Panama Canal Alternatives Study

Estudio de Alternativas al Canal de Panamá

Commission for the Study of Alternatives to the Panama Canal

20 de septiembre de 1993

Resumen Ejecutivo

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

1993

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

Volume I

Commissioners' Joint Statement

Executive Summaries

1993

Final Report

of the

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Alternatives to the

Panama Canal

Volume I

1. Commissioners' Joint Statement

Executive Summaries of the following (in order):

2. Detailed Plan of Study
3. Operating Characteristics and Capacity Evaluation Study, Phase I,
4. Engineering and Cost Estimates Study, Phase I,
5. Commodity and Traffic Projection Study, Phase I,
6. Operating Characteristics and Capacity Evaluation Study, Phase II,
7. Engineering and Cost Estimates Study, Phase II,
8. Commodity and Traffic Projection Study, Phase II,
9. Environmental Analysis,
10. Biological Inventory,
11. Economic Analysis and Impact on Users,
12. Financing Scheme, Financial Analysis and Management Arrangements,
13. Impact upon Panama Analysis,
14. A Feasibility Report.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

1. Commissioners' Joint Statement

1993

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 prescreening 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

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

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

2. Detailed Plan of Study

General Description of the FA/FR Study

1993

Section 1

General Description of the FA/FR Study

1.1 INTRODUCTION

The SINBOL Consortium has prepared the Inception Report issued on February 27, 1990 and the Interim Report issued on March 23, 1990 and submitted them to the Commission for the Study of the Alternatives to the Panama Canal. Detailed review meetings on the Interim Report were held between the Commission and the Consortium in April and for the Draft Detailed Plan of Study in July 1990.

During these meetings, a decision was made by the Commission to shorten the period of time allocated for the completion of the Feasibility Analysis/Final Report (FA/FR) Study from 48 months to 30 months. In order to meet this shortened schedule, a two-fold strategy was adopted.

- First, the FA/FR Contractor would prepare the studies of the present situation in Panama, the status of the present Panama Canal, historical trade analysis, and future transportation systems.
- Second, the FA/FR Contractor would prepare a preliminary analysis and screening of the alternatives with the objective of allowing the Commission to reduce the number of alternatives for further study by removing from consideration those that appear to be infeasible.

These steps will enable the work associated with preparing both the Component Studies and the final FA/FR report to be carried out more effectively and make it possible to meet the shortened time schedule.

1.2 DETAILED PLAN OF STUDY

The Detailed Plan of the Study (DPS) consists of two volumes:

Volume I	The description of the overall plan to execute and manage the study, including descriptions of the tasks to be performed by the Feasibility Analysis/Final Report (FA/FR) Contractor and the Component Study contractors.
Volume II	Terms of Reference for the Component Studies to be carried out by contractors other than the FA/FR Contractor and detailed work plans for prescreening tasks to be performed by the FA/FR Contractor.

Volume I describes the tasks that will be carried out by the FA/FR Contractor and Component Study contractors. Following is a brief overview of the work to be performed by the FA/FR Contractor:

- Prepare a preliminary analysis and prescreening of alternatives, including studies covering the present situation in Panama, the status of the Panama Canal, historical trade analysis, and future transportation systems
- Advise the Secretariat in selecting viable alternatives
- Assist and advise the Secretariat in selecting and overseeing the work of the Component Study contractors
- Prepare a feasibility analysis which incorporates the work of the FA/FR Contractor and the Component Study contractors
- Advise the Secretariat in recommending the best alternative
- Prepare a detailed investigation of the recommended alternative
- Prepare the final report
- Advise and assist the Secretariat in scheduling and managing of the study program

Figure 1-1 contains a task flow diagram that shows each of the tasks and their relationship with other tasks. It also shows which of the tasks will be done by the FA/FR Contractor, which will be done by the Component Study contractors and illustrates the critical path. A detailed description of each of these tasks is contained in Section 3 of this report.

1.2.1 List of Alternatives

The alternatives that will be investigated in the preliminary analysis and prescreening tasks are listed below. The main features of these alternatives are discussed in Section 2.

- Improvements to the Existing Canal
  - Status quo alternative (includes Gaillard Cut widening)
  - Non-lock improvements
  - Third Locks Plan
  - Terminal Lake Plan and Variations

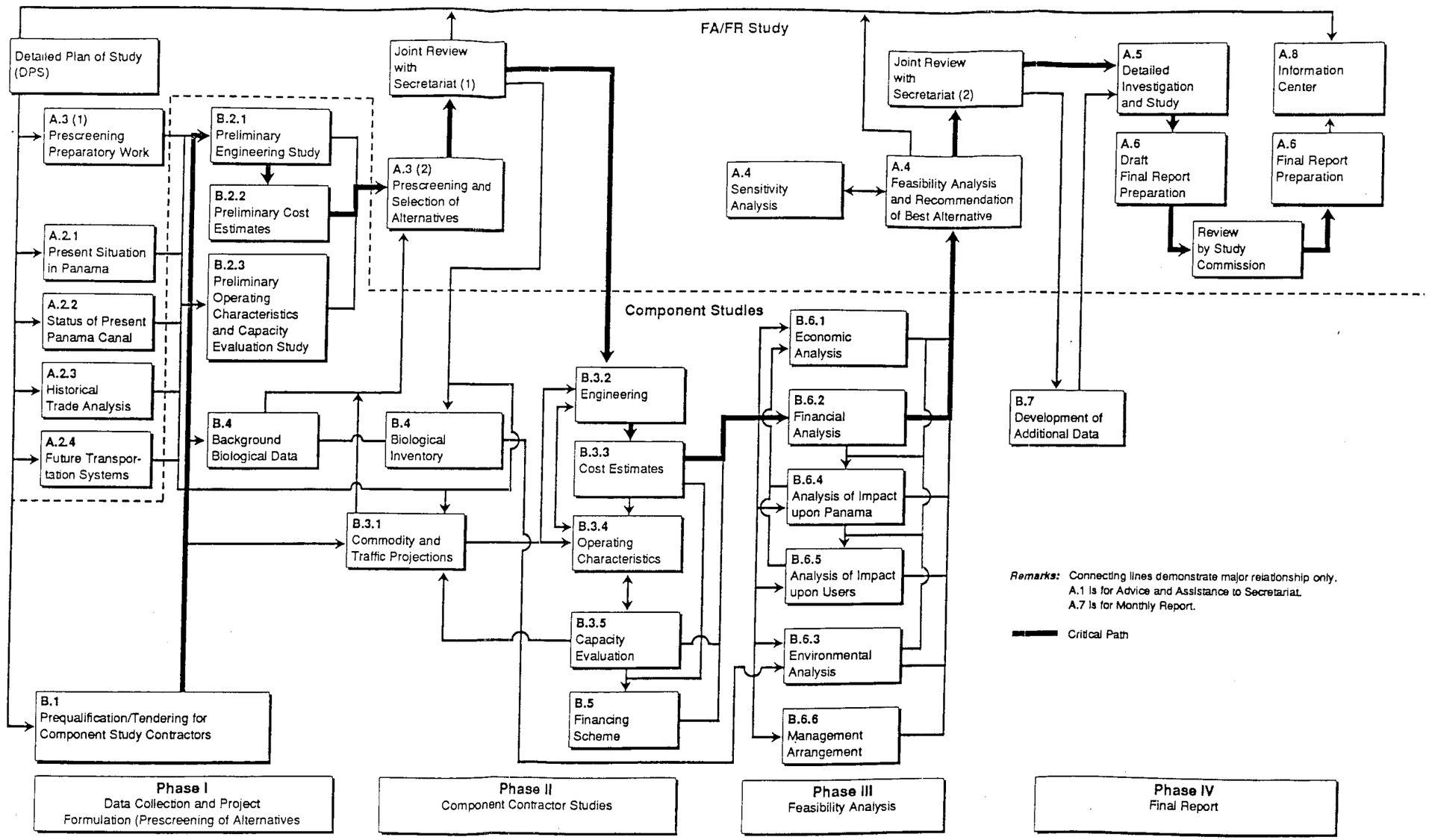

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Figure 1-1
Overall Work Plan Flow

- 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

1.2.2 Preliminary Analysis and Prescreening Tasks

The tasks that will be prepared by the FA/FR Contractor for the preliminary analysis and prescreening of alternatives include the following:

- 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
- Prescreening and Selection of Alternatives

Input from Component Studies will also be included in the prescreening effort.

1.2.3 Component Studies

The tasks that will be prepared by the Component Study contractors and their relationship to the overall study are shown in Figure 1-1. Because some of these tasks are closely related, they will be grouped into the following categories for the purpose of selecting Component Study contractors. The reasons for this grouping are

purpose of selecting Component Study contractors. The reasons for this grouping are discussed in Section 3, Part B. (preliminary studies for prescreening activities to be performed by Component Study contractors are incorporated into the TOR's of the component studies marked with an asterisk):

- Commodity and Traffic Projections*
- Engineering and Cost Estimates*
- Operating Characteristics and Capacity Evaluation*
- Background Biological Data and Biological Inventory*
- Financing Scheme and Financial Analysis
- Economic and Impact Analyses
- Environmental Analysis
- Management Arrangements
- Development of Additional Data

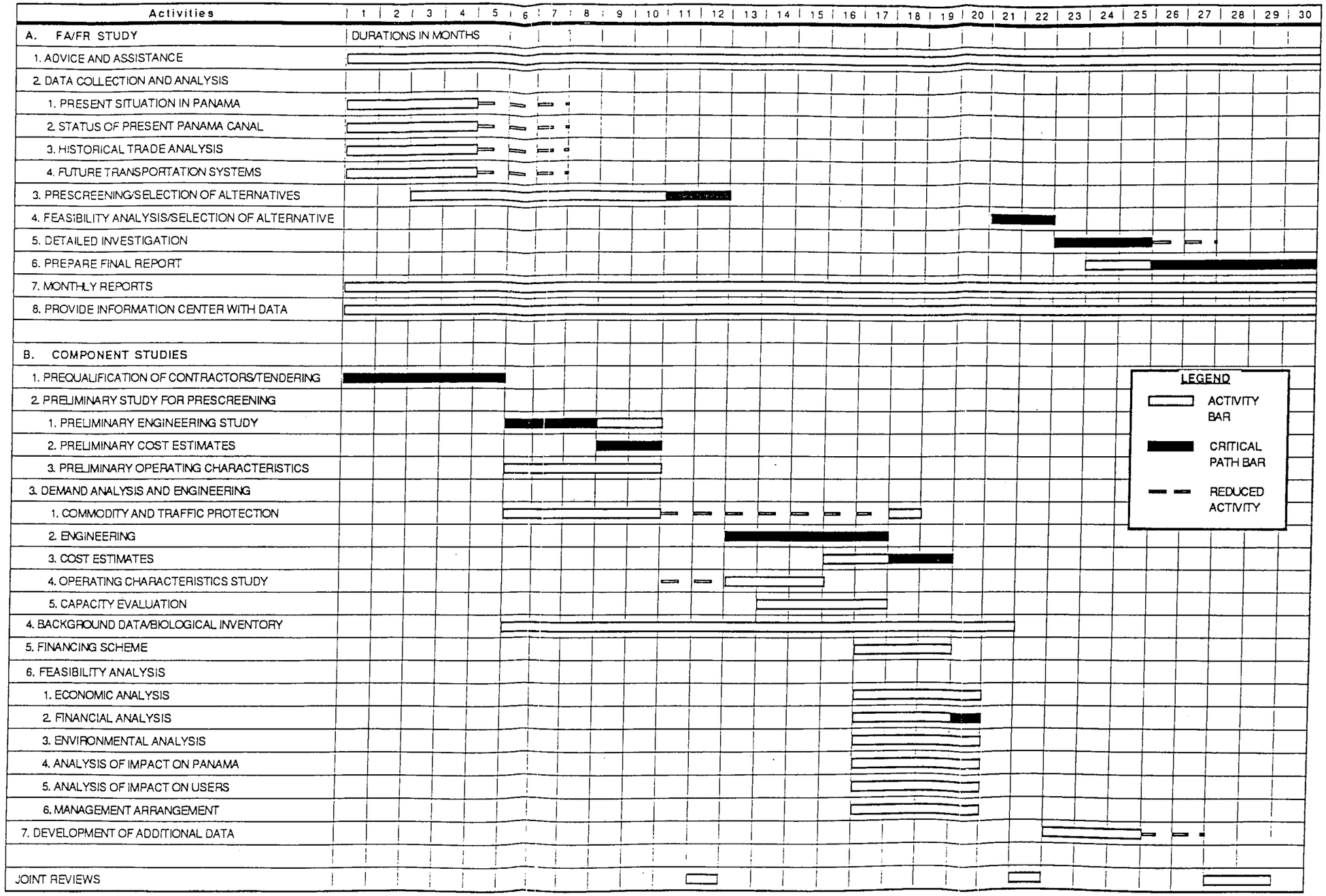
1.2.4 Feasibility Analysis and Final Report

The information from the preliminary analysis and prescreening tasks, together with input from the Component Studies, will be used to prepare the feasibility analysis. This will include economic feasibility, financial feasibility, environmental feasibility, and the analysis of the impact of the alternatives on Panama and on the users of the canal. The results of the feasibility analysis will be used to select a recommended alternative.

A detailed study of the recommended alternative will then be prepared. Additional data, as needed, will be developed and incorporated into this detailed study. An initial draft report will then be prepared, and after review by the Commission, a final report will be published.

1.3 SCHEDULE

Figure 1-2 shows the proposed schedule for the completion of the study. The initial data collection, prescreening, and selection of viable alternatives will be completed during the first 12 months of the study.



SINBOL

PANAMA CANAL ALTERNATIVES STUDY

Figure 1-2
Study Summary Schedule

Concurrently, during the first five months, the Secretariat will accomplish the prequalification and selection of component contractors. The Component Studies will vary in the amount of time allowed for completion, but they are all scheduled to be finished by the end of the 20th month with the exception of the biological inventory. With this exception, the results of the initial investigations and the Component Studies will be available to the FA/FR Contractor beginning with the 21st month.

A feasibility analysis, including sensitivity analysis, will be prepared and a preferred alternative will be identified during the following two months. A detailed investigation of this alternative will then be prepared. Simultaneously, additional data will be developed as needed to complete the detailed investigation.

The final report, including appropriate time allowed for reviews, will be prepared during the final 7 months of the schedule. Thus, judiciously integrating activities will allow the report to be completed in 30 months from the time the team is mobilized.

Preface

The Detailed Plan of the Study (DPS) of Alternatives to the Panama Canal has been prepared for the Commission for the Study of Alternatives to the Panama Canal. The SINBOL Consortium has prepared the DPS as a consultant to the Commission and under the direction of the Commission's Secretariat.

The DPS consists of two volumes:

Volume I — The description of the overall plan to execute and manage the study, including descriptions of the tasks to be performed by the Feasibility Analysis/Final Report (FA/FR) Contractor and the Component Study contractors.

Volume II — Terms of Reference for the Component Studies to be carried out by contractors other than the FA/FR Contractor and detailed work plans for prescreening tasks to be performed by the FA/FR Contractor.

The DPS has been prepared within the basic guidelines established by 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 guidance provided by the Commission and the Secretariat includes:

- A directive to schedule the Study to be completed within a 30-month period.
- Restructuring of the Study to include selected Component Studies in the scope of work of the FA/FR Contractor as per the Commission's letter of August 13, 1990. The new study structure is described in detail in the body of Volume I.
- With regard to preliminary cost estimates for the Component Studies, SINBOL has provided its best estimates using as a basis the amounts budgeted and specified in the Preparatory Committee Report.

The ability to meet the 30-month schedule presented in the DPS is subject to the following conditions and understandings:

- The Study Commission and Secretariat will perform review and approval responsibilities in a timely and unified manner.
- All component contracts are completed as scheduled.
- Recognition that delays attributable to other contractors and or the Study Commission are likely to have a significant impact on costs and schedule.

- Although the overall cost of the Study is constrained by the budget proposed by the 1985 Preparatory Committee Report, the cost of the FA/FR Contract will be increased due to the additional manpower required by the FA/FR Contractor in Panama to assist the Secretariat in the Prescreening and other activities of the Study's preliminary phase.

Introduction

This report represents Volume II of a two-volume report – the Detailed Plan of the Study (DPS) of Alternatives to the Panama Canal. The contents of Volumes I and II are described below:

VOLUME I

Volume I contains a description of the overall study work plan and a description of the major tasks that are to be accomplished. These tasks may be viewed as:

- Tasks associated with the preliminary analysis and prescreening of alternatives and the selection of viable alternatives for further study
- Tasks that will be undertaken by independent contractors, referred to as component studies
- Tasks that will be part of the final feasibility analysis and the selection of the best alternative
- Tasks associated with the detailed study of the best alternative and the preparation of the final report.

VOLUME II

Volume II contains the terms of reference (TOR) for component studies that will be undertaken as part of the overall study and detailed work plans (DWP) for selected prescreening tasks to be carried out by the FA/FR contractor. The component studies will be awarded to independent, qualified contractors, selected through an appropriate tendering process as described in Volume I.

The DPWs are:

- Present Situation in Panama
- Status of the Present Panama Canal
- Historical Trade Analysis
- Future Transportation System and Significance of Panamanian Isthmus in World Trade
- Prescreening and Selection of Alternatives

For implementation purposes, the component studies are grouped into the following categories, for which TORs appear in Volume II (preliminary studies for prescreening activities to be performed by Component Study contractors are incorporated into the TOR's of the component studies marked with an asterisk):

- Commodity and Traffic Projections*
- Engineering and Cost Estimates*
- Operating Characteristics and Capacity Evaluation*
- Background Biological Data and Biological Inventory*
- Financing Scheme and Financial Analysis
- Economic and Impact Analyses
- Environmental Analysis
- Management Arrangements
- Development of Additional Data

Development of additional data will be done as the need for additional information is determined. The work will be done by either the component study contractors or by new contractors, depending on the type of additional data needed.

PURPOSE OF VOLUME II

The purpose of this volume is to present TORs to be provided to qualified contractors selected to submit proposals for component studies and to present the detailed work plans for preliminary studies to be performed by the FA/FR contractor. The information in this volume includes:

- Background material
- Description of alternatives
- Detailed Work Plans (DWPs) for FA/FR Contractor Studies
- Detailed Terms of Reference for the component studies

Also included as a separate bound Appendix for the Commission's discretionary use., is an estimate of the cost to carry out each component study.

ORGANIZATION AND USE OF VOLUME II

This volume is organized into the following sections:

- Introduction
- Project Background
- Discussion of Alternatives
- Detailed Work Plans (for work to be performed by FA/FR Contractor)
- TORs (one for each of the component studies)
- Appendix 1: Budget Estimates (bound separately)
- Appendix 2: Work Plan Flows and Detailed Input/Output Relationships

The sections are designed so that a TOR document for each Component Study may be assembled by combining the appropriate sections. For example, to prepare a complete TOR for the Commodity and Traffic Projections study, copies of the sections Introduction, Project Background and Discussion of Alternatives sections may be assembled with the Commodity and Traffic Projection TOR to form a complete document. Each TOR contains a description of the report requirements. In addition to the written reports, computer diskettes with appropriate DOS Files (WordPerfect, dBase, Lotus, etc.) will be provided to the Commission by the component study contractors.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

3. Operating Characteristics and Capacity Evaluation Study

Phase I

Summary and Conclusions

1993

SUMMARY AND CONCLUSIONS

Reported on herein are the results of the Operating Characteristics and Capacity Evaluation (OCCE) Study that covers analyses of ship transit time, delay time and system capacity over the study period 2020 to 2060 for a variety of alternative plans, ranging from a third set of locks to a sea-level canal. These alternatives represent a synthesis of numerous proposals that have been suggested over the past decades. The OCCE Study is one of several components comprising the Study of Alternatives to the Panama Canal.

The analyses are based on vessel mix forecasts prepared under the Commodity and Traffic Projection Study (see table below) and employed computer simulations using the Waterway Analysis Model (WAM), modified to replicate the Panama Canal lock and sea-level conditions.

TRAFFIC PROJECTIONS

Maximum Ship Size (DWT)	No. of Annual Ship Transits		
	Year 1990	Year 2020	Year 2060
65,000	11,520	18,350	24,810
100,000	-	17,620	23,970
150,000	-	18,140	24,670
250,000	-	18,220	24,740
300,000	-	18,210	24,730

Source: Commodity and Traffic Projections (CTP) Study
The WEFA Group

SHIP TYPES AND ARRIVALS

The ship types used are based on the beam and draft groupings that are used by the Panama Canal Commission (PCC) for ship scheduling purposes. In addition, vessel classes 15 through 22, corresponding to ships from 100,000 to 300,000 DWT in size were added for analysis of the lock and sea-level plans. Ship underway times were generated randomly as a Poisson process, based on an analysis of the current distribution of underway times.

EXISTING CANAL

Locking Times

Existing PCC transit records for 1990 were analyzed to determine, by vessel class and travel direction, the mean, standard deviation, minimum, and maximum for approach time and locking time. Average values were assigned for entry and exit times, by vessel class, based on our field data collection in Panama in 1991. All locking time components were adjusted to provide a consistent progression from small to large ships.

Lock Downtime

Analysis of the Locks Delay Data Base provided by the PCC revealed that the frequency and duration of downtime events varied by lock, but not by day of week or month. For each lock, the downtimes recorded for 1990 were sorted by day of year. Then, within each day, the downtime event was assigned a random start time, and randomly assigned to one of the lanes. A downtime of eight hours duration was added at lane two at Pedro Miguel at midnight on every day.

The scheduled lane outages for maintenance reported by the PCC for 1990 were added. This included two 11½ day outages of one lane for gate replacement at Gatun. The resulting downtime file was modified to remove overlapping events at a single chamber, simultaneous scheduled shutdowns of both lanes at a lock, and other inconsistencies.

Ship Characteristics and Speeds

PCC records were analyzed to obtain distributions of length, width, draft, horsepower, tonnage capacity, and various ratios of these dimensions, for each vessel class. Ship block coefficients were computed to produce correct length-width-draft-displacement relationships. The resulting data were smoothed to produce consistent relationships across ship size classes.

Based on preliminary simulation results, speed coefficients were selected for restricted channels (the Gaillard Cut) and unrestricted channels (all others). The resulting model outputs included average ship speeds that were in reasonable agreement with observed data.

Model Calibration Results

The average vessel transit time for the calibration run was 11.7 hours, including 4.1 hours of delay time and 7.6 hours of running/locking time. The average time from

the SDB records was 11.1 hours. Other results also looked reasonable, so the model was deemed sufficiently accurate for the purposes of the Phase 1 analysis.

SEA-LEVEL CANAL - TIDAL HYDRAULICS AND NAVIGATION

Studies were made to analyze the tide levels and currents in a sea-level canal generated by changes in the tides of the two oceans. The TAMS program LATIS was used to formulate a mathematical model of the canal. The spring tides in the Pacific range from about +10.3 to -9.8 ft., whereas at the Atlantic end the range is only about +1.2 to -0.7 ft.. This difference of levels 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 maximum allowable currents for the safe navigation of the very large ships, however, are about 2 knots per hour for head currents and 1 knot per hour for following currents.

The Vergara alternative, which would employ a large embayment at the Pacific end of the canal to mitigate tidal effect was investigated, but the analysis indicated that although currents in the canal would be reduced, the reduction would not be sufficient for safe navigation; moreover, very fast currents would be generated at the entrance to the embayment area.

It was concluded that a system of positive closure involving two tide gates, or locks, is needed to control currents. Tide gates would be operated only at slack water, which occurs every 6¼ hours. Operating cycles would be keyed to a half-tide cycle (6¼ hours) or full-tide cycle (12½ hours).

ALTERNATIVE CONCEPTUAL PLANS

Status Quo

The bendway representing the Gaillard Cut was modified to widen the channel to 630 feet, to permit two-way traffic, in accordance with the Panama Canal Commission's improvement plans to be completed by year 2010. (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 at elevation 90 ft., with the following dimensions were 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 Gaillard Cut channel dimensions would be such that the existing night time and clear cut restrictions in transit of large ships would no longer 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 largest existing ships 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, with 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.

Based on preliminary evaluation of the effectiveness of various alternatives, it was decided to model the following cases:

- single-lane 58 km between tide gates, 12½ hour cycle;
- dual-lane 18 km; single-lane 40 km flanked by tide gates, 6¼ hour cycle;
- single-lane 58 km canal section, Pacific locks, 12½ hour cycle;
- 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 year 2060, and that the capacity with tide gates is not very sensitive to ship size, some runs that were scheduled to be made 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" similar to the Gaillard 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, with lengths and widths similar to the high-rise and low-rise 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 modelled.

Combined Systems

As noted above, some cases involving a single-lane sea-level canal used in conjunction with the status quo canal were also modelled.

SIMULATION RUNS

The Waterway Analysis Model was run for the conceptual alternative plans using a variety of input files, including:

- network files (that describe the alternative being simulated);
- ship lists files (that describe ship characteristics and arrival patterns);
- downtime files (that describe lock outage events); and,

- control files (with instructions to the program regarding system parameters).

A total of 42 simulations were run. All runs were configured to simulate one entire year of operation.

Relay lockages were assumed throughout on the assumption that the canal would be so operated as to achieve maximum capacity, even though higher operating costs would be entailed.

The outputs included resource files, which outline each ship's transit through the canal and printout files. The resource files were processed by a commercially available database management system ('FoxPro') to produce summaries of travel time, delay time and total transit times.

CAPACITY AND TRANSIT DELAY

Capacity of a transportation artery is not a definitive number, but is related to acceptable delay time. A higher capacity in a system can be achieved at a cost of greater congestion and higher delays. Capacity is a function of ship mix and the ratio of laden to ballasted ships, as well as the physical characteristics of the alternatives.

In the canal, the level of delay time is related to the rate of ship arrivals, compared with the rate at which ships transit. With ships arriving in a random fashion, a plot of delay versus the number of transits produces a hyperbolic curve, with delays increasing gradually at low traffic volumes and then accelerating rapidly as traffic continues to increase until, finally, the curve becomes asymptotic.

Research based on queuing theory analysis indicates that the delay curve may be plotted from two data points, (in OCCE--for years 2020 and 2060), with the best results achieved if one point is on the flat portion of the curve and the other on the steep portion. If both points fall on either the flat or steep portion of the curve, the results do not produce a reliable specific number, although a judgment can be formed regarding the level of capacity.

In a number of cases modeled, the delay times produced by the model increased by relatively small amounts between years 2020 and 2060, and the delay in the latter year was less than the criterion, indicating that the case is well within capacity for year 2060, but also signaling that an actual capacity could not be derived accurately from the delay curve. In those cases (namely 2, 5, 6, 7 and 8) capacity estimates were made by considering separately the simulation results for the existing Gatun Locks and the proposed new Atlantic lock, and using the simulated lock utilization and delay levels to estimate lock capacities, then adding the resultant

estimates to obtain the system capacity. These estimates were then adjusted to take into account the relationships among ship mix, weighted average lock processing time, and lock capacity.

In other cases, where capacity would be exceeded by the year 2060, it was necessary to model cases with a portion of the 2020 traffic 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 continue to obtain in the future. Considering that unimpeded travel time is usually 8 hours or less, and to account for preparation time for canal transit, an average delay of 10 hours was assumed as one basis for capacity. Capacity was also calculated based on 6 hours of delay, except in sea-level cases based on a 12½ hour cycle time, where an average time of 6¼ hours would be spent by ships merely waiting for convoys to form, leaving no time for in-transit delays.

CONCLUSIONS

The capacities of the conceptual alternatives modeled and analyzed are presented in Tables XI-1 and XI-2. Curves with plots of delay time versus capacity appear in Chapter XI.

Review of the results, including comparison of estimated capacities presented in Tables XI-1 and XI-2 with the ship transits forecasted under the Commodity and Traffic Projections Study by the WEFA Group (Table V-2) indicates the following:

- with a 10-hour delay criterion, the status quo canal barely meets ship transit requirements at year 2020. With a six-hour criterion, the capacity of the status quo canal will be exceeded by year 2020;

- the capacity of new canal alternatives is more sensitive to alternative canal configurations than to variations related to maximum ship size;

- all high-rise and low-rise lock canal alternatives, for all ship mixes studied, have adequate capacity to year 2060;

- A closure system involving either two tide gates, or locks, at the Pacific side, is needed to limit tidal currents in a sea-level canal to safe levels for navigation.

- 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;

- with a 10-hour delay criterion, an 18 km dual-lane plus a 40 km single-lane sea-level canal flanked by tide gates would barely accommodate ship transit needs in year 2020. With a 6-hour criterion, the capacity of this alternative would be exceeded by year 2020;

- 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;

- 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, with a 10-hour delay criterion;

- in the case of the high-rise and low-rise Lock alternatives, with the elimination of the constraint currently imposed by the Gaillard Cut, delay encountered at the locks is 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, and a half-tide cycle, 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.[1] An additional benefit is that the canal would always be shielded from low tide; which would allow

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1 This could be done by opening the tide gate at the Pacific and simultaneously closing the north gate at the start of a high tide half cycle. A southbound convoy approaching the Pacific tide gate would steam out against a head current and, traveling at 13 km per hour, complete its exit in 3¼ hours, just as the tide reaches its peak (Figure VIII-2). The next convoy, northbound, would start to enter the canal as the tide starts to recede, and, with the north gate still closed, the flow south of the north gate will reverse towards the Pacific, again confronting the entering convoy head-on. As soon as the second convoy completes its entry, i.e., 6¼ hours after the start of the cycle (at the start of the low tide half cycle), the south gate will close (while the north gate opens), and will remain closed until the next slack tide 6¼ hours later, when the process repeats.

the Pacific approach channel to be dredged to a depth based on mean sea-level, rather than mean low water;

- for safe navigation, ships 150,000 DWT 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.

Comisión de Estudio
de las Alternativas
al Canal de Panamá
CENTRO DE INFORMACIÓN

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

4. Engineering and Cost Estimates Study

Phase I

Summary Report

1993

SUMMARY REPORT

1. General

This report is a summary of the Final Report for Phase 1 of the Panama Canal Alternative Study. Presented herein are the study results for the four basic study groups which have been considered in Phase 1 for the prescreening of alternatives.

The Final Report itself consists of Part I Engineering for Prescreening and Part II, Cost Estimation for Prescreening and Annex.

Each historic alternative is classified into one of the following four groups.

- Group A High rise lock canal (Water level 90' - 85')
- Group B Low rise lock canal (Water level 55' - 30')
- Group C Sea level canal (Route 10)
- Group D Sea level canal (Route 14S)

Each group is further classified into 9-study cases according to the size of ships, the highest water level in the lake (lock type only), number of lifts (lock type only), number of lanes, and route centerline location. The existing canal with announced Culebra Cut Widening is included as the status quo to serve as a basis for comparison.

The Final Report describes the results of the study of all 36 study cases. The interim findings for the Group A and Group C which were included in the Interim Report have been amended as necessary before inclusion in this Final Report.

The main features of the study cases are shown on the Comparative Summation Tables for Lock Type Canal and Sea Level Canal at the end of this Summary Report.

2. Group A - High Rise Lock (W.L.=90'- 85')

2.1 Routes

For the High Rise Lock system, there are two routes. On the first route a ship from the Pacific coast side follows the existing canal route, and changes direction to the west at a point 2 km north of the present port of Balboa where the ship diverts to the new 2-lift locks. The ship passes from the new locks into a new channel excavated 2.5 km west of Cerro Aguadulce, then joins the existing canal about 2.5 km north-west of the present Pedro Miguel locks.

After joining the existing canal, the ship transits the Culebra Cut section and then proceeds on Route-I through Gatun Lake (Fig. S.1), following the existing route. The ship turns right about 3 km before Gatun dam and proceeds via the new Gatun Locks to the new canal which extends 1.5 km east from Gatun Locks and is parallel to the existing canal. The ship then rejoins the existing route at Limon Bay. For this route, the characteristics of each of the 6 study cases are shown on Fig. S.1 as L-1, L-2, L-4, L-5, L-7 and L-8.

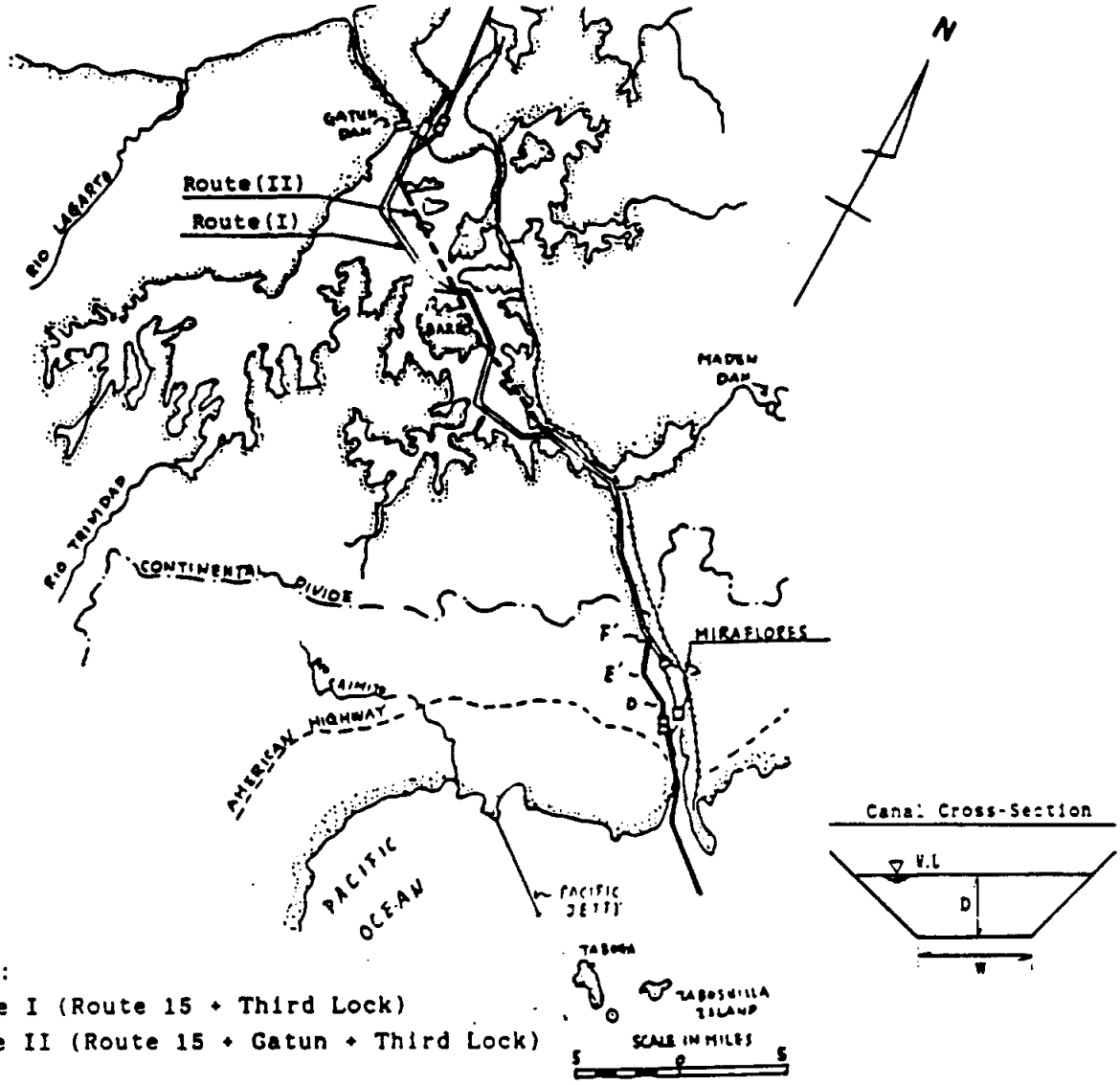
The 2nd route for the high rise lock system takes the same route from the Pacific coast side to reach Gatun Lake, then proceeds to take a modified route through Gatun Lake as shown by Route II (See dotted line) in Fig S.1. Three study cases, L-10, L-13 and L-16 adopt Route II.

2.2 Water Level

For the High Rise Lock system, the water level of Gatun Lake could be at the present water level (85'), but for the purpose of reducing the excavation volume, 90' water level cases (5' above the existing water level) have also been studied for study cases L-1, L-4 and L-7, as shown in Fig. S.1

From the studies, it was found that the 90' water level cases require no major reconstructions of existing facilities at Miraflores Locks, Gatun Locks and Gatun Dam, or of the railways and roads around the lake.

Further studies and surveys shall be required to confirm the future safety of the Panamanian people.



Note:
Route I (Route 15 + Third Lock)
Route II (Route 15 + Gatun + Third Lock)

Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
L-1	I	90'	2	2	100	301 x 18.7
2	I	85'	2	2	100	301 x 18.7
4	I	90'	2	2	150	343 x 20.9
5	I	85'	2	2	150	343 x 20.9
7	I	90'	2	2	250	399 x 24.2
8	I	85'	2	2	250	399 x 24.2
2'	I	85'	1	2	100	301 x 18.7
10	II	85'	2	2	100	301 x 18.7
13	II	85'	2	2	150	343 x 20.9
16	II	85'	2	2	250	399 x 24.2

Fig. S.1 Layout of High Rise Lock System for Group A Study Cases

2.3 New Locks

The new locks at the Pacific coast side would be located in the area already excavated for the Third Lock plan to the West of Cerro Aguadulce and Cerro Cocoli.

The new locks at the Atlantic coast side would be located in the existing excavated area running parallel to the existing Gatun Locks. The new locks have been designed for ship sizes of 100,000, 150,000 and 250,000 DWT in accordance with each study case as shown in Fig. S.1. For the High Rise Lock system, all locks would have 2 lifts, but a single lift system was primarily studied for the L-2' study case.

Gravity type lock structures have been generally adopted. The wall heights are about 50 meters maximum. As one example, Fig. S.2 shows the length and width of 250,000 DWT lock chambers, and the overall length. The size of the water supply culvert allows the filling or draining of lock water within 10 minutes for each lock chamber.

A single miter gate has been adopted for the new lock gates. Separate from the main gate, emergency gates and maintenance gates have also been proposed. For dimensions and number of gate leaves refer to the Summation Table for Lock Type Study Cases at the end of this Summary.

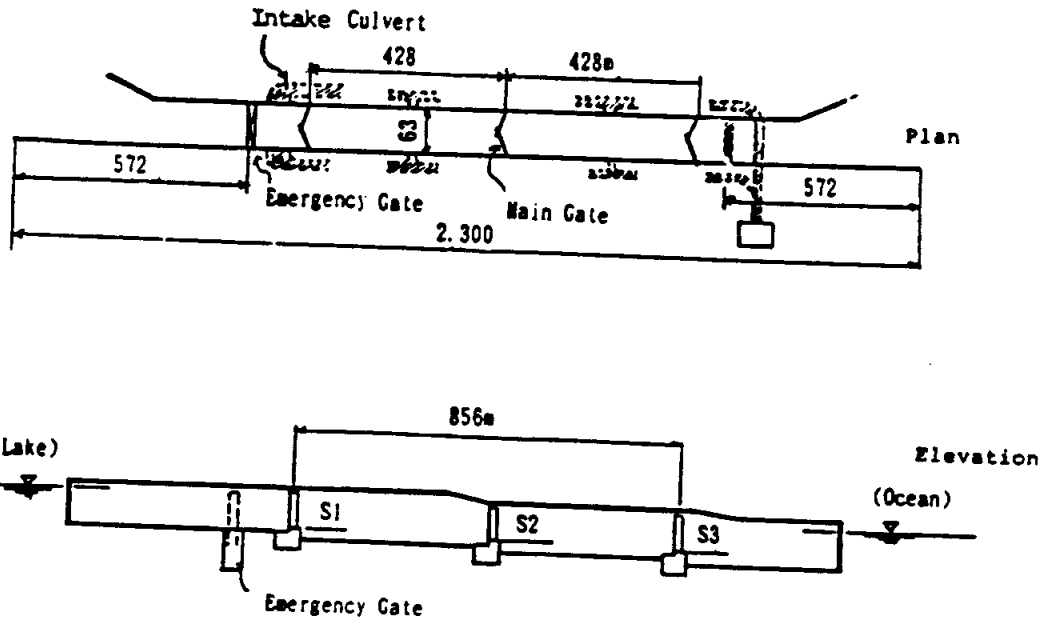


Fig. S.2 Lock Layout for 250,000 DWT Ships

2.4 Ancillary Facilities

(1) Anchorage Area

For the mooring of ships waiting for lock transit, anchorage and mooring areas are proposed above the new locks on the Pacific coast side. In Gatun Lake, no such anchorage area is required above the new locks on the Atlantic coast side because suitable areas are available in Gatun Lake.

(2) Surge Basin

The locks proposed at the Pacific coast side are directly connected by the open bypass channel to the existing canal, and surging may occur in the bypass channel as water pours from the bypass channel into the lock chambers.

To reduce the effects of surging, a surge basin is proposed in the area of the Rio Cocoli Valley. The surge basin utilizes natural terrain as much as possible. A closure dam is required at the south-east side of the basin.

(3) Recycling Pond

At the Pacific coast side, a recycling pond is proposed in the flat land on the northern part of San Juan Hill in order to hold discharged lockage water (mainly fresh water) as a source of supply for pumping operations during lock operation. The area of the pond is approximately 1.5 km^2. The effective water level would be +0.6 m - 1.6 m. A discharging channel for returning water from the recycling pond to the surge basin extends 800 meters. The width and depth of the channel have been chosen according to the number of pump stations required.

A similar recycling pond is proposed beside the approach channel on the Atlantic coast side.

(4) Pump Stations
(Recycling Pond to Surge Basin or Gatun Lake)

Approximate locations for pump stations have been proposed and the size of pump stations for each study case are shown in the Summation Table according to the number of transits.

2.5 Water Management

(1) Lockage Water

The sources of water for lock operation come from Madden Lake and Gatun Lake. The water volume of both lakes changes during the wet and dry seasons. Therefore, the available lockage water volume was calculated for each month according to the record of average discharge volume measured at several points over the last 50 years. Lockage water necessary for new lock systems are shown below in Fig. S.3. (The lockage water for existing canal is included.)

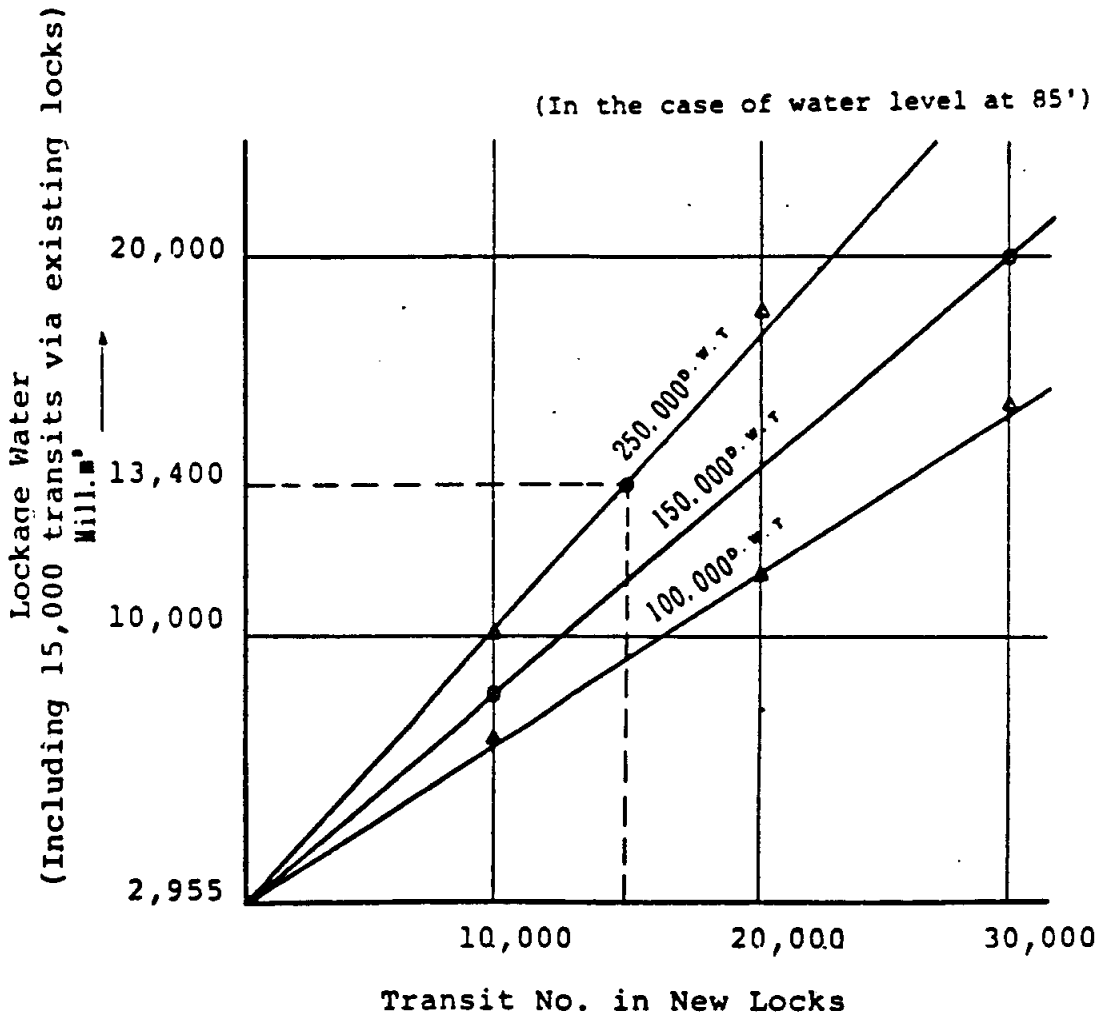


Fig. S.3 Lockage Water Volume by Transits
(Including allowance for 15,000 transits via existing locks)

For example:

a) When 15,000 ships with maximum ship size 250,000 DWT transit the new locks (85' water level) a year, the necessary lockage water volume is 13.4 billion m^3 (refer to Fig. S.3).

b) The total required lockage water for passing 10,000 ships of 100,000 DWT a year in the new locks (85') plus 15,000 transit per year in the existing locks is 6.83 billion m^3, comprising 3.88 billion m^3 for the new locks and 2.95 billion m^3 for the existing locks.

c) For 250,000 DWT, the water volume required is 9.92 billion m^3 for 10,000 transits in the new locks plus 15,000 transits in the existing canal locks (10,000 + 15,000 transits).

The water volume in Gatun Lake and Madden Lake is not sufficient for lockage water requirements. The necessary water volume for each study case, assuming transits of 10,000, 20,000 and 30,000 ships per year, are shown on the Comparative Summation Table for Lock Type Study Cases.

(2) New Dams to Increase Water Storage Capacity

To overcome the shortage of lockage water, Trinidado Dam and Ciri Dam have been proposed above Gatun Lake. Other dam sites were also considered but the two sites mentioned can most effectively provide the additional storage capacity given the limited catchment yield. These dams would reduce spillage losses at Gatun Dam but the overall catchment annual yield is not sufficient for the required volume of lockage water.

In the Summation Table, a solution to the shortage of water volume was studied by considering the increase in lockage water supply from the new dams.

(3) New Pump Stations for Solution of Water Shortage

Despite the added capacity of the possible new dams above Gatun Lake, the total annual supply of water is not sufficient in most cases to provide the required water volume for the lock systems proposed.

Therefore, the use of new pump stations to supply lockage water from a recycling pond was considered.

A pump station comprising two pumps, with an estimated capacity of 30 m^3/sec per pump, would have a total capacity of 60 m^3/sec. This total capacity becomes 1,829 million m^3 of additional available water supply per year. The Summation Table shows the necessary numbers of pump stations for each study case.

(4) Transit Capacity

For calculation of lockage water, 10,000, 20,000 and 30,000 transits per year are assumed in the new locks. Assuming also that the new locks have 2 lanes, the allowable relay time (time difference between successive ships passing the same point) between consecutive ships in the same lock would be as follows.

Transits/Year	Average Relay Time (min)
10,000	105
20,000	53
30,000	35

The actual relay time for 100,000-250,000 DWT ships would be at least 80 minutes considering the operation of locks and ship maneuvering. Hence, 13,000 transits would be the limit for 2 lane locks, and if more transits are required, then the number of lock lanes should be increased to 4 lanes or more.

Assuming that sufficient lanes of locks were available, the number of pump stations required for 10,000, 20,000 and 30,000 transits in the new locks, in addition to 15,000 transits in the existing locks, would be as shown in Table S.1.

Table S.1 No. of Pump Stations by Transits

Ship size (DWT)	Transits per year	No. of P.S's (with New Dams)	No. of P.S's (without New Dams)	Note
100,000	10,000	1-set	1-set	W.Level 85'
100,000	20,000	3-sets	4-sets	2-lift
100,000	30,000	5-sets	6-sets	locks
150,000	10,000	2-sets	2-sets	
150,000	20,000	4-sets	5-sets	
150,000	30,000	7-sets	7-sets	
250,000	10,000	2-sets	3-sets	
250,000	20,000	6-sets	7-sets	
250,000	30,000	10-sets	10-sets	

Note: P.S. = pumping station

3. Group B - Low Rise Lock Canal (W.L.-55 - 30')

In comparison to the High Rise Lock system, the feature of the Low Rise Lock System is the reduction of the water level in Gatun lake from 85' to 55' and 30'.

The location of the construction of new Low Rise Locks would be the same as for the High Rise Locks. The new locks are designed as a single lift. Ships from the Pacific side passing the new locks would follow the direction of the existing canal route after detouring from the Pedro Miguel Locks (demolished) and part of Miraflores Lake. An increase of water depth is required in the canal and in the lake waterway.

3.1 Layout for 55' Water Level

The layout for the 55' water level is shown in Fig. S.4. The following new facilities are required to reduce the water level to 55'.

(1) In order to keep the water level in other parts of Gatun Lake at the existing 85', barrier dams are required in Gatun Lake.

(2) Spillways/diversion channels are required to discharge major floods from the catchments retained by the barrier dams.

(3) At the existing Gatun Dam, spillway modification or reconstruction is required to meet the 55' water level.

(4) One of the lifts of the Gatun Locks would be demolished and it would also be necessary to demolish the Pedro Miguel Locks.

3.2 Layout for 30' Water Level

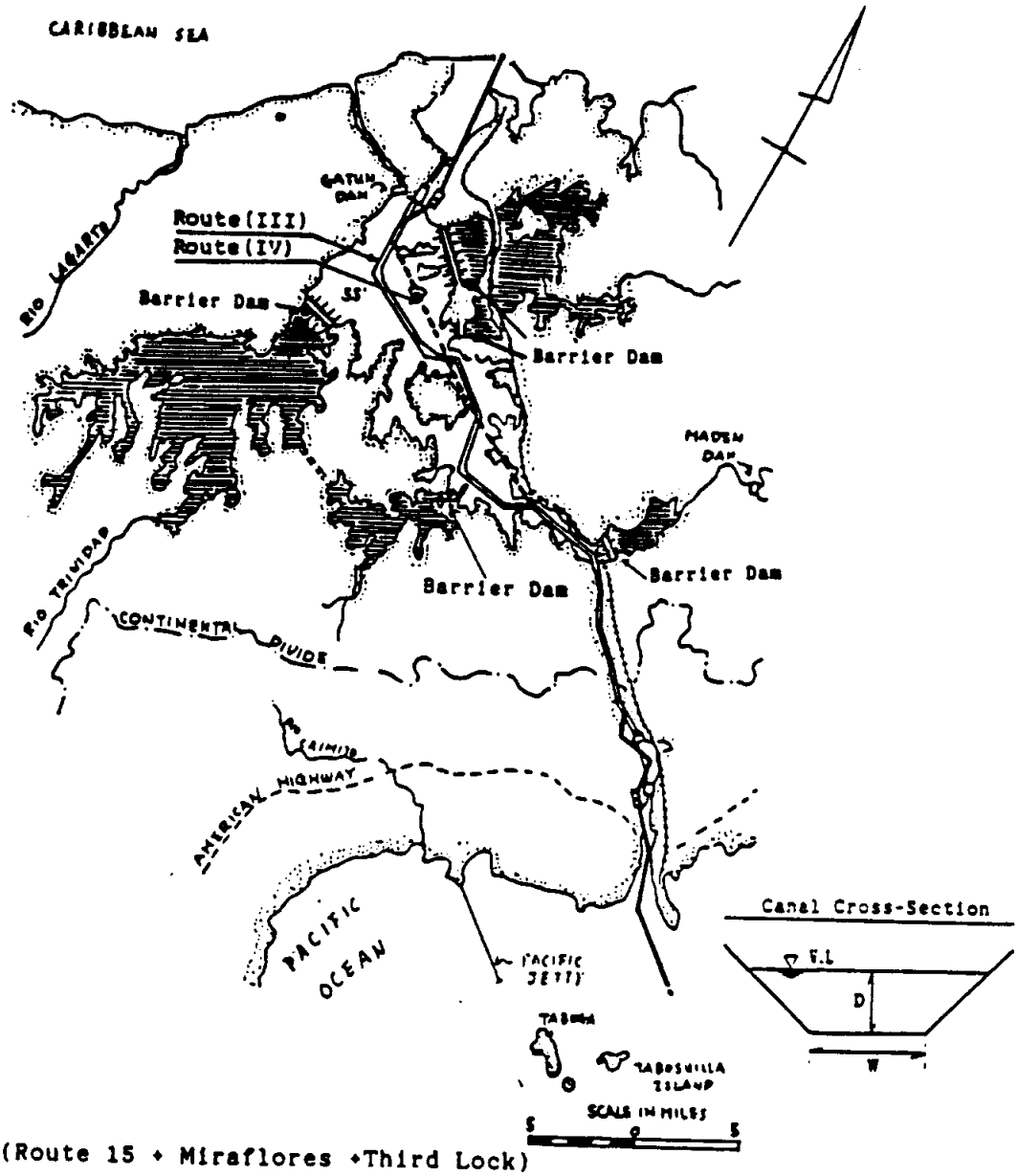
The layout for 30' water level is shown in Fig. S.5. In this case, the following points should be considered.

(1) Reconstruction, including some demolition, is required at the existing Miraflores Locks.

(2) Demolition of the Pedro Miguel Locks would be required.

(3) Ships passing the new Low Rise lock proceed along a new canal, partly along the Continental Divide after detouring away from Miraflores Lake and the Pedro Miguel Locks.

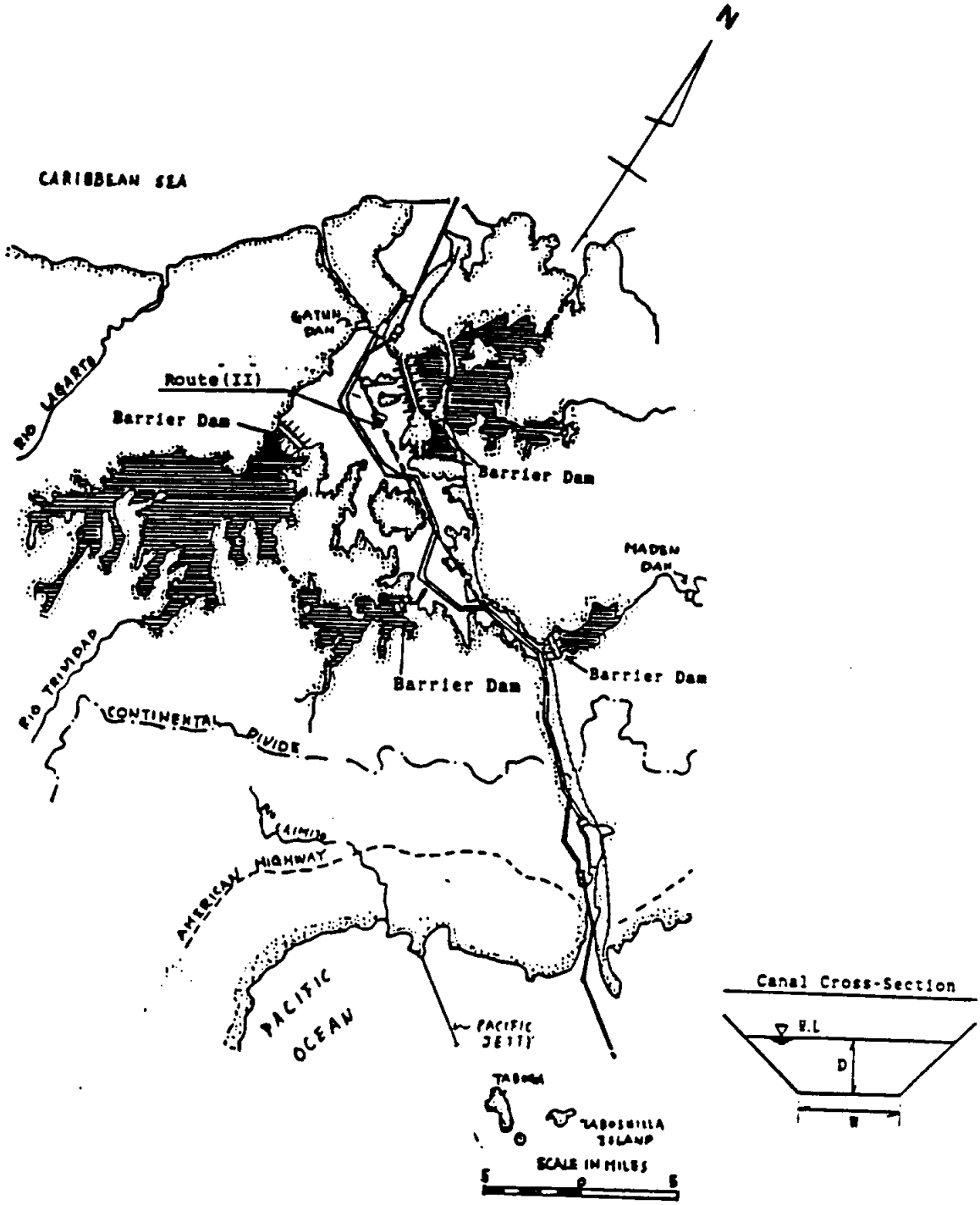
(4) Spillways/diversion channels are required to discharge major floods from the catchment retained by the barrier dams.



Note:
Route III (Route 15 + Miraflores +Third Lock)
Route IV (Route 15 + Gatun + Miraflores + Third Lock)

Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
L-3	III	55'	1	2	100	301 x 18.7
6	III	55'	1	2	150	301 x 20.9
9	III	55'	1	2	250	399 x 24.2
11	IV	55'	1	2	100	301 x 18.7
14	IV	55'	1	2	150	343 x 20.9
17	IV	55'	1	2	250	399 x 24.2

Fig. S.4 Layout of Low Rise Lock System for Group B Study Cases (55')



Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
L-12	II	30'	1	2	100	301 x 18.7
15	II	30'	1	2	150	343 x 20.9
18	II	30'	1	2	250	399 x 24.2

Fig. S.5 Layout of Low Rise Lock System for Group B Study Cases (30')

4. Group C - Sea-Level Canal (Route 10)

The Group C study cases follow Route 10 located 16 km west of and parallel to the existing canal as shown in Fig. S.6.

The Pacific terminal of the route is at the town of Puerto Caimito at the mouth of the Caimito River. The route follows the river north-westward for 8 km, crossing the Pan American Highway about 4.8 km north-east of La Chorrera. It continues to the north through generally open and rolling terrain; crosses the Continental Divide through the Chorrera Gap; and parallels the Pescado River until it reaches an arm of Gatun Lake at La Laguna. Turning in a more westerly direction, the route continues over relatively flat terrain and crosses the Trinidad arm of Gatun Lake, to Escobal. From there it runs north-westerly through low ridges that become more open towards the coast. It enters the Atlantic at the town of Lagarto. Atlantic approach channel would be only 3.2 km long; however, that on the Pacific would require 24.1 km of underwater excavation, extending past Taboga Island.

A special feature of this group of study cases is the current stream in the new canal caused by tidal differences between the two ocean levels. For example, the tidal current in a sea level canal was estimated in "Isthmian Canal Studies-1947" (Annex 7, part IV) to be 4.5 knots. This velocity computation was supported by model tests at a scale of 1:100 conducted by the Panama Canal Company during the Isthmian Canal Studies. The results of the model test and the velocity computation were similar. The IOCS study also estimated tidal currents for various canal configurations and concluded that currents would exceed 3 knots for most tide cycles.

Therefore, some form of control of tidal currents should be provided and two methods have been considered. First, currents could be controlled by the construction of tidal gates (concrete structures with steel gates). In this report, various types of tidal gates are studied and a rolling gate of triangular section is recommended.

Another method of tide control was presented in the Vergara plan "El Canal Al Nivel" in 1982. The Vergara plan intended to provide tidal control and also safe anchorage and mooring of ships. The plan proposed the construction of large embankments of 20 km in length outside each canal entrance and completely enclosed with the exception of a small opening to allow for ship passage.

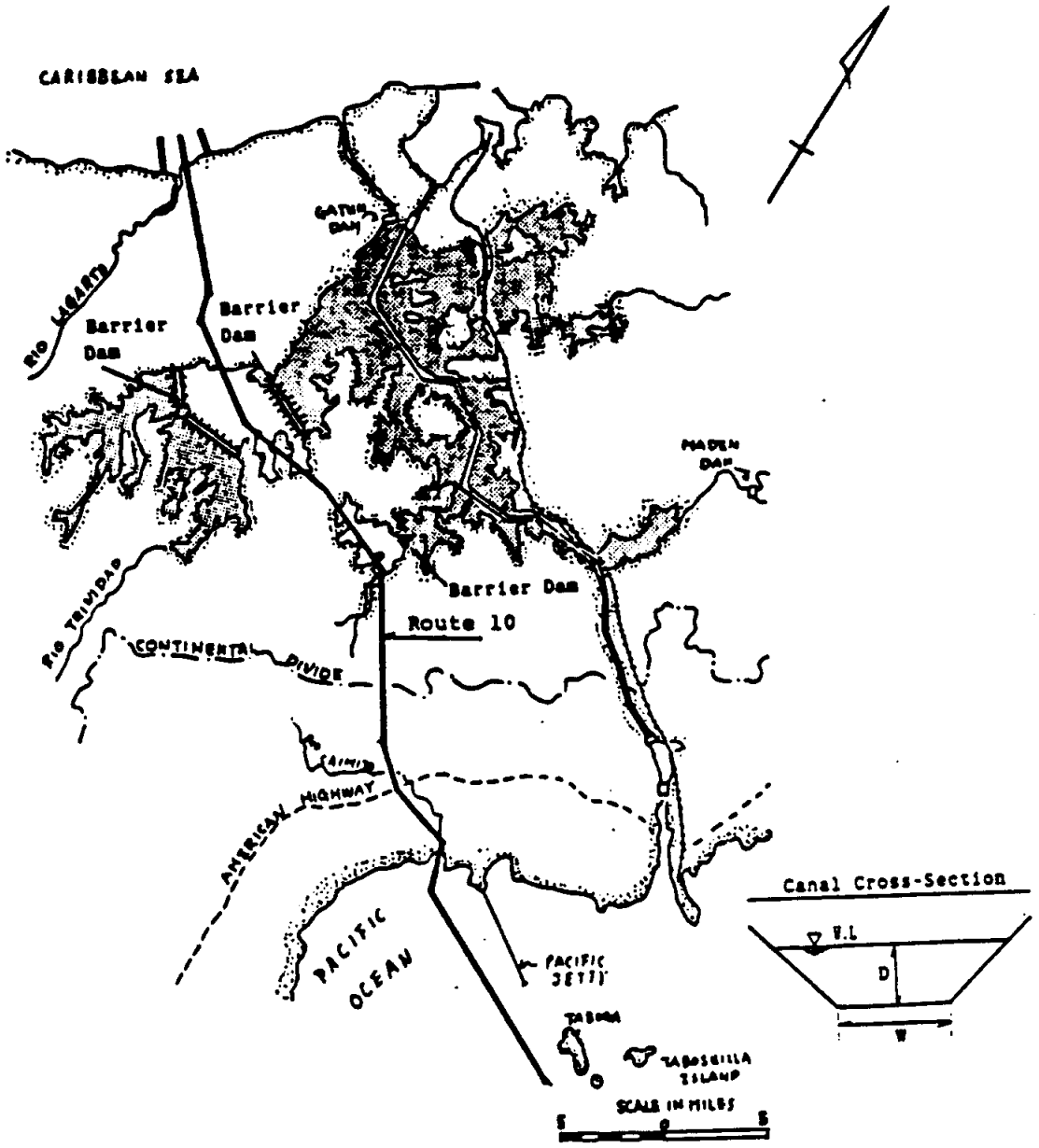
Facilities required for this sea level canal (Route 10) are as follows:

(1) Tidal gates and breakwaters are required at the Pacific Ocean side and Atlantic Ocean side except in the Vergara plan.

(2) Tidal basins are proposed according to the Vergara plan.

(3) Barrier dams and spillways are required to retain the water level of Gatun Lake from the canal route.

The layout of this study case is shown in Fig. S.6. This group of study cases is classified into 9 study cases: S-1 - 6, and S-13 - 15 in accordance with the conditions such as numbers of lanes and size of ships.

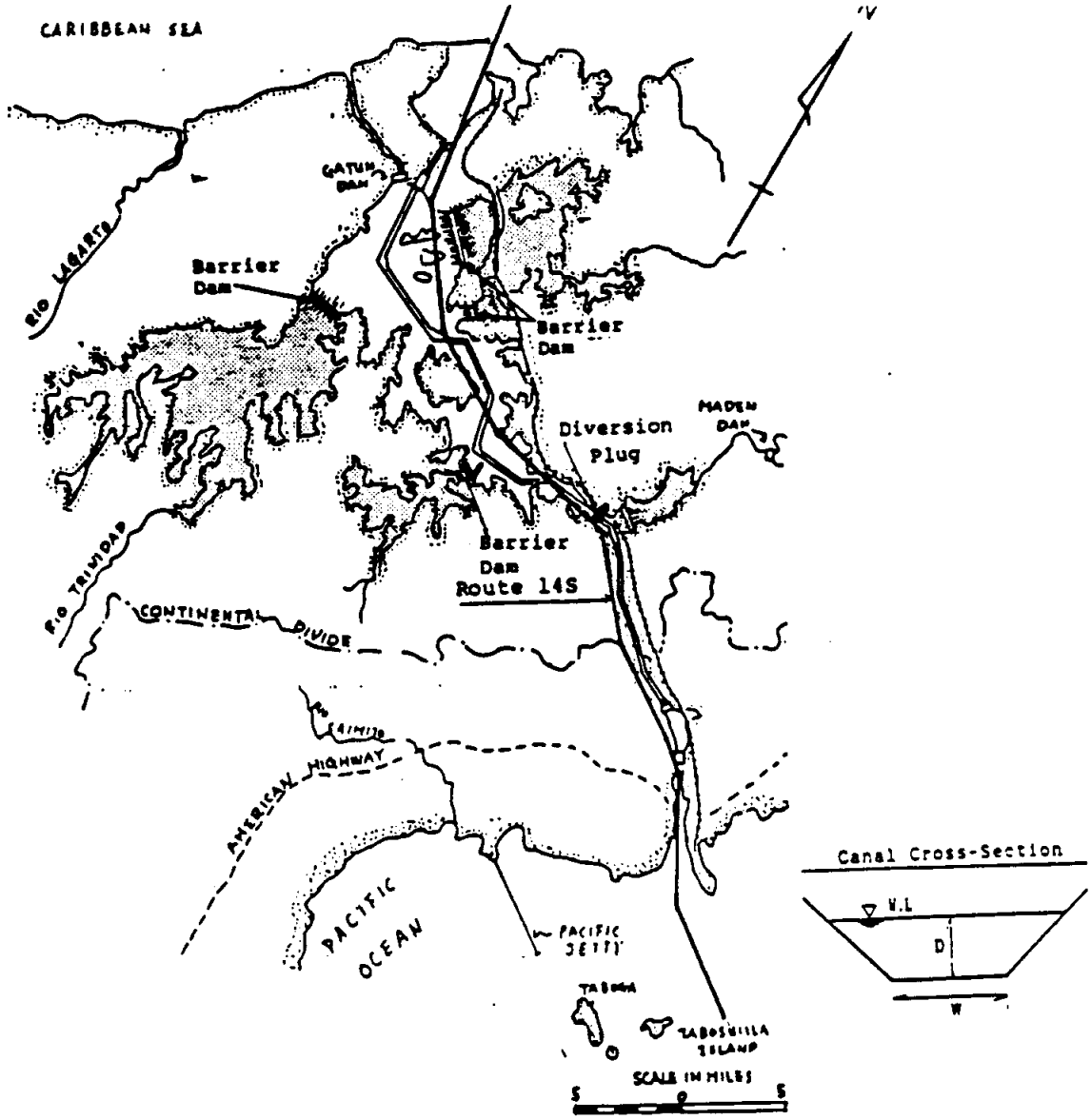


Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
S-1	10	0	-	1	150	147 x 20.9
2	10	0	-	2	150	343 x 20.9
3	10	0	-	1	250	171 x 24.2
4	10	0	-	2	250	399 x 24.2
5	10	0	-	1	300	183 x 25.3
6	10	0	-	2	300	424 x 25.3
13	10	0	-	50%-1	150	147 x 20.9
				50%-2		343 x 20.9
14	10	0	-	50%-1	250	171 x 24.2
				50%-2		399 x 24.2
15	10	0	-	50%-1	300	183 x 25.3
				50%-2		424 x 25.3

Fig. S.6 Layout of Sea Level Canal for Group C Study Cases (Route 10)

5. Group D - Sea-Level Canal (Route 14S)

5.1 The Route alignment of this group of study cases is shown in Fig. S.7. On the Pacific side, Route 14, coincides with approaches to the present lock canal until it reaches the Pacific Third Locks cut, where it follows a 12.9 km bypass through the divide. The route then generally follows the alignment of the existing canal northeast of Cerro Gord and continues toward Gatun Lake, keeping southwest of the present canal until it reaches the Darien Peninsula. Turning slightly northward, it then passes Barro Colorado on the east, touching the end of Bohio Peninsula. The route then turns north across Gatun Lake and follows the present canal route to the Caribbean. The Pacific approach channel is about 20.9 km and the Atlantic approach is 12.9 km long.



Study Case	Route	W. Level	No. of Lifts	No. of Lanes	Ship Size (1000 DWT)	Canal Size W (m) D
S-7	14S	0	-	1	150	147 x 20.9
8	14S	0	-	2	150	343 x 20.9
9	14S	0	-	1	250	171 x 24.2
10	14S	0	-	2	250	399 x 24.2
11	14S	0	-	1	300	183 x 25.3
12	14S	0	-	2	300	424 x 25.3
16	14S	0	-	50%-1 50%-2	150	147 x 20.9 343 x 20.9
17	14S	0	-	50%-1 50%-2	250	171 x 24.2 399 x 24.2
18	14S	0	-	50%-1 50%-2	300	183 x 25.3 424 x 25.3

Fig. S.7 Layout of Sea Level Canal for Group D Study Cases (Route 14S)

6. Excavation Volume

Excavation volumes were calculated separately for the areas of sea, land and lake. Volumes include associated excavation volumes for locks, mooring areas, recycling ponds, etc.

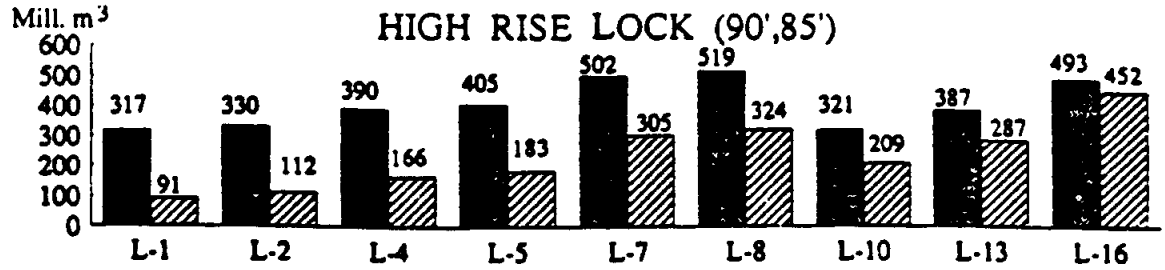
The volume of excavation in each area is classified into two categories, dry and dredging, and each category is further separated into seven sub-categories: Earth (common), Rock (weathered), Rock, Rock (underwater), Dredging (loose material), Dredging (clayey material) and Dredging (weathered softrock).

The total maximum and minimum dry and dredging excavation volumes for the Group A, B, C and D study cases are summarized in Table S.2.

Table S.2 Excavation Volume (Million m^3)

Group		Max. V Min. V	Case
A.	High rise lock	945	L-16
		408	L-1
B.	Low rise lock	1,510	L-18
		594	L-3
C.	Sea level (R-10)	2,190	S-6
		937	S-1
D.	Sea level (R-14S)	2,057	S-12
		899	S-7

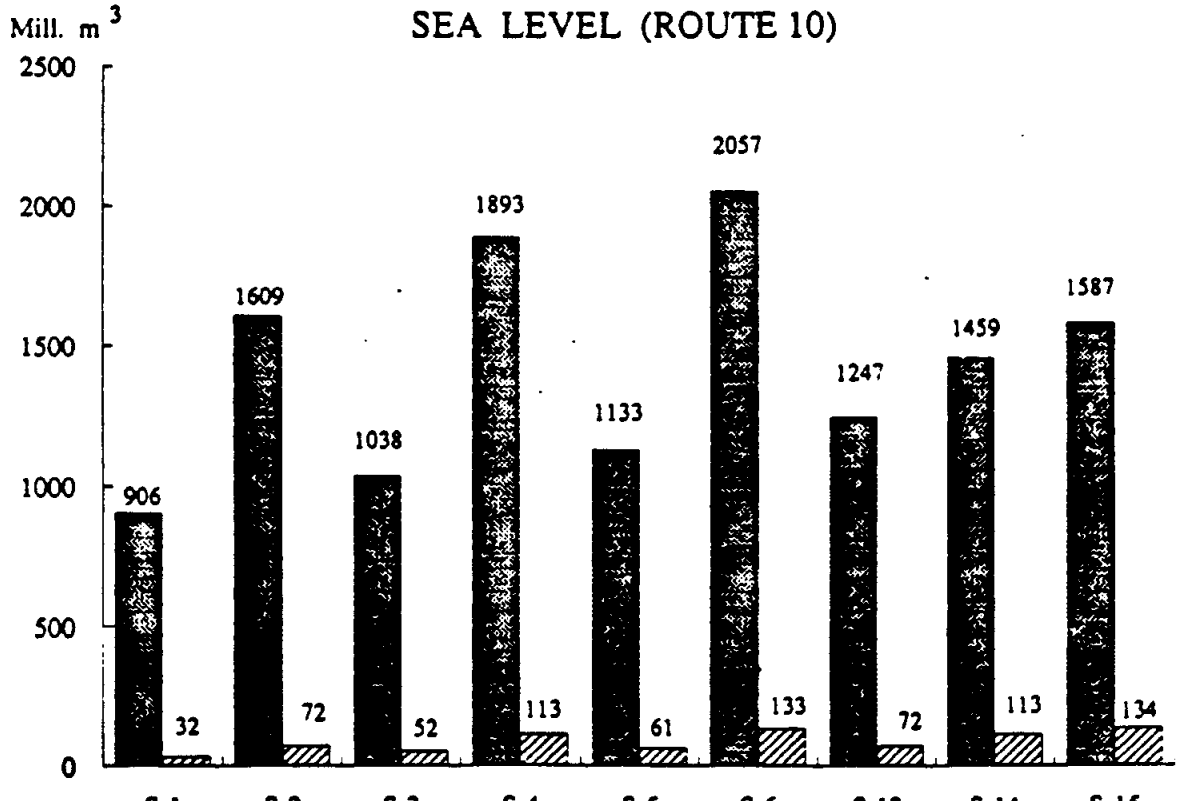
The excavation volumes for each study case are graphed in Figs. S.8 - S.11.



W. Level	90'	85'	90'	85'	90'	85'	85'	85'	85'
Ship Size(1000DWT)	100	100	150	150	250	250	100	150	250
Lane No.	2	2	2	2	2	2	2	2	2
Lift No.	2	2	2	2	2	2	2	2	2

■ Dry Excavation Volume ▨ Dredging Excavation Volume

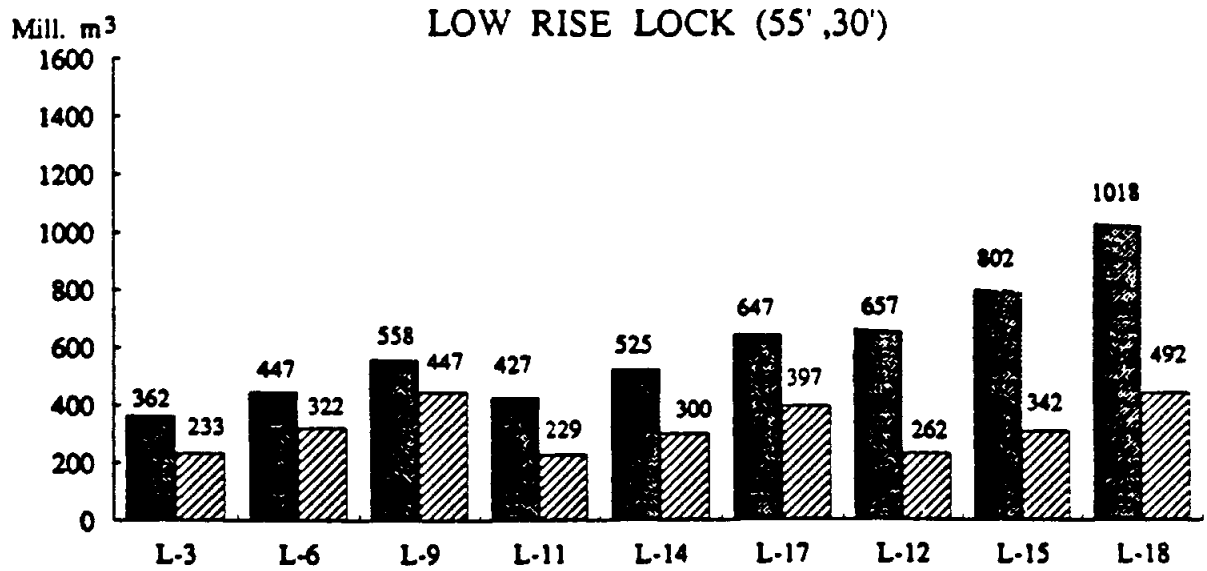
Fig. S.8 Excavation Volume (L1 - L16)



W. Level	0'	0'	0'	0'	0'	0'	0'	0'	0'
Ship Size(1000DWT)	150	150	250	250	300	300	150	250	300
Lane No.	1	2	1	2	1	2	1, 2	1, 2	1, 2

■ Dry Excavation Volume ▨ Dredging Excavation Volume

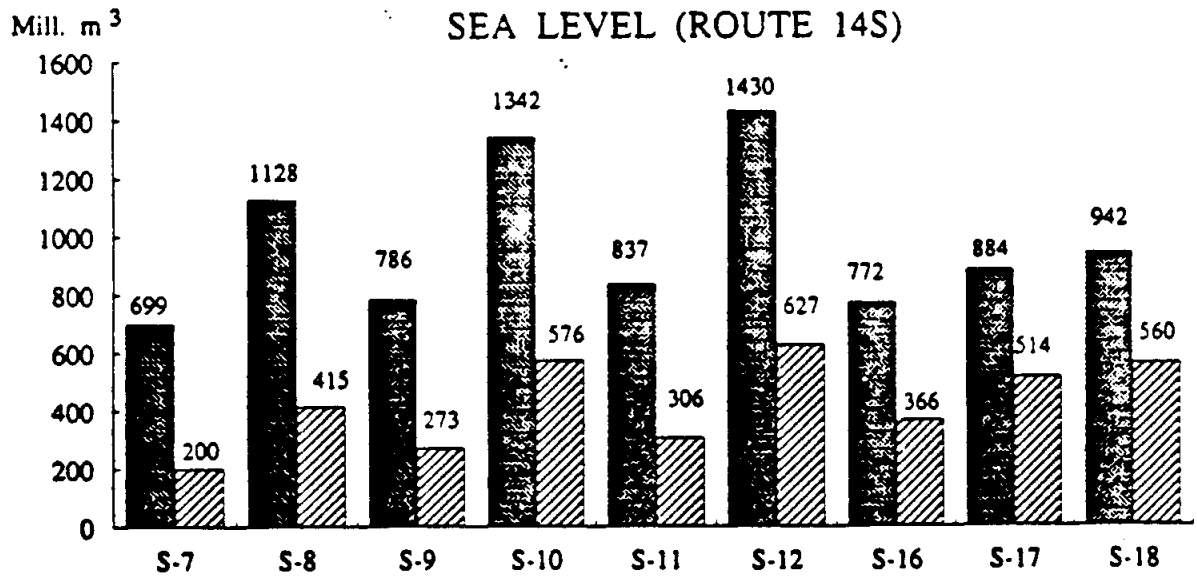
Fig. S.9 Excavation Volume (S1 - S15)



	L-3	L-6	L-9	L-11	L-14	L-17	L-12	L-15	L-18
W. Level	55'	55'	55'	55'	55'	55'	30'	30'	30'
Ship Size(1000DWT)	100	150	250	100	150	250	100	150	250
Lane No.	2	2	2	2	2	2	2	2	2
Lift No.	1	1	1	1	1	1	1	1	1

■ Dry Excavation Volume ▨ Dredging Excavation Volume

Fig. S.10 Excavation Volume (L3 - L18)



	S-7	S-8	S-9	S-10	S-11	S-12	S-16	S-17	S-18
W. Level	0'	0'	0'	0'	0'	0'	0'	0'	0'
Ship Size(1000DWT)	150	150	250	250	300	300	150	250	300
Lane No.	1	2	1	2	1	2	1, 2	1, 2	1, 2

■ Dry Excavation Volume ▨ Dredging Excavation Volume

Fig. S.11 Excavation Volume (S7 - S18)

7. Estimation of Operation and Maintenance Cost

Estimation of Operation and Maintenance costs are shown in APPENDIX 4.

8. Summation Tables

A. LOCK TYPE STUDY CASES COMPARATIVE SUMMATION TABLE(1)

I T E M S	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 ALTERNATIVES																				
(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	399x24.2	301x18.7	301x18.7	301x18.7	343x20.9	343x20.9	343x20.9	399x24.2	399x24.2	399x24.2
B - WATER MANAGEMENT PLAN (3 CASES)																				
(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	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
(2) Case 1: 10,000 transits/year in new locks																				
a. Water volume required	bil.m3	4.09	3.87	7.74	5.01	5.35	5.06	6.55	7.36	6.96	9.01	3.87	5.01	2.70	5.06	6.55	3.53	6.96	9.01	4.85
b. Total water required ((1)a + (2)a)	bil.m3	7.04	6.82	10.69	7.96	8.30	8.01	9.50	10.31	9.91	11.96	6.82	7.96	5.65	8.01	9.50	6.48	9.91	11.96	7.80
c. Countermeasures to be taken																				
- Water pumping with new dam	bil.m3	1.30	1.05	4.90	2.47	2.57	2.29	4.01	4.54	4.04	6.47	1.05	2.47	1.55	2.29	4.01	0.99	4.04	6.47	2.31
- Water pumping without new dam	bil.m3	1.55	1.33	5.20	2.47	2.81	2.52	4.01	4.82	4.42	6.47	1.33	2.47	1.55	2.52	4.01	0.99	4.42	6.47	2.31
d. - Sets of pump stations (with new dam)	set	1	1	3	2	2	2	2	3	2	4	1	2	1	2	2	1	2	4	2
- Sets of pump stations (without new dam)	set	1	1	3	2	2	2	2	3	3	4	2	2	1	2	2	1	3	4	2
(3) Case 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	13.10	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	16.05	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																				
- Water pumping with new dam	bil.m3	5.64	4.84	12.63	7.48	7.87	7.28	10.56	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	6	7	6	9	3	4	2	4	6	3	6	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
(4) Case 3: 30,000 transits/year in new locks																				
a. Water volume required	bil.m3	12.27	11.61	23.22	15.03	16.05	15.18	19.65	22.08	20.88	27.03	11.61	15.03	8.10	15.18	19.65	10.59	20.88	27.03	14.55
b. Total water required ((1)a + (4)a)	bil.m3	15.22	14.56	26.17	17.98	19.00	18.13	22.60	25.03	23.83	29.98	14.56	17.98	11.05	18.13	22.60	13.54	23.83	29.98	17.50
c. Countermeasures to be taken																				
- Water pumping with new dam	bil.m3	9.47	8.69	20.34	12.49	13.26	12.37	17.11	19.28	18.07	24.49	8.69	12.49	5.55	12.37	17.11	8.05	18.07	24.49	12.01
- Water pumping without new dam	bil.m3	9.73	9.07	20.68	12.49	13.51	12.64	17.11	19.54	18.34	24.49	9.07	12.49	5.55	12.64	17.11	8.05	18.34	24.49	12.01
d. - Sets of pump stations (with new dam)	set	5	5	11	7	7	7	9	11	10	13	5	7	3	7	9	5	10	13	7
- Sets of pump stations (without new dam)	set	6	6	12	7	8	7	9	11	10	13	5	7	3	7	9	5	10	13	7
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 weignt	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	41.9	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	10x10	9x10	10x11	7x8	8x8	6x7	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

Note*1: Lock dimensions; (A) 319x47x19, (B) 363x54x21, (C) 428x63x24

A. LOCK TYPE STUDY CASES COMPARATIVE SUMMATION TABLE(2)

I T E M S	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 Ciri 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	387	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) Power Requirement																				
a. Lock operation total requirement	1000 kW	57.7	55.5	51.6	37.0	93.4	88.9	58.7	113	108.4	69.7	56.2	37.0	25.5	89.4	58.7	38.7	108.4	71.4	46.2
- Lock gate operation	1000 kW	32.3	31.5	27.6	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																				
- Case 1: 10,000 transits (with dam)	1000 kW	18.4	18.4	55.2	36.8	36.8	18.4	36.8	55.2	36.8	73.6	18.4	36.8	18.4	36.8	36.8	18.4	36.8	73.6	36.8
- Case 2: 20,000 transits (with dam)	1000 kW	55.2	55.2	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
- Case 3: 30,000 transits (with dam)	1000 kW	92.0	92.0	202.0	129.0	129.0	129.0	166.0	202.4	184.0	239.0	92.0	129.0	55.2	129.0	166.0	92.0	184.0	239.0	129.0
c. Total power requirement																				
- Case 1 (Lock oper. + Case 1 pump sta.)	1000 kW	76	74	107	74	130	107	96	168	145	143	75	74	44	126	96	57	145	145	83
- Case 2 (Lock oper. + Case 2 pump sta.)	1000 kW	113	111	181	111	185	163	169	242	218	236	111	111	62	163	169	94	218	237	120
- Case 3 (Lock oper. + Case 3 pump sta.)	1000 kW	150	148	254	166	222	218	225	315	292	309	148	166	81	218	224	131	292	310	175
D - CONSTRUCTION COSTS																				
(1) Channel excavation																				
a. Dry excavation	mill.US$	1,055	1,683	1,683	2,053	1,955	2,042	2,528	2,494	2,589	3,154	1,645	2,402	3,622	1,955	2,944	4,495	2,465	3,632	5,580
b. Dredging	mill.US$	1,555	1,209	1,209	2,776	1,731	1,994	4,024	4,042	4,423	6,069	2,978	3,134	4,097	4,010	4,161	5,380	7,044	5,712	8,189
Total channel excavation	mill.US$	2,610	2,892	2,892	4,829	3,686	4,036	6,552	6,536	7,012	9,223	4,623	5,536	7,719	5,965	7,105	9,875	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$	-	-	-	346	-	-	346	-	-	346	-	346	346	-	346	346	-	346	346
(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	1,226	1,627	1,868	1,924	2,211	1,217	1,372	1,670	1,535	1,716	2,084	2,324	2,230	2,817
(8) Culebra Cut Widening	mill.US$	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209	-209
(9) Total Project Cost	mill.US$	5,577	6,103	6,405	8,414	7,911	8,177	11,086	12,835	13,239	15,318	8,111	9,234	11,401	10,415	11,728	14,399	16,136	15,458	19,718
(10) New bridges (for reference)	mill.US$	227	227	227	227	262	262	262	328	328	328	227	227	227	262	262	262	328	328	328
E - OPERATION AND MAINTENANCE COSTS																				
(1) Electrical power (energy)	mill.US$	40	40	64	40	64	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	16	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. Gatun Lake salinity danger	grade	S	S	L	M	M	S	M	L	M	L	S	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.

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 Powerx365daysx24hrsx(a)x0.07US$
(where (a):operating efficiency=60%, 1kw/hr=0.07US$)

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	89.55	89.55	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 (Wxd)	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	183X31.4	183X31.4	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	Mill.m2	73	73	73	73	73	73	-	-	-	-	-	-	73	73	73	-	-	-
Embankment Volume	Mill.m3	18.5	18.5	18.5	18.5	18.5	18.5	-	-	-	-	-	-	18.5	18.5	18.5	-	-	-
b. Atlantic: Basin area	Mill.m2	62	62	62	62	62	62	-	-	-	-	-	-	62	62	62	-	-	-
Embankment Volume	Mill.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	Mill.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	Mill.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	Mill.m3	906	1,609	1,038	1,893	1,133	2,057	699	1,128	786	1,342	837	1,439	1,247	1,459	1,587	772	884	942
b. Dredging Excavation	Mill.m3	32	72	52	113	61	133	200	415	273	576	306	626	72	113	134	366	514	560
Total Excavation Volume	Mill.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

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

B. 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 lanes	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	89.55	89.55	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 (Wxd)	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	Mill. US$	4,917	8,247	5,190	9,072	5,947	10,665	4,438	6,957	4,946	8,234	5,251	8,817	6,600	7,269	8,193	4,844	5,507	5,852
b. Dredging	Mill. 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	Mill. 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	Mill. US$	216	257	254	302	292	348	216	257	254	302	292	348	216	254	292	216	254	292
(3) Canal Partition Wall	Mill. US$	-	556	-	650	-	743	-	578	-	675	- -	771	-	-	-	-	-	-
(4) Tidal Gate	Mill. US$	207	240	290	335	328	379	208	240	290	335	328	379	208	290	328	208	290	328
(5) Breakwater	Mill. US$	45	45	45	45	45	45	-	-	-	-	-	-	45	45	45	-	-	-
(6) Barrier Dam	Mill. US$	182	182	182	182	182	182	346	346	346	346	346	346	182	182	182	346	346	346
(7) Flood Control System	Mill. US$	13	13	13	13	13	13	-	-	-	-	-	-	13	13	13	-	-	-
(8) Indirect Costs	Mill. US$	1,044	1,713	1,128	1,923	1,271	2,235	2,320	4,327	2,863	5,783	3,263	6,283	1,348	1,516	1,703	3,499	4,729	5,132
(9) Total Project Costs	Mill. US$	6,803	11,653	7,413	13,179	8,453	15,440	16,110	30,661	20,659	41,214	22,943	44,842	9,012	10,226	11,586	24,657	33,573	36,496
(10) New bridges (for reference)	Mill. US$	145	262	153	328	167	354	145	262	153	328	167	354	262	328	354	262	328	354
D OPERATION AND MAINTENANCE COST																			
(1) Man Power and Others O&M Cost	Mill. 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 Enviromental 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.

9. Members of the Study Team for Phase 1 Study

The members of Study Team are as follows:

Assignment	Name	Organisation
Project Manager	Dr. Akira Ishido	Yachiyo Engineering Co., Ltd.
Structural Engineer	Mr. Shuji Sekiguchi	Yachiyo Engineering Co., Ltd.
Geologist	Mr. Nobuhiko Uchiseto	Yachiyo Engineering Co., Ltd.
Geotechnical Engineer	Mr. Murao Toyama	Yachiyo Engineering Co., Ltd.
Civil/Hydraulics Engineer	Mr. Toshinobu Nakano	Sanyu Consultants Inc.
Mechanical Engineer	Mr. Hiroshi Terada	Mitsubishi Heavy Industries Co., Ltd.
Waterways Specialist	Mr. John Read	G. Maunsell & Partners
Port/Harbor Engineer	Mr. Takahisa Sogabe	Yachiyo Engineering Co., Ltd.
Railroad Engineer	Dr. Hideo Yokota	Yachiyo Engineering Co., Ltd.
Highway Specialist	Mr. Toshihiro Hotta	Yachiyo Engineering Co., Ltd.
Pipeline Engineer	Mr. Toyoichi Takeda	Japan Oil Engineering Co., Ltd.
Design/Quantities Engineer	Mr. Masaaki Naito	Seiwa Consultants Co., Ltd.
Cost Engineer (1)	Mr. Jun Iwasawa	Seiwa Consultants Co., Ltd.
Cost Engineer (2)	Mr. Koichi Nagayoshi	Yachiyo Engineering Co., Ltd.
System Engineer	Mr. Mahmoud-S. Riad	Yachiyo Engineering Co., Ltd.
Working members in Panama		
Port/Harbor Engineer	Mr. Satoru Nishino	Yachiyo Engineering Co., Ltd.
Structural Engineer	Mr. Masashi Bessho	Yachiyo Engineering Co., Ltd.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

5. Commodity and Traffic Projection Study

Phase I

Executive Summary

1993

1.0 EXECUTIVE SUMMARY

In August, 1991 the Commission for the Study of Alternatives to the Panama Canal (CAS) engaged The WEFA Group, with subcontract support from Richardson Lawrie Associates (RLA) and BST Associates, to develop preliminary projections for the years 2020 and 2060 of commodity flows and ship traffic for the existing Panama Canal and for four alternative Canals through Panama. Known as Phase I of the Commodity and Traffic Projections (CTP) Study, this is part of a group of studies, including preliminary engineering, capacity and operating characteristics studies, designed to provide sufficient information for the prescreening and selection of a very few Canal alternatives for full study. It is expected that the more detailed forecasts to be carried out in Phase II will take into account the capacity estimates as well as other Canal characteristics such as the toll structure.

The alternative Canals for the purposes of Phase I of the CTP were defined only in terms of maximum design ship size. These were defined by CAS as:

65,000 DWT (Status Quo)
100,000 DWT (Case 2)
150,000 DWT (Case 3)
250,000 DWT (Case 4)
300,000 DWT (Case 5)

The scope of Phase I CTP study excluded several issues, both from necessity and from the limited needs of the prescreening process. The study explicitly did not take into account the following issues:

- The constraints of the Panama Canal and of other pertinent parts of the world transportation system, such as the U.S. rail system;
- The effect of an enlarged or alternative Canal on the world economy, on global trade in aggregate, and on patterns of world trade;
- The effect of the Canal construction itself on the world economy and on world trade;
- The effects of projected improvements in infrastructure in Panama, such as the Centerport project;

- Alternative assumptions to those which define our baseline scenario.

The base year for the study is 1990 and the forecast periods are the years 2020 and 2060.

To accomplish this task, the WEFA team first reviewed the available data and the previous approaches to this task which had been carried out for the Panama Canal Commission (PCC). Because CAS was not able to make detailed PCC data available to us in sufficient time to be used in Phase I of the CTP, other sources of Canal transit and related data also had to be developed.

To carry out the study, the following additional work had to be carried out first:

- Develop a substitute synthetic Panama Canal vessel transit database for FY 1990;
- Combine the synthetic database with data on loadings of commodities into ship cargoes from another study and with published PCC commodity flow data to create a coherent Master Study Database;
- Develop forecasts for 2020 and 2060 of world trade, consistent with the Master Study Database in sufficient detail to develop projections of the world vessel fleet by ship type and size category for 2020 and 2060;
- Develop a forecast of the world vessel fleet for each of the alternative Canals;
- Develop the comparative economics of shipping 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".

The fundamental approach used in this study was to initially apply global trade growth rates for 1990-2020 and 2020-2060 for a given commodity and pair of trading partners to that commodity and origin/destination pair in the FY 1990 Panama Canal data, to load these commodities onto the ships available from the projected world vessel fleet according to the rules incorporated into the Master Study Database, and then to examine all bypass routes for potential shifts away from the Canal and to search forecast bypass traffic for potential shifts to the Canal.

The microeconomic approach used throughout the transportation analysis of this study is a point of departure for Panama Canal studies. Prior studies shifted trade based on trends or on judgement. In this study, we determined the least cost mode of transportation and shifted cargoes to those least-cost modes and routes. If costs per ton differed by only a few cents per ton, this was taken as being not significant, and the routing was not changed.

Therefore, the final commodity flow projections were a result of the vessel transit projections, rather than the other way round. This approach was the result of the incorporation of transport economics in the analysis, a factor which previous projections had not taken into account. The surprising nature of some of the results stem from this approach as well as of the use of top-down, bottom-up approaches to the projections of both world trade and the world vessel fleet.

The top-down, bottom-up approach in the context of the trade and fleet applications is equivalent to a supply/demand equilibration. In the case of trade, the WEFA World Model provided the top-down or demand part of the approach. This Model solves 30 country and regional macroeconomic models simultaneously with an allocation of import demand bilaterally to all of the exporting countries. The resulting trade matrix is broken into three commodities groupings: energy, non-energy primary, and manufactured goods. This matrix of trade among thirty countries and three commodities is then divided into the detail required for the study by using stochastic share equations.

This top-down approach to commodity forecasting is combined with WEFA's special world models for various industries: agriculture, energy, and steel. These cover the greater part of the commodity flows. These bottom-up forecasts use WEFA's World Model forecasts as economic drivers but focus on the supply relationships involved with renewable and non-renewable resources and the location of each part of the chain from extraction to finished goods manufacture.

The top-down, bottom-up approach to the world fleet forecasts is similar. The forecasts of world trade provide demand for shipping. Combining this with scrappage forecasts results in demand for ships to carry the forecast trade. This is the top-down part of the forecast. Then, combining this with changes in technology and vessel economics, provides the required supply of new ships each year. This is the bottom-up part of the vessel forecast.

Because of the very long term nature of this study, several departures from and additions to our normal methods had to be incorporated. In the case of the economic and trade forecasts, we shifted from the stochastically based, that is, based on historical relationships,

WEFA World Model[1] to a judgmental approach to the forecasts beyond the year 2010 of the key top-down variables: population, productivity, and the relation of trade to output. In the bottom-up part of the approach, allowance had to be made for the exhaustion of significant amounts of the world's total resource base. This was particularly true of oil, but important for the other resources which we tracked, namely, coal, natural gas, and iron ore. We estimate that approximately half of the total remaining world coal reserves, two-thirds of the remaining world oil resources and 85% of estimated natural gas resources are consumed in the 1990-2060 period.

On the vessel side, extensive research was carried out as to the technical innovations planned and possible during the course of the study. In light of this research, it was decided to adopt the following principles in developing, for particular ship types, a scenario of techno-economic changes likely to be achieved during the forecast period:

- remembering that some ships on order in 1991 will still be operational in the year 2020, we assume that the levels of technology incorporated in the newest ships of 1991 will be the average level of technology in the year 2020;

- Between 2020 and 2060, it is assumed that the 2020 level of technology will persist, excepting only cases where it is now apparent that change will be made. This includes, however, continuing trends in vessel propulsion and manning efficiencies. A particular conclusion in this regard will be the requirement for skilled crew leading to the eventual disappearance of cheap labor from the global fleet.

Because a new Panama Canal will make a qualitative change in the size of the ships being constructed, the WEFA team at an early stage needed to develop assumptions as to the construction dates of an alternative Canal. For this purpose, CAS provided us with the following assumptions:

- Start date for construction of the alternative Canal - 2000;

- Completion date for construction of the alternative Canal - 2010.

After consultation with CAS, the specific assumption was made that the Jones Act, the U.S.

[1] The WEFA World Model is a traditional structural econometric model consisting of a system of deterministic and stochastic equations which are currently used to generate projections until the year 2010.

regulation that requires intra-United States maritime trade to move in U.S. ships, would remain in force.

Because there is only one scenario in Phase I, we have made what we consider "conservative" assumptions. This should not be taken to imply that they are either pessimistic or optimistic. We believe the assumption that global warming does not become a serious policy issue to be conservative; that is, we believe that alternative assumptions would be speculative. However, this assumption leads to higher consumption of oil and coal worldwide and thus to higher levels of world trade than would be the case in a scenario where emissions of carbon dioxide and other "greenhouse gases" were limited to 1990 values, for example.

The following are other important assumptions on which we have based the study.

- Geopolitical Factors:

  We assume continued world stability, that is, no major wars or political instability in the major countries of the world.

- Environmental Policy

  WEFA assumes that the current environmental policy of each nation, such as the United States or Korea, or group of nations, such as the European Community or the Commonwealth of Independent States, is maintained and are made neither more stringent nor eased. This implies, for example, that a carbon tax to reduce greenhouse emissions is not enacted.

- Population, Labor Force and Employment

  The population figures through 2025 are from the United Nations. WEFA has extended the U.N. fertility and mortality assumptions to 2060 in a manner consistent with our projections of GDP per capita in each region.

  A long term forecast such as we have undertaken focuses on the supply side, namely the growth in labor productivity due to technological progress. Short term fluctuations in unemployment and labor force participation are ignored; rather, the equilibrium levels of these variables are assumed. That is to say, our scenario has no business cycle behavior. It is not our belief that business

cycles will never occur. Rather, we do not know when they will occur this far into the future. Taking only two points into the future requires that the scenario not involve any cyclical behavior.

- Technological Innovation and Transfer

  We assume that the long-term trends toward greater efficiency in production and toward a greater services share of consumption will continue. An important assumption in this area is the diffusion of technology now on the drawing boards to even the most undeveloped countries, allowing for a convergence of per capita GDP without an accelerated strain on the earth's resources.

- Productivity by Region

  Per capita GDP is assumed to continue on the historical trajectories and those of our short-term model based forecasts. In the most industrialized countries it is assumed to rise at slightly lower rates than historically.

  A basic assumption underlying the work is that the ranking of countries/regions in terms of per capita GDP remains fixed over the period, but that there is some convergence toward the standard of living of the most developed countries.

  As a result of these considerations, we expect total output in the developing world to rise considerably more rapidly than that in the developed world, but to still remain behind on a per capita basis. The relative levels within the groupings have more to do with the size of the countries/regions than anything else.

- Transportation Costs

  In terms of the various components of ship operating costs, between 1990 and 2020, increases in real terms are assumed for wage rates, repairs and maintenance, insurance and fuel costs. There is also likely to be a cost push effect in shipping market rates as a result of technological change. Nevertheless in the calculation of freight costs there are offsetting factors, in

particular with regard to vessel efficiency and manning levels. Between 2020 and 2060 only fuel costs and labor rates rise in real terms.

We assume that over the long term real world labor costs rise at a rate of one percent per year. Oil prices are assumed to rise more rapidly as world reserves are depleted to an expected 30 percent of their 1990 level, and to reach $55 per barrel in 1990 dollars by 2060. Note that labor compensation is related to labor cost by labor productivity. That is, real labor compensation will rise faster than real labor cost by just the increase in labor productivity. Thus, if labor productivity were rising at one percent per year, the growth in labor compensation would be one percent higher than the rise in labor cost.

Panama Canal tolls are grown with average transportation costs, as there are no basis for speculating on another growth trajectory. These were also part of the terms of reference.

In addition to transportation costs, inventory carrying costs are computed as well, based on average value per ton, differences in origin to destination trips, and interest rates.

- Structural Change

Possibly the most important factor in the relation of merchandise trade to World GDP is the structural change which world economies are undergoing, namely, the shift away from goods and toward services. The gradual depletion of non-renewable resources means that new deposits are of lower quality, harder to reach, and more expensive to extract and refine. This results in gradually rising real costs for these resources.

These structural change considerations lead to a continuation of the long-term trend in the shift from goods toward services which produces a downward curvature in the ratio of total world trade to world GDP.

- Terms of Trade

By terms of trade we mean the trade barriers or lack of them between countries. These can be unilateral, such as the barriers to agricultural products; bilateral, such as the U.S.-Canada free trade agreement; and

multilateral, such at the EC common market and the General Agreement on Trade and Tariffs (GATT). In a recent review of the economics of trade policy[2], Professor Baldwin of the University of Wisconson and the National Bureau of Economic Research states as follows: "The new [economic] trade theorists ... believe that, as a rule of thumb, free trade is the best policy for countries to follow". We assume, therefore, that the emerging world trading blocs continue the post World War trend toward freer trade, specifically toward a continued lowering of tariff and non-tariff barriers.

Because the country for which there is the greatest degree of understanding in terms of the dynamics of growth is the United States, the analysis begins there. At present, per capita U.S. GDP is growing at slightly less than 2%. This is composed of two parts: productivity is growing at about 1% and labor force relative to population is growing at less than 1%. Eventually, we expect labor force and population to grow in tandem, with the result that the growth of per capita GDP drops to the 1% we continue to assume for productivity growth. The average per capita U.S. GDP growth over the 70 year period is slightly less than 1.5% per year.

This is not to suggest that the total tons of goods produced, or any such physical measure, grows at this rate. The trend in industrialized societies has been toward a saturation in physical goods and a relative shift to services. We expect this to continue, such that eventually most of the increase in output is in ever more efficiently provided services. These services will continue to require electric power and other energy forms, and other physical goods associated with them. Thus, trade in physical goods among the developed countries can be expected to grow, but at a decreasing rate. Finally, services are assumed to take greater and greater advantage of efficiencies to be gained from electronic advances, as is the case in the U.S. at present, and which we are seeing in Europe, Japan and elsewhere: automatic teller machines, home shopping, etc.

In general, we assume continued movement toward free markets in goods and most services. This underlies both the assumption of per capita GDP convergence and continued improvement in productivity. It also has the implication of freer trade, since trade barriers are merely another form of government interference in the free functioning of markets.

The growth of energy consumption is expected to slow in the industrialized countries and

[2] Robert E. Baldwin, "Are Economists' Traditional Trade Policy Views Still Valid?", Journal of Economic Literature XXX (June 1992), pp.804-829.

level off after 2020. Passive solar heating of homes, greater energy efficiency and cogeneration in buildings, the aforementioned shifts away from heavy industry, and growth in non-fossil fuel sources of power are all expected to contribute. The ratio of energy consumption to GDP is expected to continue to fall at a 1.9% annual average rate worldwide over the period.

In this forecast, global warming is assumed not to be an issue affecting fuel choice. Nor do we assume that nuclear power growth slows, outside of the U.S. and those European countries where opposition is strong. The major sources of energy are expected to be coal and natural gas.

Many countries such as the states of the former Soviet Union lag significantly behind developed nations in agricultural productivity. We assume that, as a result of technology transfer and the shift to a market economy, food imports into these countries will decline sharply. At the same time we believe that productivity growth in agriculture will slow in the next 70 years compared to the last 70. For both of these reasons we expect the growth in exports from current producers to slow significantly.

In general, we expect countries to become more self-sufficient in goods as the technological and labor cost advantages of the newly industrialized countries wanes. However, one of the principal engines of growth in newly industrialized countries is the newer plant and equipment and the lower wages paid. Thus, it is principally as per capita GDP converges that this advantage declines.

Steel production is an example of this trend. As a result of both lower unit demand for steel, due to the substitution of other materials, and increased self sufficiency, trade in steel products is expected to grow at less than 1% per year.

In the case of energy, oil trade must clearly fall off during this period because resources will be declining markedly worldwide, falling to 30% of their 1990 value. Coal and natural gas will come into their own during the first part of the next century. Even so, by 2060 coal reserves are expected to be depleted by 50% and natural gas resources by 85% from their present published estimated values[3]. Natural gas resource estimates are more uncertain that coal or oil, and, as a result, we have assumed that methane resources will be higher than published estimates. So long as extensive reserves of coal and natural gas remain to

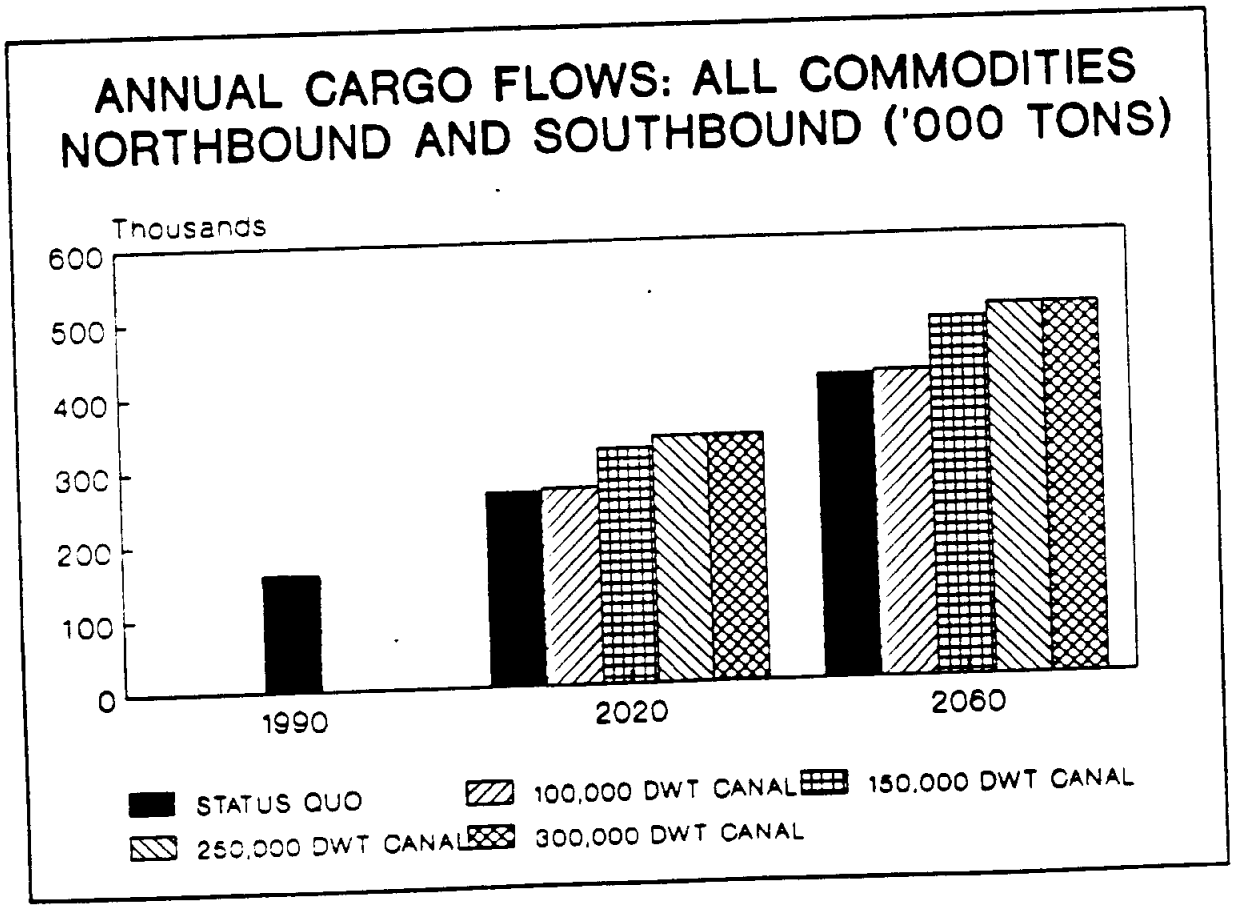
[3] BP Statistical Review of World Energy (June 1991), and C.D. Masters, D.H. Root, and E.D. Attanasi, "World Oil and Gas Resources - Future Production Realities", Annual Review of Energy, Vol. 15, 1990, pp. 23-51.

be exploited, it can be expected that it will be cheaper to transform these into sources of clean energy than to develop more costly technologies.

Therefore, coal trade is expected to become increasingly important during the first half of the next century as oil reserves fall. Natural gas trade, primarily by pipeline but also in liquified natural gas (LNG) tankers is also expected to be significant. However, these LNG tankers would not be using the Canal to any great extent as we expect most of this trade to be concentrated in the Far East while the Americas and Eurasia would depend primarily on pipelines.

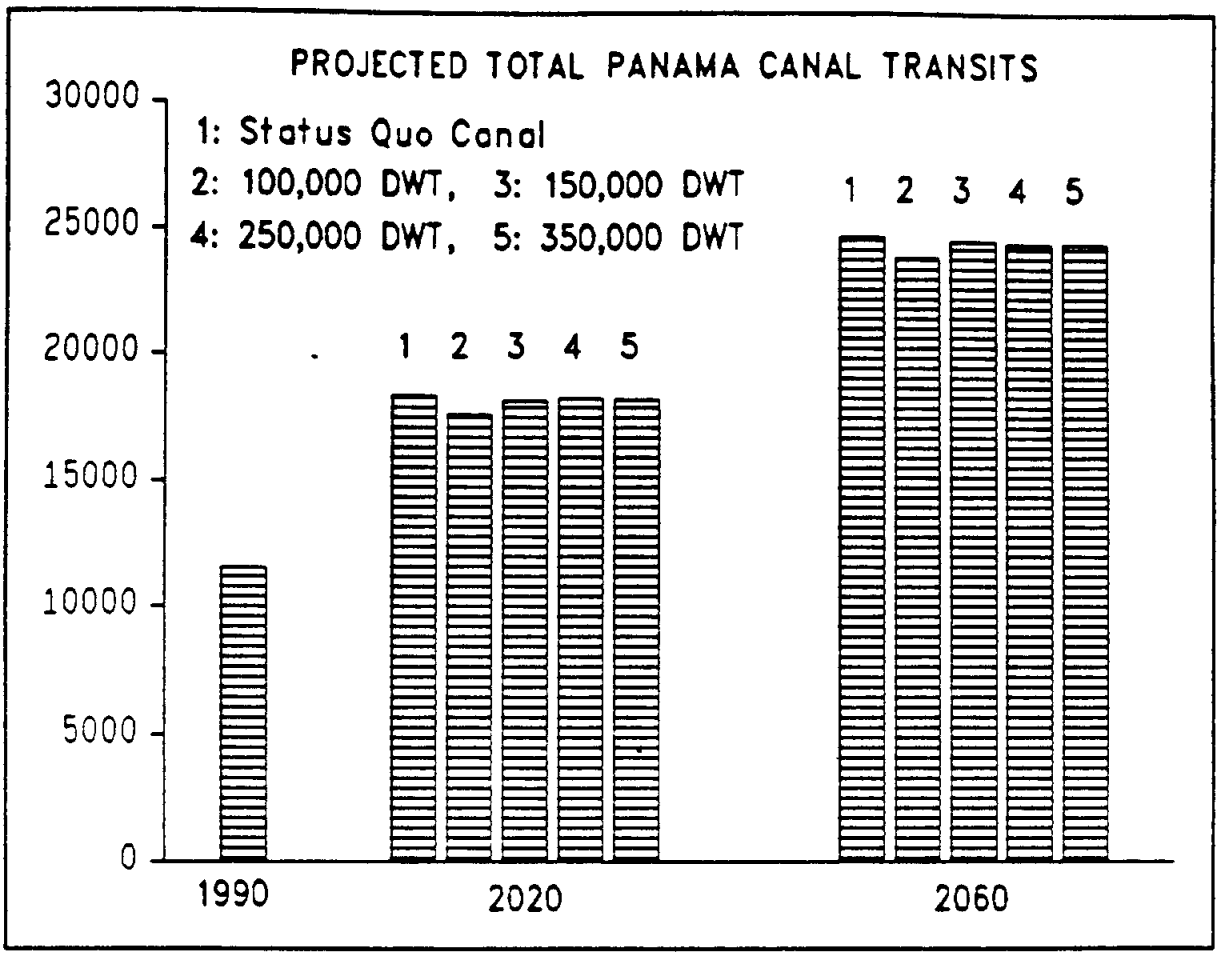
The results of the study are portrayed in Tables 1 and 2 and Figures 1 and 2.

Figure 1



Source: The WEFA Group

Figure 2



Source: The WEFA Group

Total cargo tonnage for the status quo Canal is projected to grow 1.8% per year on average for the next 30 years and 1.1% per year thereafter, averaging 1.4% annual growth over the entire period. For the largest two alternative Canals, these growth rates climb to 2.6%, 1.0%, and 1.7%, respectively. The shift to lower growth in the latter period is because of bypass capture in the first part of the projections.

Table 1

ANNUAL CARGO FLOWS BY COMMODITY TYPE

NORTHBOUND AND SOUTHBOUND

COMMODITY	('000 TONS) 1990	2020	2060	ANNUAL GROWTH RATE 1990-2020	2020-2060	1990-2060
STATUS QUO						
BULK CHEMICALS	6,473.3	21,469.7	32,152.0	4.1%	1.0%	2.3%
CONTAINERIZED	20,460.5	48,572.5	63,633.1	2.9%	0.7%	1.6%
CRUDE OIL	9,220.0	4,108.1	821.1	-2.7%	-3.9%	-3.4%
GENERAL CARGO	8,078.6	18,985.7	35,032.9	2.9%	1.5%	2.1%
MAJOR DRY BULKS	38,192.0	55,864.5	88,275.5	1.3%	1.2%	1.2%
MINOR BULKS	52,987.3	84,279.5	160,244.4	1.6%	1.6%	1.6%
OILS & FATS	1,525.1	2,148.8	3,532.3	1.1%	1.3%	1.2%
PETROLEUM PRODS	12,628.9	14,521.5	5,990.4	0.5%	-2.2%	-1.1%
REFRIG CARGOES	5,135.8	12,803.9	19,383.8	3.1%	1.0%	1.9%
VEHICLES	1,682.0	2,367.0	2,621.4	1.1%	0.3%	0.6%
TOTAL	156,383.7	265,121.1	411,687.0	1.8%	1.1%	1.4%
100,000 DWT						
BULK CHEMICALS	6,473.3	21,469.7	32,152.0	4.1%	1.0%	2.3%
CONTAINERIZED	20,460.5	48,963.4	64,825.1	3.0%	0.7%	1.7%
CRUDE OIL	9,220.0	4,108.1	821.1	-2.7%	-3.9%	-3.4%
GENERAL CARGO	8,078.6	18,985.7	35,032.9	2.9%	1.5%	2.1%
MAJOR DRY BULKS	38,192.0	57,595.0	90,492.9	1.4%	1.1%	1.2%
MINOR BULKS	52,987.3	84,279.5	160,244.4	1.6%	1.6%	1.6%
OILS & FATS	1,525.1	2,148.8	3,532.3	1.1%	1.3%	1.2%
PETROLEUM PRODS	12,628.9	14,521.5	5,990.4	0.5%	-2.2%	-1.1%
REFRIG CARGOES	5,135.8	12,803.9	19,383.8	3.1%	1.0%	1.9%
VEHICLES	1,682.0	2,367.0	2,621.4	1.1%	0.3%	0.6%
TOTAL	156,383.7	267,242.5	415,096.4	1.8%	1.1%	1.4%

Note: The Source of the 1990 Commodity Flow Data is the Panama Canal Report (Tables 10 and 11), Panama Canal Commission, FY1990. Forecasts for 2020 and 2060 were developed by The WEFA Group.

Table 1 (Continued)
Annual Cargo Flows By Commodity Type

COMMODITY	('000 TONS) 1990	2020	2060	ANNUAL GROWTH RATE 1990-2020	2020-2060	1990-2060
150,000 DWT						
BULK CHEMICALS	6,473.3	21,469.7	32,152.0	4.1%	1.0%	2.3%
CONTAINERIZED	20,460.5	48,963.4	64,825.1	3.0%	0.7%	1.7%
CRUDE OIL	9,220.0	4,108.1	821.1	-2.7%	-3.9%	-3.4%
GENERAL CARGO	8,078.6	18,985.7	35,032.9	2.9%	1.5%	2.1%
MAJOR DRY BULKS	38,192.0	109,273.3	160,778.1	3.6%	1.0%	2.1%
MINOR BULKS	52,987.3	84,279.5	160,244.4	1.6%	1.6%	1.6%
OILS & FATS	1,525.1	2,148.8	3,532.3	1.1%	1.3%	1.2%
PETROLEUM PRODS	12,628.9	14,521.5	5,990.4	0.5%	-2.2%	-1.1%
REFRIG CARGOES	5,135.8	12,803.9	19,383.8	3.1%	1.0%	1.9%
VEHICLES	1,682.0	2,367.0	2,621.4	1.1%	0.3%	0.6%
TOTAL	156,383.7	318,920.8	485,381.6	2.4%	1.1%	1.6%
250,000 DWT						
BULK CHEMICALS	6,473.3	21,469.7	32,152.0	4.1%	1.0%	2.3%
CONTAINERIZED	20,460.5	48,963.4	64,825.1	3.0%	0.7%	1.7%
CRUDE OIL	9,220.0	18,108.1	14,821.1	2.3%	-0.5%	0.7%
GENERAL CARGO	8,078.6	18,985.7	35,032.9	2.9%	1.5%	2.1%
MAJOR DRY BULKS	38,192.0	110,754.6	163,533.6	3.6%	1.0%	2.1%
MINOR BULKS	52,987.3	84,279.5	160,244.4	1.6%	1.6%	1.6%
OILS & FATS	1,525.1	2,148.8	3,532.3	1.1%	1.3%	1.2%
PETROLEUM PRODS	12,628.9	14,521.5	5,990.4	0.5%	-2.2%	-1.1%
REFRIG CARGOES	5,135.8	12,803.9	19,383.8	3.1%	1.0%	1.9%
VEHICLES	1,682.0	2,367.0	2,621.4	1.1%	0.3%	0.6%
TOTAL	156,383.7	334,402.1	502,137.1	2.6%	1.0%	1.7%
300,000 DWT						
BULK CHEMICALS	6,473.3	21,469.7	32,152.0	4.1%	1.0%	2.3%
CONTAINERIZED	20,460.5	48,963.4	64,825.1	3.0%	0.7%	1.7%
CRUDE OIL	9,220.0	18,108.1	14,821.1	2.3%	-0.5%	0.7%
GENERAL CARGO	8,078.6	18,985.7	35,032.9	2.9%	1.5%	2.1%
MAJOR DRY BULKS	38,192.0	110,754.6	163,533.6	3.6%	1.0%	2.1%
MINOR BULKS	52,987.3	84,279.5	160,244.4	1.6%	1.6%	1.6%
OILS & FATS	1,525.1	2,148.8	3,532.3	1.1%	1.3%	1.2%
PETROLEUM PRODS	12,628.9	14,521.5	5,990.4	0.5%	-2.2%	-1.1%
REFRIG CARGOES	5,135.8	12,803.9	19,383.8	3.1%	1.0%	1.9%
VEHICLES	1,682.0	2,367.0	2,621.4	1.1%	0.3%	0.6%
TOTAL	156,383.7	334,402.1	502,137.1	2.6%	1.0%	1.7%

Table 2
TOTAL PANAMA CANAL VESSEL TRANSITS

	Ballast		Laden					Percent Change
	North	South	North	South	North	South	Totals	Since 1990
1990:1	675	1,084	4,806	4,956	5,481	6,040	11,521	
2020:1	1,043	1,790	7,684	7,833	8,727	9,623	18,350	59%
2020:2	995	1,758	7,362	7,509	8,357	9,267	17,624	53%
2020:3	1,075	1,757	7,353	7,958	8,428	9,715	18,143	57%
2020:4	1,088	1,756	7,351	8,028	8,439	9,784	18,223	58%
2020:5	1,087	1,756	7,351	8,021	8,438	9,777	18,215	58%
2060:1	1,349	2,197	9,967	11,193	11,316	13,390	24,706	114%
2060:2	1,282	2,169	9,690	10,740	10,972	12,909	23,881	107%
2060:3	1,385	2,168	9,652	11,296	11,037	13,464	24,501	113%
2060:4	1,374	2,167	9,650	11,231	11,024	13,398	24,422	112%
2060:5	1,373	2,167	9,650	11,224	11,023	13,391	24,414	112%

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: Historical 1990 data: The PCC, Annnual Report, FY 1990. Forecasts: The WEFA Group.

In our approach to determining bypass traffic shifting onto or away from the Canal, we have only moved traffic when the transportation economics showed significant departure from current relationships. This is because the aggregations across commodities of very different values and other approximations necessary in this work obviate precise cost comparisons. In any case, extensive discussions were held with shippers, port personnel, WEFA's commodity experts, and others each step of the way in order to provide CAS with the most informed judgements possible on these issues[4].

[4] A list of the organizations form whom information and guidance has been sought on issues relating to the questions of bypass traffic is given below:

Because each larger Canal involved larger ships in the World Fleet, the increase in the growth in the number of transits from one size Canal to the next is less than the increase in the commodity tonnage flows. In fact, between 2020 and 2060, the average growth rate for Case 2 (100,000 DWT design ship) is less than that for the Status Quo Canal. A surprising result of the entire study is that the average annual growth in vessel transits over the entire forecast period, 1990 - 2060, is between 1 and 1.1% for all cases.

As already noted, commodity flows were only shifted between Canal routes and bypass routes if there were significant differences in the transportation economics. Estimated Canal tolls are included, as agreed in the terms of reference and based on assumptions agreed with CAS, since it is inconceivable that ships in future will transit the Canal toll free. However, we recognize the uncertainty regarding future toll levels and therefore the impact of our assumptions is clearly presented in each of our comparisons of freight economics. Lower tolls for some ships/commodities could possibly attract significant bypass traffic. Conversely, higher tolls could discourage other traffic. One conclusion we have drawn from Phase I is that potential designs for optimal toll structures, drawing on the experience of the Suez Canal inter alia, should be an integral part of Phase II.

Other fine tuning issues which have arisen in Phase I include use of the actual PCC transit data, use of PIERS data to check implied PCC loadings, effects of the Canal on the world economy and trade effects of Canal and landbridge constraints, other periods and results by beam and draft.

Another set of issues for Phase II is the question of sensitivity analyses. In constructing the global scenario which we have used for Phase I, we have been conservative in our approach. Issues such as global warming, exotic hull designs and propulsion systems, as well as unmanned ships, are among the questions we have had to avoid. In designing Phase II, CAS should be cognizant of criticisms which might arise as to these and other issues, which could clearly result in quite different results and possibly different conclusions.

Port Authority of New York and New Jersey; Fearnley Research, Oslo; Port of Mobile; H.. Clarkson & Co. (Shipbrokers); Fairwind Enterprises Ltd.; International Iron & Steel Institute; Powergen, UK; International Wheat Council; Tradax, Geneva and London; U.S. Department of Agriculture; Shell International Marine; Bitumenes Orinoco S.A. (Bitor), Caracas; Sea-Land Services Inc.; Leif Hoegh & Co., Oslo; The East Asiatic Co. Ltd., Copenhagen; Hapag-Lloyd; Evergreen; Mitsui OSK; U.S. Department of Energy; U.S. Bureau of Mines; Ports Canada; M.A. Hanna & Co.; Hammersley Iron & Steel; UNC DAD Trust Fund.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

6. Operating Characteristics and Capacity Evaluation Study

Phase II

Summary

1993

SUMMARY

INTRODUCTION

The Operating Characteristics and Capacity Evaluation (OCCE) Study is one of a group of studies of future alternatives to the Panama Canal sponsored by a study commission formed by the governments of Panama, the United States and Japan (CAS). The basic purpose of the OCCE study was to evaluate the traffic capacities of various canal alternatives.

The OCCE Study used inputs from the traffic projections and engineering component studies and defined elements needed for engineering, economic and financial analyses being undertaken by others. The basic tool for the OCCE effort has been a simulation model developed by the U.S. Army Corps of Engineers for use on the U.S. inland waterways system and adapted under OCCE for analyses of the operating characteristics and capacities of the existing Panama Canal and possible future alternatives.

The Study was conducted in two phases. For the prescreening of alternative canal schemes that was accomplished in Phase 1, a range of assumptions were used that reflected an extension of experience with the present Panama Canal. Model runs in Phase 2 involved more rigorous analyses of ship arrival patterns and the impact of normal interruptions and mishaps and the dynamic assignment to a route, of ships confronted with an alternative. The Phase 2 runs were used to evaluate in greater detail a limited number of alternative plans selected by CAS from the results of Phase 1 capacity, traffic forecasts and engineering studies.

In addition to capacity, the scope of work also included other types of studies, including: evaluation of currents that would be generated in a sea-level canal by tidal differences between the two oceans and means of ameliorating these currents, estimation of sedimentation in the sea-level canal alternatives, preparation of conceptual plans and estimates of costs for navigation support systems and estimates of fresh water consumed during lockages.

For the purpose of Phase 1 of OCCE, many alternative plans proposed historically were synthesized into two routes (Figure 1-1) and four basic groups: High-Rise Lock Canal; Low-Rise Lock Canal; Sea-Level Canal; and Status Quo. The Status Quo Canal is the existing canal with the authorized widening of the Culebra Cut (also known as the Gaillard Cut) to 630 feet completed.

Alternative nominal maximum ship sizes were considered, ranging from 65,000 DWT to 300,000 DWT during Phase 1. The 65,000 DWT class was considered the maximum size for the Status Quo Canal. The high-rise and low-rise lock canal plans were analyzed for alternative maximum sizes of 100,000 DWT, 150,000 DWT and 250,000 DWT. Under the Sea-Level Canal plans, the alternative maximum

sizes considered were 150,000 DWT, 250,000 DWT and 300,000 DWT. The capacities of approximately 25 alternative cases were evaluated during Phase 1.

During Phase 2, the high-rise locks and sea-level alternatives listed in Table 1-2 and shown schematically in Figures 1-2 and 1-3 were evaluated. All of the cases involve the continued use of the existing locks; the sea-level cases would be used in conjunction with the status quo canal. Maximum ship sizes considered were 200,000 DWT for the high-rise lock alternatives and 250,000 DWT for the sea-level alternatives.

OPERATIONAL CRITERIA, PROCEDURES AND PARAMETERS

The principal criteria governing Canal operations are: safety, capacity, costs and water use. Safety, of course, is foremost. Capacity is considered adequate if ships' times in canal water do not exceed 24 hours. The canal is operated as economically as possible, except, if excessive congestion is expected, more costly "relay" operations are employed at the multi-stage locks; these involve the use of additional crews. Water use is not a problem except during particularly dry seasons. With increased numbers of lockages in the future, and the possible addition of new, larger locks, water use would take on added importance.

The general operating procedure is "first come, first served". However, this procedure is modified by various conditions. For example, large ships and ships carrying hazardous cargoes are not permitted to navigate through the Culebra Cut at night, nor can they pass or overtake another ship in the Cut. There is also provision for reserved and preference transits for ships traveling on critical schedules.

Among the key operating parameters that impact on capacity are: size of vessel, vessel arrival rates, one-way or two-way operations, lock service times, and traffic management procedures. For sea-level canal alternatives, maximum allowable vessel speed, vessel spacing and length of operating cycles for one-way segments are also of critical importance.

ANALYSIS OF VESSEL ARRIVAL, PREPARATION AND TRAVEL TIME

The principal source of data on vessel arrival patterns and transit times was the Ship Data Bank (SDB) compiled by the Panama Canal Commission (PCC). The SDB contains data on every ship transit through the Canal, including the times of passage at key control points in the system, such as the locks and the Culebra Cut. The SDB records for 13,611 vessel transits for the year 1990 were analyzed in this study. The SDB data were supplemented by data collected at the locks over a two week period in 1991 under the OCCE study.

The SDB data were used to investigate vessel arrival patterns, and to derive detailed estimates of vessel transit times, channel speeds, and locking times, for input to the Waterway Analysis Model and for model calibration purposes. The

data collected on-site were used to assist in dividing the locking times into the specific time elements required for input to the model, and to guide the interpretation and usage of the SDB data.

Some of the principal conclusions of the data analyses conducted are as follows:

Ship arrivals were found to be distributed randomly throughout the year; that is, there were no strong seasonal or monthly patterns evident in the data.

The hourly pattern of ship underway times (the beginning of transit) strongly reflected the current scheduling practices used to restrict (for safety reasons) meetings and night passage of large ships through the Culebra Cut. The pattern of underway times did not vary significantly between the rainy season and the dry season.

Northbound and Southbound transit times were found to be different, with an average of 12.5 hours Northbound and 9.8 hours Southbound. Consequently directional differences were maintained in the model input data.

The average movement time through the Canal was found to be between eight and nine hours, which is consistent with the segment travel times used by the PCC for ship scheduling. The remaining time is waiting time.

The time interval between the arrival of a ship and its beginning of transit was also investigated, both from the SDB records and through conversations with knowledgeable individuals in Panama. This interval, on the average, exceeded 11 hours in 1990. There are minimal operational and administrative delays during this period. Rather, most of the time is accounted for by discretionary vessel activities, and by the aforementioned scheduling practices related to restrictions on passage through the Cut.

As a result of these observations, a ship generation and scheduling program was developed to prepare vessel traffic lists for input to the Waterway Analysis Model. This program uses random underway times for future systems with the Cut restrictions lifted, or allows ship scheduling to correspond approximately to the present procedures.

SEA-LEVEL CANAL - TIDAL HYDRAULICS AND NAVIGATION

Studies were made to analyze the tide levels and currents in a sea-level canal generated by changes in the tides of the two oceans. The TAMS program LATIS was used to formulate a mathematical model of the canal. The spring tides in the Pacific range from about +10.3 to -9.8 ft., whereas at the Atlantic end the range is only about +1.2 to -0.7 ft.. This difference of levels would produce currents in an open channel ranging from about 4 knots at the Pacific end to more than 5 knots at the Atlantic end. The maximum allowable currents for the safe navigation of the

very large ships, however, are about 2 knots for head currents and 1 knot for following currents.

The Vergara alternative, which would employ a large embayment at the Pacific end of the canal to mitigate tidal effect was investigated, but the analysis indicated that although currents in the canal would be reduced, the reduction would not be sufficient for safe navigation; moreover, very fast currents would be generated at the entrance to the embayment area.

It was concluded that a system of positive closure involving two tide gates, or locks, is needed to control currents. Tide gates would be operated only at slack water, which occurs every 6¼ hours and operating cycles would be keyed to this rhythm. The canal with locks can operate independently of the tide cycles. However, a cyclical operation is necessary because of the long length of one-way channel. A 12½ hour cycle was selected for analysis of the lock alternatives.

THE WATERWAY ANALYSIS MODEL

The Waterway Analysis Model (WAM) has been in use by the U.S. Army Corps of Engineers for more than ten years. The purpose of the WAM is to represent on a computer the operation of a waterway system in transporting waterborne cargo. WAM is a relatively large and detailed simulation model, providing explicit representation of individual waterway facilities, cargo consignments, and vessels. The WAM was originally developed to simulate shallow draft barge traffic on the U.S. inland waterways. The model has been used extensively to simulate parallel locks, and thus is directly applicable to the multi-lane Panama Canal operations.

The Waterway Analysis Model has two types of input data. The system description input data describe the waterway network (ports, locks, interconnecting channels), the vessel fleet, and the commodity classes to be transported. The external event input records are read into the model during the simulation process and trigger the occurrence of events, including the introduction of vessel traffic into the system and initiation of lock downtime periods. The simulation program is the operational heart of the model; it processes the input data, produces playback reports, initializes the waterway system, processes each shipment from origin to destination, records statistics for generation of performance output reports, and creates files for post-processing by other programs. 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.

The WAM was used with minor modification to simulate the operation of the Panama Canal for Phase 1 of this study. Various program modifications were made for more accurate simulation in Phase 2.

The WAM data structure was directly usable, without change, for representing both the existing canal and the proposed sea-level canal. The system consists of a port at each end, locks at Gatun, Pedro Miguel, and Miraflores, a restricted channel to represent the Culebra Cut, and the intervening reaches between these elements. The locks are represented as dual chamber facilities, where each lane is considered to be a single chamber. Configurations with a third lane of locks were represented directly as a branch in the network, with the new lock located in this branch.

The principal modifications made to the WAM for better representation of the high rise locks alternatives involved modeling of relay operations at the locks and the introduction of dynamic route assignment. Relay operations reduce throughput time, and were, therefore, included for purposes of estimating capacity. The WAM was modified to permit switching into and out of relay operations on a scheduled or demand driven basis. Relay operations commence if justified by the queue size at the start of each eight-hour shift. Additionally, relay operations are started at one lane of dual-lane locks when the other lane is down. The WAM was also modified to include internal decision rules for assigning a ship to the next sector of the network in cases where parallel routings are possible, eg. the third locks plans. The model bases the routing choice on the relative expected times to transit the next set of possible sectors. The output of the WAM was expanded to record the route selected by each vessel.

Also, for Phase 2 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 options for the Panama Canal. This effort included the development of algorithms to simulate dynamic ship assignments to alternative routes, including the sea-level and status quo options. 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? The routing module accounts for the ship arrival time, the queue of ships awaiting passage, and the schedule in effect for directional assignment of the one-way channel.

The WAM was calibrated by comparing outputs for a simulation of the system in 1990 with the corresponding operating statistics derived from the Ship Data Bank (SDB) records. The locking times, segment travel times, and overall transit times were found to be in good agreement with the SDB data. Thus the model calibration was deemed to be good enough to proceed with the simulation of the alternative conceptual plans.

PREPARATION OF SIMULATION

Given the calibrated Waterway Analysis Model (WAM) and the results of the analysis of the Ship Data Bank records, a series of further data analyses and assumptions were made to prepare the inputs needed to simulate the performance of the alternative conceptual plans for the Panama Canal under different future vessel

traffic levels. These data and analyses include the future mix of vessel traffic, vessel characteristics, and lock sizes and operating times for the new locks plans.

Vessel mix forecasts for the years 2020 and 2060, for maximum vessel sizes of 65,000, 150,000, and 250,000 DWT were obtained from the Phase 1 vessel traffic forecasts prepared by the commodity traffic projections contractor. The vessel mix for the 200,000 DWT maximum vessel size was interpolated from the 150,000 and 250,000 DWT vessel size projections. Considering all of these cases, the number of ship transits forecast for the Canal range from about 18,000 ships in 2020 to 25,000 ships in 2060.

Vessel characteristics, including length, beam, maximum draft, and engine power, were obtained by reviewing the designs of commercial ships built worldwide in recent years. For the larger ship sizes introduced for the third locks and sea-level canal plans, observations of ship designs were augmented by data on ship stopping behavior obtained from ship trial runs and from computer simulation. These latter sources also provided data on minimum ship stopping times, which were used to develop input data on minimum ship separations for the sea-level canal WAM simulations.

Lock chamber sizes for the proposed new locks were developed by considering the minimum clearances between the ship and the lock chamber required for efficient operations. Locking times were then estimated by considering the operations in the existing locks which feature similar vessel-to-lock clearances.

Simulation runs for each of the conceptual alternatives were made by preparing an input vessel traffic list with the requisite number of ships, using the vessel traffic mix for the appropriate year (usually 2060) and maximum vessel size, and configuring the network and downtime input files to represent the appropriate system. Simulation runs were made for two different traffic levels for the third locks plans, and for three traffic levels for the sea-level canal options. In all cases, the new systems were run in parallel with the status quo system, and vessel traffic was dynamically assigned to the alternative routes based on current simulated operating conditions over each route.

CAPACITY OF ALTERNATIVE ROUTES

The capacity of a canal alternative is a function of delay or transit time (travel plus delay). A higher capacity can be achieved at a cost of longer delays and greater congestion. The level of delay is a function of the rate of ship arrivals, compared with the rate of ship transits. Delays and transit time increase gradually at low traffic volumes but accelerate rapidly as traffic continues to build. The relationship is characterized by a hyperbolic curve. Capacity of an alternative is actually estimated as the number of ships that can transit the canal at an acceptable delay or transit time.

Case 8A, with a longer single-lane segment than Case 8 (55.5 Km vs. 40 Km) would have less capacity than Case 8, because, with a maximum convoy speed of 13 Km/hr., there would be insufficient time for a full convoy to transit the longer single-lane segment and allow the next convoy to enter during the 6¼ hour cycle of gate openings and closings. The result is that either cycles would have to be skipped, or, convoy lengths would have to be shortened. A longer cycle time (12½ hours) would produce higher capacity, but would require dredging deeper channels at the Pacific side. Nevertheless, the capacity of Case 8A is adequate to meet year 2060 forecasted needs.

For the High-Rise Canal cases with a two-lane Culebra Cut (cases 2-5) the model schedules vessels to begin transit immediately upon arrival. For the single-lane Culebra Cut cases (6 & 7), however, large ships arriving at night do not start their transit until early morning, using the logic outlined in Chapter 3. This waiting time is added to any transit delay that results from congestion, to arrive at a total delay.

The Sea-Level Canal alternatives are based on a cyclical operation. For the combined sea-level and status quo alternatives, 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 delay times of six hours and ten hours were assumed as the basis of capacity for the status quo and high-rise canal cases (1-7) and transit times of 15 hours and 19 hours for the combined sea-level/status quo cases (8, 8a, 9, 9a, 9b and 10). Since the travel (non-delay) portion of transit time through the status quo system is approximately 9 hours, these criteria are consistent.

The resultant capacities of the Phase 2 alternatives are presented in Table 7-4, which is reproduced herein.

SEDIMENT TRANSPORT

The sediment movement in the canal is influenced by several factors. River discharge, ocean tides, interaction of currents and waves, ship generated waves, construction of breakwaters, operation of the tide gates, and land use are some important causes that have to be considered in estimating the amount of sediment transported in a year. However, the above processes, illustrated in Figure 8-7, can be broken into several parts, as follows: (a) the canal zone between the coasts where the tides and the river flows interact, (b) the coastal zone where the waves are predominant, and (c) the entrances to the breakwaters where the combined effect of currents and waves are felt. The operation of the tide gates and locks has also been taken into account in a schematic manner.

TABLE 7-4
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	Lock Chambers	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, Pacific Locks & Status Quo	250	1	3	33,300	41,700	1,032	1,293
9a	Route 10, Pacific Locks & Status Quo	250	1	3***	34,300	45,200	1,063	1,401
9b	Route 10, Pacific Locks & Status Quo	250	1	1	20,800	24,000	645	744
10	Route 10, Pacific Locks & Status Quo	250	1	4	37,000	47,500	1,147	1,472

NOTE: See Figures 1-2 and 1-3 for schematics of alternative plans. Culebra Cut is two lanes, unless noted otherwise. Case 8a is the same as Case 8, except that a single-lane channel would be substituted for the 2-lane channel from the Atlantic end coastline to the north tide gate.

* The capacities of the sea-level canal cases (8 through 10) are based on transit times of 15 and, alternatively, 19 hours.

** Tide Gates

*** One double length chamber plus one standard chamber in parallel.

Several computer programs were used in the study. Each one had a unique application, namely,

- 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;
- 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.

The following results were achieved:

(a) The model indicated that annual dredging in the canal section between the coasts for the tide gate and lock alternatives would be in the range of 450,000 m^3/yr, due to the effects of sediment inputs from the rivers and the tidal transport. In the absence of river sediments, the model results indicated a 30% reduction in the quantity of sediment to be dredged.

(b) Bathymetric data were used to estimate sedimentation rates for the existing canal. The locations, the annual sedimentation rates per kilometer and the extrapolated values for a canal of 58 km long are summarized below.

	Sediment Deposition/Year	
	190m 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	--

Based on the above table, a mean sedimentation rate of 660,000 m^3/yr is an acceptable value.

(c) On the Atlantic side, the model predicted an annual littoral drift of 12 x 10^6 m^3/year. This would result in an accretion on the southern breakwater of 100 m, while the depletion on the northern breakwater

is 60 m per year. In other words, the shoreline adjacent to the southern breakwater moves outward along the breakwater at the rate of 100 m per year building up a beach from the trapped littoral drift. At this rate, with the length of the breakwater being 2.6 km, it will be 25 years or so after construction before any of the material transported by littoral currents enter the canal.

(d) The model predicted neither accretion nor depletion on the Pacific side. However, some accretion and depletion are expected. Climatic data, especially very close to the site, should be collected and a detailed study conducted.

For planning and estimation of annual dredging costs, a volume of 550,000 m^3/year could be used.

NAVIGATION SUPPORT SYSTEMS

Recommendations are made in several areas to improve navigation conditions, including: range lights, buoys and beacons in channels, tug assistance for vessels transiting narrow channels, for lock approach and entry and for the sea-level canal, lengths of lock approach walls, locomotives on lock walls, ship tie-up facilities at locks and at intervals along the sea-level canal.

The capital and operating costs of the proposed navigation support systems are also presented (see Chapter 10).

FRESH WATER CONSUMPTION - HIGH-RISE LOCKS

An analysis was made of the fresh water consumed in lockages of the high-rise locks for alternative canal cases 2, 4 and 8, in the years 2020 and 2060.

The Waterway Analysis Model was run for the required cases using the WEFA forecast of ship transits to obtain the number of annual chamber operations and lockages. The type of operation used was based on optimizing capacity, rather than minimizing water consumption. The results, in millions of cubic meters (M.c.m.) annually, are shown below:

	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

CONCLUSIONS AND RECOMMENDATIONS

Sea-Level Canal Navigation

- Maximum allowable currents in a sea-level canal for the safe navigation of 150,000 DWT ships and larger are 2 knots for head currents and 1 knot for following currents.

- To limit tidal currents to safe levels, a closure system would be required involving either tide gates, or locks situated close to the Pacific shore.

- To achieve maximum capacities with significant lengths of single-lane canal, scheduling of ship transits in convoy formations would be required.

- The cycle time for tide gate operations should coincide with the half-tide cycle, or every 6¼ hours. For a convoy traveling at a speed of 7 knots, the optimum spacing of the tide gates joined by a single-lane canal is about 40 Km. The ship convoy length should not exceed 35 Km.

- With the above configuration and operation, ships entering and exiting the canal at the Pacific side could be scheduled such that they would always confront a head current, not a following current. Because the canal would be shielded from the Pacific low tide, the Pacific approach channel depth could be based on mean-sea-level rather than low water.

- In a sea-level canal controlled by locks, the cycle time for convoys would be independent of the tide cycle; i.e., the water level at both sides of the lock gates could always be equalized, regardless of the tide level. An optimum balance should be sought, therefore, between limiting turnovers, which are wasteful of capacity and avoiding excessive delay time for ships that must await a following convoy.

- Ships 150,000 DWT and larger should be assisted through their transit with a 6,000 hp tug at the stern. Emergency ship tie-up stations should be provided and stand-by tugs should be placed at strategic intervals along the canal to assist in the event of break-downs.

Capacity

By comparison of the capacities indicated in Table 7-4 with the vessel mix forecasts of Table 6-1, the following are concluded:

- The capacity of the Status Quo Canal will be exceeded by year 2020.

- All of the High-Rise Canal alternatives (cases 2, 3, 4, 5, 6 and 7) have adequate capacity for vessel transit needs to year 2060, including those with a single lane of new locks and a single-lane Culebra Cut.

- For a single lane of new locks, there is no significant difference in capacity between maximum ship sizes of 150,000 and 200,000 DWT.

- The High-Rise Canal alternatives with two new lanes of locks (cases 3 and 5) have redundant capacity.

- The delays imposed by a single-lane Culebra Cut are small compared to the lock delays; therefore, cases 6 and 7 result in only a slightly lower capacity than the cases with a two-lane Cut and their capacities are still greater than forecasted traffic. The primary benefit of a widened Cut, therefore, would be improved safety rather than increased capacity.

- The combined sea-level/status quo cases 8, 8a, 9, 9a and 10, i.e., all of the cases studied except case 9b, single lock at the Pacific end, have enough capacity for vessel transit needs through the year 2060.

- Case 8A, with a longer single-lane segment than Case 8 (55.5 Km vs. 40 Km) would have less capacity than Case 8, because, with a maximum convoy speed of 13 Km/hr., there would be insufficient time for a full convoy to transit the longer single-lane segment and allow the next convoy to enter during the 6¼ hour cycle of gate openings and closings. The result is that either cycles would have to be skipped, or, convoy lengths would have to be shortened. A longer cycle time (12½ hours) would produce higher capacity, but would require dredging deeper channels at the Pacific side. Nevertheless, the capacity of Case 8A is adequate to meet year 2060 forecasted needs.

- Based on the transit time criteria selected (15 and alternatively, 19 hours), case 9b -- the status quo plus a single-lane sea-level canal with a single lock at the Pacific -- would have insufficient capacity to meet the forecasted traffic levels. A similar system with two locks at the Pacific probably would satisfy the demand.

The Sea-Level Canal cases all produce results in which the status quo operates under highly congested conditions, to allow ships to avoid the long delays that are possible due to the fixed cycles of traffic through the single lane. For case 8, congestion delays are balanced between the two parts of the system. For cases 9 and 10, however, the 15 and 19 hour criteria for transit time reflect relatively uncongested conditions in the sea-level section, indicating redundant capacity which could be realized if a less restrictive travel time criterion were applied.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

7. Engineering and Cost Estimates Study

Phase II

Executive Summary

1993

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

1. GENERAL

The objective of the study in Phase 2 is to provide engineering, preliminary design, construction planning and feasibility engineering, cost estimates for the following two alternatives:

1) High Rise Lock Canal
2) Sea Level Canal

1.1 Features of Alternatives

The main features of the High Rise Lock Canal and Sea Level Canal are listed in the table below. Details of these two alternatives are summarized in the summation tables (1) and (2) attached at the end of this Executive Summary.

Table S.1-1 Main Features of Alternatives

Alternatives		High Rise Lock Canal		Sea Level Canal		
Alignment		Along Existing Canal		Route 10 from IOCS Study		
		Shown as Fig. S.1-1		Shown as Fig. S.1-2		
Maximum Ship Size		150,000	200,000	250,000 DWT		
Number of Ship Transits	(2020) Existing C.	16,200	16,200	16,200		
	New Canal	2,000	2,000	2,100		
	Total	18,200	18,200	18,300		
	(2060) Existing C.	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		1 (approach 2)		
Number of Lifts		2		0		
Water Level		85 feet & 90 feet		Sea level		
Tidal Lock & Gate		n.a.		Case (a)	Case (b)	Case (c)
				parallel 4 locks	1 lane 2 gates	parallel 4 locks & 1 gate
				Shown in Fig. S.1-3		

n.a.: not applicable

1.2 Result of the Study

The Study proposals are phased to meet transit requirements for the years 2020 and 2060 or beyond, and it has been assumed that the existing canal and locks will continue to operate in addition to the new canal. Construction unit costs have been adjusted to take into account the enormous scale of construction.

The results of the study are as follows.

1) Details of the Study are summarized in the summation tables attached at the end of the Executive Summary.

2) Total construction cost for the year 2020 and the additional cost for the year 2060 with main facilities included in the cost are listed in the Tables S.1-2 and S.1-3.

3) Results of the sensitivity analysis for the canal bank slope and the bottom width of channel are shown in Table S.1-4 for Option Study.

Table S.1-2 Summary for the Year 2020

Item	High Rise Lock (85 feet)		Sea Level Canal		
	150,000 DWT	200,000 DWT	Case (a)	Case (b)	Case (c)
Total Cost (Mill.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 and Gate	third lane lock (one lane of new locks)		parallel 3 locks	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 Barrier	n.a.		considered		
Diversion Scheme	n.a.		considered		
Crossing Bridges	2 places		3 places		
Breakwater	existing available		additional new		

n.a.: not applicable

Table S.1-3 Summary for the Year 2060

(Additions to the Year 2020)

Item	High Rise Lock (85 feet)		Sea Level Canal		
	150,000 DWT	200,000 DWT	Case (a)	Case (b)	Case (c)
Total Cost (Mill.US$)	1,407	1,350	1,717	775	1,717
Lock and Gate	fourth lane lock (later than 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		

n.a.: not applicable

Table S.1-4 Summary of Options Study

Item	Additional Cost (Mill. US$)				
	High Rise Lock (85 feet)		Sea Level Canal		
	150,000 DWT	200,000 DWT	Case (a)	Case (b)	Case (c)
Canal Bank Slope Cotangent 0.4 Increase	n.s.	277	837	n.s.	837
Increase Bottom Width of Channel from 7B to 8B	n.s.	555	129	n.s.	129

n.s.: not studied

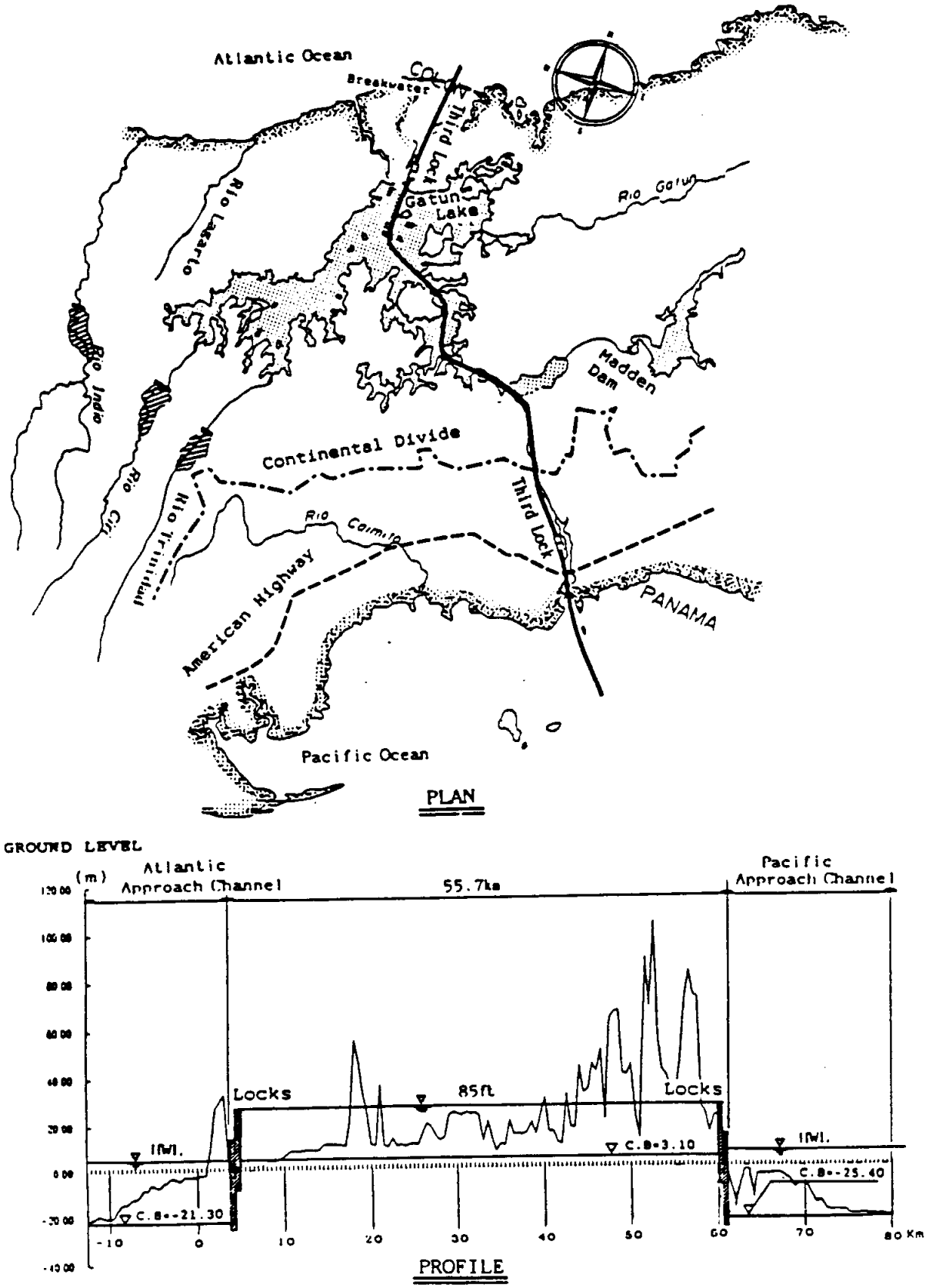


Fig. S.1-1 Layout of High Rise Lock Canal (200,000 DWT)

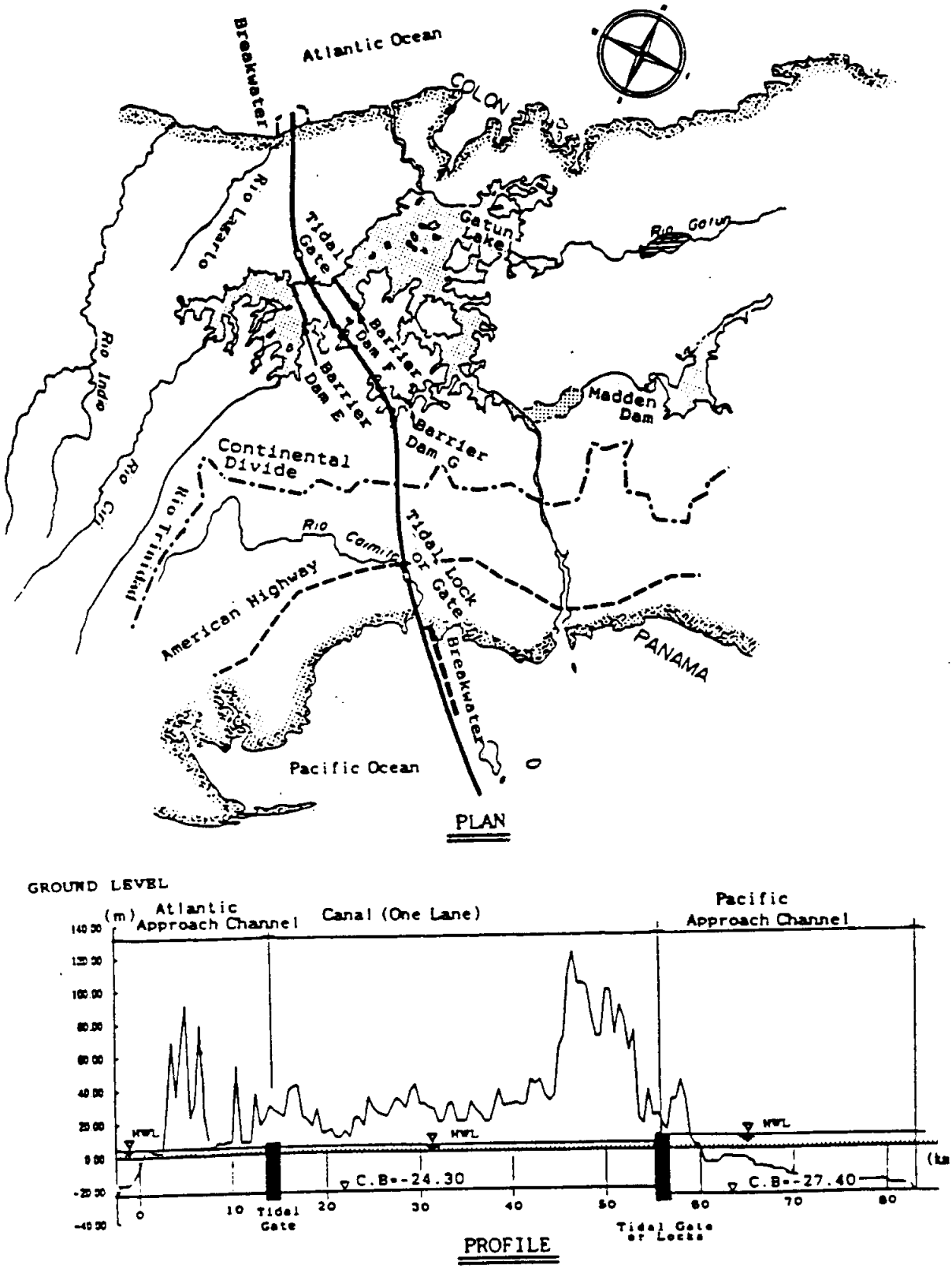


Fig. S.1-2 Layout of Sea Level Canal [Case (a) and (c)]

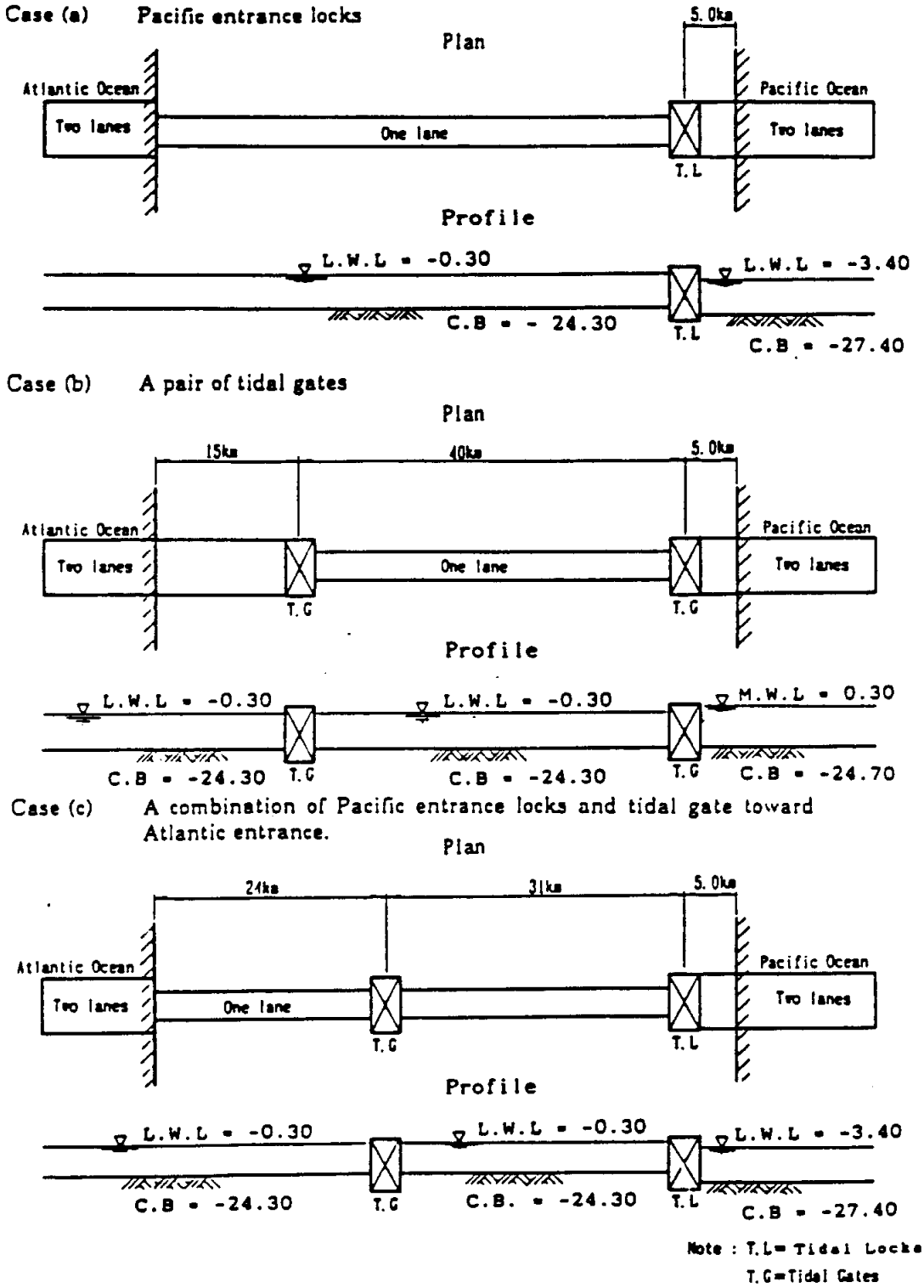


Fig. S.1-3 Case of the Sea Level Canal

2. HIGH RISE LOCK CANAL
(Part III, Section 1 Engineering and Preliminary Design)

With regard to the High Rise Lock Canal alternative, two case studies were conducted, for prospective ship sizes of 150,000 DWT and 200, 000 DWT. Two water levels, i.e. 85' and 90', were also considered for Gatun lake.

2.1 General

General engineering conditions used in Engineering and Preliminary Design are summarized in the Summation Table (1) attached in the last page. The Schematic Layout of the High Rise Lock Canal is shown in Fig. S.1-1.

2.2 Water Management Plan

2.2.1 Annual Yield

Calculation of the annual yield of the Gatun watershed of 3,339km^2 is necessary to determine the available lockage water volume for the High Rise Lock Canal. The annual yield minus municipal use (4%) and evaporation loss (10%) gives the available lockage water volume. Based on analysis of the runoff of the last 51 years, the average annual runoff (yield) of the Gatun watershed is 6.6 billion m^3. After reduction for municipal use and evaporation loss, the available lockage water volume is 5.6 billion m^3.

2.2.2 Water Balance

From the calculations, the following have become clear.

1) 150,000 DWT in the year 2020 case

   The required water volume (3,881 million m^3) for the existing and new locks can be supplied from the existing catchment and dams, and no special counter measures are needed.

2) 150,000 DWT in the year 2060 case

   The required water volume (5,872 million m^3) cannot be supplied from the existing catchment and dams, and a new water source (Indio) and regulating dam (Ciri) are necessary.

3) 200,000 DWT in the year 2020 year case

   The required water volume (4,068 million m^3) cannot be supplied from the existing catchment and dams in a dry year, and Indio Dam is needed as a new water source.

4) 200,000 DWT in the year 2060 case

The required water volume (6,303 million m^3) cannot be supplied from the existing catchment and dams even in an average year. Trinidad dam as a regulating reservoir and Indio dam as a new water source are necessary. A recycling pump system is also needed.

5) Facilities for water supply dams and pump stations are summarized in Table S.2-1.

Table S.2-1 Dams and Pump Stations

Year	Rain fall	Max. Ship Size DWT		
		High Rise Lock Canal (85 feet)		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 S	n.r.
	Dry year	Indio Ciri Pump S	Indio Trinidad Pump S	Upper Gatun

Note: n.r. : not required.
wet year : 1981 (maximum yield in last 10 years)
average year : average yield in 51 years
dry year : 1982 (minimum yield in last 10 years)

The relationship between the required water volume for the existing and new locks and the available water volume in an average year is shown in Table S.2-2 and S.2-3.

In all cases there will be no water shortage except for special situations for the high rise cases. The water shortage may occur near 2060 and especially during dry years. However with addition dams and/or pump stations there will be sufficient water for all situations.

2.2.3 Dams in Gatun Watershed (Acting as Regulating Reservoirs)

Any shortage in the lockage water cannot be compensated for regardless of how many dams are constructed in the Gatun watershed. The best way of compensating is the use of water from the Indio dam located outside the Gatun watershed or pumping to recycle water. Consequently, such planned dams as the Ciri, Trinidad or Upper Gatun, all located in the Gatun watershed, should act as regulating reservoirs for the effective use of the available water for lockages. The feasibility of such dams acting as regulating reservoirs was examined at the 3 sites as shown in Table S.2-4. The elevation of the crown, dam height and effective storage of each dam site are given in the table while the locations of these sites are shown in Fig. S.2-1. The typical dam cross section is shown in Fig. S.2-2. It was decided that the Ciri and Trinidad dams for ship size 150,000 DWT and 200,000 DWT respectively should be used as a regulating dam.

2.2.4 Indio Dam (Acting as New Water Source)

Planning of the Indio dam in the upper reach of Rio Indio will provide a new water source. The water stored by this dam will be guided to the western end of Gatun lake via an open channel. The main specifications of this dam are given in Table S.2-5 while its typical cross-section is shown in Fig. S.2-2.

2.2.5 Water Circulation Plan

This system guides the lockage water from the lock's lower chamber through an open channel to a recycling basin for temporary storage, instead of discharging it directly to the sea. The stored water is pumped to the Gatun lake side. The pump capacity used in the calculation was $30m^3$/sec with a pipe diameter of 3,600mm and a motor output of 9,200kw.

Pumping is not required for the year 2020. For the year 2060, two pump stations are proposed, one on the Atlantic side and one on the Pacific side. Allowing for outages, two pumps are required at each pump station.

It is necessary to provide a recycling basin and pump station on both the Atlantic and Pacific sides since the volume of spent lockage water discharged from the new locks on one side only is less than the volume of water required to be recycled. Separate recycling ponds and pump stations will also be an advantage in the event of an emergency.

Table S.2-2 150,000 DWT Ship Case (85 Feet)

Description	Year	2020	2060
1. Available Water (Average Year)	MCM	5,647	5,653
2. Lockage Water (for Existing Locks)	"	2,867	3,540
3. Lockage Water (for New Locks)	"	1,014	2,332
4. Total Lockage Water (2 & 3)	"	3,881	5,872
5. Water Balance	"	+1,766	-219

Table S.2-3 200,000 DWT Ship Case (85 Feet)

Description	Year	2020	2060
1. Available Water (Average Year)	MCM	5,647	5,653
2. Lockage Water (for Existing Locks)	"	2,867	3,540
3. Lockage Water (for New Locks)	"	1,201	2,763
4. Total Lockage Water (2 & 3)	"	4,068	6,303
5. Water Balance	"	+1,579	-650

Table S.2-4 Dam Dimensions in Gatun Watershed

Name	Dam Crest Elevation	Dam Height	Effective Storage Volume
Ciri Dam	125 m	60 m	120 million m^3
Trinidad Dam	145 m	80 m	475 million m^3
Upper Gatun Dam	120 m	95 m	340 million m^3

Table S.2-5 Indio Dam Dimensions

Name	Dam Crest Elevation	Dam Height	Effective Storage Volume
Indio Dam (H)	95 m	90 m	710 million m^3
Indio Dam (L)	85 m	80 m	550 million m^3

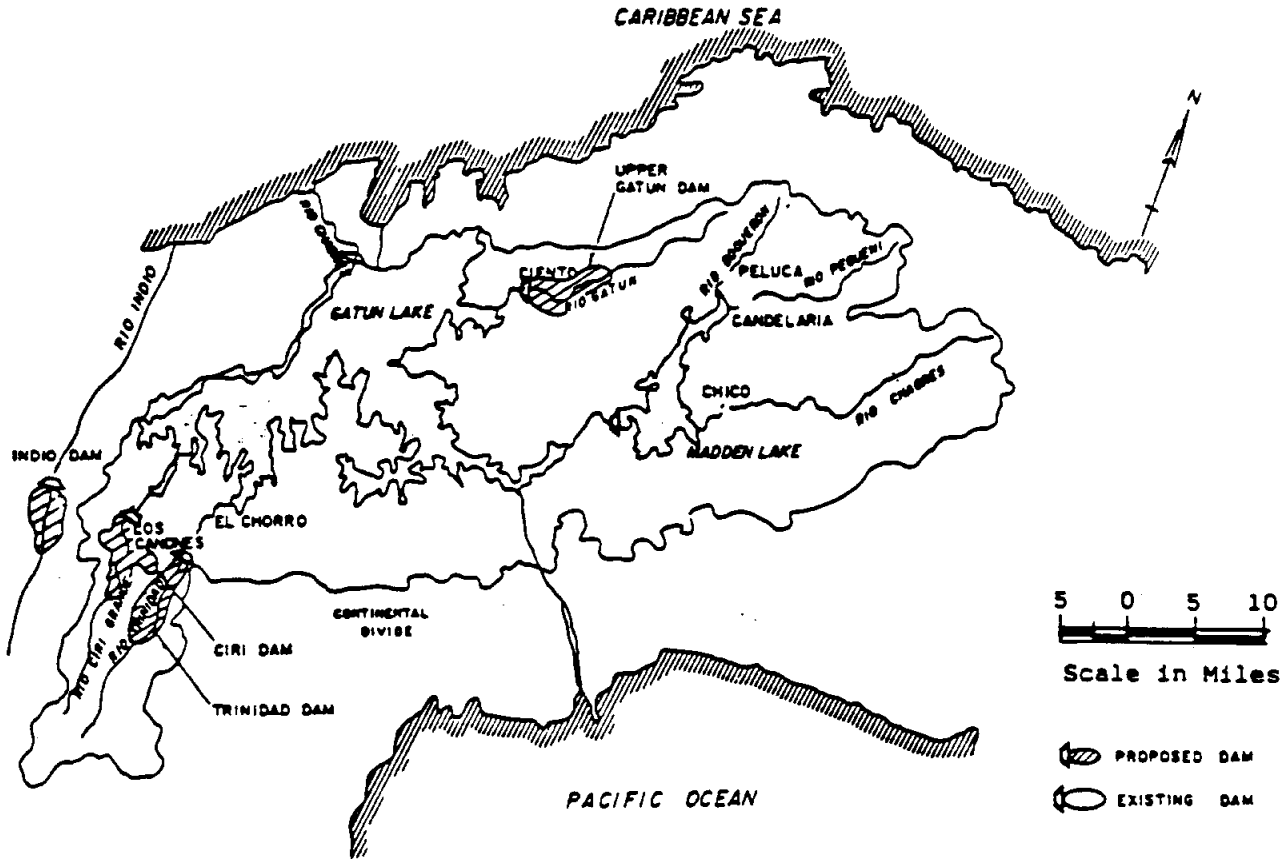


Fig. S.2-1 Dam Locations

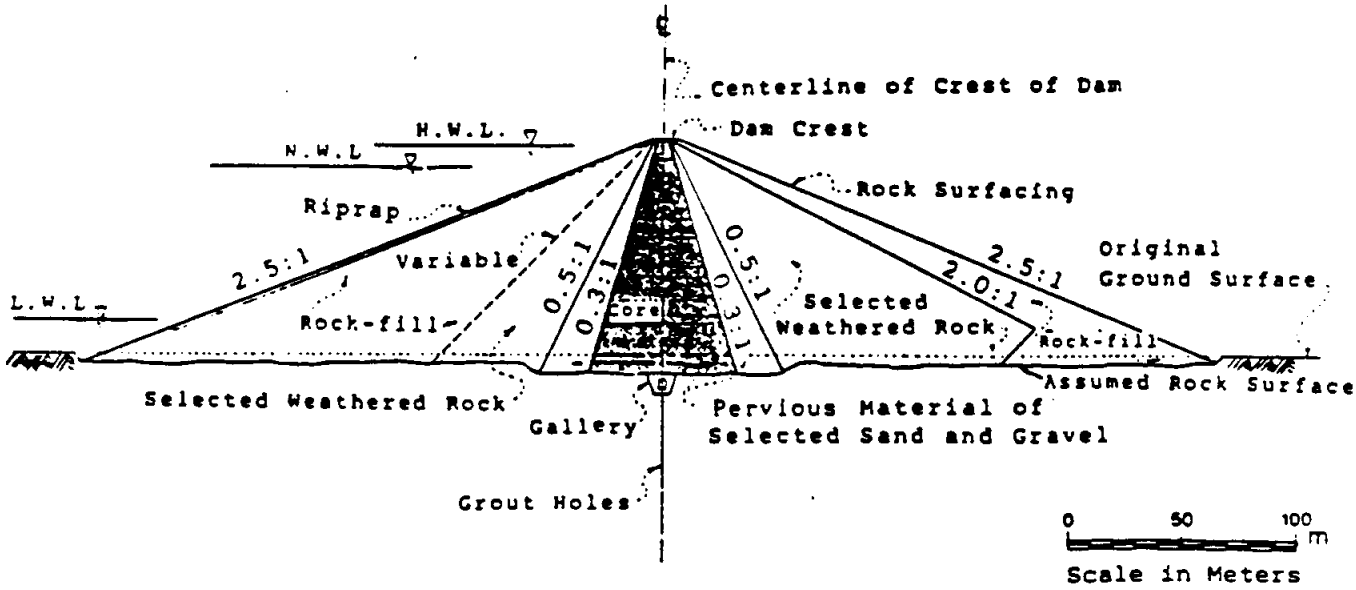


Fig. S.2-2 Typical Cross Section of Fill Type Dam

2.3 Canal Excavation Plan

2.3.1 Description

Calculation of the excavation volume was conducted for 4 different cases involving two ship sizes, i.e. 150,000 DWT and 200, 000 DWT, and two lake water levels, i.e. 85' and 90'. Topographical maps and sea charts (with a scale of 1/25,000) were used for the calculation. Moreover, five geographical types were introduced to represent the soil and rock characteristics of each zone. (See Fig. S.2-5)

2.3.2 Calculation Results

Calculation of the excavation volume was conducted separately for ground (dry) excavation and dredging. The results are given in Table S.2-6 and Fig. S.2-3. The relevant figures for Sea Level Canal Case (a) are also given for reference purposes. The excavation volume for each zone with a water level of 85' and a ship size of 200,000 DWT are given in Fig. S.2-4. Both the dry and wet excavation conditions are further classified in terms of the geological characteristics, i.e. soil, soft rock and hard rock, etc. Please refer to the main report for a more detailed description.

Table S.2-6 Excavation Volume

Water Level	Ship Size (DWT)	Dredging Volume (million m^3)	Dry Excavation Volume (million m^3)	Total Excavation Volume (million m^3)
85'	200,000	358	242	600
85'	150,000	295	217	512
90'	200,000	346	229	575
90'	150,000	286	205	491

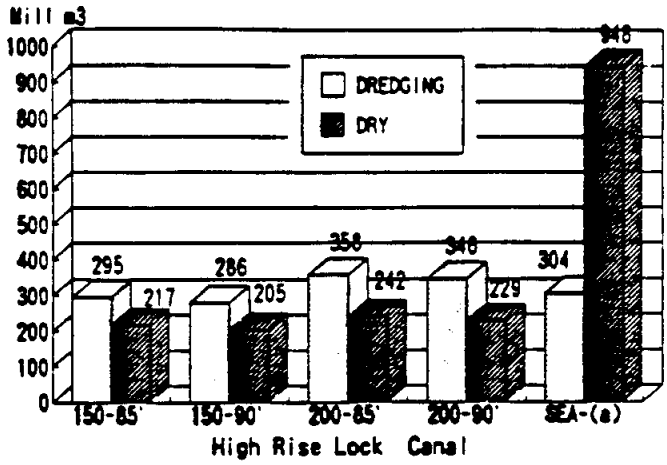


Fig. S.2-3 Excavation Volume for Each Case

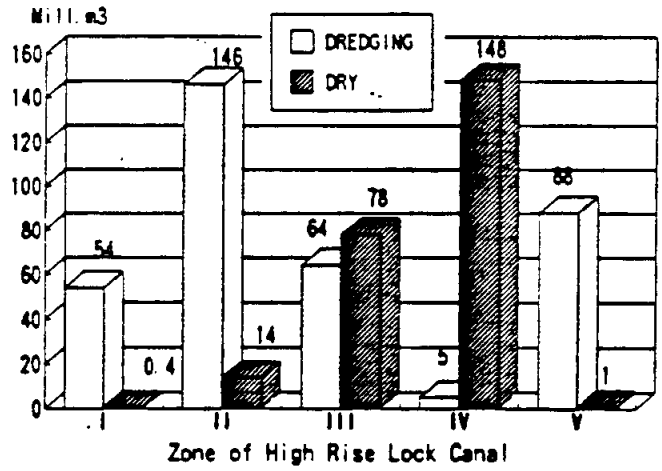


Fig. S.2-4 Excavation Volume for Each Zone (85' and 200,000 DWT Case)

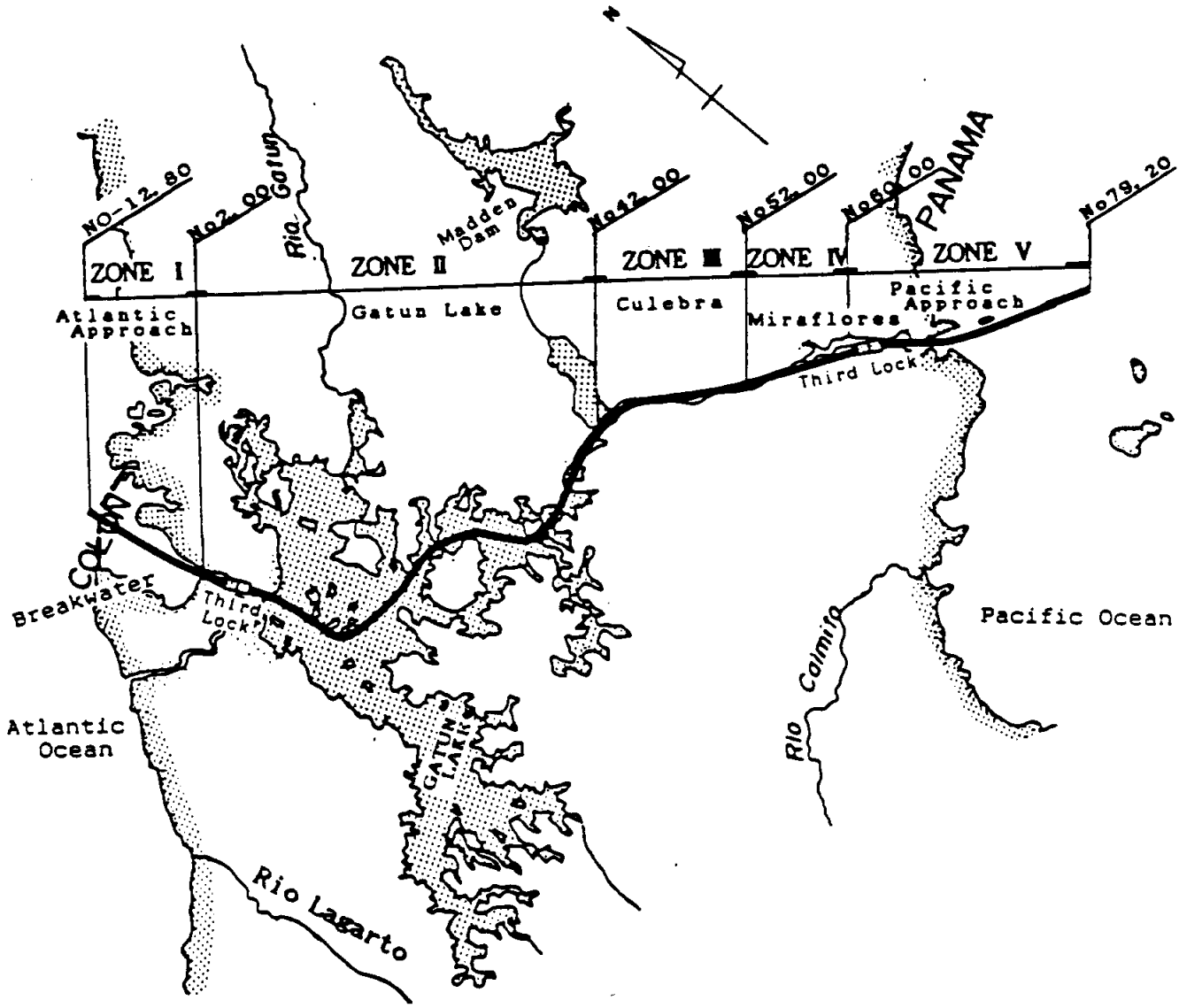


Fig. S.2-5 Zone Map of High Rise Lock Canal

2.4 Lock Structures and Mechanical Equipment

2.4.1 Lock Structures (Concrete) and Incidental Facilities

1) Lock Locations

Fig. S.2-6 and Fig. S.2-7 show the planned lock locations on the Pacific side and Atlantic side respectively. The location of the new high rise lock on the Pacific side has been slightly moved westward from the previous location suggested in Phase I because of the partial alteration of the canal alignment to enable the smoother navigation of vessels. As a result, the location of the new lock is a distance of some 1km from the existing lock. This separation is preferred on safety grounds as the canal side water level of the high rise lock is 85' which is much higher than the water level of Miraflores lake of 55'. A closure bank is introduced (as shown in Fig. S.2-6) next to the new lock to prevent the overflow of water from the new canal side to the existing lock side.

2) Surge Basin

Hydro-dynamic impact caused by the surging phenomenon may occur on the Pacific side when the canal water pours into the lock chamber in a relatively short period of time. To reduce the effects of such surge on vessels, a surge basin in proposed in the area of the Rio Cocoli valley of the new Pacific side lock using the natural topography as much as possible. A surge basin is not required on the Atlantic side since Gatun lake is immediately adjacent to the upstream end of the new locks.

3) Recycling Basin and Pump Station

The introduction of a recycling pond is proposed for the year 2060 on both the Pacific and Atlantic sides to store the spent lockage water (mainly fresh water) for subsequent recycling by pumping. A pump station with a capacity of $60m^3$/sec will also be provided on both ocean sides between the recycling basin and surge basin.

4) Lock Structure

All locks and approach walls will be the gravity type with varying cross-sections to meet the stability requirements and to incorporate a hydraulic tunnel system. The seismic coefficients used are Kh=0.1 and Kv=2/3Kh. Fig. S.2-8 shows the typical cross-section of the area around the middle operating gate.

5) Fourth Lane of Locks

Initially, just one lane of new, large locks is required at Gatun and Miraflores, however the excavation for the fourth lane of locks (ie. a second lane of larger locks) is included and costed as part of the initial works for 2020.
The fourth lane of locks may be required by or after 2060 and construction costs for the fourth lane have been included in Appendix 4.

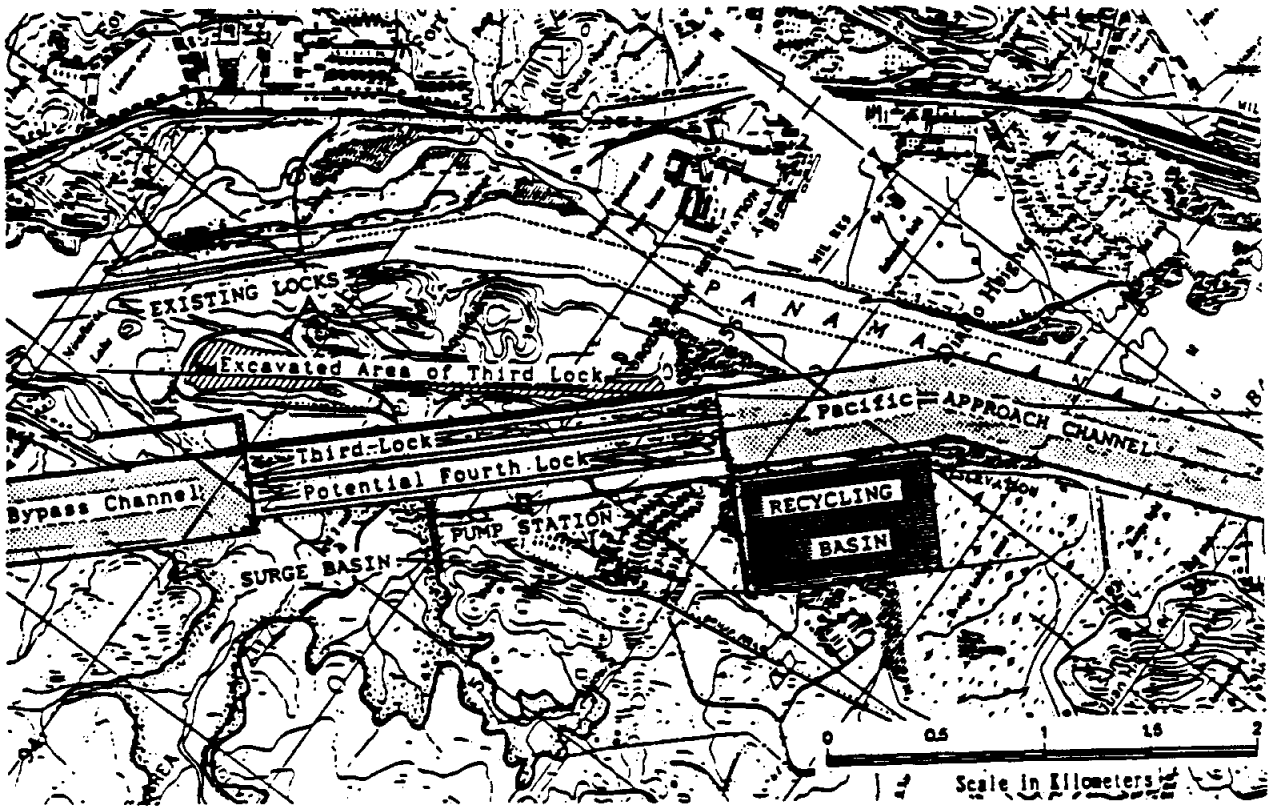


Fig. S.2-6 New Lock Layout Plan (Pacific Side)

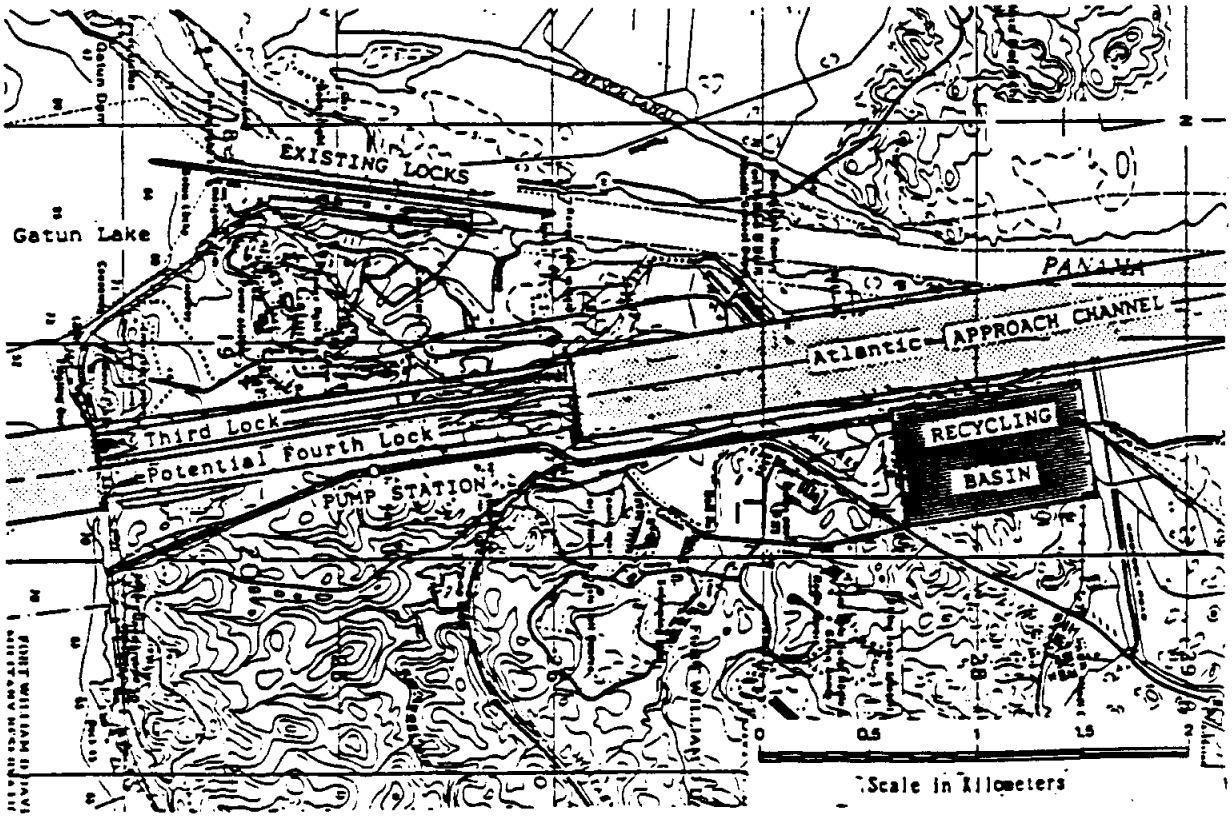


Fig. S.2-7 New Lock Layout Plan (Atlantic Side)

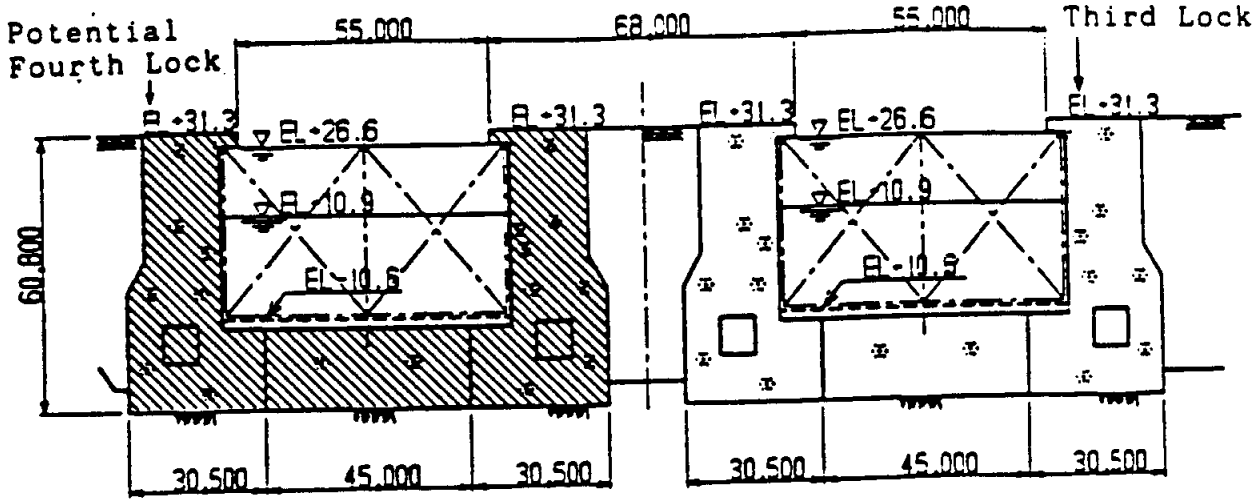


Fig. S.2-8 Typical Cross Section at middle operating Gate (200,000 DWT)

2.4.2 Gate Leaves

1) Description

The proposed gate type is the Miter type gate which was examined in Phase 1. Particular emphasis during the design stage of the main gate was put on the allowable stress for fatigue. Compared to the Phase 1 design, the number of gate operations has been reduced with the effect of increasing the allowable stress for fatigue, in turn lightening the gate weight. The assumed time required to open or close the gate is five minutes and the gate operation mechanism has been designed on this basis.

2) Main Gate Dimensions

The dimensions of the main gate are given in Table S.2-7 and S.2-8.

Table S.2-7 Main Gate Dimensions (200,000 DWT Case)

Position of Gate	Pacific Side W(m) x H(m) x W(tons)	Atlantic Side W(m) x H(m) x W(tons)
Upper Operating Gate	55.0 x 23.6 x 2,000	55.0 x 23.6 x 1,800
Middle Operating Gate	55.0 x 37.8 x 4,200	55.0 x 36.3 x 3,900
Lower Operating Gate	55.0 x 40.6 x 4,100	55.0 x 36.0 x 3,300

Table S.2-8 Main Gate Dimensions (150,000 DWT Case)

Position of Gate	Pacific Side W(m) x H(m) x W(tons)	Atlantic Side W(m) x H(m) x W(tons)
Upper Operating Gate	50.0 x 22.1 x 1,650	50.0 x 22.1 x 1,650
Middle Operating Gate	50.0 x 36.3 x 3,400	50.0 x 34.8 x 3,150
Lower Operating Gate	50.0 x 39.1 x 3,400	50.0 x 34.5 x 2,800

Note: 1) The gate weight indicates the weight of a pair of gate leaves and includes neither the weight of the gate frame which is built in to the supporting concrete structure nor the weight of the gate operation mechanism.

2) W (m) : gate width in meters
H (m) : gate height in meters
W (tons) : gate weight in tons

2.4.3 Mules

A total of 20 mules with a traction power of 64 tons will be used for both the Pacific side and Atlantic side of the new locks (totalling 40 mules). The specifications and number to be installed are the same for both the 200,000 DWT case and 150,000 DWT case.

2.5 Incidental Structures

2.5.1 Breakwater

A breakwater is currently provided on the Atlantic side to protect the approach channel to the canal and this breakwater can be used for the new High Rise Lock Canal. On the Pacific side, three islands, i.e. Naos, Perico and Falmenco, and the road connecting these islands act as a breakwater protecting the approach channel. As a result, no new breakwaters are required.

2.5.2 Berthing Facility for Small Boats

The construction of piers for the mooring of small boats, including tug boats to assist the navigation of passing vessels, is planned. These 50m long and 10m wide jetties will have a pile foundation with concrete slabs. A total of seven such piers will be constructed along the canal, including the approach channels.

2.5.3 Anchorage Area

Vessels wishing to use the canal must sometimes anchor offshore while awaiting permission to navigate the canal. The introduction of an anchorage area on the ocean side of the approach channel is necessary for the new canal as in the case of the existing canal. The planned area is sufficiently deep and no dredging is required. As the vessels use their own anchors, there is no need for the construction of new anchorage facilities.

2.5.4 Transportation Plan

With the construction of the new canal, the existing Bridge of the Americas on the Pan American Highway must be replaced by a new bridge to allow a wider approach channel and an increased bridge height for the passage of large vessels. Four canal crossing points, i.e. replacement of the Bridge of the Americas and three further crossings at Van Dam Bypass, Gamboa and Atlantic coast area, are proposed in the present plan for the widening of the canal and the construction of new high rise lock facilities. The approximate locations of these crossing points are shown in Fig. S.2-9. For the year 2020, it has been agreed that only the replacement of the Bridge of the Americas (Pacific side) and the provision of a new bridge on the Atlantic side will be costed. Addition of the other two bridges is included for the year 2060. Realignment

of some existing roads and the construction of new work roads are also required as part of the new high rise lock construction work. The construction cost for these bridges and roads, etc. is included in the estimated cost of the High Rise Lock Canal.

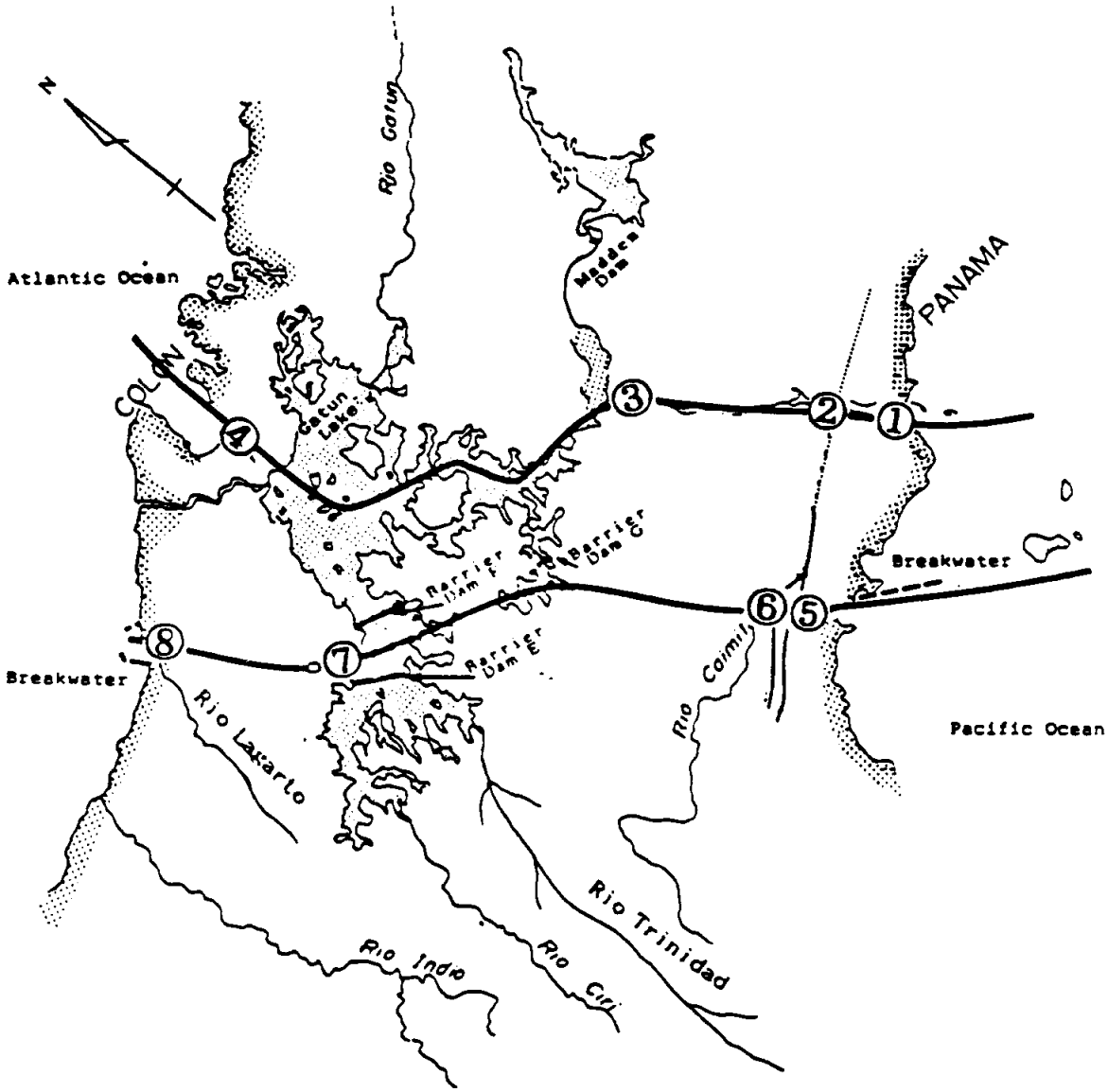


Fig. S.2-9 Road Crossing Location

For High Rise Lock Canal, road crossings at locations ① to ④ shown above are planned. For Sea Level Canal, road crossing at locations ② to ⑧ shown above are planned.

3. SEA LEVEL CANAL
(Part IV. Section 1. Engineering and Preliminary Design)

The Sea Level Canal is designed to accommodate 250,000 DWT class vessels. The case variations include tidal locks on the Pacific side, a tidal gate on the Atlantic side and combinations of these. The configurations of these different cases are shown in Fig. S.1-3. The Layout of the Sea Level Canal is shown in Fig. S.1-2.

3.1 General

General engineering conditions used in Engineering and Preliminary Design are summarized in the Summation Table (1) attached in the last page. The schematic layout of the Sea Level Canal is shown in Fig. S.1-2.

There is a possibility that the Sea Level Canal could cause an environmental problem on a large scale because of the movement of seawater between the Pacific and Atlantic. The introduction of a freshwater barrier has been examined as a method, of solving this potential problem. The study also examines the possible volume of freshwater to be poured into the canal and by what method, but the likely effects of this have not yet been studied. A more detailed examination is, therefore, required in the future prior to the official acceptance of the freshwater barrier.

3.2 Water Management Plan

3.2.1 Available Lockage Water for Existing Canal

The main water management item in the case of the Sea Level Canal is examination of the available water volume for the existing locks in view of the reduced size of Gatun lake (due to the construction of a barrier dam) upon completion of a Sea Level Canal. Upper Gatun Dam is planned to supply water to the reduced Gatun Lake as described in IV.1 Chapter 2 Water Balance.

3.2.2 Freshwater Barrier System

The freshwater barrier system proposed here to solve the problem of seawater movement between the two oceans involves the collection of rain, mainly from the watershed at the west side of the canal, and discharging as much freshwater as possible into the canal or tidal lock chambers to form a freshwater barrier to restrict the movement of seawater. However, it is questionable whether or not the movement of seawater between the two oceans will be successfully prevented by the freshwater barrier system alone. (Setting of the canal water level above HWL +3.6m on the Pacific side with the installation of tidal locks on both the Pacific and Atlantic sides could achieve the level of performance shown by the existing locks and may considerably reduce the possible adverse impact on the environment. Consideration of this option was not required as part of this study.)

3.2.3 Available Freshwater Volume

Only the available volume of water to be used by the freshwater barrier system and the water collection method are examined in the Report. The main analysis item is to determine the amount of freshwater which can be made available after meeting water requirements for the existing canal. In short, the amount of water available from reservoir (E) for the freshwater barrier is approximately 1,200 million m^3/year in an average year, plus about 700 million m^3/year from other rivers.

3.2.4 Freshwater Supply System

Freshwater for the creation of a freshwater barrier could be discharged either into the canal or into the tidal lock chambers.

1) Discharge into the Canal

Freshwater would be discharged into the canal via outlet structures from dams W-3-D, W-4-D, W-6-D and W-7-D (refer section 3.6) and from barrier dam (E). Water from other rivers such as Rio Pescado, Rio Martin Sanches, and Rio Lagarto (East) would also be discharged into the canal.
It would also be possible to discharge water directly into the tidal lock chambers as described below.

2) Discharge into Tidal Lock Chambers

The discharge into the canal could be supplemented by the discharge of freshwater directly into the tidal lock chambers. This method would probably not be very effective on its own but may be an effective supplementary measure to the discharge into the canal described in 1) above.

3.3 Canal Excavation Plan

3.3.1 Description

The excavation volume was calculated for the three different cases, i.e. (a), (b) and (c), using topographical maps and sea charts (scale: 1/25,000). Five geological types were introduced to represent the soil and rock characteristics of each zone. (See Fig. S.3-3)

3.3.2 Calculation Results

The excavation volume was separately calculated for dry excavation and dredging, and the results are given in Table S.3-1. The excavation volume for each case and the excavation volume for each zone are shown in Fig. S.3-1 and Fig. S.3-2 respectively. Both the dry excavation and dredging conditions are further classified in terms of the geological characteristics, i.e. soil, soft rock and hard rock, etc. Please refer to the main report for further details.

Table S.3-1 Excavation Volume

Case	Ship Size (DWT)	Dredging Volume (million m^3)	Dry Excavation Volume (million m^3)	Total Excavation Volume (million m^3)
Case (a)	250,000	304	948	1,252
Case (b)	250,000	351	1,034	1,385
Case (c)	250,000	304	948	1,252

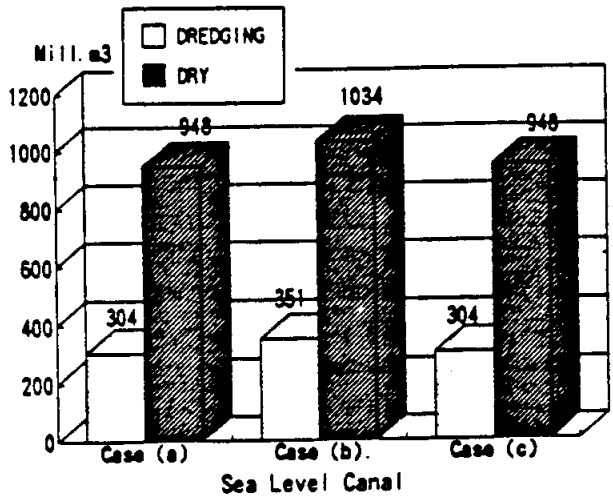


Fig. S.3-1 Excavation Volume for Each Case

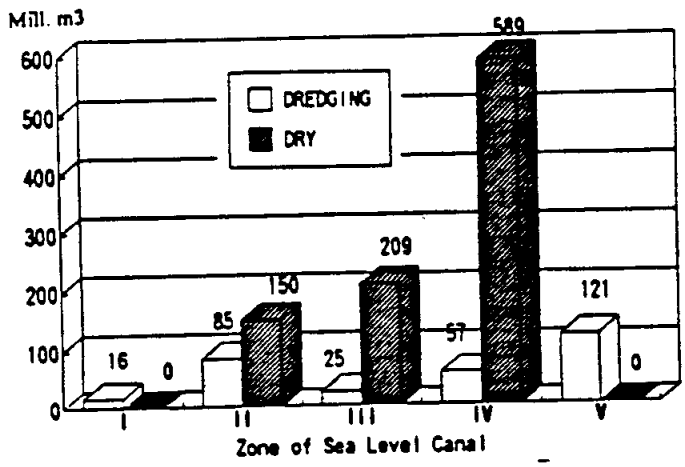


Fig. S.3-2 Excavation Volume for Each Zone (Case a)

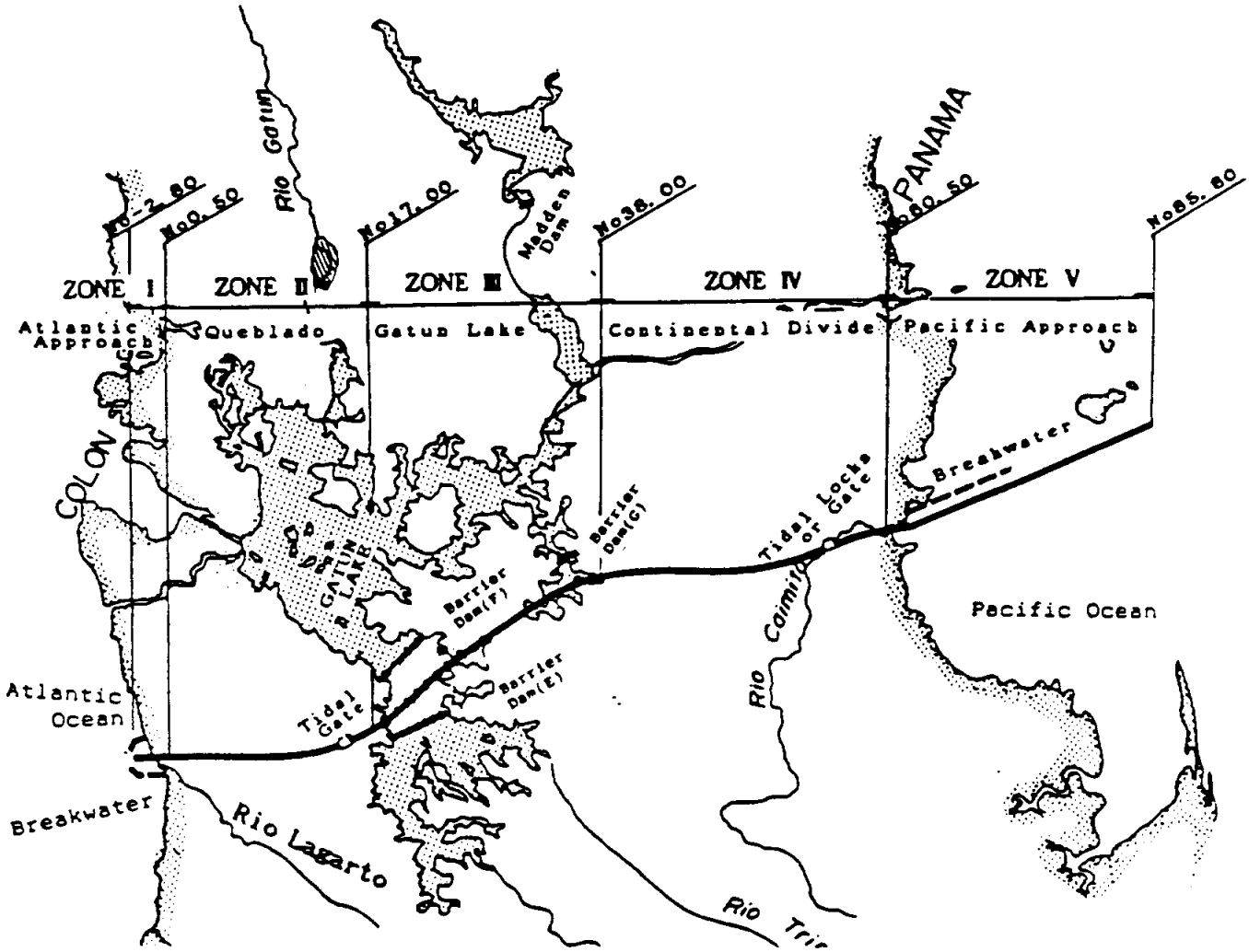


Fig. S.3-3 Zone Map of Sea Level Canal

3.4 Tidal Locks and Tidal Gates

3.4.1 Study Cases

For the Sea Level Canal, three cases were studied, i.e. (a) the introduction of tidal locks at only the canal entrance on the Pacific side, (b) the introduction of tidal gates at both the Pacific and Atlantic sides and (c) the combination of tidal locks and tidal gate.

In Case (a), the tidal locks are located 5km inland from the river mouth of Caimito river on the Pacific side and no tidal lock is constructed on the Atlantic side. As shown in Fig. S.3-4, three-lane tidal locks will be constructed by 2020 and an additional lane will be constructed by 2060, resulting in a total of four lanes.

In Case (b), tidal gates are located on both the Pacific and Atlantic sides. The location of the Pacific side tidal gates is the same as that of the tidal locks in Case (a) while the location of that on the Atlantic side is some 15km inland from the coast, near Escobal village and the existing Gatun Lake shoreline.

In Case (c), the tidal locks are constructed in the same position as in Case (a) while the tidal gate is constructed near Lagarterita village on the Atlantic side, about 24 km from the Atlantic shoreline.

3.4.2 Structures

1) Tidal Locks of Case (a) and Case (c)

The tidal lock structure will consist of a recess for torsion-type sliding gates, a lock chamber wall and guide wall. As mentioned earlier, three lanes will be constructed for 2020 and an additional lane will be constructed for 2060 to complete the 4-lane lock. The layout plan for the tidal locks is shown in Fig. S.3-4.

All structures and approach walls will be the gravity type with varying cross-sections to meet the stability requirements. The seismic coefficients to be applied are Kh=0.1 and Kv=2/3 x Kh. Table S.3-2 gives the main dimensions of the tidal lock structures and the concrete volume.

2) Tidal Gate of Case (b) and Case (c)

The tidal gate structures will consist of a recess for a triangular type rolling gate and abutment. All structures will be made of concrete. The plan for the tidal gate is given in Fig. S.3-5 while Table S.3-2 gives the main dimensions of the tidal gate structures and the required concrete volume.

Table S.3-2 Dimensions and Concrete Volume of Tidal Structures (2020)

	Dimensions (m) L	W	D	No.	Concrete Volume (m^3)
Case (a) Tidal Lock	430	60	23	3	6,000,000
Case (b) Tidal Gate	-	190	23	2	1,960,000
Case (c) Tidal Lock	430	60	23	3	6,980,000
Tidal Gate	-	190	23	1	

3.4.3 Gates

The proposed gate type for the tidal lock is the torsion type sliding gate. In view of possible emergencies, the provision of two operating gates and two emergency gates, i.e. two each at the Pacific approach channel side and canal side of the lock chamber, is proposed. Particular emphasis was put on the allowable stress for fatigue during the design stage. The assumed time required to open or close the gates is five minutes and the gate operation mechanism has been designed on this basis.

In the case of tidal gates, the triangular-type rolling gate is proposed. Two gates are planned at each tidal gate site to allow the emergency use of an extra gate. The assumed time required to open or close the gates is twenty minutes. The main dimensions of the tidal gate are given in Table S.3-3.

Table S.3-3 Main Gate Dimensions (250,000 DWT Vessel)

Structure	Dimensions W (m) x H (m)		No. per Site	Weight (tons)
Operating Gate for Tidal Lock	Sea side	60 x 30.6	4	1,650
	Canal side	60 x 27.5		1,450
Tidal Gate	190 x 27.5		2	8,500

Notes: 1) The gate weight indicates the weight of the a gate leaf and includes neither the weight of the gate frame which is built into the supporting concrete structure nor the weight of the gate operation mechanism.

2) W (m) : gate width in meters
H (m) : gate height in meters

3.4.4 Mules

A total of ten mules with a traction power of 64 tons each will be used for each tidal lock (40 units for four tidal locks). The specifications are the same as those to be used for the new high rise lock.

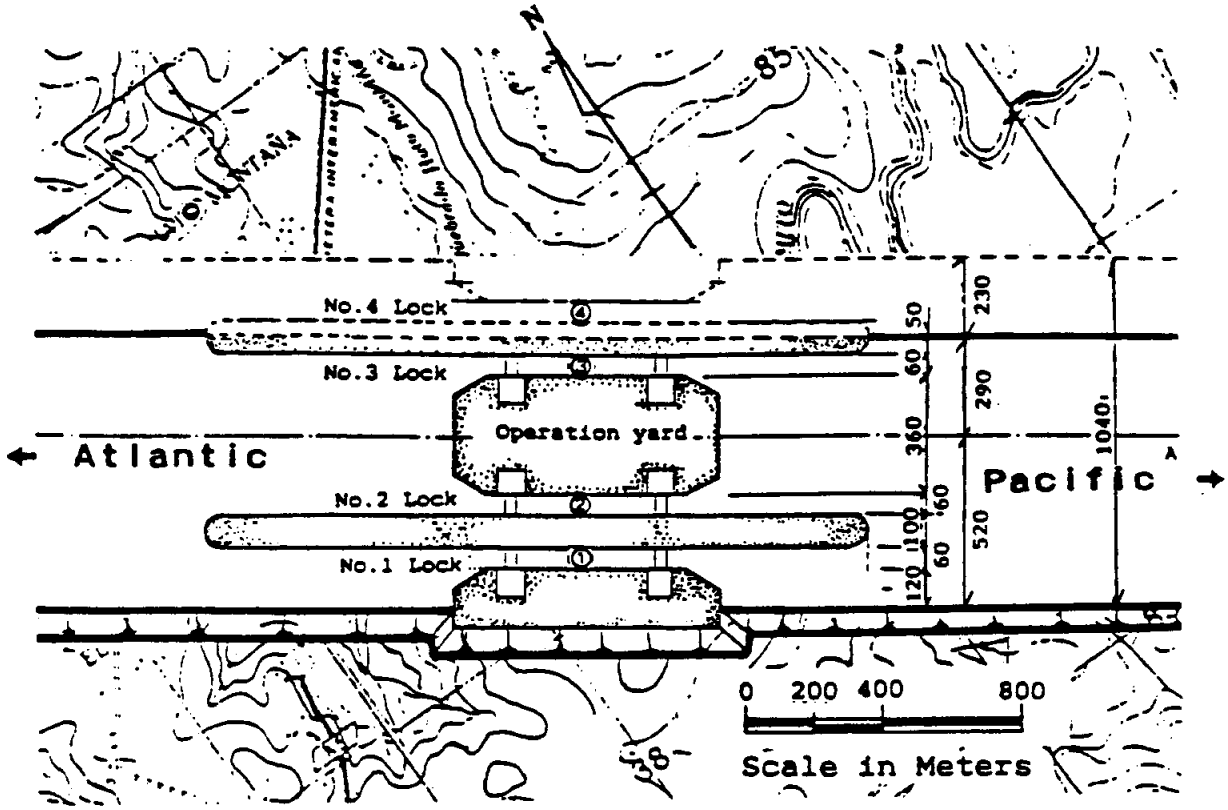


Fig. S.3-4 Tidal Lock Layout

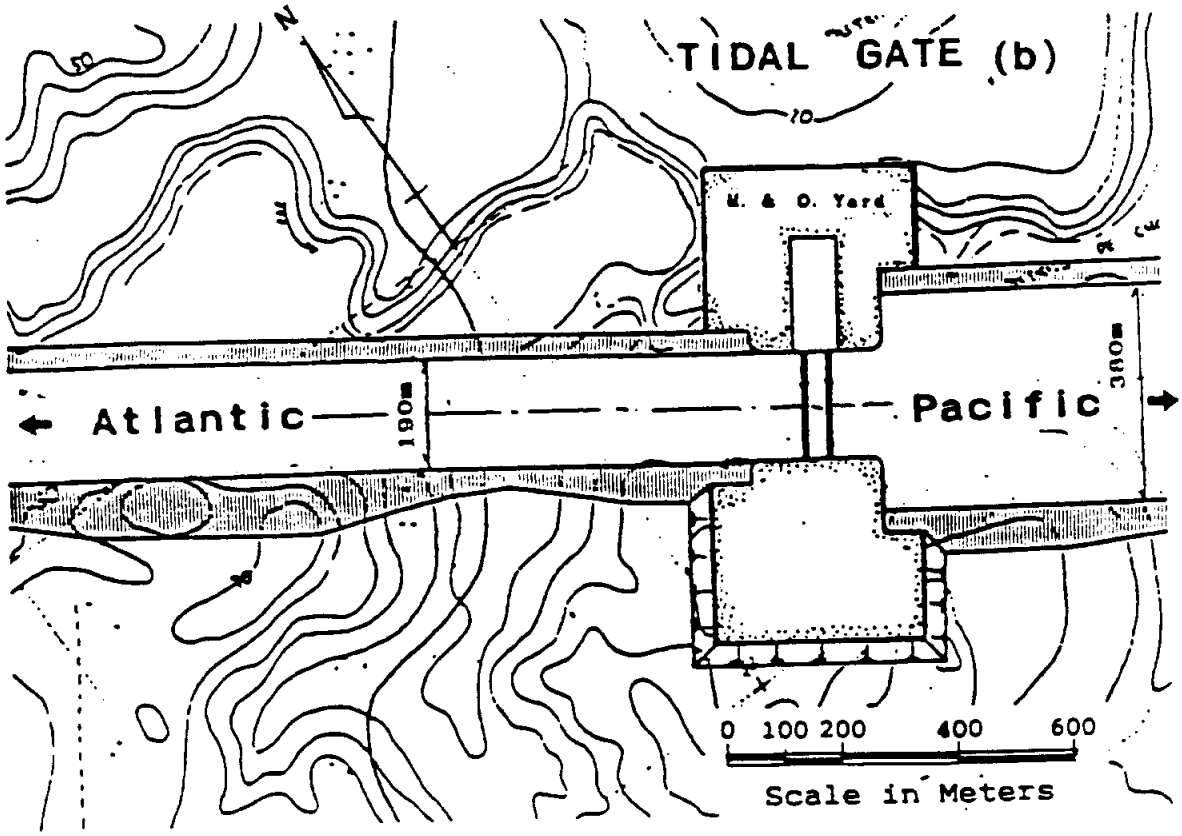


Fig. S.3-5 Tidal Gate Layout

3.5 Barrier Dams

3.5.1 Description

The main barrier dams are two almost parallel dams to be constructed in Gatun lake. These dams will ensure the present water level of Gatun lake while allowing the water level between the barrier dams to be lowered to the seawater level. The Sea Level Canal passing between these two dams can be constructed with minimal adverse effects on Gatun lake. The barrier dams will start near Escobal village at the southern tip of Gatun lake and end near Cano Gigante on the opposite side of the lake. Apart from these main barrier dams, another barrier dam is planned on the opposite coast of La Laguna village to bring the total number of barrier dams to three. Fig. S.3-6 shows the location of the barrier dams.

3.5.2 Barrier Dam Structure

All the barrier dams to be constructed will be the rock fill type. Structurally, each will consist of a core, filter and armour layer to ensure proper and stable functioning. The materials to be used are clayey soil, sand and 500-600 kg rocks for the core, filter and armour layer respectively. The foundation depth is designed to be some 10m lower than the lake bottom elevation to ensure dam stability. Instrumentation to measure subsidence will be attached to each dam to check the occurrence of dam subsidence.

3.5.3 Barrier Dam Dimensions

The main dimensions of the barrier dams are given in Table S.3-4, and Fig. S.3-7 shows a typical section of the barrier dam.

Table S.3-4 Barrier Dam Dimensions

Name	Dam Height	Crest Level	Crest Length	Volume (million m^3)
E	30 m	EL 32 m	4,200 m	13.0
F	32 m	EL 32 m	5,100 m	14.2
G	25 m	EL 32 m	900 m	2.0

3.5.4 Reservoir

An area to the west of the main barrier dam will be separated from Gatun lake to form a reservoir (E) which will be used as a freshwater supply source for the Freshwater barrier. The water level of the reservoir will be 26.6m above sea level which is the same as that of Gatun lake. The reservoir surface area will be about 80km^2 and the storage volume will be approximately 500 million m^3. The watershed serving this reservoir has an area of 685km^2 and rainwater will mainly flow into the reservoir via Rio Ciri and Rio Trinidad. The freshwater of the reservoir will flow down into the canal via a freshwater conveyance structure ordinarily. The freshwater volume from the reservoir will be 1,159 million m^3 in an average year. Surcharge water during a flood will be discharged to the Atlantic via the spillway and Rio Lagarto (see Fig. S.3-6).

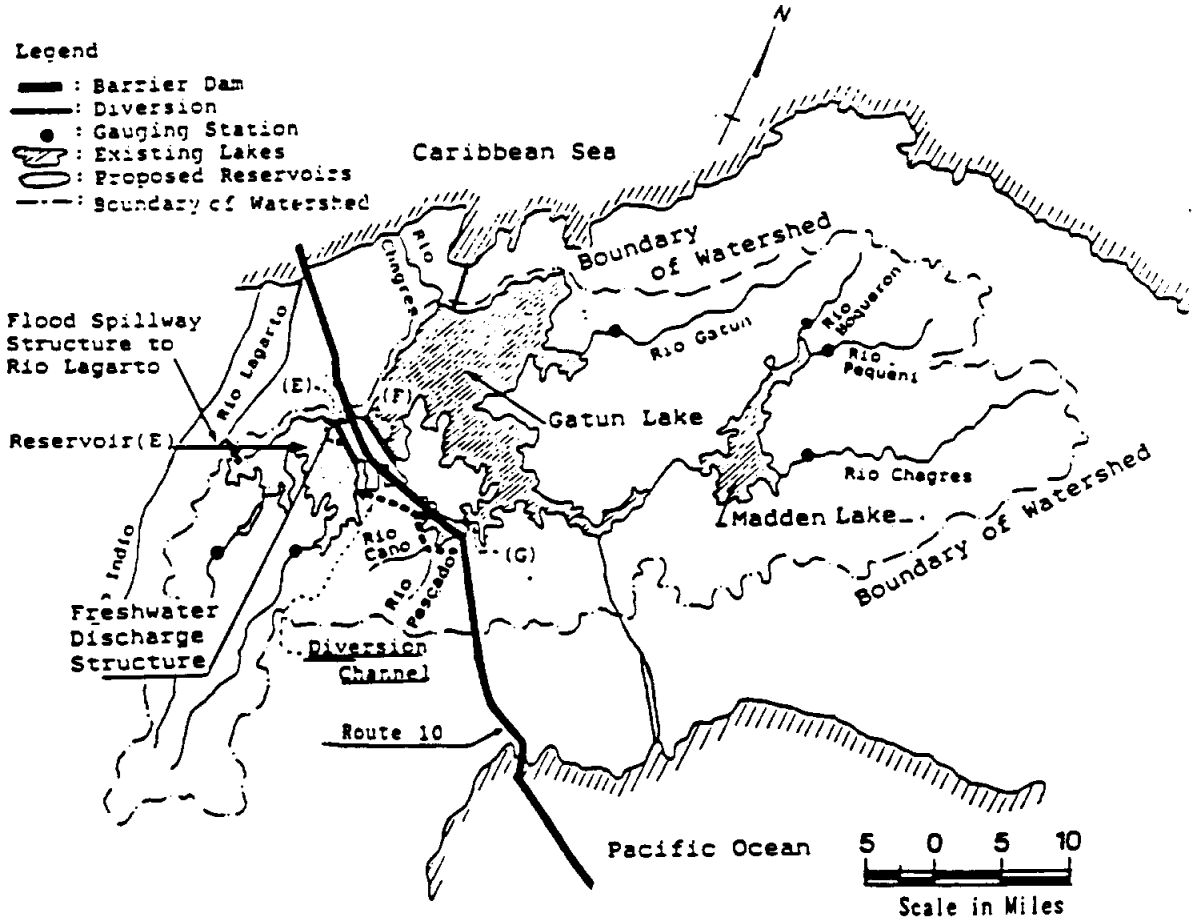


Fig. S.3-6 Barrier Dam Locations

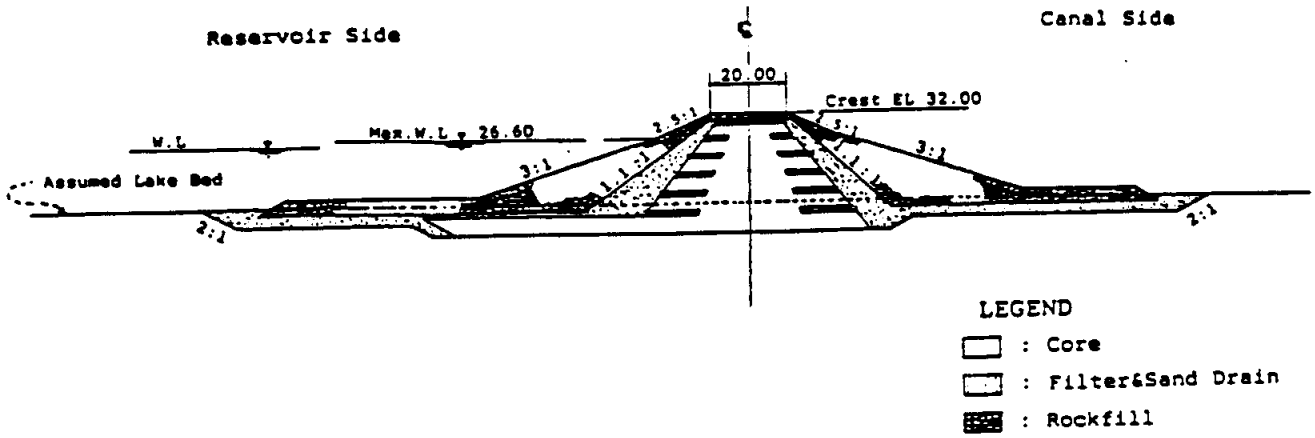


Fig. S.3-7 Typical Section of Barrier Dam

3.6 Diversion Scheme

3.6.1 Description

In view of the requirement to prevent flood water flowing into the canal during construction and to inject a huge amount of water into the canal or tidal lock chamber as freshwater, it is necessary to temporarily store freshwater from rivers in a reservoir and other facilities so that a regular supply of freshwater is available for discharge into the canal for the barrier system. Reservoir (E) is proposed for this purpose. Freshwater is obtainable from Rio Trinidad and Rio Ciri, both of which directly flow into Reservoir (E). In addition, the use of Rio Los Hules, Rio Quebrada Chica and Rio Cano is proposed to provide water for Reservoir (E) via diversion channels.

Rio Caimito, the watershed of which differs from the Gatun watershed, also has a large runoff which can be used for the freshwater barrier system. As it is difficult to guide water from the proposed Rio Caimito dam to Reservoir (E) due to topographical reasons, water from Rio Caimito will be discharged into the canal or tidal lock chambers independently of reservoir (E). Rio Lagarto (East) will be dammed near the Atlantic Ocean and a diversion channel constructed to divert water to the canal. During major floods however the water would be diverted to the Atlantic Ocean outside the Atlantic breakwaters. Water from other rivers (Rio Lagarto East, Rio Pescado and Rio Martin Sanches) will be discharged directly into the canal. Major rivers flowing into the Sea Level Canal are listed below for reference purposes.

1) Rio Lagarto (East)
2) Rio Lagarto (West)
3) Rio Trinidad
4) Rio Ciri
5) Rio Los Hules
6) Rio Quebrada Chica
7) Rio Cano
8) Rio Pescado
9) Rio Caimito (East)
10) Rio Caimito (West)
11) Rio Martin Sanchez

3.6.2 Diversion Channels and Cofferdams

The locations of rivers listed in 3.6.1 are shown in Fig. S.3-8 while the improvement measures for each river are given in Table S.3-5.

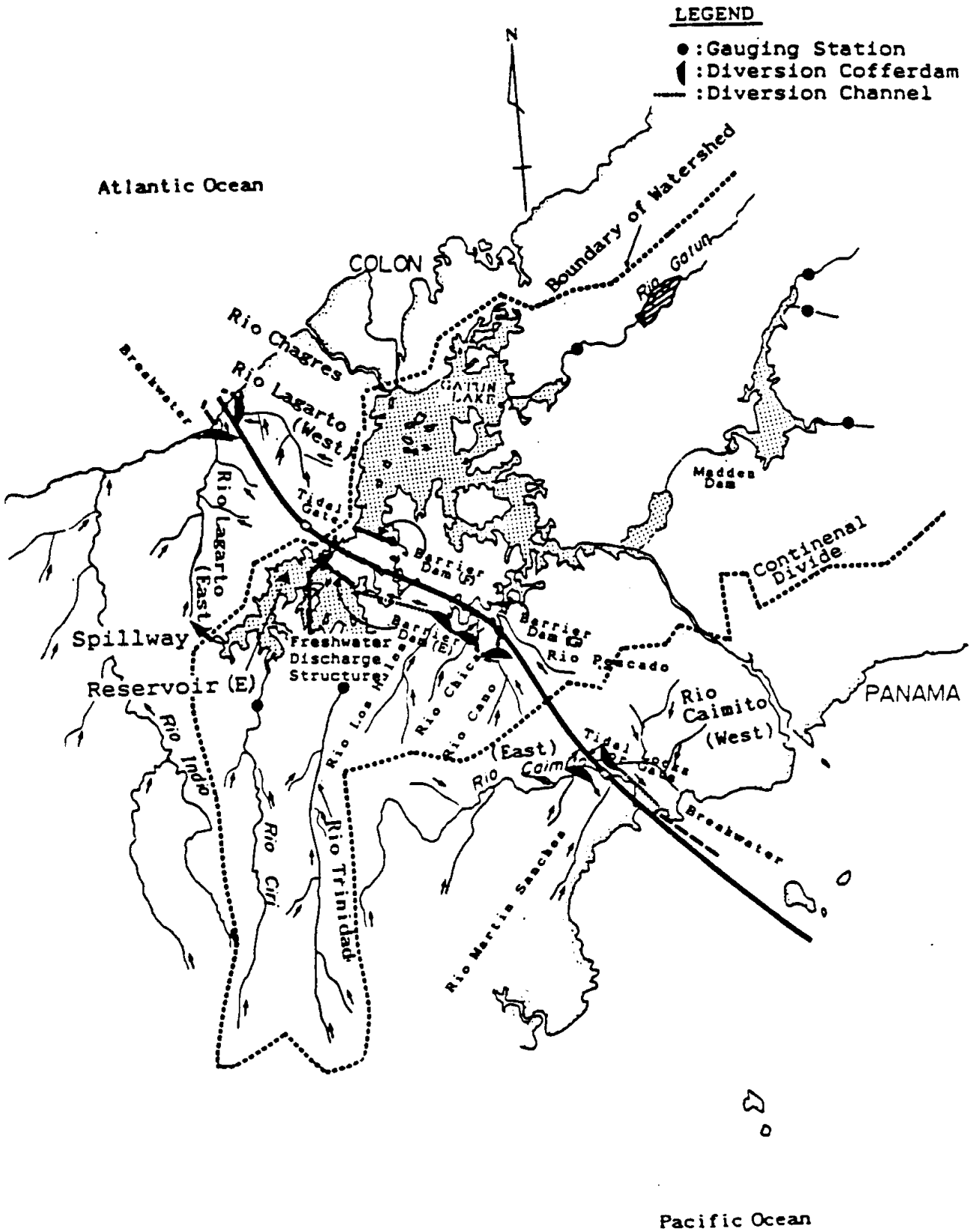


Fig. S.3-8 Diversion Scheme Layout

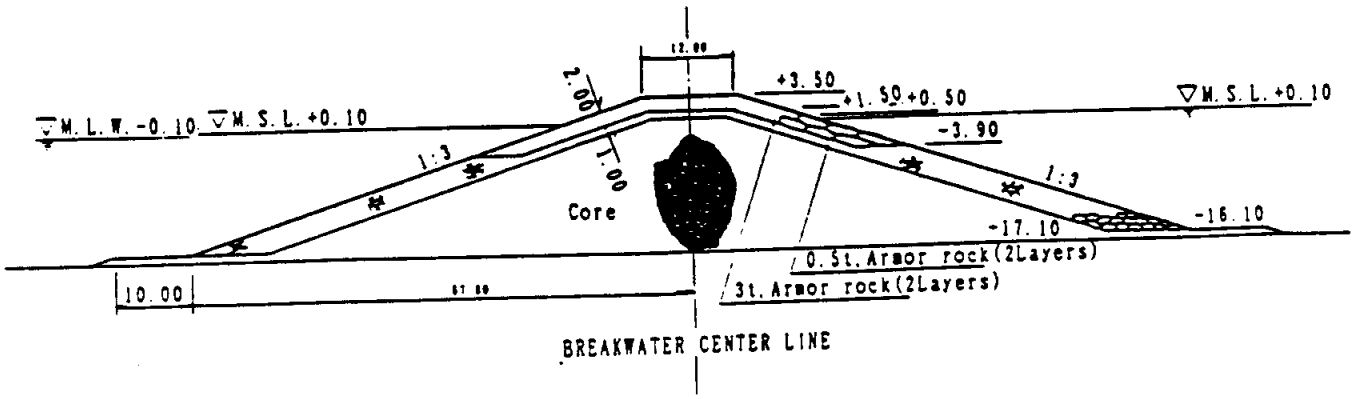
Table S.3-5 River Improvement Measures

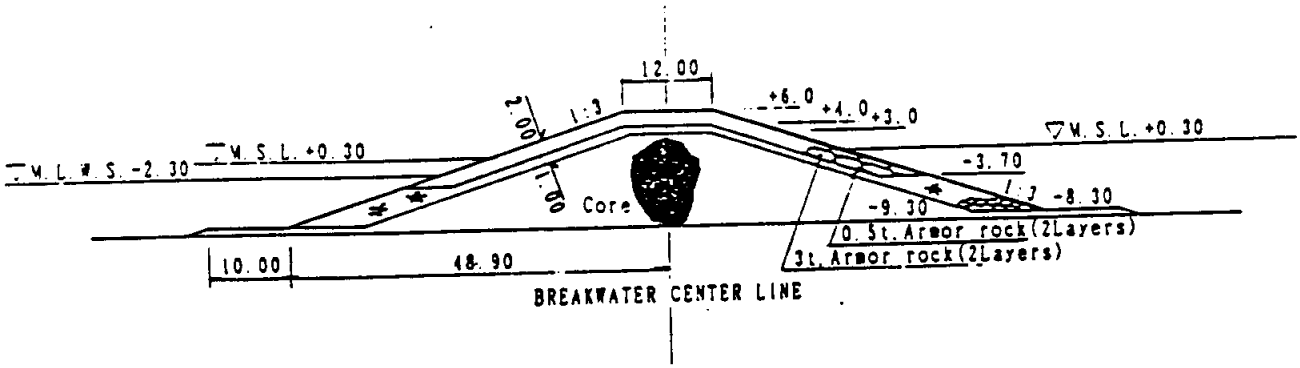
Name of River	Description	Dam	Channel
Rio Lagarto (East)	discharge directly to canal	-	-
Rio Lagarto (West)	dam and diversion channel	W-1-D	W-1-C
Rio Trinidad	directly to reservoir (E)	-	-
Rio Ciri	directly to reservoir (E)	-	-
Rio Los Hulos	dam and diversion channel	W-3-D	W-3-C
Rio Quebrada Chica	dam and diversion channel	W-4-D	W-4-C
Rio Cano	dam and diversion channel	W-6-D	W-5-C
Rio Pescado	discharge directly to canal	-	-
Rio Caimito (East)	dam and diversion channel	E-2-D	E-2-C
Rio Caimito (West)	dam and diversion channel	W-7-D	E-2-C
Rio Martin Sanchez	discharge directly to canal	-	-

3.7 Incidental Structures

3.7.1 Breakwaters

New breakwaters are proposed for the Sea Level Canal on both the Pacific and Atlantic sides. On the Pacific side, a breakwater on the eastside only is planned, as is provided for the existing canal near Panama City. The proposed slope gradient is 1:3, Fig. S.3-9 shows the typical section of the breakwaters.





Note 1: All dimensions are in meters.
2: Datum for all levels is P.L.D.(meters)

Fig. S.3-9 Typical Section of Breakwaters

3.7.2 Jetty for Small Boats

The construction of piers for the mooring of small boats, including tug boats to assist the navigation of passing vessels, is planned. These 50m long and 10m wide jetties will have a pile foundation with concrete slabs. A total of six such piers will be constructed along the canal, including the approach channels.

3.7.3 Anchorage Area

Vessels wishing to use the canal must sometimes anchor offshore while awaiting permission to navigate the canal. The introduction of an anchorage area on the ocean side of the approach channel is necessary for the new canal as in the case of the existing canal. The planned area is sufficiently deep and no dredging is required. As the vessels use their own anchors, there is no need for the construction of new anchorage facilities.

3.7.4 Transportation Plan

With the construction of the Sea Level Canal, the construction of new bridges/tunnels is essential to link the east and west sides of the canal. Four canal crossings are proposed, at the Pan American Highway, autopista, near Escobal and at the Atlantic coast area. The total number of crossings will be seven for the Sea Level Canal as three additional crossings will be provided over the existing canal. The cost of the construction of these bridges, realignment of existing roads and the construction of new roads, is included in the estimated cost for the Sea Level Canal.

The locations of the 7 proposed road crossings are ② to ⑧ shown in Fig. S.2-9.

For the year 2020, it has been agreed that three bridges over the Sea Level Canal, i.e. the Atlantic bridge, Escobal bridge, and one bridge on the Pacific side, will be costed. The remaining bridge over the Sea Level Canal and the three bridges over the existing canal are included in the costs for the year 2060.

4. MEMBERS OF THE STUDY TEAM FOR PHASE 2 STUDY

The Study Team consisted of the following 19 members;

Assignment	Name	Organisation
Project Manager	Dr. Akira Ishido	YEC
Structural Engineer (1)	Mr. Shuji Sekigushi	YEC
Structural Engineer (2)	Mr. Masashi Bessho	YEC
Geologist	Mr. Nobuhiko Uchiseto	YEC
Geotechnical Engineer	Mr. Murao Toyama	YEC
Civil/Hydraulics Engineer	Mr. Toshinobu Nakano	SANYU C.
Mechanical Engineer (1)	Mr. Hiroshi Terata	MHI
Mechanical Engineer (2)	Mr. Toshio Aketa	MHI
Waterways Specialist	Mr. John Read	MAUNSELL
Safety Operation Specialist	Mr. Takayuki Fukui	JAPMA
Port/Harbor Engineer	Mr. Satoru Nishino	YEC
Highway Specialist	Mr. Toshihiro Hotta	YEC
Transport Engineer	Mr. John Hamilton	YEC
Blasting Specialist	Mr. Lewis L Oriard	PBI
Construction Engineer	Mr. Masahiko Hatayama	SEIWA
Design/Quantities Engineer	Mr. Masaaki Naito	SEIWA
Cost Engineer (1)	Mr. Jun Iwasawa	SEIWA
Cost Engineer (2)	Mr. Koichi Nagayoshi	YEC
Electrical/Control Engineer	Mr. Noritune Chiba	YEC

YEC : Yachiyo Engineering Co., Ltd.
SANYU C. : Sanyu Consultants Inc.
MHI : Mitsubishi Heavy Industrial Co., Ltd.
MAUNSELL : Maunsell & Partners (UK)
JAPMA : Japan Association for Preventing Marine Accidents
PBI : Parsons Brinkerhoff Pty. Ltd.
SEIWA : Seiwa Consultants Co., Ltd.

5. SUMMATION TABLE

Comparative Summation Table (1)

File :sum

ITEMS	Unit	HIGH RISE LOCK ALTERNATIVES								SEALEVEL CANAL ALTERNATIVES					
		Case (1)		Case (2)		Case (3)		Case (4)		Case (a)		Case (b)		Case (c)	
		2020	2060	2020	2060	2020	2060	2020	2060	2020	2060	2020	2060	2020	2060
A. FEATURES OF ALTERNATIVES															
1. Design Ship	1000DWT	150	150	200	200	150	150	200	200	250	250	250	250	250	250
2. Route		1	1	1	1	1	1	1	1	10	10	10	10	10	10
3. Lake Level	ft	85	85	85	85	90	90	90	90	-	-	-	-	-	-
4. Number of Lift	no.	2	2	2	2	2	2	2	2	-	-	-	-	-	-
5. Canal Width	m	320	320	350	350	320	320	350	350	190	190	190	190	190	190
6. Approach Channel Width	m	320	320	350	350	320	320	350	350	380	380	380	380	380	380
7. Total Route Length	Km	84.1	84.1	87.6	87.6	84.1	84.1	87.6	87.6	88.4	88.4	86	86	88.4	88.4
- Pacific Approach	Km	14.3	14.3	17.5	17.5	14.3	14.3	17.5	17.5	25.1	25.1	22.7	22.7	25.1	25.1
- Channel	Km	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.7	60	60	60	60	60	60
- Atlantic Approach	Km	14.1	14.1	14.4	14.4	14.1	14.1	14.4	14.4	3.3	3.3	3.3	3.3	3.3	3.3
8. Channel Depth	m	21	21	22	22	21	21	22	22	24	24	24	24	24	24
B. WATER MANAGEMENT															
1. Abailable Water															
a. Average year	Mill M3	5,647	5,653	5,647	5,653	5,611	5,653	5,613	5,617	4,331	4,333	4,331	4,337	4,331	4,333
b. Dry year	Mill M3	3,951	3,952	3,952	3,952	3,916	3,952	3,916	3,916	3,148	3,149	3,148	3,149	3,148	3,149
2. Water Consumption for Existing Canal															
a. Ship Transits	no.	16,200	20,000	16,200	20,000	16,200	20,000	16,200	20,000	16,200	19,400	16,200	19,400	16,200	19,400
b. Water Volume Required	Mill M3	2,867	3,540	2,867	3,540	3,033	3,744	3,033	3,744	2,867	3,434	2,867	3,434	2,867	3,434
3. Water Consumption for New Lock															
a. Ship Transits	no.	2,000	4,600	2,000	4,600	2,000	4,600	2,000	4,600	-	-	-	-	-	-
b. Water Volume Required	Mill M3	1,014	2,332	1,201	2,763	1,073	2,467	1,271	2,922	-	-	-	-	-	-
4. Total Water Consumption: 2.b + 3.b	Mill M3	3,881	5,872	4,068	6,303	4,105	6,211	4,303	6,666	2,867	3,434	2,867	3,434	2,867	3,434
5. Available Freshwater (as barrier)															
a. Freshwater from Gatun Watershed	Mill M3	-	-	-	-	-	-	-	-	1,159	1,159	1,159	1,159	1,159	1,159
b. Freshwater from Outside Gatun	Mill M3	-	-	-	-	-	-	-	-	737	737	737	737	737	737
6. Countermesures to be taken															
a. Upper Gatun Dam (as regulating)	Mill M3	-	-	-	-	-	-	-	-	-	285	-	285	-	285
b. Trinidad Dam (as regulating)	Mill M3	-	-	-	396	-	392	-	466	-	-	-	-	-	-
c. Ciri Dam (as regulating)	Mill M3	-	102	-	-	-	-	-	-	-	-	-	-	-	-
d. Indio Dam (as water source)	Mill M3	-	461	591	-	558	-	591	102	-	-	-	-	-	-
e. Pumping Station	Mill M3	-	1459	-	1890	-	1798	-	2289	-	-	-	-	-	-
C. MAIN ELEMENTS OF ALTERNATIVES															
1. Lock & Gate															
(1) High Rise Lock															
a. Lock Chamber (LxWxD)	note*1	(A)	-	(B)	-	(A)	-	(B)	-	-	-	-	-	-	-
b. Gates															
- Max. Operating Gate Dimensions (BxH)	m	50x39.1	-	55x40.6	-	50x39.5	-	55x41.0	-	-	-	-	-	-	-
- Operating Gate Total Number(in pair)	nos.	6	-	6	-	6	-	6	-	-	-	-	-	-	-
- Operating Gate Total Weight	1000 ton	15.8	-	19.2	-	16.1	-	19.7	-	-	-	-	-	-	-
- Culvert Gate Number	nos.	18	-	18	-	18	-	18	-	-	-	-	-	-	-
- Culvert Gate Dimensions (BxH)	m	7.5x8.1	-	8.2x8.4	-	7.7x8.3	-	8.4x8.6	-	-	-	-	-	-	-
- Maintenance Gate (weight x number)	ton	5600 x 1	-	6700x1	-	5600 x 1	-	6700x1	-	-	-	-	-	-	-
- Emergency Gate (weightx number)	ton	2500 x 2	-	2950x2	-	2500 x 2	-	2950x2	-	-	-	-	-	-	-
c. Number of Mules	nos.	40	-	40	-	40	-	40	-	-	-	-	-	-	-
(2) Tidal Lock															
a. Lock Chamber (LxWxD)	m	-	-	-	-	-	-	-	-	(c)	(c)	-	-	(c)	(c)
b. Gates		-	-	-	-	-	-	-	-			-	-		
- Operating Gate Dimensions (BxH)	m	-	-	-	-	-	-	-	-	60x30.6	60x30.6	-	-	60x30.6	60x30.6
- Operating Gate Total Number	nos.	-	-	-	-	-	-	-	-	6	2	-	-	6	2
- Operating Gate Total Weight	1000 ton	-	-	-	-	-	-	-	-	9.3	3.1	-	-	9.3	3.1
- Culvert Gate Number	nos.	-	-	-	-	-	-	-	-	12	4	-	-	12	4
- Culvert Gate Dimensions (BxH)	m	-	-	-	-	-	-	-	-	6.0x6.0	6.0x6.0	-	-	6.0x6.0	6.0x6.0
- Maintenance Gate Weight	1000 ton	-	-	-	-	-	-	-	-	22.2	7.4	-	-	22.2	7.4
c. Number of Mules	nos.	-	-	-	-	-	-	-	-	30	10	-	-	30	10
(3) Tidal Gate															
- Gate Dimensions (BxH)	m	-	-	-	-	-	-	-	-	-	-	190x27.5	-	190x25.0	-
- Gate Total Number	nos.	-	-	-	-	-	-	-	-	-	-	4	-	2	-
- Gate Total Weight	1000 ton	-	-	-	-	-	-	-	-	-	-	33.8	-	11.6	-
2. Barrier Dams (E),(F),(G)in Volume	mill M3	-	-	-	-	-	-	-	-	29	-	29	-	29	-
3. Canal Excavation															
- Dry Excavation	mill M3	217	-	242	-	205	-	229	-	948	-	1,034	-	948	-
- Dredging	mill M3	295	-	358	-	286	-	346	-	304	-	351	-	304	-
- Total Volume	mill M3	512	-	600	-	491	-	575	-	1,252	-	1,385	-	1,252	-
4. Diversion Scheme															
- Cofferdams	nos.	-	-	-	-	-	-	-	-	7	-	7	-	7	-
- Channels	km	-	-	-	-	-	-	-	-	39	-	39	-	39	-
5. Canal Crossing (Bridges)	place	2	2	2	2	2	2	2	2	3	4	3	4	3	4

Note*1: (A)=390x50x20, (B)=420x55x21.5, (C)=430x60x23

Comparative Summation Table (2)

ITEMS	Unit	HIGH RISE LOCK ALTERNATIVES								SEALEVEL CANAL ALTERNATIVES					
		Case (1)		Case (2)		Case (3)		Case (4)		Case (a)		Case (b)		Case (c)	
		2020	2060	2020	2060	2020	2060	2020	2060	2020	2060	2020	2060	2020	2060
Design Ship	1000DWT	150	150	200	200	150	150	200	200	250	250	250	250	250	250
Route		1	1	1	1	1	1	1	1	10	10	10	10	10	10
Lake Level	ft	85	85	85	85	90	90	90	90	-	-	-	-	-	-
6. New Roads	km	32		32		32		32		71		71		71	
7. Breakwater	mill. m3									18		18		18	
8. Navigation Support System															
a. Jetty for Small Boats	nos.	8	-	8	-	8	-	8	-	7	-	5	-	7	-
b. Berthing Dolphin	nos.	8	-	8	-	8	-	8	-	8	-	8	-	8	-
c. Navigation Bouy	set	74	-	74	-	74	-	74	-	78	-	78	-	78	-
d. Canal Lighting	set	60	-	60	-	60	-	60	-	786	-	786	-	786	-
e. Tug Boats															
- 6000 HP	nos.	23	-	23	-	23	-	23	-	16	-	10	-	16	-
- 3000 HP	nos.	2	-	2	-	2	-	2	-	9	-	7	-	9	-
D. CONSTRUCTION COST															
1. Canal Excavation															
-Dry Excavation	mill US$	719	-	802	-	687	-	766		3,198	-	3,499	-	3,198	-
-Dredging	mill US$	1,851	-	2,171	-	1,768	-	2,077		2,051	-	2,721	-	2,051	-
-Slope Treatment etc.	mill US$	442	-	504	-	422	-	482		995	-	1,153	-	995	-
Total Canal Excavation	mill US$	3,012	-	3,477	-	2,877	-	3,325	0	6,244	-	7,373	-	6,244	-
2. Placing Area	mill US$	88	-	88	-	83	-	83	-	189	-	189	-	189	-
3. Lock & T. Gate structure	mill US$	991	-	1,127	-	991	-	1,127	-	2,037	477	429	-	2,293	477
4. Lock & T. Gate (Mechanical)															
-Gates Related	mill US$	889	-	1,011	-	898	-	1,023	-	950	316	738	-	1,252	316
5. New Dams															
a. Upper Gatun Dam (as regulating)	mill US$	-	-	-	-	-	-	-	-	-	90	-	90	-	90
b. Trinidad Dam (as regulating)	mill US$	-	-	-	93	-	93	-	61	-	-	-	-	-	-
c. Ciri Dam (as regulating)	mill US$	-	28	-	-	-	-	-	75	-	-	-	-	-	-
d. Indio Dam (as water source)	mill US$	-	173	237	-	195	-	207	-	-	-	-	-	-	-
6. Pumping Stations	mill US$	-	149	-	149		149		149	-	-	-	-	-	-
7. New Parmanent Road	mill US$	9	-	9	-	9	-	9	-	19	-	19	-	19	-
8. Canal Crossing	mill US$	450	777	501	839	450	777	501	839	222	548	309	548	222	548
9. Barrier Dams	mill US$	-	-	-	-	-	-	-	-	494	-	494	-	494	-
10. Diversion Scheme	mill US$	-	-	-	-	-	-	-	-	75	-	75	-	75	-
11. Navigation Support System	mill US$	414	-	414	-	414	-	414	-	546	-	477	-	546	-
12. Breakwater	mill US$	-	-	-	-	-	-	-	-	402	-	402	-	402	-
13. Supporting Construction	mill US$	425	88	425	85	425	88	425	85	574	66	574	38	574	66
14. Other Works *1	mill US$	-	-	-	-	474	-	474	-	-	-	-	-	-	-
15. Indirct Cost	mill US$	1,096	192	1,257	184	1,096	192	1,256	184	1,767	220	1,668	99	1,849	220
Total Project Cost	mill US$	7,374	1,407	8,546	1,350	7,912	1,299	8,844	1,393	13,519	1,717	12,747	775	14,159	1,717
E. O & M COST															
1. Electrical Power	mill US$	10.4	0.9	10.3	1.4	10.4	0.9	10.8	1.4	7.8	2.6	0.6	-	8.2	2.6
2. Man Power and Other O&M Costs	mill US$	103.9	59.9	112.2	59.9	103.9	59.9	112.2	59.9	154.6	51.2	144.3	51.2	159.7	51.2
3. Total O&M Cost	mill US$	114	61	123	61	114	61	123	61	162	54	145	51	168	54
F. CONSTRUCTION ASPECTS															
1. Adaptablity of Partial Construction	grade	Possible		Possible		Possible		Possible		Impossible		Impossible		Impossible	
2. Sufficiency of Engineering/Cost Data	grade	Fair		Fair		Fair		Fair		Poor		Poor		Poor	
3. Interference by Existing Canal Operations	grade	Heavy		Heavy		Heavy		Heavy		None		None		None	
4. Construction Period	year	10.0		10.5		10.0		10.5		15.0		15.0		15.0	
G. IMPACT ON EXISTING SITUATION															
1. Impact on Existing Panama Canal															
a. Interferences to Existing Canal Operations	grade	Considerable		Considerable		Considerable		Considerable		None		None		None	
b. Modification Works to Existing Panama Canal	grade	Minor		Minor		Minor		Minor		None		None		None	
2. Potential Envilonmental Impact															
a. Possibile Gatun Lake Salinity Increase	grade	Same with SQ		Same with SQ		Same with SQ		Same with SQ		None		None		None	
b. Both Oceans Intermixing	grade	None		None		None		None		Not Studied		Not Studied		Not Studied	
c. Ecologicaly Sensitive Areas	grade	Very Low		Very Low		Very Low		Very Low		Low		Low		Low	
3. Socioeconomic Impacts															
a. Relocation of Residents	grade	Few		Few		Few		Few		Small		Small		Small	
b. Increased Work Opportunity	grade	Large		Large		Large		Large		Very Large		Very Large		Very Large	

Note *1: Other Works include existing lock modification, Gatun Dam modification, etc.

AF/R No. 2

COMMISSION FOR THE STUDY OF ALTERNATIVES
TO THE PANAMA CANAL

THE STUDY OF ALTERNATIVES TO THE PANAMA CANAL
(COMPONENT STUDY: ENGINEERING AND COST ESTIMATES)

PHASE 2 ADDITIONAL WORK

PRELIMINARY ENGINEERING AND COST ESTIMATES

ANNEX TO FINAL REPORT

JUNE 1993

YACHIYO ENGINEERING CO., LTD.
under the contract with
JAPAN INTERNATIONAL COOPERATION AGENCY

INTRODUCTION AND OBJECTIVES

Chapter 1 - Introduction

1.1 Background and Objectives

Yachiyo Engineering Company Limited (YEC) was appointed as the Contractor for the Engineering and Cost Estimates Component Study (ECE Study) and has carried out the Study in two phases. The Phase 1 report was submitted in February 1992 and the Final Report for Phase 2 was submitted in April 1993.

At the Fourteenth Meeting of the Board of Commissioners of the Canal Alternatives Study (CAS) it was agreed that the ECE Contractor would be asked to carry out for Additional Work under Phase 2 to evaluate single lane options for both the High Rise Lock Canal and the Sea Level Canal.

Subsequently an Addendum to the Phase 2 Terms of Reference (TOR) was prepared by CAS (refer Attachment 4 of this Annex) and YEC submitted a proposal to the Japan International Cooperation Agency (JICA) to carry out the Additional Work. YEC was asked to proceed and this Annex to the Phase 2 Final Report has been prepared.

The objective of the Additional Work was to study and report on the additional variations set out in the Addendum to the Terms of Reference and to prepare construction plans and cost estimates. The additional work was carried out to a similar level of detail as the Phase 2 Study, but where work items were similar to those in the earlier Phase 2 Study then detailed descriptions have been omitted. The results are presented in a similar manner to that adopted for the Phase 2 Final Report to allow easy comparison with the earlier work.

The variations studied under the additional work are described in Chapter 2 below.

Chapter 2 – Study Alternatives for Additional Work

2.1 General

The alternative canal configurations to be studied under the additional work are presented in the TOR and are described in more detail below based on further clarification from CAS.

2.2 Variations of the High Rise Lock Canal (HRLC)

In Phase 2 the following alternatives for the High Rise Lock Canal were studied:

Case (1) :	Design Ship 150,000 DWT, Gatun Lake at 85'
Case (2) :	Design Ship 200,000 DWT, Gatun Lake at 85'
Case (3) :	Design Ship 150,000 DWT, Gatun Lake at 90'
Case (4) :	Design Ship 200,000 DWT, Gatun Lake at 90'

Under the additional works, further variations of the HRLC for 150,000 DWT and for 200,000 DWT design ships with a Gatun Lake level of 85' are studied. Whereas a two lane canal was adopted throughout for all variations of the High Rise Lock Canal considered in Phase 2, the variations considered in the additional works involve a single lane canal through the Culebra Cut section. The additional variations have been designated Case (5) and Case (6) and apart from the Culebra Cut width they are similar to Case (1) and Case (2) of the Phase 2 Final Report. The route, profile and excavation zones are shown in Fig. 2-1 (no change from Phase 2). The schematic layouts in Zones III and IV for the Phase 2 FR and the Additional Work are shown in Figs. 2-2 and 2-3 respectively. Further descriptions are given below:

(a) Engineering and Preliminary Design

- There is no widening of the Culebra Cut zone beyond the widening now being carried out by the Panama Canal Commission (630' on straight sections, up to 730' on curves).

- The Culebra Cut zone is defined as Zones III and IV from the Phase 2 Study. Refer to Fig. 2-1.

- The Culebra Cut zone is not widened but only deepened, to 21m for 150,000 DWT design ships [Case (5)] and to 22m for 200,000 DWT design ships [Case (6)].

- The deepening is required only over the width necessary to allow one way passage of the design ship. Using the one way width of 3.5 x (design ship beam) as adopted in Phase 2, the base width to be

deepened will be 160m for 150,000 DWT ships [Case (5)] and 175m for 200,000 DWT design ships [Case (6)]. See Part I, Chapter 1.1 of this Annex for more details.

- The assumed Gatun Lake level is 85'.

- Excavation for the 4th lane of locks (ie. the 2nd lane of new locks) at both Gatun and Miraflores is not be included in the additional variations to be considered.

- Engineering, preliminary design, construction planning and cost estimates for the additional variations are required for the year 2020 only and the cost of widening the canal and locks at a later date will not be considered.

- The number of canal crossings is the same as adopted in the Phase 2 Study.

- In other respects, features are unchanged from the Phase 2 Study.

(b) Construction Planning and Costing

- The highest priority must be given to maintaining canal traffic without disruption during construction. Brief closure of Culebra Cut to navigation may only be considered during underwater excavation by blasting.

- Barges hauling excavated material should use the working lane (not the navigation lane) as much as possible unless the barges need to pass the work area. In this case the barges may use the navigation channel traveling at not less than 6.5 knots.

- The dredging equipment may use the navigation channel if necessary when long distance removal of the dredging equipment from one site to another is required.

- The cost of completing a single lane Culebra should be broken down into year by year expenditure.

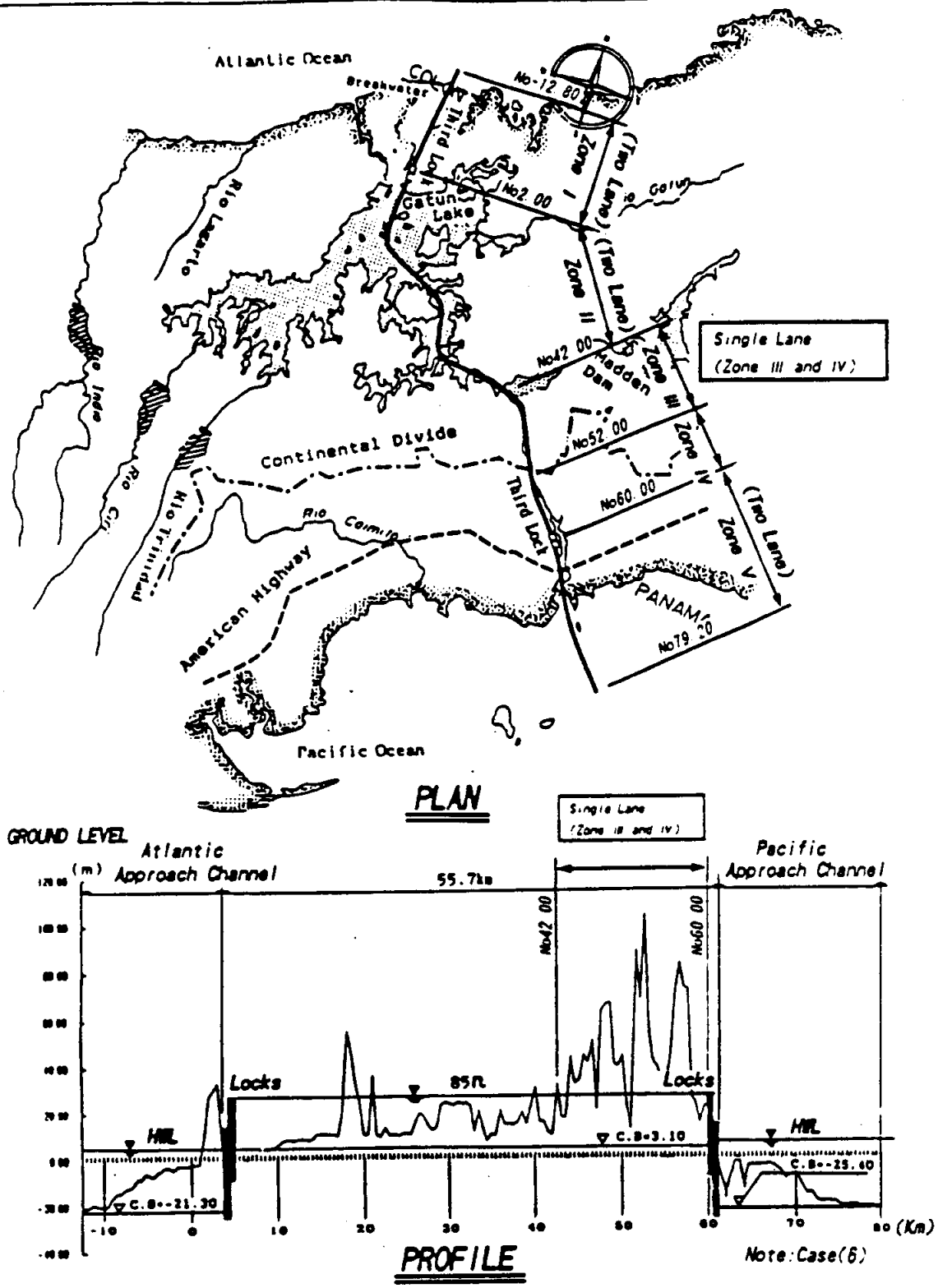


Fig. 2-1 Layout of HRLC Variations (Case (6) - 200,000 DWT)
(Case (5) - 150,000 DWT similar except for canal bottom levels)

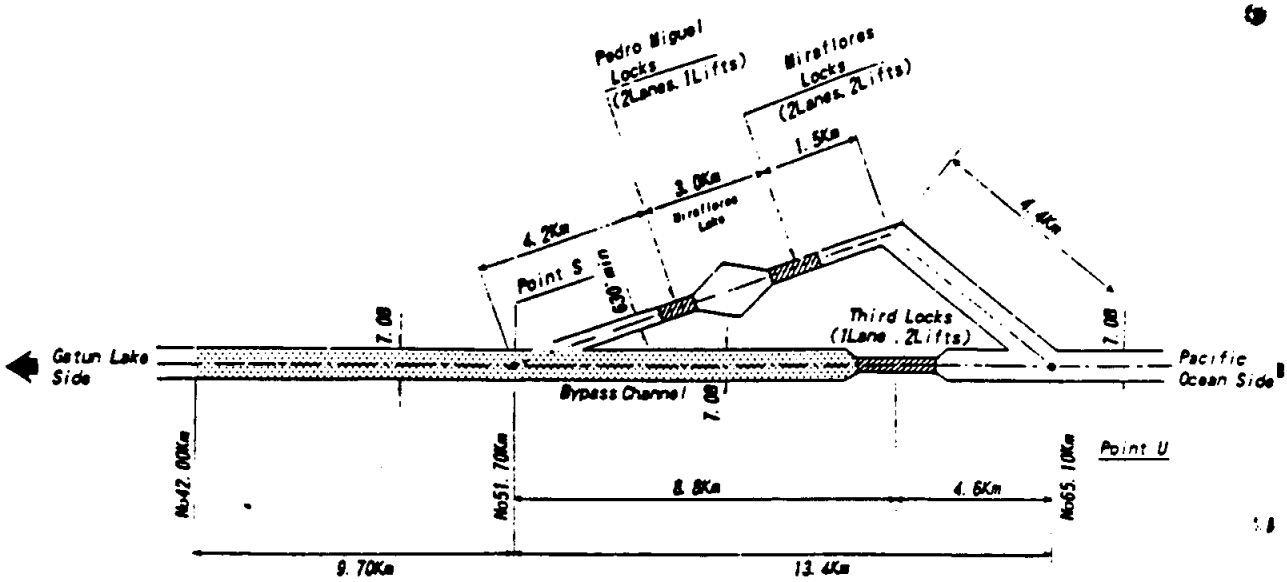


Fig. 2-2 HRLC - Layout of Zone III and Zone IV in Phase 2 FR

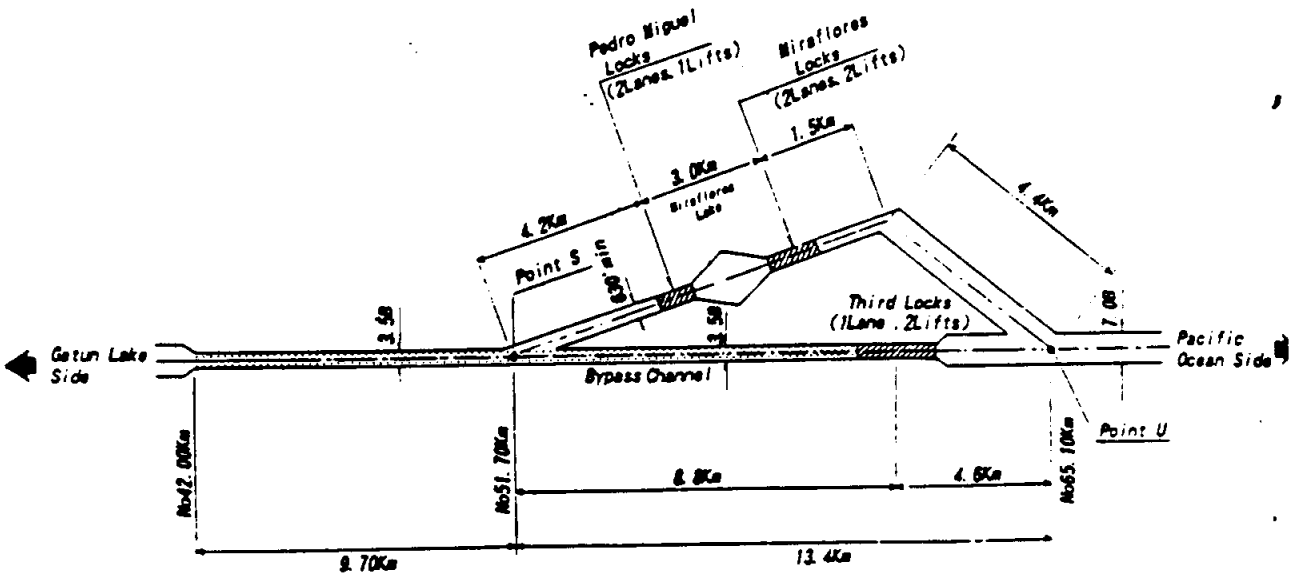


Fig. 2-3 HRLC - Layout of Zone III and Zone IV in Phase 2 Additional Work

2.3 Variations of the Sea Level Canal (SLC)

In Phase 2 the following 250,000 DWT alternatives were studied for the Sea Level Canal:

Case (a) : Single lane canal with 2 lane approaches. Tidal locks on the Pacific side (3 lanes with the option of adding a 4th lane later).

Case (b) : Single lane canal with 2 lane approaches. Tidal gates (1 lane) on both the Pacific and Atlantic sides.

Case (c) : Single lane canal with 2 lane approaches. Tidal locks on the Pacific side, as in Case (a), plus a tidal gate (1 lane) on the Atlantic side.

Under the additional works, further variations of Case (a) and Case (b) of the SLC have been studied. As a variation of Case (a), single lane tidal locks are considered [Case (d)]. As a variation of Case (b) a single lane Atlantic approach channel between the coast line and the Atlantic tidal gate is considered [Case (e)]. The route, profile and excavation zones are shown in Fig. 2-4 (no change from Phase 2). The schematic layout of the Pacific tidal locks in Case (a) and Case (d) are shown in Fig. 2-5 and the schematic layouts of the Atlantic approach in Case (b) and Case (e) are shown in Fig. 2-6. Further descriptions are given below:

- Case (d) – Pacific tidal locks:
  - The tidal locks have a single lane (chamber) only, and excavation for the additional lock chambers will not be included.
  - The widening at the lock approaches shall be reduced appropriately.
- Case (e) – A pair of tidal gates:
  - The Atlantic approach channel between the coast line and the Atlantic tidal gate is a single lane channel.
  - A transition zone over an appropriate length shall be provided at the Atlantic coast.
  - Proposals are required for the year 2020 only. The cost for later expansion to three tidal locks for Case (d) and to a two lane Atlantic approach for Case (e) will not be estimated.
  - The number of canal crossing is the same as adopted in the Phase 2 Study, but the crossing lengths are adjusted as required to suit the reduced channel and lock widths.
  - In other respects, features are unchanged from the Phase 2 Study.

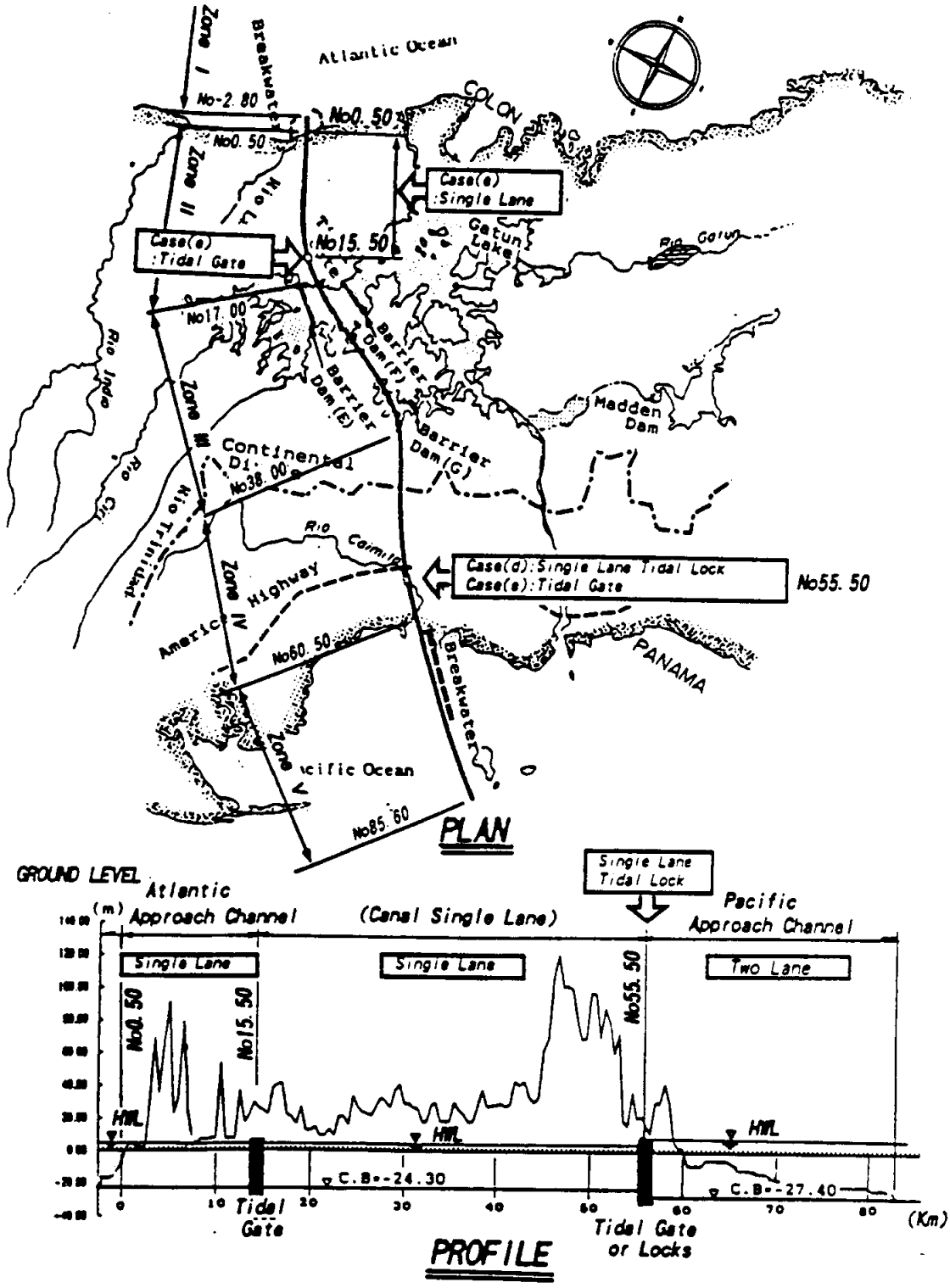


Fig. 2-4 Layout of SLC Variations [Case (d) and Case (e)]

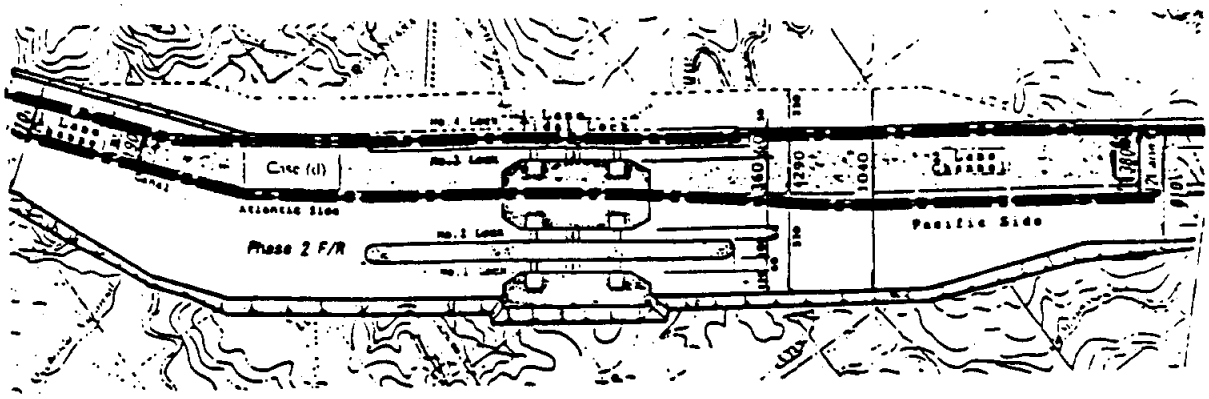
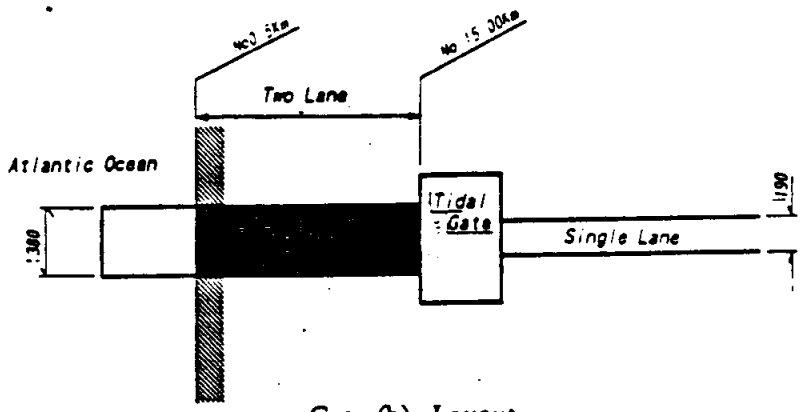
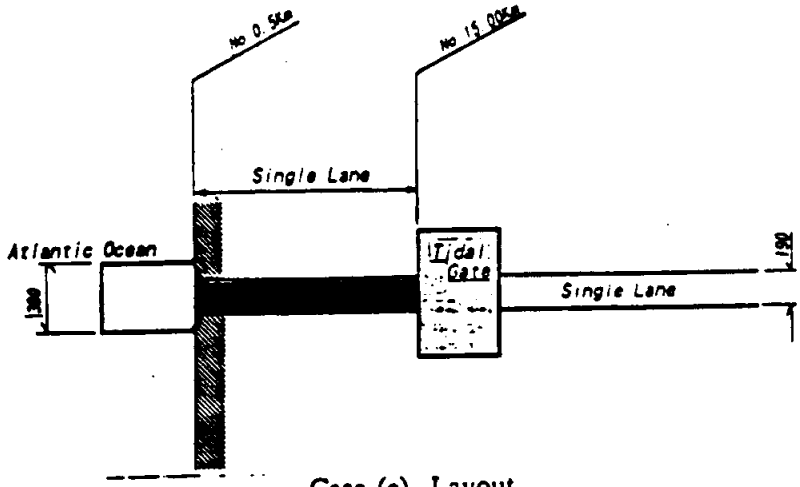


Fig. 2-5 SLC - Layout of Tidal Lock Modifications - Cases (a) and (d)



Case (b) Layout



Case (e) Layout

Fig. 2-6 SLC - Layout of Atlantic Approach - Cases (b) and (e)

Chapter 3 - Terms of Reference

An Addendum to the Phase 2 Terms of Reference was prepared to define the Additional Works and a copy is included as Attachment 4 to this Annex.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

8. Commodity and Traffic Projection Study

Phase II

Executive Summary

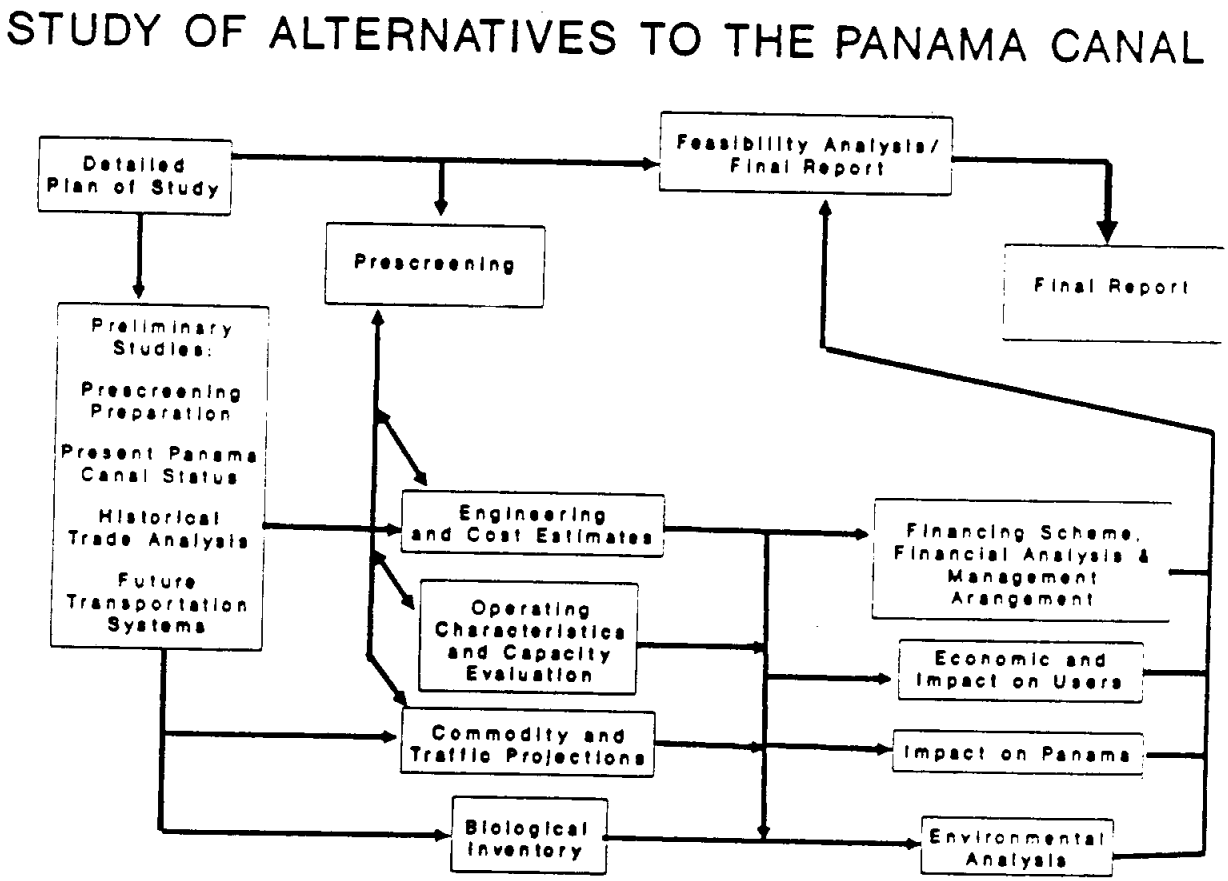
1993

1.0 EXECUTIVE SUMMARY

1.1 Introduction

In August, 1991 the Commission for the Study of Alternatives to the Panama Canal(CAS) engaged The WEFA Group, with subcontract support from Richardson Lawrie Associates (RLA) and BST Associates, to develop preliminary projections for the years 2020 and 2060 of commodity flows and ship traffic for the existing Panama Canal and for four alternative Canals through Panama. Known as the Commodity and Traffic Projections (CTP) Study, this is part of a group of studies designed to provide sufficient economic, engineering, and financial information to determine the feasibility of a range of alternatives to the existing Canal (see Fig. 1).

Figure 1



The study has taken into account the capacity of the Canal, as determined by the OCCE Study, and the capacity of North American ports and rail links, as determined and reported in this study.

The base year for the study is 1990 and the forecast periods are the years 2020 and 2060.

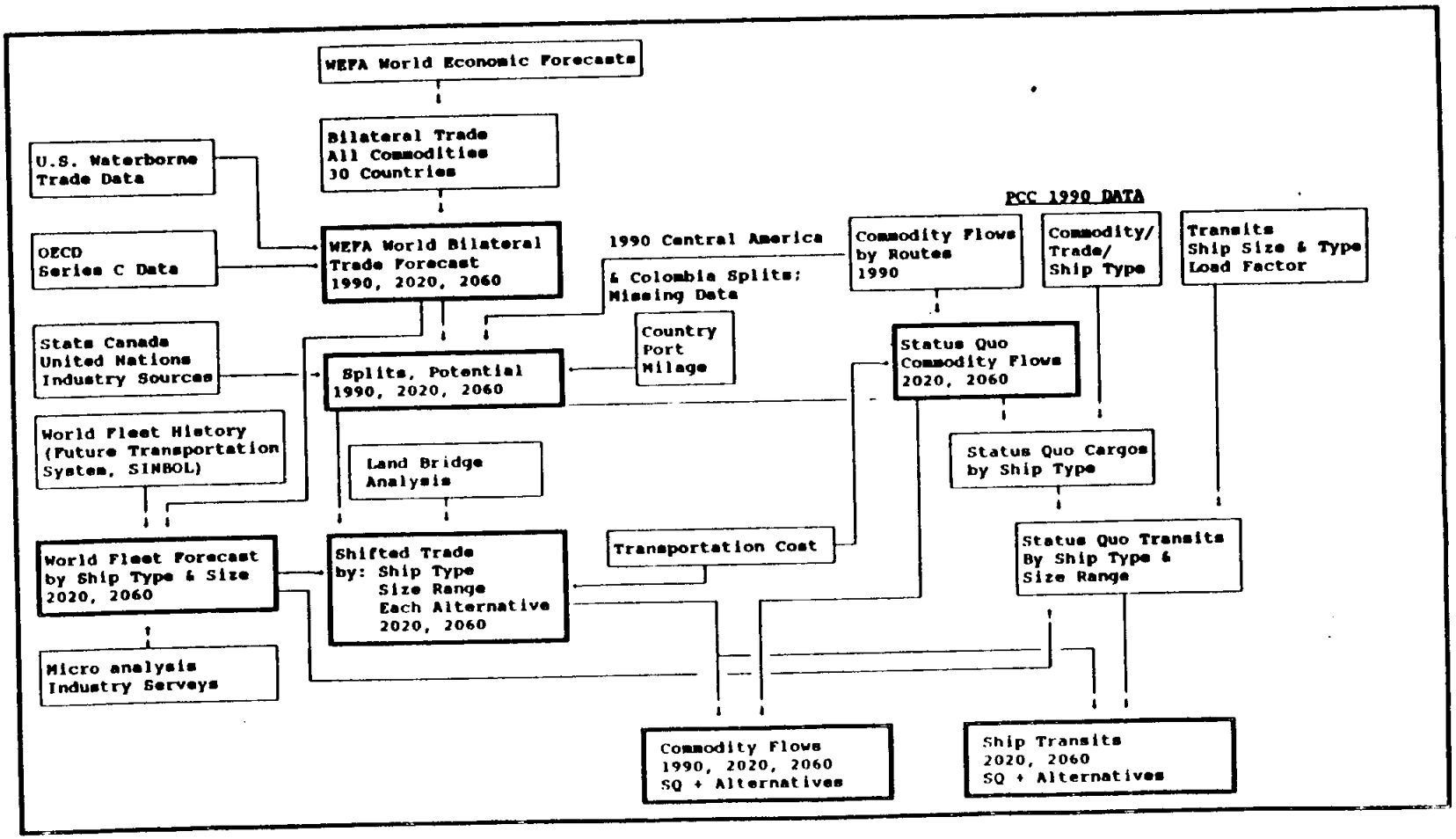
The WEFA team first reviewed the available data and previous approaches. Then, the following steps were carried out:

- We forecast world trade for 2020 and 2060 in sufficient detail to project the world vessel fleet by ship type and size category for 2020 and 2060;
- We projected the world vessel fleet for each of the alternative Canals;
- We estimated comparative costs of shipping 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";
- We determined the present and future capacity of North American seaports, port facilities, intermodal facilities and mainline railroads as they affect goods on routes competitive with the Canal;
- We developed commodity and transit databases from data provided via CAS by the Panama Canal Commission (PCC) for calendar years 1986 - 90;
- We determined that part of the bilateral trade among nations on a route and commodity basis that represents the maximum "potential" commodity flows through the Isthmus in the absence of any physical, economic or other impediment;
- We forecast potential Panama Canal trade 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:

Figure 2

Flow Chart of the Commodity and Traffic Projections Study



The top-down, bottom-up approach to the world fleet forecasts is similar. The forecasts of world trade provide demand for shipping. Combining this with scrappage forecasts results in demand for ships to carry the forecast trade. This is the top-down part of the forecast. Then, combining this with changes in technology and vessel economics, provides the required supply of new ships each year. This is the bottom-up part of the vessel forecast.

Because of the very long term nature of this study, several departures from and additions to our normal methods had to be incorporated. In the case of the economic and trade forecasts, we shifted from the stochastically based, that is, based on historical relationships, WEFA World Model[1] to a judgmental approach to the forecasts beyond the year 2010 of the key top-down variables: population, productivity, and the relation of trade to output. In the bottom-up part of the approach, allowance had to be made for the exhaustion of significant amounts of the world's total resource base. This was particularly true of oil, but important for the other resources which we tracked, namely, coal, natural gas, bauxite, and iron ore. We estimate that approximately half of the total remaining world coal reserves, two-thirds of the remaining world oil resources and 85% of estimated natural gas resources are consumed in the 1990-2060 period.

On the vessel side, extensive research was carried out as to the technical innovations planned and possible during the course of the study. In light of this research, it was decided to adopt the following principles in developing, for particular ship types, a scenario of techno-economic changes likely to be achieved during the forecast period:

- remembering that some ships on order in 1991 will still be operational in the year 2020, we assume that the levels of technology incorporated in the newest ships of 1991 will be the average level of technology in the year 2020;

- Between 2020 and 2060, it is assumed that the 2020 level of technology will persist, excepting only cases where it is now apparent that change will be made. This includes, however, continuing trends in vessel propulsion and manning efficiencies. A particular conclusion in this regard will be the requirement for skilled crew leading to the eventual disappearance of cheap labor from the global fleet.

After consultation with CAS, the specific assumption was made that the Jones Act, the U.S. regulation that requires intra-United States maritime trade to move in U.S. ships, would remain in force.

[1] The WEFA World Model is a traditional structural econometric model consisting of a system of deterministic and stochastic equations which are currently used to generate projections until the year 2010.

Because there is only one world economic scenario underlying our projections in Phase I, we have made what we consider "conservative" assumptions. This should not be taken to imply that they are either pessimistic or optimistic. We believe the assumption that global warming does not become a serious policy issue to be conservative; that is, we believe that alternative assumptions would be speculative. However, this assumption leads to higher consumption of oil and coal worldwide and thus to higher levels of world trade than would be the case in a scenario where emissions of carbon dioxide and other "greenhouse gases" were limited to 1990 values, for example.

1.3 World Economic and Trade Projections

The following are other important assumptions on which we have based the study.

- Geopolitical Factors:

  We assume continued world stability, that is, no major wars or political instability in the major countries of the world.

- Environmental Policy

  WEFA assumes that the current environmental policy of each nation, such as the United States or Korea, or group of nations, such as the European Community or the Commonwealth of Independent States, is maintained and are made neither more stringent nor eased. This implies, for example, that a carbon tax to reduce greenhouse emissions is not enacted.

- Population, Labor Force and Employment

  The population figures through 2025 are from the United Nations. WEFA has extended the U.N. fertility and mortality assumptions to 2060 in a manner consistent with our projections of GDP per capita in each region.

  A long term forecast such as we have undertaken focuses on the supply side, namely the growth in labor productivity due to technological progress. Short term fluctuations in unemployment and labor force participation are ignored; rather, the equilibrium levels of these variables are assumed. That is to say, our scenario has no business cycle behavior. It is not our belief that business cycles will never occur. Rather, we do not know when they will occur this far into the future. Taking only two points into the future requires that the scenario not involve any cyclical behavior.

- Technological Innovation and Transfer

  We assume that the long-term trends toward greater efficiency in production and toward a greater services share of consumption will continue. An important assumption in this area is the diffusion of technology now on the drawing boards to even the most undeveloped countries, allowing for a convergence of per capita GDP without an accelerated strain on the earth's resources.

- Productivity by Region

  Per capita GDP is assumed to continue on the historical trajectories and those of our short-term model based forecasts. In the most industrialized countries it is assumed to rise at slightly lower rates than historically.

  A basic assumption underlying the work is that the ranking of countries/regions in terms of per capita GDP remains fixed over the period, but that there is some convergence toward the standard of living of the most developed countries.

  As a result of these considerations, we expect total output in the developing world to rise considerably more rapidly than that in the developed world, but to still remain behind on a per capita basis. The relative levels within the groupings have more to do with the size of the countries/regions than anything else.

- Transportation Costs

  In terms of the various components of ship operating costs, between 1990 and 2020, increases in real terms are assumed for wage rates, repairs and maintenance, insurance and fuel costs. There is also likely to be a cost push effect in shipping market rates as a result of technological change. Nevertheless in the calculation of freight costs there are offsetting factors, in particular with regard to vessel efficiency and manning levels. Between 2020 and 2060 only fuel costs and labor rates rise in real terms.

We assume that over the long term real world labor costs rise at a rate of one percent per year. Oil prices are assumed to rise more rapidly as world reserves are depleted to an expected 30 percent of their 1990 level, and to reach $55 per barrel in 1990 dollars by 2060. Note that labor compensation is related to labor cost by labor productivity. That is, real labor compensation will rise faster than real labor cost by just the increase in labor productivity. Thus, if labor productivity were rising at one percent per year, the growth in labor compensation would be one percent higher than the rise in labor cost.

Panama Canal tolls are grown with average transportation costs, as there are no basis for speculating on another growth trajectory. These were also part of the terms of reference.

In addition to transportation costs, inventory carrying costs are computed as well, based on average value per ton, differences in origin to destination trips, and interest rates.

- Structural Change

Possibly the most important factor in the relation of merchandise trade to World GDP is the structural change which world economies are undergoing, namely, the shift away from goods and toward services. The gradual depletion of non-renewable resources means that new deposits are of lower quality, harder to reach, and more expensive to extract and refine. This results in gradually rising real costs for these resources.

These structural change considerations lead to a continuation of the long-term trend in the shift from goods toward services which produces a downward curvature in the ratio of total world trade to world GDP.

- Terms of Trade:

By terms of trade we mean the trade barriers or lack of them between countries. These can be unilateral, such as the barriers to agricultural products; bilateral, such as the U.S.-Canada free trade agreement; and multilateral, such at the EC common market and the General Agreement on Trade and Tariffs (GATT). In a recent review of the economics of trade policy[2], Professor Baldwin of the University of Wisconson and the National Bureau of Economic Research states as follows: "The new [economic] trade theorists ... believe that, as a rule of thumb, free trade is

[2] Robert E. Baldwin, "Are Economists' Traditional Trade Policy Views Still Valid?", **Journal of Economic Literature XXX** (June 1992), pp.804-829.

> the best policy for countries to follow". We assume, therefore, that the emerging world trading blocs continue the post World War trend toward freer trade. specifically toward a continued lowering of tariff and non-tariff barriers.

Because the country for which there is the greatest degree of understanding in terms of the dynamics of growth is the United States, the analysis begins there. At present, per capita U.S. GDP is growing at slightly less than 2%. This is composed of two parts: productivity is growing at about 1% and labor force relative to population is growing at less than 1%. Eventually, we expect labor force and population to grow in tandem, with the result that the growth of per capita GDP drops to the 1% we continue to assume for productivity growth. The average per capita U.S. GDP growth over the 70 year period is slightly less than 1.5% per year.

This is not to suggest that the total tons of goods produced, or any such physical measure, grows at this rate. The trend in industrialized societies has been toward a saturation in physical goods and a relative shift to services. We expect this to continue, such that eventually most of the increase in output is in ever more efficiently provided services. These services will continue to require electric power and other energy forms, and other physical goods associated with them. Thus, trade in physical goods among the developed countries can be expected to grow, but at a decreasing rate. Finally, services are assumed to take greater and greater advantage of efficiencies to be gained from electronic advances, as is the case in the U.S. at present, and which we are seeing in Europe, Japan and elsewhere: automatic teller machines, home shopping. etc.

In general, we assume continued movement toward free markets in goods and most services. This underlies both the assumption of per capita GDP convergence and continued improvement in productivity. It also has the implication of freer trade, since trade barriers are merely another form of government interference in the free functioning of markets.

The growth of energy consumption is expected to slow in the industrialized countries and level off after 2020. Passive solar heating of homes, greater energy efficiency and cogeneration in buildings, the aforementioned shifts away from heavy industry, and growth in non-fossil fuel sources of power are all expected to contribute. The ratio of energy consumption to GDP is expected to continue to fall at a 1.9% annual average rate worldwide over the period.

In this forecast, global warming is assumed not to be an issue affecting fuel choice. Nor do we assume that nuclear power growth slows, outside of the U.S. and those European countries where opposition is strong. The major sources of energy are expected to be coal and natural gas.

Many countries such as the states of the former Soviet Union lag significantly behind developed nations in agricultural productivity. We assume that, as a result of technology transfer and the shift to a market economy, food imports into these countries will decline sharply. At the same time we believe that productivity growth in agriculture will slow in the next 70 years compared to the last 70. For both of these reasons we expect the growth in exports from current producers to slow significantly.

In general, we expect countries to become more self-sufficient in goods as the technological and labor cost advantages of the newly industrialized countries wanes. However, one of the principal engines of growth in newly industrialized countries is the newer plant and equipment and the lower wages paid. Thus, it is principally as per capita GDP converges that this advantage declines.

Steel production is an example of this trend. As a result of both lower unit demand for steel, due to the substitution of other materials, and increased self sufficiency, trade in steel products is expected to grow at less than 1% per year.

In the case of energy, oil trade must clearly fall off during this period because resources will be declining markedly worldwide, falling to 30% of their 1990 value. Coal and natural gas will come into their own during the first part of the next century. Even so, by 2060 coal reserves are expected to be depleted by 50% and natural gas resources by 85% from their present published estimated values[3]. Natural gas resource estimates are more uncertain that coal or oil, and, as a result, we have assumed that methane resources will be higher than published estimates. So long as extensive reserves of coal and natural gas remain to be exploited, it can be expected that it will be cheaper to transform these into sources of clean energy than to develop more costly technologies.

Therefore, coal trade is expected to become increasingly important during the first half of the next century as oil reserves fall. Natural gas trade, primarily by pipeline but also in liquified natural gas (LNG) tankers is also expected to be significant. However, these LNG tankers would not be using the Canal to any great extent as we expect most of this trade to be concentrated in the Far East while the Americas and Eurasia would depend primarily on pipelines.

[3] **BP Statistical Review of World Energy** (June 1991), and C.D. Masters, D.H. Root, and E.D. Attanasi, "World Oil and Gas Resources - Future Production Realities", **Annual Review of Energy, Vol. 15**, 1990, pp. 23-51.

1.4 North American Port and Landbridge Capacity Analysis

Mini-landbridge and micro-bridge transport services are a major source of competition for Panama Canal all-water movements to and from North America for container, fully assembled automobile and grain traffic. The question remains, however, whether these advantages will continue in the future as rail cargo grows or will congestion or some other form of constraint impact North America port and/or rail systems that could reverse the advantage to using all water Canal transportation systems? The following section summarizes the constraints to port and rail systems in North America.

U.S. & Canadian Port Trends

North American ports are facing substantial challenges in attempts to redevelop or expand port facilities. Ports can no longer predict resolution of improvement projects with any degree of certainty. Exposure to potential environmental liabilities has increased dramatically as has the length of time to gain environmental permits. This has had a dramatic upward influence on development costs. In addition, in several port areas, competition for scarce waterfront land has forced out port/industrial users as land values have increased and conflicts with adjacent neighboring uses increasing.

All of these impacts may cloud the ability to respond with additional capacity and increased water depth as market opportunities warrant. It is by no means assured that deepening projects currently under consideration in Hampton Roads, Mobile Bay and the Mississippi River or deeper drafts required to service larger vessels will reach fruition. As a result, improvements to the Panama Canal may be constrained because North American ports do not gain the ability to fully load the largest vessels transiting the improved Panama Canal (i.e. 300,000 DWT vessels). However, a comparison of the economic benefits with the estimated costs of dredging selected ports appears to confirm that deepening projects could meet federal benefit/cost criteria. As a result, it is assumed that North American ports could be deepened to accommodate vessels going through the improved Canal.

Regarding terminal capacity, it should be emphasized that most ports typically have a 20 to 30 year planning horizon. Growth beyond this time period (i.e. 2020 to 2060) will require ports to plan additional facilities in response to positive market opportunities. Hence, apparent capacity constraints beyond the year 2020 may not materialize. With these provisos, North American port facility constraints do not appear to be insurmountable for coal, grain or containers which represent the largest potential North American bypass trade components.

Coal Terminals

U.S. and Canadian coal terminals appear to be capable of handling the forecasted volumes expected in 2020 and 2060 from a terminal perspective (i.e. storage and loading capabilities). However, U.S. East Coast coal exports to Asia typically move in larger vessels which are topped off in South Africa. As indicated above, deepening projects appear to meet federal benefit/cost requirement.

Grain Terminals

Grain elevator capacity is not considered a constraint to exports during the study period. PNW and Gulf Terminals are currently under-utilized (especially elevators in Longview, Seattle and Tacoma in the PNW). In addition, elevators are often worked only one shift per day. The use of additional shifts is the simplest way to improve capacity at the elevators. Existing facilities may also be improved by provision of faster loading equipment. Construction of new "state of the art" terminals is a last resort to improving regional capacity. Because of the existing over-capacity no new grain terminals are being planned in the U.S. at the present time.

Canal bypass traffic is located in those states not well served by the Mississippi River barge system (most notably Nebraska, Iowa, North Dakota and Colorado). Evaluation of relative transportation rates via the PNW or Gulf terminals indicates that exports to Asia from these states will continue to move via the PNW throughout the study period.

Grain exports are typically transported in smaller vessels (i.e. 55,000 dwt with a draft of 40 feet) due to the water depth constraints of exporting and importing elevators, the preferred shipment size of importers and the number of grades of grain in each vessel. Water depth and shipping conditions are virtually identical in the Gulf and PNW grain export elevators at the present time (i.e. same size vessels at 53,000 to 55,000 dwt drawing the same water depth).

However, over the study period, variations in water depth at major U.S. export facilities could shift cargoes from one region to another. For example, full utilization of Panamax vessels requires water depth of 42 to 43 feet. Currently, this vessel draft is restricted in both the Columbia River (due to navigation channel limitations) and in the Gulf (due to both navigation channel limitations and the Panama Canal restrictions for grain exports to Asia). However, water depth variations are unlikely to shift cargo from the PNW to the Gulf in the above mentioned inland regions. If the PNW is improved and the Gulf is not, more grain could be diverted to the PNW.

Container Terminals

Storage area capacity is the major constraint for container terminals. Existing terminals with average productivity rates (i.e. 3,000 TEUs per acre per year) are nearing capacity. With improved throughput rates (i.e. 6,000 TEUs per acre per year) and new planned capacity coming on-line, forecasted 2020 volumes will reach 56% and 37% of terminal capacity in West Coast and East Coast facilities respectively. By 2060, capacity limits will be nearly exceeded assuming additional planned capacity comes on line at higher throughput rates.
After the year 2020, it is likely that new plans will be formulated to handle additional cargo flows at existing or new container ports. Container terminal capacity at North American ports is not expected to be a determinant in shifting cargo back to the all water (i.e. Panama Canal) routes. U.S. container throughput will also be positively impacted by planned improvements in Mexican ports. In addition, numerous smaller West Coast ports are also interested in container terminal development and could become important if capacities are reached in load center ports.

North American Rail Transportation Trends

Eastern railroad traffic (which includes all major carriers east of the Mississippi River) has fallen from 872 million tons in 1929 to approximately 750 million tons in the late 1980s. Western railroads have increased from 466 million tons in 1929 to 677 million tons in 1990. Over the entire 1929 to 1990 time period, traffic increased at 0.6% per year. However, during the decade of the 1980s, traffic grew much slower at only 0.2% per year. Western railroads have experienced growth in coal, chemical, grain, auto and container traffic. Other traffic has decreased substantially. The result has been virtually no growth in the overall rail traffic base. Between 1929 and 1990, tonnage increased from 1.3 billion tons to 1.4 billion tons or at an average annual rate of growth of 0.1%.

Future rail traffic will continue to grow slowly as a result of continued improvements in productivity such as : technological improvements which allow greater loading per car, growth in utilization of unit trains which also improves mainline productivity, improvements to traffic control systems allowing more trains to use the system, faster speeds on mainline systems and improvements to tunnel ventilation systems to allow more trains to use the (primarily mountain) tunnels among other potential improvements.

What growth does occur in railroad traffic will most likely continue to focus on movements of TOFC/COFC, grain, coal, chemicals and autos on high volume mainline corridors. Of particular importance in this study, growth of grain and container traffic may begin to impact system capacity.

Grain

West Coast grain exports are expected to increase from 25.9 million tons in 1990 to 53.1 million tons in 2060. Rail grain traffic will increase from 21.4 million tons to 45.1 million tons during the period (i.e. 85% of total exports). This amounts to an average annual growth rate of approximately 1% per year. This level of demand could lead to congestion on western railroads.

Containers

West Coast Asian traffic will generate approximately 29 import and 17 export doublestack equivalent trains per day by 2060 as forecasted. Likewise, European traffic on the East Coast will generate 8 import and 11 export DST equivalents per day. Efficient and price sensitive intermodal rail service has become mandatory for container operations to maintain opportunity cost savings over all water alternatives. However, steamship line arrivals currently peak from Thursday through Saturday at west coast ports. The level of throughput indicated above will strain peak day loadings on intermodal systems and mainlines. The result of the peaking problem could be to create additional delays in shipments.
Intermodal trains depends upon the following factors :

- Vessel arrival schedules (and potential multiple vessel calls)
- Port berth and equipment availability
- Transit from vessel to upland storage point in port terminal
- Fast delivery from port terminal to rail intermodal yard (accelerated if on-dock or near dock rail is available)
- Train loading and departure schedules
- Rail line-haul schedules
- Destination terminal handling
- Destination drayage

Lack of reliability at any component of the intermodal will tear the fabric of the "seamless" intermodal movement. In order to provide reliability of 95% or better, each step must function at 99% or better reliability. If peak day loadings are not smoothed out, the time advantage provided by mini-landbridge may erode. This could tend to shift cargo back to all water movements but only for Transpacific containers bound for the eastern seaboard or Transatlantic

containers bound for the west coast.

Conclusions - Railroad Capacity

Congestion problems currently occur along several parts of the mainline system, particularly in the western mountain areas and where two mainline routes meet. However, these problems have not typically reached the stage where the addition of additional mainline track is being constructed. Examples of bottlenecks include the Burlington Northern (BN) corridor between Spokane, Washington and Sandpoint, Idaho where two busy single-track mainline segments come together into one track, and the Union Pacific (UP) line over the Blue Mountains of eastern Oregon, where steep grades are an impediment.

In California the major congestion occurs in the Los Angeles basin, where a joint effort between the railroads and the ports is now underway to allow for joint use of tracks via the Alameda corridor. The Southern Pacific (SP) has heavy traffic on the single-track mainline between Tucson, Arizona and El Paso, Texas but is not encountering major delays at this time. The Santa Fe mainline is double-tracked from Los Angeles to central New Mexico, where it splits into two single-track mains. The Santa Fe line is very under-utilized.

The Canadian carriers, Canadian National (CN) and Canadian Pacific (CP) have few capacity constraints. The CN, primarily a natural resource carrier, has seen its business drop off with the decline of its client industries, and currently has traffic densities lower than any other western railroad. The CP recently completed the new Rogers Pass tunnel through the mountains of eastern British Columbia, which eliminated the major bottleneck in the CP system.

All carriers report they can handle increased volumes even with these reported problem areas. The average east-west mainline trackage is currently only 27% utilized. The railroads have focussed on improving traffic control systems and EDI as the optimal means of improving system capacity.

Railroad capacity constraints in 2020 and 2060 are very difficult to quantify. However, peak movements of container traffic may begin to constrain the system without substantial new trackage. The likely source of the constraint will be a scheduling constraint. Peaking problems could appear at port terminals, port intermodal yards, stretches of the mainline system, inland intermodal yards and inland highway systems. As this occurs, the time savings advantage of intermodal shipments could decline for containers moving from the West Coast to the Eastern Seaboard. This could result in a shift of some containers back to all water service.

1.5 Bilateral and Potential Trade Relative to the Panamanian Isthmus

The analysis of world bilateral trade relative to the Panamanian Isthmus is the pivotal exercise in this study. The purpose of this analysis is to determine the level of **Panama potential trade**, namely the flow of commodities that would transit the Isthmus of Panama in the absence of any physical, economic or other impediment.

The term **bilateral trade** refers to the total trade between two countries. **Potential trade**, in this study, refers to that part of bilateral trade that represents the maximum possible commodity flow through the Isthmus. Potential trade, therefore, is that part of the bilateral trade that might have gone or may, in the future, go through the Isthmus in the absence of any impediment.

The approach of this study has been to determine potential trade on a mileage basis. That is, we examined the historical 1990 bilateral trade in sufficient detail to make possible country-to-country and port-to-port mileage comparisons between each Panama Canal route and the shortest alternative route.

Beyond the scope of this study were estimates of changes that would occur in **bilateral trade** if there were no physical, economic or other impediment to maritime traffic across the Panamanian Isthmus. Both the historical and forecast bilateral trade, that is the total trade between pairs of countries, were estimated assuming the existing Panama Canal to be in place.

If we had taken it into consideration in the Potential Trade Analysis, the effect of removing the Isthmus as an impediment to world trade would be two-fold. First, 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.

Secondly, the reduced overall costs of transportation would have the effect of increasing consumption, production, or, more probably, both. As we have noted, neither of these effects have been addressed in this study because they are judged to be small overall. However, for some trades, such as the Colombian example, they might not be.

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. A relatively small cargo may cost less to ship on a longer route through the Canal than on a shorter route that is not regularly travelled.

For this reason, we observe a small amount of trade on routes whose mileage is longer through the Canal. This is shown in Table 1, where we summarize the results of the analysis by route table for the aggregate routes in the study.

TABLE 1 BILATERAL AND POTENTIAL TRADE ANALYSIS FOR 1990, TOTALS EACH ROUTE, THOUSAND TONNES

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 1 BILATERAL AND POTENTIAL TRADE ANALYSIS FOR 1990, TOTALS EACH ROUTE, THOUSAND TONNES (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%

In this study, the term **bilateral trade** normally refers to the trade on the Canal routes shown in Table 1, rather than the global total of bilateral trade. In the data used in this study, the global world trade total in 1990 was 2.59 billion tonnes, but this excludes non-OECD, non-OECD trade on non-Canal routes. According to OECD estimates (Maritime Transport 1990) total 1990 world seaborne trade was 4.06 billion tonnes.

As shown in Table 1, in 1990 that part of total bilateral trade that flows on the Canal routes amounts to 0.40 billion tonnes, just 10% of the world total, the potential Panama trade amounts to 0.20 billion tonnes or 5% of world trade, and the actual trade through the Canal is 3.9% of world trade. The potential trade for the Canal is relatively small in world terms because the Canal is not in an advantageous geographical location for the bulk of world trade.

In our measurement of total potential trade from the 1990 data, we obtained a figure less than half of the total bilateral trade over routes for which trade is observed through the Canal. As shown in Table 1, this is the result of the following situation.

There are routes on which Canal commodity flows are observed, but for which the Canal is not the shortest route. A conspicuous example is trade between Europe and Asia. For no pair of countries or ports in the Europe-Asia trade is the mileage through the Canal shorter. In terms of bilateral trade, this is a very large number. In terms of potential trade it is zero. The trade between Europe and Asia alone accounts for 24% of the total of bilateral trade over all Canal routes.

A second factor is that bilateral trade is always reported on a country-to-country basis. To determine potential trade, bilateral trade for many countries must be split between coasts or ports of individual countries. For example, Canada, Mexico, Central America and Colombia all have east and west coasts with respect to the Canal. Canada is particularly important in this regard as nearly all trade between Canada and Asia is from the west coast of Canada, and nearly all to Europe from the east coast.

The detailed results of this analysis are presented in Volume III of this study. Figures 3 and 4 present the comparison of potential trade and Panama Canal commodity flows for all commodities and for major bulks, respectively. As can be seen from these charts, major bulks are the sole bypass commodity.

Figure 3

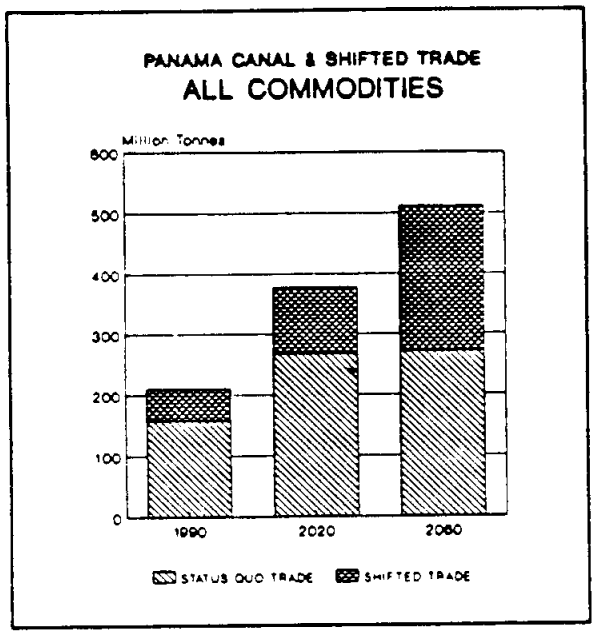
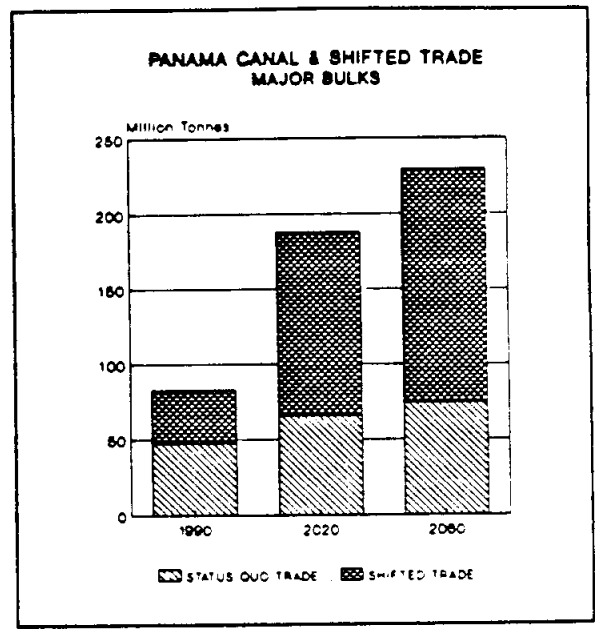


Figure 4



In Table 2, we give the aggregate results of the analysis by commodity. 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 is not the case because of differences between the PCC data and the country, OECD, and U.N. sources that we have used.

TABLE 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	20,477	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

The difficulty is that as soon as one gets away from the bulk trades the PCC data show sharp differences from the international data used in the bilateral trade analysis. These differences have four sources:

1. Containerization - WEFA estimated the containerization of general cargo in the historical data based on surveys and other information. In general, containerization of internationally traded commodities is not given in the data. On the other hand, the PCC provides data on total tonnes containerized, without indicating what specific goods are in the containers.

2. Definitional differences - the PCC has its own unique definitions of commodities. Under the leadership of the United Nations, the country data that form the basis for the bilateral trade forecasts, have moved toward a "harmonized" commodity code. This allows trade data from one country to be compared in a unique way with those from any other. 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. Assignment differences - We have assigned Panama cargoes to major categories based in large part on the type of ship in which the PCC shows the cargo being carried. In assigning the cargoes in the bilateral trade data, we have made every effort to be consistent with the PCC, but differences inevitably arise.

4. Differences in data sources - No two data sources ever agree, in part for the two reasons just noted, and differences always arise. The bilateral trade data are, at base, derived from customs data of the individual countries. The PCC is an entirely separate entity and cannot be expected to use the same definitions, etc., and the individual countries.

These issues are important for the forecasting process. The base data for the commodity forecasts have to be the PCC data to be consistent with data on cargoes and ship transits. However, the data show large differences in definition between the bilateral trade data and the PCC data. For this reason, we use growth rates rather than the levels of the potential trade forecasts for other than bulk trades.

1.6 Commodity and Transit Projections

The projections for a no-tolls scenario, taking into account capacity considerations for the North American landbridge and the Status Quo Canal, are as shown in the following tables. As expected, except for the constrained 2060 Status Quo canal, the results are not significantly different in total from Phase I.

However, there are significant differences in ship size distribution. These arise from the following considerations.

- The ship size distribution in the actual PCC data used in Phase II is different in many respects from that in the synthetic ship transit distribution developed in Phase I.

- The conclusions of our 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.

- As already noted, the exclusion of Panama Canal tolls from consideration in Phase II leads to greater switching of bypass traffic carried in very large vessels on to the Canal.

Table 3

ANNUAL CARGO FLOWS BY COMMODITY AND ROUTE
NORTHBOUND AND SOUTHBOUND
THOUSAND TONNES

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 3

ANNUAL CARGO FLOWS BY COMMODITY AND ROUTE
NORTHBOUND AND SOUTHBOUND
THOUSAND TONNES (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%

Table 4 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 4 SUMMARY OF BALLAST AND LADEN TRANSITS FOR ALL CASES (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 4 SUMMARY OF BALLAST AND LADEN TRANSITS FOR ALL CASES (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 4 SUMMARY OF BALLAST AND LADEN TRANSITS FOR ALL CASES (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%

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

9. Environmental Analysis

Executive Summary

1993

FINAL REPORT
ENVIRONMENTAL ANALYSIS COMPONENT
STUDY OF ALTERNATIVES TO THE PANAMA CANAL

PREPARED FOR THE COMMISSION FOR THE STUDY OF ALTERNATIVES TO THE PANAMA CANAL

EXECUTIVE SUMMARY

INTRODUCTION

The Environmental Analysis Component of the Study of Alternatives to the Panama Canal is an evaluation of the potential environmental effects associated with two canal upgrading alternatives under consideration by a study commission (CAS) composed by the governments of Panama, the United States and Japan. The purpose of this analysis was to review the available biological information, evaluate the environmental impacts anticipated from each of the two alternatives, identify data gaps, and recommend mitigation measures and additional environmental studies, if deemed necessary.

The Environmental Analysis evaluated the effects of different activities associated with the construction, operation, and maintenance of canal alternatives. This analysis was based on information provided in the Preliminary Engineering and Cost Estimate (ECE) Final Report, dated April 1993, prepared by Yachiyo Engineering Co. Ltd. and on results presented in the first three of four quarterly reports from the Biological Data Background and Biological Inventory (BD/BI) component prepared by the University of Panama Consortium - ANCON Consortium. Neither the fourth quarterly report nor the final report of the latter study were available during the performance of the environmental analysis. Both the ECE and the BD/BI components were undertaken by others.

Although the June 1993 Annex to the ECE Report became available for review after completion of the Environmental Analysis Final Draft Report, appropriate sections were updated, when possible, to reflect some of the most significant design modifications associated with the alternate single lane options considered in the ECE Annex for both the High-Rise Lock Canal and the Sea Level Canal.

PROJECT BACKGROUND

The existing Panama Canal consists of three sets of two-lane locks, located at Gatun on the Caribbean side, and Pedro Miguel and Miraflores on the Pacific side. Ships entering from the Caribbean Sea are raised through the three-step Gatun Locks to an Elevation (El.) of +26 meters (m), (Precise Level Datum, PLD, as adopted by PCC which corresponds to El. -0.30m Mean Sea Level datum, MSL). Ship navigation continues under their own power through Gatun Lake, and enter Gaillard Cut after passing the town of Gamboa. Ships exit Gaillard Cut at Pedro Miguel locks, where they are lowered to +16 m through a single-step

lock. They continue through Miraflores Lake to the Miraflores Locks, and are lowered through the two-step lock to the level of the Pacific Ocean.

From the time construction on the existing canal was completed in 1914, there have been additional widening activities, feasibility studies and evaluations for new canal routes. As a result of Article XII of the September 7, 1977 Torrijos-Carter Treaty, the Commission for the Study of the Alternatives to the Panama Canal (CAS) was created with the objective of evaluating the possible changes and improvements that could be incorporated into the present canal, a system that is capable of handling ships of up to 65,000 Dead Weight Tons (DWT).

After the evaluation of several canal upgrading schemes, two final alternatives remain under consideration: a High-Rise Lock Canal and a Sea-Level Canal. The alternatives selected for evaluation would complement the existing system, and not replace it. In addition to the actual construction operations related to building a canal, either alternative will require additional infrastructure support. This includes roadways, bridges, quarries, crushing plants, batching plants, temporary docks and/or jetties, equipment laydown areas, and worker camps.

HIGH-RISE LOCK CANAL

The High-Rise Lock Canal alternative contemplates the construction of additional lock structures on the Pacific Ocean and Caribbean Sea entrances. There are two options for this alternative. One would construct locks capable of handling ships of up to 150,000 DWT, and the second one would have locks for ships up to 200,000 DWT. These new locks would consist of two parallel lanes of two levels each, similar in set-up as the existing Miraflores Locks. The Caribbean Sea entrance would be constructed east of the existing Gatun Locks. The Pacific Ocean locks would be constructed west of the existing Miraflores Locks. The construction of the Pacific Ocean locks would require the excavation of a new channel that would bypass the Pedro Miguel Locks.

According to the ECE Report a 200,000 DWT High Rise Lock canal would require the movement of approximately 600 million cubic meters (MCM) of soil and rock. This volume represents 242 MCM of dry excavation and 358 MCM of dredging. The total volume of excavation will be reduced to 512 MCM for the 150,000 DWT alternative, or 217 MCM of dry excavation and 295 MCM of dredging. A breakdown of the excavation volumes by zones is presented in Table ES-1.

The majority of the material moved using dry excavation will be deposited in placing areas to the west of the existing canal. Most of the dredged material will be disposed in placing areas within Gatun Lake, and to the west of the Canal approaches in the Caribbean Sea and the Pacific Ocean.

Based on traffic projections indicated in the ECE Report, it is anticipated that the volume of water available in the Gatun Lake/Madden Lake watershed will be insufficient for the operations of both the existing and the new locks. Consequently, an additional source of water will be required. To meet this demand, one option has been identified as a dam on the Indio River, west of Gatun Lake with additional, regulator dams on either the Ciri or Trinidad rivers. If the 150,000 DWT option is constructed, the dams on the Indio and Ciri rivers will be required by the year 2060. For the 200,000 DWT option, the Indio River dam will be required by the year 2020 and the Trinidad River dam by the year 2060.

A second option to overcome the lack of natural sources of water for the High Rise Lock canal is to use a pumping scheme that would require the construction of recycling basins at both entrances. Freshwater from the lock operations would be diverted into the basins, and would later be pumped back into the upper levels of the locks. Pump stations would be required by 2060. Depending on the option selected, these would pump 1,459 to 1,890 MCM of water back into the lake each year.

Table ES-1

Breakdown of Excavation Volumes in MCM
High Rise Canal Alternative

Excavation Zone	150,000 DWT Option	200,000 DWT Option
Caribbean Approach	46.9	54.2
Gatun Lake	134.8	160.3
Gaillard Cut	125.2	142.6
Miraflores	138.3	153.2
Pacific Approach	66.9	89.2
Total Volumes	512.1	599.5

MCM = Million Cubic Meters

With the single lane canal options, the total volume of excavation for 200,000 DWT ships would be reduced to 403 MCM which corresponds to 100 MCM of dry excavation and 303 MCM of dredging. For 150,000 DWT ships, the single lane option would reduce the total volume of excavation to 337 MCM, comprised of 90 MCM of dry excavation and 247 MCM of dredging.

SEA-LEVEL CANAL

The Sea-Level Canal alternative is planned for ships up to 250,000 DWT, and would require the construction of a new canal, located between 8 and 18 kilometers (km) west of the existing canal. The Caribbean Sea entrance would be located east of the town of Palmas Bellas. The Pacific Ocean entrance would be located east of Puerto Caimito. As the proposed alignment of the Sea-Level Canal will cut through the western portion of Gatun Lake, this alternative will require construction of a set of barrier dams to hold back the lake waters. The water between the dams would be drained to allow the canal to remain at sea level. Dividing Gatun Lake would reduce the amount of water available for the operation of the existing canal, but, based on traffic projections, the canal would still be able to operate. However, a regulator dam would be required on the Gatun River. This Upper Gatun dam would be constructed by the year 2060.

The tidal fluctuations in the Caribbean Sea are about 30 centimeters (cm), while those in the Pacific Ocean can range between 5 and 6 m. Due to the difference in these fluctuations, it is expected that the net flow of seawater would be from the Pacific Ocean, into the Caribbean Sea. This would cause oscillating currents that would make navigation unsafe and would promote the movement of Pacific fauna and flora into the Caribbean. To control this condition, the design of the Sea Level canal alternative will incorporate one of the following options: a) A single tidal lock on the Pacific entrance; b) Two tidal gates, one located at the Pacific entrance and one near the town of Escobal, on the north shore of Gatun Lake; and c) One tidal lock located at the Pacific entrance and one tidal lock near the town of Lagarterita, on the south shore of Gatun Lake. Also, in order to prevent migration of Pacific Ocean biota, a fresh-water barrier has been proposed. This barrier would consist of introducing fresh-water from the western impoundment of Gatun Lake (Impoundment E in the engineering report) and/or intercepted rivers, into the sea-level canal between tidal gates, and/or into the tidal lock structures.

If the Case b option is selected, the Sea-Level Canal will require excavations of 1,385 MCM, or more than twice the volume required for the High-Rise Lock Canal. This option represents 1,034 MCM of dry excavation and 351 MCM of dredging. The total volume of excavation will be reduced to 1,252 MCM in Cases (a) and (c). Either of the two latter options will require 948 MCM of dry excavation and 304 MCM of dredging. A breakdown of the excavation volumes by zones is presented in Table ES-2.

The ECE Annex also evaluated single lane tidal locks for Case (a) and a single lane Atlantic approach channel between the coast line and the Atlantic tidal gate for Case (b).With the single lane approach canal option, the total volume of excavation would be reduced to 1,228 MCM which corresponds to 950 MCM of dry excavation and 278 MCM of dredging. The

spoil from the dry excavation operations would be deposited in placement areas primarily located to the east of the canal. Dredging spoil would be placed west of the canal.

Table ES-2

Breakdown of Excavation Volumes in MCM
Sea Level Canal Alternative

Excavation Zone	250,000 DWT Cases a & c	250,000 DWT Case b
Caribbean Approach	16.3	17.5
Queblado	234.5	398.4
Gatun Lake	234.2	234.2
Continental Divide	646.6	637.2
Pacific Approach	121.0	97.8
Total Volumes	1,252.6	1,385.1

MCM = Million Cubic Meters

BIOLOGICAL BASELINE INFORMATION

In order to obtain the necessary baseline information to evaluate environmental impacts in the project areas, the CAS commissioned the BD/BI Study to the University of Panama Consortium -ANCON Consortium (UNIPAN-ANCON). Their initial study area covered the basin of the existing canal, which stretches from Lake Alajuela to the east, to the end of Gatun Lake on the west. To the north and south, it extended beyond the breakwaters outside of Limon Bay and the Gulf of Panama, respectively. As the route for the Sea-Level Canal was added after the BD/BI Study began, the available data for an environmental analysis of this area is very scarce.

The Biological Data Background phase of the BD/BI Study was a bibliographic search and survey of the available literature regarding environmental resources within the study area. The objective of the subsequent Biological Inventory study was to provide an up-to-date survey of the biota within the study area, to be used for input to the present Environmental Analysis Component. UNIPAN-ANCON collected samples of flora and fauna, from terrestrial and aquatic environments, as well as water quality and sediment samples from the aquatic environments.

The BD/BI Study was designed to consist of four quarterly sampling events and reports, together with a Final Report, which were to be used for the Environmental Analysis. However, due to time constraints set forth by CAS, the schedule of the Environmental Analysis was accelerated. Consequently, the present analysis was based on information provided in the reports available during the study period which excluded the fourth quarter and final reports.

HABITAT CHARACTERIZATION

As the first three reports of the BD/BI Study did not include descriptions of habitats within the impact zones of each alternative, color aerial photographs were used to identify areas of different ecological characteristics (habitats). The color photographs covered entirely the alignment of the High Rise Lock canal and the central and southern portions of the Sea Level Canal. Other areas of interest, such as the northern portion of the Sea-Level Canal, and portions of the Indio and Trinidad rivers were covered only by black and white aerial photographs taken from isolated flight lines.

On the basis of the information provided in the BD/BI Study, together with the aerial photographs, additional bibliographic material, and the personal experience of the project team, a generalized habitat classification was prepared by for the purposes of this study. These included wetlands, mangroves, mature tropical forest, secondary tropical forests, grasslands, pastures, agricultural lands, open areas, lakes & rivers, mudflats, sandy beaches, rocky shores, subtidal and pelagic habitats.

ENVIRONMENTAL IMPACTS

The following sections include discussions of potential impacts on various environmental resources due to the construction, operation, and maintenance activities associated with each of the proposed project alternatives. Anticipated impacts are first categorized and described on resources in general, followed by a more detailed, alternative-specific and site-specific description of anticipated impacts.

Impacts Common to Both Alternatives

Regardless of the alternative selected for construction, a new canal will have both temporary and permanent effects on the environment. Habitats will be temporarily or permanently disturbed by equipment staging areas, materials and stock pile locations; work space requirements; and infrastructure such as worker camps, villages, electrical transmission lines, quarries, and roads. Permanent losses will occur along the sites and in the immediate vicinity of excavations and construction.

The following impacts were identified as applicable to both alternatives:

- Destruction and fragmentation of forests will produce the loss of terrestrial ecosystems, particular species, and genetic diversity of flora and fauna. Fragmentation of a particular habitat will not only reduce the total area of the habitat, but also will reduce biological diversity by direct elimination of locally-adapted populations in the newly created non-forest habitats. A significant threshold appears when the amount of forest habitat decreases below 50 percent. Species that are associated with the old mature and young successional tropical forests will be affected directly or indirectly by forest destruction. Examples include 378 species of birds that have been reported in the old mature forest, which represents over 50 percent of the 512 species reported in the project area.

- Sediments and suspended materials introduced into waters from dredging and spoils deposition will affect water transparency, reducing visibility and affecting food gathering for aquatic animals. Erosion will cause soils disturbed by construction to reach bodies of water, causing physical changes through sedimentation and alteration of water flows. Sedimentation may also impede sunlight penetration, affecting the growth of aquatic plants. The heaviest particles will settle on the bottom, potentially destroying existing plant life and affecting the animals that rely on them.

- Changes in water quality may alter the trophic balance between producers and consumers. An increase in nutrients may cause an algal bloom, reducing the dissolved oxygen in the water and producing a die-off of aquatic fauna.

- Excavation and dredging will destroy benthic habitat. The suspension of sediments in the water column will lead to an increase in dissolved solids. Some of these may be toxic to the biota, either directly or indirectly from bioconcentration in edible species.

- Disposal of excavated materials in placing areas will destroy benthic fauna and terrestrial habitats as they are covered by the spoils.

- Dust generated at quarries and batching plants will subsequently pass into rivers and lakes. Limestone in these residues can also alter the Ph of these waters.

- Construction of new roads will have adverse impacts on adjacent wetlands. Roads built on raised levees or embankments which interfere with cross drainage or obstruct the movement of water can permanently impair the biological cycles and productivity of adjacent ecosystems. Roads can also

function as dams and cause flooding by blocking water flows and increasing runoff.

- The creation of new artificial lakes will affect water flow, aquatic biota, and sedimentation patterns. During dam construction and the filling of reservoirs, there will likely be an increase in the turbidity and quality of adjacent waters.

- Changes in water regime will affect the riverine fisheries and dependent terrestrial biota. Changes in water temperature and quality, loss of spawning habitat, and creation of barriers to fish movements are all likely impacts.

- The creation of fisheries habitat in the new reservoir will benefit waterfowl and other species that forage in lentic (lake) rather than lotic (river) habitats. However, marine species which feed or spend part of their life cycle in estuaries will be negatively impacted. Alterations in watercourses, will amplify these impacts.

- Maritime development (jetties, approach channels, canals, waterways, quays, and breakwaters) will generate localized environmental impacts. The impacts of maritime development will differ by location, based on the type of facility and variations in geography, hydrology, and ecology. Mangrove swamps, salt marshes, estuaries, seagrass beds, and coral reefs are particularly susceptible to disturbance.

- Dredging and spoil disposal activities for port development and maintenance will induce short- and long-term impacts on aquatic systems, including: degradation of marine resources (beaches, estuaries, coral reefs, fisheries). resuspension and settlement of sediments, partitioning of toxic contaminants and reintroduction to the water column, contaminant uptake by and accumulation in fish and shellfish, increased turbidity causing decrease in light penetration and associated photosynthetic activity, short-term depletions of dissolved oxygen, modified bathymetry causing changes in circulation, possible saltwater intrusion to ground-water and inland surface water, altered species diversity and structure of benthic communities, fluctuations in water chemistry, changes in shoreline structure, and loss of habitat and fisheries resources.

- General construction operations for the canal, locks, dams, impoundments, roadways, spillways, construction villages and camps, as well as other activities have the potential of increasing the breeding areas for nuisance insect pests and disease vectors. Vectors that are related to water may find suitable conditions, such as malaria vectors like *Anopheles albimanus*, and the proliferation of artificial containers, which are breeding sites of *Aedes aegypti*,

vector of Dengue Fever and of Urban Yellow Fever. After construction, other water related vectors may have suitable conditions for proliferation, increasing the potential to transmit diseases. Measures to prevent outbreaks related must be considered and implemented prior to, and during construction and operation of either Canal alternative.

Impacts Associated with High-Rise Lock Canal

The estimated areas of direct impact on land and water for the excavation and spoil disposal operations, including road construction, was estimated to be approximately 76 km^2. Depending on the option chosen, the new dams and their associated watersheds would add 35 or 39 km^2 of affected areas. The placing sites for the majority of the excavated soils are currently proposed in areas that consist primarily of mature and young succesional tropical forests. It is estimated that approximately 19 km^2 of forests will be cleared and buried, with additional losses of grasslands of 1.2 km^2. Impacts will not be limited to the placement areas, but also will include the sites of access roads, bridges, and the required construction and operational infrastructure. Most of the disruption is anticipated to occur on the western area of the widening of Gaillard Cut, one of the most important remaining forested regions in the study area.

In general terms, it can be stated that, without appropriate mitigation measures, the most significant impact from the High-Rise Lock Canal alternative would be to the remaining forested areas west of Gaillard Cut as well of east of the Gatun Locks and across from Barro Colorado Island. With the current design, the spoil deposition areas would destroy important biological resources and would increase the effect of the biological barrier for animal dispersal. In addition, the construction of the dams on the Indio, Ciri, or Trinidad Rivers would have significant effects on the local environment. A recent government regulation has created the International Interoceanic Park, with the objective of protecting a stretch of forest that extends from the Pacific Ocean to the Caribbean Sea. This park will include much of the land west of Gaillard Cut, as well as the area west of Gatun Locks.

The following impacts were identified for the High-Rise Lock Canal alternative:

- Disposal of the dredged spoils in the Pacific Ocean may have greater effects than in the Caribbean Sea, as most of the commercial fisheries are located here. Disposal of dredged spoils inside of Gatun Lake are not expected to have as great an impact as in the marine placement areas.

- The construction of the Indio River dam, together with the Ciri or Trinidad rivers dams will flood 32 or 39 km^2, depending on the option selected. These areas primarily consist of pastures, with a mosaic of forest fragments. Forest coverage appears to be on the order of 50 percent in the Indio River basin,

and drops to less than 30 percent in the Ciri and Trinidad river basins. The population density in the Indio River basin appears to be lower than that of the Trinidad and Ciri River basins. The construction of the Trinidad River dam will also affect the wetlands located at the mouth of the river. It is estimated that most of the 1.4 km^2 wetland may be severely affected and progressively reduced. The loss of wetlands removes valuable feeding, breeding and nursery areas for a wide variety of fauna.

Other environmental impacts would occur when the spillway from the Indio River dam connects to Gatun Lake, allowing the migration of the Peacock Bass (*Cichla ocellaris*) into the Indio River watershed. This exotic species was accidentally introduced into Gatun Lake in the past. Due to its carnivorous habits, the Peacock Bass has severely reduced the population of native fishes at Gatun Lake.

The use of the proposed water recycling scheme will have the side effect of increasing the salinity of Gatun Lake. As the salinity increases, the probability of marine fauna surviving the crossing from one ocean to the other increases greatly. The interchange of marine biota, including fish, invertebrates, parasites, bacteria, virus, eggs and/or larval forms of any of these, have the possibility of causing major impacts on the habitat in Panama Bay, where the great majority of the Panamanian fishing industry is concentrated.

Impacts Associated With Sea Level Canal

The construction of the Sea-Level Canal is estimated to have a direct impact on approximately 176 km^2 of land. The Upper Gatun dam impoundment will add an additional 11 km^2, for a total of 187 km^2. The placing sites will cover an area of approximately 85.5 km^2 which includes about 54 km^2 on land and 31.5 km^2 in water. Except for the northern portion of the canal alignment, the placing areas are currently located in areas that consist primarily of pastures and grassland, with remnants of tropical forests.

The placing areas located between the Pacific Ocean and the south shore of Gatun Lake, cover 38.6 km^2 of land consisting mainly of pastures and open land with an estimated forest cover of 10 to 15 percent. The spoil areas located between the north shore of Gatun Lake and the Caribbean Sea will cover about 15.5 km^2 of land with an estimated forest cover of 30 to 50 percent. Spoil sites in Gatun Lake, used to construct the barrier dams, will cover an area of about 5 km^2. The remaining spoil areas in water will cover 17.6 km^2 in the Pacific Ocean and 8.8 km^2 in the Caribbean Sea.

In this alternative, most of the terrestrial disruption is anticipated to occur in the eastern area of the canal alignment. Much of this area has been subject to logging activities, slash and burn agriculture and overgrazing. The following impacts were identified for the Sea-Level Canal alternative:

- The construction of the barrier dams to divide Gatun Lake will have significant environmental impacts to the area. Upon dewatering of the proposed sections, more than 5 km^2 of wetlands from nine major systems will be lost. Chief among these areas are those of Los Hules and Pescado rivers, where each system covers approximately 1 km^2.

- The wetlands located at the mouth of the Trinidad River will be disturbed by the loss of water flow. This area currently covers approximately 1.5 km^2, and would probably be severely affected.

- The diversion scheme that will block surficial water from entering the areas separated by the barrier dams, and the construction area of the canal, will cut through and affect 15 major rivers and streams. In some cases, their waters will be diverted directly into the canal, while in others, they will be directed into the detached portion of Gatun Lake (Reservoir E).

- The diversion scheme also includes the cutting of the Caimito River. A small impoundment will be formed in this area, near the city of La Chorrera. The mangrove habitat at the mouth of the Caimito River will be severely affected, as it will be split into two portions. It currently occupies approximately 2 km^2. It is anticipated that it will lose more than 1 km^2 and will remain as two separate sections of less than 0.5 km^2 each.

- The dredging of the 26.1 km approach channel in the Pacific Ocean, together with the adjacent placement of the spoils, may have significant negative impacts on the commercial fisheries located there. Not only is it expected to affect the local fisheries, but due to the westward flow of the predominant ocean currents, it is likely that the suspended sediments may affect important breeding and nursery areas that are located in the major mangrove habitats found at Punta Chame.

- The construction of the Upper Gatun dam will flood approximately 11 km^2. This area consists primarily of pastures, grassland, logged-out areas and small farms, together with a mosaic of forest fragments. Forest coverage in this area appears to be less than 40 percent. The population density in the adjoining area appears to be much greater than what was observed in the Indio, Trinidad and Ciri river basins.

- Additional environmental impacts will occur when the spillway from Reservoir E connects to the Lagarto River. The increased volume of water onto this river may cause local erosion and sedimentation problems. In addition, the spillway will allow the migration of the Peacock Bass (*Cichla ocellaris*) into this watershed. As indicated above, this exotic species has severely reduced the population of native fishes in Gatun Lake.

- A serious consideration is the potential for Pacific Ocean biota crossing into the Caribbean Sea. One of the most serious potential problems involves the Crown of Thorns starfish (*Acanthaster planci*). Populations of this starfish have been responsible for wide-spread damage to coral reefs throughout the coral reefs of the South Pacific and the Great Barrier Reef in Australia. It has also been reported in the Gulf of Chiriquí ,west of the Bay of Panama, where it reportedly has been able to consume 18 to 47 percent of the live cover of a 20 ha reef in four months. Consequently, should the starfish cross into the Caribbean Sea, the devastation to the coral reefs and resultant loss of marine biota are anticipated to cause regional impacts.

- Eastern Pacific Ocean corallivores are more specialized and voracious than the Caribbean species. Their presence in the Caribbean will increase predation on coral. In general, there is more grazing pressure in the Eastern Pacific. Low algae and sponge cover is maintained by voracious, specialized predators. As calcareous algae and sponges contribute greatly to reef formation, the health of the Caribbean reefs will also be affected.

- Other potential environmental problems may be the introduction of parasites and competing organisms that may destroy or displace Caribbean Sea biota. Conversely, viruses have been found in the Caribbean Sea, which are absent in the Pacific Ocean. The accidental transport of these could cause major damage to the Pacific Ocean biota.

- The construction of a Sea-Level Canal will also represent an additional disruption to migration of terrestrial flora and fauna. The removal of forested areas in the placement sites located on the north portion of the Sea-Level Canal will create a barrier for forest fauna. Although the existing canal has been a barrier to migration, an additional, seawater barrier will increase the obstacles. Organisms, plants or animals, that could survive crossing the existing fresh-water barrier may not survive or be completely deterred from crossing a sea-water canal.

- Another potential impact that the Sea-Level Canal may cause is seawater intrusion into the potable water supply aquifers and/or a drop in the phreatic

surface, as the groundwater drains toward the canal. The hydrogeology of this area is poorly understood. However, the available information indicates that inland populations, away from Lake Gatun, install potable water wells that range in depth between 24 to 36 m below land surface. The coquina is the basal member of the Chagres sandstone, and it is highly permeable, and thus, would easily serve as a conduit to seawater into the groundwater.

The preliminary engineering design of the Sea-Level Canal alternative hypothesizes the incorporation of a freshwater barrier system to address the problem of seawater biota movement between the two oceans. The ECE Report discusses the possible introduction of fresh-water into the tidal locks or between the tidal gates for the purpose of creating a fresh-water barrier. However, the report indicates that there is insufficient information to be able to provide definite conclusions. The alternatives considered include introducing fresh water into the Locks, the tidal gate structures and the central section between the proposed locks and tidal gates. Their evaluation of mixing conditions indicated that there may not be enough fresh-water available to create such a barrier during low rainfall years. Available fresh water during normal years may be marginal and therefore the fresh water barrier may have questionable effects to prevent organisms from crossing the isthmus.

Even if additional fresh-water was made available, there are other factors that may make this barrier unreliable. In the existing Canal, behavioral habits of fish and other marine organisms, act to restrict the movement from an open bay situation into the confined space of a lock. However, in the Sea-Level Canal, the locks and gates are many kilometers from the coast. Once these organisms find themselves within the open boundaries of the Sea-Level Canal, crossing an open lock or gate would not be a behavioral barrier.

Overall, the Sea-Level Canal Alternative appears to have greater impacts to both terrestrial and aquatic habitats, in comparison to the High-Rise Lock Canal Alternative. In general terms, it can be stated that the major terrestrial impacts of the Sea-Level Canal Alternative will be to the forested areas north of Lake Gatun, and the removal of the wetlands in La Laguna. The major aquatic impacts will be to the Bay of Panama. The removal of the remaining forested areas north of Gatun Lake may act as a barrier to the movement of terrestrial fauna. The placement areas on the southern portion of the canal will cover 33 km^2 of pastures, grasslands and relatively small forest fragments. The dredging of the Pacific Ocean approach channel, however, will have an impact on the commercial fishing industries. As presently designed, the fresh water barrier does not appear to represent an impassable barrier to marine biota.

The major terrestrial impacts of the High Rise Lock Canal appear to be associated with the spoil disposal areas in the forested areas west of Gaillard Cut. Additional terrestrial impacts are associated with the spoil deposition areas east of Gatun Locks and Barro

Colorado Island. Aquatic impacts are associated with the deposition of additional spoil materials within Lake Gatun.

Both alternatives open up new watershed areas for invasion by the peacock bass *(Cichla ocellaris)*. The High Rise Lock Canal may open the Rio Indio Basin, and the Sea Level Canal may open up the Lagarto River Basin to this exotic predator.

RECOMMENDED MITIGATION MEASURES

General mitigation measures have been developed to avoid or reduce significant impacts of the project alternatives on the biological environment. The flow chart presented in Table ES-1 was developed to illustrate the recommended mitigation strategy.

The level of detail provided for these measure is necessarily general, since much of the baseline information collected from surveys, studies, and reports were of a regional rather than site-specific nature. Therefore, the mitigation measures are applicable for construction activities and practices over the entire project area. The recommended mitigation strategy requires that prior to construction, biologists conduct surveys to determine the presence or absence of sensitive resources within the impact areas. The initial investigation should focus on identifying and quantifying the different types of habitats that are found within the impacted areas. Based on this information, a discrete survey plan can be designed, in order to be able to evaluate a statistically valid number of representative areas for each identified habitat.

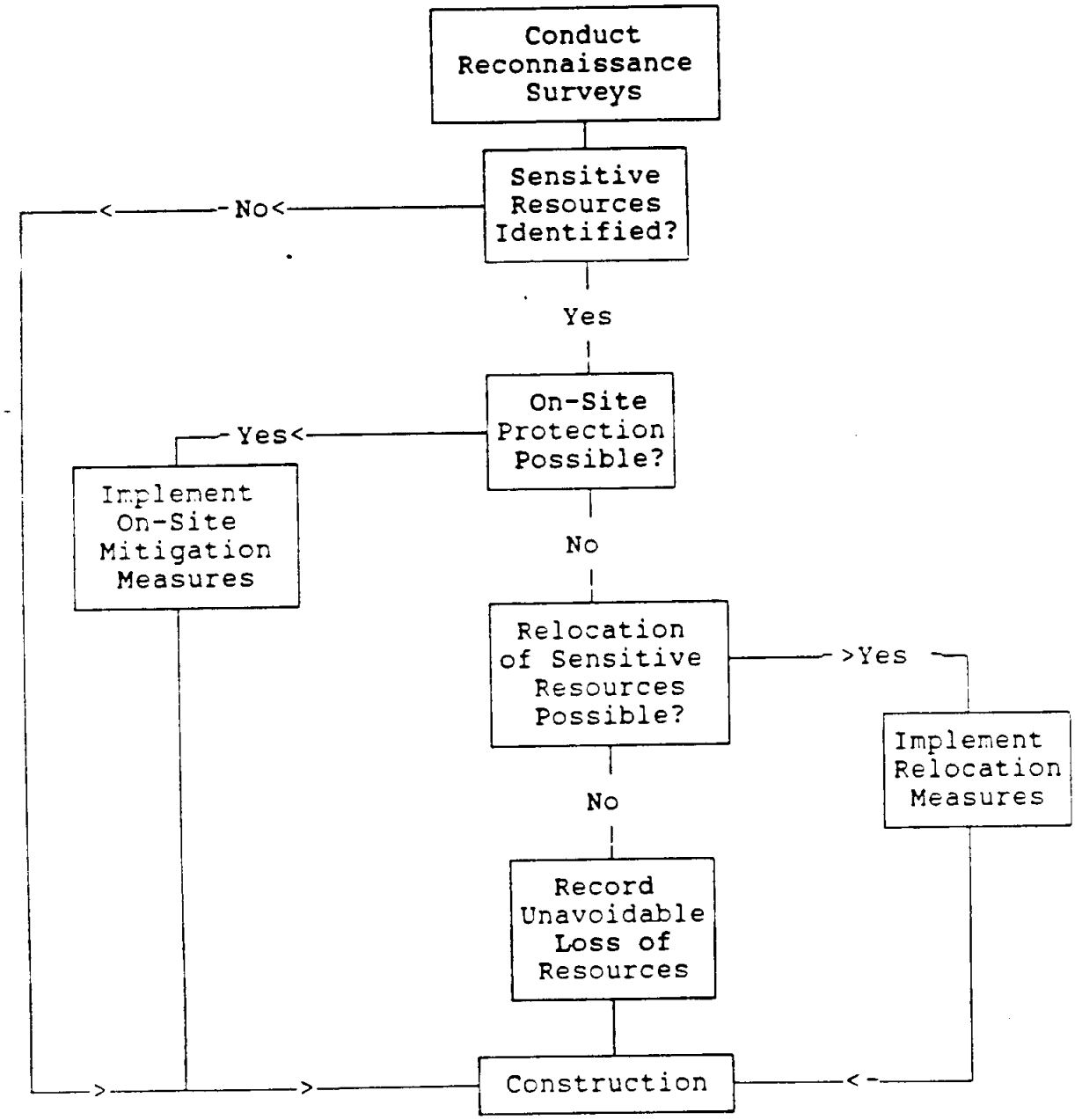
- If sensitive resources are not observed within the area of potential effect, construction activity using the general mitigation measures can commence.

- If it is determined that sensitive resources occur in the area of potential effect, then on-site protection should be evaluated. Measures that can protect on-site resources include: avoidance; establishment of buffer zones; marking, flagging, and posting of signs; scheduling construction to avoid sensitive time periods (e.g., crepuscular activity and/or breeding seasons) and; measures to encourage natural revegetation of temporarily disturbed habitats.

- Avoidance is the most effective way to reduce potential impacts to biological resources. In the cases where complete avoidance is not feasible, the possibility of partial avoidance should be evaluated. If on-site mitigation is not possible, then the possibility of relocating a sensitive resource should be considered.

Figure ES-1

Construction Mitigation Strategy
Biological Resources



If the projected impacts cannot be ameliorated on-site, then relocation options should be considered. However, relocation will not be a viable alternative if

suitable recipient habitat is not available. Examples where relocation is not feasible or realistic and where resources will be irreversibly damaged, should be documented prior to initiation of construction.

- In areas where sensitive resources cannot be salvaged, the type and extent of irrevocably committed biological resources should be recorded before construction proceeds utilizing standard mitigation measures. This record will be used as part of the documentation of the mitigation process, and also as a basis for determining the appropriate level of off-site compensation.

- Relocation of species should be combined with habitat compensation is recommended to ensure that there is no net loss of habitat quality and regional biological diversity. The purpose of such compensation is to prevent that species richness and diversity are diminished due to construction and operation of a new canal.

- When avoidance or reduction of impacts on biological resources within the project area are not possible, measures to offset unavoidable losses of habitat should be considered. The recommended strategy is to protect, when possible, similar (in-kind), unaffected habitat within the project area (on-site) or to replace those resources affected by the project.

- In the course of the project, biological resources like those in spoil deposition areas, will be irrevocably lost, with little or no chance for on-site rehabilitation. Losses which cannot be mitigated should be documented to determine the type and amount of habitat that should be acquired; however, as most other similar habitat within the project area has also already been lost or degraded from logging, agricultural clearing, and other activities, in-kind, on-site replacement of lost resources may not always be possible or practical. In these cases, calculations of unmitigated losses will be used to determine the appropriate level of compensation.

- The project Mitigation Plan should also include habitat compensation formulas. These formulas will assist design and value engineering in projecting costs to encourage the avoidance of particularly sensitive resources. Through this mechanism, a clear financial incentive to avoid biological assets will be established if, for example, the per hectare replacement ratio for mangrove forest is ten times that of agricultural lands.

Under certain circumstances, the acquisition, preservation, and maintenance of similar (in-kind) or different (out-of-kind) habitat in or near the study area may be the most practical means of compensating for a regional reduction in biological diversity caused by loss or

fragmentation of project area lands. Relatively large, contiguous blocks of habitat are required to avoid the adverse effects of habitat fragmentation on animal and plant populations.

The acquisition of undisturbed habitat adjacent to existing natural areas (i.e. Soberania National Park) may be the only way to provide for conservation of regional floral and faunal diversity. These newly acquired areas could then be placed under some form of legal protection, significantly reducing the possibility of future habitat loss or fragmentation in these areas. Even a landscape with impoverished remnants is better than one with none at all. Forest remnants can serve as important catalysts for forest regeneration and sources of botanical endemism. Ideally, smaller fragments should be connected by forest corridors and the landscape should include several large forest tracts of at least 1,000 ha (Daniel H. Janzen, University of Pennsylvania, personal communication). Locations of suitable habitat preservation areas within the study area were identified for potential acquisition and include:

1. A relatively large, contiguous block (approximately 14,000 ha) of mature tropical moist forest occurs south of Barro Colorado island, from the vicinity of Cerro Gigante eastward to the south shore of Gatun Lake, south of Gamboa.

2. An approximately 1,400 ha block of mature tropical moist forest east of Gatun locks.

3. Approximately 270 ha of freshwater wetlands at the mouth of the Trinidad River. This large wetland will possibly be lost by construction of the sea-level canal.

Other large areas of mature tropical moist forest and freshwater wetlands also still exist east of the existing canal, in the Districts of Colon and Chagres in the Province of Colon. A portion of the mitigation funds assigned for habitat preservation should be reserved in the form of an endowment. The endowment funds could be used to protect the acquired habitat, or to provide protection to existing reserved but unprotected lands. Endowment funds could also be applied to develop educational programs designed to increase local awareness of the value of the protected resources, and to develop "ecotourism" as a way to offset the financial implications of discontinuing consumptive resource exploitation in protected areas.

ADDITIONAL RECOMMENDATIONS

Because of the time frame, technical, and financial limitations associated with the performance of the Environmental Analysis component, a second phase combined Biological

Inventory and Environmental Analysis should be performed in parallel to proceeding to final design of either of the two canal alternatives.

The Phase II Environmental Analysis should include habitat mapping to obtain a relatively high degree of certainty with regards to the specific locations of sensitive resources within areas of impact. Sensitive species tend to be closely associated with a distinct community or habitat type. Therefore, studies designed to develop a map of the major and critical habitat types in the project area should be performed. Such maps will be critical for determining the least environmentally damaging alternatives for site disturbance and road alignments. These maps will also assist in determining potential resource relocation sites.

The information contained on resource maps will also be crucial for ascertaining potential site-specific impacts and for developing Mitigation Plans and Monitoring Programs. Habitat maps will document the existing environmental baseline conditions and provide a standard to measure the effectiveness of mitigation. These activities should be performed in all areas that may be affected by the construction or operation of the alternatives. Dames & Moore recommends that the area of impact to be studied include all land within a one (1) kilometer external radius from the boundary of the immediate construction, wet and dry deposition areas, roadways and all other canal related facilities.

Additional aerial photographs should be obtained to supplement the available photo coverage in the project areas. A full set of color aerial photographs, at a recommended scale of 1:18,000 should be commissioned. These should cover the entire areas of the High-Rise Lock and Sea-Level Canal routes, all deposition areas, as well as all proposed impoundment areas (Upper Gatun, Indio, Ciri and Trinidad), all diversion channels, minor impoundments and spillways.

Due to the low level of useful information regarding the areas for construction of the dams on the Indio, Trinidad and Ciri rivers, it is important that complete baseline studies be commissioned to obtain the necessary information for the Phase II Environmental Analysis. Without this information, it is not possible to adequately assess the magnitude of potential impacts to these areas.

The Sea-Level Canal Alternative presents a series of unresolved issues, such as the evaluation and design for a secure biological barrier to the marine biota and the movement of terrestrial fauna in the northern portion. These issues, among others, must be further investigated and resolved in order to properly evaluate this alternative. The existing conditions in this area are uncertain, as little site-specific information is available. Although the aerial inspection of the proposed canal route revealed that much of the southern portion has been severely affected by human activities, the northern portion still has significant areas of forest cover. In a similar fashion, insufficient information exists to assess the potential effects that the marine approaches may have to the surrounding ecosystems.

Specific studies should be performed in the proposed spoil placement areas along the route. Evaluations of the existing wetlands in the area of La Laguna should be also be commissioned. This area appears to have the greatest concentration of wetlands in Gatun Lake. The effects of the construction of the breakwater on both the Pacific and Caribbean approaches have the potential to significantly alter currents in these areas. This will have noticeable effects on current velocity, sedimentation rates, erosion and littoral drift. In order to evaluate these potential effects, it is necessary to obtain information regarding bathymetry, composition of the bottom sediments, current direction, rates and seasonal variations, to model the conditions in Panama Bay and in the Caribbean Approach areas.

As a Sea-Level Canal has the potential to affect the marine flora and fauna of the Caribbean basin and the Bay of Panama, a baseline study should be performed to establish regional marine biological conditions. Due to the large number of uncertainties regarding the possible effects of migrating Pacific marine biota to the Caribbean, it is important that existing conditions throughout the basin be properly tabulated.

Issues such as information regarding existing and historical fisheries (commercial, sport and subsistence), breeding grounds, current patterns, erosion and littoral drift, flora and fauna (both vertebrate and invertebrate), coral reef health, known contamination problems and any additional information that may serve to establish the historical and existing biological conditions within the Caribbean basin as well as the Pacific coastal countries extending from Ecuador through Mexico should be compiled.

A biological inventory, similar to the one performed for the High-Rise Lock Canal alternatives, should be performed for the areas that may be affected by the construction of a Sea-Level Canal. However, future biological inventories should be structured to provide information in areas that will be affected by the construction activities. Information regarding the local climate, geology, hydrogeology and hydrology should also be included, and additional information regarding local use of natural resources should be obtained, as this information will also be useful for future socioeconomic studies.

A recent declaration of May 25, 1993 created the Interoceanic Park of the Americas. The area that this park encompasses includes all of Gatun Lake and parts of the forested areas west of Gaillard Cut. An evaluation of the limitations on the usage of park areas should be performed, as these may have severe impacts on the activities associated with the construction of either of the two alternatives. An initial evaluation of the Park boundaries indicates that it may affect the various placement areas west of Gaillard Cut, as well as construction operations in La Laguna and the barrier dams.

LIMITATIONS OF THE PRESENT STUDY

The present study has been performed on the basis of biological information provided to Dames & Moore by CAS. The main references included the Biological Data Background Report, and the first three of four quarterly reports from the Biological Inventory. These documents included a large amount of significant information. However, due to their structure, certain limitations affected their usage. Among these conditions were the location of the sampling sites that were selected. Although most of these were within the operational areas of the existing canal, areas that would be directly affected by construction or operational impacts of either of the two alternatives were limited. As indicated before, the Biological Inventory did not provide information regarding the conditions in the area of the Sea-Level Canal alternative, nor were there any stations near any of the four proposed dam and impoundment areas.

In many cases, notably for insects, mammals, fish and birds, the methodology used did not provide a representative sample of these organisms. The reports reviewed for this study did not present descriptions of habitats, or other suitable information to relate species found with specific habitats. Certain habitats, such as mudflats, were not sampled at all. The absence of complete identifications had a large effect on the evaluation of insects, which had been classified only to the level of families, increasing the difficulty in evaluating organisms of medical importance. Other limiting conditions were encountered in the forestry data, where certain parameters, such as chest-height diameter were presented, without an estimate of tree height.

As indicated previously, aerial photograph coverage was incomplete, and certain areas, such as the Indio River basin, were only available in black & white photographs. If the Phase II Environmental Analysis is initiated within a 12 month period from the completion of this component, photographing only the missing areas may be sufficient. If the delay in performing the additional studies extends significantly beyond this period, it is recommended that full photographic coverage of the project areas be obtained.

The process to complete the recommendations for further study can require more than five years of continuous study, in order to establish patterns in areas where information is scarce or lacking. The information obtained in this fashion would be used to document existing conditions and potential impacts associated with the construction of a Sea-Level canal.

The Environmental Analysis did not provide a thorough evaluation of the design modifications set forth in the June 1993 Annex to the ECE Report, as this document was made available for review after completion of the Draft Final Report. However, the Final Report includes a limited evaluation of the impacts associated with the more significant design modifications for the High Rise Lock canal alternative.

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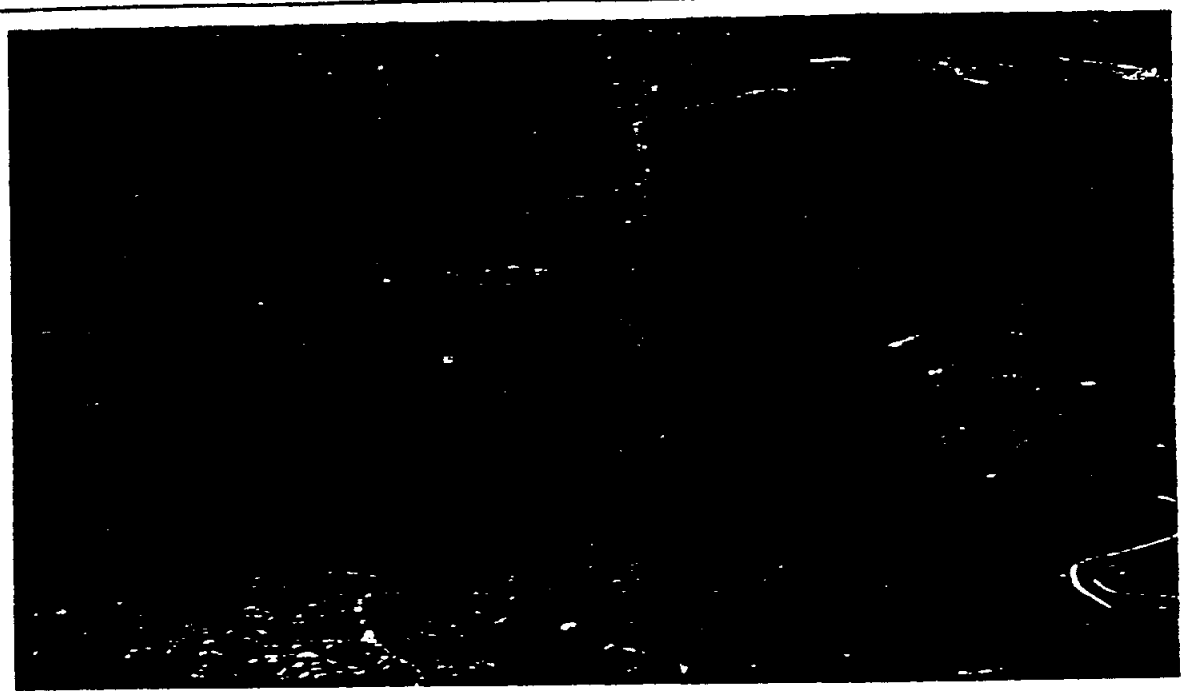
...uld be located.

Foto 2. Cerro del contratista, Corte Culebra. Observese los taludes de excavación.
Photo 2. Contractor Hill at Gaillard Cut showing the excavation faces.

Foto 3. Esclusas de Pedro Miguel entre los lagos Gatún y Miraflores.
Photo 3. Pedro Miguel Locks conecting Gatun and Miraflores lakes.



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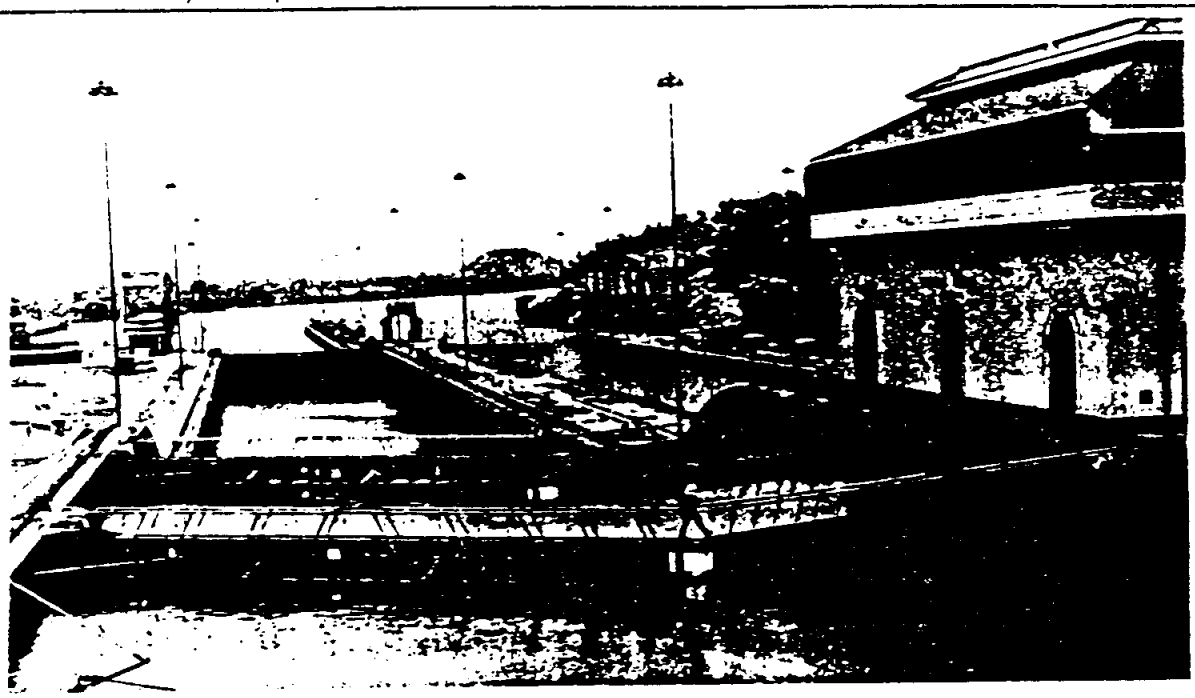

Foto 4. Esclusa de Miraflores entre el Lago Miraflores y el Océano Pacífico.
Photo 4. Miraflores Locks connecting Lake Miraflores and the Pacific Ocean.

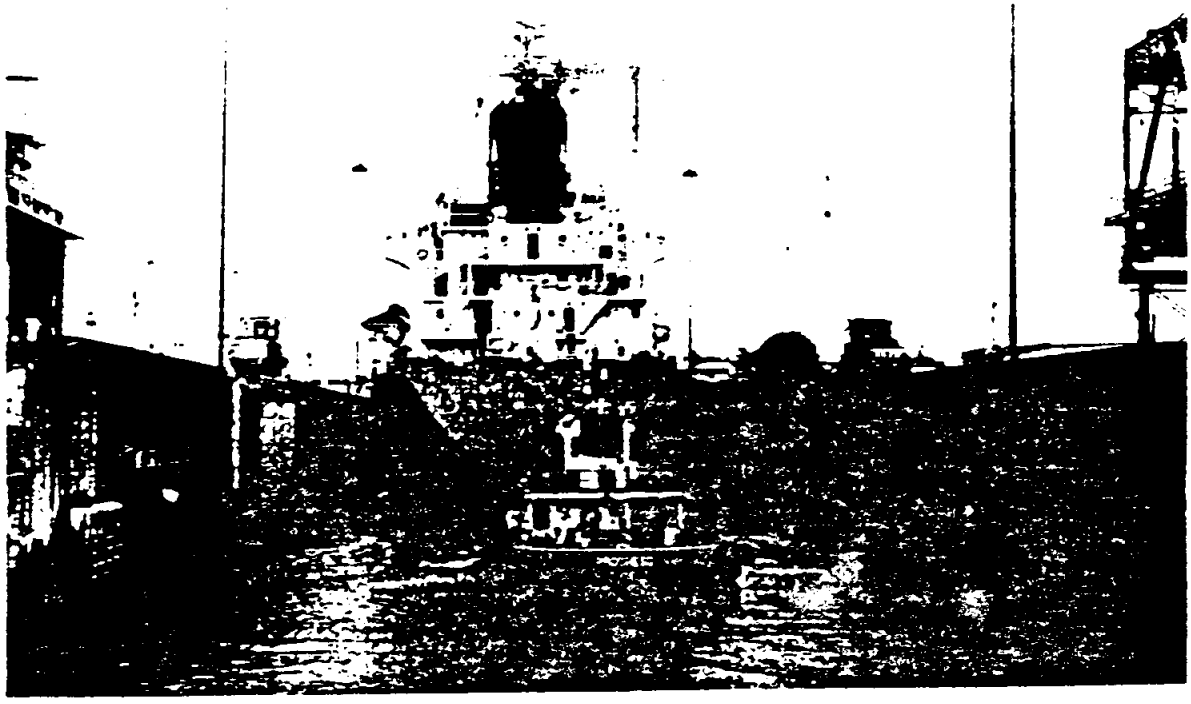

Foto 5. Remolcador asistiendo a un barco al entrar a las Esclusas de Miraflores.
Photo 5. Towboat assisting ship entering Miraflores Locks.

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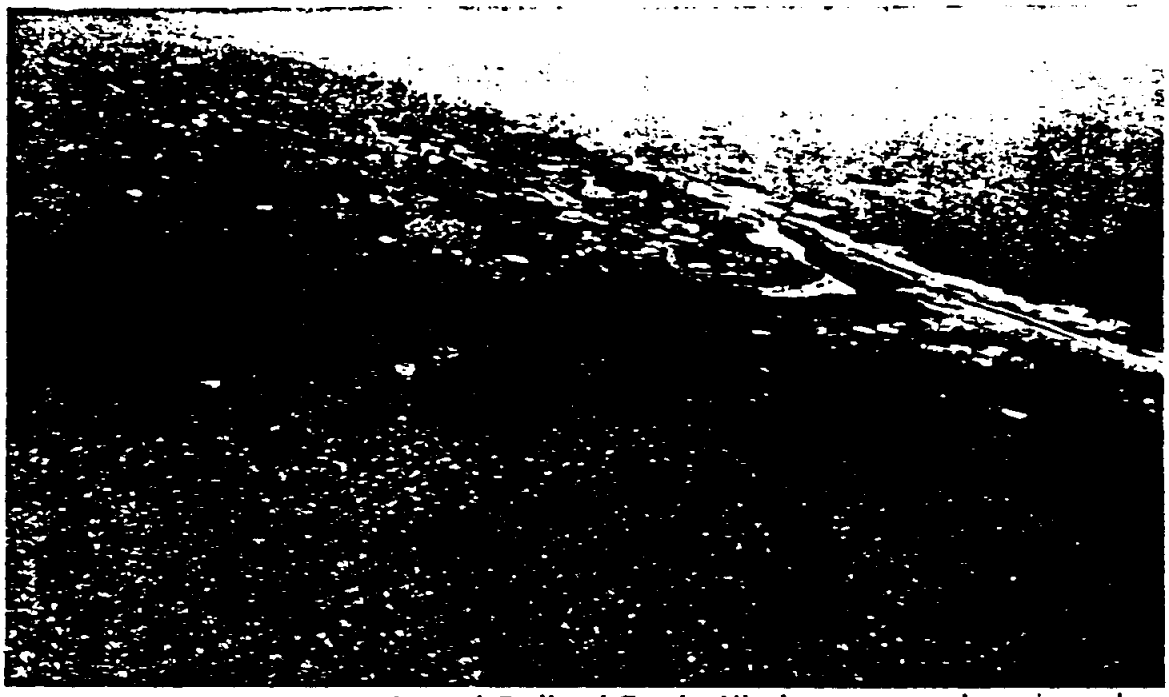

Foto 7. Río Lagarto: entrada en el Caribe al Canal a Nivel; consta con plantaciones de palma aceitera africana.
Photo 7. Lagarto River: Caribbean approach to Sea Level Canal adjacent to african oil palm plantation.

Foto 8. Area deforestada al Sur del Lago Gatún que sería atravezada por el Canal a Nivel.
Photo 8. Deforested area South of Lake Gatun which would be crossed by Sea Level Canal.

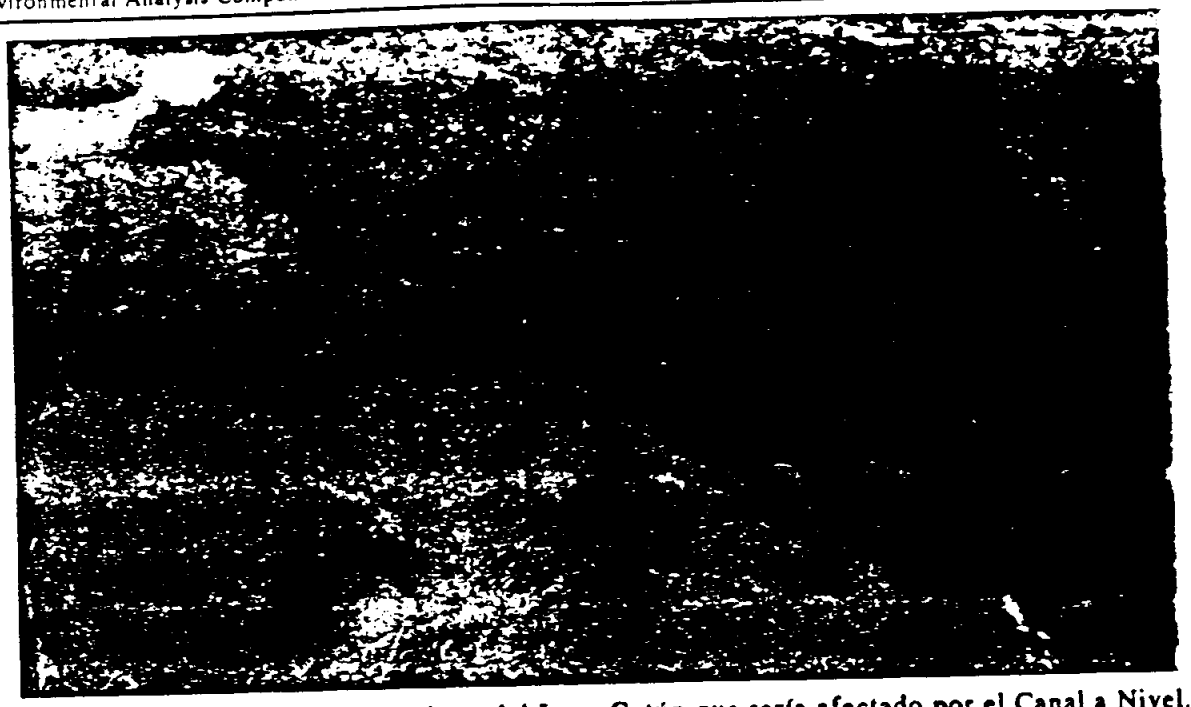

Foto 9. Fragmento de bosque al sur del Lago Gatún que sería afectado por el Canal a Nivel.
Photo 9. Forest fragment South of Lake Gatún which would be affected by Sea Level Canal.

Foto 10. Quema de herbazales junto a fragmentos de bosque al sur del Lago Gatún.
Photo 10. Grassland burning adjacent to forest fragments south of Lake Gatún.

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Foto 12. Area boscosa en las riberas de Corte Culebra.
Photo 12. Forested area adjacent to Gaillard Cut.

Foto 13. Area impactada por la expansión actual de Corte Culebra.
Photo 13. Impacted area by the current expansion of Gaillard Cut.

Foto 14. Bosque sucesional joven ubicado en el área de Gamboa.
Photo 14. Young successional forest localized in the vicinity of Gamboa.

Foto 15. Bosque tropical ubicado en las riberas del Río Chagres en al área de Chilibre.
Photo 15. Tropical forest adjacent to Chagres River in the vicinity of Chilibre.

Foto 16. Bosque tropical en la desembocadura del Río Chagres al Lago Gatún, Gamboa.
Photo 16. Tropical forest adjacent to the mouth of Chagres River at Lake Gatun, Gamboa.

Foto 17. Vista de un arrecife de coral en el Caribe de Panamá (Archipielago de San Blas).
Photo 17. Caribbean coral reef of Panama (San Blas Archipielago).
Foto cortesía de Marco Díaz. Photo courtesy of Marco Díaz.

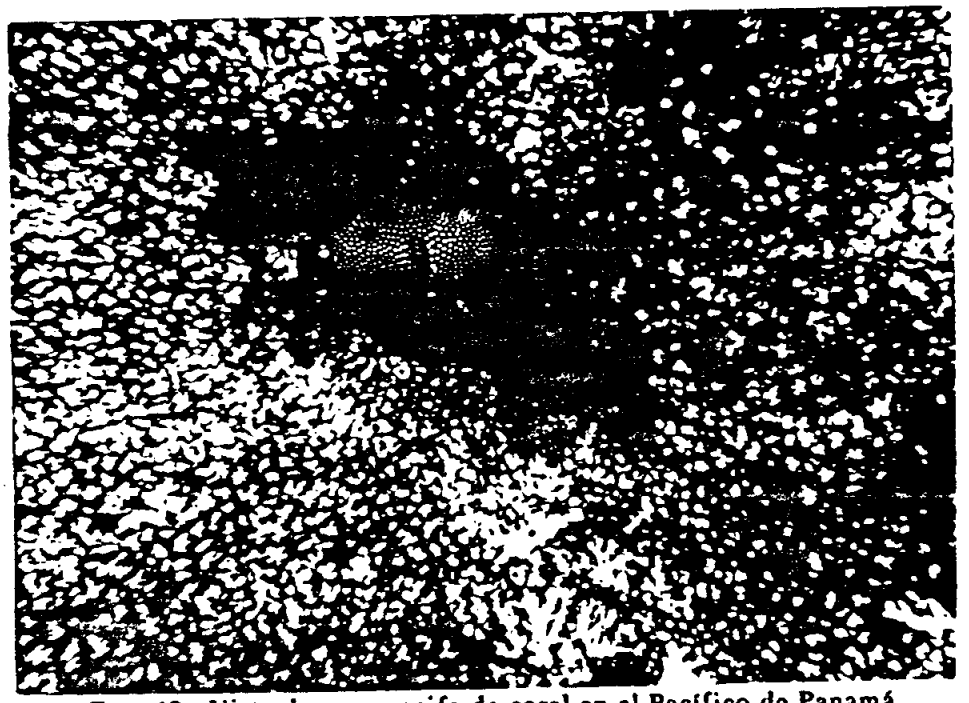

Foto 18. Vista de un arrecife de coral en el Pacífico de Panamá.
Photo 18. Pacific coral reef of Panama (Iguana Island, Pedasí).
Foto cortesía de Marco Díaz. Photo courtesy of Marco Díaz.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

10. Biological Inventory

Executive Summary

1993

1) EXECUTIVE SUMMARY

a) TERRESTRIAL

(1) The Physical Environment

Due to climatic conditions and soil evolution, the natural plant cover of the isthmus of Panama is forest.

A report on Life Zones of Panama (Tosi, 1971) following the Holdridge method of classification of plant formations of the world, recognizes most of the study area as "tropical humid". Annual rainfall varies north to south from about 3,400 mm to 1,850 mm with a 26 °C biotemperature.

The lower watershed (southwest sector) includes Gatun Lake and its tributaries (Gatun, Ciri Grande and Trinidad). The upper watershed (northeast sector) comprises Alajuela Lake and its tributaries (Chagres, Pequeni and Boqueron).

On the lower watershed, about 95% of the area has been depleted of its original forest cover. A gentle topography and relatively flat lands maintain a low rate of erosion.

On the upper watershed, even with a much lower deforestation rate, a combination of higher rainfall and steeper topography are factors accelerating erosion.

From the point of view of vegetation growth, the combination of hight temperature and rainfall plays a main role on soils.

The Rural Census of Lands and Waters of the Republic of Panama (CATAPAN), a project completed in 1965, surveyed, analyzed, and mapped soil types of Panama, including the study area. This project sampled and analyzed (both physically and chemically) the soils of the permanent sampling sites and found results that closely matched those of CATAPAN.

(2) Flora

Field work was carried out during twelve months in order to detect seasonal variation.The study area included both sections of the Panama Canal watershed (northeast or upper watershed, and southwest or lower watershed) which account for the formation of Gatun and Alajuela (Madden) lakes, the sources of all the water needed for the canal operation.

In the field, a total of 29,528 individuals were recorded; 12,948 of them provided herbarium samples for later identification in the laboratory. Of the total, 27,700 where identified to family (94%) and 27,581 to species (93.4%).

A total of 1,920 person/days were utilized to complete all field and laboratory work.

The following are the most outstanding results and conclusions from the flora inventory:

-Original plant cover (tall forest) has been reduced to approximately 30% of the total area. On cleared land a mixture of extensive grazing lands, secundary forest (pioneer, early secondary and late secondary) and abundant but small cultivated patches have been established by slow continuous colonization. This deforested area also includes all land occupied by lakes, engineering structures (canal, roads, buildings and different types of installations for the operation and maintenance of the Canal) and human dwellings are included.

-The reduction of natural plant cover increases erosion and siltation rates and threatens the expected operational life of the canal. This condition is not very serious in the lower wartershed due to a relatively gentle topography of the area, but in the high watershed, with a rough and steep topography and higher rainfall rates, the situation requires immediate attention to protect the Canal operations.

-No large volumes of commercial timber were found in the area which would support a reasonable yield in felling operation. Extraction of valuable timbers by local artisans has been occuring for many years, even before the construction of the Canal. However, this is not a recommended activity for this area, even though it produces low scale damage and poses no significative threat.

-The study area is located in the "tropical humid", the most extensive life zone of the Republic of Panama, and most of the collected species are also present in sites adjacent to the study area.

The following recomendations have been derived from the flora inventory:

-The Panama Canal watershed requires protective measures to reduce or, at least, to stabilize human activities within the area.

-Existing settlements should be technically and financially supported in order to increase permanent crops and reduce to a minimum temporary ones.

-Protected areas quickly return to a forest type cover by natural succession. This process should be complemented with plantations of native forest species on those sites so deteriorated that natural regeneration has become difficult.

-After selection of a proper alternative to the Canal, some specific biological studies should be carried out around affected areas.

(3) Fauna

(3.1) Entomology

The insects study concentrated on the following objectives:

-To identify insect species that affect man and animals, emphasizing on those that transmit diseases.

-To determine their distribution and relative abundance throughout the established sampling period.

-To identify beneficial insects acting as biological control agents, as well as insects important to forestry, agriculture and others.

The field and laboratory work was started in July 1992, with weekly surveys performed during nine months, totalling 37 sampling weeks up to June 1993.

The work was conducted at four sampling sites (Paraiso, Gamboa, Arraijan and Arenosa). These sites were chosen because of their North, South, East and West orientation to the Panama Canal and their proximity to residential areas that may be affected by the construction and operation of any of the canal alternatives.

Throughout the present study, eleven different sampling methods were used, seven of which consisted of utilizing various insect traps. These methods were systematically used during the nine months of sampling period.

A total of 138,184 insects of medical importance were collected belonging primarily to the Diptera, including the following Families: Culicidae (14,575 specimens belonging to 14 Genera and 19 species); Psychodidae (1,346 specimens which included 18 species and two genera); Ceratopogonidae (14,383 specimens, the majority belonging to the genus *Culicoides* of which 43 species were identified); Calliphoridade (21,908 individuals of the genus *Chrysomya*); 12944 Muscidae, 9,712 Sarcophagidae, and 55 Tabanidae. In addition, a total of 28,093 Formicidae, 10,134 Staphylinidae, 1,292 Apoidea, 177 Vespoidea, and 103 Battidae were collected. In addition to insects, 23,462 Acari were also collected.

Regarding the distribution and relative abundance of insects of medical importance, the following can be mentioned:

-In the Culicidae Family, *Culex* was the genus most commonly found in the four localities. *Anopheles*, *Aedes*, *Mansonia* and *Sabethes* were also collected.

As to the most prominent species captured, it is worth mentioning the presence of *Anopheles albimanus*, *A. vestitipennis*, *A. punctimacula*, *A. pseudopunctipennis*, *Aedes taeniorhynchus*, *Mansonia titillans*, and *M. indubitans*. *Anopheles albimanus* has been ordinarily known as the most important transmitter of malaria in Central America and Panama, although at present it is well known that other species are able to transmit this noxious blood parasite in the region.

Aedes taeniorhynchus and the *Mansonia* species are considered important because they are potential transmitters of the Venezuelan equine encephalitis. On the other hand, the *Culex* species are particularly important because of their transmission capability of filariasis and the encephalitis virus.

-Out of 43 species of the *Culicoides* genus (Ceratopogonidae), the highest numbers were found at Arenosa; of these, 16 species were commonly found in the four localities. The highest population density was obtained at Arenosa, and the lowest at Paraíso.

Among the anthropophilic species collected, it is worth mentioning in rank of importance the following: *C. furens*, *C. guyanensis*, *C. reticulatus*, *C. camposi*, *C. iriartei* and *C. paraensis*, the latter being considered as a transmitter of the "oropouche" virus. This group was most abundant during the rainy season, although this was not true for all the species. Their predominance varied within the different locations.

-Although the total number of individuals of the genus *Lutzomyia* (Psychodidae) was relatively low, six out of seven species ordinarily known for their anthropophilic habit and for acting as transmitters of leishmaniasis disease were collected. These species were *L. gomezi*, *L. olmeca*, *L. panamensis*, *L. pessoana*, *L. trapidoi* and *L. ylephiletor*.

Gamboa was the location where the greatest number of specimens and species were obtained. With respect to the influence the wet or dry season may have had on the populations of these groups, it seems it had little effect, except for *L. panamensis*, which was severely affected by the dry season.

-The genus *Chrysomyia* of the Family Calliphoridae was represented by four introduced species. These seem to have displaced a native species, *Cochliomyia macellaria*, a necrophagous fly, in the sampling sites.

Using the various sampling methods, it was possible to observe a high degree of diversity in groups of beneficial insects totaling 56 Families. Of these, 31 Families belong to the Hymenoptera. It is important to mention that spiders were always present in all the sampling sites.

The presence of insects important to forestry or agriculture was not particularly prominent; however, several crop and forestry pests were collected.

In conclusion, important insect groups of medical importance which are influenced by humid environments were found in considerable and stable population densities due to the prevailing conditions in the study area.

The Family Culicidae was represented by insect species and genera known to be transmitters of diseases that affect man, as well as species of *Culicoides* (Ceratopogonidae) and *Lutzomyia* (Psychodidae).

The diversity and abundance of insect groups found is common of the surveyed areas, where little or no predominance of any group or species was observed, as it frequently happens in more disturbed environments.

(3.2) Herpetology

The inventory of amphibians and reptiles was performed in six study sites: (1) Cirí, (2) Sherman, (3) Gaillard Cut (Corte Culebra), (4) Cocolí, (5) Pequení, and (6) Tranquilla. Each site was visited and sampled on five occasions during the 16 month study. Samplings were made approximately every three months. The sampling method consisted of generalized searches and walks along transects, complemented with the use of anuran vocalizations to determine the presence of some species, and questions posed to inhabitants about the threatened or endangered species in the area. The most important results and conclusions derived from this study are the following:

-During the study, a total of 60 species of amphibians and 58 species of reptiles were found. The number of species observed per site varied between 42 and 60, Cirí being the site containing the lowest diversity and Pequení the highest diversity. This could be partly associated to the existence of various types of habitats in Pequení, whereas Cirí is pasture land containing very reduced areas of forest.

-Two presently undescribed species were found during the study. A frog of the genus *Atelopus* and a fuscoauratoid *Anolis* lizard, which were known to exist in the area since about two decades ago. Also, the distribution range of the dendrobatid frog *Phyllobates lugubris* was extended.

-The species composition and their abundance varied among the study sites. Only 8 species of amphibians and 4 of reptiles were found in all the study sites, four of them being abundant in these sites: the frogs *Centrolenella fleischmanni*, *Eleutherodactylus fitzingeri* and *Hyla microcephala*, and the lizard *Anolis limifrons*. In general, the anurans seem to be more abundant than any other group of amphibians and reptiles. This abundance could be attributed to the conspicuousness of the males of several anuran species that congregate and call from the surroundings of bodies of water. Snakes are relatively scarce, being observed infrequently.

-The threatened and endangered species such as the caiman (*Caiman crocodilus*), the crocodile (*Crocodylus acutus*) and the green iguana (*Iguana iguana*), with the exception of the first one, are uncommon in the study sites. At those sites were caimans were found they were numerous, not so in the case of the crocodiles. In the sites inhabited by man, the green iguana is infrequently seen, because it is indiscriminately hunted, even during the closed hunting season.

-Walks along the transects showed the existence of a seasonal pattern in the abundance of some anurans. The frogs of the forest floor tend to concentrate in the moist areas along the margins of the streams during the dry season, and with the beginning of the rains they disperse throughout the moist forest floor. Some anurans aggregate to breed along the margins of ponds and streams during the wet season, but they are absent during the dry season. This seasonality in the reproductive behavior of several species of anurans is evident with the beginning of the rains and the formation of choruses within the surroundings of appropriate breeding sites.

(3.3) Ornithology

This study comprised the avian fauna related to tropical rain forests, open areas (grasslands), littoral and aquatic habitat, and the coastal marine zone. A total of 405 bird species were recorded out of the 564 found in the area within the last 150 years.

The most important results and conclusion from this inventory are:

-The forest habitat contained more species than the aquatic and littoral, the open area, and the marine habitat.

-Gaillard Cut, Pequení, the North Entrance to the Canal and the South Entrance to the Canal maintain some forest, and thus contain more species than Tranquilla and Cirí, where pasture lands predominate.

-Threatened and endangered species inhabit the surveyed areas; also are present birds of prey, raptors and sparrows.

-Eighty five migratory species out of the 122 registered for the country were found; certain species were in transit and others were wintering.

-Out of the 480 local species registered, 326 were located during the study period. In each habitat, and in each place, the number of resident species and individuals was greater than the migratory species.

-In general, for each place and for each habitat, seasonality was observed, where the number of species and individuals grew with the progress of the rainy and the migratory seasons. The maximum abundance was reached during the climax of the rainy season and

towards the peak of the north-south migration, in November, and later decreased in the dry season. This was very obvious for the migrants, where big groups were observed during their return flights towards the north, during February-March.

-The resident birds use the study area for all the activities that allow them to survive there in the current conditions.

-A new species was registered, *Junco hyemalis* (Linnaeus, 1758) for the ornithologic fauna of Panama, and several others for the area of the Panama Canal.

(3.4) Mammals

A species inventory of the mammals present in the area of the Panama Canal was carried out. The area was qualitatively surveyed and divided into 20 regions according to the state of the habitat. A total of 12 specific sites were visited by two teams of biologists, one concentrating on bats and the other on non-volant mammals.

The bat team placed mist nets at ground level and at about six meters above ground, at each site for each of two nights at each site. Netted animals were identified, sexed, weighed, marked with a temporary mark and released. In addition to bats, all sightings of non-volant mammals were also recorded.

The non-volant mammals were sampled at specific sites by setting out 5 lines of 10 traps each. Trapped animals were identified, sexed, roughly aged and released. In addition, mammal tracks, fruits or seeds that are eaten in specifically identifiable ways, identifiable vocalizations and other reliable signs, were recorded at each site.

A computer stored map of the study area was prepared and the data for each species entered into this.

The most prominent results and conclusion from the mammal inventory are the following:

-A total of 41 positively identified bat species was netted; in addition, two more have been identified to genus but not yet to species. Two species (*Furipterus horrens* and *Lichonycterus obscura*) have not been netted in the study area before. Eisenberg (1989) lists bats as probably occurring through Panama if they have been found in Costa Rica and Colombia or elsewhere on both sides of Panama, and lists 110 species as occurring in Panama. Most bats can only be positively identified in the hand; some of those assumed to be here have not actually been identified in Panama. A total of about 53 species has been netted on Barro Colorado Island, where netting has been most intensive in Panama. The true number of species actually present in the study area is thus probably between 53 and 110.

-Some species of mammals are very rarely seen because they are rare, others because they are cryptic, arboreal and/or nocturnal.

-The bushdog (*Speothos venaticus*) falls into the first of these categories. No specimen has ever been collected further West than the Cerro Pirre region of the Darien and there has never been even a suspicion that bushdogs exist in the study area. But one recent sighting by a pair of Smithsonian scientists and another by two ecotourist guides make it appear probable that there are at least a few (perhaps only one group of three) bushdogs in the area.

-The silky or pygmy anteater (*Cyclopes didactylus*) in the Order Edentata, falls into the second category. It is a small animal which is totally arboreal, nocturnal and very cryptic in the daytime sleeping position, and it does not have a bright "eyeshine" in the light of a headlamp so that it is difficult to see even when it is active. Only one specimen of *Cyclopes* has been observed in the present study, and two others have been reliably reported. The species is probably considerably more common in the study area than the data indicate.

-The overall impression is that the area of the Parque Nacional Soberanía, the Barro Colorado Nature Monument and the west bank of the canal opposite Gamboa together constitute a refuge for many mammalian species which should be more widely distributed in Panama, and that hunting and habitat destruction have rendered such areas as the land around the Trinidad arm of Gatun Lake and the area around Alajuela Lake practically sterile with regard to non-volant mammal species. Even in areas such as the mouth of the upper Chagres, where it enters Alajuela Lake, the forest appears to be in good condition but one does not hear howler monkeys (*Alouatta palliata*) at dawn or dusk. Howler monkeys are seldom persecuted (local hunters deny that they eat them) and their total absence from what appears to be eminently suitable habitat indicates that other, more popular, game species have been entirely eliminated. Since many of these game species are important seed dispersers, their absence may be presumed to have already precipitated a decline in the diversity of tree species in the area.

b) FRESHWATERS

(1) Water Quality

Sampling and field measurements were accomplished according to the terms of reference (TOR), followed by laboratory analysis to determine the corresponding parameters and compounds.

Available data and results are used to evaluate the state of water quality and its variation according to the season of the year. Emphasis was placed to define and evaluate the individual water quality of Lake Alajuela, Lake Gatun, and their tributaries. The study provides information which describes the role of various parameters concerning the water quality of the system.

Consequently, the following major factors are recognized to affects the water quality in the area:

-Natural changes due to seasonal variations of the area climatology and hydrography.

-Indirect induced changes caused by deforestation of the area, which contributes to increased sedimentation, a relevant aspect in the case of Lake Alajuela.

-Changes induced through the direct introduction of tributary rivers into lakes Alajuela and Gatun.

-Changes induced through direct pollution due to sewage discharges into the Panama Canal freshwater system.

The most important results and conclusions from this study are the following:

-There are seasonal changes in lakes Alajuela and Gatun. Contrary to Gatun Lake, Alajuela Lake shows thermal stratification during the rainy season. Distribution of dissolved oxygen is of a clynograde type. Higher concentrations of dissolved oxygen in the hypolimnion, as compared with the metalimnion, is due to dense currents of tributary rivers which provide oxygen to the deep waters of Lake Alajuela, except during the dry season.

The moderate oxygenation of subsurface waters of the lake during the dry season is supplied by winds, which induces the mixing process and destroys the thermal stratification present during the rainy season.

-There is an interaction between these two systems. According to the relatively low concentrations of dissolved oxygen and similar concentrations of nutrients in the bottom waters, the characteristics of Lake Alajuela derived from its tributaries, are perceived close to Gamboa, and even Paraiso, throughout the year.

-Along the Gatun Lake there is no thermal stratification during the whole year. With few exceptions, the water is very well oxygenated; the concentration of BOD, suspended solids and turbidity are low. In general, the water is free of total and fecal coliforms, and the bacterial levels are lower than the international standard for recreational waters. Sediments of Gatun and Alajuela lakes frequently present very high values of organic matter. However, there is no evidence that could indicate a serious pollution of the Panama Canal freshwater system.

-The Lake Alajuela is considered to be meso-eutrophic, this represents the third stage of eutrophication according to the general limnological classification.

-The Gatun Lake is defined as mesotrophic, in the second stage of eutrophication.

(2) **Sediments Quality**

Results of granulometric analysis from 7 sampling stations in Gatun Lake revealed that sediments in the areas of Darien and Bajo island are mostly made up of silts and clays. The remaining stations sediments had an important sand fraction.

Regarding the quality of the sediments, the chemical analysis have revealed the following:

-Total nitrogen in the sediments of the study area presented a constant distribution with values ranging between 200 and 900 ppm which, in general, is a very high concentration. The observed ratio between total organic carbon and total nitrogen ranged between 10:1 and 15:1.

-The concentration of metals in the sediments is within the normal ranges and corresponds to the values usually found in igneous rocks. There is no evidence of metal contamination in the sediments.

-The analysis of high molecular weight hydrocarbons revealed that, in general, accumulation in the sediments is very low (19.90 to 58.60 $\mu g/g$ of dry sediment). The exception is the area at the Gatun anchorage where values up to 168 $\mu g/g$ of dry sediment have been recorded. Distribution in the concentration of hydrocarbons seems to be related mostly to the transit of ships in the canal and the time ships remain at the anchorage sites in the Gatun Lake.

(3) **Aquatic Macrophytes**

The collected information on the distribution of floating aquatic macrophytes reflects a clear temporal and/or seasonal as well as cultural situation (aquatic weed control).

The most relevant results and conclusions from this study are the following:

-The plant community displays a greater variability in its abundance in response to seasonal changes. Most are the free floating macrophytes.

-The spatial and/or temporal distribution of some floating macrophytes, i.e. *Pistia* sp., as well as their abundance, seem to be associated with more long lasting cycles rather than seasonal climatic changes.

-In areas subject to the control of submerged and floating aquatic vegetation using manual, mechanic and chemical methods for a period of about 70 years, i.e., the sector of the Chagres River at Gamboa and other canal operational areas, the natural successional processes are disrupted. This causes an apparent decrease in diversity, and a clear dominance of species best fit to this system of aquatic weed control.

-Shoreline and/or emergent macrophytes, subject to periodical or seasonal floods, have greater stability within the seasonal cycles, and play an important role in the natural successional processes.

-In the aquatic ecosystem of the Panama Canal, specially in the Gatun Lake, the most widespread submerged macrophyte with the greatest biomass continues to be the *Hydrilla verticillata*, *Hydrilla* sp. and *Chara* sp. These macrophytes are colonizing parts of Lake Alajuela associated to recreational boat activities.

-All of the aquatic macrophytes identified during observations in this inventory have been recorded in previous studies.

-A very important aspect, from the ecological point of view, has been the accidental introduction in Gatun Lake (1983), of the snail *Pomacea* sp. Due to its great voracity, its high biotic potential and its present preference for *Hydrilla*, this organism has turned into an efficient biological control agent. The dispersion of the snail in the whole lake is being favoured intentionally by dwellers near lake villages to solve problems of access and aquatic mobility to their homes and working sites.

-Observations from the landing at Arenosa, scanning the shoreline zone toward the South and North, revealed that the snail *Pomacea* sp. has almost erradicated *Hydrilla* sp. from the shoreline. In most cases *Chara* sp. has replaced *Hydrilla* sp.

(4) Benthos

Benthos samples were taken at seven stations in Lake Gatun. Collections were made using a Ponar dredge in areas devoid of aquatic weeds with depths greater than 10 m.

The summarized results and conclusions from this study are as follows:

-Granulometric analysis revealed that the profundal benthic region of Gatun Lake was dominated by fine particles, mainly detrital mud. The benthic community was dominated by three taxons: gastropods (snails), pelecypods (clams) and annelids-oligochaetos (aquatic worms).

-The gastropods were represented mainly by *Melanoides*, *Potamopyrgus*, *Gyraulus* and *Lyogirus*, and the pelecypods by *Corbicula*, *Musculium* and *Sphaerium*.

-The families Tubificidae and Naididae were dominated by the annelids oligochaetos, with the prevalence in this group of the tubificid worm *Branchiura sowerbyi*.

-Of less numerical importance were the aquatic insects, nematodes (roundworms) and crustaceans. Greater densities of organisms were recorded at stations located in the mouth of Gatun River, and near the main channel. At this site, because of the proximity to one

intersection of the canal route, the ships must change direction. This requires increased engine power which creates strong turbulence and sediments upheaval. The physicochemical analysis revealed that these stations are subject to a continuous mixture of waters.

(5) **Fish and Macroinvertebrates**

In five samplings, 26 fish species were collected (9 peripheral or marine and 17 freshwater) included in 16 families (7 peripheral and 9 freshwater).

The most important results and conclusions from this fish study were the following:

-Dominant species were represented by *Cichla ocellaris*, *Hoplias microlepis*, *Brycon chagrensis*, *Cichlasoma maculicauda*, *Curimatus magdalenae* and *Rhamdia guatemalensis*, with a total of 86.6% of the catch and 86.0% of the weight.

-Except for the exotic species recently introduced, *Colossoma macropomum*, *Cyprinus carpio* and *Oreochromis niloticus*, the other species collected have been recorded in previous studies.

-Among the macroinvertebrates, five species of decapod crustaceans belonging to three families, and only one species of the recently introduced mollusk *Pomacea* sp., were captured. The most abundant and frequent species was *Callinectes toxote*, contained in more than 60% of the catchs. All these species of marine and freshwater decapods have been recorded in studies carried by Abele & Kim (1989) and Hildebrand (1939).

(6) Commercial and Sport Fishery

The most important freshwater fishing activities in Panama are concentrated in Gatun and Alajuela lakes. At present three types of fishing activities are carried: commercial fishing, subsistence fishing and sport fishing.

The most important species for the above mentioned fishing activities is the peacock bass (*Cichla ocellaris*), introduced accidentally in the Gatun Lake about 1967. Annual production of this species has been estimated between 150 to 300 metric tons for the Gatun Lake, and between 20 to 50 metric tons for Alajuela Lake.

On the whole, it is estimated that the production shares are as follows: subsistence fishing, 50%; sport fishing, 30% and commercial fishing, 25%.

Main centers for sport fishing in the Gatun Lake are Arenosa, Gamboa and Gulick. For commercial fishing the centers are Cuipo, Los Cedros, La Laguna and Gatun River.

In Lake Alajuela, commercial fishing is more important, and this activity is developed by various communities grouped in the "Union de Campesinos del Lago Alajuela", (UCLA).

(7) Aquatic Mammals

Aquatic mammals observations were carried out betweeen September 1992 to June 1993. The most important results and conclusions from the study are the following:

-Only one species of mammals in the study area was genuinely aquatic: the manatee *Trichechus manatus* (Trichechidae; Sirenia). Manatees were introduced in Gatun Lake in 1962.

-There are five species of semi-aquatic mammals, that is, mammals that principally forage in fresh water but spend much time on land, reported for the study area. These are the water opossum *Chironectes minimus* (Didelphidae; Marsupialia); the otter *Lutra longicaudis* (Mustelidae; Carnivora); the capybara *Hydrochaeris hydrochaeris* (Hydrochaeridae; Rodentia); and two small rodents: *Oryzomys couesi* and *O. alfari* (Cricetidae).

-The otter has steadily increased in numbers since the introduction of the peacock cichlid (*Cichla ocellaris*) into the study area in 1967. Otters now range throughout the Gatun Lake area, in the middle and upper Chagres River, over Lake Alajuela, up to major tributaries of these water bodies, and in many lakes and small ponds within the study area.

-The capybara arrived in the Gatun Lake area sometime in the early 60's, having spread westward from the Pacora marshes and down the upper Chagres. Capybaras are now found anywhere where there are grassy patches near bodies of water on both sides of the canal. No information is presently available on the two semi-aquatic cricetids in the area.

c) MARINE WATERS

(1) Oceanography and Water Quality

Seasonal changes in the oceanography and water quality were observed to be as follows:

-The condition of the water mass in the Bay of Panama during the rainy season indicates an uniform distribution of the properties in the water column. This includes the absence of thermal stratification and the presence of a mixed layer with relatively warm water from the surface to the bottom. This mixed layer has a relatively low salinity, low concentration of nutrients, and chlorophyll "a". All of these parameters were uniformly distributed in the water column. The concentration of dissolved oxygen in bottom waters was generally near 5 ppm.

-This study identifies and describes the development of the seasonal upwelling in the Gulf of Panama, during the dry season of 1993. This phenomenon was followed by a significant decrease in the water temperature and a pronounced increase of the salinity in the entire water column. Simultaneously with these changes, there is significant increase in the

concentration of total phosphorus (twice as much as found during the rainy season) and the concentration of nitrates (about three times more than observed during the rainy season). This same pattern was observed with chlorophyll "a".

-In contrast to these changes, the concentration of dissolved oxygen decreased below the thermocline. At the end of the dry season, the annual cycle started again.

-The yearly oceanographic cycle in the Caribbean is similar to that of the Bay of Panama. During the rainy season there is a lack of thermal stratification, while the properties are distributed uniformly in the water column. The water column indicates a rather high temperature, low salinity, high concentration of dissolved oxygen, low concentration of dissolved nutrients and chlorophyll "a".

-During the dry season the salinity of the water column is increased, which together with colder air masses that blows onshore increases the density of the surface water promoting the sink of of the water mass. This vertical mixing carry to the surface level a subsurface water mass with a low concentration of oxygen and high concentration of nutrients. By the end of the dry season, the annual cycle starts again.

-The study of the water quality, both in the Pacific and the Caribbean, showed slight levels of pollution.

-The analysis of volatile organics from samples collected during the first half of this project revealed that such compounds are not found in the area. The BOD concentrations were low and in general, the counts of total and fecal coliforms are below what the water quality standards indicate for recreational waters. This inventory has indicated that the marine area near the Fort Amador Causeway, an important recreational area, has a fairly good water quality. This same condition was observed in the studied area in the Bay of Limón, on the Caribbean side.

(2) Sediments Quality

Granulometric analysis of marine sediments revealed that 91 % (64 out of 70 samples) of all samples showed a typical muddy sediment composed of silts and clays (< 80 microns) in both the Pacific and the Caribbean study areas. The chemical analysis brought the following:

-The concentration of total nitrogen in the sediments from the Pacific remained fairly constant throughout this study. In general, the concentration of organic nitrogen ranged from 100 to 350 ppm (0.10 to 0.35%). The ratio between the total organic carbon and the organic nitrogen varied from 10:1 to 15:1. The concentration of heavy metals in these sediments indicated a uniform distribution with values similar to those reported by former studies. The ranges of metal concentration are: iron between 10,000 - 60,000, copper 30 - 65 ppm, manganese 400 -500 ppm, and zinc 80 - 135 ppm.

-The concentration of the organic nitrogen in the sediments in the Caribbean remained nearly constant throughout this study, the same as in the Pacific. The concentration of total nitrogen (0.10 to 0.20%) in sediments from the Caribbean is about half of the value normally found in the Bay of Panama. As suggested previously, this might be related to the smaller organic production in the Caribbean or to the higher concentration of dissolved oxygen. In general, the concentration of copper and zinc in sediments from the Caribbean are similar to those measured in the Bay of Panama. However, the concentration of iron and manganese in the Caribbean is higher than the reported for the Bay of Panama.

-In summary, the concentration of heavy metals, both at the Bay of Panama and in the Caribbean, are within the normal range reported for coastal areas.

-The analysis of High of Molecular Weight (HMW) hydrocarbons in the marine sediments revealed that the area with the highest concentrations (49.30 - 67.84 $\mu g/g$ dry sediment) are related to the route of navigation through the Panama Canal, the docks, and the anchorage sites. But in overall, the concentration of HMW hydrocarbons in most of the studied areas were low (< 15 $\mu g/g$ dry sediment) and do not suggest an important accumulation of oil in sediments.

-In general, the concentration of HMW hydrocarbons in sediments decreased as the rainy season progressed.

(3) Corals, Mangroves and Marine Grasses

(3.1) Corals: The total area of the coral reefs in the Caribbean was 204.6 Ha, whereas in the Pacific these were just 3.9 ha. The main characteristic of these coral reefs are the following:

-The most important reefs in the Caribbean, regarding their size, were those of Payardí Island, Largo Remo Island, Galeta Island, Media Palma, and Brujas.

-The coral reefs in the Pacific area were only found in the surrounding islands of Taboga, Urabá, and Taboguilla. The coral reef located northeast of Taboga (in front of the town) is the largest and best developed of the area and covers almost 2 ha.; however, this coral reef is completely dead.

-The diversity of coral species observed in the Caribbean coast is three times greater to that observed in the Pacific. There are 48 species of hermatypic corals and 3 species of hydrocorals in the coral reefs of the Caribbean coast, whereas only 14 species of corals have been observed in the Pacific side.

-Only 11 species of corals were observed in the reef flats in the Caribbean.

-For the first time the genus *Siderastrea* is reported for the eastern and western Pacific, and in addition, a new species of coral is reported. There is the possibility that two new species

of *Siderastrea*, which are very similar to *Siderastrea siderea*, could be reported for the Caribbean.

-The diversity of the corals within the study area represents 53% and 82% of the diversity reported for the Caribbean and Pacific coast of Panama, respectively. The diversity of octocorals is less than 30% of the species reported for the rest of the country.

-The reefs studied along the Caribbean coast have a reduced area covered by life coral (<6%) but a high coverage by macroalgae (>80%). This is clearly evidenced by a disturbance caused by the construction and operation of the Panama Canal and the oil refinery.

-The history of the coral reefs on the Pacific entrance of the Panama Canal has been less dramatic than the one described for the Caribbean, since there was more construction material available from large land excavations in Gaillard Cut and some other areas. However, these coral are subjected to a high runoff and to low sea temperatures caused by seasonal upwelling, thus affecting their distribution.

-In summary, the coral reefs at both ends of the Panama Canal are not in good condition and it is evident that continued lack of management and protection in this part of the coastal zone might continue to adversely affect these reefs.

(3.2) Mangroves: There is a total of 36.08 km^2 (=3,608 ha) of mangrove forests in the study area. The Caribbean coast have a slightly smaller amount (17.11 km^2) compared to the Pacific (18.97 km^2). The Caribbean estimate however is still greater than that of an earlier estimate for the much larger Costa Arriba de Colón (13.41 km^2) which was provided by the Instituto Geográfico Nacional "Tommy Guardia". This was apparently caused by the different definition of mangrove forests, and possibly the different interpretations of satellite photography, compared with aerial photography.

Mangrove forests were observed in the following sites in the Pacific: Perequete, Caimito, Veracruz, Balboa, and Juan Diaz, whereas in the Caribbean mangroves were observed in Chagres, Colon, and Bahia Las Minas.

Eleven mangrove species, including the putative hybrid *Rhizophora* and two forms of *Pelliciera rhizophorae*, were observed in the study area. Several notable features were observed in the studied mangrove forests:

-The occurrence of species within all sections, namely *Laguncularia racemosa*, *Avicennia germinans* and *Acrostichum* sp.;

-The unique occurrence of *Mora oleifera* in the Río Caimito (Note: this site represents the northern extent of this unusual and uncommon tree; notable, since it has the largest cotyledons of any plant), and the putative *Rhizophora* hybrid, *R. harrisonii*, in the Río

Perequeté (Note: there are, however, problems with diagnostic characters for this taxon, and its occurrence is likely to be more widespread);

-The occurrence of both forms of *Pelliciera rhizophorae* on both the Pacific and Atlantic coasts (Note: the distinction between forms has not been noted prior to this report, indicating that occurrences of *Pelliciera* elsewhere need to be revised);

-The different zonation patterns of species and their associations with each other, particularly noting the occurrence of *Laguncularia racemosa* in low intertidal positions and along rocky exposed shorelines of the Pacific coast, while this habitat on the Atlantic coast is occupied by *Rhizophora mangle*.

(3.3) Marine Grass: Ten seagrass meadows were studied in the Caribbean coast. These proved to be similar to that described in the vicinity of Bahía Las Minas. In contrast, there are no seagrass meadows in the Pacific study area. The following conditions were observed in the seagrass beds in the area:

-Extensive seagrass meadows were found in locations wherever gradual coastal slopes prevailed and where water clarity was adequate.

-Densities of *Thalassia*, *Syringodium filiforme*, *Halodule wrightii*, and algae varied from site to site.

-*H. wrigthii* was typically found in very shallow water adjacent to shorelines or on tidally exposed sand bars.

-*T. testudinum*, the most abundant seagrass, covers most shallow bottoms in areas where water clarity is adequate.

-*S. filiforme* was usually mixed with *T. testudinum* along the deeper edges of grassbeds or it occurred in monospecific seagrass stands at depths past of the point of penetration of *T. testudinum*.

-A fourth seagrass species, *Halophila decipiens* was found mixed in with dense beds of algae along the deep fringes of seagrass beds.

-The zonation pattern throughout this area is also typical of many other areas in the Caribbean.

-Thirty two species of fish were collected over seagrass beds within the study area. Several species in this collection are sought by local fishermen. They are present as juveniles in seagrass beds because of the protective covering provided by the seagrass leaves. They also feed on many of the invertebrates and fish that are abundant in Panama's seagrass beds.

-Despite the fact that total acres of seagrass are relatively small within the study area the ecological importance of the grasses should not be overlooked. Seagrasses provide juvenile and adult habitat for many species as demonstrated by the numerous fish and invertebrate species collected in this study. The loss of any significant part or the seagrass community on this coast may result in decreased stocks of the fishes that are commonly eaten by local inhabitants.

(4) Benthos

Benthic collections were quarterly performed in the Pacific and in the Caribbean. 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) yielded 171 taxa including one new isopod species of *Cyathura* found offshore from the Limon Bay stations on the Caribbean side.

The results from this study revealed the following:

-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: MB-01 and Caribbean: MB-09 and MB-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.

-Polychaeta, Crustacea and Mollusca were the dominant groups accounting for almost 90 % of total benthic organisms counted. Polychaeta was found in almost all stations within each sampling period. A total of 57 species or crustacean taxa (grouped in 13 taxonomic sub-categories: 1 Class, 6 Orders, 3 Infraorders and 3 Sections) were found. The peracarideans dominated the benthic community in terms of relative abundance, comprising about 20 % of total crustaceans, and relative diversity being represented by five orders (20 species): Mysidacea (2), Cumacea (2), Tanaidacea (1), Isopoda (7) and Amphipoda (8).

-Within the superorder Peracarida the dominated groups found were gammaridean amphipods and isopods (*Cyathura spp.*). With regards to the Mollusca a total of 58 living species were identified, of which 15 species are Gastropoda (14 genera in 12 families) and 43 species are Bivalves (24 genera in 14 families). Bivalves belonging to the Tellinidae, Veneridae, Corbulidae, Nuculanidae and Solecurtidae families were the most common molluscs found in the sediments.

-The distribution of benthic taxa, both in the Pacific and in the Caribbean, is fairly homogeneous with no apparent relationship with depth. However, mean abundance (277 vs. 175) and number of species or taxa (25 vs. 15) was greater in the offshore stations (MB-12 through MB-14) than those located within Limon Bay in the Caribbean.

(5) Meroplankton

Collections of meroplankton were carried out in July, August, November 1992, February and May 1993. The study has provided information on the abundance of eggs and larvae of fish and invertebrates.

Results showed the following:

-A peak of abundance of meroplankton during November 1992, especially at station MM-02 (Pacific) and MM-08 (Caribbean), both located at the entrances to the Panama Canal. The highest abundance of eggs of engraulid and clupeid fish was observed in the Caribbean area (17,560 and 9,091 eggs/100m^3), whereas in the Pacific the counts revealed densities of 3,503 and 2,861 eggs/100m^3 for clupeid and engraulid fish.

-The most common larvae of invertebrates at both sides were the Zoea, postlarvae of penaeid shrimps, and pteropod, gastropod, and bivalve larvae. In the Pacific area, the postlarvae of penaeids were particularly abundant 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.

-Larvae of engraulid, carangid, mugilid, and sciaenid fish were common in samples collected during November 1992 at both entrances to the Panama Canal (stations MM-02 and MM-08, respectively). In general, the overall abundance of meroplankton is higher in the Caribbean than in 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.

(6) Fishes and Macroinvertebrates

(6.1) Fish: A total of 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 results and conclusions from this study are the following:

-The highest diversity of sublittoral fish was related to the proximity to estuarine areas that are nursering 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 stations 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. This statement is supported by the high incidence of small sized fish collected within these samples.

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

-Regarding the importance of these fish within the food web, the most frequent species in both oceans are ranked as secondary consumers those that eat animals and plants (carangid and bothid fish in the Pacific and Caribbean, respectively), followed by primary consumers which feed on plankton and detritus as the gerreid fish.

-Among the commercially important fish studied in this project, the snappers *Lutjanus guttatus* and *Diplectrum euryplectrum* (Pacific), and *L. synagris* and *D. formosum* (Caribbean) showed a gut content mostly comprised by crustaceans (shrimps, stomatopods, and crabs) and small fish. These species are placed in the category of third level consumers (exclusively carnivorous).

-The study of the gonad maturation of these fish revealed several spawnings: in August, in October, and during April.

-The genus *Diplectrum* showed sexual inversion, or protandric hermaphrodite, in both oceans (males changed into females) which explained the predominance of a single sex, mostly females, in the collections. The stages of gonad maturation were observed to occur almost simultaneously in both oceans, which is probably related to the seasonality of the climate.

(6.2) Macroinvertebrates: A total of 105 species of marine invertebrates were collected during this inventory, 56 species collected in the Pacific and 49 in the Caribbean. On the whole, 13,407 specimens were collected during the 5 quarterly samplings, 7,955 from the Pacific and 5,452 from the Caribbean.

The most important characteristics from this population are the following:

-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.

(7) Commercial and Sport Fishery

Most of the fishery resources of the country are located in the Pacific. In general, the fishery resources in the area have the following features:

-The most recent fishery prospections suggest that the extractable biomass in the Gulf of Panama might be around the 400,000 m.t. per year. Most of this fish stock is comprised by demersal fish and squids which are not fished (more than 100,000 m.t.). The demersal fish stock is estimated in the vicinity of 200,000 m.t. and it is mostly comprised by estromateid fish (dollar fish), some species of serranids, and snappers.

-In the Caribbean, the most important resources are the demersal species. Among these are: the snappers *Lutjanus vivanus*, *L. synagris*, and *Rhomboplites aurorubens*, sharks as *Rhizoprionodon sp.* and *Squalus cubensis*, some carangid fish (jacks), and the pink shrimp *Penaeus duorarum*. Bottom trawling is the best fishing gear for the snappers and the shrimps, and there is 1,000 km^2 of marine bottom suitable for this type of fishing.

-Most of the fishing effort is devoted to the penaeid shrimps stock, the anchovies and herring for the production of fish meal, and fish (mostly demersals) for human consumption. This fishing activity involves some 10,000 people and it is mostly concentrated along the Pacific coast of Panama. In the Caribbean, the fishing activity is of low intensity and mostly of the subsistence type.

-Sport fishing in Panama is based on a few species and in general, sport fishery is considered a low intensity activity and the catch is believed to be small.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

11. Economic Analysis and Impact on Users

Summary

1993

Summary

1. Appraisal of the Project

(1) Economic Appraisal

1) Premises of the appraisal

(a) Source for basic data

Traffic projection	:	Commodity and Traffic Projection, Phase II Final Report
Cost	:	Engineering and Cost Estimate, Phase II Final Report

(b) Project life and period of operation

Project life	: 2010 (base year) – 2120
Period of operation	: 2020 – 2120

(c) Social Discount Rate (SDR) in the year 2010 (see I.3)

a) SDR in the year 2010 : 5%/annum (recommended by the Study Team)

b) Assumptions behind the SDR estimate:

- The U.S.A. and Japan are to be the main beneficiaries of this project, based on Origins and Destinations (OD) of major sea cargos.
- The economic growth rates and market soundness of the two countries around the year 2010 are conjectured.

2) Economic appraisal of the project

(a) Items adopted to calculate the Cost-Benefit Ratio (CBR) and Internal Rate of Return (IRR) of the project

Benefits : Direct benefits from the project such as

- Route-shifting benefits by over-panamax vessels

- Size-shifting benefits
- Route-shifting benefits by under-panamax vessels

Costs : - Project costs (Construction and Indirect costs)
- Operation, Maintenance and Management costs

These benefits and costs are measured on the With-Without Project principle.

(b) Economic efficiency of the Alternative Canal Project

Table 1-1 Economic Efficiency of Alternative Canals

(million US$)

Alternatives	C B R						Estimated IRR
	undiscounted	3%	4%	5%	6%	7%	
High-Rise- Lock 150.000DWT (Average)	151,928	22,965	14,427	9,710	6,912	5,141	6.0%
	24,977	10,133	8,634	7,618	6,879	6,308	
	6.08	2.27	1.67	1.27	1.00	0.81	
High-Rise- Lock 150.000DWT (Dry Year)	151,928	22,965	14,427	9,710	6,912	5,141	5.9%
	25,172	10,359	8,850	7,823	7,070	6,486	
	6.04	2.22	1.63	1.24	0.98	0.79	
High-Rise- Lock 200.000DWT (Average)	156,271	23,711	14,922	10,060	7,173	5,342	5.5%
	27,273	11,588	10,012	8,949	8,176	7,581	
	5.73	2.05	1.49	1.12	0.88	0.70	
High-Rise- Lock 200.000DWT (Dry Year)	156,271	23,711	14,922	10,060	7,173	5,342	5.5%
	27,312	11,705	10,132	9,065	8,288	7,686	
	5.72	2.03	1.47	1.11	0.87	0.70	
Sea Level Case(a) (Average)	163,656	24,540	15,422	10,393	7,411	5,522	4.0%
	35,237	17,098	15,285	14,075	13,210	12,557	
	4.64	1.44	1.01	0.74	0.56	0.44	
Sea Level Case(b) (Average)	163,656	24,540	15,422	10,393	7,411	5,522	4.1%
	31,326	16,608	15,155	14,186	13,493	12,970	
	5.22	1.48	1.02	0.73	0.55	0.43	
Sea Level Case(c) (Average)	163,656	24,540	15,422	10,393	7,411	5,522	3.9%
	36,639	17,932	16,059	14,808	13,913	13,236	
	4.47	1.37	0.96	0.70	0.53	0.42	

Upper : Total Present Benefits
Middle : Total Present Costs
Lower : Cost-Benefit Ratio

The High-Rise Lock Alternatives all have CBRs of over 1.0 (1.11-1.27) at a 5 percent Social Discount Rate. The CBR is lower in the case of Dry years than in that of Average years because the brunt of expenses comes earlier during Phase II of construction, although the differences are marginal. The difference in CBR between a 150,000 DWT canal and a 200,000 DWT canal is larger than that between an assumed sequence of Dry and Average years. CBRs for a 200,000 DWT canal approach 1.0, reflecting the fact that additional enlargement of maximum draft size does not add many benefits compared to the additional cost. This is because a 150,000 DWT canal would attract almost all route-shifting cargo carried by over-panamax vessels and a 200,000 DWT canal would attract very little more. Sea Level Alternatives show relatively low CBRs for the same reason. Their CBRs are 0.70-0.74, where present value of benefits remain considerably below that of present economic costs.

Very rough estimates of IRRs are also shown in Table 1-1. IRRs for a High-Rise Lock 150,000 DWT canal are 6.0 percent in the case of Average years and 5.9 percent in the case of Dry years. Both figures are 5.5 percent for a 200,000 DWT canal. In the case of a Sea Level Canal, the highest IRR is 4.1 percent. IRR for other Sea Level Canals are 4.0 percent and 3.9 percent.

Economic evaluation of alternatives depends to a great extent upon the level of Social Discount Rate. Judging from a CBR evaluated at a 5 percent of Social Discount Rate, both High-Rise Lock Alternatives are found to be economically feasible, while Sea Level Alternatives are not.

(2) Overall Appraisal of the Project

1) (Summary) Other benefits and impact of the project

Aside from the direct benefits adopted in the calculation of the CBR and IRR of this project, the following expected benefits and impact can be summarized:

Item	Description of other benefits and impact
Improvement of navigation safety	-The planned alternative canals would generally provide existing/potential users with more navigation safety than in the case of the existing canal. This is because their design standards of locks would be more in keeping with recent developments in ship construction and because alternatives have more allowance for vessels navigation.
Induced trade	-In the case of a 150,000 DWT canal, 68 million US dollars or 563 thousand tons of world trade would be induced in the year 2020, which is very small, compared with the GDPs of the beneficiary countries and the volume of transit cargo.
Saved cost-induced income	-In the case of a 150,000 DWT canal, 921 million US dollars of incremental income to the world economy is expected in the year 2020, which are very small, compared with the GDPs of the beneficiary countries.
Influence on shipping industry	-Only demand for about 20 larger ships of Full Container size is expected, which would bring in about 1,600 million US dollars at 1990 prices (less than 5% of current world annual ship construction).
Impact on adjacent countries	-Movement of labor excluding skilled labor from the adjacent countries would not be expected due to a relatively small number of new jobs created (68 thousand), almost all of which would be absorbed in Panama. -2 to 28 million US dollars of imports to Panama from the adjacent countries are expected. -The international trade of the adjacent countries would be heavily influenced by the canal price due to their high dependency on the Panama Canal.

Impact during construction	-In the case of a 150,000 DWT canal, and for 10 years from Phase I of construction: Expenditure in Panama : 845 mil.US dollars Induced industrial production in Panama : 1.518 mil. US dollars New jobs created : 68,000 jobs Panama national income induced from local expenditure : 1,685 mil. US dollars -Concentration of population in Panama City and Colon is expected. -There might be a widening difference in income distribution among the states and an increase in the social cost of keeping peace and order.
Impact of tolls	-In the case of a 150,000 DWT canal, Expenditure of Panama Canal Authority and Government : 904.3 mil. US dollars in the year 2040 Induced industrial production in Panama : 1,369 mil. US dollars in the year 2040
Socio-cultural Impact	-Necessity of preparing social infrastructures and public services for the increasing people in Metropolitan Region. -Decreased allocation of the government resource to general use.
Environmental Impact	-Water pollution due to lowered water table of the Sea Level Canal. -Hydrogical and geomorphical problems at the place for disposal of excavated earth and rock. -Inter-ocean migration of species.

2) Overall appraisal of the project

As stated in (1) above, the High-Rise Lock 150,000 DWT and 200,000 DWT alternatives were found to be economically feasible in the Cost-Benefit analysis on condition of a Social Discount Rate of 5 percent. Sea Level Canal Alternatives, on the other hand, are not economically feasible due to the relatively high construction costs compared with the expected benefits.

On the other hand, the other types of benefits and impact of the project summarized in (2) above are almost all favorable, but with relatively small impact on the aspects concerned. The impact is not so significant as to upset the economic infeasibility of the Sea Level Alternatives.

Consequently, it can be concluded that realization of the High-Rise Lock 150,000 DWT and 200,000 DWT alternatives would not encounter any serious problem when the investment efficiency is evaluated from the viewpoint of the world economy, while Sea Level Canal Alternatives need to be considered with great caution.

2. Transit Cargo Projection (Premise of the Appraisal)

(1) Transit Cargo Projection from the Year 1990 to 2060

Cargo (mil. tons)

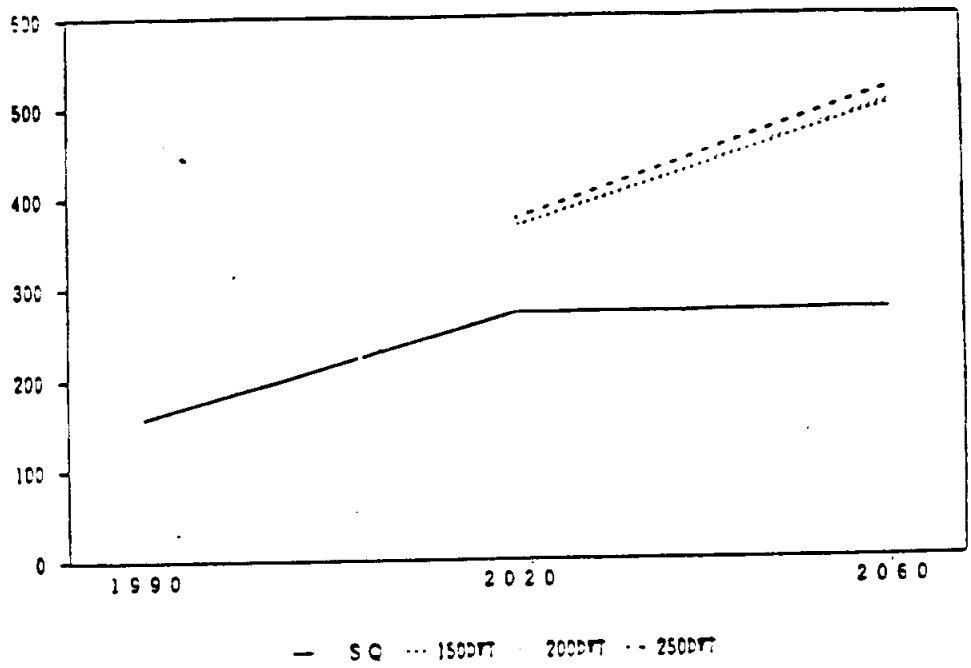

Fig. 2-1 Transit Cargo from 1990 to 2060

- Almost all incremental transit cargo generated by Alternative Canals (the difference in the transit cargo volume passing through the Alternative Canals and the SQ Canal) would be generated in the case of the 150,000 DWT Alternative Canal.

- This is because this Alternative is almost sufficient for realization of the three types of benefits in terms of volume.

- Transit cargo along the 150,000 DWT Alternative Canal is expected to increase at a rate of 0.8 percent per annum for the period of the year 2020–2060.

(2) Transit Cargo by Canal Alternatives, Ship Sizes and Ship Types from the Year 2020 to 2060

- In the year 2020, transit cargo carried by only three types of ship, Combined and Dry Bulk Carriers (CD), Full Containers (FC) and Oil Tankers (OT), would be affected by the Canal Alternatives, while that carried by the other seven types of ship would not be affected. Effects on the first three types would be realized through:

  (a) a shift of ships of these types to the alternative canals, and

  (b) an increase in the size of ships currently transiting the SQ canal

- From the year 2020 to 2060, the following factor would contribute to an increase in transit cargo, along with the above two factors:

  (c) expansion of capacity brought about by the alternative canals. In about the year 2020, the capacity of the SQ canal will be fully utilized. The alternative canals with larger capacities than that of the SQ canal would be able to accommodate excess ships of under-panamax size which would prefer to pass through the Panama Canal. Transit cargo carried by CD, FC and OT would increase through all three factors, while increases in that carried by the other seven types of ship would be realized through only the third factor.

Table 2-1 Transit Cargo by Canal Alternatives, Ship Sizes, and Ship Types (Year=2020)

(1,000 tons)

		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
C D	S Q	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
F C	S Q	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
O T	S Q	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
C B	S Q	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
C T	S Q	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
C G	S Q	838	7.858						8.696
	150	838	7.858						8.696
	200	838	7.858						8.696
	250	838	7.858						8.696
L P	S Q	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
R E	S Q	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
R R	S Q	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
V C	S Q	90	2.414						2.504
	150	90	2.414						2.504
	200	90	2.414						2.504
	250	90	2.414						2.504
TOTAL	S Q	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

Table 2-2 Transit Cargo by Canal Alternatives, Ship Sizes, and Ship Types (Year=2060)

(1,000 tons)

		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
C D	S Q	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
F C	S Q		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
O T	S Q	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
C B	S Q	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
C T	S Q	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
C G	S Q	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
L P	S Q	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
R E	S Q	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
R R	S Q	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
V C	S Q	104	2.816						2.920
	150	104	2.828						2.932
	200	104	2.828						2.932
	250	104	2.828						2.932
TOTAL	S Q	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

Note : The cargo volumes in Table 2-1 and 2-2 were calculated by summing up the cargo volumes listed in CTP(II) Final Report (FR).

3. Direct Benefits of the Project

(1) Benefits Adopted in Calculating the Cost-Benefit Ratio (CBR) and Internal Rate of Return (IRR) of the Project

1) Types of direct benefits

The direct benefits of this project maybe recapitulated as follows :

Table 3-1 Direct Benefits in the EAJU Study

Route-shifting benefit by over-panamax vessels	Benefits for cargos on over-panamax vessels which can pass through a new canal due to the enlargement of the canal
Size-shifting benefit	Benefits for cargos now carried on smaller vessels in the SQ canal and shift to larger vessels after the operation of a new canal
Route-shifting benefit by under-panamax vessels	Benefits for cargos on under-panamax vessels which cannot use the SQ canal because of the capacity limitation and come to use a new canal after the operation of a new canal

2) Formulae for estimating direct benefits

Route-shifting benefit by over-panamax vessels

$$B_o = Q_o \times (C_s - C_p)$$

B_o : benefit for route-shifting cargos carried by over-panamax vessels ($)

Q_o : cargo volume carried by over-panamax vessels which shift routes to

C_a : unit transportation cost of the least expensive alternative route ($/ton)

C_p : unit transportation cost of the canal route ($/ton)

Size-shifting benefit

$$B_s = TC_b - TC_a$$

B_s : benefit for size-shifting cargos ($)

TC_a : total transportation cost for cargos utilizing the new canal which were SQ transit cargos before the new canal opened ($)

TC_b : total transportation cost for SQ transit cargos

Route-shifting benefit by under-panamax vessels

$$B_u = Q_u \times (C_a - C_p)$$

B_u : benefit for route-shifting cargos carried by under-panamax vessels ($)

Q_u : cargo volume carried by under-panamax vessels which shift routes to the new canal (tons)

C_a : unit transportation cost of the least expensive alternative route ($/ton)

C_p : unit transportation cost of the canal route ($/ton)

(2) Estimation of Direct Benefits

1) Summary of direct benefits in the year 2020 and 2060

Table 3-2 is a summary of benefits produced by new canals in 2020 and in 2060. As mentioned in previous sections, all of the benefits in 2020 and most of the benefits in 2060 will come from CD, FC and OT.

Size-shifting benefits enjoying economies of scale will be almost the same for all canal sizes both in the year 2020 and 2060.

Compared to benefits in the year 2020, benefits in 2060 will be larger, especially due to route-shifting by over-panamax vessels. The increase in transit demand will be reflected in this benefit.

Route-shifting benefits by under-panamax vessels will be independent of canal size as long as there are no constraints on passage through the canal.

Table 3-2 Summary of Benefits

(1.000 US$)

Benefits case/year	Route-shift by over-panamax	Size-shift	Route-shift by under-panamax	Total
150,000DWT 2020	217,094	255,711	0	472,805
2060	445,406	291,395	324,306	1,061,107
200,000DWT 2020	240,284	255,971	0	496,255
2060	471,264	292,547	324,306	1,088,117
250,000DWT 2020	259,590	255,971	0	515,561
2060	498,970	292,547	324,306	1,115,823

Source : Table II-4-1

2) Direct benefits by type of ship in the year 2020 and 2060

In the year 2020, all of the benefits, and in the year 2060, 97 percent of the benefits would be realized by CD (Combined and Dry Bulk Carriers), FC (Full Container Ships) and OT (Oil Tankers).

Table 3-3 Direct Benefits by Types and Type of Ship
- 150,000 DWT case -

(unit : 1,000 US$ at 1990 price)

		Route-shift by over-panamax	Size-shift	Route-shift by under-panamax	Total
CD	2020	195,275	34,927		230,202
	2060	412,499	20,898	260,128	693,525
FC	2020	16,919	215,933		232,852
	2060	23,053	270,497	3,622	297,172
OT	2020	4,900	4,851		9,751
	2060	9,854		26,203	36,057
CB	2020				
	2060			14,254	14,254
CT	2020				
	2060			3,566	3,566
CG	2020				
	2060			5,552	5,552
LP	2020				
	2060				
RE	2020				
	2060			10,565	10,565
RR	2020				
	2060			379	379
VC	2020				
	2060			37	37
Total	2020	217,094	255,711	0	472,805
	2060	445,406	291,395	324,306	1,061,107

Source : Table II-2-8, II-3-22

3) Direct benefit by Origin-Destination (OD) pair

Table 3-4 and 3-5 present benefits by OD pair for CD, which account for 49 percent of total benefits in the year 2020 and 65 percent in 2060. The five largest benefits by OD pair (in the case of 150,000 DWT canal) are as follows:

Five Largest Benefits for Combined and Dry Bulk Carriers (CD)

(unit : 1,000 US$, %)

(a) in the year 2020

Order	OD		Benefit	Share
1	US EC	- Asia	167,566	72.8
2	S.America EC	- Asia	18,005	7.8
3	Canada WC	- Europe	14,285	6.2
4	Canada EC	- Asia	3,769	1.6
5	Oceania	- US EC	3,534	1.5
	Others		23,044	10.0
	Total		230,203	100.0

(b) in the year 2060

Order	OD		Benefit	Share
1	US EC	- Asia	237,932	34.3
2	Asia	- US EC	86,616	12.5
3	US WC	- Europe	48,278	7.0
4	Canada WC	- Africa	45,360	6.5
5	US WC	- Africa	37,634	5.4
	Others		237,705	34.3
	Total		693,525	100.0

As shown in the above Table, the route between the U.S.A. and Asia remains a major beneficiary of this project in spite of a decrease in CD's share of total benefits from 72.8 percent in the year 2020 to 46.8 percent in 2060.

Table 3-4 Benefits in the Year 2020 (Ship Type : CD)

150,000 DWT
200,000 DWT
250,000 DWT

Northbound (US$)

O \ D	AFRICA	C America East Coast	Canada East Coast	Europe	Middle East	S America East Coast	U S East Coast
Asia	0	39.037	121.432	16.603	-	45.570	3.160.146
	0	39.024	121.432	16.586	-	45.570	3.160.146
	0	39.024	121.432	16.586	-	45.570	3.160.146
C America West Coast	7.235	103.860	-	146.612	-	20.451	286.668
	7.235	103.860	-	146.612	-	20.451	286.668
	7.235	103.860	-	146.612	-	20.451	286.668
Canada West Coast	1.402.573	21.075	-	14.285.163	572.792	1.103.319	235.410
	1.402.573	21.084	-	14.741.893	572.792	1.505.754	235.410
	1.402.573	21.084	-	14.741.893	572.792	1.505.754	235.410
Oceania	0	41.450	165.155	78.360	-	182.546	3.534.477
	0	41.450	165.155	78.360	-	182.546	3.534.505
	0	41.450	165.155	78.360	-	182.546	3.534.505
S America West Coast	54.086	21.609	1.548	3.333.000	0	29.895	266.417
	54.086	21.609	1.548	4.993.432	0	29.895	266.417
	54.086	21.609	1.548	4.993.432	0	29.895	266.417
U S West Coast Hawaii	2.512.696	9.516	113.520	3.447.311	-	69.670	15.484
	2.512.722	9.516	113.520	3.447.322	-	69.670	15.484
	2.512.722	9.516	113.520	3.447.322	-	69.670	15.484

Southbound

O \ D	Asia	C America West Coast	Canada West Coast	Oceania	S America West Coast	U S West Coast
Africa	-	96.688	541.469	76.204	32.025	40.663
	-	96.688	541.469	76.204	32.025	40.663
	-	96.688	541.469	76.204	32.025	40.663
C America East Coast	159.765	68.160	0	0	46.885	47.108
	159.765	68.160	0	0	46.885	47.108
	159.765	68.160	0	0	46.885	47.108
Canada East Coast	3.768.906	-	-	13.118	23.386	-
	5.162.883	-	-	13.118	23.386	-
	5.627.543	-	-	13.118	23.386	-
Europe	87.919	199.160	176.958	44.088	59.568	1.822.542
	87.919	199.160	176.958	44.088	59.568	1.822.542
	87.919	199.160	176.958	44.088	59.568	1.822.542
Middle East	-	-	-	-	0	-
	-	-	-	-	0	-
	-	-	-	-	0	-
S America East Coast	18.005.126	37.050	16.555	-	217.387	602.169
	30.541.625	37.050	16.555	-	217.387	602.169
	37.062.999	37.050	16.555	-	217.387	602.169
U S East Coast	167.565.969	561.618	8.961	237.789	219.155	57
	167.565.969	561.618	8.961	237.789	219.155	57
	167.565.969	561.618	8.961	237.789	219.155	57

Table 3-5 Benefits in the Year 2060 (Ship Type : CD)

150,000 DWT
200,000 DWT
250,000 DWT

(US$)

Northbound

C \ D	AFRICA	C America East Coast	Canada East Coast	Europe	Middle East	S America East Coast	U S East Coast
Asia	0	3.129.055	1.793.778	0	-	171.724	86.615.812
	0	3.129.055	1.793.778	0	-	171.724	86.615.812
	0	3.129.055	1.793.778	0	-	171.724	86.615.812
C America West Coast	1.889	0	-	4.607.327	-	267.837	99.497
	1.889	0	-	4.607.327	-	267.837	99.497
	1.889	0	-	4.607.327	-	267.837	99.497
Canada West Coast	45.359.858	16.197	-	13.894.981	338.908	3.046.891	190.987
	45.359.858	16.197	-	15.445.846	338.908	3.895.932	190.987
	45.359.858	16.197	-	15.445.846	338.908	3.895.932	190.987
Oceania	0	2.128.075	2.216.165	0	-	0	4.435.232
	0	2.128.075	2.216.165	0	-	0	4.435.232
	0	2.128.075	2.216.165	0	-	0	4.435.232
S America West Coast	2.368.378	1.388.589	91.223	9.166.808	0	0	19.736.096
	2.368.378	1.388.589	91.223	10.918.570	0	0	19.736.096
	2.368.378	1.388.589	91.223	10.918.570	0	0	19.736.096
U S West Coast Hawaii	37.633.734	1.817	26.385	48.277.580	-	436.418	3.614
	37.633.734	1.817	26.385	48.277.580	-	436.418	3.614
	37.633.734	1.817	26.385	48.277.580	-	436.418	3.614

Southbound

C \ D	Asia	C America West Coast	Canada West Coast	Oceania	S America West Coast	U S West Coast
Africa	-	192.108	28.516.531	0	62.662	1.273.776
	-	192.108	28.516.531	0	62.662	1.273.776
	-	192.108	28.516.531	0	62.662	1.273.776
C America East Coast	161.600	131.996	16.856	83.031	2.759.874	45.832
	161.600	131.996	16.856	83.031	2.759.874	45.832
	161.600	131.996	16.856	83.031	2.759.874	45.832
Canada East Coast	14.792.843	-	-	356.817	1.527.877	-
	20.860.155	-	-	356.817	1.527.877	-
	22.377.303	-	-	356.817	1.527.877	-
Europe	0	260.360	2.486.690	0	513.514	1.546.280
	0	260.360	2.486.690	0	513.514	1.546.280
	0	260.360	2.486.690	0	513.514	1.546.280
Middle East	-	-	-	-	312.843	-
	-	-	-	-	312.843	-
	-	-	-	-	312.843	-
S America East Coast	19.535.528	441.378	190.938	-	0	1.721.918
	27.805.219	441.378	190.938	-	0	1.721.918
	40.275.008	441.378	190.938	-	0	1.721.918
U S East Coast	237.932.009	1.758.366	0	2.803.684	16.056.818	45
	237.932.009	1.758.366	0	2.803.684	16.056.818	45
	237.932.009	1.758.366	0	2.803.684	16.056.818	45

(3) Yearly Benefits

1) Interpolation method between the years 2020 and 2060

Benefits during the years 2020 and 2060 are estimated by applying compound rate calculations based on estimated benefits in those years.

2) Benefits after the year 2060

Taking into consideration the long lifetime of the facilities constructed during Phase I and Phase II and the expected increase in the volume of cargo passing through the canal after the year 2060, benefits after 2060 are extrapolated based on the number of transit vessels after that year. The number is extrapolated up to the corresponding canal capacity by alternatives, adopting a rate of increase calculated based on the number of the transit vessels in the year 2020 and 2060. The number remains unchanged at the level at which the extrapolated number reaches the canal capacity.

4. Costs of the Project (Premise of the Appraisal)

(1) Costs of the Project

Economic appraisal of a project is carried out from the standpoint of the whole society and economy where the project is planned. As a result not only the tangible costs of the project but also the intangible costs incurred by the project but borne ultimately by the society or the economy have to be counted as costs. The latter costs are referred to collectively as the "External Diseconomy" of a project, and the mitigation costs, costs for keeping social order and damage to natural resources expected in the case of the Panama Canal Alternative project are classified as such.

Unfortunately, the latter costs of the project are not quantified. Accordingly, only the tangible costs of the project are adopted as the basis for calculating costs in the appraisal. These can be estimated by converting the costs expressed in market price, i.e. financial costs into economic costs.

(2) Conversion of Financial Costs to Economic Costs for the Project

1) Cost items to be converted

Based on the method of measuring project costs in the Final Report issued by the ECE Study Team, and from the viewpoint of logical consistency with the social discount rate, the figure for project costs is expressed in international border prices and is adopted as the numeraire for appraisal of this project. As a result, the values of the local portion of costs have to be converted into the same unit as that used for the numeraire.

The economic cost of the local portion, especially in the field of construction costs, cannot be directly estimated based on the data presented in the Final Report. This is because the cost estimation procedure adopted in the Report is different from that for estimating the economic cost. However, individual data and information for estimating the economic cost

are scattered about in the Report itself. By referring to this data and information, the following four local cost items were ultimately selected for consideration :

(a) Unskilled labor costs,
(b) Land costs,
(c) Compensation costs, and
(d) Electrical power costs.

2) Conversion formulae

(a) In Section III.1 of the Final Report, formulae for the conversion of the values of the above cost items are presented, taking into account characteristics of the cost items as well as primary factor input shadow prices and the Conversion Factors (CF) adopted for the conversions.

(b) Adopted shadow prices and conversion factors are as follows:

Shadow prices and CFs		Adopted to
Shadow wage rate of unskilled labor	: 0.6	Cost item (a)
Conversion factor for agriculture product	: 0.912	Cost item (a)
Standard conversion factor	: 0.894	Cost item (b) and (c)
Accounting ratio for electricity in Panama	: 2.747	Cost item (d)

The above shadow prices and CFs are cited from the document "Estimación de Precios de Cuenta para Panamá" MIPPE, BID, 1990.

(3) Economic Cost of the Project

1) Financial and economic project costs

The following Table summarizes the financial and economic project costs by construction phase:

Table 4-1 Financial and Economic Project Costs by Construction Phase

(unit : mil. US$ at 1990 price)

Cost Items		High Rise Lock Canal Alternatives					
		150,000 DWT			200,000 DWT		
		Phase I	Phase II	Total	Phase I	Phase II	Total
Construction Cost	Financial	6,278.4	1,215.2	7,493.6	7,290.3	1,166.1	8,456.3
	Economic	6,232.4	1,161.3	7,393.7	7,238.1	1,210.1	8,448.3
Indirect Cost	Financial	1,096.0	191.8	1,287.8	1,255.7	184.1	1,439.8
	Economic	1,184.6	182.9	1,367.5	1,343.1	190.6	1,533.7
Project Cost	Financial	7,374.4	1,407.0	8,781.4	8,546.0	1,350.1	9,896.1
	Economic	7,417.0	1,344.2	8,761.2	8,581.2	1,400.7	9,981.9

Cost Items		Sea Level Canal Alternatives 250,000 DWT								
		Case a			Case b			Case c		
		Phase I	Phase II	Total	Phase I	Phase II	Total	Phase I	Phase II	Total
Construction Cost	Financial	11,752.7	1,497.2	13,250.0	11,079.4	675.5	11,754.9	12,310.9	1,497.2	13,808.1
	Economic	11,662.2	1,484.6	13,146.8	11,013.2	1,210.1	12,223.3	12,214.9	1,484.6	13,699.5
Indirect Cost	Financial	1,766.6	219.8	1,986.4	1,667.6	99.2	1,766.7	1,848.4	219.8	2,068.2
	Economic	1,748.3	217.8	1,966.2	1,652.1	190.6	1,842.6	1,829.3	217.8	2,047.1
Project Cost	Financial	13,519.3	1,717.0	15,236.3	12,747.0	774.7	13,521.7	14,159.3	1,717.0	15,876.3
	Economic	13,410.5	1,702.4	15,113.0	12,665.3	1,400.7	14,066.0	14,044.2	1,702.4	15,746.6

Data source : Table III-1-1, III-1-2, III-2-5, III-2-6, III-2-7

The economic construction cost is lower than the financial cost by less than 1 percent of the latter due to the effect of the conversion factors, while in the case of the indirect economic cost of the High-Rise Lock Alternatives, the economic cost of land is newly counted, resulting sometimes in a higher economic than financial cost.

2) Financial and economic maintenance, operating and management costs

The economic cost is larger than the financial cost in the cases of all alternatives due to the high economic cost of electricity.

Table 4-2 Financial Operation, Maintenance and Management Costs

Items	Unit	High-Rise Lock Alternatives				Sea Level Canal Alternatives					
		150,000 DWT		200,000DWT		Case (a)		Case (b)		Case (c)	
		2020	2060	2020	2060	2020	2060	2020	2060	2020	2060
Electrical Power	mill US$	10.4	11.3	10.8	12.2	7.8	10.4	0.6	0.6	8.2	10.8
Man power and Other O & M Cost	mill US$	103.9	163.8	112.2	172.1	154.6	205.8	144.3	195.5	159.7	210.9
Total O & M Cost	mill US$	114.3	175.1	123	184.3	162.4	216.2	144.9	196.1	167.9	221.7

Source : ECE Study Final Report

Table 4-3 Economic Operation, Maintenance and Management Costs

Items	Unit	High-Rise Lock Alternatives				Sea Level Canal Alternatives					
		150,000 DWT		200,000DWT		Case (a)		Case (b)		Case (c)	
		2020	2060	2020	2060	2020	2060	2020	2060	2020	2060
Electrical Power	mill US$	29	31	30	34	21	28	2	2	23	30
Man power and Other O & M Cost	mill US$	98	154	106	162	145	193	136	184	150	198
Total O & M Cost	mill US$	127	185	136	196	166	221	138	186	173	228

Source : The Study Team's Estimate

(4) Yearly Economic Cost of the Project

1) Annual distribution of the economic project cost

Economic cost distributions were defined under the following premises:

a) Phase I of construction with the canal opening for traffic in the year 2020 is completed in the year 2019.

b) Phase II of construction for the High-Rise Lock Canal is scheduled according to CAS's instructions as shown.
Phase II of construction for the Sea Level Canal takes five years and is completed in the year 2059.

Precondition for Phase II of Construction for High-Rise Lock Canal

	Case(I) 150,000DWT	Case(II) 200,000DWT
Average Year	2057 Indio Dam 2057 Canal Crossing (No Pump Station)	2052 Trinidad Dam 2057 Canal Crossing 2058 Pump Station I (No Pump Station II)
Dry Year	2020 Indio & Ciri Dam 2034 Pump Station I 2052 Pump Station II 2057 Canal Crossing	2020 Indio & Trinidad Dam 2029 Pump Station I 2049 Pump Station II 2057 Canal Crossing

Note : Opening year of operation

2) Annual operation, maintenance and management costs

For the period of the year 2020 to 2060 annual costs are counted based on the activity level of the alternative canals, while after the year 2060 they are considered to be the same as the one in that year.

5. Other Benefits and Impact of the Project

5-1 Improvement of Navigation Safety

As shown in a report issued by the Panama Canal Commission (PCC) to the effect that only five major accidents have occurred since 1970, serious ship accidents seldom happen on the existing Panama Canal. Moreover, the planned alternative canals would generally provide existing/potential users with greater navigation safety due to design standards of locks that are more in keeping with recent development in ship construction, and due to more allowance for vessel navigation in the channel.

5-2 Impact during Construction

(1) Objective

Estimating the impact of local construction expenditures (Phase I only) on Panama's industry and labor market, and the multiplier effect of the additional income generated through the local expenditure of construction. Impact is measured in the form of incremental/induced industrial production and employment of local labor generated by expenditures, and increment of the Panama national income.

(2) Estimation Procedure

(a) Estimation of local expenditures due to construction (see Table V-1-1 – V-1-5), and

(b) Estimation of the impact of local expenditures on local industries and the local labor market (see Table V-1-6 – V-1-8).

(c) Adaption of the well-known formula for the multiplier effect.

(3) Estimated Impaet

(a) In the case of the 150,000 DWT Alternative, 845 million US dollars in local expenditures at 1990 price over the ten years of Phase I of construction (11.5% of Phase I project cost) are expected out of the Phase I project costs. Local expenditure will induce 1,518 million US dollars of Panamanian industrial production (induced coefficient : 1.80), the annual average of which is equivalent to 3.1 percent of Panama's GNP (1990) (see Table 5-1).

(b) The additional income generated through the local expenditure due to the construction will induce 979 million US dollars of Panama national income (see Table 5-2).

(c) Induced production will create 68,000 new jobs in Panama over ten years, of which 38,000 are expected in the construction industry (see Table 5-1). Based on the existing regional job distribution, a large portion of the new jobs will be absorbed in Panama City and Colon. However, this may promote the concentration of population in these two cities.

(d) The situation stated in (b) above implies that the difference in income distribution among the states of Panama would become wider and the social cost of keeping peace and order in these two cities would increase, especially during the Phase I construction period.

Table 5-1 Repercussion Effect on the Local Economy of Panama during the Construction of 150,000 DWT Canal

Year	Local Expend. of Project ('000US$)	Agri.Exp.	Agr. Grain	Livestock	Other Agr.	Agro-ind.	Other Ind.	Construct.	Commerc.	Service	Finance	Total
Coefficient		0.0006	0.0003	0.0012	0.0029	0.0034	0.3087	1	0.1326	0.1689	0.1785	
1	9,400	6	3	11	27	32	2,902	9,400	1,246	1,588	1,678	16,893
2	9,400	6	3	11	27	32	2,902	9,400	1,246	1,588	1,678	16,893
3	32,619	20	10	39	95	111	10,069	32,619	4,325	5,509	5,822	58,620
4	136,979	82	41	164	397	466	42,285	136,979	18,163	23,136	24,451	246,165
5	106,289	64	32	128	308	361	32,811	106,289	14,094	17,952	18,973	191,012
6	126,695	76	38	152	367	431	39,111	126,695	16,800	21,399	22,615	227,684
7	120,078	72	36	144	348	408	37,068	120,078	15,922	20,281	21,434	215,792
8	152,494	91	46	183	442	518	47,075	152,494	20,221	25,756	27,220	274,047
9	100,304	60	30	120	291	341	30,964	100,304	13,300	16,941	17,904	180,256
10	50,258	30	15	60	146	171	15,515	50,258	6,664	8,489	8,971	90,319
11												
12												
13												
14												
15												
Total	844,516	507	253	1,013	2,449	2,871	260,702	844,516	111,983	142,639	150,746	1,517,680
Employment ('000)		0	0	0	0	0	11	38 *(50)	9	4	5	68

Note *: The number refers to the estimated number of laborers in the Engineering Study (ECE), inclusive foreign and local laborers.
Source: MRI and YEC Consortium. Repercussion coefficients are obtained from the MOCECA Input -output table.

Table 5-2 Impact Due to Construction

(mil. US$)

	Direct Impact		Indirect Impact
	Production	Income	(Multiplier Effects)
150,000DWT	1,518	706	979
200,000DWT	1,700	790	1,096
250,000DWT	1,953	908	1,259

Note 1 : 0.712 (Marginal propensity to consume) and 0.131 (Import ratio) are assumed, from Table V-2-2

Note 2 : Initial income of the direct impact is excluded from the indirect impact.

5-3 Induced Trade

(1) Objective

Estimating the induced world trade which would be brought about by a portion of the transportation cost savings which are expected from this project due to decrease in prices of traded goods.

(2) Estimation Procedure

As presented in Chapter V.2 in the form of formulae,

(a) Estimation of volume of induced world trade, and
(b) Estimation of value of induced trade based on (a) above.

(3) Estimated Induced Trade

In the case of the 150,000 DWT Alternative, induced world trade is estimated to be 68 million US dollars or 563 thousand metric tons in the year 2020. This is extremely small compared with the GDPs of the countries of origin and destination of transit cargo on the Panama Canal (total: 14,509 billion US dollars) and the expected volume of transit cargo.

the most significant increases in trade are expected in exports from the U.S East Coast (88% of total induced exports, in the case of the 150,000 DWT canal) and in imports to Asia (92% of total induced imports) (see Table 5-3).

Table 5-3 Induced Trade (Volume) Due to Transport Cost Savings from Canal Alternatives in the Year 2020

Regions	⊿Export('000 MT) 150DWT	200DWT	250DWT	⊿Import('000 MT) 150DWT	200DWT	250DWT
(Pacific)						
1. Asia	14	14	14	519	607	694
2. C. America WC	2	2	2	2	2	2
3. Canada WC	-8	8	2	3	3	3
4. Oceania	1	1	1	1	1	1
5. S. America WC	3	3	3	1	1	1
6. U. S. WC	19	19	19	7	7	7
(Atlantic)						
1. Africa	3	3	3	6	7	7
2. C. America EC	2	2	2	3	3	3
3. Canada EC	-2	9	8	1	1	1
4. Europe	7	7	7	3	20	14
5. Middle East	0	0	0	0	0	0
6. S. America EC	27	105	193	0	0	0
7. U. S. EC	495	495	495	17	17	17
TOTAL	563	668	749	563	668	749

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.

5-4 Impact of Tolls

(1) Objective

Estimating Panamanian industrial production induced by incremental maintenance and operation costs required for the new canal and incremental government expenditures expected based on the increase in government revenue from the Panama Canal Authority in the year 2040.

(2) Estimation Procedure

(a) Estimation of incremental maintenance and operation costs and government revenue (see Table V-3-1), as well as government expenditure in industrial sectors with the same composition ratio as that for total demand in Panama, and

(b) Estimation of induced industrial production using the inverse matrix of Panama's input coefficient matrix.

(3) Estimated Induced Industrial Production

In the case of the High-Rise Lock 150,000 DWT Alternative, incremental expenditure of 904.3 million US dollars is expected in the year 2040 from the Panama Canal Authority and Government, and additional industrial production of 1,369 million US dollars will be induced by this incremental expenditure.

5-5 Saved Cost-Induced Income

(1) Objective

Estimating the income induced from transportation cost savings through decreases in prices of traded goods.

(2) Estimation Procedure

As shown in Chapter V.4 in the form of formulae,

(a) Estimation of total income accrued from transportation cost savings,
(b) Allocation of total income to transit exporting and importing regions cargo, and
(c) Estimation of income by region through the multiplier effect.

(3) Estimated Saved Cost-Induced Income

Incremental income to the world economy from the new canal is estimated to be 921 million US dollars in the year 2020 in the case of 150,000 DWT Alternative. This is extremely small compared with the GDPs of the countries of origin and destination.

Table 5-4 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		
	150,000DWT	200,000DWT	250,000DWT	150,000DWT	200,000DWT	250,000DWT	150,000DWT	200,000DWT	250,000DWT
(Pacific)									
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. WC	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. EC	133,155	133,155	133,155	458,646	458,646	458,646	0.01%	0.01%	0.01%
TOTAL	300,854	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.

5-6 Impact on Adjacent Countries

(1) Movement of Labor

The employment increase due to Phase I of construction is estimated to be 68 thousands (in the case of a 150,000 DWT canal). This number will be absorbed in the local labor market in Panama, and there will be little need to import labor from abroad, except skilled labor required in construction.

(2) Movement of Commodity

Since major equipment for construction will be bought from the developed countries, probably from the U.S.A. and Japan, a significant amount of imports from the adjacent Central and South American countries is not expected. Only indirectly will industries in Panama stimulated by local expenditure on construction increase the amount of imports from the adjacent countries.

Based on Panama's dependency on import (26% estimated) and the structure of Panamanian imports from the adjacent countries, 2 to 28 million US dollars of imports from the adjacent Central and South American countries are expected (in the case of a 15,000 DWT canal).

(3) Impact on Adjacent Countries during Operation

Two interesting features of Panama Canal traffic can be observed:

- Countries with large economies such as the U.S.A., Canada and Japan are more important for the canal than those with small economies, and
- The canal is more important for adjacent countries with relatively small economies such as Chile, Peru, Ecuador and Mexico than those with large economies.

This implies that if these three countries were to stop using the canal for their trade (both export and import) the canal would lose more than 80 percent of its revenues and that the canal price most affects the trade of the smaller adjacent countries.

5-7 Influences Exerted by the Panama Canal Project on the Shipping Industry

(1) Objective

Estimating the demand for construction of larger ships and the value of contracts to the world's ship-building industry which would be generated through enlargement of canal ship size brought about by the project, and on the supposition of a more competitive shipping industry market.

(2) Estimation Procedure

(a) Identification of types of ships for which demand for larger vessels exists, to based on the transit cargo projections by type of ship presented by the WEFA, and analysis of the impact on the shipping industry of the introduction of such larger ships.

(b) Estimation of the number of larger ships for which new demand will arise and the value of contracts to the ship-building industry, based on analysis of and assumptions on the activities of the shipping and ship-building industries.

(3) Estimated Impact

Through estimation procedure (a) above, it is supposed that there will be demand for only Full Container with larger capacity, which would be generated through enlargement of canal ship size brought about by the project. There would be demand for about 20 Full Container Ships with a capacity of 4,000 TEU after completion of the new canal, amounting to approximately 1,600 million US dollars at 1990 prices. However, this amount is equivalent slightly less than 5 percent of current world annual ship construction.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

12. Financing Scheme, Financial Analysis and Management Arrangements

Executive Summary

1993

EXECUTIVE SUMMARY

General

- The Financing Scheme, Financial Analysis, and Management Arrangements Study (FFMS) is one of a series of component studies undertaken for the Commission for the Study of Alternatives to the Panama Canal (CAS).
- On July 24, 1992, CAS selected two of four alternatives for further study: a High-Rise Lock Canal with a 150,000- or 200,000-DWT maximum ship size and a Single-Lane Sea-Level Canal following Route 10 with a 250,000-DWT maximum ship size. Both options presuppose continued use of the existing Canal as modified by the Culebra Cut widening.
- The FFMS assignment required that five principal tasks be performed for each of the Canal alternatives:
  - Review alternative toll policies and systems and develop a recommended toll policy and system for each Canal alternative,
  - Formulate the most appropriate management arrangement and structure,
  - Define the most appropriate financing configuration or scheme,
  - Measure the financial viability of each Canal alternative, and
  - Recommend the preferred Canal alternative from a financial point of view.
- Projections of traffic and transits for each alternative were obtained from The WEFA Group, *Final Report, Commodity and Traffic Projections Study*, May 7, 1993.
- Capital cost estimates of the alternatives were obtained from Yachiyo Engineering Co., Ltd., *Final Report, Phase 2: Preliminary Engineering and Cost Estimates*, April 1993.

Toll Policy Issues and Formulation of Optimal Toll Structure and Rates

- Nathan Associates reviewed toll policy in theory and in practice. On the basis of past studies we evaluated the current Panama Canal toll policy, structure, and rates. A comparative analysis of tolls at other waterways was conducted. Alternative toll structure and rates were analyzed for each Canal alternative and optimal structure and rates were identified, specified, and recommended.

- On the basis of the historical analysis of Panama Canal tolls and the comparative analysis of tolls at the Suez Canal and the St. Lawrence Seaway, Nathan Associates specified and analyzed alternatives that included
  - The current earning-capacity–based schedule, with rates increased 50 and 100 percent; and
  - A modified earning-capacity–based schedule for which rates varied by ship type and, within a ship type, by increment of earning capacity (similar to the Suez Canal).
- For each toll schedule, toll revenues and traffic diversions were estimated and analyzed. All traffic diversion decisions were based on total transportation cost per ton of cargo carried. With the imposition of a Panama Canal toll, the total transportation cost per ton of cargo carried through the Canal increases. Traffic for which the cost per ton via the Canal exceeded the cost per ton via the least costly alternative route was diverted to the alternative route.
- The formulation of an optimal toll structure and rates was based on maximizing revenue subject to the following constraints:
  - Minimum traffic diversions (a minimum number of diverted transits),
  - Toll rate increases capped at 100 percent,[1]
  - Minimum disruption to the traffic and cargo bases (maintaining the existing diversity of vessel and cargo types to avoid traffic specialization),
  - Tolls distributed equitably by ability to pay, and
  - An administratively simple and practical structure.
- The optimal toll system that was developed is based on vessel-earning capacity. It differs from the existing Panama Canal toll structure by differentiating among ship types and, within ship types, by size.

[1]A number of toll rate increases up to 100 percent were examined. Toll increases are justified under the Panama Canal Treaty of 1977 when used to cover the costs of capital improvements. Toll increases up to 100 percent are feasible as the Canal remains the least cost alternative route for a majority of shippers, and a significant transportation cost saving will be associated with the improvements. In no iteration were tolls increased by more than 100 percent. According to a review of past increases and supporting documentation and the informed opinions of all study team members, a toll rate increase exceeding 100 percent would be poorly received and indeed viewed with alarm by the shipping community.

Analysis of Management Arrangements Models[2]

- 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. The management arrangement models evaluated were as follows.
  - **Government department**. The Canal alternative would be established as a government department and operated as a regular agency under civil service administration.
  - **Public authority.** The Canal alternative would be set up as an independent authority by Panamanian legislation (Authority Act).
  - **International public entity**. The Canal alternative would be set up by treaty or international agreement as an international public body, created for the express purpose of managing and operating the Canal alternative asset.
  - **Special purpose corporation**. The Panamanian government or one of its agencies would grant the Canal alternative—under a long-term concession agreement and operating contract—to a special purpose corporation (SPC), whose role would be to manage and operate the asset.
  - **Private company**. Operation of the Canal alternative would be fully privatized, with all functions auctioned off to one or more private firms. The entities in question would likely include a consortium of foreign private and Panamanian private corporations.
- All the models for management arrangements for the Canal alternative assume that a single entity will be established to manage and operate the existing Canal and the Canal alternative.
- Neither the private company nor government department management arrangement appears suitable to the situation in Panama. The international public entity is somewhat less risky in terms of both perception and operating stability but poses practical difficulties in terms of operating efficiency and its likely inability to incorporate other trans-isthmian commercial activities.

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[2]The management models, selection criteria, and recommendations discussed in this report pertain to a future Canal alternative, not to the existing Panama Canal. The management models analyzed were chosen and examined for their relevance to the Canal alternatives, not to the existing Panama Canal. An in-depth review of the management and operation of the existing Panama Canal was not conducted for this study.

- A Panama Canal Authority has been identified as the preferred management arrangement suitable to handle the political, financial management, and operating efficiency requirements of the Canal alternative. 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 political influence, management flexibility, labor productivity, and others.
- From a Panamanian political point of view, the Panama Canal Authority is probably a more easily comprehensible and thus acceptable formula for organizing Panama's relationship to the Canal alternative. A 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.
- 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 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.

Specification of Optimal Financing Scheme

- The total cost of each alternative and the duration of design and construction are presented below.

Canal Alternative	*Capital Cost (US$ billion)*	*Construction Period (years)*
150,000-DWT High-Rise Lock Canal	7.4	10
200,000-DWT High-Rise Lock Canal	8.5	11
Sea-Level Canal, Case A	13.5	15

- A panel of senior international financing experts (SIFE) was assembled for the development and selection of optimum financing schemes for the Canal alternatives. The panel was composed of financial practitioners with global project financing expertise in both public and private sector settings.
- To identify potential financing sources and likely terms and conditions, it was assumed that the Canal alternatives were financially viable. Thus the sources of financing selected and the assumed terms and conditions used are considered to be those that would be most favorable for the financing of the Canal

alternatives. The interest rates used represent anticipated long-term interest rates under favorable economic conditions and for a project that is considered a medium investment-grade risk. This implies that the entity operating the existing Panama Canal will be financially sound at the time financing for the alternative canal is sought and that a track record of solid operational and management performance has been established.

- A wide range of possible sources of financing was explored, including traditional and nontraditional sources. Traditional sources of project financing include governmental export-import banks for financing of plant and equipment; international development lending institutions such as the World Bank and the Inter-American Development Bank; large investment houses in the United States, Japan, and Europe for access to private bond and equity markets; and equity participation by individual countries. Nontraditional financing sources include possible equity participation by major users of the alternative canal or equity participation by multinational governmental institutions such as the United Nations or the Organization of American States.
- A critical component of the financing scheme is the establishment and preservation of a trust fund that will be endowed with net income generated from Canal tolls after Panama acquires control of the Canal in 2000. It is assumed that Panama Canal tolls could be increased nominally from 2000 through 2019 to generate resources for the trust fund, especially since the toll increase will be associated with a capital improvement project. Panama's financial equity contribution to the Canal alternative will be taken from the trust fund, and a balance of $500 million will be maintained to assure creditors of the Canal alternative's financial solvency.
- The optimal financing scheme consists of a mix of nine financing sources:
  - Capital costs for construction and other equipment are financed equally by export-import banks in the United States 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 from the toll reserve trust fund (15 percent).
  - 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 revenue trust fund (30 percent).

Financial Analysis

- The financial analysis of each of the Canal alternatives was prepared for three scenarios of alternative toll revenue estimates. These toll revenue estimates are
  - Existing Panama Canal toll structure and rates,
  - Existing Panama Canal toll structure and rates increased by 50 percent, and
  - The optimal toll system developed by Nathan Associates that differentiates toll rates by the type and size of vessel.
- The financing scheme and financial analysis of each Canal alternative were evaluated using the following criteria:
  - Is the toll reserve trust fund balance always positive?
  - Is the minimum debt service coverage ratio on a current basis greater than 1.3, and on an overall basis (including the trust fund balance) greater than 1.5 to 2.0?
  - 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?
  - 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?
  - Are the net present values of the incremental cash flow *before* and *after* financing positive values?[3]
  - Is the debt-to-equity ratio below 4.0?
  - Does the alternative remain financially viable under the various sensitivity analyses that include interest rates increased by 25 percent, capital costs increased by 25 percent, operation and maintenance costs increased by 25 percent, and status quo Canal toll rates increased by 50 percent?
- On the basis of the evaluation criteria, the 150,000-DWT High-Rise Lock Canal is financially viable under the optimal toll system scenario.

[3]A discount rate of 8 percent was used for the net present value calculations. This reflects the SIFE panel consensus of the interest rate that could be obtained on a low-risk corporate bond.

	Existing Tolls	Tolls Increased 50 Percent	Optimal Tolls
Trust fund balance always positive?	No	Yes	Yes
FIRR before financing (percent)	–3.2	4.6	10.1
FIRR after financing (percent)	–5.6	3.4	18.0
Net present value before financing (US$ million)	–4,314	–1,591	951
Net present value after financing (US$ million)	–3,806	–1,285	1,069

- The 200,000-DWT High-Rise Lock Canal is not financially viable under any of the toll system scenarios analyzed.

	Existing Tolls	Tolls Increased 50 Percent	Optimal Tolls
Trust fund balance always positive?	No	No	Yes
FIRR before financing (percent)	–3.1	3.7	8.4
FIRR after financing (percent)	–5.4	2.3	9.8
Net present value before financing (US$ million)	–4,882	–2,337	193
Net present value after financing (US$ million)	–4,308	–1,952	391

- The Sea-Level Canal, Case A, under all toll scenarios analyzed is not financially viable. The toll reserve trust fund balance in all scenarios remains negative for extended periods.

	Existing Tolls	Tolls Increased 50 Percent	Optimal Tolls
Trust fund balance always positive?	No	No	No
FIRR before financing (percent)	–5.1	1.3	4.5
FIRR after financing (percent)	–7.6	–0.5	3.3
Net present value before financing (US$ million)	–6,803	–4,648	–2,608
Net present value after financing (US$ million)	–6,014	–4,019	–2,130

- To test the robustness of the base case financial results, a series of sensitivity analyses was conducted. The sensitivity analyses were designed to include factors considered likely to affect the evaluation of the Canal alternatives and to address concerns of potential investors and financing institutions. Sensitivity analyses were conducted for
  - Interest rates increased by 25 percent,
  - Capital costs of all Canal alternatives increased by 25 percent,
  - Capital costs of all Canal alternatives decreased by 25 percent,
  - Operation and maintenance costs of the Status Quo Canal and all Canal alternatives increased by 25 percent,
  - The combination of interest rates increased by 25 percent and capital costs decreased by 25 percent,
  - Tolls for the Status Quo Canal increased by 50 percent,
  - A Special Purpose Corporation as the management arrangement, and
  - Capital costs on a unit-cost basis for the 150,000-DWT High-Rise Lock Canal as presented by Yachiyo Engineering.
- The 150,000-DWT High-Rise Lock Canal under an optimal toll system remained financially feasible under six of the eight sensitivity analyses.
- The 200,000-DWT High-Rise Lock Canal, which was not feasible under the base case results, improves in two scenarios—decreased capital costs by 25 percent and the combination of decreased capital costs and increased interest rates. However, it should be noted that these results are still less favorable than those for the 150,000-DWT High-Rise Lock Canal.
- The Sea-Level Canal, Case A, remains not financially feasible under all of the sensitivity analyses. The net present value before and after financing are negative and the balance of the trust fund turns negative for extended periods.

Conclusion

- The 150,000-DWT High-Rise Lock Canal operated by a Panama Canal Authority and using an optimal toll system is recommended as the most attractive Canal alternative and management arrangement from a financing scheme and financial viability perspective.
- This alternative provides a financial internal rate of return commensurate with estimated requirements of public and private financing and has a positive net present value before and after financing. The balance of the toll reserve trust fund is always positive and is adequate during construction to cover substantial cost overruns.
- The sensitivity analyses indicate that the 150,000-DWT High-Rise Lock Canal under the optimal toll scenario is sufficiently robust to remain financially viable if either interest rates or operation and maintenance costs are increased 25 percent.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

13. Impact Upon Panama Analysis

Executive Summary

1993

EXECUTIVE SUMMARY

COMMISSION FOR THE STUDY OF ALTERNATIVE TO THE PANAMA CANAL

COMPONENT STUDY

ANALYSIS OF IMPACT UPON PANAMA

1. PURPOSE

The purpose of this executive summary is to highlight the assumptions, the important impacts and the discriminatory findings of this component study. Background material and discussions contained in report's identification and analysis of impacts in each of the fields of study form the bases for the conclusions presented in this summary.

2. BACKGROUND

The Analysis of Impact Upon Panama Study (IOP) is one of a series of component studies undertaken for the Commission for the Study of Alternatives to the Panama Canal (CAS). Booz•Allen and Hamilton Inc. and associated firms were given Notice to Proceed with the study, March 19, 1993. The main objectives of the Analysis of Impact Upon Panama were to qualify and quantify, to the utmost extent possible, probable effects and impacts of two pre-screened Canal alternative projects on Panama and the project region, as well as to complement appropriate data and information for the Economic Analysis.

Both of the pre-screened alternatives selected by CAS for further study assume continued use of the existing Canal with the Gaillard Cut widening completed. The alternatives are:

1) High-Rise Lock Canal with a maximum capacity for 150,000-200,000 DWT vessels. In this option, the new facilities would generally follow the alignment of the existing Canal, with new larger locks constructed adjacent to the existing locks, and with works to widen and deepen the channel in order to accommodate larger vessels.

2) The Single-Lane Sea Level Canal following Route 10 with a maximum capacity for 250,000 DWT vessels. This option calls for the excavation and construction of a new waterway across Panama, roughly parallel to the current Canal, and approximately 16 kilometers to the west.

Because of the broad and varied nature of subject fields, a general methodology was followed in the study of impacts; this methodology used a dual analysis thrust and focused on the most significant impacts, as well as on those impacts which were considered discriminatory between the two alternatives. The first thrust was to develop, within specific disciplines, an in depth look at the probable impacts in the fields outlined by the scope of the study. The general approach was to conduct research on existing documentation, to interface with the other component study contractors, reviewing their inception and interim reports, to develop initial findings using subject matter experts, to identify the probable discrete impacts, and to analyze those impacts in order to determine their scope and the magnitude of their effects on Panama.

A second thrust was to use the System Dynamics Model, one of the support tools available for the Subject Matter Experts. System Dynamics Model output reflected the behavior of factors within Panama over time. The long-term, system-wide effects of the actions associated with the construction and operation of each Canal alternative were displayed to reflect the trends likely to emerge. With model output, the impact of individual actions associated with each alternative, combinations of actions, and alternative timing of sequenced actions were assessed. Model output was valuable not only in the analysis of a specific action or a Canal alternative in general, but also for the general insight into the internal dynamics of Panama which it provided. As each action or set of actions was assessed, expectations concerning the impact of the initiatives were formulated. Model results different from expectations led to an investigation of the cause and effect relationships and assumptions on which the model was based. Using both the Subject Matter Expert's methodology, which is rigorous within the discipline, and the trends and output of the model, a conclusion was reached regarding discriminating impacts.

3. ASSUMPTIONS

Assumptions used within each study field are the following:

3.1 *Economic and Financial*

3.1.1 The globalization process of the world economy will continue during the first half of the next century. This assumption is implicit in the estimates of demand for Canal services, but also in prices and costs structures presented in other studies. In this component study, the assumption is important because it confirms the need to insert the Panamanian economy in an integrated world economy as a way of promoting domestic welfare.

3.1.2 Technology for the construction of either alternative will not change on account of changes in factors and inputs relative prices The alternatives would be carried out with the mixture of resources and with the relative prices suggested in the Yachiyo Engineering project.

3.1.3 The financial surplus of the Panama Canal Authority will not be taxed by the Central Government.

3.1.4 The Panamanian economic structure will not suffer positive external shocks (discovery of resources or spontaneous capital inflows) nor negative external shocks (important natural disasters or a sudden decline in demand for major export goods involved in maritime trade using the Canal).

3.1.5 Any increase in toll revenues projected for the current Canal and new Canal alternative will be used to cover the debt of the new Canal, and to provide some return on equity to the Panamanian equity portion of the financing. This means that toll revenue increases will have no effects or only negligible ones on the local economy.

3.1.6 The final two Canal alternatives out of the five finalists (two variations on the High-Rise Lock Canal and three variations on the Single-Lane Sea Level Canal) will be those two with the best results in the analyses in both the Economic and Financial Component Studies. The two best final Canal alternatives in those two studies are:

- The High-Rise Lock Canal with a capacity for 150,000 DWT vessels.
- The Sea Level Canal, Case C, including Pacific tidal locks and Atlantic tidal locks.

3.1.7 There will be no impacts on users or very negligible ones during the construction period of the new Canal alternative. This is consistent with the assumption of the Economic Analysis and Impact on Users Component Study.

3.1.8 The "other Canal excavation" costs which are part of the costs of the Sea Level Canal will not be spent in Panama.

3.1.9 The optimal toll structure, as delineated in the Financial Component Study, will be adopted.

3.1.10 "The Panama Canal Authority" will be the administering agency in charge of Canal Management.

3.2 *Political, Socio Cultural and Population*

3.2.1 Foreign administration and control of the current canal will end during the decade preceding the construction of either alternative. This will strengthen Panama's domestic and international political structures, as well as the country's domestic and international policies.

3.2.2 During the two decades following the return to democratic institutions in the country, the political system will be strengthened, as well as Panama's position in any international negotiations.

3.2.3 The Government of Panama will take both legislative and administrative actions to ensure that the procurement system will be open, not discriminatory. This implies that construction and financing costs will be the lowest possible, due to project requirements.

3.2.4 Political decisions and arrangements for indemnification will be made by the Government of Panama as part of the planning for relocating people from the canal alternative project area.

3.2.5 The economic activity generated by the construction of the Canal and the additional economic activity in the Metropolitan Region, including the development of the areas to be reverted to Panama

under the Panama Canal Treaty, will give rise to an increase in population growth beyond current projections due to a greater flow of domestic and foreign migrants.

3.2.6 Present domestic migratory tendencies towards the Metropolitan Region will be further strengthened by the canal construction.

3.2.7 Increment growth in foreign migratory population will impact the national conscience and identity.

3.3 *Environmental and Geographic Impacts*

3.3.1 Both of the proposed alternatives, the Sea Level Canal or the High-Rise Lock Canal, will generate major impacts on Panama due to the magnitude and costs of environmental works and the costs of required environmental studies.

3.3.2 An acceleration of the growth rate of the Metropolitan Region has been anticipated without the introduction of any Canal alternative project. This will add stress to canal excavation work and to the ensuring canal operations.

3.3.3 The problem of marine life transmigration between the Pacific Ocean and the Caribbean Sea caused by a sea level canal would be of great consequences for Panama and for the world in terms of a major alteration in the sea and coastal marine environment.

3.3.4 A variation in the tropical environment and larger demographic concentrations, could maintain or reactivate known epidemics, such as cholera, dengue, yellow fever, malaria, Chagas disease, leishmaniasis, rabies, meningitis and others, in the project areas.

3.4 *Infrastructure General*

3.4.1 In terms of the impact on infrastructure costs, the percentage of increase in population due to the construction of either Canal alternative will be insignificant when compared with projections for total growth.

3.4.2 The Panamanian Government will program its investments in infrastructure according to the current projections of population growth in the project areas.

3.4.3 Panama will be able to invest in its primary infrastructure requirements, and no significant additional infrastructure will be required upon the announcement of construction works for either canal alternative or the beginning of construction proper.

3.4.4 *Ports*

3.4.4.1 The port facilities at Rodman will be eliminated in the case of the High-Rise Lock Canal alternative.

3.4.4.2 The Panamanian Government will provide indemnification for the installations at Port Caimito, which will be affected by excavation and dredging operations.

3.4.4.3 The Panamanian Government will undertake reconstruction activities in the ports of Balboa and Cristobal before the year 2000, thereby avoiding major damage during construction of the High-Rise Lock Canal.

3.4.4.4 The basin areas of the ports of Cristobal and Balboa will be affected by the widened waterway, and more sediment will be produced because of landslides and dredging operations.

3.4.5 *Electrical:* Additional electrical requirements due to canal construction will be met by the construction contractor, and will not impact the existing network.

3.4.6 *Telecommunications:* Technology will solve most telecommunications requirements through cellular and other new communications.

3.4.7 *Water Works*

3.4.7.1 The supply of drinking water from wells in the area of Arraijan will be greatly diminished or disappear as a consequence of the Sea Level Canal excavations.

3.4.7.2 The High-Rise Lock Canal will have some impact on water supply because of dredging and sedimentation affecting the actual volumes of fresh water taken from the Miraflores facility.

3.4.7.3 The pipelines interrupted by the High-Rise Lock Canal in the Atlantic side and in the Pacific side will be relocated under the new Canal.

3.4.7.4 The pipeline interrupted by the Sea Level Canal would be reinstalled using protected bridges.

3.4.7.5 Other sources of water supply for municipal use will be required in both alternatives.

3.4.8 *Road Network*

3.4.8.1 Wear and tear in the existing road system will be approximately the same in both alternatives.

3.4.8.2 New road networks, such as the Corredor Norte and the Corredor Sur, will be built prior to the year 2000, and would include modifications to adapt them to the selected alternative, if required.

3.4.9 *Structures*

3.4.9.1 For the Sea Level Canal alternative, the one-kilometer Canal control area will permit residents to continue to live in the area under the supervision of the Canal Authority.

3.4.9.2 It is assumed that the Yachiyo cost estimates for relocating of structures take into consideration equipment within the structures.

3.4.9 *Bridges:* The Van Dam (Simon Bolivar) bridge, together with the corresponding parts of the major highways, will be built before the end of the century.

3.4.10 *Railroads:* The Panama Railroad will be functioning in excellent condition by the end of the century.

4. GENERAL FINDINGS AND CONCLUSIONS

The successful construction and subsequent operation of either alternative will have long-term positive benefits in terms of providing Panama with a sustainable income source throughout the next century.

Major direct impacts on Panama occur during the mobilization for construction and during construction itself, in the case of either alternative. Major indirect impacts on Panama occur during the Operation Phase of either alternative.

4.1 *Discriminator Impacts Developed By System Dynamics Model*

While each of these impacts is discussed in the individual fields of study in the report, the following impacts were highlighted by the model as the most significant, when it considered impacts overlapping study fields or domains.

4.1.1 *Lower Water Table and Contamination.* Digging a sea level canal may lower the water table in the area of the Continental Divide and in the Pacific watershed from its present level of approximately 30 feet to as low as 150 feet. There is significant concern of the fact that the canal trench will go below the current level of the water table, and seepage of polluted water from the Sea Level Canal may enter the underground water supply. Underground water is the source of potable water for most homes and communities in that region. The Government of Panama must deal with the short-term problem of replacing wells for area residents. Because much of the surface water in this region will be used to support the Sea Level fresh water barrier, there may not be viable alternatives to underground water. A shortage of water combined with other social issues discussed in this report may lead to significant discontent in the region. The Government of Panama must take significant action in this area, as failure in coming to grips with the problem and solving it could have a significant impact on its political strength.

4.1.2 *Adequacy of Fresh Water Supplies.* Existing fresh water supplies are barely sufficient to meet current needs (including requirements for operation of the existing Canal). Likewise, while the operation of the present Canal results in some contamination of the water, such degrees of contamination are generally understood and under control. During construction, the High-Rise Lock

alternative will have an impact on the water intake from the Miraflores plant. While both alternatives include provision of additional water supplies, further studies, are required until the adequacy of the new supply in light of the greater requirements of either of the two alternatives is determined. Likewise, because there are so many unknowns associated with the Sea Level Canal, there is a significant possibility of contamination of the fresh water supply.

4.1.3 *Provision of Security and Maintenance of Legitimacy.* The opening of a predominately rural/remote area with significant job opportunities and the relocation of large numbers of people associated with the construction of the Sea Level Canal alternative will result in new security requirements. Although in the way of security and services associated with the canal alternatives much will be furnished by the Panama Canal Authority, the ultimate responsibility rests with the Government of Panama. Maintenance of full control over the area may offer a significant challenge to Panamanian authorities.

4.1.4 *Excess Migration to Canal Project Areas.* Given existing levels of poverty and existing employment conditions throughout Central America, it is most likely that migration to project areas will greatly exceed project requirements, thus increasing unemployment and underemployment. Although this may be significant in either alternative, the remote areas surrounding the Sea Level Canal alternative represent greater challenges. In addition to excess migration, there is the related indirect impact of the relatively sudden loss of approximately 10,000 direct construction and related service support jobs upon completion of either project.

4.1.5 *Unanticipated Costs/Outcomes of Major Development Projects.* Development projects often tend to establish unrealistic expectations and overly ambitious project completion dates. Both Canal alternatives include 24-hour, 7-day-week work schedules that may put both man and machine under excessive stress. A review of other development projects, such as dams and other large utility projects, indicates that failure to keep overly ambitious schedules may result in disillusionment, and thus have significant consequences on government credibility, and subsequently, on its ability to maintain popular support. While such disillusionment would be a factor in both alternatives, it may be of greater consequence in the High-Rise Lock Canal alternative where relatively short-term results are expected and a greater portion of the population is in close proximity to ongoing work. The phased construction approach for the High-Rise Lock Canal would tend to mitigate this impact.

4.1.6 *Evolving Discontent Following Relocation.* Although Canal engineering studies address the requirement to relocate significant portions of the population, they do not detail plans for such relocation. Study of relocations associated with other development projects show that, even with detailed planning, there may be numerous unanticipated consequences to relocation raising the levels of dissatisfaction. Even with relatively successful relocations, favorable attitudes often wane with time. Although relocations are associated with both alternatives, the Sea Level Canal alternative requires greater numbers to be relocated and will probably entail greater changes in environment.

4.1.7 *Security of Canal.* The construction of a Sea Level Canal alternative will require a doubling of the security force required to protect the Canal itself, a requirement that would impose a significant political consideration to the Government of Panama. While the High-Rise Lock Canal alternative will require a slight increase in the number of security forces, the associated political concern is relatively small.

4.2 *Other Significant Impacts*

The following impacts were identified as important or very important discriminating impacts within the specific field of study.

4.2.1 *Economic Impacts*

4.2.1.1 The expansion of the Panama Canal -- either by means of a High-Rise Lock or a Sea Level Canal -- will represent the single most important investment Panama has ever witnessed. The largest direct impact occurs in the Sea Level Canal option, which represents 28.6% more total expenditures than the High-Rise Lock with a capacity of up to 150,000 DWT vessels and 14.8% more than the High-Rise Lock with a capacity of up to 200,000 DWT vessels. Direct impacts are proportional to construction expenditures. The largest total direct impact during operation occurs also in the Sea level Canal option.

4.2.1.2 Annual impacts on GDP are very similar for all alternatives: close to 1% per year during construction and close to 1.2% per year during operation. Employment creation is higher for the Sea Level Canal option.

4.2.1.3 Neither alternative is expected to change the economic structure of the country during construction or during operation. During construction, most of the inputs will be imported by the contractors. Local industries will provide some materials, but there will not likely be expansions of existing capacity or investments in new ventures.

4.2.1.4 During the operation of the alternatives, the increase in GDP calculated in the study will come from the already dynamic service sector, not by new developed sectors. Income distribution, therefore, is expected to remain skewed as it is today.

Total impacts on the economy during construction (in 1990 millions) are shown in Table 1 below.

	High-Rise Lock (150,000DWT)	High-Rise Lock (200,000DWT)	Sea Level Canal
Value Added	708.1	792.9	911.1
Intermediate Purchases	809.3	906.3	1,041.3
Impact upon Total Employment	95,760	107,236	140,828
Impact upon GDP (annual average increase)	0.95%	1.06%	0.81%

Table 1: Total Impacts Upon the Economy During Construction

Total impacts (in 1990 millions) during operation (at 6% discount rate) are shown in Table 2 below.

	High-Rise Lock (150,000DWT)	High-Rise Lock (200,000DWT)	Sea Level Canal
Value Added	3819.8	3,635.6	4174.6
Intermediate Purchases	2,030.7	1,932.4	2,219.3
Impact upon Total Employment	12,853	12,233	14,046
Impact upon GDP (annual average increase)	1.3%	1.2%	1.4%

Table 2: Total Impacts Upon the Economy During Operation

Sea Level Canal alternatives show the largest direct impact, 15.3% larger than the High-Rise Lock (200,000 DWT).

4.2.2 *Financial Impacts On Panama*

4.2.2.1 The primary beneficial financial impacts on Panama will be a result of the construction of the new Canal. Primary impacts include:

- The potential for increased import duties as a result of the importation of equipment and materials for construction.

- Increased government revenues from personal income tax resulting from the increased local employment and business taxes resulting from the local purchase of goods and services.

Based on the above consideration of beneficial financial impacts only, the preferred alternative would be the Sea Level Canal, because it costs more to construct and therefore, requires more imports and local purchases of goods and services. However the heavier burden in terms of devt servicing and the more encompassing overall repercussions cannot be ignored.

4.2.2.2 A potential negative financial impacts on Panama generated by the new Canal alternative consists of a possible decline in the payments to the Panamanian Government from the Canal, as a function of the new management structure to be put in place, and that a Government guarantee of part of the financing may be required. Such a guarantee may hinder the Government's ability to obtain financing for other domestic projects, such as new infrastructure and infrastructure maintenance. In this case, the Sea level Canal alternative,with the higher cost, would present the greatest negative impact. The financial impact must be weighed in this sense, in the context of present economic situation and limitations, and in terms of the real ability of panama to maintain financial and economic flexibility in the future.

4.2.3 *Political Impacts*

Direct Impacts

4.2.3.1 Panama's selection of a Canal alternative will have international political dimensions. The international momentum behind the Rio Conference on Environment and Development, the "Earth Summit," should be a factor in either decision. The possibility that the High Rise Lock Canal alternative disturbs some areas of rain forest will become an issue with such resonance that it will be the subject of debate. This debate will cause the Government of Panama to provide justification and scientific proof that it has weighed the consequence and can take measures to safeguard the environment.

Strictly from an environmental standpoint, if the Sea Level Canal alternative were selected, the potential negative political impact on Panama is much greater than that of the High-Rise Lock alternative. The Sea Level Canal may cause interoceanic transmigration of species, with unknown and incalculable change and possibly considerable damage to marine life in the Carribbean and the Pacific; it will disturb and reduce endemic habitat for endangered species; and it will create an additional barrier to rare species migration. Just the possibility that these

situations can occur will capture the concern of almost every one of the more than 800 international non-governmental agencies concerned with environmental problems. The political pressure on the Government of Panama, from all of the Caribbean nations, worried about their coral reefs, is one anticipated reaction, which, ironically, may be of less consequence than the other anticipated reactions. International new coverage concerning the potential dangers (almost assured to be negative), coupled with anticipated activities from some groups such as Greenpeace, will place tremendous poltical pressure upon the Government of Panama. The potential for Panama being labeled as an enemy of the environment is very real.

4.2.3.2 *National Consensus.* The Government of Panama will be required to establish clearly define policies and build a national consensus among the social institutions and the people in support of Canal alternative construction issues prior to the final design phase or the start of construction. These include politically sensitive issues such as the public debt, foreign influence, foreign rights and responsibilities, and the import of a large number of foreign workers. Given the projection of increases in population and in the demand for social and technical infrastructure made without taking any canal alternative into consideration, the development of policies and the building of consensus could become a political problem and an impact stemming out of either alternative. It would be much more significant impact in the case of the Sea Level Canal on account of the expanded territory being assigned for the waterway and associated issues.

4.2.3.3 *Sovereignty and Management of the Canal.* Given the fact that over 85% of current Canal employees are Panamanian, and given the positive actions which the Government of Panama is taking to structure the management of the current canal under a new authority established by the constitution, the impact of either alternative on the political structure's capability to manage the expanded canal will be the same. With the experience of twenty years of sovereign management of the current Canal, Panama will have demonstrated its ability to manage the international waterway. The international community will have a measure against which to calculate independent sovereign capabilities to manage the construction and operation of either alternative. However, internally, the degree of independent Panamanian control of the Canal alternative project, as it is perceived and understood by the populace, will have an impact on the stability of the political system and on the strength of national institutions. If it is perceived and understood that Panama has sovereign control of the facility, a positive impact occurs. If it is

perceived or understood that Panama does not have sovereign control of the Canal facilities, a significant negative impact occurs.

4.2.3.4 *Security and Security Forces.* There will be direct political impacts regarding expansion of the area in which the political system will be required to provide security and control. This will have a greater impact during the operations. The provision of security under the Neutrality Treaty, and the development of security forces required to provide security and control over the extended area encompassed by the current canal and either alternative could have a major negative political impact. This impact will be much greater in the case of the Sea Level Canal alternative. The additional security forces required to provide day-to-day security and protection services for the High-Rise Lock Canal alternative are minimal. The location of the new locks within the current Canal area means that additional personnel and facilities will be perceived as an addition to the current force of 900 persons. The Sea Level Canal alternative requirement of an additional 900 to 1000 persons is significant. Given Panama's experience with the 1968 coup and the two decades of military dictatorship, developing and training the larger number of armed personnel along with the sophisticated equipment needed to provide surviellence and to secure the separate Canal facility could create a distabilizing influence on the political system. The problem created by such additional security forces requires additional study.

Indirect Impacts:

4.2.3.5 Relocation caused by either Canal alternative will cause an indirect political impact. The Government will be required to create means of indemnification and compensation through legislation, prior to the start of construction for either alternative or this will be a major negative impact. The Sea Level Canal alternative will cause a significantly larger displacement of the population. From the socio-cultural and political viewpoints, it may be necessary and more feasible that some communities remain where they are, requiring some realignment of the project control area or other engineering adjustments in the Sea Level Canal alternative.

4.2.3.6 Beginning with the announcement of construction work for either Canal alternative, the Government will be required to plan and fund sufficient social and technical infrastructure expansion to decrease the level of perceived relative deprivation. While for purposes of the identification of infrastructure impacts, this study assumed that the Government

would develop the required and planned infrastructure to meet the needs of an increase in population, without such planning and funding actions the Canal expansion will highlight and increase the associated problems, and therefore will have a negative impact on the political stability of the Government. This impact may be greater with the Sea Level Canal on account of the magnitude of the disruption.

4.2.3.7 Demographic indicators show that the increase in population in the Metropolitan Region will most likely produce an increased poverty, informal markets, and social pathologies. This will affect the public security system and the administration of justice. This impact may be more severe as pressures to expand the urban areas increase with the opening of significantly larger areas of the country should the Sea Level Canal be selected.

4.2.4 *Socio-Cultural And Population Impacts*

Direct Socio Cultural and Population Impacts

4.2.4.1 Anticipation and actualization of large investments in either alternative will create an accelerated flow of domestic and foreign migrants from. The growth of the Metropolitan Region will exceed present forecasts. Anticipation of development in or near the project areas of the Sea Level Canal alternative will directly impact the migration flows to that area which is less capable of providing for such an increase. Impacts stemming from the High-Rise Lock alternative will be of a smaller magnitude.

4.2.4.2 An increase in spontaneous settlements and/or population growth are expected impacts both during the mobilization for, and the construction of, either alternative. In both cases, the supply of labor will be higher than the demand estimated for either canal alternative. The need for selective qualified labor will not necessarily coincide with the usual oversupply created by migratory flows, or collateral formal activities generated by construction works.

Indirect Socio-Cultural and Population Impacts

4.2.4.3 Announcement of canal construction for either of the two canal alternatives will further increase the tendency of Panama's population to concentrate in the Metropolitan Region. This will have the indirect impact of increasing unemployment and underemployment especially in the unskilled labor categories.

4.2.4.4 During the construction period the provision for and the use of the workers camps and the housing areas for the staff could create negative indirect impacts. Conscious efforts by the Government will be required to organize and to manage these housing camps and villages in order to avoid the negative impacts experienced during and after the original Canal work. The larger number of workers for a longer period of time in the Sea Level Canal alternative, and the increased number of villages and camps to accommodate these workers, makes the impact of this alternative more significant.

4.2.4.5 The incursion on government or private lands by domestic or foreign migrants, while at the same time anticipation and speculation in land potentially inflate values could also be an indirect negative socio-cultural impact. These situations may arise in the case of either of the alternatives, but can be predicted to be greater in the case of Sea Level Canal.

4.2.2.6 Social infrastructure and public services in the Metropolitan Region absorb a large part of Panama's financial, technical and professional resources. Both alternatives will require additional resources, which, if priority is given to those services, will be detrimental to the rest of the country. This impact is anticipated to be more significant with the Sea Level Canal.

4.2.2.7 The permanence of the villages after the construction period, unless they are constructed with a view to facilitating post construction utilization by the Canal Authority as maintenance or as industrial areas, will be a reminder of the Canal Zone days, which in turn, will entail a negative impact on the national conscience. This is much more significant in the case of the Sea Level Canal, because there is no history of such separation in the areas, and because existing accommodations in the Metropolitan Region could be used during construction of the High-Rise Lock Canal alternative, especially if the phased construction concept is utilized.

4.2.5 *Geographic And Environmental Impacts On Panama*

4.2.5.1 Both canal alternatives will have a negative ecological impact by placing a greater barrier to species migration between the two Americas. In this respect, the Sea Level Canal will present a greater obstacle to land migration, while at the same time permitting species migration from one ocean to another.

4.2.5.2 During construction and operation, the Sea Level Canal alternative will have a direct impact on the habitat of some of Panama's endangered species. In 1980, the Smithsonian Tropical Research Institute (STRI) reported 82 species of wildlife in danger of extinction, some of which are endemic to Panama's habitat, such as the Tapir Tapirus bairdii, the titi monkey Sagüinus geoffroyi, the porcupine Coendou rothschildi, the white tail deer Odocoileus virginianus, etc. The findings of the Smithsonian Tropical Research Institute were subsequently supported in 1985 by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, in 1990 by the International Union for the Conservation of Nature, and by the CAS Component Study, Background of Biological Data and Biological Inventory, in 1993. The geographic zone cited for Panama's endemic habitat includes most of the area planned for the Sea Level Canal alternative. Given today's world sensibility to ecological problems, studies into possible repercussions should be conducted.

4.2.5.3 Although ocean environments are dissimilar (salinity, temperature, currents and tides) the potential exchange of species between the Pacific Ocean and the Caribbean Sea and the alteration of the sea and coastal marine life caused by the Sea Level Canal alternative will be of great consequences for Panama and the world. These consequences are significant and, since their magnitude is not known, they present a significant negative impact requiring further detailed study.

4.2.5.4 Assuming that an accelerated Metropolitan Region growth rate will add to the stress associated with the canal excavation work and with the ensuing canal operations, and that in turn, it will transform the geographic environment and the ecosystem, the economic polarization of Canal construction will affect the current Canal. This negative impact applies to both alternatives, but is much greater in the case of the Sea Level Canal which will be a source of

oceanographical, geomorphological and, above all, hydrological problems, threatening the entire system of the current locks Canal and is considered a significant negative impact.

4.2.5.5 Digging a Sea Level Canal will lower the fresh water tables presently located at an average depth of 5 meters in the Continental Divide and in the Pacific watershed, thus endangering underground water resources. Other associated problems are likely to arise, such as sedimentation, salination and other physio-chemical alterations of the water quality. The availability of water and the water quality are a matters which must be studied in greater depth prior to choosing a Canal alternative.

4.2.5.6 The Sea Level Canal alternative would generate large volumes of earth and rocks, which are hard to dispose of and hard to relocate. This would cause significant hydrological and geomorphical problems. The use of land for dumping involves a negative impact on available natural resources. Likewise, the dumping of material deposits off shore and the creation of large breakwaters will increase water turbidity. The coastal ecosystems will be greatly disturbed especially in the Caribbean, which system is adapted to transparent water. The impact of this planned engineering solution for disposal of the evacuated materials will be negative and the impact will be significantly greater with the Sea Level Canal.

4.2.5.7 An increase in demand for food and farm raw materials, created by the excavation of a new canal could give rise to agricultural intensification and more input of chemicals, with subsequent increases in agro-chemical contamination. The agro-industrial sector is currently a primary contamination source in the Central Provinces and in the West; while actions can be taken to reduce and control the use of chemicals, it is more likely that such use would increase significantly. This impact would be marginally greater in the case of the Sea Level Canal.

4.2.5.8 Oceanographic Alterations in Panama Bay. The fauna and flora of the Gulf of Panama is more adapted to changes in salinity and temperature, and therefore, the impact of sediments dumping is less than that of the Atlantic. However, there are changes in coral formation subject to adverse factors south of Taboga, and in the Pearls Archipelago. The coral formation near Taboga may be affected by coastal transformation and transmigration of species due to the construction works in the Pacific for the Sea Level Canal.

4.2.5.9 An important negative impact of the Sea Level Canal alternative is the alteration of various watercourses in the area, activating erosion processes caused by deforestation, and the change of river beds and levels. This will increase the transportation of sediment to Gatun Lake and to the current Canal. Excavated material will also be unstable, creating the potential for landslides and blockages in stream valleys, especially during the high run-off periods after the rains.

4.2.6 *Impacts On Infrastructure*

4.2.6.1 *Drinking Water Supply*

The availability of water primarily related to Canal operations and use is first addressed in the Yachiyo (ECE) report. The possibilities of tapping fresh water that could be contaminated by sea water, or by the need to dig extremely deep wells cannot be determined without further studies by hydrogeological experts The Sea Level Canal alternative with its relative depth of excavation appears to be the most risky for the ground water supply especially, if the water lens is cut by excavation works.

Significant amounts of water for municipal use will be required for the La Chorrera-Arraijan area. The Sea Level Canal will have an impact on future, planned new infrastructure, and will deplete water supplies in the areas should the water barrier system be possible.

4.2.6.2 *Ports:* The High-Rise Lock canal alternative eliminates the Port at Rodman. Current Government of Panama planning calls for the development of this facility as a commercial port as an extension of the Balboa port complex. The cost of replacing this facility is very high, and as an impact ought to be considered in the light of current planning.

4.2.6.3 *Structures:* It is estimated that approximately 1000 structures will be affected by the Sea Level Canal alternative, including small towns along the river of the Sea Level Canal route and structures within the dammed water areas. (Chapter 6, Para 6.4.3.2)

4.2.6.4 *Roads:* The Sea Level Canal alternative requires construction of a new trans-isthmian highway and new construction roads that will enable some remote towns to have better access to the Pan-American Highway and the Arraijan-La Chorrera Freeway. The construction of the Sea Level Canal alternative will require greater use of the existing road network and the Pan-American Highway resulting in increased maintenance costs, traffic congestion andlonger travel times.

4.2.6.5 *Bridges*

The ECE report provides an allowance for the Van Dam (Simon Bolivar) bridge over the current canal and the new High-Rise Lock canal in the year 2060. As currently planned, the Van Dam (Simon Bolivar) bridge will be built by Panama before the year 2000; this bridge will not span over the future facilities of the High-Rise Lock canal. If the High-Rise Lock Canal is selected, planning for the construction of the Van Dam (Simon Bolivar) bridge will be directly affected. If Panama does not allocate resources to accommodate the enlarged span prior to construction or final design of the High-Rise Lock Canal alternative, this will be a direct negative impact.

The current bridge at Gatun locks does not have the capacity for heavy machinery to cross. For the Sea Level Canal, a new bridge across the Gatun route is not to be built until the year 2020 (only the bridges across the Sea Level Canal route, Escobal, and the bridge on the Pacific side); All materials and equipment used in the construction site on the west bank of the existing canal (on the Atlantic side) will have to be transported either by sea or across Panama using the trans-isthmian highway, the Pan-American Highway, and new access roads built for the project. Therefore, the roads between Colon and the town of Nuevo Chagres will not be impacted by the construction of the Sea Level Canal.

4.2.6.6 *Electrical:* Electrical towers for high-voltage power lines, and, other projected lines will be affected equally by both alternatives. The Sea Level Canal will affect distribution lines along the Canal alignment route. In the case of the High-Rise Lock, canal distribution lines will be affected in the towns of Gatun and Cocoli.

4.2.7 *User Impacts As They Impact Panama*

4.2.7.1 There will be no indirect impacts on Panama as a result of the impacts on users, or they will be negligible.

4.2.7.2 Induced world trade resulting from transportation cost savings and lowered delivery prices for goods will not have any impact on Panama since Panama is a very minor user of the Canal. Any potential new shipbuilding orders, and induced shipbuilding economic activity, will not impact Panama, as Panama does not have a shipbuilding industry.

4.2.7.3 The major indirect impacts of the direct impacts on users are worldwide or macroeconomic in nature, that is, on those nations that are the major beneficiaries of the Panama Canal and/or its successor. The major indirect benefits of effects on users are not for Panama.

4.3 MOST IMPORTANT DISCRIMINATING IMPACTS

In Table 3 on the following page,there is a summary of the most important impacts to consider at the time of evaluating and discriminating alternatives. Economically and financially, it appears that the Sea Level Canal alternative provides the greatest positive impacts at least during construction. In every other study field, the Sea Level Canal alternative has the most significant negative impacts upon Panama. On the basis of the Analysis Impact Upon Panama, Component Study effort, findings indicate that the High-Rise Lock Canal would be the best alternative for Panama.

In developing a means to compare impacts between the two alternatives, a scale was used with a view of presenting the relative significance. The scale is from -5 to +5 in significance as shown below.

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Major	Very	Definite	Minor	Some	No	Some	Minor	Definite	Very	Major

Except for the economic and financial impacts that appear in projected numbers or dollars, the weights in Figure 3 are meant to be relative only in comparison with numbers used for the same impact.

Most Important Impacts For Evaluation

Impact	Magnitude of Impact (1)	
	High-Rise Lock	Sea Level
Economic (Short Term)		
• Expenditures in Panama (in 1990 Millions)	$1,617.4 (150,000DWT)	$1,952.4 (+28.6%)
• Monetary Impact on Panama (in 1990 Millions)	$1,354.5 (200,000DWT)	$1,605.6 (+15.3%)
• Direct and indirect Employment During Construction	95,760 (150,000DWT) 107,236 (200,000DWT)	140,828
Imports into Panama (Short Term)		
• Imports into Panama (in 1990 Millions)	$7,818 (150,000DWT)	$10,180 (+30%)
Political-Economic		
• Unanticipated Costs/Delays	-2 (2)	-5
Political		
• Provision of Security and Maintenance of Legitimacy	-2	-5
• Political Dimension of Environmental Concerns	-1	-5
Socio-Cultural		a
• Excess Migration to Project Areas	-2	-5
• Relocation	0	-3
Socio-Cultural/Infrastructure		
• Infrastructure Expansion	0	-3
Environmental and Geographic		
• Lower Water Table and Contamination	-3	-5
• Cross Ocean Migration of Species	0	-5
• Disruption of Endemic Habitat and Migration	-3	-5
Geographic and Infrastructure		
• Adequacy of Fresh Water		

(1) Except for Economic and Financial, the weights shown are meant to be relative only in comparison with the number in the same Impact area. The scale of impacts is from -5 to + 5.

(2) High-Rise Lock Canal has the capability of being phased and therefore anticipations and negative results of unanticipated costs and delays are mitigated.

Table 3: Most Important Impacts For Evaluation and Discrimination

5. OVERALL CONCLUSION AND RECOMMENDATION

The Government of Panama is currently faced with formidable challenges, that need to be solved before entering into a final design stage for a given alternative. These challenges include international pressures to restructure an enormous public debt, a Constitution developed to support the Military Dictatorship, labor laws which are complexed, inhibiting to investment and a disincentive to private business, and improved government financial capabilities to support needed infrastructure maintenance and enhancement.

The Panamanian Government also has been challenged with reconstructing the civil functions of government and the political system in a period in which extensive changes such as the reversion of the US military bases and the Panama Canal must be planned and accomplished. The capacity to accommodate these changes, while instituting structural reforms and overcoming the economic legacy of the military regime, is one the key considerations in identifying and analyzing the political impacts of either Canal alternative.

Considering the numerous economic, socio-cultural, population, and infrastructure challenges facing the government in the next two decades, and given that both altenatives will provide the needed additional capacity to meet that projected growth in use of the Canal, the conclusion of the Analysis of Impact Upon Panama Study is that the Government should choose the least intrusive alternative.

This study concludes that the High Rise Lock Canal alternative will have less impact on environment and on the geography. It will impact less on the current or planned infrastructure and will require less additional infrastructure. It will impact less on the financial and economic flexibility of Government in terms of guarantees and revenue. It will have fewer negative impacts on the population and socio cultural infrastructure. It will have less potential political impacts in terms of relocation of people and in terms of Government areas of control and protection. In every sense, the High Rise Lock Canal alternative is the least intrusive; and since the High Rise Lock Canal alternative will provide Panama with the required additional transit capacity, it is recommended that the Government of Panama select this alternative.

Final Report

of the

Commission for the Study of

Alternatives to the

Panama Canal

14. A Feasibility Report

Executive Summary

1993

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.

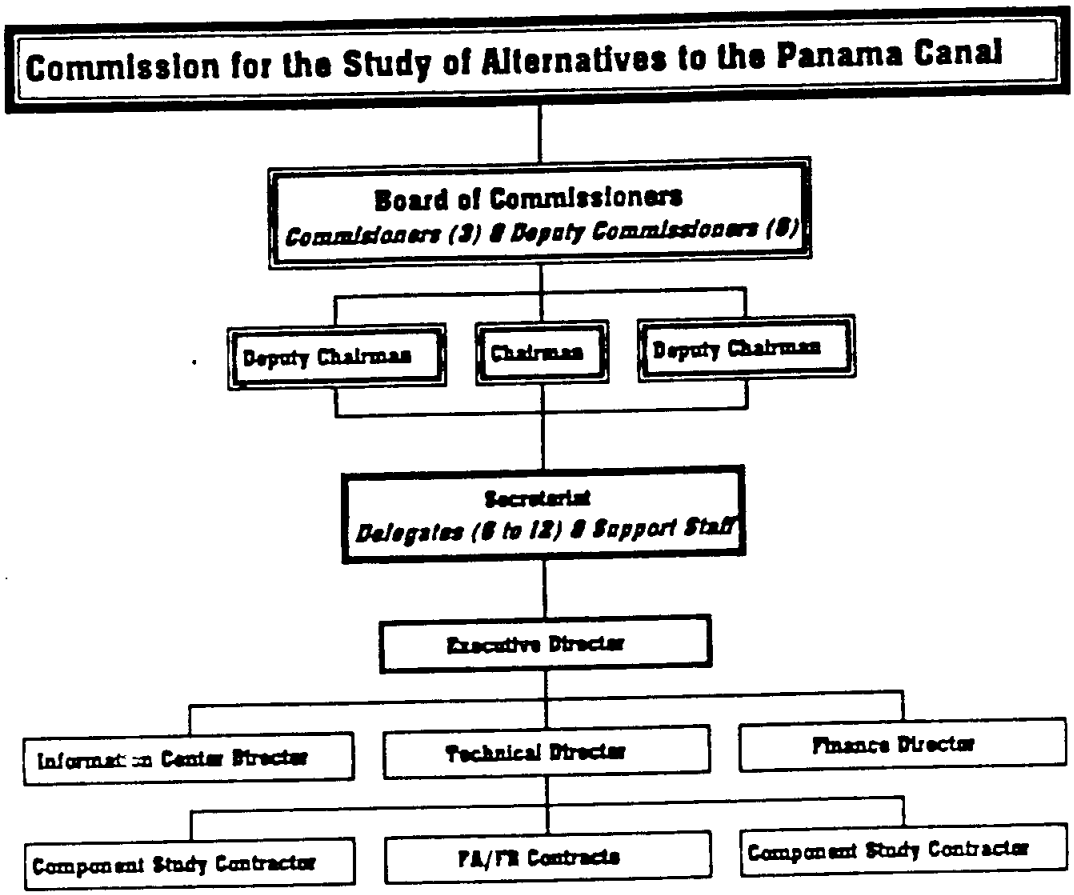
To provide a definitive answer to the question of the need for another canal and the related territorial requirements in Panama, the study envisioned by the Preparatory Committee was expanded by an exchange of notes in 1982 establishing the study commission to be much broader and comprehensive than the 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.

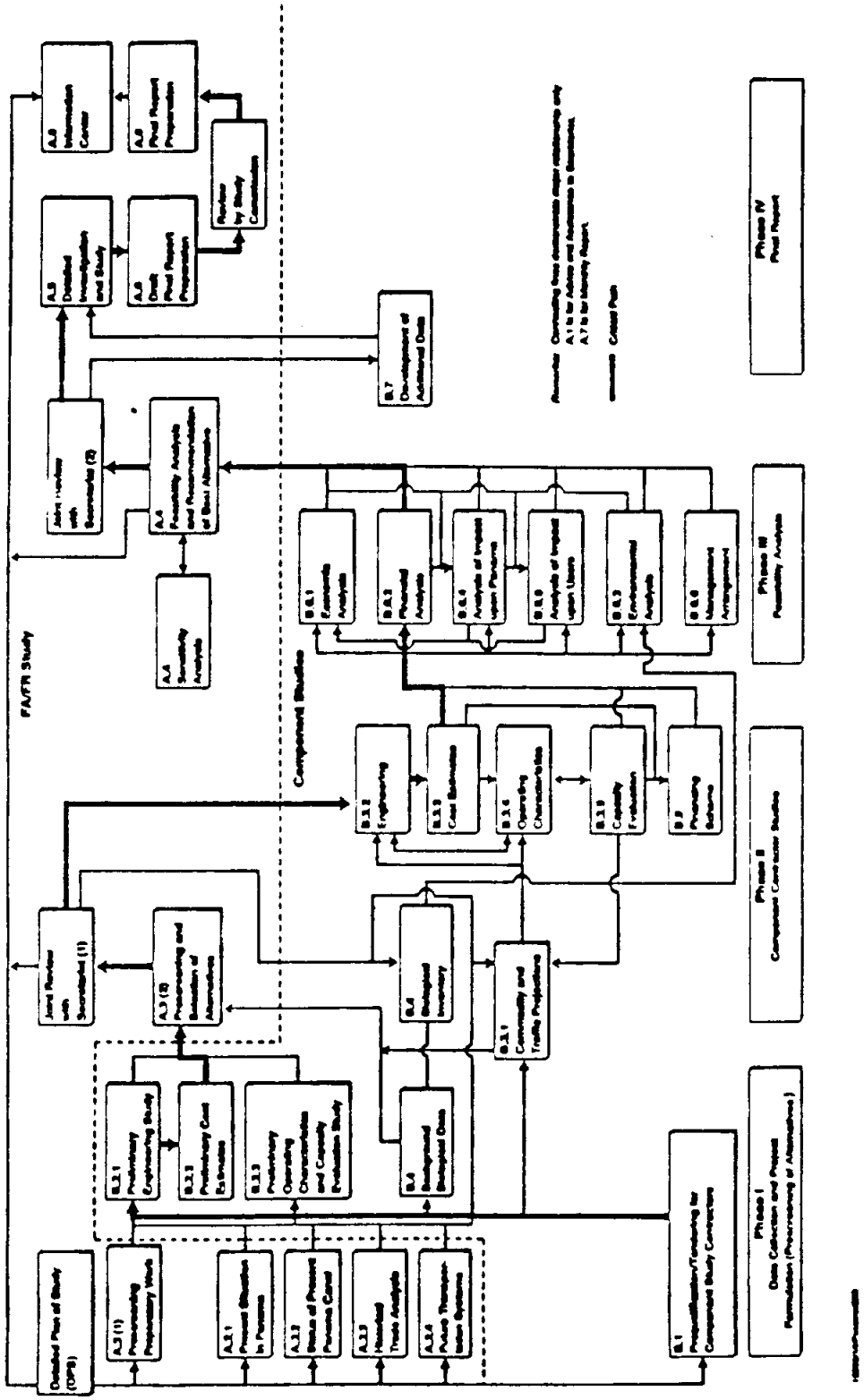
These are listed below:

- 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	Dug Size	Sunny 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 Garun 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 Garun Lake
		L - 14	150		
		L - 17	250		
	2 - c	L - 12	100	30	New Canal Alignment in Garun Lake
		L - 15	150		
		L - 18	250		
Alternative 3 Sea Level Route 14S	3 - a	S - 8	150	Nos of lanes 2	Route 14S
		S - 10	250		
		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.

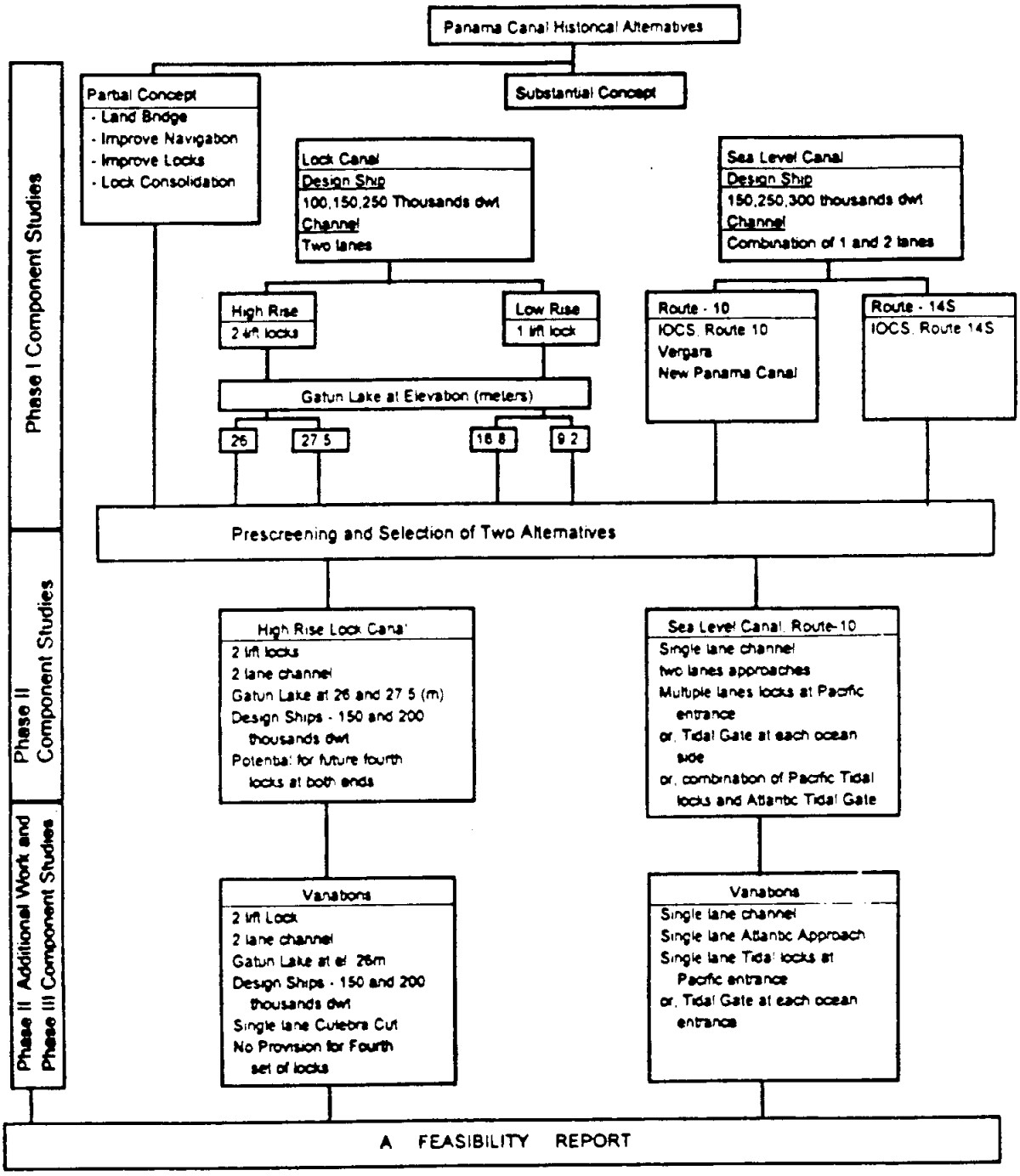
The route for the High Rise and Low Rise Lock Canal alternatives was the existing Panama Canal route with minor alignment changes to improve navigation. The number of lifts were one and two lifts. Two canal ship lanes were included in the evaluation. Different elevations for the canal Summit Lake were 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

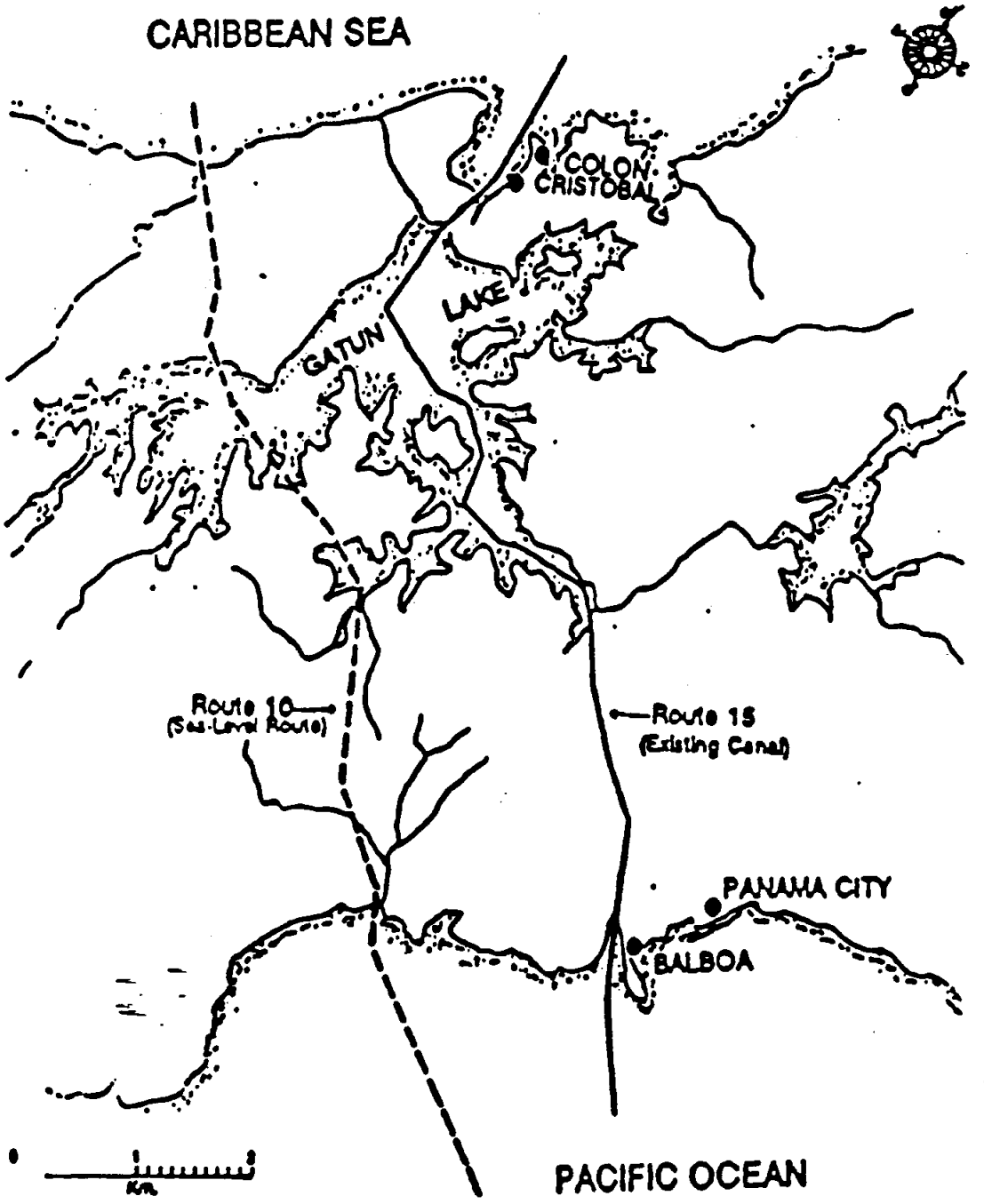


Table 1.4.1-1
Maritime Trade, Actual 1990 and Projections
(millions of metric tons)

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 Size	Channel		Lock Chamber		
	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

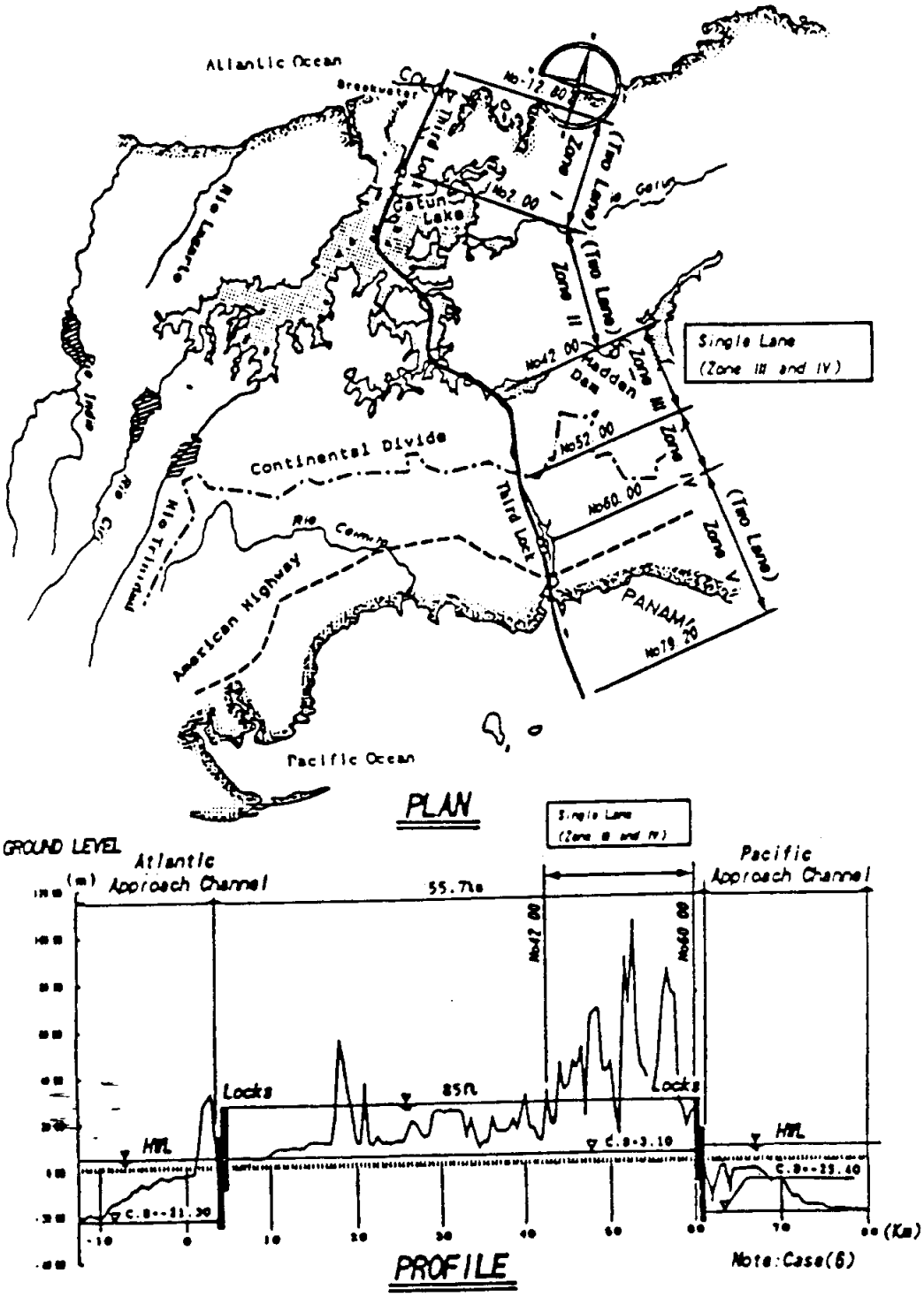
The location, route, and profile of the lock canal alternatives are shown in Figure 1.4.2-1. Both alternatives, for either 150,000 or 200,000 dwt. vessels, would use the route of the present canal except for new channels that would by-pass the existing locks at both Gatun and Miraflores Lakes. At each 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 fluches. 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



SINBOL

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.

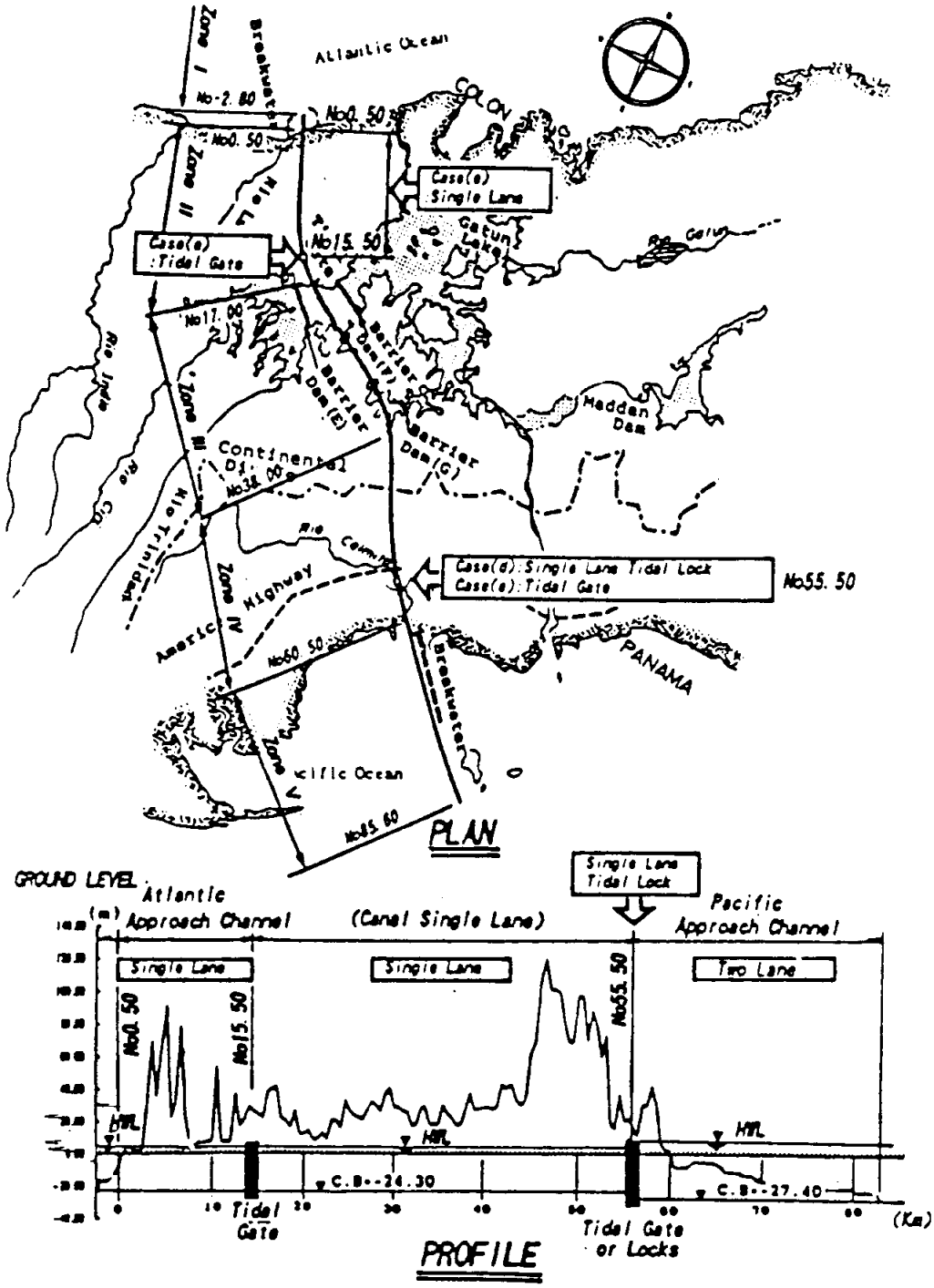
Sea-level Canal Features

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.

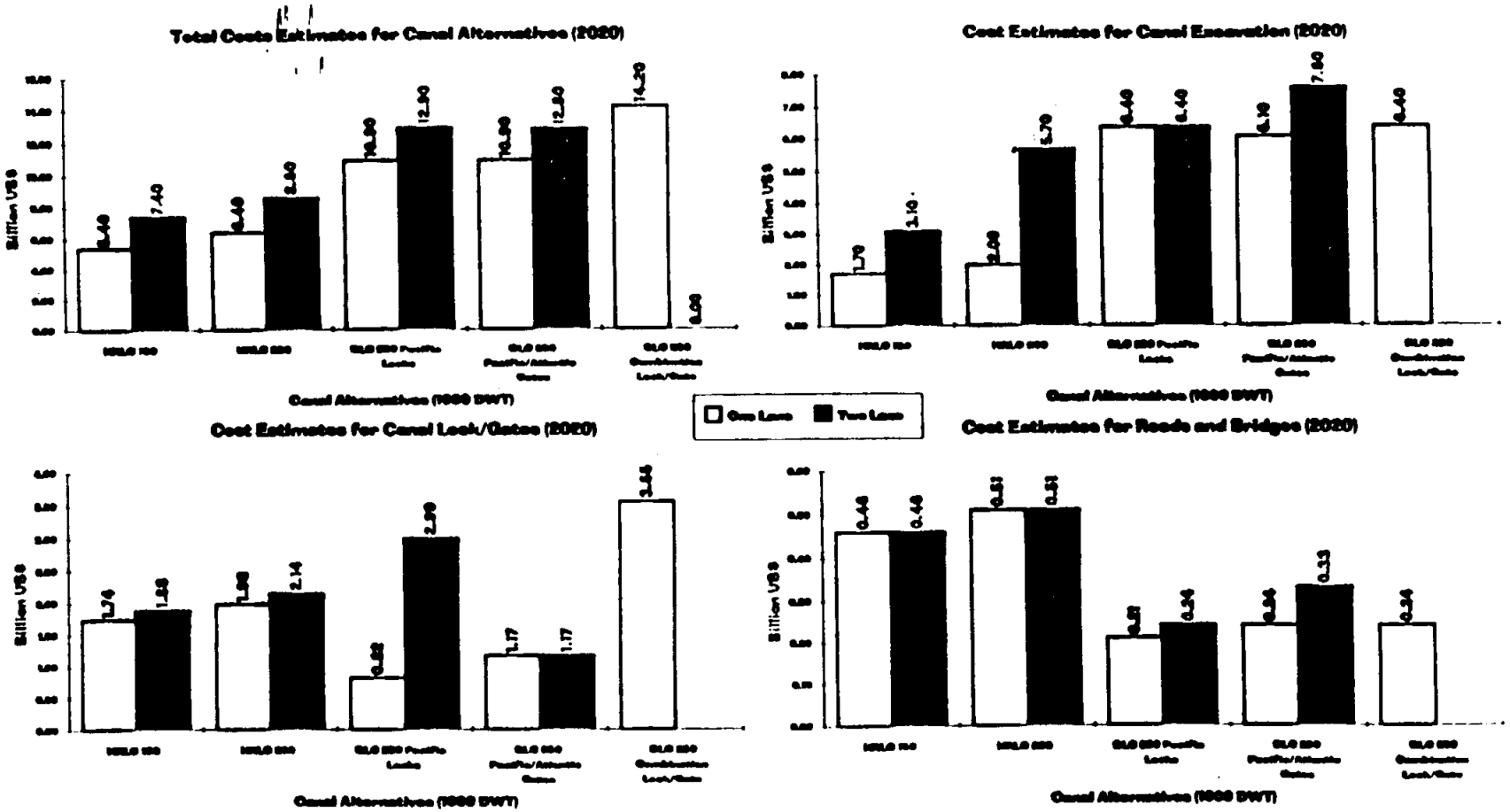
3 Hydraulic Structures includes construction of dams, breakwaters, diversion, recycling, etc.

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 km² Basin	4.3	3.3	3.1
Vergara, 100 km² 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,

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

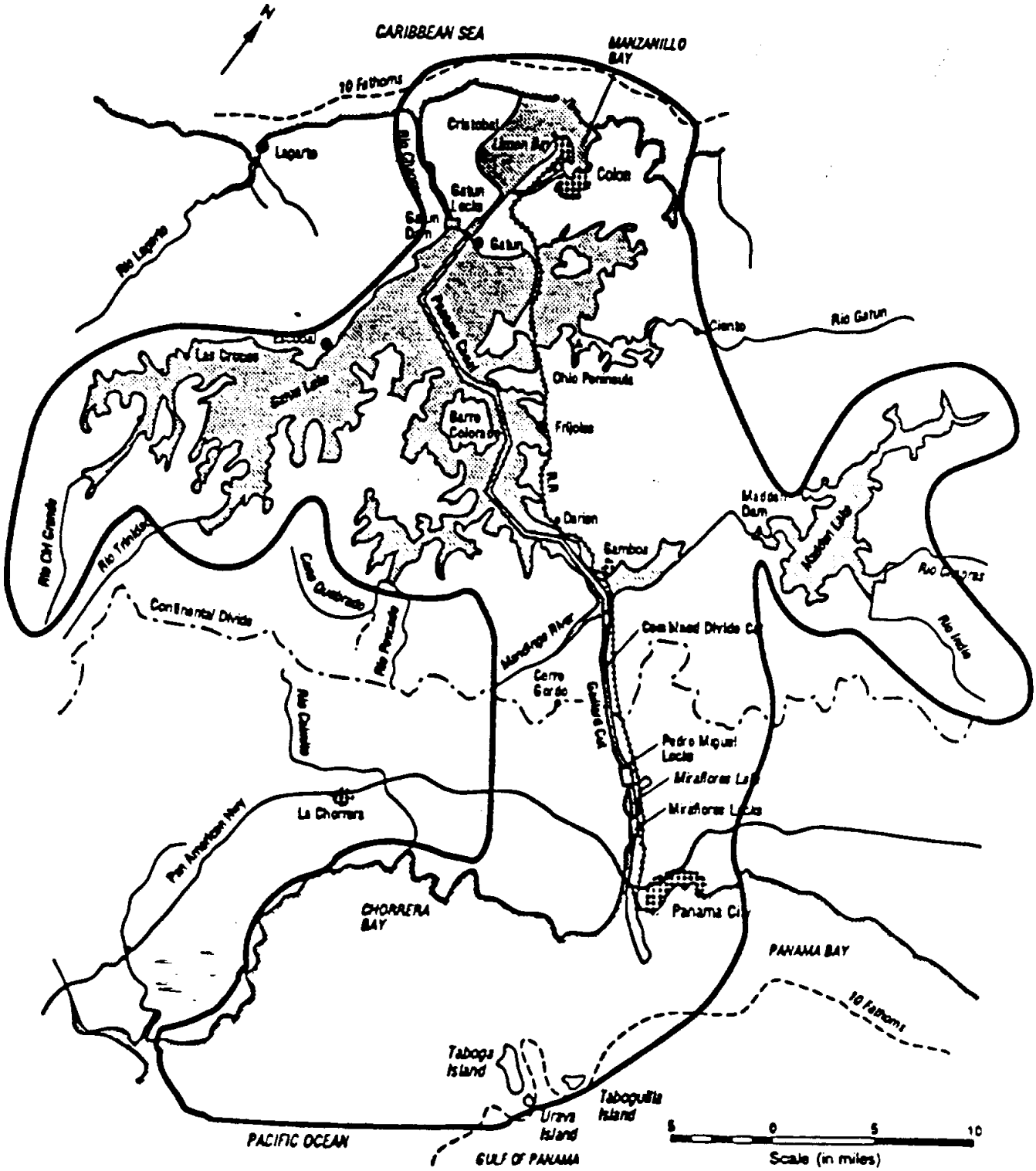
Impact identification depends on a through understanding of existing conditions, and the ability to predict future change. Within the time limits available for performing this study, sufficient information was developed to produce initial estimate of impacts of construction and operation of canal alternatives. 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.

Figure 1.4.4-1
Study Area



- 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.

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.

- 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.

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

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 1.4.5-7

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.

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

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.

- 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:

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 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:

- 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.

Table N°.	#Title & Source
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
1.4.5-5	Economic Capital Costs Source: Economic Analysis and Impacts on Users Study, Final Report and Additional Study
1.4.5-6	Economic Evaluation Source: Economic Analysis and Impacts on Users Study, Final Report and Additional Study
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.