TECHNICAL MEMORANDUM NO. 1
Draft Crest Marin Creek Flood Study / Marin County

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INTRODUCTION

The Crest Marin Creek watershed encompasses approximately 224 acres composed of open forested land cover in the upper portion of the watershed, as well as residential land cover in the lower portion. The watershed drains the southerly hills of Tamalpais Valley and is bounded by the Nyhan Creek drainage area to the east and Green Glen Way to the west. As a result of historic flooding occurrences within the lower portion of the watershed, various drainage improvements have been implemented in the past and include a sediment detention basin, a stormwater pump station, and a storm drain diversion. These improvements have targeted localized inadequacies within the system, but have not compressively addressed the system as a whole. As result, occasional flooding still occurs at the intersection of Laurel Way and Marin Avenue due to the capacity limited storm drain system.

The primary objective of this study is the analysis the existing drainage system of Crest Marin Creek and identifying current drainage deficiencies. This memorandum describes the processes used in evaluating the existing system, while focusing on alternative developments for improving the inadequacies.

DATA COLLECTION AND FIELD INVESTIGATION

The Marin County Department of Public Works provided a topographic survey of Crest Marin Creek extending from the pump station at Flamingo Way to the intersection of Laurel Way and Marin Avenue. To ensure that the channel topography and thalweg profile had remained unaltered since the survey was completed, W&K conducted a topographic survey of Crest Marin Creek from Flamingo Way to the Ross Drive footbridge on August 10, 2006. At the time of the topographic survey, roughness characteristics of both the stream channel and overbank areas were documented and photographed. On August 11, 2006 W&K staff was accompanied at the site by Tim Hampton of Marin County Public Works. Historical and current drainage deficiencies were discussed during the field investigation. Numerous flow constrictions in the upper reach were also observed and discussed at the site.

REVIEW OF PREVIOUS HYDROLOGIC STUDIES

Under the contracted Scope of Services, hydrologic studies previously conducted by LTD Engineering, Inc. (LTD) and Philip Williams & Associates (PWA), for the Crest Marin Creek Watershed, were reviewed. The LTD report investigated drainage improvement alternatives for flood prevention in adjoining properties of Crest Marin Creek. The investigation included an analysis of the storm drain system capacity at the intersection of Laurel Way and Marin Avenue. Included in the analysis were hydrological computations utilizing the Rational Formula. Flow rates were estimated at defined points of concentration within the drainage system for reoccurrence intervals of 10-, 25-, 50-, and 100-year events. Based on the results of the hydrologic computations and the capacity analysis of the existing storm drainage facilities, drainage improvement alternatives were developed and presented in the final report dated March 2004. In September 2005, PWA prepared a similar report focusing on the hydrology of the Crest Marin Creek watershed. The PWA analysis utilized the Curve Number (CN) method in HEC-HMS to estimate peak flow rates at the same points of concentration established and delineated in the LTD analysis. A comparison of the results from the two studies yielded a significant difference in peak flow rates at each point of concentration. The PWA estimates were consistently higher relative to the flow rates computed in the LTD Report. As explained in the PWA Report, LTD's Rational Method was parameterized using typical book values for the run-off coefficients and are much lower relative to the Marin County Hydrology Manual recommended values. The lower run-off coefficients used in the LTD analysis could explain the lower peak flow estimates. Based on a review of both the LTD and PWA hydrologic methods, and as preferred by the Marin County Department of Public Works, the flow rates estimated by PWA were selected to be utilized in this analysis. Table 1 below contains the flow rates estimated in both the LTD and PWA Reports. Points of concentration referred to as Flow Nodes in the table below are depicted on Figure 1.

Table 1. Peak Flow Rates Presented in the LTD and PWA Reports

Flow Node (Figure 1)	Frequency	Subwatershed No.		Peak Flow Discharge (cfs)	
		LTD (2004)	PWA (2005)	LTD	PWA
N-1	10	1A	5.1	49.4	63.6
	25			57.8	85.3
	50			64.2	101.9
	100			70.5	118.3
N-2	10	1A + 1B	5.1 + 5.2 + 3.2	51.4	85.6
	25			60.3	113.5
	50			66.9	134.6
	100			73.5	155.4
N-3	10	4B + 5A + 5B	3.3 + 3.5 + 3.4	9.1	30.3
	25			10.6	37.7
	50			11.8	43.1
	100			13.0	48.3
N-4	10	1A + 1B + 2 + 4A + 4B + 5A + 5B	5.1 + 5.2 + 5.3 + 3.2 + 3.3 + 3.5 + 3.4	64.0	123.7
	25			74.9	161.0
	50			83.1	189.0
	100			91.4	216.7

Flow Node (Figure 1)	Frequency	Subwatershed No.		Peak Flow Discharge (cfs)	
		LTD (2004)	PWA (2005)	LTD	PWA
N-5	10	1 + 2 + 3 + 4 + 5 + 6 + 7 + 8	5.1 + 5.2 + 5.3 + 6.3 + 3.2 + 3.3 + 3.5 + 3.4 + 12.2 + 12.3 +6.2	70.7	172.5
	25			82.9	222.9
	50			92.0	260.6
	100			101.1	297.8
N-6	10	Not Included in Analysis	5.1 + 5.2 + 5.3 + 6.3 + 3.2 + 3.3 + 3.5 + 3.4 + 12.2 + 12.3 +6.2 + 6.1 + 12.1	Not Included in Analysis	202.8
	25				260.8
	50				304.2
	100				346.9

NOTE:
1) The LTD hydrologic analysis did not extend past the Ross Drive footbridge, therefore the analysis did not include flow rate estimates below N-6. The PWA analysis did include the delineation of the subwatersheds (6.1 and 12.1) contributing overland flow to N-6, however these flows were not obtained from PWA, but rather provided by Marin County. It is assumed that the flows were calculated using HEC-HMS, but there is uncertainty in the time of concentration used for the computations. Because the PWA delineation of subwatershed 12.1 extended across Nyhan Creek, the flows provided by the County for subwatershed 12.1 were scaled based on the drainage area (see Appendix A).

REVIEW OF PREVIOUS HYDRAULIC STUDIES

As a component of the 2004 LTD analysis, a hydraulic capacity analysis was conducted on the stormwater drainage system at the intersection of Linda Way and Marin Avenue. The flow rates calculated by LTD utilizing the Rational Formula were used in the pipe hydraulic analysis. The pipe hydraulic analysis was performed in StormCAD, for the storm drain system shown in Figure 1. A summary of the pipe capacities are tabulated below in Table 2.

Table- 2. Pipeline Capacities Determined by LTD Engineering, 2004 for Storm Drain Pipes at the Intersection of Laurel Way and Marin Avenue

Pipe Segment	Capacity (cfs)
P-1 (inlet)	22.0
P-1	78.1
P-2	54.9
P-3	44.6
P-4	2.9
P-5	34.8
P-6	20.7
P-7	12.4
P-8	13.2
P-9	14.5
P-10	24.1
P-11	26.6
P-12	99.2
P-13	35.0
P-14	84.1
P-15	80.6

NOTES:
Pipe capacities obtained from LTD Engineering Report, March 2004.

As shown in the above table, the maximum inlet capacity of pipe 1 is 22-cfs. As explained in the LTD Report, flows exceeding 22-cfs at the inlet, result in flow entering into the roadway of Laurel Way and flowing to the intersection with Marin Avenue. The flow is commonly captured by a drop inlet at the foot of Laurel Way, and conveyed back into the storm drain system. Based on the review of the LTD analysis, it was determined that pipe 13 has the limiting capacity in the storm drain system of 35-cfs. Flows exceeding the capacity of pipe 15 create surcharging of the contributing storm drain pipes and drop inlets. As a result, excess flow encroaches in a northerly direction on Laurel Way and adjacent properties

HYDRAULIC MODEL DEVELOPMENT

For the purpose of this study, Crest Marin Creek was divided into two separate reaches, an upper reach and a lower reach, and shown in Figure 1. The upper reach consists of a small non-maintained channel that extends approximately 850 feet from the discharge of the underground storm drain pipe network at the intersection of Laurel Way and Marin Avenue, down to the Ross Drive footbridge. The lower reach extends approximately 1,000 feet from the Ross Drive footbridge, through the Marin County drainage easement, terminating at the Crest Marin Creek Pump Station on Flamingo Way. As previously discussed, the lower reach drainage easement allowed for the topographic survey conducted by Marin County to be verified by Winzler & Kelly survey crew. This provided confirmation of the channel geometry and slope, and allowed for the detailed hydraulic analysis utilizing a HEC RAS model to be performed. Conversely, topographic information provided by Marin County was not verified by Winzler & Kelly survey staff for the upper reach. A drainage easement does not exist for the upper reach, and because permission to access was not pursued from the 13 private parcels, a detailed topographic survey was not conducted.

Upper Reach Analysis

Based on visual inspection of the upper reach, it was determined that many homeowners have constructed many improvements to their property that encroach into the channel. These improvements have resulted in many modifications to the channel, creating flow constrictions and resulting in a wide variation of channel geometry through the upper reach. The observed constrictions consist of fences, footbridges, retaining walls, small outbuildings, and areas of dense vegetation. Based on the field observations, and recent channel modifications, it was determined that the topographic survey information provided by Marin County did not accurately capture the channel geometry at several observed locations. For example, the field observations conducted at 335 and 339 Linda Way indicate a smaller cross-sectional channel area relative to the topographic survey provided by the County. These channel cross-sections are shown below in Figures 2 and 3. It should be noted that other cross-sections observed in the field were consistent with the County provided survey information.

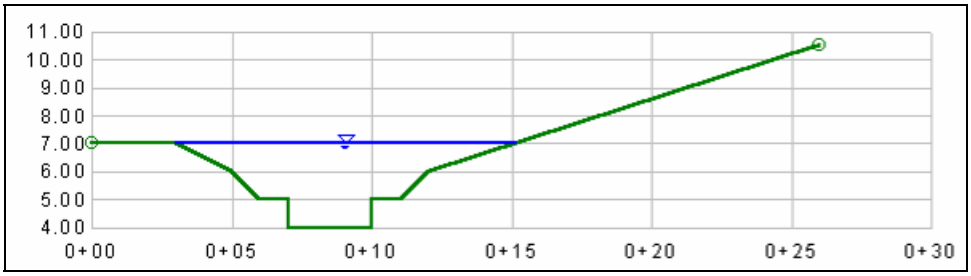

Figure 2. Typical Cross-section at 335 Linda Way
(Shown with a maximum channel capacity, looking downstream)

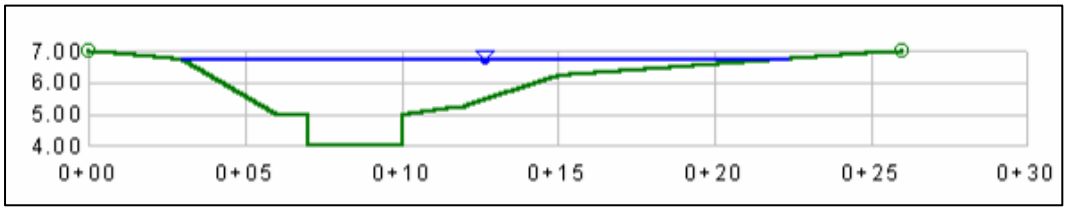

Figure 3. Typical Cross-section at 339 Linda Way
(Shown with a maximum channel capacity, looking downstream)

Utilizing the cross-sectional geometry verified in the field at 335 and 339 Linda Way, and presented above, the maximum channel capacity was calculated at each channel cross-sections. Because of the wide range of channel roughness characteristics present in the upper reach, the maximum capacity was calculated using varied Manning's n coefficients ranging from 0.03 to 0.06. An average channel slope of 0.002 feet/feet was obtained from the County provided topographic survey, and used in the normal depth calculations. The maximum channel capacity at each cross-section can best be defined as the maximum channel capacity which does not result in over-bank flow encroachment into the adjoining yards. Results of the analysis are presented below in Table 3.

Table -3. Estimated Maximum Channel Capacity for the Upper Reach of Crest Marin Creek

Manning's n	**Estimated Maximum Channel Capacity (cfs)**	
	335 Linda Way Cross-Section (cfs)	339 Linda Way Cross-Section (cfs)
0.03	46.7	44.0
0.04	35.0	33.0
0.05	28.0	26.4
0.06	23.3	22.0
NOTES: 1. Channel Slope (Energy Slope) = 0.002 feet/feet (County provided topographic survey) 2. Cross-section geometry obtained from field observation		

A similar normal depth open channel flow analysis was conducted by LTD on the upper reach, and presented in their March 2004 report. LTD estimated a maximum channel capacity flow of 43 and 29-cfs corresponding with a Manning's n coefficient of 0.04 and 0.06, respectively. However, the analysis assumed a trapezoidal channel cross-section with a 5-foot bottom width

and a 2H:1V side slopes, and an energy slope of 0.003. According to the LTD Report, the channel geometry was obtained from survey data and field verified. The upper reach does contain short channel segments where the cross-sectional geometry is best represented by a trapezoidal cross-section of similar dimensions to the cross-section used in the LTD analysis; however a majority of the upper reach is best typified by the cross-sections presented above at 335 and 339 Linda Way.

The results of the normal depth hydraulic capacity analysis presented above do not include the anticipated backwater affects created by flow constrictions present in the upper channel reach. A more complex analysis involving backwater computations would have to be conducted to better understand the impacts these various obstructions have on the open channel conveyance. The results presented above should be considered an optimistic estimate of the actual upper channel reach capacity.

Lower Reach Analysis

A one-dimensional hydraulic model for the lower reach of Crest Marin Creek was created using the current version (version 3.1.3) of the Hydraulic Engineering Center River Analysis System (HEC-RAS) software developed by the U.S. Army Corps of Engineers. The HEC-RAS model was used to calculate the water surface profile for steady gradually varied flow in the channel network extending approximately 1,080 feet from the Crest Marin Creek Pump Station at Flamingo Way to approximately 50 feet upstream of the Ross Drive footbridge. The water surface profile calculation is computed from one cross section to the next using standard step methods of solving the one-dimensional energy equation. Energy losses between cross sections include friction losses and contraction or expansion losses. Velocity and flow are calculated for each cross section using Manning's equation. The steady flow calculation is designed for application in floodplain management and flood insurance studies to evaluate floodway encroachments.

The cross sections used to represent the open channel network were created from section profiles generated from the site topography information using AutoCAD 2006. A total of 32 cross-sections were used in developing the open channel model.

In addition to the cross sections, geometric data representing the Ross Drive footbridge, the pump station inlet culvert, and the pump station vault was included in the model. The footbridge dimensions were obtained from the Winzler & Kelly topographic survey conducted on August 10, 2006, whereas pump station vault and 118-foot reinforced concrete inlet culvert dimensions were obtained from the 1978 Marin County Department of Public Works "As-Built" plans. Figure 4 shows a plan view of the reach and the cross sections included in the model.

Figure 4. Plan View of HEC-RAS Model and Cross-sections

For each cross-section entered into HEC-RAS, a Manning's roughness coefficient representing the main channel, as well as the left and right over-banks was input to the model. On August 10, 2006 channel and over-bank roughness characteristics were documented every 50 feet between Flamingo Way and Ross Drive footbridge using the Natural Resource Conservation Service (NRCS, formally SCS) method for estimating Manning's n as explained in the National Engineering Handbook (NEH-5), (NRCS, 1971).

The HEC-RAS model representing the lower reach of Crest Marin Creek was utilized to determine the capacity limitations of the lower reach system. Based on the model simulations, it was determined that a flow rate of 44-cfs results in the maximum flow capacity of the channel between stations 809.5 through 976.69, as seen in Figures 5, 6, 7, and 8.

The results indicate that flows exceeding 44-cfs will result in flow encroachment into the adjacent properties situated on the north side of Crest Marin Creek, shown below in Figure 5.

Figure 5. Station 864.69 (Facing upstream with Marin Avenue in distance)

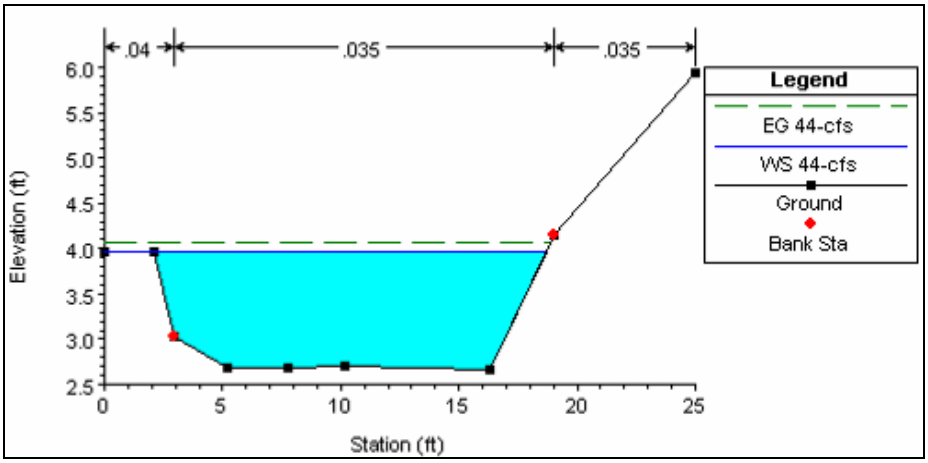

Figure 6. Cross-section at Station 897.11 (looking upstream) with a Bank-Full Capacity of 44-cfs Simulated in HEC-RAS

Figure 7. Station 897.11(Facing downstream with Marin Avenue on right)

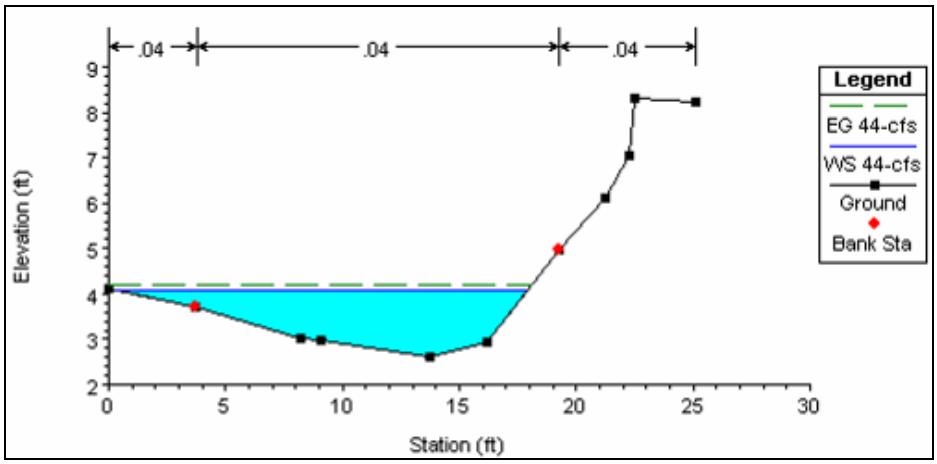

Figure 8. Cross-section at Station 897.11 (looking downstream) with a Bank-Full Capacity of 44-cfs Simulated in HEC-RAS

The HEC-RAS results, shown in profile view of the lower reach (Figure 9), indicate a channel thalweg slope through the reach spanning from station 809.5 through 976.69 with no gradient. Geomorphic features such as channel aggradation were observed through this reach during the field observations, explaining the limitations in the channel capacity.

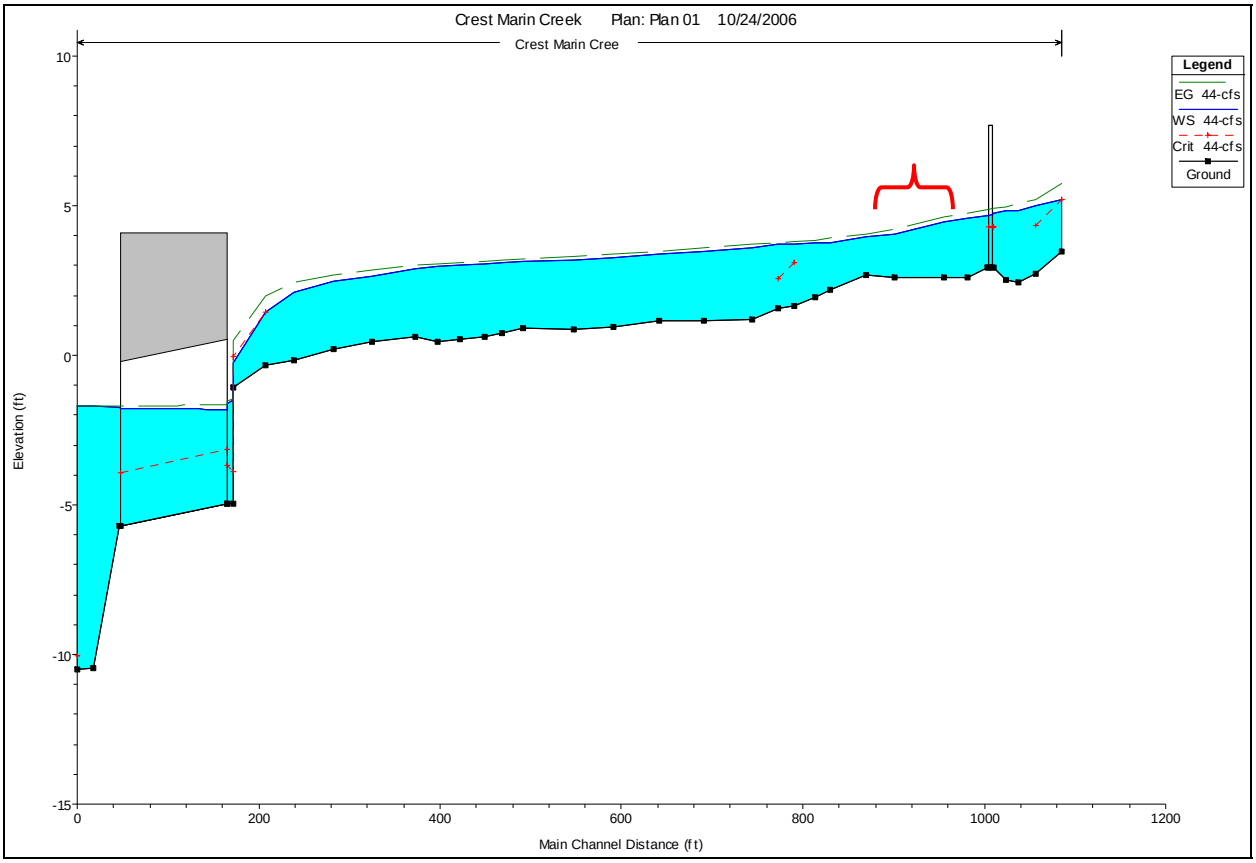

Figure 9. HEC-RAS Profile of Crest Marin Creek Lower Reach at 44-cfs (Maximum channel capacity reached from station 809.5 through 976.69. Water surface elevation in pump station vault set at -1.71 feet (NGVD) corresponding with the high-level cut-off for Pump #1)

Property owners adjacent to the channel at stations 809.5 through 976.69 were informally interviewed on August 10, 2005, where it was determined that flows had not exceeded the channel capacity at these stations in the past 15 to 20 years. Based on LTD's capacity analysis of the underground storm drain system at Laurel Way and Marin Avenue, the maximum storm drain pipe capacity of 35-cfs limits the flow discharge into the channel above the Ross Drive footbridge. It should be noted that additional overland flow does contribute to the channel flow at the Ross Drive footbridge, and shown in Table 1 as the difference in flows between Node 4 and Node 5. However, this contributing drainage is relatively small in size. Based on the property owners' observations, this combined flow at Ross Bridge has not resulted in overbank flows through the reach spanning from station 809.5 through 976.69, verifying that the HEC-RAS models predictions of channel capacity are accurate.

To further analyze the existing conditions of the modeled reach, the pumping capacity of the Crest Marin Creek Pump Station was analyzed. The Crest Marin Creek Pump Station contains four low-head, high-capacity pumps. The pump capacities were obtained from the Marin County Department of Public Works Crest Marin Creek Pump Station "As-Built" plans dated February, 1978, and tabulated in Table 4 below. The four pumps running simultaneously provide a

maximum pumping capacity of 81,000-gpm (180.5-cfs). The 10-year flow rate of 202.8-cfs, estimated by PWA, exceeds the pump station capacity.

Table 4. Crest Marin Creek Pump Station Capacity

Pump No.	Capacity (gpm)
1	3,000
2	26,000
3	26,000
4	26,000
TOTAL	81,000 (gpm) 180.5 (cfs)
NOTES: Pump capacities obtained from Marin County Department of Public Works, Crest Marin Creek Pump Station "As-Built" plans dated February 1978	

Utilizing the maximum pumping capacity of the pump station (180.5-cfs), and a normal high water surface elevation in the vault of 0.29-feet, the HEC-RAS model was utilized to estimate the corresponding water surface elevation in the modeled reached. The HEC-RAS results indicate that a flow of 180.5-cfs exceeds the channel capacity from the Ross Drive footbridge down to station 365.04. The capacity of the channel is not exceeded between the culvert inlet and station 365.04, however the model does indicate that the culvert inlet does become fully submerged as shown in the profile in Figure 10 below. The modeling capabilities of HEC-RAS do not allow for an inclined trash rack to be modeled, therefore the roughness characteristic of the corresponding cross-section at station 172 were increased to 0.1 to account for the inlet losses. A photograph of the inlet structure is shown below in Figure 11.

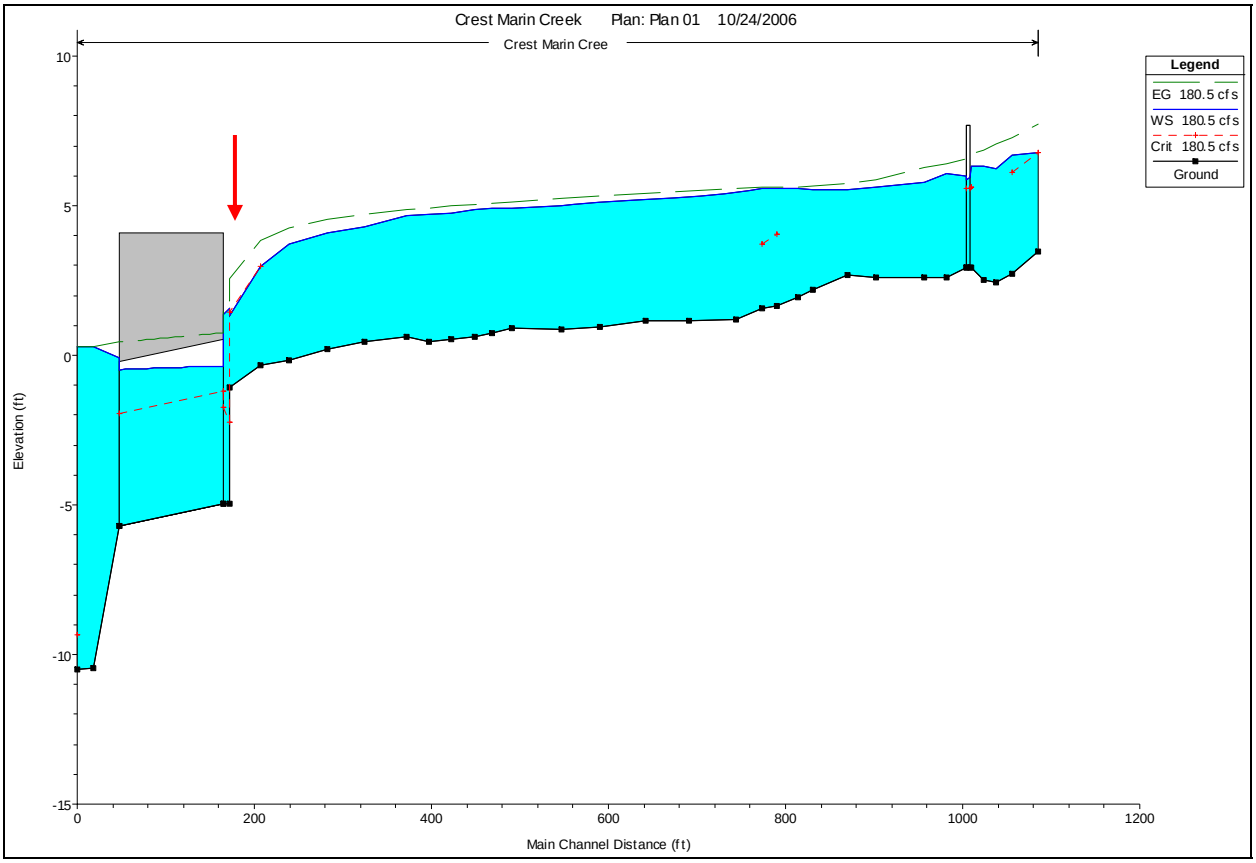

Figure 10. HEC-RAS Profile of Crest Marin Creek Lower Reach at 180.5-cfs (Water surface elevation in the pump station vault set at 0.29 feet (NGVD) corresponding with a normal high-water elevation in the pump station, and all four pumps running simultaneously)

Figure 11. Crest Marin Creek Pump Station Inlet Structure (Photograph taken on August 10, 2006)

The results indicate that the culvert inlet structure does control the conveyance capacity of flow into the vault. However, the HEC-RAS profile above was computed utilizing a normal high water surface elevation in the vault of 0.29 feet. To further analyze the inlet control culvert capacity, a *CulvertMaster* analysis will be conducted and presented in the final Technical Memorandum.

To further verify that the culvert inlet structure does limit the conveyance capacity of the culvert, the water surface elevation in the vault (tail-water depth) was decreased to a normal low water depth of -5.0 feet. The computed HEC-RAS profile utilizing the maximum pump capacity of 108.5-cfs is shown below in Figure 12.

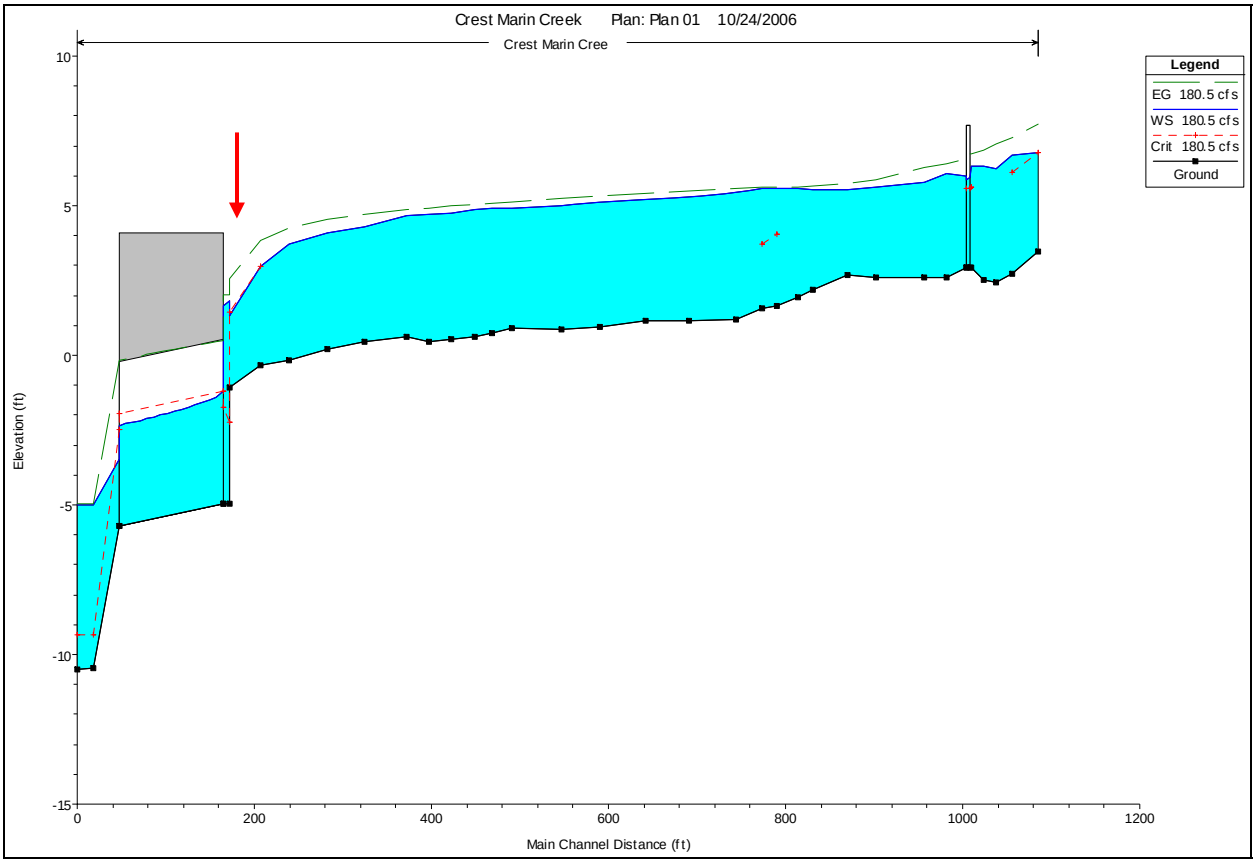

Figure 12. HEC-RAS Profile of Crest Marin Creek Modeled Reach at 180.5-cfs (Water surface elevation in the pump station vault set at -5.0 feet (NGVD) corresponding with a normal low water elevation in the pump station)

The profile further confirms that the inlet structure creates a flow constriction that controls the inlet capacity of the culvert. Even though the flow constriction created by the inlet structure does limit the culvert capacity, it does not create overbank flows in the localized areas (station 172 to 365.04). Occurrences of localized flooding in the vicinity of the culvert outlet has been recorded, and is assumed to have been associated with debris and trash clogging the trash rack.

Summary of Existing Condition Analysis

Table 5 below was provided to summarize the analyses conducted to date of the Crest Marin Creek drainage system. As a result of the analysis, locations of drainage deficiencies have been identified, and will provide the basis for alterative developments.

Table 5. Summary of Capacity Limitations within the Crest Marin Creek Drainage System

Location	Capacity (cfs)	Method Used in Estimating Maximum Capacities	PWA Flows (2005)	
Underground Storm Drain System at intersection Laurel Way and Marin Avenue	35.0	Obtained from LTD Report	Node 4	
			10-year	123.7
			25-year	161.0
			50-year	189.0
			100-year	216.7
Upper Reach (335 Linda Way)	23.3 - 46.7	Normal Depth Calculations	Node 4	
			10-year	123.7
			25-year	161.0
			50-year	189.0
			100-year	216.7
Upper Reach (339 Linda Way)	22.0 - 44.0	Normal Depth Calculations	Node 4	
			10-year	123.7
			25-year	161.0
			50-year	189.0
			100-year	216.7
Lower Reach of Crest Marin Creek (Station 8+09.5 through 9+76.69)	44.0	HEC-RAS Model	Node 5	
			10-year	172.5
			25-year	222.9
			50-year	260.6
			100-year	297.8
Crest Marin Creek Pump Station	180.5	Obtained from As-Built Plans	Node 6	
			10-year	202.8
			25-year	260.8
			50-year	304.2
			100-year	346.9

REFERENCES

1. *County of Marin, 1' contour, 1" = 100' NGVD 1929 topographic map. 2006*

2. *County of Marin, Department of Public Works. Flood Control Zone No. 3, Crest Marin Creek Pump Station As-Built Plans. February 9, 1978*

3. *LTD Engineering, Drainage Improvement Investigation Crest Marin Creek. March 2004.*

4. *Natural Resource Conservation Services (NRCS), National Engineering Handbook, Chapter 5, Supplemental B – Estimating Manning's Roughness Coefficients, April 1971.*

5. *Philip Williams & Associates, Ltd. (PWA), Laurel Way Bypass Hydrologic and Hydraulic Analyses. September 1, 2005.*

6. *Philip Williams & Associates, Ltd. (PWA), Reassessment of Coyote Creek Channel Management Requirements. January 10, 2005.*

7. *Personal Contact: Tim Hampton and John Wooley, Marin County Public Works, 2006.*

APPENDIX A

Flow rates for subwatersheds 6.1 and 12.1 provided by Marin County.

Marin County Provided Flow Rates				Scaled Subshed 12.1 Flows (cfs)	Total Flow Rate (Subshed 6.1 + 12.1) (cfs)
Subshed 6.1		Subshed 12.1			
Frequency	Peak Flow (cfs)	Frequency	Peak Flow (cfs)		
2	9.9	2	10.7	5.35	15.25
10	19.5	10	21.5	10.75	30.25
20	23.2	20	25.7	12.85	36.05
25	24.4	25	27	13.5	37.9
50	28	50	31.1	15.55	43.55
100	31.5	100	35.1	17.55	49.05