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US Army Corps of Engineers
Waterways Experiment Station

Ship Navigation Simulation Study, Sacramento River Deepwater Ship Channel Project, Phase II, Sacramento, California

by Dennis W. Webb

Prepared for U.S. Army Engineer District, Sacramento

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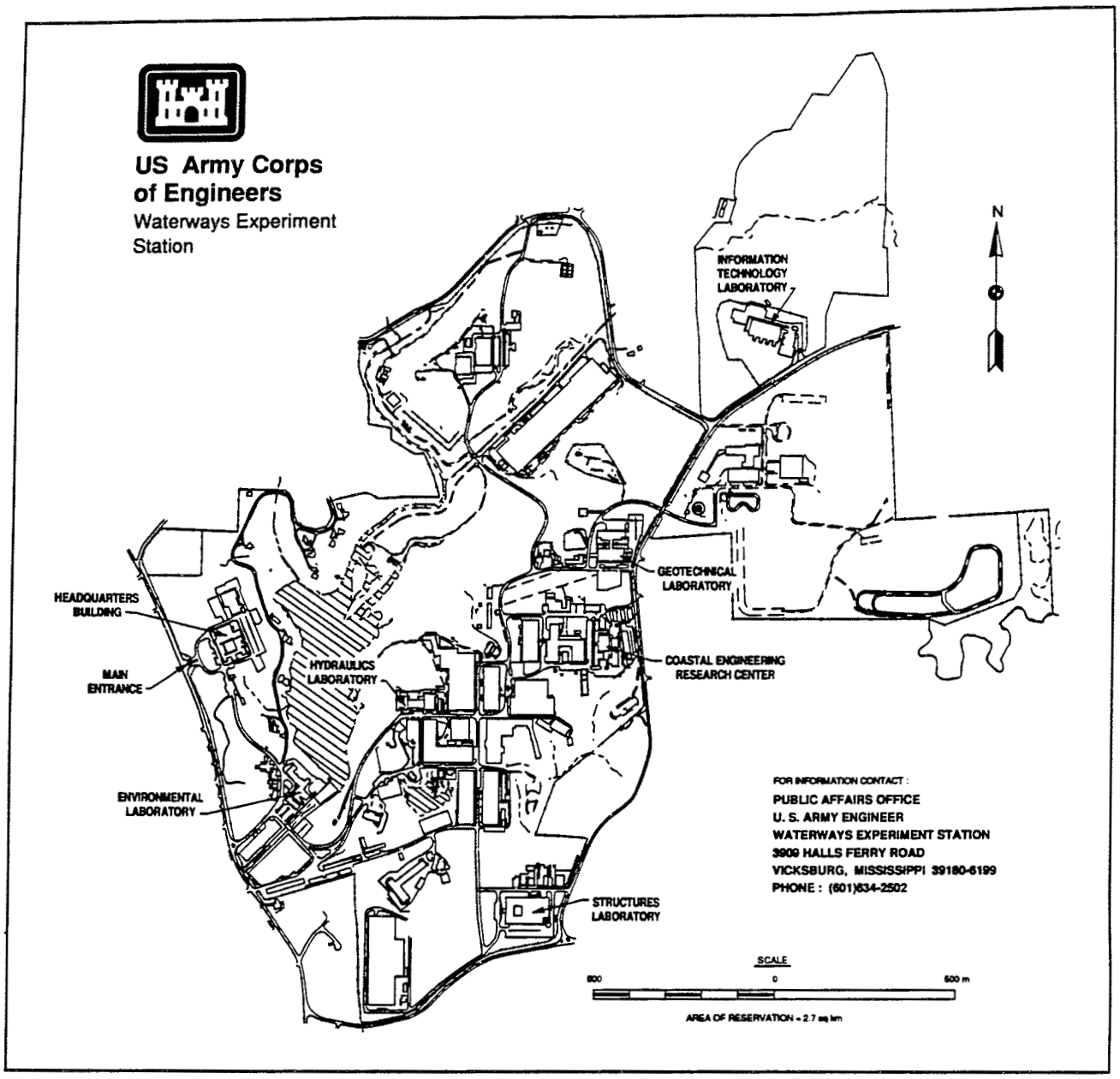

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Contents

Preface

This investigation was performed by the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES) for the U.S. Army Engineer District, Sacramento (SPK). The study was conducted with the WES research ship simulator. SPK provided survey data of the prototype area. Current modeling was conducted by Resource Management Associates, based on field data collected by the Estuarine Processes Branch, Estuaries Division, Hydraulics Laboratory. The study was conducted during the period February 1988-June 1988.

The investigation was conducted by Mr. Dennis W. Webb and Dr. Larry L. Daggett of the Navigation Branch, Waterways Division, Hydraulics Laboratory, under the general supervision of Messrs. Frank A. Herrmann, Jr., Director of the Hydraulics Laboratory; R. A. Sager, Assistant Director, Hydraulics Laboratory; and Marden B. Boyd, Chief of the Waterways Division (now retired).

Acknowledgment is made to Messrs. Mike Campbell, Eric Polson, and Fred Garcia, Engineering Division, SPK, for the cooperation and assistance at various times throughout the investigation. Special thanks should go the San Francisco Bar Pilots Association for access to an outbound ship and for furnishing professional pilots to conduct ship simulator tests on the WES ship simulator.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acre-feet	1,233.489	cubic meters
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
knots (international)	0.5144444	meters per second
mile (US statute)	1.609347	kilometers
square miles	2.589998	square kilometers

1 Introduction

The Sacramento River Deep Water Ship Channel is located in the Sacramento - San Joaquin Delta region of northern California. The 46.5 mile long channel lies within Contra Costa, Solana, Sacramento, and Yolo Counties and serves the marine terminal facilities at the Port of Sacramento (see Figure 1). The Sacramento River Deep Water Ship Channel joins the 35-feet deep San Fransico to Stockton, California (John F. Baldwin and Stockton Ship Channels) navigation project at New York Slough, thereby affording access from the Port of Sacramento to Bay Area harbors and the Pacific Ocean.

The existing Sacramento Deep Water Ship Channel Project was authorized by the River and Harbor Act (Public Law 525, 79th Congress, 2nd Session) approved July 24, 1946. The principal features of the project as authorized by Public Law 525 include the Deep Water Ship Channel, Harbor and Canal. The harbor consists of a turning basin of the same depth as the ship channel (30 feet), 1000 feet wide and 1200 feet long at Washington Lake. The barge canal, 11 feet deep and 120 feet wide with lock and draw bridge, connects the harbor and Sacramento River. The Deep Water Ship Channel is 30 feet deep and 200 to 300 feet wide from deep water in Suisun Bay to Washington Lake, including flood control intercepting works and drainage culverts. The project has been in operation for oceangoing vessels since June 1963.

Most of the water from the 64,000-square mile Central Valley watershed, or roughly one-third of the entire state of California, drains through the Sacramento - San Joaquin Delta. The water originates as run-off from winter rains in the valley and foothills and spring snowmelt from the Sierra mountains. Three-quarters of the total annual flow occurs between January and May, with January and February being the peak which produces 80 percent of the total run-off; the San Joaquin (15 percent); and other minor tributaries (5 percent). Before large scale water diversions began, the mean annual outflow from the Delta was more than 30 million acre-feet. The construction of many federal, state, and local water projects with the watershed has cut the flow to its present level of about 16 million acre-feet per year.

Water elevations in the area are influenced by hydrological and geological phenomena. Rapid melting of snow packs and rains in the tributary areas may greatly influence the waterways in the area. the combination of heavy run-off and tidal action may produce flood stages. Tidal action is an important factor

in the development of any plan to improve the navigability of waterways in the study area. Tidal ranges for an average tide and low advective outflow are 4.5 feet at Collinsville, 4.75 feet at Junction Point, and 6.0 feet at the Port of Sacramento.

Proposed Channel Improvement

The proposed channel improvement for the Sacramento River Deep Water Ship Channel involved modification to three portions of the project reach:

a. New York Slough to the junction of Cache Slough, Steamboat Slough, and the Sacramento River (Channel Mile 15.0): This portion of the channel was planned to be deepened from 30 to 35 feet, and the width increased from 300 to 350 feet.

b. The junction of Cache Slough, Steamboat Slough, and the Sacramento River to the entrance to the manmade channel (Channel Mile 18.6): The width would remain 300 feet along this reach, and the depth would be increased from 30 to 35 feet.

c. The entrance to the manmade channel to the Port of Sacramento: This portion would be deepened from 30 to 35 feet, and the width increased from 200 to 250 feet.

Channel slopes were planned to be 1 vertical on 4 horizontal in the reach between New York Slough and Channel Mile 18.6 and 1 vertical on 3 horizontal from Channel Mile 18.6 to the Port of Sacramento.

The selected plan as discussed above and as presented in the March 1986 General Design Memorandum was to deepen the existing one-way channel between New York Slough and the Port of Sacramento to 35 feet below -2 NGVD (an approximation of MLLW) and to widen the channel according to the tabulation on Table 1.

Table 1
Sacramento River Deep Water Ship Channel, California Channel Dimensions - GDM

	Existing (ft)		GDM (ft)	
Reach	Width	Slope	Width	Slope
New York Slough to Mile 15.0	300	1V:4H	350	1V:4H
Mile 15.0 to Mile 18.6	300	1V:3H	300	1V:3H
Mile 18.6 to Port of Sacramento	200	1V:3H	250	1V:3H

Purpose and Scope of Investigation

The purpose of the ship simulator investigation was to determine the effect of deepening the Sacramento Deep Water Ship Channel on navigation conditions. It was also to determine if elimination of widening in the straight reaches of the man-made portion of the channel would be engineeringly feasible while maintaining adequate navigation efficiency and safety.

The basic plan for the ship simulator investigation was to conduct the study in two phases. The first phase included the man-made channel portion from river mile 18.6 to 43 (Sacramento Harbor). The second phase included the lower portion from river 20 to mile 12, slightly downstream of the Rio Vista Bridge, Rio Vista, California. This report will only present the results of the Sacramento Deep Water Ship Channel Ship Simulation - Phase II (Figure 2). Phase I study results were presented in Nguyen and Daggett.[1]

[1] R. H. T. Nguyen and L. L. Daggett. (1990). "Ship navigation simulator study, Sacramento River Deepwater Ship Channel Project, Sacramento, California; Report 1, Phase I," Technical Report HL-90-11, Volumes I and II, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

2 Data Development

In order to simulate the study area, it is necessary to develop information relative to five types of input data:

a. Channel data base contains dimensions for the existing channel and the proposed channel modification. It includes the channel cross-sections, slope angle, overbank depth, initial conditions and autopilot trackline and speed definition.

b. Visual Scene data base which is composed of three dimensional images of principle features of the simulated area, including the aids-to-navigation, buildings, and bridges.

c. Radar data base contains the features for the plan view of the study area.

d. Ship data file contains characteristics and hydrodynamic coefficients for the test vessels.

e. Current pattern data in the channel includes the magnitude, direction, and depth of the current for each cross-section defined in the channel data base.

Channel

The information used to develop the channel data base came from the District-furnished hydrographic survey charts. This was the latest information available concerning depths, dimensions, and bank lines of the channel. State planar coordinates as shown on the annual survey were used for the definition of the data.

The ship simulator model uses eight equally spaced points to define each cross-section. At each of these points, a depth, current magnitude and direction are required. For each cross section, the width, right and left bank slopes are required. This data was obtained from the hydrographic survey data provided by the Sacramento District for use in the main program for calculating bank suction forces. The cross-section layout for the simulation of the

Sacramento River Deep Water Ship Channel - Phase II were placed as shown in Figure 3.

A typical cross-section is shown in Figure 4. This cross-section was taken from the Phase II simulation in the Cache Slough reach and is shown as if the viewer is looking downstream. Notice that the steep edge on the right, or western, side of the channel has a shallow overbank depth (2 feet) and a steep side slope (1 vertical on 3 horizontal). The left, or eastern, side of the cross-section has overbanks that are nearly as deep as the channel itself, and a nearly flat slope. These overbank depths and side slopes are used to calculate bank suction. The shallower the overbank and the steeper the side slope, the greater the computed bank force. The hydrodynamic module that computes bank force requires that the overbank depth be less than the channel bottom. It is important to note that the overbank depth is only used to calculate the bank force and does not necessarily mean that the vessel grounds in that area. A small difference (1 to 2 ft) in channel bottom and overbank depth produces negligible bank forces and moments.

The channel depths at each of the eight points were provided by the math model that computed the current magnitudes and directions.

Visual Scene

The Visual Scene data base was created from the same maps and charts noted in the discussion of the channel source. Aerial and still photographs and pilot's comments obtained aboard a transiting ship during a reconnaissance trip to Sacramento constituted another source of information for the scene. These allowed inclusion of the significant physical features and also helped determine which, if any, features the pilots use for informal ranges and location sightings.

All aids-to-navigation such as buoys, channel markers, the bridge, buildings, and tanks were included in the visual scene.

The visual scene is generated in three dimensions: North-South, East-West, and vertical elevation. As in the development of the channel data base, the state planar coordinate system was used. As the ship progresses through the channel, the three dimensional picture is constantly transformed into a two dimensional perspective graphic image representing, the relative size of the objects in the scene as a function of the vessel's position and orientation and the relative direction and position on the bridge for viewing. The graphics hardware used for the Sacramento project is a stand-alone computer (Silicon Graphics - Iris 2300) which is connected with the main computer to obtain information for updating the viewing position and orientation. This information includes parameters such as vessel heading, rate-of- turn, forward and lateral velocity, and position. Also, the viewing angle is passed to the graphics computer for the look- around feature on the simulator console which encompasses only a forty degree arc. This feature simulates the pilot's ability to see any object with a turn of his head. The pilot's position on the bridge can also

be changed from the center of the bridge to any position wing to wing to simulate the pilot walking across the bridge to obtain a better view, e.g. along the edge of the ship from the bridge wing.

It may be noted that the creation of a scenario for the project area is very demanding in terms of engineering judgment. The goal of the scenario is to provide all the required data without excessive visual clutter, bearing in mind the finite memory storage and computational resources available on the minicomputer.

Radar

The radar data base is used by the Geneisco graphic image generator to create a simulated radar for use by the test pilots. The radar data base contains X and Y coordinates which define the border between land and water. The file also contains coordinates for any structure which is built or extends into the water such a bridges and aids-to-navigation. In short, this data defines what a pilot would actually see on a shipboard radar. The radar image is a continuously updated view of the vessel's portion relative to the surrounding area. Three different ranges of 0.5 mile, 0.75 mile, and 1.5 miles were programmed in order for the pilot to choose the scale needed.

Currents

A current data base contains current magnitude and direction at eight points across the channel at each of the cross sections defined in the channel. Channel bottom depths are also given at each these eight points and are included in the channel definition.

Current data were modeled by Resource Management Associates (RMA). The modeling techniques used by RMA are covered in King and Rachiele.[1]

Both ebb and flood tides were used for outbound runs. Time limitations on testing allowed for only one tide condition to be tested on inbound runs. Based on conversations with the pilots, flood tides were chosen as the current condition for inbound runs because they presented the "worst case scenario". After completing their required tests, a few pilots had time to run slack tide for inbound or outbound. The slack tide tests were conducted in order to test the effects of fresh water inflow as the dominant source of current. These slack tide currents, while less in magnitude than the ebb tide, had different current

[1] Ian P. King and Richard R. Rachiele. (1988). "Simulation of the Sacramento River Deep Water Channel," RMA 8801, prepared by Resource Management Associates, Lafayette, CA, for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.