MYNOT CREEK CULVERT REPLACEMENT
TECHNICAL ANALYSIS AND RECOMMENDATIONS

PREPARED BY:
RANDY KLEIN, HYDROLOGIST
AND
JEFFREY K. ANDERSON, P.E.

FOR

ART REEVE, P.E., DIRECTOR
DEL NORTE COUNTY PUBLIC WORKS DEPARTMENT

P.O. NO. 10317

AUGUST, 2002

INTRODUCTION

This report provides an assessment of existing and proposed conditions for the planned culvert replacement project to improve fish passage and habitat in Mynot Creek, Del Norte County (DNC). As planned, the existing culvert on Requa Road will be replaced with a bridge with the goals of removing the structure as a barrier to salmonid migration and allowing the stream to more effectively transport sediment and adjust its bed, resulting in local habitat improvement. To facilitate the latter, aggraded bed material (gravel) will be excavated from the channel as part of the project.

HYDROLOGY

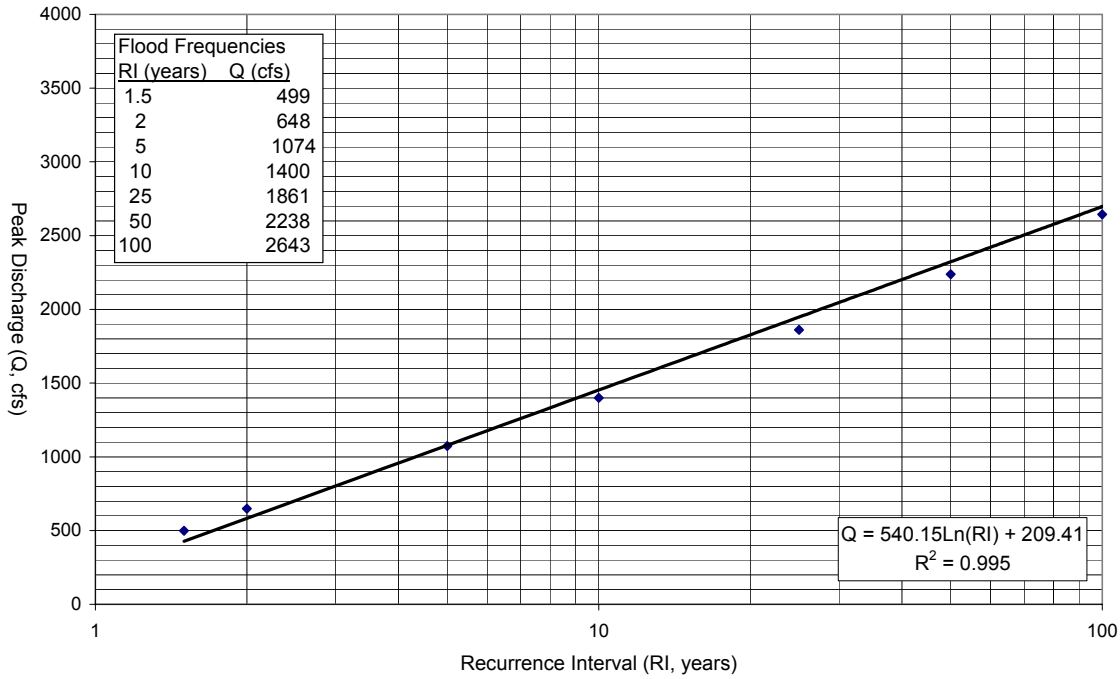
Flood frequencies for Mynot Creek at the project site were estimated based on USGS data for an abandoned gaging station on Jacoby Creek (No. 11480000). They were estimated based on scaling Jacoby Creek flood frequencies by the ratio of mean annual discharge, with the mean annual discharge for Mynot Creek derived from rainfall and evapotranspiration maps in Rantz (1964). A flood frequency curve with peak discharges at a variety of recurrence intervals (RI, years) is shown in Figure 1.

EXISTING CULVERT AND PROPOSED BRIDGE DIMENSIONS

The existing culvert, constructed in 1951, consists of two barrels approximately 12 feet effective width and 6.5 feet in height, separated by a wall at mid-span. It is skewed relative to the creek by about 45 degrees, thus the effective flow width is considerably less than the structural width of the culvert. The culvert's concrete bottom slopes relatively steeply in a downstream direction and extends beyond the roadway by about 20 feet upstream and about 8 feet downstream for a total streamwise length of about 80 feet. The culvert bottom elevates the grade of the creek by about 3-4 feet, causing aggradation that extends about 800 feet upstream. A plunge pool about 2.5 feet deep exists at the downstream end. Each barrel provides approximately 80 square feet of effective flow area, totaling about 160 square feet. A preliminary estimate of the culvert's capacity is about 1400 cfs, equivalent to the 10-year flood. The channel capacity upstream of the culvert appears to be slightly greater than that of the culvert, indicating that the culvert may cause overbank flooding at a lower discharge rate than would otherwise occur. This condition would be exacerbated by accumulation of debris at the culvert inlet during stormflows.

The proposed bridge deck would be elevated relative to the existing culvert top by an estimated 2-3 feet, resulting in a bottom chord elevation 1-2 feet higher than channel banks upstream. Combined with the anticipated 3-4 feet of channel bed lowering following removal of the culvert as a grade control, there will be a total of about six feet of additional flow height gained by replacement with the proposed bridge. Additional flow area and hydraulic efficiency will be gained by removal of the mid-span wall in the existing culvert. These improvements will provide much greater capacity to convey floodwater and debris.

Figure 1. Flood Frequency Curve for Mynot Creek at Requa Road (DA = 3.13 sq. mi.)

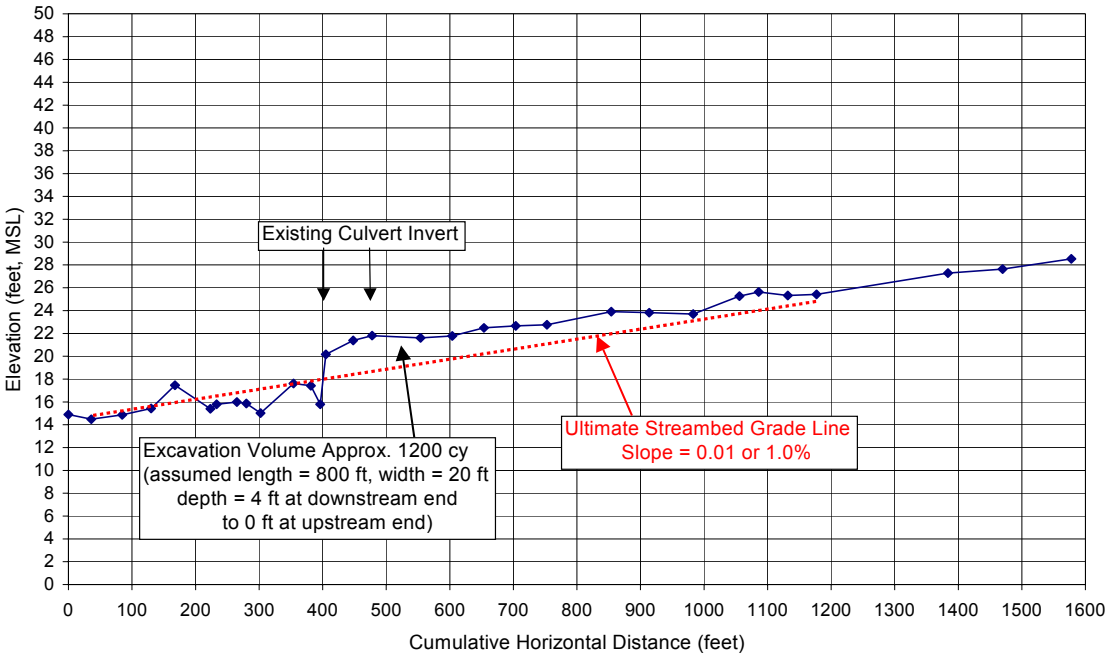


RESTORATION OF CHANNEL GEOMORPHIC AND HABITAT CONDITIONS

The channel upstream of the existing culvert is aggraded with gravel and sand sized sediment to the elevation of the existing culvert bottom. Very little channel diversity exists in this reach due to the aggraded condition, as indicated by the flat streambed profile apparent in Figure 2. In addition, riparian trees (large spruce, alder, and maple) may be at risk of drowning due to elevated groundwater levels and abrasion by bedload transport during floods because of the elevated channel bed. Lack of surface flow during much of the year may also be attributed, in part, to aggradation. By removing the artificial grade control exerted by the existing culvert, the channel will be able to be lowered by a maximum of about 3-4 feet at the project site, with this adjustment tapering to zero approximately 800 feet upstream (see Fig. 2).

Replacement of the culvert with the bridge will remove the salmonid migration barrier caused by the culvert bottom. In addition, anticipated channel bed adjustments following culvert removal should restore rearing and holding habitat to the upstream reach by allowing pools and riffles to re-form and may also cause surface flow to persist longer into the spring and summer season. Bank erosion potential is not expected to increase significantly as a result of channel bed lowering as the bank material is primarily composed of cohesive clays and silts and is heavily vegetated with large riparian trees and shrubs.

Figure 2. Longitudinal profile of Mynot Creek Project Reach, May, 2002



By simply removing the existing culvert bottom, the channel would gradually seek its own grade as bed material is scoured and transported downstream (see Fig. 2). However, release of this bed material would temporarily impact the channel downstream by causing aggradation. Consequently, aggraded gravel will be excavated from the upstream reach to accelerate the recovery of habitat upstream of the project site and to minimize impacts to existing habitat downstream.

Figure 2 shows an approximation of the ultimate streambed grade line that is proposed as the excavation grade line. Assuming an excavation width of 20 feet and length of about 800 feet (to station 1200 in Fig. 2), the volume to be excavated will be about 1200 cubic yards. A smaller excavation extending upstream only about 300 feet of the culvert (to about station 800 in Fig. 2) may be more feasible and would accomplish virtually the same level of restoration (only about one-third of the 1200 cy is located upstream of station 800).

This material can be excavated from the channel using equipment and techniques that preserve the existing riparian trees. Specifically, a bulldozer can push gravel upstream or downstream to locations in the channel adjacent to gaps in the existing riparian stand on the right bank (adjacent to the school) and removed at these discrete locations by an excavator working from the upper bank. Gravel so removed may be used for a temporary road crossing during bridge replacement and/or hauled offsite to stockpile areas for later use in road repair projects.

HYDRAULIC ANALYSIS

Methods

Objectives of Hydraulic Analysis

The hydraulic analysis was conducted to provide estimates of existing water surface elevations and velocities for flood discharges in Mynot Creek, and to determine the effects of the proposed bridge improvements on existing flood elevations and velocities. Standard hydraulic engineering methods were used to conduct the hydraulic analysis.

Project Reach Description

For this hydraulic analysis a portion of the Mynot Creek was studied in detail. The project reach begins at a point approximately 300 ft upstream of the existing culvert crossing, and extends approximately 400 ft downstream of the culvert. The total length of the Mynot Creek hydraulic analysis reach is approximately 700 ft.

HEC-RAS Analysis of Project Reach

The hydraulic analysis for the project reach of Mynot Creek was conducted using the U.S. Army Corps of Engineers HEC-RAS modeling system (USACE, 2001). The HEC-RAS model calculates water surface profiles and average channel velocities for both steady, gradually varied flow, and unsteady flow through a network of channels. Only steady gradually varied flows were analyzed for the Mynot Creek analysis. For steady state modeling, changes in water surface elevation between adjacent cross sections are computed by solving the one-dimensional conservation of mass and energy equations with an iterative numerical method (standard step method). Energy losses consist of frictional losses (based on Manning's equation) and channel contraction/expansion losses (based on the change in velocity head). The following assumptions are implicit to the steady state modeling methodology used in HEC-RAS for generating water surface profiles: (1) flow is steady, (2) flow is gradually varied (except at hydraulic structures), (3) flow is one dimensional, (4) channel slopes are small (less than 1:10), and (5) channel boundaries are rigid.

The HEC-RAS model requires channel, bridge and/or culvert cross section station and elevation data, estimates of the cross section hydraulic roughness and contraction/expansion coefficients, and flow lengths between cross sections. Two HEC-RAS models were developed consisting of an existing condition 1-d hydraulic model, and a proposed project 1-d hydraulic model.

Channel Data

Topographic and thalweg survey data of the Mynot Creek project reach was collected by Del Norte County Public Works Department (DNCPW) in 2002 as part of this project. For the existing condition 1-d hydraulic model, fifteen (15) cross sections were developed for the Mynot Creek project. The cross sections, channel and overbank reach lengths for the HEC-RAS models were developed using the Surface Water Modeling System (SMS Version 8) software, and the DNCPW topographic data. The existing culvert geometry was input into the HEC-RAS model based on field measurements taken by Klein and Anderson in a 2002 site visit, and the DNCPW topographic data.

The proposed project 1-d hydraulic model consisted of the same cross sections used in the existing condition model, however, two additional cross sections were added to better define the proposed bridge geometry (Figure 3). As required, cross sections were modified to represent expected channel improvements, and the existing culvert was replaced with the proposed bridge crossing. It was assumed that the bridge deck was 34 ft wide, and due to the skew angle of the bridge to the creek, the effective length of the bridge was 48 ft. The channel width below the proposed bridge was assumed to be 25 ft,

with vertical walls up to the bridge bottom chord. Table 1 lists the stations and thalweg elevations for the existing condition and proposed project models.

Cross-sections were located at close intervals above and below culverts, bridges and hydraulic structures to better define the hydraulics and/or backwater effects in these locations. All culverts and bridges for all models were assumed to flow unobstructed by debris or sediment.

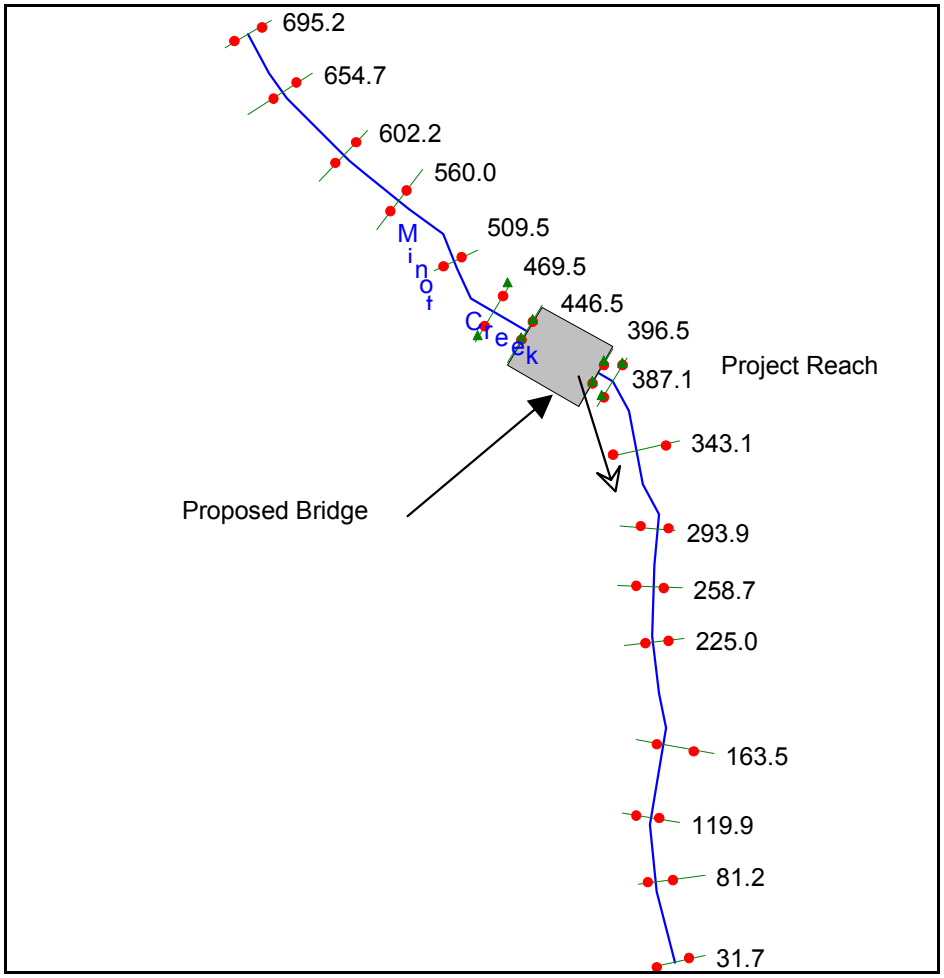


Figure 3. Schematic of Mynot Creek cross sections from HEC-RAS for project condition 1-d hydraulic model.

Table 1. Mynot Creek project reach existing and project conditions model stations and thalweg elevations

Existing Station	Description	Existing Thalweg Elev. (ft)	Project Station	Description	Project Thalweg Elev. (ft)
695.2	Channel XS	22.94	695.2	Channel XS	20.87
654.7	Channel XS	21.65	654.7	Channel XS	20.48
602.2	Channel XS	21.68	602.2	Channel XS	19.98
560.0	Channel XS	22.25	560.0	Channel XS	19.58
509.5	Channel XS	21.77	509.5	Channel XS	19.10
469.6	Channel XS	22.00	469.5	Channel XS	18.72
			446.5	Channel XS	18.50
445.6	Culvert Inlet	21.40	445.5	Bridge Inlet	18.49
403.2	Culvert Outlet	20.20	397.5	Bridge Outlet	18.03
			396.5	Channel XS	18.02
387.1	Channel XS	16.00	387.1	Channel XS	17.93
343.1	Channel XS	17.52	343.1	Channel XS	17.52
293.9	Channel XS	15.10	293.9	Channel XS	15.10
258.7	Channel XS	15.99	258.7	Channel XS	15.99
225.0	Channel XS	15.67	225.0	Channel XS	15.67
163.5	Channel XS	15.90	163.5	Channel XS	15.90
119.9	Channel XS	15.39	119.9	Channel XS	15.39
81.2	Channel XS	14.89	81.2	Channel XS	14.89
31.7	Channel XS	14.49	31.7	Channel XS	14.49

Energy Loss Coefficients

Two types of energy loss coefficients are required by HEC-RAS to account for energy losses in the channel and overbank areas: (1) Manning's roughness coefficient (*n*) to account for frictional losses, and (2) contraction/expansion losses for channel transitions. Manning' roughness coefficients (*n*) were estimated by comparing the Mynot Creek channel with published color photos, descriptive data, and verified *n* values for stream channels found in Barnes (1967). Based on visual observations of the channel, and comparison to the Barnes data, it was determined that a channel *n* value of 0.05 and an overbank *n* value of 0.1 were appropriate for this reach of channel. The channel *n* value through the proposed bridge was 0.033 (French, 1965).

For channel cross sections, the default HEC-RAS contraction/expansion coefficients (contraction = 0.1, expansion = 0.3) were used. Contraction and expansion coefficients of 0.3 and 0.5, respectively, were used for the culvert and bridge cross sections.

Design Discharge

To analyze and compare flow conditions for the proposed Mynot Creek bridge project, the existing and project hydraulic models were run for the Q_2, Q_{10} and Q_{100} flood discharges determined in the hydrology section above.

Initial Boundary Conditions

For sub-critical flow computations, a downstream water surface elevation (boundary condition) is required for HEC-RAS to generate water surface profiles. For this analysis, the downstream boundary condition was assumed normal depth at the most downstream cross section.

Results and Discussion of Hydraulic Analysis

HEC-RAS Analysis of Project Reach

To determine the effects of the proposed Mynot Creek bridge project on flood elevations and velocities, the existing and project 1-d hydraulic models were run and compared for the Q_2, Q_{10} and Q_{100} discharges. For this hydraulic analysis, it was assumed that all flood discharges were contained within the channel. As required, the HEC-RAS model extended cross section ends to contain the discharge within the channel. This assumption provided conservative results, especially for higher flood discharges, since in reality, overbank flows occur upstream at lower discharges than at the existing culvert, reducing the actual flood discharge within the channel approach to the culvert.

Tables 2, 3 and 4 present results for water surface elevation (WSE), average channel velocity (V), and average channel shear stress (SS) for the existing and project model runs for the Q_2, Q_{10} and Q_{100} discharge, respectively. It should be noted that two additional cross sections (XS 446.5 and 396.5) were added to the project hydraulic model, and do not exist in the existing condition model. Figures 4, 5 and 6 compare the existing and design project WSE for the Q_2, Q_{10} and Q_{100} discharge, respectively. Figures 7 and 8 show the HEC-RAS profile plots for the Q_{100} computer runs for the Mynot Creek project reach.

Table 2. Mynot Creek hydraulic model results for existing and project conditions for Q_2

Existing Station	Project Station	Existing WSE (ft)	Project WSE (ft)	Existing V (ft/s)	Project V (ft/s)	Existing SS (lb/ft^2)	Project SS (lb/ft^2)
695.2	695.2	27.59	26.29	5.82	5.19	1.40	1.04
654.7	654.7	27.57	26.02	3.81	5.32	0.47	0.91
602.2	602.2	27.44	25.48	3.73	5.80	0.47	1.21
560.0	560.0	27.20	25.19	4.50	5.23	0.66	1.14
509.5	509.5	26.06	23.04	8.63	10.99	3.01	6.22
469.6	469.5	26.02	22.64	4.71	7.51	0.97	2.86
	446.5		22.50		6.51		0.90
445.6	445.5	26.02	22.48	9.55	6.52		0.91
403.2	397.5	22.54	22.33	14.54	6.04		0.76
	396.5		22.32		6.05		0.76
387.1	387.1	22.54	22.50	2.36	3.22	0.19	0.44
343.1	343.1	22.43	22.43	3.02	3.02	0.41	0.41
293.9	293.9	22.17	22.17	4.24	4.24	0.63	0.63
258.7	258.7	22.03	22.03	4.45	4.45	0.66	0.66
225.0	225.0	21.84	21.84	4.88	4.88	0.81	0.81
163.5	163.5	21.73	21.73	3.82	3.82	0.59	0.59
119.9	119.9	20.43	20.43	8.79	8.79	3.69	3.69
81.2	81.2	19.96	19.96	7.25	7.25	2.53	2.53
31.7	31.7	19.66	19.66	5.72	5.72	1.55	1.55

Table 3. Mynot Creek hydraulic model results for existing and project conditions for Q_{10}

Existing Station	Project Station	Existing WSE (ft)	Project WSE (ft)	Existing V (ft/s)	Project V (ft/s)	Existing SS (lb/ft^2)	Project SS (lb/ft^2)
695.2	695.2	30.13	28.41	6.39	6.81	1.30	1.60
654.7	654.7	30.21	28.32	4.59	6.04	0.60	1.12
602.2	602.2	30.11	28.05	4.56	6.04	0.61	1.17
560.0	560.0	29.87	27.73	5.43	6.37	0.78	1.20
509.5	509.5	29.08	25.69	8.36	11.70	2.07	5.03
469.6	469.5	29.24	25.43	5.17	7.56	0.76	2.45
	446.5		24.83		8.85		1.49
445.6	445.5	29.24	24.81	12.32	8.87		1.50
403.2	397.5	25.02	24.60	17.30	8.51		1.37
	396.5		24.59		8.52		1.37
387.1	387.1	25.02	24.97	3.56	4.46	0.37	0.74
343.1	343.1	24.94	24.94	3.73	3.73	0.51	0.51
293.9	293.9	24.51	24.51	5.87	5.87	0.92	0.92
258.7	258.7	24.40	24.40	5.90	5.90	0.88	0.88
225.0	225.0	24.11	24.11	6.70	6.70	1.18	1.18
163.5	163.5	24.10	24.10	4.92	4.92	0.69	0.69
119.9	119.9	22.40	22.40	10.66	10.66	3.99	3.99
81.2	81.2	21.79	21.79	10.11	10.11	2.83	2.83
31.7	31.7	21.68	21.68	7.44	7.44	2.00	2.00

Table 4. Mynot Creek hydraulic model results for existing and project conditions for Q_{100}

Existing Station	Project Station	Existing WSE (ft)	Project WSE (ft)	Existing V (ft/s)	Project V (ft/s)	Existing SS (lb/ft^2)	Project SS (lb/ft^2)
695.2	695.2	32.81	31.16	7.85	8.19	1.67	1.90
654.7	654.7	32.98	31.22	5.88	6.93	0.86	1.31
602.2	602.2	32.85	31.00	5.93	6.95	0.89	1.36
560.0	560.0	32.57	30.64	6.87	7.66	1.06	1.47
509.5	509.5	31.30	28.83	11.03	12.35	3.06	4.66
469.6	469.5	31.64	29.24	6.99	7.78	1.04	1.67
	446.5		27.51		11.76		2.45
445.6	445.5	31.64	27.48	12.83	11.81		2.47
403.2	397.5	27.93	27.16	12.83	11.60		2.38
	396.5		27.13		11.63		2.39
387.1	387.1	27.93	27.86	4.94	5.95	0.67	1.17
343.1	343.1	27.90	27.90	4.58	4.58	0.60	0.60
293.9	293.9	27.26	27.26	7.57	7.57	1.28	1.28
258.7	258.7	27.22	27.22	7.26	7.26	1.15	1.15
225.0	225.0	26.86	26.86	8.28	8.28	1.42	1.42
163.5	163.5	26.96	26.96	5.90	5.90	0.77	0.77
119.9	119.9	24.39	24.39	13.49	13.49	3.71	3.71
81.2	81.2	23.81	23.81	12.64	12.64	3.64	3.64
31.7	31.7	23.87	23.87	9.50	9.50	2.44	2.44

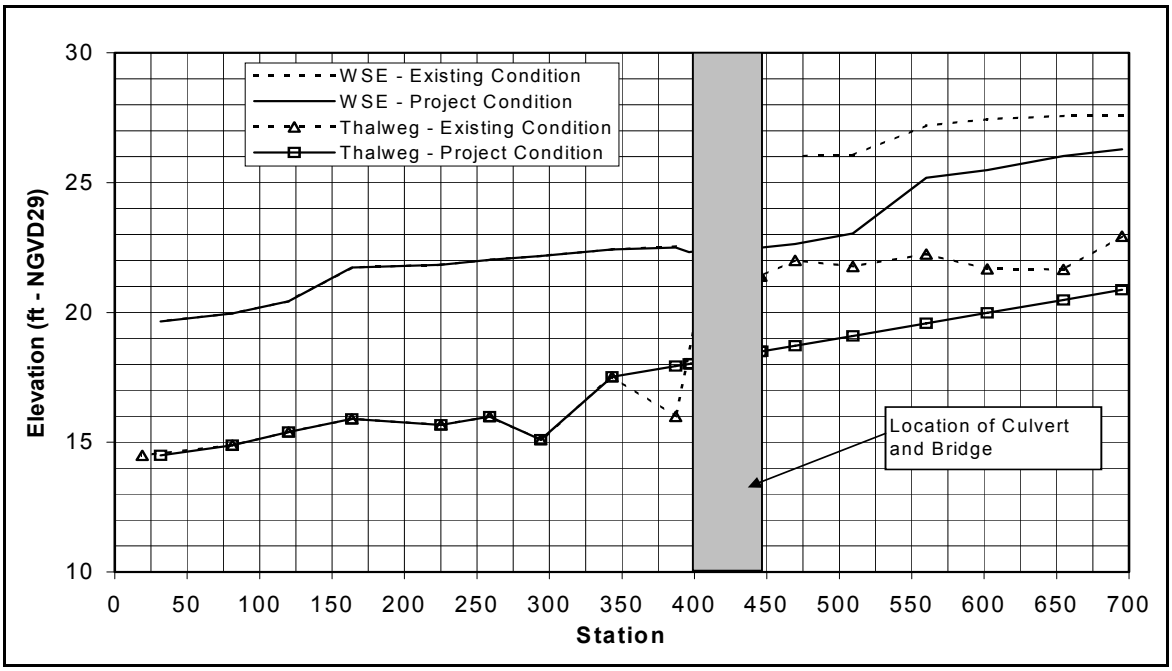


Figure 4. Computed water surface elevations for existing and project conditions for the Mynot Creek project reach at Q_2 flood discharge.

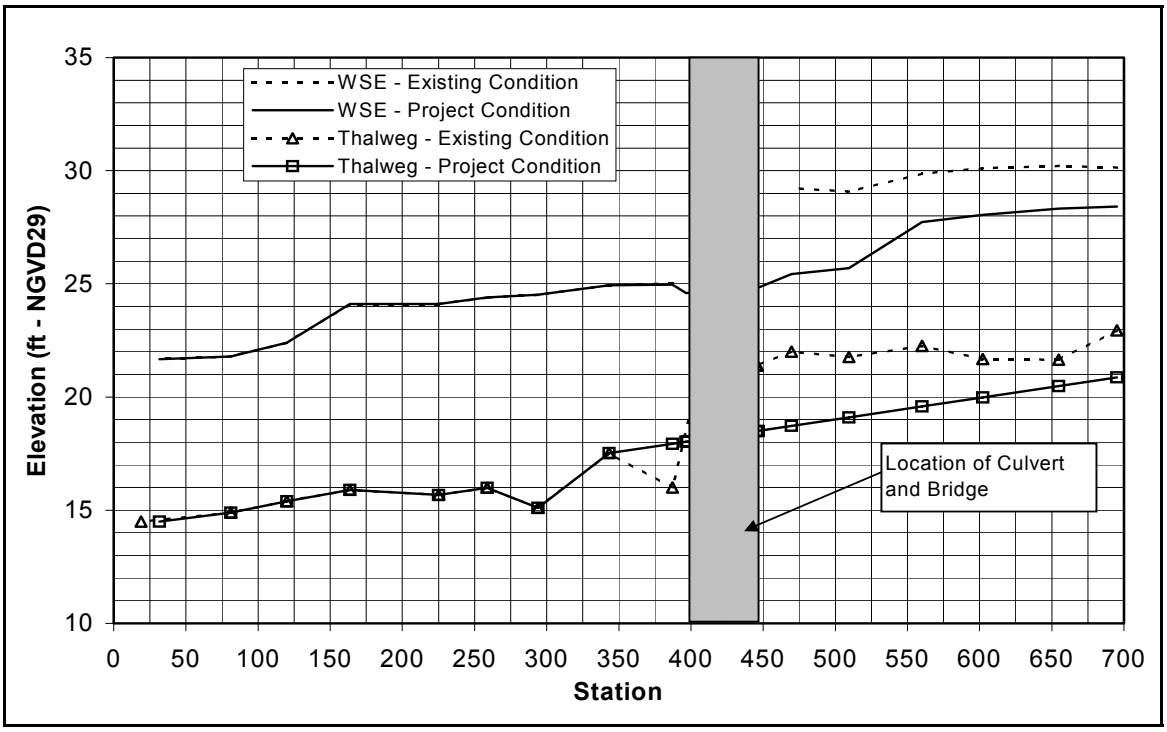


Figure 5. Computed water surface elevations for existing and project conditions for the Mynot Creek project reach at Q_{10} flood discharge.

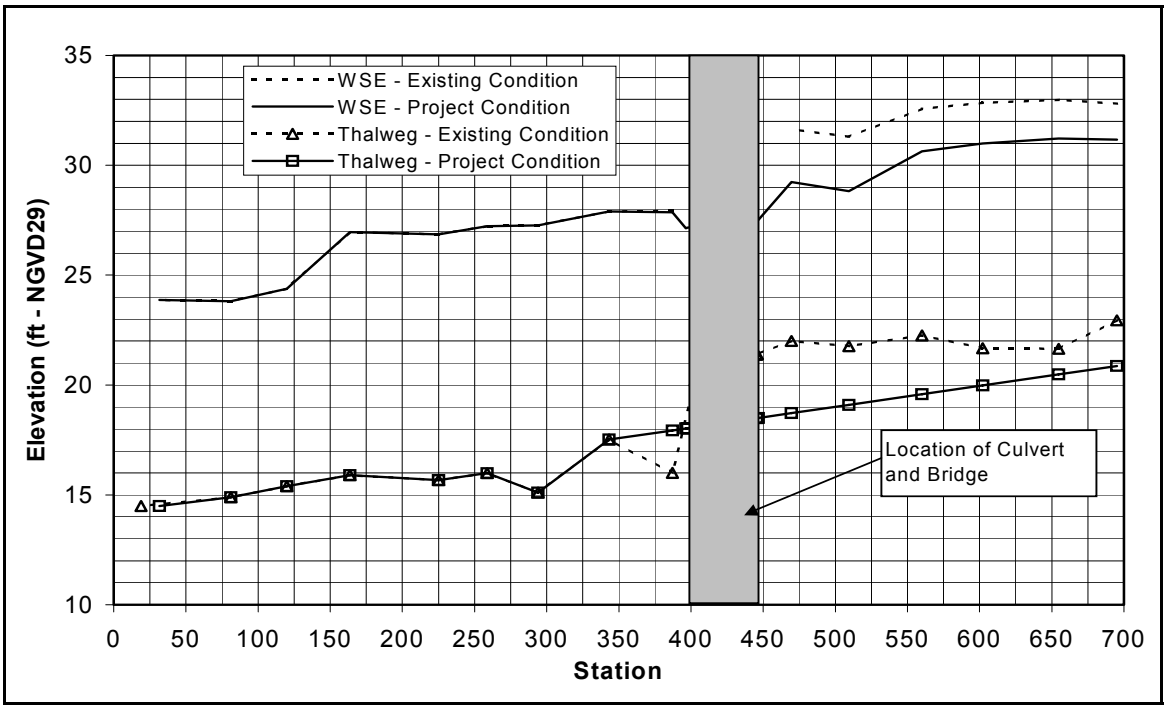


Figure 6. Computed water surface elevations for existing and project conditions for the Mynot Creek project reach at Q_{100} flood discharge.

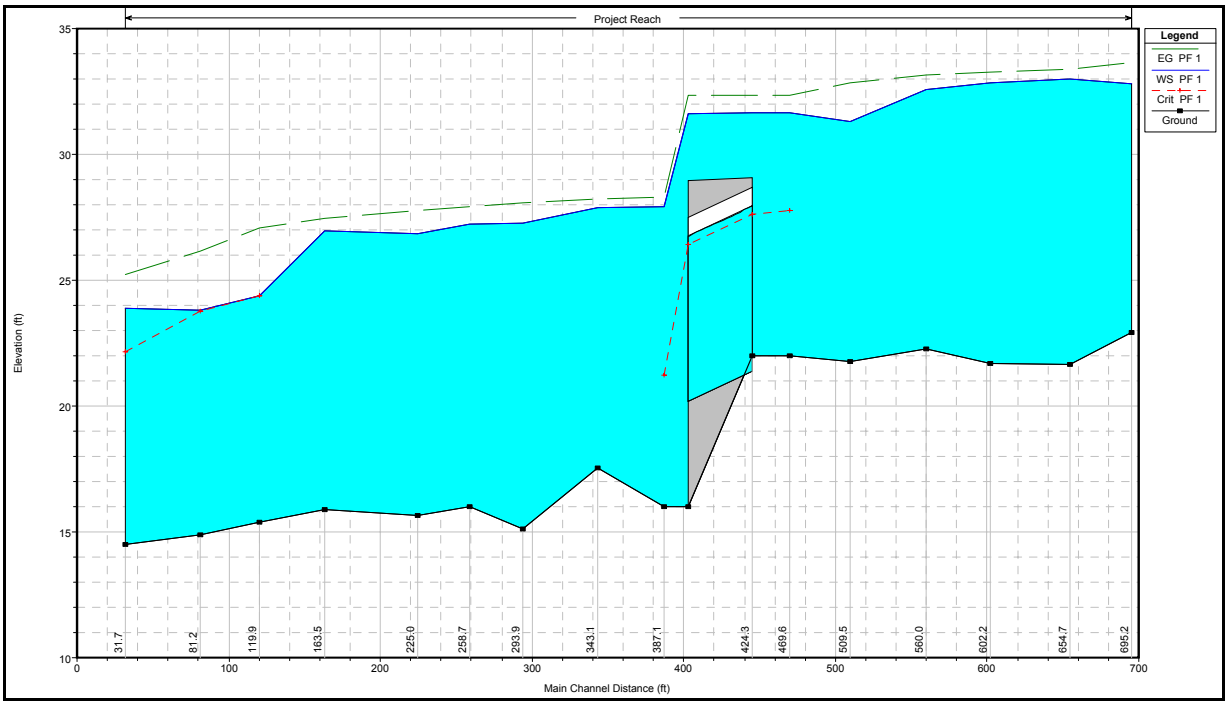


Figure 7. HEC-RAS water surface profile plot for existing conditions at Q_{100} flood discharge.

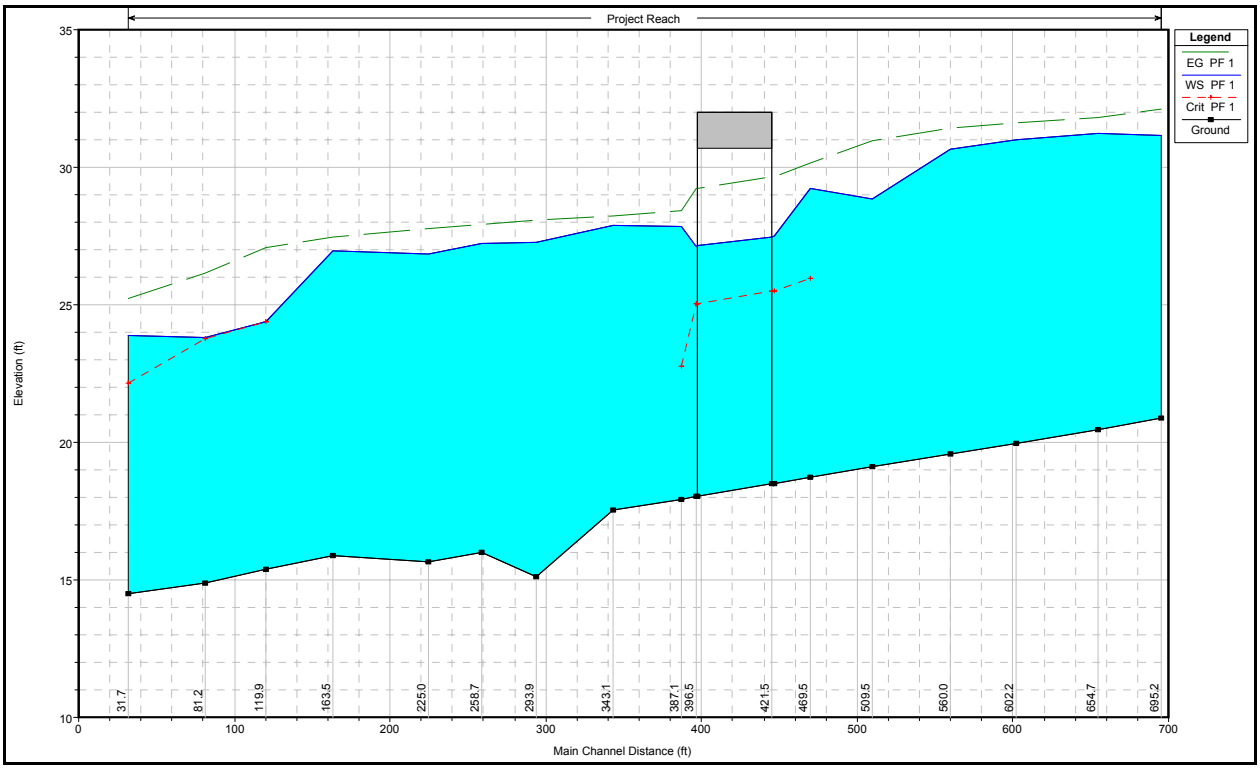


Figure 8. HEC-RAS water surface profile plot for project conditions at Q_{100} flood discharge.

CONCLUSIONS AND RECOMMENDATIONS

Hydraulic results indicate that the proposed Mynot Creek bridge will significantly improve hydraulic conditions at and upstream of the proposed bridge. For all flood discharges analyzed, WSEs are significantly reduced upstream of the proposed bridge from Station 387.1 to 695.2 (Figures 4, 5 and 6). In general it appears that WSEs are reduced approximately 1 to 3 ft for the flood discharges (Tables 2, 3 and 4). It should be noted that the WSE reduction will continue some distance upstream of Station 695.2. The WSE reduction is due to removing the existing culvert constriction and lowering the existing channel bed elevation along this portion of the project reach. Downstream of the bridge, WSEs do not change for any of the flood discharges because of downstream controls (Figures 4, 5 and 6).

The proposed bridge improvements will convey the Q_{100} flood discharge without overtopping the road surface (Figure 8). Based upon this hydraulic analysis, the existing culvert crossing is a constriction, and it appears that road overtopping occurs between 1300 and 1400cfs, which is approximately equivalent to the Q_{10} discharge. During the Q_{100} flood discharge, hydraulic results indicate that approximately 3 to 4ft of water overtops the existing culvert crossing (Figure 7).

Due to removing the culvert constriction and steeping the channel bed, the proposed Mynot Creek improvements increase average channel velocities and therefore shear stresses from approximately Station 387.1 to 695.2 for all flood discharges (Tables 2, 3 and 4). Consequently, sediment transport through the project reach should significantly improve, lessening the likelihood of aggradation.

The DNCPW can use the data in Tables 2, 3 and 4 for engineering/design of the Mynot Creek bridge improvement project. It is our recommendation that the bridge be designed for the Q_{100} discharge condition (Table 4). Furthermore, it is recommended that: 1) the bottom chord of the bridge be placed approximately 2 ft above the Q_{100} water surface elevation (27.5 ft WSE), 2) the rock gabions and/or rip-rap be designed for a maximum velocity of approximately 12 ft/s, and 3) that the bridge supports be designed to accommodate a minimum channel bed elevation of 14 ft MSL resulting from the maximum expected scour depth following bridge replacement.

The proposed Mynot Creek bridge improvements will significantly improve fish passage for all species under all discharge conditions. Review of Table 3 shows that for the Q_2 discharge, channel velocities within the bridge section coincide with upstream and downstream channel velocities, and are significantly lower then the existing culvert velocities. Since the bridge replacement consists of a natural bottom, the low flow juvenile passage criteria are not required. Furthermore, low flow channel depths through the proposed bridge section will be similar to conditions found in the adjacent natural channel. The proposed bridge improvement will also remove the downstream jump conditions for the existing culvert.

LITERATURE CITED

Barnes, H. H., 1967. Roughness Characteristics of Natural Channels: U.S. Geological Survey Water-Supply Paper 1849, U.S. Geological Survey, Washington, 213 p.

French, R. H., 1985. *Open-Channel Hydraulics*, McGraw-Hill, New York.

Rantz, S.E. 1964. Surface water hydrology of coastal basins of northern California. USGS Water Supply Paper 1758. 77p.

U.S. States Army Corps of Engineers, 2001. HEC-RAS, River Analysis System – User's Manual and Hydraulic Reference Manual, U.S. Army Corps of Engineers Hydraulic Engineering Center, Davis, California.