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Sedimentation Analysis for Existing and Proposed Development Conditions

Blake Murillo
Psomas, Inc.
555 South Flower St., Suite 400, Los Angeles, CA 90071, USA
E-mail: bmurillo@psomas.com

Soorgul Wardak, Douglas L. Hamilton, Parmeshwar L. Shrestha[1], Kristina Cydzik and Macan Doroudian
Exponent, Inc.
300 Goddard Way Suite 200, Irvine, CA 92618, USA
E-mail: [1]pshrestha@exponent.com

ABSTRACT: A sedimentation analysis was carried out to investigate a fluvial system in Big Tujunga Wash, Los Angeles, California. The study area is located on a braided channel complex, which has been subject to flooding during past years. The main channel traversing the study area branches into north and south branches and is subject to split flows during larger floods. The bed material is composed of sand, coarse gravel, cobbles and boulders. Proposed conditions include the construction of a golf course at the site. The purpose of this study is to examine if the golf course has any adverse impact in Tujunga Wash via comparison of aggradations/scour for existing and proposed conditions. The Modified Universal Soil Loss Equation (MUSLE) was selected for computing the sediment yield from a single event. Sediment analyses were conducted using HEC-6 for both existing and proposed conditions. The HEC-6 analysis was based on a previous hydraulic study using HEC-RAS. For proposed conditions, the grading of the golf course was designed such that the flow and sediments would be conveyed through the most likely natural flow paths and to ensure that the golf course would not act as a sediment trap. The hydraulic and sediment transport analyses utilized a simplified representation of the complex channel network actually present in Big Tujunga Wash and Haines Canyon. Model results for both existing and proposed conditions were very similar, despite the uncertainty in estimating sediment loads, uncertainty in sediment analysis, and the potential variation of key parameters during high flows.

INTRODUCTION

The Canyon Trails Golf Course is located within the Big Tujunga Wash at the foothills of the San Gabriel Mountains (Figure 1). The site is located on an alluvial fan, which has been subjected to significant flooding during past years. Unlike typical alluvial fans, rapid lateral shifts of channel positions during a major flood are not unexpected anywhere in the wash [10]. The Big Tujunga Wash Channel is characterized by a braided channel bottom and is composed of large deposits of sand, gravel, and boulders. Since the streambed is composed of large-sized coarse material, the extent of erosion and subsequent transport is limited. During larger floods, the flows in the wash are conveyed via braided channels.

The purpose of the study is to investigate sediment erosion and deposition in the wash for existing and proposed development conditions. Existing conditions represent the system with braided channels at the site and existing topographic elevations. Proposed development conditions represent a golf course to be built within a portion of Big Tujunga Wash. For this condition, the network of channels are similar to those for existing conditions, except that some of the channel cross sections are modified to account for the presence of the golf course. Of specific interest is to examine if the proposed golf course interferes with sediment transport through the channel network by comparing scour and aggradation between existing and proposed development conditions.

The U.S. Army Corps of Engineers' (USACE) HEC-6 model was used to conduct the sediment transport analysis for existing and proposed development conditions. Described below are delineation of Big Tujunga Wash channel network and

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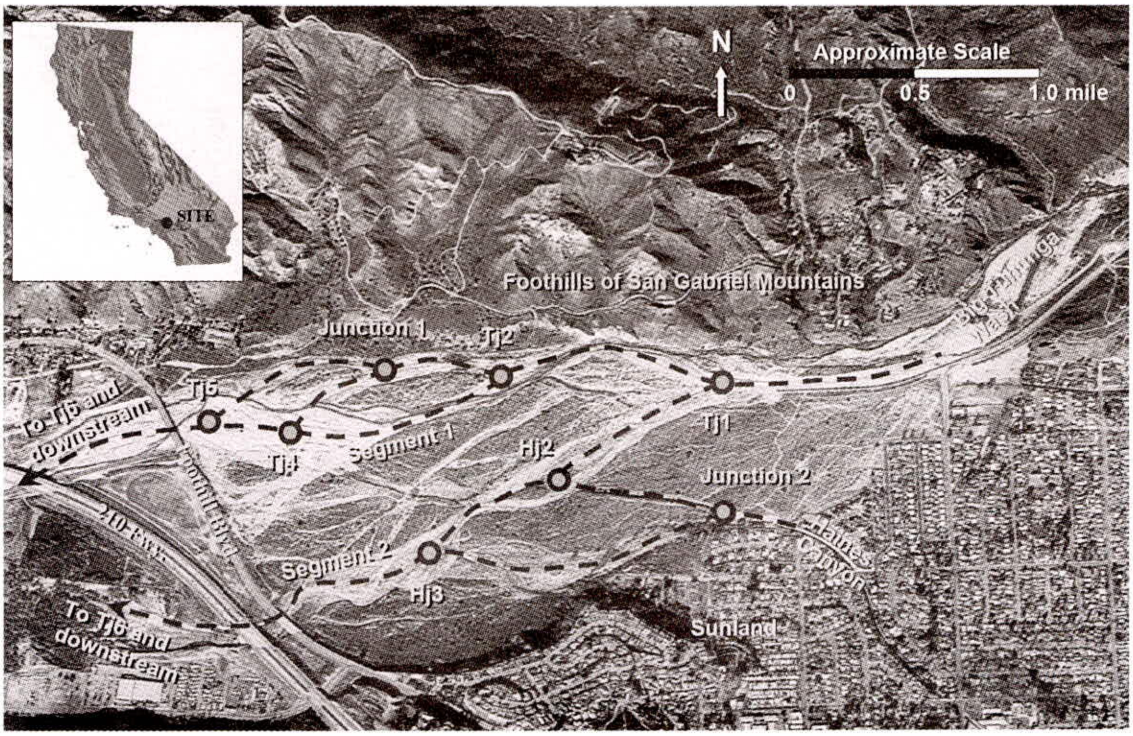

Fig. 1: Site location map showing braided channel network

development of cross sections, computation of sediment yield, specification of boundary conditions to the model, sediment transport simulations and results, and conclusions.

DELINEATION OF CHANNEL NETWORK

Figure 1 shows an aerial map of Big Tujunga Wash annotated with the channel network system, schematized as shown in Figure 2. At Tj1, the wash splits into Segments 1 and 2. For Segment 1, the flow occurs from Tj1 to Tj2. At Tj2, the flow splits and is conveyed to Junction 1 and Tj4. At Junction 1, the flow further splits to rejoin Segment 1 at locations Tj4 and Tj5. The flow continues downstream from Tj5 across Foothill Boulevard and the 210 Freeway to Tj6 and downstream. The flow from the Haines Canyon channel outlet splits at Junction 2 to enter Segment 2 at Hj2 and Segment 3, which enters Segment 2 at Hj3. From Hj3, the flow is conveyed along Segment 2 across Foothill Boulevard and the 210 Freeway to Tj6 and downstream.

The stream segment numbering and local inflows or outflows are as follows. Control Point 1 is the downstream location of Segment 1. There are four local inflows to Segment 1, which are designated as $L_{1,1}$, $L_{1,2}$, $L_{1,3}$ and $L_{1,4}$. The confluence of Segments 1 and 2 is at Control Point 2. Segment 2 has one local inflow, as $L_{2.1}$. The upstream inflow to Segments 1, 2 and 3 are respectively designated at I_1, I_2 and I_3. The HEC-6 User's Manual describes the stream network numbering system (USACE, 1993).

Geometric cross section data for the channel segments were prepared for both the existing and proposed development conditions. As described earlier, proposed development conditions represent a golf course located within the wash. The golf course is proposed to be built east of Foothill Boulevard and southwest of junction Tj1, between Segments 1 and 2, and includes portions of Segment 2 between junctions Hj2 and Hj3. Due to the grading of the golf course, the geometric data for cross sections along Segment 2 adjacent to the proposed golf course are the only sections that were modified. The other sections along Segments 1 and 3 are similar for both existing and proposed conditions.

SEDIMENT YIELD USING MUSLE

The Modified Universal Soil Loss Equation (MUSLE) was used to predict the volume of sediment erosion. The general form of the MUSLE is,

$$A = RKL_sCP \qquad \dots (1)$$

where A = average sediment yield in tons per storm event, R =storm runoff energy factor, K = soil erodability factor, L_s = slope length and steepness factor, C = vegetation cover factor, and P = erosion control practice factor.

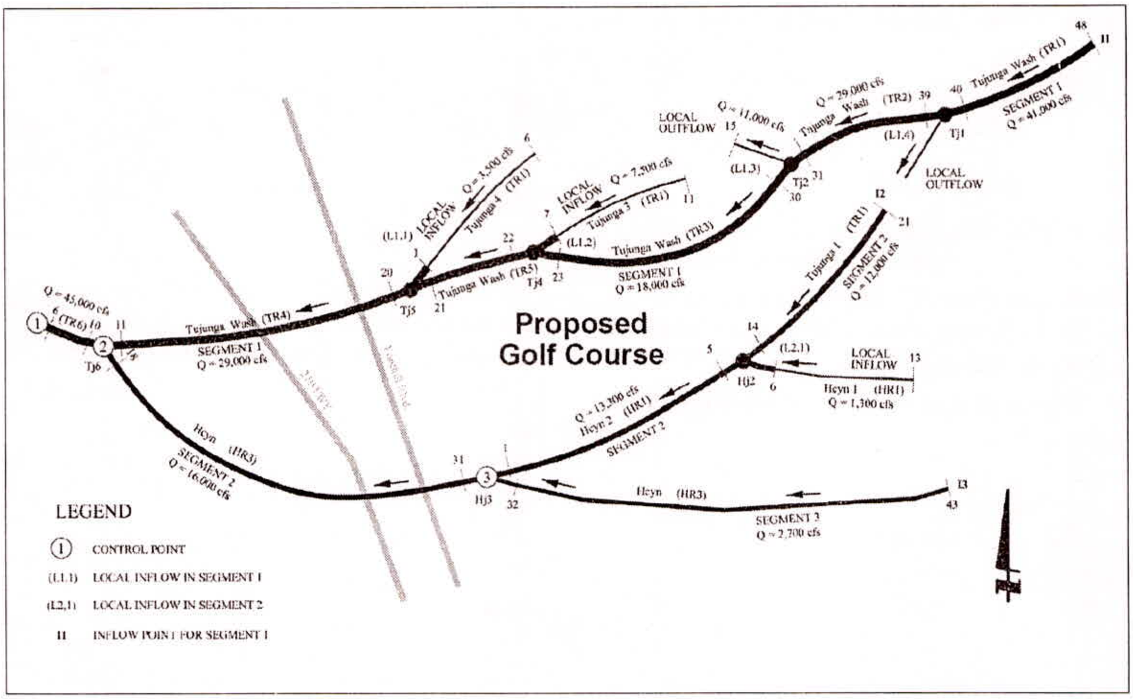

Fig. 2: Schematic diagram of braided channel network

For a single storm event, the storm energy factor, R, can be expressed as,

$$R = a\,(V\,Q)^b \qquad \ldots (2)$$

where V = the storm event runoff volume (acre-ft), Q = the storm event peak discharge (cfs), and a and b = empirical constants. Williams and Berndt (1972) using data from experimental watersheds ranging in area from 3 acres to 7 mi^2 (0.012 to 18.1 km^2) estimated the parameters a and b as 95 and 0.56, respectively. The MUSLE has been applied recently in a study by Tetra Tech (1999) for the USACE, Los Angeles District for basins ranging from 8 to about 80 mi^2 (20.7 to 207 km^2), using the above coefficients.

The soil erodability factor, K, is a measure of the susceptibility of the soil particles to be detached from the parent material by rainfall and runoff. The soil texture is the principal factor affecting the value of K. The K values may range from 0.0 to about 0.2. The values of K can be estimated using the nomograph method.

The length slope factor, L_s, describes the combined effect of the slope length and slope gradient upon transport of the eroded material. Williams (1975) developed the following relationship for slope length,

$$l = 0.5\,\frac{D_A}{L_{CH}} \qquad \ldots (3)$$

where l = slope length (ft), D_A = watershed drainage area (ft^2), and L_{CH} = total length of all channels (ft) that appear as blue lines shown on U.S. Geological Survey (USGS) 7.5 minute topographic quad sheets.

The average basin slope can be estimated as,

$$S = 25\,Z\,(L_{C25} + L_{C50} + L_{C75})\left(\frac{1}{D_A}\right) \qquad \ldots (4)$$

where S = average basin slope (%), Z = the difference in elevation between the highest and lowest points in the watershed along the longest flow path (ft), L_{C25}, L_{C50}, L_{C75} = length of the contour line that is 25%, 50% and 75% of the value of Z above the lowest point in the watershed (ft).

The slope length and steepness factor can be determined from,

$$L_s = (0.065 + .0454S + .0065\,S^2)\left(\frac{l}{72.6}\right)^n \qquad \ldots (5)$$

The exponent n = 0.2 for slopes less than 1%, 0.3 for slopes 1 to 3%, 0.4 for slopes 3 to 5%, and 0.5 for slopes greater than 5%.

The vegetation cover factor, C, is originally defined as the ratio of soil loss from the land with a specified cover or vegetation type to the corresponding loss from the bare soil. The value of C is obtained by multiplying the canopy cover factor, C_1; vegetation cover, C_2; and tillage factor, C_3, together. These values were taken from the graphs for determining cover factors C_1, C_2 and C_3 (Hamilton, 1988; USACE, 1995).

The value of C_1 = 0.78 (approximately 30% canopy cover), C_2 = 0.48 (30% root network grass), and C_3 = 0.25. The vegetation cover factor, C, was approximated as,

$$C = C_1\,C_2\,C_3 = (0.78)(0.48(0.25) \cong 0.1 \qquad \ldots (6)$$

The erosion control practice factor, P, is the ratio of soil loss from any conservation support practice to soil loss with uphill and downhill plowing. This factor has significance for disturbed areas. For undisturbed land, the erosion practice factor P = 1.0.

The peak discharge and volume of hydrograph for the 100 year frequency were prorated using the Los Angeles County Flood Control District (LACFCD) Capital Flood Hydrograph with the assumption that the shape of a 100 year hydrograph and LACFCD Capital Flood Hydrograph are similar. The other parameters (i.e., L_{CH}, Z, L_{C25}, L_{C25}, D_A) were determined from the USGS 7.5 minute topographic quad sheet. The input parameters were specified as follows:

Q = 12,090 cfs (342 m^3/sec)
V = 10,630 acre-ft (1,310 ha-m)
a = 95
b = 0.56
L_{CH} = 559,700 ft (170,597 m)
Z = 4,000 ft (1,219 m)
L_{C25} = 216,550 ft (66,004 m)
L_{C50} = 229,000 ft (69,799 m)
L_{C75} = 129,300 ft (39,411 m)
D_A = 960,628,680 ft^2 (89,245,325 m^2)

Using Eqns. (2), (3), (4) and (5), R = 3,301,700, l = 858 ft (261.6 m), S = 60%, and L_s = 90. The sediment yield, A = 4,457,300 tons (4,043,595 metric tons) from Eq. (1). Using a specific weight of sediment equal to 110 lb/ft^3 (1,762 kg/m^3), the sediment yield for Big Tujunga Wash for a 100 year event was estimated to be 1,860 acre-ft (229 ha-m). Assuming the bed load is 20% of the total sediment yield, the bed load was estimated to be 891,500 tons per day (808,755 metric tons per day). In most streams in the Western United States, bed load ranges from 10–40% of the total sediment load. It is assumed here that Big Tujunga Wash Watershed is the only source of inflowing sediment. The sediment from Haines Canyon Watershed is assumed to be negligible because the watershed is partially developed and there are debris basins to trap sediments from the undeveloped portions of the watershed.

As defined in the Los Angeles Hydrology/ Sedimentation Manual, the Design Debris Event (DDE) is that quantity of sediment produced by a saturated watershed significantly recovered from a burn as a result of a 24 hour rainfall event with a recurrence interval of once in 50 years. We believe that for any storm event, sediment production will be primarily from the portion of the Big Tujunga Wash Watershed that lies below the Big Tujunga Dam. The debris production from the lower portion of the watershed can be computed as,

$$D_p = DPR(A) \qquad \ldots (7)$$

where D_p = debris production (yd^3), DPR = debris production rate for Los Angeles Basin, and A = drainage area (mi^2) below the Big Tujunga Dam. For DPR = 88,000 yd^3/mi^2 (25,977 m^3/km^2) and A = 34.5 mi^2 (89.4 km^2), D_p = 1,880 acre-ft (232 ha-m). This value is in close agreement with the sediment yield computed using the MUSLE equation.

SEDIMENT TRANSPORT ANALYSIS

The HEC-6 model (USACE, 1992) was employed to evaluate the sediment transport in the channel network for existing and proposed development conditions. As described earlier, proposed development conditions represent a golf course located within the wash. Cross sections along all channel segments were similar for both existing and proposed conditions, except for cross sections along Segment 2, adjacent to the proposed golf course. These sections were modified to reflect the golf course grading for proposed conditions. The grading of the golf course was designed such that the sediments would be transported along pathways determined to be the most likely natural pathways. The two sources of sediment to the system are the inflowing sediment load and the sediments from the channel bed. Based on the continuity of sediment flow, changes in the streambed are calculated as a function of time and distance along a reach. For each HEC-6 cross section, the total sediment load, volume and gradation of sediment that is either deposited or scoured, and subsequent changes in bed elevation are also computed.

Sediment Gradation

The bed material samples were taken by Geo Soils Consultants, Inc., Van Nuys, California. The gradation of the five samples along with a representative grain size distribution is shown in Figure 3. The representative gradation for use in the HEC-6 analysis is tabulated in Table 1.

Sediment Rating Curve

To establish a sediment rating curve, the total inflowing sediment load in tons per day is required as input to HEC-6. The 5-, 10-, and 50 year discharges were prorated from the 100 year discharge using ratios

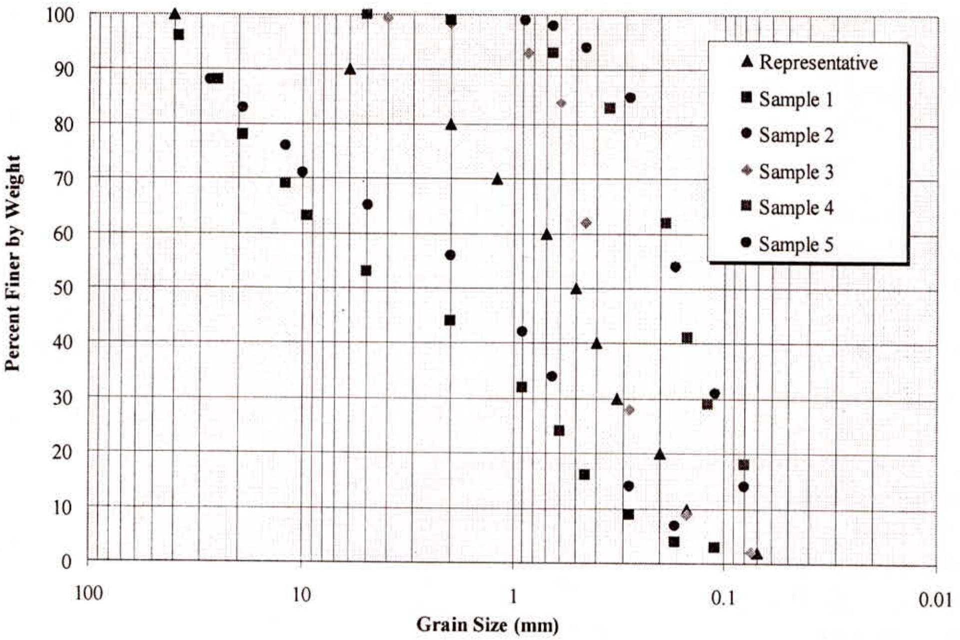

Fig. 3: Sampled and representative grain size distributions of Big Tujunga Wash sediments

Table 1: Representative Gradation of Sediment

Grain size (mm)	0.07	0.15	0.2	0.32	0.4	0.5	0.7	1.2	2	6	40
% Finer	2	10	20	30	40	50	60	70	80	90	100

of 0.59, 0.69 and 0.90, respectively. Similarly, the sediment yield for the 5-, 10-, and 50 year discharges were based on the ratios of 0.42, 0.50 and 0.85, respectively. The resulting sediment rating curve (Figure 4) has the following functional relationship,

$$Q_s = 0.0218\, Q^{1.65} \qquad \dots (8)$$

where Q_s = sediment load (tons/day), and Q = discharge (cfs). It is assumed that this sediment rating curve is applicable for all segments in the channel network.

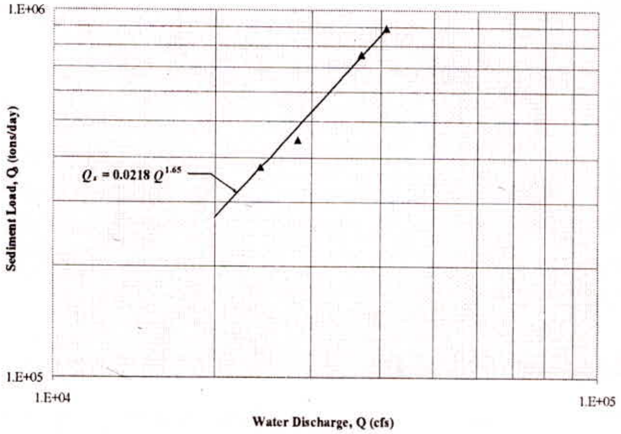

Fig. 4: Sediment-discharge rating curve based on sediment loads corresponding to water discharges at various frequencies

Boundary Conditions

Inputs to the HEC-6 model include flow histograms and a sediment rating curve at the upstream boundary and at each of the local inflow locations, and a downstream water surface elevation (stage). Figure 5 shows the flow histogram at inflow locations for Segments 1, 2, and 3 and local inflow points $L_{1,1}$, $L_{1,2}$, $L_{1,3}$, $L_{1,4}$, and $L_{2,1}$. The discharge is given as a sequence of steady flows each having a specified duration. The sediment rating curve specified in Eq. (8) was assumed for all inflows. At the downstream boundary, the water surface elevation was based on normal flow depth.

Sediment Transport Relationship

Many transport functions have been developed with the aim of computing the rate and size distribution of the transport of bed materials, for a given hydraulic and bed material distribution. In this study, sediment transport was computed according to the following relationship, Yang's (1973) stream power for sands,

$$\log C_t = 5.435 - 0.286 \log \frac{\omega d_m}{\nu} - 0.457 \log \frac{u_*}{\omega} + \left(1.799 - 0.409 \log \frac{\omega d_m}{\nu} - 0.314 \log \frac{u_*}{\omega}\right) \log\left(\frac{VS}{\omega} - \frac{V_{cr} S}{\omega}\right) \qquad \dots (9)$$

where C_t = total sediment concentration, ω = particle fall velocity, d_m = median particle diameter, ν = kinematic viscosity, u_* = shear velocity, V = average channel velocity, V_{cr} = average critical velocity for incipient motion, and S = energy gradient.

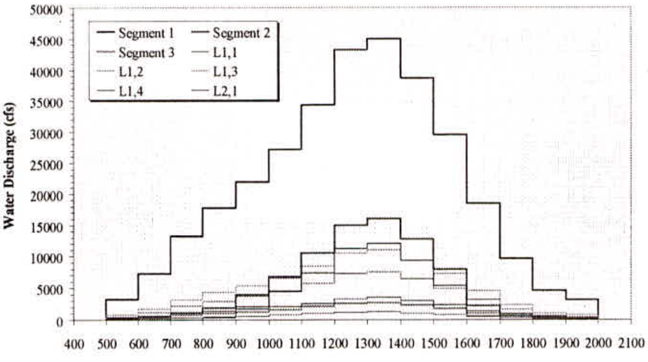

Fig. 5: Flow histograms at various inflow locations for use in the HEC-6 model

RESULTS

The results of the HEC-6 model were compared for existing and proposed development conditions. Figure 6 shows a comparison of the sediment aggradation (+) and scour (–) at cross sections along Segment 1 of the channel network. The cross sections are numbered from 49 to 6. Section 49 represents the section just downstream of Tj1 and Section 6 represents the section at Tj6. Sections 6–12 are located downstream of the 210 Freeway. As shown in the figure, the aggradation and scour for existing and proposed conditions are similar. Except for a few sections, all other channel sections are scoured. The total sediment inflow entering Segment 1 is approximately 139 acre-ft (17 ha-m). The sediment outflows for existing and proposed conditions are approximately 298 acre-ft (37 ha-m) and 282 acre-ft (35 ha-m), respectively. For proposed conditions, the outflow volume is approximately 5% lower than that for existing conditions.

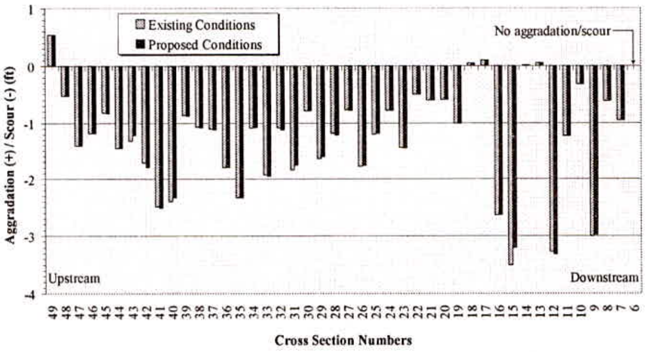

Fig. 6: Comparison of sediment aggradation (+)/scour (–) at cross sections along Segment 1

CONCLUSIONS

A sediment transport analysis was conducted for a system of braided channels in Big Tujunga Wash for existing and proposed development conditions. Proposed development conditions represent a golf course to be located within the wash. The HEC-6 model was used to estimate sediment aggradation/scour in the channels. Model features included delineation of the channel network, estimating sediment yield, developing a representative sediment grain size distribution based on field samples, and assigning model boundary conditions of discharge and sediment load at various inflow locations. The sediment load is based on a sediment rating curve. The HEC-6 model results show that the golf course does not adversely impact the sediment regime in the channel network. It is anticipated that regular maintenance measures will be in place to replenish zones of scour in the golf course.

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