Fish Passage Culvert Design Issues

I. Overview

II. Design Criteria

A. Hydraulic (depth, velocity)

B. Physical (bed roughness, slope, width)

C. Morphology (aggrading, degrading, equilibrium)

III. Culvert Design Methods

A. Highway (No Fish Passage)

B. Hydraulic

C. Morphological

IV. North Fork Little Joe Creek

A. Culvert Alternatives

B. Hydraulic Results

C. Cost Summary

V. Future Research Needs & Design Criteria

U.S. Forest Service
R-6 REGIONAL GUIDANCE FOR
FISH-PASSAGE STRUCTURE DESIGN

This guidance sets expectations for fish-passage design for new structures and replacements. Priority setting, design, and monitoring must be accomplished as part of an interdisciplinary process.

Fish passage should be our first concern for crossings of fish-bearing streams. There are other design considerations that include, in order of importance, (a) minimizing the consequences of plugging and overtopping, including the ability to prevent diversion; (b) hydraulic capacity, including the requirement that headwater depth be less than, or equal to, the height of the culvert, and (c) cost.

1. Designs will meet or exceed state requirements and guidance for fish passage.

2. All designs should provide passage for all species and life stages present at that location, unless there is a biological reason to separate or exclude populations.

3. Structure opening width should not constrict the stream or accelerate velocity at 2-year high flow (bank full width). Active channel width or bed width are also used in describing this dimension. Use the most appropriate measure that ensures that the stream is not constricted by the structure.

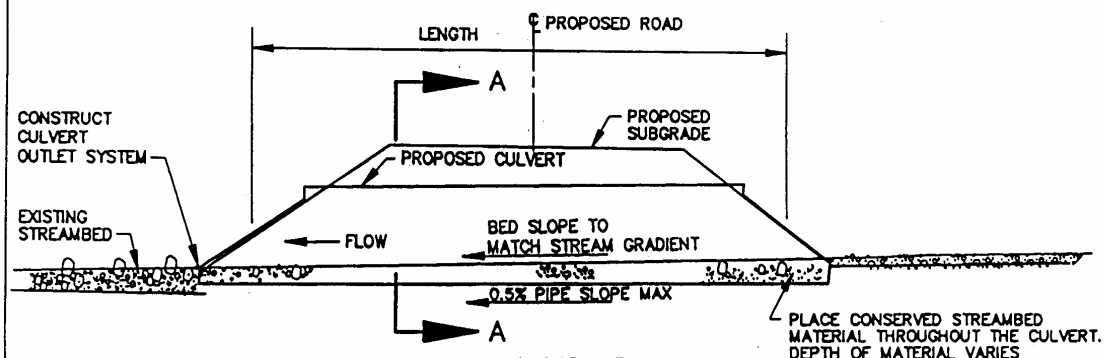
4. The natural stream gradient and substrate material, above and below the structure, will be simulated through the structure. The use of bridges, open-bottom arches, or closed pipes partially buried in the streambed is encouraged.

5. Baffles, weirs, and other mechanical devices inside the culvert should only be employed when the simulation or use of natural stream bottoms is not physically possible. Baffles or weirs should only be used by experienced designers.

6. Culvert replacement and retrofit projects should be prioritized using the fish passage culvert inventory in conjunction with watershed and roads analysis.

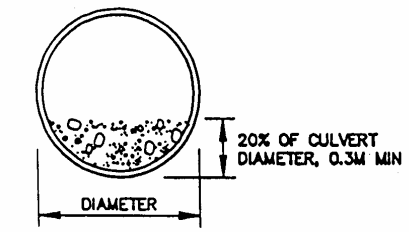
7. Crossing structures should conform to the natural stream gradient. Instream structures should not be relied upon to modify stream elevations for new installations and replacements.

PROPOSED NON-BAFFLED CULVERT INSTALLATION



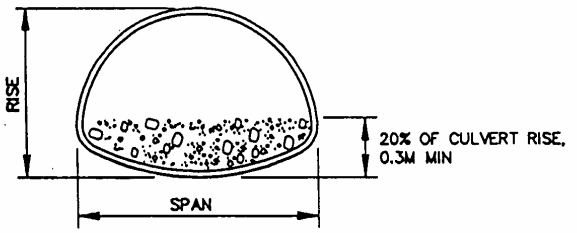
PROFILE

NOT TO SCALE



SECTION A-A

NOT TO SCALE



SECTION A-A

NOT TO SCALE

NOTES:

1. Conserve suitable material encountered in the excavation for use as streambed material.
2. Place conserved streambed material in the culvert to match the existing streambed slope as closely as possible. If sufficient streambed material is not available, use material with a gradation comparable to the natural stream.
3. Place riprap on face of culvert inlet and outlet.
4. Headwater pipe rise ratio ≤ 1.5 for 25 year peak flow.

PROPOSED CULVERT INSTALLATION

NEAR: KLAWOCK

PRINCE OF WALES ISLAND, AK

APPLICATION BY:
Federal Highway Administration

November 1995 Sheet 2 of 4

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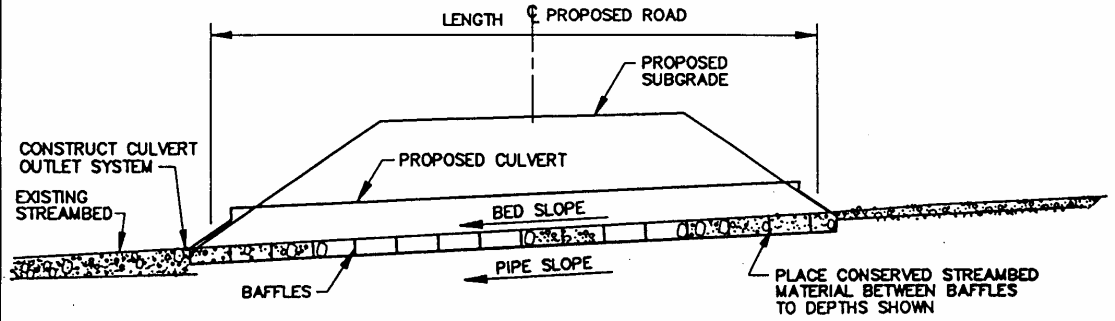
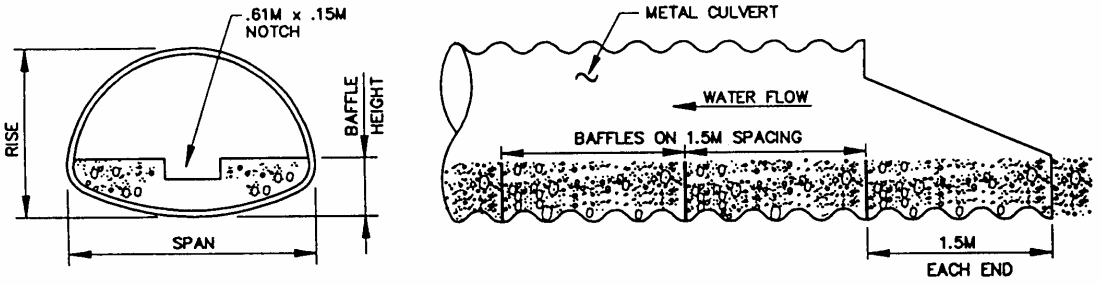
PROPOSED BAFFLED CULVERT INSTALLATION



PROFILE

NOT TO SCALE



BAFFLED CULVERT DETAIL

NOT TO SCALE

NOTES:

1. Conserve suitable material encountered in the excavation for use as streambed material.
2. Place conserved streambed material in the culvert to match the existing streambed gradient as closely as possible. If sufficient streambed material is not available, use material with a gradation comparable to the natural stream.
3. Place riprap around the culvert inlet. The riprap should extend from the culvert base to 0.6M above the culvert top. The riprap should have a width equivalent to twice the culvert diameter.
4. All baffles to be 3/8" galv steel plate, A36 steel.
5. Headwater/pipe rise ratio ≤1.5 for 25 year peak flow.

PROPOSED CULVERT INSTALLATION

NEAR: KLAWOCK

PRINCE OF WALES ISLAND, AK

APPLICATION BY:
Federal Highway Administration

November 1995 Sheet 1 of 4

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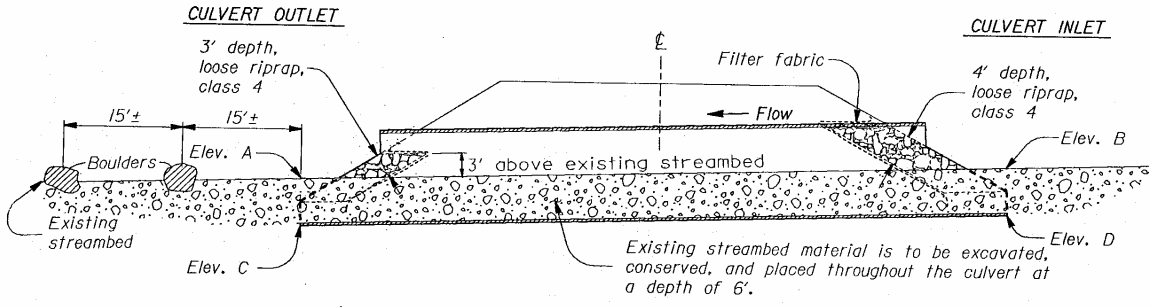
MIDDLE FORK JOHN DAY (MFJD), OREGON. 1988.

VINEGAR CREEK, MFJD, OREGON. 1991.

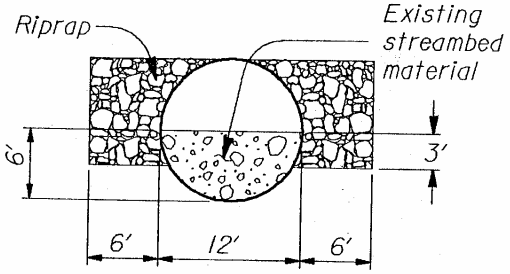


ROUND PIPE INSTALLATION

CULVERT LOCATIONS

Stream	Station	Size	Streambed Elev.		Pipe Invert Elev.		Streambed Slope*
			A	B	C	D	
Vinegar	97+14	144″	4015.8	4018.2	4009.8	4012.2	3.3%
Vincent	138+10	144″	3991.3	3993.7	3985.3	3987.7	2.5%
Caribou	223+00	144″	3962.6	3966.2	3956.6	3960.2	4.1%
Little Boulder	299+56	144″	3903.5	3907.2	3897.5	3901.2	4.7%

* The pipe shall be laid on the same slope as the approximeted streambed slope shown.



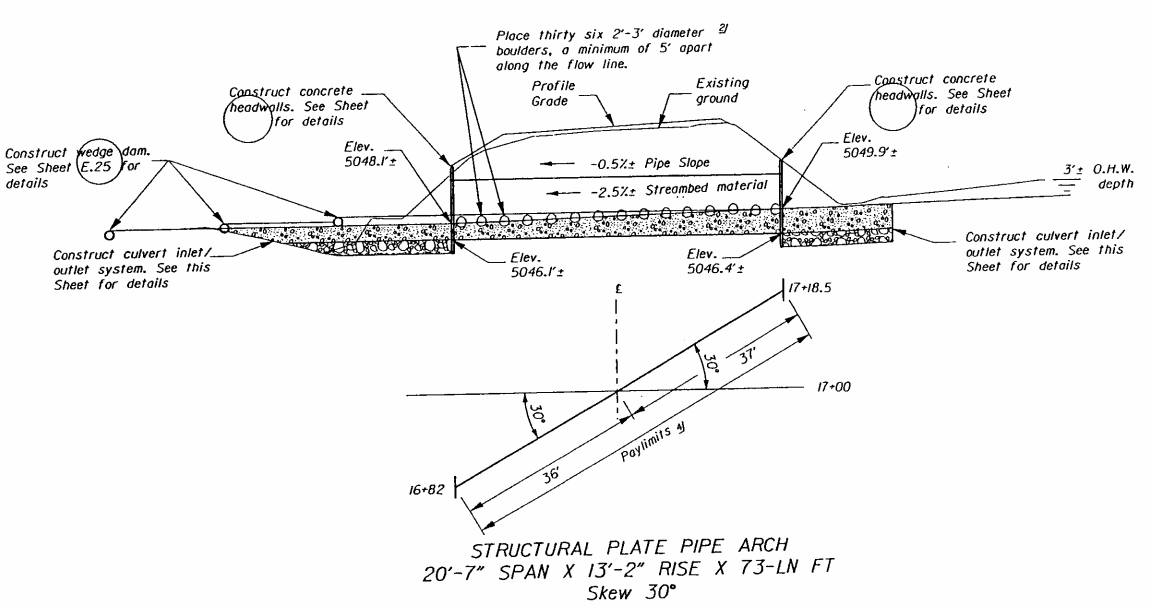
SECTION A-A

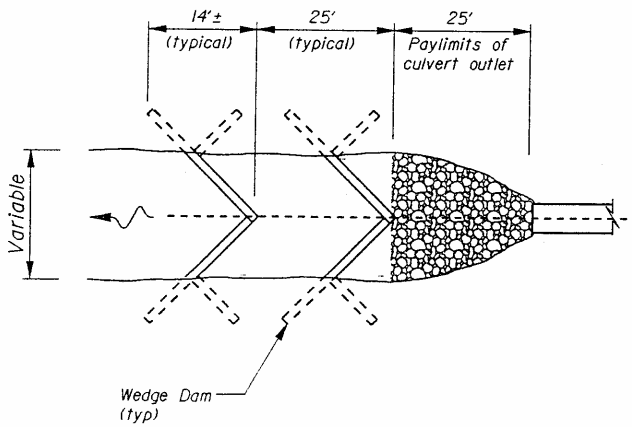
MIDDLE FORK JOHN DAY (MFJD), OREGON. 1988.

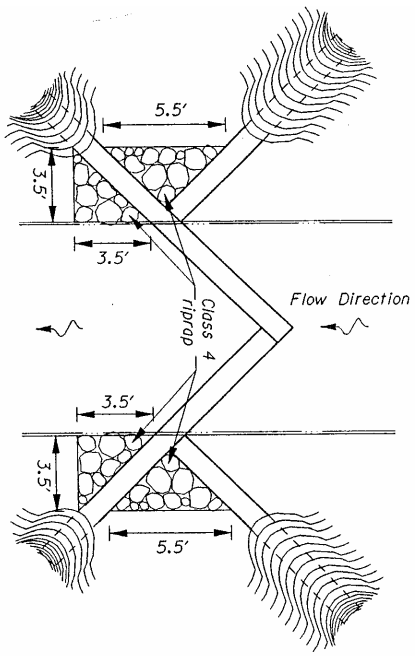
CARIBOU CREEK, MFJD, OREGON. 1991.

NORTH FORK SALMON RIVER, IDAHO. 1996.

STA 17±, OUTLET (UPPER), INLET (LOWER)







NORTH FORK SALMON RIVER, IDAHO. 1996.

NORTH FORK SALMON RIVER, IDAHO. 1996.

STA 28±, INLET (UPPER), OUTLET (LOWER)

NORTH FORK SALMON RIVER, IDAHO. 1996.

STA 28± - LOG WEDGE DAMS AT OUTLET (LOWER PHOTO)

UPSTREAM CHANNEL

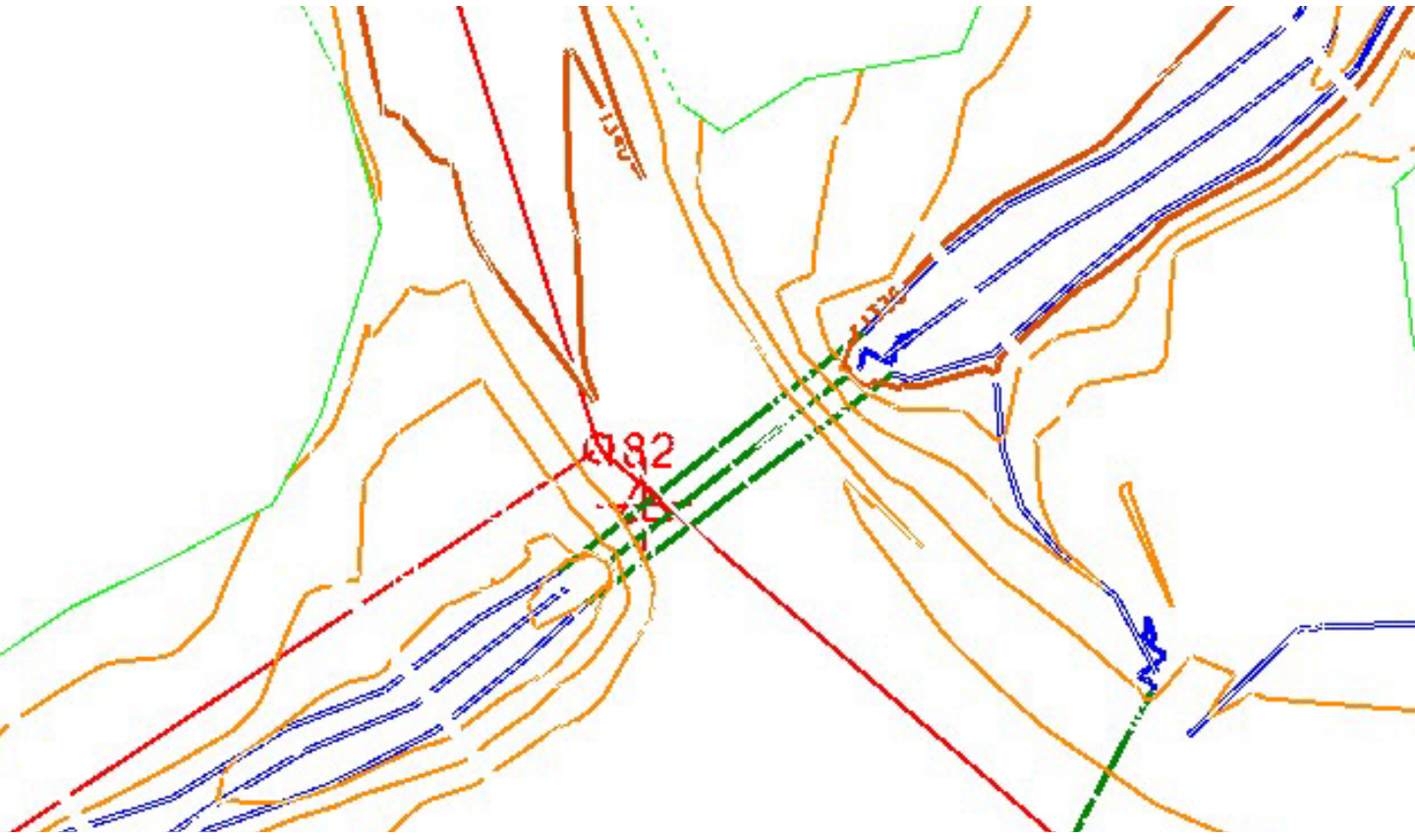
DOWNSTREAM CHANNEL

NORTH FORK LITTLE JOE CREEK (NFLJ), MONTANA. 2000.

NFLJ, CULVERT INLET, 2000.

NFLJ, CULVERT BARREL, 2000. FACING D/S.

NFLJ, CULVERT OUTLET, 2000.



NFLJ CULVERT, PLAN VIEW

NFLJ CULVERT, SITE DATA

Existing 23 m (75') x 1.8 m (6') x 2.8 m (9.33') arch with baffles, Installed in 1972

2-Year Flood (Q_2): 2.18 m^3/s (77 cfs)

50-Year Flood (Q_{50}): 6.17 m^3/s (218 cfs)

D_{50} : 75 mm (3 inches)

Bed Material: Very coarse gravel with cobbles

Bed Width: 3 to 4 m (10' to 13')

Bank full Width: 5 to 6 m (15' to 20')

Hydraulic Depths (Q_2): 0.2 to 0.5 m (0.75' to 1.5')

Typical Stream Slopes: 3% to 6%

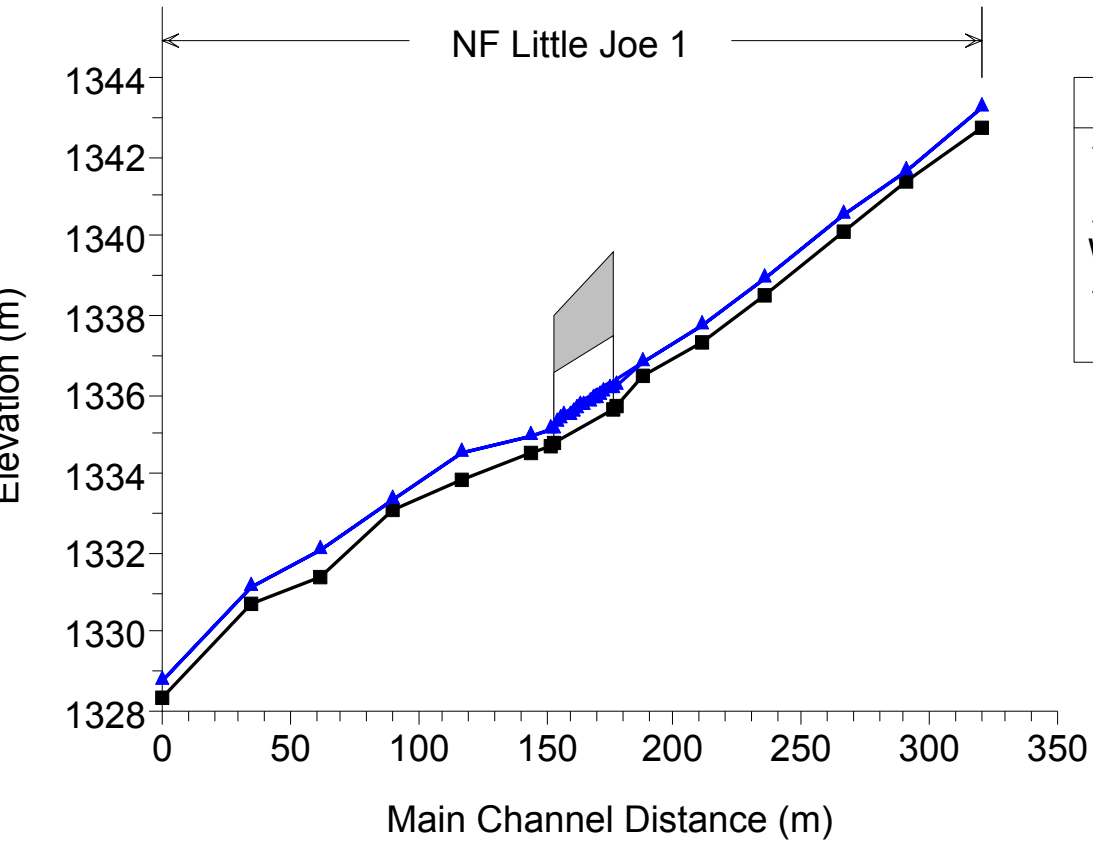
Incipient Motion: Q_2

ADT: 100 to 200

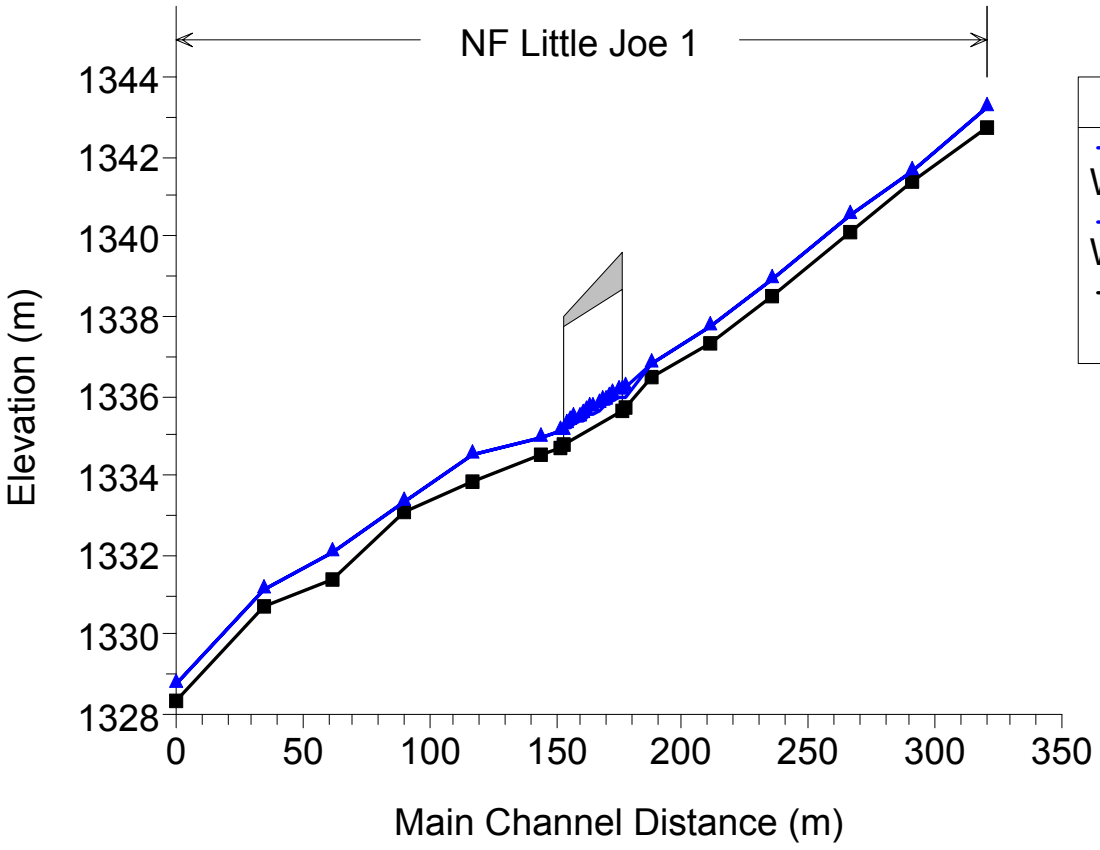
NFLJ CULVERT ALTERNATIVES

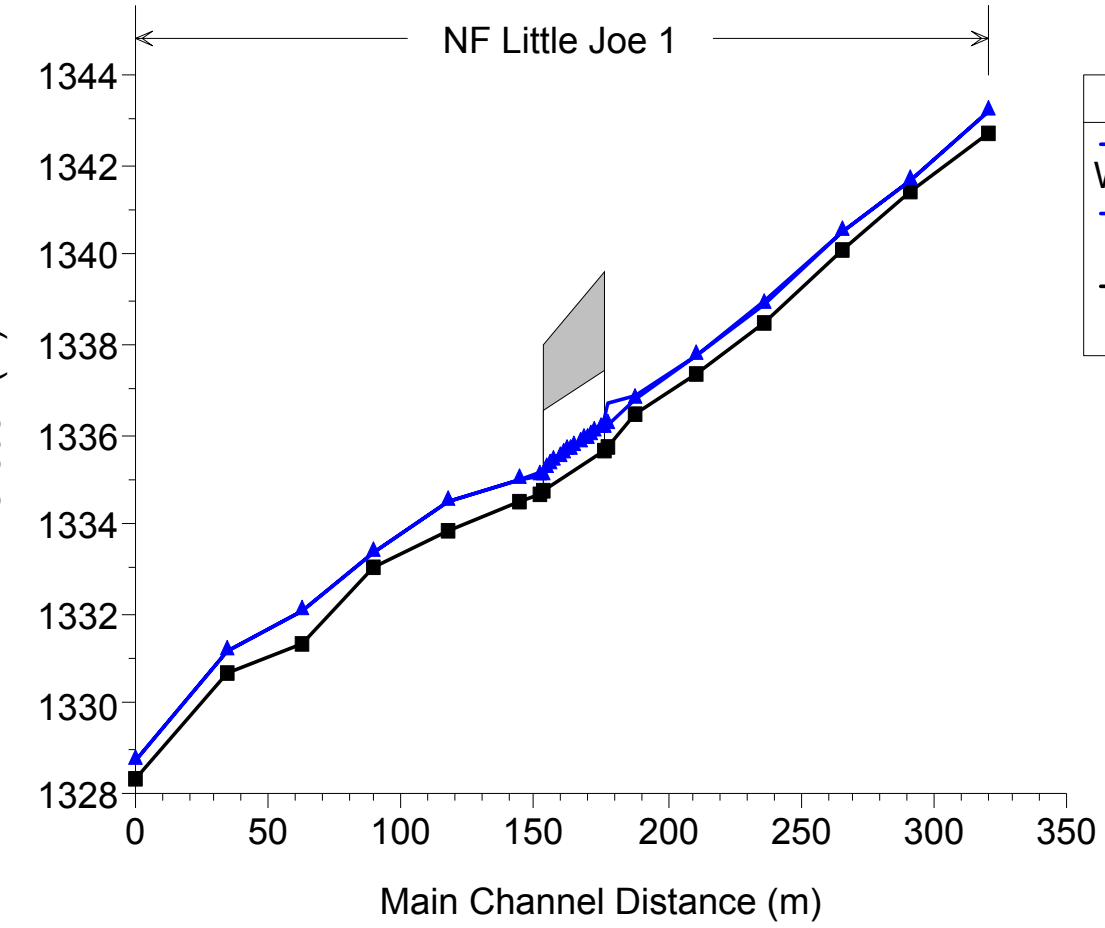
Culvert Design Method	Proposed Culvert Diameter
Highway (No Fish Passage)	1.8 m (6')
Hydraulic	3.6 m (12')*
Morphological	6.0 m (20')*

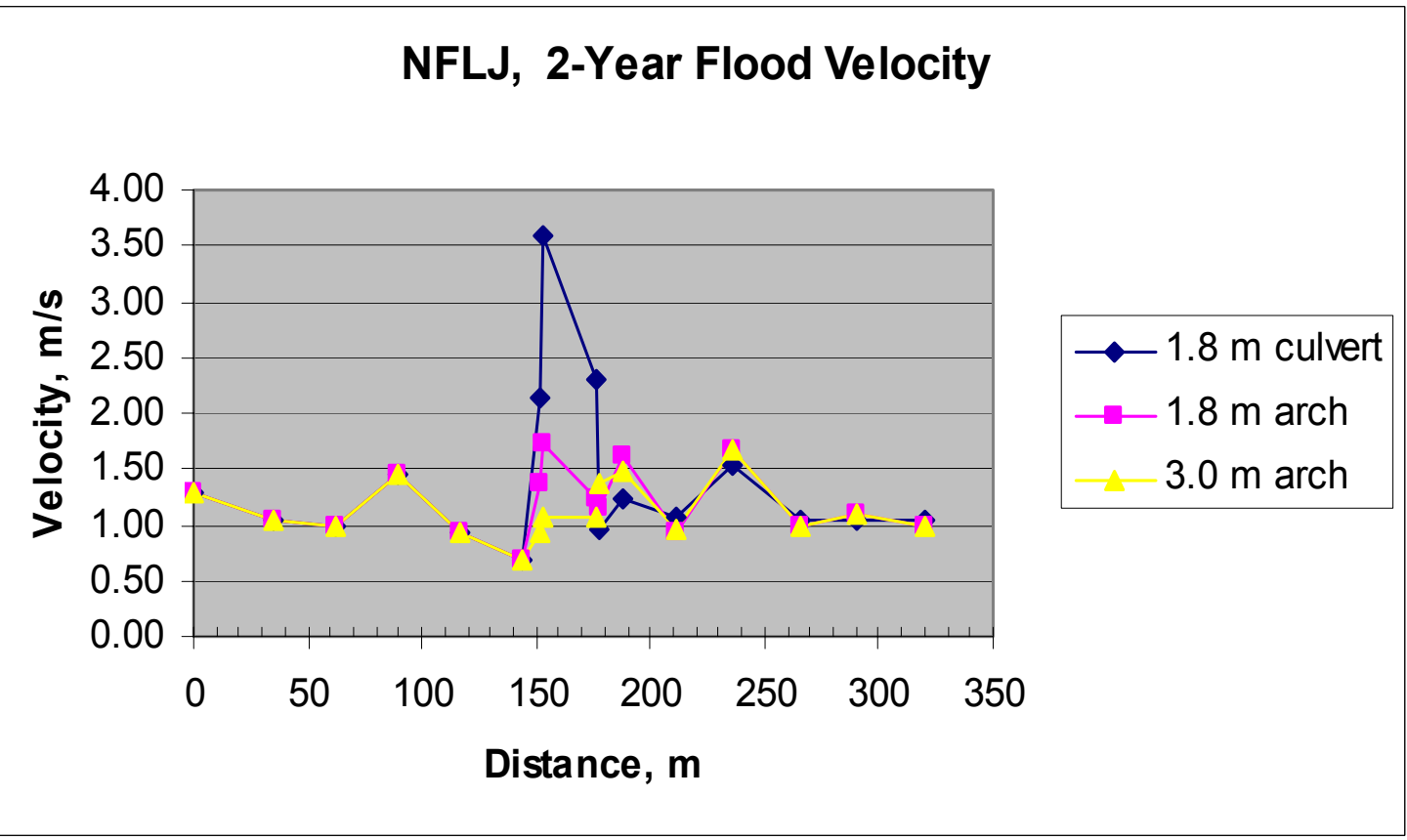
*** Culvert set ½ the diameter below the stream bed. Backfill w/ natural stream bed materials (i.e., sand, gravel, cobble, boulders).**

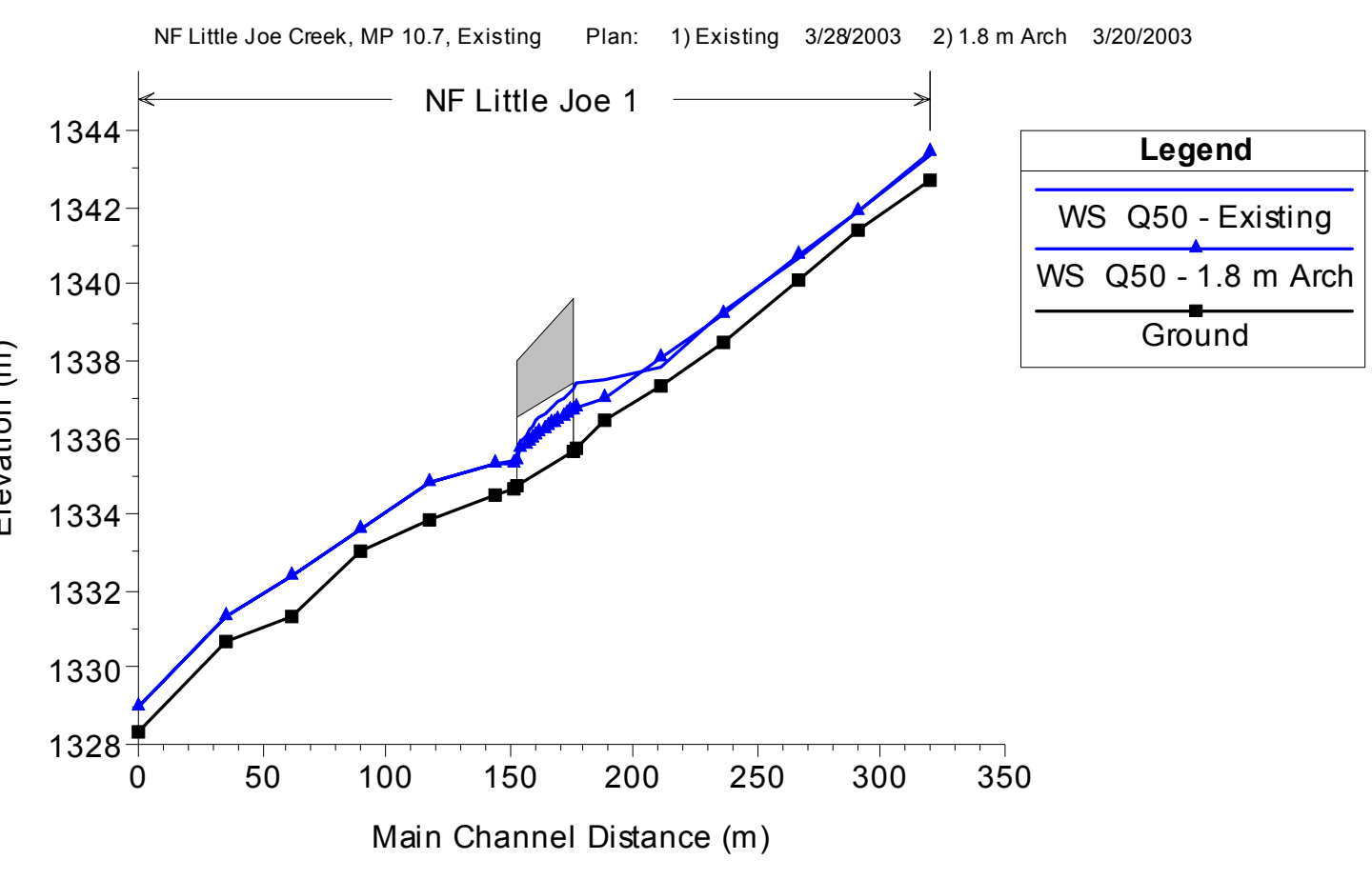


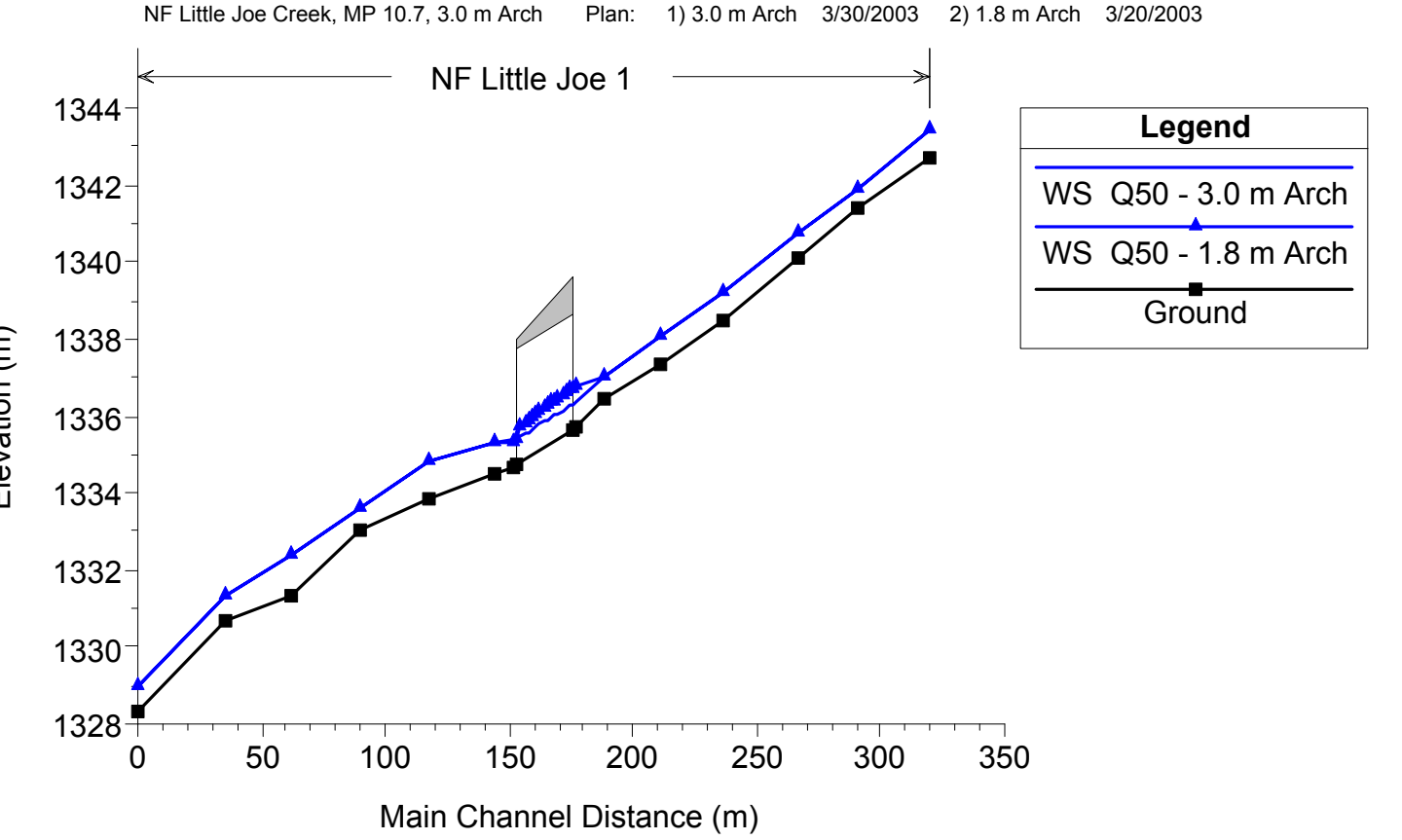
NF Little Joe Creek, MP 10.7, 3.0 m Arch Plan: 1) 3.0 m Arch 03/21/2003 2) 1.8 m Arch 03/20/2003

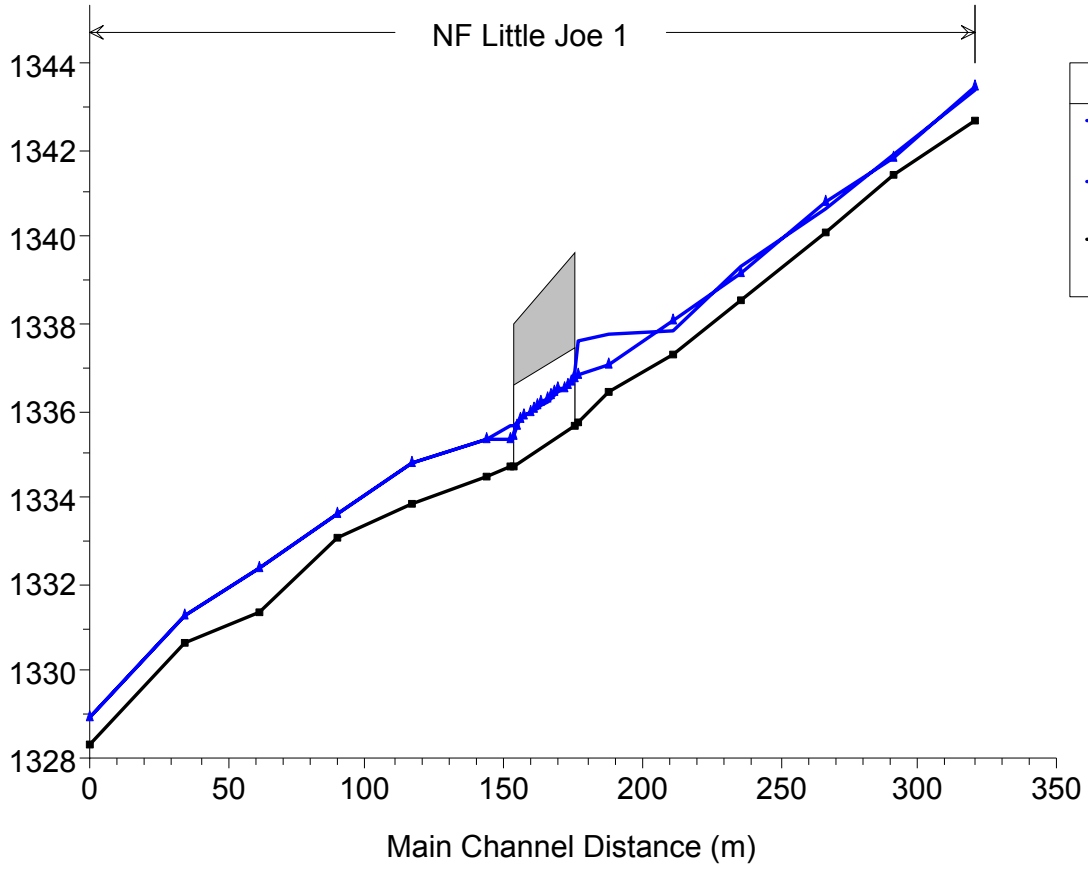


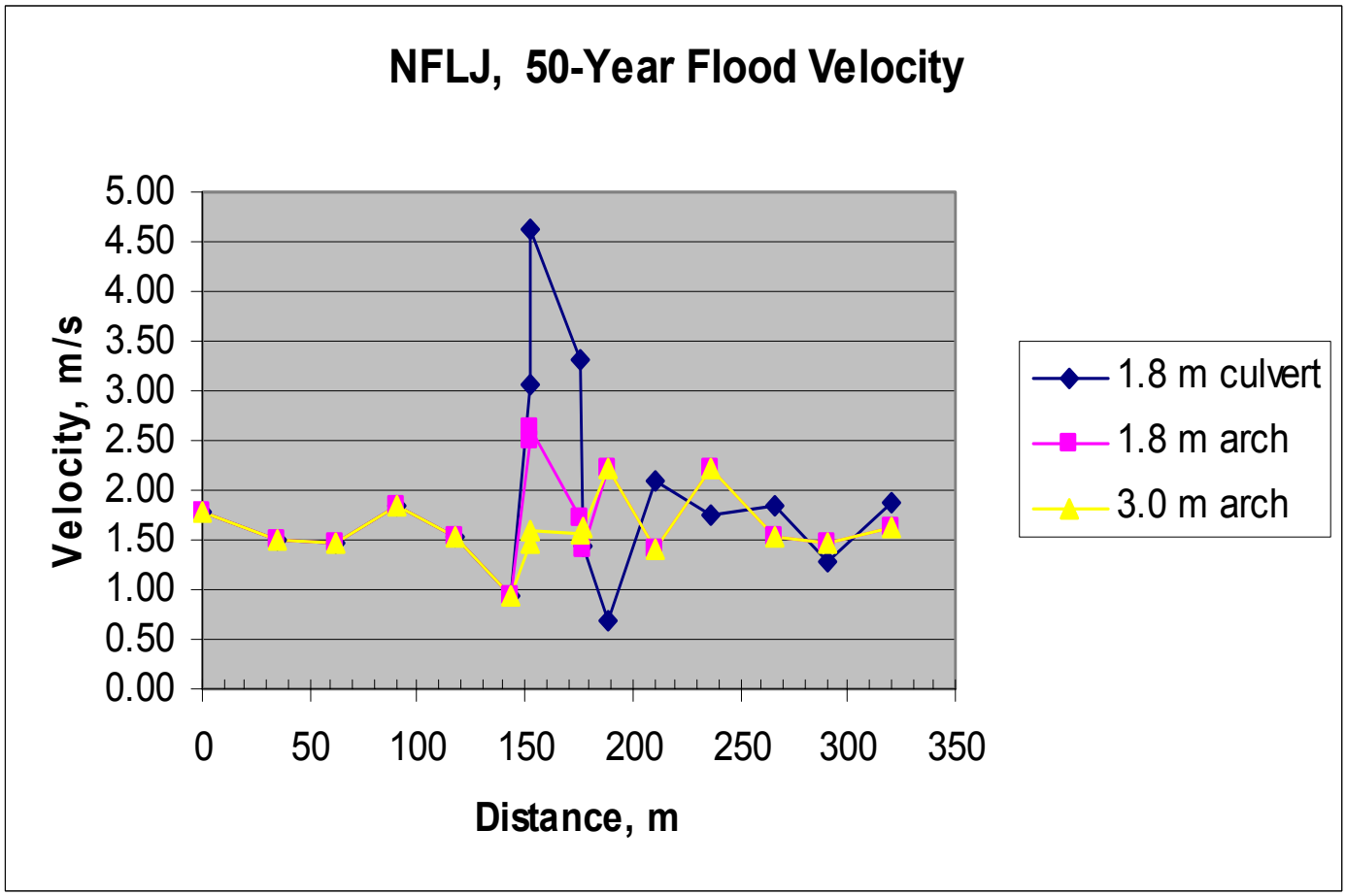

NF Little Joe 1
1344
1342
1340
1338
1336
1334
1332
1330
1328
0
50
100
150
200
250
300
350
Main Channel Distance (m)
Legend
WS Q2 - 1.8 m Culve
WS Q2 - 1.8 m Arch
Ground


NFLJ, 2-Year Flood Velocity
Velocity, m/s
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
50
100
150
200
250
300
350
Distance, m
1.8 m culvert
1.8 m arch
3.0 m arch

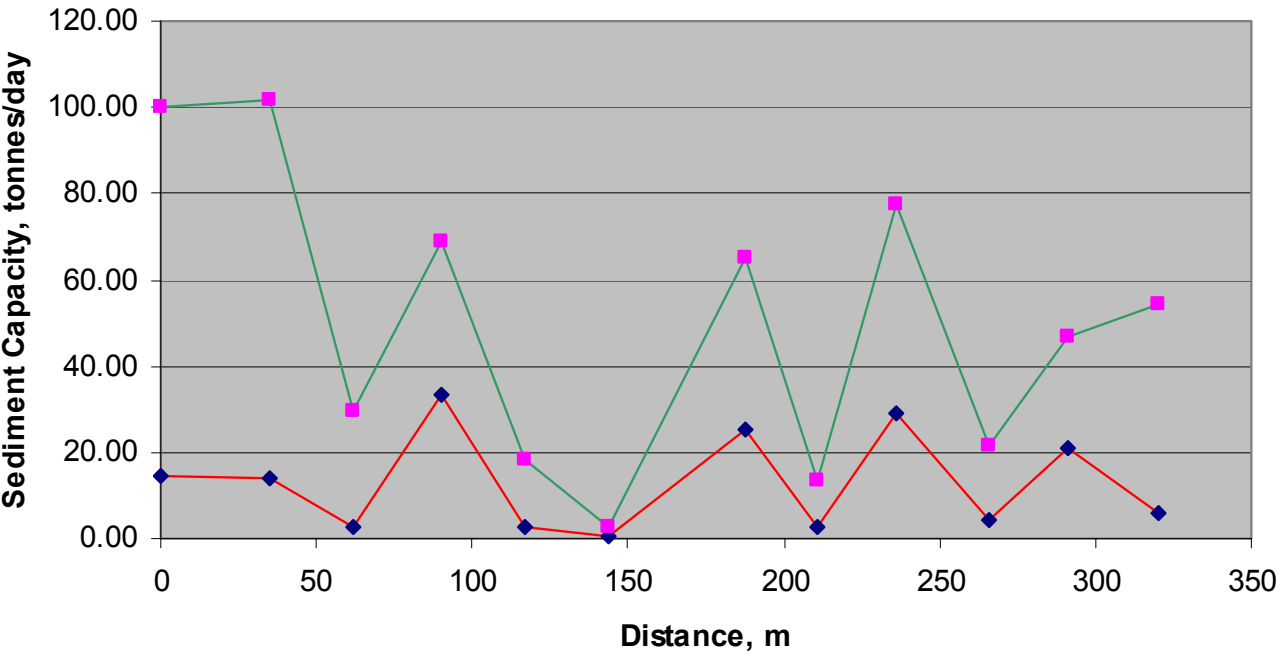

NF Little Joe Creek, MP 10.7, Existing Plan: 1) Existing 3/28/2003 2) 1.8 m Arch 3/20/2003
NF Little Joe 1
Legend
WS Q50 - Existing
WS Q50 - 1.8 m Arch
Ground
Elevation (m)
1344
1342
1340
1338
1336
1334
1332
1330
1328
0
50
100
150
200
250
300
350
Main Channel Distance (m)


NF Little Joe Creek, MP 10.7, 3.0 m Arch Plan: 1) 3.0 m Arch 3/30/2003 2) 1.8 m Arch 3/20/2003
NF Little Joe 1
Legend
WS Q50 - 3.0 m Arch
WS Q50 - 1.8 m Arch
Ground
Elevation (m)
1344
1342
1340
1338
1336
1334
1332
1330
1328
0
50
100
150
200
250
300
350
Main Channel Distance (m)


NF Little Joe 1
1344
1342
1340
1338
1336
1334
1332
1330
1328
0
50
100
150
200
250
300
350
Main Channel Distance (m)
Legend
WS Q50 - 1.8 m Culver
WS Q50 - 1.8 m Arch
Ground


NFLJ, 50-Year Flood Velocity
Velocity, m/s
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
50
100
150
200
250
300
350
Distance, m
1.8 m culvert
1.8 m arch
3.0 m arch

NF Little Joe, Sediment Capacity, Natural



NFLJ CULVERT SUMMARY

Design Method	Culvert Diameter	Costs, $
Highway (No Fish Passage)	1.8 m (6')	15,000
Hydraulic	3.6 m (12')*	30,000
Morphological	6.0 m (20')*	130,000

*** Culvert set ½ the diameter below the stream bed. Backfill w/ natural stream bed materials (i.e., sand, gravel, cobble, boulders).**

Future Research Needs & Design Criteria

I. Structural Dimensions (culvert lengths, width)

II. Boundary Roughness

III. Stream Dynamics (stream stability, sediment transport)

IV. Other Biological Design Factors (amphibian, wildlife passage)

V. FHWA's HEC-26, Hydraulic Design of Fish Passage