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STUDY ON THE PERSPECTIVES OF THE PRESENT PANAMA CANAL

TABLE OF CONTENTS

Chapter III

INVESTIGATIONS AND STUDIES ON A SEA-LEVEL CANAL

ANNEXES

This study has been prepared at the request of the Government of Panama by the Transport Section of the Mexico Office of the Economic Commission for Latin America.

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INTRODUCTION

The following is an investigation into the present traffic capacity of the Panama Canal and the form in which - according to the various projects already drawn up or still being worked on - the capacity could be increased as the volume of traffic gradually becomes greater. The projects for increased capacity range from the construction of works of a certain size, to allow the passage of an increased number of ships, to those for the conversion of the route into a sea-level canal, or even the construction of a new canal of larger size, with better facilities for navigation.

A comparison of the characteristics of the canal, with present transport needs and those estimated for the future, shows that certain large ships cannot pass through even now, and that it will not be possible in the near future to cope with an increase in important traffic unless new works are carried out. A study has been made of the adequacy, inadequacy, and possible obsolescense of the canal in the light of various estimates of future traffic, and comments made on the technical and economic aspects of the problem and of the useful life of the present canal. The possible conversion of the canal to a sea-level one has been considered in accordance with already drawn-up plans.

The data used as a basis for this study has been taken, mainly, from published documents. Due to the urgency of completing the study, exchanges of opinion with Panamanian experts and functionaries of the Panama Canal Company were limited to the minimum, and no field studies have been carried out.

/SUMMARY

SUMMARY

1. Since it was opened in 1914, the Panama Canal, in spite of its complicated works, has been of great benefit to a considerable amount of sea traffic. In order to deal with the ever-increasing amount of traffic and to allow the easier passage of larger and faster ships, technical and administrative improvements have frequently been carried out.

2. In 1958 works were initiated - estimated at 125 million dollars - for the purpose of increasing from 33 to 87 the number of ships passing through the canal daily. These works consist in the improvement of the system of locks and of the interior canals which connect them up. It seems that certain additional problems have cropped up during the course of these works, including the possible inadequacy of the water and electricity supplies, which may prevent the estimated number of ships from passing through the canal. Although there are various alternatives to overcoming these problems, the most effective would probably call for the completion of works outside the Zone.

3. On completion of the works, 57 ships per day will be able to pass through the canal. It is expected that the capacity of the canal will thus be sufficient to cope with traffic requirements for the next 20 years, and according to estimates, 42 ships per day will be using the canal by 1980. However, the expected increase in traffic will in any case call for a perfectioning of the technical-administrative organization, and there will doubtless be an increase in the time and number of delays to traffic, particularly towards the end of the period.

4. On the other hand, even if all expected increases in traffic could be handled by speeding up the action of the locks, it would still not be possible to cater for all types of ships. There are at present about 300 ships which can pass through only with a much-reduced load of cargo, and still other which cannot pass through under any circumstances.

5. The estimated greater amount of traffic, plus the ever-increasing numbers of large ships, cause one to contemplate the carrying out of works of a more important nature. The transit of 100 ships daily would

/call for

call for the installation of an additional set of locks of a large size, costing between 550 and 900 million dollars. This would not solve the problem of large commercial ships, and the cost would be prohibitive in comparison with that of the construction of a new sea-level canal.

6. Five years ago, the most economical project for a sea-level canal - a reconversion of the present one - would have cost an estimated 2,300 million dollars. More recent preliminary and unofficial studies indicate a cost of between 1,800 and 1,300 million dollars. A possibility is also being considered of making use of the new method of nuclear explosives to construct a canal which would be technical and economically better-suited to sea transportation. Two sites are at present being considered - one in Panama which would cost between 750 and 1,000 million dollars and another in Colombia to cost roughly between 1,440 and 1,500 million dollars. The Panamanian project offers economical and technical advantages which make the Colombian route a less probable choice.

7. Either of these projects - by use of conventional or nuclear methods of excavation - would require several years of detailed study before it could be carried out. Particularly as far as the method of nuclear excavation is concerned, there are at present unkown factors to consider which could make it necessary to revert to a conventional type of construction, even if the cost were greater. In such a case, the best course would appear to be the conversion of the present canal on the same site, since to construct a new canal in another country by this method would cost at least 4,000 million dollars.

8. From the technical and economic data and studies available, it is obvious that the most convenient procedure would be to site the new canal in Panama, regardless of the method of construction employed. If the construction were carried out in the Canal Zone, itself, however, the nuclear explosive method could not, of course, be utilized. It appears at this stage that the strongest reason for selecting a site outside the Republic of Panama would be to ensure greater safety against the effects of the nuclear explosions.

/Chapter I

Chapter I

OPERATION AND PRESENT AND FUTURE CAPACITY OF THE CANAL

1. Generalities

On initiating a study on the prospectives of future use of the present Panama Canal, one should keep in mind the political objectives for its construction, which took place between 1904 and 1914.[1/] The principal purpose was to effect inter-ocean communication by use of efficient methods of organization and construction approved in the United States, and within the rules of public financing which were in force in the United States at that time. Initially, it was decided to construct a lock canal, but with the provision that this would later on be converted into a sea-level canal.[2/] In order to provide the most efficient service possible, various necessary reformations and administrative and technical improvements have been brought into being from time to time. The most recent works were completed in 1959 in agreement with the United States Congress[3/] and in collaboration with the Panama Canal Company and other institutions.

The recommendations of the Commission of Consultants appointed by Congress[4/] are an indication of the conclusions reached in this respect and of the methods of improvement followed. These consist, basically, in the urgent completion of such technical improvements as the available funds

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1/ For the legal bases see Manuel B. Moreno C., Legal Status of the Agreements on the Panama Canal, Ministry of the Exterior, Panama, 1964.

2/ "Report of the Board of Consulting Engineers for the Panama Canal, 1906", United States Government, Printing Office, Washington, D.C. 1906, commented on in Proceedings, American Society of Civil Engineers, June, 1948, Vol. 74, No. 6, p. 1015, note 2.

3/ The principal work of reference on the subject is Report on a Long-Range Programme for Isthmian Canal Transits House Report, No, 1960 86th Congress.

4/ Report on a Long-Range Programme, op.cit. page 7. In recommendation 1 a plan of renovation for several of the projects studied is put forth as "Plan 1" in accordance with the nomenclature used in the studies on the reconstruction of the canal.

would allow for, i.e. to reconstruct the lock mechanism and improve the layout in order to facilitate the passage of transport which is increasing in both directions; to increase production of electricity; to study possibilities of constructing a canal in Colombia and to improve on the plan for converting the present canal and to continue studying the nuclear technique for excavation purposes. The Commission advised against commencing any study for the construction of a sea-level canal in the Zone in the near future.

A further official recommendation was made by the United States[5/] concerning the present canal in which it was pointed out that although the present canal should be serviceable until the end of the twentieth century, only a sea-level canal could meet the rising needs in sea traffic, be used for ships of larger dimensions and would fulfil the requirements for the defence of Panama. The Company would calculate the amount of investments called for by the increase in commercial traffic and would make whatever contributions were possible from the funds obtained. Improvements to ensure greater efficiency for military use or a reduction in anticipated future costs would be financed from the Defence Budget.

Concerning the financial aspect[6/] and additional investments, in the agreements made between the United States Government and the Canal Company the latter undertakes: to recover the amount invested in the operation and upkeep of the installations, plus depreciation; to credit the United States Treasury with the interest on the net investment made by the Federal Government and to reimburse to the said Treasury the annuities payable to the Government of Panama and the net costs incurred by the Government of the Zone, including depreciation of fixed assets. The rate of interest may be periodically reviewed by the Treasury. The Board of Directors of the

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5/ Report on a Long-Range Programme, op.cit. pages 5 and 42. Mentioned more recently in discussions on the sea-level canal in the United States Senate, Congressional Record, Vol. 110, No. 171, pages 21052 and 21054.

6/ These facts are referred to in the introductions to the Annual Reports of the Company (see page 2 of the Reports of 1960 and 1963).

Company must calculate its capital on an annual basis and credit to the Treasury all excess funds, which are put towards the paying off of the capital debt.

The principal source of revenue is the toll charges, which are based on the following tariffs.[7/]

a) Passage of merchant vessels, military transport, tankers, hospital ships or yachts: 90 dollar cents per net ton of 100 cubic feet capacity (in accordance with the Company's rules of measurement), for ships carrying cargo, passengers or correspondence;

b) Passage of ballast ships, carrying neither passengers nor cargo: 72 dollar cents per net ton;

c) Passage of other vessels (to which net tonnage measurement is not applicable): 50 dollar cents per ton.

These tariffs, which have been in force since 1 May 1938, are slightly less than those fixed in 1912 when the canal was first opened to traffic.

2. Description of the canal

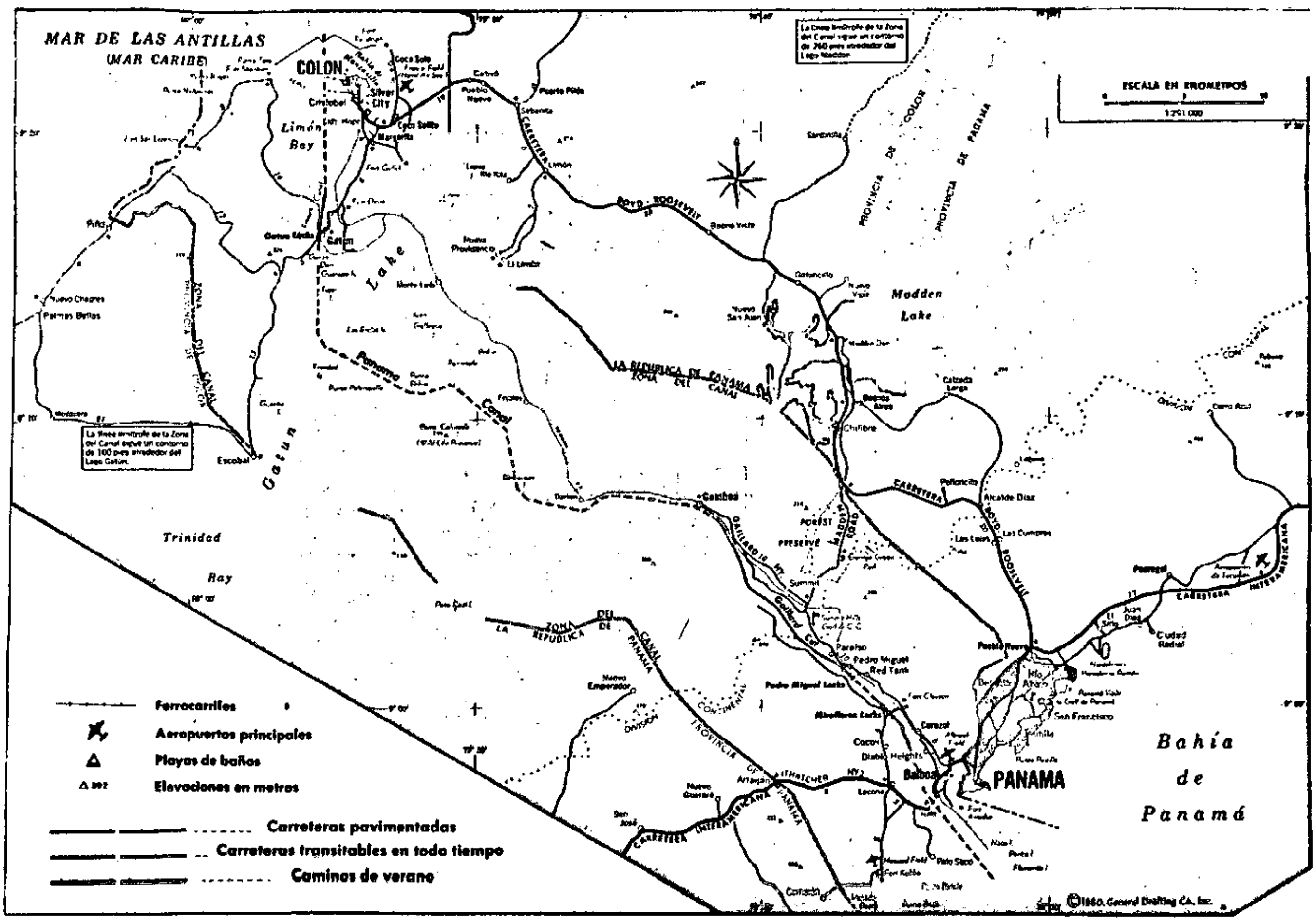
The Panama Canal is a man-made passage, 56 km long, connecting the Atlantic Ocean to the Pacific through the Isthmus of Central America, between the Bay of Limon and the Panama Gulf. It is situated at approximately 9° 7' latitude north and 79° 46' west, in the so-called Canal Zone (see map 1); except for the cities of Panama and Colon, which extend from some 8 km (5 miles) on each side of the centre of the route. Also in the Zone, but outside the area described, are certain sectors being put to military use, and the Lakes of Gatun and Madden on the River Chagres. These lakes are navigable, and suitable for both water storage and the supply of electric power. The Zone begins at 3 miles from low-tide mark and comprises a total area of 890 km^2 (553 sq. miles).

7/ Fixed by decree of the Presidency of the United States, based on the law of 24 August 1937 (50 Stat. 750, United States Congress).

/On passing

Map 1

PANAMA CANAL ZONE



On passing from the Atlantic to the Pacific Ocean, a ship enters the Bay of Limon and moves into an access canal 12 km long (6.36 naut. miles), leading to the three-step, double-chamber Gatun locks. These locks raise the ship some 27 m to allow it to pass into the interior canal in Gatun Lake. For some 36 km the route follows the valley of the River Chagres. It then passes through the Continental Divide, at 80 km above sea-level,[8/] by way of Gaillard's Cut (previously called Snake Canyon), 11.2 km in length, which leads to the Pedro Miguel locks. It then descends through the locks to Miraflores Lake, which it crosses in order to reach the double-chamber Miraflores locks, 1.5 km further on. On the last stage of its journey the ship passes through a navigation canal 12.6 km long (6.99 naut. miles), at the level of the Pacific Ocean, thus covering a distance of 82.3 km (44.4 naut. miles) in all. It takes an average of 14 hours [9/] for a ship to pass through the canal, not including the time spent in port. There are two terminal ports, Balboa Port, near Panama City and Cristobal Port[10/] in Colon. Both have facilities for the provisioning of ships and the handling of cargo.

a) Principal characteristics of the canal

As previously explained, since the lock canal was constructed it has been necessary, from time to time, to carry out certain works to improve the service or expand, to a limited extent, the traffic capacity. (See diagram 1.)

The relatively short navigational access channels are the only stretches of the canal at sea-level. They are 150 m (500 feet) wide and, at turn of tide, 12 and 13.5 m deep in the Atlantic and Pacific, respectively. They allow simultaneous transit in both directions.

8/ Before the canal was constructed this was 105 m above sea-level.

9/ The average time taken was 19.3 hours in 1960, 16.5 in 1961, 15.5 in 1962, and 13.8 in 1964.

10/ See report of the United States Corps of Army Engineers, The Panama Canal and its Ports, Port Series No. 90, Washington, 1946.

/The locks

The locks separate the sea-level stretches from the interior canal which is at a higher level. In each case the locks are double and adjacent to each other, with a common central wall. They allow for either simultaneous transit in opposite directions or the passage of two ships at a time in the same direction. The sluice-gates and valves for conducting water are operated by electric motors. The ships are towed through the locks by electric engines (mules), and in the case of large ships, 8, 10 or 12 engines may be required.

The internal dimensions of the locks are: length 305 m, width 33.5 m and height 21.40 m, and their working depth is 12.50 m (1,000 feet long, 110 wide and 41 deep). The Gatun locks on the Atlantic side raise or lower ships 25.50 m (85 feet) above sea-level, in three stages. On the Pacific side the operation is performed in a single stage by the Pedro Miguel locks, with a drop in level of 9.30 m (31 feet) and two stages in the Miraflores locks, with a total drop in level of 16.20 m (54 feet). At each operation[11/] the locks take in approximately 200,000m^3 (52 million gallons) of water through the force of gravity.

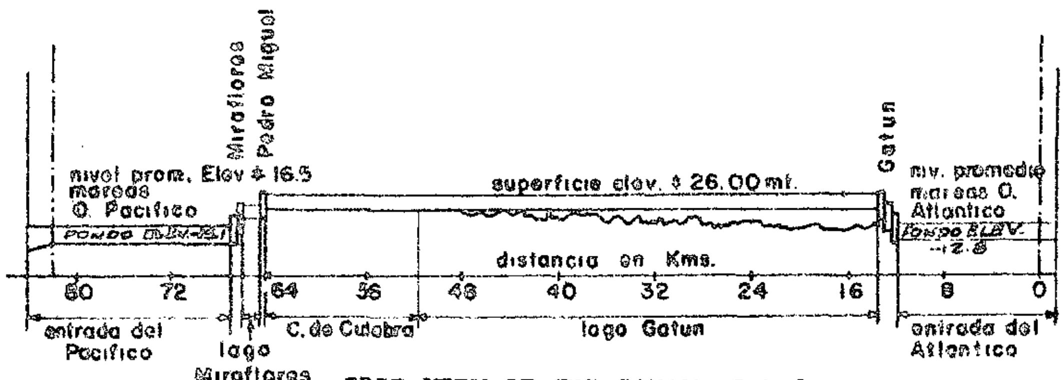
The interior (or inter-connecting) canal lies between the Gatun and Pedro Miguel locks. Its width varies between 305 m (1,000 feet) near to Gatun locks and 92 m (300 feet) at one part of Gaillard's Cut. The width in Gatun Lake varies between 320 and 490 m (1,050 and 1,600 feet). The middle stretch of Pedro Miguel, where it crosses Miraflores Lake, is 152.5 m (500 feet) wide. The depth varies between 14.0 and 12.5 m, according to the amount of water storage at a given moment.

Three dams have been constructed. On the Atlantic side, the Gatun earth dam forms the lake of the same name, and its waters can be retained at an elevation of between 25.0 and 26.5 m above sea-level (82 and 87 feet). The Miraflores earth dam is used for storing and controlling the water in the Miraflores Lake, between the Pedro Miguel and Miraflores locks. (Normal elevation is 16.5 m (54 feet) above sea-level. The Madden concrete dam, which was built in 1935, is situated at about 13 km northeast of the

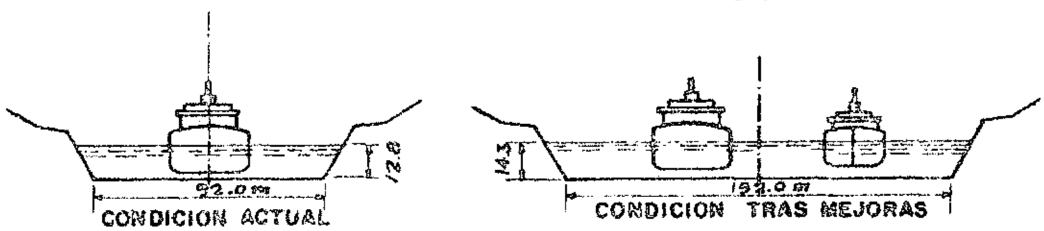
11/ "Operation" covers the working of the locks from the moment one ship enters them until they are ready to receive the next ship.

Diagram 1

PANAMA CANAL: SIDE VIEW AND TYPICAL CROSS SECTION



SIDE VIEW OF THE PANAMA CANAL



TYPICAL CROSS SECTION OF THE SNAKE CUT

canal on the River Chagres. It is used to store the water required for the operation of the canal during the summer and for flood control during the rainy season. The normal elevation of the lake is 73.2 m (240 feet) above sea-level.

Electric power is obtained from two hydro-electric plants with respective capacities of 24.0 and 22.5 MW, one at Madden and the other at Gatun. The latter is augmented by three diesel plants which operate during the summer, since the water reserves are then used primarily for navigational purposes. In 1963, a thermal plant was installed in Miraflores, which at present consists of two units, each with a capacity of 10.8 MW. The supply system of the Zone is connected up with that of the firm which supplies the area adjacent to the Panama Republic, so that power can be exchanged if necessary.

A large number of personnel is required for the operation of the canal. In 1964 the Canal Company employed nearly 11,300 persons, of which approximately 80 per cent were of Panamanian nationality and the rest United States citizens.

b) Factors which influence the capacity of the canal

The capacity is obviously limited by the size of some of the installations and by the special precautions which must be taken in navigating a man-made channel. The result is a limit on the size of ships which can be handled and on the total number of ships which can pass through within a certain length of time. The greatest capacity is obtained when the operations can be correctly synchronized and a balance achieved in the traffic passing in both directions. To date, the maximum number of ships to have passed through in one day is 33.

i) Limitations on the size of ships. As the locks are 305 m long and 33.50 wide (1,000 and 110 feet), and the sluice protectors are on the inside, the size of ships which can pass through is limited to: depth 12.50 m (41 feet), length 297 m (975) and width 31.70 m (104 feet). The draught, length, and beam of the ships must therefore be adjusted to these measurements. Further limitations are placed by the bends, width and depth of the inner canal and, in particular, by a length of Gaillard's Cut, which is the narrowest part of the route (150 m), where opposing currents are created when a ship passes through. In no case should there be a depth of less than 1.50 m of water between the keel and the bottom of the canal. As the level of Lake Gatun is reduced, at times, to 12.20 m (40 feet), this gives rise to further limits, of a temporary nature, in the maximum allowable draught. Ships must not surpass, at the very most, the limits of 31 m beam (102 feet), 244 m length (800 feet) and 11.20 m draught (37 feet).[12/] The latter measurement is reduced to 10.70 m (35 feet) in the dry season. Ships with a draught of more tan 11.30 m have to be towed.

ii) Time taken in transit. The time taken to pass through the locks is variable: the average is 40 minutes in the Pedro Miguel locks, 60 in the Miraflores and 80 in the Gatun. It depends on the size of each ship, the use of tugs and the water storage. When ships with a beam of more than 24 m (80 feet), or even 26 m (86 feet),[13/] pass through, the whole operation takes longer. In the former case it takes an additional 30 minutes and in the latter case 50 to pass through the Gatun locks, with a proportionate increase in the stated times for passage to be effected through the other locks. On the other hand, two or more ships of small size may pass through simultaneously in one operation, with a resultant saving in time and water. Statistically speaking, an average of 1.10 ships pass through each time the locks are operated. Calculating on this basis, the maximum capacity would be 40 ships per day under excellent conditions, excluding the periods when the locks are being inspected. However, the upkeep and inspection of the lock machinery and the control and watch which is kept on ships in transit, particularly in the narrowest part of the inner canal (Gaillard's Cut), result in a reduction in this capacity.

12/ There are exceptions: during the transit of a ship with special characteristics or large dimensions passing through for the first time, observations are made on any particular difficulties with the intention of trying to avoid them on future occasions.

13/ The former are referred to in reports as "large ships" and the latter as "extra large ships".

/Inspections are

Inspections are made once every five years, and until 1964, it was necessary for a whole lock to be taken out of service. It took from 13 to 21 weeks to carry out general repairs and a further two to three weeks to inspect the ducts and valves of the central wall. Repairs are normally made in stages so as to leave a complete line of locks in operation at one time. During the course of the repair works which take the longest time (Atlantic locks), the capacity of the canal is reduced to 33 ships per 24 hours.

Due to their size or cargo, some of the ships which use the canal have to pass alone through the narrow stretch of the inner canal ("clear-cut"). Others are obliged to pass through this part or through the locks during the daylight hours ("daylight clear-cut"). Four ships, each requiring sole passage through Gaillard's Cut, can reduce the capacity of the canal from 33 to 31 ships in a day.

iii) Other factors. Other limiting factors are unequal numbers of ships passing from one ocean to the other, bad weather, accidents and damages to the works. Since there is anchorage near the Atlantic locks, only, the flexibility which would help to reduce the inconveniences of greater transport in one direction is therefore restricted. Adverse weather conditions also affect capacity, and in spite of the fact that electric light has been installed in Gaillard's Cut and in the locks, nocturnal operations are impossible under conditions of heavy rain or fog. (An average of 27 nights per year of suspended operations due to these causes is calculated.) Even during the day it is dangerous for ships to enter the Cut in foggy weather.

Water storage presents another problem in that even when the water level in the inner canal is at the required depth, there are uncertainties concerning the maximum draught which can be admitted and the most suitable draught for passing through the locks. For example, to ensure the safe passage of ships of more than 240 m long, a draught of less than 11.20 m is required, whereas the draught of ships of this size is usually more than 12 m.

/The water

The water reserves are also used to generate the electricity required for the operation of the canal, and for the municipality, and to store up drinking water for the population. There is a sufficient quantity for the canal operations and for the municipal supply, but not for the generation of electricity from January to May. Of the quantity of water which is stored annually in Gatun Lake, approximately 10 per cent is lost in evaporation and more than 15 per cent passes through the spillway. Forty per cent is used by the locks, 30 per cent for generation of electricity and 2 per cent for municipal uses which, in 1964, came to 32 million m^3 for Panama City and 26 million for the Canal Zone, Colon and Cativa.

3. Recent improvements

Improvements and reconstructions have been found necessary from time to time, to cope with increasing demands on the use of the canal. Studies have been made on long-range improvements, in particular since 1929, which advised the construction of a third set of locks,[14/] the deepening of the navigation channels and the final conversion of the route into a sea-level canal. The construction of a third set of locks of a smaller size to increase both the capacity and security[15/] of the canal was begun in 1940 with a capital of 277 million dollars, but work was interrupted in 1942. Excavations ceased at Gatun and Miraflores, at a cost of 75 million dollars. It was presumed that the project would be finished after the war, but work was suspended later on.[16/]

Although since the war the possibility of a sea-level canal has been considered, projects have, nevertheless, still been worked on to improve the present canal. Reconstruction of the navigation channels as well as the use of new equipment, a process to facilitate and speed up the work of maintenance of the locks and machinery have been planned in order to increase

14/ Recommended in the Report of the Governor of the Canal Zone, submitted to the United States Congress. H. Doc. 139, 72 Cong. 1 sess. 1932.

15/ The locks should be 13.50 m wide (45 feet), 365 m long (1,200 feet) and 15 m (50 feet) deep.

16/ See Report on a Long Range Programme op.cit. pages 332 and 334.

/the transit

the transit capacity and the safety of navigation. In 1957 the United States Government approved a programme for dealing with transit requirements for a period of from 10 to 20 years. This was revised in 1959-1960, by the United States Congress, and it was then apparent that the canal could be made adequate to meet the needs of sea transport until the beginning of next century.[17]

a) Plan of reconditioning

The 1960 plan includes propositions for a series of works, installations of equipment and machinery and other improvements which are based on the recommendations of the 1957 studies, contained in the "Programme of short-term improvements" and recommendations for the enlargement of the canal taken from the "1960 Programme of long-term improvements". Some of the works were initiated in 1955 and budgets for most of the remainder were approved in 1957. Detailed studies and designs were later made which advised changes in the order of priority and the putting off of some part projects. There is, therefore, no total budget for the plan, nor is it possible to estimate the date when it will be completed. An approximate investment of 125 million dollars will be required over the construction period which will extend from 1955 to 1972. (See table 1.)

Meanwhile, some works have just been completed, others are under way and some have not yet been started. The plan, in its entirety, consists of the following: widening of Gaillard's Cut and the navigable canal of Gatun Lake; reconstruction and modification of the locks; replacement of locomotives; cranes and tugs; lighting of the canal; improvement of the access canals; improvements of the inner canal; control of maritime traffic; an increase in the water reserves; enlargement of the installations for electricity generation; conversion of the electric current from 25 to 60 cycles and the reconditioning of the Bridge of the Americas.

The capital invested by the Canal Company is in part laid aside for the improvement of the navigable route and the equipment, and in part for

17/ See Report on a Long Range Programme, op.cit., pages 3 and 4.

/ Table 1

Table 1

PANAMA CANAL: PROGRAMME OF IMPROVEMENTS, 1954 - 1972

(Thousands of dollars)

Project	Year of commencement	Year of termination	Total estimated investment	Expenditures 1958	1959	1960	1961	1962	1963	1964
Widening of Gaillard's Cut	1958	1968	43,700	...	...	...	...	5,900[a/]	2,300	1,900
Deepening; Gaillard's Cut, Gatun Canal	1959	1967	21,500[b/]	...	...	...	...	...	2,100[c/]	-
Locks	1964	1972	10,000	-	-	-	-	-	-	...
Mobile equipment										
a) Locomotives	1963	1965	8,000	-	-	-	-	500	1,200	2,300
b) Tugs	1961		2,100	-	-	-	2,100	-	-	-
Lighting	1958	1968	1,600	...	...	...	...	...	1,400[c/]	-
Sea canals	1957	...	4,200	2,500	...	...	...	...	...	...
Improvements in the interior canal	1954	...	3,100	-	-	-	-	-	-	-
Control of sea traffic	1961	1964	800	-	-	-	...	...	600[c/]	260
Water storage	1965	...	11,000	-	-	-	-	-	-	-
Electric power generation	1960	1970	9,000	-	-	-	-	1,300	2,100	1,500
Conversion of the electric system	1955	1965	3,700	...	...	...	...	...	3,100[c/]	...
Bridge of the Americas	1959	1962	20,000	...	...	...	...	...	...	-

Sources: Annual reports of the Canal Company, 1954 to 1963; Annual reports of the Board of Directors, Canal Company, 1958 to 1964; The Panama Canal Review, in Spanish, Vol. 2, Nos. 6 and 11; Vol. 3, No. 3; Report on a Long Range Programme for Isthmian Canal transits, pp. 295 to 333.

a/ Partial total for 1958-1962, 22.8 million dollars.
b/ Includes dredging in the sea canals.
c/ Expenditures up to the present year.

/the operation

the operation and administration of the canal and works in connection with the administration of the Zone.[18/] (Table 2 is a summary of the total investments made between 1954-1964.) Apart from capital investments, one must take into consideration the fact that the normal costs of operation, conservation, and amortization also have a bearing on the revenue which is received. (See table 3.)

i) Widening of Gaillard's Cut. The widening of this Cut to 150 m (500 feet) along its entire length of 13 km (8 miles), would provide a route suitable for navigation in both directions, and would do away with the need for the majority of precautions, previously mentioned, which must be taken in the case of ships which have a dangerous cargo, are difficult to handle, etc. Work was commenced at the beginning of 1958 and should be concluded in 1967 or 1968. By February 1964, widening had been completed along 76 per cent of the route. Estimated cost is 43.7 million dollars.

ii) Deepening of Gaillard's Cut and the navigable canal in Gatun Lake. The depth of Gaillard's Cut and of the navigation canal in Gatun Lake is estimated at 14.30 m (47 feet). An excavation would therefore be required of approximately 1.50 m (5 feet) - 0.60 m to facilitate the manoeuvring of ships and 0.90 m to increase water storage for lock operations during very dry summers. With this modification, the maximum draught of ships which could enter this section of the canal would be in accordance with the figure for the locks. (See section 2 b) of this chapter under "Other factors".) It will take four years to complete this project. Work on the widening of Gaillard's Cut was started in 1959, and if the project had not been suspended in 1964, so that it could be coordinated with work on the Trinidad dam (see sub-paragraph ix), it could have been completed in 1967. The estimated cost is 21.5 million dollars, including dredging of the access canals.

18/ For example, between 1961 and 1964 the following works were carried out: construction of a hospital, modernization of the telecommunication system, plans for the building of schools and houses, port services and other public works.

/Table 2

Table 2

PANAMA CANAL: CAPITAL EXPENDITURES,[a] 1954-1964

(Millions of dollars)

Year[b]	Total	Transit	Others
1954	8.7	2.3	6.4
1955	9.4	4.8	4.6
1956	6.0	1.6	4.4
1957	6.7	1.3	5.4
1958	8.7	2.1	6.6
1959	15.4	6.0	9.4
1960	19.9	12.9	7.0
1961	21.9	12.4	9.5
1962	30.4	19.2	11.2
1963	20.4	7.7	12.7
1964	15.2	5.8	9.4

Source: Direct information from the Canal Company, April 1965.

a/ Includes expenditures of the Panama Canal Company and of the Government of the Zone.

b/ The fiscal year ends on the 30 June.

/Table 3

Table 3

PANAMA CANAL: REVENUE, CURRENT AND CAPITAL EXPENDITURES,[a] 1954-1964

(Thousands of dollars)

Item	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Revenue											
Tolls	37,191	35,137	37,451	39,654	42,834	46,547	51,803	55,173	58,347	57,856	62,546
Others	49,204	48,681	51,806	46,951	40,277	40,703	41,627	43,228	41,736	45,841	50,501
Total	86,395	83,818	89,257	86,605	83,110	87,250	93,430	98,401	100,083	103,697	113,047
Disbursements											
Current expenditures											
Operations, maintenance and other net costs	56,422	66,514	61,309	58,180	53,238	52,341	51,097	54,141	53,614	61,653	72,143
Net costs of the Government of the Zone	10,366	9,779	10,078	10,136	10,737	11,646	12,801	13,366	13,663	14,980	16,300
Interest of the United States' investments	8,847	9,044	8,591	8,868	8,779	8,979	8,925	8,771	9,360	10,077	10,950
Subtotal	75,635	85,337	79,978	77,184	72,754	72,966	72,823	76,278	76,637	86,710	99,393
Capital investments											
Programme of renovation of the canal	...	...	...	...	...	...	...	10,100	8,500	8,200	6,000
Other capital investments	...	...	...	...	...	...	...	6,710	7,600	6,413	5,492
Subtotal	6,600	7,900	5,100	5,600	7,700	11,300	14,700	16,810	16,100	14,613	11,492
Total	82,235	83,237	85,078	82,784	80,454	84,266	87,523	93,088	92,737	101,322	110,885
Net revenue	4,160	581	4,179	3,821	2,656	2,984	5,907	5,313	7,346	2,375	2,162

Sources: Annual reports of the Canal Company. Government of the Canal Zone 1954 to 1963. Annual reports of the Board of Directors, Panama Canal Company, 1958 to 1964.

a/ The figures quoted refer only to the Company's current operations and programme of renovation of the canal.

iii) Reconstruction and modification of the locks. The overhauling and cleaning of the locks will be carried out by a new process which will reduce the length of time during which they are kept out of service, and modify the installations to a certain extent so as to allow for inspection and repairs to be effected more rapidly. The control machinery of the two independent water conduit systems (normally in service) is being rebuilt so that the lock will not be out of service during inspection periods. The inspection of either conduit will take only 24 hours instead of one or two weeks. The sluices will also be treated by a special process so that the locks will need to be emptied only once in 20 or 30 years instead of every five years, as before. When the locks are operating continuously the capacity of the canal will be doubled.

The cost of these works is estimated at 10 million dollars. On completion of the necessary studies, works were begun in 1964, were finished in Miraflores in 1965, will be terminated in Gatun in 1966 and will finally be completed in Pedro Miguel in 1972.

iv) Replacement of locomotives, cranes and tugs. The replacement of mobile equipment commenced, under the short-term programme, with the ordering of 59 new locomotives from Japan in 1960. The new equipment is heavier (2,000 tons), fast, and powerful. Each set of locks will be equipped with 16 locomotives for service, 3 for maintenance and 2 in reserve. By June, 1964, 23 locomotives had been received and the remainder were expected to arrive in August 1965. It is calculated that the average time taken for one operation at Gatun lock (which determines the traffic capacity) will be reduced by 20 per cent which, together with the improvement in the locks, will increase the capacity quite considerably.

Three crane-locomotives have also been purchased and these should have come into service in April 1965. The cost of the locomotives and crane-locomotives is 6.7 million dollars, but with the necessary modifications to the route, the total cost will be 8 million dollars.

In 1961, three 2,400 HP tugs were also put into service.

v) Lighting of the canal. Improvements in the lighting system, calculated at 1,600,000 dollars, were begun in 1959. It is intended to replace all lighting in the locks by a more modern system, and to install fluorescent lighting in Gaillard's Cut. This lighting, plus the present signaling system, will allow for navigation by day or by night through any part of the canal, thus eliminating extended interruptions in operation. Advantage was taken of this improvement to establish canal services during 24 hours a day.[19/]

vi) Dredging of the access canals. Reference is made in the Company's studies on short-term improvements to the three chief means of facilitating navigation of the canals. These are as follows: a) the extension of the anchorage at Cristobal, by dredging to a depth of 12 m (40 feet), to make room for five ships (work was commenced in 1957 and completed in 1958, at a total cost of 2.5 million dollars); b) the extension of the Pacific access canal - it is 150 m (500 feet) wide, but in the stretch adjacent to Balboa Port, it is reduced by 20 or 25 per cent due to winds and cross currents, so that it should be widened to 180 m (600 feet) at an estimated cost of 650,000 dollars - and c) the change in location of a fuel storage wharf, situated very near the bank and parallel to its axis, which represents a possible danger to ships because of the rush of waves which they produce in passing. For this reason, either the wharf should be removed to another site (at a cost of 1 million dollars), or this particular stretch of the canal should be modified by making a new excavation (at a cost of 2.5 million dollars). Neither of these two solutions has yet been definitely approved, but a plan has been drawn up for the dredging of the canal and work should have already commenced.

vii) Improvement of the interior canal. Since 1954, ways have been sought to improve the geometrical characteristics of the inner canal in order to facilitate navigation and increase the security of ships, particularly those which are heavily-loaded or large in size and, above all, to protect them from cross currents at the bends. With this idea

19/ Inaugurated on 12 May, 1963.

/in mind,

in mind, the bend at Paradise Point, the so-called Bend 1660, and the Cockroach-Paradise stretch, have been widened. These works were later added to the project for a widening of the entire Gaillard's Cut.

The project to widen bends 1366 and 1450-N in the Gatun Lake canal is of a similar nature. A number of islets must be removed from the area since they curtail the ships' visibility. The cost of these works is calculated at 2.6 million dollars.

There are plans to widen the stretch of the canal which is situated to the south of Miraflores lock by rectifying the western bank in order to facilitate the exit of ships to the sea. The estimated cost would be half a million dollars. The possibility has also been considered of constructing a landing stage to the north of Pedro Miguel lock for ships which have passed through the lock and are waiting to go through Gaillard's Cut. This delay may be imposed by the navigational regulations or by adverse weather conditions such as fog or rain. The locks would thus be able to continue functioning even though the ships could not proceed. The construction of such a mooring area would improve the flexibility of operations and would therefore increase the capacity of the canal. Estimated cost of the project is 1,360,000 dollars, but it is being held up because the widening of Gaillard's Cut may make it unnecessary.

viii) Control of sea transport. The Company has decided to modernize and improve the traffic control system, which has been in use ever since the canal was opened. An electronic system will be used and a control centre will be set up from which direct communications will be made with ships and lock control offices.

The control centre will be able to provide continously the information required to programme the transit of ships and will be aware of their position at any given moment. Installation of the system includes pieces of apparatus to arrange manoeuvres, locate ships and indicate their position. It also has a VHF radio station to give instructions on the road and in the canal, and to allow the repair

/engineers to

engineers to communicate with the locomotive operators.[20/] The cost of this project will be 2.3 million dollars. Part of the installations was completed in 1961 and 1962.

ix) Increase in water reserves. The increase in sea traffic calls for a large quantity of water for the lock operations, to maintain the levels in the inner canal and Gatun Lake which are required for passage of ships of the deepest draught, and for the production of electric power. The needs of the first two requisities can be met by the present storage system, but this reduces the amount available for generation of electricity. According to the renovation plan this problem will be solved by increasing the water reserves for navigation, and obtaining electric power from other sources.

According to the 1957 short-term programme, it was hoped to increase reserves by deepening the inner canal and constructing an additional dam, in the part of Lake Gatun called Trinidad, with a water-retention level of 28.50 m (95 feet) above sea-level.[21/] with an estimated cost of 33.9 million dollars. This project is not included in the improvements already underway, because it was considered that other, more feasible solutions could be found. It has been pointed out that a level higher than 24.60 m (82 feet) could be obtained in the inner canal by limiting the use of water to generate hydro-electric power, by constructing an additional reserve outside the Gatun area, by pumping in sea water or, combining these solutions, by constructing the projected dam on another site at a different altitude in order to reduce the cost of the operation.

Meanwhile, in 1963 the company carried out improvements to three of the sluices-gates of Madden lock, which allowed the level of the Lake to be raised by some 60 cm (2 feet),[22/] and revised the Trinidad project with

20/ The new locomotives will be equipped with radios instead of using manual signals for communication with repair engineers and the locks. The cost of a radio is 90,000 dollars.

21/ The increase in reserves would be 400 million m^3 (309,500 "acre feet", i.e. 28 per cent more than the present storage capacity of Lake Gatun.

22/ This implies 30,000 m^3 (1 million cu. feet) equivalent annually to 2.9 million kWh of energy and 146 additional lock operations.

the idea of achieving greater water storage.[23] The cost of the project was estimated at 11 million dollars and in 1964 it was submitted for the approval of the United States Congress. Work has not yet begun, and dredging operations have been halted in Gaillard's Cut, since it is intended to use the material which will be excavated to build the dam.

x) Extension of the installations for electricity generation. The electricity requirements have been rapidly increasing because of a greater demand for domestic use and the needs of the military forces in the Canal Zone and Panama City.[24]

The Company therefore considers it essential to increase the capacity of the system and has fixed an approximate goal of 100 MW by 1970.

In 1963, two 10.8 MW gas turbine engines were installed in Miraflores. In 1964, a contract was signed for the installation, also in Miraflores, of a 25 MW plant which will utilize steam from the gas turbines. A study is being made to decide whether it would be convenient to install a nuclear energy plant. The Company has displayed interest in the Bayano hydro-electric project which is being considered by Panama, and would be willing to purchase energy for the canal if it were realized.

xi) Conversion of the electric current from 25 to 60 cycles. The Company's entire electricity supply system had to be converted progressively from a frequency of 25 to 60 cy. This project was initiated in 1955, at an estimated cost of 13 million dollars, and is now almost complete. Only a part of this project has been included in the programme of improvements to the canal, i.e. the section relating to the electricity system of the locks. It is chiefly a case of replacing the machinery for working the sluices and valves, the auxilliary electric control machinery and other machinery which would be affected by the change in frequency. This would not affect the old locomotives which are used to tow ships through the locks. The project is scheduled for termination at the time when the new locomotives are expected to arrive. Cost of this part of the conversion is an estimated 3.7 million dollars.

23/ Calculated at 530 million m^3 (430 000 "acre feet"), representing an increase of 44.5 per cent.

24/ The interconnected systems of the Canal Zone and Panama City were used in both directions during the summer of 1964.

/xii) Bridge

xii) <u>Bridge of the Americas</u>. Situated on the Inter-American Highway in Balboa, this bridge crosses the canal at its outlet to the Pacific Ocean. It was built between 1959 and 1962 to replace the thatcher ferry. The construction of the bridge was included in part 4 of the Twelve-Point Agreement referring to relations between the Panama Republic and the United States, signed in 1942 and ratified in part 5 of the Memorandum of Understanding in 1955. The name was adopted by agreement of the Panamanian National Assembly.

The bridge is 1,655 m (5,425 feet) in length and has a maximum height of 117 m (348 feet) above the level of the canal, The minimum clearance is 61.30 m (201 feet), and the chief span is 344 m (1,128 feet). These are the required measurements to ensure safe navigation. The density of traffic - an average of 9,500 vehicles daily at the end of June 1963, with as many as 750 vehicles an hour crossing during weekdays and 900 on Sundays - fully justified the substitution of the ferry by the bridge. The cost of the work - 20 million dollars - has not been charged to the Canal Company.

b) <u>Water storage</u>

Reference has already been made to the problem of enlarging water reserves. The works already undertaken or planned cater, to a certain extent, to the short-term necessities, only, and the final solution seems to have been put off. The sources which could possibly be utilized constitute a limiting factor in the operation of the canal, since the quantity of water available depends on the rainfall and the possibilities of regulating the flow of water. The reserves which can be accumulated serve to balance the amount of storage from year to year, to satisfy the summer demand and to provide the water which is necessary when the seasonal rainfall is insufficient for navigation and for the generation of hydro-electric power. At present the latter use is of less importance than the former, but from the start it has been intented to meet the electricity requirements of the canal and the zone by means of the generation of hydro-electric power from their own reserves of water.

/In 1959

In 1959 it was calculated[25/] that precipitation and the regulation of the damming of Madden and Gatun would permit approximately 34 lock operation per day. If the depth in Gaillard's Cut were maintained at its present level of 12.20 m (40 feet), and even permit up to 40 operation if its depth is increased another 1.50 m (5 feet). These calculations are based on: i) a water flow measurement; ii) a minimum level of 72.80 m (208 feet) in Madden Lake (to allow for hydro-electric power generation); iii) the loss of from 2.8 to 3.4 m^3 (100 to 200 cu. feet) per second due to filtration and use of the water for the needs of the population; and iv) the fact that there is no hydro-electric power generation in the Gatun plant.

The capacity of the canal depends on the time required for lock operations as well as on the storage of water. When the lock alterations have been completed, up to 76 operations will be possible in a day, i.e. a much greater number than the 40 operations calculated on the basis of available reserves of water. There is the possible problem of an insufficient reserve of water in view of the fact that one must continue to depend, even if only in part, on the generation of hydro-electric power. Therefore, the water reserves will not be sufficient when the transit demands require anything above from 34 to 40 operations per day.

If the use of the water reserves in Madden and Gatun for the generation of hydro-electric power, (24 MW in Madden and 22.5 MW in Gatun), implies additional limitations on their use for purposes of navigation, the electricity demands of the Canal Zone surpass at present the amount of energy being produced by the said plants. The solution of the problem depends on the cost at which the energy can be obtained by another method and, particularly, on the combination of the systems, when selected, with those of the zones surrounding Panama and Colon. Such a system would constitute the best market for integrated electric power in the Central American Isthmus (in 1964 the companies seeking this integration were operating plants of a capacity greater than 60 MW and were producing 700 GWh of electric power).

25/ Report on a Long Range Programme, op. cit. pp 721 to 723.

/The solutions

The solutions to the problem of water and electricity provision are closely related. The cost of these solutions varies, as do the advantages which would be obtained from them. The cost is also dependent upon whether or not the solution is found within the area of the Canal Zone.

The amount of water reserves for navigational purposes can be increased by having recourse to additional dams, by pumping water back into Lake Gatun or by conducting water from other sources. Additional dams would improve the use of the natural flow of water. In the event of utilizing the streams flowing from the upper courses of the rivers (which are outside the limits of the Canal Zone), it would be possible to generate hydro-electric power. If the plant for pumping water into Lake Gatun were located in the Canal Zone, the amount of water for lock operations would be increased, but it would lose part of its use for generating hydro-electric power. The conducting of water from other sources would require other works to be completed outside the Zone, but would provide additional sources for the canal, and hydro-electric power could be generated at any of the dams.

All these economic aspects are of prime importance and they are extremely complicated when one studies the different possibilities of improving the water supply and the alternative solutions for providing electric power. It seems that the Company is intending at present to terminate the works which are already underway, and complete them with others so as to prevent the estimated capacity and navigability of the canal for the next fifteen years from being reduced due to an insufficient water supply. The Company cannot, however, guarantee the amount which the maximum capacity of lock operations would require. The level of Gatun Lake would be maintained at a minimum of 15.60 m (84 feet) above sea-level by the installation of thermo-electric plants and the construction of the Trinidad dam, or by pumping sea water into the Lake.

Some Panamanian experts[26/] consider it preferable to prolong the active life of the present canal to the utmost in order to use the

26/ See the files of the Ministry of Foreign Affairs of Panama, notes: Ing. Antonio J. Sucre, Probable life of the present Panama Canal, 17 March, 1965; Ing. Arnulfo Ho R., Possibilities of development of the minor sources of Lakes Gatun and Madden.

/investments

investments which could be obtained for the development of the country. In which case, the most economical and rational long-term solution would be to gradually construct a series of dams on the rivers which flow into Madden and Gatun lakes, so that the water potential could be exploited as the needs of the canal increased, and electric power could be generated as a by-product according to the demands of the Canal Zone and Panama.

c) Other projects

The present programme to improve the efficiency of the canal could be supplemented by further works and by the acquisition of new equipment and machinery. The plan would be in the main to facilitate navigation and canal operations in order to make them safer and quicker in relation to the increase in traffic and, in particular, to the ever greater numbers of large ships passing through, thereby increasing the capacity which it is hoped to attain by the present works. For example, more highly perfected machinery could be installed to augment the capacity of the locks, additional locomotives could be purchased to accelerate the passage of ships, etc.

i) Dredging. The Company has not yet published information on dredging projects, the areas where it would be carried out and priorities. From the comparison and analysis of projects which were prepared between 1954 and 1959, but on which no action has yet been taken, one may presume that in the near future there will be a need to improve the navigational access canals and the Gatun Lake ones. Dredging has been suggested in the access canals for the purposes of widening and deepening them, and in Gatun Lake to improve the bends.

ii) Oil pipeline. The constant increase in canal transit since 1945 has given rise to various propositions from companies interested in installing oil pipelines to reduce the transit of tankers. Petroleum and its derivatives are, in fact, the chief products which pass through the canal. However, the Company does not seem to consider that the most appropriate method for transporting petroleum is by pipeline instead of ship.

/In 1964,

In 1964, 13.5 million metric tons of petroleum and its by-products passed through the canal (18 per cent of the total amount of products for the year), in 1,334 tanker transits (11 per cent of the total number of transits). These figures are estimated at 18 million metric tons for 1980 (13 per cent of the total), with approximately the same number of transits but in tankers of a larger size than the present ones, and an average of 4 ships daily, as at present.

Transits are made in both directions, and the combination of products and routes is so varied that none, taken individually, would have sufficient weight to affect the canal operations. As a result of this, only about 50 per cent of the petroleum and its by-products could be transported by pipeline instead of ship. Such a method, however, would provide no economic advantage, and there would be no significant reduction in transits if it were employed. In any event, by 1980, the effect on the canal operations will be insignificant and the savings on the annual transit of ships will amount only to approximately 3.7 per cent.

iii) Automatization of operations. The Canal Company is trying to determine the influence which automatization of the operations could have on the capacity of the canal. Reference has already been made to the replacement of control equipment, locomotives, the control of sea traffic, and the possibility of a more or less complete automatization of certain operations is being considered.

4. Evaluation of the capacity of the canal

The sections of the overhaul plan, which was begun in 1954, concerning basic improvements to the navigable route and the modernization of structures and mobile equipment, are about to be completed. The Company is proposing to put modern methods and regulations into practice in accordance with the technical and material advances which are achieved, and hopes to increase in this way the efficiency of its employees and to improve their working conditions. Certain works still have to be carried out, including those to increase the water reserves, to achieve a smoother operation, and a safer passage for ships. These works can be carried out entirely or in part, at greater of lesser cost, according to what is definitely decided about the use of the present canal.

/If it is

If it is decided to keep the canal in active service during the remainder of the century, the works of extension must be completed at an estimated cost of 20.4 million dollars in the period from 1973 to 1980. If another canal is constructed, the additional works which would be carried out to the present canal would require investments of approximately 8 million dollars over the same period of time. (Projects for these investments are summed up in table 4.)

The Company[27/] estimates that when these improvements have been effected, the maximum capacity of the present locks will have been achieved, and ships will be able to pass through them as fast as the lock operations will allow. The capacity, in terms of transits, will be determined by the time required for the lock operations, and for the periodic total or partial revision of the locks. Whenever capacity has depended on the lock operations, the greatest time has been taken up in the regular inspections of sluice-gates, water conducts, valves, etc., which used to take months. This fact was considered to be of such importance in estimates made previous to 1959 that the capacity of the canal was calculated on the basis of a whole line of locks being out of use all the time. In the 1959 improvement programme, the necessity was pointed out for a complete overhaul so that the capacity could be calculated with the two lines of locks in continuous working order.

In the 1959 studies, it was estimated that a total of some 76 lock operations daily could be reached considering that the continuous functioning of the locks and the uninterrupted passage of ships would allow an average of 1.15 vessels to pass through at each lock operation. The effective capacity of the canal would thus be 87 ships passing through every day.[28/] This would not appear to be practical, however, in view of the studies and tests which have been carried out recently, and this estimate has been reduced.[29/] The Company has determined the capacity

27/ Annual reports of the Board of Directors, 1961, page 9 and 1963, page 11.
28/ Report on a Long Range Programme, op. cit., page 19.
29/ Report of the Board of Directors, 1964, page 7.

/Table 4

Table 4

PANAMA CANAL: PROJECTIONS OF CAPITAL EXPENDITURES, 1965-1980[a/]

(Millions of dollars)

Year[b/]	Canal operations up to the end of the century			Substitution by another route in 1981		
	Total	Transit	Other	Total	Transit	Other
1965	19.0	5.1	13.9	19.0	5.1	13.9
1966	22.3	1.6	20.7	22.3	1.6	20.7
1967	20.0	1.8	18.2	20.0	1.8	18.2
1968	23.4	5.3	18.1	13.5	1.6	11.9
1969	22.6	8.0	14.6	13.0	5.9	7.1
1970	23.9	9.2	14.7	12.5	6.0	6.5
1971	19.5	8.9	10.6	12.0	6.0	6.0
1972	18.0	6.1	11.9	7.3	2.3	5.0
1973	17.5	2.4	15.1	6.5	2.0	4.5
1974	16.0	1.5	14.5	6.0	2.0	4.0
1975	16.0	1.5	14.5	5.5	1.5	4.0
1976	16.0	1.5	14.5	4.9	1.0	3.9
1977	15.5	2.0	13.5	4.2	0.8	3.4
1978	15.5	2.0	13.5	2.8	0.8	2.0
1979	18.0	4.0	14.0	2.1	0.8	1.3
1980	19.5	5.5	14.0	0.0	0.0	0.0

Source: Direct information of the Canal Company, April 1965.

a/ Including expenditures of the Canal Company and the Government of the Zone. Two alternatives are being considered: a) operation of the present canal until the end of the century and b) substitution of the present canal by another in 1981.

b/ Fiscal year ending 30 June.

/which will

which will be reached, when the improvements and modern installations have been completed, by the method of "programmed observations and simulations".[30]

In accordance with this more recent investigation, it is considered that the improvements which have already been made, and those which are about to be completed, will allow the passage of 57 ships per day. When further improvements, not yet planned in detail and mentioned in section 3 of this Chapter, are carried out, it is estimated that the capacity will be increased to about 70 ships per day.[31]

These capacities must be thought of as the maximum attainable. Any further increase would cause too great delays to shipping and so many ships would be waiting for passage that there would not be room to accommodate them all within the canal waters. (See table 5.) Nevertheless, on making the comparison between capacity and transit, one must not overlook the affect of variations in traffic and the size of some ships.

There are considerable fluctuations in traffic rates, and the normal level is very different to the level reached on the days of heaviest traffic. At present, the arrival rate fluctuates between a fairly low level of 20 to as many as 60 ships per day. Statistically speaking, transits during the days of greatest demand are 144 per cent higher than the daily average, while the cyclical maximum is 125 per cent higher. Wherever possible, each ship is dealt with as soon as it arrives at the canal, and this implies the necessity to foresee the capacity at peak

30/ This method allows for the evaluation of aspects which are normally very complex such as: the size of ships, patterns of transport, according to type and size, arrivals of different ships according to direction of transit, periods of arrival and time tables for transits, delays imposed on ships and limitations which could be considered as reasonable ones, evaluation of the effect of bad weather, accidents, breakdowns in machinery, restrictions on navigation imposed by the rules, different levels of efficiency of the crews working the locks, etc.

31/ It is estimated that "...with the use of the new locomotives, the increase in teams of workmen on the locks and greater efficiency due to better use of working time, one may reasonably expect that the present transit figure of 31 ships can be doubled. Sixty-five operations and 71 ships appears to be an attainable figure." (Capacity of the Panama Canal, 1964 estimates, pages 28 and 29.)

Table 5

PANAMA CANAL: SUMMARY OF CAPACITY TESTS, 1964

	With one system of water conduction supplying the locks		With both systems of water conduction supplying the locks	
Daily average, ships	57	59	70	76
Average time spent in canal waters, in hours	14.9	32.5	20	38.9
Average waiting period for transits, in hours	3.8	18.2	7.1	...
Ships which wait at least 24 hours for transit, percentage	0.25	42.6	3.6	48.3
Total annual transit, ships	20,090	21,600	25,750	27,900

Source: Annual report of the Board of Directors, 1964, page 7.

/periods.

periods. Since these periods occur only a few times a year, however, a capacity is considered sufficient which covers the reasonably high levels of transit which are experienced at fairly regular intervals.

As far as the relation between lock operations and passage of ships is concerned, it would appear to be difficult to achieve in practice the estimated coefficient of 1.15 and it would be wiser to calculate this at 1.10.

On the basis of recent observations and tests, it is hoped that it will soon be possible to handle ships of a larger size than at present. Maximum measurements should be: length up to 212 m (925 feet); beam up to 31.70 m (104 feet) and draught up to 11.75 m (38 feet 6 inches). Ships with a beam of up to 32.60 (107 feet) will be able to pass through the canal, provided their draught does not exceed 9.75 m (32 feet), and it is expected that ships of the largest admissible dimensions will be towed in and out of the locks by tugs.

The above figures are considered to comprise the maximum transit capacity which the present canal can possibly reach. (See table 6.) If a greater capacity is required, it will be necessary to construct a third line of locks; to convert the present canal into a sea-level one by carrying out a complete reconstruction; or to build a new canal at a different location. It must be borne in mind, however, that although the present canal may be able to cope with the greater volume of traffic, there would be a corresponding increase in operational costs. These could quite quickly equal or exceed the annual cost of a canal which did not require intensive use of labour, as would be the case with a sea-level canal. (See ahead Chapter III.)

/Table 6

Table 6

PANAMA CANAL: CAPACITY ESTIMATES, 1964

Period	Capacity			Conditions on which estimates are based
	Ships per year	Ships per day	Lock operations	
1915-1958	9,790	26	23	Single line of locks and one system of water conduction in operation.
1959-1965	12,000	33	29	Single line of locks and both systems of water conduction in operation.
1966	15,330	42	36	As in 1959-1965, plus the effects of the use of new locomotives improvement and lighting in the locks and Gaillard's Cut.
1967-1972	17,520	48	42	Both lines of locks working with one system of water conduction, periodically out of operation due to inspection and maintenance.
1973-...	20,900	57	52	Both lines of locks can be operating including during inspection periods which require only 24 hours, even when one system of water conduction is not working.
...-2000	25,750	70	63	As in 1973 plus the effects of the continous functioning of the two systems of water conduction in all the locks.

Source: Panama Canal Company; Isthmian Canal Studies, 1964.

Chapter II

PROSPECTS OF CANAL TRAFFIC

The Panama Canal was devised to facilitate the exchange of goods between countries all over the world and, in particular, the trade of the United States. It shortens the routes of ships travelling between the Atlantic and Pacific Oceans, thereby reducing both the costs and travelling time of maritime transport.

The United States has always had top place among the countries using this route, both as exporter or importer of goods. Of the 323 million tons of cargo[1/] which passed through between 1960 and 1964, 220 million, i.e. an average of 68 per cent, was either coming from or going to the United States (see table 7). Nevertheless, only approximately one-tenth of the total overseas sea trade of the United States utilizes this route (13 per cent in 1962; 11 per cent in 1963).

The use of the canal by United States ships is naturally of considerable importance.

If around 10 per cent of the United States sea trade is transported by ships carrying the United States flag, the percentage is higher amongst canal tranportation. Fourteen per cent of the cargo was carried by United States ships in 1963 and 15 per cent in 1964. This percentage has been decreasing since 1945. Between 1958 and 1964, it was reduced from 21 to 14 per cent and, in absolute value, a decrease has been registered in both the amount of tonnage transported and the number of transits effected.

1. Transit projections

The technical limitations of the canal call for a periodic study of traffic developments so that the increased capacity of the canal can be planned sufficiently in advance. The Canal Company and the United States Government have tried to determine the time at which the present capacity may be insufficient and the time when a point of saturation, insufficiency and obsolescence may well be reached. The most complete and recent of the

1/ In this chapter figures are given in gross tons and naut. miles, in accordance with the maritime traffic practice. One gross ton equals 1.016 metric tons; one naut. mile equals 1.853 km.

/Table 7

Table 7

PANAMA CANAL: MERCHANDISE TRANSPORTED AND ITS RELATION TO THE MARKET OF THE UNITED STATES OF AMERICA, 1960-1964 a/

(Thousands of gross tons)

Item	1960	1961	1962	1963	1964
Total	59,258	63,670	67,525	62,247	70,550
Trade with the United States of America	41,551	42,452	45,223	39,803	50,561
Percentage	70.1	66.7	66.9	63.9	71.7

Source: Annual reports of the Panama Canal Company, 1960 to 1964.
a/ The figures refer to fiscal years, which end on the 30th June of the year in question.

various studies which have been carried out are those commissioned by the Canal Company and completed by the Stanford Research Institute (SRI) in 1958 and 1964. The first study[2/] was made as a result of the accelerated increase in operations between 1946 and 1955, when the number of transits and the volume of cargo transported were doubled. The second[3/] was carried out due to the even greater increase during the years 1955-1963.

The plans refer to: a) the amount of merchandise which it is estimated will be transported by the different routes and b) the estimated number of ships which will be passing through the canal, taking into consideration their dimensions, type of cargo, and the participation of passenger steamers.

In the 1958 study it was estimated that by 1975, 73.4 million gross tons of goods would pass through the canal, and by the year 2000, 102.1 million gross tons, at a daily average of 32.3 and 43.0 transits, respectively. In the 1964 revision, the figure was calculated at 105.9 million gross tons by 1980 and 152.8 by 2000, with a daily average of 42.3 and 51.8 transits, respectively. (See tables 8 and 9.) These figures are comparable to those concerning the capacity of the present canal (see section 4, Chapter I), but in order to calculate the period of useful life of the canal up to the end of this century it would be advisable to re-check the more liberal plans and to analyze the problems relating to the size of ships in greater detail. This is done in the present chapter which includes, at the end, comments on the useful life of the canal.

a) Methodology of the projections

The studies conclude with the presentation of plans on the transit of ships and merchandise and reference is made to the routes and types of ships which will be most used in the near future, and to variations which

2/ See Report on a Long-Range Programme, op. cit., pages 43 and 283.
3/ Annex IV to the report entitled Isthmian Canal Studies, 1964.

/Table 8

Table 8

PANAMA CANAL: PROJECTIONS ON TRANSIT OF PRODUCTS FOR THE YEARS 1975, 1980 AND 2000

(Millions of gross tons)

	Average 1955-1957	Average 1961-1963	1975 1/	1980 2/	2000 1/	2000 2/
Atlantic to the Pacific	21,356	35,080	40,485	56,610	66,050	81,250
Pacific to the Atlantic	22,905	29,400	32,915	49,285	36,080	71,525
Total	44,261	64,480	73,400	105,895	102,130	152,775
Atlantic to the Pacific	14,735	25,722	30,970	39,150	52,530	49,050
Pacific to the Atlantic	18,399	22,288	26,245	33,820	25,575	39,935
Group of principal products, total	33,134 a/	48,010 a/	57,215 a/	72,970 b/	78,105 a/	88,985 b/
Atlantic to the Pacific	6,621	9,358	9,515	17,460	13,520	32,200
Pacific to the Atlantic	4,506	7,112	6,670	15,465	10,505	31,590
Other products, total	11,127	16,470	16,185	32,925	24,025	63,790

Source: Stanford Research Institute: 1/ Report of 1958, Report on a Long Range Programme for Isthmian Canal Transits, Pages 42 to 283; 2/ Report of 1964, vol. 4 of the Isthmian Canal Transits, 1964.

a/ These are: petroleum and its by-products, coal and coke; ores and minerals; iron and steel products; timber; phosphates, nitrates and ammonium compounds; wheat and wheat flour, tinned and frozen food products; banana; sugar.

b/ Products included under a/ but excluding iron and steel products and adding wood pulp, paper and cardboard; soya been; hard cereals.

/Table 9

Table 9

PANAMA CANAL: ESTIMATES OF TRANSIT OF SHIPS ACCORDING TO TYPE,a/ FOR THE YEARS 1975, 1980 AND 2000

	Average 1955-1957	Average 1961-1963	1975 1/	1980 2/	2000 1/	2000 2/
Total	8,539	11,217	11,530	15,004	15,452	18,913
General cargo ships	6,870	9,111	9,980	12,230	13,500	15,700
Tankers	814	1,199	576	1,112	504	1,168
Mineral freighters	188	292	624	536	1,028	770
Other ships for bulk transport	...b/	...b/	...d/	476	...d/	625
Passenger ships	324	296	350	350	420	350
Government ships c/	...	319	...d/	300	...d/	300

Sources: Stanford Research Institute: 1/ Report of 1958, op.cit., pp. 42 to 283, 2/ Report of 1964, Annex IV; Isthmian Canal Transits, 1964. Annual reports of the Panama Canal Company, 1955 to 1957.

a/ Ships of 300 tons net and more (Panama Canal Company measurement rules) are included, and those of 500 tons and more of displacement which pay tolls according to displacement.

b/ Included among general cargo ships.

c/ Ships belonging to the Government of the United States, Panama and Colombia. They are allowed special privileges with respect to tolls.

d/ Not given separately in the 1958 study.

/will probably

will probably tend to occur towards the end of the century.[4] The method of investigation called "desagregated approach" has been followed in both studies. This consists of dividing the problem and its components in order to study them separately, coming to partial conclusions, and then considering these as a whole in order to arrive at the required total conclusion. This method would seem to be appropriate in view of the fact that in the apparent regular increase in the total volume of traffic, important changes in the pattern of products, type of ships and routes are usually balanced out or overlooked.

In this way it has been possible to: a) indentify the relations of cause and effect which exist between the various elements studied, e.g. between origin and destination of goods; b) to include the impact of technological or economic factors and c) to compare the theoretical analyses with the true facts which affect the plan under study and facilitate its revision. With this method there is the following disadvantage - like the total plan it has been based on partial estimates and, therefore, it becomes difficult to make a complete evaluation, seeing that the separate parts cannot be related with either the evaluation of the income of exporting countries or with the general plan of international trade and traffic.

b) Principal products transported

The variety of products passing through the Panama Canal has been constantly increasing, but only a certain number are of basic importance in the total volume of trade. It may be observed, too, that these goods are nearly always transported in the same direction. They are considered to constitute the group of goods which determines the total movement of the canal. In recent years, both their order of importance within the group and their direction of movement have varied, and some goods

4/ The designation of classes of merchandise and of routes is taken from the annual reports of the Canal Company and is very general. In special cases an effort has been made to identify them with greater accuracy.

have been replaced by others. The most important factors to be taken into consideration in the studies are the characteristics of the group which represents a large percentage of the total transit volume, and the individual importance of the elements constituting this. (See table 10.)

In the 1958 studies, eleven principal products were considered. These represented 74 per cent of the total movement in the years from 1955 to 1957, which is taken as a basic period: iron, ore and other metallic minerals and metals; iron and steel goods; petroleum and its by-products; wood, wheat and wheat flour; phosphates; nitrates and ammonium compounds; frozen and tinned foods; sugar; bananas. The changes which took place in the following period - 1958-1963 - caused modifications in the order and composition of the group of principal products in the 1964 study, which also included: iron, steel and metal manufactures, and wood pulp, paper and cardboard; hard cereals, chiefly maize and barley and soya beans. The new group represents 81 per cent of the total movement registered between 1961 and 1963, but it does not indicate a substantial change with respect to the 1958 study. When one excludes the new products which figure in the 1964 study, the percentage represented by these goods - 73 per cent of the total - is very similar to the previous one. Nevertheless, the part which these products will play in future increase of traffic is calculated in a different way (see table 11), and therefore there is no relation between the two studies. The 1964 study has been followed in the summary, with reference to the 1958 study for specific cases (see table 11 again).

i) <u>Petroleum and its by-products</u>. In the 1964 studies, petroleum and its by-products take pride of place. As over the last 10 years, the markets of these products - the Pacific coasts of the United States, South America, Central America and Mexico and Australasia-Asia - call for transit to the west, since supplies come from the Atlantic coast of the United States, Venezuela and the Caribbean. It is expected that the flow of transport in an easterly direction - to supply the market for these products in the United States and possible sales in Europe and South America - will be much less.

/Table 10

Table 10

PANAMA CANAL: MOVEMENT OF PRINCIPAL PRODUCTS, REGISTERED LEVELS AND PROJECTIONS

Merchandise	Average 1955-1957		Average 1961-1963		1964		1980			2000		
	Thousands of gross tons	Percentage of total traffic	Thousands of gross tons	Percentage of total traffic	Thousands of gross tons	Percentage of total traffic	Thousands of gross tons	Percentage of total traffic	Growth index 1964=100	Thousands of gross tons	Percentage of total traffic	Growth index 1964=100
Petroleum and by-products	6,079	13.7	11,682	18.2	13,328	18.9	14,500	13.7	108.8	17,900	11.7	134.3
Coal and coke	3,358	7.6	5,960	9.2	6,563	9.3	12,500	11.8	190.5	16,700	10.9	254.5
Iron ore	4,026	9.1	6,907	10.7			12,200	11.5	164.9	15,200	9.9	205.4
Mineral ores (except iron ore) and metals a/	6,242	13.9	8,086	12.5	15,427 b/	21.8	11,535	10.9	143.7	13,285	8.7	165.5
Wood pulp, paper and carboard	827	1.9	1,161	1.8	1,374	1.9	4,300	4.1	313.3	9,000	5.9	655.0
Timber	3,429	7.7	3,737	5.8	4,254	6.0	4,100	3.9	96.4	4,300	2.8	101.1
Phosphates	1,398	3.2	1,952	3.0	2,371	3.4	3,450	3.3	145.6	5,350	3.5	225.6
Nitrates and ammonium compounds	1,462	3.3	1,094	1.7	1,062	1.5	700	0.7	65.9	700	0.5	65.9
Wheat and wheat flour	2,085	4.7	1,937	3.0	2,222	3.1	2,800	2.6	126.0	3,000	2.0	135.0
Soya bean	670	1.5	1,361	2.1	1,510	2.1	3,150	3.0	208.6	3,500	2.3	231.8
Other hard cereals c/	899	2.0	2,082	3.2	2,827	4.0	2,685	2.5	95.0	3,000	2.0	106.1
Tinned foods	1,462	3.3	1,140	1.8	1,169	1.7	1,935	1.8	165.6	2,350	1.5	201.0
Frozen foods	671	1.5	897	1.4	1,040	1.5	1,350	1.3	129.8	1,700	1.1	163.5
Sugar	2,218	5.0	3,553	5.5	2,759	3.9	5,200	4.9	188.5	5,300	3.5	192.1
Bananas	822	1.9	1,065	1.7	1,291	1.8	2,700	2.5	209.1	3,200	2.1	247.9
Principal products	35,642	80.3	52,614	81.6	57,197	81.0	83,105	78.5	145.3	104,485	68.4	182.7
Other merchandise	8,619	19.5	11,866	18.4	13,353	19.0	22,790	21.5	170.1	48,290	31.6	361.6
Total	44,261	100.0	64,480	100.0	70,550	100.0	105,895	100.0	150.1	52,775	100.0	216.5

Source: Stanford Research Institute (SRI), 1958, Report on Long Range Programme for Isthmian Transits, page 82; 1964 report, Annex 4, Isthmian Canal Studies, 1964, Telle 1. Annual report of the Panama Canal Company, 1964, Table 18.

a/ Including iron and steel manufactures.

b/ Iron ore not given separately in the statistics published by the Company.

c/ Chiefly maize and barley.

/Table 11

Table 11

PANAMA CANAL: COMPARISON OF THE 1964 AND 1958 PROJECTIONS

(Millions of gross tons)

Product	Year 2000		Difference
	1964 study	1958 study	
Petroleum and by-products	17.9	6.9	+11.0
Coal and coke	16.7	20.7	- 4.0
Iron ore	15.2	21.0	- 5.8
Mineral ores (except iron ore) and metals	13.3	6.6	+ 6.7
Wood pulp, paper, cardboard	9.0	a/	+ 9.0
Timbers	4.3	4.3	-
Phosphates	5.35	1.6	+ 3.75
Nitrates and ammonium compounds	0.7	1.0	- 0.3
Wheat and wheat flour	3.0	3.1	- 0.1
Soya bean	3.5	0.9	+ 2.6
Other hard cereals	3.0	a/	+ 3.0
Tinned foods	2.35	3.2	- 0.85
Frozen foods	1.7	0.5	+ 1.2
Sugar	5.3	2.9	+ 2.4
Bananas	3.2	2.0	+ 1.2
Subtotal	104.5	74.7	+29.8
Other products	48.3	27.4	+20.9
Total	152.8	102.1	+50.7

Source: Stanford Research Institute, reports of 1958 and 1964.
a/ Included under "Other products".

/Volumes of

Volumes of traffic, in terms of transits through the canal (calculated on the basis of the demand of the various markets and presuposing that production can easily be increased at the sources of supply) are planned as follows:

	1980	2000
	(Thousands of gross tons)	
From Venezuela, the Caribbean and the United States (East) to:		
United States (West)	5,500	6,000
South America (Pacific)	3,600	4,900
Central America and Mexico (Pacific)	1,700	2,500
Asia, Australia and Oceania.	1,200	2,000
Other countries	500	500
Total	12,500	15,900
From the United States and South America (Pacific) to:		
United States and Europe	2,000	2,000
Total	14,500	17,900

The percentage represented by this group of products in the total movement of the canal - estimated at 13 per cent by 1980 and 11 per cent by 2,000 - was 20 per cent in 1963 and 18 per cent in 1964. More importance is placed on the 1964 studies than on the 1958 ones on the route towards Asia, etc. (principally Japan, which obtains its supplies from Venezuela and Curaçao) and on a speeding up of the movement on all the routes from the Atlantic to the Pacific, especially on the United States routes.

The movement over the last few years has already surpassed the calculations of the 1958 studies. The 1964 studies are more in accordance with present methods of extraction, refining, and consumption of these goods taking into account their most varied uses, their greater utilization for power production and increased industrialization in the markets being supplied. It may be presumed that during the first years of the period the movement will vary little, but that it will diminish relatively in the last years covered. Estimates are 14.5 million and 17.9 million gross tons for 1980 and 2000, respectively, and represent an increase of 9 and 35 per cent on 1964, when a movement of 13.3 gross tons was registered.

ii) Coal.[5] The shipment of coal, which is also very important, is made almost entirely from the Atlantic to the Pacific (98 per cent in 1963 and 94 per cent in 1964.) (In 1957 there was no movement whatsoever from the Pacific to the Atlantic). The coal comes from the Atlantic coast of the United States, and its principal market is Japan, followed by Chile. In the last few years there has been a certain movement towards the Atlantic due to the transporting of coal from the Pacific coast of South America to countries in Europe. Three point eight million tons were transported through the canal in 1957, 5.3 million in 1963 and 6.6 million in 1964, i.e. a relatively stable participation (8 and 9 per cent in the years referred to). More than 90 per cent was destined for Asia; the amount being sent to South America decreased from 214,000 gross tons in 1957 to 143,000 gross tons in 1963 and it was 164,000 gross tons in 1964.

It has been estimated that the United States shipments of coal will be maintained because, as in the case of iron ore, they are based on the prospects of the steel and power industries in the already established markets and in the new markets of the Pacific coast of the United States. On the other hand, prospects of sales of South American coal to Europe seem to be few. These same considerations are allowed for in the studies made in 1958 and 1964. In both it is presumed that the supply will present no problems that the transport of coal will continue to increase and that it will continue to be one of the principal products shipped through the canal. In the 1964 studies, however, lower figures are indicated, because it was considered that the needs of Japan could well be stabilized, that new sources of supply not requiring transit through the canal (Australia, USSR) will open up, and that part of the transport of coal to the Pacific coast of the United States can be made by rail.

5/ Transports of coke are few and sporadic, and need not be taken into account.

The passage of coal and coke through the canal has been planned according to the country of destination, taking into account the movement from the Atlantic to the Pacific, only, as follows:

	1975	1975	1980	2000
	1958 projections	1964 projections		
	(Thousands of gross tons)			
From the United States to:				
United States (West)	1,000	-	1,000	3,000
Asia (Japan)	12,000	9,000	11,000	13,000
South America (Chile)	400	400	500	700
Total	13,400	9,400	12,500	16,700

This movement of 12.5 million tons and 16.7 million gross tons for 1980 and 2000, signifies an increase of 89 and 153 per cent, respectively, on the 1964 levels.

The estimated volume (11 per cent for 1980 and 2000), represents a slightly higher percentage of the total shipping than at present.

iii) Mineral ores and metals. This group includes iron ore chromite, manganese, iron, scrap iron, copper, bauxite, aluminium, lead, zinc, tin and other metallic minerals and metals. Volume has always been greater than those of all the other products passing through the canal, and a larger amount of traffic comes from the Pacific to the Atlantic than passes in the opposite direction. There have been recent changes in the markets which may well affect the future volume as well as the direction of traffic. Iron ore comprises almost half the total shipment, and the remainder is made up of all the other goods. Both types of shipment have their particular characteristics and differ in many respects.

iv) Iron ore. The importance of iron ore to the canal can be compared to that of petroleum and its by-products and of coal. In 1955-1957, 4.0 million gross tons passed through each year, and in 1961-1963, 6.9 million (representing 9 and 11 per cent respectively of the total amount of shipping).

The chief direction of trade is from the Pacific to the Atlantic (approximately 97 per cent of the total). Most of the iron ore comes from Chile and Peru and is shipped to the Atlantic coast of the United States and Europe. Shipments to the Pacific are chiefly composed of Brazilian exports to Japan. Quantities are not large, although they rose from 47,000 tons per annum in 1955-1957 to 170,000 in 1961-1963.

On a world scale one may expect a continued increase in maritime transport, (more than 100 tons annually at the present time), because of the recent changes which have occurred in steel production and the possibilities of supplying the industry. Certain circumstances coincide with this growth, however, which point to the fact that there is not likely to be a corresponding increase of canal transits. The industries which make use of this commodity prefer minerals with a high iron content (more than 60 per cent) for the purpose of achieving greater economy of production, and since large deposits have been discovered in the Pacific and the Atlantic, the markets will not necessarily require canal shipment to obtain their supplies. Prices have fallen, also, and it will be necessary to try to compensate this by charging lower freight charges. The obvious solution would be to use ships of a greater capacity, thus presenting the problem of the size of vessels passing through the canal.

It is supposed that Japan will be supplied from India, Malaya and Australia; the eastern United States from Labrador and Quebec and Europe from South Africa. But South American participation should be maintained in the movement to the United States and to Europe. The integration of the steel industry in the western United States could give rise to an increase in traffic through the canal if the raw material were obtained from Venezuela, but it could also be obtained from Chile, Peru and Canada. It is thought that there will be only a small transit towards the Pacific, destined for Japan.

/The following

The following figures are estimated for the future:

	1980	2000
	(Thousands of gross tons)	
Pacific to the Atlantic:		
From Chile and Peru to the United States	5,000	15,000
From Chile and Peru to Europe	7,000	
Atlantic to the Pacific		
From South America to Japan	200	200
Total	12,200	15,200

Iron ore may thus be taken to represent 11 per cent of the total movement in 1980 and 10 per cent in 2000, which would indicate an increase of 76 per cent by 1980 and 120 per cent by 2000 on the percentage registered as the yearly average in 1961-1963, although these figures may be reduced because of the factors which have already been referred to.

v) Other metallic minerals and metals. This is a heterogeneous group of products (iron, chromite, manganese, scrap iron, copper, bauxite, alumina, aluminium, lead, zinc, tin and other minerals and metals). The volume of scrap iron, iron and copper is relatively important; none of the other minerals and metals plays a very important part in the total traffic passing through the canal.

The total movement of these products along the said route increased greatly between 1955-1957 and 1961-1963, rising from 3.8 to 8.0 million tons. It comprised 9 per cent of the total transit volume in 1955-1957 and 12 per cent in 1961-1963. Shipment of these commonodities underwent a marked change in direction between the given periods. In the first period, 44 per cent of the traffic was from the Atlantic to the Pacific, while in the second it increased to 74 per cent.

The shipment of copper from Chile and Peru to the United States and Europe is estimated at approximately 1.5 million tons in 1980 and 2 million in 2000.

/Estimates for

Estimates for <u>scrap iron</u>, <u>iron</u>, <u>ingots</u> and <u>steel</u> are 3.8 million gross tons by 1980 and 4.1 million by 2000. Average yearly volume between 1961 and 1963 was 2.1 million gross tons.

The chief routes of distribution of <u>aluminium</u>, <u>bauxite</u> and <u>alumina</u> do not pass through the canal. However, the raw material for some centres of aluminium production is shipped through the canal, as are a certain number of finished products. The following figures are thus calculated:

	1980	2000
	(Thousands of gross tons)	
Alumina from Jamaica to Canada	750	1,000
Alumina from Jamaica to Oregon, United States	650	800
Alumina from Australia to the United States (East)	100	200
Aluminium from Canada to Europe	200	350
Total	1,700	2,350

The movement of <u>zinc</u> might increase fairly radiply to 500,000 tons in 1980 and 700,000 in 2000. It would be shipped from Mexico, South America, Canada and Australia to the United States and Europe.

The transit of all this group of minerals and metals has been estimated at 11.5 million tons by 1980 and 13.3 million by 2000.

	1980	2000
	(Thousands of gross tons)	
From the Atlantic to the Pacific	6,400	6,450
From the Pacific to the Atlantic	5,135	6,835
Total	11,535	13,285

The percentage which this group is expected to form of total canal transits is 10 per cent by 1980 and 8 per cent by 2000, i.e. it should retain its present relative importance. One must bear in mind that the movement of this group will increase considerably, with respect to the level in 1955-1957, and it is estimated at approximately 210 per cent by 1980 and 260 per cent by 2000, and at 42 and 63 per cent, respectively, above the levels in the 1961-1963 period.

/vi) Wood

vi) Wood pulp, paper and cardboard. Until a short time ago these products played an unimportant role in canal traffic. They were included in the 1964 estimates because of their increase from 287,000 gross tons on a yearly average in 1955-1958 to 1,161,000 tons in 1961-1963, and to 1,374,000 tons in 1964, in which year they represented almost 2 per cent of the total annual traffic. Shipments from the Pacific to the Atlantic at present account for 60 per cent of the total movement because of the importance of the west coasts of Canada and the United States as a source of supply and that of Europe as a centre of consumption.

These products are expected to form 4.7 per cent of the total canal traffic by 1980 and 5.9 per cent by 2000. This would constitute an increase of 213 per cent by 1980 and 556 per cent by 2000 on the percentage registered in 1964, and they are the highest increases of all those projected for goods being transported through the canal. It is estimated that the increase in shipment of wood pulp will be far greater than that of either paper or cardboard. It is thought that transits from the Pacific to the Atlantic will be considerable, but shipments in the opposite direction are not expected to amount to very much. Estimates may be summed up as follows:

	1980	2000
	(Thousands of gross tons)	
Pacific to the Atlantic		
Wood pulp, from North America to:		
Europe	3,100	6,700
Other shipments (United States and South America)	200	300
Paper and cardboard, from North America to:		
Europe	400	1,400
Others	100	100
Atlantic to the Pacific	500	500
Total	4,300	9,000

/vii) Timber.

vii) Timber. Timber shipments through the canal came to 3.8 million gross tons in 1963 and 4.2 million in 1964. As it comes in the main from the west coast of the United States and Canada and is destined for the east coast of the United States and Europe, transportation is made almost entirely from the Pacific to the Atlantic. In 1957, 86 per cent of the timber transported through the canal utilized this route, in 1963, 92 per cent and in 1964, 83 per cent. Other sources of timber for the same markets are the Pacific coasts of Central America, South America and Alaska, and exports from Japan to the United States have been considerable in recent years. Shipments are also made from the United States to Africa and the East Indies, but these are not of very great importance.

Only the Pacific-Atlantic route is taken into consideration in the estimates of timber transits through the Panama Canal, since the Atlantic-Pacific shipments are insignificant and do not show much prospect of increasing. Figures for the Atlantic-Pacific route are 29,000 tons in 1957, 47,000 in 1963 and 50,000 in 1964. Very moderate increases are predicted since the level of offers of the areas from which shipment is required through the canal is expected to remain stable, and greater use will be made of railways for transport across the United States.

It is estimated that 4.1 million tons will be transported through the canal in 1980 and 4.3 million tons in 2000. These are very similar to the 1958 estimates of 4.15 million tons for 1975 and 4.25 million for 2000.

The following table gives the origin and destination of goods which are expected to be transported through the canal (according to the classification of the Canal Company), and their estimated tonnage:

/Origin

	1980	2000
	(Thousands of gross tons)	
Origin		
West coast of the United States	900	750
West coast of Canada	2,600	2,700
Asia and Oceania	400	500
West coast of South America	125	150
Alaska	75	200
Total	4,100	4,300
Destination		
East coast of the United States	2,150	2,200
Europe	1,500	1,600
Africa	200	250
Other	250	300
Total	4,100	4,300

Timber transits constituted, therefore, a steady 6 per cent of the total in 1957, 1963 and 1964. The figure is estimated at 3.8 per cent for 1980 and 2.8 per cent for 2000. While the overall volume should remain more or less stable, the percentage of the total canal shipments represented by timber is expected to decrease.

viii) Other important products. For the purposes of this report, certain other products have been grouped together. These are: phosphates; nitrate and ammonium compounds; wheat and wheat flour; soya beans; other hard cereals; tinned foods; frozen foods, sugar and bananas. Together, these goods represent the following percentage of the total of the group of most important products: 35 per cent of the yearly average in 1955-1957 and 29 per cent in 1961-1963 and in 1964. Shipments went up from 11.7 million gross tons in 1955-1957 to 15.0 million in 1961-1963, and 16.2 million in 1964, which constitutes 28, 23 and 22 per cent, respectively, of the total transit volume. Although the percentage represented by this group in the total transits has decreased, nevertheless the actual amounts of these goods being shipped have increased. The participation of each of these products in the total movement has varied from 2 to 4 per cent on an average, and little change is expected in future. Estimates for these goods are as follows:

	1980	2000
	(Thousands of gross tons)	
Phosphates	3,450	5,350
Nitrates and ammonium compounds	700	700
Wheat and wheat flour	2,800	3,000
Soya beans	3,150	3,500
Other hard cereals	2,685	3,000
Tinned foods	1,935	2,350
Frozen foods	1,350	1,700
Sugar	5,200	5,300
Bananas	2,700	3,200
Total	23,870	28,100

The movement of these products through the canal is calculated at 23.9 million gross tons by 1980 and at 28.1 million by 2000 (21.3 and 18.1 per cent of the total movement by 1980 and 2000, respectively). This would indicate a decrease in their participation over the last few years. The rythms of growth calculated for each product are very different. Considerable increases are expected in phosphates, soya beans, bananas and tinned goods and increases of approximately 50 per cent on an average on the present levels in the other commodities. A decrease is anticipated in nitrates and ammonium compounds, only.

Phosphate rock from Florida, United States, has played a great part in transits, principally to Asia and, much less important, to the Pacific coast of South America. There is a much smaller movement in the opposite direction, from Oceania to Europe. The most important factor as far as future traffic is concerned is that the chief source of supply is assured, since the Florida reserves are very large. Japan will continue to use these and the movement will be maintained towards South America. Although competition from other sources of supply coupled with technological changes could reduce the increase of traffic, especially that towards Japan, movements are expected in the order of 3.5 million gross tons by 1980 and 5.3 million by 2000, which represent increases of 45 and 126 per cent, respectively, on the 1964 level.

The changes which have come about due to the world situation regarding nitrates and ammonium compounds and competition from synthetic products, have had a negative effect on the conditions of the world market for these goods. For this reason, they are the only products in the group for which and absolute decrease in traffic is anticipated. Movements of 700,000 gross tons are estimated for 1980 and 2000, which are 34 per cent less than the 1964 figure.

Wheat and wheat flour are transported mainly from the Pacific to the Atlantic. Their passage through the canal has increased considerably over the last few years. Most shipments come from the Pacific coasts of the United States and Canada, and there are smaller shipments from Australia and Argentina. Their destination, in the main, is Europe. However, certain quantities are also transported to the Atlantic coast of South America and Africa, but amounts have been gradually diminishing in recent years. Shipments in the opposite direction from the Atlantic and Gulf of Mexico coasts of the United States to the Pacific coast of South America and to Asia have greatly increased in recent years. A moderate increase in the movement of these products is expected, and canal shipments of 2.8 million gross tons in 1980 and 3.0 million in 2000 are predicted, i.e. an increase of 26 and 35 per cent of the 1964 figure.

The soya bean is also included in the latest projections due to the rapid increase in the amounts shipped through the canal in recent years. Transits are made almost entirely from the Atlantic to the Pacific, from the Atlantic coast of the United States chiefly to Asia and, in small quantities, to the Hawaiian Islands. Brasil also exports small quantities, mostly to Japan, which is the market for 80 per cent of the amount which is exported to Asia. This movement is expected to grow in the

/future,

future, 3.2 million gross tons being estimated for 1980 and 3.5 million for 2000, i.e. an increase of 109 and 132 per cent on the 1964 figure.

Tinned foods, chiefly fruits and vegetables, are transported in both directions, but particularly from the Pacific to the Atlantic. Their transport from the United States to Europe has been rapidly increasing since 1957 and is followed in importance by shipments from Hawaii to the Atlantic coast of the United States which have been stable over the last few years, and by shipments from Asia to the United States. Trade from the Pacific coast to the Atlantic coast of the United States has decreased in recent years. There is also a limited movement towards the Antilles and from Australia to Europe. In the opposite direction, transport of tinned foods has been very small. They are shipped from Asia to the Pacific coast of South America.

A transit through the canal of 1.9 million tons by 1980 and 2.4 million by 2000 is expected, representing an increase of 69 and 106 per cent on the average yearly figures for 1961-1963.

Frozen foods are mostly meat and milk products, which are exported mainly from Australia and New Zealand to the Atlantic coast of the United States and Europe. Up to the present time volume of shipments has been small (671,000 tons on a yearly average in 1955-1957, 897,000 tons in 1961-1963 and 1,040,000 in 1964). Small increases are expected in future and movements of 1,400,000 tons by 1980 and 1,700,000 by 2000 are expected. This would represent a decrease in their percentage of the total amount of canal traffic, seeing that the figures registered recently represent approximately 1.5 per cent of the total traffic, and it is estimated that they will come down to 1.3 and 1.1 per cent by 1980 and 2000, respectively.

The movement of sugar has been increasing rapidly in both directions. The larger part of the trade is from the Pacific to the Atlantic, but lately a fairly considerable movement has been registered from the Atlantic to the Pacific. Transports of sugar underwent a marked increase from 1961, but declined in 1964. They rose to an average of 2.2 million gross tons yearly average in 1955-1957, to 3.6 million in 1961-1963, and fell to 2.7 million in 1964.

/The chief

The chief trade movement is from Peru and the Phillippines to the Atlantic coast of the United States, and in latter years there has been movement in the opposite direction from the Antilles principally to China and the USSR.

A modest increase is expected in future canal transportation of sugar and a movement of 5.2 million gross tons by 1980 and 5.3 million by 2000 is anticipated. Participation in the total canal traffic will decrease, since these estimates would amount to 4.9 and 3.5 per cent, respectively, instead of the 5, 5.5 and 3.9 per cent registered in 1955-1957, 1961-1963 and 1964.

The entire banana trade passes from the Pacific to the Atlantic. It has been growing since after the Second World War, chiefly due to the increase in exports from Ecuador to the Atlantic coast of the United States and Europe. There is also a smaller movement from the Pacific coast of Central America to the same markets. The registered amounts, on a yearly average, for the periods 1955-1957, 1961-1963 and 1964 were 822,000 gross tons, 1,065,000 and 1,291,000, respectively. It is thought that this fruit will continue to be shipped in both directions and estimates are 2.7 million gross tons by 1980 and 3.2 million by 2000, constituting an increase of 154 and 200 per cent on the figure registered for 1964.

ix) Other products. Apart from the above-mentioned products, other goods are transported through the canal which represented approximately 25 per cent of the total yearly amount of shipments during the years 1955-1957, and 18 per cent during 1961-1963. According to future estimates, this participation will be 22 per cent by 1980 and noticeably greater by 2000 (32 per cent). A corresponding increase is foreseen, on the average annual figure registered in 1961-1963, of 92 per cent by 1980 and 307 per cent by 2000, so that these products are expected to comprise one of the principal elements in the projected increase in canal traffic. The products concerned are many and of insufficient volume to influence the total traffic structure on an individual basis, quite apart from the fact that they move in small quantities along multiple routes which are difficult to define.

/The analysis

The analysis contained in the studies is not sufficiently detailed to allow for a more precise estimate of tendencies, but the total impact of the group as a whole is expected to be very considerable. It is presumed that the various products comprising this group will continue to be transported in general cargo ships with other important merchandise, and that trade will continue to be greater on the Atlantic - Pacific routes. Future projections are as follows:

	1980	2000
	(Thousands of gross tons)	
From the Atlantic to the Pacific	12.0	25.6
From the Pacific to the Atlantic	10.8	22.7
Total	22.8	48.3

c) Principal routes

When the Panama Canal is used, shipping routes from east to west are shortened by approximately 5,100 miles (see tables 12 and 13) and, consequently, there is a saving of tens of thousands of dollars on each trip, plus the possibility of increasing the number of trips in view of the greatly reduced time taken for each journey.[6/] This factor determines the practical use of the canal from the commercial point of view. Its technical characteristics would be made better use of if there were a balance between the two transit directions, but this has not been the case. During the 1930's, the tonnage which passed from the pacific to the Atlantic was more than double that which passed in the opposite direction. It declined during the war, increased again afterwards and from 1951 began to reverse. In 1957, the Atlantic - Pacific traffic was greater, and this tendency has been maintained in the last few years.

It is very important for the purpose of projections to study the possibility of future changes in traffic direction in order to determine whether balanced movements can be obtained in the two directions during the periods referred to. It seems that the present situation, with transits from the Atlantic to the Pacific slightly predominating, will be maintained

6/ It is estimated that in 1964 alone, the ships using the canal saved 170,000 sailing days. In 1956 the Company estimated the figure at 120,000.

/Table 12

Table 12

PANAMA CANAL: PRINCIPAL ROUTES ACCORDING TO DIRECTION AND TOTAL TONNAGE, 1963 AND 1964

(Thousands of gross tons)

Routes and direction	1963						1964					
	Tonnage			Percentage			Tonnage			Percentage		
	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic
Total	62,247	33,086	29,161	100.00	100.00	100.00	70,550	38,901	31,649	100.00	100.00	100.00
Total principal routes	43,737	21,262	22,475	70.34	64.30	77.10	50,147	25,656	24,491	71.08	65.95	77.38
Total other routes	18,510	11,824	6,686	29.66	35.70	22.90	20,403	13,245	7,158	28.92	34.05	22.62
Principal routes												
East coast of the United States-Asia	16,784	13,529	3,255	26.96	40.89	11.16	21,359	17,802	3,551	30.26	45.76	11.22
East coast of the United States-West coast of South America	7,067	1,398	5,669	11.35	4.22	19.44	7,031	1,612	5,419	9.97	4.14	17.12
West coast of South America-Europe	6,931	1,128	5,803	11.23	3.40	19.89	7,073	976	6,097	10.03	2.51	19.26
Coast to coast of the United States	4,265	1,447	2,818	6.85	4.37	9.66	5,291	2,007	3,284	7.50	5.16	10.38
West coast of the United States-Europe	3,173	769	2,404	5.09	2.32	8.24	3,481	853	2,628	4.93	2.19	8.30
West Coast of the United States-East coast of South America	2,939	2,818	127	4.72	8.49	0.43	2,356	2,177	179	3.34	5.60	0.57
West coast of Canada-Europe	2,578	179	2,399	4.14	0.54	8.22	3,562	229	3,333	5.05	0.59	10.53
Other routes	18,510	11,824	6,686	29.66	35.70	22.90	20,403	13,245	7,158	28.92	34.05	22.62

Source: Annual reports of the Panama Canal Company, 1963 and 1964.

Table 13

PANAMA CANAL: DISTANCES FROM PRINCIPAL ROUTES

(Nautical miles)

Representative routes and ports	Distances		
	Via Panama	Alternative route	Difference
Atlantic coast of the United States and Asia			
New York - Yokohama	9,700	13,018[a]	3,312
Atlantic coast of the United States and Pacific coast of South America			
New York - Antofagasta	4,158	8,930[b]	4,772
Coast to coast of the United States			
Galveston[c] - San Francisco	4,057	12,982[b/e]	8,925
Pacific coast of South America and Europe			
Callao - Bishop Rock[d]	5,638	9,690[b]	4,052
Pacific coast of Canada and Europe			
Vancouver - Bishop Rock[d]	8,320	13,997[b]	5,677
Oceania and Europe			
Auckland - London	11,317	12,246[b]	929
Pacific coast of the United States and Europe			
San Francisco - Bishop Rock[d]	7,533	13,207[b]	5,674
Pacific coast of the United States and Atlantic coast of South America			
San Francisco - Maracaibo	3,982	11,971[b]	7,987
Atlantic coast of the United States and Oceania			
New York - Melbourne	9,942	12,393[b]	2,451

/Continued

Table 13 (Concluded)

Representative routes and ports	Distances		
	Via Panama	Alternative route	Difference
Antilles and Asia			
Aruba - Yokohama	8,276	14,435 a/	6,159
Antilles and Pacific coast of South America			
Aruba - Antofagasta	2,840	7,850 b/	5,010
From coast to coast of South America			
Maracaibo - Antofagasta	2,877	7,779 b/e/	4,902
Europe and Asia			
London - Yokohama	12,483	11,224 a/	-1,259
Atlantic coast of the United States and Hawaii			
New York - Honolulu	6,703	13,348 b/	6,645
Antilles and Pacific coast of the United States			
Kingston - San Francisco	3,839	12,432 b/	8,593

Source: The Hydrographical Office of the United States. Table of Distances between Ports, Washington, 1948.
a/ Via Suez Canal.
b/ Via Strait of Magellan.
c/ Distances taken from the common point of the Yucatan Channel.
d/ The common point of the various routes to Europe.
e/ In this case the alternative would possibly be land transport or a combination of sea and land routes.

/in the 1980's

in the 1980's and until the end of the century. Fifty-five per cent of the total tonnage in 1964 was transported from the Atlantic to the Pacific and 45 per cent in the opposite direction. The percentage is expected to be 53 and 47, respectively in 1980.

Although there are several shipping routes which cross the Panama Canal, traffic tends to be concentrated along a certain number, only. From the Atlantic to the Pacific the outstanding routes are those which link the United States with Asia and with the Pacific coast of South America, and the east and west coasts of the United States which carried 55 per cent of the cargo in this direction in 1964. From the Pacific to the Atlantic the important routes are those which link the west and east coasts of the United States, the Pacific ports of South America with Europe, Canada with Europe and the United States with Europe, which carried 48 per cent of the cargo in 1964. But of the routes referred to only five can be considered very important in both directions because of their constant and considerable participation (around 70 per cent at present) in the total movement of traffic. In order of importance, these are the routes from the Atlantic coast of the United States to Asia, from the Atlantic coast of the United States to the Pacific coast of South America, from coast to coast of the United States from the Pacific coast of South America to Europe and from the Pacific coast of Canada to Europe. Together, they have maintained their constant predominating role in the total tonnage shipped between 1930 and 1964, although variations have occured with respect to the order of importance of each of these routes. In the projections for future traffic, it is supposed that similar trends will continue.

i) The United States and Asia. The most dynamic route is the one linking the Atlantic coast of the United States with Asia. After occupying fourth place in the 1930's, it has been in first place since 1963. In 1964 it carried 24.6 million gross tons of cargo (34 per cent of the total). Its importance is owned principally to the increasing movement of raw material, especially since the post-war period, from the United States to Japan, which is undergoing a very marked process of

/industrialization.

industrialization. In the studies it is anticipated that this route will become increasingly important because of the type of merchandise which uses it (coal, minerals, phosphates, soya beans, etc.).

ii) United States and South America. The route from the Atlantic coast of the United States to the Pacific coast of South America is also fairly dynamic, and it is the second in order of importance. In 1964, transits came to 7 million gross tons (10 per cent of the total). The chief products using this route are raw materials being exported from South America to the United States (bananas and basic products), and manufactured goods and capital goods being imported into South America.

iii) From coast to coast of the United States. This route has gone down to third place after being in first place when canal operations were commenced, at which time it was taking more than one-third of the traffic. Its importance decreased from the beginning of the past decade until its participation amounted to only approximately 10 per cent of the total. In 1964, however, total shipments along this route came to 8.2 million tons (11 per cent of the total), which indicates a slight increase in comparison with previous years. The chief cargo consists of petroleum and its by-products, timber and food products.

iv) Pacific coast of South America and Europe. Trade along this route has also increased and over the last few years it has been fourth in order of volume. In 1964, 7 million tons were transported (10 per cent), comprising mostly raw materials for European markets.

v) Canada and Europe. The route from the Pacific coast of Canada to Europe has been in fifth place over the whole period, although in 1963 the total figure fell to an amount of 3.5 million tons (5 per cent of the total). It is used chiefly to transport wood pulp, wood and cereals to Europe.

vi) Other routes. Since the amount of traffic using the remaining routes is insignificant, they are not likely to have any influence on the total growth estimated for the future (see table 14). Among these routes

/Table 14

Table 14

PANAMA CANAL: ROUTES OF LESSER IMPORTANCE ACCORDING TO DIRECTION AND TOTAL TONNAGE, 1963 AND 1964

(Thousands of gross tons)

Routes and direction	1963						1964					
	Tonnage			Percentage			Tonnage			Percentage		
	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic	Total	Atlantic Pacific	Pacific Atlantic
Total	62,247	33,086	29,161	100.00	100.00	100.00	70,550	38,901	31,649	100.00	100.00	100.00
Total chief routes	43,737	21,262	22,475	70.26	64.26	77.07	50,217	25,726	24,491	71.18	66.13	77.39
Total intermediate routes	13,818	8,856	4,962	22.20	26.77	17.02	14,984	9,641	5,343	21.24	24.78	16.88
Total other routes	4,692	2,968	1,724	7.54	8.97	5.91	5,349	3,534	1,815	7.58	9.09	5.73
Intermediate routes												
Oceania-Europe	2,032	826	1,206	3.27	2.51	4.15	2,158	879	1,279	3.05	2.26	4.04
East coast of the United States-Oceania	1,500	771	729	2.41	2.33	2.50	1,850	1,069	781	2.61	2.75	2.47
East coast of South America-Asia	1,459	1,222	237	2.35	3.69	0.81	1,522	1,301	221	2.16	3.34	0.70
West Indies-West coast of the United States	1,285	1,017	268	2.07	3.07	0.92	1,302	1,147	155	1.85	2.95	0.49
East coast of South America-West coast of South America	1,266	1,229	37	2.03	3.71	0.13	1,182	1,150	32	1.68	2.96	0.10
West Indies-Asia	1,172	1,014	158	1.88	3.06	0.54	1,319	1,164	155	1.87	2.99	0.49
West Indies-West coast of South America	1,042	997	45	1.67	3.01	0.15	1,049	1,016	33	1.49	2.61	0.10
East coast of the United States-West coast of Canada	1,011	8	1,003	1.62	0.02	3.44	1,164	8	1,156	1.65	0.02	3.65
West coast of Central America Mexico-Europe	685	317	368	1.10	0.96	1.26	766	359	407	1.09	0.92	1.29
East coast of the United States-Hawaii	645	207	438	1.04	0.63	1.50	727	191	536	1.03	0.49	1.69
East coast of the United States-West coast of Central America Mexico	625	187	438	1.00	0.57	1.50	824	284	540	1.17	0.73	1.71
West Indies-West coast of Central America Mexico	600	589	11	0.96	1.78	0.04	277	265	12	0.39	0.68	0.04
West coast of Central America-East coast of South America	496	472	24	0.80	1.43	0.08	844	808	36	1.20	2.08	0.11
Other routes	4,692	2,968	1,724	7.54	8.97	5.91	5,349	3,534	1,815	7.58	9.09	5.73

Source: Annual reports of the Panama Canal Company, 1963 and 1964.

are those of intermediate and minor importance. The volume of traffic using the intermediate ones is not very great, but it could be considerably increased if there were more trade between certain areas. There are 13 routes which together carry about 20 per cent of the total traffic, and the Atlantic - Pacific direction is the predominating one (approximately 64 per cent). There are more than 50 routes of minor importance which account for approximately 5 per cent of the total traffic. According to the 1958 studies one may not expect a substantial growth in cargo along these routes.

2. Trends in ship-building

According to the calculations in Chapter 1 on the physical characteristics of the Panama Canal, the following are the maximum permissible dimensions for ships wishing to pass through with certain exceptions:[7/]

	Metres	Feet
Beam	30.6	102
Lenght	240.0	800
Draught	11.1	37

These ships, in general, can weigh up to 50,000 tons gross, i.e. they may be transporting through the canal between 35,000 and 50,000 gross tons of cargo,[8/] but the average size of ships passing through the canal is 7,700 tons gross weight, carring an average of approximately 7,000 gross tons.

7/ The limitations depend on the design of the ship. If it is in accordance with the requirements or the ship is carrying ballast, measurements of up to 32 m (107 feet) beam and 11.70 m (39 feet) draught may be accepted.

8/ In the better known statistical and technical publications the concepts of gross weight or net weight, dead weight or displacement are usually employed, but not all of these are specified and there is no method suitable for making the necessary conversions.

/a) Large

a) Large size ships

Transits of ships with dimensions up to the maximum size have been few. They will clearly tend to increase, however, in size rather than numbers, as can be seen from the following data:[9/]

	1962	1963	1964
Percentage of ships of more than 18,000 tons gross weight	3.5	3.8	4.2
Percentage of ships of more than 24 m (80 feet) beam	4.8	5.2	5.2
Percentage of ships of more than 172.50 m (725 feet) lenght	7.7	8.3	8.9

From these figures it will be gathered, however, that they are following the tendency to increase registered by world shipping, (see table 15).

The world fleets are composed of more than 40,000 ships totalling 153 million tons gross weight, with an average tonnage per unit of 3,500 gross weight. Ships of low tonnage - 20 years or more old - operate over short routes which cannot be compared with the ships using the Panama Canal.

One may logically foresee the building of more and more modern ships with an ever-increasing tonnage. It should be noted that since 1957 the fleets have increased by approximately 10 million tons gross weight every two years, not on a basis of a larger number of ships, but of ships of greater capacity.[10/]

9/ Based on the information which appears in Chapter II of the annual report of the Canal Company in 1963 and 1964.

10/ Register of shipping, 1964, at the end of the second term of 1964 there were 1,454 ships under construction in the entire world, with a total weight of 9.7 million gross tons.

Table 15

WORLD MARITIME FLEET AND TRAFFIC, 1953 - 1964

Years	Total commercial fleet 1/		Commercial fleet in service 2/ a/ (Millions of tons gross weight)		Merchandise transported by sea 3/ (Millions of tons)	
	Ships (Units)	Tonnage (Millions of tons gross weight)	Dry cargo ships	Tankers	Dry cargo	Petroleum and by-products
1953	31,797	93.4	58.0	21.4	385	295
1954	32,358	97.4	59.4	24.0	410	320
1955	32,492	100.6	60.8	25.8	480	350
1956	33,052	105.2	63.6	27.6	520	390
1957	33,804	110.2	66.9	29.3	540	420
1958	35,202	118.0	71.0	33.0	470	440
1959	36,221	124.9	73.6	37.3	490	480
1960	36,311	129.8	75.0	40.8	530	540
1961	37,792	135.9	78.6	43.2	550	590
1962	38,661	140.0	81.3	44.7	570	660
1963	39,571	145.9	90.4	45.0	620	710
1964	40,859	153.0	94.0	47.0	...	...

Sources: 1/ Lloyd's Register of Shipping, 1964 statistical tables; 2/ Magazine Transports, No. 77, March 1963; 3/ United Nations Montly Bulletin of Statistics, January 1965.

a/ Does not include the United States reserve fleet for strategic purposes of approximately 10 million gross tons. In March 1964 (Statistics of the American Bureau of Shipping), this consisted of 1,783 ships, (including 54 tankers), weighing a total of 12 million gross tons.

/Three point

Three point one per cent of the world fleet of ships can be placed in the maximum category (according to the definition of the Canal Company, 18,000 tons gross weight or more):

	1963	1964
Ships of 18,000 to 20,000 gross tons (estimated)	270	300
Ships of 20,000 to 25,000 gross tons	507	535
Ships of 25,000 to 30,000 gross tons	222	243
Ships of 30,000 to 40,000 gross tons	157	241
Ships larger than 40,000 gross tons	49	86

If their percentage of the world fleet total seems less than that which could be expected of canal transits, this is probably due to differences of definition of the ships concerned. The Company's statistics take into consideration units of 300 tons net and above only, in accordance with their own methods of measurement. Statistics for the world fleet, on the other hand, include ships of 100 gross tons weight and more. Even more important is the fact that in the world fleet are ships which exceed the maximum dimensions for passage through the canal and, therefore,can only pass with special limitations or not at all. It is estimated that there is a present total of 300 ships of this type. Approximately 175 of these, chiefly tankers can pass only with ballast or partly loaded, but not with complete cargoes. The companies operating these ships do not consider it economical to give regular service through the canal. Apart from this, the dimensions of the locks and the depth of the water do not allow the passage of 110 large commercial ships which are in service, and 23 under construction, nor that of some modern aircraft carriers.[11/]

The formation of a fleet of large-size ships is a fairly recent innovation. It began in the 1930's with the construction of luxury liners, to ply the North Atlantic routes, weighing more than 50,000 tons gross weight, and even exceeding 80,000 tons. Among those still in service are the

11/ In the magazine Engineering News Record dated 24 December, 1964, on page 13, it is reported that 24 ships of the United States Navy cannot pass through the canal.

/Queen Mary

Queen Mary and the Queen Elizabeth. The steamship United States was put into service after the war and the steamship France fairly recently. However, the sustained growth of useful tonnage is provided by the cargo ships. Among these, the average capacity of tankers is almost 10,000 tons gross weight and of ships carrying ores and minerals almost 13,000 tons gross weight. The average age of these vessels is only eight years.

The growth in useful tonnage commenced when tankers first came into service for transporting petroleum and its by-products, consumption of which is constantly increasing. Since 1955 the type of ship used for transporting bulk minerals has been added to the group of large-size ships, and other vessels have been constructed which combine bulk transport with transport of petroleum and minerals. The demand was felt in the late 1950's for large ships to transport considerable quantities of goods in bulk form (commercial bulk carriers) and adaptable to different types of products.

The demand for large-size vessels was satisfied thanks to the advances made in the construction of commercial ships, which have met the requirements of the economic boom experienced after the war (1946-1948). The growth experienced in the size of ships is reflected, also, in the agreement made by Lloyd's Register to revise the rules on construction specification when the average gross freight of new ships had doubled (more than 100,000 tons, when the length of ships in many cases exceeded 270 m and when several shipyards with the capacity required for constructing ships of this type had been built).

Among large-size ships, the tankers form the greatest proportion. Their participation in the world fleet has grown steadily, particularly over the last 15 years, (see table 16, which gives the relation of ships according to age and tonnage). The registered tonnage of these ships increased approximately 108 per cent from 1953 to 1963, while that of other ships rose only 40 per cent.[12/] This fleet, already composed of more than 5,000 ships and with a total tonnage of 50 million tons gross weight, which represents approximately 33 per cent of the total tonnage of the world fleet, transports 53 per cent of the total cargo of international sea transport.

12/ International transport of petroleum and by-products increased in the 10 year period mentioned by 140 per cent. Transport of dry goods increased by only 61 per cent.

Table 16

SIZE AND AGE OF SHIPS OF THE WORLD FLEET, 1964

Tonnage (gross)	Age: Less than 5 years		5 to 9 years		10 to 14 years		15 years or more		Total	
	Units	Gross tonnage	Units	Gross tonnage	Units	Gross tonnage	Units	Gross tonnage	Units	Gross tonnage
All ships a/										
From 100 to 20,000	8,752	24,042,117	8,055	26,970,119	5,293	19,885,406	17,654	51,355,645	39,754	122,253,387
From 20,000 to 40,000	517	14,458,460	409	9,782,609	59	1,336,884	34	872,046	1,019	26,449,999
From 40,000 up	72	3,517,650	11	561,703	1	52,072	2	164,910	86	4,296,335
Total	9,341	42,018,227	8,475	37,314,431	5,353	21,274,362	17,690	52,392,601	40,859	152,999,621
Tankers										
From 100 to 20,000	1,012	2,816,006	979	7,431,447	934	8,728,837	1,311	6,591,923	4,236	25,568,213
From 20,000 to 40,000	404	11,526,799	377	8,980,326	40	871,607	-	-	821	21,378,732
From 40,000 up	62	3,054,667	11	561,703	-	-	-	-	73	3,616,370
Total	1,478	14,397,472	1,367	16,973,476	974	9,600,444	1,311	6,591,923	5,130	50,563,315
Ships for transporting minerals and other dry bulk goods										
From 6,000 to 20,000 b/	433	5,716,972	283	3,204,613	100	1,189,236	371	3,449,784	1,187	13,560,605
From 20,000 to 40,000	96	2,481,616	13	337,164	3	62,737	-	-	112	2,881,517
From 40,000 up	5	222,987	-	-	-	-	-	-	5	222,987
Total	534	8,421,575	296	3,541,777	103	1,251,973	371	3,449,784	1,304	16,665,109

Source: Lloyd's Register of Shipping, Statistical tables, 1964.
a/ Includes, besides tankers and ships for transporting bulk goods, vessels used for general cargo, passengers, and mixed (both passengers and cargo).
b/ By definition ships of under 6,000 tons gross weight are excluded.

The largest percentage of tankers fly the Liberian flag, after which come the United Kingdom, Norway, the United States, Japan, France and Panama. Japan takes first place among the constructing nations, followed by Sweden, Germany, the United Kingdom, France, Denmark and the Netherlands. (Table 17 gives some examples of ships built since 1958.)

Apart from tankers there are three other groups of large-size ships which have surpassed the tankers in growth (see table 16 again) both in number of units and tonnage. These are: ships for transporting ores and minerals, those carrying minerals and petroleum and general cargo vessels taking dry goods in bulk form (commercial bulk carrier).

There has been a demand since 1955 for large ships to tranport minerals, particularly iron ore, manganese and, chromium and, in lesser quantities, coal and bauxite. At present the large ships being built to carry bulk goods are intended chiefly for transport of minerals or petroleum or, in the case of dry goods, high density minerals and dry goods of less density. The growth of these ships is detailed below:13/

	1957	1960	1962
Ships for minerals and petroleum			
Units	30	64	72
Average dead weight (tons)	20,920	22,700	25,810
Mineral ships			
Units	123	263	275
Average dead weight (tons)	15,200	16,820	19,450
Ships for transporting dry bulk goods			
Units	604	858	1,335
Average dead weight (tons)	5,780	8,190	11,080

b) Traffic requiring large-size ships

World traffic which either now uses large-size ships, or will probably require them in future, includes passenger travel, petroleum and

13/ Based on statistics given in the Merchant Marine Statistics, 1963, of the United States Treasury.

/Table 17

Table 17

DETAILS OF SOME OF THE LARGEST TANKERS CONSTRUCTED OVER THE LAST FEW YEARS

(Metres)

Year of construction	Tonnage (gross)	Length	Beam	Draught
1958	40,000	213.4	29.3	10.9
	40,900	213.7	29.6	11.2
	85,000	260.6	38.1	14.0
1959	33,000	202.5	26.0	10.6
	34,150	209.1	26.2	10.6
	39,000	199.6	26.6	11.0
1960	34,250	199.7	27.0	10.7
	40,420	213.0	29.3	11.0
	48,300	225.6	...	...
	49,000	...	...	...
	50,000	229.0	...	...
	78,000	260.9	34.3	14.3
1961	...	208.5	29.9	11.1
	42,000	213.7	29.3	11.2
	54,000	223.0	33.4	11.7
	55,600	258.0	35.0	12.0
	65,000	249.3	...	...
	67,000	...	...	...
	92,750	274.3	38.7	...
1962	81,138	260.9	32.3	...
	132,000	291.0	43.0	16.5
1963	60,000	236.2	33.2	12.2
	91,000	260.0	38.0	...
	...	260.9	38.7	14.5
	92,000	274.3	38.7	...
1964	57,400	236.2	32.3	12.2
	85,000	...	...	...
	97,000	274.0	38.7	14.8
	150,000	290.0	47.5	16.0

Source: Revista Navitecnia, years 1958 to 1964. Rucalen technical publications, Buenos Aires, Argentina.

/liquid gas,

liquid gas, minerals (coal and ores), dry bulk goods, timber, general cargo and fruits. Passenger traffic represents a very small proportion of the fleet's activities. One may expect an increase in the number of large-size merchant ships in the near future, due to the economy which will be effected by transportation on a larger scale and because of the tendency of sea transportation companies to reduce their operating costs to the minimum.

Reference has already been made to the importance of the movement of petroleum and its by-products. This is expected to increase[14/] and it is estimated that by the year 2000 consumption may reach 7,000 million tons as opposed to 1,290 in 1963. The chief routes will still be those connecting the areas of greatest consumption (United States and Canada, Western Europe, South America and Japan)[15/] with the largest supply centres (Western Asia, United States and Venezuela).[16/] The greatest traffic will therefore ply the routes between Venezuela and the United States, Western Asia and Europe and Western Asia and Japan and the Far East.

The increase in petroleum transportation is followed in importance by that of minerals. The chief ports of embarkation of bulk minerals are in northern Europe (Sweden and Norway), on the Atlantic coast of America (Lake Superior, Nova Scotia, Labrador, Venezuela) and in north and west Africa (Liberia and Cameroon). The chief importing areas are Western Europe and the west coast of the United States. (The latter imports around 25 million tons annually mostly from Labrador and Venezuela.) These routes will continue to maintain their importance for some years to come.

The most important movement of coal and grain is from the North Atlantic and it exceeds 60 million tons per annum. Europe takes more than 50 per cent of the world grain production, importing chiefly from the Atlantic coast of the United States and Canada. Large shipments of coal - from 10 to 15 million tons a year - are shipped from the United States to Continental Europe and the Mediterranean.

14/ Data taken from the magazine Tranports, April, 1964, page 102. No. 89.
15/ In 1963 the consumption of these areas was 590, 270, 141 and 87 million metric tons, respectively.
16/ Estimated production in 1963 was 320, 410 and 160 million metric tons, respectively.

/c) Importance

c) Importance which large-size ships may have in canal traffic

While large-size ships are considered necessary for world shipping, it is thought that there will never be very many in use at a time. The tendency is to construct them according to a freight agreement with industrial firms, which can only be carried out when a long-term production policy has been determined in a particular branch of industry. The high cost of construction of these ships is better justified when they are for service on the most widely used routes for transport of particular merchandise. One may estimate from those already in existence the characteristics of the extra large merchant ships which must be taken into account in terminals and ports and in the Panama Canal. By 2000, for example, a ship of the following characteristics may be considered normal: 100,000 tons dead weight, 275 m (920 feet) lenght, 40 m (134 feet) beam and 14.5 m (48 feet) draught. These dimensions take for granted the 1947 plans 17/ for enlarging the present canal on the basis of a third set of large locks. There is also the possibility that ships will be used towards the end of this century which require canals from 23 to 30 m (75 to 100 feet) deep. In such a case only a sea-level canal could be used.

When the characteristics of international sea transport are compared with the foreseeable development of canal traffic in the next 15 to 20 years - on a basis of the plans analyzed in the previous section - it is estimated that the majority of ships will by then be only beginning to approach the maximum which the present canal can admit. These are the indications according to the transportations made over the various world routes and the type and volume of merchandise. Great problems are not, therefore, foreseen in the size of ships by 1980, although better service could obviously be maintained if large-size ships could use the canal completely without limitations.

The possibility of large-size ships which cannot pass through the present canal has been taken into consideration in the plans, but it has also been supposed that demands for transport by such ships will not be

17/ Report on a Long Range Programme, op. cit., pages 334 and 335.

/sufficiently

sufficiently important for them to be required over the routes which pass through the canal.[18/] It seems that this conclusion is perfectly justified in the case of petroleum transportation and passenger liners. The areas of production and consumption of petroleum and its by-products do not require passage through the canal on the chief routes which are being used by large-size ships, with the exception of those sailing from Venezuela (unrefined petroleum) and Curaçao (refined products) to the Pacific coast of the United States, Asia and Australia. If one compares this with the volume transported over the principal world routes, the petroleum route passing through the canal is unimportant, despite the fact that it takes second place among the products which ply this route (13.3 million gross tons in 1964). The use of larger ships than can pass through the Panama Canal would not, therefore, be justified.

The passenger routes using the canal are those connecting Europe with Australia and Europe with North and South America. On a world scale they are of relatively minor importance, although recently ships of greater tonnage (up to 40,000 gross ton weight) have been put into service. But no noticeable increase is expected on the chief routes (North Atlantic) nor is it anticipated that larger ships will be built for passenger travel.

Justifications for a trans-isthmian canal which could be used by ships of the greatest size would have to be based on considerations of a more general nature than can be gathered from the studies. For example, on the fact that such ships will be used on world routes for the transportation of bulk goods through the canal of up to 40,000,000 gross tons in 1980; and that transits of large ships could be intensified in future if it were possible to multiply and vary the volume, nature and composition of the movements through the canal which are the result of the general development policy of the Americas and the increase in exchange of goods between these countries. It would also help indirectly if the countries served by the canal routes were to construct ports suitable for handling large ships, and if political, technological or other changes were to come about within the next 40 years.

18/ See Annex IV to the report Isthmian Canal Studies, 1964, pages 79 to 82.

/3. Comments

3. Comments on the projections

During the fifty years that it has been in operation, the Panama Canal has facilitated the passage of 400,000 ships and 1,500 million gross tons of goods, although the importance of the routes it serves is relative when compared with the total amount of world traffic. (See diagram 2.)

In 1961 5.1 per cent of the world sea traffic passed through the canal.[19/] The percentage of dry and liquid cargo was 8.9 and 2.2 per cent, respectively, of the total shipments handled. The North Atlantic routes and those which link Europe with Asia are the routes which carry the greatest tonnage in commercial traffic. Therefore, only a small proportion of this traffic, comprising relatively specialized goods, moves through the canal.

Despite the fact that the importance of the canal and its operations is limited from the geographical and economic points of view, its influence has, nevertheless, been considerable where the areas which it serves are concerned. In general it has helped the trade in raw materials and, up to a certain extent, the trade of under-developed areas. But it is of greatest importance to the type and volume of United States trade.[20/] The studies appear to focus on this point and, in the second place, on the prospects of trade between the other countries of North and South America.

It has been supposed for the purpose of the studies that normal conditions of development will be maintained on the international level. The fact is stressed that if present political regimes were to change, and great economic blocks such as the USSR the European countries with centrally planned economies or Continental China were to be fully incorporated into world trade, the projections would have to be modified.

The focus already mentioned limits the interpretation of the prospects of expansion of regional trade. The countries concerned are in the process of studying ways of cooperation to promote trade because of its importance to the developing countries or to those in which industrialization is in

19/ SRI Studies, 1964. This increased to 5.4 per cent in 1962 but fell to 4.8 per cent in 1963.

20/ The studies do not allow for any unforseen happenings, such as war.

/the incipient

the incipient stage. Traffic expectations should keep in mind, therefore, the influence which the canal may have on Latin-American integration and on the economic development of other areas. A further study might therefore be carried out taking into account the investigations made by the various Specialized Agencies of the United Nations, in particular the Food and Agriculture Organization (FAO), the United Nations Conference on Trade and Development and the Regional Economic Commissions.

4. Comparison of transit projections and the capacity of the canal

The transit studies were based on the size of ships and their uses, the sea routes which pass through the canal and, particularly, on perspectives of production, consumption and international trade which could make use of this route in future.

Past tendencies relating to the number of ships passing through and the total annual tonnage of merchandise transported, as reflected in the Canal Company's statistics, have also been considered. Technological changes which could affect goods and methods of transport have been examined in order to calculate their possible impact on various production areas. For this reason the traffic levels which can be expected, in accordance with the past movement of ships, have been reduced.

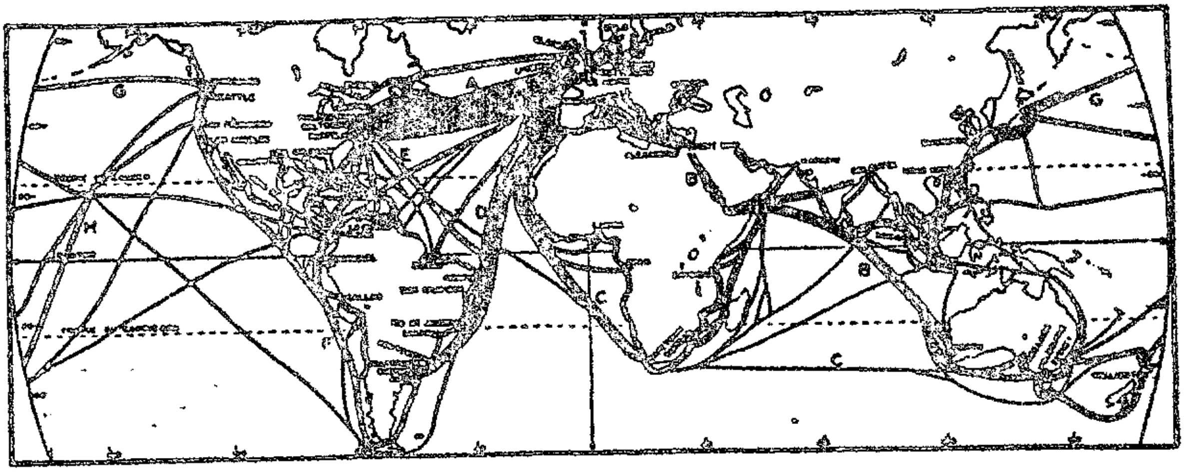
There was a steady increase in traffic in 1947-1963, from which one may calculate a total of nearly 17,000 ships by 1975 and 26,000 by the end of the century. When the necessary adjustments are made, as in the 1963 study, the growth in total transits becomes less pronounced and is calculated at 15,000 ships by 1980 and 19,000 by 2000. The analysts therefore consider the projections to be very conservative ones. The Canal Company allows for a 10 per cent margin of variation, feels that the estimates could be surpassed by the given dates - 1975, 1980 and 2000 - and that the possible volumes of maximum transits could reach 45 a day by 1975 and 64 by 2000.

One cannot take the average capacity as a guide in planning canal operations. It is necessary to achieve a transit capacity which will

/facilitate the

Diagram 2

COMMERCIAL MARITIME ROUTES



(The amount of tonnage transported is indicated by the thickness of the lines. Taken from C. H. Landon, Transportation, W. Sloane, New York, page 23.)

facilitate the passage of traffic during periods of intense activity. naturally, this capacity would more than meet the average needs (see table 18). However, even in this case the requirements of the expected traffic would be on a par with the capacity of the canal when all the planned improvements have been carried out (see again table 4).

The improvements which are being carried out are obviously necessary, seeing that the passage of 33 ships per day no more than meets the present requirements. The increase in capacity to 42 ships daily, as a result of the works scheduled for completion in 1966, will suffice to meet the demands in the immediate future, but not of the traffic estimated for 1975 onwards, according to the most recent studies. This is because, as already stated, the rate of growth of average daily transits over the last few years is twice the amount estimated in the studies and, if maintained, it would require a doubling of the present capacity before 1985. This aim could be reached if certain improvements, now underway, are completed. They would increase the capacity to 57 transits per day. Plans are still being studied, too, for the installation of a certain type of water conductor which would allow for passage of 70 ships a day. This figure would be sufficient to satisfy transit demands until almost the end of the century, the only restrictions being on ships of a certain size due to limitations in the capacity of the locks.

It would appear that this capacity cannot possibly be increased any further, and before deciding to make the required modifications one must consider the advantages of building another canal of greater capacity. From the studies one may gather that the latter project could be carried out over a long period of time, but it is necessary to bear in mind: a) the magnitude of the works which would have to be undertaken and the length of time required to carry them to completion and b) that the calculations referring to transits in general and to the size of ships may have been underestimated. In the studies which have been carried out for the purpose of finding a solution to the problem of increasing the capacity of the canal, it is thought that the capacity could be expanded to nearly 100 ships a

Table 18

PANAMA CANAL: AVAILABLE AND REQUIRED CAPACITIES, 1980 AND 2000

(Units)

Item	1980		2000
	Projections, 1963 studies	Extrapolation 1947-1964	Projections, 1963 studies
Average transit			
Number of ships per annum	15,004	19,397	18,913
Number of ships per day	41.1	53.1	51.8
Required capacity			
For cyclical peak periods estimated at 125 per cent of the daily average			
Number of ships per day	51.4	66.4	64.7
For maximum peak periods, estimated at 144 per cent of the daily average			
Number of ships per day	59.2	76.5	74.6
Available capacity			
Derived from improvements which will become effective in 1973			
Number of ships per day	57	57	-
Difference with respect to the cyclical peak periods			
Number of ships per day	+5.6	-9.4	-
Derived from improvements which will become effective after 1973			
Number of ships per day	-	70	70
Difference with respect to the cyclical peak periods			
Number of ships per day	-	3.6	5.3

Source: Panama Canal Company, Isthmian Canal Studies, 1964, Report and Annex IV.

day - this would more than cover the requirements anticipated by the year 2000 - and that many of the inconveniences caused by the passage of large-size ships could be eliminated by the construction of a further set of bigger locks (see section 3 of Chapter I). Depending on the type and size of the locks,21/ the project would call for a minimum investment of 550 million dollars for the simplest system and of up to 930 million dollars for the most perfected.

A great deal of labour will definitely be required, and the increase in productivity presupposes a parallel increment in remunerations. The operating costs of a lock canal increase in accordance with the augmentation of traffic. In a study which was recently carried out by the Canal Company, on comparing the costs of operation of the present canal with those of a sea-level canal, one reaches the conclusion that the latter investment would be economically justified by the present amount of traffic and by the volume which is anticipated for the next 20 years. The resultant savings in operating costs would justify, in 1980, the substitution of the present canal for another canal at sea-level.22/ Although the investment would be greater, labour costs would be less, and the increase in transit would influence costs in a very relative fashion, only, since the majority of ships passing through would require very little attention from Company personnel. The administration and maintenance of a sea-level canal would incur certain fixed costs which would not be affected by increases in transit. It is important, therefore, to compare the total annual costs of the various possibilities for the present canal, if fitted with a third set of locks, with those of a sea-level canal (see table 19).

The greater part of the construction of a sea-level canal could be financed from the total annual revenue obtained from a canal with three sets of locks. The annual handling costs of the 550 million dollar plan (with locks) would be approximately the same as those of the sea-level canal which would require an investment of 1,200 million dollars, although

21/ These could be made of earth or concrete and measure 43 x 365 m (140 x 1,200 feet) or 60 x 450 m (200 x 1,500 feet).
22/ See Annex VI of the report Isthmian Canal Studies, 1964.

Table 19

CANAL IN THE ISTHMUS: ANNUAL COSTS FOR EACH PROJECT, 1980 AND 2000

(Millions of dollars 1959 value)

Type of project and amount of required investment	1980			2000		
	Total[a/]	Interest[b/] and depreciation	Operation and conservation	Total[a/]	Interest[b/] and depreciation	Operation and conservation
Lock canal at a cost of 500 million dollars	85.5	41.7	43.8	95.0	41.7	53.3
Lock canal at a cost of 940 million dollars	104.1	62.6	41.5	113.2	62.6	50.6
Sea-level canal at a cost of 100 million dollars	57.8	51.2	6.6	59.3	51.2	8.1
Sea-level canal at a cost of 1,800 million dollars	85.8	79.2	6.6	87.3	79.2	8.1

Source: Report on a Long-Range Programme for Isthmian Canal Transits, 1960, pages 35 and 36.

a/ Does not include amortization.

b/ At a 3.5 per cent interest per annum, considering a 377 million dollars investment in the present canal.

a possibility appears to exist of constructing a canal with these characteristics for an investment sum of between 1,000 and 1,800 million dollars. The capacity of a sea-level canal would be more than 300 ships daily, while that of a lock canal would be 100 at the very most. The transit time for the sea-level canal would vary between 5 and 6 hours instead of the 8 hours required for passage through the lock canal.

The economic point of view supports the conclusion that the improvement which could be obtained by the additional locks would not justify the cost of investment.

Possible repercussions on Panamanian economy considered apart, it would appear that the most convenient definitive solution would be the construction of a sea-level canal.

Chapter III

INVESTIGATIONS AND STUDIES ON A SEA-LEVEL CANAL

Long-term transit planning has led to the carrying out of investigations over the entire Isthmus region in order to decide on the best solution to the problem of constructing a sea-level canal. The problem was definitely defined in 1947,[1/] and various alternative solutions were investigated, from location in the Isthmus of Tehuantepec in Mexico to the utilization of the Atrato and San Juan Rivers in Colombia. The following routes were studied:[2/]

Mexico

1. Tehuantepec

Nicaragua

2. Greytown-Bay of Fonseca
3. Greytown-Realejo
4. Greytown-Tamarindo
5. Greytown-Brito
6. Greytown-San Juan del Sur
7. Greytown-Bay of Salinas
8. Greytown-Bay of Salinas

Panama

9. Chiriquí
10. Chorrera-Lagarto
11. Chorrera-Bay of Limon
12. Chorrera-Gatun
13. Panama-paralel
14. Panama-conversion
15. Panama-present

1/ The Isthmian Canal Studies, 1947, was prepared, based on United States Law No. 79-280 of the 28th of December 1945. See also Report on a Long Range Programme, op. cit. pages 5, 30 and 333.

2/ In the official studies, as in various other articles, the numeration given here is normally employed when referring to the different projects.

16. San Blas
17. Sasardí-Mortí
18. Aglaseniqua-Asnati
19. Caledonia-Sacubti

Panama and Colombia

20. Tupisa-Tiati-Acanti
21. Arquia Paya-Tuyra
22. Tanela-Purcro-Tuyra
23. Atrato-Cacarica-Tuyra
24. Atrato-Peranchita-Tuyra

Colombia

25. Atrato-Truando
26. Atrato-Napipi
27. Atrato-Napipi-Doguado
28. Atrato-Bojaya
29. Atrato-Bando
30. Atrato-San Juan

1. Principal projects studied

The conclusions reached on the 1947 studies indicated basically that the most convenient solution would be the conversion of the present Panama Canal to a sea-level route, deemed necessary for economic and political reasons. In 1957 the possibility arose of carrying out construction by the use of nuclear explosives. This led to the above-mentioned conversion project being compared with others in which the nuclear method could be employed (see map 2).

Even if, according to estimates for conventional methods of construction, the conversion of the present canal would be the most economical project, it is not so when compared with the cost of construction by use of nuclear explosives. Various projects, if carried out by the nuclear method, would be considerably less costly than the conversion plan (see table 20), since nuclear explosives could not be used for the latter (if feasible it

Table 20

ESTIMATES FOR THE CONSTRUCTION OF A SEA-LEVEL CANAL IN THE ISTHMUS

(Millions of dollars)

Project route		Type of construction and year of commencement of proyect				
Location	Length (km)	Standard			Nuclear	
		1947 1/	1959 1/	1964 2/	1960	1964
Tehuantepec	201	...	...	...	2 270 5/	1 500 4/
Nicaragua a/	278	3 566	4 095	4 135	1 900 3/	-
Nicaragua and Costa Rica	222	-	-	-	1 850 5/	1 240 4/
Conversion of the present canal	74	2 483	2 287	2 176 b/	-	-
San Blas	52	6 272	-	-	620 5/	-
Sasardí-Mortí	70	5 132	-	-	770 3/	747 2/ c/
Atrato-Truando	160	4 594	-	-	1 200 3/	1 440 2/ d/

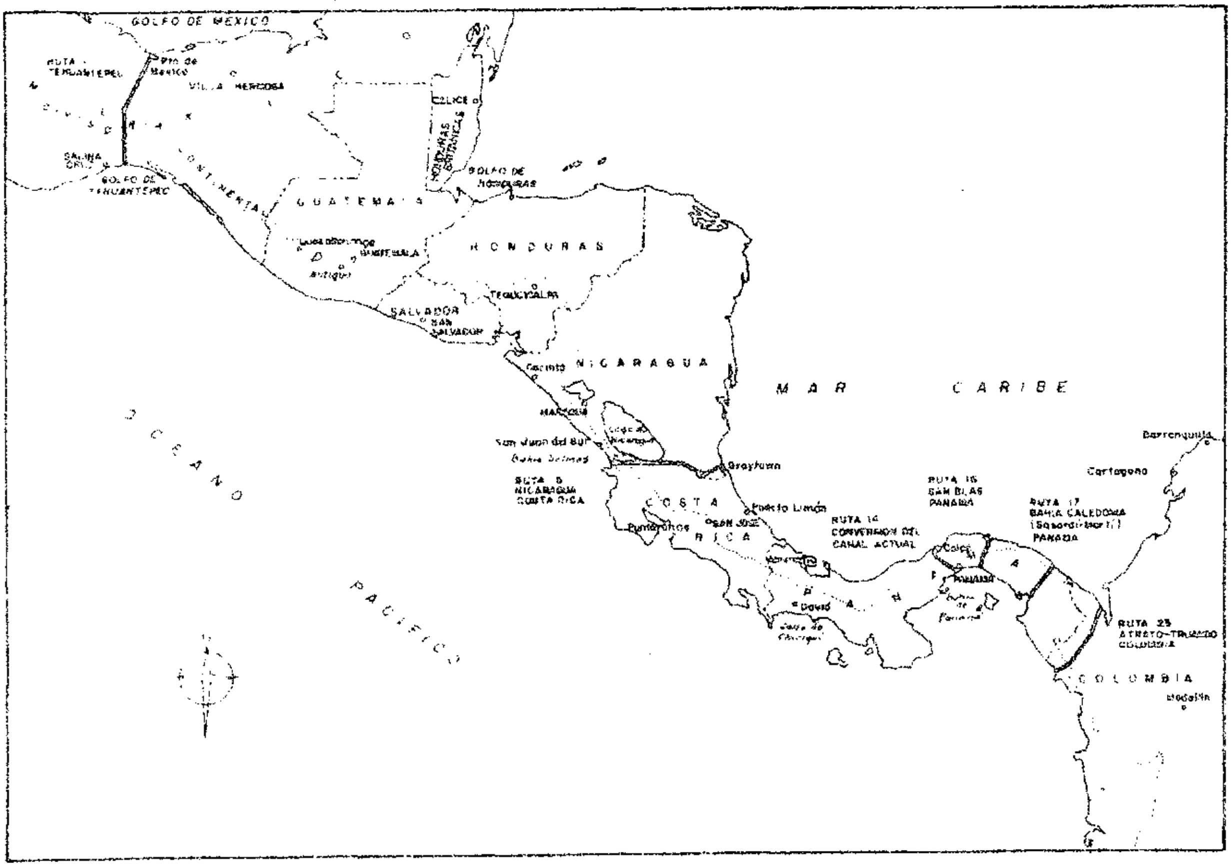
Sources: 1/ Report on a Long-Range Programme for Isthmian Canal Transits, 1960. 2/ Isthmian Canal Studies, 1964. 3/ Magazine Engineering New-Record, December, 1964. 4/ Magazine Dock and Harbour Authority, No. 527, September 1964. 5/ Magazine Civil Engineering, October 1964.

a/ This would be a lock canal.
b/ Different possible modifications vary between 1 800 and 2 560 million.
c/ From 747 to 1 000 million, subject to revision.
d/ From 1 440 to 1 500 million, subject to revision.

/would also

Map 2

ALTERNATIVE ROUTES FOR A SEA-LEVEL CANAL



would also imply a considerable saving). Construction by nuclear techniques would have to be carried out as far away as possible from centres of population for security reasons. A certain number or projects have been reconsidered from the point of view of using nuclear explosives. These include the Atrato-Truando in Colombia; Sasardí-Mortí and San Blas in Panama; Greytown-Salinas in Nicaragua (part in Costa Rica) and Tehuantepec in Mexico.

Since 1960 the studies have been particularly concentrated on the conversion of the present Panama Canal into a sea-level route by conventional methods (to try to obtain additional economies to those indicated in the original budget), and on the construction of two routes by nuclear explosives, Sasardí-Mortí in Panama and Atrato in Colombia. It is considered that these routes offer greater economy and security because of their distance from the centres of population and the fact that they are located in almost uninhabited areas.

In the projects for construction by conventional methods, it is presumed that the canal would be 18 m (60 feet) deep in the centre and 12 m (40 feet) at its widest part, which would be 180 m (600 feet) (see diagram 3). These dimensions are larger than those of the present canal in view of the needs of future sea traffic. The rest of the specifications in the design also take these needs into consideration. If locks were to be included in any of these projects, as in the Nicaragua plan, they would measure 450 m x 60 m (1,500 feet x 200) and have a water depth of 15 m (50 feet).

If the nuclear process were employed, greater dimensions would undoubtedly be obtained, and also a wider cross section in the form of a paraboloid. The greatest depth would be 60 m (200 feet) or more in the centre of the canal, and where the width was 305 m (1,000 feet) the depth would be 18 m (60 feet).

/a) <u>Projects</u>

a) Projects for a canal outside the Canal Zone

The costs of all the projects for locating the canal outside the present Canal Zone would be prohibitive if standard methods were employed. Some of these projects, however, could be carried out by the nuclear technique at a considerable reduction in cost.

i) Mexico. Since the route from the Isthmus of Tehuantepec in Mexico would be located further to the north of the hemisphere, the distances between the chief regions served by the routes which pass through the canal would therefore be shortened. More than 1,500 km would be cut off the routes carrying from 65 to 75 per cent of the goods passing through the canal from one port to another in the northern hemisphere. However, the canal would be very long and, because of the topography of the area, it would require very deep excavations, seeing that the Continental Devide is a plateau with small hills rising to as much as 200 m above sea-level. The cost of construction by standard methods, estimated at 4,000 million dollars, would be reduced to 1,500 million dollars by the nuclear method.

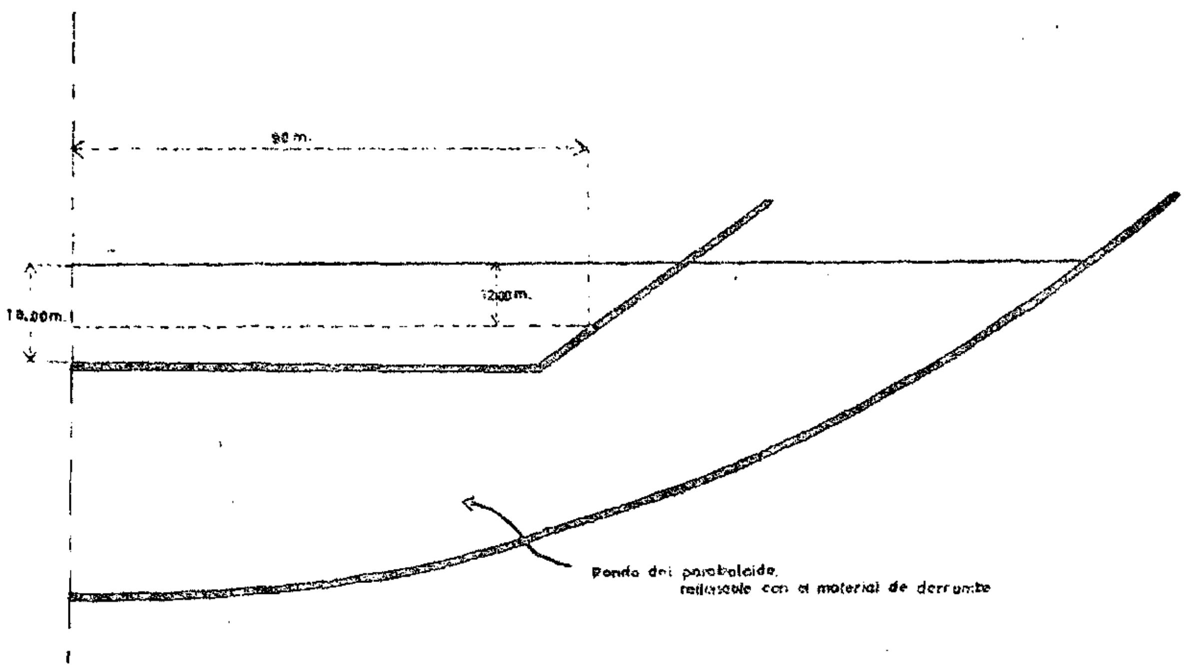
ii) Nicaragua. The various routes through Nicaragua were the object of several studies in 1947 and 1959. Amongst the projects for a lock canal there is a preliminary plan to link Brito on the Pacific coast with Greytown in the Caribbean. This route would be 270 m (173 miles) long and constituted, in the main, by an interior canal which would cross the Lake of Nicaragua. A variation of a sea-level canal has also been studied from Greytown to the Bay of Salinas which, instead of crossing the Lake, would pass near to its southern shore, approximately along the Costa Rican border, avoiding a lowering of the water level. This project would make use of the nuclear technique. However, other routes are considered to be more favourable and less costly.

iii) Colombia. In the 1947 studies there are six alternative routes for a canal in the River Atrato region. They are relatively favourable for construction by standard methods since they are situated on the alluvial plain with no important interference from the Continental Divide. It would

/be necessary

Diagram 3

CROSS SECTIONS: STANDARD AND NUCLEAR CONSTRUCTION



be necessary to solve the problems of colloidal formation at the mouth of the Atrato and others pertaining to defects in the fluvial system. As far as works of excavation and maintenance are concerned, the relative advantages of the Atrato-Truando plan stand out and steps have been taken to continue the investigations. The estimated cost of construction by conventional methods is 4,600 million dollars, but there is a possibility of employing the nuclear method at a lower cost.

iv) Panama. There are several suitable locations in Panama for a new canal to be constructed. In the 1959 studies, particular reference is made to the following possibilities:

Chiriquí. The Isthmus is only 65 km wide between the Chiriquí Lagoon and the Chiriquí Gulf, to the east of David. The geological characteristics appear to be suitable but the topography would present problems.

San Blas. The canal would be constructed in the narrowest part of the Isthmus and it would be 60 km long. The termini would probably be in the Gulf of San Blas in the Atlantic and the estuary of the River Chepo in the Pacific. As it would be situated about 70 km to the east of the present canal, some of the existing facilities for commerce, operation and maintenance could most probably be made use of. Construction costs are estimated at more than 6,000 million dollars if standard methods are employed. Nuclear explosives could not be used because of the proximity to the chief towns of Panama, although such a method would reduce costs to approximately 600 million dollars.

Sasardí-Mortí. This route would be located between the Bay of San Miguel in the Pacific and the Bay of Caledonia in the Atlantic and it would be about 70 km long. The Continental Divide is the highest land in the area (approximately 340 m above sea-level). This route would be more than 180 km from the present canal, in a very sparsely populated region, and there would be a good chance of using the nuclear method of excavation.

/b) Conversion

b) <u>Conversion of the present canal</u>

When the canal was built, the construction of the locks was not carried out in such a way as to allow the excavations to be continued to sea-level, as had been previously planned. The conversion is therefore made more complicated. Provisional works would have to be completed to protect the navigable route and keep it open to traffic, and the excavations and dredging would have to be carried out without delaying transits of ships. In the studies made by the Company this project is referred to as "The sea-level Canal Zone". It would more or less keep to the present route across the Continental Divide, and in other sections it would follow the contour of the land so that there would be no sharp curves. This canal would be 74 km long instead of 82 km as at present.

i) <u>Present state of the project</u>. The Canal Company, in 1947, recommended the project to convert the present route as being the best long-term plan to satisfy the needs of inter-ocean trade and United States interests. The estimated cost is nearly 2,300 million dollars and the time required for construction would be 12 years. The project was not formally approved, and when it was reconsidered in 1960 it was decided that the investment would not be justified from the economic point of view, apart from the fact that certain engineering problems relating to the works had not been solved.

These problems are connected with the intention to convert the Canal in one stage without suspending traffic, except for a few days when the works are finished; the carrying out of the works by methods which are somewhat complicated and burdensome, and which would require difficult and large-scale hydraulic excavations and the use of equipment and installations whose efficiency would have to be taken for granted because they would have to be made especially for these works. Nor have solutions been found to the following problems: that of the instability of several of the cross sections; the risk of a cave-in when excavations are carried out in the interior canal and a land-slide when the lakes are dredged, and the possibility of a long interruption in service. This project and its 1959

/revision is

revision is considered to be almost entirely out of the question. When making a recent revision of the estimates of the project, the company decided to reconsider some of the technical aspects, which are referred to later on.

ii) Technical problems. In the 1947 and 1959 studies, the total volume of the excavation was estimated at approximately 750 million m^3 - almost four times greater than the original excavation. The canal, with the previously mentioned dimensions of 180 m (600 feet) width and 18 m (60 feet) minimum depth, would have to go through only one large cut, almost 200 m wide, over an 800 m long stretch). Apart from this main work, estimates include 1,100 million dollars for the control of river drainage, the construction of highways and of a tunnel, electricity installations, construction of a sewage system, urbanization, temporary housing for workmen, etc.

If safe conditions are to be ensured for the passage of all ships through the canal, river control is of the greatest importance.[3/] This would require a deviation in the sources of the rivers and their tributaries of 91 per cent. It would be necessary to construct a series of small dams along the Pacific watershed in order to regulate the flow, but on the Atlantic side two large systems for deviation and damming would be required.

The system to the west of the canal along the Atlantic watershed, would be for the purpose of controlling the Caño Quebrado and Trinidad Rivers. A relatively shallow canal would be required to connect up these rivers and continue through the ancient Chagres Valley as far as Gatun Dam, passing from there on to the sea through the old bed of the Chagres River. The Gatun Dam spillway would be 152.50 m (500 feet) high and built at a height of 15.40 m (55 feet) above sea-level. During the periods of maximum operation of the spillway the waters of Trinidad and Caño Quebrado Lakes would rise to a level of 17.90 m (58.4 feet) above sea-level. A number of dykes would also be constructed - mostly of the earth removed during

3/ Report on a Long Range Programme, op. cit. page 344.

the excavations - which would begin at Gatun Dam, join up several of the islands in Gatun Lake and end 6.5 km north of Gamboa.

The system of deviation to the east of the Atlantic stretch of the canal would be chiefly for controlling the Chagres and Gatun Rivers by means of the Madden Dam, which would be made larger, and two new dams, the Monte Lirio and the Gamboa. The lakes which would thus be formed would be connected by various canals and tunnels which would allow the water to flow into the Bay of Mines. The 1947 Gamboa Dam project indicates a possible water retention of as much as 42.70 m (140 feet) above sea-level, which would cause the flooding of land outside the Zone limits. In the 1959 revision, the possibility was set forth of modifying the control system without exceeding a hight of 30.50 m (100 feet) above sea-level, in order not to go above this limit in the area concerned. Detailed studies would have to be made on this subject if a decision is taken to carry out the conversion plan.

The method of excavation which is chosen is a determining factor in the conversion of the lock canal to a sea-level canal. The need has already been pointed out for avoiding interruptions in the passage of ships during the course of the excavation work. It would also be necessary to conserve at least the present storage capacity of Gatun Lake so that water for the locks is not lacking during the construction period. The main problem is one of finance and the least costly method should be chosen. The studies contain various suggestions on methods of excavation and on the transportation of the excavated material and its disposal.

For the excavation of loose material under water the use has been proposed of suction dredging machines of the type at present being employed (up to 75 cm tube diameter) - except for one special kind (with a 1.0 m tube diameter) - for carrying out works in Gatun Lake. The excavation of solid material under water or on land would be effected with 6 m^3 mechanical shovels and 25 m^3 dredgelines.

The excavated material could be transported by truck and deposited in depressions in the ground not more than 2 km away, and the earth from the hydraulic excavations could be directly got rid of or transported in

/barges of

barges of 3 000 cu. yards to rubbish dumps - perhaps to the proposed dam sites - in Gatun Lake. The average cartage of these barges would be 25 km.

Finally, Gatun Lake would be dredged, in 11 days, from the level of the lock canal (approximately 25.70 m above sea-level). This would mean an interruption of only seven days in transits because of the need to progressively demolish the dykes and remove the plugs which would have been used as a temporary measure to avoid loss of water.

2. Feasibility of the projects in which nuclear techniques would be employed

Since 1957 the United States Atomic Energy Commission has been carrying out a large-scale operation, called Plowshare[4/] on the pacific uses of atomic energy in scientific activities, in order to obtain the temperatures and pressures required for certain chemical investigations; in underground engineering and mining, for the purpose of obtaining low alloy minerals, natural gas, petroleum, etc., by more economical methods, and in civil engineering for excavation and earth moving.

The carrying out of large-scale works such as the construction of the canal would be an example of the latter purpose, and it could be a spectacular and beneficial demonstration of the pacific uses of nuclear energy on a grand scale.

In accordance with the agreements of the United States Congress in 1960 to the possible construction of a sea-level canal, the Panama Canal Company has continued to investigate the possibility of utilizing the nuclear excavation method for the construction of a canal in the Isthmus. Various United States organizations have lent their fullest support to the company,[5/] which has carried out various works, either directly or by contract with consulting firms. These concern especially methods of

4/ The plans and results obtained are detailed in the report of the Commission Engineering with Nuclear Explosives, United States Department of Commerce, National Bureau of Standards, Springfield, Virginia, 1964.

5/ The chief collaborators in this study were the Lawrence Radiation Laboratories of the University of California, the Atomic Energy Laboratories of the United States and various engineering and consulting firms contracted by the Canal Company.

/protecting

protecting the population against radioactivity, attempts to clear up doubts connected with security which arose from the revision of the 1960 preliminary plan, and tests on nuclear excavation techniques for the construction of a canal.

a) Nuclear excavation of the canal

On the assumption that craters produced by underground nuclear explosions would be utilized, everything possible would be done to calculate the explosions, within the limits of security, so that the craters would meet the excavation requirements of the project as far as possible. The explosives would be set off in line at well-spaced intervals, so that the craters would run into one another and form a canal, and the explosions would serve both to break up the earth and to remove it from the depression, thus eliminating the work of removing the earth by mechanical methods. (See diagram 4.)

The chief characteristics of nuclear explosives which have to be considered (see also table 21), are the following:

a) The production of energy by nuclear devices, seeing that the diameter of the crater would determine the total production required,

b) The expanded gamma radioactivity which is an important factor in determining security, and the diameter of the hole, which depends on the size of the explosive. The cost of the site would increase according to the depth of the crater; and

c) The cost of the nuclear devices, which would be 350,000 dollars for an explosive charge of 10 kilotones and 600,000 dollars for a 2 megatone device, with intermediate costs in line with the semilogarithmical scale.[6]

An underground nuclear explosion produces a paraboloid crater whose shape and size depend on the power of the device, the depth at which it is placed and the geological formation of the land. The size of the crater increases according to the power of the nuclear device to a greater extent

6/ Information obtained from the Atomic Energy Commission. Details were not provided on the cost of 5, 10 and 35 megatone devices, which should also be used.

/Table 21

Diagram 4

TRANSVERSE SECTION OF A TYPICAL CRATER IN ROCK

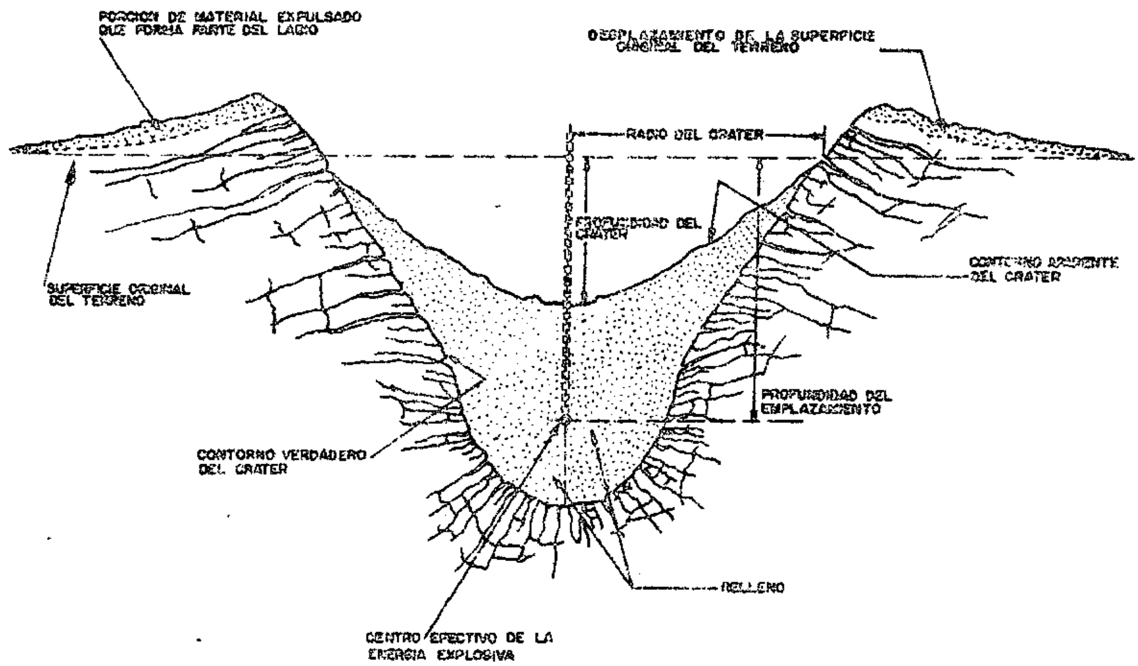


Table 21

DETAILS AND COST OF THE NUCLEAR EXPLOSIVES FOR EXCAVATION, 1964

Total product[a] per device (Kilotones)	Radioactivity gamma released per device (Kilotones)	Required diameter of hole for placing the device (Metres)	Estimated cost of device and detonation (Thousands of dollars)
100	0.1	0.90	460
200	0.1	0.90	490
500	0.2	1.35	540
1,000	0.3	1.35	570
2,000	0.5	1.35	600
5,000	1.2	1.35	...[b]
10,000	2.4	1.35	...[b]

Source: Article by Ernest Graves Jr., Excavación nuclear de un canal istmeño al nivel del mar, magazine Civil Engineering, October 1964, page 49.

a/ The 35 megatone nuclear device is not included in this table, although in the text of the article it is referred to as the largest which would be used, in the highest section of the Continental Divide.

b/ In 1958 estimated cost was one million dollars. There are indications that the costs of the devices for peaceful uses would be less than those estimated in 1958.

than either its cost or the size of the surface hole. This allows for a greater choice in deciding upon the dimensions of the canal (see again table 21). If for construction of a sea-level canal by standard methods the intention would be to have the trapezoid section 18 m (60 feet) deep and 180 m (600 feet) wide between banks 12 m (40 feet) deep, the nuclear channel would be at least 18 m (60 feet) deep and 300 m (1,000 feet) wide and, since the section would be a paraboloid, the depth would be much greater in the centre of the canal.

The theory of excavation has been provisionally drawn up and engineering formulas have been put forth for the purpose of calculating the appropriate size of the charges, the depth at which they should be placed, and the distance between each explosive, since they would have to be set off simultaneously.[7/] These are complex calculations which would have to be worked out by electric computers.

The power of the charge must be in accordance with the most appropriate depth. Either the width or the depth of the crater may be increased to the maximum, but not both at the same time.[8/] Up to a certain limit, the deeper the charge is placed, the wider and deeper will be the resultant crater. The security would be greater if the charge were placed at the greatest depth in order to obtain the most suitable width for the canal, because the radioactive remains would be buried deeper. (See again diagram 4.)

From the foregoing one can appreciate the saving which would be made if the nuclear method of excavation were employed. The reduction would be due to the low cost per unit of nuclear energy as compared to that of chemical energy, labour, and the machinery required if the excavations were to be carried out by standard methods, although it cannot always be expressed by means of a unit price index. That is to say, it would not be logical to compare the costs of a standard excavation

7/ For more detailed information see Report on the Third United Nations Conference, on the peaceful uses of atomic energy Engineering Applications of Nuclear Explosives (Doc. A/CONF.28/P/291, page 3).

8/ Luke J. Vortman, Nuclear Excavation of a Sea-Level Isthmian Canal, Proceedings of the American Society of Civil Engineers, Report 4129, Nov. 1964.

/. estimated at

- estimated at between 1.50 and 2.50 dollars per m^3 (1.18 to 2.19 per $yard^3$),[9/] with the estimates made for the Sasardí-Mortí canal, which are 26 dollar cents per m^3 (18 dollar cents per $yard^3$), seeing that the total volume of the excavation would have to be made by much greater force. In any case, a comparison of unit costs cannot reflect the difference in the two methods.

The nuclear method is important for the following reasons: i) it would allow for a complete revision of plans, even to the abandoning of the present canal, although its conversion would be the most economical of the projects for construction by standard methods; ii) the nuclear technique would simplify the solving of secondary problems, such as the protection of the canal from floods, seeing that it could be cut through the river beds; and iii) the cost of moving earth and rocks by nuclear explosives is very low. Therefore, projects which include the removal of the greatest amount of material would be far less costly in comparison with the cost of standard methods, in which the aim is to reduce the volume of earth and rocks to be removed.

b) Security methods in the employment of nuclear energy

Nuclear explosives produce many kinds of radioactivity which affect the population and the atmosphere in various ways. Their effects must therefore be controlled according to the requirements of each particular case. Nuclear excavations give rise to the problems of radioactivity, violent winds and seismic movements. The chief concern is contamination by the radioactive matter. Nuclear charges based on the fission of uranium and plutonium, which are used to detonate thermo-nuclear explosions, produce endless fragments of fission and set off some 68 different types of radioactivity whose effects could be dangerous to the population. These are four kinds of gases which are chemically inert; 16 which are partially volatile at the temperature of the melted rock; 45 which are not volatile at high temperatures. In addition, thermonuclear reactions, the same as fission, produce neutrons which can create radioactivity in the materials

9/ At present a reduced cost of 0.67 dollars per m^3 (0.45 dollar per $yard^3$) has been obtained.

/used to make

used to make the explosives. Seven of the chemical elements which are used to make explosiyes produce 13 different types of radioactivity. The neutrons freed by the fission and thermonuclear explosives radioactivate the earth and rock in the area of the explosion. The rock becomes impregnated with some 20 different types of radioactivity although none may evaporate.

All these facts are borne in mind in the making of explosives for excavation purposes, so that their effects can be lessened. The quantity of radioactive substances resulting from the fission would gradually diminish and this might reduce the amount of energy produced by the fission, i.e. the fission/fusion relation. The amount of radioactivity in the explosive materials could be diminished by selecting those least susceptible to the action of the neutrons, and the radioactivity affecting the rocks and earth could be reduced by encasing the explosives in an absorbent cap of neutrons. To achieve this, however, it would be necessary to increase the diameter of the explosives and, consequently, the cost of drilling the holes in which to place the charges.

At the moment of explosion, the explosive material and rock within a radius of 6 m (20 feet), is transformed into a gas of very high temperature and pressure, containing all the radioactivity which has been produced. As the gas expands and passes through the rock it gradually cools down. Only a part comes to the surface, approximately half of the volatile substances and one-tenth of the non-volatile radioactivity. The cloud of dust which takes on the well-known mushroom shape is formed by only one per cent of the gas. After the explosion, a large part of the material falls back into the crater (fallback) and around the edges. When the bomb is one of 100 kilotones, the entire fallback weighs 10 million tons and the cloud of dust is 20 km^3 (5 cubic miles) in volume and weighs 100,000 tons. This cloud contains the various radioactive gases, approximately half the volatile substances and one-tenth of the non-volatile material. The greatest explosion which could be required for nuclear excavation of the canal (35 megatones) would form a cloud from 10 to 13 km high and 65 km in diameter.

/The exact

The exact minimum quantity of radioactivity which could cause harmful long-term effects to the population (leukemia, cancer, genetic changes, etc.), is not yet known. A very conservative policy has therefore been followed with regard to security measures. Any increase in radioactivity above the amount absorbed naturally by human beings is considered dangerous. In a nuclear excavation it would be necessary to ensure adequate protection for the workers and the population in general, as well as the animal and plant like in the affected area.

Contamination could also be carried to far away areas by radioactive rain or by land and sea animals. E.G. iodine 131 - one of the most receptive products to nuclear fission - could be absorbed by grazing animals and become concentrated in the milk for human consumption. Strontium 90 could well be concentrated in fish, game, fruit, etc., and later absorbed by humans. The radioactivity in tritium (radioactive hydrogen) could contaminate water to be drunk by men and animals and absorbed by plants.

Another problem which would have to be considered is that of the soluble substances deposited in the crater or its surrounding areas, which could be transported by underground streams, rain or the canal water. It would depend on the solubility and dissolution of these substances and on the radioactive water which could mix with and infect other water, so that water consumption would have to be avoided all the time there was a possibility of contamination.

Apart from radioactivity, other effects such as windstorms and seismic movements are produced. Experience acquired from tests has shown that the damage caused by wind at long distances from the explosion can be avoided if the right atmospheric conditions are awaited. Also, the seismic movements are not necessarily transmitted over a great distance. It is considered that these effects would be much lessened if the excavations were made in areas far from centres of population.

/c) Sasardí-Mortí

c) <u>Sasardí-Mortí and Atrato-Truando projects</u>

In 1960 it was decided that nuclear methods could be employed and that the construction could be made with a sufficient safety margin and at very much reduced costs in comparison with the convention type of excavation. This would allow for a reconsideration to be made of certain projects, including that of Tehuantepec in Mexico and the Nicaragua route which, if carried out by nuclear explosion, would also pass through Costa Rican territory. According to the experience acquired by specialists and interested organizations in the United States between 1960 and 1964, it seems that the technical perspectives for the nuclear construction method of a canal in the Isthmus are even more favourable than before. Certain problems, especially some of a biological nature, must first be resolved, but none of these would actually impede the construction. The studies tend to confirm the opinion that: i) the Sasardí-Mortí route can be excavated by nuclear methods and the Atrato-Truando route by a combination of the nuclear method and the standard dredging method; ii) there are no unsurmountable safety problems, although steps should be taken to ensure the required methods of protection; iii) field studies should be undertaken on the two routes because the present works are based on information obtained in 1947 which does not include aspects of the problem which are considered necessary if the nuclear method of excavation is to be employed.[10/]

At present attention is focused chiefly on the two routes referred to, one in Panama and the other in Colombia, since they offer the best solutions to the following requirements: the selected route would have to be the best from the point of view of facility of construction, the least costly from the point of view of security and compensation for right of way, and it should be possible to reach an agreement with the country through whose territory the canal would pass.

i) <u>Present state</u>. There is no information available as yet to allow for a decision on the most suitable location for the nuclear excavation, taking into account the advantages and limitations of the latter.

10/ For example, it should be possible to find an alternative to the Atrato route which could be nuclear excavated along its entire length.

/These two

These two routes must be taken as indicative of the general area which is the most favourable for combining the advantages of economy and security due to distance from centres of population.

It is considered that nuclear excavation would be the best method for constructing the entire canal along the Sasardí-Mortí route (approximately 70 km), presuming that this would be cut entirely through rock. For the Atrato-Truando route, it would be necessary to carry out hydraulic dredging in the alluvium deposits from the Caribbean to the River Salaquí (88 km) and a nuclear excavation would be required over the remainder of the distance (72 km). (See table 22.)

A preliminary outline has been drawn up for each of these projects which includes: 1) a general comparative planning of the concept and development of the works; 2) an approximate budget, and 3) a construction programme.

A detailed plan, including estimated budget, has been drawn up for the following phase, covering investigations, field studies and preparation of designs.

ii) Safety measures. The explosions would be set off in series over a period of two to three years. Radioactivity would be kept to the minimum. However, safety measures would call for the population to be permanently removed from the zone where radioactive rain would be expected to fall (the areas which would have to be evacuated are shown in map 3), which would be from 50 to 80 km wide along the Atlantic coast and approximately 160 km wide on the Pacific. The temporary removal of the population would be impractical. It would therefore be necessary to reinstall some 30,000 people in new towns in the case of both the Sasardí-Mortí and Atrato-Truando routes.

A charge set off deep underground would create much less wind force than a similar surface explosion. It could nevertheless be felt as far away as Panama City, and might well cause the breaking of glass as a consequence of infraction concentration in the "ozoneosphere". It is thought that this inconvenience could be avoided by setting off the explosion under the right atmospheric conditions.

/Table 22

Table 22

SEA-LEVEL CANAL IN THE ISTHMUS: EXCAVATION DETAILS, 1964

Item	Unit	Route	
		Sasardí-Mortí *a/*	Atrato-Truando *a/*
General details			
Total length	kilometres	71	160
	miles	44	100
Greatest height above sea-level	metres	335	275
	feet	1 100	900
Nuclear excavation			
Physical characteristics of the canal			
Length of the cut	kilometres	71	72.5
	miles	44	45
Width	metres	300	300
	feet	1 000	1 000
Minimum depth	metres	18	18
	feet	60	60
Central depth	metres	60 - 115	60 - 115
	feet	200 - 380	200 - 380
Nuclear explosives			
Number of charges		300	260
Smallest charge	kilotones	100	100
Biggest charge	megatones	10	10
Total product	megatones	170	270
Hole for placing the device			
Diametre	metres	0.90 - 1.40	0.90 - 1.40
	inches	36 - 54	36 - 54
Minimum depth	metres	170	170
	feet	550	550
Maximum depth	metres	650	650
	feet	2 130	2 130
Total depth	metres	75 000	75 000
	feet	250 000	250 000

/Continued

Table 22 (concluded)

Item	Unit	Route	
		Sasardí-Mortí a/	Atrato-Truando a/
Detonations			
Number		14	21
Average product	megatones	10	10
Maximum product	megatones	35	35
Detonation charges	megatones	4 - 50	4 - 50
Length of the canal	kilometres	1.5 - 10.0	1.5 - 10.0
formed by detonations b/	miles	1 - 6	1 - 6
Standard excavation			
Physical characteristcs of the canal			
Length of the cut	kilometres	-	88
	miles	-	55
Width	metres	300	180
	feet	1 000	600
Depth	metres	18	18
	feet	60	60
Excavation by			
Hydraulic dredging	millions of m^3	12	800
	millions of cu. yards	16	1 100
Other conventional methods	millions of m^3	23	33
	millions of cu. yards	30	44

Source: Ernest Graves Jr., Civil Engineering, October 1964, pages 48 to 55.
a/ Metric system of measurement.
b/ According to the depth of the cut and product of the detonations.

/It is known

It is known that the seismic movement would not affect more than 65 km (40 miles) around the area of the explosion. The 35 and 10 megatone explosions might be felt in Panama and Colon, but they would not produce cracks in the walls of houses.

iii) Cost and organization of the project. The cost of a canal along the Sasardí-Mortí route is estimated at 747 million dollars, and along the Atrato-Truando route, 1,440 million dollars.

These estimates do not include the following: cost of agreements, cost of various necessary services, of nuclear experiments and of earth-moving which would be essential after the nuclear excavations. The agreements referred to in the studies are those concerning land rights, right of way, compensation for possible damage caused by nuclear explosions, duties to the country through whose territory the canal passes, etc.

The nuclear experiments consist of thermic preparation and the making of devices, apart from other investigations which are necessary before the project is carried out, and which have been estimated at 250 million dollars. Apart from this a programme of propaganda is being planned for the purpose of securing acceptance to the nuclear excavation plan, at a cost of 75 million dollars. This is not included in the budget, either. If the success and security hoped for in the nuclear excavation are not achieved, additional, unforeseen excavation costs could create difficulties.

The budgets include preliminary studies, detailed works of engineering, supervision and construction of the canal itself, and of auxilliary works of both a temporary and permanent nature, and the cost of evacuation and installation of the population in new areas. They also include a rough sketch of the order of development of the project, which would be carried out in three basic stages. (See table 23.)

iv) Next stage of the project. The first stage of the works would be a field investigation for the purpose of obtaining all the essential information, and this would take two years. The information thus obtained would allow for a more detailed study to be made, which would include the two routes already referred to, and should also cover the engineering aspects of the canal and the control of the atomic explosions. The budget

Map 3

SASARDI-MORTI AND ATRATO-TRUANDO ROUTES: CALCULATED PATTERNS OF RADIOACTIVE RAIN AND AREAS TO BE EVACUATED

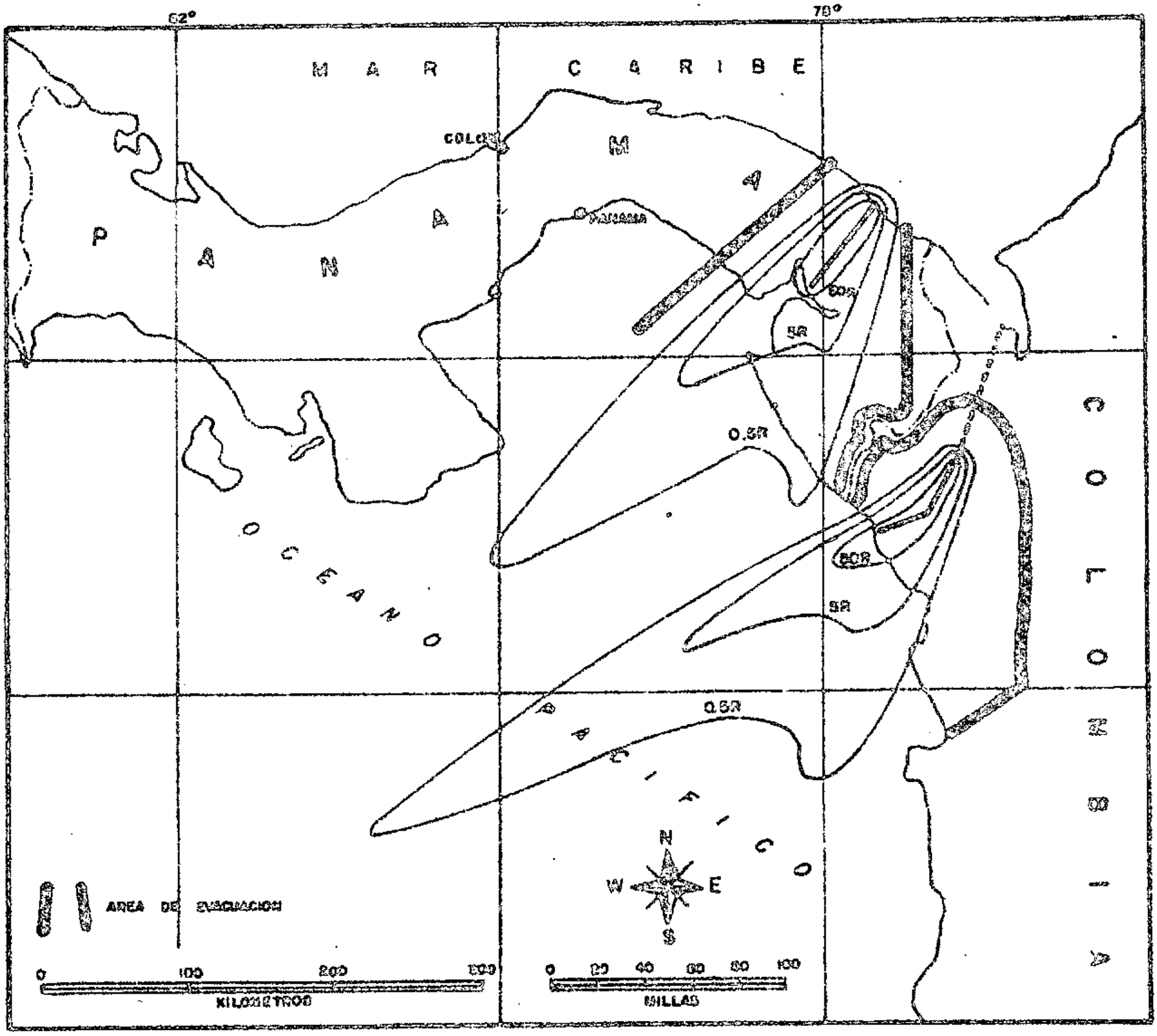


Diagram 5

SASARDI-MORTI ROUTE: LONGITUDINAL SIDE VIEW, CUT IN THE CONTINENTAL DIVIDE

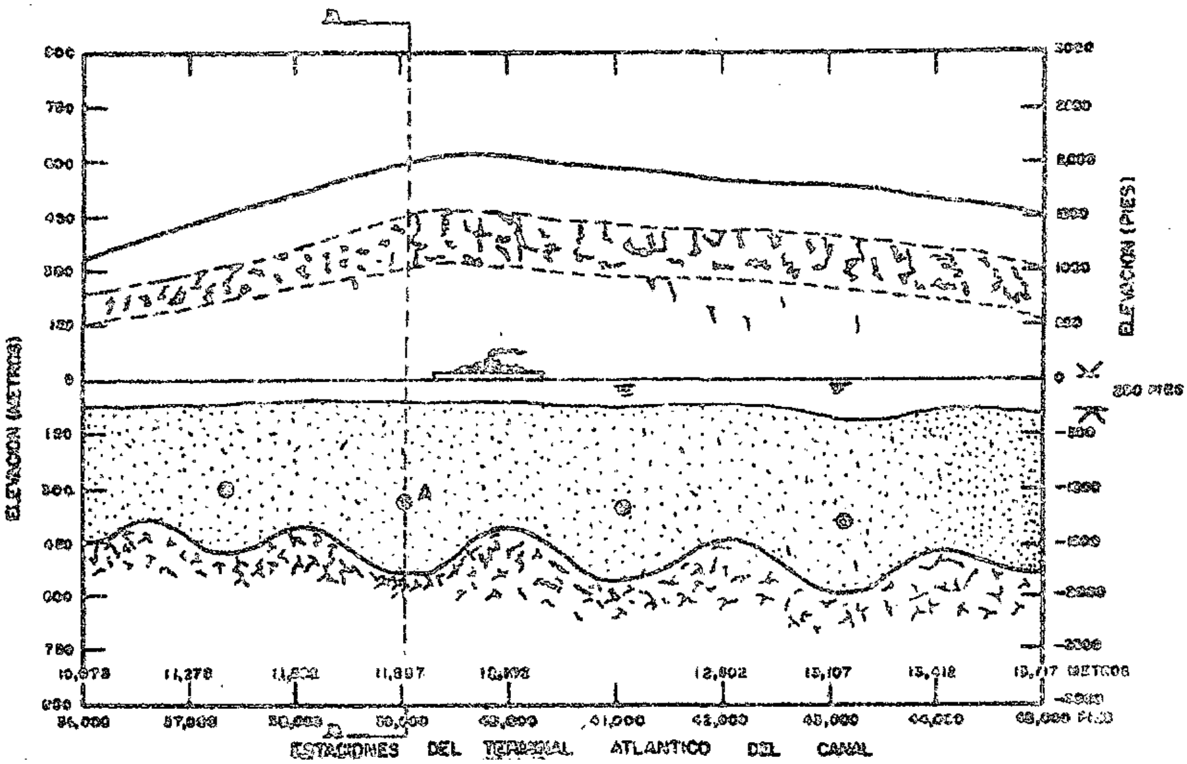
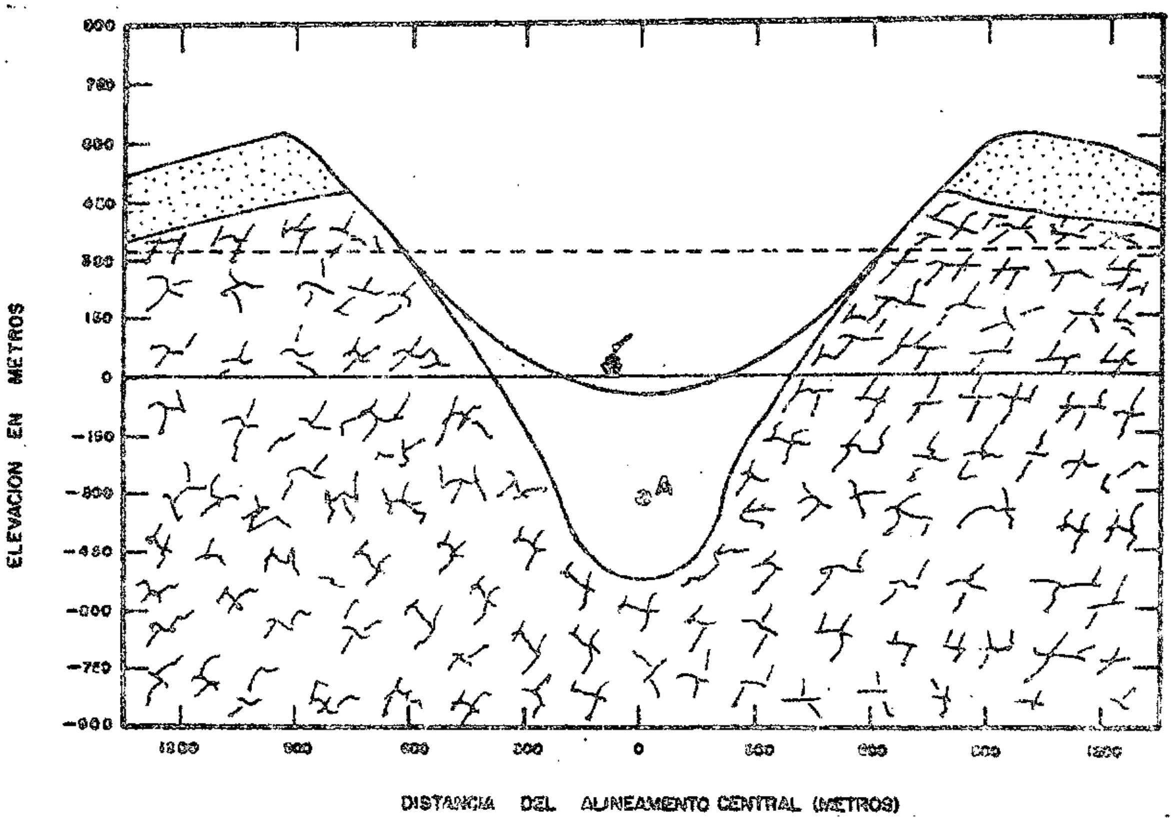


Diagram 6

SASARDI-MORTI ROUTE: CROSS SECTION ON STATION A*



* See Diagram 5.

Table 23

SEA-LEVEL CANAL IN THE ISTHMUS: COMPARISON OF PRINCIPAL PROJECTS, 1964

	Sasardí-Mortí Canal (Route 17)			Atrato-Truando Canal (Route 25)		
	Development of operations[a]	Annual average of number of workers required	Estimated cost (Millions of dollars)	Development of operations[a]	Annual average of number of workers required	Estimated cost (Millions of dollars)
Stage I						
Field investigations[e] on Routes 17 and 25	1st and 2nd years	...	17.0	1st and 2nd years		17.0
Analysis of field investigations; report on feasibility and advantages of Routes 17 and 25	3rd year	...		3rd year		
Stage II						
After selecting the route, engineering studies and designs, field work b/	4th year[c]	1,250	13.0	4th year[c]	1,000	18.00
Stage III						
Conventional construction to gain access to site	5th year	3,750	120.0	5th and 6th years	2,500[f] 4,000	166.0
Engineering	5th year		34.0	6th year	4,000	82.0
Boring of holes						
First series	6th year	4,000	60.0	7th year	5,000	67.0
Second series	8th year	2,500		8th year	4,500	
				9th year	4,000	
Evacuation of the area			30.0			30.0
Nuclear detonations						
First series	7th year	2,500	217.0	8th year	...	
Second series	9th year	1,500		10th year	4,000	218.0
Conventional excavation	9th year	1,000	89.0	11th year	3,500	
				12th year	3,500	131.0
Permanent constructions	10th year	1,850	73.0	13th year	3,500	105.0
Dredging of rivers	-	-	-	5th - 14th year	2,500 g/	423.0
Unforeseen needs (15% stage III)	...		94.0	......		183.0
Estimated total cost d/			747.0			1,440.0

Table 23 (Concluded)

Source: Panama Canal Company, Isthmian Canal Studies - 1963, Annex III.

a/ Work will be commenced as soon as the United States Congress has authorized the studies and set aside the required funds, and agreements have been reached with Panama and Colombia.

b/ The engineering studies would provide information for the detailed design of the canal along the selected route. During this stage, agreements would be signed for the initial construction of ways of access for the labour force to the site of the canal, and mobilization would be commenced.

c/ On condition that Congress has authorized the construction and approved the budget, or that other means of financing have been arranged, and that a treaty has been negotiated and ratified with the country concerned.

d/ Excluding the cost of production of the nuclear explosives.

e/ These may take anything up to 3 years.

f/ For the fifth year.

g/ For the fourteenth year.

for this is 17.5 million dollars (see table 24). The first part of the study would be for the purpose of finding solutions to the problems of construction and the second part to obtain data on the control of risks which could arise from the nuclear explosions. A further two years (possibly three) would be needed for this.

Field investigations will be carried out, and data will be obtained, on topography, geology, hydrography, hydrology, meteorology, seismology, ecology, economy of natural resources and population. Topographical and other similar studies on the Sasardí-Mortí route are expected to be undertaken first - in 1965-66 - by 25 specialists, 10 technicians, 175 workmen and 40 supply staff.

It is estimated that 150 man-months will be required for the installation of the hydrological stations, and 6 engineers and 30 workers for their maintenance and operation. Approximately 40 specialists and technicians will be required to work on meteorology during the two year duration of the project. Smaller teams, but of not less than 5 people, will take charge of other investigations. The evaluation of data will commence while it is still being gathered together and will be terminated 3 years after the study begins.

One must remember that the United States Congress[11/] created a Commission at government level to investigate and study the most suitable site for a sea-level canal and to set forth the best means of achieving this. Mr. Robert Anderson was appointed President of the Commission and a budget of 17.5 million dollars was approved. It is possible that the above-mentioned studies will be carried out under its auspices. The commission should present its first report on 31 July 1965, and will issue annual reports on its activities. The work of the commission is expected to reach completion on 30 June 1968.

11/ See Congressional Record - Senate: September 8, 1964, pages 21052 on the Bill (S. 2701). The Law itself is 88609 of 22 September 1964.

/Table 24

Table 24

SEA-LEVEL CANAL IN THE ISTHMUS: SUMMARY OF ESTIMATED COSTS FOR FIELD STUDIES, a/ 1964-1966

(Thousands of dollars)

	First year	Second year	Total
Total	7,734	9,766	17,500
Collection of data	7,019	7,444	14,463
Topography, geology and hydrography	1,082	1,174	
Meteorology and "windstorms"	2,177	2,090	
Seismic effects	46	114	
Population, ecology, economic resources	524	1,530	
Administration and supply	2,312	1,939	
Evaluation of data	361	1,676	2,037
Studies on nuclear excavation	39	99	
Studies on safety measures	212		
Design	110		
Attendance at the Ministerial Commission and special studies	354	646	1,000

Source: Panama Canal Company, Isthmian Canal Studies, 1964, Annex III.
a/ These consist of a study of the Sasardí-Mortí and Atrato-Truando routes.

/3. Theoretical

3. Theoretical and technical studies which should be carried out

The comments contained in previous sections on the projects for constructing a sea-level canal include many of the problems which require investigation. The conversion of the canal calls for the perfecting of some of the technical aspects of the construction. The alternative nuclear method, on the other hand, calls for a comprehensive study of the total project and of various scientific investigations.

The location of the new canal will have to be definitely settled on, as will the question of whether the standard or nuclear method will be used for its excavation. It will also be necessary to determine whether the problems to which the construction by the nuclear method gives rise can be solved as economically as is thought.

a) Standard method of construction

The design of the sea-level route in the Canal Zone is the most advanced of the various projects. However, the methods of conversion and excavation still have to be revised and definitely decided upon, and the problems relative to the excavation indicated in 1960 must be taken into consideration. In 1963 the Canal Company prepared a revision of the estimated cost of the project,[12/] according to which this plan could compete with the ones for nuclear construction. By taking advantage of the advances made since 1958, and of new methods of construction, the cost of the orginal project for conversion in a single stage could be reduced. It seems, however, that an even greater reduction could be obtained by conversion in two or three stages, although such a method was previously considered to be more costly. This is a very important point, seeing that it is considered preferable from the technical point of view to carry out the work in two or three stages.

Construction in two stages would be initiated by dredging the interior canal between the Gatun and Pedro Miguel locks in order to make these 9 m (30 feet) deep, thus allowing for the elimination of one of the

12/ Isthmian Canal Studies, 1964, Section VI.

three sets of locks in Gatun and Pedro Miguel. On the termination of this work, the costs of operation would have been considerably reduced and the transit time of ships made shorter. The second stage would be carried out over a fairly long period, in accordance with the needs, and would consist in the deepening of the canal to a depth of 15 m, thereby eliminating the need for the rest of the locks. The conversion would be terminated by deepening the canal to the 18 m required for future navigation. A conversion in three stages would be similar. After a first stage similar to the one described, the second stage would be a deepening of the interior canal by approximately 9 m, and the construction of a provisional set of locks in Miraflores and Gatun, which would be of no further use after the third stage had been carried out. The feasibility of this course would depend, essentially, on whether the water required for the duration of the second stage could be obtained in sufficient quantity and at a reasonable cost to operate the reconstructed locks.

The following economies could be effected: i) reduction in excavation and dredging costs, seeing that it would not be necessary to obtain machinery specially designed for the work; ii) reduction in the stocks of machinery, since the mobile equipment would be more or less worn out if the construction period were prolonged; iii) reduced annual expenditure from construction funds; iv) progressive reduction in operation costs since, on the termination of the various stages, the sets of locks would be eliminated one by one.

For the three stage conversion it would be necessary to add the additional construction cost of temporary locks and of the water storage system, which could be compensated by a greater economy in the dredging and excavations.

On the basis of the modifications mentioned and other less important revisions, the cost of the project is estimated at 2,176 million dollars. Methods of construction at even more reduced cost might well be found if more complete studies were carried out. A tentative figure of as little as 1,800 million dollars has been suggested.

/As far as

As far as the conversion of the present canal in one stage is concerned, recent technical advances and a better knowledge of the problem allow for the possibility of technically more advanced solutions at a lower cost than that envisaged in 1958. The problem has been studied by a Panamanian expert in a preliminary plan presented to the Canal Zone Authorities. From a first analysis, this would appear to allow for substantial reductions in the cost, since the investment is estimated at between 1,300 and 1,500 million dollars. A summary of this preliminary plan has been prepared, which has been drawn up separately.13/

This study should be carried on further. Its principal suggestion is the construction of an auxilliary canal in the extreme south of Gatun Lake to deviate traffic from the section of the present Canal between Punta Juan Grande and Punta Palenquilla. The auxilliary canal would be separated from the rest of Gatun Lake by a temporary dyke built between the lake and the sea-level canal. This would facilitate the excavation of the corresponding stretch of the sea-level canal situated in the part of Gatun Lake which should be drained in stages because of its weak geological formation. The progressive lowering of water levels would thus be made easier, and the possibility of landslides due to rapid changes in the water level would be prevented.

The plan also includes substantial modifications on the control and deviation of the rivers, suggests certain changes in the alignment of particular sections of the sea-level canal in order to simplify the dredging, and advises important modification in the selection of machinery and working methods.

b) Nuclear tests

As has already been stated, there still remain to be solved problems and unknown factors related to the control of the dangers of radioactivity, violent winds and seismic movements. It is considered that there is already a basis in existence upon which to prepare a system for controlling these

13/ Note by Engineer Francisco J. Morales Brid: Some recommendations on the construction of a sea-level canal in the Present Zone, Panama, April 1965.

/effects.

effects. The United States Atomic Energy Commission, which is in charge of these investigations, has stated that it has made advances on various aspects, particularly on the design of thermo-nuclear explosives of reduced initial radioactivity. It is planning to carry out multiple tests over two or three years which will provide further information on the required safety measures.

In some references[14/] to the excavation of the canal by means of nuclear explosives, attention is drawn to terms of the Treaty signed in Moscow on 5 August 1963 by which nuclear tests are forbidden in the atmosphere, outer space and under water. It is pointed out that by virtue of the same Treaty the carrying out of atomic explosions, including those underground, is forbidden when the radioactive material could go beyond national frontiers.[15/] It is thought, nevertheless, that the terms of the Treaty could be revised in order to permit nuclear explosions to carry out works of public benefit. A supplement should be prepared to this note on the revision of the said Treaty.

c) Studies on nuclear excavation

The cut through the central part of the Continental Divide, which rises to a height of more than 300 metres,[16/] would require charges of a size not yet experimented with. This would be the deepest cut of the entire canal, and it is presumed that it would be made by one explosion. The greatest problem concerning the technical feasibility of excavation by means of nuclear explosives is one of safety, and when this is applied to the canal project, the need for two types of investigation clearly stands out. The first concerns to the yet unknown force of the explosion in the stretch of the canal in the highest part of the Continental Divide, by means of one charge to be kept within the safety limits. The second is a question of soil mechanics, since the effect of the explosions on the earth will have to be investigated.

14/ Engineering News-Record, 24 December 1964 and 14 January 1965.
15/ Article I, Document ENDC/100/Rev.1 of the United Nations, Conference of the Committee on Disarmament constituted by eighteen countries.
16/ Exact data is not available. One of the first studies to be undertaken is the determination of the height of the Continental Divide, due to the fact that the explosive power would depend on the depth of the cut.

/Although the

Although the plan is considered feasible, the following should first be confirmed: i) whether the calculations used up to the present to determine the size of craters could be applied to 35 megatone explosions with the certainty that the explosion would produce a sufficiently deep cut; ii) whether a cut of this depth, produced by nuclear explosion, would be sufficiently stable and without risk of lateral landslides which could obstruct the canal; iii) if such a large-scale explosion could be effected without any danger from far-reaching windstorms and seismic movements.

In the case of a negative answer to any of these points, the problem would have to be solved in another way, as yet undecided upon. One way could be by 10 megatone explosions, when the cut would be completed by machinery. The rock would be broken up by the explosion, but the earth would have to be removed from the excavation, with a consequent rise in cost. A shallower cut made by nuclear explosions and completed by standard methods of excavation could give greater stability to the slopes.

In order to reduce the force of the blast, two successive explosions could be carried out, the second at a greater depth than the first.

The only experience which has been acquired on nuclear excavations, also called "excavations by diffusion", and on setting off a line of charges, has been on desert formations and dry rock. Nuclear explosions in the Isthmus jungle with its complicated geology may call for a revision of the concepts on the formation of slopes and the behaviour of the subsoils after fallback.

Experiments would have to be made on the form of excavation by trenches, and on the stability and other characteristics of both the slopes through which the canal would be cut and the surrounding areas. The decision to construct a sea-level canal by the nuclear method will depend on the results of these experiments.

The pilot project called "Carryall",[17/] which should be completed by 1967, may provide more knowledge on the subject. It is presumed that a technique will be tried out which would be used on a large scale to build the canal through the Isthmus.

17/ The United States Atomic Energy Commission has proposed the excavation of a cut 3 km long in the Baldwin Mountains (California), for the construction of a stretch of highway and the new branch of the railway.

/4. Comments

4. Comments on the various projects for a sea-level canal

There are three very feasible possibilities at present for the construction of a sea-level canal. These are: (a) the conversion of the present canal; (b) the construction of a canal in the Darien by the Sasardí-Mortí route and (c) the construction of a canal in Colombia by the Atrato-Truando route. The costs of these projects would vary considerably, but it seems that any of them would be economically justified over a period of years if one takes into account the effects they would have on Panamanian economy, as much in the saving to canal users as in the greater revenue which would be received and the lower operational costs for the company.

Although the benefits to canal users have not been valued in monetary terms, it is important to realise that in 1964, alone, the ships which used the canal saved approximately 170,000 sailing days. If one calculates the average cost of operation per hour of a ship at 100 dollars, a saving of 400 million dollars would be achieved annually. If the calculation is made in consideration of the reduction in the cost of freight, one may estimate that around 350 000 million tons per nautical mile were saved at a cost of .003 of a dollar per ton-mile. The saving in 1964 was therefore approximately 1,000 million dollars. The investment sum required for the construction of a new canal compares very favourably with either of these two amounts.

The relation of revenue and costs of operation for the three possibilities is detailed in the following paragraphs. The information is based on the study of hypothetical projects of cost which vary between 500 and 2,500 million dollars.[18/] It is therefore possible to note only some of the indications of economic justification and preference. This aspect should be gone into more closely because of its importance on the locating of the sea-level canal and on the date on which it could start to operate. (See table 25.)

18/ Annex VI to the report Isthmian Canal Studies, 1964.

/Table 25

Table 25

COMPARISON OF ANNUAL COSTS[a] OF A SEA-LEVEL CANAL WITH THOSE OF THE PRESENT LOCK CANAL, 1980-2000 b/

(Thousands of dollars)

Projects and costs	1963	1970	1975	1980	1985	1990	1995	2000
Present canal	60,973	78,066	90,817	102,534	114,089	125,644	137,199	148,755
Sea-level canal[c]								
(600 million dollars)	-	-	-	63,743	63,085	62,425	61,765	61,765
(1,000 million dollars)	-	-	-	82,343	80,885	79,425	76,965	76,505
(1,500 million dollars)	-	-	-	105,543	103,085	100,625	98,165	95,705
(2,000 million dollars)	-	-	-	128,703	125,245	121,785	118,325	114,865
(2,500 million dollars)	-	-	-	151,903	147,445	142,985	138,525	134,065

Source: Isthmian Canal Studies, 1964.

a/ Including interests, amortization, depreciation, operation and conservation.

b/ On the supposition that a new canal would be put into operation in 1980.

c/ Annual cost includes amortization and interest on the investment in the present canal of 616.2 million dollars.

/a) Conversion

a) Conversion of the present canal

The investment would be 2,000 million dollars and the total annual cost (operation, conservation, interests and amortization) would be 128.7 million dollars for the first year and 114.9 million dollars for the twentieth year. The annual cost of the present lock canal is expected to gradually increase by 1990 to 125.6 million dollars. It is possible to plan the putting into service of the sea-level canal after 1990 so that the cost will be less than that of the present canal from the moment of inauguration.

b) Canal in the Darien (Sasardí-Mortí route)

An investment of 1,000 million dollars is estimated. Its operational costs in 1980 would be 82.3 million dollars, 20.2 million less than those of the present canal (102.5 million dollars). Consequently, from the financial point of view, it would seem advisable to initiate operations this year.

c) Canal in Colombia (Atratò-Truando route)

Investment costs would be approximately 1,500 million dollars. The total annual costs of operation would be some 105.5 million dollars, i.e. only 3 million dollars more than those of the present canal. Within two years, however, they would be the same, and by 1990 they would be 23.5 million dollars less.

From the comparison of costs and annual revenue between the present canal and a sea-level canal (see table 26), including those for the most expensive plan, one may conclude that the required investment would not create insurmountable problems concerning the debt capacity of the company which administers the new interocean route.

According to the studies it appears that the project for a canal in the Darien implies very low costs. However, the difference between these costs and those for a canal in the Canal Zone may well be reduced when

Table 26

ESTIMATED OPERATING RESULTS, 1980 AND 2000

(Millions of dollars)

Item	Present canal		Sea-level canal in the Canal Zone a/		Canal in the Darien b/	
	1980	2000	1980	2000	1980	2000
Cost of operation	48.5	73.3	14.5	20.4	14.5	20.4
Total cost	102.5	148.8	128.7	114.9	82.3	76.5
Total revenue	105.0	150.0	105.0	150.0	105.0	150.0
Superavit	2.5	1.2	-	35.1	24.7	73.5
Deficit	-	-	23.7	-	-	-

Source: Isthmian Canal Studies, 1964.
a/ With an investment of 2,000 million dollars.
b/ With an investment of 1,000 million dollars.

the findings of the present studies are known and comparisons made of the various estimates.[19/] If the cost of the canal in the Darien is increased, that of the Colombia project will also go up, and the difference in cost between the two projects will be maintained. The Colombia plan cannot possibly compete on cost with the Darien project because of the more complicated nature of its construction and operation requirements. It would have the advantage, on the other hand, of ensuring greater security and control of the nuclear excavations. But even in this case, the Colombia project would probably work out at a similar cost to that of the Darien one. The only way to obtain a fairly considerable saving would be by proving the advantages of the Darien project over the conversion of the present canal.

One should therefore study both alternatives more closely, bearing in mind all the modifications or rectification of the possible projects in

19/ For example, in the conversion project approximately 1,100 million dollars are included for public works, auxilliary structures, etc., while in the Darien plan only 250 million dollars are calculated for this purpose.

/order to

order to better compare the respective benefits and costs and try to settle on the most convenient date of opening for the new canal. One must also remember that certain important technical data is still lacking, which must be obtained before a decision can be reached on whether to construct the new canal by standard or nuclear methods of excavation. The nuclear excavation could well open up attractive new perspectives, but it implies possible risks of contamination by radioactive material which have not been clearly defined.

It would seem that the two most likely locations are in Panamanian territory. The preliminary studies appear to be in favour of the use of the nuclear excavation method for constructing a canal in the Darien. If this method were not possible, however, the best solution would seem to be the conversion of the present canal into a sea-level one. When the advantages of these two projects are studied in detail, the conversion project is perhaps the more preferable.

5. Other implications involved in the construction of a sea-level canal

The projections indicate the possibility of constructing a sea-level canal in the near future. The most economical project, which calls for an investment of some 1,000 million dollars, would be justified and would allow for the recovery of the investment capital from 1980 on. The most costly plan would have to be finished after 1990, in order to avoid the losses which would occur in the first years of operation if the present toll level was maintained.

If 1980 would be a good year economically for the opening of a new canal, the formulation of the corresponding programme of activities should be based as much on the period required for the construction as on the time required for the preceding studies. It seems that the carrying out of both phases, either together or separately, may take longer than the time which has been calculated. It would therefore be inconvenient to fix 1980 as the year when the sea-level canal will be opened without first having solved certain important problems which are still pending.

The programme of activities will depend on whether the present canal is to be converted to a sea-level one, or a new canal is to be constructed in the Darien. In the first case, the period of investigation would be shorter, and would be dedicated, in the main, to resolving problems on the known scientific and practical aspects of the problem. If the nuclear technique is decided upon, the varied and extensive investigations which would have to be completed have already been pointed out. It would, nevertheless, be a good idea to lengthen the construction period. This would allow more time for obtaining the maximum advantages, investment costs would not rise, and the service of the present canal would not be affected.

It is estimated that the construction of the sea-level canal in the Zone will require two years of technical investigations and administrative planning, once the recommendations for the canals in the Darien and Colombia are known - these are receiving priority - and once the most convenient method of excavation has been decided upon. The construction will be carried out in a minimum period of 12 years. If the construction by stages is adopted, the final conversion of the present canal would be terminated after 1980, perhaps by 2000, according to whether construction is carried out in one, two or three stages, as already explained.

It seems that new solutions have not been found to the first alternative. It is thought[20/] that the standard methods of excavation and dredging by stages require more detailed engineering studies and more precise cost estimates.

In the case of the method of construction in two or three stages, periods of reduced activity could be alternated with the various stages, in the way which would allow for the best advantage to be taken of both machinery and funds. It is thought that after completion of the first stage the costs of operation would be reduced.

The use of the nuclear technique is dependent upon the results of the investigations already mentioned in this chapter. According to the different (and contrary) opinions set forth in the studies which have been consulted, a working calendar of the following type would be required for the nuclear canal:

20/ Isthmian Canal Studies, 1964, Annex IV, page 74.

/1965 signing

1965 signing of formal agreements with Panama and Colombia for the carrying out of the required studies in their respective territories;

1965 and 1966 examination of the effects which the location of a canal outside the Zone could have on Panamanian economy;

1965 to 1968 study of the layout and method of construction;

1965 to 1970 study of the mechanics of the soils affected by the nuclear excavation;

1966 to 1969 preparation of treaties relating to the new canal;

1967 to 1969 pilot excavation project "Carryall" of the United States Atomic Energy Commission in the Baldwin Mountains, California, and evaluation of the results;

1968 to 1970 field studies and preparation of the design;

1968 to 1975 production of the nuclear charges;

1971 to 1980 construction of the canal.

The efficient operation and conservation of the lock canal has been taking up a large area of the present Zone in order for complete use to be made of the lakes, dams, dykes and various other installations, and of the water reserve necessary for lock operations and to produce hydro-electric power. These considerations would no longer be of any importance if the decision were made to construct a sea-level canal outside the Zone.

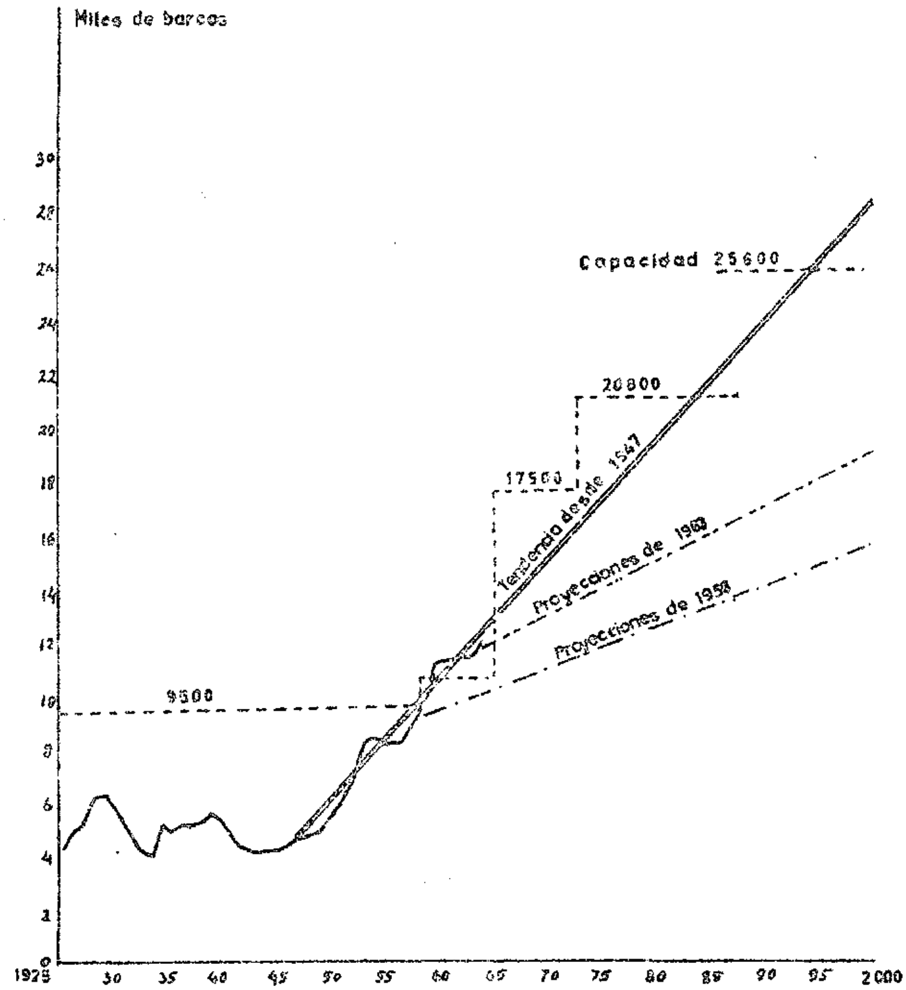
In the studies on the construction of a canal in the Darien or in Colombia, no reference is made to the future administration of the present Canal Zone. There are, however, estimates of costs of public services, police, customs, etc., which assume the existence of an autonomous administration by the authorities which will be administering the canal. The budgets would appear sufficient to cover the needs of canal operations, of the administration of the required areas and of the conservation of the works.

If the sea-level canal is constructed in the same area as the present lock canal, installations need not be made for the storage of water or for the control of the source of the rivers outside the present limits of the Canal Zone. The operation and conservation of this new route would be easier and its handling would take up a smaller area.

/Annex 1

Diagram 7

PANAMA CANAL: CAPACITY AND TRANSIT PROJECTIONS



Annex 1

WORKS TO BE CARRIED OUT

When the details of this note were being worked out problems and doubts arose which the available material does not make sufficiently clear. It would therefore be a good idea for complementary studies to be undertaken on at least the following points:

1. Comparison of costs and benefits between the project for conversion of the present canal and the construction of a canal in the Darien

If a strict evaluation is to be made of the various projects for construction of the sea-level canal, it would seem that the systematic application of various criteria must be made for the purpose of judging their economic advantages and disadvantages. From the point of view of the projects in themselves, it would be a good idea to apply the method of costs-benefits (brought up to date), taking the alternatives of the conversion of the present canal by standard methods and the construction of the sea-level canal in Sasardí-Mortí by nuclear excavation.

In the same way it would be extremely useful to evaluate the projects not on a basis of their individual characteristics, but by taking into consideration their effects on Panamanian economy. The various technical possibilities of construction would have to be qualified in relation to the employment of the labour force, the demand for construction materials of national origin, the depressive impact which would be provoked in some of the productive activities in connection with the present canal and the opening of new areas which would be directly incorporated into Panamanian production and the market of the country.

2. Legal problems related to the 1963 Treaty on the prohibition of nuclear tests

If the decision were made to construct the sea-level canal by means of nuclear explosions Panama, as a signatory to the treaty on the prohibition of nuclear tests in the atmosphere, outer-space and under water, would have to carry out legal studies in order to propose to the other signatories the necessary amendments to article I of the said treaty, which states as follows:

"1. Each of the Parties to this Treaty promises to prohibit, prevent and not carry out any test explosions with nuclear weapons, or any other nuclear explosions, in any place under its jurisdiction or authority:

a) either in the atmosphere or beyond its limits, including outer-space, or under water, including territorial waters or the high seas;

b) in any other medium if such an explosion would cause the presence of radioactive particles outside the territorial limit of the State under whose jurisdiction or sovereignty the explosion may be effected. It should be understood in this respect that the terms of this section are not against the making of a treaty to permanently prohibit all nuclear test explosions, including all underground explosions. The Parties are indeed hoping to reach such an agreement, as is manifested in the Preamble to this Treaty.

2. Each of the Parties to this Treaty promises to abstain from causing or encouraging the carrying out of test explosions with nuclear weapons, or of any other nuclear explosions, or from participating in any way in such explosions, and to abide by the terms of paragraph 1 of this article."

3. Construction of the sea-level canal in the Canal Zone

It is intended to carry out detailed studies on the construction of the sea-level route where the present canal is situated. However, it would be a good idea to inquire into certain technical an economic questions which have been reiterated in various reports.[1/] These refer, for example, to the alternatives for the conversion of the canal in a single stage or in two or three successive stages, the analysis of the different ways in which the fluvial waters can be controlled, and other key elements in the conversion project.

1/ F.S. Morales, Algunas recomendaciones sobre la construcción de un canal a nivel en la zona actual.

/4. Traffic

4. Traffic projections

If one takes into account the recent increases in the amounts of cargo transported, the calculations of future traffic elaborated by the Canal Company could be underestimated. It would therefore be useful to bring the traffic projections up to date, taking into consideration some of the suggestions contained in previous paragraphs.

/Annex 2

Annex 2

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/Annex 3