Cucamonga Channel/Mill Creek Diversion Flow HEC-RAS Analysis Alternative 2B

This memorandum summarizes analyses performed for establishment of existing flow rates in Cucamonga Channel and Mill Creek for the "Mill Creek Wetlands Recreation and Restoration Demonstration Project – Alternative 2B" (Wetlands). It also supplements results detailed in technical memorandum titled "Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010).

The proposed project will be constructed on the westerly bank of the Cucamonga Channel and Mill Creek and will be located within Army Corps and private properties. Alternative 2B consists of the construction of two wetland ponds flowing in series and a parallel braided stream (bioswale) system. The ponds will require 1.25 cfs of continuous inflow of fresh water diverted from Cucamonga Channel to maintain a 4-foot deep permanent pool for the maintenance of wetland vegetation. The expected treatment residency time of the proposed wetland system will be approximately 1 to 6 days, depending on the level of treatment. The braided streams will require 7 cfs of continuous inflow diverted from Mill Creek to maintain a 4-inch deep flow through the bioswales. This flow is also called the "low flow" or "dry weather" flow condition. The dry weather flow will be diverted at proposed diversion structures in the west bank of the improved section of Cucamonga Channel for the ponds and the west bank of the unimproved Mill Creek for the braided streams (see Figure 2). The high storm events or high flows will be intercepted by a larger diversion structure, with total design flow interception rate around 275 cfs.

The proposed wetland ponds will be comprised of three basins (see Figure 2). The first basin, most upstream basin will be a de-silting basin and remaining two will function as treatment ponds flowing in series. Once flow exits the de-silting basin it will flow through the two consecutive treatment ponds before exiting the wetlands and discharging back into the unimproved Mill Creek. The ponds are designed to provide wetland treatment for dry weather flow and extended detention treatment for higher storm flows (wet weather flow) regulated by the diversion structure described above. The expected treatment residency time for extended detention is 48 hours. The wetlands project will have the capacity hold and treat up to 87 acre-feet of water. (per "Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010).

The braided stream treatment system will be comprised of a series of parallel streams or bioswales (see Figure 2). It will be designed to treat approximately 7 cfs in dry weather flow conditions. Treatment for higher storm flows during wet weather, similar to the extended detention treatment in the ponds, is not a feature of the braided stream system since the effectiveness of the treatment processes in bioswales are limited to flows with shallow depths designed with a required residency time. As the flow increases during surcharge events, this treatment process diminishes. The streams also don't offer sufficient volume for extended detention treatment. Additionally, flows that overtop the bankfull section of Mill Creek will inundate the braided stream system and interrupt the treatment function of the streams. Inundation may also result in erosion damage to the braided streams that will require repair in order to restore the treatment capacity. A 2 year storm event will cause approximately 3,000 cfs to flow in Mill Creek and will overtop the 5 foot bank and fully inundate the braided stream system. This will result in loss of vegetation causing impairment in the treatment process

- **Field Cross Section Survey**

A field survey was performed to identify the existing cross section of the creek at various locations along the length of the project. Information collected included side slope elevations, creek bottom elevations, and the water surface at the time of the survey. The goal of this analysis was to develop a more accurate hydraulic model of the creek, in comparison to the use of aerial topography, in order to more accurately model variations in low flows through the creek.

- **Dry weather Analysis**

The average dry weather flow was approximated by evaluating the field survey data, historic water flow records in Cucamonga Channel, and projections from the Inland Empire Utility Agency for outflow from wastewater treatment facilities discharging into Cucamonga Channel. Utilizing HEC-RAS software, channel flow was developed for a variety of dry weather conditions. Characteristics such as flow rate, water surface elevation, and the top width of the water flow, were calculated for each condition. This analysis allowed for a comparison of water depths within Cucamonga Channel and Mill Creek before and after the implementation of dry weather flow diversions into the proposed wetland and braided stream systems.

According to the historic flow data the average flow rate in the creek is between 30 cfs and 60 cfs, with predominant flow around 35 cfs. The design of both the extended detention basins and braided stream system in the wetlands facility requires a dry weather diversion. The maximum diversion could range from 7 cfs to 15 cfs during dry weather conditions. This determination shall be made as part of permitting discussions. An analysis was performed to determine what effect the diversion will have on the top width and water surface elevation within the reach of Mill Creek between the proposed diversion structure and proposed wetlands outlet channel. Using 35 cfs as a typical flow, flow rates of 35 cfs, 30 cfs, 25 cfs, and 20 cfs were evaluated and are summarized in the Table 1 below.

Dry Weather Water Surface and Top Width Summary (Table 1)								
X-Sect No.	Q Total (cfs)	Water Surface Elevation (feet)	Incremental Flow Elevation Delta (inches)	Max Flow Elevation Delta (inches)	Top Width (feet)	Incremental Top Width Delta (feet)	Max Top Width Delta (feet)	Channel Velocity (ft/s)
13-Diversion	20	541.1	0.2	0.7	103.3	4.4	7.3	1.9
13-Diversion	25	541.1	0.2		107.8	1.2		2.0
13-Diversion	30	541.2	0.2		108.9	1.7		2.1
13-Diversion	35	541.2			110.6			2.2
12	20	536.0	1.2	3.4	24.5	4.1	11.7	2.1
12	25	536.1	1.2		28.7	4.1		2.0
12	30	536.2	1.0		32.7	3.5		2.0
12	35	536.2			36.2			1.9
11	20	535.8	0.8	2.4	60.5	0.3	1.0	0.4
11	25	535.9	0.8		60.8	0.3		0.4
11	30	536.0	0.7		61.1	0.3		0.5
11	35	536.0			61.4			0.5
10	20	535.5	0.4	1.1	45.3	1.8	14.1	2.3
10	25	535.6	0.4		47.1	5.3		2.6
10	30	535.6	0.4		52.4	7.0		2.6
10	35	535.6			59.4			2.7
9	20	535.5	0.8	2.4	101.9	0.6	1.6	0.4
9	25	535.6	0.8		102.5	0.5		0.4
9	30	535.6	0.7		103.1	0.5		0.5
9	35	535.7			103.5			0.5
8.5	Culvert - Chino-Corona Road							

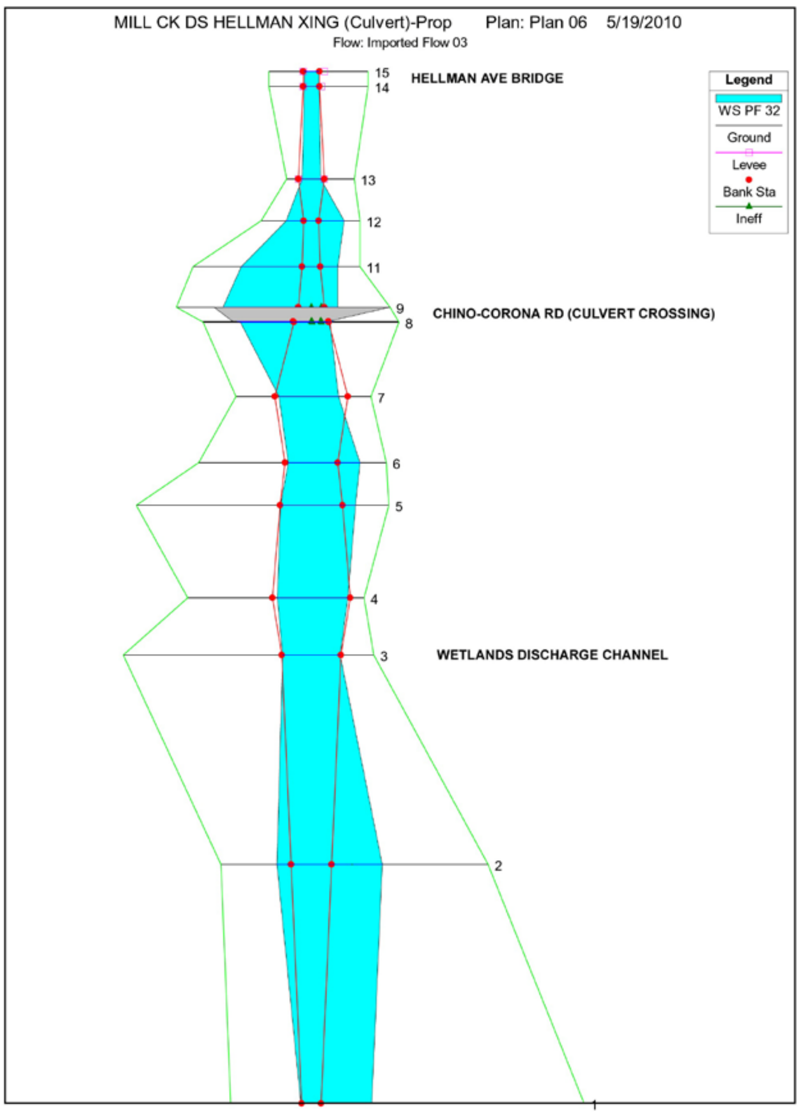
Dry Weather Water Surface and Top Width Summary (Table 1, Cont'd)								
X-Sect No.	Q Total (cfs)	Water Surface Elevation (feet)	Incremental Flow Elevation Delta (inches)	Max Flow Elevation Delta (inches)	Top Width (feet)	Incremental Top Width Delta (feet)	Max Top Width Delta (feet)	Channel Velocity (ft/s)
8	20	530.1	0.7	1.8	19.6	0.6	1.6	3.2
8	25	530.1	0.6		20.2	0.5		3.4
8	30	530.2	0.5		20.7	0.4		3.6
8	35	530.2			21.2			3.8
7	20	521.8	1.3	3.5	37.6	0.7	1.3	0.8
7	25	521.9	1.1		38.2	0.4		0.9
7	30	522.0	1.1		38.6	0.2		0.9
7	35	522.1			38.8			1.0
6	20	521.3	1.2	3.0	43.8	0.6	1.7	0.6
6	25	521.4	0.8		44.5	0.5		0.7
6	30	521.4	1.0		45.0	0.5		0.7
6	35	521.5			45.5			0.8
5	20	520.8	1.3	3.4	33.5	5.4	8.0	1.6
5	25	520.9	1.1		38.8	1.3		1.5
5	30	521.0	1.0		40.2	1.3		1.5
5	35	521.0			41.4			1.5
4	20	519.9	1.2	3.5	38.6	0.6	1.4	0.6
4	25	520.0	1.2		39.2	0.4		0.7
4	30	520.1	1.1		39.6	0.4		0.7
4	35	520.2			40.0			0.8
3-Discharge	20	519.4	1.1	2.9	27.0	0.3	0.7	1.5
3-Discharge	25	519.5	1.0		27.3	0.3		1.6
3-Discharge	30	519.6	0.8		27.5	0.2		1.7
3-Discharge	35	519.6			27.8			1.8

Per Table 1 above, the water surface elevation will not change by more than 4 inches at any point along the entire reach as a result of the proposed flow diversions. This includes segments above and below Chino-Corona Road. Depending on the location of the section evaluated, the "Top Width" of the water surface may be reduced up to 14 feet above Chino-Corona Road and diversion structure and up to 8 feet

below Chino-Corona Road and discharge channel. Although a combined total of 8.25 cfs is expected to be diverted under dry weather flow conditions, the values in the table are based on an evaluation of limited locations should a maximum of 15 cfs be diverted. See Figure 1 for cross section locations.

Due to the unimproved and irregular state of the creek, it is difficult to establish critical diversion volume on a purely mathematical model. The analysis shown in Table 2 only applies to the current configuration, which is likely to be altered frequently by annual storm events. It may be surmised that locations with the largest decrease in "top width" have fairly flat existing side slopes and the ones with the least change are along steeper embankments. Since a detailed survey of the creek bottom was not performed, it cannot be predicted if this trend would continue at these locations.

Figure 1 (Cross Section Locations)



- **Maximum Wet Weather Flow Analysis**

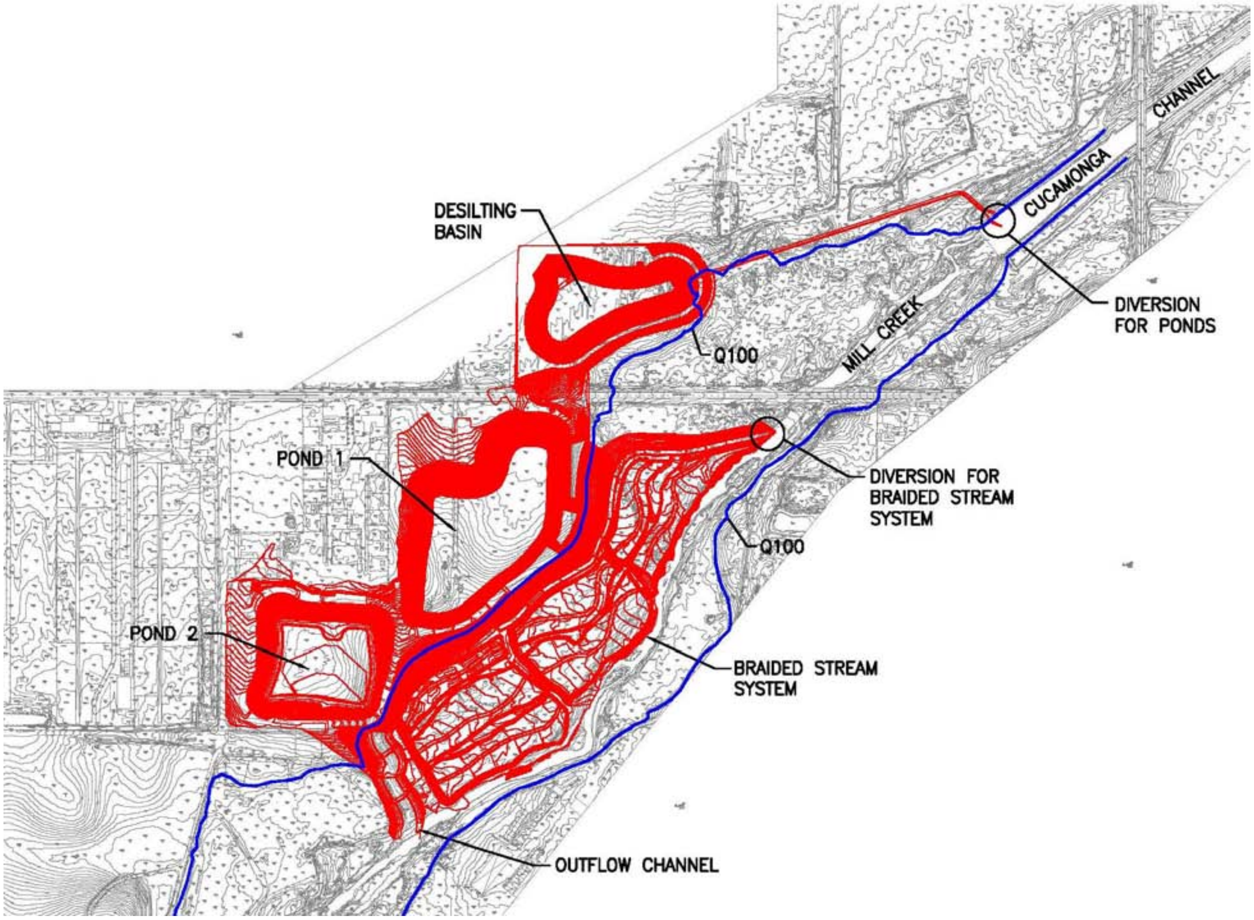
Maximum flow for Cucamonga and Mill Creek were established based on the “General Design for Flood Control and Recreation – Cucamonga Creek” report prepared by U.S Army Cops of Engineers in June 1973. Based on this information a variety of flow conditions were evaluated ranging from 0 cfs to 52,000 cfs.

It has been identified that 32,000 cfs is a 100-year flow as specified per U.S Army Corps of Engineers. Based on the HEC-RAS analysis during a 100-year event, water surface elevations vary from 538 to 548 feet in the project area. It is anticipated that during the 100-year event the ponds will not be inundated by floodwaters (see Figure 2). However, the braided stream system is located within the 100-yr floodplain and will likely be inundated by flood flows between 1,000 cfs and 3,000 cfs; flow that is likely produced by storms with a return period of less than 2 years.[1] Flow velocity during this event is expected to exceed 5 fps. Further analysis is recommended in order to fully assess the potential for soil erosion in these flow conditions.

During a very wet rain season where Prado Dam might fill up to its 100-year flood elevation of 552, all of the basins will be flooded, since the lowest berm elevation of the levees surrounding the wetlands is set at elevation 540. Under the Prado Dam maximum flood control retention and a current weir elevation of 566, also referenced as a “200 year plus” event, the project area will be completely inundated.

[1] Flow records for the USGS Stream Gaging Station #11073495 Cucamonga C NR Mira Loma CA were reviewed and resulted in the following conclusions: 1) a 39-yr record (1969 – 2008) of annual peak flow indicates that 1,000 cfs was exceeded 30/39 years (77%) and 3,000 cfs was exceeded 19/39 years (49%). Therefore, a flow of 3,000 cfs is statistically less than a 2-yr storm event; and 2) a 10-yr record (1988 – 2008) of daily flow indicates that 1,000 cfs was exceeded on 222 days and 3,000 cfs was exceeded on 81 days.

Figure 2 (100 year Flood Elevation)



- **Wetland/Pond Diversion Structure Analysis**

A permanent diversion structure will be constructed at the southerly end of Cucamonga Channel in the westerly levee. The diversion structure will have two functions. First, the smaller and lower diversion will intercept dry weather flow that is necessary to maintain a permanent pool of water in the treatment ponds. Second, the larger and higher diversion will intercept higher flow events for extended detention treatment. Sluice gates or valves will be installed at the intakes of both pipes. This will allow for the system to be taken off-line as needed for maintenance or during prolonged storm events.

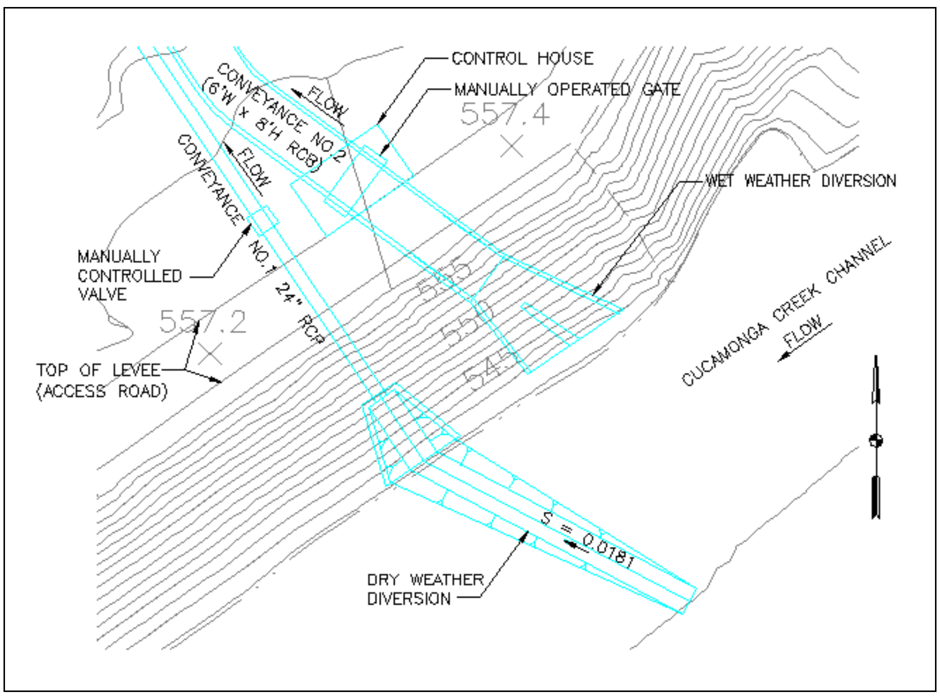
The proposed location of the diversion structure was selected in consideration of existing and possible future conditions downstream at Chino Corona Road, which crosses Mill Creek approximately 1,000 feet south of the proposed diversion site. Current dry weather flow crosses the road through a series of culverts comprised of ten elliptical CMP's 4.5 feet wide by 4 feet high. During significant storm events, the roadway acts as an Arizona Crossing and, based on this analysis, the roadway overtops during a 2 year storm. The roadway impedes flow in the creek and creates a backwater effect. This analysis includes the effect the backwater curve caused by the roadway will have on the diversion structure.

Diversion of flow to the wetlands will occur in the Cucamonga Creek riprap transition to Mill Creek, north of Chino-Corona Road. The diversion consists of two inlets: one for low flow (dry weather) and one for higher first flush/peak storm flows (wet weather).

The dry weather flow diversion consists of a new trapezoidal variable depth channel constructed transversely in the riprap portion of Cucamonga Creek. It extends across two-thirds of the invert of Cucamonga Creek Channel and traverses the invert nearly perpendicular to the flow in Cucamonga. The diversion channel, which is approximately 1 foot lower (maximum depth) than the invert of Cucamonga Creek and has a one percent fall toward the western bank, will convey dry weathers to a 24-inch RCP (Conveyance No. 1) (see Figure 3 and Figure 4). This flow will be controlled by the size of the inlet pipe at the diversion structure.

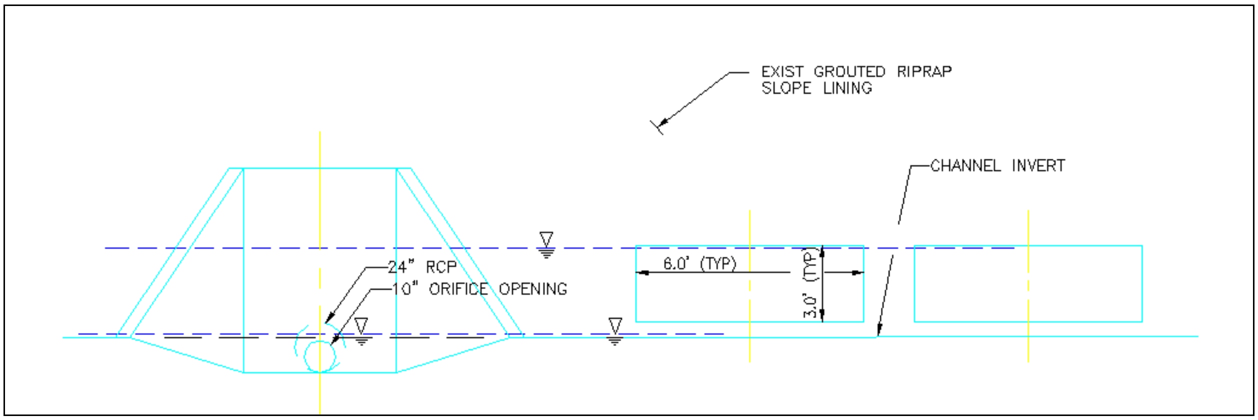
Located at an elevation of approximately 540' above sea level, Conveyance No. 1 will have sufficient hydraulic gradient to gravity flow the diverted flow to the forebay. The conveyance is a 24-inch diameter RCP, approximately 950 feet in length with a 10" orifice opening at the inlet to control the intake flow rate.

Figure 3 – Diversion Structure (Plan View)



The wet weather flow diversion consists of a 6 foot wide by 8 foot high RCB (Conveyance No. 2) (Figure 1 and Figure 2) located just upstream of Conveyance No. 1 in the riprap lined west bank of the Creek. The inlet is designed approximately a half foot above the invert of the creek to prevent the intake of dry weather flows. Located at an elevation of approximately 542' above sea level, it will have sufficient hydraulic gradient to gravity flow the diverted storm water to the forebay during the first flush storm event. This parallel storm conveyance system is also approximately 950 feet long.

Figure 4 – Diversion Structure (Front Elevation)



During the wet weather flow condition, the flow rate and depth in Cucamonga Creek increase and, depending on the volume of water stored in the wetlands, the intercepted flow rates also increase relative to dry weather diversion rates.

- **Braided Streams Diversion Structure Analysis**

A diversion structure and conduit from Mill creek will divert dry- and wet-weather flows to the distribution channel for the braided stream system. It is anticipated that a series of orifices or equivalent design will connect the distribution pipe to a plunge pool within Mill Creek. The plunge pool will be constructed within Mill Creek in the vicinity of the diversion to control the desired dry-weather flow rate to the distribution channel. The plunge pool and diversion are described in more detail in the report entitled "Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative, Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010). During wet-weather flows the braided streams will operate in two conditions, below overflow flood stage and above overflow flood stage. The wet weather operations are also discussed in more detail in the above mentioned report.

- **Wetlands Outflow Channel Analysis**

During extreme storm flow conditions in Cucamonga Creek, the diversion structure and the rate of diverted flow will be surcharged. Based on this possible high flow condition, the outflow channel (see Figure 2) from the wetlands will require a maximum peak design flow capacity of 140 cfs since the wetlands will be operating in a flow through condition. During a 100-yr storm the flow will spill over emergency spillways into the outflow channel and back into Mill Creek. However, from an erosion control perspective this flow is not identified as the most critical condition to the design of the outflow channel since the water surface in Mill Creek will be at or near a 100-year water surface elevation that will most likely inundate the outflow channel. A more critical flow condition will occur during smaller storm events, such as the Q_2. During these smaller events, the outflow channel will flow into a lower water surface within Mill Creek resulting in higher velocities and a higher erosion potential within the overflow channel. This condition was evaluated to size the channel properly and will be the basis for developing recommendations for erosion control protection. This analysis is summarized in Table 2.

Mill Creek Wetlands Outlet Velocities for Q_2 Design Storm (Table 2)

Design Storm	Approximate Flow in Mill Creek	Water Surface Elevation in Cucamonga Creek at Diversion	Water Surface Elevation in Mill Creek at Confluence with Outflow Channel	Flow Diverted (See Note 1)	Velocity of Outflow Channel into Mill Creek (fps)	Existing Flow Velocity in Mill Creek at Discharge Channel (fps)
Q_2	3,000 cfs	544.37 ft	529.20 ft	85 cfs	0.10- 0.32	3 - 6

Note: 1. Based on "Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative, Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010).

Each of the flows in Table 2 was evaluated to develop an outflow channel section and slope that will contain the anticipated flows and produce a flow velocity at the discharge location to Mill Creek that will prevent surface erosion. The analysis resulted in the flow velocities summarized in Table 2 that demonstrate velocities in the improved outfall channel are well below the velocities that would produce significant erosion.

During a storm, flows in Mill Creek will overtop the west bank and flood depths will become greater than the height of the berm between the braided stream system and the channel. Under such conditions, the depth and velocity of flow in the braided streams will be significantly greater than design conditions. Velocities under the inundation condition may result in a washout of the braided stream system including vegetation and previously retained pollutants. This is dicussed in more detail in the report entitled "Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative, Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010).

Dry weather flows in the outflow channel were also analyzed for erosion potential. The results are summarized in Table 3 and also show a low potential for erosion.

Mill Creek Wetlands Outlet Velocities for Dry Weather Conditions (Table 3)		
Flow Diverted	Water Surface Elevation in Mill Creek at Confluence with Outflow Channel	Velocity of Outflow Channel into Mill Creek
5	519 ft +/-	0.1 fps
10	519 ft +/-	0.2 fps
15	519 ft +/-	0.3 fps

- **Limitations**

This study is for preliminary engineering only to supplement environmental studies.

- **References**

"General Design for Flood Control and Recreation – Cucamonga Creek" report prepared by U.S Army Cops of Engineers in June 1973

"Deer Canyon Debris Basin, San Bernardino County" report prepared by State of California Resources Agency, June 21, 2002

"Conceptual Hydrologic and Hydraulic Project Design and Function: Braided Channel Alternative Cucamonga Creek Watershed Water Quality Project" (Geosyntec, 2010).

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