HYDROLOGIC/HYDRAULIC MODELING OF WESTMINSTER WATERSHED ORANGE COUNTY, CALIFORNIA

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Abstract: The Westminster Watershed is in the southwestern corner of Orange County, California. It includes portions of the cities of Anaheim, Cypress, Fountain Valley, Garden Grove, Huntington Beach, Los Alamitos, Santa Ana, Seal Beach, Stanton, and Westminster. The watershed is drained by a manmade channel system, which includes the Orange County drainage facilities East Garden Grove Wintersburg Channel (C05), Oceanview Channel (C06), Slater Channel (C05S04) and pump station, Haster Retarding Basin, and storm drains. These facilities collect storm runoff from a highly urbanized 27.3 mi^2 drainage area. The channel ends at the Pacific Ocean at Bolsa Bay in the city of Huntington Beach.

A watershed feasibility study was conducted for the Westminster Watershed. Orange County and the Corps of Engineers sponsored this study. The main objectives of the feasibility study was to address the flooding problems in detail, investigate potential measures and an array of associated alternative plans for the purpose of flood damage reduction, and identify the Federal interest in a recommended plan. A list of preliminary alternative measures was analyzed in this study. A secondary purpose was to investigate opportunities for ecosystem restoration.

A rainfall runoff model was developed for the watershed using HEC-1. The HEC-RAS model was developed with the help of HEC-GeoRAS and the county as-built drawings. Flow breakout analysis for the C05 and C06 channels were conducted using the HEC-RAS model. The starting breakout discharge for the C05 channel is 36% of the 100-year flood frequency flows or a discharge between 10-year to 15-year event; any higher flows would overtop the channel. The starting breakout discharge for the C06 channel is 32% of the 100-year flood frequency flows. This is roughly a discharge event between 5-year to 10-year return period. Several major technical issues had to be addressed and resolved as a part of the H&H analysis. First, the development of the rainfall runoff model required the consideration of the local sponsor's hydrologic methods. Second, the on-going piecemeal sponsor channel projects make it difficult to establish the baseline condition. Third, the watershed is in a relatively flat coastal alluvial floodplain that required numerous assumptions pertaining to channel capacity and levee breaches, and modeling applications with the non-Corps program FLO-2D. Lastly development/analysis of alternatives required working non-conventional means for flood damage reduction.

This paper will present the application of HEC-1, HEC-RAS, and FLO-2D models for the C05 & C06 channel system of the Westminster Channel Watershed. Model simulation results of the watershed based on the current condition and with project conditions will also be presented in this paper.

INTRODUCTION

The U.S. Army Corps of Engineers, Los Angeles District is currently conducting the Feasibility Phase of the Westminster Watershed Management Study, a cost shared effort between the U.S. Army Corps of Engineers and the Orange County Resources & Development Management Department (RDMD). Previously, RDMD was named Public Facility & Resources Department (PFRD).

The Westminster Watershed covers 74.1 square miles in the southwestern corner of Orange County. It includes portions of the cities of Anaheim, Cypress, Fountain Valley, Garden Grove, Huntington Beach, Los Alamitos, Santa Ana, Seal Beach, Stanton, and Westminster. There are three main channels that drain this watershed. The Los Alamitos Channel drains into the San Gabriel River. The Bolsa Chica Flood Control (BCFC) Channel empties into the Anaheim Bay-Huntington Harbor complex. The East Garden Grove-Wintersburg (EGGW) Channel drains through Bolsa Bay into Huntington Harbor. Figure 1 presents the Westminster Watershed boundary on the USGS quad map. The figure also shows the EGGW and BCFC channel systems.

This paper presents the hydrology and hydraulic analyses for the present without and with project conditions for East Garden Grove-Wintersburg (C05) and Oceanview (C06) channel system

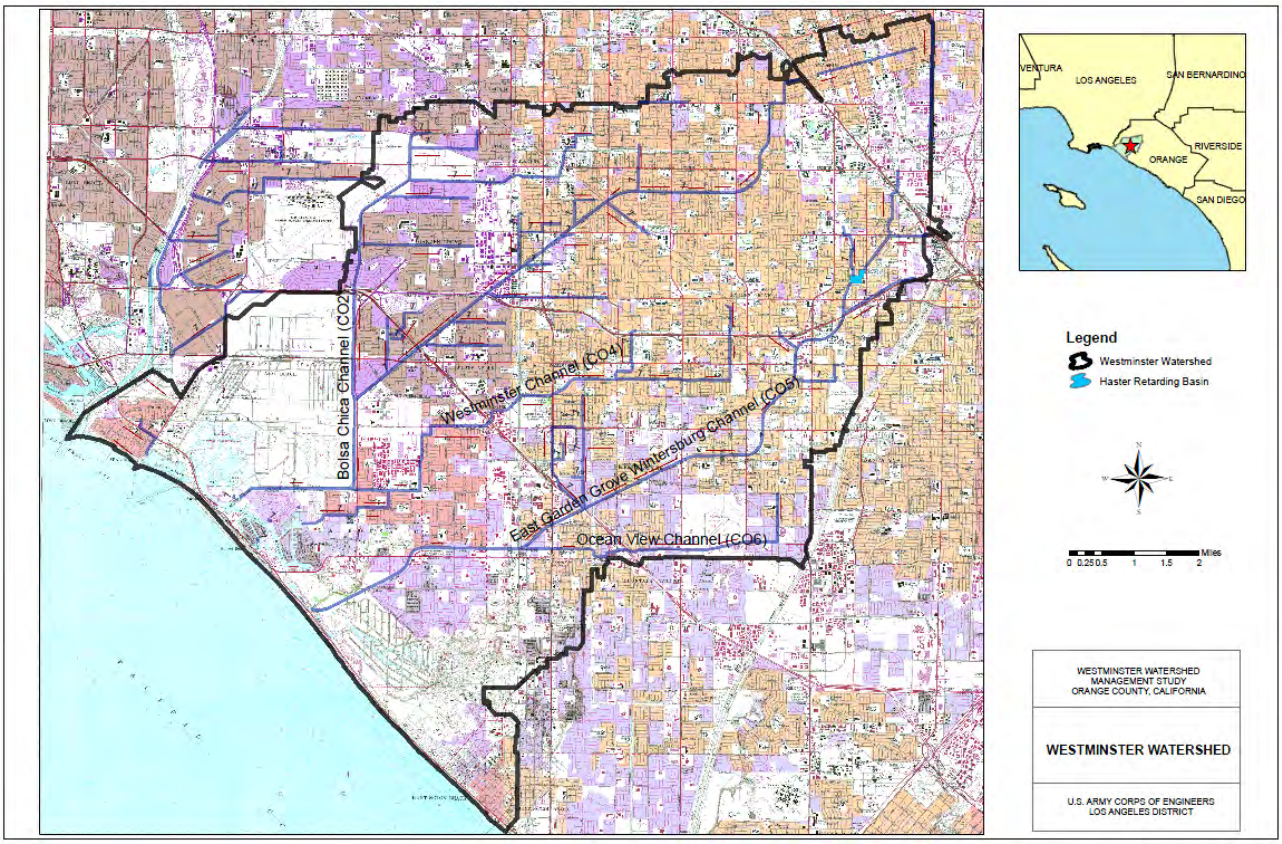

Figure 1 Westminster Watershed

HYDROLOGIC MODEL DEVELOPMENT

The East Garden Grove-Wintersburg Channel sub-watershed lies on a flat coastal plain. Figure 2 is an aerial photo of the C05 and C06 Channel System. The watershed is drained by a manmade channel system which includes the Orange County drainage facilities EGGW Channel (C05), Oceanview Channel (C06), Slater Channel (C05S04) and pump station, and storm drains. The only stream gage station at Gothard Street has limited records and was discontinued due to the tidal backwater conditions. San Diego Creek Watershed is adjacent to the Westminster Channel Watershed and has a similar hydrological characteristic. Using the computed 100-year discharge at San Diego Creek Culver Drive gage station to relate to EGGW Channel at Gothard Street, the 100-year discharge for a drainage area of 20 square miles is 8,000 cfs. The HEC-1 rainfall runoff model for EGGW Channel was calibrated to this value.

The calibration parameters were loss rates, basin n, base flow, and Muskingum channel routing parameters. Initial model parameters were assumed based on the Orange County Hydrology Manual (OCHM) guideline. Model runs were conducted and the model discharge values at the CP18 (Gothard Street) were compared to the discharge value of 8,000 cfs. Then, the model parameters were adjusted and new model runs were conducted. Through this iterative process the model was calibrated. The model calculated discharge at CP18 is 7,980 cfs which is 2% different from the calibration target value.

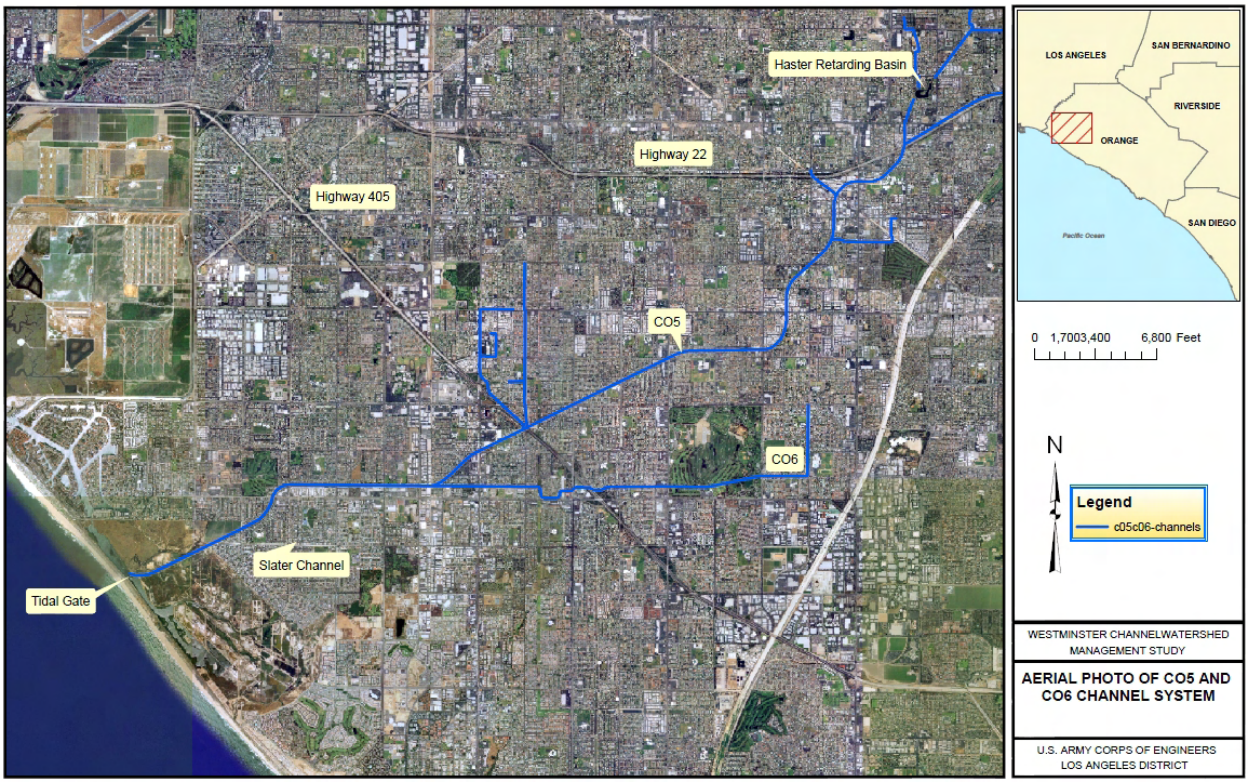

Figure 2 Aerial Photo of the C05 and C06 Channel System

Orange County RDMD also independently conducted a hydrology analysis for the C05 and C06 channel drainage area using OCHM procedures. Orange County Hydrology procedures were developed using stream gage data collected from all the county watersheds. The procedures include Orange County storm, rational method, and unit hydrograph. In the county's hydrology report, the 100-year expected discharge values were calculated at points of interest for the C05 and C06 channel drainage area. As mentioned earlier in this report, the HEC-1 model developed for this study by the Corps of Engineers was based on the Orange County storm and county suggested parameters. The model was calibrated against the adjacent watershed stream gage data. Therefore, it will be beneficial to further compare the county's 100-year expected discharge values with the calibrated HEC-1 model results. Table A presents the comparisons between Orange County 100-year expected discharge values and the calibrated HEC-1 model results for the C05 & C06 drainage area. As shown in the table, the calibrated model results are very close to the County's results. The differences between the two models simulated values range from 0.2% to 7.9%. The comparison serves as verification for the HEC-1 model. In summary, the HEC-1 model was calibrated with an adjacent watershed stream gage data and then verified with the Orange County hydrology analysis results. Figure 3 shows the C05 & C06 sub-drainage areas and the simulated Hydrograph.

Table A – Comparisons between Orange County & HEC-1 100-year Discharge Values for C05 & C06 Drainage Area

Concentration Point	Drainage Area ($mile^2$)	County Q (cfs)	HEC-1 Model Q (cfs)	Difference in cfs	Difference in %
C05-CP2	3.47	990	980	10	1.0
C05-CP4	4.30	1540	1520	20	1.3
C05-CP6	6.84	3380	3330	50	1.5
C05-CP8	7.94	3790	3720	70	1.9
C05-CP10	9.54	4530	4460	70	1.6
C05-CP12	10.58	4770	4780	-10	-0.2
C05-CP14	11.91	5150	5210	-60	-1.1
C05-CP16	14.48	5910	5980	-70	-1.2
C05-CP18	20.37	7710	7980	-270	-3.4
C05-CP20	22.76	8300	8420	-120	-1.4
C05-CP22	27.70	9290	9340	-50	-0.5
C05-CP23	28.02	9290	9260	30	0.3
C06-CP2	1.12	920	920	0	0.0
C06-CP4	2.19	1280	1280	0	0.0
C06-CP6	3.20	1770	1640	130	7.9
C06-CP8	3.84	2020	2030	-10	0.5
C06-CP10	4.83	2310	2320	-10	0.4
C06-CP12	5.28	2420	2410	10	0.4

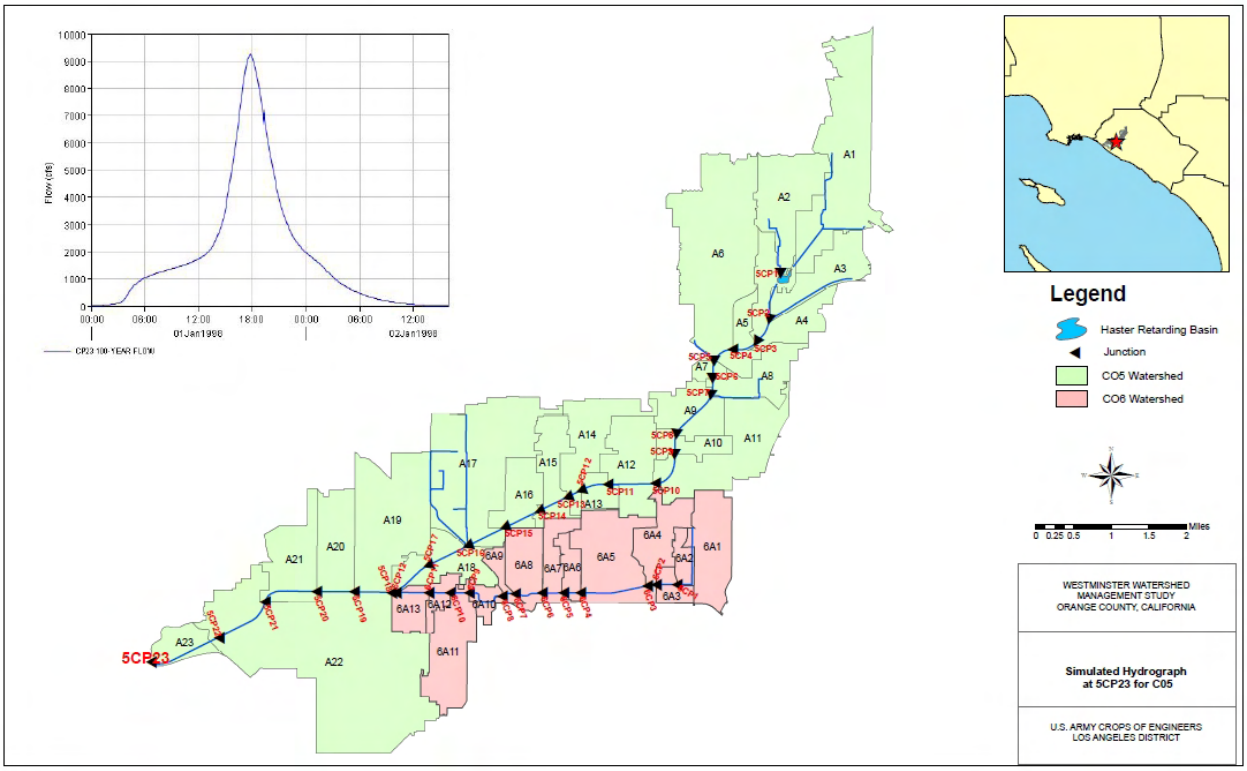

Figure 3 Sub-Drainage Areas and Simulated Hydrograph of the C05 and C06 Channel System

HYDRAULIC MODEL DEVELOPMENT

Channel Hydraulic Simulations The C05 & C06 channel system was separated into the following two reaches:

Reach 1 – EGGW Channel (C05) from the Haster Retarding Basin to the Tidal Gate.
Reach 2 – Oceanview Channel (C06) from the Newhope Avenue to the confluence with EGGW Channel (C05)

HEC-GeoRAS was used to assist the HEC-RAS model development. The model development included the processing of cross sections and bridges, defining Manning n-values and flow regime, and setting boundary conditions. The scope of this study included the hydraulic analysis of the entire EGGW Channel (C05) and Oceanview Channel (C06). After an extensive review of in-house and Orange County's available data, it was determined that as-built drawings were adequate to modify the channel geometry because these channels were man-made.

Profile computations began at a cross section with known or assumed starting conditions and proceeded upstream for subcritical flow or downstream for supercritical flow. The flow regime (subcritical, supercritical, or mixed flow regime) was specified on the Steady Flow Analysis window of the user interface. For the C05 & C06 system, the program was run in a mixed flow regime mode because the flow regime passed from subcritical to supercritical, or from supercritical to subcritical.

The general trend of the flow regime in the C05 and C06 channel system was subcritical flow because the slope of the channel was mild.

Flow breakout analysis for the C05 and C06 channels were conducted using the HEC-RAS model. Discharges for 2-, 5-, 10-, 15-, 20-, and 25-year events were tested for the C05 and C06 channels to find the frequency events when the breakout flow started to occur. The starting breakout discharge for the C05 channel was 36% of the 100-year flood frequency flows or a discharge between 10-year to 15-year event; any higher flows would overtop the channel.

The starting breakout discharge for the C06 channel was 32% of the 100-year flood frequency flows. This was roughly a discharge event between 5-year to 10-year return period.

The simulated breakout areas were compared and verified with the county's historical flooding records.

Overflow Simulations The Westminster watershed is in a coastal alluvial fan area. HEC-RAS model was used for the channel hydraulic analysis and breakout analysis as presented in the above section. For the overflow and floodplain analysis in the alluvial fan area, a two-dimensional model with volume and mass conservation simulation capacity was considered to be more appropriate. FLO-2D is a two-dimensional flood routing model with volume conservation capacity that can be used for delineating flood hazards and maps. The model was used to simulate floodplain maps for the C05 & C06 channel system. The 25-, 50-, 100-, 200-, and 500-year event floodplain maps were simulated in this study. During the simulation runs, overtop breakout and levee failure at the lower reach of the C05 channel was assumed.

To better examine the flooding area, the overflow map area was divided into lower, middle, and upper portions. The significant regions of flooding were the following for the 100 year frequency flood:

- Flooding south of the C05 downstream of the C05 and C06 confluence, inundating the nearby residential area east to Gothard Street and extending south into Bolsa Chica and to the Ocean.
- Flooding north of C05 downstream of the C05/ C06 confluence into the residential area.
- Flooding shown from 1st Street to the confluence of C05 and C06. Most of the flooding occurs between the two channels and the floodwaters co-mingle.
- Residential flooding from C05 from the Haster Basin to 1st Street occurs on both sides of the channel. The flooding extends west to the C04 channel.

The results were compared to historical flooding events of East Garden Grove Channel provided by the County of Orange. However, the associated discharges and frequencies were not available.

- Flooding at Graham Street in 1993
- Flooding at Warner Avenue in 1995
- Flooding at Springdale Street in 1995
- Flooding at Edwards Street in 1995

- Flooding at Goldenwest in 1974, 1983, 1993, 1995
- Flooding downstream of Newland 1995
- Flooding between Newland and Magnolia in 1992
- Flooding at Euclid Street in 1986 and 1992
- Flooding at 1st Street in 1992, 1995
- Flooding at Haster Basin in 1986 and 1995
- Flooding between Lapson Avenue and Chapman Avenue in 1992

Flooding events on Ocean View Channel:

- Flooding between Magnolia Street and Bushard Street
- Flooding between Bushard Street and Brookhurst Street
- Flooding between Euclid Street and Newhope Street

The 100-year flood event maps the entire channel flooding areas with exception to the flooding between Lapson Avenue and Chapman Avenue in 1992. Figure 4 shows the simulated 100-year overflow map for C05 and C06 drainage area using FLO-2D.

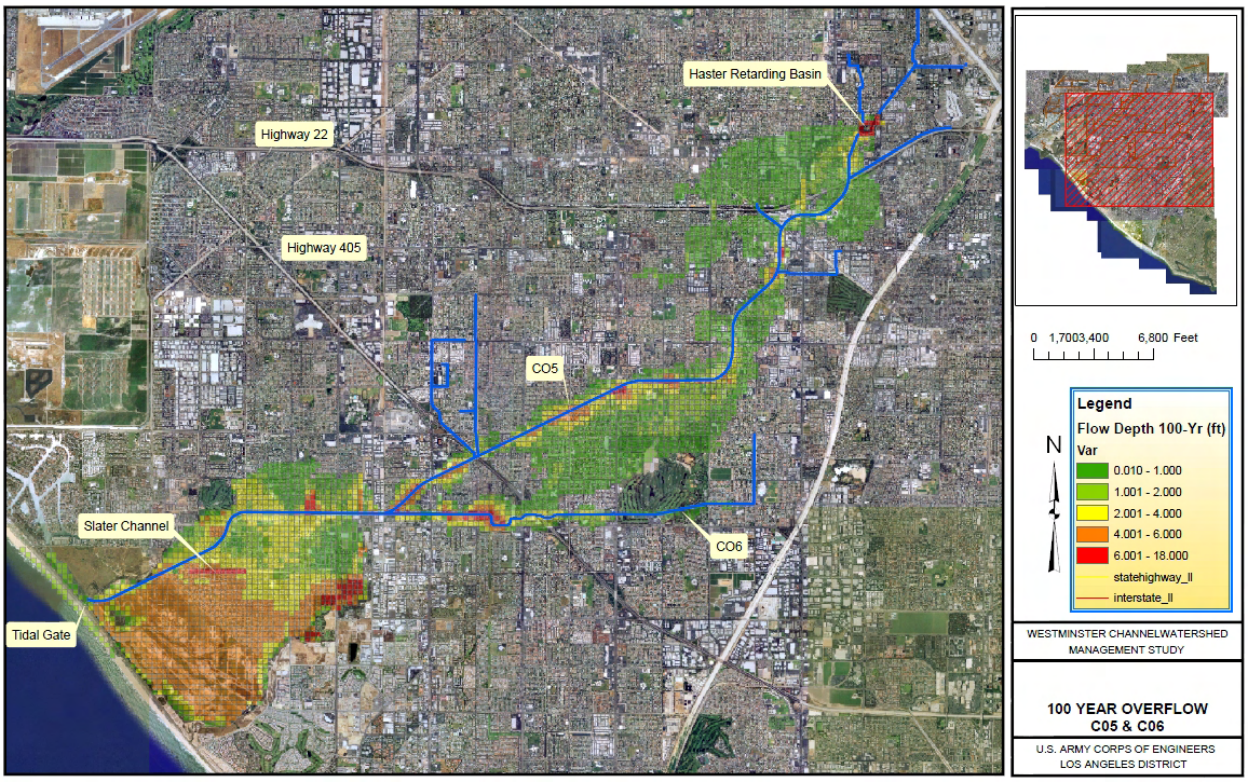

Figure 4 Simulated 100-Year Overflow Map for C05 and C06 Using FLO-2D

Flood Damage Analysis Normally, the HEC-RAS model would generate direct output data for the economic analysis using the Flood Damage Analysis (FDA) program. Since both the HEC-RAS and

FLO-2D models were used in this study, a special data arrangement based on the two models output was prepared for the FDA program. Water surface elevations for 1-, 2-, 5-, and 10-year events were simulated with HEC-RAS model for the FDA program. Water surface elevations for 25-, 50-, 100-, 200-, and 500-year events were simulated with the FLO-2D model for the FDA program. In addition to the special data arrangement, the baseline flood condition was defined and established for the FDA analysis. However, the county revised the study boundary and locally modified the channel configuration in piecemeal fashion during the study progress. This caused the definition of the baseline condition difficult.

SEDIMENT TRANSPORT ANALYSIS

As described in the Hydraulic Model Development, HEC-RAS model was developed for the C05 and C06 channel system based on the as-built drawings. The HEC-RAS model input file was converted directly using RAS2H6T into input file compatible to the HEC-6T program. A known water surface elevation of 5.36 ft was used as the downstream boundary condition for all discharges. This elevation corresponded to the mean higher high water (mhhw). The converted input file contained the geometry and hydraulics for the C05 and C06 channel system.

The Corps computer program SAMAID was used to select the most appropriate sediment transport relationship. SAMAID results indicated that the Laursen-Madden, Brownlie, and Schoklitch sediment transport functions were the first, second, and third best sediment transport relations for the hydraulic and bed material characteristics of the study reach. The Laursen-Madden transport function was used for this study.

Field inspection and the as-built drawings showed that most sections of C05 were rip-rap or concrete channels. Only the lower section of C05, downstream of Golden West Street, is a trapezoidal earthen channel. Three sections of C06 were trapezoidal earthen channels. Because the watershed was fully urbanized, there was limited or no sediment supply from upstream into the system. The sediment transport modeling showed that sedimentation or erosion may have only happened along the earthen channel sections. Therefore, sedimentation problems for the C05 and C06 channel system were negligible and no further analysis would be conducted.

PROJECT ALTERNATIVES

Seven project alternatives were analyzed for the C05 and C06 channel system. These included:

1. No action
2. 50-year flood protection channel improvement
3. 100-year flood protection channel improvement
4. 200-year flood protection channel improvement
5. Haster Basin improvement
6. Detention basin using Mile Square Park
7. Detention basin using Huntington Beach Central Park.

The initial economic analysis showed that annual damages for the C05 & C06 channel system were over $35 million for the current condition. As a result, the No Action alternative was not an acceptable alternative. The conventional flood control alternative generally use channel improvement. In this study, the channel improvement, the off-line detention basins, and a combination of the channel improvement alternative and the off-line detention basin were all analyzed and considered.

Detention basin alternatives were analyzed using the calibrated HEC-1 model. Approximately 3,300 cfs of flows from the C05 channel were redirected through a culvert to Mile Square Park detention basin. Through the C06 channel and the confluence area, water stored at Mile Square Park was then gradually directed back to the C05 channel.

The simulation results showed that for the 100-year storm the diversion flow into Mile Square detention basin would reach 1200 acre-feet within 6 hours. Once the detention basin storage reached 500 acre-feet, water would be redirected to the C06 channel and the C05 channel. The Muskingum-Cunge routing method was used in the HEC-1 model to calculate channel flow. The routing procedure showed insufficient C05 and C06 channel capacity downstream of Mile Square Park and downstream of the confluence due to the combined normal flow and the detention basin flow. Based on the 137 acres of available land, a 500 acre-feet detention basin would require a depth of 3.65 feet. In addition, a diversion channel or culvert about a mile long would be required for the connection of the C05 channel and the Mile Square Park detention basin. Based on the HEC-1 analysis, this alternative would cause more overflow downstream of the detention basin. A larger detention basin would require a larger area or deeper excavation, which would encounter groundwater problems. In summary, using Mile Square Park as a detention basin would not be analyzed further.

Huntington Central Park was also analyzed as a detention basin to reduce flood flow. Since the park is close to the confluence of the C05 and C06 channels, it may redirect flow from the C05 channel along Slater Avenue or Golden West Street to the park. The water stored in the park would be redirected back to the C05 channel or recharged to the groundwater aquifer. Redirecting water back to the C05 channel would require the construction of a 3-mile-long channel or culvert. Using groundwater recharge at the park to remove the flood flows may not be feasible due to the high groundwater table in the area. As mentioned above, the park has many facilities and activities therefore, available land for the use of a detention basin was very limited. Considering all the factors, the use of Huntington Central Park as a detention basin was not feasible.

Since the No Action, Detention Basin with Mile Square Park, and Detention Basin with Huntington Basin State Park alternatives are not feasible, the three channel improvement alternatives combined with the Haster Basin improvement are currently being analyzed. The results from the with-project hydrologic analyses will be used for the economic analysis and for the design studies.

CONCLUSION

This paper presents the hydrologic analyses for the present without (baseline) and with project conditions for EGGW(C05) and Oceanview(C06) channel system.

The baseline studies included hydraulic and sediment data collection, site visit, development of HEC-1, HEC-RAS, HEC-6T, and FLO-2D models, channel breakout analysis, simulation and delineation of floodplain, and sediment transport and erosion analysis. The baseline hydrologic analyses were used for economic/damage analysis. The economic/damage analysis showed that there is a federal interest for the project.

Seven project alternatives were analyzed for the C05 and C06 channel system. These include no action, 50-year flood protection channel improvement, 100-year flood protection channel improvement, 200-year flood protection channel improvement, Haster Basin improvement, detention basin using Mile Square Park, and detention basin using Huntington Beach Central Park. For the C05 and C06 channel system, the combination of Haster Basin improvement and the channel improvement alternative were recommended for economic analysis.

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