

Analysis of Flood Hazards for a Residential Development

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Abstract

An investigation was carried out to investigate the flood potential at a proposed residential development located in Indio, California. The existing floodplain area adjacent to the project area is designated to receive flood flows originating from Thousand Palms Wash, The Indio Hills and the riverine drainage area along Interstate 10. These flood flows pass through the existing residential development via three flood control channels. A two-dimensional flood routing model (FLO-2D) was applied to study the progression of a flood flow in the interim floodplain area. Model results were analyzed to depict contour plots of the maximum flow depths in the interim floodplain for two discharge conditions that were simulated. The peak discharges entering the project area were estimated from the model results. Two flood control channels are proposed to accept these floodwaters and carry them out of the project area. The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) computer program was used to compute water surface profiles in the two flood control channels for the peak discharges. A sediment transport analysis was also conducted for one of the channels using the U.S. Army Corps of Engineers HEC-6 model. Model results showed that sediment passes through the system well and is not expected to interfere with the function of the flood control channel. Maintenance measures will be in place in order to clean the sediment out of the channel after a large flood event. The design water surface elevations in the flood control channel are based on the greater of either the HEC-RAS calculations using bulked flow, or the HEC-6 computed maximum water surface elevation using the unbulked flow. All sections have adequate freeboard between the design water surface elevation and the top of pad for the design flood event.

Introduction

The project area (Figure 1) is bounded on the north by Avenue 40, on the east by the Coachella Canal, on the south by Avenue 41, and on the west by Jefferson Street. The project area is part of an existing floodplain that straddles portions of the alluvial fans derived from Thousand Palms Canyon and Pushawalla Canyon. The existing floodplain has historically received floodwaters originating from Thousand Palms Wash, The Indio Hills, and riverine drainage along Interstate 10. These flood flows pass through the existing Sun City Palm Desert development located about 1 mile (1.6 km) west of the project site, via three flood control channels, Channel No. 2 north of Avenue 38 at Adams Street, Channel No. 1 at Avenue 39 and Adams Street, and Channel No. 1b at Adams Street south of Avenue 39. Flood control infrastructure in the Sun City Palm Desert development, combined with the geomorphology and natural features on the intervening lands, dictate the location and timing of peak flows that would potentially cross the project area.

An examination of historical flood records indicated one major flood in the Thousand Palms alluvial fan. This flood occurred on September 10, 1977. Aerial photographs taken one day after the storm indicate that floodwaters approached the project area from two locations (Figure 2). The first is from the west, crossing Jefferson south of Avenue 40. The second is from the north crossing Avenue 40 at Madison Street. Some floodwater is visible on the project site flowing south along the Coachella Canal.

Two channels are proposed for intercepting offsite floodwaters at the historical locations and conveying them through and out of the project area, as follows:

1. A regional flood control channel that is designed to convey floodwaters emanating from Channels No. 1 and No. 1b. The ultimate conditions discharge (100-year peak flow) for Channel No. 1 and No. 1b combined is 31,000 cfs (878 m^3/s), which includes the 23,000 cfs (652 m^3/s) contribution from Thousand Palms Wash and potential overflows from Morongo Wash.

   Discussed herein is the development of a hydraulic model for the regional flood control channel including a sediment transport analysis for purposes of determining if the channel effectively mitigates the floodwaters through the project site.

2. A flood control channel (hereinafter referred to as the driving range channel) that is designed to convey a portion of the floodwaters emanating from Channel No. 2. The ultimate conditions discharge (100-year peak flow) for Channel No. 2 is 23,000 cfs (652 m^3/s).

   Described herein is the development of a two-dimensional flood routing model for the existing floodplain for the ultimate conditions discharge of 23,000 cfs (652 m^3/s) from Channel No. 2 to estimate peak flows crossing the project boundaries. In addition, this paper describes the development of a hydraulic model for the aforementioned channel using the peak flows determined from the flood routing model.

Regional Flood Control Channel

The regional flood control channel is designed to convey a peak flow of 31,000 cfs (878 m^3/s), which is the capacity of the largest flood control channel in Sun City Palm Desert. Although there is currently no connection between the Sun City Palm Desert channels (i.e., Channels No. 2, No. 1, and No. 1b) and the proposed regional flood control channel in the project area, the design of the regional flood control channel is based on the assumption that, in the future, there will be a continuous channel that connects the Sun City Palm Desert channels, which terminate on Adams Street, to the regional flood control channel, which starts at Jefferson Street.

Hydraulic Analysis for Regional Flood Control Channel

The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) computer program was used to compute the water surface profile in the flood control channel. The flood control channel is a "dual-use" facility serving as a golf course and a flow corridor. At the main entrance to the project, the flow in the channel is via two concrete arch culverts 48 feet x 10 feet (14.6 m x 3 m). The main entrance would be submerged during the design flood event. For flows of 10,500 cfs (300 m^3/s), all the floodwaters would pass through the culverts. For flows in excess of this amount, the additional flow would pass over the top of the road. The downstream grass-lined channel is designed to have a backwater effect, which would create a submergence condition as water flows over the top of the weir. The water surface profile plot is shown in Figure 3. Model results show maximum shear stresses along the grass-lined channel are less than or equal to 1.6 lbs/ft^2 (0.08 kPa), which are well within the maximum allowable shear stress of 3 lbs/ft^2 (0.14 kPa). The shear stress increases locally at the siphon section. This section is concrete lined, however, so it will remain stable.

Sediment Transport Analysis for Regional Flood Control Channel

The U.S. Army Corps of Engineers HEC-6 model was used to simulate sediment transport through the flood control channel. The outflow sediment transport loads for the Sun City Palm Desert channel are used as inflowing sediment loads for the flood control channel. This is a conservative assumption, because there is likely to be substantial deposition of sediment between Adams Street and the beginning of the regional flood control channel at Jefferson Street. An unbulked peak discharge of 28,465 cfs (805 m^3/s) was used as the maximum design flood discharge. The HEC-6 model accounts for scour and deposition depths during a design flood event, and the maximum water surface elevations considering a moveable bed condition. In general, sediment passes through the system well and is not expected to interfere with the function of the flood control channel. Maintenance measures will be in place in order to clean the sediment out of the channel after a large flood event. The design water surface elevations in the flood control channel are based on the greater of either the HEC-RAS calculations using bulked flow, or the HEC-6 computed maximum water surface elevation using the unbulked flow. All sections have more than 2.5 feet (0.75 m) of freeboard between the design water surface elevation and the pad grade for the design flood event.

Driving Range Channel

The driving range channel will convey the peak flow crossing Avenue 40 near Madison Street. The peak flow will be estimated from two separate discharge conditions: (1) the ultimate conditions discharge of 31,000 cfs for Channels No. 1 and No. 1b combined, and (2) the ultimate conditions discharge of 23,000 cfs for Channel No. 2.

Two-dimensional Flood Routing Model for Driving Range Channel

A two-dimensional flood routing model (FLO-2D) was developed to investigate the propagation of floodwaters in the existing floodplain. Model simulations were carried out without the Tamarisk berms aligned along Jefferson Street north of its intersection with Avenue 40. This allowed for determination of maximum discharges that are likely to cross Avenue 40 into the driving range channel. Processes simulated in the model include overland flow, infiltration and the presence of bottom roughness. The model computational domain for the interim floodplain area was discretized using 14,873 uniform square grids of dimension 25m x 25m (82 ft x 82 ft). The elevation of each grid element was based on USGS DEM, a rough grading plan for the project area, and high-resolution LiDAR survey data (Figure 4). Topographic features identified from a field reconnaissance survey were also included in the model. Figure 5 shows the topographic elevations in the interim floodplain. Floodplain areas with existing buildings, walls, berms, and trees were modeled using adjusted roughness factors.

Model simulations were carried out for a period of 20 hours. Initial conditions to the model included grid elevations, floodplain storage, change in floodplain depth, average hydraulic conductivity, average capillary suction head, initial and final saturation, initial abstraction, soil porosity, and Manning's roughness coefficient. Table 1 shows the FLO-2D model parameters.

Model results were analyzed to depict contour plots of the maximum flow depths in the interim floodplain for the two discharge conditions simulated. Inflows from Channels No. 1 and No. 1b are routed in the east and southeast direction towards Jefferson Street (Figure 6). The floodwaters cross Jefferson Street and enter the regional flood control channel in the project area. The peak discharge into the regional flood control channel was estimated to be 28,280 cfs (800 m^3/s). There is no flow contribution from this source to the driving range channel. Inflows from Channel No. 2 are routed in the east and southeast direction towards Jefferson Street and Avenue 40 (Figure 7). Some of the floodwaters cross Avenue 40 and Jefferson

Street into the regional flood control channel, and some of the floodwaters cross Avenue 40 near Madison Street. The peak discharge into the regional flood control channel and the driving range channel were estimated to be 5,250 cfs (148 m^3/s) and 7,500 cfs (213 m^3/s), respectively. Hydraulic and sediment transport analysis for the regional flood control channel were described earlier.

Hydraulic Analysis for Driving Range Channel

Based on the model results, a peak discharge of approximately 7,500 cfs (213 m^3/s) was estimated to enter the project area at Avenue 40 and Madison Street. This discharge enters a channel that conveys the flows through a driving range located in the project area. The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) computer program was used to compute water surface profiles in the driving range channel. The water surface profile plot is shown in Figure 8. Model results show that the computed water surface elevations in the channel are below the pad elevations specified in the rough grading plan of the project area.

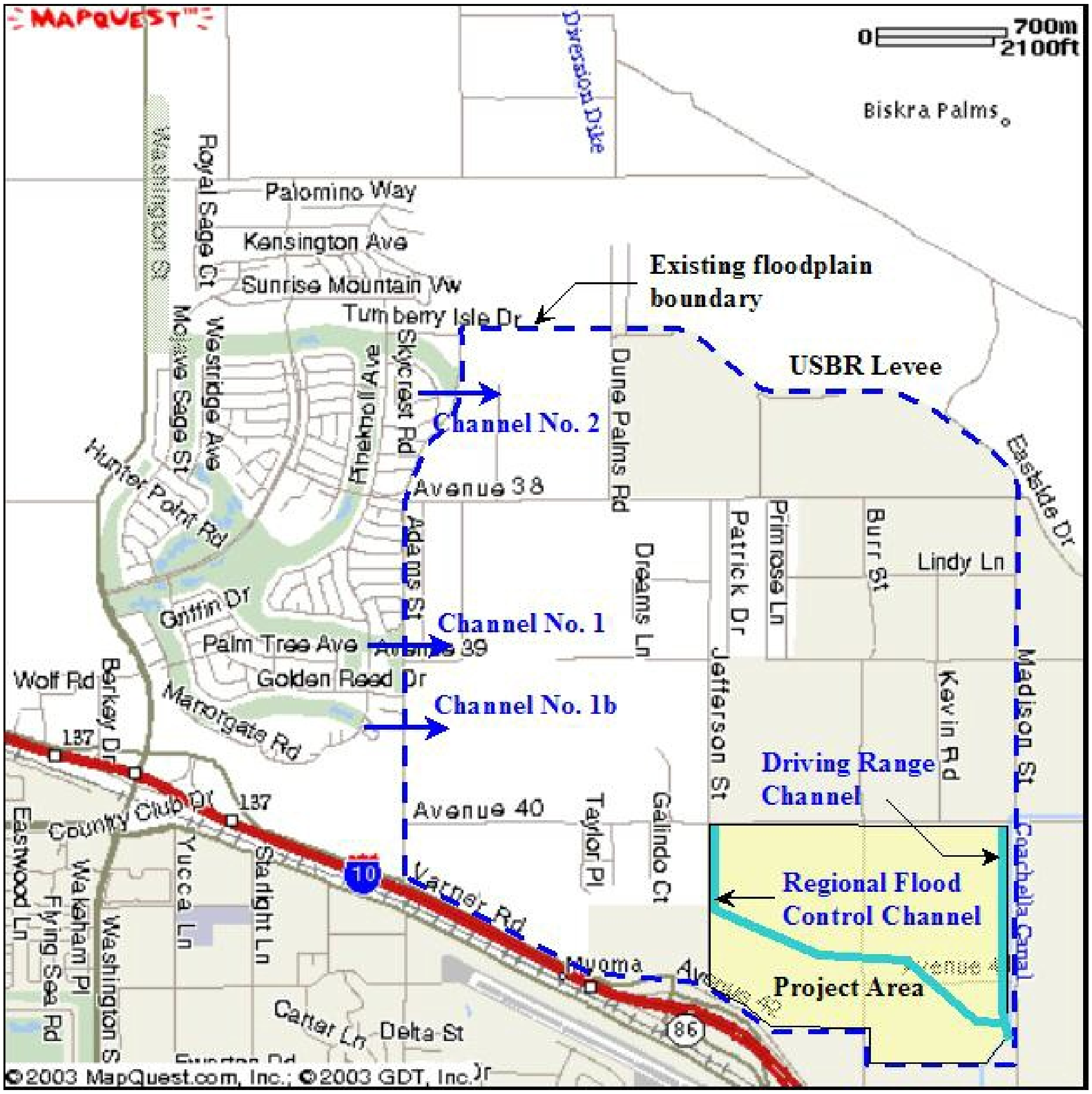

Figure 1. Location of project area, the interim floodplain area, the inflow channels No. 2, No. 1 and No. 1b, the regional flood control and driving range channels.

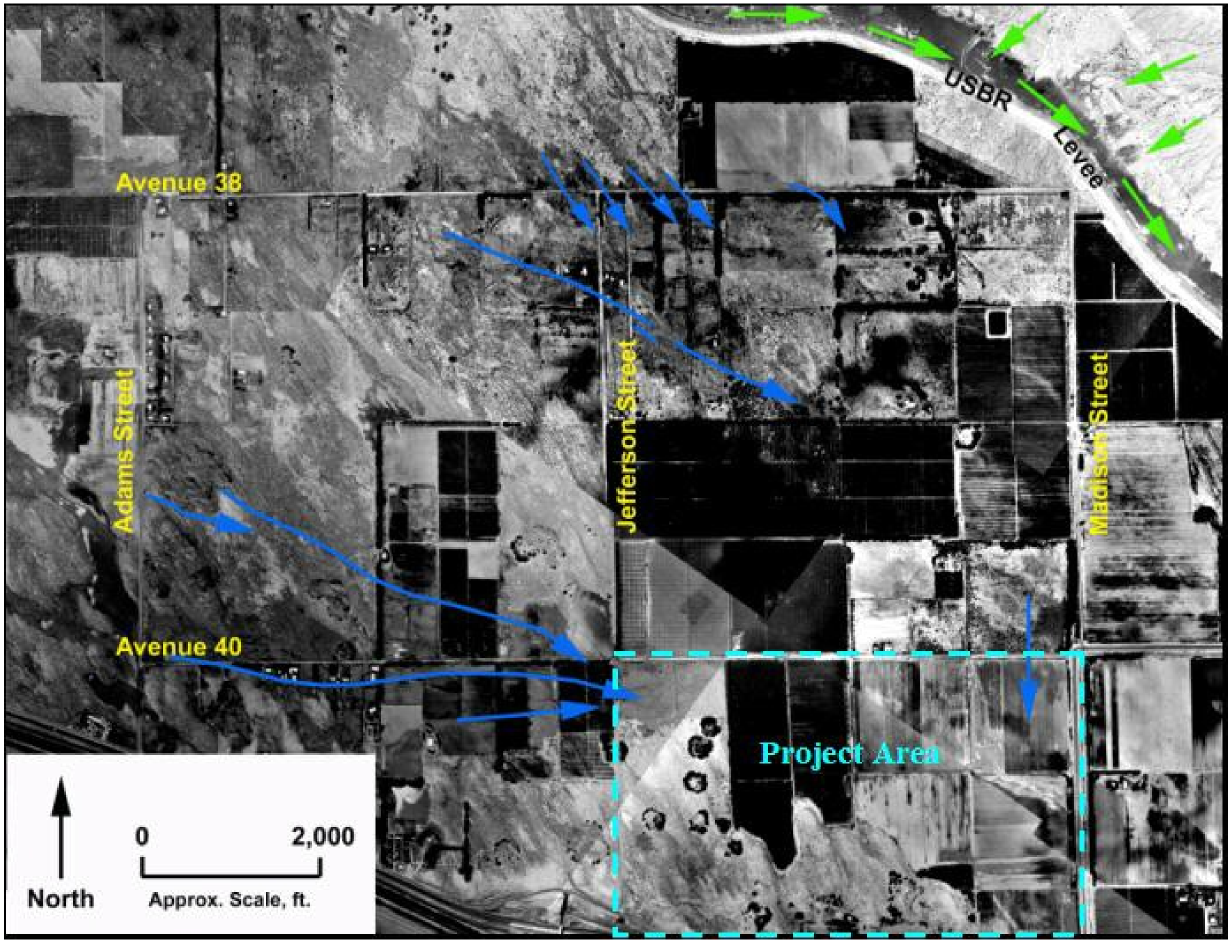

Figure 2. Mosaic of black and white aerial photos of the project area taken one day after the major storm of September 10, 1977. Flood paths to the north represent potential outflows from Channel No. 2. Flood paths to the south represent potential outflows from Channel No. 1 / 1b (Frames 2, 3, 4, 17, 18 and 19, 9-11-77, Riverside County Flood Control).

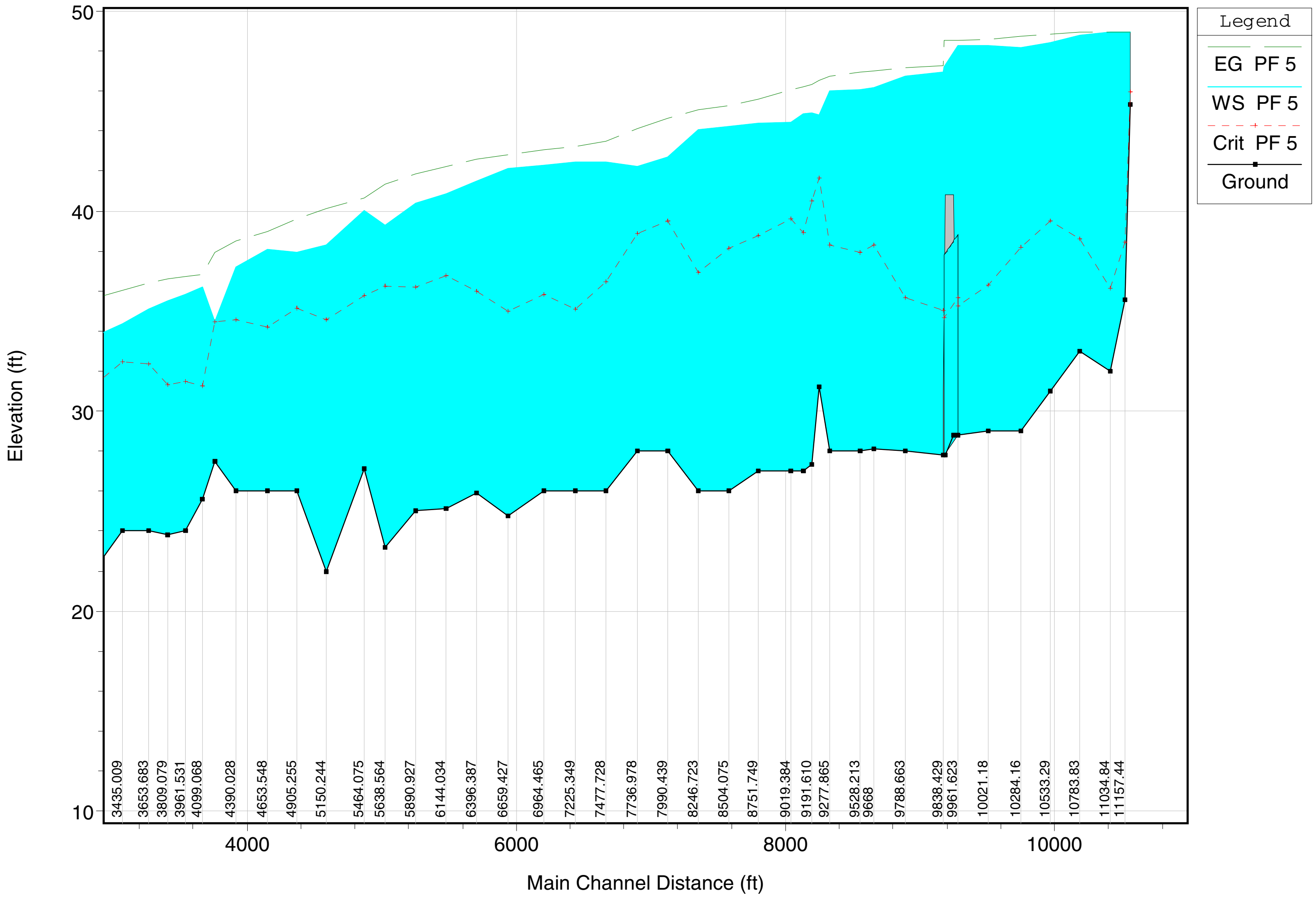

Figure 3. Water surface profile for 31,000 cfs design flow in regional flood control channel.

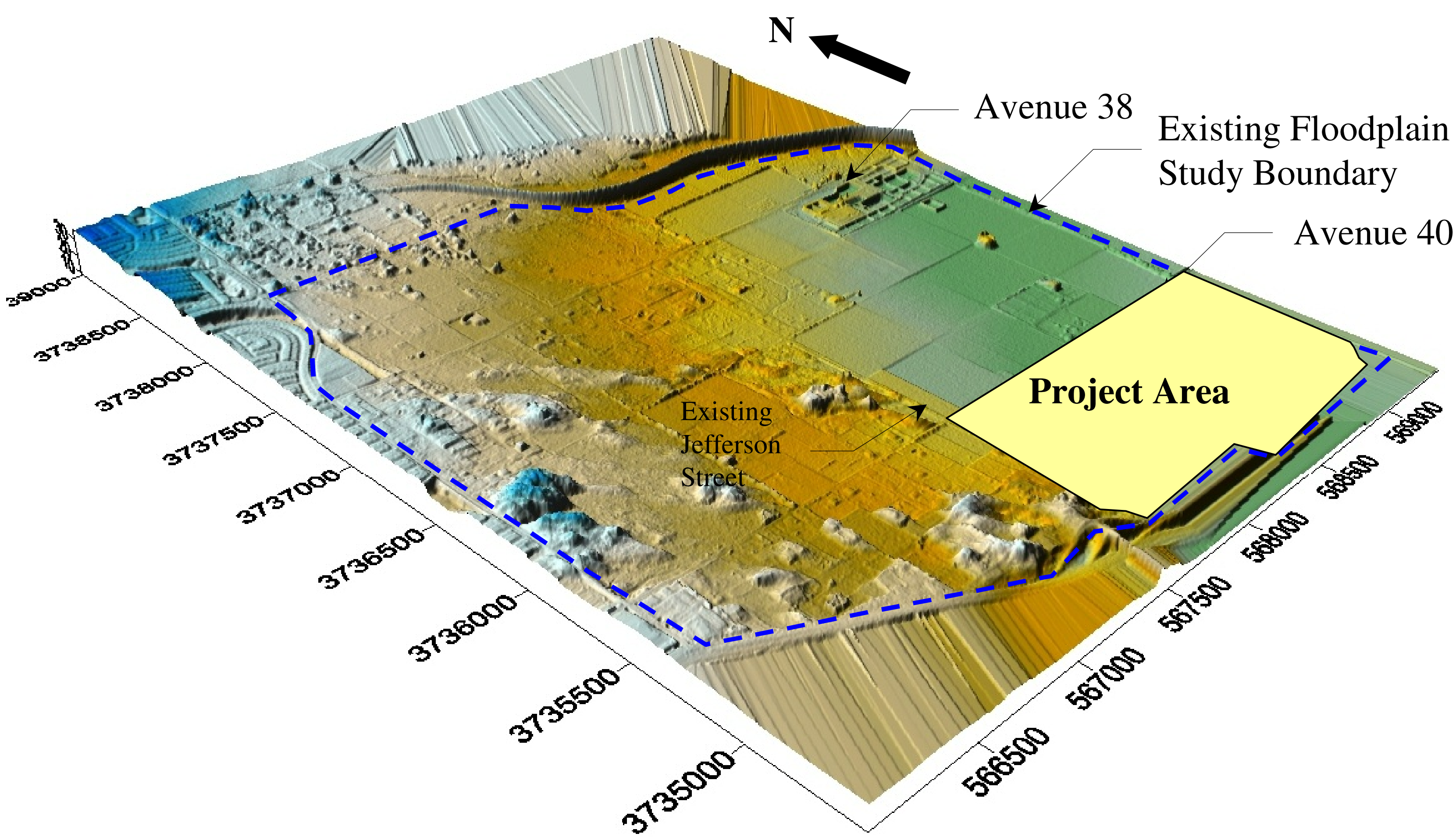

Figure 4. Three-dimensional view of floodplain using LiDAR data.

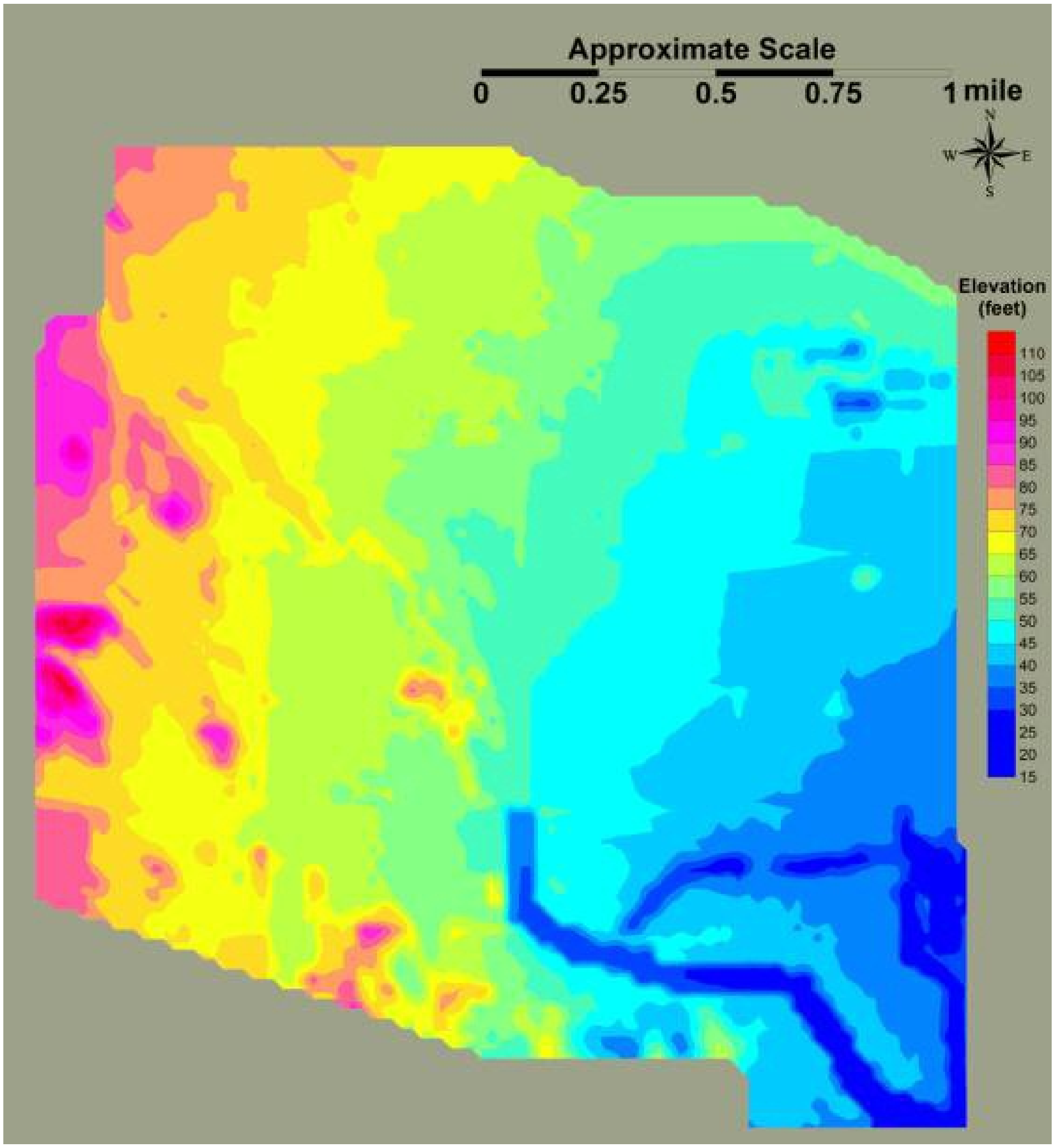

Figure 5. Interim floodplain area with topographic elevations (in feet).

Table 1. FLO-2D model parameters

Description	Value	Units
Number of elements	14,873	-
Element size	25 x 25	m
Simulation type	Full dynamic wave	-
Simulation period	20	hours
Minimum time step	0.01	seconds
Maximum time step	45	seconds
Flood plain storage (surface detention)	0.03	m
Change in floodplain depth	30	%
Average hydraulic conductivity	0.65	mm/hr
Average capillary suction head	15	mm
Initial saturation	50	%
Final saturation	80	%
Soil porosity	0.44	-
Initial abstraction	3.84	mm
Manning's n	0.03 – 0.05	-
Manning's n for shallow water flow	0.05	-

Figure 6. Maximum water depth contours (ft) for inflows from Channels No. 1/1b.

Figure 7. Maximum water depth contours (ft) for inflow from Channel No. 2.

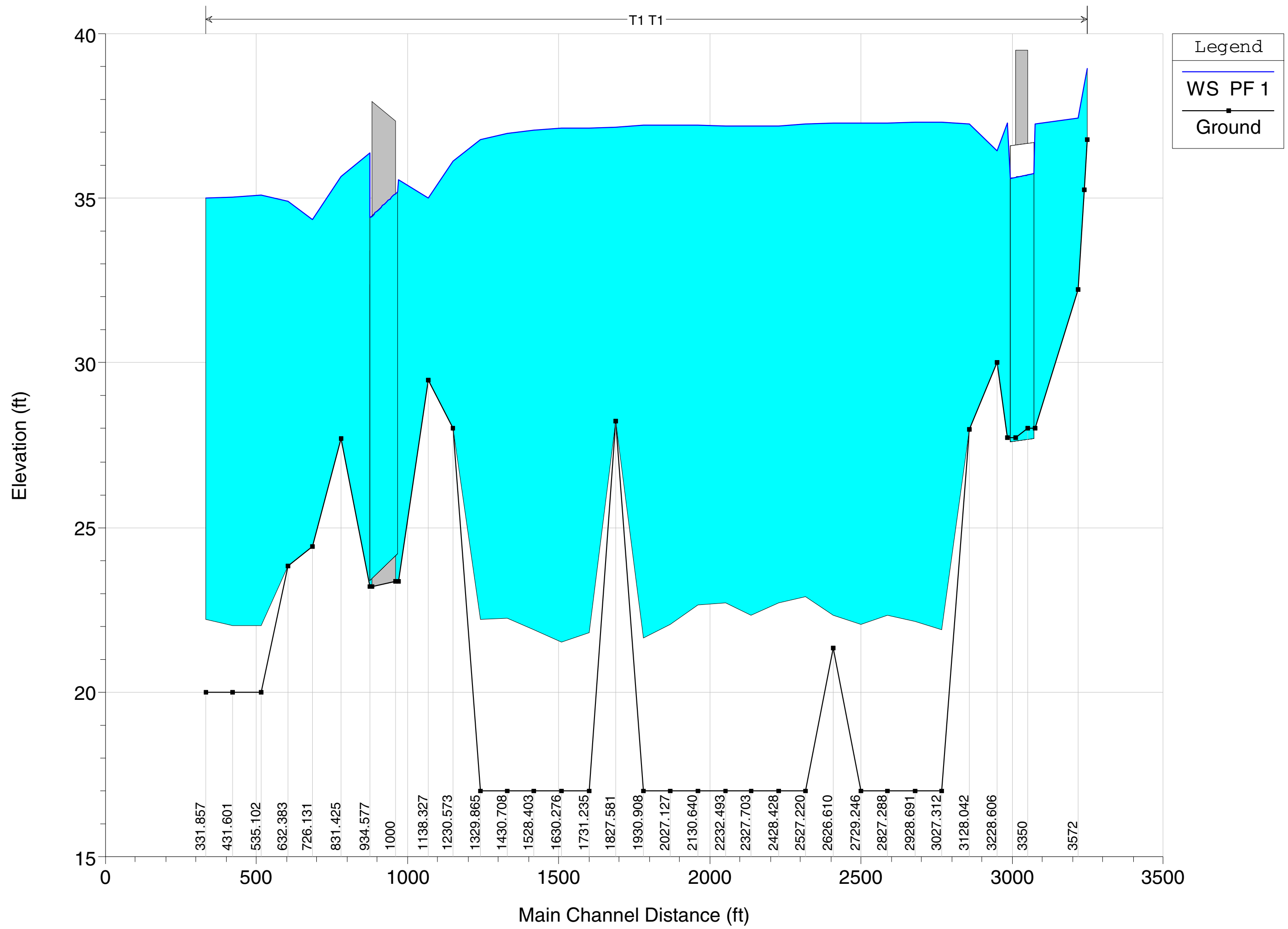

Figure 8. Water surface profile for driving range channel for 7,500 cfs flow.