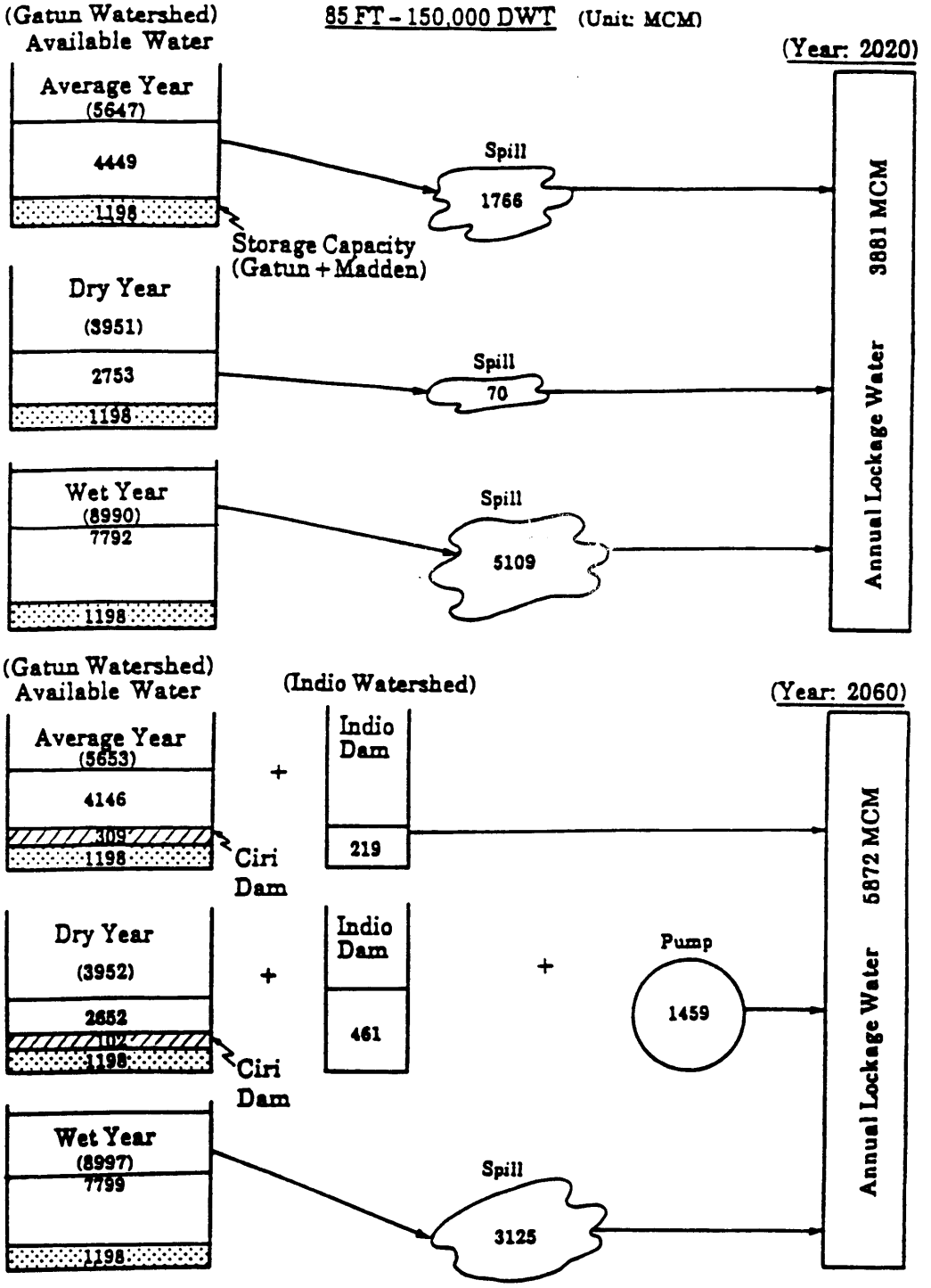
Water balance analysis was conducted for Gatun Lake at El. 26.0 m indicated the following preliminary conclusions:

- For 150 thousands dwt ship and year 2020, a water surplus of 70 million m^3 is calculated for a dry year. For the same design ship and year 2060, the water shortage is calculated at 1,920 million m^3 and is proposed to be made up by a dam and pump stations.

- For 200 thousands dwt ship and year 2020, a water shortage of 116 million m^3 is calculated for a dry year to be made up by Indio dam for same design ship and year 2060, the water shortage would be 2,351 million m^3 to be made up by Indio dam and pump stations. A summary of water makeup for the target years of 2020 and 2060 is presented in Table 6.3.5-3.

Figure 6.3.5-1

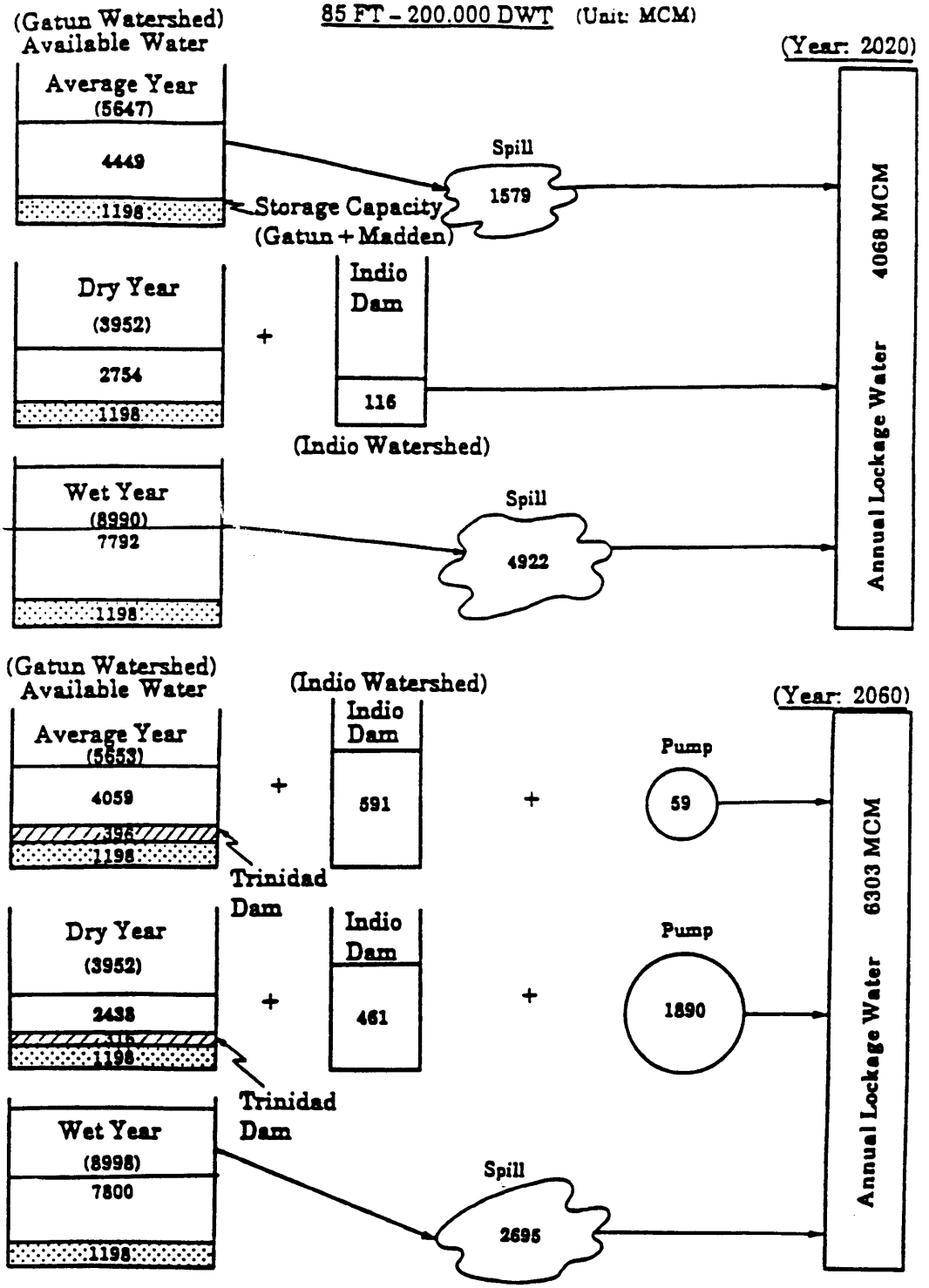
Water Balance for 150,000 dwt Case



Note: Available water = Total runoff – Municipal water – Evaporation

Figure 6.3.5-2

Water Balance for 200,000 dwt Case



Note: Available water = Total runoff – Municipal water – Evaporation

Table 6.3.5-2

Annual Transits and Lockage Water

Case				Existing Lock		New Lock		Total
Case	Rise	dwt	Year	Transit	MCM	Transit	MCM	MCM
(1)	85 ft or 26.0 m	150	2020	16,200	2,867	2,000	1,014	3,881
			2060	20,000	3,540	4,600	2,332	5,872
(2)		200	2020	16,200	2,867	2,000	1,201	4,068
			2060	20,000	3,540	4,600	2,763	6,303
(3)	90 ft or 27.5 m	150	2020	16,200	3,033	2,000	1,073	4,105
			2060	20,000	3,744	4,600	2,467	6,211
(4)		200	2020	16,200	3,033	2,000	1,271	4,303
			2060	20,000	3,744	4,600	2,922	6,666

Note: Number of transits are based on OCCE - Phase I Report

Table 6.3.5-3

Water Make Up Required by Dams and Pump Stations

Year	Design Year	Maximum Ship Size dwt		
		High Rise Lock Canal 85' (26 m)		Sea Level Canal
		150,000 dwt	200,000 dwt	250,000 dwt
2020	Wet Year	n.r.	n.r.	n.r.
	Average Year	n.r.	n.r.	n.r.
	Dry Year	n.r.	Indio	n.r.
2060	Wet Year	n.r.	n.r.	n.r.
	Average Year	Indio, Ciri	Indio, Trinidad, Pump Station	n.r.
	Dry Year	Indio, Ciri, Pump Station	Indio, Trinidad, Pump Station	Upper Gatun

Subsequent to the YEC-Phase II Final Report, the OCCE - Phase II Final Report was published by TAMS in June 1993, which included the transit capacity for Phase II conceptual alternative studied. CAS requested that TAMS provide the estimated volumes of water required for lockage using Phase II Canal alternative capacities. The TAMS study was presented to the Commission via letter report dated May 21, 1993. The Canal capacity numbers and water requirements are different from those used by YEC and reported in the YEC-Phase II Final Report. A summary of water makeup for the target years of 2020 and 2060 is presented in Table 6.3.5-3.

It was important for CAS to resolve the discrepancy and issue a policy decision providing direction to resolve this difference since it has a substantial impact on the cost estimate. This policy decision and statement describing reasons are summarized in Dr. Koji Kobune's Memorandum issued to all Delegates on May 29, 1993. This memorandum makes comparison between ECE and OCCE Studies of number of lockage and water consumption which is presented in Tables 6.3.5-4 and 6.3.5-5. OCCE analysis indicated larger volumes are needed for lockage because the number of transits through the new locks is substantially larger than that used by ECE Study although the total capacity is essentially the same.

As indicated in the above comparison tables, water consumption calculated by the OCCE Study is approximately 50 percent larger than ECE Study for the forecast year 2020 and 40 percent larger than YEC for the forecast year 2060.

Table 6.3.5-4

Number of Lockages and Water Consumption

(Design Ship: 150,000 dwt) (From OCCE)

	Water Volume spilled per ship	Transit/Year	
		2020	2060
S.Q. Lock			
Gatun	95,200 m^3	9,692	12,646
Miraflores	95,200 m^3	8,602	12,414
New Lock			
Atlantic	252,500 m^3	8,246	9,204
Pacific	252,500 m^3	10,458	10,649
Number of Transits	-	18,500	22,500
Water Consumption mil. m^3	-	6,381	8,029

Table 6.3.5-5

Number of Lockages and Water Consumption

(Design Ship: 150,000 dwt) (From ECE)

	Water Volume spilled per ship	Transit/Year	
		2020	2060
S.Q. Lock			
Gatun	88,500 m^3	16,200	20,000
Miraflores	88,500 m^3	16,200	20,000
New Lock			
Atlantic	253,500 m^3	2,000	4,600
Pacific	253,500 m^3	2,000	4,600
Number of Transits		18,200	24,600
Water Consumption mil. m^3	mil. m^3	3,881	5,874

(Based on Dr. Kobune's Work)

It should be noted that the OCCE Study (TAMS) optimized transit time by routing ships through existing and new locks; whereas ECE (YEC) study optimized cost of construction by minimizing water consumption.

Depending on which approach is taken, the decision will have capital cost implications. The OCCE approach will require construction of water makeup structures earlier than the phased construction approach used by ECE approach.

Tables 6.3.5-6 and 6.3.5-7 and Figure 6.3.5-3 (based on Dr. Kobune's work) show deficient lockage water and the years makeup water will be required based on OCCE study.

In practice, lockage water makeup requirements will probably be somewhere in between the OCCE and ECE depending on the controlling factor of either drought (optimization of water consumption used by ECE) or congestion and shorter transit time (optimization of canal transit time used by OCCE).

The policy decision made was to adopt the approach used by ECE (YEC) study of optimization of water consumption therefore minimizing construction cost and allowing for a phased construction approach.

Table 6.3.5-6

Water Management Facilities for 150,000 dwt Case

(Dry Year) (Based on Dr. Kobune's Work)

				Indis. Ctrl				
Year	Transit	Rec. Water	No Dam	Dam	Pump 1	Pump 2	Total	Residual
2020	18,200	3,881	3,951	—	—	—	3,951	70
2021	18,328	3,919	3,951	461	—	—	4,412	493
2022	18,457	3,957	3,951	461	—	—	4,412	455
2023	18,587	3,994	3,951	461	—	—	4,412	418
2024	18,719	4,032	3,951	461	—	—	4,412	380
2025	18,852	4,071	3,951	461	—	—	4,412	341
2026	18,986	4,110	3,951	461	—	—	4,412	302
2027	19,122	4,150	3,951	461	—	—	4,412	262
2028	19,260	4,190	3,951	461	—	—	4,412	222
2029	19,399	4,231	3,951	461	—	—	4,412	181
2030	19,539	4,273	3,951	461	—	—	4,412	139
2031	19,681	4,315	3,951	461	—	—	4,412	97
2032	19,825	4,358	3,951	461	—	—	4,412	54
2033	19,970	4,402	3,951	461	—	—	4,412	10
2034	20,117	4,446	3,951	461	946	—	5,358	912
2035	20,265	4,491	3,951	461	946	—	5,358	867
2036	20,415	4,536	3,951	461	946	—	5,358	822
2037	20,567	4,582	3,951	461	946	—	5,358	776
2038	20,721	4,629	3,951	461	946	—	5,358	729
2039	20,876	4,677	3,951	461	946	—	5,358	681
2040	21,033	4,726	3,951	461	946	—	5,358	632
2041	21,192	4,775	3,951	461	946	—	5,358	583
2042	21,353	4,825	3,951	461	946	—	5,358	533
2043	21,515	4,875	3,951	461	946	—	5,358	483
2044	21,680	4,927	3,951	461	946	—	5,358	431
2045	21,846	4,979	3,951	461	946	—	5,358	379
2046	22,015	5,033	3,951	461	946	—	5,358	325
2047	22,185	5,087	3,951	461	946	—	5,358	271
2048	22,358	5,142	3,951	461	946	—	5,358	216
2049	22,532	5,197	3,951	461	946	—	5,358	161
2050	22,709	5,254	3,951	461	946	—	5,358	104
2051	22,888	5,312	3,951	461	946	—	5,358	46
2052	23,069	5,370	3,951	461	946	946	6,304	934
2053	23,252	5,430	3,951	461	946	946	6,304	874
2054	23,437	5,490	3,951	461	946	946	6,304	814
2055	23,625	5,551	3,951	461	946	946	6,304	753
2056	23,815	5,614	3,951	461	946	946	6,304	690
2057	24,008	5,677	3,951	461	946	946	6,304	627
2058	24,203	5,742	3,951	461	946	946	6,304	562
2059	24,400	5,808	3,951	461	946	946	6,304	496
2060	24,600	5,874	3,951	461	946	946	6,304	430

Table 6.3.5-7

Water Management Facilities for 200,000 dwt Case

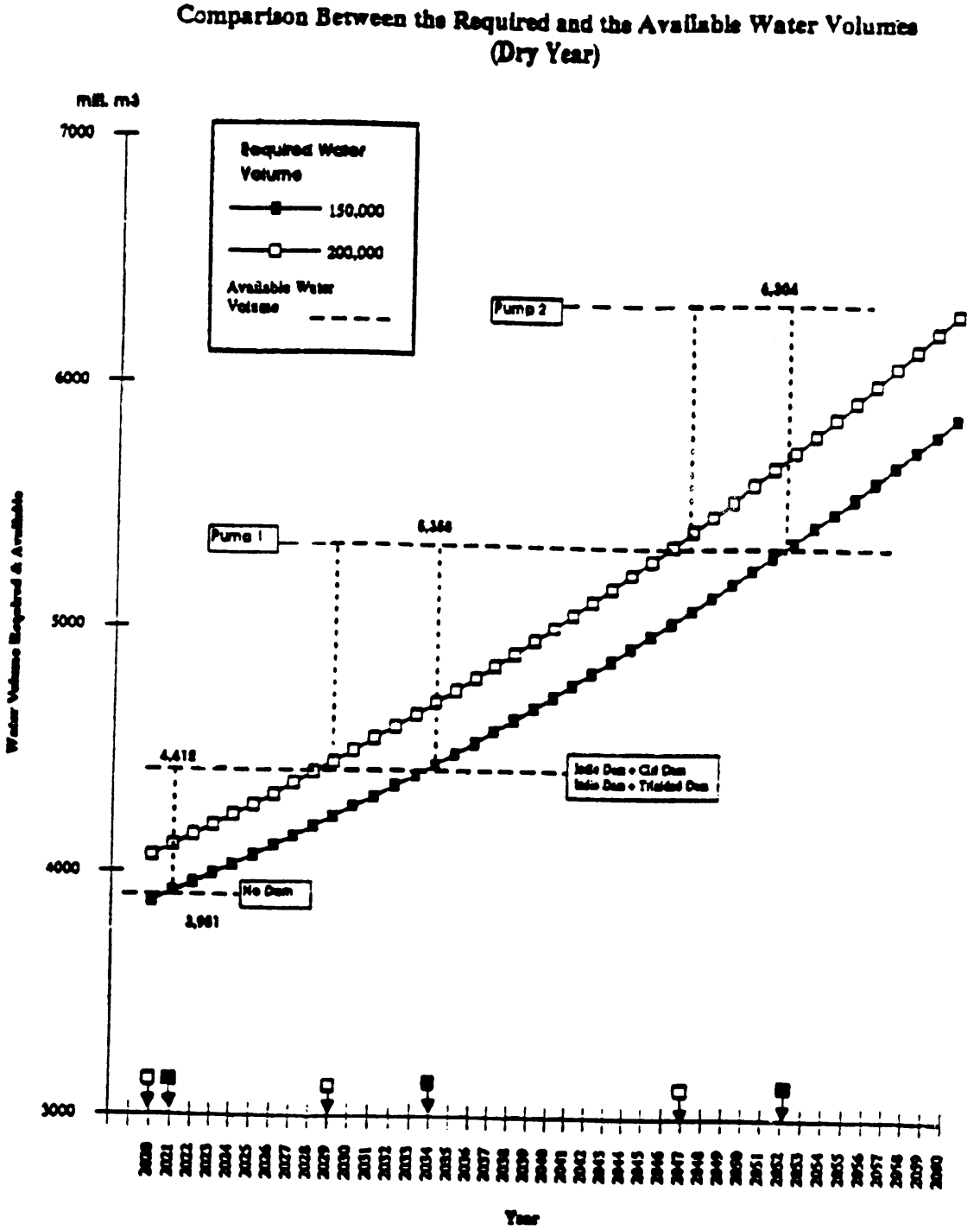
(Dry Year) (Based on Dr. Kobune's Work)

				Indio. Trinidad				
Year	Transit	Rec. Water	No Dam	Dam	Pump 1	Pump 2	Total	Residual
2020	18,200	4,068	3,951	461	--	--	4,412	344
2021	18,328	4,110	3,951	461	--	--	4,412	302
2022	18,457	4,151	3,951	461	--	--	4,412	261
2023	18,587	4,193	3,951	461	--	--	4,412	219
2024	18,719	4,235	3,951	461	--	--	4,412	177
2025	18,852	4,278	3,951	461	--	--	4,412	134
2026	18,986	4,322	3,951	461	--	--	4,412	90
2027	19,122	4,366	3,951	461	--	--	4,412	46
2028	19,260	4,411	3,951	461	--	--	4,412	1
2029	19,399	4,457	3,951	461	946	--	5,358	901
2030	19,539	4,503	3,951	461	946	--	5,358	855
2031	19,681	4,550	3,951	461	946	--	5,358	808
2032	19,825	4,598	3,951	461	946	--	5,358	760
2033	19,970	4,647	3,951	461	946	--	5,358	711
2034	20,117	4,696	3,951	461	946	--	5,358	662
2035	20,265	4,746	3,951	461	946	--	5,358	612
2036	20,415	4,797	3,951	461	946	--	5,358	561
2037	20,567	4,849	3,951	461	946	--	5,358	509
2038	20,721	4,901	3,951	461	946	--	5,358	457
2039	20,876	4,955	3,951	461	946	--	5,358	403
2040	21,033	5,009	3,951	461	946	--	5,358	349
2041	21,192	5,064	3,951	461	946	--	5,358	294
2042	21,353	5,120	3,951	461	946	--	5,358	238
2043	21,515	5,177	3,951	461	946	--	5,358	181
2044	21,680	5,235	3,951	461	946	--	5,358	123
2045	21,846	2,594	3,951	461	946	--	5,358	2,764
2046	22,015	5,354	3,951	461	946	--	5,358	4
2047	22,185	5,415	3,951	461	946	946	6,304	889
2048	22,358	5,477	3,951	461	946	946	6,304	827
2049	22,382	5,539	3,951	461	946	946	6,304	765
2050	22,709	5,603	3,951	461	946	946	6,304	701
2051	22,888	5,668	3,951	461	946	946	6,304	636
2052	23,069	5,734	3,951	461	946	946	6,304	570
2053	23,252	5,801	3,951	461	946	946	6,304	503
2054	23,437	5,870	3,951	461	946	946	6,304	434
2055	23,625	5,939	3,951	461	946	946	6,304	365
2056	23,815	6,010	3,951	461	946	946	6,304	294
2057	24,008	6,081	3,951	461	946	946	6,304	223
2058	24,203	6,154	3,951	461	946	946	6,304	150
2059	24,400	6,229	3,951	461	946	946	6,304	75
2060	24,600	6,304	3,951	461	946	946	6,304	0

Figure 6.3.5-3

Comparison Between the Required and the Available Water Volumes

(Dry Year) (Based on Dr. Kobune's Work)



Excavation

The central isthmus linking the North and South American continents is located in an area characterized by complex geological condition due to the overlapping of four plates, i.e. Cocos, Nazca, Caribbean and Americas, as explained by the plate tectonics theory. The topography near the canal vividly reflects the area's geological characteristics. On the one hand, this highly altered, soft igneous rock region and the sedimentary rocks of the Tertiary have produced a hilly area with gentle slopes. On the other hand, the intrusive body of basalt or dacite has produced protruding tableland or a conical topography, showing a marked difference to the hilly area. The bedrock of the existing canal route consists of sedimentary rocks and extrusive or intrusive igneous rocks of the Tertiary. Alluvial deposits of the Quaternary are distributed in the flat area along the Pacific and Caribbean. Coral reefs are found along the coast to the east of Colon facing the Caribbean. An active volcano (Cerro Gaital) is located some 75 km southeast of Panama and has no direct bearing on the canal.

For more details on the geologic characterization of the canal area consult the following references:

1) Geological Map of Gaillard Cut Area, Panama Canal, from Gamboa to Pedro Miguel (1/250,000);

2) Geological Map of Panama Canal and Vicinity, Republic of Panama (1/100,000), 1980, R. H. and J. L. Stewart in collaboration with W. P. Wooding;

3) JAX-85 (IOCS Memorandum), 1969; and,

4) Study of clay shale slopes along the Panama Canal Report I, II, III, Technical Report S-70-90 (R. J. Lotton, R. W. Hunt, etc. 1974).

The canal area is largely classified into four geologic zones: (1) Caribbean coast zone, (2) Gatun Lake Zone, (3) central divide zone, and (4) Pacific coast zone, based on the bedrock formation. Excavation along the HRLC was divided into five zones, i.e. 1) Atlantic (Caribbean) approach, 2) Gatun Lake, 3) Culebra, 4) Miraflores, and 5) Pacific approach. The YEC-Phase II Final Report describes these zones in detail and provide typical excavation cross-sections for each zone.

- Excavation Slopes

Excavation slopes suggested in the IOCS (1970) Report and later proposed by Nagano (1981) for the SLC-10 formed the basis for this study. The stable excavation slopes proposed and adopted in this study is slightly different from IOCS and Nagano as shown in Table 6.3.5-8.

The differences are discussed in the YEC-Phase II Final Report, Section 1.4.2:

Table 6.3.5-8

Comparison of Excavation Slope Gradient Criteria

Type	Rock Type	Slope	Cotangent
		IOCS and Nagano Plan (cotangent)	Proposed YEC (cotangent)
1	High quality rock	0.4	0.6 to 0.7
2	Intermediate quality rock	0.6	1.0 to 1.3
3	Low quality rock	1.0 to 2.8	2.0 to 4.4
4	Soft rock	1.0 to 6.7	2.0 to 4.4
5	Unconsolidated sediments	2.5[1] 10[2]	2.5

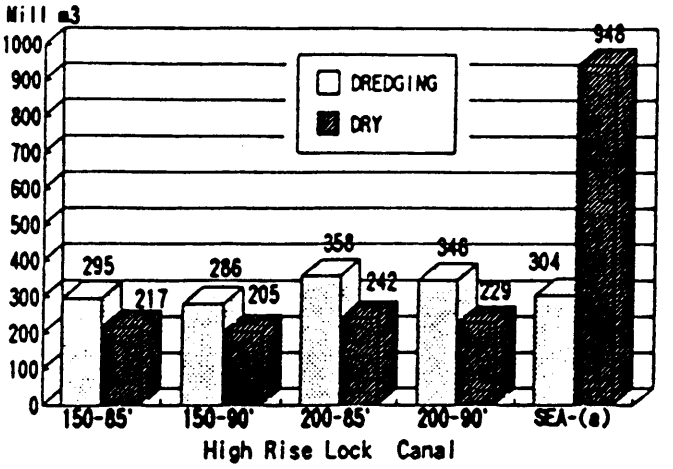
Note: (1) in navigation prism
(2) above navigation prism

Adoption of different stable excavation slopes in the future would depend on additional geotechnical investigations and analysis to be conducted early and in some instances, may even be decided during construction. To estimate excavation volumes and analysis to be conducted early, the HRLC route was divided into sections at one-half kilometer intervals and a geologic cross-section was constructed for each section. The excavation volumes were calculated and the topographic contours were obtained from maps of the area.

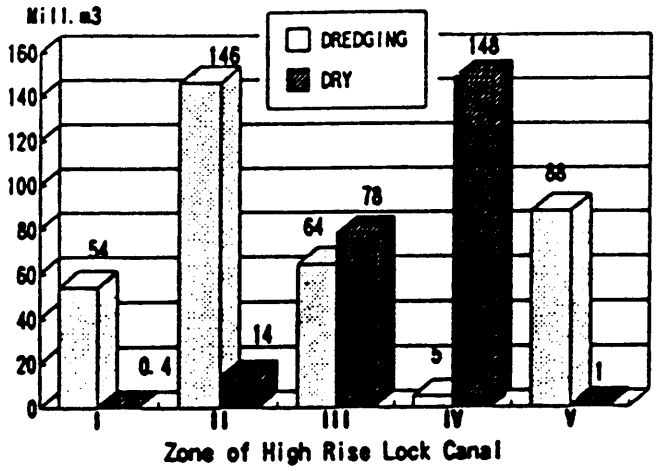
Excavation quantities were calculated for four different cases of the HRLC; namely, design ships of 150 and 200 thousand dwt and Gatun Lake at El. 26 and El. 27.5 meters. The estimated excavation quantities, both dry and wet (dredged), are presented in Figure 6.3.5-4.

This figure shows that for a design of 150 thousand dwt, total excavation range between 491 million m^3 (Gatun El 27.5 m) and 512 million m^3 (Gatun El 26 m) and that wet excavation volume is larger than dry excavation volume by an average of 37%. Similarly for a design ship of 200 thousand dwt, total excavation ranges between 575 million m^3 (Gatun at 27.5 m) and 600 million m^3 (Gatun El 26 m) and that wet excavation volume is larger than dry excavation volume by an average of 50%.

Fig. 6.3.5-4
Cumulative Excavation Volume



Excavation Volume for Each Case



Excavation Volume for Each Zone (85' and 200,000 DWT Case)

- Culebra Cut Excavation

As indicated in other sections of this report, widening and deepening of the Culebra (Gaillard) Cut section of the canal is considered as part of the Status Quo (Existing Panama Canal), and will be completed by the PCC and its successor authority. The methodology employed by the ECE Component Contractor for this section included estimated excavation quantities including Culebra Cut and adjusting (downward) these quantities by the estimated excavation (Culebra) volumes as reported by the PCC in May 1991.

The following table (6.3.5-9) included PCC estimated volumes in million cubic yards by sectors deducted from total sector estimated excavation volumes by ECC to adjust for Culebra Cut project currently in progress.

Table 6.3.5-9
Status Quo Culebra Cut Excavation Quantities
(Million Cubic Yards)

Material	North Sector	Central Sector	South Sector	Total Sector
Dry Common	1.8	4.3	3.2	9.3
Dry Rock	2.0	6.5	5.5	14.0
Dredging	3.4	5.0	3.2	11.6
Total	7.2	15.8	11.9	34.9

Source: PCC, May 1991

Lock Structures and Ancillary Facilities

Basic data and design criteria used in the conceptual design of lock structures were summarized in Tables 6.3.4-1 through 6.3.4-4 and Figure 6.3.4-2.

The existing Panama Canal locks are of gravity type concrete walls and have performed well since completion of construction in 1914. Similar type walls may be designed for the new third lock structures and were actually used by the ECE Component Study. However, in the final design of the lock structure, a slurry wall (diaphragm structure) should be investigated and if more economical and environmentally appealing, it could be used.

The new Pacific third locks are located slightly west of the 1940's excavation in order to improve navigation and eliminate interference with navigation in Miraflores Lake. The new Gatun third lock location is identical to the 1940's excavation. Both locks will be single lane.

The Pacific side third lock structure will be founded on basalt with adequate bearing capacity to design a conventional foundation. The Gatun Lake third lock structure will be founded in sandstone and tuff of the Gatun formation with adequate bearing capacity to permit construction of conventional foundation. Other details concerning design water elevations, chambers, culverts, etc., are included in the YEC-Phase II Final Report, Part III, Section I, Chapter 4.

Ancillary facilities consist of a surge basin, recycling basin, and pump stations. The surge basin will be required between the new Pacific third lock and Gatun Lake to minimize pitching and rolling of vessels as lockage water is released to the bypass channel towards Gatun lake. No such basin is required for Gatun Locks since lockage water is directly released to a large (Gatun Lake or Caribbean Sea) water body.

Recycling basins are required near both the Pacific and Gatun Lake locks to conserve, store and recycle the spent lockage water by pumping. The recycling basin on the Pacific Side will be connected to the surge basin via a pump station. Other pump stations will be required after year 2020 and locations of lock structures and other ancillary facilities are discussed and shown in the YEC-Phase II Final Report, Section 4.3.

Lock Gates

The HRLC new third lock will have three operating gates, nine culvert gates, and one emergency gate. Operating gates play an important role in the canal lock function by opening and closing lock chamber to ship transit. Culvert gates open and close culvert tunnels constructed in lock walls to regulate and control flow of lockage water. Emergency gates provide safe closure of lock in case of an emergency such as ship collision and fracture or failure of operating gates. In addition to the above gates, there are also maintenance gates used during scheduled closure for lock chamber maintenance.

A miter type gate was recommended for the operating gate. This type was selected for its excellent operating and maintenance history in Panama and elsewhere. In the detailed design phase, a thorough study should be made in order to optimize the selection of the operating gate as it appears that a torsion type rolling gate may also be feasible and probably more economical.

Details of gate unit weight, leaf, frame and drive mechanism and other features including design load combinations and allowable stress are included in the YEC-Phase II Final Report, Part III, Section 1, Chapter 5.

A reversed radial gate is recommended for culvert gates, and a drop type rolling gate is recommended for an emergency gate. Filling time is an important consideration in culvert gates and automatic closure of the channel during an emergency to hold lake lockage water from escaping is an important feature in an emergency gate.

At each lock, recessed seats and stepped bottom sills are articulated to allow for the installation of maintenance gate at the lower operating gate in the lower chamber and at the upstream side of the emergency gate lakeside. One floating maintenance gate is provided at both the Atlantic and Pacific sides and is used to dewater lock chambers during maintenance. The maintenance gate type recommended is a floating type caisson gate. Culvert maintenance gates are the culvert bulkhead type consisting of steel logs.

Other structural and mechanical details including allowable stresses, pressure distribution, installation and removal, lock dimension, source of operating power, and chamber details are discussed in the YEC-Phase II Final Report. Locomotives are recommended to provide secondary power for navigation through the locks, while the ship engine is the primary power source.

Dams

Large volume of lockage water will be required to operate the existing Panama Canal and new HRLC. New dams to regulate run-off in the Gatun watershed are planned. A new dam outside Gatun watershed is planned on Rio Indio. Figure 6.3.5-5 shows location of potential dam sites and the estimated catchment area for each.

Topographical, geological, and hydrological conditions of a given site are important in selection of dam sites. Sometimes availability of construction material tips the economic balance of a dam site. The selection of any of the potential dam sites is to be optimized based on foundation consideration, thickness of river deposit, permeability of founding level and availability of construction materials. For the HRLC 150 thousands dwt option, Ciri is selected as regulating dam, and Indio-L as the new water supply dam; whereas, for the 200 thousands dwt-HRLC option, Trinidad is selected as the regulating dam, and Indio (591 million m^3) is selected as the water supply dam.

Dams are designed to withstand earthquakes, appropriate considerations of pore pressures and seepage, and loading combinations; during construction, operation, and rapid draw down. Dams are to be constructed of material that is not susceptible to liquefaction induced by earthquake loadings. Seismic load combinations considered are presented in Table 6.3.5-10 and features of dams and reservoirs are presented in Table 6.3.5-11.

Figure 6.3.5-5

Existing and Proposed Dams

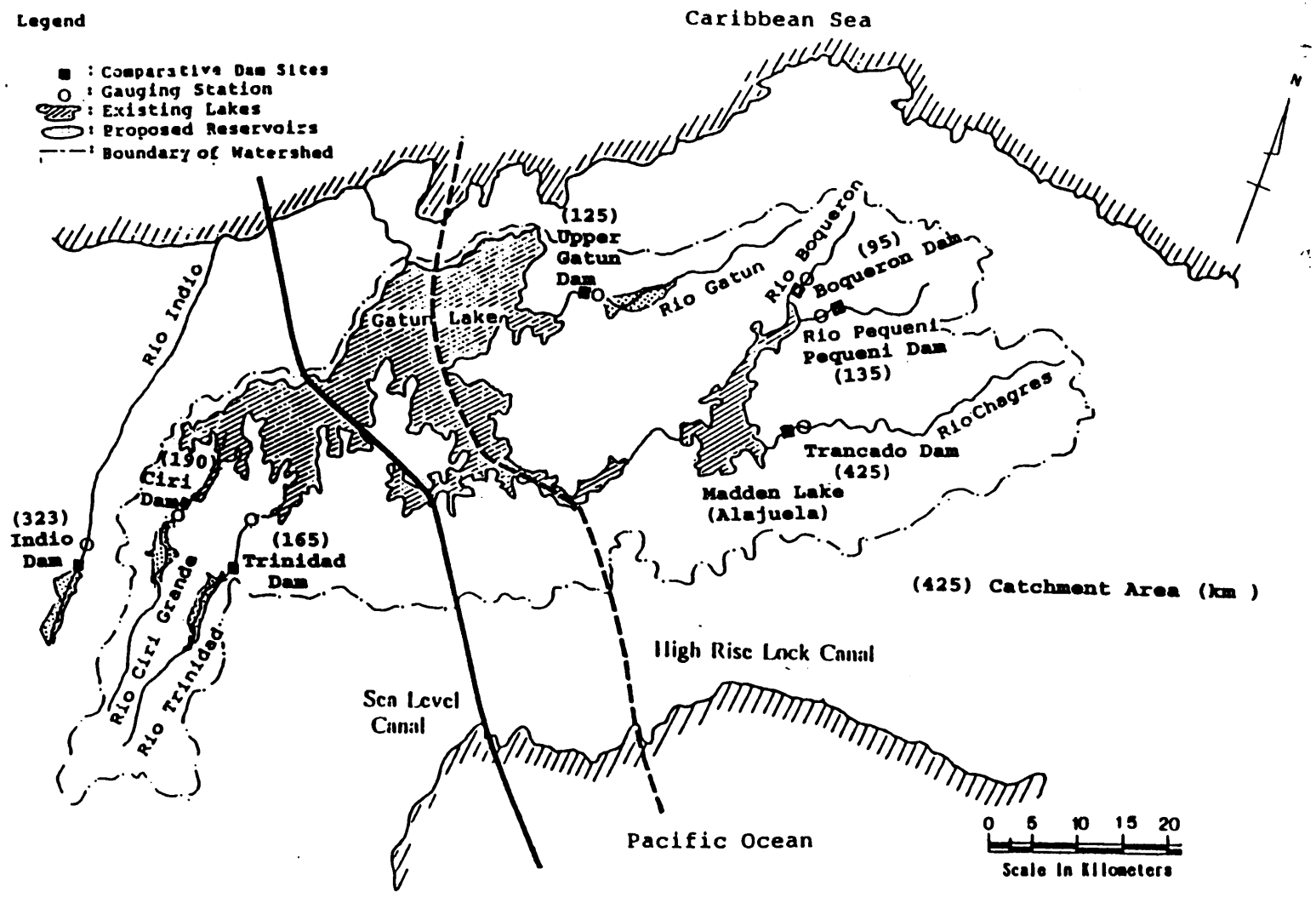


Table 6.3.5-10
Seismic Load Combination for Dams

Reservoir Water Level	Seepage and Pore Pressure	Seismic Coefficient
Normal Water Level	Steady Seepage	0.10
High Water Level	Steady Seepage	0.05
Rapid Drawdown	Pressure in core at normal water level	0.05
End of Construction	No seepage load or rising water level (Hypothetical)	0.10

Table 6.3.5-11
Main Features of Dams and Reservoirs

Canal Type		(200,000 dwt)		(150,000 dwt)		SLC 10
Dam Site Location		Trinidad	Indio (H)	Ciri	Indio (L)	Upper Gatun
Type: Earth and rockfill						
Crest EL	(m)	145	95	125	85	120
Foundation EL	(m)	65	5	65	5	25
Height	(m)	80	90	60	80	95
Crest length	(m)	800	1,630	190	1,560	830
Crest width	(m)	15	15	15	15	15
Core volume	(mill m^3)	0.9	2.0	0.23	1.5	0.9
Filter volume	(mill m^3)	0.8	1.7	0.21	1.3	0.8
Rockfill volume	(mill m^3)	4.4	10.0	0.96	7.0	4.5
Total(Reservoir)		6.1	13.7	1.40	9.8	6.2
Catchment area	(km)	165	323	190	323	125
Capacity total	(mill m^3)	485	730	130	770	350
Effective vol.	(mill m^3)	475	710	120	550	340
Sediment vol.	(mill m^3)	10	20	10	20	10
Reservoir surface	(km2)	17	22	13	19	11
Low water level (m)	(LWL)	90	40	100	40	50
Norm.water level (m)	(NWL)	140	90	120	80	115
High water level (m)	(HWL)	142.5	92.5	122.5	82.5	117.5

Notes: H = High Dam and Water Level and L = Low dam and Water level

Dams are proposed to be designed and constructed as earth and rockfill dams consisting of impervious core and rockfill shell including a foundation drainage gallery and grout holes, if necessary.

Ungated spillway structures and outlet structures (shafts, submerged intake and valve) will be provided for flood control and flood stage discharges. Preliminary design discharges are indicated in Table 6.3.5-12.

Table 6.3.5-12
Main Features of Spillway and Outlet
(Ungated Spillway)

Item		Trinidad	Indio (H)	Ciri	Indio (L)	Upper Gatun
Design discharge	(m^3/s)	470	920	540	920	360
Crest EL	(m)	140	90	120	80	115
Crest length	(m)	60	120	70	120	50
(Spillway)						
Type		Intake: shaft and submerged upstream intake				
		Valved discharge control				
Design discharge	(m^3/s)	7	20	11	20	7
valve ⊘	(m)	0.70	1.30	0.90	1.30	0.80

Notes: m^3/s = cubic meter per second
⊘ = Diameter

Incidental Structures

Vessels seeking transit through the Canal may have to temporarily anchor offshore to obtain permission for transit. Areas to be provided for anchorage are at both ocean ends of the approach channels. No dredging is required because of sufficient water depth. Mooring facilities are not necessary because vessels are equipped with their own anchors. In addition to anchoring near the end of approach channels, anchorage is also possible in Gatun Lake or emergency tie-up stations or near the locks. Other possibilities for anchorage depending on fleet grouping and designated available areas are discussed in the YEC-Phase II Final Report, Part III, Section 1, Chapter 8.

Tie-up stations will be located in Gatun Lake and near Miraflores locks to accommodate disabled ships. Moorings facilities adjacent to the locks could be used as emergency tie-up stations.

The existing breakwater on the Atlantic Side will serve the HRLC without modifications and there is no need for a breakwater on the Pacific Side.

There will be several small berthing facilities for boats, launches, and barges which are used in assisting the navigation of ships through the locks including requirements of Canal Pilots and Line Handlers. These facilities will be scattered throughout the Canal to provide for efficient operation and quick response to specific needs. Details as to number of tug boats, launches, barges, and jetties, including locations are provided in the YEC-Phase II Final Report, Part III, Section I, Chapter 8.

Gatun Lake at El 90 feet

Although raising Gatun Lake level to El. 27.9 m (90 feet) may be economically beneficial because it will require less canal excavation; it may present other problems. These may outweigh the economic benefits outlined below which were superficially examined and discussed by YEC.

Detailed discussion of specific impacts are not possible at this time due to a lack of data and information needed to support such discussion. Comparison of Gatun at El 26 m with El 27.5 m should not be attempted because the level of data and information available for Gatun at El 27.5 is not adequate. Potential areas of concern are:

1) Adverse environmental impact and disturbance of an otherwise existing stable ecosystem,

2) Encroachment on dry land by flooding area around the lake which are presently below El 27.5 m,

3) Disturbing the existing stable lake bank which may cause failure and/or erosion,

4) Gatun Lake at El 27.5 m will have adverse impact on existing railway, and

5) It will be necessary to raise and modify Gatun dam including gates.

It is estimated that excavation volume will be reduced by approximately 25 million cubic meters for the 200 thousand dwt case and is about equally divided between dry and wet excavation. It should be noted that this volume is less than 5% of the total excavation for this case.

It is estimated that to mitigate some of the above mentioned problems, it will cost approximately 474 million dollars. This estimate does not include mitigating environmental impacts, potential landslides and erosion.

HRLC Project Impacts

Evaluation of project construction and operational impacts are presented in Sections 1, 7, 8, and 9 of this report.

Potential For Future Expansion

The High Rise Lock Canal alternative provides potential of future expansion by construction of a fourth set of locks at both the Miraflores and Gatun Lake bypass channels. The preliminary design incorporates provision for construction of a fourth set of locks including the requirements for lockage water supply and other operational and navigational support requirements.

Subsequent to the Phase II Final Report, ECE conducted study and cost estimates for Single Lane Culebra Cut area which included elimination of two lane excavation for a potential future fourth lane of lock construction. Therefore if this option is selected, the potential for future expansion by construction of fourth set of locks will become much difficult and costly.

6.3.6 Project Description, Sea Level Canal-Route 10 (SLC-10)

Introduction

Phase I Study results indicated that a SLC may be constructed along Route-10 with a design ship of 250 thousand dwt, and some type of tidal controls.

The Phase II Engineering and Cost Study considered this alternative and tidal control provided by either tidal gate on the Atlantic Side, tidal lock on the Pacific Side, or a combination of both as presented earlier in Figure 6.3.1-3.

Construction of any sea level canal may potentially have major environmental impacts by allowing movement of sea water between the Pacific and Atlantic Oceans. Potential environmental mitigations were identified but not studied in detail to assess their viability.

Other environmental impacts and potential mitigations are presented in Section 7 and 8 of this report. The Route that SLC-10 takes is parallel to and about 16 kilometer west of the existing Panama Canal as presented earlier in Figure 6.3.1-2.

SLC-10, Design Features

- Basic Engineering Data

Basic engineering data and assumptions made and used by the ECE Component Contractor (YEC) are summarized in Table 6.3.6-1.

Table 6.3.6-1
Basic Engineering Criteria
(Sea Level Canal Route 10)

Item		Description
1	Route	Ref. Sea Level Canal Layout Fig. 6.3.1-2
2	Ship Size	250,000 dwt
3	Lane No. (1)	Approach Channel 2-lanes, Canal 1-lane
4	Canal Width and Depth (1)	3.5 * B = 190 m Canal depth = 24.0 m 7.0 * B = 380 m (Approach Channel)
5	Lock Chamber Dimensions & No. of Lane (1)	250,000 dwt, 420 m * 60 m * 23.0 m 3-lanes. Plus additional one lane [Case (a)]
6	Tidal Gate Dimension & No. of Lane (1)	Gate width = 190 m Draft = 23 m Tidal Gates at both Ocean sides [Case (b), (c)] One lane
7	No. of Transits (2)	Existing Locks = 10,866 (2020) 12,078 (2060) Sea Level = 2,100 (2020) 5,100 (2060)
8	Tidal Levels	High Water Level = +3.6 m (Pacific) Lowest Water Level = -3.4 m (Pacific) High Water Level = +0.5 m (Atlantic) Lowest Water Level = -0.3 m (Atlantic)
9	Earthquake (3)	Kh = 0.1, Kv = Kh * 2/3

Notes: (1) See Section 6.4 for changes
(2) Based on TAMS, Phase I Report
(3) Kh = horizontal acceleration coefficient
Kv = vertical acceleration coefficient

- Water Management

Water Management concerns for SLC-10 alternative includes investigation of available lockage water for the existing Panama Canal while SLC-10 is under construction. This is because of separation of Gatun Lake by barrier dams. The result of a water balance analysis indicated that sufficient lockage water is available even in the worst case (dry years). However, a regulating dam on upper Gatun River may be required for the year 2060.

A freshwater barrier system somewhere in the sea level canal was proposed for study. The purpose of this system is to introduce freshwater separation somewhere in the canal to prevent or minimize mixing the Pacific and Atlantic waters. Only the technical feasibility of providing sufficient quantity of freshwater to form a barrier was studied and no analysis and conclusions as to its environmental viability and effectiveness was made. Sections 7 and 8 report on environmental impact analysis and evaluation, includes a brief discussion of a freshwater barrier.

- Water Balance for Existing Panama Canal

By construction of barrier dams "E" as shown earlier in Figure 6.3.1-2, the storage capacity and catchment basin for Gatun Lake may be reduced by 20 to 30 percent. Water balance simulation shown in Table 6.3.6-2 was performed for years 2020 and 2060. The results presented in this table indicate that shortages will occur in dry years (worst case) for canal capacity projection year 2060. All other cases indicate no water shortages. To mitigate the water shortage in a dry year for canal traffic of year 2060, a regulating dam (upper Gatun River) within the Gatun watershed area will assure the availability of required water.

- Freshwater Barrier

Reservoir (E) will be used as one source of freshwater for the barrier system. Water from Rio Ciri and Rio Trinidad flows into reservoir (E) directly, and water from Rio Los Hules, Rio Chica and Rio Cano also will flow into reservoir (E) via proposed diversion channels. The total catchment area formed is approximately 850 sq. km. and the available water quantity range between 720 and 1909 million m^3 (dry and wet year).

Freshwater from Rio Lagarto (Atlantic Side), Rio Caimito and Rio Sanchez (Pacific Side) can be discharged into the canal directly and can contribute to the freshwater barrier. Of these rivers, only Rio Caimito can be discharged in the central portion of the canal between the tidal lock/gate structures. The discharge of these three rivers range between 482 and 1,174 million m^3 (dry and wet year). Therefore, total available quantity of freshwater from reservoir E and other rivers range between 1,202 and 3,083 million m^3 (dry and wet years).

Various options of utilizing a freshwater barrier were considered and briefly discussed in the YEC-Phase II Final Report, Part IV, Section 1, Chapter 2. It can be concluded that if it is theoretically required to sustain a ratio of 10 freshwater to one seawater in order to create a freshwater barrier (according to Dr. Tamai, Density Flow Hydraulic, Civil Engineering Society of Japan, 1980), a shortage of water will occur in dry design years but sufficient water exist in average and wet years. It should be noted that the ratio (10:1) is calculated by dividing the annual freshwater available by the volume of water required to fill the channel between the tidal lock and tidal gate. As of this writing, it is not possible to conclude that a freshwater barrier system is viable and can be proven to be effective in mitigating major environmental impacts created by mixing the two ocean waters.

Table 6.3.6-2

Water Balance (Sea Level Canal)

(1)2020 Year Case

Water Resource Catchment area(sq.km)	Revised Gatun Lake 2365.0		
Design Ship		65000	
Transits through existing lock		16200	
Transits through sea level canal		—	
CASE NO.(Average, Dry and Wet Years)	1(Ave)	2(Dry)	3(Wet)
①Total runoff(MCM)	5117	3931	7629
②Municipal water(MCM)	274	274	274
③Evaporation(MCM)	512	509	520
④Available water for lockage(①-②-③)(MCM)	4331	3148	6835
⑤Existing Lock(MCM)	2867	2867	2867
⑥Water Balance(④-⑤)(MCM)	1464	281	3968

(2)2060 Year Case

Water Resource Catchment area(sq.km)	Revised Gatun Lake 2365.0		
Desin Ship		65000	
Transits through existing lock		19400	
Transits through sea level canal		—	
CASE NO.(Average, Dry and Wet Years)	1(Ave)	2(Dry)	3(Wet)
①Total runoff(MCM)	5117	3931	7629
②Municipal water(MCM)	274	274	274
③Evaporation(MCM)	510	508	518
④Available water for lockage(①-②-③)(MCM)	4333	3149	6837
⑤Existing Lock(MCM)	3434	3434	3434
⑥Water Balance(④-⑤)(MCM)	899	-285	3403

(3)Available Water for Freshwater barrier

Water Resource Catchment area(sq.km)	Reservoir 'E' 846.5		
Design Ship		250000	
Transits through existing lock		—	
Transits through sea level canal		5100	
CASE NO.(Average, Dry and Wet Years)	1(Ave)	2(Dry)	3(Wet)
①Total runoff(MCM)	1268	829	2018
②Municipal water(MCM)	0	0	0
③Evaporation(MCM)	109	109	109
④Available water for freshwater (①-②-③)(MCM)	1159	720	1909

Note:(1)Average year is the average for 51 years(1933～1983)
(2)Wet year is 1981
(3)Dry year is 1982
(4)By constructing diversion channel, the catchment area of Reservoir 'E' will have an additional catchment area of 161.5 sq.km (685+161.5=846.5) (See Chapter 7.5)

Substantial studies in the field and laboratory including modelling may be required to support this scheme. Such an undertaking is commensurate with the risk associated with spending over $10 billion required for construction of a sea level canal. Other methods may be available and a feasibility study to determine the viability of a freshwater barrier should be conducted prior to undertaking the design and construction of a sea level canal.

SLC-10, Excavation

Although some geological, hydrological, seismological and geotechnical site investigation including laboratory testing was performed for IOCS (1970) Study, it was not nearly sufficient to make specific recommendations for excavation and stable slopes. The IOCS (1970) Report provided a recommendation for additional investigation along Route 10 alignment and specifically in the Continental Divide area where The IOCS Report discussed potential shift in the alignment to a more geologically favorable alignment. The geology of this alignment is assumed to be similar to the description provided in Section 6.3.5 for the HRLC. Geologic description and characterization including classification into excavation zones is presented in the YEC-Phase II Final Report, Part IV, Section I, Chapter 3.

Discussions of design criteria for excavation slopes are presented in Section 6.3.5. Excavation volumes were estimated by dividing the SLC-10 route into five zones namely; Atlantic Approach, Quebrado, Gatun Lake, Continental Divide, and Pacific Approach. Volumes were estimated based on methodology presented in Section 6.3.5 for the HRLC. Excavation volume were generated using the cases (a), (b), and (c) depending on the type of tidal control used as shown in Figure 6.3.1-3. Excavation volumes by zones and dry or wet type are presented in Figure 6.3.6-1.

Hydraulic Structures

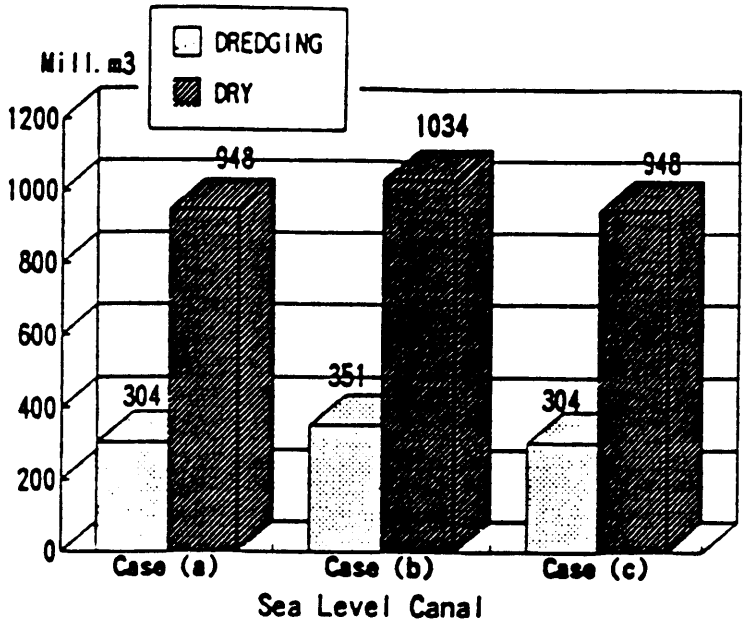
- Basic Data and Design Criteria

The Sea Level Canal is designed to accommodate 250,000 dwt class vessels. The case variations include tidal locks on the Pacific side (a), a tidal gate on the Atlantic side (b) and a combination of both (c). The configurations of these different cases are shown in Fig. 6.3.1-3. Design data and criteria used for the Sea Level Canal are summarized in Table 6.3.6-1.

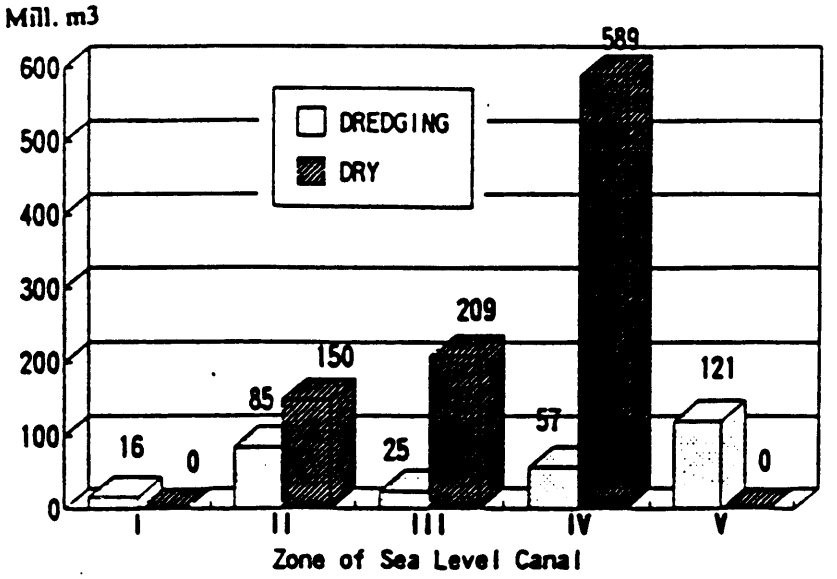
- Tidal Lock and Tidal Gate

The canal will have two lane approaches from both the Pacific and Atlantic Sides and a single lane interior canal. Details on locations, dimensions, facilities layout, and description of structures type for both tidal lock and tidal gate, design water levels, freeboard, material selection, allowable stresses, seismic design basis, and corrosion protection are presented in the YEC - Phase II Final Report, Part IV, Section 1, Chapters 4 and 5. The approaches and Pacific Locks were modified in Phase II, Additional Work, and are discussed in Section 6.4.

Figure 6.3.6-1
Excavation Volume
(Sea Level Canal Route 10)



Excavation Volume for Each Case



(Case a only)

For operating, maintenance and emergency gates, a torsion type slide gate was selected. This gate moves laterally on wheels mounted on the gate leaf bottom. The leaf consist of steel box structure with its torsional rigidity providing strength to withstand hydraulic pressures on the leaf. The gate structures must provide necessary equipment to allow for periodic flushing of sediment from around the gate which may potentially impair its operation.

A optimization study also selected a reversed radial gate as a culvert gate (similar to the HRLC). Power supply, lock controls, shops, service building, pumps, compressed air and other required support for the locks are provided nearby or adjacent to the lock structure.

A tidal gate optimization study selected a triangular leaf rolling gate. Tidal gates consist of one operating gate and one emergency gate, both identical and are installed in parallel. Structural and mechanical details including corrosion protection and maintenance are presented in the YEC-Phase II Final Report, Part IV, Section I, Chapter 5.

- Dams and Reservoirs

Barrier dams are necessary to allow canal excavation of the SLC-10 to the required design grades in the Gatun Lake zone during construction and will be needed to permanently impound Gatun Lake water and keep it at its present elevation of 26 m. Therefore, barrier dams in this case are two near parallel dams impounding water on both the east and west side of a divided Gatun Lake. As shown in Figure 6.3.1-2, barrier dams E through G will be constructed as a permanent dam. The western portion of Gatun Lake cut-off from the main Gatun Lake called reservoir E will have a spillway constructed at its western most location to be used in an emergency to spill into Rio Lagarto and eventually the Caribbean Sea. Also a diversion channel and discharge structure, as required, will be constructed should the freshwater barrier system be proven viable. As shown on Table 6.3.6-2, a water shortage for forecast year 2060 will occur during dry years. This shortage may be eliminated by construction of the proposed upper Gatun dam on Rio Gatun. Design features for this regulating dam and reservoir are presented in Tables 6.3.5-11 and 6.3.5-12.

Dams are designed for earthquakes in combination with various loading conditions including; during construction, slow reservoir drawdown, rapid reservoir drawdown, and reservoir at normal and high water levels. Seismic load combination are presented in Table 6.3.5-10.

Other dam design consideration are; selection of construction materials (such as impermeable core, sand drains) cofferdam to support the core, effective foundation blanket to minimize seepage, spillways, and foundation preparation. Construction of barrier dams underwater will require exceptional design details, tight specifications, and good procedures for construction, inspection and controls. For discussion of dam design features, i.e. (typical design cross section, spillway, diversion schemes, freshwater discharge structures, culverts, and inlet structure), see the YEC-Phase II Final Report, Part IV, Section I, Chapter 7.

- Freshwater Barrier and Diversion Schemes

As discussed in previous section, consideration is given in this study to a freshwater barrier scheme to separate the two ocean waters. An elaborate system for capturing freshwater from Gatun and other watersheds are outlined.

Details of the rivers flowing into the proposed sea level canal, the catchment areas of these rivers, list of reservoirs formed, series of dikes, diversion channels, and diversion dams are presented in the YEC-Phase II Final Report, Part IV, Section I, Chapter 8.

- Incidental Structures

These structures consist of anchorage facilities, tie-up stations, breakwaters, and berthing facilities for small boats. Results of the OCCE Phase I Study of queue length and average waiting times was used for anchorage analysis. The study indicated demand at both the Atlantic and Pacific entrances for the sea level canal over and above that presently existing for the Status Quo (SQ). Tie-up stations to be used in emergency are proposed near barrier dams (E) and (G) and near the Pacific lock or gate.

Breakwaters will be required on both the Atlantic and Pacific entrance to the sea level canal. Armor stones for construction of the breakwaters will be quarried from canal excavation and will be designed using U.S. Corps of Engineers standards or equal.

The alignments, typical cross section, estimated quantities, and design criteria for both the Atlantic and Pacific breakwaters are provided in the YEC-Phase II Final Report, Part IV, Section I, Chapter 9.

Berthing facilities for tugboats, launches and barges will be required at both the Atlantic and Pacific entrances, and at locations between Gatun Lake and the Pacific Side. Type and number of berthing facilities are included in the YEC Report referenced above.

SLC-10 Project Impacts

Evaluation of project construction and operation impacts are presented in Section 1, 7, 8, and 9 of this report.

Potential for Future Expansion

Future canal expansion can be accomplished by widening the Canal between the Atlantic and Pacific Coasts or by construction of an inland canal bypass section. This and construction of additional lanes of locks and/or gates can also be achieved at considerable cost.

6.3.7 Construction Plans

High Rise Lock Canal

Construction plans for clearing & grubbing, spoil disposal areas, hauling distances to disposal areas, proposed excavation methodology for each zone, proposed dewatering, dredging methodology, as well as dry and wet excavation quantities are provided in YEC-Phase II Final Report, Part III, Section 2, Chapter I.

A methodology for lock construction, concrete work, dams construction, pumping stations, highway and bridge construction, and construction of housing and labor camps including all required supporting facilities are outlined in details in the above referenced report.

Constructability of the HRLC was evaluated and found to be feasible within the present state of construction technology, equipment, and construction management know how. Potential difficulties may be encountered in excavation, underwater blasting, quarry operation, and navigation during construction, all of which may be solved by proper construction planning and employment of experienced construction management staff.

Excavation difficulties may be tied together with navigation since a well balanced construction scheme needs to be developed whereby efficiency of construction is not severely impaired by navigation demands and viceversa. Underwater blasting will require well developed construction procedures and a experienced professional work force. It is important to use proper construction equipment such as Self Elevated Platforms (SEP) where all of the construction needs for drilling and blasting are self contained in order to provide a high degree of mobility and quick response.

Managing canal construction in a way that will minimize its effect on canal navigation and ship transit may be challenging. Construction plans and cost estimates were based on the criteria that canal navigation is given priority always over construction activities.

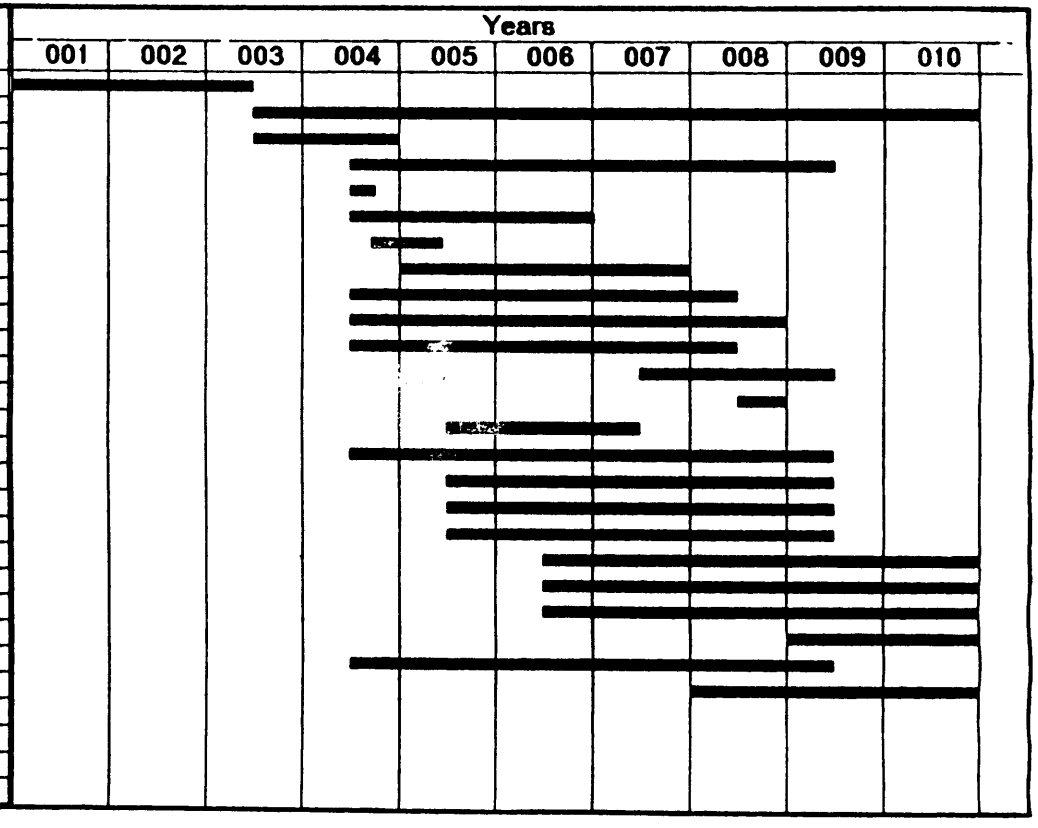
Land and underwater blasting may have the greatest impact on navigation if it is not well planned and properly scheduled and controlled. Blasting operation should be controlled to not cause damage to nearby structure, endanger existing canal slopes, affect existing communication systems, have little environmental impacts, and provide means to contain the scatter of debris beyond the safe distance used for ship passage. Obstacles resulting from this operation (if any) should be cleared immediately and prior to ship passage.

It should be noted that an experienced professional staff can design and monitor blasting operation to not interfere with navigation. Construction schedules, equipment and vessel requirements, and manpower distribution schedules are presented in Figures 6.3.7-1 to 6.3.7-4, and Tables 6.3.7-1 and 6.3.7-2, for both the 150 and 200 thousand dwt ship options of the HRLC.

Figure 6.3.7-1

Overall Work Schedule High Rise Lock Canal (150,000 dwt, 85', 2,020)

Task Name	Q'ty
Engineering.Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	322,000m3
Zone I Dredging	46,613,000m3
Zone II Dry Excavation	12,954,000m3
Zone II Dredging	121,866,000m3
Zone III Dry Excavation	69,113,000m3
Zone III Dredging	56,057,000m3
Zone IV Dry Excavation	133,529,000m3
Zone IV Dredging	4,801,000m3
Zone V Dry Excavation	777,000m3
Zone V Dredging	66,093,000m3
Placing Area	22.5 km2
Lock Structure	
Atlantic Side	3,200,000m3
Pacific Side	3,200,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	32 km
Canal Crossing(Bridges)	2 Bridges
Navigation System	1 ls



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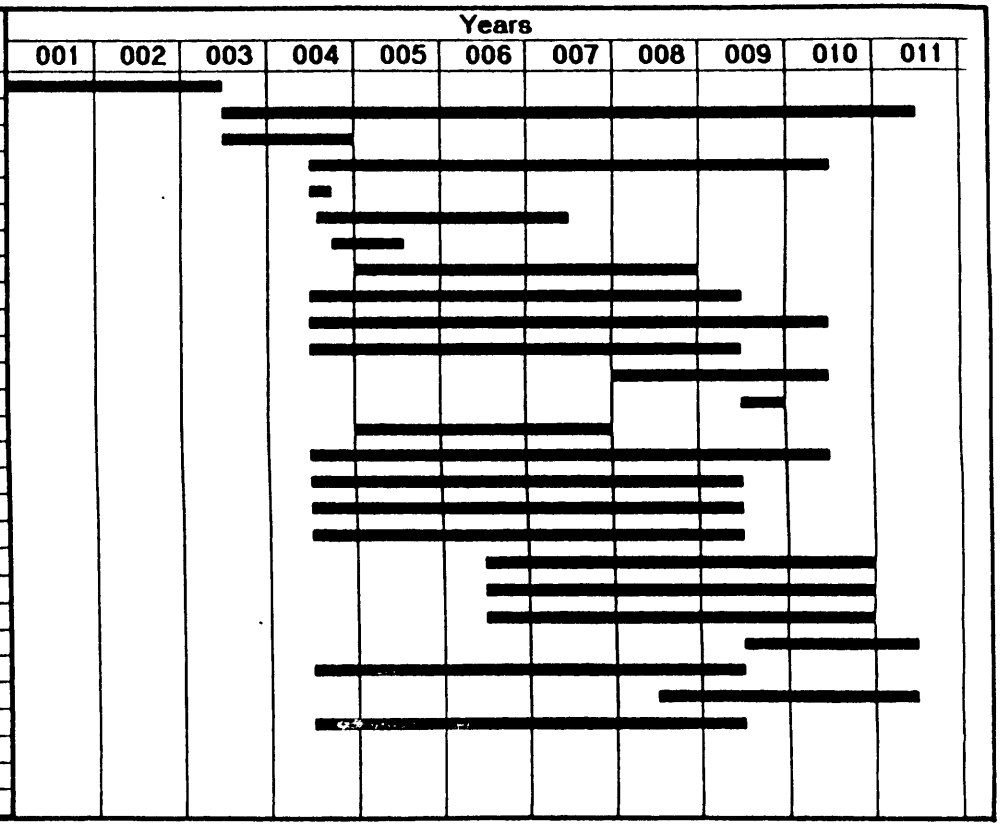
Milestone Δ Summary

Figure 6.3.7-2

Overall Work Schedule High Rise Lock Canal (200,000 dwt, 85', 2,020)

Task Name	Q'ty
Engineering,Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	358,000m3
Zone I Dredging	53,847,000m3
Zone II Dry Excavation	14,287,000m3
Zone II Dredging	145,984,000m3
Zone III Dry Excavation	78,192,000m3
Zone III Dredging	64,419,000m3
Zone IV Dry Excavation	148,024,000m3
Zone IV Dredging	5,206,000m3
Zone V Dry Excavation	929,000m3
Zone V Dredging	88,227,000m3
Placing Area	22.5 km2
Lock Structure	
Atlantic Side	3,600,000m3
Pacific Side	3,600,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	32 km
Canal Crossing(Bridges)	2 Bridges
Navigation System	1 ls
New Dam	1 ls



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Milestone Δ Summary ⊏

Figure 6.3.7-3
Manpower Schedule

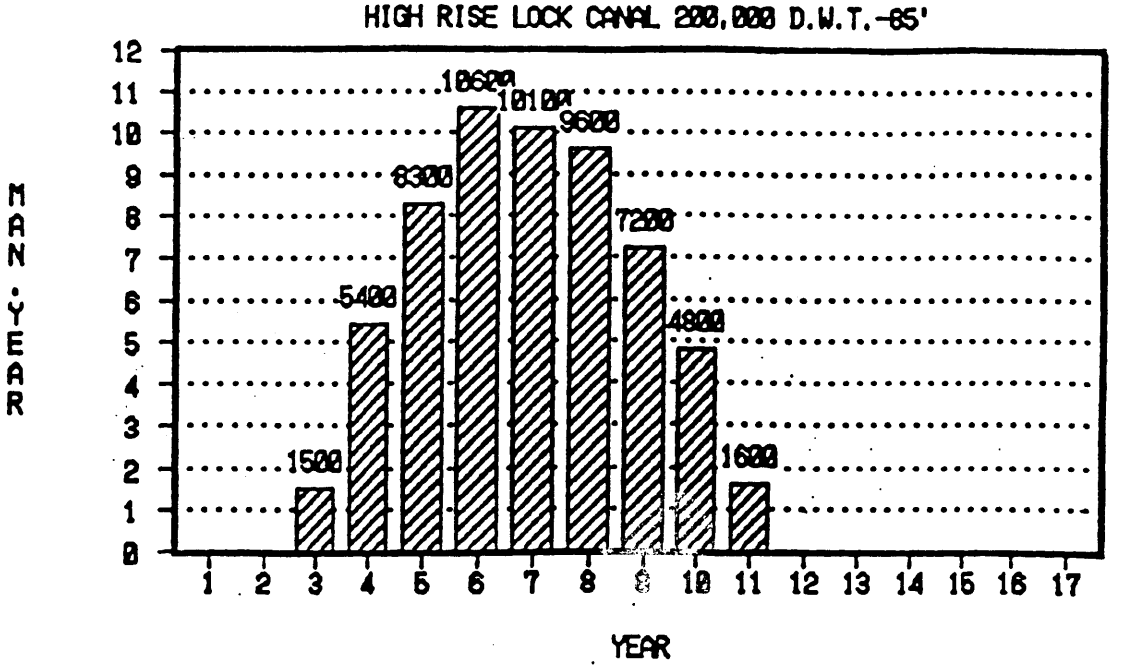

Figure 6.3.7-4
Manpower Schedule

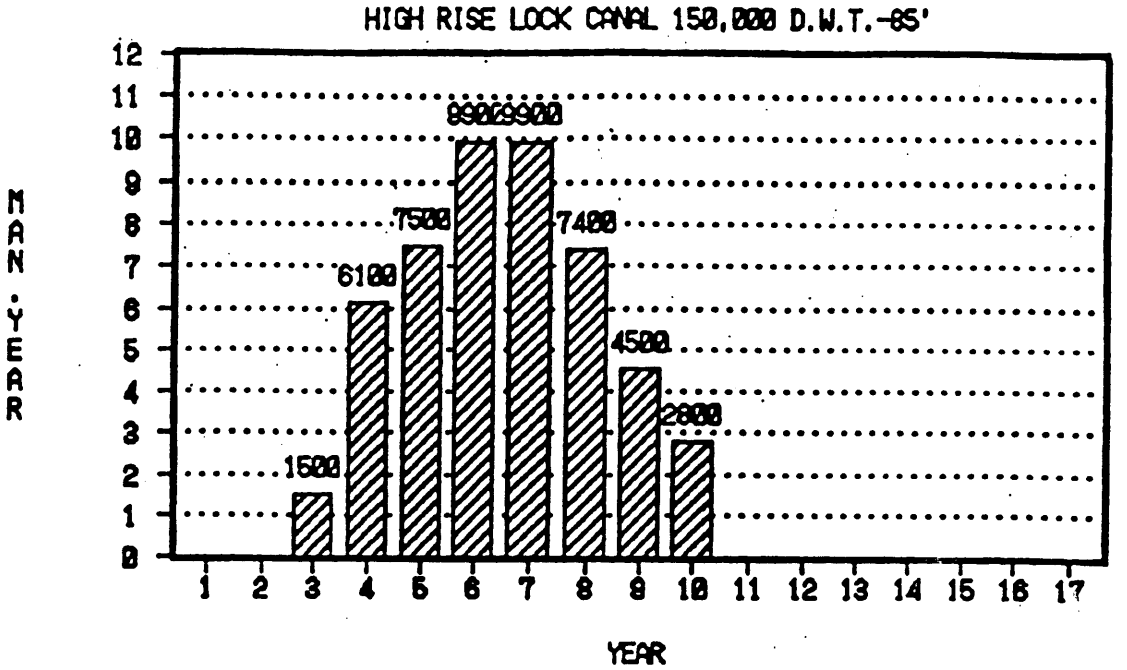

Table 6.3.7-1

Schedule for Equipment and Vessels (High Rise Lock Canal 150,000 dwt, 85')

File:EQSH1502

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Canal Excavation(Dry)																		
Crawler Drill(32ton-225mm)						3	3	3										734,760
Bulldozer(98ton)				83	83	71	71	71										1,002,430
Shovel(30m3)				7	7	6	6	6										7,521,696
Dump Truck(240ton)				80	80	72	72	72										1,621,807
Canal Excavation(Dredging)																		
Grab(50m3)				2	3	2	2	2	1									13,314,286
Split Barge(5000m3)				16	22	35	30	13										3,850,000
Split Barge(1500m3)							3	3	2									2,652,857
Pusher Tug(3200HP)				10	13	21	18	8										3,646,429
Pusher Tug(1300HP)							2	2	1									2,088,571
Trailer(10000m3)				1	2	1												82,557,143
Cutter(18000HP)				2	1	2	2	1										27,485,714
Cutter(27500HP)				2	5	10	9	4										40,771,429
Blasting Barge w/t Assisting Vessels							1	1	1									26,196,343
Lock Construction																		
Crawler Drill(32ton-225mm)																		734,760
Bulldozer(98ton)				82														1,002,340
Shovel(30m3)				7														7,521,696
Dump Truck(240ton)				77														1,621,807
Batching Plant(70m3/hr)					6	6	6	6										1,191,240
Generator(450KVA)					6	6	6	6										175,160
Jib Crane(13.5ton-75m)					8	8	8	8										5,230,000
Generator(800KVA)					4	4	4	4										270,960
Agitating Car(4.5m3)					42	42	42	42										81,400
Aggregate Production																		
Crawler Drill(32ton-225mm)					1	1	1	1										734,760
Bulldozer(98ton)					1	1	1	1										1,002,340
Shovel(3.3m3)					2	2	2	2										946,194
Dump Truck(32ton)					5	5	5	5										430,505
Crushing Plant(500ton/hr)					2	2	2	2										14,909,332
Generator(800KVA)					8	8	8	8										270,960
Shovel(3.3m3)					2	2	2	2										946,194
Dump Truck(32ton)					34	34	34	34										430,505

Table 6.3.7-2

Schedule for Equipment and Vessels (High Rise Lock Canal 200,000 dwt, 85')

File:EQSH2002

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Canal Excavation(Dry)																		
Crawler Drill(32ton-225mm)						3	3	3	3									734,760
Bulldozer(98ton)				83	83	71	71	71	71									1,002,340
Shovel(30m3)				7	7	6	6	6	6									7,521,696
Dump Truck(240ton)				80	80	72	72	72	72									1,621,807
Canal Excavation(Dredging)																		
Grab(50m3)				2	3	3	2	2	1	2								13,314,286
Split Barge(5000m3)				13	25	39	35	21	10	9								3,850,000
Split Barge(1500m3)								3	3	5								2,652,857
Pusher Tug(3200HP)				8	15	23	21	13	6	5								3,646,429
Pusher Tug(1300HP)								2	2	3								2,088,571
Trailer(10000m3)				1	2	1												82,557,143
Cutter(18000HP)				2	3	3	2	2										27,485,714
Cutter(27500HP)				1	4	10	10	6	4	4								40,771,429
Blasting Barge w/t Assisting Vessels								1	1	2								26,196,343
Lock Construction																		
Crawler Drill(32ton-225mm)				8														734,760
Bulldozer(98ton)				82														1,002,340
Shovel(30m3)				7														7,521,696
Dump Truck(240ton)				77														1,621,807
Batching Plant(70m3/hr)					6	6	6	6										1,191,240
Genarator(450KVA)					6	6	6	6										175,160
Jib Crane(13.5ton-75m)					8	8	8	8										6,230,000
Genarator(800KVA)					4	4	4	4										270,960
Agitating Car(4.5m3)					42	42	42	42										81,440
Aggregate Production																		
Crawler Drill(32ton-225mm)					1	1	1	1										734,760
Bulldozer(98ton)					1	1	1	1										1,002,340
Shovel(3.3m3)					2	2	2	2										946,194
Dump Truck(32ton)					6	6	6	6										430,605
Crushing Plant(500ton/hr)					2	2	2	2										14,909,332
Genarator(800KVA)					8	8	8	8										270,960
Shovel(3.3m3)					2	2	2	2										946,194
Dump Truck(32ton)					34	34	34	34										430,605

Sea Level Canal, Route 10

Similar discussion and level of technical details including construction methodology are presented for the SLC-10 alternative in the YEC - Phase II Final Report, Part IV, Section 2, Chapter 1. However, the level of technical knowledge about the route, topography, geology, hydrology, and geotechnical engineering is considerably less than that presently known about the HRLC.

Constructability of a SLC-10 was evaluated and found to be feasible from an engineering standpoint within the present state-of-the-art of construction equipment, technology, and management capabilities, pending resolution of environmental concerns.

Strict controls on land and underwater blasting would require safety control procedures to eliminate effects on; existing dams and hydraulic structures, operating communication networks, and the environment.

Construction of barrier dams may be difficult and challenging because it will have to be substantially performed underwater. Preparation of dam foundations may be particularly difficult especially preparation of founding elevation. Placement and compaction of embankment material including core sections, filter materials and cofferdams will require detailed construction drawings and specification and tight supervision and controls.

Presently proposed design of dam slopes may not be feasible and stable while constructing underwater. Adjustment in the design may be required prior and during construction. Failure of these dams, although unlikely, may be disastrous. Mitigation of environmental impacts may be difficult and provide interesting and challenging engineering opportunities.

Construction schedules, equipment and vessel requirements, and manpower distribution schedules are presented in Figures 6.3.7-5 to 6.3.7-10 and Tables 6.3.7-3 to 6.3.7-8.

Figure 6.3.7-5

Overall Work Schedule (Sea Level Canal, Case A - 250,000 dwt, 2020)

Task Name	Q'ty
Engineering,Design&Tender	1 ls
Construction	
Supporting construction	1 ls
Canal Excavation	
Zone I Dry Excavation	0m3
Zone I Dredging	16,262,000m3
Zone II Dry Excavation	149,516,000m3
Zone II Dredging	84,939,000m3
Zone III Dry Excavation	209,417,000m3
Zone III Dredging	24,753,000m3
Zone IV Dry Excavation	589,204,000m3
Zone IV Dredging	57,369,000m3
Zone V Dry Excavation	0m3
Zone V Dredging	21,020,000m3
Placing Area	51.0 km2
Lock Structure	
Atlantic Side	0m3
Pacific Side	6,000,000m3
Gate Leaves, etc.	
Atlantic Side	-
Pacific Side	1 ls
New Permanent Road	71 km
Canal Crossing(Bridges)	3 Bridges
Navigation System	1 ls
Barrier Dams E.F.G Dams	3 Dams
Breakwater	
Atlantic Side	1 ls
Pacific Side	1 ls
Diversion Scheme	1 ls

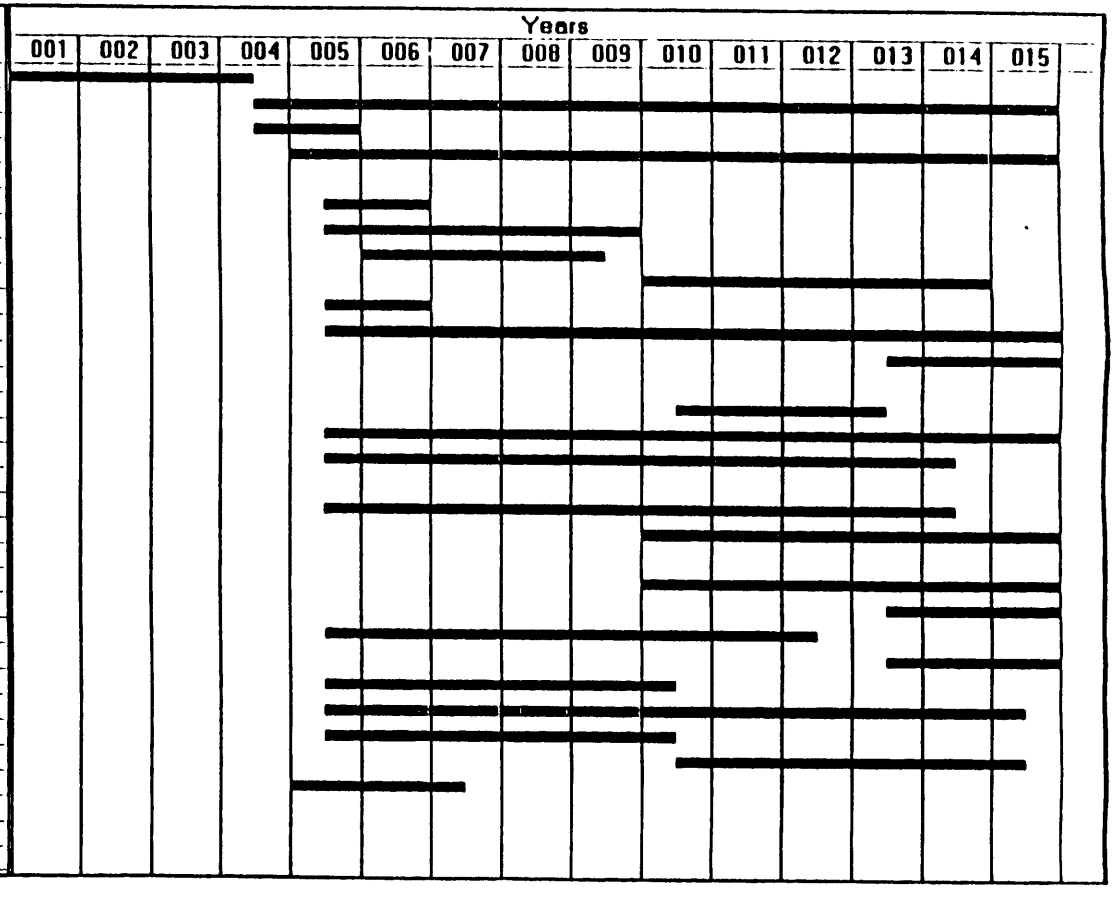

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Figure 6.3.7-6

Overall Work Schedule (Sea Level Canal, Case B - 250,000 dwt, 2020)

Task Name	Q'ty
Engineering,Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	0m3
Zone I Dredging	17,495,000m3
Zone II Dry Excavation	239,581,000m3
Zone II Dredging	158,772,000m3
Zone III Dry Excavation	209,417,000m3
Zone III Dredging	24,753,000m3
Zone IV Dry Excavation	684,574,000m3
Zone IV Dredging	52,582,000m3
Zone V Dry Excavation	0m3
Zone V Dredging	97,776,000m3
Placing Area	51.0 km2
Lock Structure	
Atlantic Side	980,000m3
Pacific Side	980,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	71 km
Canal Crossing(Bridges)	3 Bridges
Navigation System	1 ls
Barrier Dams E.F.G Dams	3 Dams
Breakwater	
Atlantic Side	1 ls
Pacific Side	1 ls
Diversion Scheme	1 ls

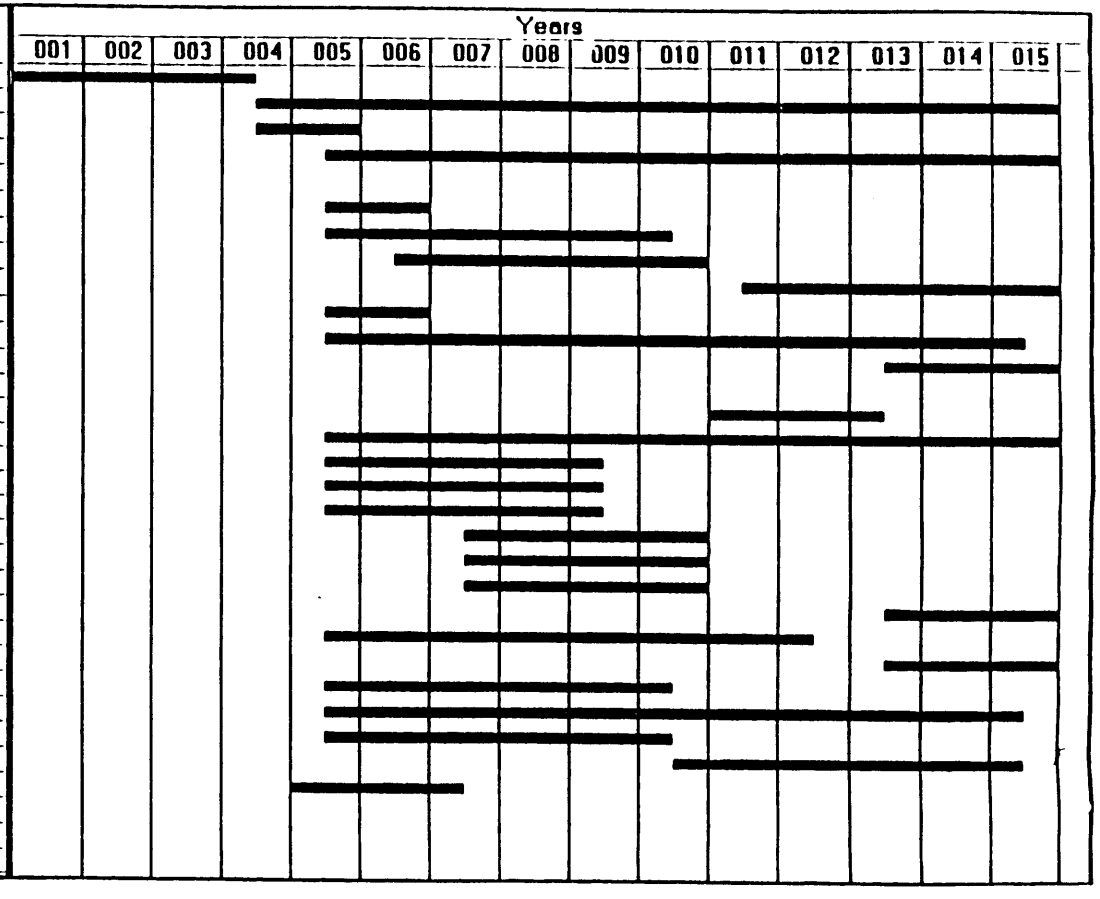

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Figure 6.3.7-7

Overall Work Schedule (Sea Level Canal, Case C - 250,000 dwt, 2020)

Task Name	Q'ty
Engineering,Design&Tender	1 ls
Construction	
Supporting construction	1 ls
Canal Excavation	
Zone I Dry Excavation	0m3
Zone I Dredging	16,282,000m3
Zone II Dry Excavation	149,516,000m3
Zone II Dredging	84,839,000m3
Zone III Dry Excavation	208,417,000m3
Zone III Dredging	24,753,000m3
Zone IV Dry Excavation	589,204,000m3
Zone V Dry Excavation	0m3
Zone V Dredging	121,020,000m3
Zone IV Dredging	57,369,000m3
Placing Area	51.0 km2
Lock Structure	
Atlantic Side	980,000m3
Pacific Side	8,000,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	71 km
Canal Crossing(Bridges)	3 Bridges
Navigation System	1 ls
Barrier Dams E.F.G Dams	3 Dams
Breakwater	
Atlantic Side	1 ls
Pacific Side	1 ls
Diversion Scheme	1 ls

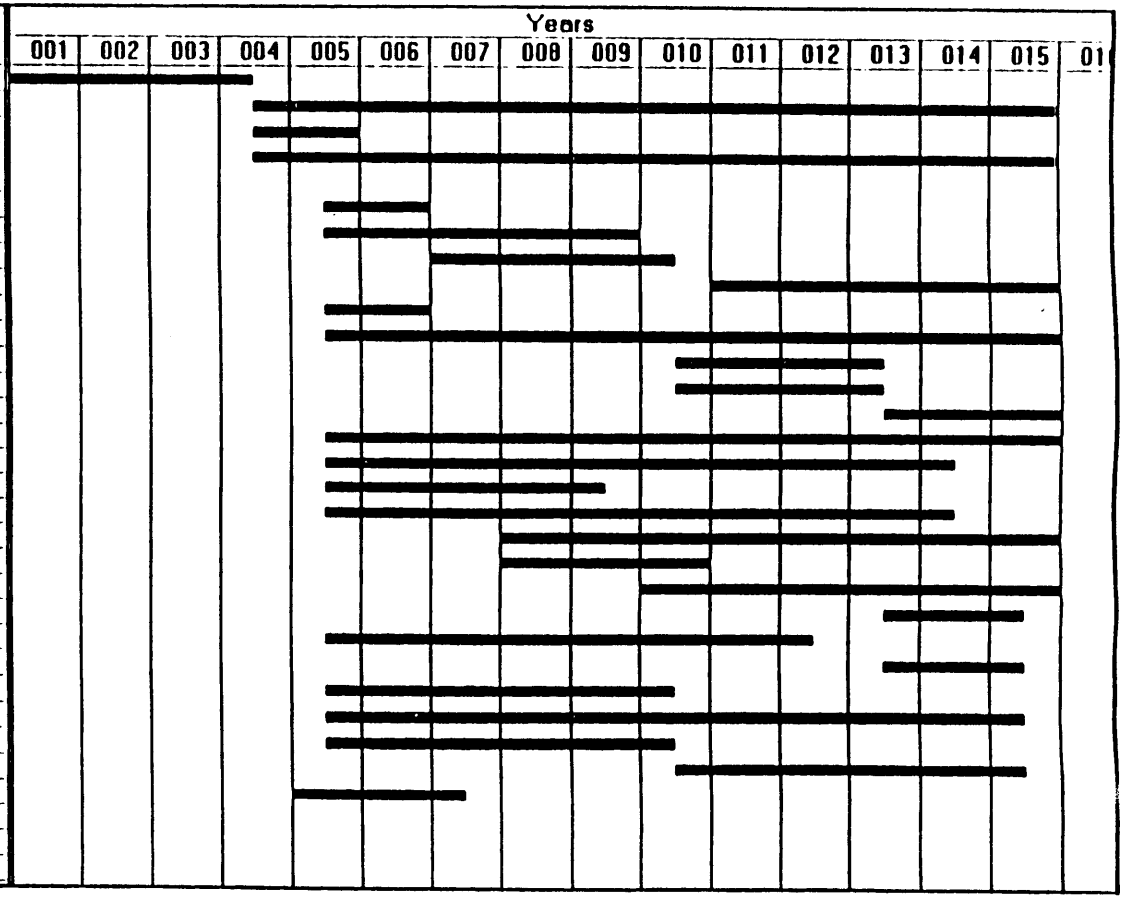

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Figure 6.3.7-8
Manpower Schedule

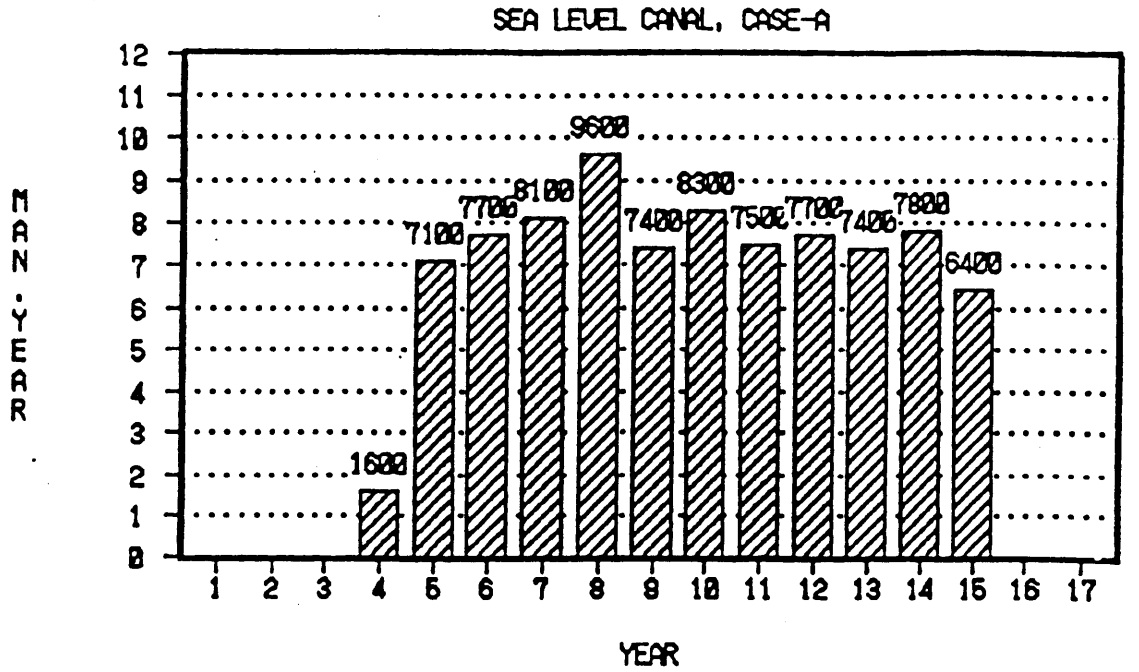

Figure 6.3.7-9
Manpower Schedule

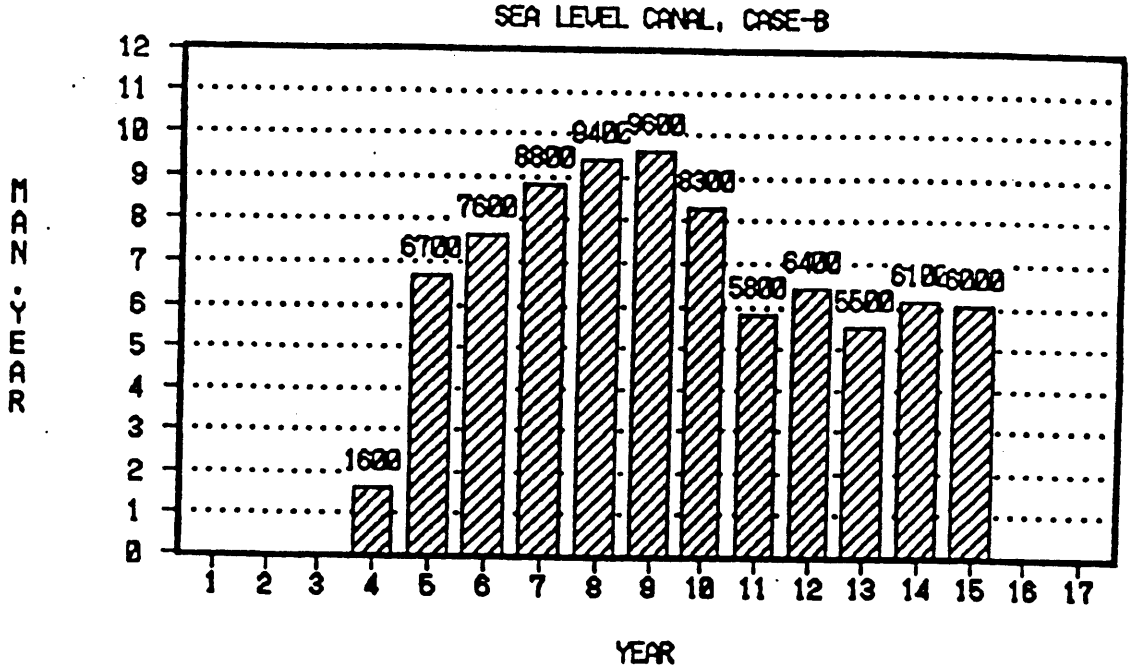

Figure 6.3.7-10
Manpower Schedule

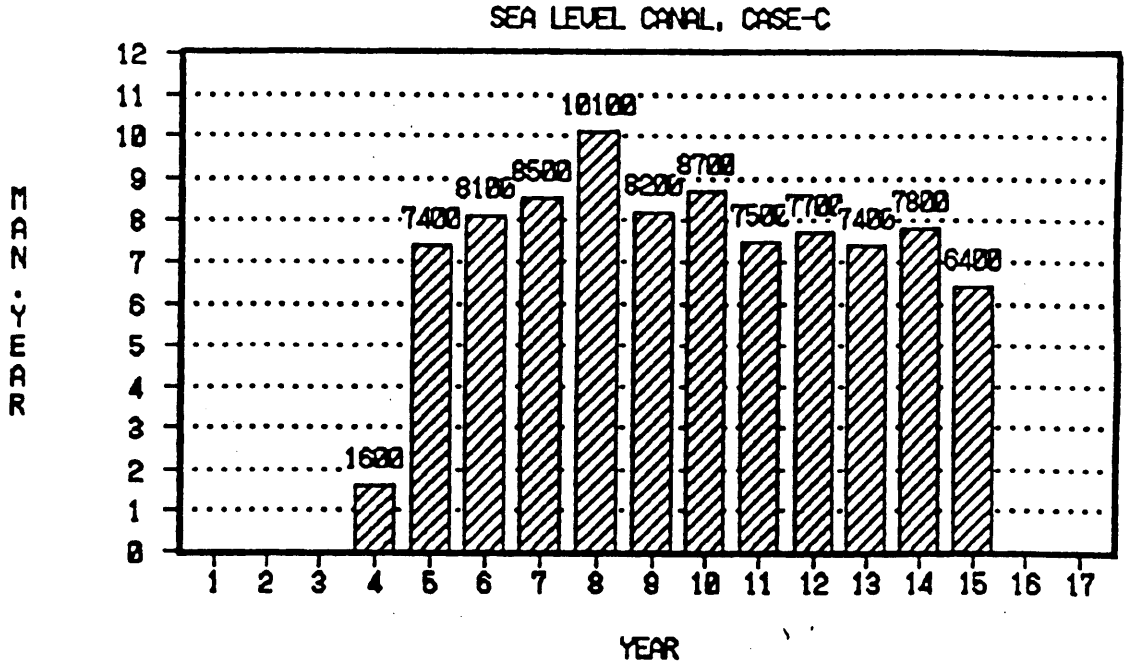

Table 6.3.7-3

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case A)

File:EQSSA02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Canal Excavation(Dry)																		
Crawler Drill(32ton-225mm)						1	3	3	3	2	2	2	4	4	4			734,760
Bulldozer(98ton)					129	129	129	129	129	82	141	141	141	141	141			1,002,340
Shovel(30m3)					11	11	11	11	11	7	12	12	12	12	12			7,621,696
Dump Truck(240ton)					137	137	137	137	137	84	138	138	138	138	138			1,621,807
Canal Excavation(Dredging)																		
Grab(50m3)					2	1		2	2	2	2	2	2	2	2			13,314,286
Split Barge(5000m3)					6	8	8	8	6	6	10	10	12	8	8			3,850,000
Split Barge(1500m3)								4	4	4				4	4			2,652,857
Pusher Tug(3200HP)					3	4	4	4	3	3	5	5	6	4	4			3,646,429
Pusher Tug(1300HP)								2	2	2				2	2			2,088,571
Trailer(10000m3)						1					1	1	1					82,557,143
Cutter(18000HP)					1	2	1	1			1	1	2					27,485,714
Cutter(27500HP)					1	2	3	3	3	3	2	2	2	4	4			40,771,429
Blasting Barge w/t Assisting Vessels								2	2	2				2	2			26,196,343
Lock Construction																		
Crawler Drill(32ton-225mm)						3	3	3										734,760
Bulldozer(98ton)					118	118	118	118										1,002,340
Shovel(30m3)					10	10	10	10										7,621,696
Dump Truck(240ton)					120	120	120	120										1,621,807
Batching Plant(70m3/hr)								3	3	3	3	3	3	3				1,191,240
Genarator(450KVA)								3	3	3	3	3	3	3				175,160
Jib Crane(13.5ton-75m)								4	4	4	4	4	4	4				5,230,000
Generator(800KVA)								2	2	2	2	2	2	2				270,960
Agitating Car(4.5m3)								21	21	21	21	21	21	21				81,440
Aggregate Production																		
Crawler Drill(32ton-225mm)								1	1	1	1	1	1	1				734,760
Bulldozer(98ton)								1	1	1	1	1	1	1				1,002,340
Shovel(3.3m3)								2	2	2	2	2	2	2				946,194
Dump Truck(32ton)								5	5	5	5	5	5	5				430,505
Crushing Plant(500ton/hr)								1	1	1	1	1	1	1				14,909,332
Generator(800KVA)								4	4	4	4	4	4	4				270,960
Shovel(3.3m3)								1	1	1	1	1	1	1				946,194
Dump Truck(32ton)								15	15	15	15	15	15	15				430,505

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Final Report

Table 6.3.7-4

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case A)

File:EQSSA02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Barrier Dam Construction																		
Grab Dredger(50m3)					2	2	2											13,314,286
Split Barge(5,000m3)					4	4	4											3,850,000
Pusher Tug(3,200HP)					2	2	2											3,646,429
Stone Barge(2,000ton)						18	24	12	2	2								5,085,390
Crawler Crane(70 ton)						38	54	40	18	16								559,857
Backhoe Barge(8 m3)						1	3	3	2	1								650,572
Flat Top Barge(2,000ton)						3	8	7	5	2								2,141,143
Pusher Tug(1,300HP)						3	8	11	9	6								2,088,571
Stone Barge(1,000ton)								1	1	1								4,018,214
Crane Barge(50tx2)								2	2	2								1,397,857
Flat Top Barge(1,000ton)								4	4	4								1,430,000
Breakwater Construction																		
Split Barge(5,000m3)					2	2				3								3,850,000
Pusher Tug(3,200HP)					1	1				2								3,646,429
Crawler Crane(70 ton)					16	18	12	8	8	12	6	12	10	8	8			559,857
Cutter Suction(18,000HP)										1								27,485,714
Backhoe Barge(8 m3)						1	2				1	2	1					650,572
Flat Top Barge(2,000ton)						3	5				3	5	3					2,141,143
Pusher Tug(1,300HP)						3	13	8	8	8	3	13	11	8	8			2,088,571
Stone Barge(2,000ton)					6	6				2	2							5,085,390
Stone Barge(1,000ton)																		4,018,214
Crane Barge(50tx2)							4	4	4	4		4	4	4	4			1,397,857
Flat Top Barge(1,000ton)							8	8	8	8		8	8	8	8			1,430,000

Based on YEC-Phase II
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Table 6.3.7-5

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case B)

File:EQSSD02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Canal Excavation(Dry)																		
Crawler Drill(32ton-225mm)							4	4	4	2	2	2	4	4	4			734,760
Bulldozer(98ton)					153	153	153	153	153	82	153	153	153	153	153			1,002,340
Shovel(30m3)					13	13	13	13	13	7	13	13	13	13	13			7,621,696
Dump Truck(240ton)					163	163	163	163	163	84	148	148	148	148	148			1,621,807
Canal Excavation(Dredging)																		
Grab(50m3)					2	1		3	3	3	2	2		2	2			13,314,286
Split Barge(5000m3)					6	8	14	14	14	14	6	10	8	6	6			3,860,000
Split Barge(1500m3)								6	6	6				4	4			2,652,857
Pusher Tug(3200HP)					3	4	7	7	7	7	3	5	4	3	3			3,646,429
Pusher Tug(1300HP)								3	3	3				2	2			2,088,571
Trailer(10000m3)						1					1	1						82,557,143
Cutter(18000HP)						2	1	1	1	1	1	1	2					27,485,714
Cutter(27500HP)					1	2	6	6	6	6		2	2	3	3			40,771,429
Blasting Barge w/t Assisting Vessels								3	3	3				2	2			26,196,343
Lock Construction																		
Crawler Drill(32ton-225mm)					4													734,760
Bulldozer(98ton)					48													1,002,340
Shovel(30m3)					4													7,621,696
Dump Truck(240ton)					57													1,621,807
Batching Plant(70m3/hr)						2	2	2	2									1,191,240
Genarator(450KVA)						2	2	2	2									175,160
Jib Crane(13.5ton-75m)						4	4	4	4									5,230,000
Generator(800KVA)						2	2	2	2									270,960
Agitating Car(4.5m3)						14	14	14	14									81,440
Aggregate Production																		
Crawler Drill(32ton-225mm)						2	2	2	2									734,760
Bulldozer(98ton)						2	2	2	2									1,002,340
Shovel(3.3m3)						4	4	4	4									946,194
Dump Truck(32ton)						10	10	10	10									430,505
Crushing Plant(500ton/hr)						2	2	2	2									14,909,332
Generator(800KVA)						8	8	8	8									270,960
Shovel(3.3m3)						2	2	2	2									946,194
Dump Truck(32ton)						59	59	59	59									430,505

Based on YEC-Phase II
Final Report

Table 6.3.7-6

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case B)

File:EQSSB02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Barrier Dam Construction																		
Grab Dredger(50m3)					2	2	2											13,314,286
Split Barge(5,000m3)					4	4	4											3,860,000
Pusher Tug(3,200 HP)					2	2	2											3,646,429
Stone Barge(2,000ton)						18	24	12	2	2								5,085,390
Crawler Crane(70 ton)						38	54	40	18	16								659,857
Backhoe Barge(8 m3)						1	3	3	2	1								650,572
Flat Top Barge(2,000ton)						3	8	7	5	2								2,141,143
Pusher Tug(1,300 HP)						3	8	11	9	6								2,088,671
Stone Barge(1,000ton)								1	1	1								4,018,214
Crane Barge(50tx2)								2	2	2								1,397,857
Flat Top Barge(1,000ton)								4	4	4								1,430,000
Breakwater Construction																		
Split Barge(5,000m3)					2	2				3								3,860,000
Pusher Tug(3,200 HP)					1	1				2								3,646,429
Crawler Crane(70 ton)					16	18	12	8	8	12	6	12	10	8	8			659,857
Cutter Suction(18,000HP)										1								27,486,714
Backhoe Barge(8 m3)						1	2				1	2	1					650,572
Flat Top Barge(2,000ton)						3	6				3	6	3					2,141,143
Pusher Tug(1,300 HP)						3	13	8	8	8	3	13	11	8	8			2,088,671
Stone Barge(2,000ton)					6	6				2	2							5,085,390
Stone Barge(1,000ton)							4	4	4	4		4	4	4	4			4,018,214
Crane Barge(50tx2)							8	8	8	8		8	8	8	8			1,397,857
Flat Top Barge(1,000ton)																		1,430,000

Based on YEC-Phase II
Final Report

Table 6.3.7.2-7

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case C)

File:EQSSC02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Canal Excavation(Dry)																		
Crawler Drill(32ton-225mm)						1	3	3	3	2	2	2	4	4	4			734,760
Bulldozer(98ton)					129	129	129	129	129	82	141	141	141	141	141			1,002,340
Shovel(30m3)					11	11	11	11	11	7	12	12	12	12	12			7,521,696
Dump Truck(240ton)					137	137	137	137	13[illegible]	[illegible]	138	138	138	138	138			1,621,807
Canal Excavation(Dredging)																		
Grab(50m3)					2	1		2	2	2	2	2	2	2	2			13,314,286
Split Barge(5000m3)					6	8	8	8	6	6	10	10	12	8	8			3,850,000
Split Barge(1500m3)								4	4	4				4	4			2,652,857
Pusher Tug(3200HP)					3	4	4	4	3	3	5	5	6	4	4			3,646,429
Pusher Tug(1300HP)								2	2	2				2	2			2,088,571
Trailer(10000m3)						1					1	1	1					82,557,143
Cutter(18000HP)					1	2	1	1			1	1	2					27,485,714
Cutter(27500HP)					1	2	3	3	3	3	2	2	2	4	4			40,771,429
Blasting Barge w/t Assisting Vessels								2	2	2				2	2			26,196,343
Lock Construction																		
Crawler Drill(32ton-225mm)						3	3	3										734,760
Bulldozer(98ton)					142	118	118	118										1,002,340
Shovel(30m3)					12	10	10	10										7,521,696
Dump Truck(240ton)					146	120	120	120										1,621,807
Batching Plant(70m3/hr)						1	1	4	4	3	3	3	3	3				1,191,240
Generator(450KVA)						1	1	4	4	3	3	3	3	3				176,160
Jib Crane(13.5ton-75m)						2	2	6	6	4	4	4	4	4				5,230,000
Generator(800KVA)						1	1	3	3	2	2	2	2	2				270,960
Agitating Car(4.5m3)						7	7	28	28	21	21	21	21	21				81,440
Aggregate Production																		
Crawler Drill(32ton-225mm)						1	1	2	2	1	1	1	1	1				734,760
Bulldozer(98ton)						1	1	2	2	1	1	1	1	1				1,002,340
Shovel(3.3m3)						2	2	4	4	2	2	2	2	2				946,194
Dump Truck(32ton)						5	5	10	10	5	5	5	5	5				430,505
Crushing Plant(500ton/hr)						1	1	2	2	1	1	1	1	1				14,909,332
Generator(800KVA)						4	4	8	8	4	4	4	4	4				270,960
Shovel(3.3m3)						1	1	2	2	1	1	1	1	1				946,194
Dump Truck(32ton)						44	44	59	59	15	15	15	15	15				430,505

Based on YEC-Phase II
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Table 6.3.7-8

Schedule for Equipment and Vessels (Sea Level Canal - 250,000 dwt - Case C)

File:EQSSC02

DESCRIPTION	YEAR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	PRICE CIF PANAMA ($/unit)
Barrier Dam Construction																		
Grab Dredger(50m3)					2	2	2											13,314,286
Split Barge(5,000m3)					4	4	4											3,850,000
Pusher Tug(3,200 HP)					2	2	2											3,646,429
Stone Barge(2,000ton)						18	24	12	2	2								5,085,390
Crawler Crane(70 ton)						38	54	40	18	16								559,857
Backhoe Barge(8 m3)						1	3	3	2	1								650,572
Flat Top Barge(2,000ton)						3	8	7	5	2								2,141,143
Pusher Tug(1,300 HP)						3	8	11	9	6								2,088,571
Stone Barge(1,000ton)								1	1	1								4,018,214
Crane Barge(50tx2)								2	2	2								1,397,857
Flat Top Barge(1,000ton)								4	4	4								1,430,000
Breakwater Construction																		
Split Barge(5,000m3)					2	2				3								3,850,000
Pusher Tug(3,200 HP)					1	1				2								3,646,429
Crawler Crane(70 ton)					16	18	12	8	8	12	6	12	10	8	8			559,857
Cutter Suction(18,000HP)										1								27,485,714
Backhoe Barge(8 m3)						1	2				1	2	1					650,572
Flat Top Barge(2,000ton)						3	5				3	5	3					2,141,143
Pusher Tug(1,300 HP)						3	13	8	8	8	3	13	11	8	8			2,088,571
Stone Barge(2,000ton)					6	6				2	2							5,085,390
Stone Barge(1,000ton)																		4,018,214
Crane Barge(50tx2)							4	4	4	4		4	4	4	4			1,397,857
Flat Top Barge(1,000ton)							8	8	8	8		8	8	8	8			1,430,000

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6.3.8 Cost Estimates

Construction costs were estimated for all alternatives based on the following assumptions:

(1) All costs are Present Day 1990.

(2) All dollars are in millions.

(3) Selection of contractors and the type of contracts shall be based on an international competitive tender in accordance with the FIDIC, 4th Edition, 1987, or equal.

(4) It is assumed that progressive payments will be made during construction such that no interest payment will occur and more are not included in the cost.

(5) Taxes and custom duties are not included in the construction cost estimate. It is assumed that the project will be exempt.

(6) No allowance is provided for retainage.

(7) Construction costs as generated by YEC included a 10% salvage credit for all major construction equipment.

(8) No credit has been allowed for major construction equipment with remaining useful life at completion of construction activity.

(9) Costs for all Major Construction Equipment reflect costs of freight to Panama, based on U.S. source.

(10) Other (Permanent Plant) Equipment has been priced by YEC on the basis of fabrication in Japan and shipment to Panama.

(11) Contingency is 10% of the redistributed Total Direct Costs per year. The total contingency value remains unchanged from the YEC estimate.

(12) Overtime premiums and social benefits are included in labor cost and are based on Panamanian labor market for the year 1990.

(13) Loading and unloading facilities exist in country.

(14) Operating hours are as detailed in the YEC - Phase II Final Report, Parts III and IV, Section 3.

(15) Cost of Culebra (Gaillard) Cut Widening Project is not included, it is considered as part of Status Quo.

(16) Operating and maintenance costs are based on PCC-O&M schedule with minor modification.

(17) Detailed cost estimate for HRLC at El 27.5 m is not provided. Rough cost estimates are provided in Section 6.3.5.8 of this report.

Based on the above assumptions, schedule of construction equipment, permanent plant equipment, and labor, the project construction cost estimates are provided in Tables 6.3.8-1 and 6.3.8-2 for all cases of the HRLC and SLC-10 (see YEC - Phase II - Final Report).

In addition, SINBOL provided to the Financing and Financial Analysis Component Contractor a cash flow distribution per year of construction based on equipment acquisition year, equipment useful life and year of replacement. The schedule of yearly cash flow was provided for direct construction cost for both construction equipment and permanent plant equipment.

The indirect construction cost including contingency was based on direct cost. These schedules were provided for three cost estimate included in the Phase II Draft Final, Phase II Final, and Phase II Additional Work (Annex). It should be noted that cash flow distribution tables were generated using YEC-Phase II construction schedules, labor distribution and construction equipment schedules. The purpose of this SINBOL work was to provide construction cost in a format suitable for project financing schemes considered by this Component Study.

Subsequent to providing the above cost estimates, YEC was requested to provide new construction cost estimates for additional work including a single lane Culebra Cut, single lane tidal gate at the Pacific entrance and other items which were included as an Annex to the Phase II Final Report.

New construction cost estimates of this Annex is provided in Section 6.4.

Table 6.3.8-1

Project Cost Summary of High Rise Lock Canal

(Currency In US dollars) (File : SUMHRLC)

	Description	200,000 DWT			160,000 DWT		
		Rise 86'			Rise 86'		
		the year of 2,020 ($)	the year of 2,060 ($)	Total ($)	the year of 2,020 ($)	the year of 2,060 ($)	Total ($)
I	CONSTRUCTION COSTS						
(A)	CIVIL WORKS						
1	Canal Excavation	3,477,383,640	-	3,477,383,640	3,011,946,860	-	3,011,946,860
2	Placing Area	87,794,350	-	87,794,350	87,794,350	-	87,794,350
3	Lock Construction	1,127,257,294	-	1,127,257,294	991,170,516	-	991,170,516
5	New Dams	236,998,948	92,605,538	329,604,486	-	201,134,249	201,134,249
6	Pump Station	-	149,374,284	149,374,284	-	149,374,284	149,374,284
7	New Permanent Roads	8,752,280	-	8,752,280	8,752,280	-	8,752,280
8	New Canal Crossing	501,187,828	839,491,140	1,340,678,968	450,199,285	776,534,190	1,226,733,475
10	Barrier Dams	-	-	-	-	-	-
11	Breakwater	-	-	-	-	-	-
12	Diversion Scheme	-	-	-	-	-	-
13	Supporting Construction	426,434,300	84,586,000	510,020,300	426,434,300	88,150,000	513,584,300
	Subtotal	5,864,808,632	1,166,056,962	7,030,865,594	4,975,297,591	1,215,192,723	6,190,490,314
(B)	PLANT FORMING A PART OF PERMANENT WORKS						
4	Gate Leaves and Related Facilities	1,011,237,358	-	1,011,237,358	888,887,600	-	888,887,600
9	Navigation Support System	414,209,530	-	414,209,530	414,209,530	-	414,209,530
	Subtotal	1,426,446,888	-	1,426,446,888	1,303,097,030	-	1,303,097,030
	CONSTRUCTION COSTS, TOTAL(I)	7,290,256,612	1,166,056,962	8,456,312,474	6,278,394,621	1,215,192,723	7,493,587,344
II	INDIRECT COSTS						
1	Administrative Costs	89,542,200	14,322,000	103,864,200	77,114,100	14,926,500	92,039,600
2	Headquarter's Costs	152,853,000	24,448,400	177,301,400	131,637,600	25,478,600	157,116,200
3	Construction Supervision	179,283,000	28,675,800	207,958,800	154,399,200	29,884,200	184,283,400
4	Land Aquisition & Rights	-	-	-	-	-	-
5	Compensation Costs	105,000,000	-	105,000,000	105,000,000	-	105,000,000
6	Contingency	729,026,000	116,606,000	845,632,000	627,839,000	121,519,000	749,358,000
	INDIRECT COSTS, TOTAL(II)	1,255,704,200	184,052,200	1,439,756,400	1,095,989,900	191,807,300	1,287,797,200
	PROJECT COSTS,GRAND TOTAL(I+II)	8,545,959,712	1,350,109,162	9,896,068,874	7,374,384,521	1,407,000,023	8,781,384,544

Table 6.3.8-2

Project Cost Summary of Sea Level Canal

(Currency in US Dollars) (File: SUWSLC)

	Description	260,000 DWT								
		Case a			Case b			Case c		
		the year of 2,020 ($)	the year of 2,060 ($)	Total ($)	the year of 2,020 ($)	the year of 2,060 ($)	Total ($)	the year of 2,020 ($)	the year of 2,060 ($)	Total ($)
I	CONSTRUCTION COSTS									
(A)	CIVIL WORKS									
1	Canal Excavation	8,244,222,840	-	8,244,222,840	7,373,058,330	-	7,373,058,330	8,244,222,840	-	8,244,222,840
2	Placing Area	188,682,691	-	188,682,691	188,682,691	-	188,682,691	188,682,691	-	188,682,691
3	Lock Construction (Tidal Lock/Gate)	2,037,412,827	477,348,130	2,514,760,957	428,836,820	-	428,836,820	2,292,871,454	477,348,130	2,770,219,584
5	New Dams	-	89,963,144	89,963,144	-	89,963,144	89,963,144	-	89,963,144	89,963,144
6	Pump Station	-	-	-	-	-	-	-	-	-
7	New Permanent Roads	19,419,590	-	19,419,590	19,419,590	-	19,419,590	19,419,590	-	19,419,590
8	New Canal Crossings	221,836,760	547,713,010	769,649,770	309,088,760	547,713,010	856,801,770	221,836,760	547,713,010	769,649,770
10	Barrier Dams	493,502,306	-	493,502,306	493,502,306	-	493,502,306	493,502,306	-	493,502,306
11	Breakwater	482,815,840	-	482,815,840	482,815,840	-	482,815,840	482,815,840	-	482,815,840
12	Diversion Scheme	76,285,156	-	76,285,156	76,285,156	-	76,285,156	76,285,156	-	76,285,156
13	Supporting Construction	574,412,520	66,149,000	640,561,520	574,412,520	37,830,000	612,242,520	574,412,520	66,149,000	640,561,520
	Subtotal	10,258,090,530	1,181,173,284	11,439,263,814	9,864,400,013	675,506,154	10,539,906,167	10,513,348,167	1,181,173,284	11,693,522,441
(B)	PLANT FORMING A PART OF PERMANENT WORKS									
4	Gate Leaves and Related Facilities	949,550,400	316,000,430	1,265,550,830	737,960,800	-	737,960,800	1,262,234,600	316,000,430	1,578,243,030
9	Navigation Support System	546,295,047	-	546,295,047	477,046,333	-	477,046,333	546,295,047	-	546,295,047
	Subtotal	1,495,845,447	316,000,430	1,811,853,877	1,215,007,133	-	1,215,007,133	1,808,529,647	316,000,430	2,124,538,077
	CONSTRUCTION COSTS, TOTAL(I)	11,753,935,977	1,497,173,714	13,249,017,691	11,079,407,146	675,506,154	11,754,913,300	12,321,877,814	1,497,173,714	13,819,051,528
II	INDIRECT COSTS									
1	Administrative Costs	120,063,000	15,271,300	135,334,300	113,010,000	6,890,200	119,900,200	125,671,000	15,271,300	140,942,300
2	Headquarter's Costs	203,059,130	25,867,700	228,926,830	191,425,600	11,671,100	203,096,700	212,782,500	25,867,700	238,650,200
3	Construction Supervision	227,322,500	28,958,600	256,281,100	214,298,900	13,065,700	227,364,600	238,110,100	28,958,600	267,068,700
4	Land Acquisition & Rights	27,337,175	-	27,337,175	27,337,175	-	27,337,175	27,337,175	-	27,337,175
5	Compensation Costs	13,557,600	-	13,557,600	13,557,600	-	13,557,600	13,557,600	-	13,557,600
6	Contingency	1,175,374,000	149,718,000	1,324,992,000	1,107,941,000	67,551,000	1,175,492,000	1,231,888,000	149,718,000	1,380,606,000
	INDIRECT COSTS, TOTAL(II)	1,766,713,405	219,815,600	1,986,429,005	1,667,570,275	99,178,000	1,766,748,275	1,848,374,375	219,815,600	2,068,189,975
	PROJECT COSTS, GRAND TOTAL(I+II)	13,519,649,382	1,716,997,314	15,236,646,696	12,746,977,421	774,684,154	13,521,661,575	14,169,253,189	1,716,997,314	15,886,250,503

6.4 Engineering and Cost Estimate, Phase II, Additional Work

6.4.1 Introduction

At the conclusion of the fourteenth meeting of the Board of Commissioners on July 14, 1992, for the Study of Alternatives to the Panama Canal, it was decided to develop costs and benefits of single lane canal options for both the HRLC and SLC-10. During the Phase II Final Report joint review meeting between CAS and ECE, an Addendum to Terms of Reference (TOR) for additional work was issued to the ECE Component Contractor. The additional work included:

(1) High Rise Lock Canal

Provide cost estimates for a single lane Culebra Cut excavation zones III and IV as defined in the ECE Draft Final Report. It was specifically indicated that only deepening to the design depth of the PCC completed (193 ft. wide) Culebra Cut (Status Quo base) will require costing. Construction procedures for this work were also provided in the Addendum.

(2) Sea Level Canal

a. Tidal Lock option (variation of case 'a' now called case 'd') - Provide cost estimates for a single lane chamber for the Pacific Locks with excavation for additional lock chambers eliminated. Widening at the lock approaches should be appropriately reduced.

b. A pair of tidal gates (variation of case 'b' now called case 'e') - Provide cost estimate for the following conditions:

- Single lane for the Atlantic approach channel between the coast line and the Atlantic tidal gate. An appropriate length of transition zone shall be provided at the Atlantic Coast.
- Cost estimates are only for year 2020
- An appropriate adjustment in the length of canal crossing should be accounted for.

The schematics of the changes are depicted in Figures 6.4.1-1 through 6.4.1-6 and basic data and cost are included in Table 6.4.1-1.

Table 6.4.1-1

Summary of the Phase II Additional Work (Year 2020)

Item		High Rise Lock Canal (85')		Sea Level Canal	
Case		(5)	(6)	(d)	(e)
Ship Size	1,000 dwt	150	200	250	
Canal Width (m)	1 lane	160	175	190	
	2 lane	320	350	380	
New Facilities					
Canal		2 lane canal with 1 lane Culebra Cut		1 lane canal and 2 lane approach *	
Lock and Gate		third lane of locks (one lane of new locks)		1 lane tidal lock	1 lane, 2 tidal gates
Water Supply		n.a.	Indio	n.a.	
Pump Station (MCM)		n.a.			
Barrier Dam		n.a.		3	
Freshwater Barrier		n.a.		considered	
Diversion Scheme		n.a.		considered	
Bridge Crossing		2 places		3 places	
Breakwater		existing		new addition	
Project Cost mill US Dollar		5,418	6,375	10,888	10,851

Note: n.a. not applicable
* One lane Atlantic approach channel for Case 'e' only.

Figure 6.4.1-1

Layout of HRLC Variations

(Case (6) - 200,000 dwt) (Case (5) - 150,000 dwt similar except for canal bottom levels)

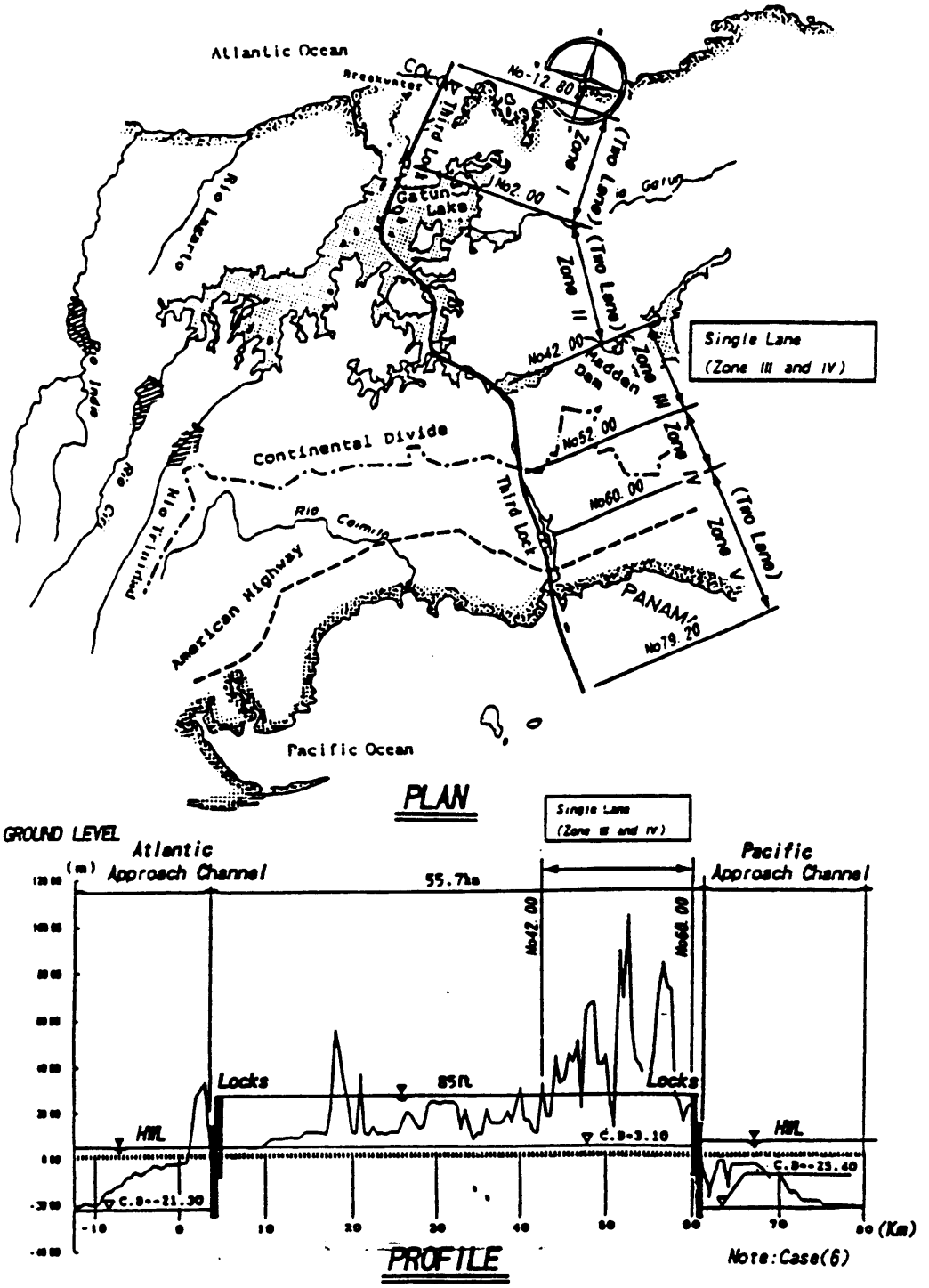


Figure 6.4.1-2
HRLC Variations
Layout of Zone III and Zone IV in Phase II FR

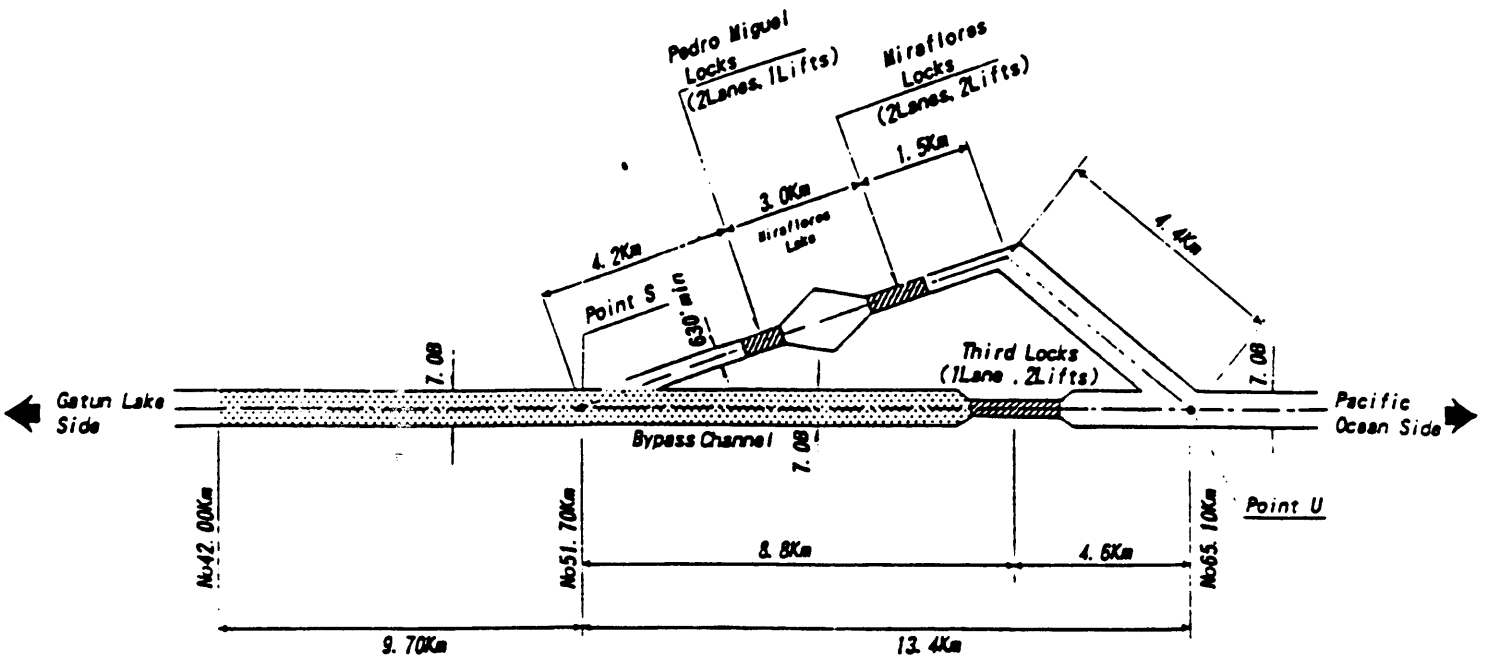


Figure 6.4.1-3

HRLC Variations

Layout of Zone III and Zone IV in Phase II Additional Work

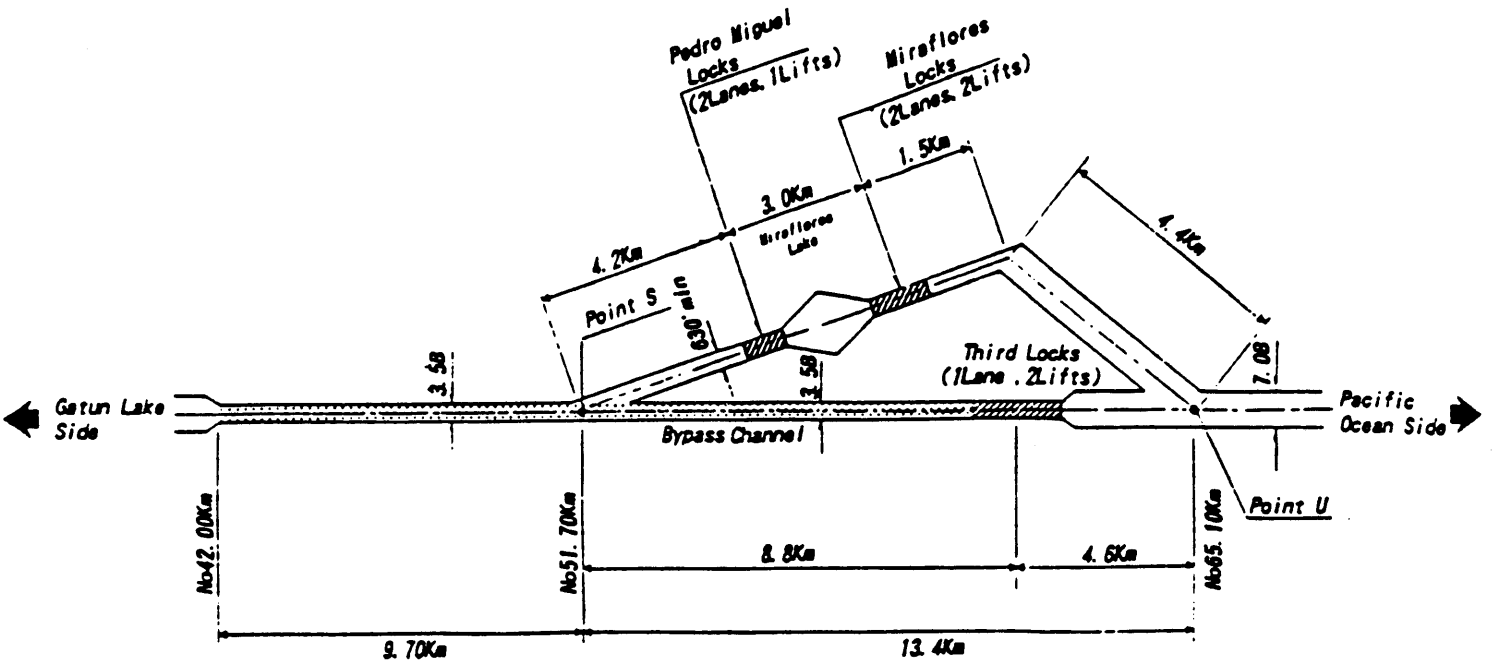


Figure 6.4.1-4
Layout of SLC Variations
[Case (d) and Case (e)]

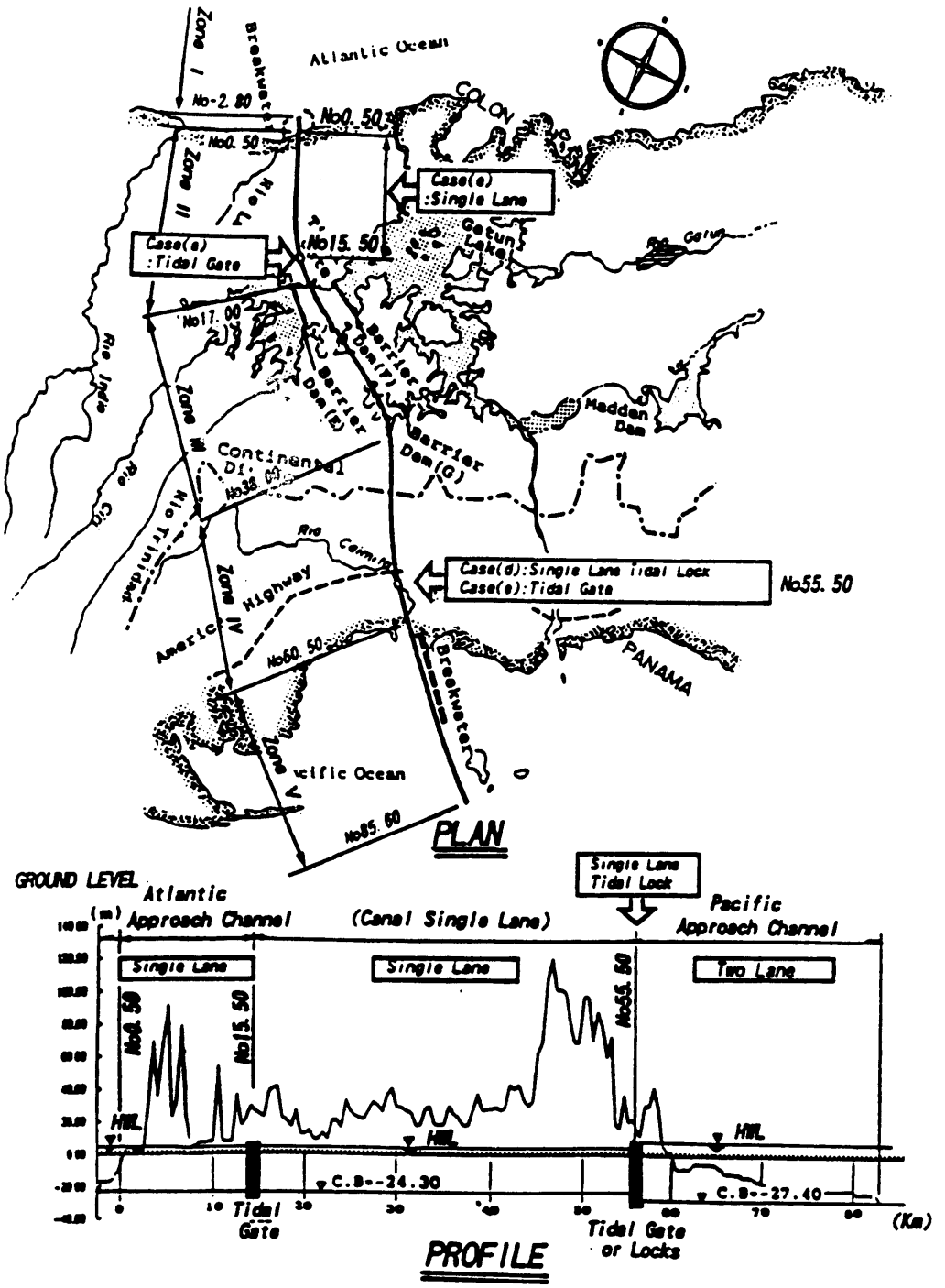


Figure 6.4.1-5

SLC Variations

Layout of Tidal Lock Modifications - Cases (a) and (d)

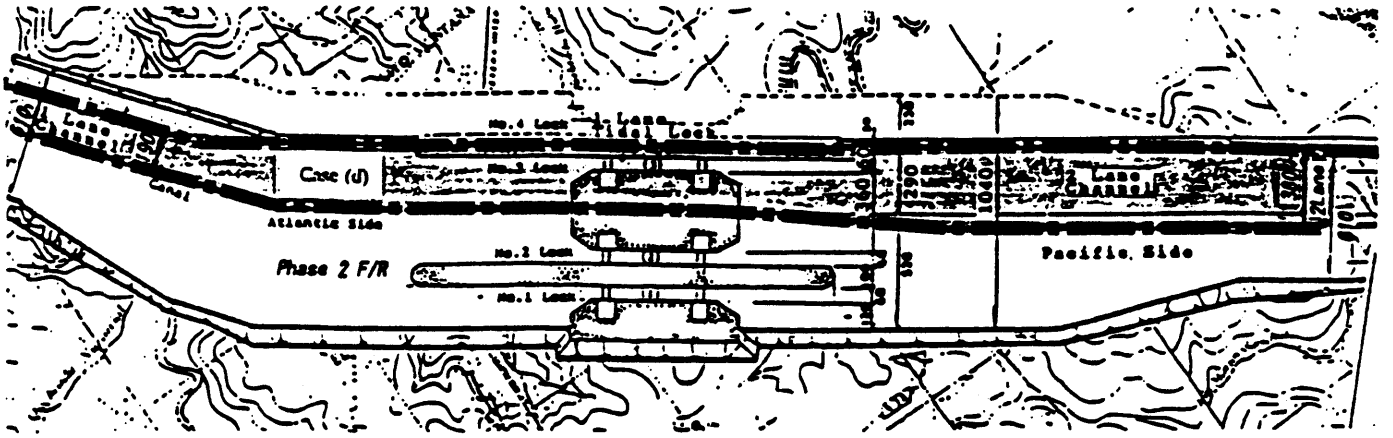
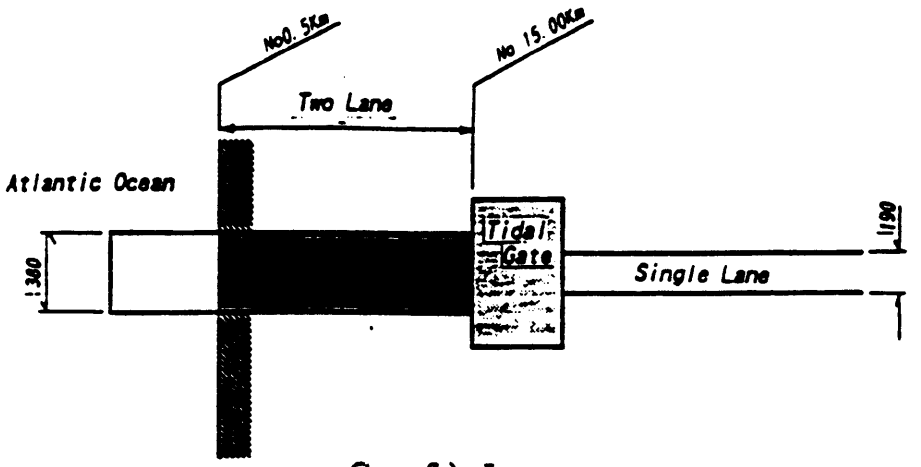


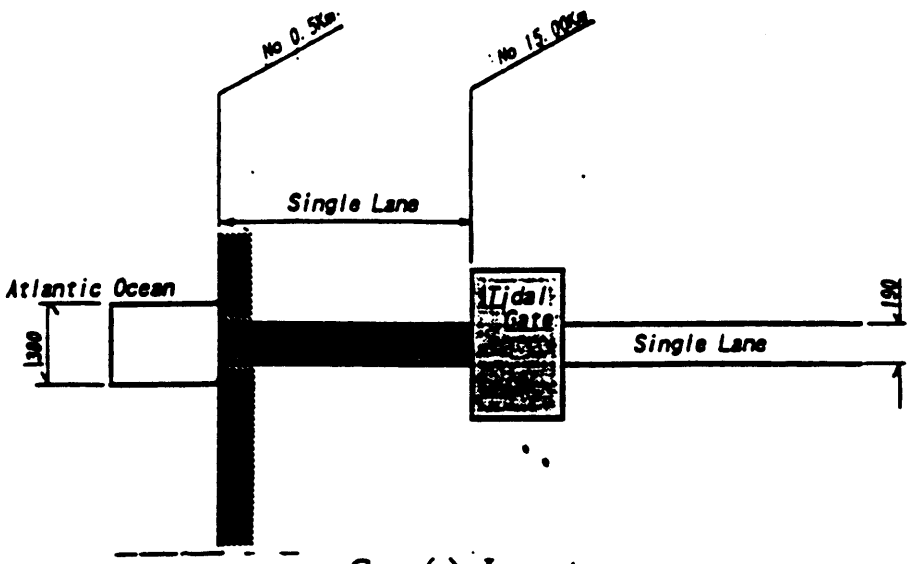
Figure 6.4.1-6

SLC Variations

Layout of Atlantic Approach - Cases (b) and (e)



Case (b) Layout



Case (e) Layout

6.4.2 Basic Engineering Criteria

Basic Engineering Criteria used is Phase II work for both HRLC and SLC-10 are also used for the additional work.

The design ships remained unchanged as 150 and 200 thousand dwt for the HRLC and 250,000 dwt for the SLC-10.

Canal cross - section remained at 3.5 B (where B is the beam of a design ship beam) for a single lane and 7 B for two lane canal as shown in Figure 5.4.2-1. Therefore, the width of a single lane HRLC is 160 m for 150,000 dwt, 175 m for 200,000 dwt, and for the SLC-10, its width is 190 m for a 250,000 dwt.

6.4.3 Excavation Quantities

The same design slope criteria, excavation zones and marine charts for Gatun Lake and approach channels used for Phase II work were also used for the Phase II Additional work.

For the HRLC excavation, a two lane canal was maintained from the Phase II Final Report except for excavation zones III and IV (Culebra Cut Area) which were changed to a single lane canal for the additional work. The widened Culebra Cut will be dredged for a width of 160 m to an additional average depth of 7 m for the 150,000 dwt ship and dredged a width of 175 m to an additional average depth of 8 m for the 200,000 dwt ship.

For the SLC-10, the Atlantic Approach Channel to the Atlantic tidal gate was changed to a single lane (190 m) instead of two lanes (380 m) used in Phase II Final Report.

Results of these changes are presented in Figures 6.4.3-1.

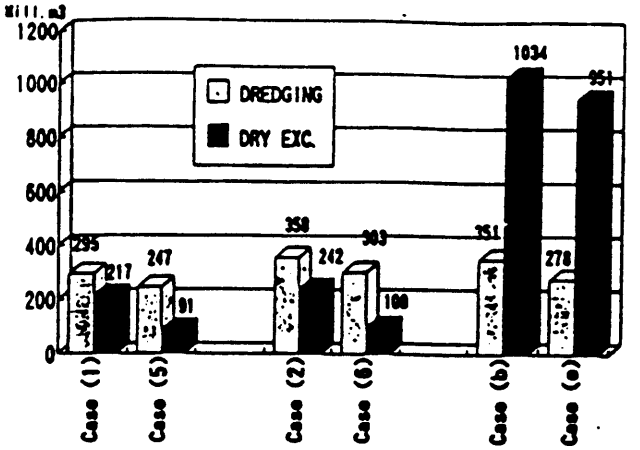
6.4.4 Transportation Plan

The Transportation Plan for the HRLC did not change from that studied for Phase II Final Report. This plan consisted of adding two bridge crossings in the year 2020, one bridge (2 lanes) crossing near Gatun Locks on the Atlantic and another bridge crossing (4 lanes) at the Pacific entrance to replace the existing Bridge of the Americas.

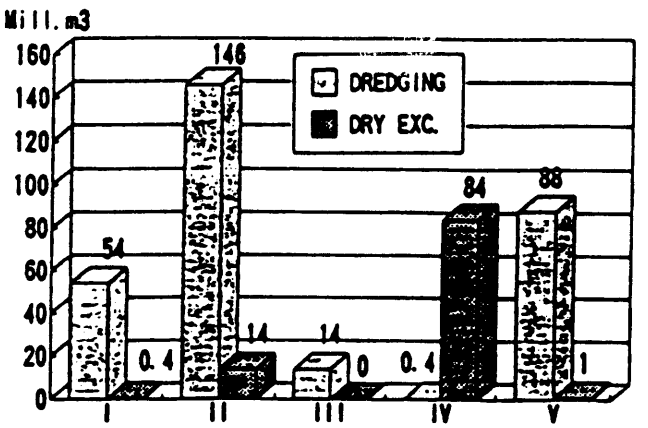
The Transportation Plan for SLC-10 did not change from that studied for Phase II Final Report. For the year 2020, three bridge crossings were included in the SLC-10 estimate. These were Atlantic Coast (2 lanes), Escobal (2 lanes) and at the Pan American Highway (4 lanes) on the Pacific entrance. The only change considered in this addendum is to shorten the bridge span due to changes in canal width discussed above. Figure 6.4.4-1 shows the bridge locations of this study.

Figure 6.4.3-1

Excavation Volume by Case and Zone



Excavation Volume for Each Case



Excavation Volume for Each Zone - HRLC Case (6)

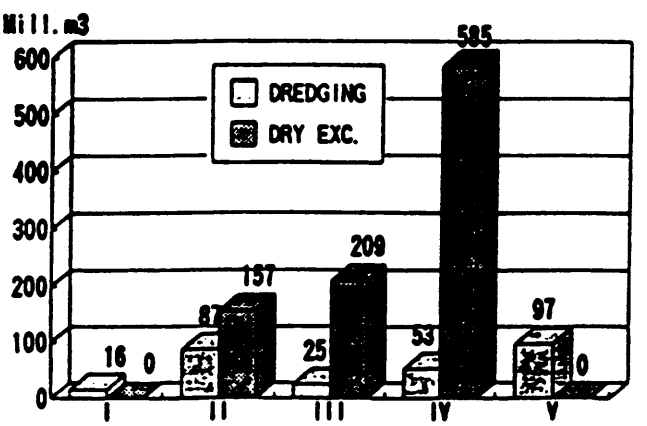
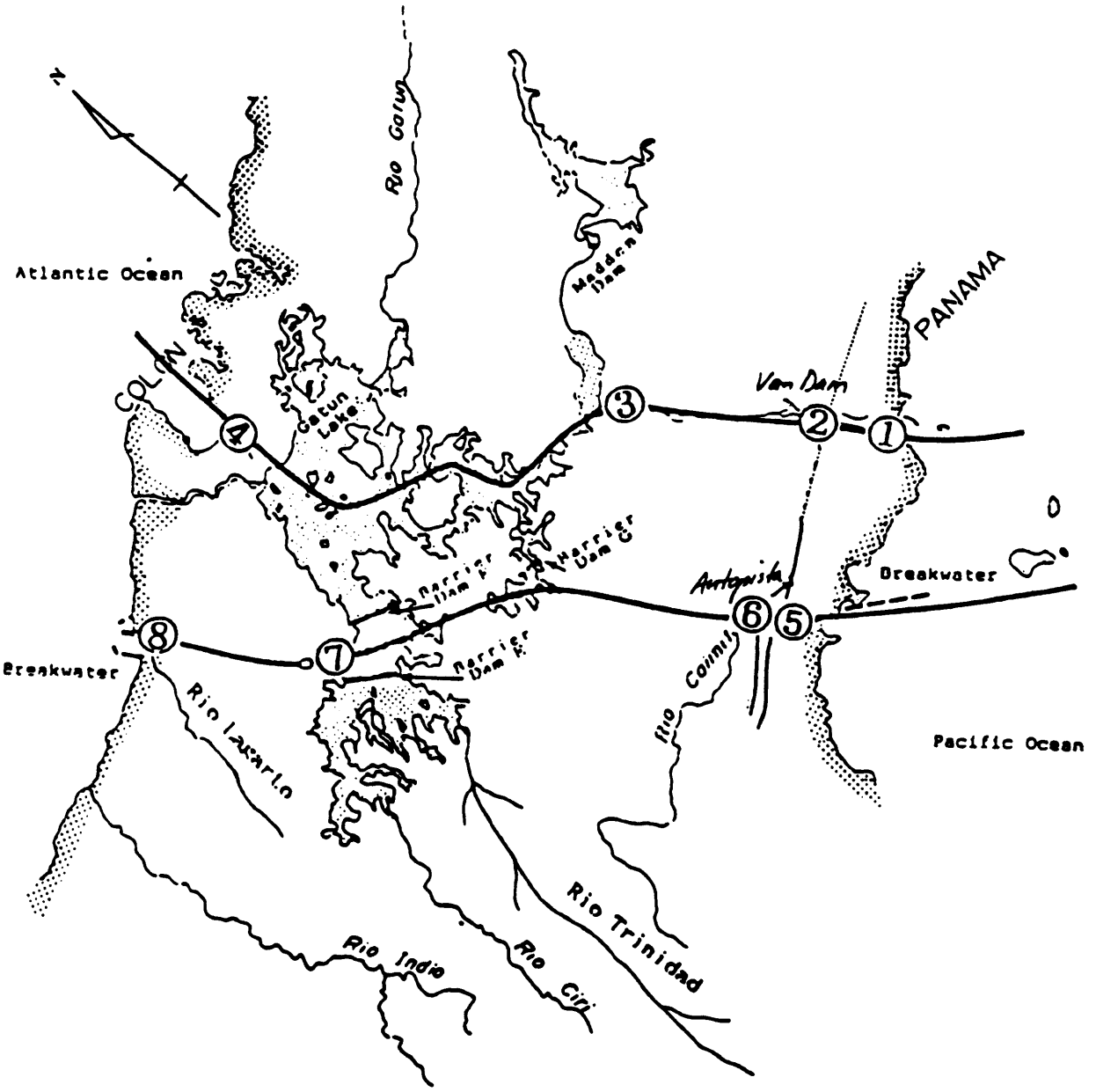


Figure 6.4.4-1
Canal Crossing Locations



6.4.5 Construction Plan

A detailed construction planning and good management will be required to minimize interference or interruption of canal traffic (Panamax vessels) during deepening (dredging) of the Culebra Cut area. As was indicated earlier, the Culebra Cut Project would have widened the Canal in this reach to a minimum width of 192 m and an appropriate single lane width would be dredged to the depth of the design ship. In order to minimize interference between ship traffic and construction dredging, the Canal will be shared between these two operations; namely, a ship lane and a construction lane.

The minimum required ship lane is 3B and for Panamax ship it is 96 m (3 x 32), and the remaining canal width for dredge work is 96 m. The same dredging equipment used for Phase II Final Report will be used for Phase II (Additional Work). This equipment consisted of grab and cutter suction dredgers and a mobile self elevating platform (SEP) housing drilling and blasting rigs. Figure 6.4.5-1 is a graphical presentation of construction stages suggested for this operation. As shown, the western one-half of the Canal will be dredged first and Panamax ships will have only a single lane (eastern one-half) to use for transit.

A similar procedure will be used to dredge the remaining eastern one-half of the Canal. This construction procedure will allow single lane traffic in the Culebra Cut open during construction provided the Canal width is a minimum of 192 m. Sections 6.3 and 9.2 include discussion concerning excavation equipment.

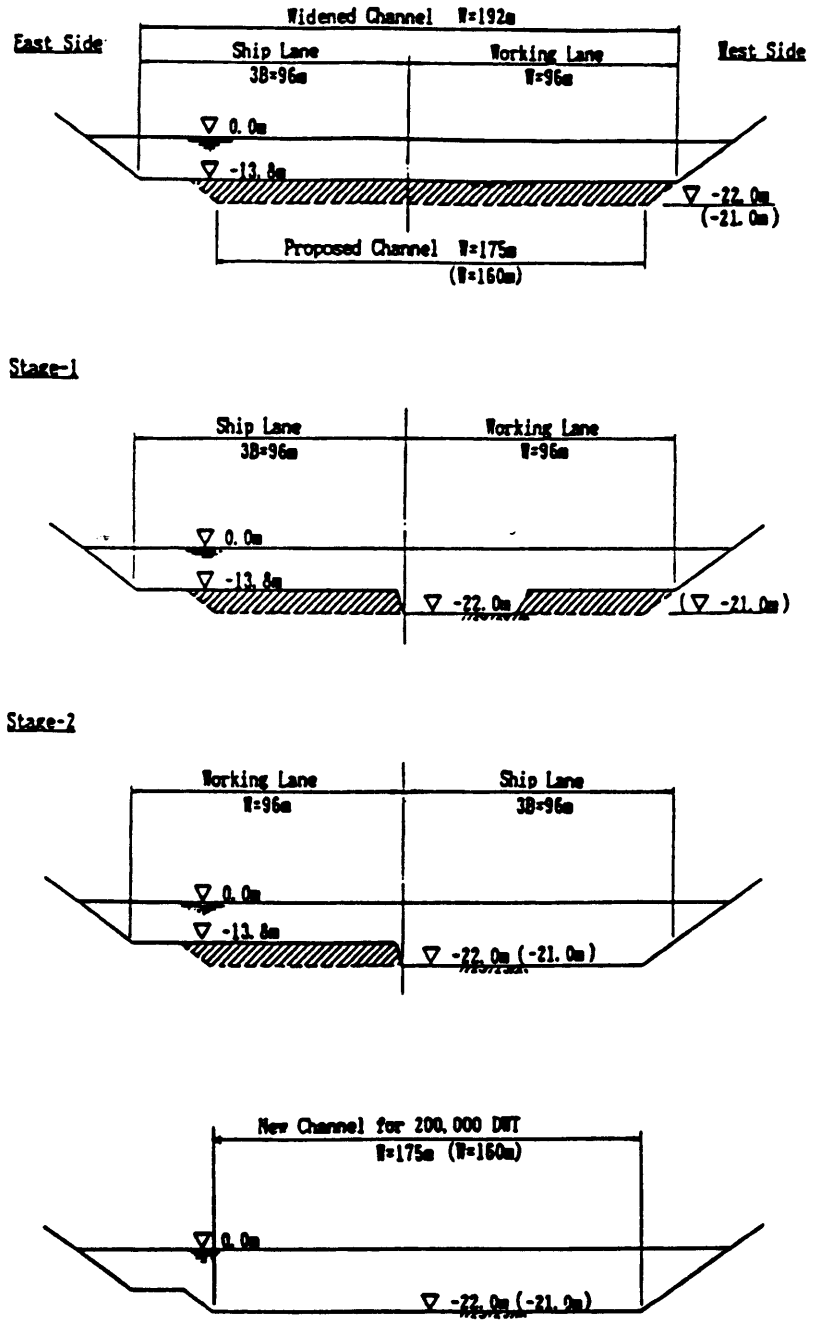
Other construction management tasks include selection of appropriate dredging equipment, maximum possible size of dredging equipment, blasting safety measures and dredging efficiency. Phase II Annex to the Final Report included a brief discussion about the above items and the cost estimates which are based on the construction efficiency extrapolated from the Suez Canal and the forecasted transit capacity of the Canal for the year 2020. It is determined that only about 14 hours per day will be available for construction and about 4 of these working hours may be used for blasting. It is also estimated that 10 hours will be needed by both the Atlantic and Pacific bound ships to clear this work area.

6.4.6 Construction Schedule

Based on the above assumptions, procedures, and construction staging, a new construction schedule was developed for both options of the HRLC (150,000 and 200,000 dwt) as well as the two options of the SLC-10. Figure 6.4.6-1 to 6.4.6-4 show the overall work schedule for all options studied. The following observations are noted:

- Total construction schedule for HRLC - 150,000 dwt option has not changed from Phase II Final Report and remained at 10 years.

Figure 6.4.5-1
Dredging Sequence



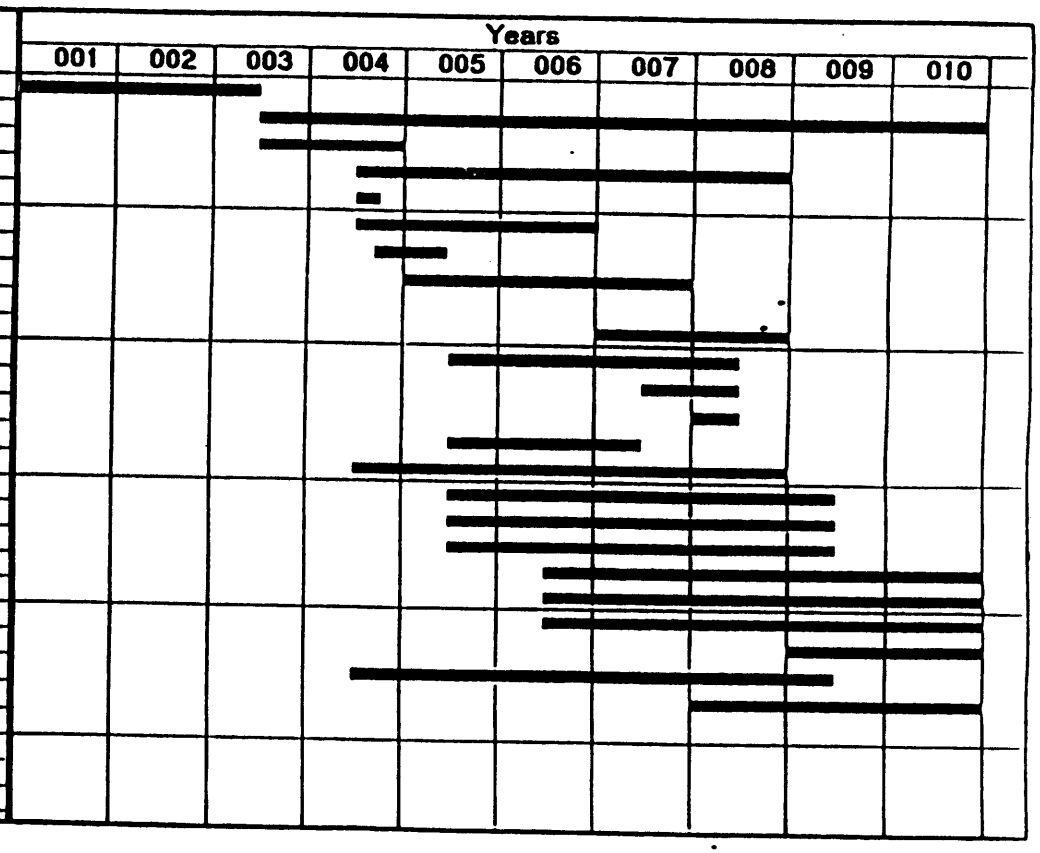
( ): 150,000 DWT Option

Figure 6.4.6-1

Overall Work Schedule - HRLC, Single Lane Culebra Cut Option

Case - (5), 150,000 dwt, 85', 2020

Task Name	Q'ty
Engineering,Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	322,000m3
Zone I Dredging	48,813,000m3
Zone II Dry Excavation	12,954,000m3
Zone II Dredging	121,868,000m3
Zone III Dry Excavation	0m3
Zone III Dredging	11,705,000m3
Zone IV Dry Excavation	78,538,000m3
Zone IV Dredging	345,000m3
Zone V Dry Excavation	777,000m3
Zone V Dredging	68,083,000m3
Placing Area	22.5 km2
Lock Structure	
Atlantic Side	3,200,000m3
Pacific Side	3,200,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	32 km
Canal Crossing(Bridges)	2 Bridges
Navigation System	1 ls



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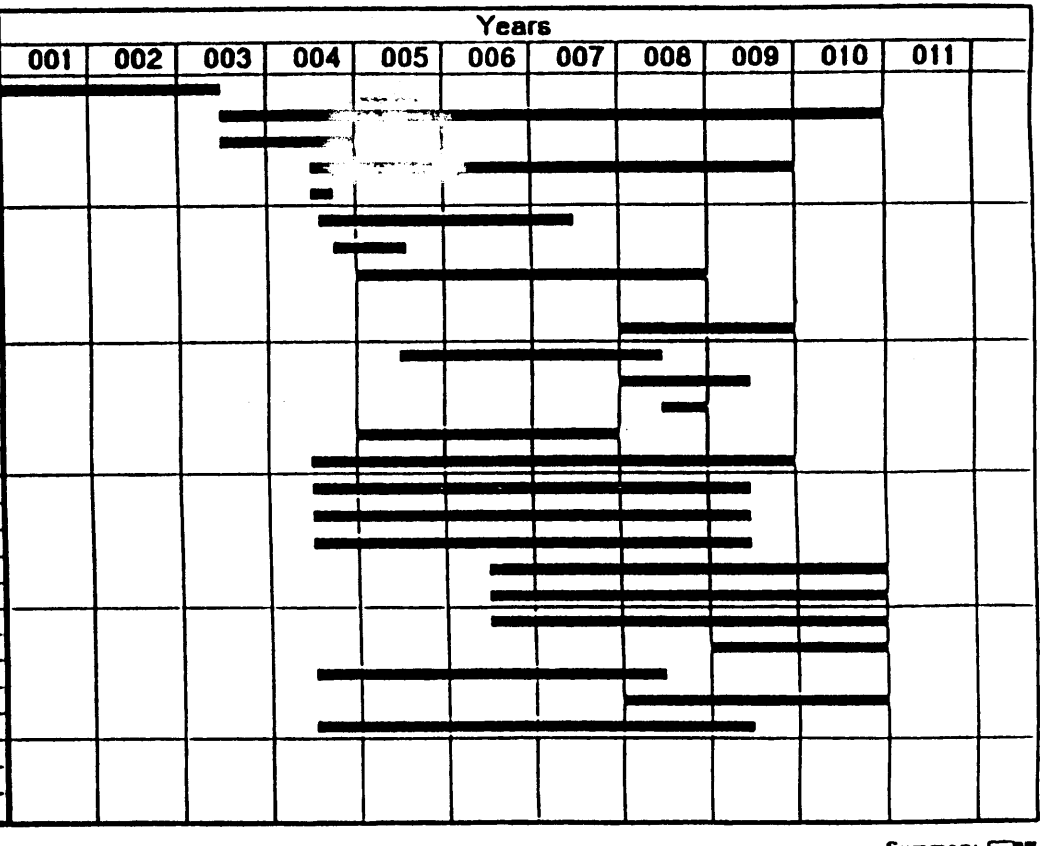
Summary

Figure 6.4.6-2

Overall Work Schedule - HRLC, Single Lane Culebra Cut Option

Case - (6), 200,000 dwt, 85', 2020

Task Name	Q'ty
Engineering,Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	358,000m3
Zone I Dredging	53,847,000m3
Zone II Dry Excavation	14,287,000m3
Zone II Dredging	145,964,000m3
Zone III Dry Excavation	0m3
Zone III Dredging	14,434,000m3
Zone IV Dry Excavation	84,246,000m3
Zone IV Dredging	414,000m3
Zone V Dry Excavation	929,000m3
Zone V Dredging	88,227,000m3
Placing Area	22.5 km2
Lock Structure	
Atlantic Side	3,600,000m3
Pacific Side	3,600,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	32 km
Canal Crossing(Bridges)	2 Bridges
Navigation System	1 ls
New Dam	1 ls



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Summary

Figure 6.4.6-3

Overall Work Schedule - Sea Level Canal, Route 10, Case - (d)

250,000 dwt, 2020

Task Name	Q'ty
Engineering,Design&Tender	1 ls
Construction	
Supporting construction	1 ls
Canal Excavation	
Zone I Dry Excavation	0m3
Zone I Dredging	16,200,000m3
Zone II Dry Excavation	140,510,000m3
Zone II Dredging	94,000,000m3
Zone III Dry Excavation	209,417,000m3
Zone III Dredging	24,700,000m3
Zone IV Dry Excavation	800,204,000m3
Zone IV Dredging	67,200,000m3
Zone V Dry Excavation	0m3
Zone V Dredging	121,000,000m3
Placing Area	61.0 km2
Lock Structure	
Atlantic Side	0m3
Pacific Side	2,000,000m3
Gate Leaves, etc.	
Atlantic Side	
Pacific Side	1 ls
New Permanent Road	71 km
Canal Crossing(Bridges)	2 Bridges
Navigation System	1 ls
Barrier Dams E.F.G Dams	3 Dams
Breakwater	
Atlantic Side	1 ls
Pacific Side	1 ls
Diversion Scheme	1 ls

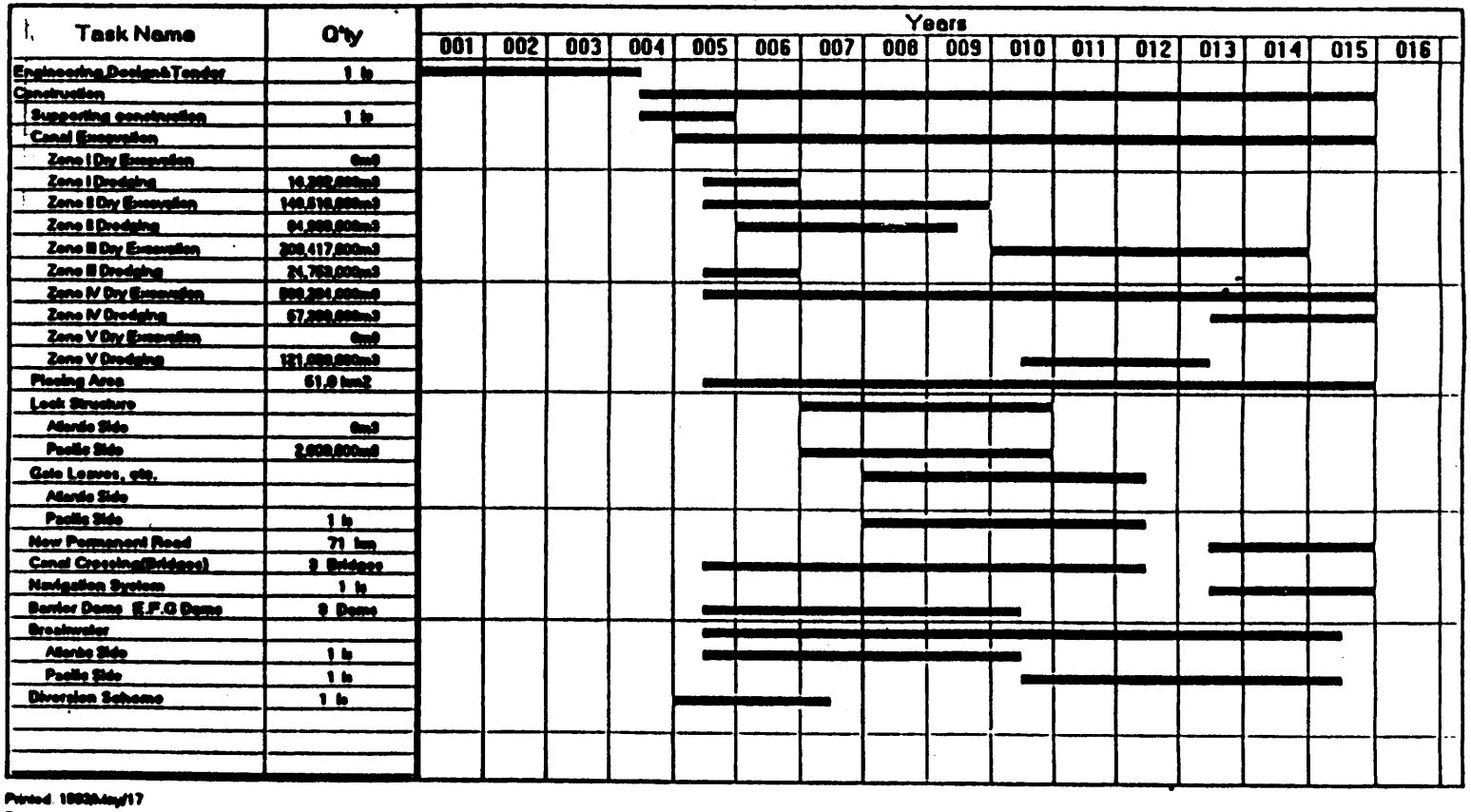

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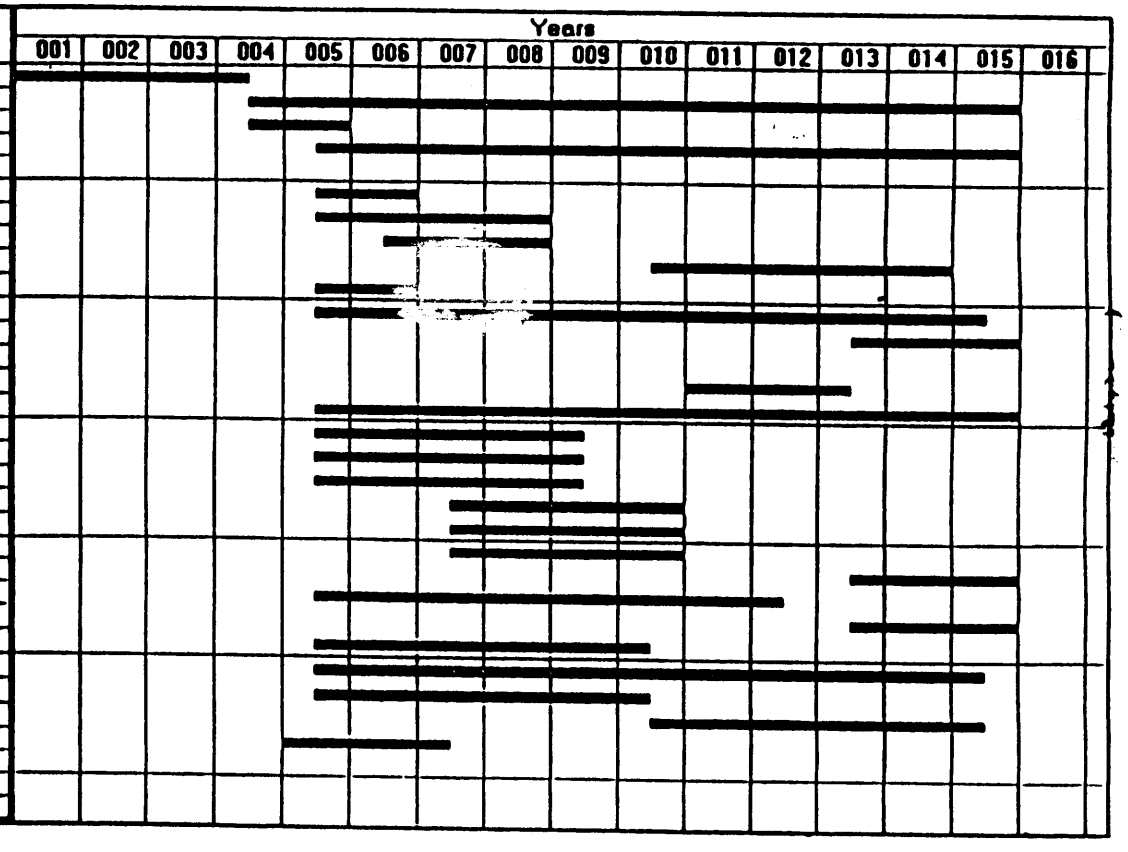
Figure 6.4.6-4

Overall Work Schedule - Sea Level Canal, Route 10, Case - (e)

250,000 dwt, 2020

Task Name	Q'ty
Engineering,Design&Tender	
Construction	
Supporting construction	
Canal Excavation	
Zone I Dry Excavation	0m3
Zone I Dredging	16,262,000m3
Zone II Dry Excavation	166,985,000m3
Zone II Dredging	67,289,000m3
Zone III Dry Excavation	208,417,000m3
Zone III Dredging	24,783,000m3
Zone IV Dry Excavation	994,674,000m3
Zone IV Dredging	62,862,000m3
Zone V Dry Excavation	0m3
Zone V Dredging	97,188,000m3
Placing Area	51.9 km2
Gate Structure	
Atlantic Side	600,000m3
Pacific Side	600,000m3
Gate Leaves, etc.	
Atlantic Side	1 ls
Pacific Side	1 ls
New Permanent Road	71 km
Canal Crossing(Bridges)	9 Bridges
Navigation System	1 ls
Barrier Dams E,F,G Dams	3 Dams
Breakwater	
Atlantic Side	1 ls
Pacific Side	1 ls
Diversion Scheme	1 ls



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- Total construction schedule for the HRLC - 200,000 dwt option is shorter by one-half year due to scheduling construction of the new permanent roads and installation of navigation systems earlier than scheduled for Phase II Report. Therefore, total construction time is now 10 years instead of 10.5 years.

- Total construction schedule for SLC-10, 250,000 dwt option remained at 15 years as was estimated for the Phase II Report.

It should be noted that for both HRLC, 150,000 and 200,000 dwt options, the total construction schedule can be shorten by 1/2 to 1 year by earlier rescheduling of the Atlantic and Pacific gate leaf and navigation systems delivery and installation. A much closer fabrication site (for gate leaf) than Japan may help realize time and cost savings.

6.4.7 Cost Estimate

The same assumptions and criteria used to estimate cost of construction for the Phase II Report presented in Section 6.3.8 were used to generate costs for options studied in Phase II-Additional Work. Tables 6.4.7-1 and 6.4.7-2 present summary of construction material and equipments and the total construction cost for the new options studied. It should be noted that the changes made during the Phase II Additional Work if included in the final design will provide the following construction cost savings.

- For the HRLC-150,000 dwt option, a reduction in total construction cost of 38% or $3.36 billion from that of Phase II Report will be realized. For the HRLC-200,000 dwt option, the reduction is 35% or $3.52 billion dollars.

- For the SLC-10, 250,000 dwt options, the average reduction in construction cost of 30% or $4.69 billion will be realized.

Table 6.4.7-1
Construction Cost Estimates

(File: Sum-1)

Alternatives / ITEMS	Unit	High Rise Lock Canal Case (5) 2020	High Rise Lock Canal Case (6) 2020	SEA LEVEL CANAL Case (d) 2020	SEA LEVEL CANAL Case (e) 2020
A. FEATURES OF ALTERNATIVES					
1. Design Ship	1000DWT	150	200	250	250
2. Route		1	1	10	10
3. Lake Level	ft	85	85	-	-
4. Number of Lift	no.	2	2	-	-
5. Canal Width	m	160, 320	175, 350	190	190
6. Approach Channel Width	m	320	350	190, 380	190, 380
7. Total Route Length	Km	84.1	87.6	88.4	86
- Pacific Approach	Km	14.3	17.5	25.1	22.7
- Channel	Km	55.7	55.7	60	60
- Atlantic Approach	Km	14.1	14.4	3.3	3.3
8. Channel Depth	m	21	22	24	24
B. WATER MANAGEMENT					
1. Available Water					
a. Average year	Mill M3	5,647	5,647	4,331	4,331
b. Dry year	Mill M3	3,951	3,952	3,148	3,148
2. Water Consumption for Existing Canal					
a. Ship Transits	no.	16,200	16,200	16,200	16,200
b. Water Volume Required	Mill M3	2,867	2,867	2,867	2,867
3. Water Consumption for New Lock					
a. Ship Transits	no.	2,000	2,000	-	-
b. Water Volume Required	Mill M3	1,014	1,201	-	-
4. Total Water Consumption: 2.b + 3.b	Mill M3	3,881	4,068	2,867	2,867
5. Available Freshwater (as barrier)					
a. Freshwater from Gatun Watershed	Mill M3	-	-	1,159	1,159
b. Freshwater from Outside Gatun	Mill M3	-	-	737	737
6. Countermesures to be taken					
a. Upper Gatun Dam (as regulating)	Mill M3	-	-	-	-
b. Trinidad Dam (as regulating)	Mill M3	-	-	-	-
c. Ciri Dam (as regulating)	Mill M3	-	-	-	-
d. Indio Dam (as water source)	Mill M3	-	591	-	-
e. Pumping Station	Mill M3	-	-	-	-
C. MAIN ELEMENTS OF ALTERNATIVES					
1. Lock & Gate					
(1) High Rise Lock					
a. Lock Chamber (LxWxD)	note-1	(A)	(B)	-	-
b. Gates					
- Max. Operating Gate Dimensions (BxH)	m	50x39.1	55x40.6	-	-
- Operating Gate Total Number (in pair)	nos.	6	6	-	-
- Operating Gate Total Weight	1000 ton	15.8	19.2	-	-
- Culvert Gate Number	nos.	18	18	-	-
- Culvert Gate Dimensions (BxH)	m	7.5x8.1	8.2x8.4	-	-
- Maintenance Gate (weight x number)	ton	5600 x 1	6700x1	-	-
- Emergency Gate (weightx number)	ton	2500 x 2	2950x2	-	-
c. Number of Mules	nos.	40	40	-	-
(2) Tidal Lock					
a. Lock Chamber (LxWxD)	m	-	-	(c)	-
b. Gates		-	-		-
- Operating Gate Dimensions (BxH)	m	-	-	60x30.6	-
- Operating Gate Total Number	nos.	-	-	2	-
- Operating Gate Total Weight	1000 ton	-	-	3.1	-
- Culvert Gate Number	nos.	-	-	4	-
- Culvert Gate Dimensions (BxH)	m	-	-	6.0x6.0	-
- Maintenance Gate Weight	1000 ton	-	-	7.4	-
c. Number of Mules	nos.	-	-	10	-
(3) Tidal Gate					
- Gate Dimensions (BxH)	m	-	-	-	190x27.5
- Gate Total Number	nos.	-	-	-	4
- Gate Total Weight	1000 ton	-	-	-	33.8
2. Barrier Dams (E),(F),(G)in Volume	mill M3	-	-	29	29
3. Canal Excavation					
- Dry Excavation	mill M3	91	100	948	951
- Dredging	mill M3	247	303	304	278
- Total Volume	mill M3	338	403	1,252	1,229
4. Diversion Scheme					
- Cofferdams	nos.	-	-	7	7
- Channels	km	-	-	39	39
5. Canal Crossing (Bridges)	place	2	2	3	3

Note-1: (A)=390x50x20, (B)=420x55x21.5, (C)=430x60x23

Table 6.4.7-2
Construction Cost Estimates

(File: Sys-1)

ITEMS	Unit	High Rise Lock Canal		SEA LEVEL CANAL	
		Case (5) 2020	Case (6) 2020	Case (d) 2020	Case (e) 2020
Design Ship	1000DWT	150	200	250	250
Route		1	1	10	10
Lake Level	ft	85	85	-	-
6. New Roads	km	32	32	71	71
7. Breakwater	mill.m3			18	18
8. Navigation Support System					
a. Jetty for Small Boats	nos.	8	8	7	5
b. Berthing Dolphin	nos.	8	8	8	8
c. Navigation Bouy	set	74	74	78	78
d. Canal Lighting	set	60	60	786	786
e. Tug Boats					
- 6000 HP	nos.	23	23	16	10
- 3000 HP	nos.	2	2	9	7
D. CONSTRUCTION COST					
1. Canal Excavation	mill US$	1,593	1,893	6,244	5,900
2. Placing Area	mill US$	88	88	189	189
3. Lock & T. Gate structure	mill US$	855	971	504	429
4. Lock & T. Gate (Mechanical) -Gates Related	mill US$	889	1,011	316	738
5. New Dams					
a. Upper Gatun Dam (as regulating)	mill US$	-	-	-	-
b. Trinidad Dam (as regulating)	mill US$	-	-	-	-
c. Ciri Dam (as regulating)	mill US$	-	-	-	-
d. Indio Dam (as water source)	mill US$	-	237	-	-
6. Pumping Stations	mill US$	-	-	-	-
7. New Parmanent Road	mill US$	9	9	19	19
8. Canal Crossing	mill US$	450	501	188	222
9. Barrier Dams	mill US$	-	-	494	494
10. Diversion Scheme	mill US$	-	-	75	75
11. Navigation Support System	mill US$	414	414	546	477
12. Breakwater	mill US$	-	-	402	402
13. Supporting Construction	mill US$	291	291	481	481
14. Indirct Cost	mill US$	829	960	1,430	1,425
Total Project Cost	mill US$	5,418	6,375	10,888	10,851
E. O & M COST					
1. Electrical Power	mill US$	10.4	10.8	2.6	0.6
2. Man Power and Other O&M Costs	mill US$	103.9	112.2	154.6	144.3
3. Total O&M Cost	mill US$	114	123	157	145
F. CONSTRUCTION ASPECTS					
1. Adaptability of Partial Construction	grade	Possible	Possible	Impossible	Impossible
2. Sufficiency of Engineering/Cost Data	grade	Fair	Fair	Poor	Poor
3. Interference by Existing Canal Operations	grade	Heavy	Heavy	Some	Some
4. Construction Period	year	10.0	10.0	15.0	15.0
G. IMPACT ON EXISTING SITUATION					
1. Impact on Existing Panama Canal					
a. Interference to Existing Canal Operations	grade	Considerable		Some	
b. Modification Works to Existing Panama Canal	grade	Minor		Minor	
2. Potential Environmental Impact					
a. Possible Gatun Lake Salinity Increase	grade	Same as SQ		Same as SQ	
b. Both Oceans Intermixing	grade	Same as SQ		Significant	
c. Ecologically Sensitive Areas	grade	Low		Medium	
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A Feasibility Report

7.0 Phase III - Feasibility Analysis

7.1 Economic Analyses

7.1.1 Introduction

Economic analysis of the pre-screened alternatives including the additional cases of the Culebra Cut Single Lane (High Rise Lock Canal) and Sea Level Canal with single lane approach was presented in Final Report of EAIU (Economic Analysis and Impact on Users) component study. The purpose of Economic Analysis was cost-benefit analysis of alternatives. This sub-section focuses on economic analysis of alternatives; the EAIU's study on impact on users is discussed and analyzed in the sub-section of 7.5.

Estimation of direct benefit is an important study item of Economic Analysis. Results of Commodity and Traffic Projection (CTP) study in Phase II are the valuable inputs for estimation of direct benefits. SINBOL analyzed both component studies of CTP and EAIU, and identified some issues regarding benefit estimates. These issues are discussed in the chapter 8.2.3 and 8.3.3

7.1.2 Alternatives

Pre-screened Alternatives

As a result of optimization study in section 5.5, the conceptual alternatives selected were 1) High Rise Lock Canal (HRLC), and 2) Sea Level Canal Route 10 (SLC 10). In Phase II the following alternatives for HRLC were studied in the ECE study.

- Design ship 150,000 DWT, Gatun Lake at 85 ft
- Design ship 200,000 DWT, Gatun Lake at 85 ft
- Design ship 150,000 DWT, Gatun Lake at 90 ft
- Design ship 200,000 DWT, Gatun Lake at 90 ft

In Phase II, the following 250,000 DWT cases were studied for the SLC Route 10:

- Single lane canal with 2 lane approaches. Tidal locks on the Pacific side (3 lanes with the option of adding a 4th lane later);

- Single lane canal with 2 lane approaches. Tidal gates (1 lane) on both Pacific and Atlantic sides; and,

- Single lane canal with 2 lane approaches. Tidal locks on the Pacific side (case 5) plus a tidal gate (1 lane) on the Atlantic side.

Additional Cases (Variation of Pre-screened Alternatives)

Further variations of the HRLC for 150,000 and 200,000 DWT design ship size with a Gatun Lake level of 85 ft were studied. The variations considered in the additional works involve a single lane canal through the Culebra Cut section, were:

- Design ship 150,000 DWT, Gatun Lake at 85, ft Culebra Cut Single Lane; and,

- Design ship 200,000 DWT, Gatun Lake at 85, ft Culebra Cut Single Lane.

Further variations of the SLC Route 10 were also studied. The variation considered in the additional works were:

- Variation of case 5 Tidal locks on the Pacific side have a single lane only; and,

- Variation of case 6 The Atlantic approach channel between the coastal line and the Atlantic tidal gate is a single lane approach.

Alternatives for Economic Analysis

In the case of HRLC, an option of Gatun Lake at El 90 ft was not considered as alternatives of Economic Analysis because HRLC with a Gatun Lake at 85 ft was proved to be the least-cost alternative.

Accordingly, the alternatives of case (3) and (4) were excluded from those for Economic Analysis.

7.1.3 Concept of Direct Benefits

Methodology

Direct benefits were defined as transportation costs saved by implementation of the enhancement of the canal. Transportation costs saving was measured by cost difference between "with and without project conditions." Transportation costs of "with and without project conditions" means ocean shipping costs in the canal route and the least-cost alternative routes by each of origin-destination pair.

Types of Benefits

Types of direct benefits were defined in EAIU study as follows:

(a) *Route-shifting by over-panamax:* Benefits of cargos on over-panamax vessels which can pass through a new canal due to the enlargement of the canal.

(b) *Route-shifting by under-panamax:* Benefits of cargos on under-panamax vessels which can not use the existing SQ canal in "without project condition" because of the capacity limitation and come to use a new canal after the operation of a new canal.

(c) *Size-shifting:* Benefits of cargos carried on small vessels in the SQ canal in "without project condition" and come to be carried on larger vessels after the operation of a new canal in "with project condition."

7.1.4 CTP Study as Base Data

The base data employed for estimation of direct benefits were 1) transit cargo flow projection of each origin-destination pair by type of ship and size range of ship, and 2) unit transportation cost of ships in each origin-destination pair by type of ship and size range of ship. Both data are derived from the CTP study in Phase II.

Transit Cargos

Size distribution of transit cargos for the SQ, 150,000 DWT, 200,000 DWT, and 250,000 DWT in 2020 and 2060 by origin-destination (O-D) route and type of ship (with project condition) are presented in volume IV of CTP (II) Final Report. O-D pairs are 69 routes in total. Ships for transit cargos are 10 types. Ship types are given below with abbreviation presented in Table 7.1.4-1.

Table 7.1.4-1
Abbreviations of Types of Vessels

CB :	container-breakbulk ships	LP :	liquid petroleum ga
CD :	combined and dry bulk carriers	RE :	refrigerated cargo ships
CG :	conventional general cargo ships	RR :	roll-on roll-off ships
CT :	chemical tankers	OT :	oil tankers
FC :	full container ships	VC :	vehicle carriers

Table 7.1.4-2
By-Pass Commodities

O-D Routes		Commodity	Trade Flow (10^6 ton)		Mileage (n.m.)	
			2020	2060	P.C.	Alt
1	USEC-Far East	Coal	56.97	75.05	9748	15126
2	Colombia-Far East	Coal	0.41	0.50	8041	13834
3	Canada W.C.-Europe	Coal	2.59	1.84	9008	14475
4	Canada W.C.-Brazil	Coal	0.85	0.90	7395	10362
5	North Brazil-Far East	Iron ore	43.48	47.42	10253	12657
6	Venezuela-Far East	Iron ore	1.77	1.23	9051	13787
7	Canada E.C.-Far East	Iron ore	1.72	3.03	10738	15480
8	Chile-Europe	Iron ore	2.90	3.89	7197	9360
9	Venezuela-Far East	Orimulsion	14.0	14.0		
10	Asia-USEC	Container	11.2	13.0	-	-
11	USEC-Asia	Container	17.8	21.8	-	-
12	Europe-USWC	Container	2.8	3.1	-	-
13	USWC-Europe	Container	3.4	3.8	-	-

Source: Vol. I of, CTP (II)

Data on bypass commodities with respect to size distribution and unit cost by ship size are shown in Vol. I of CTP (II).

Both size distribution (ship mix) and unit cost are given for the canal route and the least-cost alternative routes. Data on bypass commodities are essential for estimation of route-shifting benefit by over-panamax vessels. Ports of origin and destination were implicitly given for calculation of mileage between ports of O-D for both the canal route and the least-cost alternative route. Accordingly ports of O-D are specific to each bypass commodities. The features of those commodities are summarized in Table 7.1.4-2.

Comparison of transportation costs of container cargo between the Canal route and alternative (land bridge) is based on the different transportation mode. The following table (Table 7.1.4-3) shows comparison of unit transportation cost of Full Containers ships via the Panama canal and alternative routes in trade route of Europe-USWC and Asia-USEC in 2020.

Table 7.1.4-3

Unit Transportation Costs of Container Cargo via Panama Canal and Alternative Routes (US$ per ton)

Routes	DWT				
	20,700	32,700	48,080	90,000	148,000
(1) Europe-USWC					
Panama Canal	244	203	199	184	179
Land Bridge	242	217	214	202	199
(2) Asia-USEC					
Panama Canal	340	290	285	266	260
Land Bridge	316	280	276	260	255

Source: CTP FR of Phase II

The table shows that ocean transportation costs via PC is higher than landbridge costs in the trade route of Asia-USEC. Accordingly route-shifting benefits of container cargo can not be expected in the Asia-USEC route.

Unit Cost for SQ Case

Unit transportation cost for the SQ case is given in Volume II of CTP (II) FR with respect to O-D routes, ship types, and ship size. An example is shown below presented in Table 7.1.4-4.

O-D routes:	From USEC to Asia
Type of ships:	CD (Combine and dry bulk carriers)
Mileage:	Via Panama Canal (PC) 9375
	Via Alt. route 15525

Table 7.1.4-4

Unit Transportation Costs of CD Cargo via Panama Canal and Alternative Routes

US$ per ton

Unit Cost ($/ton)	0 9,999	10,000 24,999	25,000 39,999	40,000 64,999	65,000 99,999
Panama Canal			17	14	12
Alternate Route			25	21	18
Balance			8	7	6

Use of Base Data

Base data were employed to estimate direct benefits in the EAIU study. The formula of benefits estimate was defined as follows:

(a) Route-shifting benefit

$$B = Q \times (Ca - Cp)$$

where
- B: Benefits attributable to over-panamax or under-panamax vessels
- Q: Cargo volume to be carried by over-panamax or under-panamax vessels which shift from alternative routes to the canal route
- Ca: Unit transportation cost of the least cost alternative route
- Cp: Unit transportation cost of the canal route

(b) Size-shifting benefits

$$B = TCb - TCa$$

where
- TCb: Total transportation cost of SQ transit cargos (without project condition)
- TCa: Total transportation cost of SQ transit cargos for 150,000 DWT, 200,000 DWT, and 250,000 DWT (with project condition).

Size shifting benefits will be expected on the assumption that the transportation cost saved is ascribed to the difference of ship size distribution of SQ transit cargos between with and without project conditions. This is because some of SQ transit cargos will be carried by larger ship in "with project condition," resulting in lower transportation costs.

Benefits estimated by O-D and type of ships, benefits attributable to bypass commodities were separately discussed in Final Report of EAIU. The route-shifting benefit attributable to over-panamax vessels are commodity-specific benefits.

7.1.5 Estimation of Direct Benefits

Benefit Estimate of First Step

Benefit estimate of first step was conducted with the following conditions:

(a) Three types of benefits for 150,000 DWT, 200,000 DWT and 250,000 DWT in 2020 and 2060 were estimated. Then benefit streams between 2020 and 2060 for 150,000 DWT, 200,000 DWT and 250,000 DWT were made on the assumption that benefits would increase at a constant rate.

(b) As to route-shifting benefits by under-panamax vessels, the capacity of SQ canal was taken into account based on the result of Phase I OCCE Study. Transit cargo for SQ, 150,000 DWT, 200,000 DWT and 250,000 DWT by ship type and size in 2020 and 2060 were shown in Table 7.1.5-1 and 7.1.5-2. The SQ transit cargo shown in Table 7.1.5-1 and 7.1.5-2 is a constrain demand projection.

Three types of benefits for 150,000 DWT, 200,000 DWT and 250,000 DWT in 2020 and 2060 by ship type are summarized in Table 7.1.5-3 and 7.1.5-4.

Benefit estimate of first step was featured as follows:

(c) Route-shifting benefits by over-panamax vessels are derived from ship types of CD, FC and OT. Derivation of route-shifting benefits is related to bypass commodities. Bypass commodities (coal, iron ore and orimulsion) are bulky cargos transported by CD and OT. Commodities to be carried by FC are container cargo between USWC and Europe and between Asia and USEC

(d) Route-shifting benefits by under-panamax vessels was none in 2020 but substantial in 2060 because demand for the SQ transit cargo in 2060 is the constraint projection. Transit cargos for 150,000 DWT, 200,000 DWT and 250,000 DWT are not the constraint projection. Accordingly cargos to be carried by under-panamax vessels over SQ transit cargos will have to divert to alternative routes in the case of "without-project condition."

(e) Increase of total benefits in proportion to enlargement of canal size from 150,000 DWT to 250,000 DWT is marginal. Total benefits marginally increase from 473 to 516 million US$ in 2020, and from 1061 to 1116 million US$ in 2060. Such incremental benefits are mostly derived from route-shifting benefits by over-panamax vessels.

The calculation method of route-shifting benefit by over-panamax vessels and size-shifting benefits is somewhat complicated because those cargos corresponding to both types of benefits were not projected separately in of CTP (II). An example is given below (Table 7.1.5-5)

Table 7.1.5-1

Transit Cargo by Canal Alternative, Ship Sizes, and Ship Types

(Year=2020) Range of Vessel Size (DWT) (1,000 tons)

Ship Type	Max. Vess. Size 1,000 DWT	0 9,999	10,000 39,999	40,000 64,999	65,000 99,999	100,000 149,999	150,000 199,999	200,000 250,000	Total
CD	SQ	0	47,355	65,692	14,519				127,566
	150	0	43,684	57,973	24,678	78,485			204,820
	200	0	43,735	57,973	24,626	62,938	17,868		207,140
	250	0	43,735	57,973	24,626	62,938	17,404	6,986	213,662
FC	SQ	6	16,151	26,260					42,417
	150	6	14,738	17,707	13,786				46,237
	200	6	14,738	17,707	13,786				46,237
	250	6	14,738	17,707	13,786				46,237
OT	SQ	392	6,755	13,537	1,299				21,983
	150	392	6,790	8,354	6,447	14,000			35,983
	200	392	6,790	8,354	6,447		14,000		35,983
	250	392	6,790	8,354	6,447			14,000	35,983
CB	SQ	0	16,389	9,164					25,553
	150	0	16,389	9,164					25,553
	200	0	16,389	9,164					25,553
	250	0	16,389	9,164					25,553
CT	SQ	1,580	18,927	3,776					24,283
	150	1,580	18,927	3,776					24,283
	200	1,580	18,927	3,776					24,283
	250	1,580	18,927	3,776					24,283
CG	SQ	838	7,858						8,696
	150	838	7,858						8,696
	200	838	7,858						8,696
	250	838	7,858						8,696
LP	SQ	177	1,970	449					2,596
	150	177	1,970	449					2,596
	200	177	1,970	449					2,596
	250	177	1,970	449					2,596
RE	SQ	4,072	7,237						11,309
	150	4,072	7,237						11,309
	200	4,072	7,237						11,309
	250	4,072	7,237						11,309
RR	SQ	213	1,482	802					2,497
	150	213	1,482	802					2,497
	200	213	1,482	802					2,497
	250	213	1,482	802					2,497
VC	SQ	90	2,414						2,504
	150	90	2,414						2,504
	200	90	2,414						2,504
	250	90	2,414						2,504
Total	SQ	7,368	126,538	119,680	15,818	0	0	0	269,404
	150	7,368	121,489	98,225	44,911	92,485	0	0	364,478
	200	7,368	121,540	98,225	44,859	62,938	31,868	0	366,798
	250	7,368	121,540	98,225	44,859	62,938	17,404	20,986	373,320

Source: Final Report of EAIU

Table 7.1.5-2

Transit Cargo by Canal Alternative Ship Size, and Ship Types

(Year=2060) Range of Vessel Size (DWT) (1,000 tons)

Ship Type	Max. Vess. Size 1,000 DWT	0 9,999	10,000 39,999	40,000 64,999	65,000 99,999	100,000 149,999	150,000 199,999	200,000 250,000	Total
CD	SQ	0	26,070	56,387	32,732				115,189
	150	0	59,527	76,178	65,315	87,026			288,046
	200	0	59,527	76,178	65,315		91,105		292,125
	250	0	59,527	76,178	65,315		88,973	15,933	305,926
FC	SQ		15,381	31,439					46,820
	150		19,168	18,660	12,962	8,076			58,866
	200		19,168	18,660	12,962	8,076			58,866
	250		19,168	18,660	12,962	8,076			58,866
OT	SQ	244	2,719	2,325	728				6,016
	150	372	5,081	5,973	3,044	14,000			28,470
	200	372	5,081	5,973	3,044		14,000		28,470
	250	372	5,081	5,973	3,044			14,000	28,470
CB	SQ	0	23,019	11,635					34,654
	150	0	28,944	15,161					44,105
	200	0	28,944	15,161					44,105
	250	0	28,944	15,161					44,105
CT	SQ	1,455	24,079	7,381					32,915
	150	1,648	25,624	7,739					35,011
	200	1,648	25,624	7,739					35,011
	250	1,648	25,624	7,739					35,011
CG	SQ	1,326	12,183						13,509
	150	1,705	14,281						15,986
	200	1,705	14,281						15,986
	250	1,705	14,281						15,986
LP	SQ	150	656	265					1,071
	150	150	1,087	265					1,502
	200	150	1,087	265					1,502
	250	150	1,087	265					1,502
RE	SQ	2,385	13,721						16,106
	150	2,894	14,919						17,813
	200	2,894	14,919						17,813
	250	2,894	14,919						17,813
RR	SQ	407	1,666	925					2,998
	150	414	2,516	1,280					4,210
	200	414	2,516	1,280					4,210
	250	414	2,516	1,280					4,210
VC	SQ	104	2,816						2,920
	150	104	2,828						2,932
	200	104	2,828						2,932
	250	104	2,828						2,932
Total	SQ	6,071	122,310	110,357	33,460	0	0	0	272,198
	150	7,287	173,975	125,256	81,321	109,102	0	0	496,941
	200	7,287	173,975	125,256	81,321	8,076	105,105	0	501,020
	250	7,287	173,975	125,256	81,321	8,076	88,973	29,933	514,821

Source:Final Report of EAIU

Table 7.1.5-3

Summary of Benefits in the Year 2020

(1,000 US$)

Type	Benefit / Alternatives	Route-shift by Over-panamax	Size-shift	Route-shift by Under panamax	Total	(%)
CB	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
CD	150,000 DWT	195,275	34,927	0	230,202	48.7%
	200,000 DWT	211,465	35,187	0	246,652	49.7%
	250,000 DWT	218,451	35,187	0	253,638	49.2%
CT	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
FC	150,000 DWT	16,919	215,933	0	232,852	49.2%
	200,000 DWT	16,919	215,933	0	232,852	46.9%
	250,000 DWT	16,919	215,933	0	232,852	45.2%
CG	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
LP	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
RE	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
RR	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
OT	150,000 DWT	4,900	4,851	0	9,751	2.1%
	200,000 DWT	11,900	4,851	0	16,751	3.4%
	250,000 DWT	24,220	4,851	0	29,071	5.6%
VC	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
Total	150,000 DWT	217,094	255,711	0	472,805	100.0%
	200,000 DWT	240,284	255,971	0	496,255	100.0%
	250,000 DWT	259,590	255,971	0	515,561	100.0%

Source: Final Report of EAIU

Table 7.1.5-4
Summary of Benefits in the Year 2060
(1,000 US$)

Type	Benefit / Alternatives	Route-shift by Over-panamax	Size-shift	Route-shift by Under panamax	Total	(%)
CB	150,000 DWT	0	0	14,254	14,254	1.3%
	200,000 DWT	0	0	14,254	14,254	1.3%
	250,000 DWT	0	0	14,254	14,254	1.3%
CD	150,000 DWT	412,499	20,898	260,128	693,525	65.4%
	200,000 DWT	429,536	22,050	260,128	711,714	65.4%
	250,000 DWT	443,523	22,050	260,128	725,701	65.4%
CT	150,000 DWT	0	0	3,566	3,566	0.3%
	200,000 DWT	0	0	3,566	3,566	0.3%
	250,000 DWT	0	0	3,566	3,566	0.3%
FC	150,000 DWT	23,053	270,497	3,622	297,172	28.0%
	200,000 DWT	23,053	270,497	3,622	297,172	27.3%
	250,000 DWT	23,053	270,497	3,622	297,172	26.6%
CG	150,000 DWT	0	0	5,552	5,552	0.5%
	200,000 DWT	0	0	5,552	5,552	0.5%
	250,000 DWT	0	0	5,552	5,552	0.5%
LP	150,000 DWT	0	0	0	0	0.0%
	200,000 DWT	0	0	0	0	0.0%
	250,000 DWT	0	0	0	0	0.0%
RE	150,000 DWT	0	0	10,565	10,565	1.0%
	200,000 DWT	0	0	10,565	10,565	1.0%
	250,000 DWT	0	0	10,565	10,565	0.9%
RR	150,000 DWT	0	0	379	379	0.0%
	200,000 DWT	0	0	379	379	0.0%
	250,000 DWT	0	0	379	379	0.0%
OT	150,000 DWT	9,854	0	26,203	36,057	3.4%
	200,000 DWT	18,675	0	26,203	44,878	4.1%
	250,000 DWT	32,394	0	26,203	58,597	5.3%
VC	150,000 DWT	0	0	37	37	0.0%
	200,000 DWT	0	0	37	37	0.0%
	250,000 DWT	0	0	37	37	0.0%
Total	150,000 DWT	445,406	291,395	324,306	1,061,107	100.0%
	200,000 DWT	471,261	292,547	324,306	1,088,117	100.0%
	250,000 DWT	498,970	292,547	324,306	1,115,823	100.0%

Source:Final Report of EAIU

Table 7.1.5-5

Transit Cargo By CD from Canada WC to Europe

(Million ton)

	0 9,999	10,000 39,999	40,000 64,999	65,000 99,999	100,000 149,999	Total
SQ		2.98	5.65	1.18	-	9.81
150,000 DWT		2.51	4.20	1.87	2.60	11.18
150,000 DWT-SQ		-0.47	-1.45	0.69	2.60	1.37
PC cost ($/ton)		17	14	12	8	
Alt cost ($/ton)		24	20	17	11	

Source: FR of EAIU (page A-II-6)

This table shows transit cargo by CD in the route from Canada WC to Europe in 2020. The followings were discussed in EAIU study:

1) Incremental cargo between SQ and 150,000 DWT is 1.37 million tons corresponding to route-shifting cargo by over-panamax vessels.

2) About 2.6 million tons are carried by CD with size range from 100,000 to 149,999 DWT. The cargo difference of 2.6 less 1.37 (1.23 million tons) is considered to be size-shifting cargo.

   0.47 and 1.45 million tons switching from 10,000 - 39,999 and 40,000 - 64,999 DWT ships are also considered to be size-shifting cargos. But this point was not clearly stated in EAIU study. Both benefits of size-shifting and route-shifting are calculated as follows:

3) Size-shifting $= (2.98\times17+5.65\times14+1.18\times12)$

   $- (2.51\times17+4.20\times14+1.87\times2+1.23\times8)$

   $= 10.2\times10^6$ US$

   Route-shifting $= (1.37\times11-1.37\times8) = 4.1\times10^6$ US$

   Total benefits $= 14.3 \times 10^6$ US$

The split of cargos into route-shifting and size-shifting is actually difficult. Taking into account that three types of benefits are measured by transportation cost saving separation of benefits into three types is not necessary for estimation of total benefits. Transit cargos by CD from Canada WC to Europe includes trade of the Canadian coal.

The following table shows the commodity, specific benefit separately.

Table 7.1.5-6

Size Distribution of Coal from Canada WC to Europe by CD
(Million ton)

	0 9,999	10,000 39,999	40,000 64,999	65,000 99,999	100,000 149,999	100,000 149,999	Total
SQ				1.24	(0.41)	(0.95)	2.60
150 DWT					2.60		2.60
200 DWT					0.78	1.82	2.60
250 DWT-SQ					0.78	1.82	2.60
PC cost ($/ton)				17.1	11.9	10.5	
Alt cost ($/ton)					15.0	13.3	

Source: FR of CTP (II) Vol. I (page 5-22)

The above table (Table 7.1.5-6) shows the Canadian coal by CD from Canada WC to Europe in 2020. Parentheses indicate coal to be transported in alternative route in "without project condition" Total benefits for 150,000 DWT are calculated as follows:

$$B_1 = (1.24\times17.1+0.41\times15.0+0.95\times13.3)-(2.60\times11.9)$$
$$= 9.05\times10^6 \text{ US\$}$$

In EAIU study transportation cost of alternative route should have been shown for SQ case for calculation for transport cost saving, as shown in Table 7.1.5-7.

Table 7.1.5-7

Size Distribution of Transit Cargo From Canada WC to Europe by CD

(Million ton)

	0 9,999	10,000 39,999	40,000 64,999	65,000 99,999	Total
SQ 150 DWT	2.98 2.51	5.65 4.20	- 1.87		8.6 8.6
PC cost ($/ton) Alt cost ($/ton)	17 24	14 20	12 17		

Source: CTP (II) Vol. IV (Total cargo is rounded-up.)

The above table shows cargo by under-panamax vessel for SQ and 150,000 DWT cases. Benefit is simply calculated as follows:

$$B_2 = (2.98\times17+5.65\times14)-(2.51\times17+4.20\times14+1.87\times12)$$
$$= 5.85\times10_6 \text{ US\$}$$

Total benefits are equal to $(B_1+B_2) = 14.9 \times 10_6$ US$

The advantages of calculation method above are:

1) Commodity-specific benefits can be calculated separately.

2) Split of benefits into route-shifting and size-shifting is not necessary.

Benefit Estimate of Second Step

Benefit estimate of second step was conducted with the following conditions in the EAIU Study.

(a) The capacity of SQ and alternative canal is taken into account. The capacity is defined as the maximum passable number of transit vessels for SQ and each canal alternative (see FR of OCCE in Phase II). The capacity of SQ and that of each alternative plus SQ is given below in Table 7.1.5-8.

Table 7.1.5-8
Capacity of Alternatives

Case	Conceptual Alternative	Ship Size	No. of New Lanes		Remarks	Capacity Annual Transits
			Channel	Lock/Gate		
	SQ					17,000
1 1-a	HRLC HRLC	150,000 DWT 150,000 DWT	2 2	1 1	Culebra Cut Single Lane	34,600 34,400
2 2-a	HRLC HRLC	200,000 DWT 200,000 DWT	2 2	1 1	Culebra Cut Single Lane	35,300 34,600
3 3-a	SLC SLC	250,000 DWT 250,000 DWT	1 1	3+1 1+1	Pacific Tidal Locks Variation of (3)	47,500 24,000
4 4-a	SLC SLC	250,000 DWT 250,000 DWT	1 1	1 1	Tidal gates Single Lane Atlantic Channel	44,000 35,800
5	SLC	250,000 DWT	1	3+1	3 locks plus 1 tidal gate	—

Source: Final Report OCCE (II)

The capacity of a case-5 was not shown in Final Report of Phase II OCCE Study.

The projection of transit vessels estimated by CTP Phase II study is given in Table 7.1.5-9

Table 7.1.5-9
Transit Projection

	1990	2020	2060
SQ	11,162	17,359	18,078
150,000 dwt	-	17,796	23,934
200,000 dwt	-	17,844	24,074
250,000 dwt	-	17,856	24,053

Source: FR of CTP Phase II

The SQ capacity was estimated to be 17,000 vessels. Taking into account transit projection, the SQ canal is expected to reach the capacity in the year of around 2020. Thus residual vessels exceeding over 17,000 will have to divert to alternative routes. Route-shifting benefits by under-panamax vessels has to be re-estimated.

The capacity of each alternative including that of SQ well exceeds over transit vessels projected, except for a case of 3-a. A case of SLC 250,000 DWT Tidal Locks with single lane is expected to reach the capacity in the year of around 2060. Thus benefits of case 3-a beyond 2060 was assumed to be constant in the EAIU Study..

(b) Project life of alternatives is determined to be a period of 101 years from 2020 to 2120. Therefore the year when the number of transit reaches the capacity has to be estimated for each alternative.

Increase rate of transit vessels beyond 2060 was assumed to be constant. As to all cases of High Rise Lock Canal (HRLC) the year when transit reaches the capacity would be around 2110.

The case 4-a of SLC 250,000 DWT, TG with Atlantic single lane approach would reach the capacity around the year of 2060.

The original cases of SLC, cases of (3), (4) and (5) would not be constrained by capacity.

Because of the SQ capacity of around 17,000 vessels route-shifting benefits by under-panamax vessels was re-estimated, Three concepts were introduced in EAIU study.

1) Remove vessels whose cost saving are the smallest.

2) Remove vessels whose cost saving are not negative but the smallest.

3) Remove vessels randomly.

Number of SQ transit vessels and transit cargos associated with transit vessels by O-D route and ship type was put in order on the basis of transportation cost saving presented in Table 7.1.5-10.

Table 7.1.5-10

Transportation Cost Saving by Route, Ship Size and Ship Type

(1) O-D routes	(2) Type	(3) Size	(4) Cost Saving ($/ton)	(5) Cargo Tons	(6) Total Cost (US$)	(7) Nos. of Ships
CAWC-CAEC	V		179	1,143	204,597	1
CAWC-CAEC	F		173	2,261	391,153	2
SAEC-SAWC	OT		0	1,501,709	0	30
Asia-Europe			-26	54,868	0	10

Note:Source: Materials supplied from MRI/YEC (EAIU contractor)

The concept of 1) seems to be reasonable. Vessels navigating in O-D routes where cost saving is zero or negative have no strong incentive of choosing the Canal route.

The concept of 2) is somewhat ambiguous in the reason for excluding vessels in O-D routes where cost saving is negative.

The concept of 3) is in a way reasonable because there is no rule of removing vessels in O-D routes where cost saving is zero or negative in real world. Accordingly vessel in all O-D routes must be the target of vessel to be removed.

The number of vessels to be removed was estimated to be about 260 and 920 in 2020 and 2060 respectively (see Additional Study of EAIU page 14 and 16). Route-shifting benefit by under-panamax vessels corresponding to 260 and 920 is regarded as additional benefits to those estimated at First Step.

For the year of 2020, about 1190 vessels have negative cost saving.

The case of 1) has no additional benefits. In the case of 2), 1190 vessels were excluded. The additional benefit was estimated to be 298 thousand US$.

In the case of 3), average cost saving per ton was calculated. Then this value was multiplied by number of vessels to be removed in order to estimate additional benefits, 77,869 thousand US$.

In the same way, for the year of 2060, the additional benefits of 1), 2) and 3) were estimated to be 135,207, 182,838, and 357,580 thousand US$ respectively.

Additional benefits by case are summarized in Table 7.1.5-11.

Table 7.1.5-11
Additional Benefit
(thousand US$)

	2020	2060
Case 1	0	135,207
Case 2	298	182,838
Case 3	77,869	357,580

Source: Additional Study of EAIU

In EAIU study the case of 3) was adopted as additional benefits. The case of 3) is conceptually justifiable. Nevertheless, when the SQ canal is beginning to be saturated in terms of capacity, most vessels diverting to alternative route would be those in O-D routes where cost saving is negative or zero.

Vessels navigating in O-D routes where cost saving is substantially positive would continue to transit through the Canal even if a Canal Water Time becomes more than 24 hours. Under such circumstance the case of 1) is also the justifiable concept even though benefits are reduced.

Total benefits including additional benefits for 150,000 DWT, 200,000 DWT and 250,000 DWT are shown in Table 7.1.5-12.

Since evaluation period of benefits was determined to be 100 years, the maximum level of benefit for each alternative was estimated based on projection of year when vessel transits projected reach the capacity of each alternative.

Beyond the year of 2060, benefits are assumed to increase in proportion to incremental rate of vessels until the year when transits reach the capacity. After that year, benefits of alternatives are assumed to be constant.

Table 7.1.5-12
Total Direct Benefits
(10^3 US$)

	2020	2060
150,000 DWT		
Original (First Step)	472,805	1,061,107
Additional	77,869	357,580
Total	550,674	1,418,687
200,000 DWT		
Original (First Step)	496,255	1,088,116
Additional	77,869	357,580
Total	574,124	1,445,696
250,000 DWT		
Original (First Step)	515,561	1,115,823
Additional	77,869	357,580
Total	593,430	1,473,403

Source: Additional Study of EAIU

7.1.6 Costs of Alternatives

ECE Study

Project costs of each alternative were originally presented in the Final Report of ECE Phase II study. Project costs consist of those for Phase I (construction period up to the year of 2020) and those for Phase II (construction of later stage). Project costs for Phase II are reserved for construction of dams and pumping stations for the purpose of water requirement.

The amount of project costs of High Rise alternatives in Phase II depends on two conditions. One is Average year rainfall case. The other is Dry year rainfall case. The former was the base case for project costs of each alternative in ECE study. The latter was the additional case instructed by CAS. Project costs in Dry year case is more expensive than those in Average year case. Because construction of large dams is required for 150,000 DWT and installment of pumping stations is required for both 150,000 DWT and 200,000 DWT. Project costs of High Rise alternatives in Dry year case were not presented in the original ECE Final Report.

Estimation of Economic Costs

The base for estimation of economic costs is international prices (border prices). Prices of capital equipments are international prices because those equipments are assumed to be supplied from major industrial countries. Prices of local resources procured in Panama should be converted to border prices by using various conversion factors. Those conversion factors were applied to the cost items below:

1) Unskilled labor

2) Land cost and compensation cost

3) Electricity purchase cost

A portion of depreciation cost was excluded from operation and maintenance costs estimated in Final Report of ECE study because such cost does not reflect resource cost. Economic project costs of each alternative is given in Table 7.1.6-1.

7.1.7 Comparison of Costs and Benefits

Condition and Assumptions

The conditions and assumptions employed for cost-benefit analysis were as follows:

1) Base year is 2010.

2) Project life is 101 years between 2010 and 2020.

3) Commencement year of operation is 2020.

4) Social Discount Rate (SDR) recommended by EAIU study is estimated to be 5 percent per annum as the average value of SDR in USA and Japan because U.S.A. and Japan continue to be the main beneficiaries of the project.

Results

The summary of cost-benefit ratios and internal rate of return of each canal alternative is shown in Table 7.1.7-1. The High Rise alternative of 150,000 DWT Culebra Cut Single Lane attained the best score of IRR (8.5%) and B/C ratio of 2.06 at the discount rate of 5%. In the case of HRLC 150,000 DWT, benefits in 2 lane option is the same as those in single lane option because the capacity of both alternatives are almost the same.

Table 7.1.6-1
Economic Project Costs

Case	Alternatives (Average Year Case)			Economic Costs Million US$
1	HRLC	150,000 DWT		8.761
1-a	HRLC	150,000 DWT	Culebra Cut Single Lane	6.670
2	HRLC	200,000 DWT		9.877
2-a	HRLC	200,000 DWT	Culebra Cut Single Lane	7.721
3	SLC	250,000 DWT	4 Lanes of Pacific tidal locks	15.113
3-a	SLC	250,000 DWT	2 Lanes of Pacific tidal locks	12.004
4	SLC	250,000 DWT	Tidal gates (TG)	14.000
4-a	SLC	250,000 DWT	TG Single Lane Atlantic Approach	11.551
5	SLC	250,000 DWT	3 Tidal Locks plus tidal gate	15.747
(Dry Year Case)				
1	HRLC	150,000 DWT		8.807
1-a	HRLC	150,000 DWT	Culebra Cut Single Lane	6.865
2	HRLC	200,000 DWT		9.916
2-a	HRLC	200,000 DWT	Culebra Cut Single Lane	7.759

Source: Final Report of EAUI

Costs are lower for a single lane options than for a 2 lane option. Accordingly a single lane option results in higher IRR and B/C ratios than those of 2 lane options.

Sea Level Canal which attained the best score was the SLC 250,000 DWT (TG) with Atlantic Single Lane Approach. Improvement of B/C and IRR regarding the SLC 250,000 DWT (TL) from 3 Lanes to Single Lane was marginal because benefits of single lane tidal lock option is constrained by its capacity.

Table 7.1.7-1

Economic Evaluation of Alternatives

(Average Rainfall Year)

Case	SDR 5%			IRR
	Benefit	Cost	B/C	
1	12,507	7,595	1.65	7.1
1-a	12,507	6,082	2.06	8.5
2	13,146	8,908	1.44	6.5
2-a	11,713	7,182	1.78	7.6
3	13,146	13,975	0.94	4.8
3-a	11,713	11,805	0.99	5.0
4	13,146	13,022	1.01	5.0
4-a	13,129	11,374	1.15	5.0
5	13,146 13,129	14,648	0.90	4.7
Dry Year				
1	12,507	7,799	1.60	7.0
1-a	12,507	6,287	1.99	8.3
2	12,806	9,026	1.42	6.4
2-a	12,806	7,279	1.72	7.5

Source:FR Additional Study of EAIU
Remarks:unit of benefits and costs is million US$

7.1.8 Further Consideration

SINBOL would like to point out the following items for further consideration with respect to "Economic Analysis the issues for further consideration are discussed in the chapter 8.2.3 and 8.3.3."

1) Types of benefits discussed in EAIU study is conceptually understandable. Division of cargo into the different type of benefit (size-shifting and route-shifting) is a bit complicated.

The nature of benefit is simply defined as transportation cost saving with and without project conditions. Thus approach of benefit calculation recommended is the difference of transportation cost via the canal route and that via the least-cost alternative route.

2) The capacity of the SQ canal was estimated to be 17,000 vessels. The difference between demand and capacity with respect to the SQ cargo was counted as additional benefits. The approach of estimating additional benefit in EAIU study is justifiable. The other method (Case 1) was also recommended as sensitivity analysis.

3) Project life was determined to be 100 years. However such a "physical" concept does not need to be applied to evaluation period for calculation of B/C or IRR. Demand projection is limited to projection of transit cargo and vessels in 2020 and 2060. Thus it is recommended that the different scenarios for evaluation period for benefit stream would be considered, i.e. 40 years, 60 years. Reduction of evaluation period from 100 to 40 years would not affect relative ranking of alternatives.

4) The Sea Level Canal 250,000 DWT tidal Locks (TL) with single lane has only a single lane Pacific tidal lock in the initial construction phase and another lane of the tidal lock is scheduled to be constructed before 2060. The capacity of this alternative presented in EAIU study was 24,000 ships. This capacity seemed to be based on only one tidal lock, whereas project costs were those for two tidal locks. Thus benefit has to be re-estimated so as to be compatible with project costs.

7.2 Financing Scheme and Financial Analysis

7.2.1 Introduction

Financing Scheme and Financial Analysis were studied in one of a series of component studies, FFMS (The Financing Scheme, Financial Analysis, and Management Arrangement Study).

Nathan Associates and its associated firms were given Notice to Proceed November 23, 1992, and submitted a Final Report August 7, 1993. This Final Report presented the results of the toll system and revenue studies, the management arrangement review, and the financing scheme and financial analysis for the selected Alternatives. An Annex to the Draft Final Report, which was submitted July 23, 1993, presented the results of the financing scheme and financial analysis for the Variations of the selected Alternatives, which use reduced capital cost estimates of a Culebra Cut Single Lane for the High Rise Lock Canal alternatives and a Single Lane Atlantic approach channel for the Sea Level Canal alternative.

The following description is a summary of the role of Financing Scheme and Financial Analysis in this study. As for Management Arrangements, description will be made in section 7.3.

7.2.2 Main Tasks and Overall Approach of the FFMS Study

The FFMS Study assignment required that the following main tasks to be performed:

- Develop a recommended toll policy and system for each of the Canal alternatives;
- Formulate the most appropriate management arrangement and structure.
- Define an appropriate financing scheme for each of the Canal alternatives;
- Measure the financial viability of each of the canal alternatives; and
- Identify feasible Canal alternatives

The overall approach of the FFMS Study was structured so as to achieve all of these tasks, which is shown in the Figure 7.2.2-1. First of all, an optimal toll schedule and rates were developed through various toll policy analyses and the iterative process of specifying and analyzing alternative toll schedules and rates and identifying the optimal schedule and rates. Then, toll revenues under the above toll schedule and rates were estimated.

These toll revenues together with other revenues, projected annual operating & maintenance costs capital costs of canal alternative, and assumed management arrangement models were input for the financial analysis of the Canal alternatives.

This financial analysis was made based on a reasonable assumption of an appropriate financing configuration or scheme. Finally, as the result of this analysis, the feasible Canal alternatives were identified.

In the FFMS Study, the following Panama Canal alternatives were studied, which include the variations of the selected Alternatives (*) in the list below):

1) High Rise Lock Canal Alternatives

   - High Rise 150,000 DWT Alternative
   - High Rise 200,000 DWT Alternative
   - High Rise 150,000 DWT Culebra Cut Single Lane Alternative (*)
   - High Rise 200,000 DWT Culebra Cut Single Lane Alternative (*)

2) Sea Level Canal Alternatives

- Sea Level 250,000 DWT Pacific Locks Alternative (case A)

- Sea Level 250,000 DWT Tidal Gates Atlantic Single Lane Approach Alternative (case E) (*)

All options presupposed continued use of the existing Canal as modified by the Culebra Cut Widening.

The FFMS Study has obtained the following key inputs from other CAS component studies:

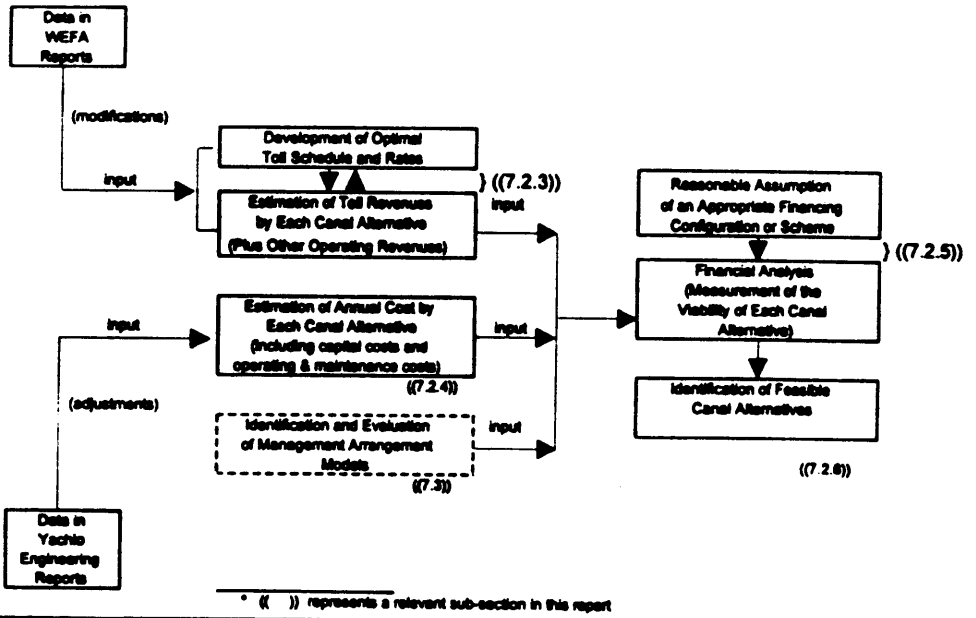
1) Projections of the traffic and transits for each alternative prepared in The WEFA Group, *Final report, Commodity and Traffic Projections Study,* May 7, 1993.

2) Estimations of capital costs and operating & maintenance costs of each of the alternatives prepared in Yachiyo Engineering Co., LTD., *Final Report, Phase 2: Preliminary Engineering and Cost Estimates*, April 1993, and *Annex to Final Report, Phase 2 Additional Work: Preliminary Engineering and Cost Estimates*, June 1993.

Some modifications and adjustments were made to both traffic and transit projections and capital and operating & maintenance costs estimations before imputing them into the financial analysis.

Rationales behind these modifications and adjustments will be explained in Sub-sections 7.2.3 and 7.2.4.

Figure 7.2.2-1
Overall Approach in the FFMS Study



* (( )) represents a relevant sub-section in this report

7.2.3 *Development of Optimal Toll Schedule and Rates and Estimation of Toll and Other Revenues*

Estimates of toll revenues for each Panama Canal alternative under a variety of toll schedules and rates are a critical input for the financial analysis of the Canal alternatives. In this sub-section, firstly the general approach of toll policy analysis is discussed; secondly, based on this approach, detailed methodology for determining optimal toll schedule and rates, which are most relevant among various toll schedule and rates, are explained, and thirdly estimated toll revenues together with other operating revenues are presented.

General Approach of Toll Policy Analysis

The general approach of toll policy analysis consists of the following four steps.

Firstly, the FFMS Study crystallized five basic principles for developing the optimal toll schedule and rates they are:

(a) Maximization of revenue to be generated by the toll rates and traffic volume;

(b) Equity or fairness, that is, whether the toll rates reflect the:
- User's ability to pay which can be measured by value of cargo
- Cost of providing service through the waterway, and
- Value of service to the user.

(c) Promotion of traffic growth in terms of transits and tons carried;

(d) Efficiency of capacity utilization of the waterway; and

(e) Administrative simplicity

At the same time, the first criterium or maximization of revenue was constrained by the following conditions:

(i) Minimum traffic diversions to alternative routes;

(ii) Minimum disruption to the traffic and cargo bases, or to maintain the existing diversity of ship and cargo types to avoid traffic specialization; and

(iii) Toll rate increases capped at 100 percent[1].

[1] Although the Panama Canal remains the least cost alternative route for most shippers, a toll rate increase exceeding 100 percent would be poorly received and indeed viewed with alarm by the shipping community, according to FFMS's review of supporting documentation and interview to shipliners.

As the second step, the current Panama Canal toll policy and rate structure were evaluated in the light of the above five basic principles. Major findings through this step include the point that there is potential to generate significant additional revenues by increasing tolls because the current toll structure does not directly differentiate among ship types, ship sizes, commodity types, and tons carried.

As the third step, a comparative analysis of toll policies and rate schedules was conducted at facilities similar to the Panama Canal, such as Suez Canal and St. Lawrence Seaway. As a result, the FFMS Study specified the following three types of toll policies with rates schedules to be analyzed:

- An earning-capacity-based schedule (the current Panama Canal type)
- A modified earning-capacity-based schedule for which rates varied by ship type and ship size (the Suez Canal type, see Table 7.2.3-1)
- A combination cargo- and earning-capacity-based schedule for which the cargo-based toll varied by cargo type and the earning-capacity-based toll remained the same for all ship types and capacity intervals (the St. Lawrence Seaway type, see Table 7.2.3-2).

Finally, as the fourth step, the optimal toll schedule and rates were developed through re-specifications of alternative schedules and rates. Because of the diversity of cargoes moving through the Panama Canal, a combination cargo- and earning-capacity-based schedule (the St. Lawrence Seaway type) was not considered to be optimal for the Panama Canal from the viewpoint of administrative simplicity[2]. The following iterations then were made:

- Initially, toll revenues and traffic diversions were analyzed and estimated for the current toll schedule with rates increased 50 percent.
- Subsequently, same analysis was made based on the specified current toll schedule with rates increased 100 percent.

[2] Whereas the St. Lawrence Seaway tracks 4 major commodity group and 22 commodities according to St. Lawrence Seaway Department Corporation, Traffic Summary 1991, Table 11 the Panama canal monitors 15 major commodity groups and 115 commodities according to PCC, Annual Report for FY 1991, Table 7.

Table 7.2.3-1

Suez Canal Toll Structure, 1993

(Special Drawing Rights per Suez Canal Net Ton)

	Suez Canal Net Tons Interval											
	First 5,000		Next 5,000		Next 10,000		Next 20,000		Next 50,000		Remaining	
Vessel and Cargo Types	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast	Laden	Ballast
Tankers of crude oil	7.21	6.13	4.02	3.42	3.61	3.07	1.55	1.32	1.55	1.32	1.34	1.14
Tankers of petroleum products	7.21	6.13	4.02	3.42	3.66	3.07	2.06	1.32	2.06	1.32	2.06	1.14
Dry bulk carriers	7.21	6.13	4.02	3.42	2.88	2.45	1.03	0.88	0.98	0.83	0.98	0.83
Combined carriers												
Crude oil only	7.21	—	4.02	—	3.61	—	1.55	—	1.55	—	1.34	—
Petroleum products only	7.21	—	4.02	—	3.66	—	2.06	—	2.06	—	2.06	—
More than one kind of cargo	7.21	—	4.02	—	3.66	—	2.06	—	2.06	—	2.06	—
Dry bulk cargo only	7.21	—	4.02	—	2.88	—	1.03	—	0.98	—	0.98	—
In ballast	—	6.13	—	3.42	—	3.07	—	1.32	—	1.32	—	1.14
Containerships and car carriers	7.21	6.13	4.02	3.42	3.30	2.80	2.37	2.02	2.37	2.02	2.37	2.02
Con-bulker vessels												
Dry bulk cargo	7.21	—	4.02	—	2.88	—	1.03	—	0.98	—	0.98	—
Containerized cargo	7.21	—	4.02	—	3.30	—	2.37	—	2.37	—	2.37	—
Bulk and containerized	7.21	—	4.02	—	3.30	—	2.37	—	2.37	—	2.37	—
In ballast	—	6.13	—	3.42	—	2.45	—	0.88	—	0.83	—	0.83
Empty containers	—	6.13	—	3.42	—	2.80	—	2.02	—	2.02	—	2.02
Other, including gas carriers	7.21	6.13	4.02	3.42	3.66	3.11	2.58	2.19	2.58	2.19	2.58	2.19

Note: Dashes indicate data not applicable. US$1.36887 per Special Drawing Right (SDR) in 1992.
Source: Nathan Associates Inc.

Table 7.2.3-2

St. Lawrence Seaway Toll Structure, 1993 (US$)

Charge Type	Between Montreal and Lake Ontario	Between Lake Ontario and Lake Erie
Vessel charge per gross registered ton	0.11	0.13
Cargo charge per metric ton		
Bulk	1.10	0.55
Containerized	1.10	0.55
Feed grains	0.68	0.55
Food grains	0.68	0.55
General	2.66	0.88
Lock charge		
Per passenger per lock	1.88	1.88
Per cargo vessel per Welland Canal trip		
Laden per lock	—	440.00
In ballast per lock	—	325.00

Note: Dashes indicate data not applicable.
Source: Nathan Associates Inc.

- In additional iterations, the FFMS Study re-specified rates to recapture diverted traffic while maximizing toll revenues. Rates were varied by ship type and size, like those in the Suez Canal.

The detailed methodology for the development of the optimal toll schedule and rates will be described in a previous sub-section.

Detailed Methodology for Determining Optimal Toll Schedule and Rates

Before specifying and analyzing alternative toll schedules and rates, first of all, preliminary modifications were made to the WEFA Group database, including a Panama Canal traffic forecast for 2020 and 2060 for each Canal alternative on "no-toll" basis, so that they could enhance the analysis of Panama Canal tolls. Preliminary data modifications here include:

- Disaggregation of important trade routes from the WEFA Group trade routes and identification of transits and transportation costs for these desegregated routes, such as dry bulk transits from the east coast of South America to Asia and container transits from Asia to the east coast of the United States and vice versa.

- Specification of the distributions of transits by ship type and DWT size interval for the least costly alternative route.

- Computation of the distributions of cargo tons carried by each ship size interval for each trade route via the Panama Canal and the least costly alternative route in 2020 and 2060.

- Computation of the weighted average transportation costs via the Panama Canal and the least costly alternative route in 2020 and 2060.

Based on a result of above modifications, the FFMS Study analyzed and estimated "no-tolls" diversions on a premise of a least-transportation cost approach. That is, the transits and tonnage carried of some ship types and trade routes, in which the weighted average transportation cost via the Panama Canal without a toll was higher than that via the least costly alternative route, were excluded from further analyses of Panama Canal traffic data.

The number of transits (and tonnage carried) excluded is shown in Table 7.2.3-3.

Table 7.2.3-3

"No Tolls" Diversions in the WEFA's Forecast of Canal Traffic

Panama Canal Alternative		2020		2060	
		Transits	Tonnage Carried (thousands)	Transits	Tonnage Carried (thousands)
Status Quo		2,097.6	35,976.6	933.9	22,985.3
High Rise	150,000 DWT	2,111.0	51,867.4	2,536.3	56,215.5
	150,000 DWT Single Lane				
	200,000 DWT	1,981.4	37,003.6	2,480.4	49,528.6
	200,000 DWT Single Lane				
Sea Level	250,000 DWT (case A)	1,981.4	37,003.6	2,480.4	49,528.6
	250,000 DWT (case E)				

After the analysis and estimation of "no-tolls" diversions, the FFMS Study proceeded into the iterative process of specifying and analyzing alternative tolls schedules and rates and identifying the optimal schedule and rates. Detailed method consisted of the following steps:

(i) Specifying Canal toll schedule and rates per Panama Canal net ton (PCNT);

(ii) Applying this toll rates to transits within each ship size interval and computing effective toll per ton carried (to compute the effective toll per ton carried, total toll revenue from all transits within the interval was divided by total tonnage carried by transits within this interval);

(iii) Weighing the effective toll in each ship size interval by the interval's share of tons carried;

(iv) Computing total weighted average transportation cost per ton carried through the Panama Canal;

(v) Estimating traffic diversions on "with-tolls" basis on the assumption that traffic would divert to the least costly route whenever imposition of the Panama Canal toll raised the total transportation cost per ton through the Canal above the cost per ton by way of the alternative route;

(vi) Estimating total toll revenue; and

(vii) Re-specifying different Canal toll schedule and rates, if the result of estimating total toll revenue is not optimal.

Under the constraints such as minimum traffic diversion to alternative routes, maintenance of a diversity of ship type to avoid traffic specialization, and no toll rate increases exceeding 100 percent of the current rates, specialization/re-specification in step (i) was made for:

- current toll structure and rates;
- current toll structure with a 50 percent increase in rates;
- current toll structure with a 100 percent increase in rates; and
- optimal toll structure and rates.

Throughout these steps, revenues from both laden and ballast transits were estimated for each ship type. Because the projections of ballast transits had not been prepared on a trade route basis, and no transportation costs for ballast transits have presented, revenues for ballast transits by ship type were estimated in relation to the impact of alternative toll rates on corresponding laden transits by ship type.

In optimal toll structure, toll rates varied across ship types and, within a ship type, across size intervals on the basis of current toll structure with a 100 percent increase in rates, so that these variations could generate higher revenues through recapture of traffic diverted under previous specifications.

The FFMS Study suggested that toll rate reductions should be applied to dry bulk carriers[3] in the 200,000 DWT Canal alternatives in 2020 and to tankers[4] in each alternative in 2020.

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[3] See the FFMS Study Report Volume 1, p.3-14.

[4] See the FFMS Final Report Volume 1, p.3-14

The optimal toll structure and rates developed for 2020 and 2060 by Canal alternative are presented in Table 7.2.3-4. All ballast movements are charged a toll based on the increase in toll rates realized on each ship type's laden transits and maintaining the proportion of ballast transits to laden transits. Please note that the re-specification of tolls for certain ship types that was required to recapture Canal traffic in 2020 is not applied in 2060 because large vessels represent a greater portion of the 2060 ship size mix, and the resulting lower average transportation costs offset the impact of the toll increases[5].

Estimation of Toll and Other Revenues

Estimated toll revenues from laden and ballast transits by each Canal alternative in 2020 and 2060 are summarized in Table 7.2.3-5. Please note that Section 6.2 has explained that toll revenues of the Variations of the Selected Alternatives are not different from those of corresponding original selected Alternatives.

In addition, the operating revenues other than toll revenues, which are separated into three categories (i.e., transit operations, supporting services, and administrative and general) by the Panama Canal Commission's Statement of Operations, were calculated by each Canal alternative on the basis of FY 1991 revenues and increased according to the annual average growth in Canal transits projected for the 1991-2020 and 2020-2060 periods by WEFA. Thus, toll and other revenues in 1990 U.S. dollars have been estimated for imputing to financial analysis, which will be described in sub-section 7.2.5.

7.2.4 Estimation of Annual Cost by Each Canal Alternative

Since estimation of revenue side has been made, the rest of our task is the estimation of cost side, which consists of capital costs and operating & maintenance costs, for the purpose of financial analysis.

Estimates of Capital Costs

Capital costs were presented in the Final Report of the ECE Study conducted by Yachiyo Engineering Co., Ltd. ("YEC") for High Rise 150,000 DWT Alternative, High Rise 200,000 DWT Alternative, and Sea Level 250,000 DWT Alternative (case A), and in Annex to Final Report for High Rise 150,000 DWT Culebra Cut Single Lane Alternative, High Rise 200,000 DWT Culebra Cut Single Lane Alternative, and Sea Level 250,000 DWT Alternative (case E).

5 The FFMS Study suggests the entity operating the Canal alternative will regularly monitor the toll structure and rates and, as conditions warrant, will revise the optimal toll system consistently with its toll policy objectives.

Table 7.2.3-4

Optimal Toll Structure and Rates (1990 US$)

Project Year, Scenario, and Ship Type	Laden	Ballast
2020		
Status Quo		
All Vessels	4.02	3.20
150,00 DWT		
Tankers less than 40,000 Panama Canal Net Tons	4.02	3.20
Tankers larger than or equal to 40,000 Panama Canal Net Tons	3.30	2.63
All Other Vessels	4.02	3.20
200,00 DWT		
Dry Bulk Carriers less than 70,000 Panama Canal Net Tons	4.02	3.20
Dry Bulk Carriers larger than or equal to 70,000 Panama Canal Net Tons	1.51	1.20
Tankers less than 40,000 Panama Canal Net Tons	4.02	3.20
Tankers larger than or equal to 40,000 Panama Canal Net Tons	3.30	2.63
All Other Vessels	4.02	3.20
250,00 DWT		
Tankers less than 40,000 Panama Canal Net Tons	4.02	3.20
Tankers larger than or equal to 40,000 Panama Canal Net Tons	3.30	2.63
All Other Vessels	4.02	3.20
2060		
Status Quo		
All Vessels	4.02	3.20
150,000 DWT		
All Vessels	4.02	3.20
200,000 DWT		
All Vessels	4.02	3.20
250,000 DWT		
All Vessels	4.02	3.20

Source: Nathan Associates Inc.

Table 7.2.3-5

Summary of Estimated Revenues from Laden and Ballast Transit by Project Scenario, Toll Structure, and Year (1990 US$ million)

	--2020--				--2060--			
	Status Quo	150,000 DWT	200,000 DWT	250,000 DWT	Status Quo	150,000 DWT	200,000 DWT	250,000 DWT
Current Toll Structure and Rates	482	612	630	637	591	869	895	908
Current Toll Structure with a 50 Percent Increase in Rates	702	904	904	938	861	1,279	1,319	1,335
Current Toll Structure with a 100 Percent Increase in Rates	934	1,123	1,169	1,215	1,110	1,638	1,732	1,754
Optimal Toll Structure and Rates	934	1,175	1,186	1,221	1,110	1,638	1,732	1,754
Maximum Non-Diverting Toll Rates	3,461	4,014	4,062	4,118	5,251	6,355	6,541	6,609

Notes:

1. Status Quo is a 65,000 DWT Scenario. Toll Structure and rates were not optimized for the Status Quo Canal but were maintained at the 100 percent increase level.
2. Both 150,000 DWT and 200,000 DWT represent High Rise Alternatives and High Rise Culebra Cut Single Lane Alternatives.
3. 250,000DWT represents both Sea Level 250,000 DWT Alternative (Case A) and Sea Level 250,000 DWT Alternative (Case E).
4. Maximum Non-Diverting Toll revenue was estimated based on theoretical toll scenario, in which toll and shipping cost via Panama Canal are equal to the transportation cost via least costly alternative route.

Source: Nathan Associates Inc., based on "no toll" forecasts of traffic and transportation costs provided by The WEFA Group. Table 3-37 and Table A-1 of FFMA Final Report.

The total capital cost of each canal alternative and the duration of design and construction are presented in Table 7.2.4-1.

Table 7.2.4-1

Capital Cost And Construction Period For Each Canal Alternative

Canal Alternative	Capital Cost (1990 US$ billion)	Construction Period (years)
High Rise 150,000 DWT	7.4	10
High Rise 200,000 DWT	8.5	11
High Rise 150,000 DWT Culebra Cut Single Lane	5.9*	10
High Rise 200,000 DWT Culebra Cut Single Lane	6.7*	11
Sea Level 250,000 DWT - Case A	13.5	15
Sea Level 250,000 DWT - Case E	10.9	15

Note: As for two High Rise single lane alternatives, capital costs include the construction cost of new dams for with standing dry year conditions.

YEC's cost estimates were prepared on a unit-cost basis that allocated all costs to discrete physical work elements. This approach, which is consistent with guidelines by the Fédération Internationale des Ingénieurs - Conseils ("FIDIC"), is based on the premise that contractors will be fully responsible for acquiring the necessary equipment to complete the construction. The FIDIC unit cost approach, however, does not permit the disaggregation of equipment acquisition costs needed for the financial scheme analysis which requires estimates of the acquisition cost of construction equipment and other equipment used in operating the alternative canal to be desegregated from total construction costs. Accordingly, CAS requested that Stone &Webster prepare these estimates on the basis of YEC data. Because the financing scheme and financial analyses use estimates of annual project financial cash flows to determine the amounts of financing required each year and to calculate financial evaluation ratios such as financial internal rate of return (FIRR) and debt service coverage ratio, TAMS Consulting Inc. (TAMS) recommended to make the following adjustments to the Stone & Webster estimates to reflect typical cash flow elements of payments to construction contractors in such a large scale infrastructure construction project as the Canal alternatives:

- An amount of 3.0 percent of total construction cost (which includes civil works and equipment but excludes contingencies) was taken to reflect advance payments to be made in equal parts in the first 2 years of construction.

- Each of the annual construction cost figures was reduced by 3.0 percent because of the extraction of amounts for advance payments. The resulting figures were further reduced by 5.0 percent to reflect retainages to be held for one year.

- For indirect costs, advance payments of 10 percent of total costs for administration, headquarters, and construction supervision were allocated equally over the first 3 years in which those services are to be performed (i.e., 3.33 percent each for project years 1 to 3). The annual cost figures were reduced by 10.0 percent because of the extraction of amounts for advances. The resulting figures were further reduced by 5.0 percent to reflect retainages to be held for one year.

As for the selected Alternatives, for example, the annual project costs as estimated by YEC (on a unit-cost basis) and the TAMS (reflecting cash flow implications for equipment acquisition costs and payments to contractors) are presented for each Canal alternative in the Table 7.2.4-2.

Estimates of Operating and Maintenance Costs

Table 7.2.4-3

Operating & Maintenance Costs for Each Canal Alternative

(1990 US$ million)

Canal Alternative	2020	2060
Status Quo	371.2	419.2
High Rise 150,000 DWT	475.1	583.0
High Rise 150,000 DWT Culebra Cut Single Lane		
High Rise 200,000 DWT	483.4	591.3
High Rise 200,000 DWT Culebra Cut Single Lane		
Sea Level 250,000 DWT Case A	525.8	625.0
Sea Level 250,000 DWT Case E		

Table 7.2.4-2

Differences in Annual Project Costs as Estimated by Yachiyo Engineering Ltd. and TAMS Consultants, Inc. (1990 US$ millions)

	High-Rise Lock Canal 150,000 DWT			High-Rise Lock Canal 200,000 DWT			Sea-Level Canal Case A		
Project year	Yachiyo a/	TAMS b/	Difference	Yachiyo a/	TAMS b/	Difference	Yachiyo a/	TAMS b/	Difference
1	81.9	88.4	6.5	88.3	95.7	7.4	74.6	84.5	9.9
2	81.9	90.2	8.3	88.3	97.8	9.5	74.6	87.1	12.5
3	284.7	274.0	-10.7	250.9	297.7	46.8	71.3	83.0	11.7
4	1,196.2	956.3	-239.9	1,703.6	924.3	-779.3	330.1	329.1	-1.0
5	928.1	1,288.7	360.6	865.5	1,295.7	430.2	2,856.6	2,205.4	-651.2
6	1,106.4	1,158.5	52.1	1,125.5	[illegible]	158.4	878.0	1,277.9	399.9
7	1,048.6	1,181.5	132.9	1,059.8	[illegible]	236.1	851.8	1,018.5	166.7
8	1,331.5	1,016.5	-315.0	1,255.1	[illegible]1.0	25.9	868.7	1,207.9	339.2
9	875.9	723.3	-152.6	1,172.1	994.9	-177.2	868.7	869.1	0.4
10	438.9	596.9	158.0	781.1	780.5	-0.6	1,069.1	1,060.1	-9.0
11	--	--	--	155.7	198.3	42.6	925.0	964.1	39.1
12	--	--	--	--	--	--	1,047.9	1,046.2	-1.7
13	--	--	--	--	--	--	1,176.0	1,241.2	65.2
14	--	--	--	--	--	--	1,245.9	1,070.6	-175.3
15	--	--	--	--	--	--	1,181.0	974.7	-206.3
Total project costs	7,374.1	7,374.3		8,545.9	8,545.7		13,519.3	13,519.4	

Note: Differences in total project costs are due to rounding.

a/ Estimated costs for Yachiyo are on a per unit cost basis.

b/ Estimated costs for TAMS are on an equipment acquisition basis, adjusted for annual payments due contractors.

Sources: Data for Yachiyo are from "Phase 2: Preliminary Engineering and Cost Estimates," April 1993, and data for TAMS were prepared for Nathan Associates on the basis of Yachiyo estimates, as adjusted by Stone & Webster.

Estimates of the annual operating & maintenance costs for the status quo Canal and each of the Canal alternatives are also needed for the financial analyses. YEC estimated operating & maintenance costs as well for 2020 and 2060. After some adjustments regarding the return of the Canal to the Republic of Panama on December 31, 1999, the projected costs for the status quo Canal and each of the Canal alternatives for 2020 and 2060 are presented in Table 7.2.4-3.

7.2.5 Financing Scheme and Financial Analyses

Now that the estimates of revenue side and cost side have been made and a Panama Canal Authority has been identified as the preferred management arrangement model through the analysis described in 7.3, we are on the stage of financial analysis. In this stage, firstly possible financing sources and their terms and conditions were identified; secondly, an appropriate financing scheme were assumed by each canal alternative; and, thirdly, various financial analyses were made for measuring the financial viability of each canal alternative.

Identification of Financing Sources and their Terms and Conditions

The FFMS Study organized a panel of Senior International Financing Experts (SIFE), which was composed of financial practitioners with global project financing expertise in both public and private sectors, in order to identify potential financing sources and likely terms and conditions.

The Financial experts explored a wide range of possible financing sources, such as:

- Export-Import Bank of Japan
- Export-Import Bank of United States (Eximbank)
- Equipment Suppliers
- Inter-American Development Bank (IDB)
- The World Bank
- Japanese Overseas Economic Cooperation Fund (OECF)
- Commercial Banks
- Private bond markets in the U.S. and Japan
- Panama Canal Toll Reserve Trust Fund
- Equity from Canal users or foreign governments

- Grants from foreign governments

Based on the premise that the Canal alternatives were financially viable, the applicability and likely terms and conditions of above financing sources were summarized in Table 7.2.5-1.

In general, the interest rates used here represent anticipated long-term interest rates under favorable political, economic, and financial conditions and it is assumed that the project is considered a medium investment-grade risk, corresponding to a Moody's Investor Service rating of Baa and a Standard and Poor's rating of BBB.

Financing Scheme by Canal Alternative

The proposed financing scheme for each High Rise alternative is presented in Table 7.2.5-2 through Table 7.2.5-5, and for each Sea Level alternative in Table 7.2.5-6 and Table 7.2.5-7. The trust fund in referred to these schemes is funded from toll revenues.

As a model for management arrangement for each Canal alternative a Panama Canal Authority was assumed because it has been identified as the preferred formula, which will be discussed in section 7.3.

As shown in Table 7.2.5-2, the proposed financing scheme for High Rise 150,000 DWT Alternative combined a diverse set of nine sources of financing.

The basic ideas behind this scheme are:

- Capital costs for construction and other equipments are financed equally by export-import banks in the U.S. and Japan - up to 80 percent of the equipment cost;

- The remaining 20 percent of equipment cost is financed by equipment suppliers (5 percent) and capital contribution from the toll reserve trust fund (15 percent); and

- Other construction costs and indirect costs are financed by development banks (27 percent), foreign bonds (34 percent) split between U.S. and Japanese private markets), commercial bank loans (5 percent), ODA loans (4 percent), and capital from the toll reserve trust fund (30 percent).

Table 7.2.5-1

Panama Canal Alternatives: Sources of Financing, Assumed Terms and Conditions

Source of financing	Interest rate	Grace period	Total term	Conditions
U.S. Export-Import Bank (suppliers credit)	7.00	3 years	12 years	Up to 85 percent of value of equipment exported
Japan Export-Import Bank (suppliers credit)	6.70 a/	0 years	10 years	Up to 85 percent of value of equipment exported; MITI insurance required
Commercial Banks	6.75	5 years	10 years	Terms for a medium grade investment; participation of multilateral development bank in project preferred
Equipment Suppliers	6.75	3 years	5 years	5 percent of value of equipment; terms for a medium grade investment
Development Banks	7.50	5 years	20 years	Requires Panamanian Government guarantee; economically feasible project
U.S. Private Bonds	8.25	5 years	15 years	Participation of multilateral development bank in project preferred; terms for a medium-grade investment
Japanese Private Bonds	7.35 a/	0 years	20 years	Yen-denominated; participation of multilateral development bank in project;
OECF/ODA Loans	4.50 a/	7 years	20 years	Loan to Panamanian Government ; FIRR should be between 10 and 20 percent; yen-denominated; Panamanian Government guarantee required;
Japan-EXIM Overseas Investment	6.70 a/	0 years	10 years	Possible for SPC entity; MITI insurance required; Panamanian Government guarantee; limited to 60 percent of Japanese non-financial corporations participation in project.
Toll Reserve Trust Fund	n.a.	n.a.	n.a.	Trust fund should maintain balance of $500 million;
Other Equity	n.a.	n.a.	n.a.	Would require a Special Purpose Corporation or an International Public Entity management arrangement
Government Grants	n.a.	n.a.	n.a.	Not anticipated under current conditions

n.a.= not applicable

a\ Includes cost of currency swap, hedging or currency risk insurance of 150 basis points for yen-denominated loans. Swap rates used are those for 10-year maturities as a liquid swap market does not exist for maturities beyond 10-years.

Source: Nathan Associates Inc.

Table 7.2.5-2

High Rise Lock Canal 150,000 DWT: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U S	Export-Import Banks Japan	Commercial Banks	Equip Suppliers	Develop Banks	Foreign Bonds U S	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	1,124 2	15 2	40 0	40 0	0 0	5 0	0 0	0 0	0 0	0 0	0 0	15 0	0 0	0 0	100 0
Other equipment	1,223 7	16 6	40 0	40 0	0 0	5 0	0 0	0 0	0 0	0 0	0 0	15 0	0 0	0 0	100 0
Other construction costs	4,558 3	61 8	0 0	0 0	5 0	0 0	27 0	17 0	17 0	4 0	0 0	30 0	0 0	0 0	100 0
Indirect costs	468 1	6 3	0 0	0 0	5 0	0 0	27 0	17 0	17 0	4 0	0 0	30 0	0 0	0 0	100 0
Total	7,374.3	100 0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	1,124 2	15 2	449 7	449 7	0 0	56 2	0 0	0 0	0 0	0 0	0 0	168 6	0 0	0 0	1,124 2
Other equipment	1,223 7	16 6	489 5	489 5	0 0	61 2	0 0	0 0	0 0	0 0	0 0	183 6	0 0	0 0	1,223 7
Other construction costs	4,558 3	61 8	0 0	0 0	227 9	0 0	1,230 7	774 9	774 9	182 3	0 0	1,367 5	0 0	0 0	4,558 3
Indirect costs	468 1	6 3	0 0	0 0	23 4	0 0	126 4	79 6	79 6	18 7	0 0	140 4	0 0	0 0	468 1
Total	7,374 3	100 0	939 2	939 2	251 3	117 4	1,357 1	854 5	854 5	201 1	0 0	1,860 1	0 0	0 0	7,374 3
Financing source as a percent of total cost			12 7	12 7	3 4	1 6	18 4	11 6	11 6	2 7	0 0	25 2	0 0	0 0	100 0

Source: Project costs from Table 4-7 and financing sources from Table 6-1

Table 7.2.5-3

High Rise Lock Canal 200,000 DWT: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U S	Export-Import Banks Japan	Commercial Banks	Equip Suppliers	Develop Banks	Foreign Bonds U S	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	1,207.7	14.1	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other equipment	1,356.1	15.9	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other construction costs	5,455.5	63.8	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Indirect costs	526.4	6.2	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Total	8,545.7	100.0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	1,207.7	14.1	483.1	483.1	0.0	60.4	0.0	0.0	0.0	0.0	0.0	181.2	0.0	0.0	1,207.7
Other equipment	1,356.1	15.9	542.4	542.4	0.0	67.8	0.0	0.0	0.0	0.0	0.0	203.4	0.0	0.0	1,356.1
Other construction costs	5,455.5	63.8	0.0	0.0	272.8	0.0	1,473.0	927.4	927.4	218.2	0.0	1,636.7	0.0	0.0	5,455.5
Indirect costs	526.4	6.2	0.0	0.0	26.3	0.0	142.1	89.5	89.5	21.1	0.0	157.9	0.0	0.0	526.4
Total	8,545.7	100.0	1,025.5	1,025.5	299.1	128.2	1,615.1	1,016.9	1,016.9	239.3	0.0	2,179.1	0.0	0.0	8,545.7
Financing source as a percent of total cost			12.0	12.0	3.5	1.5	18.9	11.9	11.9	2.8	0.0	25.5	0.0	0.0	100.0

Source: Project costs from Table 4-8 and financing sources from Table 6-1

Table 7.2.5-4

Single Lane High Rise Lock Canal 150,000 DWT: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U S	Export-Import Banks Japan	Commercial Banks	Equip Suppliers	Develop Banks	Foreign Bonds U S	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	684 9	12.1	40 0	40 0	0 0	5 0	0 0	0 0	0 0	0 0	0 0	15 0	0 0	0 0	100 0
Other equipment	1,223 7	21 6	40 0	40 0	0 0	5 0	0 0	0 0	0 0	0 0	0 0	15 0	0 0	0 0	100 0
Other construction costs	3,356 3	59 2	0 0	0 0	5 0	0 0	27 0	17 0	17 0	4 0	0 0	30 0	0 0	0 0	100 0
Indirect costs	404 8	7.1	0 0	0 0	5 0	0 0	27 0	17 0	17 0	4 0	0 0	30 0	0 0	0 0	100 0
Total	5,669.7	100 0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	684 9	12 1	274 0	274 0	0 0	34 2	0 0	0 0	0 0	0 0	0 0	102 7	0 0	0 0	684 9
Other equipment	1,223 7	21 6	489 5	489 5	0 0	61 2	0 0	0 0	0 0	0 0	0 0	183 6	0 0	0 0	1,223 7
Other construction costs	3,356 3	59 2	0 0	0 0	167 8	0 0	906 2	570 6	570 6	134 3	0 0	1,006 9	0 0	0 0	3,356 3
Indirect costs	404 8	7.1	0 0	0 0	20 2	0 0	109 3	68 8	68 8	16 2	0 0	121 4	0 0	0 0	404 8
Total	5,669.7	100.0	763.4	763 4	188 1	95 4	1,015.5	639 4	639.4	150 4	0 0	1,414 6	0 0	0 0	5,669 7
Financing source as a percent of total cost			13 5	13 5	3 3	1 7	17.9	11 3	11.3	2 7	0 0	25 0	0 0	0 0	100 0

Note: The total project costs do not include costs of $168.6 million for two new pump stations

Source: Project costs from Table 4 and financing sources from Table 7

Table 7.2.5-5

Single Lane High Rise Lock Canal 200,000 DWT: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U S	Export-Import Banks Japan	Commercial Banks	Equip Suppliers	Develop Banks	Foreign Bonds U S	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	692.5	10.7	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other equipment	1,356.2	20.9	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other construction costs	4,008.0	61.7	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Indirect costs	434.0	6.7	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Total	6,490.7	100.0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	692.5	10.7	277.0	277.0	0.0	34.6	0.0	0.0	0.0	0.0	0.0	103.9	0.0	0.0	692.5
Other equipment	1,356.2	20.9	542.5	542.5	0.0	67.8	0.0	0.0	0.0	0.0	0.0	203.4	0.0	0.0	1,356.2
Other construction costs	4,008.0	61.7	0.0	0.0	200.4	0.0	1,082.2	681.4	681.4	160.3	0.0	1,202.4	0.0	0.0	4,008.0
Indirect costs	434.0	6.7	0.0	0.0	21.7	0.0	117.2	73.8	73.8	17.4	0.0	130.2	0.0	0.0	434.0
Total	6,490.7	100.0	819.5	819.5	222.1	102.4	1,199.3	755.1	755.1	177.7	0.0	1,639.9	0.0	0.0	6,490.7
Financing source as a percent of total cost			12.6	12.6	3.4	1.6	18.5	11.6	11.6	2.7	0.0	25.3	0.0	0.0	100.0

Note: The total project costs do not include costs of $188.6 million for two new pump stations

Source: Project costs from Table 5 and financing sources from Table 7

Table 7.2.5-6

Sea Level Canal Case A: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U.S.	Export-Import Banks Japan	Commercial Banks	Equip. Suppliers	Develop. Banks	Foreign Bonds U.S.	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv.	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	2,060.5	15.2	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other equipment	1,941.7	14.4	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other construction costs	8,925.8	66.0	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Indirect costs	591.4	4.4	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Total	13,519.4	100.0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	2,060.5	15.2	824.2	824.2	0.0	103.0	0.0	0.0	0.0	0.0	0.0	309.1	0.0	0.0	2,060.5
Other equipment	1,941.7	14.4	776.7	776.7	0.0	97.1	0.0	0.0	0.0	0.0	0.0	291.3	0.0	0.0	1,941.7
Other construction costs	8,925.8	66.0	0.0	0.0	446.3	0.0	2,410.0	1,517.4	1,517.4	357.0	0.0	2,677.7	0.0	0.0	8,925.8
Indirect costs	591.4	4.4	0.0	0.0	29.6	0.0	159.7	100.5	100.5	23.7	0.0	177.4	0.0	0.0	591.4
Total	13,519.4	100.0	1,600.9	1,600.9	475.9	200.1	2,569.6	1,617.9	1,617.9	380.7	0.0	3,455.5	0.0	0.0	13,519.4
Financing source as a percent of total cost			11.8	11.8	3.5	1.5	19.0	12.0	12.0	2.8	0.0	25.6	0.0	0.0	100.0

Source: Project costs from Table 4-8 and financing sources from Table 6-1.

Table 7.2.5-7

Sea Level Canal Case E: Project Costs and Sources of Financing Assuming a Panama Canal Authority

Cost component	Total Project Cost	Percent of Project Cost	Source of Financing: Export-Import Banks U.S.	Export-Import Banks Japan	Commercial Banks	Equip Suppliers	Develop Banks	Foreign Bonds U.S.	Foreign Bonds Japan	ODA Loans	Japan-EXIM Overseas Inv	Trust Fund	Outside Equity	Gov't Grants	Total
			Share of Financing by Source (Percent)												
Construction equipment	1,766.1	16.3	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other equipment	1,726.7	15.9	40.0	40.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	100.0
Other construction costs	6,875.6	63.4	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Indirect costs	481.9	4.4	0.0	0.0	5.0	0.0	27.0	17.0	17.0	4.0	0.0	30.0	0.0	0.0	100.0
Total	10,850.3	100.0													
			Share of Financing by Source (1990 US$ millions)												
Construction equipment	1,766.1	16.3	706.4	706.4	0.0	88.3	0.0	0.0	0.0	0.0	0.0	264.9	0.0	0.0	1,766.1
Other equipment	1,726.7	15.9	690.7	690.7	0.0	86.3	0.0	0.0	0.0	0.0	0.0	259.0	0.0	0.0	1,726.7
Other construction costs	6,875.6	63.4	0.0	0.0	343.8	0.0	1,856.4	1,168.9	1,168.9	275.0	0.0	2,062.7	0.0	0.0	6,875.6
Indirect costs	481.9	4.4	0.0	0.0	24.1	0.0	130.1	81.9	81.9	19.3	0.0	144.6	0.0	0.0	481.9
Total	10,850.3	100.0	1,397.1	1,397.1	367.9	174.6	1,986.5	1,250.8	1,250.8	294.3	0.0	2,731.2	0.0	0.0	10,850.3
Financing source as a percent of total cost			12.9	12.9	3.4	1.6	18.3	11.5	11.5	2.7	0.0	25.2	0.0	0.0	100.0

Note: The total project costs do not include costs of $188.6 million for two new pump stations

Source: Project costs from Table 6 and financing sources from Table 7.

The p oposed financing schemes for other alternatives are basically the same as that for High Rise 0,000 DWT Alternative in terms of mixture of total cost. The amounts of financing requir for other three High Rise Canal Alternatives are indeed of the same order of magnitude as Hi Rise 150,000 DWT Alternative. Although Sea Level alternatives require substantially more tal, the same financing scheme was used to test the feasibility of these alternatives on the sa footing as High Rise alternatives.

One he most important features of the financing scheme is the establishment and the prese on of a toll reserve trust fund that will be endowed with net income generated from Canal s after Panama acquires control of the Canal in 2000. It is assumed that Canal tolls will b creased from 2000 through 2019 to generate resources for the trust fund.

For e anal alternative and financing scheme, the annual amounts of financing required from each cing source were determined by a mix of financing by source and the distribution of annua ject costs by type. For instance, the resulting estimate of annual financing for High Rise 00 DWT Alternative was presented in Table 7.2.5-8.

Finan nalyses

In the S Study, various financial analyses were made for measuring the financial viability of ea nama Canal alternative. For each of the Canal alternatives, the following three scena alternative toll structures and rates, which have been specified in sub-section 7.2.3, were ed

- ing Panama Canal toll structure and rates
- ing Panama Canal toll structure and rates increased by 50 percent, and
- ptimal toll system that differentiates toll rates on the basis of ship type and ship size

We scribe (a) assumptions to be set for financial analyses, (b) evaluation criteria for meas nancial viability of each alternative and their calculation methodology, and (c) resul ancial analyses.

(a) nptions

Becau cial analyses require an estimate of annual project financial cash flows to calculate vario cial evaluation ratios such as FIRR, the following assumptions were made. All of the fi analyses and results were conducted on the basis of constant 1990 U.S. dollars.

Table 7.2.5-8

High Rise Lock Canal 150,000 DWT: Summary of Sources of Financing on Annual Basis

		Summary of Sources of Financing for All Project Costs												
	Project	Export-Import Banks		Commer.	Equip.	Dev. Bank	Foreign Bonds		ODA	Japan-EXIM	Trust	Outside	Gov't	
Year	Year	U.S.	Japan	Banks	Suppliers	Loans	U.S.	Japan	Loans	Overseas. Inv	Fund	Equity	Grants	Total
2010	1	0.0	0.0	4.4	0.0	23.9	15.0	15.0	3.5	0.0	26.5	0.0	0.0	88.4
2011	2	0.0	0.0	4.5	0.0	24.4	15.3	15.3	3.6	0.0	27.1	0.0	0.0	90.2
2012	3	0.0	0.0	13.7	0.0	74.0	46.6	46.6	11.0	0.0	82.2	0.0	0.0	274.0
2013	4	133.6	133.6	31.1	16.7	168.0	105.8	105.8	24.9	0.0	236.8	0.0	0.0	956.3
2014	5	238.6	238.6	34.6	29.8	186.9	117.7	117.7	27.7	0.0	297.1	0.0	0.0	1,288.7
2015	6	102.8	102.8	45.1	12.8	243.4	153.3	153.3	36.1	0.0	309.0	0.0	0.0	1,158.5
2016	7	107.7	107.7	45.6	13.5	246.3	155.1	155.1	36.5	0.0	314.1	0.0	0.0	1,181.5
2017	8	126.4	126.4	35.0	15.8	189.2	119.1	119.1	28.0	0.0	257.6	0.0	0.0	1,016.5
2018	9	111.8	111.8	22.2	14.0	119.9	75.5	75.5	17.8	0.0	175.1	0.0	0.0	723.3
2019	10	118.4	118.4	15.1	14.8	81.3	51.2	51.2	12.0	0.0	134.7	0.0	0.0	596.9
2020	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2021	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2022	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2023	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2024	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	939.2	939.2	251.3	117.4	1,357.1	854.5	854.5	201.1	0.0	1,860.1	0.0	0.0	7,374.3

Source: Shares of financing by source from Table 6-2; annual project costs by component from Yachiyo Engineering Co., Ltd. as adjusted by Stone & Webster and by TAMS Consultants to reflect contracting flows such as mobilization, contract advances, and retainages.

Toll Revenues - For the 2000 - 2019 period, toll revenues under the existing toll rate were estimated on the basis of the average annual growth rate of toll revenues between actual 1991 and projected 2020 toll revenues. For the 50 percent increase toll and optimal toll scenarios, toll revenues in 2000-2019 were estimated based upon the average annual growth of toll revenues calculated between 1999 Status Quo existing tolls and the projection for 2020 Status Quo toll revenue for each corresponding toll scenario.

As for the intervening years between 2020 and 2060, annual revenues were assumed by the same interpolation method, based on estimated revenues of 2020 and 2060 in each alternative.

Other Revenues - Other canal operating revenues were calculated on the basis of the FY 1991 revenues and increased according to the annual average growth in the Canal transits projected for the 1991 - 2020 and 2020 - 2060 periods.

Operating and Maintenance Costs - For each of the Canal alternatives, estimates of operating and maintenance costs were prepared by YEC and adjusted in the FFMS Study as presented in sub-section 7.2.4 for 2020 and 2060. Annual revenues were assumed by interpolation.

Payment to the Republic of Panama - It is unlikely that the government treasury would be willing to part entirely with the flow of funds generated by Canal operations. To the contrary, in order for the Canal alternative to be able to attract the proposed financing, limits need to be established on the amount of funds that will be paid to the national treasury. Because of these reasons, the FFMS Study assumed that annual payment to the Republic of Panama would be 10 percent of total Canal revenues.

Trust Fund and Dividend Policy - Funds that are maintained in the toll reserve trust fund are assumed to earn 4 percent interest on the prior year's balance. Dividend distributions are assumed to be released only when current year's net income after debt service and Payment to Panama is positive and when trust fund balance always exceeds $500 million.

(b) Criteria and Methodology

The FFMS Study set the following evaluation criteria for measuring financial viability of each canal alternative[6]:

1. The balance of toll reserve trust fund --- Is the toll reserve trust fund balance always positive?

[6] The specific target results for the evaluation criteria were determined by SIFE, which was assembled for the development and selection of optimum financing schemes for the Canal alternatives.

2. FIRR before financing --- Is the Financial Internal Rate of Return (FIRR) of the incremental cash flow before financing greater than 8 percent in order to encourage international development institutions and agencies to participate in the project?

3. FIRR after financing --- Is the FIRR of the incremental cash flow after financing greater than 12 percent in order to encourage private investors and commercial banks to participate in the project?

4. The net present values before financing --- Is the net present value before financing, discounted at 8 percent which could be obtained on a low-risk corporate bond of the incremental cash flow, positive value?

5. The net present value after financing --- Is the net present value after financing, discounted at 8 percent, positive value?

6. The debt service coverage ratio on a current basis --- Is the minimum debt service coverage ratio on a current basis greater than 1.3?

7. The debt service coverage ratio on an overall basis --- Is the debt service coverage ratio on an overall basis greater than 1.5?

8. The debt-to-equity ratio --- Is the debt-to-equity ratio below 4.0?

9. The results of sensitivity analyses --- Does the alternative remain financially viable under the various sensitivity analyses, such as interest rates increased by 25 percent, capital costs increased by 25 percent, operating & maintenance costs increased by 25 percent, and Status Quo toll rates increased by 50 percent[7]. In particular, whether or not the balance of trust fund can remain positive even in the cases in sensitivity analyses is the most important.

The calculating methodology of these evaluation criteria will be as follows.

1. The balance of toll reserve trust fund

   (i) Net income after debt service and Payment to Panama was calculated as net income from operation minus Payment to Panama minus debt service requirements.

[7] In base cases, Status Quo toll rates were assumed at existing toll rates for without-project scenarios for FIRR calculations. This sensitivity analysis assumed the case that tolls would be increased by 50 percent in without-project scenarios.

(ii) Trust fund balance equals the above net income after debt service and Payment to Panama plus accumulated trust fund (trust fund balance of previous year times 1.04) minus contribution to capital cost.

2. FIRR before financing

(i) Consistent with the guidelines established by CAS for The FFMA Study, it was premised that the Canal alternative and the status quo canal would be managed by a single entity.

(ii) Based on this premise, the FFMS Study deemed incidental effects on the status quo canal were included for estimating cash flows on an incremental basis as well as cash flow to be directly generated by the Canal alternative.

(iii) To calculate incremental income, net income from operation in a without-project scenario was deducted from that in a with-project scenario.

(iv) The FFMS Study assumed tolls at rates increased by 50 percent (in 50 percent increased cases) or at optimal rates (in optimal toll cases) for with-project scenarios whereas it assumed at existing toll rates for without-project scenarios.

(v) Incremental cash flow before financing was calculated as the sum of incremental income as a cash inflow and annual project capital costs as a cash outflow.

(vi) FIRR was calculated based upon the cash flow above.

3. FIRR after finance

(i) To calculate incremental cash flow after financing, the financing stream, which consisted of loan proceeds as a cash inflow and debt service requirements as a cash outflow, was added to incremental cash flow before financing.

(ii) FIRR was calculated based upon the cash flow above.

4&5. The net present values

(i) The net present values before and after financing were calculated based upon the cash flows determined in calculating FIRR before financing and FIRR after financing, respectively.

(ii) A discount rate of 8 percent was used for the calculations. This reflects the Section International Financial Experts consensus of the interest rate that could be obtained on a low-risk corporate bond.

6&7. The debt service coverage ratios

(i) The debt service coverage ratio on a current basis was calculated annually as net income from operations less payments to Panama divided by total debt service requirements, and that on an overall basis was calculated annually as net income from operations less payments to Panama plus trust fund balance divided by total debt service requirements.

(ii) The minimum debt service coverage ratio was identified from annually calculated debt service coverage ratios.

(c) Results of financial analyses

The results of calculating and analyzing these evaluation criteria by each Canal alternative and toll scenario in Selected Alternative and the Variations of the Selected Alternative are summarized in Table 7.2.5-9 and Table 7.2.5-10, respectively and the detailed results of the sensitivity analyses are presented in Table 7.2.5-11 and Table 7.2.5-12, respectively.

In the light of the evaluation criteria, High Rise 150,000 DWT Alternative, High Rise 150,000 DWT Culebra Cut Single Lane Alternative, and High Rise 200,000 DWT Culebra Cut Single Lane Alternative appear to be financially viable under the optimal toll system scenario because Table 7.2.5-9 and Table 7.2.5-10 show that these three alternatives reach almost all targets of these criteria.[8] On the other hand, High Rise 200,000 DWT Alternative and Sea Level 250,000 DWT Alternatives both in Case A and Case E are not financially viable under any of the toll system scenarios analyzed.

For your reference, detailed results of financial analyses for feasible alternatives such as High Rise 150,000 DWT Alternative, High Rise 150,000 Culebra Cut Single Lane Alternative, and High Rise 200,000 DWT Culebra Cut Single Lane Alternative under the optimal toll system scenario assuming a Panama Canal Authority are shown in Tables 7.2.5-13 through 7.2.5-15.

[8] In two High Rise Culebra Cut Single Lane alternatives, even with a 50 percent increase in toll, trust fund balance can be kept always positive, which means cash shortage will not occur. However, these two alternatives with a 50 percent increase were found to be unfeasible in the FFMS Study, because they didn't satisfy several other criteria. In 150,000 dwt case, FIRR before financing (6.7%), for example, didn't meet the target (8.0%).

Table 7.2.5-9

Summary of Financial Results by Canal Alternative and Toll Scenario (The Selected Alternatives)

Evaluation criteria	Target Result	High-Rise Lock Canal 150,000 DWT			High-Rise Lock Canal 200,000 DWT			Sea-Level Canal Case A		
		Existing Tolls	Tolls Increased 50 percent	Optimal Tolls	Existing Tolls	Tolls Increased 50 percent	Optimal Tolls	Existing Tolls	Tolls Increased 50 percent	Optimal Tolls
1. Trust Fund balance always positive	Yes	No	Yes	Yes	No	No	Yes	No	No	No
2. Financial internal rate of return before financing (%)	8-10	-3.2	4.6	10.1	-3.1	3.7	8.4	-5.1	1.3	4.5
3. Financial internal rate of return after financing (%)	12-15a/	-5.6	3.4	18.0	-5.4	2.3	9.8	-7.6	-0.5	3.3
4. Net present value before financing (US$MM) b/	Positive value	-4,314	-1,591	951	-4,882	-2,337	193	-6,803	-4,648	-2,608
5. Net present value after financing (US$MM) b/	Positive value	-3,806	-1,285	1,069	-4,308	-1,952	391	-6,014	-4,019	-2,130
6. Minimum debt service coverage ratio - current	1.3	0.3	0.6	0.9	0.2	0.5	0.7	0.2	0.3	0.5
7. Minimum debt service coverage ratio - overall	1.5-2.0	n.a.	1.1	1.8	n.a.	n.a.	1.9	n.a.	n.a.	n.a.
8. Debt/equity ratio	Below 4.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9
9. Is the alternative financially viable with:										
a. Interest rates increased 25 percent	Yes	–	No	Yes	–	No	No	–	No	No
b. Capital costs increased 25 percent	Yes	–	No	No	–	No	No	--	No	No
c. Operation and Maintenance costs increased 25 percent	Yes	–	No	Yes	–	No	No	--	No	No
d. Status Quo Canal tolls increased 50 percent	Yes	–	--	No	–	--	No	--	–	No
Conclusion										
Is project financially feasible?		No	No	Yes	No	No	No	No	No	No

n.a.= not applicable

a/ With a Panama Canal Authority as the management entity,a rate of return of 12-15 percent would be acceptable. If foreign equity was sought, the return would need to be in the range of 15-20 percent.

b/ Based upon an interest rate of 8 percent.

Source: Tables 6-7 through 6-24 and Appendix J.

Table 7.2.5-10

Summary of Financial Results by Canal Alternative and Toll Scenario (The variations of the Selected Alternatives)

Evaluation Criteria and Conclusion	Target Result	Single Lane High Rise Lock Canal 150,000 DWT			Single Lane High Rise Lock Canal 200,000 DWT			Sea Level Canal Case E		
		Existing Tolls	Tolls Increased 50 percent	Optimal Tolls	Existing Tolls	Tolls Increased 50 percent	Optimal Tolls	Existing Tolls	Tolls Increased 50 percent	Optimal Tolls
Evaluation Criteria										
1. Trust Fund balance always positive	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No
2. Financial internal rate of return before financing (%)	8-10	-2.6	6.7	15.8	-2.4	5.5	12.3	-4.5	2.3	6.0
3. Financial internal rate of return after financing (%)	12-15 a/	-4.9	6.4	28.0	-4.6	4.6	21.2	-6.9	0.7	5.3
4. Net present value before financing (US$MM) b/	Positive value	-3,179	-455	2,086	-3,554	-1,009	1,521	5,418	-3,264	1,223
5. Net present value after financing (US$MM) b/	Positive value	-2,802	-280	2,073	-3,133	-777	1,566	-4,787	2,792	902
6. Minimum debt service coverage ratio - current	1.3	0.4	0.8	1.2	0.3	0.6	1.0	0.2	0.4	0.6
7. Minimum debt service coverage ratio - overall	1.5-2.0	n.a.	2.4	2.2	n.a.	2.1	2.0	n.a.	n.a.	n.a.
8. Debt/equity ratio	Below 4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
9. Is the alternative financially viable with:										
a. Interest rates increased 25 percent	Yes	No	No	Yes	No	No	Yes	No	No	No
b. Capital costs increased 25 percent	Yes	No	No	Yes	No	No	Yes	No	No	No
c. Operation and maintenance costs increased 25 percent	Yes	No	No	Yes	No	No	Yes	No	No	No
d. Status Quo toll rates increased 50 percent	Yes	--	--	No	--	--	No			
Conclusion										
Is project financially viable?		No	No	Yes	No	No	Yes	No	No	No

n.a. = not applicable.

a/ With a Panama Canal Authority as the management entity, a rate of return of 12-15 percent would be acceptable. If foreign equity was sought, the return would need to be in the range of 15-20 percent.

b/ Based upon interest rate of 8 percent.

Source: Tables 11 through 28 and Table 30.

Table 7.2.5-11

Sensitivity Analyses: Financial Results by Canal Alternative and Toll Scenario (The Selected Alternatives)

Sensitivity scenario and evaluation criteria	Target Result	High-Rise Lock Canal 150,000 DWT: Tolls Increased 50 percent	High-Rise Lock Canal 150,000 DWT: Optimal Tolls	High-Rise Lock Canal 200,000 DWT: Tolls Increased 50 percent	High-Rise Lock Canal 200,000 DWT: Optimal Tolls	Sea-Level Canal Case A: Tolls Increased 50 percent	Sea-Level Canal Case A: Optimal Tolls
a Interest Rates Increased by 25 Percent a/							
1. Trust Fund balance always positive	Yes	No	Yes	No	Yes	No	No
2. Financial internal rate of return before financing (%)	8-10	4.6	10.1	3.7	8.4	1.3	4.5
3. Financial internal rate of return after financing (%)	12-15 c/	2.8	13.9	1.8	8.0	-0.9	2.7
4. Net present value before financing (US$MM) b/	Positive value	-1,591	951	-2,337	193	-4,648	-2,608
5. Net present value after financing (US$MM) b/	Positive value	-1,637	716	-2,353	-10	-4,552	-2,863
6. Minimum debt service coverage ratio - overall	1.3	0.5	0.8	0.4	0.6	0.3	0.4
7. Minimum debt service coverage ratio - current	1.5-2.0	n.a.	2.0	n.a.	1.7	n.a.	n.a.
8. Debt/equity ratio	Below 4.0	3.0	3.0	2.9	2.9	2.9	2.9
9. Is project financially viable?		No	Yes	No	No	No	No
b Capital Costs Increased by 25 Percent							
1. Trust Fund balance always positive	Yes	No	Yes	No	No	No	No
2. Financial internal rate of return before financing (%)	8-10	3.3	7.7	2.5	6.4	0.4	3.1
3. Financial internal rate of return after financing (%)	12-15 c/	1.7	8.2	0.9	5.9	-1.5	1.6
4. Net present value before financing (US$MM) b/	Positive value	-2,732	-190	-3,630	-1,100	-7,023	-4,982
5. Net present value after financing (US$MM) b/	Positive value	-2,294	60	-3,096	-754	-6,120	-4,231
6. Minimum debt service coverage ratio - overall	1.3	0.5	0.7	0.4	0.6	0.2	0.4
7. Minimum debt service coverage ratio - current	1.5-2.0	n.a.	1.9	n.a.	n.a.	n.a.	n.a.
8. Debt/equity ratio	Below 4.0	3.0	3.0	2.9	2.9	2.9	2.9
9. Is project financially viable?		No	No	No	No	No	No
c Operation and Maintenance Costs Increased by 25 Percent							
1. Trust Fund balance always positive	Yes	No	Yes	No	No	No	No
2. Financial internal rate of return before financing (%)	8-10	4.2	9.8	3.3	8.1	0.9	4.2
3. Financial internal rate of return after financing (%)	12-15 c/	2.8	17.0	1.8	9.1	-1.0	2.9
4. Net present value before financing (US$MM) b/	Positive value	-1,757	785	-2,502	29	-4,807	-2,786
5. Net present value after financing (US$MM) b/	Positive value	-1,438	915	-2,104	239	-4,166	-2,277
6. Minimum debt service coverage ratio - overall	1.3	0.4	0.7	0.4	0.6	0.2	0.4
7. Minimum debt service coverage ratio - current	1.5-2.0	n.a.	1.2	n.a.	n.a.	n.a.	n.a.
8. Debt/equity ratio	Below 4.0	3.0	3.0	2.9	2.9	2.9	2.9
9. Is project financially viable?		No	Yes	No	No	No	No

Table 7.2.5-11 (Continued)

Sensitivity scenario and evaluation criteria	Target Result	High-Rise Lock Canal 150,000 DWT: Tolls Increased 50 percent	High-Rise Lock Canal 150,000 DWT: Optimal Tolls	High-Rise Lock Canal 200,000 DWT: Tolls Increased 50 percent	High-Rise Lock Canal 200,000 DWT: Optimal Tolls	Sea-Level Canal Case A: Tolls Increased 50 percent	Sea-Level Canal Case A: Optimal Tolls
d **Status Quo Canal Tolls Increased 50 Percent d/**							
1. Trust Fund balance always positive	Yes	- -	Yes	- -	Yes	- -	No
2. Financial internal rate of return before financing (%)	8-10	- -	5.4	- -	4.7	- -	2.1
3. Financial internal rate of return after financing (%)	12-15 c/	- -	4.5	- -	3.6	- -	0.5
4. Net present value before financing (US$MM) b/	Positive value	- -	-1,284	- -	-1,956	- -	-4,389
5. Net present value after financing (US$MM) b/	Positive value	- -	-1,001	- -	-1,599	- -	-3,779
6. Minimum debt service coverage ratio - overall	1.3	- -	0.9	- -	0.7	- -	0.5
7. Minimum debt service coverage ratio - current	1.5-2.0	- -	1.8	- -	1.9	- -	n.a.
8. Debt/equity ratio	Below 4.0	- -	3.0	- -	2.9	- -	2.9
9. Is project financially viable?			No		No		No

n.a. = not applicable

a/ All interest rates were increased by 25 percent prior to any additional factor for currency swap costs.

b/ Based upon an interest rate of 8 percent.

c/ With a Panama Canal Authority as the management entity,a rate of return of 12-15 percent would be acceptable. If foreign equity was sought, the return would need to be in the range of 15-20 percent.

d/ Based on existing Panama Canal tolls increased by 50 percent from Table 6-5.

e/ Based on project costs on a unit-cost methodology from Table 4-1, and a revised financing scheme as presented in Appendix Table J-76.

Source: As noted above and from Appendix J.

Table 7.2.5-12

Sensitivity Analyses: Financial Results by Canal Alternative and Toll Scenario (The Variations of Selected Alternatives)

Sensitivity scenario and evaluation criteria	Target Result	Single Lane High Rise Lock Canal 150,000 DWT			Single Lane High Rise Lock Canal 200,000 DWT			Sea Level Canal Case E		
		Tolls			Tolls			Tolls		
		Existing Tolls	Increased 50 percent	Optimal Tolls	Existing Tolls	Increased 50 percent	Optimal Tolls	Existing Tolls	Increased 50 percent	Optimal Tolls
a Interest Rates Increased by 25 Percent a/										
1 Trust Fund balance always positive	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No
2 Financial internal rate of return before financing (%)	8-10	2.6	6.7	15.8	2.4	5.5	12.3	4.5	2.3	6.0
3 Financial internal rate of return after financing (%)	12-15 c/	5.1	5.3	26.0	4.8	3.8	18.8	7.1	0.3	4.5
4 Net present value before financing (US$MM) b/	Positive value	-3,179	-455	2,086	-3,554	-1,009	1,521	-5,419	3,264	1,223
5 Net present value after financing (US$MM) b/	Positive value	-3,063	541	1,812	-3,427	-1,071	1,272	-5,209	3,214	1,325
6 Minimum debt service coverage ratio - current	1.3	0.3	0.7	1.0	0.3	0.6	0.9	0.2	0.4	0.6
7 Minimum debt service coverage ratio - overall	1.5-2.0	n.a.	2.5	2.0	n.a.	1.4	1.8	n.a.	n.a.	n.a.
8 Debt/equity ratio	Below 4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
9 Is project financially viable?		No	No	Yes	No	No	Yes	No	No	No
b Capital Costs Increased by 25 Percent										
1 Trust Fund balance always positive	Yes	No	Yes	Yes	No	No	Yes	No	No	No
2 Financial internal rate of return before financing (%)	8-10	-3.3	5.0	11.2	-3.1	4.0	9.2	5.1	1.3	4.5
3 Financial internal rate of return after financing (%)	12-15 c/	-5.6	3.8	18.5	5.4	2.7	14.0	7.8	0.5	3.3
4 Net present value before financing (US$MM) b/	Positive value	-4,029	1,306	1,236	-4,506	-1,961	569	6,797	4,642	2,602
5 Net present value after financing (US$MM) b/	Positive value	-3,554	-1,032	1,321	-3,975	-1,619	724	6,005	4,010	2,121
6 Minimum debt service coverage ratio - current	1.3	0.3	0.6	1.0	0.2	0.5	0.8	0.2	0.3	0.5
7 Minimum debt service coverage ratio - overall	1.5-2.0	n.a.	2.3	1.8	n.a.	n.a.	1.8	n.a.	n.a.	n.a.
8 Debt/equity ratio	Below 4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
9 Is project financially viable?		No	No	Yes	No	No	Yes	No	No	No
c Operation and Maintenance Costs Increased by 25 Percent										
1 Trust Fund balance always positive	Yes	No	No	Yes	No	No	Yes	No	No	No
2 Financial internal rate of return before financing (%)	8-10	4.5	6.2	15.3	4.0	5	11.9	7.0	1.8	5.6
3 Financial internal rate of return after financing (%)	12-15 c/	6.9	5.5	26.5	6.4	3.9	20.5	9.6	0.1	4.8
4 Net present value before financing (US$MM) b/	Positive value	-3,345	621	1,920	-3,718	1,174	1,357	5,577	3,423	1,382
5 Net present value after financing (US$MM) b/	Positive value	2,956	434	1,920	3,285	929	1,413	4,934	2,939	1,049
6 Minimum debt service coverage ratio - current	1.3	0.1	0.6	1.0	0.1	0.5	0.8	0.0	0.3	0.5
7 Minimum debt service coverage ratio - overall	1.5-2.0	n.a.	n.a.	2.0	n.a.	n.a.	2.0	n.a.	n.a.	n.a.
8 Debt/equity ratio	Below 4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
9 Is project financially viable?		No	No	Yes	No	No	Yes	No	No	No

Table 7.2.5-12 (Continued)

Sensitivity scenario and evaluation criteria	Target Result	Single Lane High Rise Lock Canal 150,000 DWT Tolls: Existing Tolls	Increased 50 percent	Optimal Tolls	Single Lane High Rise Lock Canal 200,000 DWT Tolls: Existing Tolls	Increased 50 percent	Optimal Tolls	Sea Level Canal Case E Tolls: Existing Tolls	Increased 50 percent	Optimal Tolls
d Status Quo Canal Tolls Increased 50 Percent d/										
1. Trust Fund balance always positive	Yes	--	--	Yes	--	--	Yes	--	--	--
2. Financial internal rate of return before financing (%)	8-10	--	--	7 6	--	--	6 6	--	--	--
3. Financial internal rate of return after financing (%)	12-15 c/	--	--	8 0	--	--	6 2	--	--	--
4. Net present value before financing (US$MM) b/	Positive value	--	--	-149	--	--	-627	--	--	--
5. Net present value after financing (US$MM) b/	Positive value	--	--	4	--	--	-424	--	--	--
6. Minimum debt service coverage ratio - current	1.3	--	--	1 2	--	--	1 0	--	--	--
7. Minimum debt service coverage ratio - overall	1.5-2 0	--	--	2 2	--	--	2 0	--	--	--
8. Debt/equity ratio	Below 4 0	--	--	3 0	--	--	3 0	--	--	--
9. Is project financially viable?		--	--	No	--	--	No	--	--	--

n.a. = not applicable.

a/ All interest rates were increased by 25 percent prior to any additional factor for currency swap costs

b/ Based upon an interest rate of 8 percent

c/ With a Panama Canal Authority as the management entity, a rate of return of 12-15 percent would be acceptable. If foreign equity was sought, the return would need to be in the range of 15-20 percent.

d/ Based on existing Panama Canal tolls increased by 50 percent from Table 6.5 of the Draft Final Report

Source: As noted above and from Appendix A.

Table 7.2.5-13

High Rise Lock Canal 150,000 DWT: Estimated Net Income After Debt Service, 2000-2060 Assuming a Panama Canal Authority and an Optimal Toll System

(1990 US$ millions)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper & Maint c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int	Debt Service Requirements e/: Princ	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2000		417.6	97.1	514.7	349.7	164.9	51.5	0.0	0.0	0.0	113.5	0.0	0.0	113.5	--	--
2001		434.7	98.6	533.4	350.8	182.6	53.3	0.0	0.0	0.0	129.2	0.0	0.0	247.2	--	--
2002		462.6	100.2	562.8	361.9	200.9	55.3	0.0	0.0	0.0	145.6	0.0	0.0	402.7	--	--
2003		471.2	101.7	572.9	353.0	220.0	57.3	0.0	0.0	0.0	162.7	0.0	0.0	581.5	--	--
2004		490.5	103.3	593.9	354.0	239.9	59.4	0.0	0.0	0.0	180.5	0.0	0.0	785.3	--	--
2005		510.7	105.0	615.7	366.1	260.6	61.6	0.0	0.0	0.0	199.0	0.0	0.0	1,015.7	--	--
2006		531.7	108.6	639.3	356.2	282.1	63.8	0.0	0.0	0.0	218.3	0.0	0.0	1,274.6	--	--
2007		553.5	108.3	661.8	357.2	304.6	66.2	0.0	0.0	0.0	238.4	0.0	0.0	1,564.0	--	--
2008		576.3	110.0	686.3	358.3	327.9	68.6	0.0	0.0	0.0	259.3	0.0	0.0	1,885.9	--	--
2009		599.9	111.7	711.7	360.4	352.3	71.2	0.0	0.0	0.0	281.1	0.0	0.0	2,242.4	--	--
2010	1	624.6	113.5	738.1	360.5	377.6	73.8	4.6	0.8	5.3	298.5	26.5	0.0	2,604.0	57.0	545.6
2011	2	650.3	115.3	765.6	361.5	404.0	76.6	9.2	1.5	10.7	316.7	27.1	0.0	2,987.8	30.6	310.4
2012	3	677.0	117.1	794.0	362.6	431.4	79.4	23.0	3.8	27.1	324.9	82.2	0.0	3,360.5	13.0	136.9
2013	4	704.8	119.9	823.7	363.7	460.0	82.4	74.0	22.5	96.9	280.7	236.8	0.0	3,538.8	3.9	40.4
2014	5	733.7	120.8	854.5	364.8	489.7	85.5	143.0	52.2	195.3	209.0	297.1	0.0	3,592.3	2.1	20.5
2015	6	763.9	122.7	886.5	366.8	520.7	88.7	200.8	74.2	275.0	157.1	309.0	0.0	3,584.0	1.6	14.6
2016	7	795.3	124.6	919.9	368.9	552.9	92.0	257.9	119.9	377.8	83.1	314.1	0.0	3,496.4	1.2	10.5
2017	8	827.9	126.5	954.5	369.0	585.5	95.4	303.0	192.6	495.6	-4.5	257.6	0.0	3,374.2	1.0	7.8
2018	9	862.0	128.5	990.5	369.1	621.4	99.0	327.9	245.3	573.2	-50.8	176.1	0.0	3,283.2	0.9	6.6
2019	10	897.4	130.5	1,027.9	370.1	657.8	102.8	342.6	295.4	638.0	-83.0	134.7	0.0	3,198.9	0.9	5.9
2020	11	1,175.0	132.6	1,307.6	475.1	832.5	130.8	320.5	352.6	673.1	28.6	0.0	2,726.5	627.9	1.0	2.0
2021	12	1,184.8	133.6	1,318.4	477.8	840.6	131.8	294.4	407.5	701.9	6.9	0.0	134.8	525.1	1.0	1.8
2022	13	1,194.7	134.6	1,329.3	480.5	848.8	132.9	284.3	451.7	716.1	-0.2	0.0	0.0	545.9	1.0	1.8
2023	14	1,204.6	135.6	1,340.3	483.2	857.1	134.0	231.9	447.9	679.9	43.2	0.0	88.1	521.8	1.1	1.8
2024	15	1,214.7	136.7	1,351.4	486.9	865.5	135.1	200.0	425.5	625.4	104.9	0.0	126.7	520.9	1.2	2.0
2025	16	1,224.8	137.7	1,362.5	489.6	873.9	136.3	188.7	391.2	580.9	176.8	0.0	197.7	520.8	1.3	2.2
2026	17	1,235.0	138.8	1,373.8	491.3	882.5	137.4	142.1	344.2	486.2	258.9	0.0	279.7	520.8	1.5	2.6
2027	18	1,245.3	139.8	1,385.2	494.0	891.2	138.6	117.5	308.5	425.9	326.7	0.0	347.5	520.8	1.8	3.0
2028	19	1,255.7	140.9	1,396.6	496.7	899.9	139.7	95.5	270.3	365.8	394.5	0.0	415.3	520.8	2.1	3.5
2029	20	1,266.2	141.9	1,408.1	499.4	908.8	140.8	76.3	229.6	305.9	462.0	0.0	482.9	520.8	2.6	4.2
2030	21	1,276.8	143.0	1,419.8	502.1	917.7	142.0	58.9	199.3	258.2	516.6	0.0	537.4	520.8	3.0	5.0
2031	22	1,287.4	144.1	1,431.5	504.8	926.7	143.2	45.8	168.0	213.8	569.8	0.0	590.7	520.8	3.7	6.1
2032	23	1,298.1	145.2	1,443.4	507.5	935.9	144.3	33.9	147.9	181.9	609.7	0.0	630.5	520.8	4.4	7.2
2033	24	1,309.0	146.3	1,455.3	510.2	945.1	145.5	23.7	122.0	145.7	653.9	0.0	674.7	520.8	5.5	9.1
2034	25	1,319.9	147.4	1,467.3	512.9	954.4	146.7	15.4	96.4	111.8	695.9	0.0	716.7	520.8	7.2	11.9
2035	26	1,330.9	148.5	1,479.4	515.6	963.9	147.9	9.0	69.7	78.7	737.2	0.0	758.0	520.8	10.4	17.0
2036	27	1,342.0	149.7	1,491.7	518.3	973.4	149.2	4.5	42.8	47.3	777.0	0.0	797.8	520.8	17.4	28.5
2037	28	1,353.2	150.8	1,504.0	521.0	983.0	150.4	1.8	22.0	23.8	808.8	0.0	829.6	520.8	34.9	56.8

Table 7.2.5-13 (Continued)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper & Maint c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements c/: Int	Debt Service Requirements c/: Princ	Debt Service Requirements c/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs i/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2038	29	1,364 5	152 0	1,516 4	523 7	992 8	151 8	0 5	8 9	9 4	831 8	0 0	862 6	520 8	88 7	146 2
2039	30	1,375 8	153 1	1,528 0	526 4	1,002 6	152 9	0 0	0 0	0 0	849 7	0 0	870 5	520 8	--	--
2040	31	1,387 3	154 3	1,541 6	529 1	1,012 6	154 2	0 0	0 0	0 0	858 4	0 0	879 2	520 8	--	--
2041	32	1,398 9	155 5	1,554 3	531 7	1,022 6	155 4	0 0	0 0	0 0	867 2	0 0	888 0	520 8	--	--
2042	33	1,410 6	156 6	1,567 2	534 4	1,032 7	156 7	0 0	0 0	0 0	876 0	0 0	896 9	520 8	--	--
2043	34	1,422 3	157 8	1,580 1	537 1	1,043 0	158 0	0 0	0 0	0 0	885 0	0 0	906 8	520 8	--	--
2044	35	1,434 2	159 0	1,593 2	539 8	1,053 4	159 3	0 0	0 0	0 0	894 0	0 0	914 9	520 8	--	--
2045	36	1,446 1	160 2	1,606 4	542 5	1,063 8	160 6	0 0	0 0	0 0	903 2	0 0	924 0	520 8	--	--
2046	37	1,458 2	161 4	1,619 7	545 2	1,074 4	162 0	0 0	0 0	0 0	912 5	0 0	933 3	520 8	--	--
2047	38	1,470 4	162 7	1,633 0	547 9	1,085 1	163 3	0 0	0 0	0 0	921 8	0 0	942 6	520 8	--	--
2048	39	1,482 8	163 9	1,646 5	550 6	1,095 9	164 7	0 0	0 0	0 0	931 3	0 0	952 1	520 8	--	--
2049	40	1,495 0	165 2	1,660 2	553 3	1,106 8	166 0	0 0	0 0	0 0	940 8	0 0	961 6	520 8	--	--
2050	41	1,507 5	166 4	1,673 9	556 0	1,117 9	167 4	0 0	0 0	0 0	950 5	0 0	971 3	520 8	--	--
2051	42	1,520 0	167 7	1,687 7	558 7	1,129 0	168 8	0 0	0 0	0 0	960 2	0 0	981 1	520 8	--	--
2052	43	1,532 7	169 0	1,701 7	561 4	1,140 2	170 2	0 0	0 0	0 0	970 1	0 0	990 9	520 8	--	--
2053	44	1,545 5	170 2	1,715 7	564 1	1,151 6	171 6	0 0	0 0	0 0	980 0	0 0	1,000 9	520 8	--	--
2054	45	1,558 4	171 5	1,729 9	566 8	1,163 1	173 0	0 0	0 0	0 0	990 1	0 0	1,010 9	520 8	--	--
2055	46	1,571 4	172 8	1,744 2	569 5	1,174 7	174 4	0 0	0 0	0 0	1,000 3	0 0	1,021 1	520 8	--	--
2056	47	1,584 5	174 1	1,758 6	572 2	1,186 4	175 9	0 0	0 0	0 0	1,010 6	0 0	1,031 4	520 8	--	--
2057	48	1,597 7	175 5	1,773 2	574 9	1,198 3	177 3	0 0	0 0	0 0	1,021 0	0 0	1,041 8	520 8	--	--
2058	49	1,611 0	176 8	1,787 8	577 6	1,210 2	178 8	0 0	0 0	0 0	1,031 4	0 0	1,052 3	520 8	--	--
2059	50	1,624 5	178 1	1,802 6	580 3	1,222 3	180 3	0 0	0 0	0 0	1,042 0	0 0	1,062 9	520 8	--	--
2060	51	1,638 0	179 5	1,817 5	583 0	1,234 5	181 8	0 0	0 0	0 0	1,052 8	0 0	1,073 6	520 8	--	--
	Total	69,730 8	8,611 7	78,342 5	28,889 7	49,452 9	7,834 3	3,793 5	5,514 2	9,307 7	32,310 9	1,880 1	32,494 5			

a/ Toll revenues from Table 6-5

b/ Estimated from revenues for transit operations and Canal advance reservation service, which total $84 4 million in 1991 Revenues are increased by 1 57 percent annually through 2020 and 0 76 percent annually from 2020 to 2060 in accordance with the growth of total transits

c/ Operation and maintenance costs from Tables 4-13 and 4-14

d/ Assumed to be 10 percent of total revenues

e/ From Appendix I

f/ From Appendix H

g/ Current year's net income (if positive) and prior year's cumulative net income in excess of $500 million

h/ Includes earnings on the prior year's cumulative net income of 4 percent less contributions to capital costs and dividend distributions

i/ Net income from operations less payments to Panama divided by total debt service requirements

j/ Net income from operations less payments to Panama plus trust fund balance divided by total debt service requirements

Table 7.2.5-14

Single Lane High Rise Lock Canal 150,000 DWT: Estimated Net Income After Debt Service, 2000-2060 Assuming a Panama Canal and an Optimal Toll System

(1990 US$ millions)

		Revenues				Net	Payment	Debt Service Requirements a/			Net Income	Toll Reserve Trust Fund			Current	Overall
	Prepaid				Oper &	Income	to				After Debt	Contribution		Trust	Debt	Debt
Year	Year	Tolls a/	Other b/	Total	Maint c/	from Operations	Panama d/	Int	Princ	Total	Service and Payment to Panama	to Capital Costs e/	Dividend Distributions g/	Fund Balance h/	Service Coverage Ratio i/	Service Coverage Ratio j/
2000		417.6	97.1	514.7	349.7	164.9	51.5	0.0	0.0	0.0	113.5	0.0	0.0	113.5	--	--
2001		434.7	98.6	533.4	350.0	182.6	53.3	0.0	0.0	0.0	129.2	0.0	0.0	247.2	--	--
2002		452.6	109.2	562.8	351.9	209.9	56.3	0.0	0.0	0.0	146.6	0.0	0.0	402.7	--	--
2003		471.2	101.7	572.9	353.0	220.0	57.3	0.0	0.0	0.0	162.7	0.0	0.0	565.5	--	--
2004		490.5	108.3	583.0	354.0	230.9	60.4	0.0	0.0	0.0	180.5	0.0	0.0	745.3	--	--
2005		510.7	105.0	615.7	356.1	259.6	31.9	0.0	0.0	0.0	199.0	0.0	0.0	1,015.7	--	--
2006		531.7	108.6	630.3	358.2	282.1	33.8	0.0	0.0	0.0	218.3	0.0	0.0	1,274.6	--	--
2007		553.5	108.3	661.8	357.2	304.6	35.2	0.0	0.0	0.0	238.4	0.0	0.0	1,564.0	--	--
2008		576.3	110.0	686.3	358.3	327.9	68.6	0.0	0.0	0.0	259.3	0.0	0.0	1,885.9	--	--
2009		600.0	111.7	711.7	359.4	352.3	71.2	0.0	0.0	0.0	281.1	0.0	0.0	2,242.4	--	--
2010	1	624.6	113.5	738.1	360.5	377.6	73.8	3.9	0.6	4.6	299.2	22.8	0.0	2,608.5	68.4	636.4
2011	2	650.3	116.3	766.6	361.5	404.0	76.6	7.9	1.3	9.2	318.2	23.2	0.0	3,000.0	36.7	383.2
2012	3	677.0	117.1	794.0	362.6	431.4	79.4	19.3	3.2	22.5	329.5	66.8	0.0	3,391.0	15.6	166.3
2013	4	704.8	118.9	823.7	363.7	460.0	82.4	47.1	13.9	61.0	316.7	125.4	0.0	3,717.9	6.2	87.2
2014	5	733.7	120.8	854.5	364.8	489.7	85.5	85.2	32.0	117.2	287.1	156.9	0.0	3,986.8	3.5	37.6
2015	6	763.9	122.7	886.6	365.9	520.7	88.7	116.1	46.0	162.2	269.8	160.7	0.0	4,266.8	2.7	29.0
2016	7	795.3	124.6	919.9	366.9	552.9	92.0	171.5	81.2	252.7	208.2	292.8	0.0	4,361.9	1.8	18.0
2017	8	827.9	126.5	954.5	368.0	586.5	95.4	218.3	136.2	354.6	136.5	249.7	0.0	4,412.8	1.4	13.8
2018	9	862.0	128.5	990.5	369.1	621.4	99.0	247.8	172.7	420.3	102.1	176.0	0.0	4,515.4	1.2	12.0
2019	10	897.4	130.6	1,027.9	370.1	657.8	102.8	268.6	211.8	480.4	74.6	140.4	0.0	4,630.3	1.2	10.8
2020	11	1,175.0	132.8	1,307.8	475.1	832.5	130.8	253.0	249.9	502.9	198.9	0.0	4,329.2	685.2	1.4	2.8
2021	12	1,184.0	133.8	1,318.4	477.8	840.6	131.8	234.3	300.9	535.2	173.5	0.0	358.8	527.4	1.3	2.3
2022	13	1,194.7	134.6	1,329.3	480.5	848.8	132.9	212.1	343.1	555.1	160.7	0.0	188.2	521.1	1.3	2.2
2023	14	1,204.6	135.8	1,340.3	483.2	857.1	134.0	187.4	347.6	535.0	188.1	0.0	209.2	520.8	1.4	2.3
2024	15	1,214.7	136.7	1,351.4	486.0	865.5	135.1	162.5	338.1	500.6	229.7	0.0	250.6	520.8	1.5	2.5
2025	16	1,224.8	137.7	1,362.5	488.8	873.9	136.3	136.4	317.9	456.3	281.3	0.0	302.2	520.8	1.6	2.8
2026	17	1,235.0	138.8	1,373.8	491.3	882.5	137.4	116.0	291.7	397.7	347.5	0.0	368.3	520.8	1.9	3.2
2027	18	1,245.3	139.8	1,385.2	494.0	891.2	138.6	96.0	250.9	346.9	405.7	0.0	426.6	520.8	2.2	3.7
2028	19	1,255.7	140.9	1,396.6	496.7	899.9	139.7	78.3	218.0	296.3	464.0	0.0	484.8	520.8	2.6	4.3
2029	20	1,266.2	141.9	1,408.1	499.4	908.8	140.8	62.6	183.3	246.2	521.8	9.7	542.6	511.1	3.1	5.2
2030	21	1,276.8	143.0	1,419.8	502.1	917.7	142.0	49.7	161.0	210.7	565.1	13.6	576.2	505.8	3.7	6.1
2031	22	1,287.4	144.1	1,431.5	504.8	926.7	143.2	38.3	131.2	169.6	614.0	14.7	620.9	505.6	4.6	7.6
2032	23	1,298.1	145.2	1,443.4	507.5	935.9	144.3	29.0	113.2	142.2	649.3	53.0	654.9	487.2	5.6	8.9
2033	24	1,309.0	146.3	1,455.3	510.2	945.1	146.5	21.1	96.2	117.3	682.3	53.0	0.0	1,115.2	6.8	16.3
2034	25	1,319.9	147.4	1,467.3	512.9	954.4	148.7	14.5	80.9	95.4	712.3	0.0	1,327.5	544.6	8.5	14.2
2035	26	1,330.9	148.5	1,479.4	515.6	963.9	147.9	9.0	67.6	76.5	739.4	0.0	784.0	521.8	10.7	17.5
2036	27	1,342.0	149.7	1,491.7	518.3	973.4	149.2	4.6	42.6	47.2	777.0	0.0	798.8	520.9	17.5	29.5

Table 7.2.5-14 (Continued)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper & Maint c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int	Debt Service Requirements e/: Princ	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2037	28	1,363 2	160 8	1,604 0	621 0	983 0	150 4	1 9	22 7	24 6	808 1	0 0	828 9	520 8	33 9	55 1
2038	29	1,364 5	152 0	1,516 4	523 7	992 8	151 6	0 5	9 5	10 0	831 2	0 0	852 0	520 8	84 4	136 6
2039	30	1,375 8	153 1	1,529 0	526 4	1,002 6	152 9	0 0	0 0	0 0	849 7	0 0	870 5	520 8	- -	- -
2040	31	1,387 3	154 3	1,541 6	529 1	1,012 6	154 2	0 0	0 0	0 0	858 4	0 0	879 2	520 8	- -	- -
2041	32	1,398 9	155 5	1,554 3	531 7	1,022 6	155 4	0 0	0 0	0 0	867 2	0 0	888 0	520 8	- -	- -
2042	33	1,410 6	156 6	1,567 2	534 4	1,032 7	156 7	0 0	0 0	0 0	876 0	0 0	896 9	520 8	- -	- -
2043	34	1,422 3	157 8	1,580 1	537 1	1,043 0	158 0	0 0	0 0	0 0	885 0	0 0	906 8	520 8	- -	- -
2044	35	1,434 2	159 0	1,593 2	539 8	1,053 4	159 3	0 0	0 0	0 0	894 0	0 0	914 9	520 8	- -	- -
2045	36	1,446 1	160 2	1,606 4	542 5	1,063 8	160 6	0 0	0 0	0 0	903 2	0 0	924 0	520 8	- -	- -
2046	37	1,458 2	161 4	1,619 7	545 2	1,074 4	162 0	0 0	0 0	0 0	912 5	0 0	933 3	520 8	- -	- -
2047	38	1,470 4	162 7	1,633 0	547 9	1,085 1	163 3	0 0	0 0	0 0	921 8	0 0	942 6	520 8	- -	- -
2048	39	1,482 6	163 9	1,646 5	550 6	1,095 9	164 7	0 0	0 0	0 0	931 3	0 0	952 1	520 8	- -	- -
2049	40	1,495 0	165 2	1,660 2	553 3	1,106 8	166 0	0 0	0 0	0 0	940 8	3 2	961 6	517 6	- -	- -
2050	41	1,507 5	166 4	1,673 9	556 0	1,117 9	167 4	0 0	0 0	0 0	950 5	19 7	968 1	501 0	- -	- -
2051	42	1,520 0	167 7	1,687 7	558 7	1,129 0	168 8	0 0	0 0	0 0	960 2	19 7	981 2	500 3	- -	- -
2052	43	1,532 7	169 0	1,701 7	561 4	1,140 2	170 2	0 0	0 0	0 0	970 1	0 0	970 4	520 0	- -	- -
2053	44	1,545 5	170 2	1,715 7	564 1	1,151 6	171 6	0 0	0 0	0 0	980 0	0 0	1,000 1	520 8	- -	- -
2054	45	1,558 4	171 5	1,729 9	566 8	1,163 1	173 0	0 0	0 0	0 0	990 1	0 0	1,010 9	520 8	- -	- -
2055	46	1,571 4	172 8	1,744 2	569 5	1,174 7	174 4	0 0	0 0	0 0	1,000 3	0 0	1,021 1	520 8	- -	- -
2056	47	1,584 5	174 1	1,758 6	572 2	1,186 4	175 9	0 0	0 0	0 0	1,010 6	0 0	1,031 4	520 8	- -	- -
2057	48	1,597 7	175 5	1,773 2	574 9	1,198 3	177 3	0 0	0 0	0 0	1,021 0	0 0	1,041 8	520 8	- -	- -
2058	49	1,611 0	176 8	1,787 8	577 6	1,210 2	178 8	0 0	0 0	0 0	1,031 4	0 0	1,052 3	520 8	- -	- -
2059	50	1,624 5	178 1	1,802 6	580 3	1,222 3	180 3	0 0	0 0	0 0	1,042 0	0 0	1,062 9	520 8	- -	- -
2060	51	1,638 0	179 5	1,817 5	583 0	1,234 5	181 8	0 0	0 0	0 0	1,052 8	0 0	1,073 8	520 8	- -	- -
	Total	69,730 8	8,611 7	78,342 5	29,889 7	49,452 9	7,834 3	2 895 0	4 255 1	7,150 1	34,468 5	1,801 2	35,166 4			

a/ Toll revenues from Table A-70

b/ Estimated from revenues for transit operations and Canal advance reservation service, which total $84 4 million in 1991 Revenues are increased by 1 57 percent annually through 2020 and 0 78 percent annually from 2020 to 2060 in accordance with the growth of total transits

c/ Operation and maintenance costs from Tables 4-13 and 4-14 of the Draft Final Report

d/ Assumed to be 10 percent of total revenues

e/ From Appendix A

f/ From Appendix A The capital costs incurred from 2029 to 2033 and 2049 to 2051 are for two new pump stations

g/ Current year's net income (if positive) and prior year's cumulative net income in excess of $500 million

h/ Includes earnings on the prior year's cumulative net income of 4 percent less contributions to capital costs and dividend distributions

i/ Net income from operations less payments to Panama divided by total debt service requirements

j/ Net income from operations less payments to Panama plus trust fund balance divided by total debt service requirements

Table 7.2.5-15

Single Lane High Rise Lock Canal 200,000 DWT: Estimated Net Income After Debt Service, 2000-2060 Assuming a Panama Canal Authority and an Optimal Toll System

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper & Maint c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int	Debt Service Requirements e/: Princ	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2000		417.8	97.1	514.7	349.7	164.9	51.5	0.0	0.0	0.0	113.5	0.0	0.0	113.5		
2001		434.7	98.6	533.4	350.8	182.6	53.3	0.0	0.0	0.0	129.2	0.0	0.0	247.2		
2002		452.8	100.2	552.8	351.9	200.9	55.3	0.0	0.0	0.0	145.6	0.0	0.0	402.7		
2003		471.2	101.7	572.9	353.0	220.0	57.3	0.0	0.0	0.0	162.7	0.0	0.0	581.5		
2004		490.5	103.3	593.9	354.0	239.9	59.4	0.0	0.0	0.0	180.5	0.0	0.0	785.3		
2005		510.7	105.0	615.7	355.1	260.6	61.6	0.0	0.0	0.0	199.0	0.0	0.0	1,015.7		
2006		531.7	106.6	638.3	356.2	282.1	63.8	0.0	0.0	0.0	218.3	0.0	0.0	1,274.6		
2007		553.5	108.3	661.8	357.2	304.6	66.2	0.0	0.0	0.0	238.4	0.0	0.0	1,564.0		
2008		576.3	110.0	686.3	358.3	327.9	68.6	0.0	0.0	0.0	259.3	0.0	0.0	1,885.9		
2009	1	599.9	111.7	711.7	359.4	352.3	71.2	4.2	0.7	4.9	276.2	24.6	0.0	2,212.9	56.9	505.1
2010	2	624.6	113.5	738.1	360.5	377.6	73.8	8.5	1.4	9.9	293.9	25.1	0.0	2,570.2	30.6	289.7
2011	3	650.3	115.3	765.5	361.5	404.0	76.6	18.7	3.1	21.8	305.7	59.4	0.0	2,919.3	15.0	149.2
2012	4	677.0	117.1	794.0	362.6	431.4	79.4	47.7	14.2	61.9	290.1	131.3	0.0	3,194.9	5.7	57.3
2013	5	704.8	118.9	823.7	363.7	460.0	82.4	89.0	32.2	121.2	256.4	179.0	0.0	3,400.0	3.1	31.2
2014	6	733.7	120.8	854.5	364.8	489.7	85.5	126.6	48.9	175.5	228.8	192.4	0.0	3,572.4	2.3	22.7
2015	7	763.9	122.7	886.5	365.8	520.7	88.7	165.4	81.9	247.4	184.7	199.7	0.0	3,700.3	1.7	16.7
2016	8	795.3	124.6	919.9	366.9	552.9	92.0	227.3	139.2	366.4	94.5	324.0	0.0	3,618.8	1.3	11.1
2017	9	827.9	126.5	954.5	368.0	586.5	95.4	270.9	181.9	452.8	38.2	256.2	0.0	3,545.6	1.1	8.9
2018	10	862.0	128.5	990.5	369.1	621.4	99.0	301.5	227.1	528.6	6.2	195.1	0.0	3,486.1	1.0	7.6
2019	11	897.4	130.5	1,027.9	370.1	657.8	102.8	293.8	274.5	568.4	-13.4	53.2	0.0	3,559.0	1.0	7.2
2020	12	1,186.0	132.6	1,318.6	483.4	835.2	131.9	273.6	313.8	587.4	115.9	0.0	3,174.9	642.4	1.2	2.3
2021	13	1,197.3	133.6	1,330.9	486.1	844.8	133.1	250.3	366.2	616.5	95.2	0.0	237.6	525.7	1.2	2.0
2022	14	1,208.7	134.6	1,343.3	488.8	854.5	134.3	223.8	380.2	604.0	116.2	0.0	141.9	521.0	1.2	2.1
2023	15	1,220.2	135.6	1,355.8	491.5	864.3	135.6	196.4	378.2	574.6	154.1	9.7	175.1	511.1	1.3	2.2
2024	16	1,231.8	136.7	1,368.4	494.2	874.3	136.8	169.2	364.0	533.2	204.2	13.6	215.4	506.8	1.4	2.3
2025	17	1,243.5	137.7	1,381.2	496.9	884.3	138.1	143.4	332.3	475.7	270.5	14.7	277.3	505.6	1.6	2.6
2026	18	1,255.3	138.8	1,394.1	499.6	894.5	139.4	119.8	295.9	415.7	339.4	53.0	345.0	467.2	1.8	2.9
2027	19	1,267.3	139.8	1,407.1	502.3	904.8	140.7	98.8	259.6	358.4	405.6	53.0	0.0	838.6	2.1	4.5
2028	20	1,279.3	140.9	1,420.2	505.0	915.2	142.0	80.4	217.6	298.0	475.2	0.0	813.7	533.5	2.6	4.4
2029	21	1,291.5	141.9	1,433.4	507.7	925.8	143.3	64.8	190.8	255.6	526.8	0.0	560.3	521.3	3.1	5.1
2030	22	1,303.8	143.0	1,446.8	510.4	936.4	144.7	51.2	164.8	216.0	575.8	0.0	597.1	520.9	3.7	6.1
2031	23	1,316.2	144.1	1,460.3	513.1	947.2	146.0	39.4	143.9	183.3	617.9	0.0	838.8	520.8	4.4	7.2
2032	24	1,328.7	145.2	1,473.9	515.8	958.1	147.4	29.3	122.1	151.3	659.4	0.0	880.2	520.8	5.4	8.8
2033	25	1,341.3	146.3	1,487.6	518.5	969.2	148.8	20.8	101.5	122.3	698.1	0.0	719.0	520.8	6.7	11.0
2034	26	1,354.1	147.4	1,501.5	521.2	980.3	150.2	13.9	82.6	96.5	733.7	0.0	754.6	520.8	8.6	14.0
2035	27	1,367.0	148.5	1,515.5	523.9	991.6	151.6	8.2	66.7	74.9	765.1	0.0	786.0	520.8	11.2	18.2
2036	28	1,380.0	149.7	1,529.6	526.6	1,003.1	153.0	4.0	40.5	44.4	805.7	0.0	826.5	520.8	19.1	30.9
2037	29	1,393.1	150.8	1,543.9	529.3	1,014.6	154.4	1.4	19.7	21.1	839.1	0.0	860.0	520.8	40.7	65.4
2038	30	1,406.3	152.0	1,558.3	532.0	1,026.3	155.8	0.3	5.2	5.5	865.0	0.0	885.8	520.8		
2039	31	1,419.7	153.1	1,572.8	534.7	1,038.2	157.3	0.0	0.0	0.0	880.9	0.0	901.7	520.8		
2040	32	1,433.2	154.3	1,587.5	537.4	1,050.2	158.8	0.0	0.0	0.0	891.4	0.0	912.2	520.8		

Table 7.2.5-15 (Continued)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper & Maint c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int	Debt Service Requirements e/: Princ	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2041	33	1,446 9	155 5	1,602 3	540 0	1,062 3	160 2	0 0	0 0	0 0	902 0	0 0	922 9	520 8	..	..
2042	34	1,460 6	156 6	1,617 3	542 7	1,074 5	161 7	0 0	0 0	0 0	912 8	0 0	933 6	520 8	..	..
2043	35	1,474 5	157 8	1,632 3	545 4	1,086 9	163 2	0 0	0 0	0 0	923 7	0 0	944 5	520 8	..	..
2044	36	1,488 5	159 0	1,647 6	548 1	1,099 4	164 8	0 0	0 0	0 0	934 7	3 2	955 5	517 6	..	..
2045	37	1,502 7	160 2	1,662 9	550 8	1,112 1	166 3	0 0	0 0	0 0	945 8	19 7	963 4	501 0	..	..
2046	38	1,517 0	161 4	1,678 4	553 5	1,124 9	167 8	0 0	0 0	0 0	957 1	19 7	958 1	500 3	..	..
2047	39	1,531 4	162 7	1,694 1	556 2	1,137 9	169 4	0 0	0 0	0 0	968 5	0 0	968 8	520 0	..	..
2048	40	1,546 0	163 9	1,709 9	558 9	1,151 0	171 0	0 0	0 0	0 0	980 0	0 0	1,000 0	520 8	..	..
2049	41	1,560 7	165 2	1,725 9	561 6	1,164 2	172 6	0 0	0 0	0 0	991 6	0 0	1,012 4	520 8	..	..
2050	42	1,575 5	166 4	1,742 0	564 3	1,177 6	174 2	0 0	0 0	0 0	1,003 4	0 0	1,024 3	520 8	..	..
2051	43	1,590 5	167 7	1,758 2	567 0	1,191 2	175 8	0 0	0 0	0 0	1,015 4	0 0	1,036 2	520 8	..	..
2052	44	1,605 7	169 0	1,774 6	569 7	1,204 9	177 5	0 0	0 0	0 0	1,027 4	0 0	1,048 3	520 8	..	..
2053	45	1,620 9	170 2	1,791 2	572 4	1,218 7	179 1	0 0	0 0	0 0	1,039 6	0 0	1,060 5	520 8	..	..
2054	46	1,636 3	171 5	1,807 9	575 1	1,232 8	180 8	0 0	0 0	0 0	1,052 0	0 0	1,072 8	520 8	..	..
2055	47	1,651 9	172 8	1,824 7	577 8	1,246 9	182 5	0 0	0 0	0 0	1,064 5	0 0	1,085 3	520 8	..	..
2056	48	1,667 6	174 1	1,841 8	580 5	1,261 3	184 2	0 0	0 0	0 0	1,077 1	0 0	1,097 9	520 8	..	..
2057	49	1,683 5	175 5	1,859 0	583 2	1,275 7	185 9	0 0	0 0	0 0	1,089 9	0 0	1,110 7	520 8	..	..
2058	50	1,699 5	176 8	1,876 3	585 9	1,290 4	187 6	0 0	0 0	0 0	1,102 8	0 0	1,123 6	520 8	..	..
2059	51	1,715 7	178 1	1,893 8	588 6	1,305 2	189 4	0 0	0 0	0 0	1,115 8	0 0	1,136 7	520 8	..	..
2060	52	1,732 0	179 5	1,911 5	591 3	1,320 2	191 2	0 0	0 0	0 0	1,129 1	0 0	1,149 9	520 8	..	..
Total		71,707 1	8,611 7	80,318 8	29,230 0	51,088 9	8,031 9	3,342 7	4,850 8	8,193 5	34,863 5	1,826 5	35,108 3			

a/ Toll revenues from Table A-70

b/ Estimated from revenues for transit operations and Canal advance reservation service, which total $84 4 million in 1991 Revenues are increased by 1 57 percent annually through 2020 and 0 76 percent annually from 2020 to 2060 in accordance with the growth of total transits

c/ Operation and maintenance costs from Tables 4-13 and 4-14 of the Draft Final Report

d/ Assumed to be 10 percent of total revenues

e/ From Appendix A

f/ From Appendix A The capital costs incurred from 2029 to 2033 and 2049 to 2051 are for two new pump stations

g/ Current year's net income (if positive) and prior year's cumulative net income in excess of $500 million

h/ Includes earnings on the prior year's cumulative net income of 4 percent less contributions to capital costs and dividend distributions

i/ Net income from operations less payments to Panama divided by total debt service requirements

j/ Net income from operations less payments to Panama plus trust fund balance divided by total debt service requirements

7.2.6 Identification of the Feasible Canal Alternatives

As the result of financial analyses, the following three High Rise Canal Alternatives are identified as financially feasible alternatives under optimal toll scenario and rates.

- High Rise 150,000 DWT Alternative
- High Rise 150,000 DWT Culebra Cut Single Lane Alternative
- High Rise 200,000 DWT Culebra Cut Single Lane Alternative

The Sea Level Canal alternatives are not found to be financially feasible under any of the scenarios analyzed.

7.3 Management Arrangements

This component study has largely been changed in its scope of works and, therefore, the original scope of works and TOR defined in Detailed Plan of Study (DPS) are considered no longer valid. Newly defined scope of works drafted by CAS are;

i) to investigate various management arrangements of other large scale canals and large scale projects of a similar nature and

ii) to recommend the best suited management arrangements for the canal.

The main objective of the study thus defined is to identify the most desirable management arrangements or canal operating entity, including canal ownership, as the presupposition of financial analysis and financing scheme to the project.

7.3.1 Approach

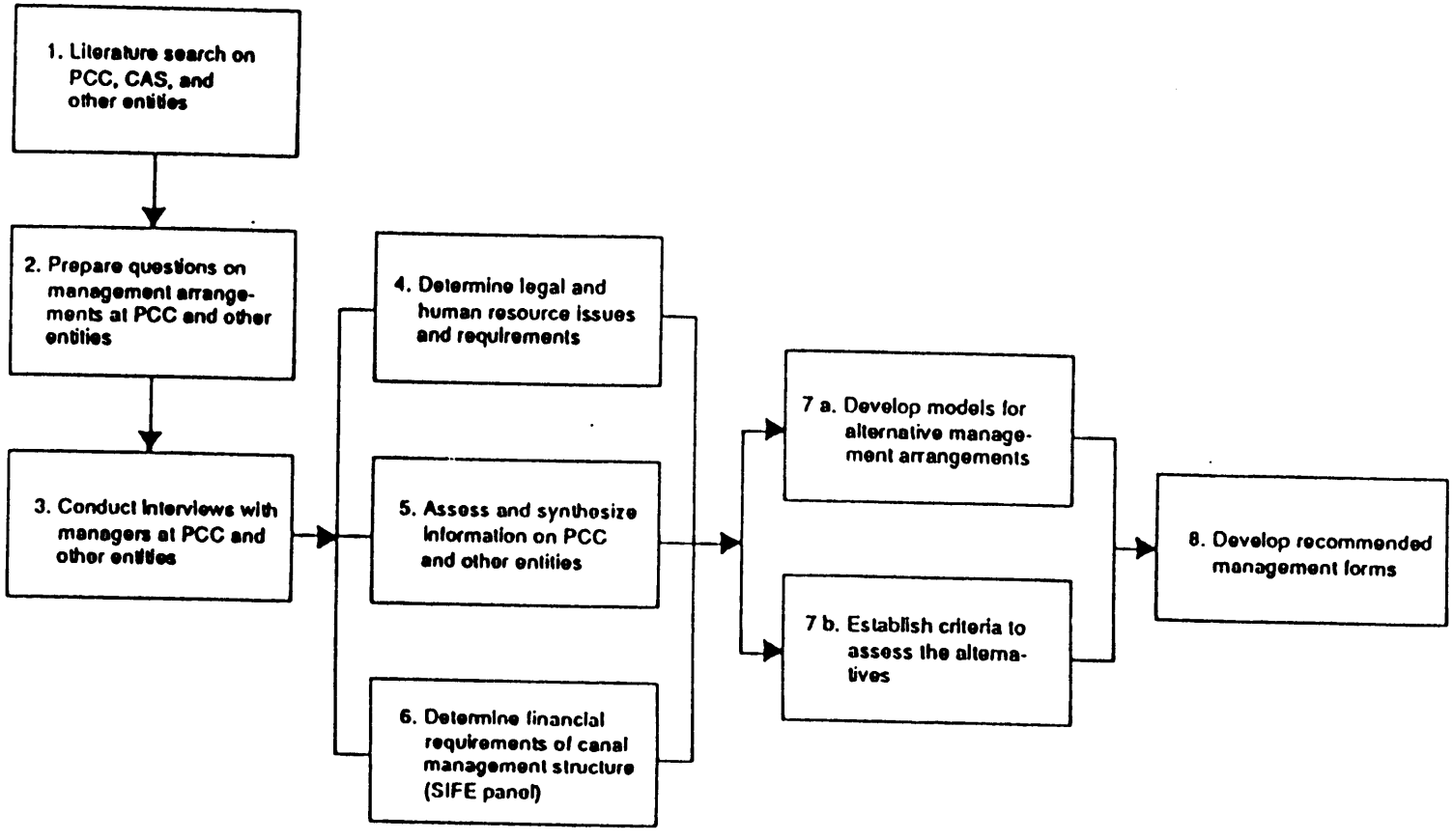
Based on the above, following approach to the study is taken by the consultant.

i) A range of management arrangement models for the Canal alternative was identified and evaluated to determine which would be most suitable to handle the political, financial, management and operating requirements of the Canal alternative.

ii) Surveys of management arrangements of the existing Panama Canal and other international waterways and transportation entities were reviewed and evaluated as possible management models for the Canal alternative.

Figure 7.3.1-1

Management Arrangements Analyses Tasks and Work Flow



iii) General management issues relevant to the design of the management arrangements for the Canal alternative were examined.

iv) Five models for managing the Canal alternative were defined and evaluated against a comprehensive set of criteria that addressed a range of political, financial, managerial, commercial, personnel, and international issues relevant to the alternative canal's efficient management and operation.

v) A set of recommended management arrangement models emerged from the evaluations and analysis, and a preferred management arrangement model was selected.

Figure 7.3.1-1 presents an overview of the management arrangements analyses tasks and work flow.

7.3.2 Review on Similar Entities

As the first step of the study, literature search and interviews are conducted for the seven international waterways and transportation entities.

These entities are;

i) the Panama Canal,

ii) the St. Lawrence Seaway

iii) the Suez Canal,

iv) the Rhine Main-Danube Canal,

v) the Channel Tunnel, and to the lesser extent

vi) the Port Authority of New York and New Jersey, and

vii) Los Angeles Coalport.

Based on the examination of the above seven entities, five key issues, relevant to the design of management arrangements for the canal, are extracted and highlighted. These are;

i) Public purpose versus commercial objective,

ii) Financial self-sufficiency,

iii) Operating and management autonomy,

iv) Private and public role, and

v) Multinational and multijurisdictional entities.

7.3.3 Need for Single Management Entity

Then the consultant establishes the need for a single management entity by the analysis of two alternatives namely, High Rise Lock Canal Alternative and Single-Lane Sea-Level Canal Alternative.

For the High Rise Lock Canal Alternative, this requirement is considered rather imperative because of the alternative's inseparable nature from the existing canal.

For the Single-Lane Sea-Level Canal Alternative, which needs to be operated with the existing canal,

i) needs for coordinations including traffic management and toll policy,

ii) to avoid uneconomic competition, and

iii) over all administrative advantages are quoted as the main reasons to support single management entity.

Models for Management of Canal Alternative

Now, the consultant introduces five different types of models for management of canal alternatives for the evaluation and selection of the best one.

These are;

i) Government department (government agency, civil service operation),

ii) Public authority (Panamanian public sector ownership, operating autonomy),

iii) International public entity (international public owner-ship, operating autonomy),

iv) Special purpose corporation (mixed public-private sector and Panamanian/foreign ownership, operating autonomy), and private company (private ownership, operating autonomy).

Evaluation Criteria

To evaluate the above five models, 11 criteria are set;

i) Compatibility with Panamanian sovereignty,

ii) Compatibility with existing international law,

iii) Insulation from local politics,

iv) Financial integrity and stability,

v) Capacity for long-term planning,

vi) Customer responsiveness,

vii) Management autonomy and flexibility,

vii) Labor productivity,

ix) Ability to evolve and absorb or spin off functions,

x) Compatibility with evaluation of the existing Panama Canal entity, and

xi) Ability to consolidate Panama's other interoceanic transportation initiatives.

Evaluation

These evaluation criteria are applied to the five prototype management arrangements models in Table 7.3.3-1.

The results of this application are measured on a scale of "Poor" through "Excellent" and permit preliminary judgments on the effectiveness and practicability of the various management arrangements. As the direct corollary of this evaluation, three models are recommended for further evaluation namely, Panama Canal Authority, International Public Entity, and Special Purpose Corporation. The remaining two models namely, Government Department, and private company are rejected by this examination.

- A Panama Canal Authority: Preferred Management Arrangement Model.

Through the final evaluation among the three recommendable models, a Panama Canal Authority is selected as the most suitable management arrangement model with the following supporting reasons.

1) Either the Panama Canal Authority model or the SPC model for management arrangements would appear to be suitable to handle the political, financial management,and operating efficiency requirements of the Canal alternative.

The international public entity is deemed to pose practical difficulties in terms of operating efficiency and its likely inability to incorporate other trans-isthmian commercial activities.

2) Between the two, the Panama Canal Authority solution seems to be the more pragmatic option.

- From a Panamanian domestic political point of view, the Canal authority is probably a more easily comprehensible and thus acceptable formula for organizing Panama's relationship to the Canal alternative.

- At the same time, a strong"Authority Act" could be drafted to preserve all the necessary characteristics for effective operation and development of the Canal alternative in a competitive environment: financial integrity, insulation from politics, management flexibility, labor productivity, and others.

- The Panama Canal Authority may well prove to be most similar organizationally to the form of institution that succeeds the present Panama Canal Commission after December 31, 1999. This similarity would ensure a smooth transition into the new pattern of activity featuring the simultaneous, integrated operations of the existing Canal and the eventual Canal Alternative.

3) The Panama Canal Authority model has the additional advantage of an ability to evolve toward a Special Purpose Corporation (SPC) concept. If, over time, the ownership and operating characteristics of an SPC presented clear benefits for the development and management of the Canal Alternative, the Authority could easily establish and even invest in an SPC and contract out day-to-day operation and management of the Canal Alternative to that entity.

Table 7.3.3-1

Management Arrangements: Analysis of Models

Evaluation Criteria	Panamanian Government Department	Panama Canal Authority	International Public Entity	Special Purpose Corporation (SPC)	Private Company
Compatibility with Panamanian sovereignty	●●●●● Indistinguishable from any government agency	●●●●● Chartered under Panama's law and exercised through presidential appointment of board	●●● Sovereignty limited by international agreement	●●●● Full but indirectly exercised through concession agreement	●●● Fully controlled by Panamanian law
Compatibility with existing international law	●●●● As long as toll policies are controlled	●●●● Authority Act would be drafted to conform	●●● Depends on relationship of participating countries to neutrality treaties	●●●● SPC concessions would be drafted to conform	● Would require significant revision of existing agreements
Insulation from local politics	● No insulation possible	●●● Created by strong Authority Act	●●●● International agreement would govern	●●●● Depends on legal framework of SPC and its concession	● Panamanian private sector and government are interdependent
Financial integrity and stability	● Must fight for resources; could become a "cash cow" for government	●●●● Created by strong Authority Act including monopoly granted and ability to manage finances	●●●● Depends on approvals of other governments for toll setting and financing	●●●● Depends on legal framework of SPC and its concession	●●● Financial viability and ability to raise capital could be uncertain
Capacity for long-term planning	● Horizons may be limited by political pressures	●●●● Given minimal interference and secure revenues	●●●● International agreement provides considerable planning autonomy	●●●● Depends on SPC concession terms and renewal options	●● Depends on corporate profit-planning horizons
Customer responsiveness	● Political connections and objectives intrude	●●● Depends on degree of operating autonomy granted by Authority Act	●●● Depends on bureaucracy	●●●● Especially favorable with participation of shipping lines in SPC but long-term concession and possible "cost-plus" arrangement could weaken	●●●●● Profit motivation requires customer service or natural monopoly

Table 7.3.3-1 (Continued)

Evaluation Criteria	Panamanian Government Department	Panama Canal Authority	International Public Entity	Special Purpose Corporation (SPC)	Private Company
Management autonomy and flexibility	● Civil service; government regulations and political decision making prevail	● ● ● ● Management independence would be created by a Sound Authority Act	● ● ● Depends on Board of Directors but could be problematic if international politics intrude (NATO) (UN)	● ● ● ● Concession contract provides latitude for independent management but ownership structure may influence result	● ● ● Theoretically favorable, but subject to outside political influence
Labor productivity	● Undermined by lower pay scales and bureaucratic personnel procedures	● ● ● ● Special labor statutes encourage productivity	● ● ● Special labor statutes can be established but international bureaucratic practice intrudes	● ● ● ● Special labor statutes encourage productivity	● ● Theoretically favorable but vulnerable to threat of strike
Ability to evolve and absorb other functions	● ● Subject to bureaucratic in-fighting and nonoperating considerations	● ● ● Depends on Authority Act	● Limited amendment of initial charter difficult in multilateral setting	● ● ● Depends on terms of concession and contract	● ● ● Theoretically favorable, but depends on insulation from local politics
Compatibility with the evolution of the existing Panama Canal entity	● Very distant organizationally from existing entity	● ● ● ● Depends on Authority Act but transition could be smooth	● ● Distant organizationally from existing entity	● ● ● Depends on terms of concession and contract but somewhat distant from existing entity	● Very distant organizationally from existing entity
Ability to consolidate Panama's other interoceanic transportation activities	● Difficult given purely commercial character of likely other project	● ● ● ● Depends on Authority Act but consolidation could be smooth	● Difficult given private and purely commercial character of other activities	● ● ● Depends on terms of concession and contract but variety of SPC sources could present difficulties	● Would be difficult unless company had resources to execute mergers and acquisitions

Key: ● ● ● ● ● - Excellent; ● ● ● ● - Good; ● ● ● - Medium; ● ● - Fair; ● - Poor

7.4 Impacts Upon Panama

In general, the construction and operation of either alternative will have a long-term beneficial economic impact on Panama by providing a sustainable income source throughout the next century. Given the type and scale of activities which would be associated with the construction and operation of either of the proposed alternatives for canal expansion, it is inevitable that the project will also have negative impacts upon the country. The ability to identify impacts prior to project implementation is essential to developing programs that will minimize or control the negative impacts and capitalize on the benefits.

Following is a summary of the potential socio-cultural, infrastructure, political, environmental, geographic, economic and financial effects of the alternatives as they might impact Panama, as well as the conclusions reached regarding the probable benefits and costs of each alternative.

The foundation for this information is the Booz-Allen & Hamilton, Inc. component study, Impacts Upon Panama, dated July 16, 1993.

7.4.1 Scope

The objective of this section is to qualify and quantify, to the greatest extent possible, potential impacts of the Canal alternatives that survived the pre-screening process. Because of the broad and varied nature of subject fields, a general methodology was followed in the component study Impacts Upon Panama. This methodology used a dual analysis and focused on the most significant impacts, as well as on those impacts which are considered discriminatory between the two alternatives.

The first approach was to develop a detailed analysis of probable impacts in the disciplines outlined in the terms of reference for this study. The second approach was to use the System Dynamics Model. Model results which differed from expectations were subjected to further investigation to determine the validity of the cause-effect relationships used by the model, and corrections were made, where appropriate, as a result of these investigations.

Using both the discipline specific methodologies and the output of the model, impacts which discriminated between the alternatives were determined.

In the course of the study, impacts were defined for both the construction and operating phases of each alternative. Impacts can be both positive and negative, are defined as costs and/or benefits and can be either social or economic. The term "discriminatory impacts" is used when referring to an impact which has consequences of importance for choosing one canal alternative over the other.

7.4.2 *Discussion of Potential Impacts Upon Panama*

Any large engineering project such as the one proposed will have a significant effect on the surrounding region. As identified in the Component Study, Impacts Upon Panama, the entire country of Panama was considered as the impact area. To allow for more refined assessment, two geographic reference areas were used for analysis of impacts: the Metropolitan Region and the Project Area.

The "Metropolitan Region" refers to the area and political units included in the Provinces of Panama and Colon. In 1990, the Metropolitan Region contained 53.2% of the Country's population.

The "Project Area" contains more than 400 town sites located within the current 1990 Canal watershed but differs according to the two study alternatives. The project area has been defined to include one kilometer from the center line of either Canal alternative and all watershed supporting facilities for construction and operation of either effort.

The "Interoceanic Region" was established by law by the Panamanian National Assembly in 1993. The region is slightly larger than the Metropolitan Region and includes all of the old "Canal Zone", the Canal watershed area (including Gatun Lake, Madden Lake, Alajuela Lake, Miraflores Lake), and the urban areas and surrounding rural environs.

Economic Impacts

While neither alternative is expected to change the economic structure of the country during construction or operation, the improvements to the Panama Canal, either by means of a High-Rise Lock Canal (HRLC) or a Sea Level Canal (SLC), will represent one of the largest investments ever witnessed by Panama. The economic impacts in this section focuses on the potential effect that expenditures from each alternative will have on the local and national economy. The greatest direct economic impacts will result from construction and operation of the SLC alternative which will generate larger expenditures in Panama, a larger monetary impact, and greater employment opportunities for Panamanians.

The annual impact on GDP for both alternatives will be approximately the same, around 1% per year during construction and 1.2% during operation. Neither alternative will change the economic structure of the country, nor will income distribution be altered by either alternative since the increase in GDP will come from the existing service sector and not from newly developed sectors.

Table 7.4.2-1 shows the total impacts of each of the alternatives upon the GDP during construction and Table 7.4.2-2 shows the impact of each alternative on GDP during operation.

Table 7.4.2-1

Impacts Upon the Economy During Construction

(1990 millions of dollars)

	150,000 DWT High-Rise Lock Canal	200,000 DWT High-Rise Lock Canal	Sea Level Canal
Value Added	708.1	792.9	911.1
Intermediate Purchases	809.3	906.3	1,041.3
Impact Upon GDP (annual average increase)	0.95%	1.06%	0.81%

Source: Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993

Table 7.4.2-2

Impacts Upon the Economy During Operation

(1990 millions of dollars)

	150,000 DWT High-Rise Lock Canal	200,000 DWT High-Rise Lock Canal	Sea Level Canal
Value Added	3,819.8	3,635.6	4,174.6
Intermediate Purchases	2,030.7	1,932.4	2,219.3
Impact Upon GDP (annual average increase)	1.3%	1.2%	1.4%

Source: Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993

In terms of overall costs, total investments may fluctuate between $7.4 billion for the 150,000 DWT HRLC, $8.5 billion for the 200,000 DWT HRLC, and $12.7 billion for the SLC. These figures are in 1990 dollars and do not include necessary cost expansions beyond 2060.

It is estimated that the construction period will last between 10 years for the HRLC, to 15 years for the SLC. During the construction period, direct expenditures in local goods and services are estimated to be approximately $844.5 million for the 150,000 DWT HRLC, $945.7 million for the 200,000 DWT HRLC, and $1,086 million for the SLC Option A. These are monetary impacts directly attributable to construction activity. At peak construction, approximately 9,576 jobs will be created for the 150,000 DWT HRLC: 10,723 for the 200,000 DWT HRLC; and 9,388 for the SLC. In all cases, a majority of the jobs will be created in the construction sector followed by the manufacturing industry. These jobs represent a short-term benefit which, for the most part, will be lost when construction is completed.

Jobs on construction of any of the alternatives will be highly desirable to both qualified and unqualified workers in the country. The construction industry in Panama normally guarantees a job duration of less than two years. The construction of the Canal improvements will represent a potential job duration of ten years and probably better wages. Under these circumstances, a high percentage of qualified construction workers will be likely to leave their current positions within the existing Panamanian economy to try to join the canal construction workforce. This could severely impact the economy since it would deplete the non-canal construction industry of a large number of its workers, technicians, engineers and managers. Other economic sectors in Panama, such as agricultural and industrial, could also be adversely affected by this movement of workers away from established employment sectors.

Financial Impacts

Beneficial impacts will result from an increase in government revenues from personal income tax derived from a larger workforce and from business taxes arising from local purchases of goods and services. Evaluating the alternatives based on financial benefits, the SLC would be the preferred alternative.

A potential negative financial impact on Panama derived from either alternative may be a decline in the payments to the Panamanian Government from the Canal due to the independent character of the management structure to be implemented for the Canal.

Another negative financial impact will be the Government's diminished ability to obtain international financing for domestic projects as a result of having to guarantee part of the financing for the Canal improvements. The SLC alternative, being much costlier, will have the largest negative impact in this respect.

Table 7.4.2-3 lists the major financial impacts from a quantitative point of view and Table 7.4.2-4 provides a qualitative description of financial impacts.

Table 7.4.2-3

Summary of Major Financial Impacts of the Two Canal Alternatives

(Millions of Dollars)

Construction	High Rise Lock Canal	Sea Level Canal	Difference
Imports into Panama	$7,818	$10,180	30%
Purchases in Panama			
- Goods & Materials	349	352	1%
- Labor	569	696	22%
Operation			
Direct Government			
- Revenues from Canal	123.7	127.5	3%

Source: Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993

Figure 7.4.2-4

Major Financial Impacts on Panama

MAJOR IMPACTS	RESULTING FINANCIAL IMPACTS ON
During Construction	
Imports of Equipment and Materials	Panama's Trade Deficit May Increase
Local Purchases of Goods and Materials	Government Revenues From Corporate Taxes
	Government Revenues From Public
Local Employment of Labor	Government Revenues From Personal Income
During Operations	
Change in Canal Management Arrangement	Government Revenues from Panama Canal
Government Guarantee of Financing (Partial)	Government Ability To Finance Other Projects May Decline

Source: Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993

Political Impacts

Political impacts of any action are difficult, at best, to predict and next to impossible to quantify. Given the magnitude of either of the proposed alternatives as well as the international significance of the Canal, it is likely that national as well as international political concerns could arise. The Panama Canal has always been a subject which has stirred up great passion among the Panamanian population. Given the degree of independence to be provided to the new Canal authority, it may be perceived by the populace that Panama is not truly sovereign over the Canal. In this respect, a carefully constructed public information program should be developed to provide the information necessary for the general population of Panama to understand the true purpose and goals of the new canal authority in charge of management and operation of the Canal.

In addition, to successfully mitigate potential social impacts which might result from project development, it will be important for the Government of Panama to establish clearly defined policies with regard to construction issues such as the public debt, foreign influence, relocation of population, and foreign immigration.

The security of the Canal improvements will require additional security forces. Given the overwhelming distaste of the people for the military establishment, the augmentation of security forces to take care of canal security matters will represent a negative political impact which may encounter strong resistance. This increase in security responsibilities to be assumed by the government will be much larger in the case of the SLC due to the fact that this alternative extends across unpopulated areas, apart from the existing canal. For the HRLC alternative, existing security forces guarding the present canal can be supplemented with new security forces for the improvements, therefore security augmentation will be considerably smaller.

Relocation of the population for either alternative could cause significant negative political impacts. The means to indemnify and compensate displaced populations must be effective right from the onset of displacements, otherwise the dissatisfaction of the people may become a powerful obstacle to government administration. This problem would be more significant with the SLC alternative due to the larger number of people who would be displaced.

The Metropolitan Region is currently experiencing a rapid population growth, and this growth is projected to continue well into the next century. The beginning of construction activities for either alternative will attract migration from the countryside to the Metropolitan Region as well as from outside the country. Given the anticipated demands to infrastructure and housing from non-canal projected population growth, the additional population increase from the immigrating population attracted by possibilities of canal employment would severely affect the country's ability to meet the increased infrastructure demands. Without careful pre-planning by the Government, the demands placed on infrastructure and housing could exceed capacity causing frustration among the population. This will be a greater problem for the SLC than for the HRLC.

Environmental awareness has been awakening on a global basis. Both alternatives are likely to attract attention from international environmental groups concerned with protection of environmental resources. For the HRLC, the primary concern is likely to focus on the need to disturb some areas of the rain forest. The SLC alternative will attract attention around the issue of possible interoceanic transmigration of species. Regardless of which alternative is chosen, the potential political debate surrounding environmental issues will cause the Government of Panama to justify the choice made and provide proof that protective measures will be taken.

In summary, from a political perspective, the SLC alternative will create more political consequences due to the disruption which could be caused to the population and the environment.

Socio-Cultural Impacts

The Impacts Upon Panama component study has estimated population growth rates (without canal construction) within the Metropolitan Area, in excess of 20% for the first three decades of the twenty-first century. This growth rate is considerably lower than the rates which have been experienced during the later half of the 20th Century: as high as 50% between 1960 and 1970 (see Table 7.4.2-5). However, this rapid growth has serious implications to the government with regard to the need to plan for expansion of public services and facilities in order to meet the increased demands that this continued growth will cause.

Table 7.4.2-5

Metropolitan Region Population by Province and District and Growth Rate Among Census: 1960; 1970; 1980 and 1990

Province District	Inhabitants				Growth Rates		
	1960	1970	1980	1990	60-70	70-80	80-90
REGION TOTAL	457,725	686,250	942,250	1,240,421	0.041	0.032	0.028
Colon Province	85,332	109,605	133,833	168,294	0.025	0.020	0.023
Colon District	73,547	95,421	113,153	140,908	0.026	0.017	0.022
Chagres District	4,206	6,063	7,735	9,205	0.037	0.025	0.018
Portobelo District	1,779	1,545	5,110	5,920	(0.014)	0.127	0.015
Santa Isabel District	2,595	2,044	2,068	2,679	(0.024)	0.001	0.026
Donoso District	3,205	4,532	5,767	9,582	0.035	0.024	0.052
Panama Province	372,393	576,645	809,100	1,072,127	0.045	0.034	0.029
Arraijan District	11,128	19,347	37,186	61,849	0.057	0.068	0.052
Capira District	12,744	17,289	21,581	28,303	0.031	0.022	0.027
Chame District	8,063	9,961	12,295	15,152	0.021	0.021	0.021
Chepo District	6,484	14,469	20,499	29,145	0.084	0.035	0.036
La Chorrera District	26,317	45,269	66,974	89,780	0.056	0.040	0.030
Panama District	281,384	386,627	477,107	584,803	0.032	0.021	0.021
San Carlos District	7,289	9,108	10,440	12,443	0.023	0.014	0.018
San Miguelito District	12,975	68,400	156,611	243,025	0.181	0.086	0.045
Taboga District	1,879	1,741	1,495	1,810	(0.008)	(0.015)	0.019
Chiman District	1,258	1,678	1,973	3,066	0.029	0.016	0.045
Balboa District	2,872	2,756	2,939	2,751	(0.004)	0.006	(0.007)

Source: Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993.

The most significant negative socioeconomic impact of either of the proposed alternatives will be an additional canal induced population increases in the Metropolitan area which is likely to result from the immigration of workers from the countryside and from other countries outside of Panama. The anticipation of a large project, such as that represented by either alternative, is likely to accelerate the rate of migration from the countryside and increase the amount of foreign immigration from the Central American region. This increase, over and above that which has been projected, will increase the burden placed on the government to develop the additional public services and facilities required to accommodate this growth.

It is anticipated that a majority of the project induced immigrants will be unskilled laborers who will not be absorbed by the canal construction activities or by the existing Panamanian employment sectors. While some of this labor may be able to be absorbed into some of the jobs vacated by individuals moving from existing jobs into employment on the canal construction project, it is likely that a large portion of this group may remain unemployed.

The additional population resulting from increased project induced immigration could cause an increase in spontaneous settlements within the Metropolitan Region. Proper forethought and planning will be required in order to minimize poverty and accompanying social pathologies such as substance abuse, prostitution, and an increase in criminal activities. The health care system may need to be expanded in order to avoid becoming strained beyond its capacity by the increased demand placed on it from the growing population.

While there may be some minor variation in the chosen residence location of migrants depending on which alternative is constructed, the problem of project induced immigration will not be significantly different for the two alternatives. In addition, the expanded effort to be undertaken by the government in developing social infrastructure and public services to overcome the problems associated with rapid population growth are likely to be expensive to the entire country and will be required regardless of whether or not the canal improvements take place.

While the number of workers employed by the canal will be a fairly insignificant proportion of the population, provision of housing and services to some or all of these workers and their families for the duration of construction will free up some existing housing within the remainder of the Metropolitan Region for use by others.

In addition to reducing some of the demand placed on public services and facilities, the provision of these facilities to canal workers, should help to maintain a stable and productive workforce for the duration of the project. This will be particularly important for the SLC alternative which is further away from the more populated areas with the facilities and services required to support the population which will be directly associated with construction. Care will have to be taken in the development of canal labor related facilities in order to avoid the creation of negative images of worker's camps which were used for the construction of the existing canal.

Attention also needs to be paid to the disposition of the worker's complexes following completion of construction. The permanence of these complexes could create resentment of the population if carefully planned policies are not developed and implemented by the government for the effective and rational utilization of these resources.

Geographic and Environmental Impacts

A number of impacts will occur to the environment as a result of the construction of either alternative. The most significant environmental impacts will result from the SLC. General environmental impacts from the construction and operation of either of the proposed alternatives are discussed in Section 7.5 of this report. This section will focus on the impacts to the population of Panama which might result from environmental changes caused by canal construction.

The primary environmental impact of concern to the population of Panama may be the potential affects of the SLC alternative on the underground fresh water supply for the Metropolitan Region. With the construction of the canal, the water table would be lowered and the potential for contamination of underground freshwater sources with saline ocean water may need to be investigated in areas of proximity to fresh water wells. The existing fresh water reservoirs of Gatun and Miraflores are positioned well above sea level and would therefore generally develop seepage gradients toward the sea level canal thus tending to maintain their quality. Some localized areas of salt water intrusion may necessitate detailed study. Further studies will be needed to determine the true impacts on underground and surface water quality in specific areas.

One important impact to be considered is the alteration of watercourses that may increase erosion. This may lead to induced landslides, river deviations and further changes to the hydrologic behavior of the canal tributary areas unless adequate control measures are implemented to mitigate such effects. As a result, the geography of areas adjacent to the SLC alternative may be affected.

Geographically, the value of the country will increase with either alternative. This will come from planned financial development, enhanced tourism and increased economic activities. It will also include strengthening of the banking system, the insurance sector, the ports, airports and communication activities.

Impacts on Infrastructure

The HRLC alternative will eliminate the port at Rodman. At present, the government of Panama is planning to develop this facility as an extension of the Balboa port complex once it is turned over to the country. The cost of replacing this facility will be very high once the improvement of the facility is complete and can no longer be used. This impact does not occur with the SLC.

It is estimated that about 1000 structures will be affected by construction of the SLC alternative. A much smaller number of structures would be displaced by the HRLC options. Table 7.4.2-6 identifies areas with numbers of structures to be affected by the SLC and flooded areas.

While there may be some temporary disruption while initial construction of facilities (eg. roads, utility lines) takes place, both alternatives will have positive impacts on roads since roads will have to be improved during construction. For the SLC alternative, a new transisthmian road will be added alongside the canal as well as several new roads serving remote towns.

The plan for the Simon Bolivar bridge, planned for construction before the year 2000, does not currently include the required span for the HRLC alternative. If no changes to design take place, the HRLC will require the replacement of this bridge. Both alternatives would, however, add several new bridges to the transportation network, so a positive impact would also be expected.

One of the most significant negative impacts of the SLC would be its detrimental effect on water resources and water supply. The extent that existing water resources are contaminated with saline water or from deposition of sediments or from chemical changes, a more distant sources will be required to meet demand. This would require more infrastructure to carry water from more distant places to the Metropolitan Region or would require digging of deeper wells in order to find adequate water sources.

7.4.3 Conclusions

A number of impacts were identified in the Impacts Upon Panama Component Study as significant discriminating impacts, or impacts which would allow for comparison between the two alternatives.

For an infrastructure/environmental perspective, the potential for lowering the water table and contaminating the existing fresh water supply is the most significant impact. This possibility exists primarily for the Sea Level Alternative and would not be a significant problem for the High Rise Lock Canal. A shortage of water would also be a significant concern from a political and public health perspective and the potential for contamination needs to be further studied to determine the actual potential for an extent of contamination which might occur.

The need for increasing the number of security forces for either alternative is also a serious political concern. The Sea level Canal alternative would require a doubling of the security force required to protect the canal itself as well as additional security for public safety of newly opened rural/remote areas. While some security will have to be added for the High Rise Lock alternative, the addition would be minor in comparison to the number required for the Sea Level Canal.

Table 7.4.2-6

Structures to be affected with the SLC Alternative

No.	LOCATION	WARD	DWELLINGS	PERSONS	CHURCHES	SCHOOLS	HEALTH CENTERS	SHOPS	FACTORIES	CEMETERIES	COMMUNITY CENTERS	OTHERS
1	Punta Grande	Chagres	14	55	1			1			1	1
2	Nuevo Chagres	Chagres	164	599		2						
3	Pueblo Nuevo	Palmas Bellas	83	348								
4	Maseo	Palmas Bellas	16	66								
5	La Loma	Palmas Bellas	8	35								
6	Paulino	Achiote	15	18								
7	LLano Bonito	Achiote	7	36								
8	Vino Tinto	Achiote	1	7								
9	Caño Quebrado	Achiote & Escobal	14 19	39 80		1						
10	La Chunga	Achiote	2	10		1						
11	Frijolito	Achiote	5	17								
12	La Tagua	Achiote	14	67		1						
13	La Escobe	Escobal	17	66		1						
14	Portachuelo	Escobal	6	14								
15	Quebrabón	Escobal	14	60		1						
16	Brazito	Escobal	5	31								
17	Los Negros	Escobal	3	12								
18	Lagartarita	Amador	40	134		1		1	1	1		
19	Las Pavas	Amador	63	247	2	2		1				
20	Gigante	Amador	5	25								
21	La Laguna	La Represa	47	187	1	2	1	5			2	
22	Cañito	La Represa	22	56								
24	Celebacito	La Represa	7	25								
25	Río Pescado	Represa/El Arado	2/ 5	0/ 16								
26	El Lirio	El Arado	101	415								
27	Río Viejo	El Arado	5	15								
28	Celestina	El Arado	17	61								
29	Moecú	El Arado	13	34								
32	Loma Alta	El Arado	71	242				1	1	1		1
33	Río Congo	El Arado	140	599								
34	El Limón	Barrio Colón	213	867	2	1		1	3			
35	Río Caimito	JD Arosemena										
36	Hato Montaña	JD Arosemena	25	109								
37	Pto. Caimito	Pto. Caimito	367	1449	2	1		18	5	1		
38	Los Chorros	Cirí de los Sotos	38	135	1	0		2				1
39	Nuevo Paraíso	Cirí de los Sotos	25	120	1	1				1		
40	Los Uveros	Cirí de los Sotos	38	135	1	2		4				1
41	Boca de Uracillo	Río Indio	8	45	1	1	1	1		1	1	2
42	El Limón	La Encantada	34	137	1	1	1	1	1	1	1	
43	Qda. La Conga	Cirí de los Sotos	22	118								
44	Gatún	Pto. Limón	8	31								
45	Cerro Azul	Limón	13	79								
46	Nuevo Limón	Mendoza	20	84								
47	Casas a lo largo del	Río Gatún	10									
TOTAL			1792	7134	13	19	3	36	11	6	5	6

SOURCE ANALYSIS OF IMPACT UPON PANAMA

Demographic and political concerns arise over both the displacement and relocation of individuals during construction and also over the increase in population due to project induced migration to the Canal Project area. Both alternatives would induce excess migration into the Metropolitan Region of individuals looking for employment on canal construction. However, this situation would be considerably more severe in the case of the Sea Level Canal where the population would be accommodated in remote and currently undeveloped areas without the basic services and facilities which would be required to support the population. In addition, the relocation of individuals, without careful planning, could cause increased levels of dissatisfaction which could be difficult for the government to manage. Since the Sea Level Canal Alternative would require a significantly larger number of relocations than the High Rise Lock Canal alternative, the High Rise Lock Canal is the preferred alternative on this issue.

In summary, the Impacts Upon Panama study concludes that "In every sense, the High Rise Lock Canal alternative is the least intrusive." It further states that the High Rise Lock Canal will have the least impact on current or planned infrastructure, on financial and economic flexibility of the Government in terms of guarantees and revenue, on the population and socio-cultural infrastructure in terms of relocation of people and government areas of control and protection, and on the environment and geography.

7.5 Impacts Upon Users

7.5.1 Introduction

Impact of alternatives in EAIU Study were analyzed for the following contents:

(a) Impact during construction, operation and maintenance

(b) Induced trade

(c) Impact of tolls

(d) Saved Cost-induced income

(e) Impact upon adjacent countries

(f) Influence on shipping industry

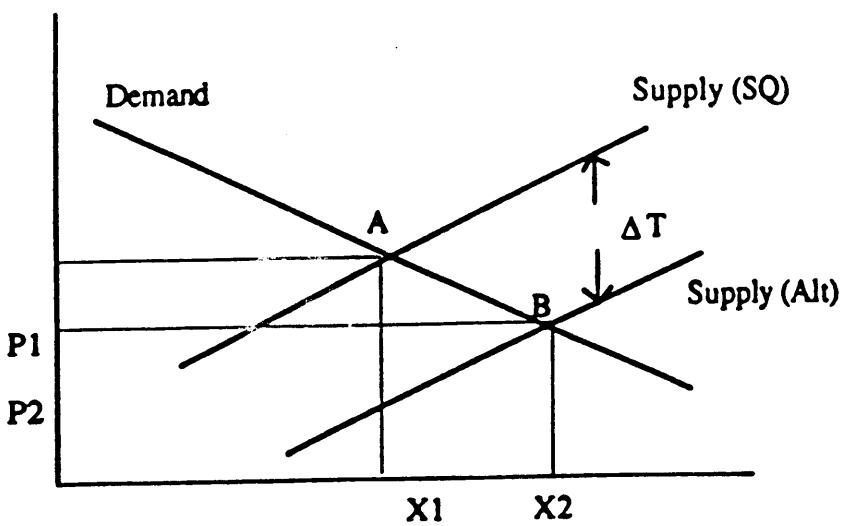
(g) Improvement of navigation safety, and

(h) Socio cultural and environment impact during operation

The term "Users" is conceptually defined as shipping industry and user countries enjoying beneficiary effects of alternative canals. Thus the major scopes of impact study regarding "impacts upon users" are both quantitative and qualitative analyses of impacts on global economy and trade concerning user countries, and of impacts on shipping industry. Some of EAIU's impact studies i.e. (a), and (h) are characteristically related to "Impacts upon Panama" and "Environmental Impact Analysis". Accordingly this sub-section of "Impacts upon Users" are discussed with respect to study items of (b), (c), (d), (e), (f) and (g).

7.5.2 Induced Trade

Transportation cost saved due to enlargement of canal size would contribute to reduction of commodity prices in the international markets. The expected price change would induce trade volume in importing countries. The mechanism of estimation of induced trade was graphically illustrated in the Final Report of EAIU study as follows:



The supply curve (SQ) indicates supply in exporting countries with transport costs for the SQ canal (without project condition). The supply curve (Alt) indicates supply in exporting countries with transport cost with project condition. The reduction of transportation cost marked by ΔT shifts down commodity price from P1 to P2. Accordingly the market equilibrium condition shifts from A to B. The resultant effect is increase of induced trade marked by ΔX=X2-X1.

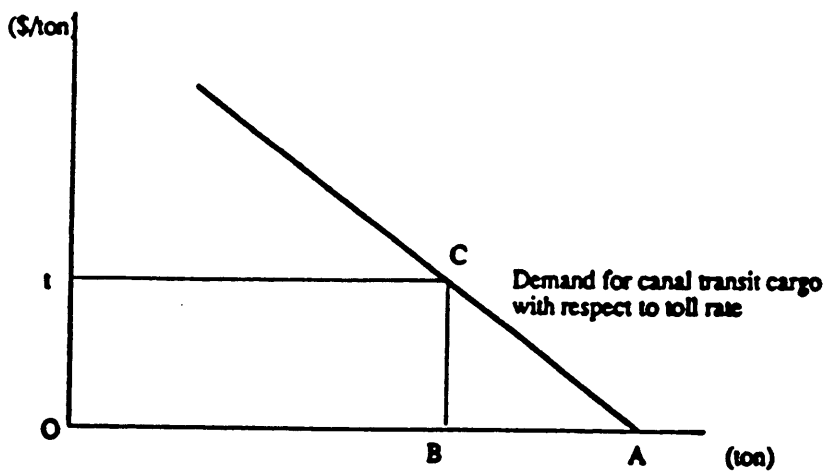
The extent of induced trade ΔX depends on price elasticity of demand in importing countries. Demand curve of developed economy is generally the slope curve on the downward. This means that price elasticity of demand is high. In the case of developing economy price elasticity of demand is low. Thus the effect of ΔP on ΔT is more positive in developed countries than in developing countries. Value of induced trade was calculated in EAIU Study with the following formula:

$$\text{Value of induced trade} = \Delta X \times (P - \Delta P)$$
$$\text{where } \Delta P = P1 - P2$$

Table 7.5.2-1 and 7.5.2-2 show induced trade and trade value for the year of 2020 respectively. For the case of 250,000 DWT, cargo of about 750 thousands tons would be expected as induced trade volume. The trade value was estimated to be about 90 million US$. Asia is expected to be the prominent import region, whereas U.S.E.C. is markedly the export region in terms of induced trade.

7.5.3 Impacts of Tolls

Impact of tolls was studied with respect to 1) revenue impact on the Panamanian economy, and 2) impact of toll rates change upon users. The second item is discussed in this section. Impact of change of toll rate was qualitatively evaluated in EAIU Study. Direct benefits measured by transportation cost saving is the cost difference between the canal route (with condition) and the least-cost alternate route (without condition). Toll was not included in transportation cost in the canal route. Direct benefits is graphically illustrated below:



If no toll is charged to users cargo, traffic in relation to the Panamanian Isthmus reaches point of A. Under such circumstance the world enjoys benefits corresponding to the area under demand curve. If toll rate (t) is charged to users, canal transit cargo would reduce from A to B. The world loses consumer surplus corresponding to the area of ABC.

Table 7.5.2-1

Induced Trade Volume Due to Transport Cost Savings from Canal Alternatives (Year 2020) Unit: thousands Metric Tons

Regions	Export			Import		
	150,000 DWT	200,000 DWT	250,000 DWT	150,000 DWT	200,000 DWT	250,000 DWT
(Pacific)						
Asia	14	14	14	519	607	694
C. America WC	2	2	2	2	2	2
Canada WC	-8	8	2	3	3	3
Oceania	1	1	1	1	1	1
S. America WC	3	3	3	1	1	1
U.S.W.C.	19	19	19	7	7	7
(Atlantic)						
Africa	3	3	3	6	7	7
C. America EC	2	2	2	3	3	3
Canada EC	-2	9	8	1	1	1
Europe	7	7	7	3	20	14
Middle East	0	0	0	0	0	0
S. America EC	27	105	193	0	0	0
U.S.E.C	495	495	495	17	17	17
Total	563	668	749	563	668	749

Source: Final Report, EAIU Study

Table 7.5.2-2

Induced Trade Volume to Transport Cost Savings from Canal Alternatives (Year 2020) Unit: thousands US$

Regions	Export			Import		
	150,000 DWT	200,000 DWT	250,000 DWT	150,000 DWT	200,000 DWT	250,000 DWT
(Pacific)						
Asia	1,669	1,669	1,669	62,431	73,081	83,538
C. America WC	288	288	288	287	287	287
Canada WC	-1,015	1,004	293	347	347	347
Oceania	64	64	64	71	71	71
S. America WC	375	397	397	84	84	84
U.S.W.C.	2,266	2,266	2,266	818	818	818
(Atlantic)						
Africa	358	358	358	774	796	796
C. America EC	230	230	230	327	327	327
Canada EC	-185	1,121	983	119	120	120
Europe	851	851	851	397	2,416	1,705
Middle East	0	0	0	0	0	0
S. America EC	3,260	12,603	23,198	0	0	0
U.S.E.C	59,525	59,525	59,525	2,029	2,029	2,029
Total	67,684	80,376	90,122	67,684	80,376	90,122

Source: Final Report, EAIU Study

Loss of consumer surplus would be expected by reduction of import demand for commodities since inclusion of toll pushes up import prices of commodities. Bulk cargo like coal, iron ore and crude oil carried by large size of dry bulk carriers enjoys low shipping cost. If new tolls doubles the present tolls, negative impact on importing countries would be substantial.

In some O-D routes where cost savings are marginal, inclusion of toll would drastically affect trade flow in these O-D routes. However such analyses were not developed in the EAIU study. It is recommended to identify these commodities by O-D route.

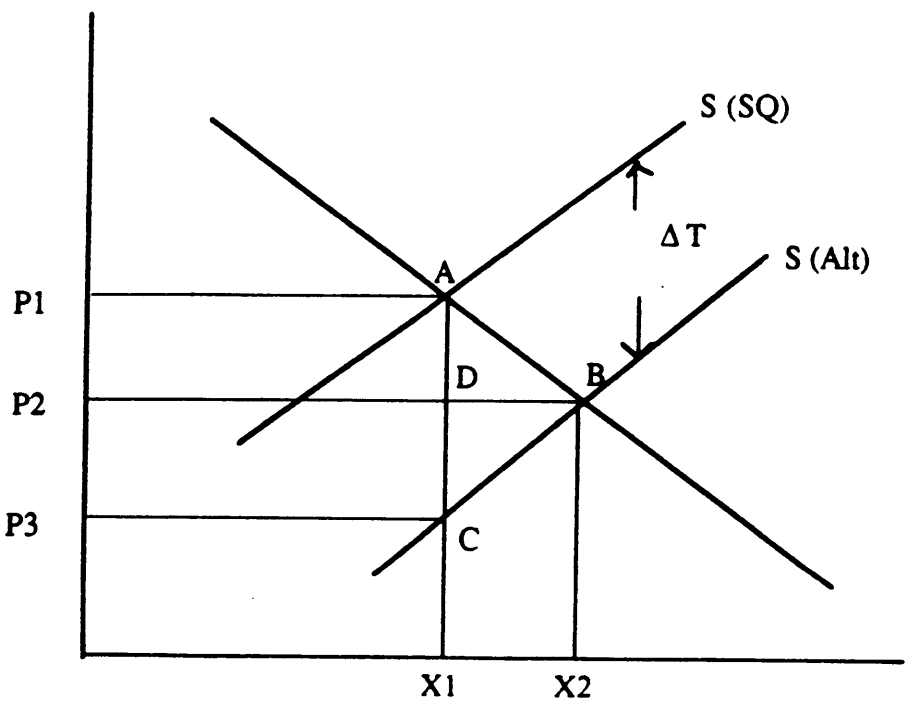
7.5.4 Saved Cost - Induced Income

The term "saved cost - induced income" is defined as the multiplier effect of transportation cost saving on the world economy. Multiplier effect was measured by increase of national income by region or country. The method to calculate the multiplier effect consists of two steps:

1) First, direct income accrued from transportation cost saving was estimated for both exporting and importing regions

2) Secondly, the multiplier effect of direct income on would economy was estimated based on classic formula presented in the textbook of Economics.

The figure below explains low direct income was estimated.



Due to transportation cost saved by ΔT, supply curve in exporting country shifts down from S (SQ) to S(Alt). Equilibrium price goes down from A to B. For exporting country having supply curve of S (Alt), point P3 is the price where quantity X1 is produced. As production increases from X1 to X2 suppliers enjoys incremental income corresponding to the area P2 BC P3. This incremental income is direct income belonging to exporting countries. Consumers of importing countries also enjoy incremental income corresponding to the area P1 A B P2. The amount of direct income to be expected depends on price elasticity of demand and supply curves (slope of both curves).

The decrease of prices (ΔP = P1 - P2) was estimated based on price elasticity of demand and ΔT by O-D route. Likewise increase of prices (ΔP = P2 - P3) was estimated based on price elasticity of supply and ΔT by O-D route. For simplicity of calculation, direct income of an exporting country is the area P2 D C P3. Thus direct income of a exporting country or region was calculated by X1 x (P2 - P3). X1 indicates cargo volume benefiting from cost saving. Direct income of importing countries was calculated in the same way.

The multiplier effect was estimated with the following formula:

$$\Delta Yi = 1/(1-ai+mi) \times \Delta I$$

where
- ai = marginal propensity to consume
- mi = import ratio
- ΔI = Direct income

Table 7.5.4-1 shows direct (induced) income and multiplier effect. In the case of 250,000 DWT, direct income is expected to be about 350 million US$. The multiplier effect is about 1 billion US$ in 2020. East Coast of the U.S. and Asia are the regions who will enjoy effect of saved cost -induced income.

7.5.5 Influence on Shipping Industry

The enlargement of canal size will result in the following types of impacts on the shipping industry:

1) Larger ships of more than 65,000 DWT shifting back to the Isthmian route from alternative routes would result in reduction of ton-miles and reduction of sailing time. This implies an increase of carrying-capacity of vessels without increase in number of ships.

   Increase of carrying capacity of vessels would lead to the condition of over-supply, especially dry bulk carriers (CD) and oil tankers (OT). Accordingly, demand for new CD and OT would be reduced.

Table 7.5.4-1

Induced Income and Multiplier Effect Due to Transport Cost Savings from Canal Alternatives in the Year 2020

Regions	Income ('000 US$)			Multiplier Effect ('000 US$)			% to GNP		
	150,000	200,000	250,000	150,000	200,000	250,000	150,000	200,000	250,000
1. Asia	133,980	140,779	146,002	389,378	409,139	424,317	0.01%	0.01%	0.01%
2. C. America WC	1,152	1,152	1,152	1,502	1,502	1,502	0.00%	0.00%	0.00%
3. Canada WC	-1,016	2,113	996	-1,963	4,084	1,924	0.00%	0.00%	0.00%
4. Oceania	207	207	207	170	170	170	0.00%	0.00%	0.00%
5. S. America WC	758	789	789	764	795	795	0.00%	0.00%	0.00%
6. U.S.W.C.	13,140	13,140	13,140	45,259	45,259	45,259	0.00%	0.00%	0.00%
(Atlantic)									
1. Africa	3,357	3,387	3,387	2,314	2,334	2,334	0.00%	0.00%	0.00%
2. C. America EC	846	846	846	1,173	1,173	1,173	0.00%	0.00%	0.00%
3. Canada EC	-101	1,907	1,696	-195	3,686	3,278	0.00%	0.00%	0.00%
4. Europe	10,363	13,492	12,374	17,198	22,390	20,536	0.00%	0.00%	0.00%
5. Middle East	0	0	0	0	0	0	0.00%	0.00%	0.00%
6. S. America EC	5,014	19,389	35,690	6,279	24,280	44,693	0.00%	0.01%	0.01%
7. U.S.E.C	133,155	133,155	133,155	458,646	458,646	458,646	0.01%	0.01%	0.01%
Total	300,355	330,355	349,433	920,525	973,459	1,004,629			

Source: MRI and YEC Consortium

Note: Minus figures imply reduced trade caused by higher tolls and other transportation costs for the alternative canal than for the SQ canal.

2) The enlargement of the canal would give large size Full Container (FC) ships the opportunity to pass through the canal route. Container ships currently navigating the Panama Canal carries containers of about 2,000 TEU. CTP Phase II Study predicted that new FC ships passing through the Canal route would be expected to navigate in the O-D routes connecting U.S.E.C. with Asia, and Europe with U.S.W.C. Under such circumstance, there will be demand for construction of new FC ships capable of carrying 4,000 TEU. Sea routes and navigation conditions of new FC ships are assumed as follows:

Table 7.5.5-1

Sea Routes and Navigating Conditions of New FC Ships

Route	Distance (miles)	Round Voyage (days)	Annual Number of Voyage
Asia - USEC	9,672	48	7.3
Europe - USWC	7,985	40	8.8

A new FC ship is assumed to be 4,000 TEU. The price of a 4,000 TEU FC ship is assumed to be about 80 million US$. Size distribution of container cargo for 150,000 DWT case in 2020 was predicted in CTP (II) Study as shown in Table 7.5.5-2:

About 13.8 millions ton will be transported by new FC ships (4,000 TEU) corresponding to size range of 65,000 - 99,999 DWT. Number of FC ships (4,000 TEU) to be required was calculated as follows:

- USEC ↔ Asia 12 million tons /(4,000 TEU x 20 ton / TEU x 7.3)= 20
- Europe ↔ USWC 1.8 million tons / (4,000 TEU x 20 ton / TEU x 8.8) = 3

It is estimated that about 23 FC ships will be constructed. The value of these new FC ships will be approximately 1,840 million US$.

Table 7.5.5-2
Size Distribution of Container Cargo
Unit: Millions $ Tons

Route	0 < to 9,999 DWT	10,000 < to 39,999 DWT	40,000 < to 64,999 DWT	65,000 < to 99,999 DWT
1) Asia - USEC		0.6	5.6	5.0
2) USEC - Asia		2.1	8.7	7.0
3) Europe - USWC		1.2	0.7	0.9
4) USWC - Europe		1.6	0.9	0.9

7.5.6 Improvement of Navigation Safety

In EAIU Study improvement of navigation safety was discussed with respect to safety conditions of alternative canals compared to the SQ canal. These aspect of navigation safety should have been focused on safety conditions of vessels navigating in ocean routes.

Some dry bulk carriers currently bypassing the Panama Canal would shift back to the canal route if enhancement of the canal is implemented.

There are many critical points or straits in ocean routes where vessels are currently navigating. The enlargement of the canal would improve navigation conditions of vessels by helping then avoid unsafe conditions. This would probably lend to a reduction of running costs. Such an analysis is missing and should be addressed in the future.

7.6 Environmental Analysis

The Environmental Analysis study evaluated the different ecological effects of the activities associated with the construction, operation, and maintenance of the two canal alternatives, recommended mitigation measures, and identified additional environmental studies that would be required.

7.6.1 Approach

The Environmental Analysis impact determination was restricted to an ecological assessment, considering marine, freshwater, and terrestrial habitats. The assessment was based on the conceptual plans for High Rise Lock and Sea Level Canals, prepared by the Engineering and Cost Estimates Component Studies. The ecological baseline was based on the information gathered by the Biological Background Study and Biological Inventory Study component, as well as additional information obtained by the Environmental Analysis Component Contractor.

The Terms of Reference for the Environmental Analysis Component, unlike the Biological Background/Biological Inventory, was intended to evaluate both sea-level and high-rise lock canals, with the understanding that much more baseline information was available for the high-rise alternative. The study was conducted over a four month period, beginning March 19, 1993.

7.6.2 Methodology

The Analysis considered construction, operation, and maintenance of each canal alternative, and evaluated resultant ecological effects. This evaluation emphasized important species (e.g. representative, sensitive, endangered, or of economic importance), as well as important ecological habitats and communities. Among the issues considered were changes (biological, physical, and water quality) in fresh and marine waters, effects on terrestrial flora and fauna, effects on protected and unique habitats, and potential for interoceanic transport of marine organisms.

The various construction, operation, and maintenance features of each of the two Alternatives (from the Phase I and II Engineering and Cost Estimate Study) were evaluated as to their potential for ecological impact. The ecological baseline conditions were determined from the Background Biological Data and Biological Inventory studies. Since this information was primarily related to the lock canal alternative, data were extrapolated from this study to the Route 10 Sea Level Canal area, based on existing literature, general ecological principles, and other studies. Where possible, supplemental information gathered by the Environmental Analysis Contractor in the field.

7.6.3 Summary of Results and Conclusions

Environmental Impacts

The impacts resulting from construction, operation, and maintenance of a canal vary according to the environmental resources in each of the two areas. There are however, a number of impacts that are common to both Alternatives. These common impacts are both temporary and permanent.

Impacts of High Rise Locks Canal

- Destruction of forested areas will damage and destroy terrestrial habitats, species, biological and genetic diversity of the flora and fauna.

- Aquatic disposal of excavated material will increase turbidity and reduce visibility, causing changes to aquatic and marine habitats. Dredging will also remove and destroy aquatic organisms in the dredged areas.

- Construction of new roads will have adverse impacts on adjacent wetlands and movement of water in the area.

- Creation of new artificial lakes will affect water flow, aquatic biota and sedimentation patterns. They will also result in loss of fish spawning areas and create barriers to fish movements. There will be a negative impact on fish which rely on estuaries for part of their life cycle. Impoundments will create new lake habitat which will benefit species that prefer a lentic environment.

- Marine development will generate localized environmental impacts, including potentially impacts to mangrove swamps, salt marshes, estuaries, seagrass beds, and coral reefs.

  The general construction and excavation procedures have the potential to provide habitats for various insect disease vectors.

Specific Impacts

A. High Rise Lock Canal

In general, the High Rise Lock Canal has a greater potential for impact to terrestrial rather than aquatic resources.

- Large areas will be impacted by the construction of this alternative to meet canal capacity forecasted for year 2060, particularly from the development of water supply reservoirs in the Indio, Trinidad, and Ciri rivers. The loss of forested areas is more significant than reduction of open grasslands or pasture areas. Further studies of the impacts of these reservoirs may be required prior to development for year 2060.

- Additional significant forested areas impacted are to the west of Culebra Cut (principally from the disposal of excavated materials) and east of Gatun Locks. Note that much of this can be mitigated by relocation of spoil disposal areas.

- Disposal of excavated material in the Bay of Panama has the potential to adversely impact the commercial fisheries in the area.

- The impoundment of the Indio, Ciri, and Trinidad Rivers would inundate significant tropical forest resources. Construction in the Trinidad basin will also affect wetlands at the mouth of the river.

- Connection of Gatun Lake and Rio Indio by a drainage canal will allow the migration of peacock bass into the Indio River basin, probably causing major changes to the species composition in the river.

- The recycling of lockage water may increase the salinity of Gatun Lake.

In general, the sea level canal has a greater potential for impact to aquatic resources. Among those impacts which are significant are:

- Impede the movement of terrestrial organisms along the isthmus through the introduction of a separate, more effective aquatic barrier than the existing Canal.

- A major increase in the potential for inter-oceanic movement of marine organisms, with resultant major impacts to Caribbean coral reefs, Pacific fisheries, and other important components of the marine ecosystem in both oceans. The present concept of a freshwater barrier in the sea level canal does not appear likely to be effective in preventing inter-oceanic movement.

- The diversion canal from the isolated portion of Gatun Lake to the Lagarto River would allow the migration of peacock bass into the river basin, probably causing major changes to the species composition in the river.

  Even though spilling into this diversion canal will occur only during flood emergency, it will be used more extensively during construction. Therefore, it is predicted that the first time spillways are used, it will transfer potential peacock bass into the river even if the spillway is never used again.

- The barrier dams dividing Gatun Lake would, in addition to removing large areas of the Lake itself, would also impact large areas of wetlands, including the wetland areas at the mouth of the Trinidad River.

- The construction in the Caimito River would severely impact the mangrove swamps at the mouth of the river.

- Construction activities, and diversion of surface waters would impact fifteen important rivers and streams.

- The construction of the new dam on the Gatun River will inundate additional diverse terrestrial habitats.

- The construction and operation of a sea-level canal could also potentially impact water supply aquifers in the area.

Impact Mitigation

Standardized impact reduction practices would be instituted for all construction activities. This would include the establishment of construction zones and the restriction of workers and equipment to these zones; education of workers on the protection of resources; erosion control; protection of air quality; and the development of contingency plans to control the spill of hazardous substances.

Further site-specific field studies would be conducted to determine presence of sensitive ecological resources within specific impact areas.

Where on-site mitigation is judged to be possible, appropriate measures would be instituted, such as avoidance, establishment of buffer zones, proper scheduling of construction, and encouragement of natural revegetation.

Wherever possible, avoidance of sensitive areas, such as relocation of spoil disposal sites, should be given the highest priority. If avoidance is not possible, other measures such as relocation of the sensitive resource should be considered. Relocation should be combined with habitat compensation to ensure that there is no net loss of habitat and regional biodiversity. This would include acquisition, preservation, and maintenance of similar or other significant ecological resources within the area or region.

Financial compensation, in terms of an endowment for the management and protection of these areas, should also be undertaken.

Specific mitigation recommendations were made for each of the two alternatives. For the High-Rise Lock Canal, this included: relocation of certain terrestrial spoil disposal areas to less ecologically sensitive locations; careful selection of dredge spoil disposal areas and stringent control of sedimentation and turbidity during the dredging process; clearing and removal of vegetation in new reservoir areas prior to impoundment.

Similarly, for the Sea-Level Canal; relocation of terrestrial spoil disposal areas to less ecologically sensitive locations; careful selection of dredge spoil areas and stringent control of sedimentation and turbidity during the dredging process; creation of new wetlands to partially compensate for the extensive wetland elimination caused by the construction of the canal.

Recommendations for Future Studies

The following recommendations were made for future studies:

- Complete habitat mapping of all areas within 1 km radius of all construction, operation, and maintenance activities for the selected Alternative. (Note that at present, little information exists for the sea-level canal area.)

- Updated sets of aerial photographs (1:18,000) of all areas that would be effected by the selected Alternative.

- Complete baseline studies prior to its development for year 2060 of the Indio, Trinidad, and Ciri Rivers (if effected by the selected Alternative).

- Additional studies related to the inter-oceanic biological barrier issue, if it is a consideration for marine biological baseline studies of both oceans.

- Thorough studies of effected wetlands.

- Oceanographic studies related to breakwater impacts on current velocity, erosion, sedimentation, and littoral drift. Operating Characteristics and Capacity Evaluation Studies indicated that erosion, sedimentations and littoral drift are not a problem on either the Atlantic or Pacific Sides.

- A complete Biological Inventory study of the Route 10 Sea-Level Canal area if that is the selected Alternative.

- Evaluation of other issues, such as the restrictions on use of the recent Interoceanic Park of the Americas, needs to be done.

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A Feasibility Report

8.0 Overall Evaluation of Selected Alternatives

8.1 Approach

The overall development of this study has been achieved in general conformance with the Detailed Plan of Study (DPS). Modifications have been introduced within some of the component studies due mainly to the imposed time constraints.

Within the previous Chapter 1 through 7, SINBOL focused its effort to provide a concise summary of the Component Contractor's studies prepared for the Commission which SINBOL has helped monitor.

In this chapter, SINBOL provides an overall evaluation for the selected alternatives and their variations in the belief that any future decision making should take into consideration the body of knowledge acquired during this study of alternatives. The recommendations for future investigations and considerations are outlined in Chapter 9.

The feasibility of major infrastructure development projects needs to be established in four major areas namely:

i) engineering soundness;

ii) economic feasibility;

iii) financial viability; and,

iv) compatibility with social and environmental requirements.

The engineering soundness for the selected Canal alternatives and their variations are discussed in Chapter 5 and 6. Economic and financial analysis are discussed in Chapter 7, however, it is considered worthwhile to synthesize the results of those analysis into a more easy to understand summary. Compatibility with social and environmental requirements will be provided to the extent possible based upon the availability of component study results.

Throughout this chapter, numbers of 1, 2, 3, and 4 are assigned for prescreened alternatives and 1-a, 2-a, 3-a, and 4-a are assigned to their respective variations.

Each index number corresponds to the alternative case studies as shown in Table 8.1-1.

Table 8.1-1
Alternative Case Index Number

Case	Description
1	150,000 dwt High Rise Lock Alternative
1-a	150,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut
2	200,000 dwt High Rise Lock Alternative
2-a	200,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut
3*	250,000 dwt Sea Level Alternative with (3 plus 1) Pacific Tidal Locks
3-a	250,000 dwt Sea Level Alternative with (1 plus 1) Pacific Tidal Locks
4**	250,000 dwt Sea level Alternative with Tidal Gates
4-a	250,000 dwt Sea Level Alternative with Tidal Gates and Single Lane Atlantic Approach

Notes: * This case is referred to as CASE A in financial analysis.
** This case is referred to as CASE E in financial analysis.

The component study results of Commodity and Traffic Projections Study (CTP), Engineering and Cost Estimates Study (ECE), and Operating Characteristics and Capacity Evaluation Study (OCCE) were used as framework for the evaluation.

8.2 High Rise Lock Canal Alternative

8.2.1 Construction, Cost and Schedule

The constructability of structures and systems was an important element in evaluating the feasibility of the conceptual alternatives studied.

Excavation of the High Rise Alternative would widen and deepen most of the existing Panama Canal channel cross-sections to accommodate much larger size design ships. Even within the Culebra Cut, where transit capacity studies indicate a single lane option may be adequate, this section will be deepened to accommodate larger design ships. Widening and deepening of the navigation channel whether dry excavation or dredging is feasible and well within the present state of technology and construction know how.

Dry excavation, especially optimization of excavating and hauling equipment, will require additional investigation during the detailed design of the preferred alternative. In particular, the use of conveyor belts as a hauling system should be investigated and studied in detail.

The announcement of construction of a huge excavation project such as this may substantially advance the state-of-the-art of construction equipment design, especially excavation and hauling equipment. In making wet excavation, the present available equipment is more than adequate to perform the required channel excavation work.

Construction challenges will include the following: development of safety precautions related to blasting underwater including its impacts on navigation and the environment; implementing and managing a well thought out construction procedure whereby navigation in the present Panama Canal is not interrupted by excavation; and determining applications where Grab Dredges are employed in excavation underwater. The project construction cost estimates are based in part upon utilizing grab dredging for underwater excavation. The efficiency of such equipment and appropriate applications should be carefully considered during a future detailed design stage. Completion of the above mentioned optimizations and studies should result in cost saving and a shorter construction schedule.

The construction of water resource impoundments, circulating and surge basins, dams, culverts and water conveying structures are feasible and well within the present state of engineering, design and construction. During the future detailed design stage for the preferred alternative, a refined water balance analysis should be conducted using future up-to-date data, realistic expectations as to canal capacity, risks, costs and benefits.

The construction of hydraulic structures and lock chambers is feasible. Concrete for these structures will be manufactured using aggregate processed from excavation and local quarry sites. Earth and rock material for impoundments will come from excavation sites along the Canal. No unusual problem is anticipated from this construction. Lock leafs will be constructed from steel members fabricated-as assumed in the YEC-Phase II Final Report, transported in manageable pieces to the site, and completed in-place for permanent use. A fabrication site for gate leafs should be thoroughly investigated during final design and the most economical site should be selected.

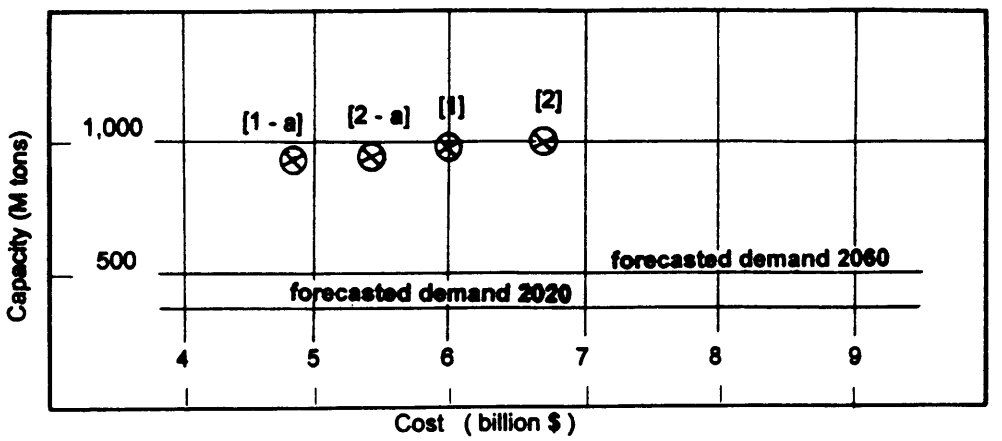
Other construction items such as pumping stations, canal crossing, and incidental structures are feasible and are conventional construction where complications are not expected. Based on engineering and cost estimates for Phases II and II Additional Work Studies, the construction schedule and cost estimates are presented in Section 6 (Figures 6.3.7-1 and 6.3.7-2 and Table 6.3.8-1).

8.2.2 Operating Characteristics and Capacity

Cost Effectiveness

An essential characteristic for all the High Rise Lock Canal Alternatives taken up for financial analysis is summarized in terms of capacity vs. cost and shown in Figure 8.2.2-1.

Figure 8.2.2-1
Cost vs Capacity for High Rise Cases



Legenda

[1] 150,000 DWT High Rise Lock Alternative

[1 - a] 150,000 DWT High Rise Lock Alternative with Culebra Cut Single Lane

[2] 200,000 DWT High Rise Lock Alternative

[2 - a] 200,000 DWT High Rise Locak Alternative with Culebra Cut Single Lane

Note: Costs represent the present value for the alternatives at the start of construction work (2010) discounted at 8% over the project life.

Project costs are calculated based upon the following conditions:

i) Basis of the project costs calculation are YEC's cost estimates allocated overtime by SINBOL for use in the financial analysis; and,

ii) Project costs shown in the figure are the net present value of the alternatives, at the start of construction work*, discounted at 8% over the project life.

Capacities, in terms of million tons per year, corresponding to alternatives are taken from TAMS's calculation for the 6 hour transit delay cases.

Cost effectiveness of alternatives are calculated by:

$$\frac{\text{(Capacity of each alternative - capacity of Status Quo)}}{\text{Net present cost of each alternative}}$$

and summarized in order as follows:

Table 8.2.2-1
Cost Effectiveness of High Rise Alternatives
(unit: ton/1,000 $US)

1-a	150,000 dwt High Rise Lock Alternative with Culebra Cut Single Lane	0.117
2-1a	200,000 dwt High Rise Lock Alternative with Culebra Cut Single Lane	0.109
1	150,000 dwt High Rise Lock Alternative	0.101
2	200,000 dwt High Rise Lock Alternative	0.093

The following interesting corollaries can be drawn from Figure 8.2.2-1 and Table 8.2.2.-1:

i) All the alternatives illustrated are well over the WEFA's forecasted traffic demand at 2060. In all the cases, calculated capacities are about twice as large as the forecasted traffic demand.

* Assuming the same start of operation, start of construction works are; 2005 for sea level alternatives, 2009 for 200,000 dwt alternatives, and 2010 for 150,000 dwt alternatives.

ii) Cost reductions achieved by the introduction of Single Lane Culebra Cut alternatives are considered substantial. For both cases, 150,000 dwt and 200,000 dwt, cost reductions are about 20% of the corresponding original plans with only a slight reduction in capacity.

iii) The cost/effectiveness of 150,000 dwt cases, both for the original and the single lane option, are always higher than those of the 200,000 dwt case.

iv) For both cases, 150,000 dwt and 200,000 dwt, cost/effectiveness is increased by the adoption of a Single Lane Culebra Cut options by about 15%.

Summarizing the above discussions, it is concluded that 150,000 dwt Alternative with Single Lane Culebra Cut is the best selection among the High Rise Lock Alternatives. This aspect will be evaluated more definitively in the economic and financial analyses.

Water Management

Except for the system robustness under accidental emergency (i.e. resulting from ship collision, engine failure, etc), which has not yet been analyzed and shall be examined in a future engineering study, other operating characteristics for various alternatives have been fully discussed in Section 6, and therefore, these aspects are not duplicated in this section.

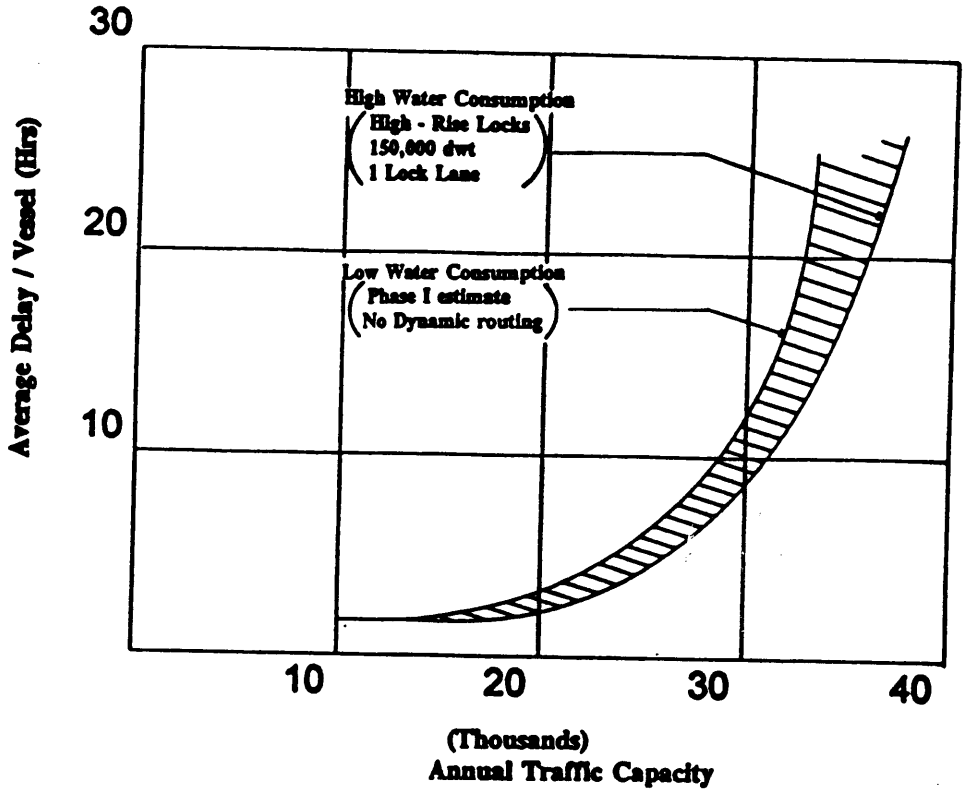
It is, however, considered worthwhile to mention one aspect, namely, water management/fresh water requirement versus the capacities of High Rise alternatives.

Substantial capacity increases have been achieved in The Phase II OCCE Study by the introduction of a dynamic route assignment procedure at the cost of rather high fresh water consumption. In view of the above, water management facilities have been re-designed for 150,000 dwt and 200,000 dwt High Rise Alternatives with a Single Lane Culebra Cut by shifting the design condition from an average year basis to a dry year basis in order to provide for more lockage water.

In this sense, the design of water management facilities for these alternatives are said to be more conservative than other high rise alternatives.

The assumed ratio of lock utilization, in the Phase II OCCE Study design exercise, between the existing locks and new locks are 1.0 to 0.11 in 2020 and 1.0 to 0.19 in 2060, and are far below the optimal utilization of new locks under the dynamic route assignment procedure which is approximately one to one. Accordingly, the transit capacity in the dry year would be reduced by about 17% or the average delay of a transit vessel will follow capacity - delay curve as shown in Figure 8.2.2-2. Full transit capacity under the present set up will be realized only for the wet year, and transit capacity in a normal year will be somewhere in between the two extreme cases depending on the fresh water availability to the system.

Figure 8.2.2-2
Capacity-Delay Curve
(under different operating conditions)



8.2.3 Economic Analysis

Approach

The project economic analysis was made by MRI under the Economic Analysis and Impact on Users Study (EAIU Study), one of Phase III Component Studies. Data for this study is based on the Commodity and Traffic Projections Study (CTP Study) by WEFA, the Operating Characteristics and Capacity Evaluation Study (OCCE Study) by TAMS, and the Preliminary Engineering and Cost Estimates (ECE Study) conducted by YEC, all of which are Phase II Component Studies.

Based on the economic analysis made in the EAIU Study, SINBOL has developed a sensitivity analysis presented below.

(1) Interpolation and Extrapolation Method of Benefit

The EAIU Study assumed an annual increase in benefits at a constant annual growth rate throughout the proposed benefit evaluation period from 2020 until 2120.

Benefits are basically derived from the potential cargo flows through the new canal, which does not increase at a constant annual growth rate according to the CTP Study as shown in Table 8.2.3-1.

Table 8.2.3-1
Average Annual Growth Rate of Cargo Flows

Year	Potential Isthmus Flow		SQ Flow	Incremental New Canal Flow	
	(Million Tons)[1]	(Annual Growth Rate)	(Million Tons)[2]	(Million Tons)[3]	(Annual Growth Rate)
1990	196.2	-	157.5	38.7	-
2020	377.1	2.20%	266.0	111.1	3.58%
2060	514.3	0.78%	276.5	237.8	1.92%

Notes: [1] Potential Cargo Flow across Panamanian Isthmus
[2] Cargo for Status Quo Canal
[3] Potential Cargo Flow - SQ = Incremental New Canal Flow

Source: CTP (II) Vol. I, Table 2

Therefore, a linear interpolation and extrapolation method is also assumed to examine a sensitivity of this issue on economic indicators such as a net present value (NPV), B-C ratio and an economic internal rate of return (EIRR).

(2) Economic Life of the Project

The EIAU Study assumed an economic life of the project to be 100 years. For a large scale infrastructure development project, an economic life of around 60 years is normally taken even if a physical life of a project is considered much longer, such as in a dam project.

Analysis is made to see how sensitive the project is to a economic life shorter than 100 years.

(3) Capacity Limit of SQ Canal

The EAIU Additional Study assumed a capacity of the SQ canal to be exactly 17,000 transits per year. According to the Operating Characteristics and Capacity Evaluation Study (OCCE Study) which is also one of the Phase II Studies, the SQ canal capacities were estimated as follows, depending on allowable average delay time per vessel (Table 8.2.3-2).

Table 8.2.3-2
Status Quo Canal Capacities

Allowable Average Delay in Hours	Capacity in Annual Transit Number of Ships
6	16,100
10	17,000

The annual transit numbers of ships of 17,359 for 2020 and 18,078 for 2060 as projected in the CTP Study for the SQ canal with a capacity limit may also be reasonable if more delay is allowed in the future. This idea was applied in the EAIU Study, Final Report.

Another point under this issue is benefit valuation of the marginal cargo of 359 transits (17,359 - 17,000) in 2020 and 1,078 transits (18,078 - 17,000) in 2060. The EAIU Study assumed that due to the capacity limit, ships would shift the route from the Canal route to the alternative route randomly. This means that unit benefits of US$16.0/ton for 2020 and US$21.8/ton for 2060 were applied for benefit calculation of the marginal cargo.

These unit benefits, when compared with unit benefit values for incremental cargo for the SQ of US$4.6/ton to US$5.0/ton, seem to be high. See Table 8.2.3-3 for unit benefit calculation. As discussed in the Additional EAIU Study, a concept that the cargo with smaller benefit will switch from the canal route seems to be reasonable. With the above discussions, a sensitivity analysis is made when the benefit of the marginal cargo is dispensed with.

Table 8.2.3-3
Unit Benefit Calculation

Canal Max. Size (1000 dwt)	Trade Volume (million tons)		Benefit (million US$)	Unit Benefit (US$/ton)
Year 2020	[1] -	[2]		
SQ	269.4	-	4,311[3]	16.00
150	364.5	95.1	458[4]	4.82
200	366.8	97.4	482[4]	4.96
250	373.3	103.9	502[4]	4.83
Year 2060				
SQ	272.2	-	5,924[3]	21.76
150	496.9	224.7	1,061[4]	4.72
200	501.0	228.8	1,088[4]	4.76
250	514.8	242.6	1,115[4]	4.60

Notes:
[1] From EAIU Study - Final Report, Tables II-1-2 and II-1-3
[2] Incremental Trade Volume from SQ
[3] From EAIU Additional Study Report, Tables II-2-1 and II-3-1
[4] From EAIU Additional Study Report, Tables II-2-2 and II-3-2

(4) Development Timing of the Project

In the EAIU Study, the project was assumed to commence services in 2020. From a purely economic point of view, optimal development timing can be determined, applying the cost and benefit streams, by means of comparing cost reduction owing to a delayed investment with a benefit loss due to a delayed opening of the project. The optimal opening year of the new canal is calculated and compared with the assumed opening year of 2020.

(5) Capacity of New Canal

Capacities of the new canals are discussed and the proposed phased construction of the project is reviewed. Probable effect of the revised phased construction on the economic benefit of the project is studied.

Sensitivity analysis of the above issues is made for the four cases presented in Table 8.2.3-4.

Table 8.2.3-4
Alternative Cases of High Rise Lock Canal

Study Case	Conceptual Alternative	Maximum Ship Size	No. of New Lanes	
			Channel	Lock/Gate
1	HRLC	150,000 dwt	2	1
1-a	HRLC	150,000 dwt	2*	1
2	HRLC	200,000 dwt	2	1
2-a	HRLC	200,000 dwt	2*	1
*Culebra Cut Single Lane				

Water management for a high rise lock operation is one of the key issues. As the number of ship transits increases, more water will be needed for the high rise lock operation. Facilities to secure a required quantity of water such as dams, pumping stations, etc. should be developed in a timely manner. Development timing of such facilities depends on an assumption on hydrological condition.

In the EAIU Study, development timing of these water management facilities was studied both for hydrologically average years and dry years. The EAIU Study calculated economic indicators of the High Rise Lock Canal Alternative for two cases, average years and dry years.

The Panama canal must be operated even in dry years considering its importance to world trade. Therefore, water management facilities should be constructed to secure canal operation even in dry years. In this economic analysis, only a dry year case of the High Rise Lock Alternative is considered for further analysis.

Benefits

Benefit streams are prepared for eight (8) scenarios as shown in Table 8.2.3-5 and total benefits are calculated in terms of discounted values to 2010 for a range of discount rates as shown in Tables 8.2.3-6 through 8.2.3-7.

Table 8.2.3-5
Conditions for Sensitivity Analysis

Scenario	Items for Sensitivity Analyses		
	Evaluation Period	Growth of Benefit	SQ Capacity
1.	101 years (2020-2120)	Constant Growth Rate	17,000 Transits
2.	61 years (2020-2080)	Constant Growth Rate	17,000 Transits
3.	101 years (2020-2120)	Linear Growth	17,000 Transits
4.	61 years (2020-2080)	Linear Growth	17,000 Transits
5.	101 years (2020-2120)	Constant Growth Rate	Variable*
6.	61 years (2020-2080)	Constant Growth Rate	Variable*
7.	101 years (2020-2120)	Linear Growth	Variable*
8.	61 years (2020-2080)	Linear Growth	Variable*

* Projected by WEFA to be 17,359 in 2020 and 18,078 in 2060.

Scenario 5 was applied to the EAIU Study, Final Report for Case 1 and Case 2 and Scenario 1 was applied to the EAIU Additional Study for Case 1-a and Case 2-a and also for Case 1 and Case 2 for reference.

Tables 8.2.3-6

Total Benefits in Present Values for Case 1 And Case 1a

High Rise Alternative - 150,000 dwt with or without Culebra Cut Single Lane

(Million US$)

Scenario	Discount Rate (%)						
	3	4	5	6	7	8	9
1. Base Case SQ Cap'y: 17,000 101 yrs. (2020-2120) Constant growth rate	[illegible]	[illegible]	12,507	8,751	6,422	4,889	3,830
2. Base Case with Reduced Evaluation Period 61 yrs. (2020-2080)	21,054	13,768	10,681	7,944	6,060	4,723	3,753
3. 101 yrs. (2020-2120) Linear growth SQ Cap'y: 17,000	28,075	18,103	12,398	8,915	6,662	5,152	4,048
4. Scenario 3 with Reduced Evaluation Period 61 yrs. (2020-2080)	21,612	15,321	11,178	8,370	6,414	5,017	3,994
5. 101 yrs. (2020-2120) Constant growth rate SQ Cap'y as projected by WEFA	22,965	14,427	9,710	6,912	5,141	-	-
6. 61 yrs. (2020-2080) Constant growth rate SQ Cap'y as projected by WEFA	16,433	11,643	8,500	6,376	4,899	-	-
7. 101 yrs. (2020-2120) Linear growth SQ Cap'y as projected by WEFA	21,443	13,985	9,677	7,022	5,288	4,100	3,253
8. 61 yrs (2020-2080) Linear growth SQ Cap'y as projected by WEFA	16,772	11,973	8,794	6,627	5,109	4,017	3,214

Note: Shaded area = highest benefit for a given discount rate.

Tables 8.2.3-7

Total Benefits in Present Values for Case 2 And Case 2a

High Rise Alternative - 200,000 dwt with or without Culebra Cut Single Lane

(Million US$)

Scenario	Discount Rate (%)						
	3	4	5	6	7	8	9
1. Base Case SQ Cap'y: 17,000 101 yrs. (2020-2120) Constant growth rate	31,405	19,350	12,806	8,990	6,614	5,046	3,959
2. Base Case with Reduced Evaluation Period 61 yrs. (2020-2080)	21,520	15,172	10,994	8,189	6,253	4,881	3,882
3. 101 yrs. (2020-2120) Linear growth SQ Cap'y: 17,000	28,704	18,542	12,720	9,160	6,854	5,285	4,173
4. Scenario 3 with Reduced Evaluation Period 61 yrs. (2020-2080)	22,152	15,722	11,482	8,607	6,602	5,169	4,118
5. 101 yrs. (2020-2120) Constant growth rate SQ Cap'y as projected by WEFA	23,711	14,922	10,060	7,173	5,342	-	-
6. 61 yrs. (2020-2080) Constant growth rate SQ Cap'y as projected by WEFA	16,978	12,050	8,810	6,619	5,092	-	-
7. 101 yrs. (2020-2120) Linear growth SQ Cap'y as projected by WEFA	22,073	14,425	10,000	7,267	5,480	4,254	3,378
8. 61 yrs (2020-2080) Linear growth SQ Cap'y as projected by WEFA	17,313	12,375	9,099	6,864	5,279	4,169	3,338

Note: Shaded area = highest benefit for a given discount rate.

Total benefits in present values are highest in Scenario 1 for discount rates lower than or equal to 5% and in Scenario 3 for discount rates higher than or equal to 6%. In Scenarios 2 and 4 where a project evaluation period is reduced from 101 years to 61 years, total benefits are higher in Scenario 4 than in Scenario 2. Total benefits in Scenario 4 are even higher than those in Scenario 1 for discount rates higher than or equal to 8%. If the SQ capacity is taken to be variable, 17,359 transit No. of ships in 2020 and 18,078 transit No. of ships in 2060, as projected in the CTP Study for the SQ canal with a capacity limit, total benefits are reduced by about 20% for Scenarios 5 to 8 compared with Scenarios 1 to 4.

Costs

Total costs including capital and O&M costs in discounted values to 2010 are calculated for Case 1, Case 1-a, Case 2 and Case 2-a based on the economic cost streams studied in the EAIU Study and given in Table 8.2.3-8. If the Culebra Cut Single Lane option is taken, the costs are reduced by about 20%. Cost differences between the evaluation period up to 2120 and 2080 are minor, less than 2% for a discount rate of 5%. The costs summed up to 2120 correspond to Scenarios 1, 3, 5 and 7 and those to 2080 correspond to Scenarios 2, 4, 6 and 8.

Comparison of Benefits with Costs

The benefits and present costs are used to calculate the economic internal rates of return (EIRR), Benefit Cost Ratios (B/C). The Net Present Values (NPV) based on a Social Discount Rate of 5% and shown in Table 8.2.3-9 for Case 1 and Case 1-a, and in Table 8.2.3-10 for Case 2 and Case 2-a. The highest EIRR is obtained in Scenario 3 and the lowest in Scenario 6. The EIRR are summarized in Table 8.2.3-11 for the 4 Cases and 8 Scenarios. Case 1-a gives higher EIRR than Case 1. Also, Case 2-a gives higher EIRR than Case 2. This is because the Culebra Cut Single Lane option reduces the cost by about 20% while the benefits remained the same.

Table 8.2.3-11

Economic Internal Rates of Return (%)

Scenario	Case 1	Case 1-a	Case 2	Case 2-a
1	6.96	8.31	6.40	7.50
2	6.69	8.11	5.98	7.24
3	7.16	8.63	6.51	7.71
4	6.96	8.53	6.26	7.57
5	5.92	7.08	5.47	6.46
6	5.55	6.84	4.94	6.08
7	5.97	7.27	5.48	6.55
8	5.73	7.07	5.10	6.31

Tables 8.2.3-8

Total Costs in Present Value for High Rise Lock Canal Alternative

(Million US$)

Scenario	Discount Rate (%)						
	3	4	5	6	7	8	9
Case 1:High Rise Lock Canal 150,000 dwt							
1,3,5,7 Base Case 110 yrs. (2010-2120)	10,359	8,850	7,823	7,070	6,486	-	-
2,4,6,8 70 yrs. (2010-2080)	9,593	8,615	7,719	7,023	6,465	-	-
Case 1-a:High Rise Lock Canal 150,000 dwt Culebra Cut Single Lane							
1,3,5,7 Base Case 110 yrs. (2010-2120)	8,676	7,243	6,287	5,602	5,081	4,665	4,323
2,4,6,8 70 yrs. (2010-2080)	8,136	7,008	6,183	5,555	5,060	4,655	4,319
Case 2:High Rise Lock Canal 200,000 dwt							
1,3,5 7 Base Case 110 yrs. (2010-2120)	11,705	10,132	9,065	8,288	7,686	-	-
2,4,6,8 70 yrs. (2010-2080)	11,133	9,883	8,954	8,238	7,663	-	-
Case 2-a:High Rise Lock Canal 200,000 dwt Culebra Cut Single Lane							
1,3,5 7 Base Case	9,795	8,295	7,297	6,585	6,044	5,615	5,260
2,4,6,8 70 yrs. (2010-2080)	9,223	8,046	7,186	6,535	6,021	5,604	5,255

Remarks: Numbers 1 to 8 are sensitivity scenarios.

Table 8.2.3-9

Economic Internal Rate of Return, Benefit Cost Ratio and Net Present Value for HRLC, 150,000 dwt

Assumptions	SQ Capacity	
	17,000 Transit No. of Ships	Variable as Projected by WEFA
Case 1: High Rise Lock Canal, 150,000 dwt		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 6.96%, 1.60 US$4,684 million	(5) 5.92%, 1.24 US$1,887 million
Linear Growth of Benefit	(3) 7.16%, 1.58 US$4,545 million	(7) 5.97%, 1.24 US$1,854 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 6.96%, 1.38 US$2,962 million	(6) 5.55%, 1.10 US$781 million
Linear Growth of Benefit	(4) 6.96%, 1.45 US$3,459 million	(8) 5.73%, 1.14 US$1,075 million
Case 1-a: High Rise Lock Canal, 150,000 dwt Culebra Cut Single Lane		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 8.31%, 1.99 US$6,220 million	(5) 7.08%, 1.54 US$3,423 million
Linear Growth of Benefit	(3) 8.63%, 1.97 US$6,110 million	(7) 7.27%, 1.54 US$3,390 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 8.11%, 1.73 US$4,498 million	(6) 6.84%, 1.37 US$2,317 million
Linear Growth of Benefit	(4) 8.53%, 1.81 US$4,995 million	(8) 7.07%, 1.42 US$2,611 million

Remarks:

a. Numbers 1 to 8 in parenthesis are sensitivity scenario numbers.

b. Scenario 5 for Case 1 and Scenario 1 for Case 1-a were studied in the EAIU Study. Scenario 1 was also studied for Case 1 for reference in the EAIU Study.

c. Benefit-Cost Ratios and Net Project Values are based on a Social Discount Rate of 5%.

Table 8.2.3-10

Economic Internal Rate of Return, Benefit Cost Ratio and Net Present Value for HRLC, 200,000 dwt

Assumptions	SQ Capacity	
	17,000 Transit No. of Ships	Variable as Projected by WEFA
Case 2: High Rise Lock Canal, 200,000 dwt		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 6.40%, 1.41 US$3,741 million	(5) 5.47%, 1.11 US$995 million
Linear Growth of Benefit	(3) 6.51%, 1.40 US$3,655 million	(7) 5.48%, 1.10 US$935 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 5.98%, 1.23 US$2,040 million	(6) 4.94%, 0.98 -US$144 million
Linear Growth of Benefit	(4) 6.26%, 1.28 US$2,528 million	(8) 5.10%, 1.02 US$145 million
Case 2-a: High Rise Lock Canal, 200,000 dwt Culebra Cut Single Lane		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 7.50%, 1.75 US$5,509 million	(5) 6.46%, 1.38 US$2,763 million
Linear Growth of Benefit	(3) 7.71%, 1.74 US$5,423 million	(7) 6.55%, 1.37 US$2,703 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 7.24%, 1.53 US$3,808 million	(6) 6.08%, 1.23 US$1,624 million
Linear Growth of Benefit	(4) 7.57%, 1.60 US$4,296 million	(8) 6.31%, 1.27 US$1,913 million

Remarks:

a. Numbers 1 to 8 in parenthesis are sensitivity scenario numbers.

b. Scenario 5 for Case 1 and Scenario 1 for Case 1-a were studied in the EAIU Study. Scenario 1 was also studied for Case 1 for reference in the EAIU Study.

c. Benefit-Cost Ratios and Net Project Values are based on a Social Discount Rate of 5%.

Comparing Case 1-a (150,000 dwt) with Case 2-a (200,000 dwt), Case 1-a gives a higher EIRR than Case 2-a because the benefit increase from 150,000 dwt to 200,000 dwt is marginal while the cost increase is considerable.

Among four cases of HRLC alternatives the IRR of Case 1-a and Case 2-a are high. Therefore, Case 1-a and Case 2-a are considered for further analyses to include the following:

- Optimal development timing
- Canal capacity
- Possible deviation of commodity and traffic projections from those estimated in the CTP Study

Optimal Development Timing for Culebra Cut Single Lane Option

The project has been assumed to commence its operation in 2020. An opening year of the new canal is herein analyzed from an economic point of view.

If the canal opening year is delayed by one year, a cost reduction is attainable in terms of discounted value of the construction cost owing to a delayed investment. The O&M cost for one year can also be saved owing to one year delay in the canal opening year. At the same time, a one year delay in the canal opening year causes a loss of benefit for that year which could be enjoyed if the canal was opened without delay.

A year when the benefit loss becomes larger than the cost reduction is the optimal year for a new canal opening.

The optimal canal opening years are calculated to be 2014 for Case 1-a and 2018 for Case 2-a as shown in Tables 8.2.3-12 and 8.2.3-13, respectively, applying a social discount rate of 5%. The optimal development timing of a project is sensitive to a social discount rate. If a social discount rate of 6% is applied, the optimal canal opening years are 2022 for Case 1-a and 2027 for Case 2-a.

This analysis may conclude that the assumed canal opening year of 2020 is reasonable from a purely economic point of view.

Canal Capacity

If 10 hours of average delay time is allowed to pass through the Panama Canal, canal capacities are estimated in the OCCE Study as presented in Tables 8.2.3-14.

Table 8.2.3-12

Development Time for High Rise Lock Canal

150,000 dwt w/ Culebra Cut Single Lane (Case 1a)

(Discounted Values to 2010 in Million US$)

New Canal Opening Year	Construction Cost 1/	Difference 2/	O&M Cost 3/	Cost Reduction 4/	Benefit Loss 5/	Benefit Loss 6/
2011	6,813	-	121	445	445	424
12	6,489	324	115	424	456	414
13	6,180	309	110	404	467	403
14 7/	5,886	294	104	385	478	393
15	5,605	281	100	366	489	383
16	5,339	266	95	350	501	374
17	5,084	255	90	332	513	365
18	4,842	242	86	316	525	355
19	4,612	230	82	302	538	347
2020	4,392	220	78	-	551	338

Remarks: Discount rate is 5%.

1/ Discounted values to 2010 of construction cost. If canal is opened in 2020, the construction cost is US$4,392 million.

2/ Reduction in 2010 present value of construction cost owing to a delayed investment by one year. US$324 million can be saved if the canal opening year is delayed from 2011 to 2012.

3/ Reduction in 2010 present value of OM cost owing to a delayed canal opening if canal opening is delayed from 2011 to 2012, OM cost for 2011, US$121 million, can be saved.

4/ Cost reduction owing to delayed canal opening, 3/ + 2/ of the next year. If canal opening is delayed from 2011 to 2012, a cost reduction of US$445 million (324+121) can be attained.

5/ Annual Benefits extrapolated from 2020 to 2011 applying an annual growth rate of 2.394%. Not discounted values.

6/ Discounted Annual benefits to 2010 present value. If canal opening is delayed by one year from 2011 to 2012, US$424 million of benefit for 2011 is lost.

7/ Benefit loss becomes larger than cost reduction in year 2014, which indicates that the optimal opening year of the project should be 2014.

Table 8.2.3-13

Development Time for High Rise Lock Canal

200,000 dwt w/ Culebra Cut Single Lane (Case 2a)
(Discounted Values to 2010 in Million US$)

New Canal Opening Year	Construction Cost	Difference	O&M Cost	Cost Reduction	Benefit Loss	
2015	6,713	-	107	426	512	401
16	6,394	319	101	406	523	390
17	6,089	305	97	387	536	381
18	5,799	290	92	364	548	371
19	5,523	276	88	351	561	362
2020	5,260	263	83	333	574	352
21	5,010	250	80	-	588	344

Remarks: Discount rate is 5%.
Optimal opening year of the project is 2018.

For explanations on how to understand this table, refer to the remarks of Table 8.2.3-12.

Table 8.2.3-14

Canal Capacities of HRLC (Case 1-a and Case 2-a)

Study Case	Canal Capacity (Annual Transits)
150,000 dwt (Case 1-a) including SQ	34,400
200,000 dwt (Case 2-a) including SQ	34,600
Status Quo canal (SQ)	17,000

The annual transits (Number of Ships) are projected in the CTP Study as presented in Table 8.2.3-15.

Table 8.2.3-15
Transit Projection for 150,000 dwt and 200,000 dwt

Study Case	YEAR		
	1990	2020	2060
150,000 dwt (Case 1-a) including SQ	11,162[1]	17,796[2]	23,934[2]
200,000 dwt (Case 2-a) including SQ	11,162[1]	17,844[2]	24,074[2]

Notes: [1] Actual transits in 1990 through SQ.
[2] Projected Annual Transits

If the transits are assumed to increase at a constant annual growth rate, the transits are projected to reach 37,600 for Case 1-a and 38,000 for Case 2-a in the year 2120, both of which exceed the estimated canal capacities. This effect on the project benefit was duly taken into account in the EAIU Study. On the other hand, if the transits are assumed to increase in a straight line, the transits will reach 33,300 and 33,600 for Case 1-a and Case 2-a, respectively, in the year 2120, both of which are within a capacity limit.

Effect of Possible Deviation in Commodity and Traffic Projections on Project Benefit

It is not an easy task to make a long-term projection of trade volumes and transit numbers of ships through the Panamanian Isthmus till 2060. The effect of possible deviation in traffic projections on the project benefit is discussed hereunder.

According to the CTP Study, trade volumes are projected as shown in Table 8.2.3-16.

Table 8.2.3-16
Trade Volume (Million Tons)

Year	SQ	150,000 dwt	Increment
2020	266.0	361.0	95.0
2060	276.5	490.6	214.1

If the project benefit is assumed to be proportional to the trade volume for each projection year, 2020 and 2060, a change of the project benefit (y%) can be expressed as a function of a possible deviation (x%) of the projected trade volume, as follows.

For Year 2020	$361.0(1+x)-266.0$	=	$(361.0-266.0)(1+y)$
	y	=	$3.80x$
For Year 2060	$490.6(1+x)-276.5$	=	$(490.6-276.5)(1+y)$
	y	=	$2.29x$

Trade volumes in SQ are not subject to deviation because these are constrained values due to a capacity limit of SQ. The above functions mean that a 10% deviation in trade volume projection in 2020 will lead to a 38% change of the benefit in 2020, and that the same 10% deviation in 2060 will result in a 23% change of the benefit. The trade volume is assumed to virtually reach the SQ capacity in or before the year 2020.

An economic feasibility of the project is therefore proved to be very sensitive to the commodity and traffic projections.

8.2.4 Financial Analysis

As discussed in Section 7.2 "Financing Scheme and Financial Analysis", financial results by each Canal alternative under the optimal toll system scenario are summarized in Table 8.2.4-1.

As a result, the FFMS Study concluded that the following three High Rise Canal alternatives are feasible under the optimal toll system scenario.

- High Rise 150,000 dwt Alternative
- High Rise 150,000 dwt Culebra Cut Single Lane Alternative
- High Rise 200,000 dwt Culebra Cut Single Lane Alternative

Among three feasible alternatives under optimal toll system scenarios, the High Rise 150,000 dwt Culebra Cut Single Lane Alternative found to be the most attractive from a financial viewpoint, because both FIRR and the net present value of this alternative are the highest among those of three, which is shown in the Table 8.2.4-2.

Table 8.2.4-1

Summary of Financial Results by Canal Alternative under Optimal Toll System Scenario

Evaluation Criteria	Target Result	High Rise 150,000 dwt	High Rise 200,000 dwt	High Rise 150,000 dwt Culebra Cut Single Lane	High Rise 200,000 dwt Culebra Cut Single Lane	Sea Level Case A	Sea Level Case E
Trust Fund balance always positive	Yes	O	O	O	O	X	X
Financial internal rate of return before financing (%)	8-10	O	O	O	O	X	X
Financial internal rate of return after financing (%)	12-15	O	X	O	O	X	X
Net present value before financing (US$Million)*	Positive Value	O	O	O	O	X	X
Net present value after financing (US$Million)*	Positive Value	O	O	O	O	X	X
Minimum debt service coverage ratio-current	1.3	X	X	X	X	X	X
Minimum debt service coverage ratio-overall	1.5-2.0	O	O	O	O	X	X
Debt/equity ratio	Below 4.0	O	O	O	O	O	O
Is the alternative financially feasible with:							
a. Interest rates increased 25 percent	Yes	O	X	O	O	X	X
b. Capital costs increased 25 percent	Yes	X	X	O	O	X	X
c. Operation and Maintenance costs increased 25 percent	Yes	O	X	O	O	X	X
Conclusion Is project financially feasible?		O	X	O	O	X	X

* Based upon a discount rate of 8 percent

Notes: O represents meeting the target. X represents not meeting the target.
The results of sensitivity analysis with Status Quo Canal tolls increased 50 percent are excluded.
Source: The FFMS Study, Final Report Volume I, Tables 6-7 through 6-24 and Appendix J, and Annex to Draft Final Report. Tables 11 through 28 and Table 30.

Table 8.2.4-2

Comparison Among Three Feasible Canal Alternatives Under Optimal Toll System Scenario

Alternatives	FIRR (%)		Net Present Value[1] (1990 US$Million)	
	before financing	after financing	before financing	after financing
High Rise 150,000 dwt	10.1	18.0	951	1,069
High Rise 150,000 dwt Culebra Cut Single Lane	15.8	28.0	2,086	2,073
High Rise 200,000 dwt Culebra Cut Single Lane	12.3	21.2	1,521	1,566

Notes: [1] Based upon a discount rate of 8 percent.

It is important to note that feasibility analysis in the FFMS Study implies that these three alternatives even under the optimal toll scenario are feasible only when the following two conditions are met:

(1) The Status Quo Canal and Alternative Canal are managed by one entity and the net income from both Status Quo Canal operation and the Alternative Canal operation will be applied to debt service requirements of Alternative Canal construction.

If the Status Quo and Alternative Canals are managed separately, and if the entity which solely manages the Alternative Canal cannot access the net income generated from the Status Quo operation for its debt service, then all three Alternatives will be financially unfeasible.

It can be determined from Table 8.2.4-3 that even High Rise 150,000 dwt Culebra Cut Single Lane Alternative, which was found to be the most attractive alternative among three, turns out to be unfeasible should the management entity not be allowed to use the net income generated from the Status Quo Canal operation. This results from the FIRR before financing of only 2%.

The High Rise 200,000 dwt Culebra Cut Singe Lane Alternative and High Rise 150,000 dwt Alternative are also not feasible, in the same way.

(2) The entity which will manage both the Status Quo and Alternative canals will have obtained and reserved a certain amount of fund by means of either a toll increase in advance or some other source of cash injection before the Alternative Canal will start to operate in 2020.

In order to preserve the required fund, the FFMS Study suggested that Panama Canal Toll Reserve Trust Fund be established which would be endowed with net income generated from Canal tolls after Panama acquires control of the Canal in the year 2000, and that tolls for the Status Quo Canal transits be increased beginning in the year 2000, in advance of the Alternative Canal operation.

Without raising the toll in advance of starting canal operation, a High Rise 150,000 dwt Culebra Single Lane Alternative would be unfeasible. Table 8.2.4-4 shows it is still not feasible, even if the entity can successfully raise the toll up to the optimal level in and after 2020. This results from the fact that its Trust Fund balance would turn out to be negative between the year 2018 and 2060 in the case of Capital Cost Increased by 25%.

In the same way, it can be shown by analysis that a High Rise 200,000 dwt Culebra Cut Single Lane Alternative and a High Rise 150,000 dwt Alternative would also be unfeasible, because their Trust Fund balances would become negative in the year 2018 even for the base cases.

Thus, either a toll increase before 2020 or some cash injection from external sources is at least required to ensure that the Panama Canal Toll Reserve Trust Fund always remains positive.

Table 8.2.4-3

Financial Analysis Assuming Optimal Toll System

High Rise 150,000 DWT Culebra Cut Single Lane Alternative (1990 US$ million)

Year	<Net Income from Operation> With Project	Without Project	Incremental Income	Capital Cost	Cashflow before financing	Financing Stream	Cashflow after financing
2000	165.0	165.0	0.0				
2001	182.5	182.5	0.0				
2002	200.9	200.9	0.0				
2003	219.9	219.9	0.0				
2004	239.8	239.8	0.0				
2005	260.6	260.6	0.0				
2006	282.0	282.0	0.0				
2007	304.6	304.6	0.0				
2008	327.9	327.9	0.0				
2009	352.2	352.2	0.0			53.1	53.1
2010	377.5	377.5	0.0	75.9	(75.9)	49.5	(26.4)
2011	404.0	404.0	0.0	77.2	(77.2)	146.7	69.5
2012	431.4	431.4	0.0	222.7	(222.7)	370.2	147.5
2013	459.9	459.9	0.0	518.1	(518.1)	495.5	(22.6)
2014	489.6	489.6	0.0	713.4	(713.4)	343.4	(370.0)
2015	520.6	520.6	0.0	621.3	(621.3)	653.7	32.4
2016	553.9	553.9	0.0	1,108.6	(1,108.6)	487.9	(620.7)
2017	586.3	586.3	0.0	990.3	(990.3)	195.8	(794.5)
2018	621.2	621.2	0.0	726.3	(726.3)	55.2	(671.1)
2019	657.6	657.6	0.0	615.9	(615.9)	(480.4)	(1,096.3)
2020	832.5	695.4	137.1	0.0	137.1	(502.9)	(365.8)
2021	840.6	699.2	141.4	0.0	141.4	(535.2)	(393.8)
2022	848.8	703.1	145.7	0.0	145.7	(555.2)	(409.5)
2023	857.0	707.0	150.1	0.0	150.1	(535.0)	(384.9)
2024	865.5	711.0	154.5	0.0	154.5	(500.6)	(346.1)
2025	873.9	714.9	159.0	0.0	159.0	(456.3)	(297.3)
2026	882.5	718.9	163.6	0.0	163.6	(397.7)	(234.1)
2027	891.1	722.8	168.3	0.0	168.3	(346.9)	(178.6)
2028	899.9	726.9	173.0	0.0	173.0	(296.3)	(123.3)
2029	908.7	730.9	177.8	9.7	168.1	(246.1)	(78.0)
2030	917.7	735.0	182.7	13.6	169.1	(210.7)	(41.6)
2031	926.7	739.1	187.6	14.7	172.9	(169.5)	3.4
2032	935.8	743.2	192.6	53.0	139.6	(142.2)	(2.6)
2033	945.1	747.4	197.7	53.0	144.7	(117.3)	27.4
2034	954.4	751.6	202.8	0.0	202.8	(95.4)	107.4
2035	963.8	755.8	208.0	0.0	208.0	(76.6)	131.4
2036	973.4	760.1	213.3	0.0	213.3	(47.2)	166.1
2037	983.0	764.3	218.7	0.0	218.7	(24.6)	194.1
2038	992.8	768.7	224.1	0.0	224.1	(10.0)	214.1
2039	1,002.5	772.9	229.6	0.0	229.6	0.0	229.6
2040	1,012.5	777.3	235.2	0.0	235.2	0.0	235.2
2041	1,022.7	781.7	241.0	0.0	241.0	0.0	241.0
2042	1,032.8	786.0	246.7	0.0	246.7	0.0	246.7
2043	1,043.0	790.5	252.5	0.0	252.5	0.0	252.5
2044	1,053.4	794.9	258.4	0.0	258.4	0.0	258.4
2045	1,063.8	799.4	264.4	0.0	264.4	0.0	264.4
2046	1,074.4	803.9	270.5	0.0	270.5	0.0	270.5
2047	1,085.2	808.5	276.6	0.0	276.6	0.0	276.6

Table 8.2.4-3 (continued)

Year	<Net Income from Operation> With Project	Without Project	Incremental Income	Capital Cost	Cashflow before financing	Financing Stream	Cashflow after financing
2048	1,095.9	813.1	282.8	0.0	282.8	0.0	282.8
2049	1,106.9	817.7	289.2	3.2	286.0	0.0	286.0
2050	1,117.9	822.3	295.5	19.7	275.8	0.0	275.8
2051	1,129.0	827.0	302.0	19.7	282.3	0.0	282.3
2052	1,140.3	831.7	308.6	0.0	308.6	0.0	308.6
2053	1,151.6	836.4	315.2	0.0	315.2	0.0	315.2
2054	1,163.1	841.1	322.0	0.0	322.0	0.0	322.0
2055	1,174.7	845.9	328.8	0.0	328.8	0.0	328.8
2056	1,186.4	850.7	335.7	0.0	335.7	0.0	335.7
2057	1,198.3	855.6	342.7	0.0	342.7	0.0	342.7
2058	1,210.2	860.5	349.8	0.0	349.8	0.0	349.8
2059	1,222.3	865.3	356.9	0.0	356.9	0.0	356.9
2060	1,234.5	870.3	364.2	0.0	364.2	0.0	364.2
Total	49,451.8	39,585.4	9,866.3	5,856.3	4,010.0	(2,895.0)	1,115.0
	Financial Internal Rate of Return				2.06%		0.59%
	Net Present Value at 8% discount rate				(2,379.0)		(2,061.2)

Note

This FIRR calculation is based on the assumption that the management entity can only access to the net income generated from the Alternative Canal operation, and that it cannot access to that from the Status Quo operation. This analysis was conducted for proving that High Rise 150,000 DWT Culebra Cut Single Lane Alternative under the optimal toll scenario is not feasible unless the Status Quo and Alternative Canals are managed by one entity.

Table 8.2.4-4

Financial Analysis Assuming Optimal Toll System After 2020 (No Toll Increase Until 2019)

High Rise 150,000 dwt Culebra Cut Single Lane Alternative, Capital Cost Increased by 25 percent (1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.0	350.0	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	320.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,228.6		
2009	549.5	359.4	190.1	54.9	0.0	135.1	0.0	0.0	1,404.5		
2010	555.1	360.5	194.6	55.5	5.6	133.5	28.5	0.0	1,565.7	24.7	274.4
2011	560.8	361.5	199.3	56.1	11.5	131.7	29.0	0.0	1,731.1	12.5	148.6
2012	566.5	362.6	203.9	56.7	28.1	119.1	83.5	0.0	1,836.0	5.2	66.8
2013	572.3	363.7	208.6	57.2	76.3	75.1	156.8	0.0	1,827.8	2.0	26.1
2014	578.2	364.8	213.4	57.8	146.5	9.8	196.2	0.0	1,713.8	1.1	13.5
2015	584.1	365.8	218.3	58.4	202.6	(42.8)	200.9	0.0	1,538.7	0.8	9.2
2016	590.0	366.8	224.2	59.0	315.9	(150.7)	366.0	0.0	1,083.6	0.5	5.4
2017	596.0	368.0	228.0	59.6	443.1	(274.7)	312.1	0.0	540.1	0.4	2.8
2018	602.1	369.1	233.0	60.2	525.4	(352.5)	220.0	0.0	(10.8)	0.3	1.4
2019	608.3	370.1	238.2	60.8	608.5	(423.1)	175.5	0.0	(609.8)	0.3	0.3
2020	1,307.6	475.1	832.5	130.8	628.6	73.1	0.0	0.0	(561.1)	1.1	0.1
2021	1,318.4	477.8	840.6	131.8	669.8	39.8	0.0	0.0	(543.8)	1.1	0.2
2022	1,329.3	480.5	848.8	132.9	694.8	21.9	0.0	0.0	(543.7)	1.0	0.2
2023	1,340.2	483.2	857.0	134.0	668.8	54.3	0.0	0.0	(511.2)	1.1	0.3
2024	1,351.4	485.9	865.5	135.1	625.8	104.6	0.0	0.0	(427.8)	1.2	0.4
2025	1,362.5	488.6	873.9	136.3	570.4	167.3	0.0	0.0	(276.8)	1.3	0.5
2026	1,373.8	491.3	882.5	137.4	497.1	248.0	0.0	0.0	(39.9)	1.5	0.9
2027	1,385.1	494.0	891.1	138.5	433.6	319.0	0.0	0.0	277.5	1.7	1.6
2028	1,396.6	496.7	899.9	139.7	370.4	389.9	0.0	178.0	500.5	2.1	2.8
2029	1,408.1	499.4	908.7	140.8	307.6	460.3	9.7	471.0	500.1	2.5	4.1
2030	1,419.8	502.1	917.7	142.0	263.4	512.3	13.6	518.0	500.8	2.9	4.8
2031	1,431.5	504.8	926.7	143.2	211.9	571.7	14.7	577.0	500.8	3.7	6.1
2032	1,443.3	507.5	935.8	144.3	177.8	613.8	53.0	581.0	500.6	4.5	7.3
2033	1,455.3	510.2	945.1	145.5	146.6	652.9	53.0	620.0	500.5	5.5	8.9
2034	1,467.3	512.9	954.4	146.7	119.3	688.4	0.0	709.0	500.0	6.8	11.0
2035	1,479.4	515.6	963.8	147.9	95.8	720.1	0.0	740.0	500.1	8.5	13.7

Table 8.2.4-4 (continued)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,491.7	518.3	973.4	149.2	59.0	765.2	0.0	785.0	500.3	14.0	22.4
2037	1,504.0	521.0	983.0	150.4	30.7	801.8	0.0	822.0	500.1	27.1	43.3
2038	1,516.5	523.7	992.8	151.6	12.5	828.6	0.0	848.0	500.7	67.3	107.3
2039	1,528.9	526.4	1,002.5	152.9	0.0	849.6	0.0	870.0	500.4		
2040	1,541.6	529.1	1,012.5	154.2	0.0	858.4	0.0	878.0	500.8		
2041	1,554.4	531.7	1,022.7	155.4	0.0	867.2	0.0	888.0	500.1		
2042	1,567.2	534.4	1,032.8	156.7	0.0	876.0	0.0	896.0	500.1		
2043	1,580.1	537.1	1,043.0	158.0	0.0	885.0	0.0	905.0	500.1		
2044	1,593.2	539.8	1,053.4	159.3	0.0	894.1	0.0	914.0	500.2		
2045	1,606.3	542.5	1,063.8	160.6	0.0	903.2	0.0	923.0	500.4		
2046	1,619.6	545.2	1,074.4	162.0	0.0	912.4	0.0	932.0	500.9		
2047	1,633.1	547.9	1,085.2	163.3	0.0	921.9	0.0	942.0	500.7		
2048	1,646.5	550.6	1,095.9	164.7	0.0	931.3	0.0	952.0	500.1		
2049	1,660.2	553.3	1,106.9	166.0	0.0	940.9	3.2	957.0	500.7		
2050	1,673.9	556.0	1,117.9	167.4	0.0	950.5	19.7	951.0	500.5		
2051	1,687.7	558.7	1,129.0	168.8	0.0	960.3	19.7	961.0	500.1		
2052	1,701.7	561.4	1,140.3	170.2	0.0	970.1	0.0	990.0	500.2		
2053	1,715.7	564.1	1,151.6	171.6	0.0	980.0	0.0	1,000.0	500.3		
2054	1,729.9	566.8	1,163.1	173.0	0.0	990.1	0.0	1,010.0	500.4		
2055	1,744.2	569.5	1,174.7	174.4	0.0	1,000.3	0.0	1,020.0	500.6		
2056	1,758.6	572.2	1,186.4	175.9	0.0	1,010.5	0.0	1,031.0	500.2		
2057	1,773.2	574.9	1,198.3	177.3	0.0	1,021.0	0.0	1,041.0	500.2		
2058	1,787.8	577.6	1,210.2	178.8	0.0	1,031.4	0.0	1,051.0	500.6		
2059	1,802.6	580.3	1,222.3	180.3	0.0	1,042.0	0.0	1,062.0	500.6		
2060	1,817.5	583.0	1,234.5	181.8	0.0	1,053.6	0.0	1,073.0	500.4		
Total	74,571.6	28,888.6	45,683.0	7,457.2	8,937.6	29,288.2	1,954.9	28,096.0			

Note:
1. The revenue upto 2019 is mainly based on Table 11 of FFMS's Annex to Draft Final Report.
2. The other data are mainly based on Table A-30 of FFMS's Annex to Draft Final Report.
3. Slight difference with FFMS data exits.
4. Overall DSCR is net income from operations less payments to Panama plus trust fund balance of previous year divided by total debt service requirements.

8.2.5 Environmental Aspects - High Rise Locks

Any major construction project will have ecological impacts. The extent of these impacts, their severity, and their acceptability in relation to the project feasibility depend principally on the size of the project, the ecological conditions in the area impacted, and the extent that mitigation can be successfully accomplished.

Because of the size of the project and its location, the addition of the third set of locks to the present Panama Canal (and associated activities) will have ecological impacts. In this evaluation, it is assumed that the impacts are mitigated to the greatest reasonable extent.

Areas of valuable forest habitat will be altered by excavation, spoil disposal, facility placement, and river impoundment. The careful selection of alternate spoil disposal areas, flexibility in facility siting, relocation of species, and acquiring other similar areas of Panama for protection, can mitigate these impacts to some extent.

Excavation and dredged spoil disposal in the marine and freshwater environments will impact fish and other aquatic populations in the area. Excavation, dredging, and erosion control measures designed to minimize sedimentation and turbidity will reduce the areas directly impacted. Where possible, disposal of spoil will de limited to areas which will minimize the impact upon valuable fisheries resources.

Future construction beyond year 2020 will impact both terrestrial and riverain resources. These impacts can be somewhat mitigated by proper design and operation of the facilities.

The construction of single lane culebra cut and locks would reduce the volume of excavated and dredged material and consequently the size of the excavation disposal areas. If land use conversion is avoided in forests areas and in agricultural lands, the sedimentation could be mitigated. Also, useful programs such as those relating to soil conservation practices, reforestation, creation of banks of seeds, propagation of the flora with sheet pile system and relocation of the most sensitive resources would be necessary in conjunction with any change in land use pattern.

Sediment nets can provide physical controls of sedimentation and turbidity. The initial analysis of sediments that must be dredged is recommended. If the relocation of species is not possible, it is recommended to establish a record, to evaluate, the potential of mitigation in other areas.

In summary, construction of the High Rise Lock Canal will have aquatic and terrestrial ecological impacts requiring mitigation.

8.3 Sea Level Canal Alternative

8.3.1 Construction, Cost and Schedule

The constructability of structures and systems was made an important consideration in evaluating the feasibility of each conceptual alternative studied.

Excavation of the Sea Level Canal alternative is new construction which will be conducted along the proposed Route 10 and which may encounter similar difficulties experienced in the construction of the existing Panama Canal, especially in the Continental Divide Section.

It should be noted that topographical, geological, hydrological, and geotechnical data specific for the proposed SLC-10 route are not available in the same level of knowledge as exist for the HRLC alternative. Therefore, where necessary, reasonable assumptions were made and data from the HRLC route were projected and used for analysis and studies along the proposed SLC-10. Both dry and wet excavation are feasible and are well within existing construction technology, management capabilities and know how. Concerns related to optimization of excavation and hauling should be undertaken during a final design stage. Construction of barrier dams will present a significant challenge, particularly if poor foundation material exists in the Gatun Lake area. Substantial hydrostatic head from the lake will exist during construction of a Sea Level Canal between newly constructed barrier dams. To maintain Gatun Lake at its present level will present a potential embankment stability problem. Although failure of the proposed barrier dams is unlikely, it could have disastrous effects on construction and operation of the existing Panama Canal. Safety precautions should therefore be implemented during blasting in order that stability of the barrier dams and other water controlling structures is not impaired. Appropriate dredge equipment should be used keeping in mind efficiency of operation and hence schedule and cost.

Concerns related to water resources for the HRLC are applicable for this alternative since the existing Panama Canal will continue to operate during construction of the SLC-10.

The existing canal and the completed SLC-10 will operate simultaneously to meet capacity after construction of several barrier dams. If this alternative is selected for construction, a refined water balance analysis will be required based on site specific data including data outside the Gatun Lake watershed. Particular attention should be paid to the stability of barrier dams especially during construction when large hydrostatic heads may exist.

The construction of hydraulic structures including tidal locks, tidal gates, water conveying systems and spillways, are feasible and well within the present state of design and construction. Concrete for these structures will be manufactured using aggregate processed from excavation and local quarry sites. Earth and rock material for impoundments will come from excavation sites along the proposed route and no particular problems are anticipated.

Lock and gate leafs will be of steel construction fabricated- as assumed in the YEC- Phase II Final Report - and transported in manageable pieces to the site and assembled in-place for permanent use. No problem with such construction exist but the fabrication assumption should be studied during detailed design. An economical location for the fabrication site should be selected.

The design and construction of locks, gates or a combination of both to regulate tides in the sea level canal is feasible and is well within present state-of-the-art. The EA Component Study did not clearly demonstrate that a freshwater barrier for a sea-level canal alternative is infeasible, although the study included a statement to this effect. Should a sea level alternative be selected for construction, the engineering and design of a freshwater barrier system to mitigate potential environmental concerns would require extensive physical and theoretical studies including scale modeling prior to engineering and design.

The Engineering and Cost Estimate Component Study included analysis and study of availability of water from the present Gatun or other watershed areas to supply water for this concept. It is also not clear how much water is enough for an effective freshwater barrier system. It has been advanced by theory that a ratio of 10:1 freshwater to saltwater may be required for such a barrier. It is very important to emphasize that the concept of a freshwater barrier should be thoroughly studied, including the construction of a physical model to obtain design data and confirm theoretical analysis. Breakwaters, jetties, anchorage, and tie-stations will be required for both alternatives. These structures are feasible and are considered conventional construction. Other construction items such as pump stations, canal bridge crossing, and incidental structures are feasible and are conventional construction where complications are not anticipated.

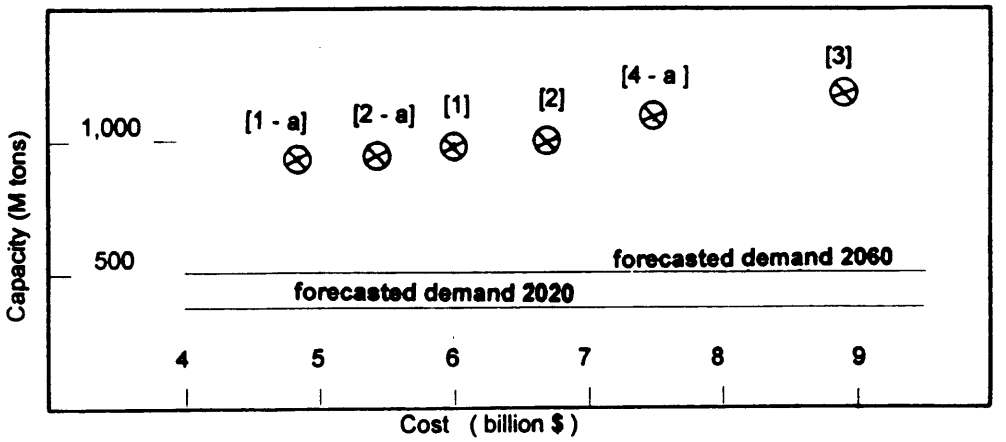
Based on the Engineering and Cost Estimates Studies conducted for Phases II and II Additional Work Studies, the construction schedule and cost estimates are presented in Figures 6.4.6-3 and 6.4.6-4 and Tables 6.4.7-1 and 6.4.7-2. The cost estimates and schedule should be confirmed by additional work to be undertaken as a part of any eventual detailed design development.

8.3.2 Operating Characteristics and Capacity

In Figure 8.3.2-1, two points namely, 3(250,000 dwt Sea Level Alternative, 3+1 Tidal Locks) and 4-a (250,000 dwt Sea Level Alternative, Tidal Gates, with Single Lane Atlantic approach), are added on Figure 8.2.2-1. Assumptions used for the costs and capacities calculation of points 3 and 4-a are identical to those of the High Rise cases. Though the adoption of Single Lane Atlantic approach brings in about 16% cost reduction in 250,000 dwt Sea Level Alternative and 5% increase in cost/effectiveness, Sea Level Alternatives are considered less attractive than High Rise Alternatives under the present conditions. It is, therefore, concluded that 150,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut is the best selection among all the alternatives studied, under the present project set up. This aspect will be evaluated more definitively by the following economic and financial analyses.

Figure 8.3.2-1

Cost vs. Capacity for All the Cases



Legenda

[1]	150,000 DWT High Rise Lock Alternative
[1 - a]	150,000 DWT High Rise Lock Alternative with Culebra Cut Single Lane
[2]	200,000 DWT High Rise Lock Alternative
[2 - a]	200,000 DWT High Rise Locak Alternative with Culebra Cut Single Lane
[3]	250,000 DWT Sea Level, Tidal Locks 3 + 1 Alternative
[4 - a]	250,000 DWT Sea Level, Tidal Gates Alternative with Single Lane Atlantic Approach

Note: Costs represent the present value for the alternatives at the start of construction work (2010) discounted at 8% over the project life.

8.3.3 Economic Analysis

Approach

For an economic analysis of the Sea Level Canal Alternative, the same approach as taken for the economic analysis of the High Rise Lock Canal Alternative described in Section 8.2.3 herein is applied.

Issues studied for a sensitivity analysis are:

(1) Intra- and extra-polation method of project benefit, using the annual benefits determined for only two points of time, 2020 and 2060;

(2) Project evaluation period or a project life for economic analysis;

(3) Capacity limit of the SQ canal;

(4) Development timing of the proposed new canal;

(5) Capacity of the new canal; and,

(6) Possible deviation in commodity and traffic projections.

Sensitivity analysis of the above issues are made for the following four (4) study cases.

Table 8.3.3-1
Study Cases

Study Case	Conceptual Alternative	Maximum Ship Size	No. of Channels	New Lanes Lock/Gate
3	Sea Level Canal Pacific Tidal Locks	250,000 dwt	1	3+1
3-a	Sea Level Canal Pacific Tidal Locks	250,000 dwt	1	1+1
4	Sea Level Canal Tidal Gates	250,000 dwt	1	1
4-a	Sea Level Canal Tidal Gates Single lane Atlantic approach channel	250,000 dwt	1	1

Benefits

Benefit streams for a sea level canal alternative are prepared for the eight (8) scenarios shown in Table 8.3.3-2 and total benefits are calculated in terms of discounted values to 2010 (2010 present values) for a range of discount rates, as shown in Table 8.3.3-3.

Table 8.3.3-2

Scenario	Items for Sensitivity Analyses		
	Evaluation Period	Growth of Benefit	SQ Capacity
1.	101 years (2020-2120)	Constant Growth Rate	17,000 Transit (No. of ships)
2.	61 years (2020-2080)	Constant Growth Rate	17,000 Transit (No. of ships)
3.	101 years (2020-2120)	Linear Growth	17,000 Transit (No. of ships)
4.	61 years (2020-2080)	Linear Growth	17,000 Transit (No. of ships)
5.	101 years (2020-2120)	Constant Growth Rate	Variable Projected *
6.	61 years (2020-2080)	Constant Growth Rate	Variable Projected *
7.	101 years (2020-2120)	Linear Growth	Variable Projected *
8.	61 years (2020-2080)	Linear Growth	Variable Projected *

* Projected by WEFA to be 17,359 in 2020 and 18,078 in 2060.

As mentioned in Section 8.2.3, Scenario 5 was applied to the EAIU Study, Final Report, for Case 3 and Case 4 and Scenario 1 was applied to the EAIU Additional Study for Case 3-a and Case 4-a and also for Case 3 and Case 4 for reference.

Total benefits in 2010 present value are highest in Scenario 1 for discount rates lower than or equal to 5% and in Scenario 3 for discount rates higher than or equal to 6%. In Scenarios 2 and 4 where a project evaluation period is reduced from 101 years to 61 years, total benefits are higher in Scenario 4 than in Scenario 2. Total benefits in Scenario 4 are even higher than those in Scenario 1 for discount rates higher than or equal to 8%. If the SQ capacity is taken to be variable, 17,359 transit number of ships in 2020 and 18,078 transit number of ships in 2060, as estimated in the CTP Study by WEFA for the SQ canal with a capacity limit, total benefits are reduced by about 20% for Scenarios 5 to 8 compared with Scenarios 1 to 4.

Table 8.3.3-3

Total Benefits in 2010

Present Value for Cases 3, 3a, 4 and 4a Sea Level Canal - 250,000 dwt

(Million US$)

Scenario	Discount Rate (%)						
	3	4	5	6	7	8	9
1. Base Case SQ Cap'y: 17,000 101 yrs. (2020-2120) Constant growth rate	32,338	19,881	13,146	9,230	6,794	5,186	4,071
2. Base Case with Reduced Evaluation Period 61 yrs. (2020-2080)	22,109	15,550	11,275	8,406	6,424	5,017	3,993
3. 101 yrs. (2020-2120) Linear growth SQ Cap'y: 17,000	29,143	18,858	12,957	9,343	6,999	5,402	4,269
4. Scenario 3 with Reduced Evaluation Period 61 yrs. (2020-2080)	22,544	16,017	11,710	8,786	6,746	5,285	4,214
5. 101 yrs. (2020-2120) Constant growth rate SQ Cap'y as projected by WEFA	24,540	15,422	10,393	7,411	5.522	-	-
6. 61 yrs. (2020-2080) Constant growth rate SQ Cap'y as projected by WEFA	17,485	12,420	9,090	6,834	5,262	-	-
7. 101 yrs. (2020-2120) Linear growth SQ Cap'y as projected by WEFA	22,683	14,841	10,298	7,491	5,653	4,391	3,489
8. 61 yrs (2020-2080) Linear growth SQ Cap'y as projected by WEFA	17,820	12,746	9,378	7,079	5,466	4,305	3,448

Note: Shaded area = highest benefit for a given discount rate

Costs

Total costs in 2010 present value are calculated for Case 3, Case 3-a, Case 4 and Case 4-a based on the economic cost streams presented in the EAIU Study, and given in Table 8.3.3-4. If only one lane tidal lock is constructed in the initial construction phase (Case 3-a), the costs are reduced by about 16% from those of Case 3. On the other hand, if a single lane Atlantic approach channel (Case 3-a) is adopted, the costs are reduced by about 20% from those of Case 4. Cost differences between the evaluation period up to 2120 and 2080 are minor, only about 1% for a discount rate of 5%. The costs summed up to 2120 correspond to Scenarios 1, 3, 5 and 7, and those to 2080 correspond to Scenarios 2, 4, 6 and 8.

Comparison of Benefits with Costs

The benefits are compared with the costs, and economic internal rates of return (EIRR), Benefit-Cost Ratios (B/C) and Net Present Values (NPV) based on a Social Discount Rate of 5% are calculated and shown in Table 8.3.3-5 for Case 3 and Case 3-a, and in Table 8.3.3-6 for Case 4 and Case 4-a. The highest EIRR is obtained in Scenario 1 and the lowest in Scenario 6. The EIRR are summarized as follows, for 4 Cases and 8 Scenarios.

Table 8.3.3.4-7

Economic Internal Rates of Return (%)

Scenario	Case 3	Case 3-a	Case 4	Case 4-a
1	4.83	5.43	4.82	5.55
2	4.17	4.88	4.18	5.00
3	4.76	5.41	4.75	5.54
4	4.31	5.01	4.32	5.19
5	4.04	4.64	4.07	4.76
6	3.29	3.93	3.36	4.13
7	3.93	4.56	3.95	4.70
8	3.38	4.03	3.45	4.26

Apparently, Case 3-a gives higher EIRR than Case 3. Also, Case 4-a gives higher EIRR than Case 4. This is because the saving of the initial lock construction cost from three lanes to a single lane (Case 3-a) and the saving of the Atlantic approach channel construction cost from two lanes to a single lane (Case 4-a) contribute the total cost reduction by about 16% for Case 3 and by about 20% for Case 4, while the project benefits are maintained practically at the same level.

Table 8.3.3-4

Total Costs in 2010

Present Value for Sea Level Canal

(Million US$)

Scenario	Discount Rate (%)						
	3	4	5	6	7	8	9
Case 3: Sea Level Canal, 250,000 dwt Tidal Locks (3 lanes + 1 lane)							
1,3,5,7 Base Case 116 yrs. (2005-2120)	17,098	15,285	14,075	13,210	12,557	-	-
2,4,6,8 76 yrs. (2005-2080)	16,453	15,004	13,950	13,154	12,531	-	-
Case 3-a: Sea Level Canal, 250,000 dwt Tidal Lock (1 lane + 1 lane)							
1,3,5,7 Base Case 116 yrs. (2005-2120)	14,714	12,960	11,805	10,990	10,383	9,910	9,529
2,4,6,8 76 yrs. (2005-2080)	14,069	12,679	11,680	10,934	10,357	9,898	9,523
Case 4: Sea Level Canal, 250,000 dwt Tidal Gates							
1,3,5,7 Base Case 116 yrs. (2005-2120)	16,608	15,155	14,186	13,493	12,970	-	-
2,4,6,8 76 yrs. (2005-2080)	16,065	14,919	14,081	13,446	12,948	-	-
Case 4-a: Sea Level Canal, 250,000 dwt Tidal Gates Single Lane Atlantic Approach Channel							
1,3,5,7 Base Case 116 yrs. (2005-2120)	13,768	12,330	11,374	10,691	10,176	9,769	9,437
2,4,6,8 76 yrs. (2005-2080)	13,225	12,094	11,269	10,644	10,154	9,759	9,432

Table 8.3.3-5

Economic Internal Rate of Return, Benefit-Cost Ratio and Net Present Value - for Cases 3 and 3-a

Assumptions	SQ Capacity	
	17,000 Transit No. of Ships	Variable as Projected by WEFA
Case 3:Sea Level Canal, 250,000 dwt, Tidal Locks (3 lanes + 1 lane)		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 4.83%, 0.93 -US$929 million	(5) 4.04%, 0.74 -US$3,682 million
Linear Growth of Benefit	(3) 4.76%, 0.92 -US$1,118 million	(7) 3.93%, 0.73 -US$3,777 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 4.17%, 0.81 -US$2,675 million	(6) 3.29%, 0.65 -US$4,860 million
Linear Growth of Benefit	(4) 4.31%, 0.84 -US$2,240 million	(8) 3.38%, 0.67 -US$4,572 million
Case 3-a: Sea Level Canal, 250,000 dwt, Locks (1 lane & 1 lane)		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 5.43%, 1.11 US$1,341 million	(5) 4.64%, 0.88 -US$1,412 million
Linear Growth of Benefit	(3) 5.41%, 1.10 US$1,152 million	(7) 4.56%, 0.87 -US$1,507 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 4.88%, 0.97 -US$405 million	(6) 3.93%, 0.78 -US$2,590 million
Linear Growth of Benefit	(4) 5.01%, 1.00 US$30 million	(8) 4.03%, 0.80 -US$2,302 million

Remarks:

1. Numbers 1 to 8 in parenthesis are scenario numbers.
2. Scenario 5 for Case 3 and Scenario 1 for Case 3-a were studied in the EAIU Study. Scenario 1 was also studied for Case 3 for reference.
3. Economic indicators in Scenario 1 for Case 3-a are different from those presented in the EAIU Study because of different capacity assessment of Case 3-a.
4. Benefit-Cost Ratios and Net Present Values are based on a Social Discount Rate of 5%.

Table 8.3.3-6

Economic Internal Rate of Return, Benefit-Cost Ratio and Net Present Value - for Cases 4 and 4a

Assumptions	SQ Capacity	
	17,000 Transit No. of Ships	Variable as Projected by WEFA
Case 4:Sea Level Canal, 250,000 dwt,Tidal Gates		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 4.82%, 0.93 -US$1,040 million	(5) 4.07%, 0.73 -US$3,793 million
Linear Growth of Benefit	(3) 4.75%, 0.91 -US$1,229 million	(7) 3.95%, 0.73 -US$3,888 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 4.18%, 0.80 -US$2,806 million	(6) 3.36%, 0.65 -US$4,991 million
Linear Growth of Benefit	(4) 4.32%, 0.83 -US$2,371 million	(8) 3.45%, 0.67 -US$4,703 million
Case 4-a: Sea Level Canal, 250,000 dwt, Tidal Gate, Single Lane Atlantic Approach		
Evaluation Period: 101 yrs. (2020-2120)		
Constant Growth Rate of Benefit	(1) 5.55%, 1.16 US$1,772 million	(5) 4.76%, 0.91 -US$981 million
Linear Growth of Benefit	(3) 5.54%, 1.14 US$1,583 million	(7) 4.70%, 0.91 -US$1,076 million
Evaluation Period: 61 yrs. (2020-2080)		
Constant Growth Rate of Benefit	(2) 5.00%, 1.00 US$6 million	(6) 4.13%, 0.81 -US$2,179 million
Linear Growth of Benefit	(4) 5.19%, 1.04 US$441 million	(8) 4.26%, 0.83 -US$1,891 million

Remarks:

1. Numbers 1 to 8 in parenthesis are scenario numbers.
2. Scenario 5 for Case 4 and Scenario 1 for Case 4-a were studied in the EAIU Study. Scenario 1 was also studied for Case 4 in the EAIU Study for reference.
3. Benefit-Cost Ratios and Net Present Values are based on a Social Discount Rate of 5%.

Comparing Case 3-a (Single lane tidal lock option) with Case 4-a (Single lane Atlantic approach channel option), Case 4-a gives slightly higher EIRR than Case 3-a because the cost is slightly lower in Case 4-a than in Case 3-a though the benefit is almost at an equal level.

Since the service quality is similar in both Case 3-a and Case 4-a, and the economic indicators are also similar, only Case 3-a is taken up for further analysis including:

- Optimal development timing
- Canal capacity
- Possible deviation of commodity and traffic projections from those estimated in the CTP Study

Optimal Development Timing

The project has been assumed to commence its operation in 2020. An optimal year for canal opening is analyzed from an economic point of view. If a canal opening year is delayed by one year, a cost reduction is attainable in terms of the discounted value of the construction cost owing to a delayed investment.

An O&M cost can also be saved for one year owing to one year delay in a canal opening year. At the same time, one year delay in a canal opening year causes a loss of benefit for that year which could be enjoyed if the canal was opened without delay.

A year when the benefit loss exceeds the cost reduction is the optimal year for a new canal opening from purely an economic viewpoint. The optimal canal opening year are calculated to be 2037 for Case 3-a as shown in Table 8.3.3-8, applying a social discount rate of 5%.

It may be concluded that the assumed canal opening year of 2020 is too early for the Sea Level Canal Alternative, judging from only an economic view point.

Canal Capacity

According to the OCCE Study, canal capacities are estimated for the Sea Level Canal Alternative as shown in Table 8.3.3-9 if average delay time of 10 hours is allowed to pass through the Panama canal.

Table 8.3.3-8

Development Timing for Sea Level Canal with Tidal Lock for Cases 3a

(Discounted Values to 2010 in Million US$)

New Canal Opening Year	Construction Cost 1/	Difference 2/	O&M Cost 3/	Cost Reduction 4/	Benefit Loss 5/
2020	9,415				
2035	4,399	-	49	259	246
2036	4,189	210	47	246	240
2037 6/	3,990	199	44	234	234
2038	3,800	190	42	223	228
2039	3,619	181	40	212	222
2040	3,447	172	38	-	-

Remarks: Discount rate is 5%.

1/ Initial construction cost in discounted values to 2010. If the new canal is opened in 2020, the cost is US$9,415 million.

2/ Reduction of construction cost in 2010 present value owing to a delayed investment by one year. If the canal opening year is delayed from 2035 to 2036, US$210 million can be saved.

3/ Reduction of O&M cost owing to a delayed canal opening by one year. If the canal opening is delayed from 2035 to 2036, the O&M cost of US$49 million for 2035 can be saved.

4/ Cost reduction owing to delayed canal opening by one year, 3/ + 2/ of the next year. If canal opening is delayed by one year from 2035 to 2036, a cost saving of US$259 million can be attained.

5/ Annual benefit of the project in 2010 present value. If canal opening is delayed by one year from 2035 to 2036, US$246 million of benefit for 2035 is lost.

6/ Annual benefit loss becomes larger than or equal to annual cost saving in the year 2037, which indicates that the optimal canal opening year is 2037.

Table 8.3.3-9

Canal Capacity in Annual Transit Number of Ships

250,000 dwt with 3 Lanes of Pacific Tidal Locks (Case 3) including SQ	41,700
250,000 dwt with Single Lane Tidal Gates (Case 4) including SQ	44,000
250,000 dwt with 4 Lanes of Pacific Tidal Locks including SQ	47,500
Status Quo Canal (SQ)	17,000

Case 3-a has only a single lane Pacific tidal lock in the initial construction phase and another lane of the tidal lock is scheduled to be constructed before 2060.

Canal capacities for Case 3-a (2 lane locks) is discussed hereunder because canal capacity for Case 3-a was not evaluated in the OCCE Study.

The SQ capacity is 17,000 annual transits if SQ is operated alone. Based on the OCCE Study, SINBOL estimated the capacity for Case 3-a (2 lane locks) to be 34,000 transits per year by interpolation as shown in Table 8.3.3-10.

Table 8.3.3-10

Canal Capacity in Annual Transit Number of Ships

Combination of Canals	SQ	250,000 dwt Tidal Locks	Total
Status Quo Canal	17,000	-	17,000
SQ + 4 Lanes of Tidal	17,000	30,500	47,500
SQ + 3 Lanes of Tidal	17,000	24,700	41,700
SQ + 2 Lanes of Tidal	17,000	17,000	34,000
SQ + 1 Lanes of Tidal	17,000	7,000	24,000

Canal capacity of Case 3-a may be assumed to be 24,000 annual transits from 2020 to 2060 and 34,000 annual transits from 2061 onward. The annual transits of ships are projected in the CTP Study as follows.

Table 8.3.3-11
Annual Transit (No. of Ships)

Study Case	Annual Transits of Ships		
	1990	2020	2060
250,000 dwt including SQ	11,162[1]	17,856	24,053

[1] Actual transits of ships through SQ in 1990.

If the annual transits are assumed to increase at a constant annual growth rate, the transits are projected to reach 27,920 in 2080 and 37,610 in 2120. The capacity of Case 3-a of 34,000 transits will be reached in 2106. This effect on the project benefit will be minor because a benefit loss in far future, from 2106 onward, is discounted to 2010 value which should be negligibly small. On the other hand, if the transits are assumed to increase in a straight line, the annual transits will reach 33,350 in 2120, which is within a capacity limit.

Effect of Possible Deviation on Commodity and Traffic Projections on Project Benefit

According to the CTP Study, trade volumes are projected as shown in Table 8.3.3-12.

Table 8.3.3-12
Trade Volume (in Million Tons)

Year	SQ	250,000 dwt	Increment
2020	266.0	369.8	103.8
2060	276.5	508.5	232.0

Under the following three assumptions, i.e.

(1) Possible deviation takes place only in the projected trade volume for 250,000 dwt and projected trade volumes for SQ are not subject to deviation because these are constrained volumes due to a capacity limit of the SQ canal.

(2) The trade volume reaches virtually the SQ canal capacity in or before the year 2020.

(3) Project benefit is proportional to the trade volume in excess of the SQ capacity.

A change of the project benefit (y%) can be expressed as a function of a possible deviation (x%) of the projected trade volume as follows:

For year 2020

$$369.8(1+x)-266.0 = (369.8-266.0)(1+y)$$
$$y = 3.56x$$

For year 2060

$$508.5(1+x)-276.5 = (508.5-276.5)(1+y)$$
$$y = 2.19x$$

The above equations indicate that a 10% deviation of the trade volumes from the projected ones for 2020 will lead to 36% change of the 2020 benefit, and that the same 10% deviation of the trade volumes from the projected ones for 2060 will result in a 22% change of the 2060 benefit.

An economic feasibility of the project is rather sensitive to the commodity and traffic projections as also discussed in Section 8.2.3.

For example, if we assume a 15 % deviation of the trade volumes from the projected ones for both 2020 and 2060, the annual benefits will increase by 53% in 2020 and by 33 % in 2060, which causes about 46% increase in total project benefit during the evaluation period. Then the costs and benefits are summarized as follows for case 3-a, Sea Level Canal, Route 10, 250,000 dwt with Pacific Tidal Locks (1 lane first and another lane later).

(2010 Present Value in Million US$)

	Discount Rate (%)				
	5	6	7	8	9
Cost	11.805	10.990	10.383	9.910	9.529
Benefit	13.146	9.230	6.794	5.186	4.071
Increased Benefit (15% increased in CTP)	19.193	13.476	9.919	7.572	5.944

From the above table, economic indicators are calculated and compared with the original values as follows.

Indicators	Case 3-a	Case 3-a with 15% Increase in CTP
EIRR	5.43 %	6.84%
NPV	US$ 1.341 Million	US$ 7.388 Million
B/C	1.11	1.63

8.3.4 Financial Analysis

Feasibility Analysis in the FFMS Study concluded that the Sea Level Canal alternatives, such as Sea Level 250,000 dwt Pacific Locks Alternative (Case A) and Sea Level 250,000 dwt Tidal Gates Atlantic Single Lane Approach Alternative (Case E), are not financially viable even under the optimal toll scenario. In other words, the Sea Level Canal alternatives under the optimal toll system scenario are not feasible even when the Status Quo and Alternative Canals are managed by one entity and net income generated from Status Quo Canal operation can be applied to debt service requirements of Alternative Canal construction. In order to make the Sea Level Canal alternatives feasible, the management entity will have to procure an external source of funding (i.e. such as a grant from foreign governments, equity injection from Canal users or foreign governments, and so on) before a cash deficiency will occur, as illustrated by the following:

(A) Sea Level 250,000 dwt Pacific Locks Alternative (Case A)

Table 8.3.4-1 shows that Case A under the optimal toll system scenario will require at least $6.2 billion to be supplied from external sources between 2013 and 2025 even in a base case, in order to keep the toll reserve trust fund balance always positive.

(B) Sea Level 250,000 dwt Tidal Gates Atlantic Single Lane Approach Alternative (Case E)

Table 8.3.4-2 shows that Case E under the optimal toll scenario will require at least $2.9 billion to be supplied from external sources between 2015 and 2023, even in the base case.

Thus the Sea level Canal alternatives are not feasible unless the management entity can procure a huge amount of "no-cost" funds from external sources for covering the above cash shortage and/or for its capital expenditure so that the required debt amount for construction will be reduced.

Table 8.3.4.1

Financial Analysis Assuming an Optimal Toll System, Sea Level Canal Case A (1990 US$ millions)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper. & Maint. c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int.	Debt Service Requirements e/: Princ.	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2000		417.0	97.1	514.7	340.7	164.0	51.5	0.0	0.0	[illegible]	113.5	0.0	0.0	113.5	--	--
2001		434.7	99.0	533.4	360.0	162.0	33.3	0.0	0.0	0.0	129.2	0.0	0.0	247.2	--	--
2002		462.6	100.2	562.8	361.9	200.9	56.3	0.0	0.0	[illegible]	144.5	0.0	0.0	402.7	--	--
2003		471.2	101.7	572.9	363.0	209.0	67.3	0.0	0.0	[illegible]	142.[illegible]	0.0	0.0	561.5	--	--
2004		488.5	100.3	588.9	364.0	224.9	64.4	0.0	0.0	0.0	160.5	0.0	0.0	796.3	--	--
2005	1	510.7	105.0	615.7	365.1	250.6	61.0	4.4	0.7	5.1	103.9	26.4	0.0	896.3	20.1	232.5
2006	2	531.7	100.0	630.3	366.2	262.1	63.8	0.0	1.5	10.3	208.0	26.1	0.0	1,306.5	21.2	130.4
2007	3	550.5	100.3	651.8	367.2	284.6	66.2	13.8	2.2	16.2	223.2	24.9	0.0	1,653.1	16.7	111.4
2008	4	570.3	110.0	680.3	368.3	327.9	69.6	20.9	5.0	34.9	224.4	66.7	0.0	1,838.9	7.4	64.4
2009	5	589.9	111.7	711.7	369.4	362.3	71.2	161.5	69.6	210.2	62.9	467.3	0.0	1,308.6	1.3	7.3
2010	6	604.0	113.5	738.1	370.5	377.6	73.8	216.9	95.5	312.4	-8.6	310.7	0.0	1,041.9	1.0	4.3
2011	7	609.3	116.3	765.5	371.5	404.0	76.0	263.9	114.9	377.9	-50.5	277.9	0.0	764.3	0.9	2.9
2012	8	677.9	117.1	794.9	372.6	431.4	79.4	317.2	231.9	549.2	-196.2	328.0	0.0	280.3	0.6	1.1
2013	9	704.8	119.9	823.7	373.7	450.0	82.4	346.9	289.9	636.9	-258.2	347.0	0.0	-234.5	0.6	0.2
2014	10	730.7	123.8	854.5	374.8	480.7	85.5	391.4	322.5	709.9	-299.6	299.6	0.0	-630.3	0.6	-0.8
2015	11	759.9	122.7	882.6	376.0	506.7	88.7	409.9	376.2	786.0	-363.0	261.7	0.0	-1,470.1	0.6	-1.3
2016	12	786.3	124.0	910.9	377.9	532.9	92.0	437.9	434.0	871.9	-410.0	276.2	0.0	-2,223.4	0.5	-2.0
2017	13	827.9	126.5	954.5	379.0	566.5	95.4	472.9	513.9	986.9	-494.8	301.4	0.0	-3,108.5	0.5	-2.7
2018	14	862.0	129.5	990.5	380.1	621.4	99.0	491.4	576.1	1,067.5	-545.1	281.2	0.0	-4,080.2	0.5	-3.3
2019	15	897.4	130.5	1,027.9	379.1	657.8	102.8	502.3	543.5	1,046.7	-530.7	352.3	0.0	-5,004.8	0.5	-4.1
2020	16	1,321.8	132.0	1,360.8	525.8	827.8	136.4	469.5	530.5	1,000.0	-367.6	0.0	0.0	-5,002.3	0.6	-4.5
2021	17	1,362.1	139.6	1,396.7	529.3	837.4	139.6	416.1	583.4	1,009.4	-307.6	0.0	0.0	-4,123.6	0.7	-5.4
2022	18	1,343.3	134.6	1,377.9	530.8	847.2	137.8	371.8	596.2	967.9	-257.6	0.0	0.0	-3,528.1	0.7	-6.1
2023	19	1,364.6	135.8	1,399.3	533.2	867.8	139.9	328.2	601.9	930.1	-212.1	0.0	0.0	-7,103.3	0.8	-6.9
2024	20	1,388.8	136.7	1,422.7	535.7	887.0	140.3	284.4	588.0	872.4	-146.7	0.0	0.0	-7,533.1	0.8	-7.8
2025	21	1,377.6	137.7	1,415.3	538.2	877.1	141.5	241.8	555.3	797.1	-61.6	0.0	0.0	-7,898.6	0.9	-8.9
2026	22	1,399.2	138.8	1,437.9	540.7	897.3	142.8	202.6	513.5	716.4	20.0	0.0	0.0	-8,182.8	1.0	-10.4
2027	23	1,399.9	139.6	1,440.7	543.2	897.6	144.1	166.4	469.6	635.9	120.5	0.0	0.0	-8,261.6	1.2	-12.2
2028	24	1,312.7	140.9	1,453.6	545.8	909.9	146.4	132.7	406.6	539.5	223.1	0.0	0.0	-8,483.7	1.4	-14.3
2029	25	1,324.7	141.9	1,466.6	548.1	918.5	148.7	104.3	328.5	432.8	330.0	0.0	0.0	-8,484.5	1.6	-17.0
2030	26	1,338.7	143.0	1,479.8	550.6	929.2	149.0	81.1	280.0	361.0	420.2	0.0	0.0	-8,414.1	2.2	-21.1
2031	27	1,349.9	144.1	1,493.9	553.1	940.9	149.3	61.4	229.9	291.3	499.3	0.0	0.0	-8,251.4	2.7	-25.6
2032	28	1,361.2	145.2	1,506.4	555.6	950.8	150.6	46.4	187.0	233.2	566.9	0.0	0.0	-8,014.5	3.4	-30.9
2033	29	1,373.5	146.3	1,519.8	558.0	961.8	152.0	32.3	151.2	183.6	626.3	0.0	0.0	-7,708.8	4.4	-37.6
2034	30	1,386.0	147.4	1,533.5	560.5	972.9	153.3	22.1	114.0	136.1	683.5	0.0	0.0	-7,333.7	--	--
2035	31	1,398.7	148.5	1,547.2	563.0	984.2	154.7	14.4	90.9	105.3	724.2	0.0	0.0	-6,902.9	--	--
2036	32	1,411.4	149.7	1,561.1	565.5	995.6	156.1	8.3	67.4	75.7	763.8	0.0	0.0	-6,415.2	--	--
2037	33	1,424.2	150.9	1,575.0	568.0	1,007.1	157.5	3.9	44.7	48.6	801.0	0.0	0.0	-5,870.9	--	--
2038	34	1,437.2	152.9	1,590.1	570.4	1,019.7	159.0	1.1	20.9	22.0	837.7	0.0	0.0	-5,268.0	--	--
2039	35	1,450.2	153.1	1,603.4	572.9	1,030.4	160.3	0.0	0.0	0.0	870.1	0.0	0.0	-4,608.6	--	--
2040	36	1,463.4	154.3	1,617.7	575.4	1,042.3	161.8	0.0	0.0	0.0	880.5	0.0	0.0	-3,912.4	--	--
2041	37	1,476.7	155.5	1,632.2	577.9	1,054.3	163.2	0.0	0.0	0.0	891.1	0.0	0.0	-3,177.6	--	--
2042	38	1,490.2	156.6	1,646.8	580.4	1,066.5	164.7	0.0	0.0	0.0	901.8	0.0	0.0	-2,403.1	--	--

Note: The sum of boxes numbers (contribution to capital costs as cash outflow) amounts to be $6,170 million, which is required to be supplied from external sources in order to keep the toll reserve trust fund balance always positive

Source: The FFMS Study

Table 8.3.4.2

Financial Analysis Assuming an Optimal Toll System, Sea Level Canal Case E (1990 US$ millions)

Year	Project Year	Revenues: Tolls a/	Revenues: Other b/	Revenues: Total	Oper. & Maint. c/	Net Income from Operations	Payment to Panama d/	Debt Service Requirements e/: Int.	Debt Service Requirements e/: Princ.	Debt Service Requirements e/: Total	Net Income After Debt Service and Payment to Panama	Toll Reserve Trust Fund: Contribution to Capital Costs f/	Toll Reserve Trust Fund: Dividend Distributions g/	Toll Reserve Trust Fund: Trust Fund Balance h/	Current Debt Service Coverage Ratio i/	Overall Debt Service Coverage Ratio j/
2000		417.0	97.1	514.7	348.7	164.0	51.5	0.0	0.0	0.0	113.5	0.0	0.0	113.5	--	--
2001		434.7	95.6	530.4	360.0	162.6	33.3	0.0	0.0	0.0	129.2	0.0	0.0	247.2	--	--
2002		462.6	100.2	562.8	361.9	200.9	55.3	0.0	0.0	0.0	145.6	0.0	0.0	402.7	--	--
2003		471.2	101.7	572.9	363.0	209.9	57.3	0.0	0.0	0.0	152.7	0.0	0.0	561.5	--	--
2004		488.5	100.3	588.9	364.0	224.9	59.4	0.0	0.0	0.0	165.5	0.0	0.0	726.3	--	--
2005	1	510.7	105.0	615.7	366.1	249.6	61.5	3.7	0.6	4.3	184.7	21.3	0.0	890.1	46.5	277.8
2006	2	531.7	106.6	638.3	366.2	272.1	63.6	7.4	1.2	8.6	208.7	21.9	0.0	1,217.4	25.3	168.1
2007	3	553.5	108.3	661.8	367.2	294.6	65.2	10.9	1.8	12.7	229.7	20.5	0.0	1,471.4	18.6	136.0
2008	4	576.3	110.0	686.3	368.3	317.9	66.6	24.2	4.9	29.3	251.1	76.2	0.0	1,663.1	9.2	69.7
2009	5	600.9	111.7	711.7	369.4	342.3	71.2	122.4	56.7	179.1	102.0	361.5	0.0	1,300.9	1.6	9.9
2010	6	624.6	113.5	738.1	370.6	367.6	73.8	169.9	79.1	249.0	57.8	212.8	0.0	1,408.1	1.2	7.0
2011	7	649.3	115.3	765.6	371.8	393.8	76.6	208.1	95.1	301.2	26.3	227.0	0.0	1,281.6	1.1	5.3
2012	8	677.0	117.1	794.0	372.6	421.4	79.4	252.4	187.4	449.8	-97.8	272.5	0.0	941.6	0.8	2.9
2013	9	704.8	118.9	823.7	373.7	449.0	82.4	269.9	242.8	512.7	-135.1	169.0	0.0	675.3	0.7	2.1
2014	10	733.7	120.8	854.5	374.8	479.7	85.5	300.6	208.5	509.1	-161.8	237.4	0.0	300.2	0.7	1.2
2015	11	763.9	122.7	886.6	375.9	510.7	88.7	323.7	308.1	631.7	-199.7	214.5	0.0	-69.0	0.7	0.5
2016	12	795.3	124.6	919.9	376.9	542.9	92.0	346.5	354.5	700.9	-249.0	224.1	0.0	-568.9	0.7	-0.2
2017	13	827.9	126.6	954.5	378.0	576.5	95.4	377.7	422.9	800.6	-309.6	251.9	0.0	-1,151.1	0.6	-0.8
2018	14	862.0	128.5	990.5	379.1	611.4	99.0	392.6	469.1	861.7	-339.3	226.3	0.0	-1,762.7	0.6	-1.4
2019	15	897.4	130.5	1,027.9	379.1	647.8	102.8	409.8	470.8	871.6	-318.6	202.6	0.0	-2,362.3	0.6	-2.1
2020	16	1,221.0	132.6	1,360.6	380.6	827.8	126.4	388.3	508.8	872.0	-170.6	0.0	0.0	-2,626.6	0.6	-2.2
2021	17	1,232.1	133.6	1,365.7	380.3	837.4	130.8	330.3	470.0	800.2	-107.4	0.0	0.0	-2,838.4	0.9	-2.8
2022	18	1,243.3	134.6	1,377.9	380.6	847.2	137.8	295.6	476.5	772.1	-62.7	0.0	0.0	-3,014.7	0.9	-3.0
2023	19	1,254.6	135.6	1,390.3	380.2	857.8	139.8	260.7	481.9	742.6	-24.6	0.0	0.0	-3,150.9	1.0	-3.3
2024	20	1,266.0	136.7	1,402.7	380.7	867.9	140.3	225.8	468.9	694.6	32.1	0.0	0.0	-3,254.1	1.0	-3.6
2025	21	1,277.6	137.7	1,415.3	380.2	877.1	141.5	191.9	443.1	635.0	100.5	0.0	0.0	-3,283.6	1.2	-4.0
2026	22	1,289.2	138.8	1,427.9	380.7	887.3	142.8	160.1	407.1	567.2	177.2	0.0	0.0	-3,237.9	1.3	-4.4
2027	23	1,300.9	139.8	1,440.7	381.2	897.8	144.1	131.2	369.5	491.8	261.7	0.0	0.0	-3,105.7	1.5	-4.8
2028	24	1,312.7	140.9	1,453.6	381.6	908.0	145.4	-105.6	330.0	429.6	337.8	0.0	0.0	-2,892.9	1.8	-5.6
2029	25	1,324.7	141.9	1,466.6	382.1	918.5	146.7	83.2	258.0	341.3	430.6	0.0	0.0	-2,570.6	2.3	-6.3
2030	26	1,336.7	143.0	1,479.8	382.6	929.2	148.0	64.9	222.6	287.5	493.7	0.0	0.0	-2,187.5	2.7	-4.9
2031	27	1,348.9	144.1	1,493.0	383.1	939.9	149.3	49.3	182.7	232.0	558.6	0.0	0.0	-1,716.3	3.4	-4.0
2032	28	1,361.2	145.2	1,506.4	383.6	950.8	150.6	36.5	146.7	183.2	615.0	0.0	0.0	-1,170.6	4.3	-2.8
2033	29	1,373.6	146.3	1,519.9	384.0	961.9	152.0	26.2	122.2	148.4	661.4	0.0	0.0	-566.4	5.5	1.7
2034	30	1,386.0	147.4	1,533.5	384.5	972.9	153.3	17.9	92.3	110.2	709.4	0.0	0.0	131.8	--	--
2035	31	1,398.7	148.5	1,547.2	385.0	984.2	154.7	11.6	73.6	85.2	744.3	0.0	0.0	881.4	--	--
2036	32	1,411.4	149.7	1,561.1	385.5	995.6	156.1	6.7	54.6	61.3	778.2	0.0	1,150.6	535.3	--	--
2037	33	1,424.2	150.8	1,575.0	386.0	1,007.1	157.5	3.1	36.2	39.3	810.2	0.0	845.5	521.4	--	--
2038	34	1,437.2	152.0	1,589.1	376.4	1,010.7	158.9	0.9	16.9	17.8	842.0	0.0	863.4	520.8	--	--
2039	35	1,450.2	153.1	1,603.4	372.9	1,030.4	160.3	0.0	0.0	0.0	870.1	0.0	881.8	520.8	--	--
2040	36	1,463.4	154.3	1,617.7	373.4	1,042.3	161.8	0.0	0.0	0.0	880.5	0.0	901.4	520.8	--	--

Note: The sum of boxes numbers (contribution to capital costs as cash outflow) amounts to be $2,899 million, which is required to be supplied from external sources in order to keep the toll reserve trust fund balance always positive

Source: The FFMS Study

8.3.5 Environmental Aspects - Sea Level Canal

The Sea-Level Canal Alternative through Route 10 is a large project which will have major ecological impacts. The significance of these impacts, and their relevance to the feasibility of the project, depends on the type of construction methods involved, the extent and success of mitigation efforts, and the cost and schedule of the overall environmental studies. In this evaluation it is assumed that the impacts are mitigated to the greatest extent.

Access of valuable forest habitat will be impacted by excavation, spoil disposal, facility placement, and river impoundment. However, careful selection of alternate spoil disposal areas, flexibility in facility siting, relocation of species, and acquiring other similar areas of Panama for protection can somewhat mitigate these impacts.

Excavation and dredged spoil disposal in the marine and freshwater environments will impact fish and other aquatic population in the area. Excavation, dredging, sedimentation and erosion control measures designed to minimize sedimentation and turbidity will reduce the areas directly impacted. Disposal of spoil will be limited to areas which will minimize impact to valuable fisheries resources.

This alternative will cause a greater amount of direct impacts, even eliminating some natural habitats in some areas, specially those where excavation spoil would be disposed.

The reduction of a migration process of terrestrial organisms between North and South America would be of greater concern if this alternative is constructed due to the location of an isolated land corridor between the existing Panama Canal and the new sea level canal.. Of greater concern is the potential for movement of marine organisms between the Pacific and Caribbean. Colonization of organisms from different oceans could have severe ecological effects on the immediate area, as well as throughout the region, endangering aspects as diverse as Panama's Pacific fisheries and Caribbean coral reefs. It should be noted that in order to properly evaluate this impact, substantial amount of data and studies will be required.

The communication that would be established between the Gatun Lake and the Lagarto River would allow the migration of species that could endanger the fluvial fauna already established there. In addition, a large number of existing rivers will be diverted or otherwise modified. Gatun Lake will be divided by large barrier dams. Extensive mangrove areas near the mouth of Rio Caimito will be impacted.

In summary, a large number of existing rivers will be diverted or otherwise modified. Gatun Lake will be divided by large barrier dams. Extensive mangrove areas near mouth of Caimito River will be severely impacted. The new canal with its ancillary facilities, will impede the ability of many terrestrial species to move through the isthmus. There is little that mitigation can do to ameliorate these impacts. Relocation of the canal alignment may be an appropriate measure.

8.4 Summary of Overall Evaluation

Table 8.4-1 shows an overall evaluation of the selected alternatives. Although the table does not go into detail, it does reveal the whole structure and relative importance essential for an overall evaluation.

Table 8.4-1
Overall Evaluation of Alternatives

Alternative	Criteria				Overall Evaluation
	Engineering	Economic	Financial	Cost/ Effectiveness	
1	o	△	△	o	△
1-a	◎	o	◎	◎	◎
2	o	△	x	o	x
2-a	●	o	o	●	o
3	o	x	x	o	x
3-a	o	x	n.a.	△	x
4	o	x	n.a.	o	x
4-a	o	△	x	o	x

Key: ● Good o Fairly Good △ Marginal x Poor n.a. not available

Alternatives 3-a and 4 have been evaluated in economic terms, but not evaluated in financial term. In the case of alternative 4, however, it is almost certain that the result if evaluated could not be any better than that of Case 4-a.

The most probable evaluation for Case 3-a will be similar to Case 4-a.

Above two inferences can be easily understood by checking costs stream with respect to economic evaluations.

Engineering Soundness

For the prescreened four alternatives namely, Case 1, 2, 3 and 4, their engineering soundness was discussed and established in SINBOL's Prescreening Report.

The remaining four variations namely, Case 1-a, 2-a, 3-a and 4-a, are considered simple scale-down versions of Case 1, 2, 3 and 4, respectively. In Case 3-a, two Pacific Locks out of three are eliminated from Case 3, and for other variations, reduction in channel excavation volume is the only difference. Therefore, engineering soundness for alternatives 1-a, 2-a, 3-a and 4-a is said to be established by engineering judgement and experience.

Economic Evaluation

The results of economic evaluation of this project in general are not so favorable because of the relatively large capital investment needed at the start of the project. A summary of economic internal rate of return (EIRR) calculated for each alternative is shown below.

Alternative	1	1-a	2	2-a	3	3-a	4	4-a
EIRR (%)	7.1	8.5	6.5	7.6	4.8	5.0	5.0	5.5
Evaluation	Δ	o	Δ	o	x	x	x	Δ

In the light of MRI recommended social discount rate of 5 percent, the above EIRR could be translated into three judgmental classes namely, fairly good (EIRR over 7.5%), marginal (EIRR between 5% and 7.5%), and poor (EIRR 5% or less).

Financial Evaluation

Evaluation in financial terms appears in Table 8.2.4-1 "Summary of Financial Results by Canal Alternative under Optimal Toll System Scenario". For details of this evaluation, please refer Section 8.2.4. Financial internal rate of return (FIRR) is calculated based on the incremental cash flow of with and without project basis. Following are the FIRR for each alternative under the optimal toll system scenario.

Alternative	1	1-a	2	2-a	3	3-a	4	4-a
FIRR (%)	10.1	15.8	8.4	12.3	4.5	n.a.	n.a.	6.0

In conventional infrastructure development projects, the EIRR is usually higher than the respective FIRR because of the fact that generated incomes from the project in financial terms can only be materialized within the limit of expected economic benefits of the project.

As shown in Figure 8.4-1, the EIRR and FIRR show a close correlation. The FIRR is always larger than the respective EIRR in the project.

The reason for the above reversion is an assumption adopted for the financial analysis of the project. The main financial benefit of the project is generated by the toll revenue for which approximately 100 percent of the toll hike is assumed under the optimal toll system scenario. Since one operating entity, a new Panama Canal Authority, is recommended and adopted as the basis of financial analysis, the new toll system will apply not only for the newly developed part of the canal but also for the Status Quo Canal. The component contractor in the FFMS Study, assume that this toll hike becomes possible with the new development project and not possible in the case where the Status Quo Canal remain as it is. Accordingly, a majority of the toll revenue is attributed to the new project. In the economic analysis of the project; however, economic benefits induced by the incremental transit volume are evaluated. These are the brief explanations for the reversion of EIRR and FIRR.

Project Robustness against Traffic Demand

As shown in Figure 8-2-2-1, capacities of all the alternatives except 3-a, have far large capacities than forecasted in the traffic projection. Because of the nature of the Canal Project, downsizing would be difficult. Under this circumstance, the results of the CTP Study is no longer the controlling factor of the project formulation. Even the start of the Study heavily depended on the figures derived from commodity and traffic projections.

In a case where traffic demand increase twice as large, its effect on the project will the betterment of project benefits. In other words, the recommended set up of the project is formulated to be less sensitive to the traffic projection.

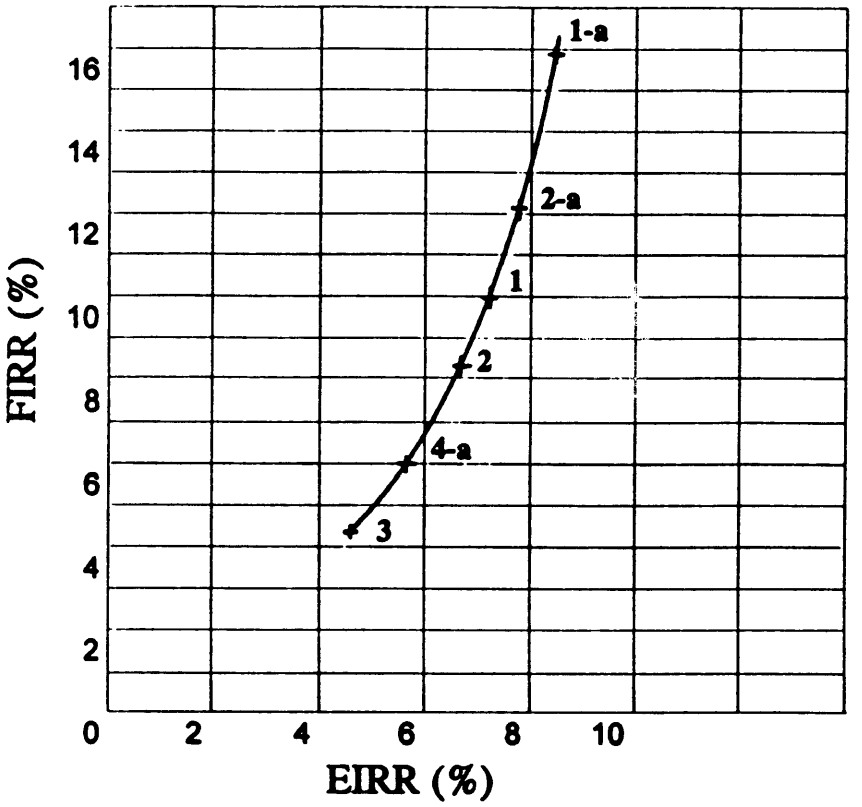
Project Sensitivity to Traffic Forecast

Since the benefit of this project is incremental, the results of economic and financial evaluations of alternatives are quite sensitive to traffic forecasts. Based on the results of sensitivity analysis in Section 8.3.3, one can argue that EIRR of case 4-a, 250,000 dwt Sea Level Alternative with Tidal Gates and Single Lane Atlantic Approach, will increase to 6.8 percent from the original 5.4 percent if traffic demand increase by 15 percent of WEFA's forecast. This means that associated FIRR will be about 9.5 percent because Fig. 8.4-1 suggests the following relation between FIRR and EIRR;

$$FIRR = 0.205\ (EIRR)^2$$

Various kinds of possible cost reduction measures have not yet fully discussed for Sea Level Route-10 alternative. Summarizing above discussions, it may be concluded that there is certain possibility in which case 4-a, including its variations, will be a feasible alternative, though it could not exceed case 1-a (in relative evaluation) under any circumstances.

Figure 8.4.1
Relation of EIRR and FIRR



Timing of New Canal Opening

For the economic and financial evaluation, the Secretariat decided the opening year of new canal at 2020. This decision is considered reasonable for the above analyses, however, its underlying condition of "10 hours average delay" have to be further examined from the practicable project implementation viewpoint. Firstly, an essential characteristic of general congestion phenomenon, delays build up exponentially as traffic intensifies beyond the threshold. In our case, 10 hours average delay occurs at around the threshold in Status Quo case. Taking this into account, TAMS, in addition to 10 hours average delay case, estimated canal capacity for 6 hours average delay. The capacity difference among the two is approximately 5 percent. In other words, if the canal system is operated under 6 hours average delay basis, 5 percent increase in traffic demand will produce 70 percent high average delay time. Based on the practical engineering judgement, it is not recommendable to operate the system beyond this point namely, 6 hours average delay time. Secondly, the capacity delay curve for Status Quo case is rather sensitive to the ship mix assumed. PCC 2010 ship mix, for example, produces 7 percent smaller transit capacity at 10 hours average delay time basis. In the light of WEFA's compound growth rate of 1.69 percent, 7 percent decrease in capacity means an earlier saturation of capacity by four years. Summarizing the above discussions, SINBOL would recommend 2015 as the preferable target when the new canal will be put into operation.

Other considerations

At this stage of Study, it is very difficult to evaluate the total environmental impact of each alternative, however, environmental mitigations appears more feasible and conventional in the High Rise Alternative than in the Sea Level Alternatives.

Conclusion

As a result of overall evaluation, it is concluded that the most promising alternative to be pursued in their order of preference are as follows:

1st High Rise Lock Alternative - 150,000 dwt design vessel Single Lane Culebra Cut option

2nd High Rise Lock Alternative - 200,000 dwt design vessel Single Lane Culebra Cut option

List of Tables and Sources

Table N°.	#Title & Source
8.1	Alternative Case Index Number Source: SINBOL
8.2.2-1	Cost Effectiveness of High Rise Alternatives Source: SINBOL
8.2.3-1	Average Annual Growth Rate of Cargo Flows Source: Final Report Volume I, Phase II CTP study
8.2.3-2	Status Quo Canal Capacities Source: Final Report, Phase II OCCE study
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8.2.3-6	Total Benefits in Present Values for Case I and Case Ia Source: SINBOL based on EAIU study
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8.2.3-9	Economic Internal Rate of Return, Benefits Cost Ratio and Net Present Value for HRLC, 150,000 dwt Source: SINBOL
8.2.3-10	Economic Internal Rate of Return, Benefit Cost Ratio and Net Present Value for HRLC,, 200,000 dwt Source: SINBOL
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8.2.3-16 Trade Volume
Source: Final Report Phase II CTP study

8.2.4-1 Summary of Financial Results by Canal Alternative Under Optimal Toll System Scenario
Sources: SINBOL, based on Financing Scheme, Financial Analysis, and Management Arrangement Study ("the FFMS Study") Final Report Volume I, Tables 6-7 through 6-24 and Appendix J, and Annex to Draft Final Report, Tables 11 through 28 and Table 30

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A Feasibility Report

9.0 Future Investigation and Study

9.1 General

Pending the future final acceptance of a conceptual alternative to be chosen for detailed design development and construction, a number of future investigations and studies should be undertaken in an effort to improve present state of knowledge about the two conceptual alternatives. The additional data and studies recommended below will be required in order to select the most viable alternative and to engineer, design and construct the preferred alternative.

The many component study reports made specific recommendations for further investigations and some of these significant recommendation are included below.

The traffic projection through year 2020 can be meet by the present Panama Canal and a decision to select the preferred alternative is not urgent. However, some of the studies recommended below may require long lead times to carefully and proper plan, implement, analyze and study the data collected.

It should be noted that the minimum construction schedule estimated in this study for any alternative is 10 years and all future studies should be conducted before the detailed engineering and design of the preferred canal alternative in authorized.

9.2 Engineering and Cost

9.2.1 Aerial Survey

A complete and current set of colored stereo-paired aerial surveys are not available at the present time. This survey is an important tool for complete geologic mapping and investigation. It will point out problem areas where geological faults exist and whether or not evidence exists for any tectonic interpretations. These photographs will also provide information on past and recent landslides, as well as erosion and sedimentation occurrences.

The specifications required for performing an aerial survey should be coordinated among all disciplines to obtain one set suitable for geologic, hydrologic, geotechnical, environmental, socio-economic and other project use.

9.2.2 Geologic, Geophysical and Geotechnical Investigation

Design of stable excavation slopes requires a detailed knowledge of the geology. For either canal alternative, where excavation cost is at least 31% for the HRLC and 56% for SLC-10, knowledge of the area geology is essential. It is known from previous Panama Canal work that the geology, especially that of the continental divide are complex and can generally be characterized as a hard basalt cap overlying much weaker materials.

Substantial cost saving can be realized if the stable slopes can be designed steeper than the criteria used in the Phase II cost estimate. The degree of confidence needed to make this change is obtained by more site subsurface information including excavated test sections and laboratory testing on both disturbed and undisturbed samples. Subsurface geological and geophysical investigations along the alignment of a sea level canal Route 10 are essential in order to increase the reliability of the excavation slope designs. Field and laboratory testing and analysis of existing clay shale formations, especially in the Continental Divide area, are very important to construction of a sea level canal considering the history of several landslides in this formation in the existing Panama Canal.

Selecting a canal alignment which minimizes excavation costs would be possible if sufficient subsurface geological information are available. Characterizing rock formation will assist in the selection of a balanced and most economical canal. The cost of this subsurface program will be more than offset by the potential saving in construction costs and minimize the volume of changed conditions and cost of potential litigations during construction. The site subsurface investigation program should be conducted either prior to or in the very early stages of the final engineering and design process. It should be noted that such a program may be time consuming, requiring mobilization of drilling equipment both on-land and offshore, geophysical testing equipment, and experienced crews for both drilling and geophysical testing. Test shafts and test borings should be drilled at reasonable intervals, soil and rock samples obtained, and laboratory testing performed. Geophysical testing should be conducted to assist in the interpolation between geologic boreholes and to obtain elastic parameters of subsurface stratum for design purposes. It should be noted that regardless of the detailed subsurface investigation, testing and analysis; slides in the new canal, especially in the sea level canal, would occur because of the existing nature of the geologic structures. Minimizing the damage from potential landslides will remain an important task of qualified and experienced construction forces.

9.2.3 Hydrogeology

Hydrogeological investigations are necessary to define the groundwater regime along the proposed canal route. The purpose of better defined groundwater conditions is to determine appropriate methods of dewatering during construction, provide better understanding of the effect of groundwater on slope stability, establish a basis of groundwater levels and fluctuations along the proposed canal alignment and establish groundwater aquifer quality and users.

9.2.4 Landslides and Geotechnical Analysis

The study of slope stability, especially those section involving clay shale deposits, is required. Several landslides occurred during and after completion of the existing canal construction. A better understanding of the clay shale material properties will most probably result in construction cost savings. This effort would consist of obtaining samples of soil and rock, performing appropriate laboratory testing and conducting slope stability analysis during construction and long term.

As a result of the field and laboratory analysis, a monitoring program could be recommended for installation prior to the start of construction in order to insure that the excavated slopes are behaving in accordance with the design and early signs of problems detected to remedy problem areas. The cost estimates presented in this report which are based on YEC-Phase II work are generated using conservative slope criteria used by IOCS, Nagano and others. Construction cost savings are assured if steeper slopes than those used in this report are possible. Existing studies by the Corps of Engineers and the PCC are to be augmented and used in the slope stability study.

9.2.5 Excavation

Further studies of excavation costs should be made in the detailed design phase. Results obtained from work performed in Section 9.2.2 (above) will provide improved and more reliable information to estimate the cost of project excavation. Results of additional geological, geophysical and geotechnical investigations will better characterize geologic units and define consolidated versus unconsolidated units. Distinguishing between weathered and hard rock will make a great difference in the cost of excavation. For example: excavation in weathered rock is estimated at $\$3.69/m^3$, for hard rock at $\$5.64/m^3$ whereas soil excavation is estimated at $\$2.57/m^3$. In a project including huge excavations, differences in costs such as presented above will yield substantial changes in construction costs. And thorough study to reduce the costs is more than justified. In addition to additional reliable subsurface information, a study balancing excavation and hauling equipment should be undertaken. Huge volumes of material will be excavated and hauled to a designated disposal sites and since excavation cost are very sensitive to hauling distance, compatible construction equipment, where bottle neck and idle time are eliminated is required. For this reason, we believe a thorough study of the hauling system should be undertaken especially where hauling distances are less than 10 kilometers.

A study to select appropriate dredging equipment compatible with the geologic formations, production rate and efficiency should be undertaken. Experience gained by the PCC from Culebra Cut projects and maintenance dredging in the past eighty years should be incorporated in the selection of appropriate dredging equipment. Applicability and efficiency of using grab dredge should be evaluated.

Phase II Final Report included discussions about shifting the HRLC Pacific third lock bypass channel to improve navigation in Miraflores Locks and Lake. It is not clear as of this writing

how the Phase II Study incorporated excavation of the third locks conducted in the 1940's construction. It is our recommendation to take full advantage and credit for this work in the final design stage by conducting surveys and soundings in the excavated areas to determine present elevations. It has been reported that substantial work was done on both the Atlantic and Pacific Lock excavation at the time it was interrupted. Aerial photographs show this excavation to be substantial. Furthermore, shifting Pacific excavation about 2 km West of 1940's excavation to improve navigation should also be studied to justify added cost. Surveys and soundings may substantially reduce the cost of the HRLC alternatives.

9.2.6 Cost Estimates

Additional studies including field work, laboratory testing and engineering analysis were recommended in YEC-Phase II Final Report. An estimated cost of these studies was also presented in the Appendix to the said report. This Appendix included cost estimate for test borings, geologic survey, groundwater survey/analysis, laboratory testing and aerial survey.

It is believed that the cost for test borings is underestimated by a factor of 2.5 because the number of borings should be approximately 210 instead of 70 drilled to a depth ranging between 45 and 95 meters. Therefore, estimated cost of test boring program may be $12 million, including mobilization and demobilization. In addition to the test borings, large diameter shafts and adits will be required to better define the geology and conditions of soil and rock for excavation and slope stability evaluation. The estimated cost of the proposed 1500 liner meter of shafts and adits is $2.5 million, including mobilization and demobilization of equipment and personnel. The estimated cost for geologic and geophysical surveys at $1.47 million. Hydrogeologic survey/analysis at estimated cost of $0.96 million appear to be reasonable if we include recommendations made by the Environmental Component Contractor related to water well surveys. The laboratory testing cost estimate at $1.4 million is reasonable provided sloped stability analysis are included in this cost estimate. Finally, the cost estimate for aerial surveys included in the Phase II Final Report of $2.23 million is too high and should not exceed $1.0 million including the report. The total cost of additional geologic, hydrogeologic (including those required for environmental impact evaluation), aerial surveys and geotechnical analysis will be approximately $22 millions including a 15% contingency.

9.2.7 Water Resources

The water balance analysis conducted in Phase II studies should be revisited in the final design stage to address socio-economic and environmental impacts resulting from the construction of new dams and reservoirs. Basin data, assumptions and boundary conditions should be current. Data taken from JAX Memorandums of the IOCS (1970) study should be updated to include current hydrological data. Gatun watershed should be evaluated to determine accuracy of boundary conditions used in the original water balance analyses.

Using dry design year based on only 10 years of records should be modified to include a study

and evaluation of over 75 years of records to determine if there is only one year as assumed or multiple dry years in succession that may exist in one cycle. Lockage water requirements depend on the projected canal transits and on how this transit is routed and managed. A decision should be made early in the detailed design stage to use either optimization of water consumption or optimization of canal transit time to determine water resource requirements. Therefore, these issues should be finalized prior to conducting the water requirement study.

9.2.8 Locks and Gates

The miter gate selection for the HRLC was based on many years of existing operating and maintenance experience records in Panama and elsewhere. Studies conducted in Phase I indicated other type gates (torsion type) may be much more economical than miter gate. It is recommended that an economical optimization study should be undertaken during the detailed design stage to establish the most economical selection since the total cost of locks represent approximately 30% of the total project construction cost. A study of lock/gate manufacturing and fabrication sites should be conducted during detailed design stage. Project construction cost is based on Japanese location and transportation to Panama. Other locations closer to Panama site should be investigated and selected to save costs.

9.2.9 Project Construction Cost and Contract

Few items which are considered cost sensitive and which may have effect on total construction costs are:

- Labor contract - construction schedule of at least ten years would attract skilled labor because it will afford stability. Other projects with a similar scope and construction schedule were successful in negotiating a no-strike clause to ensure continuity of construction without interruptions by strikes. Contracts such as this may be attractive to financial institutions and may provide for better financing schemes.

- Equipment financing - cost of purchases by contractor(s) of construction equipment and permanent plant equipment are substantial and saving can be realized by all contracting parties if negotiation with equipment suppliers is initiated to benefit all parties.

- Annual working days - study to increase available working days for construction should be made to decrease construction cost. This study may reduce the construction schedule, decrease the number of construction equipment items to be purchased and have an effect on other construction items with cost sensitivity to schedule; such as aggregate production, concrete batching plant and both wet and dry excavation.

9.3 Commodity and Traffic Projection

The "Commodity and Traffic Projection" is one of the key elements in the Canal Alternative Study and is summarized below:

- In determining cargo and traffic forecast for the Panamanian Isthmus route, different scenarios of demand projection will be required to justify alternative canals.

  A set of assumptions and conditions regarding basic variables such as population, GDP and trade were considered for bilateral trade forecast in the CTP Phase II study to configure a base scenario. Other scenarios are also possible. Examples are as follows:

  - As stated in Final Report, Volume I in page 1-17 of the CTP (II) Study, the reduced cost of the Isthmus route and its availability to ships larger than can now transit the Panama Canal would shift patterns of bilateral trade. To name one example, the share of Colombian coal going to Asian markets would probably rise relative to the share going to European markets. The proposed alternatives to the Panama Canal would make the Colombian competitive with South African and Australian coal in the Asian market.

  - A scenario of low economic growth was given to China which is now growing rapidly. In China will probably be the biggest country in the world not only in its population but also in economic Terms. If the economic growth continues through 2020, the Chinese economy will have a significant influence on world trade and consequences on the transit cargo through the Panama Canal.

- Bilateral trade divided into potential and non-potential trade was forecast in detail on the basis of a pair of origin and destination countries or regions in the CTP phase II study. Basic data for ports of origin and destination was not sufficient. Ports of origin and destination directly affect calculation of economic benefits (transportation cost saving). Further investigation of commodity flows on the port basis will be necessary as a tool of "bottom-up approach" in order to be consistent with bilateral trade forecast on the country/region basis (top-down approach).

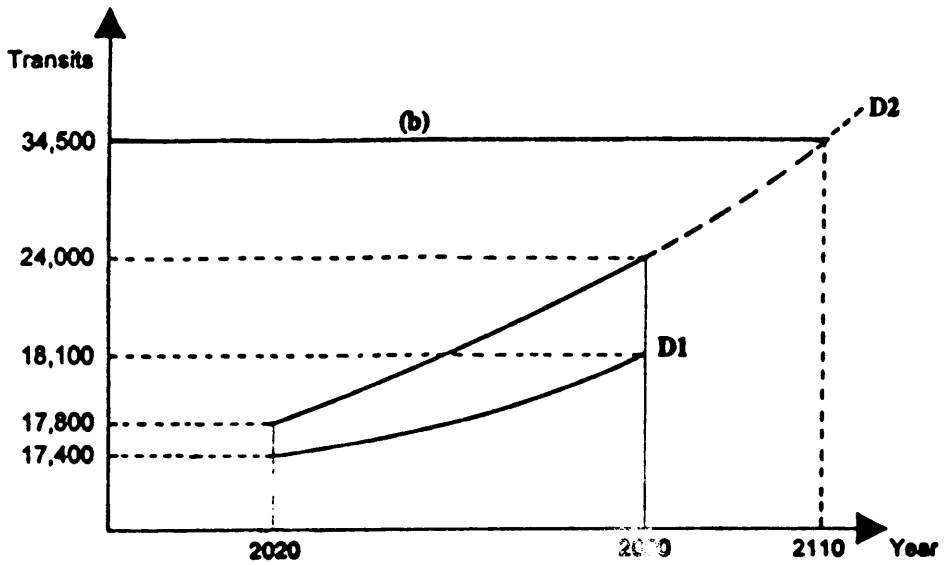
The objectives of further investigation and study for Commodity and Traffic Projection are:

- Sensitivity analysis of commodity and traffic projection

- Investigation of loading/unloading statistics of principal ports by commodity and by a pair of origin and destination options in order to select ports of origin and destination.

9.3.1 Sensitivity Analysis

A contrast of traffic projection estimated by WEFA with capacity of alternatives estimated by TAMS is illustrated below:



Demand curves of D1 and D2 indicate transits for the SQ and a 150,000 dwt case respectively. As the capacity of SQ was estimated to be about 17,000 transits, enhancement of the SQ should be completed before 2020. The horizontal line (b) indicates the capacity of the most likely alternatives (HRLC 150,000 dwt or 200,000 dwt, Culebra Cut Single Lane). Two alternatives have adequate capacity over transits projected.

If demand (transits projection) changes, both demand curves D1 and D2 will shift upward. The following points would have to be considered:

1) Whether the year of 2020 is still the most probable year for commencement of canal operation.

2) A check to see if newly projected transits still can be sustained by capacity of the likely alternatives. Depending on the degree of the shift in the demand curves, another canal alternative might become a promising one in terms of demand versus capacity.

In this respect, the sensitivity analysis of demand projection is necessary to confirm how the change in demand affects the basic assumption concerning opening year, and judgement of the most likely alternatives.

The scope of work for sensitivity analysis of demand projection should include changes in the

following:

a) The forecast of basic variables such as population and labor force, productivity of labor, technical progress, GDP, structural change of GDP and ratios of export/import to GDP. Projection of such basic variables should be confined to countries where high economic growth would be expected in the future. Those countries are, in particular, South East Asia, China, Japan, NIEs such as Taiwan, Singapore, South Korea , and Hong Kong.

   As for other countries, projection of variable would be similar to those projected in WEFA's Final Report, of Phase II.

b) Short and long-term trade forecast of country-country (bilateral trade) where forecast of basic variables change.

c) Forecasts of potential commodity flows relating to the Panamanian Isthmus.

d) Forecasts of SQ commodity flows.

e) Forecasts of transits for SQ, 150,000 dwt, 200,000 dwt, and 250,000 dwt under conditions of "with and without toll".

9.3.2 Selection of Ports of Origin and Destination

Actual commodity flows from origin areas to those in destination areas are the essential data in selecting ports of origin and destination. The effort should be made to collect statistics on loading and unloading by commodity. The scope of works are expected to be:

a) Collection of data on loading and unloading volume of commodities on major trade routes,

b) Evaluation of port ranking by commodity on major trade routes,

c) Selection of ports of origin and destination by commodity on major trade routes,

d) Calculation of mileage connecting ports of origin and destination by commodity in both the canal route and the shortest alternative routes.

In the case of general cargo, ports of origin and destination would be represented by principal ports in each trade route.

9.3.3 Transportation Costs

Transportation costs in the Final Report of CTP Phase II were given by unit transportation cost per cargo ton in each trade route by vessel type and size range. These data are compiled in Volume II (Cost Comparison of Using Panama Canal and Alternative Routes). As explained in Volume I (page 3-56 through 3-61), shipping costs largely consist of a) capital costs, b) operating costs, and c) voyage costs. Vessels are classified into 10 types. Shipping cost per day and ship by vessel type is regarded as a base data. These base data should be reexamined in the future. The following items should be taken into account for preparation of such base data.

1) Capital costs of ships were based on second hand values in the Final Report. Capital costs based on prices to build new ships should also be provided for calculation of economic benefits. Costs mean resource cost in economic terms. New building prices reflect the value of vessels (resource cost).

2) The range of vessel size for shipping cost should be consistent with those for cargo transit.

9.4 Operating Characteristics and Capacity

Among seven alternatives discussed in Chapter 8, the 150,000 dwt High Rise Lock Alternative with Single Lane Culebra Cut (hereinafter referred to as Case 1-a) was found to be the most promising. From the OCCE Study results, the following key issues will deserve future consideration.

9.4.1 Design Ship Size

There is a possibility for reducing the total project cost by downsizing the maximum ship size. Even Case 1-a has a projected capacity of 1.9 times larger than transits in 2060 projected by WEFA. This downsizing will also have a favorable by-product effect of reducing the total fresh water consumption.

9.4.2 Water Management and Dynamic Routing

A substantial increase in fresh water consumption induced by the dynamic route assignment is the critical constraint of this alternative (Case 1-a). In this study only two extreme conditions, namely dry and wet years, are substantially covered. Further analysis is necessary to establish the optimal level of utilization of the dynamic route assignment procedure under a given level of fresh water supply. Thus the best possible capacity and maximum convenience for users may be achieved. The modified WAM computer program used in the Phase II Study with the dynamic route assignment program becomes sensitive to size distribution of transit vessels.

In the early stages of a future study, a sensitivity analysis is to be formulated and carried out in order to evaluate these effects.

9.4.3 Analysis on Emergency Operation

In this study, lock down time effect and foggy conditions are reflected in the simulation model; however, emergency conditions such as collision of ships, engine failure and large scale repair work of the existing canal have not been sufficiently examined. To evaluate such conditions adequately, additional simulation needs to be carried out.

9.4.4 Navigation Support Systems

The study of navigation support systems covers a wide variety of alternatives. In future studies, an extensive analysis of navigation support systems is needed for the selected alternative.

9.5 Economic Aspects

Under the Economic Analysis and Impact on Users (EAIU) Study, Phase II, various studies were conducted by the component contractor (Mitsubishi Research Institute) regarding impacts to the users by the different alternatives. These studies are divided into two types: macroeconomic and microeconomic analyses. The former deal with Induced Trade and Cost Saved/Induced Income.

Transportation cost saved due to enlargement of canal size would contribute to reduction of commodity prices in the international markets, resulting in induced trade volume in importing countries. The "saved cost-induced income" was defined as the multiplier effect of transportation cost saving, which was measured by increase of national income.

The latter address Improvements of Navigation Safety and Influence on Shipping Industry. Macroeconomic analyses are quantitative studies based on Economics theory while the microeconomic analysis are descriptive and qualitative.

Future impact studies should focus on issues related to toll impacts on changes in trade flows in various trade routes. The objective of these studies should be to investigate how much the trade flows in some trade routes would be influenced by the application of various levels of tolls. For instance it is expected that if toll rates increase for some commodities such as coal, iron ore and crude oil, import prices of such bulk cargoes would rise due to higher shipping costs. The canal route would be less competitive waterway for transferring some goods as compared to other routes, with the outcome that some exporting countries would find themselves in a less competitive situations vis-a-vis other countries not facing the situation of increased cost in shipping. Future impacts on user studies should therefore focus on specific case studies related to discrete bulk commodities in selected pairs of origin-destination routes.

9.6 Financial and Management Aspects

In considering the financial and management aspects of this study, the following issues have been identified for further investigation and study.

9.6.1 More User-oriented Toll Scenarios

In the FFMS Study, the optimal toll system scenario was developed based on five basic principles discussed in Section 7.2.3. In particular, the FFMS Study de facto placed the first priority on revenue maximization, while meeting the condition that toll rate increases be capped at 100% compared to the existing toll level. This is because the FFMS Study was for examining the existence of the feasibility of each Canal alternative from the viewpoint of potential project sponsor(s).

SINBOL believes it is also important to investigate more user-oriented toll scenarios in the light of the importance of the Panama Canal to international trade, admitting that this issue will heavily depend on the future form of management arrangement. That is, it is worth while to investigate a more user-oriented toll scenario, within the range where the Canal alternative will still remain financially feasible.

From this standpoint, it is suggested that further investigation considers and resolves the following two approaches/questions:

(A) Are there more user-oriented toll increasing scenarios between 2000 and 2019 than that suggested in the FFMS Study, assuming the optimal toll scenario would be used?

(B) Are there more user-oriented toll rate levels after 2020 than the optimal toll scenario of the FFMS Study, assuming the same toll increasing scheme between 2000 and 2019 as proposed in the FFMS Study?

More specific explanation on each approach is outlined as follows:

(A) More User-oriented Toll Increasing Scenarios between 2000 and 2019

In Figure 9.6.1-1, a dash-dotted line represents the toll increasing scenario assumed in the FFMS Study, in which a toll increase will be implemented from 2000 through 2019. On the other hand, a solid line represents the new toll scenario in which toll rates will remain at the existing level (in real terms) until 2009 in two High Rise 150,000 dwt alternatives or until 2008 in a High Rise 200,000 dwt alternative. That is, toll rates will not be raised until the construction of a Canal alternative will start. The latter scenario can be considered to be more acceptable to Canal users, because there will be actual construction or development to the Canal while toll rates are increasing.

Results of the financial analyses based on the latter toll scenario are summarized in Table 9.6.1-1. This table shows that High Rise 150,000 dwt Culebra Cut Single Lane Alternative and High

Rise 200,000 dwt Culebra Cut Single Lane Alternative remain feasible even in this toll increasing scenario, in the light of evaluation criteria used in the FFMS Study.

(B) More User-oriented Toll Rate Level after 2020

The FFMS Study concluded that three High Rise alternatives (i.e., High Rise 150,000 dwt Culebra Cut Single Lane Alternative, High Rise 200,000 dwt Culebra Cut Single Lane Alternatives, and High Rise 150,000 dwt Alternative) under the optimal toll system scenario are viable, whereas the above three High Rise alternatives with a 50 percent increase in tolls are unfeasible[1]. As shown in Figure 9.6.1-2, it is natural that the following question occurs: "which percent increase in tolls is marginally feasible in each High Rise Canal alternative?"

Results of the financial analyses for three High Rise Canal alternatives with a 75 percent increase, for example, are summarized in Table 9.6.1-2. This revenue derived from an average of the optimal toll system scenario and a 50% increase in toll. Hereinafter it is referred as 75% increase in toll. This table shows that two High Rise Culebra Cut Single Lane alternatives still remain feasible even in a toll scenario with a 75 percent increase. Furthermore, this table shows that a 75 percent increase in toll for the High Rise 150,000 dwt Culebra Cut Single Lane Alternative will remain feasible even in the case with a more user-oriented toll increasing scenario which was defined in (A) above.

These examples illustrate some room for investigating more user-oriented toll increasing scenarios between 2000 and 2019 and well as increased toll rate levels after 2020, while still meeting almost all requirements specified in the evaluation criteria for measuring the financial viability of each Canal alternative.

[1] As discussed in section 7.2, in two High Rise Single Lane alternatives trust fund balance can be kept always positive even with a 50 percent increase in toll. However, these two alternatives with a 50 percent increase were found to be unfeasible in the FFMS Study, because they didn't meet the targets in several criteria. In 150,000 dwt case, FIRR before financing (6.7%), for example, didn't reach the target (8.0%).

Figure 9.6.1-1

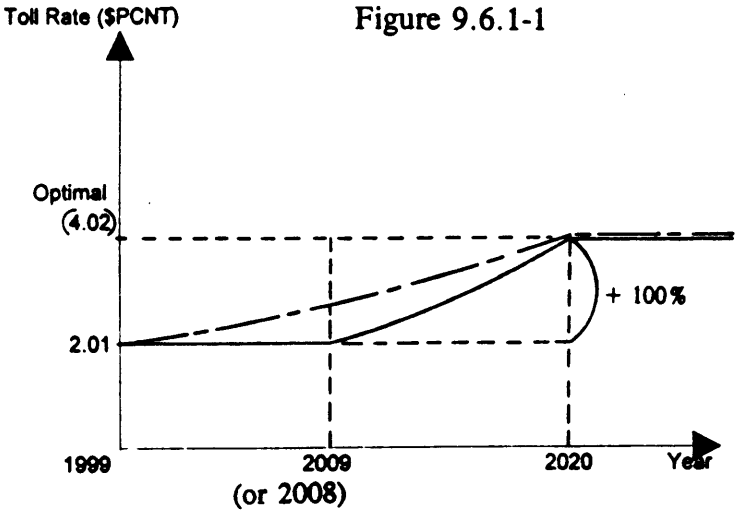


Figure 9.6.1-2

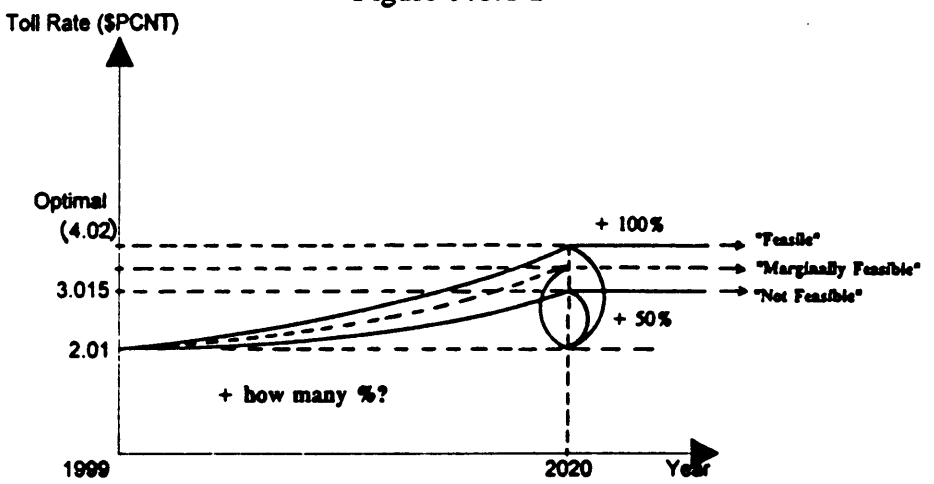


Figure 9.6.1-3

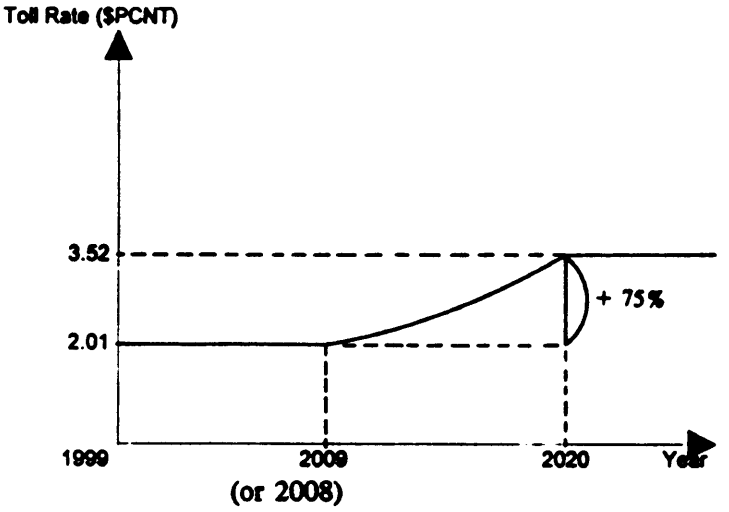


Table 9.6.1-1

Summary of Financial Results by Canal Alternative under the Optimal Toll System with a More User-oriented Toll Increasing Scenario*1

Evaluation Criteria	Target Result	High Rise 150,000 dwt Culebra Cut Single Lane	High Rise 200,000 dwt Culebra Cut Single Lane	High Rise 150,000 dwt
Trust Fund balance always positive	Yes	O	O	O
Financial internal rate of return before financing (%)	8-10	O	O	O
Financial internal rate of return after financing (%)	12-15	O	O	X
Net present value before financing (US$Million)*2	Positive Value	O	O	O
Net present value after financing (US$Million)*2	Positive Value	O	O	O
Minimum debt service coverage ratio-current	1.3	X	X	X
Minimum debt service coverage ratio-overall	1.5-2.0	O	O	O
Debt/equity ratio	Below 4.0	O	O	O
Is the alternative financially feasible with:*3				
a. Interest rates increased 25 percent	Yes	O	O	O
b. Capital costs increased 25 percent	Yes	X (O: up to 20% increase)	X (O: up to 13% increase)	X (X: even 10% increase)
c. Operation and Maintenance costs increased 25 percent	Yes	X (O: up to 20% increase)	X (O: up to 13% increase)	X (X:even 10% increase)
Conclusion: Is project financially feasible?		O	O	X

Note:

O represents meeting the target. X represents not meeting the target.

*1 Toll increasing starts in 2010 in two High Rise 150,000 dwt alternatives, and 2009 in a High Rise 200,000 dwt alternative.

*2 Based upon a discount rate of 8 percent

*3 Judged by whether or not the balance of trust fund can remain positive.

Source: Appendix 9.6

Table 9.6.1-2
Summary of Financial Results by Canal Alternative with a 75% Increase in Tolls

Evaluation Criteria	Target Result	With FFMS Toll Increasing Scenario between 2000-2019			With a More User-oriented Toll Increasing Scenario *1		
		High Rise 150,000 dwt Culebra Cut 1 Lane	High Rise 200,000 dwt Culebra Cut 1 Lane	High Rise 150,000 dwt	High Rise 150,000 dwt Culebra Cut 1 Lane	High Rise 200,000 dwt Culebra Cut 1 Lane	High Rise 150,000 dwt
Trust Fund balance always positive	Yes	O	O	O	O	O	O
Financial internal rate of return before financing (%)	8-10	O	O	X	O	X	X
Financial internal rate of return after financing (%)	12-15	O	O	X	X (over 10%)	X	X
Net present value before financing (US$MM)*2	Positive Value	O	O	X	O	X	X
Net present value after financing (US$MM)*2	Positive Value	O	O	O	O	X	O
Minimum debt service coverage ratio-current	1.3	X	X	X	X	X	X
Minimum debt service coverage ratio-overall	1.5-2.0	O	O	O	O	O	O
Debt/equity ratio	Below 4.0	O	O	O	O	O	O
Is the alternative financially feasible with:*3							
a. Interest rates increased 25 percent	Yes	O	O	O	O	O	O
b. Capital costs increased 25 percent	Yes	O	O	O	O	X	X
c. Operation and Maintenance costs increased 25 percent	Yes	O	X (O: up to 19% increase)	O	X (O: up to 15% increase)	X (x: 10% increase)	X (x: 10% increase
Conclusion Is project financially feasible?		O	O	X	O	X	X

Note: O represents meeting the target. X represents not meeting the target

*1 Toll increasing starts in 2010 in two High Rise 150,000 dwt alternatives, and 2009 in a High Rise 200,000 dwt alternative.
*2 Based upon a discount rate of 8 percent
*3 Judged by whether or not the balance of trust fund can remain positive.

Source: Appendix 9.6

9.6.2 Toll Reserve Trust Fund Contribution to Capital Costs

The FFMS Study has designed an optimal mix of various financing sources for each Canal alternative, regardless of toll scenarios. The mixture of financing sources is the same for all presented toll scenarios, such as Existing Panama Canal Tolls Scenario, a 50 percent Increase in Tolls Scenario, and an Optimal Toll Scenario. Accordingly, the ratio of toll reserve trust fund contribution to capital costs is fixed around 25 percent for all toll scenarios.

It also seems reasonable that in the case of the toll scenarios with the higher toll rates, the ratio of trust fund contribution should be raised within a range where cash flow of the entity remains ample enough to endure in "down-side" cases to be analyzed in various sensitivity analyses. Such cases may include interest rates increased by 25%, capital costs increased by 25%, operation and maintenance costs increased by 25%.

A higher ratio of trust fund contribution enables the financial ratios, such as debt service coverage ratio and the debt-to-equity ratio, improve. This will encourage financial institutions to participate in financing for the project. Also this will make it easier to procure funds for the project, because the required amount of debt itself will be reduced.

For example, if the ratio of Trust Fund contribution to capital costs is raised from 25% to 50% in the High Rise 150,000 dwt Culebra Cut Single Lane Alternative with the optimal toll system scenario, then the debt contribution to total capital costs is reduced from 75% to 50% (assuming the financing amount of each source will be reduced on pro-rata basis). In this case, the alternative will remain viable, because the toll reserve trust fund balance will still remain positive even in "down-side" cases in various sensitivity analyses, while other financial criteria[2] such as debt service coverage ratios and the debt-to-equity ratio have improved as, which is shown in Table 9.6.2-1. The same result can be obtained in High Rise 200,000 dwt Culebra Cut Single Lane Alternative, as shown in Table 9.6.2-2.

Using a similar approach presented above, future investigation is recommended for specifying the optimum ratio of trust fund contribution to capital costs for each Alternative under the optimal toll scenario, or under an alternative toll scenario which will be determined as the result of a user-oriented toll scenario study.

[2] Please note that FIRR before financing will not be affected by the change of the ratio of trust fund contribution, and that FIRR after financing will be affected nominally.

Table 9.6.2-1

Financial Analysis Assuming Trust Fund Contribution to Capital Cost is Raised from 25% to 50% and an Optimal Toll System (1990 US$ million)

High Rise 150,000 dwt Culebra Cut Single Lane Alternative

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	514.7	349.7	165.0	51.5	0.0	113.5	0.0	0.0	113.5		
2001	533.3	350.8	182.5	53.3	0.0	129.2	0.0	0.0	247.3		
2002	552.8	351.9	200.9	55.3	0.0	145.6	0.0	0.0	402.8		
2003	572.9	353.0	219.9	57.3	0.0	162.6	0.0	0.0	581.5		
2004	593.8	354.0	239.8	59.4	0.0	180.4	0.0	0.0	785.2		
2005	615.7	355.1	260.6	61.6	0.0	199.0	0.0	0.0	1,015.6		
2006	638.2	356.2	282.0	63.8	0.0	218.2	0.0	0.0	1,274.4		
2007	661.8	357.2	304.6	66.2	0.0	238.4	0.0	0.0	1,563.8		
2008	686.2	358.3	327.9	68.6	0.0	259.3	0.0	0.0	1,885.7		
2009	711.6	359.4	352.2	71.2	0.0	281.0	0.0	0.0	2,242.1		
2010	738.0	360.5	377.5	73.8	3.0	300.7	40.5	0.0	2,592.0	101.3	849.1
2011	765.5	361.5	404.0	76.5	6.1	321.3	41.2	0.0	2,975.8	53.4	476.3
2012	794.0	362.6	431.4	79.4	15.0	337.0	118.8	0.0	3,313.0	23.5	222.0
2013	823.6	363.7	459.9	82.4	40.6	336.9	256.5	0.0	3,525.9	9.3	90.8
2014	854.4	364.8	489.6	85.4	78.1	326.1	342.7	0.0	3,650.4	5.2	50.3
2015	886.4	365.8	520.6	88.6	108.0	324.0	314.4	0.0	3,805.9	4.0	37.8
2016	919.7	365.8	553.9	92.0	168.4	293.6	565.1	0.0	3,686.7	2.7	25.3
2017	954.3	368.0	586.3	95.4	236.2	254.7	496.9	0.0	3,591.9	2.1	17.7
2018	990.3	369.1	621.2	99.0	280.0	242.1	359.6	0.0	3,618.1	1.9	14.7
2019	1,027.7	370.1	657.6	102.8	320.1	234.7	299.1	0.0	3,698.4	1.7	13.0
2020	1,307.6	475.1	832.5	130.8	335.1	366.7	0.0	3,713.0	500.1	2.1	13.1
2021	1,318.4	477.8	840.6	131.8	356.6	352.2	0.0	372.0	500.2	2.0	3.4
2022	1,329.3	480.5	848.8	132.9	369.9	346.0	0.0	366.0	500.2	1.9	3.3
2023	1,340.2	483.2	857.0	134.0	356.4	366.6	0.0	386.0	500.8	2.0	3.4
2024	1,351.4	485.9	865.5	135.1	333.5	396.8	0.0	417.0	500.6	2.2	3.7
2025	1,362.5	488.6	873.9	136.3	304.0	433.7	0.0	454.0	500.3	2.4	4.1
2026	1,373.8	491.3	882.5	137.4	265.0	480.2	0.0	500.0	500.5	2.8	4.7
2027	1,385.1	494.0	891.1	138.5	231.1	521.5	0.0	542.0	500.0	3.3	5.4
2028	1,396.6	496.7	899.9	139.7	197.4	562.8	0.0	582.0	500.9	3.9	6.4
2029	1,408.1	499.4	908.7	140.8	164.0	603.9	9.7	615.0	500.2	4.7	7.7
2030	1,419.8	502.1	917.7	142.0	140.4	635.3	13.6	641.0	500.9	5.5	9.1
2031	1,431.5	504.8	926.7	143.2	112.9	670.6	14.7	676.0	500.8	6.9	11.4
2032	1,443.3	507.5	935.8	144.3	94.7	696.8	53.0	664.0	500.6	8.4	13.6
2033	1,455.3	510.2	945.1	145.5	78.2	721.4	53.0	689.0	500.0	10.2	16.6
2034	1,467.3	512.9	954.4	146.7	63.6	744.1	0.0	764.0	500.1	12.7	20.6
2035	1,479.4	515.6	963.8	147.9	51.0	764.8	0.0	784.0	500.9	16.0	25.8

Table 9.6.2-1 (continued)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,491.7	518.3	973.4	149.2	31.4	792.8	0.0	813.0	500.7	26.2	42.1
2037	1,504.0	521.0	983.0	150.4	16.4	816.2	0.0	837.0	500.0	50.8	81.4
2038	1,516.5	523.7	992.8	151.6	6.7	834.5	0.0	854.0	500.4	126.2	201.3
2039	1,528.9	526.4	1,002.5	152.9	0.0	849.6	0.0	870.0	500.1		
2040	1,541.6	529.1	1,012.5	154.2	0.0	858.4	0.0	878.0	500.4		
2041	1,554.4	531.7	1,022.7	155.4	0.0	867.2	0.0	887.0	500.7		
2042	1,567.2	534.4	1,032.8	156.7	0.0	876.0	0.0	896.0	500.8		
2043	1,580.1	537.1	1,043.0	158.0	0.0	885.0	0.0	905.0	500.8		
2044	1,593.2	539.8	1,053.4	159.3	0.0	894.1	0.0	914.0	500.9		
2045	1,606.3	542.5	1,063.8	160.6	0.0	903.2	0.0	924.0	500.1		
2046	1,619.6	545.2	1,074.4	162.0	0.0	912.4	0.0	932.0	500.6		
2047	1,633.1	547.9	1,085.2	163.3	0.0	921.9	0.0	942.0	500.5		
2048	1,646.5	550.6	1,095.9	164.7	0.0	931.3	0.0	951.0	500.8		
2049	1,660.2	553.3	1,106.9	166.0	0.0	940.9	3.2	958.0	500.5		
2050	1,673.9	556.0	1,117.9	167.4	0.0	950.5	19.7	951.0	500.2		
2051	1,687.7	558.7	1,129.0	168.8	0.0	960.3	19.7	960.0	500.8		
2052	1,701.7	561.4	1,140.3	170.2	0.0	970.1	0.0	991.0	500.0		
2053	1,715.7	564.1	1,151.6	171.6	0.0	980.0	0.0	1,000.0	500.0		
2054	1,729.9	566.8	1,163.1	173.0	0.0	990.1	0.0	1,010.0	500.1		
2055	1,744.2	569.5	1,174.7	174.4	0.0	1,000.3	0.0	1,020.0	500.3		
2056	1,758.6	572.2	1,186.4	175.9	0.0	1,010.5	0.0	1,030.0	500.9		
2057	1,773.2	574.9	1,198.3	177.3	0.0	1,021.0	0.0	1,041.0	500.9		
2058	1,787.8	577.6	1,210.2	178.8	0.0	1,031.4	0.0	1,052.0	500.4		
2059	1,802.6	580.3	1,222.3	180.3	0.0	1,042.0	0.0	1,062.0	500.4		
2060	1,817.5	583.0	1,234.5	181.8	0.0	1,052.8	0.0	1,073.0	500.1		
Total	78,340.4	28,888.6	49,451.8	7,834.0	4,763.8	36,854.0	3,021.4	35,916.0			

Note:
1. Trust fund contribution to capital costs is roughly estimated based on half of project cost upto 2019 ($5,669.7 million). Total amount in the column of Contribution includes future costs (after 2020, $186.4 million).
2. Debt service requirement is reduced based on the reduced borrowing.
3. The other data is mainly based on Table 15 of FFMS's Annex to Draft Final Report.
4. Slight difference with FFMS data exists.
5. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous year divided by total debt service requirements.

Table 9.6.2-2

Financial Analysis Assuming Trust Fund Contribution to Capital Cost is Raised from 25% to 50% and an Optimal Toll System (1990 US$ million)

High Rise 200,000 dwt Culebra Cut Single Lane Alternative

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	514.7	349.7	165.0	51.5	0.0	113.5	0.0	0.0	113.5		
2001	533.3	350.8	182.5	53.3	0.0	129.2	0.0	0.0	247.3		
2002	552.8	351.9	200.9	55.3	0.0	145.6	0.0	0.0	402.8		
2003	572.9	353.0	219.9	57.3	0.0	162.6	0.0	0.0	581.5		
2004	593.8	354.0	239.8	59.4	0.0	180.4	0.0	0.0	785.2		
2005	615.7	355.1	260.6	61.6	0.0	199.0	0.0	0.0	1,015.6		
2006	638.2	356.2	282.0	63.8	0.0	218.2	0.0	0.0	1,274.4		
2007	661.8	357.2	304.6	66.2	0.0	238.4	0.0	0.0	1,563.8		
2008	686.2	358.3	327.9	68.6	0.0	259.3	0.0	0.0	1,885.7		
2009	711.6	359.4	352.2	71.2	3.3	277.7	43.5	0.0	2,195.3		
2010	738.0	360.5	377.5	73.8	6.6	297.1	44.4	0.0	2,535.8	45.9	377.3
2011	765.5	361.5	404.0	76.5	14.6	312.8	105.3	0.0	2,844.7	22.5	196.3
2012	794.0	362.6	431.4	79.4	41.4	310.6	267.1	0.0	3,002.0	8.5	77.2
2013	823.6	363.7	459.9	82.4	81.1	296.4	377.0	0.0	3,041.5	4.7	41.7
2014	854.4	364.8	489.6	85.4	117.4	286.8	375.8	0.0	3,074.1	3.4	29.3
2015	886.4	365.8	520.6	88.6	165.4	266.6	396.5	0.0	3,067.2	2.6	21.2
2016	919.7	365.8	553.9	92.0	245.2	216.7	638.1	0.0	2,768.5	1.9	14.4
2017	954.3	368.0	586.3	95.4	302.9	187.9	504.2	0.0	2,563.0	1.6	10.8
2018	990.3	369.1	621.2	99.0	353.6	168.5	399.2	0.0	2,434.8	1.5	8.7
2019	1,027.7	370.1	657.6	102.8	380.2	174.6	94.2	0.0	2,612.6	1.5	7.9
2020	1,318.6	483.4	835.2	131.9	393.0	310.4	0.0	2,527.0	500.5	1.8	8.4
2021	1,330.9	486.1	844.8	133.1	412.4	299.3	0.0	319.0	500.7	1.7	2.9
2022	1,343.3	488.8	854.5	134.3	404.1	316.1	0.0	336.0	500.8	1.8	3.0
2023	1,355.8	491.5	864.3	135.6	384.4	344.3	0.0	365.0	500.2	1.9	3.2
2024	1,368.5	494.2	874.3	136.8	356.7	380.7	0.0	400.0	500.9	2.1	3.5
2025	1,381.2	496.9	884.3	138.1	318.2	427.9	0.0	448.0	500.8	2.3	3.9
2026	1,394.1	499.6	894.5	139.4	278.1	477.0	0.0	497.0	500.9	2.7	4.5
2027	1,407.1	502.3	904.8	140.7	239.8	524.3	0.0	545.0	500.2	3.2	5.3
2028	1,420.2	505.0	915.2	142.0	199.4	573.8	0.0	594.0	500.0	3.9	6.4
2029	1,433.4	507.7	925.7	143.3	171.0	611.3	9.7	621.0	500.7	4.6	7.5
2030	1,446.8	510.4	936.4	144.7	144.5	647.2	13.6	654.0	500.3	5.5	8.9
2031	1,460.3	513.1	947.2	146.0	122.6	678.5	14.7	684.0	500.1	6.5	10.6
2032	1,473.9	515.8	958.1	147.4	101.3	709.4	53.0	676.0	500.5	8.0	12.9
2033	1,487.6	518.5	969.1	148.8	81.8	738.5	53.0	706.0	500.1	10.0	16.1
2034	1,501.5	521.2	980.3	150.1	64.6	765.6	0.0	785.0	500.7	12.9	20.6
2035	1,515.5	523.9	991.6	151.5	50.1	789.9	0.0	810.0	500.6	16.8	26.8

Table 9.6.2-2 (continued)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,529.7	526.6	1,003.1	153.0	29.8	820.3	0.0	841.0	500.0	28.6	45.4
2037	1,543.9	529.3	1,014.6	154.4	14.1	846.1	0.0	866.0	500.1	60.9	96.4
2038	1,558.3	532.0	1,026.3	155.8	3.7	866.8	0.0	886.0	500.9	236.6	372.5
2039	1,572.8	534.7	1,038.1	157.3	0.0	880.8	0.0	901.0	500.8		
2040	1,587.5	537.4	1,050.1	158.8	0.0	891.4	0.0	912.0	500.2		
2041	1,602.4	540.0	1,062.4	160.2	0.0	902.1	0.0	922.0	500.4		
2042	1,617.2	542.7	1,074.5	161.7	0.0	912.8	0.0	933.0	500.2		
2043	1,632.3	545.4	1,086.9	163.2	0.0	923.7	0.0	943.0	500.9		
2044	1,647.5	548.1	1,099.4	164.8	0.0	934.7	0.0	955.0	500.6		
2045	1,662.9	550.8	1,112.1	166.3	0.0	945.8	0.0	966.0	500.4		
2046	1,678.4	553.5	1,124.9	167.8	0.0	957.1	0.0	977.0	500.5		
2047	1,694.1	556.2	1,137.9	169.4	0.0	968.5	0.0	989.0	500.1		
2048	1,709.9	558.9	1,151.0	171.0	0.0	980.0	0.0	1,000.0	500.1		
2049	1,725.9	561.6	1,164.3	172.6	0.0	991.7	3.2	1,008.0	500.6		
2050	1,741.9	564.3	1,177.6	174.2	0.0	1,003.5	19.7	1,004.0	500.4		
2051	1,758.2	567.0	1,191.2	175.8	0.0	1,015.4	19.7	1,016.0	500.1		
2052	1,774.7	569.7	1,205.0	177.5	0.0	1,027.5	0.0	1,047.0	500.6		
2053	1,791.1	572.4	1,218.7	179.1	0.0	1,039.6	0.0	1,060.0	500.3		
2054	1,807.9	575.1	1,232.8	180.8	0.0	1,052.0	0.0	1,072.0	500.2		
2055	1,824.7	577.8	1,246.9	182.5	0.0	1,064.5	0.0	1,084.0	500.7		
2056	1,841.7	580.5	1,261.2	184.2	0.0	1,077.1	0.0	1,097.0	500.8		
2057	1,859.0	583.2	1,275.8	185.9	0.0	1,089.9	0.0	1,110.0	500.7		
2058	1,876.3	585.9	1,290.4	187.6	0.0	1,102.8	0.0	1,123.0	500.5		
2059	1,893.8	588.6	1,305.2	189.4	0.0	1,115.8	0.0	1,136.0	500.4		
2060	1,911.5	591.3	1,320.2	191.2	0.0	1,129.1	0.0	1,149.0	500.4		
Total	80,317.2	29,228.9	51,088.3	8,031.7	5,481.3	37,575.2	3,431.9	35,964.0			

Note:
1. Trust fund contribution to capital costs is roughly estimated based on half of project cost upto 2019 ($6,490.7 million). Total amount in the column of Contribution includes future costs (after 2020, $186.4 million).
2. Debt service requirement is reduced based on the reduced borrowing.
3. The other data is mainly based on Table 21 of FFMS's Annex to Draft Final Report.
4. Slight difference with FFMS data exists.
5. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous year divided by total debt service requirements.

9.6.3 Effect of Inflation

In the FFMS Study, revenues and costs were expressed in constant 1990 dollar or in real terms, while interest rates and a discount rate used for the net present value calculations in financial analyses were expressed in nominal terms. In effect this means, the FFMS Study assumed the expected inflation rate would be zero[3]. Some may say that the assumption that expected inflation rate will be zero is unrealistic for the project; however, it is not an unreasonable assumption taking the recent tendency of low inflation routes in Japan and U.S.A. into account, recognizing that it is a conservative approach. In future investigations, the financial analysis should apply the expected inflation factor appropriate to the economic environment at the time of financing.

9.6.4 The Optimum Financing Scheme under the Political, Economic and Financial Conditions at the Time of Financing

The financing scheme presented in the FFMS Study was assumed on an appropriate and reasonable basis. In identifying potential financing sources and likely terms and conditions, the following two assumptions were made: (1) the project would be under favorable political and economic conditions throughout the project life; (2) the project was considered a medium investment-grade risk. The above assumptions implied that the entity operating the existing Panama Canal would be financially sound at the time of financing and that a track record of solid operational and management performance has been established.

Therefore, investigation of the optimum financing scheme is required in future studies, when the political, economic and financial conditions around the project at the time of financing would become more clear and could be reasonably presumed.

The potential lenders and investors will be definitely interested in how various project risks will be minimized in so-called "project finance" scheme. They will make financial decisions in accordance with the result of their risk assessment. Among various project risks, their main concerns about the Canal project may exist in:

- Construction risks, especially cost overrun risk and delay-in-completion risk;
- Transit volume risk; and
- Political risk and credit risk of Panama Canal Authority

[3] The interest rate in real terms equals the nominal rate minus the expected inflation rate. Therefore, the assumption that the rates in real terms equal those in the nominal terms means that the expected inflation rate is zero.

9.6.5 Preparation of Balance Sheet for the Management Entity

Owing to the limited information on the asset of the PCC and various other conditions, the FFMS Study did not project a balance sheet of the management entity for each Canal alternatives. Consequently, the most preferable alternative has been identified by a financial rate of return and other criteria described in Chapter 7.2. through the analysis of projected cash flow up to year 2060.

Further investigation is required by future study including a projected balance sheet for a more precise financial assessment.

9.6.6 Management Arrangement

The main objective of the present management arrangement study, as described in Section 7.3, is to establish the most desirable management arrangement or canal operating entity as the presupposition of financial analysis and financing scheme for the project. Most parts of the original TOR defined in the DPS are still considered valid, and therefore, details of management need to be studied in the next stage.

Major areas of study will be;

i) Re-assessment of the most suited management for this internationally important infrastructure, which will be welcomed by both the Panamanian Government and user countries.

ii) A thorough review of the activities necessary to operate the canal, and categorize these activities into the core activities to be directly assigned to the authority and other activities which may be contracted out. This shall be examined not only from the viewpoint of the authority's interest but also the overall effects on Panamanian industry.

iii) Maximum utilization of the existing PCC's assets including its real estate, man power, and know-how.

Since the Panama Canal Authority model has been recommended in the present management arrangement study, and the High Rise Lock Canal Alternative is recommended as the most promising alternative, a future management arrangement study should reflect the specific situation derived from the above conditions.

In the course of study, due consideration shall be given to the rapidly growing information and data processing tools including i) Management Information System (MIS), ii) Office automation (OA), and iii) Electronic Mail System.

9.7 Socioeconomic Aspects

9.7.1 Access Issues

Should the SLC alternative be further investigated, detailed studies should be undertaken to identify remote access roads (improved and unimproved) to residences and small towns which would be affected by construction of the canal. For those roads which would be removed, plans should be developed to ensure that remote residences maintain access throughout the construction period and are provided with permanent access following construction. As part of this effort, a program should be developed for disseminating information to affected populations describing the access changes and providing schedules for when changes will occur.

9.7.2 Population Relocation

Relocation plans for displaced population would need to be developed prior to the announcement of the project. Considering the publicity that the project may receive and the immediate concern it might raise in residents in its proposed corridor, it is important that some thought be paid to the relocation issue prior to project announcement. Preparation of the plan would require several steps. First, detailed demographic and land use studies should be performed to identify and describe the population to be displaced by construction of the chosen canal alternative. Information to be collected should include a description of the household including ethnic affiliation, the name of the head of the household, number of family members at that residence, occupation, location of work place, and any available information relating to relationship with neighboring residences (eg. extended family). Information should also be collected on land use activities which relate to the specific lifestyle of the inhabitants that will also be displaced by the project.

Next, using the information collected, the data should be studied to identify the specific needs of the population who will require relocation assistance. Household descriptions should include residential space requirements, land use needs, proximity to extended family or support group (eg. long-term neighbors) and place of work.

Finally, the results of this analysis should then form the basis for identifying compensation, relocation sites and establishing accommodations for the displaced population.

9.7.3 Cultural Resources

Should the SLC alternative be chosen, an archaeological survey of the corridor should be conducted to identify and recover any resources of significance. This survey could take a considerable amount of time to complete so attention needs to be paid to this concern at least 1 to 2 years prior to start of construction. In recent years there has been a growing awareness of the importance of the role marine archaeology plays in our understanding of older civilizations and cultures.

In addition to the land based portion of the corridor, there is also a possibility that ship wrecks or prehistoric boats could be preserved in the waters off the coast of the canal in areas that have not previously been dredged or excavated. Marine surveys should be conducted to determine the presence or absence of such resources and data recovery should take place as appropriate.

9.7.4 Economic Considerations

There are several areas which require further consideration and study under economic concerns. First plans should be developed to assist in relocating businesses (including agricultural activities) which are to be displaced by the chosen canal option. Second, the potential for drawing labor away from existing jobs to work on the canal needs to be further studied to prevent serious impacts to existing economic activities.

Businesses (including agricultural activities) which would be displaced by the proposed canal should be identified and described with regards to their specific activity, space needs, access needs (road or rail access for receipt of raw materials or shipping of produced goods) and employment. Using this information, plans should be developed to assist businesses in identifying and in moving to the new locations.

Regarding the potential movement of labor from existing jobs to work on the canal, further analysis needs to take place to better define the potential and to establish plans or policies for training new labor to replace the former workers, and/or to assist businesses in finding appropriate replacement workers.

In addition to the above, detailed plans need to be developed for the shut-down and replacement of the port at Rodman should that be required. This should include consideration not only of port facilities but also of businesses who are directly tied to the port and may be affected by the relocation of those activities.

9.7.5 Worker's Complexes

Concern has been expressed in the Impacts Upon Panama report over the establishment of worker's complexes and the potential negative public response to them. The development of these complexes should be studied further along with the potential for integration of them into adjacent communities. Attention should be paid to their usefulness following completion of construction and potential for adaptive reuse.

9.7.6 Immigration Policy

Among the key issues of concern from a socioeconomic perspective is the potential for large scale immigration of workers from other countries in response to the announcement of the canal project.

High population growth rates have been projected for the Metropolitan Region without the canal project, and a large immigrating population will only exacerbate problems associated with provision of housing and public facilities. Prior to the announcement of the canal project, consideration should be given to the development of a government policy regarding canal specific immigration. Consideration should be given to length of stay in Panama and whether or not those individuals who obtain employment on the canal are allowed to remain following completion of canal construction.

9.7.7 Security Issues

Under the political discussion in the Impacts Upon Panama report, considerable attention is paid to the political implications of the expansion of security forces for protection of the canal and, in the case of the SLC alternative, the remote areas surrounding the canal. It is recommended that additional study should be done on this issue. Among the areas covered should be the identification of the specific security requirements as well as the organizational structure of the group.

9.7.8 Public Information

Among the issues of concern raised in the report is the concern over the potential political impacts which might result from various aspects of the project. Upon announcement of the proposed project, a considerable amount of public attention is likely to be focused on it with questions asked on a variety of issues. To minimize speculation and confusion, a public information program should be developed and in place to answer questions prior to the project announcement. The program should be developed to provide press releases describing the project as well as the policies and programs which have been developed to manage potential impacts associated with it. It should also have a mechanism for receiving and responding to questions from the public at large.

9.8 Environmental Aspects

The Background Biological and Biological Inventory baseline studies that have been conducted as part of this project have provided much useful data. These data have been adequate, within the context of the present study, to evaluate and analyze the ecological impacts of the High Rise Lock Canal, and to a lesser extent the Route 10 Sea-Level Canal.

A considerable amount of additional ecological and environmental information is needed however, in order to properly accomplish either Canal Alternative. The Environmental Analysis Component Contractor has estimated that these studies would require more than five years to accomplish, and could cost in excess of six million dollars (at present-day costs). These studies and analyses are necessary to:

1) Properly evaluate design, and optimize various mitigation measures, and

2) Provide input to a full environmental impact study

The following specific recommendations for future studies are made:

9.8.1 General Studies

Habitat Mapping

Perform a complete habitat mapping of all areas within 1 km radius of all construction, operation, and maintenance activities for the alternatives. (note that at present, little information exists for the sea-level canal area).

Wetlands

Through studies of affected wetlands should be undertaken.

Aerial Photographs

Sets of aerial photographs of all areas that would be effected by the selected Alternative.

Biologic Baseline Studies

Biological baseline for different parameters to be affected must be undertaken for both alternative in order to overcome the current existing limitations of these data. Factors such as vegetation, mammals, birds, insects, herpetology, fisheries, epidemiology and public health must be identified.

9.8.2 High Rise Lock Canal

The following issues should be considered:

Spoil disposal Areas D-1 and D-2

In spoil area D-1, forest and wildlife is still active. Spoil area D-2 is located east of the Barro Colorado Island and seems to be an important migration point for terrestrial fauna. Consideration must be given to the possibility of placing excavated material in dredge area W-2.

Spoil disposal areas D-3, D-5, D-6 and D-8

Some of these areas contain wetlands and estuaries. These sites act as reproduction and feeding grounds for local fauna.

The impact of disturbing these areas needs to be assessed and mitigation measures developed.

Dams and Impoundments

Complete baseline studies of the Indio, Trinidad and Ciri rivers (if effected by the selected Alternative).

Aquatic Studies

A program to gather physical, chemical and biological data on the rivers and streams discharging into Gatun Lake needs to be developed and implemented. This will be necessary for an impact assessment of the waterbed areas which are vital to the hydrologic regime of the region.

9.8.3 Sea-Level Canal

The existing conditions at the site of this alternative are almost unknown. Thus a thorough an extensive investigation must be undertaken in order to acquire information necessary to determine the environmental impacts caused by construction of the Canal alternative.

Sedimentation, Erosion and Littoral drift

The proposed breakwaters may affect ocean currents thereby causing sedimentation, erosion and littoral drift. It is thence recommended that hydrogeographic surveys, current pattern and sediment composition be determined.

Regional Marine Biological Conditions

A detailed marine biological study should be performed. This study may provide answers to the ongoing concern about transmigration of biota from ocean to ocean. The scope of this study should include requirements to obtain necessary information on existing fisheries, reproduction areas, flora, fauna and coral formations.

Local Biological Conditions

A study is required to obtain information that would link the different habitats to their respective flora and fauna in very specific terms.

Spoil Disposal areas D-1 to D-6, D-19 to W-3

The spoil areas D-1 through D-6 contain significant forest that if destroyed would create a barrier for the migrations action of terrestrial fauna. The spoil areas D-19 to W-3 contain important mangrove and wetlands on the mouth of the Caimito River.

Diversion Scheme

Several rivers and streams could be affected as a result of diversions scheme proposed. A study is recommended in order to determine the consequences on the flora and fauna resulting from diversions.

Aquatic Studies

It is of a great importance to conduct studies intended to disclose information about life cycles and trophic characteristics of species for fisheries, of plants and animals with medical properties. Further knowledge is also required on basic physical conditions on both coastlines (wave actions, coastal zones types, sediments, coastal currents and ocean currents). Studies to determine feasibility of several coastal protection barriers are recommended.

Hydrogeologic Studies

Very little information exists on the hydrogeology of the Sea-Level Canal Route. An inventory of existing water wells should be taken identifying water quality, depth and different water sources for drinking or industrial purposes.

List of Tables and Sources

Table N°.	#Title & Source
9.6.1-1	Summary of Financial Results by Canal Alternative Under the Optimal Toll System With a More User-oriented Toll Increasing Scenario Sources: SINBOL, based on the results of financial analyses in Financing Scheme, Financial Analysis and Management Arrangement Study (the FFMS Study)
9.6.1-2	Summary of Financial Results by Canal Alternative With a 75 percent Increase in Tolls Sources: SINBOL, based on the results of financial analyses in the FFMS Study
9.6.2-1	Financial Analysis Assuming Trust Fund Contribution to Capital Cost is Raised from 25% to 50% and an Optimal Toll System, High Rise 150,000 dwt Culebra Cut Single Lane Alternative Sources: SINBOL, based on the results of financial analyses in the FFMS Study
9.6.2-2	Financial Analysis Assuming Trust Fund Contribution to Capital Cost is Raised from 25% to 50% and an Optimal Toll System, High Rise 200,000 dwt Culebra Cut Single Lane Alternative Sources: SINBOL, based on the results of financial analyses in the FFMS Study

Appendix 9.6

Table A.9.6-1 High Rise 150,000 DWT Culebra Cut Single Alternative:
Assuming an Optical Toll System after 2020 (Tolls start to Increase in 2010)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	549.5	359.4	190.1	54.9	0.0	135.1	0.0	0.0	1,404.5		
2010	582.5	360.5	222.0	58.3	4.5	159.3	22.8	0.0	1,597.2	36.4	348.5
2011	617.7	361.5	256.2	61.8	9.2	185.3	23.2	0.0	1,823.2	21.1	194.7
2012	655.4	362.6	292.8	65.5	22.5	204.7	66.8	0.0	2,034.0	10.1	91.1
2013	695.6	363.7	331.9	69.6	61.0	201.3	125.4	0.0	2,191.3	4.3	37.6
2014	738.6	364.8	373.8	73.9	117.2	182.7	156.9	0.0	2,304.8	2.6	21.3
2015	784.6	365.8	418.8	78.5	162.1	178.2	160.7	0.0	2,414.4	2.1	16.3
2016	833.7	365.8	467.9	83.4	252.7	131.8	292.8	0.0	2,350.0	1.5	11.1
2017	886.1	368.0	518.1	88.6	354.5	75.0	249.7	0.0	2,269.3	1.2	7.8
2018	942.3	369.1	573.2	94.2	420.3	58.7	176.0	0.0	2,242.8	1.1	6.5
2019	1,002.3	370.1	632.2	100.2	480.4	51.6	140.4	0.0	2,243.7	1.1	5.8
2020	1,307.6	475.1	832.5	130.8	502.9	198.8	0.0	2,032.0	500.3	1.4	5.9
2021	1,318.4	477.8	840.6	131.8	535.2	173.6	0.0	193.0	500.9	1.3	2.3
2022	1,329.3	480.5	848.8	132.9	555.2	160.7	0.0	181.0	500.6	1.3	2.2
2023	1,340.2	483.2	857.0	134.0	535.0	188.0	0.0	208.0	500.6	1.4	2.3
2024	1,351.4	485.9	865.5	135.1	500.6	229.8	0.0	250.0	500.4	1.5	2.5
2025	1,362.5	488.6	873.9	136.3	456.3	281.4	0.0	301.0	500.8	1.6	2.7
2026	1,373.8	491.3	882.5	137.4	397.7	347.5	0.0	368.0	500.2	1.9	3.1
2027	1,385.1	494.0	891.1	138.5	346.9	405.7	0.0	426.0	500.0	2.2	3.6
2028	1,396.6	496.7	899.9	139.7	296.3	464.0	0.0	483.0	500.9	2.6	4.3
2029	1,408.1	499.4	908.7	140.8	246.1	521.8	9.7	533.0	500.1	3.1	5.2
2030	1,419.8	502.1	917.7	142.0	210.7	565.0	13.6	571.0	500.4	3.7	6.1
2031	1,431.5	504.8	926.7	143.2	169.5	614.1	14.7	619.0	500.8	4.6	7.6
2032	1,443.3	507.5	935.8	144.3	142.2	649.3	53.0	617.0	500.1	5.6	9.1
2033	1,455.3	510.2	945.1	145.5	117.3	682.2	53.0	649.0	500.4	6.8	11.1
2034	1,467.3	512.9	954.4	146.7	95.4	712.3	0.0	732.0	500.6	8.5	13.7
2035	1,479.4	515.6	963.8	147.9	76.6	739.2	0.0	759.0	500.9	10.7	17.2

Table A.9.6-1 (Continued)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,491.7	518.3	973.4	149.2	47.2	777.0	0.0	798.0	500.0	17.5	28.1
2037	1,504.0	521.0	983.0	150.4	24.6	808.0	0.0	828.0	500.0	33.8	54.2
2038	1,516.5	523.7	992.8	151.6	10.0	831.1	0.0	851.0	500.1	84.1	134.1
2039	1,528.9	526.4	1,002.5	152.9	0.0	849.6	0.0	869.0	500.7		
2040	1,541.6	529.1	1,012.5	154.2	0.0	858.4	0.0	879.0	500.1		
2041	1,554.4	531.7	1,022.7	155.4	0.0	867.2	0.0	887.0	500.4		
2042	1,567.2	534.4	1,032.8	156.7	0.0	876.0	0.0	896.0	500.4		
2043	1,580.1	537.1	1,043.0	158.0	0.0	885.0	0.0	905.0	500.4		
2044	1,593.2	539.8	1,053.4	159.3	0.0	894.1	0.0	914.0	500.5		
2045	1,606.3	542.5	1,063.8	160.6	0.0	903.2	0.0	923.0	500.7		
2046	1,619.6	545.2	1,074.4	162.0	0.0	912.4	0.0	933.0	500.2		
2047	1,633.1	547.9	1,085.2	163.3	0.0	921.9	0.0	942.0	500.1		
2048	1,646.5	550.6	1,095.9	164.7	0.0	931.3	0.0	951.0	500.4		
2049	1,660.2	553.3	1,106.9	166.0	0.0	940.9	3.2	958.0	500.0		
2050	1,673.9	556.0	1,117.9	167.4	0.0	950.5	19.7	950.0	500.8		
2051	1,687.7	558.7	1,129.0	168.8	0.0	960.3	19.7	961.0	500.4		
2052	1,701.7	561.4	1,140.3	170.2	0.0	970.1	0.0	990.0	500.6		
2053	1,715.7	564.1	1,151.6	171.6	0.0	980.0	0.0	1,000.0	500.6		
2054	1,729.9	566.8	1,163.1	173.0	0.0	990.1	0.0	1,010.0	500.7		
2055	1,744.2	569.5	1,174.7	174.4	0.0	1,000.3	0.0	1,021.0	500.0		
2056	1,758.6	572.2	1,186.4	175.9	0.0	1,010.5	0.0	1,030.0	500.5		
2057	1,773.2	574.9	1,198.3	177.3	0.0	1,021.0	0.0	1,041.0	500.5		
2058	1,787.8	577.6	1,210.2	178.8	0.0	1,031.4	0.0	1,052.0	500.0		
2059	1,802.6	580.3	1,222.3	180.3	0.0	1,042.0	0.0	1,062.0	500.0		
2060	1,817.5	583.0	1,234.5	181.8	0.0	1,052.8	0.0	1,072.0	500.7		
Total	76,496.9	28,888.6	47,608.3	7,649.7	7,150.1	32,808.5	1,601.2	32,645.0			

Note: 1. The data are mainly based on Table 11 and 15 of FFMS's Annex to Draft Final Report
2. Slight difference with FFMS data exists.

Table A.9.6-2 High Rise 200,000 DWT Culebra Cut Single Alternative:
Assuming an Optical Toll System after 2020 (Tolls start to Increase in 2009)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	574.3	359.4	214.9	57.4	4.9	152.6	24.6	0.0	1,397.4		
2010	606.6	360.5	246.1	60.7	9.9	175.5	25.1	0.0	1,603.8	18.7	159.9
2011	640.9	361.5	279.4	64.1	21.8	193.5	59.4	0.0	1,802.0	9.9	83.4
2012	677.4	362.6	314.8	67.7	61.9	185.2	131.3	0.0	1,928.0	4.0	33.1
2013	716.2	363.7	352.5	71.6	121.2	159.6	179.0	0.0	1,985.0	2.3	18.2
2014	757.5	364.8	392.7	75.7	175.5	141.4	192.4	0.0	2,014.2	1.8	13.1
2015	801.3	365.8	435.5	80.1	247.3	108.1	199.7	0.0	2,003.1	1.4	9.6
2016	848.0	365.8	482.2	84.8	366.5	30.9	324.0	0.0	1,790.2	1.1	6.5
2017	897.6	368.0	529.6	89.8	452.8	(12.9)	256.2	0.0	1,592.7	1.0	4.9
2018	950.5	369.1	581.4	95.0	528.6	(42.3)	195.1	0.0	1,419.1	0.9	3.9
2019	1,006.7	370.1	636.6	100.7	568.3	(32.4)	53.2	0.0	1,390.3	0.9	3.4
2020	1,318.6	483.4	835.2	131.9	587.4	115.9	0.0	1,061.0	500.9	1.2	3.6
2021	1,330.9	486.1	844.8	133.1	616.5	95.2	0.0	116.0	500.1	1.2	2.0
2022	1,343.3	488.8	854.5	134.3	604.0	116.1	0.0	136.0	500.3	1.2	2.0
2023	1,355.8	491.5	864.3	135.6	574.6	154.1	9.7	164.0	500.7	1.3	2.1
2024	1,368.5	494.2	874.3	136.8	533.2	204.2	13.6	211.0	500.3	1.4	2.3
2025	1,381.2	496.9	884.3	138.1	475.7	270.5	14.7	276.0	500.1	1.6	2.6
2026	1,394.1	499.6	894.5	139.4	415.7	339.4	53.0	306.0	500.5	1.8	3.0
2027	1,407.1	502.3	904.8	140.7	358.4	405.7	53.0	373.0	500.2	2.1	3.5
2028	1,420.2	505.0	915.2	142.0	298.0	475.2	0.0	495.0	500.4	2.6	4.3
2029	1,433.4	507.7	925.7	143.3	255.6	526.7	0.0	547.0	500.2	3.1	5.0
2030	1,446.8	510.4	936.4	144.7	216.0	575.7	0.0	595.0	500.9	3.7	6.0
2031	1,460.3	513.1	947.2	146.0	183.3	617.8	0.0	638.0	500.7	4.4	7.1
2032	1,473.9	515.8	958.1	147.4	151.4	659.3	0.0	680.0	500.1	5.4	8.7
2033	1,487.6	518.5	969.1	148.8	122.3	698.1	0.0	718.0	500.1	6.7	10.8
2034	1,501.5	521.2	980.3	150.1	96.5	733.6	0.0	753.0	500.8	8.6	13.8
2035	1,515.5	523.9	991.6	151.5	74.9	765.1	0.0	785.0	500.9	11.2	17.9

Table A.9.6-2 (Continued)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,529.7	526.6	1,003.1	153.0	44.5	805.6	0.0	826.0	500.6	19.1	30.4
2037	1,543.9	529.3	1,014.6	154.4	21.1	839.1	0.0	859.0	500.7	40.8	64.5
2038	1,558.3	532.0	1,026.3	155.8	5.5	865.0	0.0	885.0	500.8	158.3	249.3
2039	1,572.8	534.7	1,038.1	157.3	0.0	880.8	0.0	901.0	500.6		
2040	1,587.5	537.4	1,050.1	158.8	0.0	891.4	0.0	912.0	500.0		
2041	1,602.4	540.0	1,062.4	160.2	0.0	902.1	0.0	922.0	500.2		
2042	1,617.2	542.7	1,074.5	161.7	0.0	912.8	0.0	933.0	500.0		
2043	1,632.3	545.4	1,086.9	163.2	0.0	923.7	0.0	943.0	500.7		
2044	1,647.5	548.1	1,099.4	164.8	0.0	934.7	3.2	952.0	500.2		
2045	1,662.9	550.8	1,112.1	166.3	0.0	945.8	19.7	946.0	500.3		
2046	1,678.4	553.5	1,124.9	167.8	0.0	957.1	19.7	957.0	500.7		
2047	1,694.1	556.2	1,137.9	169.4	0.0	968.5	0.0	989.0	500.2		
2048	1,709.9	558.9	1,151.0	171.0	0.0	980.0	0.0	1,000.0	500.2		
2049	1,725.9	561.6	1,164.3	172.6	0.0	991.7	0.0	1,012.0	500.0		
2050	1,741.9	564.3	1,177.6	174.2	0.0	1,003.5	0.0	1,023.0	500.4		
2051	1,758.2	567.0	1,191.2	175.8	0.0	1,015.4	0.0	1,035.0	500.9		
2052	1,774.7	569.7	1,205.0	177.5	0.0	1,027.5	0.0	1,048.0	500.4		
2053	1,791.1	572.4	1,218.7	179.1	0.0	1,039.6	0.0	1,060.0	500.0		
2054	1,807.9	575.1	1,232.8	180.8	0.0	1,052.0	0.0	1,072.0	500.0		
2055	1,824.7	577.8	1,246.9	182.5	0.0	1,064.5	0.0	1,084.0	500.5		
2056	1,841.7	580.5	1,261.2	184.2	0.0	1,077.1	0.0	1,097.0	500.5		
2057	1,859.0	583.2	1,275.8	185.9	0.0	1,089.9	0.0	1,110.0	500.5		
2058	1,876.3	585.9	1,290.4	187.6	0.0	1,102.8	0.0	1,123.0	500.3		
2059	1,893.8	588.6	1,305.2	189.4	0.0	1,115.8	0.0	1,136.0	500.1		
2060	1,911.5	591.3	1,320.2	191.2	0.0	1,129.1	0.0	1,149.0	500.1		
Total	78,662.5	29,228.9	49,433.6	7,866.3	8,193.3	33,374.1	1,826.4	32,828.0			

Note: 1. The data are mainly based on Table 17 and 21 of FFMS's Annex to Draft Final Report.
2. Slight difference with FFMS data exists.
3. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous year divided by total debt service requirements.

Table A.9.6-3 High Rise 150,000 DWT Alternative:
Assuming an Optical Toll System after 2020 (Tolls start to Increase in 2010)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	549.5	359.4	190.1	54.9	0.0	135.1	0.0	0.0	1,404.5		
2010	582.5	360.5	222.0	58.3	5.4	158.4	26.5	0.0	1,592.5	30.3	290.4
2011	617.7	361.5	256.2	61.8	10.7	183.8	27.1	0.0	1,812.9	18.2	167.0
2012	655.4	362.6	292.8	65.5	27.1	200.1	82.2	0.0	2,003.4	8.4	75.3
2013	695.6	363.7	331.9	69.6	96.9	165.4	236.8	0.0	2,012.2	2.7	23.4
2014	738.6	364.8	373.8	73.9	195.2	104.7	297.1	0.0	1,900.3	1.5	11.8
2015	784.6	365.8	418.8	78.5	275.0	65.3	309.0	0.0	1,732.6	1.2	8.1
2016	833.7	365.8	467.9	83.4	377.8	6.7	314.1	0.0	1,494.5	1.0	5.6
2017	886.1	368.0	518.1	88.6	495.6	(66.1)	257.6	0.0	1,230.6	0.9	3.9
2018	942.3	369.1	573.2	94.2	573.2	(94.2)	175.1	0.0	1,010.5	0.8	3.0
2019	1,002.3	370.1	632.2	100.2	638.0	(106.0)	134.7	0.0	810.2	0.8	2.4
2020	1,307.6	475.1	832.5	130.8	673.1	28.6	0.0	0.0	871.3	1.0	2.2
2021	1,318.4	477.8	840.6	131.8	701.9	6.9	0.0	0.0	913.0	1.0	2.3
2022	1,329.3	480.5	848.8	132.9	716.0	(0.1)	0.0	0.0	949.4	1.0	2.3
2023	1,340.2	483.2	857.0	134.0	679.8	43.2	0.0	530.0	500.6	1.1	2.5
2024	1,351.4	485.9	865.5	135.1	625.5	104.9	0.0	125.0	500.4	1.2	2.0
2025	1,362.5	488.6	873.9	136.3	560.9	176.8	0.0	197.0	500.2	1.3	2.2
2026	1,373.8	491.3	882.5	137.4	486.3	258.9	0.0	279.0	500.1	1.5	2.6
2027	1,385.1	494.0	891.1	138.5	426.0	326.6	0.0	346.0	500.7	1.8	2.9
2028	1,396.6	496.7	899.9	139.7	365.8	394.5	0.0	415.0	500.2	2.1	3.4
2029	1,408.1	499.4	908.7	140.8	305.9	462.0	0.0	482.0	500.2	2.5	4.1
2030	1,419.8	502.1	917.7	142.0	259.2	516.5	0.0	536.0	500.7	3.0	4.9
2031	1,431.5	504.8	926.7	143.2	213.8	569.8	0.0	590.0	500.4	3.7	6.0
2032	1,443.3	507.5	935.8	144.3	181.8	609.7	0.0	630.0	500.2	4.4	7.1
2033	1,455.3	510.2	945.1	145.5	145.7	653.8	0.0	674.0	500.0	5.5	8.9
2034	1,467.3	512.9	954.4	146.7	111.8	695.9	0.0	715.0	500.9	7.2	11.7
2035	1,479.4	515.6	963.8	147.9	78.7	737.1	0.0	758.0	500.0	10.4	16.7

Table A.9.6-3 (Continued)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,491.7	518.3	973.4	149.2	47.3	776.9	0.0	797.0	500.0	17.4	28.0
2037	1,504.0	521.0	983.0	150.4	23.8	808.8	0.0	828.0	500.7	35.0	56.0
2038	1,516.5	523.7	992.8	151.6	9.4	831.7	0.0	852.0	500.5	89.5	142.7
2039	1,528.9	526.4	1,002.5	152.9	0.0	849.6	0.0	870.0	500.1		
2040	1,541.6	529.1	1,012.5	154.2	0.0	858.4	0.0	878.0	500.5		
2041	1,554.4	531.7	1,022.7	155.4	0.0	867.2	0.0	887.0	500.8		
2042	1,567.2	534.4	1,032.8	156.7	0.0	876.0	0.0	896.0	500.8		
2043	1,580.1	537.1	1,043.0	158.0	0.0	885.0	0.0	905.0	500.9		
2044	1,593.2	539.8	1,053.4	159.3	0.0	894.1	0.0	915.0	500.0		
2045	1,606.3	542.5	1,063.8	160.6	0.0	903.2	0.0	923.0	500.2		
2046	1,619.6	545.2	1,074.4	162.0	0.0	912.4	0.0	932.0	500.6		
2047	1,633.1	547.9	1,085.2	163.3	0.0	921.9	0.0	942.0	500.5		
2048	1,646.5	550.6	1,095.9	164.7	0.0	931.3	0.0	951.0	500.8		
2049	1,660.2	553.3	1,106.9	166.0	0.0	940.9	0.0	961.0	500.7		
2050	1,673.9	556.0	1,117.9	167.4	0.0	950.5	0.0	971.0	500.2		
2051	1,687.7	558.7	1,129.0	168.8	0.0	960.3	0.0	980.0	500.5		
2052	1,701.7	561.4	1,140.3	170.2	0.0	970.1	0.0	990.0	500.6		
2053	1,715.7	564.1	1,151.6	171.6	0.0	980.0	0.0	1,000.0	500.7		
2054	1,729.9	566.8	1,163.1	173.0	0.0	990.1	0.0	1,010.0	500.8		
2055	1,744.2	569.5	1,174.7	174.4	0.0	1,000.3	0.0	1,021.0	500.1		
2056	1,758.6	572.2	1,186.4	175.9	0.0	1,010.5	0.0	1,030.0	500.6		
2057	1,773.2	574.9	1,198.3	177.3	0.0	1,021.0	0.0	1,041.0	500.6		
2058	1,787.8	577.6	1,210.2	178.8	0.0	1,031.4	0.0	1,052.0	500.1		
2059	1,802.6	580.3	1,222.3	180.3	0.0	1,042.0	0.0	1,062.0	500.1		
2060	1,817.5	583.0	1,234.5	181.8	0.0	1,052.8	0.0	1,072.0	500.8		
Total	76,496.9	28,888.6	47,608.3	7,649.7	9,307.6	30,651.0	1,860.1	30,043.0			

Note:
1. The revenue upto 2009 is mainly based on Table 6-7 of FFMS's Final Report.
2. The other data are mainly based on Table 6-11 of FFMS's Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous year divided by total debt service requirements.

Table A.9.6-4 High Rise 150,000 DWT Culebra Cut Single Lane Alternative: Assuming a 75% Increase in Tolls after 2020 (Tolls start to Increase in 2000)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	512.1	349.7	162.4	51.2	0.0	111.2	0.0	0.0	111.2		
2001	527.9	350.8	177.1	52.8	0.0	124.3	0.0	0.0	239.9		
2002	544.3	351.9	192.4	54.4	0.0	138.0	0.0	0.0	387.5		
2003	561.1	353.0	208.1	56.1	0.0	152.0	0.0	0.0	555.0		
2004	578.6	354.0	224.6	57.9	0.0	166.7	0.0	0.0	743.9		
2005	596.7	355.1	241.6	59.7	0.0	181.9	0.0	0.0	955.6		
2006	615.3	356.2	259.1	61.5	0.0	197.5	0.0	0.0	1,191.3		
2007	634.5	357.2	277.3	63.5	0.0	213.9	0.0	0.0	1,452.8		
2008	654.4	358.3	296.1	65.4	0.0	230.6	0.0	0.0	1,741.6		
2009	674.9	359.4	315.5	67.5	0.0	248.0	0.0	0.0	2,059.2		
2010	696.1	360.5	335.6	69.6	4.5	261.5	22.8	0.0	2,380.3	59.1	516.7
2011	718.0	361.5	356.5	71.8	9.2	275.5	23.2	0.0	2,727.9	30.9	289.7
2012	740.6	362.6	378.0	74.1	22.5	281.5	66.8	0.0	3,051.7	13.5	134.7
2013	763.9	363.7	400.2	76.4	61.0	262.9	125.4	0.0	3,311.2	5.3	55.3
2014	788.1	364.8	423.3	78.8	117.2	227.3	156.9	0.0	3,514.0	2.9	31.2
2015	813.0	365.8	447.2	81.3	162.1	203.8	160.7	0.0	3,697.7	2.3	23.9
2016	838.6	365.8	473.0	83.9	252.7	136.4	292.8	0.0	3,689.2	1.5	16.2
2017	865.3	368.0	497.3	86.5	354.5	56.3	249.7	0.0	3,643.4	1.2	11.6
2018	892.8	369.1	523.7	89.3	420.3	14.1	176.0	0.0	3,627.3	1.0	9.7
2019	921.2	370.1	551.1	92.1	480.4	(21.4)	140.4	0.0	3,610.6	1.0	8.5
2020	1,172.1	475.1	697.0	117.2	502.9	76.9	0.0	3,331.0	500.9	1.2	8.3
2021	1,181.9	477.8	704.1	118.2	535.2	50.7	0.0	71.0	500.7	1.1	2.0
2022	1,191.9	480.5	711.4	119.2	555.2	37.0	0.0	57.0	500.7	1.1	2.0
2023	1,201.8	483.2	718.6	120.2	535.0	63.5	0.0	84.0	500.1	1.1	2.1
2024	1,212.0	485.9	726.1	121.2	500.6	104.3	0.0	124.0	500.5	1.2	2.2
2025	1,222.2	488.6	733.6	122.2	456.3	155.0	0.0	175.0	500.5	1.3	2.4
2026	1,232.5	491.3	741.2	123.2	397.7	220.2	0.0	240.0	500.8	1.6	2.8
2027	1,242.8	494.0	748.8	124.3	346.9	277.6	0.0	298.0	500.4	1.8	3.2
2028	1,253.2	496.7	756.5	125.3	296.3	334.9	0.0	355.0	500.3	2.1	3.8
2029	1,263.7	499.4	764.3	126.4	246.1	391.8	9.7	402.0	500.5	2.6	4.6
2030	1,274.3	502.1	772.2	127.4	210.7	434.1	13.6	441.0	500.0	3.1	5.4
2031	1,285.1	504.8	780.3	128.5	169.5	482.3	14.7	487.0	500.6	3.8	6.8
2032	1,295.9	507.5	788.4	129.6	142.2	516.6	53.0	484.0	500.2	4.6	8.2
2033	1,306.7	510.2	796.5	130.7	117.3	548.6	53.0	515.0	500.7	5.7	9.9
2034	1,317.7	512.9	804.8	131.8	95.4	577.6	0.0	598.0	500.4	7.1	12.3
2035	1,328.8	515.6	813.2	132.9	76.6	603.7	0.0	624.0	500.1	8.9	15.4

Table A.9.6-4 (Continued)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,340.0	518.3	821.7	134.0	47.2	640.5	0.0	660.0	500.6	14.6	25.2
2037	1,351.2	521.0	830.2	135.1	24.6	670.5	0.0	691.0	500.2	28.3	48.6
2038	1,362.6	523.7	838.9	136.3	10.0	692.7	0.0	712.0	500.8	70.3	120.3
2039	1,374.0	526.4	847.6	137.4	0.0	710.2	0.0	731.0	500.1		
2040	1,385.6	529.1	856.5	138.6	0.0	717.9	0.0	738.0	500.0		
2041	1,397.3	531.7	865.6	139.7	0.0	725.8	0.0	745.0	500.9		
2042	1,408.9	534.4	874.5	140.9	0.0	733.6	0.0	754.0	500.5		
2043	1,420.8	537.1	883.7	142.1	0.0	741.6	0.0	762.0	500.2		
2044	1,432.7	539.8	892.9	143.3	0.0	749.6	0.0	769.0	500.8		
2045	1,444.7	542.5	902.2	144.5	0.0	757.8	0.0	778.0	500.6		
2046	1,456.9	545.2	911.7	145.7	0.0	766.0	0.0	786.0	500.6		
2047	1,469.2	547.9	921.3	146.9	0.0	774.4	0.0	795.0	500.0		
2048	1,481.5	550.6	930.9	148.1	0.0	782.7	0.0	802.0	500.8		
2049	1,494.0	553.3	940.7	149.4	0.0	791.3	3.2	808.0	500.9		
2050	1,506.5	556.0	950.5	150.6	0.0	799.8	19.7	801.0	500.1		
2051	1,519.2	558.7	960.5	151.9	0.0	808.6	19.7	809.0	500.0		
2052	1,532.0	561.4	970.6	153.2	0.0	817.4	0.0	837.0	500.4		
2053	1,544.8	564.1	980.7	154.5	0.0	826.2	0.0	846.0	500.6		
2054	1,557.8	566.8	991.0	155.8	0.0	835.2	0.0	855.0	500.8		
2055	1,570.8	569.5	1,001.3	157.1	0.0	844.3	0.0	865.0	500.1		
2056	1,584.0	572.2	1,011.8	158.4	0.0	853.4	0.0	873.0	500.5		
2057	1,597.4	574.9	1,022.5	159.7	0.0	862.8	0.0	883.0	500.3		
2058	1,610.8	577.6	1,033.2	161.1	0.0	872.1	0.0	892.0	500.4		
2059	1,624.3	580.3	1,044.0	162.4	0.0	881.6	0.0	902.0	500.0		
2060	1,638.0	583.0	1,055.0	163.8	0.0	891.2	0.0	911.0	500.2		
Total	71,025.3	28,888.6	42,136.7	7,102.5	7,150.1	27,884.1	1,601.2	28,291.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,039.5 million and $1,450.5 million, respectively.
2. The other data are mainly based on Table 15 of FFMS's Annex to Draft Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income operations less payments to Panama plus trust fund balance of previous year divided by total debt service requirements.

Table A.9.6-5 High Rise 200,000 DWT Culebra Cut Single Alternative:
Assuming a 75% (*) Increase in Tolls after 2020 (Tolls start to Increase in 2000)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	512.1	349.7	162.4	51.2	0.0	111.2	0.0	0.0	111.2		
2001	527.9	350.8	177.1	52.8	0.0	124.3	0.0	0.0	239.9		
2002	544.3	351.9	192.4	54.4	0.0	138.0	0.0	0.0	387.5		
2003	561.1	353.0	208.1	56.1	0.0	152.0	0.0	0.0	555.0		
2004	578.6	354.0	224.6	57.9	0.0	166.7	0.0	0.0	743.9		
2005	596.7	355.1	241.6	59.7	0.0	181.9	0.0	0.0	955.6		
2006	615.3	356.2	259.1	61.5	0.0	197.5	0.0	0.0	1,191.3		
2007	634.5	357.2	277.3	63.5	0.0	213.9	0.0	0.0	1,452.8		
2008	654.4	358.3	296.1	65.4	0.0	230.6	0.0	0.0	1,741.6		
2009	674.9	359.4	315.5	67.5	4.9	243.1	24.6	0.0	2,029.8		
2010	696.1	360.5	335.6	69.6	9.9	256.1	25.1	0.0	2,342.0	26.9	231.9
2011	718.0	361.5	356.5	71.8	21.8	262.9	59.4	0.0	2,639.2	13.1	120.5
2012	740.6	362.6	378.0	74.1	61.9	242.1	131.3	0.0	2,855.5	4.9	47.5
2013	763.9	363.7	400.2	76.4	121.2	202.7	179.0	0.0	2,993.4	2.7	26.2
2014	788.1	364.8	423.3	78.8	175.5	169.0	192.4	0.0	3,089.7	2.0	19.0
2015	813.0	365.8	447.2	81.3	247.3	118.6	199.7	0.0	3,132.2	1.5	14.0
2016	838.8	365.8	473.0	83.9	366.5	22.6	324.0	0.0	2,956.2	1.1	9.6
2017	865.3	368.0	497.3	86.5	452.8	(42.0)	256.2	0.0	2,776.2	0.9	7.4
2018	892.8	369.1	523.7	89.3	528.6	(94.2)	195.1	0.0	2,598.1	0.8	6.1
2019	921.2	370.1	551.1	92.1	568.3	(109.3)	53.2	0.0	2,539.5	0.8	5.4
2020	1,177.6	483.4	694.2	117.8	587.4	(11.0)	0.0	0.0	2,630.1	1.0	5.3
2021	1,188.5	486.1	702.4	118.9	616.5	(32.9)	0.0	0.0	2,702.4	0.9	5.2
2022	1,199.6	488.8	710.8	120.0	604.0	(13.2)	0.0	0.0	2,797.3	1.0	5.5
2023	1,210.7	491.5	719.2	121.1	574.6	23.5	9.7	2,423.0	500.0	1.0	5.9
2024	1,222.0	494.2	727.8	122.2	533.2	72.4	13.6	78.0	500.8	1.1	2.1
2025	1,233.3	496.9	736.4	123.3	475.7	137.4	14.7	143.0	500.5	1.3	2.3
2026	1,244.8	499.6	745.2	124.5	415.7	205.0	53.0	172.0	500.6	1.5	2.7
2027	1,256.3	502.3	754.0	125.6	358.4	270.0	53.0	237.0	500.6	1.8	3.1
2028	1,268.0	505.0	763.0	126.8	298.0	338.2	0.0	358.0	500.8	2.1	3.8
2029	1,279.7	507.7	772.0	128.0	255.6	388.5	0.0	409.0	500.3	2.5	4.5
2030	1,291.7	510.4	781.3	129.2	216.0	436.1	0.0	456.0	500.4	3.0	5.3
2031	1,303.7	513.1	790.6	130.4	183.3	476.9	0.0	497.0	500.4	3.6	6.3
2032	1,315.8	515.8	800.0	131.6	151.4	517.0	0.0	537.0	500.4	4.4	7.7
2033	1,328.0	518.5	809.5	132.8	122.3	554.4	0.0	574.0	500.8	5.5	9.6
2034	1,340.3	521.2	819.1	134.0	96.5	588.6	0.0	609.0	500.5	7.1	12.3
2035	1,352.8	523.9	828.9	135.3	74.9	618.7	0.0	639.0	500.2	9.3	15.9

Table A.9.6-5 (Continued)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to Capex	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,365.4	526.6	838.8	136.5	44.5	657.8	0.0	678.0	500.0	15.8	27.0
2037	1,378.1	529.3	848.8	137.8	21.1	689.9	0.0	709.0	500.8	33.7	57.4
2038	1,390.9	532.0	858.9	139.1	5.5	714.3	0.0	735.0	500.2	130.9	221.9
2039	1,403.8	534.7	869.1	140.4	0.0	728.7	0.0	748.0	500.9		
2040	1,416.9	537.4	879.5	141.7	0.0	737.8	0.0	758.0	500.8		
2041	1,430.1	540.0	890.1	143.0	0.0	747.1	0.0	767.0	500.9		
2042	1,443.3	542.7	900.6	144.3	0.0	756.3	0.0	777.0	500.2		
2043	1,456.7	545.4	911.3	145.7	0.0	765.7	0.0	785.0	500.9		
2044	1,470.3	548.1	922.2	147.0	0.0	775.1	3.2	792.0	500.9		
2045	1,483.9	550.8	933.1	148.4	0.0	784.7	19.7	785.0	500.9		
2046	1,497.7	553.5	944.2	149.8	0.0	794.4	19.7	795.0	500.7		
2047	1,511.7	556.2	955.5	151.2	0.0	804.3	0.0	825.0	500.1		
2048	1,525.7	558.9	966.8	152.6	0.0	814.3	0.0	834.0	500.4		
2049	1,540.0	561.6	978.4	154.0	0.0	824.4	0.0	844.0	500.8		
2050	1,554.2	564.3	989.9	155.4	0.0	834.5	0.0	855.0	500.3		
2051	1,568.7	567.0	1,001.7	156.9	0.0	844.9	0.0	865.0	500.2		
2052	1,583.3	569.7	1,013.6	158.3	0.0	855.3	0.0	875.0	500.5		
2053	1,598.0	572.4	1,025.6	159.8	0.0	865.8	0.0	886.0	500.3		
2054	1,612.8	575.1	1,037.7	161.3	0.0	876.5	0.0	896.0	500.7		
2055	1,627.8	577.8	1,050.0	162.8	0.0	887.3	0.0	908.0	500.0		
2056	1,643.0	580.5	1,062.5	164.3	0.0	898.2	0.0	918.0	500.2		
2057	1,658.3	583.2	1,075.1	165.8	0.0	909.3	0.0	929.0	500.5		
2058	1,673.7	585.9	1,087.8	167.4	0.0	920.4	0.0	941.0	500.0		
2059	1,689.2	588.6	1,100.6	168.9	0.0	931.7	0.0	951.0	500.7		
2060	1,705.0	591.3	1,113.7	170.5	0.0	943.2	0.0	963.0	500.9		
Total	72,379.3	29,228.9	43,150.4	7,237.9	8,193.3	27,719.2	1,826.4	27,951.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,045 million and $1,525.5 million, respectively.
2. The other data are mainly based on Table 21 of PFMS's Annex to Draft Final Report.
3. Slight difference with PFMS data exists.
4. Overall DSCR is net income from operations less payments to Panama plus trust fund balance of previous year divided by total debt service requirements.

Table A.9.6-6 High Rise 150,000 DWT Alternative:
Assuming a 75% (*) Increase in Tolls after 2020 (Tolls start to Increase in 2000)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	512.1	349.7	162.4	51.2	0.0	111.2	0.0	0.0	111.2		
2001	527.9	350.8	177.1	52.8	0.0	124.3	0.0	0.0	239.9		
2002	544.3	351.9	192.4	54.4	0.0	138.0	0.0	0.0	387.5		
2003	561.1	353.0	208.1	56.1	0.0	152.0	0.0	0.0	555.0		
2004	578.6	354.0	224.6	57.9	0.0	166.7	0.0	0.0	743.9		
2005	596.7	355.1	241.6	59.7	0.0	181.9	0.0	0.0	955.6		
2006	615.3	356.2	259.1	61.5	0.0	197.5	0.0	0.0	1,191.3		
2007	634.5	357.2	277.3	63.5	0.0	213.9	0.0	0.0	1,452.8		
2008	654.4	358.3	296.1	65.4	0.0	230.6	0.0	0.0	1,741.6		
2009	674.9	359.4	315.5	67.5	0.0	248.0	0.0	0.0	2,059.2		
2010	696.1	360.5	335.6	69.6	5.4	260.6	26.5	0.0	2,375.7	49.3	430.6
2011	718.0	361.5	356.5	71.8	10.7	274.0	27.1	0.0	2,717.7	26.6	248.6
2012	740.6	362.6	378.0	74.1	27.1	276.9	82.2	0.0	3,021.0	11.2	111.5
2013	763.9	363.7	400.2	76.4	96.9	227.0	236.8	0.0	3,132.0	3.3	34.5
2014	788.1	364.8	423.3	78.8	195.2	149.3	297.1	0.0	3,109.5	1.8	17.8
2015	813.0	365.8	447.2	81.3	275.0	90.9	309.0	0.0	3,015.8	1.3	12.6
2016	838.8	365.8	473.0	83.9	377.8	11.3	314.1	0.0	2,833.7	1.0	9.0
2017	865.3	368.0	497.3	86.5	495.6	(84.8)	257.6	0.0	2,604.6	0.8	6.5
2018	892.8	369.1	523.7	89.3	573.2	(138.8)	175.1	0.0	2,395.0	0.8	5.3
2019	921.2	370.1	551.1	92.1	638.0	(179.0)	134.7	0.0	2,177.1	0.7	4.5
2020	1,172.1	475.1	697.0	117.2	673.1	(93.3)	0.0	0.0	2,170.9	0.9	4.1
2021	1,181.9	477.8	704.1	118.2	701.9	(116.0)	0.0	0.0	2,141.7	0.8	3.9
2022	1,191.9	480.5	711.4	119.2	716.0	(123.8)	0.0	0.0	2,103.6	0.8	3.8
2023	1,201.8	483.2	718.6	120.2	679.8	(81.3)	0.0	0.0	2,106.4	0.9	4.0
2024	1,212.0	485.9	726.1	121.2	625.5	(20.6)	0.0	0.0	2,170.0	1.0	4.3
2025	1,222.2	488.6	733.6	122.2	560.9	50.4	0.0	1,807.0	500.3	1.1	5.0
2026	1,232.5	491.3	741.2	123.2	486.3	131.6	0.0	151.0	500.9	1.3	2.3
2027	1,242.8	494.0	748.8	124.3	426.0	198.5	0.0	219.0	500.4	1.5	2.6
2028	1,253.2	496.7	756.5	125.3	365.8	265.4	0.0	285.0	500.9	1.7	3.1
2029	1,263.7	499.4	764.3	126.4	305.9	332.0	0.0	353.0	500.0	2.1	3.7
2030	1,274.3	502.1	772.2	127.4	259.2	385.6	0.0	405.0	500.6	2.5	4.4
2031	1,285.1	504.8	780.3	128.5	213.8	438.0	0.0	458.0	500.5	3.0	5.4
2032	1,295.9	507.5	788.4	129.6	181.8	477.0	0.0	497.0	500.5	3.6	6.4
2033	1,306.7	510.2	796.5	130.7	145.7	520.2	0.0	540.0	500.7	4.6	8.0
2034	1,317.7	512.9	804.8	131.8	111.8	561.2	0.0	582.0	500.0	6.0	10.5
2035	1,328.8	515.6	813.2	132.9	78.7	601.6	0.0	621.0	500.6	8.6	15.0

Table A.9.6-6 (Continued)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,340.0	518.3	821.7	134.0	47.3	640.4	0.0	661.0	500.0	14.5	25.1
2037	1,351.2	521.0	830.2	135.1	23.8	671.3	0.0	691.0	500.3	29.2	50.2
2038	1,362.6	523.7	838.9	136.3	9.4	693.3	0.0	713.0	500.6	74.8	128.0
2039	1,374.0	526.4	847.6	137.4	0.0	710.2	0.0	730.0	500.9		
2040	1,385.6	529.1	856.5	138.6	0.0	717.9	0.0	738.0	500.8		
2041	1,397.3	531.7	865.6	139.7	0.0	725.8	0.0	746.0	500.7		
2042	1,408.9	534.4	874.5	140.9	0.0	733.6	0.0	754.0	500.4		
2043	1,420.8	537.1	883.7	142.1	0.0	741.6	0.0	762.0	500.0		
2044	1,432.7	539.8	892.9	143.3	0.0	749.6	0.0	769.0	500.7		
2045	1,444.7	542.5	902.2	144.5	0.0	757.8	0.0	778.0	500.5		
2046	1,456.9	545.2	911.7	145.7	0.0	766.0	0.0	786.0	500.5		
2047	1,469.2	547.9	921.3	146.9	0.0	774.4	0.0	794.0	500.8		
2048	1,481.5	550.6	930.9	148.1	0.0	782.7	0.0	803.0	500.6		
2049	1,494.0	553.3	940.7	149.4	0.0	791.3	0.0	811.0	500.9		
2050	1,506.5	556.0	950.5	150.6	0.0	799.8	0.0	820.0	500.8		
2051	1,519.2	558.7	960.5	151.9	0.0	808.6	0.0	829.0	500.4		
2052	1,532.0	561.4	970.6	153.2	0.0	817.4	0.0	837.0	500.8		
2053	1,544.8	564.1	980.7	154.5	0.0	826.2	0.0	847.0	500.1		
2054	1,557.8	566.8	991.0	155.8	0.0	835.2	0.0	855.0	500.2		
2055	1,570.8	569.5	1,001.3	157.1	0.0	844.3	0.0	864.0	500.5		
2056	1,584.0	572.2	1,011.8	158.4	0.0	853.4	0.0	874.0	500.0		
2057	1,597.4	574.9	1,022.5	159.7	0.0	862.8	0.0	882.0	500.7		
2058	1,610.8	577.6	1,033.2	161.1	0.0	872.1	0.0	892.0	500.9		
2059	1,624.3	580.3	1,044.0	162.4	0.0	881.6	0.0	902.0	500.5		
2060	1,638.0	583.0	1,055.0	163.8	0.0	891.2	0.0	911.0	500.7		
Total	71,025.3	28,888.6	42,136.7	7,102.5	9,307.6	25,726.6	1,860.1	25,967.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,039.5 million and $1,458.5 million, respectively.
2. The other data are mainly based on Table 6-11 of FFMS's Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous yea divided by total debt service requirements.

Table A.9.6-7 High Rise 150,000 DWT Culebra Cut Single Lane Alternative:
Assuming a 75% (*) Increase in Tolls after 2020 (Tolls start to Increase in 2010)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	549.5	359.4	190.1	54.9	0.0	135.1	0.0	0.0	1,404.5		
2010	576.9	360.5	216.4	57.7	4.5	154.2	22.8	0.0	1,592.1	35.3	347.4
2011	605.8	361.5	244.3	60.6	9.2	174.5	23.2	0.0	1,807.2	20.0	193.0
2012	636.3	362.6	273.7	63.6	22.5	187.5	66.8	0.0	2,000.2	9.3	89.7
2013	668.4	363.7	304.7	66.8	61.0	176.9	125.4	0.0	2,131.6	3.9	36.7
2014	702.5	364.8	337.7	70.2	117.2	150.2	156.9	0.0	2,210.2	2.3	20.5
2015	738.4	365.8	372.6	73.8	162.1	136.6	160.7	0.0	2,274.5	1.8	15.5
2016	776.3	365.8	410.5	77.6	252.7	80.1	292.8	0.0	2,152.8	1.3	10.3
2017	816.3	368.0	448.3	81.6	354.5	12.1	249.7	0.0	2,001.4	1.0	7.1
2018	858.6	369.1	489.5	85.9	420.3	(16.6)	176.0	0.0	1,888.8	1.0	5.7
2019	903.3	370.1	533.2	90.3	480.4	(37.5)	140.4	0.0	1,786.5	0.9	4.9
2020	1,172.1	475.1	697.0	117.2	502.9	76.9	0.0	1,434.0	500.8	1.2	4.7
2021	1,181.9	477.8	704.1	118.2	535.2	50.7	0.0	71.0	500.6	1.1	2.0
2022	1,191.9	480.5	711.4	119.2	555.2	37.0	0.0	57.0	500.6	1.1	2.0
2023	1,201.8	483.2	718.6	120.2	535.0	63.5	0.0	84.0	500.1	1.1	2.1
2024	1,212.0	485.9	726.1	121.2	500.6	104.3	0.0	124.0	500.4	1.2	2.2
2025	1,222.2	488.6	733.6	122.2	456.3	155.0	0.0	175.0	500.5	1.3	2.4
2026	1,232.5	491.3	741.2	123.2	397.7	220.2	0.0	240.0	500.7	1.6	2.8
2027	1,242.8	494.0	748.8	124.3	346.9	277.6	0.0	298.0	500.3	1.8	3.2
2028	1,253.2	496.7	756.5	125.3	296.3	334.9	0.0	355.0	500.3	2.1	3.8
2029	1,263.7	499.4	764.3	126.4	246.1	391.8	9.7	402.0	500.4	2.6	4.6
2030	1,274.3	502.1	772.2	127.4	210.7	434.1	13.6	440.0	500.9	3.1	5.4
2031	1,285.1	504.8	780.3	128.5	169.5	482.3	14.7	488.0	500.5	3.8	6.8
2032	1,295.9	507.5	788.4	129.6	142.2	516.6	53.0	484.0	500.1	4.6	8.2
2033	1,306.7	510.2	796.5	130.7	117.3	548.6	53.0	515.0	500.7	5.7	9.9
2034	1,317.7	512.9	804.8	131.8	95.4	577.6	0.0	598.0	500.4	7.1	12.3
2035	1,328.8	515.6	813.2	132.9	76.6	603.7	0.0	624.0	500.1	8.9	15.4

Table A.9.6-7 (Continued)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contri-bution to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,340.0	518.3	821.7	134.0	47.2	640.5	0.0	660.0	500.6	14.6	25.2
2037	1,351.2	521.0	830.2	135.1	24.6	670.5	0.0	691.0	500.1	28.3	48.6
2038	1,362.6	523.7	838.9	136.3	10.0	692.7	0.0	712.0	500.8	70.3	120.3
2039	1,374.0	526.4	847.6	137.4	0.0	710.2	0.0	731.0	500.0		
2040	1,385.6	529.1	856.5	138.6	0.0	717.9	0.0	738.0	500.0		
2041	1,397.3	531.7	865.6	139.7	0.0	725.8	0.0	745.0	500.8		
2042	1,408.9	534.4	874.5	140.9	0.0	733.6	0.0	754.0	500.5		
2043	1,420.8	537.1	883.7	142.1	0.0	741.6	0.0	762.0	500.1		
2044	1,432.7	539.8	892.9	143.3	0.0	749.6	0.0	769.0	500.8		
2045	1,444.7	542.5	902.2	144.5	0.0	757.8	0.0	778.0	500.6		
2046	1,456.9	545.2	911.7	145.7	0.0	766.0	0.0	786.0	500.6		
2047	1,469.2	547.9	921.3	146.9	0.0	774.4	0.0	795.0	500.0		
2048	1,481.5	550.6	930.9	148.1	0.0	782.7	0.0	802.0	500.7		
2049	1,494.0	553.3	940.7	149.4	0.0	791.3	3.2	808.0	500.9		
2050	1,506.5	556.0	950.5	150.6	0.0	799.8	19.7	801.0	500.0		
2051	1,519.2	558.7	960.5	151.9	0.0	808.6	19.7	808.0	500.9		
2052	1,532.0	561.4	970.6	153.2	0.0	817.4	0.0	838.0	500.3		
2053	1,544.8	564.1	980.7	154.5	0.0	826.2	0.0	846.0	500.5		
2054	1,557.8	566.8	991.0	155.8	0.0	835.2	0.0	855.0	500.7		
2055	1,570.8	569.5	1,001.3	157.1	0.0	844.3	0.0	865.0	500.0		
2056	1,584.0	572.2	1,011.8	158.4	0.0	853.4	0.0	873.0	500.5		
2057	1,597.4	574.9	1,022.5	159.7	0.0	862.8	0.0	883.0	500.3		
2058	1,610.8	577.6	1,033.2	161.1	0.0	872.1	0.0	892.0	500.4		
2059	1,624.3	580.3	1,044.0	162.4	0.0	881.6	0.0	902.0	500.0		
2060	1,638.0	583.0	1,055.0	163.8	0.0	891.2	0.0	911.0	500.2		
Total	69,623.0	28,888.6	40,734.4	6,962.3	7,150.1	26,622.0	1,601.2	26,394.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,039.5 million and $1,458.5 million, respectively.
2. The other data are mainly based on Table 15 of FFMS's Annex to Draft Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income from operations less payments to Panama plus trust fund balance of previous ye divided by total debt service requirements.

Table A.9.6-8 High Rise 200,000 DWT Culebra Cut Single Lane Alternative:
Assuming a 75% Increase in Tolls after 2020 (Tolls start to Increase in 2009)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	569.2	359.4	209.8	56.9	4.9	148.0	24.6	0.0	1,392.8		
2010	595.8	360.5	235.3	59.6	9.9	165.8	25.1	0.0	1,589.3	17.8	158.4
2011	623.8	361.5	262.3	62.4	21.8	178.1	59.4	0.0	1,771.6	9.2	82.1
2012	653.2	362.6	290.6	65.3	61.9	163.4	131.3	0.0	1,874.5	3.6	32.3
2013	684.1	363.7	320.4	68.4	121.2	130.7	179.0	0.0	1,901.3	2.1	17.5
2014	716.6	364.8	351.8	71.7	175.5	104.6	192.4	0.0	1,889.5	1.6	12.4
2015	750.8	365.8	385.0	75.1	247.3	62.6	199.7	0.0	1,828.0	1.3	8.9
2016	786.8	365.8	421.0	78.7	366.5	(24.2)	324.0	0.0	1,553.0	0.9	5.9
2017	824.6	368.0	456.6	82.5	452.8	(78.6)	256.2	0.0	1,280.3	0.8	4.3
2018	864.5	369.1	495.4	86.4	528.6	(119.7)	195.1	0.0	1,016.8	0.8	3.2
2019	906.4	370.1	536.3	90.6	568.3	(122.6)	53.2	0.0	881.7	0.8	2.6
2020	1,177.6	483.4	694.2	117.8	587.4	(11.0)	0.0	0.0	906.0	1.0	2.5
2021	1,188.5	486.1	702.4	118.9	616.5	(32.9)	0.0	0.0	909.3	0.9	2.4
2022	1,199.6	488.8	710.8	120.0	604.0	(13.2)	0.0	0.0	932.5	1.0	2.5
2023	1,210.7	491.5	719.2	121.1	574.6	23.5	9.7	483.0	500.6	1.0	2.7
2024	1,222.0	494.2	727.8	122.2	533.2	72.4	13.6	79.0	500.4	1.1	2.1
2025	1,233.3	496.9	736.4	123.3	475.7	137.4	14.7	143.0	500.1	1.3	2.3
2026	1,244.8	499.6	745.2	124.5	415.7	205.0	53.0	172.0	500.1	1.5	2.7
2027	1,256.3	502.3	754.0	125.6	358.4	270.0	53.0	237.0	500.1	1.8	3.1
2028	1,268.0	505.0	763.0	126.8	298.0	338.2	0.0	358.0	500.4	2.1	3.8
2029	1,279.7	507.7	772.0	128.0	255.6	388.5	0.0	408.0	500.8	2.5	4.5
2030	1,291.7	510.4	781.3	129.2	216.0	436.1	0.0	457.0	500.0	3.0	5.3
2031	1,303.7	513.1	790.6	130.4	183.3	476.9	0.0	496.0	500.9	3.6	6.3
2032	1,315.8	515.8	800.0	131.6	151.4	517.0	0.0	537.0	500.9	4.4	7.7
2033	1,328.0	518.5	809.5	132.8	122.3	554.4	0.0	575.0	500.4	5.5	9.6
2034	1,340.3	521.2	819.1	134.0	96.5	588.6	0.0	609.0	500.0	7.1	12.3
2035	1,352.8	523.9	828.9	135.3	74.9	618.7	0.0	638.0	500.7	9.3	15.9

Table A.9.6-8 (Continued)

(1990 US$ million)

'Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,365.4	526.6	838.8	136.5	44.5	657.8	0.0	678.0	500.5	15.8	27.0
2037	1,378.1	529.3	848.8	137.8	21.1	689.9	0.0	710.0	500.4	33.7	57.4
2038	1,390.9	532.0	858.9	139.1	5.5	714.3	0.0	734.0	500.7	130.9	221.9
2039	1,403.8	534.7	869.1	140.4	0.0	728.7	0.0	749.0	500.5		
2040	1,416.9	537.4	879.5	141.7	0.0	737.8	0.0	758.0	500.3		
2041	1,430.1	540.0	890.1	143.0	0.0	747.1	0.0	767.0	500.4		
2042	1,443.3	542.7	900.6	144.3	0.0	756.3	0.0	776.0	500.7		
2043	1,456.7	545.4	911.3	145.7	0.0	765.7	0.0	786.0	500.4		
2044	1,470.3	548.1	922.2	147.0	0.0	775.1	3.2	792.0	500.4		
2045	1,483.9	550.8	933.1	148.4	0.0	784.7	19.7	785.0	500.4		
2046	1,497.7	553.5	944.2	149.8	0.0	794.4	19.7	795.0	500.2		
2047	1,511.7	556.2	955.5	151.2	0.0	804.3	0.0	824.0	500.5		
2048	1,525.7	558.9	966.8	152.6	0.0	814.3	0.0	834.0	500.8		
2049	1,540.0	561.6	978.4	154.0	0.0	824.4	0.0	845.0	500.2		
2050	1,554.2	564.3	989.9	155.4	0.0	834.5	0.0	854.0	500.8		
2051	1,568.7	567.0	1,001.7	156.9	0.0	844.9	0.0	865.0	500.6		
2052	1,583.3	569.7	1,013.6	158.3	0.0	855.3	0.0	876.0	500.0		
2053	1,598.0	572.4	1,025.6	159.8	0.0	865.8	0.0	885.0	500.7		
2054	1,612.8	575.1	1,037.7	161.3	0.0	876.5	0.0	897.0	500.2		
2055	1,627.8	577.8	1,050.0	162.8	0.0	887.3	0.0	907.0	500.5		
2056	1,643.0	580.5	1,062.5	164.3	0.0	898.2	0.0	918.0	500.7		
2057	1,658.3	583.2	1,075.1	165.8	0.0	909.3	0.0	930.0	500.0		
2058	1,673.7	585.9	1,087.8	167.4	0.0	920.4	0.0	940.0	500.5		
2059	1,689.2	588.6	1,100.6	168.9	0.0	931.7	0.0	952.0	500.2		
2060	1,705.0	591.3	1,113.7	170.5	0.0	943.2	0.0	963.0	500.4		
Total	71,120.6	29,228.9	41,891.7	7,112.1	8,193.3	26,586.3	1,826.4	26,012.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,045 million and $1,525.5 million, respectively.
2. The other data are mainly based on Table 21 of FFMS's Annex to Draft Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income from operations less payments to Panama plus trust fund balance of previous ye divided by total debt service requirements.

Table A.9.6-9 High Rise 150,000 DWT Alternative:
Assuming a 75% Increase in Tolls after 2020 (Tolls start to Increase in 2010)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2000	501.7	349.7	152.0	50.2	0.0	101.9	0.0	0.0	101.9		
2001	506.8	350.8	156.0	50.7	0.0	105.3	0.0	0.0	211.2		
2002	512.0	351.9	160.1	51.2	0.0	108.9	0.0	0.0	328.6		
2003	517.1	353.0	164.1	51.7	0.0	112.4	0.0	0.0	454.1		
2004	522.3	354.0	168.3	52.2	0.0	116.1	0.0	0.0	588.4		
2005	527.7	355.1	172.6	52.8	0.0	119.9	0.0	0.0	731.8		
2006	533.0	356.2	176.8	53.3	0.0	123.5	0.0	0.0	884.6		
2007	538.5	357.2	181.3	53.8	0.0	127.4	0.0	0.0	1,047.4		
2008	544.0	358.3	185.7	54.4	0.0	131.3	0.0	0.0	1,220.6		
2009	549.5	359.4	190.1	54.9	0.0	135.1	0.0	0.0	1,404.5		
2010	576.9	360.5	216.4	57.7	5.4	153.3	26.5	0.0	1,587.5	29.4	289.5
2011	605.8	361.5	244.3	60.6	10.7	173.0	27.1	0.0	1,796.9	17.2	165.5
2012	636.3	362.6	273.7	63.6	27.1	182.9	82.2	0.0	1,969.5	7.8	74.1
2013	668.4	363.7	304.7	66.8	96.9	141.0	236.8	0.0	1,952.5	2.5	22.8
2014	702.5	364.8	337.7	70.2	195.2	72.2	297.1	0.0	1,805.7	1.4	11.4
2015	738.4	365.8	372.6	73.8	275.0	23.7	309.0	0.0	1,592.6	1.1	7.7
2016	776.3	365.8	410.5	77.6	377.8	(45.0)	314.1	0.0	1,297.3	0.9	5.1
2017	816.3	368.0	448.3	81.6	495.6	(129.0)	257.6	0.0	962.7	0.7	3.4
2018	858.6	369.1	489.5	85.9	573.2	(169.5)	175.1	0.0	656.6	0.7	2.4
2019	903.3	370.1	533.2	90.3	638.0	(195.1)	134.7	0.0	353.0	0.7	1.7
2020	1,172.1	475.1	697.0	117.2	673.1	(93.3)	0.0	0.0	273.8	0.9	1.4
2021	1,181.9	477.8	704.1	118.2	701.9	(116.0)	0.0	0.0	168.8	0.8	1.2
2022	1,191.9	480.5	711.4	119.2	716.0	(123.8)	0.0	0.0	51.7	0.8	1.1
2023	1,201.8	483.2	718.6	120.2	679.8	(81.3)	0.0	0.0	(27.5)	0.9	1.0
2024	1,212.0	485.9	726.1	121.2	625.5	(20.6)	0.0	0.0	(49.2)	1.0	0.9
2025	1,222.2	488.6	733.6	122.2	560.9	50.4	0.0	0.0	(0.8)	1.1	1.0
2026	1,232.5	491.3	741.2	123.2	486.3	131.6	0.0	0.0	130.8	1.3	1.3
2027	1,242.8	494.0	748.8	124.3	426.0	198.5	0.0	0.0	334.6	1.5	1.8
2028	1,253.2	496.7	756.5	125.3	365.8	265.4	0.0	113.0	500.4	1.7	2.6
2029	1,263.7	499.4	764.3	126.4	305.9	332.0	0.0	352.0	500.4	2.1	3.7
2030	1,274.3	502.1	772.2	127.4	259.2	385.6	0.0	406.0	500.0	2.5	4.4
2031	1,285.1	504.8	780.3	128.5	213.8	438.0	0.0	458.0	500.0	3.0	5.4
2032	1,295.9	507.5	788.4	129.6	181.8	477.0	0.0	497.0	500.0	3.6	6.4
2033	1,306.7	510.2	796.5	130.7	145.7	520.2	0.0	540.0	500.1	4.6	8.0
2034	1,317.7	512.9	804.8	131.8	111.8	561.2	0.0	581.0	500.4	6.0	10.5
2035	1,328.8	515.6	813.2	132.9	78.7	601.6	0.0	622.0	500.0	8.6	15.0

Table A.9.6-9 (Continued)

(1990 US$ million)

Year	Revenue	O&M Cost	Net Income fr. Ope.	Pay. to Panama	Debt Serv Req.	Net Income	Contribut to CapEx	Dividend Distribut	Tr. Fund Balance	Current DSCR	Overall DSCR
2036	1,340.0	518.3	821.7	134.0	47.3	640.4	0.0	660.0	500.4	14.5	25.1
2037	1,351.2	521.0	830.2	135.1	23.8	671.3	0.0	691.0	500.7	29.2	50.2
2038	1,362.6	523.7	838.9	136.3	9.4	693.3	0.0	714.0	500.0	74.8	128.0
2039	1,374.0	526.4	847.6	137.4	0.0	710.2	0.0	730.0	500.2		
2040	1,385.6	529.1	856.5	138.6	0.0	717.9	0.0	738.0	500.2		
2041	1,397.3	531.7	865.6	139.7	0.0	725.8	0.0	746.0	500.1		
2042	1,408.9	534.4	874.5	140.9	0.0	733.6	0.0	753.0	500.7		
2043	1,420.8	537.1	883.7	142.1	0.0	741.6	0.0	762.0	500.3		
2044	1,432.7	539.8	892.9	143.3	0.0	749.6	0.0	770.0	500.0		
2045	1,444.7	542.5	902.2	144.5	0.0	757.8	0.0	777.0	500.8		
2046	1,456.9	545.2	911.7	145.7	0.0	766.0	0.0	786.0	500.8		
2047	1,469.2	547.9	921.3	146.9	0.0	774.4	0.0	795.0	500.2		
2048	1,481.5	550.6	930.9	148.1	0.0	782.7	0.0	802.0	500.9		
2049	1,494.0	553.3	940.7	149.4	0.0	791.3	0.0	812.0	500.3		
2050	1,506.5	556.0	950.5	150.6	0.0	799.8	0.0	820.0	500.1		
2051	1,519.2	558.7	960.5	151.9	0.0	808.6	0.0	828.0	500.7		
2052	1,532.0	561.4	970.6	153.2	0.0	817.4	0.0	838.0	500.1		
2053	1,544.8	564.1	980.7	154.5	0.0	826.2	0.0	846.0	500.3		
2054	1,557.8	566.8	991.0	155.8	0.0	835.2	0.0	855.0	500.5		
2055	1,570.8	569.5	1,001.3	157.1	0.0	844.3	0.0	864.0	500.8		
2056	1,584.0	572.2	1,011.8	158.4	0.0	853.4	0.0	874.0	500.2		
2057	1,597.4	574.9	1,022.5	159.7	0.0	862.8	0.0	883.0	500.0		
2058	1,610.8	577.6	1,033.2	161.1	0.0	872.1	0.0	892.0	500.1		
2059	1,624.3	580.3	1,044.0	162.4	0.0	881.6	0.0	901.0	500.7		
2060	1,638.0	583.0	1,055.0	163.8	0.0	891.2	0.0	912.0	500.0		
Total	69,623.0	28,888.6	40,734.4	6,962.3	9,307.6	24,464.5	1,860.1	23,618.0			

Note:
1. "75% toll increase scenario" is roughly estimated based on the average of "50% toll increase scenario" and "optimal toll system scenario", at this time. The revenues in 2020 and 2060 are $1,039.5 million and $1,458.5 million, respectively.
2. The other data are mainly based on Table 6-11 of FFMS's Final Report.
3. Slight difference with FFMS data exists.
4. Overall DSCR is net income from operations less payment to Panama plus trust fund balance of previous year divided by total debt service requirements.

Issue: 1
7 Oct. 1993

A FEASIBILITY REPORT
(FA/FR COMPONENT STUDY)
SINBOL
LIST OF CORRECTIONS

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
Cover letter	Paragraph 2, line 4/correct spelling: "vigorous"	Err.
Abstract - 3	Line 13/spelling: permanent	Err.
Preface iv	First title/add: "AREA" after COASTAL	Err.
Contents iv	Line 12/Drop 4th order subhead: "5.5.3.7 Optimization of Conceptual Alternatives"	Err.
Acronyms -1	Add the following: CB Container - Breakbulk Ships CD Combined and Dry Bulk Carriers CG Conventional General Cargo Ships CT Chemical Tankers FC Full Container Ships	Add
Acronyms -2	Add the following: LP Liquid Petroleum Ships PCA Panama Canal Authority RE Refrigerated Cargo Ships RR Roll-on Roll-off Ships	Add
Acronyms -3	Add the following: OT Oil Tankers O-D Origin - Destination Routes SPC Special Purpose Corporation VC Vehicle Carriers	Add
1-8	First line/change location of heading: "1.2.1 Preliminary Studies, Prescreening and Selection of Alternatives" to follow second paragraph on page 1-8	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
1-10	Bottom line/delete Table 1.3-1 and relocate to top of page 1-11	Err.
1-11	Heading/identify Table 1.3-1	Err.
1-11	Page no./re-number: 1-12	Err.
1-12	Page no./re-number: 1-11	Err.
1-14	Last par., line 6/change: "desegrated" to disaggregated	Err.
1-17	First line/change: "desegrated" to disaggregated	Err.
1-20	Figure 1.4.2-1/Delete Figure (same information given on Fig. 1.4.2-4)	Err.
1-23	Par. 2, Line 7/correct to read: "As shown in Table 1.4.2-4, $237 to $931 million..."	Err.
1-30	Par. 2/correct to read: "...Initial excavation for the present Panama Canal was 237 million cubic meters."	Err.
1-34	Par. 6, line 2/delete the sentence: "Freshwater physical and chemical parameters were measured throughout the study area."	Err.
1-40	Par. 4, line 2/change "area" to areas	Err.
1-41	Last par., line 2/correct spelling: through	Err.
1-43	Par 1, line 2/word correction: "...direct benefits were estimated for each design ship..."	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
1-45	Table 1.4.5-5/add a footnote below Table: "The economic costs of Case 1, 1-a, 2 and 2-a are based upon required water augmentation schemes for a dry year design condition."	Err.
1-45	Last Par./add: "...single lane Atlantic Approach (case 4a)."	Err.
1-46	Table 1.4.5-6, Case 1/change B/C ratio: from "1.60" to "1.65"	Err.
1-46	Table 1.4.5-6, Case 3a/change benefits from "13,140" to "13,146"	Err.
1-54	Par. 1/correct to read: "For the period 2000 through 2019, toll revenues..."	Err.
1-55	Line 22/correct to read: "None of the six alternatives in the FFMS study are..."	Err.
1-55	Last two paragraphs/combine into a single paragraph	Err.
1-56	Note at bottom of Table/correct source to read: "Tables 6-7 through 6-24 and appendix J in Final Report of FFMS study." and "Tables 11 through 28 and Table 30 in Annex to the Draft Final Report for the FFMS study."	Err.
1-58	Line 1/change to read: "Acceptance of impacts upon..."	Err.
1-58	Line 18/change sentence to read: "Evaluation of the impacts..."	Err.
1-60	Table 1.4.1-2/change title to: "Protection of World Fleet Composition by Vessel Size and Type"	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
1-62	List of Figures and sources/correct the following Figure Numbers: 1.4.2-1 becomes 1.4.2-3 1.4.2-2 becomes 1.4.2-1 1.4.2-3 becomes 1.4.2-2	Err.
4-15	Dates on two maps/add typed captions: "1962" (for map on the left), and "1984" (for the map on the right).	Err.
4-18	New insert after first paragraph/(Entire discussion of Marine Environment is missing from the Background Biological Study section). Insert just before Section 4.3.2 "Marine Environment" and note new pages 4-18.1 to 4-18.2.	Err. and Pages Insert
4-19 thru 4-22	All genus and species names to be italicized: (Examples include: *Aedomyia*, *Aedes*, *Hydrilla*, etc.)	Err.
4-22	Third paragraph, first line/word corrections: "...Pacific study area are small (less.."	Err.
4-24	Paragraph 6, first line/word correction: should be "...occurred as follows: the..."	Err.
5-30	Second Paragraph, Last sentence/change "...have been briefly...", to "...are briefly..."	Err.
5-33	Third bullet/change: "...across the complete Isthmus...": to read "...across the Isthmus..."	Err.
5-41	Third paragraph, fourth line/change "Change River" to "Chagres River"	Err.
5-48	Second Paragraph, last sentence/change "Figures 5.4.3.3" and Figure 5.4.3.4 " to read Figure 5.4.3-3 and Figure 5.4.3-4	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
5-54	Table 5.4.3-1/revise to include entry of the following two lines: Design Ship Size (1,000 dwt) Available lockage Water (mcm)	Replace pg. 5-54 rev. 1
5-57	Table 5.4.3-2/revise to include footnote numbers	Replace pg. 5-57 rev. 1
5-64	First paragraph, line 15/change last part to read: "20 years, increasing with both ship size and number of lanes."	Err.
5-69	Section 5.5.1, fifth line/change to read "...was to select at least two conceptual alternatives..."	Err.
5-80	Entire page/material same as on page 5-79: omit page	Err.
5-88	First line/omit number "5.5.3.7" and italicize *Optimization of Conceptual Alternatives*	Err.
5-88	Second paragraph/add at end of paragraph: "in Figures 5.5.3-2 to 5.5.3-5."	Err.
5-103	Table 5.5.3-7/change title to read: "Incremental Cargo Flow Proportions"	Err.
5-103	Table 5.5.3-9/change title to read: "Net Benefits and Benefit Cost Ratios"	Err.
5-103	Table 5.5.3-10/change title to read: "Optimum Scale of Canal and B/C Ratio"	Err.
5-104	Figure no. 5.4.3-2/change to read: "5.4.3-1"	Err.
5-104	Figure no. 5.4.3-3/change to read: "5.4.3-2"	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
5-104	Figure no. 5.4.3-4/change to read: "5.4.3-3"	Err.
5-104	Figure no. 5.4.3-5/change to read: "5.4.3-4"	Err.
5-104	Figure no. 5.4.3-6/change to read: "5.4.3-5"	Err.
5-104	Figure no. 5.4.3-7/change to read: "5.4.3-6"	Err.
6-43	Table heading/change table number from: "6.2.3-6" to 6.2.3-7	Err.
6-64	Line 25/change to read: "...are appended as Appendix 6-C, but the..."	Err.
6-85	Table 6.3.1-3, first Column and second row/the word "tan" should read "than"	Err.
6-89	Fourth bullet, first line/omit "a" to read: "...determination of suitable transportation needs..."	Err.
6-119	Table 6.3.6-2, bottom page under note/delete: "(see Chapter 7.5)"	Err.
6-144	Section 6.3.8, item (4), second line/change to read: "...will occur and are not..."	Err.
6-157	Figure 6.4.301/add title to the bottom Chart to read: "Excavation volume for Each zone - SLC case (e)"	Err.
Appendices 6-A 6-B 6-C	Following page 6-176/ insert new title page and pages 6A-1 to 6A-10 insert new title page and pages 6B-1 to 6B-4 insert new title page and pages 6C-1 to 6C-3	Add

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
7-22	Table 7.1.7-1/correct the following values for B/C: Case B/C 2 1.48 2-a 1.63 Also delete the benefit "13,129" for Case 5	Err.
7-81	Table 7.4.2-5/replace table: Insert page 7-85 rev.1 in place of page 7-85	Replace
7-90	Table 7.5.2-2 Heading/change title to read: "Induced Trade Value Due To Transport Cost Savings From Canal Alternatives (year 2020) Unit: Thousands US $"	Err.
7-91	Line 16/change sentence to read: "The figure below illustrates how direct income was estimated."	Err.
7-97	First line/delete heading "Impacts of High Rise Locks Canal"	Err.
7-97	Sixth Paragraph/should be bulleted: "● The general construction and excavation..."	Err.
7-98	After the third bulleted item/insert the title: "B. Sea Level Canal"	Err.
7-100	Fourth bulleted item/second line - missing text: "...consideration for the selected Alternative. This would include extensive marine biological..."	Err.
7-104	Insert missing Table reference/Table 7.4.2-6 Structures to be Affected with the SLC Alternative	Add
7-104	Table 7.5.4-1/change title to read: "Induced Income and Multiplier Effect...."	Err.

PAGE	LOCATION/CORRECTION	ERRATA OR PAGE REPLACED
8-36	Table 8.3.3-2/add title: Conditions for Sensitivity Analysis	Err.
8-38	Table 8.3.3.4.7/change to: Table 8.3.3-7	Err.
8-56	Table 8.1/change to: Table 8.1-1	Err.
8-57	Table 8.2.3-15/change title to read: "Transit Projection for..."	Err.
8-57	Table 8.3.3-3/change title to read: "Total Benefits in 2010"	Err.
8-57	Table 8.3.3-4/change title to read: "Total Costs in 2010"	Err.
8-58	Line 15/add table: 8.3.4-2 Financial Analysis Assuming an Optimal Toll System, Sea Level Canal, Case E	Add
9-13	Figure 9.6.1-1/add the following title: "Optimal Toll Scenario"	Err.
9-13	Figure 9.6.1-2/add the following title: "Marginal Toll Scenario"	Err.
9-13	Figure 9.6.1-3/add the following title: "User - Oriented Toll Scenario"	Err.

MARINE ENVIRONMENT

Oceanography and Water Quality

In the Caribbean littoral currents move from west to east along this coast throughout the year. Average tide fluctuation is 0.3m (1 ft). The dry season (December to April) is characterized by high solar radiation, strong northerly trade winds, lower air and water temperatures and higher salinity. The rainy season has more cloud cover, light winds, higher temperatures and lower salinity. Studies of Limon and Manjanillo Bays have shown areas of high bacterial contamination, due to the sewage outfalls in the area.

On the Pacific side there is an intricate system of currents within the Gulf of Panama, dominated by the east-west Equatorial countercurrent. There are two tidal cycles per day with the average tidal range being 6 m (19.7 ft). The oceanographic day characteristic that distinguishes this area of the Pacific from the Caribbean coastal Study Area, is the presence of a seasonal upswelling. During the dry season (December through April), the northerly trade winds push the warmer surface waters southward, away from the coast. These waters are replace by colder, oxygen and nutrient-rich waters from depth of 75-150 m. This phenomenon affects many water quality parameters as well as the biological productivity of the waters of the Bay of Panama.

There are a number of sewage outfalls in the vicinity of the Canal Entrance. Major bacterial contaminants come from the mouth of the Curundu River, La Boca, and Amador boardwalk sector of Balboa. Considerable hydrocarbon pollution has been found around the docks at Balboa.

Predominant Species

There are 50 species of corals that have been identified on the Caribbean coast of Panama. Environmental stress has reduced some areas of coral coverage within the vicinity of the Canal as well as declines in species diversity. In Las Minas Bay, average live coverage was reduced from 25% to 12% following a petroleum spill in 1986. Sedimentation has also resulted in a 9% decrease in coral coverage in other areas in the vicinity.

In the Pacific side coral reefs in the Gulf of Panama are limited to small, isolated patches with some small natural coral communities off Taboga and Taboguilla islands. The coralivorous crown of thorns starfish is common in the reef in the Gulf of Chiriqui. If unchecked, this species can destroy up to 47% of coral coverage in a 20 hectare reef within 4 months. In this area of Panama, it is kept under control by crustacean species living within the reef.

Panama has the most extensive mangrove areas of any Central American country. Mangroves play important ecological and economic roles. They perform shoreline stabilization and land expansion functions, and are vital nursery and habitat areas for many marine species, including most important commercial species on the Pacific coast of Panama. The presence of a species in a particular location in an estuary is due to a defined zonation, controlled by tides, salinity of soil and water, soil quality and permeability, rainfall and water flow. The most extensive system of mangrove on the Caribbean coast of Panama is located between the Canal entrance and Maria Chiquita. There are 34 plant and animal species of commercial importance that are currently extracted from mangrove areas in Colon. Commercial development in Las Minas Bay has resulted in considerable reduction in mangroves in this area over the last 15 years.

There have been 48 invertebrate species identified from beaches on both coasts of Panama and 775 invertebrate species have been identified in association with coral reefs in the Caribbean. The sandy beaches on the Pacific are

more productive than those on the Caribbean coast of Panama, with three times the diversity and nine times the biomass.

A total of 148 species of decapods have been identified from rock shoreline habitats on both coasts of Panama. The Pacific coast contains greater invertebrate densities in the high and medium tidal zones, while on the Caribbean coast densities are lower. The low tidal zone on the Pacific is dominated by filamentous algae, bryozoans, and hydroids, while the Caribbean is dominated by a wide variety of macro algae.

There are a total of nine seagrass species that have been identified from both coasts of Panama: five from the Pacific and four from the Caribbean. There is very little information available about seagrass in the Pacific coast of the Study Area. Seagrass beds are more abundant in the Caribbean coast. They are found mainly in lagoons and mangrove swamps.

Both the Pacific and Caribbean fish populations have been widely studied and reported, but few studies are directly relevant to the Study Area. A total of 26 species have been collected form estuaries in the Caribbean and 63 estuarine species in the Pacific.

Sport and commercial fishing takes place on both coasts, but is more extensive in the Pacific. There are 206 commercially important marine species on both coasts of Panama, including 152 finfish. The most commercially significant finfish are anchovies and herring. Of importance to artesanal fishing are the snappers, mackerels, jacks, and croakers. There are two marine mammal species within the Study Area, the bottle nose and the speckled dolphin. Both are protected under international fishing agreements. Marine reptiles include the baula and hawksbill turtles which have been reported from the Caribbean in the vicinity of the Canal. Both are protected by law in Panama. The highly poisonous sea snake is found in the Bay of Panama, and does not occur naturally in the Caribbean.

Table 5.4.3-1

Annual Lockage Water and Water Balance Table

(Based on YEC Final Report - Phase I)

Case N°.		L-12	L-15	L-18	L-3, 11	L-6, 14	L-9, 17	L-2, 10	L-2'	L-5, 13	L-8, 16	L-1	L-4	L-7
Design Water Level (Ft)		30	30	30	55	55	55	85	85	85	85	90	90	90
Design Ship Size (1000 dwt)		100	150	250	100	150	250	100	100	150	250	100	150	250
Available Lockage Water (MCM)		5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500	5,500
+ 10,000	Transits lockage water (MCM)	5,685	6,485	7,805	7,965	9,505	11,965	6,825	10,695	8,015	9,915	7,045	8,305	10,315
	Water shortage (MCM)	185	985	2,305	2,465	4,005	6,465	1,325	5,195	2,515	4,415	1,545	2,805	4,815
	Water release from new dam (MCM)	0	0	0	0	0	0	273	297	229	376	245	235	279
	Water pumping (MCM)	185	985	2,305	2,465	4,005	6,465	1,052	4,898	2,286	4,039	1,300	2,570	4,536
	Pump capacity (CU.M/SEC) without new dam	10	30	70	70	120	200	30	150	70	120	40	80	140
	Sets of pump stations	1	1	2	2	2	4	1	3	2	2	1	2	3
	Pump capacity (CU.M/SEC) without new dam	10	30	70	70	120	200	60	180	90	150	60	100	170
	Sets of pump stations	1	1	2	2	2	4	1	3	2	3	1	2	3
+ 20,000	Transits lockage water (MCM)	11,885	13,545	17,305	17,985	22,605	29,985	14,565	26,175	18,135	23,835	15,225	19,005	25,035
	Water shortage (MCM)	5,585	8,045	8,045	12,485	17,105	24,485	9,065	20,675	12,635	18,335	9,725	13,505	19,535
	Water release from new dam (MCM)	0	0	0	0	0	0	373	339	262	268	251	247	256
	Water pumping (MCM)	5,585	8,045	8,045	14,485	17,105	24,485	8,692	20,336	12,373	18,067	9,474	13,258	19,276
	Pump capacity (CU.M/SEC) without new dam	180	250	380	380	540	770	270	640	390	570	300	420	610
	Sets of pump stations	3	3	7	7	9	13	5	11	7	10	5	7	11
	Pump capacity (CU.M/SEC) without new dam	180	250	380	380	540	770	300	670	410	600	320	440	630
	Sets of pump stations	3	3	7	7	9	13	6	7	7	10	6	8	11
Actual pump head (meters)		(9.0)			(16.7)			(25.8)				(27.3)		

Note:
1) Lockage water includes the water for existing 15,000 transits.
2) Design water level 30' - 50' cases have barrier dams.
3) New dam capacity is shown in AFI-9 (Water balance simulation).
4) Pump capacity (1 set) = 60 cu.m/sec

Table 5.4.3-2

Comparison of Gate Types for Lock Gates

(Based on YEC Final Report - Phase I)

Movement	Direction of Movement	N°.[1]	Structural Type	Function		Initial Cost	Maintenance Cost			Hoist Load		
				Chamber L[2] Efficiency	Stab. Against Propulsion[3]		Sand & Sk	Removal & Reset	Mecha-nical Part	Friction	Grav. El. Change[4]	Hydr. Inert.[5]
Rotation	Vertical	2	Radial	O	O	●	O	X	▲	O	O	O
		3	Miter	O	▲	O	▲	O	O	O	O	▲
	Horizontal	4	Torsional	X								
		5	Bending	X								
		6	Radial	X								
Linear	Vertical	9+	Slide[6]	O	O	●	▲	O	O	▲	X	O
		11	Torsional									
	Horizontal	10	Triangle	X								
		11	Torsional	O	O	●	●	O	O	▲	O	O

Note:
1. N°. corresponds to N°. of sketches on Fig 4.6.3 YEC Report
2. Chamber L Efficiency = Effective chamber length for lockage over actual chamber lengths. The effective chamber length = actual chamber length - the chamber length which cannot be used for lockage because of existence of a lock gate.
3. Stab. against propulsion = Stability of gate leaf supports against ship propulsion brows.
4. Grav. El. Change = Gravity center elevation change of a gate leaf. X means that there is the change during leaf operations.
5. Hydro. Inert. = Hydraulic inertia force. ▲ means that hydraulic inertia force will act on leaf skins during leaf operations.
6. Slide (drop) is a gate type corresponding to N°. 9 in YEC Report (Fig. 4.6.2), except that slide shoes replace rollers and the gate leaf is a torsional type instead of bending.
7. ~~Elevation~~ Evaluation Marks: X = Not acceptable ▲ = Just acceptable level O = Acceptable without conditions ● = Strongly recommendable

Shows results of quantitative studies

APPENDIX 6 - A

PANAMA CANAL SIMULATIONS

Observations on WAM Outputs for Each Case

Case 2 - High Rise, Single Lane Locks, 150K DWT (Water Use) 24,200 Ships

Results are very similar to the Case 2 run at lower traffic.

Travel time across routes is nearly equalized, ranging from 9.2 to 10.2 hours.

Utilization levels at Gatun and the new locks are 86 to 89 percent, with average delay of 0.9 to 1.1 hours.

Relay operations are used very little (maximum of 15 percent at Gatun, Lane 1).

Case 4 - High Rise, Single Lane Locks, 200K DWT (Water use) 24,000 Ships

Compare with Case 2.

Movement time nearly same as Case 2.

Lockage utilization and delay at the new locks are slightly lower, due to larger chamber size.

Travel time variability across routes similar to Case 2.

Case 8 - Sea Level, Tide Gates and Status Quo (Water Use) 24,254 Ships

Results are very similar to the low traffic run for Case 8.

Average transit time for status quo is about 1.5 hours longer than for sea-level canal.

Case 8A - Sea Level, Tide Gates,
Single Lane Approach and Status Quo 36,824 Ships

This is an approximate simulation of the proposed system.

The results for the half-cycle case are summarized here.

Results are similar to Case 8, in that about 40% of ships choose the status quo. However, traffic level are much lower for a given transit time, due to the constraining effect of the 15.5 km single lane approach channel.

Spread of travel times is slightly greater than in Case 8 at low and medium traffic levels, and markedly greater at the high traffic level.
The approximate full cycle simulation produces a better traffic and transit time balance.

Case 9B - Sea Level, 1 Tidal Lock and Status Quo 28,466 Ships

Results are very similar to Case 9 at the low traffic level, but differ markedly thereafter.

As in Case 9, only 13% of the ships go to the sea level canal at low traffic; most of these are the ships too large for the status quo.

Sea level canal use rises to only 37% at high traffic, which is the lowest use level of any of the sea-level canal alternatives.

The single lane tidal lock is clearly the controlling element, rather than the delay due to convoy operations. Consequently, transit times for the routes (sea-level and status quo) are nearly equal at the high traffic level.

PANAMA CANAL SIMULATION
CASE 1 - STATUS QUO - 65,000 DWT - 2020

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	505	3.54	2.10	1.42	7.06	2.31	0.00	2.31	9.37
2	2,140	4.00	2.04	1.58	7.62	4.03	0.00	4.03	11.64
3	4,962	4.62	2.14	1.79	8.55	3.92	0.00	3.92	12.47
4	352	3.88	2.53	1.53	7.93	4.06	0.00	4.06	11.99
5	1,676	4.74	2.56	1.85	9.15	3.92	0.00	3.92	13.07
6	151	4.04	2.69	1.58	8.31	4.04	0.00	4.04	12.35
7	1,623	5.15	2.83	1.99	9.96	3.83	0.00	3.83	13.79
8	47	4.85	3.40	1.88	10.12	4.25	0.00	4.25	14.37
9	376	3.71	2.84	1.47	8.02	3.96	0.00	3.96	11.98
10	242	4.35	3.47	1.71	9.53	4.01	0.00	4.01	13.54
11	1,997	4.93	4.02	1.91	10.86	3.78	0.00	3.78	14.64
12	627	4.85	4.70	1.88	11.43	3.48	0.00	3.48	14.92
13	223	4.13	2.46	1.61	8.20	4.02	0.00	4.02	12.22
	14,921	4.56	2.67	1.78	9.00	3.84	0.00	3.84	12.84

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	577	3.54	2.07	1.42	7.04	4.76	0.00	4.76	11.79
2	2,418	4.00	1.97	1.58	7.55	9.49	0.00	9.49	17.05
3	5,603	4.62	2.06	1.79	8.47	9.44	0.00	9.44	17.91
4	400	3.88	2.44	1.54	7.85	9.62	0.00	9.62	17.47
5	1,895	4.74	2.52	1.85	9.11	9.59	0.00	9.59	18.70
6	172	4.04	2.53	1.57	8.14	9.20	0.00	9.20	17.34
7	1,830	5.15	2.75	1.99	9.89	9.09	0.00	9.09	18.98
8	54	4.84	3.23	1.88	9.95	8.17	0.00	8.17	18.12
9	425	3.70	2.79	1.47	7.96	9.11	0.00	9.11	17.07
10	269	4.35	3.34	1.71	9.40	9.75	0.00	9.75	19.15
11	2,249	4.93	3.91	1.91	10.75	9.15	0.00	9.15	19.90
12	706	4.85	4.52	1.88	11.25	9.11	0.00	9.11	20.37
13	255	4.13	2.37	1.62	8.12	10.11	0.00	10.11	18.23
	16,853	4.56	2.59	1.78	8.92	9.22	0.00	9.22	18.14

PANAMA CANAL SIMULATION
CASE 1A - PCC SHIP MIX - 65,000 DWT - 2010

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	272	3.54	2.08	1.41	7.03	1.16	0.00	1.16	8.19
2	1,144	4.00	2.10	1.57	7.68	1.18	0.00	1.18	8.85
3	2,667	4.62	2.19	1.79	8.60	1.24	0.00	1.24	9.84
4	192	3.88	2.58	1.53	7.99	1.31	0.00	1.31	9.30
5	905	4.75	2.58	1.85	9.18	1.25	0.00	1.25	10.43
6	98	4.04	2.70	1.57	8.30	1.38	0.00	1.38	9.69
7	1,044	5.15	2.91	1.98	10.04	1.19	0.00	1.19	11.22
8	30	4.84	3.33	1.88	10.06	0.98	0.00	0.98	11.04
9	397	3.71	2.87	1.46	8.04	1.28	0.00	1.28	9.32
10	251	4.35	3.47	1.71	9.52	1.17	0.00	1.17	10.69
11	2,087	4.93	4.09	1.91	10.92	1.13	0.00	1.13	12.05
12	654	4.85	4.76	1.88	11.49	1.13	0.00	1.13	12.62
13	144	4.13	2.51	1.61	8.24	1.08	0.00	1.08	9.32
	9,885	4.60	2.94	1.79	9.32	1.20	0.00	1.20	10.52

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	109	3.53	2.05	1.42	7.00	7.70	0.00	7.70	14.70
2	442	4.01	1.93	1.59	7.53	16.11	0.00	16.11	23.64
3	1,073	4.62	2.04	1.80	8.46	15.96	0.00	15.96	24.42
4	66	3.90	2.45	1.55	7.89	14.39	0.00	14.39	22.28
5	359	4.70	2.49	1.83	9.03	15.96	0.00	15.96	24.98
6	40	4.09	2.48	1.59	8.15	15.19	0.00	15.19	23.34
7	411	5.13	2.70	1.98	9.81	17.14	0.00	17.14	26.95
8	11	4.97	3.38	1.94	10.28	15.02	0.00	15.02	25.30
9	160	3.71	2.73	1.48	7.92	16.40	0.00	16.40	24.32
10	96	4.37	3.35	1.72	9.45	15.88	0.00	15.88	25.33
11	820	4.92	3.94	1.91	10.76	15.63	0.00	15.63	26.39
12	276	4.83	4.52	1.87	11.22	15.64	0.00	15.64	26.86
13	57	4.17	2.36	1.62	8.16	15.76	0.00	15.76	23.92
	3,920*	4.59	2.79	1.79	9.17	15.76	0.00	15.76	24.93

* 92 days of ships.

PANAMA CANAL SIMULATION
CASE 2 - HIGH-RISE - 150,000 DWT - 2060

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	896	3.06	1.79	1.28	6.14	1.34	0.00	1.34	7.48
2	1,936	3.47	1.75	1.45	6.67	1.69	0.00	1.69	8.36
3	9,848	4.07	1.82	1.68	7.57	1.69	0.00	1.69	9.26
4	112	3.55	2.05	1.46	7.06	1.92	0.00	1.92	8.98
5	253	4.01	2.12	1.63	7.76	1.65	0.00	1.65	9.41
6	507	3.65	2.18	1.51	7.35	1.77	0.00	1.77	9.12
7	1,199	4.58	2.25	1.88	8.71	1.68	0.00	1.68	10.39
8	2,790	4.17	2.53	1.71	8.41	1.79	0.00	1.79	10.20
9	409	3.29	2.25	1.39	6.93	1.83	0.00	1.83	8.76
10	373	3.73	2.63	1.54	7.90	1.93	0.00	1.93	9.83
11	123	4.07	2.87	1.70	8.64	2.03	0.00	2.03	10.67
12	2,515	4.30	3.41	1.76	9.47	1.72	0.00	1.72	11.18
13	336	3.66	2.04	1.53	7.24	1.64	0.00	1.64	8.88
15	183	4.03	1.69	1.96	7.68	2.65	0.00	2.65	10.33
16	1,344	4.63	1.72	2.28	8.63	2.30	0.00	2.30	10.93
17	107	4.61	1.75	2.20	8.56	2.45	0.00	2.45	11.02
18	695	4.87	2.06	2.42	9.35	2.18	0.00	2.18	11.52
	23,626	4.07	2.13	1.71	7.91	1.76	0.00	1.76	9.67

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	318	3.04	1.81	1.29	6.15	3.88	0.00	3.88	10.03
2	667	3.53	1.67	1.46	6.66	8.22	0.00	8.22	14.88
3	3,640	4.11	1.75	1.67	7.53	8.62	0.00	8.62	16.15
4	41	3.49	1.91	1.48	6.87	8.31	0.00	8.31	15.19
5	106	4.02	2.02	1.62	7.67	8.75	0.00	8.75	16.42
6	168	3.69	2.05	1.52	7.27	9.16	0.00	9.16	16.42
7	413	4.62	2.17	1.86	8.65	9.04	0.00	9.04	17.69
8	977	4.21	2.45	1.71	8.37	8.97	0.00	8.97	17.33
9	148	3.33	2.15	1.41	6.89	9.30	0.00	9.30	16.18
10	121	3.80	2.52	1.54	7.86	8.55	0.00	8.55	16.41
11	44	4.06	2.73	1.69	8.48	10.27	0.00	10.27	18.74
12	887	4.33	3.26	1.75	9.34	8.96	0.00	8.96	18.30
13	128	3.67	1.93	1.53	7.13	8.40	0.00	8.40	15.53
15	63	4.05	1.58	1.97	7.61	8.71	0.00	8.71	16.31
16	490	4.63	1.57	2.28	8.47	8.85	0.00	8.85	17.32
17	47	4.62	1.65	2.21	8.48	8.04	0.00	8.04	16.52
18	259	4.87	1.82	2.42	9.11	8.95	0.00	8.95	18.06
	8,515*	4.10	2.03	1.71	7.84	8.55	0.00	8.55	16.40

* 92 days of ships.

PANAMA CANAL SIMULATION
CASE 3 - HIGH-RISE - 150,000 DWT - 2060

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	1,151	2.94	1.63	1.35	5.92	0.92	0.00	0.92	6.84
2	2,521	3.35	1.60	1.51	6.47	1.19	0.00	1.19	7.65
3	12,577	3.94	1.65	1.74	7.32	1.17	0.00	1.17	8.50
4	140	3.42	1.85	1.53	6.80	1.43	0.00	1.43	8.23
5	334	3.84	1.80	1.71	7.34	1.34	0.00	1.34	8.68
6	645	3.51	1.87	1.59	6.98	1.25	0.00	1.25	8.23
7	1,525	4.43	1.96	1.94	8.33	1.24	0.00	1.24	9.57
8	3,548	4.03	2.13	1.78	7.93	1.23	0.00	1.23	9.17
9	517	3.19	1.98	1.47	6.64	1.24	0.00	1.24	7.88
10	484	3.58	2.19	1.62	7.40	1.34	0.00	1.34	8.73
11	155	3.94	2.38	1.75	8.07	1.17	0.00	1.17	9.24
12	3,180	4.15	2.77	1.82	8.74	1.28	0.00	1.28	10.02
13	437	3.53	1.81	1.59	6.94	1.13	0.00	1.13	8.06
15	235	4.04	1.68	1.98	7.69	1.39	0.00	1.39	9.08
16	1,722	4.64	1.70	2.29	8.63	1.19	0.00	1.19	9.81
17	135	4.61	1.75	2.22	8.58	1.21	0.00	1.21	9.79
18	876	4.87	2.04	2.43	9.34	1.22	0.00	1.22	10.56
	30,182	3.94	1.88	1.77	7.59	1.20	0.00	1.20	8.79

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	1,006	2.95	1.68	1.38	6.01	4.92	0.00	4.92	10.93
2	2,198	3.37	1.54	1.53	6.45	15.67	0.00	15.67	22.12
3	11,167	3.96	1.58	1.75	7.29	17.29	0.00	17.29	24.59
4	114	3.41	1.73	1.56	6.69	18.13	0.00	18.13	24.83
5	302	3.88	1.80	1.70	7.38	18.08	0.00	18.08	25.46
6	598	3.57	1.82	1.59	6.98	18.38	0.00	18.38	25.36
7	1,348	4.47	1.86	1.93	8.26	18.34	0.00	18.34	26.60
8	3,066	4.06	2.03	1.77	7.86	17.75	0.00	17.75	25.61
9	474	3.22	1.91	1.51	6.64	17.89	0.00	17.89	24.52
10	440	3.62	2.07	1.63	7.32	18.23	0.00	18.23	25.55
11	141	4.03	2.31	1.75	8.10	18.99	0.00	18.99	27.09
12	2,785	4.17	2.56	1.82	8.55	18.00	0.00	18.00	26.55
13	396	3.55	1.71	1.61	6.87	17.01	0.00	17.01	23.88
15	197	4.05	1.57	1.99	7.61	15.73	0.00	15.73	23.34
16	1,551	4.65	1.54	2.29	8.48	15.65	0.00	15.65	24.13
17	119	4.61	1.61	2.23	8.46	14.99	0.00	14.99	23.45
18	789	4.87	1.78	2.43	9.08	15.91	0.00	15.91	24.99
	26,691*	3.97	1.78	1.78	7.53	16.78	0.00	16.78	24.31

* 6 months of ships.

PANAMA CANAL SIMULATION
CASE 4 - HIGH-RISE - 200,000 DWT - 2060

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	944	2.98	1.77	1.26	6.01	1.36	0.00	1.36	7.37
2	2,038	3.42	1.75	1.43	6.59	1.73	0.00	1.73	8.33
3	10,337	4.01	1.82	1.65	7.48	1.80	0.00	1.80	9.28
4	114	3.47	2.09	1.45	7.00	1.86	0.00	1.86	8.87
5	264	3.90	2.05	1.63	7.57	1.82	0.00	1.82	9.39
6	530	3.60	2.13	1.51	7.24	1.83	0.00	1.83	9.07
7	1,259	4.52	2.26	1.85	8.63	1.73	0.00	1.73	10.36
8	2,932	4.10	2.52	1.69	8.31	1.88	0.00	1.88	10.19
9	427	3.23	2.23	1.38	6.84	2.06	0.00	2.06	8.91
10	392	3.65	2.64	1.52	7.81	1.83	0.00	1.83	9.64
11	131	4.03	2.91	1.66	8.61	1.94	0.00	1.94	10.55
12	2,631	4.23	3.38	1.73	9.34	1.79	0.00	1.79	11.13
13	349	3.61	2.03	1.51	7.16	1.78	0.00	1.78	8.94
15	191	3.97	1.53	1.93	7.43	2.26	0.00	2.26	9.70
16	1,413	4.55	1.57	2.24	8.36	2.31	0.00	2.31	10 67
18	94	5.20	1.68	2.52	9.41	2.33	0.00	2.33	11.73
19	94	4.97	1.77	2.37	9.11	2.26	0.00	2.26	11.37
20	522	5.17	2.04	2.58	9.79	2.24	0.00	2.24	12.03
	24,662	4.01	2.11	1.69	7.81	1.83	0.00	1.83	9.64

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	349	2.98	1.82	1.28	6.08	4.45	0.00	4.45	10.53
2	721	3.44	1.65	1.44	6.53	12.96	0.00	12.96	19.49
3	3,901	4.04	1.73	1.65	7.42	13.85	0.00	13.85	21.27
4	43	3.41	1.89	1.48	6.78	13.90	0.00	13.90	20.68
5	102	4.01	2.01	1.63	7.65	13.30	0.00	13.30	20.95
6	185	3.67	2.03	1.51	7.21	14.05	0.00	14.05	21.25
7	450	4.51	2.10	1.85	8.46	13.80	0.00	13.80	22.26
8	1,058	4.13	2.38	1.68	8.19	14.26	0.00	14.26	22.45
9	148	3.28	2.11	1.41	6.79	14.72	0.00	14.72	21.51
10	126	3.68	2.55	1.53	7.76	14.17	0.00	14.17	21.93
11	49	4.05	2.75	1.66	8.46	13.92	0.00	13.92	22.38
12	948	4.26	3.19	1.73	9.17	14.60	0.00	14.60	23.76
13	123	3.63	1.89	1.51	7.03	14.02	0.00	14.02	21.04
15	73	3.99	1.42	1.94	7.35	13.34	0.00	13.34	20.69
16	525	4.53	1.44	2.24	8.21	12.52	0.00	12.52	20.73
18	29	5.22	1.56	2.53	9.31	14.17	0.00	14.17	23.48
19	39	4.98	1.58	2.38	8.93	12.31	0.00	12.31	21.24
20	198	5.18	1.77	2.58	9.53	11.91	0.00	11.91	21.44
	9,067*	4.03	1.99	1.69	7.72	13.43	0.00	13.43	21.14

* 92 days of ships.

PANAMA CANAL SIMULATION
CASE 5 - HIGH-RISE - 200,000 DWT - 2060

Type	Count	Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit (Travel+Delay)
		Reach	Lock	Cut	Total	Lock	Cut	Total	
1	1,159	2.87	1.60	1.33	5.79	0.80	0.00	0.80	6.59
2	2,520	3.30	1.59	1.48	6.38	0.99	0.00	0.99	7.37
3	12,656	3.87	1.65	1.72	7.23	1.04	0.00	1.04	8.27
4	145	3.36	1.81	1.49	6.67	1.20	0.00	1.20	7.87
5	332	3.79	1.85	1.67	7.31	1.05	0.00	1.05	8.36
6	646	3.48	1.89	1.57	6.93	1.10	0.00	1.10	8.03
7	1,537	4.35	1.97	1.92	8.24	0.98	0.00	0.98	9.22
8	3,564	3.95	2.14	1.74	7.84	1.06	0.00	1.06	8.90
9	523	3.12	1.93	1.46	6.51	1.12	0.00	1.12	7.63
10	478	3.51	2.22	1.58	7.32	1.19	0.00	1.19	8.51
11	161	3.89	2.48	1.74	8.12	1.06	0.00	1.06	9.17
12	3,192	4.06	2.70	1.80	8.55	1.10	0.00	1.10	9.65
13	435	3.49	1.79	1.59	6.87	0.98	0.00	0.98	7.85
15	235	3.98	1.55	1.95	7.48	1.11	0.00	1.11	8.59
16	1,739	4.55	1.56	2.25	8.36	1.03	0.00	1.03	9.39
18	109	5.21	1.71	2.53	9.45	1.11	0.00	1.11	10.56
19	115	4.97	1.77	2.38	9.11	0.98	0.00	0.98	10.10
20	633	5.18	2.03	2.58	9.79	1.06	0.00	1.06	10.85
	30,179	3.88	1.86	1.75	7.49	1.04	0.00	1.04	8.52

Type	Count	Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit (Travel+Delay)
		Reach	Lock	Cut	Total	Lock	Cut	Total	
1	1,055	2.88	1.70	1.36	5.94	4.04	0.00	4.04	9.97
2	2,294	3.32	1.54	1.52	6.38	11.51	0.00	11.51	17.89
3	11,730	3.90	1.58	1.73	7.21	13.79	0.00	13.79	21.00
4	126	3.37	1.69	1.55	6.60	14.39	0.00	14.39	20.99
5	307	3.80	1.78	1.69	7.26	13.18	0.00	13.18	20.45
6	618	3.50	1.77	1.59	6.85	14.32	0.00	14.32	21.17
7	1,414	4.39	1.85	1.91	8.15	14.05	0.00	14.05	22.20
8	3,222	3.98	2.01	1.75	7.74	14.33	0.00	14.33	22.07
9	496	3.17	1.88	1.49	6.53	14.18	0.00	14.18	20.72
10	441	3.55	2.18	1.61	7.35	14.86	0.00	14.86	22.21
11	139	3.92	2.22	1.74	7.88	14.00	0.00	14.00	21.88
12	2,906	4.09	2.51	1.80	8.39	14.62	0.00	14.62	23.02
13	409	3.50	1.68	1.61	6.78	13.86	0.00	13.86	20.64
15	209	3.99	1.42	1.96	7.37	12.11	0.00	12.11	19.48
16	1,627	4.56	1.44	2.26	8.26	12.59	0.00	12.59	20.85
18	98	5.19	1.58	2.53	9.31	13.40	0.00	13.40	22.71
19	102	4.98	1.60	2.39	8.97	11.69	0.00	11.69	20.65
20	594	5.18	1.80	2.58	9.56	12.22	0.00	12.22	21.78
	27,787*	3.91	1.77	1.76	7.43	13.30	0.00	13.30	20.73

* 6 months of ships.

PANAMA CANAL SIMULATION
CASE 6 - ONE-LANE CULEBRA CUT - 150,000 DWT - 2060

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	898	3.04	1.78	1.31	6.13	1.41	0.13	1.53	7.67
2	1,935	3.46	1.74	1.47	6.67	1.84	0.19	2.02	8.70
3	9,846	4.07	1.82	1.69	7.58	1.87	0.17	2.04	9.62
4	112	3.54	2.09	1.48	7.11	2.03	0.18	2.21	9.32
5	252	3.99	2.04	1.67	7.69	1.84	0.16	2.00	9.69
6	505	3.63	2.15	1.55	7.33	1.91	0.18	2.09	9.41
7	1,199	4.60	2.29	1.88	8.77	1.78	0.15	1.93	10.70
8	2,791	4.18	2.57	1.72	8.48	1.89	0.16	2.06	10.53
9	410	3.28	2.22	1.41	6.92	1.92	0.28	2.20	9.12
10	372	3.70	2.56	1.57	7.84	1.93	0.18	2.11	9.95
11	122	4.08	3.06	1.72	8.85	2.12	0.19	2.32	11.17
12	2,514	4.31	3.43	1.77	9.51	1.79	0.23	2.02	11.53
13	336	3.64	2.02	1.55	7.22	1.77	0.18	1.95	9.17
15	183	4.03	1.74	1.97	7.74	2.72	0.59	3.32	11.06
16	1,346	4.63	1.72	2.29	8.65	2.43	0.43	2.86	11.51
17	107	4.61	1.76	2.22	8.60	2.57	0.72	3.29	11.89
[illegible]	695	4.87	2.03	2.43	9.33	2.33	0.37	2.70	12.03
	23,623	4.07	2.13	1.73	7.93	1.90	0.20	2.10	10.03

		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	324	3.06	1.83	1.33	6.21	4.18	0.26	4.44	10.65
2	670	3.52	1.67	1.51	6.70	9.26	0.32	9.58	16.28
3	3,689	4.11	1.74	1.71	7.56	9.68	0.35	10.03	17.58
4	41	3.58	2.00	1.52	7.10	10.15	0.36	10.50	17.61
5	106	4.02	2.03	1.67	7.71	9.77	0.41	10.18	17.89
6	166	3.67	2.02	1.58	7.26	9.83	0.44	10.27	17.53
7	417	4.62	2.17	1.88	8.67	10.19	0.28	10.47	19.15
8	992	4.21	2.43	1.73	8.37	9.93	0.29	10.22	18.59
9	152	3.33	2.16	1.44	6.93	10.58	0.56	11.15	18.08
10	126	3.73	2.48	1.58	7.78	9.32	0.38	9.70	17.47
11	44	4.15	2.97	1.68	8.80	11.75	0.32	12.07	20.87
12	901	4.34	3.25	1.78	9.36	9.90	0.37	10.27	19.64
13	131	3.68	1.88	1.58	7.13	9.39	0.21	9.60	16.73
15	64	4.05	1.61	2.00	7.66	9.33	0.86	10.19	17.85
16	495	4.63	1.56	2.30	8.49	9.53	0.68	10.20	18.69
17	47	4.62	1.69	2.24	8.55	8.79	1.07	9.87	18.42
18	267	4.87	1.80	2.44	9.10	9.50	0.53	10.03	19.14
	8,632*	4.10	2.02	1.74	7.87	9.52	0.37	9.89	17.76

* 92 days of ships.

PANAMA CANAL SIMULATION
CASE 7 - ONE-LANE CULEBRA CUT - 200,000 DWT - 2060

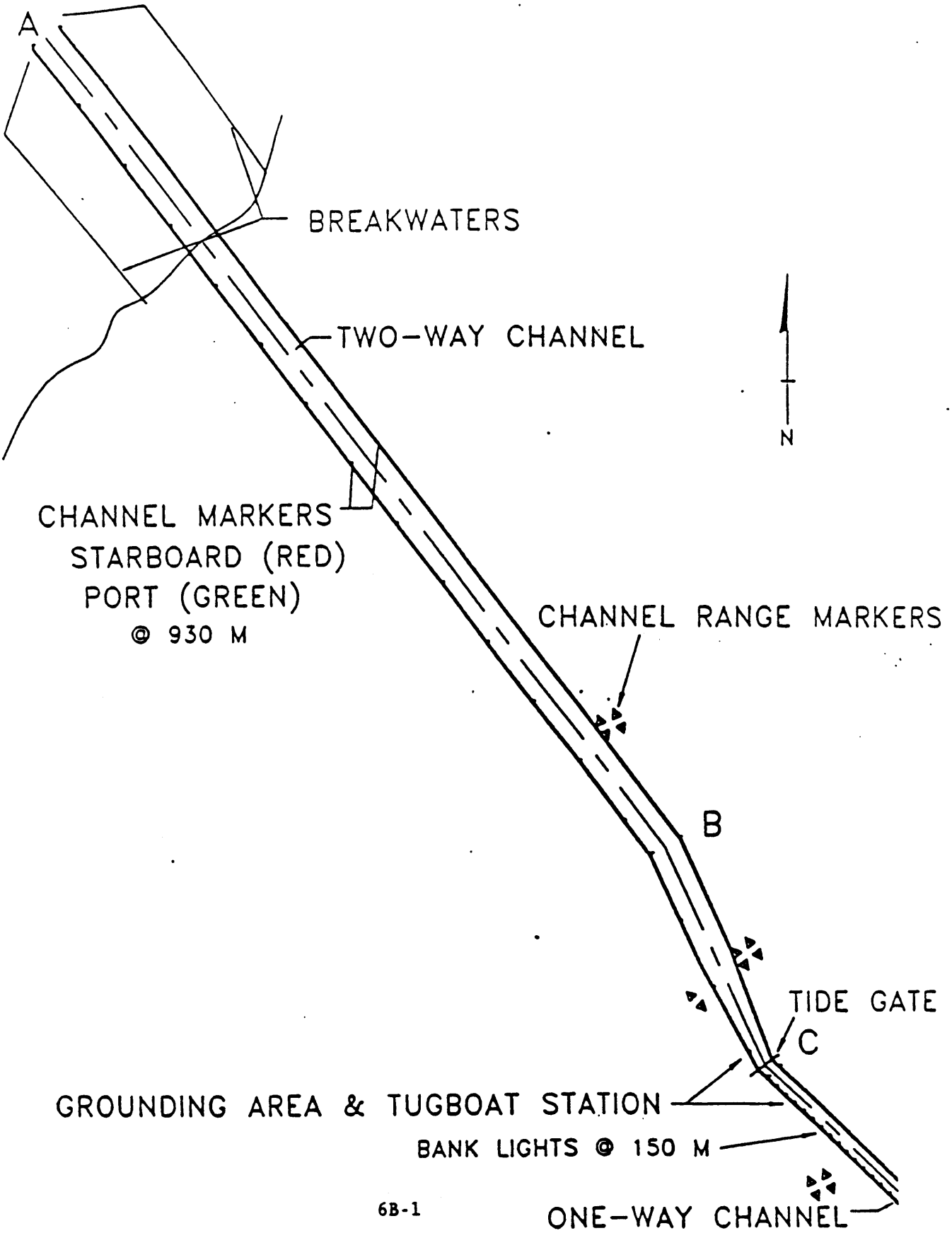
		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	904	2.99	1.76	1.29	6.04	1.27	0.15	1.42	7.46
2	1,946	3.41	1.75	1.44	6.60	1.62	0.19	1.81	8.41
3	9,898	4.01	1.81	1.67	7.49	1.68	0.19	1.87	9.37
4	111	3.46	2.02	1.50	6.97	1.59	0.19	1.78	8.76
5	249	3.91	2.06	1.62	7.59	1.76	0.21	1.97	9.56
6	508	3.61	2.13	1.54	7.28	1.65	0.22	1.88	9.16
7	1,208	4.50	2.24	1.87	8.61	1.65	0.18	1.83	10.43
8	2,805	4.10	2.52	1.70	8.32	1.79	0.19	1.97	10.30
9	410	3.25	2.24	1.41	6.89	1.76	0.25	2.01	8.90
10	379	3.67	2.64	1.53	7.83	1.79	0.26	2.05	9.88
11	124	4.06	2.94	1.67	8.67	2.03	0.18	2.21	10.88
12	2,524	4.23	3.40	1.74	9.37	1.70	0.22	1.93	11.30
13	336	3.59	1.96	1.53	7.08	1.47	0.16	1.63	8.71
15	185	3.97	1.56	1.95	7.47	2.50	0.58	3.08	10.55
16	1,352	4.55	1.58	2.25	8.39	2.26	0.45	2.71	11.09
18	91	5.20	1.72	2.54	9.46	2.52	0.49	3.01	12.47
19	90	4.97	1.73	2.38	9.08	2.09	0.65	2.73	11.81
20	502	5.18	2.05	2.58	9.81	2.20	0.34	2.54	12.35
	23,622	4.01	2.11	1.71	7.82	1.73	0.22	1.95	9.77

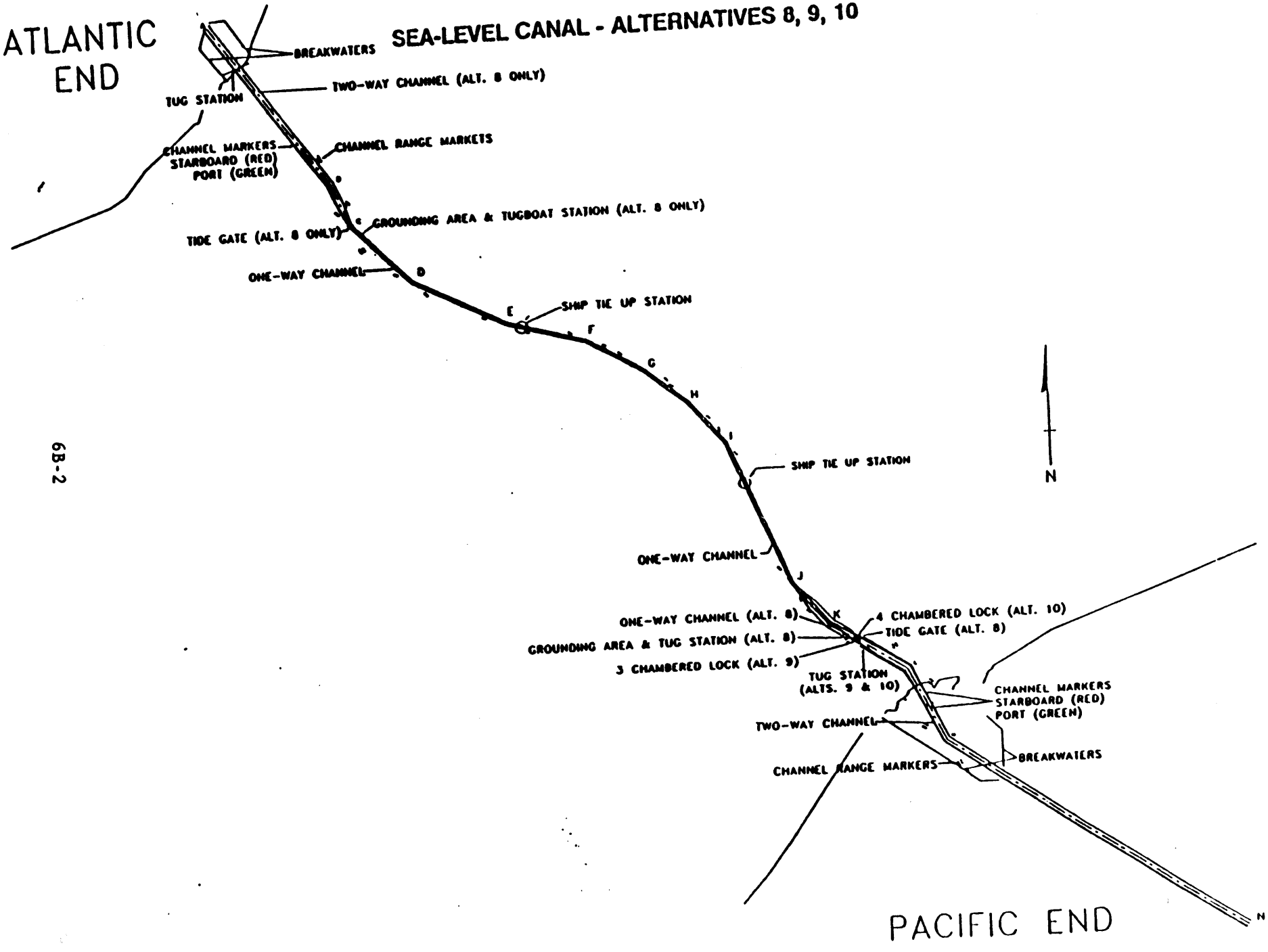
		Avg. Travel Time (hrs)				Avg. Delay Time (hrs)			Total Transit
Type	Count	Reach	Lock	Cut	Total	Lock	Cut	Total	(Travel+Delay)
1	349	2.98	1.81	1.34	6.13	4.75	0.40	5.16	11.29
2	720	3.42	1.62	1.49	6.53	12.91	0.49	13.40	19.93
3	3,897	4.03	1.72	1.70	7.45	14.44	0.48	14.92	22.37
4	43	3.49	1.95	1.47.	6.92	13.69	0.52	14.21	21.13
5	102	3.97	2.03	1.69	7.69	13.93	0.44	14.37	22.06
6	184	3.63	1.95	1.56	7.14	14.77	0.49	15.26	22.40
7	450	4.53	2.13	1.87	8.53	14.02	0.39	14.42	22.95
8	1,060	4.14	2.40	1.72	8.26	14.80	0.44	15.24	23.50
9	147	3.30	2.19	1.47	6.96	15.21	0.62	15.83	22.79
10	126	3.74	2.60	1.57	7.92	14.19	0.50	14.69	22.61
11	48	3.99	2.64	1.73	8.36	13.57	0.36	13.93	22.29
12	950	4.26	3.15	1.76	9.17	15.14	0.49	15.63	24.80
13	123	3.63	1.86	1.55	7.04	13.97	0.32	14.29	21.32
15	73	3.99	1.40	1.98	7.37	13.82	1.17	14.99	22.36
16	523	4.53	1.42	2.27	8.22	12.58	0.74	13.32	21.54
18	29	5.22	1.53	2.58	9.33	15.20	0.55	15.75	25.08
19	39	4.98	1.55	2.44	8.97	12.83	1.20	14.03	23.00
20	199	5.18	1.78	2.59	9.55	11.95	0.60	12.55	22.10
	9,062*	4.03	1.98	1.74	7.75	13.86	0.49	14.36	22.11

* 92 days of ships.

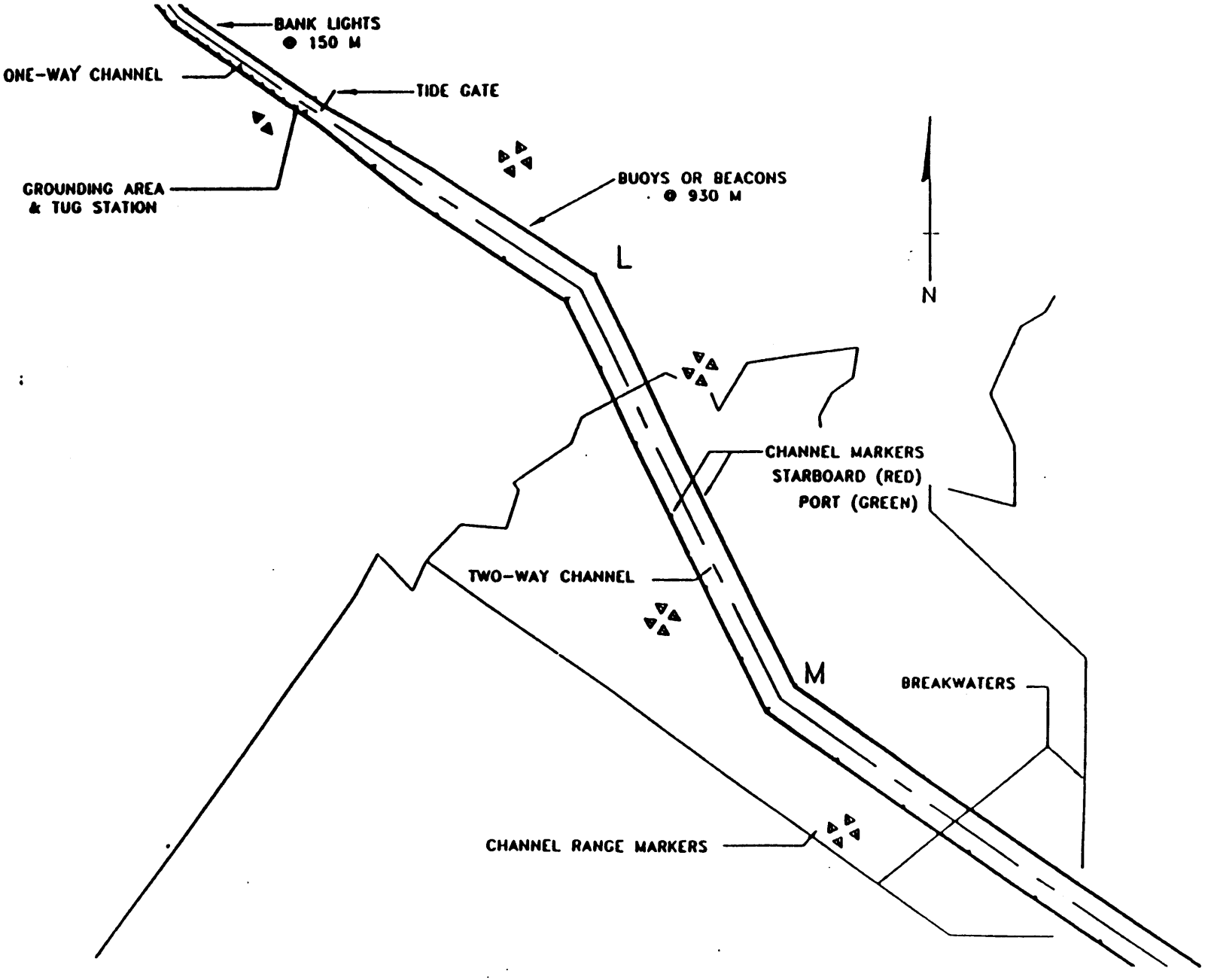
APPENDIX 6 - B

ATLANTIC END - SEA-LEVEL CANAL - ALTERNATIVE 8

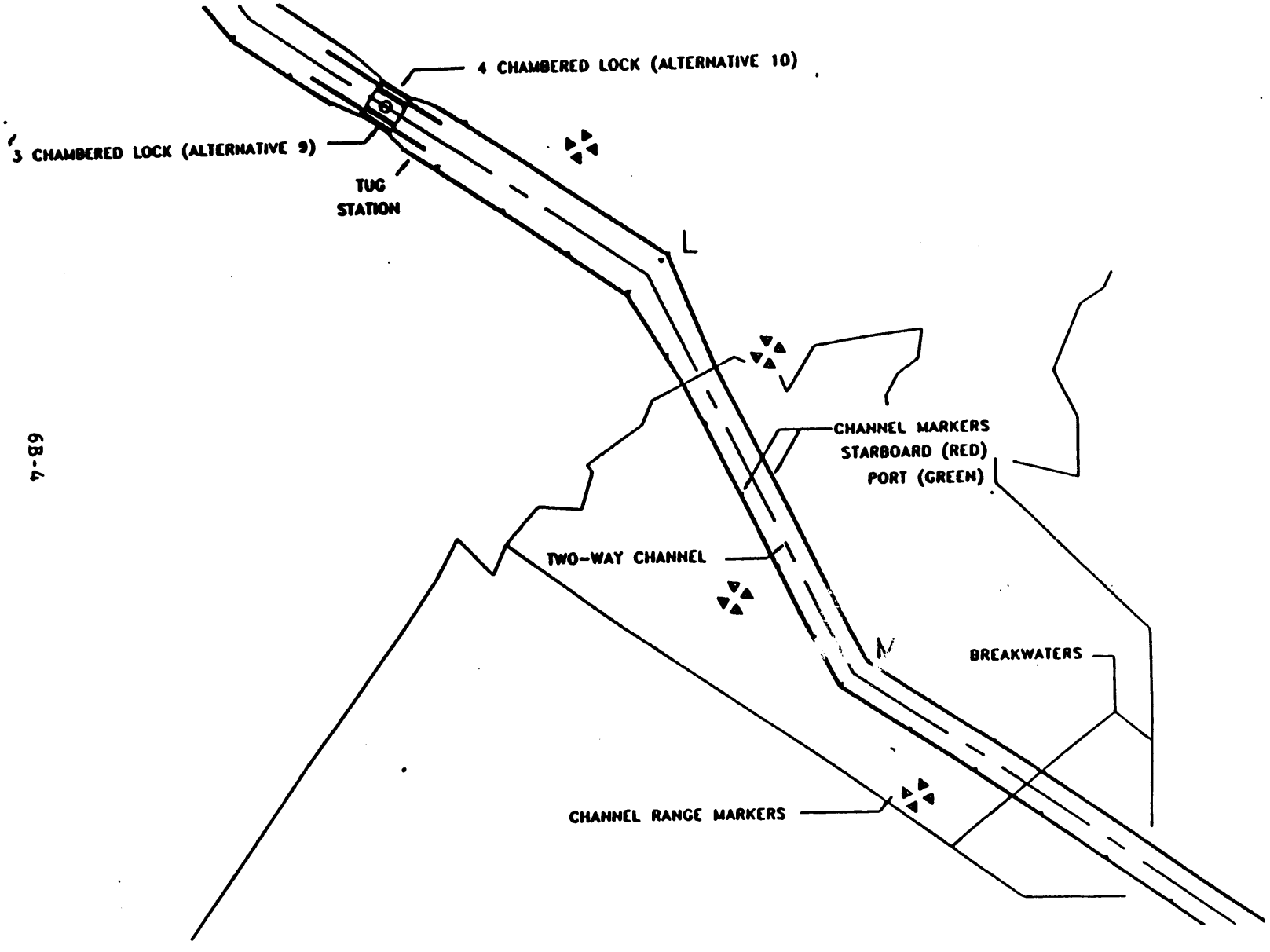



SEA-LEVEL CANAL - ALTERNATIVES 8, 9, 10
ATLANTIC END
BREAKWATERS
TWO-WAY CHANNEL (ALT. 8 ONLY)
TUG STATION
CHANNEL MARKERS STARBOARD (RED) PORT (GREEN)
CHANNEL RANGE MARKETS
GROUNDING AREA & TUGBOAT STATION (ALT. 8 ONLY)
TIDE GATE (ALT. 8 ONLY)
ONE-WAY CHANNEL
D
E
SHIP TIE UP STATION
F
G
H
I
SHIP TIE UP STATION
N
ONE-WAY CHANNEL
J
K
ONE-WAY CHANNEL (ALT. 8)
4 CHAMBERED LOCK (ALT. 10)
TIDE GATE (ALT. 8)
GROUNDING AREA & TUG STATION (ALT. 8)
3 CHAMBERED LOCK (ALT. 9)
TUG STATION (ALTS. 9 & 10)
CHANNEL MARKERS STARBOARD (RED) PORT (GREEN)
TWO-WAY CHANNEL
BREAKWATERS
CHANNEL RANGE MARKERS
PACIFIC END
N

PACIFIC APPROACH - SEA-LEVEL CANAL - ALTERNATIVE 8



PACIFIC APPROACH - SEA-LEVEL CANAL - ALTERNATIVES 9 & 10



APPENDIX 6 - C

GENERAL REQUIREMENTS FOR THE NEW HIGH-RISE LOCKS (85 FT) -- ALTERNATIVES 2 THROUGH 7

The approach walls at both ends of both locks (Atlantic and Pacific) should be at least 1,500 feet (457 meters) long with locomotive tracks extending, as far as practical, to the end of the wall to facilitate timely and safe lock entry for large ships.

With proper fendering and sufficient lock width, it may be feasible to operate the new locks with locomotives on one wall only. Locomotive tracks should be constructed on the opposite wall, at least on the first lock lane put into service, in case this does not work out in practice.

Tug assistance should be provided for lock approach and entry, as follows:

1 tug -	all vessels over 25,000 DWT;
2 tugs -	all vessels over 30,000 DWT at the Pacific locks southbound and all vessels over 35,000 DWT fir ither locks and directions;
3 togs -	all vessels over 75,000 DWT.

Strict traffic control will have to be exercised at the points of convergence of the original and new canal channels, particularly where they join in the Culebra Cut north of Pedro Miguel Locks.

HIGH RISE LOCKS (85 FT) 150,000 AND 200,000 DWT, SINGLE-LANE LOCKS, CULEBRA CUT TWO-WAY -- ALTERNATIVES 2 AND 4

To equip the canal with the locks operating at capacity would require at each of the two locks (Atlantic and Pacific) ten locomotives for one-wall operation (allowing two down for maintenance) and twice that number for two-wall operation.

Seven 6,000 hp (minimum power) tugs would cover the maximum needs at the Pacific locks and the Cut and five tugs could handle these needs at the Atlantic locks. Allowing for three down for maintenance, a total of 15 tugs of 6,000 hp or greater would be required, building up to 19 tugs at capacity, in addition to the tug fleet needed to operate the original locks.

With the Culebra Cut handling two-way traffic, additional tie-up facilities at the north end of the Pacific locks locks would not be required and ships would have more expeditious transits.

HIGH-RISE LOCKS (85 FT) 150,000 AND 200,000 DWT, DOUBLE-LANE LOCKS, CULEBRA CUT TWO-WAY -- ALTERNATIVES 3 AND 5

To equip the canal to operate these locks at capacity would require at each of the two locks (Atlantic and Pacific ends) 19 locomotives for one-wall operation (allowing for three down for maintenance) and twice the number for two-wall operation.

The undesirable migration of sea life between the oceans should be prevented. If a fresh water barrier from side streams is used, any significant proportion of fresh water would require a deeper channel to allow for deeper freshwater drafts.

SEA-LEVEL WITH PACIFIC LOCKS, ROUTE 10
250,000 DWT -- ALTERNATIVES 9 AND 10

Locks should be designed in units of two lanes each, with adequate separation between the units to allow for safe approach and exit of ships.

Locks preferably should be angled about 10° to the right of the channel alignment to aid single screw ships in approach an entry.

The concept of Pacific locks, to adjust to tidal differences, would eliminate the necessity of having to schedule ships according to the tidal cycles. The length of timethat the canal would operate southbound and northbound could be adjusted to best suit the actual arrivals, and provide maximum capacity.

The area of the canal north of the Pacific locks would be operated at the level of the Atlantic end which only varies about two feet (0.6 meters) at spring and one foot (0.3 meters) at neap tides. Tidal currents in the canal north of the locks would be negligible.

The Pacific tides have a maximum spring tidal range of about 21 feet (6.4 meters) and the neap tidal range is about eight feet (2.4 meters). High water occurs on the Pacific side about three hours at the Atlantic side of the isthmus. Therefore, the greatest to up or down about 22 feet (6.7 meters), which translates to up or down 11 feet (3.4 meters) from the Canal Operating Level. The average tidal range would be about 15 feet (4.6 meters) or about 7.5 feet (2.3 meters) up or down. The average lockage would be half of that or about 3.75 feet (1.14 meters).

To facilitate a change in direction of canal traffic without unduly delaying ships, it would be a desirable practice to "stack up" a few northbound ships in the aea just north of the locks while the one-way canal channel is operating southbound. Another lock with one lane would suffice for the purpose of "stacking up" three large northbounds (or more smaller ships). This could be done during the last hour or two while southbound traffic was procceding through the one-way portion of the canal. The north approach walls should be at least 2,400 feet (732 meters) in length so as to provide easy and rapid tie-up for two large (or more smaller) ships. Locomotive tracks should extend to as near to the extreme end os the wall as practicable. An additional lockage could be held in the chamber.

If another lock with only one lane is to be built, it should be laid out in such a way as to allow easy conversion to a two-lane lock at a later date should that prove to be necessary; for instance, in connection with widening the canal channel for twoway traffic. To allow for the safe and timely entry of large ships, the south approach walls should be at least 1,500 feet (457 meters) in length with locomotive tracks wxtending as near to the extreme end of the wall as practicable.

With proper fendering and sufficient lock width, it may be possible to operate these locks with locomotives on one wall only. Locomotive tracks should be built into the other wall, at least on the first lock lane put into operation, in case this does not work out in practice. The type of locomotives used in the present Canal should be suitable. For one wall operation, eight working locomotives should be supplied for each operating lane at the locks plus two spares for maintenance down time. For two-wall operation, twice as many locomotives will be required.

The channel at the lock approach (on both ends) should be at least 2,000 feet (610 meters) wide for at least three km to facilitate two-way traffic, the slowing of ships and their maneuvering to enter and exit the locks.

Tug assistance should be provided for lock approach and entry, as follows:

1 tug -	all vessels over 25,000 DWT;
2 tugs -	all southbound vessels over 30,000 DWT and northbound vessels over 35,000 DWT;
3 tugs -	all vessels over 75,000 DWT.

Based on projected ship mixes, a fleet of eight tougs should be sufficient to handle the channel traffic. In addition to this four tugs should be on standby duty (at the two ends of the canal and at the two tie-up stations) to assist, as needed, and about seven tugs would be required to assist ships at the locks. Allowing for four tugs being down for maintenance, a total of 23 tugs would be required. About 16 of these should be 6,000 hp or greater and the others could be 3,000 to 4,000 hp.

As in the case os Alternative 8, the undesirable migration of sea life between the oceans should be prevented.

TABLE 7.4.2-5
ACTUAL AND PROJECTED GROWTH OF THE
METROPOLITAN AREA POPULATION
(WITHOUT CANAL INDUCED POPULATION)

	1960-1970	1970-1980	1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
Province of Panama	55%	40%	33%	30%	27%	20%	19%
Province of Colon	30%	22%	26%	26%	27%	28%	29%
Metro-politan area	50%	37%	32%	30%	27%	21%	20%

SOURCE: Growth rates calculated from population data in Chart III-A-6 of the Component Study, Analysis of Impacts Upon Panama, Booz-Allen & Hamilton, Inc. July 16, 1993.