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VALIDATING AND IMPROVING EXISTING JLOTS THROUGHPUT MODELS WITH THE USE OF HISTORICAL WEATHER DATA

by

Harold Thomas Workman

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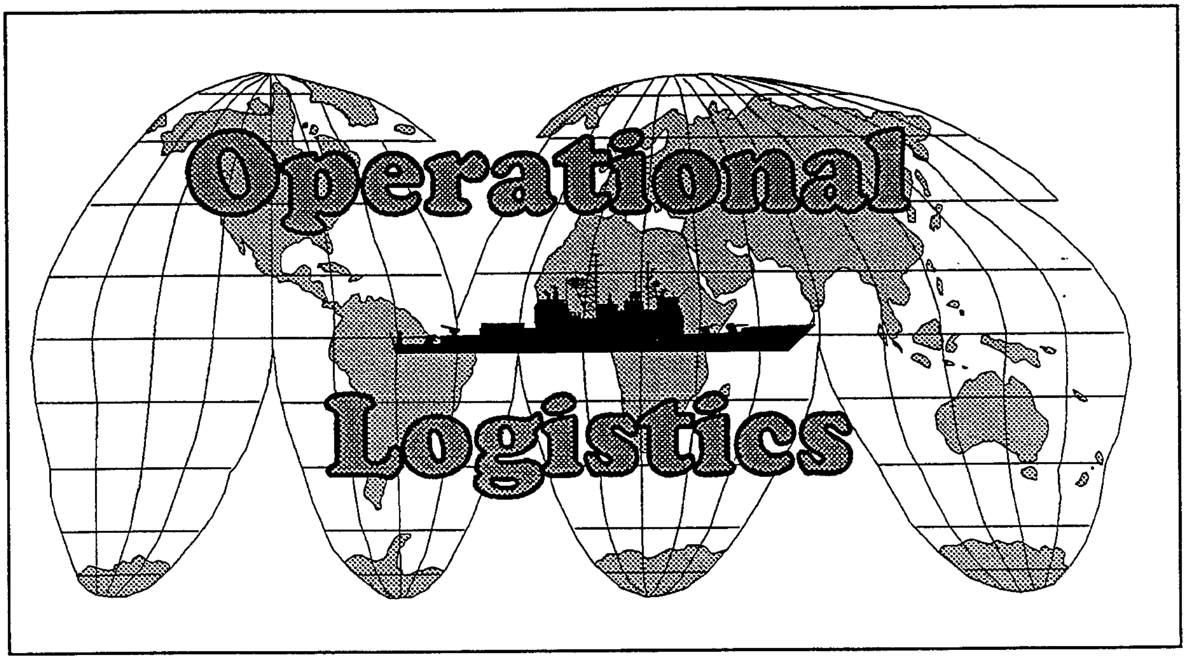
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The practice of Joint Logisitics Over the Shore (JLOTS), whereby strategic sealift assets are off-loaded without the benefit of fixed port facilities has emerged as one viable technique which could alleviate certain situational sustainment problems. The ability to successfully conduct JLOTS operations, however, is presently limited by several factors, the most significant of which is the dependency of JLOTS operations upon favorable wind, weather, and sea state condtions. Presently, the few analytical JLOTS throughput models in existence have very limited incorporation of environmental parameters.

With this in mind, this thesis attempts to both validate and improve the most widely acclaimed JLOTS throughput model, the Joint Over the shore Transportation Estimator (JOTE) developed by the Logistics Management Institute (LMI). The validation centers upon identifying the demands placed upon the user when employing JOTE as well as assessing the validity of its computational methodology. As a means of improving JOTE and rendering it more viable as a planning tool, this thesis introduces a supplement entitled the SEA_STATE_CALC package which facilitates both site and time specificity in the most crucial input parameters to the JOTE model. By helping to identify time periods in which sea state conditions threaten JLOTS operations, the SEA_STATE_CALC package services the planning needs of its true client, the JLOTS commander.

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by

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ABSTRACT

The practice of Joint Logisitics Over the Shore (JLOTS), whereby strategic sealift assets are off-loaded without the benefit of fixed port facilities has emerged as one viable technique which could alleviate certain situational sustainment problems. The ability to successfully conduct JLOTS operations, however, is presently limited by several factors, the most significant of which is the dependency of JLOTS operations upon favorable wind, weather, and sea state condtions. Presently, the few analytical JLOTS throughput models in existence have very limited incorporation of environmental parameters.

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THESIS DISCLAIMER

The reader is cautioned that the computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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EXECUTIVE SUMMARY

As the context and scope of military operations continue to change and grow, the ability to sustain the forces involved in newer, more unique operations becomes increasingly flexed. More frequently today than at any other time in history, military logisticians find themselves faced with the dilemma of meeting sustainability requirements for forces operating in locations which cannot facilitate the receipt of large-scale replenishment. It is for this reason that the concept of Joint Logistics Over The Shore (JLOTS) has not only emerged, but is becoming a CINC-driven requirement.

Over the past decade, the growth of JLOTS has been limited by a combination of equipment, doctrinal, and training-related factors. Not withstanding the significance of these issues, the growth of JLOTS has arguably been limited most by its physical dependence upon environmental conditions. Indeed, it has been this limitation which has produced the existing concerns about the capabilities of U.S. JLOTS equipment and the proficiency of JLOTS-trained military and civilian personnel. Surprisingly, not until very recently (over the past two to three years) has the significance of the profound wind, weather, and sea state dependencies of JLOTS been fully realized. This heightened awareness was triggered primarily by concern at the CINC level for the need to secure a JLOTS operating capability in sea state conditions up to and including Sea State Three. It was the profession of this desire that prompted both military staff planners and the respective Services to commence assessments of the present JLOTS operating capability.

Prior to this point analytical research into the factors affecting JLOTS operations had been nonexistent. Primitive throughput models began to be developed which did not accurately encompass environmental dependencies. The maturing of analytical JLOTS research culminated with the development of the Joint Over the shore Transportation Estimator (JOTE) by the Logistics Management Institute (LMI) in 1994. This model received wide acclaim at both the Service and Joint Staff levels for its relative superiority. Still today, JOTE is the best JLOTS throughput modeling device available.

Despite its use in many high-level JLOTS equipment feasibility studies, JOTE does remain somewhat generic in its incorporation of the most important JLOTS planning factor, namely, expected sea state conditions. It is this characteristic which also limits JOTE in its recently foreseen role, namely, as a planning tool for the tactical level JLOTS commander rather than merely a large-scale capability assessment tool.

This thesis attempts to analyze the suitability of JOTE for its new mission. The validation conducted within this thesis evaluates not only the flexibility of JOTE, but also the integrity of its foundation, and the demands which it places upon its user both prior to and during its execution. Subsequently, this thesis enhances JOTE and makes it more capable of fulfilling its new mission. This thesis will, thus, serve as a forum for the introduction of a supplement to JOTE entitled the SEA_STATE_CALC package.

This personal computer based application consists of two modules and is designed to calculate the most critical input parameter for a revised JOTE model, namely, the expected percentage of time sea state conditions equal or exceed Sea State Two. The SEA_STATE_CALC package will render the throughput predictions obtained from JOTE to be both site and time specific, thereby addressing the needs of the JLOTS commander. The SEA_STATE_CALC package is designed to process actual maritime weather observations obtained by the user from the National Climatic Data Center (NCDC) for the location in which the planned operation will take place. Most importantly, this enhancement to JOTE will operate free of user interaction which is another important concern to the tactical level JLOTS commander.

With the use of the SEA_STATE_CALC package, the JLOTS commander can identify time periods which historically have not offered sea state conditions which are conducive to successful JLOTS throughput operations, thereby allowing him/her to plan accordingly. Because of these characteristics, incorporation of the SEA_STATE_CALC package into a revised version of JOTE, which improves upon the shortfalls identified within this thesis, can render JOTE successful in its use as a planning tool.

I. INTRODUCTION AND PURPOSE

A. BACKGROUND

To experienced Department of Defense (DOD) planners, LOTS is defined as "the loading and unloading of strategic sealift assets, without the benefit of fixed port facilities, in either friendly or undefended territory and, in time of war, during phases of theater development [Ref. 1:p I-2]." JLOTS, therefore, refers to "LOTS operations conducted jointly by two or more Service component forces of a unified combatant commander [Ref. 1:p. I-4]." Since JLOTS focuses upon the criticality of expeditiously providing valuable materials to forces ashore, enhancing throughput in terms of quantity, timeliness, and efficiency is paramount. In the areas of JLOTS throughput modeling and the subsequent feasibility studies regarding potential equipment and doctrinal modifications, the majority of analytical research has rested with three entities, namely, the Logistics Management Institute (LMI), the Center for Naval Analysis (CNA), and the private firm McCaffery and Whitener, Inc. Of these research facilities, LMI has developed the most inclusive and most widely acclaimed throughput model which is entitled the Joint Over the Shore Transportation Estimator (JOTE). Originally constructed as the primary tool in evaluating the JLOTS program relative to Commander in Chief of Unified Command (CINC) requirements, the JOTE model is now being employed by LMI in several high-level feasibility studies, the most significant of which entails the potential benefits to the Army, Navy, and Marine Corps by replacing existing causeway lighterage with the Navy's multi-million dollar Amphibious Cargo Beaching Lighter (ACBL). Both the JLOTS program manager, OPNAV N-42, and the Joint Staff J-4, Logistics and Mobility Division, have not only used the JOTE model in conjunction with studies relating to current JLOTS requirements and capabilities, but also recognize the value of employing such a tool in assessing and defining future JLOTS requirements and capabilities so as to best leverage limited resources in support of emerging JLOTS equipment advancements such as the ACBL. Additionally, both of these commands also share the desire to provide an improved version of JOTE to not only to CINCs, but also to tactical commanders for use as a tool in planning JLOTS operations.

In support of this desire, the focus of this thesis will be two-fold. Initially, an extensive validation of the JOTE model will be undertaken. Here, the objective will be not only to dissect, evaluate, and critique the methodologies and computational accuracy of JOTE but also to analyze the demands placed upon the user in employing JOTE as a planning tool in its present form. The results of this validation will assist OPNAV N-42, the Joint Staff J-4, and LMI in both the establishment of design criteria for follow-on versions of JOTE and the interpretation of results obtained from ongoing JLOTS equipment feasibility studies in which JOTE has been employed.

From within this validation, the second goal of this thesis will be introduced. This latter objective centers upon the presentation of a computer-based enhancement to the JOTE model, entitled the SEA_STATE_CALC package. This program was developed as a supplement to JOTE in its growth toward becoming a planning tool for the JLOTS commander and his/her staff. The SEA_STATE_CALC program, along with its internal subsidiary the ARRANGE_DATA program, will render JOTE to be both a site and time specific JLOTS throughput model. This package allows the user the ability to process historical weather observations for a desired location in order to obtain highly precise values for the requisite input parameters of the JOTE model. Consequently, like the results of the JOTE model validation, the SEA_STATE_CALC program could also be implemented in future versions of the JOTE model.

The criticality of weather data analysis in planning JLOTS operations cannot be overstated. The nature of JLOTS operations, as well as the equipment utilized, render throughput to be highly wind, weather, and sea state dependent. In fact, until the delivery of emerging technologies such as the ACBL, U.S. JLOTS capabilities are deemed to be limited to Sea States Two and below. Consequently, prevailing and existing wind, weather, and sea state conditions are of paramount importance and must be properly modeled.

For its initial incorporation of weather data, LMI obtained, from the Fleet Numerical Meteorology and Oceanography Center (FNMOC), the overall percentages of time for which sea state(s) 0-1, 2, and 3-above could be observed within each CINC region. This FNMOC provided data could be improved in the following two ways. First, enhanced resolution can be obtained by identifying geographically smaller areas of interest within each CINC region and assessing the percentages (and associated variances) of sea state occurrence for those areas as opposed to the entire CINC region. Second, a more detailed wind, weather, and sea state analysis can be performed by altering the methods by which such meteorological data is processed. For use in the initial JLOTS capability assessment for which JOTE was employed, LMI was provided with averages obtained from the Summary of Synoptic Meteorological Observations (SSMO) which covers the period from 1875-present. For each month of each year in this collection, a page of tabulated averages is given. Those averages, were then averaged again over the 12 months of the year, and finally, averaged a third time over their desired time period. Averaging the averages in this manner could potentially cause some degree of validity loss.

B. COURSES OF ACTION

If both the recommendations resulting from the JOTE model validation and the SEA_STATE_CALC program are implemented in future versions of JOTE, not only will the validity loss associated with averaging the averages be eliminated, but more importantly, commonality and efficiency will be established regarding the manner in which useful data is obtained and processed in planning JLOTS operations. The ARRANGE_DATA component of the SEA_STATE_CALC program is designed to receive and process standardized weather observations obtained from the National Climatic Data Center (NCDC) in Asheville, NC. NCDC is the U. S. archive for all national and international maritime weather observations. The ARRANGE_DATA program is designed to analyze the various data fields of standard weather observations (compiled over very large time intervals) for a given geographic location in order to produce an input file of significant wave height observations to be used by the remainder of the SEA_STATE_CALC program. Within this program, the user is offered the opportunity to construct this input file over one, three, or 12 month time intervals, depending upon the expected execution time of the JLOTS operation being planned.

Through techniques which will be described in great detail over the course of subsequent chapters, the SEA_STATE_CALC program applies a Rayleigh probability density function (PDF) to that input file in order to compute the theoretical percentage of time sea state conditions equal or exceed Sea State Two for the geographic region in question. This percentage is the most important input parameter of the JOTE model. By providing the user with the computer-based ability to process data obtained from the facility most capable of providing it (in terms of quantity, period of record, and location of interest), he/she will always possess the ability to define the most crucial parameter of the JLOTS operation as accurately as possible.

The operation of the SEA_STATE_CALC program will be presented initially within the JOTE model validation portion of this thesis, for it was used in defining the various sea state scenarios under which JOTE was evaluated. Subsequently, the SEA_STATE_CALC program will be employed for predicting expected percentages of time in which sea state conditions equal or exceed Sea State Two for several geographic areas in which OPNAV-N42, the Joint Staff J-4, and the various CINCs consider JLOTS to be a vital tactical capability.

These site/time specificity supplements to the JOTE model could not only enhance its capabilities as a planning tool, but also further substantiate the conclusions of any feasibility study which employs JOTE. If these enhancements are implemented, upon receipt of the revised JOTE model, the various CINC staffs could potentially contract NCDC to compile a long-term (30 - 50 yr.) database of maritime weather observations for all geographic areas in their respective CINC regions in which the need for JLOTS capability is warranted. Having such databases on hand at the CINC staff level would eliminate any time lag in receipt of that material from NCDC.

In order to understand and critique the mechanisms of the JOTE model and/or postulate the analytical improvements outlined above and in follow-on chapters, one must first develop a sound knowledge of the personnel, equipment, and procedures which characterize a JLOTS operation. With a mere elementary understanding, one cannot fully appreciate the various components of throughput within a JLOTS operation, nor the potential shortcomings caused by its dependence on factors such as wind, weather, and sea state. Consequently, Chapter II is designed to greatly enhance the reader's cognizance both of the manner in which JLOTS operations bridge the fiord between ship and shore, and the potential shortcomings which could hinder U.S. JLOTS capabilities in the future.

II. A PRESENTATION OF CURRENT JLOTS CAPABILITIES

A. INITIAL INSIGHTS

Without question, a majority of today's Department of Defense (DOD) personnel (both military and civilian) are distinctly unfamiliar with the definition, scope, and procedures of JLOTS operations. Indeed, a high percentage of personnel have never heard the acronym "JLOTS". Many of those who have heard the term, often ignorantly parallel the discharge of material from ship to shore which occurs during JLOTS operations with that which occurs during an amphibious landing. By inexperienced personnel, this relationship is made based upon the cursory knowledge that both JLOTS operations and amphibious landings are conducted in geographic areas where port facilities are either inaccessible, insufficient, or non-existent. Although this comparison is understandable, it is inaccurate for a multitude of reasons, the most significant of which is that amphibious landings are conducted upon hostile shores, whereas JLOTS operations involve off-loading logistics assets in a benign environment. The definition of JLOTS, as promulgated by the Joint Staff, was given in Chapter I. This definition, however, offers little insight into the level of combined military/civilian planning and execution, nor into the wide ranging equipment, utilized in JLOTS operations.

B. THE WHO(S) AND HOW(S) OF JLOTS

The first step in understanding the integration of personnel, equipment, and procedures which yield throughput in a JLOTS operation is to establish a visual frame of reference. Figure 1 characterizes a typical LOTS operating area (LOA). This figure

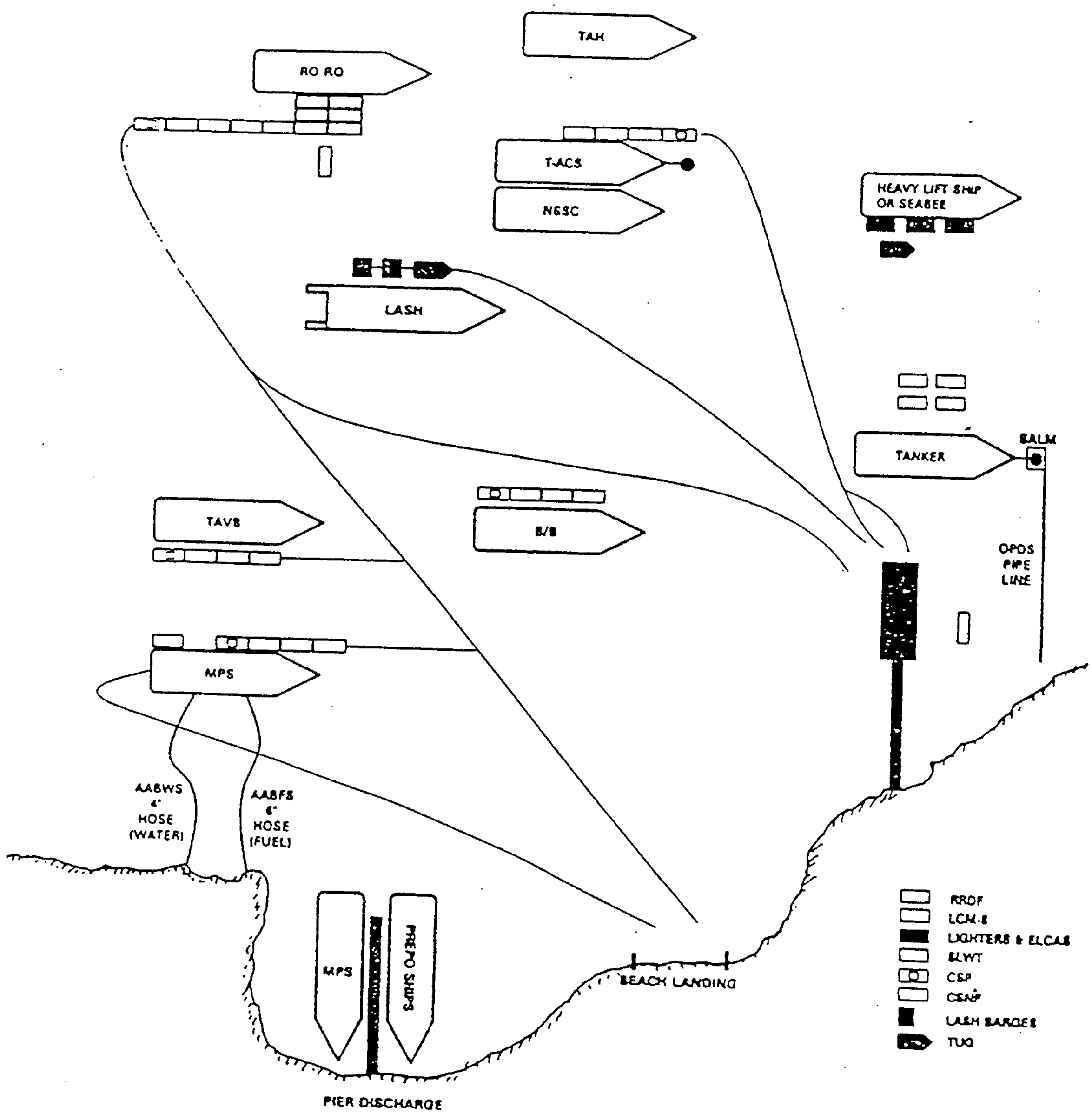

Figure 1. LOTS Operating Area, From Ref. [1].

depicts every major cargo carrying vessel (including crane ships for off-load capability) presently being utilized for JLOTS operations. Additionally, Figure 1 illustrates several major forms of supporting equipment utilized in JLOTS operations, such as: the Off-shore Petroleum Discharge System (OPDS), the Amphibious Assault Bulk Water and Fuel System (AABWS/AABFS), the elevated causeway (ELCAS), and the RO/RO discharge facility (RRDF). Moreover, Figure 1 clarifies that minimal pier facilities may or may not exist, and the draft of the various cargo vessels may promote or inhibit the use of those facilities. Finally, Figure 1 provides visual substantiation that JLOTS operations are conducted over unimproved shorelines, through fixed ports not accessible to deep draft shipping, or through fixed ports which have inadequate pier-side support equipment such as crane services. This visual representation expertly clarifies the very distinct differences between JLOTS operations and the discharge of equipment which occurs during an amphibious landing. Not shown in Figure 1, however, are the various forms lighterage and shore-side equipment employed during JLOTS operations. The term, lighterage, collectively refers to the various shipping assets, landing craft, tugs, and air-cushion vehicles used to transit off-loaded cargo to the beach.

In a JLOTS operating area (JLOA), the numbers and sizes of the strategic sealift assets, as well as the sophistication of supporting equipment, dwarfs that of an amphibious landing. This disparity is perhaps best exemplified by the lighterage vessels cited above. The amphibious landing employs lighterage vessels such as MIKE boats and/or Landing Craft Air Cushions (LCAC) which are carried in the bowels of other ships. JLOTS operations, however, can employ fully blue water capable ships of up to 275 ft. in length, such as the Army Logistics Support Vessel (LSV), as lighterage vessels. Appendix H contains a visual representation of the various shipping assets, and support equipment shown in Figure 1, as well as the each form of lighterage presently utilized in JLOTS operations and discussed throughout the remainder of this thesis. Within Appendix H, each strategic sealift asset, lighterage vessel, and supporting equipment entity is individually labeled for clarification and ease of reference. The photographs contained in Appendix H also provide a keen insight into the unique support equipment used in the inland marshaling and staging areas which comprise shoreside component of JLOTS. As established by the Joint Staff, this shoreside arm defines the furthest inland boundary of JLOTS operations. "The scope of a JLOTS exercise thereby extends from the acceptance region where the ships off-load, through the arrival of equipment and cargo at these inland marshaling and staging areas [Ref. 1:p. I-4]."

The following subsections explain five major aspects of JLOTS planning and execution. Each of these components is equally vital in ensuring that a large-scale JLOTS exercise of the magnitude shown in Figure 1 can be smoothly executed. Consequently, shortcomings in any one of these aspects will also hinder future JLOTS capabilities.

1. Military/Civilian Duties and Responsibilities

Although the military chain of command within the JLOTS operating theater is complex, within their area of responsibility (AOR), the supported CINCs maintain overall responsibility for JLOTS operations. The CINC may thus designate, or act himself, as Joint Forces Commander (JFC). In either case, his responsibilities include:

1. Develop JLOTS concept of operation and initiating directive.
2. Exercise combatant command (COCOM) of assigned forces.
3. Ensure security of JLOTS operations.
4. Allocate resources.
5. Provide intelligence on threat assessment and available inland transportation. [Ref. 1:p. II-1]

The JFC designates a JLOTS commander, from any service, who is responsible for the detailed planning and execution of JLOTS off-load operations [Ref. 1:p. II-6]. The JLOTS commander's responsibility begins with the acceptance of ships for off-load and continues through the arrival of the last quantity of dry or liquid cargo at the inland staging and marshaling areas. The JLOTS operating staff, which supports the JLOTS commander, will be comprised of an appropriate representation of the participating Service components. The senior officers of each Service component then, through the JLOTS commander, oversee the interests and assignments of their respective services during the exercise.

Complexity enters this command structure at the point of common-user sealift, which normally remains under the command of USCINCTRANS, unless otherwise directed by the Secretary of Defense (SECDEF). Reexamination of Figure 1 reveals that many of the shipping assets used during JLOTS operations fall under this category. During the initial mobilization for a JLOTS operation, USTRANSCOM, under the direction of the Joint Chiefs of Staff (JCS), will inform Military Sealift Command (MSC) which specific ship types and quantities are required. MSC fulfills these shipping requirements from within its own inventory first. For any shipping shortages incurred, MSC must then acquire the necessary assets from the Maritime Administration (MARAD) or via commercial contract, in that order. In fulfilling MSC's request, MARAD activates the necessary vessels from the Ready Reserve Force (RRF) in accordance with the respective reserve operating status (ROS) of each ship type. As MSC continues to acquire the necessary types and quantities of ships, Military Traffic Management Command (MTMC) may often assist MSC in the loading process by coordinating the mobilization and transportation of personnel and equipment from their respective areas of location to the ports of embarkation of each strategic sealift asset. Once the ships arrive in the theater, operational control (OPCON) of these vessels is normally delegated to the Commander, Military Sealift Command (COMSC), and tactical control (TACON) is delegated to the on-scene naval officer in tactical command (OTC). For tactical matters involving strategic shipping during the JLOTS operation, the JLOTS commander is considered subordinate to the OTC. Consequently, as the following subsection explains, command, control, and communication (C^3) is of paramount importance.

2. C^3 During Cargo Discharge Operations

One of the most noteworthy provisions for maintaining sound C^3 within the JLOTS task force is the presence of an MSC area commander's representative. Since only an MSC representative has the contractual authority to provide legally binding direction to the master of a common-user strategic sealift asset, the MSC representative's primary function is to resolve any sensitive issues which arise between the JLOTS commander and the masters of commercial vessels. His presence is also crucial in resolving differences between embarked military personnel and civilian mariners. During operations such as Offshore Petroleum Discharge System (OPDS) employment, where exact coordination between military and civilian personnel is vital, this individual is an invaluable asset. In addition to these duties, the MSC representative serves as a special staff adviser to the JLOTS commander regarding the usage and positioning of strategic commercial shipping assets. This individual is always located aboard ship and, if possible, with the JLOTS commander.

Despite the on-scene command assets such as the presence of the MSC representative, the most significant component of JLOTS C^3 is the union of prior planning with sound on-scene communication. Consequently, the timely construction and distribution of an operational order (OPORD) from the JLOTS commander to the respective Service commanders, prior to the commencement of the operation, is paramount. Each of the component services has both individual and collective assignments in the JLOTS environment. This OPORD establishes both a sequence and time-line for these assignments. Every provision of the OPORD from the selection of landing sites, through the positioning of ships, to the consideration of inland access requirements reflects the level of prior planning conducted by the JLOTS commander and Service component commanders. In most JLOTS operations, the degree of forethought and completeness instilled into the joint planning phase is consistent with the level of C^3 observed during the execution of the operation(s). For these reasons, any modeling tool and/or analytic medium which can enhance operational planning, such as an improved JOTE model, is highly warranted.

Certainly, specifics such as weather, environment, scale, and force structure serve to complicate or alleviate the C^3 problem in a JLOTS environment. Unfortunately, the most intricate JLOTS scenario (from a C^3 standpoint) is also the most common, namely, JLOTS operations subsequent to an amphibious landing. In this scenario, the smooth turnover of command responsibilities from Commander, Amphibious Task Force (CATF), to the Navy OTC, and subsequently to the JLOTS commander is vital in maintaining proficient cargo discharge. The specific criteria for turnover are highly situationally dependent, and are outlined in detail in Reference 1.

3. Cargo Off-load and Discharge System (COLDS) -- The Backbone of JLOTS

Having now developed this knowledge of the JLOTS command structure and its inherent dependence on strong C^3, the next step in understanding how throughput is achieved in a JLOTS operation is to explore the systems and equipment components which form the skeleton of JLOTS operations. Referring again to the JLOTS scenario depicted in Figure 1, the operation represented epitomizes the full execution of the Cargo Off-load and Discharge System (COLDS). In short, COLDS is an integrated system for discharging and transitting both liquid and solid cargo from a series of ships to various receiving points ashore. As Figure 1 represents, however, COLDS employs numerous diverse shipping, lighterage, and supporting equipment assets. As Figure 2 illustrates, COLDS is divided into two primary components, namely the Container Off-loading and Transfer System (COTS) and the Offshore Bulk Fuel System (OBFS). These subsystems are designed to operate simultaneously, sustaining an uninterrupted flow of supplies and bulk fuel from ship to shore. "The COTS portion of the COLDS is designed to provide the Navy Amphibious Forces with the capacity to off-load and back-load current and

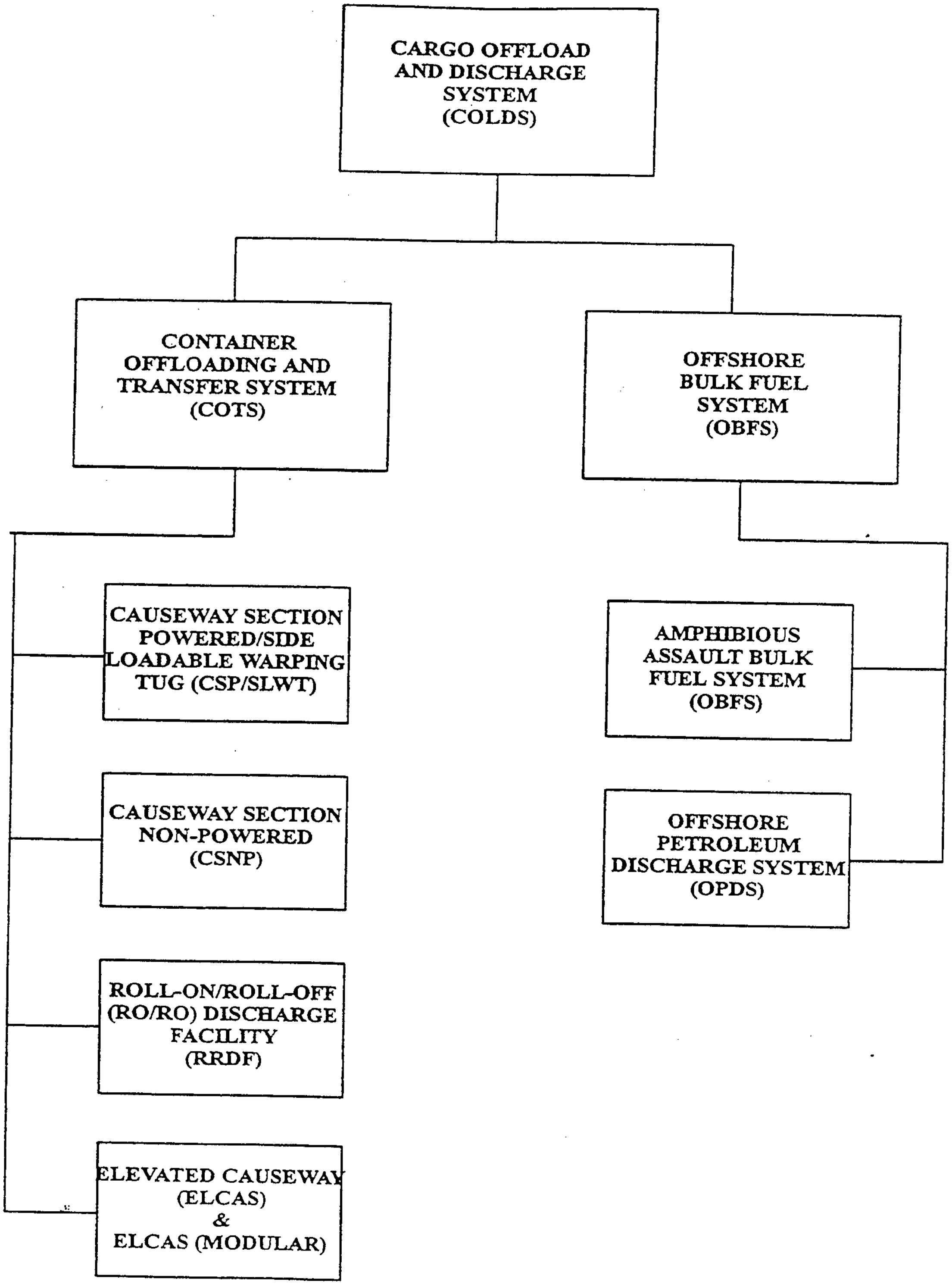

Figure 2. COLDS Overview, From Ref. [2].

future generations of containerized cargo vessels while moored offshore; and to deliver the container and vehicular cargo to the beach as required [Ref. 3:p. I-7]." Concurrently, the OBFS portion is intended to "provide all of the Armed Forces with the ability to off-load large quantities of petroleum products from military, Maritime Prepositioning Force (MPF), and commercial tankers [Ref. 3:p. I-6]". At this point, the best method for expanding upon the intricacies of the six sub-components of the COLDS is not to traverse them individually, but rather to examine them collectively by classifying JLOTS into two primary areas, namely, commercial shipping and military/civilian support equipment. Using the operation in Figure 1 as a reference, the following description(s) will clarify the COLDS sub-divisions shown in Figure 2 while eliminating overlap in equipment usages among the subdivisions.

a. Commercial Shipping and the Ready Reserve Force (RRF)

Thus far, the dominance of common-user strategic sealift assets in JLOTS operations has been cited without highlighting the unique mission capabilities of each of these vessels. There are seven primary strategic sealift assets utilized in JLOTS operations (each represented pictorially in Appendix H) namely: Sea Barge (SEABEE) vessels, OPDS vessels, Tactical Auxiliary Crane Ships (T-ACS), Lightweight Amphibious Container Handler (LASH) vessels, Roll-On/Roll-Off vessels (RO/ROs), container ships, and breakbulk ships. These strategic sealift assets are contained in the inventories of MSC, MARAD, or the commercial sector and, for JLOTS purposes, can be separated into two primary categories, special purpose vessels (SEABEE vessels, OPDS vessels, and crane ships) and cargo carriers (LASH vessels, RO/ROs, container ships, and breakbulk ships). Admittedly, the method of cargo discharge does vary among the cargo carriers but nonetheless, this general classification holds. The following elaboration of the capabilities of each of these vessels should be considered in conjunction with viewing the pictorial representations provided in Appendix H. Special purpose ships will be examined first.

The SEABEE vessels have been deemed the world's most versatile cargo liners. The SEABEE multi-mission cargo system employed on these vessels is an integrated combination of barges, containers, upper deck loaded oversized cargo capability, and RO/RO capability. Under this system, four types of barges are utilized for the purpose of transporting cargo from ship to shore or for bridging between causeways and the ship. The SEABEE standard barge (SSB) is an 84 ft. by 30 ft. barge with hatch covers to facilitate storage both above and below decks. The SEABEE building barge (SBB) is a three-story, covered barge capable of transporting 55,000 ft^3. The SEABEE transportation barge (STB) is self-propelled and used both to ferry vehicles from ship to shore, and as a tug to push other barges. Lastly, the SEABEE liquid barge (SLB) is used either to transport liquid provisions or as a floating gas station servicing other forms of lighterage. The SEABEE container system is characterized by a multitude of portable adapters which allow 20 ft. and 40 ft. containers to be carried both above and below decks. These adapters render the SEABEE capable of carrying up to 304 40 ft. containers or 15 2 40 ft. and 304 20 ft. containers [Ref. 4:p. 18]. The vast upper deck of the SEABEE easily facilitates the carrying of large equipment weighing up to 1700 lbs/ft^2 [Ref. 4:p. 19]. Additionally, there exists sufficient open deck space for landing of any helicopter in the U.S. Navy. Finally, the SEABEE's RO/RO capability is unmatched in terms of its ability to independently off-load vehicles onto the over three miles of 9.5 ft. wide roadway which it can carry if configured exclusively for RO/RO operations, or two miles of roadway if configured normally [Ref. 5:p. 7]. Each SEABEE can also perform RO/RO operations in the following three ways:

1. By backing to a pier or causeway and using its stern elevator as a bridge.
2. By docking alongside a pier or causeway and using an STB as a bridge.
3. By partially submerging the stern elevator and driving vehicles on to STBs. [Ref. 5:p. 7]

Because the SEABEE can be configured in a multitude of ways, the flexibility and diversity which it brings to JLOTS operations are unparalleled. Each of the following vessels performs a much less diversified, but equally important role.

OPDS ships provide the timely delivery of bulk petroleum products from an off-shore tanker to forces ashore. Unlike ships which employ the AABFS and/or AABWS where the fuel/water hose rests atop the water, OPDS ships employ the single anchor mooring leg (SALM) which maintains fuel hoses beneath the surface, thereby maintaining all sea lanes for lighterage craft. Figure 3 illustrates the placement of the SALM during OPDS operations. This system not only allows the tanker to be located up to four miles offshore, but nominally maintains stability in up to 40 kt. winds, 12 ft seas, 4 kt currents, and 200 ft. water depths [Ref. 6]. The final and most important benefit of the OPDS is its ability to deliver 1.2 million gallons of fuel per 20 hr. discharge time [Ref. 6]. Consequently, the AABFS and AABWS are utilized primarily as their names imply; during the actual amphibious assault. The OPDS, which is much more time, labor, and C^3 intensive, is commenced only when a beachhead is well secured and a benign environment

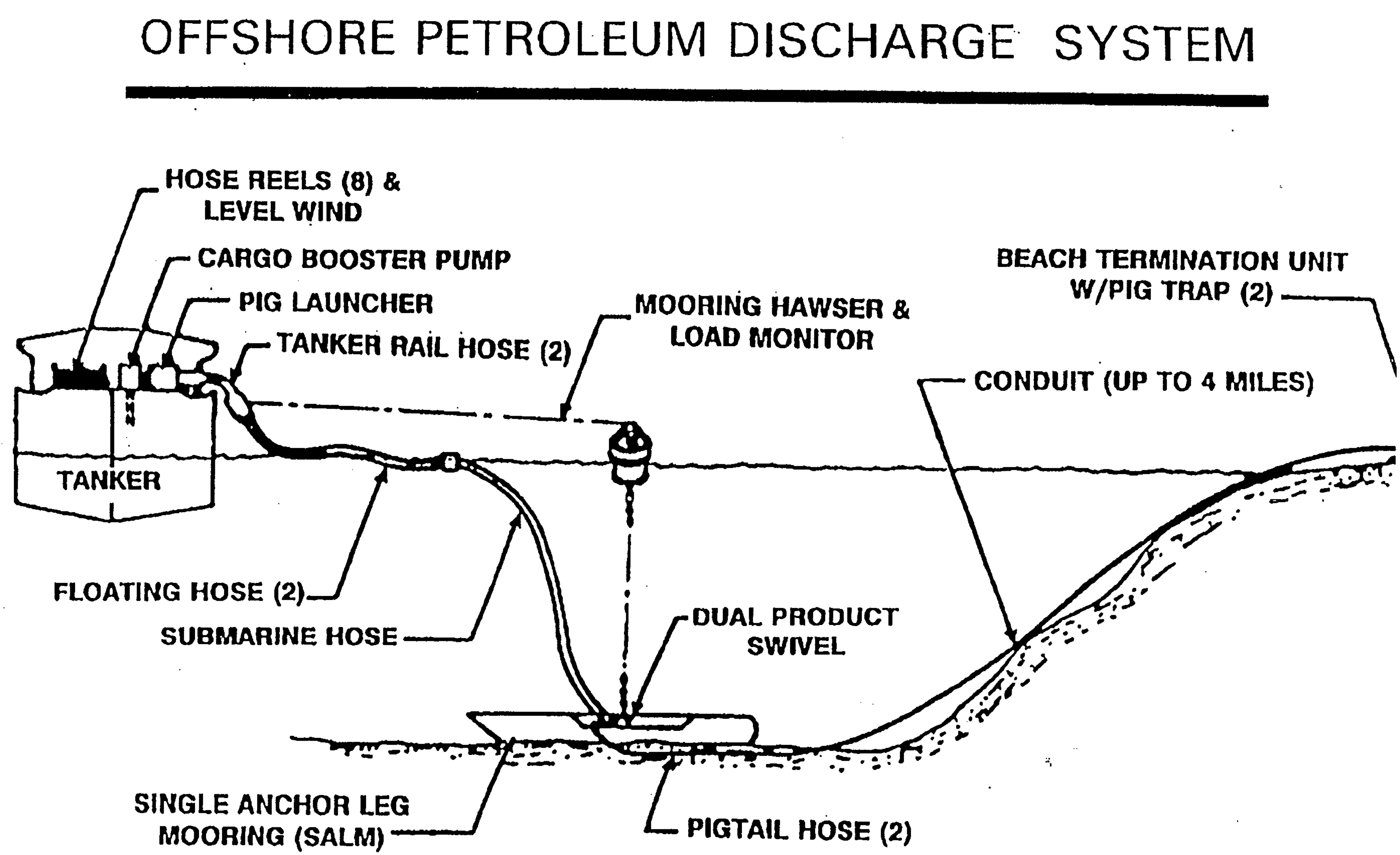

Figure 3. SALM Placement During OPDS Operations, From Ref. [6].

has been established; specifically, after the evolution has graduated from an amphibious assault to a JLOTS operation [Ref. 6].

The final mission-specific ship which warrants discussion is the T-ACS ship. The employment of these vessels in JLOTS operations is obvious. Specifically, their mission is to off-load containers and other outsized cargo from non-self-sustaining cargo ships offshore. These vessels are extremely self-sufficient in their scope of operation by carrying their own causeway sections for staging off-loaded cargo, as well as their own lighterage for transporting cargo ashore. This lighterage includes LCM-8s and causeway ferries (CWF), which are self-propelled are used to transport cargo ashore as well as to position other causeway sections. A secondary asset of the crane ship is its own ability to carry a moderate level of 20 ft. and 40 ft. containers both above and below decks [Ref. 7]. Trim and stability do restrict its capability in this area. This problem will be analyzed in great detail in the following section(s).

Collectively, the remaining four strategic sealift assets comprise the cargo carriers. The functions of three of these vessels, RO/ROs, container ships, and breakbulk ships, in JLOTS operations are self explanatory by their names. LASH vessels, however, do warrant independent discussion. These vessels carry and discharge container-like, ventilated barges which are off-loaded via a gantry crane. Since no other cargo or supporting equipment is carried aboard LASH vessels, they offer the ability to expeditiously off-load large amounts of cargo. A second benefit of LASH ships exploited in JLOTS operations is the ability to interconnect several LASH modules, thereby requiring the pushing services of only one tug or lighterage vessel. The LASH off-loading system is extremely efficient in JLOTS situations since several modules can be staged alongside the ship, interconnected, and moved as a group. While the first group is being moved, a second group can be assembled.

b. Military/Civilian Support Equipment

Perhaps the most widely recognized support equipment, unique to JLOTS operations, is the causeway. These floating roadways provide the primary means of transporting vehicles, off-loaded primarily from RO/ROs, to the shore. Additionally, causeway sections are carried by nearly all JLOTS shipping assets in order to be employed as floating staging areas for cargo off-loaded from ships which is awaiting the availability of lighterage for transportation ashore. Research and development is ongoing in the area of increasing the strength of causeways in terms of both carrying capacity and sea state stability. Currently, the Army is recognized as having the technological edge in the development of floating causeways. The Army Modular Causeway System (MCS), which is approximately ten years old, is a vast improvement over the 40 yr. old Navy Lighter (NL), a pontoonlike, non-modular causeway. The compactness of the MCS facilitates its carrying various JLOTS sealift assets. Unfortunately, however, the modular sections of the MCS must be assembled while waterborne. This greatly increases assembly and deployment time and thereby serves to counteract the stowage benefits inherent in the modular design.

The modular elevated causeway (ELCAS M), the Navy's latest design, which reached the fleet in the summer of 1996, does possess greater stability, but also fosters increased, labor-intensive assembly time compared to floating causeway. As Appendix H illustrates, elevated causeways are essentially constructed to resemble piers when completed. The NL causeway is capable of being transformed into an elevated causeway (ELCAS). Under this transformation, a series of support stanchions are constructed from the beachhead toward the sea, while pontoon causeway sections are subsequently floated ashore. The pontoon sections are then hoisted atop the support stanchions, thereby forming a crude pier-like structure. The ELCAS M greatly overshadows the ELCAS in terms of stability, versatility, and assembly time. Its framework and roadway are constructed simultaneously, as sections, from the beach outward to a maximum distance in excess of 3000 ft.. The large pierhead assembly at the seaward end of the ELCAS M houses two heavy lift cranes and two independent turntables. These fixtures facilitate the simultaneous loading and turning of two trucks. This design, combined with sufficient width along the roadway section of the ELCAS M, facilitates two-way truck traffic and greatly enhanced throughput.

Other modifications of MCS and NL causeway sections, include their use as CWFs and RO/RO Discharge Facilities (RRDF). In the CWF configuration, several nonpowered pontoon causeway sections are interconnected and propelled by a single motorized causeway section placed at one end of the unit. Both the NL and MCS causeways can be configured as CWFs, however, the NL causeway sections are predominantly used due to long standing propulsion problems with the powered sections of the Army MCS. Although the transit time from ship to shore for CWFs is exceptionally long due to their slow transit speed of approximately 5 kts., CWFs remain the work horse of our joint lighterage inventory [Ref. 1]. This is due to the ease with which both rolling stock and containerized cargo can be loaded onto CWFs for transit ashore. The RRDF configuration is characterized by causeway sections being interconnected to form either a square or rectangular shaped platform onto which the ramp of a RO/RO can be lowered and/or discharged cargo can be staged. Unfortunately, however, like the T-ACS and all other JLOTS strategic sealift assets and support equipment, the CWF and RRDF are extremely susceptible to wind, weather, and sea state conditions. Therefore, the validity of any JLOTS throughput or capability assessment model is highly dependent upon the proper incorporation of data in each of these three areas. Each of these causeway types, and the unique configurations thereof, are represented pictorially in Appendix H along with the Navy's present developmental causeway design, the Amphibious Cargo Beaching Lighter (ACBL) [Ref. 8]. It is the ACBL and its configurations which are expected to render JLOTS operations far less susceptible to the environmental shortfalls discussed above.

Amphibious transport boats, LCUs, and air cushion vehicles comprise the majority of remaining lighterage used to transport cargo from ship to shore. Many of these vessels are pre-loaded with their initial load and self-deployed from their parent ship. They are then available for transport from any of the cargo ships involved in the operation. Several have extremely specific functions. The LACV-30, for example is the primary transport platform for heavy-lift vehicles such as the M-1A1 tanks. Others, such as the LCU-2000, LCU-1600, and LSV are classified as lighterage merely because of their ship-to-shore transport employment. These three vessels are each fully functioning ships of 135 ft. - 272 ft. in length. Their role in JLOTS operations is similar to that of a shuttle ship in standard carrier battle group (CVBG) underway replenishment. In the CVBG, the smaller shuttle ships either transport cargo from the shore to the replenishment ship or distribute cargo from the replenishment ship to the other ships of the battle group. In the JLOTS scenario, large amounts of primarily containerized cargo are loaded onto these ships via crane ships from the larger, deep draft cargo vessels. These smaller, more maneuverable, and more easily off-loadable vessels then transport the cargo to existing shore facilities or to the pierhead sections of ELCAS piers.

Many of the strategic sealift assets possess unique equipment from which compound benefits are realized in a JLOTS operation. Equipment such as:

1. The submersible elevator of the SEABEE ships.
2. The gantry crane of the LASH vessels.
3. The loading/unloading ramps of the RO/ROs.
4. The SALM of the OPDS ships.

not only facilitates the mission accomplishment of its respective parent platform but also increases the overall self-sufficiency of that platform unit in the JLOTS task force. Although the JLOTS operation is a team effort, greater self-sufficiency among individual assets directly eases the C^3 problem.

4. Shoreside Components of JLOTS Operations

No matter how capable and efficient the sea component of the JLOTS operation becomes, if the marshaling and shoreside infrastructure does not operate with the same proficiency, the operation will inevitably fail. The shore-side cargo discharge operations are both scenario and Service support dependent [Ref. 1]. Additionally, the shore-side phase of the operation normally incorporates a simultaneous involvement between Army and Navy personnel. During the sea-side phase, construction of causeways and deployment of lighterage and support equipment is primarily a Navy function, whereas the actual off-load of cargo is primarily Army driven. The ultimate shore-side goal is to maximize throughput. Consequently, the first cargo to reach the shore is that which is needed for the construction of temporary piers, as well as a multitude of off-loading equipment and heavy ground transportation assets. A full scale JLOTS operation, as shown in Figure 1 will normally involve the construction of both Army and Navy piers (PHIBCBs and floating causeways respectively) as well as an ELCAS or ELCAS M. These temporary piers will be relied upon for all off-load until ELCAS construction is complete. Once constructed, the ELCAS is used for container off-load. The temporary piers are then used to form a floating bridge for landing ships and watercraft, thus facilitating the off-load of wheeled and tracked vehicles.

The preceding subsections have offered a broad and in-depth overview of both the hardware and doctrinal components of a JLOTS operation. Admittedly, the U.S. presently possesses a moderate JLOTS inventory, especially relative to other nations of the world. As the next section illustrates, however, present JLOTS throughput capabilities are drastically limited by two primary factors, namely, lack of training and the lack of a Sea State Three operating capability.

C. AN ANALYSIS OF NECESSARY JLOTS IMPROVEMENTS

Over the past 15 yrs., there have been only a handful of full scale JLOTS test evolutions. These tests included:

1. JLOTS II 1982
2. JLOTS III 1991
    a. Display Determination 1991 (DD91)
    b. Ocean Venture 1992 (OV92)
    c. Ocean Venture 1993 (OV93)

and yielded two primary realizations. First and foremost, these exercises revealed that present JLOTS throughput capabilities are drastically lower than prescribed levels as promulgated in Reference 1 for all types of strategic sealift assets and supporting equipment within the joint JLOTS inventory. This observed shortfall was due, in large part, to nonexistent operations during any weather conditions which yielded sea states above Sea State Two. Secondly, they indirectly added a great deal of credence to the contention that JLOTS training for both military and civilian personnel is seriously lacking. Certainly, the lack of training, and therefore diminished proficiency levels, was an additional contributing factor in the unacceptable throughput levels attained in the above exercises. More importantly, however, is the fact that these test evolutions were the only full scale JLOTS operations conducted during this time period. Thus, this schedule begs the question "How could proficiency levels increase without training exercises?" Not only is the answer to this question obvious, but the serious lack of training within the JLOTS community has resulted in speculation among test evaluators that the proficiency of senior military officer and civilian masters in planning and executing the operation is equally as poor as the ability of enlisted servicemen and civilian mariners to operate the multitude of JLOTS support equipment.

1. The Shortfall Between Present Capabilities and Requisite Levels

Admittedly, all the blame for substandard throughput levels does not rest solely in the areas cited above; however, those areas are certainly the most culpable. Other contributing factors include the rapidly increasing ages of highly JLOTS proficient civilian mariners and a lack of funding for an aged RRF fleet. It has also been suggested that perhaps the nominal throughput levels in Reference 1 are too high and should be lowered to meet present capabilities. Arguably, this contention fosters complacency. A potentially better course of action is to first increase training, and therefore proficiency levels, by conducting more exercises before concluding that the nominal figure should be lowered. Concurrent with this action, enhanced research and development must continue in order to produce supporting equipment capable of breaching the Sea State Three threshold. Additionally, any analytical medium which can ease the planning burden upon the JLOTS commander by better predicting Sea State Three occurrences in a given location is highly warranted.

a. The Sea State Three Problem

Despite the magnitude of the hindrance of Sea State Three conditions upon JLOTS operations, it is only within the past two to three years that major JLOTS planners, such as United States Transportation Command (USTRANSCOM), have changed their position regarding Sea State Three operations. In the period immediately following JLOTS III, USTRANSCOM's position was that the difficulty and danger of JLOTS operations in Sea State Three or above outweighed the need to operate under these operations. USTRANSCOM maintained that the time lost in waiting for winds and seas to fall below Sea State Three was acceptable when compared to the dangers of operating in such conditions, and was therefore satisfied with ceasing the vast majority of JLOTS operations at the upper limits of Sea State Two. The change in this position was brought about largely due to an assertion from the various CINCs in the mid 1990s that a Sea State Three JLOTS capability was desired. The efforts of OPNAV N-42, who recognized not only that throughput levels to the supported CINC ashore must be increased under all weather conditions, but also that research and development projects such as the ACBL could potentially breach the Sea State Three barrier also assisted in changing USTRANSCOM's position. The Joint Staff J-4 shared OPNAV N-42's concern and recognized that JLOTS throughput must be increased in terms of quantity, speed, and efficiency. It was this mutual concern, and a fear that U.S. JLOTS capabilities may not be sufficient to satisfy the requirements of all CINCs, that prompted the tasking for LMI's initial JLOTS assessment, and hence, the development of the JOTE model.

The specific dilemma created by Sea State Three or higher conditions differs among the various JLOTS strategic sealift assets and supporting equipment. In some cases the limiting factor is the height of Sea State Three waves, which is three to five feet. In other cases, the shortfall can be caused by either the frequency, "choppiness," associated with Sea State Three waves, or simply by the wind conditions which characterize Sea State Three conditions, which are 30 kt. winds blowing over a 10 nm area for 1-2 hrs. Referring again to the pictorial representations of Appendix H, it is evident that for each of the strategic sealift assets, the major Sea State Three problems are:

1. Launching any self-serving forms of lighterage (barges, LASH modules, etc.).
2. The need for excessive fendering between the ship and its cargo carrying and/or staging lighterage.
3. The inability to off-load cargo via heavy lift or gantry cranes due to excessive relative motion differences between the cargo delivery vessel and the cargo receiver.
4. The inability to deploy the SALM unit in support of OPDS operations.

Likewise, for JLOTS supporting equipment, the major Sea State Three obstacles affecting throughput are:

1. Extreme difficulty in constructing either type of elevated causeway.
2. The inability to join either NL or MCS causeway sections in order to construct CWFs or RRDFs.
3. Sea water engulfing the surface of CWFs and RRDFs due to the minimal freeboard of NL and MCS causeway sections.

Figure 4 was compiled by U.S. Army Waterways Experimentation Station (WES) using test data from JLOTS II [Ref. 9]. This figure aggregates container discharge operations for all vessels used in JLOTS II, and depicts the manner in which cargo off-load operations are diminished in an upper Sea State Two to Sea State Three environment. Although an identical graph was not constructed for JLOTS III, the JLOTS III Ocean Venture 93 Summary Report does cite that throughput levels for both container discharge and RO/RO operations conditions were lower than those observed under the same conditions during JLOTS II [Ref. 10:p. 13, 15].

2. Corrective Actions for JLOTS Deficiencies

OPNAV N-42, the Joint Staff J-4, and USTRANSCOM have taken the first steps toward correcting the Sea State Three problem by collectively realizing that a JLOTS operating capability in Sea State Three conditions is a requirement. All three now

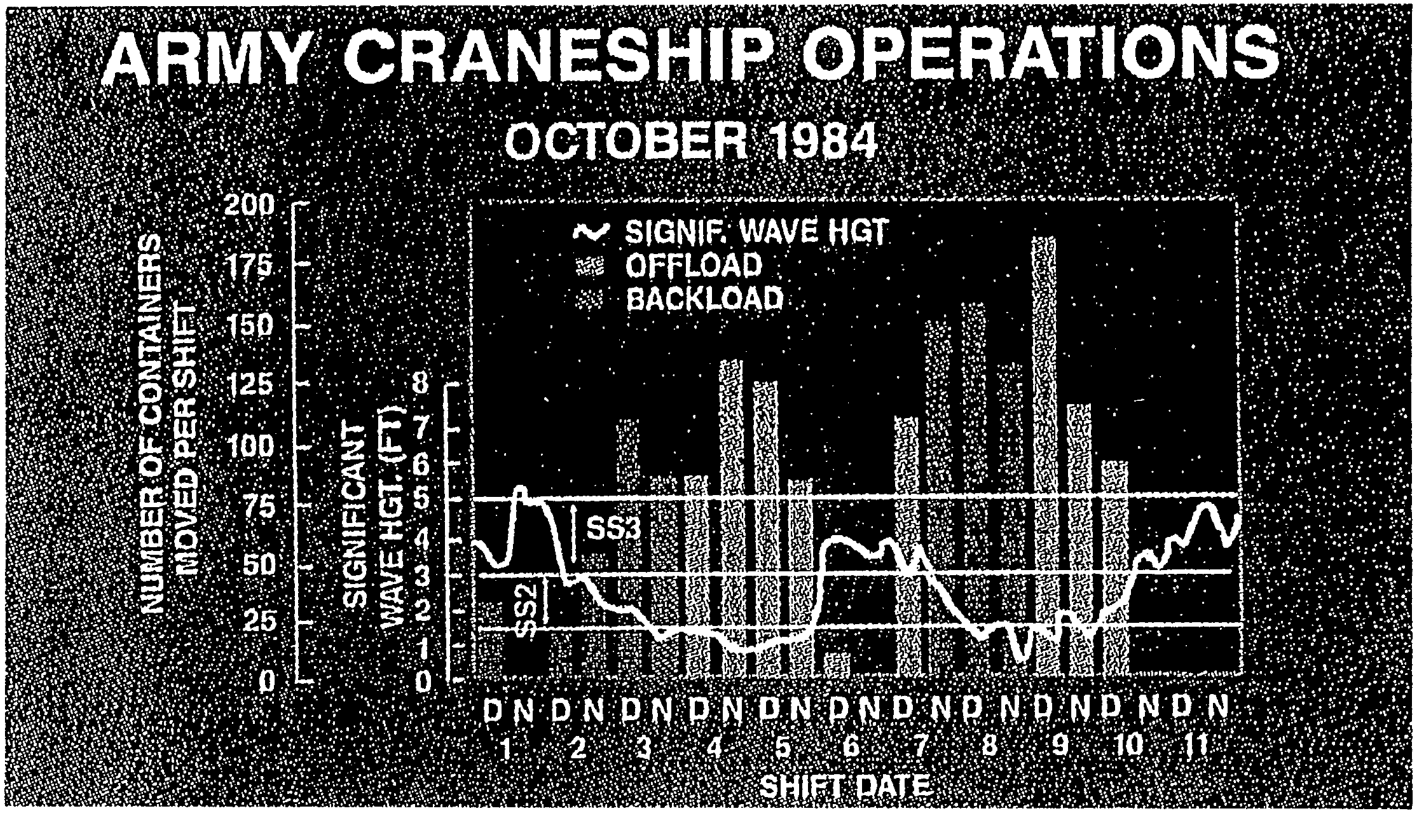

Figure 4. Container Discharge Operations During JLOTS II, From Ref. [9].

advocate this position not only for the purpose of better fulfilling the throughput requirements of the various CINCs today, but also, for enhancing U.S. JLOTS capabilities as a means of preparedness for the military challenges of tomorrow. Additionally, the ACBL project, an engineering effort undertaken at the Naval Facilities Engineering Service Center (NFESC), Port Hueneme, CA, is presently being expanded from a Navy research and development project into to a joint project at the recommendation of the Joint Staff J-4. The design objective is to develop a causeway system which expands upon the technology of the Army MCS. Specifically, the proposed Amphibious Cargo Beaching Lighter (ACBL) would employ the same modularized design, however, each module would have dimensions of 24 ft. wide, 40 ft. long, and 8 ft. deep [Ref. 11]. These dimensions would produce drastically more freeboard area and thereby render much greater stability in high sea states. Tank testing has shown that this design does not succumb to the effects of wave action until Sea State 5 conditions are imposed. While greatly enhancing stability, this modular design would still facilitate stowage aboard any container ship having a three wide container cell space, which most container ships employed in JLOTS evolutions do possess. This size difference between ACBL, the MCS, and the NL are illustrated pictorially in Appendix H.

Despite its vast improvement over existing lighterage, it must be emphasized that the ACBL alone does not guarantee a full Sea State Three operating capability. That end result can only be obtained with the concurrent development of new crane system technology capable of overcoming the relative motion differential problem between T-ACS and lighterage under Sea State Three conditions. Several viable research and development projects in crane technology are presently being considered by the Naval Surface Warfare Center, Carderock Division in Bethesda, MD.

Certainly, the development of the ACBL addresses the most glaring Sea State Three equipment limitation, namely, incapable lighterage. In response to shortfalls cited in JLOTS III, however, numerous other equipment modifications have been made both to the strategic sealift assets within the MSC and MARAD inventories and the supporting equipment within the joint military inventory. These changes range in complexity from new hydraulic transporter systems for maneuvering barges inside SEABEE vessels, to increased fendering on both strategic sealift assets and lighterage, to revitalized stowage plans.

Without question, all the senior level military commands having an interest in JLOTS have not only realized the significance and ramifications of the Sea State Three problem, but have also undertaken equipment-related actions to overcome this problem. This chapter has also emphasized, however, that in addition to the Sea State Three problem, the proficiency of equipment operators and military/civilian leadership in JLOTS operations is also in need of improvement. It is for the purpose of addressing both of these areas that research facilities, such as LMI, are tasked with developing analytical models for use in capability assessments, new equipment feasibility studies, and enhanced planning tools.

As Chapter III will demonstrate, with the JOTE model, LMI has served their tasking better than any other research facility. Chapter III will also illustrate, however, that JOTE is not without limitations and shortfalls in its potential to assess JLOTS capabilities. Additionally, Chapter III will expose an entirely new application of JOTE, namely, as a much needed planning tool for the JLOTS commander. This application as a planning tool will assist the JLOTS commander not only in determining a target date for launching the operation and thereby forcing timely mobilization, loadout and deployment, but also by constructing that target date from a positive weather standpoint and thereby minimizing the effects of the Sea State Three problem.

Despite the substantiality of its documentation, a mastery of the mathematics of the Sea State Three problem has been curiously absent from JLOTS throughput models up to, and in some sense including, JOTE. With this in mind, Chapter III begins with an analysis of this concept. This analysis will serve as a baseline from which to highlight the areas in which LMI's predecessors have fallen short, as well as the areas in which JOTE must improve.

III. ANALYTICAL RESEARCH EFFORTS IN JLOTS OPERATIONS

A. AN ANALYSIS OF WAVE MEASUREMENTS

The multiple figures of Appendix A clearly quantify the limitation of JLOTS operations due to significant wave heights consistent with Sea State Three conditions. The terms sea state and significant wave height, however, are somewhat vague. Table 1 clarifies the wind and wave characteristics which define the various sea state conditions. The term significant wave height mathematically refers to the average of the one-third highest waves and is expressed as $H_{1/3}$. This definition is enlightening when one considers that since JLOTS operations are limited to Sea States 3 and below (and thereby significant wave heights ranging from 3.3 ft. to 4.6 ft.), the inference is that two thirds of the observed waves are therefore less than 3.3 ft. in height. This scenario communicates that relatively tranquil conditions can maximize the present JLOTS operating capability. Moreover, it must be emphasized that JLOTS operations are conducted in the littoral region only. Significant wave height within this region is determined as a function not only of the wind conditions within that region, but also, of the swell produced by the prevailing wind conditions in the off-shore region. Within the littoral region, the fetch (the distance over which the prevailing winds are blowing) can be relatively small. In the off-shore region, however, the fetch can be hundreds of miles, thereby generating offshore waves which easily produce a swell which raises littoral significant wave height above JLOTS operating limits. Figure 5 depicts the methodology for calculating significant wave height as a function of surface wind speed, fetch, and duration in the off-shore region.

SEA-GENERAL		SEA			WIND		
SEA STATE	DESCRIPTION	SIGNIFICANT WAVE HEIGHT (FEET)	AVERAGE WAVE PRD (SECS)	AVE WAVE LENGTH (FEET)	RANGE (KNOTS)	MINIMUM FETCH (NMs)	MINIMUM DURATION (HOURS)
0	Sea like a mirror	0	-	-	1	-	-
	Ripples with the appearance of scales formed, but w/out foam crests	0.08	0.5	0.3	1 - 3	5	0.3
1	Small wavelets, short but pronounced; crests have a glassy appearance, but do not break	0.29	1.4	6.7	4 - 6	8	0.65
	Large wavelets, crests beginning to break. Foam of glassy appearance. Perhaps scattered white caps.	1.0	2.4	20	7 - 10	9.3	1.7
2		1.4	2.9	27		20	2.4
	Small waves, becoming larger; fairly frequent white caps	2.2 2.9	3.4 3.9	40 52	11 - 16	18 24	3.3 4.3
3		3.3 4.6	4.0 4.6	59 71		28 40	5.2 6.6
4	Moderate waves, taking a more pronounced long form; many white caps are formed. (Chance of some spray)	6.1 6.9	5.1 5.4	90 99	17 - 21	55 65	8.3 9.2
5		8.0	5.7	111		75	10
	Large waves begin to form; white foam crests are more extensive everywhere. (Probably some spray)	10 12	6.3 6.8	134 160	22 - 27	100 130	12 14
6		13 15	7.0 7.4	164 188		140 180	15 17

Table 1. Sea State Definitions and Characteristics, From Ref. [12].

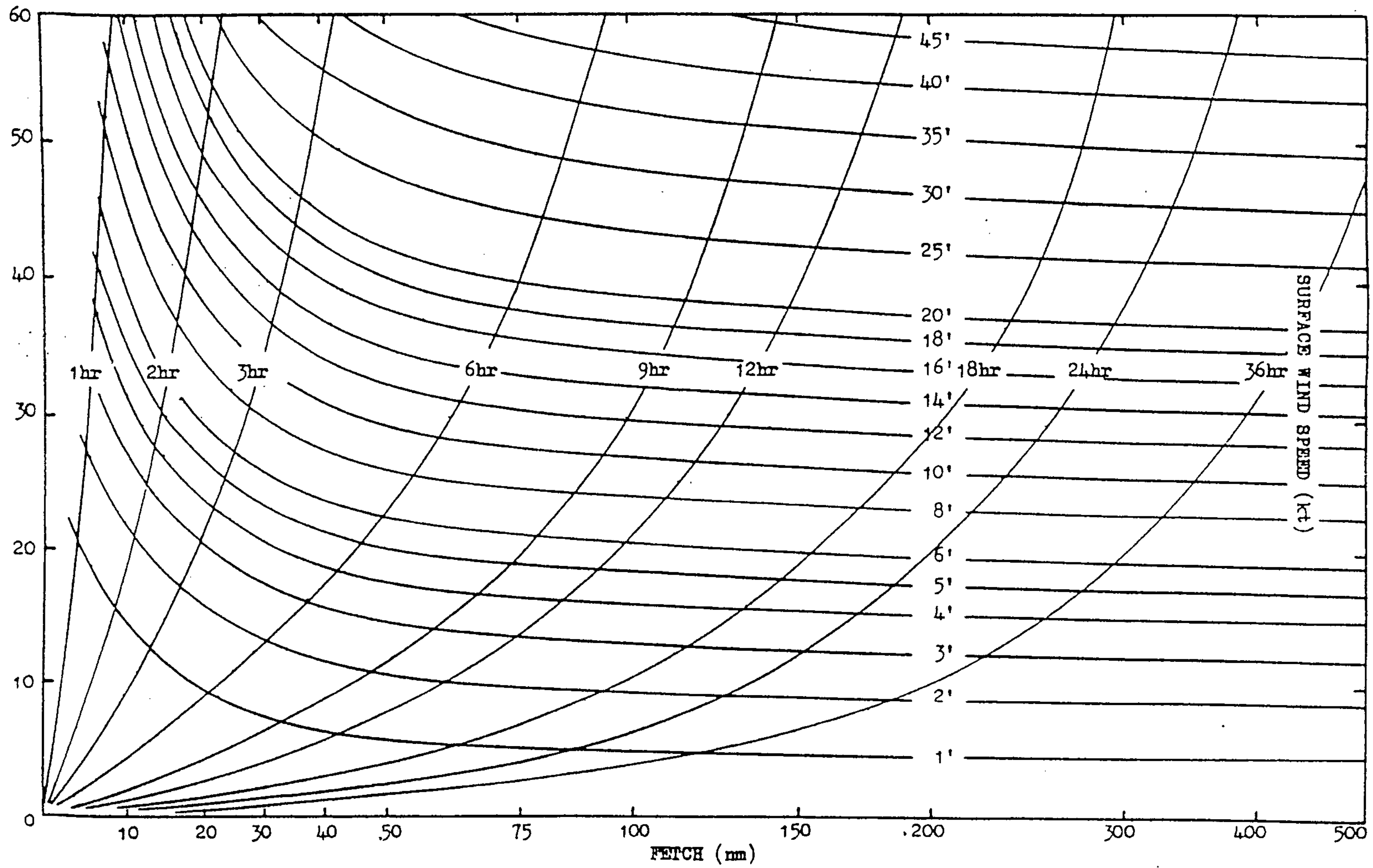

Figure 5. Approximating Significant Wave Height as a Function of Surface Wind Speed, Fetch, and Duration, From Ref. [13].

Most individuals correctly realize that sea state is determined by wave height. A common error however, is the failure to understand that wave height, in either the littoral or off-shore region, is determined by wind waves and sea waves. Wind waves represent the waves generated by the fetch of the prevailing wind. Sea waves, on the other hand, represent the swell observed at a given location, either littoral or off-shore, which is caused by fetch of an off-shore wind. Consequently, swell is a determining factor of wave height, and therefore sea state, in both the littoral and off-shore regions. The following visual and mathematical analysis of the littoral and off-shore wave spectra not only clarifies the effects of swell in both regions, but also, specifically addresses the unique characteristics of shallow water versus open ocean waves.

In off-shore areas, a given sea state can be expressed mathematically as the sum of simple harmonic waves each possessing a specific amplitude, wave length, frequency and direction of propagation. Phases of the components are considered randomly distributed over 360°. Under this type of representation, each component wave moves at a phase speed that depends upon its wave length, causing a dispersion of the longest waves ahead of the shortest. Wave spectra provide the distribution of surface wave variance as a function of frequency and/or direction. The variance due to wave components within a frequency range is obtained by summing the variance contributions within the range as shown in Equation 1.

$$E(f) = 1/2 \sum_{\Delta f} a_n^2, \tag{1}$$

(a_n = *amplitude of a simple harmonic wave* [*Ref.* 14:*p.* 11])

This formula results in spectra being defined with units of variance/frequency. The distribution of variance as a function of frequency and direction is deemed the two dimensional or directional spectrum. Figure 6A represents the directional spectrum that would result from an idealized sea-state having only one component with frequency, f_η, traveling along the positive x-axis, $\theta = 0$. The resulting spectrum, $E(f,\theta)$ is zero except for a spike at the point corresponding to the frequency and propagation direction of the single wave. The variance in the small frequency range, Δf, and direction range, $\Delta\theta$, is given by Equation 2.

$$VARIANCE = E(f,\theta)\ \Delta f\ \Delta\theta \quad [Ref.\ 14{:}p.\ 12] \qquad (2)$$

Obviously, this ideal wave spectrum does not exist for either shallow water or open ocean waves. It does, however, provide the framework for understanding the wave spectra associated with each of those areas. Figures 6B and 6C represent the two possible wave spectra scenarios for open ocean wave patterns. Figure 6B depicts a situation whereby multiple harmonic waves of various amplitudes and directions converge to form a dominant wave pattern propagating in nearly a single X-direction. The resulting one-dimensional spectrum, $E(f)$, represents a series of component waves of different amplitudes and frequencies traveling in one direction $\theta = 0$. Figure 6C, however, represents the more common open ocean sea surface scenario, whereby waves of varying amplitudes propagate in multiple directions. This figure shows a typical short-crested, multi-component sea state that is represented by the two-dimensional energy spectrum, $E(f,\ \theta)$. From this figure, one can truly grasp the nonlinearity associated with the

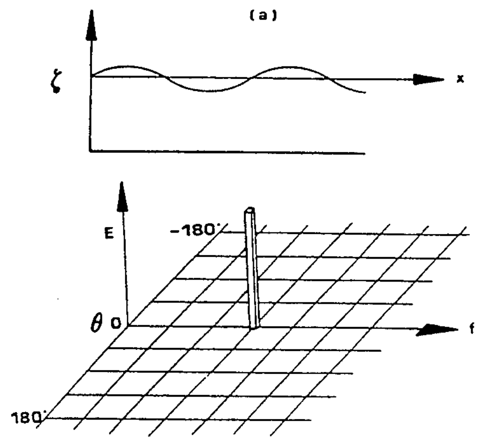

Figure 6A. Idealized Sea State Condition, From Ref. [14:p. 12].

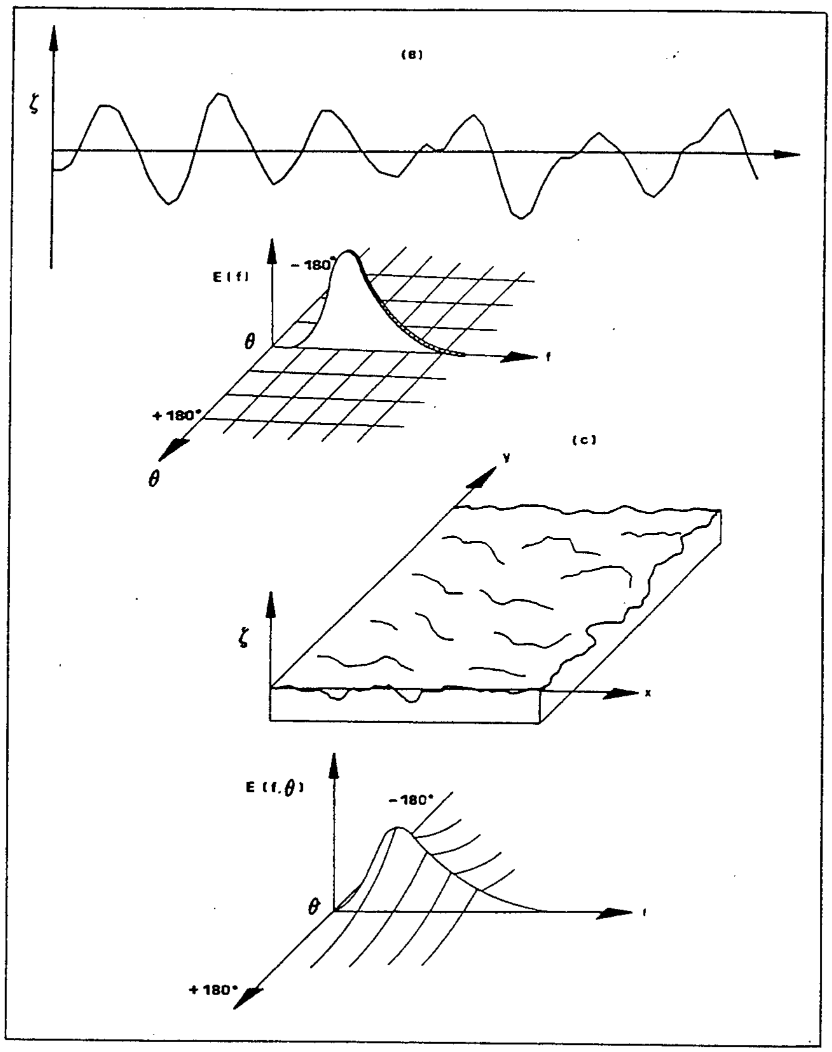

Figure 6B. Convergence of Multiple Harmonic Waves, From Ref. [14:p. 13].
Figure 6C. Multi-Directional Wave Propagation, From Ref. [14:p. 13].

propagation of waves upon the seas. This nonlinearity is even further characteristic of the shallow water region due to the distinct effects of swell within that region. Sea waves (swells) are characterized by long crests which translate into long wave lengths and periods. Consequently, a wave spectrum which includes a swell component would resemble Figure 6C, but would possess two peaks. The lead peak would characterize wind waves and would be similar to that shown in Figure 6C, while the second peak, representing the propagation and direction of the swell component, would be much sharper resembling that shown in Figure 6A.

Despite the sea state scenario at hand, both the one-dimensional spectral density, $E(f)$, and the two-dimensional spectrum, $E(f, \theta)$, offer the means by which several important statistical properties can be calculated. Keeping in mind that both $E(f)$ and $E(f, \theta)$ represent the variance of waves upon the surface of the sea, the following relationships exist. First, the one dimensional spectrum, $E(f)$, is obtained by integrating $E(f, \theta)$ over all possible directions as illustrated in Equation 3

$$E(f) = \int_{-180^\circ}^{180^\circ} E(f,\theta)\, d\theta \quad [Ref.\ 14{:}p.\ 14] \tag{3}$$

Using either $E(f)$ or $E(f, \theta)$ one can also calculate the total wave variance on the surface of the sea in the manner shown in Equations 4 and 5.

$$Total\ Variance = \int_{0}^{\infty}\int_{-180^\circ}^{180^\circ} E(f, \theta)\, d\theta\, df \quad [Ref.\ 14{:}p.\ 14]$$
$$Total\ Variance = \int_{0}^{\infty} E(f)\, df \quad [Ref.\ 14{:}p.\ 14] \qquad (4), (5)$$

The significant wave height, $H_{1/3}$, can then be estimated from the *Total Variance* as illustrated in Equation 6.

$$H_{1/3} = 4 * \sqrt{Total\ Variance} \quad [Ref.\ 14{:}p.\ 14] \qquad (6)$$

Admittedly, this theoretical, mathematical definition of significant wave height is far more difficult to calculate than the previous method demonstrated, namely, averaging the heights of the one-third highest waves. Indeed, the focus of the above paragraphs was not to graduate into a mathematical analysis of surface wave characteristics, but was instead designed to highlight the distinct difference in surface wave characteristics between off-shore and near-shore waves. Additionally, a collective analysis of the wave spectra presented in the previous pages should reveal the magnitude of the Sea State Three inoperability problem to the JLOTS commander. Specifically, because littoral waves in coastal areas possess a significant swell component, Sea State Three conditions can easily exist even when prevailing wind speeds are negligible and the amplitude of local wind waves is nonexistent. In fact, in various regions of the world, at certain times of the year, a situation such as that depicted in Figure 7 is not uncommon. Here, a Sea State Four to Sea State Five situation is occurring in a littoral region where local winds are producing waves of only 2.5 ft. heights. Figure 8 characterizes that situation in the context of spectrum graphs by displaying most probable and worst case combinations of sea state and swell within this particular littoral region. In Figures 7 and 8 the X-axis is expressed in terms of wave frequency, ω, which is defined in units of $\left(\frac{Radians}{Second}\right)$. The Y-axis in each of these figures is expressed in terms of the swell height, $S(\omega)$, which is produced by a

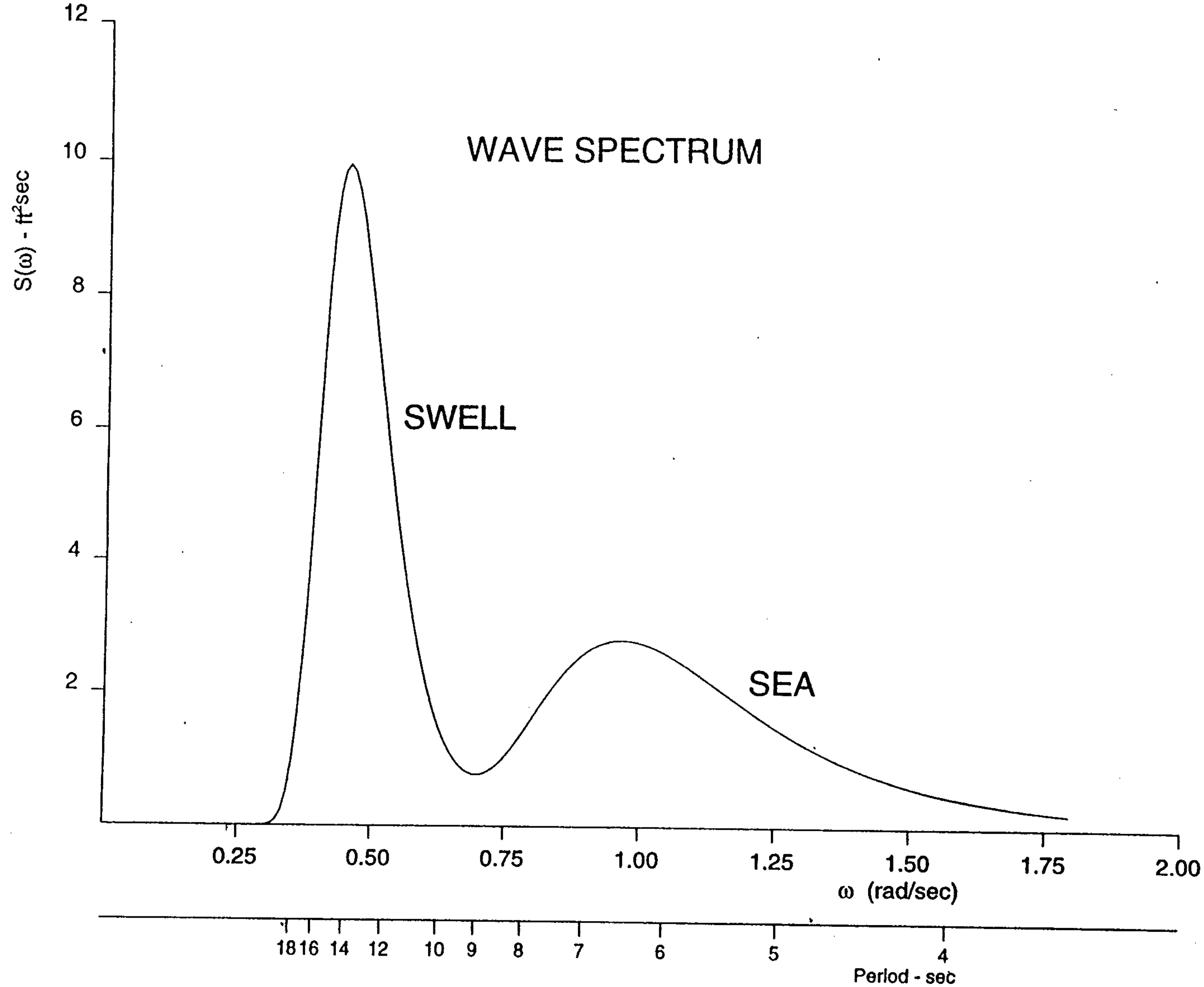

Figure 7. The Potential Impact of High Swell, From Ref. [15].

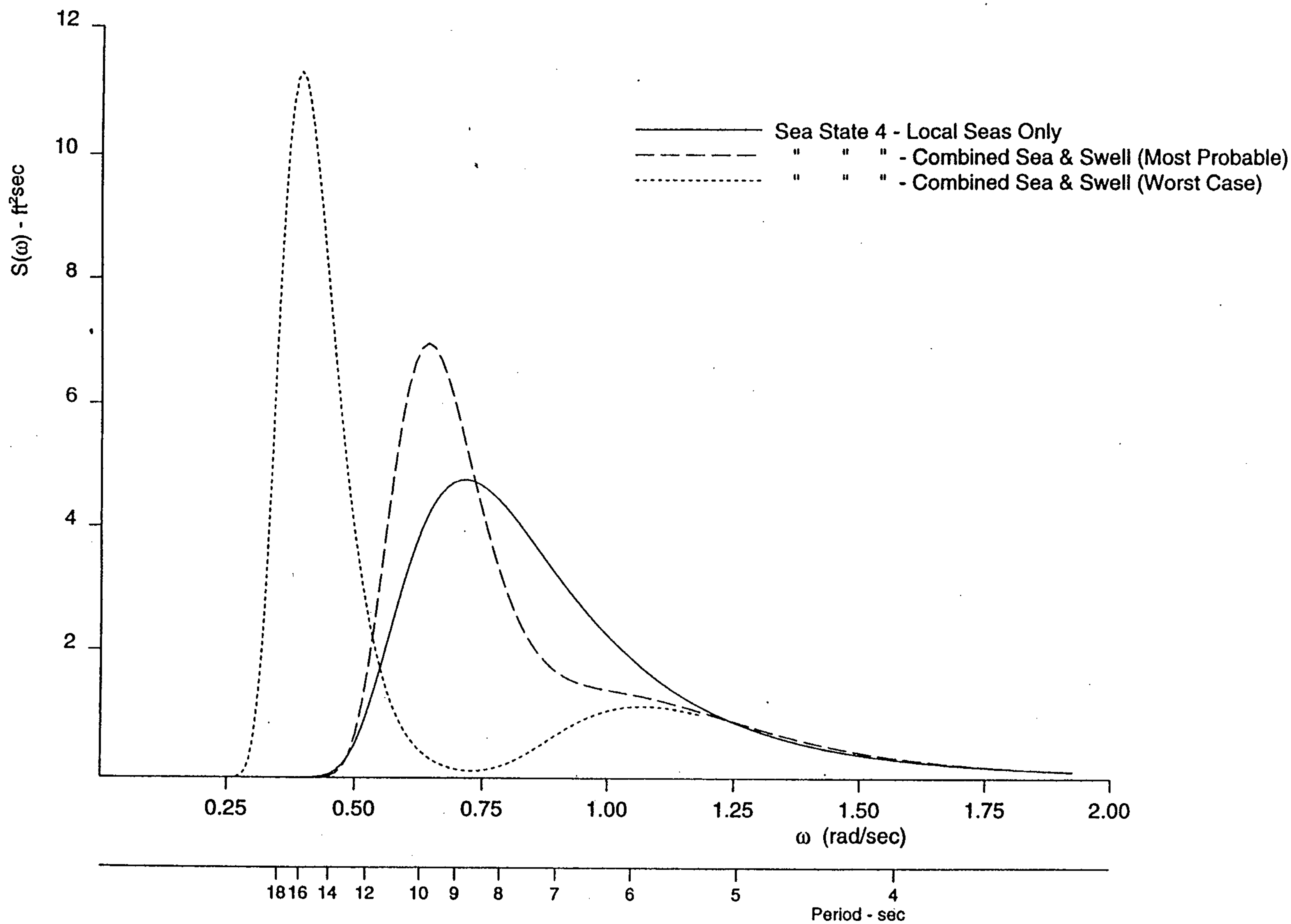

Figure 8. Potential Impact of High Swell --- Most Probable Versus Worst Case Scenarios, From Ref. [15].

wave with the frequency ω. The units of measurement for the Y-axis of Figures 7 and 8 is $(Feet^2 * Second)$.

Despite the many sources which contribute to wave heights within the littoral region, there does exist a validated medium by which wave heights within this region can be predicted over time. Regardless of the determining factors of wave height, wave heights in both the littoral and off-shore regions follow a Rayleigh probability which has a PDF characterized by Equation 7.

$$f_R(r) = r\, e^{-r^2/2} \quad [Ref.\ 16{:}p.\ 96] \tag{7}$$

Figure 9 represents the Rayleigh probability distribution, $P(H)$, as applied to wave heights, H. The X-axis corresponds to the ratio of a given wave height, H, to the root mean square wave height, H_{RMS}, of all waves observed during a particular wave record (sequence of wave observations). The Y-axis represents the frequency of occurrence of a wave of any given height. Here significant wave height, $H_{1/3}$, is calculated as shown in Equation 8:

$$H_{1/3} = 1.42\sqrt{\overline{H^2}} = 1.42 H_{RMS} \quad [Ref.\ 14{:}p.\ 16] \tag{8}$$

In Equation 8, $\overline{H^2}$ represents the average value of square of the wave heights, while $H_{RMS} = \frac{H_{Average}}{\sqrt{2}}$. Most importantly, Figure 9 reveals that, for any wave record, the most frequently occurring waves possess wave heights of $H = 0.707 H_{RMS}$. The parameter H_{RMS}, however, can assume a different form for certain unique data sets. For data sets covering very specific, short-term, time intervals, the theoretical H_{RMS} may

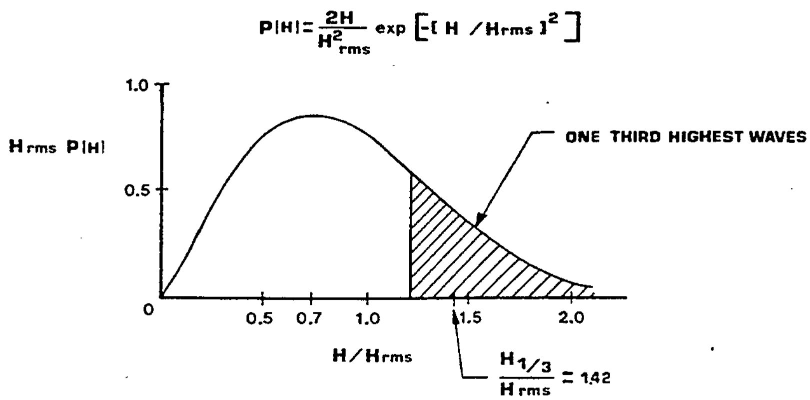

Figure 9. The Rayleigh Probability Distribution P(H) as applied to Wave Heights, From Ref. [14:p. 17].

be better represented by the formula $H_{RMS} = \frac{H_{Peak}}{\sqrt{2}}$. This occurrence arises because for a given short- term time interval, the computed $H_{Average}$ may be a poor representation of the long-term $H_{Average}$. In these unique situations, the limit form of the H_{RMS} expression applies and is represented by Equation 9.

$$\lim_{N \to 0}\left[H_{RMS} = \left(\frac{H_{Average}}{\sqrt{2}}\right)\right] = \lim_{T \to 0}\left[H_{RMS} = \left(\frac{H_{Average}}{\sqrt{2}}\right)\right] = \left[H_{RMS} = \left(\frac{H_{Peak}}{\sqrt{2}}\right)\right] \tag{9}$$

$$\begin{pmatrix} N = \textit{Number of significant wave height observations} \\ T = \textit{Length of time interval for which observations are recorded} \end{pmatrix}$$

For situations in which observations are recorded over a substantial time interval, there is no question that H_{RMS} should be calculated from the formula $H_{RMS} = \frac{H_{Average}}{\sqrt{2}}$. For situations such as OV93, however, where observations were recorded over a mere 19 day period, the Rayleigh PDF should be calculated twice, once with H_{RMS} defined in each of the two ways described. Two guidelines for determining which of these two Rayleigh PDFs best approximates the long-term theoretical conditions for the geographic location in question are as follows. First, a comparison of the number of observations recorded at the mode of the data set to the number of observations recorded at the most common wave height returned from each Rayleigh PDF can be made. The Rayleigh PDF whose most common wave height contains the highest number of observations within the data set should then be selected. Secondly, from each Rayleigh PDF the Y-axis $\left[H_{RMS} * P(H)\right]$ value can be computed for a wave height corresponding the mode of the data set. The Rayleigh PDF returning the highest $\left[H_{RMS} * P(H)\right]$ value should then be selected.

From the detailed mathematical and graphical analysis contained within this section, it is certainly evident that H_{RMS}, and therefore H, is highly variable within the littoral region. Because present U.S. JLOTS capabilities are limited to Sea State Two and below, this high variability of littoral wave heights causes a high probability of delay(s) in JLOTS operations at nearly every potential JLOTS site around the world. Since a full-scale JLOTS operation can vary in length from seven to nearly 30 days, with an approximate mean length of seven to 14 days, the probability of observing continuous sea state conditions within operating capability is very low, despite the location and/or the time of year. Consequently, it is sea state conditions which, above all other factors, are driving JLOTS equipment research and development, strategic site selection, and thankfully, detailed analytical modeling.

Equipment research and development designed to conquer the Sea State Three inoperability problem has been a top priority of the U.S. Navy's JLOTS program manager, OPNAV N-42, for the past two to three years. Equipment proposals, such as the Navy sponsored ACBL, are rapidly escalating from futuristic designs to jointly funded procurement projects. Previous equipment designs such as the High Sea Container Transportation System (HISEACOTS), shown in Appendix H, represented the earliest innovative, but unsuccessful, attempts at maintaining throughput operations, in accordance with CINC desires, as sea state conditions approached Sea State Three. The ACBL, the dimensions of which are shown in Appendix H, receives its high expectation and acclaim not only because of its increased area, carrying capacity, and freeboard, but also because its length spans the period of most Sea State Three waves, as defined in Table 1. Not withstanding the specific capabilities of the ACBL, the equipment objective for all Services, the Joint Staff J-4, and all commands with a JLOTS interest, is to respond to the CINC stated equipment requirements. In 1993, **all** CINCs promulgated, via message to USTRANSCOM, that conducting JLOTS operations well into Sea State Three conditions was not a desire, but was instead a requirement.

Obviously, the equipment capabilities of 1993 did not meet this requirement, nor do they today. In fact, the requirement will not be met until at least the year 2001, which is the expected delivery date of the first ACBL causeway sections. Faced with this unfortunate time frame, CINC planning staffs throughout the world must select potential JLOTS sites in their respective theaters based not only upon the strategic significance of the proposed geographic location, but also upon expected sea state conditions surrounding the potential site.

Concern for the inability to meet the stated JLOTS throughput requirements of each CINC initially arose among the Services and at the Joint Staff level in 1993 following the distinctly sub-par performance during JLOTS III. As alluded to in Chapter I, numerous equipment, C^3, doctrinal, and training-related shortfalls surfaced during that exercise. It was from this concern that analytical JLOTS throughput modeling was born. The following sections will dissect and critique the modeling efforts of three research entities, focusing most heavily upon the JOTE model developed by LMI. It must be stressed that each of these models is a throughput calculator. Consequently, imposed sea state conditions are a limiting factor whose significance has not been adequately captured by any of the three. Each model has accounted for throughput degradation due to sea state conditions in only a cursory form. Indeed, the individual Services and their respective JLOTS concerned commands have only begun to investigate the use of meteorology, climatology, and wave hindcasting models as a means greatly enhancing existing JLOTS throughput models in the last year. Through this thesis and a concurrent JLOTS environmental study conducted by NSWC Carderock, the individual Service JLOTS program managers, the Joint Staff J-4, and the JLOTS Board have been exposed to specific military commands and government agencies which have undertaken sea state prediction projects from which the JLOTS community and its throughput modelers could benefit.

B. THE LIGHTER MODEL BY McCAFFERY & WHITENER, INC.

One of the earliest and most elementary modeling tools developed to support JLOTS operations was the Lighter model developed by the private consulting firm of McCaffery & Whitener, Inc [Ref. 17]. The Novell Quattro Pro 5.0 based throughput model, Lighter, was the product of the research efforts, however specific development of a throughput model was not part of the original tasking. McCaffery & Whitener, Inc. was contracted by OPNAV N-42 to evaluate the ability of current and future Navy lighterage programs to support the discharge of the equipment and dry cargo of a Marine Corps Expeditionary Force Assault Follow-on Echelon (MEF-AFOE) and the associated Naval Support Element (NSE). The Lighter model was the analytical tool developed and utilized as a means of conducting the assessment.

The scope of the McCaffery & Whitener Inc. tasking included analyzing dry cargo throughput capability of current LOTS lighterage forms by determining the minimum cargo discharge time for a MEF-AFOE and NSE under varying lighterage combinations. A secondary objective was therefore to determine optimal (in terms of the aforementioned objective) combinations of the newer JLOTS lighterage platforms including LCACs, LSVs, LCU-2000s, and the ACBL. Using the results of their analysis, the research group was also tasked with developing specific recommendations regarding the most beneficial improvements needed to ensure cargo throughput in conditions beyond Sea State Two.

The methodology of Lighter realistically mandates that all cargo transported ashore reaches the beach by direct lighter transit, via NL elevated causeway or via ELCAS M. As provided by Headquarters, United States Marine Corps (USMC), the standard dry cargo configuration of an MEF-AFOE and NSE is illustrated in Table 2. Commodities in Table 2 are expressed in terms of short tons (s/tons), measurement tons (m/tons), and 20 ft. equivalent units (TEUs).

In a very detailed manner, McCaffery & Whitener, Inc. conducted a parametric analysis whereby they evaluated throughput based upon three variable parameters:

CARGO	QUANTITIES	PALLETS	TEUs
Unit Equip. (Lifts)	---	8,392	1,421
Ammunition	69,173 S/Tons	24%	76%
Ammunition	46,885 M/Tons	24%	76%
Supplies	67,061 M/Tons	3%	97%

Table 2. MEF-AFOE and NSE Cargo Configuration, After Ref. [17].

1. ELCAS M length/construction time (1,500 ft., 2,000 ft., 2,500 ft., 3,000 ft., 3,300 ft.)
2. Transit distance from ship to shore (2 nm, 3 nm, 4 nm, 5 nm)
3. Modal (most common) sea heights (0, 1 ft., 2 ft., 3 ft., 4 ft.)

All other parameters including discharge rates, construction times, etc. were taken as constants from Reference 1. The base case for reference was a modal sea height of 0 ft., a transit distance of 2 nm, and an ELCAS M length of 3,000 ft. From that reference, one parameter was changed per model run. Appendix B contains excerpts from the spreadsheet format of the Lighter model constructed for the base case described above. These excerpts correspond to the sections of the program which represent the various forms of lighterage being modeled. Additionally, Appendix B provides a tabular and graphical representation of each lighterage configuration considered in the assessment as well as a selective representation of the results obtained.

Of paramount importance to the Lighter model, however, is Figure 10. This figure represents McCaffery & Whitener Inc.'s assessment of the throughput degradation caused by increasing wave height (where wave height is again caused by local wind waves and swell). In the Lighter model, once the parameter Wave Height is provided by the user, it

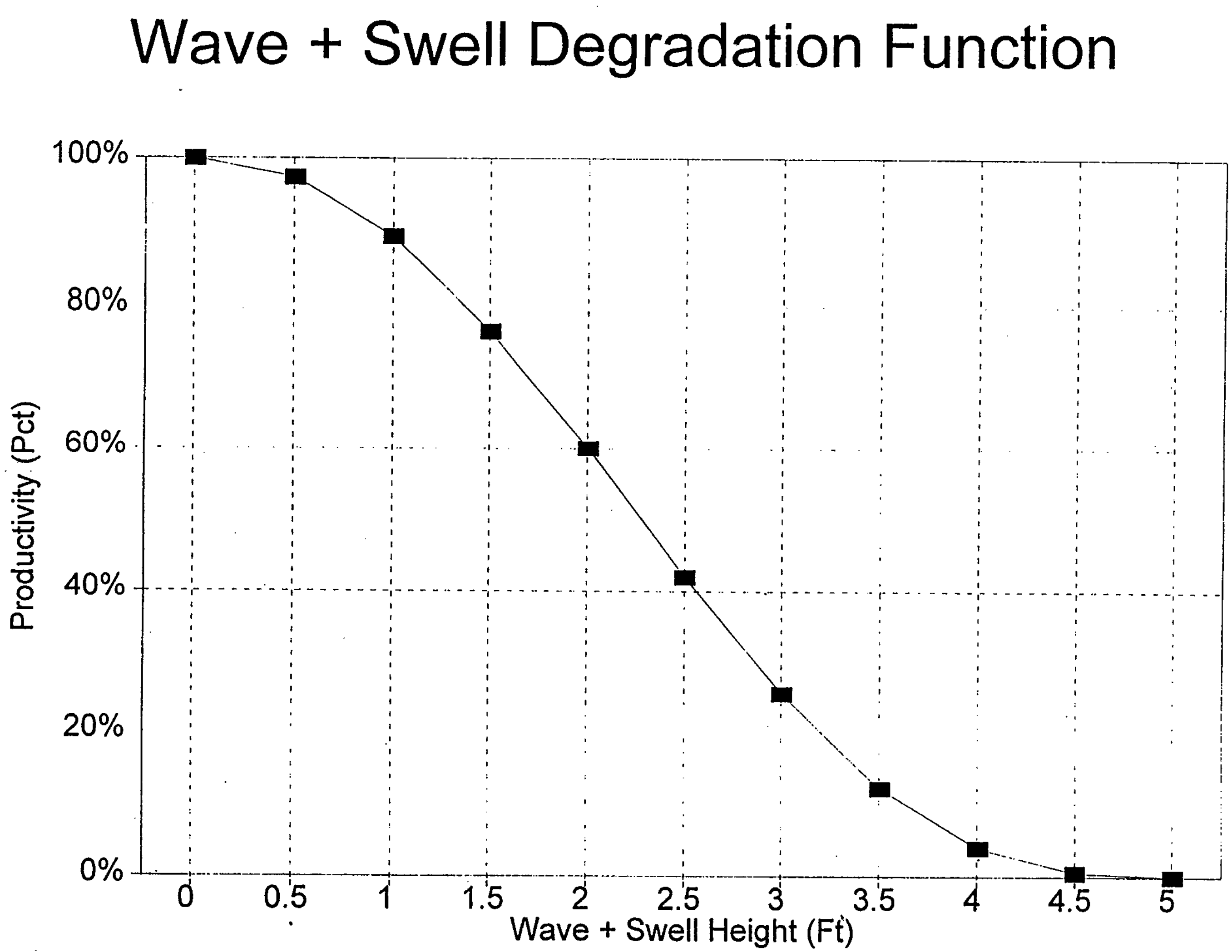

Figure 10. Lighter Model Throughput Degradation Function, From Ref. [17].

is this degradation function which is applied in calculating the values of each of the following fields for all forms of lighterage modeled:

1. Cargo delivered/day - RO/RO (ft.^{2})
2. Cargo delivered/day - Pallets (ELCAS)
3. Cargo delivered/day - Pallets (Beach)
4. Cargo delivered/day - TEU (ELCAS)
5. Cargo delivered/day - TEU (Beach)

Mathematically, the degradation function shown can be approximated by Equation 10.

$$Y \approx \left[\frac{(5 - X)}{5}\right]^{X^{.5}} \quad \downarrow \quad \begin{pmatrix} Y = \textit{Percentage of productivity/throughput attained} \\ X = \textit{Total wave height} \end{pmatrix}. \tag{10}$$

It is certainly correct to model a decrease in the percentage of ideal throughput attained as wave height increases. The degradation function shown in Figure 10, however, improperly captures the essence of JLOTS operations in two ways. First, the function represents an essentially linear degradation in productivity between wave heights of 1.5 and 3.5 ft.. Second, the function represents an immediate degradation in productivity as wave heights grow to any height greater than zero.

In reality, a more accurate degradation function resembles that illustrated in Figure 11A which represents a summarization of throughput attained not only in previous JLOTS exercises, but also in several cargo off-load tests conducted by Amphibious Construction Battalions One and Two on the west and east coasts respectively. Here, the percentage of productivity degradation remains essentially constant until wave heights of approximately

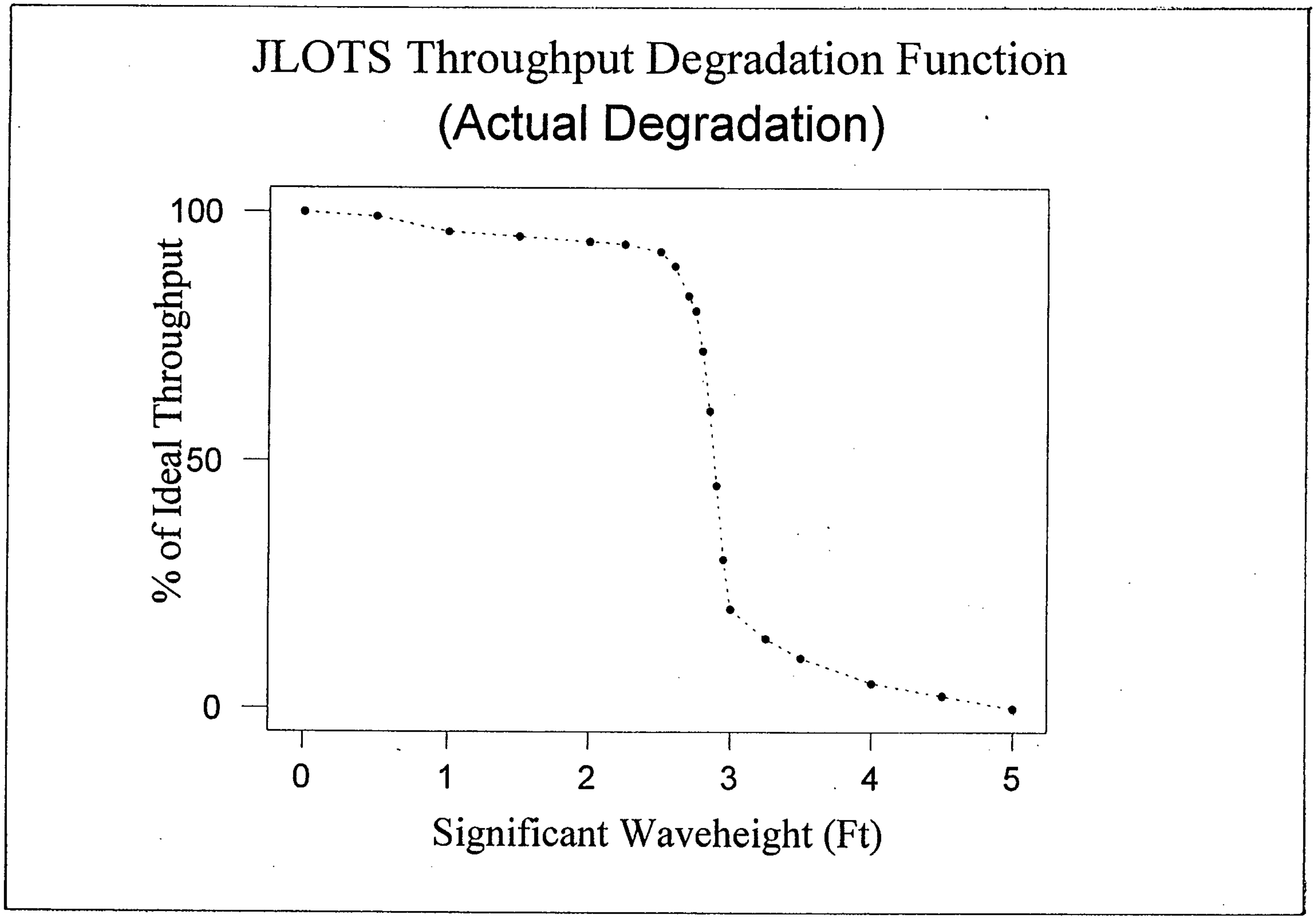

Figure 11A. Actual Throughput Degradation Due to Sea State.

2 ft. to 2.5 ft. are observed. Additionally, at the wave heights where appreciable degradation begins, this degradation is highly nonlinear.

Figure 11B illustrates a comparison between the approximate degradation function employed by McCaffery & Whitener, Inc. within the Lighter model with the more realistic degradation function illustrated in Figure 11A. The productivity degradation function illustrated in Figure 11A directly parallels the occurrences of JLOTS III. During that test and training exercise, throughput levels remained nearly constant until wave heights corresponding to the upper region of Sea State Two were observed. In the lower sea states, relative motion differences between T-ACS and lighterage were not problematic, nor did lighterage experience any appreciable hindrances from sea conditions during the transit phase from ship to shore. After the onset of Sea State Three conditions, however, relative motion differences between the T-ACS and its various discharge platforms coupled with unsafe transit conditions aboard lighterage to cause an immediate cease of all throughput operations.

Additional evidence that the degradation function employed by McCaffery & Whitener, Inc. is incorrect lies within the results of their assessment. Examination of the numerous result graphs (contained in Appendix B) where modal sea height appears on either axis reveals that, for multiple lighterage combinations, productivity/throughput levels remained essentially constant until Sea State Three waves were imposed at which time productivity dropped rapidly. The fact that many of the graphs resulting from the assessment bear the correct shape, while the degradation function applied in constructing

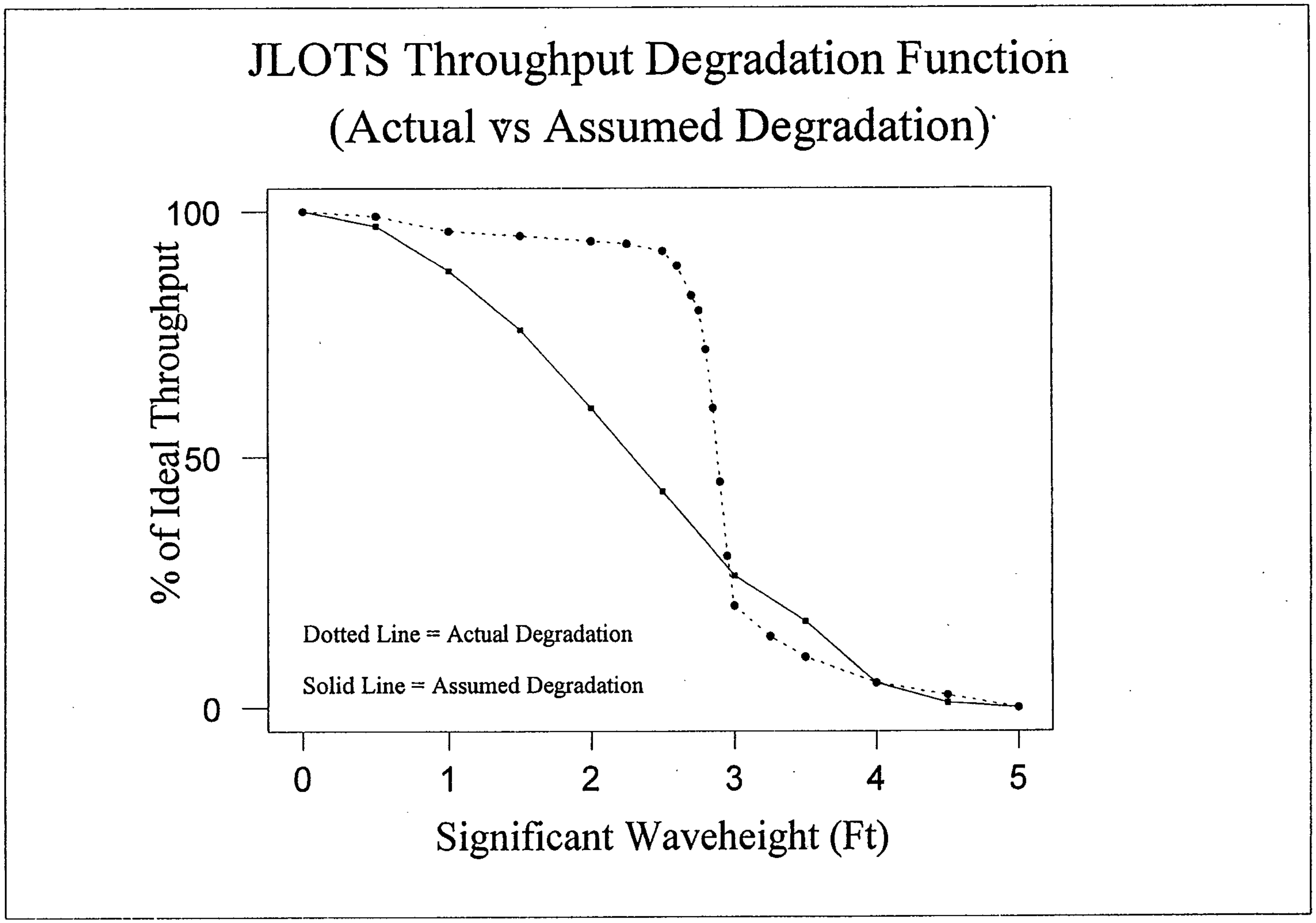

Figure 11B. Lighter Model Throughput Degradation Function Versus Actual Degradation.

them is incorrect, indicates that the weighting assigned to the degradation function in calculating minimum cargo discharge time may also be incorrect.

Despite its weaknesses, the Lighter model does represent the first incorporation of productivity limitations based upon sea state conditions into a JLOTS throughput model. Although lacking precision, its general results are usable and consistent with expectations. The model output showed that sea state is the single most significant limiting factor on JLOTS operations for all lighter combinations. Nonetheless, the assessment did conclude that the ACBL could significantly enhance Sea State Three operating capabilities. Unfortunately, however, accepting a user-provided wave height parameter for purposes of extracting a productivity percentage offers the JLOTS commander no information relevant to the uniqueness of his specific JLOTS operation. This is a major flaw of all, JLOTS throughput models, including JOTE. As the next two sections will demonstrate, other research facilities have essentially exhausted the growth potential of JLOTS throughput models within their present confines. Consequently, JLOTS throughput modeling will stagnate, and the JLOTS commander will continue to be inadequately serviced, until analytical researchers merge existing throughput models with the powerful wind, weather, and sea state prediction tools presented in follow-on chapters.

C. MPF MODELING BY CNA

For nearly ten years, CNA has conducted a respectable level of analytical research and modeling designed to improve the doctrine, equipment inventory, and operation of the MPF. Many of the assessment and feasibility studies CNA has conducted in support of MPF-related tasking parallel those that presently being conducted by various entities for

JLOTS purposes. Due to the operational similarities between JLOTS and MPF in terms of equipment and procedures, especially within the AFOE phase of ship-to-shore sustainment, many of the modeling techniques employed for MPF purposes are highly relevant to JLOTS operations. Likewise, however, the present and future proficiency of these MPF-oriented analytical tools is equally dependent upon enhanced incorporation of quantifiable wind, weather, and sea state data.

The most extensive MPF study conducted by CNA was completed in July 1991 and addressed the following three issues:

1. Off-load environments that favor the construction of an RRDF.
2. How an RRDF should operated for maximum efficiency.
3. How changes in the current mix of lighterage sections would affect RRDF and non-RRDF operations [Ref. 18].

In support of these concerns, CNA developed an extensive simulation entitled the MPF Off-load Model which was designed to evaluate different off-load environments (where environment refers to the types and configurations of lighterage and cargo utilized) in order to identify the scenario resulting in the shortest MPF off-load time. Each off-load scenario was modeled and run 100 times, employing different random number seeds for various parameters in order to identify trends which are scenario dependent.

This study was preceded by a theoretical mathematical examination designed to identify the parameters, and their associated distributions, for which random numbers would be generated in the actual simulation. This analysis was conducted in February 1991 and focused upon the individual components of barge cycle time which include: loading time, transit time, and unloading time. Here, the objective was to determine which variables statistically affect the distributions of the individual barge cycle component times and whether those distributions can be accurately represented by theoretical distributions as well as by empirical data. CNA analysts hoped to take advantage of the known characteristics of theoretical distributions which would allow them to alter factors in their off-load simulation while still maintaining a logical structure.

The CNA researchers began their study by analyzing barge cycle component times from seven exercises:

1. Agile Sword 86 (AS-86)
2. Freedom Banner 86 (FB-86)
3. Solid Shield 87 (SS-87)
4. Freedom Banner 87 (FB-87)
5. Ocean Venture 88
6. Team Spirit 88 (TS-88)
7. Freedom Banner (FB-89)

Their approach was to analyze available observations in order to determine whether the data satisfied any known theoretical distribution. Justifiably, the researchers believed that if an underlying theoretical distribution could be identified and programmed into a simulation, they could examine the effect(s) of varying the mean and/or shifting the distribution in order to represent occurrences such as increased transit distances or adverse weather conditions. Herein lies a major flaw in the tactic undertaken by CNA. In selecting barge cycle time as the parameter with which to analyze the theoretical component distributions, the researchers believed they were studying the single most important factor in overall MPF off-load time. By doing so, CNA was overlooking the dependence of each component of barge cycle time upon existing sea state conditions. Certainly, an approach more focused upon the root of the off-load problem should have commenced with, or at least included, the examination of the theoretical distributions of sea state within small-scale geographic areas. CNA believed that once the theoretical distribution of barge cycle time was arrived at (based upon the distributions of individual components), the mean and standard deviation could be varied and the MPF off-load simulation model executed in order to assess total off-load time for a given sea state. This approach, however, warrants two major questions which would have been eliminated if the sea state analysis discussed above had been conducted:

1. Is the resultant distribution of barge cycle time (and the component distributions) correct given that probabilistic sea state examination was not conducted?
2. By how much should the mean and standard deviation of barge cycle time be varied to reflect respective changes in sea state?

That theoretical distributions for sea state conditions were not considered, is the most fundamental flaw in the CNA study. Despite the initial omission of sea state analysis, the component distributions discovered would bear more credence if the sea state conditions had been better incorporated into the methodology employed. In arriving at the underlying distributions for each of the components of barge cycle time, the CNA researchers first attempted to identify the factors of influence. Subgroups of data influenced by common factors were combined for additional analysis; subgroups differing because of factors unrelated to distribution were separated. To accomplish this, the two-sample Kolmogorov-Smirnov test (with 99% confidence) was applied to determine which variables, from among a specific set, influenced the distribution. The flaw in this methodology, however, lies in the fact the set of potential influencing variables was limited to exercise, ship type, barge configuration, and cargo type. Wind/Weather/Sea State was reduced to a nonquantitative variable along with factors such as level of training. A single numerical value was applied to each of the nonquantitative variables for each of these exercises in the study. Additionally, the assumption was made that the nonquantitative factors remain nearly constant throughout the exercise. For factors such as training, perhaps this assumption is true. Certainly, this assumption is incorrect regarding sea state conditions.

The end result was, therefore, that the limiting effects of sea state were innappropriately downplayed in determining the component distributions of barge cycle time. In defense of CNA, however, it must be re-emphasized that only within the past six to 12 months have analytical researchers and military decision makers begun to appreciate the importance and impact of sea state conditions upon MPF and JLOTS operations. As was the case with the Lighter model by McCaffery & Whitener, Inc., the results of CNA's barge cycle time analysis overtly reflect the lack of attention toward sea state modeling. For example, Freedom Banner-86 was the only one of the seven exercises considered which was characterized by adverse weather conditions. Appendix C contains several tables depicting the results of Kolmogorov-Smirnov goodness of fit tests for each of the three components of barge cycle time as well as the plots of the theoretical distributions deemed applicable to each of these components. Barge loading time, transit time, and unloading time were all concluded to follow lognormal distributions. The tables of Appendix C reveal that, for many two-sample comparisons involving Freedom Banner-86, there was a significant difference between compared values.

In the case of barge loading times, researchers concluded that since ten of 11 scenarios resulted in no significant difference, qualitative factors such as weather, training, etc. do not have an influence upon the distribution. This contention would be true if there indeed existed more than one adverse weather scenario. Since only one such scenario was considered, and that was the scenario for which a significant difference in parameter importance was realized, the value of the weather information from that scenario cannot be overstated. When an identical situation arose regarding the distribution of barge unloading times, CNA researchers again failed to further investigate the weather information of Freedom Banner-86. Moreover, they dismissed the data from Freedom Banner-86 completely when determining which quantifiable variables had significant importance upon barge unloading times.

Although the methodologies employed by CNA researchers are questionable, the basic concept of applying theoretical mathematics to selected JLOTS and MPF operational parameters is undisputable. Identifying the underlying distribution of many of these parameters is a very difficult process. As the first section of this chapter illustrated, however, wave heights are known to follow a Rayleigh distribution Ref. [14:p. 17]. Therefore, if by analytical means, researchers can identify the H_{RMS} for a desired area at a desired time, they can employ this theoretical distribution within a throughput simulation or optimization model such as JOTE. As the next section will demonstrate, the JOTE model has superceeded all others in modeling JLOTS off-load operations. Consequently, the task for researchers in taking JOTE to the next level, and thereby increasing its validity in feasibility studies and its application as a planning tool, is to become equally proficient at modeling the sea state characteristics of the specific JLOTS operating area. As Chapter

IV will demonstrate, because of the research efforts of various installations which specialize in wave hindcasting and climatology, this task is not as ominous as it may first appear.

D. THE JOTE MODEL BY LMI

1. The Purpose of JOTE

At the request of the Director for Logistics of the Joint Staff, LMI analyzed DOD's capability to conduct JLOTS operations in support of Regional Unified Commands (RUCs). The assessment was designed to draw upon earlier work performed by USTRANSCOM, namely, the 1993 tasking to all RUCs to review their need for a JLOTS capability and provide a summary of cargo movement requirements. LMI's objective was to determine whether the existing JLOTS equipment inventory and standard operating procedures could sufficiently meet the independent throughput requirements of each of the respective CINCs. In support of this objective, the JOTE model was originally created as an in-house analytical tool.

Unlike their JLOTS analytical predecessors, LMI did realize that weather and sea state conditions are the most influential variables on throughput calculations. Unfortunately, however, not included in the JOTE model is the degradation in JLOTS throughput capabilities observed as the upper threshold of Sea State Two is approached. Despite the intricacy and relative superiority of the JOTE model, many realizations regarding the criticality of sea state conditions and the prediction thereof are only primitively incorporated into JOTE. The following comprehensive overview of the JOTE model will highlight these as well as other shortfalls. Additionally, it will be shown that these limitations not only influence the results obtained from JOTE when employed as an in-house analytical tool, but, more importantly, limit its extended viability as a JLOTS planning tool, an application for which strong support exists.

2. A Dissection and Analysis of the JOTE Model

Subsequent to the Persian Gulf conflict of 1991, the need for the DOD joint logistics community to develop and maintain the ability to deliver and sustain combat force ashore in areas in which deep draft ports were unavailable gained much deserved attention. The increasing frequency of operations other than war (OOTW) further epitomized the need for such capability. In order to address the concerns regarding existing lighterage assets and additional procurement, more powerful modeling tools such as JOTE were required.

JOTE is a Visual Basic application which operates via a Microsoft Excel 5.0 based linear programming optimizer. Consequently, the JOTE model can be operated on any personal computer capable of running Microsoft Excel 5.0. JOTE is designed to minimize the daily shortfall encountered on each of a predetermined number of transit lanes from ship to shore by employing optimal combinations of pre-established types and quantities of lighterage. Prior to any detailed analysis of the input/output parameters and computational processes of JOTE, an overview of the linear program comprising the framework of JOTE is highly warranted. The following represents a formulation of the JOTE model in terms of indices, data, and objective function [Ref. 19:p. B-7].

Indices

i = Types of Lighters $\{I = 1...8\}$

1. LCM-8
2. ACBL
3. LCAC
4. LCU-2000
5. LCU-1600
6. LSV
7. CSP+3
8. CSP+2

j = Sea Lane Index Number $\{j = 1...24\}$

k = Type of Cargo Moved $\{k = 1...4\}$

1. RO/RO tracked
2. RO/RO wheeled
3. LO/RO vehicles
4. LO/LO containers

Data

$OPRATE = 0.84$ = Percentage of each 24 hr. period JLOTS is conducted

S = Percentage of time sea state conditions are Sea State Three or greater

L = Distance from ship to shore

M_i = Maximum number of available lighters of type i

R_i = Operational readiness of lighter type i

G_i = Transit time for 1 lighter type i to travel 1 mi. in each direction

$A_{i,k}$ = Beach/Ship loading/unloading times for lighter type i when carrying cargo type k

$A'_{i,j}$ = Maximum beach/ship loading/unloading time for lighter type i when carrying cargo type k

Decision Variables

$T_{i,j}$ = Trips by lighter type i on lane j

$P_{i,k}$ = Productivity by lighter type i when carrying cargo type k on a given trip

$D_{j,k}$ = 1 if lane j is assigned to carry cargo type k
0 otherwise

C_j = Total amount of cargo moved on lane j

Formulation

Minimize $$\sum_{j=1}^{24}\left\{C_j - \sum_{i=1}^{7}\left[\sum_{k=1}^{4}\left(D_{j,k}P_{i,k}T_{i,j}\right)\right]\right\} \quad \text{(SHORTFALL)} \qquad (11)$$

Subject to $$\sum_{j=1}^{24}\left\{T_{i,j}\left[LG_i + \sum_{k=1}^{4}\left(D_{j,k}A_{i,k}\right)\right]\right\} \le \left[(OPRATE)(R_i)(M_i)\right] \quad \forall\, i \qquad (12)$$
(LANES)

$$\sum_{j=1}^{24}\left\{\sum_{i=1}^{7}\left[\sum_{k=1}^{4}\left(D_{j,k}A_{i,k}Ti,j\right)\right]\right\} \le \left[(OPRATE)*(S)\right] \quad \forall\, j \qquad (13)$$
(LIGHTERS)

$$\sum_{i=1}^{7}\left[\sum_{k=1}^{4}\left(D_{j,k}T_{i,j}P_{i,k}\right)\right] \le C_j \quad \forall\, j \quad \text{(LIFT)} \qquad (14)$$

$$T_{i,j} \ge 0 \quad \forall\, i, j \qquad \text{(NON-NEGATIVITY)} \qquad (15)$$

$$T_{i,j} \in Z \quad \forall\, i, j \qquad \text{(INTEGER)} \qquad (16)$$

There are two primary inputs to the JOTE model; those specified by the user at run-time within a series of initial pop-up menus, and those embedded within the spreadsheet which must be manually varied. JOTE's run-time input parameters include the following:

1. The distance from ship to shore.
2. The lighter fleet available by type of lighter.
3. The number of discharge lanes to be used in the operation.
4. The type of discharge to be conducted on each lane.
5. The tonnage to be moved on each discharge lane.

The various individual macros of the JOTE model are constructed to allow the user to model a specific off-load scenario, obtain results, vary one or more of the above input parameters, and compute updated results without re-entering all the original parameters. As subsequent sections will illustrate, this process, unfortunately, does not operate as smoothly for the user as the designers may have intended. In several cases there actually exist miscalculations when executing some of the macros designed for recalculation based on updated input parameters.

The second set of input parameters, those embedded within the spreadsheet, are perhaps misleadingly labeled by LMI. This group represents those parameters which can not be altered via a pop-up macro. To claim, however, that these parameters are altered by merely changing a cell entry(ies) within the JOTE spreadsheet is an understatement in many cases. Altering several of these parameters requires modifying many lines of code within one or more macros, any number of which may be hidden and/or write-protected by the designers. These embedded parameters include the following:

1. The average travel time for a lighter to conduct a round trip from ship-to-shore from a ship 1 nm off-shore.
2. The average amount of time required for a lighter to:
    a. Approach and moor at the ship.
    b. Load cargo at a ship.
    c. Cast-off and clear a ship.
    d. Approach and moor at the beach or pier.
    e. Unload at the beach or pier.
    f. Cast-off and clear the beach or pier.
3. The average load (in stons) carried by each lighter on each discharge lane.
4. The average fraction of time the sea state is **Sea State Three** or above.
5. The operational readiness of the lighter fleet.

The most notable of these parameters is certainly the fraction of time the sea state conditions equal or exceed Sea State Three. The detailed analysis of the previous chapters revealed the profound limitations of JLOTS capabilities in the upper regions of Sea State Two. Therefore, despite being far more complex than any other JLOTS throughput model, JOTE is equally lacking in modeling the true impact of sea state conditions upon JLOTS operations. The extent of this limitation will be quantified in a later section. Additionally, a supplemental program for the JOTE model, entitled SEA_STATE_CALC, which will not only capture the probability of Sea State Two conditions but will also facilitate site-specific analysis, will be introduced. Presently within the JOTE model, throughput degradation based upon sea state conditions originates from a spreadsheet cell entry representing the percentage of time sea state conditions are strictly greater than Sea State Two. For all studies conducted by LMI using JOTE, the entries in this cell have originated from Table 3. Table 3 represents LMI's database of sea state conditions per geographic location, where the locations are subdivided no further than CINC region and no degree of site or time specificity is achieved.

The output of JOTE is a display of the trips required by day by lighter type in each discharge lane to achieve optimal throughput based upon the various input parameters. A representative sample of this output is shown in Appendix D. Appendix D represents the output of a comprehensive modeling of JLOTS III test conditions using JOTE. This process was undertaken in order to validate the JOTE model, expose its weaknesses and limitations, introduce the supplemental program SEA_STATE_CALC, and illustrate the comprehensive off-line data collection and calculations which the user must perform prior

AREA	TIME PERCENTAGE SEA STATE(S) ZERO OR ONE	TIME PERCENTAGE SEA STATE TWO	TIME PERCENTAGE SEA STATE(S) THREE OR ABOVE
CINC 1	40	20	40
CINC 2	48	14	38
CINC 3	57	13	30
CINC 4	60	16	24
CINC 5	53	17	30

Table 3. Expected Sea State Percentages by CINC Region, From Ref. [19:p. 2-12].

to executing JOTE. The contents of Appendix D will be referenced throughout the remainder of this chapter. Its relevance here, however, is simply to illustrate the output of the JOTE model. As shown in the daily output tables of Appendix D, JOTE also displays the short tons (stons) remaining on each type of discharge lane after the projected movements for each day, as well as the number of operational hours remaining on each discharge lane out of an assumed maximum of 20 operational hours per lane per day. The final output parameter(s) displayed by JOTE is comprised of the usage by lighter type on each lane, and represents the summation of the various columns of the lower table for each day shown in Appendix D. This output takes on the form shown in Table 4.

In addition to its dependence upon proper incorporation of sea state data, the JOTE model is also highly dependent upon several key assumptions regarding JLOTS operations, as well as the uniform requirement and capability measurement thereof. Several of these assumptions are indeed more theoretical, doctrinal, and operational than computational in nature. For example, within an operational scenario, several of

DESIRED PARAMETER	LIGHTER TYPE
NUMBER AVAILABLE	W
NUMBER USED	X
NUMBER REMAINING	Y
NUMBER REMAINING GIVEN OPERATIONAL READINESS RATE	Z

Table 4. JOTE Summary Output by Discharge Lane, After Ref. [19:p. B-6].

the seven possible lighterage selections employed by the JOTE model must self-deploy to the objective area in order to actually be available. Furthermore, it is assumed that all joint assets within the respective CINC theater have been allocated for the JLOTS operation. These assets include such items as Army/Navy watercraft (causeway sections and other lighterage) within the APF/MPF. LMI has also incorporated the following list of additional assumptions:

1. JLOTS operations halt at Sea State Three.
2. JLOTS operations degrade between Sea States Two and Three.
3. JLOTS discharge lanes are assigned based upon ship characteristics:
    a. RO/RO - four lanes (total), two RO/RO lanes each with one RRDF, two LO/RO or LO/LO lanes depending upon ship crane capabilities.
    b. Container Ship - three lanes (total when T-ACS is used)
    c. Breakbulk Ship - five lanes (total when ships cranes used)

This list of assumptions is somewhat deceiving. First and foremost, the list implies that a throughput degradation function, which nullifies all JLOTS operations when Sea State Three conditions are observed, is applied beginning when sea state conditions reach the upper bounds of Sea State Two. As described in the preceding paragraphs, however, JOTE mistakenly applies no throughput degradation until Sea State Three conditions are indeed observed. Additionally, the inference of the above list of assumptions is that JOTE assigns discharge lanes in accordance with Assumption C. The subsequent model validation of JOTE will reveal that discharge lane configurations per ship type is, instead, a tedious scheme developed by the user prior to executing JOTE. Assumption Three is merely a guideline by which the user can operate. For RO/RO and breakbulk vessels, the proposed guideline is accurate and therefore, usable. Regarding container ships, however, Assumption Three is valid only for non-self-sustaining container ships. In the case of self-sustaining container ships, the number of discharge lanes would increase by one for each on-board crane.

Equally important as sea state assumptions to the accuracy of JOTE are the built-in assumptions regarding the establishment of a uniform CINC requirement and capability measurement methodology. This terminology refers to the standardization of measurement criteria for computational uniformity. This need for standardization arose since three of five Regional Unified Commands provided JLOTS requirement data to LMI in the form of measurement tons (mtons) of general or containerized cargo and ammunition. The two remaining CINCs provided more specific information on units and classes of supply, Class I (Subsistence) through Class IX (Repair Parts). At this point, it was necessary for LMI to make, essentially, two sets of assumptions regarding measurement standardization, one for purposes of the their assessment of CINC capabilities, and another specifically for calculations within the JOTE model. The first set of assumptions focused upon determining a proper ratio of equipment to supplies. This process commenced with a conversion of mtons to stons which was followed by the application of the Army Interim Heavy Brigade Afloat Ratio of tracked/wheeled vehicles and containerized unit equipment in order to determine a cargo inventory which was both appropriate for the respective CINC mission and translatable to the JOTE model. The results of this process would constitute the baseline cargo inventory from which LMI would conduct their assessment for each of the CINC regions. The breakdown of this inventory was as follows [Ref. 19:p. B-10]:

1. Tracked vehicles = 23% of total stons.
   (average weight per tracked vehicle = 31 stons).
2. Wheeled vehicles = 68% of total stons.
   (average weight per wheeled vehicle = 13 stons).
   (average weight per wheeled trailer = 15 stons).
   (overall average per vehicle = 14 stons).
3. Containerized unit equipment = 14 stons.

Because the primary focus in this thesis is to analyze, validate, and improve upon the JOTE model rather than the quality of the assessments resulting from its use, the second set of assumptions made by LMI is more important here. This group of assumptions focuses principally upon arriving at the standard unit of measurement used within the JOTE model, namely, the ston. In order to standardize measurement units, with the ston as the frame of reference, LMI incorporated the following conversions for cargo classified by mton and containerized cargo into the JOTE model development [Ref. 19:p. B-9,10]:

1. Breakbulk and containerized ammunition - 1.06 stons per mton.
2. Breakbulk and containerized cargo - 2.42 stons per mton.
3. Unit equipment - 6 stons per container [20 ft. equivalent unit (TEU)].
4. General supplies - 9 stons per container (20 ft.TEU).
   18 stons per container (40 ft. TEU).
5. Ammunition - 14 stons per container (20 ft.TEU).

Obviously, this second set of assumptions is far less scenario dependent than the first. Certainly, a given CINC can and will change the baseline mix of tracked and wheeled vehicles and accompanying unit equipment for any given scenario. The conversion factors outlined in the second set of assumptions, however, are far less susceptible to variance. Not coincidentally, these are the same conversions utilized by MTMC [Ref. 19:p. B-10]. It must be understood, however, that while JOTE performs all calculations in terms of stons, these conversions are not performed internal to the model. They are, instead, employed by the user prior to executing JOTE. The upcoming JOTE model validation will clarify the tedious calculations which the user must perform prior to executing the JOTE model. In short, however, the user must apply the above conversions to the unique cargo inventory for the respective JLOTS scenario at hand. Without the assistance of JOTE, the user must determine the number of stons to place upon each of the desired discharge lanes. This is an exceptionally difficult process given that the normal JLOTS operation consists of many discharge lanes due to the presence of multiple cargo ships of each type and, literally, thousands of vehicles and containers. Consequently, once executed JOTE provides the user with the following information.

1. The optimum lighter assignments to each of the discharge lanes.
2. An assessment of the daily shortfall observed on each of the discharge lanes.
3. A means of updating the expected daily shortfall based upon varying input parameters such as sea state, operational readiness of lighterage, and varying lighter assignments.

JOTE is therefore designed to be executed daily, in order to evaluate the JLOTS scenario for the upcoming day. Unfortunately, this aspect of JOTE is also not without flaw. As the model validation will reveal, flaws in several automatic features of JOTE, including a macro designed specifically for the reassignment of discharge lane capacities, compel the user to update lane capacities manually in certain situations. On days preceding those on which all throughput on a given lane is to be completed the user must manually update the capacity of that lane so as to avoid having JOTE continue to simulate the movement of cargo at a constant rate, and therefore creating negative lane capacity.

It seems apparent that the deficiencies in JOTE regarding the modeling of sea state conditions and their effects upon throughput is attributable to a general lack of proficiency in this area throughout the JLOTS analytical community. The remaining limitations and/or errors associated with JOTE are largely the result of a lack of validation. Despite JOTE being employed in JLOTS capability assessments in each of five CINC regions, there exists no documentation of its validation through application to past scenarios such as JLOTS III, as is done in this thesis. In defense of LMI, however, the original justification for JOTE must not be forgotten. JOTE was initially constructed as an in-house analytical tool for the purpose of completing a JLOTS capability assessment. This fact alone certainly does not excuse any lack of validation since this practice would expose any errors which could potentially affect the results of a capability assessment. The significance is that until the very recent past, the only users of JOTE were its developers. Only now is the potential of JOTE as a planning tool for the JLOTS commander being realized. Consequently, many of the shortfalls and potential improvements presented within this thesis would have been irrelevant to the designers during the creation of JOTE, and are only of importance now for other potential users. Other shortfalls outlined here, however, could potentially affect the validity of JOTE as an analytical tool for quantifying

JLOTS throughput potential in meeting CINC requirements, for assessing the relative benefits of the ACBL, as well as other feasibility studies in which JOTE is employed.

3. JOTE Model Validation - The Demands Placed Upon the User

Like the validation of any model, validating the JOTE model requires careful analysis of a past scenario for which extensive data exists. Regarding JLOTS operations, no single exercise was as large nor as well documented than JLOTS III. With the data from this exercise, all facets of the JOTE model discussed within this thesis can be analyzed and evaluated. The most obvious objective is to evaluate the accuracy of JOTE in predicting the overall off-load time for the evolution. Inherent within that process, however, are three specific and independent evaluations which are of utmost importance, namely:

a. The accuracy of JOTE in its incorporation (or lack thereof) of throughput degradation caused by sea state conditions.
b. The identification of any errors or inconsistencies in the spreadsheet calculations and/or operation of the various individual macros of the JOTE model.
c. An analysis of the quantity and depth of user calculations necessary to execute JOTE and the number of cell manipulations needed during its execution.

The JLOTS III test exercise, entitled Ocean Venture 93 (OV93), consisted of five vessels namely, the T-ACS EQUALITY STATE, the self-sustaining containership SS CORPUS CHRISTI, the SEABEE vessel CAPE MOHICAN, and the FSSs BELLATRIX and REGULUS. Both FSSs were employed exclusively as RO/RO and LO/RO vehicle carriers and despite being a self-sustaining containership, the SS CORPUS CHRISTI did not utilize its on-board cranes and was therefore non-self-sustaining. The exact manner in which these vessels were employed is of paramount importance for it directly determines the number of sea lanes of discharge which can be operated.

All other performance data needed for model validation can be extracted from the countless tables, graphs, and documentation of the JLOTS III Test and Evaluation Report compiled by a Joint Test Directorate (JTD) [Ref. 20]. This extensive report contains the necessary loadout, configuration, and off-load information necessary for all input parameters to the JOTE model, including a comprehensive database of sea state consisting of over 1350 observations spanning the entire period of off-load operations. Admittedly, extraction of all necessary information from the extensive, three-volume JTD report was a painstaking process which would be somewhat easier for a JLOTS commander when planning for an upcoming JLOTS operation. Nonetheless, the process must be undertaken in order to complete the aforementioned evaluations of the JOTE model.

In modeling the off-load operations of OV93, the first obstacle which must be overcome is obtaining the most accurate representation of the lighterage mix employed during that operation. The latest version of the JOTE model allows the user to select from among any of seven possible forms of lighterage. This collection is comprised only of lighterage types which are in the current DOD inventory and also represent LMI's assessment of the most likely forms of lighterage to be employed. Platforms such as the LARC-LX, LACV-30, and double-wide modular causeway ferry (DWMCF), of which only the LACV-30 is no longer in the DOD inventory, are not selections available to the user. Although it is possible to modify the lighterage selections available to the user by either inserting a new lighterage option or by altering carrying capacity, speed, stability, and performance parameters of an existing type of lighterage, the complexity of the various macros of JOTE render these to be undesired options even to the designers of the JOTE model. Therefore, when possessing the desire to employ a lighterage type which is not covered by JOTE, the user must find a suitable substitute (in terms of type and quantity) from among the available forms of lighterage. This selection is made by evaluating the available selections in terms of those criteria listed above, in search of the best match. It is highly unlikely that an exact capability match will be found. Therefore, because the user will be employing JOTE as a planning tool, the most conservative capability match should be selected. Table 5 represents the lighter types and quantities utilized in OV93 and within this model validation. The calculations associated with the types and quantities of lighterage selected as replacements for those not listed as JOTE selection options then follow.

From Table 5, it is evident that for purposes of the model validation presented within this thesis, two LCM-8s are considered to be an acceptable conservative representation of the capabilities of six LARC-LXs in terms of overall performance capability. The calculations which follow Table 5 highlight the various factors which determine the relative capabilities of each type of lighterage. These factors combine to form the product referred to as overall carrying capacity which serves as the performance criterion by which lighterage performance can be equated.

Here, overall carrying capacity is a function of the total number of stons the platform can carry, the speed at which it can travel, and the distance of round trip travel

OCEAN VENTURE 93		JOTE MODEL VALIDATION	
LIGHTER TYPE	**QUANTITY**	**LIGHTER TYPE**	**QUANTITY**
LARC-LX	6	LCM-8	2
LACV-30	12	LCAC	3
LCU-2000	8	LCU-2000	8
LCU-1600	5	LCU-1600	5
LSV	2	LSV	2
DWMCF	1	ACBL	1
CSP+3	6	CSP+3	6

Table 5. Lighterage Comparison Between OV93 and JOTE Model Validation.

from ship to shore. The objective in this substitution is to assess the overall carrying capacity of six LARC-LXs by computing the product shown in Equation 17.

$$\left\{\begin{matrix} NUMBER\ OF\ ROUND\ TRIPS \\ FOR\ EACH\ LARC\text{-}LX \\ ON\ EACH\ WORKDAY \end{matrix}\right\} * \left\{\begin{matrix} TOTAL \\ NUMBER \\ LARC\text{-}LXs \end{matrix}\right\} * \left\{\begin{matrix} LARC\text{-}LX \\ CARGO \\ CAPACITY \end{matrix}\right\} (STONS) = \left\{\begin{matrix} OVERALL \\ LARC\text{-}LX \\ CARRYING\ CAPACITY \end{matrix}\right\} \tag{17}$$

Here, the number of round trips made by each LARC-LX in a given workday is computed by Equation 18. Noteworthy within this formula is the fact that JOTE assumes a 20 hr. continuous JLOTS workday vice a 24 hr. workday with interruptions. Given present JLOTS proficiency at all levels of the military and civilian chains of command, this assumption may indeed be optimistic.

$$\left\{\begin{matrix} MAXIMUM \\ LARC\text{-}LX \\ SPEED \end{matrix}\right\} \left(\frac{NM}{HR}\right) * \left\{\begin{matrix} 20\text{-}HR \\ JLOTS \\ WORKDAY \end{matrix}\right\} (HR) * \left[\frac{1}{\left[\begin{matrix} ROUND\ TRIP \\ TRANSIT \\ DISTANCE \end{matrix}\right]}\right] \left(\frac{1}{NM}\right) = \left\{\begin{matrix} NUMBER\ OF\ ROUND\ TRIPS \\ FOR\ EACH\ LARC\text{-}LX \\ ON\ EACH\ WORKDAY \end{matrix}\right\} \tag{18}$$

In an identical manner, six LCACs are considered appropriate conservative estimates of the overall carrying capacity of 12 LACV-30s and the capabilities of one DWMCF can be modeled by one ACBL. The calculations for each of these substitutions are provided as follows:

<u>6 LARC-LXs = 2 LCM-8s</u> (19)

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 6\ LARC\text{-}LXs \end{matrix} = 5.6\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 6 * 60(STONS) = 4289.3617\ STONS \tag{20}$$

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 1\ LCM\text{-}8s \end{matrix} = 12\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 1 * 65(STONS) = 1659.5744\ STONS \tag{21}$$

$$\left(\frac{4289.3617}{1659.5744}\right) = 2.5846 \approx 2\ LCM\text{-}8s\ (CONSERVATIVE\ ESTIMATE) \tag{22}$$

<u>12 LACV-30s = 6 LCACs</u> (23)

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 12\ LACV\text{-}30s \end{matrix} = 30\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 12 * 23(STONS) = 17{,}617.0212\ STONS \tag{24}$$

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 1\ LCACs \end{matrix} = 40\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 1 * 60(STONS) = 5106.3892\ STONS \tag{25}$$

$$\left(\frac{17{,}617.0212}{5106.3892}\right) = 3.4499 \approx 3\ LCM\text{-}8s\ (CONSERVATIVE\ ESTIMATE) \quad (26)$$

$$\underline{1\ \text{DWMCF} = 1\ \text{ACBL}} \quad (27)$$

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 1DWMCF \end{matrix} = 30\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 1 * 450(STONS) = 3829.7872\ STONS \quad (28)$$

$$\begin{matrix} OVERALL \\ CARRYING \\ CAPACITY \\ 1\ ACBL \end{matrix} = 5\left(\frac{NM}{HR}\right) * 20(HR) * \frac{1}{9.4\left(\frac{NM}{HR}\right)} * 1 * 350(STONS) = 3723.4042\ STONS \quad (29)$$

$$\left(\frac{3829.7872}{3723.4042}\right) = 1.0285 \approx 1\ ACBL\ (CONSERVATIVE\ ESTIMATE) \quad (30)$$

The second formidable challenge in modeling and analyzing a JLOTS scenario via JOTE is to determine the types and quantities of discharge lanes to be operated as well as the capacity (in stons) to be moved on each of the respective discharge lane types. Regarding the determination of discharge lane types and quantities, the guideline suggested by LMI and presented in the previous section is very viable, assuming the initial loadout of the cargo carrying vessels was done strategically so as to keep rolling and containerized cargo separate wherever possible. Fortunately, in OV93 this was indeed the case. During that exercise, the vast majority of containerized cargo was placed on board the containership SS CORPUS CHRISTI and the SEABEE vessel CAPE MOHICAN while wheeled, tracked, and towed vehicles were loaded exclusively on the FSSs

BELLATRIX and REGULUS, with BELLATRIX receiving the majority of wheeled and towed vehicles and REGULUS receiving the entire inventory of tracked vehicles. Tables 6 and 7 provide a breakdown of cargo inventories of each of the four ships used in OV93.

CONTAINER CARRYING VESSELS		
CONTAINER TYPE	**SS CORPUS CHRISTI**	**SEABEE CAPE MOHICAN**
20' Containers	560	0
40' Containers	1	70
Ammunition Containers	73	0
TOTAL CONTAINERS	634	70

Table 6. Loadout for OV93 Container Carrying Vessels, From Ref. [20:p. 3-15].

VEHICLE CARRYING VESSELS		
VEHICLE TYPE	**FSS BELLATRIX**	**FSS REGULUS**
Wheeled Vehicles	576	84
Tracked Vehicles	0	363
Towed Vehicles	318	38
TOTAL VEHICLES	894	485

Table 7. Loadout for OV93 Vehicle Carrying Vessels, After Ref.[20:p. 4-24].

Using this loadout configuration, the guideline suggested by LMI, and most importantly knowledge of the on-board capabilities of each of the four vessels involved, 13 ship-to-shore discharge lanes can be calculated as the appropriate number for this scenario. Table 8 represents a ship-by-ship breakdown of the points of origin for each of the 13 discharge lanes.

NUMBER OF DISCHARGE LANES	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
LO/LO	3	3	0	0
LO/RO	0	0	2	1
RRDF WHEELED	0	0	2	0
RRDF TRACKED	0	0	0	2

Table 8. Assignment of Discharge Lanes for OV93 Sealift Assets in JOTE Validation.

During OV93, the actual discharge lane assignments were certainly not as simple as illustrated in Table 8. Due to the lack of any established off-load sequencing plan, as well as numerous equipment malfunctions, large queues of lighters accumulated at some discharge points while other lighterage and discharge facilities waited idlely. Nonetheless, if the proper planning had been done by senior officials (both military and civilian) prior to the start of the evolution, discharge lane configurations should have been in accordance with Table 8. The following explanation clarifies why this contention can be asserted with confidence.

Because only containerized cargo was carried on board the SS CORPUS CHRISTI and the SEABEE CAPE MOHICAN, there was obviously no need to operate anything other than LO/LO discharge lanes from either of these vessels. Additionally, the justification for there existing exactly three LO/LO discharge lanes from each of these two vessels hinges upon their lack of utilization as non-self-sustaining cargo carriers. By being employed in this manner, the number of discharge lanes originating from either of these vessels is limited to the number of operating crane pedestals on board the T-ACS from which they were off-loaded. Since the T-ACS EQUALITY STATE employed each of its three cranes during off-load operations, three is the appropriate number of discharge lanes. While the SEABEE CAPE MOHICAN has no self-sustaining crane capability, the SS CORPUS CHRISTIE does have two self-sustaining cranes which, if utilized, could have resulted in a maximum of five discharge lanes from this particular vessel.

For the vehicle-carrying vessels, the methodology for determining the quantity and types of discharge lanes is identical. Neither BELLATRIX nor REGULUS carried any containerized cargo, therefore there existed no need for LO/LO discharge lanes originating from either vessel. Both vessels did discharge their respective cargo onto RRDFs. The large surface area of RRDFs assembled from either Navy NL or Army MCS causeway sections is sufficient from which to operate two cargo discharge lanes as was done in OV93. Despite the lack of well defined discharge lanes of transit during this operation, multiple types of lighterage did traverse to two distinct locations at both RRDFs. Because BELLATRIX carried exclusively wheeled and towed vehicles, two RRDF wheeled discharge lanes were established from this vessel. Likewise, the dominance of tracked vehicles on board REGULUS warranted two RRDF tracked discharge lanes originating from this vessel. Thus, the first part of LMI's guideline regarding discharge lanes from RO/RO vessels is quite valid.

The second part of this guideline states that in addition to the two discharge lanes originating from each RRDF placed alongside a cargo vessel, a total of two other discharge lanes may be operated from that same cargo vessel. These additional discharge lanes my be LO/LO or LO/RO depending upon the desires of the cargo ship and the availability of shoreside equipment. This half of the guideline is also valid. In actuality, it is desirable for a vessel engaged in RO/RO discharge operations on one side to utilize its on-board cranes for LO/LO or LO/RO operations on the opposing side. Most vessels which are sufficiently large to conduct RO/RO discharge operations have at least two on-board cranes to employ in this companion operation. Those RO/RO capable vessels which have more than two on-board cranes are, however, logistically restricted from operating more than two while an RRDF is along either side. This physical restriction arises because more than two forms of lighterage cannot safely fit along the same side of a RO/RO capable vessel, while still maintaining sufficient maneuvering space. Standard operating procedures for a self-sustaining cargo vessel which possesses three or more cranes is to conduct discharge operations to two forms of lighterage along one side while one or more other lighterage platforms are positioned along the opposing side. The presence of a (minimum) 140 ft. RRDF and two RRDF discharge lanes along one side, however, prohibit this standard procedure.

The RO/RO capable vessels of OV93 exemplify not only this physical dilemma but also the tactical dilemma discussed in previous paragraphs regarding the balance of number of discharge lanes versus quantity of available lighterage. The FSS BELLATRIX possesses three on-board cranes, only two of which could be employed for LO/RO operations to two LO/RO discharge lane loading sites. Although the FSS REGULUS possesses two on-board cranes, a tactical decision was made not to utilize the aft crane during OV93. Admittedly, this decision does increase the cargo capacity on the one additional LO/RO discharge lane which REGULUS did operate, however, it also decreased the probability of each remaining discharge lane encountering the misfortune of no available lighterage.

On the surface, the methodology discussed in the preceding paragraphs may appear trivial. For the JLOTS commander planning an upcoming off-load operation, however, calculating the desired number of discharge lanes is a very difficult decision, because increasing the number of discharge lanes **does not** necessarily translate into increasing the overall discharge rate and/or decreasing the total discharge time. The cause for this dilemma is that an increased number of sea lanes unavoidably means increased taxation upon the lighterage fleet which causes idle discharge points on board the cargo carrying vessels. It is for this reason that the user requires a model for which throughput productivity can be examined in terms of varying numbers of discharge lanes, lighterage types, and/or other parameters. Most importantly, however, the user also needs a model which stands the test of validation. Perhaps JOTE will prove to be that model.

After standardizing his/her lighterage fleet with that which JOTE will accept, meticulously analyzing the cargo inventories of all vessels involved in the operation, and deciding the number of discharge lanes to operate, the JLOTS commander must then calculate the cargo capacities to place upon each discharge lane before he/she is able to execute JOTE for the first time. This calculation commences with a computation of the total cargo loading of each vessel. For the OV93 exercise modeled here, the cargo loading of each vessel is computed in stons using the LMI suggested conversion factors discussed in the previous section. These computations are shown as follows for each of the four strategic sealift assets.

SS CORPUS CHRISTI

$$560\ (20'\ CONTAINERS) * 9 \left(\frac{STONS}{CONTAINER} \right) = 5{,}040\ (STONS) \tag{31}$$

$$1\ (40'\ CONTAINERS) * 18 \left(\frac{STONS}{CONTAINER} \right) = 18\ (STONS) \tag{32}$$

$$TOTAL\ CARGO\ LOADING = 5{,}058\ (STONS) \tag{33}$$

SEABEE CAPE MOHICAN

$$70\ (40'\ CONTAINERS) * 18 \left(\frac{STONS}{CONTAINER} \right) = 1{,}260\ (STONS) \tag{34}$$

$$73 \begin{pmatrix} 20' \\ AMMUNITION \\ CONTAINERS \end{pmatrix} * 14 \left(\frac{STONS}{CONTAINER} \right) = 1{,}022\ (STONS) \tag{35}$$

$$TOTAL\ CARGO\ LOADING = 2{,}282\ (STONS) \tag{36}$$

FSS BELLATRIX

$$576 \begin{pmatrix} WHEELED \\ VEHICLES \end{pmatrix} * 14 \left(\frac{STONS}{WHEELED\ VEHICLE} \right) = 8{,}064\ (STONS) \tag{37}$$

$$318 \begin{pmatrix} TOWED \\ VEHICLES \end{pmatrix} * 15 \left(\frac{STONS}{TOWED\ VEHICLE} \right) = 4{,}770\ (STONS) \tag{38}$$

$$TOTAL\ CARGO\ LOADING = 12{,}834\ (STONS) \tag{39}$$

FSS REGULUS

$$84\left(\frac{WHEELED}{VEHICLES}\right) * 14\left(\frac{STONS}{WHEELED\ VEHICLE}\right) = 1{,}176\ (STONS) \quad (40)$$

$$38\left(\frac{TOWED}{VEHICLES}\right) * 15\left(\frac{STONS}{TOWED\ VEHICLE}\right) = 570\ (STONS) \quad (41)$$

$$363\left(\frac{TRACKED}{VEHICLES}\right) * 31\left(\frac{STONS}{TRACKED\ VEHICLE}\right) = 11{,}253\ (STONS) \quad (42)$$

$$TOTAL\ CARGO\ LOADING = 12{,}999\ (STONS) \quad (43)$$

Once these calculations have been completed, the assignment of capacity to all the discharge lanes used by both container-carrying vessels is relatively straightforward. Both CORPUS CHRISTI and CAPE MOHICAN have been assigned LO/LO discharge lanes only (three each) for cargo off-load. Consequently, the total cargo loading for each of those vessels can be distributed linearly across the three respective lanes of discharge. Tables 9 and 10 represents the assigned cargo capacities for each of the first six discharge lanes which are those assigned to CORPUS CHRISTI and CAPE MOHICAN.

Unfortunately, the assignment of discharge lane capacities for those lanes originating at vehicle-carrying vessels is more complicated. For these discharge lanes, a linear distribution of the total cargo loading of the respective vessels will not suffice. Here the user must first distinguish the exact quantities of vehicles from each vessel which will be loaded on board lighterage via the respective RRDFs from those which will travel

SS CORPUS CHRISTI TOTAL CARGO LOADING = 5058 STONS		
DISCHARGE LANE NUMBER	**DISCHARGE LANE TYPE**	**DISCHARGE LANE CAPACITY**
1	LO/LO	1686
2	LO/LO	1686
3	LO/LO	1686

Table 9. SS CORPUS CHRISTI Off-load Plan for JOTE Model Validation.

SEABEE CAPE MOHICAN TOTAL CARGO LOADING = 2282 STONS		
DISCHARGE LANE NUMBER	**DISCHARGE LANE TYPE**	**DISCHARGE LANE CAPACITY**
4	LO/LO	760
5	LO/LO	760
6	LO/LO	761

Table 10. SEABEE CAPE MOHICAN Off-load Plan for JOTE Model Validation.

to the shore via LO/RO discharge lanes. Although many factors can influence this decision, the most prevalent are:

1. Cargo loadout configuration on board the RO/RO capable vessel.
2. The size of the lighterage to be used.
3. The surface area of the RRDF to be used.
4. Lift capacity of on board cranes.

From the JTD report of OV93, the exact quantities of vehicles which traversed over RRDFs as well as those which were loaded aboard lighterage via cranes from both BELLATRIX and REGULUS can be extracted. These vehicle loadout schemes as well as the appropriate conversions to stons are indicated as follows:

FSS BELLATRIX

$$TOTAL\ CARGO\ LOADING = 12{,}834\ (STONS) \tag{44}$$

$$265 \begin{pmatrix} RRDF \\ WHEELED \\ VEHICLES \end{pmatrix} * 14 \left(\frac{STONS}{RRDF\ WHEELED\ VEHICLE} \right) = 3{,}710\ (STONS) \tag{45}$$

$$194 \begin{pmatrix} RRDF \\ TOWED \\ VEHICLES \end{pmatrix} * 15 \left(\frac{STONS}{RRDF\ TOWED\ VEHICLE} \right) = 2{,}910\ (STONS) \tag{46}$$

$$RRDF\ CARGO\ LOADING = 6{,}620\ (STONS) \tag{47}$$

$$311 \begin{pmatrix} LO/RO \\ WHEELED \\ VEHICLES \end{pmatrix} * 14 \left(\frac{STONS}{LO/RO\ WHEELED\ VEHICLE} \right) = 4{,}354\ (STONS) \tag{48}$$

$$124 \begin{pmatrix} LO/RO \\ TOWED \\ VEHICLES \end{pmatrix} * 15 \left(\frac{STONS}{LO/RO\ TOWED\ VEHICLE} \right) = 1{,}860\ (STONS) \tag{49}$$

$$LO/RO\ CARGO\ LOADING = 6{,}214\ (STONS) \tag{50}$$

FSS REGULUS

$$TOTAL\ CARGO\ LOADING = 12{,}999\ (STONS) \tag{51}$$

$$57 \begin{pmatrix} RRDF \\ WHEELED \\ VEHICLES \end{pmatrix} * 14 \left(\frac{STONS}{RRDF\ WHEELED\ VEHICLE} \right) = 798\ (STONS) \tag{52}$$

$$37 \begin{pmatrix} RRDF \\ TOWED \\ VEHICLES \end{pmatrix} * 15 \left(\frac{STONS}{RRDF\ TOWED\ VEHICLE} \right) = 555\ (STONS) \tag{53}$$

$$145 \begin{pmatrix} RRDF \\ TRACKED \\ VEHICLES \end{pmatrix} * 31 \left(\frac{STONS}{RRDF\ TRACKED\ VEHICLE} \right) = 4{,}495\ (STONS) \tag{54}$$

$$RRDF\ CARGO\ LOADING = 5{,}848\ (STONS) \tag{55}$$

$$27 \begin{pmatrix} LO/RO \\ WHEELED \\ VEHICLES \end{pmatrix} * 14 \left(\frac{STONS}{LO/RO\ WHEELED\ VEHICLE} \right) = 378\ (STONS) \tag{56}$$

$$1 \begin{pmatrix} LO/RO \\ TOWED \\ VEHICLES \end{pmatrix} * 15 \left(\frac{STONS}{LO/RO\ TOWED\ VEHICLE} \right) = 15\ (STONS) \tag{57}$$

$$145 \begin{pmatrix} LO/RO \\ TRACKED \\ VEHICLES \end{pmatrix} * 31 \left(\frac{STONS}{LO/RO\ TRACKED\ VEHICLE} \right) = 6{,}578\ (STONS) \tag{58}$$

$$LO/RO\ CARGO\ LOADING = 7{,}151\ (STONS) \tag{59}$$

Tables 11 and 12 incorporate the above calculations and represent the assigned cargo capacities for discharge lanes seven through 13 which are those assigned to BELLATRIX and REGULUS.

These calculations and the methodologies involved have been presented in exhausting detail in order to capture the extent of user effort which is necessary to execute the JOTE model. With this in mind, two additional points must be understood. First, these calculations do not represent the entirety of the demands placed upon the user in utilizing JOTE. The following overview of the computational components of JOTE will reveal the exact locations where user interaction is required in the form of spreadsheet cell

FSS BELLATRIX TOTAL CARGO LOADING = 12,834 STONS		
DISCHARGE LANE NUMBER	**DISCHARGE LANE TYPE**	**DISCHARGE LANE CAPACITY**
7	RRDF WHEELED	3310
8	RRDF WHEELED	3310
9	LO/RO	3107
10	LO/RO	3107

Table 11. FSS BELLATRIX Off-load Plan for JOTE Model Validation.

FSS REGULUS TOTAL CARGO LOADING = 12,999 STONS		
DISCHARGE LANE NUMBER	**DISCHARGE LANE TYPE**	**DISCHARGE LANE CAPACITY**
11	RRDF TRACKED	2924
12	RRDF TRACKED	2924
13	LO/RO	7151

Table 12. FSS REGULUS Off-load Plan for JOTE Model Validation.

manipulations due to malfunctioning calculations in various Visual Basic macros. A subsequent section will address the malfunctions identified during this validation. The majority of these items are correctable only by LMI due to their locations in hidden and/or write protected files.

Second, when employing a computer-based optimizer, a user justifiably assumes that the results obtained are indeed optimal. With JOTE, however, two significant shortfalls limit the optimality of its results. First and foremost, is JOTEs inability to apply theoretical mathematical and data analysis principles in order to process site-specific sea state data for the purpose of improving upon validity of the spreadsheet cell entry (O-38) which represents the percentage of time sea state conditions are degrading to throughput operations. More specifically, cell entry O-38 of the JOTE model represents the percentage of time sea state conditions are strictly greater than Sea State Two. As sections A and B of this chapter confirmed, throughput is significantly curtailed in the upper regions of Sea State Two. A strict inequality in the spreadsheet cell O-38 entry is therefore, inaccurate, and should be replaced by a loose inequality.

A second critical degradation of optimality of JOTE results arises because JOTE is designed with the assumption that all ships involved in off-load operations are positioned equidistant from the shoreline. The user has no way, via either macro or spreadsheet cell manipulation, to stagger the distances of ships involved in cargo discharge. During an actual JLOTS scenario, the number of vessels involved will almost always guarantee that ship-to-shore distances are not equal. Consequently, if the cargo distribution among all vessels involved is roughly consistent (as was the case in OV93), prudence requires the user to select the longest of the ship-to-shore distances of all vessels in order as the single entry. After doing so, the user is assured that the results obtained are worst case scenario conditions, rather than optimal. For this validation, a ship-to-shore distance of 4.7 nm was used as the single allowable value. In actuality, the container and vehicle carrying vessels were anchored 4.7 and 3.5 nm off-shore respectively.

The reality of this latter shortfall, however, is not necessarily detrimental to the user. In the context of being a JLOTS planning tool, JOTE, perhaps in spite of itself, provides the user with a needed piece of information. Without question, the user does require the optimal results, but the user must also have knowledge of the worst case conditions. Modifying JOTE to accept multiple ship-to-shore distances would require a complete restructuring of the various macros of the Visual Basic program. Perhaps with future funding LMI can undertake such modifications to correct this shortfall, as well as those addressed in the final section of this chapter. In the meantime, however, satisfying the immediate needs of the user, the JLOTS commander, must be the primary objective. To this end, the JOTE model validation continues in the next section with the introduction of the supplemental program SEA_STATE_CALC which is designed to expose and correct the limitations of JOTE regarding the acquisition and processing of site-specific sea state data.

E. SEA_STATE_CALC - A SUPPLEMENT TO JOTE

At this point, a validation of JOTE is far from complete. In fact, the analysis of the preceding section focused exclusively upon the prerequisites of JOTE use. In order to analyze the execution of JOTE and validate the results illustrated in Appendix D, an understanding of the supplemental program SEA_STATE_CALC is crucial. This program was constructed in order to correct limitations of the JOTE model and thus improve its value to the JLOTS commander. It was also directly employed in the JOTE validation presented within this thesis by providing a methodology for calculating the percentages of occurrence of sea state conditions in excess of Sea State Two. These percentages segregate the four JOTE execution outputs depicted in Appendix D.

For each of the off-load scenarios presented in Appendix D, all input parameters are consistent and are identical to those presented in the previous section. The only cell entry which differs among the scenarios is the percentage of time sea state conditions equal or exceed Sea State Two. All scenarios were modeled using a loose inequality, vice the well substantiated, but incorrect, strict inequality originally utilized by LMI. Additionally, because OV93 (the data source for this model validation) was conducted in the waters off the coast of Fort Story, VA, throughput productivity under various percentages of sea state occurrence will be evaluated relative to the percentages shown in the row entitled CINC 1 of Table 3. CINC 1 in Table 3 corresponds to the entire Atlantic theater which is obviously a far too large geographical area to be of any use to the user. The two critical entries in this row are those in columns two and three, namely, 20% of all observed waves being Sea State Two waves and 40% being Sea State Three or above waves respectively.

The first off-load scenario modeled was a situation in which 40% of all sea state conditions equaled or exceeded Sea State Two. Because cell O-38 of the JOTE spreadsheet, as it presently and incorrectly exists, calls for the percentage of time sea state conditions strictly exceeding Sea State Two, LMI suggests the user simply extract the value in column three of Table 3 for the respective CINC region in which the user plans to conduct JLOTS operations. Due to the realization of LMI's error, for all four off-load scenarios depicted in Appendix D, cell O-38 has been appropriately redefined as the percentage of time in which sea state conditions equal or exceed Sea State Two. With this modification, a suitable cell O-38 entry for the initial off-load scenario is 40%, which is the column three entry of Table 3. Cell O-38 entries for the subsequent scenarios will be calculated via the SEA_STATE_CALC program from a site-specific input file of near-shore significant wave height (NSSWH) observations measured at Fort Story, VA during the entire test period of OV93.

1. The Criticality of the Rayleigh Distribution

Once initiated, the program SEA_STATE_CALC operates free of user interaction. The program seeks out and acquires the input file SSDATA.TXT. This input file contains up to 16,300 observations of NSSWHs, as well as the date/time groups of those observations. As discussed in Chapter II, the program subsequently applies a Rayleigh probability distribution to the input data set in order to confirm that the most common waves do occur at $0.7071H_{RMS}$. A theoretical Rayleigh distribution would resemble that shown in Figure 12.

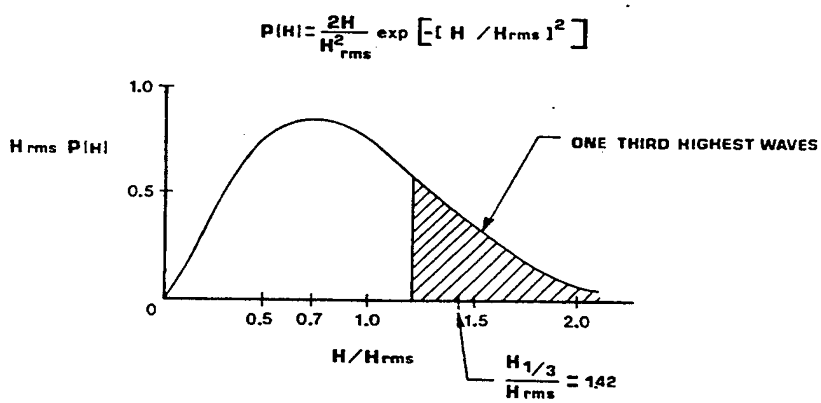

Figure 12. The Rayleigh Probability Distribution P(H) as applied to Wave Heights, From Ref. [14:p. 17].

Indeed, if it were possible to observe wave heights in a given location for an infinite amount of time, the Rayleigh distribution plot of those observations would resemble the Figure 12 plot. Specifically, over an infinite time interval one would eventually observe both nonexistent wave heights corresponding to a value of zero, and increasingly infrequent, but drastically high, wave heights as well. These two extreme value situations form the respective tails of the Rayleigh probability plot. In reality, however, infinite observations are not possible. Therefore, a Rayleigh distribution plot of sea state observations will, most often, not contain complete tails on either end. Figure 13 represents a Rayleigh distribution plot of the observed wave heights during OV93.

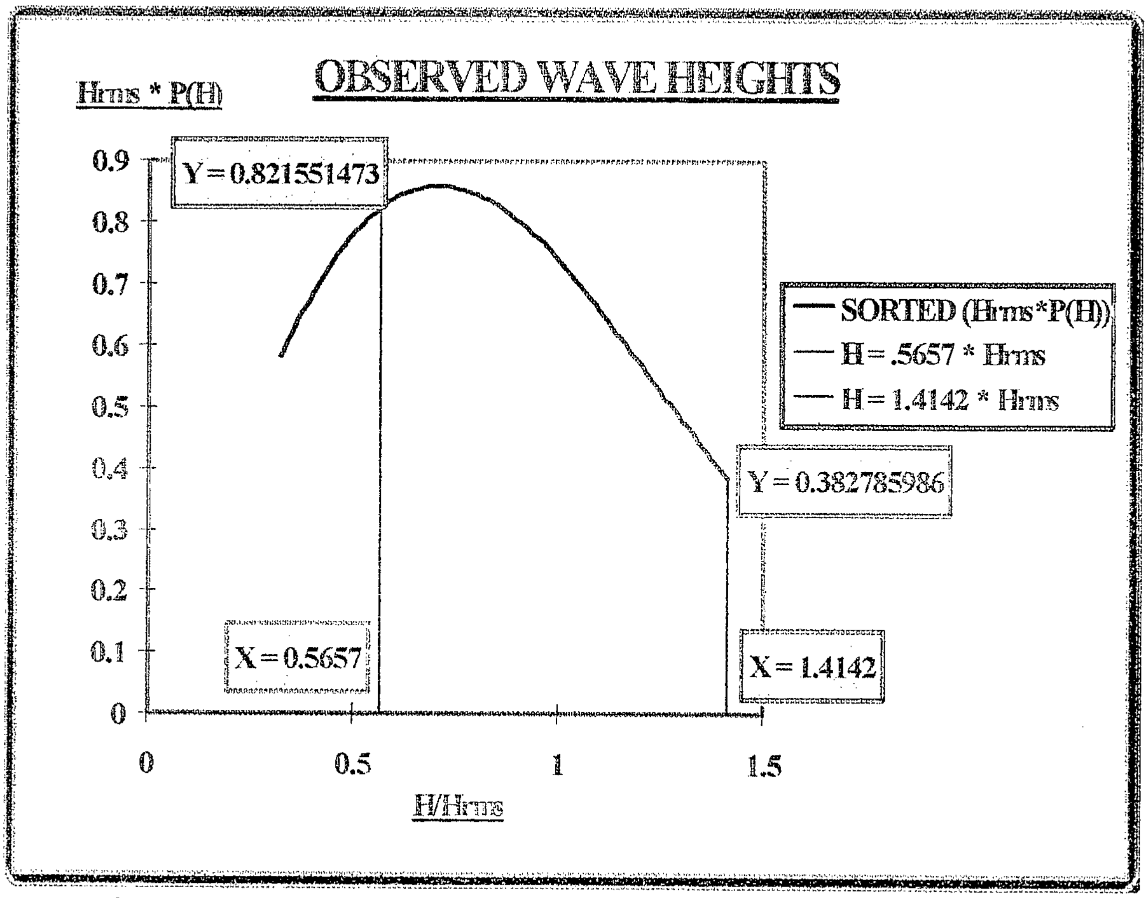

Figure 13. Rayleigh Distribution of Observed Wave Heights During OV93.

This probability density function (PDF) is shown in blue in Figure 13. In this plot, the X-axis represents the ratio $\frac{H}{H_{RMS}}$, while the Y-axis is defined by the product of $H_{RMS} * P(H)$, where $P(H)$ depicts the Rayleigh probability function applied to the respective wave height observation H. As defined in Chapter II, the Rayleigh probability function $P(H)$ is given by Equation 60.

$$P(H) = \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{H}{H_{RMS}}\right)^2\right]} \tag{60}$$

For the wave height data of OV93, $H_{RMS} = 2.474874$, thus $0.7071 H_{RMS}$, which represents the theoretical most common wave height for the Fort Story, VA area based upon the data set used, is 1.749 ft. which is well within the Sea State Two range which begins at approximately 1.4 ft. As Figure 14 illustrates, the apex of the Rayleigh PDF actually occurs at a NSSWH 1.8 ft. which suggests that an adequate approximation of the theoretical wave height conditions in this area is being obtained from applying a Rayleigh distribution to this data set. Subsequent sections will address several means of assessing the quality of fit obtained from this data set.

Figure 14 displays the relative occurrence of observed NSSWH. On this graph, the X-axis represents the actual wave height values, H, of the data set while the Y-axis depicts the Rayleigh probability function values, $P(H)$, corresponding to the respective NSSWH values. Obviously, the greater the Rayleigh probability function value at a given point along the X-axis, the greater the probability of observing that particular NSSWH during the period covered by the data set.

Assessing the relative probability of occurrence of wave height values is, however, not the primary function of the SEA_STATE_CALC program. The primary objective of this program is to utilize those relative probabilities for the purpose of determining the

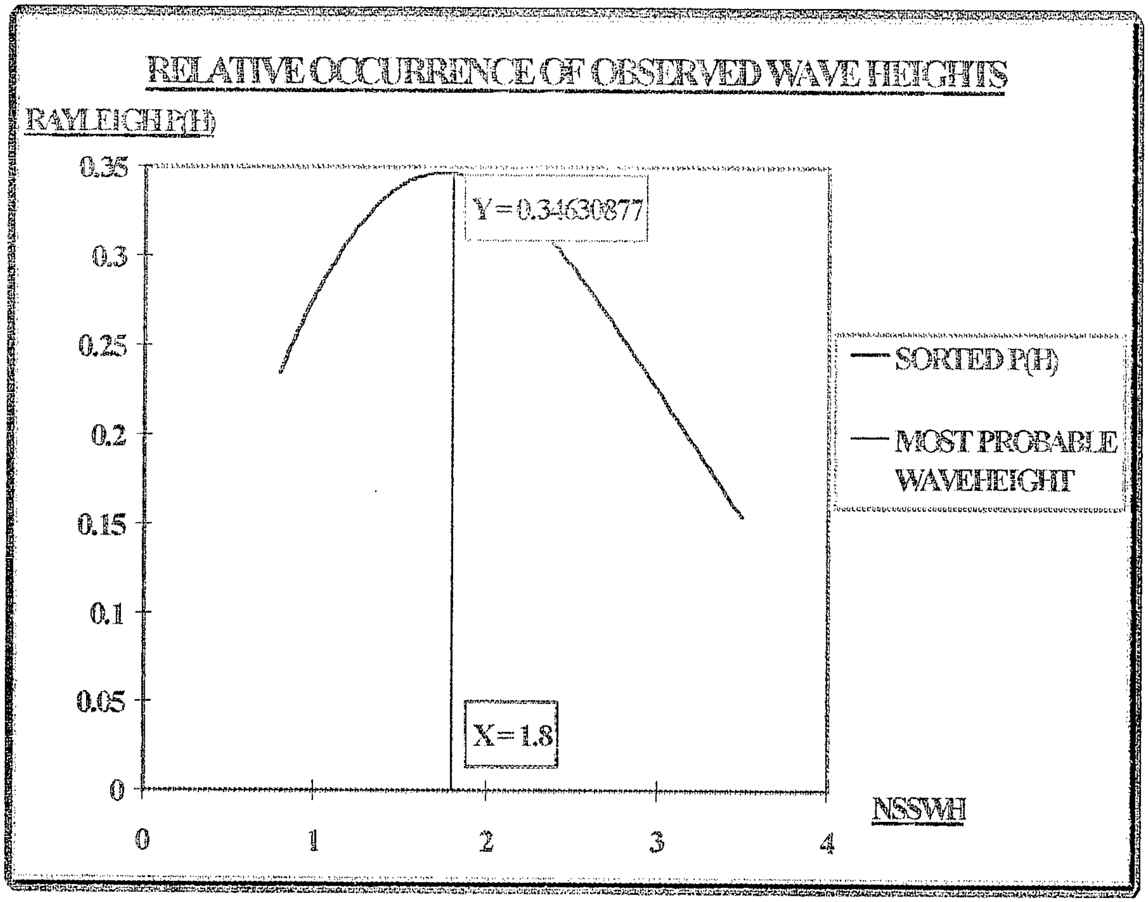

Figure 14. Rayleigh Distribution of Relative Occurrence of Observed Wave Heights During OV93.

percentage of time sea state conditions equal or exceed Sea State Two. A reexamination of Figure 13 will explain the manner in which the program accomplishes this task.

2. Requirements and Methodologies for SEA_STATE_CALC

In addition to the PDF of observed wave heights shown in blue in Figure 13, there also exist two vertical lines shown in red. The left-hand vertical line corresponds to the line $H = 0.5657H_{RMS}$, while the right-hand line represents $H = 1.4142H_{RMS}$. The vertical line $H = 0.5657H_{RMS}$ corresponds to the point on the PDF where wave height observations from this data set cross the Sea State Two threshold, with Sea State Two being defined to occur at $H = 1.4\ ft. = 0.5657H_{RMS}$. Likewise, the vertical line $H = 1.4142H_{RMS}$ corresponds to the rightmost value of the Rayleigh PDF which occurs at the highest observed wave height within this data set, namely $H = 3.5\ ft. = 1.4142H_{RMS}$. The purpose of annotating these positions with vertical lines extending from the X-axis to the PDF curve is to delineate specific areas under the PDF curve. Mathematically, the integral of a theoretical PDF from zero to a specific value on the X-axis represents the area under the PDF curve up to that point, or more precisely, the value of the cumulative distribution function (CDF) at that point. Unfortunately, however, a theoretical PDF curve cannot be generated from the size-limited OV93 data set.

If the data set of NSSWH observations for OV93 were of infinite size, the PDF curve shown in blue in Figure 13 would contain both its left and right-hand tails and would therefore, represent a theoretical PDF curve. Under that scenario, the area under the PDF curve to the right of the vertical line annotating $H = 0.5657H_{RMS}$ would represent the right tail probability , or more exactly, the complement of the CDF up to that line. In the theoretical case, this value of $1 - CDF$ at the point $H = 0.5657H_{RMS}$ would represent the percentage of time sea state conditions equal or exceed Sea State Two. Because the limited size of the OV93 data set prohibits the existence of a theoretical PDF, the following relationships will be used to explain the situation as it exists not only for the OV93 scenario, but also, for all scenarios since a theoretical PDF is never attainable.

The following quantities are now defined:

a = The ratio of the lower threshold of Sea State Two conditions (1.4 ft.) to the H_{RMS} for the respective data set. {a = .5657 for OV93};

b = The ratio of the largest observed wave height in the respective data

set to the H_{RMS} for that data set. {b = 1.4142 for OV93};
f(H) = The Rayleigh PDF of observed wave heights; and
F(H) = The Rayleigh CDF of observed wave heights.

Due to the nonexistence of a theoretical Rayleigh PDF for the OV93 data set or any other data set, the modeler/user has two options. First, he/she may assume that his/her respective data set sufficiently approximates a theoretical Rayleigh distribution so as to justify utilizing $1 - F(a)$ as an appropriate substitute for the theoretical right tail probability and thus, the percentage of time sea state conditions equal or exceed Sea State Two. Second, and more fittingly, the user can correctly postulate that the Rayleigh PDF for the observed data set is merely an excerpt of the theoretical Rayleigh PDF of NSSWHs for that particular geographic area. After formulating this hypothesis, the modeler can compute the right tail probability for the excerpt of the Rayleigh PDF curve which is unique to the data set at hand. This is done by first computing the right tail probability $1 - F(b)$ and subtracting that value from the right tail probability $1 - F(a)$. With the help of Figure 15, the following segment outlines these calculations and subsequently displays the results obtained for the OV93 scenario. For this scenario, both techniques were employed in model validation in order to not only assess the relative accuracy and precision of each, but also, to determine which is the more viable technique to be applied for purposes improving the JOTE model.

<u>Right tail probabilities</u>

$$1 - F(a) = 1 - \int_0^a f(x)\,dx \quad (61) \qquad 1 - F(b) = 1 - \int_0^b f(x)\,dx \quad (62)$$

Area under PDF between a and b

$$[F(b) - F(a)] = \left\{ \left[\int_0^b f(x)\, dx \right] - \left[\int_0^a f(x)\, dx \right] \right\} \tag{63}$$

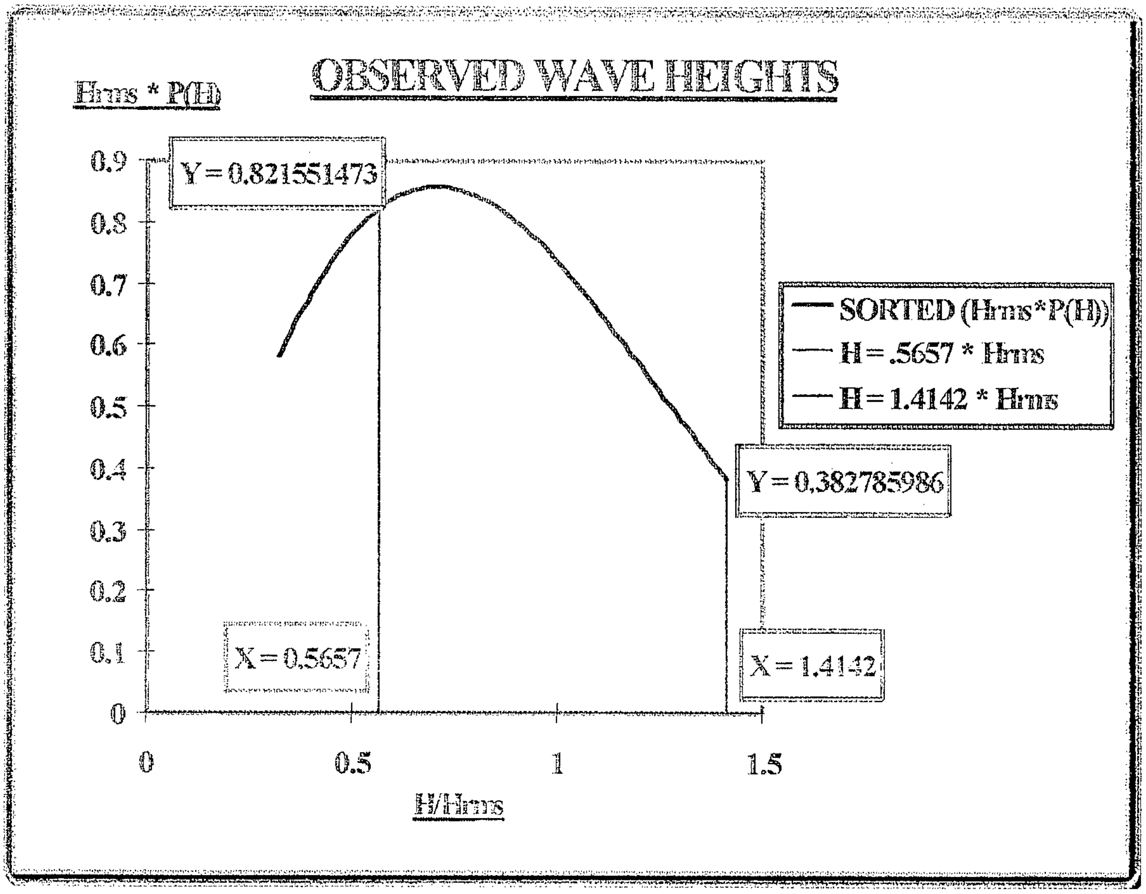

Figure 15. Rayleigh Distribution of Observed Wave Heights During OV93.

Obviously, both the theoretical and observed percentages of time in which sea state conditions equal or exceed Sea State Two can, and should, be calculated for a data set of observations in any location. The modeler must therefore determine which of these two computable percentages more accurately represents the actual conditions at hand. Under ideal conditions, the theoretical percentage is unquestionably more accurate. In this context, however, ideal conditions refer to the existence of either an infinite or an uncharacteristically large data file, in terms of both number of observations and the time period covered by those observations. Indeed, as the size and quality of the data file of sea state observations approaches this definition of ideal, the theoretical and observed percentages will more closely approximate each other. This phenomenon occurs because as more wave height observations are recorded and the time period over which those observations are collected is increased, both tails of the Rayleigh distribution PDF are formed. As the right-hand tail of the Rayleigh PDF of observed wave heights is increasingly formed, the right-most PDF value (the b value from the previous calculations) obviously occurs at a numerically higher coordinate along the X-axis. As Figure 15 demonstrates, the further to the right along the Rayleigh PDF curve on which the b value occurs, the closer the expressions $1 - F(a)$ and $F(b) - F(a)$ become. In a probability context, this means that, as the b value is moved further to the right along the Rayleigh PDF curve, the right tail probability $1 - F(b)$ approaches zero, which means the quantity $F(b)$ approaches 1 and thereby, approximates $1 - F(a)$.

Through the use of the right tail probability formulas, Figure 15, and the OV93 observed wave height data set, an approximation of the theoretical percentage of time sea state conditions equal or exceed Sea State Two in the waters off the coast of Fort Story, VA is computed as follows:

Theoretical percentage of sea state conditions $[1 - F(a)]$

$$f(H) = \frac{2H}{(H_{RMS})^2} * EXP\left[-\left(\frac{H}{H_{RMS}}\right)^2\right] = \frac{2H}{(H_{RMS})^2} * EXP\left[-\left(\frac{1}{H_{RMS}^2}\right)H^2\right] \qquad (64)$$

$$F(H) = \int_0^{0.5657H_{RMS}} \left\{ \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{1}{H_{RMS}^2} \right) H^2 \right]} \right\} dH \quad (For\ a = 0.5657) \tag{65}$$

$$F(H) = \int_0^H f(H)\ dH = F(u) = \int_0^u f(u)\ du \quad (After\ u\ substitution) \tag{66}$$

$$u = -\left(\frac{1}{H_{RMS}^2} \right) H^2 \tag{67}$$

$$du = -\left(\frac{2}{H_{RMS}^2} \right) H\ dH \tag{68}$$

$$\frac{du}{\left(\frac{-2}{H_{RMS}^2} \right)} = H\ dH \tag{69}$$

$$When\ H = .5657H_{RMS} \qquad u = -\left(\frac{1}{H_{RMS}^2} \right) * (.5657)^2 H_{RMS}^2 = -0.3200 \tag{70}$$

$$When\ H = 0 \qquad u = 0 \tag{71}$$

$$F(u) = \left(\frac{2}{H_{RMS}^2} \right) \left\{ \int_0^{-0.3200} EXP^u \frac{du}{\left(\frac{-2}{H_{RMS}^2} \right)} \right\} = -\int_0^{-0.3200} EXP^u\ du \tag{72}$$

$$F(a) = -\left(EXP^{-0.3200} - EXP^0 \right) = 0.27385 = 27.385\% \tag{73}$$

$$1 - F(a) = 1 - .27385 = 0.72615 = 72.615\% \tag{74}$$

$$\left\{ \begin{matrix} THEORETICAL\ \%\ OF\ TIME \\ SEA\ STATE\ CONDITIONS \\ \geq SEA\ STATE\ 2 \end{matrix} \right\} = 72.615\% \tag{75}$$

By employing the same resources as used in the above calculations, the actual percentage of time sea state conditions equal or exceed Sea State Two for the OV93 data set can be obtained via the following methodology.

Observed percentage of sea state conditions $[F(b) - F(a)]$

$$f(H) = \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{H}{H_{RMS}}\right)^2\right]} = \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{1}{H_{RMS}^2}\right)H^2\right]} \quad (76)$$

$$F(H) = \int_0^{1.4142H_{RMS}} \left\{ \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{1}{H_{RMS}^2}\right)H^2\right]} \right\} dH \quad (For\ b = 1.4142) \quad (77)$$

$$F(H) = \int_0^H f(H)\ dH = F(u) = \int_0^u f(u)\ du \quad (After\ u\ substitution) \quad (78)$$

$$u = -\left(\frac{1}{H_{RMS}^2}\right)H^2 \quad du = -\left(\frac{2}{H_{RMS}^2}\right)H\ dH \quad \frac{du}{\left(\frac{-2}{H_{RMS}^2}\right)} = H\ dH \quad \begin{matrix}(79)\\(80)\\(81)\end{matrix}$$

$$When\ H = 1.4142H_{RMS} \quad u = -\left(\frac{1}{H_{RMS}^2}\right) * (1.4142)^2H_{RMS}^2 = -1.9999 \quad (82)$$

$$When\ H = 0 \quad u = 0 \quad (83)$$

$$F(u) = \left(\frac{2}{H_{RMS}^2}\right)\left\{\int_0^{-1.9999} EXP^u \frac{du}{\left(\frac{-2}{H_{RMS}^2}\right)}\right\} = -\int_0^{-1.9999} EXP^u\ du \quad (84)$$

$$F(b) = -\left(EXP^{-1.9999} - EXP^0\right) = 0.86465 = 86.465\% \quad (85)$$

$$1 - F(b) = 1 - 0.86465 = 0.13535 = 13.535\% \quad (86)$$

$$F(b) - F(a) = 0.86465 - 0.27385 = 0.5908 = 59.08\% \quad (87)$$

$$\left\{\begin{matrix} OBSERVED\ \%\ OF\ TIME \\ SEA\ STATE\ CONDITIONS \\ \geq SEA\ STATE\ 2 \end{matrix}\right\} = 59.08\% \quad (88)$$

As expected, the quantities $1 - F(a)$ and $F(b) - F(a)$ differ by an appreciable amount for the OV93 wave height data set. Independently, however, this difference is not necessarily indicative of a poor application of the Rayleigh distribution. Instead, it simply implies that the particular data set being used may not be as good as others for making conclusions about the long-term theoretical wave height conditions for the Fort Story, VA area. Several determining factors could render one data set sub-par to another. Examples of these criteria are not limited to characteristics such as:

1. Number of observations.
2. Period of record.
3. Frequency of observations under both storm and idle sea state conditions.

The OV93 data set does possess a modest number of observations (1350). These observations, however, span only a 19 day period in which no idle sea state or storm conditions were observed. Hence, the difference between the values $1 - F(a)$ and $F(b) - F(a)$. The SEA_STATE_CALC program is responsive to the susceptibility of an input data set to the above shortfalls. It is for this reason that in addition to returning both the $1 - F(a)$ and $F(b) - F(a)$ values, the program contains the following inherent goodness of fit tests.

3. Assessing the Quality of the Input File

Based upon the above discussion, the user must have a means of assessing the quality of the input data file of NSSWH observations. This quality assessment must be two-fold. First, the user must have the means of assessing the degree to which the wave height data set at hand is modeled by a Rayleigh distribution. Subsequently, he/she must have the means of determining whether the excerpt of the Rayleigh PDF of NSSWHs obtained from the input data file sufficiently approximates the theoretical Rayleigh PDF for the geographic region in question. Here, the term sufficiently is certainly relative, therefore, any means of validation must be quantifiable in order to avoid being subject to discretion. The SEA_STATE_CALC program essentially provides three unique means of input file validation which are increasingly quantifiable.

The first method of validation directly corresponds to the discussion which concluded the previous section and addresses the latter goal of input file quality assessment discussed in the preceding paragraph. Specifically, as the quantities $1 - F(a)$ and $F(b) - F(a)$ increasingly approximate each other, the excerpt of the Rayleigh PDF of NSSWH observations obtained from the input data set increasingly approximates the long term theoretical Rayleigh PDF for the respective geographic region.

At this point, the value of an input data set containing as many values as possible, measured over a time period as large as possible, has been firmly established. The second method of input file validation employed by the SEA_STATE_CALC program, however, provides yet another justification for constructing an input file in this manner. A Rayleigh PDF, whether it be a long term theoretical curve, or merely an excerpt of such, is constructed based upon the parameter $H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}} \right)$. This dependency was illustrated in the formula for a Rayleigh PDF presented previously and is reintroduced in Equation 89.

$$P(H) = \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{H}{H_{RMS}} \right)^2 \right]} \tag{89}$$

As the number of observations taken and the length of time over which they are recorded are increased, the quantity and frequency of observations approaching the maximum NSSWH, H_{PEAK}, for the geographic region at hand are also increased. Understandably, a period of record must be sufficiently long so as to encompass enough larger wave height observations to counteract the mathematical effects of idle sea state observations, which are more common, upon the magnitude of $H_{AVERAGE}$. Consequently, due to the definition of H_{RMS}, an input data set encompassing a more accurate value of H_{PEAK} for a given geographic region often translates into a more accurate parameter H_{RMS} (assuming the data set is not limited only to observations during storm periods). Obviously, enhancing the validity of the parameter H_{RMS} renders the Rayleigh PDF obtained from the input data set to be a more accurate assessment of the long term theoretical Rayleigh PDF. Measuring the quality of the parameter H_{RMS} is possible by understanding the manner in which NSSWHs follow a Rayleigh distribution. Figure 14 illustrated that for a theoretical Rayleigh PDF of NSSWHs, the apex of the PDF curve delineated the most common NSSWH of those contained in the input data set. Additionally, Figure 12 revealed that, under theoretical conditions, the most common NSSWH will occur at $0.7071 H_{RMS}$. As this value deviates from the mode of the observed NSSWH data file, the quality of that data file is diminished.

The discussion of the preceding paragraph is provided solely because the OV93 data set is one in which a much better approximation of the theoretical H_{RMS} is obtained from the formula $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}}\right)$ than with the formula $H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}}\right)$. The 19 day snapshot taken during OV93 yields a data set which is characterized by an overabundance of low wave height observations and an insufficient quantity of higher observations. Figures 13, 14, and 15 were all produced with H_{RMS} defined as $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}}\right)$. Figures 16 and 17 represent the same plots with H_{RMS} now being efined as $H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}}\right)$. These plots only minimally resemble the shape of the Rayleigh PDF.

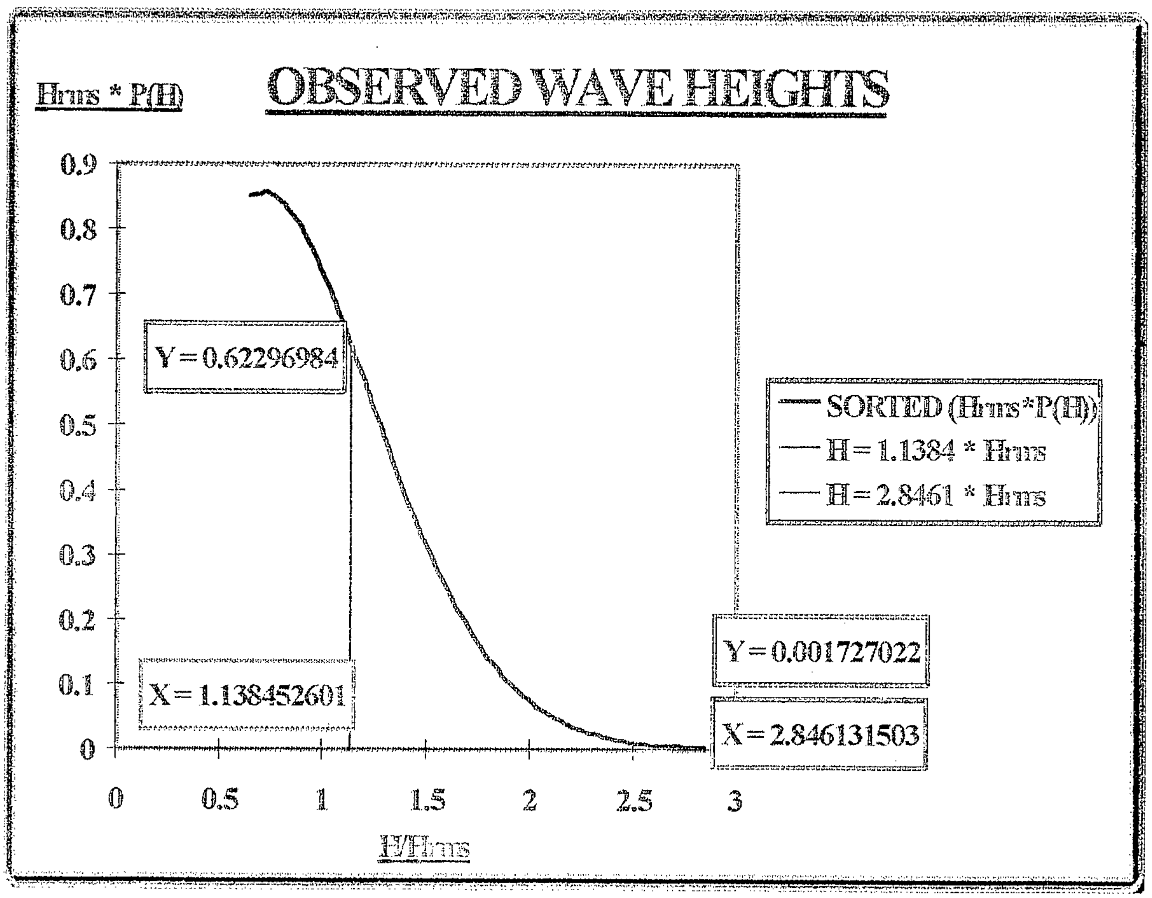

Figure 16. Rayleigh Distribution of Observed Wave Heights During OV93 (Incorrect H_{RMS}).

In addition to the visually obvious limitations of Figures 16 and 17, employing each of the guidelines proposed in Section A of Chapter II, also confirms the inaccuracy of

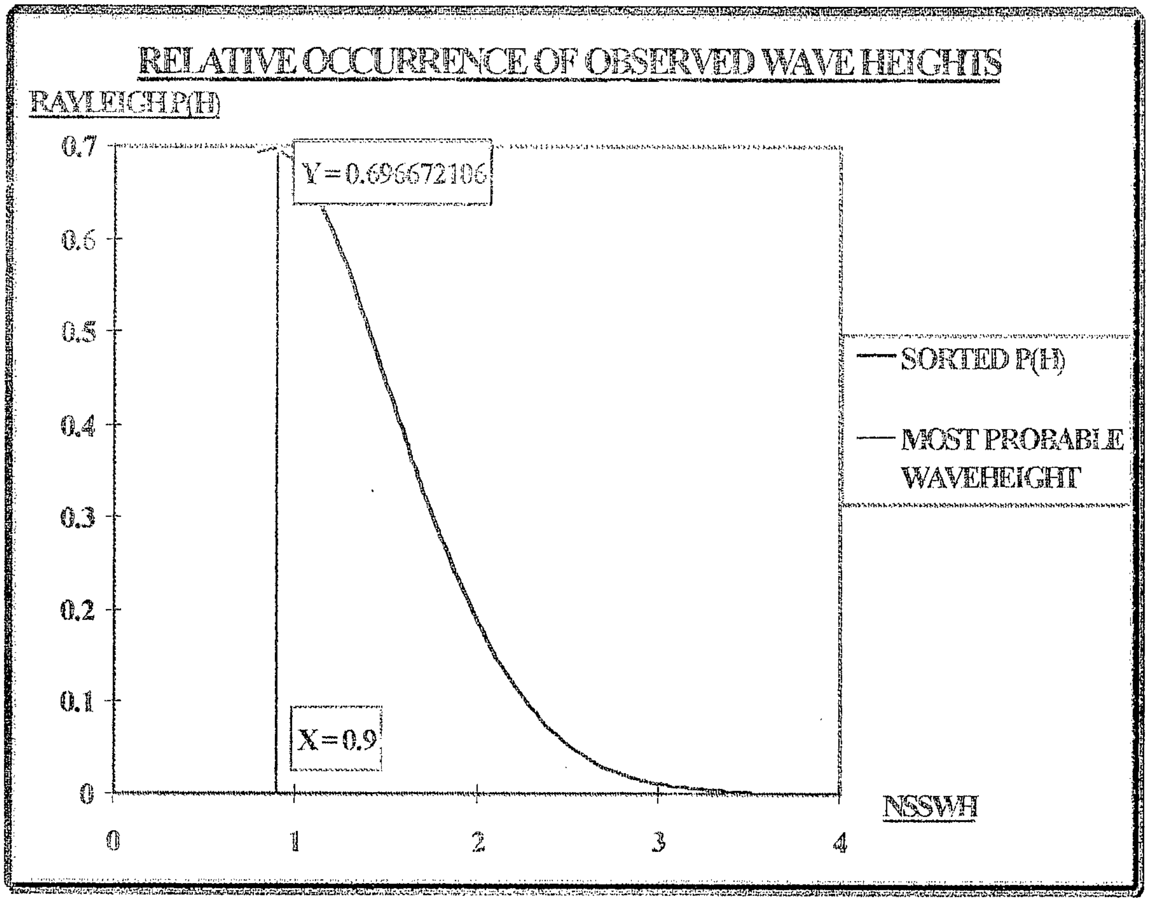

Figure 17. Rayleigh Distribution of Relative Occurrence of Observed Wave Heights During OV93 (Incorrect H_{RMS}).

defining H_{RMS} as $H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}} \right)$ for the OV93 data set. Specifically, the mode of the OV93 wave height data set is 1.4 ft., of which 121 observations exist. From Figure 14, where $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}} \right)$, the apex of the Rayleigh PDF (depicting the most common wave height) occurs at 1.8 ft., of which there are 87 observations within the OV93 data set. From Figure 17, however, the most common wave height is determined to be 0.9 ft., of which there are only seven observations in the OV93 data set. Additionally, a comparison of the Y-axis values in Figures 13 and 16, for a wave height $H = 1.4\ ft.$, which represents the actual mode of the OV93 data set, yields $H_{RMS} * P(H)$ values of

0.821543 for $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}}\right)$ in Figure 13, and 0.622225 for $H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}}\right)$ in Figure 16. The higher Y-axis value at the actual mode of the data set is indicative of the preferred H_{RMS} definition. A final verification that the results shown in Figures 13 and 14 are more theoretically accurate than those shown in Figures 16 and 17 involves no mathematics, but simply the common sense affirmation that the most common wave height in the coastal waters of Fort Story, VA is certainly somewhat higher than the 0.9 ft. suggested by Figure 17.

This comparison is presented not for purposes of arguing the conditions under which different definitions of H_{RMS} should be employed. It is provided, instead, in order to clarify the reasons why $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}}\right)$ was used in the SEA_STATE_CALC execution(s) conducted during JOTE model validation.

a. The Chi-Square Goodness of Fit Test.

The final, and most computationally intensive, method of input file quality assessment employed by the SEA_STATE_CALC program is the application of a Chi-Square Goodness of Fit Test. The Chi-Square Goodness of Fit Test performed within the SEA_STATE_CALC program evaluates the quality of the fitted relationship between the unknown parameters of Equations 90 and 91. These equations represent equivalent forms of the Rayleigh PDF as illustrated by Equations 92 and 93 respectively.

$$P(H) = \frac{2H}{(H_{RMS})^2} * EXP^{\left[-\left(\frac{H}{H_{RMS}}\right)^2\right]}, \qquad (90)$$

$$EXPECTED\ P(H) = \frac{H}{MLE\ \theta} * EXP\left[-\left(\frac{H^2}{2 * (MLE\ \theta)^2}\right)\right] \qquad (91)$$

$$f(H) = \frac{2H}{H_{RMS}^2} * EXP^{-\left(\frac{H}{H_{RMS}}\right)^2} \qquad (92) \qquad\qquad f(X|\theta) = \frac{X}{\theta^2} * EXP^{-\left(\frac{X^2}{2\theta^2}\right)} \qquad (93)$$

In Equations 92 and 93, $X = H$. Consequently, the relationship obtained between the unknown parameters of the respective forms of the Rayleigh PDF is given by Equation 94.

$$\left(\frac{2}{H_{RMS}^2}\right) = \left(\frac{1}{\theta^2}\right) \dashrightarrow \theta^2 = \left(\frac{H_{RMS}^2}{2}\right) \dashrightarrow \theta = \sqrt{\frac{H_{RMS}^2}{2}} \qquad (94)$$

In Equation 90, $P(H)$, represents the Rayleigh PDF of observed wave height values, where the unknown parameter H_{RMS} is defined by Equation 95.

$$H_{RMS} = \left(\frac{H_{AVERAGE}}{\sqrt{2}}\right) = \left(\frac{\frac{\sum_{i=1}^{n} H}{2}}{\sqrt{2}}\right) \qquad (95)$$

$$\downarrow$$

$$\left(\begin{array}{l} n = Number\ of\ wave\ height\ observations \in dataset. \\ H = Individual\ wave\ height\ value. \end{array}\right)$$

In Equation 91, *EXPECTED P(H)*, also represents the Rayleigh PDF of observed wave height values. In this case, however, a Maximum Likelihood Estimator (MLE) is applied for the unknown parameter θ, where θ takes on the form shown in Equation 94.

Using the definitions on the preceding page, the Chi-Square Goodness of Fit Test employed within the SEA_STATE_CALC program determines whether or not the data set at hand supports computation of the parameters H_{RMS} and $\hat{\theta}$ such that the resulting distributions of *P(H)* and *EXPECTED P(H)* are indeed Rayleigh. Consequently, the null (H_0) and alternative (H_A) hypotheses used within this test are defined as follows:

H_0 : The distributions of *P(H)* and *EXPECTED P(H)* are both Rayleigh.
H_A : The distributions of *P(H)* and *EXPECTED P(H)* are not both Rayleigh.

b. The Use of an MLE

Because the Chi-Square Goodness of Fit Test demands an estimation of the unknown parameter(s) of the function being modeled, the maximum likelihood technique is employed in order to determine the MLE of the unknown parameter θ. This method was selected, not only due to the high regard for the accuracy of its results relative to other techniques, but also, because the concept of maximizing the likelihood of a quantity or occurrence is inherently consistent with the effects of employing a Rayleigh distribution in modeling NSSWHs. The derivation of the formula for estimating the parameter θ, via the MLE method, is presented as follows:

$$LIKELIHOOD(\theta) = \prod_{1}^{N} \left(\frac{X_i}{\theta^2} * EXP^{-\frac{X_i^2}{2\theta^2}} \right) = \left[\frac{(\pi X_i)}{\theta^{2n}} * EXP^{-\frac{X_i^2}{2\theta^2}} \right] \qquad (96)$$

$$L(\theta) = LOG(LIKELIHOOD(\theta)) = \left\{ \left[LOG(\pi X_i)\right] - \left[2n * LOG(\theta)\right] - \left[\sum_{i=1}^{n} \left(\frac{X_i^2}{2\theta^2} \right) \right] \right\} \qquad (97)$$

$$\frac{dL}{d\theta} = -\left(\frac{2n}{\theta}\right) + \left(\frac{\sum_{i=1}^{n} X_i^2}{\theta^3}\right) = 0 \dashrightarrow \left(\frac{2n}{\hat{\theta}}\right) = \left(\frac{\sum_{i=1}^{n} X_i^2}{\hat{\theta}^3}\right) \tag{98}$$

$$\hat{\theta}^2 = \left[\left(\frac{1}{2n}\right) * \sum_{i=1}^{n} X_i^2\right] \dashrightarrow \hat{\theta} = \sqrt{\left(\frac{1}{2n}\right) * \sum_{i=1}^{n} X_i^2}. \tag{99}$$

Once the parameter, $MLE\ \theta = \hat{\theta}$, has been uniquely calculated for the data set at hand via the method discussed above, both the Rayleigh probability, $P(H)$, and the expected Rayleigh probability, $EXPECTED\ P(H)$, can be calculated via their respective parameters, H_{RMS} and $MLE\ \theta$, for each value within the data set at hand. Any Chi-Square Goodness of Fit Test, however, is based upon the number of observations which occur in a predetermined quantity and segmentation of cells. For the Chi-Square Goodness of Fit Test conducted within the SEA_STATE_CALC program, cells are segmented into 0.1 ft. increments of observed wave heights. The number of cells created is equal to the number of unique 0.1 ft. wave height increments contained within the data set. Any Chi-Square Goodness of Fit Test also requires the provision of an observed quantity designated as O_i, and an expected quantity designated as E_i, for each cell i. In accordance with the summation shown in Equation 100, a Chi-Square Statistic is then computed from the tabulated data across all n cells.

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \tag{100}$$

Within the Chi-Square Goodness of Fit Test of the SEA_STATE_CALC program, the observed values, O_i, represent the results obtained from the Rayleigh PDF, $P(H)$, while the expected values, E_i, correspond to the results obtained from the expected Rayleigh PDF, *EXPECTED P(H)*, for each 0.1 ft. wave height cell.

The Chi-Square Statistic, X^2, is a random variable due to its dependency upon the sample data set at hand. It is this randomness, however, which forms the basis for the methodology of any fully computer-aided Chi-Square Goodness of Fit Test such as that performed within the SEA_STATE_CALC program. Once the Chi-Square Statistic is obtained (via computer or otherwise), the Chi-Square Goodness of Fit Test can be completed manually by comparing the Chi-Square Statistic with the Chi-Square distribution value, $X^2_{(df,\, p)}$, where df and p represent the degrees of freedom and the desired percent confidence respectively. The Chi-Square distribution value can be extracted from Chi-Square tables using the appropriate degrees of freedom and percent confidence. For a Chi-Square distribution, the degrees of freedom are computed in accordance with Equation 101.

$$df = Number\ of\ Cells - Number\ of\ Independent\ Parameters\ Fitted - 1. \qquad (101)$$

Under this procedure, a good fit (namely, one which confirms H_0) occurs when $X^2_{(df,\, p)} > X^2$. For a fully computer-aided Chi-Square Goodness of Fit Test such as the Excel 5.0 CHITEST function, however, the methodology is somewhat different. Here, CHITEST returns the probability that a random occurrence, x^2, of the Chi-Square Statistic, X^2, exceeds the value of X^2 obtained from the data set at hand. This probability, p^*, is defined as a measure of evidence against the modeled fit and is characterized by Equation 102.

$$p^* = PROBABILITY\left[x^2 > X^2 | FITTED\ MODEL\ IS\ CORRECT\right] \qquad (102)$$

In the context of a Chi-Square Goodness of Fit Test (as opposed to other forms of hypothesis testing in which the following may not be true), a p^* value which numerically approaches one is indicative of a good fit (thereby, confirmation of H_0). This concept is more easily understood by the realization that a large p^* value is produced from a small X^2 value which increases the probability that $X^2_{(df,\ p)} > X^2$ for the appropriate degrees of freedom and percent confidence. For the Chi-Square Goodness of Fit Test performed within the SEA_STATE_CALC program, a p^* value approaching one would indicate insignificance in the data used to compute the parameters of the equivalent forms of the Rayleigh PDF shown in Equations 92 and 93, thereby suggesting a good fit.

The precision associated with results obtained from the Chi-Squared Goodness of Fit Test eliminates subjectivity in assessing the extent to which the wave height observations of the data set at hand are modeled by a Rayleigh distribution. Unlike the preceding two methods of input file validation, however, the Chi-Square Goodness of Fit Test offers no insight regarding the degree to which Rayleigh PDF excerpt, obtained from the unique data file used, approximates the theoretical Rayleigh PDF for the geographic region in question. For the OV93 scenario used as the data source for the JOTE model validation presented within this thesis, the results of the three forms of data file quality assessment contained within the SEA_STATE_CALC program are presented below. Two of these three techniques have been indirectly utilized in previous sections since the characteristics of Technique A were employed as a means of introducing the results obtained from the SEA_STATE_CALC program, and the concept involved in Technique B was a primary means of determining that the best approximation of the theoretical H_{RMS} for the Fort Story, VA area was $H_{RMS} = \left(\frac{H_{PEAK}}{\sqrt{2}} \right)$ using the OV93 data.

Technique A

A comparison of the quantities $1 - F(a)$ and $F(b) - F(a)$ is illustrated by Figure 18 and Table 13, which are both excerpts of the SEA_STATE_CALC program. In each of these visual aids, $A = 0.5657$ and $B = 1.4142$. Several crucial pieces of information can be extracted from the results shown in these excerpts. First and foremost, for the time period covered by the OV93 NSSWH data set, 59.08% of all observations equaled or exceeded Sea State Two conditions. Secondly, because the quantities $1 - F(a)$ and $F(b) - F(a)$ differ by 13.5335% (an appreciable amount), the excerpt Rayleigh PDF shown above is moderate at best in its representation of the theoretical Rayleigh PDF for the Fort Story, VA area. The Chi-Square Goodness of Fit Test (Technique C) will reveal a p^* value equal to one, thereby suggesting that the NSSWH observations taken during OV93 do follow a Rayleigh distribution. Consequently, the discrepancy between the quantities $1 - F(a)$ and $F(b) - F(a)$ is caused only by the lack of NSSWH observations within the left and right tail regions of the Rayleigh PDF obtained from the OV93 NSSWH data set, and is not caused by any shape difference(s) between the theoretical Rayleigh PDF and the excerpt of that PDF shown above. Based upon this clarification, the primary attribute of Technique A is to provide the user with the most accurate computation of the observed percentage of NSSWHs which equal or exceed Sea State Two.

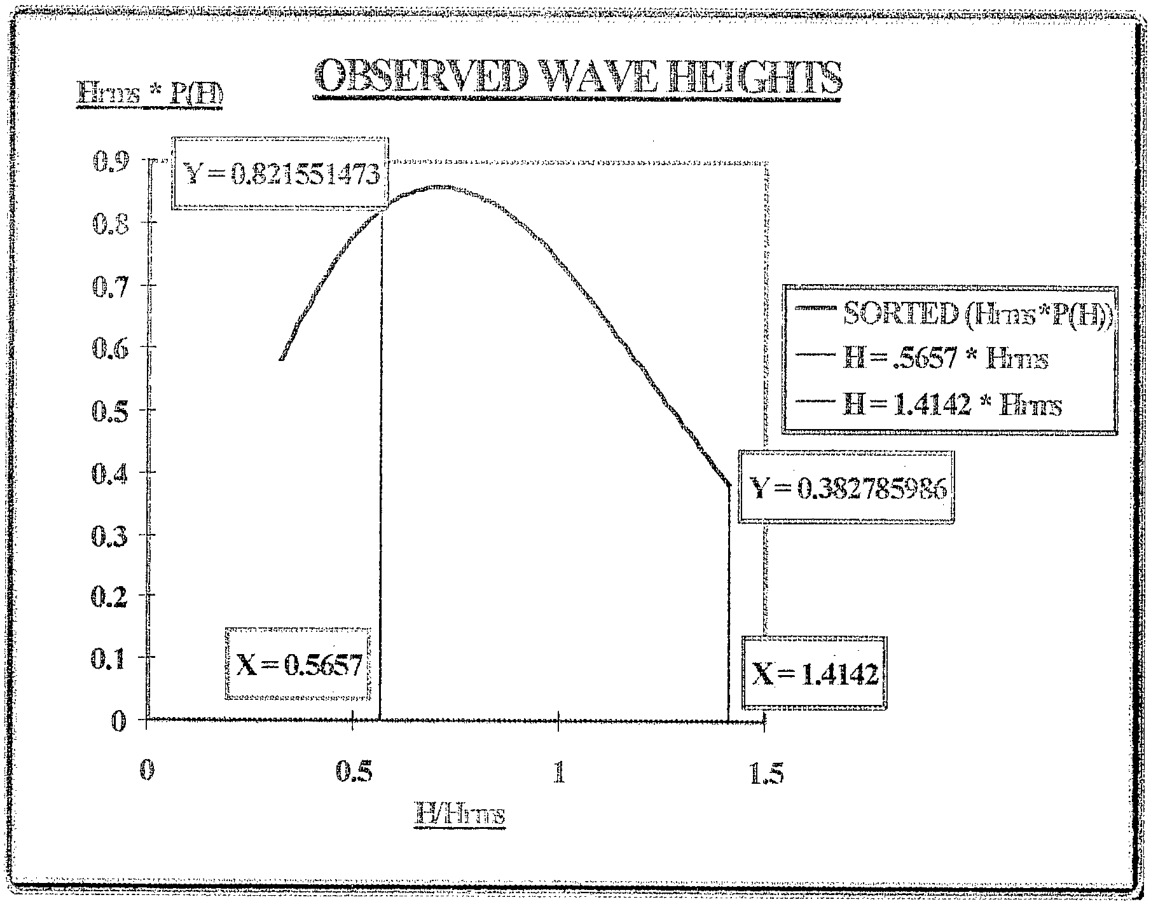

Figure 18. Rayleigh Distribution of Observed Wave Heights During OV93
a = 0.5657, b = 1.4142.

DESIRED PARAMETER	PROBABILITY EXPRESSION	RESULT
Theoretical Percentage of Time ≥ Sea State Two	1 - F(a)	72.6149
Actual Percentage of Time ≥ Max "X" Value	1 - F(b)	13.5335
Observed Percentage of Time ≥ Sea State Two	F(b) - F(a)	59.0814

Table 13. SEA_STATE_CALC Results for OV93 Wave Height Data Set.

Technique B

This technique verifies that the X-coordinate of the apex of the Rayleigh PDF obtained from the input data set of NSSWH observations is numerically approximates the mode of that data set. Figure 19 and the subsequent calculations verify this occurrence for the OV93 data set.

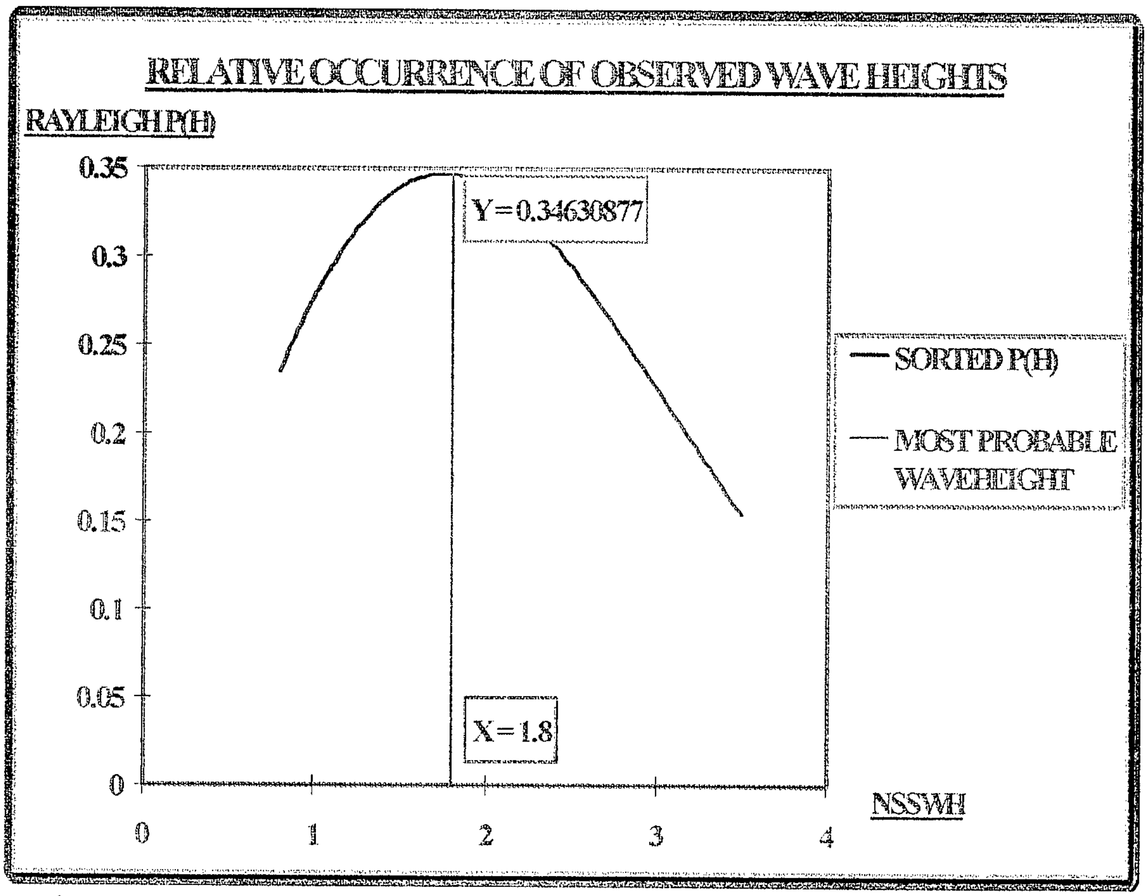

Figure 19. Rayleigh Distribution of Relative Occurrence of Observed Wave Heights During OV93.

The mode of the OV93 data set of NSSWHs occurs at $H = 1.8$ *ft*. In keeping with the requirements of a theoretical Rayleigh PDF of NSSWHs, the excerpt of the theoretical Rayleigh PDF, shown in Figure 18, does fulfill the requirement that the most common wave height must occur at $H = 0.7071 H_{RMS}$. For the OV93 data set where $H_{RMS} = 2.4748\ ft.$, the most common NSSWH, computed from this formula, occurs at $H = 1.7499\ ft.$ Additionally, Figure 19 whose X and Y axes correspond to OV93 NSSWH observations and Rayleigh PDF values respectively, confirms that the highest value on the PDF curve is $P(H) = 0.34630$ which occurs at $H = 1.8\ ft.$ This X-axis value is computed via Equation 103 which is a manipulation of the Rayleigh probability function given in Equation 90.

$$H = \left\{ \frac{\left[P(H) * H_{RMS}^2\right]}{\left[2 * EXP^{-\left(\frac{H}{H_{RMS}}\right)^2}\right]} \right\} \tag{103}$$

$$WHERE:\quad P(H) = 0.34630 \qquad H_{RMS} = 2.4748 \qquad \left(\frac{H}{H_{RMS}}\right) = 0.7273$$

<u>Technique C</u>

Unlike Techniques A and B, The Chi-Square Goodness of Fit Test which comprises Technique C offers no assistance in assessing the quality with which the input data file represents the theoretical Rayleigh PDF for the geographic location at hand. Instead, it focuses upon satisfying the first requirement of input file validation, namely, quantifying the degree to which the wave height observations contained in that input file are approximated by a Rayleigh distribution. This technique employs no plots to be reviewed, but rather performs all the calculations discussed within this section internally and returns a single test value in the form of Table 14.

FIT TEST TO BE PERFORMED	RESULT
CHITEST Result (p^* value)	1

Table 14. SEA_STATE_CALC Generated CHITEST result (p^* Value).

For the OV93 data set, the p^* value equal to one solidifies the affirmation that, despite the nonexistence of both of its tails due to limited period of record for the observations, the OV93 wave height data values are Rayleigh distributed.

4. Employing the Results of SEA_STATE_CALC in JOTE Validation

Despite the proficiency with which the SEA_STATE_CALC program assesses the quality of an input data file, this attribute is not the primary objective of the program. Instead, this characteristic serves to add credence to the main objective of the program which is to calculate the percentage time sea state conditions equal or exceed Sea State Two in a given geographic location. Upon obtaining this percentage, both the general validity of JOTE and its value to the JLOTS commander as a planning tool are immediately and exponentially increased.

For purposes of the JOTE model validation presented within this thesis, the SEA_STATE_CALC program provided the JOTE spreadsheet cell O-38 entry for two of the four scenarios presented in Appendix D. These two percentages were directly extracted from Table 13. Specifically, the values $1 - F(a) = 72.6149\%$ and

$F(b) - F(a) = 59.0814\%$ were used for two independent JOTE scenarios. Percentages of 40% and 60% respectively, obtained from Table 3, were used for the remaining two scenarios.

In conducting these four executions of JOTE, the objective was two-fold. First and foremost, the goal was to confirm that JOTE results could be more accurate if site-specific sea state data was adequately processed and utilized as the input to JOTE rather than mere extraction of sea state percentages from Table 3. Secondly, a relative comparison of the JOTE results for spreadsheet cell O-38 entries corresponding to the values $1 - F(a)$ and $F(b) - F(a)$ was necessary in order to provide the user with the best recommendation of spreadsheet cell O-38 input.

The actual time line of throughput operations during OV93 is depicted on Table 15. The individual commencement and completion times for discharge operations on each of the four vessels, as shown in this table, will form the baseline against which the results of the following scenarios will be evaluated.

The first scenario depicted in Appendix D corresponds to a spreadsheet cell O-38 entry of 40%. As explained in Subsection 2 of Section 3 of this chapter, this value was used since it was the value extracted from Table 3 representing the percentage of time sea state conditions equal or exceed Sea State Three, which was the way LMI originally defined the spreadsheet cell O-38 entry. Realizing this definition of cell O-38 was incorrect and redefining it accordingly, this first scenario was modeled using the original 40% value with the expectation that the results obtained would not be appropriately accurate. As Appendix D reveals, this expectation was confirmed. The value of 40%

underestimated the actual time percentage in which sea state conditions equaled or exceeded Sea State Two, which was the way spreadsheet cell O-38 was redefined. Consequently, under this scenario, throughput operations experienced overproductivity in the form of early completion of some intermediate events and thereby several days of idle operations.

Under the 40% scenario, JOTE throughput calculations were, as expected, uninhibited by sea state conditions, thereby rendering the entire cargo capacities of each discharge lane originating from SS CORPUS CHRISTI, FSS BELLATRIX, and FSS REGULUS completely exhausted by 16 July, two days prior to the arrival of SEABEE CAPE MOHICAN. Thus, 17 July saw no throughput requirements or operations under this scenario. One could potentially claim that two possible explanations exist for this phenomenon. First, one could speculate that the degradation functions built into JOTE are incorrect. More careful analysis, however, reveals that this is not the case. By modeling four different sea state condition percentages, all under the same series of input parameters, one can clearly see the manner in which throughput times increase and throughput efficiency decreases as sea state conditions are degraded. Therefore, the obvious cause for the discrepancy between actual and calculated throughput performance(s) is primarily due to utilizing an incorrect prediction of sea state conditions. This realization, supported by the results of Appendix D, provides the utmost justification for the development and use of the SEA_STATE_CALC program as a supplement to JOTE. Table 16 summarizes the start and completion times for off-load of each vessel used in OV93 under the cell O-38 equal 40% scenario.

Throughput Operations By Day	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
7 July 1993	Commence 3 LO/LO Lanes		Commence 2 RRDF Wheeled 2 LO/RO Lanes	
8 July 1993	Off-load		Off-load	
9 July 1993	Off-load		Off-load	Commence 1 LO/RO Lane
10 July 1993	Off-load		Cease Operations	Commence 1 RRDF Tracked Lane
11 July 1993	Off-load			Commence 1 RRDF Tracked Lane
12 July 1993	Off-load			Off-load
13 July 1993	Off-load			Cease Operations
14 July 1993	Off-load			
15 July 1993	Off-load			
16 July 1993	Off-load			
17 July 1993	Off-load			
18 July 1993	Cease Operations	Commence 3 LO/LO Lanes		
19 July 1993		Cease Operations		

Table 15. Actual Time-line for Cargo Off-load Operations During OV93.

The second OV93 scenario modeled with JOTE and contained in Appendix D is contingent upon 59.08% of all sea state conditions equaling or exceeding Sea State Two (revised cell O-38 entry). This value was directly extracted from the output of the SEA_STATE_CALC program and represents the $F(b) - F(a)$ value under the Rayleigh PDF excerpt corresponding to unique input data file used. As shown in Appendix D, the results obtained for this scenario are extremely consistent with the actual throughput productivity levels observed during OV93. This accuracy occurs not only because 59.08% is a much more accurate estimation of the actual percentage of sea state observations which equal or exceed Sea State Two in the Fort Story, VA area than is 40%, but also because the time period in which the evolution was conducted is exactly the same time period covered by the input data set of NSSWH observations. This fact is extremely significant because it decisively answers a question presented earlier in this chapter; namely, which output of the SEA_STATE_CALC program $1 - F(a)$ or $F(b) - F(a)$ is the most accurate assessment of sea state conditions for a given area for the user to employ?

This answer now becomes very clear. If the CHITEST result returned by the SEA_STATE_CALC program is numerically equal to one, or extremely close thereto, the Rayleigh PDF obtained from the respective input file approximates the theoretical Rayleigh PDF exceptionally well, and the value $1 - F(a)$ should be used as the spreadsheet cell O-38 entry in the JOTE program. In the unique case, however, where the CHITEST result is numerically equal to one and the evolution being planned is to be conducted in the same calendar period as that covered by the data file, the value

Throughput Operations By Day	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
7 July 1993	Commence 3 LO/LO Lanes		Commence 2 RRDF Wheeled 2 LO/RO Lanes	
8 July 1993	Off-load		Off-load	
9 July 1993	Off-load		Off-load	Commence 1 LO/RO Lane
10 July 1993	Cease Operations		Off-load	Commence 1 RRDF Tracked Lane
11 July 1993			Cease Operations	Commence 1 RRDF Tracked Lane
12 July 1993				Off-load
13 July 1993				Off-load
14 July 1993				Off-load
15 July 1993				Off-load
16 July 1993				Cease Operations
17 July 1993				
18 July 1993		Commence 3 LO/LO Lanes		
19 July 1993		Cease Operations		

Table 16. Cargo Off-load Synopsis with JOTE Spreadsheet Cell O-38 = 40%.

$F(b) - F(a)$ could potentially be a more appropriate cell O-38 entry in the JOTE program. Obviously, the user will never be faced with the luxury offered within this validation, whereby, the data file corresponds exactly to the period covered by the operation since his/her objective will always be to model an upcoming scenario by using historical sea state data. A situation which is very possible, if not probable, however, is one in which the user is planning an evolution which is to occur in a very specific time period (month) and possesses a data file of historical sea state observation corresponding to that exact time period (month). If the historical period of record is sufficiently long, the CHITEST result may still approach one. In this case, the user should model his/her evolution with two unique JOTE executions, the first using the value $F(b) - F(a)$ as the spreadsheet cell O-38 entry, and the second using the value $1 - F(a)$ for this entry. In the context of this example, the value $1 - F(a)$ would represent a worst case scenario.

In modeling the OV93 scenario with JOTE, using a spreadsheet cell O-38 entry of 59.08% yields the throughput summarization described by Table 17. This summarization most accurately parallels the actual throughput operations illustrated by Table 15 because off-load operations on all four vessels start and finish between the calendar days of 7-19 July 1993, no single day contains nonexistent throughput, and the strongest relationships exist between actual and modeled off-load times of individual commodities of cargo, specifically, containers and vehicles.

In comparing the actual OV93 operations to those modeled using JOTE, no further similarities can, or should, be expected between any of the four output scenarios and the actual off-load times of each individual vessel. Numerous work stoppages due to equipment malfunction(s) and poor planning during OV93 resulted in increased time needed to off-load several sealift assets. JOTE, however, does not incorporate these shortfalls. Instead, it merely assumes a 20 hr. JLOTS workday with linear efficiency across the workday as determined by the user-provided sea state conditions. JOTE also encompasses no means of accounting for off-load operations which commence at some point during the course of a day. A vessel is either considered present and ready for a 20 hr. off-load period at the start of a given day, or not present until the following day. These factors combine to create JOTE's tendency to slightly overestimate throughput capability for LO/LO operations, despite even the most accurate sea state modeling.

As an example of this tendency, Table 18 clarifies the numerous throughput stoppages which occurred during off-load of the SS CORPUS CHRISTI during OV93. As Table 15 illustrated, these operations spanned the entire period of 7-17 July 1993, a total of 264 hrs. A summation of all the shortages of Table 18 (121.8667 hrs.), however, reveals that the actual off-load of SS CORPUS CHRISTI consumed only 142.1333 hrs. (5.922 days). With spreadsheet cell O-38 equal to 59.08%, JOTE estimates the off-load of SS CORPUS CHRISTI will consume five days. This estimation is 15.57% faster than actual capabilities during OV93.

The accuracy of the value 59.08% as a percentage of time sea state conditions equaled or exceeded Sea State Two during OV93, the criticality of the precision of this value to the proper operation of JOTE, and potential shortfalls in the planning factors upon which JOTE is constructed are further confirmed by the following analysis of RO/RO discharge operations. As Table 15 illustrates, the actual discharge times for FSS

Throughput Operations By Day	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
7 July 1993	Commence 3 LO/LO Lanes		Commence 2 RRDF Wheeled 2 LO/RO Lanes	
8 July 1993	Off-load		Off-load	
9 July 1993	Off-load		Off-load	Commence 1 LO/RO Lane
10 July 1993	Off-load		Off-load	Commence 1 RRDF Tracked Lane
11 July 1993	Cease Operations		Off-load	Commence 1 RRDF Tracked Lane
12 July 1993			Off-load	Off-load
13 July 1993			Cease Operations	Off-load
14 July 1993				Off-load
15 July 1993				Off-load
16 July 1993				Off-load
17 July 1993				Off-load
18 July 1993		Commence 3 LO/LO Lanes		Cease Operations
19 July 1993		Cease Operations		

Table 17. Cargo Off-load Synopsis with JOTE Spreadsheet Cell O-38 = 59.08%.

Date	Time	Event
30 June	1045	CORPUS CHRISTI Arrives
	1824	SELF DISCHARGE STARTS
03 July	0125	Collision of Cranes #1B & 2A
05 July	0742 - 0842	CORPUS CHRISTI#1 Moors S/S2
06 July	0710	Cranes # 1B & 2A static load test
	1758	THROUGHPUT STARTS S/S 2
	1845 - 1925	#2A Birdnested (tangled wires)
	1920 - 2100	Wrecker wedged in Sea Shed
	2342 - 2400	Shutdown due to swell-induced roll S/S 2
07 July	0000 - 0430	Shutdown due to swell-induced roll S/S 2 decreasing to 1
	0435 - 0800	Shutdown #3 for electrical problem
	0610 - 0635	#3B Birdnested
	0830 - 0855	#2 Birdnested
	0858 - 0906	#1 Crane lost power
	0912 - 1055	Shutdown #3 due to utility launch alongside
	1020 - 1145	Cranes #'s 1 & 2 Shutdown due to roll S/S 2
	1145 - 1509	All Operations shutdown due to roll S/S 2
	1600 - 1615	#3B Shutdown spreader changed
	1750 - 1808	#3B Shutdown repair spreader
	2245 - 2400	Shutdown due to roll S/S 2
08 July	0000 - 0045	Shutdown due to roll S/S 2
	0435 - 0800	Electrical malfunction crane #3B
	0650 - 0800	#1B Birdnested
	0715 - 0805	Crane #1A slewing malfunction
	1322 - 1330	Reconfigure spreader bar for ops.
	1635 - 1710	Shutdown due to weather alert
	2245- 2400	#3 Shutdown due to roll
09 July	0000 - 0100	#3 Shutdown due to roll S/S 2
	0210 - 0440	No mooring at Pedestal #1 LCU-2001 at #2
	0305 - 0340	#2A RBTS winch malfunction
	0850 - 0930	#2A Birdnested
	2130 - 2155	#2B Birdnested
09 July	2300 - 2325	Sling dropped between container stacks
10 July	0300 - 0500	Loading stopped due to repositioning cargo on LSV
	1128 - 1145	RBTS wire jumped sheave, #1B
	1445 - 1910	Fender problems, used crane
11 July	0830 - 1035	Warping vessels S/S 2
	0940 - 1100	No lighters alongside
	1100 - 1110	#2B Birdnested
	1252 - 1258	#2B Birdnested
	1657 - 1930	Shutdown due to thunderstorms
12 July	2000 - 2010	Shutdown due to electrical problem in #1 crane controls
13 July	0425 - 0820	Shutdown due to roll S/S 2
	1041- 1241	Shutdown due to roll S/S 2
	1300	Shut down all operations
	1845	CORPUS CHRISTI #1 Breakaway S/S 3
14 July	0000 - 2400	Operations remain shut down S/S 3 decreasing to 2
15 July	1100 - 1518	T-ACS discharges 8 containers S/S 2
	1340 - 1453	Fire / Boat drill on the T-ACS
	1725 - 1820	CORPUS CHRISTI #2 Moors S/S 3
	1518 - 2400	No Cargo Ops S/S 3 decrease to 2
16 July	0000 - 1000	No Cargo Ops S/S 2 decrease to 1
	0800 - 0900	Warping vessels S/S 1
	0945 - 1000	Fire drill
	1000	CORPUS CHRISTI #2 Discharge Operations Resume S/S 1
	1345 - 1402	#1 Birdnested
17 July	1800	CORPUS CHRISTI #2 Departs S/S 2
	2100	CAPE MOHICAN Moors S/S 2
	2130	Start Cargo Operations
18 July	2025 (17th) 0200 (18th)	NAVCHAPGRU to MPS ship BOBO. Pedestal #3 unmanned
	0945 - 2330	#2B slip-ring burned out
	2228	THROUGHPUT ENDS
19 July	0742	CAPE MOHICAN Departs

* S/S denotes Sea State

Table 18. Chronology of T-ACS Operations During OV93, From Ref. [20].

BELLATRIX and FSS REGULUS were four and five days respectively. In JOTE execution with cell O-38 equal to 59.08%, these discharge times were seven and ten days respectively. This essentially linear increase is caused by two distinct factors. First, the inability of JOTE to accept multiple ship to shore transit distances forced the conservative estimate that both container and vehicle carrying vessels were positioned 4.7 nm off-shore. In actuality, both FSS BELLATRIX and FSS REGULUS were positioned only 3.5 nm off-shore. Second, conservative conversions of lighterage capabilities were made between those types of lighterage used during OV93 and those acceptable by JOTE. As presented earlier in this chapter, these conversions were required for LARC-LXs to LCM-8s, LACV-30s to LCACs, and DWMCFs to ACBLs. This two-fold conservatism resulted in JOTE returning total off-load times 75% and 100% in excess of those actually observed for FSS BELLATRIX and FSS REGULUS respectively.

Mathematically, the imposition of a 4.7 nm ship-to-shore transit distance for all sealift assets resulted in a 34.23% increase in total transit distance for all lighterage traveling to and from RO/RO capable platforms. Additionally, the following conservative lighterage estimates collectively resulted in a 38.43% degradation in the total cargo carrying capacity for lighterage:

$$2.5846\ LCM\text{-}8s \approx 2\ LCM\text{-}8s$$
$$3.4499\ LCACs \approx 3\ LCACs$$
$$1.025\ ACBLs \approx 1\ ACBL.$$

Therefore, regarding vehicle discharge operations, the JOTE modeled operation was essentially 72.72% more restrictive than the actual OV93 vehicle off-load operation. With this in mind, the 75% time increase in off-loading wheeled vehicles from FSS

BELLATRIX returned from the JOTE model is understandable. The 100% time increase in off-loading tracked vehicles from FSS REGULUS returned by JOTE, however, raises justifiable suspicion. In the same manner in which JOTE overestimated throughput capability for LO/LO operations by 15.57%, the current planning factors regarding tracked vehicle discharge rates upon which the linear program is constructed appear to be slightly in error. The result of this error is a 27.28% underestimation of throughput capability for tracked vehicle off-load. In reality, tracked vehicle off-load is the fastest type of cargo discharge within a JLOTS operation. It is faster than standard vehicle off-load due to the normally high quantity of towed vehicles inherent in this type of discharge. Positioning, hookup, and breakdown times are all characteristics of towed vehicle off-load which drastically slow this discharge relative to the rate of off-load of tracked vehicles.

Admittedly, the results obtained, and the conclusions drawn from those results, for this JOTE scenario are highly dependent upon the accuracy of the value placed in spreadsheet cell O-38. Despite the multitude of quality assessments of this value inherent within the SEA_STATE_CALC program and presented in the preceding section, it must also be noted that for no other cell O-38 entry do the results obtained from JOTE more closely resemble the actual throughput operation of OV 93 than for the entry 59.08%. This is indeed the value which produces results that most closely approximate the following:

1. Overall start and finish date of the OV93 throughput operations.
2. Start and finish dates of throughput operations for each cargo commodity (containers and vehicles)
3. The elimination of days of nonexistent throughput operations.

4. The minimization of the percentage by which JOTE overestimates LO/LO throughput productivity.
5. The minimization of the percentage by which JOTE underestimates the throughput productivity of tracked vehicle off-load via RRDF.

To substantiate both this contention and other non-related affirmations, two additional JOTE scenarios were modeled, each with spreadsheet cell O-38 entries in excess of 59.08%.

The third JOTE output scenario presented in Appendix D corresponds to a spreadsheet cell O-38 entry of 60%. This scenario was modeled for two reasons. First, despite the minimal numerical difference between this value and the 59.08% entry of the previous scenario, the difference is sufficient to illustrate the benefits of using the 59.08% entry extracted from the SEA_STATE_CALC program discussed on the preceding page. Second, 60% represents the sum of columns two and three in the CINC 1 row of Table 3. As explained in previous sections, LMI originally designed JOTE such that the cell O-38 entry represented the percentage of time sea state conditions strictly exceeded Sea State Two. Because Table 3 represented their only sea state data base, normal procedure for modeling via JOTE was to simply extract the column three value from Table 3 corresponding to the desired CINC region. Once cell O-38 was properly redefined as a loose inequality, if Table 3 is to be used, the summation of columns two and three is necessary for each row. Without question, the better approach would be to disregard Table 3 completely since it possesses no site specificity. Chapter IV will clarify the various means by which the data file necessary to operate the

SEA_STATE_CALC program can be obtained, thereby correctly eliminating Table 3 and providing the user with a more helpful planning tool.

Obviously, the results obtained from the cell O-38 equal 60% scenario should, and do, closely resemble those obtained from the 59.08% scenario. The results of the 60% scenario are illustrated in Table 19. The close proximity of these percentages, however, does reveal several trends and potential shortfalls regarding the manner in which JOTE executes its underlying linear program. Additionally, the comparison of these nearly identical scenarios provides firm confirmation of the value 59.08% as the most accurate assessment of the percentage of time sea state conditions equal or exceed Sea State Two in the waters surrounding Fort Story, VA, for the time period spanned by OV93. Under the cell O-38 equal 60% scenario, throughput operations on the final day of OV93 (19 July 1993) are conducted on discharge lanes from two vessels: three LO/LO lanes originating from the SEABEE CAPE MOHICAN and one LO/RO lane originating from the FSS REGULUS. Using all cell O-38 entries less than 60%, the events of the simulated last day of OV93 model the actual throughput operations of 19 July 1993 with complete precision. Specifically, cargo discharge on all vessels except SEABEE CAPE MOHICAN is completed prior to the simulated day of 19 July 1993, as was the situation during OV93. The inability of the 60% scenario to accurately model the reality of this particular day can be attributed to no explanation other than the inaccuracy of the spreadsheet cell O-38 value. Any discrepancies between actual and modeled operations observed in the previous two scenarios could be attributed to such criteria as the inabilities of JOTE to process certain forms of lighterage and allow for multiple ship-to-shore transit distances. Because it is known with complete certainty that SEABEE CAPE MOHICAN was the only OV93 vessel to conduct cargo off-load on 19 July 1993 and all input parameters are identical for this scenario as for the previous two, the extended time needed to complete cargo discharge on lane 13 can be attributed only to an improper cell O-38 entry.

Not only does the cell O-38 equal 60% scenario confirm the validity of the sea state predictions obtained from the SEA_STATE_CALC program, it also clarifies the following methodological characteristics and/or shortfalls of JOTE. Concurrent analysis of the results obtained (by day) for the 59.08% and 60% scenarios reveals that planning factors have been incorporated into JOTE such that a hierarchy of lighterage is created for each type of cargo. For example, in these as well as the other two scenarios presented, JOTE assigns CSP+3s for LO/LO operations and ACBLs for LO/RO operations before assigning any other form of lighterage for these respective types of cargo off-load. Additionally, for multiple LO/LO lanes each possessing identical quantities of cargo to be moved, JOTE applies a consistent quantity to be moved on each lane every day until the capacity is expended despite the presence of discharge on other lanes. For LO/RO lanes, the ACBL is always assigned to the lane possessing the highest capacity to be moved. In all scenarios, the lighterage platforms of choice for off-load of wheeled and tracked vehicles after all available ACBLs have been assigned are LSV and the LCU-2000, in that order. This prioritization on both LO/LO and LO/RO discharge is very consistent with the present feelings of JLOTS operational personnel regarding the capabilities of CSP+3s, ACBLs, and LSVs.

Throughput Operations By Day	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
7 July 1993	Commence 3 LO/LO Lanes		Commence 2 RRDF Wheeled 2 LO/RO Lanes	
8 July 1993	Off-load		Off-load	
9 July 1993	Off-load		Off-load	Commence 1 LO/RO Lane
10 July 1993	Off-load		Off-load	Commence 1 RRDF Tracked Lane
11 July 1993	Cease Operations		Off-load	Commence 1 RRDF Tracked Lane
12 July 1993			Off-load	Off-load
13 July 1993			Cease Operations	Off-load
14 July 1993				Off-load
15 July 1993				Off-load
16 July 1993				Off-load
17 July 1993				Off-load
18 July 1993		Commence 3 LO/LO Lanes		Off-load
19 July 1993		Cease Operations		Cease Operations

Table 19. Cargo Off-load Synopsis with JOTE Spreadsheet Cell O-38 = 60%.

Of great significance, however, is the drastic unemployment of LCM-8s, LCU-1600s, and LCACs throughout the four scenarios examined. For these three forms of lighterage, the only recorded usage is for the LCU-1600 on 10 July 1993 under the cell O-38 equal 40% scenario. Initially, one may suspect a potential cause for this unemployment is the relative ineffectiveness of smaller lighterage platforms such as LCM-8s, or even the larger LCU-1600s, in increasingly high sea state conditions. With further insight, however, it is clear that LCACs are almost completely uninhibited by sea state conditions during either their transit or loadout phase due to the use of air cushion vehicle landing platforms (ACVLAP). Despite this flexibility, LCACs have been curiously avoided by JOTE in all four scenarios.

Another reason for the lack of employment is the manner in which JOTE degrades throughput based upon sea state conditions. JOTE utilizes the cell O-38 entry in order to determine the number of operating hours available (out of an assumed 20 hour JLOTS workday) on each discharge lane. This number is then expressed in the column entitled "Hours Left With Sea State," which is column 13 on the lower table for each day of each scenario in Appendix D. By JOTE's calculations, on every day of each scenario considered, the number of available operating hours on each discharge lane, after sea state conditions were considered, was consumed completely by the largest capacity lighterage. In theory, this practice is somewhat understandable since the cast-off and clearing times associated with smaller lighterage inefficiently consume operating time which could be used by large capacity lighterage. Essentially, JOTE consumes the available operating time on each discharge lane with the form of lighterage from which the largest net throughput gain can be obtained. Unfortunately, however, for each of the four scenarios considered, JOTE does not appear to be consuming any of the small time periods remaining on each lane, after or between the employment of a large lighter, with the complete loadout of any smaller lighter or even the partial loadout of another large lighter. Admittedly, partial loading of lighters is inefficient and therefore, in most cases, should be avoided by an analytical model. In situations where a specific period of available operating time does not facilitate the full loadout of a large capacity lighter, however, it is equally inefficient to allow this time to be wasted.

As two of many examples, in the cell O-38 equal 59.08% and 60% scenarios, 9 July represents a day in which discharge on lanes seven through ten was conducted by LSV, with one LSV transit per lane. There were, however, only two available LSVs throughout the entire operation. Consequently, while each LSV conducted discharge operations on any two of these lanes, JOTE should have assigned another form of lighterage to conduct discharge operations on the two lanes to which the LSVs were not presently assigned. Moreover, the tabulated results confirm that, for those discharge lanes to which it was assigned, the LSV consumed the entire available operating time. Because all vessels are assumed to be at the exact same location and subjected equally to the existing sea state conditions, the period of operability is identical on all discharge lanes. Consequently, assigning only LSVs to these discharge lanes and achieving positive throughput on each lane is an impossibility. By not consuming the periods of inoperability between arrivals of large lighters at a given discharge point with off-load to any other platform, JOTE is not maximizing the amount of throughput conducted on each discharge lane, and is therefore not minimizing the shortfall on those lanes as its underlying linear program suggests. No matter how minimal the benefits of eliminating these periods of idle discharge operations on each lane may be, by not eliminating them, the present form of JOTE does not fulfill its true potential as a planning tool for the JLOTS commander. Most importantly, this characteristic of JOTE raises suspicion regarding the extent of the validity of its results for use in JLOTS capability assessments, equipment feasibility studies, etc.

Unfortunately, this is not the only difficulty which is discoverable through analysis of Appendix D. Consistent throughout all four scenarios presented are occurrences of throughput taking place (in terms of stons being moved) on a given day, with no lighterage trips by any form of lighterage being assigned to that particular discharge lane. One of several examples of this shortfall occurs on 10 July of the cell O-38 = 40% scenario. Additionally, there exists numerous examples where the quantity of stons moved on a given discharge lane on a given day is not consistent with the capabilities of the respective lighterage assigned to that lane. Referring again to 8 and 9 July in both the cell O-38 equal 59.08% and 60% scenarios, it is clear that the total capacities moved on discharge lane seven on this day were 600 and 587 respectively. In both cases, one LSV was employed as the single form of lighterage on this lane. For both scenarios, the following day, 9 July, saw the employment of one LSV on discharge lane seven along with several other lighterage assets: 3 LCU-2000s for the 59.08% scenario and 2 LCU-2000s for the 60% scenario. On 9 July, despite the vastly increased lighterage carrying capacities, the quantities moved on lane seven for the 59.08% and 60% scenarios were

565 stons and 557 stons respectively. The gross inefficiency associated with employing increased lighterage capacity for the purpose of transitting less cargo suggests that JOTE does not properly solve the linear program presented to it. The final section of this chapter will summarize the various shortfalls presented throughout this model validation as well as suggest several possible causal factors.

In spite of the insights gained into the operation of JOTE, its demands upon the user, its limitations and shortfalls, and its enhancement as a planning tool by the SEA_STATE_CALC program up to this point, one final output scenario is presented in Appendix D. This scenario corresponds to a spreadsheet cell O-38 entry of 72.62%. This value is also obtained from the SEA_STATE_CALC program and represents the estimation of the theoretical percentage of time sea state conditions equal or exceed Sea State Two obtained from the input data file at hand. Within this scenario, one can observe identical shortfalls as those present in the previous three cases. Therefore, the primary objective for illustrating the daily output of this scenario is to highlight the significantly longer time periods needed not only for the overall completion of the operation, but also for the off-load of individual sealift assets. Table 20 reveals the extended time periods needed to off-load each of the four vessels of OV93 under this scenario.

The problems JOTE has in recording the lighters used for cargo discharge on each lane are evident from the first day of this scenario. Inspection of the tabulated data for 7, 8, and 9 July 1993 of this scenario in Appendix D, reveals that no lighter is assigned to discharge lane nine, yet 369 stons are moved on this lane on each of these three days. An identical situation occurs on discharge lane ten on both 12 and 14 July, and on both lanes seven and eight on 15 July. In addition, throughout the period of 7-23 July, only large capacity lighters are employed. Over the period of 10-12 July, the number of discharge lanes on which cargo is to be moved is greater than in any other period during any of the four scenarios considered. Despite this heavy tasking, only the four largest capacity lighters are employed. On 11 July, 23 lighter transits were used to complete off-load operations on ten discharge lanes. On this day, only lanes seven, 11, and 12 were assigned multiple lighter transits, and of these, only on lane 11 were discharge operations conducted with more than one type of lighter. Each of these characteristics would allow for one lighter to arrive at a discharge location when another departs, thereby maximizing the use of available operating time on each lane. Lanes eight, nine, ten, and 11 are plagued by the same shortfalls here as in previous scenarios. Specifically, two LSVs are used for a total of six transits on four different discharge lanes. With no other lighters employed on any of these lanes, the only possible result is wasted operating time on some or all of the four lanes while awaiting the arrival of one of the LSVs. The employment of smaller forms of lighterage on some or all of these lanes during these idle periods would definitely render some, if not an appreciable amount of, enhanced throughput. The extent to which JOTE appears to favor the larger lighters is further evidenced by the fact that even on lane 11 (the only lane on which multiple types of lighters are employed), only large capacity lighters are selected.

One positive trait inherent within the JOTE calculations which is exhibited in this scenario is the manner in which JOTE utilizes the ACBL. This scenario further highlights the trend established in the three previous scenarios whereby, the ACBL is repeatedly

Throughput Operations By Day	SS CORPUS CHRISTI	SEABEE CAPE MOHICAN	FSS BELLATRIX	FSS REGULUS
7 July 1993	Commence 3 LO/LO Lanes		Commence 2 RRDF Wheeled 2 LO/RO Lanes	
8 July 1993	Off-load		Off-load	
9 July 1993	Off-load		Off-load	Commence 1 LO/RO Lane
10 July 1993	Off-load		Off-load	Commence 1 RRDF Tracked Lane
11 July 1993	Off-load		Off-load	Commence 1 RRDF Tracked Lane
12 July 1993	Off-load		Off-load	Off-load
13 July 1993	Cease Operations		Off-load	Off-load
14 July 1993			Off-load	Off-load
15 July 1993			Cease Operations	Off-load
16 July 1993				Off-load
17 July 1993				Off-load
18 July 1993		Commence 3 LO/LO Lanes		Off-load
19 July 1993		Off-load		Off-load
20 July 1993		Cease Operations		Off-load
21 July 1993				Off-load
22 July 1993				Off-load
23 July 1993				Cease Operations

Table 20. Cargo Off-load Synopsis with JOTE Spreadsheet Cell O-38 = 72.62%.

chosen as the preferred lighter for the vehicle discharge lane possessing the highest quantity of stons to be moved. JOTE has obviously been constructed with very accurate planning factors with regard to the cargo capacity and high sea state stability of the ACBL relative to other lighterage. Over the period spanning 9-11 July, the one ACBL is continually moved to the newest discharge lane possessing the highest quantity of cargo to be moved. Once the capacities of these latest discharge lanes have been rendered more consistent with the remaining active lanes, the ACBL, over the period spanning 11-14 July, is shifted between the LO/RO lanes with the largest remaining capacity.

The final, but perhaps most important benefit of this scenario is to provide the user with throughput expectations (in terms of both quantity and time) for the long term theoretical sea state conditions of the specific geographic location in question. The spreadsheet cell O-38 entry of 72.62% was obtained from the SEA_STATE_CALC program and corresponds to the $1 - F(a)$ value of the Rayleigh PDF excerpt for the data set at hand. Because the CHITEST result for the data set used was numerically equal to one, validity of the Rayleigh distribution for that particular data set is confirmed. Consequently, for a user planning an upcoming JLOTS operation for which the time period is unknown (i.e. the construction of an OPLAN or tactical contingency plan), the $1 - F(a)$ value is the safest spreadsheet cell O-38 entry for the JOTE program since it represents a worst case scenario. If the time period in which the operation is to be conducted is known and a data file of NSSWH observations for area in question can be obtained (as was the case in this model validation), the $F(b) - F(a)$ value obtained from the excerpt Rayleigh PDF of the SEA_STATE_CALC program is the most appropriate cell O-38 entry, provided the CHITEST result for that data set is approximately equal to one. Chapter IV will provide the necessary means of obtaining, critiquing, and processing this data file.

F. A SUMMARY OF THE FLAWS OF JOTE

The extensive model validation conducted throughout this chapter was undertaken for two primary reasons. First and foremost, it was necessary to establish the forum in which methodologies and benefits of the SEA_STATE_CALC program could be presented as the means of improving JOTE as a planning tool for the JLOTS commander. Second, and no less important, this model validation provides LMI, OPNAV N-42, and the Joint Staff J-4, with an insightful analysis of the shortfalls encountered in the operation of JOTE, from a user standpoint. The criteria from this validation will not only benefit LMI in follow-on development efforts, but will also provide N-42 and J-4, the organizations who fund those efforts, with a overview of modifications which enhance the viability of JOTE as a planning tool which is the common desire of all parties involved.

In summarizing the findings of this validation, results have been divided into three areas: pre-operation, execution, and output. Additionally, because the detailed analysis associated with each of these findings has been provided over the course of the preceding sections, all explanation will be eliminated from the following summarization.

1. Pre-operational Shortfalls

This phase of JOTE operation is characterized by extensive user calculations conversions, and planning decisions all of which are necessary for proper JOTE operation. The user is tasked with deciding the quantity and types of discharge lanes to operate as well as meticulously breaking down the overall cargo inventories of each vessel to be off-loaded in order to ascertain the capacities which will be placed upon each of the discharge lanes created. This process involves numerous calculations in order to express all cargo (each type of containerized cargo and every form of vehicular cargo) in terms of stons. The final, and perhaps most important, user calculation occurs if the user desires to employ any lighterage not acceptable by JOTE. In these cases the user must conservatively attempt to express the capabilities of the lighters he/she desires to employ with one or more of those within the acceptable JOTE inventory. In doing so, the user must equate lighterage in terms of carrying capacity, speed, size, total ship-to-shore transit distance, and quantity. By conservative estimation, the user guarantees planning is geared toward a worst case scenario rather than obtaining optimal throughput results. Each of these time-consuming computations must presently be done by hand, and are highly prone to both subjectivity and computational error.

Perhaps the single most unrealistic characteristic of JOTE is its inability to accept multiple ship-to-shore transit distances. Without question, no full scale, or even limited, JLOTS operation is conducted under conditions where all strategic sealift assets are positioned equidistant from the shoreline. To guarantee the avoidance overestimation of his/her own throughput capabilities, the user's only available option is to inform JOTE that all vessels involved are located at the same distance as the furthest ship offshore. This assumption alone singlehandedly ensures that the results obtained from JOTE are not optimal. When combined with the shortfalls of the preceding paragraph, the deviation from optimality becomes even more appreciable.

Finally, the results of Appendix D unequivocally confirm the criticality of the spreadsheet cell O-38 entry to the validity of JOTE results. The undeniable benefits of proper utilization and extraction of results from the SEA_STATE_CALC program have been well documented in preceding sections. The lack of site specificity inherent in Table 3 raises considerable concern as to the validity of the conclusions of any JLOTS capability assessments and/or equipment feasibility studies for which cell O-38 entries were obtained from this table.

2. Execution Shortfalls

Up to this point specific errors in the operation of individual or groups of macros within the JOTE program have been addressed only in the context of their resultant output. Because of these errors, however, several JOTE macros must be operated in very precise ways to ensure computational correctness of results, regardless of the degree of optimality attained. In many cases, the requisite methods of operation of these macros do not meet the original design plans of the developers, but are still functional. In short, methodological errors do exist in certain macros of which the developers have been made aware (by multiple sources including this researcher). Because JOTE is only now being considered as a marketable planning tool rather than an in-house analytical tool, these errors must be corrected for user ease.

The first of these errors occurs with the REEVAL macro. This macro is designed to be executed upon generation of lane assignments and throughput results for a given day in order to calculate the same criteria for the following day under identical or varied input conditions. JOTE is designed such that the first execution of the REEVAL macro follows the first and only execution of the UBERALLES macro. The UBERALLES macro commences JOTE execution. In this macro, all input parameters are specified and throughput results for the first day of the JLOTS operation are obtained. In executing the REEVAL macro, the first problem arises when the user is prompted for a desire to alter the next day's lane assignments. If the user elects to do so, he/she is presented with a screen showing the current capacities of all discharge lanes which have been created. From this screen, the capacity of any lane may be altered. When this is done for any number of lanes and the screen exited, calculation of the throughput results for the following day begins. In the column entitled "Throughput Requirements (Stons)" atop the spreadsheet, the user expects to, and does temporarily, view the new lane capacities which were recently entered. When calculations are completed, the user then justifiably expects the quantity in the column entitled "Stons Left" to represent the numerical difference between entries in the columns entitled Throughput Requirements (Stons) and Stons Moved for each discharge lane. Because of inherent programming errors, the entry in the Stons Left column becomes the entry in the Throughput Requirements (Stons) column, and the Stons Left column is then replaced by a value equal to twice the appropriate Stons Moved entry. In short, the correct calculation improperly occurs twice and all column entries are altered to reflect this error.

To avoid this error, the user must manually alter the desired spreadsheet entries of the Throughput Requirements (Stons) column and subsequently execute the GOPHERIT macro. This macro was originally designed to recalculate the expected throughput for a given day based upon the modification of a single input parameter, such as the spreadsheet cell O-38 entry, while maintaining all other input parameters constant. Utilizing the GOPHERIT macro for changing lane capacities on a given day bypasses the aforementioned error, but unfortunately, exposes the user to another calculational undesirability, namely, increased run-time. The UBERALLES macro requires approximately 5-8 minutes of calculational run time on a Pentium 90 MHz personal computer. Revising calculations via the GOPHERIT macro consumes an additional five to eight minutes, while the execution of the REEVAL macro requires only 30 seconds. Because most JLOTS operations last two weeks or more, and JOTE properly provides daily throughput results, planning a lengthy JLOTS operation can be a very time consuming ordeal. Consequently, the user should and will employ the REEVAL macro to obtain throughput calculations for each upcoming day on which no lane capacities are in need of change.

The REEVAL macro, however, has another crucial flaw which significantly limits its value. Specifically, REEVAL can be employed and throughput results properly obtained for every day until the day on which the entire throughput capacity on a given discharge lane has been exhausted. On this day and the ensuing days, the REEVAL macro will erroneously continue to move cargo on the lane in question even after all capacity has been exhausted, thereby gradually building an increasing negative entry in the "Stons Left" column for that particular discharge lane. This error has multiple effects since by continuing to move cargo which does not exist, JOTE is employing lighterage which could be more suitably used on other lanes. The result is inaccurate throughput calculations on all lanes rather than simply the lane for which the negative entry appears in the "Stons Left" column.

This error is also avoidable through the use of the GOPHERIT macro. Upon achieving a negative number in the Stons Left column for a given discharge lane, the GOPHERIT macro can be executed and new, more accurate, throughput results obtained. The GOPHERIT macro must be executed prior to saving that day's results. Upon execution, the GOPHERIT macro treats the negative entry in the Stons Left column as a numerical zero and updates the throughput results across all lanes accordingly. Understandably, this process drastically increases the computation time of the JOTE program. During the course of daily throughput planning, the commencement of off-load operations on newly arrived ships and the exhaustion of capacity on any of multiple (10-15 or more) discharge lanes creates the need to execute the longer running GOPHERIT macro on nearly a daily basis. Eliminating the flaws of the REEVAL macro would facilitate its use in place of the GOPHERIT macro, thereby diminishing the run-time of JOTE as was originally intended by the designers.

3. Output Shortfalls

In terms of output, the results obtained from JOTE, under the most accurate sea state predictions for the specific location in which the JLOTS evolution is to be conducted, appear to overestimate actual capabilities for LO/LO operations by approximately 15.57% and to underestimate actual throughput capabilities for tracked vehicle off-load by 27.28%. The throughput predictions obtained from JOTE appear to most closely approximate actual capabilities for wheeled vehicle off-load.

In addition to the conservative assumptions the user is forced to make within the pre-execution phase of JOTE, the output tables obtained, and presented in Appendix D, suggest that several computational errors exist which further move the numerical results away from optimality. Numerous examples have been identified where positive throughput exists on discharge lanes on which no lighterage is assigned.

Within the output, the most significant evidence of undermining of the linear program upon which JOTE is based resides within the numerous examples of apparent wasted operational time on discharge lanes. Because JOTE tends to favor large capacity lighterage, smaller capacity lighterage is unused and discharge lanes, in some cases, wait idlely for the arrival of large capacity lighterage rather than filling these time gaps with either complete loadout of small capacity lighters or partial loadout of other large lighters. Even if these time periods yielded only minimal throughput, they should still be consumed by some form of off-load since the goal of the underlying linear program is to minimize total daily shortfall. This objective function is only satisfied by maximizing daily throughput which, for all of the aforementioned reasons, is not being realized by the JOTE program.

IV. OBTAINING AND PROCESSING SEA STATE DATA

A. AN OPERATIONAL OVERVIEW OF SEA_STATE_CALC AND ARRANGE_DATA

The preceding chapter provided a mathematical analysis of the methodologies employed by the SEA_STATE_CALC program to accomplish each of the following objectives:

1. The application of the Rayleigh probability distribution to an input file of significant wave heights.
2. The use of the resultant Rayleigh PDF in determining both the theoretical and observed percentages of time that sea state conditions equal or exceed Sea State Two in a given geographic region.
3. Graphical and quantitative analysis of the suitability of a particular input file for use in the ways described above.
4. A site and time specific computation of the most critical input parameter to the JOTE model, namely, the spreadsheet cell O-38 entry.

The degree of mathematical detail presented in Chapter III was necessary to provide immediate explanation and justification for the results obtained from the SEA_STATE_CALC program since those results were employed in the validation of JOTE. With the underlying theoretical principles of the SEA_STATE_CALC program firmly established, the objective of this chapter is to provide an operational walkthrough of the calculations and usage of both the SEA_STATE_CALC program and its subsidiary, the ARRANGE_DATA program. The various pop-up menus in both of these programs are succinct and self-explanatory. The most important attribute of the package comprised of these two applications, however, is its ability to operate completely free of all user interaction beyond the initial user provision of the calendar period of interest. This feature is a significant improvement to the existing version of JOTE which places heavy demands upon the user in the form of lengthy pre-execution calculations in order to determine input parameters. As the JOTE model validation of the preceding chapter confirmed, there are several computational shortfalls which adversely affect the optimality, and in some cases validity, of the results obtained from JOTE. Regardless of any contractual efforts by LMI to address these concerns in the future, the SEA_STATE_CALC package is a supplement which can immediately facilitate JOTE's use as a planning tool for JLOTS operations.

This supplement physically commences with a single, independent run of the ARRANGE_DATA component which is a Borland Turbo Pascal 1.5 application. Ideologically, however, execution of the SEA_STATE_CALC package begins long before the JLOTS commander or his/her staff energizes a single personal computer. As alluded to in Chapter III, the ARRANGE_DATA program offers the JLOTS commander the ability to quickly and easily process large quantities of actual maritime weather reports for the geographic location of interest. By providing this processing capability, in a user friendly environment, the ARRANGE_DATA program forces the prudent JLOTS planning staff to initiate the obtaining of this data from NCDC. In a relatively short time period, NCDC can compile and distribute a data file containing all maritime weather observations on record for a given geographic location over any time interval spanning the period of 1854-present. For the vast majority of United States military points of interest world-wide, specifically JLOTS areas of opportunity, a designated interval encompassing the preceding half century will provide more than enough maritime observation reports than will be needed to produce a nearly undisputable spreadsheet cell O-38 entry. NCDC can distribute this large data file by any of several medium including: CD-ROM, magnetic tape, and FTP via Internet. By obtaining and utilizing this data, the user has taken the first major step toward attaining site specific sea state predictions rather than a mere generic prediction extracted from Table 3.

Facilitating site specificity, however, is only half of the objective of the ARRANGE_DATA program. Its most important attribute is utilizing the NCDC observations and the user inputs to create a data file which is both site and time specific to the JLOTS operation being planned. Figure 20 provides a synopsis of the flow of control during the execution of the ARRANGE_DATA program. Additionally, a complete copy of the code for ARRANGE_DATA is contained in Appendix E. As Figure 20 illustrates, the first objective of the program on its initial execution is to ensure that the individual observations contained within the NCDC data file are uniquely distinguishable by the presence of carriage returns. If carriage returns are present, the ARRANGE_DATA program renames the NCDC data file as SSDATA1.TXT, the first of four temporary holding files which it will create during its execution. These holding files are created for two reasons. First, their creation ensures that no data observations are mistakenly lost during the flow of control between procedures of the program. Second, because the contents of each temporary file are unique, flexibility is offered to the user in the event a data file is needed for analysis of any other parameter besides sea state. In the event carriage returns were not present between the original observations (which may occur if Internet transmission was used at any time), the ARRANGE_DATA program will insert them and rename the file as SSDATA1.TXT. Henceforth, the program will operate from the file entitled SSDATA1.TXT, thus securing the integrity of the NCDC observations.

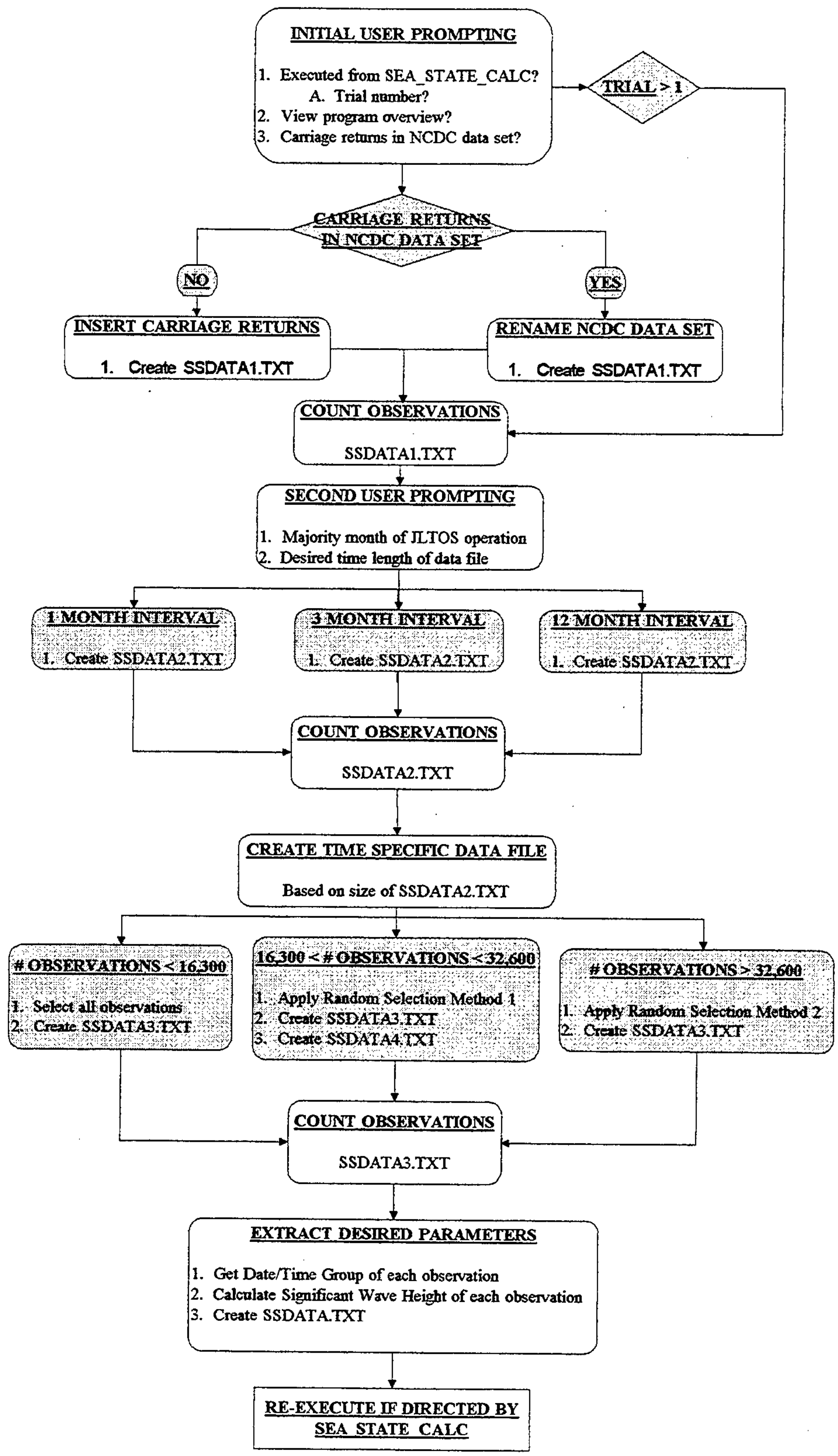

Figure 20. Flowchart for the ARRANGE_DATA Module.

The inherent ability of ARRANGE_DATA to process NCDC provided data files is dictated by the standardization of all international maritime weather observations as text fields of 148 characters. Since groups of characters represent specific data parameters, ARRANGE_DATA can identify, via character position, those data fields necessary for the computation of significant wave height and subsequent use in the SEA_STATE_CALC program. The data fields extracted by the ARRANGE_DATA program are those representing date, time, observed wave height, and observed swell height. Table 21 illustrates the respective character positions in which these data fields are located. A complete synopsis of the element names, allowable data field entries, and code definitions for each of the remaining record positions of an international maritime weather observation can be found in Reference 21. By accessing and reviewing the characters contained in these fields and subsequently comparing the entries against user-provided responses to pop-up menus, increasingly specific data files are created.

In this manner, ARRANGE_DATA first prompts the user for the month in which the majority of the JLOTS operation being planned will take place. Subsequently, the program obtains from the user the desired time interval for the final input file. This selection is made from one of three available choices which are indicated as follows:

1. A one month interval corresponding to the majority month of the JLOTS operation.
2. A three month interval centered upon the majority month of the JLOTS operation.
3. A 12 month interval which could be used in the event the user was highly uncertain regarding the time period for the actual JLOTS operation.

Desired Data Field	Character Position Location
Year - Greenwich Mean Time (GMT)	17 - 20
Month - GMT	21 - 22
Day - GMT	23 - 24
Hour -GMT	25 - 26
Height of Waves (½ Meters)	72 - 73
Height of Swell (½ Meters)	77 - 78

Table 21. Data Fields Extracted From Each NCDC Weather Observation by ARRANGE_DATA, After Ref. [21].

After obtaining this input, the program screens the month data field of all observations in SSDATA1.TXT, and records those which match the user's desires in the file entitled SSDATA2.TXT. After computing and returning the number of observations contained within SSDATA2.TXT, this file will become the source file for the flow of control through the program. Although it will now be ignored, the file SSDATA1.TXT will not be deleted.

The size of the file SSDATA2.TXT will determine which of three methods the program employs for constructing the next temporary file. Because the SEA_STATE_CALC program can accept and process a maximum of 16,300 observations (thereby, remaining under 16,384 which is the maximum number of rows in a Microsoft Excel 5.0 spreadsheet), if SSDATA2.TXT contains fewer than that maximum, all observations in SSDATA2.TXT will be transferred to SSDATA3.TXT. If the number of observations in SSDATA2.TXT is larger than 16,300, but smaller than 32,600, ARRANGE_DATA will initiate a repetitive process whereby a filter will be established through which each individual observation in SSDATA2.TXT will pass. This filter is characterized by the assignment of a random number on the interval (0, 1) to every observation in SSDATA2.TXT. A test criterion is then established whereby, for each observation, the random number assigned is evaluated in magnitude against the pre-established value of 0.9. If the random number assigned to a given observation of SSDATA2.TXT exceeds 0.9 that observation is recorded and is moved forward to the file SSDATA3.TXT. If the random number assigned to a given observation of SSDATA2.TXT is less than 0.9, however, that observation is placed in a holding file entitled SSDATA4.TXT. This process continues until either the number of observations in SSDATA3.TXT reaches the maximum of 16,300 or all observations in SSDATA2.TXT have been screened. If the latter is true and the former is false, ARRANGE_DATA then reverses the names of the files SSDATA2.TXT and SSDATA4.TXT and recommences the filtering process. This technique continues until the number of observations in SSDATA3.TXT reaches the maximum of 16,300.

Although the relatively high filter criterion of 0.9 does increase the run-time of ARRANGE_DATA, it more importantly ensures that those observations selected to join SSDATA3.TXT will have been dispersed randomly throughout the file SSDATA2.TXT. This need for true randomness in the selection of observations which move to the next level of the program arises because the original observations obtained from NCDC will be arranged in chronological order over the desired period of record upon receipt. Hence, ARRANGE_DATA ensures that the Rayleigh PDF which will be calculated from these observations is indeed constructed from observations spanning a time period which is as large as possible.

The third and final technique for processing the observations of SSDATA2.TXT which ARRANGE_DATA possesses is employed if the number of observations in that file is equal to or exceeds 32,600. In this case, a distinctly different random selection technique from that discussed above is employed. This technique commences with the obtaining of the quotient shown in Equation 104 (truncated to its integer value).

$$Y = \left(\frac{Number\ of\ Observations \in SSDATA2.TXT}{16{,}300} \right) \tag{104}$$

A random number X is then generated on the interval (0,Y). To again ensure that observations selected are not concentrated to any specific chronological location within the original NCDC data file, the first observation selected will be the observation on line X of the file SSDATA2.TXT. Thereafter, every X^{th} observation will be selected. Those observations selected will be individually stored in the file SSDATA3.TXT which now becomes the controlling file. Here, again, the file SSDATA2.TXT will be ignored but not deleted.

The justification for employing different random selection techniques between the latter of the aforementioned scenarios lies in maintaining the ability to facilitate re-execution of the ARRANGE_DATA program should the user desire to obtain a different data set for the same specified month and time interval. As subsequent paragraphs will demonstrate, the SEA_STATE_CALC program reserves the ability to re-execute the

ARRANGE_DATA module to perform this function. If the random selection technique employed for the situation in which the number of observations in SSDATA2.TXT equals or exceeds 32,600 were also employed during the scenario in which the number of observations in this file was between 16,300 and 32,600, the user would possess the ability of extracting one and only one data set from the file SSDATA2.TXT, since the truncated quotient value, Y, would equal one.

The final procedure of the ARRANGE_DATA module accesses, from each observation in SSDATA3.TXT, only those data fields corresponding to date/time group, wave height, and swell height. From each observation, ARRANGE_DATA next confirms that the entries within these fields are non-blank, since it is not unusual for a given observations to possess missing data fields. For each observation containing both wave height and swell height data fields, ARRANGE_DATA computes an estimate of significant wave height via Equation 105.

$$\textit{Significant Wave Height} = \sqrt{\textit{Wave Height}^2 + \textit{Swell Height}^2} \qquad (105)$$

If, however, a given observation contains only a wave height data field, the swell height parameter is eliminated and Equation 106 is used.

$$\textit{Significant Wave Height} \approx \sqrt{\textit{Wave Height}^2} \qquad (106)$$

This approximation is still valid for two reasons. First, between wave height and swell height, wave height has a more dominant influence upon significant wave height. More importantly, however, because the wave height data fields of maritime weather observations represent visual recordings, this parameter can be considered a close approximation of significant wave height based upon the tendency of the human eye to focus upon the larger, rather than smaller, waves. If ARRANGE_DATA determines blank entries in both the wave height and swell height data fields, the observation will be eliminated from consideration. For those observations from SSDATA3.TXT which pass this screening process, the date/time group data fields and resulting significant wave height computation will be recorded in fixed space interval format in the final text file entitled SSDATA.TXT. This file will serve as the input file for the remainder of the SEA_STATE_CALC package.

The ARRANGE_DATA module possesses two final characteristics worthy of discussion. First, it provides the user with both visual and quantitative feedback of its actions as it creates each temporary file. This is accomplished through the combination of screen messages and repeated calls to a function designed to count the number of observations (one observation per line) in a specified file. Each time a new file is created the user is provided with a message indicating such, as well as the number of observations contained within that new file. In this manner the user is able to verify proper operation of the various procedures, since the number of observations in each sequentially created file should either decrease or remain constant. The user is able to confirm these messages and control the flow through the program by depressing the Enter key after each message. A second design feature of ARRANGE_DATA ensures that the program will not undergo unnecessary actions if it is reexecuted from within the SEA_STATE_CALC program. The initial question posed to the user at the outset of execution is whether or not the program has been started from within the SEA_STATE_CALC program. If the user indicates a "YES" response to this question, the program prompts the user for the number of data files which have been previously obtained for the desired month and the desired time interval. The program utilizes the "YES" response to bypass the procedure(s) dealing with the presence or lack of carriage returns in the original NCDC data set since this obstacle would have already been successfully overcome during the first execution. The program employs the number of previous data sets obtained for the desired month and time interval along with the size of the holding file SSDATA2.TXT in order to display proper feedback to the user regarding the creation of the holding file SSDATA3.TXT and the final file SSDATA.TXT. Specifically, if the file SSDATA2.TXT contains fewer than 16,300 observations (the maximum processable by SEA_STATE_CALC) the program will inform the user that insufficient observations exist to facilitate the creation of another data file for this month which covers the identical time interval as the one previously created.

From start to finish, including the time consumed awaiting user responses to pop-up menu questions, this initial execution of ARRANGE_DATA requires approximately three minutes of operating time using a Pentium 90 MHZ processor. Because the SEA_STATE_CALC program is fully implemented in both Visual Basic and Microsoft Excel 5.0, as is the JOTE model, after completion of this initial execution of ARRANGE_DATA, the user is fully prepared to commence JOTE. Prior to executing the UBERALLES macro of JOTE (where non-embedded input parameters are specified and calculations are automatically commenced), the user has the ability to manually modify those input parameters embedded within the main spreadsheet, in particular, the cell O-38 entry. From this screen, the user can open and execute the SEA_STATE_CALC program. A pictorial representation of the flow of control through this program is depicted by Figure 21, and a complete copy of Visual Basic code for SEA_STATE_CALC is contained in Appendix F.

Because SEA_STATE_CALC is designed to both eliminate user calculations and operate with only minimal user interaction, the program is commenced by simply depressing the task button entitled "Open Input File and Start Calculations" which is found (along with the other task buttons) beneath the program overview on Sheet 1. Once initiated, the program will automatically access and open the Windows text file SSDATA.TXT created by the ARRANGE_DATA module. The program then implements a macro which will convert this file to a Microsoft Excel text file entitled SSDATA.XLS, and prompts the user for his/her desires regarding the saving of this file. Subsequently, the program shifts its focus to Sheet 2 which contains the column data from the input file of the previous execution as well as the column data representing the calculations and sorting necessary for the creation of both Rayleigh plots and the Chi-Squared Goodness of Fit Test as explained and shown in Chapter III. The program then automatically performs each of the following operations in sequential order regardless of the size of the Microsoft Excel text file from which it will operate:

1. Clear all column data from Sheet 2.
2. Open the newly created Microsoft Excel text file and extract all column data contained therein.
3. Place the extracted data in the appropriate columns of Sheet 2.
4. Commence all calculations and sorting necessary on Sheet 2.

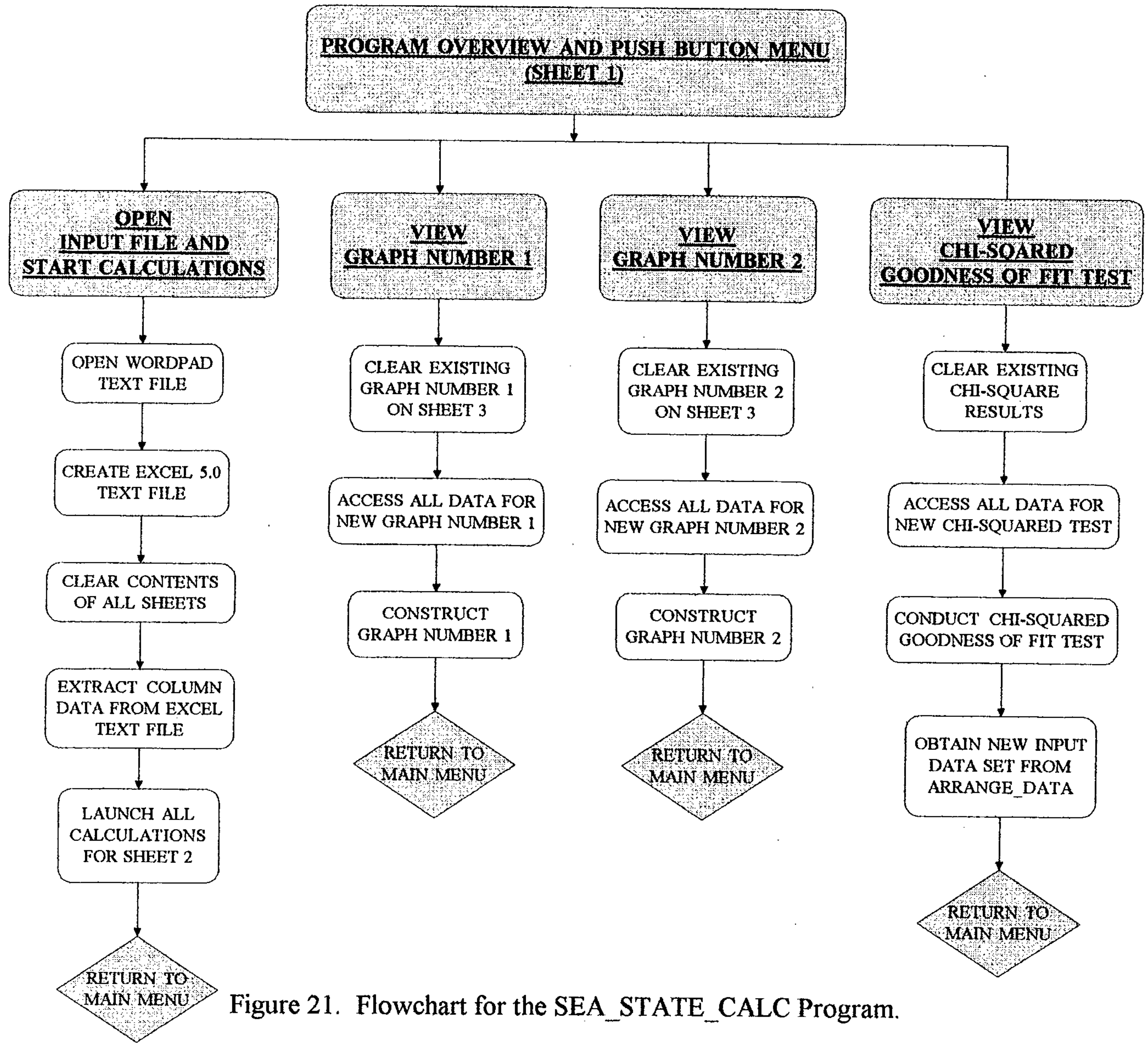

Figure 21. Flowchart for the SEA_STATE_CALC Program.

5. Sequentially access and clear all column data, plotted data series, and text information from Sheets 3, 4, 5 which represent the Rayleigh PDF of Observed Wave Height, Relative Occurrence of Observed Wave Heights, and Chi-Squared Goodness of Fit Test results, respectively.

As is the case with all four command button options in the main menu on Sheet 1, upon completion of their pre-programmed operations, the cursor will remain on the last active screen thereby affording the user the opportunity to review all operations which have been conducted. Each screen contains a command button allowing the user to return to the main menu. Upon doing so the program awaits the user's command(s) to begin constructing the plots which will yield the potential values for spreadsheet cell O-38 entry and the verification of the quality of input file contained in SSDATA.XLS. Each of these tasks are initiated by the depressing of the appropriate command button on the main menu, and like their predecessor, all operate free of any user interaction.

Upon the selection of "View Graph Number 1", the Rayleigh PDF of Observed Wave Height, the program extracts the coordinate axes, $X = \left(\frac{H}{H_{RMS}}\right)$ and $Y = \left[(H_{RMS}) * P(H)\right]$ from the appropriate columns of Sheet 2 and shifts control to Sheet 3. After pasting the data for those axes into their respective columns on Sheet 3, the program then extracts all the unique data pairs from this series. This revised and smaller data series will be used for plotting an approximation to the actual Rayleigh curve for the data set. By utilizing only the unique data pairs the program ensures that the desired plot will remain within the plotting capabilities of Microsoft Excel 5.0 which is a maximum of 4000 data pairs. Equally important, is that utilizing only the unique data pairs guarantees that the resultant plot will not be unduly influenced by the presence of an abundance of observations of the most common wave height. When utilizing large data sets the presence of these observations would otherwise drive the connected scatterplot toward linearity. The plot generated on Sheet 3 contains not only the Rayleigh PDF curve obtained from the unique data pairs, but also two vertical line segments the lower endpoints of which correspond to the X-axis values at which Sea State Two begins ("A" value) and the largest $\frac{H}{H_{RMS}}$ ratio within the data set ("B" value) respectively. For nearly every data set spanning a large time interval, the "B" value will not be visibile since it will be located at a numerically high $\frac{H}{H_{RMS}}$ value, thereby indicating that the vast majority of the right tail of the theoretical Rayleigh PDF can be obtained by the data set at hand. An example of the plot engineered from this command button option is shown in Figure 22. This plot represents the Rayleigh PDF of observed wave height for the eastern Korean Peninsula during the month of July. A computational overview of the results obtained from this and other site/time specific executions of the SEA_STATE_CALC program will be presented in the following section.

The upper endpoints of these vertical line segments (the coordinates of which are contained in the cell locations depicted by the text boxes in Figure 22) correspond to the actual $H_{RMS} * P(H)$ values of the Rayleigh PDF at the "A" and "B" value respectively. Consequently, by noting the position at which the approximated Rayleigh PDF curve (shown in blue) crosses the vertical line segment (shown in red), the user is afforded a visual representation of the extent to which the Rayleigh PDF approximated from the unique data values differs from the theoretical Rayleigh PDF for complete data set. This slight offset arises because the endpoints of the vertical line segment are determined by the

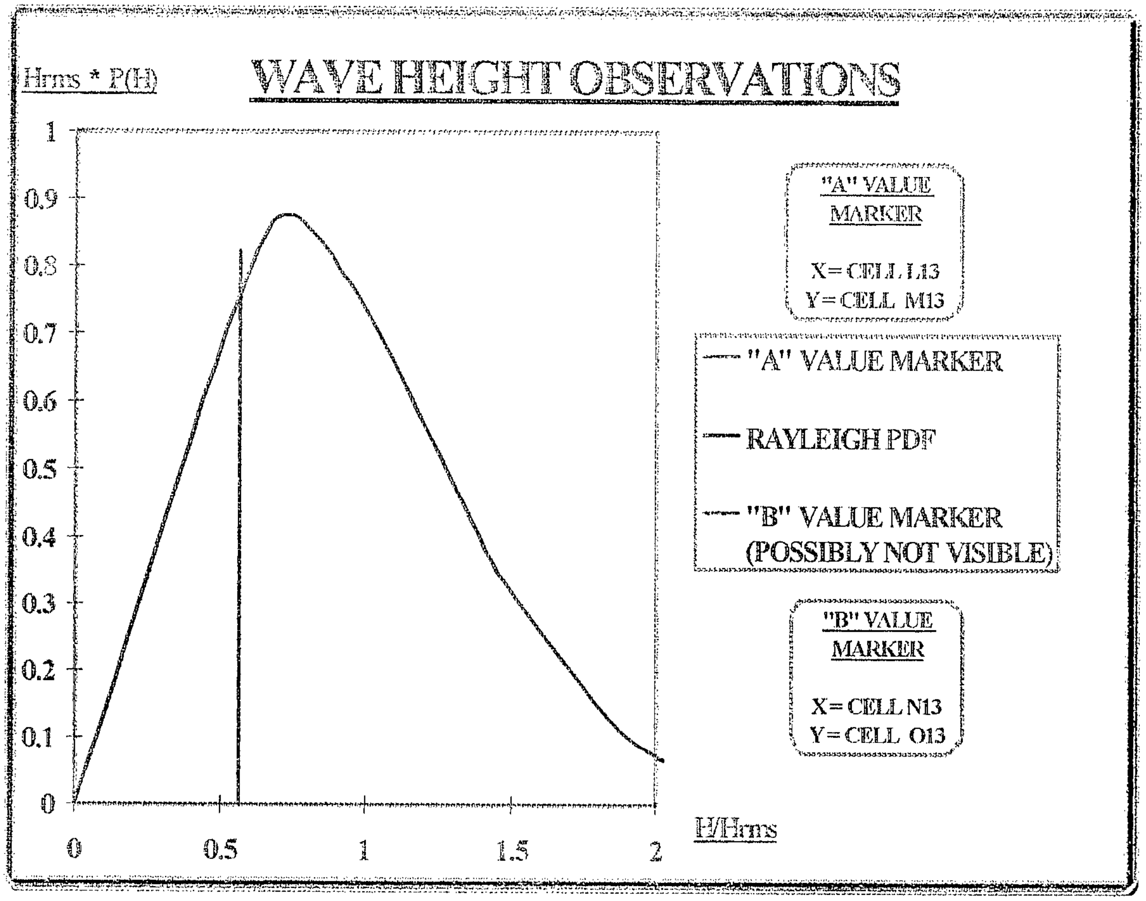

Figure 22. Sample Output Obtained From "View Graph Number 1" Command Button of SEA_STATE_CALC Program.

value of H_{RMS} (which is equally influenced by all of observations considered), while the connected scatterplot shown is determined by a fraction of those observations. Because the graphs presented in Chapter III were constructed from the OV93 data set which contained 1350 observations, this offset was not observed because this relatively small number of observations could all be plotted in a Microsoft Excel 5.0 scatterplot. Most importantly, it must be understood that the graph is constructed merely as a visual aid for the user. All computations extracted from this sheet are performed on the theoretical Rayleigh PDF curve, and are thus reflective of the entire data set.

After the plot described above has been constructed, it is followed by the computations which determine the spreadsheet cell O-38 entry. The mathematical interpretation and justification for the $[1 - F(A)]$, $[1 - F(B)]$, and $[F(B) - F(A)]$ values was explained in detail in Chapter III. Because that presentation arose from an execution of SEA_STATE_CALC which utilized NSSWH data from OV93 (which only spanned only a 19 day interval) an appreciable $[1 - F(B)]$ value existed. For the scenarios presented in the next section of this chapter, obtaining and processing large scale data sets from NCDC resulted in $[1 - F(B)]$ values of zero. For these cases the Rayleigh PDF obtained from the data set is a nearly perfect representation of the long term theoretical Rayleigh PDF of NSSWH in those respective areas. Obviously, these calculations are the determining factors of the spreadsheet cell O-38 entry, and thus, constitute the most important attribute of the SEA_STATE_CALC program.

The final two command buttons on the main menu, however, provide the user with graphical and computational information which is not only useful, but also substantiates the calculations of Sheet 3. The push button entitled "View Graph Number 2" directs the user to Sheet 4 of the SEA_STATE_CALC program. Here, a Rayleigh plot representing entitled "Relative Occurrence of Observed Wave Height" will be produced. Figure 23 shows an example of this type of plot, again for the eastern Korean peninsula during the month of July. This plot provides the user with a visual representation of the most significant contribution of the Rayleigh probability distribution to wave height measurement, namely, the identification of the most common wave height for a specific geographic area over a specific time.

It has been previously documented that the apex of the theoretical Rayleigh PDF occurs above the point on the X-axis which represents the most common wave height. Additionally, for a plot in which the coordinate axes are defined as $X = \left(\frac{H}{H_{RMS}}\right)$ and $Y = \left[(H_{RMS}) * P(H)\right]$, this value should occur at the point along the X-axis where $H = 0.7071 H_{RMS}$. As Figure 23 illustrates, the plot produced on Sheet 4 eliminates the parameter H_{RMS} from both axes, redefining them as $X = NSSWH$ and $Y = P(H)$ respectively. For this graph, the lower endpoint of the vertical line segment represents the most common NSSWH value as determined by the Rayleigh PDF. The upper endpoint (the coordinates of which are contained in the cell locations depicted in the text box on Figure 20) represents the maximum Rayleigh probability computed from the actual data set employed. Here again, this vertical line provides a visual interpretation of the extent to which the Rayleigh PDF obtained from plotting only the unique values of the data set differs from the theoretical Rayleigh PDF since the apex of the PDF curve (shown in blue) does not coincide exactly with the upper endpoint of the vertical line segment (shown in red) as it theoretically should. Finally, the architecture of constructing this plot is identical to that of constructing the previous plot. Upon execution, of the "View Graph Number 2" module, the program obtains the appropriate coordinate axes from Sheet 2, positions them in their appropriate locations on Sheet 4, and subsequently extracts the unique data pairs.

The final module of the SEA_STATE_CALC program is initiated by depressing the push button entitled "View Chi-Squared Goodness of Fit Test". This macro is implemented as a means of substantiating the conclusions drawn from the other modules by assessing the quality of fit obtained from applying a Rayleigh distribution to the input

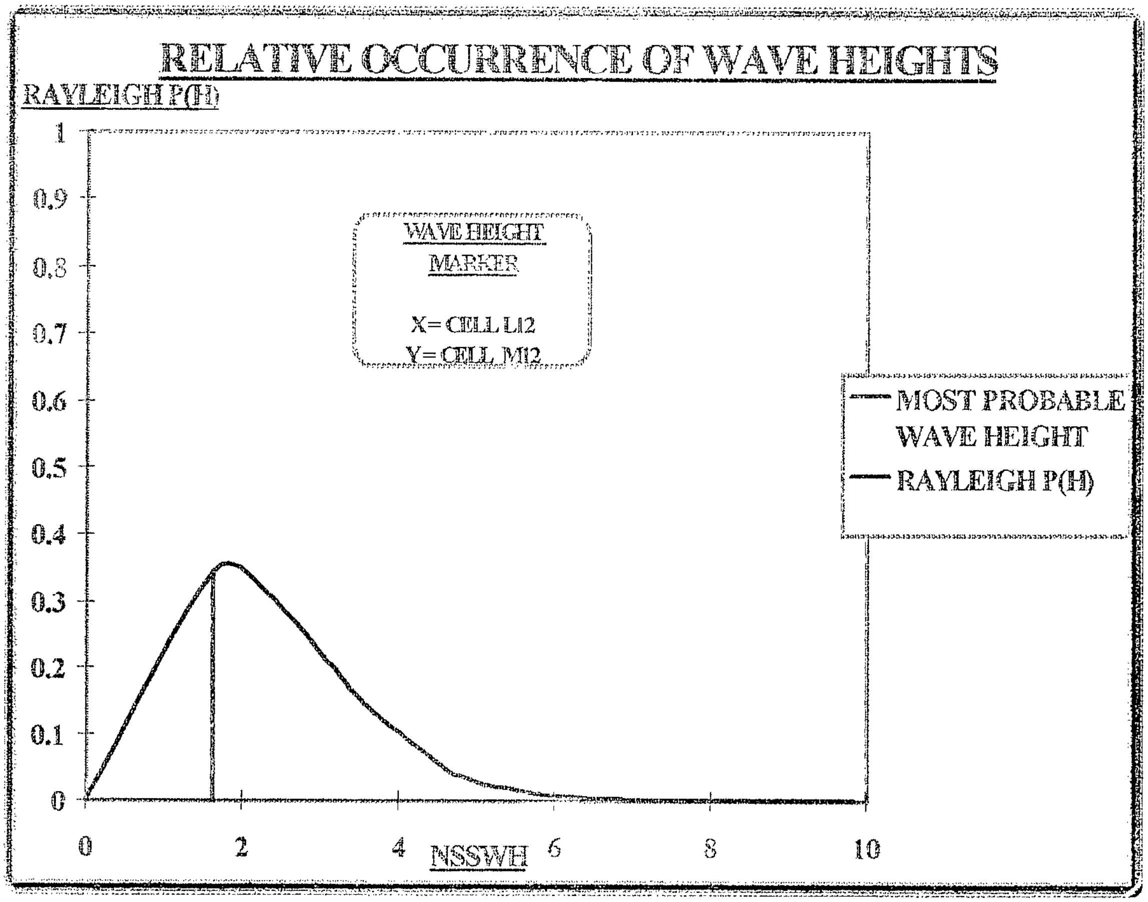

Figure 23. Sample Output Obtained From "View Graph Number 2" Command Button of SEA_STATE_CALC Program.

data set. As Chapter III explained the goodness of fit measured within this module is between the unknown parameters, H_{RMS} and $\hat{\theta}$, of equivalent forms of the Rayleigh PDF. With the use of these two equivalent forms of the Rayleigh PDF, *Rayleigh P(H)* computed from the original data set of wave height observations, and the *Expected Rayleigh P(H)*, computed from the same data set with the use of the MLE, are computed as the O_i and E_i entries respectively for each 0.1 ft. incremented wave height cell. Here again, the limitations of the capabilities of Microsoft Excel 5.0 are avoided by performing the CHITEST on those data pairs of *Rayleigh P(H)* and

Expected Rayleigh P(H) extracted from unique wave height increments (cells). The Microsoft Excel 5.0 capability for a Chi-Squared Goodness of Fit Test is limited to approximately 5000 data pairs. Employing only the unique 0.1 ft. wave height increments not only ensures the problem remains within acceptable dimensions, but also incurs no validity loss since the omitted data pairs are merely repetitions of pairs which are being considered within the fit test. Indeed, because the Rayleigh distribution so strongly applies to wave height observations, only in very extreme situations will the CHITEST result not equal or approach one. Even for the OV93 data set discussed in Chapter III, where the difference between the quantities $[1 - F(B)]$ and $[F(B) - F(A)]$ was appreciable due to the limited number of observations in the right tail area, the CHITEST result between *Rayleigh P(H)* and *Expected Rayleigh P(H)* for recorded observations was still numerically equal to one. In short, this means that the OV93 wave height data is Rayleigh distributed, but the Rayleigh PDF obtained from this data set is merely a moderate approximation of the theoretical Rayleigh PDF for the Fort Story, VA area.

Identical to the previous two modules described, initiation of this module commands data copying from Sheet 2 to Sheet 5 and the subsequent extraction of unique data pairs. Within this module, however, there exists additional coding which eliminates any data pairs of (0, 0) since the fit between these pairs is perfect. The final component of this module is a command button allowing the user to re-execute the ARRANGE_DATA program (thereby obtaining a new input data set) in the rare event that the CHITEST result is less than 0.975 for the present data set.

encompasses only the very extreme northern Persian Gulf at the Iraqi border. Therefore, these observations, although minimal in number, can still provide insightful results because they represent the conditions at a very specific point of interest and are measured over a long period of record.

Appendix G contains the graphical and computational output of the SEA_STATE_CALC program for each of these three geographic areas along with a synopsis of the number of observations employed in each scenario. For each geographic region, both a one month interval for the month of July, and a three month interval centered on the month of July were modeled. By extending this process to obtain output for each of the 12 possible one and three month intervals, a logistician on the JLOTS commander's staff could identify a great deal of vital information not limited to: trends in sea state conditions, and periods prone to storm activity. The SEA_STATE_CALC program therefore, in addition to increasing the site and time specificity of JOTE's most important parameter, the spreadsheet cell O-38 entry, can also stand alone as a simplistic early planning tool for JLOTS operations. Admittedly, in the days immediately preceding the operation, the JLOTS commander is far more concerned with items as commonplace as the upcoming weather forecast than with the results of program which employs historical weather data analysis. During the planning stages, however, which occurred weeks or even months earlier, a tool such as SEA_STATE_CALC could have been his/her greatest asset as a supplement to the JOTE model in predicting expected throughput times and evaluating the relative performance of various lighterage combinations, off-load schemes, and discharge lane capacities.

Analysis of the tabulated computational results which accompany each of the graphs contained in Appendix G reveals the viability of the SEA_STATE_CALC package as a planning tool for the JLOTS commander. These results indicate that only in the northern Persian Gulf can one expect to find conditions below Sea State Two over 50% of long-run time. For both the eastern Korean Peninsula and the southern Persian Gulf, the SEA_STATE_CALC program tell the JLOTS commander that he/she can expect to encounter sea state conditions which equal or exceed Sea State Two over 70% of long-run time. Consequently, the benefits of employing these percentages as the spreadsheet cell O-38 entries in the JOTE model cannot be overstated.

C. UTILIZING SEA STATE INFORMATION FROM OTHER MILITARY SOURCES

In addition to exposing the shortfalls of JOTE and highlighting the potential benefits of the SEA_STATE_CALC package, the research of this thesis also yielded the realization that a majority of the JLOTS community is unaware of ongoing research efforts in areas such as weather, wave, and sea state analysis. Indeed, only within the past nine to 12 months has a definitive effort been made, primarily by the Joint Staff, J-4, to expose the remainder of the JLOTS community to installations within the U.S. military which can provide analytical environmental tools which could greatly assist in JLOTS planning. In recent years, a major error in analytical tools used for JLOTS planning was a lack of understanding of the extent to which JLOTS is inherently dependent upon sea state conditions. Since that realization has been made, analytical modelers are struggling to find the most appropriate means of incorporating sea state conditions into their work. In the midst of this growth period, the need for a theoretical approach to sea state modeling within a deterministic JLOTS model is becoming increasingly clear. Certainly the objective of this thesis is not to expose the multitude theoretical approaches to sea state modeling being performed at various military and government funded installations. Only because of the lack of awareness in the JLOTS community of the data available at NCDC and its potential enhancement to JLOTS planning encountered during the research of this thesis are the efforts of the following two installations highlighted here. If tasked in sufficient time prior to the start of the JLOTS operation, both could provide theoretical sea state research which could profoundly impact JLOTS planning.

1. The Efforts of the Naval Oceanographic Office (NAVOCEANO)

The first installation whose work warrants such attention is NAVOCEANO. In addition to composing a vast amount of publications regarding ocean modeling, predictions of wave spectra, and environmental guides in support of other littoral operations, such as mine warfare, around the world, the diversity of its data archive repeatedly renders it the office/agency of choice for short-term, high-priority climatology studies. For example, during the late spring and early summer of 1996 in response to military need, NAVOCEANO compiled a six week intensive climatology study in support of military operations in the Taiwan Straits. This study addressed expected weather, sea state, tidal, and current information. Their ability to perform this work is directly attributable to being both a data archive and analytical research facility. Consequently, both data and the personnel/equipment necessary to analyze it are located on site. If given sufficient notice, this installation could produce a study which could influence JLOTS planning in any geographic location around the world.

2. The Efforts of U.S. Waterways Experimentation Station

The second installation, which is perhaps worthy of even more attention for its ability to assist in JLOTS planning, is the U.S. Army Waterways Experimentation Station (WES). The most influential capability which WES brings to the forefront is the concept of wave hindcasting. By definition, wave hindcasting refers to the practice of utilizing historical wave height observations and prevailing wind conditions from a multitude of surrounding locations to predict the conditions at another location for which data observations are sparse but bathymetric data is known. The process of hindcasting usually requires large scale computer models and processing equipment, but does produce highly detailed results. Hindcasting, therefore, has two profound JLOTS applications.

First, because NCDC-provided maritime weather observations are subject to the presence of military and/or civilian shipping traffic and the placement of specialized buoys, there may exist a given geographic region for which insufficient observations exist upon which draw sound conclusions can be drawn. In this case hindcasting may provide, if nothing else, a guideline regarding expected sea state conditions.

The second, and most important, application of hindcasting for JLOTS planning focuses upon the fact that JLOTS is a littoral operation. Keeping in mind that the Marsden Squares in which maritime weather observations are recorded are ten-degree by ten-degree boxes, the observations contained in those boxes could be relatively far away from the site of the proposed JLOTS operation. Additionally, because Marsden Square subdivisions are one-degree by one-degree boxes, observations from within the same subdivision could still be as much as 60 nm away from the proposed JLOTS operating area. This problem, in conjunction with the fact that many merchant vessels do not make weather observation reports when within five miles of land, creates a situation whereby the number of available littoral wave height observations may be limited. Hindcasting serves not only to alleviate this problem, but also emerges as the best means of fully capturing the effects of the off-shore swell component on littoral region wave height.

V. SUMMARY AND CONCLUSIONS

A. ASSESSMENT OF MEETING STATED OBJECTIVES

In addition to providing the forum for both the presentation of a problem and the proposal of a viable solution technique, this thesis had several milder objectives as well. Initially, it attempted to provide an in-depth overview of the strategic, tactical, and administrative nature of JLOTS operations. The intent was to clarify the conduct of JLOTS in order to provide a sufficient framework upon which to build a presentation of both our present JLOTS capability/proficiency and of the dependency of JLOTS upon sea state conditions. This physical dependency was then mathematically substantiated with an analysis of the manner in which wave height and swell combine to determine sea state conditions within the littoral region. The final modest objective encompassed within this thesis was a profession of the learning curve which JLOTS analytical researchers have been climbing in recent years regarding the realism of their throughput models. In this context, realism refers to the proper incorporation of sea state data, and its degrading impact upon throughput, within those models.

Without question, the JOTE model by LMI is the most encompassing JLOTS throughput model presently available. JOTE, however, is not without limitations and shortfalls. Consequently, the primary objectives of this thesis focused solely upon advancing JOTE forward toward becoming a JLOTS planning tool, usable by those who need it most, namely, the JLOTS commanders and their staffs. With this in mind, this thesis focused upon achieving the following goals.

First and foremost, it was designed to fulfill the needs of clientele, namely, the Joint Staff J-4, OPNAV N-42, and LMI. The model validation contained herein attempted to critique JOTE in terms of the accuracy and efficiency of its methodologies, the optimality of its results, and the computational burdens it placed upon the user. Hopefully, the results of this validation will become design specifications in a future version of JOTE. If such a revision is not possible due to funding constraints or otherwise, it is hoped that the overview of requisite user computations and the observed shortfalls and limitations of JOTE be documented in the form of a user's guide to accompany JOTE upon its distribution to the tactical commander level.

Second, and perhaps more importantly, this thesis built upon its assertion of the criticality of sea state conditions to JLOTS operations with the development of a software package designed to supplement the JOTE model. This application, entitled SEA_STATE_CALC, is designed to compute JOTE's most crucial input parameter, the spreadsheet cell O-38 entry, in a completely automated format requiring minimal user interaction. This cell entry was itself properly redefined during the model validation portion of this thesis to represent the percentage of time sea state conditions equal or exceed Sea State Two.

Admittedly, an even larger increase in the accuracy of the results obtained from JOTE could be realized by redefining the spreadsheet cell O-38 entry to be the percentage of time sea state conditions equal or exceed a predetermined wave height amidst the Sea State Two region, such as 2.0 ft. Defining spreadsheet cell O-38 in this manner would eliminate any superfluous conservatism associated with a definition which begins at the start of the Sea State Two region (wave heights of 1.4 ft.) The JOTE model, however, is constructed upon throughput parameters and planning factors collected from a multitude of sources, all of which are constructed in the general terms of sea state rather than the specific terms of wave height. Consequently, while the SEA_STATE_CALC package can be easily modified to reflect this proposal, it would offer no benefit to the present version of JOTE. Indeed, in keeping with the increasing awareness for the importance of sea state conditions upon JLOTS operations, not only must JLOTS throughput models become more site and time specific, but the precision of data collection techniques used in building those models must also increase.

The objective of the SEA_STATE_CALC package is to supplement JOTE in its present form and thereby render it to be an immediate planning tool for the JLOTS commander. In this manner, the SEA_STATE_CALC supplement affords JOTE the most significant attribute which it was previously lacking, namely, site and time specificity. Regardless of the course of action taken concerning any of the results of the JOTE model validation presented within this thesis, the SEA_STATE_CALC package is immediately viable as a JOTE supplement since both it and JOTE are constructed in Visual Basic and are executed in Microsoft Excel 5.0.

The final objective of this thesis focused upon heightening the awareness of the JLOTS community to the various data collection and analytical research facilities specializing in weather databases, wave height, and sea state research from which the JLOTS commander could acquire vital planning information. Here, an important distinction between agencies must be understood for it clarifies the type of contribution each agency makes to the problem of JLOTS throughput planning. From NCDC, JLOTS commanders can obtain raw data observations which, upon receipt of the SEA_STATE_CALC package, can be processed at the staff level. From agencies such as NAVOCEANO and WES, however, completed site and time specific climatological and/or oceanographic studies potentially can be obtained.

Two years ago, an outsider could have claimed that the most significant problem facing the JLOTS analytical research community was realizing the significance of sea state conditions upon JLOTS throughput operations. One year ago, the same outsider could have claimed that the most significant problem facing this community was properly incorporating sea state conditions into JLOTS throughput models. Today, the same outsider could claim that the most auspicious problem for this community is realizing what agencies can offer assistance and how to request it. Hopefully, this same outsider would view the SEA_STATE_CALC package as a step in the right direction for improving JLOTS throughput planning.

B. FOLLOW-ON RESEARCH EFFORTS

From the standpoint of the clientele for whom this work was performed, the follow-on efforts have been made very clear in the preceding section. For a future thesis researcher, however, writing the ARRANGE_DATA module of the SEA_STATE_CALC package in Visual Basic would be a suitable undertaking. This would eliminate the need for the user to possess both Microsoft Excel 5.0 and Borland Turbo Pascal 1.5 on his/her PC.

APPENDIX A. THROUGHPUT DEGRADATIONS IN SEA STATE III

The multiple figures contained within this appendix illustrate the profound sea state dependence of both containerized and vehicular cargo off-load during JLOTS operations. Figures 24 through 26 provide a chronological synopsis of the throughput levels attained during the discharge phase of OV93. These figures indicate that after the initial startup (the first day) of discharge operations, the majority of instances of low throughput of both containers and vehicles were consistent with the periods of highest sea state. Figures 27 through 29 then demonstrate that the overall ability to conduct JLOTS operations (as measured by achieved throughput) has noticeably diminished over the ten year period between the JLOTS II and JLOTS III exercises. Although multiple factors such as decreased training exercises and increased safety concerns have contributed to this productivity decrease, the fact remains that during this same ten year period all CINCs collectively professed that Sea State Three operating capabilities were an essential need.

The final, and perhaps most important, conclusion to be drawn from the figures of this appendix is that significant reductions in throughput do occur well before Sea State Three conditions are observed. Hence, the ability to include predictions of the expected sea state conditions in a given geographic region into the planning of a JLOTS operation is crucial to the success of that operation.

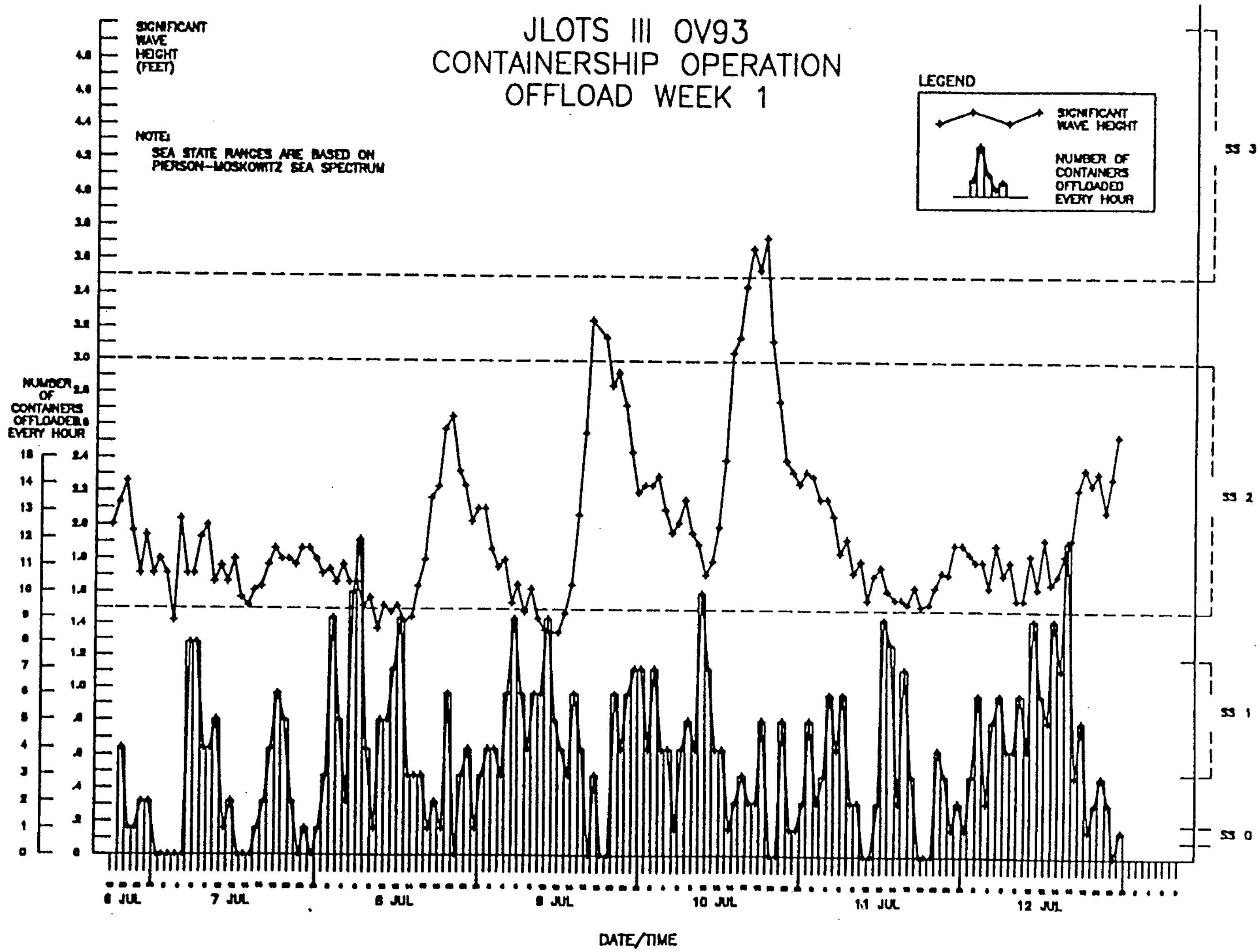

Figure 24. JLOTS III OV93 Containership Operation Off-load Week 1, From Ref. [22:p. 7].

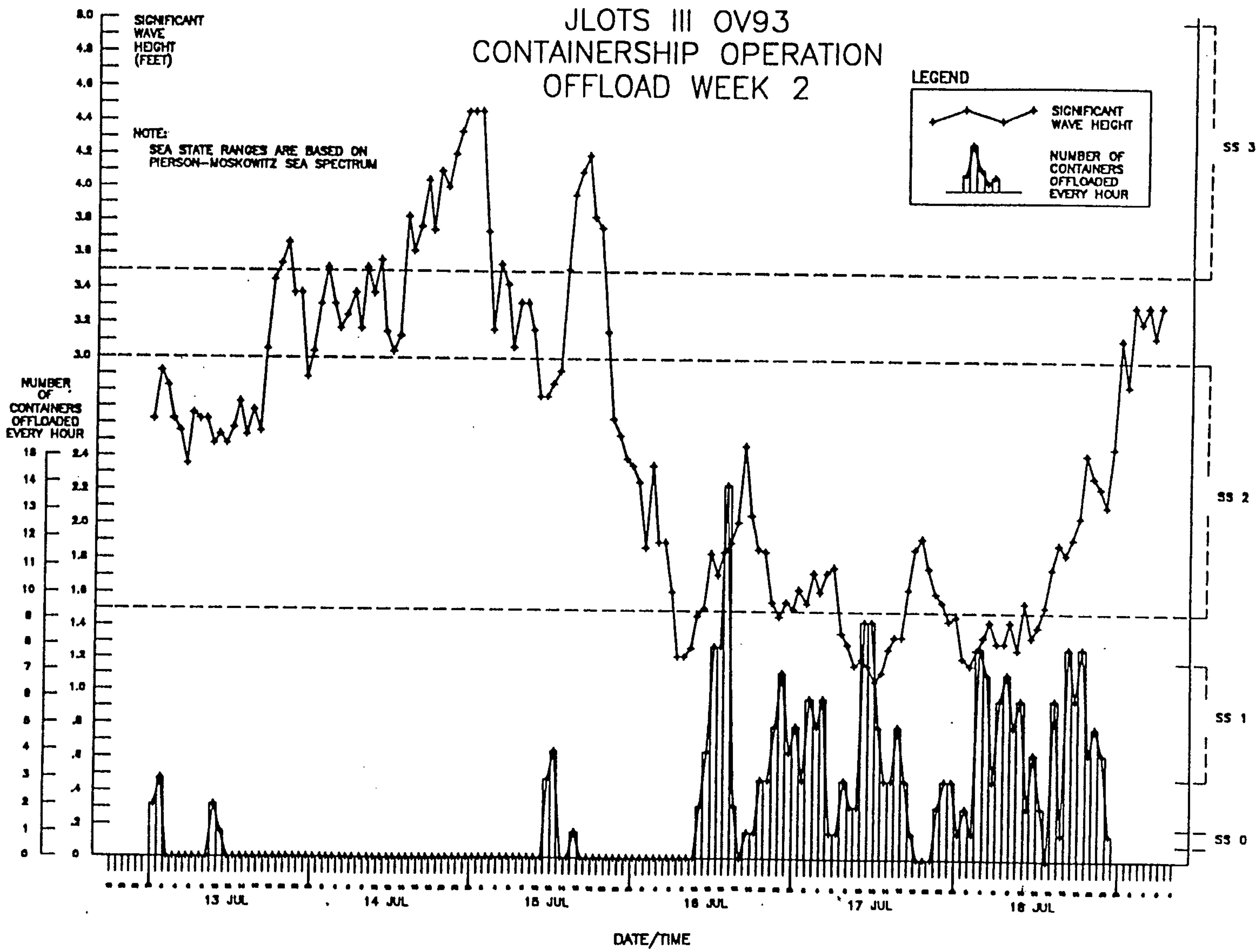

Figure 25. JLOTS III OV93 Containership Operation Off-load Week 2, From Ref. [22:p. 8].

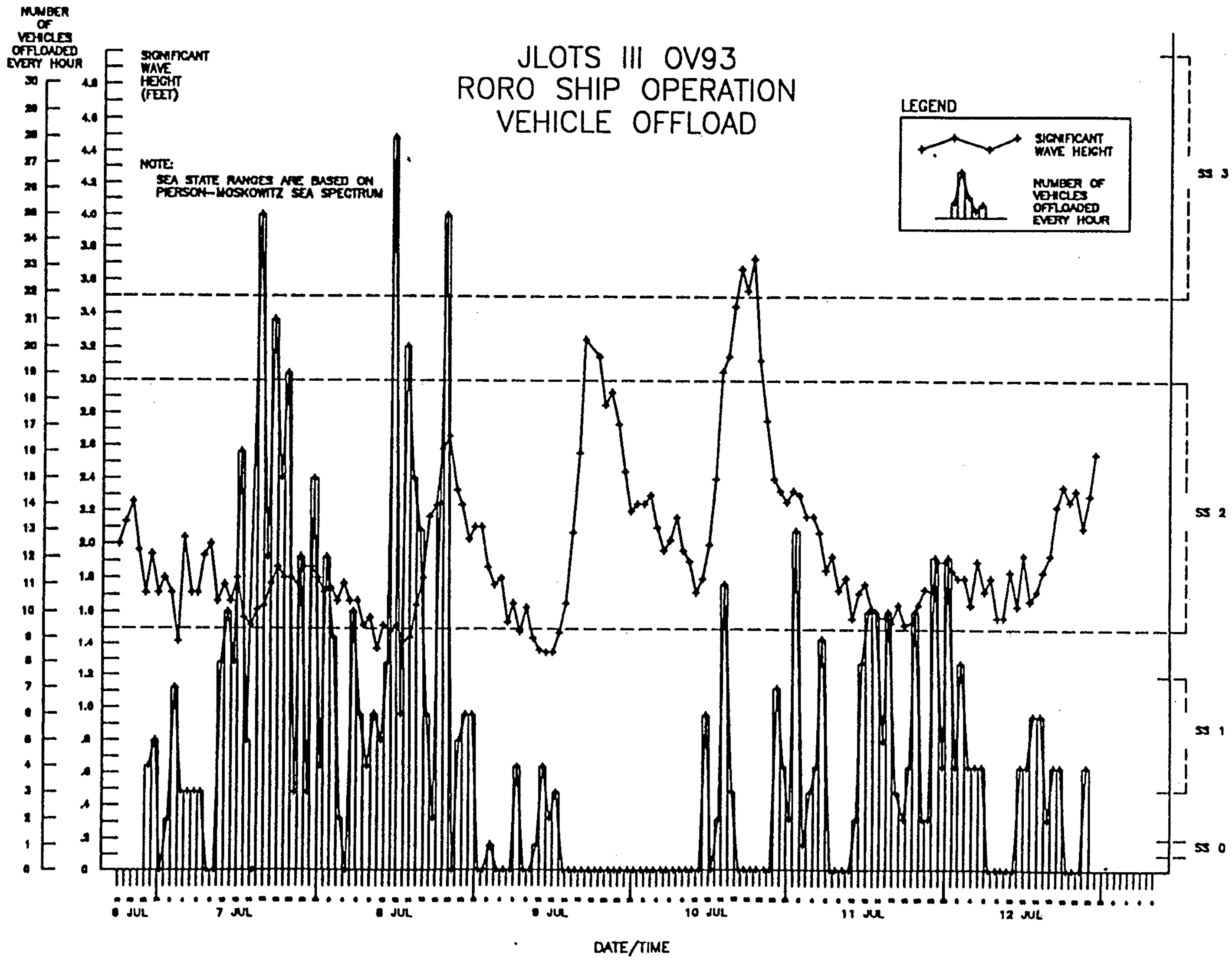

Figure 26. JLOTS III OV93 RO/RO Operation Vehicle Off-load, From Ref. [22:p. 9].

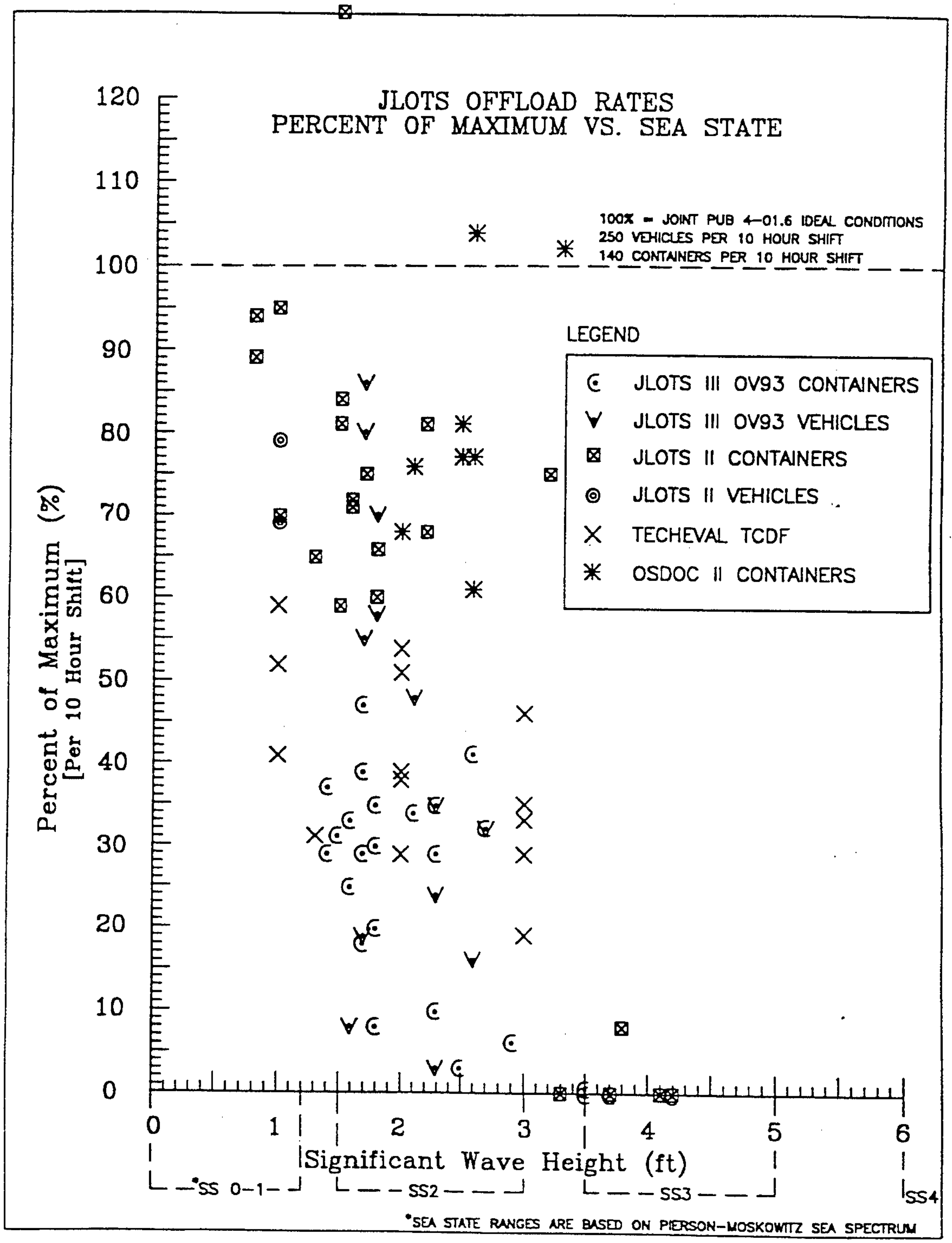

Figure 27. JLOTS Off-load Rates --- Percent of Maximum Versus Sea State, From Ref. [22:p. 3].

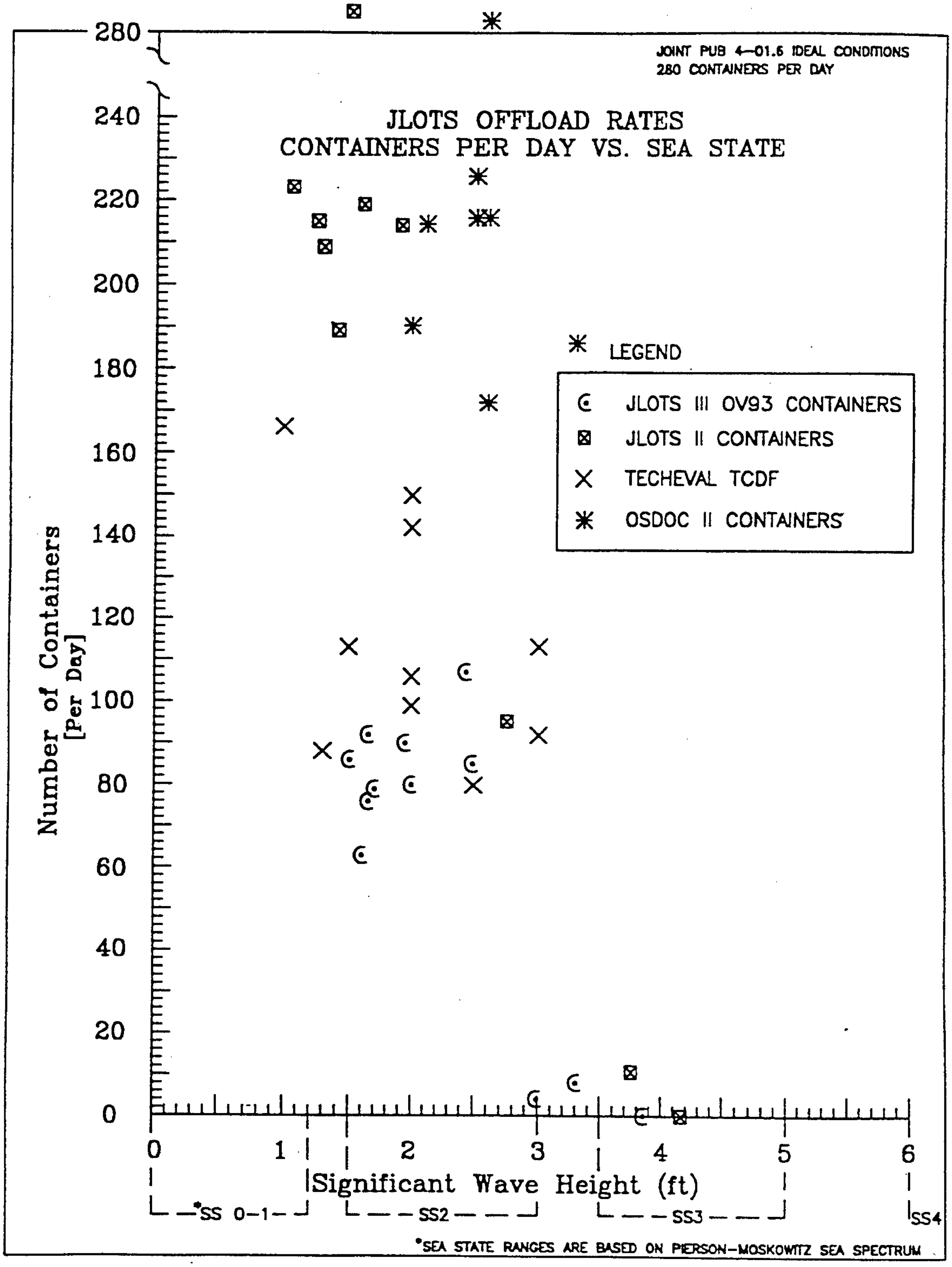

Figure 28. JLOTS Off-load Rates --- Containers Per Day Versus Sea State, From Ref. [22:p. 4].

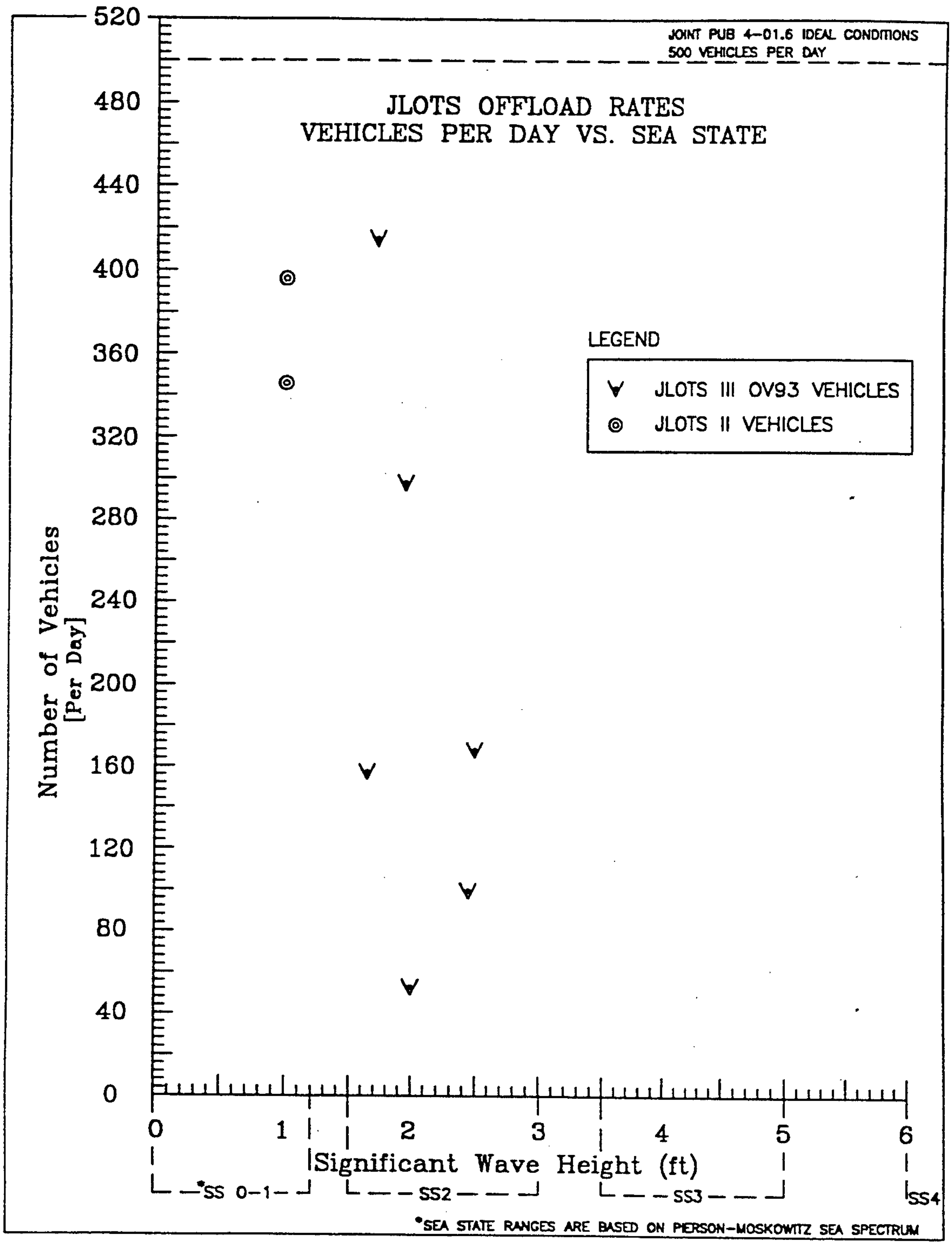

Figure 29. JLOTS Off-load Rates --- Vehicles Per Day Versus Sea State, From Ref. [22:p. 5].

APPENDIX B. LIGHTER MODEL EXCERPTS

Base Case Data (Extracted From Lighter Spreadsheet)

ENVIRONMENTAL DATA	Value
Wave Height (Wind Wave + Swell) (ft)	0.00
Distance Ship-to-Shore (n/m)	2.00
ELCAS Length	3000
ELCAS Erection Rate (ft/day)	440
Preparation Time (days)	5

CAUSEWAY FERRY DATA (3 CSNP + 1 CSP)		Units/Hr
Average Operating Speed (kts)	3.00	
Daily Downtime (hrs)	4.00	
Capacity - RO/RO (sqft)	5292.00	
Capacity - Pallets	240.00	
Capacity - TEU	26.00	
Load Time - RO/RO (hrs)	2.09	22.00
Load Time - Pallets (hrs)	12.00	20.00
Load Time - TEU (hrs)	8.67	3.00
Discharge Time - RO/RO (hrs)	0.77	60.00
Discharge Time - Pallets (hrs) ELCAS	15.00	16.00
Discharge Time - Pallets (hrs) Beach	6.67	36.00
Discharge Time - TEU (hrs) ELCAS	3.25	8.00
Discharge Time - TEU (hrs) Beach	1.30	20.00
Cargo delivered/day - RO/RO (sqft)	25248	100.00%
Cargo delivered/day - Pallets (ELCAS)	169	100.00%
Cargo delivered/day - Pallets (Beach)	240	100.00%
Cargo delivered/day - TEU (ELCAS)	39	100.00%
Cargo delivered/day - TEU (Beach)	46	100.00%

LCU DATA		Units/Hr
Average Operating Speed (kts)	7.00	
Daily Downtime (hrs)	4.00	
Capacity - RO/RO (sqft)	1700.00	
Capacity - Pallets	216.00	
Capacity - TEU	4.00	
Load Time - RO/RO (hrs)	1.23	12.00
Load Time - Pallets (hrs)	10.80	20.00
Load Time - TEU (hrs)	0.67	6.00
Discharge Time - RO/RO (hrs)	0.30	50.00
Discharge Time - Pallets (hrs) ELCAS	13.50	16.00
Discharge Time - Pallets (hrs) Beach	6.00	36.00
Discharge Time - TEU (hrs) ELCAS	0.60	6.67
Discharge Time - TEU (hrs) Beach	0.60	6.67
Cargo delivered/day - RO/RO (sqft)	16198	100.00%
Cargo delivered/day - Pallets (ELCAS)	174	100.00%
Cargo delivered/day - Pallets (Beach)	249	100.00%
Cargo delivered/day - TEU (ELCAS)	44	100.00%
Cargo delivered/day - TEU (Beach)	44	100.00%

LCM DATA		Units/Hr
Average Operating Speed (kts)	7.00	
Daily Downtime (hrs)	4.00	
Capacity - RO/RO (sqft)	464.00	
Capacity - Pallets	40.00	
Capacity - TEU	1.00	
Load Time - RO/RO (hrs)	0.34	12.00
Load Time - Pallets (hrs)	4.00	10.00
Load Time - TEU (hrs)	0.33	3.00
Discharge Time - RO/RO (hrs)	0.08	50.00
Discharge Time - Pallets (hrs) ELCAS	2.50	16.00
Discharge Time - Pallets (hrs) Beach	1.11	36.00
Discharge Time - TEU (hrs) ELCAS	0.15	6.67
Discharge Time - TEU (hrs) Beach	0.15	6.67
Cargo delivered/day - RO/RO (sqft)	9389	100.00%
Cargo delivered/day - Pallets (ELCAS)	113	100.00%
Cargo delivered/day - Pallets (Beach)	141	100.00%
Cargo delivered/day - TEU (ELCAS)	19	100.00%
Cargo delivered/day - TEU (Beach)	19	100.00%

FACILITY THROUGHPUT FACTORS (per day)		Max Units/Hr
RORO Discharge Facility (sqft)	50600	22
Lo/Lo Station (pallets)	200	10
Lo/Lo Station (TEU)	60	3
ELCAS (pallets)	320	16
ELCAS (TEU)	160	8
Beach Site - RO/RO (sqft)	138000	60
Beach Site (pallets)	520	26
Beach Site (TEU)	400	20
Operating Hours/24 Hour Period		20

Selected Lighter Model Output

Tables 24 and 25 represent a synopsis of the lighterage combinations evaluated in the McCaffery & Whitener, Inc. JLOTS study. Additionally, Figures 27 through 29 summarize the results obtained for the lighterage combinations comprising Cases 1 through 4, while Figures 30 and 31 illustrate the results obtained from Cases 1A through 3A. The distinctions between Cases 1 & 1A, 2 & 2A, and 3 & 3A are outlined as follows:

Case 1 vs. 1A

Case 1A analyzes the same lighterage combination as Case 1, without the use of the ELCAS (M).

Case 2 vs. 2A

Case 2A differs from Case 2 only by eliminating the use of the LCAC.

Case 3 vs. 3A

Cases 3 & 3A expand upon Case 2 & 2A by including the LCU-2000. Case 3 deletes the LSV while Case 3A deletes the LCAC.

	CASE 1	CASE 2	CASE 3	CASE 4
ELCAS (M)	2	2	2	3
CAUSEWAY FERRIES (3+1)	16	None	None	None
ACBL (2+1)	None	16	16	48
LCU 1600	5	None	None	None
LCM 8	4	None	None	None
LSV	None	3	None	None
LCU 2000	None	None	4	16
LCAC	None	12	12	12
RRDF	2	2	2	2

Table 24. LOTS Equipment Utilized in Cases 1, 2, 3, 4 of McCaffery & Whitener, Inc. JLOTS Study, From Ref. [17].

	CASE 1A	CASE 2A	CASE 3A
ELCAS (M)	None	2	2
CAUSEWAY FERRIES (3+1)	16	None	None
ACBL (2+1)	None	16	16
LCU 1600	5	None	None
LCM 8	8	None	None
LSV	None	3	2
LCU 2000	None	None	4
LCAC	None	None	None
RRDF	2	2	2

Table 25. LOTS Equipment Utilized in Cases 1A, 2A, 3A of McCaffery & Whitener, Inc. JLOTS Study, From Ref. [17].

As discussed in Section B of Chapter II, analysis of Figures 30 through 34 suggest that the throughput degradation function employed by McCafferey & Whitener, Inc. incorrect and improperly weighted.

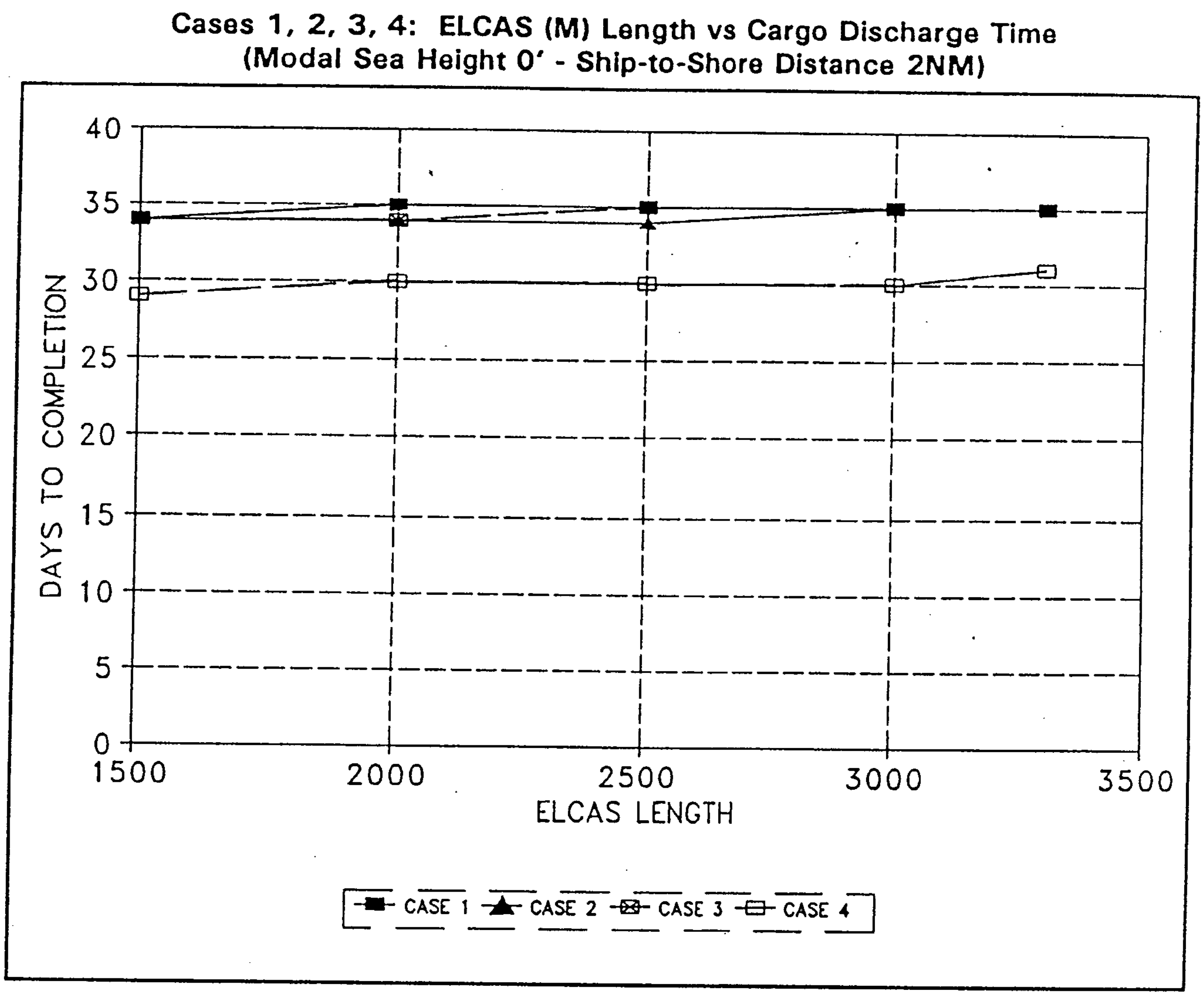

Figure 30. Cases 1, 2, 3, 4 ELCAS M Versus Cargo Discharge Time, From Ref. [17:p. 31].

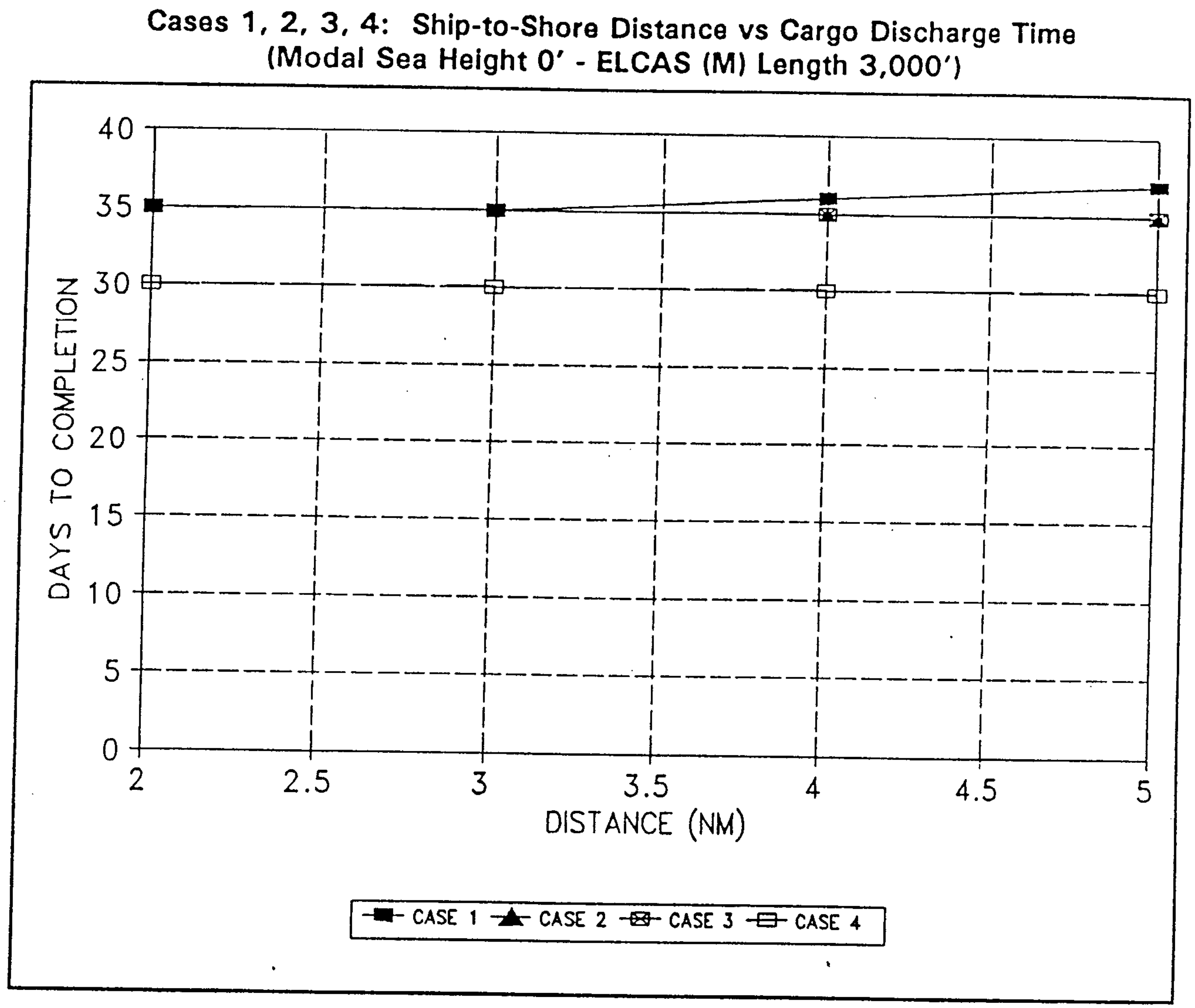

Figure 31. Cases 1, 2, 3, 4 Ship-to-Shore Distance Versus Cargo Discharge Time, From Ref. [17:p. 32].

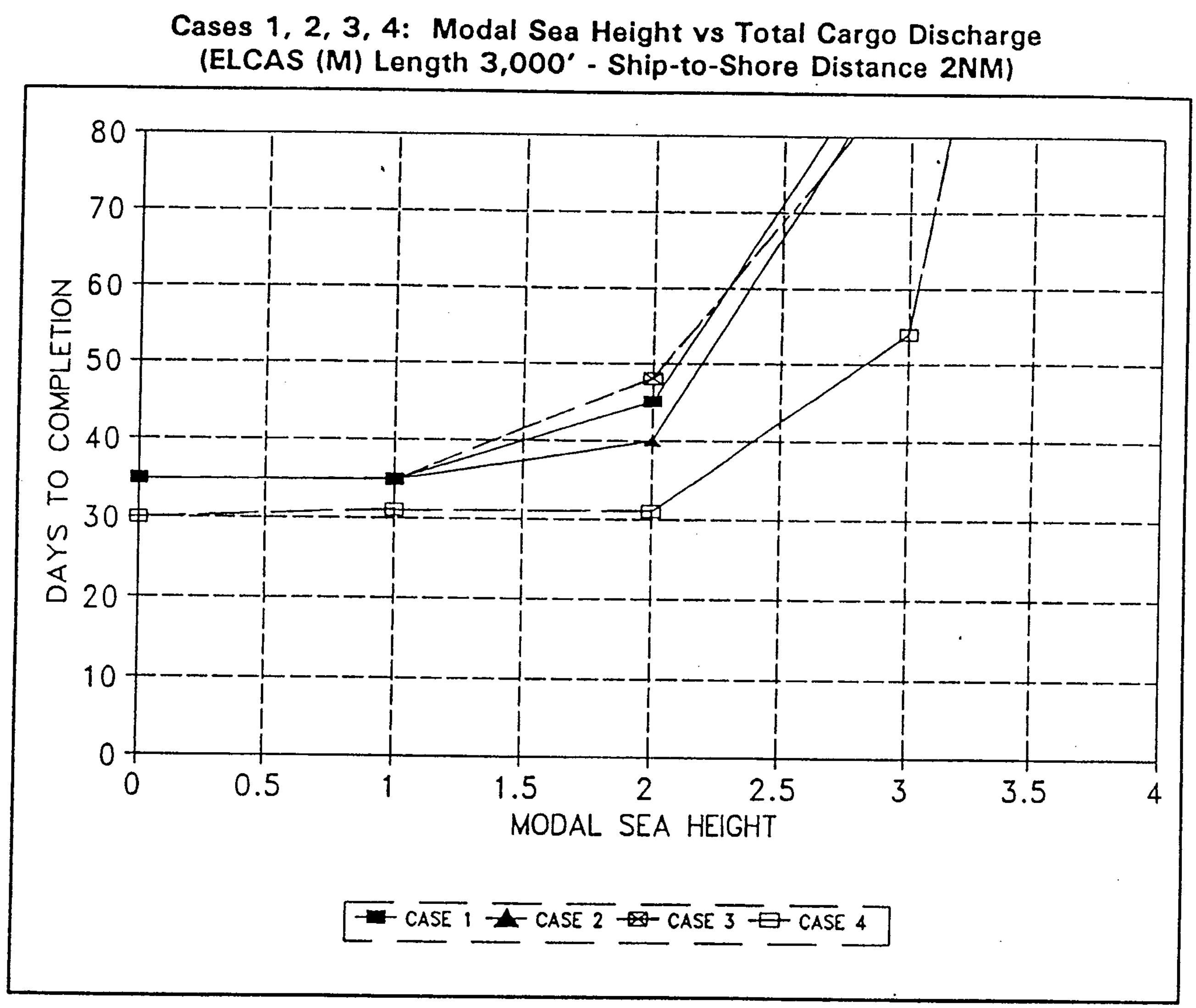

Figure 32. Cases 1, 2, 3, 4 Modal Sea Height Versus Total Cargo Discharge, From Ref. [17:p. 33].

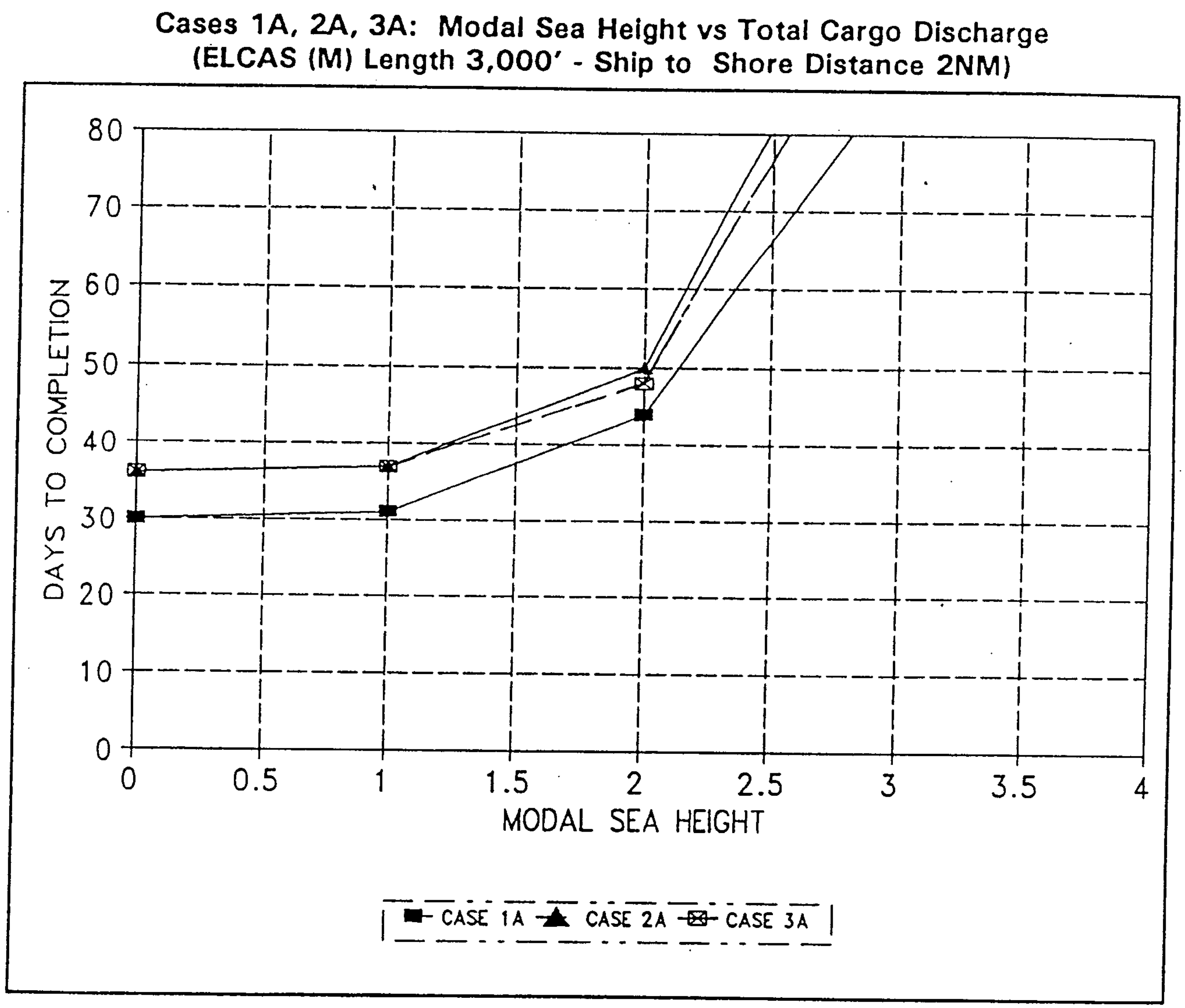

Figure 33. Cases 1A, 2A, 3A Modal Sea Height Versus Total Cargo Discharge, From Ref. [17:p. 36].

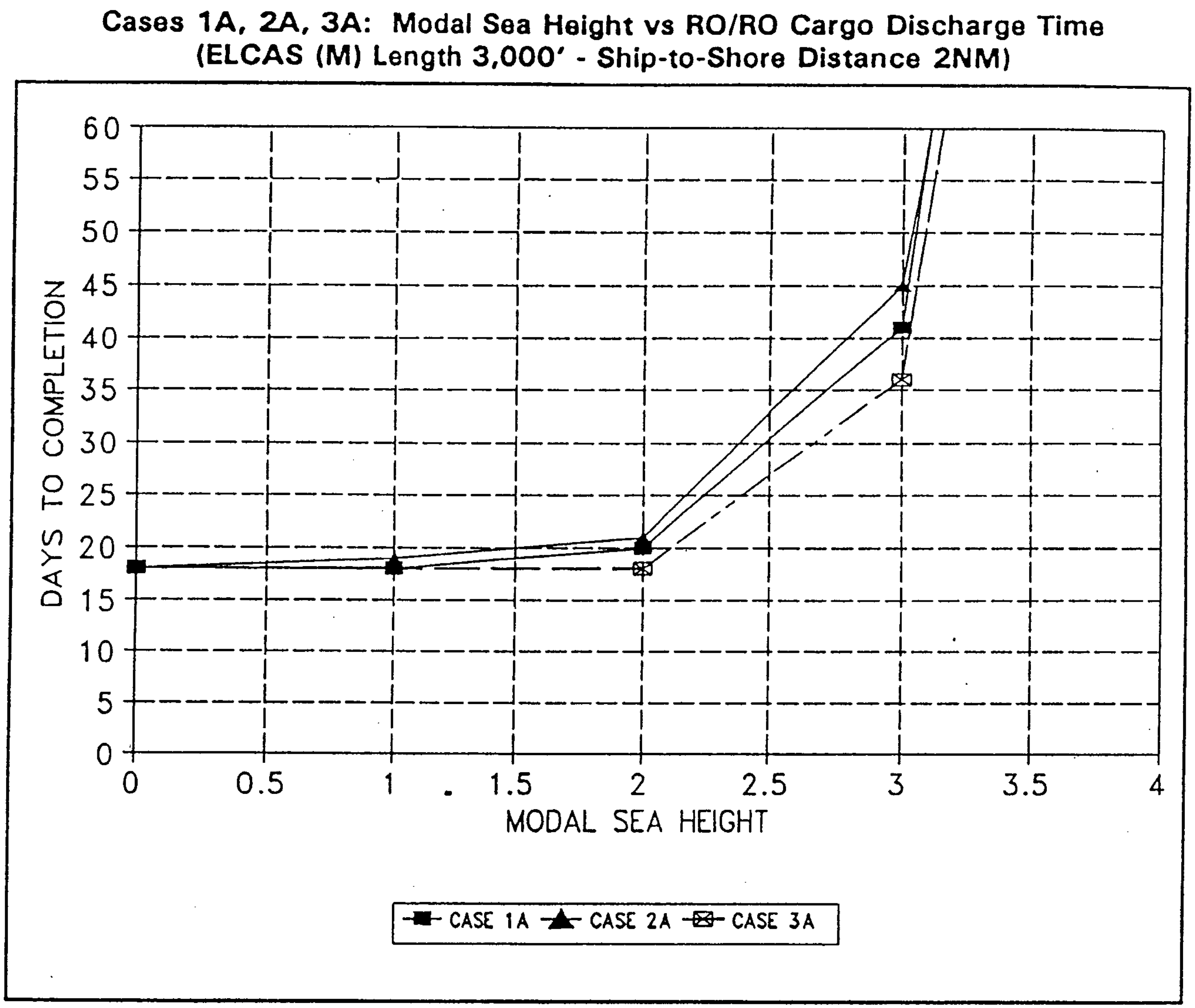

Figure 34. Cases 1A, 2A, 3A, Modal Sea Height Versus RO/RO Cargo Discharge Time, From Ref. [17:p. 37].

APPENDIX C. RESULTS OF CNA STUDIES

The contents of this appendix represent the results of the MPF Exercise Study conducted by CNA in February 1990. The relevance of these results to the efforts of this thesis is two-fold. First, they illustrate the lack of understanding of the magnitude of impact which wind, weather, and sea state conditions have upon littoral region operations which was characteristic of many analytical researchers in the early 1990s. Second, and more positively, they represent the first applications of theoretical probability distributions to cargo throughput operations within the littoral region.

Tables 26 and 27 illustrate the results of selected two sample Kolmogorov-Smirnov tests for the operations considered. These tables highlight that for many of the comparisons conducted involving FB-86 (the one and only foul weather scenario considered) a significant difference was observed among the parameters considered. Despite the prevalence of inconsistencies between the results of goodness of fit tests conducted using FB-86 data and any fair weather exercise data versus data obtained from two fair weather scenarios, CNA failed to expand the scope of their analysis to include wind, weather, or sea state as variables of examination. Table 28 reflects a summary of those variables which were examined and the respective influence upon ship-to-shore component times which they were determined to have.

This appendix concludes with Figures 35 through 39 which represent CNA's findings regarding the distributions of the components overall barge cycle time, without the influence of wind, weather and sea state conditions.

BARGE LOADING TIMES			
BARGE SIZE	**CARGO TYPE**	**MPF EXERCISES**	**SIGNIFICANTLY DIFFERENT**
1 + 1	Containers	AS-86, FB-86 AS-86, TS-88 FB-86, TS-88	No No No
1 + 1	Rolling Stock	AS-86, FB-86 AS-86, TS-88 FB-86, TS-88	Yes No No
2 + 1	Rolling Stock	AS-86, FB-87 AS-86, TS-88 FB-87, TS-88	No No No
3 + 0	Rolling Stock	FB-87, TS-88	No
3 + 1	Rolling Stock	FB-86, TS-88	No

Table 26. Kolmogorov-Smirnov Goodness of Fit Test Results for Barge Loading Times of CNA MPF Study, From Ref. [18:p. 7].

BARGE UNLOADING TIMES		
BARGE SIZE	**MPF EXERCISES**	**SIGNIFICANTLY DIFFERENT**
1 + 1	AS-86, FB-86 AS-86, OV-88 AS-86, TS-88 AS-86, FB-89 FB-86, OV-88 FB-86, TS-88 FB-86, FB-89 OV-88, TS-88 OV-88, FB-89 TS-88, FB-89	Yes No No No No No Yes No No No
2 + 1	AS-86, OV-88 AS-86, FB-89 OV-88, FB-89	No No No

Table 27. Kolmogorov-Smirnov Goodness of Fit Test Results for Barge Unloading Times of CNA MPF Study, From Ref. [18:p. 20].

COMPONENT	VARIABLES EXAMINED	VARIABLES SIGNIFICANTLY AFFECTING OVERALL BARGE CYCLE TIME
BARGE LOADING TIME	Exercise, MPF Ship Type, Barge Size, Cargo	MPF Ship Type
BARGE TRANSIT TIME	Transit Distance, Barge Size	Transit Distance
BARGE UNLOADING TIME	Exercise, Barge Size, Cargo	Cargo

Table 28. Summary of Variables Examined and Their Respective Effects on Barge Cycle Component Times in CNA MPF Study, From Ref. [18:p. 24].

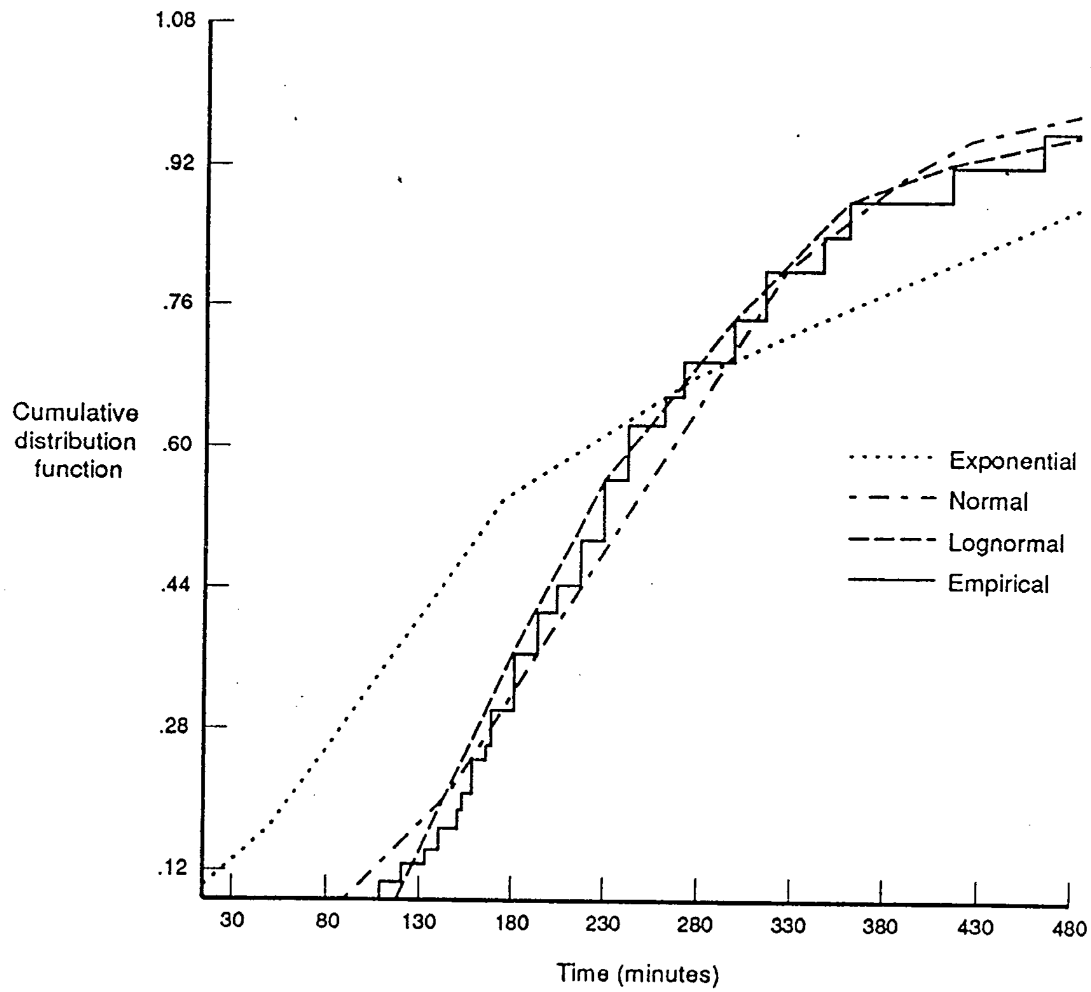

Figure 35. Theoretical and Empirical Cumulative Distribution Functions for Barge Loading Times at Maersk Ships Calculated in CNA MPF Study, Ref. [17:p. 13].

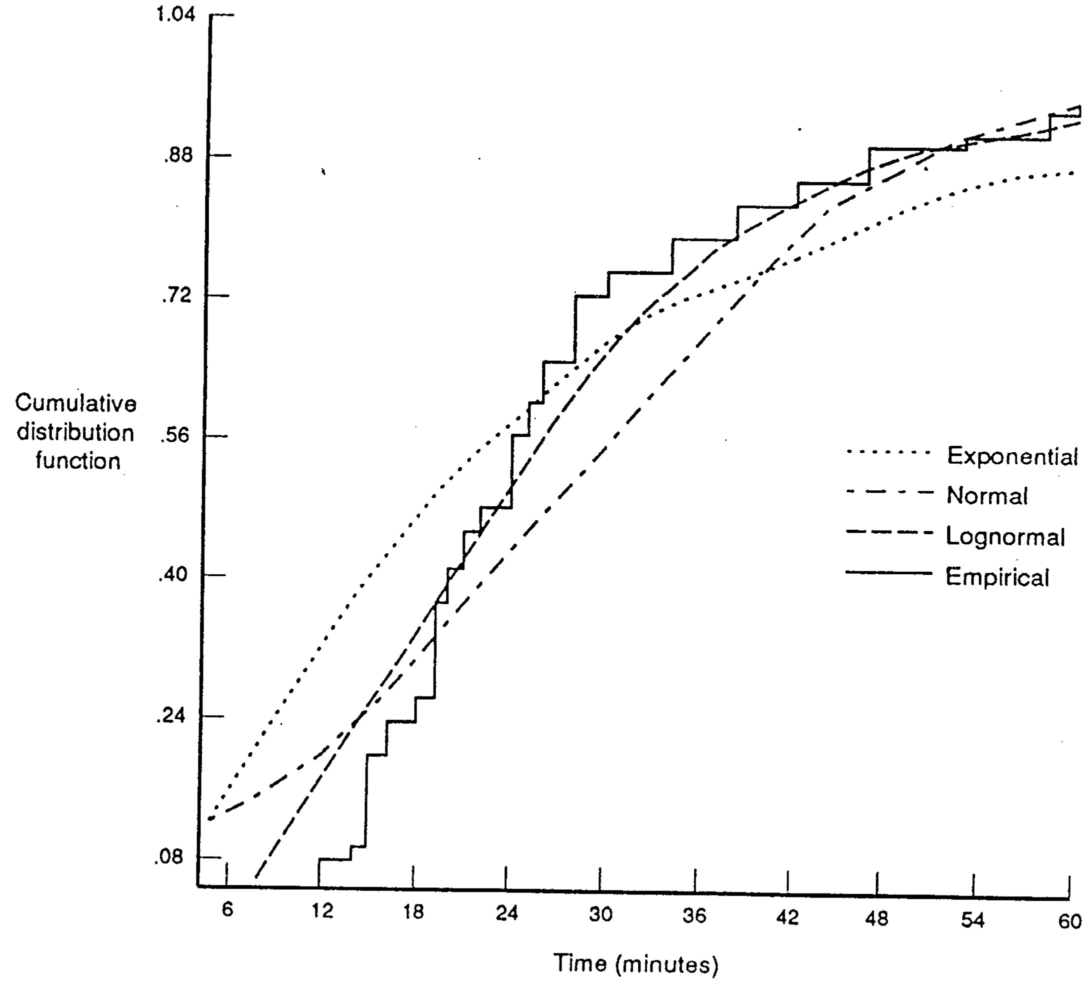

Figure 36. Theoretical and Empirical Cumulative Distribution Functions for Barge Transit Times at Freedom Banner 87 Calculated in CNA MPF Study, Ref. [17:p. 18].

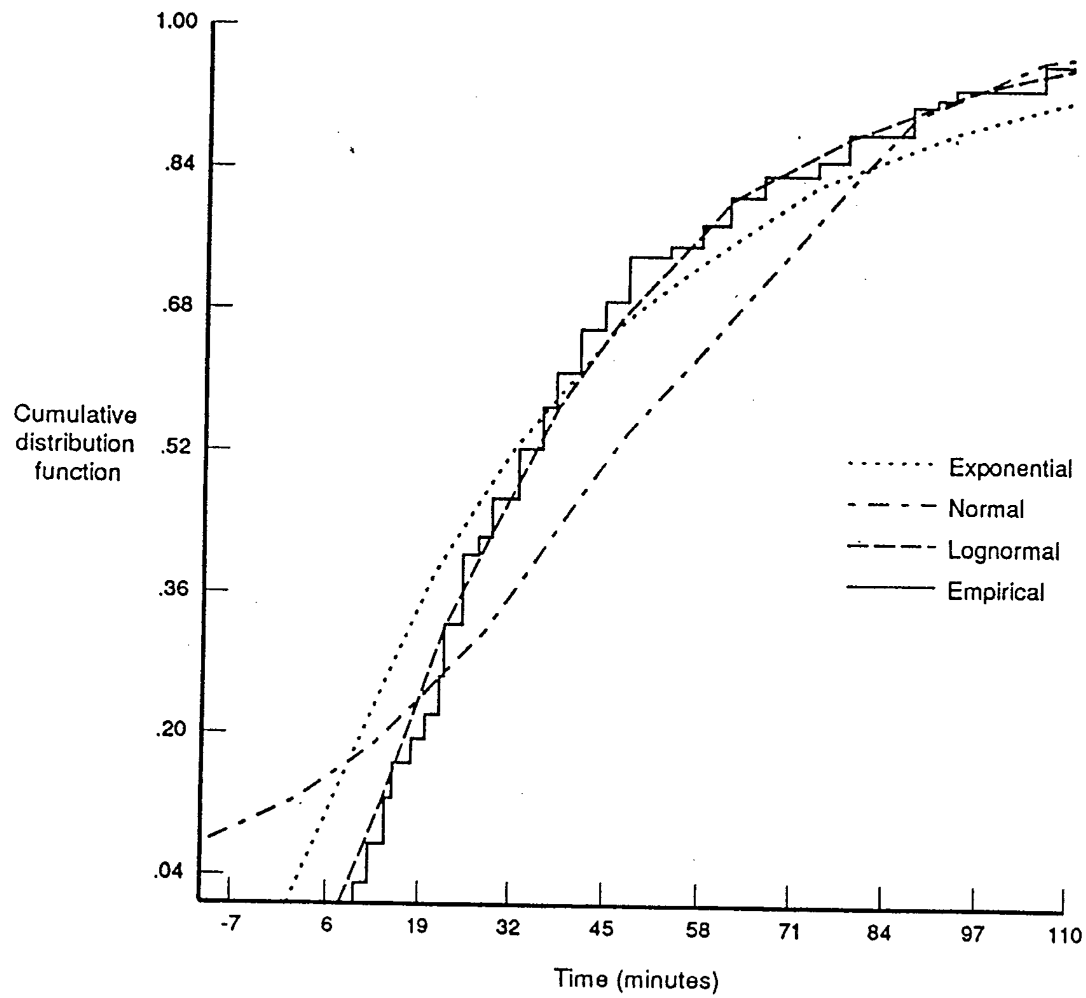

Figure 37. Theoretical and Empirical Cumulative Distribution Functions for Barge Unloading Times for Rolling Stock Calculated in CNA MPF Study, Ref. [17:p. 23].

APPENDIX D. JOTE MODEL THROUGHPUT RESULTS

The entirety of this appendix is devoted to the throughput results obtained from the JOTE model for four independent simulations of the OV93 JLOTS exercise. For each of the four scenarios, all input parameters were identical with the exception of the spreadsheet cell O-38 entry which was redefined to represent the percentage of time sea state conditions equaled or exceeded Sea State Two for geographic region in question (Fort Story, VA). The specific cell O-38 entries used were: 40.00%, 59.08%, 60.00%, and 72.61%. Because JOTE is designed to be executed each day as a means of calculating the expected throughput for the following day, throughput results are displayed for each day of each scenario commencing with 7 July 1993 (the first day of cargo discharge during OV93) and extending until all cargo has been moved from ship to shore on every discharge lane.

The start/stop times for cargo discharge operations from each of the four strategic sealift assets, as well as the types, quantities, and sequencing of lighterage assignments shown in tabular format for each operating day, form the basis for the model validation presented in Chapter III. Additionally, because two of the four spreadsheet cell O-38 entries employed in the JOTE model validation were obtained from the SEA_STATE_CALC package, the precision with which the results contained in this appendix for those scenarios correspond to the actual throughput operations of OV93 serves not only to validate JOTE but also quantifies the degree of enhancement realized by employing SEA_STATE_CALC as a supplement to JOTE.

40% Sea State ≥ 2

7 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	3310
RRDF-veh	3310
LO/RO-veh	3107
LO/RO-veh	3107
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	2	0	0	0	552	1,134	8	(0)	1,134
2	0	0	0	0	2	0	0	0	552	1,134	8	(0)	1,134
3	0	0	0	0	2	0	0	0	552	1,134	8	(0)	1,134
4	0	0	0	0	0	0	0	0	0	0	20	12	(0)
5	0	0	0	0	0	0	0	0	0	0	20	12	(0)
6	0	0	0	0	0	0	0	0	0	0	20	12	(0)
7	0	0	0	2	0	0	0	0	880	2,430	8	(0)	2,430
8	0	0	7	0	0	0	0	0	790	2,520	8	(0)	2,520
9	0	0	0	1	0	0	0	0	644	2,463	8	0	2,463
10	0	0	0	1	0	0	1	0	996	2,111	8	0	2,111
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	(0)
13	0	0	0	0	0	0	0	0	0	0	20	12	(0)

8 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1134
LO/LO-cont	1134
LO/LO-cont	1134
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2430
RRDF-veh	2520
LO/RO-veh	2463
LO/RO-veh	2111
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	2	0	0	0	552	582	8	(0)	582
2	0	0	0	0	2	0	0	0	552	582	8	(0)	582
3	0	0	0	0	2	0	0	0	552	582	8	(0)	582
4	0	0	0	0	0	0	0	0	0	0	20	12	(0)
5	0	0	0	0	0	0	0	0	0	0	20	12	(0)
6	0	0	0	0	0	0	0	0	0	0	20	12	(0)
7	0	0	0	2	0	0	0	0	880	1,550	8	(0)	1,550
8	0	0	7	0	0	0	0	0	790	1,730	8	(0)	1,730
9	0	0	0	1	0	0	0	0	644	1,819	8	0	1,819
10	0	0	0	1	0	0	1	0	996	1,115	8	0	1,115
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	(0)
13	0	0	0	0	0	0	0	0	0	0	20	12	(0)

9 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	582
LO/LO-cont	582
LO/LO-cont	582
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1550
RRDF-veh	1730
LO/RO-veh	1819
LO/RO-veh	1115
RRDF-track	0
RRDF-track	0
LO/RO-veh	7151

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	2	0	0	0	552	30	8	0	30
2	0	0	0	0	2	0	0	0	552	30	8	0	30
3	0	0	0	0	2	0	0	0	552	30	8	0	30
4	0	0	0	0	(0)	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	7	0	0	0	0	0	790	760	8	(0)	760
8	0	0	4	1	0	0	0	0	827	903	8	0	903
9	0	0	0	1	0	0	1	0	996	823	8	0	823
10	0	0	0	1	0	0	0	0	644	471	8	0	471
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	(0)
13	0	0	0	1	0	0	0	0	644	6,507	8	(0)	6,507

10 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	30
LO/LO-cont	30
LO/LO-cont	30
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	760
RRDF-veh	903
LO/RO-veh	823
LO/RO-veh	471
RRDF-track	0
RRDF-track	2924
LO/RO-veh	6507

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	30	0	19	11	0
2	0	0	0	0	0	0	0	0	30	0	19	11	0
3	0	0	0	0	0	0	0	0	30	0	19	11	0
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	5	0	1	0	0	0	760	0	8	0	(0)
8	0	0	6	0	0	0	0	0	799	104	8	0	104
9	0	0	0	1	0	0	1	0	823	0	8	0	0
10	0	0	4	0	0	0	0	0	471	0	9	1	0
11	0	0	0	0	0	0	0	0	0	0	20	12	0
12	0	11	0	4	0	0	0	0	2,924	0	8	(0)	0
13	0	0	0	1	0	0	1	0	818	5,689	8	0	5,689

11 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	104
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	2924
RRDF-track	0
LO/RO-veh	5689

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	(0)	0	0	0	0	0	0	20	12	0
2	0	0	0	(0)	0	0	0	0	0	0	20	12	0
3	0	0	0	(0)	0	0	0	0	0	0	20	12	0
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	(0)
8	0	0	0	0	0	0	0	0	104	0	19	11	0
9	0	0	0	0	0	0	0	0	0	0	20	12	(0)
10	0	0	0	(0)	0	0	0	0	0	0	20	12	0
11	0	0	0	5	0	0	0	0	2,924	0	9	1	0
12	0	0	0	(0)	0	0	0	0	0	0	20	12	0
13	0	0	0	1	0	0	1	0	996	4,693	8	(0)	4,693

12 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4693

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	(0)
8	0	0	0	(0)	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	1	0	0	1	0	996	3,697	8	0	3,697

13 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3697

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	(0)
8	0	0	0	(0)	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	1	0	0	1	0	996	2,701	8	0	2,701

14 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	2701

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	(0)
8	0	0	0	(0)	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	1	0	0	1	0	996	1,705	8	0	1,705

15 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	1705

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	(0)
8	0	0	0	(0)	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	(0)
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	1	0	0	1	0	996	709	8	0	709

16 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	709

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	0
8	0	0	0	0	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	0
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	0	0	0	1	0	709	0	13	5	(0)

17 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	0	0	0	0	0	0	20	12	0
5	0	0	0	0	0	0	0	0	0	0	20	12	0
6	0	0	0	0	0	0	0	0	0	0	20	12	0
7	0	0	0	0	0	0	0	0	0	0	20	12	0
8	0	0	0	0	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	0
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	0	0	0	1	0	0	0	20	12	(0)

18 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	760
LO/LO-cont	760
LO/LO-cont	761
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	(0)
2	0	0	0	0	0	0	0	0	0	0	20	12	(0)
3	0	0	0	0	0	0	0	0	0	0	20	12	(0)
4	0	0	0	0	1	0	2	0	672	88	8	(0)	88
5	0	0	0	0	2	0	0	0	552	208	8	(0)	208
6	0	0	0	0	2	0	0	0	552	209	8	(0)	209
7	0	0	0	0	0	0	0	0	0	0	20	12	0
8	0	0	0	0	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	0
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	0	0	0	0	0	0	0	20	12	0

19 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	88
LO/LO-cont	208
LO/LO-cont	209
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	12	0
2	0	0	0	0	0	0	0	0	0	0	20	12	0
3	0	0	0	0	0	0	0	0	0	0	20	12	0
4	0	0	0	0	0	0	0	0	88	0	18	10	0
5	0	0	0	1	0	0	0	0	208	0	15	7	(0)
6	0	0	0	1	0	0	0	0	209	0	15	7	(0)
7	0	0	0	0	0	0	0	0	0	0	20	12	0
8	0	0	0	0	0	0	0	0	0	0	20	12	0
9	0	0	0	0	0	0	0	0	0	0	20	12	0
10	0	0	0	0	0	0	0	0	0	0	20	12	0
11	0	0	0	0	0	0	0	0	0	0	20	12	0
12	0	0	0	0	0	0	0	0	0	0	20	12	0
13	0	0	0	0	0	0	0	0	0	0	20	12	0

59.08% Sea State ≥ 2

7 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	3310
RRDF-veh	3310
LO/RO-veh	3107
LO/RO-veh	3107
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	376	1,310	12	(0)	1,310
2	0	0	0	0	1	0	0	0	376	1,310	12	(0)	1,310
3	0	0	0	0	1	0	0	0	376	1,310	12	(0)	1,310
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	(0)
6	0	0	0	0	0	0	0	0	0	0	20	8	(0)
7	0	0	0	1	0	0	0	0	600	2,710	12	(0)	2,710
8	0	0	0	1	0	0	0	0	600	2,710	12	(0)	2,710
9	0	0	0	1	0	0	0	0	439	2,668	12	(0)	2,668
10	0	0	0	0	0	0	1	0	791	2,316	12	0	2,316
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	(0)
13	0	0	0	0	0	0	0	0	0	0	20	8	(0)

8 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1310
LO/LO-cont	1310
LO/LO-cont	1310
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2710
RRDF-veh	2710
LO/RO-veh	2668
LO/RO-veh	2316
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	376	934	12	(0)	934
2	0	0	0	0	1	0	0	0	376	934	12	(0)	934
3	0	0	0	0	1	0	0	0	376	934	12	(0)	934
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	(0)
6	0	0	0	0	0	0	0	0	0	0	20	8	(0)
7	0	0	0	1	0	0	0	0	600	2,110	12	(0)	2,110
8	0	0	0	1	0	0	0	0	600	2,110	12	(0)	2,110
9	0	0	0	1	0	0	0	0	439	2,229	12	(0)	2,229
10	0	0	0	0	0	0	1	0	791	1,525	12	0	1,525
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	(0)
13	0	0	0	0	0	0	0	0	0	0	20	8	(0)

9 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	934
LO/LO-cont	934
LO/LO-cont	934
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2110
RRDF-veh	2110
LO/RO-veh	2229
LO/RO-veh	1525
RRDF-track	0
RRDF-track	0
LO/RO-veh	7151

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	376	558	12	0	558
2	0	0	0	0	1	0	0	0	376	558	12	0	558
3	0	0	0	0	1	0	0	0	376	558	12	0	558
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	3	1	0	0	0	0	565	1,545	12	(0)	1,545
8	0	0	0	1	0	0	0	0	600	1,510	12	0	1,510
9	0	0	0	1	0	0	0	0	439	1,790	12	0	1,790
10	0	0	0	1	0	0	0	0	439	1,086	12	(0)	1,086
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	6,360	12	0	6,360

10 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	558
LO/LO-cont	558
LO/LO-cont	558
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1545
RRDF-veh	1510
LO/RO-veh	1790
LO/RO-veh	1086
RRDF-track	0
RRDF-track	2924
LO/RO-veh	6360

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	376	182	12	0	182
2	0	0	0	0	1	0	0	0	376	182	12	0	182
3	0	0	0	0	1	0	0	0	376	182	12	0	182
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	5	0	0	0	0	0	539	1,006	12	(0)	1,006
8	0	0	5	0	0	0	0	0	539	971	12	0	971
9	0	0	0	1	0	0	0	0	439	1,351	12	0	1,351
10	0	0	2	0	0	0	0	0	421	665	12	(0)	665
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	4	0	0	3	0	2,924	0	12	0	0
13	0	0	0	1	0	0	0	0	439	5,921	12	(0)	5,921

11 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	182
LO/LO-cont	182
LO/LO-cont	182
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1006
RRDF-veh	971
LO/RO-veh	1351
LO/RO-veh	665
RRDF-track	2924
RRDF-track	0
LO/RO-veh	5921

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	182	0	16	4	(0)
2	0	0	0	0	1	0	0	0	182	0	16	4	(0)
3	0	0	0	0	1	0	0	0	182	0	16	4	(0)
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	5	0	0	0	0	0	539	467	12	0	467
8	0	0	5	0	0	0	0	0	539	432	12	0	432
9	0	0	0	1	0	0	0	0	439	912	12	0	912
10	0	0	2	0	0	0	0	0	383	282	12	0	282
11	0	0	0	4	0	0	3	0	2,924	0	12	0	0
12	0	0	(0)	0	0	0	0	0	0	0	20	8	0
13	0	0	0	1	0	0	0	0	477	5,444	12	0	5,444

12 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	467
RRDF-veh	432
LO/RO-veh	912
LO/RO-veh	282
RRDF-track	0
RRDF-track	0
LO/RO-veh	5444

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	(0)	0	0	0	0	0	0	20	8	0
2	0	0	0	(0)	0	0	0	0	0	0	20	8	0
3	0	0	0	(0)	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	1	0	0	0	0	467	0	14	2	(0)
8	0	0	0	1	0	0	0	0	432	0	14	2	(0)
9	0	0	0	1	0	0	0	0	439	473	12	0	473
10	0	0	0	1	0	0	0	0	282	0	15	3	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	4,653	12	(0)	4,653

13 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	473
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4653

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	1	0	0	0	0	473	0	12	0	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	758	3,895	12	0	3,895

14 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3895

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	(0)	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	3,104	12	0	3,104

15 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3104

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	(0)	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	2,313	12	0	2,313

16 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	2313

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	(0)	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	1,522	12	0	1,522

17 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	1522

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	(0)	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	791	731	12	0	731

18 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	760
LO/LO-cont	760
LO/LO-cont	761
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	731

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	1	0	0	0	397	363	12	0	363
5	0	0	0	0	1	0	0	0	376	384	12	0	384
6	0	0	0	0	1	0	0	0	376	385	12	0	385
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	731	0	12	(0)	0

19 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	363
LO/LO-cont	384
LO/LO-cont	385
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	1	0	0	0	0	363	0	12	0	(0)
5	0	0	0	1	0	0	0	0	384	0	12	(0)	(0)
6	0	0	0	1	0	0	0	0	385	0	12	(0)	(0)
7	0	0	0	0	0	0	0	0	0	0	20	8	0
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	0	0	0	0	20	8	(0)

60% Sea State ≥ 2

7 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	3310
RRDF-veh	3310
LO/RO-veh	3107
LO/RO-veh	3107
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	368	1,318	12	(0)	1,318
2	0	0	0	0	1	0	0	0	368	1,318	12	(0)	1,318
3	0	0	0	0	1	0	0	0	368	1,318	12	(0)	1,318
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	(0)
6	0	0	0	0	0	0	0	0	0	0	20	8	(0)
7	0	0	0	1	0	0	0	0	587	2,723	12	(0)	2,723
8	0	0	0	1	0	0	0	0	587	2,723	12	(0)	2,723
9	0	0	0	1	0	0	0	0	430	2,677	12	(0)	2,677
10	0	0	0	0	0	0	1	0	781	2,326	12	0	2,326
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	(0)
13	0	0	0	0	0	0	0	0	0	0	20	8	(0)

8 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1318
LO/LO-cont	1318
LO/LO-cont	1318
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2723
RRDF-veh	2723
LO/RO-veh	2677
LO/RO-veh	2326
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	368	950	12	(0)	950
2	0	0	0	0	1	0	0	0	368	950	12	(0)	950
3	0	0	0	0	1	0	0	0	368	950	12	(0)	950
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	(0)
6	0	0	0	0	0	0	0	0	0	0	20	8	(0)
7	0	0	0	1	0	0	0	0	587	2,136	12	(0)	2,136
8	0	0	0	1	0	0	0	0	587	2,136	12	(0)	2,136
9	0	0	0	1	0	0	0	0	430	2,247	12	(0)	2,247
10	0	0	0	0	0	0	1	0	781	1,545	12	0	1,545
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	(0)
13	0	0	0	0	0	0	0	0	0	0	20	8	(0)

9 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	950
LO/LO-cont	950
LO/LO-cont	950
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2136
RRDF-veh	2136
LO/RO-veh	2247
LO/RO-veh	1545
RRDF-track	0
RRDF-track	0
LO/RO-veh	7151

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	368	582	12	0	582
2	0	0	0	0	1	0	0	0	368	582	12	0	582
3	0	0	0	0	1	0	0	0	368	582	12	0	582
4	0	0	0	0	0	0	0	0	0	0	20	8	(0)
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	2	1	0	0	0	0	557	1,579	12	0	1,579
8	0	0	0	1	0	0	0	0	587	1,549	12	0	1,549
9	0	0	0	1	0	0	0	0	430	1,817	12	0	1,817
10	0	0	0	1	0	0	0	0	430	1,115	12	(0)	1,115
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	6,370	12	0	6,370

10 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	582
LO/LO-cont	582
LO/LO-cont	582
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1579
RRDF-veh	1549
LO/RO-veh	1817
LO/RO-veh	1115
RRDF-track	0
RRDF-track	2924
LO/RO-veh	6370

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	368	214	12	0	214
2	0	0	0	0	1	0	0	0	368	214	12	0	214
3	0	0	0	0	1	0	0	0	368	214	12	0	214
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	5	0	0	0	0	0	527	1,052	12	(0)	1,052
8	0	0	5	0	0	0	0	0	527	1,022	12	0	1,022
9	0	0	0	1	0	0	0	0	430	1,387	12	(0)	1,387
10	0	0	0	1	0	0	0	0	430	685	12	0	685
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	4	0	0	3	0	2,924	0	12	0	0
13	0	0	2	0	0	0	0	0	393	5,977	12	(0)	5,977

11 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	214
LO/LO-cont	214
LO/LO-cont	214
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1052
RRDF-veh	1022
LO/RO-veh	1387
LO/RO-veh	685
RRDF-track	2924
RRDF-track	0
LO/RO-veh	5977

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	214	0	15	3	0
2	0	0	0	0	1	0	0	0	214	0	15	3	0
3	0	0	0	0	1	0	0	0	214	0	15	3	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	5	0	0	0	0	0	527	525	12	(0)	525
8	0	0	5	0	0	0	0	0	527	495	12	0	495
9	0	0	0	1	0	0	0	0	430	957	12	0	957
10	0	0	0	1	0	0	0	0	430	255	12	(0)	255
11	0	0	0	4	0	0	3	0	2,924	0	12	0	0
12	0	0	0	0	0	0	0	0	0	0	20	8	(0)
13	0	0	2	0	0	0	0	0	393	5,584	12	0	5,584

12 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	525
RRDF-veh	495
LO/RO-veh	957
LO/RO-veh	255
RRDF-track	0
RRDF-track	0
LO/RO-veh	5584

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	(0)	0	0	0	0	0	0	20	8	0
2	0	0	0	(0)	0	0	0	0	0	0	20	8	0
3	0	0	0	(0)	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	1	0	0	0	0	525	0	13	1	(0)
8	0	0	0	1	0	0	0	0	495	0	13	1	(0)
9	0	0	0	1	0	0	0	0	430	527	12	(0)	527
10	0	0	0	1	0	0	0	0	255	0	15	3	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	(0)
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	4,803	12	0	4,803

13 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	527
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4803

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	(0)
9	0	0	0	1	0	0	0	0	527	0	12	0	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	684	4,119	12	(0)	4,119

14 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4119

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	3,338	12	0	3,338

15 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3338

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	2,557	12	0	2,557

16 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	2557

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	1,776	12	0	1,776

17 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	1776

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	0	0	0	0	0	0	20	8	0
5	0	0	0	0	0	0	0	0	0	0	20	8	0
6	0	0	0	0	0	0	0	0	0	0	20	8	0
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	995	12	0	995

18 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	760
LO/LO-cont	760
LO/LO-cont	761
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	995

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	0	1	0	0	0	368	392	12	0	392
5	0	0	0	0	1	0	0	0	368	392	12	0	392
6	0	0	0	0	1	0	0	0	368	393	12	0	393
7	0	0	0	0	0	0	0	0	0	0	20	8	(0)
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	(0)
10	0	0	0	0	0	0	0	0	0	0	20	8	(0)
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	1	0	781	214	12	(0)	214

19 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	392
LO/LO-cont	392
LO/LO-cont	393
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	214

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	8	0
2	0	0	0	0	0	0	0	0	0	0	20	8	0
3	0	0	0	0	0	0	0	0	0	0	20	8	0
4	0	0	0	1	0	0	0	0	392	0	12	(0)	0
5	0	0	0	1	0	0	0	0	392	0	12	(0)	0
6	0	0	0	1	0	0	0	0	393	0	12	(0)	0
7	0	0	0	0	0	0	0	0	0	0	20	8	0
8	0	0	0	0	0	0	0	0	0	0	20	8	0
9	0	0	0	0	0	0	0	0	0	0	20	8	0
10	0	0	0	0	0	0	0	0	0	0	20	8	0
11	0	0	0	0	0	0	0	0	0	0	20	8	0
12	0	0	0	0	0	0	0	0	0	0	20	8	0
13	0	0	0	0	0	0	0	0	214	0	18	6	0

72.61% Sea State ≥ 2

7July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	1686
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	3310
RRDF-veh	3310
LO/RO-veh	3107
LO/RO-veh	3107
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	1,434	15	(0)	1,434
2	0	0	0	0	1	0	0	0	252	1,434	15	(0)	1,434
3	0	0	0	0	1	0	0	0	252	1,434	15	(0)	1,434
4	0	0	0	0	0	0	0	0	0	0	20	5	(0)
5	0	0	0	0	0	0	0	0	0	0	20	5	(0)
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	1	0	0	0	0	402	2,908	15	(0)	2,908
8	0	0	0	1	0	0	0	0	402	2,908	15	(0)	2,908
9	0	0	0	0	0	0	0	0	369	2,738	15	(0)	2,738
10	0	0	0	0	0	0	1	0	571	2,536	15	0	2,536
11	0	0	0	0	0	0	0	0	0	0	20	5	(0)
12	0	0	0	0	0	0	0	0	0	0	20	5	(0)
13	0	0	0	0	0	0	0	0	0	0	20	5	(0)

8 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1434
LO/LO-cont	1434
LO/LO-cont	1434
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2908
RRDF-veh	2908
LO/RO-veh	2738
LO/RO-veh	2536
RRDF-track	0
RRDF-track	0
LO/RO-veh	0

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	1,182	15	(0)	1,182
2	0	0	0	0	1	0	0	0	252	1,182	15	(0)	1,182
3	0	0	0	0	1	0	0	0	252	1,182	15	(0)	1,182
4	0	0	0	0	0	0	0	0	0	0	20	5	(0)
5	0	0	0	0	0	0	0	0	0	0	20	5	(0)
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	1	0	0	0	0	402	2,506	15	(0)	2,506
8	0	0	0	1	0	0	0	0	402	2,506	15	(0)	2,506
9	0	0	0	0	0	0	0	0	369	2,369	15	(0)	2,369
10	0	0	0	0	0	0	1	0	571	1,965	15	0	1,965
11	0	0	0	0	0	0	0	0	0	0	20	5	(0)
12	0	0	0	0	0	0	0	0	0	0	20	5	(0)
13	0	0	0	0	0	0	0	0	0	0	20	5	(0)

9 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	1182
LO/LO-cont	1182
LO/LO-cont	1182
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2506
RRDF-veh	2506
LO/RO-veh	2369
LO/RO-veh	1965
RRDF-track	0
RRDF-track	0
LO/RO-veh	7151

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	930	15	0	930
2	0	0	0	0	1	0	0	0	252	930	15	0	930
3	0	0	0	0	1	0	0	0	252	930	15	0	930
4	0	0	0	0	0	0	0	0	0	0	20	5	(0)
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	1	0	0	0	0	402	2,104	15	0	2,104
8	0	0	0	1	0	0	0	0	402	2,104	15	0	2,104
9	0	0	0	0	0	0	0	0	369	2,000	15	0	2,000
10	0	0	0	1	0	0	0	0	294	1,671	15	(0)	1,671
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	6,580	15	(0)	6,580

10 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	930
LO/LO-cont	930
LO/LO-cont	930
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	2104
RRDF-veh	2104
LO/RO-veh	2000
LO/RO-veh	1671
RRDF-track	0
RRDF-track	2924
LO/RO-veh	6580

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	678	15	0	678
2	0	0	0	0	1	0	0	0	252	678	15	0	678
3	0	0	0	0	1	0	0	0	252	678	15	0	678
4	0	0	0	0	0	0	0	0	0	0	20	5	(0)
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	1	0	0	0	0	399	1,705	15	0	1,705
8	0	0	3	0	0	0	0	0	361	1,743	15	0	1,743
9	0	0	0	1	0	0	0	0	294	1,706	15	(0)	1,706
10	0	0	0	1	0	0	0	0	294	1,377	15	0	1,377
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	3	0	0	3	0	2,263	661	15	0	661
13	0	0	0	1	0	0	0	0	294	6,286	15	(0)	6,286

11 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	678
LO/LO-cont	678
LO/LO-cont	678
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1705
RRDF-veh	1743
LO/RO-veh	1706
LO/RO-veh	1377
RRDF-track	2924
RRDF-track	661
LO/RO-veh	6286

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	426	15	0	426
2	0	0	0	0	1	0	0	0	252	426	15	0	426
3	0	0	0	0	1	0	0	0	252	426	15	0	426
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	3	0	0	0	0	0	361	1,344	15	0	1,344
8	0	0	0	1	0	0	0	0	399	1,344	15	(0)	1,344
9	0	0	0	1	0	0	0	0	294	1,412	15	0	1,412
10	0	0	0	1	0	0	0	0	294	1,083	15	0	1,083
11	0	0	0	3	0	0	3	0	2,263	661	15	0	661
12	0	0	7	0	0	0	0	0	661	0	16	1	0
13	0	0	0	1	0	0	0	0	294	5,992	15	0	5,992

12 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	426
LO/LO-cont	426
LO/LO-cont	426
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	1344
RRDF-veh	1344
LO/RO-veh	1412
LO/RO-veh	1083
RRDF-track	661
RRDF-track	0
LO/RO-veh	5992

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	1	0	0	0	252	174	15	0	174
2	0	0	0	0	1	0	0	0	252	174	15	0	174
3	0	0	0	0	1	0	0	0	252	174	15	0	174
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	1	0	0	0	0	402	942	15	(0)	942
8	0	0	0	1	0	0	0	0	402	942	15	(0)	942
9	0	0	0	0	0	0	1	0	571	841	15	0	841
10	0	0	0	0	0	0	0	0	369	714	15	0	714
11	0	0	0	1	0	0	0	0	661	0	18	3	0
12	0	0	0	0	0	0	0	0	0	0	20	5	(0)
13	0	0	0	1	0	0	0	0	294	5,698	15	0	5,698

13 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	174
LO/LO-cont	174
LO/LO-cont	174
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	942
RRDF-veh	942
LO/RO-veh	841
LO/RO-veh	714
RRDF-track	0
RRDF-track	0
LO/RO-veh	5698

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	174	0	16	2	(0)
2	0	0	0	0	0	0	0	0	174	0	16	2	(0)
3	0	0	0	0	1	0	0	0	174	0	16	2	0
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	1	0	0	0	0	402	540	15	0	540
8	0	0	0	1	0	0	0	0	402	540	15	0	540
9	0	0	0	1	0	0	0	0	294	547	15	(0)	547
10	0	0	0	0	0	0	1	0	571	143	15	(0)	143
11	0	0	0	(0)	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	0	0	369	5,329	15	0	5,329

14 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	540
RRDF-veh	540
LO/RO-veh	547
LO/RO-veh	143
RRDF-track	0
RRDF-track	0
LO/RO-veh	5329

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	(0)	0	0	0	0	0	0	20	5	0
2	0	0	0	(0)	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	1	0	0	0	0	402	138	15	0	138
8	0	0	0	1	0	0	0	0	402	138	15	0	138
9	0	0	0	0	0	0	1	0	547	0	15	0	(0)
10	0	0	0	0	0	0	0	0	143	0	17	3	(0)
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	0	0	393	4,936	15	0	4,936

15 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	138
RRDF-veh	138
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4936

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	0	0	0	0	0	138	0	18	4	(0)
8	0	0	0	0	0	0	0	0	138	0	19	4	(0)
9	0	0	0	(0)	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	(0)
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	4,365	15	0	4,365

16 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	4365

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	0	0	0	(0)	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	(0)
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	3,794	15	0	3,794

17 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3794

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	0	0	0	(0)	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	(0)
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	3,223	15	0	3,223

18 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	760
LO/LO-cont	760
LO/LO-cont	761
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	3223

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	1	0	0	0	277	483	15	0	483
5	0	0	0	0	1	0	0	0	252	508	15	0	508
6	0	0	0	0	1	0	0	0	252	509	15	0	509
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	2,652	15	0	2,652

19 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	483
LO/LO-cont	508
LO/LO-cont	509
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	2652

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	1	0	0	0	277	206	15	0	206
5	0	0	0	0	1	0	0	0	252	256	15	0	256
6	0	0	0	0	1	0	0	0	252	257	15	0	257
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	2,081	15	0	2,081

20 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	206
LO/LO-cont	256
LO/LO-cont	257
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	2081

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	1	0	0	0	0	206	0	15	1	(0)
5	0	0	0	1	0	0	0	0	256	0	15	(0)	(0)
6	0	0	0	1	0	0	0	0	257	0	15	(0)	(0)
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	1,510	15	0	1,510

21 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	1510

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	(0)	0	0	0	0	0	0	20	5	0
5	0	0	0	(0)	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	939	15	0	939

22 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	939

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	(0)	0	0	0	0	0	0	20	5	0
5	0	0	0	(0)	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	(0)
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	571	368	15	0	368

23 July 1993

Type of Discharge Lane	Throughput Requirement (STONS)
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
LO/LO-cont	0
RRDF-veh	0
RRDF-veh	0
LO/RO-veh	0
LO/RO-veh	0
RRDF-track	0
RRDF-track	0
LO/RO-veh	368

Lane	LCM-8	LCU-1600	LCU-2000	LSV	CSP +3	CSP +2	ACBL	LCAC	STONS Moved	STONS Left	Hrs Left	Hrs Left w/SS	STONS Shortfall w/SS
1	0	0	0	0	0	0	0	0	0	0	20	5	0
2	0	0	0	0	0	0	0	0	0	0	20	5	0
3	0	0	0	0	0	0	0	0	0	0	20	5	(0)
4	0	0	0	0	0	0	0	0	0	0	20	5	0
5	0	0	0	0	0	0	0	0	0	0	20	5	0
6	0	0	0	0	0	0	0	0	0	0	20	5	0
7	0	0	0	0	0	0	0	0	0	0	20	5	0
8	0	0	0	0	0	0	0	0	0	0	20	5	0
9	0	0	0	0	0	0	0	0	0	0	20	5	0
10	0	0	0	0	0	0	0	0	0	0	20	5	0
11	0	0	0	0	0	0	0	0	0	0	20	5	0
12	0	0	0	0	0	0	0	0	0	0	20	5	0
13	0	0	0	0	0	0	1	0	368	0	16	2	0

APPENDIX E. ARRANGE_DATA MODULE

This appendix contains the Turbo Pascal 1.5 coding for the ARRANGE_DATA module of the SEA_STATE_CALC package. This module is designed to be executed once prior to commencing execution of the JOTE model. ARRANGE_DATA can also be commenced from within the SEA_STATE_CALC program based upon user desires and the results obtained from that program. The purpose of this module is to process of text file of international maritime weather observations obtained from NCDC, in order to produce a site and time specific input file of significant wave height observations and their associated date/time groups for use by the SEA_STATE_CALC program. This input file will be entitled SSDATA.TXT. All variable, function, and procedure names used within this module have literal meanings consistent with the quantities they hold and/or the operations they perform.

```
PROGRAM ARRANGE_DATA;

   USES
      WinCrt;

   VAR
      Number_Of_Trials, Majority_Month_Number :  Integer;


   Function Compute_Number_Of_Observations (Test_File_Name : String): Longint;

      Type
         Character_File_Type = File of Char;

      Var
         Number_Of_Lines   :  Longint;
         Input_File_Name   :  Character_File_Type;

      Begin
         Assign(Input_File_Name, Test_File_Name);
         Reset(Input_File_Name);
         Number_Of_Lines:= Filesize(Input_File_Name) Div 148;
         Compute_Number_Of_Observations:= Number_Of_Lines;
         Close(Input_File_Name);
      End;



   Procedure Program_Overview (Var Number_Of_Chi_Square_Tests : Integer);

      Var
         User_Response_1, User_Response_2 :  String;

      Begin
         ClrScr;
         Writeln('STARTUP PROCEDURES FOR "ARRANGE_DATA"');
         Writeln('------------------------------------');
         Writeln;
         Writeln;
         Repeat
            Write('1)  Is this program is being executed from the');
            Writeln(' SEA_STATE_CALC program?');
            Writeln;
            Write('    From SEA_STATE_CALC? (Y/N)  ');
            Readln(User_Response_1);
            Writeln;
         Until (User_Response_1 = 'Y') Or (User_Response_1 = 'y') Or
               (User_Response_1 = 'N') Or (User_Response_1 = 'n');
         If (User_Response_1 = 'Y') Or (User_Response_1 = 'y') Then
            Begin
               Writeln;
               Writeln;
               Write('2)  Enter the number of Chi-Square Goodness of Fit
             Tests');
               Writeln(' you have performed on');
               Writeln('    this type of input file.');
               Writeln;
               Write('    Number of Chi-Square Tests?  ');
               Readln(Number_Of_Chi_Square_Tests);
            End
         Else
            Begin
               Number_Of_Chi_Square_Tests:= 0;
            End;
         Writeln;
```

```
Writeln;
Writeln;
Repeat
   If (User_Response_1 = 'Y') Or (User_Response_1 = 'y') Then
      Begin
         Write('3)  Do you wish to view the capabilities and tasks
             of');
         Writeln(' the program?');
         Writeln;
         Write('    View capabilities/tasks? (Y/N)  ');
      End
   Else
      Begin
         Write('2)  Do you wish to view the capabilities and tasks
             of');
         Writeln(' the program?');
         Writeln;
         Write('    View capabilities/tasks? (Y/N)  ');
      End;
   Readln(User_Response_2);
   Writeln;
Until (User_Response_2 = 'Y') Or (User_Response_2 = 'y') Or
      (User_Response_2 = 'N') Or (User_Response_2 = 'n');
If (User_Response_2 = 'Y') Or (User_Response_2 = 'y') Then
   Begin
      ClrScr;
      Write('The objective of the ARRANGE_DATA program is tocreate');
      Writeln(' an input file of');
      Write('significant wave height observations for the SEA_STATE');
      Writeln('_CALC program.');
      Writeln;
      Writeln;
      Write('This program is designed to accept, evaluate, and
          process');
      Writeln(' a data file of ');
      Write('weather and sea state observations, corresponding to a');
      Writeln(' specific geographic');
      Write('location, obtained from the National Climatic Data
         Center');
      Writeln(' (NCDC)');
      Writeln('in Asheville, NC.');
      Writeln;
      Writeln;
      Write('These observations are provided by NCDC as string data');
      Writeln(' entries, each of');
      Write('148 characters in length.  As the program executes, it');
      Writeln(' will maintain all');
      Write('data fields for each observation in all intermediate');
      Writeln(' files.  Many of these');
      Write('fields could be useful in further studies.  The final');
      Writeln(' file created');
      Write('(C:\JLOTS\SSDATA.TXT), however, will contain only the');
      Writeln(' significant wave height');
      Writeln('observed, and its corresponding date/time group.');
      Writeln;
      Writeln;
      Writeln('DEPRESS THE ENTER KEY TO VIEW FUNCTIONS OF THE PROGRAM');
      Writeln('------------------------------------------------------');
      ReadKey;
      ClrScr;
      Write('The program will perform each of the following
         functions.');
      Writeln;
      Writeln;
      Write('      1.  Prompt the user regarding the format in which');
      Write(' the observations were');
```

```
Writeln('            provided from NCDC.');
Writeln;
Write('     2.  If the individual observations within the data');
Writeln(' file cannnot be ');
Write('         distinguished to do a lack of ');
Writeln('returns, insert a carriage return');
Write('         after each observation of 148 characters
        thereby');
Writeln(' creating a revised');
Writeln('         data file.');
Writeln;
Write('     3.  Calculate the total number of observations');
Writeln(' provided by NCDC for the');
Writeln('         desired geographic location.');
Writeln;
Write('     4.  Prompt the user regarding the calendar month in');
Writeln(' which the majority');
Writeln('         of the JLOTS evolution is to be conducted.');
Writeln;
Writeln;
Write('DEPRESS THE ENTER KEY TO CONTINUE VIEWING PROGRAM');
Writeln(' FUNCTIONS');
Write('-----------------------------------------------------');
Writeln('----------');
ReadKey;
ClrScr;
Write('     5.  Prompt the user regarding the type of input
        data');
Writeln(' file he desires');
Write('         to create as the input file for the SEA_STATE');
Writeln('_CALC program.');
Writeln;
Write('             A.  A file corresponding to a 1 month');
Writeln(' interval which represents');
Write('                 the majority month of the JLOTS');
Writeln(' operation.');
Write('             B.  A file corresponding to a 3 month');
Writeln(' interval centered upon');
Write('                 the majority month of the JLOTS');
Writeln(' operation.');
Write('             C.  A file consisting of observations');
Writeln(' throughout the entire year.');
Writeln;
Writeln;
Write('     6.  Based upon the response to function 5, create a');
Writeln(' site/time specific');
Writeln('         data file by:');
Writeln;
Write('             A.  Temporarily disregarding all
                observations');
Writeln(' which are not');
Write('                 within the month in which a majority of');
Writeln(' the JLOTS operation');
Writeln('                 is to be conducted.');
Write('             B.  Temporarily disregarding all
                observations');
Writeln(' which are not');
Write('                 within one month of the month in which a');
Writeln(' majority of the');
Writeln('                 JLOTS operation is to be conducted.');
Write('             C.  Create a site specifc data file by');
Writeln(' considering observations');
Writeln('                 throughout the calendar year.');
Writeln;
Writeln;
Write('DEPRESS THE ENTER KEY TO CONTINUE VIEWING PROGRAM');
```

```
        Writeln(' FUNCTIONS');
        Write('--------------------------------------------------');
        Write('----------');
        ReadKey;
        ClrScr;
        Write('     7.  If the site/time specific data file contains');
        Writeln(' less than 16,300');
        Write('         observations (the maximum acceptable by the');
        Writeln(' SEA_STATE_CALC program),');
        Write('         select all observations as the input file,');
        Writeln(' SSDATA.TXT, for the');
        Writeln('           SEA_STATE_CALC program.');
        Writeln;
        Write('     8.  If the site/time specific data file contains
             more');
        Writeln(' than 16,300');
        Write('         observations, but less than 32,600
             observations,');
        Writeln(' randomly select');
        Write('         16,300 as the input file for the SEA_STATE_CALC');
        Writeln(' program.');
        Writeln;
        Write('     9.  If the site/time specific data file contains
             more');
        Writeln(' than 32,600');
        Write('         observations, divide the total number of');
        Writeln(' observations by 16,300 to');
        Write('         obtain a quotient, X.  Generate a random
          number,');
        Writeln(' Y, on the interval');
        Write('         (0, X).  Obtain the requisite 16,300');
        Writeln(' observations by selecting');
        Write('         observation Y as the first, observation Y + X
             as');
        Writeln(' the second, ');
        Write('         Y + X + X as the third, and so on, thereby');
        Writeln(' creating the input file');
        Writeln('           SSDATA.TXT for the SEA_STATE_CALC program.');
        Writeln;
        Write('    10.  Re-execute function 8 or 9 (whichever is');
        Writeln(' applicable), if');
        Write('         commanded to do so by the SEA_STATE_CALC');
        Writeln(' program.');
        Writeln;
        Writeln;
        Writeln('DEPRESS THE ENTER KEY TO COMMENCE THE PROGRAM');
        Writeln('---------------------------------------------');
        ReadKey;
        ClrScr;
      End
    Else
      Begin
        System.Exit;
      End;
  End;

Procedure Process_NCDC_Data;

  Var
    NCDC_Raw_Data_File,
    NCDC_Processed_Data_File   :  Text;
    Character_Position         :  Char;
    Counter                    :  Integer;
```

```
   Begin
      Assign(NCDC_Raw_Data_File, 'C:\JLOTS\NCDC.TXT');
      Reset(NCDC_Raw_Data_File);
      Assign(NCDC_Processed_Data_File, 'C:\JLOTS\SSDATA1.TXT');
      Rewrite(NCDC_Processed_Data_File);
      Counter := 0;
      While Not EOF (NCDC_Raw_Data_File) Do
         Begin
            Counter:= 1;
            Repeat
               Read(NCDC_Raw_Data_File, Character_Position);
               Write(NCDC_Processed_Data_File, Character_Position);
               Counter:= Counter + 1;
            Until Counter=149;
            Writeln(NCDC_Processed_Data_File);
         End;
      Close(NCDC_Raw_Data_File);
      Close(NCDC_Processed_Data_File);
   End;


Procedure Ask_Configuration_Of_NCDC_Data (Number_Of_Executions : Integer);

   Var
      User_Response_3, File_To_Be_Analyzed  :  String;
      NCDC_Processed_Data_File              :  Text;

   Begin
     ClrScr;
     Writeln('STEP 1:  FORMAT OF NCDC DATA UPON RECEIPT');
     Writeln('----------------------------------------');
     Writeln;
     Writeln;
     If Number_Of_Executions = 0 Then
        Begin
           Repeat
              Write('1)  Are the individual NCDC weather/sea state
         observations');
              Writeln(' seperated by');
              Writeln('    carriage returns?');
              Writeln;
              Write('    Carriage returns (Y/N)?  ');
              Readln(User_Response_3);
              Writeln;
           Until (User_Response_3 = 'Y') Or (User_Response_3 = 'y') Or
                 (User_Response_3 = 'N') Or (User_Response_3 = 'n');
           If (User_Response_3 = 'Y') Or (User_Response_3 = 'y') Then
              Begin
                 Assign(NCDC_Processed_Data_File, 'C:\JLOTS\WORK1.TXT');
                 Rename(NCDC_Processed_Data_File, 'C:\JLOTS\SSDATA1.TXT');
                 Writeln;
                 Writeln;
              End
           Else
              Begin
                 Process_NCDC_Data;
              End;
        End
     Else
        Begin
           Assign(NCDC_Processed_Data_File, 'C:\JLOTS\WORK1.TXT');
           Rename(NCDC_Processed_Data_File, 'C:\JLOTS\SSDATA1.TXT');
        End;
     File_To_Be_Analyzed := 'C:\JLOTS\SSDATA1.TXT';
     Writeln('The total number of observations provided by NCDC is: ----- ',
```

```
            Compute_Number_Of_Observations(File_To_Be_Analyzed));
    Writeln;
    Writeln;
    Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
    Writeln('---------------------------------------------');
    ReadKey;
  End;


Procedure Obtain_Majority_Month (Var Month_Number : Integer);

  Begin
    ClrScr;
    Writeln('STEP 2:  MAJORITY MONTH OF THE JLOTS OEPRATION');
    Writeln('----------------------------------------------');
    Writeln;
    Writeln;
    Write('Inidicate the 1 or 2 digit month number corresponding to the');
    Writeln(' month in which');
    Writeln('the majority of the JLOTS evoution is to be conducted.  ');
    Writeln;
    Writeln('EX.  July = 7');
    Writeln('EX.  December = 12');
    Writeln;
    Writeln;
    Write('The majority month number is:  ');
    Readln(Month_Number);
    Writeln;
    Writeln;
    Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
    Writeln('---------------------------------------------');
    ReadKey;
  End;


Procedure Create_One_Month_Interval_Data_File (Single_Month_Number: Integer);

  Var
    Two_Digit_Month_Code, Individual_Observation,
    Month_Code_In_Each_Observation                  :  String;
    NCDC_Data_File_With_Carriage_Returns            :  Text;
    Time_Specific_NCDC_Data_File                    :  Text;

  Begin
    Case Single_Month_Number Of
      1: Two_Digit_Month_Code:= '01';
      2: Two_Digit_Month_Code:= '02';
      3: Two_Digit_Month_Code:= '03';
      4: Two_Digit_Month_Code:= '04';
      5: Two_Digit_Month_Code:= '05';
      6: Two_Digit_Month_Code:= '06';
      7: Two_Digit_Month_Code:= '07';
      8: Two_Digit_Month_Code:= '08';
      9: Two_Digit_Month_Code:= '09';
      10: Two_Digit_Month_Code:= '10';
      11: Two_Digit_Month_Code:= '11';
      12: Two_Digit_Month_Code:= '12';
    End;
    Assign(NCDC_Data_File_With_Carriage_Returns, 'C:\JLOTS\SSDATA1.TXT');
    Reset(NCDC_Data_File_With_Carriage_Returns);
    Assign(Time_Specific_NCDC_Data_File, 'C:\JLOTS\SSDATA2.TXT');
    Rewrite(Time_Specific_NCDC_Data_File);
    While Not EOF (NCDC_Data_File_With_Carriage_Returns) Do
      Begin
```

```
            Readln(NCDC_Data_File_With_Carriage_Returns,
               Individual_Observation);
            Month_Code_In_Each_Observation:=
                 Copy(Individual_Observation, 21, 2);
            If Month_Code_In_Each_Observation = Two_Digit_Month_Code Then
               Begin
                  Writeln(Time_Specific_NCDC_Data_File,
                          Individual_Observation);
               End;
         End;
      Close(NCDC_Data_File_With_Carriage_Returns);
      Close(Time_Specific_NCDC_Data_File);
   End;


Procedure Create_Three_Month_Interval_Data_File (Middle_Month_Number:
                                                 Integer);

    Var
      Lower_Month_Bound, Upper_Month_Bound                  :  Integer;
      Two_Digit_Lower_Month_Code, Two_Digit_Middle_Month_Code,
      Two_Digit_Upper_Month_Code, Individual_Observation,
      Month_Code_In_Each_Observation                        :  String;
      NCDC_Data_File_With_Carriage_Returns,
      Time_Specific_NCDC_Data_File                          :  Text;

   Begin
      Lower_Month_Bound:= Middle_Month_Number - 1;
      Upper_Month_Bound:= Middle_Month_Number + 1;
      If Lower_Month_Bound < 1 Then
         Begin
           Lower_Month_Bound:= 12;
         End;
      If Upper_Month_Bound > 12 Then
         Begin
            Upper_Month_Bound:= 1
         End;
      Case Lower_Month_Bound Of
         1: Two_Digit_Lower_Month_Code:= '01';
         2: Two_Digit_Lower_Month_Code:= '02';
         3: Two_Digit_Lower_Month_Code:= '03';
         4: Two_Digit_Lower_Month_Code:= '04';
         5: Two_Digit_Lower_Month_Code:= '05';
         6: Two_Digit_Lower_Month_Code:= '06';
         7: Two_Digit_Lower_Month_Code:= '07';
         8: Two_Digit_Lower_Month_Code:= '08';
         9: Two_Digit_Lower_Month_Code:= '09';
         10: Two_Digit_Lower_Month_Code:= '10';
         11: Two_Digit_Lower_Month_Code:= '11';
         12: Two_Digit_Lower_Month_Code:= '12';
      End;
      Case Middle_Month_Number Of
         1: Two_Digit_Middle_Month_Code:= '01';
         2: Two_Digit_Middle_Month_Code:= '02';
         3: Two_Digit_Middle_Month_Code:= '03';
         4: Two_Digit_Middle_Month_Code:= '04';
         5: Two_Digit_Middle_Month_Code:= '05';
         6: Two_Digit_Middle_Month_Code:= '06';
         7: Two_Digit_Middle_Month_Code:= '07';
         8: Two_Digit_Middle_Month_Code:= '08';
         9: Two_Digit_Middle_Month_Code:= '09';
         10: Two_Digit_Middle_Month_Code:= '10';
         11: Two_Digit_Middle_Month_Code:= '11';
         12: Two_Digit_Middle_Month_Code:= '12';
      End;
```

```
      Case Upper_Month_Bound Of
         1: Two_Digit_Upper_Month_Code:= '01';
         2: Two_Digit_Upper_Month_Code:= '02';
         3: Two_Digit_Upper_Month_Code:= '03';
         4: Two_Digit_Upper_Month_Code:= '04';
         5: Two_Digit_Upper_Month_Code:= '05';
         6: Two_Digit_Upper_Month_Code:= '06';
         7: Two_Digit_Upper_Month_Code:= '07';
         8: Two_Digit_Upper_Month_Code:= '08';
         9: Two_Digit_Upper_Month_Code:= '09';
         10: Two_Digit_Upper_Month_Code:= '10';
         11: Two_Digit_Upper_Month_Code:= '11';
         12: Two_Digit_Upper_Month_Code:= '12';
      End;
      Assign(NCDC_Data_File_With_Carriage_Returns, 'C:\JLOTS\SSDATA1.TXT');
      Reset(NCDC_Data_File_With_Carriage_Returns);
      Assign(Time_Specific_NCDC_Data_File, 'C:\JLOTS\SSDATA2.TXT');
      Rewrite(Time_Specific_NCDC_Data_File);
      While Not EOF (NCDC_Data_File_With_Carriage_Returns) Do
         Begin
            Readln(NCDC_Data_File_With_Carriage_Returns,
                   Individual_Observation);
            Month_Code_In_Each_Observation:=
                  Copy(Individual_Observation, 21, 2);
            If (Month_Code_In_Each_Observation =
                     Two_Digit_Lower_Month_Code) Or
               (Month_Code_In_Each_Observation =
                     Two_Digit_Middle_Month_Code) Or
               (Month_Code_In_Each_Observation =
                     Two_Digit_Upper_Month_Code) Then
               Begin
                  Writeln(Time_Specific_NCDC_Data_File,
                          Individual_Observation);
               End;
         End;
      Close(NCDC_Data_File_With_Carriage_Returns);
      Close(Time_Specific_NCDC_Data_File);
   End;


Procedure Create_Year_Long_Data_File;

   Var
      Two_Digit_Month_Code, Individual_Observation,
      Month_Code_In_Each_Observation                    :  String;
      NCDC_Data_File_With_Carriage_Returns,
      Time_Specific_NCDC_Data_File                      :  Text;

   Begin
      Assign(NCDC_Data_File_With_Carriage_Returns, 'C:\JLOTS\SSDATA1.TXT');
      Reset(NCDC_Data_File_With_Carriage_Returns);
      Assign(Time_Specific_NCDC_Data_File, 'C:\JLOTS\SSDATA2.TXT');
      Rewrite(Time_Specific_NCDC_Data_File);
      While Not EOF (NCDC_Data_File_With_Carriage_Returns) Do
         Begin
            Readln(NCDC_Data_File_With_Carriage_Returns,
                   Individual_Observation);
            Writeln(Time_Specific_NCDC_Data_File, Individual_Observation);
         End;
      Close(NCDC_Data_File_With_Carriage_Returns);
      Close(Time_Specific_NCDC_Data_File);
   End;


Procedure Determine_Desired_Data_File_Configuration (Month_Of_Interest :
```

```
                                        Integer);

Var
   Month_Spelling, File_To_Be_Analyzed  : String;
   Desired_Data_File_Selection          : Char;

Begin
   ClrScr;
   Writeln('STEP 3:  TYPE OF DATA FILE TO BE CONSTRUCTED');
   Writeln('---------------------------------------------');
   Writeln;
   Writeln;
   Case Month_Of_Interest Of
      1: Month_Spelling:= 'January';
      2: Month_Spelling:= 'February';
      3: Month_Spelling:= 'March';
      4: Month_Spelling:= 'April';
      5: Month_Spelling:= 'May';
      6: Month_Spelling:= 'June';
      7: Month_Spelling:= 'July';
      8: Month_Spelling:= 'August';
      9: Month_Spelling:= 'September';
      10: Month_Spelling:= 'October';
      11: Month_Spelling:= 'November';
      12: Month_Spelling:= 'December';
   End;
   Write('Select the letter of the type of data file you desire to');
   Writeln(' construct from the');
   Writeln('original file of NCDC observations at the given location.');
   Writeln;
   Write('     A.  A file containing only observations obtained in the');
   Writeln(' month of ',Month_Spelling,'.');
   Writeln;
   Write('     B.  A file containing observations assembled from a 3');
   Writeln(' month interval');
   Writeln('         which is centered on the month of Month_Spelling,'.');
   Writeln;
   Write('     C.  A file containing observations assembled throughout');
   Writeln(' every month of');
   Writeln('         the calendar year.');
   Writeln;
   Writeln;
   Write('Enter the letter of your selection:  ');
   Readln(Desired_Data_File_Selection);
   Writeln;
   Writeln;
   File_To_Be_Analyzed := 'C:\JLOTS\SSDATA2.TXT';
   Case Desired_Data_File_Selection Of
      'a', 'A': Begin
                   Create_One_Month_Interval_Data_File (Month_Of_Interest);
                   ClrScr;
                   Write('A file containing only observations obtained');
                   Writeln(' in the month of ',Month_Spelling,' has');
                   Writeln('been created.');
                   Writeln;
                   Writeln('This file is entitled C:\JLOTS\SSDATA2.TXT.');
                   Writeln;
                   Writeln('The file contains ',
                      Compute_Number_Of_Observations (File_To_Be_Analyzed),
                      ' observations.');
                End;
      'b', 'B': Begin
                   Create_Three_Month_Interval_Data_File
                        (Majority_Month_Number);
                   ClrScr;
                   Write('A file containing observations assembled from
```

```
                    a');
                     Writeln(' 3 month interval which is');
                     Write('centered on the month of ',Month_Spelling);
                     Writeln(' has been created.');
                     Writeln;
                     Writeln('This file is entitled C:\JLOTS\SSDATA2.TXT.');
                     Writeln;
                     Writeln('The file contains ',
                        Compute_Number_Of_Observations (File_To_Be_Analyzed),
                        ' observations.');
                  End;
      'c', 'C': Begin
                     Create_Year_Long_Data_File;
                     ClrScr;
                     Write('A file containing observations assembled');
                     Writeln(' throughout every month of the');
                     Writeln('calendar year has been created.');
                     Writeln;
                     Writeln('This file is entitled C:\JLOTS\SSDATA2.TXT.');
                     Writeln;
                     Writeln('The file contains ',
                        Compute_Number_Of_Observations (File_To_Be_Analyzed),
                        ' observations.');

                  End;
      End;
      Writeln;
      Writeln;
      Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
      Writeln('---------------------------------------------');
      ReadKey;
   End;


Procedure Create_Desired_Input_Data_File_Type
             (Number_Of_Data_Files_Created_Of_Desired_Type : Integer);

   Var
      File_To_Be_Analyzed, Individual_Observation, File_Name_Alpha,
      File_Name_Bravo, File_Name_Charlie                           : String;
      File_Size_Determination, File_Size_Determination_First_Pass,
      Accumulated_Number_Of_Observations,
      Rejected_Number_Of_Observations                              : Longint;
      Upper_Bound_For_Random_Number, Accepted_Observation_Counter,
      Excluded_Observation_Counter,
      Randomly_Selected_Observation_Increment                      : Integer;
      Random_Number_Test_Value                                     : Real;
      Time_Specific_NCDC_Data_File,
      Final_Data_File_Of_148_Character_Observations,
      Data_File_Of_Extra_Observations                              : Text;
      First_Time_Through_Loop                                      : Boolean;

   Begin
      Randomize;
      If Number_Of_Data_Files_Created_Of_Desired_Type = 0 Then
         Begin
            File_To_Be_Analyzed:= 'C:\JLOTS\SSDATA2.TXT';
            File_Size_Determination:=
                        Compute_Number_Of_Observations (File_To_Be_Analyzed);
            If (File_Size_Determination < 16300) Then
               Begin
                  Assign(Time_Specific_NCDC_Data_File,
                     'C:\JLOTS\SSDATA2.TXT');
                  Reset(Time_Specific_NCDC_Data_File);
                  Assign(Final_Data_File_Of_148_Character_Observations,
```

```
            'C:\JLOTS\SSDATA3.TXT');
      Rewrite(Final_Data_File_Of_148_Character_Observations);
      While Not EOF (Time_Specific_NCDC_Data_File) Do
         Begin
            Readln(Time_Specific_NCDC_Data_File,
                   Individual_Observation);
            Writeln(Final_Data_File_Of_148_Character_Observations,
                    Individual_Observation);
         End;
      Close(Time_Specific_NCDC_Data_File);
      Close(Final_Data_File_Of_148_Character_Observations);
      ClrScr;
      Write('The SEA_STATE_CALC program can process a maximum');
      Writeln(' of 16,300 significant wave');
      Writeln('height observations.');
      Writeln;
      Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained
         only ',File_Size_Determination);
      Writeln(' observations,');
      Write('all of these observations were moved to the next
         holding');
      Writeln(' file entitled,');
      Writeln('"C:\JLOTS\SSDATA3.TXT".');
      Writeln;
      Write('From this file, the input data set of significant');
      Writeln(' wave height observations');
      Writeln('will be created.');
      Writeln;
      Writeln;
      Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
      Writeln('---------------------------------------------');
      ReadKey;
   End
Else If (File_Size_Determination > 16300) And
        (File_Size_Determination < 32600) Then
   Begin
      File_Name_Alpha:= 'C:\JLOTS\SSDATA2.TXT';
      File_Name_Bravo:= 'C:\JLOTS\SSDATA4.TXT';
      Assign(Final_Data_File_Of_148_Character_Observations,
            'C:\JLOTS\SSDATA3.TXT');
      First_Time_Through_Loop := True;
      Accumulated_Number_Of_Observations:= 0;
      Rejected_Number_Of_Observations:= 0;
      Repeat
         Assign(Time_Specific_NCDC_Data_File, File_Name_Alpha);
         Reset(Time_Specific_NCDC_Data_File);
         Assign(Data_File_Of_Extra_Observations, File_Name_Bravo);
         Rewrite(Data_File_Of_Extra_Observations);
         If First_Time_Through_Loop = True Then
            Begin
               Rewrite(Final_Data_File_Of_148_
                       Character_Observations);
               File_Size_Determination_First_Pass:=
                    Compute_Number_Of_Observations
                         (File_Name_Alpha);
            End
         Else
            Begin
               Append(Final_Data_File_Of_148_
                      Character_Observations);
               File_Size_Determination:=
                    Compute_Number_Of_Observations
                         (File_Name_Alpha);
            End;
         First_Time_Through_Loop := False;
         While (File_Size_Determination > 0) And
```

```
                (Accumulated_Number_Of_Observations < 16300) Do
             Begin
                Random_Number_Test_Value:= Random;
                File_Size_Determination:=
                     File_Size_Determination -1;
                If Random_Number_Test_Value > 0.9 Then
                   Begin
                      Readln(Time_Specific_NCDC_Data_File,
                             Individual_Observation);
                      Writeln(Final_Data_File_Of_148_
                              Character_Observations,
                              Individual_Observation);
                      Accumulated_Number_Of_Observations:=
                           Accumulated_Number_Of_Observations + 1;
                   End
                Else
                   Begin
                      Readln(Time_Specific_NCDC_Data_File,
                             Individual_Observation);
                      Writeln(Data_File_Of_Extra_Observations,
                              Individual_Observation);
                      Rejected_Number_Of_Observations:=
                      Rejected_Number_Of_Observations + 1;
                   End;
             End;
          Close(Time_Specific_NCDC_Data_File);
          Close(Data_File_Of_Extra_Observations);
          If (File_Size_Determination = 0) Then
             Begin
                File_Name_Charlie:= File_Name_Alpha;
                File_Name_Alpha:= File_Name_Bravo;
                File_Name_Bravo:= File_Name_Charlie;
             End;
       Until (Accumulated_Number_Of_Observations = 16300);
       Close(Final_Data_File_Of_148_Character_Observations);
       ClrScr;
       Write('The SEA_STATE_CALC program can process a maximum');
       Writeln(' of 16,300 significant wave');
       Writeln('height observations.');
       Writeln;
       Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained ',
              File_Size_Determination_First_Pass);
       Writeln(' observations, a random');
       Write('sample of these observations was moved to the next');
       Writeln(' holding file entitled,');
       Writeln('"C:\JLOTS\SSDATA3.TXT".');
       Writeln;
       Writeln('The file "C:\JLOTS\SSDATA3.TXT" contains ',
                Compute_Number_Of_Observations
                     ('c:\JLOTS\SSDATA3.TXT'),' observations.');
       Writeln;
       Write('From this file, the input data set of significant');
       Writeln(' wave height observations');
       Writeln('will be created.');
       Writeln;
       Writeln;
       Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
       Writeln('--------------------------------------------');
       ReadKey;
    End
 Else If (File_Size_Determination >= 32600) Then
    Begin
       Assign(Time_Specific_NCDC_Data_File,
         'C:\JLOTS\SSDATA2.TXT');
       Reset(Time_Specific_NCDC_Data_File);
       Assign(Final_Data_File_Of_148_Character_Observations,
```

```
                'C:\JLOTS\SSDATA3.TXT');
          Rewrite(Final_Data_File_Of_148_Character_Observations);
          Upper_Bound_For_Random_Number :=
               (File_Size_Determination) Div (16300);
          Randomly_Selected_Observation_Increment:=
               Trunc(Random(Upper_Bound_For_Random_Number));
          Accepted_Observation_Counter:= 0;
          For Accepted_Observation_Counter:= 1 To
               (Randomly_Selected_Observation_Increment - 1) Do
             Begin
                Readln(Time_Specific_NCDC_Data_File);
             End;
          Readln(Time_Specific_NCDC_Data_File,
             Individual_Observation);
          Writeln(Final_Data_File_Of_148_Character_Observations,
                  Individual_Observation);
          For Accepted_Observation_Counter:= 2 To 16300 Do
             Begin
                Readln(Time_Specific_NCDC_Data_File,
                       Individual_Observation);
                Writeln(Final_Data_File_Of_148_Character_Observations,
                        Individual_Observation);
                Excluded_Observation_Counter:= 0;
                For Excluded_Observation_Counter:= 1 To
                    (Upper_Bound_For_Random_Number - 1) Do
                   Begin
                      Readln(Time_Specific_NCDC_Data_File);
                   End;
             End;
          Close(Time_Specific_NCDC_Data_File);
          Close(Final_Data_File_Of_148_Character_Observations);
          ClrScr;
          Write('The SEA_STATE_CALC program can process a maximum');
          Writeln(' of 16,300 significant wave');
          Writeln('height observations.');
          Writeln;
          Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained ',
                 File_Size_Determination);
          Writeln(' observations, a random');
          Write('sample of these observations was moved to the next');
          Writeln(' holding file entitled,');
          Writeln('"C:\JLOTS\SSDATA3.TXT".');
          Writeln;
          Writeln('The file "C:\JLOTS\SSDATA3.TXT" contains ',
                  Compute_Number_Of_Observations
                       ('C:\JLOTS\SSDATA3.TXT'),' observations.');
          Writeln;
          Write('From this file, the input data set of significant');
          Writeln(' wave height observations');
          Writeln('will be created.');
          Writeln;
          Writeln;
          Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
          Writeln('---------------------------------------------');
          ReadKey;
       End;
   End
Else
   Begin
      File_To_Be_Analyzed:= 'C:\JLOTS\SSDATA2.TXT';
      File_Size_Determination:=
             Compute_Number_Of_Observations (File_To_Be_Analyzed);
      If (File_Size_Determination < 16300) Then
         Begin
            Assign(Final_Data_File_Of_148_Character_Observations,
                   'C:\JLOTS\SSDATA2.TXT');
```

```
      Rename(Final_Data_File_Of_148_Character_Observations,
             'C:\JLOTS\SSDATA3.TXT');
      ClrScr;
      Write('The SEA_STATE_CALC program can process a maximum');
      Writeln('of 16,300 significant wave');
      Writeln('height observations.');
      Writeln;
      Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained
     only ',File_Size_Determination);
      Writeln(' observations,');
      Write('all of these observations were moved to the next
    holding');
      Writeln(' file entitled,');
      Writeln('"C:\JLOTS\SSDATA3.TXT".');
      Writeln;
      Write('From this file, the input data set of significant');
      Writeln(' wave height observations');
      Writeln('will be created.');
      Writeln;
      Writeln;
      Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
      Writeln('--------------------------------------------');
      ReadKey;
   End
Else If (File_Size_Determination > 16300) And
        (File_Size_Determination < 32600) Then
   Begin
      File_Name_Alpha:= 'C:\JLOTS\SSDATA2.TXT';
      File_Name_Bravo:= 'C:\JLOTS\SSDATA4.TXT';
      Assign(Final_Data_File_Of_148_Character_Observations,
             'C:\JLOTS\SSDATA3.TXT');
      First_Time_Through_Loop := True;
      Accumulated_Number_Of_Observations:= 0;
      Rejected_Number_Of_Observations:= 0;
      Repeat
         Assign(Time_Specific_NCDC_Data_File, File_Name_Alpha);
         Reset(Time_Specific_NCDC_Data_File);
         Assign(Data_File_Of_Extra_Observations, File_Name_Bravo);
         Rewrite(Data_File_Of_Extra_Observations);
         If First_Time_Through_Loop = True Then
            Begin
               Rewrite(Final_Data_File_Of_148_
                          Character_Observations);
               File_Size_Determination_First_Pass:=
                     Compute_Number_Of_Observations
                           (File_Name_Alpha);
            End
         Else
            Begin
               Append(Final_Data_File_Of_148_
                         Character_Observations);
               File_Size_Determination:=
                     Compute_Number_Of_Observations
                           (File_Name_Alpha);
            End;
         First_Time_Through_Loop := False;
         While (File_Size_Determination > 0) And
               (Accumulated_Number_Of_Observations < 16300) Do
            Begin
               Random_Number_Test_Value:= Random;
               File_Size_Determination:=
                     File_Size_Determination - 1;
               If Random_Number_Test_Value > 0.9 Then
                  Begin
                     Readln(Time_Specific_NCDC_Data_File,
                            Individual_Observation);
```

```
                    Writeln(Final_Data_File_Of_148_
                            Character_Observations,
                            Individual_Observation);
                    Accumulated_Number_Of_Observations:=
                         Accumulated_Number_Of_Observations + 1;
                 End
              Else
                 Begin
                    Readln(Time_Specific_NCDC_Data_File,
                           Individual_Observation);
                    Writeln(Data_File_Of_Extra_Observations,
                            Individual_Observation);
                    Rejected_Number_Of_Observations:=
                         Rejected_Number_Of_Observations + 1;
                 End;
           End;
        Close(Time_Specific_NCDC_Data_File);
        Close(Data_File_Of_Extra_Observations);
        If (File_Size_Determination = 0) Then
           Begin
              File_Name_Charlie:= File_Name_Alpha;
              File_Name_Alpha:= File_Name_Bravo;
              File_Name_Bravo:= File_Name_Charlie;
           End;
     Until (Accumulated_Number_Of_Observations = 16300);
     Close(Final_Data_File_Of_148_Character_Observations);
     ClrScr;
     Write('The SEA_STATE_CALC program can process a maximum');
     Writeln(' of 16,300 significant wave');
     Writeln('height observations.');
     Writeln;
     Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained ',
            File_Size_Determination_First_Pass);
     Writeln(' observations, a random');
     Write('sample of these observations was moved to the next');
     Writeln(' holding file entitled,');
     Writeln('"C:\JLOTS\SSDATA3.TXT".');
     Writeln;
     Writeln('The file "C:\JLOTS\SSDATA3.TXT" contains ',
             Compute_Number_Of_Observations
                  ('C:\JLOTS\SSDATA3.TXT'),' observations.');
     Writeln;
     Write('From this file, the input data set of significant');
     Writeln(' wave height observations');
     Writeln('will be created.');
     Writeln;
     Writeln;
     Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
     Writeln('---------------------------------------------');
     ReadKey;
  End
Else If (File_Size_Determination >= 32600) Then
  Begin
     Assign(Time_Specific_NCDC_Data_File,'C:\JLOTS\SSDATA2.TXT');
     Reset(Time_Specific_NCDC_Data_File);
     Assign(Final_Data_File_Of_148_Character_Observations,
            'C:\JLOTS\SSDATA3.TXT');
     Rewrite(Final_Data_File_Of_148_Character_Observations);
     Upper_Bound_For_Random_Number :=
          (File_Size_Determination) Div (16300);
     Randomly_Selected_Observation_Increment:=
          Trunc(Random(Upper_Bound_For_Random_Number));
     Accepted_Observation_Counter:= 0;
     For Accepted_Observation_Counter:= 1 To
          (Randomly_Selected_Observation_Increment - 1) Do
        Begin
```

```
                  Readln(Time_Specific_NCDC_Data_File);
               End;
            Readln(Time_Specific_NCDC_Data_File,
               Individual_Observation);
            Writeln(Final_Data_File_Of_148_Character_Observations,
                  Individual_Observation);
            For Accepted_Observation_Counter:= 2 To 16300 Do
               Begin
                  Readln(Time_Specific_NCDC_Data_File,
                        Individual_Observation);
                  Writeln(Final_Data_File_Of_148_Character_Observations,
                         Individual_Observation);
                  Excluded_Observation_Counter:= 0;
                  For Excluded_Observation_Counter:= 1 To
                     (Upper_Bound_For_Random_Number - 1) Do
                     Begin
                        Readln(Time_Specific_NCDC_Data_File);
                     End;
               End;
            Close(Time_Specific_NCDC_Data_File);
            Close(Final_Data_File_Of_148_Character_Observations);
            ClrScr;
            Write('The SEA_STATE_CALC program can process a maximum');
            Writeln(' of 16,300 significant wave');
            Writeln('height observations.');
            Writeln;
            Write('Because the file "C:\JLOTS\SSDATA2.TXT" contained ',
                  File_Size_Determination);
            Writeln(' observations, a random');
            Write('sample of these observations was moved to the next');
            Writeln(' holding file entitled,');
            Writeln('"C:\JLOTS\SSDATA3.TXT".');
            Writeln;
            Writeln('The file "C:\JLOTS\SSDATA3.TXT" contains ',
                   Compute_Number_Of_Observations
   ('C:\JLOTS\SSDATA3.TXT'),'observations.');
            Writeln;
            Write('From this file, the input data set of significant');
            Writeln(' wave height observations');
            Writeln('will be created.');
            Writeln;
            Writeln;
            Writeln('DEPRESS THE ENTER KEY TO CONTINUE THE PROGRAM');
            Writeln('---------------------------------------------');
            ReadKey;
         End;
      End;
   End;


Procedure Delete_Unnecessary_Data_Fields;

   Var
      Final_Data_File_Of_148_Character_Observations,
      Final_Input_Data_File_Of_SWH_Observations              : Text;
      Entire_Observation, Date_Time_Group_Data_Field,
      Wave_Height_Data_Field, Swell_Height_Data_Field        : String;
      Wave_Height_Data_Value, Swell_Height_Data_Value,
      Wave_Height_Intermediate, Swell_Height_Intermediate,
      Significant_Wave_Height_Data_Parameter                 : Real;
      Number_Of_Significant_Wave_Height_Observations,
      Error_Code                                             : Integer;
```

```
Begin
   Assign(Final_Data_File_Of_148_Character_Observations,
      'C:\JLOTS\SSDATA3.TXT');
   Reset(Final_Data_File_Of_148_Character_Observations);
   Assign(Final_Input_Data_File_Of_SWH_Observations,
      'C:\JLOTS\SSDATA.TXT');
   Rewrite(Final_Input_Data_File_Of_SWH_Observations);
   Number_Of_Significant_Wave_Height_Observations:= 0;
   While Not EOF (Final_Data_File_Of_148_Character_Observations) Do
      Begin
         Readln(Final_Data_File_Of_148_Character_Observations,
                Entire_Observation);
         Date_Time_Group_Data_Field:= Copy(Entire_Observation, 17, 10);
         Wave_Height_Data_Field:= Copy(Entire_Observation, 72, 2);
         Swell_Height_Data_Field:= Copy(Entire_Observation, 77, 2);
         If Wave_Height_Data_Field <> '  ' Then
            Begin
               Val(Wave_Height_Data_Field, Wave_Height_Intermediate,
               Error_Code);
               Wave_Height_Data_Value:=
                    (Wave_Height_Intermediate/2) * 3.281;
               If Swell_Height_Data_Field <> '  ' Then
                  Begin
                     Val(Swell_Height_Data_Field,
                     Swell_Height_Intermediate, Error_Code);
                     Swell_Height_Data_Value:=
                     (Swell_Height_Intermediate/2) * 3.281;
                     Significant_Wave_Height_Data_Parameter:=
                          Sqrt(Sqr(Wave_Height_Data_Value) +
                           Sqr(Swell_Height_Data_Value));
                  End
               Else
                  Begin
                     Significant_Wave_Height_Data_Parameter:=
                      Sqrt(Sqr(Wave_Height_Data_Value));
                  End;
               If Significant_Wave_Height_Data_Parameter < 75.00 Then
                  Begin
                     Writeln(Final_Input_Data_File_Of_SWH_Observations,
                     Copy(Date_Time_Group_Data_Field, 5, 2),'/',
                     Copy(Date_Time_Group_Data_Field, 7, 2),'/',
                     Copy(Date_Time_Group_Data_Field, 3, 2),'  ',
                     Copy(Date_Time_Group_Data_Field, 9, 2),':00','',
                               Significant_Wave_Height_Data_Parameter:6:4);
                     Number_Of_Significant_Wave_Height_Observations:=
                        Number_Of_Significant_Wave_Height_Observations + 1;
                  End;
            End;
      End;
   ClrScr;
   Writeln('INPUT DATA FILE CREATION HAS BEEN COMPLETED!!!');
   Writeln('---------------------------------------------');
   Writeln;
   Writeln;
   Writeln('The data file "C:\JLOTS\SSDATA.TXT" has been created.');
   Writeln;
   Write('This file contains contains ',
          Number_Of_Significant_Wave_Height_Observations,' significant',
          ' wave height');
   Writeln(' observations and');
   Writeln('their corresponding date/time groups.');
   Writeln;
   Write('"C:\JLOTS\SSDATA.TXT" will be called as the input file by the');
   Writeln(' SEA_STATE_CALC');
   Writeln('program.');
End;
```

```
BEGIN
   Program_Overview (Number_Of_Trials);
   Ask_Configuration_Of_NCDC_Data (Number_of_Trials);
   Obtain_Majority_Month (Majority_Month_Number);
   Determine_Desired_Data_File_Configuration (Majority_Month_Number);
   Create_Desired_Input_Data_File_Type (Number_Of_Trials);
   Delete_Unnecessary_Data_Fields;
END.
```

APPENDIX F. SEA_STATE_CALC_PROGRAM

This appendix contains the Visual Basic computer coding for the SEA_STATE_CALC program. This program is designed to be executed from Excel 5.0 subsequent to the execution of the ARRANGE_DATA module and concurrent with the execution of JOTE model. Once initiated, the SEA_STATE_CALC program will access the input file SSDATA.TXT created by the ARRANGE_DATA module. The program will operate free of user interaction and is designed to return the possible values for the spreadsheet cell O-38 entry of the JOTE model, thereby rendering the calculations of JOTE to be both site and time specific. All macro names used within this program have literal meanings consistent with the function(s) they perform.

```
' GET_DATA_and_START_CALC Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub GET_DATA_and_START_CALC()
    CREATE_EXCEL_TEXT_FILE
    Sheets("Sheet2").Select
    Range("A34:D16384").Select
    Selection.ClearContents
    Range("A1").Select
    ChDir "C:\Jlots"
    Workbooks.Open Filename:="C:\Jlots\SSDATA.xls"
    Windows.Arrange ArrangeStyle:=xlVertical
    Range("A1:B16300").Select
    Selection.Copy
    Range("F1").Select
    Windows("mymacro2f.xls").Activate
    Range("A34").Select
    ActiveSheet.Paste
    Range("A1").Select
    Windows("ssdata.xls").Activate
    ActiveWindow.Close
    ActiveWindow.WindowState = xlMaximized
        Range("A34").Select
    ActiveWindow.ScrollRow = 16343
    Range("A34:B16384").Select
    With Selection
        .HorizontalAlignment = xlCenter
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
    End With
    Range("C34").Select
    ActiveWindow.ScrollRow = 16343
    Range("C34:D16384").Select
    Selection.ClearContents
    Range("C34").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-2]="""","""",RC[-2])"
    Range("C34").Select
    Selection.Copy
    Range("C35").Select
    ActiveWindow.ScrollRow = 16343
    Range("C35:C16384").Select
    ActiveSheet.Paste
    Range("D34").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "=IF(RC[-2]="""","""",RC[-2])"
    Range("D34").Select
    Selection.Copy
    Range("D35").Select
    ActiveWindow.ScrollRow = 16343
    Range("C34:D16384").Select
    ActiveSheet.Paste
        With Selection
        .HorizontalAlignment = xlGeneral
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
    End With
    Range("L34").Select
    ActiveWindow.ScrollRow = 16343
    Range("L34:O16384").Select
    Selection.ClearContents
    Range("I34").Select
    ActiveWindow.ScrollRow = 16343
    Range("I34:I16384").Select
    Selection.Copy
    ActiveWindow.ScrollRow = 1
    Range("L34").Select
    Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
        SkipBlanks:=False, Transpose:=False
        Range("C34").Select
```

```
Application.CutCopyMode = False
Selection.NumberFormat = "m/d/yy h:mm AM/PM"
Selection.Copy
Range("C35").Select
ActiveWindow.ScrollRow = 16343
Range("C35:C16384").Select
ActiveSheet.Paste
Range("C34").Select
ActiveWindow.ScrollRow = 16343
Range("C34:D16384").Select
Application.CutCopyMode = False
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
Range("K34").Select
ActiveWindow.ScrollRow = 16343
Range("K34:K16384").Select
Application.CutCopyMode = False
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("M34").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("C34").Select
Application.CutCopyMode = False
Selection.NumberFormat = "m/d/yy h:mm AM/PM"
Selection.Copy
Range("C35").Select
ActiveWindow.ScrollRow = 16343
Range("C35:C16384").Select
ActiveSheet.Paste
Range("C34").Select
ActiveWindow.ScrollRow = 16343
Range("C34:D16384").Select
Application.CutCopyMode = False
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
Range("D34").Select
ActiveWindow.ScrollRow = 16343
Range("D34:D16384").Select
Application.CutCopyMode = False
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("N34").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("C34").Select
Application.CutCopyMode = False
Selection.NumberFormat = "m/d/yy h:mm AM/PM"
Selection.Copy
Range("C35").Select
ActiveWindow.ScrollRow = 16343
Range("C35:C16384").Select
ActiveSheet.Paste
Range("C34").Select
ActiveWindow.ScrollRow = 16343
Range("C34:D16384").Select
Application.CutCopyMode = False
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
```

```
Range("J34").Select
ActiveWindow.ScrollRow = 16343
Range("J34:J16384").Select
Application.CutCopyMode = False
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("O34").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("C34").Select
Application.CutCopyMode = False
Selection.NumberFormat = "m/d/yy h:mm AM/PM"
Selection.Copy
Range("C35").Select
ActiveWindow.ScrollRow = 16343
Range("C35:C16384").Select
ActiveSheet.Paste
Range("C34").Select
ActiveWindow.ScrollRow = 16343
Range("C34:D16384").Select
Application.CutCopyMode = False
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
Range("L33").Select
ActiveWindow.ScrollRow = 16343
Range("L33:M16384").Select
Application.CutCopyMode = False
Selection.Sort Key1:=Range("L34"), Order1:=xlAscending, Header:= _
    xlGuess, OrderCustom:=1, MatchCase:=False, Orientation:= _
    xlTopToBottom
Range("N33").Select
ActiveWindow.ScrollRow = 16343
Range("N33:O16384").Select
Selection.Sort Key1:=Range("N34"), Order1:=xlAscending, Header:= _
    xlGuess, OrderCustom:=1, MatchCase:=False, Orientation:= _
    xlTopToBottom
Range("P33").Select
ActiveWindow.SmallScroll ToRight:=6
Range("T34").Select
ActiveWindow.ScrollRow = 16343
Range("T34:U16384").Select
Selection.ClearContents
Range("J34").Select
ActiveWindow.ScrollRow = 16343
Range("J34:J16384").Select
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("T34").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("S34").Select
ActiveWindow.ScrollRow = 16343
Range("S34:S16384").Select
Application.CutCopyMode = False
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("U34").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("T33").Select
ActiveWindow.ScrollRow = 16343
Range("T33:U16384").Select
Application.CutCopyMode = False
Selection.Sort Key1:=Range("T34"), Order1:=xlAscending, Header:= _
    xlGuess, OrderCustom:=1, MatchCase:=False, Orientation:= _
    xlTopToBottom
Range("U29").Select
```

```
Sheets("Sheet3").Select
Cells.Select
Selection.ClearContents
ActiveWindow.SmallScroll ToRight:=13
ActiveWindow.SmallScroll Down:=6
ActiveSheet.DrawingObjects("Chart 38").Select
Selection.Left = 1395.75
ActiveSheet.ChartObjects("Chart 38").Activate
ActiveChart.DrawingObjects("Text 4").Select
Selection.Left = 435
Selection.Width = 129
Selection.Width = 151
Selection.Height = 63
Selection.Left = 445
Selection.Width = 141
Selection.Width = 135
ActiveChart.DrawingObjects("Text 3").Select
Selection.Left = 453
Selection.Width = 129
Selection.Height = 55
Selection.Height = 61
ActiveChart.DrawingObjects("Text 4").Select
Selection.Left = 448
Selection.Top = 90
ActiveChart.ChartArea.Select
ActiveChart.Legend.Select
ActiveChart.Legend.LegendEntries(1).Select
Selection.Delete
ActiveChart.Legend.Select
ActiveChart.Legend.LegendEntries(1).Select
Selection.Delete
ActiveChart.ChartArea.Select
ActiveWindow.Visible = False
Windows("mymacro2f.xls").Activate
ActiveWindow.ScrollColumn = 1
ActiveWindow.ScrollColumn = 8
ActiveChart.ChartWizard Source:=Range("L12:M13"), PlotBy:=xlColumns, _
     CategoryLabels:=1, SeriesLabels:=0
Range("P43").Select
ActiveWindow.SmallScroll ToRight:=5
Range("A1").Select
Sheets("Sheet4").Select
Cells.Select
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
Selection.ClearContents
ActiveWindow.ScrollColumn = 1
Cells.Select
Range("A6").Activate
Selection.ClearContents
Range("A6").Select
ActiveWindow.SmallScroll ToRight:=12
ActiveSheet.DrawingObjects("Chart 11").Select
ActiveSheet.ChartObjects("Chart 11").Activate
ActiveChart.Legend.Select
ActiveChart.Legend.LegendEntries(2).Select
Selection.Delete
ActiveWindow.Visible = False
Windows("mymacro2f.xls").Activate
Range("N29").Select
Range("A1").Select
Sheets("Sheet5").Select
Cells.Select
With Selection
    .HorizontalAlignment = xlCenter
    .VerticalAlignment = xlBottom
    .WrapText = False
```

```
        .Orientation = xlHorizontal
    End With
    Selection.ClearContents
    Range("A1").Select
    Sheets("Sheet2").Select


    Range("A1").Select
End Sub
'
'
'
'
'
' VIEW_GRAPH_1 Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub VIEW_GRAPH_1()
    Sheets("Sheet3").Select
    Range("I6").Select
    ActiveWindow.SmallScroll ToRight:=0
    Range("B11").Select
    ActiveCell.FormulaR1C1 = "SORTED (H/Hrms)"
    Range("C11").Select
    ActiveCell.FormulaR1C1 = "SORTED (Hrms * P(H))"
    Range("E10").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("F10").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("E11").Select
    ActiveCell.FormulaR1C1 = "SORTED (H/Hrms)"
    Range("F11").Select
    ActiveCell.FormulaR1C1 = "SORTED (Hrms * P(H))"
    Range("H10").Select
    ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
    Range("H11").Select
    ActiveCell.FormulaR1C1 = "SORTED (H/Hrms)"
    Range("I11").Select
    ActiveCell.FormulaR1C1 = "SORTED (Hrms * P(H))"
    Range("L11").Select
    ActiveCell.FormulaR1C1 = """A"" VALUE"
    Range("M11").Select
    ActiveCell.FormulaR1C1 = "H = ""A"" * Hrms"
    Range("N11").Select
    ActiveCell.FormulaR1C1 = """B"" VALUE"
    Range("O11").Select
    ActiveWindow.SmallScroll ToRight:=2
    ActiveCell.FormulaR1C1 = "H = ""B"" * Hrms"
    Range("M17").Select
    ActiveCell.FormulaR1C1 = "   NUMBER OF NON-REPEATED DATA VALUES"
    With ActiveCell.Characters(Start:=1, Length:=3).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlNone
        .ColorIndex = 5
    End With
    With ActiveCell.Characters(Start:=4, Length:=34).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
```

```
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("M19").Select
ActiveCell.FormulaR1C1 = "LINE NUMBER FOR LAST"
Range("M20").Select
ActiveCell.FormulaR1C1 = "NON-REPEATED DATA VALUE"
Range("M22").Select
ActiveWindow.ScrollColumn = 1
Range("A1").Select
Sheets("Sheet3").Select
Range("A1").Select
Sheets("Sheet2").Select
Range("L34").Select
ActiveWindow.ScrollRow = 16343
Range("L34:M16384").Select
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("A1").Select
Sheets("Sheet3").Select
Range("B12").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("B12").Select
ActiveWindow.ScrollRow = 16321
ActiveWindow.SmallScroll Down:=28
Range("B12:B16384").Select
Application.CutCopyMode = False
Range("B11:B16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
    :=Range("E11:E16384"), Unique:=True
Range("C12").Select
ActiveWindow.ScrollRow = 16321
ActiveWindow.SmallScroll Down:=29
Range("C12:C16384").Select
Application.CutCopyMode = False
Range("C11:C16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
   :=Range("F11:F16384"), Unique:=True
Range("E12").Select
ActiveWindow.ScrollRow = 16321
ActiveWindow.SmallScroll Down:=27
Range("E12:E16384").Select
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("H12").Select
ActiveSheet.Paste
Range("I12").Select
Application.CutCopyMode = False
ActiveCell.FormulaR1C1 = _
    "=IF(AND(RC5<>"""",RC6=""""),0,IF(RC6<>"""",RC6,""""))"
Range("I12").Select
Selection.Copy
Range("I13").Select
ActiveWindow.ScrollRow = 16343
Range("I13:I16384").Select
ActiveSheet.Paste
Range("J12").Select
Range("G11").Select
ActiveWindow.SmallScroll ToRight:=3
Range("O17").Select
ActiveCell.FormulaR1C1 = "=COUNTA(R[-5]C[-7]:R[16367]C[-7])-1"
Range("O20").Select
ActiveCell.FormulaR1C1 = "=R[-3]C + 11"
Range("L18").Select
Range("L12").Select
ActiveCell.FormulaR1C1 = "=1.4/Sheet2!R34C8"
Range("L13").Select
ActiveCell.FormulaR1C1 = "=1.4/Sheet2!R34C8"
Range("M12").Select
ActiveCell.FormulaR1C1 = "0"
Range("M13").Select
ActiveCell.FormulaR1C1 = _
```

```
"=Sheet2!R34C8*(((2*(R13C9*Sheet2!R34C8))/((Sheet2!R34C8)^2))*(EXP(-1*((R13C9*Sheet2!R34C8
)/(Sheet2!R34C8))^2)))"
    Range("H15").Select
    ActiveWindow.SmallScroll ToRight:=3
    Range("N12").Select
    ActiveCell.FormulaR1C1 = "=MAX(R12C5:R16384C5)"
    Range("N13").Select
    ActiveCell.FormulaR1C1 = "=MAX(R12C5:R16384C5)"
    Range("O12").Select
    ActiveCell.FormulaR1C1 = "0"
    Range("O13").Select
    ActiveCell.FormulaR1C1 = _

"=Sheet2!R34C8*(((2*(R13C14*Sheet2!R34C8))/((Sheet2!R34C8)^2))*(EXP(-1*((R13C14*Sheet2!R34
C8)/(Sheet2!R34C8))^2)))"
    Range("L14").Select
    Range("M13").Select
    ActiveWindow.SmallScroll Down:=28
    ActiveWindow.SmallScroll ToRight:=6
        Range("S58").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = _
        "THEORETICAL % OF TIME > OR = SS2 ------------------------ [1 - F(a)]
-------------------------"
    Range("S60").Select
    ActiveCell.FormulaR1C1 = _
        "ACTUAL % OF TIME > OR = MAX ""X"" VALUE --------------- [1- F(b)]
--------------------------"
    Range("S62").Select
    ActiveCell.FormulaR1C1 = _
        "OBSERVED % OF TIME > OR = SS2 ---------------------------- [F(b) - F(a)]
----------------------"
    Range("AB63:AB64").Select
    Range("AB64").Activate
    Range("AB58").Select
    ActiveCell.FormulaR1C1 = "=(EXP(-1*(1.4/Sheet2!R34C8)^2))*100"
    Range("AB60").Select
    ActiveCell.FormulaR1C1 = _
        "=EXP(-1*(MAX(R12C5:R16384C5)^2))*100"
    Range("AB62").Select
    ActiveCell.FormulaR1C1 = _
        "=((EXP(-1*(1.4/Sheet2!R34C8)^2)) - EXP(-1*(MAX(R12C5:R16384C5)^2)))*100"
    Range("O63").Select
    Range("H12:I" & (Range("O20").Value)).Select
    Selection.Copy
    ActiveSheet.DrawingObjects("Chart 38").Select
    ActiveChart.SeriesCollection.Paste Rowcol:=xlColumns, SeriesLabels _
        :=False, CategoryLabels:=True, Replace:=False, NewSeries:= _
        True
    Application.CutCopyMode = False
    Range("N12:O13").Select
    Selection.Copy
    ActiveSheet.DrawingObjects("Chart 38").Select
    ActiveChart.SeriesCollection.Paste Rowcol:=xlColumns, SeriesLabels _
        :=False, CategoryLabels:=True, Replace:=False, NewSeries:= _
        True
    Application.CutCopyMode = False
    ActiveWindow.SmallScroll ToRight:=5
    ActiveSheet.ChartObjects("Chart 38").Activate
    ActiveChart.SeriesCollection(1).Select
    With Selection.Border
        .ColorIndex = 3
        .Weight = xlThick
        .LineStyle = xlContinuous
    End With
    With Selection
        .MarkerBackgroundColorIndex = 2
        .MarkerForegroundColorIndex = 1
        .MarkerStyle = xlNone
        .Smooth = True
```

```
End With
With ActiveChart.SeriesCollection(1)
     .Name = "=""""""A"""" VALUE MARKER"""
     .Values = "=Sheet3!R12C13:R13C13"
End With
Selection.ApplyDataLabels Type:=xlShowLabel, LegendKey:=False
Selection.DataLabels.Select
Selection.AutoText = True
ActiveChart.SeriesCollection(2).Select
With Selection.Border
     .ColorIndex = 5
     .Weight = xlThick
     .LineStyle = xlContinuous
End With
With Selection
     .MarkerBackgroundColorIndex = 2
     .MarkerForegroundColorIndex = 1
     .MarkerStyle = xlNone
     .Smooth = True
End With
With ActiveChart.SeriesCollection(2)
     .Name = "=""RAYLEIGH PDF"""
     .Values = "=Sheet3!R12C9:R30C9"
End With
ActiveChart.Axes(xlCategory).Select
With ActiveChart.Axes(xlCategory)
     .MinimumScaleIsAuto = True
     .MaximumScale = 15
     .MinorUnitIsAuto = True
     .MajorUnitIsAuto = True
     .Crosses = xlAutomatic
     .ReversePlotOrder = False
     .ScaleType = False
End With
ActiveChart.SeriesCollection(3).Select
ActiveChart.SeriesCollection(3).Points(2).Select
ActiveChart.Axes(xlCategory).Select
ActiveChart.SeriesCollection(3).Select
With Selection.Border
     .ColorIndex = 3
     .Weight = xlThick
     .LineStyle = xlContinuous
End With
With Selection
     .MarkerBackgroundColorIndex = 2
     .MarkerForegroundColorIndex = 1
     .MarkerStyle = xlNone
     .Smooth = True
End With
With ActiveChart.SeriesCollection(3)
     .Name = "=""""""B"""" VALUE MARKER"""
     .Values = "=Sheet3!R12C15:R13C15"
End With
ActiveChart.SeriesCollection(3).Points(2).Select
ActiveChart.PlotArea.Select
ActiveChart.SeriesCollection(3).Select
ActiveChart.SeriesCollection(3).Points(2).Select
ActiveChart.PlotArea.Select
ActiveChart.SeriesCollection(3).Select
With ActiveChart.SeriesCollection(3)
     .Name = "=""""""B"""" VALUE MARKER (POSSIBLY NOT VISIBLE)"""
     .Values = "=Sheet3!R12C15:R13C15"
End With
ActiveWindow.Visible = False
ActiveSheet.DrawingObjects("Chart 38").Select
ActiveSheet.ChartObjects("Chart 38").Activate
ActiveChart.Axes(xlCategory).Select
With ActiveChart.Axes(xlCategory)
     .MinimumScaleIsAuto = True
     .MaximumScale = 2
     .MinorUnitIsAuto = True
```

```
        .MajorUnitIsAuto = True
        .Crosses = xlAutomatic
        .ReversePlotOrder = False
        .ScaleType = False
    End With
    ActiveChart.SeriesCollection(1).Select
    Selection.ApplyDataLabels Type:=xlNone, LegendKey:=False
    ActiveWindow.Visible = False
    Windows("mymacro2f.xls").Activate
    Range("P25").Select
    Windows("mymacro2f.xls").Activate
    Range("Q27").Select
End Sub
'
'
'
'
'
' VIEW_GRAPH_2 Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub VIEW_GRAPH_2()
    Sheets("Sheet4").Select
    Range("A1").Select
    Range("B11").Select
    ActiveCell.FormulaR1C1 = "SORTED NSSWH"
    Range("C11").Select
    ActiveCell.FormulaR1C1 = "SORTED P(H)"
    Range("D10").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("D11").Select
    ActiveCell.FormulaR1C1 = "SORTED NSSWH"
    Range("C11").Select
    ActiveCell.FormulaR1C1 = "SORTED P(H)"
    Range("B11").Select
    ActiveCell.FormulaR1C1 = "SORTED NSSWH"
    Range("C11").Select
    ActiveCell.FormulaR1C1 = "SORTED P(H)"
    Range("D10").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("D11").Select
    ActiveCell.FormulaR1C1 = "SORTED NSSWH"
    Range("E10").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("E11").Select
    ActiveCell.FormulaR1C1 = "SORTED P(H)"
    Range("F10").Select
    ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
    Range("F11").Select
    ActiveCell.FormulaR1C1 = "SORTED NSSWH"
    Range("G11").Select
    ActiveCell.FormulaR1C1 = "SORTED P(H)"
    Range("H9").Select
    ActiveCell.FormulaR1C1 = _
        "                                      DESCENDING SORTED"
    With ActiveCell.Characters(Start:=1, Length:=34).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlNone
        .ColorIndex = 5
    End With
    With ActiveCell.Characters(Start:=35, Length:=17).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
```

```
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("H10").Select
ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
Range("H11").Select
ActiveCell.FormulaR1C1 = "SORTED NSSWH"
Range("H10").Select
ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
Range("I11").Select
ActiveCell.FormulaR1C1 = "SORTED P(H)"
Range("J15").Select
ActiveWindow.SmallScroll ToRight:=4
Range("L11").Select
ActiveCell.FormulaR1C1 = "NSSWH VALUE"
Range("M11").Select
ActiveCell.FormulaR1C1 = "MOST PROBABLE WAVE HEIGHT"
Range("L17").Select
ActiveCell.FormulaR1C1 = "       NUMBER OF NON-REPEATED DATA VALUES"
With ActiveCell.Characters(Start:=1, Length:=7).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = 5
End With
With ActiveCell.Characters(Start:=8, Length:=34).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("L19").Select
ActiveCell.FormulaR1C1 = "                         LINE NUMBER FOR LAST"
With ActiveCell.Characters(Start:=1, Length:=25).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = 5
End With
With ActiveCell.Characters(Start:=26, Length:=20).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
```

```
        .Underline = xlSingle
        .ColorIndex = 5
    End With
    Range("L20").Select
    ActiveCell.FormulaR1C1 = "                    NON-REPEATED DATA VALUE"
    With ActiveCell.Characters(Start:=1, Length:=19).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlNone
        .ColorIndex = 5
    End With
    With ActiveCell.Characters(Start:=20, Length:=24).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlSingle
        .ColorIndex = 5
    End With
    Range("L19").Select
    ActiveCell.FormulaR1C1 = "                         LINE NUMBER FOR LAST"
    With ActiveCell.Characters(Start:=1, Length:=25).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlNone
        .ColorIndex = 5
    End With
    With ActiveCell.Characters(Start:=26, Length:=20).Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Strikethrough = False
        .Superscript = False
        .Subscript = False
        .OutlineFont = False
        .Shadow = False
        .Underline = xlSingle
        .ColorIndex = 5
    End With
    Range("F10").Select
    ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
    Range("F10").Select
    With Selection
        .HorizontalAlignment = xlLeft
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
    End With
    ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
    Range("H10").Select
    With Selection
        .HorizontalAlignment = xlLeft
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
```

```
End With
ActiveCell.FormulaR1C1 = "DATA PAIRS FOR NON-REPEATING VALUES"
Range("H11").Select
ActiveWindow.SmallScroll ToRight:=6
Range("L17").Select
With Selection
    .HorizontalAlignment = xlLeft
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
ActiveCell.FormulaR1C1 = "       NUMBER OF NON-REPEATED DATA VALUES"
With ActiveCell.Characters(Start:=1, Length:=7).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = 5
End With
With ActiveCell.Characters(Start:=8, Length:=34).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("L19").Select
With Selection
    .HorizontalAlignment = xlLeft
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
ActiveCell.FormulaR1C1 = "                         LINE NUMBER FOR LAST"
With ActiveCell.Characters(Start:=1, Length:=25).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = 5
End With
With ActiveCell.Characters(Start:=26, Length:=20).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("L20").Select
With Selection
    .HorizontalAlignment = xlLeft
```

```
    .VerticalAlignment = xlBottom
    .WrapText = False
    .Orientation = xlHorizontal
End With
ActiveCell.FormulaR1C1 = "                    NON-REPEATED DATA VALUE"
With ActiveCell.Characters(Start:=1, Length:=19).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlNone
    .ColorIndex = 5
End With
With ActiveCell.Characters(Start:=20, Length:=24).Font
    .Name = "Arial"
    .FontStyle = "Bold"
    .Size = 10
    .Strikethrough = False
    .Superscript = False
    .Subscript = False
    .OutlineFont = False
    .Shadow = False
    .Underline = xlSingle
    .ColorIndex = 5
End With
Range("M22").Select
ActiveWindow.SmallScroll Down:=14
ActiveWindow.SmallScroll ToRight:=6
ActiveWindow.ScrollColumn = 1
ActiveWindow.SmallScroll Down:=-14
Range("A1").Select
Range("L12").Select
ActiveCell.FormulaR1C1 = "=R12C8"
Range("M12").Select
ActiveCell.FormulaR1C1 = "=R12C9"
Range("N17").Select
ActiveCell.FormulaR1C1 = "=COUNTA(R[-5]C[-8]:R[16367]C[-8])-1"
Range("N20").Select
ActiveCell.FormulaR1C1 = "=R17C14+11"
ActiveSheet.DrawingObjects("Chart 11").Select
ActiveChart.ChartWizard Source:=Range("L11:M13"), PlotBy:=xlColumns, _
     CategoryLabels:=1, SeriesLabels:=1
ActiveWindow.ScrollColumn = 1
Sheets("Sheet2").Select
Range("N34").Select
ActiveWindow.ScrollRow = 16343
Range("N34:O16384").Select
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("A2").Select
Sheets("Sheet4").Select
Range("B12").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("B12").Select
ActiveWindow.ScrollRow = 16343
Range("B12:B16384").Select
ActiveWindow.ScrollRow = 1
Application.CutCopyMode = False
Range("B11:B16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
    :=Range("D11:D16384"), Unique:=True
Range("C12").Select
ActiveWindow.ScrollRow = 16343
Range("C12:C16384").Select
Range("C11:C16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
    :=Range("E11:E16384"), Unique:=True
Range("F12").Select
```

```
ActiveWindow.SmallScroll Down:=-3
Range("D12").Select
ActiveWindow.ScrollRow = 16343
Range("D12:D16384").Select
Selection.Copy
ActiveWindow.ScrollRow = 1
Range("F12").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("G12").Select
Application.CutCopyMode = False
Range("G12").Select
ActiveCell.FormulaR1C1 = _
    "=IF(AND(RC4<>"""",RC5=""""),0,IF(RC5<>"""",RC5,""""))"
Range("G12").Select
Selection.Copy
Range("G13").Select
ActiveWindow.ScrollRow = 16343
Range("G13:G16384").Select
ActiveSheet.Paste
Range("F12:G" & (Range("N20").Value)).Select
Application.CutCopyMode = False
Selection.Copy
Range("H12").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
    SkipBlanks:=False, Transpose:=False
Range("H11").Select
ActiveWindow.ScrollRow = 16343
Range("H11:I16384").Select
ActiveWindow.ScrollRow = 1
Application.CutCopyMode = False
Selection.Sort Key1:=Range("I12"), Order1:=xlDescending, Header:= _
    xlGuess, OrderCustom:=1, MatchCase:=False, Orientation:= _
    xlTopToBottom
Range("J12").Select
ActiveWindow.SmallScroll ToRight:=3
Range("L12").Select
Selection.Copy
Range("L13").Select
ActiveSheet.Paste
Range("M13").Select
Application.CutCopyMode = False
ActiveCell.FormulaR1C1 = "0"
Range("M26").Select
ActiveWindow.SmallScroll ToRight:=-5
Range("A1").Select
Sheets("Sheet4").Select
Range("F12:G" & (Range("N20").Value)).Select
Selection.Copy
ActiveSheet.DrawingObjects("Chart 11").Select
ActiveChart.SeriesCollection.Paste Rowcol:=xlColumns, SeriesLabels _
    :=False, CategoryLabels:=True, Replace:=False, NewSeries:= _
    True
Application.CutCopyMode = False
ActiveSheet.ChartObjects("Chart 11").Activate
ActiveChart.SeriesCollection(2).Select
With Selection.Border
    .ColorIndex = 5
    .Weight = xlThick
    .LineStyle = xlContinuous
End With
With Selection
    .MarkerBackgroundColorIndex = 2
    .MarkerForegroundColorIndex = 1
    .MarkerStyle = xlNone
    .Smooth = True
End With
With ActiveChart.SeriesCollection(2)
    .Name = "=""RAYLEIGH P(H)"""
    .Values = "=Sheet4!R12C7:R30C7"
End With
```

```
    ActiveWindow.Visible = False
    Windows("mymacro2F.xls").Activate
    Range("O27").Select
End Sub
'
'
'
'
'
' VIEW_CHI_SQUARED_TEST Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub VIEW_CHI_SQUARED_TEST()
    Sheets("Sheet5").Select
    ActiveWindow.SmallScroll Down:=-8
    ActiveWindow.ScrollColumn = 1
    Range("B13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("B14").Select
    ActiveCell.FormulaR1C1 = "P(H)"
    Range("C13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("C14").Select
    ActiveCell.FormulaR1C1 = "EXPECTED P(H)"
    Range("E12").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("E13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("E14").Select
    ActiveCell.FormulaR1C1 = "P(H)"
    Range("F12").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("F13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("F14").Select
    ActiveCell.FormulaR1C1 = "EXPECTED P(H)"
    Range("H11").Select
    ActiveCell.FormulaR1C1 = "NON-ZERO"
    Range("H12").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("H13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("H14").Select
    ActiveCell.FormulaR1C1 = "P(H)"
    Range("I11").Select
    ActiveCell.FormulaR1C1 = "NON-ZERO"
    Range("I12").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED"
    Range("I13").Select
    ActiveCell.FormulaR1C1 = "SORTED"
    Range("I14").Select
    ActiveCell.FormulaR1C1 = "EXPECTED P(H)"
    Range("I3").Select
    ActiveCell.FormulaR1C1 = "NUMBER OF NON-REPEATED DATA VALUES"
    Range("I5").Select
    ActiveCell.FormulaR1C1 = "LINE NUMBER FOR LAST"
    Range("I6").Select
    ActiveCell.FormulaR1C1 = "NON-REPEATED DATA VALUE"
    Range("K14").Select
    ActiveWindow.SmallScroll Down:=13
    ActiveWindow.SmallScroll ToRight:=7
    Range("R44").Select
    ActiveCell.FormulaR1C1 = _
        "CHI-SQUARED GOODNESS OF FIT VALUE ---------------------------------------"
    Range("R46").Select
    ActiveCell.FormulaR1C1 = _
        "MINIMUM DESIRED CHI-SQUARED GOODNESS OF FIT VALUE ------"
    Range("V46").Select
    ActiveCell.FormulaR1C1 = "=0.975"
    Range("O39").Select
    Sheets("Sheet2").Select
```

```
    Range("T34").Select
    ActiveWindow.ScrollRow = 16343
    Range("T34:U16384").Select
    Selection.Copy
    ActiveWindow.ScrollRow = 1
    Sheets("Sheet2").Select
    Range("V28").Select
    Sheets("Sheet5").Select
    Range("B15").Select
    Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, _
        SkipBlanks:=False, Transpose:=False
    Range("B15").Select
    ActiveWindow.ScrollRow = 16324
    ActiveWindow.SmallScroll Down:=24
    Range("B15:B16384").Select
    Application.CutCopyMode = False
    Range("B14:B16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
        :=Range("E14:E16384"), Unique:=True
    Range("C15").Select
    ActiveWindow.ScrollRow = 16324
    ActiveWindow.SmallScroll Down:=25
    Range("C15:C16384").Select
    Range("C14:C16384").AdvancedFilter Action:=xlFilterCopy, CopyToRange _
        :=Range("F14:F16384"), Unique:=True
    Sheets("Sheet5").Select
    Range("H15").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC5=0,RC6=0),"""",RC5)"
    Range("H15").Select
    Selection.Copy
    Range("H16").Select
    ActiveWindow.ScrollRow = 16343
    Range("H16:H16384").Select
    ActiveSheet.Paste
    Range("I15").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "=IF(AND(RC5=0,RC6=0),"""",RC6)"
    Range("I15").Select
    Selection.Copy
    Range("I16").Select
    ActiveWindow.ScrollRow = 16343
    Range("I16:I16384").Select
    ActiveSheet.Paste
    Range("K3").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = "=COUNTA(R[12]C5:R[16381]C5)-1"
    Range("K6").Select
    ActiveCell.FormulaR1C1 = "=R3C11+14"
    Range("K3:K6").Select
    With Selection
        .HorizontalAlignment = xlCenter
        .VerticalAlignment = xlBottom
        .WrapText = False
        .Orientation = xlHorizontal
    End With
    Range("K7").Select
    ActiveWindow.SmallScroll Down:=16
    ActiveWindow.SmallScroll ToRight:=6
    ActiveWindow.SmallScroll Down:=-8
    Range("R44").Select
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = _
        "CHI-SQUARED GOODNESS OF FIT VALUE ---------------------------------"
    Range("R46").Select
    ActiveCell.FormulaR1C1 = _
        "MINIMUM DESIRED CHI-SQUARED GOODNESS OF FIT VALUE ---"
    Range("V44").Select
    ActiveCell.FormulaR1C1 = _
        "=CHITEST(R[-29]C8:R[4956]C8,R[-29]C9:R[4956]C9)"
    Range("W44").Select
    Range("E1").Select
End Sub
```

```
'
'
'
'
'
' VIEW_MAIN_MENU Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub VIEW_MAIN_MENU()
    Sheets("Sheet1").Select
    ActiveWindow.ScrollRow = 1
    Range("A1").Select
End Sub
'
'
'
'
'
' OBTAIN_NEW_INPUT_DATA_SET Macro
' Macro recorded 9/26/96 by Tom Workman
'
Sub OBTAIN_NEW_INPUT_DATA_SET()
    LimitVal = Range("P44").Value
    If Range("P46").Value < LimitVal Then
       MyAppID = Shell("C:\JLOTS\Arrange2", 1)
       AppActivate MyAppID
    End If
End Sub
'
'
'
'
'
' CREATE_EXCEL_TEXT_FILE Macro
' Macro recorded 9/26/96 by Tom Workman
'
'
Sub CREATE_EXCEL_TEXT_FILE()
    ChDir "C:\JLOTS"
    Workbooks.OpenText Filename:="C:\JLOTS\SSDATA.TXT", Origin:= _
        xlWindows, StartRow:=1, DataType:=xlFixedWidth, FieldInfo:= _
        Array(Array(0, 3), Array(18, 1))
    Columns("A:A").ColumnWidth = 13.43
    Columns("A:A").ColumnWidth = 15.71
    Range("A1").Select
    Selection.Copy
    Range("A2").Select
    ActiveWindow.ScrollRow = 7695
    ActiveWindow.LargeScroll Down:=1
    Range("A7726").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A7757").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A7788").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A7819").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A7850").Select
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    Range("A7881").Select
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    ActiveWindow.LargeScroll Down:=1
    Range("A7943").Select
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    Range("A7974").Select
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    Range("A8005").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A8036").Select
    ActiveWindow.LargeScroll Down:=1
```

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Range("A8129").Select
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```

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```

```
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```

```
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Range("A13554").Select
```

```
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ActiveWindow.LargeScroll Down:=1
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ActiveWindow.LargeScroll Down:=1
Range("A14174").Select
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ActiveWindow.LargeScroll Down:=1
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Range("A14639").Select
ActiveWindow.LargeScroll Down:=1
```

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ActiveWindow.LargeScroll Down:=1
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ActiveWindow.LargeScroll Down:=1
Range("A15755").Select
```

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    Range("A16034").Select
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    Range("A16065").Select
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    Range("A16127").Select
    ActiveWindow.LargeScroll Down:=1
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    Range("A16220").Select
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    Range("A16251").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A16282").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A16313").Select
    ActiveWindow.LargeScroll Down:=1
    Range("A16344").Select
    ActiveWindow.LargeScroll Down:=1
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    ActiveSheet.Paste
    Range("B16383").Select
    ActiveWindow.ScrollRow = 1
    ActiveWindow.ScrollRow = 13487
    ActiveWindow.ScrollRow = 16354
    Range("A16375:A16384").Select
    Application.CutCopyMode = False
    Selection.Clear
    Range("A16371").Select
    ActiveWindow.ScrollRow = 1
    ActiveWorkbook.SaveAs Filename:="C:\JLOTS\SSDATA.xls", FileFormat:= _
        xlText, CreateBackup:=False
    ActiveWorkbook.SaveAs Filename:="C:\JLOTS\SSDATA.xls", FileFormat:= _
        xlText, CreateBackup:=False
    ActiveWindow.Close
End Sub
```

APPENDIX G. APPLYING THE SEA_STATE_CALC PACKAGE TO LOCATIONS WITH JLOTS POTENTIAL.

This appendix contains the graphical and computational results of the SEA_STATE_CALC package for three geographic locations in which the potential for military activity, and thereby JLOTS operations, has been deemed high by the respective CINCs, the Joint Staff J-4, and/or OPNAV N-42. The specific sites addressed were the northern and southern Persian Gulf and the eastern Korean peninsula. A total of 12 executions were conducted, with four in each region. At each location, two time intervals were considered, namely, a one month interval focusing upon the month of July and a three month interval centered upon the month of July. Over each interval, all command button options of the SEA_STATE_CALC package were exercised. Consequently, for each time interval at each location, both the Rayleigh distribution plot of observed wave heights and the Rayleigh distribution of relative occurrence of observed wave heights are provided. The calculations associated with each plot assess the quality of the Rayleigh fit for each data set as well as the degree to which the excerpt Rayleigh PDF obtained from each data set approximates the theoretical Rayleigh PDF for that respective location.

A profound realization of the impact which the SEA_STATE_CALC package could have upon JLOTS planning (whether incorporated into JOTE as a means of determining the cell O-38 entry, or used independently) is obtained by considering that for two of these three locations, the SEA_STATE_CALC package is informing its user that sea state conditions will challenge present JLOTS operating capabilities in excess of 70% of the time intervals considered, as determined by the respective $1 - F(a)$ values.

Eastern Korean Peninsula (1 Month Interval) - July

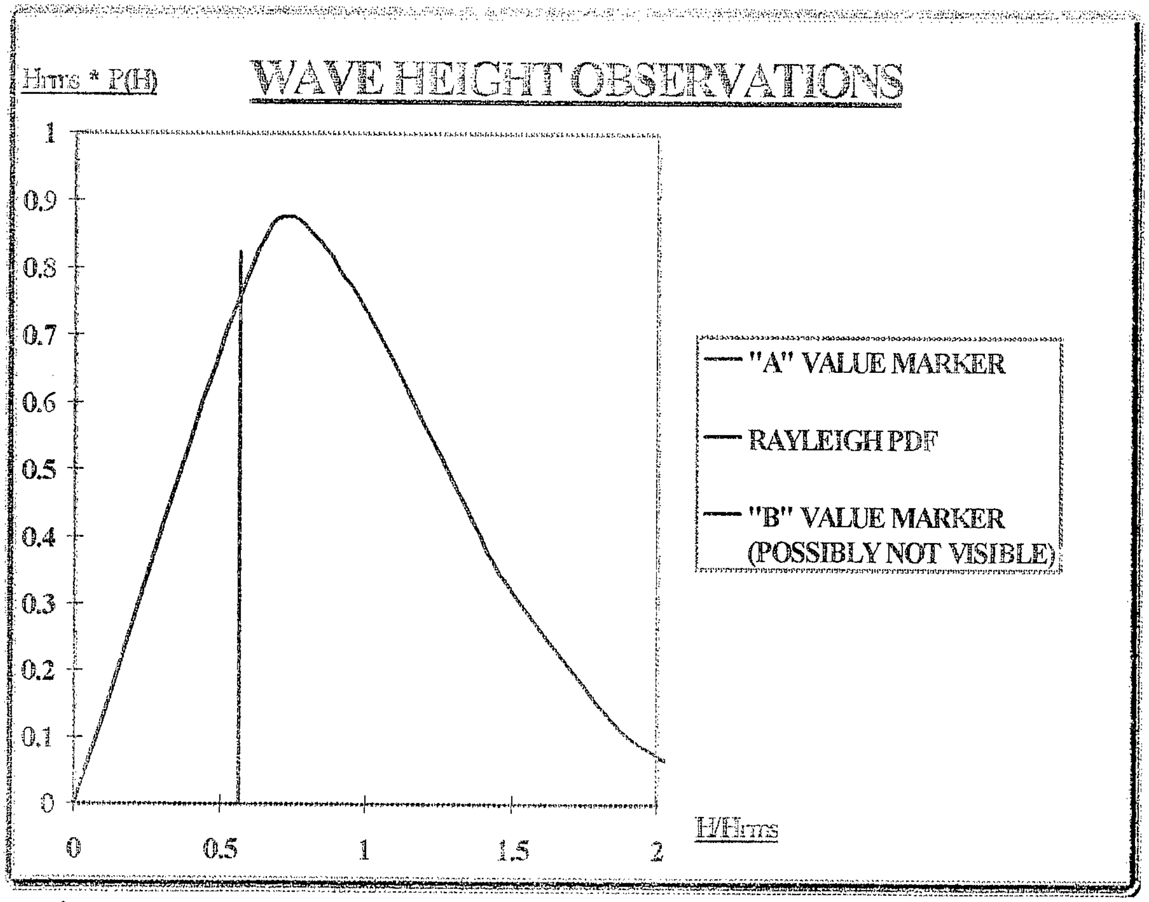


Figure 38. Rayleigh Distribution of Eastern Korean Peninsula Wave Heights in July.

Endpoints of "A" Value Marker
Base = (0.5624, 0)
Top = (0.5625, 0.8235)

Endpoints of "B" Value Marker
Base = (26.5023, 0)
Top = (26.5023, 0)

1 - F(a) = 72.6507
1 - F(b) = 0
F(b) - F(a) = 72.6507

Number of Observations = 7236
CHITEST Result (p^* *Value*) = 1

Eastern Korean Peninsula (1 Month Interval) - July

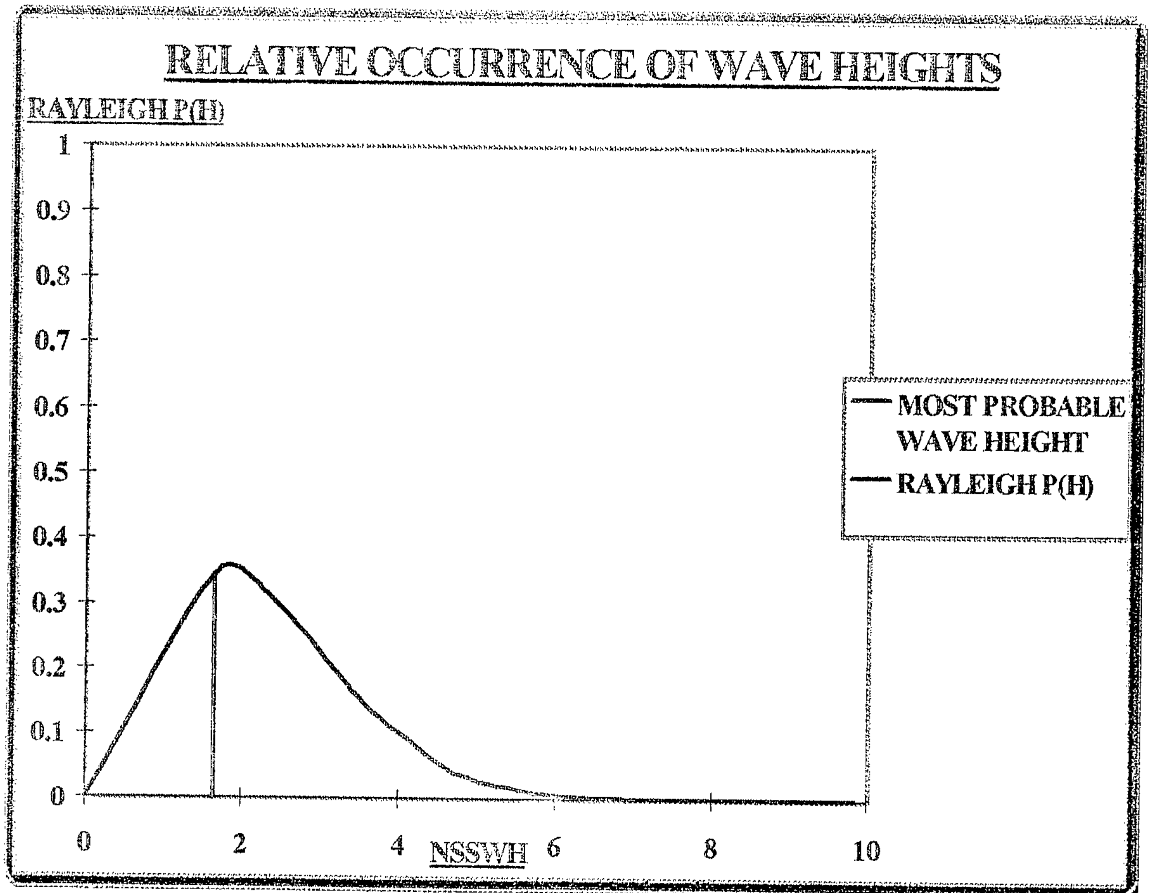


Figure 39. Rayleigh Distribution of Relative Occurrence of Eastern Korean Peninsula Wave Heghts in July.

Endpoints of Most Probable Wave Height Marker

Base = (1.6405, 0)

Top = (1.6405, .34490)

Eastern Korean Peninsula (3 Month Interval) - June, July, August

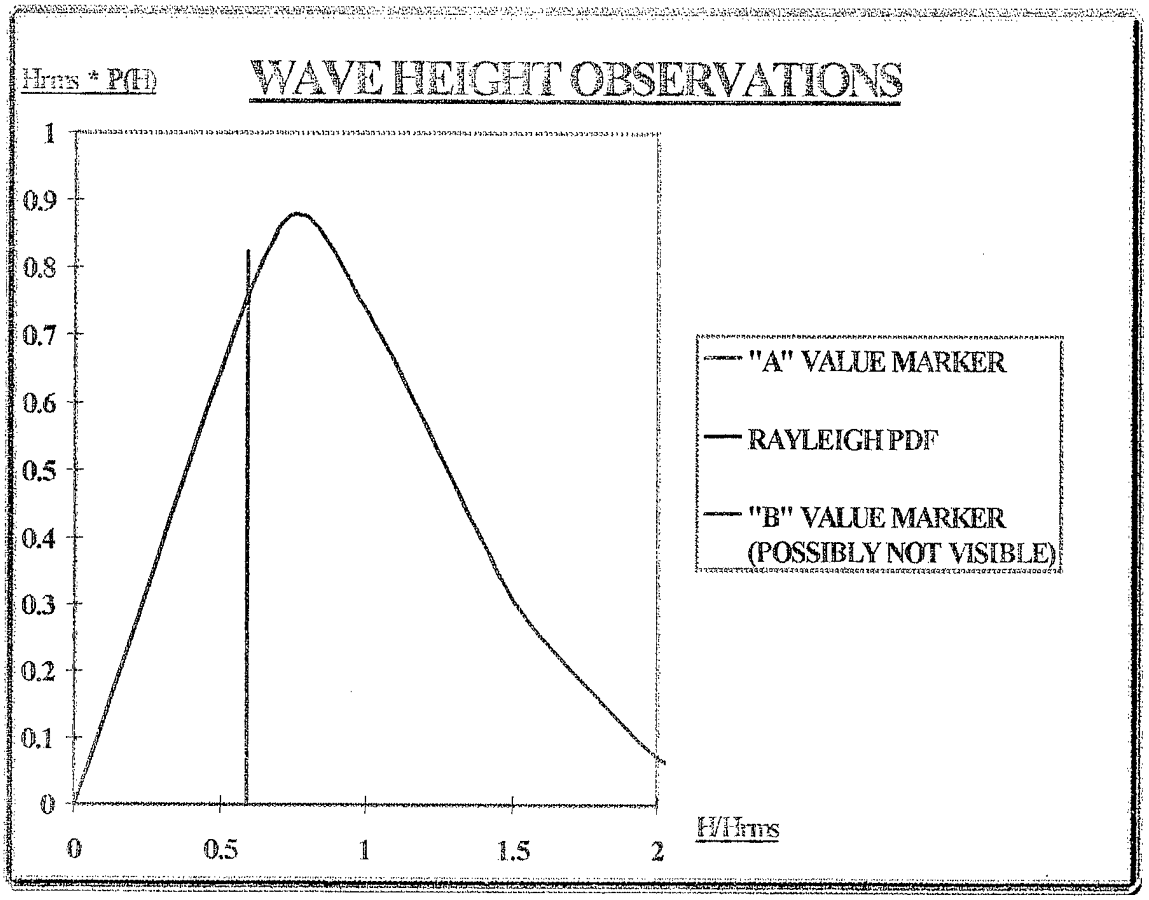


Figure 40. Rayleigh Distribution of Eastern Korean Peninsula Wave Height in the Period Covering June, July, August Time Period.

Endpoints of "A" Value Marker
- Base = (0.5947, 0)
- Top = (0.5947, 0.82206)

Endpoints of "B" Value Marker
- Base = (27.8833, 0)
- Top = (27.8833, 0)

1 - F(a) = 70.2104
1 - F(b) = 0
F(b) - F(a) = 70.2104

Number of Observations = 10,707
CHITEST Result (p^* *Value*) = 1

Eastern Korean Peninsula (3 Month Interval) - June, July, August

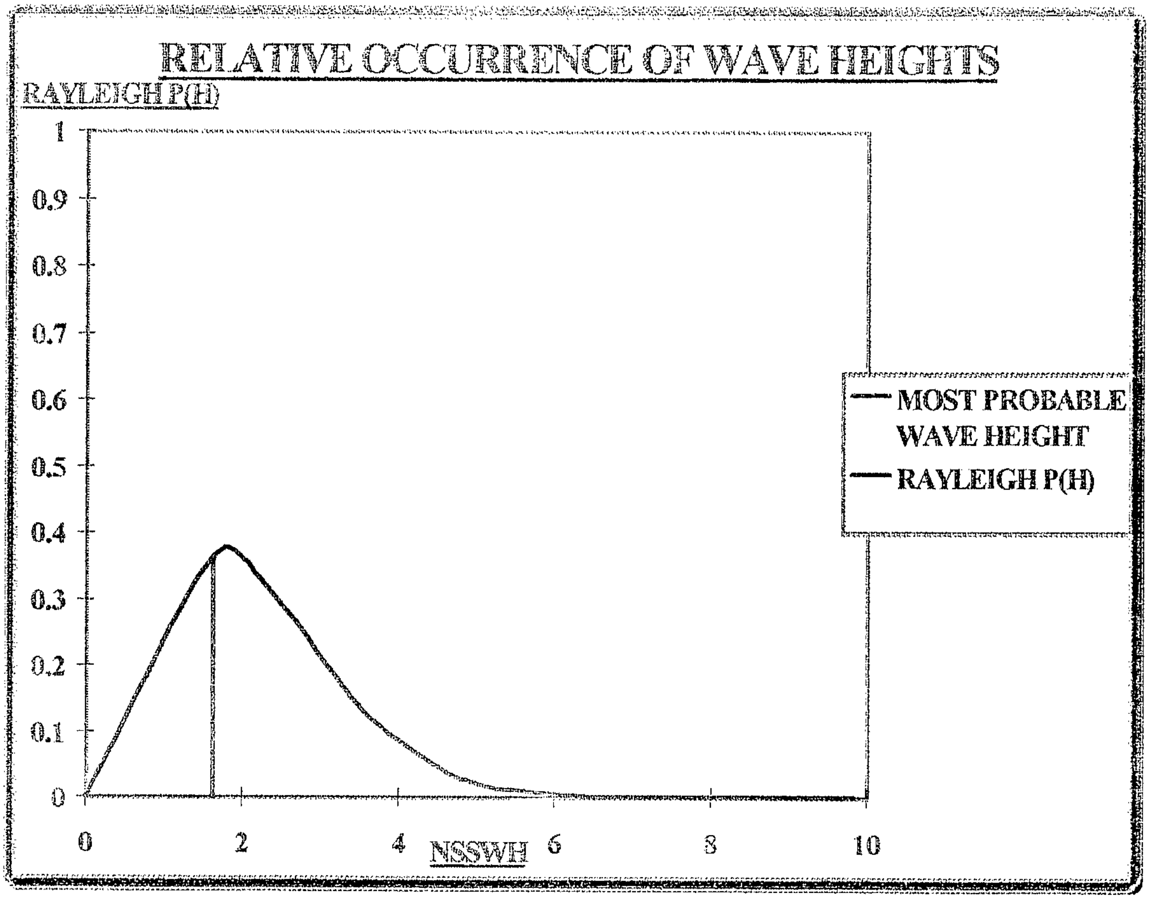


Figure 41. Rayleigh Distribution of Relative Occurrence of Eastern Korean Peninsula Wave Height in the Period Covering June, July, August.

Endpoints of Most Probable Wave Height Marker

Base = (1.6405, 0)

Top = (1.6405, .36421)

Southern Persian Gulf (1 Month Interval) - July

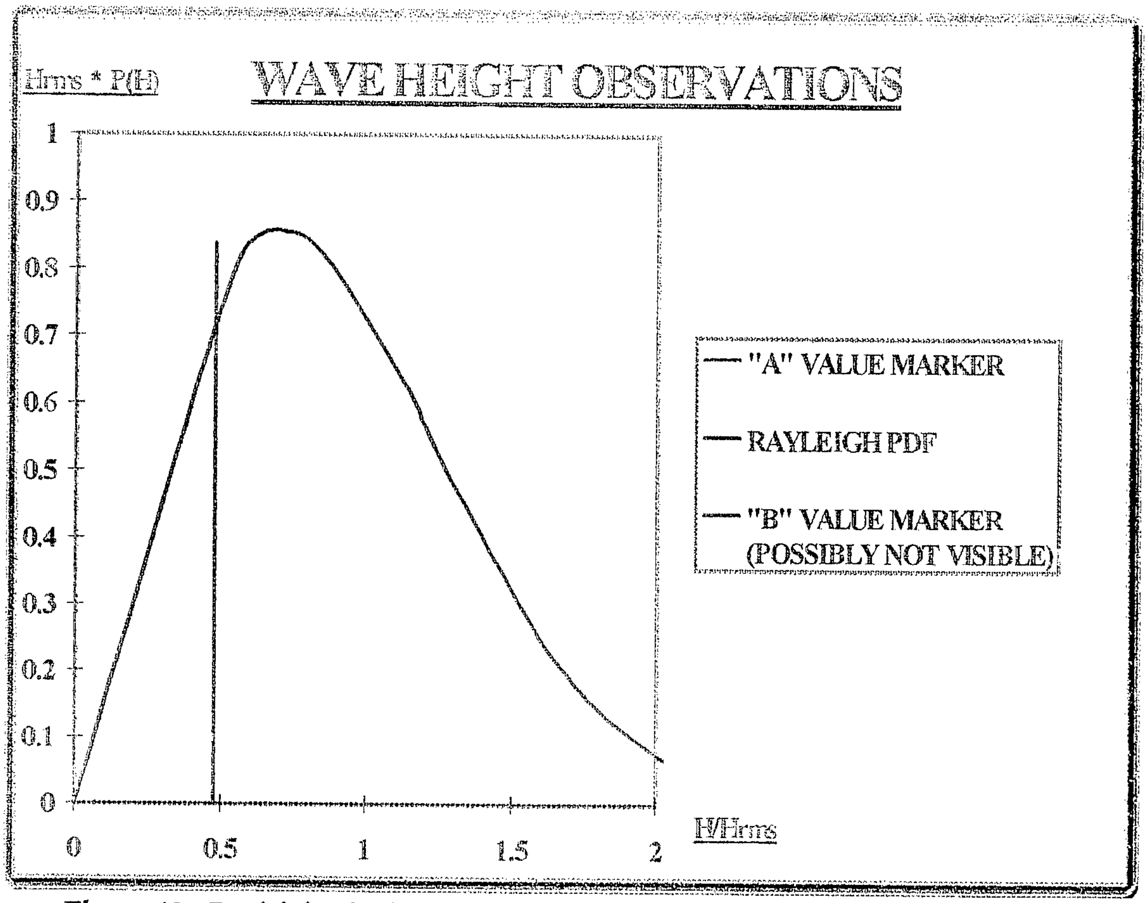


Figure 42. Rayleigh Distribution of Southern Persian Gulf Wave Heights in July.

Endpoints of "A" Value Marker

Base = (0.4808, 0)

Top = (0.4808, 0.8370)

Endpoints of "B" Value Marker

Base = (25.35, 0)

Top = (25.35, 0)

1 - F(a) = 79.3573

1 - F(b) = 0

F(b) - F(a) = 79.3573

Number of Observations = 7365

CHITEST Result (*p* * *Value*) = 1

Southern Persian Gulf (1 Month Interval) - July

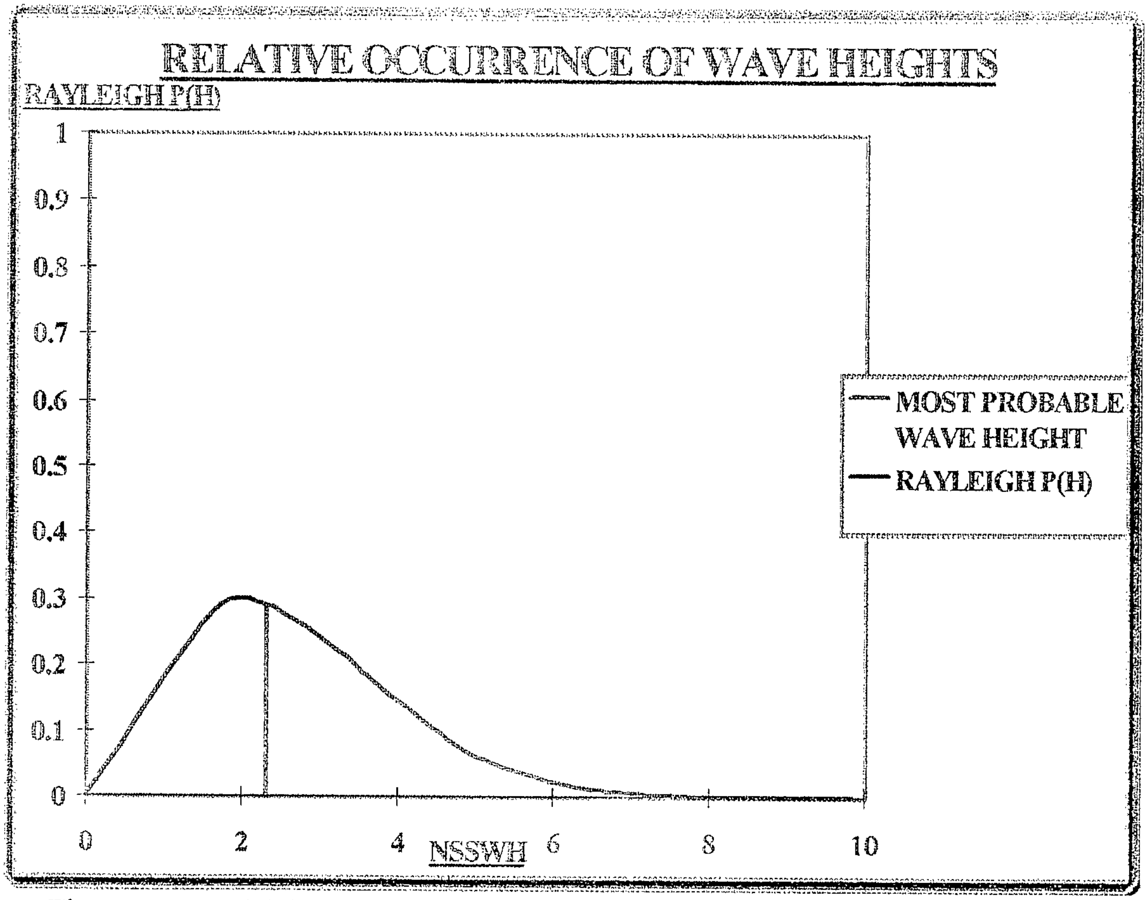


Figure 43. Rayleigh Distribution of Relative Occurrence of Southern Persian Gulf Wave Height in July.

Endpoints of Most Probable Wave Height Marker

Base = (2.3216, 0)

Top = (2.3216, .29008)

<u>Southern Persian Gulf</u> (3 Month Interval) - June, July, August

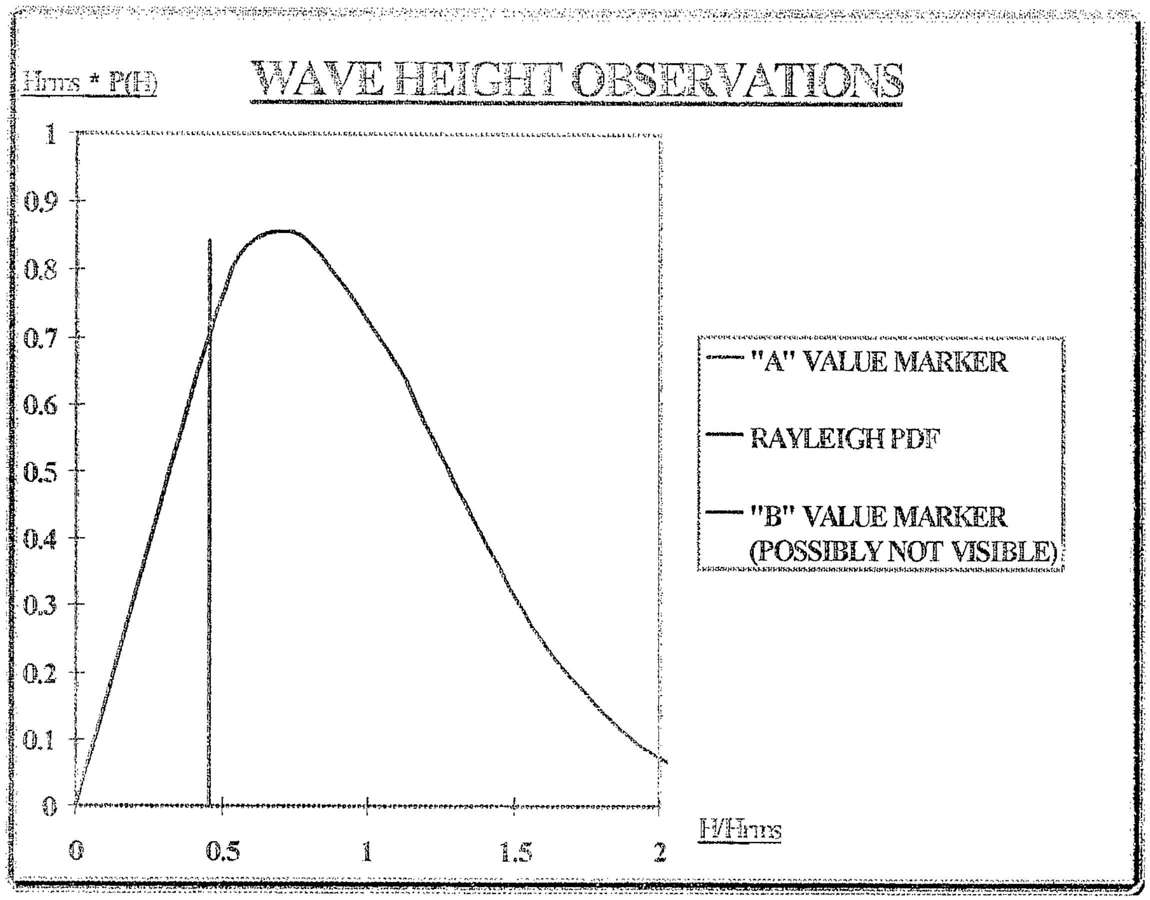


Figure 44. Rayleigh Distribution of Southern Persian Gulf Wave Heights in the Period Covering June, July, and August.

Endpoints of "A" Value Marker
Base = (0.4562, 0)
Top = (0.4562, 0.8426)

Endpoints of "B" Value Marker
Base = (25.6758, 0)
Top = (25.6758, 0)

1 - F(a) = 81.2061
1 - F(b) = 0
F(b) - F(a) = 81.2061

Number of Observations = 7981
CHITEST Result (p^* *Value*) = 1

Southern Persian Gulf (3 Month Interval) - June, July, August

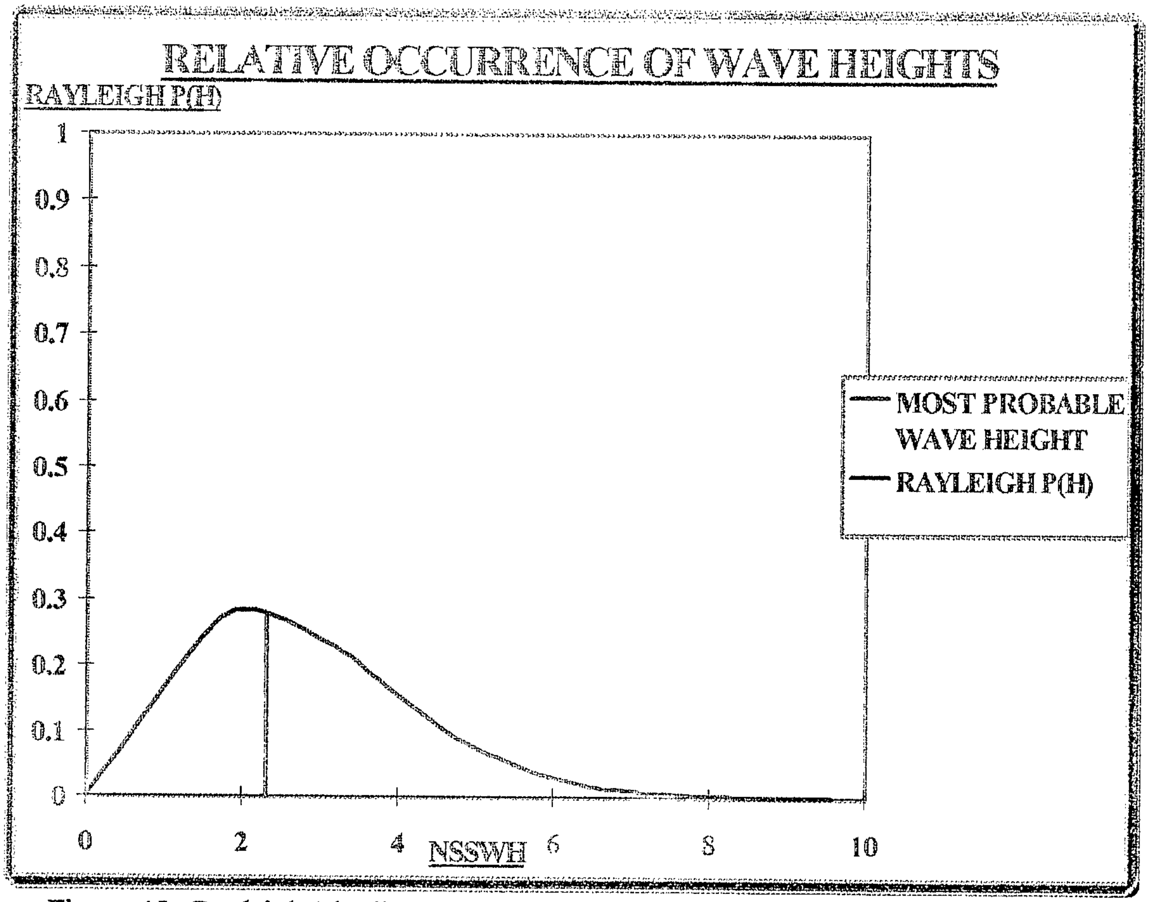


Figure 45. Rayleigh Distribution of Relative Occurrence of Southern Persian Gulf Wave Height in the Period Covering June, July, August.

Endpoints of Most Probable Wave Height Marker

Base = (2.3216, 0)

Top = (2.3216, .2782)

Northern Persian Gulf (1 Month Interval) - July

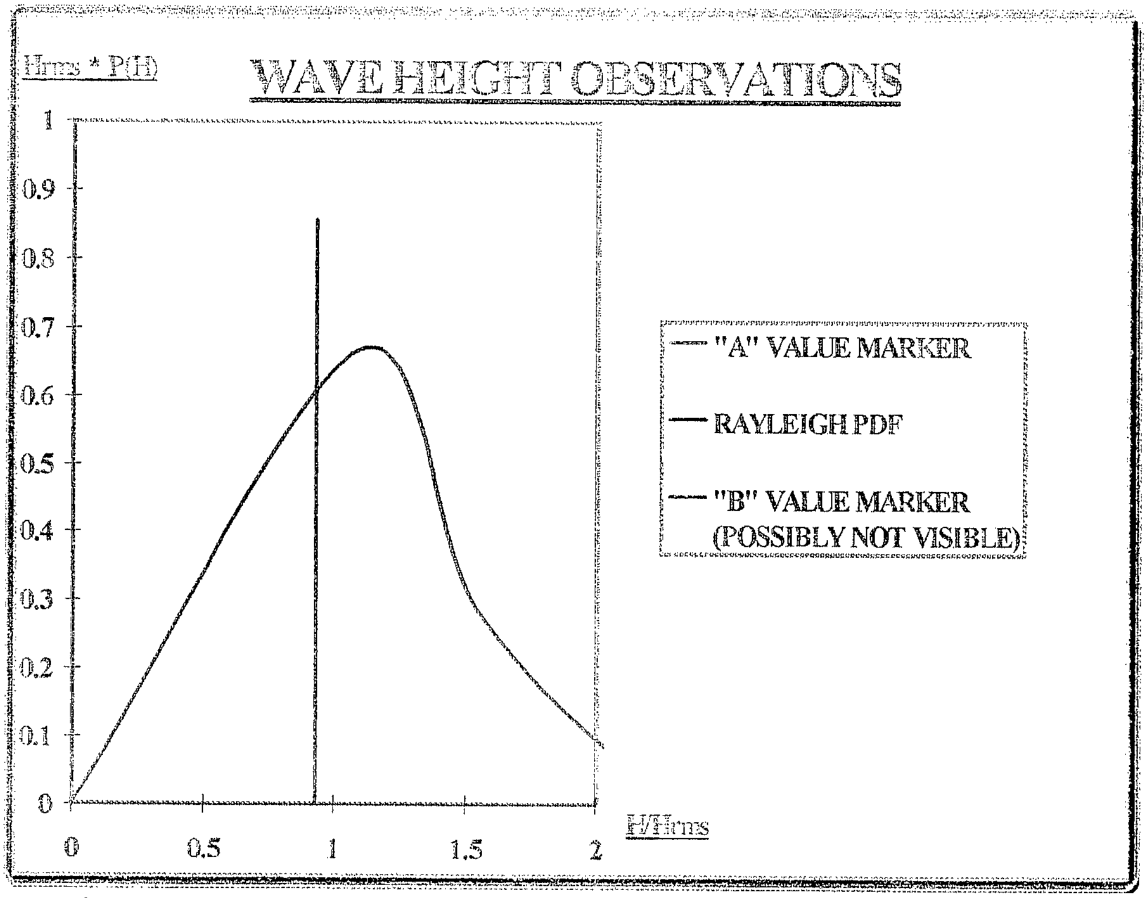


Figure 46. Rayleigh Distribution of Northern Persian Gulf Wave Heights in July.

Endpoints of "A" Value Marker
Base = (0.9295, 0)
Top = (0.9295, 0.8546)

Endpoints of "B" Value Marker
Base = (40.08, 0)
Top = (40.08, 0)

1 - F(a) = 42.145
1 - F(b) = 0
F(b) - F(a) = 42.145

Number of Observations = 406
CHITEST Result (p^* *Value*) = 1

Northern Persian Gulf (1 Month Interval) - July

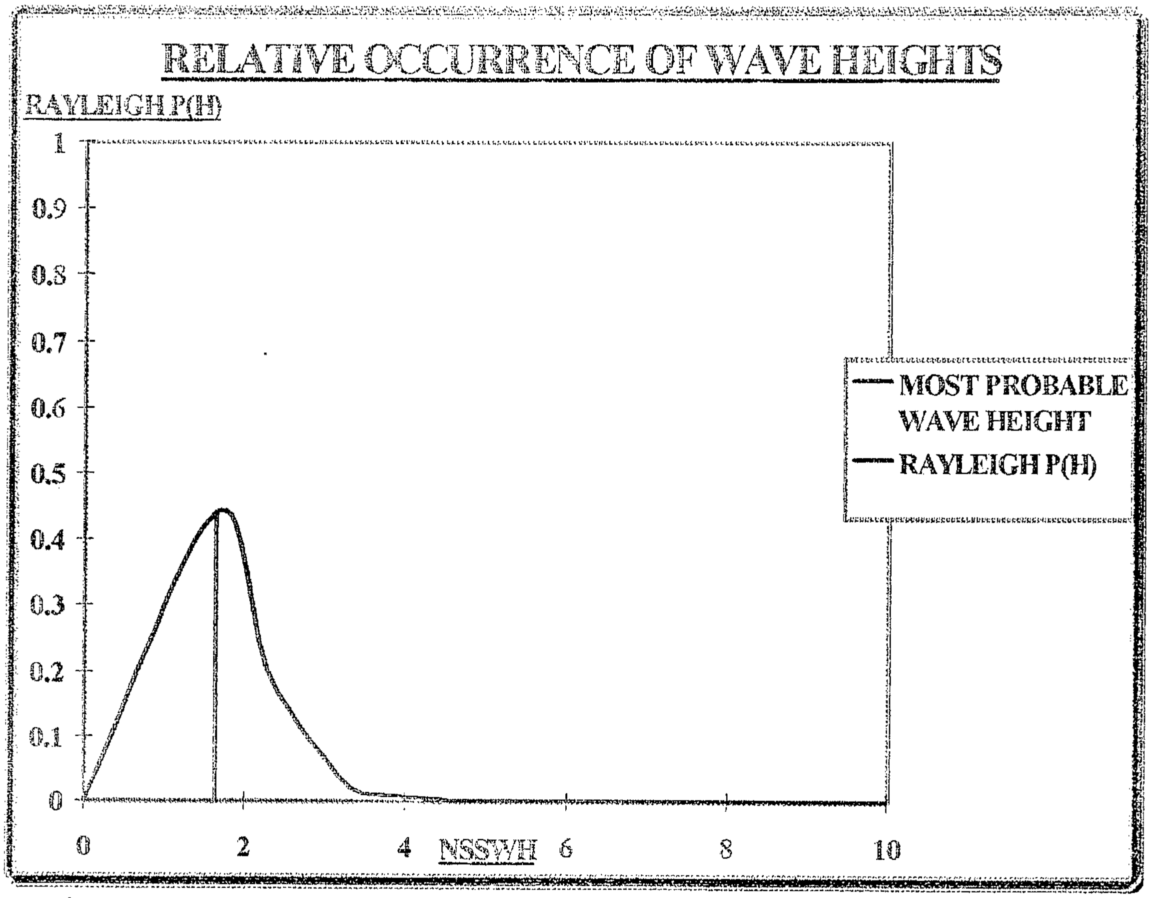


Figure 47. Rayleigh Distribution of Relative Occurrence of Northern Persian Gulf Wave Height in July.

Endpoints of Most Probable Wave Height Marker

Base = (1.6405, 0)

Top = (1.6405, 04416)

Northern Persian Gulf (3 Month Interval) - June, July, August

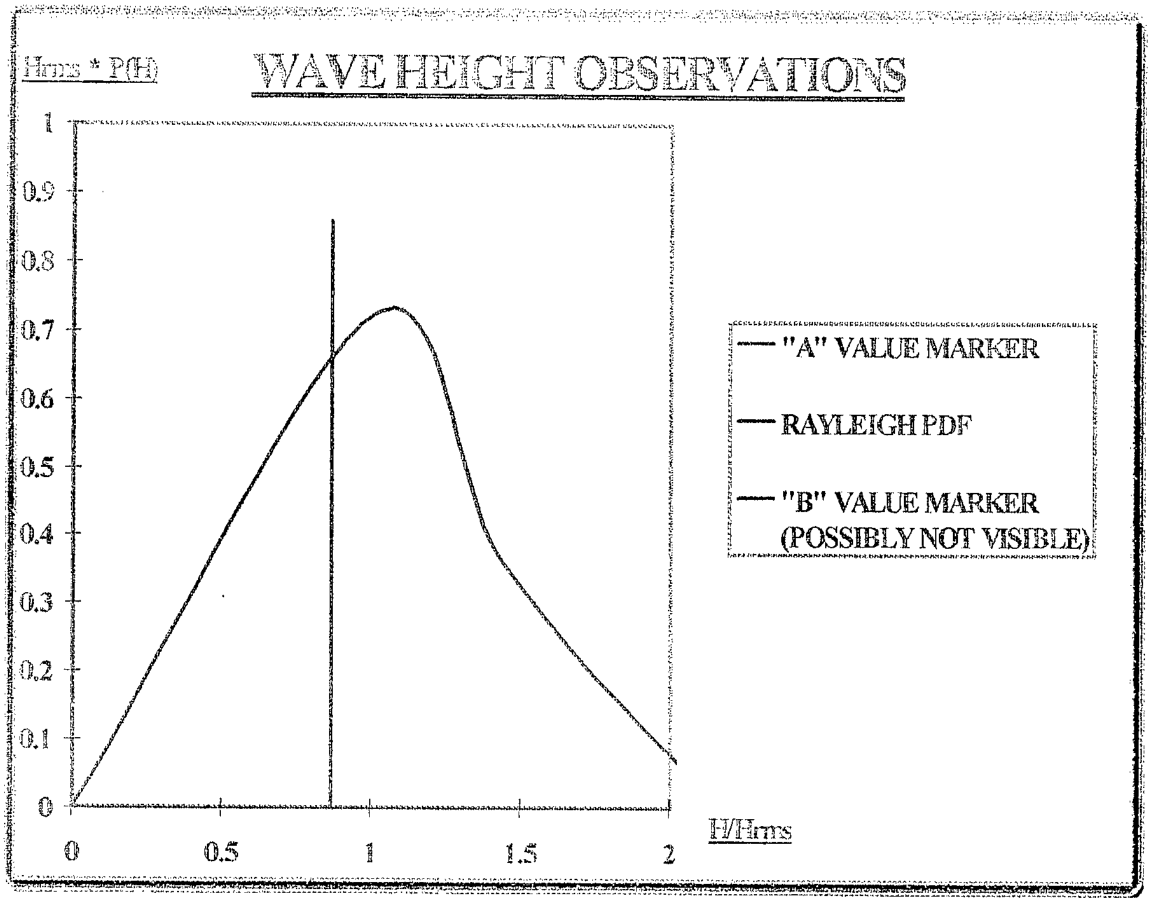


Figure 48. Rayleigh Distribution of Nouthern Persian Gulf Wave Heights in the Period Covering June, July, and August.

Endpoints of "A" Value Marker
Base = (0.8660, 0)
Top = (0.8660, 0.8572)

Endpoints of "B" Value Marker
Base = (42.63, 0)
Top = (42.63, 0)

1 - F(a) = 47.2382
1 - F(b) = 0
F(b) - F(a) = 47.2382

Number of Observations = 406
CHITEST Result (p^* *Value*) = 1

Northern Persian Gulf (3 Month Interval) - June, July, August

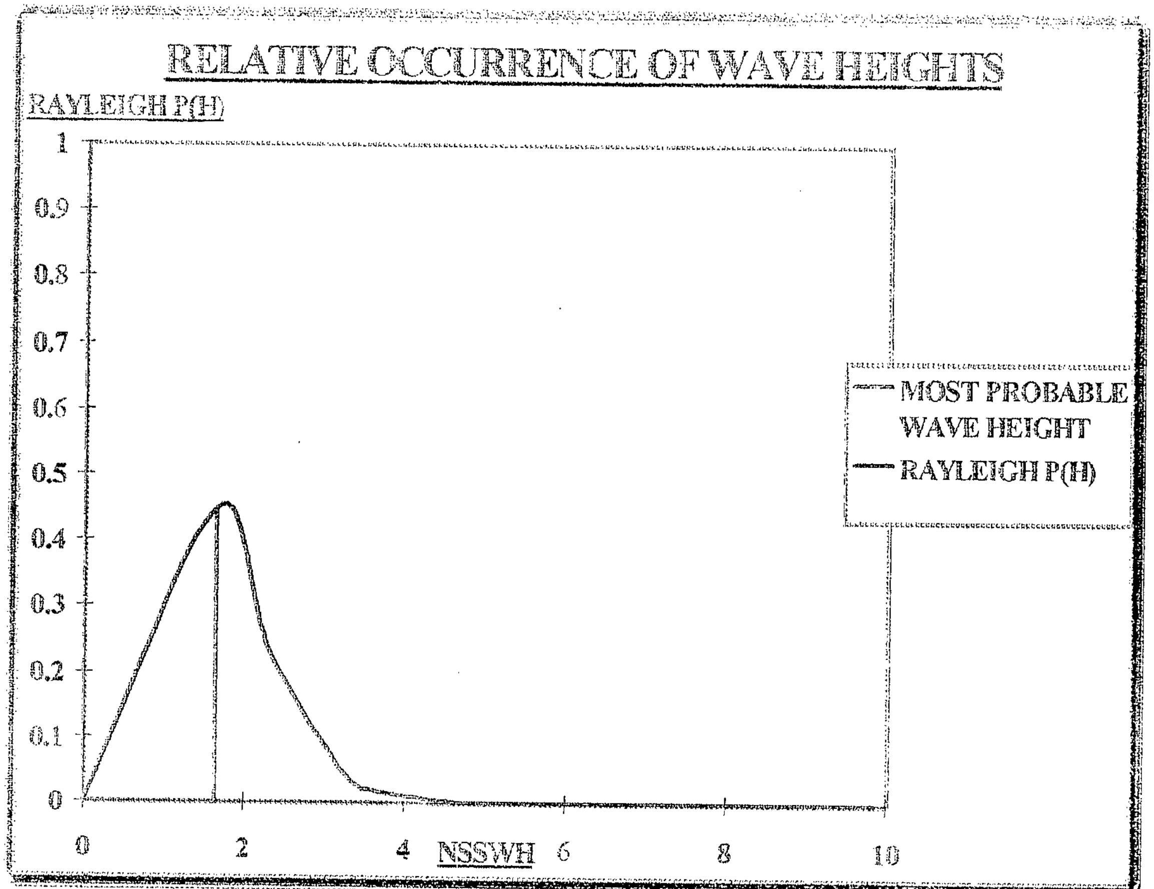


Figure 49. Rayleigh Distribution of Relative Occurrence of Northern Persian Gulf Wave Height in the Period Covering June, July, and August.

Endpoints of Most Probable Wave Height Marker

Base = (1.6405, 0)

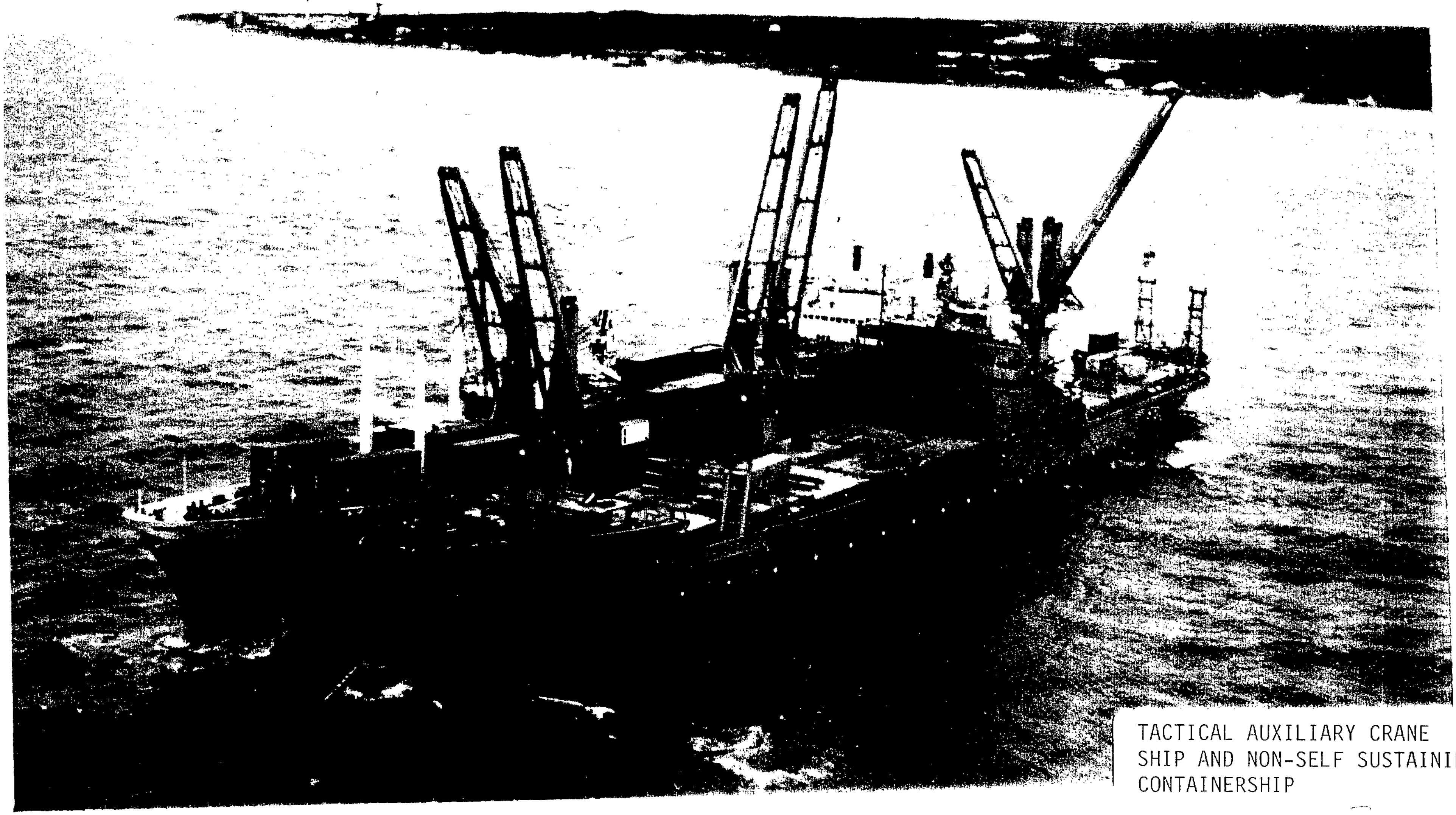
Top = (1.6405, 04483)

APPENDIX H. JLOTS PICTORIAL OVERVIEW

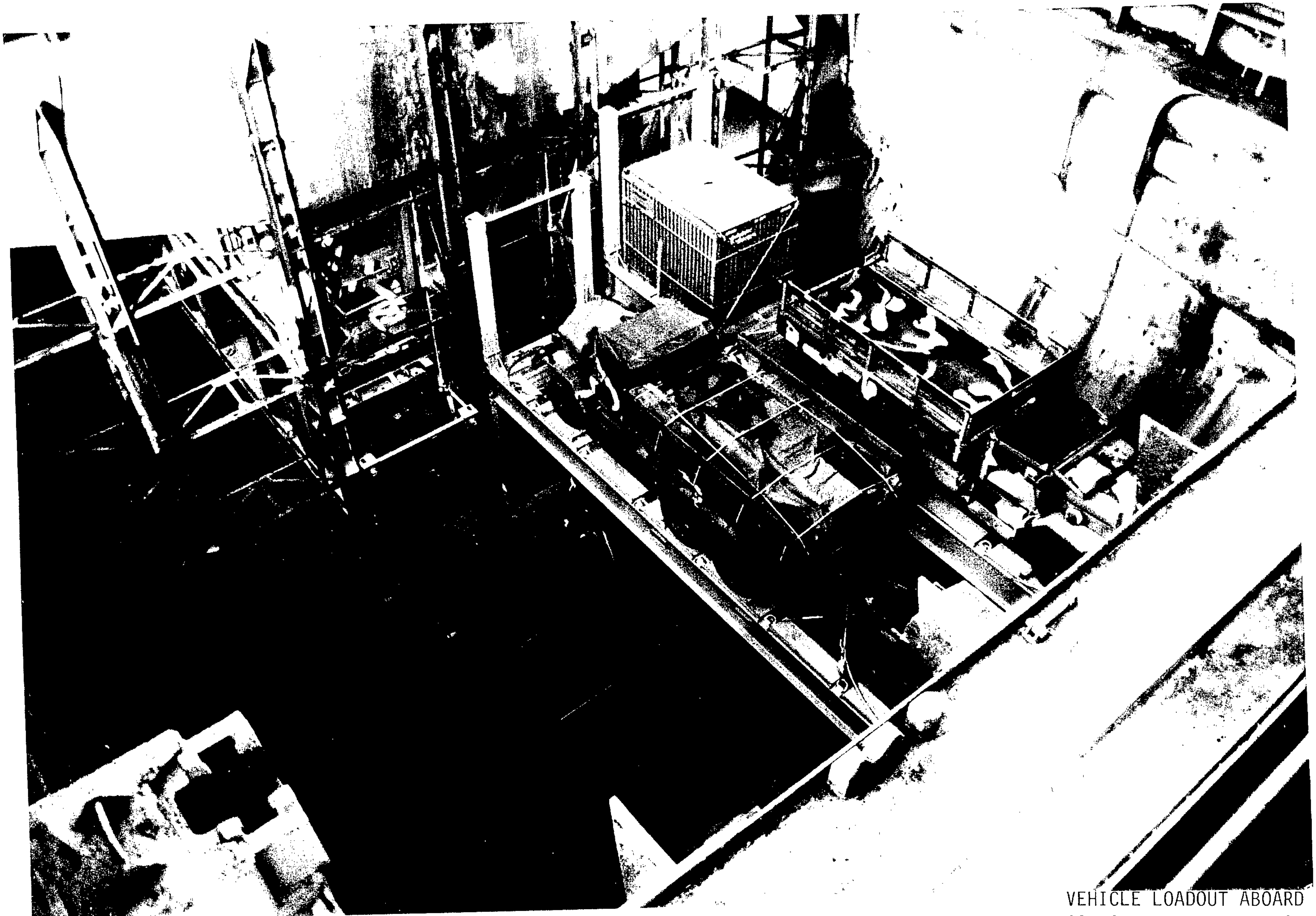
The contents of this appendix represent pictorially all forms strategic sealift assets, lighterage, and support equipment (both surf-side and shore-side) employed during JLOTS operations. Each photograph is inidvidually labelled and like equipment is classified together producing the following categories of photographs:

1. Strategic sealift assets.
2. Lighterage and lighter operations.
3. Supporting equipment.
4. Shoreside equipment and operations.
5. JLOTS in high sea states.

Collectively, the photographs provide not only an understanding of the conduct of JLOTS operations, but also the distinct dependency of these operations upon wind, weather, and sea state conditions.

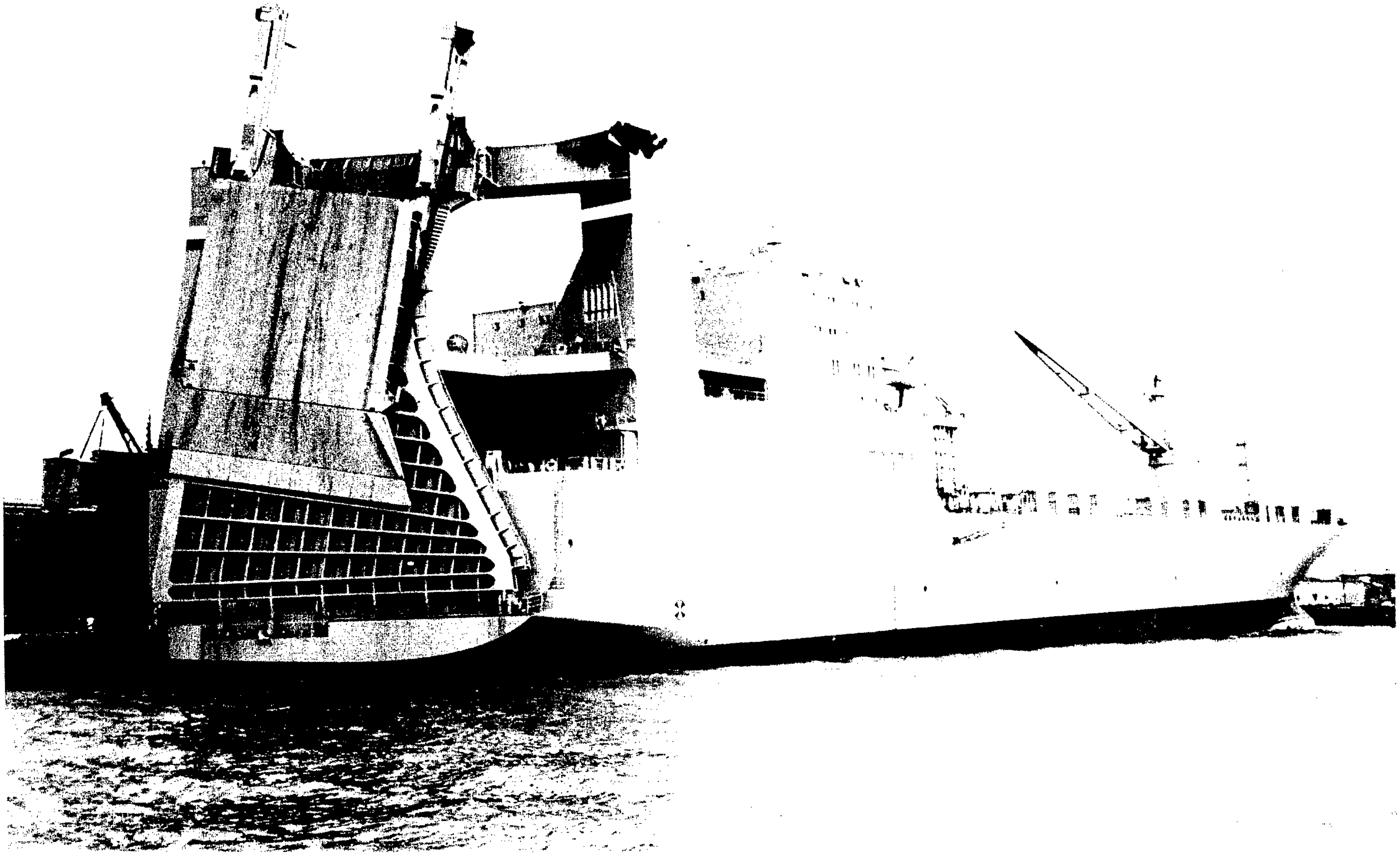


TACTICAL AUXILIARY CRANE SHIP AND NON-SELF SUSTAINING CONTAINERSHIP

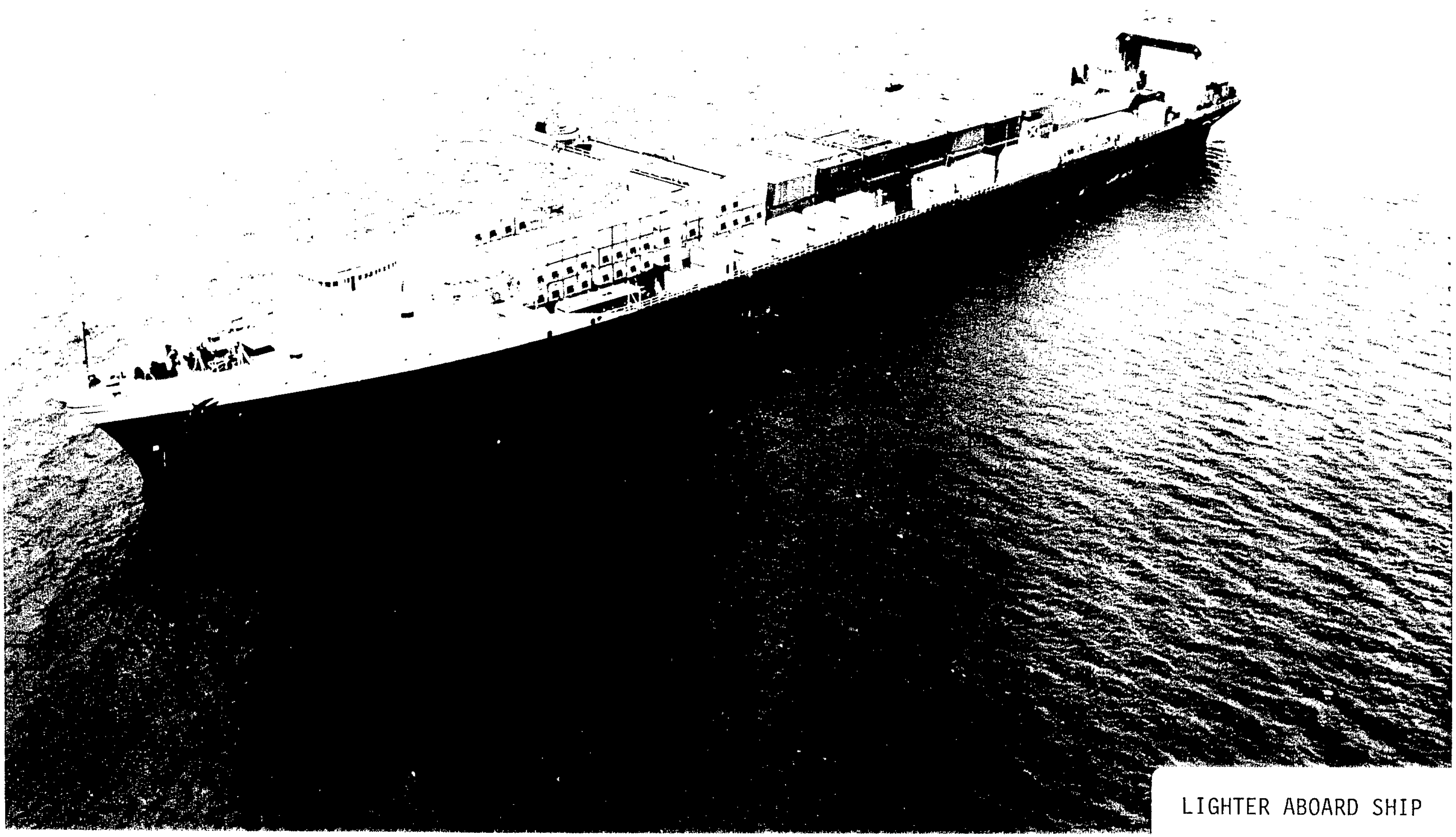


VEHICLE LOADOUT ABOARD CONTAINERSHIP. PERFORMED DUE TO INSUFFICIENT QUANTITY OF RO/RO VESSELS OR RRDF LIGHTERAGE.

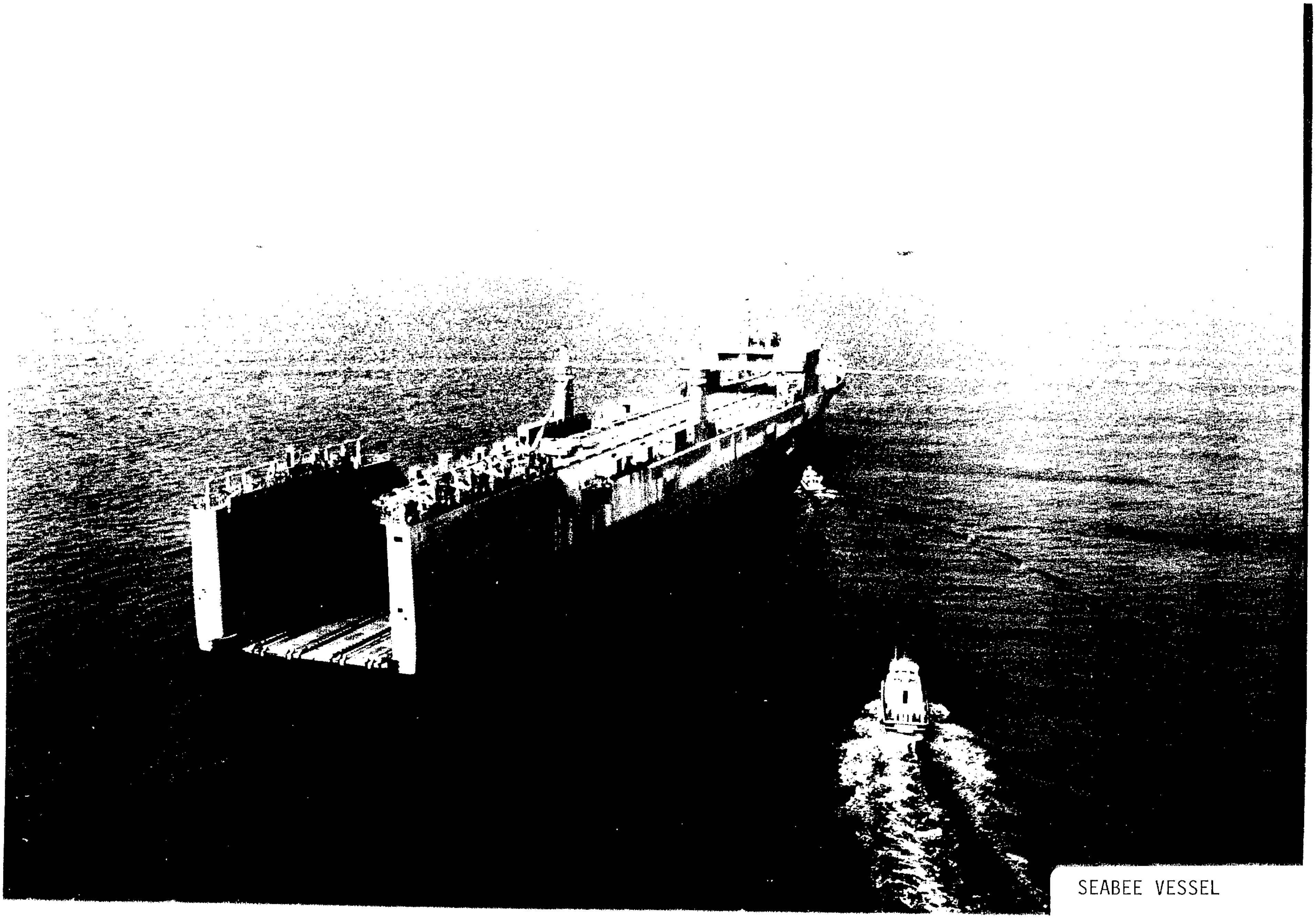
MAIN DECK STOWAGE AREA



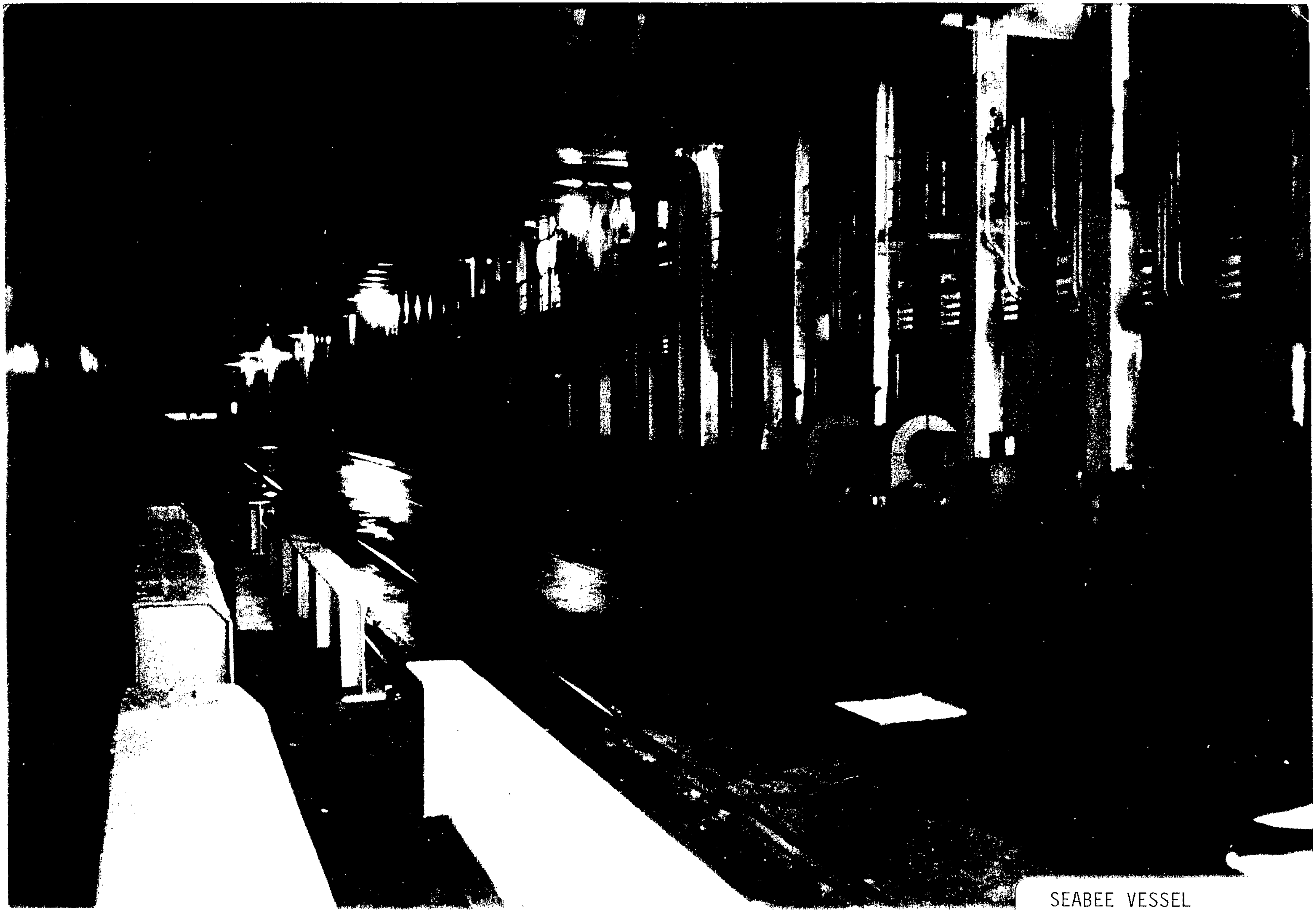
RO/RO CAPABLE
MARAD OWNED SEALIFT VESSEL



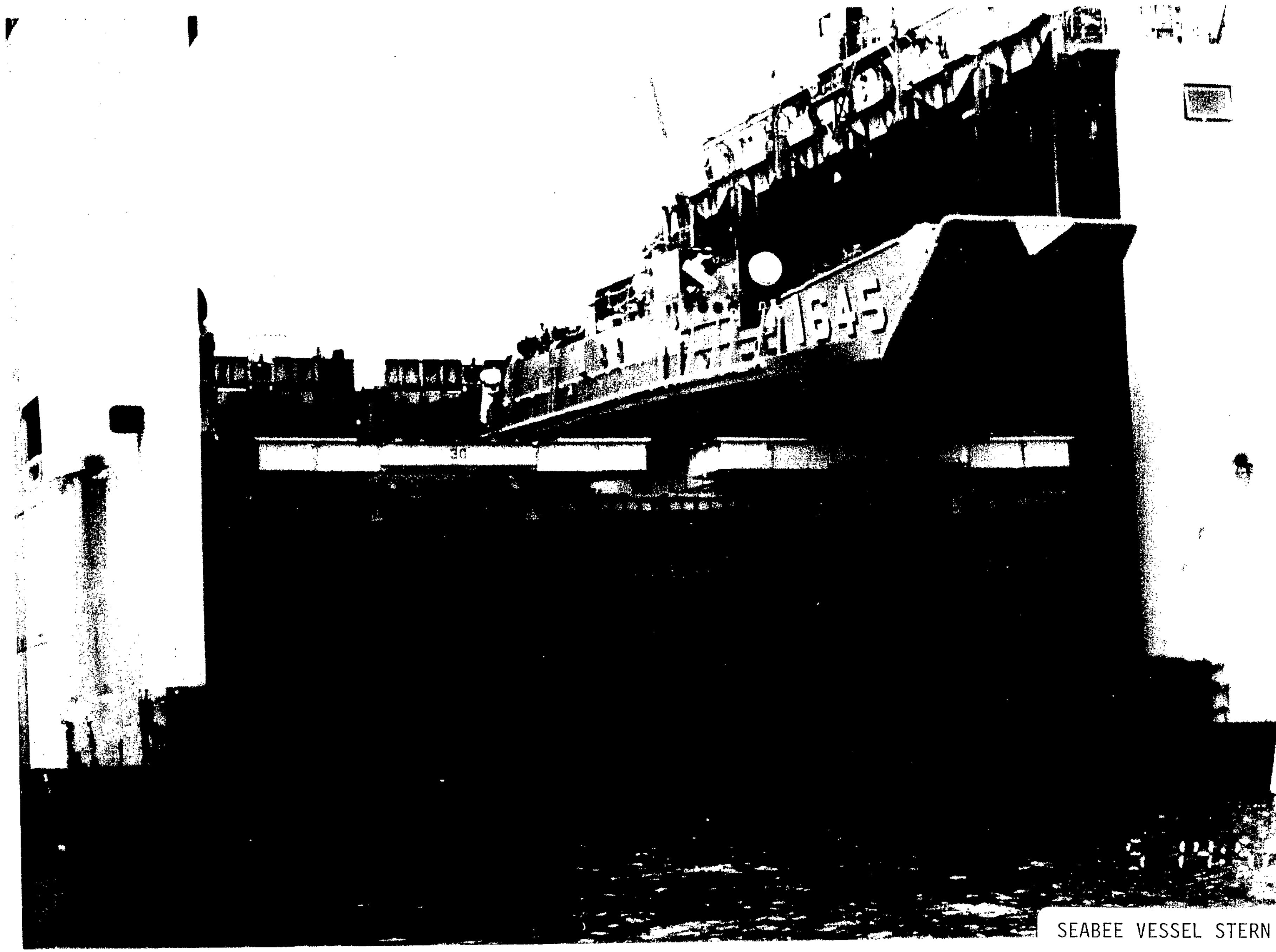
LIGHTER ABOARD SHIP



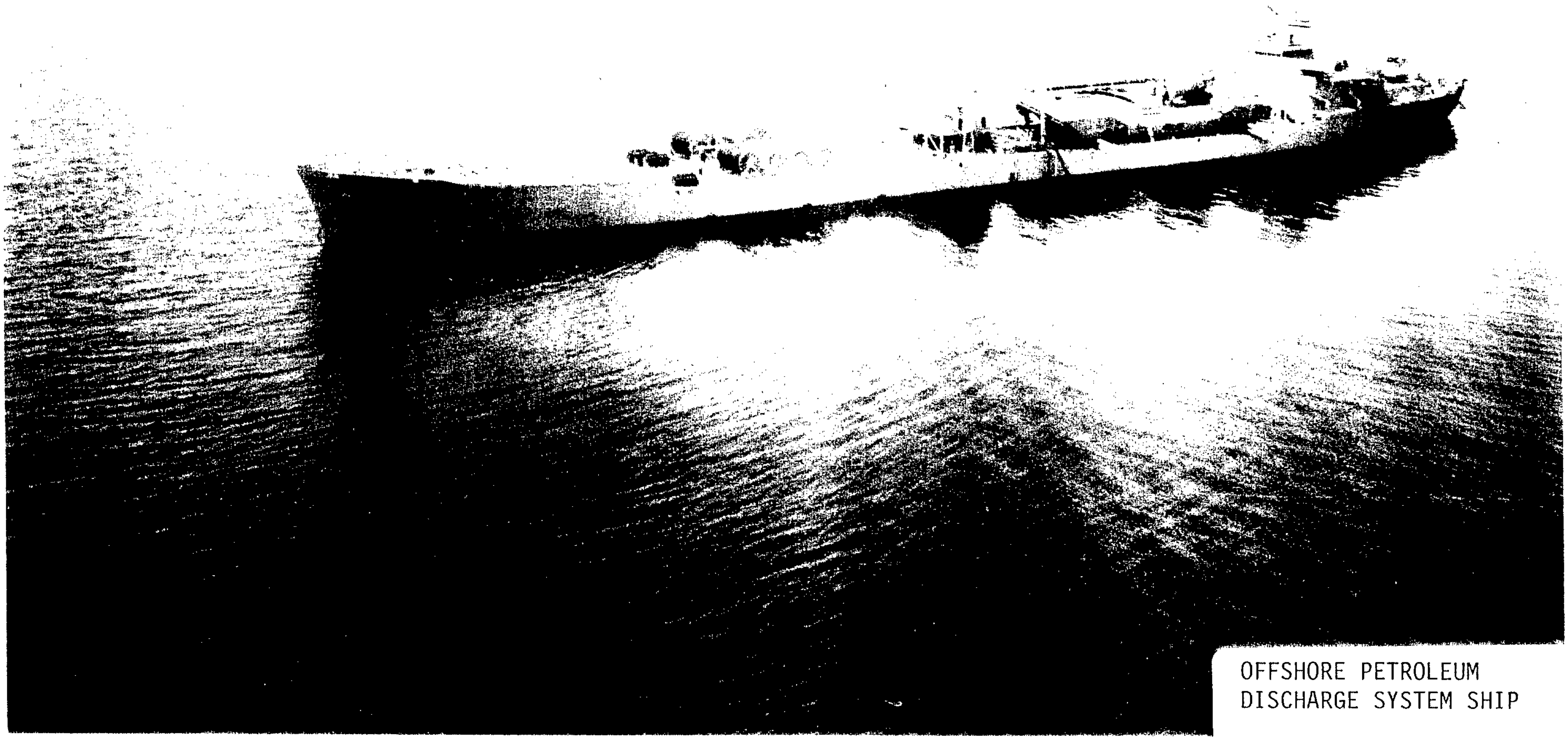
SEABEE VESSEL



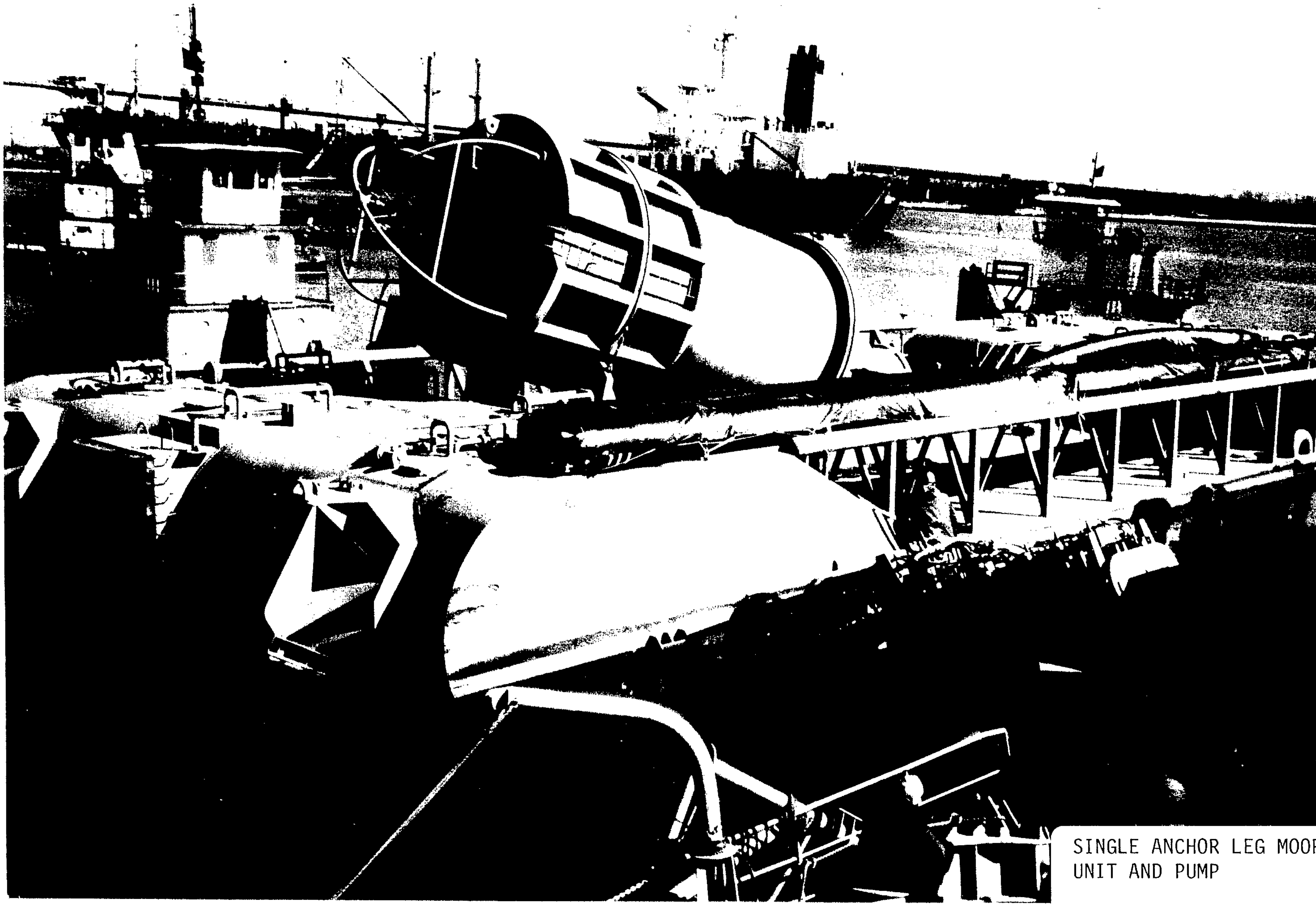
SEABEE VESSEL
BARGE WELL DECK



SEABEE VESSEL STERN ELEVATOR

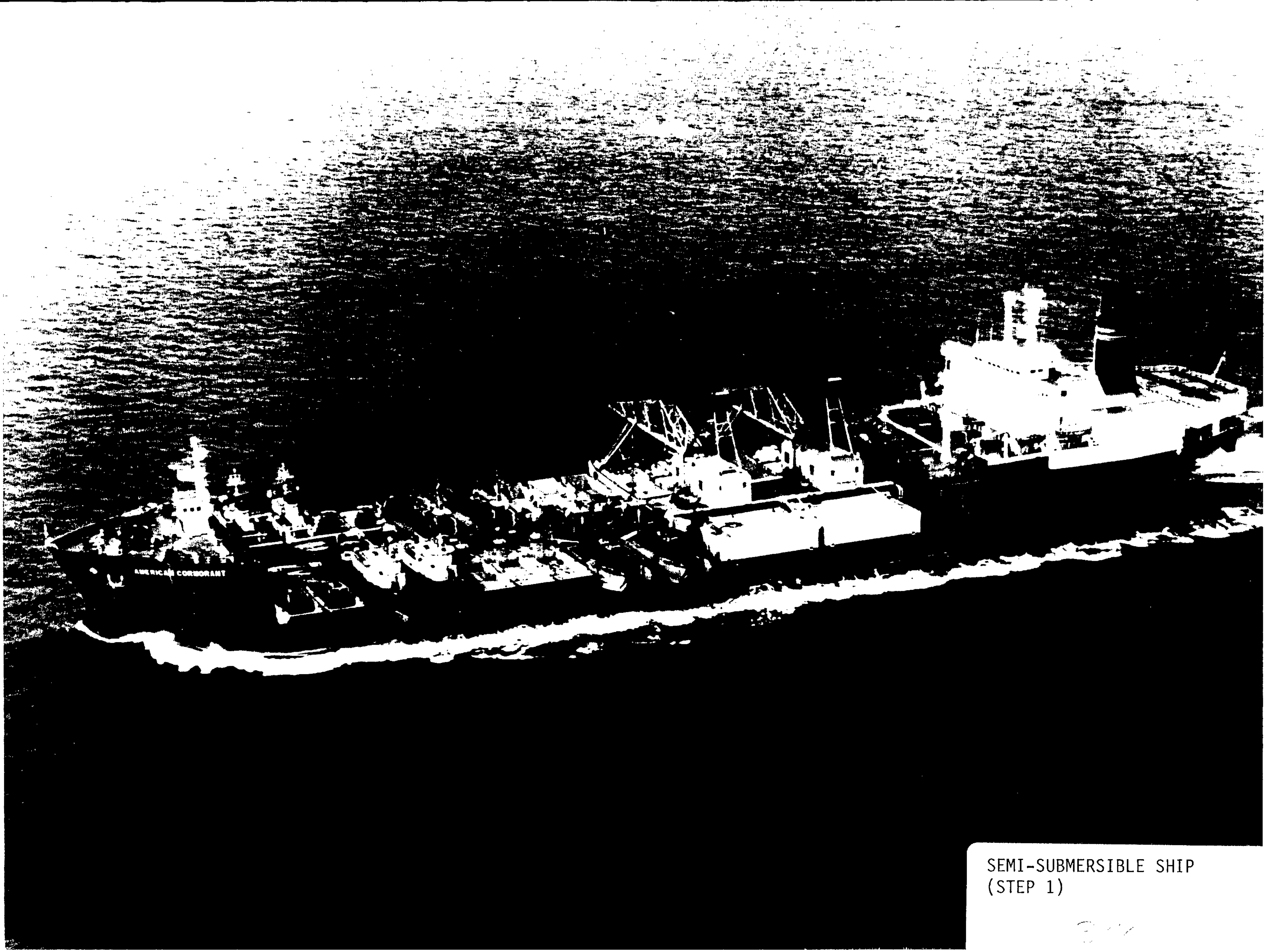


OFFSHORE PETROLEUM
DISCHARGE SYSTEM SHIP

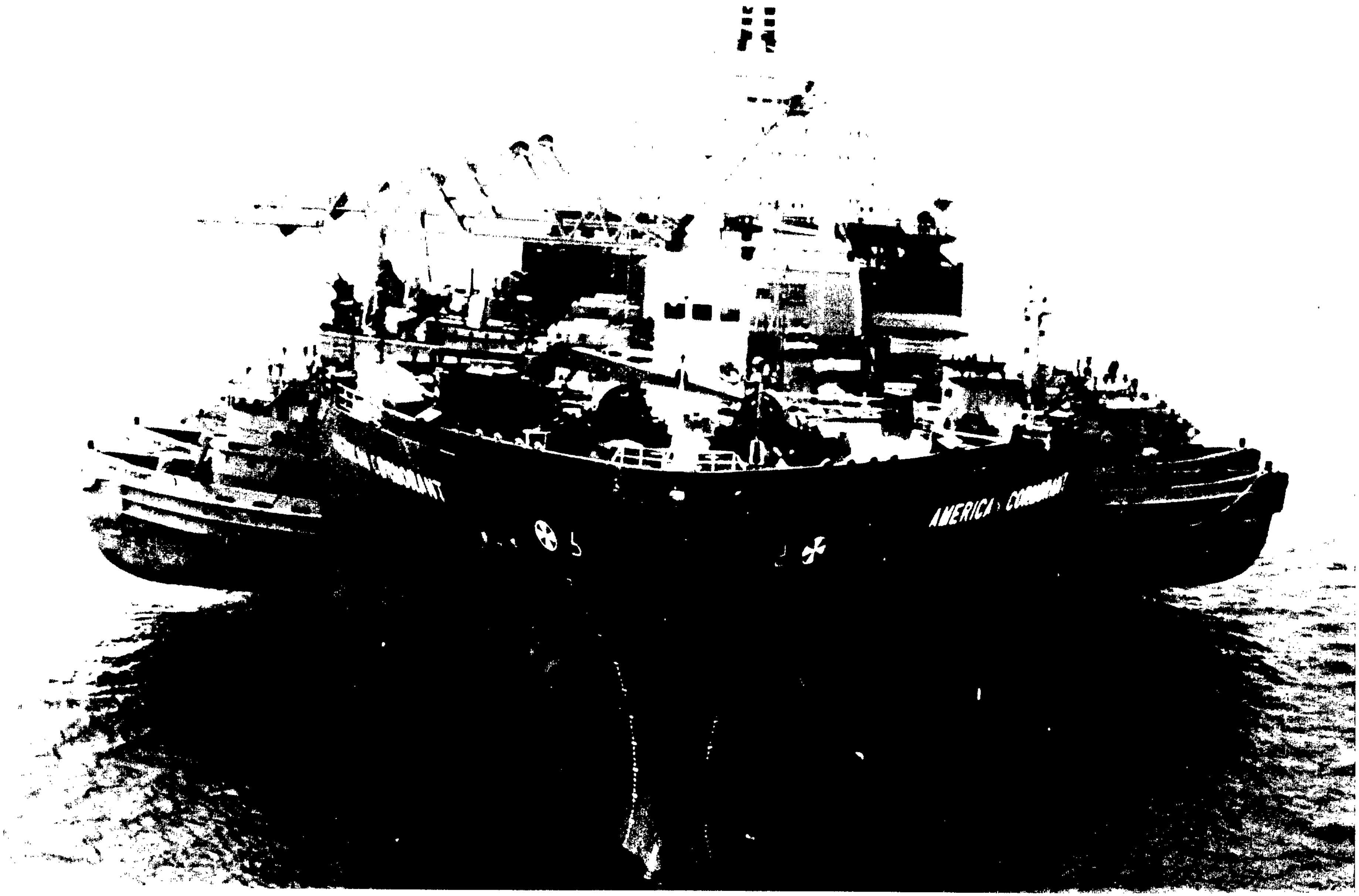


SINGLE ANCHOR LEG MOORING
UNIT AND PUMP

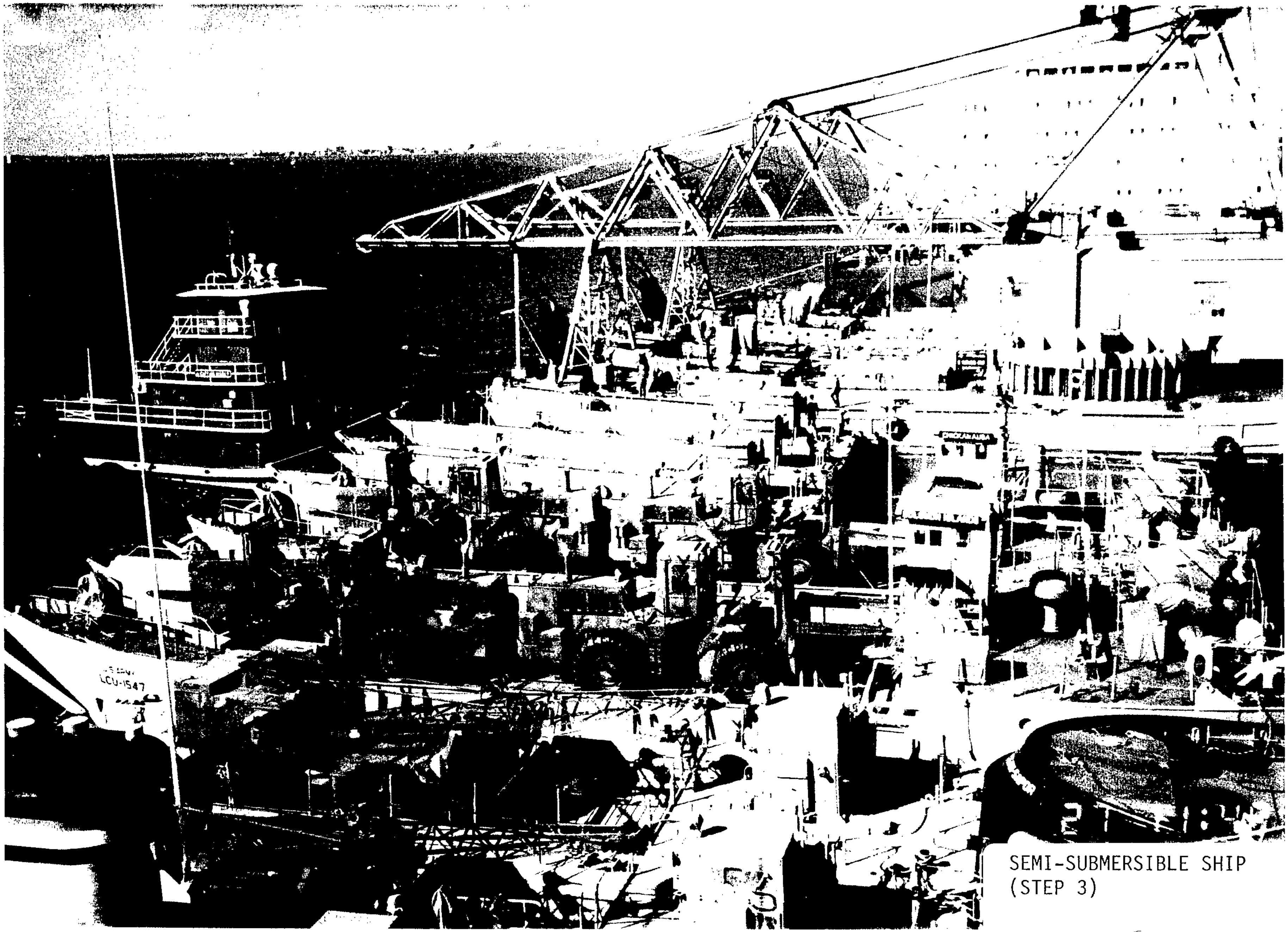
SHORESIDE OPDS RECEIVING
AND PUMPING STATION



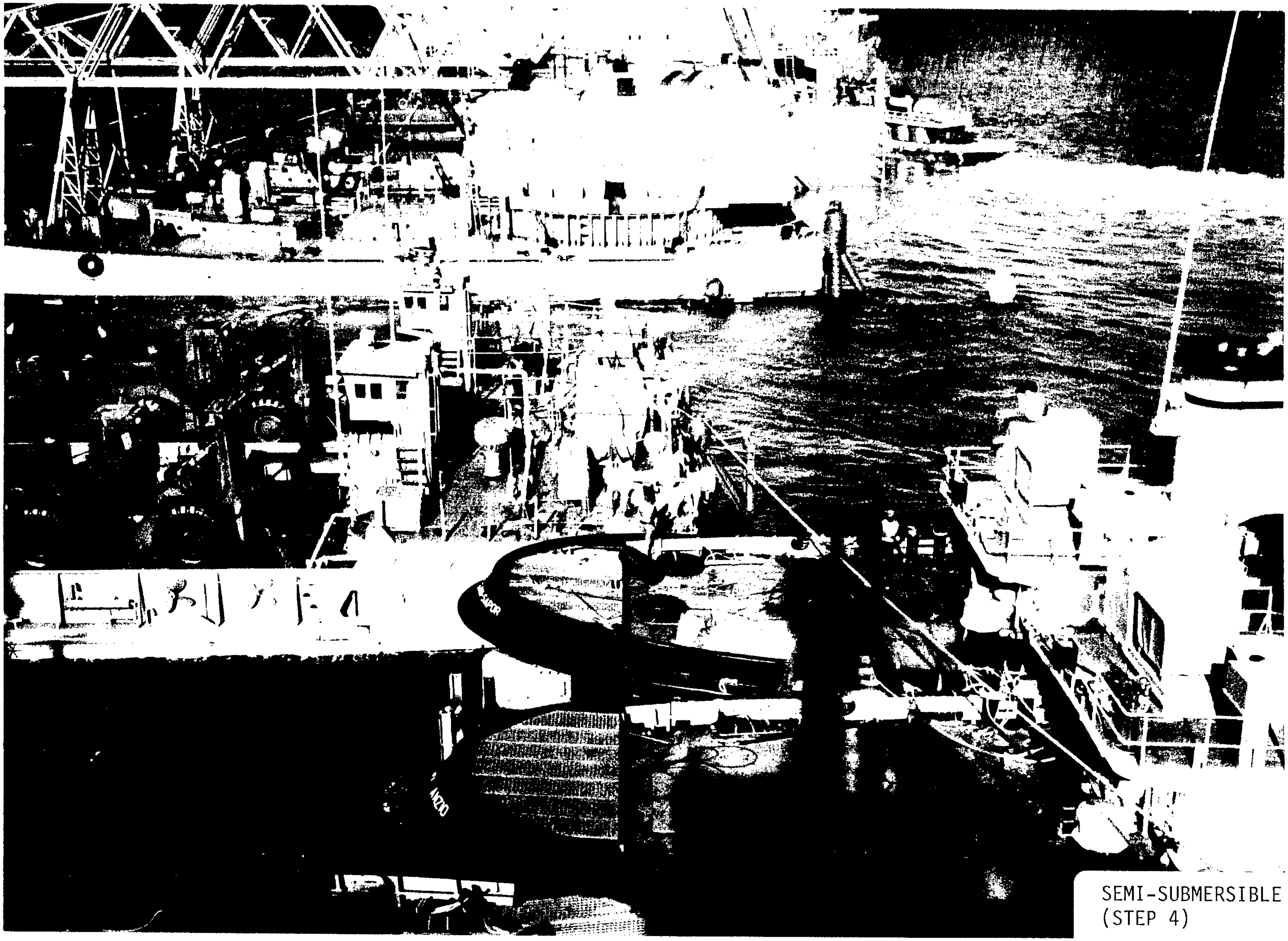
SEMI-SUBMERSIBLE SHIP
(STEP 1)



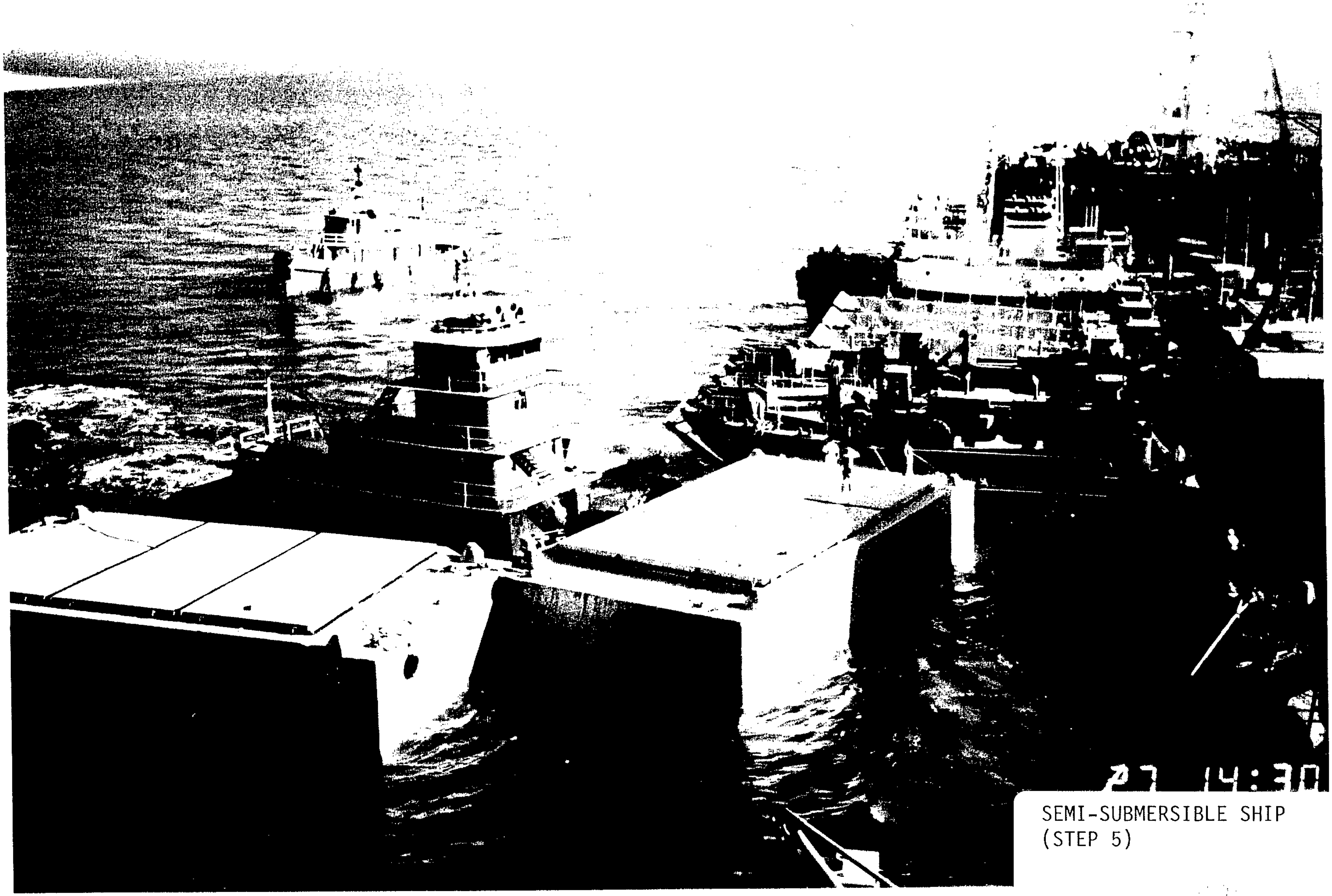
SEMI-SUBMERSIBLE SHIP
(STEP 2)



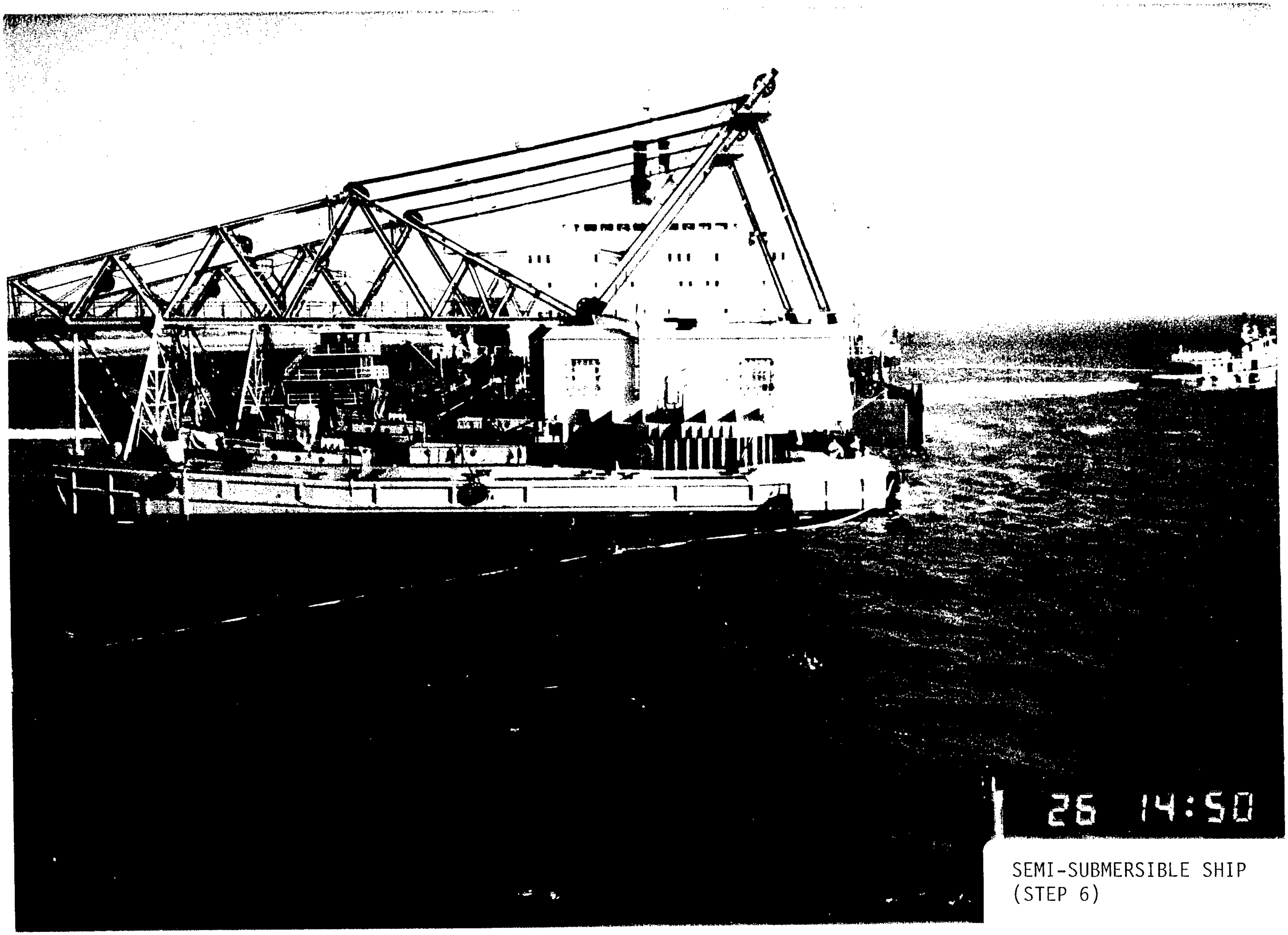
SEMI-SUBMERSIBLE SHIP
(STEP 3)



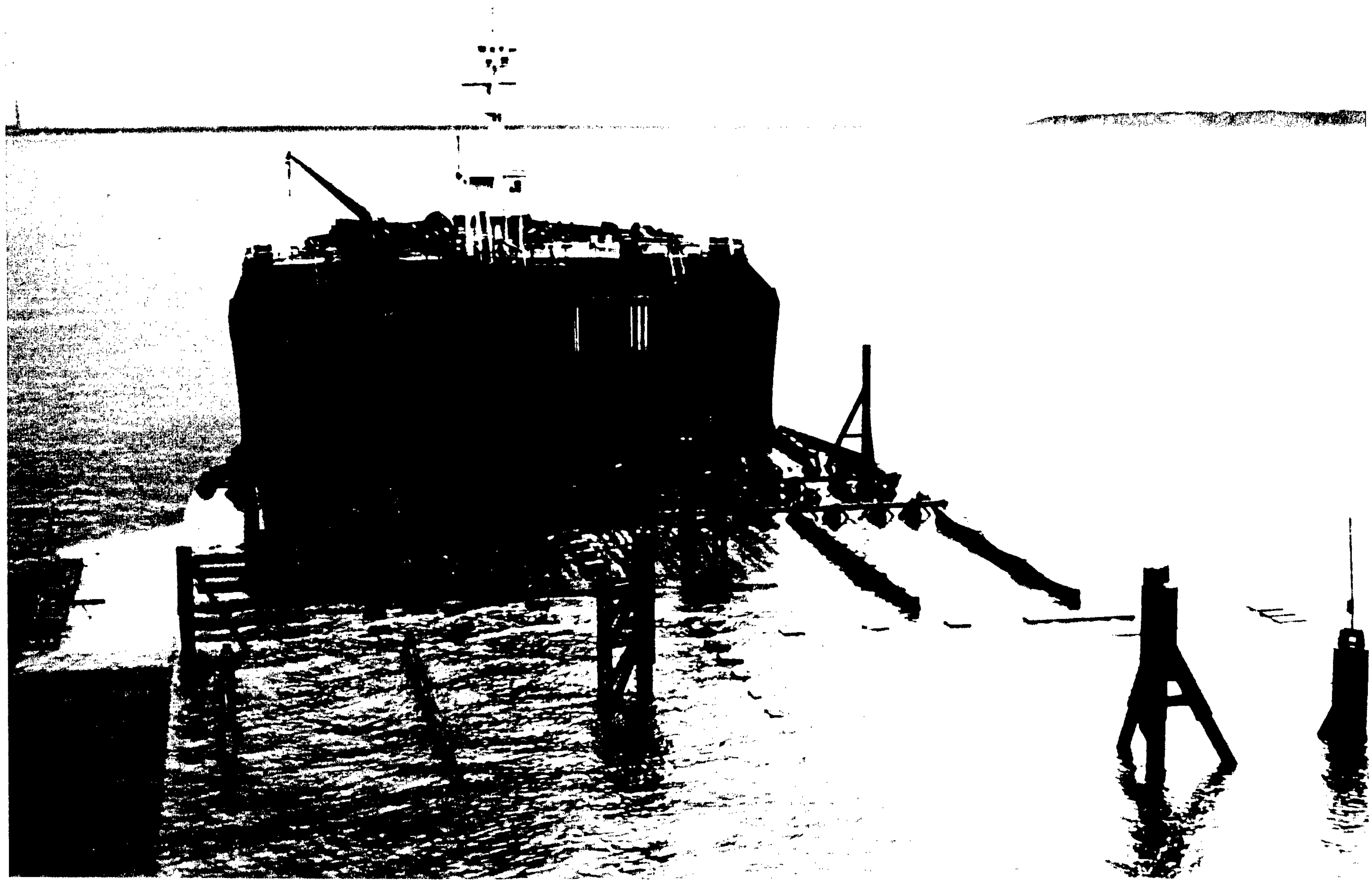
SEMI-SUBMERSIBLE SHIP
(STEP 4)



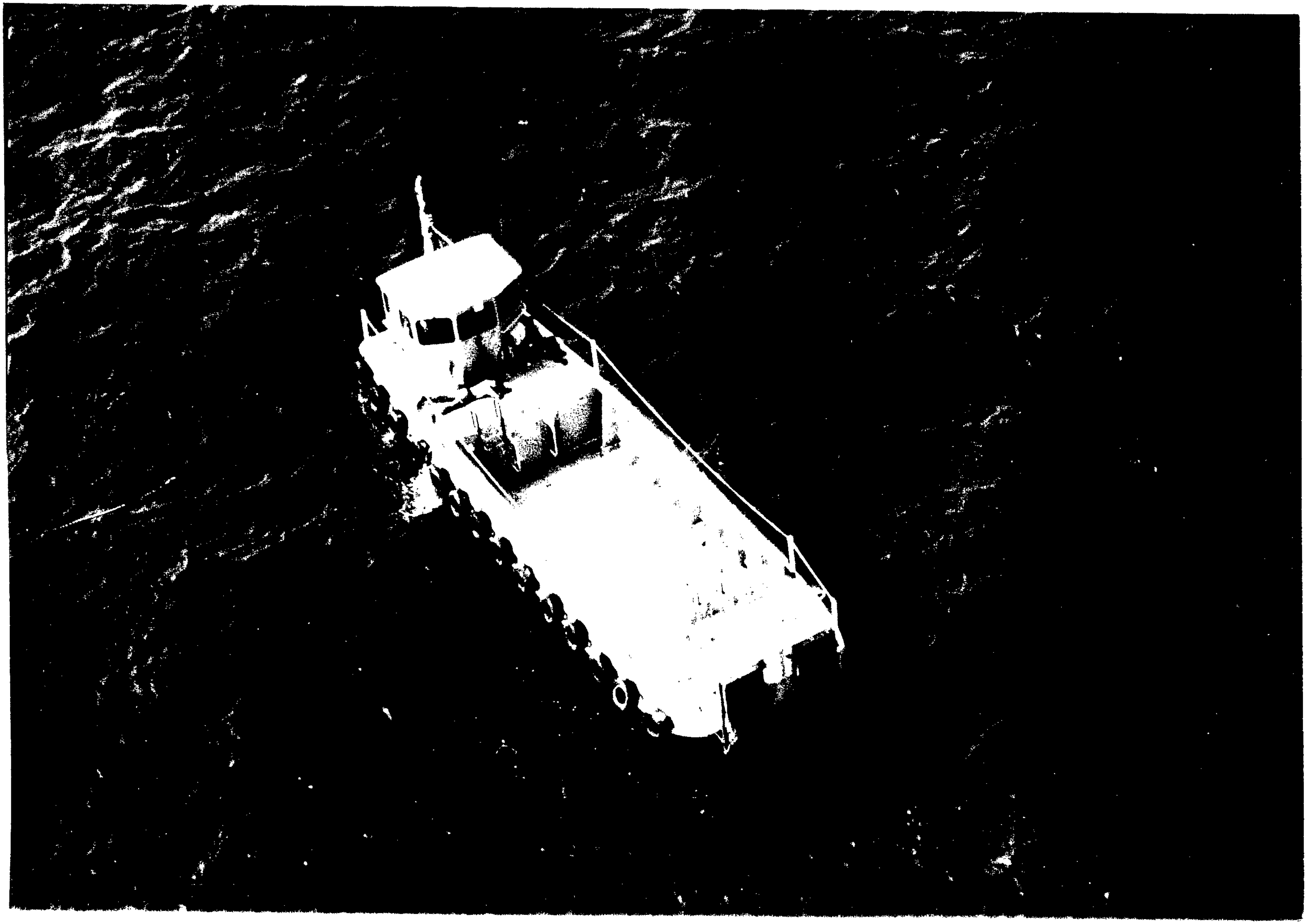
SEMI-SUBMERSIBLE SHIP
(STEP 5)



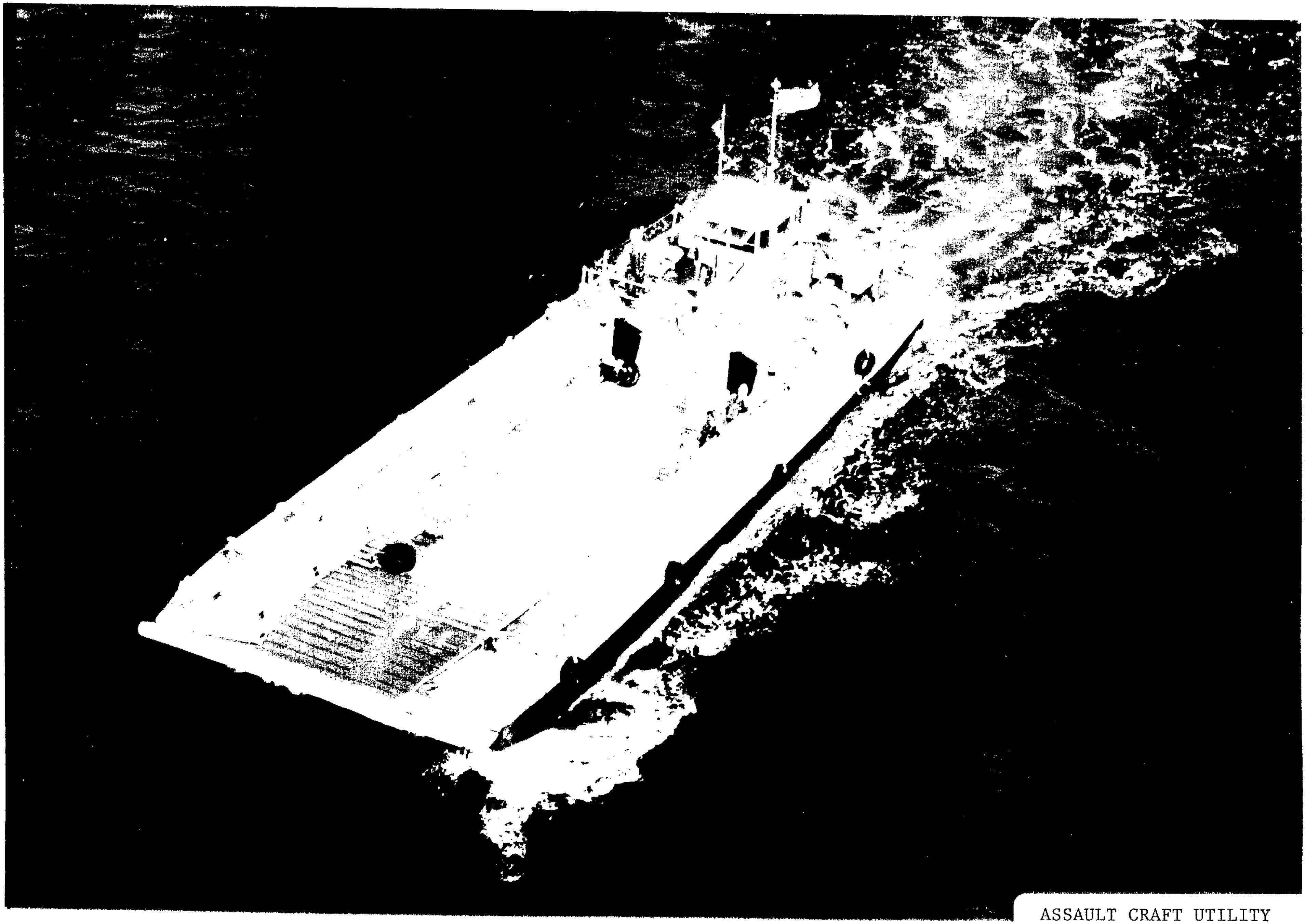
SEMI-SUBMERSIBLE SHIP
(STEP 6)



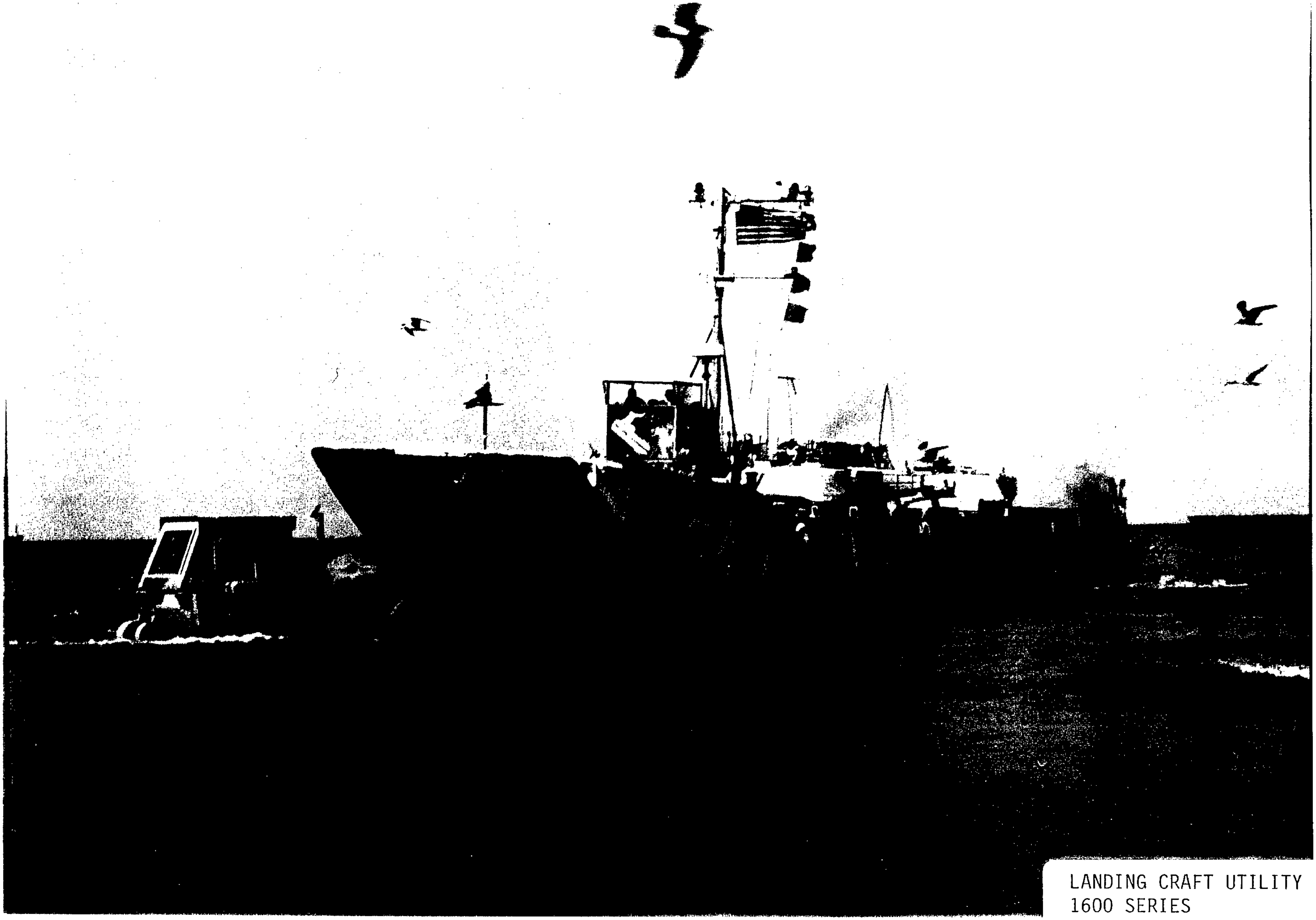
SEMI-SUBMERSIBLE SHIP
(STEP 7)



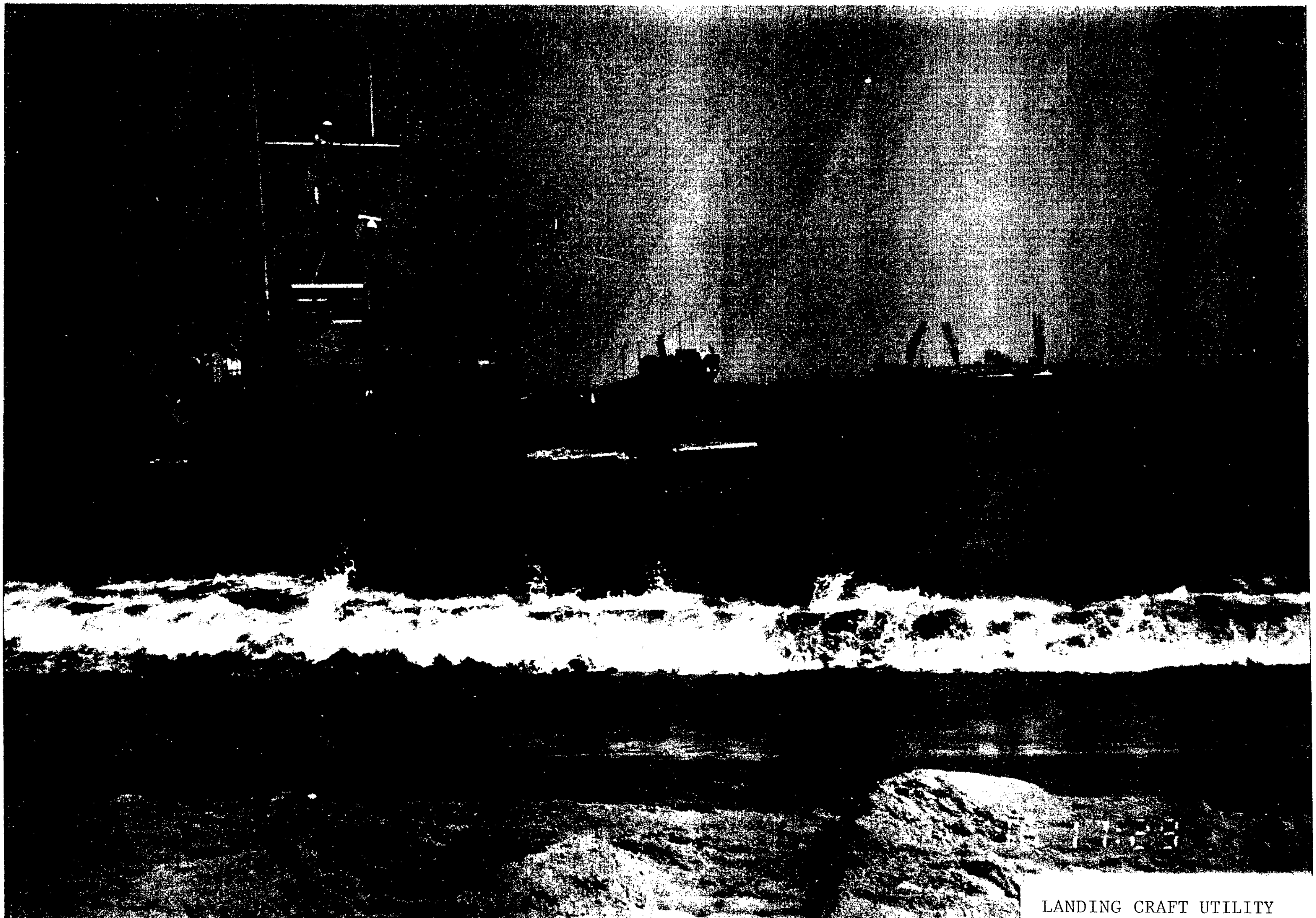
LANDING CRAFT MARINE - 8
(MIKE BOAT)



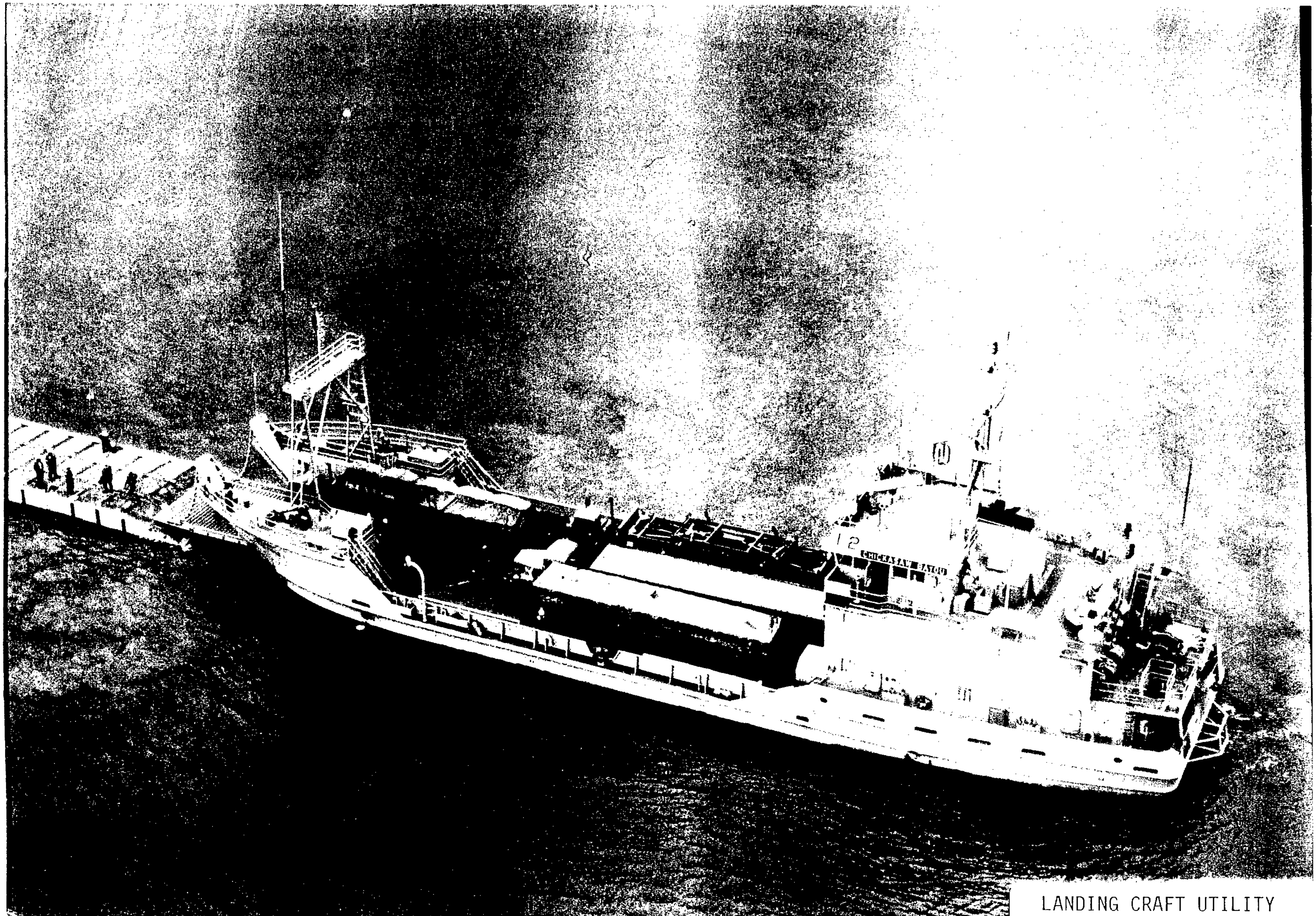
ASSAULT CRAFT UTILITY UNIT



LANDING CRAFT UTILITY
1600 SERIES

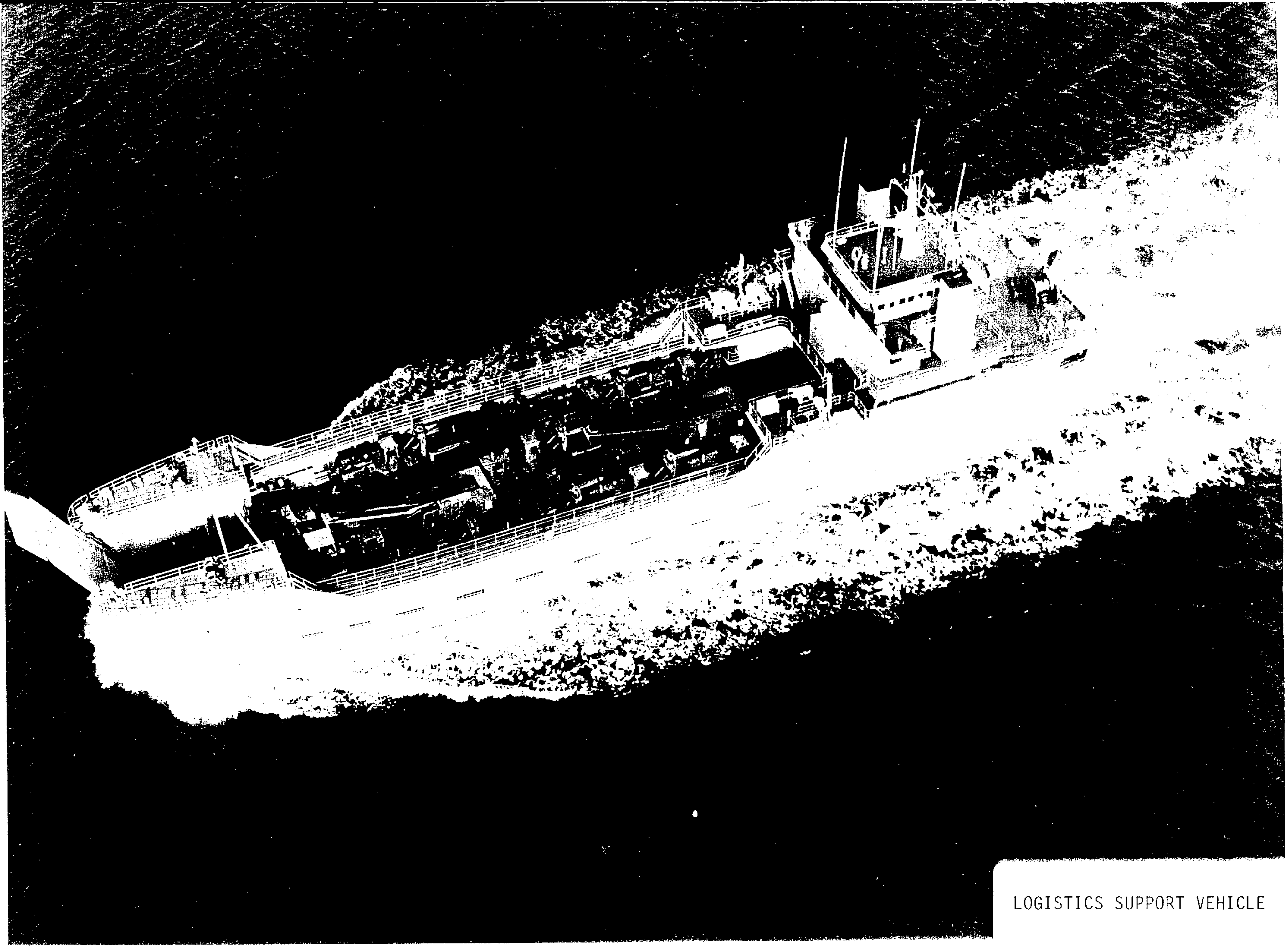


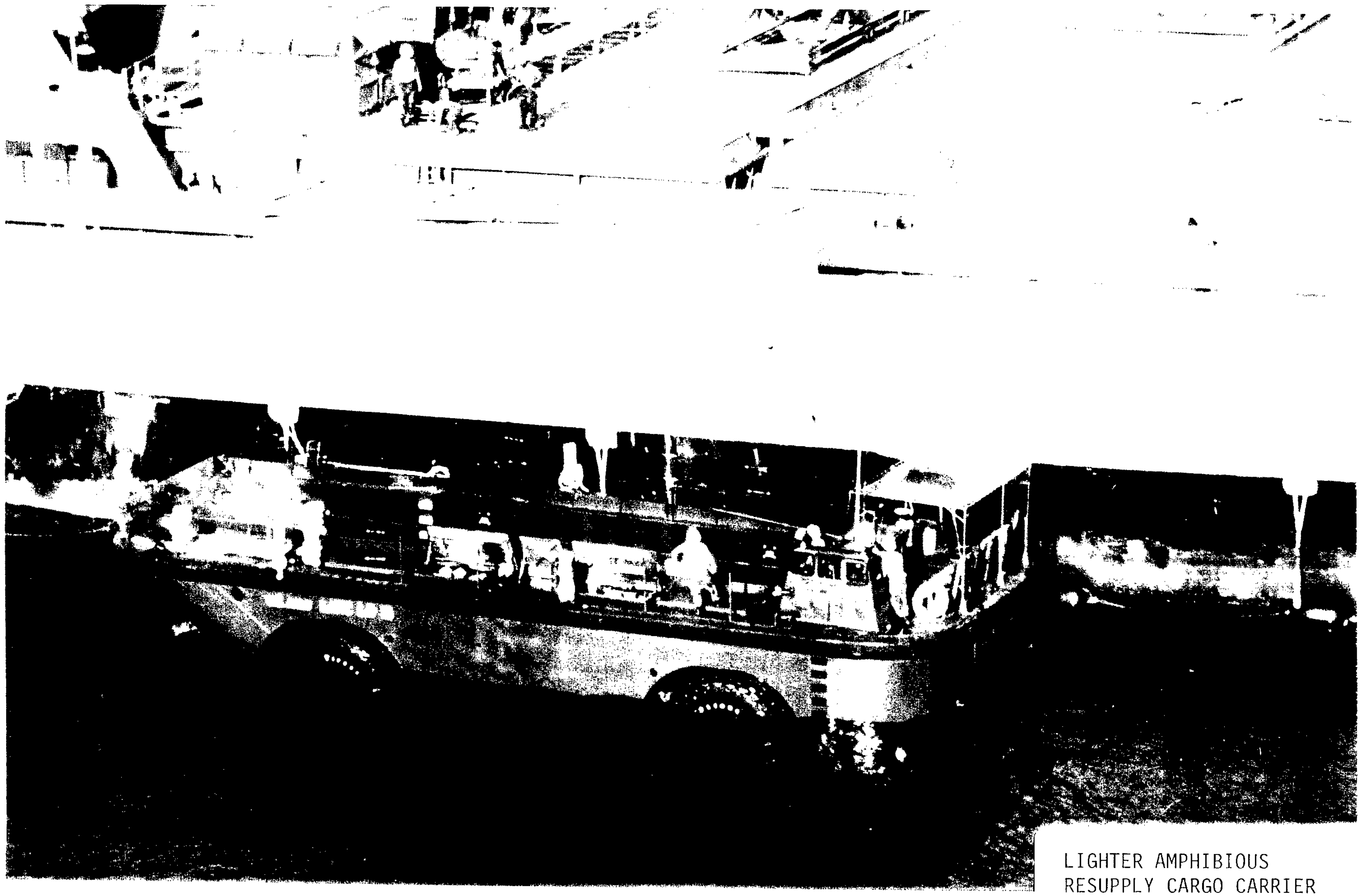
LANDING CRAFT UTILITY
1600 SERIES
(BEACHED)



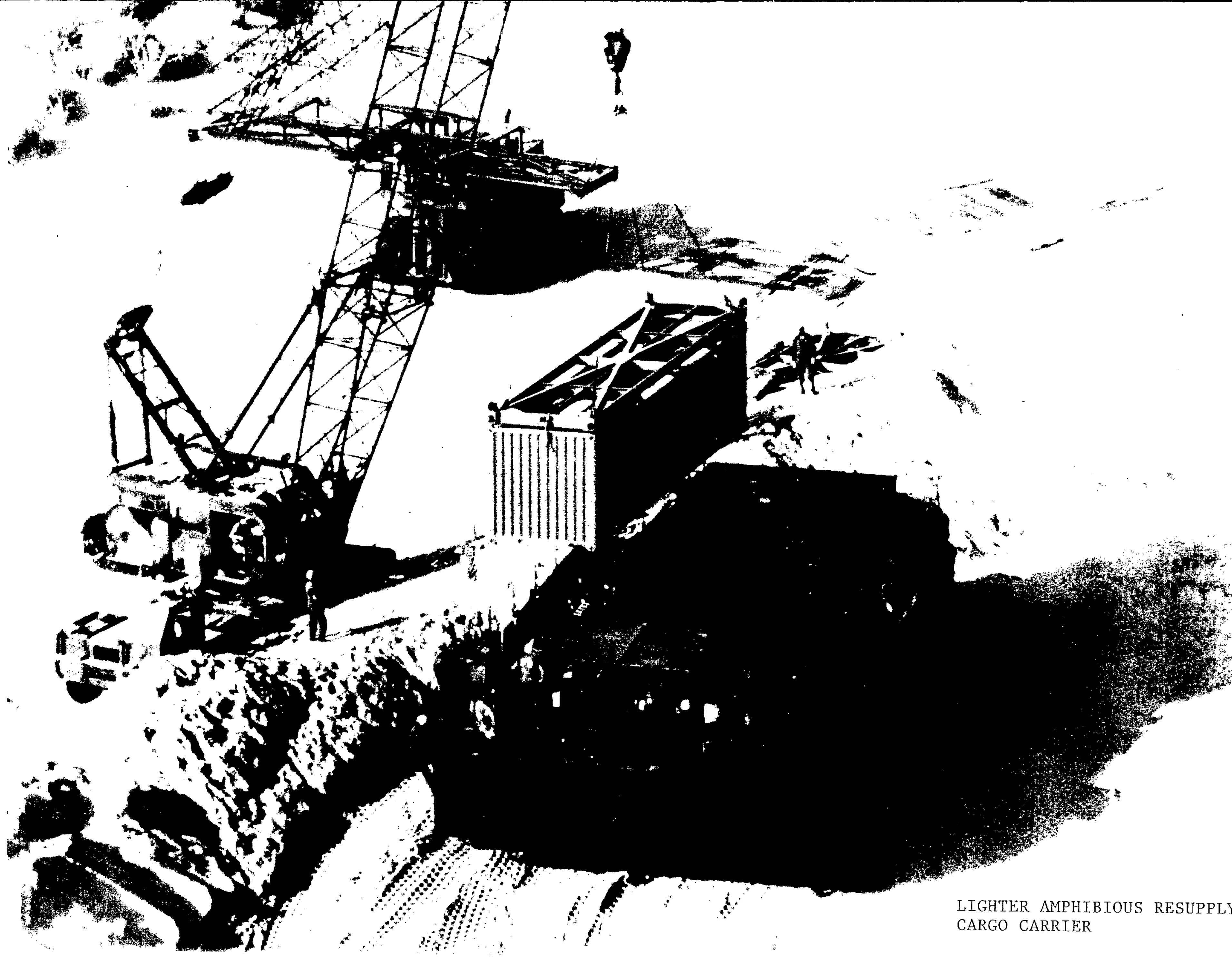
LANDING CRAFT UTILITY
2000 SERIES

LANDING CRAFT UTILITY
2000 SERIES
(BOWRAMP DISCHARGE)

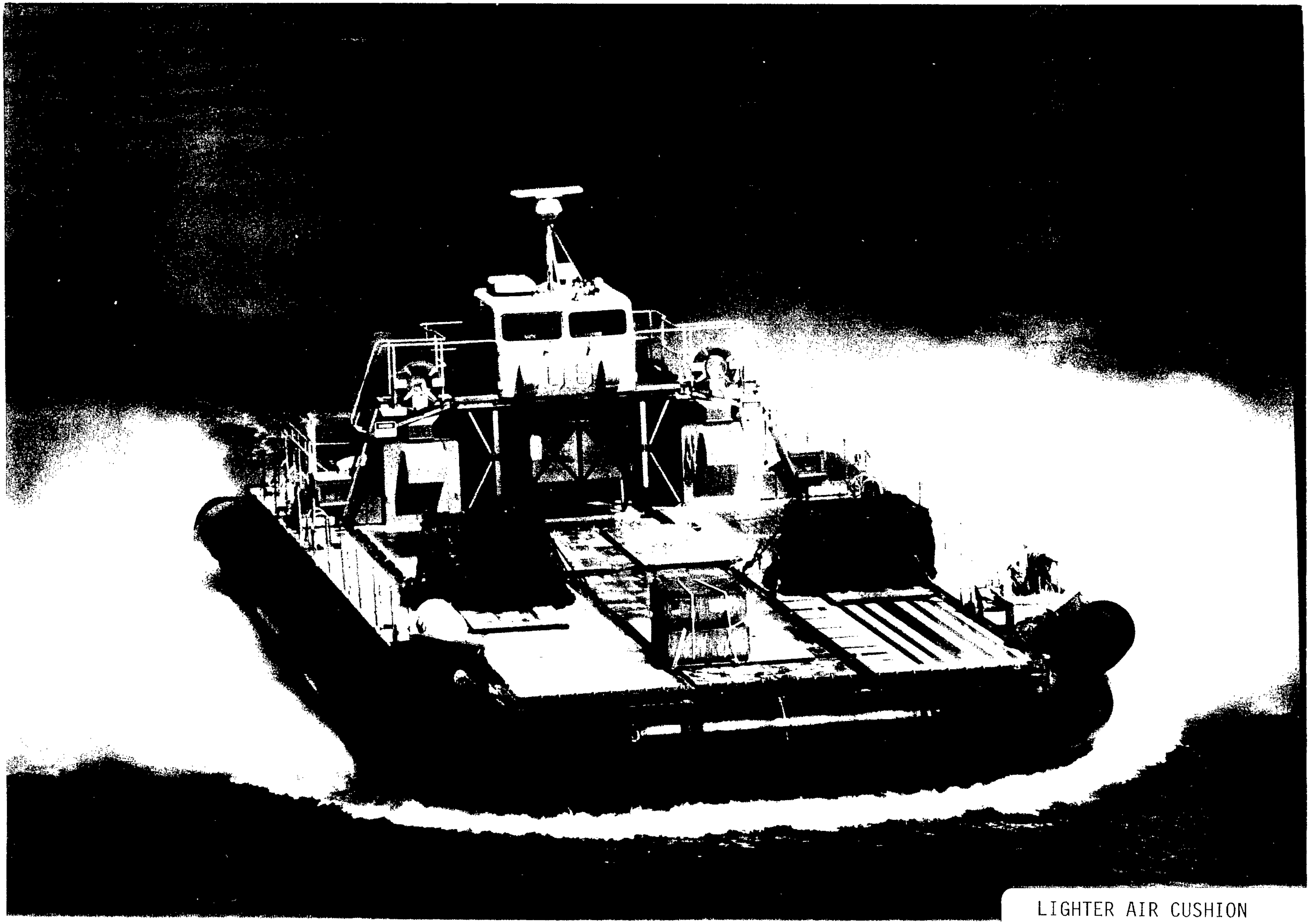

LOGISTICS SUPPORT VEHICLE



LIGHTER AMPHIBIOUS
RESUPPLY CARGO CARRIER

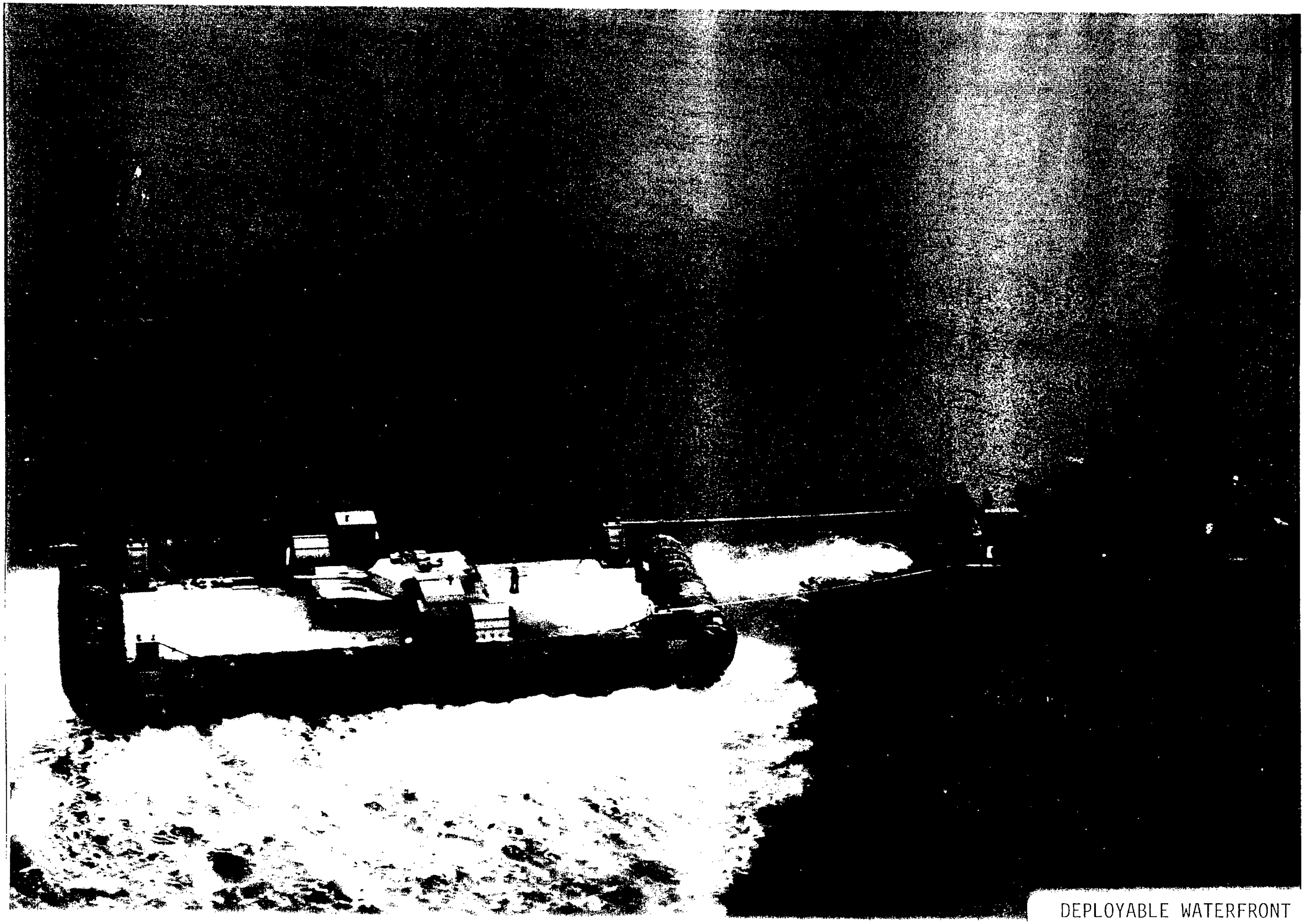


LIGHTER AMPHIBIOUS RESUPPLY
CARGO CARRIER

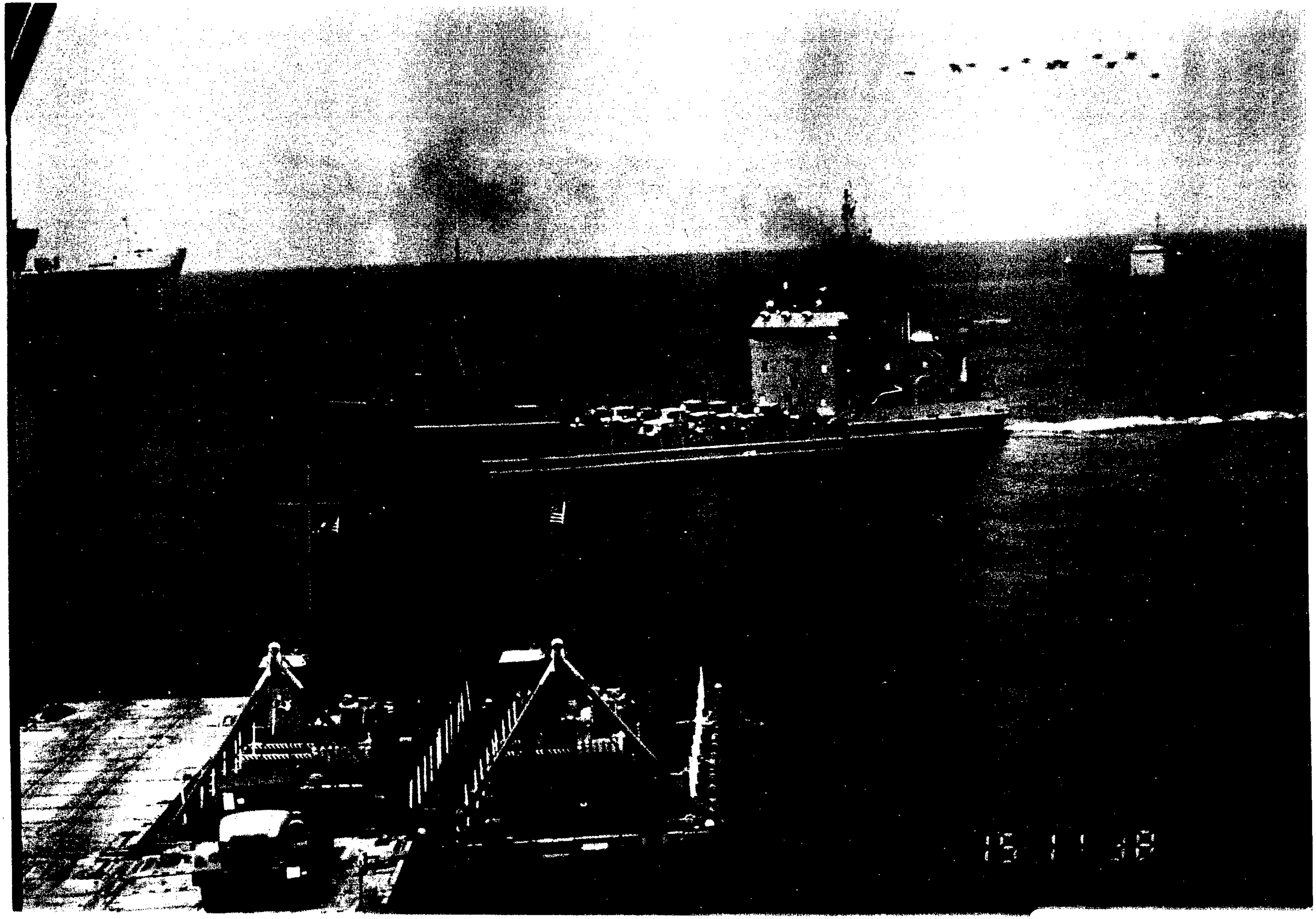


LIGHTER AIR CUSHION
VEHICLE (30 TON)

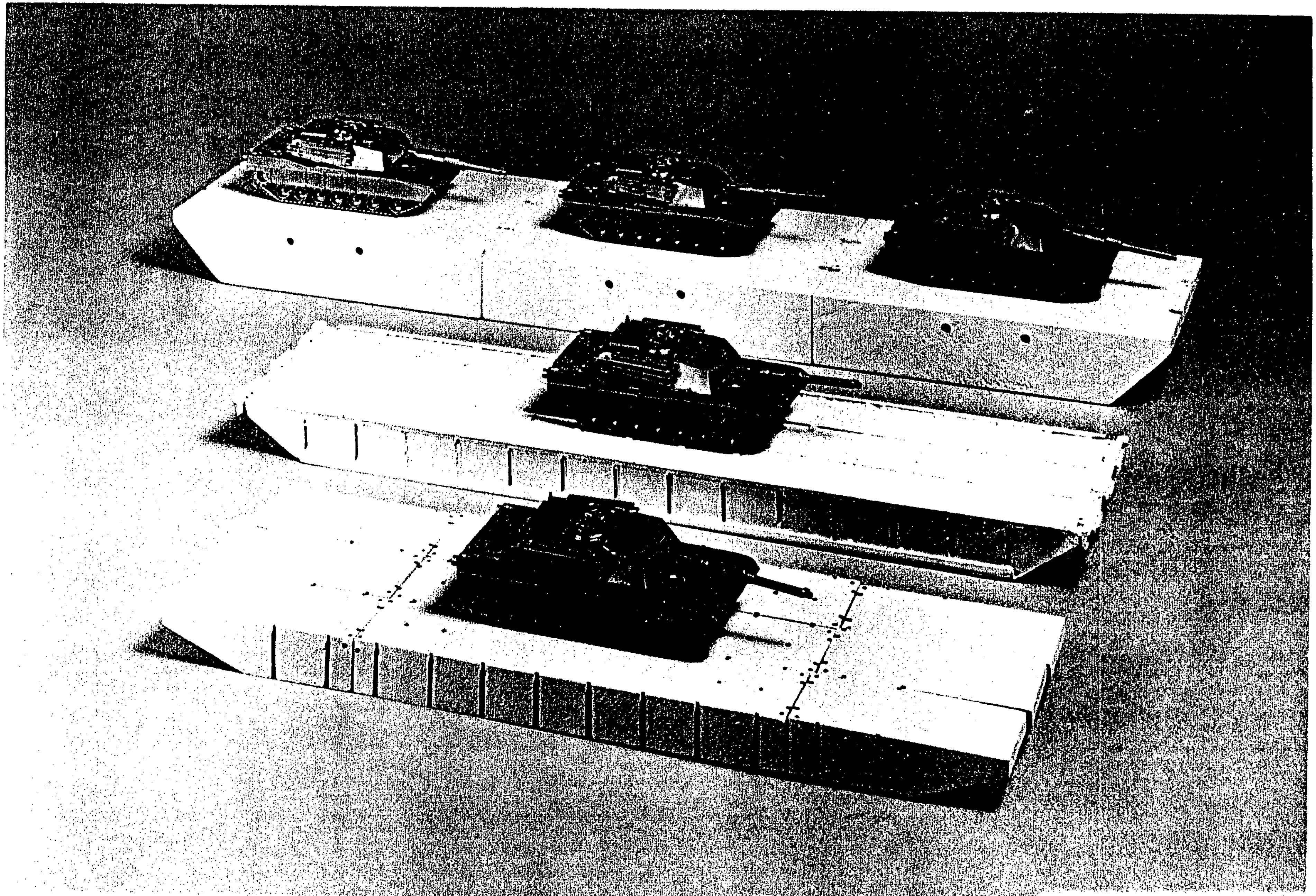
LANDING CRAFT AIR CUSHION
AND AIR CUSHION VEHICLE
LANDING PLATFORM



DEPLOYABLE WATERFRONT



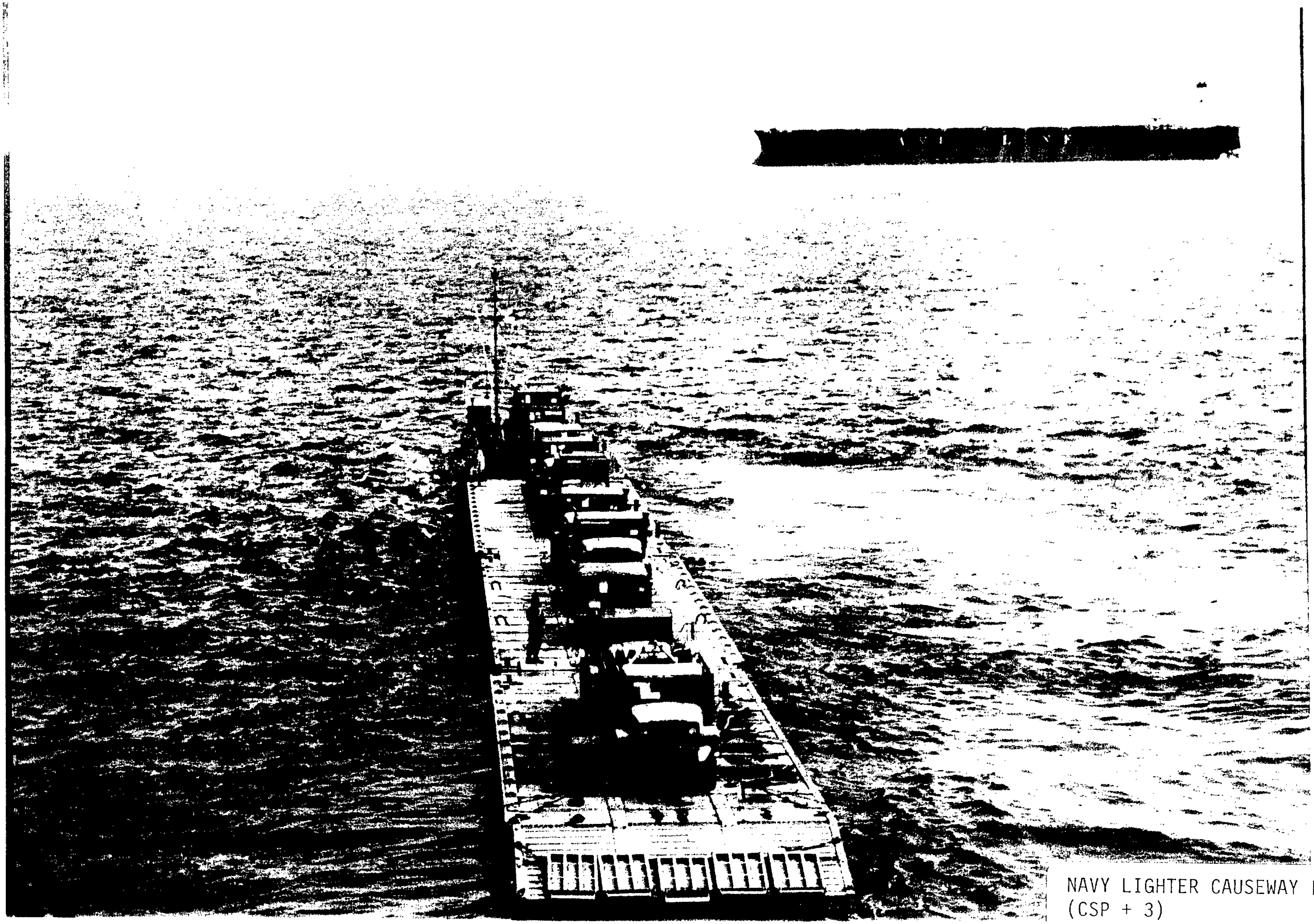
MULTIPLE LIGHTER DISCHARGE OPERATIONS BETWEEN SEVERAL SEALIFT VESSELS



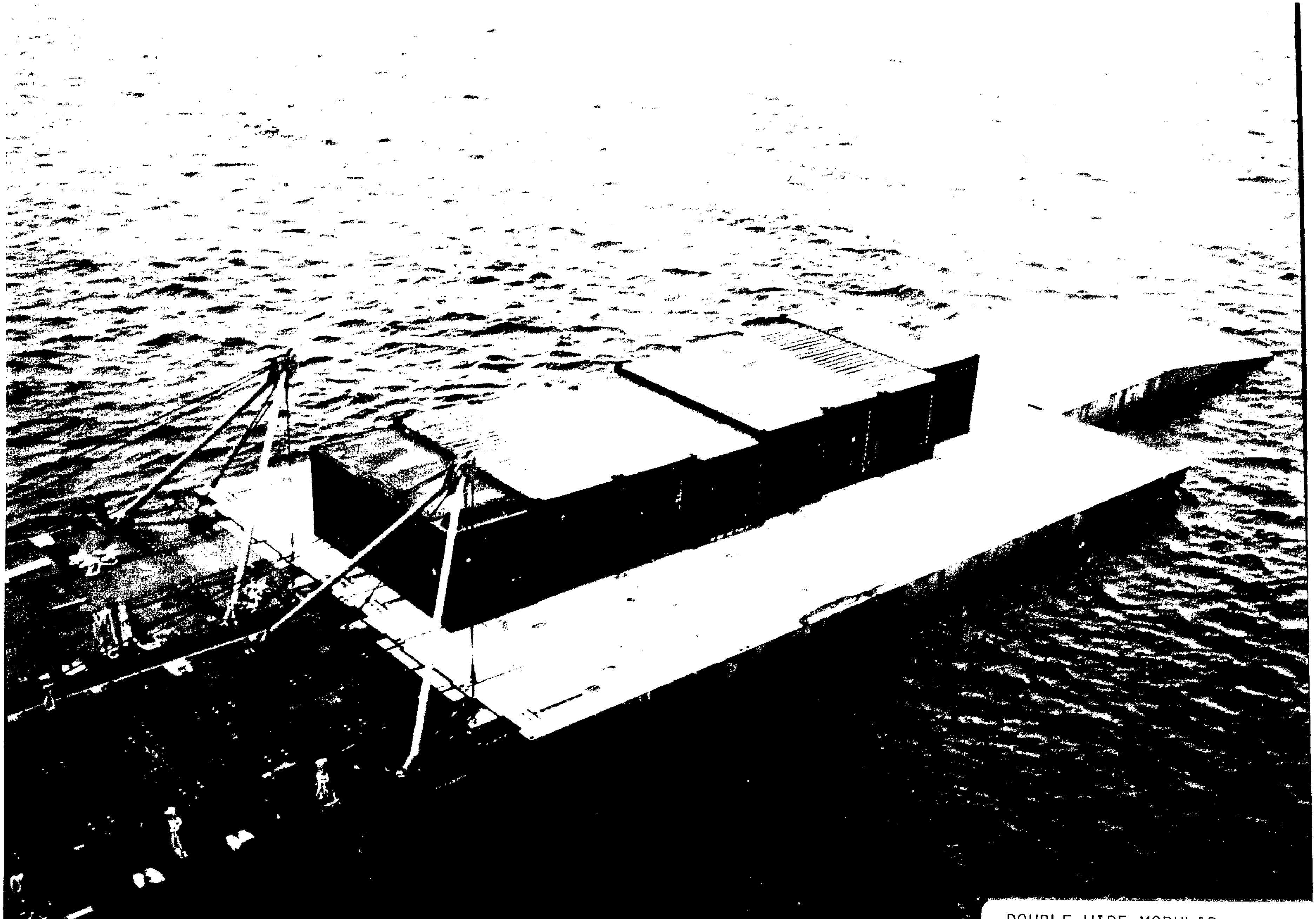
ACBL CAUSEWAY - TOP
NL CAUSEWAY - MIDDLE
MCS CAUSEWAY - BOTTOM

NAVY LIGHTER CAUSEWAY
(1 SECTION)

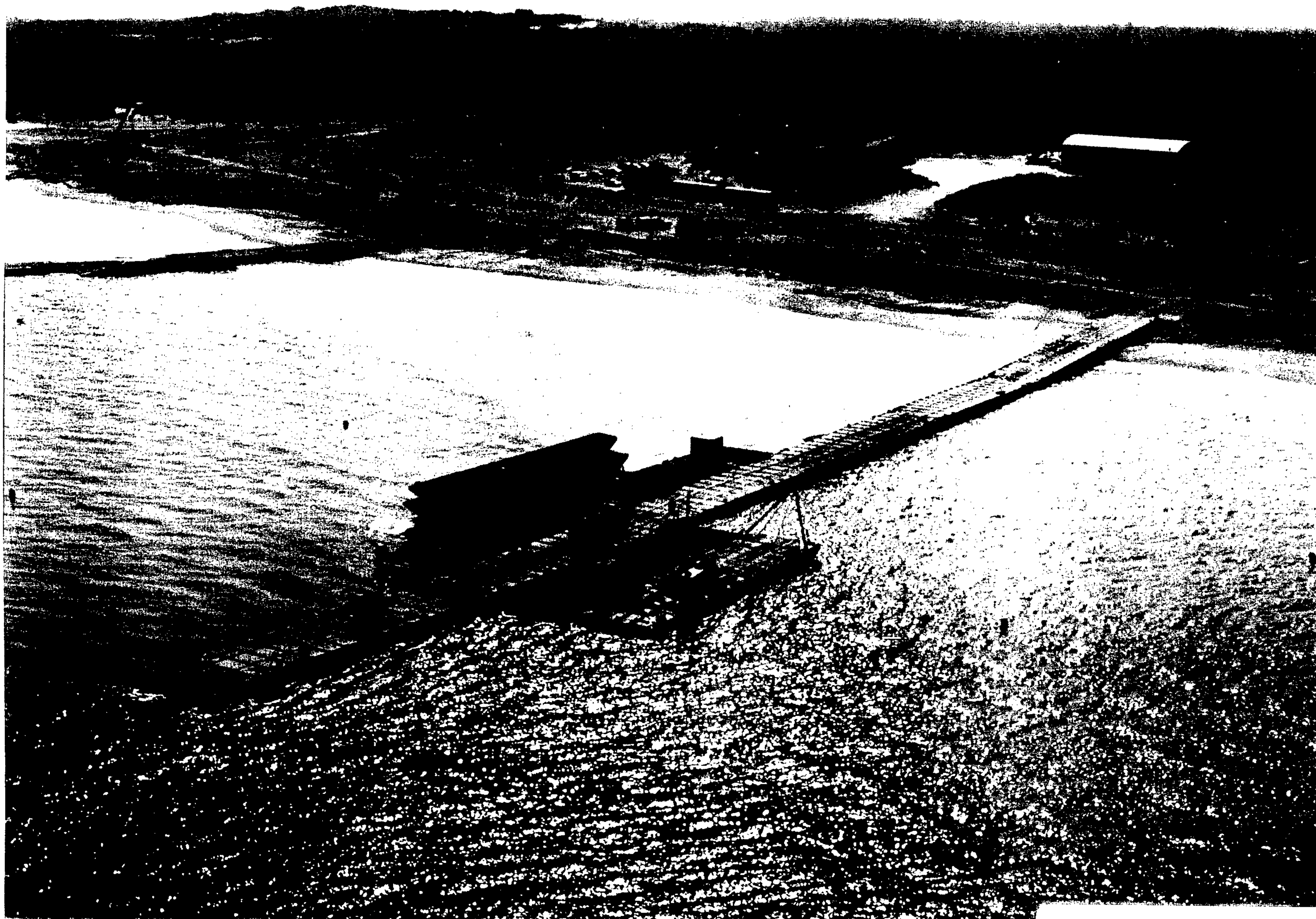
ARMY MODULAR CAUSEWAY
(ABOARD CONTAINERSHIP)



NAVY LIGHTER CAUSEWAY FERRY
(CSP + 3)

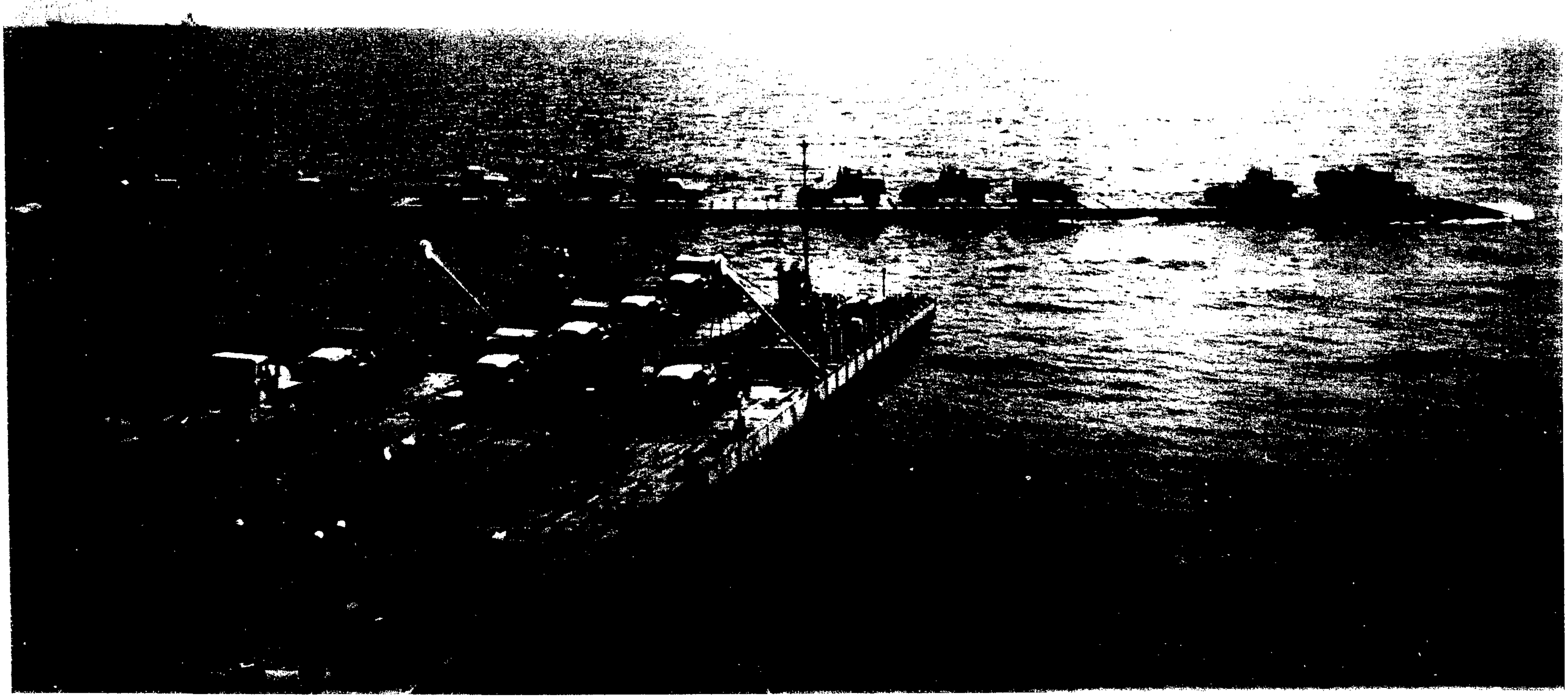


DOUBLE WIDE MODULAR
CAUSEWAY FERRY

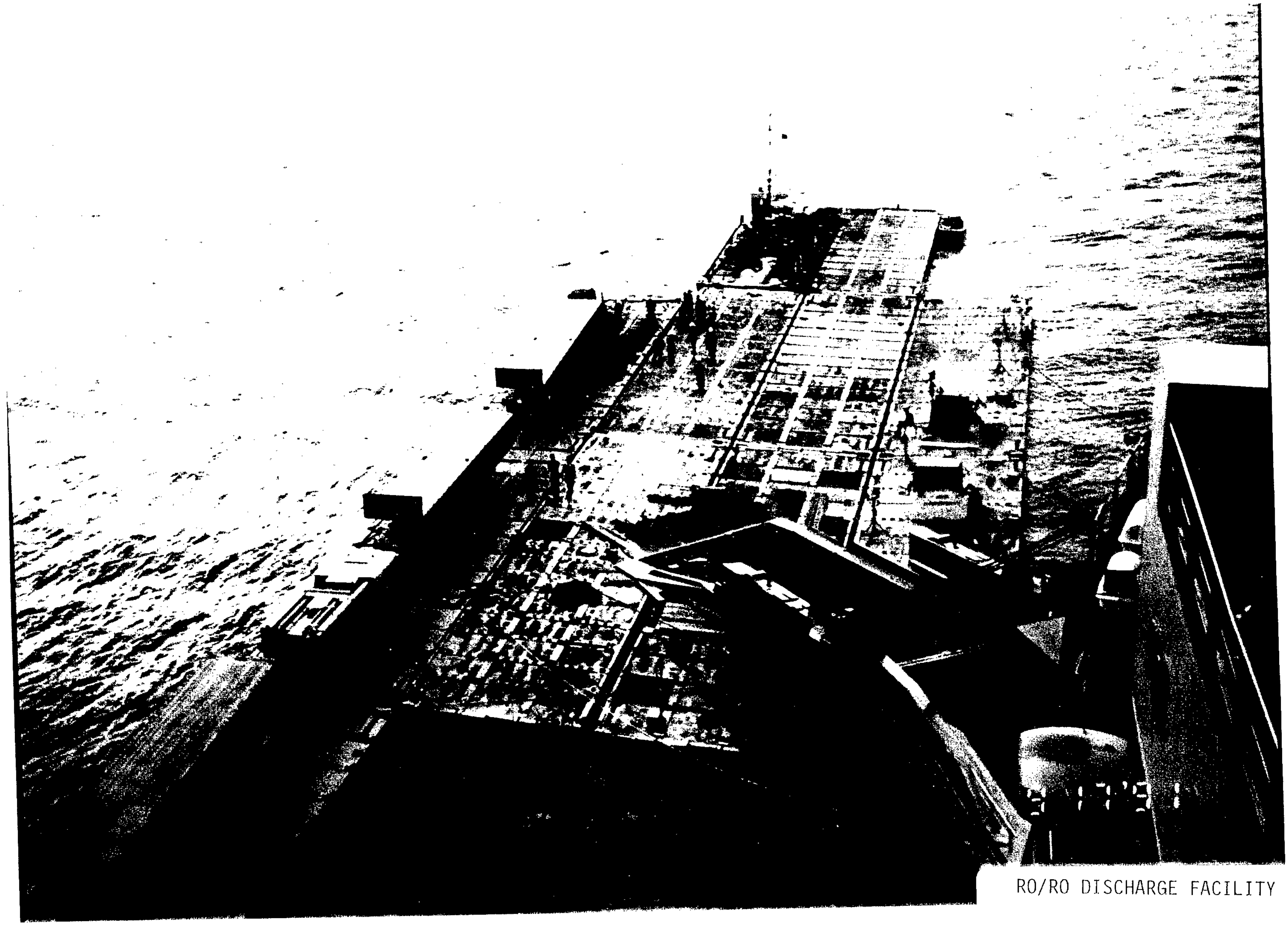


NAVY LIGHTER CAUSEWAY PIER

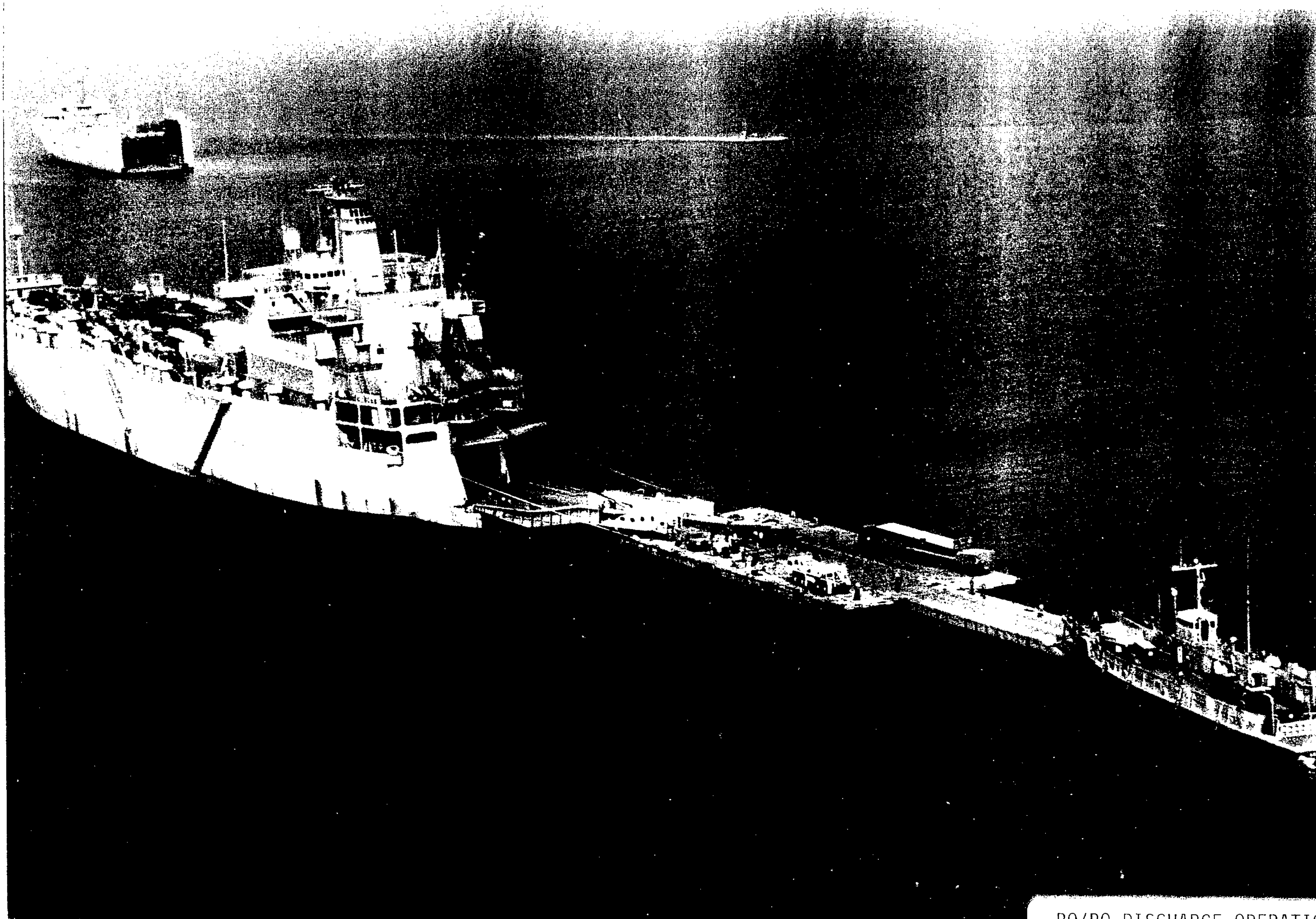
NAVY LIGHTER CAUSEWAY PIER
DISCHARGE OPERATIONS



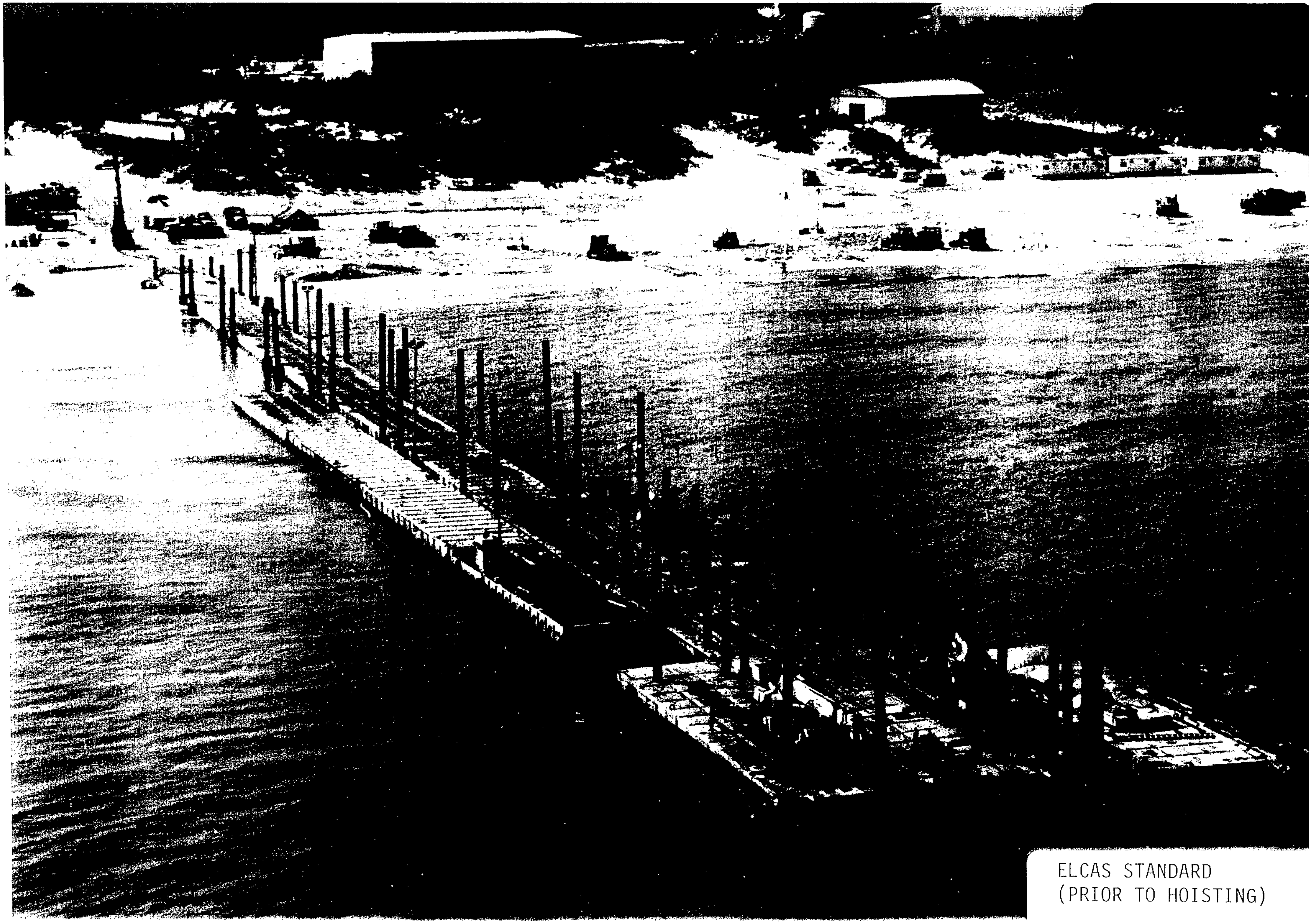
CAUSEWAY FERRY THROUGHPUT OPERATIONS



RO/RO DISCHARGE FACILITY



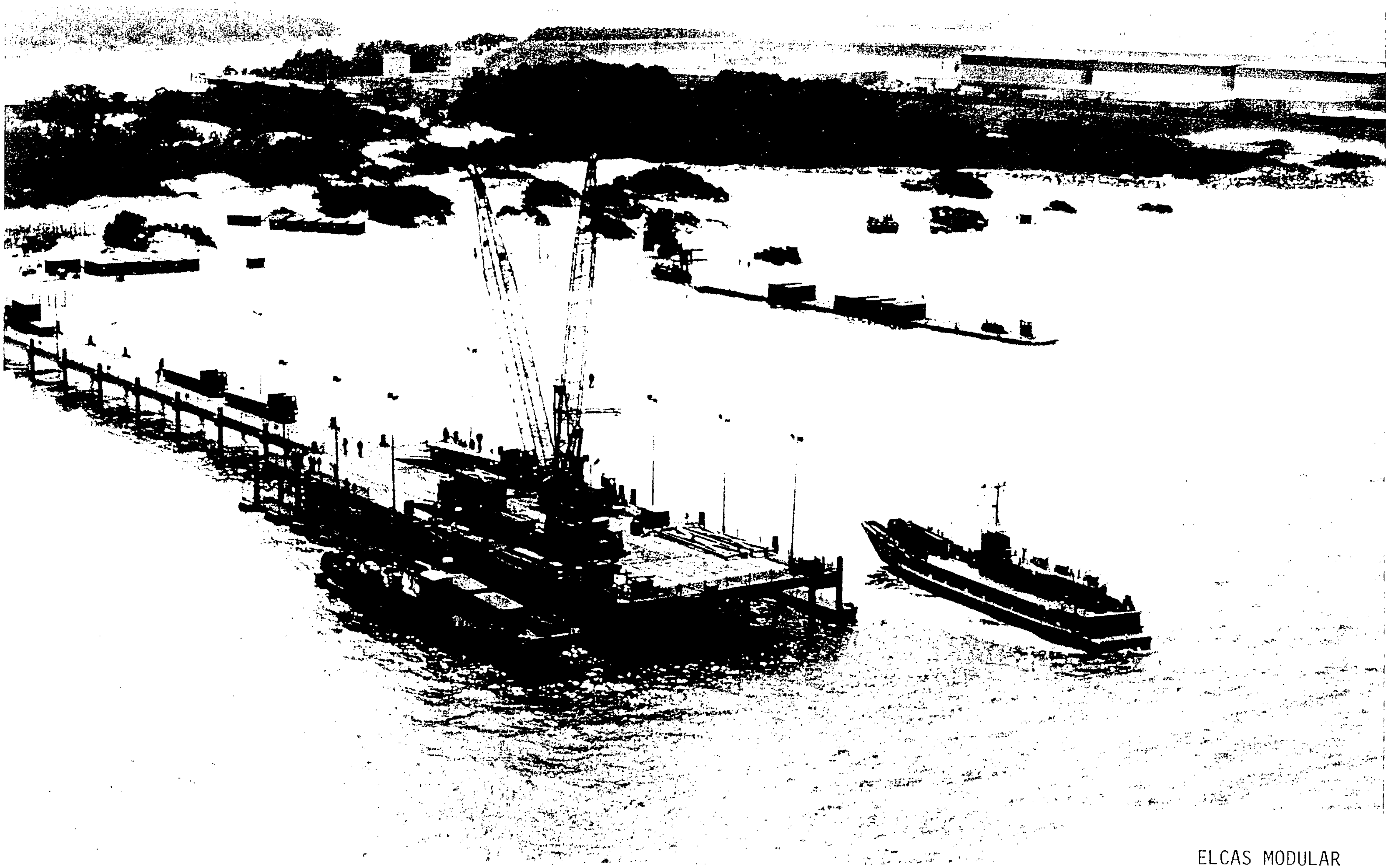
RO/RO DISCHARGE OPERATION



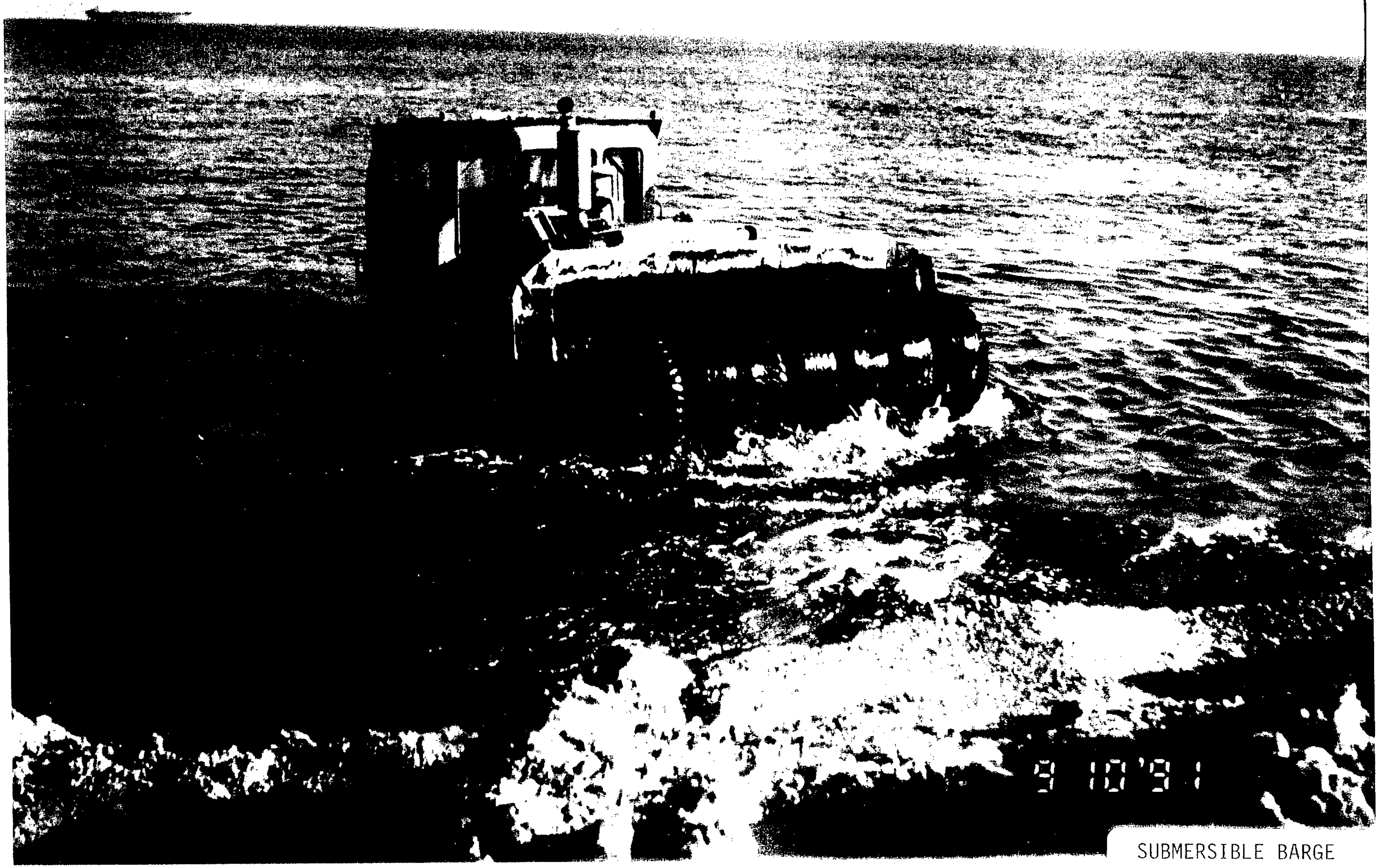
ELCAS STANDARD
(PRIOR TO HOISTING)

ELCAS STANDARD
(HOISTING STAGE)

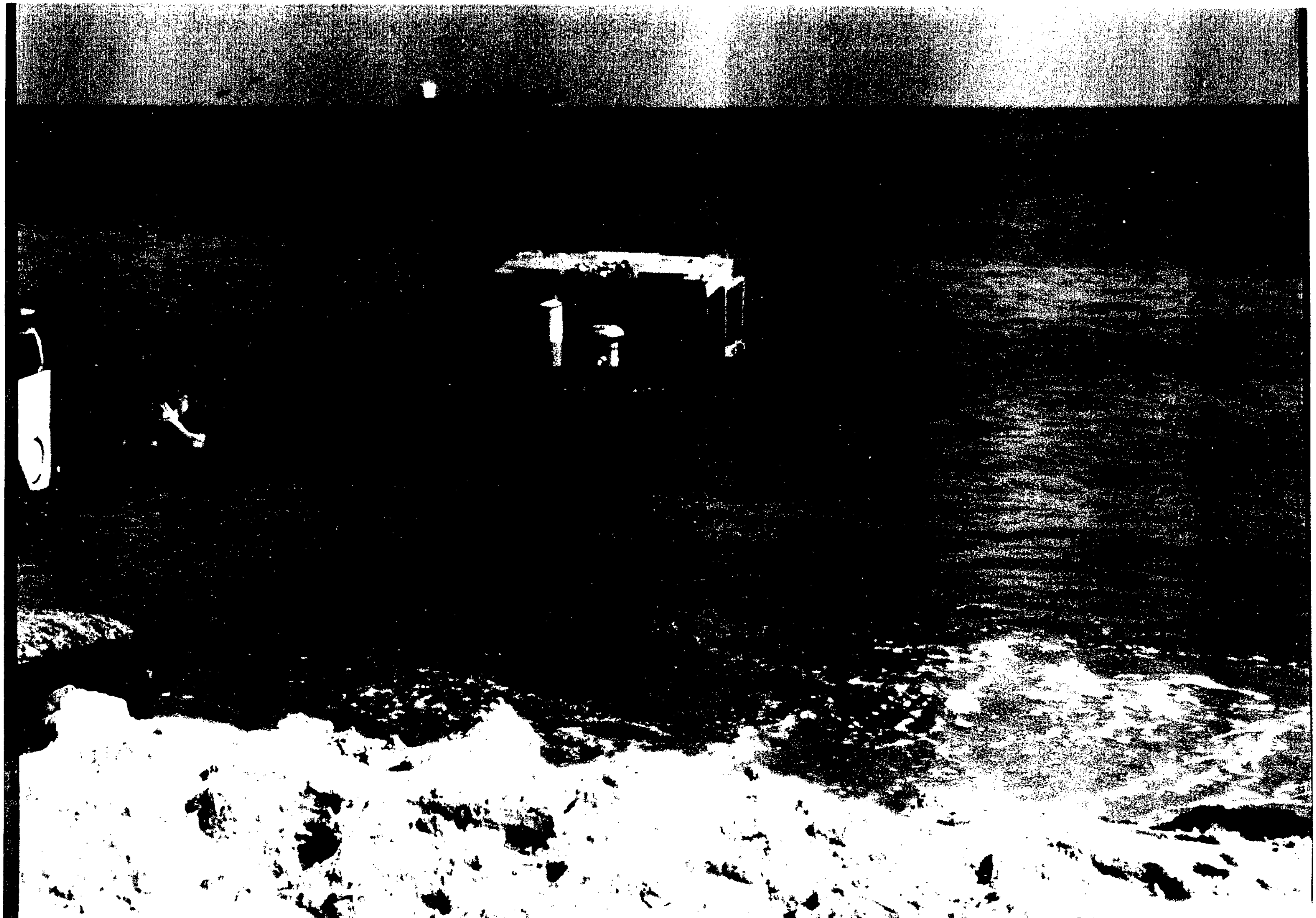
ELCAS STANDARD
(AFTER COMPLETION)



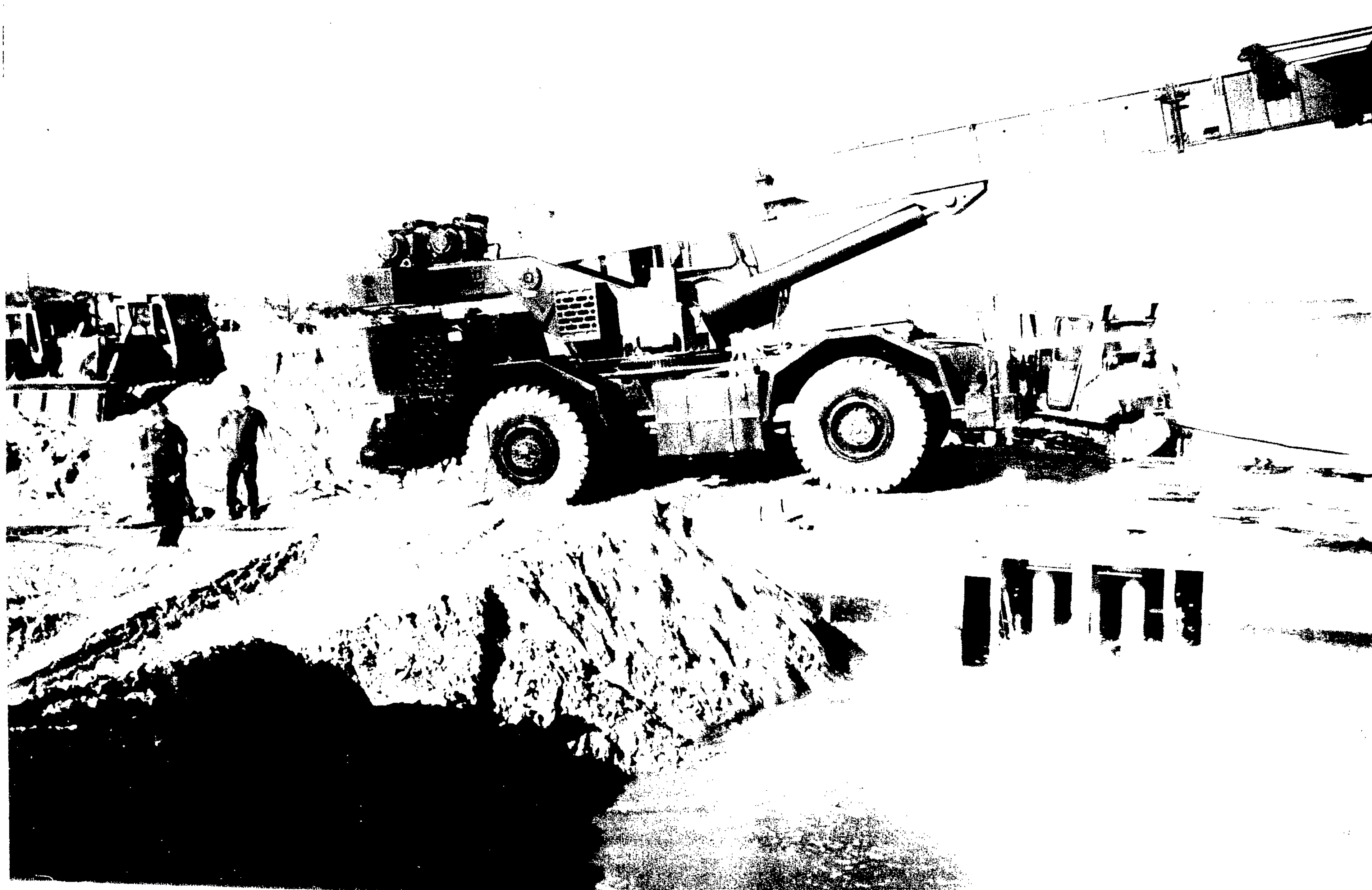
ELCAS MODULAR



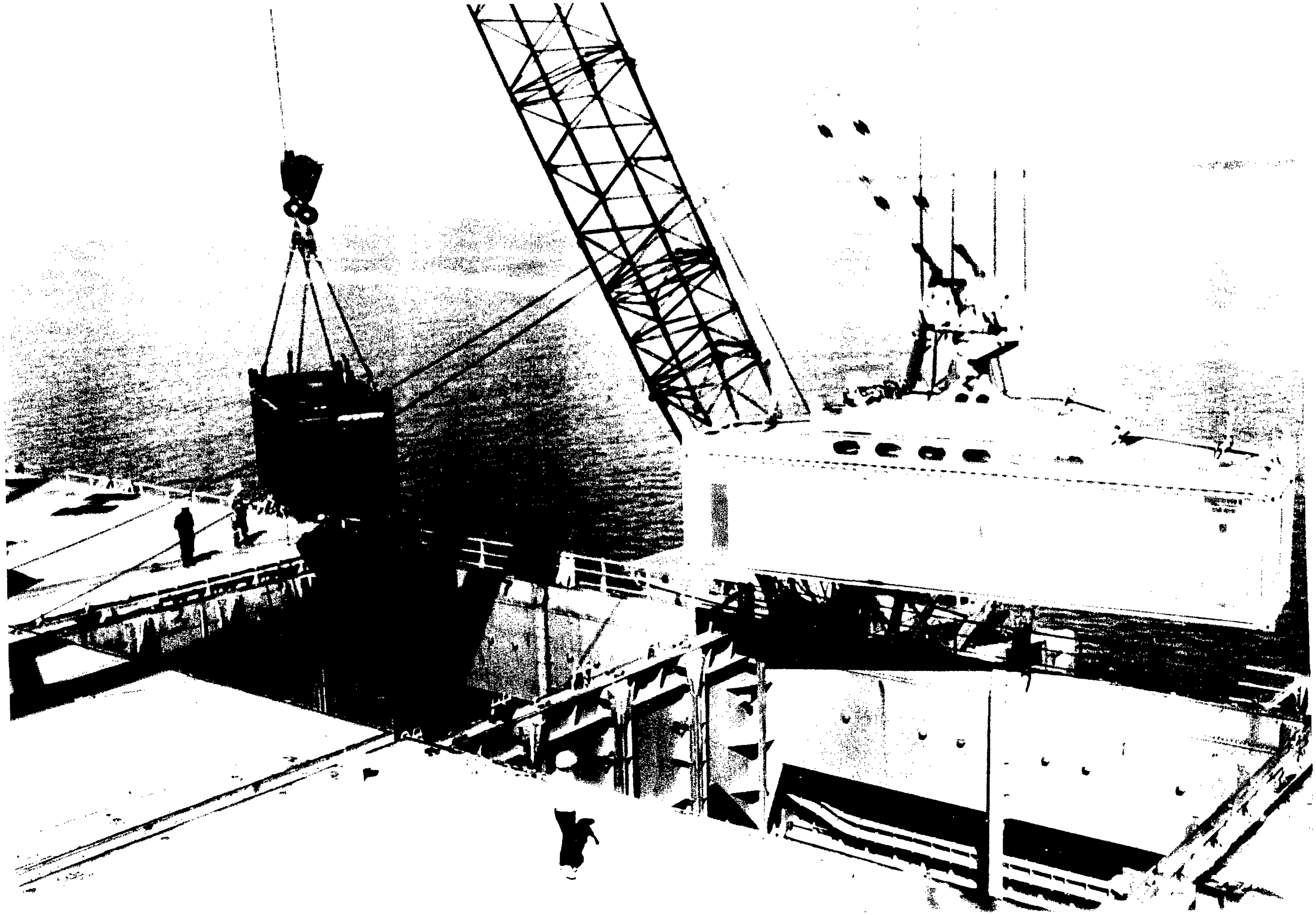
SUBMERSIBLE BARGE
POSITIONING UNIT



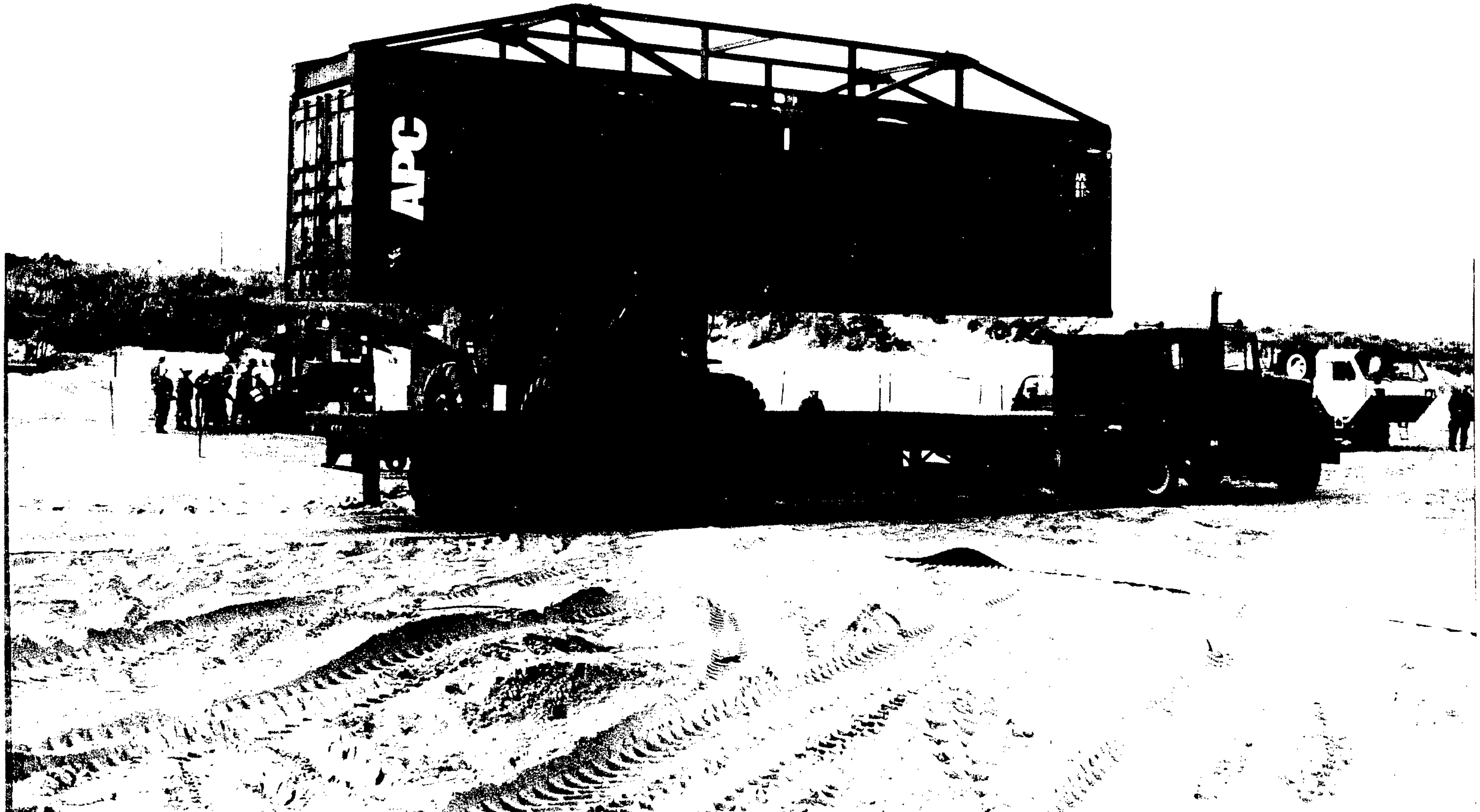
SUBMERSIBLE BARGE
POSITIONING UNIT



STANDARD LIFT CRANE

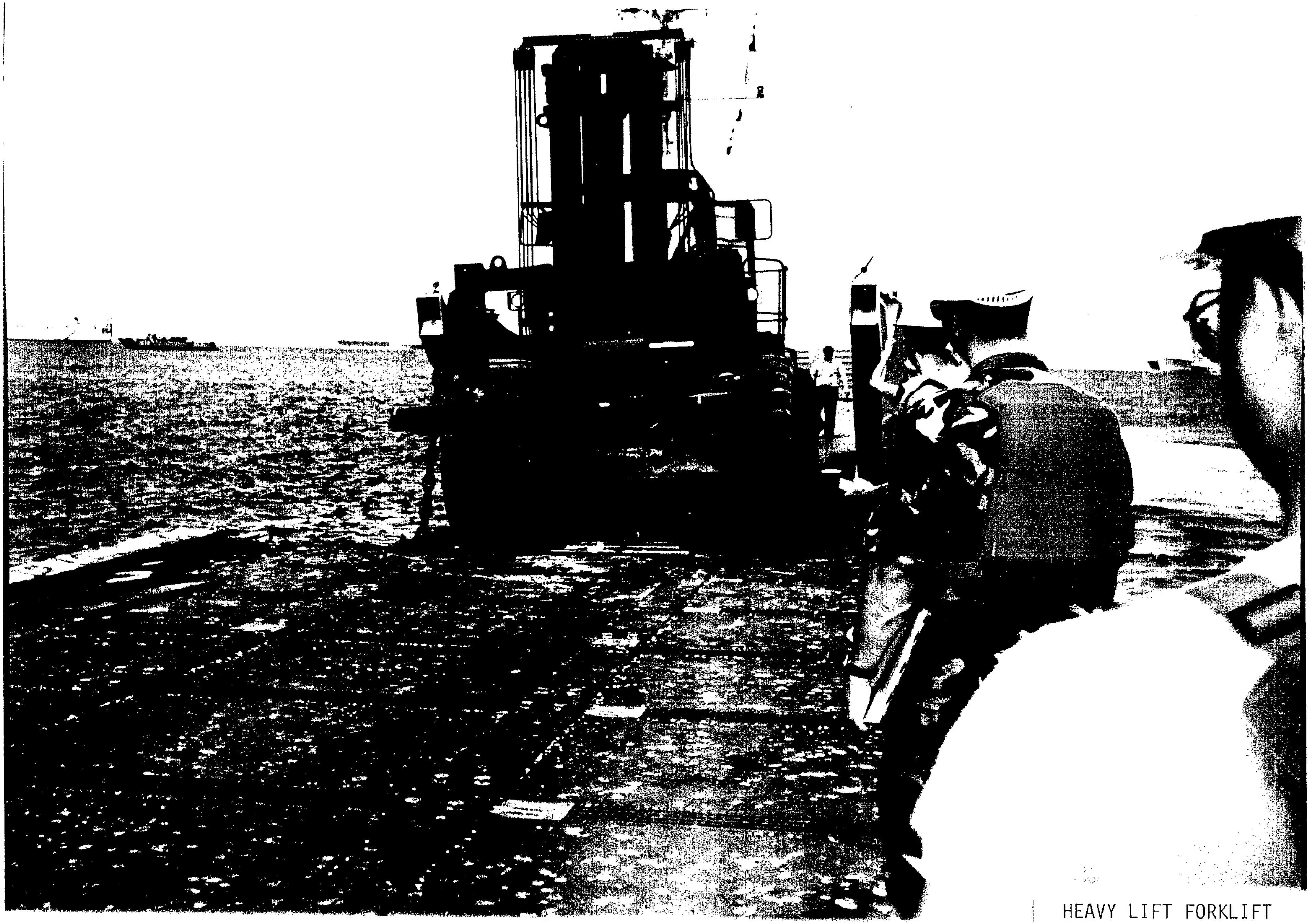


HEAVY LIFT CRANE
CONTAINER SPREADER BAR



ROUGH TERRAIN CARGO
HANDLING UNIT WITH SPREADEF
BAR ATTACHMENT

ROUGH TERRAIN CARGO
HANDLING VEHICLE



HEAVY LIFT FORKLIFT

SHORESIDE ROADWAY
(STEP 1)

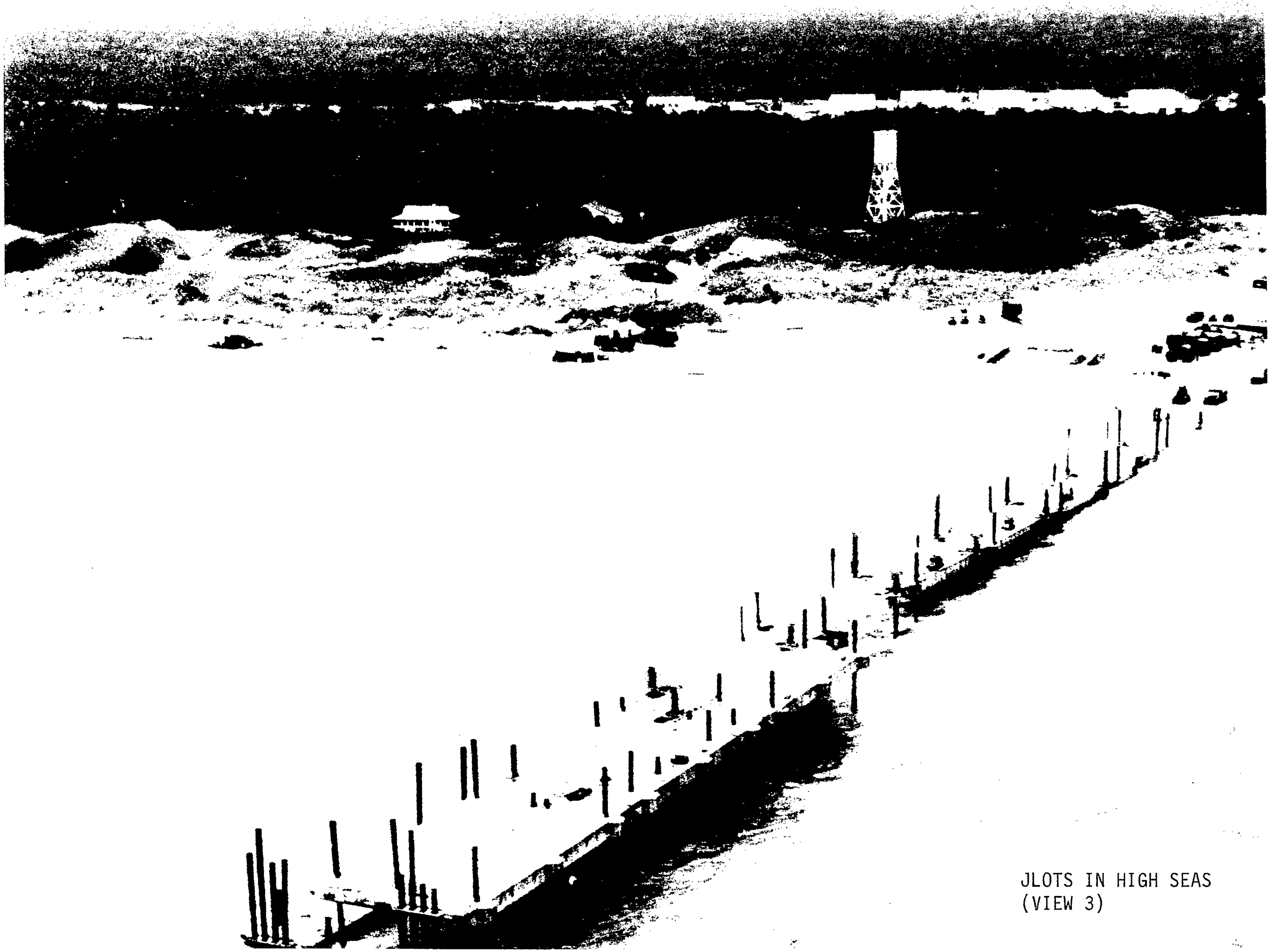
SHORESIDE ROADWAY
(STEP 2)

SHORESIDE ROADWAY
(STEP 3)

SHORESIDE MARSHALLING DEPOT

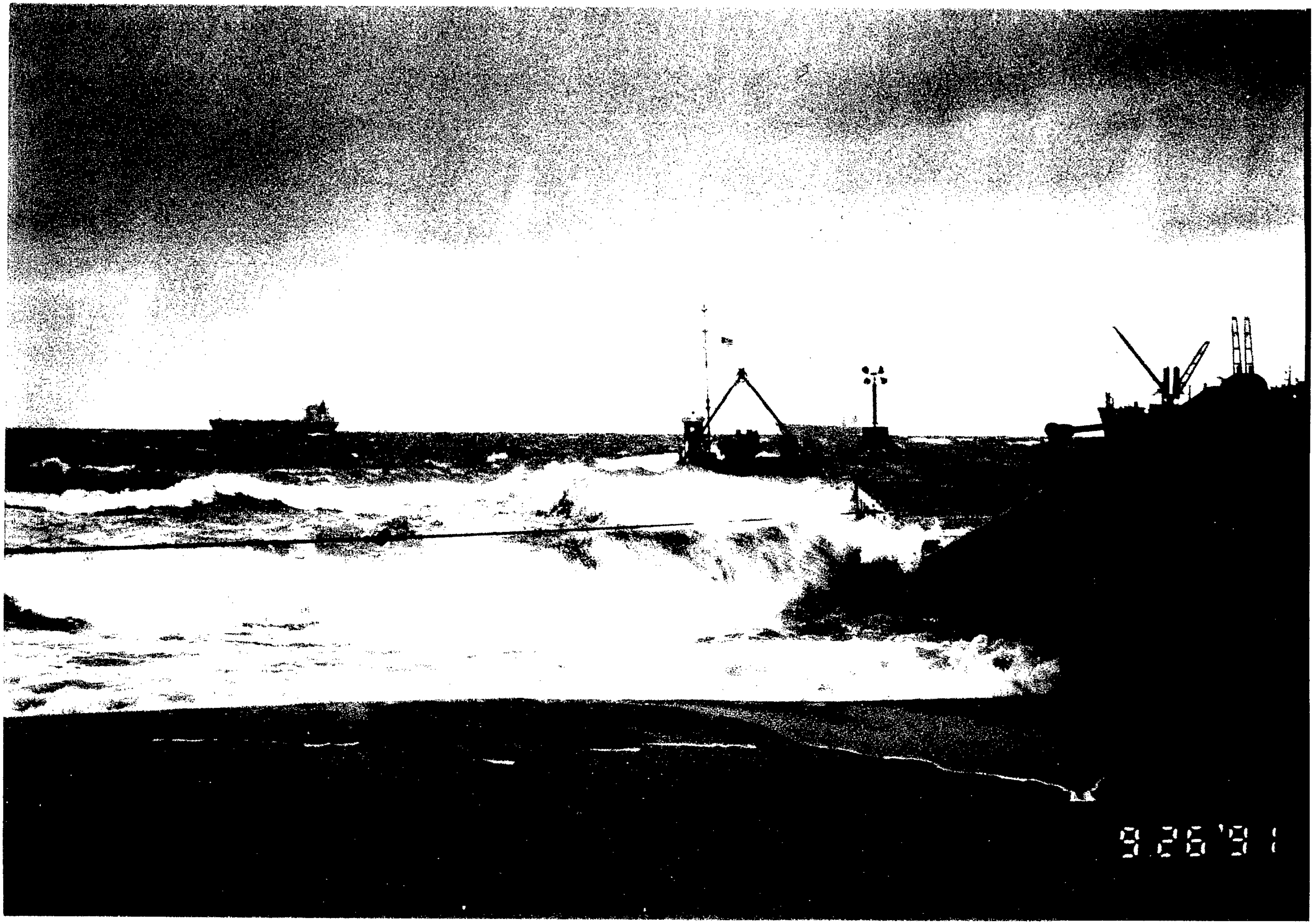
JLOTS IN HIGH SEAS
(VIEW 1)

JLOTS IN HIGH SEAS
(VIEW 2)

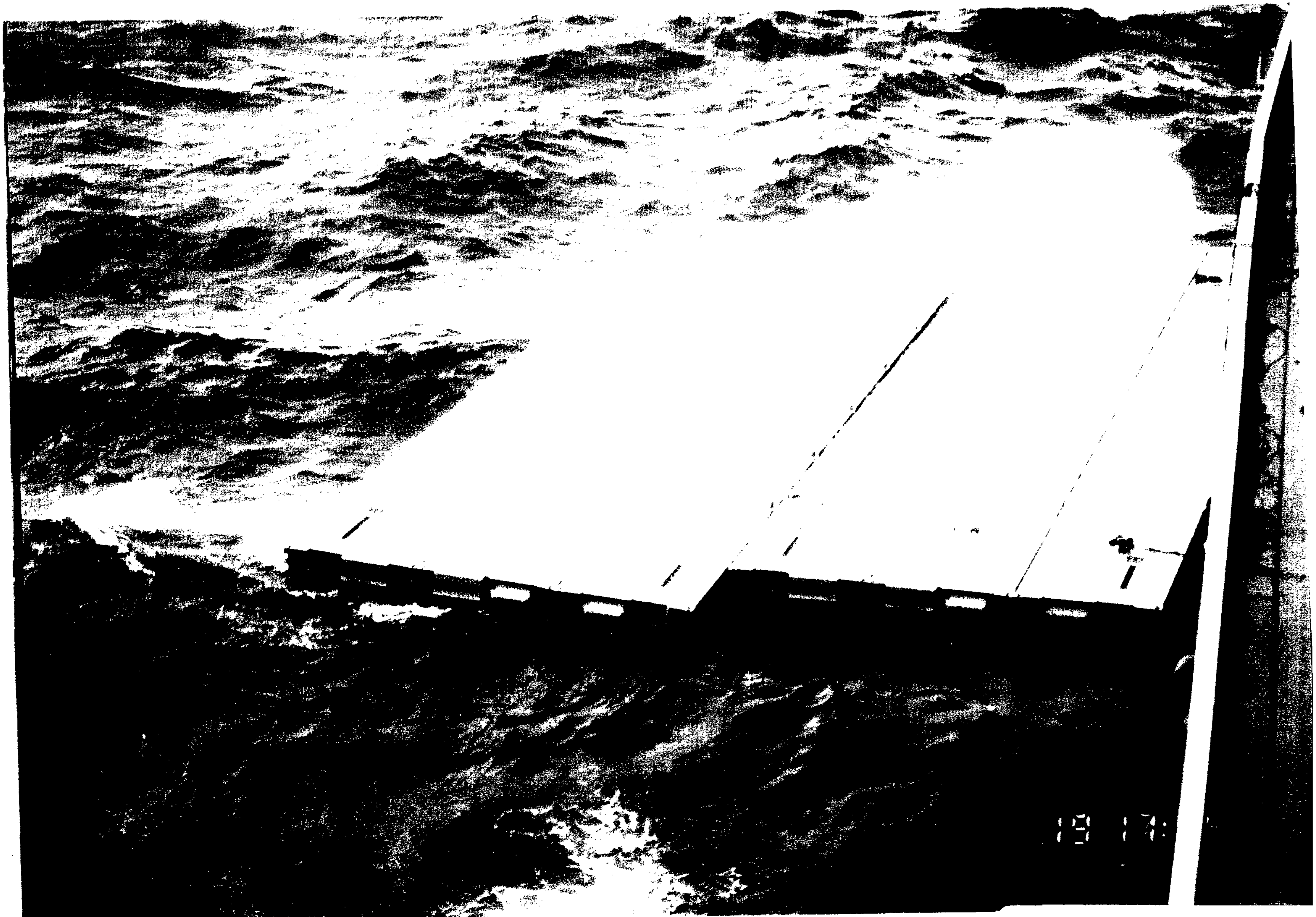


JLOTS IN HIGH SEAS
(VIEW 3)

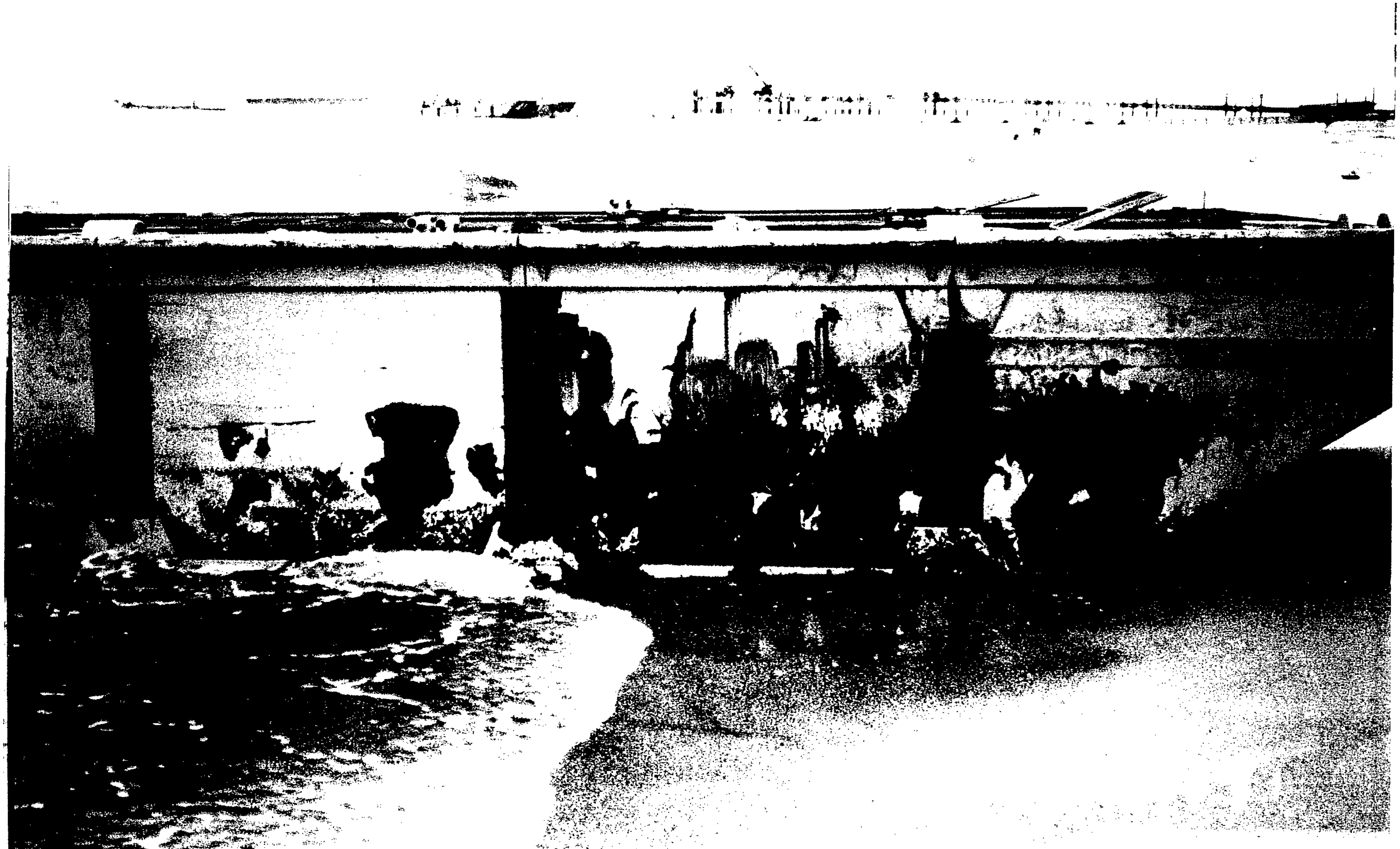
JLOTS IN HIGH SEAS
(VIEW 4)



JLOTS IN HIGH SEAS
(VIEW 5)



JLOTS IN HIGH SEAS
(VIEW 6)



JLOTS IN HIGH SEAS
(VIEW 7)

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