APPENDIX L

DESIGN EXAMPLE - STREAM SIMULATION DESIGN OPTION

Stream Simulation Design Option

Problem Statement

In scenic Mono County, an existing 2-lane, 5-mile segment of Route 333 has a history of head-on collisions and is scheduled for widening to 4 lanes with a wide median to improve safety.

Within the project limits, Stormy Creek crosses Route 333 and is currently conveyed by a 6-foot diameter, 50-foot long, corrugated metal pipe. From visual inspection, the existing culvert is in reasonable structural condition, although Maintenance has expressed longevity concerns with this culvert given its 75-year age. As for hydraulic condition, Maintenance has also reported highway overtopping during a series of significant storms in January 1995. Therefore, hydraulic analysis of the existing condition is important in assessing the culvert's capacity during less frequent storm events (25-year, 50-year, and 100-year storms).

The Mono Lake Committee has been monitoring the Stormy Creek watershed for the past decade. In May 2004, stream restoration strategies were recommended in a report sponsored by the Mono Lake Committee, CalTrout, and the Sierra Club to improve ecological conditions within the watershed. The Route 333 culvert was identified as contributing to an ecologic disconnect between the lower and upper reaches of the stream. Also, identified in the report, brown and rainbow trout have been seen congregating at the outlet of the existing culvert. Based on the habitat and ecological problems, the stream restoration report calls for a replacement of the Route 333 culvert that will be fish-friendly, as well as providing a more seamless connection of the upstream and downstream reaches of the creek.

NOTE: Route 333 and Stormy 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, and a stream restoration report from May of 2004 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 Stormy 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 a copy of the May 2004 stream restoration report sponsored by the Mono Lake Committee, CalTrout, and the Sierra Club.

As for site access, the field investigations cannot be done within Caltrans right-of-way; therefore, right-of-entry will be required.

EXISTING DATA AND INFORMATION SUMMARY			FORM 1
Project Information Route 333 4-Lane		Computed: EKB	Date: 8/1/06
		Checked: LEF	Date: 8/2/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

Proposed Project Type	☐ New Culvert	☐ New Bridge
	X Replacement Culvert	☐ Replacement Bridge
	☐ Retrofit Culvert	☐ Retrofit Bridge
	X Proposed Culvert Length= 140 ft	☐ Proposed Bridge Length= ft
	☐ Other	☐ Other

Design Species/Life Stage	X All Species	Source: Contact: Date: State of CA Dept of Fish & Game Bill Hook 1-422-351-9322 Contacted on 7/20/06
	☐ 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	☐	X
As-Built Drawings	☐	X
Assessor's Parcel Map	☐	X
Previous Studies Performed: (i.e. FEMA Flood Insurance Studies, Army Corps of Engineering Studies, Other)		
Hydrology Analysis	☐	X
Hydraulics Analysis	☐	X
Floodplain Mapping	☐	X
Other Studies Types Available: (i.e. Watershed Management Plans, Stream Restoration Plans (circled), Other)	X	☐
Existing Land Use Map	☐	X
Proposed Land Use Map	☐	X
Precipitation Gage Data	☐	X
Stream Flow Gage Data	☐	X

EXISTING DATA AND INFORMATION SUMMARY				FORM 1
Topographic Mapping: (i.e. USGS Topographic Quadrangle, DEM Data, LIDAR Data, Other)	☒	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		Computed: EKB	Date: 8/1/06
Route 333 4-Lane		Checked: LEF	Date: 8/2/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

Date of Contact	Person Contacted	Subject Discussed
7/20/06	Bill Hook, St. of CA	all species info
	Dept of Fish & Game	
	422-351-9322	

EXISTING INFORMATION INDEX

Project Information	Computed: EKB	Date: 8/1/06
Route 333 4-Lane	Checked: LEF	Date: 8/2/06
Stream Name: Stormy Creek County: Mono	Route: 333	Postmile: 34.1

Report Date	Report Name and Source
5/2004	Stream Restoration Plan for Stormy Creek

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

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 Route 333 6-Lane		Computed: EKB	Date: 8/11/06
		Checked: LEF	Date: 8/13/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

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: 7883.16 ft (NGVD 29 [circled] or NAVD 88)

Barrel Characteristics

Diameter: 72 in	Fill height above culvert: approx. 11.0 ft
Height/Rise: — ft	Length: 50 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		
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:		
		Scour hole depth: ft		
Outlet Apron	☐ Channel scour	☐ Excessive deposition	☐ Debris Accumulation	☒ None Applicable
Skew Angle: NONE °		Downstream Invert Elevation: 7882.38 ft (NGVD 29 (circled) or NAVD 88)		

Obtain Physical Characteristics of Existing Bridge 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) ☐				
Number of Piers:		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	0.020 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		

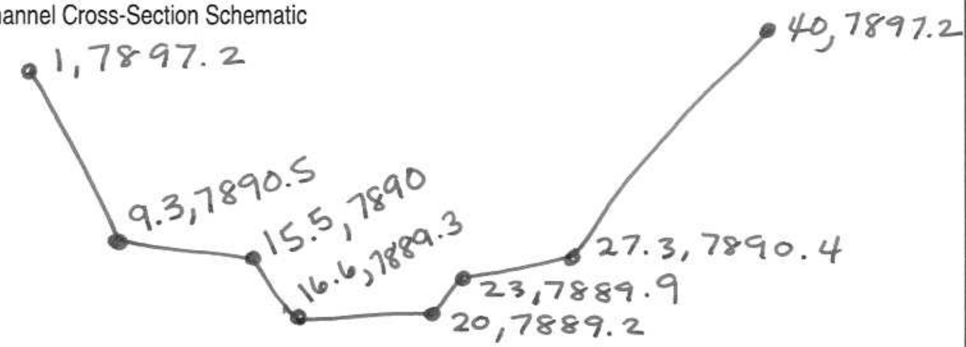
Recommended Permissible Velocities for Unlined Channels (Source: Caltrans Highway Design Manual, Table 862.2)

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

SITE VISIT SUMMARY — FORM 2

Coarse Gravel	7.9 (circled)	6.6
Gravel to Cobbles (Under 150mm)	8.8	6.9
Gravel and Cobbles Over 200mm)	9.8	7.9
Flow Estimation 4 cfs	☐ Supercritical flow	☒ Subcritical flow

Channel Cross-Section Schematic



Channel depth = 0.64 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 = 16.6 ft

1) 16.2 ft	2) 18.9 ft	3) 13.6 ft	4) 17.5 ft	5) 16.8 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 Normal depth

Upstream Normal depth	slope 0.015 ft/ft
Downstream normal depth	slope 0.015 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

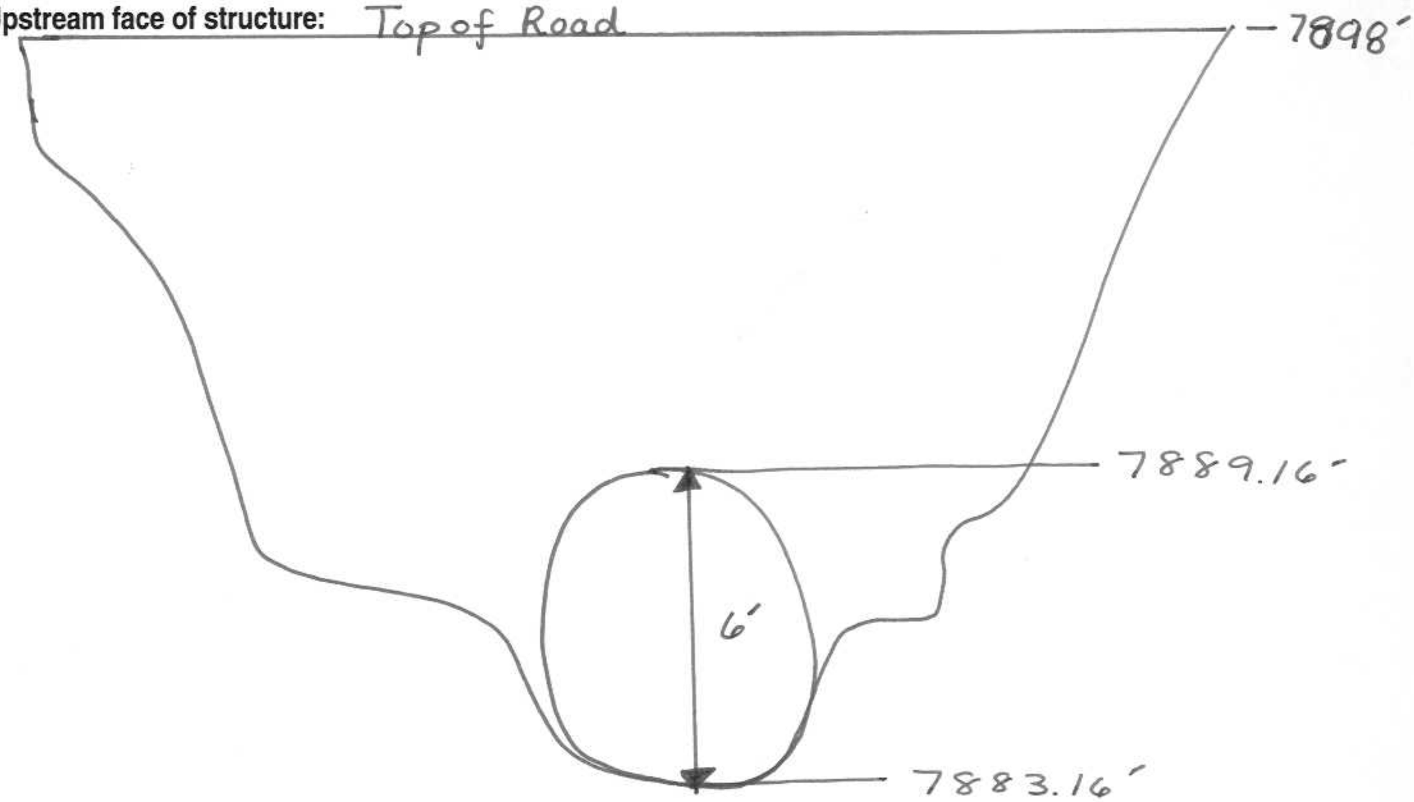
Site Photograph Documentation Attached ☒ Yes ☐ No

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

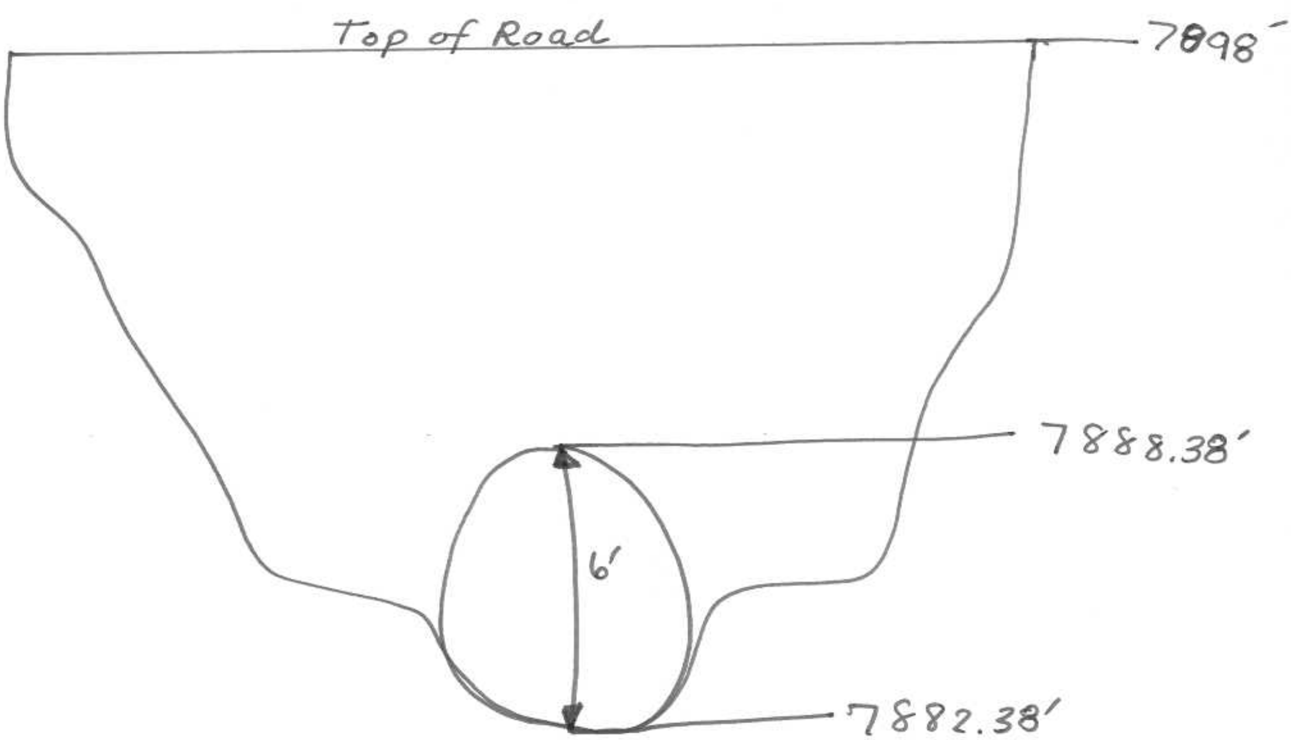
Field Notes Attached ☒ Yes ☐ No

CROSS-SECTION SKETCH

Upstream face of structure:



Downstream face of structure:

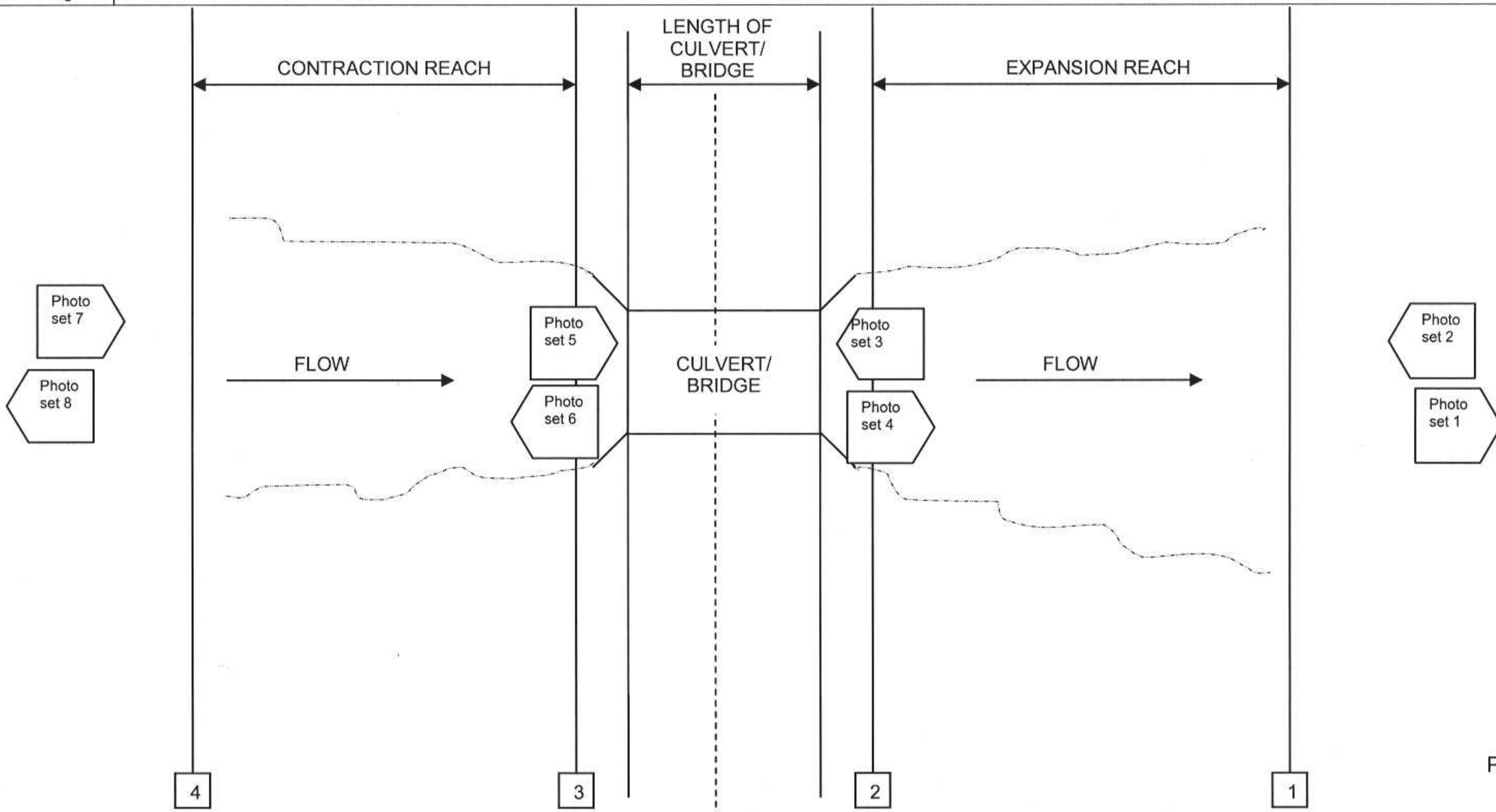


SITE PHOTOGRAPH DOCUMENTATION

Project Information Route 333 4-Lane		Computed:	EKB	Date:	8/11/06
		Checked:	LEF	Date:	8/13/06
Stream Name: Stormy Creek	County: Mono	Route:	333	Postmile:	34.1

Crossing Type	☒ Culvert	☐ Bridge	☐ Other Type/Comments

Distance From:	X-sec. 1 to X-sec. 2: 100 ft	X-sec. 2 to DS face of structure / ft	US face of structure to X-Sec. 3 / ft	X-sec. 3 to X-sec. 4 200 ft
Distance From:	Photo Sets 1 & 2 to DS face of structure — ft	Photo Sets 3 & 4 to DS face of structure / ft	Photo Sets 5 & 6 to US face of structure — ft	Photo Sets 7 & 8 to US face of structure — ft
Length of Culvert/Bridge:	50 ft			



SITE PHOTOGRAPH DOCUMENTATION

Photo Descriptions:

Photo Set 1	—
Photo Set 2	—
Photo Set 3	Culvert outlet looking upstream
Photo Set 4	—
Photo Set 5	—
Photo Set 6	—
Photo Set 7	—
Photo Set 8	—

Culvert outlet looking upstream

Manning's n Computation Summary

Project Information		Computed: EKB		Date: 8/11/06
Route 333 4-Lane		Checked: LEF		Date: 8/13/06
Stream Name: Stormy Creek	County: Mono	Route: 333		Postmile: 34.1

Aerial Picture Attached: none available

Photographs (#'s and locations) #1

Summary of n-Values:

Reach	Left Overbank	Main Channel	Right Overbank
	0.062	0.055	0.062

Notes:

Manning's n Computation - Main Channel

Project Information	Computed: EKB	Date: 8/11/06
Route 333 4-Lane	Checked: LEF	Date: 8/13/06
Stream Name: Stormy Creek / County: Mono	Route: 333	Postmile: 34.1
Aerial Picture Attached: none available		
Photographs (#'s and locations) #1		

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? no 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: Channel bottom - variation of rock and soil sizes

- soil samples were taken at reference reach site
- grain size distribution curve created

nb = 0.030

Manning's n Computation - Main Channel

Surface Irregularity

n1:	Smooth	Is channel smooth? *no*	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

Notes: *Slight erosion occurring on channel side slopes*

n1 = *0.004*

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 = *0.004*

Notes: *Main flow slightly shifts from side to side at lower flows*

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: *Few Large boulders located in 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 = 0.015

Notes: Medium seasonable vegetation present in main channel.

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 0

Notes: Not an issue

Manning's n - Main Channel n = 0.055

Manning's n Computation - Overbank

Project Information		Computed: EKB	Date: 8/11/06
Ronde 333 4-Lane		Checked: LEF	Date: 8/13/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1
Aerial Picture Attached: none available			
Photographs (#'s and locations) #1			

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 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? no 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: same conditions found in main channel

nb = 0.030

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 = 0.008

Notes: Floodplain has many rises and dips in elevation.

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 = 0.003

Notes: large boulders

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 = 0.021

Notes: Medium vegetation - both seasonal and year round

Sinuosity/meandering factor

m = 1.00

Notes: Not applicable to floodplains.

Manning's n - Overbank n = 0.062

Form 3- Guidance on Selection of Fish Passage Design Option

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

Because all species of fish must be passed through the culvert conveying Stormy Creek and individual species swimming abilities are unknown, the Active Channel and Stream Simulation options are two viable strategies. Unlike the Hydraulic Design option, both of these options do not require fish swimming data and the development of low and high fish-passage flows, as well as their corresponding velocity and depth calculations.

Since the restoration of Stormy Creek is a high priority to environmental groups in Mono County, the Route 333 culvert has been identified as a contributor to the ecologic disconnect within the watershed, and the existing culvert is 75 years old with questionable hydraulic capacity, the culvert will be replaced instead of rehabilitated and extended.

Given the addition of two lanes and inside/outside shoulders, as well as the addition of a wide median, the new culvert will be 140 feet in length. This new length is greater than the 100-foot length limit stated in the Active Channel guidelines. Therefore, Stream Simulation is the best design option for Stormy Creek by strict definition.

This design option is also more attractive than the Active Channel based on the environmental sensitivity of the watershed and the need to satisfy local environmental groups in restoring the ecological connectivity within it. While both the Stream Simulation and Active Channel strategies attempt to mimic stream conditions through a culvert, the Stream Simulation design process is more detailed in performing this task. When designing a Stream Simulation culvert, a reference reach is selected and its substrate, cross-sectional, and channel formation properties are used in specifying the simulated bed through the culvert. As noted in the *CA Fish & Game Culvert Criteria,* the Active Channel method is a more simplified version of this process where a culvert is oversized and embedded into the channel to allow the formation of a stable streambed inside the culvert. In Active Channel design, the individual characteristics of the stream are not specifically mimicked inside a culvert.

Again, given the more robust Stream Simulation design process and goal of restoring ecological connectivity with the watershed, this is best fish-passage design option for Stormy Creek in addition to the culvert length requirement.

Because the new, larger diameter culvert and its potential to convey higher flow more effectively, 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 Route 333 4-Lane		Computed: EKB	Date: 8/15/06
		Checked: LEF	Date: 8/17/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

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 taragcteristics 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

- ☐ 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: Stream Simulation Design Option

Basis for Selection: All criteria was met, emphasis on bed stability of the channel and within culvert

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. Mono County is located in the South Lahontan-Colorado Region.

GUIDANCE ON METHODOLOGY FOR HYDROLOGIC ANALYSIS [1, 2]			FORM 4
Project Information Route 333 4-Lane		Computed: EKB	Date: 8/19/06
		Checked: LEF	Date: 8/20/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

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

GUIDANCE ON METHODOLOGY FOR HYDROLOGIC ANALYSIS [1, 2] FORM 4

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 Analysis

Basis for Selection:

All parameters needed to calculate peak discharges using regional regression equations were readily available

[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)	4% Annual Probability (25-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	N/A
Recommended Peak Discharges	7	47	342	516	880	N/A	N/A

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	Computed: EKB	Date: 8/19/06
Route 333 4-Lane	Checked: LEF	Date: 8/20/06
Stream Name: Stormy Creek — County: Mono	Route: 333	Postmile: 34.1

Flooding Source/Stream Name	Hydrologic Method/Model Used	Method/Model Analysis Date	Exhibit No.	
			Paper Copy	Electronic Copy
Stormy Creek	Regional Regression	Site Location: South Lahotan-Colorado Desert Region	1	—
Source: National Summary of USGS Regional Regression Equations for Estimating Magnitude & Frequency of Floods for Ungaged sites, 1993.				

Regional Regression Computation Summary

Project Information:	Route 333 4-Lane	Computed: EKB	Date: 6/31/2006
		Checked: LEF	Date: 7/1/2006
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 12.8

Calculations:

-Site Located in South Lahontan-Colorado Desert

A, Drainage Area = 0.75 mi^2

Regional Regression Equations

Q2 = 7.3A^0.30
Q2 = 7 cfs

Q10 = 53A^0.44
Q10 = 47 cfs

Q25 = 410A^0.63
Q25 = 342 cfs

Q50 = 700A^0.68
Q50 = 576 cfs

Q100 = 1080A^0.71
Q100 = 880 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

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

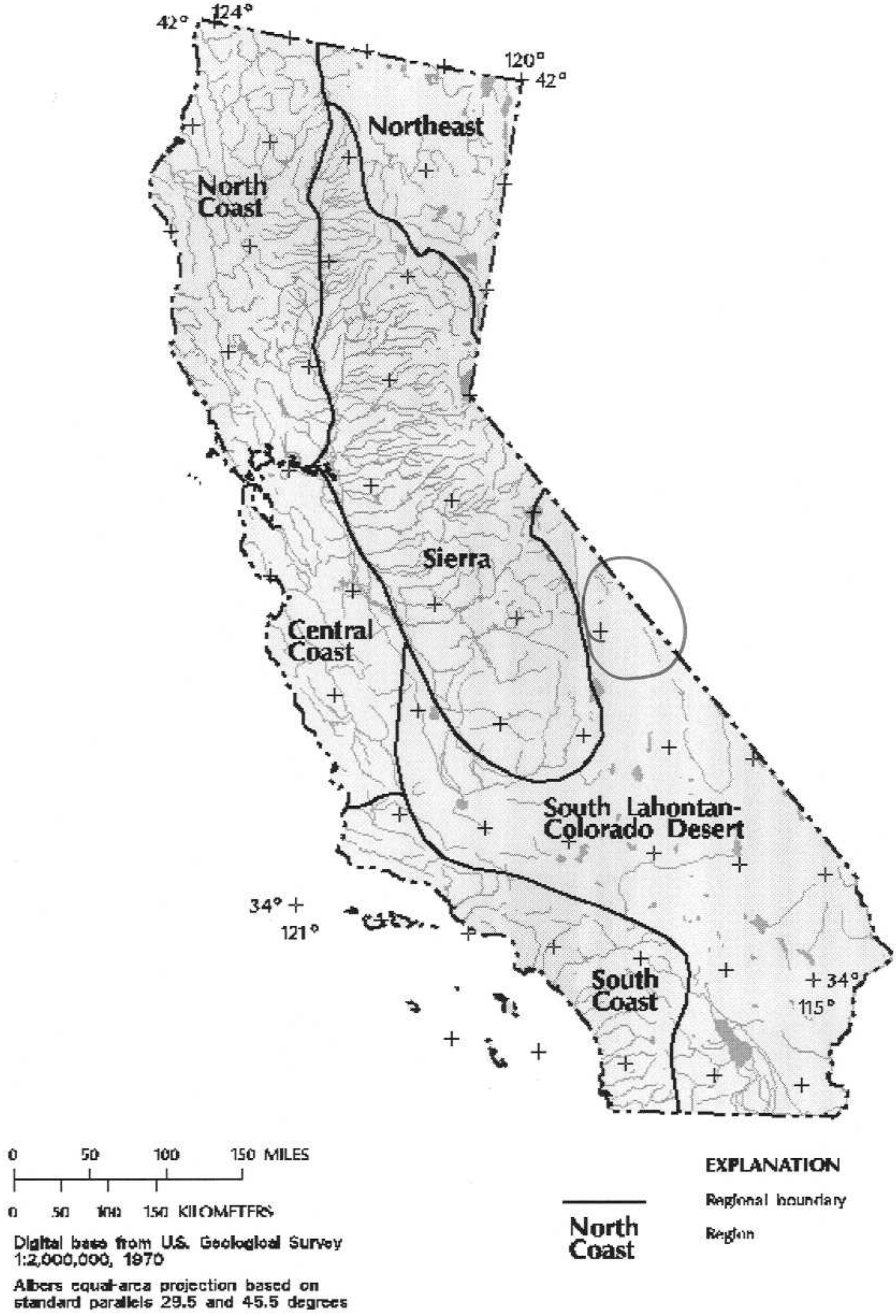


Figure 1. Flood-frequency region map for California.

Form 5 - Guidance on Methodology for Hydraulic Analysis

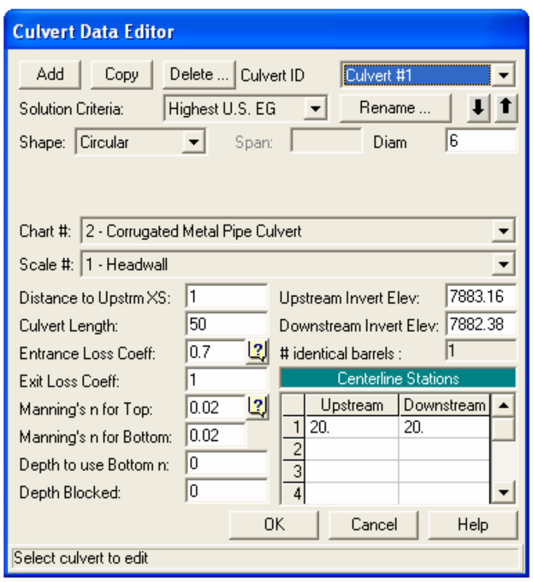
Form 5 summarizes the acceptable methods available for hydraulic analysis. The modeling methods include FHWA Design Charts, HY8 - Culvert Analysis, and HEC-2/HEC-RAS, and Fish Xing for pre- or post-design assessment.

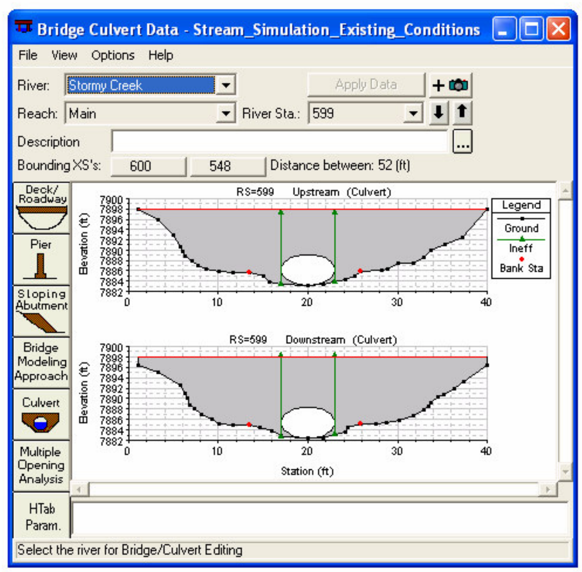
For this particular example, HEC-RAS was used to model existing and proposed conditions. HEC-RAS easily allowed a quick comparison between existing and proposed water surface elevations and velocities.

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.

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.

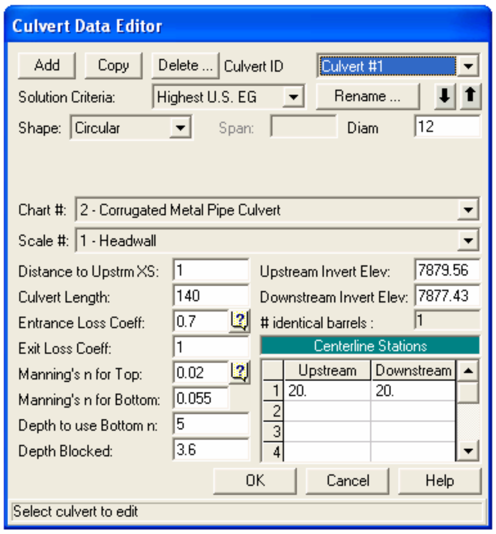
The Culvert Data Editor and Bridge Culvert Data windows are captured below.

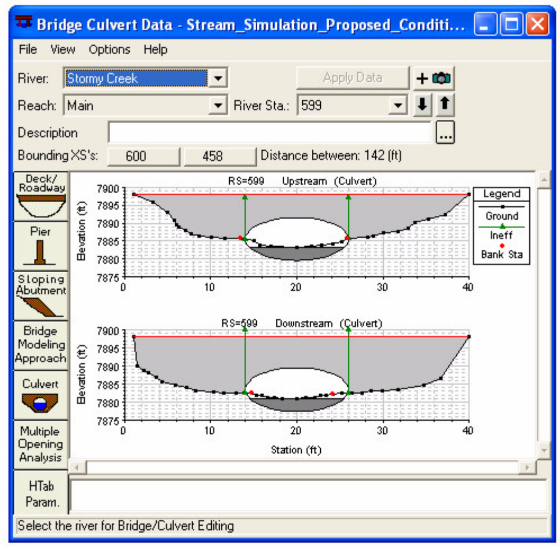




The proposed culvert geometry was also modeled using the Culvert Data Editor in HEC-RAS. The depth blocked feature and higher Manning's n-values for the culvert bottom was used to model the bed embedment.

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





GUIDANCE ON METHODOLOGY FOR HYDRAULIC ANALYSIS — FORM 5

Project Information Route 333 4-Lane		Computed: EKB	Date: 8/22/06
		Checked: JJL	Date: 8/23/06
Stream Name: Stormy Creek	County: Mono	Route: 333	Postmile: 34.1

Summary of Methods for Hydraulic Analysis

- ☐ **FHWA Design Charts**
- ☐ **HY8 - Culvert Analysis or other HDS-5 Based Software**
- ☒ **HEC-2 / HEC-RAS** (HEC-RAS circled)
- ☐ **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

Basis for Selection:

- X-section geometry for upstream and downstream readily available
- Steady flow modeling

Verify Reasonableness and Recommended Flows ☒ Yes ☐ No

Hydraulic Analyses Index Attached ☒ Yes ☐ No

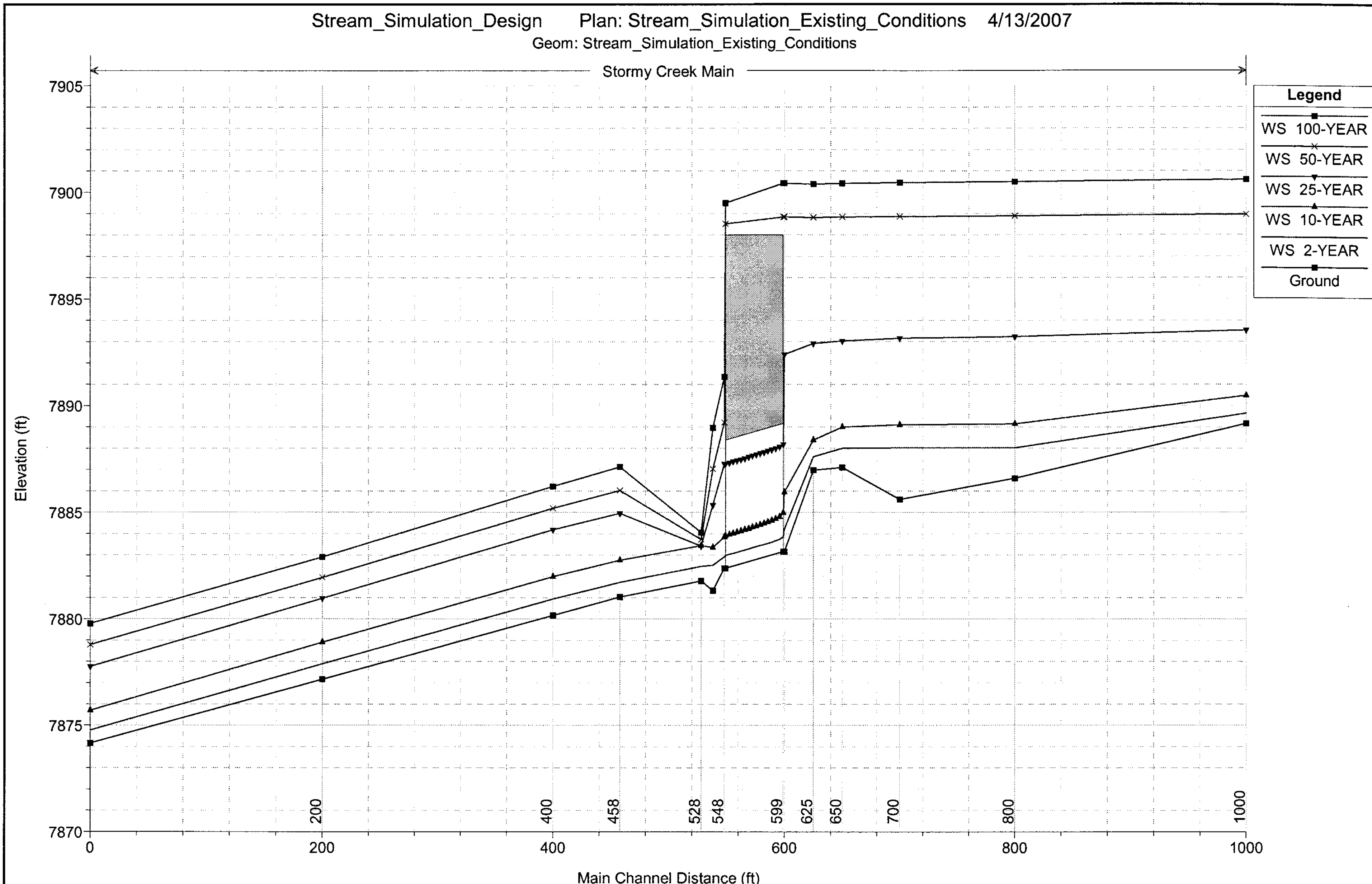
Hydraulic Analysis Calculation Attached ☒ Yes ☐ No

HYDRAULIC ANALYSES INDEX

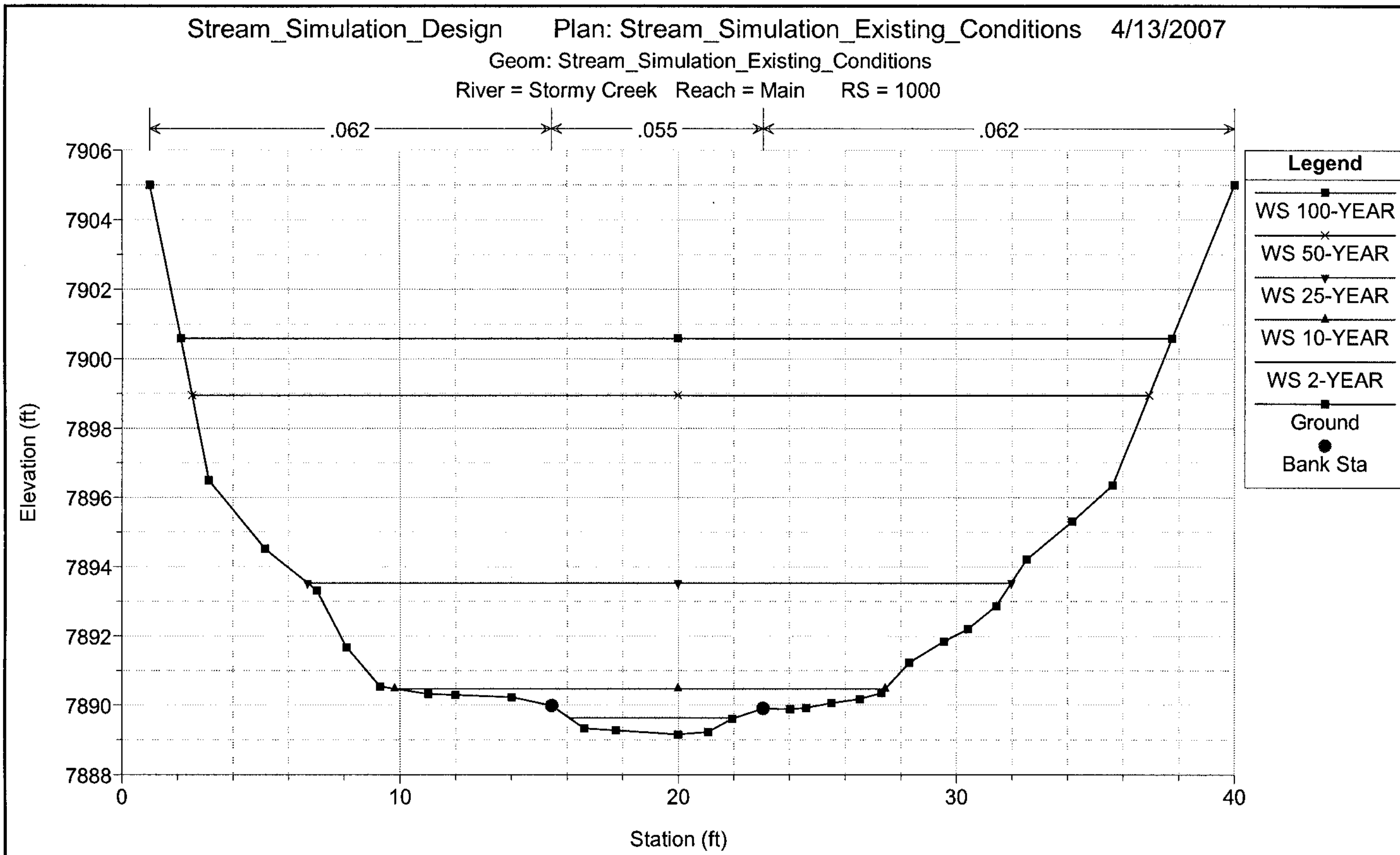
FORM 5

Project Information		Computed: EKB	Date: 8/22/06
Route 333 4-Lane		Checked: LEF	Date: 8/23/06
Stream Name: Stormy Creek	County: Mono	Route 333	Postmile 34.1

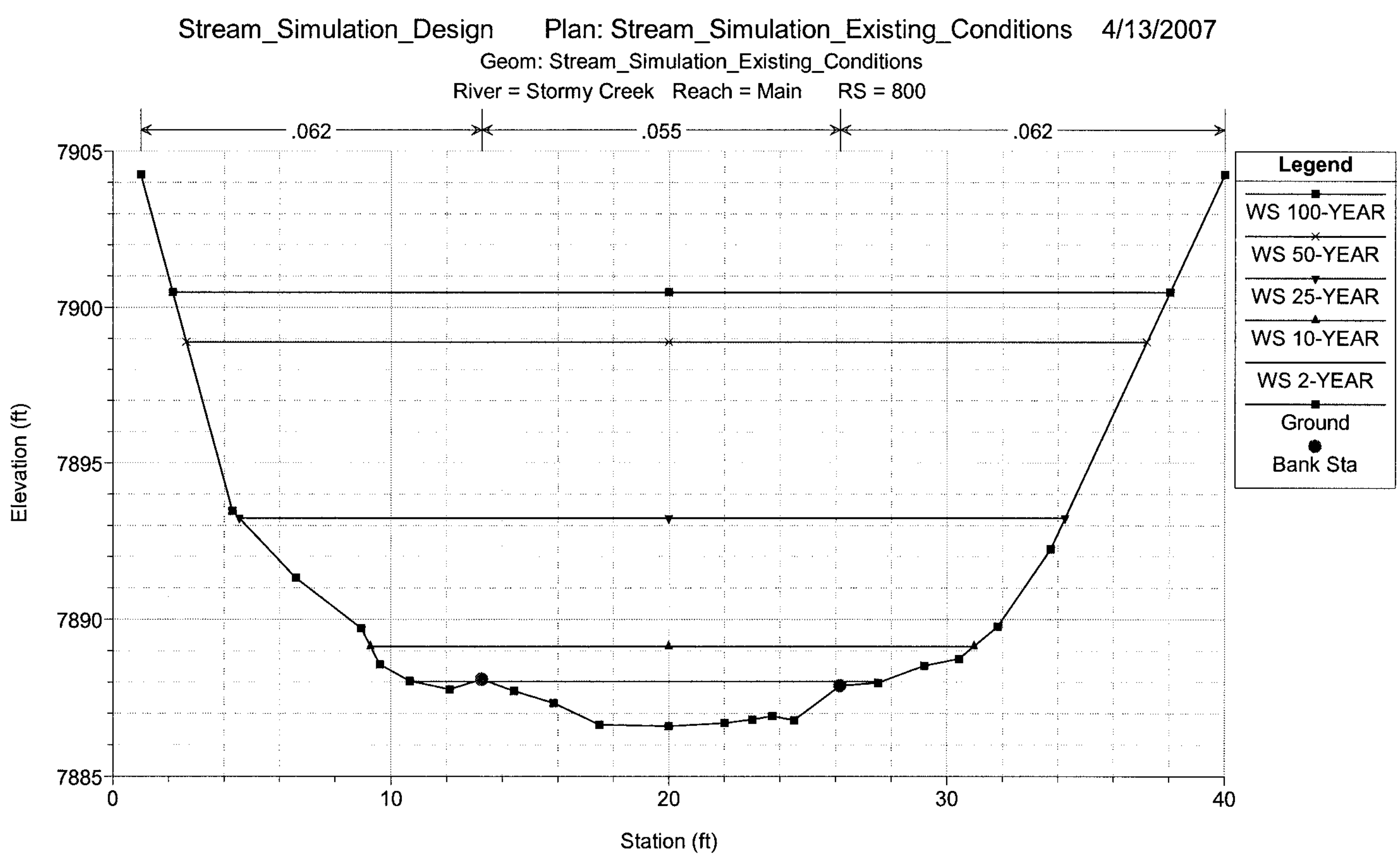
Flooding Source/Stream Name	Hydraulic Method/Model Used	Method/Model Analysis Date	Exhibit No.	
			Paper Copy	Electronic Copy
Stormy Creek	HEC-RAS	model created: 8/23/06	1	
	Existing Conditions			.p01 .g01 .f01
	Proposed Conditions			.p02 .g02 .f01



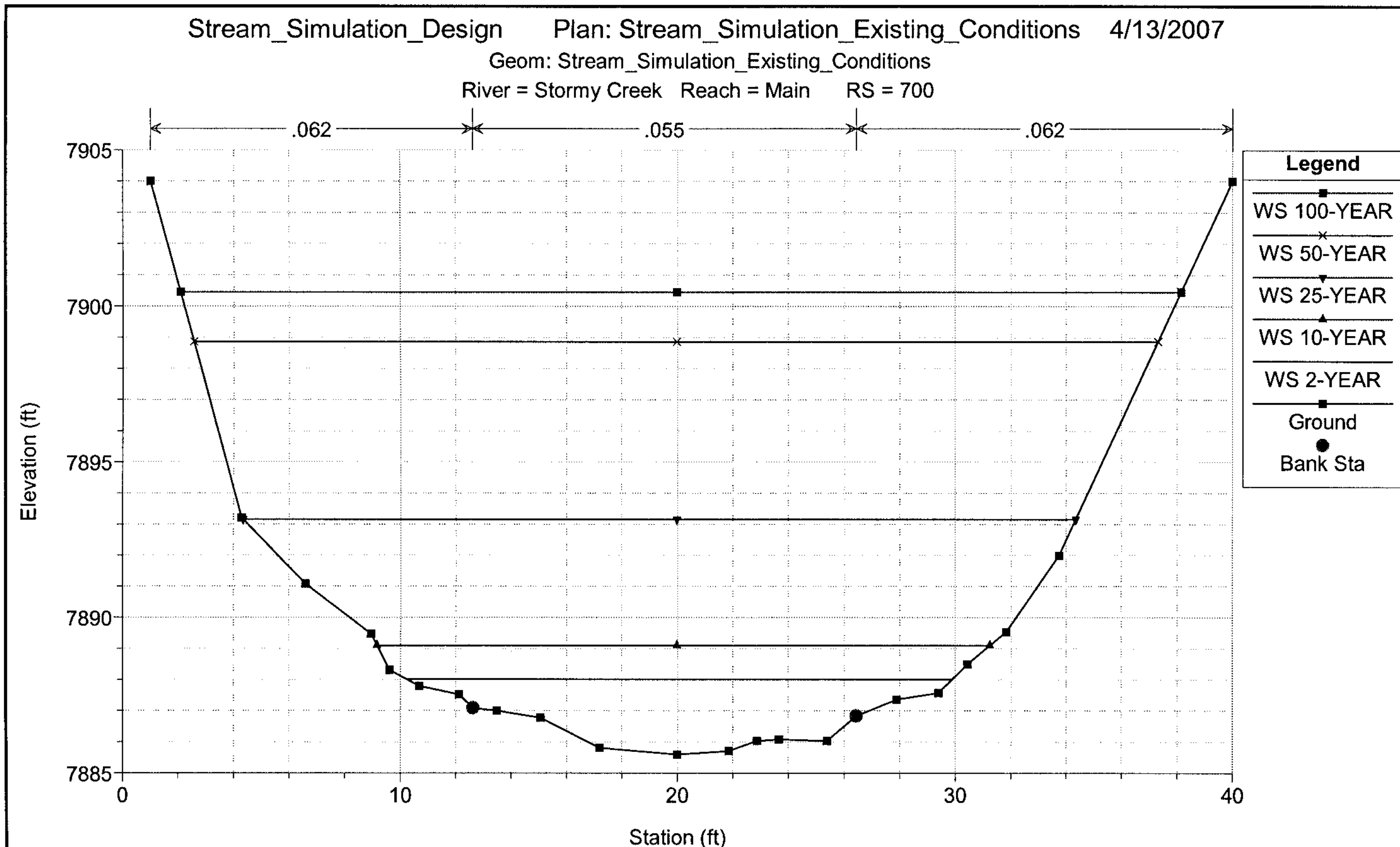
Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
Stormy Creek Main
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Elevation (ft)
7905
7900
7895
7890
7885
7880
7875
7870
200
400
458
528
548
599
625
650
700
800
1000
0
200
400
600
800
1000
Main Channel Distance (ft)



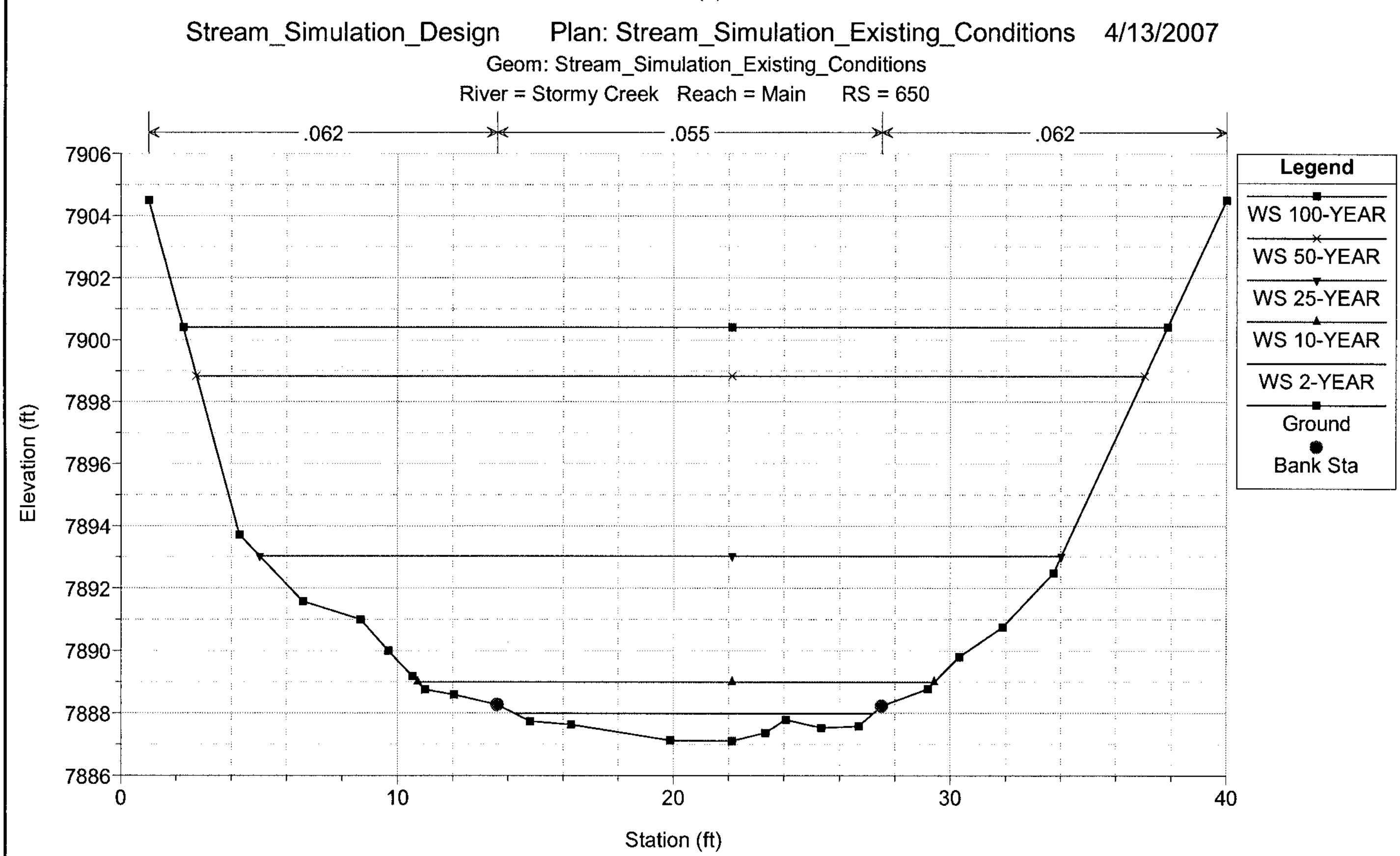
Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 1000
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
7906
7904
7902
7900
7898
7896
7894
7892
7890
7888
0
10
20
30
40
Station (ft)



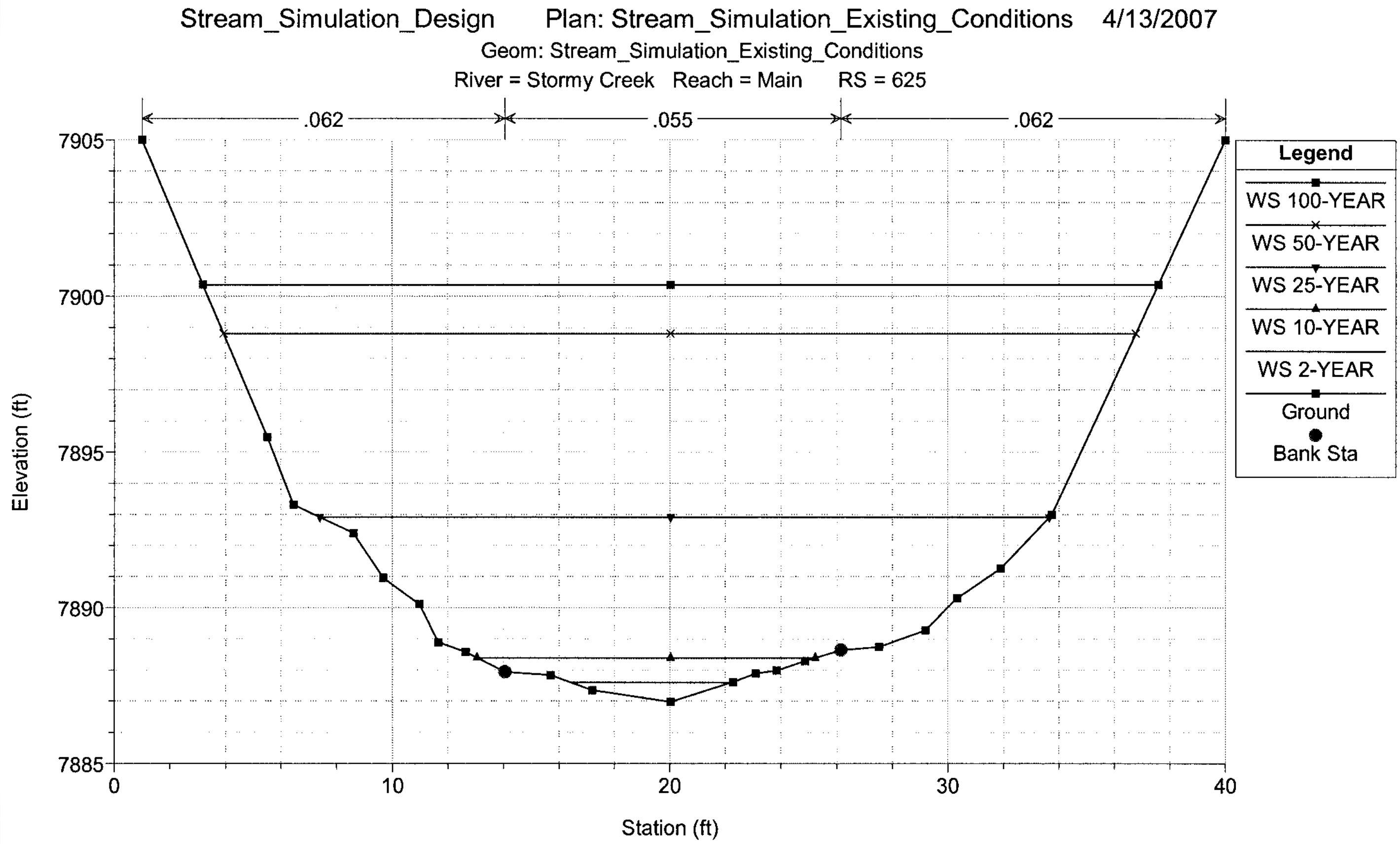
Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 800
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
7905
7900
7895
7890
7885
0
10
20
30
40
Station (ft)

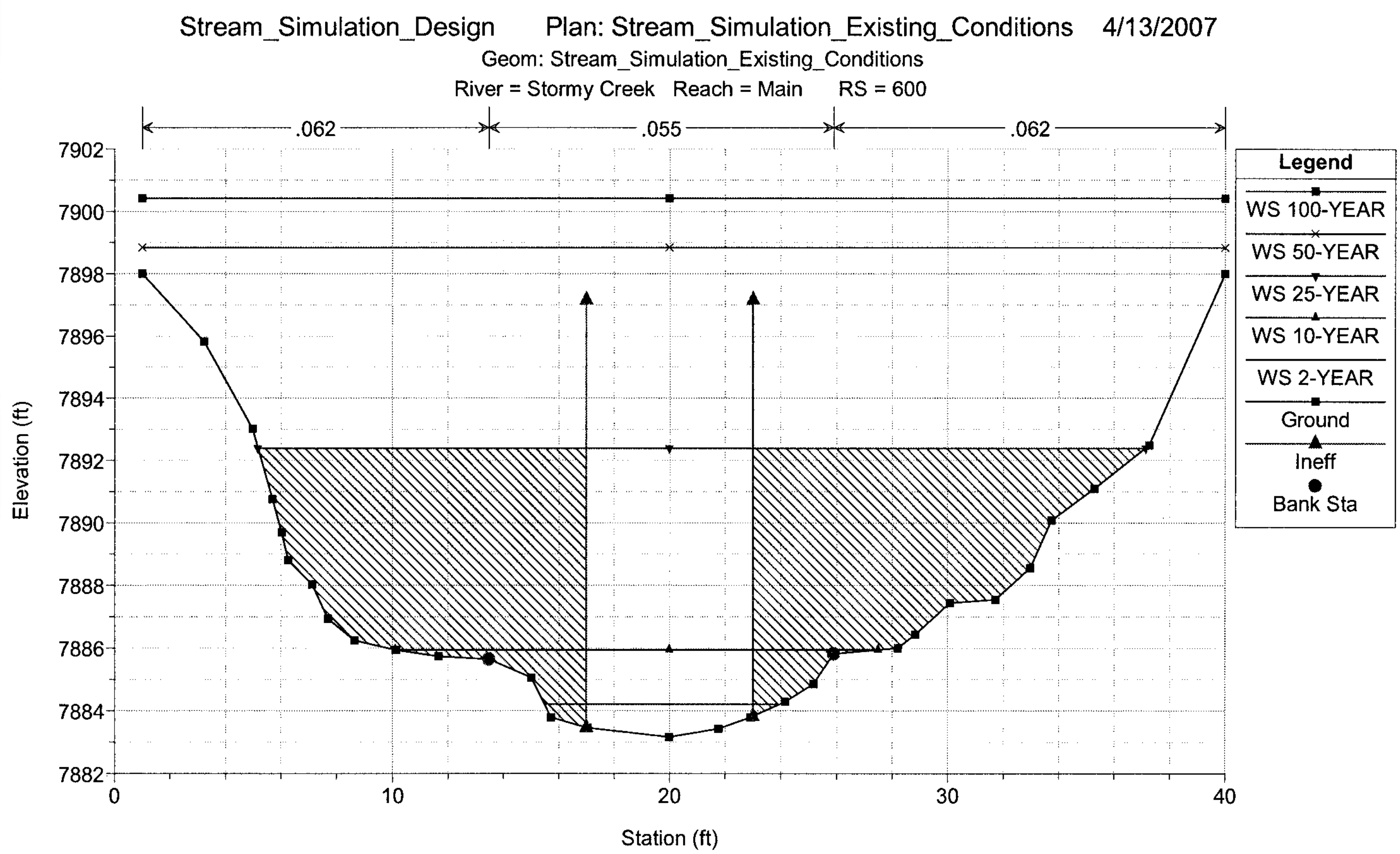


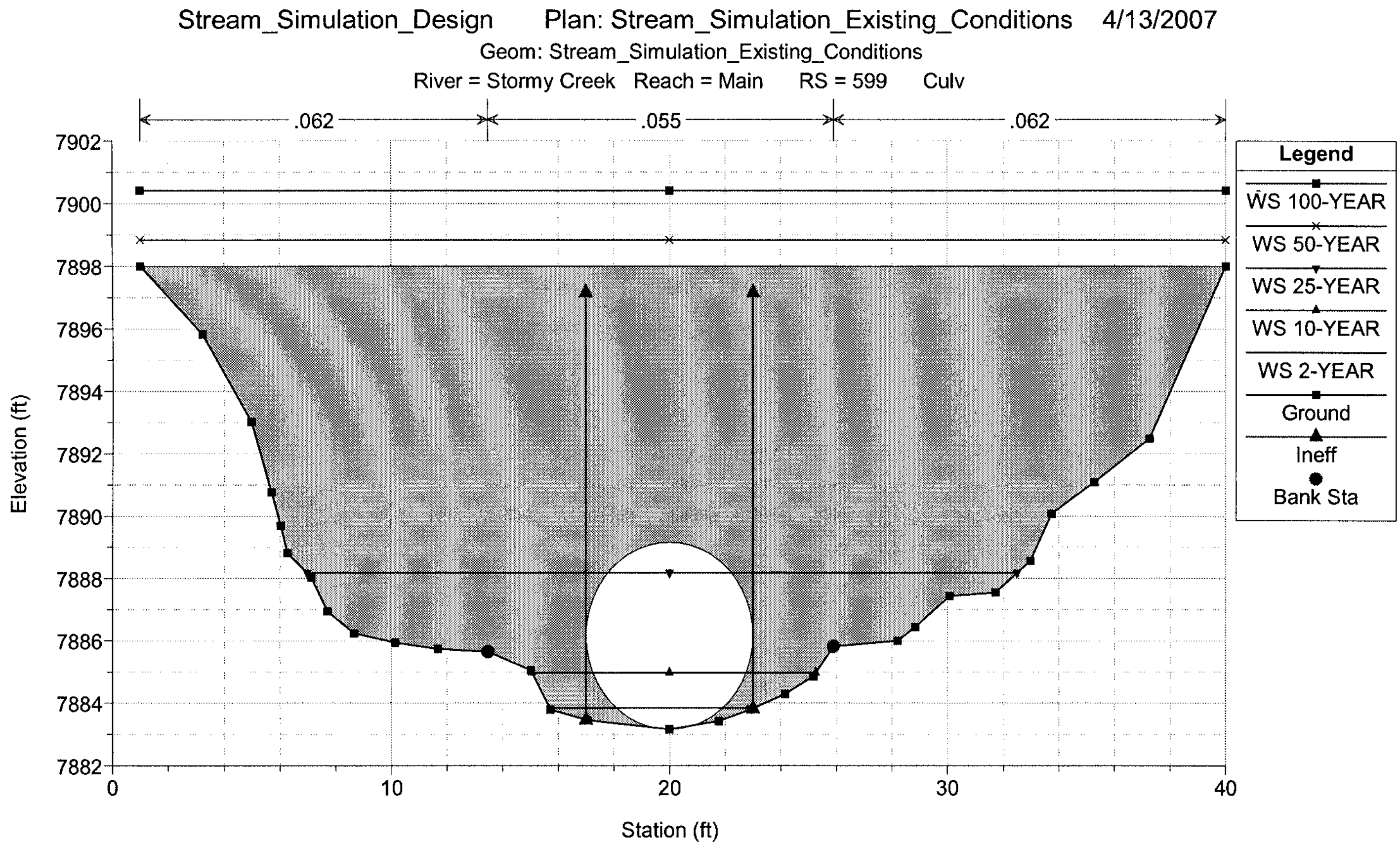
Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 700
.062
.055
.062
7905
7900
7895
7890
7885
Elevation (ft)
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta



Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 650
.062
.055
.062
7906
7904
7902
7900
7898
7896
7894
7892
7890
7888
7886
Elevation (ft)
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 625
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
Station (ft)


Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 600
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)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Geom: Stream_Simulation_Existing_Conditions
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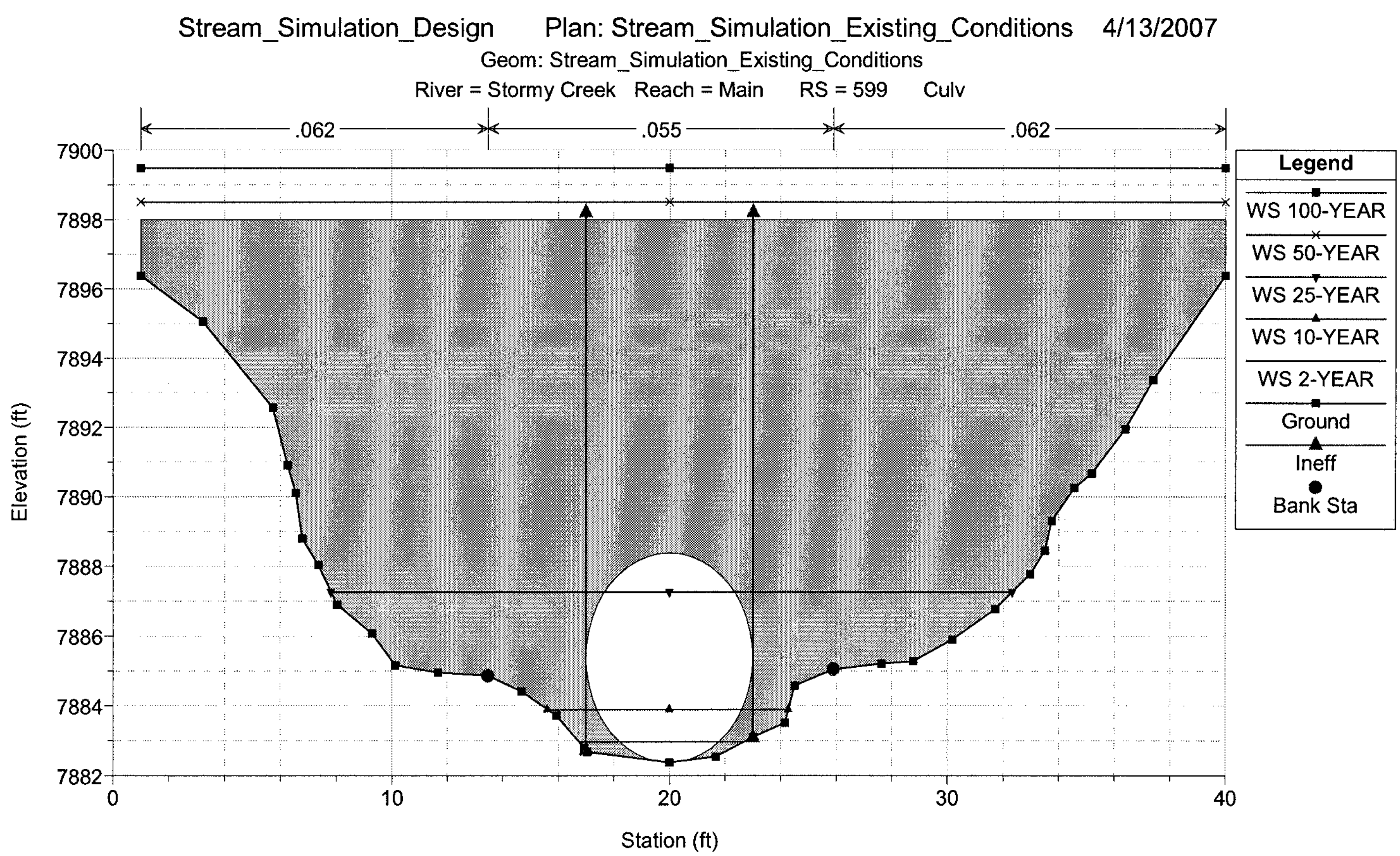
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)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Geom: Stream_Simulation_Existing_Conditions
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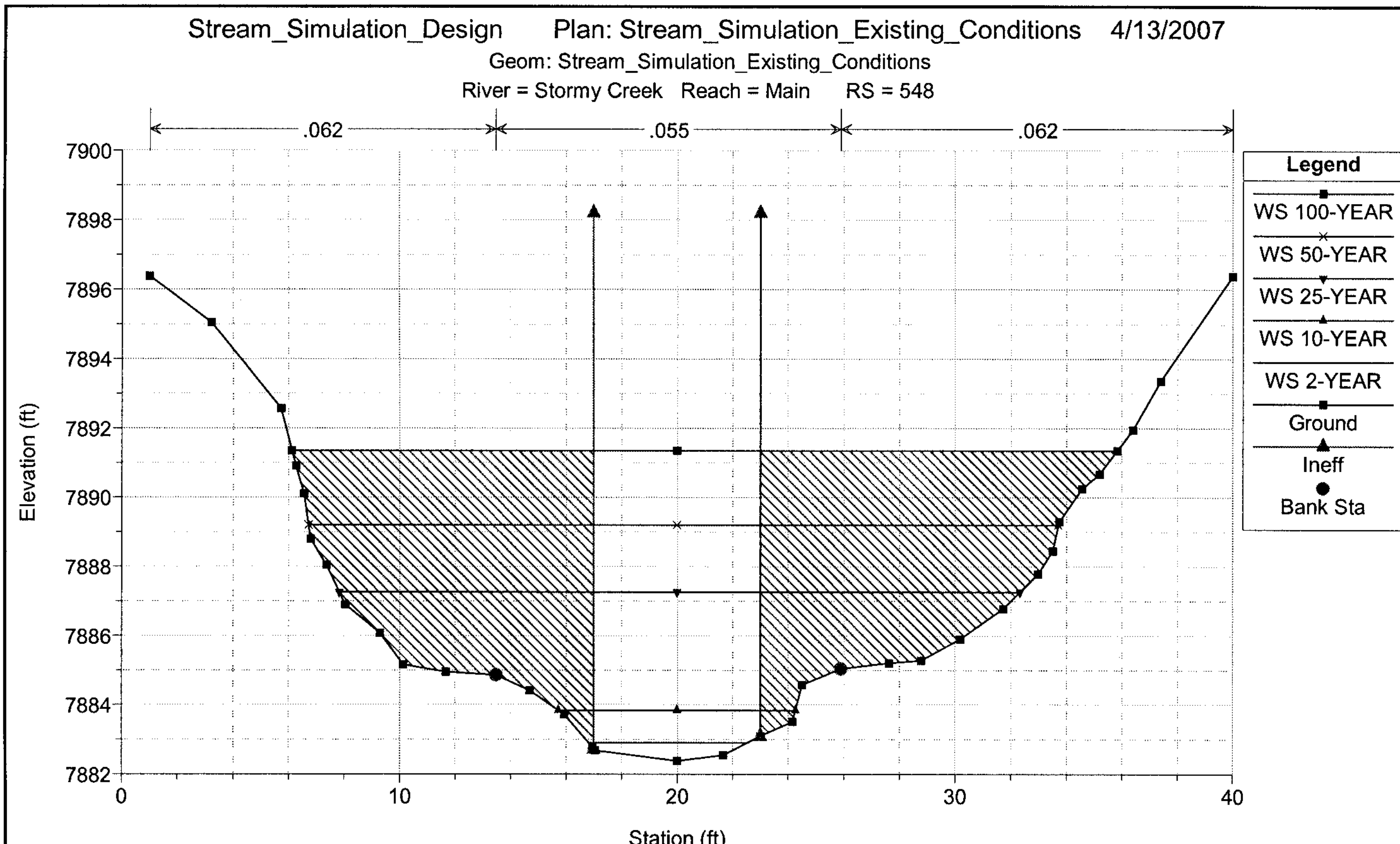
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)



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Geom: Stream_Simulation_Existing_Conditions
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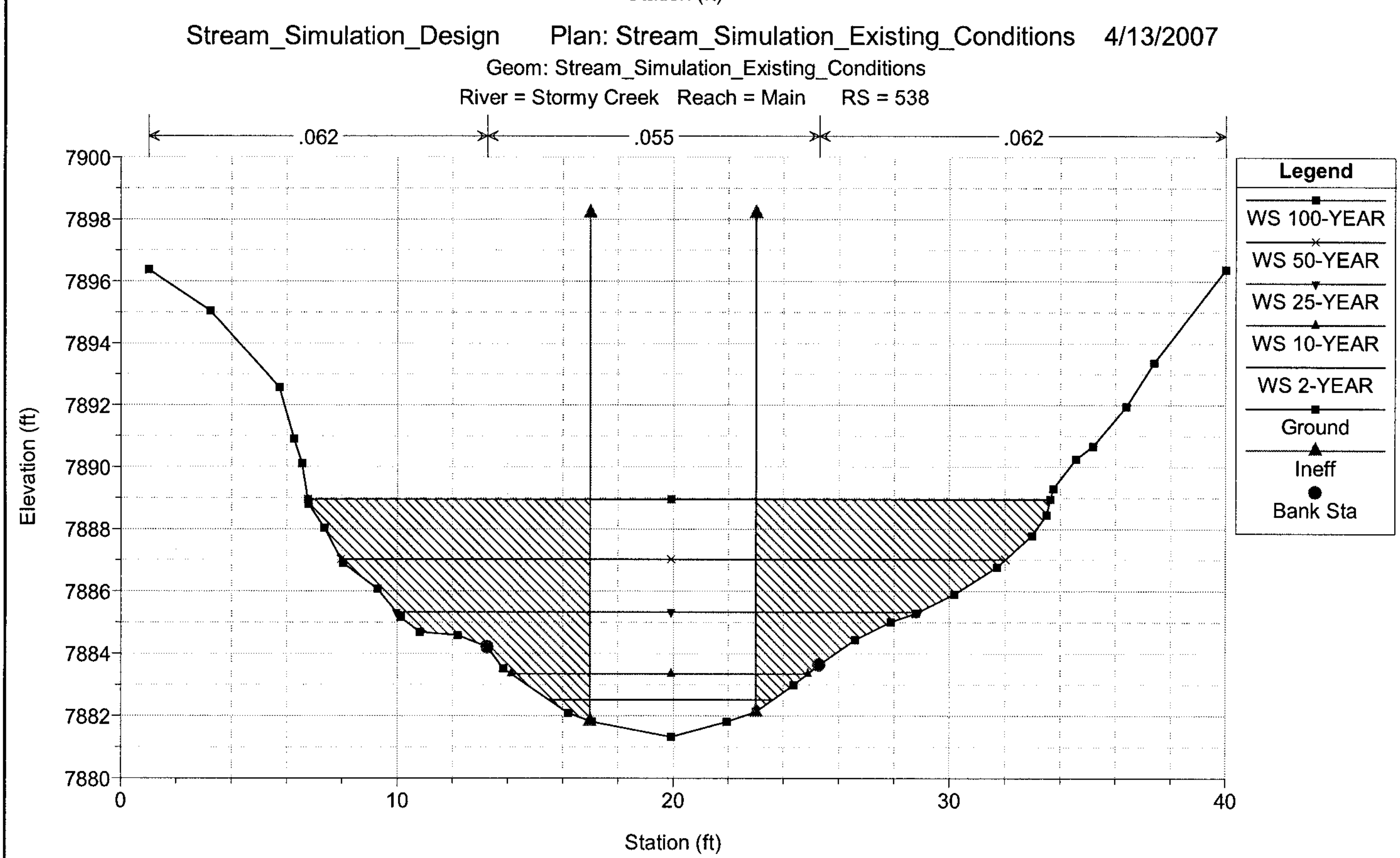
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta
Elevation (ft)
7900
7898
7896
7894
7892
7890
7888
7886
7884
7882
0
10
20
30
40
Station (ft)



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Geom: Stream_Simulation_Existing_Conditions
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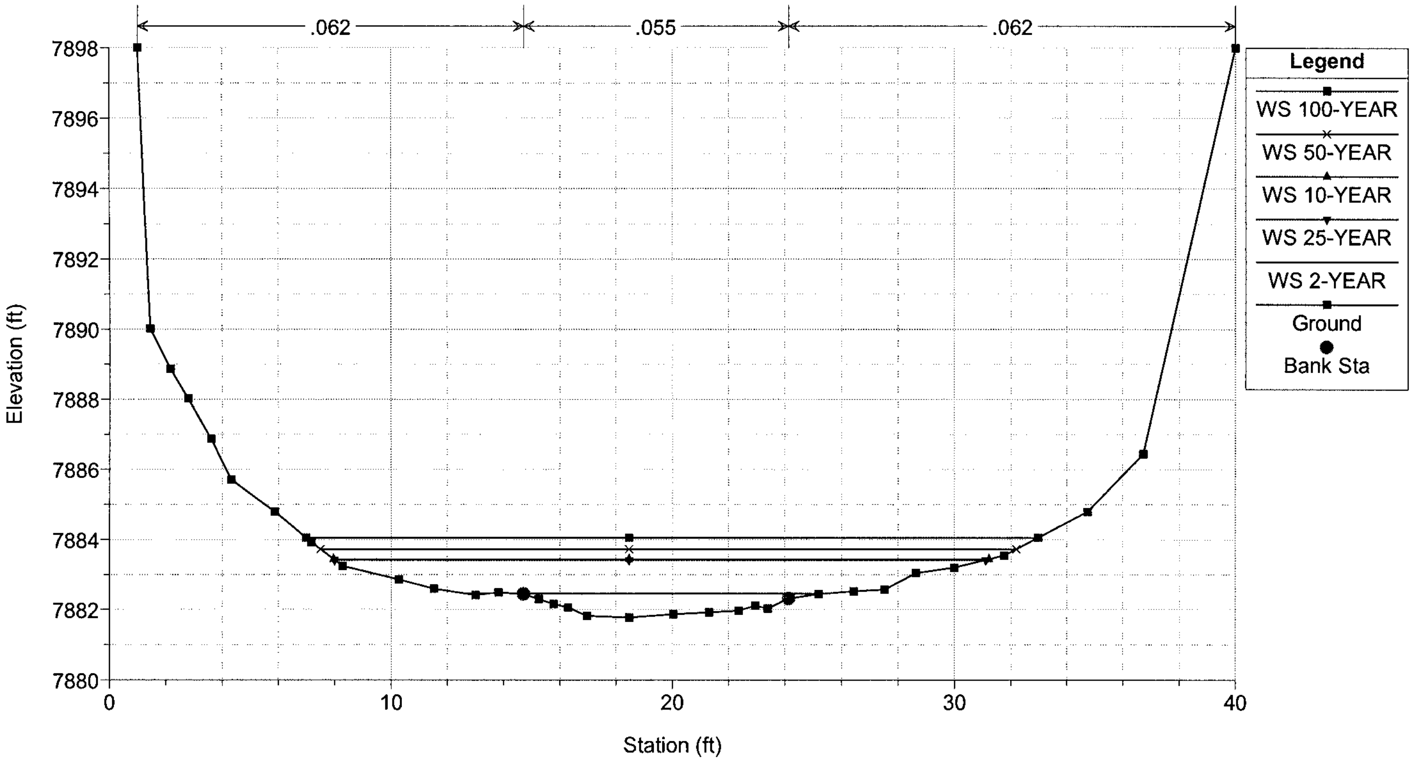
.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta
Elevation (ft)
7900
7898
7896
7894
7892
7890
7888
7886
7884
7882
7880
0
10
20
30
40
Station (ft)

Stream_Simulation_Design Plan: Stream_Simulation_Existing_Conditions 4/13/2007
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 528



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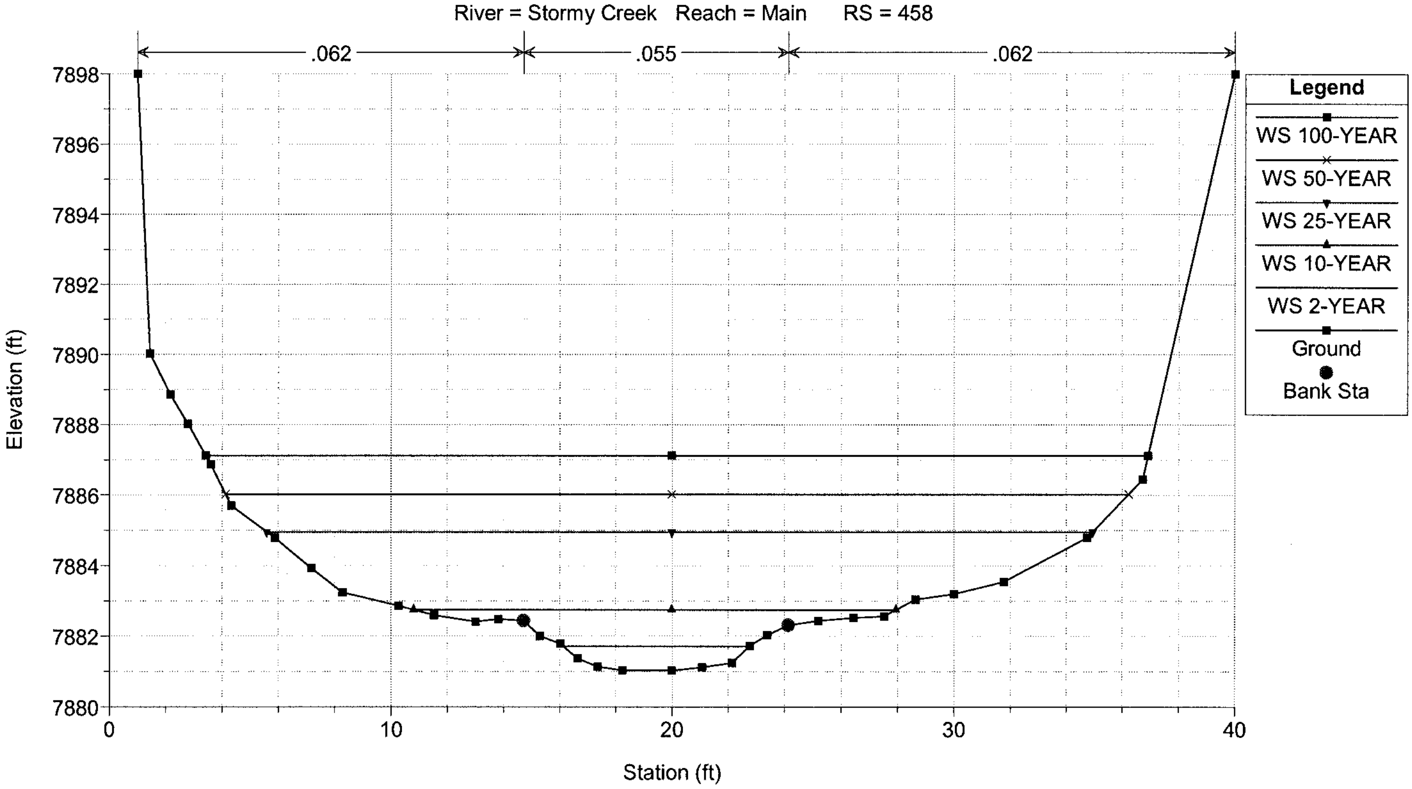
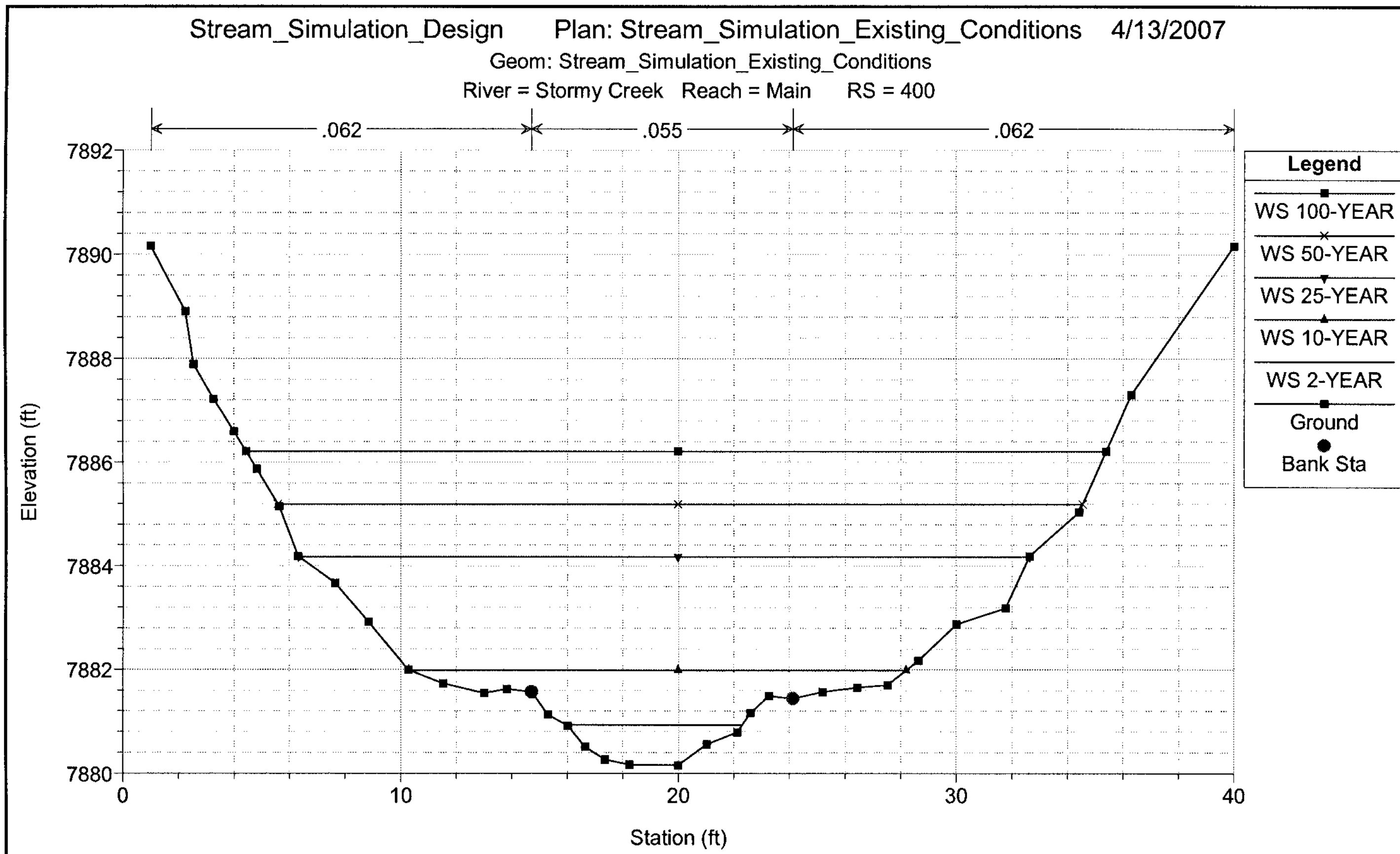
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 458

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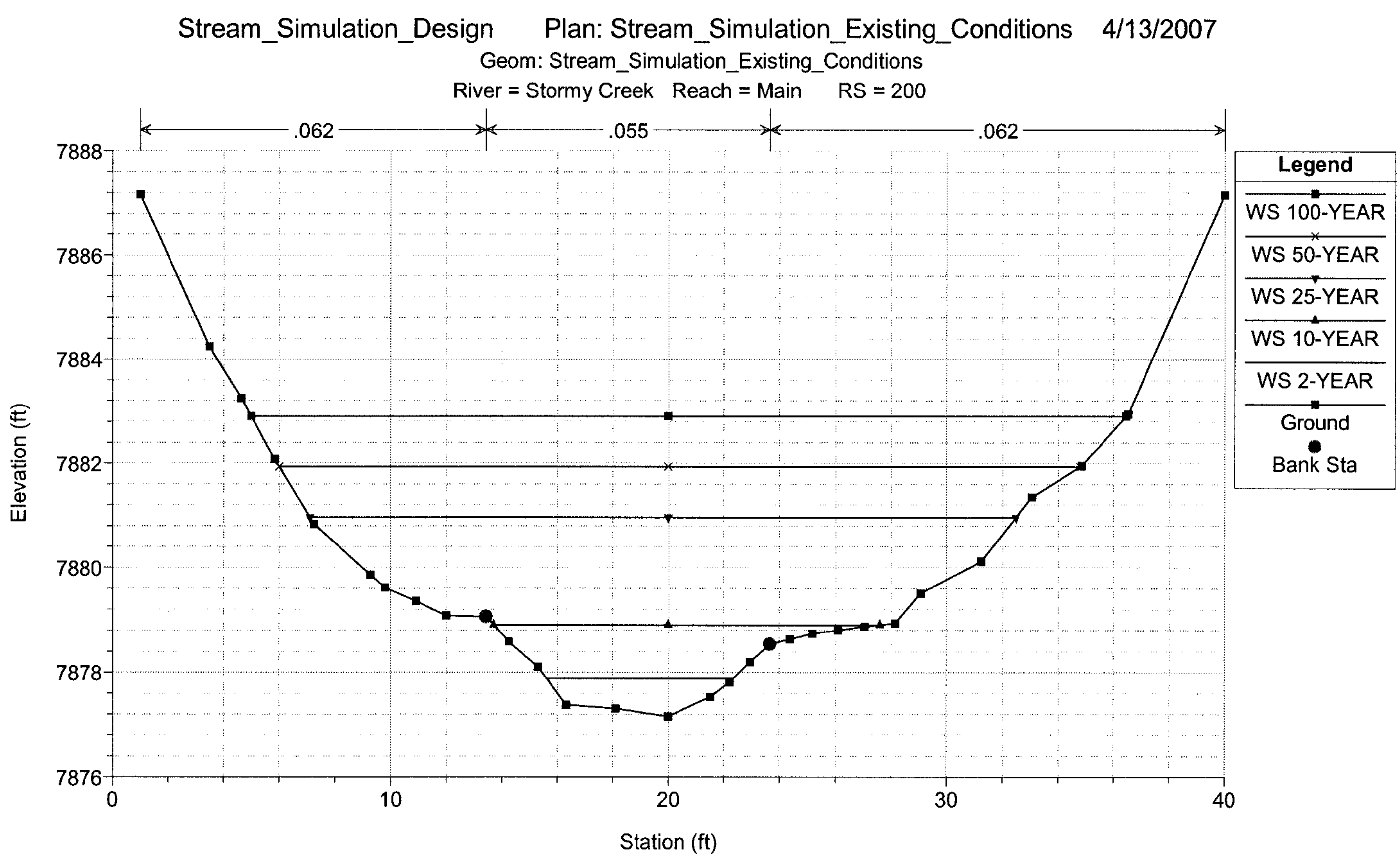
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 400
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta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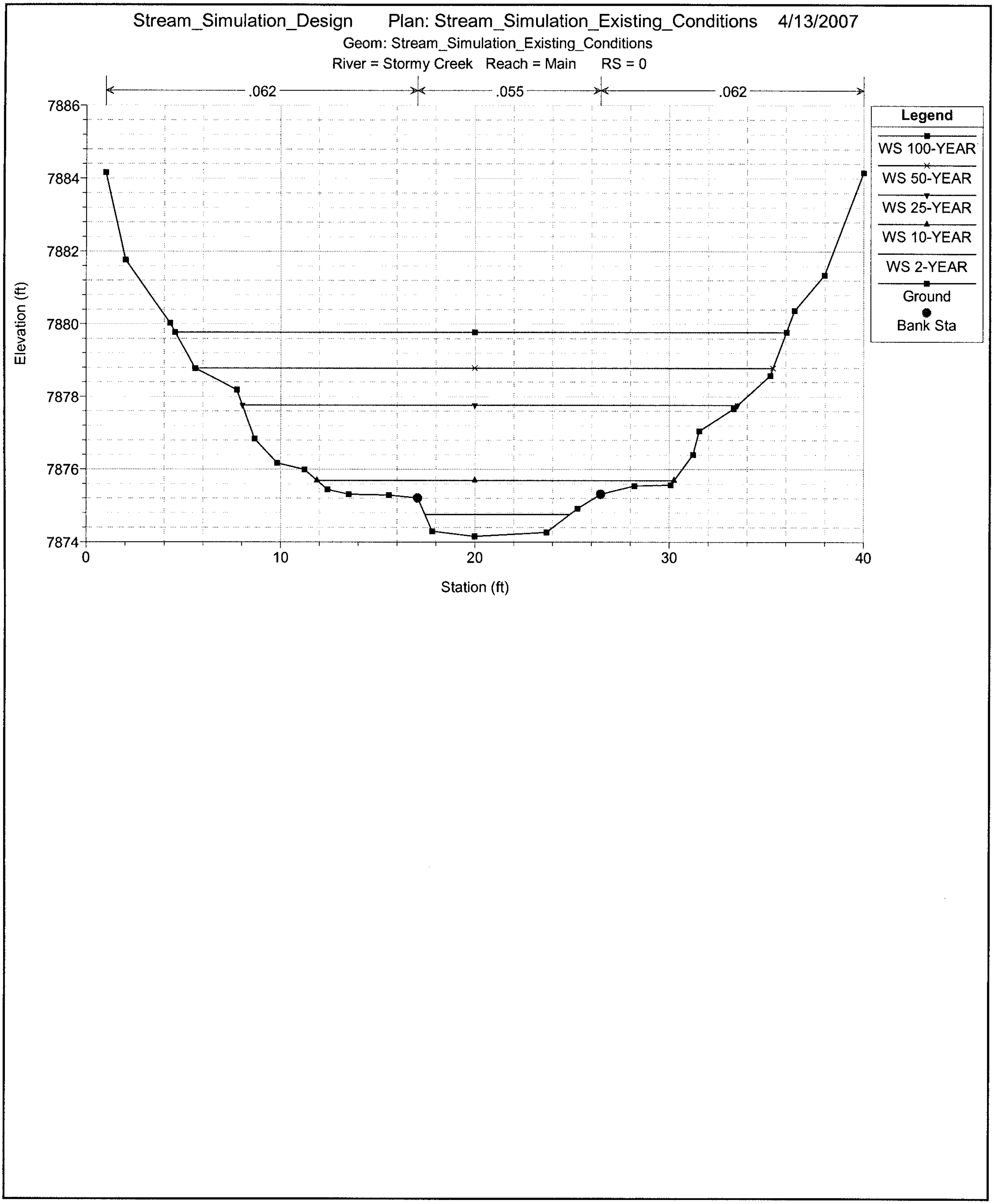
Geom: Stream_Simulation_Existing_Conditions
River = Stormy Creek Reach = Main RS = 200
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta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Geom: Stream_Simulation_Existing_Conditions
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.062
.055
.062
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta
Elevation (ft)
7886
7884
7882
7880
7878
7876
7874
0
10
20
30
40
Station (ft)

HEC-RAS Plan: Existing River: Stormy Creek Reach: Main

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	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/s)	(sq ft)	(ft)	
Main	1000	7.00	7889.16	7889.64	7889.64	7889.82	0.064837	3.34	2.09	6.01	1.00
Main	1000	47.00	7889.16	7890.47	7890.47	7890.82	0.032256	4.97	11.25	17.63	0.84
Main	1000	342.00	7889.16	7893.53	7892.20	7893.89	0.006998	5.68	78.13	25.30	0.49
Main	1000	576.00	7889.16	7898.95	7893.08	7899.06	0.000770	3.29	246.46	34.42	0.19
Main	1000	880.00	7889.16	7900.59	7894.00	7900.75	0.000996	4.16	303.63	35.66	0.22
Main	800	7.00	7886.60	7888.02	7887.00	7888.03	0.000407	0.54	13.39	16.45	0.09
Main	800	47.00	7886.60	7889.14	7887.71	7889.17	0.001196	1.50	35.45	21.70	0.18
Main	800	342.00	7886.60	7893.24		7893.35	0.001145	3.00	141.66	29.72	0.21
Main	800	576.00	7886.60	7898.89		7898.95	0.000305	2.38	323.79	34.57	0.12
Main	800	880.00	7886.60	7900.49		7900.60	0.000453	3.16	380.21	35.89	0.15
Main	700	7.00	7885.60	7888.02		7888.02	0.000041	0.26	29.19	19.69	0.03
Main	700	47.00	7885.60	7889.10		7889.11	0.000352	1.02	51.87	22.09	0.10
Main	700	342.00	7885.60	7893.16		7893.25	0.000761	2.66	158.76	29.99	0.18
Main	700	576.00	7885.60	7898.87		7898.93	0.000243	2.23	343.63	34.75	0.11
Main	700	880.00	7885.60	7900.46		7900.56	0.000371	2.99	399.92	36.07	0.14
Main	650	7.00	7887.10	7887.99		7888.01	0.003130	0.99	7.08	13.00	0.24
Main	650	47.00	7887.10	7888.99		7889.06	0.003965	2.17	22.94	18.69	0.31
Main	650	342.00	7887.10	7893.03		7893.19	0.001764	3.46	119.75	28.99	0.26
Main	650	576.00	7887.10	7898.84		7898.91	0.000348	2.48	304.84	34.32	0.13
Main	650	880.00	7887.10	7900.41		7900.54	0.000509	3.27	359.90	35.62	0.16
Main	625	7.00	7886.97	7887.60	7887.60	7887.78	0.065664	3.40	2.06	5.85	1.01
Main	625	47.00	7886.97	7888.39	7888.39	7888.79	0.048978	5.12	9.33	12.19	1.00
Main	625	342.00	7886.97	7892.91		7893.13	0.002628	4.12	102.11	26.26	0.32
Main	625	576.00	7886.97	7898.81		7898.90	0.000442	2.79	278.43	32.83	0.15
Main	625	880.00	7886.97	7900.37		7900.52	0.000639	3.66	330.84	34.38	0.18
Main	600	7.00	7883.16	7884.22	7883.71	7884.25	0.003327	1.38	5.08	8.50	0.26
Main	600	47.00	7883.16	7885.94	7884.62	7886.09	0.003683	3.04	15.44	17.38	0.33
Main	600	342.00	7883.16	7892.40	7888.05	7893.02	0.002971	6.31	54.16	31.96	0.37
Main	600	576.00	7883.16	7898.84	7889.98	7898.88	0.000154	1.86	425.05	39.00	0.08
Main	600	880.00	7883.16	7900.42	7892.14	7900.49	0.000246	2.52	486.60	39.00	0.11
Main	599	Culvert									
Main	548	7.00	7882.38	7882.91	7882.91	7883.09	0.064486	3.46	2.02	5.73	1.01
Main	548	47.00	7882.38	7883.84	7883.84	7884.44	0.040288	6.22	7.56	8.55	0.98
Main	548	342.00	7882.38	7887.27	7887.27	7889.56	0.026699	12.16	28.12	24.51	0.99
Main	548	576.00	7882.38	7889.20	7889.20	7892.46	0.023890	14.49	39.75	27.00	0.99
Main	548	880.00	7882.38	7891.36	7891.36	7895.69	0.021820	16.71	52.68	29.72	0.99
Main	538	7.00	7881.33	7882.52	7881.98	7882.55	0.003015	1.33	5.24	8.14	0.25
Main	538	47.00	7881.33	7883.35	7882.88	7883.67	0.014738	4.60	10.21	10.76	0.62
Main	538	342.00	7881.33	7885.33	7886.31	7889.04	0.059193	15.45	22.14	18.93	1.42
Main	538	576.00	7881.33	7887.02	7888.27	7891.97	0.047865	17.85	32.26	24.06	1.36
Main	538	880.00	7881.33	7888.95	7890.43	7895.20	0.040118	20.06	43.87	26.88	1.31
Main	528	7.00	7881.78	7882.46		7882.50	0.008381	1.52	4.72	12.11	0.38
Main	528	47.00	7881.78	7883.44		7883.52	0.005359	2.52	23.05	23.26	0.37
Main	528	342.00	7881.78	7883.41	7884.46	7887.83	0.301564	18.70	22.56	23.11	2.75
Main	528	576.00	7881.78	7883.72	7885.23	7890.73	0.382945	23.98	29.95	24.70	3.20
Main	528	880.00	7881.78	7884.05	7886.03	7893.90	0.438796	28.81	38.32	26.01	3.52
Main	458	7.00	7881.03	7881.72		7881.78	0.012734	1.96	3.58	6.63	0.47
Main	458	47.00	7881.03	7882.75		7882.94	0.013464	3.61	14.35	17.15	0.55
Main	458	342.00	7881.03	7884.96	7884.29	7885.43	0.011508	6.43	68.54	29.36	0.60
Main	458	576.00	7881.03	7886.02	7885.09	7886.63	0.010684	7.39	101.43	32.10	0.61
Main	458	880.00	7881.03	7887.12	7885.91	7887.87	0.010247	8.35	137.62	33.49	0.62
Main	400	7.00	7880.16	7880.93	7880.69	7881.00	0.014280	2.06	3.40	6.34	0.50

HEC-RAS Plan: Existing River: Stormy Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	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/s)	(sq ft)	(ft)	
Main	400	47.00	7880.16	7881.98	7881.63	7882.17	0.013311	3.55	14.99	17.89	0.55
Main	400	342.00	7880.16	7884.18		7884.72	0.012878	6.75	63.88	26.30	0.64
Main	400	576.00	7880.16	7885.19		7885.93	0.013056	8.05	91.87	28.95	0.67
Main	400	880.00	7880.16	7886.21		7887.18	0.013383	9.34	122.46	30.95	0.70
Main	200	7.00	7877.16	7877.88		7877.95	0.016265	2.10	3.34	6.75	0.53
Main	200	47.00	7877.16	7878.90		7879.13	0.017406	3.86	12.61	13.89	0.62
Main	200	342.00	7877.16	7880.96	7880.64	7881.68	0.017999	7.56	55.66	25.38	0.74
Main	200	576.00	7877.16	7881.94		7882.89	0.017612	8.92	81.88	28.81	0.77
Main	200	880.00	7877.16	7882.90		7884.10	0.017553	10.22	111.05	31.45	0.79
Main	0	7.00	7874.16	7874.76	7874.56	7874.82	0.015003	1.97	3.56	7.46	0.50
Main	0	47.00	7874.16	7875.69	7875.41	7875.89	0.015014	3.69	14.42	18.37	0.58
Main	0	342.00	7874.16	7877.76	7877.19	7878.36	0.015017	7.06	60.53	25.47	0.68
Main	0	576.00	7874.16	7878.79	7878.07	7879.60	0.015017	8.45	88.50	29.75	0.71
Main	0	880.00	7874.16	7879.78	7879.07	7880.81	0.015018	9.69	118.83	31.46	0.74

Plan: Existing Stormy Creek Main RS: 599 Culv Group: Culvert #1 Profile: 25-YEAR

Q Culv Group (cfs)	342.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	13.54
Q Barrel (cfs)	342.00	Culv Vel DS (ft/s)	13.86
E.G. US. (ft)	7893.02	Culv Inv El Up (ft)	7883.16
W.S. US. (ft)	7892.40	Culv Inv El Dn (ft)	7882.38
E.G. DS (ft)	7889.56	Culv Frctn Ls (ft)	0.77
W.S. DS (ft)	7887.27	Culv Exit Loss (ft)	0.69
Delta EG (ft)	3.46	Culv Entr Loss (ft)	1.99
Delta WS (ft)	5.13	Q Weir (cfs)	
E.G. IC (ft)	7892.80	Weir Sta Lft (ft)	
E.G. OC (ft)	7893.02	Weir Sta Rgt (ft)	
Culvert Control	Inlet	Weir Submerg	
Culv WS Inlet (ft)	7888.18	Weir Max Depth (ft)	
Culv WS Outlet (ft)	7887.27	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	4.89	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	5.02	Min El Weir Flow (ft)	7898.01

Errors Warnings and Notes

Note:	During the supercritical calculations a hydraulic jump occurred at the outlet of (leaving) the
	culvert.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid,
	energy was used.
Note:	During supercritical analysis, the culvert direct step method went to normal depth. The program
	then assumed normal depth at the outlet.
Note:	The flow in the culvert is entirely supercritical.

Form 6C - Stream Simulation Design Option

Form 6C provides guidance to correctly design a culvert that meets streambed stability requirements, while also satisfying traffic safety, hydraulic impacts, and scour concerns.

The Stream Simulation Design Option requires a second site visit to correctly identify an appropriate reference reach, and to take soil samples in order to perform a sieve analysis. These two items were not included in Form 2 - Site Visit Summary because they can be time consuming, costly, and are not required for the other design options.

An acceptable reference reach is determined by selecting a channel reach that best represents the creek in profile, cross section, and bed material, as well as forming features such as banklines, bed forms, and key features. For this particular example, a reference reach was found about 120 feet upstream of the culvert inlet that was identified as a "plane-bed" channel type having a gravel-cobble bottom. The banks of this reference reach are lined with rocks with a rough diameter range of 8 inches to 18 inches, which qualifies as a ¼ -Ton RSP material class. Based on field observation, a cross section of the reference reach was sketched on Form 6C.

While sketching the reference reach cross section in the field, the channel bankfull width was determined. The bankfull channel is defined by the bankfull discharge, which is the discharge that fills a stable alluvial channel up to the elevation of the active floodplain. Identification of the bankfull channel was based on the determination of the minimum channel width to depth ratio determined from cross sectional measurements of stable channel reaches upstream and downstream of the proposed culvert location. For this particular example, the bankfull channel width was determined at 12 feet. The culvert width for the Stream Simulation Design Option is required to span the bankfull channel; therefore, the proposed culvert width was also 12 feet in diameter.

Within the reference reach, the District Lab collected four samples at random locations from the creek bed in order to perform a sieve analysis of each sample. After reviewing the test results of each sample prepared by the Lab, the average sample was selected and a grain-size distribution curve was developed.

The long profile illustrates or predicts the effects on stream behavior due to an undersized culvert with high velocities. The average equilibrium state is identified, which allows the deposition at the inlet to be removed and the scour pool at the outlet filled.

As a part of the Stream Simulation design process, the streambed and creek features (ie. rock bands, boulder clusters, and banklines) must be analyzed and designed properly to mimic conditions outside the culvert within the culvert. The first step in performing this task is to check bed stability and creek feature stability.

Bed stability is checked by using the average sample test results. The bed material to be placed in the culvert must be stable for a Q_{25} storm at a minimum. If the existing bed material from the reference reach is not stable for a Q_{25}, considering the hydraulic conditions inside the culvert, a new bed-material gradation must be developed that will be stable for at least a Q_{25} storm event.

For this design example, the existing bed material from the reference reach was found to be unstable using Laursen's critical-velocity equation given a Q_{25} storm event. The D_{50} target particle size of the reference reach is 0.85 inches, while the calculated D_{50} is 1.38 inches. Therefore, a parallel and proportional gradation curve was generated using the controlling D_{50} equal to 1.38 inches, which will comprise stable material for a Q_{25} storm event.

Based on the new gradation curve, in addition to bankline and bed features found in the field, a typical cross section of the culvert and interior bed material was created. This simulated streambed also includes a low-flow channel that is intended to provide shape to the initial bed. As calculated, the initial bed will remain stable for Q_{25} flows and less.

Creek feature stability is also checked by determining if the field measured rough rock diameter is appropriate for the Q_{25} storm. A creek feature to be placed in the culvert must be stable for a Q_{25} storm at a minimum. If the existing bed material from the reference reach is not stable for a Q_{25}, considering the hydraulic conditions inside the culvert, a new creek feature RSP class must be selected so that it will be stable for at least a Q_{25} storm event.

The banks of this reference reach are lined with rocks with a rough diameter range of 8 inches to 18 inches, which qualifies as a ¼ -Ton RSP material class. This ¼ -Ton RSP material must be checked for stability.

The proposed average culvert velocity for the Q_{25} storm is 7.4 ft/s calculated by the HEC-RAS model. The corresponding minimum stable diameter found in *Appendix N - Rock Weir Design, Table N-3: Boulder Cluster Design Method - Minimum Rock Diameter*, is approximately 0.45 ft. The minimum stable diameter is equivalent to the rough D_{50} provided in *Table N-1: Caltrans RSP Class Rough Diameter*. A rough D_{50} of 0.45 ft is equivalent to a Caltrans RSP class of cobbles. Therefore, the proposed creek feature RSP class of ¼ -ton will create a more than stable condition in the culvert.

Appendix N - Table N-3: Boulder Cluster Design Method - Minimum Rock Diameter

GENERIC ROCK CLASS	**MIN. STABLE DIAMETER (D_{50}) (inches)**	**τ_c (lb/sf)**	**v_c (ft/s)**
Very Large Boulder	6.67 ft (>80)	37.4	25
Large Boulder	3.33 ft (>40)	18.7	19
Medium Boulder	1.67 ft (>20)	9.3	14
Small Boulder	0.83 ft (>10)	4.7	10
Large Cobble	0.42 ft (>5)	2.3	7
Small Cobble	0.21 ft(>2.5)	1.1	5

Appendix N - Table N-1: RSP Class Rough Diameter

Caltrans RSP CLASS	**ROUGH D_{50} (FEET)**
Cobble	0.66
Backing No. 1	0.95
Light	1.32
¼ Ton	1.79
½ Ton	2.26
1 Ton	2.85
2 Ton	3.59
4 Ton	4.50
8 Ton	5.70

Although no specific species, depth, or velocity criteria had to be met, hydraulic analyses for hydraulic impacts and scour were satisfied.

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION — FORM 6C

Project Information			
Route 333 4-Lane		Computed: EKB	Date: 8/29/06
		Checked: LEF	Date: 8/26/06
Stream Name: Stormy Creek	County: Morro	Route: 333	Postmile: 34.1

General Considerations

The **Stream Simulation** method strives to result in the same passage conditions within the culvert as those seen in the selected reference reach, to the extent practical. The Stream Simulation process includes these four steps: 1) Develop long profile and define the reference reach, 2) Establish proposed structure settings and dimensions, 3) Design bed material and shape, and 4) Check bed stability.

Hydrology Results - Peak Discharge Values

50% Annual Probability (2-Year Flood Event)	7 cfs	10% Annual Probability (10-Year Flood Event)	47 cfs
4% Annual Probability (25-Year Flood Event)	342 cfs	2% Annual Probability (50-Year Flood Event)	576 cfs
1% Annual Probability (100-Year Flood Event)	880 cfs		

Develop Long Profile and Define the Reference Reach

Attach channel profile sheet. ☒ Yes ☐ No

Identify reference reach on long profile with characteristics that will be appropriate for the replacement culvert. ☒ Yes ☐ No

Identify channel type and key features that vary depending on the bed mobility. ☒ Yes ☐ No

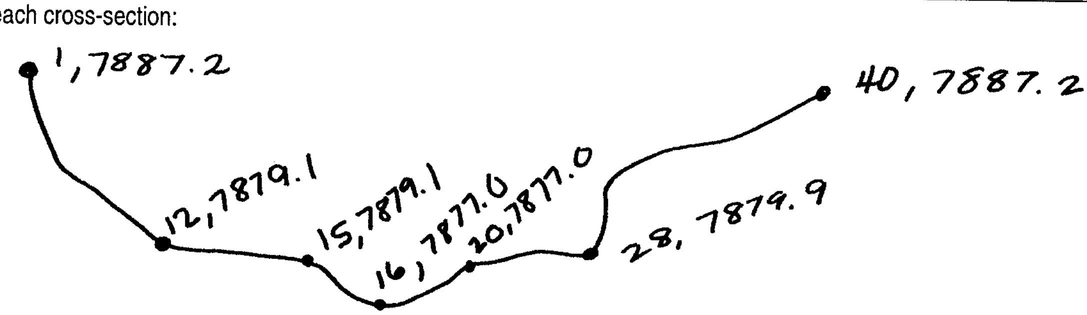
Identify location of bed material samples on profile. ☒ Yes ☐ No

Identify typical channel cross-sections. ☒ Yes ☐ No

Identify channel characteristics and processes on long profile. ☒ Yes ☐ No

Plot stream/culvert profile or range of profiles for consideration. ☒ Yes ☐ No

Illustrate the typical reference reach cross-section:



FISH PASSAGE: STREAM SIMULATION DESIGN OPTION — FORM 6C

Bankfull Channel: The channel defined by the bankfull discharge, which is the discharge that fills a stable alluvial channel up to the elevation of the active floodplain. Identification of the bankfull channel should be based on the determination of the minimum channel width to depth ratio determined from cross sectional measurements of stable channel reaches upstream and downstream of the proposed culvert location.

Bankfull channel width = 12 ft

Estabilsh Proposed Culvert Settings and Dimensions

Culvert Width: Culvert width is the width needed to span the bankfull channel. If permanent banklines are constructed of rock, adequate culvert width must be provided to span the bed plus the size of the rock on both banks. For an initial estimate of the minimum culvert width, add twice the diameter of the largest material in the bed to the bankfull width. A stability analysis might show that other bed material is needed.

Culvert Width = 12 ft

Culvert Length: Culvert length must be greater than 100 feet

Culvert Length = 140 ft

Culvert Embedment: A circular culvert embedded into the streambed no less than 30% but no more than 50% of its rise is a good practical guide.

Upstream embedment = 3.6 ft	Downstream embedment = 3.6 ft

Culvert Slope Culvert slope does not greatly exceed slope of natural channel, slopes of 6% or less

Upstream invert elevation = 7883.16 ft (NGVD 29 [circled] or NAVD 88)	Downstream invert elevation = 7881.03 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: °

Barrel Characteristics

Diameter: 144 in	Fill height above culvert: approx. 8.8 ft
Height/Rise: ft	Length: 140 ft
Width/Span: ft	Number of barrels:

Culvert Type	☐ Arch	☐ Box	☒ Circular
	☐ Pipe-Arch	☐ Elliptical	

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION — FORM 6C

Culvert Material	☐ HDPE ☐ Spiral Rib / Corrugated Metal Pipe	☐ Steel Plate Pipe	☐ Concrete Pipe

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

Outlet Characteristics

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

Summarize Proposed Bridge Physical Characterstics N/A

Bridge Physical Characteristics

Elevation of high chord (top of road): ft (NGVD 29 or NAVD 88)	Elevation of low chord: ft (NGVD 29 or NAVD 88)

Channel Lining	☐ No lining	☐ Concrete	☐ Rock	☐ Other

Pier Characteristics (if applicable) ☐

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

Define Bed Material and Shape

Create reference grain-size distribution curve from reference reach material. ☒ Yes ☐ No

Bed Stability Analysis

1. Establish bed design flows	25-Year design storm, Q = 342 cfs
2. Determine average water depth in culvert	Culvert inlet water depth, y = 4.09 ft
	Culvert outlet water depth, y = 4.37 ft

	Average water depth, y =	4.23 ft
3. Determine average water velocity in culvert	Culvert inlet velocity, V_c =	7.12 ft/s
	Culvert outlet velocity, V_c =	6.68 ft/s
	Average culvert velocity, V_c =	6.90 ft/s

4) Solve the bed stability equation by calculating D_{50} using Laursen's Equation.

Solve Laursen's equation for Culvert bed material D_{50} Where V_c is critical velocity above which bed material of size D and smaller will be transported, (ft/s), y is average depth of flow within the culvert structure, (ft), and D_{50} is particle size in a mixture of which 50 percent are smaller, (ft).	$D_{50} = (V_c / 11.17y^{1/6})^3$	D_{50} = 0.115 (1.38 in) ft

5. Is the calculated D_{50} equal to or less than the reference reach D_{50}? ☐ Greater than or equal to ☒ Less than

If greater than or equal to, use reference bed material in culvert. ☐

If less than, adjust reference grain-size distribution curve to match caclulated D_{50}. ☒

Creek Feature Stability Analysis (ie. Rock bands, Boulder Clusters, Banklines)

1. Establish bed design flows	25-Year design storm, Q =	342 cfs
2. Determine average water velocity in culvert	Culvert inlet velocity, V_c =	7.12 ft/s
	Culvert outlet velocity, V_c =	7.68 ft/s
	Average culvert velocity, V_c =	7.40 ft/s
3. Determine average field rock size diameter	Average field rock size diameter, D_{field} =	1/4-ton 1.79 ft
4. Select minimum stable diameter (D_{50}) corresponding to average culvert velocity	Minimum stable diameter, D_{50} =	0.45 ft
5. Calculated Caltrans RSP Class rough diameter	Calculated Caltrans RSP Class rough diameter, D_{rsp} =	0.66 ft

If minimum stable diameter is greater than average field rock size diameter, the average field rock size diameter must be increased.
If minimum stable diameter is less than the average field rock size diameter, select the corresponding RSP class rough diameter.

6. Selected Caltrans RSP Class	Selected Caltrans RSP Class = Cobble

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION	FORM 6C

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: 7891.56 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: 7897.56 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 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 impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in 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.

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 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

Water surface elevation at inlet for the 10-year peak discharge: 7884.38 ft

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

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

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge: 25-Year

Range of velocities for Inlet transition:	7.82	ft/s	to		ft/s
Range of velocities for Culvert portion:	7.12	ft/s	to	6.68	ft/s

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION	FORM 6C

Range of velocities for Outlet Transition:	7.06 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 verfiy, 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	Difference	100-Year WSEL	100-Year WSEL	Difference
	Existing Conditions (ft)	Future Conditions (ft)	(ft)	Existing Conditions (ft)	Future Conditions (ft)	(ft)
1 400	7881.98	7881.98	0	7886.21	7886.21	0
2 548/458	7883.84	7882.75	-1.09	7891.36	7887.22	-4.14
3 600	7885.94	7884.50	-1.44	7900.42	7893.06	-7.36
4 800	7889.33	7888.04	-1.29	7900.49	7894.56	-5.93

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☒ No — Maximum elevation: 7897.56 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

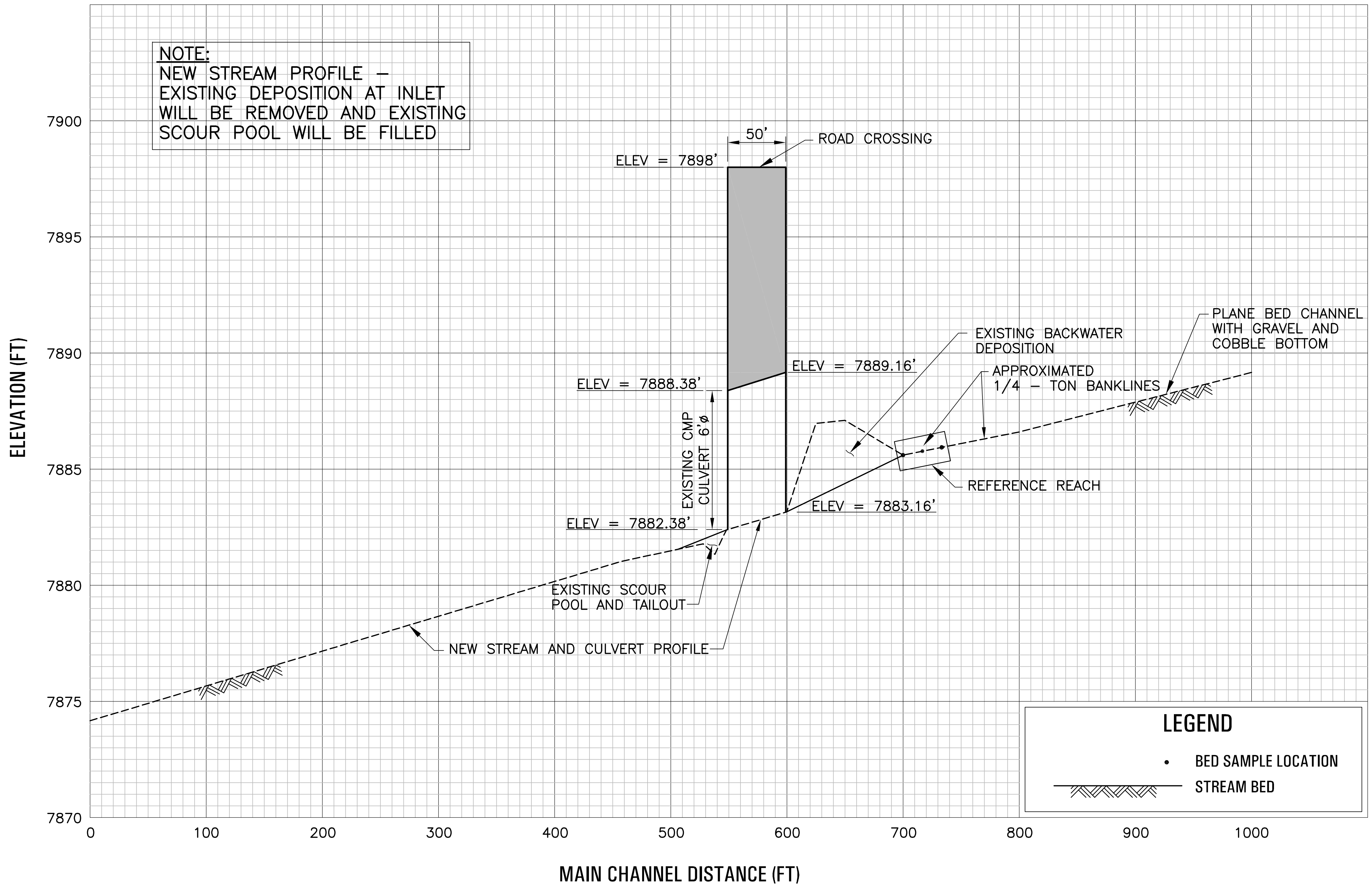
If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

Proposed Profile Drawing Attached ☒ Yes ☐ No

Hydraulic Analysis Index Sheet Attached ☒ Yes ☐ No

Bed Stability Analysis Calculations Attached ☒ Yes ☐ No

Grain-Size Distribution Curve Attached ☒ Yes ☐ No



Project Manager	LEF
Designed	EKB
Designed	
Checked	
Drawn	AJ

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

Route 333 6 Lane at Stormy Creek

STREAM SIMULATION DESIGN

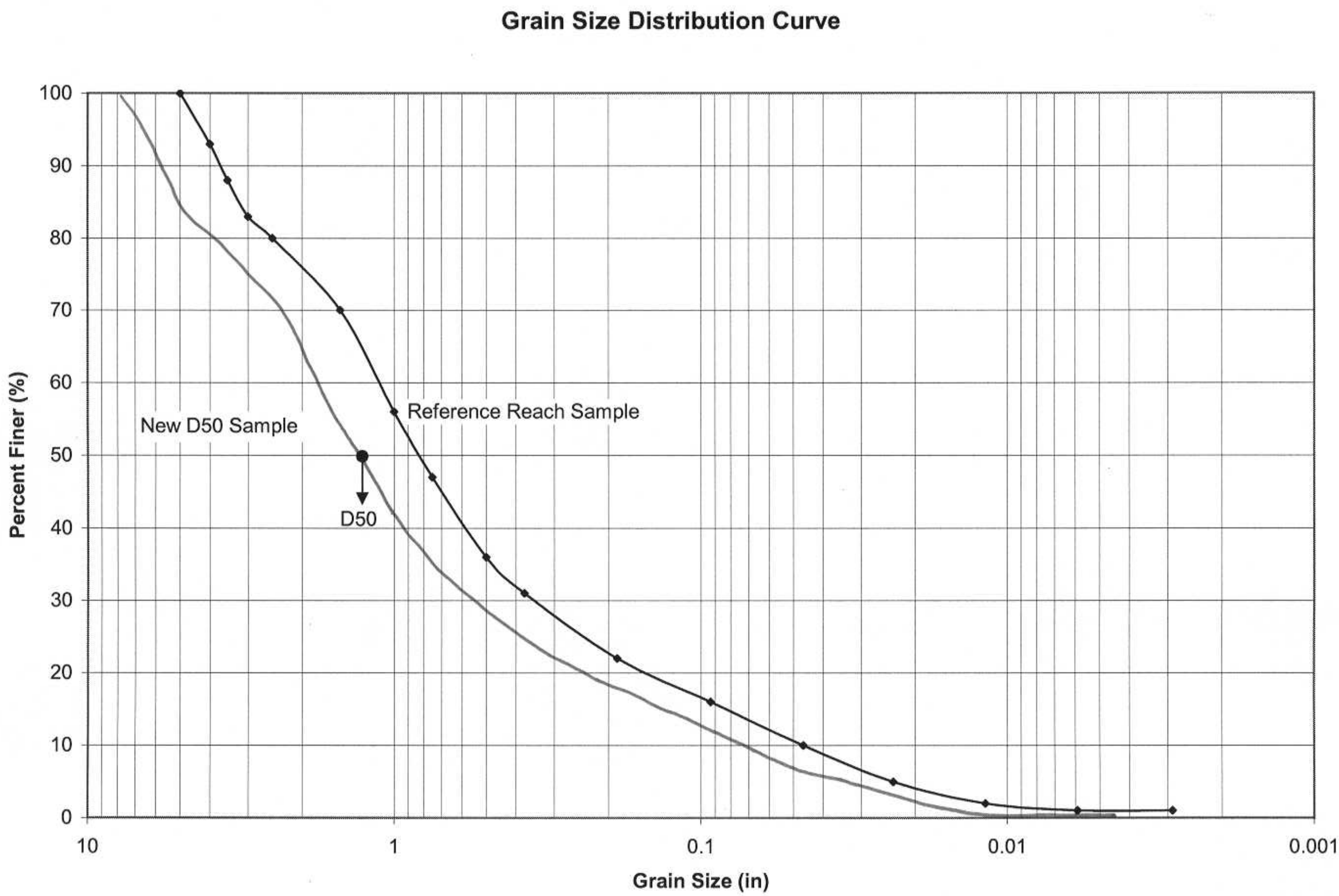
LONG PROFILE

Date	Project No.	Drawing No.	Issue
	06938–38713	1	

Scale: HORIZ: 1" = 50' VERT: 1" = 5'

File Name: Stream–Stimulation–exist.DWG

P:/06938/38713 TO7 Fish Passage/5.0 Project Data/AutoCAD/General Details/Stream–Stimulation–exist.DWG
05–10–07 AJACKSON 18:23:23



Grain Size Distribution Curve
Percent Finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
0.001
Grain Size (in)
New D50 Sample
Reference Reach Sample
D50

Bed Stability Computation Summary

Project Information:		Route 333 4-Lane	Computed:	EKB	Date:	6/31/2006
			Checked:	LEF	Date:	7/1/2006
Stream Name:	Stormy Creek	County: Mono	Route:	333	Postmile:	12.8

Calculations:

1) Establish Bed Design Flows

25-Year Design Storm, Q = 342 cfs

2) Determine Average Water Depth in culvert:

inlet depth: 7887.25 ft - 7883.16 ft = 4.09 ft
outlet depth: 7885.40 ft - 7881.03 ft = 4.37 ft

average depth: 4.09 ft + 4.37 ft / 2 = 4.23 ft

3) Determine Average Velocity in culvert:

inlet velocity: 7.12 ft/s
outlet velocity: 6.68 ft/s

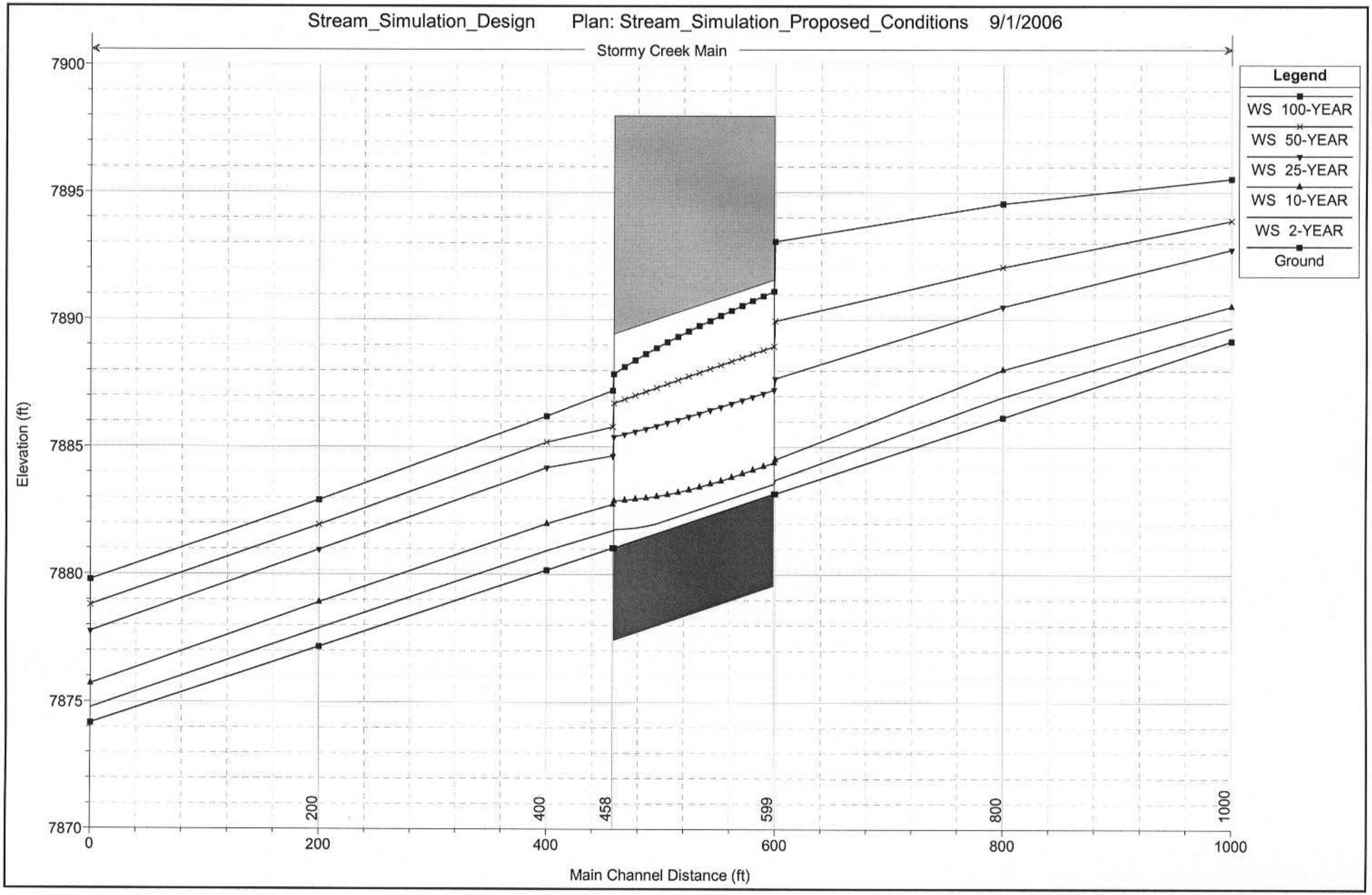
average velocity: 7.12 ft/s + 6.68 ft/s / 2 = 6.90 ft/s

4) Solve for D50

Larsen's Equation was selected to solve for D50

D50 = (Vc / 11.17 y^(1/6))^3
D50 = (6.90 ft/s / 11.17 * (4.23 ft^(1/6)))^3

D50 = 0.115 ft = 1.38 in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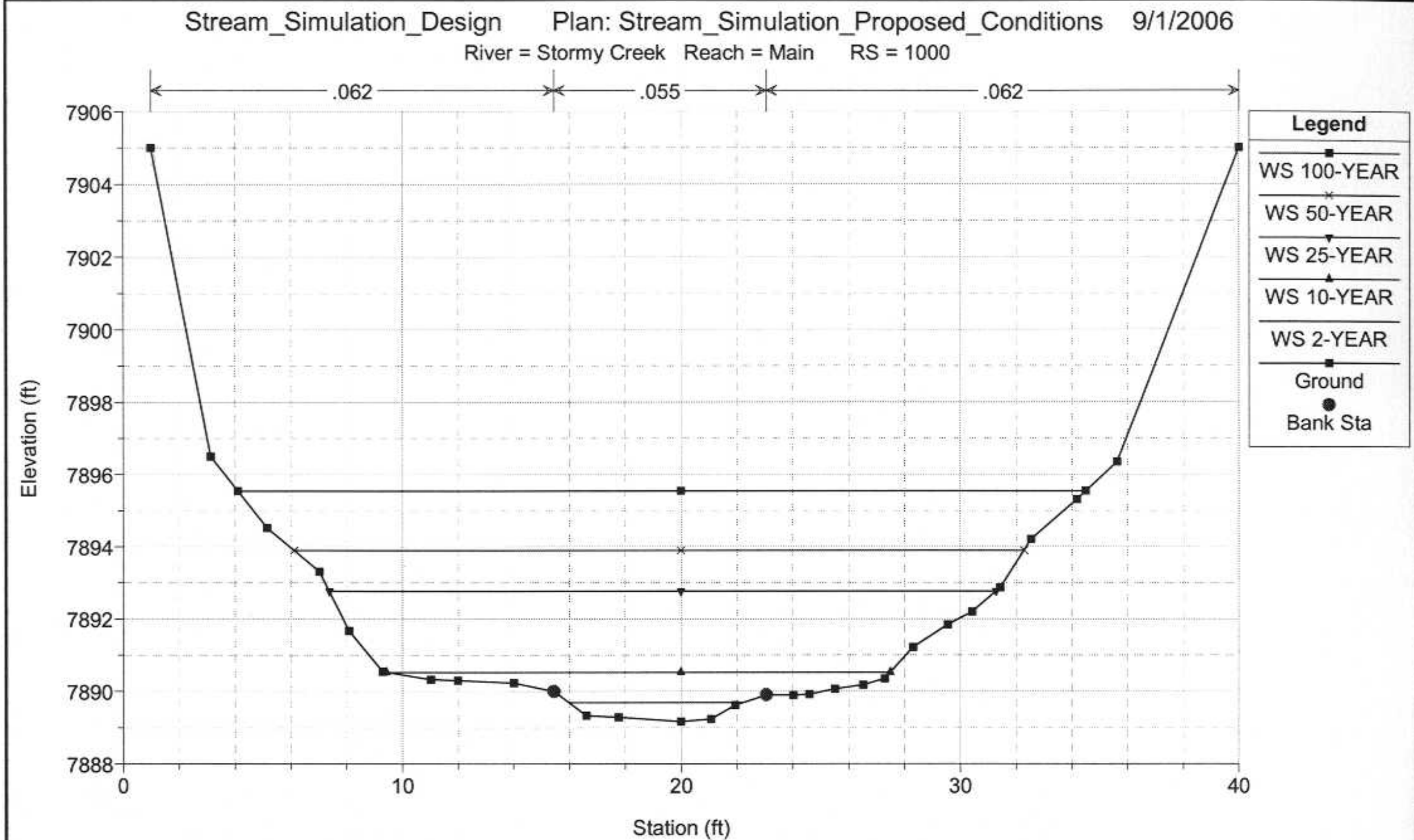
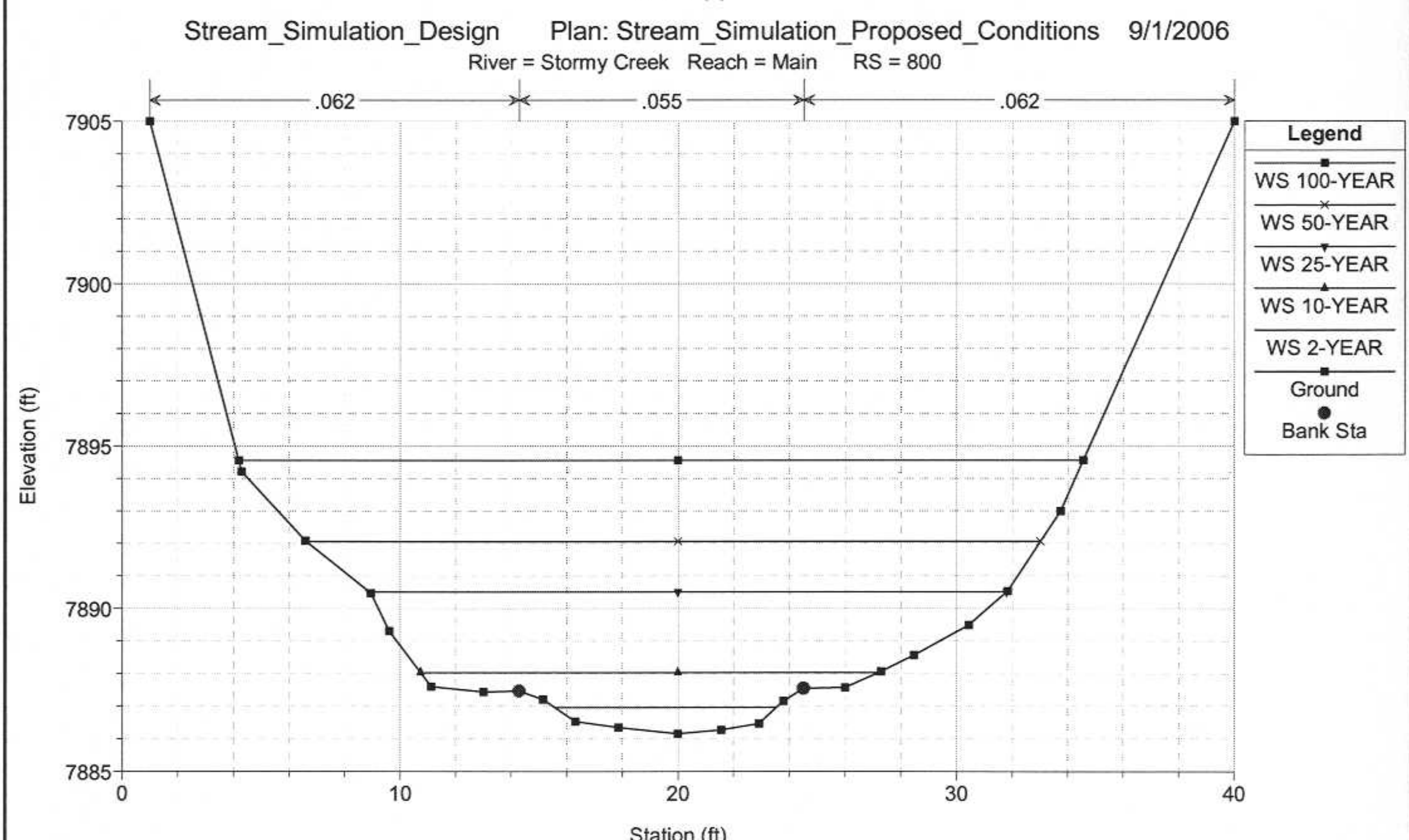
Stormy Creek Main
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Elevation (ft)
7900
7895
7890
7885
7880
7875
7870
200
400
458
599
800
1000
0
200
400
600
800
1000
Main Channel Distance (ft)



Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 1000
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta



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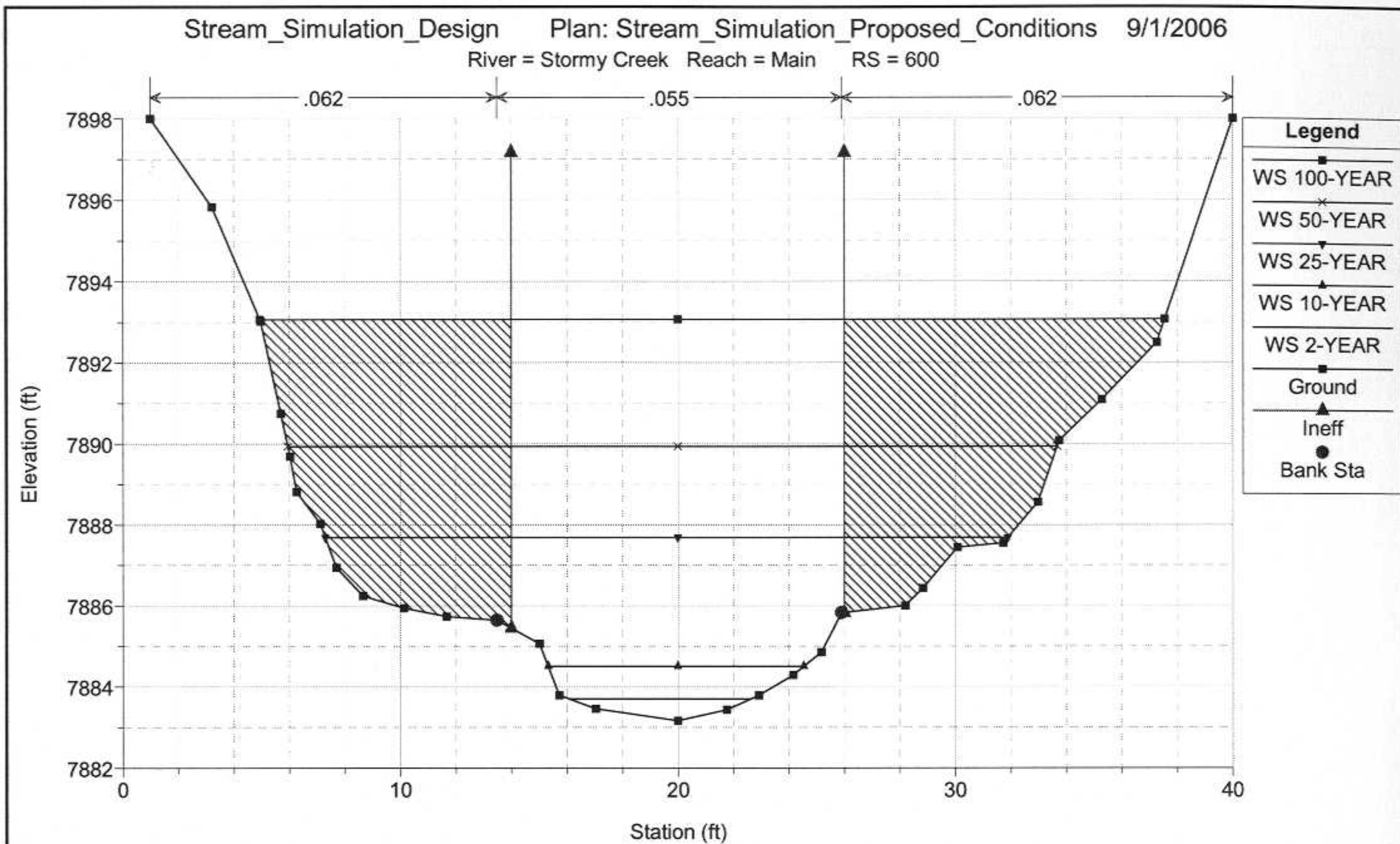
River = Stormy Creek Reach = Main RS = 800
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta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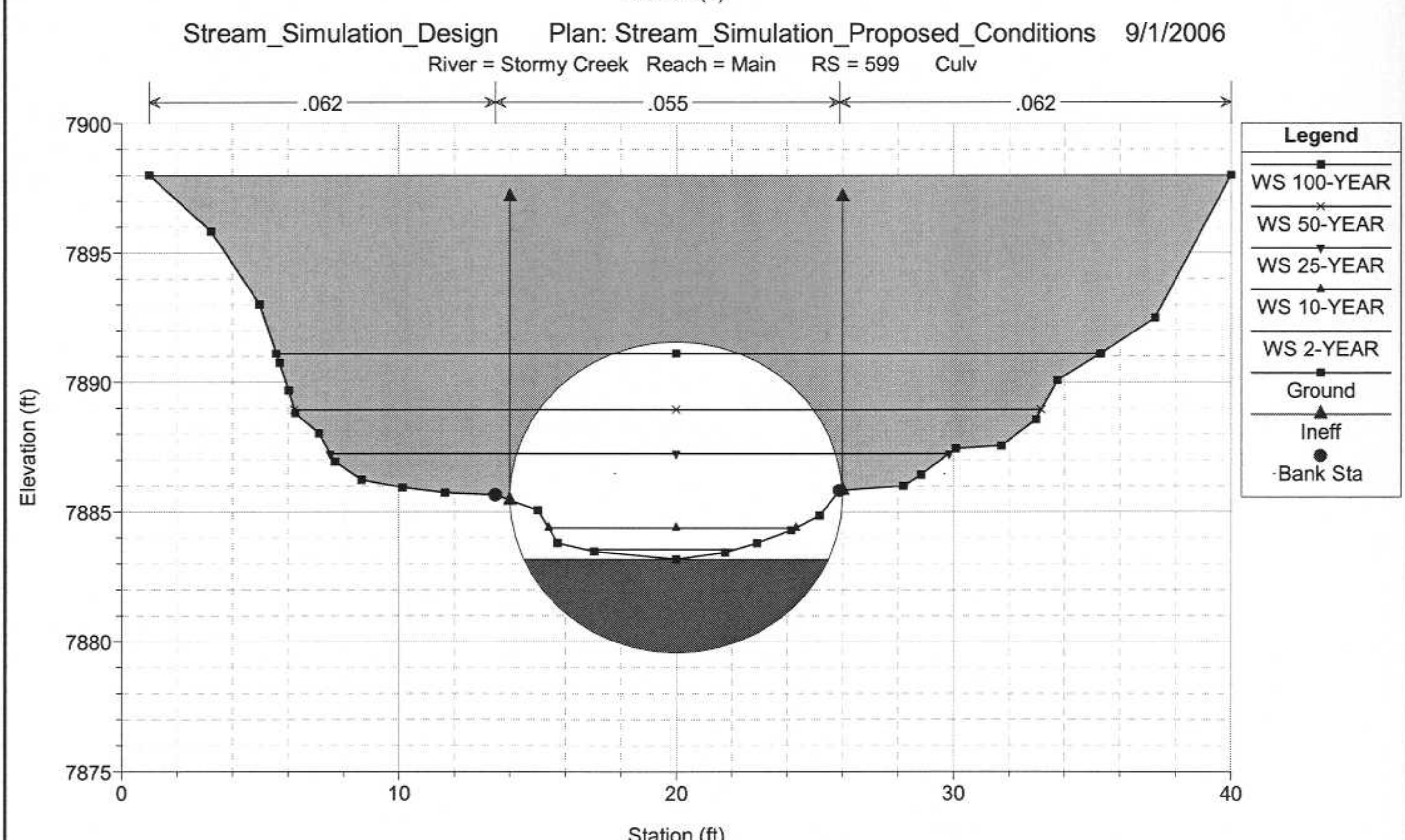
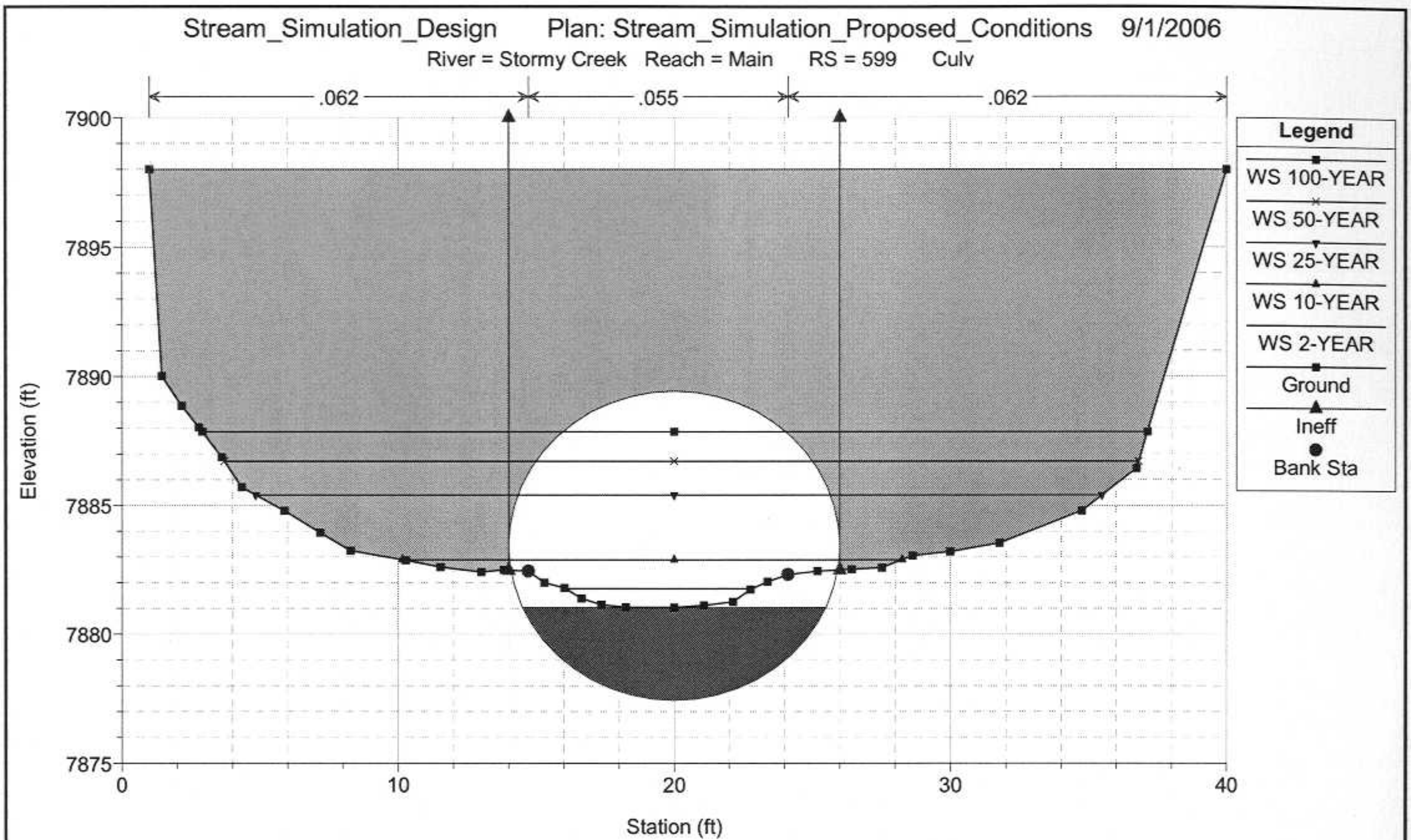
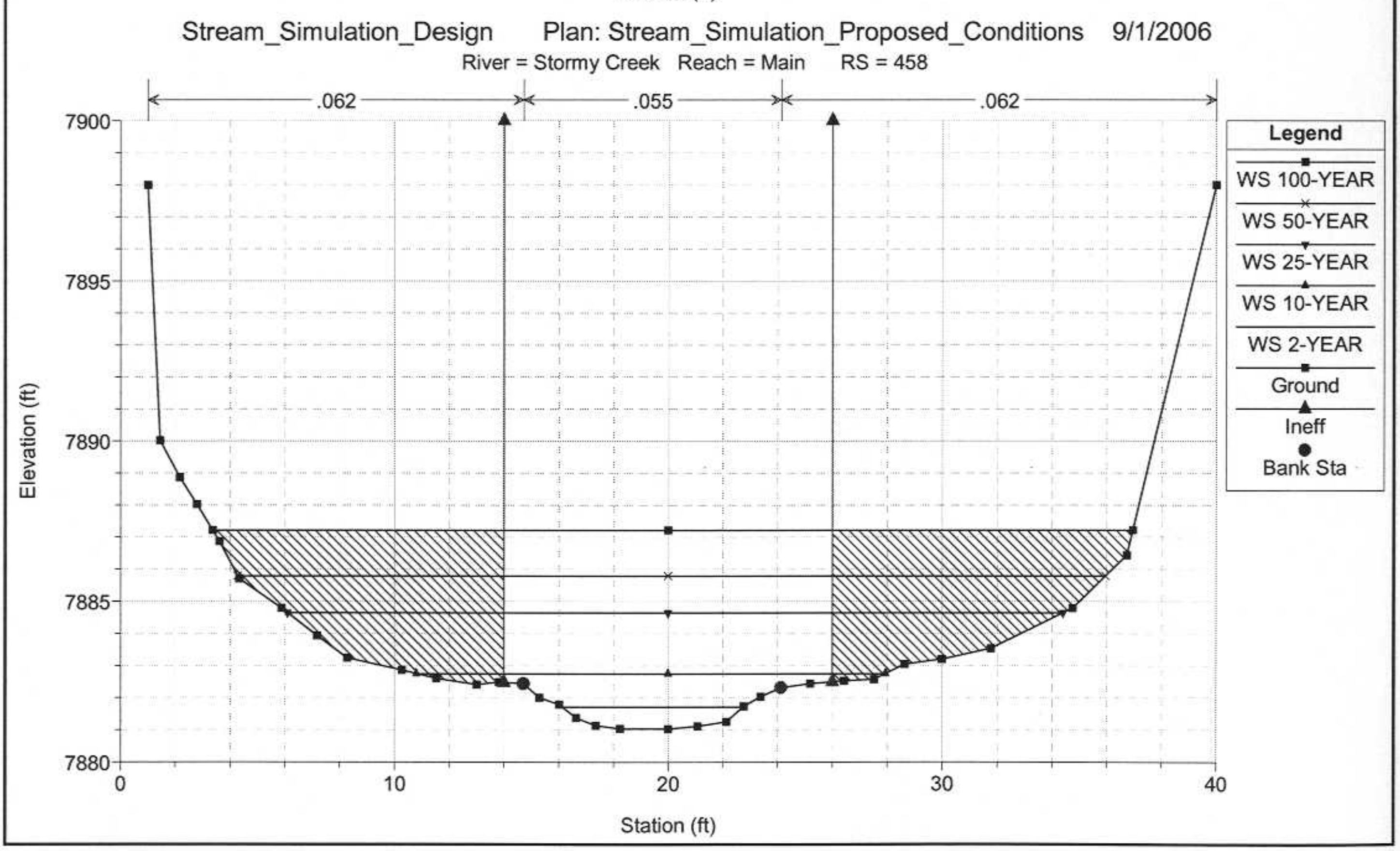
River = Stormy Creek Reach = Main RS = 600
.062
.055
.062
Elevation (ft)
7898
7896
7894
7892
7890
7888
7886
7884
7882
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 599 Culv
.062
.055
.062
Elevation (ft)
7900
7895
7890
7885
7880
7875
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 599 Culv
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta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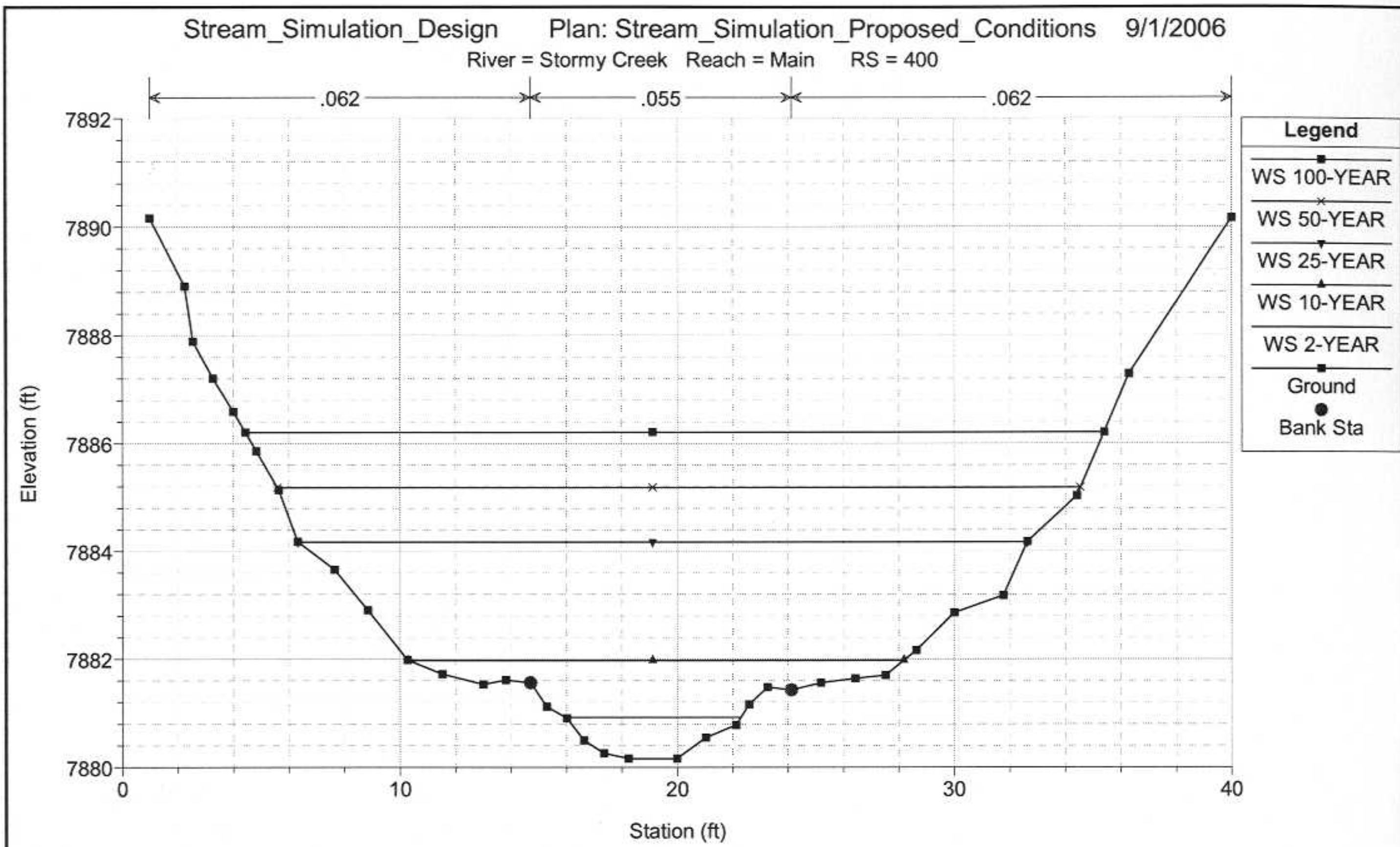
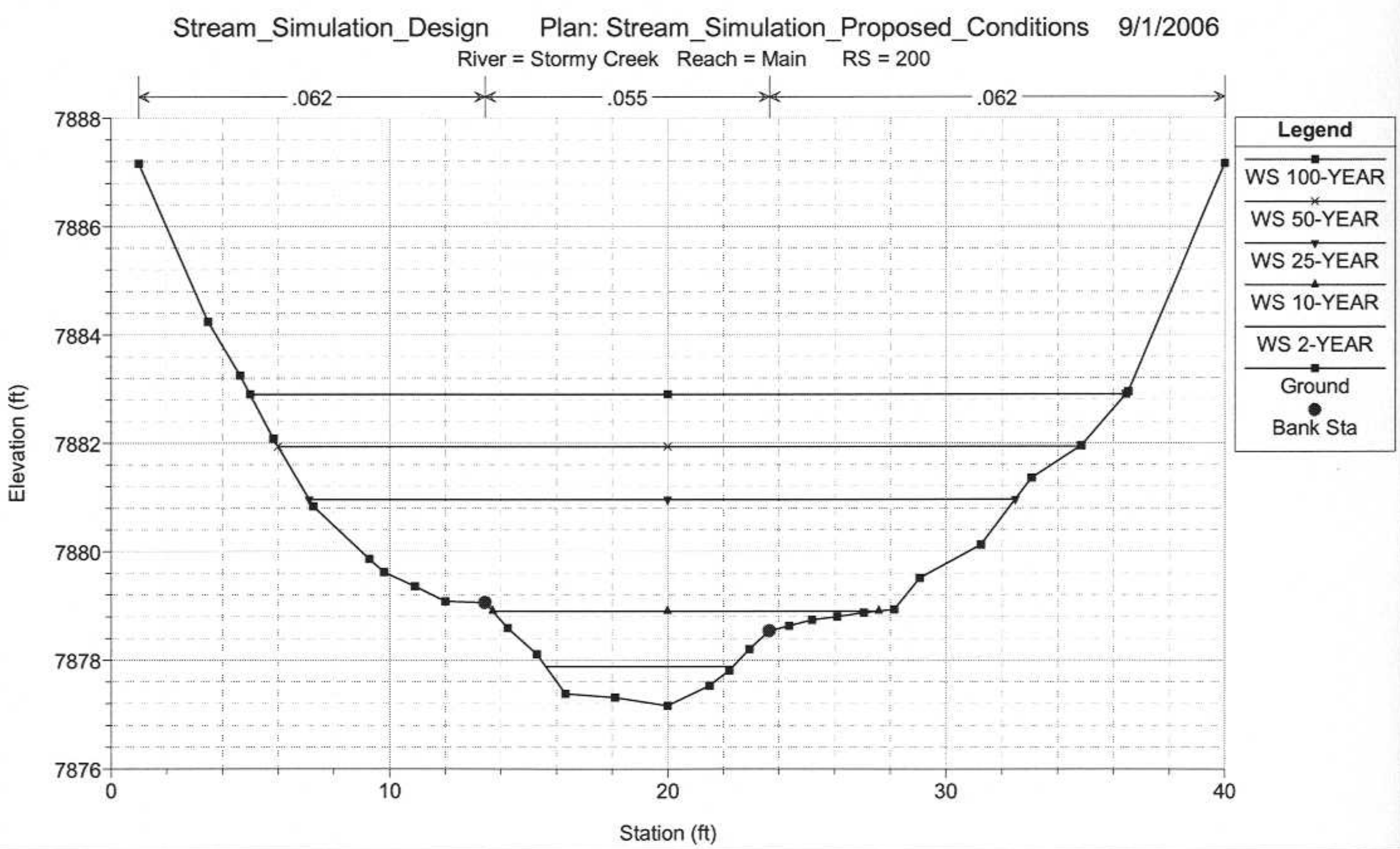
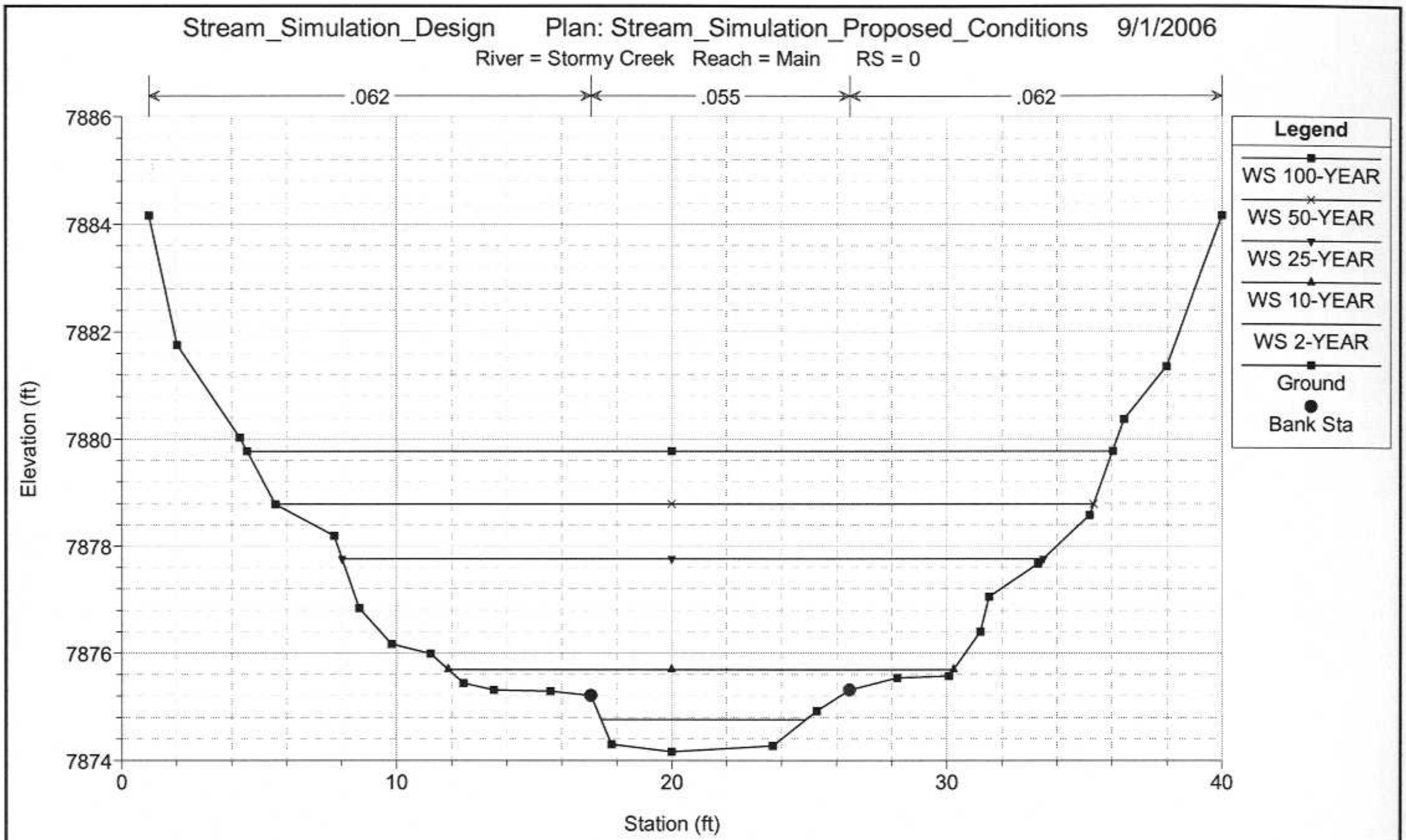
River = Stormy Creek Reach = Main RS = 458
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Ineff
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 400
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 200
.062
.055
.062
Elevation (ft)
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta


Stream_Simulation_Design Plan: Stream_Simulation_Proposed_Conditions 9/1/2006
River = Stormy Creek Reach = Main RS = 0
.062
.055
.062
Elevation (ft)
7886
7884
7882
7880
7878
7876
7874
0
10
20
30
40
Station (ft)
Legend
WS 100-YEAR
WS 50-YEAR
WS 25-YEAR
WS 10-YEAR
WS 2-YEAR
Ground
Bank Sta

HEC-RAS Plan: Proposed River: Stormy Creek Reach: Main

Reach	River Sta	Profile	Q Total	W.S. Elev	Min Ch El	Diff	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/s)	(sq ft)	(ft)	
Main	0	2-YEAR	7.00	7874.76	7874.16	0.60	7874.56	7874.82	0.015003	1.97	3.56	7.46	0.50
Main	0	10-YEAR	47.00	7875.69	7874.16	1.53	7875.41	7875.89	0.015014	3.69	14.42	18.37	0.58
Main	0	25-YEAR	342.00	7877.76	7874.16	3.60	7877.19	7878.36	0.015017	7.06	60.53	25.47	0.68
Main	0	50-YEAR	576.00	7878.79	7874.16	4.63	7878.07	7879.60	0.015017	8.45	88.50	29.75	0.71
Main	0	100-YEAR	880.00	7879.78	7874.16	5.62	7879.07	7880.81	0.015018	9.69	118.83	31.46	0.74
Main	200	2-YEAR	7.00	7877.88	7877.16	0.72		7877.95	0.016265	2.10	3.34	6.75	0.53
Main	200	10-YEAR	47.00	7878.90	7877.16	1.74		7879.13	0.017406	3.86	12.61	13.89	0.62
Main	200	25-YEAR	342.00	7880.96	7877.16	3.80		7881.68	0.017999	7.56	55.66	25.38	0.74
Main	200	50-YEAR	576.00	7881.94	7877.16	4.78		7882.89	0.017604	8.92	81.90	28.81	0.77
Main	200	100-YEAR	880.00	7882.90	7877.16	5.74		7884.10	0.017547	10.22	111.06	31.46	0.79
Main	400	2-YEAR	7.00	7880.93	7880.16	0.77	7880.69	7880.99	0.014294	2.06	3.40	6.35	0.50
Main	400	10-YEAR	47.00	7881.98	7880.16	1.82	7881.63	7882.16	0.013217	3.54	15.03	17.92	0.55
Main	400	25-YEAR	342.00	7884.18	7880.16	4.02		7884.72	0.012826	6.74	63.97	26.31	0.64
Main	400	50-YEAR	576.00	7885.18	7880.16	5.02	7884.38	7885.92	0.013052	8.05	91.87	28.95	0.67
Main	400	100-YEAR	880.00	7886.21	7880.16	6.05	7885.28	7887.17	0.013336	9.33	122.60	30.96	0.70
Main	458	2-YEAR	7.00	7881.72	7881.03	0.69	7881.49	7881.78	0.012907	1.97	3.56	6.63	0.47
Main	458	10-YEAR	47.00	7882.75	7881.03	1.72	7882.35	7882.96	0.014048	3.69	13.27	17.15	0.57
Main	458	25-YEAR	342.00	7884.65	7881.03	3.62	7884.59	7886.09	0.031092	9.94	36.02	28.32	0.98
Main	458	50-YEAR	576.00	7885.79	7881.03	4.76	7885.79	7887.92	0.030459	12.05	49.76	31.68	1.02
Main	458	100-YEAR	880.00	7887.22	7881.03	6.19	7887.22	7889.95	0.026734	13.63	66.87	33.58	1.00
Main	599		Culvert										
Main	600	2-YEAR	7.00	7883.70	7883.16	0.54	7883.70	7883.87	0.068433	3.29	2.13	6.57	1.02
Main	600	10-YEAR	47.00	7884.50	7883.16	1.34	7884.50	7884.97	0.049529	5.47	8.60	9.22	1.00
Main	600	25-YEAR	342.00	7887.69	7883.16	4.53	7886.89	7888.58	0.015953	7.59	45.16	24.60	0.69
Main	600	50-YEAR	576.00	7889.94	7883.16	6.78	7888.09	7890.93	0.009497	7.99	72.18	27.73	0.57
Main	600	100-YEAR	880.00	7893.06	7883.16	9.90	7889.46	7894.07	0.005505	8.04	109.65	32.60	0.47
Main	800	2-YEAR	7.00	7886.97	7886.16	0.81		7887.00	0.006721	1.50	4.65	7.98	0.35
Main	800	10-YEAR	47.00	7888.04	7886.16	1.88	7887.43	7888.16	0.007664	2.93	17.70	16.49	0.43
Main	800	25-YEAR	342.00	7890.51	7886.16	4.35		7890.99	0.009150	6.20	67.33	22.92	0.55
Main	800	50-YEAR	576.00	7892.06	7886.16	5.90		7892.63	0.007309	6.91	105.59	26.40	0.52
Main	800	100-YEAR	880.00	7894.56	7886.16	8.40		7895.05	0.003997	6.57	177.07	30.37	0.41
Main	1000	2-YEAR	7.00	7889.69	7889.16	0.53	7889.64	7889.82	0.044613	2.94	2.38	6.27	0.84
Main	1000	10-YEAR	47.00	7890.52	7889.16	1.36	7890.47	7890.82	0.026834	4.67	12.10	18.06	0.78
Main	1000	25-YEAR	342.00	7892.77	7889.16	3.61	7892.20	7893.38	0.015607	7.39	59.30	23.90	0.71
Main	1000	50-YEAR	576.00	7893.90	7889.16	4.74	7893.09	7894.70	0.014386	8.61	87.48	26.16	0.72
Main	1000	100-YEAR	880.00	7895.54	7889.16	6.38	7893.99	7896.35	0.010162	8.90	134.01	30.39	0.63

Plan: Proposed Stormy Creek Main RS: 599 Culv Group: Culvert #1 Profile: 25-YEAR

Q Culv Group (cfs)	342.00	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	7.12
Q Barrel (cfs)	342.00	Culv Vel DS (ft/s)	6.68
E.G. US. (ft)	7888.59	Culv Inv El Up (ft)	7879.56
W.S. US. (ft)	7887.69	Culv Inv El Dn (ft)	7877.43
E.G. DS (ft)	7886.09	Culv Frctn Ls (ft)	1.95
W.S. DS (ft)	7884.65	Culv Exit Loss (ft)	0.00
Delta EG (ft)	2.50	Culv Entr Loss (ft)	0.55
Delta WS (ft)	3.04	Q Weir (cfs)	
E.G. IC (ft)	7887.69	Weir Sta Lft (ft)	
E.G. OC (ft)	7888.59	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	7887.25	Weir Max Depth (ft)	
Culv WS Outlet (ft)	7885.40	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	7.66	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	6.59	Min El Weir Flow (ft)	7898.01

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 all species, 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 Stream Simulation 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 site, completing the hydrology and efficiently brainstorming and completing the hydraulic modeling, and finally meeting all requirements of the Stream Simulation Design Option.

Recreating the bankfull within the culvert was a viable alternative to the other design options. Continuous continuity between the culvert and natural channel was possible by using the Stream Simulation Design Option. This method can be extremely beneficial to the passage of fish over lengths greater than 100 ft.

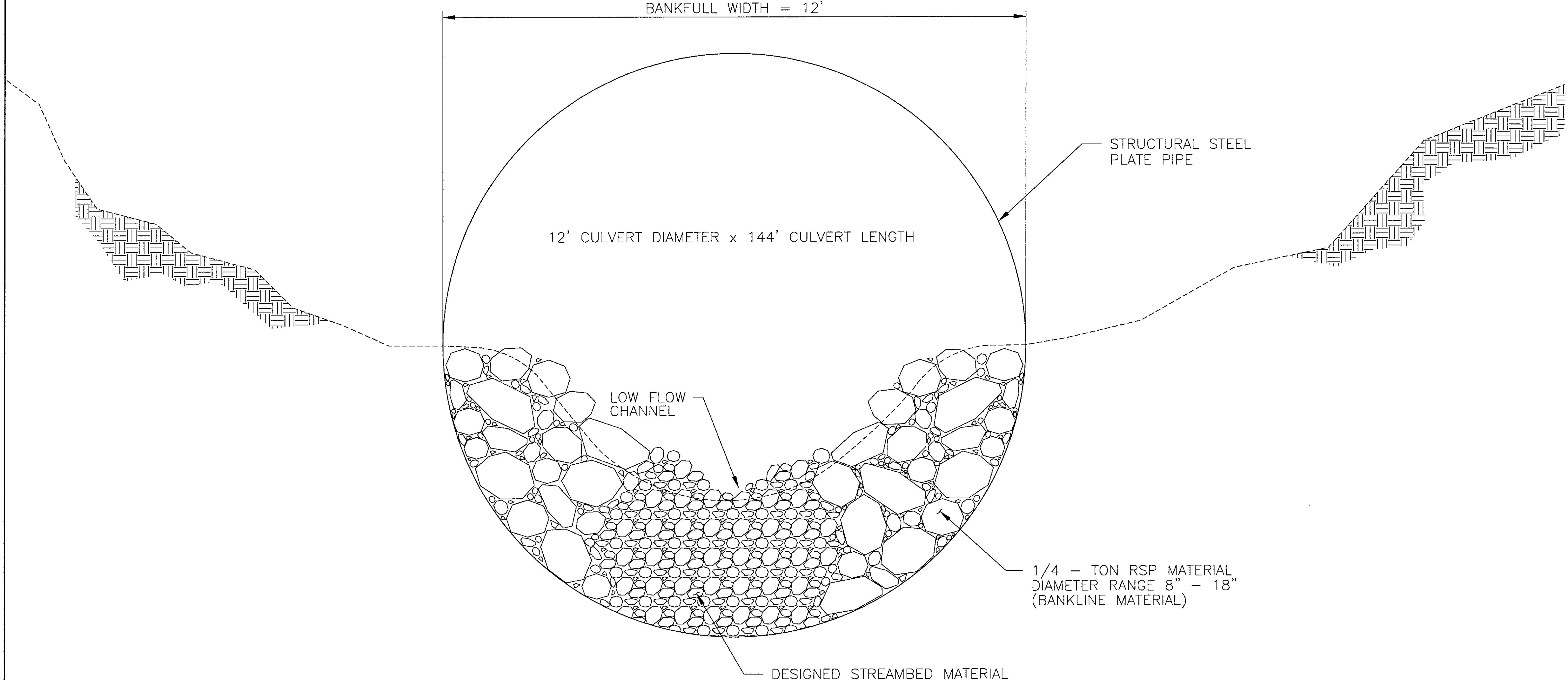
As found in the problem statement, the goal was providing cross drainage for Stormy Creek that met hydraulic standards in the Caltrans Hydraulic Design Manual, as well as fish standards in the California Department of Fish and Game Culvert Criteria and the NOAA Fisheries Guidelines for Salmonid Passage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

Summary Data Table1: Culvert Velocities

Geometry Condition and Flood Event	Permissible Velocity for Intermittent (25 -Year Event) Flows in Unlined Channels (ft/s)	Upstream Velocity in Culvert (ft/s)	Downstream Velocity in Culvert (ft/s)
Existing Conditions 25-Year Event	7.90	5.00	8.00
Proposed Conditions 25-Year Event	7.90	7.82	7.06

Summary Data Table 2: Culvert Depths

Geometry Condition	Flood Event	Water Depth inside Culvert at Inlet (ft)	Water Depth inside Culvert at Outlet (ft)
Existing Conditions	4% Annual Probability (25-Year Event)	5.02	4.89
Proposed Conditions	4% Annual Probability (25-Year Event)	4.09	4.37



P:/06938/38713 T07 Fish Passage/5.0 Project Data/AutoCAD/General Details/Culvert-Detail.DWG
09-28-06 AJACKSON 11:29:20

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

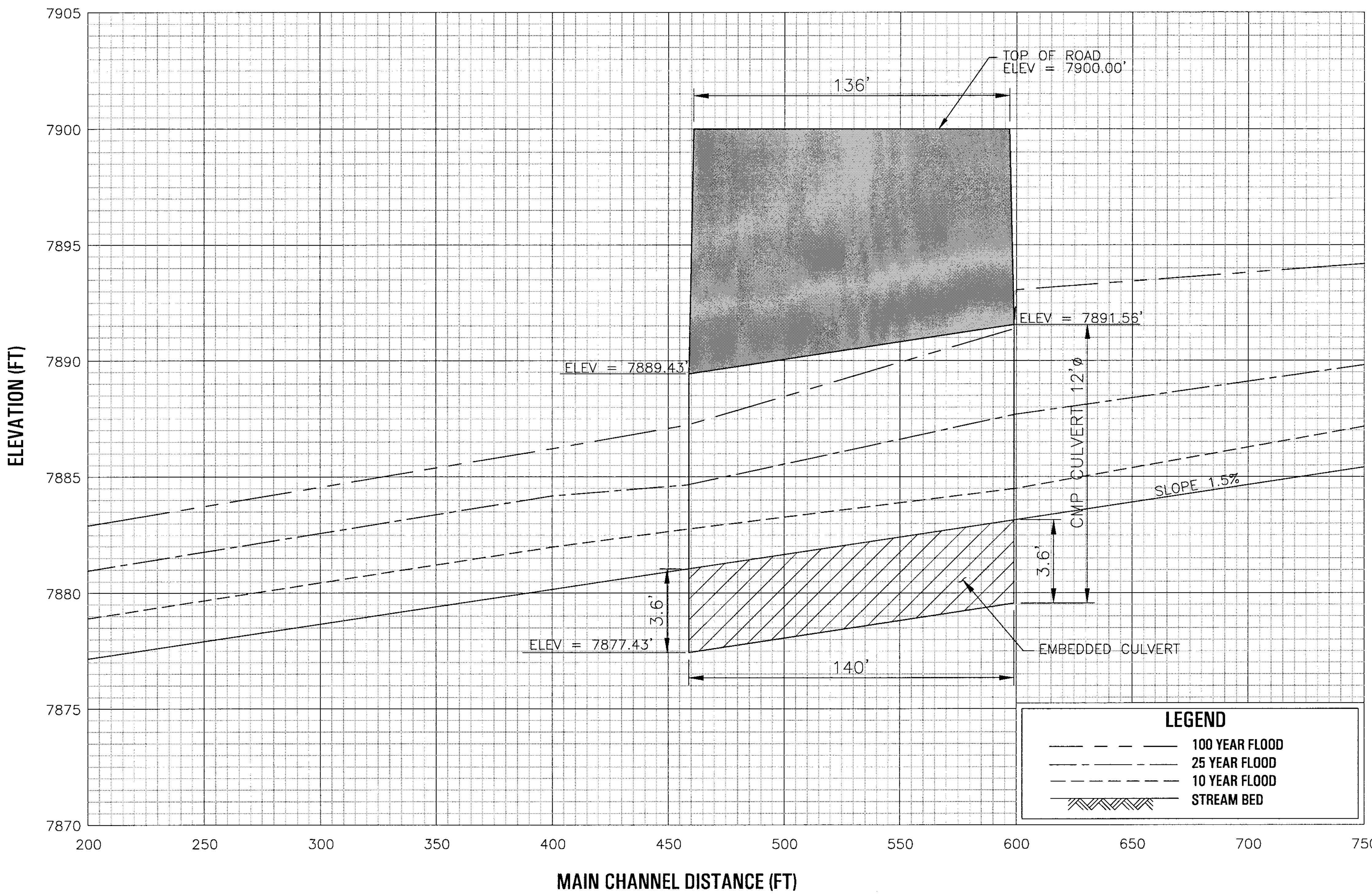
Project Manager: LEF
Designed: EKB
Designed:
Checked: JJL
Drawn: AJ

ROUTE 333 4 LANE
@ STORMY CREEK

STREAM SIMULATION DESIGN

PROPOSED CULVERT CONDITIONS

Date:
Scale: 1" = 1'
Project No.: 06938-38713
File Name: Culvert-Detail.DWG
Drawing No.: 1
Issue:



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

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

Route 333 6 Lane at Stormy Creek

STREAM SIMULATION DESIGN

PROPOSED CONDITIONS

Date:
Project No.: 06938-38713
Drawing No.: 1
Issue:
Scale: HORIZ: 1" = 50' VERT: 1" = 5'
File Name: Stream-Stimulation.DWG

P:/06938/38713 T07 Fish Passage/5.0 Project Data/AutoCAD/General Details/Stream-Stimulation.DWG
09-01-06 AJACKSON 14:24:47