Memorandum

To: *Santa Ana Stormwater Quality Standards Task Force*

From: *CDM Smith*

Date: *October 3, 2013*

Subject: *Hydraulic Calculation Method used for High Flow Suspension Analysis*

This technical memorandum describes the methodologies used in the technical analysis that supported the recommendation of a high flow suspension to be included in the Basin Plan amendment for select reaches of Mill-Cucamonga Creek, Temescal Creek, and Santa Ana Delhi Channel (CDM Smith's analysis memo dated March 3, 2010). Supplemental detail regarding the derivation of flow, depth, velocity, and depth-velocity product described within the 2010 analysis is provided below.

The proposed suspension triggers included:

- Stream velocity greater than or equal to 8 ft/s; or
- Steam depth-velocity product greater than or equal to 10 ft^2/s.

The Task Force requested CDM Smith evaluate the relationship between these triggers and a rainfall depth of 0.5 inches.

Rainfall data were used to identify the start and end dates and total event depths for all historical storm events at meteorological stations representative of weather patterns in each of the respective watersheds with reaches considered for high flow suspension. The dates were used to determine the maximum flow resulting from each distinct rainfall event by comparing a concurrent time series dataset of flow from historical gages along the reaches where Use Attainability Analysis (UAA) reports have been prepared.

The metrics considered for high flow suspension are based on the depth (ft) and velocity (ft/sec) of runoff, thus it was necessary to convert flow rate (cfs) reported at the gage by developing a rating curve for the cross section. Haested Methods Flow Master was used to develop rating curves for each cross section which was then used to convert peak event flows into depths and velocities. Flow Master employs simple hydraulic calculations to solve energy equations for a range of flow rates for given channel dimensions and a menu

of friction loss methods. Input data for channel dimensions were extracted from record drawings of each reach (see reach-specific UAA reports). For these open channels, the Manning's formula was used to estimate friction losses and compute expected water depths and velocities for a range of flows.

These methods and time series analyses facilitated the investigation of relationships between peak event flow and total event rainfall. Results showed a wide range of channel flow responses for similar size storm events, which could be due to different antecedent moisture conditions, control release point operations, or spatial and temporal distribution of rainfall across the watershed. Storms can distribute rainfall in one portion of a watershed more than another (different spatial distribution). A storm producing rainfall mostly east of a rain gauge and a storm producing rainfall mostly west of the gauge could show a similar total rainfall at the gauge, but produce very different flow responses in drainage channels east and west of the gauge. Temporal distribution of rainfall also affects channel flow response. For a specific rainfall amount, peak flow in the channel will be lower if the rainfall occurs over a 3-hour period than if the same amount of rain falls over a 30-minute, more intense period. For example, a 0.5 inch 24-hour storm in the Santa Ana Delhi Channel watershed can result in a peak flow anywhere from 20 cfs to more than 1,700 cfs, resulting in velocities ranging from 0.9 to 4.1 ft/s, and depth-velocity products ranging from 1.2 to 35.7 ft^2/s.

Table 1 shows a summary of the range of peak flows, velocities, and depth-velocity products for all storms with total rainfall between 0.4" to 0.59" at representative gages for Santa Ana Delhi, Temescal Wash, and Mill-Cucamonga Creek over the period of 1988 to 2008. Further analysis results are contained within the 2010 analysis memo.

Table 1 – Summary of Peak Flow Ranges

	Peak Flow		Velocity at Peak Flow Rate			Depth-Velocity Product		
	Range (cfs)	Average (cfs)	Range (ft/s)	Average (ft/s)	% storms greater than 8 ft/s	Range (ft^2/s)	Average (ft^2/s)	% storms greater than 10 ft^2/s
Santa Ana Delhi	23 to 1,765	557.2	0.9 to 4.1	2.6	0%	1.2 to 35.7	12.4	50%
Temescal Wash	77 to 908	459.0	3.1 to 10.6	8.6	71%	3.5 to 25.7	18.3	75%
Mill-Cucamonga Creek	403 to 5,150	1474.7	5.7 to 24.5	12	80%	4.8 to 62	17.9	60%

* storm sizes ranged from 0.4" to 0.59"