Scour Critical Bridge Plan of Action and Recommendations

for

SH 30 (Havana Street) Bridge over Cherry Creek

Structure F-17-AE

Prepared for FHWA & Colorado Department of Transportation

Prepared by Region 6 Hydraulics Unit

September 2009

Table of Contents

List of Figures

List of Tables

Appendices

I. Introduction

Structure F-17-AE is located at mile post 3.098 on Havana Street (SH 30) in Denver County. The structure crosses Cherry Creek approximately 1 mile downstream of Cherry Creek Reservoir. Structure F-17-AE has a Sufficiency Rating of 41.2 and is found to be in good condition. Visual monitoring during large storm events is the current scour countermeasure for the bridge. Structural changes to the channel such as armoring with rip rap, and slope protection, are not required at this time and are not recommended. The "Scour Plan of Action" recommendation is to monitor the structure during periods when Cherry Creek is experiencing high flows. At a stream elevation of 5476, or within 3 feet of the low chord of the substructure, it is recommended that the bridge be closed to traffic. A detour for traffic is to be made at the intersection of Hampden Avenue (SH 30) and I-25. Traffic should be routed south on I-25 to I-225, then west on I-225 to Parker Road (SH 83), then north on Parker Road (SH 83) to Havana Street. This detour should be used until the Cherry Creek stage subsides.

II. Channel Description

Cherry Creek Channel in this segment is relatively flat and located in an open terrain that is bordered by the Kennedy Golf Course and Open Space. The bed consists of silt and sand. The overbank areas adjacent to the active channel are vegetated in various wetland and riparian species of grasses, shrubs, and trees.

Structure F-17-AE has experienced erosion in the channel, at its abutments, and piers. The structure is rated as scour critical, Item Number 113 in the Structure Inventory and Appraisal of the Nation's Bridges (Item 113 = 5). The Colorado Department of Transportation (CDOT) Bridge Inspection personnel make biennial inspections of this structure. Records indicate Cherry Creek has experienced a lowering in elevation, at abutments and piers, between 3 inches and 2 feet due to scour. The berm at Abutment 1 has eroded exposing up to 15 inches of piles. The berm at Abutment 5 is up to 3 inches low for the full length with some exposed piles. Piers 2 has experienced scour which has exposed approximately 2 feet of piles. A concrete footer was place below the pier wall to stabilize this condition. The Pier 3 wall has been undercut exposing 6 inches to 1 foot of pipe piles.

III. Location Map

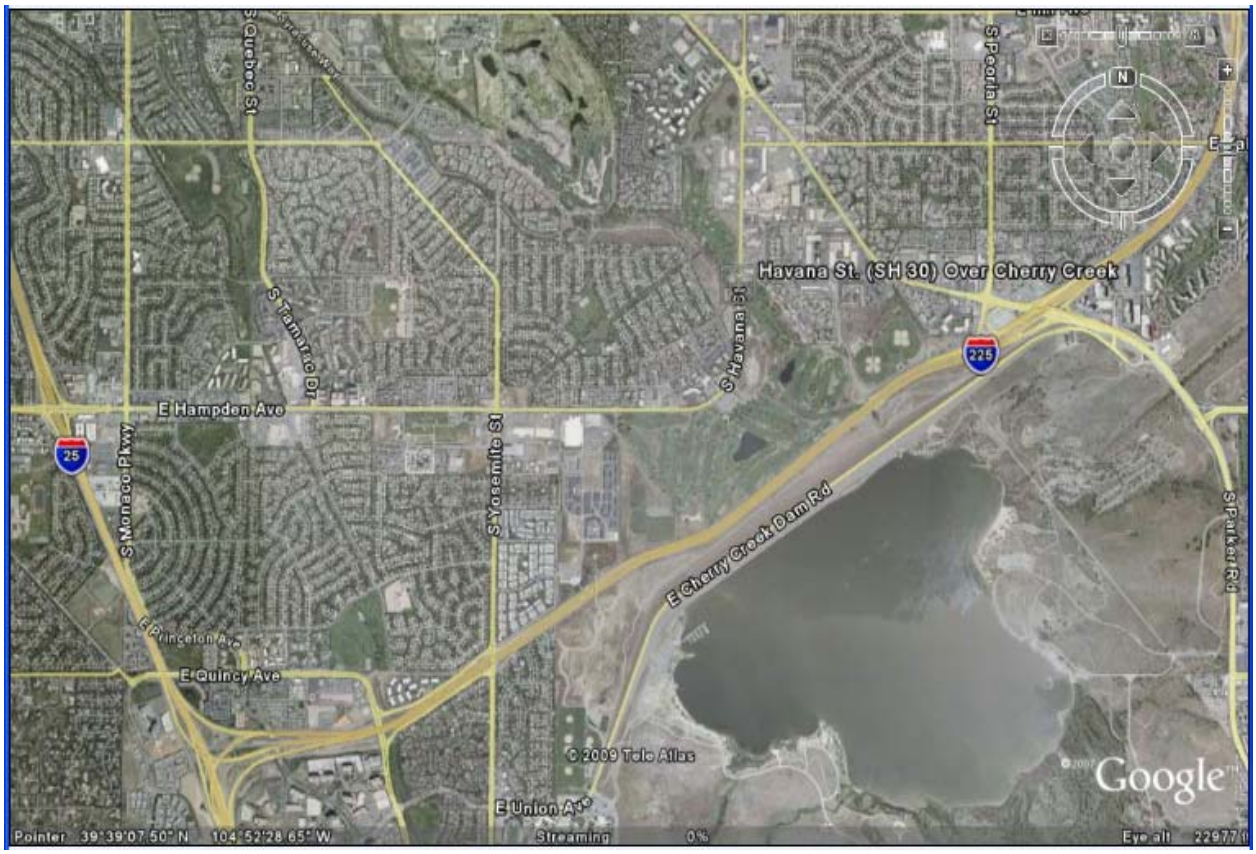


Figure 1 Project Location Map – Havana St. (SH 30) Over Cherry Creek

IV. Hydrologic Analysis

The basin that contributes runoff to the bridge crossing Cherry Creek at Havana Street is controlled by the Cherry Creek Dam just upstream of the bridge. Construction of Cherry Creek Dam was completed in 1950. The basin between Cherry Creek Dam and Structure F-17-AE is urbanized with highways, golf courses, open space, commercial and residential land uses.

The Flood Insurance Study for the City and County of Denver, in which CDOT Structure F-17-AE is found, defines the 100 year flow rate for Cherry Creek as 1,500 cfs. The Cherry Creek Dam just upstream of Structure F-17-AE is design for a maximum allowable release rate of 5,000 cfs which could be sustained for 5 to 10 days. The channel downstream from the dam may handle the maximum allowable release without flooding areas outside the channel, however, sustained flows could severely erode the sandy channel and scour structures at piers and abutments.

The Plan of Action (POA) for Scour Critical Bridges and Bridges with Unknown Foundations requires a hydraulic analysis for the 50-yr, 100-yr, 250-yr, and 500-yr flood frequency events. Because Structure F-17-AE is located downstream from Cherry Creek Dam and flow is controlled by the outlet works for the dam, flow rates associated

with a traditional return interval frequency do not apply for this structure. However, there is an existing gage station on Cherry Creek approximately ½ mile upstream of Structure F-17-AE which was analyzed to estimate flow rates for the required flood frequency events. The largest peak flow rate recorded, from 1950 through 2004, was 1,600 cfs. For this study, the estimated peak flow rates used in the HEC-RAS model for Cherry Creek are as follows:

Flood Frequency Event	Peak Discharge (cfs)
50-yr	1,900
100-yr	2,300
250-yr	2,800
500-yr	3,200
Maximum Release Rate	5,000

Table 1 Hydrology – Peak Discharge Summary [(1)]

[(1)] Peak stream flow data for USGS 06713000, Cherry Creek below Cherry Creek Lake, CO was obtained from the National Water Information System. All streamflow data is affected by Cherry Creek Dam outlet release. The data was analyzed by Dennis Cress, CDOT R-2 Hydraulics Unit, using techniques outlined in the Interagency Advisory Committee On Water Data, Guidelines for Determining Flood Flow Frequency, Bulletin #17B, 1982. A Log-Pearson Type III Distribution flood frequency analysis was used to determine flood frequency/discharge values.

V. Hydraulic Analysis

Bridge scour analysis will be based upon four selected events; the 50 year, 100 year, 250 year, and the 500 year using the procedures outlined in HEC 18 and HEC 23, 2001 Edition.

The Cherry Creek channel is modeled using the Watershed Modeling Software (WMS) and with topographic data taken from CDOT field survey of the channel approximately 1000’ upstream and downstream of the bridge, shown below.

The existing bridge structure is modeled with a total span of 125 feet, a length of 72 feet, and with abutment slopes of 1.5 to 1. The distance between the deck and bottom chord of the structure is estimated at 3.39 feet. The bridge was constructed in 1956 with abutments and piers set on 10 ¾ inch steel pipe piles filled with concrete. As-built drawings show the length of the pipe piles at 40 to 42 feet and extending down to approximate elevation 5440. The structure was widened in 1968 with abutments and piers set on 12 ¾ inch steel pipe piles filled with concrete. As-built drawings show the estimated length of the pipe piles at 42 feet.

The plans note that piles are end bearing and that the average terminal depths for piles are as follows:

Abut 1	5435.35
Pier 2	5435.30
Pier 3	5446.28
Pier 4	5447.58
Abut 5	5422.70

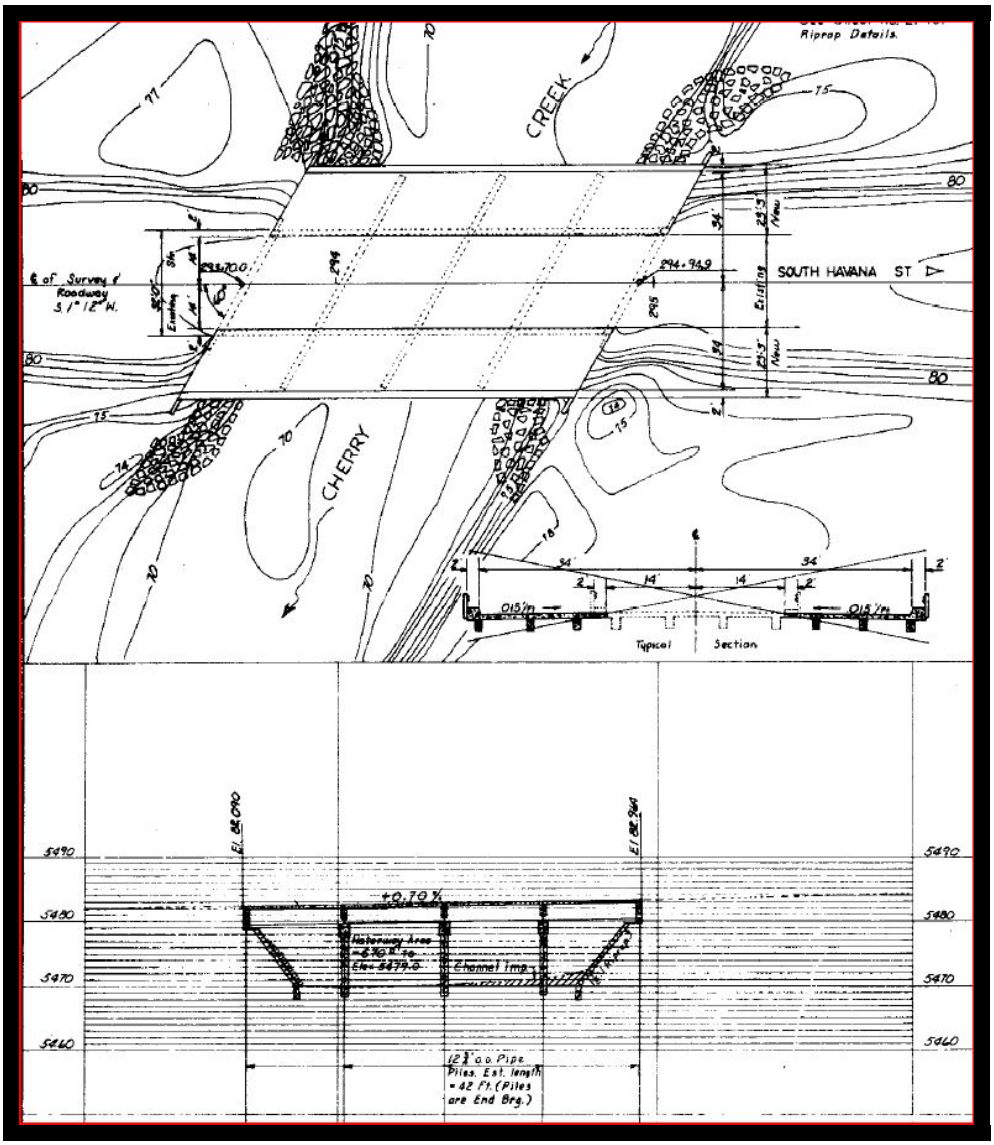


Figure 2 Existing Bridge Structure – CDOT As Built Drawings

The bridge is modeled without ineffective flow areas because the bridge opening is very nearly the same width as the approaching channel flow area. This is also the case downstream of the bridge.

A steady flow, mixed flow regime was used to model the river. The Cherry Creek thalweg, and banks, were established on the CDOT survey terrain model. After setting the thalweg alignment, the cross sections were extracted at key locations along the creek. The thalweg, the bank geometries, and the cross sectional information, were exported from the WMS software into the river modeling software, HEC-RAS. Results from HEC-RAS were imported back to WMS to depict flood delineations overlain on the FIRM panel.

The channel n values are taken from "Flood Plain Modeling Using HEC-RAS" first edition, Table 5.7. The internal bridge cross sections were assigned an n value of 0.025 for the creek and banks. After modeling the water surface profile and mapping the flood plain, the n values were accepted as they produced results that are very consistent with the values shown on the FEMA FIRM map panel.

VI. Geology Report

Geotechnical field activities were completed on April 27th through 30th, 2009. The general geology consists of loose to dense, clayey to well graded sand overlying firm to very hard sandy claystone bedrock. Bedrock was encountered between 5,436 to 5,455 feet above mean sea level (amsl). Bedrock characteristics were consistent among borings.

VII. Stream Stability

Low flows are conveyed in a sandy active channel which is usually devoid of vegetation. Over the years, channel degradation has become apparent. The cannel degradation is a consequence of increased runoff due to urbanization, and Cherry Creek Dam, which traps all of the incoming sediment supply from the upstream watershed. The average channel slope downstream of the dam is approximately 0.4%.

VIII. Scour Analysis

The results of the water surface mapping for the required flood flow frequencies are shown in Table 2. The HECRAS model produced a very similar water surface profile for the proposed structure as compared to the existing structure. The flow area under the bridge is roughly the same and the result of the proposed design on the water surface profile is only slightly increased over the existing.

Cherry Creek – Structure F-17-AE (At Cross Section 1500 BU)			
Flood Frequency Event	Water Surface Elevation (ft)	Distance to Low Chord (ft)	Depth of Scour (ft)
Low Chord Elevation[(2)]	5479.15		
50-yr	5476.20	2.95	10.24
100-yr	5476.70	2.45	11.05
250-yr	5477.25	1.90	17.30
500-yr	5477.67	1.48	18.29
Max. Release Rate	5479.29	-0.14	21.73

Table 2 Hydraulic Analysis Summary
[(2)] Low chord elevation taken at Pier 3 (center pier).

The depth of scour predicted by the scour model under the structure is moderate. The soil type and the large flow rate discharge from the reservoir combine to produce a deep scour under the structure. Since the structure is on piles the bridge may experience the hydraulic scour and removal of the embankment soils on both abutments, piers and in the channel. The results of the scour model are shown in the scour appendix.

IX. Bridge Pier Scour Protection

There are no bridge pier scour protection recommendations at this time.

X. Bridge Abutment Slope Protection

There are no bridge abutment slope protection recommendations at this time.

XI. Summary Recommendations for Structure F-17-AE

The recommended “Scour Plan of Action” to monitor the structure during periods when Cherry Creek is experiencing high flows. At a stream elevation of 5476, or within 3 feet of the low chord of the substructure, it is recommended that the bridge be closed to traffic. The recommended detour for traffic is at the intersection of Hampden Avenue (SH 30) and I-25. Traffic should be routed south on I-25 to I-225, then west on I-225 to Parker Road (SH 83), then north on Parker Road (SH 83) to Havana Street. This detour should be used until the Cherry Creek stage subsides.

XII. References

CDOT Drainage Design Manual, 2004

CDOT As-Build Record Drawings, S0055(2) and U016-1(36) of Structure F-17-AE.

CDOT Region 6 Survey Files, BR 030A-027, Havana St. over Cherry Creek.

Urban Drainage & Flood Control District, Denver, Glendale, Arapahoe County, Flood Hazard Area Delineation, Cherry Creek, Merrick and Company, July 1976.

Cherry Creek Stabilization Plan, University Boulevard to Cherry Creek Dam, Muller Engineering Company, February 1991.

HEC RAS, River Analysis System, Version 4.0.0, March 2008.

WMS software, Version 8.1 BYU, EMSI, inc.

Floodplain Modeling Using HEC-RAS; Haestead Dyhouse Hatchett Benn, first ed.

FEMA Map Service Center.

Geotechnical Recommendations for Replacement of Structure F-17-AE, David Thomas, CDOT Region 6, Geotechnical Program, June 30, 2009

APPENDIX A – Scour Critical Bridge, Plan Of Action Form

SCOUR CRITICAL BRIDGE - PLAN OF ACTION

1. GENERAL INFORMATION

Structure number: F-17-AE	**City, County, State:** 20000 Denver, 031 Denver, CO	**Waterway:** Cherry Creek
Structure name: -1 (NA)	**State highway or facility carried:** SH 30 ML / Havana St.	**Owner:** 1 (State)

Year built: 1956	**Year rebuilt:** -1 (Widened 1969)	**Bridge replacement plans (if scheduled):** Yes **Anticipated opening date:** 2010-2011

Structure type: ☒ Bridge ☐ Culvert
Structure size and description: CSGC Concrete Slab & Girder, Continuous (L = 125', W = 72')

Foundations: ☒ Known, type: Piles Depth: 41' ☐ Unknown

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

Bridge ADT: 37,200	**Year/ADT:** 2005	**% Trucks:** 2

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

2. RESPONSIBILITY FOR POA

Author(s) of POA (name, title, agency/organization, telephone, pager, email):
Scott Leiker, PE, Region 6 Hydraulics Unit, CDOT, 303-757-9668, Scott.Leiker@dot.state.co.us
Date: 9/30/2009

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

POA updated by (name, title, agency, organization): _____ **Date of update:** ___
Items update: _____

POA to be updated every 24 **months by (name, title, agency/organization):** R-6 Hydraulics Unit

Date of next update: 9/30/2011

3. SCOUR VULNERABILITY

a. Current Item 113 Code: ☐ 3 ☐ 2 ☐ 1 Other: 5

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

c. Scour Evaluation Summary: Origionally rated as a 5 but down graded to a 4 because of exposed piles. Changed back to 5 when action to protect exposed foundations was completed.

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		**02/04/2009**	**03/22/2007**
Item 113	**Scour Critical**	**5 (Changed 03/02/09 by Jeff Anderson)**	**4 Stable, needs action**
Item 60	**Substructure**	**6**	**5 Fair**
Item 61	**Channel & Channel Protection**	**5**	**5 Bank Prot Eroded**
Item 71	**Waterway Adequacy**	**8**	**8 Equal Desirable**
Comments: (drift, scour holes, etc. - depict in sketches in Section 10)		**See POA Report**	_____

6. MONITORING PROGRAM

☐ **Regular Inspection Program** ☐w/surveyed cross sections
Items to Watch: None

☐ **Increased Inspection Frequency of __ mo.** ☐w/surveyed cross sections
Items to Watch: None

☐ **Underwater Inspection Required**
Items to Watch: None

☐ **Increased Underwater Inspection Frequency of __ mo.**
Items to Watch: None

☐ **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 5476
☒ Elev. measured from Bottom of Substructure
☐ 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*): Monitor until water recedes.
Action(s) required if scour critical elevation detected (*include notification and closure procedures*): Close approaches until channel is repaired.

Agency and department responsible for monitoring: CDOT, Region 6, Maintenance Section 8

Contact person (*include name, title, telephone, pager, e-mail*): Steve Pineiro, M) 303-619-1905

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 $0

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

Priority Ranking	**Estimated cost**
(1) _____	$ _____
(2) _____	$ _____
(3) _____	$ _____
(4) _____	$ _____
(5) _____	$ _____

Basis for the selection of the preferred scour countermeasure: _____

Countermeasure implementation project type:
☐ Proposed Construction Project ☐ Maintenance Project
☐ Programmed Construction - Project Lead Agency:
☐ Bridge Bureau ☐ Road Design ☐ Other _____

Agency and department responsible for countermeasure program (if different from Section 6 contact for monitoring): _____

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 _____ at _____
- ☐ 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

Contact persons (name, title, agency/organization, telephone, pager, email): Steve Pineiro, M) 303-619-1905

Criteria for re-opening the bridge: CDOT Staff Bridge

Agency and person responsible for re-opening the bridge after inspection: Steve Pineiro, M) 303-619-1905

9. DETOUR ROUTE

Detour route description (route number, from/to, distance from bridge, etc.) - Include map in Section 10, Attachment E. A detour for traffic is to be made at the intersection of Hampden Avenue (SH 30) and I-25. Traffic should be routed south on I-25 to I-225, then west on I-225 to Parker Road (SH 83), then north on Parker Road (SH 83) to Havana Street. This detour should be used until the Cherry Creek stage subsides.

Bridges on Detour Route:

Bridge Number	Waterway	Sufficiency Rating/ Load Limitations	Item 113 Code
F-17-ES	Goldsmith Gulch	70.0	8
F-17-OK & F-17-DY	Cherry Creek	95.1 & 70.9	8

Traffic control equipment (detour signing and barriers) and location(s): Variable Message Boards, Traffic Control Signing, Barricades, Cones, Drums, Detour Signing.

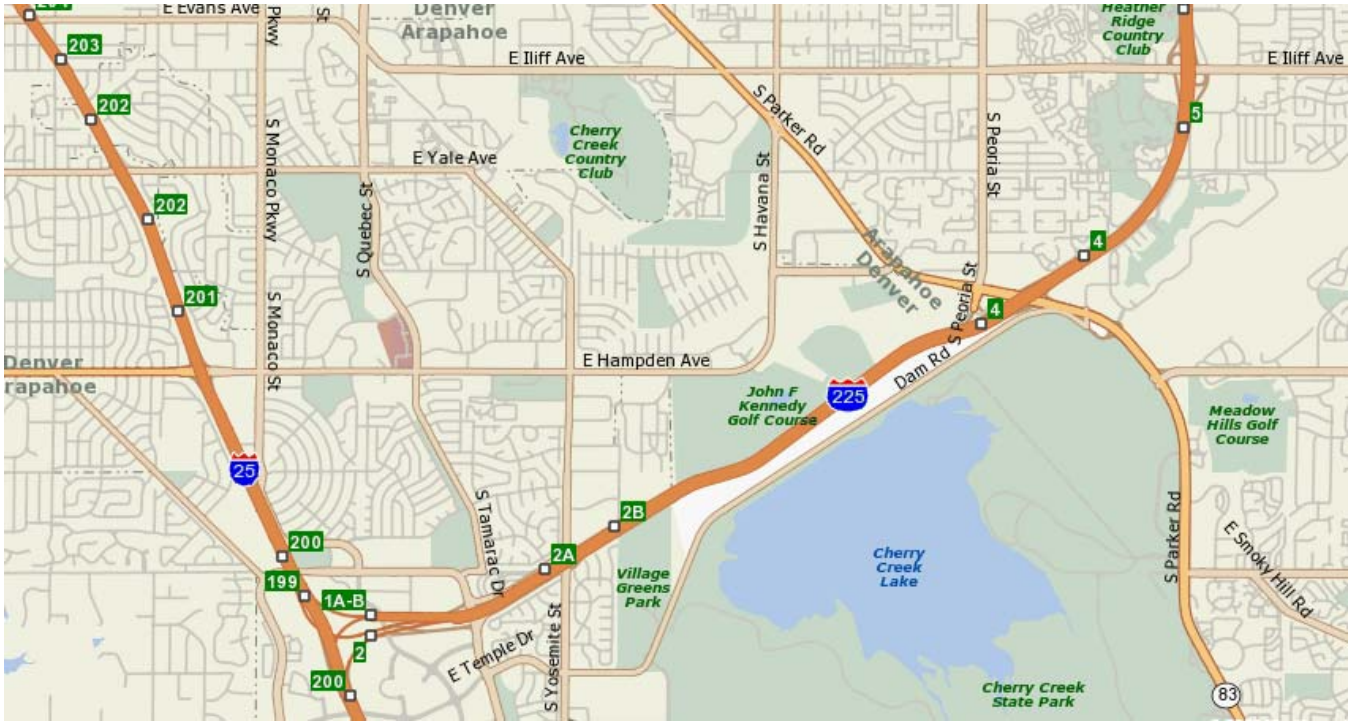
Additional considerations or critical issues (susceptibility to overtopping, limited waterway adequacy, lane restrictions, etc.) : _____

News release, other public notice (include authorized person(s), information to be provided and limitations): _____

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: _____**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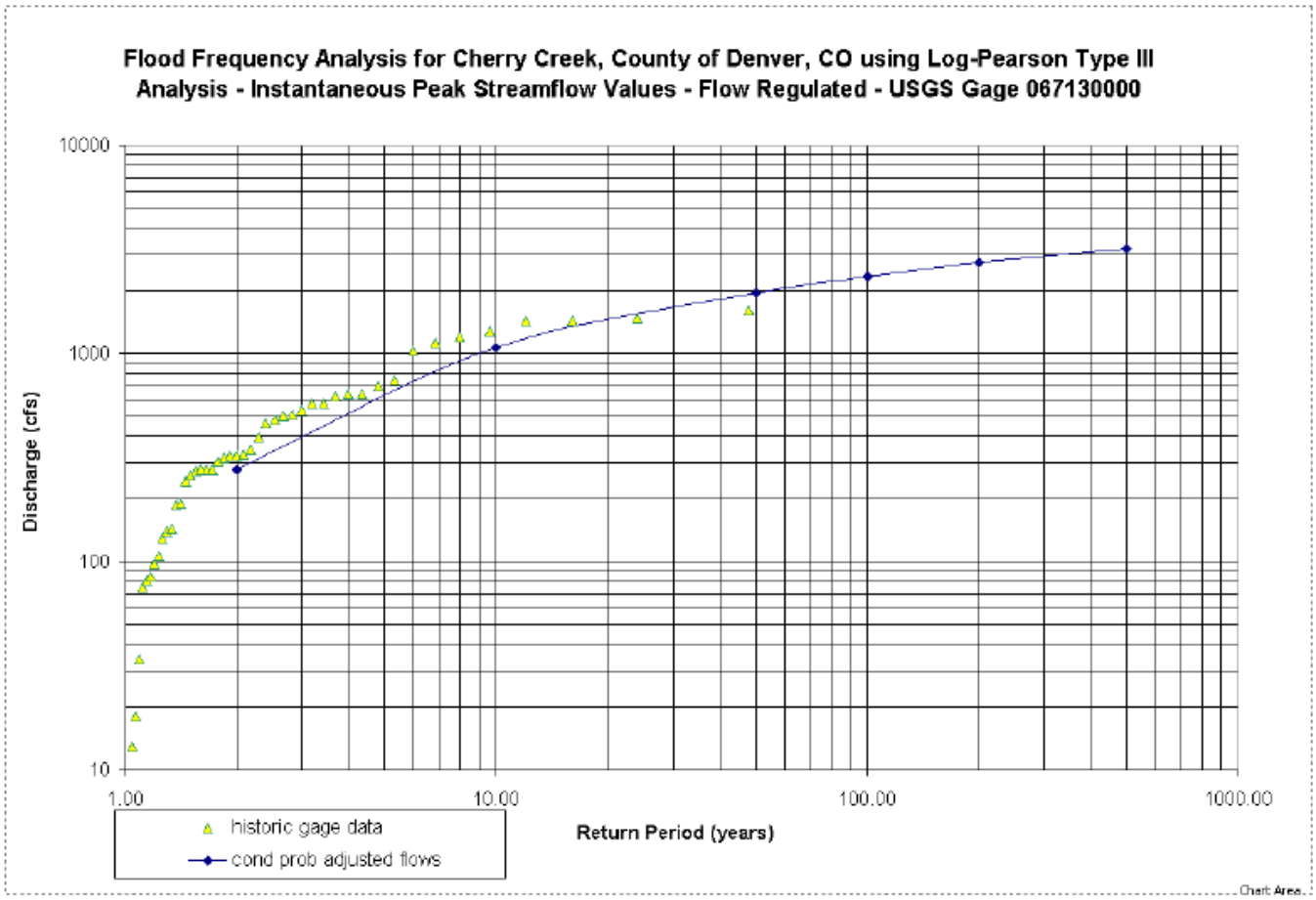
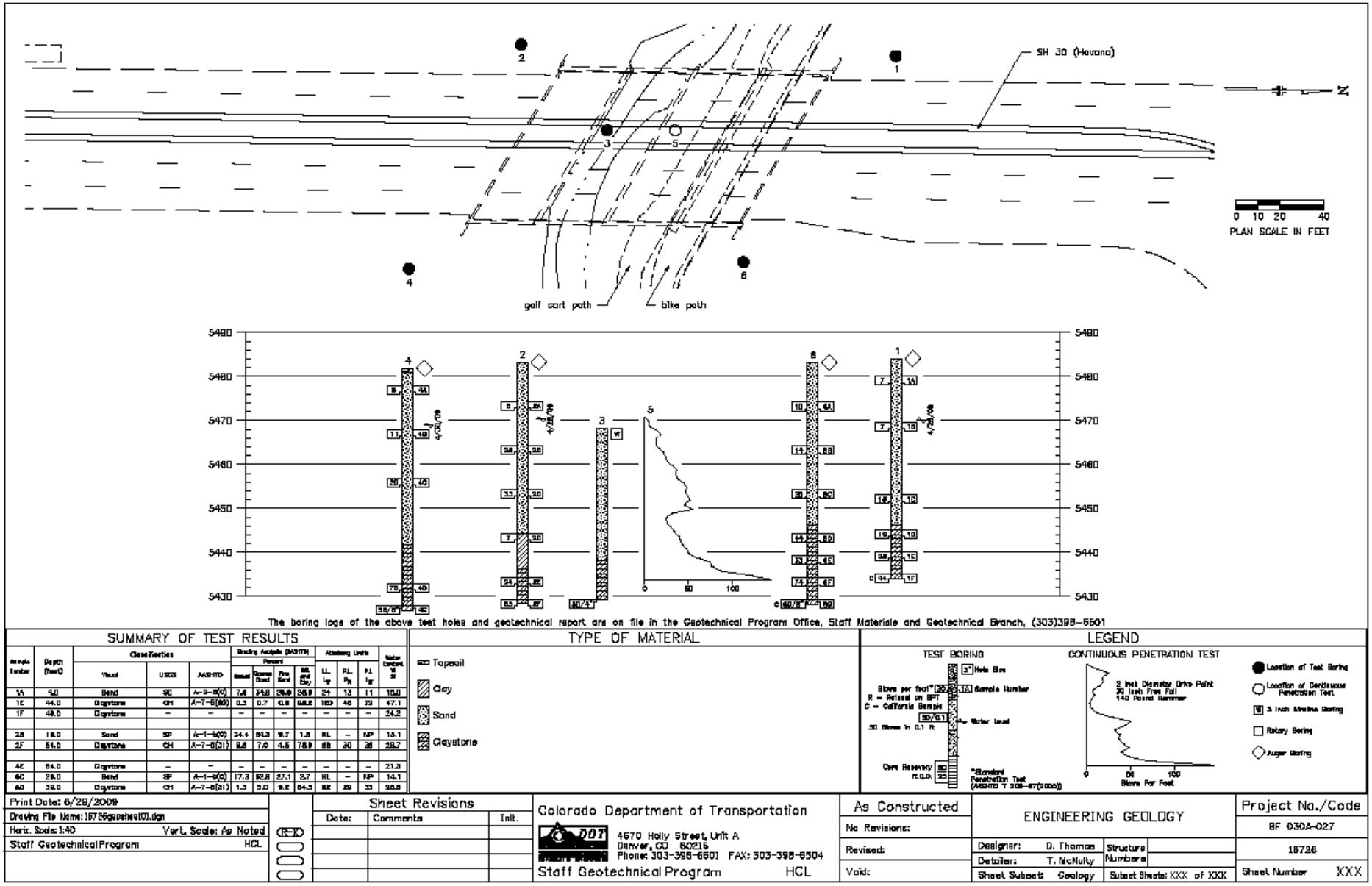
Denver
Arapahoe
E Iliff Ave
Heather Ridge Country Club
E Iliff Ave
203
202
202
201
S Monaco Pkwy
S Quebec St
Cherry Creek Country Club
E Yale Ave
S Havana St
S Parker Rd
S Peoria St
5
4
4
Arapahoe
Denver
S Peoria St
Denver
rapahoe
E Hampden Ave
John F Kennedy Golf Course
225
Dam Rd
Meadow Hills Golf Course
25
S Tamarac Dr
2B
200
2A
199
1A-B
Village Greens Park
Cherry Creek Lake
S Parker Rd
E Smoky Hill Rd
E Temple Dr
S Yosemite St
2
200
Cherry Creek State Park
83

APPENDIX B - Hydrology

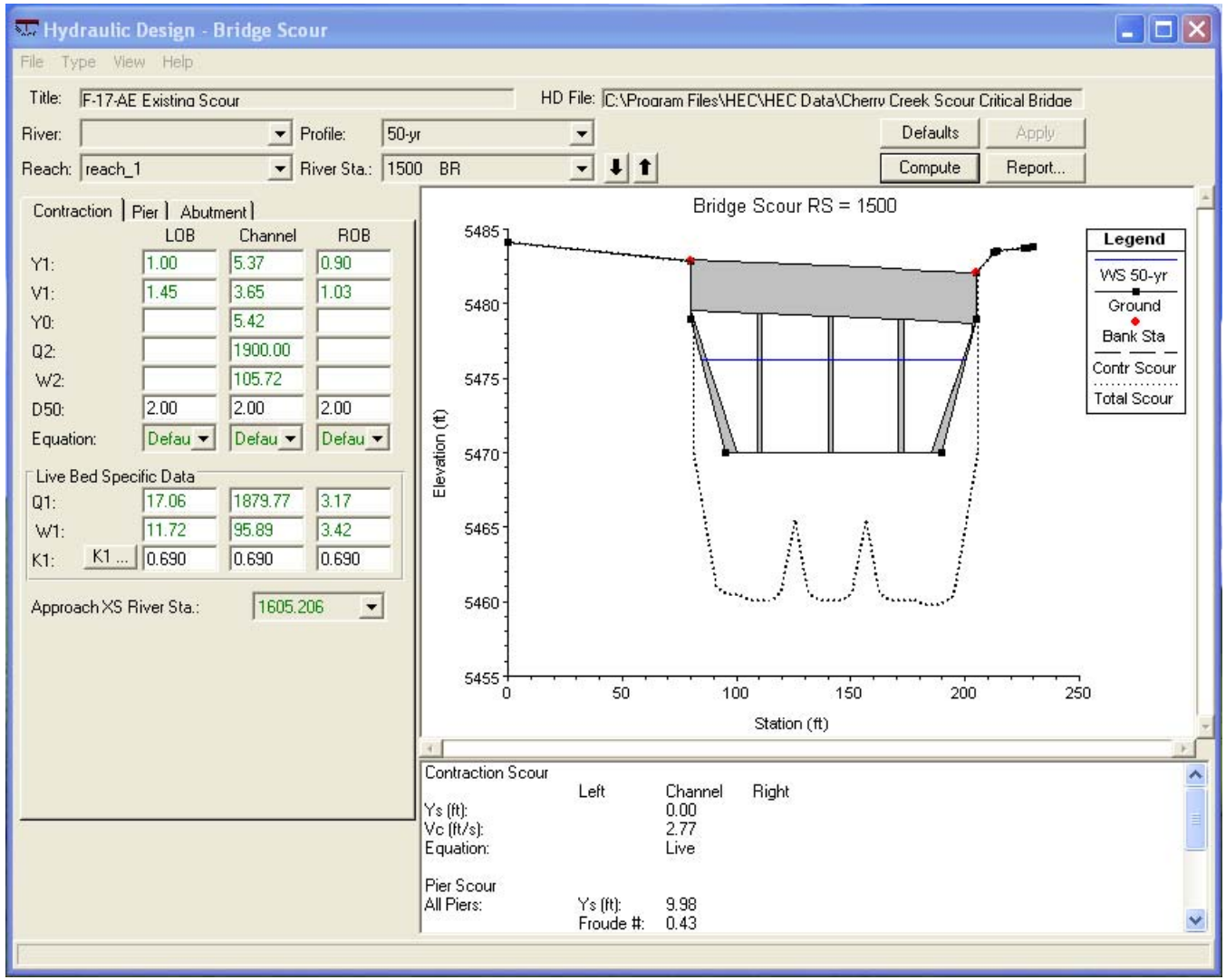


APPENDIX C – Geology

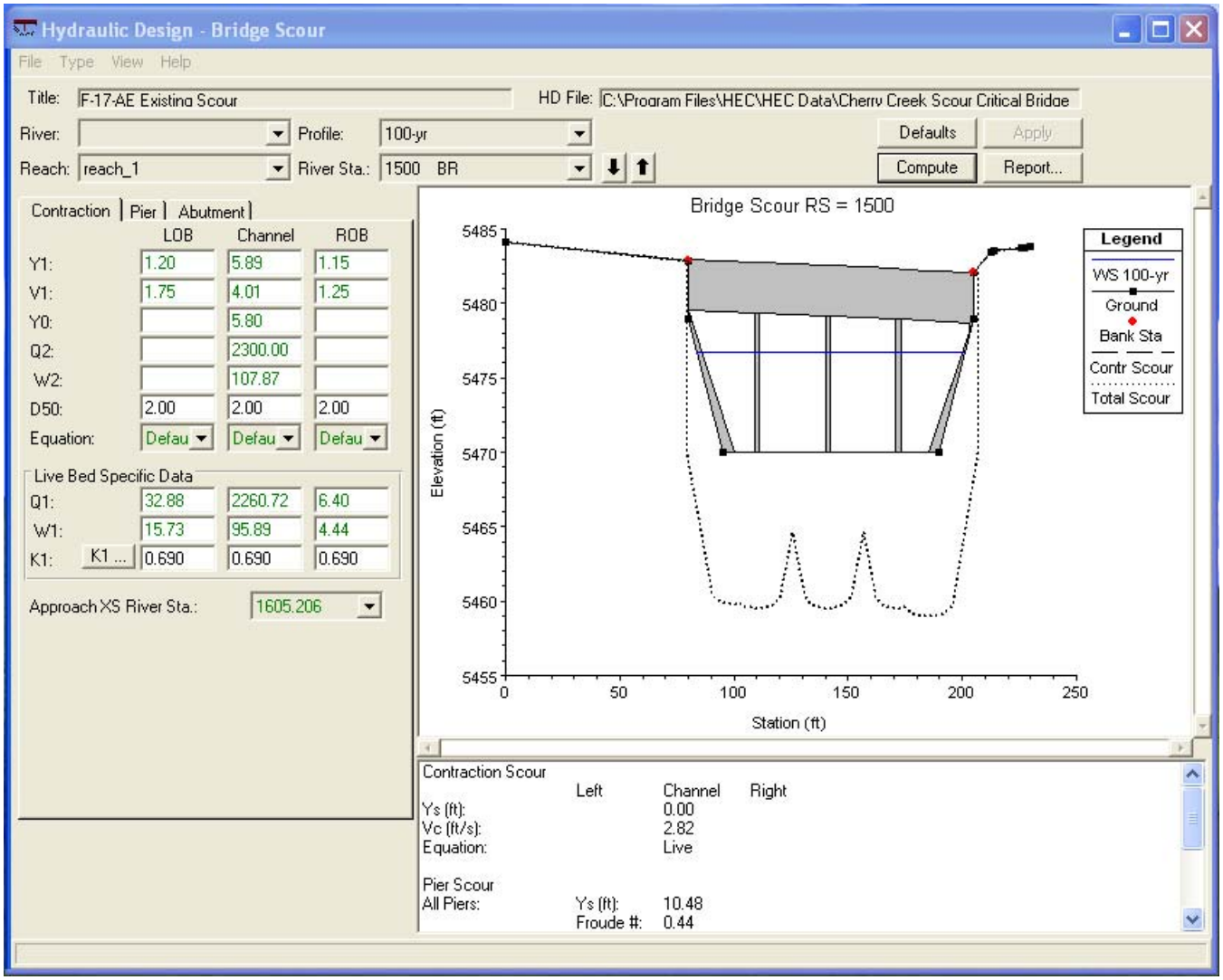


Engineering Geology Sheet (from Geotechnical Recommendations for Replacement of Structure F-17-AE, June 30, 2009)

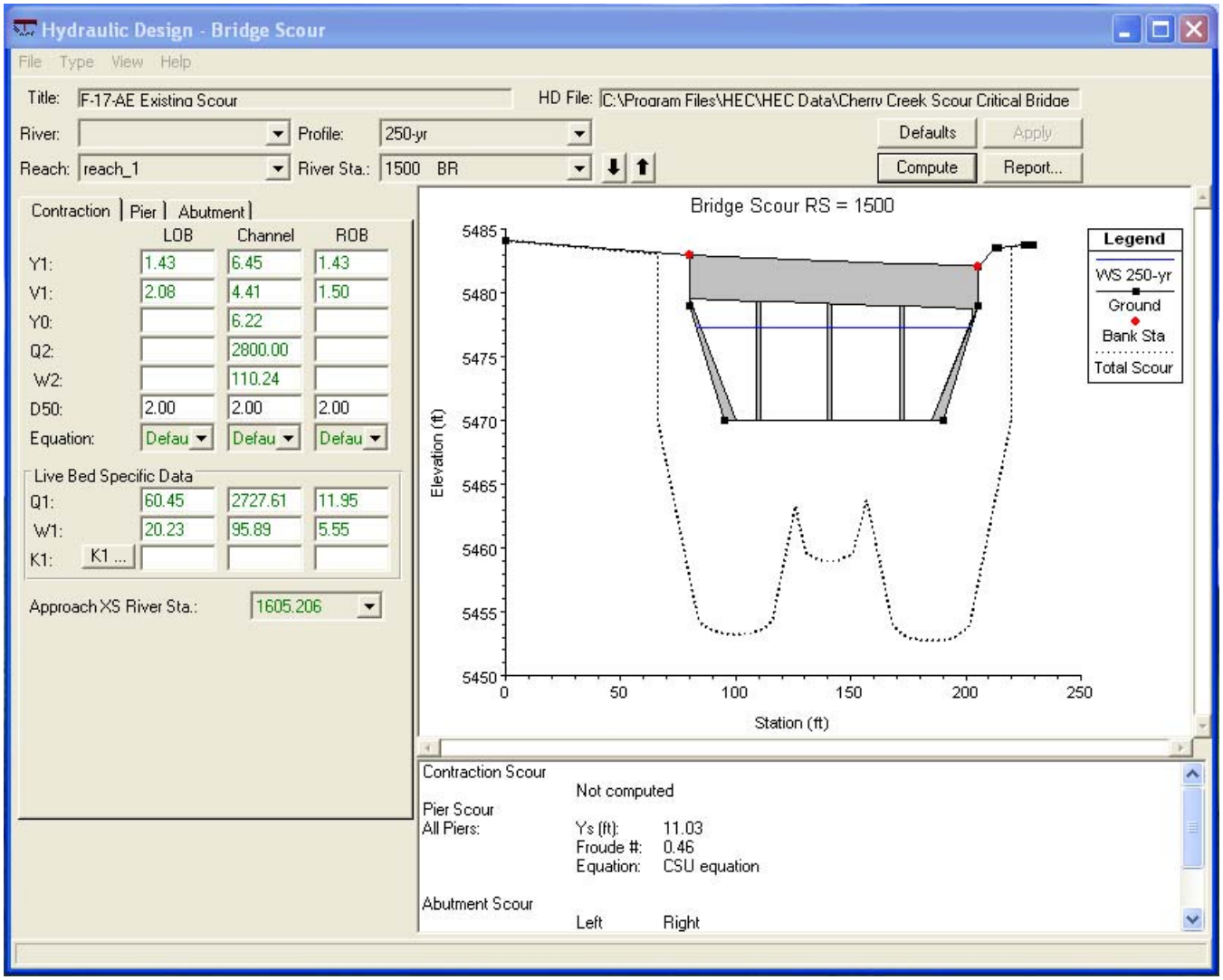
APPENDIX D – HEC-RAS Analysis



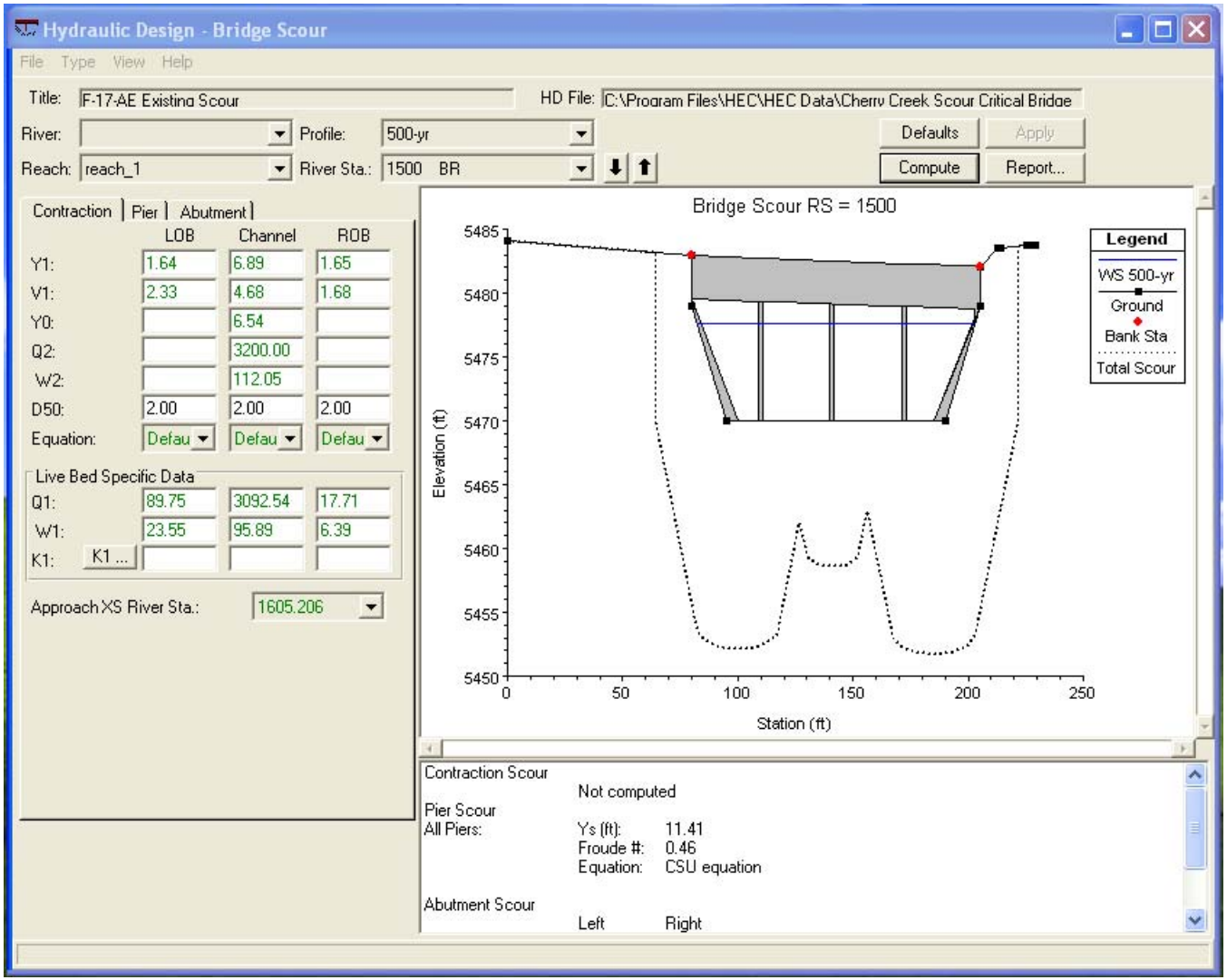
50 Year Bridge Scour Analysis



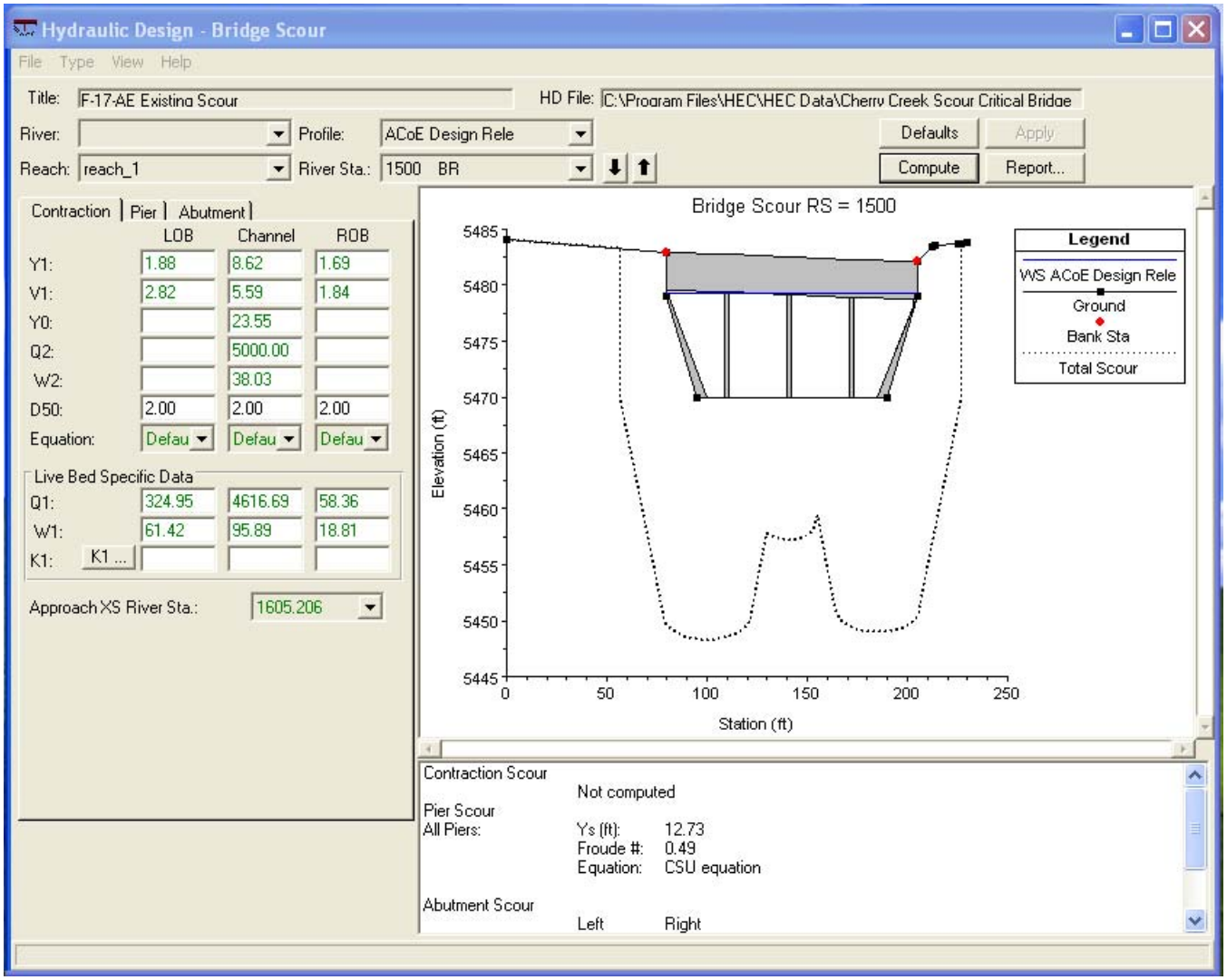
100 Year Bridge Scour Analysis



250 Year Bridge Scour Analysis



500 Year Bridge Scour Analysis



Maximum Allowable Release Bridge Scour Analysis