PROCEEDINGS

ENGINEERING WORKSHOP
ON
STORMWATER MANAGEMENT

May 8, 1993

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CALIFORNIA STATE UNIVERSITY, LONG BEACH

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American Society of Civil Engineers
Los Angeles Section, Orange County Branch

and

Department of Civil Engineering

California State University, Long Beach

EAST GARDEN GROVE-WINTERSBURG (CO5) AND OCEANVIEW (CO6) CHANNEL INUNDATION STUDY USING THE DIFFUSION HYDRODYNAMIC MODEL

by

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ABSTRACT

A flood flow inundation study for a fully urbanized area was performed by using the two-dimensional Diffusion Hydrodynamic Model (DHM) as prepared for the USGS in 1987 and modified for Orange County Environmental Management Agency (OCEMA) needs. In this study, all of the local pipe flow drainage systems, pump station, retarding basins, and regional flood control channels were modeled by the DHM as one-dimensional unsteady flow elements. Flood flows were pursuant to the OCEMA design storm specifications found in that Agency's Hydrology Manual. Because the DHM is a fully dynamic unsteady, two-dimensional flow model, both the temporal and spatial flood plain characteristics are estimated. The DHM has been extended to include hydraulic effects for OCEMA study needs.

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INTRODUCTION

In general, flood plain studies are based on an one-dimensional steady-state flow analysis. Flood depths are calculated by assuming normal depth in wide, shallow rectangular sections taken parallel to major contour lines. The overflow boundaries are determined by judgment, and inspection of overflow maps and aerial photographs of historical floods. The above procedures are strictly subjective to the analyst. The DHM computer program used in the current study is a two-dimensional, unsteady flow model which simplifies the two-dimensional St. Venant equations to eliminate local acceleration and inertial terms, and combines the simplified flow equations with the equation of continuity to form a set of diffusion-type partial differential equations. Because the DHM provides a two-dimensional hydrodynamic response, use of the model eliminates the uncertainty in predicted flood depth due to variability in the choice of cross-sections used in the one-dimensional models. Additionally, the DHM accommodates storage, backwater effects, and unsteady flow. In this study, all of the local pipe flow drainage systems, pump stations, and retarding basins were modeled by the DHM as one-dimensional unsteady flow elements. For details regarding the development and verification of the DHM, the reader should refer to the U.S.G.S. Water Resources Investigations Report 87-4137 (Hromadka and Yen,1987).

STUDY AREA

The Orange County Flood Control District's East Garden Grove-Wintersburg Channel (facility C05) and its tributary Ocean View Channel(C06), drain an area of approximately 18,000 acres (28.13 square miles) within the cities of Anaheim, Fountain Valley, Garden Grove, Huntington Beach, Orange, Santa Ana, and Westminster. The watershed (see Figures 1 and 2) lies on a flat coastal plain and is generally bounded by the Santa Ana River to the east, Talbert Valley watershed (facilities D01, D02, and D05) to the south, the Pacific Ocean to the west and the Westminster Channel watershed (facility C04) to the north.

DHM MODELING APPROACHES

In this inundation study, a DHM model was used to analyze the existing flood control systems for t-year events (i.e., 100-, 50-, 25-, and 10-year design storms). The DHM model encompasses the entire C05/C06 watershed. The local terrain slopes southwesterly at a mild gradient (about 0.1% to 0.4%) and is fully developed with mixed residential and commercial land development. The storm runoff is collected by the local storm drain systems and then transported to the C05/C06 channel system, which in turn conveys the storm water into Bolsa Chica Marsh and ultimately the Pacific Ocean at Anaheim Bay.

The DHM flood plain grid schematic, using a 1000-foot grid discretization, is shown on Figure 3. Mean ground elevations for each grid were estimated from U.S.G.S. topographic 7.5 minute quadrangle maps (2000 scale). Not all of the grid area is assumed to carry storm flow. to Account for flow obstructions such ad buildings, an average value of 30-percent of the total grid area is used as the effective grid area for fully developed areas. Average street section flow widths within each grid element are estimated to be a total of 100 feet with a Manning's roughness coefficient of 0.02. Thus, the global Manning's roughness coefficient for each 1000-foot grid is 0.20 (i.e., 0.02*1000 feet/ 100 feet) except in locations including open areas where a Manning's roughness coefficient of 0.05 is used, and freeway underpasses where an effective flow path factor and Manning's roughness coefficient of 0.02 are used.

The DHM model was developed with the following elements:

Freeway Element

The Santa Ana Freeway, the Garden Grove Freeway, and the San Diego Freeway are major topographic features in the watershed. In addition to flowing through flood control channels, storm runoff may flow through freeway underpasses, which carry streets and railroads. An effective flow path and the roughness coefficient of n = 0.02, was used to simulate the hydraulic characteristics for all the freeway underpasses. Table 1 lists the effective widths and freeway elements at each freeway underpass which conveys surface runoff under the freeway embankments.

Table 1.
FREEWAY UNDERPASSES & GRID ELEMENTS

Location	Grid Element Number	Width of Underpass
Old Southern Pacific Railroad at I-5 Freeway	(786,769)	20 feet
Garden Grove Boulevard at 22 Freeway	(714,618)	100 feet
Harbor Boulevard at 22 Freeway	(675,833)	120 feet
Trask Avenue at 22 Freeway	(622,563)	80 feet
Newhope Street at 22 Freeway	(649,527)	200 feet
Euclid Street at 22 Freeway	(823,827)	100 feet
Taft Avenue at 22 Freeway	(824,919)	60 feet
Brookhurst Street at 22 Freeway	(903,915)	100 feet
Magnolia Street at 22 Freeway	(898,910)	100 feet
Beach Boulevard at 405 Freeway	(280,255)	120 feet

Culverts that convey storm runoff through the freeways are identified in Table 2. Estimated depth-versus-discharge relationships are used to represent freeway culvert hydraulics.

Table 2
FREEWAY CULVERTS & GRID ELEMENTS

Location	Grid Element Number
State College Boulevard at I-5 Freeway	(786,759)
Katella Avenue at I-5 Freeway	(762,745)
Orangewood Avenue at I-5 Freeway	(773,752)
C05 at 22 Freeway	(700,601)
C05 at 405 Freeway	(309,260)
C06 at 405 Freeway	(353,267)
Newland Avenue at C06	(245,246)
C05 at Tide Gate	(1)

Storage Element

A storage element is a special flood plain element which has a specified depth versus storage relationship other than the ordinary grid flood plain element. For an ordinary flood plain element, the flood depth is calculated by dividing its flood flow volume by its effective area. On the other hand, the flood depth at storage element is determined from a user-specified depth-versus-storage relationship. The outflow from the storage element is based upon the specified depth-versus-discharge relationship which differs from the regular flood plain element which conveys flood flow based on the two-dimensional unsteady flow equations.

There are two retarding basins (Haster and West Street Basins) on the north side of the Garden Grove Freeway, and three storage facilities (Talbert Lake, Huntington Lake and Sand and Gravel Pit) in the City of Huntington Beach. The storage-elevation-discharge relationships were obtained from the feasibility study of the East Garden Grove-Wintersburg Channel by the U.S. Army Corps of Engineers (1988). In this study, the initial water elevations for the Haster and West Street Basins are assumed to be flow line elevations at the outlet structures. For other storage facilities (Talbert Lake, Huntington Lake and Sand and Gravel Pit) which are not Orange County Flood Control District Facilities, the initial water surface elevations are assumed to be at spillway elevation, i.e. no flood control storage was assumed.

Channel Element

A Channel element can be described as a trapezoidal section which is situated at the center of a flood plain element. The relative depth of the channel is defined as the difference between the representative flood plain and channel bottom elevations as shown in Figure 4. The relative levee height of the channel is defined as the difference between the top-of-berm elevation and the representative flood plain elevation. It is assumed in the flood plain and channel interface model that overflow from the channel is evenly distributed to the associated flood plain element, and the overland flow that enters the channel is tributary from the entire flood plain element. Thus, the interface model serves as a source/sink model for an associated DHM grid element.

Surcharged Pipe Element

The surcharged pipe element can be used to model the closed conduit drainage systems. It assumes a circular pipe system flowing under pressure with a hydraulic grade line that coincides with the water surface elevations of the connecting flood plain elements or flood plain and channel elements as shown in Figure 5. Non-circular pipe systems were converted into equivalent circular pipe systems for the entire study area. Flood water is transported in a surcharged pipe element by first calculating the friction slope corresponding to the water surface elevations of two connecting elements. By Manning's equation, flood water is transported between these two connecting elements and results in a discrete instantaneous change in water surface elevation at both connecting elements.

Pump Stations

There are five pump stations in the Cities of Huntington Beach and Fountain Valley. The Slater, Shields, and Marilyn Pump Stations convey storm water directly into the C05 Channel system. The Heil and Sandalwood Pump Stations pump storm water into a local storm drain system which eventually connects to the C05 Channel System. Simplified rating curves were used to model all pump stations.

T-Year Storm Events and Storm Centers

The temporal and spatial variabilities of a t-year storm event are simulated by applying different storm centerings over the entire C05/C06 watershed for each event. Due to the uncertainties of storm locations, six storm centers, which progressed from the top of the watershed to the C05 Bolsa Chica outlet, were used for each event to analyze the entire watershed response. Data from the Hydrology Report of East Garden Grove-Wintersburg Channel by Orange County Environmental Agency (OCEMA) were used to obtain effective rainfall information for the above-mentioned storm events and storm centerings.

Initial Conditions and Boundary Conditions

If the initial condition of the DHM modeling area is "dry" (e.g. zero flooding depth), the computer program initially advances its time domain in less than 1-second increments. This results in unreasonably long computation time. To speed computation, yet introduce negligible change in final calculated flooding depths, an initial flooding depth of 0.15 feet was assigned to the entire DHM modeling area. This depth is the average gutter-hike depth and allows the minimum modeling time to be set at 5 seconds.

Three types of outflow boundary conditions are used in the modeling area. "No flow" boundary conditions are assigned to the flood plain boundaries where no flow is allowed to cross. Surface water that migrates into neighboring watersheds without returning to the modeling area is modeled by critical depth boundary conditions. The third boundary conditions uses the specified rating curve (i.e. a depth-versus-discharge relationship) to model a control outlet structure. Rating curves are used to model the flow conditions at the C05 Bolsa Chica outlet, Haster Basin, West Street Basin, and channel undercrossings at various freeways and pump stations.

DHM MODELING RESULTS

For each t-year event, the maximum flood depths from all six storm centerings were compiled to model the worst possible flooding within the entire watershed. Figure 6 depicts the maximum flood depths in the study area for the 100-year event. Flooding may occur either by inadequate local storm drain system capacity or by inadequate regional (C05/C06) system Capacity, or a combination of both. The model showed that inadequate local storm drain system would cause local ponding and storage, in most cases less than 0.5 foot deep. Sufficient storm volume would be stored locally to significantly decrease the load on regional flood control facilities.

Even with this local storage, the model showed that West Street Basin would be overtopped during any t-year event. Haster Basin would not be overtopped, but would experience emergency spillway flow during the 25-, 50-, and 100-year events.

The model also showed two types of channel overtopping which might occur for the estimated flooded areas due to the interface between channel and flood plain elements. Type I overtopping indicates that the channel has limited capacity and the water surface elevations are the same for both the channel and flood plain elements. Type II overtopping indicates that water overtops the channel levee from flood plain element. Modeled regional type I overtopping areas along the C05 channel system are: near Anthony School in the City of Westminster, between Bushard Street and Brookhurst Avenue, downstream of 405 Freeway, between Golden West Street and Springdale Avenue, and Slater Pump Station. Modeled local type I overtopping areas are: Heil street storm channel (C5-SC-2) and Slater storm channel in the City of Huntington Beach. Most of the type I overtopping along the C05 channel system occurred for the t-year events. No type I or type II overtopping was modeled for the C06 Channel system for the t-year events. The causes of the type II overtopping may be due to either the deficiencies of the local storm drain systems or the cascaded flows from type I overtopping areas, or both. Modeled regional type II overtopping areas along the C05 channel system are: south of Bushard Street, upstream of 405 Freeway, and downstream of 405 Freeway.

The Corps of Engineers 1988 feasibility study reported five areas of significant potential flooding: C05 downstream of I-405 Freeway, Slater Pump Station, Edwards Street and Heil Avenue intersection, Newland Street and Warner Avenue intersection, and C06 downstream of I-405 Freeway. Because of different methodology used by the Corps study, inundated areas and flooding depths were different from the DHM modeling results.

Nevertheless, the same number of areas subject to potential flooding were identified by both studies. In general, DHM reported a greater number of local flood areas with shallower flooding.

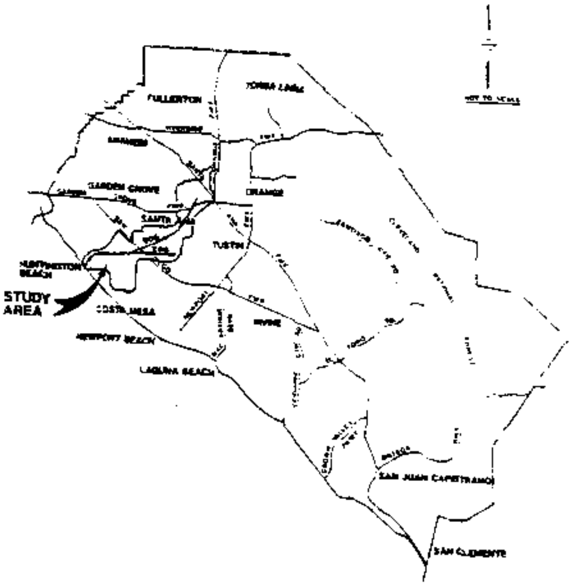


FIGURE 1. REGIONAL LOCATION MAP

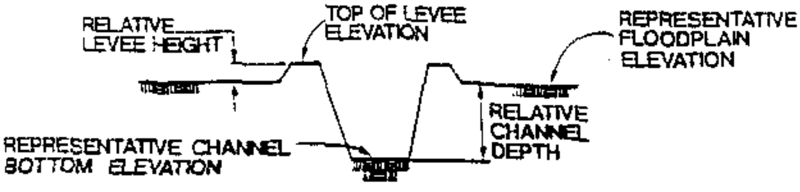
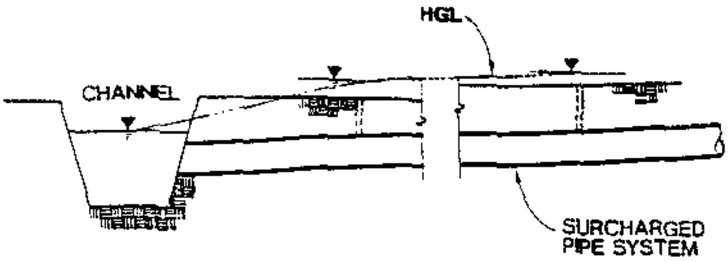


FIGURE 4. DHM MODEL TRAPEZOIDAL LEVEED CHANNEL ELEMENT



FIRGURE 5. DHM MODEL SURCHARGED PIPE ELEMENT

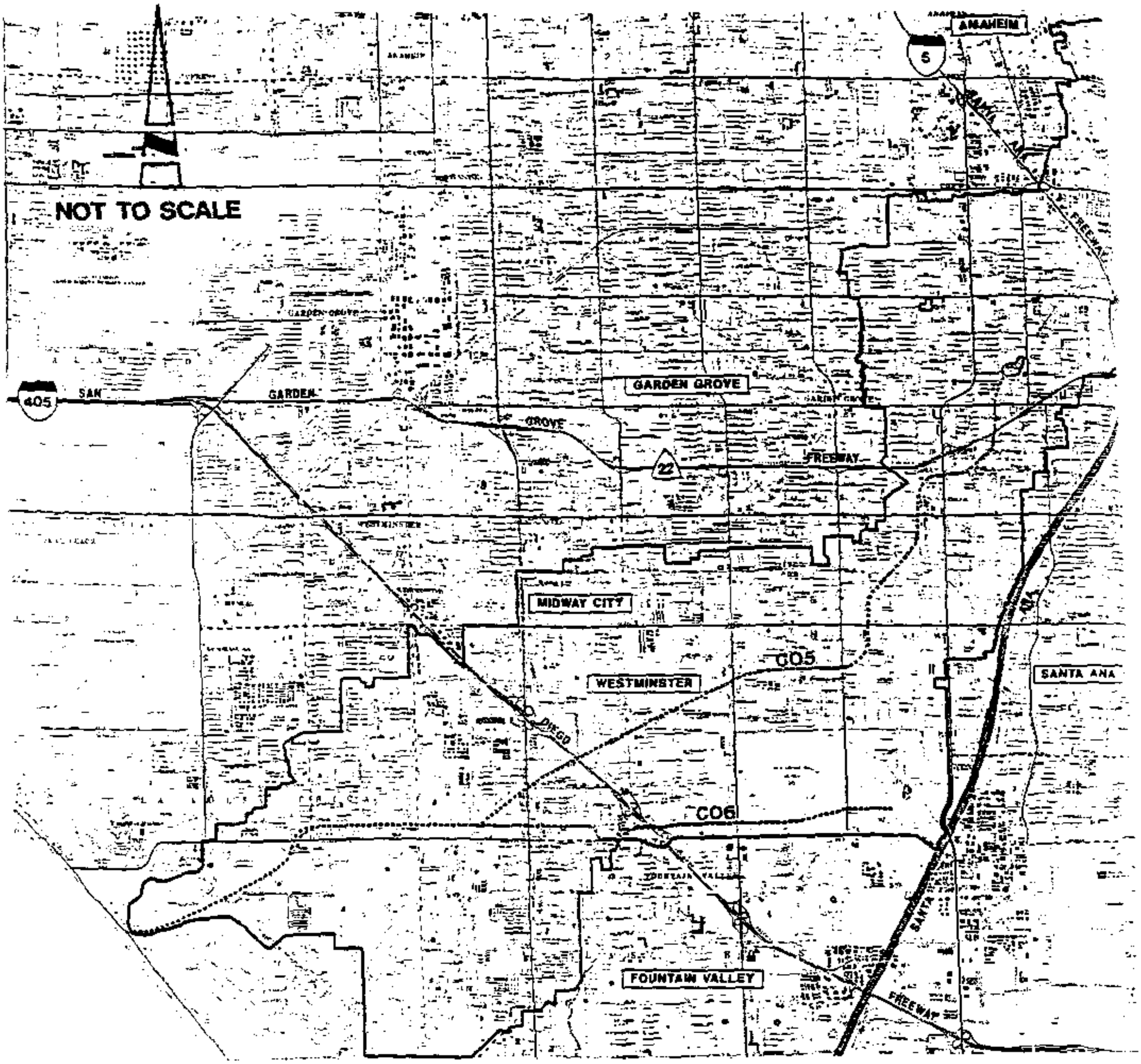


FIGURE 2. VINCITY MAP

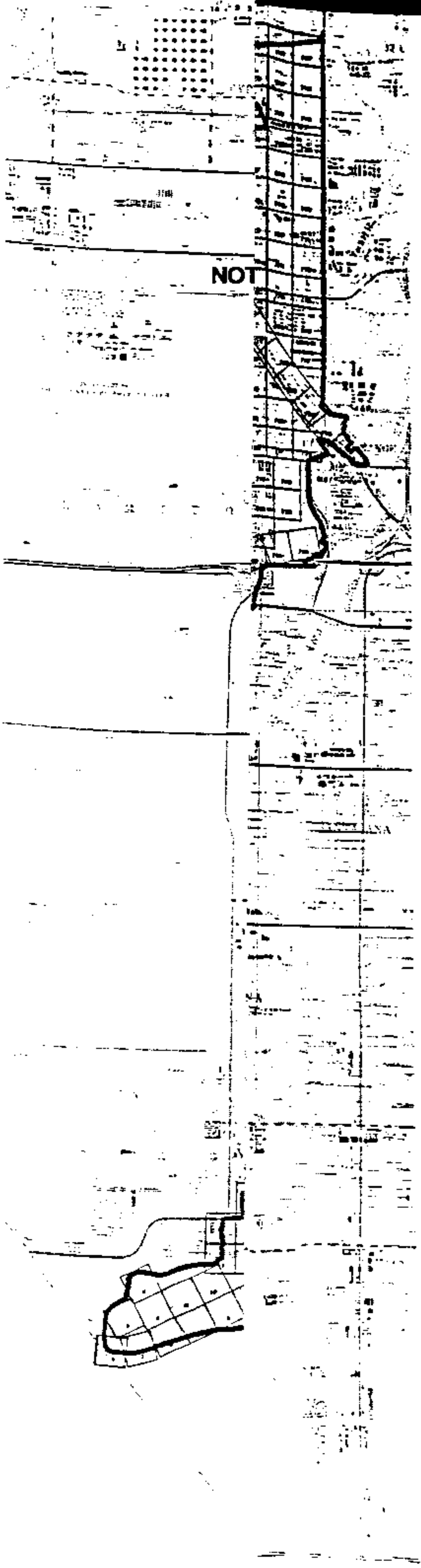


FIGURE 3. DHM MODEL

GRID NETWORK SCHEMATIC

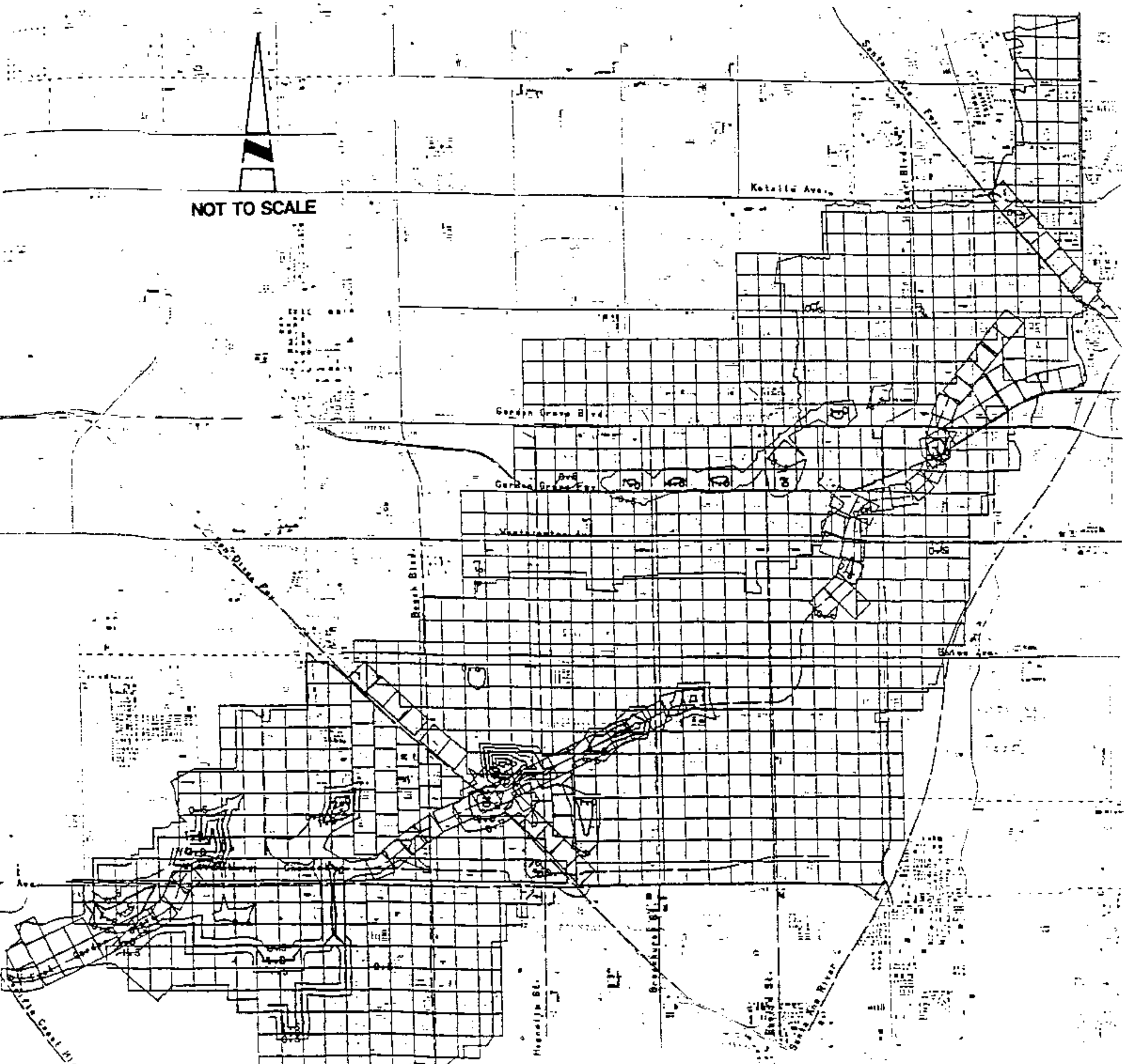


FIGURE 6. DHM MODEL RESULTS, 100-YEAR MAXIMUM FLOODING DEPTHS

CONCLUSION

DHM, a fully dynamic unsteady two-dimensional flow model was used to model a major regional drainage area. The DHM accommodates pipe flow drainage, pump stations, and retarding basins as one-dimensional unsteady flow elements; regional and overland flow as two-dimensional unsteady flow elements; and temporal and spatial storm centering over the watershed area. By applying different storm centering over the watershed area, the watershed response was analyzed under conditions of uncertainty of storm locations.

DHM proved to be a versatile and practical tool in modeling surface runoff problems related to regional flood protection. DHM significantly advances the current of the art for flood control system modeling and regional flood plain mapping.

A significant advantage conferred by the DHM analysis is the display of the aerial extent and depth of flooding under a wide range of recurrence intervals without the necessity of assigning, *a prior*, the flow paths for overbank flows. Such *a priori* flow path designation is a significant source of uncertainty in the results of non-dynamic models for the analysis of flood plains and is especially critical in watersheds with very flat transverse slopes or on alluvial fans where overbank flows may be spread widely and unpredictably from the main channel.

REFERENCES

1. East Garden Grove-Wintersburg (C05) and Oceanview (C06) Channels Inundation Studies prepared by Williamson and Schmid, 1992.

2. Hromadka II, T.V. and Yen, C. C., A Diffusion Hydrodynamic Model (DHM), U.S.G.S. Water Resources Investigations Report 87-4137, 1987.

3. Hydrologic Documentation for Feasibility Study, Santa Ana River Basin and Orange County, Interim 3, East Garden Grove-Wintersburg Channel, U.S. Army Corps of Engineers, Los Angeles District, 1988.

4. Hydrology Report for East Garden Grove-Wintersburg Channel, Orange County Environmental Management Agency, 1991.

5. Orange County Hydrology Manual, Orange County Environmental Management Agency, 1986.

6. Storm Drain Pump Station Analysis prepared for the City of Huntington Beach by L.D. King Engineering, 1979.

Question:

Is there a technical paper or manual available for the DHM?

Answer:

Yes, please see the paper's references.

Question:

Have you applied DHM to any calibrated storm events and compared the results of study with the actual flooding data?

Answer:

Perhaps the baseline test for evaluation purposes is the well-known Grand Teton Dam Failure. The DHM was evaluated for that case study.

Question:

Is the data (topo) used in the DHM an average of the topo in the 1-mile square?

Answer:

Yes

Question:

Assuming the former statement is true, does this imply the model should be used only in *constant slope* terrain?

Answer:

No. One selects grid sizes that accommodate variable topographic trends.

Question:

Have *modifications* been considered to include local effects i.e., walls, freeways, depressed/raised roadways?

Answer:

Yes. Such enhancements were developed for the subject C05 and C06 application.

Question:

How did you model levee degradation?

Answer:

Levee degradation is modeled as a channel outflow rate versus time.

Question:

At what point in time and space levee brake occurs?

Answer:

This is a specific condition of the problem.

Question:

Why use the Diffusion Hydrodynamic Model if its results compare closely to HEC and other modeling techniques?

Answer:

For studies where HEC or other modeling techniques are appropriate, other models may be so preferred.

Question:

What are DHM's specific advantages?

Answer:

The DHM is a fully dynamic, unsteady flow, two-dimensional coupled topographic, channel, and pipe flow routing model. HEC, and other similar models do not have these properties.