REPORT NO. DOT-TSC-SLS-73-1

SEAWAY INFORMATION SYSTEM
MANAGEMENT AND CONTROL REQUIREMENTS

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OCTOBER 1973
FINAL REPORT

Prepared for
DEPARTMENT OF TRANSPORTATION
ST. LAWRENCE SEAWAY DEVELOPMENT CORPORATION
Washington DC 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-TSC-SLS-73-1		

4. Title and Subtitle	5. Report Date
SEAWAY INFORMATION SYSTEM MANAGEMENT AND CONTROL REQUIREMENTS	October 1973
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
D.E. Brayton, R.D. Reymond, P.A. Bashaw*	DOT-TSC-SLS-73-1
9. Performing Organization Name and Address	10. Work Unit No.
Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142	R-3553/OS336
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation St. Lawrence Seaway Development Corporation Washington DC 20590	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

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16. Abstract

This report examines in detail the control and information system requirements of the St. Lawrence Seaway Development Corporation in terms of the needs of the vessel traffic controllers and the management users. Structured control models of Seaway operations are presented and used as a framework for the development of information utilization and vessel control concepts. Data files for the controller and management user models are given and analyzed in terms of inputs, format, display and control action. The requirements of the controller model provide the principal constraints to be met in the development of a Seaway Traffic Control and Management Information System.

17. Key Words	18. Distribution Statement
Marine Traffic Control, Management Information Systems, Vessel Control Model, Information System Requirements	APPROVED FOR U.S. GOVERNMENT ONLY. THIS DOCUMENT IS EXEMPT FROM PUBLIC AVAILABILITY. THIS PUBLICATION IS LIMITED TO U.S. GOVERNMENT DISTRIBUTION ONLY UNTIL THE INTEGRATED MARINE TRAFFIC AND INFORMATION SYSTEM IS IMPLEMENTED AND THE CANADIAN AUTHORITIES SPECIFICALLY IDENTIFY THEIR PROPOSED USE OF IT.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	80	

Form DOT F 1700.7 (8-69)

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1. INTRODUCTION

This report reflects the principal activity on PPA OS336, "Technical Support to the St. Lawrence Seaway Development Corporation." This PPA covers Transportation Systems Center (TSC) assistance to the St. Lawrence Seaway Development Corporation (SLSDC) in the areas of planning and computer sciences. The thrust of this activity is directed toward the implementation of the St. Lawrence Seaway Authority (SLSA) (Canada) - designed Integrated Marine Traffic Information and Control (IMTIC) System in the United States sectors of the Seaway. This effort comprises four tasks: a determination of SLSDC management information and traffic control requirements; an evaluation of the ability of the IMTIC System to fulfill these requirements; a comparison of SLSDC requirements versus IMTIC System capabilities; and, recommendations for a system specifically for SLSDC needs using the Canadian system as a base. The principal pace of this project is governed by the progress of the SLSA in the IMTIC System development.

This report presents the results of the primary tasks completed under this PPA. The purpose of these tasks was to examine in detail the information requirements of the SLSDC in terms of the needs of the management and control users. These results will provide a base against which the Canadian system can be compared.

This report does not consider specific U.S. information needs with respect to Seaway operations and traffic flows, e.g. vessel, cargo, commodity and trade movements. These information requirements are alluded to in the analyses of management and controller summary files and are properly the subject of future analyses.

The preparation of this report is a joint product of the TSC and the Operations Directorate of the SLSDC. It is the integrated result of a close working arrangement which has developed between the two agencies.

2. DISCUSSION OF THE PROBLEM

2.1 BACKGROUND

In March 1972, TSC conducted a systems analysis of current and projected operations on the St. Lawrence Seaway (Reference 1). The study was undertaken at the joint request of the Undersecretary and the Administrator of the St. Lawrence Seaway Development Corporation to determine the need, benefits and costs of a marine traffic control and information system. The results of the study provided the justification for the U.S. involvement in the IMTIC Program.

The study indicated that the St. Lawrence Seaway cannot meet current demand under conditions of sustained peak loading and that under such peak conditions, safety is degraded. Projections indicate that the demand will grow in the future. If such growth is to continue and the Seaway is not to become the bottleneck for waterborne commerce to mid-America, then the assured throughput capacity (measured in vessels and tonnage) must be increased with no decrease in safety margins. Of the options open for increasing throughput, it appears that better use of the present facilities through the incorporation of a centralized flow control facility would produce the most return for the least investment.*

An attempt to perform flow control was conducted by a joint U.S.-Canadian controller team at Cornwall, Ontario, during the shipping congestion crisis which occured in the fall of 1971. The system consisted of teletype links and terminals with a manually maintained Seaway status board. Although the result was encouraging, the attempt revealed that such a system could not sustain the data update rate necessary for effective flow control.

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*Flow control is defined as a system-wide monitoring and control of vessel movements in order to optimize usage of critical or bottleneck facilities. The objective is to increase throughout while minimizing average vessel waiting time.

Concurrently with the efforts at Cornwall, the St. Lawrence Seaway Authority developed and started operating two computer based systems for use in Seaway management. These systems are the locks and facilities usage system at St. Lamberts and the Computerized Information Lakes System (CILS) for Lake Ontario traffic control at St. Catharines. An obvious next step was to develop a computer based system for Seaway-wide traffic flow control. The Canadians proceeded with the specification of such a system in the spring of 1972 and by summer had initiated the procurement of the necessary software and hardware for the computer-based IMTIC System.

This development has indicated the need for an analysis of the data utilization and information requirements of the management and operations users in the SLSDC. This study is the result. Previous studies have identified what data are processed by the traffic controllers at Massena and how it is communicated (References 2,3). This study considers not only data processing and communication, but also provides an in-depth analysis of data structure and data update and access frequency. In addition, it considers the impact of the introduction of a computer into the current manual information and control system.

2.2 OVERVIEW

The basic processes of control can be likened to a driver controlling the speed of his car. Although there are many factors of the moving auto that must be known, the main or most sensitive parameter is its speed as displayed by the speedometer. The speed requirement of a particular section of highway is displayed as speed limit signs. The driver continually accelerates or decelerates his car in order to attempt to match his speed at the moment (status) to the speed limit (requirements). The control function is when the driver accelerates or decelerates his vehicle thereby changing the vehicle status. This concept is shown diagrammatically in Figure 1.

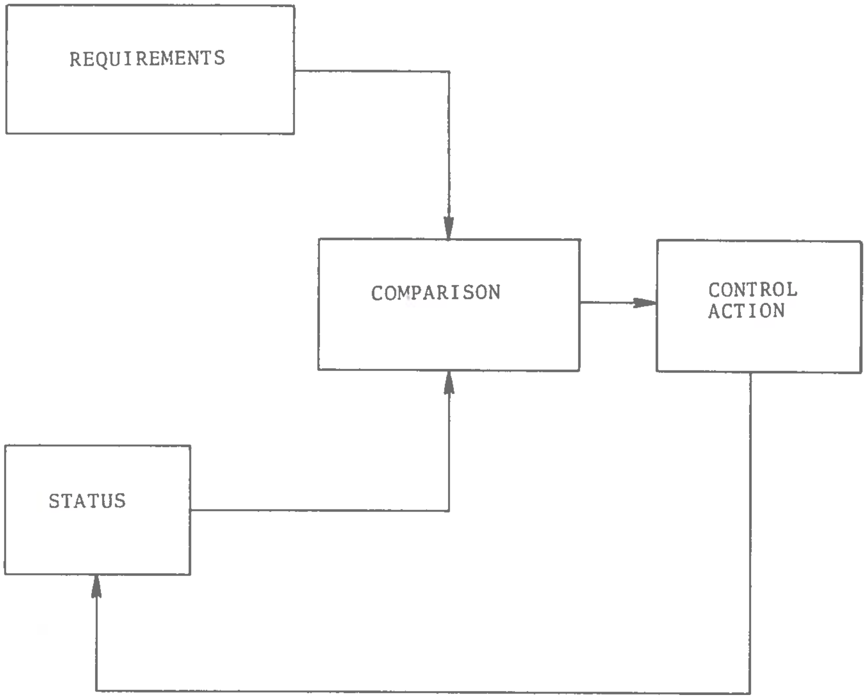


Figure 1. Basic Control Function

Many factors affect the auto's status speed such as wind velocity, road grade, etc., yet the driver generally does not sense these factors directly but relies mainly on their being shown as a modifying effect on his speedometer. This can be in the form of a specific numerical difference between his speed and his desired or required speed or as an effect upon the rate at which his control action causes his actual speed to approach his desired speed.

Seaway vessel traffic control is similar to the driver/vehicle control example. However, in vessel control the principal parameter is not speed, but rather vessel location in space and time. In the vehicle control example, the differential between speed limits (requirements) and the actual speed (current status) is the control to be ordered. In the Seaway, the control order is the differential between the actual vessel position and the desired vessel position at a given time. The space/time location desired of the vessel is translated by the master or pilot into a requirement for action. He may cause the vessel to speed up, slow down, or maintain a status quo. Thus the process of traffic control on the Seaway is not control of the vessel itself, but rather control of the desired vessel positions at various times.

It is the function of the vessel traffic controller to determine a desired vessel position. This desired position is a dynamic vessel space/time location, continually moving through the Seaway and subject to operational and environmental constraints. It is the function of the master to attempt to match his actual vessel position to the desired, dynamic vessel position as determined by the controller. Control is exercised, not on actual vessels, but, on a phantom vessel which represents a desired vessel position.

In normal situations, Seaway vessel control and automotive vehicle control is principally focused on the monitoring or control of a single parameter - the time/location parameter in the former case, and the speed parameter in the latter case. However, in times of stress, other parameters can become predominant. For example, when a car overheats, this fact is conveyed to the driver by a gauge or warning light. Engine temperature then becomes more important for control than speedometer-speed limit. Similarly, in Seaway vessel control, other parameters can become more predominant than the one of time/location. Such events could include hazards to navigation, vessel loss of steering or breakdown, the unavailability of pilots or visibility limitations. Although the Seaway controller must principally monitor vessel position, under any given stress situation other parameters may predominate.

2.3 BASIC ASSUMPTIONS

The IMTIC System specifications were established by the SLSA and cited in their Request for Proposals for the IMTIC procurement (Reference 4). These system specifications identified the Canadian data requirements and made a preliminary identification of data format and data processing requirements. On these specifications, the system was defined in terms of an average workload, and a worst case was defined as a percentage increase of the normal workload.

The approach taken by TSC in the determination of data requirements differs from that in the IMTIC request for proposals. After discussions with SLSDC personnel, it was agreed that what is necessary for effective operation and control is a system that has the capability of processing a normal operational and management workload, under normal conditions; but in times or in areas of stress, the system should be able to supply timely, in-depth operational information. For example, two vessels, one upbound and one downbound are expected to enter and meet in a patch of fog at a hazardous section of the Seaway. The controllers would require very frequent and detailed vessel position and intention information for this instance.

The approach to the determination of data requirements in this analysis is based upon a stressed case situation wherein the stressed case is defined as the maximum data update frequency required to present valid data to a control system user. A system capable of processing and supplying the data for the stressed case operational situation will have sufficient capacity to handle the needs of both operational and management users under normal conditions.

2.4 OBJECTIVES

This requirement analysis is based upon a determination of the answers to the following questions:

- What data of a centralized file will be accessed (queried)?
- At what frequency are undivided subsets of the centralized file accessed (queried)?
- At what rate must the centralized data be updated?
- What format is required in order to process the data?
- What is the nature of the processing performed?

- What load does an action resulting from the data processing imply to the system?

The answers to these questions provide the form and substance for the user requirements. These are answered in detail in the succeeding sections of this report.

3. MANAGEMENT AND CONTROL SYSTEM MODEL

3.1 GENERAL

As a first step in determining the data management requirements of the SLSDC, a generalized model of vessel control and management information functions was developed. A diagrammatic representation of this model is shown in Figure 2. This diagram expands upon the basic principles shown in Figure 1 through the inclusion of the general Seaway data management functions. These additional functions include the collection and the formatting of data. This generalized functional diagram was used as a base upon which the specific activities of the controller and management user were modeled.

A subsequent step in determining the data management requirements involved the modeling of current vessel control procedures using the generalized model described above. A similar model was also developed using the current management information system. Both of these models were validated through direct discussions with Seaway operating and management personnel. In the future, these models which establish the Seaway data management requirements will be compared with the capabilities of the IMTIC System. Through cross-product analysis and system development it is expected that the IMTIC System will be able to be structured in a manner to meet these requirements.

The underlying philosophy of these models is based on an extrapolation of the functions normally performed to control vessels through the Seaway. The major difference between the traditional functions and the functions portrayed by the models is that through the introduction of a computer, data become dynamic or animated, whereas in the past the data were static.

The conceptual basis of the models is that each user of the system, either management or control, performs the same basic functions. These functions include collecting data, formatting it so as to describe the Seaway status, comparing the existing

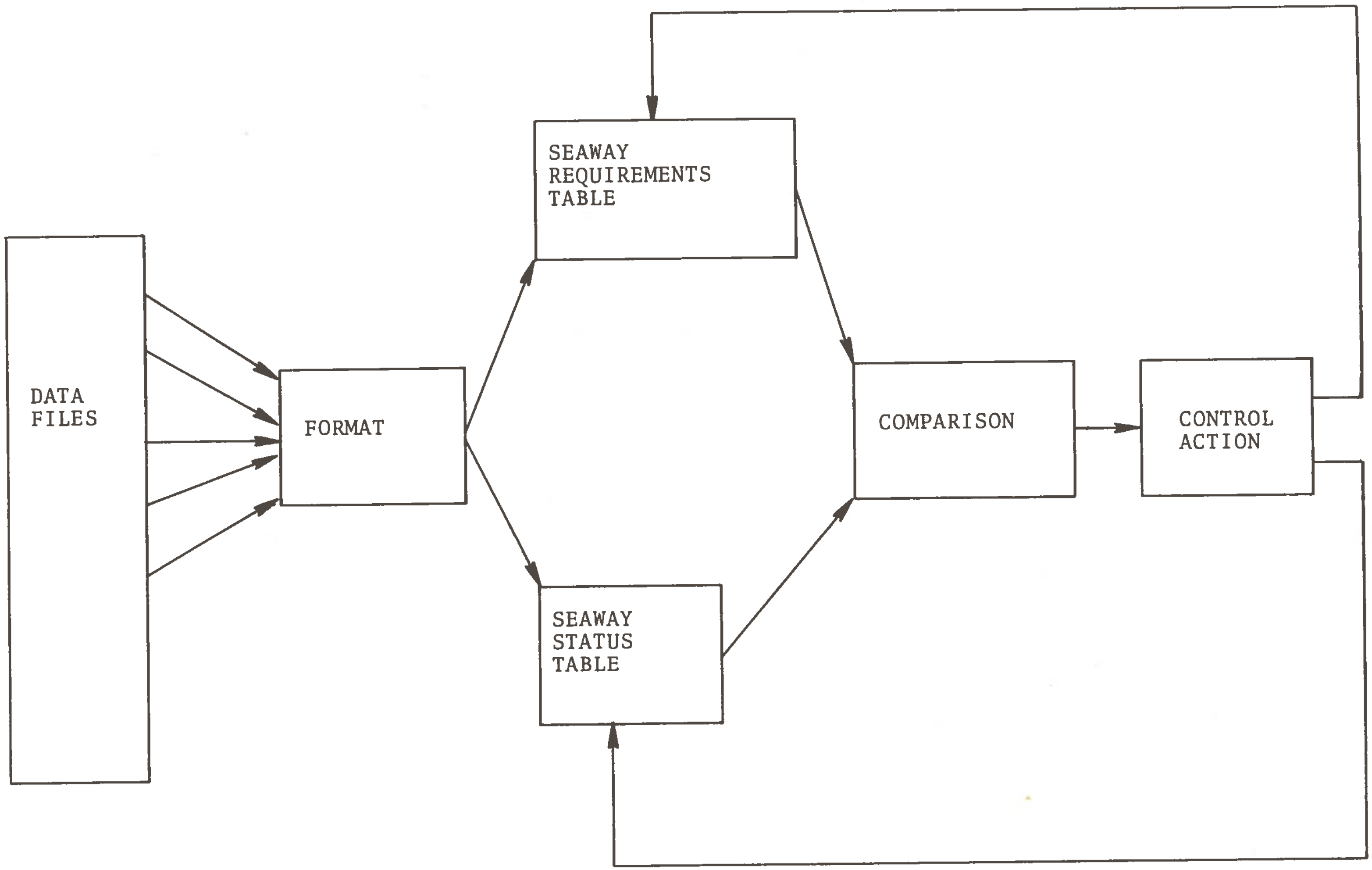


Figure 2. Generalized Seaway Model

status with a desired (required) status and, if warranted, executing a control action that will tend to bring the existing status in line with the desired status. The management and controller functions are similar and differ only in level of control. These differences are in the frequency of access of data and the description of a particular data item, either implied or expressed. The models force the actions of the controller and management user into a uniform format containing the following elements:

- A list of the data collected,
- A description of how these data are formatted,
- A breakdown of how the formatted data are processed to effect a comparison of status with desired status (requirements),
- What thresholds of correlation are maintained between status and desired status (requirements),
- How the total record is kept, and
- Data sampling rates.

The models were developed using block diagrams of the elements of the modeled system including a structuring of the input-output relations of the elements. The input-output parameters were further defined by descriptive equations of the relationships including a list of the variables used, their units and their descriptive names. Subsequent sections of this report will describe these qualitative and quantitative relationships in detail.

3.2 ASSUMPTIONS

The development of general and specific models was based upon the following assumptions with respect to current Seaway operations.

The traffic control function consists principally of the activities of the vessel traffic controller and the assistant vessel traffic controller. These functions are to:

- Develop and maintain a Seaway status table. At present the Seaway status table is an informal arrangement consisting of a large collection of paper messages distributed around the controller's and assistant controller's desk.

- Make comparisons of the status table with operational procedures.
- Exercise control to effect a specific degree of correlation of the actual with the desired tables, i.e., a comparison of the status table with the requirements table.
- Access the tables and disseminate data to preassigned locations at regular intervals.
- Access the tables and disseminate data to random locations on a request basis.
- Record status data and system function data.

The management user functions have been structured into a system which has been formalized to the extent that data lists are maintained, data are formatted, operational procedures established and records kept. Records are maintained and updated on a twenty-four hour time base (average case).

The traffic control team performs reformatting, calculation and control with an unformalized and loosely structured system using the data stored in management user system.

3.3 MODEL DEVELOPMENT

3.3.1 Introduction

The following describes the development of the preliminary models for the controller and management user requirements. They form the basis for an iterative process leading eventually to an extensive model of Seaway operations. The information presented gives both qualitative and quantitative descriptions of the data treated and develops approaches as to how it could be processed for use in the required control functions.

3.3.2 Overall Requirements

A review with SLSDC personnel has developed quantitative values of the parameters in the models and has served as a preliminary sensitivity analysis. The most important parameter of the controller's requirement is where each ship is, at each point in time. The second most important parameter is what data are required to process the ship through the Seaway system.

On the other hand, the management user requires data for developing an overall picture of Seaway operations in order to ensure that the total facilities necessary for effective vessel throughput are in working and effective order. In terms of the models developed, the interaction between them is one of management having developed an effective system for generating, maintaining, and setting requirements for an optimum vessel throughput system; controller using that system; and the data used in the controller system being the data base of the management user system.

The models contain parametric descriptions for a reasonably large number of the controller and management user actions, and although not considered complete, it is believed they do form a structure and base for developing a more complete description.

3.3.3 Computational Requirements

Although the concepts are straightforward, the implementation of these models in order to optimize ship throughput through the Seaway is not trivial, nor an easy task. For example, the vessel position requirement for the controller model is a greater task than merely presenting to the controller the navigational charts and observations of all ships on the Seaway once per minute. At least it involves the additional considerations of vessel characteristic, riverine characteristics, environment, and vessel interactions. Although these computational requirements in human terms are strict, when considered in light of the capability of modern computers, they become manageable. The process of specifying the requirements of the SLSDC for a controller system and a management system is itself an iterative process. The requirements are generated within a framework of knowledge of the general capabilities of modern computation power, both hardware and software.

The models describe the data in computer terminology and are presented as simple algebraic equations. For example, the calculation of vessel Expected Time of Arrival (ETA) is a linear extrapolation of the present position using a single time increment and present velocity. This calculation may be unrealistic in the final analysis when considered in light of the cross currents, cross winds, freeboard sail area, power on board, pilot and masters' operating procedures, etc., used by the controller today to develop ETA's. However, the capability of a computer to develop extrapolations on a one-minute time base may develop a picture closer to the real world. The ability of the computer to extrapolate information in such a brute force method forms the very basis of the models developed. The calculations of the stressed case stituations use simple computational methods, which in turn require greater computational power. More sophisticated extrapolations require less computational power, but more complexity.

3.3.4 Management User Model

The management user model processes data contained in the following files:

- Vessel Transit Summary,
- Alien Entry,
- Message Accounting,
- Vessel Detail and Classification,
- Incident and Delay, and
- Environment.

The management data in these files are formatted according to text. Comparisons between the data so formatted in the status file will be made item by item with the requirements stored according to text in the requirements file. When the status does not fall between preassigned limits, those items will be collected into an exception file and displayed as text. Details on these files are given in Section 4.

3.3.5 Controller User Model

The controller user model processes data contained in the following files:

- Time Location File (Positional File),
- Pilotage File,
- Environmental File,
- Seaway Navigational Structure File,
- Vessel Situation File (Ship Anchor and Docking File),
- Vessel Detail and Classification File, and
- Summary File.

The control data in these files are structured as a pictorial representation of the Seaway. This is analogous to a TV view of the Seaway from five miles up having a zoom capability to within 1000 feet. Superimposed on this picture are data blocks representative of data from the above files.

The requirements table is structured as a simulation of Seaway operations and appears as two pictures, actual and required. The two pictures are superimposed so that a comparison can be made between where a vessel is supposed to be and where it actually is, provided real time/vessel locational information can be introduced into the system. Otherwise, estimated positional information will be used. A detailed discussion of these files is given in Section 5.

These models represent idealized versions of systems presently in use. The detailed specifications contained in the subsequent sections are all small modifications of these idealizations necessary for computer implementation. For example, in the controller user model the Seaway Navigational Structure File (SNSF) is nothing more or less than a series of navigational charts digitized and assembled dynamically. Figures 3 through 6 show how the SNSF might appear on a CRT to the controller. A zoom feature can be included which would be analogous to changing from a regional chart to a harbor chart. Figures 4 through 6 show how this zoom feature could be used to examine traffic in the Snell-Eisenhower Locks section of the Seaway.

A moving positional requirement blip can be used to indicate where the vessel is required to be. This feature is similar to a dynamic update of the Position and Intended Movement (PIM) familiar to Navy operating personnel. Similar analogs hold throughout and similar comparisons can be made.

3.3.6 Computer Resource Allocation

The analysis has been directed toward exposing or separating the elements of the requirements into basic computer-system implementation subsets. The subsets are:

- The data being handled;
- How those data are structured both for presentation and for processing;
- How the structured data will be processed.

These elements have been broken down explicitly and allow for a clear separation of: 1) what fraction of the computational resources applied toward meeting the requirements is directed to performing a job of message switching, e.g., transmitting and receiving data, or machine terminal transmission; 2) what fraction is to be allocated to the man/machine interaction e.g., formatting for display in a format analogous to a seaway chart; and 3) what fraction is to be allocated to performing data extrapolation comparisons and thresholding, e.g., processing the data.

The data rates requirements are based upon the data rates necessary for the user to perform his job at the finest grid, i.e., under the stressed case condition. The data rates required for vessel position information are based upon the controller's keeping a running record on a harbor scale chart. This situation

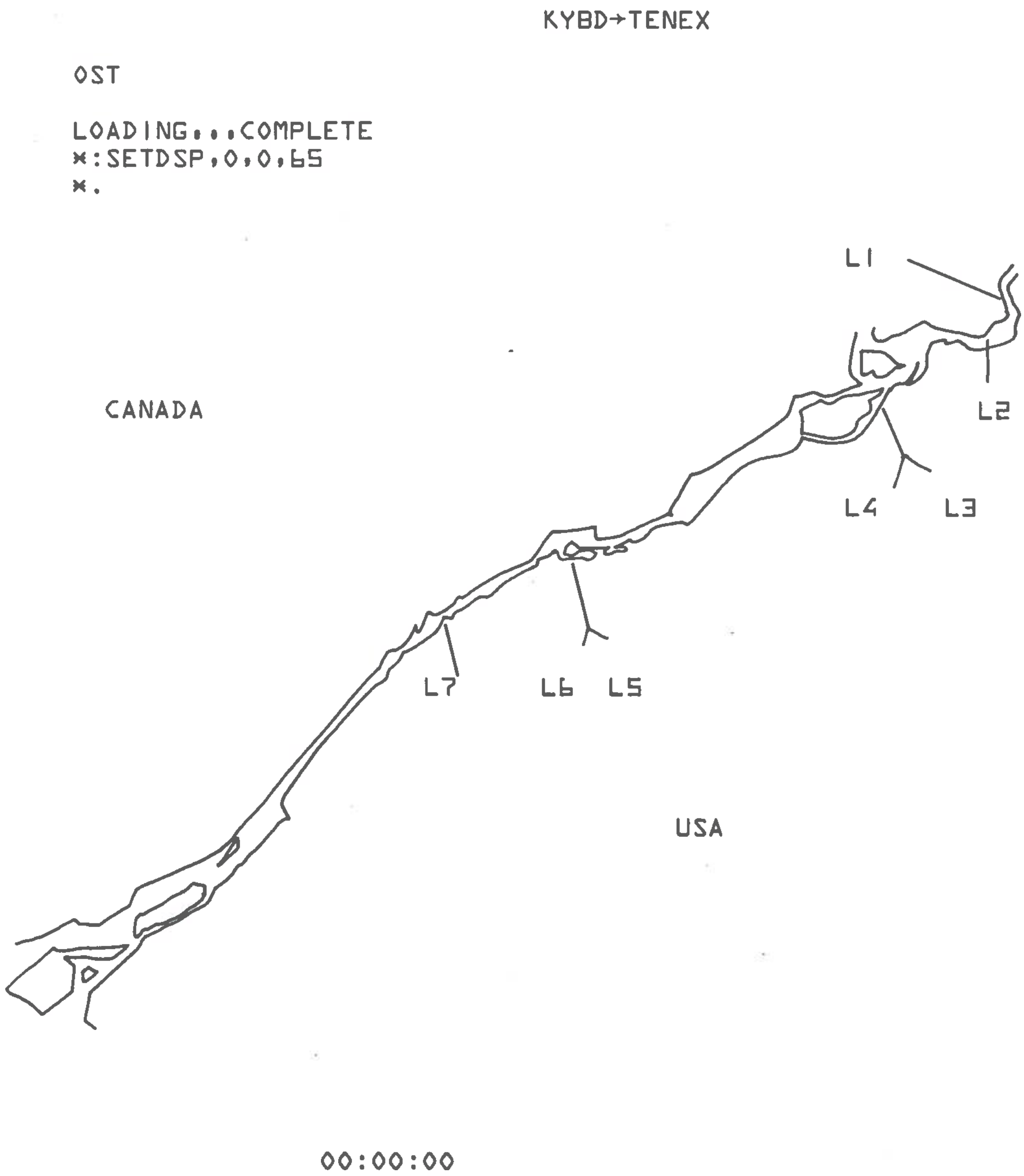


Figure 3. Seaway Navigation File - Seaway Display

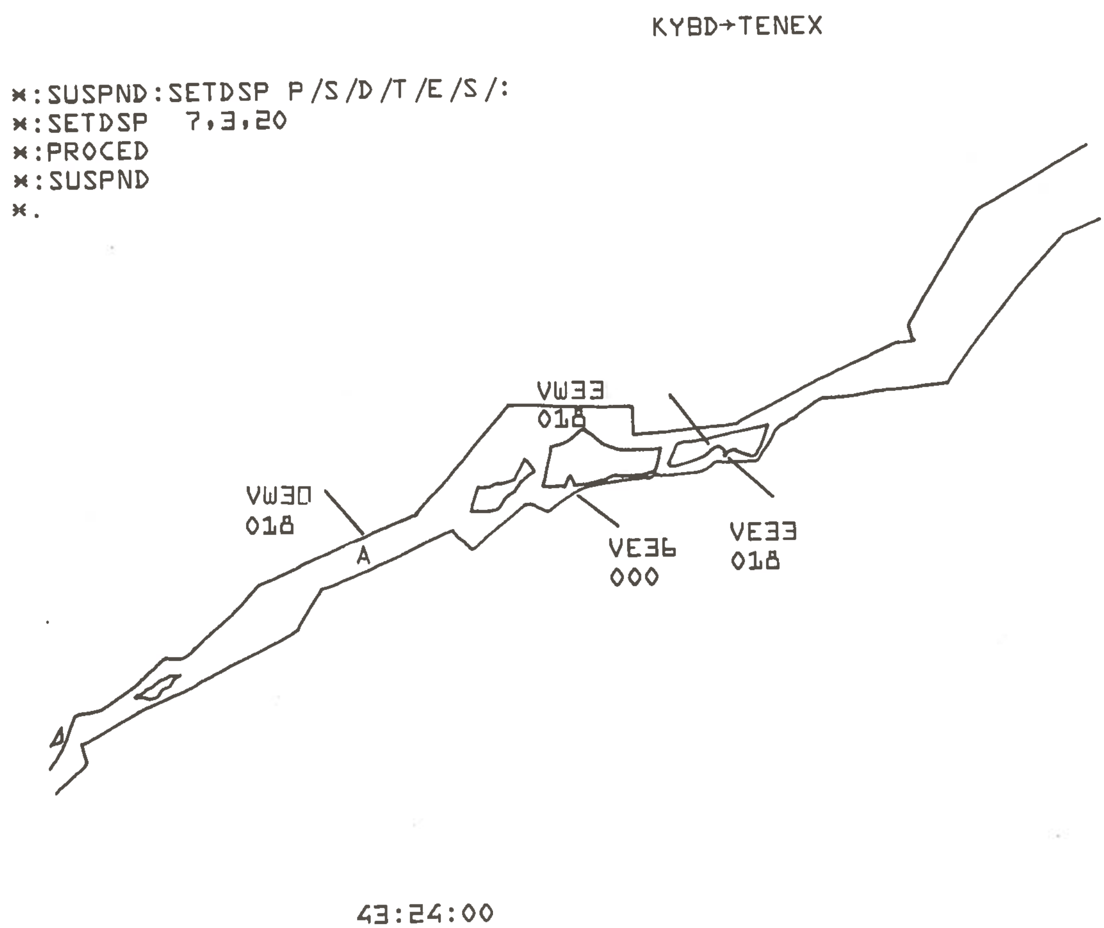


Figure 4. Seaway Navigation Structure File, Eisenhower-Snell Display

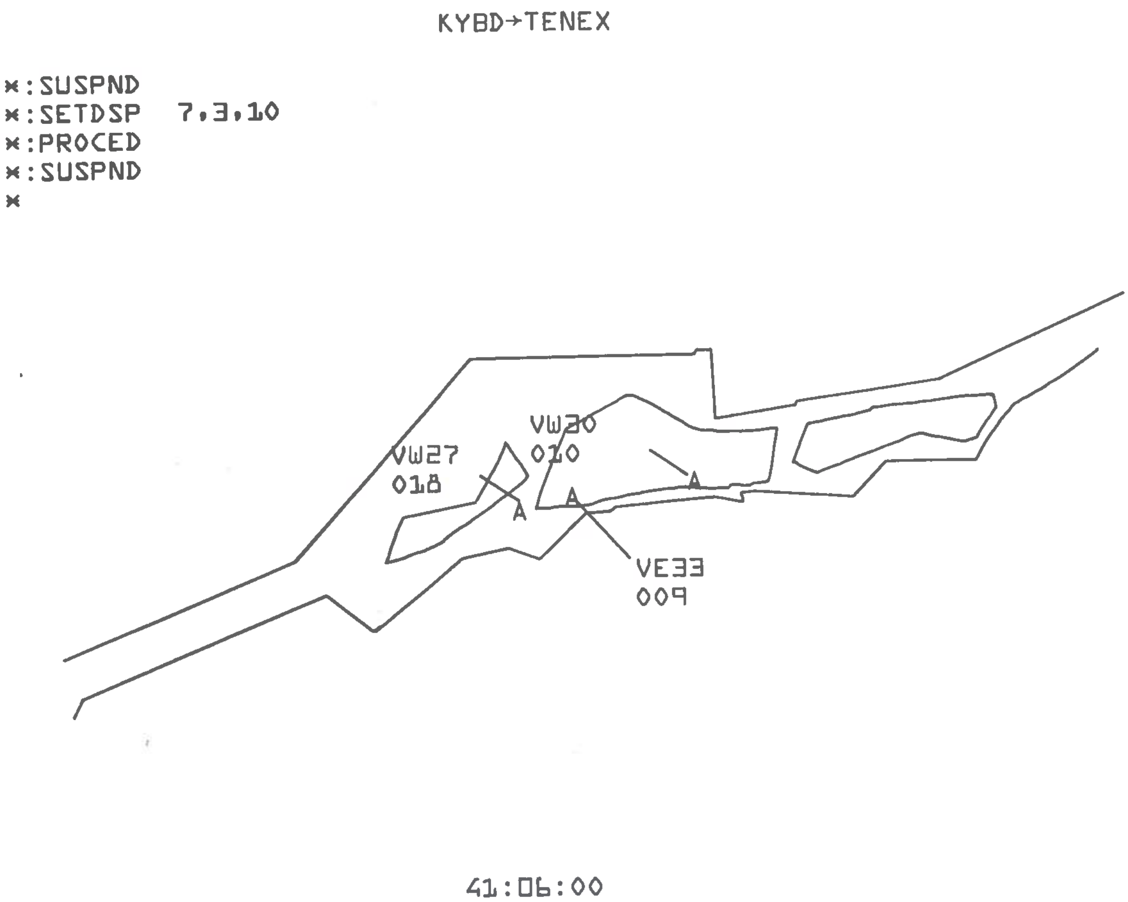


Figure 5. Seaway Navigational Structure File; Eisenhower-Snell Display with Zoom Feature

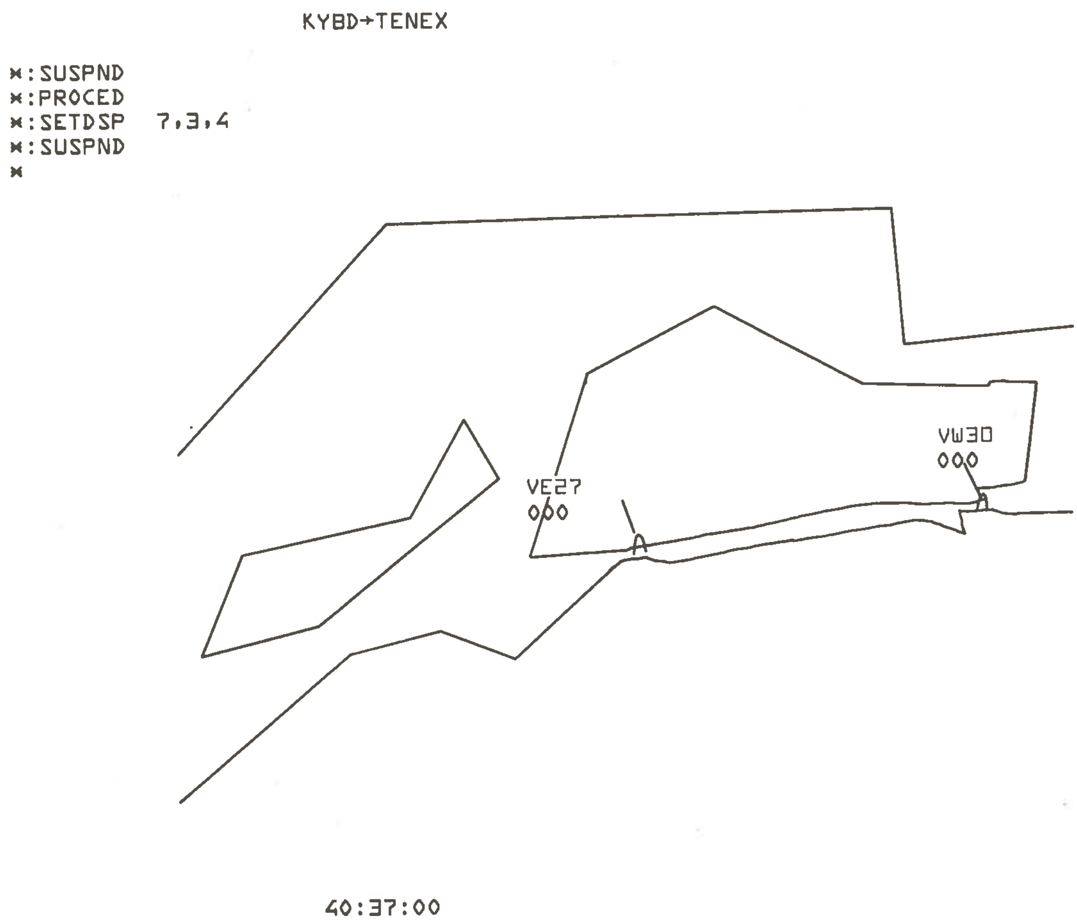


Figure 6. Seaway Navigational Structure File; Eisenhower-Snell Display with Zoom Feature

requires that the single controller file, "vessel situation," must be updated once per minute. This is in order to present the controller with enough data to control a vessel at the finest level of control, i.e., the highest data rates required for a single file.

This is not a worst case, but simply a single file at a single station worst case. A worst case situation would involve a number of stations working with their finest grid files. This element of this requirement model has been spelled out explicitly because the previous analysis of the IMTIC System has been based upon average loads on a large number of terminals (Reference 4). The average load had not been described here in that it represents a situation whereby any individual file would be sampled at a considerably slower rate.

It is possible that the average workload would be more taxing to the IMTIC resources than the workload where one file is being sampled at its maximum rate. Consider the example of a controller with a situation of two vessels about to meet in a bad section of the river. This instance would require the vessel position information file to be accessed at its finest grid and the controller to devote the major portion of his attention to that file. He would thereby spend less of his time accessing other files necessary to illuminate other seaway situations.

3.3.7 System Comparison

Although these models of the SLSDC requirements are structured in a manner amenable to description in terms of system design, they have not been generated for that purpose, and the temptation to design a system to them was resisted. These models were developed in this manner in order that the requirements could be more easily matched against the facilities being developed for the IMTIC System. With that view in mind, no lengthy, colorful picture of systems has been presented. That type of presentation is deferred until after it has been established what percentage of these requirements can be supplied by IMTIC.

These requirements, suggest some rather novel, and intriguing concepts for control, namely the dynamically developed requirement in terms of moving blips etc., and the concept of a phantom vessel whereby the controller matches his requirements model with the controlled ships performance. These concepts are not presented as fixed requirements, but as suggestions of a method of implementing some of the desires specified by SLSDC personnel. In fact, the basic desire of this presentation is to form a structure whereby the desires of SLSDC personnel can be presented in a format amenable to computer implementation.

4. MANAGEMENT USER REQUIREMENTS

4.1 GENERAL

The management data system requires six files to supply the basic information necessary for the management users to perform their functions. These data files have been identified as:

- Vessel Transit Summary,
- Alien Entry,
- Message Accounting,
- Vessel Detail and Classification,
- Incident and Delay, and
- Environment.

How those data in the files are to be formatted, what processing is to be done and what action and records are kept are supporting functions of the system and are discussed in the subsequent sections.

The management user system is shown as a diagrammatic model in Figure 7. This diagram builds upon the general model shown in Figure 2. The principal additions are centered about the data inputs, the record keeping and the dynamic update functions.

The data inputs are derived from the data files mentioned above which are, in turn, subsets of the controller files as discussed in Section 3. In fact, the controller files are the principal data source for both the management user and controller user models.

The record keeping function is a significant role for management and critical to the preparation of reports and their timely submission. The dynamic update feature of the model is dependent upon the report submission cycle and upon the unscheduled demands of external and internal management. Most reports are a daily, weekly, or monthly occurrence and hence the average case should be no more frequent than every twenty-four hours. The stressed case,

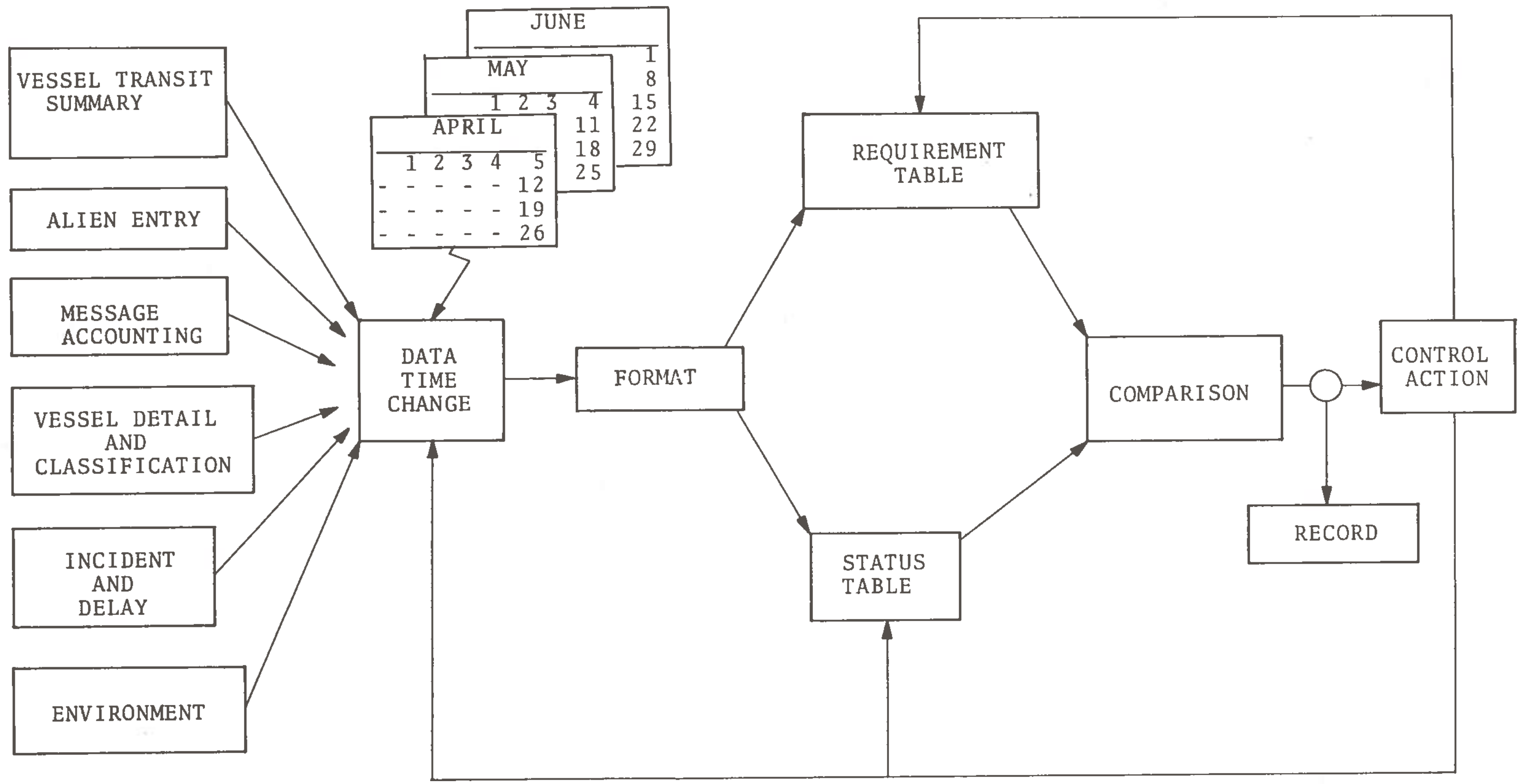


Figure 7. Seaway Management User System

however, requires an hourly update. Under such situations the management function is usurped by the control function and the controller model predominates. The time dependency of the management model is shown as a calendar in the diagram. In the controller model the stressed case requires a data update rate of once per minute and hence is the driving requirement for access frequency in the overall Seaway model.

The management data files and their role in the management user model are discussed in the subsequent sections. Each data file is also presented in tabular form which details the data, its format, the status requirements, comparison and control activity, and the supporting records and reports.

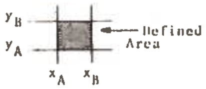
4.2 VESSEL TRANSIT SUMMARY FILE (Table 1)

The Vessel Transit Summary file of the management user model is generated in its entirety from the information supplied to it from the vessel traffic controller files (Vessel Time-Location, Vessel Detail and Classification, Environment, Pilotage and Seaway Navigational Structure Files). It summarizes for the non-controller the activities of the Seaway (vessel transit and delays), but more importantly, provides a measure of Seaway performance.

The position file of the controller model contains all the data needed for location analysis. A vessel identified by its pre-clearance number can be located or its performance checked by a comparison of ETA with Actual Time of Arrival (ATA) for fixed calling-in points (CIP) or other check points, existing, or to be established. For example, an ATA for CIP 8 can be compared with the ETA; the difference of times being a partial measurement of the vessel's performance.

The relative loading of the Seaway can be generated by the position file from the controller model. Since any area can be defined by two sets of coordinates (x_1,y_1) (x_2,y_2) and a vessel position by a set of coordinates, (x,y), the number of vessels within a limited number of areas throughout the Seaway can be tabulated.

TABLE 1. VESSEL TRANSIT SUMMARY FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	Pilot Record
Name: Vessel Location Units: (x,y) coordinates How Generated: VTC Model – Time location file – Vessel situation file Generation frequency: 2/hr	1) Vessel Name - Location [Preclearance # - ETA (minutes) or ATA at a defined CIP] (Vessel Transit) 2) No. of vessels - within a defined area [Integer - location name] (Vessel situation)	1) Name: L_s (PC#,t) Actual location - ATA at position (x,y) generated by time location file (vessel call in-radio) 2) Name: $N_s(x_A,y_A,x_B,y_B,t,z)$ Number of vessels within a particular area (limited # of areas specified) How Generated:  count all vessel (type=z) with coordinates $x_B > x > x_a,\ y_B > y > y_A$ information directly of use to VTC-vessel situation although presently management uses more 3) Pattern developed	1) Name: L_R(PC#,t) Estimate or proposed position ETA at position (x,y) Generated from VTC time location file 2) Name: $N_R(x_A,y_A,x_B,y_B,t,z)$ Safe vessel density determined by management from past experience. 3) Best relative distribution in areas throughout seaway	1) Vessel Performance - time behind proposed pattern $\sum_{t_1}^{t_2} L_S(PC\#,t) - \sum_{t_1}^{t_2} L_R(PC\#,t)$ a constant prescribed by management as acceptable → $N_S > N_R$ → compare actual pattern with desired to determine deficiencies	→ corrective actions (pilots, masters, agents or ship companies) → show controller areas of deficiency - good continuous training → Management Involved – Director of Operations & Deputy – Shift superintendent – General use	Daily activity report to Administrator – Daily Vessel Traffic Report – Vessel Situation Report – Teletype Report (lockage) – Transit Records
Name: Delays to Navigation type of delay along with estimate and actual duration How Generated – VTC environment file – Pilotage & Seaway Navigational Structures file Freq. of Generation: 2/hr	1) Type - cause-time in minutes	Name ΔT_{SD}(cause) running time of a delay delay time is a function of cause How Generated: $\Delta T_{SD} = \delta t_{actual} - \delta t_o$ δt actual - is the actual time δt_o t_o-time delay occurred or first noticed	Name: ΔT_{RD} - estimated delay duration $\Delta T_{RD} = \delta t_r - \delta t_o$ δt_r = time delay relieved δt_o = Beginning time How Generated - ΔT_{RD} is an management assessment of time required to relieve situation	ΔT_{RD} established $\Delta t_{SD} > \Delta t_{RD}$ if ΔT_{RD} > constant	→ notify controller VTC file → contact people involved recalculate ΔT_{RD} time may be used by marine services & maintenance to perform work on locks and channels not possible during shipping Management involved – Director & deputy – Shift supervisor – Maintenance & marine services	– Daily activity report – Delays to navigation
Name: Navigation Characteristics Units: Items of navigation changes or determined by management – speed limit – river flows – river elevations – alterations - old NAV aids – new NAV aids – new items-locks (facilities failure) – changes in channel determined by sweeping How Generated: Determined by support groups - maintenance, engineering marine services	1) Location - change may be in form of a map grid	Location and Change	Represents the Seaway Navigational Structures file-VTC model. An up to date layout of all factors on the river	Status table ≠ Requirements table Status table = Requirements table →	change requirement table = status table VTC Navigational Structures file	Notice to mariners
Name: Simulation Information from vessel transit summary file; 1/month	Simulated summary file	Set of conditions under simulation	Existing condition	Error = Seaway performance under actual conditions - seaway performance under simulated conditions	negative value improve performance - positive values hinder	involved management – Director & Deputy – Shift Super. – Engineering
Name: Vessel Accumulation Units: Integer #'s of vessels How Generated: Time location file Freq. of Generation: 2/hr	1) Number of upbound vessels of type "z"/day and accumulated for year 2) Number of downbound vessels of type"z"/day and accumulated for year	Present year $N^D_{Su}(z)$ - upbound day total $N^A_{Su}(z)$ - upbound accumulated $N^D_{SD}(z)$ - downbound day total $N^A_{SD}(z)$ - downbound accumulated	Previous – $N^D_{Ru}(z)$ – $N^A_{Ru}(z)$ – $N^D_{RD}(z)$ – $N^A_{RD}(z)$	Present year values Previous year values	→ Print → Print	– Daily activity Report – Comparative vessel transit report

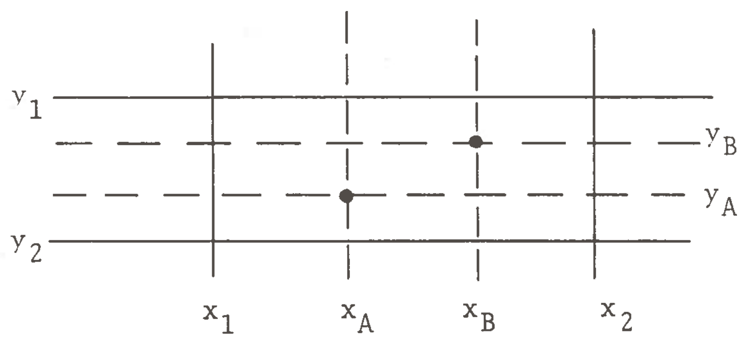


Figure 8. Vessel Density

In the example above, 2 vessels, A and B, with

$$x_1 \leq x \leq x_2$$

and

$$y_1 \leq y \leq y_2.$$

The count of vessels within any area may also be divided into subsets. For example, vessels can be divided by categories or classifications, such as the number of lakers between Tibbets Point and Whaleback Shoal, or the number of category vessels in the system.

Related to the relative loading of the Seaway are the traffic patterns generated, vessel progress, and the delays encountered. Weather, structure failure and incident all play a major role in vessel delays. To the manager, the prediction, prevention or dissolution of delays are of vital importance. Mechanical delays must be repaired quickly to minimize down time. The scheduling and coordination of work during extended shipping delays is a management problem. During localized delays, i.e., lock failure or localized fog, the entire traffic picture changes and joint management/controller planning must follow.

Each of the above allow the comparison of the actual situation (status table) to an extrapolated, average, or required situation (requirement table) to permit performance measurements. The control procedure and the performance which results from this action is an index of the effectiveness of the management decisions.

In the controller mode/index model the Seaway Navigational Structure File is used as an up-to-date facility status of the seaway. This file inputs to the Vessel Transit Summary File of the management model. Many changes to the Seaway Navigational Structure File are made by management. Engineering contracts for new navigational aids, marine services to sweep to the river bottom, and the establishment of new speed limits are examples of additions to the structures file made by management. This is a control action from the management model.

Also included in this file is vessel tabulation information where the daily accumulated transits for the present year are compared with previous years. Although formatted for just Ocean and Laker, this could conceivably be expanded to include other classifications as well, e.g., nationality, hull, cargo type, etc. This information is gleaned from transit reports from the controller model and its supporting vessel detail and classification file.

4.3 ALIEN ENTRY FILE (Table 2)

This file is designed to record alien entry into the United States from vessels transiting the Seaway. The persons may be pilots, crew members or passengers authorized to leave the vessel at a pilot exchange point or along the river. A weekly report to the U.S. Customs would be automatically compiled.

4.4 MESSAGE ACCOUNTING FILE (Table 3)

The Message Accounting File serves two purposes. First, it provides a confirmation of receipt of messages and a retransmission if confirmation has not been received. Second, it allows

TABLE 2. ALIEN ENTRY FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	RECORD
<u>Alien Entry file</u> – Pilots & crew members debarking U.S. territory <u>How Generated</u>: – Direct entry – U.S. custpms – Pilotage file VTC Model <u>Frequency of Generation</u> 2/hr	II Name - Date - Details	Actual debarking Name-Date-Details	Previous authorization – Pilotage List – Special List Name-Date of authorization	if actual $\neq$ authorized → status table →	determine reason may require getting authorization or instituting search (record details) → Print	→ weekly report to U.S. Customs

TABLE 3. MESSAGE ACCOUNTING FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	RECORD
Message Accounting – Message sent generated internally to computer 6/day	– Message indication function of – time – point of origin – point or points of destination – subject – duration	All messages to be accounted for, Parameters Recorded Origin, destination subject and duration	Management establishes message controls	A comparison is made between messages sent and allowed messages	Enforcement of message procedures Involved managers – Safety Officer – Shift Superintendent	– message number check sheet – message unit summary file is kept

determination of system loading by accumulating the messages by location and subject.

4.5 VESSEL DETAIL AND CLASSIFICATION FILE (Table 4)

The Vessel Detail and Classification File is basically an information file containing vessel status and accounting information. This file is similar to the Vessel Detail and Classifications File in the controller model, but contains information not included in the controller model. The major concern in the vessel detail file is that the information remains current.

The vessel status information is first introduced at the start of the vessels transit and checked periodically throughout the transit. Vessel status information includes draft, cargo, destination, dimensions, registry, port of origin. It also includes the vessel's capability for all weather operations. If at anytime during a transit the information changes, the file must be updated. The vessel status information also includes the vessel inspection report but these data are not readily accessible to SLSDC management.

The vessel accounting information is information not contained in its structure as part of the controller model. A vessel's preclearance into, progress through and exit from the Seaway is contained in the accounting file. The file is a partial log of accounting information pertinent to the financial processing of a vessel through the system. The information is gathered from the transit declaration form and other accounting documents as well as lockage and transit records. It is not the function of the file to contain all the information needed to perform the accounting duties of SLSA.

4.6 INCIDENT AND DELAY FILE (Table 5)

Vessel incidents and delays represent a divergence from normal operations. The Incident and Delay File contains all the details required for follow-up action and to assist in assessing responsibility.

After an incident occurs it must be investigated and reported and the traffic pattern adjusted. Damage must be inspected and evaluated. The circumstances of the incident must be collected, incident classified for statistical purposes, and action taken to restore the situation to normal. The course and assessment of responsibility must be established, and a financial settlement reached. Department of Transportation reports must be filed. To accomplish the above items, a complete detail file on each incident must be accumulated, including interviews of pilots and masters, voice tapes, and field inspections.

Details to navigation include vessel incidents which cause a stoppage or slow up in traffic. Other causes of delay are inclement weather, poor visibility, low water, vessel or lock mechanical failures, and pilotage, The duration of the delay is critical. To effectively minimize delay time, the responsible person must be immediately notified, and corrective action undertaken and monitored. Also important is the identification and evaluation of any persistent or reoccurring delay. An estimate of down time must be determined in order to facilitate the evaluation of progress toward the elimination of the cause of delay and to inform users of the Seaway system. All delay details must be recorded and a tabulation made of actual delay duration by cause. The basic purpose of the Incident and Delay File is to supply a historical record and to provide a bookkeeping function to pinpoint and better understand and correct these problem areas.

4.7 ENVIRONMENT FILE (Table 6)

The Environment File is an attempt to cope effectively with the uncertainties of both day-to-day and seasonal weather. The environment of the St. Lawrence River region is less than ideal and because of its extremes, its effect on shipping must be carefully observed and determined. The effect of the daily weather on vessel performance (e.g., fog, visibility, wind and vessel stability), of the river water levels and wind on navigation, and of the winter climate on season extension are all of vital interest to management.

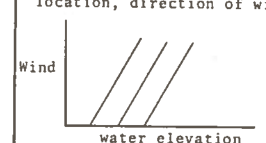
TABLE 4. VESSEL DETAIL AND CLASSIFICATION FILE

DATA	TEXT FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	RECORD
Vessel Detail and Classification Name: Vessel Detail Units: Weather equipped – General information Draft Cargo Destination Dimensions Registry Port of origin – Vessel inspection	Form Vessel name - weather limitation Form P_C # - name list of items Form PC # - Inspection Data List	→ W(PC#) weather Limitations → List of data - L_S → Q_S(PC#) - actual status vessel quality	→ List of PC# - vessel Name up to date Previously recorded List L_R	if for each active PC# This a corresponding W(PC#) If not $L_S \neq L_R$ L_R $Q_S \neq Q_R$	→ Store inquiry change $L_R = L_S$ → Print on request → Bar vessel till correction or waiver	Transit records Involved managers – Shift superintendent – Director & Deputy – Engineer – Other (general use)
Name Vessel Accounting -General Information (see Vessel Detail) -Vessel Progress thru canal -Vessel Preclearance	PC# - Last record location - Destination Preclearance #-vessel name (Preclearance into)	PC# - last recorded location Generated - Transit record-VTC PC# in question	PC# - Destination PC# - seven digit (2)-vessel type	%complete = $\frac{\text{last location}}{\text{Destination}}$ X 100 if last location = Destination if $0500 < z < 4899$ $4900 \leq z \leq 4999$ $5000 \leq z \leq 6999$ $7000 \leq z \leq 7999$ $8000 \leq z \leq 8999$ $9000 \leq z \leq 9999$	→ Daily progress report → completion message → Laker → Ocean vessel operating in lakes → Ocean → Not assigned → Construction → Government	Pilot record

TABLE 5. INCIDENT AND DELAY FILE

DATA	TEXT FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	RECORD
Incident and Delay file Name Vessel incidents Units -vessel name & PC# -vessel details -description of incident -Damage to vessel -Damage SLSDC Property -Damage other -Action taken -Delays caused -Weather How Generated (3/day) -VTC -Inspectors -Shift superintendents	Titles - answers ↕ list of questions	↕ List of answers → Example: Estimate of Damage SLSDC property -Delay status Yes-Duration No	↕ List of answers <$1000 >$1000 Delay?	all questions are answered → Estimate <$1000 Estimate >$1000 Delay = yes - duration	Print & Distribute [counsel, etc.] requires telegram of intent before vessel may proceed requires Bond before vessel may proceed Add to delay file	-Report of incident involving vessel in transit -Description of Damage -DOT Reports -Shipping Incidents in channels Mgr included -Director & Deputy -Shift superintendent -Counsel -Comptroller -maint & marine services
Name- Delays to Navigation -cause -weather -incident -facility failure -pilotage How Generated mgr model-environment -vessel incident -vessel transit summary VTC MODEL	Type cause - Descriptions Estimate of Duration (mins) ↕ Details	cause & location Description of Action Intities envolved Running time Answers ↔	predicted duration (past history) Question on Delay	Compare present incident with past incidents of a similar nature if question have appropriate answers →	Adjust Management Requirements store for retrieval	Downtime Report Management user- -Shift superintendent -maintenance -marine services

TABLE 6. ENVIRONMENT FILE

DATA	TEXT FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL	RECORD
Weather Name: Weather Humidity Temperature Precipitation Visibility Wind Units: (%, Degrees, Inches, feet & mph) How Generated: from VTC Environment file frequency of Generation: 3/day frequency of Access: 1/day	Present & Forcast Wind Precipitation Temperature Visibility humidity	$W_s(L,t)$ - Dynamic Conditions	$W_r(L,t)$ - Set of all acceptable conditions for Navigation	if $W_s(L,t) > W_R(L,t)$ →	Restrictions can be made on vessel transit Summary file - determine vessels involved	-Weather Report (FAA) -Management user -Shift superintendent
Water Level Units: -ft above sealevel -miles per hour & direction How Generated: from -VTC Environment file -weekly Operations Advisory meeting -frequency 3/day	<u>Type</u> Location-Elevation Wind/Direction <u>Units</u> - Location - ft Above Sea level - Degree Water level = f(wind, river flows)	$E_s(L,t)$ - contains Elevation and Wind information	$E_D(L,t)$ - Wind & Water level to assure at least low water datum. Function of location, direction of wind 	<u>Example</u> At Eisenhower wind from east 20 mph is critical if $E_s(L,t) < E_R(L,t)$ →	 Restrictions made on vessel transit <u>ex</u> 1)change allowable draft 2)stop all shipping	-Water Use Computation report -Reports - Operations Advisory Group & IJC Management -user -Director & Deputy -Engineering
Name: Climate Unit: Water Temperature and Ice Conditions & -amount of sunlight -Temperature-°F -% Icecover & (feet and inches) How generated: -VTC Environment file -individual researchers -engineering & Office of Development frequency of generation 3/day frequency of access-1/day	<u>Type</u> Water temp - In the Fall Ice conditions - Fall and Spring Sunlight - Winter Months <u>Units</u> Temp - °F Ice - % & feet & inches - radiant heat (Calorie/area)	Present conditions T^W_s (L,t) $D_s(L,t)$ $R_s(L,t)$	Previous Years T^W_R (L,t) D_R (L,t) R_R (L,t)	T^W_S T^W_R → D_S → D_R → R_S → R_R → $T^W_S = 32°$ →	 print print print print print Print freeze up warning	-Daily activity report -Water temp. comparison Management & use -Engineering -Office of Development

In an effort to maximize traffic flow, it is necessary to move all vessels efficiently and safely. If wind conditions have an adverse effect on a particular vessel's stability, then this vessel must be restricted in its movements or it will affect the movements of all vessels in its vicinity. To set norms to provide for this type of selective shipping, the manager needs to have;

1) Vessel characteristics and limitations due to weather, and

2) Complete and accurate weather information (daily and forecast). Information of this type is supplied from the various Seaway centers, Canadian and U.S. aviation and weather agencies, and U.S. and Canadian Coast Guard offices.

A second environmental factor influencing navigation are the water levels along the Seaway. The channel has been designed to a 27-foot draft, although in practice the maximum allowable vessel draft is 26 feet. Most natural river sections present no problems, but in the man-made sections, the level fluctuates with wind and runoff. Uniform water level and flow have to be maintained to ensure uninterrupted hydroelectric power. As a result, Seaway goals at times conflict with those of power or private entities. To accommodate the requirements of these various groups, environmental and hydrological information must include: water levels along the St. Lawrence River and Great Lakes water supplied into the Lakes, river flows and water usage.

The season extension program has placed emphasis on information not presently employed by a traffic controller, but necessary to management and engineering. This information includes water temperature, light radiation, and ice conditions. While methods of ice control are being investigated and developed, procedures for vessel transit in these conditions have yet to be established. The Environment File is an attempt to cope effectively with the uncertainties of both day to day and seasonal weather.

5. CONTROLLER USER REQUIREMENTS

5.1 GENERAL

The controller model consists of the following files:

- Time - Location (Position),
- Pilotage,
- Environmental,
- Seaway Navigational Structure,
- Vessel Situation (Ship Anchor and Docking),
- Vessel Detail and Classification, and
- Summary.

These files and their relationship to the controller model are discussed and summarized in tabular form in subsequent paragraphs of this section.

The controller model is developed from the generalized model shown in Figure 2. It incorporates the data inputs from the above files, adds a data time sequencer and dynamic update capability and expands upon the control function. A diagrammatic representation of this model is shown in Figure 9.

The controller model is similar to the management model discussed previously. The principal difference is in the dynamic update rate. In the management model, the average case is on a twenty-four-hour basis; however, in the controller model, both the average and stressed case situations are updated on a minute-by-minute basis. The most severe stressed case is in the Time-Location file which requires a frequency of update of five times per minute. Hence the dynamic update is shown on the diagrammatic model as a clock rather than a calendar as shown in the management model.

Although the controller and management user models are discussed as two separate models, they do interact between each other and present many areas of common interface. Together they comprise

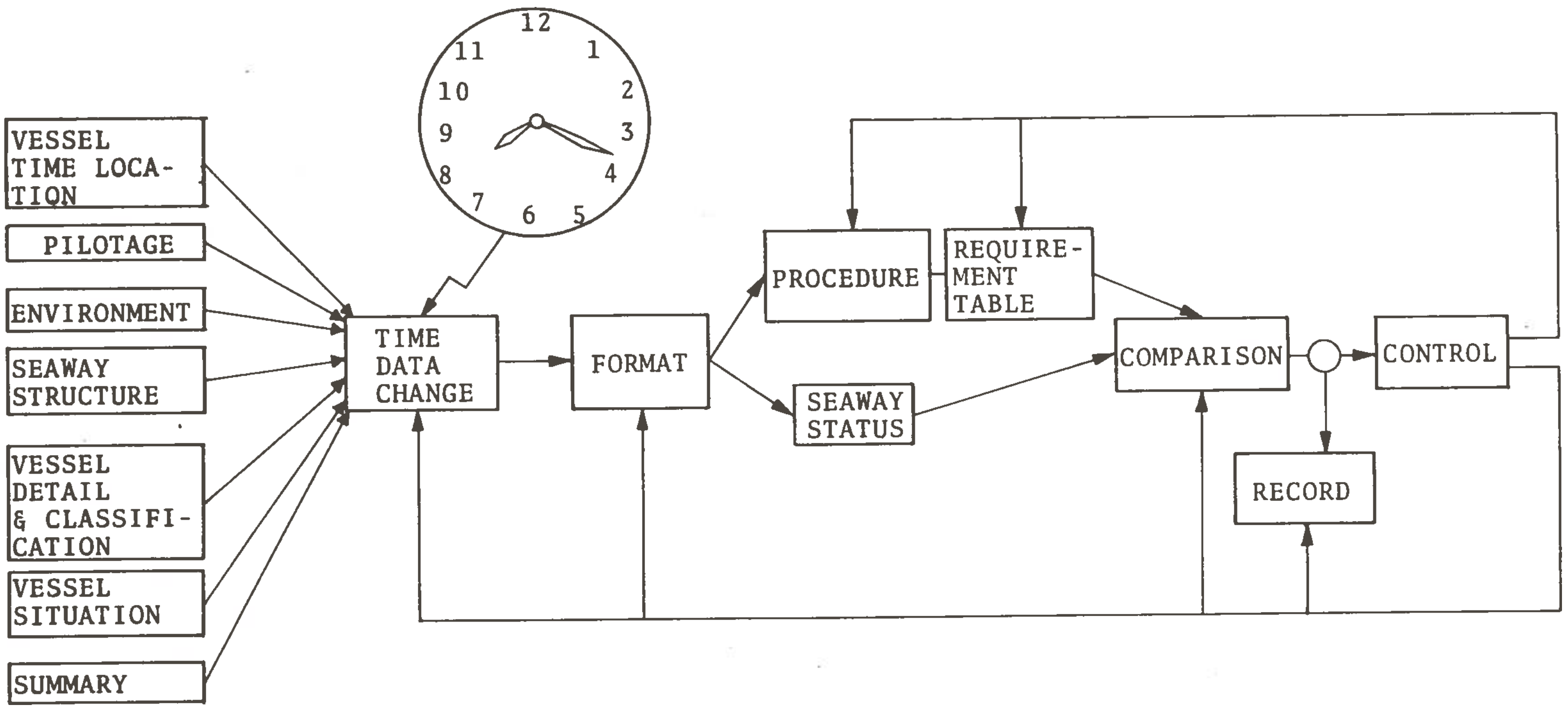


Figure 9. Seaway Controller User System

the generalized Seaway model. Management control functions can feed into the controller model and affect the controller actions. Data inputs are similar and differ principally in access and update frequency. Report preparation is a critical function of management, and a secondary function of the controller user. Both use the same data files. These examples show the commonality between the two models. In actuality, one model will provide the structure for both functions. The principal difference is in the data update rate.

The data for the controller model is formatted as a large map of the Seaway with vessels moving across it. This map can be displayed on a graphic CRT. Portrayed on this map are formatted data which represent the Seaway status table. Also portrayed are vessel position and amplifying text. Projected along with this map are desired vessel positions and data. These latter projections represent the requirements to be met of all elements of the Seaway status table. The model describes how each element of the data are compared with its referenced requirement and what action might be taken by a controller to effect a better match between status and requirement.

Critical to the controller model is the data formatting performed. It affects both the requirements table and the status table and is a function of the update rate. The data in the Seaway status table is being generated on a faster time base than the data in the requirement table but both are displayed in the same format. The data base for the Seaway status table is generated on a real time basis; the data in the requirements table are generated by a decision process. The latter represent data that have been processed. For example, a method of control of vessel movement might be through the use of a dynamic requirements display in the form of phantom position of a ship. This position is moved along the Seaway according to a mathematical model and is therefore, the requirements table data. The actual ship position projection is an image position updated by actual vessel movement. This position is the status table data.

The data discussed in the following subsections are quantative descriptions of the elements of the controller model. Given for each element of data are:

- Data name including data units, how it is generated, frequency of generation and data limits.
- Data format - How it is formatted for the status, requirements and comparison functions.
- Status table including frequency of update, how it is updated, frequency of access, and limits.
- Requirements table including frequency of update, how it is updated, frequency of access and limits.
- Comparison function - how comparisons are made; what thresholds of data limits are set.
- Control function - how corrective actions are initiated when data thresholds are exceeded.
- Record - what data is recorded and reported.

5.2 TIME-LOCATION (POSITION) FILE (Table 7)

The Time-Location file is the principal element in the controller model and provides the vessel traffic controller with the predominant information he requires to control traffic on the Seaway. The data are displayed against a scaled map of the Seaway (Figure 10). The vessel is represented as a continuous presentation (blip). The blip is identified by a vessel data block and the data and data block follow the ship's position as it moves across the map. The data are reformattable in order to present a larger scale presentation of a particular situation (Figure 11).

Vessel positional data for the status table is generated from the last positive position report and the last positive vessel velocity information. Currently vessel position information is gathered at the rate of about once per hour. Estimated positions between informational collection points are extrapolated.

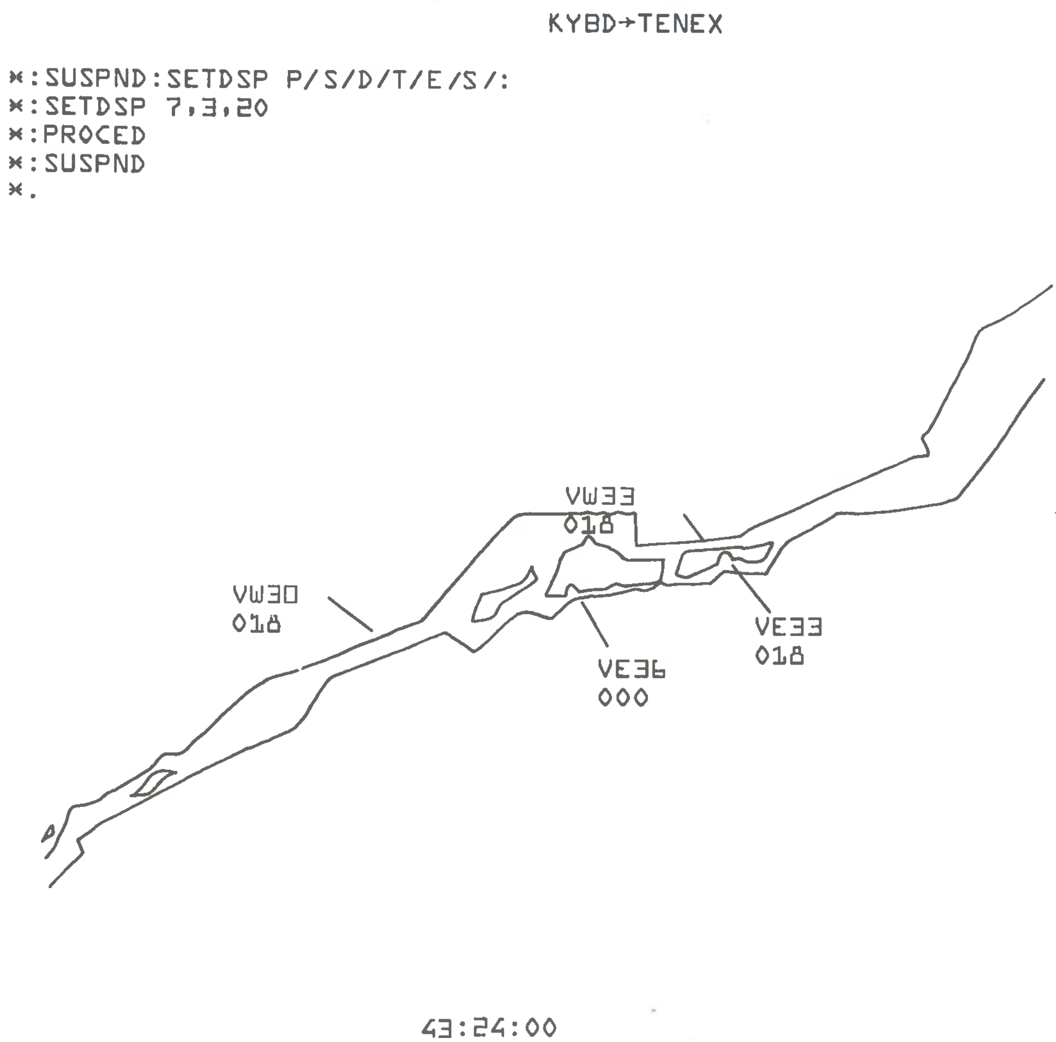


Figure 10. Seaway Display with Vessel Presentation

TABLE 7. TIME-LOCATION (POSITION) FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
X_S-Vessel position along the Seaway. Measured in miles. Determined by radio contact or automatically when AVLIS becomes available. Data generated once per minute Acceptable error is ± 500 feet	Vessel position appears as a blip scaled in feet to the Seaway Navigational Structure chart	X_S-Appears as a continuous picture generated by computer interpolation of reported position and velocity information $X_{S_t} = X_{S_{t-1}} + V_S \Delta t$		$\frac{\lvert X_S - X_R \rvert}{\dot{X}_S} = t_X$ $t_X \geq 5$ minutes $t_T \geq 30$ minutes t_X values can be stated in terms of ETA's. vessel Seaway position, X_S, can be used to set vessel separation standards	Request master to increase or decrease his speed Initiate search and rescue proceedures Notify master and request intent	ATA at CIP's
X_R-Vessel required position along the Seaway. Measured in miles. Required position is developed by computer. Generated 10 times per minute. Acceptable error is ± 50 feet.	Vessel required position appears as an ETA at various check-in points, measured in minutes. Also appears as a blip scaled in feet to the Seaway Navigational Structure chart.		X_R-Appears as a continuous picture based on linear upgrade from desired position and desired velocity. Desired velocity is a function of the environmental file requirement $X_{R_t} = X_{R_{t-1}} + \dot{X}_R \Delta t$			
Y_S-Vessel position across the channel, measured in feet from the center line of the channel. Determined by radio contact or by AVLIS when available Generated 5 times per minute. Acceptable error is ± 125 feet.	Vessel cross channel position appears as a blip scaled in feet to the Seaway Navigational Structure chart.	Y_S-Appears as a continuous picture generated by computer interpolation of reported position and velocity information $X_{S_t} = Y_{S_{t-1}} + \dot{Y}_S \Delta t$		$\frac{\lvert Y_S - Y_r \rvert}{\dot{Y}_S} = t_Y$ $t_Y \geq$	Advise master of danger and direct him to center line of channel	
Y_R-Vessel required across channel position, measured in feet from the center line. Generated by computer, 50 times per minute with a Δt=0.02 feet. Acceptable error is ± 12.5 feet.	Required position appears as a blip scaled to the Seaway Navigational Structure chart.		Y_R-Continuous picture based on linear upgrade from the desired position and input velocity from the controller $Y_{Rt} = Y_{Rt-1} + \dot{Y}_R \Delta t$			
$\dot{X}_S$-Vessel velocity along the Seaway, in mph. Tolerable error is ± 6 mph	Rate at which the vessel position blip moves, scaled to the Seaway chart. Appears as a number in the ship's data block	$\dot{X}_{Stn} = \frac{X_{Stn-2} - X_{Stn-1}}{\Delta t}$		$\lvert \dot{X}_S - \dot{X}_R \rvert = \Delta\dot{X}$ $\Delta\dot{X}_{MIN} \leq \Delta\dot{X} \leq \Delta\dot{X}_{MAX}$	Speed Control Advise master to speed up or slow down	
$\dot{X}_R$-Vessel required velocity in mph. Computer input by controller tolerable error is ± 0.6 mph	Rate at which the required vessel position blip moves, scaled to the Seaway chart		Required speed is a controller input to the computer			

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
$\dot{Y}_S$-Vessel cross channel velocity in feet per second	Rate at which the vessel position blip moves across channel. Appears as a number in the Ship's data block	Continuous picture based on linear update from last position report		$\lvert \dot{Y}_S - \dot{Y}_R \rvert = \Delta\dot{Y}$ $\Delta\dot{Y}_{MIN} \leq \Delta\dot{Y} \leq \Delta\dot{Y}_{MAX}$	Advise master to speed up or slow down	
$\dot{Y}_R$-Required vessel cross channel velocity in feet per second. Computer input by controller	Rate at which the required vessel position blip moves cross channel. Appears as a number in the Ship's data block		Required speed as a controller input to the computer			

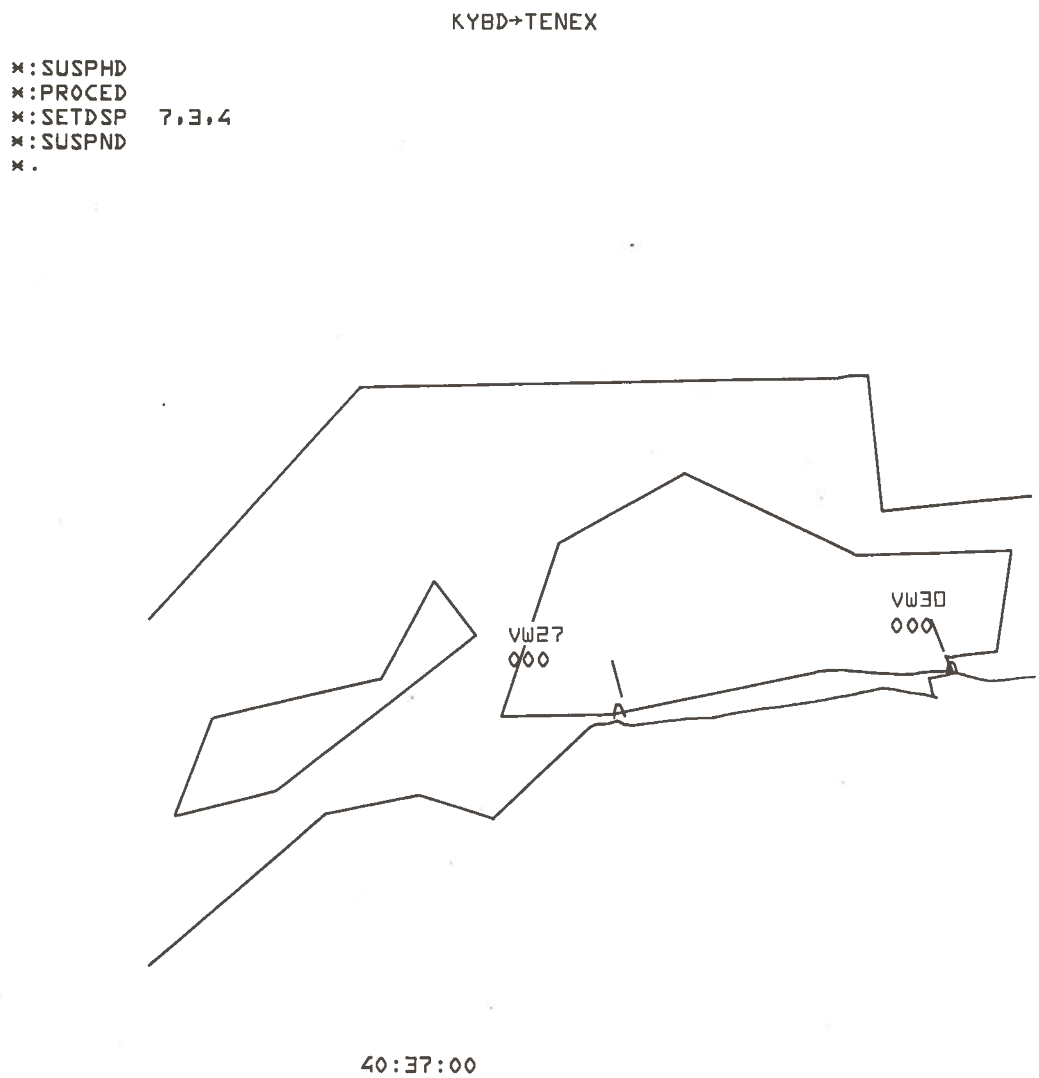


Figure 11. Detailed Seaway Display

In the controller model, the positional data are updated at the rate of once every minute along the channel and five times per minute across the channel and are monitored continuously. Estimated positional information would be updated using equations of motion, the complexity of the equations being proportional to the data update rate. With the advent of real time-vessel position information, positive data will be continuously supplied. Tolerable errors in position are ± 500 feet along the channel; and ± 125 feet across the channel.

The data in the status table also include vessel velocity along and across the channel. Vessel velocity information along the channel is updated at each call-in point by radio contact with the master; with a real time positional information system it can be updated continuously from differentials of vessel positions. Vessel channel velocities are complex since they include the effects of current, wind, vessel cross-section, etc. This area requires extensive investigation. Tolerable velocity errors are ± 10 feet per minute along the channel and ± 10 feet per minute across the channel.

The data for the requirements table is computer-generated and formatted as a blip on the map to represent a desired vessel position. These computer-generated positions are developed using controller-assigned vessel velocities and extrapolations from known positions. They provide the controller with immediate knowledge as to where the ship should be at any time. The data are generated and accessed continuously. The tolerable positional errors are ± 50 feet both along and across the channel. The veloccities are analogous to Seaway speed limits and the accuracies should be within 10 feet per minute. Athwart channel velocity requirements have not been determined.

The comparison and control functions in the Time-Location File encompass the principal control activities in the Seaway. Comparisons are effected between actual (or extrapolated) and required values. When the differentials between actual and required exceed certail predetermined values, control action is taken. These actions include:

- If the vessel is more than 5 minutes ahead of or behind his required position, the controller notifies the master and resets his requirement blip.
- If the vessel is more than 30 minutes behind his required position, then the controller initiates search and rescue procedures.
- If the vessel exceeds his required cross-channel position, the master is notified and the requirement blip is reset.
- In other situations the controller notifies the master of the problem areas.

The tolerable errors in position are ± 500 feet along the channel and ± 125 feet across the channel. Velocity differential tolerances are ± 0.5 mph along the channel and ± 10 feet per minute across the channel.

The records kept for this file are inputs to the Management Model.

5.3 PILOTAGE FILE (Table 8)

The Pilotage File serves to determine the location, status, requirements and availabilities of the pilots who serve the various sectors of the Seaway. In a sense, it is a scheduling algorithm designed to optimize the distribution of pilots among the vessels requiring them.

Pilotage data will be displayed on a scaled Seaway chart showing locations and availabilities. In addition, data will be accumulated and displayed in a pilotage data block which can be called up upon demand by the controller. A computer calculation is made of the pilot's position and availability and is a function of current location, distance to travel to a pilot change point, sleep and rest periods and work history. Update and access of the status table will be once every five minutes with a ± 1 minute error.

Pilotage requirements are derived from a radio request from the Ship's Master for services and are fed to the model by the controller. Required times are within ± 1 minutes.

Comparisons are made between the pilots' actual locations and times of availability and required times and locations. This comparison is actually a vector comparison between pilot requirements at a particular position and availability at that position. The control action resulting from the comparison function are:

- The controller notifying the master of pilot availability and keeping the vessel in sequence.
- The controller also notifies the master of pilot non-availability and holds the vessel in the vicinity of the pilot change point until the pilot is available.

5.4 ENVIRONMENTAL FILE (Table 9)

The Environmental File consists of those factors which could affect operations on the Seaway. This file contains five subfiles:

- Weather,
- Ice,
- Visibility,
- Water Temperature, and
- Pollution.

The data in the Environmental File are shown as appropriate symbols on the Seaway map presentation. In addition, a data table for each subfile can be displayed on demand.

The weather subfile contains the current meteorological factors at the weather stations along the Seaway, and, more importantly, the wind direction and speed at each of these positions. The data are updated and accessed continuously; the wind direction and speed is shown in miles per hour within ± 10 feet per minute accuracy. The wind vector is used to generate a vessel velocity component

TABLE 8. PILOTAGE FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
PILOTAGE FILE						
PPA_S-Pilots position and availability. Time in hours on a 24 hour clock. Where available. Computer developed availabilities based on position, ships, distance to travel, etc. Generated once every 5 minutes within a tolerable error of ± 2 minutes	Appears as a blip and data block on the Seaway chart when requested by the controller	PPA_S-time and location		Controller bases vessel passage into Snell lock or not as to whether he has a pilot on board	Advise master Notify pilots association	
PPA_R-Pilot position requirement. Time and location required, ship request. Input from the controller. Continuous update tolerable error of ± 10 minutes	Appears as a blip and a data block on the Seaway chart		PPA_R = Time and location			

TABLE 9. ENVIRONMENTAL FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
Environment File Weather - prevailing conditions V_W - wind direction and velocity in mph Continuous input from Weather Station	Displayed as text and as weather symbols on the Seaway Navigational Sturcture chart	$\dot{W}_X, \dot{W}_Y$ -shown as a velocity degradation	$\dot{W}_{XR}, \dot{W}_{YR}$ = f(vessel type, location, etc.)	$\dot{X}_S - \dot{X}_R = \dot{W}_{X(actual)}$ $\dot{W}_{X(actual)} \leq \dot{W}_{X(limit)}$	Advise Master Change velocity requirements	
Visibility - in feet or miles; location; continuous input from Weather Station, vessels; tolerable error of ± 20 feet	Displayed as text on Navigational Structure chart	V_{SX}-vessel forward visibility V_{SY}-vessel lateral visibility	V_{RX}, V_{RY} = required visibility as established by Seaway management	$V_{SX} - V_{RX} \leq 0$ $V_{SY} - V_{RY} \leq 0$ for minimum conditions	Advise Master Suspend Operations	
Ice - thickness in inches; location, updated once per day	Displayed as text on Navigational Structure chart	T_S	T_R	$T_S - T_R > 0$ for minimum operations	Advise master Suspend operations	
Water temperature in degrees F, location of Weather Station, tolerable error of ± 1°F	Displayed as text on Navigational Structure chart				Advise master	
Pollution - location, kind, percent of area covered, locks affected	Displayed as text on Navigational Structure chart				Affix Responsibility Initiate corrective measures	

for use with the vessel velocity requirements data. The wind vector inputs to the vessel time-location file. Comparisons are made between actual wind velocities and wind velocity limitations for various vessel classes on the Seaway. Control action is made by weather and wind advisories broadcast to the masters and pilots.

The ice subfile contains an inventory of the ice conditions at selected sampling locations throughout the Seaway. It is updated and accessed at least once per day. The data are displayed as a computer symbol and text at the sampled location on a map. Ice navigation constraints are set by the management. Comparisons are made between actual and limiting conditions; when the limits are reached or exceeded, the Seaway is closed to navigation and advisories promulgated.

The visibility subfile is displayed as a number of feet or miles of forward visibility as monitored at various sampling points along the Seaway. It is shown on the Seaway map together with the weather condition or the cause of the visibility restriction, e.g., fog, smoke, snow, smog. etc. It is updated and accessed at five minute intervals. Accuracies are within ± 20 feet. Operating limits are established by management; when limits can not be met, operations are reduced or suspended and the vessels so advised.

Other subordinate files include the water temperature file and the pollution file. These files are updated and accessed once per day. The inputs are displayed on a Seaway map at the sampling locations or where the event occurs. Temperature inputs are within an accuracy of ± 1°F. Pollution inputs appear as descriptive events, e.g., where it occurs, type of pollution, such as oil spill or overboard discharge, severity and extent, and responsibility. The water temperature subfile is for informational purposes only and rarely results in a control action. The pollution subfile on the other hand requires a control action for every event including the ordering of corrective action, cause and responsibility.

5.5 SEAWAY NAVIGATIONAL STRUCTURE FILE (Table 10)

The purpose of this file is to present a continuous background chart of the Seaway. It sets the stage and provides the scale necessary for the Time Location File and all other files that require a geographical frame of reference for the structuring of the data. This file forms the key to all of the controller's activities and almost all of the information concerning the status and requirements tables are displayed against this base.

The display is in the form of a digitized projection of Seaway charts. The data projected are based on annual surveys and soundings of the waterways and channels. The chart can be projected as an overall display of the total Seaway or zoomed down to harbor chart detail. This latter capability has a resolution of 100 feet. The display is continuous and is upgraded as information is received on changes in status.

The Seaway Navigational Structure File includes four subfiles:

- Navigational Aids,
- Water Level,
- Current Condition,
- Navigational Hazards.

The information is these subfiles is displayed against the background of the Seaway chart. The information is upgraded based on surveys, observations and vessel reports.

The navigational aids are shown as computer projected symbols against the chart display. When the navigational aid is reported as being inoperative or out of position, e.g. exceeding specified limits, each vessel within or entering the Seaway is so informed and the event is recorded in the navigational aid file. In addition, the required position and condition of all Seaway navigational aids are maintained in this file.

The water level is shown as a contour on the display of the waterways. The contour is based upon depth measurements at

TABLE 10. STRUCTURE FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
Seaway structure in latitude and longitude. Based on surveys and soundings taken once per year. Accuracies in seconds of arc	Displayed as a computer projection of a navigation chart. Zoom capability from overall view down to harbor chart detail		This file is the basic background projection for all data to be displayed. Its data are the requirement table for most files	Comparison of actual vs recorded, e.g., channel depths		
Navigational aids-generated by controller input based on vessel reports and surveys. Updated 3 times a day or when occurs. Tolerable error in ± feet	Displayed as projections on the Seaway structure chart, e.g. a bouy is displaced or missing	Positions of navigational aids based on reports and surveys	As above	$\lvert(X_S,Y_S) - (X_R,Y_R)\rvert = A(X,Y)$ $A(X,Y) \leq$ limited amount, i.e. if a navitational aid is displaced more than a specified amount it is cited and reported	A report is furnished each vessel as it enters the sector	Input to Navigational Aids file
Water level - from Seaway survey report, in feet. Updated 3 times per day. Tolerable error ± 1 foot	Displayed as a contour on the Seaway Structure chart	A contour on the Seaway Structure chart	Minimum depth of water necessary to permit normal Seaway navigation	$h_{survey} - h_{status} = \Delta h$ $h_{min} \leq \Delta h \leq h_{max}$	Change in Seaway operating procedures	Input to Water Level file
Current conditions - from Seaway surveys, in ft/sec; location, also determined from vessel performance and master reports. Updated once per hour. Tolerable error ± 1.0 ft/sec.	A vector addition to the vessel requirements blip in the Time-Location file	V_{CS} - Velocity of current, used once per minute by computer to update vessel location blip	V_{CR} - operating requirements data. Used to project vessel position requirements blip	$V_{CS} - V_{CR} = \Delta V_C$ $V_{C_{min}} < \Delta V_C \leq V_{C_{max}}$	Warning to masters Change in Seaway operating procedures	Current file
Navigational Hazards - from Seaway surveys, vessel reports, location. Updated once per hour. Tolerable error ± 10 feet	An obstruction and modification to the basic Seaway Navigational Structure file	A modification to the Seaway Navigational Structure file	Normal conditions for the structure file	CW_S - channel width status CW_R - channel width requirement $CW_S - CW_R = \Delta CW$ $\Delta CW \leq \Delta CW_{req}$	Warning to masters Changes in Seaway operating procedures	Hazard file

specific points, and the contour is generated from those data. Depths are measured once per eight hour shift and measured with an accuracy of ± 0.5 foot. When water levels are less than the surveyed data and exceeding safe navigational limits, Seaway operating procedures are changed or suspended and the masters and pilots are so informed. If safe navigating limits are not exceeded, operating procedures are unchanged but the masters are informed of the water levels. The data are recorded in the water level file.

Current conditions are shown as a computer-generated symbol on the Seaway chart. The data are based upon surveys, observations of vessel behavior and pilot reports. Current conditions are inputted to the Vessel Time-Location File and are supplied as a vector addition to be used to update the vessel requirement blip. The current data are updated once per hour and can be accessed as frequently as once per minute for vessel time-location update. Current status data are compared with historical current data. If differentials exist which exceed limits to safe operations as determined by management, then operating procedures are changed and warnings issued to vessel masters. The data are recorded in the current file.

The Hazards to Navigation File is based on vessel reports and surveys. The hazards are displayed on the digitized chart as appropriate obstruction symbols and as modifications to the basic Seaway Navigational Structure File. The status table is updated and accessed continuously, the requirements table on a hourly basis. Comparisons are made between status and requirements for channel widths and depths. When normal operating limits are exceeded, warnings are issued to masters, and operating procedures are changed. Records are maintained in the Hazards to Navigation File.

5.6 VESSEL SITUATION (SHIP ANCHOR AND DOCKING) FILE (Table 11)

The Vessel Situation File contains the anchoring and docking information on the vessels within the Seaway System. The anchoring subfile is a subset of the Vessel Time-Location File and the Seaway Navigational Structure File. It is displayed as a detail chart of the anchorage area which has been requested and includes the appropriate vessel blips and data blocks. The docking subfile is a subset of the Vessel Time-Location File. Data are displayed against a harbor scale chart of specific dock areas and the vessel is shown as a computer-generated blip on this chart. As with the Seaway Navigational Structure File, a zoom capability is available down to the 100 foot resolution level. The two subfiles are updated continuously and accessed once every five minutes.

The size, depth, location, availabilities and facilities of the docks and anchorages are maintained in this file. Those data include the status such as if a dock or anchorage is occupied or if a vessel has been ordered to or from the anchorage or dock space. Vessel docking requirements are submitted by the vessel master as determined by the controller based upon developing situations in the Seaway, e.g., vessel breakdowns, suspended operations due to reduced visibility, lack of pilots or accidents. Such situations require vessels to be sent to anchorage. The status and requirements are compared and anchorage and docking assignments made. Comparisons are made between vessel positions and vessel assignments and docking or anchorage times are determined.

The requirements table is updated once every five minutes and accessed continuously. Resolution errors for the Time To Dock are within ± 1 minute. Records are maintained in the Dock and Anchorage File.

5.7 VESSEL DETAIL AND CLASSIFICATION FILE (Table 12)

The Vessel Detail and Classification File is the controller model version of a similar file in the management model. It differs from the management version in that it does not contain accounting data. It does, however contain the information on a vessel's status and characteristics as it enters, transits and leaves the Seaway. All the data items in this file are handled

TABLE 11. VESSEL SITUATION (SHIP ANCHOR AND DOCKING) FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
VESSEL SITUATION (ANCHOR AND DOCKING) FILE						
DOCKS-Location in latitude and longitude, on Seaway chart. Vessel position from controller input or real-time system (AVLIS). Updated once per incident. Tolerable error ± feet	Vessel blip and data block Dock positions on harbor scale chart or Anchorages on a harbor scale chart	Scaled placement of a vessel blip and data block against the Seaway Navigational Structure File	Dock positions on a harbor scale chart Anchorages on a harbor scale chart Also shown as a requirement for a controller to issue a command to go to or leave from dock or anchorage	$P = (X_S, Y_S)$ $V = (\dot{X}_S, \dot{Y}_S)$ $P_{dock} - P_{vessel} = \Delta P$ $P_{min} \leq \Delta P \leq P_{max}$ Also shown as time: $\frac{P_{dock} - P_{vessel}}{V_{vessel}} = t_{to\ dock}$ $t_{min} \leq t_{to\ dock} \leq t_{max}$	Order vessel to dock or anchorage, or to leave dock or anchorage	Dock File
Anchorage-Location in latitude and longitude on Seaway chart. Vessel position from controller input on real-time system (AVLIS). Updated once per incident. Tolerable error ± feet				$P_{anchor} - P_{vessel} = \Delta P$ $P_{min} \leq \Delta P \leq P_{max}$ $\frac{P_{anchor} - P_{vessel}}{V_{vessel}} = t_{to\ anchor}$ $t_{min} \leq t_{to\ dock} \leq t_{max}$		Anchorage File

TABLE 12. VESSEL DETAIL AND CLASSIFICATION FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
VESSEL DETAIL AND CLASSIFICATION FILE						
Contains the following subordinate files: Preclearance Report Vessel Draft Ocean Fitted Tows Yachts Military All the data items are treated similarly. Data obtained by inspection or measurement, updated once per transit	Formatted as data blocks, projected as text or data blocks linked to vessel position blip. Accessed from text by name position blip	As observed or measured	Seaway management requirements	Requirements data compared to status data. Infractions flagged and displayed when ship enters control sector	Vessel infractions Control and fines	Vessel infraction file

and formatted in the same way. The data are keyed to the Vessel Time-Location File and are displayed as text. It may be either an expanded vessel data block adjacent to the vessel position blip or a page format addressable through the position blip. The data elements in this file are:

- Preclearance report,
- Vessel draft,
- Ocean Fitted Vessels,
- Tows,
- Yachts, and
- Military Vessels.

All of these elements are formatted and manipulated in the same manner.

The requirements table contains the operating limits for those vessel parameters which must be checked when a vessel enters the Seaway system or a control sector. These requirements are established by management for vessel transits and are displayed to the controller as a special data block. The vessel status table contains the details of the data elements in this file. A matrix comparison is made of all elements of the Vessel Detail and Classification File at the time of input or at the time of vessel entry into the control sector. Requirements data are compared with status data. Infractions are tagged and displayed. The control action can include restriction on vessel movement, fines or modification in operational procedures.

One of the elements in the Vessel Detail and Classification File, for example, is vessel draft. The vessel is inspected and the draft is measured once per Seaway trip. Tolerable errors are within ± 0.5 feet. The maximum limit for Seaway transits is 26.5 feet. When the actual exceeds this requirement, the vessel is either prohibited from entering the Seaway or forced to off-load in order to meet the requirement. The event is recorded in the vessel infraction file and serves as an input to the management model.

5.8 SUMMARY FILE (Table 13)

The Summary File is the most highly aggregated of all files, not only in the controller model, but in the management model as well. The purpose of the file is to provide operating and management personnel and the Seaway system user with overview and planning data on current and near-term operations. The file requires more definition at present, but it is conceived of as a collection of inputs from the controller and management files. It is displayed as text tagged to the vessel data block. It will provide such planning data as the number of ocean vessels above Eisenhower Lock. It will provide warnings of when the Seaway status table exceeds Seaway requirements (capabilities) and of events demanding upper level management and control attention. Definition of this file will follow development of the subordinate files in the models.

TABLE 13. SUMMARY FILE

DATA	FORMAT	STATUS TABLE	REQUIREMENTS TABLE	COMPARISON	CONTROL ACTION	RECORD
SUMMARY FILE						
Summaries of the management user files and the controller files. All data handled in the same manner. Subordinate files undefined	Text tagged to vessel data block for access and display	As aggregated, observed or measured	Seaway operational or management requirements	Requirements compared to status	Change operating procedures Management action	

6. CONCLUSIONS

Based upon the results of this study, the following conclusions are derived.

The controller and the management user models are similar and have complementary relationships and inputs. In these models there is one basic system structure which serves two purposes. Hence, there is, in fact, only one model which fulfills both functions.

The requirements of the controller model are paramount and govern the structure and form of both models. If the requirements of the controller model can be met, then the requirements of the management model are also met.

The Time-Location File of the controller model establishes the most stringent constraints for data update and access. This file is the determining factor in the controller model and the management model as well. If the data processing requirements of this file can be met, then there is sufficient computational power in the system to meet the needs of all other files.

The stressed case condition governs the system loading, access and update requirements. This has been determined to occur in the Time-Location File. Frequency of update for vessel position along the channel is once per minute; for cross-channel position is five times per minute. Frequency of access for both conditions is continuous.

Vessel control is exercised not upon the vessel itself but upon the desired location of the vessel. This desired location is a dynamic position which moves through the Seaway and is subject to operational and environmental factors. How this desired vessel position is attained is the responsibility of the master; where this position is located is the responsibility of the controller.

7. REFERENCES

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