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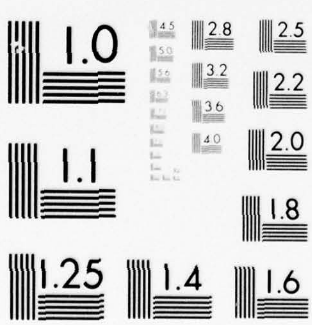

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The Role of River Training in Improving Waterway Transportation Efficiency in Central Thailand

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PREFACE

This report is one of a series of publications concerned with development topics in Southeast Asia. The research detailed in this report represents a portion of a larger study sponsored by the Applied Scientific Research Corporation of Thailand which dealt with an analysis of transportation systems in Thailand. This study, designated as Research Project 30, was the joint undertaking of the University of Michigan and the Applied Scientific Research Corporation of Thailand and was funded by the University from a research contract with the Geography Branch of the Office of Naval Research (Research Project Nonr 1224 (56) N.R. No. 388080). Research and analysis was conducted by both Corporation and University personnel under the direction of Professor L. A. Peter Gosling, Department of Geography, University of Michigan. Co-ordination of the project publications and editorial assistance were provided by Catherine J. Baker. Inquiries regarding the publication series should be directed to the Department of Geography, University of Michigan, Ann Arbor, Michigan, U.S.A. The conclusions, opinions and recommendations of the various authors in these reports do not necessarily reflect the views of any of the sponsoring organizations.

This report, The Role of River Training in Improving Waterway Transportation Efficiency in Central Thailand, was originally part of a dissertation offered for the degree of Ph.D. in Geography by Peter R. Ingold. Field work was conducted in Thailand as a part of Applied

Scientific Research Corporation of Thailand's Project 30 and with the valued assistance of Corporation personnel including Dr. Phiphit Suphaphiphat, Khun Mit Pramuanvorachat and Khun Phaijayant Uathavikul. Special thanks go to the Royal Irrivation Department and its hydrological and Engineering sections, and particular gratitude is extended to Khun Jumsak Tejasen of the Construction Section for the extensive assistance and guidance he provided the author of this report.

This report examined the feasibility improving the main Chao Phaya river through river training and presents a preliminary cost-benefit analysis of river training. The study indicates that even without taking into account all possible benefits from the enhanced waterway transportation which would result from river training, such a program could pay for itself within twenty-five years. The addition of secondary benefits and the calculation of other costs to be attributed to competing land transportation can substantially reduce the cost recovery period and therefore increase the competitive advantage of water transport.

L. A. Peter Gosling
Project Director

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CHAPTER I

METHODS OF IMPROVING THE MIDDLE CHAO PHAYA FOR ALL SEASON BARGE USE

Introduction

The Chao Phaya river undergoes wide variations in flow during each twelve month cycle. At mean stage the river flows along its alluvial bed and is flanked by steepsided banks over much of its course along the middle and upper reaches. At peak flood, the river swells to a great reddish-brown torrent filling the entire bed to a point where little of the bank is exposed. Occasionally it even overruns the confines of its banks and floods the area beyond.

In sharp contrast is the situation at the time of low water. During this time of year, flow is limited to a narrow channel that winds its way between sandy bars and dunes lying atop the general floor of the river bed. Under these conditions, the steep banks of the river frequently stand many meters back from the edge of the water while only a small portion of the bed is utilized.

At the time of low water, navigation on the middle Chao Phaya becomes the most troublesome or even impossible for most commercial carriers. As is common with other rivers displaying similar hydrologic characteristics, at low water, vessel passage becomes increasingly difficult as the navigation channel increases in sinuosity and the water current increases in velocity while, at the same time, channel depth and width diminish.[1] Generally, in most rivers and streams, the position of those bars composed of heavier gravels tends to remain nearly stable on the river bed.[2] In the case of sedimentary deposits composed of finer materials, a condition characteristic of streams of gentle gradient like the Chao Phaya, the tendency is for these deposits to shift position and move downstream; their upstream face being worn by scour while their downstream side is experiencing deposition.[3]

During the falling stage of the yearly flow cycle, when water volume and velocity decrease, sedimentation begins along the river bed.[4] At this time, depositional landforms, composed of materials too heavy for the river to transport at low water volume and velocity, begin to appear. As water levels continue to diminish, flow becomes restricted to one or more of the lesser channels that meander back and forth between the elevated deposits of sand and gravel.[5] The configuration of these often widely swinging streams is one of deeper pools separated by shallow shoals or sills. It is these shoals or sills lying across the channel that offer the main obstacle to dry season navigation. They are rather flat in surface and usually many feet in width. When found near bends in the river, sills can maintain a relatively stable position; on the other hand, those located in the straighter raches of the river are unstable and prone to move slowly downstream.[6] The instability of such sedimentary deposits along a river bottom offers grave problems, for the task of maintaing an effective system of navigational markers is severely complicated.[7] Regardless of their permanency or lack of it, by virtue of their elevated nature and their position between deeper segments of the water channel, all sills offer a potential problem to navigation.[8]

The exact nature and location of navigational barriers in the middle Chao Phaya are summarized in Appendix I. In these river profiles is depicted a longitudinal representation of the river bottom with indications of mean river surface levels as calculated for nine critical months of the year during rising and falling water stages. The situation shown in the diagrams represents conditions as they existed in 1965 prior to experimentation with river training but following some dredging on the part of the Royal Irrigation Department.

An examination of the information contained in the appendix documents the extreme seasonal variability of flow and stage on the middle Chao Phaya and indicates those months when cargo vessels must opt to use the longer, slower alternative routes via the Noi and the Suphan rivers. The diagrams also illustrate the short duration that the river is passable for vessels with drafts in excess of one meter.

Analysis of Passability Profiles
Appearing in Appendix I

Each of the five segments used to represent the middle Chao Phaya river is rendered twice: once with water surfaces as they exist during the months of falling water and again for the months of the year when water surfaces are rising. Water levels for the months of higher surface, September through November, are not presented owing to the fact that barge passability was deemed to be of no problem over any part of the middle Chao Phaya river at this time. For these three months, water surface lines could not be plotted as they exceeded the verticle extent of each profile (see statistics for mean monthly flow that are presented as a part of Appendix I).

For the sake of a more meaningful analysis of the effect of these differential mean monthly water levels on the barge industry and its ability to operate over the middle Chao Phaya river, the writer measured the impact of barges having 1.00, 1.50 and 2.00 meter drafts on the navigational channel through each of the five segments. These vessel drafts were selected as being within the range of most barges loaded or empty. The result of this analysis is presented below in Figure 1. Each XX represents one or more instances in which a vessel would make contact with the river bottom. Obviously, when contact occurs, water level are too low for safe barge passage. Consideration of Figure 1 illustrates that boats of one meter draft can pass through the entire middle Chao Phaya river during all months of the year. Vessels of one and a half meter and two meter draft are able to negotiate the river freely for only four months: August, September, October and November.

With few exceptions, all attempts at changing the physical configuration of the Chao Phaya river bed and the condition of the waters flowing through it have as a goal the increase of dry season channel depth at those places where it is insufficient for safe barge passage. This goal can be achieved either by a manipulation of channel configuration, thus concentrating flow through a single, narrow but deeper water

Months	2.00 Meter Draft Segments A	B	C	D	E	Months	1.50 Meter Draft Segments A	B	C	D	E	Months	1.00 Meter Draft Segments A	B	C	D	E
Oct.						Oct.						Oct.					
Nov.						Nov.						Nov.					
Dec.	XX	XX	XX			Dec.		XX				Dec.			No		
Jan.	XX	XX	XX	XX	XX	Jan.	XX	XX	XX	XX	XX	Jan.			Contact Made		
Feb.	XX	XX	XX	XX	XX	Feb.	XX	XX	XX	XX	XX	Feb.			with		
Mar.	XX	XX	XX	XX	XX	Mar.	XX	XX	XX	XX	XX	Mar.			Bottom		
April	XX	XX	XX	XX	XX	April	XX	XX	XX	XX	XX	April					
May	XX	XX	XX	XX	XX	May	XX	XX	XX	XX	XX	May					
June	XX	XX	XX	XX	XX	June	XX	XX	XX			June					
July	XX	XX	XX	XX		July	XX	XX	XX			July					
Aug.						Aug.						Aug.					
Sept.						Sept.						Sept.					

Figure 1. Months when vessels make contact with river bottom. Segments refer to profiles as presented in Appendix I. Each XX represents one or more contacts with bottom of the middle Chao Phaya river.

course, or by introducing more water into the river, thus elevating the river's general surface at the times of year when navigation becomes difficult. A combination of both approaches may be the most effective solution.

Regardless of which approach is selected, there are several kinds of possible corrective measures within each category. The experts at the Centre De Recherches et D'Essais De Chatou, in their report entitled "General Note Relating to the Improvement of Inland Water Transport by Means of Bottom Panels," have divided corrective measures into two categories based on the durability of the system that they employ.[9] The point of separation between each category hinges on whether the remedial system under consideration is permanent and designed to function for an indefinite length of time or impermanent and destined to be destroyed at the time of peak flood within each twelve month cycle.[10]

Atop the two group categorization suggested in the French report, the writer wishes to superimpose still another pair of groupings. In this case the major criterion for division into two separate groups lies in each remedial system's flexibility of application. Some water deepening systems lack the capacity of being modulated in any part. Their impact is total throughout the waterway and thus can be considered as being inflexible in nature. Other solutions, in contrast, can be very flexible in their implementation and impact on the waterway. Their effect on a given stretch of river can be modulated and thus precise in fitting the requirements of each section.

A good example of the inflexible kind of deepening system or device is a dam. If of any size, its impact is felt over wide stretches of the water course without respect to local variations in channel depth. In this case no selectivity can be installed into the system to enable it to distinguish between areas which need more water and areas which do not. This inability to be selective in point or degree of impact makes water deepening by impoundment an inflexible solution to navigational improvement. To obtain deepening in one place requires deepening everywhere.

At the opposite extreme, a good example of maximum flexibility is to be found in channel deepening by mechanical dredging. This approach can be applied in a very measured and selective fashion, treating only those areas where deepening is needed while expending no energy on those stretches of the river with sufficient depth or on secondary channels not used for navigation.

What follows is a discussion of the several possibilities open to the engineers embarking on a program of river channel improvement through deepening and stabilization. Discussion is based on the results of research carried on by the Centre de Recherches et D'Essais De Chatou.[11]

Discussions of Engineering Solutions That Could Be Applied to Improving the Middle Chao Phaya River Through Deepening

Impermanent Solutions

Mechanical Dredging

This approach to channel deepening is among the most flexible of all possible solutions. A dredge possesses a high degree of mobility and can be shifted from place to place quickly with a minimum of preparations. Deepening can be limited to only those spots on the channel that are critical to vessel movement. One of the main drawbacks to this type of operation, however, is the short duration of its impact. The effect of the work of a dredging machine is especially short-lived on alluvial streams which have siltation problems like those of the Chao Phaya.[12] It is conceivable that, to assure safe vessel passage, a given reach of a channel should be deepened several times a year. Under these circumstances, if the channel assigned to one dredge is extensive, keeping it open might prove an impossible task.[13] In addition to the problem of rapid resiltation of a dredged channel, there is the equally vexing one of disposing of the dredge tailings. This problem becomes compounded everytime redredging is necessary.[14]

Bandalling

A bandal is an impermanent structure that is placed in the water in such a fashion as to promote controlled scour.[15] This technique calls for the insertion of a series of these structures along a channel at sharp angle to the flow of the water current. Each bandal is a screen-like object made of some locally available, inexpensive material such as bamboo.[16] It is fastened to poles that have been driven into the river bottom.[17] Although providing a very flexible approach to channel deepening, the major problem is the large number of structures that are required and the fact that they must be reconstructed after the passage of each flood season. Bandals are not strong enough to withstand the swift currents of the high water period.[18]

Surface Panels

A surface panel consists of a rectangular screen fixed beneath a floating wooden structure, such as a barge, which in turn is held stationary atop the place designated for deepening.[19] The panel itself is set at a sharp angle to the current's flow and, as is the case with the bandal, it causes turbulence and scour. The floating apparatus is attached to an anchorage upstream of the sill.[20] By lengthening and shortening the lines that secure the barge to the anchorage, a surface panel can be slowly drawn over the sill. Depending on the extent of the area designated for deepening, the process requires one or two weeks time.[21] This approach to channel management has the advantage of being flexible in application but it shares the drawback inherent in mechanical dreding in that its effectiveness is limited in duration. After treatment of a shallow area is concluded, the channel is free to silt up once again. If the reach of a river placed under the charge of one surface panel is long, maintaining adequate depth over its entire length may prove impossible.

Permanent Solutions

Weir

A weir is a permanent structure designed to impound water behind its works. It functions like a dam and is often referred to by that name. The major difference between a weir and a dam is not necessarily its construction or function but rather its purpose. A weir is designed primarily with the intention of retaining water so as to increase levels behind the structure. Little attention is given to downstream channel depths.[22] A properly constructed weir is a permanent control device but it also suffers from an inability to be selective in the areas receiving its impact.

Storage Dam

A storage dam is a structure whose primary purpose is to catch and hold water during periods of high water for release in measured amounts when downstream flow becomes insufficient for irrigation or navigation.[23] Like the weir, the storage dam is a water impoundment device, but in this case the emphasis is placed on need downstream of the dam and its impact on water levels above the structure is a secondary consideration. As is the case with a weir, the storage dam's impact on the navigation channel is very general in nature. In order to increase downstream water depths even slightly, large increases in total flow are required. This is so because at places where downstream channel configuration has been unaltered by man, any increase in flow causes water to run laterally across the shallow sills.[24] To effect a general deepening of the navigation channel under such conditions, large amounts of water are wasted in the unavoidable creation of countless shallow pools and multiple secondary channels.

Dykes and Other River Narrowing
Structures

The function of such devices is to concentrate all available water into one narrow channel. This is accomplished by cutting off all secondary flows of water by the erection of artificial banks along both sides of the desired channel. In effect it is like building a canal atop the old river bed.[25] Especially in rivers with great seasonality of flow, it was found that, at high water, localizing works such as these were subjected to severe erosion along their banks. In instances where the navigation channel was successfully localized, siltation and the ensuing formation of new sills within the channel became a problem once again.[26]

Bottom Panels

Like surface panels and bandals, bottom panels are structures that are placed in the current in order to induce self-correcting measures. This approach to channel deepening will be discussed in detail below.

The Chao Phaya River Training Project

Background to the Project

At the request of the Royal Irrigation Department, the French Association Pour L'Organization des Missions de Cooperation Technique organized a mission composed of hydrologists and economists. They were charged with the task of making recommendations regarding the feasibility of improving navigation on the Chao Phaya river. The ensuing studies made by these experts were sponsored by the United Nation's Economic Commission for Asia and the Far East (ECAFE).[27] The mission began work in 1963. In cooperation with engineers from the Royal Irrigation Department, the French team set out to assess the problems faced by cargo vessels attempting to negotiate the middle and upper Chao Phaya river especially in times of low water.

On the upper portions of the river it was noted that the reservoir created by the Chai Nat dam was sufficient to assure ample depths for safe navigation as far upstream as Phayuha Khiri. Beyond this point, however, certain stretches upstream to Nakhorn Sawan were considered to be critically shallow during the low water season.[28]

After cursory surveys of the upper reaches of the Chao Phaya were completed, the experts turned their attention to the middle portion of the river lying between the Chai Nat dam and Ayutthaya.[29] Here they identified seven sections of the channel where deepening was needed. From north to south they are located at: Wat Sri Mongkol, Wat Kam Pang, Bang Chom, Wat Pra Non, Yan Samak, Wat Chaiyo and Pong Peng.[30] Taken together, the combined length of shallow areas is approximately 25 to 30 kilometers.[31] Of the several trouble spots, the one at Wat Chaiyo was considered to be the most extensive having a series of sandy sills over a 6 kilometer stretch of the river. In the past, the Irrigation Department had deepened this shallow area with a mechanical dredge.

After investigating the middle Chao Phaya, the French team came to the conclusion that a navigable channel of sufficient dry season depth to afford the passage of commercial cargo vessels was in the realm of both economic as well as technical feasibility. It was advised that, before absolute certainty could be achieved, more research would be required. For the sake of confirmation, it was recommended that a model of the Chaiyo stretch of the river be constructed and that more data be collected on the seasonal variations of the river bed and water flow on that part of the Chao Phaya.[32] The forthcoming hydrologic and limnologic data would then be used to calibrate a model that was being constructed by the Irrigation Department near Bangkok.

At the time that the information for this study was being collected in 1966 and 1967, Royal Irrigation Department engineers and their French colleagues had completed extensive tests with the Chaiyo model. Also, they had installed experimental bottom panels along a portion of the Chaiyo sill. Based upon this experimentation, it was calculated that the bottom panel method of channel improvement, if coupled with controlled water release during the dry season from dams upstream, would work successfully. Surveys made in the period of December 1965 to February 1966 showed that the insertion of ten experimental panels along a sill at Chaiyo had resulted in a channel with a minimum width of 5 meters and a depth that had been increased by 0.50 meters.[33] In terms of the river bottom profile presented in Appendix I and discussed earlier in this chapter, a deepening of the middle Chao Phaya channel by 0.50 meters means that vessels of at least 1.50 meters can travel the route at times of lowest flow. In the estimation of the French hydrologist, ". . . the channel formed by the . . . panels was perfectly navigable and navigation required normal buoyance only."[34]

At this point in the discussion, it must be underlined that an important factor contributing to the decision to pursue channel improvement with the aid of bottom panels was the Phomiphol dam's ability to supply a measured amount of water to the Chao Phaya river throughout the dry season. This large water storage facility had gone into operation in 1966 on the Ping river, one of the northern tributaries of the Chao Phaya river.

According to a report completed in July 1966:[35]

> The large Yanghee storage dam was a tremendous advantage for experimenting [with] the planning of bottom panels not only during

> receding flood but also at low water, the discharge of which being from now on maintained [italics mine] at some $100 m^3/s$.

In an earlier report, dated 1963, mention of the Yanghee (technically, the Phomiphol dam at Yanghee) dam's importance to successful river deepening is also made.[36] As these reports indicate, from its early beginnings, the project was conceived of as one employing the benefits of water storage in upstream reservoirs as well as the more flexible approaches of both dredging and bottom panels. According to the literature, the use of surface panels was considered but soon dismissed owing to the length of many of the sills that required treatment.[37] To some extent, dredging was employed but only until a more permanent solution could be put into operation.[38] At the time of this study in 1966-1967, bottom panels were proving to be the best workable solution.

In summation, the choice had been made to use a balanced approach dividing the task of channel deepening and stabilization between large, permanent but inflexible water impoundment structures and permanent but flexible bottom panels. Working in combination, it was felt that these two systems would guarantee dry season barge passability on the middle Chao Phaya river.

It should be mentioned that water release through the Phomiphol dam is conditioned by factors other than navigational needs alone. Both the demands of irrigation and power generation must be met by this multipurpose structure and these water uses do take precedence over inland navigation. It is possible that future developments in agricultural or energy needs may detract from the supply of water that the Phomiphol dam can release for water transportation. Based on the findings presented by the French engineers and the Royal Irrigation Department in their river training studies, it can be assumed that this problem does not, at present, interfere with plans for successful river training on the middle Chao Phaya river.

Bottom Panels and Their Operation

The bottom panels that are being employed on the middle Chao Phaya are permanently fixed structures that have been submerged beneath the surface of the river. Their design and spacing is calculated to create water turbulence of a helical configuration whose action excavates the river bottom along one side and redeposits these materials behind the other side[39] (see Figure 2). The ability of the bottom panel to build up deposits along one of its sides is also used to good advantage. Often this sandbank is employed to close off secondary channels while building stable river margins.[40]

It is critical that the panels be placed at the correct angle to the river current in order to assure the desired results. Also, the panels must be placed on the area of highest water velocity across the sill selected for treatment.[41] This process of river deepening and channel stabilization is referred to as river training.

In the Chaiyo stretch of the Chao Phaya river, a single panel consists of four identical individual components each attached to two metal rails that have been driven into the river bed (see Figure 3). Each of these four-part panels has an overall length of 23 meters and a height of 0.75 meters.[42] They are spaced 50 meters apart and set at angles of 25 to 30 degrees to the water current. The extent of the angle depends on the desired curvature of the channel being deepened.[43] At the time of initial experimentation along the Chaiyo reach, the

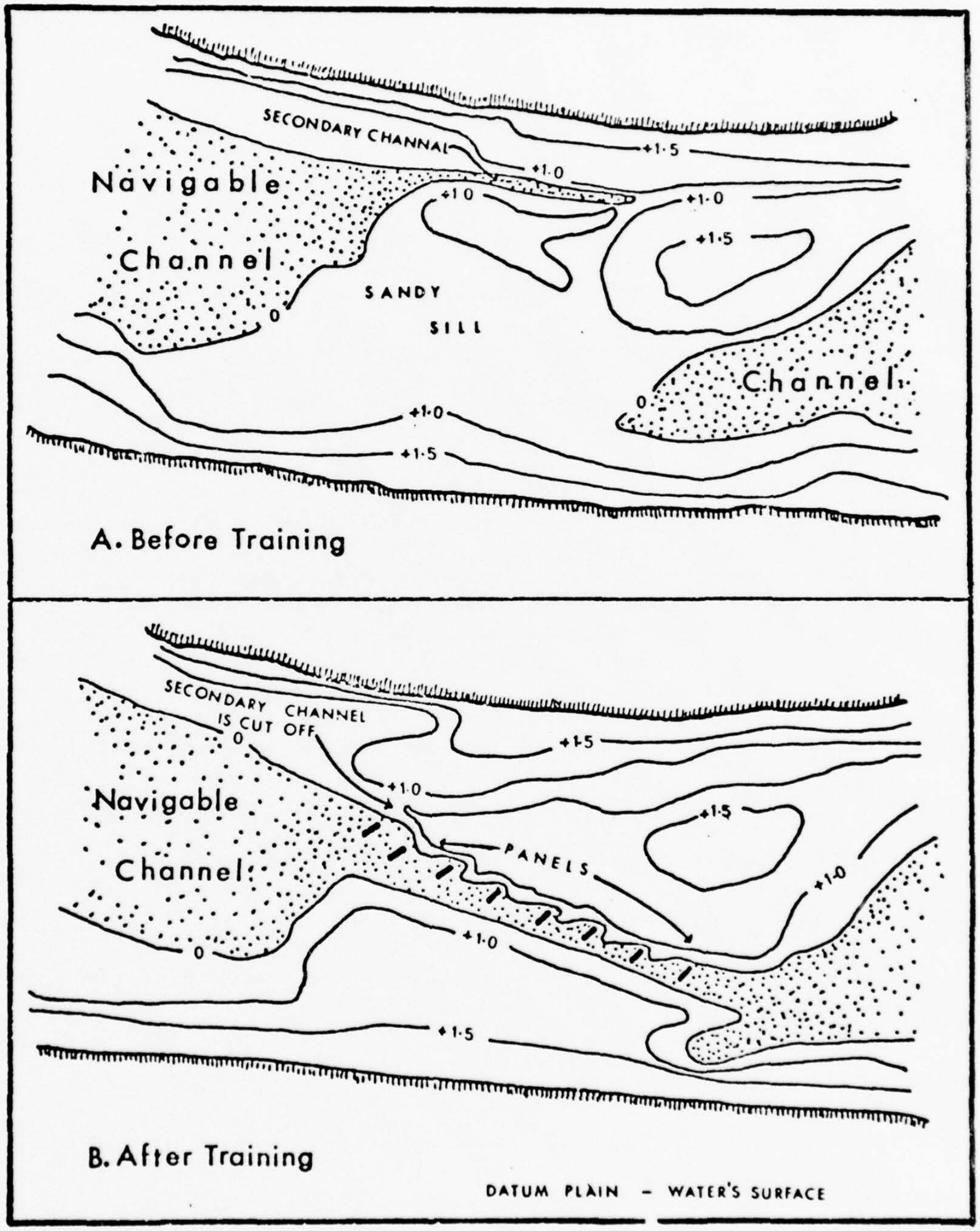


Figure 2. The impact of river training on a typical section of river bottom. Diagram A shows conditions before the insertion of bottom panels, diagram B shows how panels create a navigation channel.

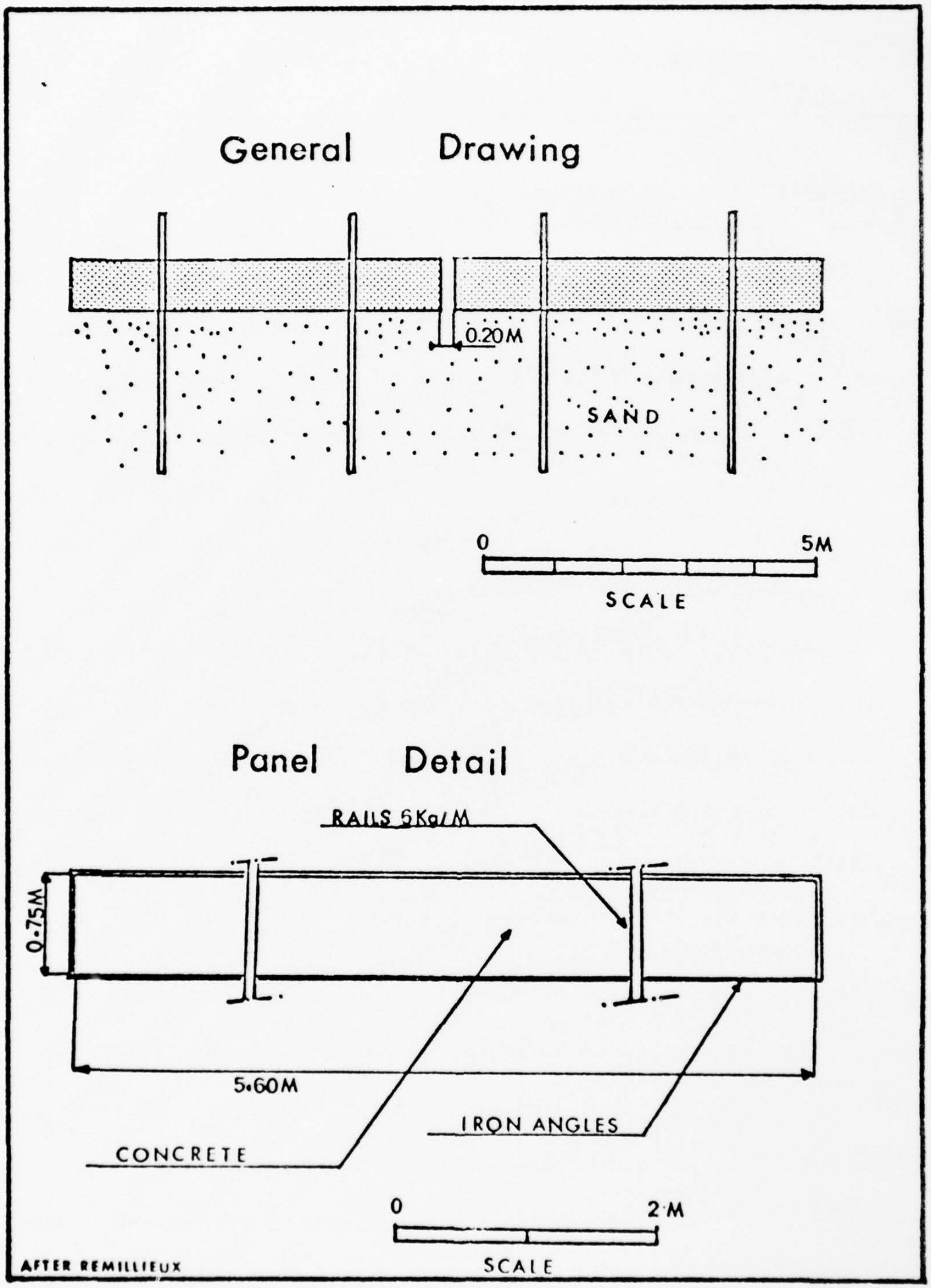


Figure 3. General drawing of typical bottom panels.

panels were made of metal. However, after the undertaking was considered to be a success, permanent panels of reinforced concrete were inserted in their place.[44]

The Estimated Costs of Training the Middle Chao Phaya River

Based on cost data compiled by the Royal Irrigation Department over the last five years, 1965 to 1970, it is estimated that river training on the middle Chao Phaya will cost 240,000 baht ($12,000) per kilometer over a distance of 120 kilometers of the middle Chao Phaya river. In addition to this initial outlay for construction, experience has shown that maintenance costs can be expected to be 13,000 baht ($650) per kilometer per year.[45]

Using the figure of 120 kilometers, the distance being treated by river training, the undertaking along the middle Chao Phaya will cost approximately 28,800,000 baht ($1,440,000). An additional maintenance expenditure of 1,560,000 baht ($78,000) per year will follow each year after initial construction is completed.[46] Chapter II will discuss the costs of river training in greater detail.

Conclusion

After four years of experimentation by the Royal Irrigation Department and their French team of technical advisors, a decision was made to continue with a program of river training along the middle reaches of the Chao Phaya. Experiments carried out on the Wat Chaiyo region showed that the navigation channel could be stabilized and deepened to the point where a minimum of 0.50 meters would be added to the depth of the water at all times of the year. If this increase in depth is transferred to the passability profile representing monthly depth conditions on the middle Chao Phaya before river training (see Appendix I), it is clear that after river training, vessels of at least 1.50 meter draft will be able to use the middle Chao Phaya river during periods of lowest water. If, in addition, we accept the statement appearing in the Harbor Department-National Statistical Office study that ". . . the depth of approximately 96% of the long-haul craft examined were between 0.4 and 1.3 meters . . ." it is evident that with completion of river training, a great majority of the long-haul vessels will begin using the Chao Phaya river during the dry season.[47] Official figures must be approached with some caution. They are based on long-haul vessel drafts compiled during a twelve month period. It can thus be expected that many of the vessels enumerated during this survey could have been carrying less than a full load and thus could have accommodated more cargo at the cost of increasing their draft requirements. Continuing this line of reasoning, many vessels encountered during the span of this survey were traveling light in order to conform to the depth restrictions imposed upon them by the water routes available in 1963 and 1964. Assuming this to have been the case, the recorded vessel drafts were lower due to vessel capacity left unused. Had deeper routes been available, especially during the dry season, the statistical node of 1.0-1.3 meters that is presented in the Harbor Department-National Statistical Office survey would have been skewed in an upward direction. If one looks at Figure 4, this assumption is further reinforced. According to this figues, over one-half of the vessels

Total Capacity Sacks of Rice	Draft when Empty in Centimeters	Draft at Half Capacity in Centimeters	Draft at Full Capacity in Centimeters
16	25		80
50	30		110
160	25	55	110
180	50	110	120
190	27		120
250	30	100	140
265	50		110
300	50		130
320	30	100	140
340	20		80
350	50		110
360	50		120
370	30	100	125
400	75		140
400	35	90	130
500			150
500	25	130	160
500	27		140
600	50	150	200
600	50		200
615	100		250
800	50	120	150
900	25		180
1,000	75		200

Figure 4. Relationships between barge size, cargo load and vessel draft requirements. The information is based on a questionnaire administered to barge operators by Project 30 field workers. Each entry represents the response of one barge operator. Note the wide differences between draft requirements of various barges with similar capacities.

registered had at full capacity draft requirements in excess of 1.3 meters.

Tests have proven river training to be feasible from an engineering point of view, and an estimation of construction and maintenance costs provides some measure of the investment that will be required to improve the middle Chao Phaya. The second part of this report will examine the possible benefits to water transport of river training and suggest how this alone might improve the competitive position of this traditional industry.

CHAPTER II

THE BENEFITS AND THE COSTS OF IMPROVING THE MIDDLE CHAO PHAYA RIVER FOR ALL SEASON BARGE USE

Introduction

The major objective of this chapter is to estimate a portion of the savings that river training on the middle Chao Phaya will afford the shipping industry and the national economy. Analysis of economic data will draw on various transportation cost-benefit studies and on barge cost information collected and analyzed by Project 30 personnel. Emphasis will be placed on the primary benefits and costs of river training with only minor stress placed on secondary cost-benefit factors.

Following this introductory section, Chapter II is divided into three additional sections. The first of these is devoted to the savings that will be realized by individual barge operators if the Chao Phaya route to Bangkok were open for shipping all year long. If this were the case, each bargeman would be able to increase his profit by making more trips each year.[1] This first section will examine the economics of barge operation through the middle Chao Phaya region as they existed in the middle 1960's.

The section following the above mentioned presents a comparison study of the annual savings that the inland water shipping industry would realize if all traffic could use the Chao Phaya route exclusively. Cost statistics that are compared are drawn from three recent studies of barge costs on Thailand's Central Plain.

In the final section a comparison is made of the costs and the benefits of river training. These comparisons are then projected into the 1970's on a yearly basis.

Savings to the Individual Barge Operator Assuming He Could Use the Route Through the Middle Chao Phaya Region All Year

Some Components in the Cost of Barge Operations

The prime mover in Thailand's inland water shipping system is the unmotorized cargo barge. This vessel is usually operated by a family and thus plays a dual role in their lives by providing them with both a dwelling and an income. In terms of primary costs, the barge as an economic unit is extremely insensitive to many of the cost factors common in the transport industry. Having no engine of its own to consume fuel or oil or to be maintained, barge time spent in transit while hauling cargo is only indirectly sensitive to time and distance. The costs incurred over time and distance appear in the rates charged to the barge operator for towboat service and in the tolls collected at the various navigation locks.[2]

Because it is operated by a family who make it their home, the average cargo barge does not generally employ outside labor and, if on occasion one does, the terms of employment vary from daily wages to merely a ride to Bangkok. Acting as a family dwelling, subsistance costs do not change whether the vessel is engaged in trade or moored and idle at some provincial town or in the nation's capital. Excluding the increased hazards involved in traveling along a waterway as opposed to remaining stationary, vessel maintenance costs are the same whether the barge is employed in trade or not.[3] For these reasons, this discussion of barge transportation costs will begin with an examination of the most outstanding time-distance sensitive operating components in the cost of barge operations. Any reduction in these cost variables should be quickly reflected in a reduction of the overall cost of barge operations. For this reason their reduction should be considered as a possible source of savings.

Variable Towboat Operating Costs

In an attempt to identify some of the primary costs involved in moving cargo on each of the system's major routes, it is necessary to examine the most time and distance sensitive operating unit of the water transport industry, the towboat.

The expenses incurred in towboat operation are transmitted to the barge operator in the form of towboat rates and thus affect the cost of water transport over distance and time.

Based on Nelson's tabulation of data recorded in Project 30's first and second river surveys, it can be estimated that each channel displayed the following ratio of towboats to barges.[4]

Suphan	7.5 Barges per Towboat
Noi	7.5 Barges per Towboat
Chao Phaya	8.5 Barges per Towboat

A comparison of these ratios of barges to towboats with the total number of southbound barges counted in the 1966 second Harbor Department, National Statistical Office survey reveals that the Suphan route required 292.13 towboat trips, the Noi route required 452.26 towboat trips, and the Chao Phaya route required 251.05 towboat trips. The combined routes through the middle Chao Phaya region carried a total of 995.44 southbound long-haul towboat trips pulling an aggregate of 7,717 barges, all bound for the Bangkok market.[5]

The writer recognizes that the operation and ownership of a long-haul towboat involves many expenses, the cost of which must be defrayed through the towing fees charged each barge availing itself of towboat service. Many of these expenses are fixed, such as license fees, depreciation costs, maintenance expenditures, etc., and have little sensitivity to the actual distance traveled and the work accomplished. Other expenses, such as wages, fuel and tolls, are sensitive to distance traveled and the work done by the vessel. These can be thought of as line-haul costs. In this category, costs increase in direct proportion to the extent of the towing operation undertaken as expressed in both distance and time. In the following discussion of towboat costs, the writer will limit the focus of this examination to these variable operating (line-haul) costs that are incurred while pulling a string of loaded barges southward on the middle Chao Phaya region's three major water routes: the Suphan, the Noi and the Chao Phaya.

In the operation of a towboat, the most distance related cost variable is the consumption of fuel and oil. The most time sensitive cost is the wages paid to hired labor which, in this study, will be computed on a working day basis. Finally, a major variable towboat operating expense is the fee paid at each navigation lock. This last cost item is dependent on the route chosen for transit through the middle Chao Phaya region.

Towboat Fuel Consumption

In a recent transportation study completed in 1970, it was calculated that an average long-haul towboat consumed twelve liters of fuel for every hour of operation.[6] In addition, it was estimated that oil consumption was 0.6 liters per hour. Within the Chao Phaya system, the operating time along each route varies in accordance with the distance and the speed at which a towboat can haul a string of barges.

Under optimum wet season conditions towboats are able to operate on the Chao Phaya route on a day and night schedule, and since the trip through the middle Chao Phaya region to Bangkok under such conditions requires three days, it can be safely assumed that the towboat actually is underway for 36 hours or two days and one night.[7] In contrast, on the Suphan and the Noi routes through the middle Chao Phaya region, operation generally stops during the hours of darkness thus limiting the activity of a towboat to about twelve hours a day. On the Suphan route the trip from the town of Chai Nat to Bangkok requires seven days while on the Noi route it takes five days. In terms of actual hours of operation during which time consumables are being depleted, the Suphan route requires eighty-four running hours and the Noi sixty running hours.

In order to present as fair a picture of fuel and oil costs as possible, some allowance for waiting time at locks has to be included in the calculations. Although a towboat is still in transit, its engines are shut off while waiting to pass through a lock. The writer has allowed a deduction of two operating hours for each lock on each of the three routes under study. The fuel and oil consumed by an average towboat engaged in hauling barges from Chai Nat to Bangkok is presented by route in Table 1.

Towboat Toll Fees

The toll fee levied on an average towboat passing through one of the Royal Irrigation Department's locks within the middle Chao Phaya region is 22 baht per lock. This figure was arrived at by comparing average towboat sizes with the Royal Irrigation Department's lock toll schedule.[8] Table 1 presents a total of the major operating expenses just outlined.

Comparison of Variable Towboat Operating Costs by Route Through the Middle Chao Phaya Region

If a comparison is drawn between the primary variable operating expenditures (line-haul costs) for towboats traveling on the three routes through the middle Chao Phaya region, it is seen that the Chao Phaya route is the least costly. Towboat costs via the Noi are 62.94 percent greater than on the Chao Phaya while on the Suphan they are 127.63 percent higher. Extension of the 1966 twenty-four day Harbor Department National Statistical Office survey establishes that a total of 452.2 towboat trips were made to Bangkok via the Noi route, 292,13 via the Suphan route, and 251.05 trips via the Chao Phaya route.[9] If all towboat costs for the twenty-four days in 1966 are combined by channel,

TABLE 1

VARIABLE PER TRIP OPERATING COSTS FOR A TOWBOAT PULLING LOADED BARGES THROUGH THE MIDDLE CHAO PHAYA REGION TO BANGKOK VIA THE SUPHAN, NOI AND CHAO PHAYA ROUTES (IN BAHT)

Route	Trip/Days	Hours of Operation[a]	Locks		Wages	Oil Costs	Fuel Costs	Total Costs
			Number	Fees				
Suphan	7 days	72	6	132	490.00	388.80	864.00	1,874.80
Noi	5 days	60	4	88	350.00	280.80	624.00	1,342.00
Chao Phaya	3 days	34	1	22	210.00	183.60	408.00	823.60

[a]Hours of actual operation after deduction of two hour waiting time for each lock on the route.

aggregate figures are as follows:

Suphan Route	549,560.12 ฿
Noi Route	607,294.73 ฿
Chao Phaya Route	206,764.78 ฿
Total	1,363,619.63 ฿

From the above statistics based on samples taken over twenty-four days in 1966, it is seen that 1,363,619.63 baht was spent over those twenty-four days on towboats operating through the middle Chao Phaya Region. Of a total of 996.44 towboat trips recorded over those days, only 251.05 were made over the less costly Chao Phaya route. This low number of trips on the Chao Phaya route can be attributed to the fact that this channel is passible for only a few months each year--during the wet season.[10] For the sake of comparison, assume that all 996.44 towboat trips could have been made via the Chao Phaya route. Had this been the case, total operating expenses over the twenty-four days of the survey would have been 542,915.65 baht less. This represents a savings of 39.82 percent. Applying these same figures to the remaining 341 days during which barge traffic was not counted, we see that total savings would have been approximately fifteen times greater.

Barge Toll Fees

The fees that barge operators must pay vary to a great degree from channel to channel through the middle Chao Phaya region. Most costly in this respect is the Suphan river route which requires that a vessel pay a toll at six locks. The Noi is not as expensive with four tolls and least expensive is the Chao Phaya route which has only one lock at the Chao Phaya dam. Depending on the route used, the fees charged for passing Royal Irrigation Department locks can be quite expensive.

Primary barge costs are more difficult to arrive at than are those of the towboat. As mentioned earlier, the difficulty lies in the fact that since a barge has no engine of its own and serves not only as a commercial transport vessel but also, in a majority of cases, as a family residence, barge operation is very insensitive to factors of distance and time. In most cases, a barge is operated by members of a family whose subsistence expenses are the same whether the boat is underway or moored, working or idle. Since the barge has no engine, no consumable items can be calculated as being depleted over distance or time. In total, the major primary variable (line-haul) barge costs are limited to towboat fees and navigation lock fees. From locations below Nakhon Sawan, towboat fees remain the same for each shipping point regardless of route used or season.[11] Under these conditions, the only primary operating costs with any degree of variability from route to route and thus season to season is the lock fees which do add considerably to vessel line-haul costs in accordance with the route selected.

As was the case with towboat traffic, barge toll fees are based on the dimensions of the vessel. In the latter case, however, the sole determining factor is vessel width.[12] The dimensions of a barge have some bearing on capacity but due to some slight difference in vessel shape, the relationship between capacity and width is not always the same. Thus within certain vessel categories, there are some differences in toll fee.

TABLE 2

RESULTS OF A SAMPLE TAKEN TO ESTABLISH A CORRELATION BETWEEN BARGE CAPACITY AND TOLL FEES

RID Regulations[a]		Results of Sample[b]	
Toll in Baht	Width in Meters	Barge Size Groupings in Toll Category	Range of Cargo Carried in Tons of Rice
4.00	3 - 3 1/2	Mostly Ob size craft and small capacity barges	No cargo tonnage registered
6.00	3 1/2 - 4	Large Ob size craft and small barges	12 - 36
8.00	4 - 5	Small barges only	30 - 50
10.00	5 - 6	Medium and large barges	55 - 130
10.00+	6+	No vessels recorded	

[a]Royal Irrigation Department toll fee categories.

[b]Based on information gathered in the general questionnaire.

Based on the records of the four Project 30 river surveys, the average load carried by barges in transit on the three channels of the middle Chao Phaya region were of the following magnitude:

Suphan Route	41.56 Tons
Noi Route	27.91 Tons
Chao Phaya Route	32.06 Tons

If these average barge-load statistics are compared with the barge-load dimension correlations presented in Table 2, the relationships presented below in Table 3 emerge.

TABLE 3

CORRELATION BETWEEN AVERAGE BARGE TON LOAD, POSSIBLE TOTAL CAPACITY AND LOCK FEES

Route	Cargo Ton Average	Cargo Size Range[a]	Lock Fee
Suphan	41.56	30-50 Tons	8.00 ฿
Noi	27.91	12-36 Tons	6.00 ฿
Chao Phaya[b]	32.06	12-36 Tons 30-50 Tons	6.00 8.00 = 7.00 ฿

[a]Size range taken from Table 2.

[b]A vessel with a capacity of 32.06 tons can fall within the 6 or 8 baht lock fee category.

In 1963 and 1964, the Harbor Department in cooperation with the Economic Development Board and the National Statistical Office conducted a survey of water traffice on the Central Plain. In the report which emerged from this survey there is a table presenting an enumeration of long distance barges classified by changwat of origin that were estimated to have entered the Bangkok area during a twelve-month period.[12] Of the ten northern changwats listed as having been the origin of barge cargo, five are located above the middle Chao Phaya region and, presumably, shippers located in these changwats would have a choice of shipping via any of the region's three wet season transport routes and two dry season ones. The five changwats in question and the vessels estimated to have originated from their ports are as follows:

Chai Nat	2,424 Barge Trips
Uthai Thani	864 Barge Trips
Nakhon Sawan	8,196 Barge Trips
Phichit	6,156 Barge Trips
Phitsanulok	2,208 Barge Trips
Total	19,848 Barge Trips

In 1966 another vessel survey was conducted by the same governmental agencies. This time enumeration was limited to traffic moving in and out of the Bangkok area over a twelve-month period.[13] Of the survey days in which barge enumeration was made, twenty-four in total spread evenly over the year, approximately 37.41 percent used the Suphan route, 34.41 percent used the Noi route and approximately 28.39 percent used the Chao Phaya route.

If these estimated percentages, general as they may be, are applied to the 1963-1964 survey of vessel trips by changwat of origin, it is seen that each of the middle Chao Phaya region's three routes carried the following number of vessels:[14]

Route	Vessel Trips
Suphan	7,410.14
Noi	6,815.70
Chao Phaya	5,622.85
	19,848.69

In Table 3, the first column presents the average vessel cargo tonnages that moved on the three middle Chao Phaya region routes as established during the four Project 30 river surveys. If these averages are applied to the barges that entered the Bangkok area from the five changwats above the middle Chao Phaya region, it can be estimated that each route passed the following cargo tonnage in the twelve month period in 1963-1964.

Route	Tonnage Carried
Suphan	308,588.69 Tons
Noi	190,616.84 Tons
Chao Phaya	180,653.20 Tons
	679,858.73 Tons

Table 4 presents collective statistics on the barges that used each of the middle Chao Phaya region's three routes and the combined cargo tonnage and lock tolls paid. Assuming that conditions had allowed all barge trips to have been made via the Chao Phaya route, the costs would have been 19,601.69 baht in the twelve months of the survey as opposed to the actual estimated cost of 76,364.49 baht. Put another way, if the Chao Phaya route could have been used for all commodity tonnage

TABLE 4

BARGE TOLLS PAID ON THE THREE MIDDLE CHAO PHAYA ROUTES
DURING THE FIRST HARBOR DEPARTMENT SURVEY
1963-1964

Route	Locks	Fee/Lock Average	Total Barge Trips	Total Collected /Lock	Total Collected All Locks
Suphan	6	8฿	6,815.70	7,305.14	43,830.84
Noi	4	6฿	5,622.85	6,745.70	26,982.80
Chao Phaya	1	7฿	7,410.14	5,550.85	5,550.85
Totals			19,848.69	19,601.69	76,364.49

reported in the first Harbor Department survey, there could have been a savings in tolls paid of 56,762.80 baht.

In the next section of this chapter, transit cost statistics will be cited as they apply to shipping expenses from the town of Chai Nat to Bangkok along the middle Chao Phaya region's three water routes: the Suphan, the Noi and the middle Chao Phaya river. These figures are drawn from mid-1960 cost estimates and reflect water transportation at a time when the middle Chao Phaya was closed to most shipping during the dry season.

In the preceding discussion it was established that opening the middle Chao Phaya to shipping on a twelve month basis would allow a 40 percent reduction in towboat operating expenses and a 74 percent reduction in barge toll costs. It is impossible to speculate what proportion of these savings would be translated into a lowering of water shipping rates, but they should contribute to a substantial decrease in costs incurred by water transport in the middle 1960's.

Comparison Study of the Annual Costs of Water Transport Through the Middle Chao Phaya Region

Barge Shipping Costs as Related to Ton Distance

In recent years, several studies have been conducted on barge operating costs. In most cases, these studies made no distinction between the cost of using various navigation channels or the different seasons of the hydrologic year; both of which undergo wide fluctuations in condition. The results arrived at by such studies represent an average of barge operation costs as drawn from many routes in the Central Plain and for all seasons of the year.

What follows is a brief review and manipulation of cost figures arrived at in three separate studies: one prepared by a Project 30 staff member, Mr. Phaijayont Uathavikul, in a Master's thesis,[15] a second, entitled "Thailand Transportation Coordination Study," prepared by Wilbur Smith and Lyon Associates,[16] and a third prepared by the Mission Française de Cooperation Technique.[17]

Mr. Uathavikul's Barge Cost Evaluation

In this Project 30 member's evaluation of the economic data gathered in a general barge questionnaire, the average ton kilometer operating cost for a barge engaged in trade on the Central Plain is .0619 baht.[18] If this information on average ton kilometer cost is calculated for the distance through the middle Chao Phaya region from Chai Nat to Bangkok via the three major routes, the following cost relationships emerge:

Route	Cost/Ton Trip
Suphan (271 km.)	16.774 Baht
Noi (242 km.)	14.979 Baht
Chao Phaya (234 km.)	14.484 Baht

According to these statistics, the savings per ton trip realized by using the Chao Phaya route exclusively over the Suphan and the Noi routes is ฿ 2.290 and ฿ 0.495 respectively.

Wilbur Smith and Lyon Associates'
Cost Evaluation

In this study the cost for barge transport in what is termed the northern sector, is given as ฿ 0.206 per ton kilometer.[19] If this figure is applied to the journey through the middle Chao Phaya region from Chai Nat to Bangkok, the following cost figures per ton trip emerge:

Route	Cost/Ton Trip
Suphan (271 km.)	55.826 Baht
Noi (242 km.)	49.852 Baht
Chao Phaya (234 km.)	48.204 Baht

Using the above figures, it will be seen that the Chao Phaya route costs ฿ 7.622 per ton trip less than the Suphan route and ฿ 1.648 per ton trip less than the Noi route.

Mission Française De Cooperation
Technique's Cost Evaluation

In this report, barge operation costs are divided into two categories based on the passability conditions each displays. Group one is concerned with costs incurred while negotiating narrow channels with multiple locks often with decreasing cargo loads. The channelized portions of the Noi and the Suphan from the northern beginnings of each to Sena fall within this category. Group two is concerned with barge costs as incurred while traveling on wider, deeper channels with little or no interference from locks thus enabling better travel times to market. The wet season Chao Phaya route fits within this grouping.

From the standpoint of this study, it must be underlined that the two-fold approach to cost allocation is the most meaningful when considered in light of the fact that this study is attempting to compare the efficiencies of cargo transport through the three main separate channels of the middle Chao Phaya region. In essence, this report issued by the French technical team fits best with the objectives of this paper since the category division corresponds to dry season route costs and wet season route costs within the middle Chao Phaya region.

According to the data issued by the Mission Françaíse de Cooperation Technique, barge costs along the system's broad, deep waterways like the Chao Phaya river (category two) during the wet season are $0.007 per ton kilometer within a distance of 300 kilometers from the capital city.[20] Using this factor as a basis for calculation and projection, barge costs through the middle Chao Phaya region via the Chao Phaya route to Bangkok can be set at $1.14 or ฿ 22.80 per ton trip.

The report estimates that barge costs when traveling on category one channels exceeds category two channel barge costs by 50 percent. Since the Suphan and the Noi routes fall within the category one grouping over much of their distance (from their beginnings at Chai Nat south to Sena), the higher cost factor applies in part to barges using these

TABLE 5

THE COSTS INCURRED FOR SHIPPING ALL COMMODITIES THROUGH THE MIDDLE CHAO PHAYA VIA THE SUPHAN, NOI AND CHAO PHAYA ROUTES AS ESTIMATED BY HARBOR DEPARTMENT SURVEY IN A TWELVE-MONTH PERIOD, 1963 AND 1964

(Cost in Baht)

Route	Uathavikul[a]	Smith/Lyon Associates[b]	French Mission[c]
Suphan	5,176,266.69	17,227,272.21	19,317,651.99
Noi	2,855,249.65	5,464,618.70	4,209,286.66
Chao Phaya	2,619,557.84	5,237,518.85	2,477,293.00
Total	10,651,074.18	27,929,409.76	26,004,231.65

[a]Cost statistics are based on Phaijayont Uathavikul's unpublished Master's thesis. It is entitled, "Inland Waterway Transportation," 1972.

[b]Cost statistics taken from Wilbur Smith and Lyon Associates Report, "Thailand Transportation Coordination Study," Bangkok, 1970.

[c]Taken from Mission Française de Cooperation Technique, unpublished report, 1963.

two routes. The higher cost can be applied to 176 kilometers of the Suphan route and 89.50 kilometers of the Noi route. Below Sena, south to Bangkok, the lower category two rates are once again applicable. Combining the two rates, the ton per trip costs through the middle Chao Phaya region to the Bangkok market are as follows for the Suphan and the Noi routes:

Route	Cost/Ton Trip
Suphan	3.13 Dollars
Noi	1.92 Dollars

Comparing the middle Chao Phaya's wet and dry season routes, it becomes clear that the Suphan and the Noi routes exceed the Chao Phaya route by a cost of $1.99 or ฿39.60 and $0.78 or ฿15.60 per ton trip respectively.

A Comparison of Barge Costs as Estimated in the Three Economic Studies

If the statistics of cargo tonnage estimated to have moved via the Suphan, the Noi and the Chao Phaya routes in 1963-1964 (see p. 34) are applied to each of the three study's cost projections, the annual aggregate costs appearing in Table 5 emerge.

Assuming that the middle Chao Phaya river were open to shipping on a year-round basis and that all the tonnage that moved via the Suphan and the Noi routes had been moved instead via the Chao Phaya, the total cost per ton as computed from each study's estimates would, in every instance, have been lower:

Total Tonnage	Uathavikul	Smith/Lyon Associates	French Mission
679,858.73	9,847,073.84฿	25,396,698.22฿	12,012,379.00฿

A comparison of the data presented in Table 5, showing the actual estimated cost, and the data presented above, showing the hypothetical cost if all tonnage had gone exclusively via the Chao Phaya route, reveals that use of the Chao Phaya route would have resulted in a reduction in total operating costs in the amounts shown below:

Uathavikul Estimate	
a. Actual estimated cost	10,651,074.18฿
b. Cost if all had used Chao Phaya	9,847,073.84฿
Savings	804,000.34฿
Wilbur Smith and Lyon Associates	
a. Actual estimated cost	27,929,409.77฿
b. Cost if all had used Chao Phaya	25,396,698.22฿
Savings	2,532,711.50฿
Mission Française	
a. Actual estimated cost	26,004,231.65฿
b. Cost if all had used Chao Phaya	12,012,379.00฿
Savings	13,991,852.65฿

Summary of Barge Operating Cost Estimates

Of the three cost estimates considered in the previous pages, only one divided barge costs into wet and dry season categories. The other two studies gave one average barge cost estimate for all seasons. By joining the ton kilometer cost estimates given by each study with the actual average annual tonnages estimated to have moved to Bangkok via the three routes in the 1963-64 survey, a total annual cost estimate was provided for each study.

Uathavikul	10,657,074.18฿
Wilbur Smith and Lyon Associates	27,929,409.76฿
Mission Française	26,004,231.65฿

To establish some basis for projecting the monetary benefits to the shipping industry and the nation's economy by improvement of the middle Chao Phaya route to the point where all year shipping is possible, the savings were computed by comparing present costs with costs when all shipping can exclusively use the less expensive Chao Phaya route.

Uathavikul	804,000.34฿ Savings
Wilbur Smith and Lyon Associates	2,532,711.50฿ Savings
Mission Française	13,991,852.65฿ Savings

A Projection of Water, Rail and Road Transportation Costs on the Central Plain

In the seventies, it is expected that all modes of transport will be required to carry increasing amounts of cargo. According to Wilbur Smith and Lyon Associates' calculations, the water, road and rail routes connecting Bangkok with the northern areas of Thailand, between the years 1968 and 1978, will register a total increment of 7,335,000 tons of cargo.[21] The following portion of this chapter will examine the impact that projected 1978 cargo loads will have on road, rail and water costs.

In Chapter Nine, entitled "Future Requirements," the Wilbur Smith and Lyon Associates' study presents a projection for 1978 of all the goods expected to move over Thailand's transport arteries.[22] This information is presented in the Study's Table 99 which is entitled: "Distance Distribution of Corridor and Modal Volumes, Kingdom of Thailand, 1973 and 1978."[23] In Table 99, the origins of commodity tonnages are lumped together within five 100 kilometer zones. Each zone encircles the other in concentric fashion with Bangkok as the center at kilometer zero. These circular zones are in turn pierced by transportation corridors: the northern corridor (including the Central Plain), the northeastern corridor, the southern corridor, and the western corridor.

In order to apply the contents of the above described table to the requirements and purpose of this chapter, the writer has taken the liberty of making some alterations in the data as presented therein.

First of all, because all origins (with the exception of Bangkok at kilometer zero) were not specific as to place but were merely any location within each 100 kilometer zone, the writer arbitrarily designated the point of origin to be midway within each zone. This assigned starting point for all cargo represents an average of all distances within each concentric zone. Such manipulation allows the writer to amend the original Wilbur Smith and Lyon Associates' calculations to include a more accurate distance factor. The one exception is within the 100 to 200 kilometer zone. In this zone shippers in only three prominent shipping points would benefit from river training on the middle Chao Phaya river: Sing Buri, Chai Nat, and Uthai Thani. For this reason, the starting point within the zone was advanced to 175 kilometers instead of 150. Also, as a concession to this reduction in shipping points within the 100 to 200 kilometer zone, only 1/3 of all cargo tonnage originally assigned by Wilbur Smith and Lyon Associates was used in the calculations.

Secondly, liberty was taken to exclude the consideration of all cargo tonnages traveling within the 0 to 100 kilometer zone and traveling to and from areas beyond the 400 kilometer zone. The first zone, 0 to 100 kilometers, was excluded from consideration as cargo movements within that distance of Bangkok are not considered as falling within the long-haul category. The last area, beyond the 400 kilometer zone, is poorly served by road, rail and water and it was found difficult to assign tonnages to distance points so far removed from the center of the kingdom. Thus, this modified version of the Wilbur Smith and Lyon Associates' projection for 1978 was limited to a consideration of cargo movements within an area of the northern corridor lying between 100 and 400 kilometers distance from Bangkok.

To the above described statistics on tonnage, distance and transport mode, the writer assigned a cost per ton trip estimate. The cost estimates used for barge shipment were drawn from an average cost derived from calculating the expense of moving all commodities over the Central Plain.[24] The figure used includes both fixed and variable expenses and amounts to .0619 baht per ton kilometer.

Truck costs are based on a Wilbur Smith and Lyon Associates' estimate of 1.952 baht per ten ton capacity vehicle operating within the confines of the northern corridor. On a ton kilometer basis, truck costs can be set at .1952 baht.[25] This cost estimate includes both variable and fixed truck costs.

Rail freight costs are drawn from Wilbur Smith and Lyon Associates' study as well.[26] These figures are divided into two categories: line-haul costs, which amount to .1225 baht per ton kilometer within the northern corridor, and terminal costs, which are placed at 8.25 baht per ton and apply to the entire nation. Table 6 presents in summary fashion a potpourri of the foregoing statistics as they apply to each of the shipping zones between kilometer 100 and 400.

TABLE 6

ESTIMATED SHIPPING COSTS BY WATER, ROAD AND RAIL IN 1978 TO AND FROM ZONES BETWEEN 100 AND 400 KILOMETERS DISTANT FROM BANGKOK (IN BAHT)[a]

Zone	Water	Road	Rail
100-200	5,466,826.75	21,862,400.00	9,861,250.00
200-300	5,571,000.00	24,985,600.00	11,545,625.00
300-400	14,060,585.00	77,406,560.00	21,094,500.00
	25,098,411.75	124,254,560.00	42,501,375.00
		Terminal	10,964,250.00
			53,465,625.00

[a]The 1978 tonnages moving to and from each zone and Bangkok are as follows:

Zone	Water	Rail	Road
100-200 km.	504,669 tons	460,000 tons	640,000 tons
200-300 km.	360,000 tons	377,000 tons	512,000 tons
300-400 km.	649,000 tons	492,000 tons	1,133,000 tons
	1,513,669	1,329,000	2,285,000

All tonnage statistics are taken from Wilbur Smith and Lyon Associates', "Thailand Transportation Coordination Study," p. 449.

As was pointed out earlier, barge haulage costs are the lowest of the three modes of transport competing for cargo on the Central Plain. Per ton kilometer rail costs are 1.98 times greater than barge costs, and road costs are 3.15 times greater per ton kilometer. The Wilbur Smith and Lyon Associates' 1978 tonnage projection for the northern corridor assigns the lowest percentage of all cargo moved to barge (29.97%) while both rail and truck are given a higher percentage (31.01% and 39.02% respectively).[27] If the Chao Phaya river were opened to year-round barge navigation, the writer feels that much of the cargo now moving by rail and road under present dry season conditions of negative passability would be shifted to water transport.

An examination of the Harbor Department's 1966 survey of vessel trips into Bangkok by survey day shows that during the wet season an average of 99.60 vessels entered Bangkok from areas above the middle Chao Phaya region.[28] During the dry season, however, this average dropped to 48.70 daily vessel trips. Put another way, barge traffic from changwats above the Chao Phaya dam dropped by 36.12 percent during the dry season. The writer assumes that a large portion of this dry season decrease represents cargo shipped to Bangkok by the faster means of road and rail. Also, if the middle Chao Phaya river were improved to a point where shipping could use it all year, some of this lost cargo would, once again, be reassigned by the shipper to less expensive water transport. Substantial savings could be realized by making such a reallocation of cargo.

There is little doubt that improvement of the Chao Phaya would reinforce the competitive position of water transportation. By shortening the travel time through the middle Chao Phaya by four or five days and by increasing the safety of this passage, two steps would be taken in the direction of eliminating the two most important points of criticism expressed by shippers, speed and safety. The fact that opening the middle Chao Phaya river during the dry season would also help to reduce barge operating costs should also improve that transport mode's ability to compete with road and rail. Thus, if the river is improved, we can expect an increase in water transport's share of the long-haul shipping trade.

Other Benefits of River Training

The writer wishes to make it very clear that, in addition to the primary costs and benefits previously outlined, there are others of a more secondary nature that also have significance for the costs and the benefits stemming from river training. Although no detailed account of these several factors will be attempted here, mention, nevertheless, should be made of them.

Opportunity Costs

Any improvements that decrease the time it takes a loaded barge to travel through the middle Chao Phaya region also decrease the cost in terms of economic opportunity. Ordinarily, if it takes a barge seven days to make the journey from Chai Nat to Bangkok and this trip, after river training, can be reduced to three, there is a saving of four days in which time the bargeman can spend, hypothetically, his energies in some other economically rewarding pursuit. The savings thus realized can be calculated various ways. Mr. Uathavikul, in his Master's thesis, allows ten baht a day for a bargeman's time.[29] This is the wage a similarly unskilled laborer would receive on the Bangkok labor market. Every day that the barge operator is engaged in transfering cargo has a cost of opportunity attached to it valued at ten baht. Another approach toward calculating opportunity cost is to consider both man and barge as a single production unit attaching some daily income value to them. Each day saved by being able to employ the middle Chao Phaya route, four days over the time it takes via the Suphan and two days over what it takes over the Noi, can be calculated as one in which the income value of the barge operator and his vessel can be added to the benefit side of the cost-benefit ledger. Without going into the numerical calculations, it is evident that opportunity costs will be reduced significantly after the middle Chao Phaya becomes operative all year long. These savings can be added to the benefits derived from river training.

Taking Advantage of an Already Available Transportation Link

Another factor that helps to strengthen the argument in favor of improving the Chao Phaya river is the fact that to do otherwise would be to neglect taking advantage of a natural transport network that, in terms of potential capacity, costs little per kilometer to construct and maintain when compared with the other, completely man-made transport links. For instance, in 1966 the cost of building a heavy duty first-class roadway over a flooded plain like that found on much of the Central Plain was approximately 3,780,404 baht per kilometer.[30] On the other hand, river training on the middle Chao Phaya costs 240,000 baht per kilometer.[31] Once a highway is completed, maintenance is another significant cost item. The cost quoted in the General Engineering Company's cost-benefit study on the Thon Buri-Paktho highway, quoted in part below, indicated that the maintenance of a heavy duty highway is considerably greater in cost than those figures of 13,000 baht per kilometer quoted for river training on the middle Chao Phaya.[32]

> The unit cost over the approximate distance of 85 kilometers and the 20-year life [of the Thon Buri-Paktho highway] is approximately 52,000 bahts per kilometer per year. . . . Maintenance records for various types of highways in Thailand have been tabulated for only the past four years, and these records are not entirely comparable as they generally include both minor and major reconstruction. An analysis of these records indicates, however, that higher-class highways require an annual maintenance expenditure in the order of 40,000 bahts per kilometer per year. The higher estimated maintenance cost for the Thonburi-Paktho highway is attributed to considerably poorer subgrade soil conditions, heavy and dense truck traffic and an anticipated higher standard of maintenance.

Using the lower maintenance statistic of 40,000 baht per kilometer per year, it can be estimated that it would cost 4,800,000 baht per year for upkeep on 120 kilometers of first-class highway as opposed to 1,560,000 baht for the improved middle Chao Phaya. Also to be considered is the fact that a highway, as with a rail line, must be elevated above the flood plain in all sections to avoid inundation during the rainy season. In contrast, only certain portions of a waterway system like that found on the Central Plain need treatment. The Chao Phaya river provides a good example of this as only sections along a 120 kilometer portion of the 225 kilometers of river channel between Chai Nat and Bangkok must be subjected to training.

Savings of Foreign Exchange

Still another area where improvement of the inland waterway system benefits the nation's economy is the foreign exchange that such a transportation system conserves. Of all modes of transportation, that of waterway shipping requires the least expenditure of foreign currency. The cargo barges are completely built in Thailand of domestic raw materials. In the operation of moving cargo over the inland waterway system, only towboats require imported equipment in the form of internal combustion engines and only the towboat consumes imported fuels. Both truck and rail transport, on the other hand, require the importation of most of their operating components and, with the present effort to dieselize the entire railroad system, rail freight now runs almost exclusively on imported fuels.

Other Economies Inherent in Barge Shipment

Improving the time efficiency of barge cargo movement will help to stimulate the barge industry and will make it more competitive with road and rail. There are certain advantages to barge shipment which should be discussed in context with this, the catch-all section of Chapter II.

Barges not only function as transporters of cargo but also as places in which to store non-perishable cargo. Many shippers move goods to market prior to sale and hold them in the cargo vessel until a suitable price is worked out at the marketplace. Of a sample of sixteen barges questioned about storage operations, the indicated average waiting time until the vessel was unloaded was 4.8 days. Barges carrying grains registered the longest average wait: rice barges (seven questioned) 5.9 waiting days, and maize barges (four vessels questioned) 4.6 days average waiting time.[33] Occasionally vessels are asked to wait for longer periods of time. The average maximum waiting time for all sixteen vessels was fourteen days with rice cargoes again requiring the longest maximum waiting period at a sixteen day average. The average maximum waiting time for maize was 11.9 days.

Given the congested situation in marketplaces like Bangkok, barge storage provides inexpensive space not so readily available to the shipper who employs road or rail transport. Shippers using land transport must unload their cargo immediately upon arrival at the market. It is safe to assume that if all the cargo presently stored in barge holds had to find immediate godown space upon reaching Bangkok, the result would be even more congestion along the waterfront and increased pressure on already heavily taxed land storage facilities.

Another related advantage inherent in barge shipment is that cargo destined for export need not be transshipped before being transferred to ocean going vessels. Much of the rice crop and almost all of the maize harvest are exported through the Port of Bangkok. By holding these commodities in barges until they are loaded onto deep sea vessels, the already overcrowded streets and godowns of Bangkok's water front are relieved of a great deal of potential additional burden.

A Comparison of the Costs and the Benefits of River Training on the Middle Chao Phaya River

The Costs of River Training

In Chapter I, the construction cost estimate for training the middle Chao Phaya river was set at 28,800,000 baht. In the ensuing comparison of river training costs and benefits, this 28,800,000 baht initial investment expenditure will be discounted over a twenty year period.[34] Assuming that the opportunity cost of capital for such a project is 12 percent per annum, the total construction plus capital opportunity cost, when distributed over twenty years, is 96,288,000 baht.[35]

Added to the above estimate of construction and financing costs must also be an annual maintenance cost. In the case of the middle Chao Phaya this amounts to 1,560,000 baht per year for the entire length of the trained area. Table 7 presents a cost breakdown as it would appear over the twenty years in which the initial cost of river training would be absorbed. For the sake of the ensuing comparison with economic benefits that is made below, the first year of depreciation will be set at 1973.

The Benefits of River Training

Compared with the costs of river training must be the benefits derived from such an undertaking to the shipping industry and, ultimately, to the nation's economy. As a comparison of the statistics in Tables 8 and 9 indicate, if all projected 1978 barge cargo were to move exclusively via the shorter, faster Chao Phaya route instead of along the Suphan and Noi routes as is the case currently in the dry season, there would be a savings in shipping costs of 1,552,992.59 baht. It should be pointed out that this savings figure is on the conservative side owing to the limits placed in these computations on cargo origins and destinations.

According to Wilbur Smith and Lyon Associates' projections of barge cargo growth between 1973 and 1978 within the 100 to 400 kilometer radius of Bangkok in the northern corridor, water cargo inputs will

TABLE 7

RIVER TRAINING CONSTRUCTION PLUS MAINTENANCE COSTS FOR THE MIDDLE CHAO PHAYA RIVER WITH CONSTRUCTION COSTS WRITTEN OFF OVER TWENTY YEARS[a]
(IN BAHT)

Year	Principal	Payments on Principal	12% Per Annum Capital Opportunity Costs	Per Annum Maintenance Costs	Total Yearly Cost
1	28,800,000	1,440,000	3,456,000	1,560,000	6,456,000
2	27,360,000	"	3,283,200	"	6,283,200
3	25,920,000	"	3,110,400	"	6,110,400
4	24,480,000	"	2,937,600	"	5,937,600
5	23,040,000	"	2,764,800	"	5,764,800
6	21,600,000	"	2,592,000	"	5,592,000
7	20,160,000	"	2,419,200	"	5,419,200
8	18,720,000	"	2,246,400	"	5,246,400
9	17,280,000	"	2,073,600	"	5,073,600
10	15,840,000	"	1,900,800	"	4,900,800
11	14,400,000	"	1,728,000	"	4,728,000
12	12,960,000	"	1,555,200	"	4,555,200
13	11,520,000	"	1,382,400	"	4,382,400
14	10,080,000	"	1,209,600	"	4,209,600
15	8,640,000	"	1,036,800	"	4,036,800
16	7,200,000	"	864,000	"	3,864,000
17	5,760,000	"	691,200	"	3,691,200
18	4,320,000	"	518,400	"	3,518,400
19	2,880,000	"	345,600	"	3,345,600
20	1,440,000	"	172,800	"	3,172,800
	Total	28,800,000	36,280,000	31,200,000	96,288,000

[a]Based on Royal Irrigation Department Estimated Costs--1965 to 1970.

TABLE 8

ESTIMATED COST OF MOVING COMMODITY TONNAGES IN 1978 THROUGH THE MIDDLE CHAO PHAYA REGION TO AND FROM LOCATIONS IN ZONES 100-400 KMS. AND BANGKOK

Route	Share of Total[a]	1978 Tonnage[b]	Distance[c]	Cost per Ton Trip[d]	Barge Costs by Route
Suphan	37.41%	566,263.57	271 km.	16.774 ฿	9,498,505.12 ฿
Noi	34.20%	517,674.80	242 km.	14.979 ฿	7,754,250.83 ฿
Middle Chao Phaya	28.39%	429,730.63	234 km.	14.484 ฿	6,224,218.44 ฿
	100.00%	1,513,669.00 Tons Total			23,476,974.39 ฿

[a]See page 33 for an account of how percentage breakdown of total barge cargo was arrived at for each of the three routes.

[b]See Table 6 for tonnage breakdown by zone.

[c]Distance from Chai Nat to Bangkok as determined in Technical Report No. 3.

[d]Cost per ton trip is based on Mr. Uathavikul's cost statistics of .0619 baht per ton kilometer on the Central Plain.

TABLE 9

ESTIMATED COST OF MOVING COMMODITY TONNAGES IN 1978 THROUGH THE MIDDLE CHAO PHAYA REGION TO AND FROM LOCATIONS IN ZONES 100-400 KMS. AND BANGKOK IF ALL COULD HAVE GONE VIA CHAO PHAYA RIVER

Total Tonnage 1978	Cost per Ton Trip	Total Barge Costs
1,513,669.00	14.484	21,923,981.80

TABLE 10

REALLOCATION TO WATER TRANSPORT OF 10 PERCENT OF ALL CARGO ASSIGNED TO ROAD AND RAIL IN 1978 BY WILBUR SMITH AND LYON ASSOCIATES. ALL CARGO ORIGINATING FROM SING BURI NORTHWARD (IN BAHT)[a]

Km. Zones	10% Road and Rail Tonnage	Cost to Ship Reallocated Cargo by Rail & Road	Cost to Ship Reallocated Cargo by Barge	Savings if 10% of Road and Rail Cargo Went by Barge
1-200	11,000	317,248.00	120,560.00	196,688.00
2-300	8,890	365,293.40	137,528.30	227,765.10
3-400	16,250	984,986.00	351,975.00	633,011.00
Totals	36,140	1,667,527.40[b]	610,063.30	1,057,464.10[e]
		+ 109,642.50[c]		
		1,858,169.90[d]		1,248,106.60 (Savings)[f]

[a]See Table 6 for estimate of total tonnages moved by zone.

[b]Road and rail costs before inclusion of rail terminal costs of Ƀ8.25 per ton handled.

[c]Rail terminal cost.

[d]Road and rail costs after inclusion of Ƀ8.25 per ton rail terminal costs.

[e]Savings before inclusion of rail terminal costs.

[f]Total savings after inclusion of rail terminal costs.

increase by 4.27 percent per annum.[36] Using the 1978 barge cargo statistics as a point of departure and including a factor for yearly barge growth, within a twenty year period, 1974 to 1994, there would be a cumulative savings of 43,269,031.86 baht assuming that river training had made it possible for all long-haul shipping through the middle Chao Phaya region to use the Chao Phaya river all year. Table 11 column A contains statistics that present the cumulative savings each year if all goods had traveled exclusively via the Chao Phaya route to and from Bangkok.

If the middle Chao Phaya were to undergo training and become navigable all year, water transport's ability to compete with road and rail would become markedly improved. The speed and safety afforded cargo shippers by a channel improvement program in addition to a diminuation of the usually lower river transport rates, would, it is assumed, help attract cargo to water transport from the region's highways and rails. In the section of this chapter entitled "A Projection of Water, Rail and Road Transportation Costs on the Central Plain," it was determined that in the dry season there is an approximate 36.12 percent drop in vessel traffic as compared to wet season levels. It is assumed that much of this cargo decrease can be accounted for by a switching over to road and rail service on the part of the up-country shipper. If, in the future, the middle Chao Phaya river were open and transit to Bangkok was thus improved during the dry season, it is probable that a portion of this shipping now lost to road and rail would return to the barge industry. Just how much cargo will be allocated in this fashion is impossible to say, but the 10 percent reallocation to water traffic from road

TABLE 11

THE BENEFITS OF RIVER TRAINING ON THE MIDDLE CHAO PHAYA RIVER OVER A TWENTY-ONE YEAR PERIOD 1974-1994 BEFORE CONSIDERATION OF SECONDARY BENEFITS (IN BAHT)

Year	Savings if All Cargo Went via Chao Phaya (A)	Savings if 10% of Rail and 10% of Road Cargo Went by Barge (B)	Total Savings (Benefits) (C)
1974	1,313,815.53	1,037,857.76	2,351,673.29
1975	1,369,913.48	1,086,841.71	2,456,755.19
1976	1,428,406.73	1,138,137.57	2,566,544.30
1977	1,489,397.55	1,191,854,44	2,681,251.99
1978	1,552,992.59[a]	1,248,106.60[b]	2,801,099.19
1979	1,619,305.37	1,307,017.23	2,926,322.60
1980	1,688,449.71	1,368,708.44	3,057,158.15
1981	1,760,546.51	1,433,311.47	3,193,857.98
1982	1,835,721.84	1,500,963.77	3,336,685.61
1983	1,914,107.16	1,571,809.26	3,485,916.42
1984	1,995,839.53	1,645,998.66	3,641,838.19
1985	2,081,061.88	1,723,689.80	3,804,751.68
1986	2,169,923.22	1,805,047.96	3,974,971.18
1987	2,262,578.94	1,890,246.22	4,152,825.16
1988	2,359,191.06	1,979,465.84	4,338,656.90
1989	2,459,928.52	2,072,896.63	4,532,825.15
1990	2,564.967.47	2,170,737.35	4,735,704.82
1991	2,674,491.58	2,273,196.15	4,947,687.73
1992	2,788,692.37	2,380,491.01	5,169,183.38
1993	2,907,769.53	2,492,850.18	5,400,619.71
1994	3,031,931.29	2,610,512.71	5,642,444.00
	43,269,031.86		76,198,772.62

[a]See Tables 8 and 9 . Also page 58.

[b]From the savings column in Table 10.

and rail included in the computations presented in Table 11 can be considered as being on the conservative side. It is reasonable to expect a greater than 10 percent reallocation of road and rail tonnage to water transit in the event that the middle Chao Phaya river is opened to dry season traffic.

The cumulative savings calculations presented in column B of Table 11 take into account a road and rail per annum growth factor of 4.72 percent. This figure represents an average struck between the rail and road cargo growth rates as calculated between 1973 and 1978 as they apply to the projected shipping patterns in the three 100 to 400 kilometer zones of the northern corridor.[37]

As is shown in Table 12, the initial cost of construction plus the capital opportunity cost of 12 percent per annum is written off within twenty years leaving only the annual cost of 1,560,000 baht for maintenance after 1993. Within the first twenty years of operation, costs or losses decrease each year (Table 7) while savings or benefits increase (Table 11, column C). In 1988, although benefits have yet to overtake total costs, the yearly benefits begin to outweigh yearly costs. Thereafter, benefits increasingly offset costs each year until 1998 when the entire project has been paid off. It should be noted that in Table 11 Column B, yearly benefit calculations include the savings realized from a 10 percent reallocation of rail and road cargo to water shipment.

In several ways the savings calculations presented above are conservative. First of all, they only take into account cargo originating from locations north from Sing Buri and do not include any goods

TABLE 12

COMPARISON OF THE COSTS AND THE BENEFITS OF RIVER TRAINING OVER A TWENTY-ONE YEAR PERIOD AND BEFORE INCLUSION OF SECONDARY BENEFITS

Year	Losses	Year	Gains
1974	4,104,327 ฿		
1975	3,826,425 ฿		
1976	3,543,856 ฿		
1977	3,256,348 ฿		
1978	2,963,701 ฿		
1979	2,665,677 ฿		
1980	2,362,042 ฿		
1981	2,052,542 ฿		
1982	1,736,914 ฿		
1983	1,414,884 ฿		
1984	1,086,162 ฿		
1985	750,448 ฿		
1986	407,429 ฿		
1987	56,775 ฿		
	30,227,530 ฿	1988	301,857 ฿
		1989	668,825 ฿
		1990	1,044,505 ฿
		1991	1,429,288 ฿
		1992	1,823,582 ฿
		1993	2,227,800 ฿
		1994	4,082,444 ฿[a]
		1995	4,335,124 ฿
		1996	4,599,047 ฿
		1997	4,874,921 ฿
		1998	5,911,232 ฿
			31,298,625 ฿[b]

[a]After 1994 the construction cost of the river training project is paid off. After this date only maintenance cost of 1,560,000 per year remain.

[b]In 1998 benefits (savings) outweigh costs.

that might have originated or been destined for locations beyond the 400 kilometer zone. Secondly, the savings shown in Table 11 column A, are somewhat understated. Barge ton trip shipping costs are based on an average cost for shipping cargo through each of the three middle Chao Phaya routes. Under the conditions that river training on the middle Chao Phaya will create, these cost figures can be expected to decrease as use of the more expensive Noi and Suphan routes will not be necessary.

In the foregoing cost-benefit calculations, water transport costs were based on Mr. Uathavikul's calculations. These statistics were chosen instead of those put forth in the Wilbur Smith and Lyon Associates' or the French Technical Mission's reports because it was felt by the writer and his Project 30 colleagues that Mr. Uathavikul's source data are the most accurate available. Road and rail transport costs, however, were taken from the Wilbur Smith and Lyon Associates' report. It is thought that of all sources, this one appears to be the most thorough and up-to-date with regard to these modes of transport. If, instead of using the Uathavikul statistics for barge transport, the one quoted by Wilbur Smith and Lyon Associates is substituted, there would be some realignment of the costs and benefits over the amortization period. The overall impact on the costs and benefits, however, would be small. If Wilbur Smith and Lyon Associates' ton kilometer water rate of 0.206 baht per ton kilometer is used instead of Mr. Uathavikul's 0.0619 baht per ton kilometer, two things would happen to the statistics presented in Table 11. The savings in column A would increase in magnitude but those in column B would decrease. The savings in column A would grow larger because barge ton kilometer costs, according to Wilbur

Smith and Lyon Associates, are higher thus emphasizing the distance differentials between the three routes through the middle Chao Phaya region. The savings statistics shown in column B, however, would decrease in magnitude because less would be saved by reallocating road and rail cargo to barge.

As already discussed in this chapter, there are several important benefits which have not been given a numerical value in this study but should not be lost sight of in this comparison of the costs and the benefits of river training. These additional benefits consist of the savings that would be realized in the form of decreased barge operator opportunity costs; the savings inherent in using a natural waterway system as opposed to building a highway and rail system from the ground up; the savings of foreign exchange inherent in the operation of the barge transport industry as opposed to the heavily import-oriented needs of both the road and the rail sectors of the transport industry; and the savings that are realized when barges are used for storage in Bangkok, something that cannot be practically done by a truck or a freight car. Benefits realized in these kinds of savings and others like them only help to underline the fact that river training is an undertaking well worth the initial expense.

FOOTNOTES

Chapter I

[1] M. Remellieux and M. Ramette, "General Note Relating to the Improvement of Inland Water Transport by Means of Bottom Panels" (unpublished report, Centre De Recherches Et D'Essais De Chatou, Department Laboratoire National D'Hydralique, 1967), p. 1.

[2] Luna B. Leopold, M. Gordon Wolman, John P. Miller, Fluvial Processes in Geomorphology (San Francisco: W. H. Freeman and Company, 1964), p. 215.

[3] Ibid.

[4] Ibid., p. 227.

[5] M. Remellieux and M. Ramette, "General Note Relating to the Improvement of Inland Water Transport by Means of Bottom Panels," p. 2.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Ibid., p. 3.

[10] Ibid.

[11] Discussion taken from: M. Remellieux and M. Ramette, "General Note Relating to the Improvement of Inland Water Transport by Means of Bottom Panels."

[12] Ibid., p. 3.

[13] Ibid.

[14] Ibid.

[15] Ibid.

[16] Ibid., p. 4.

[17] *Ibid.*

[18] *Ibid.*

[19] *Ibid.*

[20] *Ibid.*

[21] *Ibid.*

[22] *Ibid.*

[23] *Ibid.*

[24] *Ibid.*, p. 5.

[25] *Ibid.*

[26] *Ibid.*

[27] *Ibid.*

[28] M. Remellieux and J. Chabert, "Reports of the Mission Carried Out in Thailand in November 1965 and in March 1966, under the auspices of the Economic Commission for Asia and the Far East" (unpublished report of the French Technical Cooperation for the Study of the Improvement of Fluvial or Maritime Navigation, Centre De Recherches Et D'Essais De Chatou, Department Laboratoire National D'Hydraulique, July, 1966), p. 27.

[29] "Rapport De La Mission Effectuée En Thailand Sous Les Auspices De La Commission Economique Pour L'Asie Et L'Extreme Orient" (unpublished report of the Mission Française De Cooperation Technique Pour L'Etude Des Possibilities D'Application De Nouvelles Methods D'Amenagement Des Riveres Par Utilisatisation Des Courants Secondaires Crées Par Panneaux De Fond Ou De Surface, August, 1963), p. 17.

[30] *Ibid.*

[31] *Ibid.*, p. 16.

[32] *Ibid.*, p. 17.

[33] *Ibid.*, p. 19.

[34] M. Remellieux and J. Chabert, "Reports of the Mission Carried Out in Thailand in November 1965 and March 1966," p. 8.

[35] *Ibid.*

[36] Ibid., p. 10.

[37] "Report De La Mission Effectuée En Thailand Sous Les Auspices De La Commission Economique Pour L'Asie Et L'Extreme Orient," p. 18.

[38] Ibid., p. 23.

[39] M. Remellieux, "Report on the Mission Carried Out in Thailand in December 1966, Under the Auspices of the Economic Commission for Asia and the Far East" (unpublished report of the French Technical Cooperation for the Improvement of Water Transport Centre De Recherches Et D'Essais De Chatou Department Laboratoire National D'Hydraulique, March 1967), p. 7.

[40] M. Remellieux and M. Ramette, "General Note Relating to the Improvement of Inland Water Transport by Means of Bottom Panels," p. 8.

[41] Ibid., p. 7.

[42] Ibid., p. 13.

[43] M. Remillieux and J. Chabert, "Reports of the Mission Carried Out in Thailand in November 1965 and March 1966," p. 7.

[44] M. Remillieux, "Report on the Mission Carried Out in Thailand in December 1966," p. 6.

[45] This information is based on interviews conducted in the field by the writer and Project 30 personnel.

[46] Wilbur Smith and Lyon Associates' study [Wilbur Smith and Lyon Associates, Inc., "Thailand Transportation Coordination Study" (unpublished report prepared for the Agency for International Development, U.S. Department of State in cooperation with the Ministry of Communications, Royal Thai Government, 3 vols.; Bangkok, August, 1970), Table 58, p. 286] presents a breakdown of the cost figures for river training. Their figures vary quite a bit from those presented in this dissertation. This difference is due to the fact that their statistics take into account dredging and other reclamation work done in other sections of the river system and not in the middle Chao Phaya alone. In this study, the writer will operate under the assumption that the Wilbur Smith and Lyon Associates' figures are not an accurate representation of the costs of river training on the middle Chao Phaya river and that the figures of 240,000 baht per kilometer as established by Project 30 from field interviews is the correct statistic in regards to the cost of training the middle Chao Phaya river.

[47] Thailand, Harbor Department, Survey of Inland Waterway Transportation, Central Rivers Basin, 1964. Report prepared in co-operation with the National Economic Development Board and the National Statistical Office (Bangkok: Harbor Department, n.d.), p. 44.

Chapter II

[1]There is the possibility that by speeding up the journey down the Central Plain an overcapacity in shipping would be created and many barge operators would be thrown out of work. This situation, however, would be only a temporary one. As water transport speed is increased, more and more commodities will seek shipment by barge thus reabsorbing any overcapacity that might have been generated at the outset.

[2]For toll fees and towboat rates, the reader is referred to Tables 18 and 23 in Chapter II of Peter R. Ingold, The Role of River Training in the Improvement of Inland Water Transportation in Central Thailand, Ann Arbor: University Microfilms, 1973 (Ph.D. dissertation in Geography).

[3]One slight exception should be mentioned in this connection. Hull maintenance must be more extensive on vessels plying or moored in salty or brackish waters than those remaining exclusively upstream. Brackish or salty water contains small organisms that attack wooden hulls.

[4]Charles R. Nelson, "Report on a Survey of Commercial Water Transportation in Central Thailand" (paper written for the University of Michigan, Department of Geography, August 15, 1967), p. 17 (typewritten).

[5]In 1966, 7,717 individual barge trips were counted in the second Harbor Department, National Statistical Office survey of vessels inbound to Bangkok as having passed through one of the middle Chao Phaya region's three north-south water routes: The Suphan, the Noi and the Chao Phaya rivers. Of this total number, 2,191 used the Suphan route, 3,392 used the Noi route, and 2,134 used the Chao Phaya route.

[6]Wilbur Smith and Lyon Associates, Inc., "Thailand Transportation Coordination Study" (unpublished report prepared for the Agency for International Development, U.S. Department of State in cooperation with the Ministry of Communications, Royal Thai Government, 3 vols.; Bangkok, August 1970), p. 272.

[7]Travel time statistics are based on information gathered in Project 30's general questionnaire and in field notes.

[8]The figure given for the lock fees paid by the average towboat in long-haul service on the Central Plain was computed in the following manner:

From a questionnaire administered by Project 30 field teams to towboat crews operating through the study region, it was established that the average length of a vessel is 11.8 meters. From a study entitled Remote Area Water Mobility: Annex to Shallow Draft Boat Report, put out by the Joint Thai-U.S. Military Research and Development Center in 1966, it is estimated that the average beam of a long-haul towboat is eight feet or 2.44 meters. Based on these two sources, the writer has adopted the dimensions of 11.18 by 2.44 meters for the average towboat.

A schedule of toll fees appearing in the Royal Irrigation Department's Lock Tender's Handbook indicates that the fee for a towboat whose width exceeds two meters is computed at two baht for each meter of length. Based on the observations of Project 30 field workers, the vessel lengths upon which toll fees are based are usually rounded downward to the nearest full meter by the lock attendant collecting the toll. Thus the average fee paid by towboats passing over the routes of the middle Chao Phaya region is 22 baht per lock.

[9]Thailand, Harbor Department, Survey of Inland Waterway Transportation, Central Rivers Basis, 1964, Report prepared in cooperation with the National Economic Development Board and the National Statistical Office (Bangkok: Harbor Department, n.d.).

The work cited above is the first report on a two-part survey of river traffic. The data referred to in this footnote were collected in 1966 during the second part of the survey and the writer knows of no final report having been issued on this portion of the survey. The writer's information used in this dissertation concerning this second survey comes from a computer printout provided to Project 30 by the National Statistical Office.

[10]See Appendix I for a detailed profile of the middle Chao Phaya river.

[11]Peter R. Ingold, op. cit., Table 23, p. 145.

[12]Thailand, Harbor Department, Survey of Inland Waterway Transportation, Central Rivers Basin, 1964, p. 68.

[13]Data are taken from the second Harbor Department, National Statistical Office Survey of Vessels that moved in and out of the Bangkok area in 1966. The information presented in this dissertation, that is based on a 1966 survey, has been taken from a computer printout provided to Project 30 by the National Statistical Office.

[14]The vessel trip totals have been adjusted to compensate for a .21% error in percentage totals.

[15]Phaijayont Uathavikul, "A Study of Inland Waterway Transportation in the Central Plain of Thailand" (unpublished Master's Thesis, Central Michigan University, Mount Pleasant, Mich., 1972).

[16]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study."

[17]Mission Française De Cooperation Technique, Centre De Recherches Et D'Essais De Chatou, Department Laboratoire National

D'Hydraulique, "Rapport De La Mission Effectuée En Thailand Sous Les Auspices De La Commission Economique Pour L'Asie Et L'Extreme-Orient" (unpublished report for the improvement of river training, Thailand, August, 1963).

[18]This cost figure is based on a personal communication with Mr. Phaijayont Uathavikul and represents an average cost for moving various goods on the Central Plain by barge.

[19]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 281.

[20]The report issued by the Mission Française De Cooperation Technique expresses cost data in U.S. dollars.

[21]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 488.

[22]According to this report, "these figures do not include the distribution from Bangkok of imported consumer's goods, capital goods, or raw materials except for some sulphur and wood pulp. They consist of intraregional movements, excluding the large volume of intra-regional traffic except for the Central Plain. It is necessary for forecast purposes to take some formal account of this other." Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 439.

[23]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 449.

[24]Based on personal communication with Mr. Uathavikul.

[25]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 45.

[26]_Ibid._, p. 21.

[27]_Ibid._, p. 449.

[28]This information comes from a computer printout of the Harbor Department's second survey. This survey of vessels entering and departing the Bangkok area was made in 1966.

[29]Phaijayont Uathavikul, "A Study of Inland Water Transportation in the Central Plain of Thailand," p. 66.

[30]Canada, General Engineering Company Limited, "Feasibility Report Thonburi-Paktho Highway, Kingdom of Thailand" (unpublished report prepared under contract to the Government of Canada for the Colombo Plan Programe, Bangkok, January, 1967), p. 8p3.

[31]The cost estimates are based on interviews and other sources of information collected in Thailand.

[32]Canada, General Engineering Company Limited, "Feasibility Report Thonburi-Paktho Highway," p. 8p8.

[33]This information concerning barge storage is derived from a questionnaire administered to barge operators by Project 30.

[34]According to the General Engineering Company (Canada, General Engineering Company, Limited, "Feasibility Report Thonburi-Paktho Highway, Kingdom of Thailand," pp. 7-8), the economic life of the highway that they had designed was 20 years. The writer used the same figure as a guide for defraying the cost of construction of river training.

[35]According to the General Engineering Company's chapter on economic costs, capital opportunity costs in Thailand are set at 12 percent per annum. Canada, General Engineering Company Limited, "Feasibility Report Thonburi-Paktho Highway, Kingdom of Thailand," p. 27.

[36]Wilbur Smith and Lyon Associates, "Thailand Transportation Coordination Study," p. 449.

[37]Ibid.

APPENDIX I

MIDDLE CHAO PHAYA RIVER PASSABILITY PROFILE

Executed at a scale of 1:100,000 is a profile of the middle Chao Phaya river. The presentation is divided into four separate but continuous segments. Each segment slightly overlaps the next. The total distance depicted in this profile is just in excess of 113 kilometers, stretching from the Chao Phaya dam southward to klong Bang Luang.

In the bottom portion of each segment, a cross sectional profile of the river bottom is given. Information for this part of each segmentation is based on a similar unpublished profile provided to the writer by the Royal Irrigation Department and entitled "Royal Irrigation Department, Changing and Conservation of Waterways Showing the Level of the River and the Relationship Between the Level and Quantity of Water in the River from the Chao Phaya dam to Pongpeng." This document was drafted in 1965.

Above each segment's cross section of the river bottom are lines representing the *mean monthly surface* level of the water flowing through the navigation channel. It will be noted that each segment is presented twice: the first representation showing the water surface for the months of falling water levels, December through April; and the other showing the months of rising water levels, May through August. The water levels for three months, September through November, are not given.

During these months water levels are sufficient to pass commercial vessels with no problem. In all cases during these three months, water levels exceeded the vertical extent of each profile segment. See table showing mean monthly flow that is presented below.

The mean monthly water surface levels given in the segments are based on unpublished flow data compiled by the Royal Irrigation Department's Hydrology Section and are derived from readings taken at Wat Pho Ngarm, a station in Amphoe Sanphaya located slightly below the Chao Phaya dam. From these unpublished flow statistics, the writer calculated a mean flow value for each month of the year. This data was then compared with the water surface levels as they appear on the Royal Irrigation Department's 1965 profile of the middle Chao Phaya river. On this profile, engineers of the Royal Irrigation Department had translated flow information into lines depicting surface levels. Their representations, however, were not executed on a monthly basis. To make the transition from the arbitrary flow water surface levels provided on the Irrigation Department's profile and the mean monthly flow data derived from the Sanphaya station, the writer had to make some adjustments. Once an interpolated relationship between the two groups of data was achieved for the Sanphaya gauging station area, it was maintained and extended southward through each of the remaining four segments.

MEAN MONTHLY FLOW OF THE MIDDLE CHAO PHAYA RIVER

AT WAT PHO NGARM, AMPHOE SANPHAYA

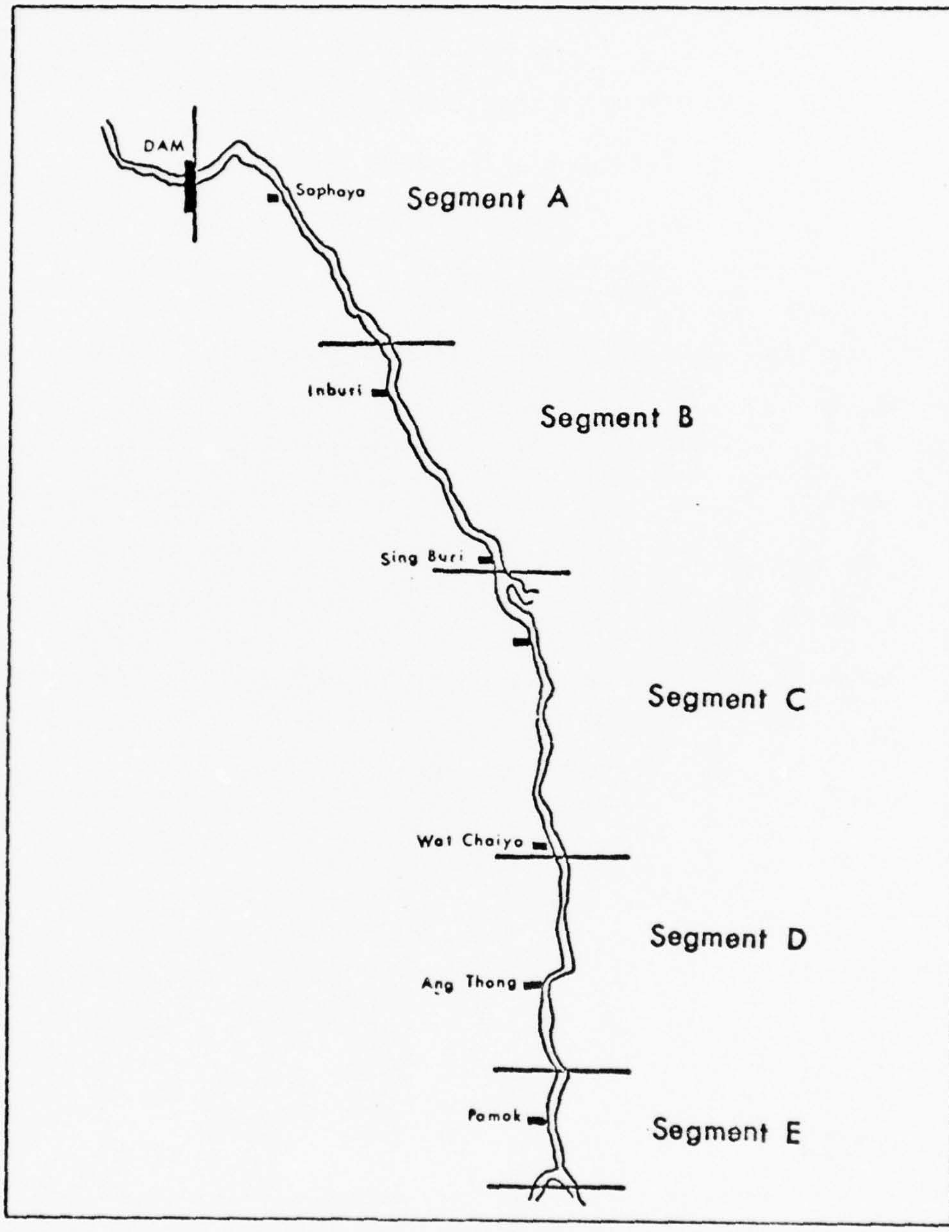
1958-1965

(in ccm^3)[a]

Month	Mean
January	109.50
February	72.38
March	65.86[b]
April	57.43[b]
May	74.75
June	171.25
July	206.88
August	509.50
September	1,300.13
October	2,326.63
November	976.50
December	289.38

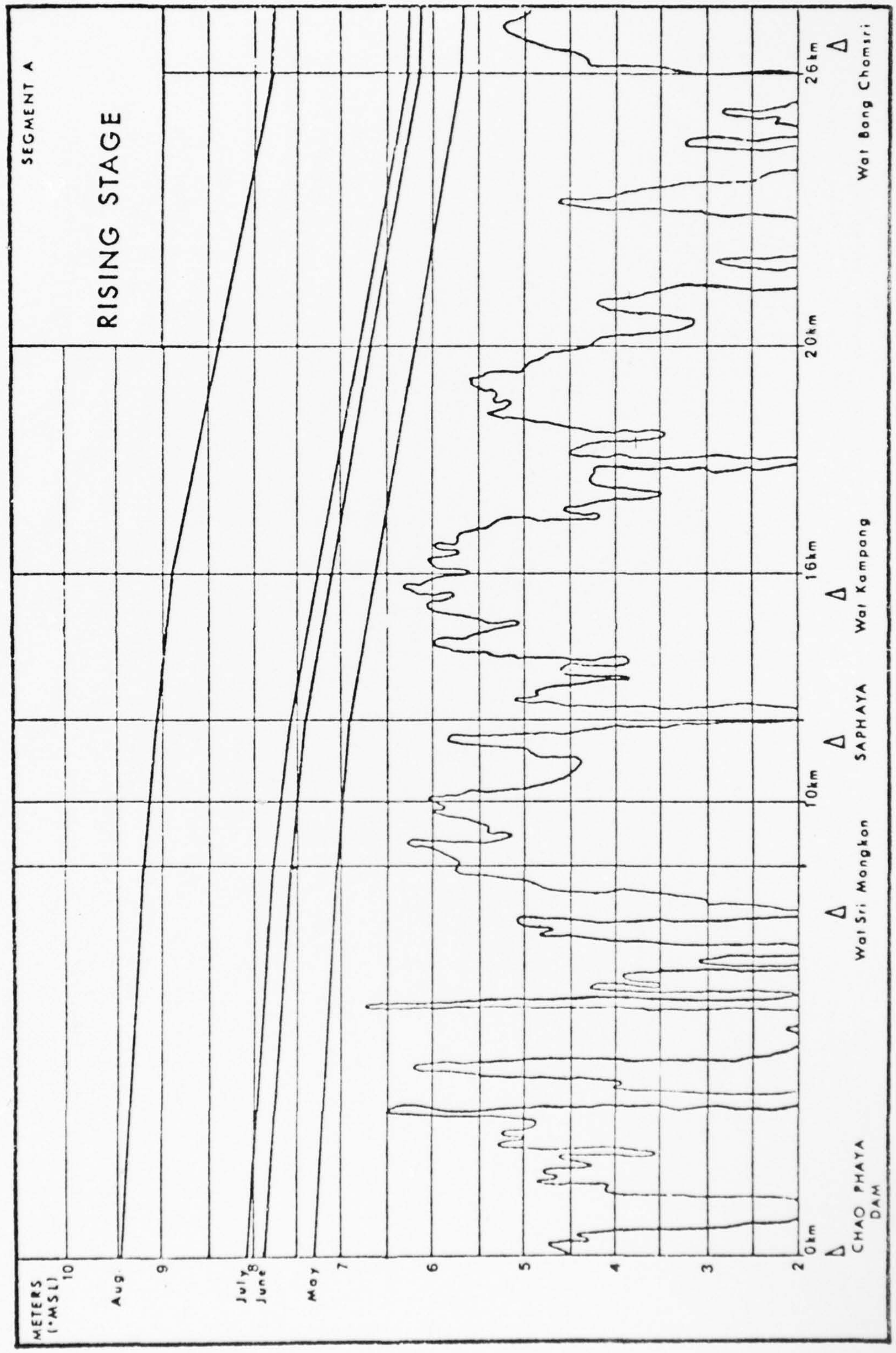
[a]Calculated from: Thailand, Ministry of Agriculture, Royal Irrigation Department, Hydrology Section (unpublished records compiled February 13, 1967).

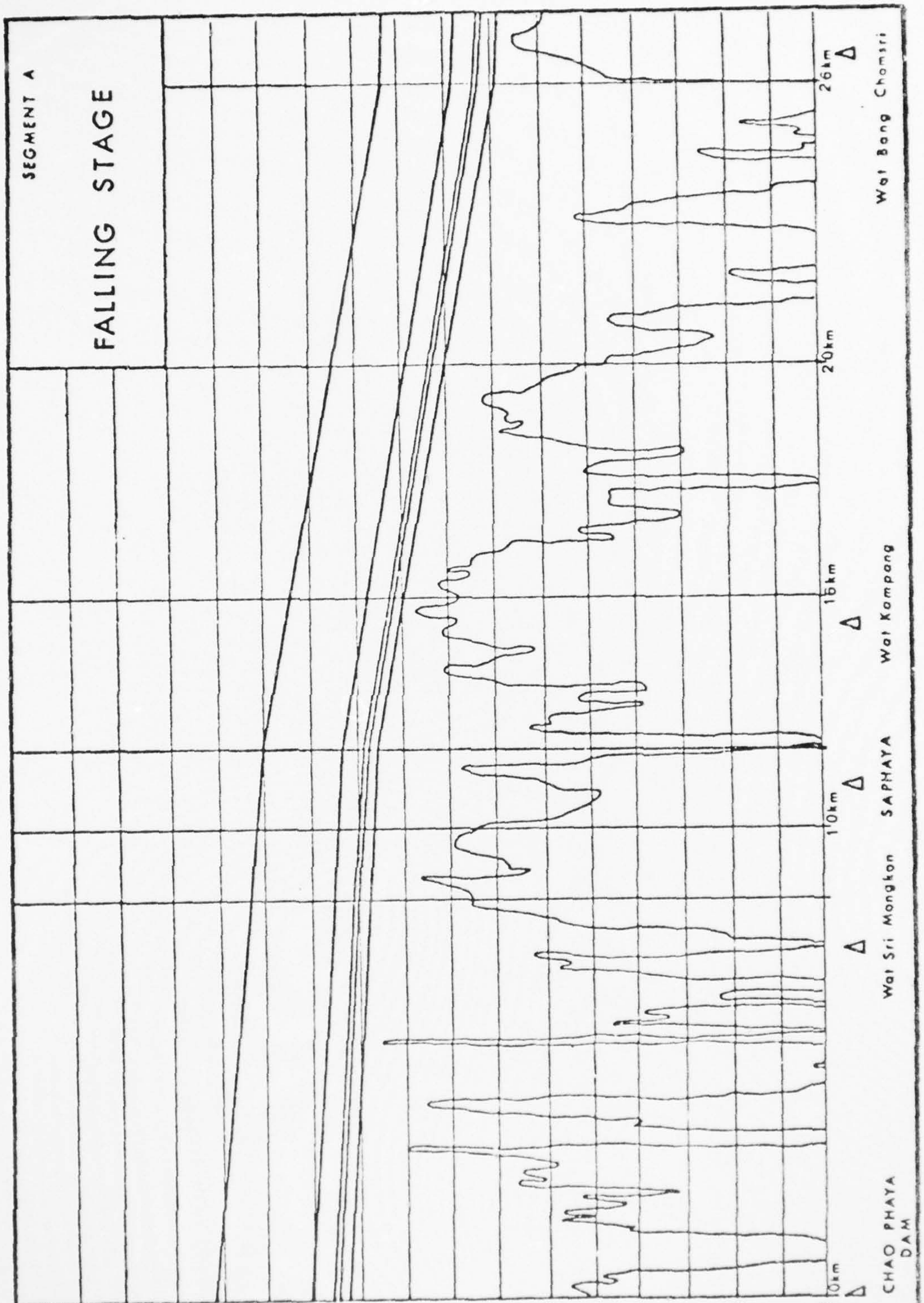
[b]Mean based on a seven year average only. No record in 1962.

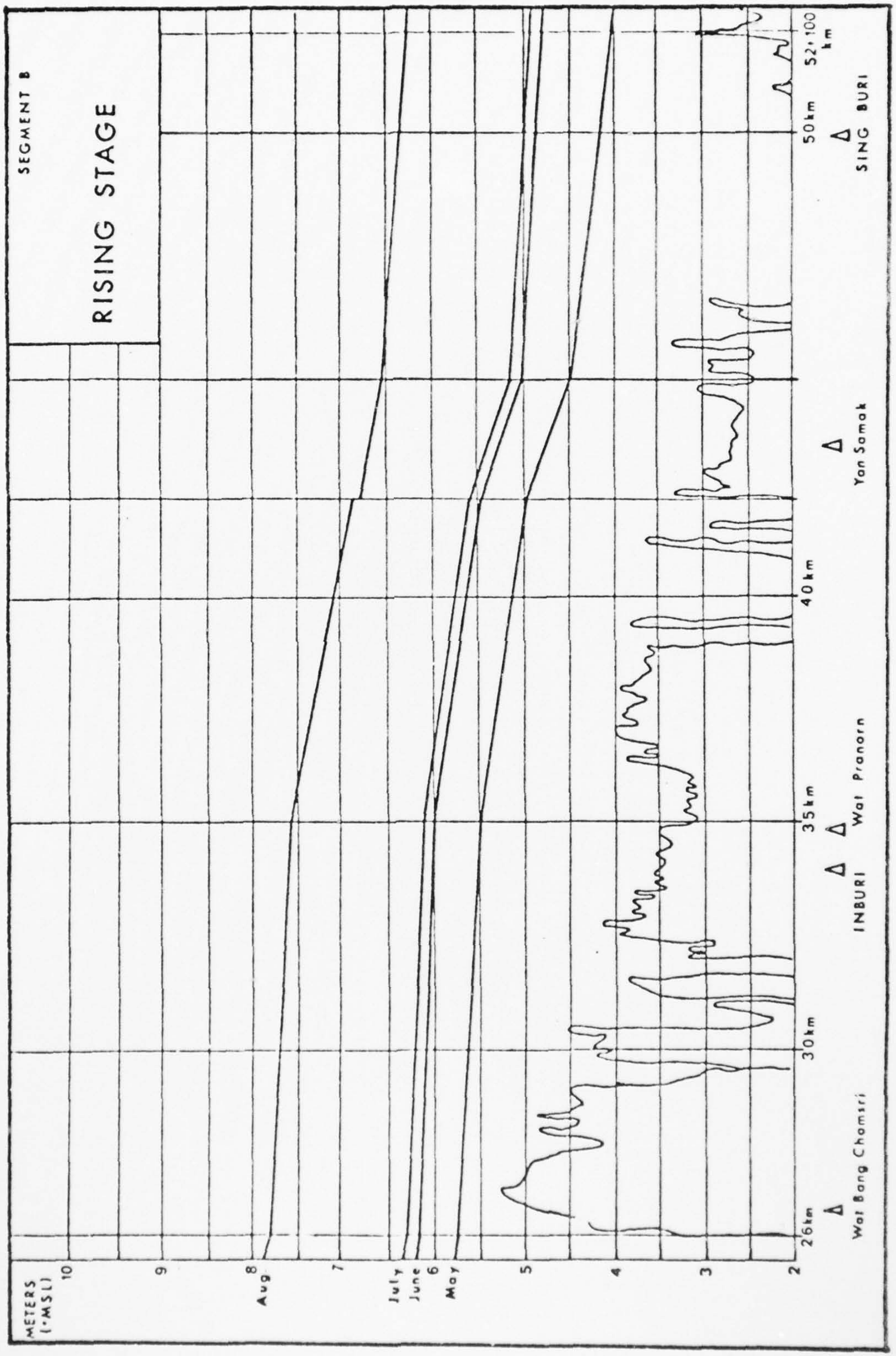


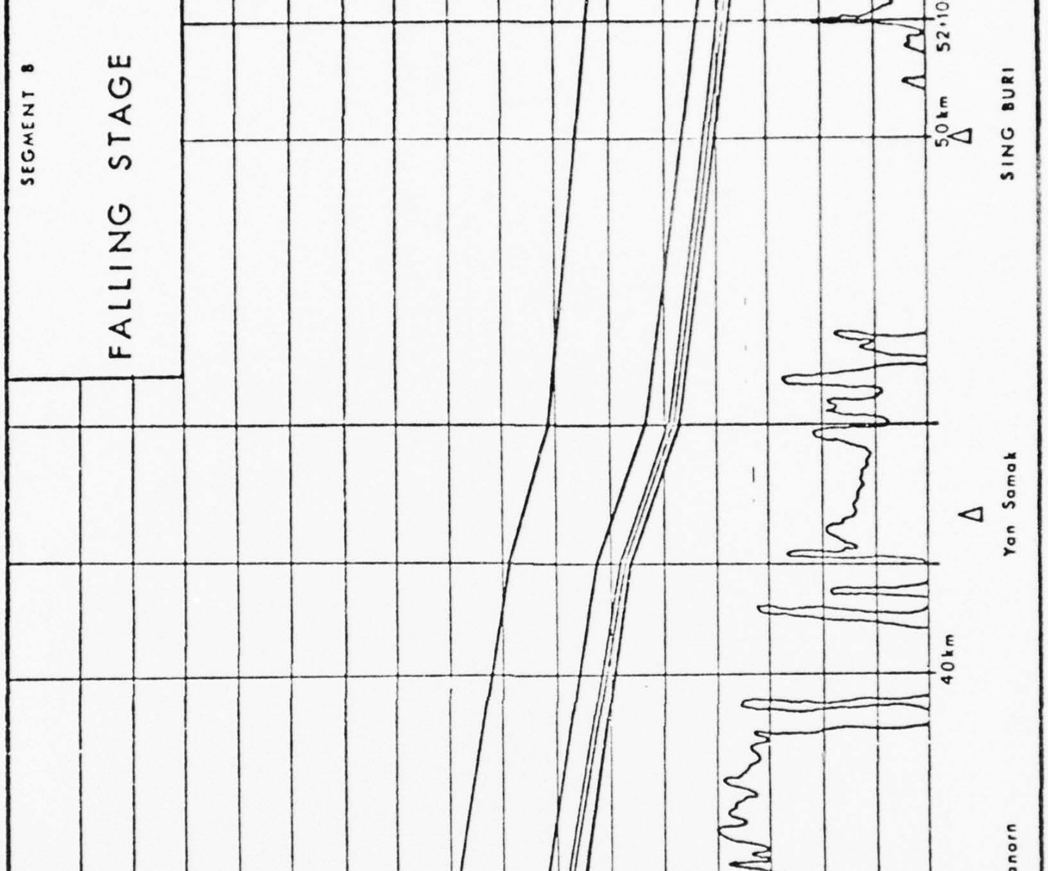
Middle Chao Phaya River:

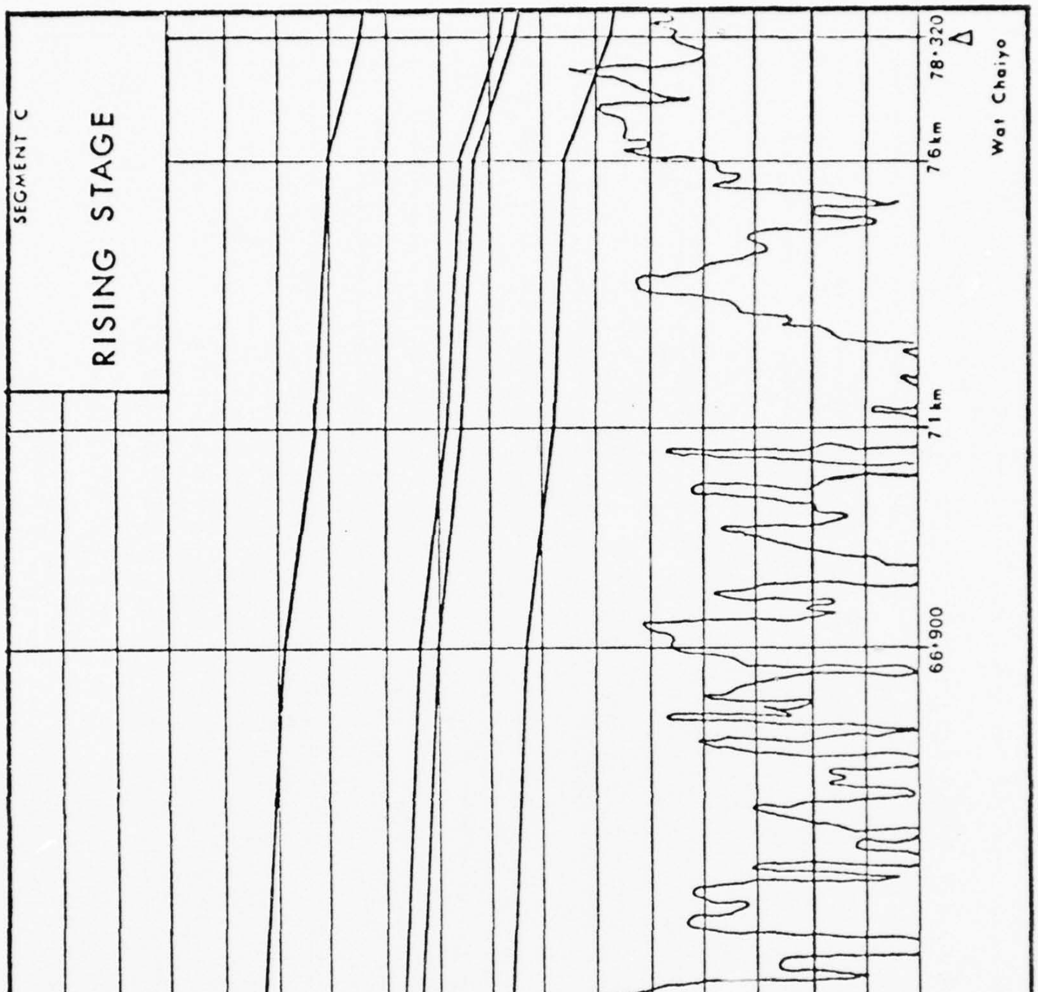
Key to Passability Profile Segmentation

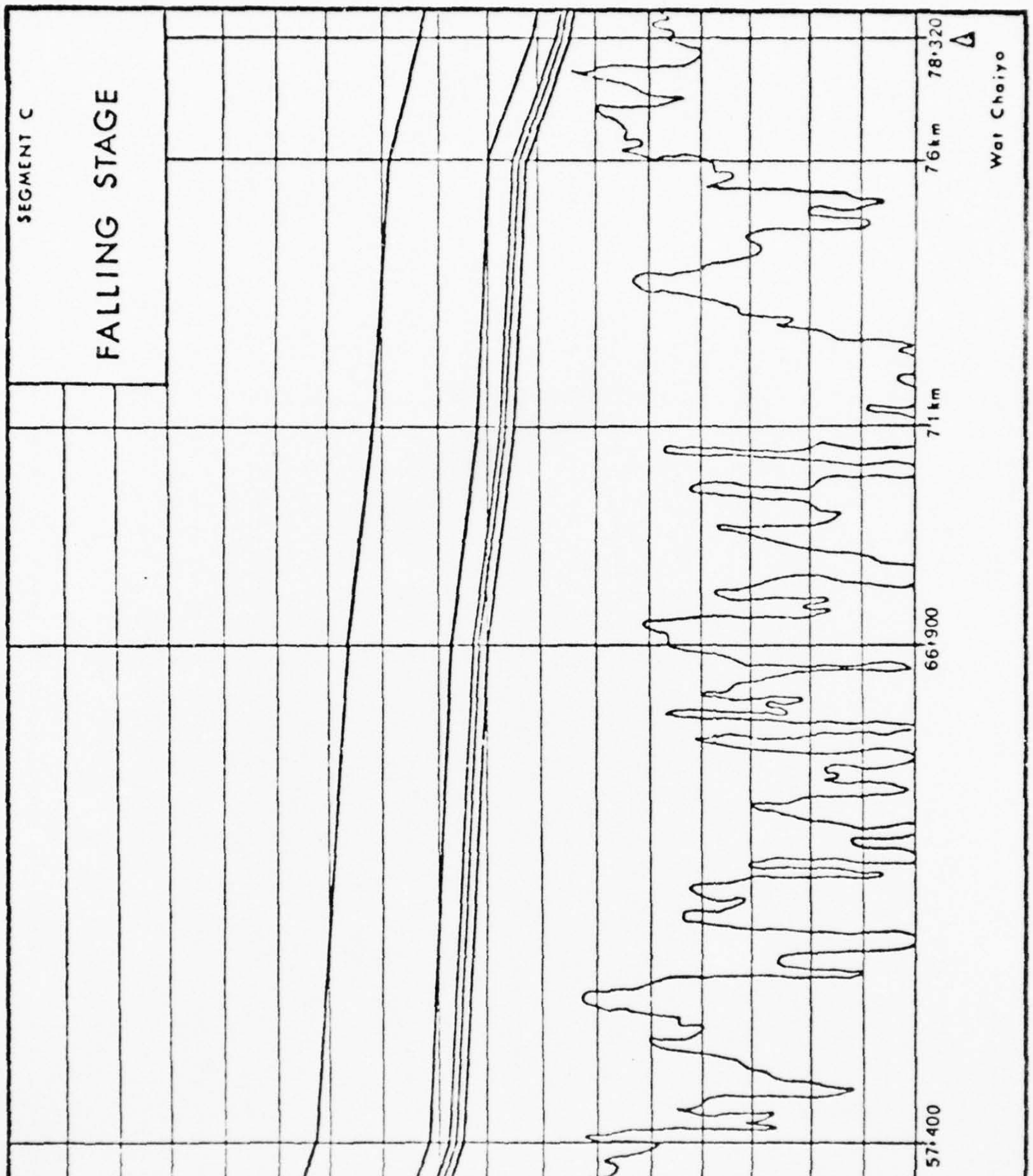

SEGMENT A
RISING STAGE
METERS (*MSL)
10
Aug
9
July
June
8
May
7
6
5
4
3
2
0km
10km
16km
20km
26km
CHAO PHAYA DAM
Wat Sri Mongkon
SAPHAYA
Wat Kampang
Wat Bong Chomsri


SEGMENT A
FALLING STAGE
METERS (+MSL)
10
9
Dec.
8
Jan.
Feb
March
April
7
6
5
4
3
2
0km
10km
16km
20km
26km
CHAO PHAYA DAM
Wat Sri Mongkon
SAPHAYA
Wat Kompang
Wat Bang Chomsri

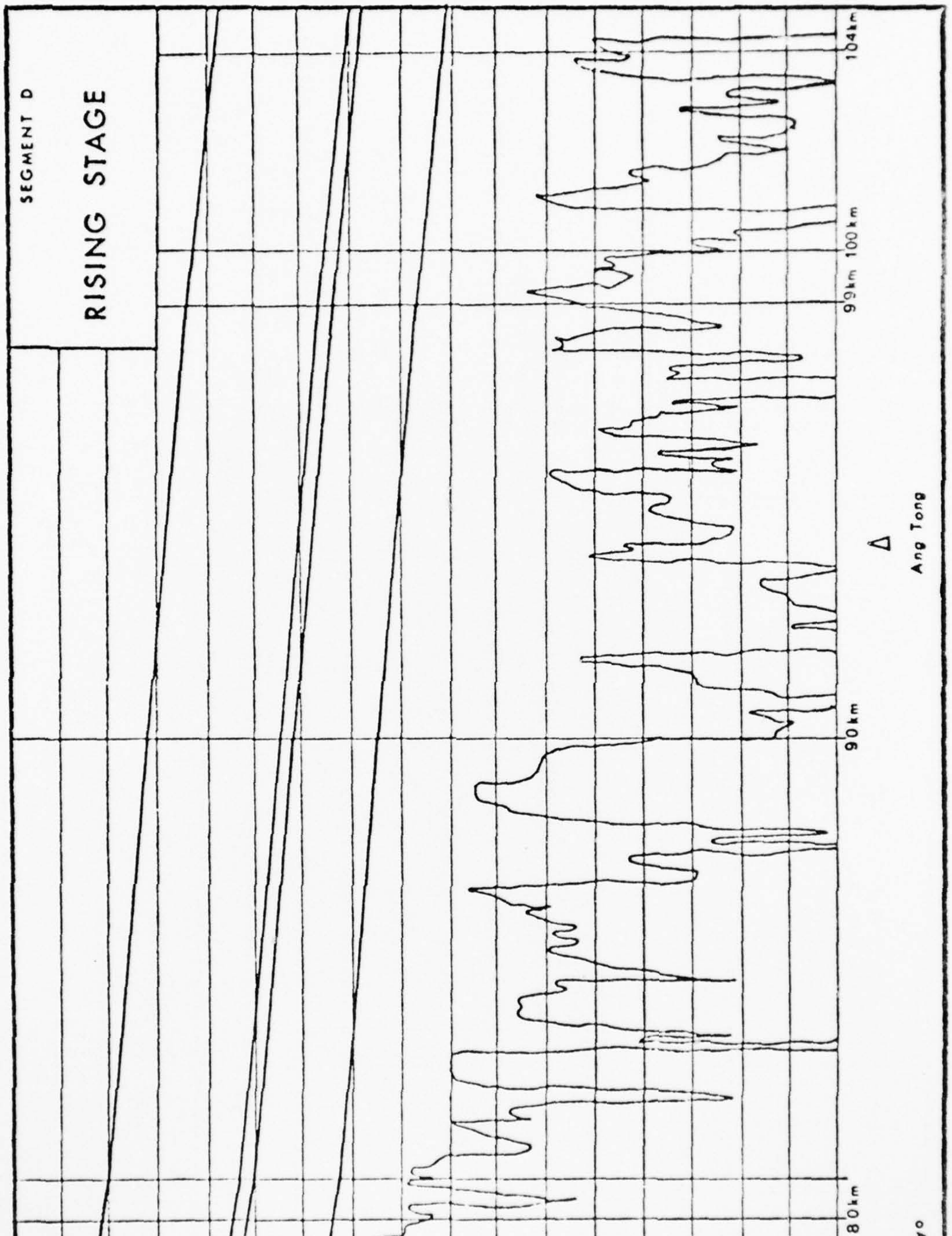

RISING STAGE
SEGMENT B
METERS (+MSL)
10
9
8
7
6
5
4
3
2
Aug
July
June
May
26km
30km
35km
40km
50km
52+100 km
Wat Bang Chomsri
INBURI
Wat Pranorn
Yan Samak
SING BURI

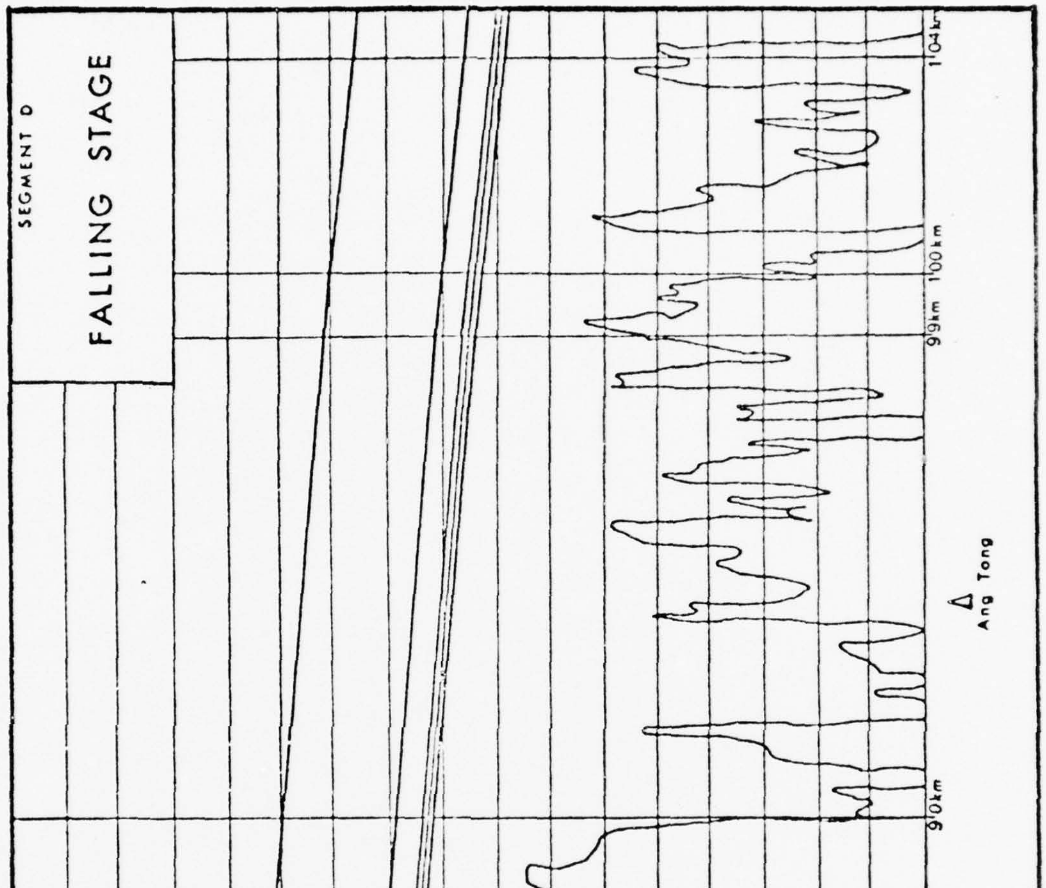

SEGMENT 8
FALLING STAGE
METERS
(+MSL)
10
9
8
7
Dec.
Jan.
Feb.
6
March
April
5
4
3
2
26km
30km
35km
40km
50km
52+100
Wat Bang Chomsri
INBURI
Wat Pranarn
Yan Samak
SING BURI

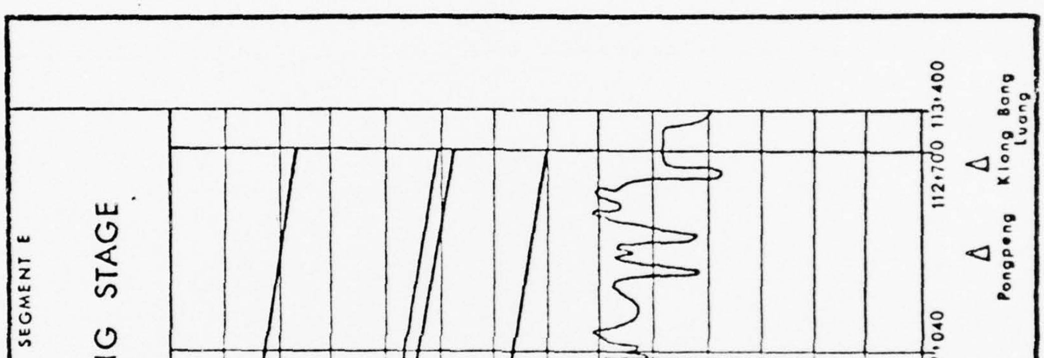

SEGMENT C
RISING STAGE
METERS (MSL)
7
6
Aug.
5
July
June
4
May
3
2
1
0
-1
52+100
Wat Sawang
57+400
66+900
71km
76km
78+320
Wat Chaiyo

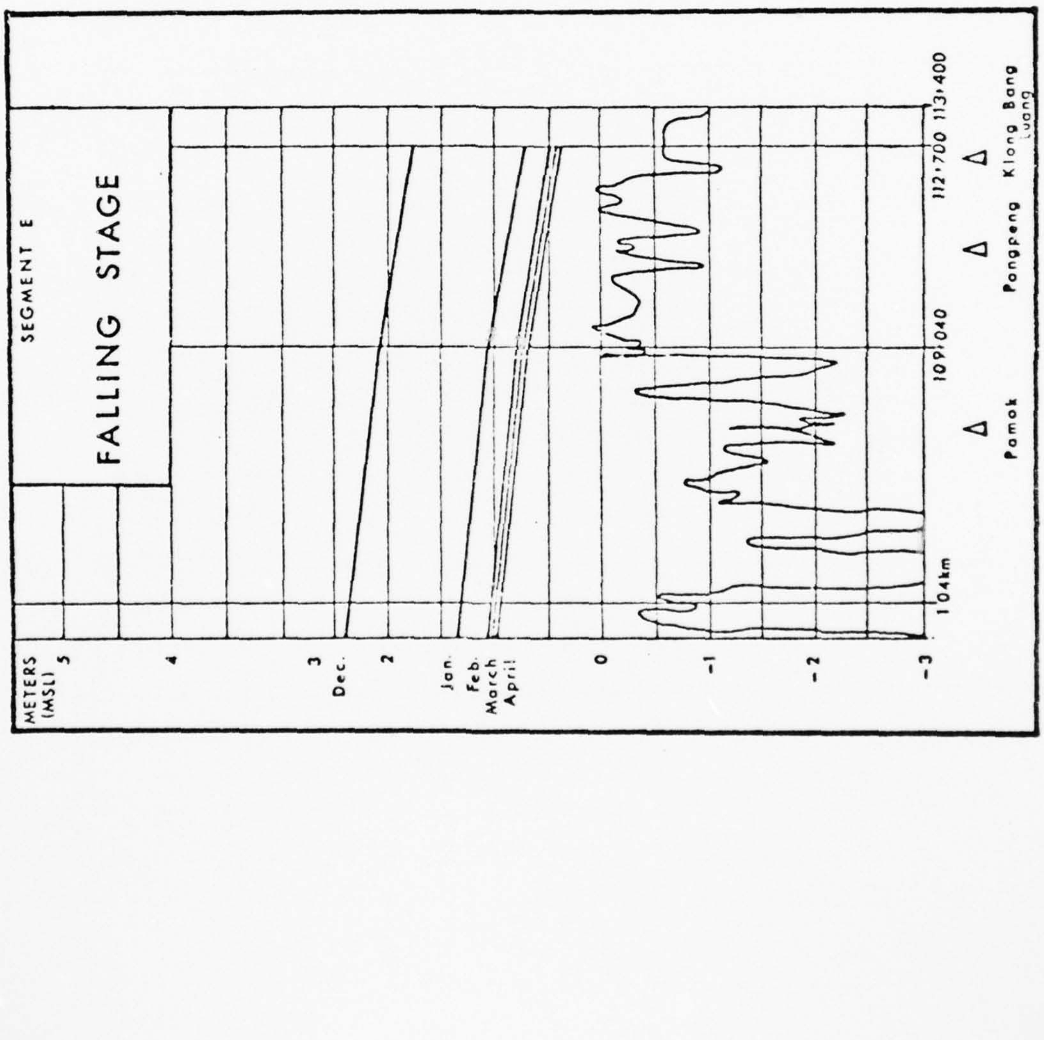


SEGMENT C
FALLING STAGE
METERS (MSL)
7
6
Dec.
5
Jan.
Feb.
March
April
4
3
2
1
0
-1
52·100
57·400
66·900
71 km
76 km
78·320
Wat Sawang
Wat Chaiyo


SEGMENT D
RISING STAGE
METERS (MSL)
5
Aug.
4
July
June
3
May
2
1
0
-1
-2
-3
78.320
80km
90km
99km
100km
104km
Wat Chaiyo
Ang Tong


SEGMENT D
FALLING STAGE
METERS (MSL)
5
4
3
2
1
0
-1
-2
-3
Dec.
Jan.
Feb.
March
April
78·320
8'0km
9'0km
9'9km
1'00km
1'04km
Wat Chaiyo
Ang Tong


SEGMENT E
RISING STAGE
METERS (MSL)
5
4
Aug.
3
July
June
May
0
-1
-2
-3
104km
109,040
112,700
113,400
Pamok
Pongpeng
Klong Bang Luang


SEGMENT E
FALLING STAGE
METERS (MSL)
5
4
3
Dec.
2
Jan.
Feb.
March
April
0
-1
-2
-3
104km
109+040
112+700
113+400
Pamok
Pongpeng
Klong Bang Luang

APPENDIX II

WILBUR SMITH AND LYON ASSOCIATES' ESTIMATE OF THE COSTS OF RIVER TRAINING 1964-1969[a]

Work Program	1964	1965	1966	1967	1968	1969
Preliminary Preparation	140,925	117,061	246,875	708,370	1,885,010	1,087,118
Survey, Data Collection	160,905	268,022	717,870	1,473,980	993,280	1,305,662
Calculation, Design, Administrative Work	262,375	255,161	444,895	1,268,830	631,680	1,150,410
Model Construction, Experiment	368,705	295,637	517,619	915,800	432,900	976,330
Dredging Work	690,990	823,391	2,140,271	14,675,450	3,140,985	7,179,990
Construction (Underwater)	212,850	83,187	1,076,250	3,612,750	3,261,895	4,060,350
Checking and Maintenance	234,850	265,187	485,720	1,013,820	577,150	1,240,140
	2,071,600	2,170,490	5,593,500	23,669,000	10,863,900	17,000,000

[a]This table was taken from Wilbur, Smith and Lyon Associates' study on Transportation Coordination in the Kingdom of Thailand, p. 286. The cost estimates given in this table are much higher than those used in this study. This can be explained by the fact that costs given in the above table include work done by the Royal Irrigation Department in more locations than on the middle Chao Phaya river. The above figures are very much inflated.

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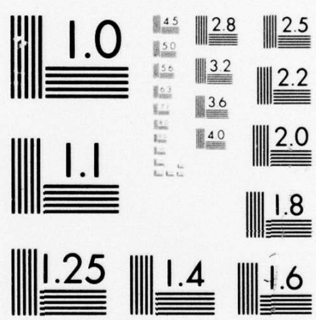

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ABSTRACT

In the interest of improving the competitive position of inland water transport in Thailand, this report investigates the possibility of increasing both the speed and safety of water shipment by implementing a program of river training through the construction of bottom panels along the middle reaches of the Chao Phaya river. This study also presents an analysis of the costs involved in such a project and of the benefits that would accrue to the transport sector of the nation's economy by making lower cost water transportation more attractive to the shipper of bulk commodities. Finally, the report concludes that the savings derived from river training even when secondary benefits are not considered would exceed the cost of such a project within a period of twenty-five years, thus making it a worthwhile investment.

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Transportation, River training, Thailand, Inland Waterway, Cost Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the interest of improving the competitive position of inland water transport in Thailand, this report investigates the possibility of increasing both the speed and safety of water shipment by implementing a program of river training through the construction of bottom panels along the middle reaches of the Chao Phaya river. This study also presents an analysis of the costs involved in such a project and of the benefits that would accrue to the transport sector of the nation's economy by making lower → next page

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cost water transportation more attractive to the shipper of bulk commodities. Finally, the report concludes that the savings derived from river training even when secondary benefits are not considered would exceed the cost of such a project within a period of twenty-five years, thus making it a worthwhile investment.