APPENDIX I

DESIGN EXAMPLE - HYDRAULIC DESIGN OPTION

Hydraulic Design Option
(Culvert Replacement)

Problem Statement

In the County of Del Norte, a rehabilitation project has been initiated for a 3-mile segment of Route 777, which will include outside shoulder widening. Because shoulder widening is involved in the project, existing culverts must be lengthened or replaced depending on field and hydraulic conditions.

Within the project limits, Rose Creek is conveyed under Route 777 by a 70-foot long 8-foot diameter corrugated metal pipe culvert with a headwall at both its entrance and outlet. In close proximity to this culvert, a 54-inch diameter high-pressure gas main runs parallel with the culvert and is located 7 feet right of the Rose Creek culvert centerline.

Currently in Rose Creek, adult anadromous salmonids are prevented from traveling upstream of the Route 777 culvert due to its high velocity. High velocities through the culvert had been observed and noted in a previous fish-passage assessment.

In addition to the existing culvert being a fish barrier, it has questionable hydraulic capacity, as well as perforations in its invert. Based on past Maintenance records, the culvert and roadway have been overtopped twice in the past ten years. As for the perforations in the culvert invert, the metal has obviously corroded and is in need of attention as well.

As a part of the design for this rehabilitation project, a solution must be found for the culvert conveying flows from Rose Creek that addresses structural integrity, hydraulic capacity, and fish-passage performance.

NOTE: Route 777 and Rose Creek are fictitious and created for the purpose of presenting a design example for this fish-passage training guidance.

Form 1-Existing Data and Information Summary

Form 1 provides a list of suggested data references that would be beneficial to collect before the beginning of design process.

For this particular example, USGS topographic quadrangle map, DEM data, as-built drawings, target fish species and life stage data, and stream flow gage data was available for reference.

The USGS topographic quadrangle data and DEM data was downloaded from the USGS website, www.usgs.gov.

The FEMA Map Service Center, http://msc.fema.gov/, was accessed to determine if a previous hydrologic study, hydraulic study, and/or floodplain mapping had been performed. For Rose Creek, no previous detailed or approximate studies had been performed; therefore, no effective data was available for reference.

The County's engineering department was able to provide as-built drawings for the stream crossing and fish species and life stage data.

California Department of Water Resources (CDEC, http://cdec.water.ca.gov/), was searched for precipitation and stream flow gage data. Recording flow gages are located on Blue Creek.

As for site access status, the field investigations can be done within Caltrans Right-of - Way, therefore rights-of-entry will not be required.

EXISTING DATA AND INFORMATION SUMMARY — FORM 1

Project Information: Road Widening Route 777	Computed: EKB	Date: 2/6/06
	Checked: JJL	Date: 2/7/06

Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Proposed Project Type	☐ New Culvert	☐ New Bridge
	☒ Replacement Culvert	☐ Replacement Bridge
	☐ Retrofit Culvert	☐ Retrofit Bridge
	☐ Proposed Culvert Length= 86 ft	☐ Proposed Bridge Length= ft
	☐ Other	☐ Other

Design Species/Life Stage	☐ All Species	Source: State of CA Contact: Dept. of Fish & Game Bill Hook 1-422-351-9322 Date: contacted on: 1/22/06
	☒ Adult Anadromous Salmonids	
	☐ Adult Non-Anadromous Salmonids	
	☐ Juvenile Salmonids	
	☐ Native Non-Salmonids	
	☐ Non-Native Species	

Collect Existing Data

	Yes	No
Included in Caltrans Culvert Inventory	☐	☒
As-Built Drawings: AS-built date Sept 1981	☒	☐
Assessor's Parcel Map	☐	☒
Previous Studies Performed: (i.e. FEMA Flood Insurance Studies, Army Corps of Engineering Studies, Other)		
Hydrology Analysis	☐	☒
Hydraulics Analysis	☐	☒
Floodplain Mapping	☐	☒
Other Studies Types Available: (i.e. Watershed Management Plans, Stream Restoration Plans, Other)	☐	☒
Existing Land Use Map	☐	☒
Proposed Land Use Map	☐	☒
Precipitation Gage Data	☐	☒
Stream Flow Gage Data	☒	☐

EXISTING DATA AND INFORMATION SUMMARY	FORM 1
Topographic Mapping: (i.e. USGS Topographic Quadrangle, DEM Data, LIDAR Data, Other) Quad Name: Hiouchi (1:24K)	☒ Yes ☐ No
District Hydraulics Library	☐ Yes ☒ No

Obtain Access Permission

Will Project study limits extend beyond Caltrans R/W? ☐ Yes ☒ No

If yes, obtain right-of-entry.

Contact Report Index Attached ☒ Yes ☐ No

Existing Information Index Attached ☒ Yes ☐ No

CONTACT REPORT INDEX

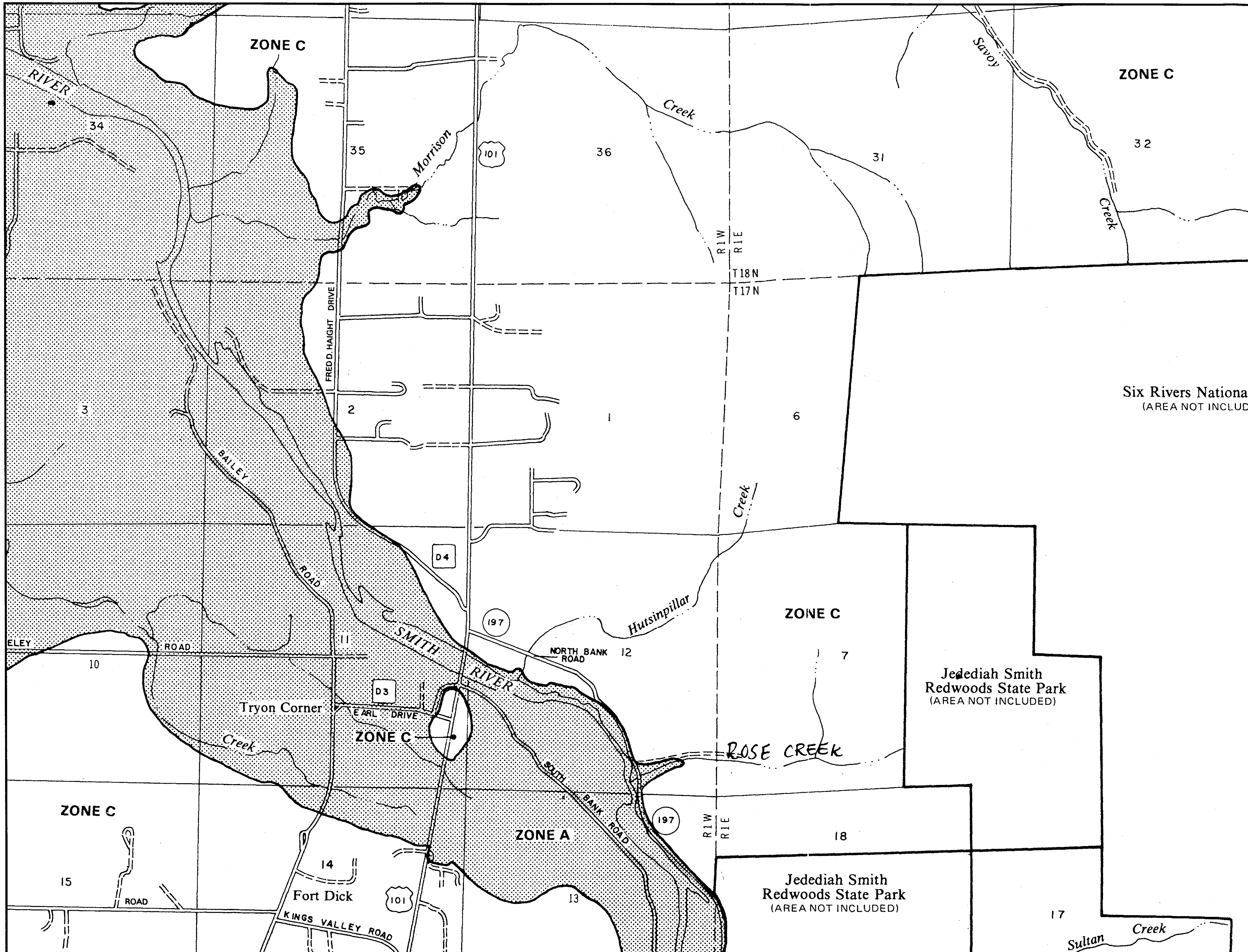
Project Information Road Widening Route 777		Computed: EKB	Date: 2/6/06
		Checked: JJL	Date: 2/7/06
Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Date of Contact	Person Contacted	Subject Discussed
1/22/06	Bill Hook 422-351-9322	Adult Anadromous Salmonids

EXISTING INFORMATION INDEX

Project Information Road Widening Route 777		Computed: EKB	Date: 2/6/06
		Checked: JJL	Date: 2/7/06
Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Report Date	Report Name and Source
2/6/06	California Dept. of Water Resources (CDEC)
	Station Locator



NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

DEL NORTE COUNTY, CALIFORNIA

UNINCORPORATED AREA

PANEL 25 OF 325

(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
065025 0025 B

EFFECTIVE DATE:
JANUARY 24, 1983

FEDERAL EMERGENCY MANAGEMENT AGENCY

Federal Emergency Management Agency

Form 2- Site Visit Summary

Form 2 captures the existing conditions of the hydraulic structure including channel and structure roughness values. By completing the Site Visit Summary form, the drainage designer will have all necessary parameters required to complete any of the fish passage design options.

At the Rose Creek site, various culvert and creek properties were investigated, such as layout configuration, roughness, velocity, and flow regime.

As mentioned above, it was noted in the field, as well as the As-Built plans, that a headwall/endwall exists at the culvert inlet and outlet. Also, the existing culvert lies at a 0% slope, which certainly creates hydraulic capacity issues.

For the creek, roughness characteristics of the main channel, the left overbank channel, and the right overbank channel were also investigated and ultimately Manning's n-values were estimated. Based on field observation, the left and right overbank channels were found to have the same n-values in the vicinity of the culvert crossing and the project study area.

In addition, flow in the creek at the time of the field visit was determined from appropriate measurements. The flow was calculated by measuring a velocity and depth, calculating wetted area from a field developed creek cross section, and dividing velocity by wetted area to achieve flow according to the continuity of flow equation. By placing a small leaf in the creek and timing its travel over a set length, a velocity was determined. In order to find a representative velocity for the creek, this operation was performed three times, where the leaf was placed near the left bank, near the right bank, and around the center of the creek. The velocity corresponding to each leaf placement was added together and averaged to find a representative velocity.

Finally, the flow regime for the creek was estimated in the field by tossing a small rock in the center of the creek and noting the propagation of the ripples. When ripples propagate upstream, the flow regime is subcritical, while supercritical flow is denoted by downstream ripple propagation.

SITE VISIT SUMMARY	FORM 2

Project Information Road Widening Route 777	Computed: EKB	Date: 2/15/06
	Checked: JJL	Date: 2/16/06

Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Obtain Physical Characteristics of Existing Culvert

Confined Spaces

Is the culvert height 5 ft or greater?	☒ Yes ☐ No
Can you stand up in the culvert?	☒ Yes ☐ No
Can you see all the way through the culvert?	☒ Yes ☐ No
Can you feel a breeze through the culvert?	☒ Yes ☐ No

If answer is "No" to any of the above questions, do not enter the culvert without confined spaces equipment for surveying.

Inlet Characteristics

Inlet Type	☐ Projecting ☒ Headwall ☐ Wingwall ☐ Flared end section ☐ Segment connection
Inlet Condition	☐ Channel scour ☐ Excessive deposition ☐ Debris accumulation ☒ None applicable
Inlet Apron	☐ Channel scour ☐ Excessive deposition ☐ Debris accumulation ☒ None applicable

Skew Angle: NONE °	Upstream Invert Elevation: 681.1 ft (NGVD 29 (circled) or NAVD 88)

Barrel Characteristics

Diameter: 8.0 in	Fill height above culvert: 8.9 ft
Height/Rise: ft	Length: 70.0 ft
Width/Span: ft	Number of barrels:

Culvert Type	☐ Arch ☐ Box ☒ Circular ☐ Pipe-Arch ☐ Elliptical
Culvert Material	☐ HDPE ☐ Steel Plate Pipe ☐ Concrete Pipe ☒ Spiral Rib / Corrugated Metal Pipe
Barrel Condition	☒ Corrosion ☐ Debris accumulation ☐ Structural damage ☐ Abrasion ☐ Bedload accumulation ☐ None applicable

SITE VISIT SUMMARY	FORM 2

Horizontal alignment breaks: NONE ft	Vertical alignment breaks: NONE ft

Outlet Characteristics

Outlet Type	☐ Projecting	☒ Headwall	☐ Wingwall	
	☐ Flared end section	☐ Segment connection		
Outlet Condition	☐ Scour hole	☐ Backwatered	☐ Debris accumulation	☐ None applicable
	☐ Perched	Outlet elevation drop: ft		
		Outlet drop condition: Freefall onto rocks		
		Scour hole depth: ft		
Outlet Apron	☐ Channel scour	☐ Excessive deposition	☐ Debris Accumulation	☒ None Applicable

Skew Angle: NONE °	Downstream Invert Elevation: 680.7 ft (NGVD 29 or NAVD 88)

Bridge Physical Characteristics N/A

Elevation of high chord (top of road): ft	Elevation of low chord: ft

Channel Lining	☐ No lining	☐ Concrete	☐ Rock	☐ Other

Skew Angle: °	Bridge width (length): ft

Pier Characteristics (if applicable) ☐ N/A

Number of Piers: ft	Upstream cross-section starting station: ft
Pier Width: ft	Downstream cross-section starting station: ft
Pier Centerline Spacing: ft	

Pier Shape	☐ Square nose and tail	☐ Semi-circular nose and tail	☐ 90° triangular nose and tail
	☐ Twin-cylinder piers with connecting diaphragm	☐ Twin-cylinder piers without connecting diaphragm	☐ Ten pile trestle bent
Pier Condition	☐ Scour	☐ Corrosion	☐ Debris accumulation
Skew angle	°		

Channel Characteristics

Hydraulic Structure Roughness Coefficients

(Source: Caltrans Highway Design Manual Table 864.3A)		(Source: HEC-RAS User's Manual)	
Type of Structure	**n- value**	**Type of Structure**	**n- value (normal)**

SITE VISIT SUMMARY			FORM 2
Linned Channels:		**Corrugated Metal:**	
Portland Cement Concrete	0.014	Subdrain	0.019
Air Blown Mortar (troweled)	0.012	Storm Drain	0.024
Air Blown Mortar (untroweled)	0.016	**Wood:**	
Air Blown Mortar (roughened)	0.025	Stave	0.012
Asphalt Concrete	0.018	Laminated, treated	0.017
Sacked Concrete	0.025	**Brickwork:**	
Pavement and Gutters:		Glazed	0.013
Portland Cement Concrete	0.015	Lined with cement mortar	0.015
Asphault Concrete	0.016		
Depressed Medians:			
Earth (without growth)	0.040		
Earth (with growth)	0.050		
Gravel	0.055		

Recommended Permissible Velocities for Unlined Channels (Source: Caltrans Highway Design Manual, Table 862.2)

Type of Material in Excavation Section	Intermittent Flow (f/s)	Sustained Flow (f/s)
Fine Sand (Noncolloidal)	2.6	2.6
Sandy Loam (Noncolloidal)	2.6	2.6
Silt Loam (Noncolloidal)	3.0	3.0
Fine Loam	3.6	3.6
Volcanic Ash	3.9	3.6
Fine Gravel	3.9	3.6
Stiff Clay (Colloidal)	4.9	3.9
Graded Material (Noncolloidal)		
Loam to Gravel	6.6	4.9
Silt to Gravel	6.9	5.6
Gravel	7.5	5.9

Coarse Gravel	7.9	6.6
Gravel to Cobbles (Under 150mm)	8.8	6.9
Gravel and Cobbles Over 200mm)	9.8	7.9
Flow Estimation 30 cfs	☐ Supercritical flow	☒ Subcritical flow

Channel Cross-Section Schematic

Channel depth = ft

Average Active Channel Width
Take at least five channel width measurments to determine the active channel width. The active channel stage or ordinary high water level is the elevation delineating the hightest water level that has been maintained for a sufficient period of time to leave evidence on the landscape.

Average Active Channel Width = 23.2 ft

1) 23.1 ft	2) 23.5 ft	3) 23.1 ft	4) 23.2 ft	5) 23.2 ft

Boundary Conditions The normal depth option (slope area method) can only be used as a downstream boundary condition for an open-ended reach. Is normal depth appropriate? If no, what is the known starting water surface elevation? Yes	Upstream	slope ft/ft
	Downstream Normal Depth	slope 0.01 ft/ft
	Known starting water surface elevation Source:	ft

General Considerations

Identify Physical restrictions	☐ Right-of-way	☒ Utility conflict	☐ Vegetation
	☐ Man-made features	☐ Natural features	☐ Other

Cross-Section Sketches Attached ☒ Yes ☐ No

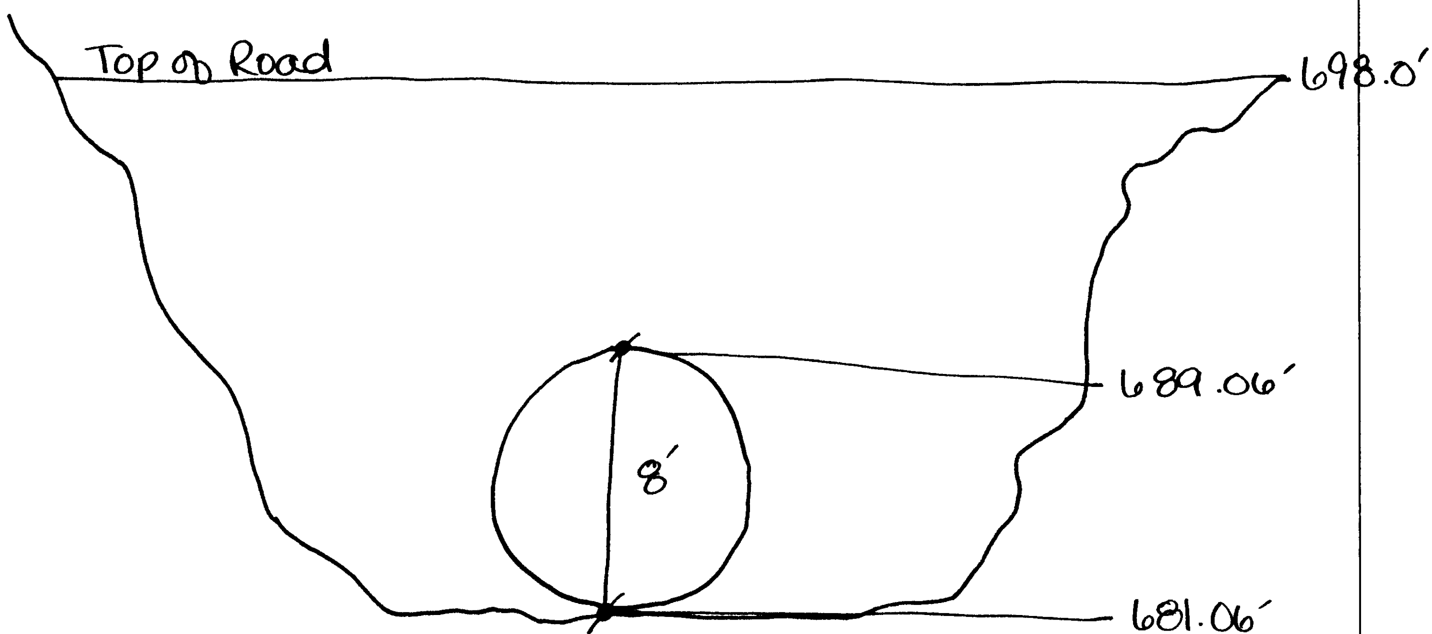
Site Photograph Documentation Attached ☒ Yes ☐ No

Channel / Overbank Manning's n-value Calculation Attached ☒ Yes ☐ No

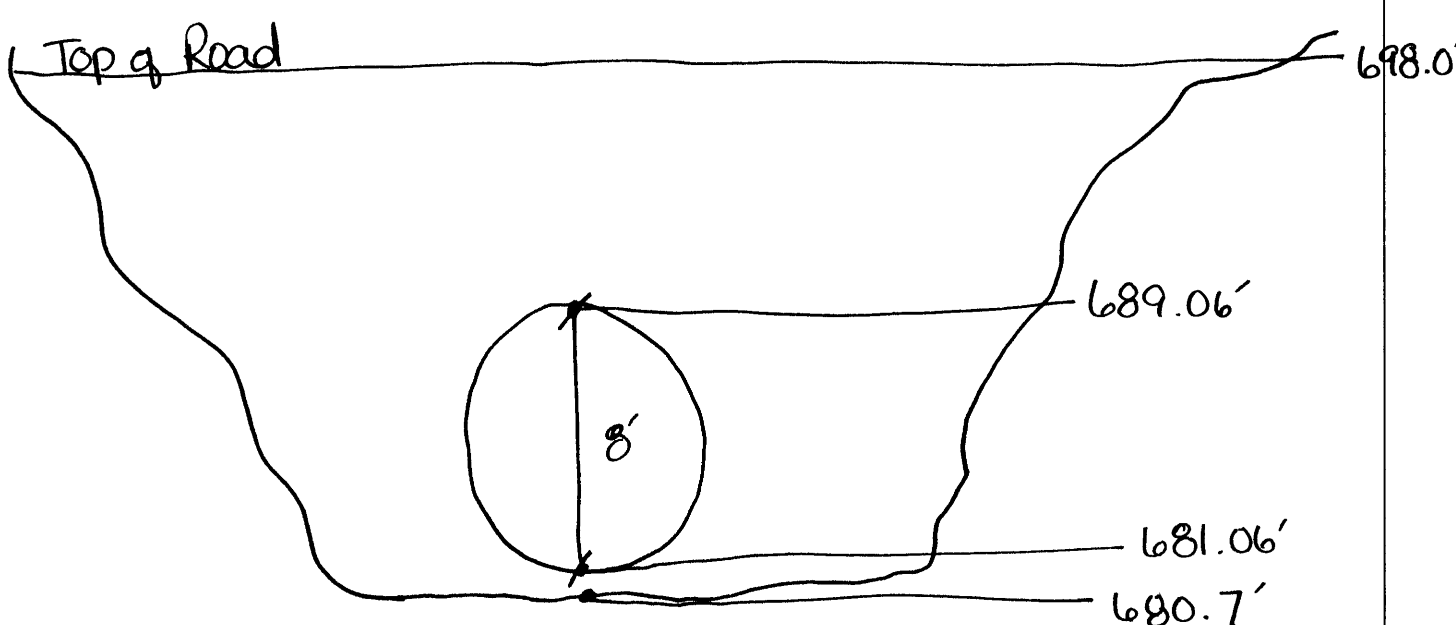
Field Notes Attached ☒ Yes ☐ No

Cross-Section Sketch

Upstream face of structure:



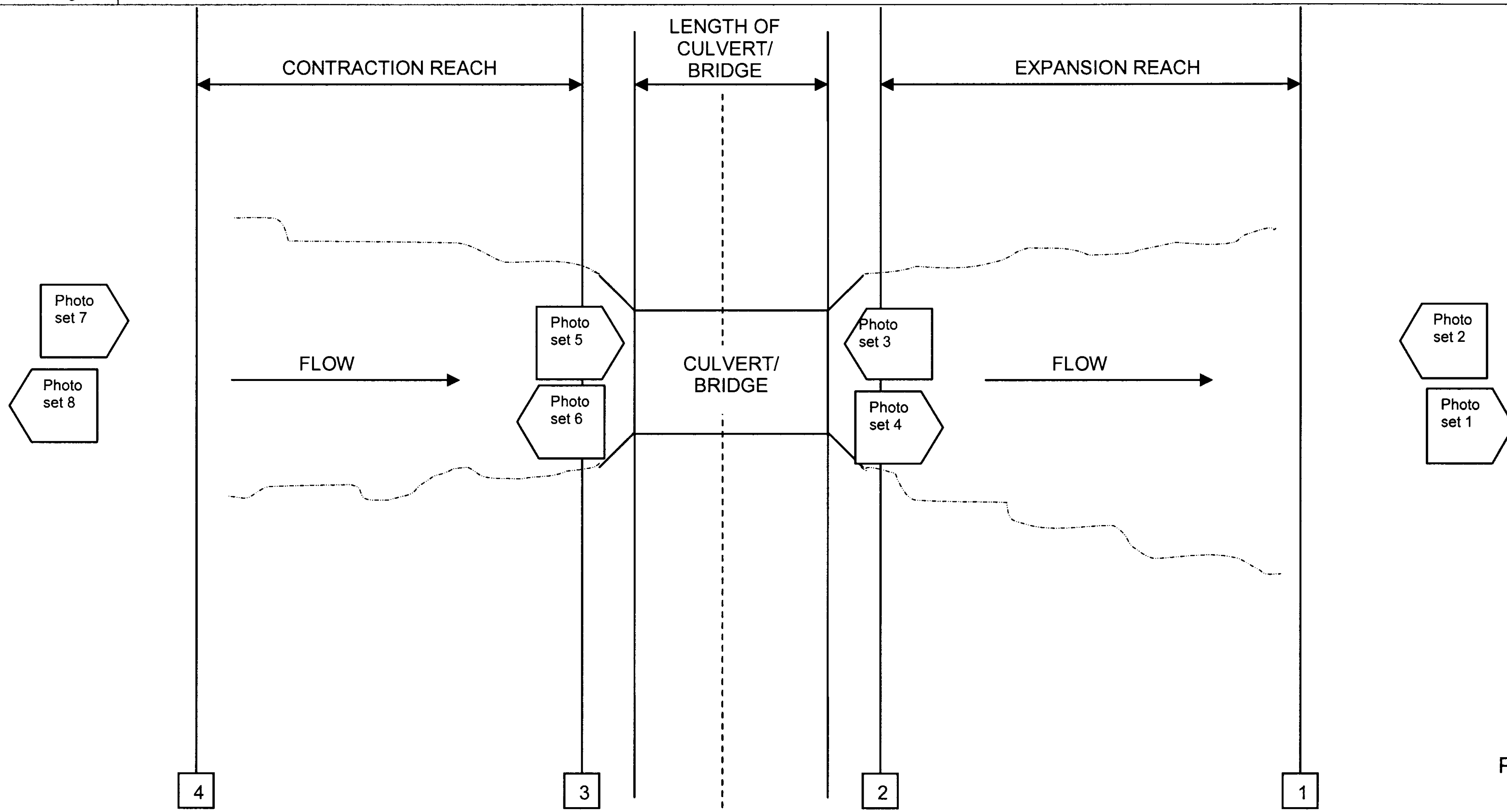
Downstream face of structure:



Rocky conditions
@ outlet

SITE PHOTOGRAPH DOCUMENTATION

Project Information	Road Widening Route 777			Computed:	EKB	Date:	2/15/06
				Checked:	JJL	Date:	2/16/06
Stream Name	Rose Creek	City/County	Del Norte, CA	Road	777	Postmile	6.15
Crossing Type	☒ Culvert		☐ Bridge		☐ Other Type/Comments		
Distance From:	X-sec. 1 to X-sec. 2: 88 ft	X-sec. 2 to DS face of culvert 2 ft		US face of culvert to X-Sec. 3 2 ft		X-sec. 3 to X-sec. 4 58 ft	
Distance From:	Photo Sets 1 & 2 to DS face of culvert 60 ft	Photo Sets 3 & 4 to DS face of culvert 10 ft		Photo Sets 5 & 6 to US face of culvert 15 ft		Photo Sets 7 & 8 to US face of culvert 80 ft	
Length of Culvert/Bridge:	70.0' ft						



SITE PHOTOGRAPH DOCUMENTATION	
Photo Descriptions:	
Photo Set 1	upstream channel
Photo Set 2	
Photo Set 3	looking DS @ culvert inlet
Photo Set 4	
Photo Set 5	looking US @ culvert outlet
Photo Set 6	
Photo Set 7	
Photo Set 8	looking DS away from culvert outlet

Culvert Inlet

Culvert Outlet

Looking Downstream of Culvert Outlet

Looking Upstream from Culvert Inlet

Manning's n Computation Summary

Project Information	Computed: EKB	Date: 2/15/06
Road Widening Route 777	Checked: QJL	Date: 2/16/06

Stream Name: Rose Creek	County: Del Norte	Route: 777	Postmile: 6.15

Aerial Picture Attached: NONE

Photographs (#'s and locations) # 1, 2, 3, 4

Summary of n-Values:

Reach	Left Overbank	Main Channel	Right Overbank
	0.054	0.0485	0.054

Notes:

Manning's n Computation - Main Channel

Project Information	Computed: EKB	Date: 2/15/06
Road Widening Route 777	Checked: JJL	Date: 2/16/06
Stream Name: Rose Creek / County: Del Norte, CA	Route: 777	Postmile: 6.15
Aerial Picture Attached: NONE		
Photographs (#'s and locations) # 1, 2, 3, 4		

Is roughness uniform throughout the reach? NO

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? NO

Is a division between the channel and floodplain necessary? Yes

Calculation of n-value:
n = (nb + n1 + n2 + n3 + n4)m

where:	Description of Range
nb = base n value for surface	*median size btwn 1" and 2.5"=0.028 to 0.035, btwn 2.5" and 10"=0.030 to 0.050*
n1 = surface irregularity factor	*smooth = 0 up to severe at 0.020*
n2 = cross section variation factor	*gradual = 0 up to alternating frequently at 0.015*
n3 = obstructions factor	*negligible = 0 up to severe (over 50% of cross section) at 0.05*
n4 = vegetation factor	*small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100*
m = sinuosity/meandering factor	*minor = 1.0, appreciable = 1.15, Severe = 1.30*

Base n value for surface

nb: Sand channel? ________ if yes, median size of bed material? ________

nb =

median size (in)	nb
0.008	0.012
0.012	0.017
0.016	0.020
0.020	0.022
0.024	0.023
0.031	0.025
0.039	0.026

All other channels:

median size (in)	nb
.04 to .08	0.026 to 0.035
1 to 2.5	0.028 to 0.035
→ 2.5 to 10	0.030 to 0.050
>10	0.040 to 0.070

Notes:

Main Channel consists of small rocks

nb = 0.040

Manning's n Computation - Main Channel

Surface Irregularity

n1:	Smooth	Is channel smooth? ________	if yes, n1 = 0
	Minor	Is channel in good condition with slightly eroded or scoured side slopes?	→ if yes, n1 = 0.001 - 0.005
	Moderate	Is channel a dredged channel having moderate to considerable bed roughness and moderately sloughed or eroded side slopes in rock?	if yes, n1 = 0.006 - 0.010
	Severe	Is channel badly sloughed, scalloped banks or badly eroded or sloughed sides or jagged and irregular surface?	if yes, n1 = 0.011 - 0.020

n1 = 0.0025

Notes: Gradual elevation changes

Cross Section Variation Factor

n2:	Gradual	Does the size and shape of the channel cross section change gradually?	if yes, n2 = 0.000
	Alternately occasionally	Does the cross section alternate to large to small, *occasionally* or does the main flow *occasionally* shift from side to side?	→ if yes, n2 = 0.001 - 0.005
	Alternately frequently	Does the cross section alternate to large to small, *frequently* or does the main flow *frequently* shift from side to side?	if yes, n2 = 0.010 - 0.015

n2 = 0.002

Notes: The main channel X-section width is slightly pinched around bends

Obstructions factor

n3:	Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	→ if yes, n3 = 0.000 - 0.004
	Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions?	if yes, n3 = 0.005 - 0.015
	Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, n3 = 0.020 - 0.030
	Severe	Obstructions occupy more than 50% of the cross-sectional area or the spacing between obstructions causes turbulence?	if yes, n3 = 0.040 - 0.050

n3 = 0.002

Notes:

A few larger rocks are present within the channel

Manning's n Computation - Main Channel

Vegetation factor

n4:

Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc?	→ if yes, n4 = 0.002 - 0.010
Medium	Does the channel have turf grass where the average depth of flow is 1 to 2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2 to 3 times the height of the vegetation?	if yes, n4 = 0.010 - 0.025
Large	Does the channel where the average depth of flow is equal to the height of the vegetation; 8 to 10 years-old willows or cottonwoods intergrown with weeds and brush; where the hydraulic radius exceeds1.97 ft or bushy willows about 1 year old intergrown with some weeds along side slopes, and no significant vegetation exists along the channel bottom, where the hydraulic radius is greater than 2.0 ft.	if yes, n4 = 0.025 -0.050
Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, n4 = 0.050 - 0.100

n4 = 0.002

Notes: Little vegetation is present in the main channel. Some vegetation has grown up around the culvert inlet

Sinuosity/meandering factor

m	Minor	Ratio of the channel length to valley length in 1.0 to 1.2	→ if yes, m = 1.00
	Appreciable	Ratio of the channel length to valley length in 1.2 to 1.5	if yes, m = 1.15
	Severe	Ratio of the channel length to valley length > 1.5	if yes, m = 1.30

m = 1.0

Notes:

The stream centerline meanders very little. Not an issue

Manning's n - Main Channel n = 0.0485

Manning's n Computation - Overbank

Project Information	Computed: EKB	Date: 2/15/06
Road Widening Route 777	Checked: JJL	Date: 2/16/06

Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Aerial Picture Attached:

Photographs (#'s and locations) #1, 2, 3, 4

Is roughness uniform throughout the reach? NO

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? NO - Left & Right banks are displaying the same characteristics

Is a division between the channel and floodplain necessary? yes

Calculation of n-value:

n = (nb + n1 + n2 + n3 + n4)m

where:

	Description of Range
nb = base n value for surface	*median size between 1" and 2.5"=0.028 to 0.035, between 2.5" and 10"=0.030 to 0.050*
n1 = surface irregularity factor	*smooth = 0 up to severe at 0.020*
n2 = cross section variation factor	*gradual = 0 up to alternating frequently at 0.015*
n3 = obstructions factor	*assumed to equal 0*
n4 = vegetation factor	*small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100*
m = sinuosity/meandering factor	*equals 0 for floodplains*

Base n value for surface

nb: Sand channel? ________ if yes, median size of bed material? ________

nb =

median size (in)	nb
0.008	0.012
0.012	0.017
0.016	0.020
0.020	0.022
0.024	0.023
0.031	0.025
0.039	0.026

All other channels:

median size (in)	nb
.04 to .08	0.026 to 0.035
→ 1 to 2.5	0.028 to 0.035
2.5 to 10	0.030 to 0.050
>10	0.040 to 0.070

Notes: Smaller rocks held by firm soil

nb = 0.028

Surface Irregularity

n1:			
	Smooth	Compares to the smoothest, flattest floodplain in a given bed material.	if yes, n1 = 0
	Minor	Is the floodplain slightly irregular in shape. A few rises and dips or sloughs may be more visible on the floodplain.	→ if yes, n1 = 0.001 - 0.005
	Moderate	Has more rises and dips. Sloughs and hummocks may occur.	if yes, n1 = 0.006 - 0.010
	Severe	Floodplain very irregular in shape. Many rises and dips or sloughs are visible.	if yes, n1 = 0.011 - 0.020

n1 = 0.003

Notes: Slightly steep slopes

Manning's n Computation - Overbank

Cross Section Variation Factor

n2 = 0.000

Notes: Not applicable to floodplains.

Obstructions factor

n3:

Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	if yes, n3 = 0.000 - 0.004
Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions? →	if yes, n3 = 0.005 - 0.015
Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, n3 = 0.020 - 0.030

n3 = 0.005

Notes: Large boulders present in overbanks very minimal obstruction

Vegetation factor

n4:

Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc where the average depth of flow is at least three times the height of the vegetation?	if yes, n4 = 0.002 - 0.010
Medium	Does the channel have turf grass where the average depth of flow is 1-2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2-3 times the height of vegetation? Brushy, moderately dense vegetation, similar to 1-2 year old willow trees in dormant season. →	if yes, n4 = 0.010 - 0.025
Large	Does the channel where the average. depth of flow is equal to the height of the vegetation; 8 to 10 year old. willows, cottonwoods intergrown with weeds and brush; where the R = 1.97 ft or bushy willows of 1 year old are in the channel bottom, where R =2.00 ft?	if yes, n4 = 0.025 -0.050
Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, n4 = 0.050 - 0.100
Extreme	Does the channel have dense bushy willow, mesquite, and salt cedar (full foliage), or heavy stand of timber, few down trees, depth of reaching branches?	if yes, n4 = 0.100 - 0.200

n4 = 0.018

Notes: Low bush vegetation present trees present with small diameter trunks

Sinuosity/meandering factor

m = 1.00

Notes: Not applicable to floodplains.

Manning's n - Overbank n = 0.054

Form 3- Guidance on Selection of Fish Passage Design Option

This form summarizes all requirements for each design option in order for the designer to select the appropriate fish-passage design option.

Because the existing culvert has hydraulic capacity issues, structural deficiencies (perforated invert), as well as a velocity barrier to fish passage, culvert rehabilitation is not an option and it must be replaced. In replacing the culvert, special attention must be given to the existing high-pressure gas line that runs roughly parallel and is offset by approximately 7 feet from the culvert centerline on its inlet side.

Initially both the Active Channel and Stream Simulation design options could be viable strategies for the Rose Creek culvert, but each would yield a large culvert size and most likely encroach on the high-pressure gas line. If either one of these options were used, the new culvert would have to span at least 1.5 times the active channel or span the bankfull channel, which would be a much larger culvert than the existing culvert.

Since the target species/life stage (adult anadromous salmonids) are known for this project and the replacement culvert slope will be less than 3%, the Hydraulic Design option is another possibility. While more time and effort is required in the analysis/design phase of the project, this method is advantageous in that it will yield smaller diameter culverts and reduced impacts during construction. Unlike the Active Channel and Stream Simulation options, the engineer must show that velocity and depth meet CDFG and NOAA Fisheries guidelines under site-specific low and high fish passage flow conditions.

Because of the possible utility conflict at Rose Creek, the smallest diameter culvert that will properly convey flood flows and allow fish movement is most important. Ultimately, this is the overriding reason for choosing the Hydraulic Design option over other strategies. By avoiding utility conflict and difficult relocation, it is worth the additional analysis and design effort.

Given the new, larger diameter culvert and its potential to convey higher flow more efficiently, District Hydraulics must be consulted so that any negative impacts to downstream properties or facilities can be assessed prior to final design.

GUIDANCE ON SELECTION OF FISH PASSAGE DESIGN OPTION			FORM 3
Project Information Road Widening Route 777		Computed: EKB	Date: 2/17/06
		Checked: JJL	Date: 2/18/06
Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Design Species/ Life Stage		
	☐	All Species
	☒	Adult Anadromous Salmonids
	☐	Adult Non-Anadromous Salmonids
	☐	Juvenile Salmonids
	☐	Native Non-Salmonids
	☐	Non-Native Species

☐ **Active Channel Design Option -** The Active Channel Design Option is a simplified design method that is intended to size a crossing sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable streambed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since with stream hydraulic charagcteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. However, hydraulic analyses for traffic safety, hydraulic impacts, and scour are required.

Criteria for choosing option:

- ☒ New and replacement culvert/bridge installations
- ☐ Passage required for all species
- ☒ Proposed culver/bridge length less than 100 feet
- ☒ Channel slope less than 3%

☒ **Hydraulic Design Option** - The Hydraulic Design Option is a design process that matches the hydraulic performance of a culvert with the swimming ablitities of a target species and age class of fish. This method targets distinct species of fish and, therefore, does not account for ecosystem requirments of non-target species.

Criteria for choosing option:

- ☒ New and replacement culvert/bridge installations (If retrofit installation, see Baffle or Rock Weir Design Options)
- ☒ Target species identified for passage
- ☒ Low to moderate channel slopes (less than 3%)
- ☒ Active channel design or stream simulation design options are not physically feasible

Retrofit Culvert/Bridge Installations

☐ **Baffle Design Option -** The Baffle Design Option is a Hydrualic Design process that is intended to increase flow depth, or to add roughness elements as a measure to reduce flow velocity within the culvert/bridge structure. Determination of the high and low fish passage design flows, water velocity, and water depth is required for this option.

- ☐ Retrofit culvert/bridge installation
- ☐ Little bedload material movement

GUIDANCE ON SELECTION OF FISH PASSAGE DESIGN OPTION — FORM 3

- ☐ Existing culvert/bridge is structurally sound
- ☐ Target species identified for passage
- ☐ Low to moderate channel slopes
- ☐ Active channel design or stream simulation design options are not physically feasible

☐ **Rock Weir Design Option -** The Rock Weir Design Option is a Hydraulic Design process that is intended to increase flow depth, or add roughness elements as a measure to reduce flow velocity, or to increase the channel slope downstream of the culvert/bridge. Determination of the high and low fish passage design flows, water velocity, and water depth is required for this option.

- ☐ Retrofit culvert/bridge installations
- ☐ Perched condition at outlet
- ☐ Steep slope at inlet
- ☐ Target species identified for passage
- ☐ Active channel design or stream simulation design options are not physically feasible

☐ **Stream Simulation Design Option -** The Stream Simulation Design Option is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the crossing are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this options since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.

Criteria for choosing option:

- ☒ New and replacement culvert/bridge installations
- ☐ Passage required for all species
- ☐ Culvert/bridge length greater than 100 feet
- ☒ Channel width should be less than 20 feet
- ☒ Minimum culvert/bridge width no less than 6 feet
- ☒ Culvert/bridge slope does not greatly exceed slope of natural channel, slopes of 6 % or less
- ☐ Narrow stream valleys

Selected Design Option: Hydraulic Design Option

Basis for Selection: Adult Anadromous Salmonid criteria must be met

Seek Agency Approval: ☒ Yes ☐ No

Form 4- Guidance on Methodology for Hydrologic Analysis

Form 4 summarizes methods for estimating peak design discharges that will be used in a hydraulic analysis. Data requirements, limitations, and guidance are provided to assist in the hydrologic method selection.

For this particular example, all data requirements needed to calculate peak discharges by regional regression equations were readily available.

Stream flow data was also available allowing a stream flow hydrograph and stream duration curve to be created. Upper and lower fish passage flows were calculated.

GUIDANCE ON METHODOLOGY FOR HYDROLOGIC ANALYSIS [1, 2]			FORM 4
Project Information Road Widening Route 777		Computed: EKB	Date: 2/22/06
		Checked: JJL	Date: 2/23/06
Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Summary of Methods for Estimating Peak Design Discharges for Use in Hydraulic Analysis

Ungaged Streams

☒ **Regional Regression[3, 4]**

Data Requirements	Limitations	Guidance
▪ Drainage area ▪ Mean annual precipitation ▪ Altitude index	▪ Peak discharge value for flow under natural conditions unaffected by urban development and little or no regulation by lakes or reservoirs ▪ Ungaged channel	The most recently published USGS report for estimating peak discharges may be used. The user should exercise caution to ensure that the reports are used only for the conditions and locations for which they are recommended.

Rainfall-Runoff Models

☐ **NRCS (TR 55)[5]**

Data Requirements	Limitations	Guidance
▪ 24-hour Rainfall ▪ Rainfall distribution ▪ Runoff curve number ▪ Concentration time ▪ Drainage area	▪ Small or midsize catchment (<8 km^2) ▪ Maximum of 10 subwatersheds ▪ Concentration time range from 0.1-10 hour (tabular hydrograph method limit <2 hour) ▪ Runoff is overland and channel flow ▪ Simplified channel routing ▪ Negligible channel storage	TR-55 focuses on small urban and urbanizing watersheds.

☐ **HEC-1/HEC-HMS[6, 7] (SCS Dimnesionless, Snyder Unit, Clark Unit Hydrographs)**

Data Requirements	Limitations	Guidance
▪ Watershed/subbasin parameters ▪ Precipitation depth, duration, frequency, and distribution ▪ Precipitation losses ▪ Unit hydrograph parameters ▪ Streamflow routing and diversion parameters	▪ Simulations are limited to a single storm event ▪ Streamflow routing is performed by hydrologic routing methods and is therefore not appropriate for unsteady state routing conditions.	Can be used for watersheds which are: small or large, simple or complex, and developed or undeveloped.

[1] Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge
[2] FEMA Guidelines and Specifications, Appendix C, Section C.1
[3] USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)
[4] USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)
[5] United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
[6] HEC-1 User's Manual
[7] HEC-HMS User's Manual
[8] Bulletin 17B

GAGED STREAMS

☐ **Statistical Methods**[8]

Data Requirements	Limitations	Guidance
▪ 10 or more years of gaged flood records	▪ Gage data is usually only available for midsized and large catchments ▪ Appropriate station and/or generalized skew coefficient relationship applied	For watersheds with less than 50 years of record, compare with results of appropriate USGS regional regression equations. For watersheds with less than 25 years of record, compare with results of appropriate USGS regional regresssion equations and/or HEC-1/HEC-HMS model results.

☐ **Basin Transfer of Gage Data**

Data Requirements	Limitations	Guidance
▪ Discharge and area for gaged watershed ▪ Area for ungaged watershed	▪ Similar hydrologic characteristics ▪ Channel storage	Must obtain approval of transfer technique from hydraulics engineer prior to use.

☒ **Fish Passage Flows**

▪ ~~Streamflow hydrograph~~ ▪ Flow duration curve		Lower and upper fish passage flows define the range of flows a culvert should contain suitable conditions for fish passage.

Selected Hydrologic Method: Regional Regression + Fish Passage Flows

Basis for Selection:

Must meet Adult Anadromous Salmonid depth + velocity criteria

[1] Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge
[2] FEMA Guidelines and Specifications, Appendix C, Section C.1
[3] USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)
[4] USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)
[5] United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
[6] HEC-1 User's Manual
[7] HEC-HMS User's Manual
[8] Bulletin 17B

GUIDANCE ON METHODOLOGY FOR HYDROLOGIC ANALYSIS [1,2]						FORM 4
Verify Reasonableness and Recommended Peak Discharges						
Source	**50% Annual Probability (2-Year Flood Event) (cfs)**	**10% Annual Probability (10-Year Flood Event) (cfs)**	**2% Annual Probability (50-Year Flood Event) (cfs)**	**1% Annual Probability (100-Year Flood Event) (cfs)**	**High Fish Passage Design Flow (cfs)**	**Low Fish Passage Design Flow (cfs)**
Effective Study Peak Discharges	N/A	N/A	N/A	N/A	N/A	N/A
Recommended Peak Discharges	245	510	800	900	146	18

Hydrologic Analysis Index Attached ☒ Yes ☐ No

Hydrologic Analysis Calculations Attached ☒ Yes ☐ No

[1] Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge
[2] FEMA Guidelines and Specifications, Appendix C, Section C.1
[3] USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)
[4] USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)
[5] United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
[6] HEC-1 User's Manual
[7] HEC-HMS User's Manual
[8] Bulletin 17B

HYDROLOGIC ANALYSES INDEX			FORM 4
Project Information Road Widening Route 777	Computed: EKB	Date: 2/22/06	
	Checked: JJL	Date: 2/23/06	
Stream Name: Rose Creek	County: Del Norte, CA	Route: 777	Postmile: 6.15

Flooding Source/Stream Name	Hydrologic Method/Model Used	Method/Model Analysis Date	Exhibit No.	
			Paper Copy	Electronic Copy
Rose Creek	Regional Regression >	Sierra Region	1	—
Rose Creek	Upper + Lower Fish Passage Flow		—	1

Regional Regression Computation Summary

Project Information: Route 777 Road Widening		Computed: EKB	Date: 2/22/2006
		Checked: JJL	Date: 2/23/2006
Stream Name: Rose Creek	County: Del Norte	Route: 777	Postmile: 6.15

Calculations:

-Site Located in North Coast Region

A, Drainage Area = 1.48 mi^2
P, Mean Annual Precipitation = 79 inches
H, Altitude Index = 1 thousands of feet

Regional Regression Equations

$Q2 = 3.52A^{0.90}P^{0.89}H^{-0.47}$
Q2 = 245 cfs

$Q10 = 6.21A^{0.88}P^{0.93}H^{-0.27}$
Q10 = 510 cfs

$Q50 = 8.57A^{0.87}P^{0.96}H^{-0.08}$
Q50 = 800 cfs

$Q100 = 9.23A^{0.87}P^{0.97}$
Q100 = 900 cfs

The following documentation was taken from:

U.S. Geological Survey Water-Resources Investigations Report 94-4002:
Nationwide summary of U.S. Geological Survey regional regression equations for estimating magnitude and frequency of floods for ungaged sites, 1993

CALIFORNIA

STATEWIDE RURAL

Summary

California is divided into six hydrologic regions (fig. 1). The regression equations developed for these regions are for estimating peak discharges (QT) having recurrence intervals T that range from 2 to 100 years. The explanatory basin variables used in the equations are drainage area (A), in square miles; mean annual precipitation (P), in inches; and an altitude index (H), which is the average of altitudes in thousands of feet at points along the main channel at 10 percent, and 85 percent of the distances from the site to the divide. The variables A and H may be measured from topographic maps. Mean annual precipitation (P) is determined from a map in Rantz (1969). The regression equations were developed from peak-discharge records of 10 years or longer, available as of 1975, at more than 700 gaging stations throughout the State. The regression equations are applicable to unregulated streams but are not applicable to some parts of the State (see fig. 1). The standard errors of estimate for the regression equations for various recurrence intervals and regions range from 60 to over 100 percent. The report by Waananen and Crippen (1977) includes an approximate procedure for increasing a rural discharge to account for the effect of urban development. The influences of fire and other basin changes on flood magnitudes are also discussed.

Procedure

Topographic maps, the hydrologic regions map (fig. 1), the mean annual precipitation from Rantz (1969), and the following equations are used to estimate the needed peak discharges QT, in cubic feet per second, having selected recurrence intervals T.

North Coast Region

$Q2 = 3.52\ A^{0.90}\ P^{0.89}\ H^{-0.47}$
$Q5 = 5.04\ A^{0.89}\ P^{0.91}\ H^{-0.35}$
$Q10 = 6.21\ A^{0.88}\ P^{0.93}\ H^{-0.27}$
$Q25 = 7.64\ A^{0.87}\ P^{0.94}\ H^{-0.17}$
$Q50 = 8.57\ A^{0.87}\ P^{0.96}\ H^{-0.08}$
$Q100 = 9.23\ A^{0.87}\ P^{0.97}$

Northeast Region

$Q2 = 22\ A^{0.40}$
$Q5 = 46\ A^{0.45}$
$Q10 = 61\ A^{0.49}$
$Q25 = 84\ A^{0.54}$
$Q50 = 103\ A^{0.57}$
$Q100 = 125\ A^{0.59}$

Sierra Region

$Q2 = 0.24\ A^{0.88}\ P^{1.58}\ H^{-0.80}$
$Q5 = 1.20\ A^{0.82}\ P^{1.37}\ H^{-0.64}$
$Q10 = 2.63\ A^{0.80}\ P^{1.25}\ H^{-0.58}$
$Q25 = 6.55\ A^{0.79}\ P^{1.12}\ H^{-0.52}$
$Q50 = 10.4\ A^{0.78}\ P^{1.06}\ H^{-0.48}$
$Q100 = 15.7\ A^{0.77}\ P^{1.02}\ H^{-0.43}$

Central Coast Region

$Q2 = 0.0061\ A^{0.92}\ P^{2.54}\ H^{-1.10}$
$Q5 = 0.118\ A^{0.91}\ P^{1.95}\ H^{-0.79}$
$Q10 = 0.583\ A^{0.90}\ P^{1.61}\ H^{-0.64}$
$Q25 = 2.91\ A^{0.89}\ P^{1.26}\ H^{-0.50}$
$Q50 = 8.20\ A^{0.89}\ P^{1.03}\ H^{-0.41}$
$Q100 = 19.7\ A^{0.88}\ P^{0.84}\ H^{-0.33}$

South Coast Region

$Q2 = 0.14\ A^{0.72}\ P^{1.62}$
$Q5 = 0.40\ A^{0.77}\ P^{1.69}$
$Q10 = 0.63\ A^{0.79}\ P^{1.75}$
$Q25 = 1.10\ A^{0.81}\ P^{1.81}$
$Q50 = 1.50\ A^{0.82}\ P^{1.85}$
$Q100 = 1.95\ A^{0.83}\ P^{1.87}$

South Lahontan-Colorado Desert Region

$$Q2 = 7.3A^{0.30}$$
$$Q5 = 53A^{0.44}$$
$$Q10 = 150A^{0.53}$$
$$Q25 = 410A^{0.63}$$
$$Q50 = 700A^{0.68}$$
$$Q100 = 1080A^{0.71}$$

In the North Coast region, use a minimum value of 1.0 for the altitude index (H). Equations are defined only for basins of 25 mi^2 or less in the Northeast and South Lahontan-Colorado Desert regions.

Reference

Waananen, A.O., and Crippen, J.R., 1977, Magnitude and frequency of floods in California: U.S. Geological Survey Water-Resources Investigations Report 77-21, 96 p.

Additional Reference

Rantz, S.E., 1969, Mean annual precipitation in the California region: U.S. Geological Survey Open-File Map (Reprinted 1972, 1975).

Figure 1. Flood-frequency region map for California. (PostScript file of Figure 1.)

Back to NFF main page

USGS Surface-Water Software Page

U.S. Geological Survey
National Flood Frequency Program
Water-Resources Investigations Report 94-4002

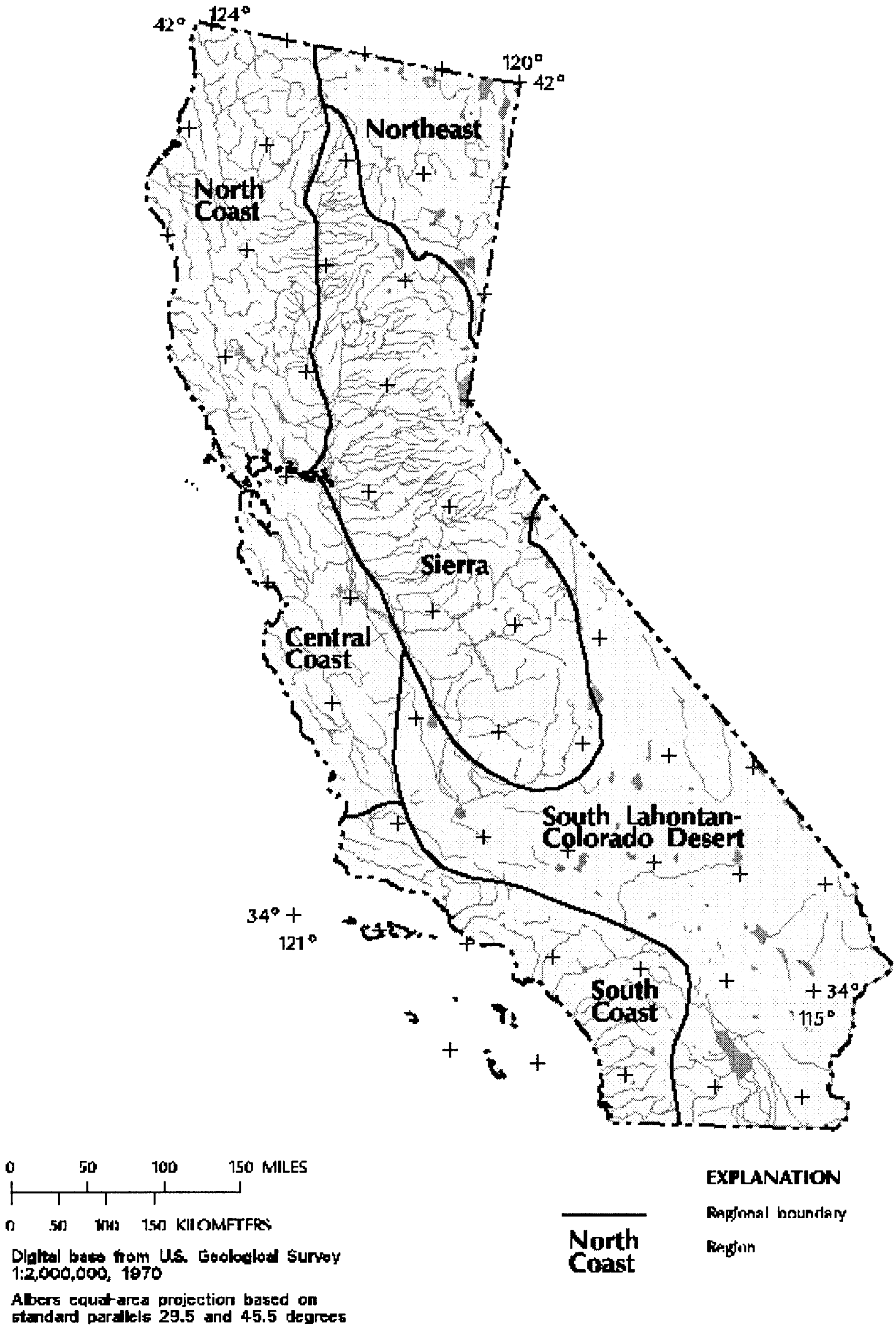
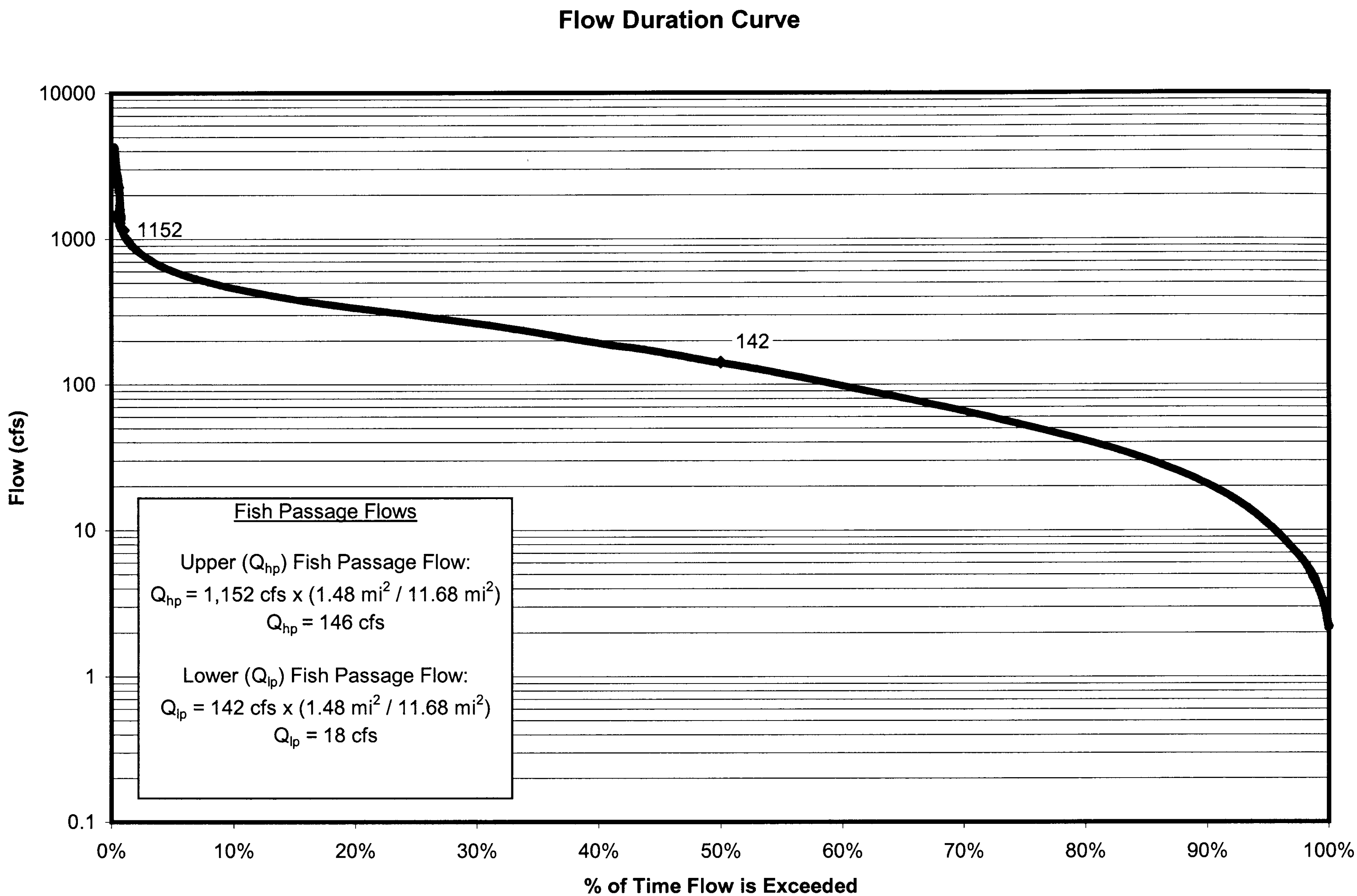


Figure 1. Flood-frequency region map for California.



Flow Duration Curve
10000
1000
100
10
1
0.1
Flow (cfs)
1152
142
Fish Passage Flows
Upper (Q_{hp}) Fish Passage Flow:
Q_{hp} = 1,152 cfs x (1.48 mi^2 / 11.68 mi^2)
Q_{hp} = 146 cfs
Lower (Q_{lp}) Fish Passage Flow:
Q_{lp} = 142 cfs x (1.48 mi^2 / 11.68 mi^2)
Q_{lp} = 18 cfs
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% of Time Flow is Exceeded

Form 5 - Guidance on Methodology for Hydraulic Analysis

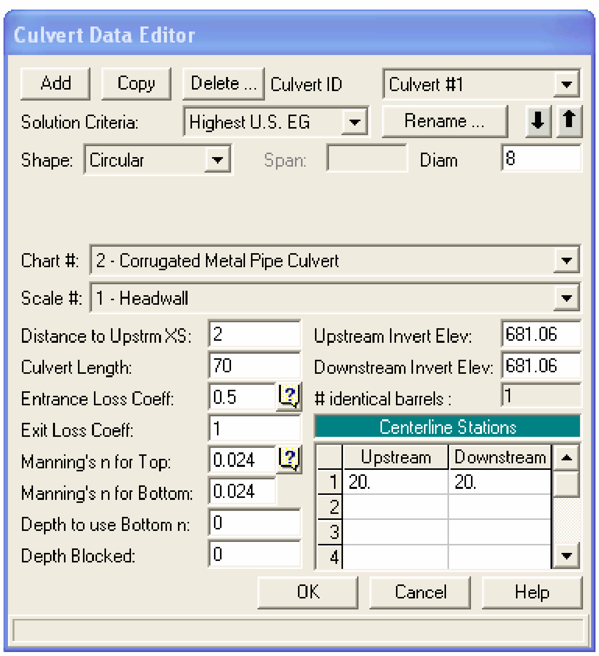
Form 5 summarizes the acceptable methods available for hydraulic analysis. The modeling methods include FHWA Design Charts, HY8 - Culvert Analysis, HEC-2/HEC-RAS, and Fish Xing (only for pre/post-design assessment).

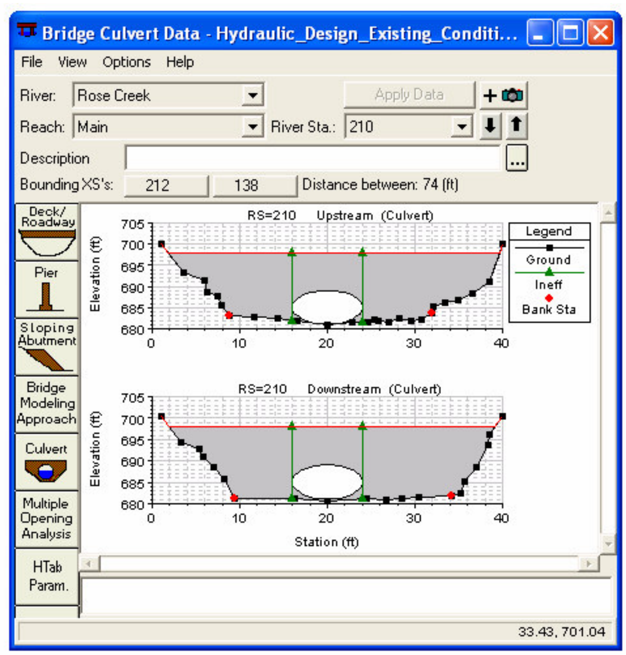
For this particular example, HEC-RAS was used to model existing and proposed conditions. HEC-RAS easily allowed a quick comparison between existing and proposed water surface elevations and velocities. Fish Xing software was also used to assess the post-design condition.

The HEC-RAS model consists of two plans: existing geometry and proposed geometry conditions. Both plans use the same peak discharges estimated by regional regression analysis and the flow hydrograph and stream duration curve.

The existing culvert geometry was modeled using the Culvert Data Editor. The existing culvert parameters that had been measured and captured in Form 2 - Site Visit Summary, were entered into the Culvert Data Editor within HEC-RAS.

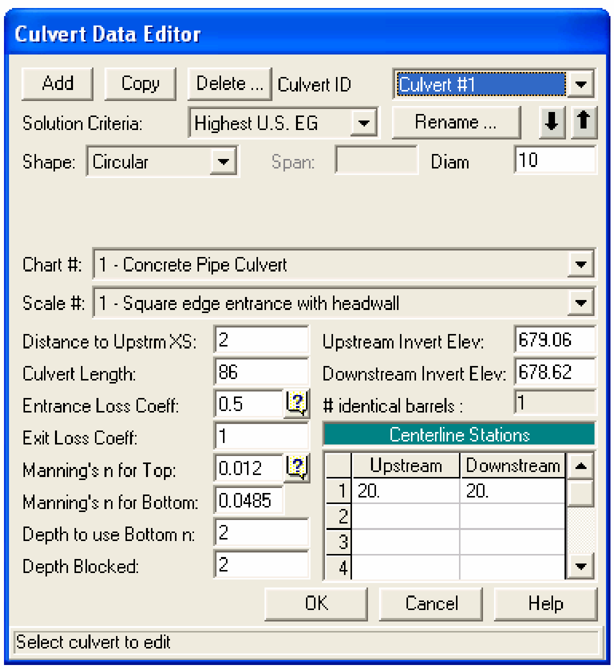
The Culvert Data Editor and Bridge Culvert Data windows are captured below.

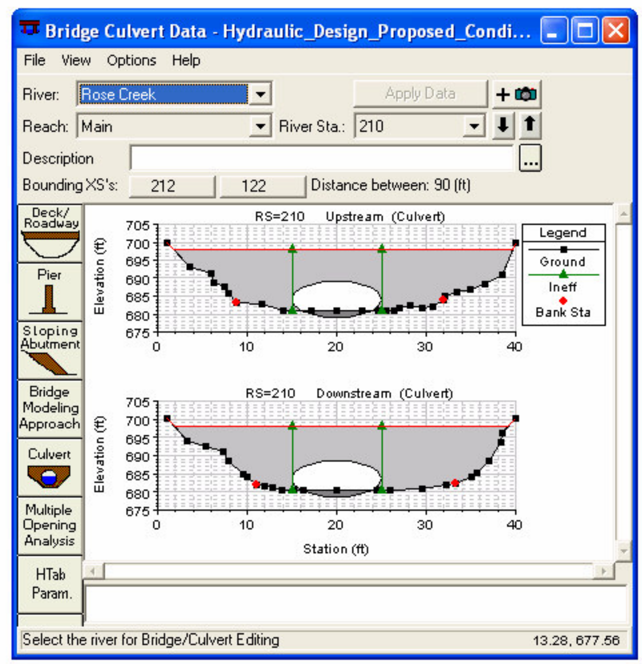




The proposed culvert geometry was also modeled using the Culvert Data Editor in HEC-RAS. Since the culvert embedment is a constant depth throughout the culvert, the culvert embedment was modeled by blocking the appropriate depth out of the bottom of the culvert using the “depth blocked” function.

The Culvert Data Editor and Bridge Culvert Data windows are captured below.





GUIDANCE ON METHODOLOGY FOR HYDRAULIC ANALYSIS — FORM 5

Project Information	Computed: EKB	Date: 2/22/06
Road Widening Route 777	Checked: JJL	Date: 2/23/06

Stream Name: Rose Creek	County: Del Norte	Route: 777	Postmile: 6.15

Summary of Methods for Hydraulic Analysis

☐ **FHWA Design Charts**

☐ **HY8 - Culvert Analysis or other HDS-5 Based Software**

☒ **HEC-2 / HEC-RAS**

☒ **Fish Xing (Pre-design assessment or post-design assessment when applicable)**

Is the hydraulic model used to create the effective FIRM available? ☐ Yes ☒ No
If yes, update and use this model for the hydraulic model.

Selected Method: HEC-RAS and Fish Xing

Basis for Selection:

HEC-RAS - upstream and downstream channel geometry available
- model as steady state flow
- peak discharges available

Fish Xing -
for post design assessment

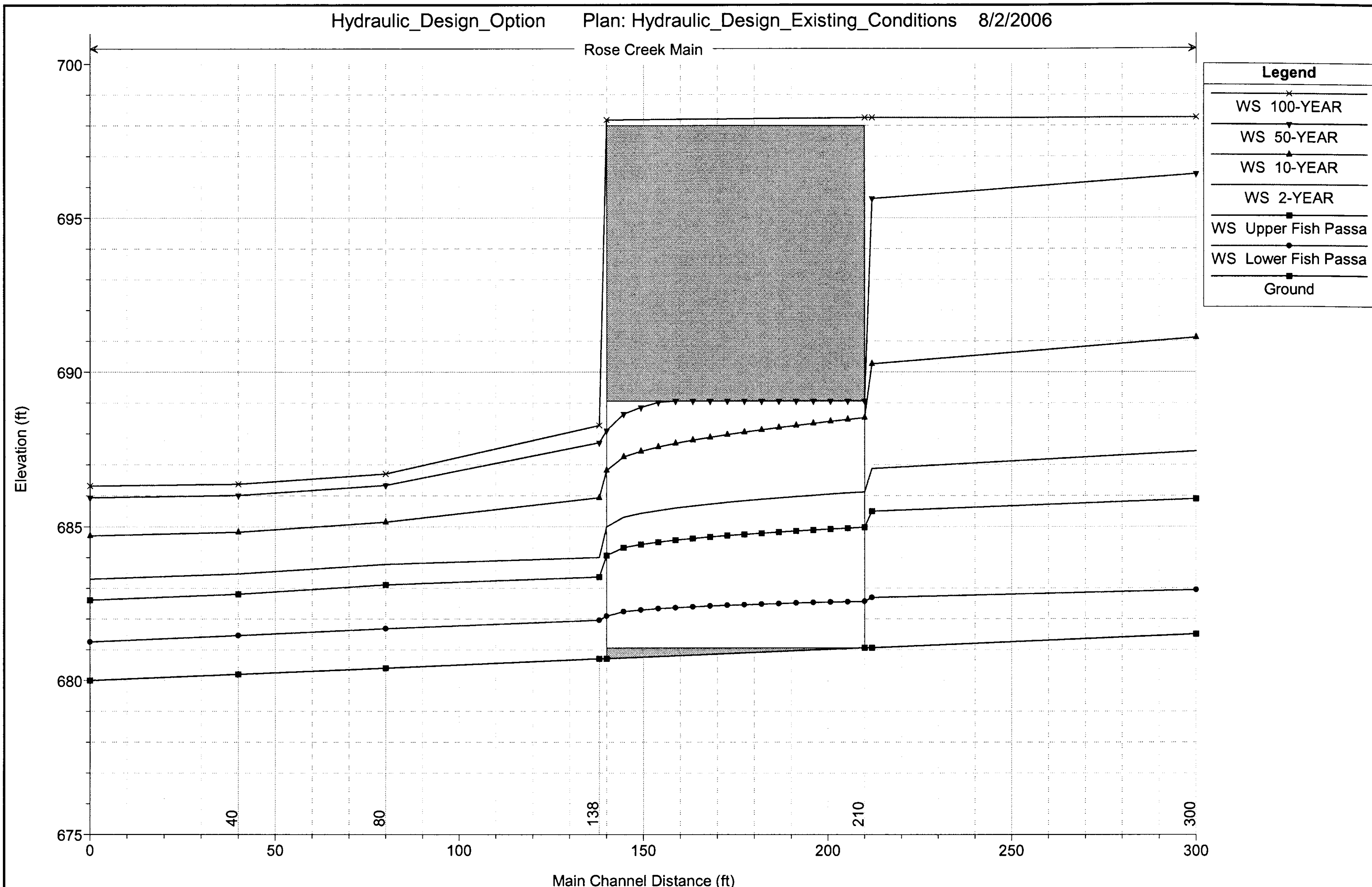
Verify Reasonableness and Recommended Flows ☒ Yes ☐ No

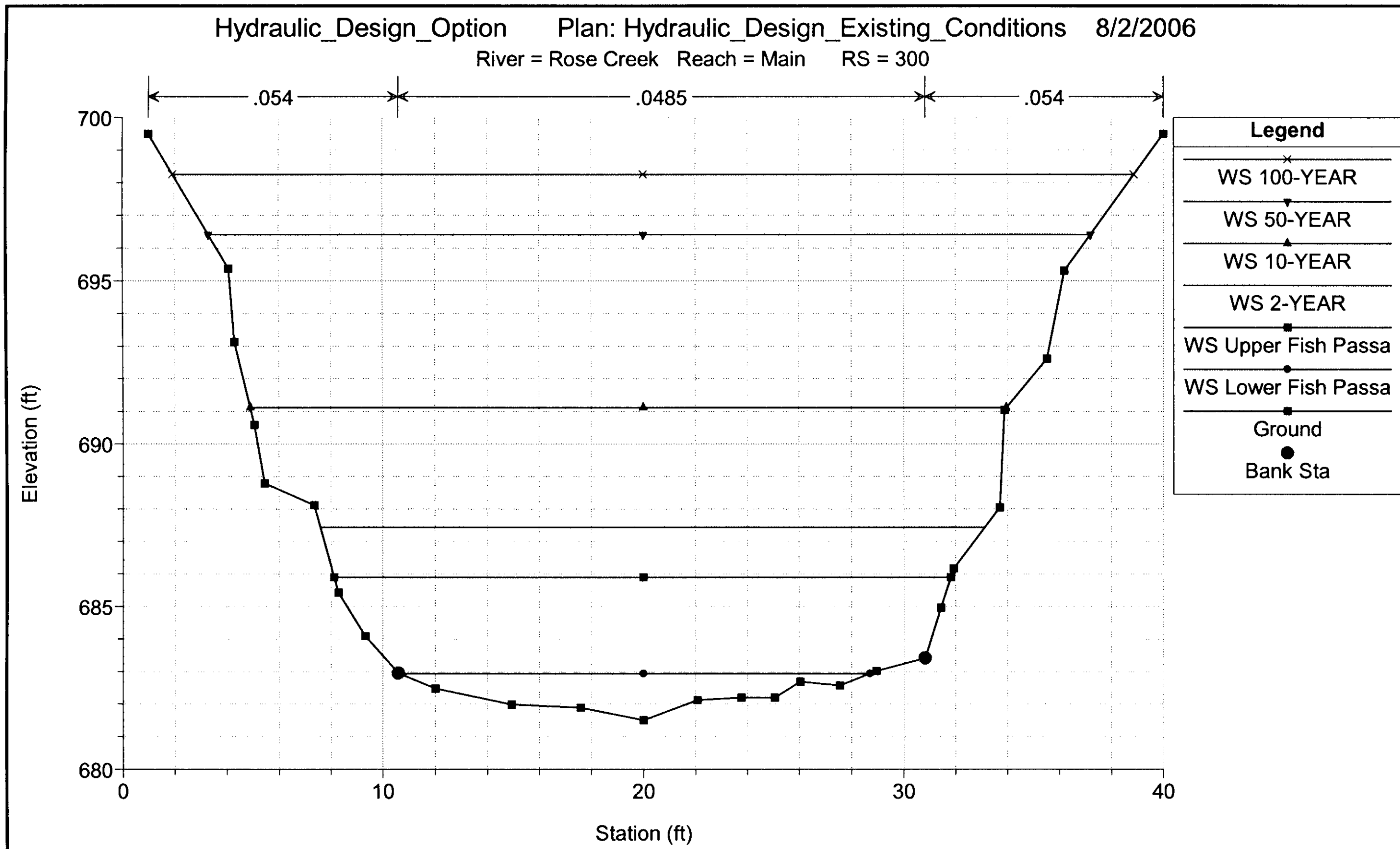
Hydraulic Analyses Index Attached ☒ Yes ☐ No

Hydraulic Analysis Calculation Attached ☒ Yes ☐ No

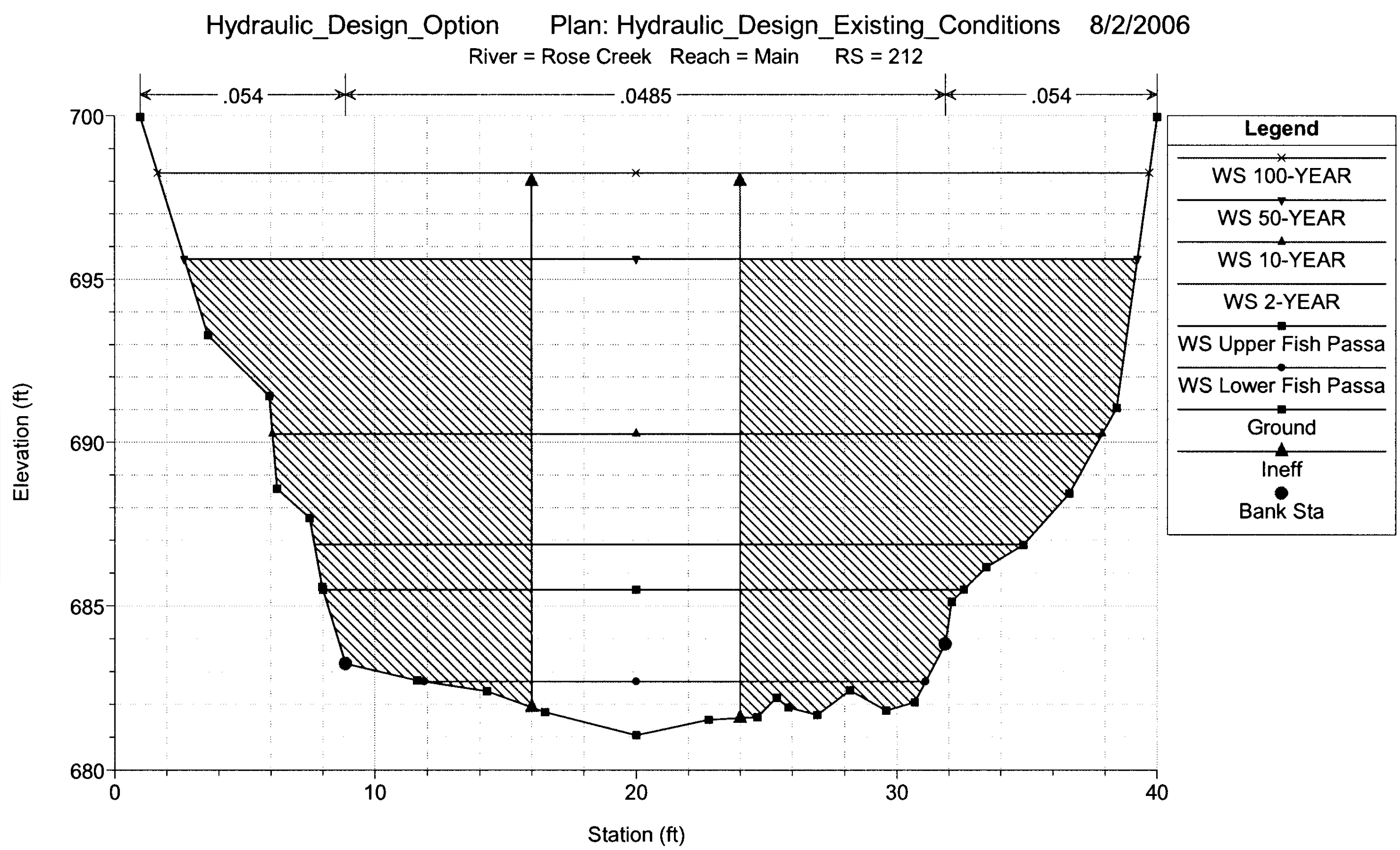
HYDRAULIC ANALYSES INDEX			FORM 5
Project Information Road Widening Route 777		Computed: EKB	Date: 2/22/06
		Checked: JJL	Date: 2/23/06
Stream Name: Rose Creek	County: Del Norte	Route: 777	Postmile: 6.5

Flooding Source/Stream Name	Hydraulic Method/Model Used	Method/Model Analysis Date	Exhibit No.	
			Paper Copy	Electronic Copy
Rose Creek	HEC-RAS	Existing/2/23/06	1	.p01 .g01 .f01
	HEC-RAS	Proposed 2/23/06	1	.p02 .g02 .f01
Rose Creek	FISH XING	Post-Design assessment	1	Rose Creek Culvert @ Route 777.xng

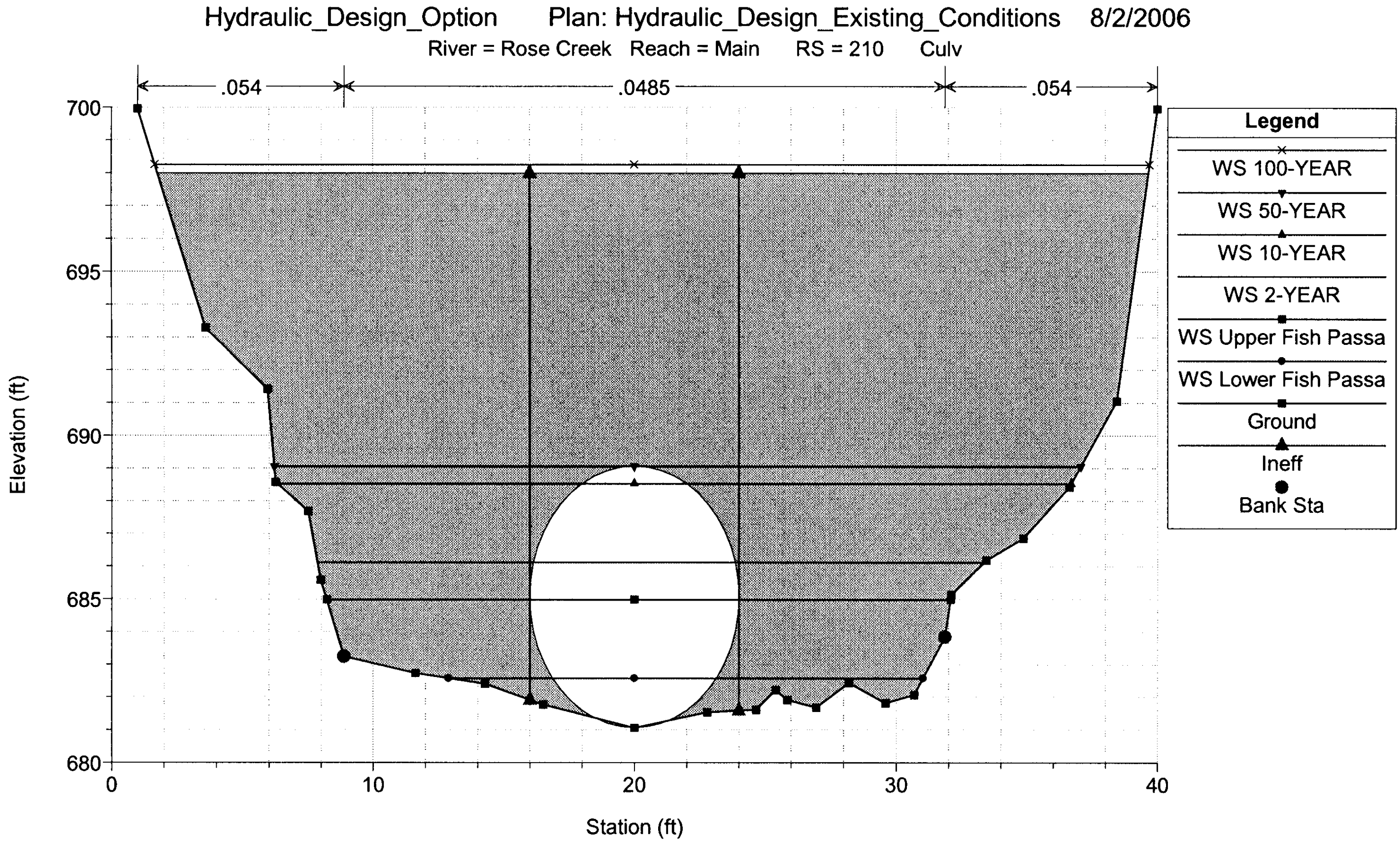

Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
Rose Creek Main
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Elevation (ft)
700
695
690
685
680
675
40
80
138
210
300
0
50
100
150
200
250
300
Main Channel Distance (ft)



Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 300
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta
Elevation (ft)
700
695
690
685
680
0
10
20
30
40
Station (ft)



Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 212
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta
Elevation (ft)
700
695
690
685
680
0
10
20
30
40
Station (ft)


Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 210 Culv
.054
.0485
.054
700
695
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Elevation (ft)
0
10
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Station (ft)
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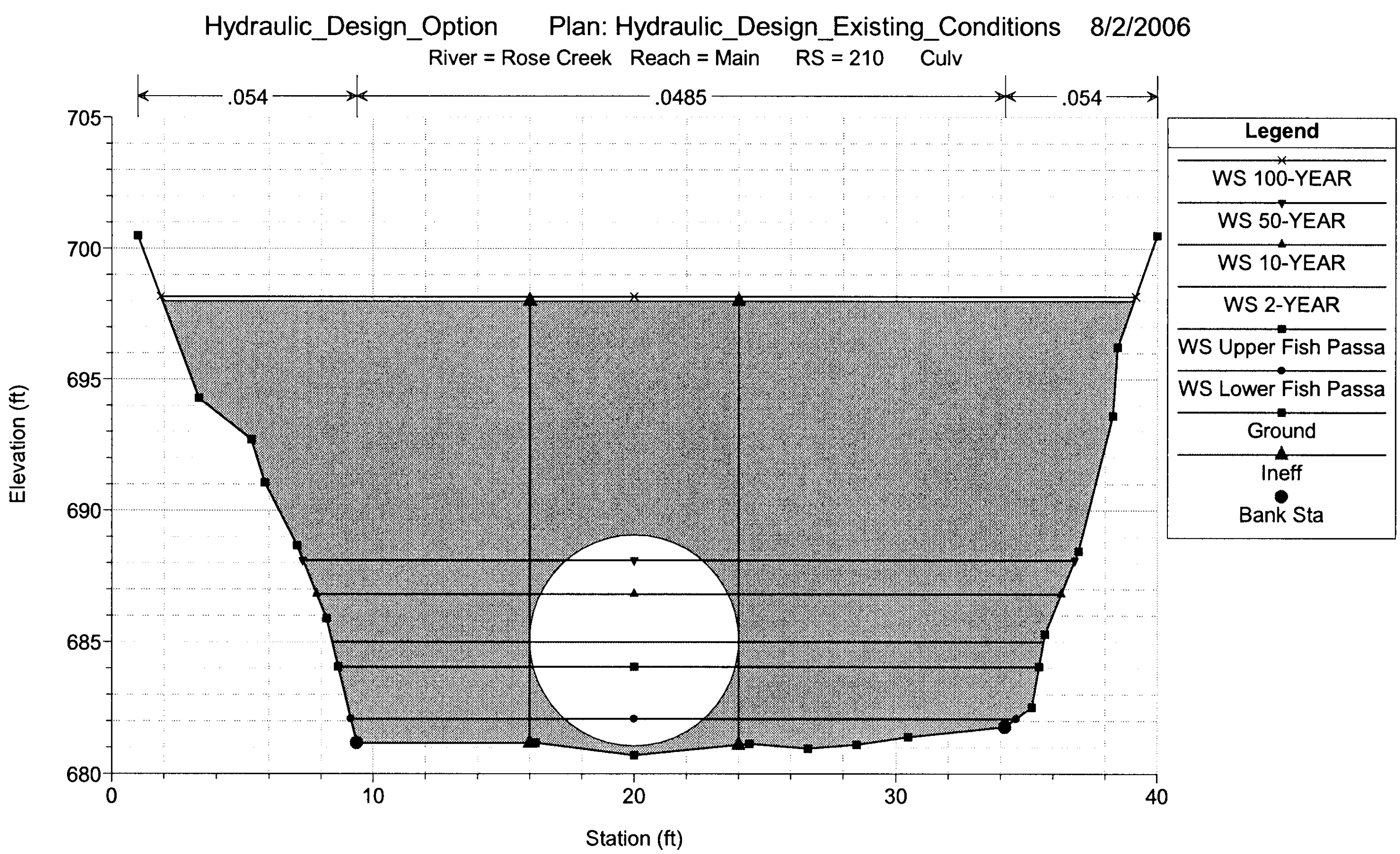
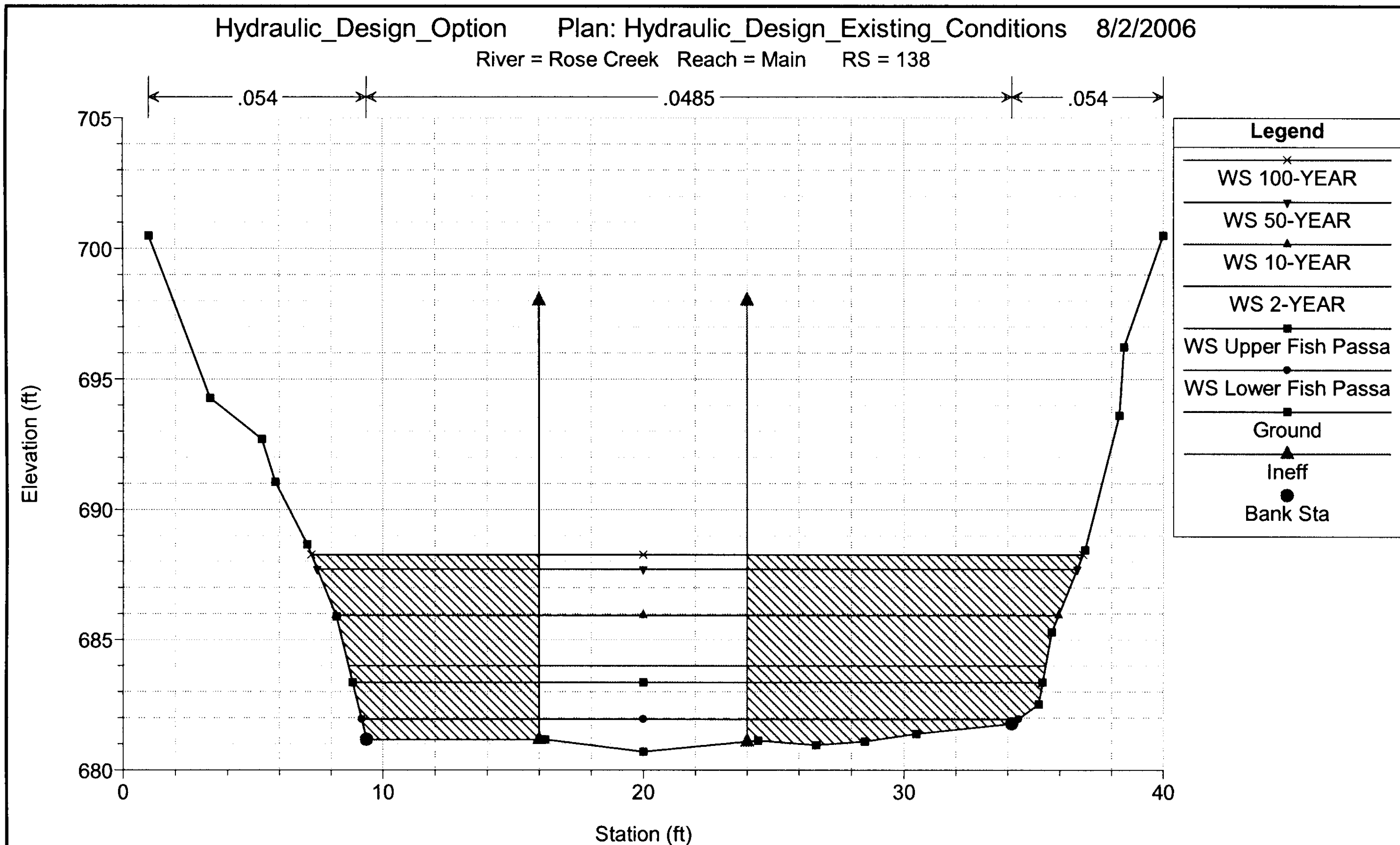
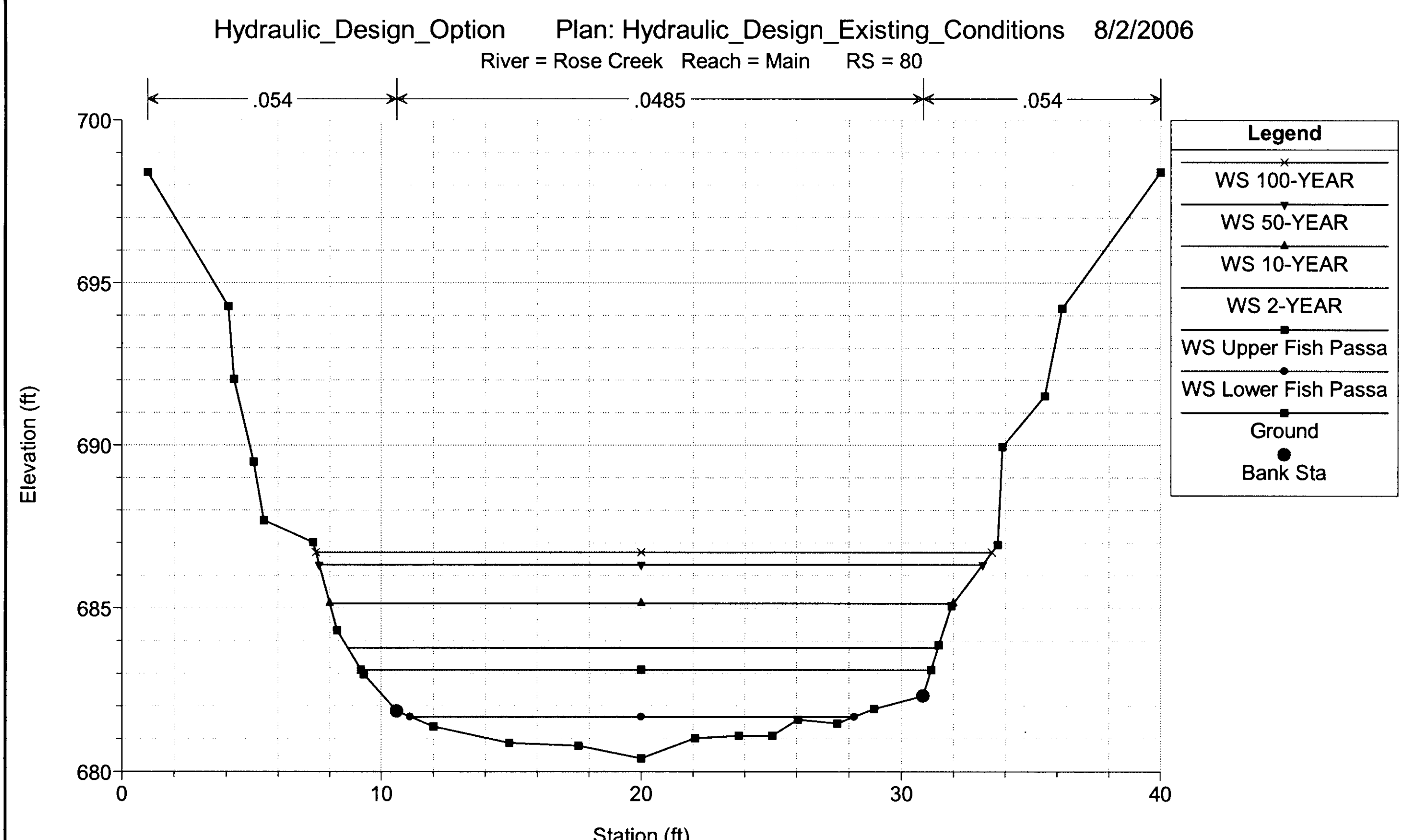
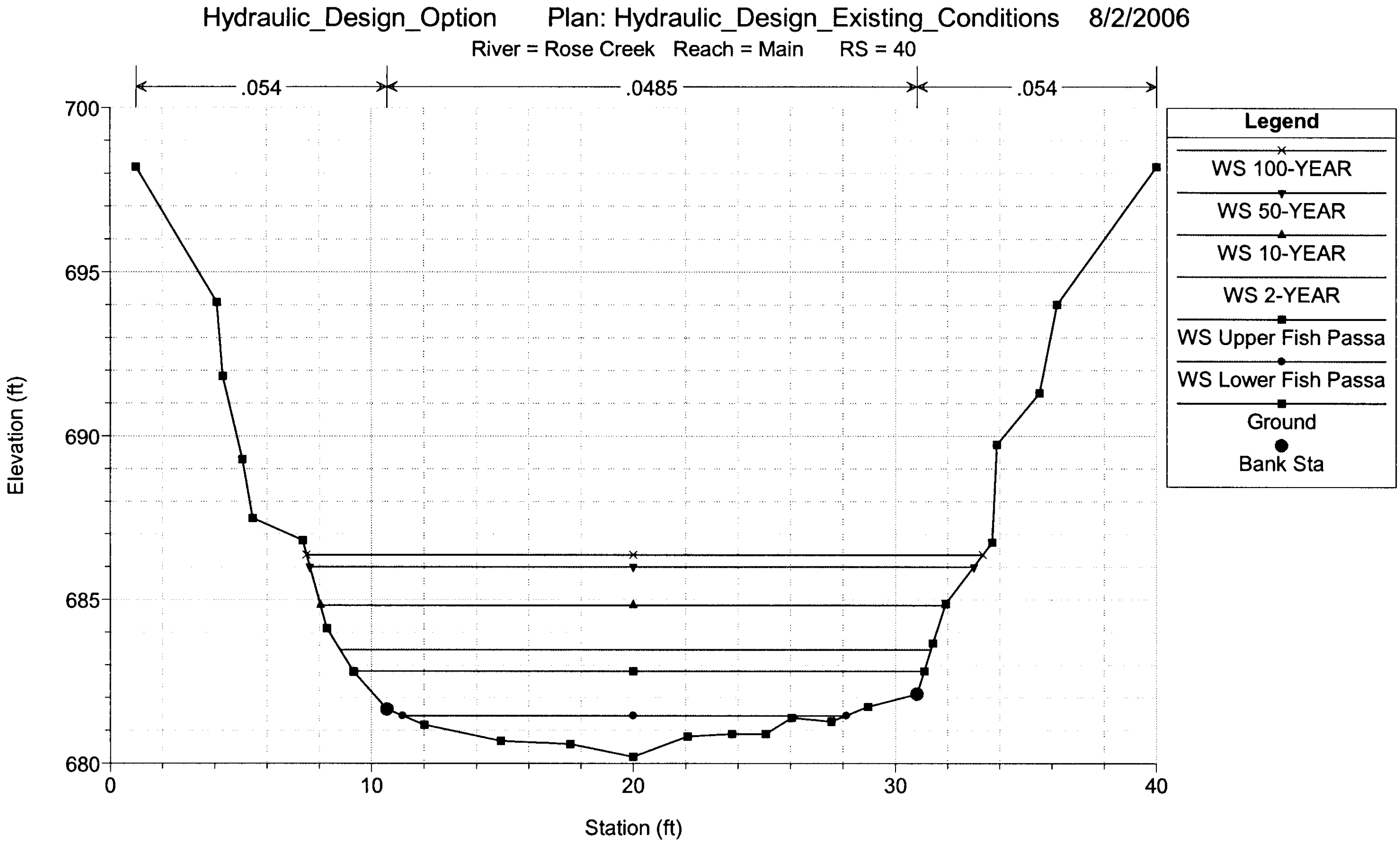
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta

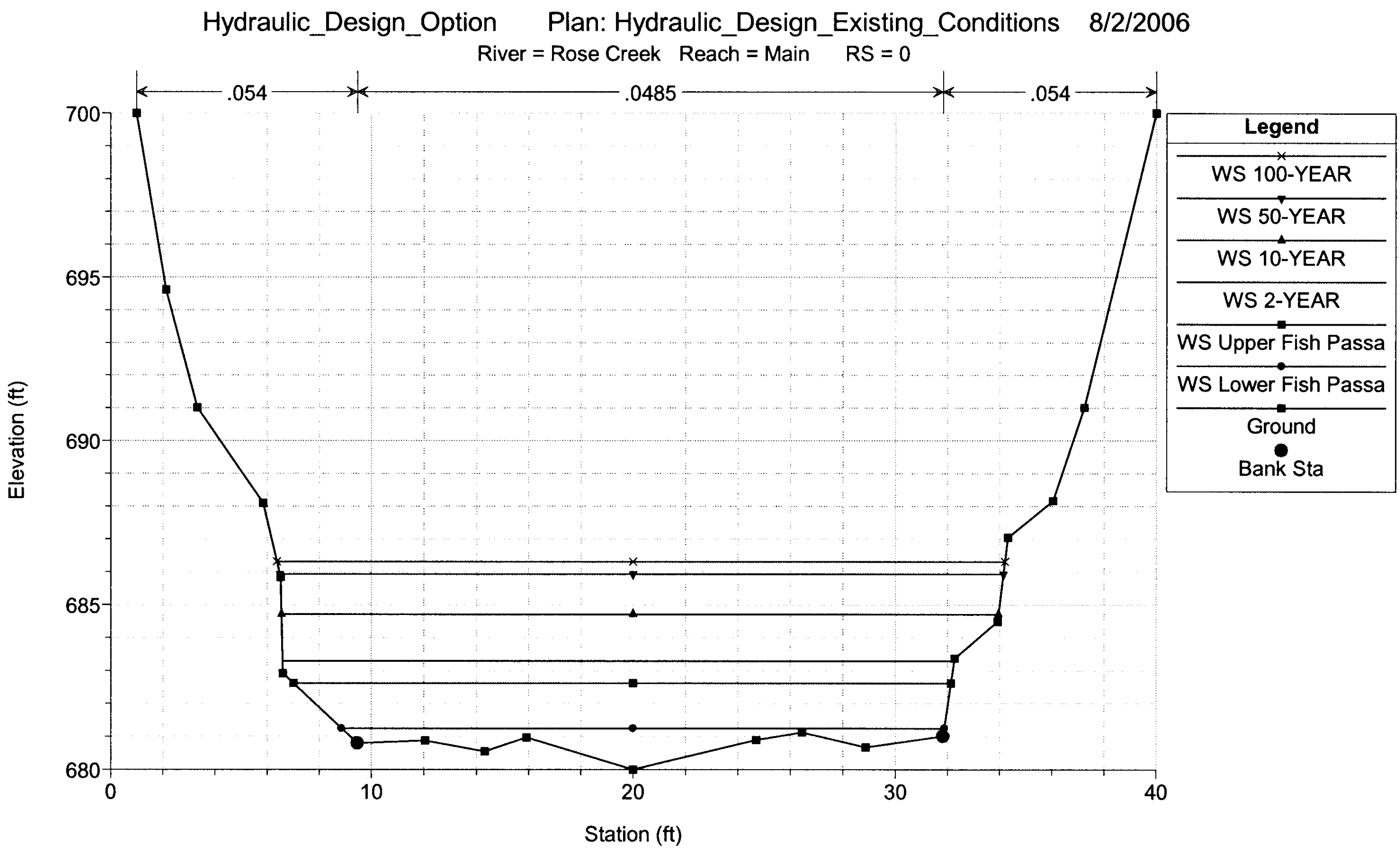

Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 210 Culv
.054
.0485
.054
705
700
695
690
685
680
Elevation (ft)
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta


Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 138
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta
Elevation (ft)
705
700
695
690
685
680
0
10
20
30
40
Station (ft)


Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 80
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta
Elevation (ft)
700
695
690
685
680
0
10
20
30
40
Station (ft)



Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 40
.054
.0485
.054
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta



Hydraulic_Design_Option Plan: Hydraulic_Design_Existing_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 0
.054
.0485
.054
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta

HEC-RAS Plan: Existing Conditions River: Rose Creek

River Sta	Profile	Q Total	Min Ch El	W.S. Elev	W. Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
0	2-YEAR	245	680	683.3	3.3	682.22	683.55	0.005	4.06	62.87	25.67	0.44
0	10-YEAR	510	680	684.71	4.71	683.18	685.15	0.005001	5.41	100.33	27.4	0.48
0	50-YEAR	800	680	685.93	5.93	684.02	686.55	0.005	6.46	134.01	27.65	0.5
0	100-YEAR	900	680	686.31	6.31	684.28	686.99	0.005002	6.77	144.51	27.83	0.5
0	Upper Fish Passage	146	680	682.62	2.62	681.78	682.78	0.005001	3.31	45.43	25.12	0.42
0	Lower Fish Passage	18	680	681.25	1.25	680.95	681.28	0.005002	1.45	12.53	23.02	0.34
40	2-YEAR	245	680.2	683.47	3.27		683.82	0.007482	4.79	52.51	22.58	0.54
40	10-YEAR	510	680.2	684.83	4.63		685.44	0.007396	6.37	84.07	23.87	0.57
40	50-YEAR	800	680.2	686	5.8		686.86	0.007306	7.56	113.08	25.36	0.59
40	100-YEAR	900	680.2	686.37	6.17		687.31	0.007265	7.9	122.45	25.84	0.6
40	Upper Fish Passage	146	680.2	682.81	2.61		683.05	0.00753	3.92	37.86	21.81	0.51
40	Lower Fish Passage	18	680.2	681.46	1.26		681.5	0.005839	1.69	10.64	16.95	0.38
80	2-YEAR	245	680.4	683.78	3.38		684.1	0.006451	4.58	55.03	22.7	0.5
80	10-YEAR	510	680.4	685.15	4.75		685.72	0.006641	6.16	87.03	24	0.55
80	50-YEAR	800	680.4	686.33	5.93		687.15	0.006695	7.36	116.38	25.53	0.57
80	100-YEAR	900	680.4	686.7	6.3		687.59	0.006693	7.71	125.83	26.01	0.58
80	Upper Fish Passage	146	680.4	683.11	2.71		683.32	0.006272	3.7	40.09	21.93	0.47
80	Lower Fish Passage	18	680.4	681.68	1.28		681.72	0.00521	1.63	11.05	17.1	0.36
138	2-YEAR	245	680.7	684	3.3	684	685.54	0.023656	9.94	24.65	26.8	1
138	10-YEAR	510	680.7	685.94	5.24	685.94	688.45	0.020231	12.71	40.11	27.78	1
138	50-YEAR	800	680.7	687.71	7.01	687.71	691.08	0.018144	14.73	54.3	29.22	1
138	100-YEAR	900	680.7	688.26	7.56	688.26	691.91	0.017673	15.32	58.73	29.68	1
138	Upper Fish Passage	146	680.7	683.36	2.66	683.11	684.23	0.01827	7.48	19.53	26.52	0.84
138	Lower Fish Passage	18	680.7	681.96	1.26	681.46	682.03	0.004864	2.18	8.27	25.24	0.38
210		Culvert										
212	2-YEAR	245	681.06	686.88	5.82	684.49	687.37	0.003566	5.61	43.67	27.21	0.42
212	10-YEAR	510	681.06	690.26	9.2	686.43	691.06	0.003099	7.21	70.71	31.83	0.43
212	50-YEAR	800	681.06	695.63	14.57	688.2	696.4	0.001566	7.04	113.69	36.57	0.33
212	100-YEAR	900	681.06	698.25	17.19	688.75	698.32	0.000133	2.15	500.57	38.04	0.09
212	Upper Fish Passage	146	681.06	685.5	4.44	683.59	685.81	0.003349	4.48	32.61	24.56	0.39
212	Lower Fish Passage	18	681.06	682.7	1.64	681.96	682.74	0.002432	1.76	10.22	19.22	0.27
300	2-YEAR	245	681.5	687.44	5.94		687.52	0.000625	2.25	116.53	25.54	0.17
300	10-YEAR	510	681.5	691.11	9.61		691.21	0.00042	2.64	219.01	29.05	0.16
300	50-YEAR	800	681.5	696.42	14.92		696.5	0.000201	2.5	385.9	33.89	0.12
300	100-YEAR	900	681.5	698.25	16.75		698.34	0.000165	2.46	450.92	36.93	0.11
300	Upper Fish Passage	146	681.5	685.9	4.4		685.95	0.000747	1.94	78.61	23.69	0.18
300	Lower Fish Passage	18	681.5	682.94	1.44		682.97	0.002614	1.29	13.91	18.1	0.26

Plan: Existing Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: Lower Fish Passa

Q Culv Group (cfs)	18.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	2.73
Q Barrel (cfs)	18.00	Culv Vel DS (ft/s)	4.77
E.G. US. (ft)	682.75	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	682.70	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	682.03	Culv Frctn Ls (ft)	0.25
W.S. DS (ft)	681.96	Culv Exit Loss (ft)	0.41
Delta EG (ft)	0.72	Culv Entr Loss (ft)	0.06
Delta WS (ft)	0.74	Q Weir (cfs)	
E.G. IC (ft)	682.44	Weir Sta Lft (ft)	
E.G. OC (ft)	682.75	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	682.57	Weir Max Depth (ft)	
Culv WS Outlet (ft)	682.09	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	1.03	Min El Weir Flow (ft)	698.01

Plan: Existing Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: Upper Fish Passa

Q Culv Group (cfs)	146.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	5.97
Q Barrel (cfs)	146.00	Culv Vel DS (ft/s)	8.47
E.G. US. (ft)	685.81	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	685.50	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	684.23	Culv Frctn Ls (ft)	0.35
W.S. DS (ft)	683.36	Culv Exit Loss (ft)	0.95
Delta EG (ft)	1.58	Culv Entr Loss (ft)	0.28
Delta WS (ft)	2.13	Q Weir (cfs)	
E.G. IC (ft)	685.24	Weir Sta Lft (ft)	
E.G. OC (ft)	685.81	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	684.98	Weir Max Depth (ft)	
Culv WS Outlet (ft)	684.06	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	3.00	Min El Weir Flow (ft)	698.01

Plan: Existing Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: 2-YEAR

Q Culv Group (cfs)	245.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	7.31
Q Barrel (cfs)	245.00	Culv Vel DS (ft/s)	9.95
E.G. US. (ft)	687.37	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	686.88	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	685.54	Culv Frctn Ls (ft)	0.42
W.S. DS (ft)	684.00	Culv Exit Loss (ft)	1.00
Delta EG (ft)	1.83	Culv Entr Loss (ft)	0.41
Delta WS (ft)	2.87	Q Weir (cfs)	
E.G. IC (ft)	686.72	Weir Sta Lft (ft)	
E.G. OC (ft)	687.37	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	686.12	Weir Max Depth (ft)	
Culv WS Outlet (ft)	685.00	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	3.94	Min El Weir Flow (ft)	698.01

Plan: Existing Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: 10-YEAR

Q Culv Group (cfs)	510.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	10.45
Q Barrel (cfs)	510.00	Culv Vel DS (ft/s)	13.17
E.G. US. (ft)	691.07	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	690.26	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	688.45	Culv Frctn Ls (ft)	0.71
W.S. DS (ft)	685.94	Culv Exit Loss (ft)	1.06
Delta EG (ft)	2.62	Culv Entr Loss (ft)	0.85
Delta WS (ft)	4.32	Q Weir (cfs)	
E.G. IC (ft)	690.34	Weir Sta Lft (ft)	
E.G. OC (ft)	691.07	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	688.52	Weir Max Depth (ft)	
Culv WS Outlet (ft)	686.82	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	5.76	Min El Weir Flow (ft)	698.01

Plan: Existing   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: 50-YEAR

Q Culv Group (cfs)	800.00	Culv Full Len (ft)	54.86
# Barrels	1	Culv Vel US (ft/s)	15.92
Q Barrel (cfs)	800.00	Culv Vel DS (ft/s)	17.06
E.G. US. (ft)	696.40	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	695.63	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	691.08	Culv Frctn Ls (ft)	1.80
W.S. DS (ft)	687.71	Culv Exit Loss (ft)	1.55
Delta EG (ft)	5.32	Culv Entr Loss (ft)	1.97
Delta WS (ft)	7.92	Q Weir (cfs)	
E.G. IC (ft)	696.18	Weir Sta Lft (ft)	
E.G. OC (ft)	696.40	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	689.06	Weir Max Depth (ft)	
Culv WS Outlet (ft)	688.11	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	7.05	Min El Weir Flow (ft)	698.01

Plan: Existing   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: 100-YEAR

Q Culv Group (cfs)	884.26	Culv Full Len (ft)	61.38
# Barrels	1	Culv Vel US (ft/s)	17.59
Q Barrel (cfs)	884.26	Culv Vel DS (ft/s)	18.41
E.G. US. (ft)	698.31	Culv Inv El Up (ft)	681.06
W.S. US. (ft)	698.25	Culv Inv El Dn (ft)	681.06
E.G. DS (ft)	691.91	Culv Frctn Ls (ft)	2.30
W.S. DS (ft)	688.26	Culv Exit Loss (ft)	1.70
Delta EG (ft)	6.40	Culv Entr Loss (ft)	2.40
Delta WS (ft)	9.99	Q Weir (cfs)	15.74
E.G. IC (ft)	698.31	Weir Sta Lft (ft)	1.65
E.G. OC (ft)	698.28	Weir Sta Rgt (ft)	39.71
Culvert Control	Inlet	Weir Submerg	0.00
Culv WS Inlet (ft)	689.06	Weir Max Depth (ft)	0.29
Culv WS Outlet (ft)	688.34	Weir Avg Depth (ft)	0.29
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	11.17
Culv Crt Depth (ft)	7.28	Min El Weir Flow (ft)	698.01

Errors Warnings and Notes

Note:	During supercritical analysis, the culvert direct step method went to critical depth. The program
	then assumed critical depth at the outlet.
Note:	During the supercritical calculations a hydraulic jump occurred inside of the culvert.

Form 6B - Hydraulic Design Option

Form 6B provides guidance to correctly design a culvert that meets specific fish passage design criteria, while also considering hydraulic impacts and scour concerns.

For this particular example, the culvert design had to satisfy the upper and lower fish passage design requirements for depth and velocity. For the adult anadromous salmonids the maximum average velocity at high fish design flow was 5 ft/sec. This had to be satisfied while meeting a minimum flow depth at the low fish design flow of 1 foot. Hydraulic analyses for hydraulic impacts and scour were also satisfied.

FISH PASSAGE: HYDRAULIC DESIGN OPTION		FORM 6B

Project Information Road Widening Route 777		Computed: EKB	Date: 2/26/06
		Checked: JJL	Date: 2/27/06
Stream Name: Rose Creek	County: Del Norte	Route: 777	Postmile: 6.15

General Considerations

Hydraulic controls (e.g. boulders weirs, log sills, etc.) in the channel upstream and/or downstream of a crossing can be used to provide a continuous low flow path through the crossing and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: control depth and water velocity within the crossing, concentrate low flows, provide resting pools upstream and downstream of the crossing, and control erosion of the streambed and banks.

Baffles or weirs shall not be used in the design of new or replacement culverts in order to meet the hydraulic design criteria.

The following **Adverse Hydraulic Conditions** are generally considered to be detrimental to efficient fish passage and should be avoided. The degree to which they impede fish passage depends upon the magnitude of the condition. Crossing designed by the Hydraulic Design Option should be evaluated for the following conditions at high design flow for fish passage: Super critical flow, Hydraulic jumps, Highly turbulent conditions, and Abrubt changes in water surface elevation in inlet and outlet.

Hydrology Results - Peak Discharge Values

50% Annual Probability (2-Year Flood Event)	245 cfs	10% Annual Probability (10-Year Flood Event)	510 cfs
2% Annual Probability (50-Year Flood Event)	800 cfs	1% Annual Probability (100-Year Flood Event)	900 cfs
High Fish Passage Design Flow	146 cfs	Low Fish Passage Design Flow	18 cfs

Estabilsh Proposed Culvert Setting and Dimensions

Culvert Width - The minimum culvert width shall be 3 feet.

Proposed Culvert Width: 10.0 ft

Culvert Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified.

Upstream Embedment: 2.0 ft (≥ 1 foot)

Downstream Embedment: 2.0 ft (≥ 20% of culvert rise and ≥ 1 foot)

Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which the crossing is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.

Upstream invert elevation: 681.06 ft (NGVD 29 [circled] or NAVD 88)	Downstream invert elevation: 680.59 ft (NGVD 29 [circled] or NAVD 88)

Summarize Proposed Culvert Physical Characterstics

Inlet Characteristics

Inlet Type	☐ Projecting	☒ Headwall	☐ Wingwall
	☐ Flared end section	☐ Segment connection	☐ Skew Angle: °

FISH PASSAGE: HYDRAULIC DESIGN OPTION — FORM 6B

Barrel Characteristics

Diameter: 120 in	Fill height above culvert: approx. 9.0 ft
Height/Rise: — ft	Length: 86 ft
Width/Span: — ft	Number of barrels: 1

Culvert Type	☐ Arch	☐ Box	☒ Circular
	☐ Pipe-Arch	☐ Elliptical	
Culvert Material	☐ HDPE	☐ Steel Plate Pipe	☒ Concrete Pipe
	☐ Spiral Rib / Corrugated Metal Pipe		

Horizontal alignment breaks: NONE ft	Vertical alignment breaks: NONE ft

Outlet Characteristics

Outlet Type	☐ Projecting	☒ Headwall	☐ Wingwall
	☐ Flared end section	☐ Segment connection	Skew Angle: °

Bridge Physical Characteristics N/A

Elevation of high chord (top of road): ft	Elevation of low chord: ft

Channel Lining	☐ No lining	☐ Concrete	☐ Rock	☐ Other

Skew Angle: °	Bridge width (length): ft

Pier Characteristics (if applicable) ☐ N/A

Number of Piers: ft	Upstream cross-section starting station: ft
Pier Width: ft	Downstream cross-section starting station: ft
Pier Centerline Spacing: ft	Skew angle: °

Pier Shape	☐ Square nose and tail	☐ Semi-circular nose and tail	☐ 90° triangular nose and tail
	☐ Twin-cylinder piers with connecting diaphragm	☐ Twin-cylinder piers without connecting diaphragm	☐ Ten pile trestle bent

Establish High Design Flow for Fish Passage - Depending on species, develop high design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Percentage of 2-Yr Recurrence Interval Flow	Design Flows (cfs)
☒ Adult Anadromous Salmonids	1%	50%	146
☐ Adult Non-Anadromous Salmonids	5%	30%	

☐ Juvenile Salmonids	10%	10%	
☐ Native Non-Salmonids	5%	30%	
☐ Non-Native Species	10%	10%	

Establish Low Design Flow for Fish Passage - Depending on species, develop low design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Alternate Minimum Flow (cfs)	Design Flow (cfs)
☒ Adult Anadromous Salmonids	50%	3	18
☐ Adult Non-Anadromous Salmonids	90%	2	
☐ Juvenile Salmonids	95%	1	
☐ Native Non-Salmonids	90%	1	
☐ Non-Native Species	90%	1	

Establish Maximum Average Water Velocity and Minimum Flow Depth in Culvert (At high design flow) - Depending on culvert length and/or species, select Maximum Average Water Veolcity and Minimum Flow Depth.

Species/Life Stage	Maximum Average Water Velocity at High Fish Design Flow (ft/sec)	Minimum Flow Depth at Low Fish Design Flow (ft)
☒ Adult Anadromous Salmonids	6 (Culvert length <60 ft)	1.0
	5 (Culvert length 60-100 ft)	
	4 (Culvert length 100-200 ft)	
	3 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
☐ Adult Non-Anadromous Salmonids	4 (Culvert length <60 ft)	0.67
	4 (Culvert length 60-100 ft)	
	3 (Culvert length 100-200 ft)	
	2 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
☐ Juvenile Salmonids	1	0.5

☐ Native Non-Salmonids	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.
☐ Non-Native Species	

Establish Maximum Outlet Drop

Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, it's magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown below. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

Species/Life Stage	Maximum Drop (ft)
☒ Adult Anadromous Salmonids	1 (circled)
☐ Adult Non-Anadromous Salmonids	1
☐ Juvenile Salmonids	0.5
☐ Native Non-Salmonids	Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
☐ Non-Native Species	

Maximum Allowable Inlet Water Surface Elevation

Culvert ☒

A culvert is required to pass the 10-year peak discharge without causing pressure flow in the culvert,	Allowable WSEL: 689.06 ft
And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.	Allowable WSEL: 694.06 ft

Bridge ☐ N/A

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,	Allowable WSEL: ft
While passing the 100-year peak or design discharge under low chord of the bridge.	Allowable WSEL: ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?
☐ Yes ☒ No

If yes, establish allowable hydraulic imacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in the increase capacity of an existing crossing? ☒ Yes ☐ No

If yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☒ No

If yes, consult District Hydraulics. Further analysis may be needed.

FISH PASSAGE: HYDRAULIC DESIGN OPTION — FORM 6B

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☒ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities fo the low fish passage design flow, the high fish passage design flow and for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions.
☒ Yes ☐ No

Evaluate computed water surface elevations, flow depths, and channel velocities: ☒ Yes ☐ No

Maximum average velocity in culvert at high fish design flow: 5 ft/s

Does the velocity exceed the maximum allowable for the culvert length and design species? ☐ Yes ☒ No

If yes, modify design to comply and rerun hydraulic anaylses to verify.

Minimum flow depth in culvert at low fish design flow: 1 ft

Does the depth equal or not exceed the mimimum allowable for the culvert length and design species? ☐ Yes ☒ No

If yes, modify design to comply and rerun hydraulic anaylses to verify.

Drop between the water surface elevation in the culvert and the outlet channel for:

High Fish Passage Flow: NONE ft | Low Fish Passage Flow: NONE ft

Does the drop between the water surface in the culvert and the outlet channel at high or low design fish flows exceed the maximum allowable for the design species? ☐ Yes ☒ No

If yes, modify design to avoid a drop if possible. If a drop is unavoidable modify design to meet criteria and provide a jump pool at least two feet in depth. Rerun hydraulic analyses to verfiy.

Water Surface elevation at inlet for the 10-year peak discharge:

Does the water surface elevation exceed the allowable? ☐ Yes ☒ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge: high fish passage flows

Range of velocities for Inlet transition:	4.43	ft/s	to		ft/s
Range of velocities for Culvert portion:	5.25	ft/s	to	5.88	ft/s
Range of velocities for Outlet Transition:	5.46	ft/s	to		ft/s

Do the velocities exceed the permissible scour velocities? ☐ Yes ☒ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	WSEL Difference	100-Year WSEL	100-Year WSEL	WSEL Difference

FISH PASSAGE: HYDRAULIC DESIGN OPTION FORM 6B

	Existing Conditions (ft)	Future Conditions (ft)	(ft)	Existing Conditions (ft)	Future Conditions (ft)	(ft)
1 80/80	685.15	685.15	0.0	686.70	686.70	0.0
2 138/122	685.94	684.94	-1.0	688.26	686.93	-1.33
3 212/212	690.26	688.11	-2.15	698.25	692.49	-5.76
4 300/300	691.11	688.97	-2.14	698.25	693.44	-4.81

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☒ No

Maximum elevation: Top of road deck 698.0 ft

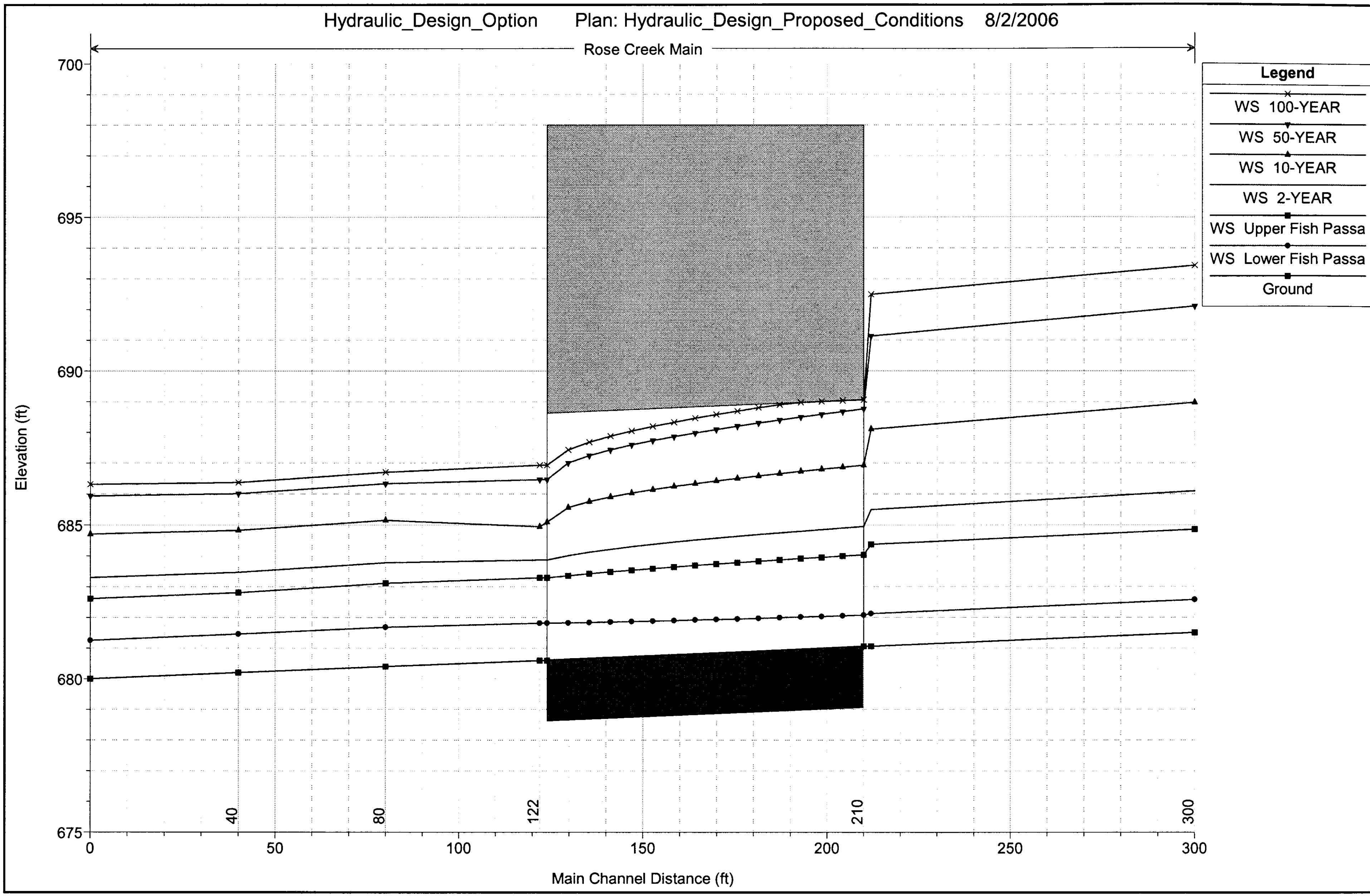
If yes, revise the design and rerun hydraulic analyses to verify.

If WSELs decrease, does it appear that the attenuation of peak flow will significally change? ☐ Yes ☒ No

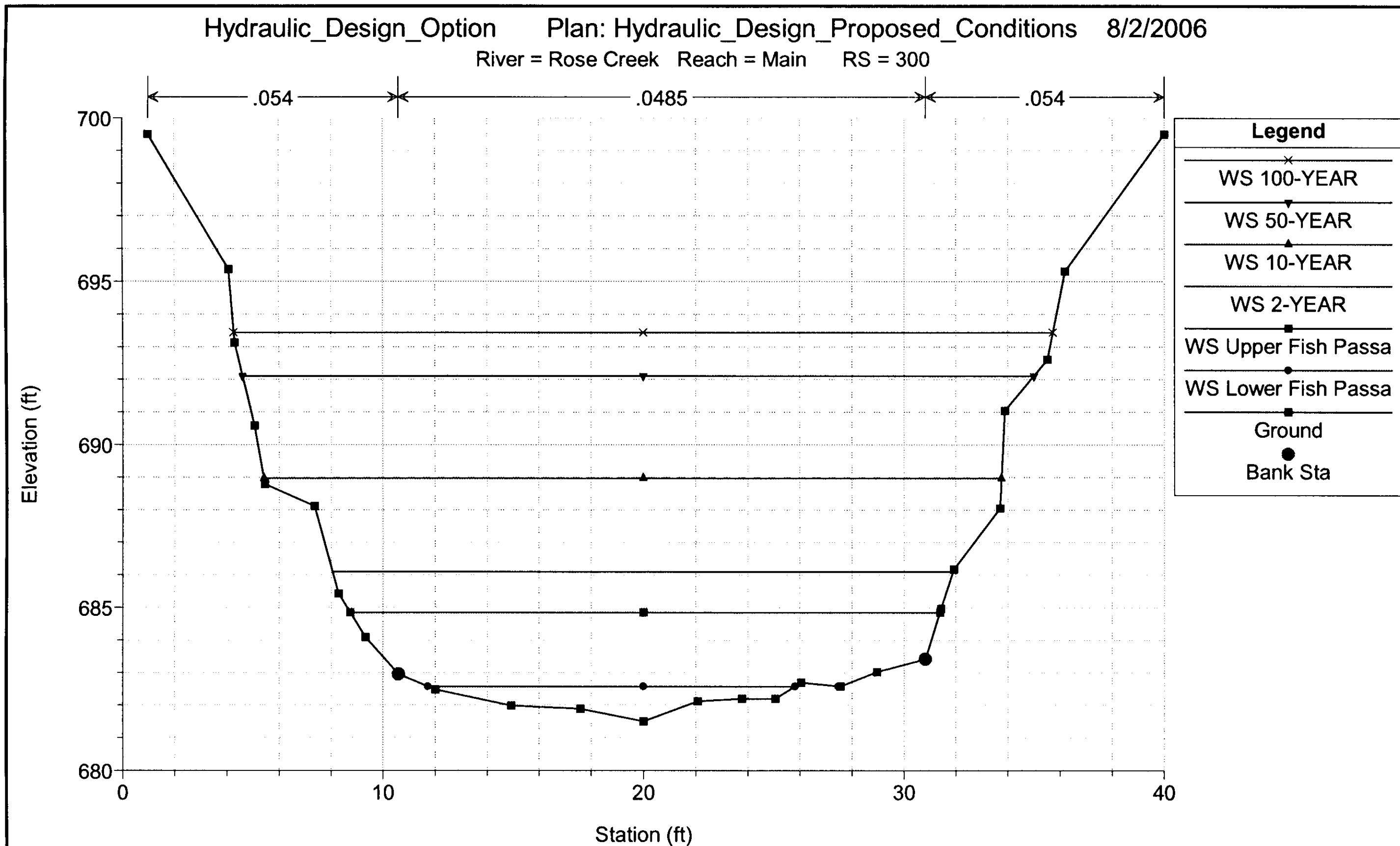
If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

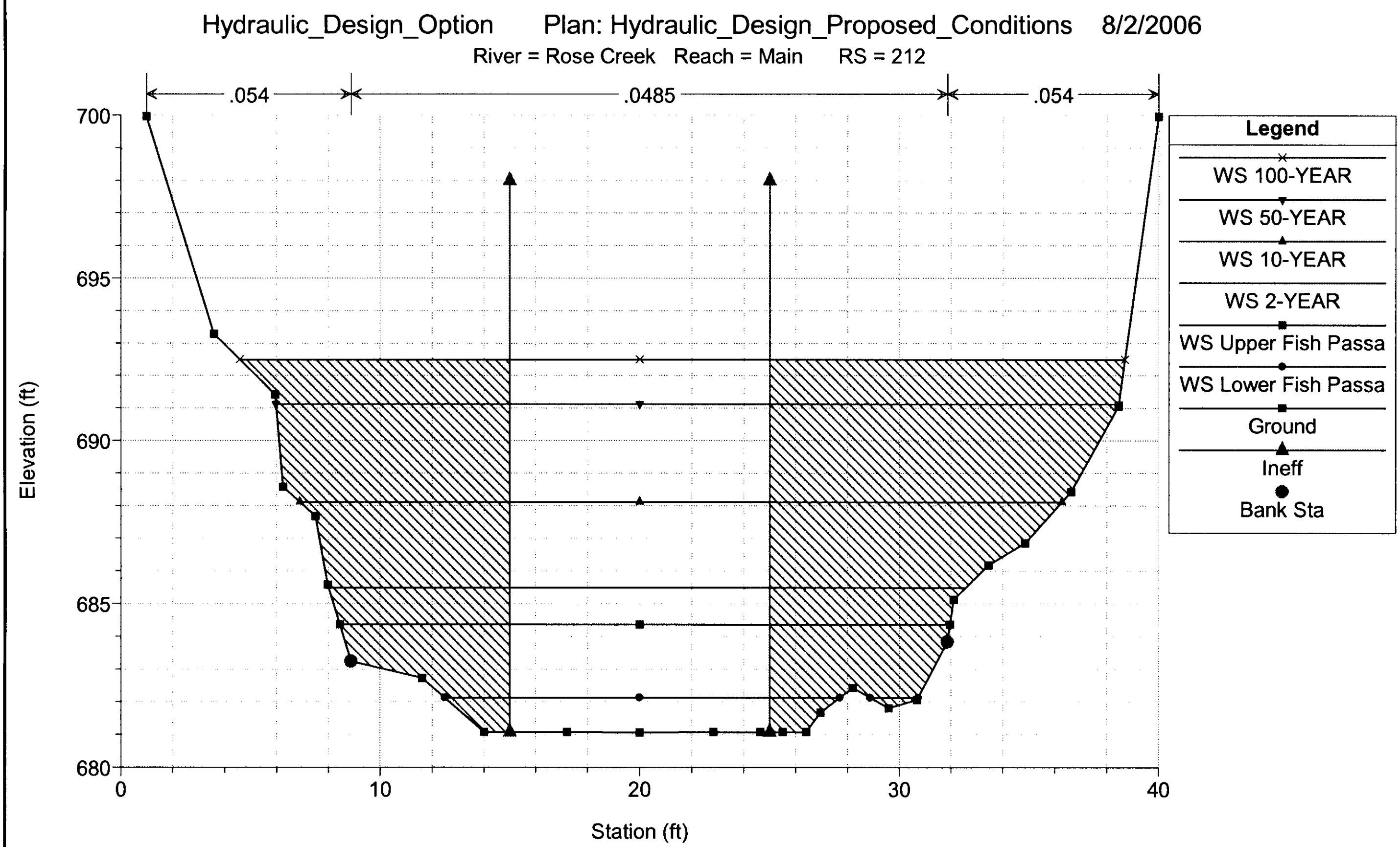
Proposed Plan and Profile Drawing Attached ☒ Yes ☐ No

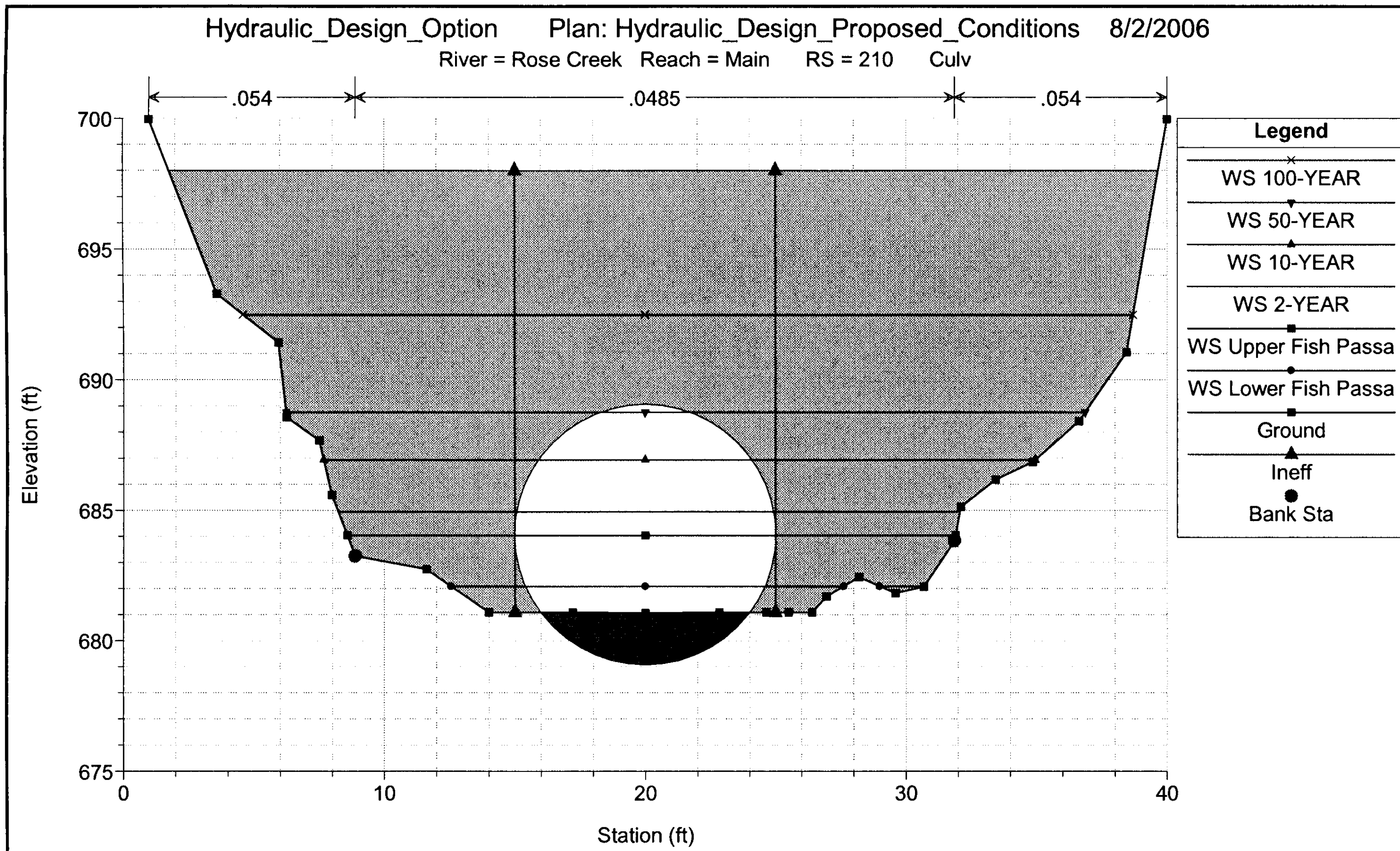
Hydraulic Analysis Index Sheet Attached ☒ Yes ☐ No



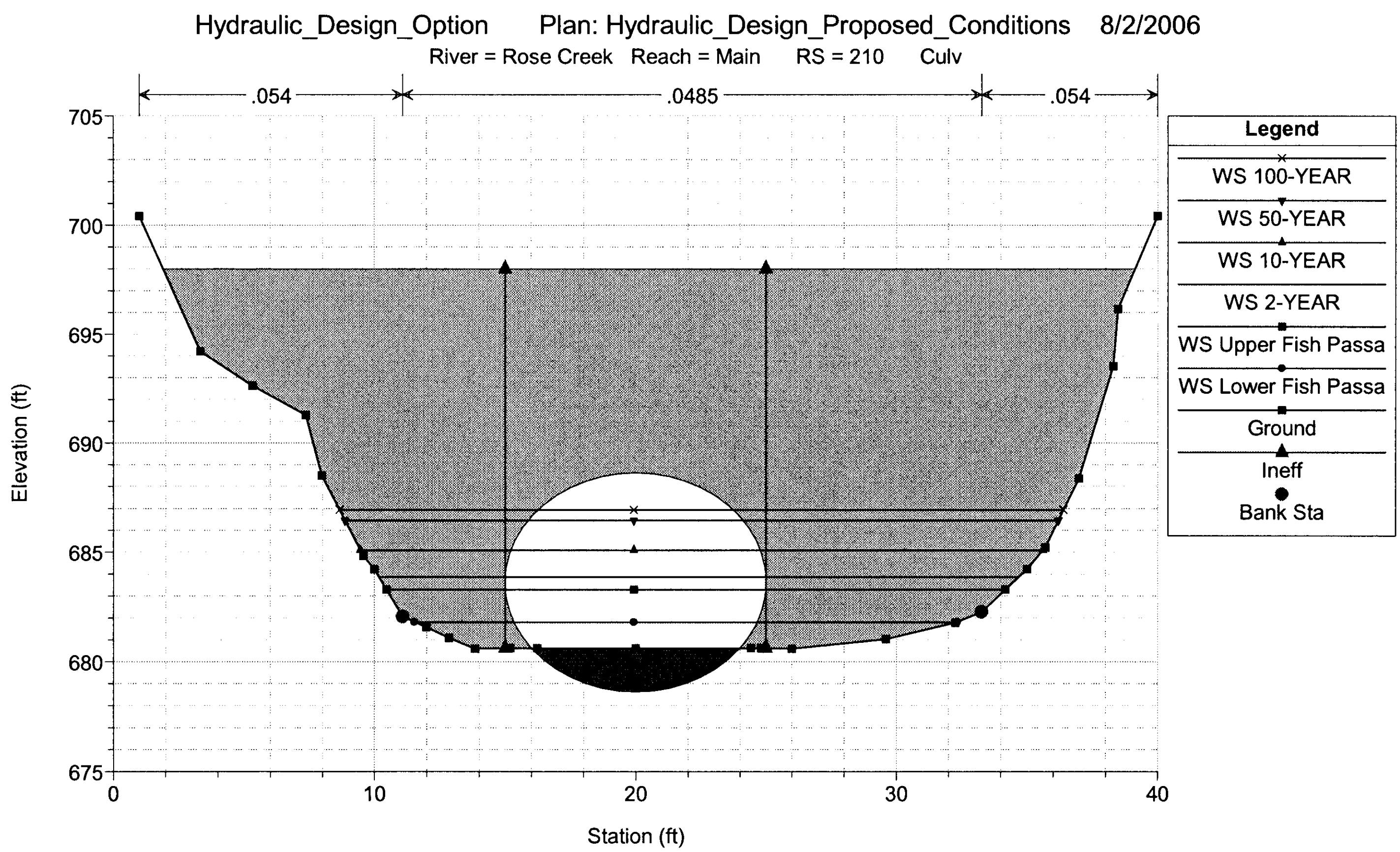
Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
Rose Creek Main
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Elevation (ft)
700
695
690
685
680
675
40
80
122
210
300
0
50
100
150
200
250
300
Main Channel Distance (ft)


Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 300
.054
.0485
.054
Elevation (ft)
Station (ft)
700
695
690
685
680
0
10
20
30
40
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta

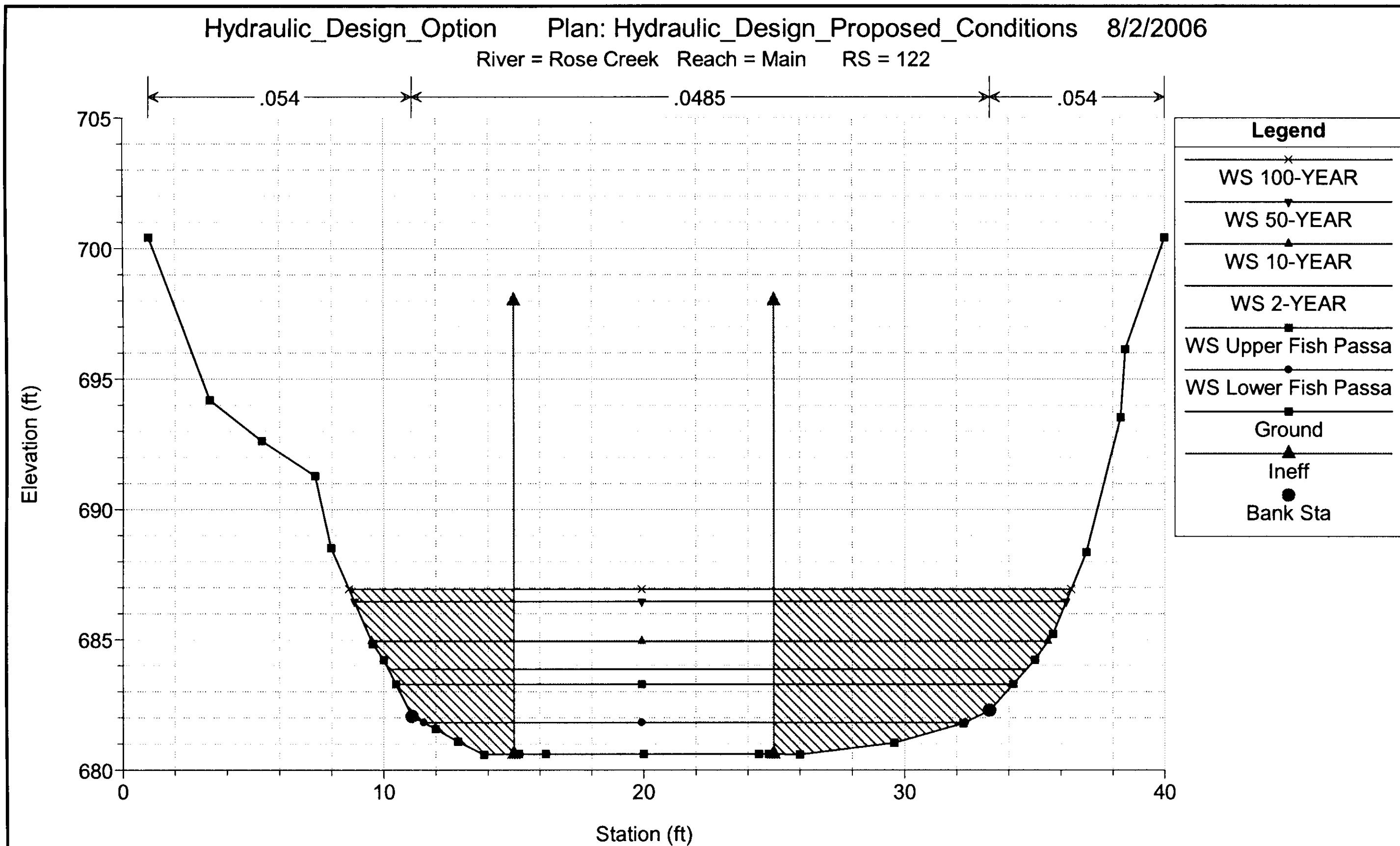

Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 212
.054
.0485
.054
Elevation (ft)
Station (ft)
700
695
690
685
680
0
10
20
30
40
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta



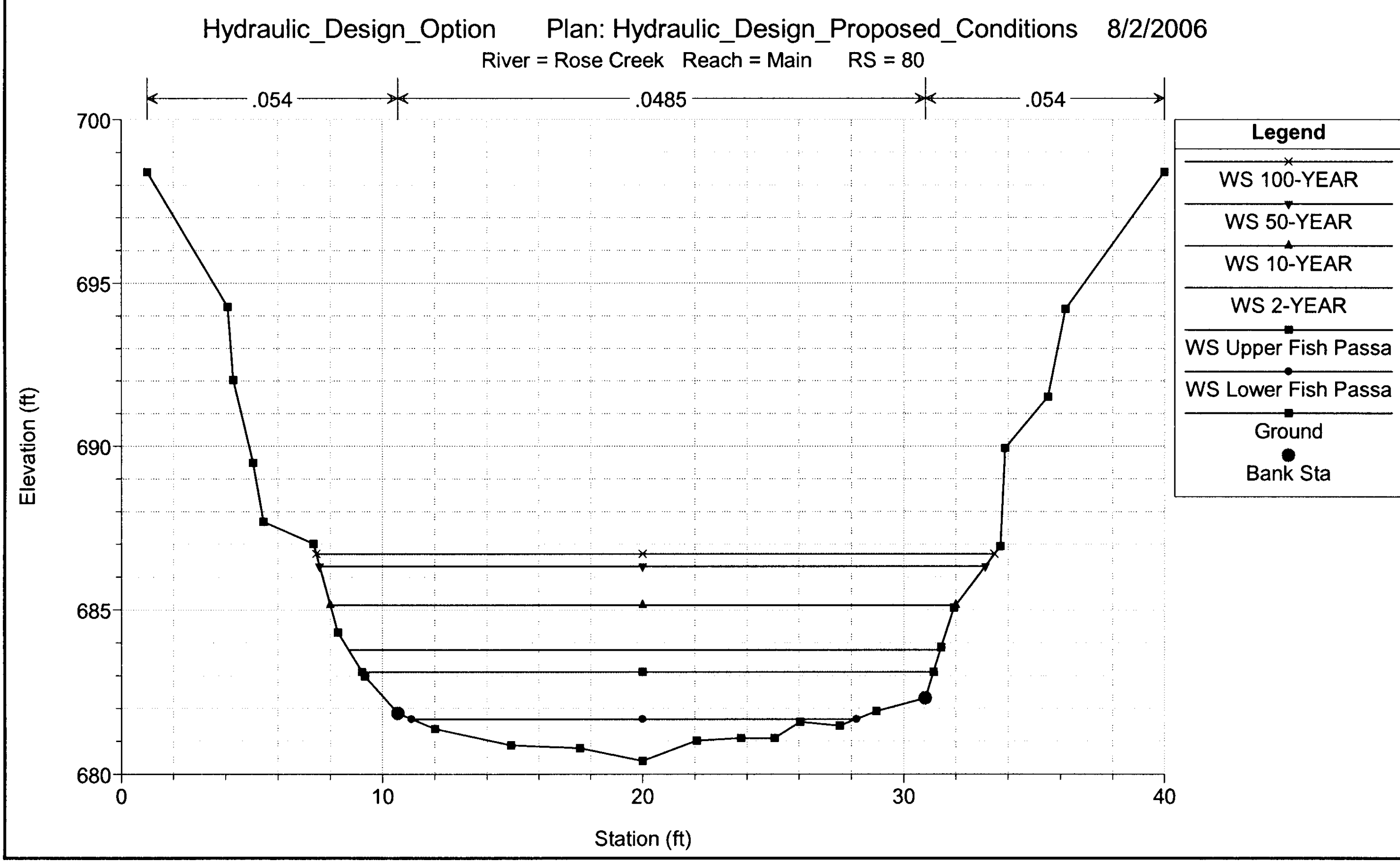
Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 210 Culv
.054
.0485
.054
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta



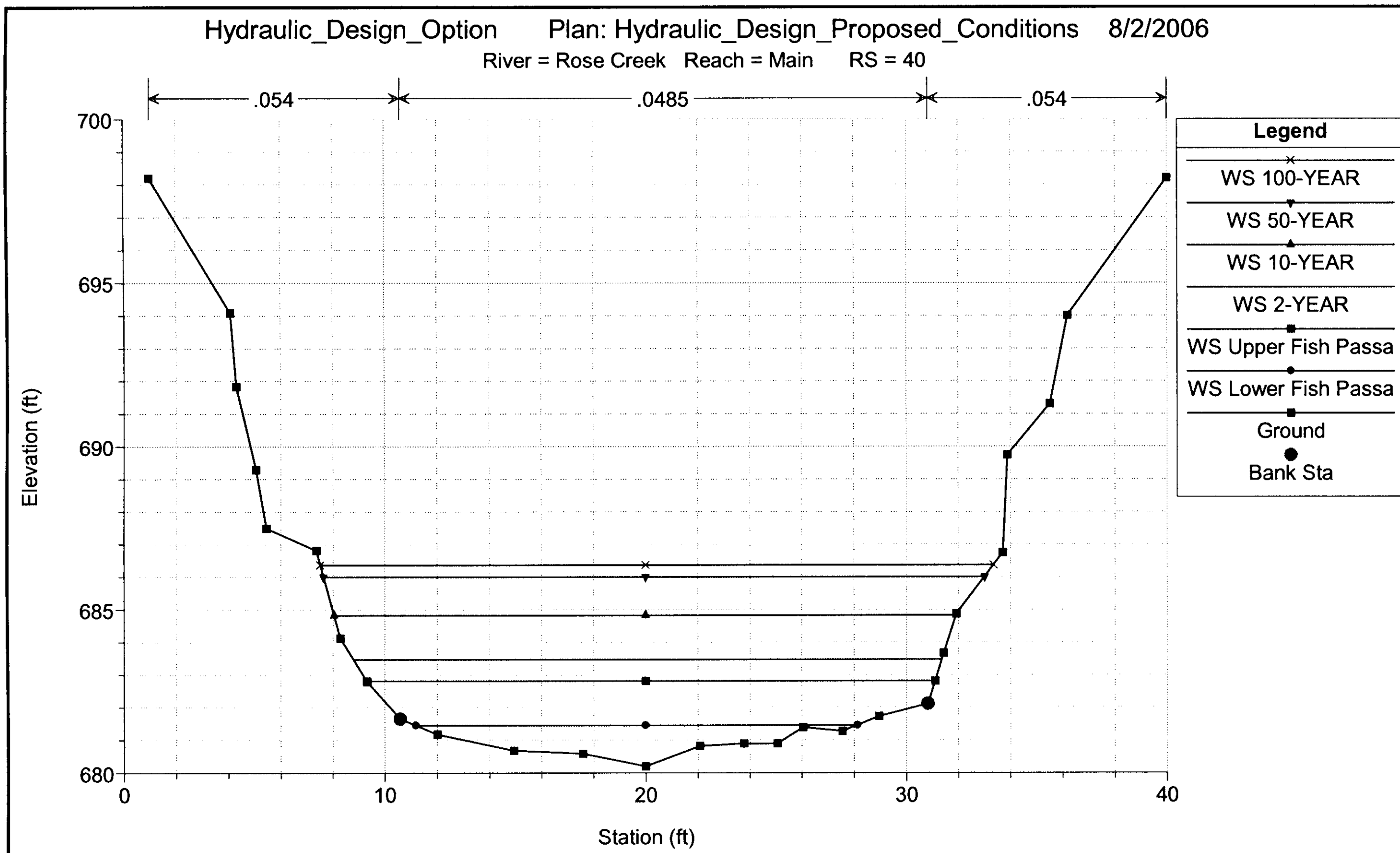
Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 210 Culv
.054
.0485
.054
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta

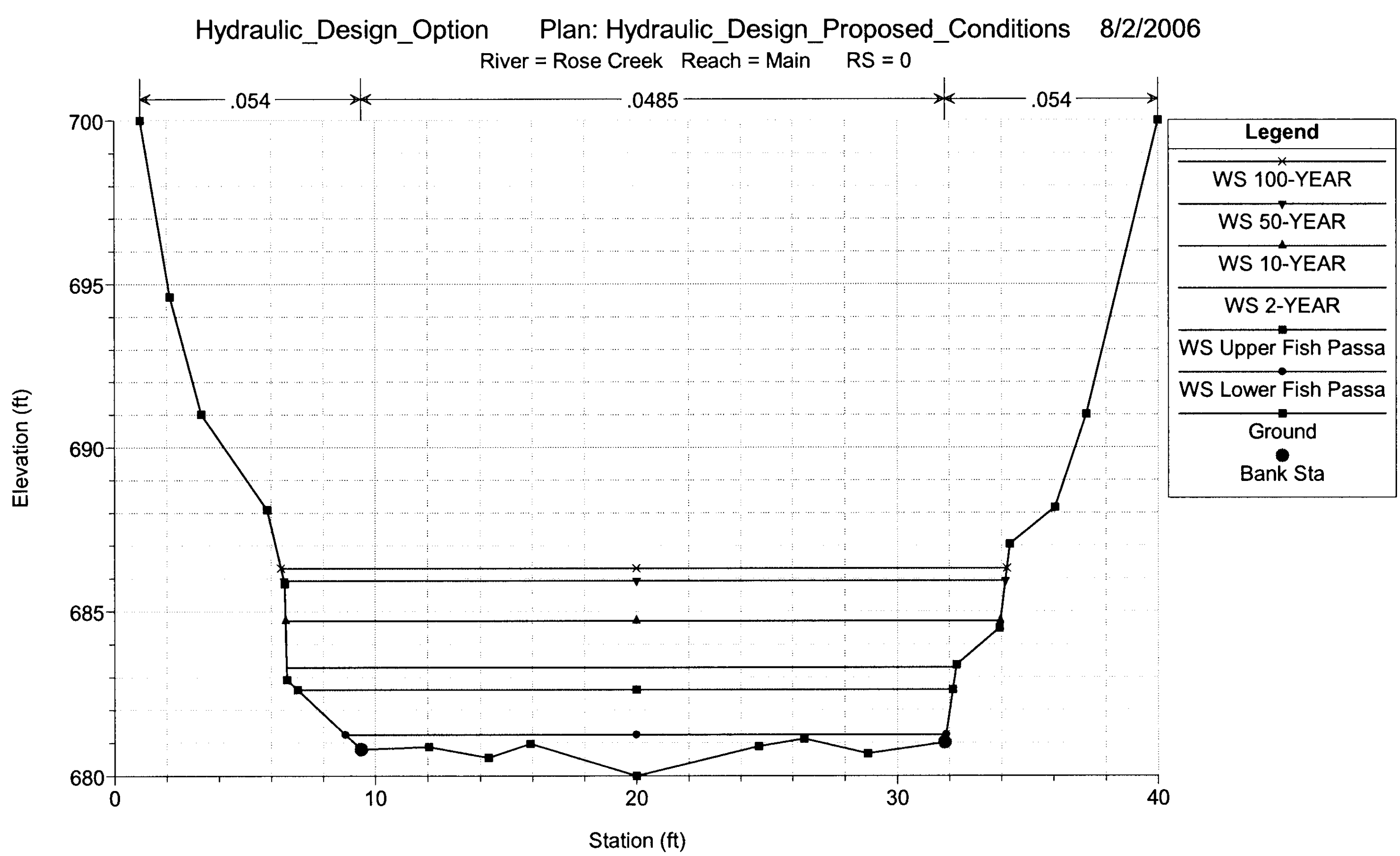


Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 122
.054
.0485
.054
705
700
695
690
685
680
0
10
20
30
40
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Ineff
Bank Sta



Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 80
.054
.0485
.054
700
695
690
685
680
0
10
20
30
40
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta


Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 40
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta
Elevation (ft)
700
695
690
685
680
0
10
20
30
40
Station (ft)


Hydraulic_Design_Option Plan: Hydraulic_Design_Proposed_Conditions 8/2/2006
River = Rose Creek Reach = Main RS = 0
.054
.0485
.054
Legend
WS 100-YEAR
WS 50-YEAR
WS 10-YEAR
WS 2-YEAR
WS Upper Fish Passa
WS Lower Fish Passa
Ground
Bank Sta
Elevation (ft)
700
695
690
685
680
0
10
20
30
40
Station (ft)

HEC-RAS Plan: Proposed Conditions River: Rose Creek

River Sta	Profile	Q Total	Min Ch El	W.S. Elev	W. Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
0	2-YEAR	245	680	683.3	3.3	682.22	683.55	0.005	4.06	62.87	25.67	0.44
0	10-YEAR	510	680	684.71	4.71	683.18	685.15	0.005001	5.41	100.33	27.4	0.48
0	50-YEAR	800	680	685.93	5.93	684.02	686.55	0.005	6.46	134.01	27.65	0.5
0	100-YEAR	900	680	686.31	6.31	684.28	686.99	0.005002	6.77	144.51	27.83	0.5
0	Upper Fish	146	680	682.62	2.62	681.78	682.78	0.005001	3.31	45.43	25.12	0.42
0	Lower Fish	18	680	681.25	1.25	680.95	681.28	0.005002	1.45	12.53	23.02	0.34
40	2-YEAR	245	680.2	683.47	3.27		683.82	0.007482	4.79	52.51	22.58	0.54
40	10-YEAR	510	680.2	684.83	4.63		685.44	0.007396	6.37	84.07	23.87	0.57
40	50-YEAR	800	680.2	686	5.8		686.86	0.007304	7.56	113.09	25.37	0.59
40	100-YEAR	900	680.2	686.37	6.17		687.31	0.007265	7.9	122.45	25.84	0.6
40	Upper Fish	146	680.2	682.81	2.61		683.05	0.007528	3.92	37.87	21.81	0.51
40	Lower Fish	18	680.2	681.46	1.26		681.5	0.005839	1.69	10.64	16.95	0.38
80	2-YEAR	245	680.4	683.78	3.38		684.1	0.006451	4.58	55.03	22.7	0.5
80	10-YEAR	510	680.4	685.15	4.75	683.86	685.72	0.006641	6.16	87.03	24	0.55
80	50-YEAR	800	680.4	686.33	5.93	684.79	687.15	0.006694	7.36	116.38	25.53	0.57
80	100-YEAR	900	680.4	686.7	6.3	685.07	687.59	0.006693	7.71	125.83	26.01	0.58
80	Upper Fish	146	680.4	683.11	2.71		683.32	0.006271	3.7	40.09	21.93	0.47
80	Lower Fish	18	680.4	681.68	1.28		681.72	0.00521	1.63	11.05	17.1	0.36
122	2-YEAR	245	680.59	683.87	3.28	683.28	684.75	0.012591	7.54	32.49	24.51	0.74
122	10-YEAR	510	680.59	684.94	4.35	684.94	687.1	0.021057	11.8	43.23	25.99	1
122	50-YEAR	800	680.59	686.46	5.87	686.46	689.37	0.018962	13.69	58.44	27.35	1
122	100-YEAR	900	680.59	686.93	6.34	686.93	690.09	0.01856	14.26	63.13	27.74	1
122	Upper Fish	146	680.59	683.29	2.7	682.5	683.76	0.008575	5.46	26.72	23.71	0.59
122	Lower Fish	18	680.59	681.81	1.22	681.09	681.85	0.001917	1.51	11.93	20.8	0.24
210		Culvert										
212	2-YEAR	245	681.06	685.5	4.44	683.73	685.97	0.00451	5.54	44.21	24.56	0.46
212	10-YEAR	510	681.06	688.11	7.05	685.39	688.92	0.004158	7.25	70.33	29.38	0.48
212	50-YEAR	800	681.06	691.13	10.07	686.89	692.11	0.003105	7.95	100.57	32.49	0.44
212	100-YEAR	900	681.06	692.49	11.43	687.4	693.46	0.002575	7.88	114.17	34.11	0.41
212	Upper Fish	146	681.06	684.37	3.31	682.96	684.67	0.004273	4.43	32.93	23.52	0.43
212	Lower Fish	18	681.06	682.13	1.07	681.54	682.17	0.002895	1.71	10.54	17.07	0.29
300	2-YEAR	245	681.5	686.1	4.6	683.93	686.24	0.001753	3.08	83.36	23.84	0.28
300	10-YEAR	510	681.5	688.97	7.47	684.96	689.16	0.001112	3.57	157.55	28.34	0.24
300	50-YEAR	800	681.5	692.11	10.61	685.89	692.31	0.000713	3.7	248.64	30.39	0.21
300	100-YEAR	900	681.5	693.44	11.94	686.17	693.63	0.000579	3.62	289.95	31.46	0.19
300	Upper Fish	146	681.5	684.85	3.35	683.45	684.97	0.002387	2.76	54.31	22.67	0.3
300	Lower Fish	18	681.5	682.58	1.08	682.37	682.66	0.013035	2.31	7.78	14.19	0.55

Plan: Proposed Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: Lower Fish Passa

Q Culv Group (cfs)	18.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	2.05
Q Barrel (cfs)	18.00	Culv Vel DS (ft/s)	1.73
E.G. US. (ft)	682.17	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	682.13	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	681.85	Culv Frctn Ls (ft)	0.28
W.S. DS (ft)	681.81	Culv Exit Loss (ft)	0.01
Delta EG (ft)	0.33	Culv Entr Loss (ft)	0.03
Delta WS (ft)	0.32	Q Weir (cfs)	
E.G. IC (ft)	681.83	Weir Sta Lft (ft)	
E.G. OC (ft)	682.17	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	682.08	Weir Max Depth (ft)	
Culv WS Outlet (ft)	681.81	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	2.95	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	2.53	Min El Weir Flow (ft)	698.01

Plan: Proposed   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: Upper Fish Passa

Q Culv Group (cfs)	146.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	5.25
Q Barrel (cfs)	146.00	Culv Vel DS (ft/s)	5.88
E.G. US. (ft)	684.67	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	684.37	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	683.76	Culv Frctn Ls (ft)	0.63
W.S. DS (ft)	683.29	Culv Exit Loss (ft)	0.07
Delta EG (ft)	0.92	Culv Entr Loss (ft)	0.21
Delta WS (ft)	1.08	Q Weir (cfs)	
E.G. IC (ft)	684.09	Weir Sta Lft (ft)	
E.G. OC (ft)	684.67	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	684.03	Weir Max Depth (ft)	
Culv WS Outlet (ft)	683.29	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	5.16	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	4.05	Min El Weir Flow (ft)	698.01

Plan: Proposed   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: 2-YEAR

Q Culv Group (cfs)	245.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	6.64
Q Barrel (cfs)	245.00	Culv Vel DS (ft/s)	8.01
E.G. US. (ft)	685.97	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	685.50	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	684.75	Culv Frctn Ls (ft)	0.76
W.S. DS (ft)	683.87	Culv Exit Loss (ft)	0.11
Delta EG (ft)	1.22	Culv Entr Loss (ft)	0.34
Delta WS (ft)	1.63	Q Weir (cfs)	
E.G. IC (ft)	685.34	Weir Sta Lft (ft)	
E.G. OC (ft)	685.97	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	684.95	Weir Max Depth (ft)	
Culv WS Outlet (ft)	683.87	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	6.31	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	4.84	Min El Weir Flow (ft)	698.01

Plan: Proposed   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: 10-YEAR

Q Culv Group (cfs)	510.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	9.25
Q Barrel (cfs)	510.00	Culv Vel DS (ft/s)	11.98
E.G. US. (ft)	688.92	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	688.11	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	687.10	Culv Frctn Ls (ft)	0.94
W.S. DS (ft)	684.94	Culv Exit Loss (ft)	0.21
Delta EG (ft)	1.82	Culv Entr Loss (ft)	0.66
Delta WS (ft)	3.16	Q Weir (cfs)	
E.G. IC (ft)	688.30	Weir Sta Lft (ft)	
E.G. OC (ft)	688.92	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	686.93	Weir Max Depth (ft)	
Culv WS Outlet (ft)	685.09	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	10.00	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	6.47	Min El Weir Flow (ft)	698.01

Errors Warnings and Notes

Note:	The normal depth exceeds the height of the culvert. The program assumes that the normal depth is equal to the height of the culvert.

Plan: Proposed   Rose Creek   Main RS: 210   Culv Group: Culvert #1   Profile: 50-YEAR

Q Culv Group (cfs)	800.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	12.00
Q Barrel (cfs)	800.00	Culv Vel DS (ft/s)	14.57
E.G. US. (ft)	692.11	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	691.13	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	689.37	Culv Frctn Ls (ft)	1.24
W.S. DS (ft)	686.46	Culv Exit Loss (ft)	0.39
Delta EG (ft)	2.74	Culv Entr Loss (ft)	1.12
Delta WS (ft)	4.67	Q Weir (cfs)	
E.G. IC (ft)	692.01	Weir Sta Lft (ft)	
E.G. OC (ft)	692.11	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	688.76	Weir Max Depth (ft)	
Culv WS Outlet (ft)	686.46	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	10.00	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	7.82	Min El Weir Flow (ft)	698.01

Errors Warnings and Notes

Note:	The normal depth exceeds the height of the culvert. The program assumes that the normal
	depth is equal to the height of the culvert.

Plan: Proposed Rose Creek Main RS: 210 Culv Group: Culvert #1 Profile: 100-YEAR

Q Culv Group (cfs)	900.00	Culv Full Len (ft)	21.08
# Barrels	1	Culv Vel US (ft/s)	13.36
Q Barrel (cfs)	900.00	Culv Vel DS (ft/s)	15.36
E.G. US. (ft)	693.46	Culv Inv El Up (ft)	679.06
W.S. US. (ft)	692.49	Culv Inv El Dn (ft)	678.62
E.G. DS (ft)	690.09	Culv Frctn Ls (ft)	1.47
W.S. DS (ft)	686.93	Culv Exit Loss (ft)	0.51
Delta EG (ft)	3.37	Culv Entr Loss (ft)	1.39
Delta WS (ft)	5.56	Q Weir (cfs)	
E.G. IC (ft)	693.51	Weir Sta Lft (ft)	
E.G. OC (ft)	693.46	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	689.06	Weir Max Depth (ft)	
Culv WS Outlet (ft)	686.93	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	10.00	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	8.21	Min El Weir Flow (ft)	698.01

Errors Warnings and Notes

Note:	The normal depth exceeds the height of the culvert. The program assumes that the normal
	depth is equal to the height of the culvert.
Note:	During supercritical analysis, the culvert direct step method went to critical depth. The program
	then assumed critical depth at the outlet.
Note:	During the supercritical calculations a hydraulic jump occurred inside of the culvert.
Note:	The culvert inlet is submerged and the culvert flows full over part or all of its length. Therefore,
	the culvert inlet equations are not valid and the supercritical result has been discarded. The
	outlet answer will be used.

Culvert Report for Rose Creek Culvert @ Route 777

Project: Hydraulic Design Rose Creek

Culvert Location Information
Road: Route 777
Mile Post: 6.15
Stream Name: Rose Creek
Length of Historical Upstream Habitat: 3000

Biological Data
Species: Adult Coho
Fish Length: 610 mm
Minimum Water Depth: 1 ft
Migration Period: August to January
Prolonged Swimming Speed: 6 ft/s
Prolonged Time to Exhaustion: 30 min
Burst Swimming Speed: 11.9 ft/s
Burst Time to Exhaustion: 5 s
Jumping Speed: 14 ft/s
Velocity Reduction Factors:
Inlet: 1.00
Barrel: 1.00
Outlet: 1.00

Culvert Installation Data
Culvert Type: 120 in Circular
Construction: Concrete
Installation: Sunken
Countersunk Depth: 2 ft
Culvert Length: 86 ft
Culvert Slope: 0.51%
Culvert Roughness Coefficient: 0.012
Natural Bottom Roughness Coefficient: 0.045
Inlet Invert Elevation: 679.06 ft
Outlet Invert Elevation: 678.62 ft
Inlet Headloss Coefficient (Ke): 1

Design Flows
Low Passage Flow: 18 cfs
High Passage Flow: 146 cfs

Table 1. Uniform Flow Calculations.

Discharge (cfs)	Velocity (ft/s)	Normal Depth (ft)	Critical Depth (ft)	Outlet Velocity (ft/s)	Tailwater Depth (ft)	Pool Depth (ft)	Min Rqd. Leap Velocity (ft/s)	Vert. Leap Distance (ft)	Comments
0.00	0.00	0.00	0.00	0.00	1.78	0.00			
0.42	0.51	0.10	0.04	0.02	2.32	0.54	0.00	0.00	Depth
1.34	0.82	0.20	0.10	0.06	2.57	0.79	0.00	0.00	Depth
2.68	1.09	0.30	0.15	0.10	2.76	0.98	0.00	0.00	Depth
4.39	1.32	0.40	0.21	0.16	2.95	1.17	0.00	0.00	Depth
6.45	1.55	0.50	0.27	0.22	3.12	1.34	0.00	0.00	Depth
8.86	1.76	0.60	0.33	0.29	3.28	1.50	0.00	0.00	Depth
11.60	1.96	0.70	0.40	0.36	3.44	1.66	0.00	0.00	Depth
14.66	2.15	0.80	0.46	0.43	3.60	1.82	0.00	0.00	Depth
18.00	2.33	0.90	0.53	0.51	3.75	1.97	0.00	0.00	LPF; Depth
18.04	2.34	0.90	0.53	0.51	3.75	1.97	0.00	0.00	Depth
21.74	2.52	1.00	0.60	0.59	3.89	2.11	0.00	0.00	
25.75	2.69	1.10	0.67	0.67	4.04	2.26	0.00	0.00	
30.06	2.87	1.20	0.74	0.75	4.19	2.41	0.00	0.00	
34.67	3.04	1.30	0.81	0.84	4.34	2.56	0.00	0.00	
39.57	3.20	1.40	0.89	0.93	4.49	2.71	0.00	0.00	
44.77	3.36	1.50	0.96	1.01	4.64	2.86	0.00	0.00	
50.25	3.52	1.60	1.04	1.10	4.79	3.01	0.00	0.00	
56.01	3.68	1.70	1.11	1.19	4.95	3.17	0.00	0.00	
62.05	3.83	1.80	1.19	1.28	5.10	3.32	0.00	0.00	
68.36	3.98	1.90	1.26	1.37	5.26	3.48	0.00	0.00	
74.94	4.13	2.00	1.34	1.46	5.41	3.63	0.00	0.00	
81.77	4.27	2.10	1.42	1.55	5.57	3.79	0.00	0.00	
88.86	4.42	2.20	1.50	1.65	5.73	3.95	0.00	0.00	
96.20	4.56	2.30	1.57	1.74	5.89	4.11	0.00	0.00	
103.79	4.70	2.40	1.65	1.84	6.05	4.27	0.00	0.00	
111.61	4.83	2.50	1.73	1.93	6.21	4.43	0.00	0.00	
119.66	4.97	2.60	1.81	2.03	6.36	4.58	0.00	0.00	
127.93	5.10	2.70	1.89	2.13	6.53	4.75	0.00	0.00	
136.43	5.23	2.80	1.97	2.23	6.69	4.91	0.00	0.00	
145.13	5.36	2.90	2.04	2.33	6.85	5.07	0.00	0.00	
146.00	5.37	2.91	2.05	2.34	6.87	5.09	0.00	0.00	HPF
154.04	5.48	3.00	2.12	2.43	7.01	5.23	0.00	0.00	
163.14	5.61	3.10	2.20	2.54	7.18	5.40	0.00	0.00	
172.43	5.73	3.20	2.28	2.65	7.34	5.56	0.00	0.00	
181.90	5.85	3.30	2.36	2.76	7.50	5.72	0.00	0.00	
191.55	5.97	3.40	2.44	2.88	7.66	5.88	0.00	0.00	Vel
201.35	6.09	3.50	2.51	3.00	7.82	6.04	0.00	0.00	Vel
211.32	6.20	3.60	2.59	3.14	7.98	6.20	0.00	0.00	Vel
221.43	6.31	3.70	2.67	3.29	8.14	6.36	0.00	0.00	Vel
231.68	6.43	3.80	2.74	3.44	8.30	6.52	0.00	0.00	Vel
242.05	6.54	3.90	2.82	3.59	8.46	6.68	0.00	0.00	Vel
252.55	6.64	4.00	2.90	3.75	8.64	6.86	0.00	0.00	Vel

Comment Codes:

LPF - Low Passage Flow
HPF - High Passage Flow
Depth - Insufficient Depth

Vel - Excessive Velocity
Leap - Excessive Leap
Pool - Shallow Leap Pool

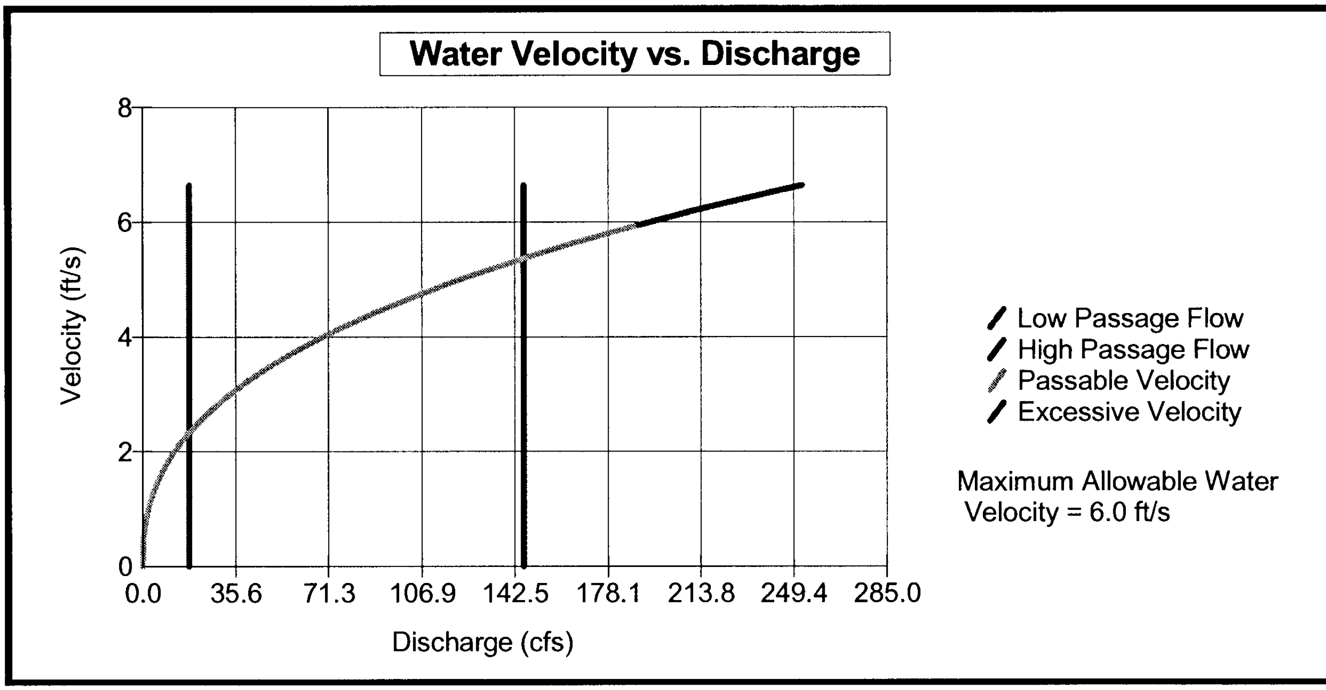


Figure 1. Velocity at Uniform Flow

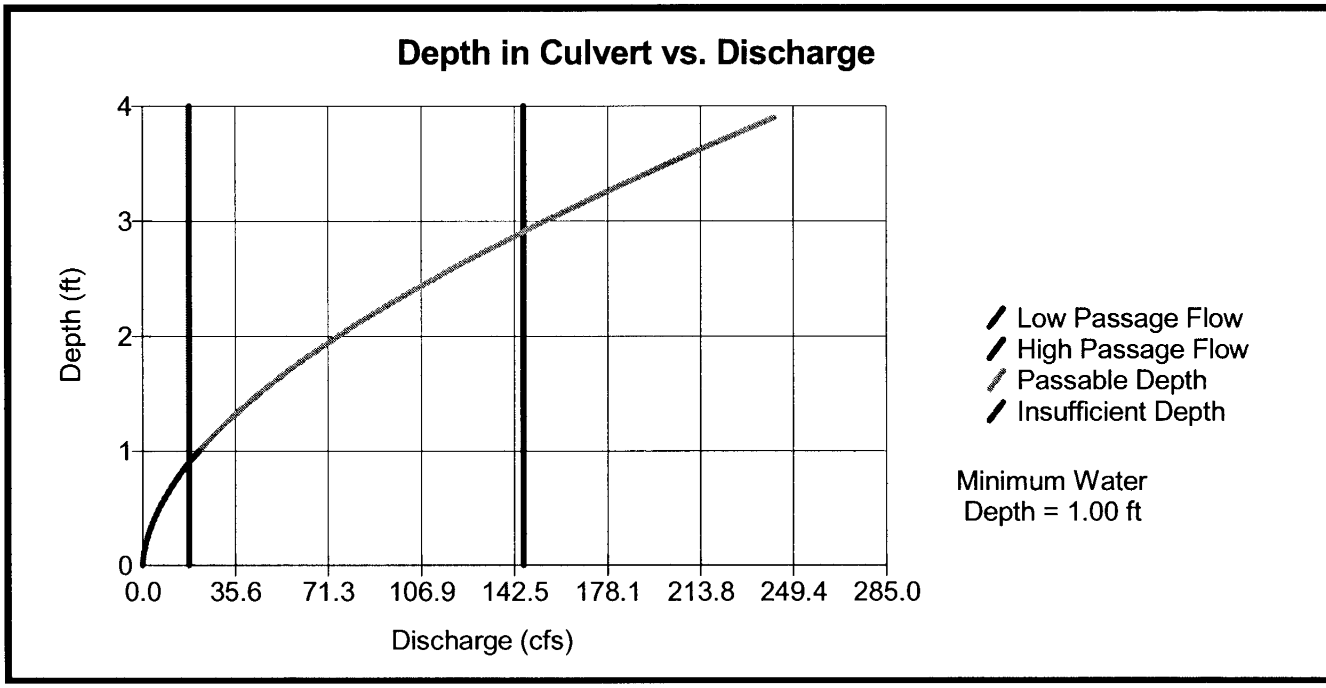


Figure 2. Depth at Uniform Flow

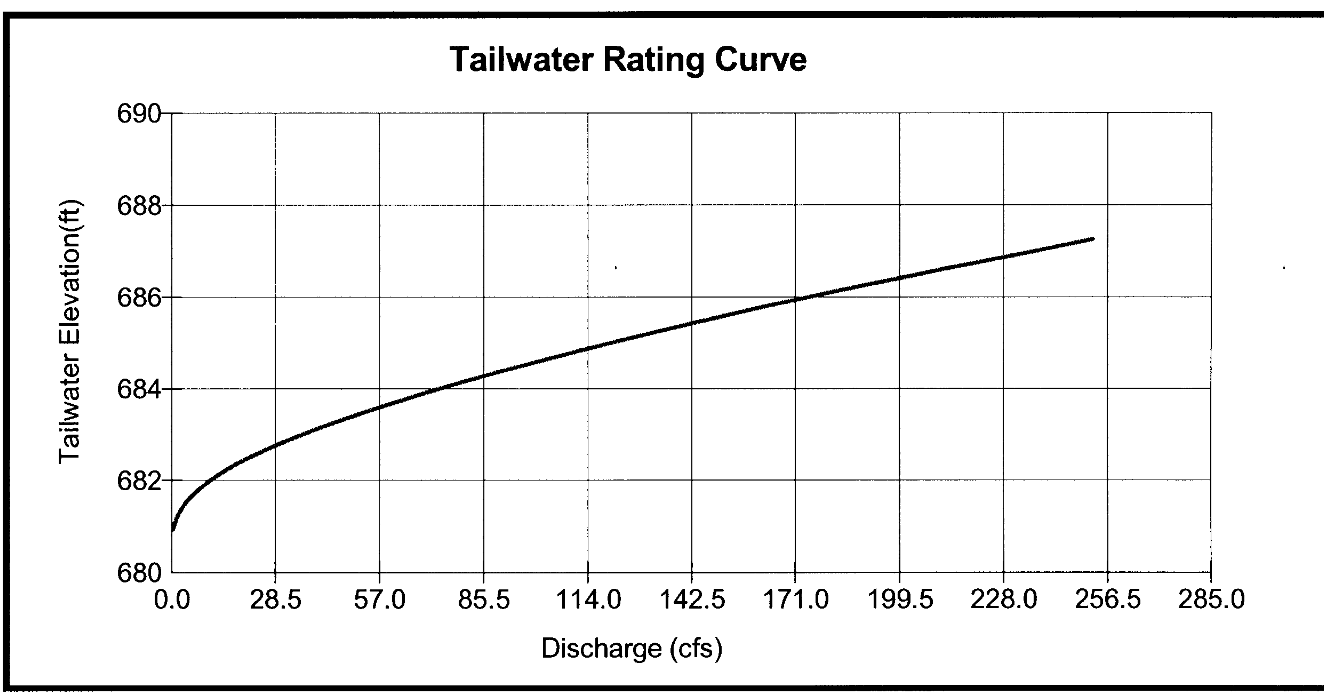


Figure 3. Tailwater Rating Curve at Uniform Flow

Table 2. Gradually Varied Flow Calculations for 18 cfs.

Q = 18.0 cfs				
Dist Down Culvert (ft)	Depth (ft)	Velocity (ft/s)	Curve	Swim Mode
0	3.30	0.00	Inlet	
3	3.29	0.82	M1	Prolonged
6	3.31	0.58	M1	Prolonged
10	3.33	0.57	M1	Prolonged
14	3.35	0.57	M1	Prolonged
18	3.38	0.57	M1	Prolonged
22	3.40	0.56	M1	Prolonged
26	3.42	0.56	M1	Prolonged
30	3.44	0.55	M1	Prolonged
34	3.46	0.55	M1	Prolonged
38	3.48	0.55	M1	Prolonged
42	3.51	0.54	M1	Prolonged
46	3.53	0.54	M1	Prolonged
50	3.55	0.54	M1	Prolonged
54	3.57	0.53	M1	Prolonged
58	3.59	0.53	M1	Prolonged
62	3.62	0.53	M1	Prolonged
66	3.64	0.52	M1	Prolonged
70	3.66	0.52	M1	Prolonged
74	3.68	0.52	M1	Prolonged
78	3.70	0.51	M1	Prolonged
82	3.72	0.51	M1	Prolonged
86	3.75	0.51	M1	Prolonged

Table 3. Gradually Varied Flow Specifications for 18 cfs.

	18.0 cfs
Normal Depth (ft)	0.90
Critical Depth (ft)	0.53
Headwater Depth (ft)	3.30
Inlet Velocity (ft/s)	0.82
Tailwater Depth (ft)	3.75
Burst Swim Time (s)	0.00
Prolonged Swim Time (min	0.26
Barrier Code	NONE

Barrier Codes

NONE - No Barrier

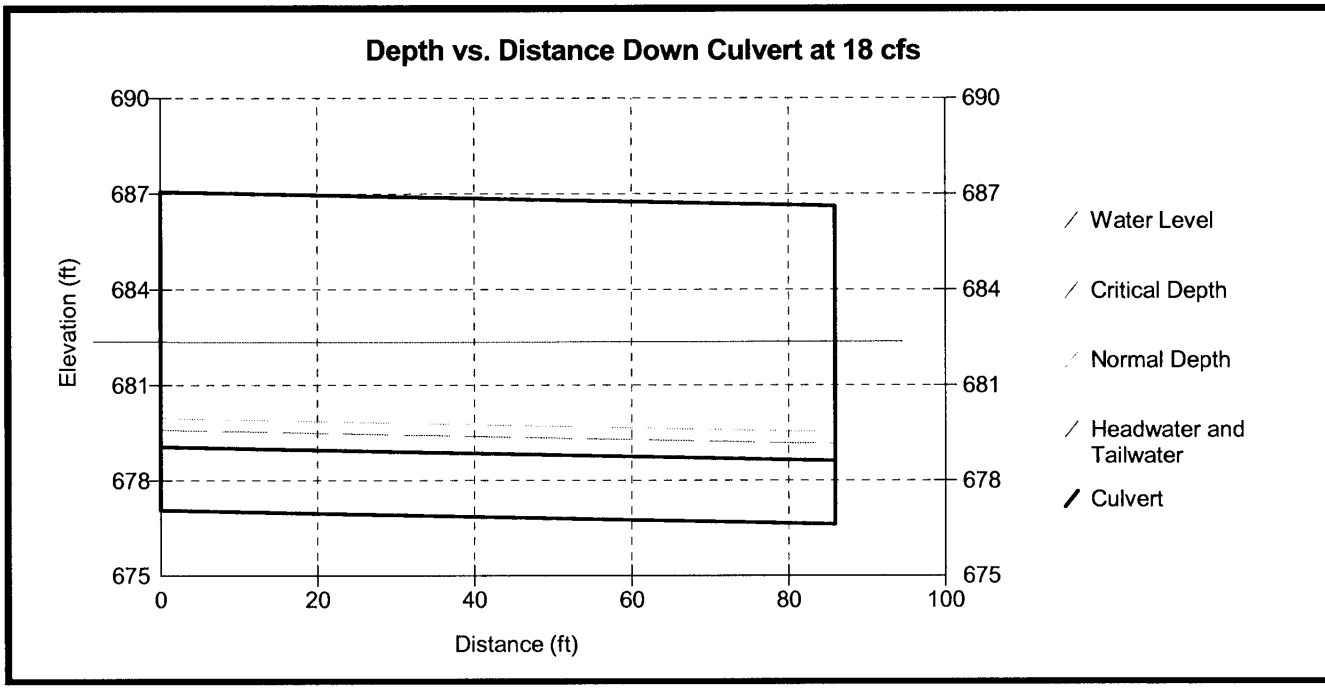


Figure 4. Water Surface Profile at 18 cfs

Table 4. Gradually Varied Flow Calculations for 82 cfs.

Q = 82.0 cfs				
Dist Down Culvert (ft)	Depth (ft)	Velocity (ft/s)	Curve	Swim Mode
0	5.27	0.00	Inlet	
3	5.18	2.36	M1	Prolonged
6	5.20	1.66	M1	Prolonged
10	5.21	1.66	M1	Prolonged
14	5.23	1.65	M1	Prolonged
18	5.25	1.65	M1	Prolonged
22	5.27	1.64	M1	Prolonged
26	5.29	1.63	M1	Prolonged
30	5.31	1.63	M1	Prolonged
34	5.33	1.62	M1	Prolonged
38	5.35	1.62	M1	Prolonged
42	5.37	1.61	M1	Prolonged
46	5.39	1.61	M1	Prolonged
50	5.41	1.60	M1	Prolonged
54	5.42	1.60	M1	Prolonged
58	5.44	1.59	M1	Prolonged
62	5.46	1.59	M1	Prolonged
66	5.48	1.58	M1	Prolonged
70	5.50	1.58	M1	Prolonged
74	5.52	1.57	M1	Prolonged
78	5.54	1.57	M1	Prolonged
82	5.56	1.56	M1	Prolonged
86	5.58	1.56	M1	Prolonged

Table 5. Gradually Varied Flow Specifications for 82 cfs.

	82.0 cfs
Normal Depth (ft)	2.10
Critical Depth (ft)	1.42
Headwater Depth (ft)	5.27
Inlet Velocity (ft/s)	2.36
Tailwater Depth (ft)	5.58
Burst Swim Time (s)	0.00
Prolonged Swim Time (min	0.33
Barrier Code	NONE

Barrier Codes

NONE - No Barrier

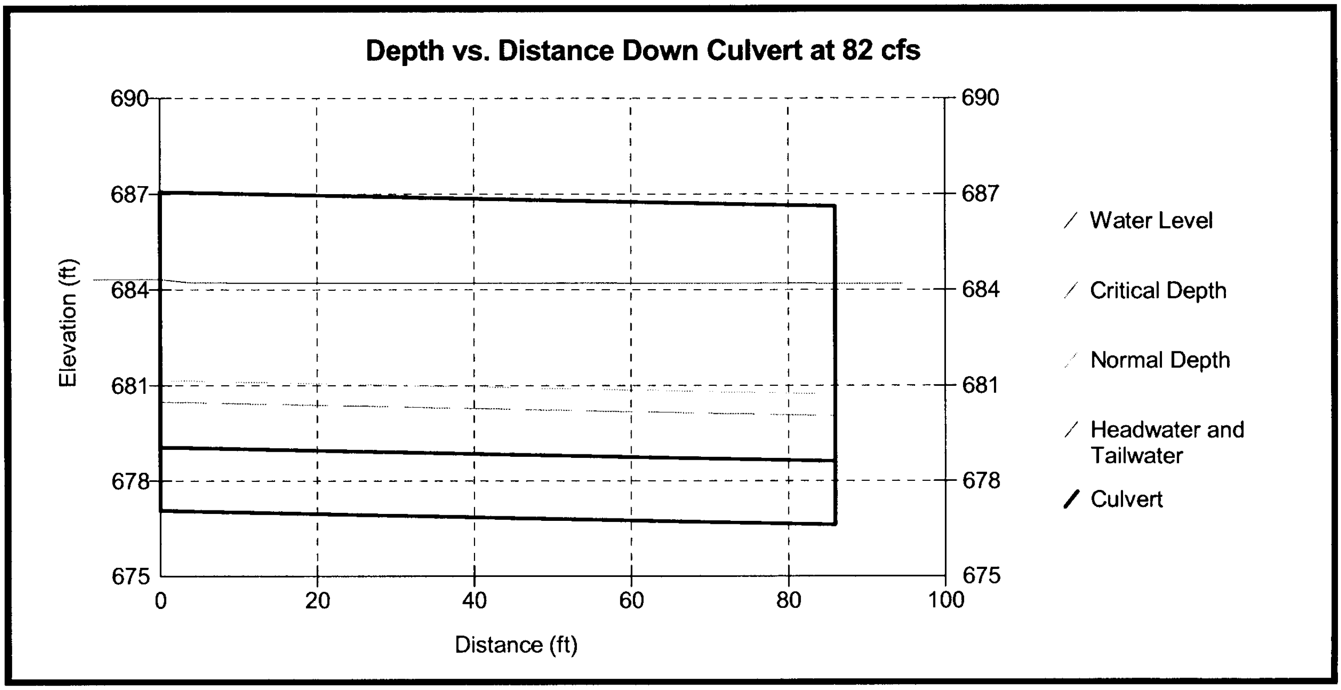


Figure 5. Water Surface Profile at 82 cfs

Table 6. Gradually Varied Flow Calculations for 146 cfs.

Q = 146.0 cfs				
Dist Down Culvert (ft)	Depth (ft)	Velocity (ft/s)	Curve	Swim Mode
0	6.58	0.00	Inlet	
3	6.40	3.49	M1	Prolonged
6	6.41	2.46	M1	Prolonged
10	6.44	2.45	M1	Prolonged
14	6.46	2.45	M1	Prolonged
18	6.48	2.44	M1	Prolonged
22	6.50	2.43	M1	Prolonged
26	6.53	2.43	M1	Prolonged
30	6.55	2.42	M1	Prolonged
34	6.57	2.41	M1	Prolonged
38	6.60	2.41	M1	Prolonged
42	6.62	2.40	M1	Prolonged
46	6.64	2.40	M1	Prolonged
50	6.66	2.39	M1	Prolonged
54	6.69	2.38	M1	Prolonged
58	6.71	2.38	M1	Prolonged
62	6.73	2.37	M1	Prolonged
66	6.76	2.37	M1	Prolonged
70	6.78	2.36	M1	Prolonged
74	6.80	2.35	M1	Prolonged
78	6.82	2.35	M1	Prolonged
82	6.85	2.34	M1	Prolonged
86	6.87	2.34	M1	Prolonged

Table 7. Gradually Varied Flow Specifications for 146 cfs.

	146.0 cfs
Normal Depth (ft)	2.91
Critical Depth (ft)	2.05
Headwater Depth (ft)	6.58
Inlet Velocity (ft/s)	3.49
Tailwater Depth (ft)	6.87
Burst Swim Time (s)	0.00
Prolonged Swim Time (min	0.40
Barrier Code	NONE

Barrier Codes

NONE - No Barrier

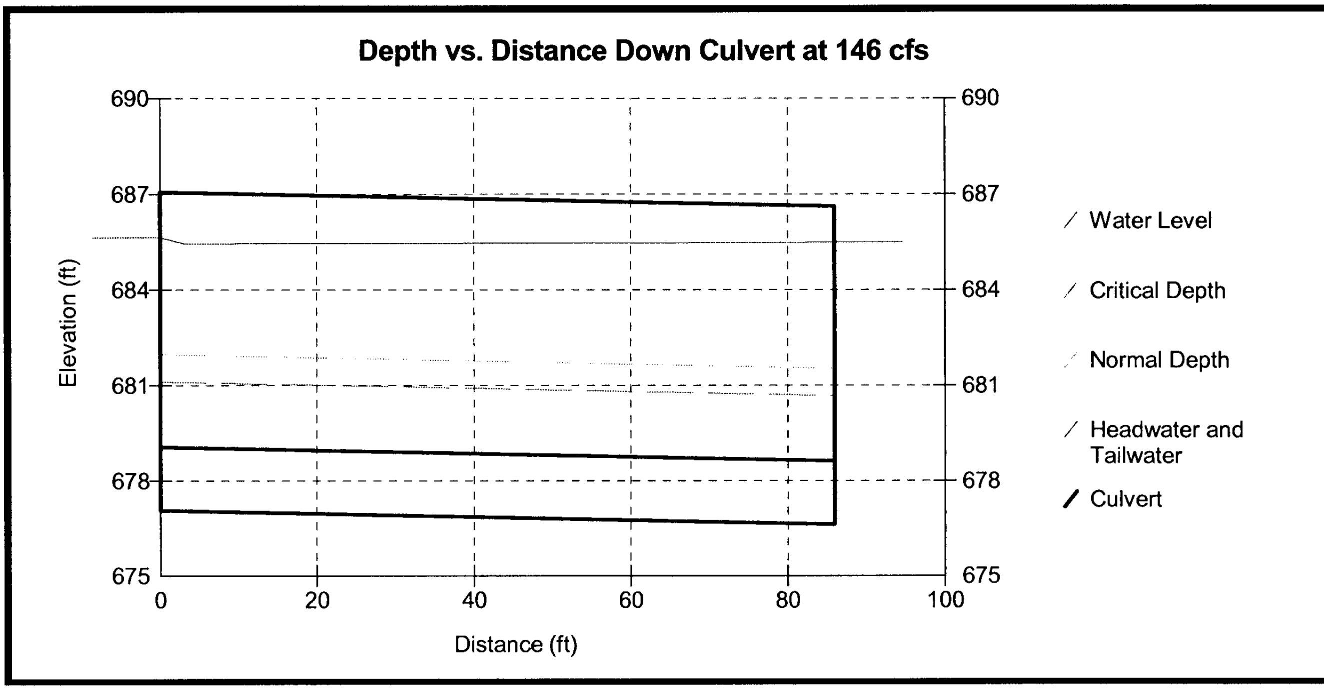


Figure 6. Water Surface Profile at 146 cfs

Tailwater Information

Channel Bottom Slope: 0.051%

Outlet-Pool Bottom Elevation: 680.4 ft

Manning's Roughness Downstream of Tailwater: 0.0485

Table 8. Tailwater Cross Section Data.

Obs. No.	Station (ft)	Elevation (ft)
1	5.06	689.49
2	5.45	687.69
3	7.36	687.01
4	8.29	684.32
5	9.32	682.98
6	10.60	681.85
7	12.01	681.38
8	14.93	680.88
9	17.59	680.79
10	20.00	680.40
11	22.08	681.02
12	23.77	681.10
13	25.06	681.10
14	26.04	681.59
15	27.55	681.47
16	28.96	681.92
17	30.83	682.31
18	31.44	683.86
19	31.93	685.07
20	33.70	686.94
21	33.88	689.94
22	35.52	691.51

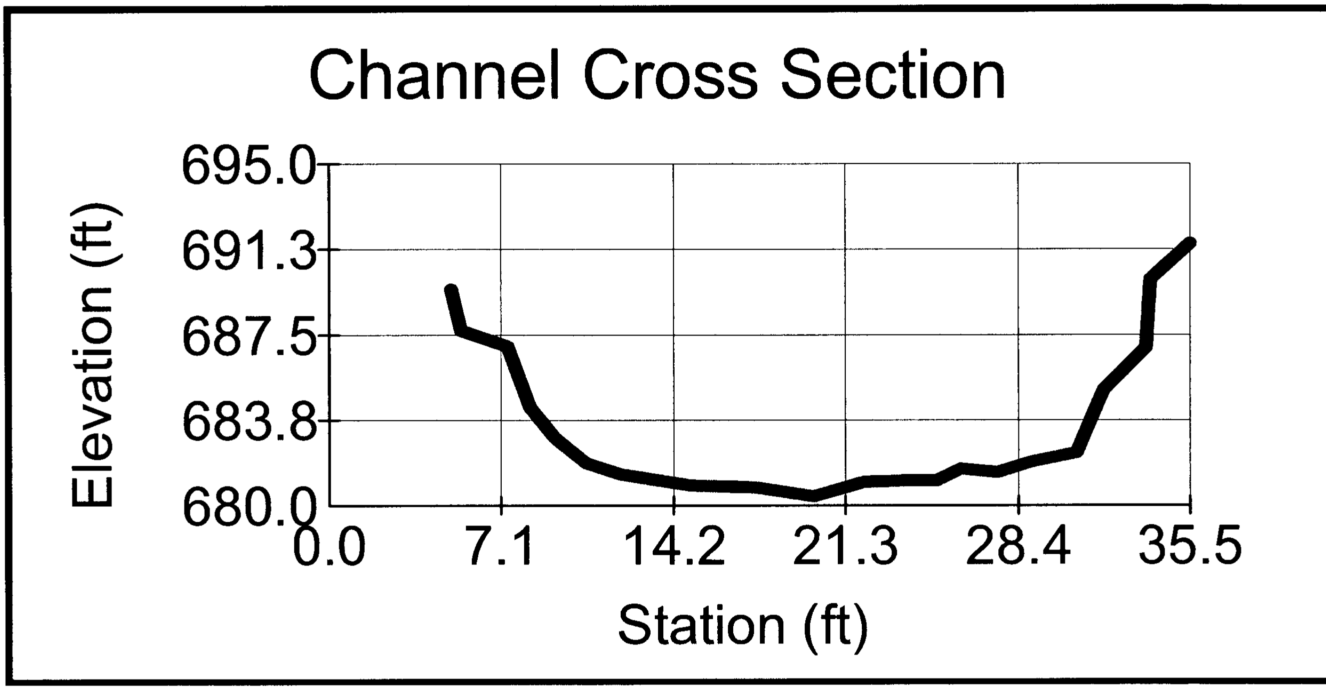


Figure 7. Channel Cross Section at Tailwater Crest.

Table 9. Tailwater Rating Table Information.

Discharge (cfs)	Tailwater Elevation (ft)	Wetted Perimeter (ft)	Cross-Sect. Area (sq. ft)
0.0	680.4	0.00	0.00
0.0	680.5	0.98	0.05
0.0	680.6	1.95	0.19
0.1	680.7	2.93	0.43
0.2	680.8	4.14	0.76
0.3	680.9	6.97	1.33
0.6	681.0	7.91	2.06
0.9	681.1	10.27	2.94
1.4	681.2	12.37	4.12
2.0	681.3	13.19	5.38
2.9	681.4	13.95	6.72
3.7	681.5	14.97	8.12
4.6	681.6	16.95	9.69
5.9	681.7	17.60	11.38
7.3	681.8	18.24	13.14
8.9	681.9	18.80	14.95
10.6	682.0	19.41	16.81
12.4	682.1	20.05	18.73
14.3	682.2	20.70	20.71
16.4	682.3	21.34	22.75
18.8	682.4	21.63	24.83
21.4	682.5	21.89	26.93
24.1	682.6	22.15	29.04
26.9	682.7	22.41	31.17
29.8	682.8	22.67	33.31
32.8	682.9	22.93	35.47
36.0	683.0	23.18	37.64
39.3	683.1	23.41	39.83
42.7	683.2	23.65	42.02
46.2	683.3	23.88	44.23
49.8	683.4	24.11	46.45
53.5	683.5	24.35	48.68
57.3	683.6	24.58	50.93
61.2	683.7	24.81	53.18
65.2	683.8	25.05	55.45
69.3	683.9	25.28	57.73
73.4	684.0	25.52	60.02
77.7	684.1	25.75	62.32
82.1	684.2	25.98	64.63
86.6	684.3	26.22	66.96
91.2	684.4	26.44	69.30
95.8	684.5	26.65	71.64
100.6	684.6	26.86	73.99
105.4	684.7	27.08	76.35
110.4	684.8	27.29	78.71
115.4	684.9	27.50	81.09
120.4	685.0	27.72	83.47
125.6	685.1	27.94	85.86

Discharge (cfs)	Tailwater Elevation (ft)	Wetted Perimeter (ft)	Cross-Sect. Area (sq. ft)
130.7	685.2	28.18	88.26
135.9	685.3	28.43	90.67
141.2	685.4	28.67	93.10
146.6	685.5	28.91	95.54
152.1	685.6	29.16	97.99
157.7	685.7	29.40	100.45
163.3	685.8	29.64	102.93
169.0	685.9	29.89	105.42
174.8	686.0	30.13	107.92
180.7	686.1	30.38	110.44
186.6	686.2	30.62	112.97
192.7	686.3	30.86	115.51
198.8	686.4	31.11	118.07
205.0	686.5	31.35	120.64
211.2	686.6	31.59	123.22
217.6	686.7	31.84	125.81
224.0	686.8	32.08	128.42
230.5	686.9	32.32	131.04
237.2	687.0	32.54	133.67
243.2	687.1	32.92	136.32
249.2	687.2	33.32	138.99
255.3	687.3	33.72	141.69
261.5	687.4	34.12	144.43
267.8	687.5	34.52	147.19
274.2	687.6	34.91	149.98
280.8	687.7	35.29	152.79
288.4	687.8	35.50	155.62
296.1	687.9	35.70	158.46
303.8	688.0	35.90	161.30
311.6	688.1	36.10	164.13
319.5	688.2	36.31	166.98
327.4	688.3	36.51	169.82
335.4	688.4	36.71	172.67
343.4	688.5	36.91	175.52
351.4	688.6	37.12	178.37
359.6	688.7	37.32	181.23
367.7	688.8	37.52	184.09
376.0	688.9	37.72	186.95
384.2	689.0	37.93	189.81
392.6	689.1	38.13	192.68
400.9	689.2	38.33	195.55
409.4	689.3	38.53	198.42
417.8	689.4	38.74	201.30
425.5	689.5	38.92	203.89

Summary Statement

The initial goals of this replacement culvert design project included widening the roadway, designing a structurally sound culvert, passing the 100-Year storm event, creating a friendly fish passage design for adult anadromous salmonids, preventing hydraulic design threats downstream, meeting permissible scour velocities in the channel, and meeting species-specific depth and velocity criteria.

Specifically for fish passage, all criteria for the Hydraulic Design Option were successfully met by following the process laid out within the forms. An overview of the steps include researching existing data and available information, collecting all required parameters at the site, selecting the best fish passage design option for the project site, completing the hydrology and efficiently brainstorming and completing the hydraulic modeling, and finally meeting all requirements of the Hydraulic Design Option.

As found in the problem statement, the goal was providing cross drainage for Rose Creek that met hydraulic standards in the Caltrans Hydraulic Design Manual, as well as fish standards in the California Department of Fish and Game Culvert Criteria and the NOAA Fisheries Guidelines for Salmonid Passage at Stream Crossings.

Three different hydraulic analysis software programs were used to compute culvert velocities. Those software programs include HEC-RAS and Fish Xing. Results from the three separate analyses are shown below in Summary Data Table 1 and 2.

Summary Data Table1: Culvert Velocities

	Maximum Average Water Velocity at High Fish Design Flow for Adult Anadromous Salmonids (ft/s)	High Fish Design Downstream Velocity in Culvert (ft/s)	High Fish Design Upstream Velocity in Culvert (ft/s)	High Fish Design Average Water Velocity in Culvert (ft/s)
Existing Conditions (HEC-RAS)	5.00	8.47	5.97	7.22
Proposed Conditions (HEC-RAS)	5.00	5.88	5.25	5.57
Proposed Conditions (Fish Xing)	5.00	3.49	2.34	2.92

Summary Data Table 2: Culvert Depths

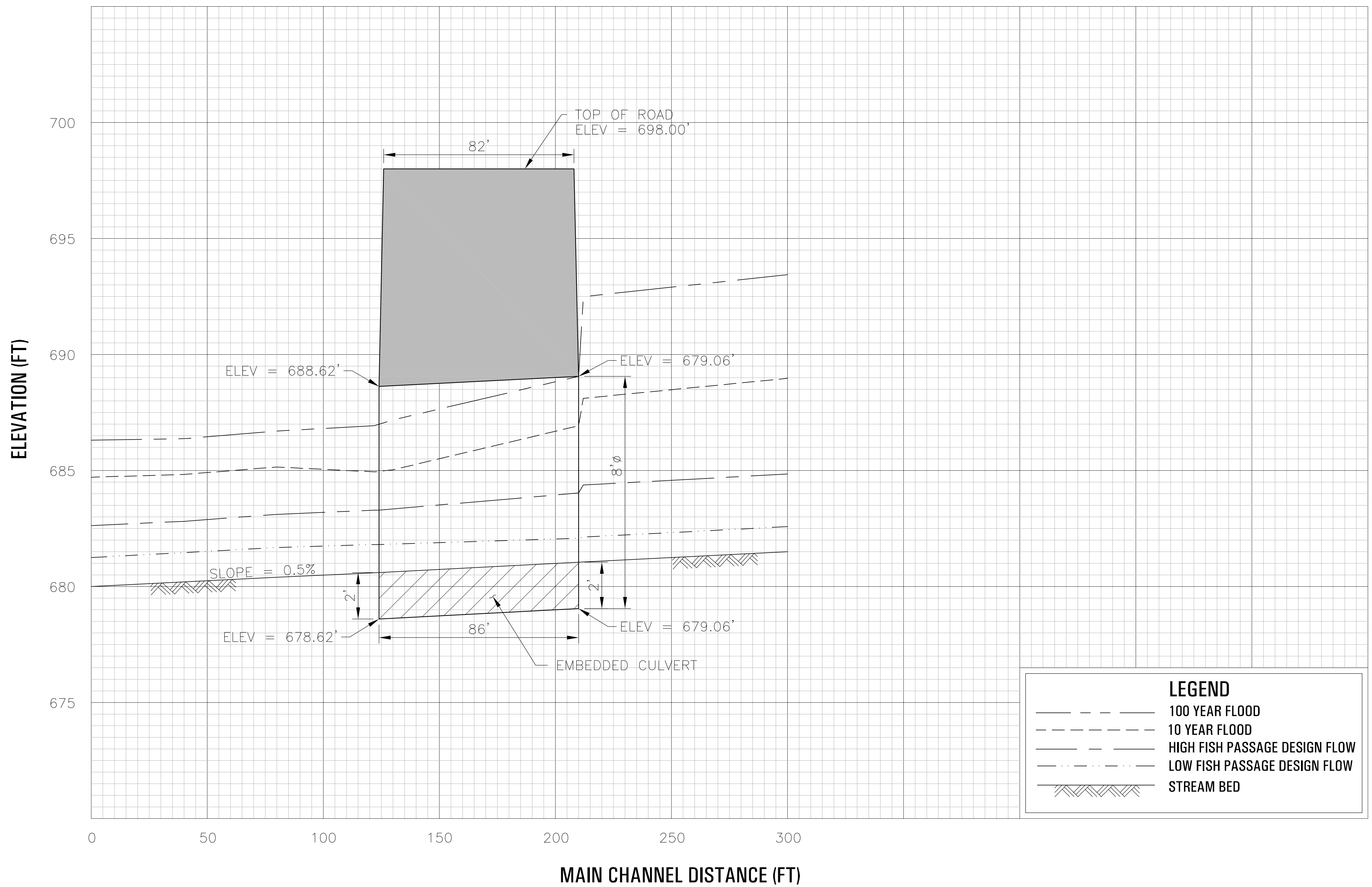
	Minimum Flow Depth at Low Fish Design Flow (ft)	Water Depth inside Culvert at Inlet (ft)	Water Depth inside Culvert at Outlet (ft)
Existing Conditions (HEC-RAS)	1.00	1.51	1.50
Proposed Conditions (HEC-RAS)	1.00	1.02	1.22
Proposed Conditions (Fish Xing)	1.00	3.75	3.75

Although the proposed conditions velocities slightly exceed the maximum average water velocity, the County's engineering team felt that the proposed velocities were acceptable due to the high-pressure gas main constraining the channel geometry. It is recommended that a limiting value for acceptable outlet velocity be defined as it relates to site-specific conditions, such as the natural stream velocity occurring during a specific flood event. Had there been the possibility for severe bank erosion, this proposed condition would have not been acceptable.

Slight variation of velocities and depths were calculated using the Fish Xing software and HEC-RAS.

The Fish Xing software provided the lowest velocity and highest depth results. For High Fish Passage Design flows, no barriers were found within the culvert. Only a prolonged swim mode through the entire culvert was required. Fish Xing only considers the tailwater channel cross-section, while the other programs consider at least two cross-sections for calculations. Channel velocities and depths using Fish Xing may not be accurately represented due to the limited channel information required for Fish Xing calculations.

HEC-RAS results were considered the most accurate and were used to determine the acceptability of the proposed culvert design. HEC-RAS calculates results reflecting the upstream and downstream channel geometry in addition to the culvert.



P:/06938/38713 T07 Fish Passage/5.0 Project Data/AutoCAD/General Details/Hydraulic-design-Rose-Creek.DWG
08-29-06 AJACKSON 11:38:14

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

Project Manager: LEF
Designed: EKB
Designed:
Checked: JJL
Drawn: AJ

Road Widening Route 777 at Rose Creek

HYDRAULIC DESIGN

PROPOSED CONDITIONS

Date:
Scale: HORIZ: 1" = 50' VERT: 1" = 5'
Project No.: 06938-38713
File Name: Hydraulic-design-Rose-Creek.DWG
Drawing No.: 1
Issue: