1-1-1992

Revised Hydraulic Design of the Los Angeles County Flood Control System

Michael E. Mulvihill
Loyola Marymount University

Scott E. Stonestreet
US Army Corps of Engineers

Published in Hydraulic Engineering: Saving a Threatened Resource—In Search of Solutions: Proceedings of the Hydraulic Engineering sessions at Water Forum '92.
Baltimore, Maryland, August 2–6, 1992. Published by American Society of Civil Engineers.

Revised Hydraulic Design of the Los Angeles County Flood Control System

Michael E. Mulvihill[1], M ASCE and Scott E. Stonestreet[2]

Abstract

The US Army Engineer District, Los Angeles, recently completed a study regarding the adequacy of an existing flood control system in Los Angeles County. Results of this study indicate that the level of protection afforded by the system is as low as 25-year in heavily urbanized areas. The Corps of Engineers plans to increase the capacity in two mainstem channels, raising the level of protection to greater than 100-year, by constructing parapet walls on top of existing levees and modifying constrictive bridges. A physical model study will be conducted to aid in analysis of complex design problems and will provide opportunities to develop new designs and design criteria.

Introduction

The US Army Engineer District, Los Angeles, has completed a major review study of the Los Angeles County Drainage Area (LACDA) to determine the adequacy of the existing flood control system.

The LACDA watershed area, shown on Figure 1, has varied terrain consisting of precipitous mountains, low-lying foothills, valleys, and coastal plains. The majority of urban development is found on flat alluvial plains and uplifted terraces which are surrounded by various mountain ranges. Ground elevations vary from sea level to 11,000 feet. The watershed feeding the mainstem system covers 1459 square miles, a large percentage of which is

---

[1]Professor of Civil Engineering, Loyola Marymount University, 7101 W. 80th St., Los Angeles, CA 90045; Hydraulic Engineer, US Army Corps of Engineers, Los Angeles District, PO Box 2711, Los Angeles, CA 90053

[2]Hydraulic Engineer, US Army Corps of Engineers, Los Angeles District, PO Box 2711, Los Angeles, CA 90053

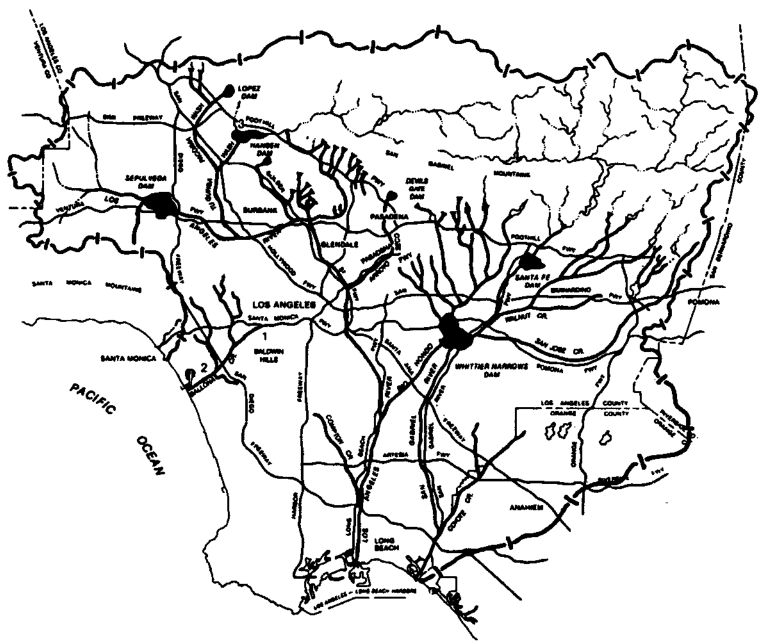

Figure 1 Los Angeles County Drainage Area (LACDA)

urbanized, and crossed by three major rivers: the Los Angeles, Rio Hondo, and San Gabriel.

The existing flood control system includes 20 dams, 129 debris basins, and 240 miles of improved flood control channels. Flow in the channels varies between subcritical and supercritical with critical depth controls located at bridges, grade breaks, and channel transitions. Along some reaches, unstable flow (i.e. Froude numbers of 0.86 to 1.13) exists for long distances in the improved channels since the concrete inverts were constructed approximately at critical slope.

Flooding Problem

The LACDA flood control system was constructed as a result of destructive floods in 1914, 1934, and 1938. The system was initially designed with approximately a 50-year overall level of protection. However, based on a longer period of record and denser urbanization than originally anticipated, it appears that some reaches of the system have only a 25-year level of protection. Unfortunately, many of these deficient reaches include leveed channels located in highly urbanized areas.

Proposed Plan

As a result of the review study, the Corps of Engineers, along with the Los Angeles County Department of Public Works plans to increase the capacity of two mainstem flood control channels by constructing concrete parapet walls on top of the existing channels levees and walls for a distance of about 17 miles. Additionally, it is proposed that a total of 26 highway, railroad, and utility bridges be raised or modified at locations where they currently constrict the flow.

As discussed above, long reaches of unstable flow will occur in the improved flood control channels at the revised design discharge. Undesirable wave action may be caused by the unstable flow requiring additional wall height for containment.

The large number of bridge modifications increases the overall cost of the project significantly. The average cost for a highway bridge modification is estimated at five million dollars.

Physical Model Study

Due to the uncertainties associated with a project of this size and its complexity, the US Army Engineer District, Los Angeles, decided to conduct a physical model study of three selected channel reaches. Physical models totalling a prototype distance of over 13 miles are currently being constructed and tested at the Waterways Experiment Station in Vicksburg, Mississippi. The purpose of the model study is to eliminate uncertainties associated with unstable flow and to test innovative designs which will increase the hydraulic capacity of existing bridges and thus eliminate the need for expensive bridge modifications.

Innovative Designs

A schedule, or matrix, for testing has been developed for the physical model study which outlines a scheme for testing each bridge modification (see Figure 2). In general, the existing configuration of each bridge will be tested to determine its capacity and the condition of flow through the piers. Where necessary, bridge modifications will be tested from least to most expensive, the most expensive usually being complete reconstruction of a bridge.

When the flow capacity under an existing bridge is found to be inadequate, the first modification to be considered depends on the type of flow at the bridge and possibly the flow regime of the open channel in the vicinity

ALTERNATIVE BRIDGE MATRIX
FOR RIO HONDO CHANNEL
(Reach 1)

BRIDGE	Existing Conditions	Pier Extensions	Streamline Soffit	Smooth Sides	Adjust Slope	Transition w/in Channel	Transition w/in R/W	Raise Bridge	New Bridge	Diversion Channel
Whittier	●	●	●		●	●	●	●	●	●
UPRR	●	●			●					●
Diversion Strct.	●				●		●			●
Washington	●	●	●		●					●
AT & SFRR	●	●	●	●	●	●	●	●	●	●
Slauson	●	●	●	●	●	●	●	●	●	●
PERR	●	●		●	●	●	●	●	●	●
Telegraph	●									
Santa Ana Fwy	●									
Suva	●	●	●	●	●	●		●	●	
Florence	●	●	●	●	●	●		●	●	
SPRR	●	●		●	●	●		●	●	
Firestone	●	●	●	●	●	●		●	●	

ALTERNATIVE BRIDGE MATRIX
FOR LOS ANGELES RIVER
(Reaches 2 & 3)

	BRIDGE	Existing Conditions	Pier Extensions	Streamline Soffit	Smooth Sides	Adjust Slope	Transition w/in Channel	Transition w/in R/W	Raise Bridge	New Bridge	Diversion Channel
Reach 2	Century Fwy	●									
	Standard Oil Util	●		●		●	●		●	●	
	Rosecrans	●	●	●		●	●		●	●	
	Compton	●	●	●		●	●		●	●	
	Alondra	●									
	Atlantic	●	●	●		●	●	●	●	●	
	Artesia Fwy	●									
	Artesia Blvd	●									
	Long Beach	●	●	●		●	●	●	●	●	
Reach 3	Del Amo	●		●		●	●	●	●	●	
	UPRR	●					●	●		●	
	LA-LB Lite Rail	●	●			●	●	●	●	●	
	San Diego Fwy	●									
	Union Oil Util	●									
	Wardlow	●									
	Texas Oil Util	●	●	●		●	●	●	●	●	
	Willow	●		●		●	●	●	●	●	
Other	Pacific Coast Hwy	●									
	PERR	●									

Figure 2 Alternative bridge matrix

of the bridge. For example, at bridges located in supercritical reaches with critical depth occurring at the bridge, pier extensions will be tested. Pier extensions may increase the capacity of a bridge in this situation by forcing the critical depth control to move upstream, out from under the bridge deck.

At bridges located in subcritical channel reaches, additional capacity may be added by locally widening the channel or adjusting the invert slope such that flow may be accelerated and "shot" under a bridge. At some bridges, a combination of modifications will be necessary in order to increase the flow capacity.

Channel Verification

A channel verification program has just been initiated by the US Army Engineer District, Los Angeles to determine the hydraulic roughness of flow in a concrete channel. Specifically, this study will focus on the effective roughness of concrete with supercritical flow.

A reach of the Rio Hondo flood control channel immediately below the Whittier Narrows Flood Control Basin has been selected for the initial detailed prototype study. A series of staff gages has been painted along this 2700-foot long reach of concrete, trapezoidal channel. Discharges are determined by a

USGS gaging station located in this reach in combination with detailed reservoir release data from the dam.

At the time of this writing, two significant reservoir releases have occurred and observations of the resulting profiles made (see Figure 3). The peak of the first discharge was 15,700 cfs and the peak of the second was 5320 cfs. Manning's n-values calculated for these discharges are 0.0123 and 0.0102, respectively.

These n-values translate into an equivalent roughness height, k, of 0.00076 and 0.00013 feet, respectively, which is independent of the depth of flow. Current Corps guidance suggests that a minimum k-value of 0.002 be used for velocity determinations in concrete channels and 0.007 be used for designing top of wall elevations.

The above results represent only two data points and are insufficient to draw any hard conclusions regarding the appropriate hydraulic roughness associated with supercritical flow in concrete channels. However, these results are a starting point for further data collection and investigation.

Additional hydraulic channel verification locations will soon be established at other locations where discharges are well measured and where

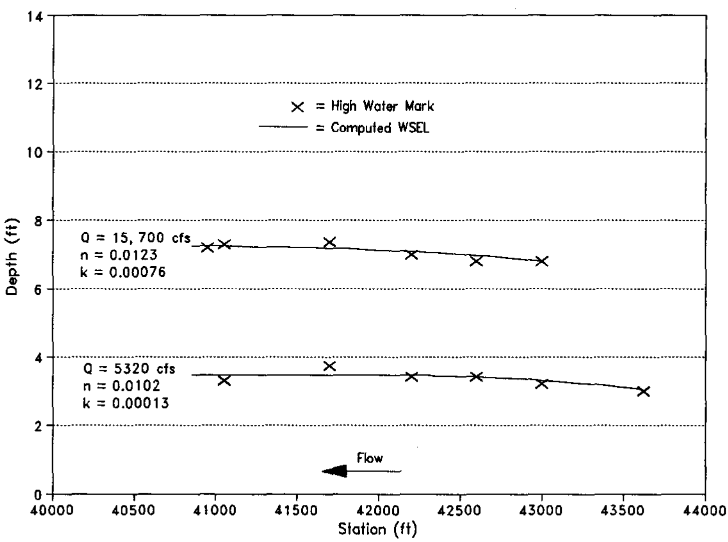

Figure 3 Observed and computed profiles for Rio Hondo channel

significant discharges occur on a relatively frequent basis. This verification program will focus on hydraulic phenomena such as waves, unstable flow, and hydraulic roughness in supercritical, concrete prototype channels. Channel observers are armed with video cameras and wet weather gear in order to document the flow during floods.

Summary

An extensive physical model study is being undertaken as the next phase of the Los Angeles County flood control system study. The fluctuations in water surface associated with depths of flow in the unstable zone will be delineated in the model. This will provide information necessary to set the heights of the required parapet walls. Additionally, a variety of physical modifications at bridges will be tested to determine if the existing bridges can be retained. It is anticipated that several bridges will be saved. A systematic testing program will be employed to reduce the number of tests. However, sufficient tests will be conducted so that the model results may also be used to develop new design criteria for future use by hydraulic design engineers.

When sufficient results of the recently instituted hydraulic verification program described in this paper are available, they will be used to assist design engineers in selecting roughness coefficients for future channel designs.

Appendix I. Conversion Factors, Units of Measurement

To Convert	To	Multiply By
foot (ft)	metre (m)	0.305
mile (mi)	kilometre (km)	1.6
square mile (mi^2)	square kilomtre (km^2)	2.59
cubic foot per second (cfs)	cubic metre per second (m^3/s)	0.0283

Appendix II. References

US Army Engineer District, Los Angeles. 1991. "Los Angeles County drainage area review, feasibility report, draft interim report and environmental impact statement."

Scott E. Stonestreet, H.L. Chu, and Michael E. Mulvihill. 1990. Critical flow through bridge piers. In Hydraulic engineering: Proceedings of the 1990 national conference, by the American Society of Civil Engineers. New York: American Society of Civil Engineers, 1054-1059.