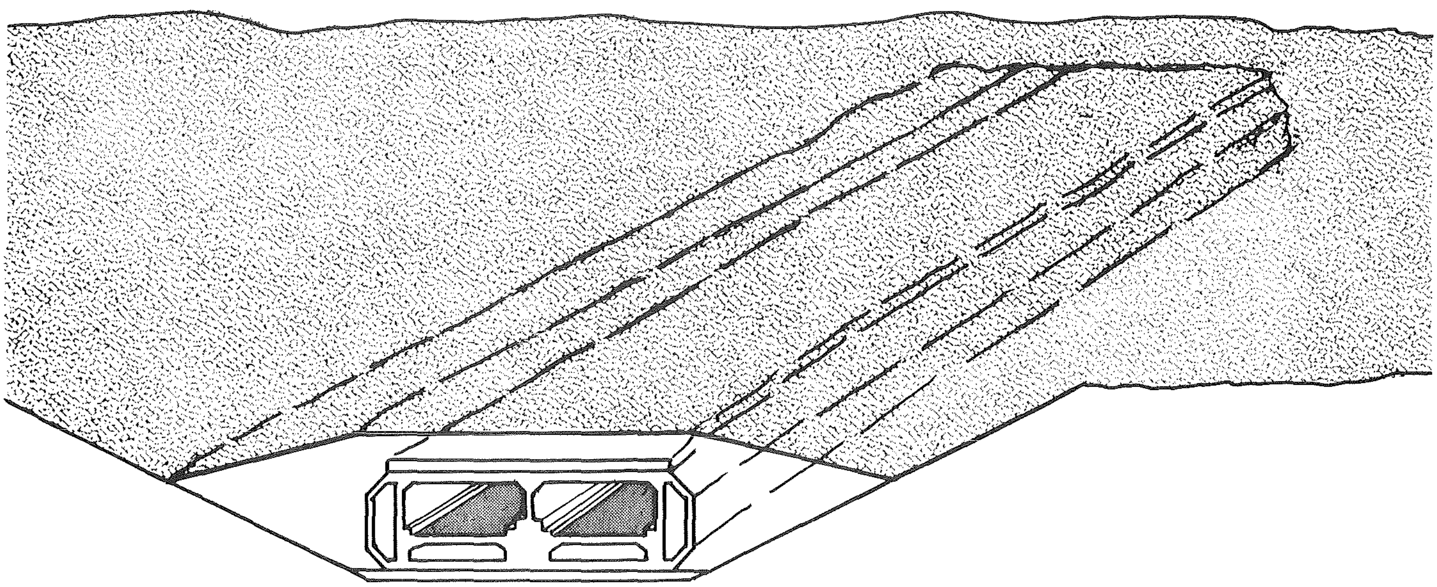
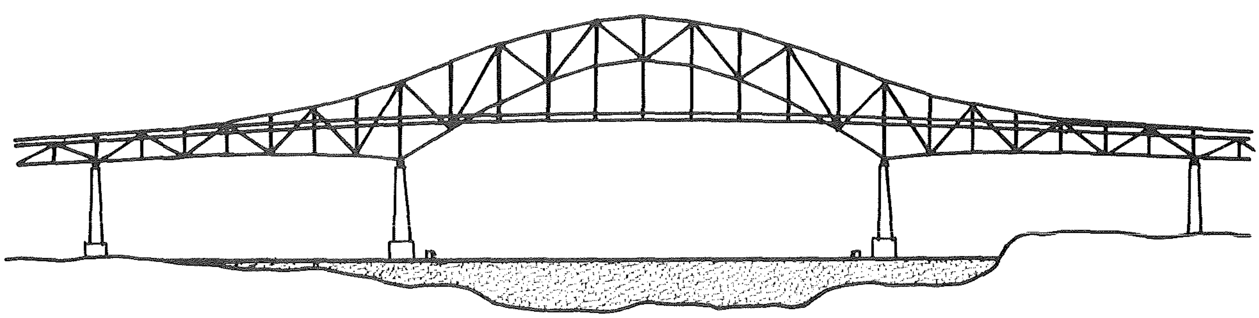
BRIDGE / TUNNEL CROSSING STUDY
PORTLAND HARBOR
FORE RIVER

PORTLAND — SOUTH PORTLAND





PREPARED FOR THE

MAINE DEPARTMENT OF TRANSPORTATION
AUGUSTA, MAINE

FAY, SPOFFORD & THORNDIKE, INC.
ENGINEERS
BOSTON, MASSACHUSETTS

JANUARY 1973

FAY, SPOFFORD & THORNDIKE, INC.
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BOSTON, MASS.

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MAINE DEPARTMENT OF TRANSPORTATION

Mr. David H. Stevens

Commissioner of Transportation

AUGUSTA, MAINE
1973

Report By
Fay, Spofford & Thorndike, Inc.
Engineers
Boston, Massachusetts

FAY, SPOFFORD & THORNDIKE, INC.
ENGINEERS

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January 9, 1973

Mr. David H. Stevens
Commissioner of Transportation
Department of Transportation
State Office Building
Augusta, Maine 04330

Attention: Mr. Roger L. Mallar
Deputy Commissioner
Planning and Administration

Subject: BRIDGE/TUNNEL CROSSING STUDY
PORTLAND HARBOR - FORE RIVER
PORTLAND - SOUTH PORTLAND

Dear Sir:

We are pleased to submit herein the results of our study for the Bridge/Tunnel Crossing between Portland and South Portland. This project was undertaken in accordance with our agreement, dated November 17, 1971, and with the statements outlined in the legislative act of authorization (H.P. 404).

Principal tasks of the study were: 1) to establish locations which were considered feasible for bridge and/or tunnel construction and which could be integrated into the present and future plans of the communities; 2) to estimate the construction costs of the various alignments and alternate facilities, and to recommend the best location and type of structure for use in a financial analysis; 3) to perform a traffic analysis on the future usage of the facility; 4) to undertake a cost-effectiveness analysis which considers the travel benefits to the motorist and relates this to the facility costs; and 5) to prepare a financial analysis including considerations of tolls and other alternate sources of capital funding.

For the nine locations presented in the report over sixteen alignments were explored for either a bridge or tunnel. Sufficient detail studies on route location and comparable costs were made to select the most feasible of the many alternate designs. Through the preparation of a series of interim reports and meetings with members of the Department, we were able to narrow the selection to the locations most logical and feasible, and these are presented herein. Large scale plans and profiles were prepared for these routes, but are being submitted separately, at full size, for ease of usage and availability.

We appreciate the opportunity to conduct this study and wish to acknowledge the assistance and cooperation received from the members of your staff, the representatives of the cities of Portland and South Portland, and from the members of the South Portland Board of Industry.

Very truly yours,
FAY, SPOFFORD & THORNDIKE, INC.
By E C Keane
Edward C. Keane, Vice President

ECK:hcd
Enclosure

STATE OF MAINE
EDWARD C. KEANE 1366
REGISTERED PROFESSIONAL ENGINEER

ACKNOWLEDGMENT

The cooperation and assistance received from representatives of the Maine Department of Transportation contributed significantly to the completion of this study. In particular, the assistance provided by the following individuals is gratefully acknowledged:

Roger L. Mallar	Deputy Commissioner - Planning and Administration
Richard A. Luettich	Deputy Commissioner - Operations
Gedeon G. Picher	Assistant Director - Bureau of Transportation Planning and Services
Theodore Karasopoulos	Bridge Design Engineer
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INTRODUCTION

The Fore River, forming Portland Harbor at its easterly end, presents a natural barrier separating the Portland Peninsula to the north from South Portland and the residential communities located farther to the south and west. Two bridges cross this active waterway: (1) the Veterans Memorial Bridge, located at the southwesterly end of the Peninsula, which services primarily through traffic moving between points to the north and south, and (2) the Portland Bridge (often referred to as the Million Dollar Bridge) over which passes primarily local, suburban traffic moving to and from the south. The latter bridge is a low-level bridge with a draw span at the deep water channel. The Veterans Memorial Bridge (also a low-level bridge) is located beyond the last major docking facility currently used by commercial vessels. A third bridge is currently under construction further upstream as part of the Interstate Route 295 project.

The Portland Peninsula is an employment center for the whole region, and traffic on the two bridges reflects this characteristic. A large percentage of the traffic to and from Portland is generated by commuters, support services and businesses serving the area. In recent years, local interests have raised the question of whether or not the Portland Bridge can adequately meet the needs of the communities in the immediate future considering its age and physical condition, the estimated future vehicular traffic volumes passing between South Portland and Portland, and future water traffic restricted by the confining limitations of the existing draw span.

A preliminary report concerning the feasibility of rebuilding the existing Portland Bridge versus building a high-level bridge on the same location or at a new location was submitted to the Maine State Highway Commission in August of 1970 by Fay, Spofford & Thorndike, Inc. That report presented the results of a preliminary investigation which was made to determine the comparative cost magnitudes of alternative solutions to the problem of updating the existing crossing. Actual field surveys and subsurface investigations were not made but available information was utilized. The conclusions reached in that report were (1) that it was not feasible to increase the draw span and rebuild the existing Portland Bridge, and (2) that the best location for a new bridge was in the same general vicinity as the existing bridge due to established routing of traffic, physical constraints and cost. The latter conclusion recognized the fact that the existing Portland Bridge would have to remain in service during the construction of any new facility.

In 1971 the Maine legislature passed "An Act Providing for a Feasibility Study of Alternative Methods for Crossing Fore River" (Legislative Document No. 517; H.P. 404). This act "authorized and directed" the Maine Department of Transportation "to study the feasibility and cost of alternative methods of crossing the Fore River between the Cities of Portland and South Portland, in the County of Cumberland, to replace or supplement the existing state highway bridge between said cities, referred to as the Portland Bridge. This study may include consideration of high level bridges or tunnels and financing alternatives including tolls." The "Statement of Fact" further notes that "the purpose of this legislation is to provide for a feasibility study to determine alternate methods of providing improved traffic service between Portland and South Portland where an existing draw bridge creates a difficult traffic situation."

In accordance with the charge of the legislature, the Department of Transportation requested Fay, Spofford & Thorndike, Inc., to broaden the 1970 report by including the investigation of possible tunnel alignments with preliminary estimates of construction costs; to study in more detail the alternative bridge alignments and to refine and update the respective estimates of construction costs to reflect 1977 prices; and to investigate possible means of financing the new facility, including tolls. It was agreed that if feasible locations could be found for tunnel alignments and termini, preliminary cost estimates would be prepared and a comparative analysis would be made with relative bridge costs. At that point a decision would be made on the feasibility of including tunnel alternatives in subsequent investigations to be made as part of the study.

The results of the studies are contained in the following report. The intent of this report is to establish the magnitudes of costs for the various alternatives and their financial feasibility. Local access and approaches were analyzed only to the extent necessary to establish their general alignment and cost. Final planning and details for local access would be undertaken in later planning stages. At that time current traffic circulation information and land-use details would be taken into account in determining the final location of connections to local streets.

SUMMARY OF FINDINGS

An analysis was performed in this study for determining the feasibility of constructing a new, high-level bridge or a tunnel between Portland and South Portland. Several alternative corridors were investigated in terms of physical conditions, improvement costs, traffic patterns, and land use. Corridor C (see FIGURE 1 on page 2 of the report) was considered the most practical alignment; it passes from the Knightville section of South Portland to the vicinity of Commercial, High and State Streets in Portland. The estimated bridge and tunnel construction costs (excluding right-of-way, engineering, legal, administrative and financial costs) were compared and it was concluded that the tunnel alternative would not be desirable due to its prohibitively high costs. The construction costs at the 1977 level, considered the earliest possible opening date for a high-level bridge, were estimated at approximately $39 million, and tunnel construction costs at approximately $80 million. Total project costs (including right-of-way, engineering, legal, administrative and financial elements) were then estimated for a bridge in Corridor "C" at approximately $51 million.

The extent of future traffic flow between South Portland and Portland was investigated in order to determine the demands which would be placed upon the existing bridge or a new bridge located in the same approximate area. Based upon past and present usage of the Portland Bridge, total traffic on the existing or on the new facility could reach 36,200 vehicles per day by the year 1992, a 29.3 per cent

increase from 1970 levels. Either the existing or a new four-lane facility should be adequate to accommodate estimated traffic to the year 2027. However, congestion will be much greater on the existing facility in those later years due primarily to its relatively narrow lane widths and restrictive alignment (on the Portland side).

User benefits versus facility costs were also investigated. The net annual incremental benefit to motorists of replacing the existing Portland Bridge with a high-level bridge will amount to only $46, 500 in 1977, increasing to $94, 000 by 1992 (based on 1977 conditions). The incremental benefit-cost ratio derived from comparing the high-level bridge to the existing drawbridge will be 0. 16 over a forty-year period. This finding illustrates that final justification for a new high-level bridge will depend on other considerations such as convenience, public safety, emergency vehicle operations and navigational requirements which are difficult to assess with a monetary value.

The charging of tolls was investigated and it was determined that no appreciable future traffic diversion will occur from the new bridge to the alternative route, the Veterans Memorial Bridge, as long as the toll is 20 cents or less. Maximum revenue will occur when a 25 cent toll is charged, even though off-peak traffic diversion will amount to 25 per cent in 1977. This off-peak traffic diversion is expected to decrease to about 10 to 15 per cent by 1992.

The financial analysis of the high-level bridge indicates that toll revenue on the facility will not cover all of the associated costs. More explicitly, the facility will incur a loss of $2 million in the first year (1977) alone, assuming revenue bond financing, and this deficit will increase with time. This indicates that the proposed bridge is not financially feasible from the standpoint of revenue bonds alone, and consequently the State and possibly the Cities of Portland and South Portland would have to back the bonds and guarantee the payment of interest. Even though state-backed bonds command a lower interest rate, the facility is still not capable of meeting its fiscal obligations from revenue, and state or federal subsidy will be required. The average annual deficit for the least expensive means of financing investigated amounted to approximately $2.4 million annually for a twenty-year period.

Programs currently available for financial assistance were investigated. Among the federal funding sources from which monies could be provided are the Federal-Aid Secondary (FAS), Urban "C", Bridge Replacement and Coast Guard Bridge Alteration Programs. FAS and Urban "C" funds are extremely limited. Currently, total state and federal allocations for the two programs are $6,425,000 and $1,800,000, respectively. These are not sufficient to finance a new, high-level bridge, or a large portion thereof, in light of current needs throughout the rest of the State. The allocation of funds from the Bridge Replacement program is based on a national priority rating system which relates primarily to importance of the structure and public safety. This program covers bridges on all federal-aid highways throughout the country and the amount of funds available was established at $100 million for 1972 and $150 million for 1973. Eligibility for the Coast Guard Bridge Alteration Program and the amount of funding contributed to a specific project are based primarily on navigational needs and the elimination of hazards to shipping. Funding is established on an individual project basis and included within the annual Coast Guard Budget, which is subject to the President's review and approval by Congress. The Cities of Portland and South Portland should also be considered as sources of funding. Alternatively, a regional governmental authority could be established which would aid in guaranteeing a bond issue and retiring the debt. It is important that the status of all programs be reviewed periodically, because changes in funds and eligibility requirements frequently occur.

An additional recommendation is that the study by the U. S. Army Corps of Engineers concerning the feasibility of an oil pipeline from the outer to the inner harbor be closely followed. The construction of a pipeline may substantially reduce or eliminate the number of oil tankers which utilize the inner harbor and consequently could lessen the need for a high-level bridge.

REPORT

SECTION 1 GENERAL BACKGROUND - LOCATION STUDY

In the early stages of the study, meetings were held with representatives of the planning departments and with the chief engineers of the Cities of Portland and South Portland. A meeting was also held with members of the South Portland Board of Industry. The U. S. Army Corps of Engineers was contacted to determine whether any recent developments had occurred in their investigations of Portland Harbor.

The planning and renewal directors in South Portland are attempting to define a pattern for the future growth and development of the city related to current land use trends established within local sections of the community. The planning director noted that the construction of a bridge, or a tunnel, at the Ferry Village location would not be compatible with existing or proposed land use in this section, and would in fact have an extremely detrimental effect (see FIGURE 1) on the surrounding residential neighborhood.

The representatives of South Portland indicated that for overall circulation, accessibility, and for commercial activity, the best location for the terminus of a new facility would be in the vicinity of the existing bridge in the Knightville section of the city. This location would best fit the existing and proposed land use and have the least effect on present traffic patterns.

The South Portland Board of Industry provided information from its study of the existing Portland Bridge. The findings indicate that the bridge

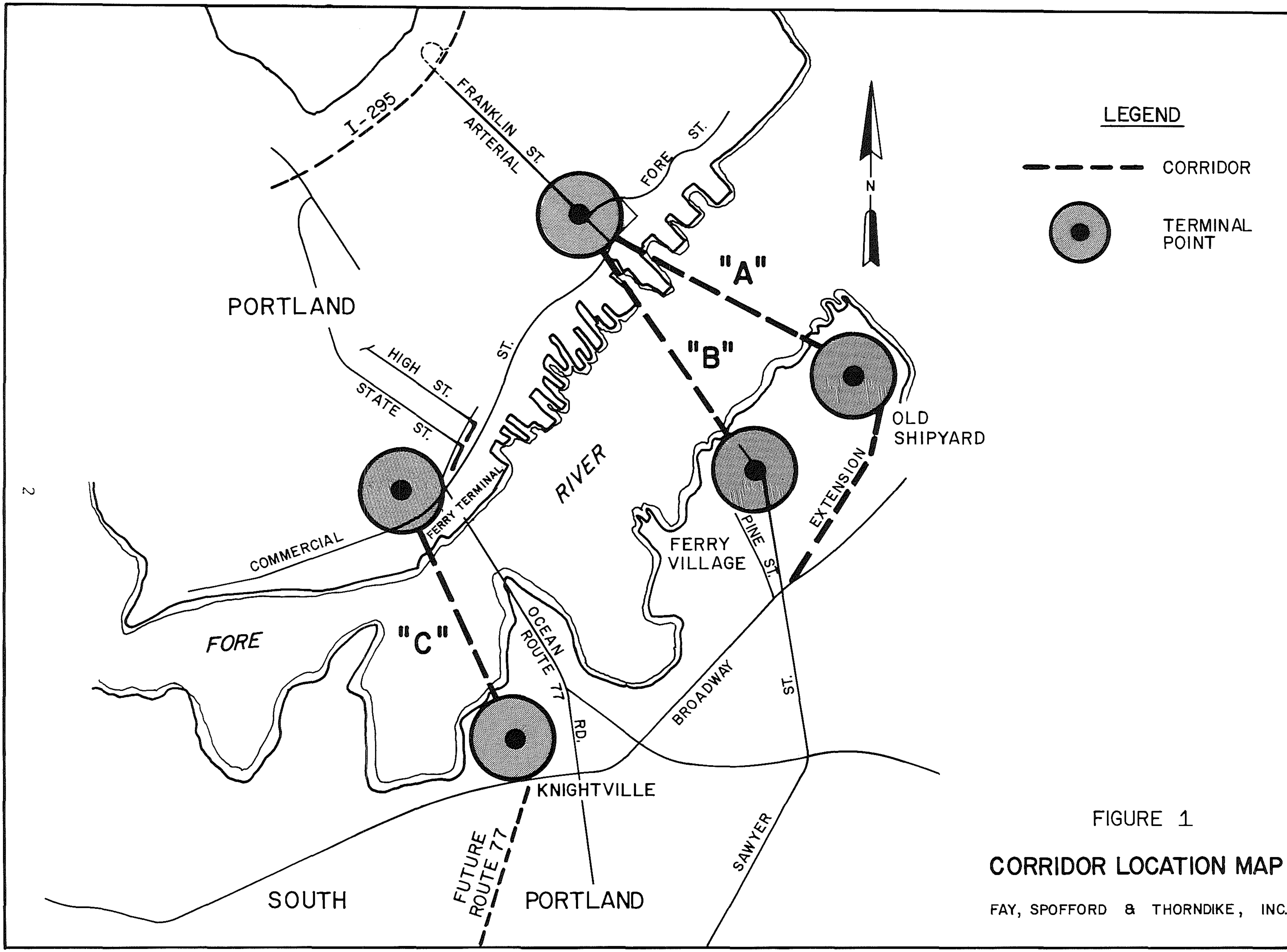


FIGURE 1

CORRIDOR LOCATION MAP

FAY, SPOFFORD & THORNDIKE, INC.

does not serve vehicular traffic well and is also a hazard to navigation. Collisions or malfunctions have caused extensive traffic congestion due to the closing of the bridge for repairs. Each closing results in a detour for approximately 30,000 vehicles daily. The only alternative route is via the Veterans Memorial Bridge, which requires the motorist to travel eight extra miles per round trip. The bridge also serves as the main route for emergency fire and ambulance vehicles, which have been delayed during periods when the draw is in the up position. In addition to vehicular considerations, the narrow opening of the draw creates a difficult navigation problem which has resulted in many collisions, with damages to the bridge structure and to ships. With each collision, there exists a potential pollution problem due to spillage of materials into the harbor.

The South Portland Board of Industry, realizing that the time required for the planning, design, and construction phases is something between five and ten years, has started campaigning for a new high-level bridge or a tunnel. They feel that the need exists now, and a decision should be made in the immediate future.

The Portland Planning Department also has plans for the waterfront extending from the existing Portland Bridge to the Maine State Pier and beyond (see FIGURE 2). Long range plans call for waterfront industry and residential land uses in the area to be serviced by Commercial Street. The Planning Department does not anticipate that Commercial Street would ever be able to handle large volumes of through traffic between the existing bridge and the Franklin Street Arterial destined for Interstate

Route 295. However, direct access between Commercial Street and the new crossing, whether a bridge or a tunnel, would be essential to the development of the area.

A Neighborhood Development Program (NDP) is planned for the area adjacent to the approach of the existing Portland Bridge in Portland. The planning department has already met with representatives of the Maine Department of Transportation concerning the feasibility of modifying the alignment for this approach under the TOPICS program. The proposed changes would make it possible for the city to close off certain streets in the neighborhood and to assemble several attractive parcels for development. The planning department suggests that any alignment for a new bridge should consider and preserve the view of the harbor, reduce the scale of the approach roadways as they pass through the residential neighborhood and provide access to the waterfront and the central business district. It also suggests that an alignment toward State and High Streets with connections to Commercial Street, or an alignment toward the Franklin Street Arterial, would provide good vehicular access to the City. Designs should be integrated with the city's TOPICS program and the master plan for development.

SECTION 2 ALTERNATIVE FACILITIES AND LOCATIONS

2.1 TUNNEL

2.1.1 Alignment

Three basic corridors were studied for possible tunnel alignments (See FIGURE 1 - CORRIDOR LOCATION MAP):

1) Corridor "A", located at the mouth of the Fore River and extending from the Franklin Street Arterial and Fore Street in Portland, through the old shipyard to Broadway in South Portland;

2) Corridor "B", extending from the Franklin Street Arterial in Portland to Sawyer or Pine Streets in Ferry Village on the South Portland side of the harbor; and

3) Corridor "C", extending from Commercial Street in Portland, south of the Ferry Terminal (with ramp connections to State and High Streets), to the Knightville section at Ocean Street or on new location in South Portland.

Corridor A: Line TA-1 (see FIGURE 2) is the most easterly alignment, located at the mouth of the Fore River. In Portland, the approach from Fore Street requires major modifications of the existing street in order to provide terminal connections, local access to abutters and through access to the Franklin Street Arterial. A number of properties are affected. Considering the takings required, the amount of work required

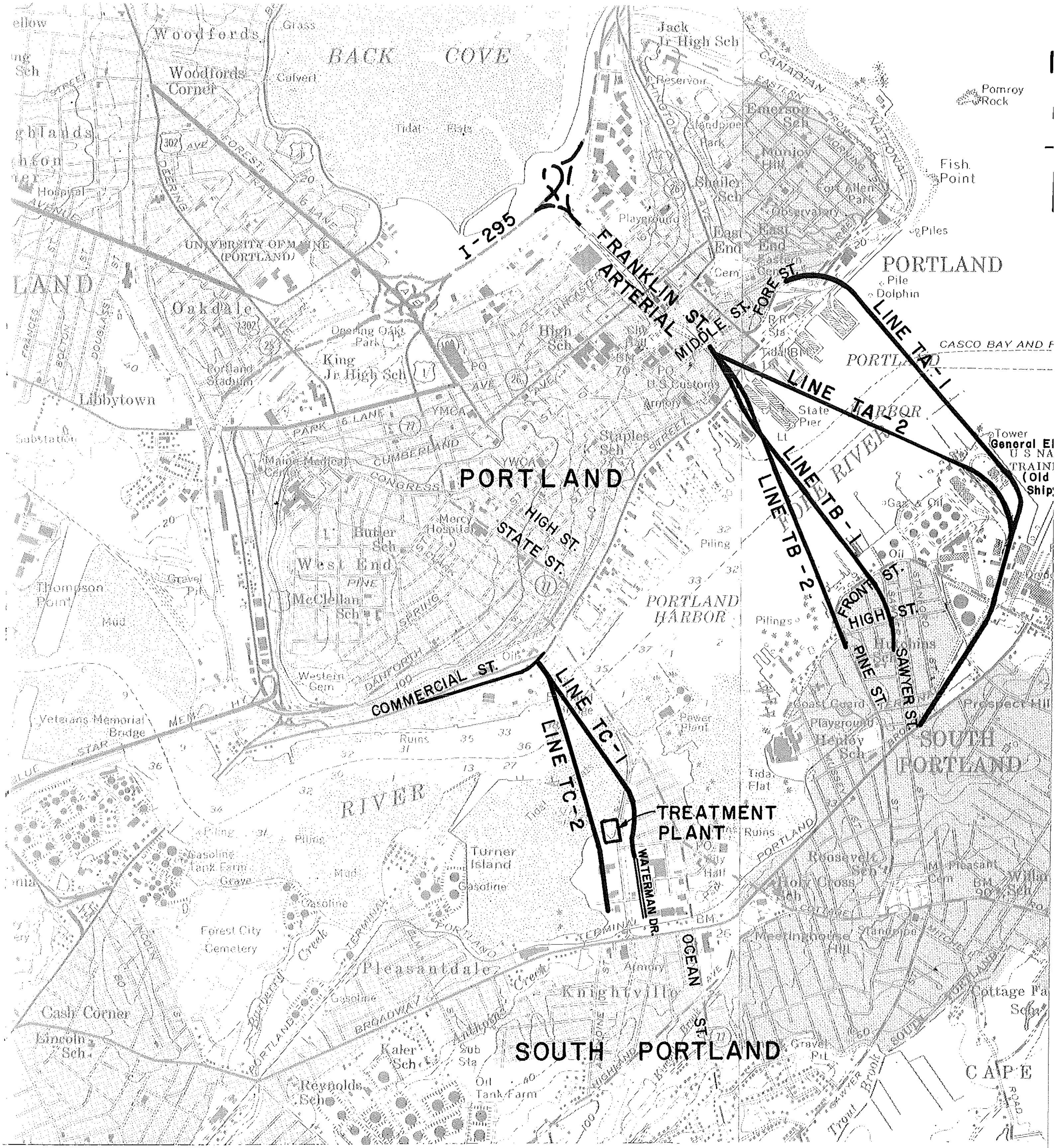


FIGURE 2

LOCATION MAP
TUNNEL STUDY

1000 0 1000 2000 3000

SCALE IN FEET

on Fore Street, and the fact that this line still does not offer a convenient means of getting to and through Portland, this alignment was judged unsatisfactory at an early stage. Line TA-2 has considerable merit in Portland since it provides through access to I-295 and direct local access to Middle Street, Congress Street and Cumberland Avenue. In South Portland, both lines come to grade in the vicinity of the General Electric plant in the old shipyard. A connection is made to Broadway which is of sufficient width to serve as an arterial and provide a connection to Route 77. Most of the property takings in South Portland would be relatively minor for this route. The General Electric plant would be the major obstacle. The connection to Broadway is shown located within the Portland Terminal Railroad right-of-way from the old shipyard to the intersection of Broadway and Sawyer Street.

There are several problems related to these two alignments. They are (1) the tunnel and approach profiles on the Portland side of the harbor require relatively steep gradients of 6.0 percent and 7.0 percent, respectively; (2) the high construction costs due to the tunnel length; and (3) the indirect flow of traffic between major origin and destination points.

Corridor B: Lines TB-1 and TB-2 offer Portland and South Portland better connections to their respective centers of activity. The connection to the Franklin Street Arterial provides the same benefits as Line TA-2, i.e. - access to I-295 and major local streets. In South Portland, the lines follow the existing location of Sawyer and Pine Streets and connect with Broadway. Broadway then serves as the main feeder to Route 77 for those motorists going south.

There are also, however, several disadvantages associated with lines TB-1 and TB-2. In Portland, these two alignments would probably require taking the Randall and McAlister Wharf located on the southerly side of the State Pier. The profiles on the Portland side include gradients of 6.7 per cent and 6.2 per cent, respectively. In South Portland these two alternate alignments pass through a residential neighborhood, discussed earlier. They would also require major widening of Sawyer Street, resulting in land takings, family relocations and demolition.

Corridor C: In Portland, Lines TC-1 and TC-2 have the same point of origin and the same geometrics. The interchange is located to provide direct access to and from the main established north-south routes on the peninsula via High and State Streets. It also provides direct access to Commercial Street in both directions and to local abutters.

In South Portland, Line TC-2 is located on the west side of the proposed sewage treatment plant and behind the existing strip of commercial development fronting on Waterman Drive. An at-grade connection is made at Broadway and is tentatively shown connecting to Route 77 on a new location, as suggested in a study prepared by others for the Department of Transportation. The exact configuration of local access to existing streets has not been detailed at this time. Line TC-1 is directed into the heart of the Knightville section and connects to Ocean Street (Route 77). This alignment calls for major changes of existing street alignments and land use in this area. The possibility of major renewal activity for Knightville is currently under consideration by city officials; tunnel approaches could be coordinated with the rebuilding program.

Lines TC-1 and TC-2 have several advantages over the other lines studied. They provide:

1. Direct connections to the major arteries, i.e., State and High Streets in Portland (Route 77), and Waterman Drive and/or Ocean Street (Route 77) in South Portland;
2. Shortest tunnel route of the three corridors making them the least costly;
3. An acceptable location for both communities, in close proximity to the existing Portland Bridge.

Due to the definite merits of this corridor, more time was spent in developing the interchange requirements than on other lines for cost considerations.

In South Portland, the gradients from the tunnel are 4.5 percent, and in Portland they are 5.8 percent (TC-2) and 6.5 percent (TC-1). The latter gradient matches the profiles of existing State and High Streets. The disadvantage of these lines would be the construction of a tunnel with a curved alignment. Line TC-2 has a degree of curvature of 2° 30' ± and TC-1 a degree of curvature of 4° 00' ±. The latter is especially critical under the sunken tube method of construction.

2.1.2 Structural Elements

Studies were undertaken to determine the best tunnel cross section considering: the anticipated traffic; existing physical constraints; the most feasible methods of construction; and methods of ventilation, lighting and drainage. The sunken tube method of construction, with prefabricated section, was chosen as the most appropriate type for a tunnel of this size and at these locations.

Available soils data indicate that the harbor bottom at the proposed location consists primarily of silty sand about 35 feet thick overlying bedrock, which is between 70 feet and 90 feet below mean low water. With a projected channel depth of 45 feet below mean low water and 3 feet of selected fill over the structure, the top of the tunnel ballast would be at least 48 feet below mean low water for the entire width of the channel (see FIGURE 3).

Two basic tunnel cross sections were considered. Twin circular tubes, each with a diameter of about 38 feet, and a rectangular section, approximately 88 feet wide by 26 feet high, were compared structurally and found to be nearly equal both in construction methods and in cost. Because of the desirability of minimizing profile grades and avoiding the existing rock line, the shallower rectangular section was selected (see FIGURE 4).

The recommended cross section for the tunnel consists of reinforced concrete, enclosed by a welded steel shell which serves both as a waterproof liner for the tunnel and an outside form for the concrete. Two 26-foot roadways with a minimum vertical clearance of 14 feet-6 inches are provided. A patrol walk, a fresh air duct and an exhaust duct are included for each

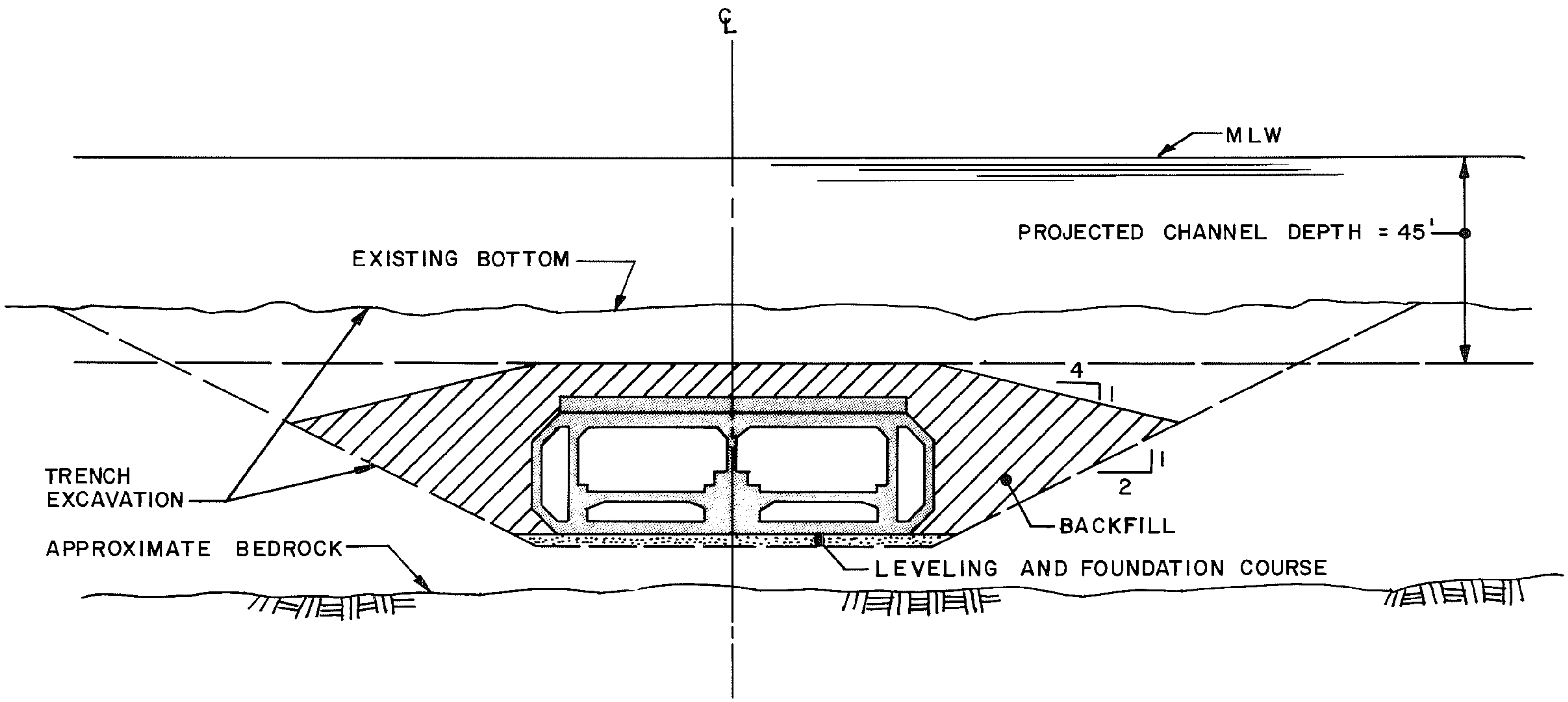


FIGURE 3

PREFABRICATED
SUNKEN TUBE TUNNEL

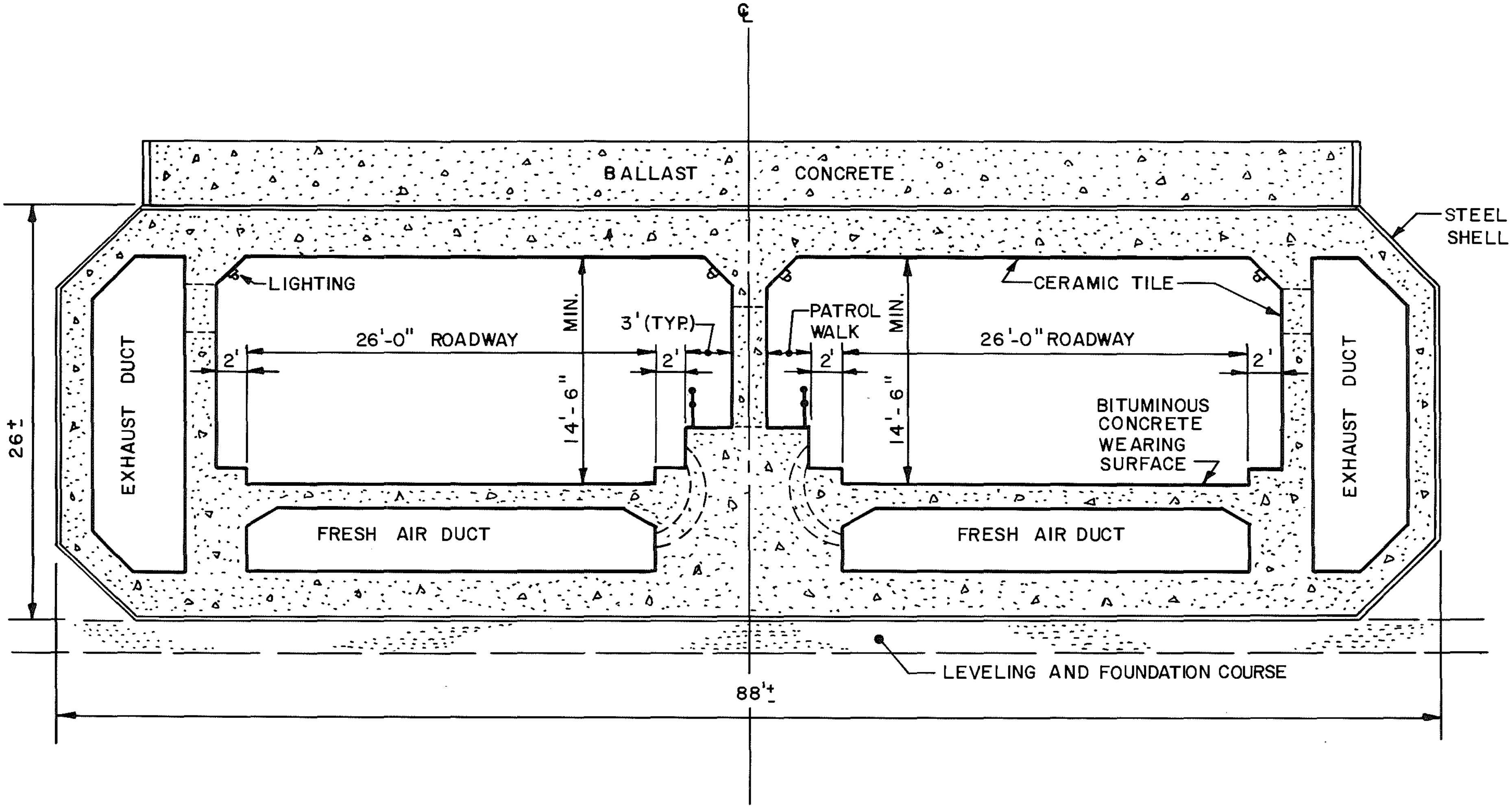


FIGURE 4

TUNNEL SECTION

roadway. The roadway wearing surface is bituminous concrete and the walls and ceilings are faced with ceramic tile.

The suggested method of construction is to: (1) excavate the trench across the river and provide a uniform bed or base course; (2) float into position the tube sections (prefabricated in length of 200 to 300 feet, with the ends closed by temporary bulkheads) and sink them into the prepared trench; (3) position the adjacent sections of the tunnel and complete the connections; and (4) backfill the trench and complete the tunnel interior.

Ventilation requirements are dictated primarily by the need to prevent carbon monoxide in the tunnel from exceeding a safe level. A flow of fresh air must also be maintained to sufficiently dilute other gases and impurities. Ventilation is provided by fresh air blowers and exhaust fans housed in two buildings, one near each portal.

Detailed studies of drainage, lighting, control and communications, and surveillance were not within the scope of this report; however, they are important items which would be considered in further development of the preliminary design.

2.1.3 Construction Costs Estimates

The tunnel studies were developed in sufficient detail to permit a realistic estimate of construction costs. The estimates were limited to the tunnel structures and were based on the lengths between portals for comparative purposes (see TABLE 1). Construction costs for 1977 were derived from 1972 estimates which were adjusted to account for expected increases due to inflation. Available sources indicate that construction costs have been rising at an average annual rate of 10 percent for the past several years. Combining this average with the Engineering News-Record Building Cost and Construction Cost indicies, a factor of approximately 1.6 was established and was used to adjust 1972 prices to reflect 1977 costs.

The costs for the interchanges and approaches in Portland and South Portland were considered but percentage-wise they are insignificant. Right-of-way and other non-construction costs, i. e., engineering, legal, toll facility costs, administrative and financial expenses are not included in the construction costs. These elements are important for the determination of the total project cost and are considered in a later section.

TABLE 1

ESTIMATED TUNNEL CONSTRUCTION COSTS

LINE	LENGTH	1977 COST*
TA-1	4000'	$83,000,000
TA-2	5300'	105,100,000
TB-1	5000'	99,500,000
TB-2	5500'	108,000,000
TC-1	3500'	74,200,000
TC-2	3900'	80,800,000

*Portal to portal only

The costs in TABLE 1 were derived from quantities and unit prices and compare favorably on a linear foot basis with three similar vehicular tunnels, one of which is currently under construction.

2.2 HIGH-LEVEL BRIDGE

2.2.1 Alignment

The same three basic corridors outlined in SECTION 2.1 were studied for possible bridge locations (see FIGURES 1, 2 and 5).

Corridor A: The outermost corridor, Corridor A, was considered undesirable due to difficulties encountered with the basic alignments. A bridge approach to and from Fore Street in Portland (similar to Line TA-1) presented the same basic problems outlined in SECTION 2.1.1, that is, a large number of takings, realignment of the existing street layout, and a poor connection to the Franklin Street Arterial for access to Interstate 295 and the major local streets. Alignment problems such as curvature that would be excessive for a through truss design (discussed in SECTION 2.2.2) and the limited area available for the location of foundation structures made a bridge unfeasible between the Franklin Street Arterial in Portland and the shipyard in South Portland.

Corridor B: Line BB-1 is the same as Line D in the 1970 preliminary report and its location offers the same advantages and disadvantages as tunnel Lines TA-1 and TA-2 described in SECTION 2.1. A second line to Pine Street was not considered desirable due to problems with curved alignment and location of piers similar to those mentioned under Corridor A.

Corridor C: Lines BC-1 and BC-2 are approximately the same as alternative alignments B and C, respectively, presented in the 1970 report.

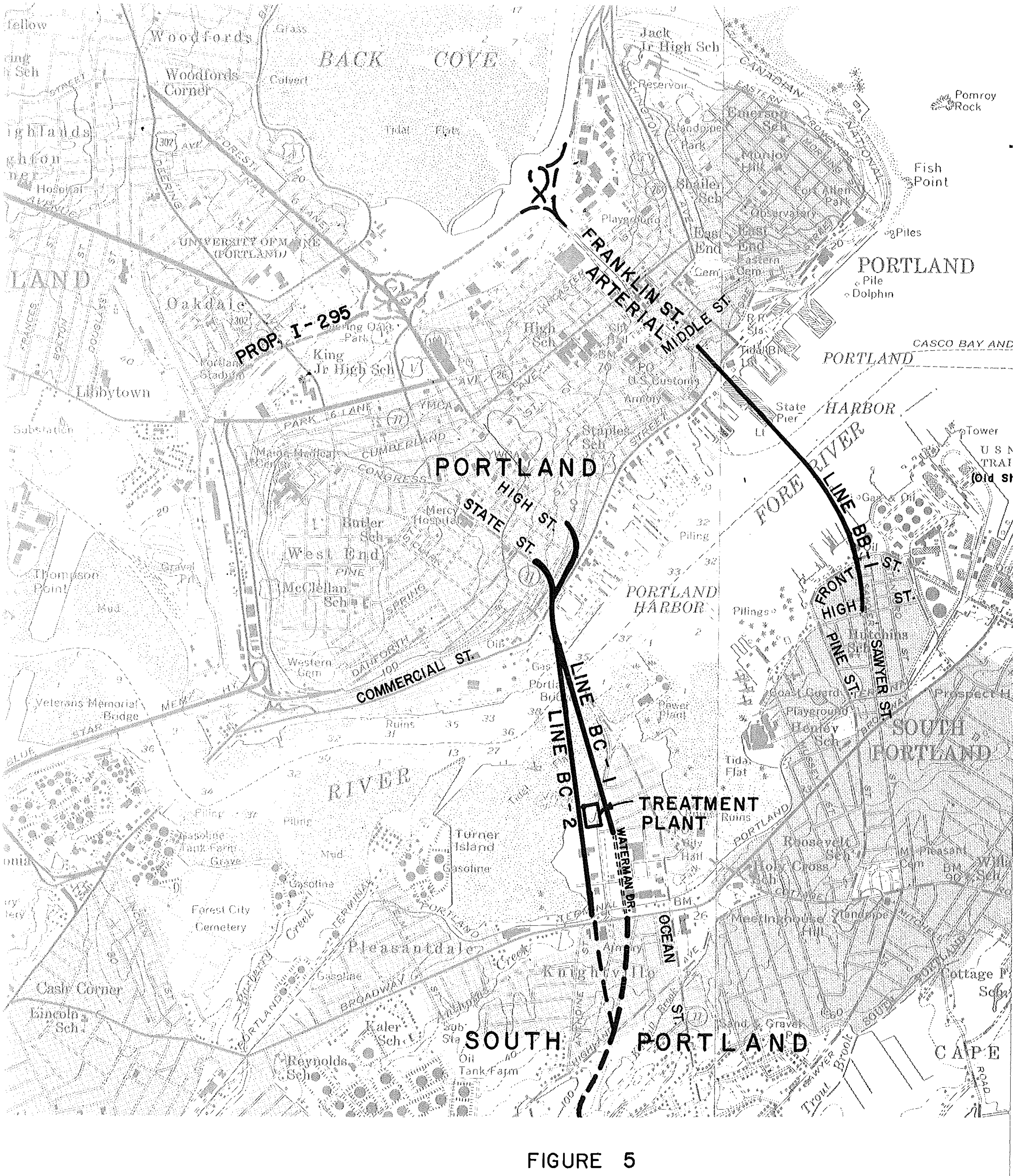


FIGURE 5

LOCATION MAP

HIGH LEVEL BRIDGE STUDY

1000 0 1000 2000 3000

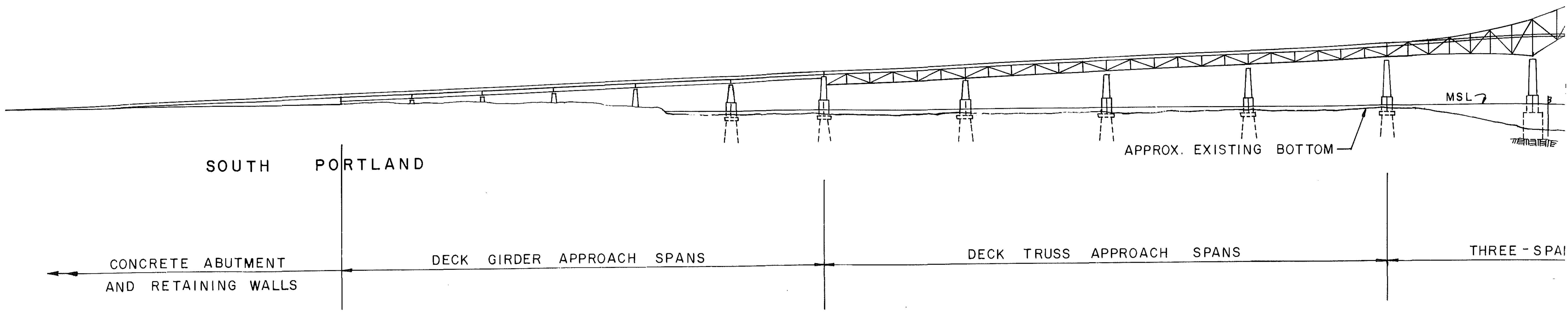
SCALE IN FEET

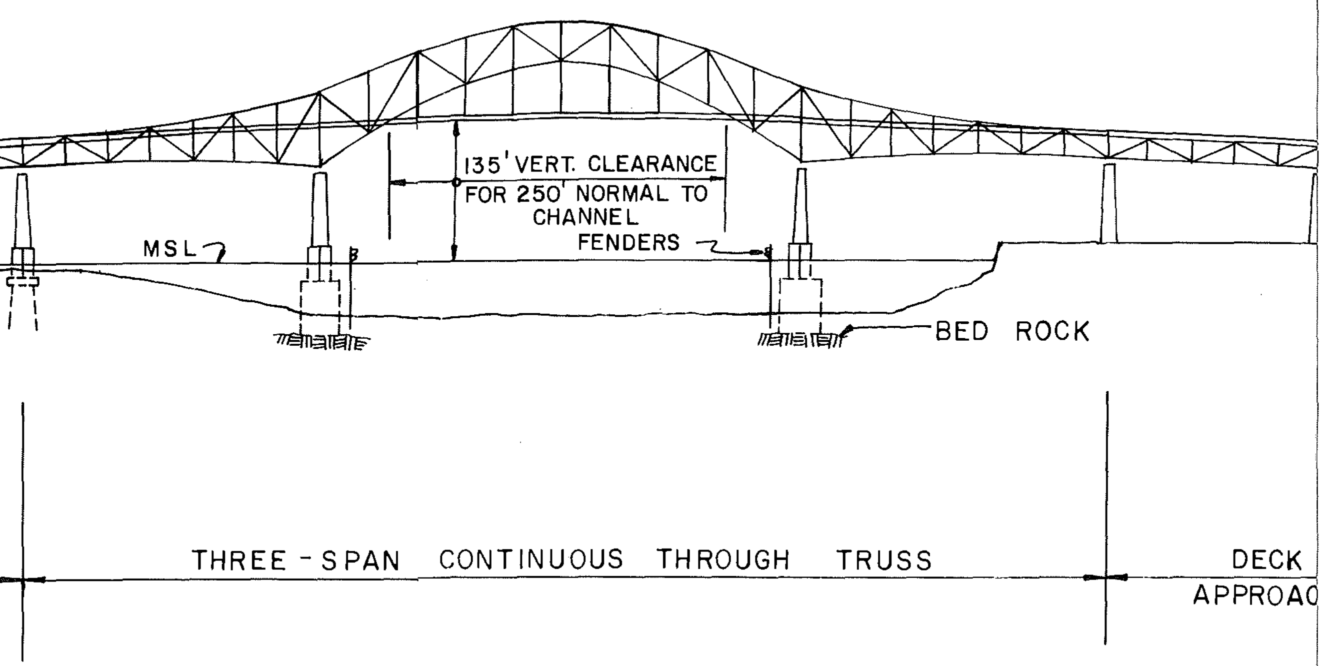
Adjustments were made in the 1970 lines to reflect recent developments and long-range planning of both Portland and South Portland. Line BC-1 terminates at Waterman Drive instead of at Ocean Street (where TC-1 terminates) in the Knightville section of South Portland. This is due to the geometric requirements, in Portland, necessary to avoid the City's neighborhood development program and to provide access to Commercial Street. Consequently, the alignment had to be moved southwest of the locations shown in the earlier study. Utilizing the through-truss bridge design, the main span should be on a tangent, thus limiting the point of touchdown in South Portland to Waterman Drive or a new location as indicated in FIGURE 5.

Lines BC-1 and BC-2 have a different interchange arrangement, in Portland, from the one shown in the 1970 study. Overall, this alignment improves the profiles for both lines.

2.2.2 Structural Elements

A high-level, three-span, continuous, through-truss bridge was investigated for the channel crossing between Portland and South Portland (see FIGURES 6 and 7). The selection of the through-truss design for the channel span allows flatter highway grades to be used while providing required vertical clearances above mean high water. Approach spans are deck trusses or plate girders, depending upon the span lengths. The deep-water piers adjacent to the channel are two-column reinforced concrete founded on bedrock at an approximate elevation of -85. The two-column reinforced concrete piers for the approach spans in shallow water and on land are pile supported.


MSL
APPROX. EXISTING BOTTOM
SOUTH PORTLAND
CONCRETE ABUTMENT
AND RETAINING WALLS
DECK GIRDER APPROACH SPANS
DECK TRUSS APPROACH SPANS
THREE-SPA



135' VERT. CLEARANCE
FOR 250' NORMAL TO
CHANNEL
FENDERS
MSL
BED ROCK
THREE - SPAN CONTINUOUS THROUGH TRUSS
DECK
APPROAC

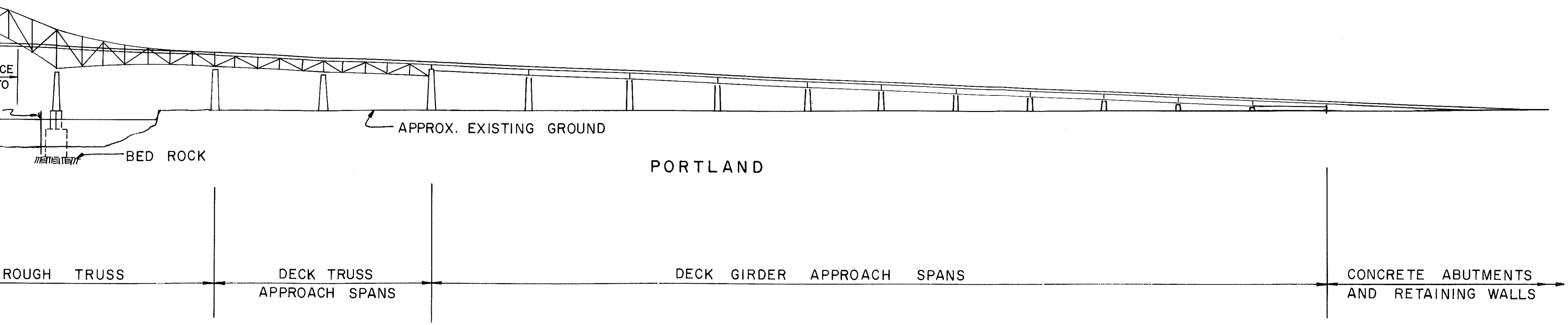
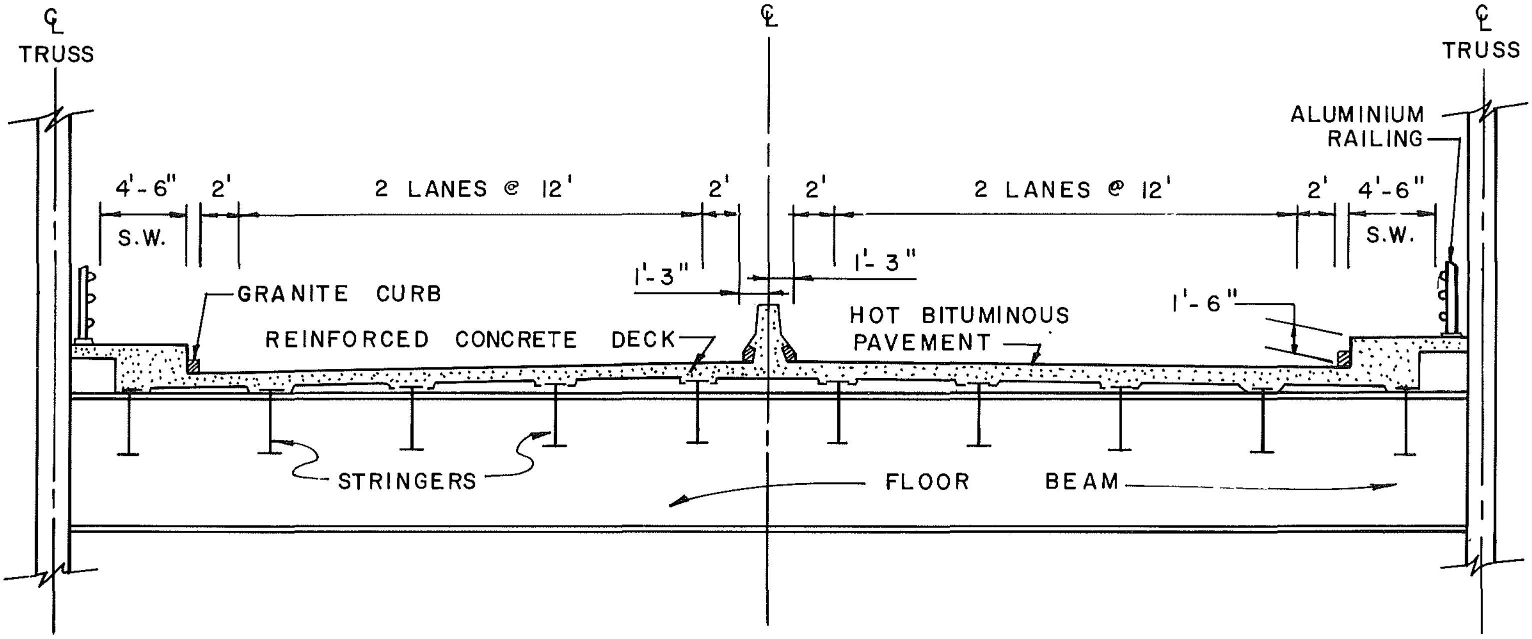
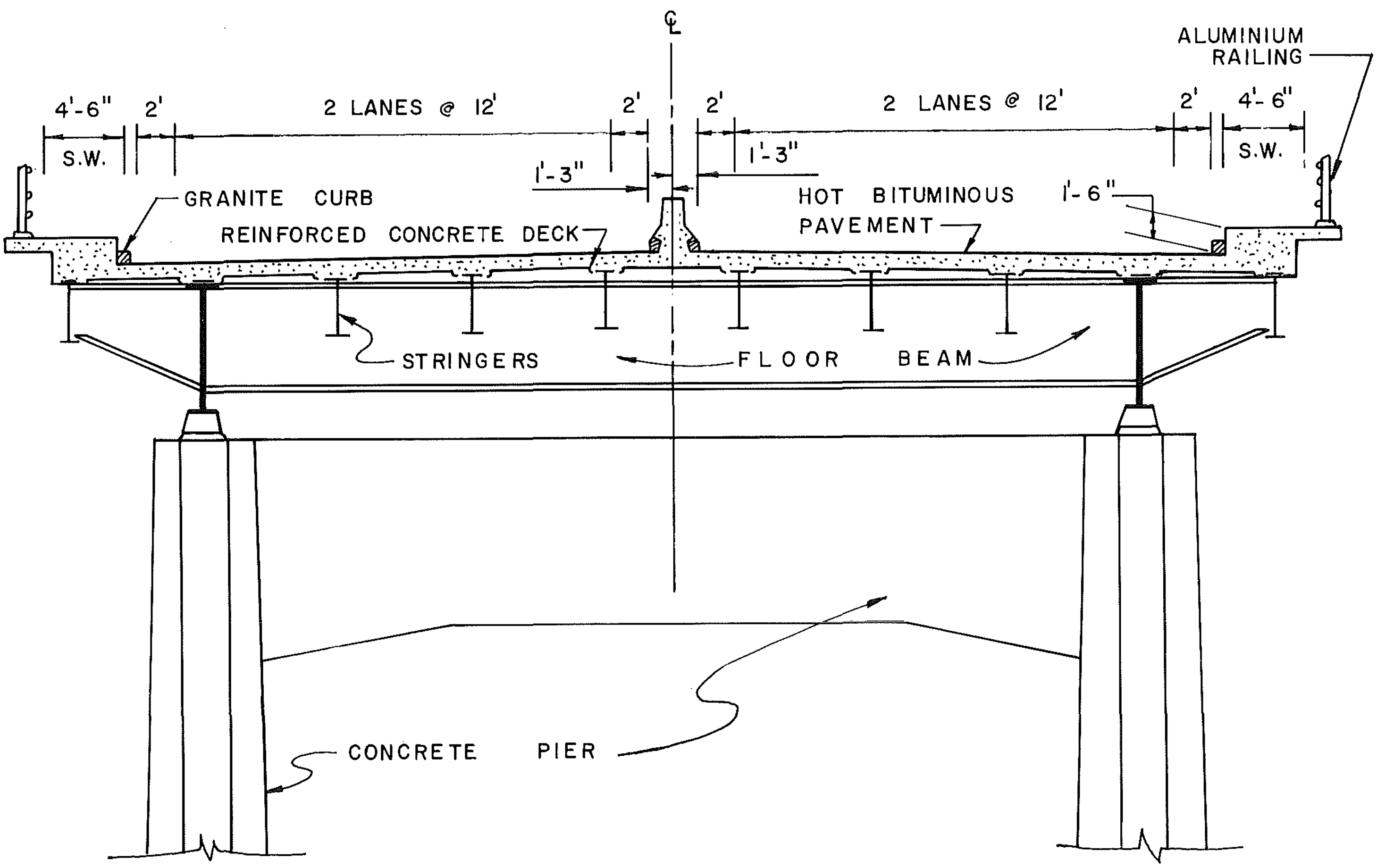


FIGURE 6

HIGH - LEVEL BRIDGE
ELEVATION



THROUGH TRUSS



DECK GIRDER AND DECK TRUSS

FIGURE 7

TYPICAL BRIDGE CROSS SECTIONS

The bridge cross section provides for two 28-foot roadways divided by a median barrier. A sidewalk 4 feet, 6 inches in width is provided on each side of the bridge separated from the roadway by a stepped curb 1 foot, 6 inches high. The bridge provides a minimum vertical clearance of 135 feet above mean high water along a 250-foot section normal to the channel centerline.

2.2.3 Construction Cost Estimates

The 1977 construction costs for the channel spans are nearly identical for all of the locations studied, the variables being foundation costs for different depths to bedrock. Construction costs for the approach spans vary somewhat for the lines studied due to the length of approaches, the different number of spans required, and the varying depth of foundations. The estimated costs are summarized in TABLE 2 below.

TABLE 2

ESTIMATED BRIDGE CONSTRUCTION COSTS

LINE	1977 COST
BB-1	$38,400,000
BC-1	$37,000,000
BC-2	$39,500,000

The estimates of bridge construction costs were derived from quantities and unit prices for the through-truss structure and for the approaches. They include all the structural elements for the bridge and for the interchange connections in Portland to State, High and Commercial Streets. Other surface roadway portions of the interchange were not considered at this stage as they do not affect the comparison of alternative alignments and alternative facilities. Non-construction costs such as right-of-way, engineering, administration, legal, underwriting, miscellaneous and contingencies were also omitted at this stage. All of these cost elements are taken into a account in later sections. The same factor of 1.6, discussed on page 14, was used to adjust 1972 prices to reflect 1977 costs.

SECTION 3 - COMPARISON OF CONSTRUCTION COSTS - TUNNEL VS. BRIDGE

For purposes of comparison, the 1977 construction costs of each alternative alignment and respective type of facility are summarized below in TABLE 3.

It is interesting to note that for each bridge alternative, the construction cost studied is approximately $39 Million; whereas, the construction costs for the tunnel alternatives vary between $74 Million and $108 Million, plus approaches. The tunnel costs range from a minimum of 1.9 to a maximum of 2.9 times the bridge costs.

Other factors must also be considered. Annual maintenance and operating costs are appreciably higher for a tunnel than for a high-level bridge. Experience has shown that the ratio is approximately 2 to 1. Operating costs for tunnels include a staff of guards and maintenance personnel, twenty-four hour operation of ventilation, lighting and drainage systems; and periodic cleaning and replacement of damaged tiles. With a high-level bridge, the primary costs would be for maintenance of the roadway surface, painting and snow removal.

It is evident from the cost comparison in TABLE 3 that the total construction cost of a tunnel would be substantially greater than that of a high-level bridge. In light of this evidence a decision was made at this point by the Maine Department of Transportation to eliminate the tunnel alternative from further investigation. The remainder of the analysis contained in this report will concentrate on a high-level bridge facility located in Corridor C.

TABLE 3

COMPARISON OF 1977 CONSTRUCTION COSTS

CORRIDOR	BRIDGE		TUNNEL	
A	BA-1	-	TA-1	$83,000,000
	BA-2	-	TA-2	$105,100,000
B	BB-1	$38,400,000	TB-1	$99,500,000
	BB-2	-	TB-2	$108,000,000
C	BC-1	$37,000,000	TC-1	$74,200,000
	BC-2	$39,500,000	TC-2	$80,800,000

SECTION 4 TRAFFIC ANALYSIS

Existing traffic volumes and volumes forecast for the future were examined along the established Route 77 (Corridor "C") between Portland and South Portland.

4.1 DEFINITION OF THE BASIC NETWORK

From the travel desire lines of the PACTS study of traffic utilizing the existing Portland Bridge, two points - one on each side of the harbor - were identified as portals through which all traffic crossing the bridge would pass. The South Portland portal was assumed to be located at the Route 77 (Ocean Street)-Broadway intersection and the Portland portal was assumed to be located at the intersection of High Street and Congress Street (FIGURE 8). In this analysis, directional traffic flows were examined to arrive at conclusions concerning total two-way traffic movements. The two directions of flow were assumed to be symmetrical.

Traffic between South Portland and Portland which would utilize the existing bridge or the new facility was assumed to originate at the South Portland portal and terminate at the Portland portal using an assigned Route A. To travel between the same two points, the motorist also has the alternative of using the assigned Route B, via the Veterans Memorial Bridge. Routes A and B were segmented into three and four links, respectively, as shown in FIGURE 8. Some links were composed of more than one parallel route.

For each link thus defined, a travel speed and corresponding travel volume were determined for each level of service (capacity level). They

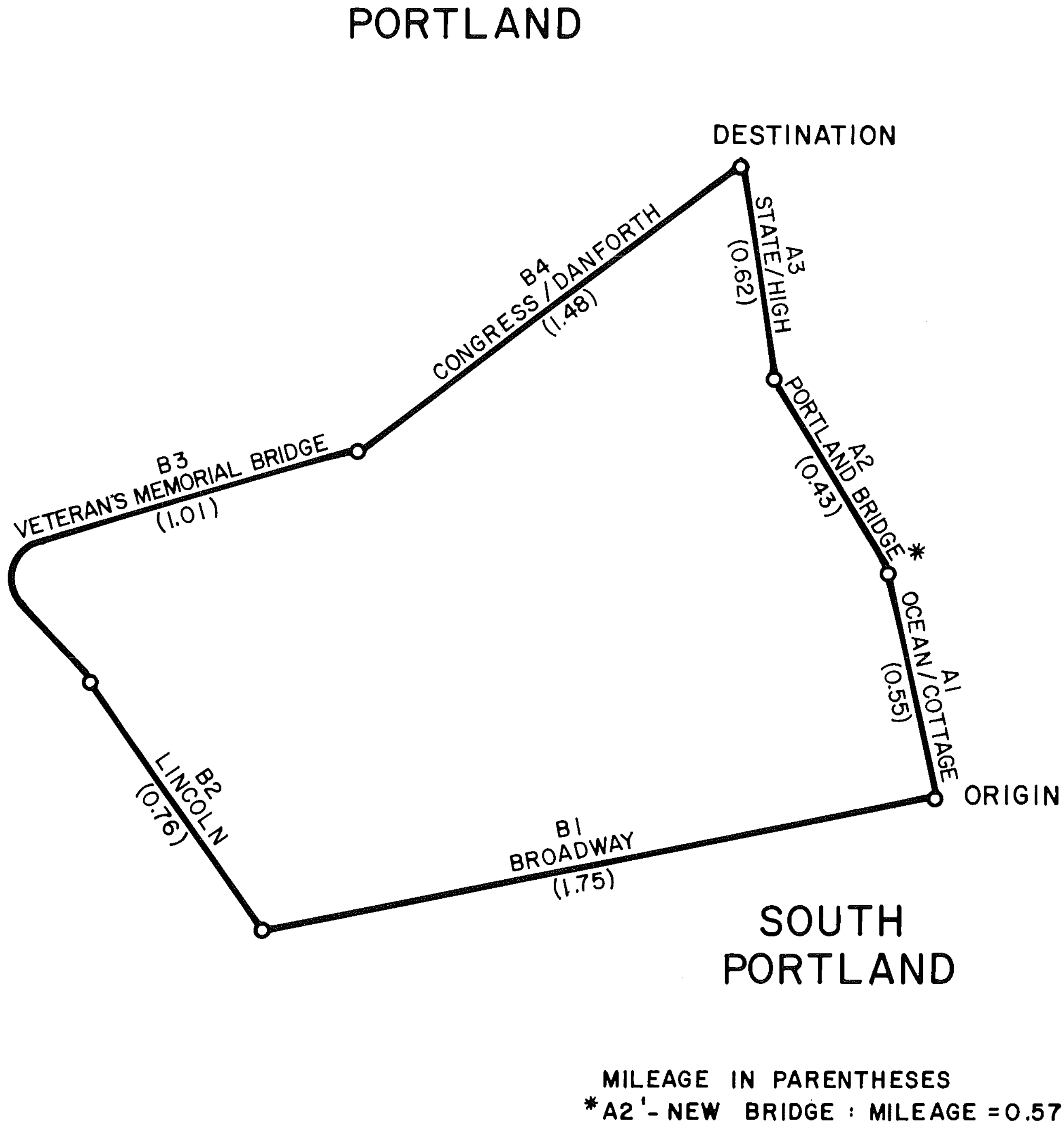


FIGURE 8

BASIC STREET NETWORK

were based on travel speed data from the PACTS reports and on engineering judgment for each level of service. Utilizing the speed-volume data for each link and the link mileages, travel time-volume curves were developed for all links on both routes (FIGURE 9). These curves show the direct impacts of increased traffic volumes or congestion on increased travel times on each link.

4.2 EXISTING AND FUTURE TRAFFIC FLOWS

Historical traffic volumes and forecasts for the specific roadway links of interest were obtained from sources such as the PACTS reports and the State Route 77 Corridor Planning Study. The 1990 traffic forecasts by PACTS, updated in 1970 to include the impacts of changes in land use since 1963 and committed improvements to the roadway network (i.e., Interstate 295) also made since that time, were used to develop traffic volume time-series curves for each link for the time period 1972 to 1992 (FIGURE 10). The implicit assumption behind these straight-line projections is that no unforeseeable physical or economic events will occur in the future to change travel patterns radically.

The estimated total two-way traffic desiring to use the existing or new bridge up to the year 1992 is presented in TABLE 4. The opening date for the new facility was assumed to be 1977. Bridge traffic by the year 1992 is forecast to have increased by almost 30 per cent of its existing (1970) level.

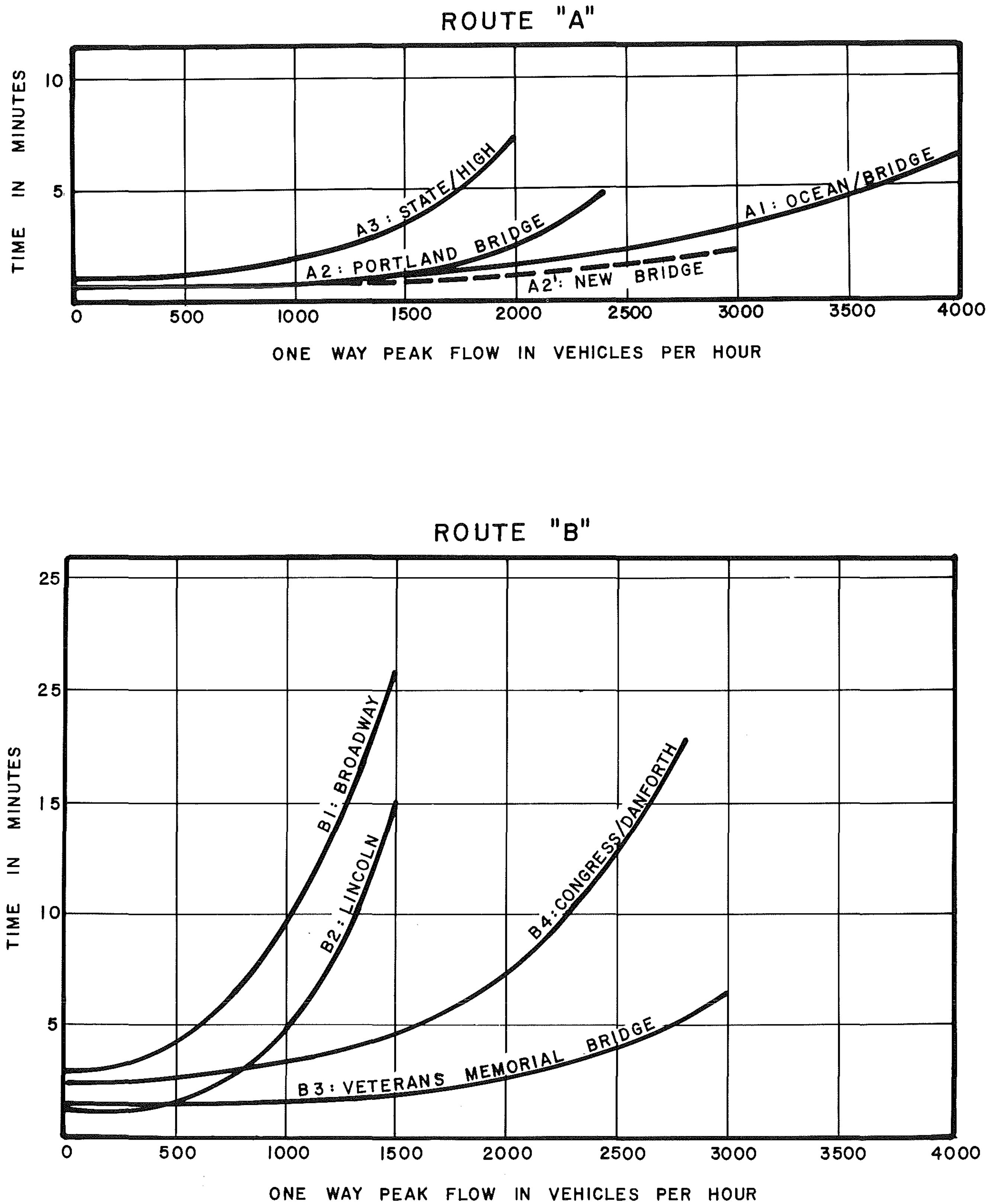


FIGURE 9

TRAVEL TIME - VOLUME RELATIONSHIPS

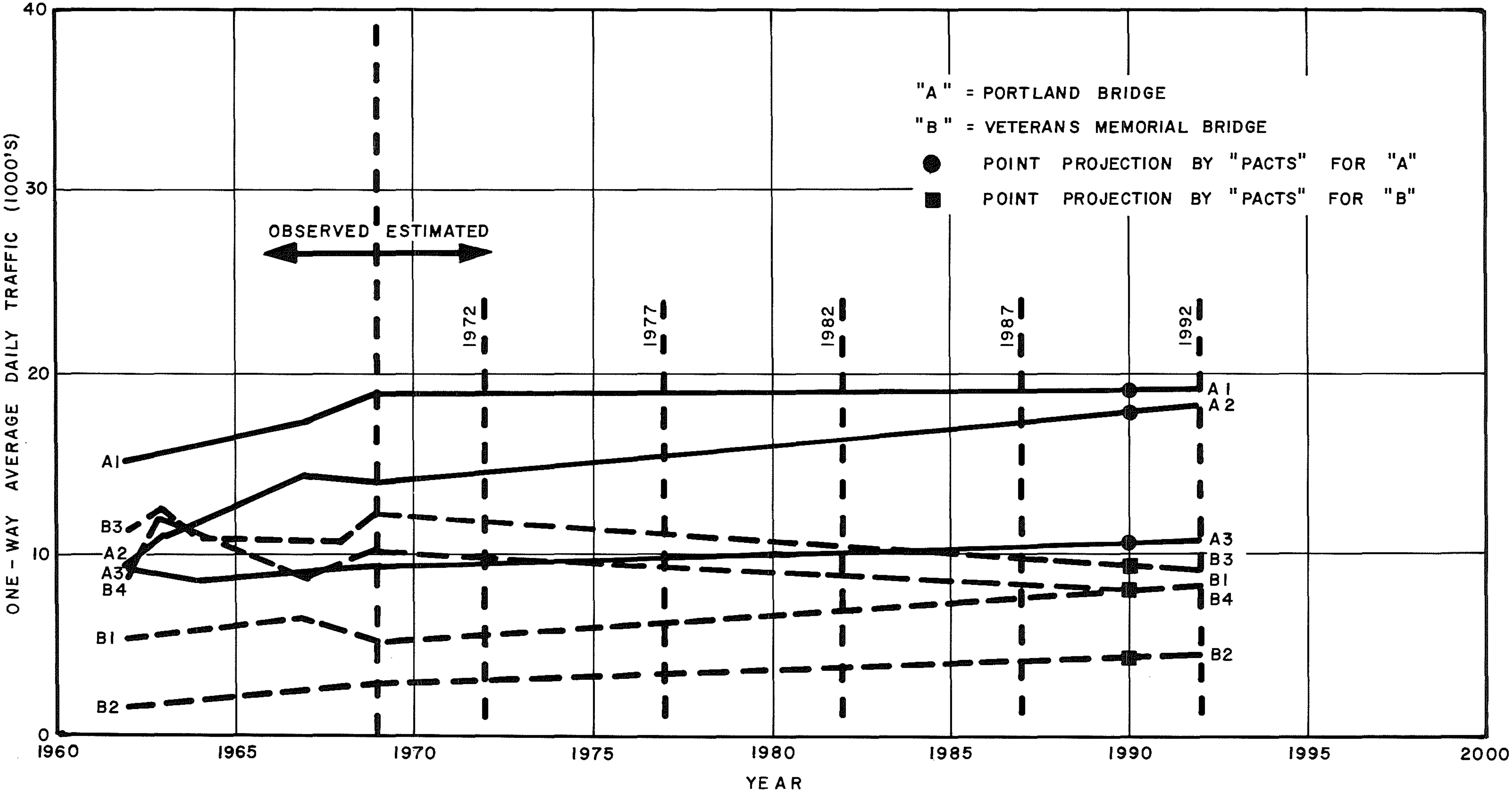


FIGURE 10

TRAFFIC VOLUME FORECASTS BY LINK

TABLE 4

ESTIMATED FUTURE TWO-WAY TRAFFIC VOLUMES CROSSING THE FORE RIVER BETWEEN PORTLAND AND SOUTH PORTLAND

YEAR	ADT (vpd)	% INCREASE FROM 1970
1970	28, 000	-
1977	30, 600	9. 3
1982	32, 500	16. 1
1987	34, 300	22. 5
1992	36, 200	29. 3

Projecting bridge traffic even further into the future at the same rate, approximately 1. 33 per cent per year from its 1970 base, estimated average daily traffic in the year 2027 would be approximately 49, 000 vehicles per day, or 4, 900 vehicles during the peak hour (peak hour traffic is typically 10 per cent of daily traffic). The hourly capacity of the existing four-lane bridge is approximately 4, 800 vehicles per hour (1, 200 per lane). The volume of peak hour traffic desiring to use the existing facility, therefore, will slightly exceed its capacity by the year 2027. The hourly capacity of the new four-lane bridge would be approximately 6, 000 vehicles per hour (1, 500 per lane). The new facility, therefore, would adequately accommodate future traffic for more than 50 years after its opening. In summary, both facilities will generally accommodate estimated traffic volumes far into the future, but the new facility will do so with far less congestion than will the existing facility, as a result of the improved design.

4. 3 TRAFFIC SUMMARY AND CONCLUSIONS

The preceding discussions have attempted to demonstrate the extent to which traffic flowing between South Portland and Portland will continue to utilize the existing Portland Bridge or a new bridge located in the same approximate area. Based on past and existing usage of the Portland Bridge, total traffic on the existing or on the new facility could reach 36,200 vehicles per day by the year 1992, a 29.3 per cent increase from 1970 levels. Either the existing or a new four-lane facility should be adequate to accommodate estimated traffic to the year 2027, although congestion will be much greater on the existing facility in those later years due to its relatively narrow lane widths (by current design standards), and to the tightly curved alignment, limited sight distances and intersecting ramps at the Portland end.

SECTION 5 COST-EFFECTIVENESS ANALYSIS

5.1 USER BENEFITS

5.1.1 General

Basically, two types of congestion costs are incurred by motorists: travel-time costs and costs of vehicle operation. Based on previous research (see Value of Time References) and the socio-economic characteristics of greater Portland (provided by the Portland Planning Department), motorists will value their time spent in travel at approximately $1.50 per hour in 1977, the assumed opening date of a new bridge facility. Operating costs may be either fixed (invariant with distance travelled) or variable (variant with distance travelled). Variable costs include such items as gasoline, oil, tire wear, maintenance and repair, and vehicle depreciation due to wear, and are estimated to equal 10 cents per mile by 1977. Fixed costs include insurance, garaging, parking, and depreciation due to age, and are estimated to equal 6 cents per mile by 1977. (See Automobile Operating Cost Reference.)

The next section will examine the incremental benefits to motorists of replacing the existing bridge with a new bridge between South Portland and Portland. These incremental benefits are travel-time savings which motorists will realize due to increased roadway capacity on the new high-level bridge over that provided on the existing bridge. Narrow lanes and lateral obstructions, which decrease possible capacity, are replaced by wide lanes free from lateral obstructions. The high-level bridge also obviates the need for opening a draw to permit water traffic to pass through the span.

A later section then procedes to analyze motorists' willingness to pay a toll on a new high-level bridge facility. The level of toll is determined based upon the savings in travel time and operating cost mororists should perceive in using the new facility rather than the closest alternative crossing between South Portland and Portland, the Veterans Memorial Bridge.

5.1.2 Actual Savings

Traffic volumes and congestion vary throughout the course of a typical day. In urban areas like Portland, traffic during a single peak hour is often as high as ten per cent of average daily traffic (ADT). During typical off-peak periods, hourly traffic usually averages approximately five per cent of ADT. Total traffic during off-peak periods for urban areas like Portland averages approximately 70 per cent of ADT, leaving 30 per cent during peak periods. Since travel conditions (i.e., congestion conditions) are different during the off-peak and peak travel periods, motorists' travel characteristics were examined separately for each.

On a per-trip basis, travel-time savings on the new bridge over the existing bridge during peak travel periods will amount to only one cent in 1977, increasing to three cents by 1992. No significant travel-time savings will occur during off-peak travel periods from 1977 to 1992. On an annual basis, travel time savings realized by motorists using the new high-level bridge will amount to $34,000 in 1977, increasing to $80,000 in 1992 (based on 1977 conditions). The congestion effects caused by traffic growth were measured by means of the travel time-volume curves in Section 4. These values do not reflect, however, the costs and annoyance to motorists delayed on the existing Portland Bridge when the draw is raised to permit water traffic to pass.

In 1969, 481 openings were recorded for the Portland Bridge by the Maine Department of Transportation. During a six-day period that year, they also determined that the average opening time was 8.2 minutes and the average vehicle delay was 4.8 minutes per vehicle. In recent years, bridge openings have been limited to off-peak travel periods on a voluntary basis.

No other historic data were available for use in making projections of future water traffic – commercial or recreational. Since openings can be controlled, and since past trends were not available, it was assumed that openings would remain approximately constant at 500 annually during the 1977 to 1992 study period. Assuming uniform vehicle arrivals, the yearly delay due to openings of the Portland Bridge was calculated for the 1977 to 1992 period, and is summarized in TABLE 5.

TABLE 5

ANNUAL VEHICLE DELAY DUE TO OPENINGS OF THE PORTLAND BRIDGE, 1977 TO 1992

YEAR	1977	1982	1987	1992
Vehicles Delayed	104,500	111,000	117,000	123,500
% Yearly Traffic	0.9	0.9	0.9	0.9
Hours of Delay	8,360	8,880	9,360	9,880
Cost of Delay (1977 Conditions)	$12,540	$13,320	$14,030	$14,820

Less than one per cent of the annual traffic estimated to utilize the Portland Bridge in the future will be delayed due to openings of the draw. This delay, translated to motorists' time savings via the new bridge, will amount to $12,500 to $14,800 annually from 1977 to 1992 (based on 1977 conditions).

FIGURE 11 shows the net annual time savings (in dollars) which motorists will realize in using the new high-level bridge in place of the existing drawbridge, allowing for both the effects of increased capacity and elimination of bridge openings. The net incremental benefit to motorists will only be $46,500 in 1977, increasing to $94,800 by 1992 (based on 1977 conditions). In 1977, 27 per cent of this net benefit will be due to the elimination of bridge openings, decreasing to only 16 per cent by 1992.

Whether these benefits, along with other considerations (i.e., convenience, interruption of emergency services, and shutdown for repairs), are significant enough to justify replacement of the Portland Bridge by a new facility is explored in more depth in SECTION 6 of this report. The next section examines motorists' willingness to pay a toll to use a new high-level facility in the place of the existing drawbridge. The perceived time and cost savings it offers them over the alternative Veterans Memorial Bridge route is related to the toll which can be charged on the new facility.

5.1.3 Perceived Savings Versus Possible Tolls

Tolls Versus Traffic Diversion

Tolls in an urban context can be viewed as a price paid to avoid

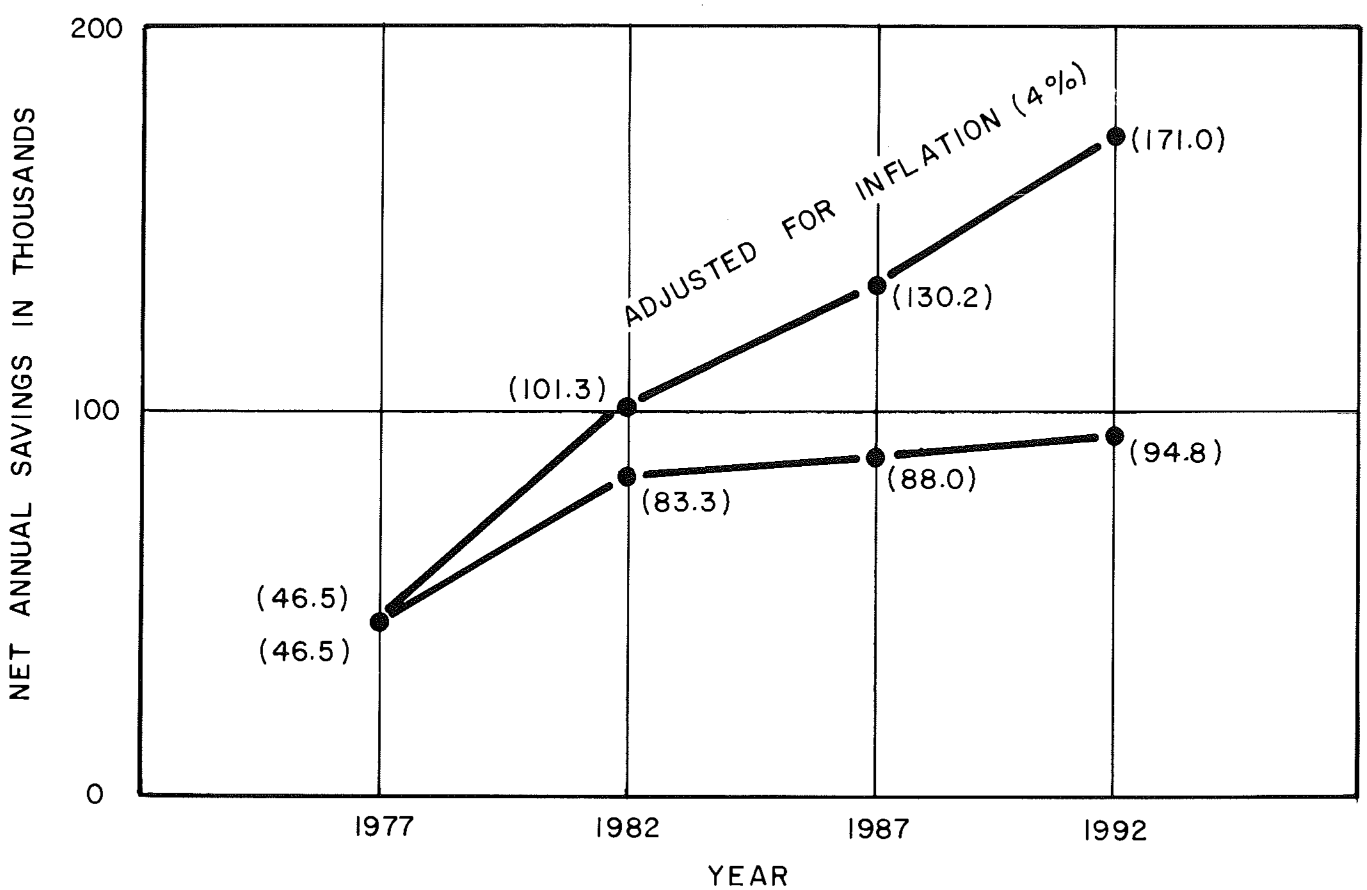


FIGURE 11

NET ANNUAL SAVINGS:
NEW BRIDGE VERSUS PORTLAND BRIDGE
1977 - 1992

congestion. On a toll facility, people are most often paying for a time saving which can be realized over an alternative free facility. If the toll facility shortens the distance travelled, an operating cost saving (gas, oil, etc.) is also realized. Such a distinction can be made between Route A, where travellers' times and distances between South Portland and Portland are shortened by the new bridge at the possible expense of a toll, and Route B, where travellers using the Veterans Memorial Bridge must travel a greater distance, but pay no tolls.

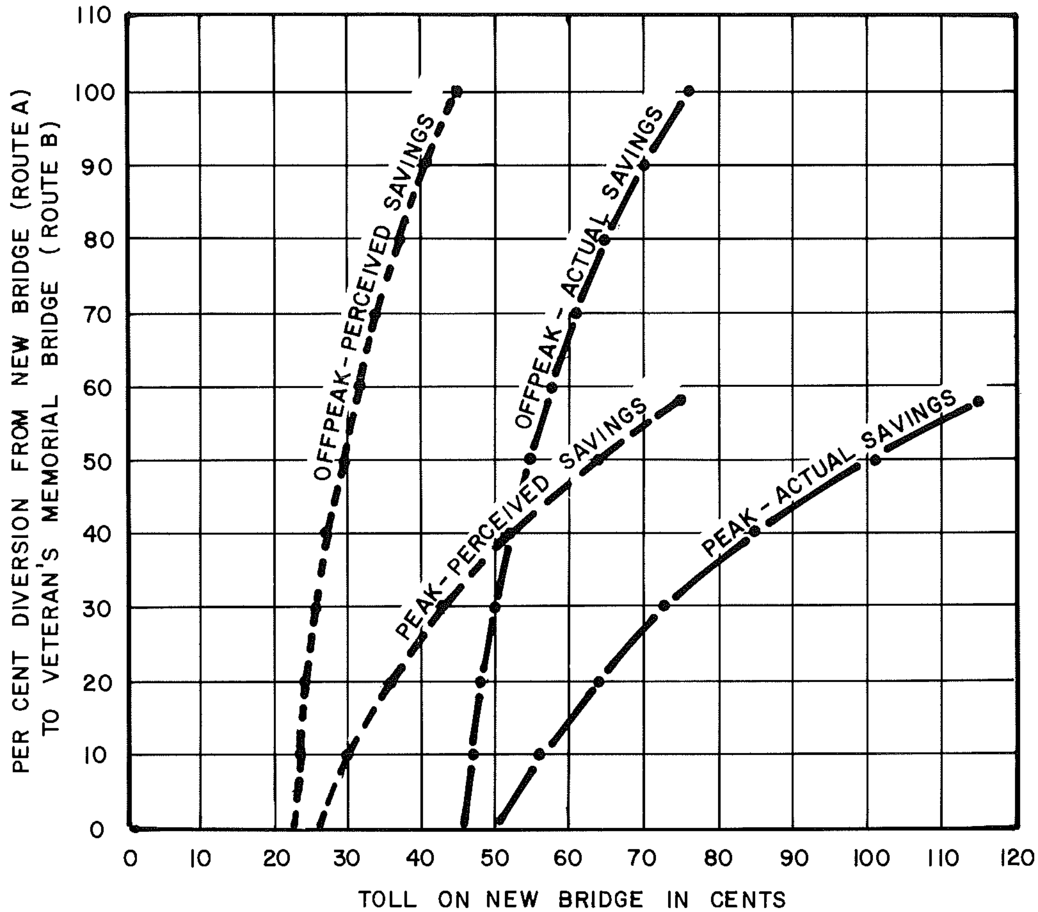
When the toll on a new facility equals or is less than the time and cost savings travellers perceive by its use, negligible diversion of traffic away from this facility will occur, other factors being equal. When the toll exceeds travellers' perceptions of their time and cost savings realized, a noticeable diversion or shift to the alternative route, Route B in this case, will occur. This shift will continue until the increased congestion on Route B due to diverted traffic results in an increase in perceived total trip costs on Route B to a level equal to the toll on Route A. The system is then again in equilibrium. For this study, it was assumed that motorists would perceive on the average approximately 75 per cent of their time costs and 40 per cent of their variable operating costs based on the following justifications.

With regard to travel time savings, most people do not usually measure time differences exactly. Time differences are usually perceived in general terms, such as five minutes, ten minutes, etc. The time differentials in this study for 1977 varied between five minutes with no diversion during the off-peak hours to 33 minutes with 58 per cent diversion during the peak hours. Assuming that the smallest round unit of time measure in this case is five minutes with a maximum variance, therefore, of plus or minus 2.5 minutes, motorists on the average can be assumed to perceive 50 per cent (2.5/5) to 107 per cent (35.5/33) of their actual time savings. The approximate half-way mark, 75 per cent, was chosen as representative of all conditions.

The justification for the operating cost percentage (40 per cent) is that the average motorist at least perceives his out-of-pocket costs of vehicle operation, namely, gasoline and oil purchases. From a previous study (see first Automobile Operating Cost Reference) performed by the Bureau of Public Roads, this amounts to approximately 40 per cent of the variable costs of vehicle operation.

A diversion curve or "route choice indifference curve" is often used to depict traffic diverted to a free route from a toll route for given levels of tolls. The curve represents the boundary conditions where travel costs on both routes are equal and the motorist, therefore, would be indifferent in his choice of route on the basis of cost.

FIGURE 12 illustrates diversion curves developed for travel during peak and off-peak periods between South Portland and Portland in 1977, based on motorists' perceptions of 75 per cent of their travel time savings and 40 per cent of their operating cost savings. Also shown are hypothetical diversion curves based on actual motorist savings, or the diversion which would occur if motorists perceived fully (100 per cent)



NOTE: IN REALITY, THERE WILL BE SOME TRAVELLERS WHO WILL NEVER USE THE BRIDGE AS LONG AS A TOLL IS CHARGED, NO MATTER HOW LOW IT MAY BE. CONVERSELY, THERE WILL BE SOME TRAVELLERS WHO WILL PAY ALMOST ANY TOLL TO USE IT. (HENCE THE COMMONLY SEEN S-SHAPED CURVES FOR ROUTE CHOICE OR MODE CHOICE.) THESE SEGMENTS OF THE TRAVEL POPULATION ARE ASSUMED TO BE SMALL HERE, AND THE ANALYSIS PROCEEDS IN TERMS OF HOW THE AVERAGE TRAVELLER WOULD BEHAVE IN A TOLL SITUATION.

FIGURE 12

DIVERSION OF TRAFFIC FROM NEW BRIDGE AS A FUNCTION OF TOLLS CHARGED - 1977

their time and cost savings. Both peak diversion curves – perceived savings and actual savings – were calculated only to the level of 58 per cent traffic diversion from Route A to Route B. Above this level, traffic diverted to Route B would cause link B1, Broadway in South Portland (FIGURE 8), to operate at capacity. An attempt to measure time delays exactly when volume equals or exceeds capacity on a link is difficult and the results would be questionable. Therefore, it is sufficient to realize that increased volumes of diverted traffic above any link capacity on Route B will result in more than proportional increases in congestion and delays on that route.

The base year, 1977, was selected as the analysis year because the toll charged at the opening of a new facility will probably remain fixed for some period to follow. The analysis should, therefore, reflect motorists' willingness to pay the toll during the early years of operation when congestion on the alternative free route has not yet reached a critical point and the toll facility is not as attractive as it ultimately would be.

The general conclusion drawn from the perceived savings curves is that traffic diversion is extremely sensitive to tolls during off-peak travel conditions. A slight increase in tolls will result in an appreciable decrease in usage of the toll facility. During peak travel conditions, the heavy utilization of Route B by local traffic causes the congestion on that route due to diverted traffic to increase at a greater rate than during the off-peak periods. This makes Route A more attractive and its traffic diversion less sensitive to tolls during peak travel periods.

It is politically and operationally impractical to use one toll rate during off-peak travel conditions and another toll during peak travel conditions. Because approximately 70 per cent of the traffic occurs during off-peak conditions, the toll charges should reflect travellers' willingness to pay during the predominant off-peak travel periods.

For maximum patronage of the new bridge, the base toll in 1977 should be 23 cents or less to minimize traffic diversion. A 25 cent toll would divert an estimated 25 per cent of off-peak traffic. A 30 cent toll would divert approximately 10 per cent of peak traffic and 50 per cent of off-peak traffic. A 45 cent toll would divert more than 30 per cent of peak traffic and practically all of the off-peak traffic. A desirable toll, therefore, based on willingness to pay, appears to be 20 cents. However, the next section demonstrates that the most desirable toll based on willingness to pay will result in maximum patronage, but will not provide maximum revenue.

Tolls Versus Revenues

The revenue obtained from a toll facility is a function of both the toll charged and the traffic volumes on the facility. It is not necessarily true that a policy of charging a toll which will result in no traffic diversion will also yield the maximum revenue. This section explores the relationships between tolls, volumes, and revenues.

As FIGURE 13 indicates, the maximum revenue for 1977 traffic conditions will be realized if a 25 cent toll is charged, even though 25 per cent of traffic will be diverted from the new bridge during off-peak travel

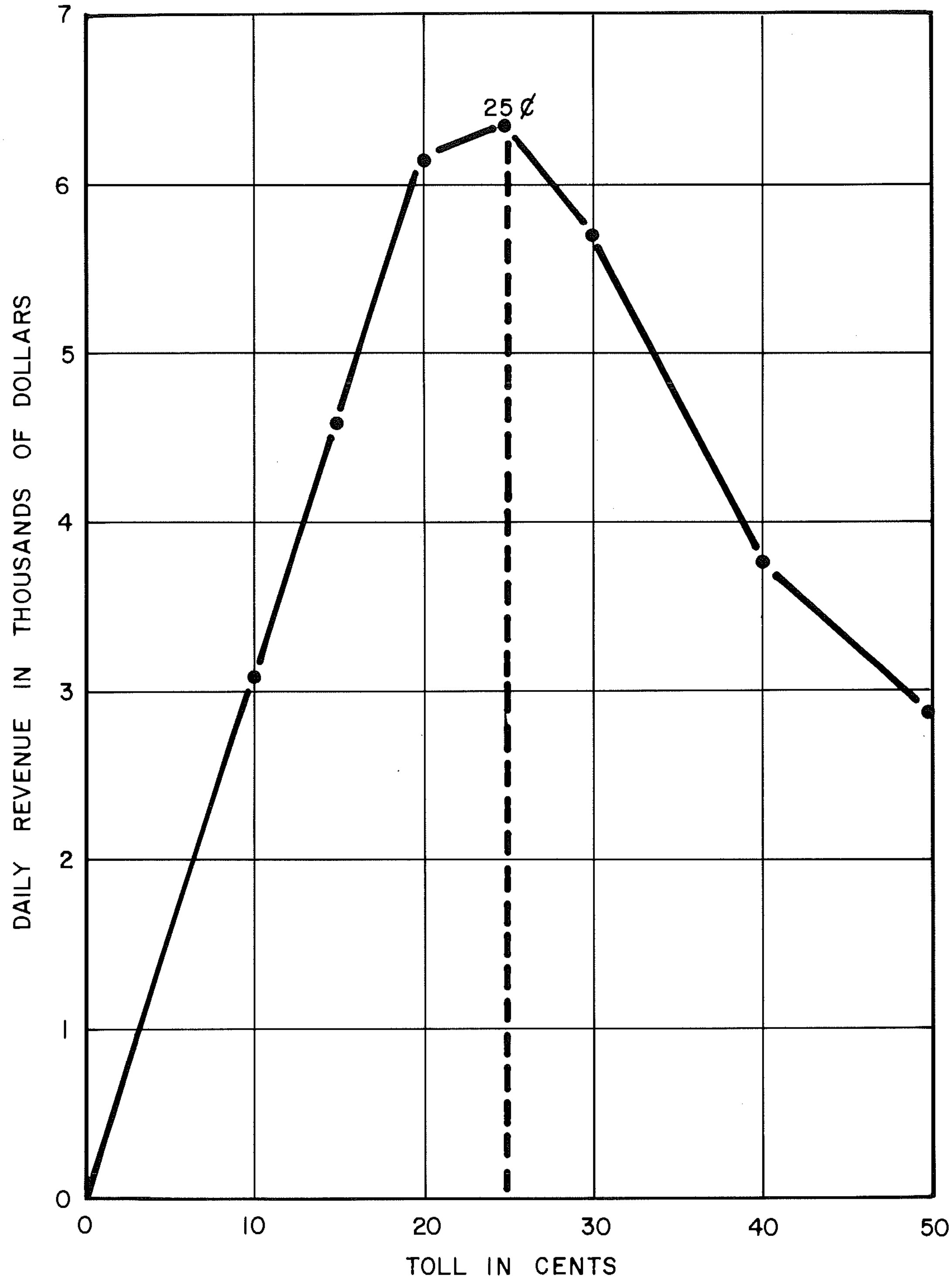


FIGURE 13

DAILY REVENUES ACHIEVED UNDER ALTERTIVE TOLL PRICING POLICIES - 1977 periods. The actual, and therefore the the perceived time and cost savings of motorists using the new bridge will increase from 1977 to 1992. This is due to the fact that the increase in traffic congestion in the future on Route B will be in greater-than-direct proportion to that on Route A. Motorists will, therefore, be willing to pay more to use the new bridge. Off-peak traffic diversion for a 25 cent toll will decrease from 25 per cent in 1977 to approximately 10 to 15 per cent by 1992.

5.1.4 Summary of User Benefits and Conclusions

The net incremental benefit to motorists of replacing the Portland Bridge by the new bridge (in terms of time savings) will amount to $46,500 in 1977, increasing to $94,800 by 1992 (based on 1977 conditions). In 1977, only 27 per cent of this net benefit will be due to the elimination of bridge openings; this percentage will decrease to 16 per cent by 1992. The greater share of total motorist time savings results from the increased capacity and higher level of service which will accompany the improved design.

If a new high-level bridge facility is implemented, careful consideration should be given to the issue of whether tolls should be charged, and if so, what the toll rate should be at the outset (1977). Since a differential toll pricing policy — one toll during off-peak travel conditions and a different toll during peak travel conditions — is infeasible, the single level of toll chosen should reflect the least attractive condition on the new facility, that is, off-peak travel periods when congestion on the alternative free route will be minimal.

Maximum traffic flows (i. e., no appreciable diversion) will occur on the new bridge as long as no toll, or a toll no greater than 20 cents, is charged at the outset. To maximize revenue, a 25 cent toll should be charged at the outset, even though daily usage would be decreased by 17 per cent.

A general conclusion, therefore, is that if a toll pricing policy on the new bridge is considered desireable, the level of toll which could be imposed on the motorists should not exceed 20 to 25 cents in the base year (1977), so that maximum bridge utilization and revenue from the tolls will be achieved. Even though differential toll pricing is not practical or desireable, practices such as special rates for commuters should be considered further if they would result in increased patronage and toll revenues.

5.2 FACILITY COSTS

5.2.1 General

Construction costs for the bridge were derived from estimated quantities and units prices as outlined earlier (SECTION 2), and were updated to reflect 1977 prices. Structural costs for bridge approaches, have also been calculated using estimated quantities and unit prices.

Other elements of the total project cost include contingencies, engineering services, right-of-way acquisition and reconstruction of local streets, legal and administrative fees, and underwriting charges for a bond issue.

Maintenance costs for the bridge were derived from a comparative analysis of known costs on similar facilities. Operational costs for toll facilities were determined in a similar fashion. The costs for maintenance and operation were established for the base year 1977 and forecast over a period of forty years. The procedure followed used factors reflecting actual increases in the amount of maintenance and operational costs and also accounted for the effect of inflation.

5.2.2 Project Costs

The total project costs for the proposed facility have been determined according to standard procedures which are outlined in Manual 45 of the American Society of Civil Engineers. These procedures provide a basis for estimating actual costs from the estimated construction cost.

The Manual shows that the associated costs, i.e., non-construction and financial costs, can increase the total cost of a project by as much as 30 to 45 percent.

In order to compensate for the absence of contract drawings and specifications from which a detailed estimate could be made, an allowance for contingencies is added to the preliminary engineer's estimate. These contingencies provide funds for unanticipated construction expenses due to an increase in quantities, unavailability of materials, larger equipment, or other items which could increase the construction cost. In this particular case, information on existing foundation conditions is limited and unforeseen problems could result in increased costs.

In addition to contingencies, provisions should be made for engineering design (basic and special), legal, administrative, right-of-way, and underwriting expenses. Basic engineering charges include the costs for services related to the design of the project, while special services may include such costs as the preparation of supporting documents to be filed with regulatory agencies, field surveys including preparation of plans showing existing detail, and resident engineering and inspection. Legal, administrative, and underwriting costs are relatively self-descriptive. Right-of-way costs may include land acquisition, relocation of families and businesses, and the reconstruction of local streets.

The actual breakdown and percentages used in determining the total project cost are summarized in TABLE 6. Short-term interest costs

TABLE 6

ESTIMATED TOTAL PROJECT COSTS (HIGH-LEVEL BRIDGE)

CONSTRUCTION COSTS:	1972	1977
Portland Approaches		
Substructure	$1,455,000	$2,327,000
Superstructure	5,667,000	9,124,000
Main Span (Three-Span Continuous Through Truss)		
Substructure	3,473,000	5,592,000
Superstructure	4,103,000	6,606,000
South Portland Approach		
Substructure	2,045,000	3,293,000
Superstructure	6,642,000	10,694,000
Subtotal	$23,375,000	$37,636,000
Miscellaneous 5 percent (Includes demolition of existing bridge)	1,169,000	1,882,000
Subtotal	$24,544,000	$39,518,000
NON-CONSTRUCTION COSTS:		
Contingencies (10 percent)	-	3,952,000
Right-of-Way and Reconstruction of Local Streets (3 percent)	-	1,186,000
Engineering		
Basic (6.5 percent)	-	2,569,000
Special (6.5 percent)	-	2,569,000
Legal and Administrative (9 percent)	-	790,000
Subtotal	-	$11,066,000
PROJECT COSTS:		
Underwriting (1 percent)	-	395,000
TOTAL COST		$50,979,000

during construction of the facility have not been specifically included under financial costs in the breakdown of total project costs, but instead appear in the annual bond cost of the various programs studied (see FIGURES 20, 21, and 22 in SECTION 6.3.3).

5.2.3 Operating and Maintenance Costs

High-Level Bridge

Curves representing the operational and maintenance costs of the proposed bridge facility have been developed, assuming the collection of tolls, and are shown in FIGURE 14. These curves can be used to determine the cost components for a given year. The operating costs of a non-toll facility, however, will be approximately $300,000 a year less than that of toll facility. This difference is due primarily to the administration and personnel costs, and the maintenance of electrical toll equipment.

The initial 1977 operating and maintenance costs were determined from a cost analysis of similar bridge facilities. Available data was extrapolated and estimates were made of the probable expenses which would likely be incurred in the initial years. Having determined a reasonable starting base, future costs were then forecast assuming a constant annual increase in the amount of additional expenses to be incurred yearly.
The actual amount of these costs has been based on an annual increase of 4 percent above the base year which reflects actual increases necessary

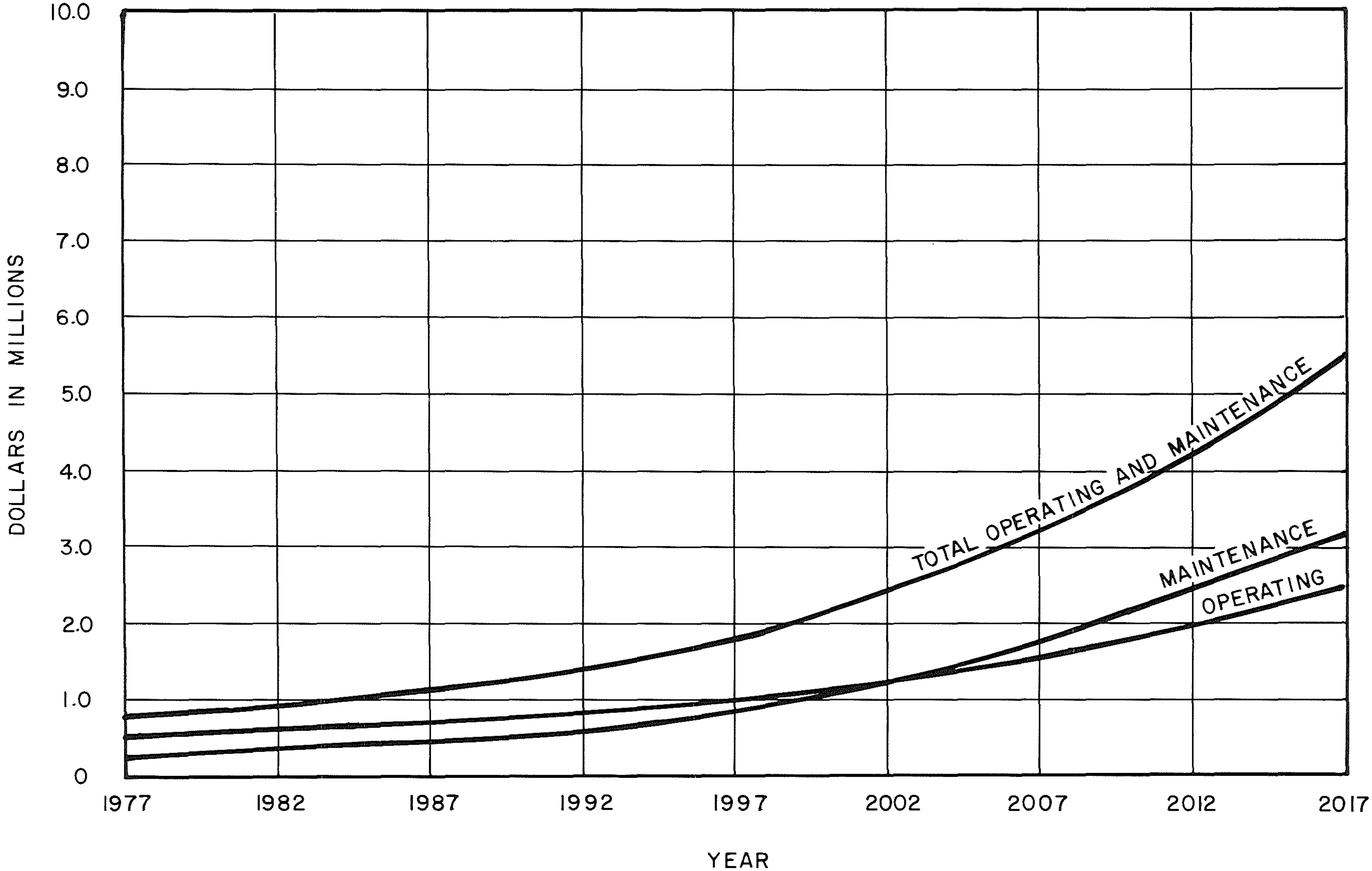


FIGURE 14

OPERATING & MAINTENANCE COSTS ON HIGH-LEVEL BRIDGE to maintain the facility in a proper manner. This incremental increase is based upon empirical evidence available from previous costs of existing facilities and from future projections. An important assumption, however, concerning a constant 4 percent annual increase relative to the base year, is that a continuous conscientious program of maintenance will be implemented and maintained.

In essense, this means that if maintenance is performed annually and the facility is not neglected, the actual costs should increase at this approximate rate. As an example of a continuous maintenance program, painting would be done annually by sections such that the painting process would be continued in small amounts and consequently not mushroom into a large capital expense in any particular year.

In addition to the actual increases in the costs, the effect of inflation has been taken into account. An annual inflation rate of 4 percent has been assumed and it is the influence of inflation which causes the increasing slope of the cost curves.

High-Level Bridge Versus Portland Bridge

In order to obtain the proper perspective concerning the comparison of costs between the existing bridge and the proposed high-level bridge, it is necessary to investigate the incremental cost differences. FIGURE 15 summarizes the forecasted annual operating and maintenance costs for

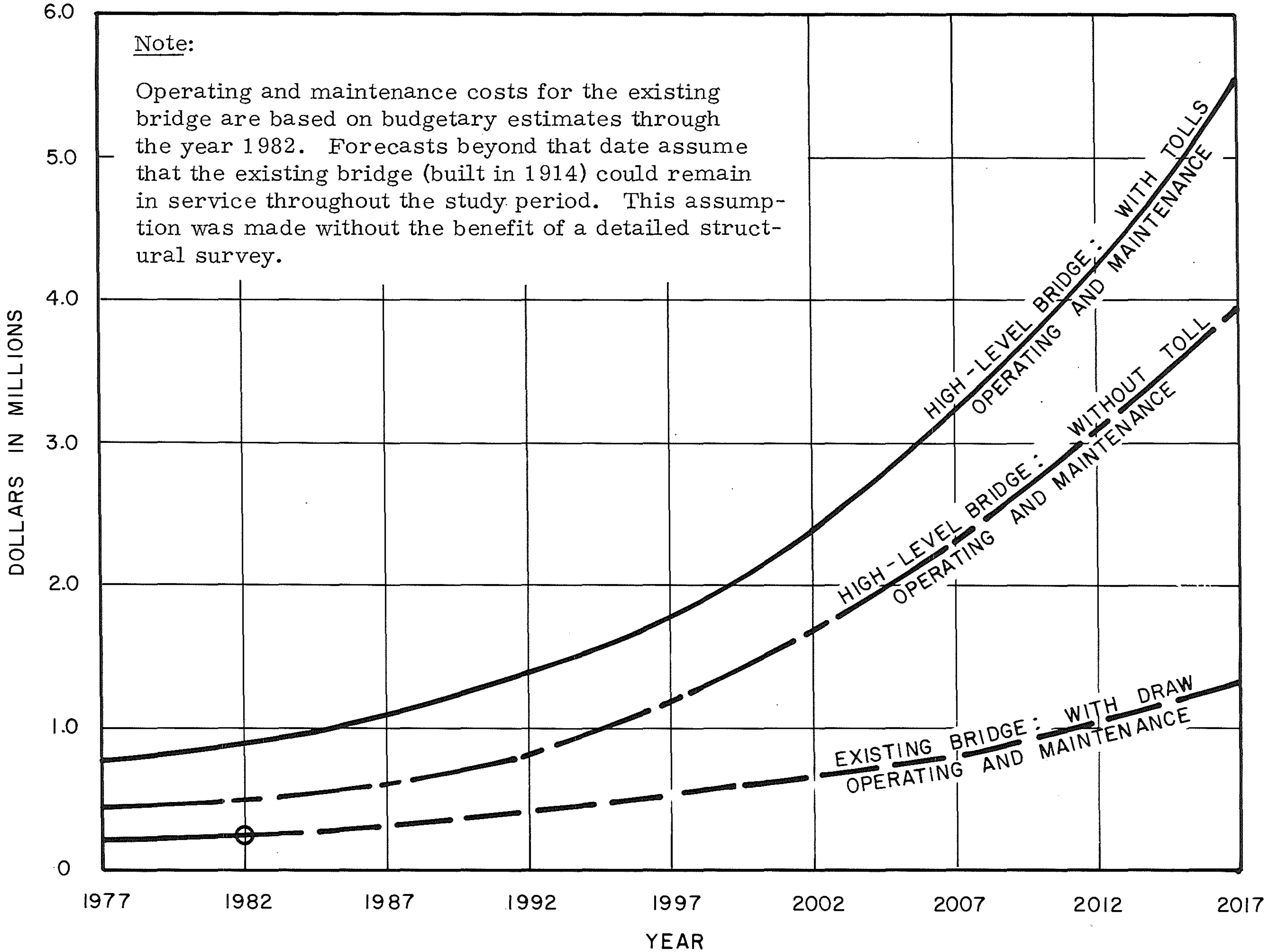


FIGURE 15

COMPARISON OF OPERATING AND MAINTENANCE COST FORECASTS
HIGH - LEVEL BRIDGE VERSUS EXISTING BRIDGE

the two bridges over a forty-year period. It is apparent that the operating and maintenance costs of the high-level bridge are considerably higher than those of the existing facility, due to steel construction versus concrete, size of the structure, difficulties in plowing, insurance, lighting costs, etc. The forecasts for capital improvements on the existing bridge for the next ten years amount to approximately $600,000, and operating and maintenance costs are forecast at about $120,000 annually.* This totals to about $1.8 million for the ten-year period. Operating and maintenance on the high-level bridge would sum to $4.9 million over the same time period, or $8.3 million if the operation of toll facilities were to be included.

5.3 USER BENEFITS VERSUS FACILITY COSTS

The total 1977 construction cost of the bridge facility has been estimated at about $51 million (TABLE 6). Assuming that the bridge would be financed by means of a bond issue and that the interest rate would be 5-1/2 percent over a forty-year period, the total financial cost of the facility would approach $127 million. The total costs of financing (principal plus interest), operating and maintenance sum up to $203 million. The incremental benefits of the proposed facility for a forty-year period, over and above the existing bridge, amount to only $32.5 million. This yields a benefit-cost ratio of 0.16 over the forty-year period. The significance of this value must be weighed against considerations other than time and operating cost savings of the motorist.

*Obtained from Maine Department of Transportation

SECTION 6 FINANCIAL ANALYSIS

6.1 FINANCING WITHOUT TOLLS

Based on the construction and associated costs, a curve was developed which could be used to evaluate the number of years desired to finance the project as a function of the annual payment (FIGURE 16). It represents the total of the construction costs, miscellaneous, contingencies, engineering, legal, right-of-way, and administration costs. In addition to the range of the annual payments as a function of the amortization period, it is also enlightening to investigate the manner in which the total financial cost of the project (i.e., principal plus interest) varies with time. FIGURE 17 graphically depicts the nature of this increasing function.

The costs obtained from FIGURE 17 are the amounts which the State of Maine would be required to pay for a given period of time if it were to assume total financial responsibility for the actual construction, and associated costs. In addition to these costs, the state must also cover the operating and maintenance costs of the facility.

For example, if a twenty-year program for financing the bridge is considered at a total cost of approximately $82 million, as shown in FIGURE 17, the annual payment to retire the debt would be approximately $4.1 million, as shown in FIGURE 16. Correspondingly, the operating and maintenance costs for the first year (see FIGURE 15) would be $460,000, and the total annual cost to the state in 1977 would be approximately $4.5 million. For the twenty-first year the bond would be retired and the total annual expense would include only the operating and maintenance costs.

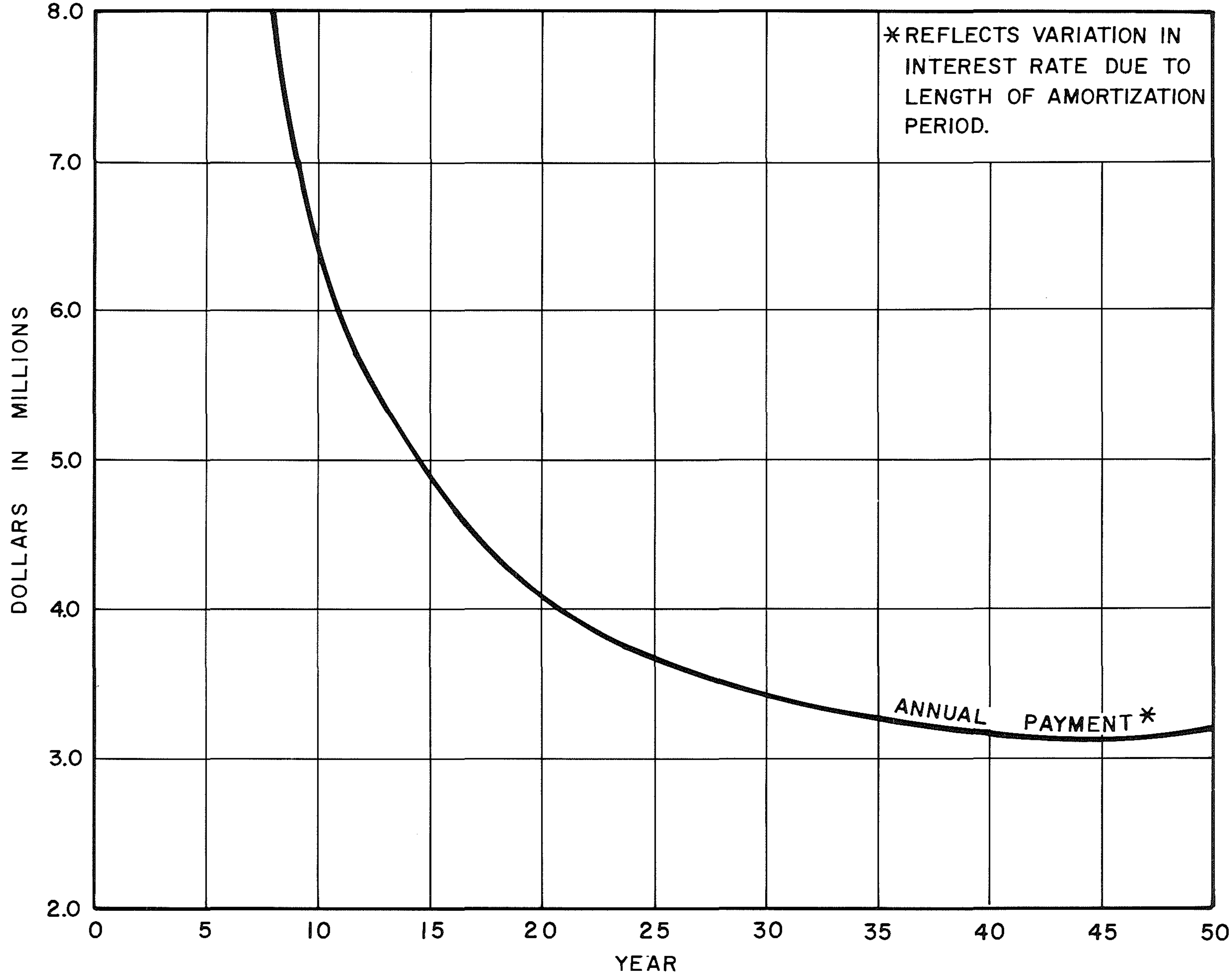


FIGURE 16

ANNUAL PAYMENT (PRINCIPAL PLUS INTEREST) VERSUS AMORTIZATION PERIOD

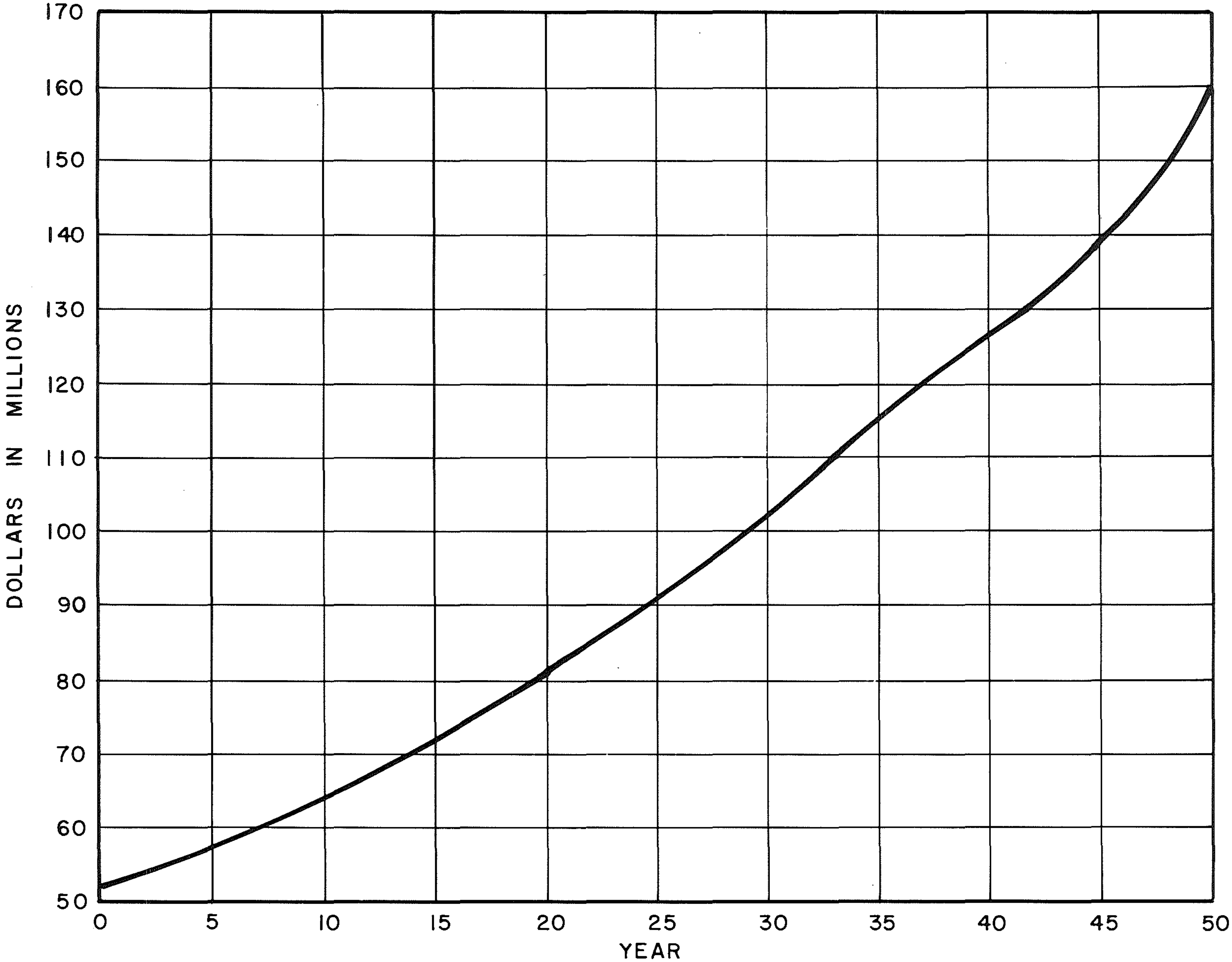


FIGURE 17
TOTAL COST OF FINANCING (PRINCIPAL PLUS INTEREST)
VERSUS AMORTIZATION PERIOD

6.2 FINANCING WITH TOLLS

6.2.1 General

In order to consider the charging of a toll as an alternative method of financing, several factors should be considered. If the bridge facility is financed through the sale of bonds which will be payable only from the revenue collected in tolls, the investor has to be assured that his investment will be sound. He has to be shown, through studies, that a safe margin exists between the estimated revenue to be collected and expenses incurred (principal, interest and operating and maintenance costs). This is called the Debt Service Coverage Ratio (DSC), and is expressed as the ratio of net annual revenue to annual financial costs. Net revenue is equal to the gross revenue (annual traffic multiplied by toll) less costs of operation, administration, and maintenance. The annual financial payment is equal to the product of the total principal amount (i.e., construction plus associated costs) and the Capital Recovery Factor (CRF). The Capital Recovery Factor is a factor which divides a lump sum cost (principal plus interest) into a given number of equal payments over a time period based on a specific interest rate.

Very often, the ratio is improved by having portions of the project financed from other sources and thus decreasing the annual cost. Such items as land acquisition, maintenance, operations, etc., might be absorbed by the state rather than financed as part of the toll facility costs. Another approach might be to have the state and possibly even local governing bodies (cities), back the bonds and be responsible for the difference between revenues and the annual cost of retiring the debt and maintenance. Under this framework, the toll is subsidized by the state to insure the meeting of the financial obligation.

6.2.2 Revenue Forecasts

The amount of revenue that can be generated, if the bridge is operated as a toll facility, is dependent upon the amount of traffic which passes over the bridge. Traffic flow has been discussed in detail in SECTION 4. Some of the results arrived at in SECTION 4 must again be considered. The optimal toll was determined to be 25 cents for the diversion of 25 per cent of offpeak traffic, with the proportion of total traffic being 30 per cent peak and 70 offpeak. As is indicated in SECTION 4, traffic volume on the bridge is forecast to increase with time at the simple rate of 1.33 per cent annually until 1992. Due to the fact, however, that amortization periods greater than fifteen years may be encountered, it was necessary to forecast the traffic volume beyond 1992. It is important to note that most traffic volume forecasts are usually limited to a twenty-year period. Forecasting traffic over longer periods tends to be increasingly risky, for changes in land use, transportation technology, travel networks, and travel desires can markedly alter the resultant traffic patterns. An assumption was made that traffic volume on the new bridge would continue to increase at the simple annual rate of 1.33 per cent. This is reasonable in light of the fact that the capacity of the bridge is not reached prior to 2027, and that since the growth rate is small, such an increase may be viewed as being conservative.

As was stated in SECTION 5, the amount of off-peak diversion will most likely decrease with time. In forecasting the toll revenue, the diversion was assumed to be 10 per cent by 1992 and to have reached zero diversion by 2012.

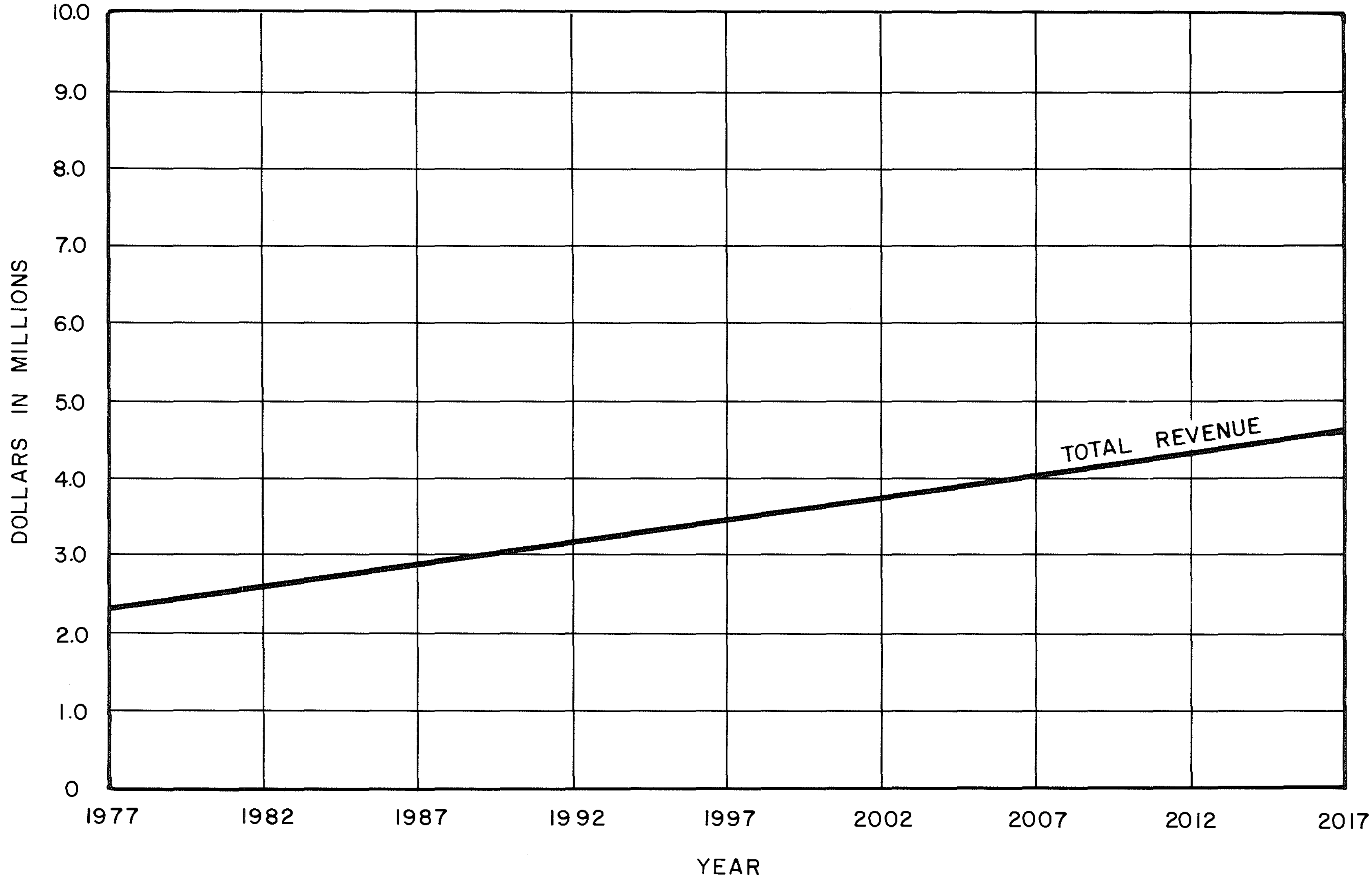
Having taken into account the above considerations and maintaining the toll at 25 cents per vehicle, the annual revenues have been forecast and are graphed in FIGURE 18. Also included in the revenue forecasts is the interest which conceivably could be earned on the toll income prior to the annual payment of expenses.

6.2.3 Comparison of Total Revenues to Total Costs

In order to determine the financial feasibility of a toll facility, it is useful to compare the revenues to costs in order to determine the route which further financial planning should follow.

As a first step in this process the forecasted income was compared to the total forecasted operating and maintenance costs of the facility over a forty-year period (see FIGURE 19). In addition, the costs of financing the bridge through 6-1/2 per cent revenue bonds was considered (see FIGURE 20). It is obvious from FIGURE 20 that financing the facility will not be possible from revenue bonds alone. A large deficit occurs from the very beginning ($2 million) and increases with time.

As a rule, underwriters or investors analyzing the feasibility of a project financed with revenue bonds require that the Debt Service Coverage in the early years be 1.1 to 1.2. This is the time period when



*INCLUDES POTENTIAL INTEREST INCOME

FIGURE 18

TOLL REVENUE FORECAST*

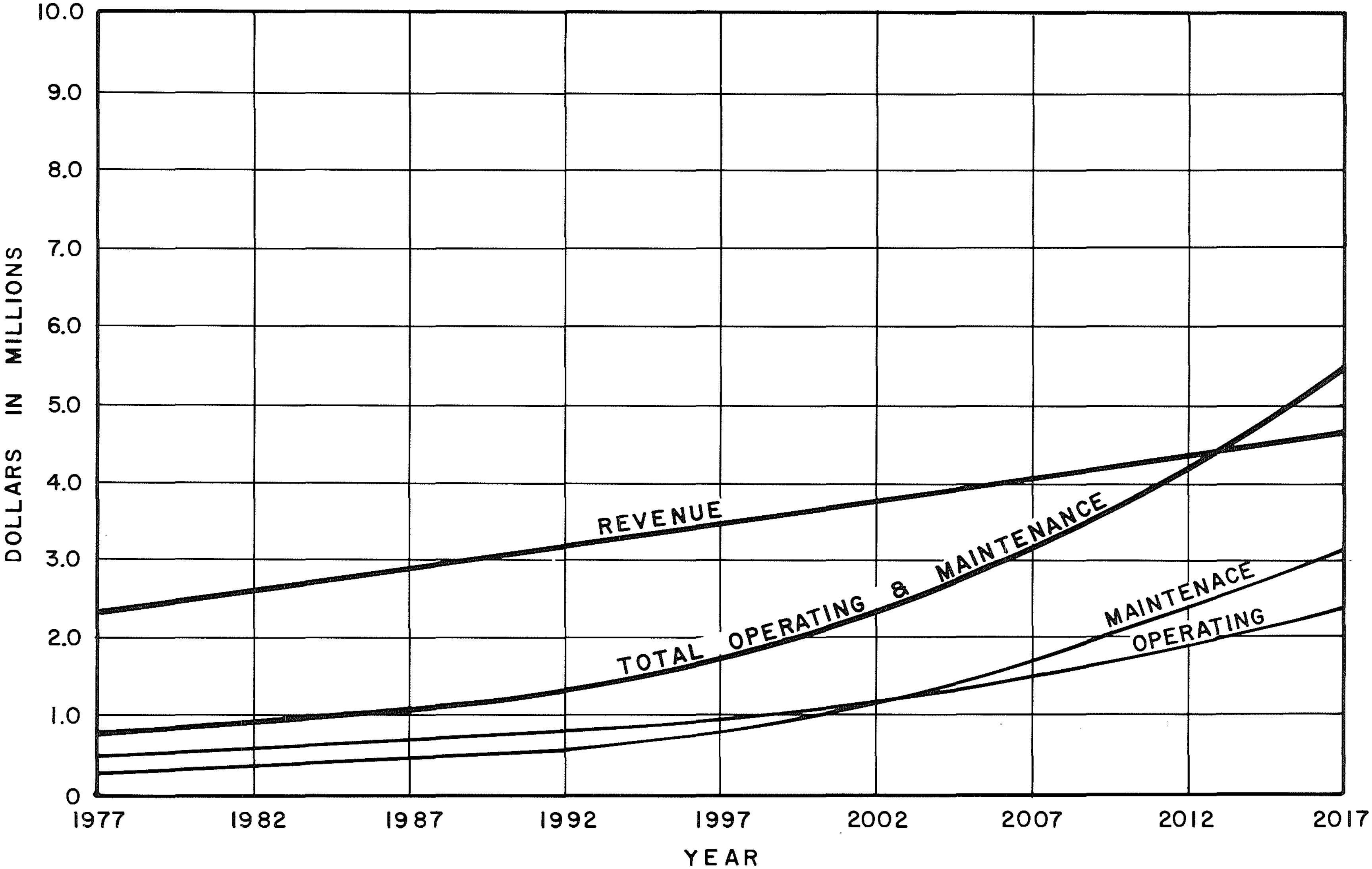


FIGURE 19

COMPARISON OF OPERATING AND MAINTENANCE COSTS VERSUS REVENUE FOR HIGH - LEVEL BRIDGE

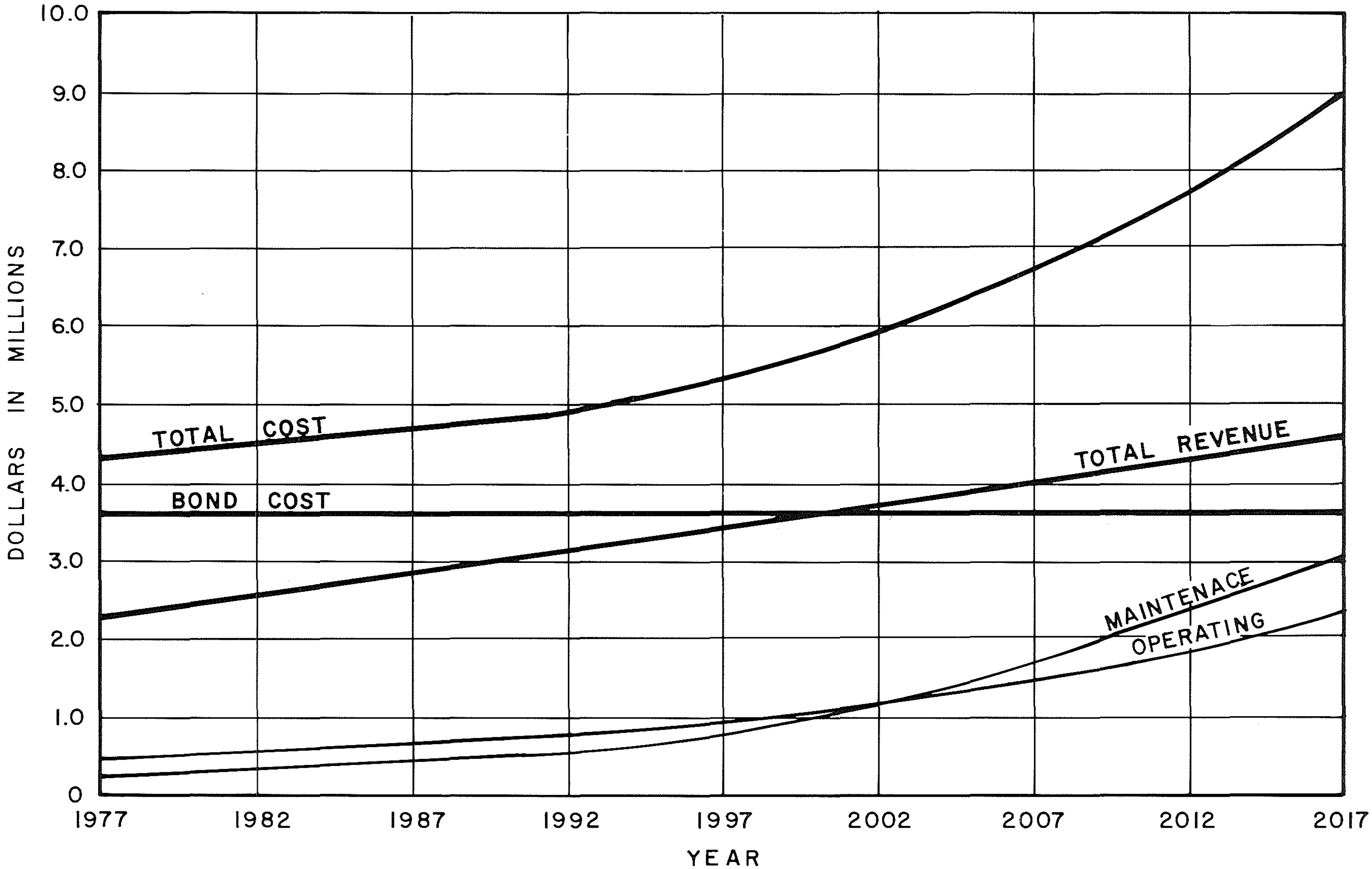


FIGURE 20

COMPARISON OF REVENUE TO COSTS
6½% REVENUE BOND

estimates are likely to be more accurate. In the latter years, where future traffic, maintenance costs, and operation costs are difficult to assess because of economic conditions and other developments, a ratio of 1.5 or greater is generally required in order to provide a reasonable margin of safety.

The second step considered was to investigate the possibility of forty-year state-backed revenue bonds at an annual rate of 5-1/2 per cent. FIGURE 21 indicates that financing the total facility is also not possible under this alternative from the toll revenue generated.

A twenty-year state-backed bond at 5 per cent was also investigated to determine the necessary cash flow. This alternative is depicted in FIGURE 22.

6.2.4 Toll Financing Summary and Conclusions

As was determined in the previous section, the bridge facility will not be able to cover all of its associated costs from the revenue which it is forecast to generate. More explicitly, the facility will incur a loss of $2 million in the first year alone, assuming revenue bond financing, and this deficit only increases with time (see FIGURE 20). This indicates that the proposed bridge is not financially feasible from the standpoint of revenue bonds alone, and consequently, involved governmental bodies would have to consider backing the bonds and guaranteeing the payment of interest. Even though government-backed bonds command a lower interest rate, the facility is still not capable of meeting its fiscal obligations from tolls. In

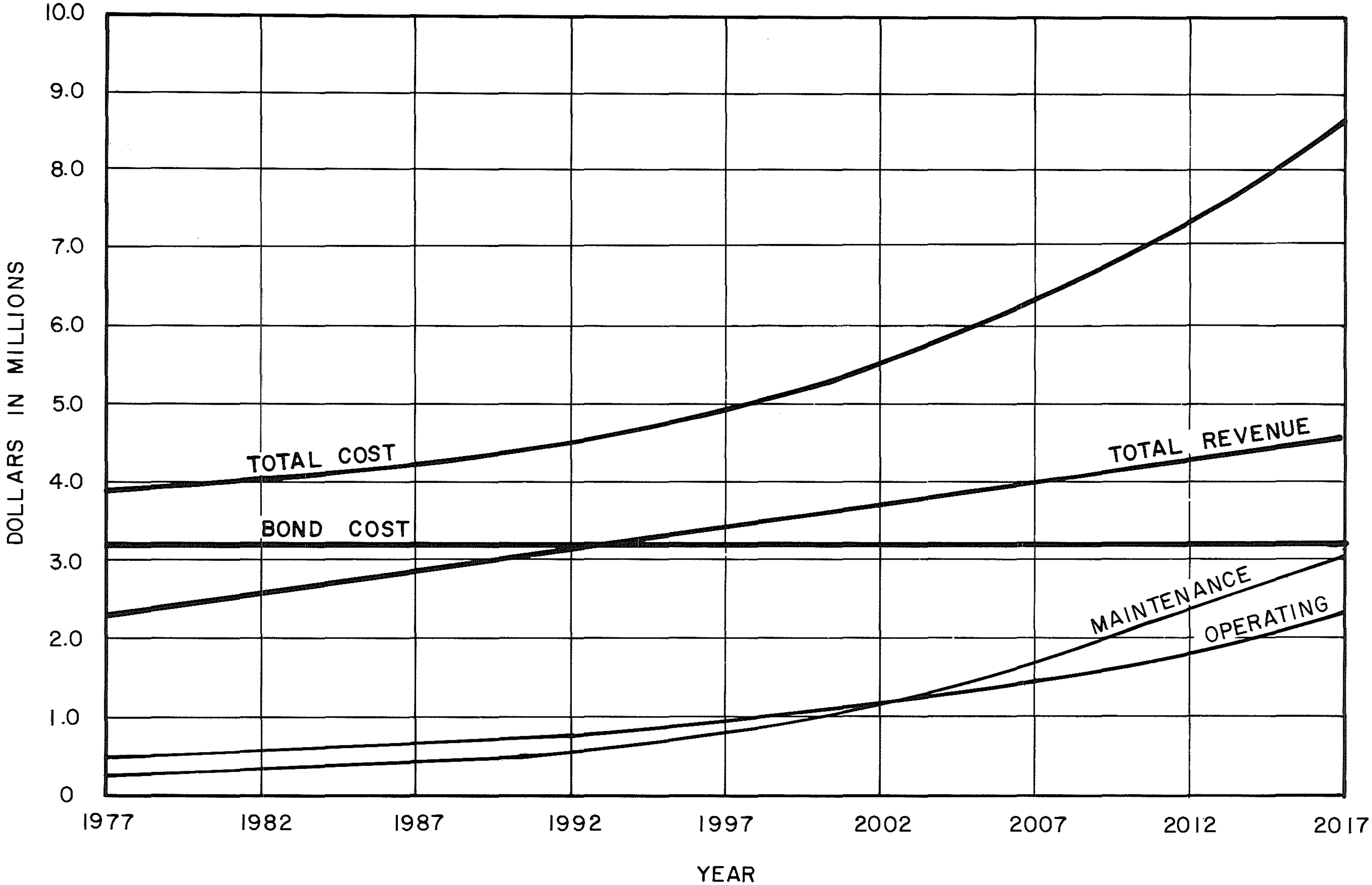


FIGURE 21

COMPARISON OF REVENUE TO COSTS
5 1/2 % STATE BACKED BONDS

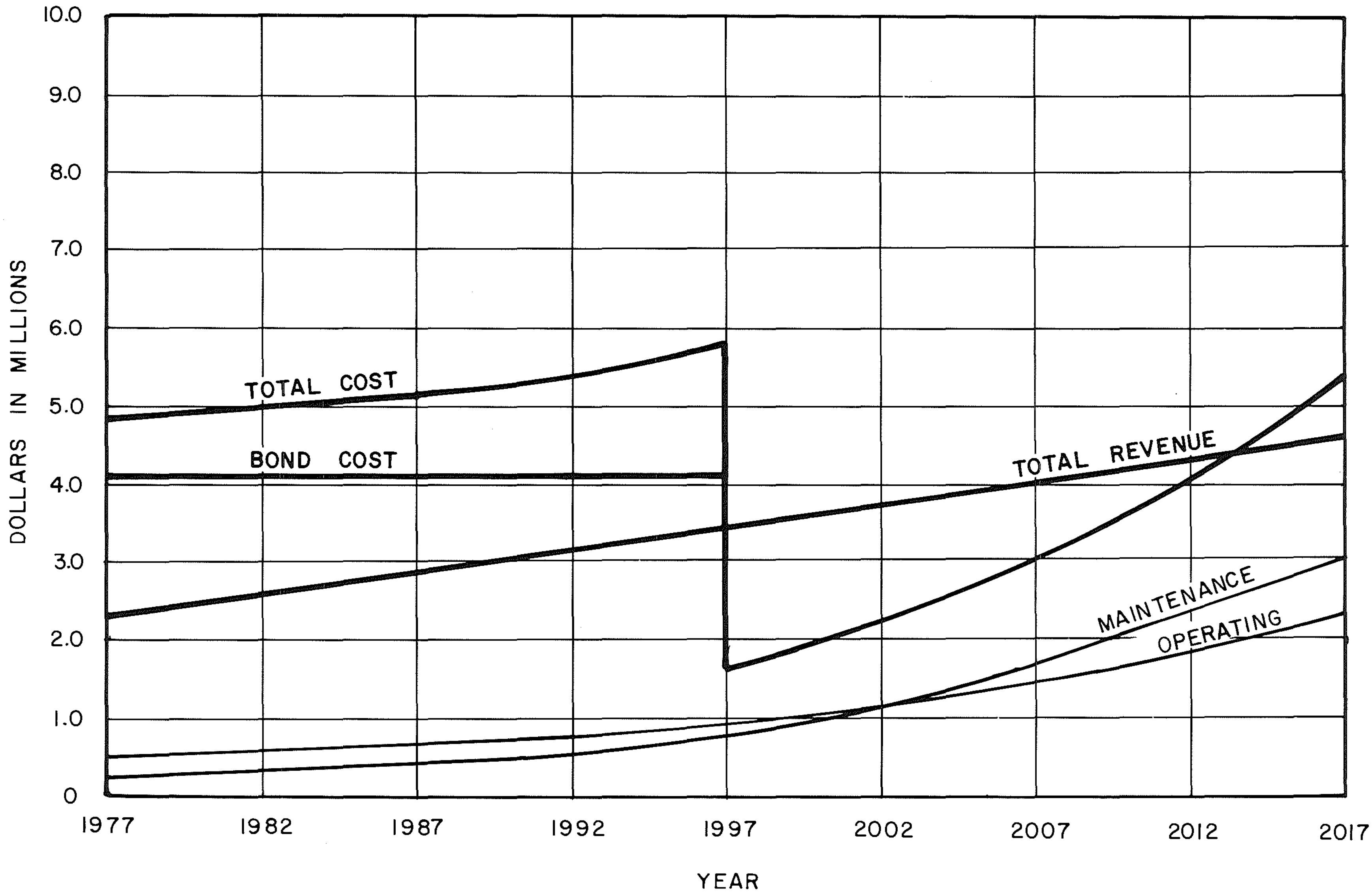


FIGURE 22

COMPARISON OF REVENUE TO COSTS
TWENTY-YEAR, STATE-BACKED BOND @ 5 %

order to delineate the actual deficits which are forecast to occur, FIGURE 23 has been developed which indicates the annual cash shortages that would have to be assumed by the owner(s).

Since the state would most likely be responsible for at least a large portion of the facility if it is implemented, the financial burden which the bridge would place upon the highway budget is of importance and should be considered.

Assuming the least expensive case of a 5 per cent, twenty-year bond, the average annual deficit for the twenty-year period is approximately \$2.4 million (see FIGURE 23). This amounts to approximately 26 per cent of the estimated 1973 state highway funds available for a project in this category. Federal assistance funds are available, but the actual amount is a function of the state's budget. Taking into account possible federal aid, the \$2.4 million average annual deficit would still amount to approximately 18 per cent of the eligible state and federal funds.

6.3 POSSIBLE SOURCES OF FEDERAL ASSISTANCE FOR CAPITAL FUNDING

The federal programs under which financial assistance could be made available, for a project of this type, were investigated and are outlined in the paragraphs which follow.

6.3.1 Federal Aid Secondary Program

Federal funds are available for highways which are part of the Federal-Aid Primary (FAP), or Federal-Aid Secondary (FAS) system. The Portland Bridge is part of Route 77 which is currently on the FAS

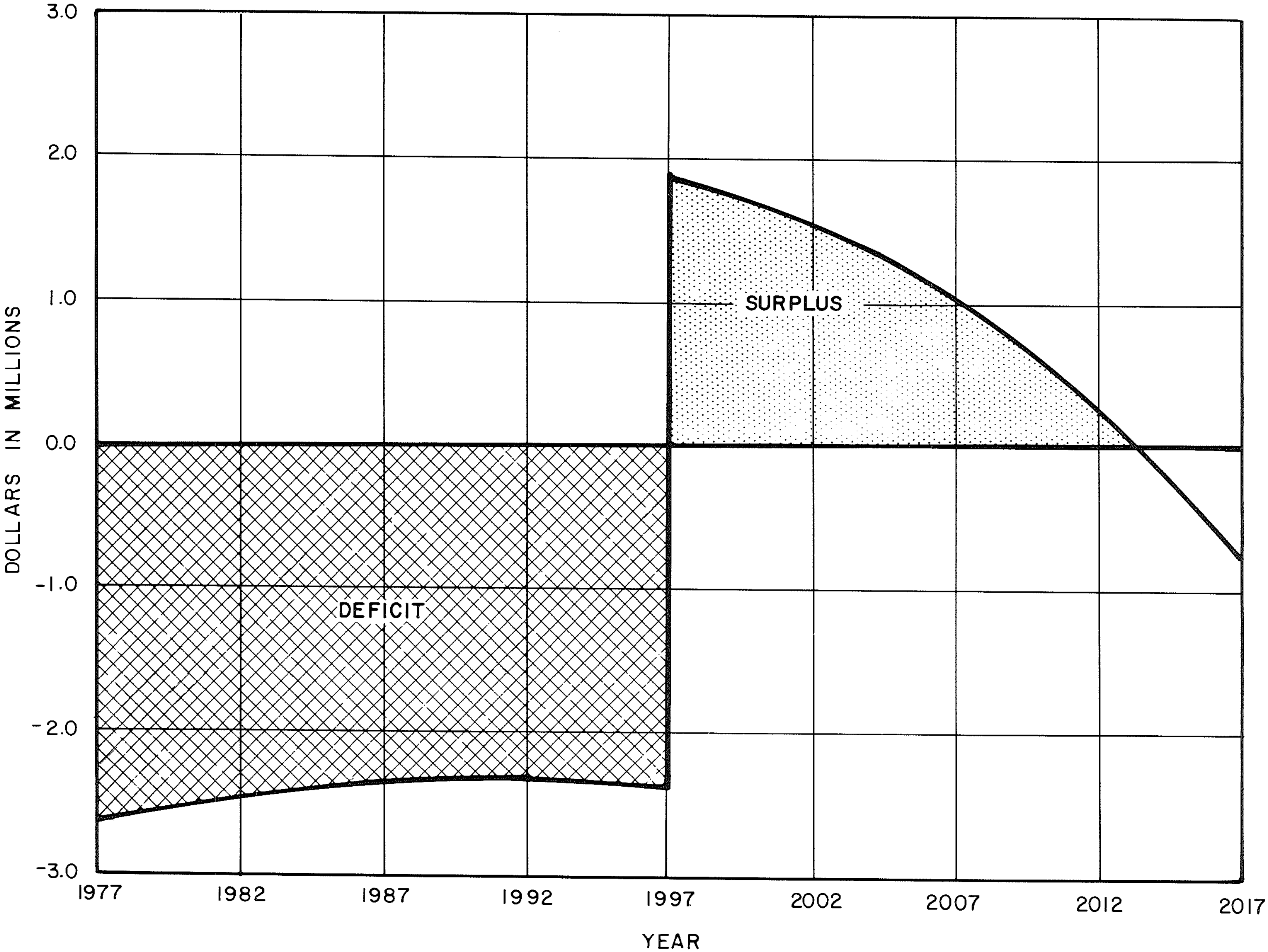


FIGURE 23

NET ANNUAL CASH FLOW
WITH 5%, TWENTY-YEAR, STATE-BACKED BONDS

system, and consequently is eligible for federal funds. The allocation of FAS funds to a particular state, such as the State of Maine, is determined currently by dividing the total amount of funds in the program into thirds, and then distributing each third to the fifty states in proportion to their (1) rural population, (2) area, and (3) miles of rural post roads. The total amount of FAS funds currently allocated for the State of Maine is $3,084,000. At the present time, each dollar of federal aid provided is matched with a dollar of state funds. The current fiscal budget calls for matching state funds in the amount of only $3,341,000. These funds are not sufficient to finance the proposed bridge.

Federal funds, however, are not available for routine operation, maintenance or administration. The acceptance of federal aid does require that the state assume responsibility for maintenance, but not necessarily for the costs incurred. Federal aid funds may therefore be used only to initiate and complete the construction or reconstruction of a highway project. This includes engineering planning, design, construction, right-of-way acquisition and relocation, and engineering supervision. The present law allows for full federal participation in both right-of-way acquisition and relocation.

6.3.2 Urban "C" Program

Federal aid for primary and secondary highway construction is also distributed under the Urban "C" program established in the 1970 Transportation Act. This program provides funds for extensions into urban areas of routes included in the primary or secondary systems.

The current federal contribution to the State of Maine under this program is $914,000, matched by $990,000 in state funds. The extent of federal contributions in the future is unknown at this time; however, the program is gaining legislative and public support.

6.3.3 Coast Guard Bridge Alteration Program

There also is a possibility that financial assistance for a new bridge could be made available through the Coast Guard Bridge Alteration Program. However, the primary factor in determining eligibility for this program is navigation.

The existence of a hazard to navigation must be established first through hearings and investigations at the local district level. Once a definite hazard has been established the project is transferred to Coast Guard Headquarters in Washington, D.C. There, the engineering staff determines the most economically feasible method of eliminating the problem and the amount which the federal government will contribute to the total cost of the project.

Funds are allocated on an individual basis. There is not an established fund from which the distributions are made. Historically, these allocations have been approximately 50 to 60 per cent of the total project costs. Each project is evaluated individually and the amount of funds allocated depends on the seriousness of the hazard and the extent of its reduction.

When a project reaches the final design stages the federal share of the construction cost is included as part of the Coast Guard budget for the next fiscal year. The budget is then reviewed by the President and submitted to the Congress for approval. In the past, projects have often been delayed or postponed at this stage due to political pressures, budget cuts, etc.

6.3.4 Special Bridge Replacement Program

In addition to the previously described federal programs, there is a special bridge replacement program established under the 1970 Highway Act, which provides financial assistance to states for replacing bridges over waterways or other topographical barriers. The first requirement is to establish that the bridge is of significant importance and is in an unsafe condition due to structural deficiencies, physical deterioration, or functional obsolescence. All bridges on the federal-aid system will be inventoried (by the Secretary of Transportation) and will be classified according to replacement priority. Consideration will first be given to those bridges which are in greatest danger of failure.

The federal share of any bridge replacement costs under this program cannot exceed 75 per cent. Appropriations from the Highway Trust Fund amount to $100 million for 1972 and $150 million for 1973.

Due to the total amount of funds available and the priority rating system, it is unlikely that a significant amount of funds would be available in the immediate future for a project of the magnitude outlined in this report.

REFERENCES

Travel Activity in Portland - South Portland Area

Maine State Highway Commission and Maine Department of Economic Development. Portland Area Comprehensive Transportation Study (PACTS), Final Report, Summary Report, and supplemental maps, Figures, etc. Edwards and Kelcey, 1965.

Maine State Highway Commission and Maine Department of Economic Development. Portland Area Comprehensive Transportation Study - Updating Study. Edwards and Kelcey, 1970.

Maine State Highway Commission. State Route 77 Corridor Planning Study. Edwards and Kelcey, July, 1971.

Maine State Highway Commission. Bridge Crossing Study, Portland Harbor - Fore River, Portland - South Portland. Fay, Spofford & Thorndike, Inc., 1970.

Value of Time Estimation and Usage

Beesley, M. E. "The Value of Time Spent in Traveling - Some New Evidence." Economics, March, 1965.

Harrison, A. J. and D. A. Quarmby. "The Value of Time in Transportation Planning - A Review." Great Britain Ministry of Transport, November, 1969.

Lisco, Thomas E. "The Value of Commuters' Travel Time, A Study in Urban Transportation." Unpublished Doctor of Philosophy Thesis, University of Chicago, Department of Economics, June, 1967.

Quarmby, D. A. "Choice of Travel Mode for the Journey to Work." Journal of Transport Economics and Policy. September, 1967.

Stafford, Joseph H., Plourde, R. P. and Richard deNeufville. "Dial-A-Bus Revenue Potential." Papers - Eleventh Annual Meeting, Transportation Research Forum. Oxford, Indiana: Richard E. Cross Company, 1970.

Stopher, Peter R. "A Probability Model of Travel Mode Choice for the Work Journey." Highway Research Record 283, 1969.

Thomas, T. C. and G. I. Thompson. "The Value of Time for Commuting Motorists as a Function of Their Income Level and Amount of Time Saved." Highway Research Record 314, 1970.

Automobile Operating Costs

Wilbur Smith and Associates. Transportation and Parking for Tomorrow's Cities. New Haven, Connecticut: 1966.

"Boston Car Costs Seen Highest in U. S.", results of a survey by the Automobile Legal Association, Boston Globe, June 18, 1972.

Payment Factors and Time Periods

Grant and Ireson. Principles of Engineering Economy. Fourth Edition, New York, New York: 1964.

Cost Estimates and Evaluations

American Society of Civil Engineers. Consulting Engineering, A Guide for the Engagement of Engineering Services. New York, New York: Headquarters of the Society, 1972.

Massachusetts Port Authority - 1971 Annual Report

Massachusetts Turnpike Authority - 1971 Annual Report

Massachusetts Turnpike Authority; Third Crossing Boston Harbor - Preliminary Feasibility Study; Howard, Needles, Tammer & Bergendoff; Boston, Mass., 1968