PLAN OF ACTION
SCOUR CRITICAL BRIDGE REPORT

Structure B-16-H at US 287 over Spring Creek
Mile Marker 344.87
City of Fort Collins, Colorado

Prepared by:

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Region 4 Hydraulics Unit

DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation
Federal Highway Administration

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TABLES

I. INTRODUCTION

The purpose of this report is to provide scour analysis and to prepare a scour critical plan of action for CDOT bridge structure B-16-H. This structure is currently listed as one of the scour critical bridges on the Maintenance Scour Critical Bridge Watchlist (Spring 2008) issued by CDOT Staff Bridge.

Figure 1 – Structure B-16-H Upstream (West) side

Figure 2 – Structure B-16-H Downstream (East) side

II. PROJECT SITE LOCATION

The structure is located in the City of Fort Collins, Larimer County, Colorado, and is about 0.1 miles south of mile marker 345 on US-287 (S. College Ave), at 40.5622 degrees N by 105.0769 degrees W (NAD 83).

The structure B-16-H is a single span steel flange bridge with a total span of 38.0 feet. It spans the Spring Creek waterway and was built in 1948. B-16-H has a sufficiency rating of 78.9 (inspection date Oct 29, 2007).

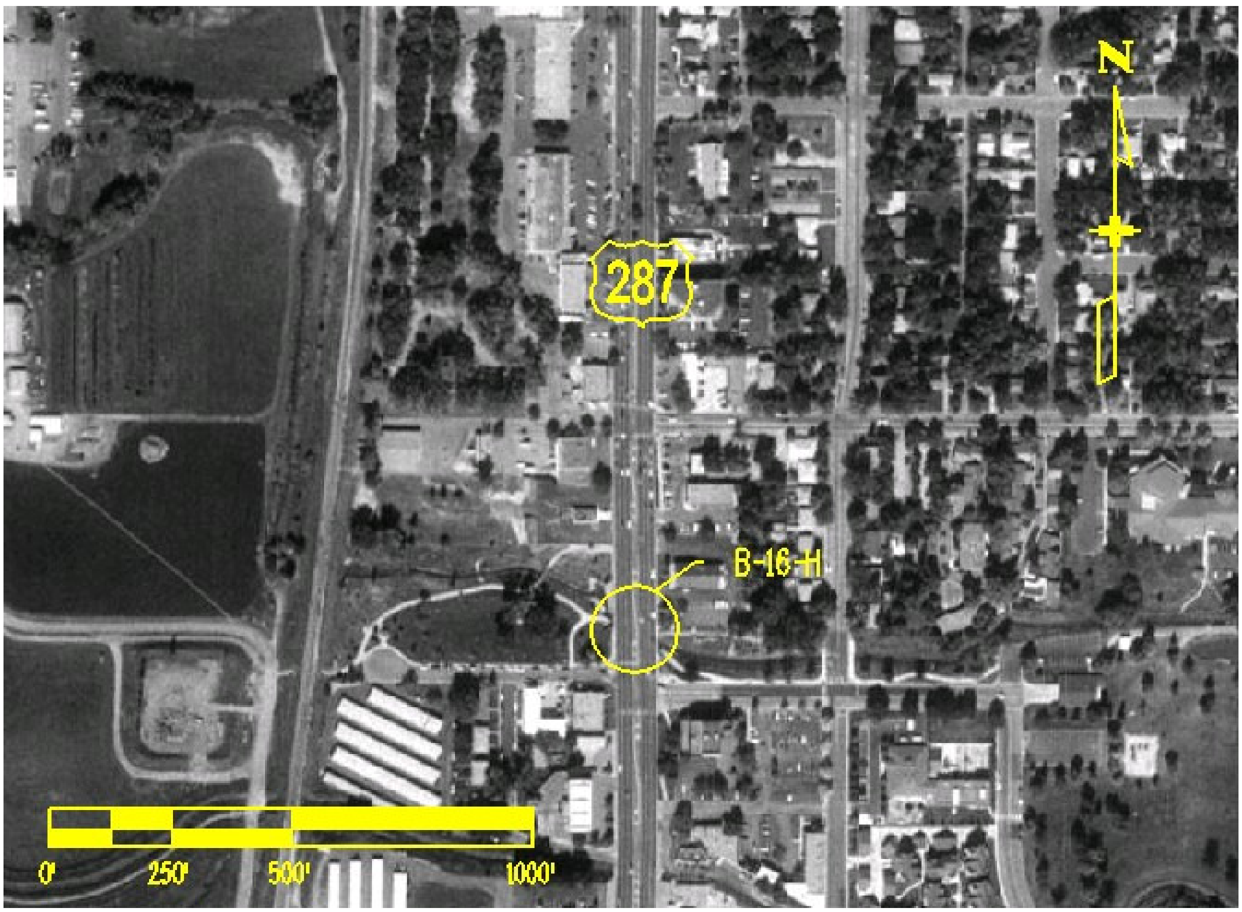


Figure 3 – Project Location Map

III. HYDROLOGY

The total drainage area of Spring Creek at structure B-16-H is approximately 7.0 mi^2 (Figure 4). The drainage area was obtained by analysis of the digital elevation map (DEM, downloaded from www.emrl.byu.edu/gsda/) into the Watershed Modeling System software (WMS, Version 8.3). Land use is mixed between urban and sporadically developed foothills. The general flow pattern is from the west/southwest direction.

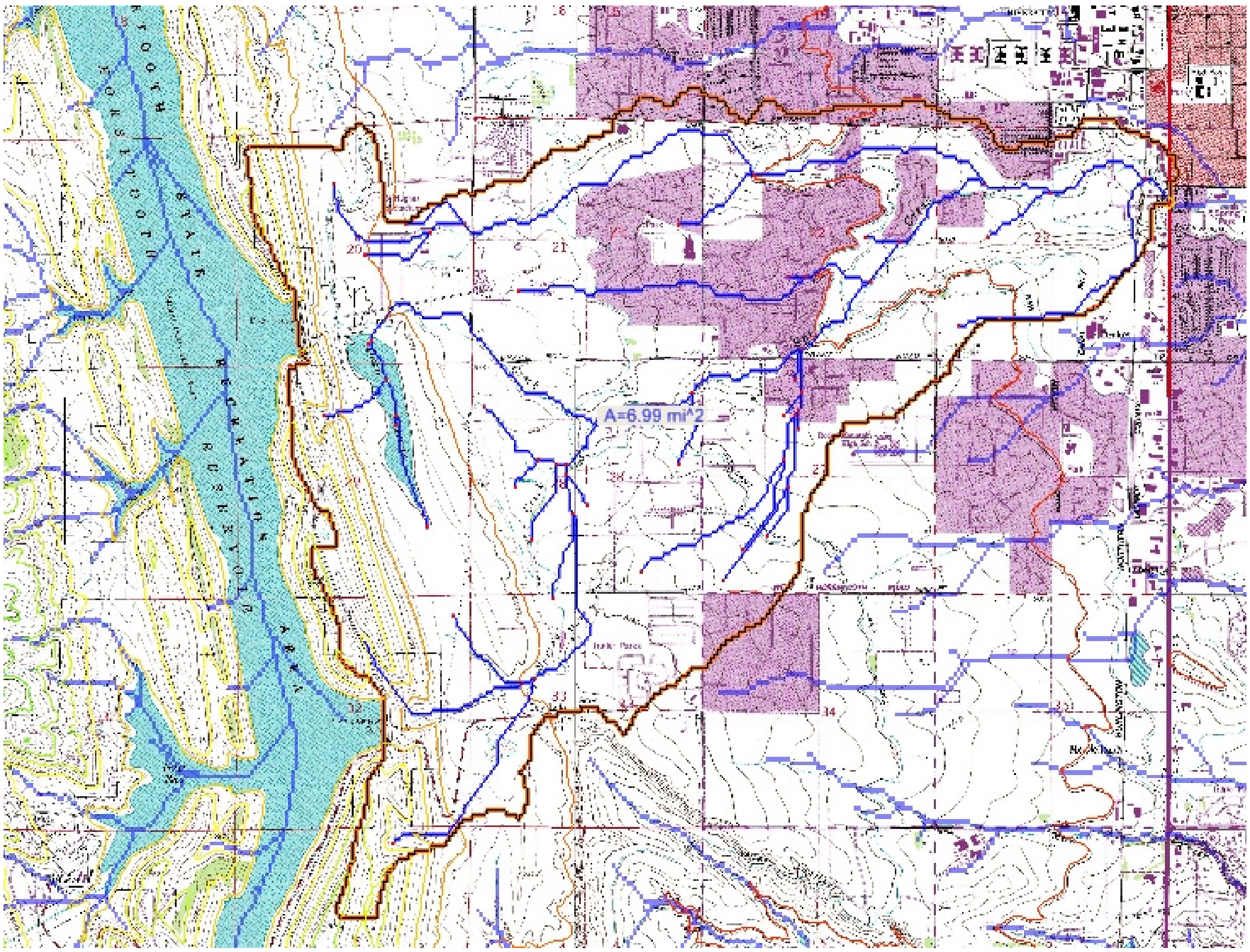


Figure 4 – B-16-H Drainage Basin Map

Table 1 below lists the 100 and 500 year peak flows which were used for the scour estimating and hydraulic analysis.

Reach	Structure	100 yr (cfs)	500 yr (cfs)
Spring Creek	B-16-H	2940	5880

Table 1 – Peak Discharges Summary

A complete hydrologic analysis of the Spring Creek contributing basin would be highly complex, and is beyond the scope of the current study. Many peer-reviewed journal articles and hydrologic studies have been produced as regards the Spring Creek basin, mostly spurred by the 1997 flood.

The current effective Flood Insurance Study (FEMA, 2006) only includes data for the 10-year and 100-year discharges. Thus, the 500-year recurrence flood needed to be estimated by using the approximation $Q_{500}/Q_{100} = 2.0$ as found in the CDOT Drainage Design Manual (Table 7.3, 2004). **Thus, it is crucial to note that the scour results obtained within the current study are based upon this approximation for the 500-year flood.** Should a more thorough hydrologic study be performed in the future, the hydraulic performance and scour potential will likely be found to be different from that contained within the current study.

IV. HYDRAULICS

A digital 2-foot contour map of the City of Fort Collins and Flood Hazard mapping downloaded from FEMA's website (hazards.fema.gov) were imported into Microstation and Inroads (V8) software. A TIN file was created from the 2 foot interval mapping. Cross-section locations were replicated from the current effective study.

The 2-foot contour map, as well as the As-Built plans for structure B-16-H and the roadway profile, is provided in the 1929 vertical datum. Since the current study was to be performed in the 1988 vertical datum, elevations from the contour map and plans were adjusted up (see Appendix I).

A Manning's roughness coefficient of 0.035 was used for the thalweg of the channel, and a value of 0.040 was used for the overbank areas. Downstream boundary conditions were set for a normal depth calculated from the local bedslope of 0.012 ft/ft.

The peak flow data in Table – 1, channel cross-sections, and bridge data obtained from the bridge as-built plans were input into HEC-RAS software (US Army Corps of Engineers, Version 4.0). From the HEC-RAS analysis, scour calculations at the 100-year and 500-year flow rates were performed.

The Energy Method was used for the low flow calculations, and the Pressure and/or Weir option was chosen for the High Flow Method. The Subcritical flow regime was chosen for the analysis, as opposed to the Mixed flow regime which gave high (supercritical) froude numbers downstream of the structure. While the Subcritical flow regime may produce slightly conservative results with regards to estimated water surface profiles, a natural channel (such as downstream of the structure) likely would not exhibit supercritical flows for long stretches, thus the Subcritical results were seen as more realistic.

Table 2 – Hydraulic Performance of B-16-H

	Recurrence Interval (yrs)	
	100	**500**
Deck Elev (ft)	4989.0	4989.0
Low Chord Elev (ft)	4987.3	4987.3
Q_{total} (cfs)	2940.0	5880.0
$Q_{overtop}$ (cfs)	0.0	3440.0
Upstream WSE (ft)	4988.3	4991.6
Vel_{bridge} (ft/s) avg.	9.3	7.7

V. SCOUR ANALYSIS

Estimation of potential scour at structure B-16-H followed the procedures provided in Hydraulic Engineering Circular No. 18 (HEC – 18, FHWA 2001)
.
Also, in order to estimate the sediment particle distribution, the methodology found in Stream Channel Reference Sites: An Illustrated Guide to Field Technique (US Forest Service RM-245) was used. Sediment samples were measured in the field upstream of the bridge, since artificial flood control measures have increased the sediment size directly under the bridge. Thus, the scour results do not directly consider the effects of the larger sediment size under the bridge opening, as these particles are irregularly placed and would not necessarily provide dependable scour protection for the abutments.

Appendix C of this report provides the detailed scour calculations. Tables 3 and 4 below summarize the scour calculations at structure B-16-H. Orientation is looking downstream. Long-term degradation was measured from the base of the low chord to the channel bottom, the difference in elevation taken between the bridge inventory records of 1973 and 2005.

	Ground Elev (ft)	Long-Term Degradation (ft) 1973-2005	Contraction Scour (ft)	Abutment Scour (ft) *	Pressure Scour (ft)	Total Scour (ft)	Scour Elev (ft)
Channel	4974.98	5.0	1.1		1.6	7.7	4967.3
Left abutment (Abutment 2)	4974.98	6.8	1.1	24.7	1.6	34.2	4940.8
Right abutment (Abutment 1)	4974.98	0.0 (2.5 ft Aggradation)	1.1	25.2	1.6	27.9	4947.1

Table 3 – 100-year Scour for Structure B-16-H

	Ground Elev (ft)	Long-Term Degradation (ft) 1973-2005	Contraction Scour (ft)	Abutment Scour (ft) *	Pressure Scour (ft)	Total Scour (ft)	Scour Elev (ft)
Channel	4974.98	5.0	0.00		0.00	5.0	4970.0
Left abutment (Abutment 2)	4974.98	6.8	0.00	29.8	0.00	36.6	4938.4
Right abutment (Abutment 1)	4974.98	0.0 (2.5 ft Aggradation)	0.00	25.1	0.00	25.1	4949.9

Table 4 – 500-year Scour for Structure B-16-H

* Froehlich's Abutment Scour Equation will generally result in deeper scour predictions than will be experienced in the field

Tables 3 and 4 present scour depths for the associated hydraulic event. If a soil horizon exists beneath the bed which is resistant to scour, the estimated scour depths could be reduced to reflect the competence of the material. This reduction would require examination and approval by a qualified geotechnical engineer with knowledge of the properties of the material.

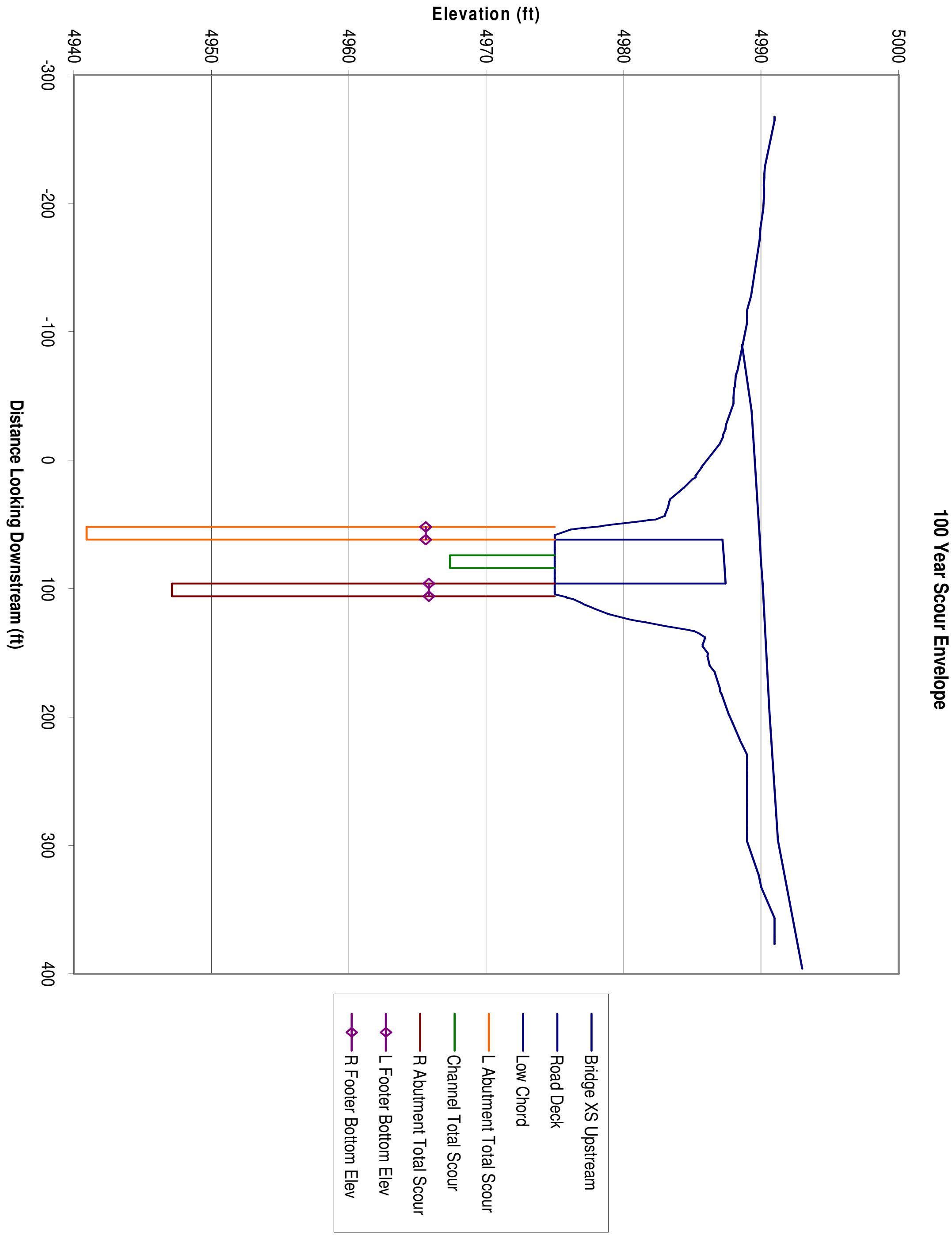


Figure 5 – 100-Yr Scour Envelope

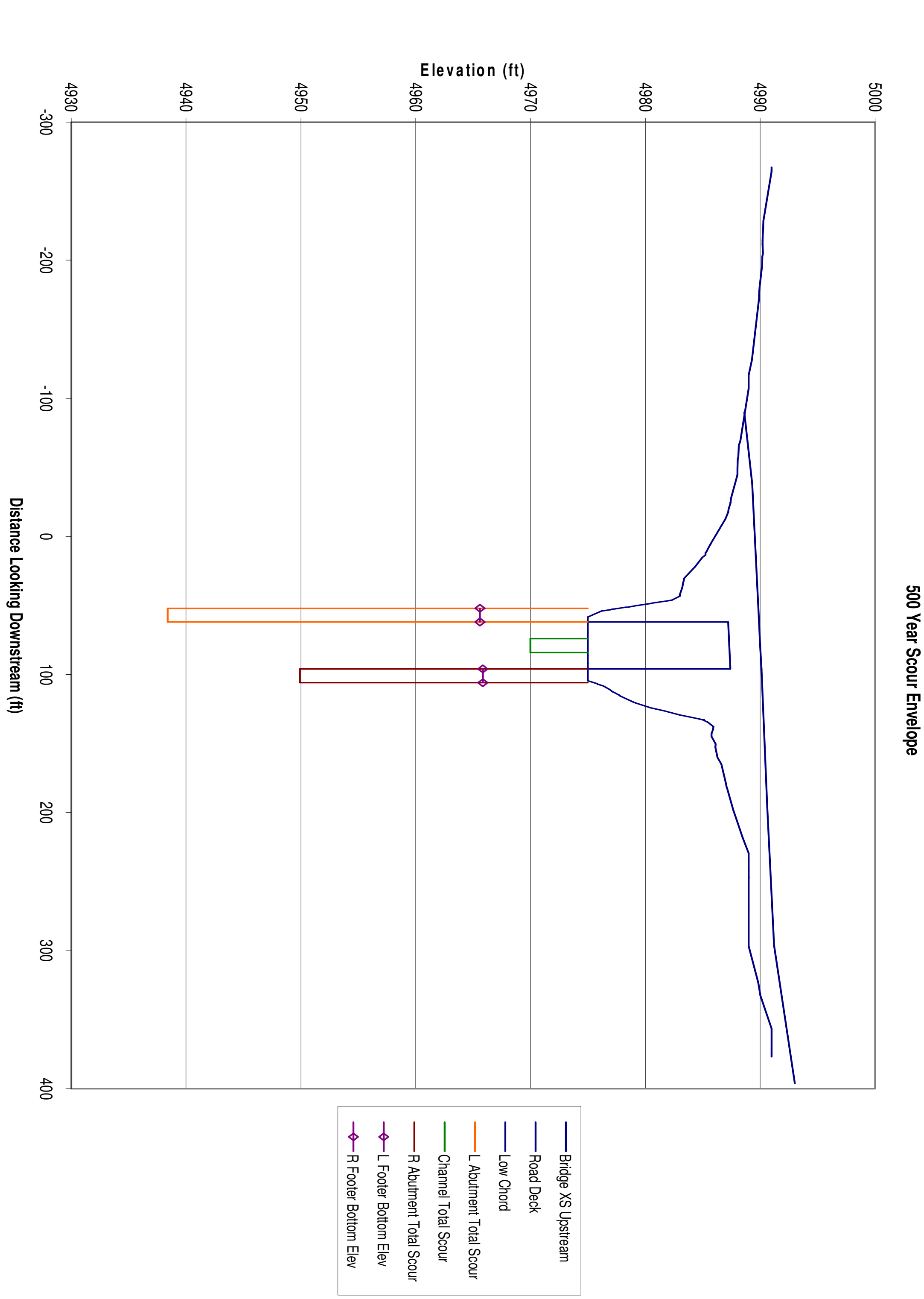


Figure 6 – 500-yr Scour Envelope

VI. RECOMMENDATIONS

OPTION 1: CHANNEL REALIGNMENT

The alignment of the Spring Creek channel on the upstream side of structure B-16-H forces the flows directly into the north-west wing before entering the bridge opening (Figures 7 and 8). The effects of this misalignment are evident in the scour results above, which show significantly greater scour depths on the left abutment as opposed to the right.

The channel re-alignment should aim to more closely match the main channel upstream with the bridge opening, and to eliminate the sharp transition from north to south of the channel at the upstream face of B-16-H. Close coordination would be required with the City of Fort Collins (the upstream property owner) to achieve such a re-alignment, which would also require a revision of flood hazard mapping to reflect the changes.

This option should serve to greatly relieve the abutment scour on this structure. It may also serve to somewhat lessen the estimated contraction scour, though this will largely remain due to the undersized structure.

Figure 7 – Alignment of Spring Creek channel and B-16-H Bridge.

Figure 8 – Area of Spring Creek Channel Re-Alignment.

OPTION 2 – RIPRAP PROTECTION

This option involves sizing and placing additional armoring at the upstream face of B-16-H, particularly around Abutment 2 (the left abutment looking downstream). While this option would partially or fully negate the estimated abutment scour at the 100-yr and 500-yr floods, it would not necessarily protect against the contraction scour or pressure scour (which is significant around the 100-year flood due to the water surface impacting upon the bridge low chord). Some of the protection would likely need to be placed outside of ROW to be fully effective, which would require some type of agreement with the City of Fort Collins and possibly a permanent easement to maintain the riprap.

OPTION 3 – BRIDGE REPLACEMENT

Through this study, the structure B-16-H has been shown to be undersized both by current CDOT design standards and hydraulically. Since the as-built date, multiple flood control structures and revisions in hydrology for the Spring Creek have been implemented, most as a result of the 1997 flood.

While the current FEMA 100-year estimated flow does clear the bridge without causing overtopping, it has been shown to impact the low chord which causes an undesirable pressure flow scenario. There is no freeboard at this flow rate for the current structure, as would be required for a new structure. Also, the existing bike/pedestrian trail placement causes a significant reduction and obstruction to the bridge's hydraulic conveyance.

The scour critical status of the structure could be largely eliminated by a larger structure. This would eliminate the contraction scour due to the larger opening. Lower flow velocities through the larger opening would, in turn, reduce the abutment scour, and the pressure scour would be eliminated by providing freeboard at the upstream face of the structure for the 100-year design flow.

It should be noted that this option has only been evaluated from a hydraulic perspective. It is not assumed at this time that the bridge's sufficiency rating or a thorough cost-benefit analysis would show that Option 3 is necessarily practical or the most viable option in terms of reducing or eliminating the scour issues at this location. From a strictly hydraulic perspective, though, a bridge replacement would have the most positive effect in reducing or negating the scour potential.

PREFERRED OPTION

While Option 2 is likely the cheapest option, it is also the least effective option in reducing total scour depths. Option 1 would be a much more effective option as far as reducing total scour depths without the cost of replacing the entire structure. Option 3, easily the most costly and least likely to be performed, would largely eliminate the scour potential at this site.

Given these factors, a combination of Options 1 and 2 is recommended for further consideration at this time.

VII. REFERENCES

1. *Drainage Design Manual* (2004), Colorado Department of Transportation.

2. *Final Hydraulic Report – SH 52 at Boulder Creek, Boulder County, Colorado – Structure D-16-U Bridge Replacement, CDOT Design Project 15550* (March 2008), CDOT Region 4 Hydraulics Unit.

3. *Flood Insurance Study – Larimer County, Colorado and Incorporated Areas (Volume 1 of 4)* (December 2006), Federal Emergency Management Agency (FEMA).

4. *HEC-RAS River Analysis System User's Manual* (November 2002), US Army Corps of Engineers, Version 4.0

5. *Hydraulic Engineering Circular No. 18 - Fourth Edition* (May 2001), Federal Highway Administration (FHWA).

6. *Spring Creek – Fort Collins, Larimer County, Colorado – Major Drainageway Plan – City of Fort Collins, Colorado Water Conservation Board* (August 1980), Gingery Associates, Inc.

7. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* by Cheryl C. Harrelson, C. L. Rawlins, and John P. Potyondy (April 1994), United States Department of Agriculture, Forest Service – Rocky Mountain Research Station, General Technical Report RM-245.

8. Watershed Modeling System (WMS), Brigham Young University, Version 8.1

SCOUR CRITICAL BRIDGE - PLAN OF ACTION

1. GENERAL INFORMATION

Structure number: B-16-H

City, County, State: Fort Collins, Larimer, Colorado

Waterway: Spring Creek

Structure name: B-16-H

State highway or facility carried: US 287 ML

Owner: Colorado Department of Transportation

Year built: 1948 | **Year rebuilt:** 1959 | **Bridge replacement plans (if scheduled):** _____ **Anticipated opening date:** _____

Structure type: ☒ Bridge ☐ Culvert
Structure size and description: 92 feet wide by 38 feet length, single span

Foundations: ☒ Known, type: Footer Depth: 4965.6, 4965.8 ☐ Unknown

Subsurface soil information (*check all that apply*): ☒ Non-cohesive ☒ Cohesive ☒ Rock

Bridge ADT: 42,300 | **Year/ADT:** 2005 | **% Trucks:** _____

Does the bridge provide service to emergency facilities and/or an evacuation route (Y/N)? N
If so, describe: _____

2. RESPONSIBILITY FOR POA

Author(s) of POA (name, title, agency/organization, telephone, pager, email):
Colorado Department of Transportation
Date: October 2009

Concurrences on POA (name, title, agency/organization, telephone, pager, email):
_____

POA updated by (name, title, agency, organization): Steven Griffin, Hydraulic Engineer, CDOT Region 4 **Date of update:** October 2009
Items update: General Update

POA to be updated every _____ months by (name, title, agency/organization):_____

Date of next update:_____

3. SCOUR VULNERABILITY

a. Current Item 113 Code: ☒ 3 ☐ 2 ☐ 1 Other: _____

b. Source of Scour Critical Code: ☐ Observed ☐ Assessment ☐ Calculated Other: _____

c. Scour Evaluation Summary: Scour depths are estimated to be largest at Abutment 2 (north end) at both 100-yr and 500-yr events. Caused by a combination of poor channel alignment upstream, inadequate hydraulic conveyance through the structure, and unknown elev. of bedrock, if any.

d. Scour History: _____

4. RECOMMENDED ACTION(S) (see Sections 6 and 7)

	Recommended		Implemented	
a. Increased Inspection Frequency	☒ Yes	☐ No	☐ Yes	☐ No
b. Fixed Monitoring Device(s)	☐ Yes	☒ No	☐ Yes	☐ No
c. Flood Monitoring Program	☒ Yes	☐ No	☐ Yes	☐ No
d. Hydraulic/Structural Countermeasures	☒ Yes	☐ No	☐ Yes	☐ No

5. NBI CODING INFORMATION

		Current	Previous
Inspection date		**Oct 29, 2007**	**Dec 27, 2005**
Item 113	**Scour Critical**	**3 – Unstable**	**3 - Unstable**
Item 60	**Substructure**	**7 – Good**	**7 – Good**
Item 61	**Channel & Channel Protection**	**8 – Protected**	**8 – Protected**
Item 71	**Waterway Adequacy**	**8 – Equal Desirable**	**8 – Equal Desirable**
Comments: (drift, scour holes, etc. - depict in sketches in Section 10)		_____	_____

6. MONITORING PROGRAM

☐ **Regular Inspection Program** ☐ w/surveyed cross sections
Items to Watch: _____

☒ **Increased Inspection Frequency of 12 mo.** ☐ w/surveyed cross sections
Items to Watch: Scour depths at Abutment 2, particularly at the upstream face

☐ **Underwater Inspection Required**
Items to Watch: _____

☐ **Increased Underwater Inspection Frequency of __ mo.**
Items to Watch: _____

☐ **Fixed Monitoring Device(s)**
Type of Instrument: _____
Installation location(s): _____
Sample Interval: ☐ 30 min. ☐ 1 hr. ☐ 6 hrs. ☐ 12 hrs. ☐ Other: _____
Frequency of data download and review: ☐ Daily ☐ Weekly ☐ Monthly ☐ Other _____
Scour alert elevation(s) for each pier/abutment: _____
Scour critical elevations(s) for each pier/abutment:_____
Survey ties: _____

Criteria of termination for fixed monitoring: _____

☒ **Flood Monitoring Program**

Type: ☒ Visual inspection
☐ Instrument (*check all that apply*):
☐ Portable ☐ Geophysical ☐ Sonar ☐ Other: _____

Flood monitoring required: ☒ Yes ☐ No

Flood monitoring event defined by (*check all that apply*):

☐ Discharge _____ ☐ Stage _____

☒ Elev. measured from bottom of superstructure ☐ Rainfall _____ (in/mm) per _____ (hour)

☐ Flood forecasting information: _____

☐ Flood warning system: _____

Frequency of flood monitoring: ☐1 hr. ☒3 hrs. ☐6 hrs. ☐ Other: _____

Post-flood monitoring required: ☐ No ☐Yes, within _____ days

Frequency of post-flood monitoring: ☐Daily ☐Weekly ☐Monthly ☐Other: _____

Criteria for termination of flood monitoring: _____

Criteria for termination of post-flood monitoring: _____

Scour alert elevation(s) for each pier/abutment: _____

Scour critical elevation(s) for each pier/abutment: _____

Note: Additional details for action(s) required may be included in Section 8.

Action(s) required if scour alert elevation detected (*include notification and closure procedures*): _____

Action(s) required if scour critical elevation detected (*include notification and closure procedures*): _____

Agency and department responsible for monitoring: CDOT Region Maintenance 4

Contact person (*include name, title, telephone, pager, e-mail*): Maintenance Supervisor Jeff Tatkenhorst LTC OP's I c 970-381-7177 o 970-622-1243

7. COUNTERMEASURE RECOMMENDATIONS

Prioritize alternatives below. Include information on any hydraulic, structural or monitoring countermeasures.

☐ **Only monitoring required (see Section 6 and Section 10 – Attachment F)**

Estimated cost $_____

☒ **Structural/hydraulic countermeasures considered (see Section 10, Attachment F):**

Priority Ranking	**Estimated cost**
(1) Channel Re-Alignment	$ UNK
(2) Riprap Abutment Protection	$ UNK
(3) _____	$ _____
(4) _____	$ _____
(5) _____	$ _____

Basis for the selection of the preferred scour countermeasure: Poor upstream channel alignment and undersized structure causing increased scour at abutments

Countermeasure implementation project type:

☒ Proposed Construction Project ☐ Maintenance Project
☒ Programmed Construction - Project Lead Agency: City of Fort Collins
☐ Bridge Bureau ☐ Road Design ☐ Other _____

Agency and department responsible for countermeasure program (if different from Section 6 contact for monitoring): Design: Region 4 Hydraulics Monitoring: Maintenance Superintendent

Contact person (*include name, title, telephone, pager, e-mail*): _____

Target design completion date: _____

Target construction completion date: _____

Countermeasures already completed: _____

8. BRIDGE CLOSURE PLAN

Scour monitoring criteria for consideration of bridge closure:

☒ Water surface elevation reaches low chord at 4987.3 ft
☒ Overtopping road or structure
☐ Scour measurement results / Monitoring device (See Section 6)
☐ Observed structure movement / Settlement
☐ Discharge: _____ cfs/cms
☐ Flood forecast: _____
☐ Other: ☐ Debris accumulation ☐ Movement of riprap/other armor protection
☐ Loss of road embankment

Emergency repair plans (*include source(s), contact(s), cost, installation directions*): _____

Agency and department responsible for closure: CDOT Maintenance

Contact persons (name, title, agency/organization, telephone, pager, email): Maintenance Patrol-04 970-679-0269, Superintendent 970-381-4104 or Bridge Inspector 970-302-5606

Criteria for re-opening the bridge: Contact CDOT Staff Bridge and Region 4 Hydraulics

Agency and person responsible for re-opening the bridge after inspection: Maintenance Supervisor Jeff Tatkenhorst 970-381-7177

9. DETOUR ROUTE

Detour route description (route number, from/to, distance from bridge, etc.) - Include map in Section 10, Attachment E.

Southbound on Hwy 287 you would detour onto eastbound Hwy 14 for approximately 4.2 miles, south on I-25 for 4 miles to Harmony Road, west on Harmony Road for 3.9 miles south onto Hwy 287.

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load Limitations	Item 113 Code

Traffic control equipment (detour signing and barriers) and location(s): 2-VMS boards, 24 Detours signs with arrows

Additional considerations or critical issues (susceptibility to overtopping, limited waterway adequacy, lane restrictions, etc.) : _____

News release, other public notice (include authorized person(s), information to be provided and limitations): Mindy Crane 303-757-9469

10. ATTACHMENTS

Please indicate which materials are being submitted with this POA:

☐ **Attachment A: Boring logs and/or other subsurface information**

☐ **Attachment B: Cross sections from current and previous inspection reports**

☒ **Attachment C: Bridge elevation showing existing streambed, foundation depth(s) and observed and/or calculated scour depths**

☐ **Attachment D: Plan view showing location of scour holes, debris, etc.**

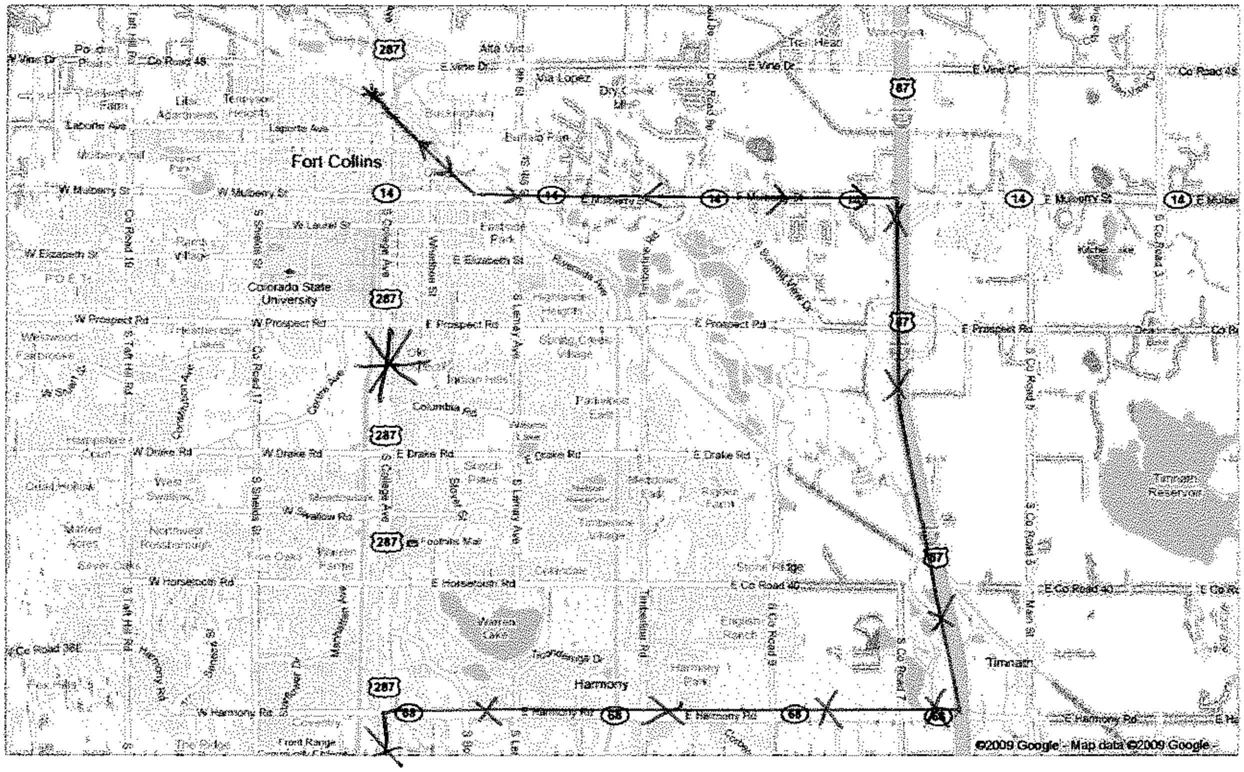
☒ **Attachment E: Map showing detour route(s)**

☒ **Attachment F: Supporting documentation, calculations, estimates and conceptual designs for scour countermeasures.**

☐ **Attachment G: Photos**

☐ **Attachment H: Other information: _____**

Google maps


Fort Collins
Colorado State University
W Mulberry St
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W Drake Rd
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W Horsetooth Rd
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W Harmony Rd
E Harmony Rd
E Vine Dr
W Vine Dr
S College Ave
S Lemay Ave
Timberline Rd
S Shields St
Riverside Ave
Columbia Rd
E Co Road 40
Harmony
Timnath
Timnath Reservoir
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