# Appendix D Hydraulic Model Results

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# Appendix D. Hydraulic Model Results

## Introduction

The California Department of Water Resources (DWR) Fish Passage Improvement Program (FPIP), in cooperation with Stockton East Water District, evaluated anadromous fish passage through structures on the Calaveras River System from New Hogan Dam to its confluence with the San Joaquin River. This report summarizes the models created to characterize the performance of 17 of these structures and the criteria used to evaluate them. We split the structures into two groups: 2004 modeled structures and 2005 modeled structures.

The 8 structures selected for modeling in 2004 were:

Stockton Diverting Canal
- Central California Traction Railroad Bridge
- Budiselich Flashboard Dam

Mormon Slough
- Caprini Low-flow Road Crossing
- Hogan Low-flow Road Crossing
- Hosie Low-flow Road Crossing
- Watkins Low-flow Road Crossing

Calaveras River
- Murphy Flashboard Dam
- Clements Road Flashboard Dam

The 9 structures selected for modeling in 2005 were:

Mormon Slough
- Lavaggi Flashboard Dam
- Fujinaka Low-flow Road Crossing
- Mormon Slough Railroad Bridge
- Piazza Flashboard Dam
- Fine Road Bridge

Calaveras River
- Gotelli Low-flow Road Crossing (RM 6.2)
- McAllen Road Bridge
- McAllen Flashboard Dam
- Cherryland Flashboard Dam

## Goals and Objectives

The objective of this work was to verify the point system developed for ranking structures in the Phase I fish passage evaluations by modeling a subset of the potential barriers to fish passage on the Calaveras River system. The models are required to accurately reflect the hydraulic performance of each structure, and must also be useful for identifying potential problems of adult salmonids (Chinook and *O. mykiss*) and juvenile salmonid downstream fish passage. Output from these models will be evaluated using a set of criteria developed by DWR in 2004 using guidelines set forth by California Department of Fish and Game (DFG) and the National Marine Fisheries Service (NMFS).

## Overview of Hydraulic Models

A one dimensional (1-D) hydraulic model was developed for each of the structures. Modelers used Hydrologic Engineering Centers River Analysis System. HEC-RAS is the US Army Corps of Engineers step-backwater computer program in subcritical, supercritical, and mixed flow regimes to generate water surface profiles.

Cross-sectional survey data used for the analysis were obtained from surveys performed by DWR in the fall of 2003 using conventional ground survey techniques using a Sokkia Set 3B total station and a Sokkia SDL30 Autolevel. All elevation datums used were arbitrary with respect to each structure, and were not tied into any established local datum. Horizontally, each survey was located globally using a Trimble handheld GPS with sub-meter accuracy. All surveys are monumented to allow for recovery, which means it would also be possible to place them in a global coordinate system, both horizontally and vertically, at a later date.

Survey cross sections were placed both upstream and downstream of the structures. They were placed at distances of up to 5 to 10 times the active channel width at each structure. Sections were also placed so as to define the structures and any riprap present, as well as any changes in channel width, direction, or roughness. Most sections were surveyed to the top of each bank of the channel, but some additional data was taken from US Geological Survey (USGS) electronic quads when deemed necessary during the modeling process. Initial Manning's "n" values were based on experience and commonly used values to compile an uncalibrated model.

The models were run assuming the flows would either remain subcritical at all sections, slow and deep relative to the section geometry; or that the flows could be supercritical at some sections, fast and shallow relative to the section geometry. For a model that is run subcritical at all sections, the program uses the downstream boundary conditions to determine the water surface profile of the next section up. In contrast, if a model is run as supercritical at all sections the program uses the upstream boundary conditions to determine the water surface profile. In our case "Mixed Flow" was selected in areas of the model where it was determined that a supercritical solution might be necessary. Running a model as "Mixed Flow" starts the program like a subcritical model but if the profile at a section can not be determined it will attempt a supercritical solution utilizing upstream boundary conditions.

Water surface elevations were also recorded at each of the cross sections to help calibrate the models and develop starting conditions. Flow measurements were taken using a Rickly Hydrological Co. USGS type AA model 6200 current meter and additional waterline surveys were also performed, using the same conventional ground survey techniques used for cross sectional surveys, to assist with the calibration.

Flow accuracy is dependent on the flow area matching the measured area where the measured area is determined from the sum of areas in 2-foot steps along the section and using averaged velocities within subsections.

The range of steady state discharges used in the hydraulic models varied according to the location of each structure on the Calaveras River System and/or the flow capacity of the structure and channel banks. In general, discharges used in the analysis of each structure ranged from 1 to 750 cubic feet per second on the Calaveras River, and from 2 to 6,000 cfs on Mormon Slough and the Stockton Diverting Canal. The ranges were incrementally divided to provide a smooth line for the performance curves developed for each structure.

## Hydraulic Model Calibration

Data for calibration of the models were obtained during high flow events. Water surfaces were marked with stakes, and flows were measured during each event according to the procedure described in the April 12, 2004, DWR draft calibration report (DWR 2004a). In some cases where measurement of flow was dangerous or not possible, flow was estimated using a combination of measurements, rating tables, and professional judgment. After staking the surface, the waterlines were surveyed. Surveys included the horizontal and vertical location of high water marks (HWMs) to the nearest 0.1 feet.

Calibration of the models was carried out by adjusting “n” (roughness) values for the channels and overbanks until modeled water elevations were roughly within 0.10 feet of surveyed values. This level of accuracy was not expected in the more complex portions of the channel, such as the instances of riprap scour protection on the channel bed. Many of the structures have riprap scour protection on their downstream side within the channel, which in some cases is quite extensive, and those areas were far too topographically diverse to be characterized within the context of this project. The level of topographic detail needed would be far too expensive to gather for the accuracy gained. Bank stations used in the models were relocated to the top of banks, where water would overtop levees or flow onto the surrounding floodplain, when problems were discovered with bank station placement at the active channel.

The models are all reasonably accurate when run within or near the range of calibration flows. However, accuracy is reduced as flows deviate substantially from the calibration flows. This is especially true for the higher flows modeled, such as the maximum flow of 6,000 cfs on Mormon Slough. The only way to increase accuracy of the model at those flows is to calibrate the model at or near those flows via water surface surveys and flow measurements. Other considerations include whether or not those flows are problematic for the structures in question, and the frequency of occurrence of the higher flows. When those aspects are considered, it seems far more important to invest time and resources into calibrating the models for lower flows where small differences have more significant effects with respect to our objectives.

# Criteria Used to Evaluate Structure Performance

Criteria used to evaluate the structures were taken from guidelines for all types of stream crossings summarized in a draft fish passage criteria report (DWR 2004b). The sources for those criteria were DFG and NMFS, as well as personal communications with George Heise of DFG. The following tables (Table D-1 and Table D-2) taken from the report list the maximum velocity, slope, fall, and minimum depths for juvenile and adult salmon for the structures and the riprap.

**Table D-1. Recommended criteria for unimpaired passage of juvenile and adult salmonids**

| | Velocity (fps) | | Depth (ft) | | Slope (%) | | Fall (ft) | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Juvenile | Adult | Juvenile | Adult | Juvenile | Adult | Juvenile |
| Structures | See Table 2 | 1.0 | 1.0 | 0.5 | 3.0 | 3.0 | 1.0 | 0.5 |
| Riprap | See Table 2 | 1.0 | 2.0 | 1.0 | 5.0 | 5.0 | 1.0 | 0.5 |

fps= feet per second

**Table D-2. Recommended maximum velocities vs. structure length for adult salmonids**

| Structure length vs Maximum average water velocity for adult salmonids | |
|---|---|
| Structure length (ft) | Adult anadromous salmonids (fps) |
| <20 | 10 |
| 20-40 | 8 |
| 40-60 | 6 |
| 60-100 | 5 |
| 100-200 | 4 |
| 200-300 | 3 |
| >300 | 2 |

fps = feet per second

Criteria used for velocity and depth in the channel, as listed in the 2004 draft criteria report, originated from the DFG restoration manual (DFG 2003) under the adult anadromous salmonids prolonged swimming mode. The prolonged swimming speed of 6.0 fps and the minimum depth of 1 foot for adults were used to evaluate channel sections.

The “structure length”, derived from adding the length of the structure to the estimated length of the riprap, was used to select the corresponding maximum velocity (see Table D-2). The length of riprap is measured from the downstream end of the concrete structure to the point on the estimated hydraulic profile at which the depth of flow on the riprap is 2.0 feet or greater. This implies that as the flow and depth across the structure and riprap increase maximum allowable velocity will also increase.

# Hydraulic Model Results

To illustrate the performance of each of the structures, a range of steady state discharges was used in the models to create depth and velocity rating curves for the structure, riprap, and the immediate channel. Output used from each model included the depths and velocities at each cross-section for each flow profile modeled. In addition, calculated water surface profiles along the structures were used to determine effective "structure length" at each flow.

The 17 model results contained in this appendix, including performance summaries and velocity and depth curves, are based on original raw data. Over time, the model runs were refined and resulting graphs and charts were enhanced to the extent shown in the 17 model performance summaries and curves depicted in the main body of this report. As such, the material provided in Appendix D is intended for background information only. It is important to note that the 17 model results shown in both the body of this report and Appendix D are based on one-dimensional modeling techniques, and therefore it is recommended that further, more sophisticated modeling be done during the preliminary and final structure retrofit design processes.

# Analysis of Structure Performance

Various curves were developed from model output to use in analyzing the performance of each structure with respect to the goals of the project. Those curves are presented here for each structure. The first figure in each group shows how the length of the structure changes with respect to flow, and also shows the maximum allowable velocity for the specified lengths according to information shown in Table D-2. This creates a step curve that is shown on each of the velocity rating curves for the structure and riprap sections.

The curves were then used to identify flows at which passage was unimpeded. A cross section was considered to have impeded fish passage when maximum velocities or depths did not meet the established criteria. This was considered by section type (structure, riprap, and channel) and only one of the sections needed to exceed the criteria before the entire section type was considered impaired (for example, when one structure section exceeded maximum velocities, the entire structure was considered impaired at that flow). When evaluating a structure with more than one component (for example, weir and 3-culverts), it assumed that passage was good when any one of the components was unimpeded.

# 2004 Modeled Structures

## *Central California Traction Railroad Bridge*

**Photo D-1. Central California Traction Railroad Bridge – Taken downstream during high flow condition**

**Photo D-2. Central California Traction Railroad Bridge – Taken downstream during low flow condition**

## Structure Details

| | | | |
|---|---|---|---|
| Name of structure: | Central California Traction Railroad Bridge | | |
| Type of structure: | Bridge | | |
| Tributary: | Stockton Diverting Canal | | |
| Number of sections: | upstream-3 | downstream-4 | structure-9 |
| Length of model: | upstream -342 ft | | downstream: 334 ft |

*Description of structure.* A railroad trestle characterized by a rough concrete apron and low flow flume. Riprap is also placed on the downstream side of the structure.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel bottom: | 0.035, 0.04 |
| Side slopes and banks | 0.08 |
| Concrete structure: | 0.022-0.04 |
| Riprap: | 0.07–0.12 |
| Flume: | 0.012 |

*Calibration*

Number of flows: 2

1. Flow: 111 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. A split flow was measured as 92 in the flume and 19 over the weir.

2. Flow: 2,128 cfs Survey method: Total Station

Comments: Estimated flow from velocity measurements and estimates from Budiselich Flashboard Dam. All points taken on left bank.

*Starting conditions used for the model.* Both profiles were modeled in the mixed flow regime and used the known water surface elevations.

*Assumptions:* The structure was modeled with two components: one representing the concrete apron as a weir, and the other representing the flume. The components were modeled as a split flow with the weir on one branch and the flume on the other.

## Performance Summary

The flume handles all of the flow up to around 40 cfs, at which point water begins to flow over the weir, or apron, beneath the crossing. The flume velocities exceed the maximum for velocities from 12 to 1,970 cfs. Depths in the flume are below the minimum for flows up to 30 cfs for adults and 11 cfs for juveniles. The weir does not have any velocity problems throughout the range of modeled flows, however there are problems with depth below 190 cfs for adults and 75 cfs for juveniles. Velocities across the riprap sections are below the maximum, but minimum depths are not met until 210 cfs for adults and 10 cfs for juveniles. The channel appears to meet maximum passage velocity requirements, but has depth problems at low flows. In summary the structure has impaired passage for flows up to 210 cfs for adults and 11 cfs for juveniles.

**Figure D-1. Cross section locations for Central California Traction Railroad Bridge HEC-RAS model**

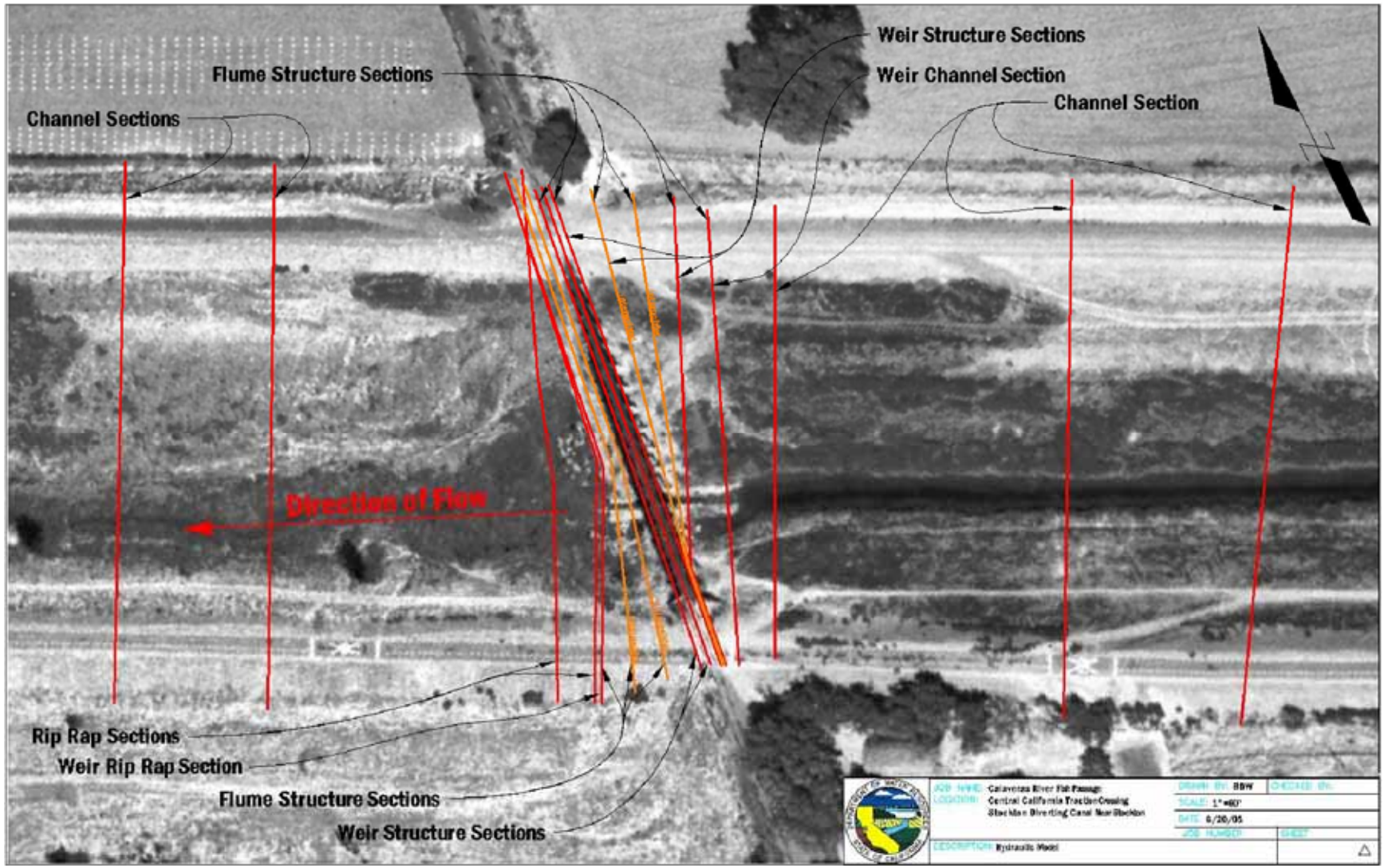


**Figure D-2. Central California Traction Railroad Bridge – Relationship of length to maximum velocity**

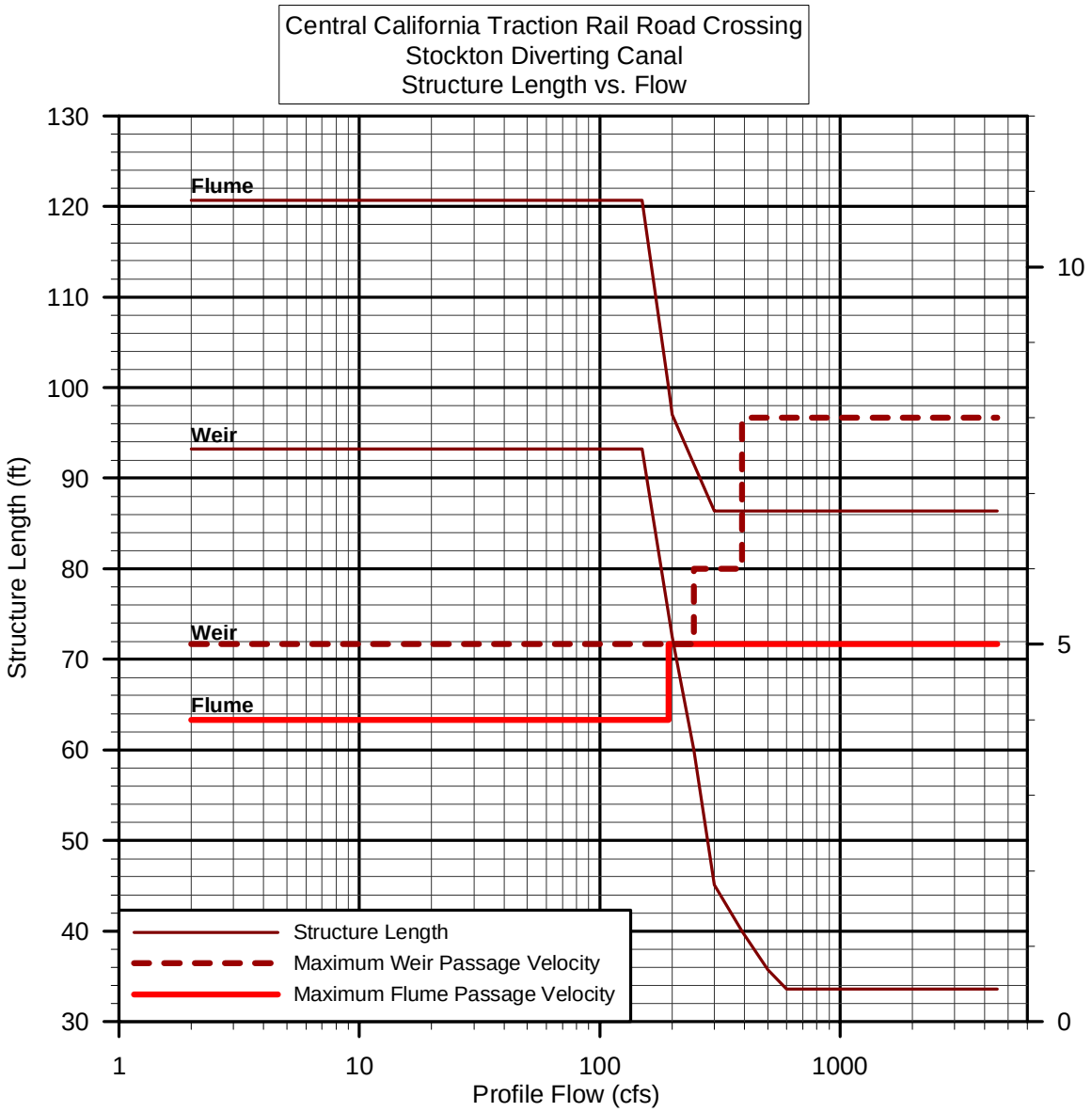


**Figure D-3. Central California Traction Railroad Bridge – Velocity rating curves for the weir**

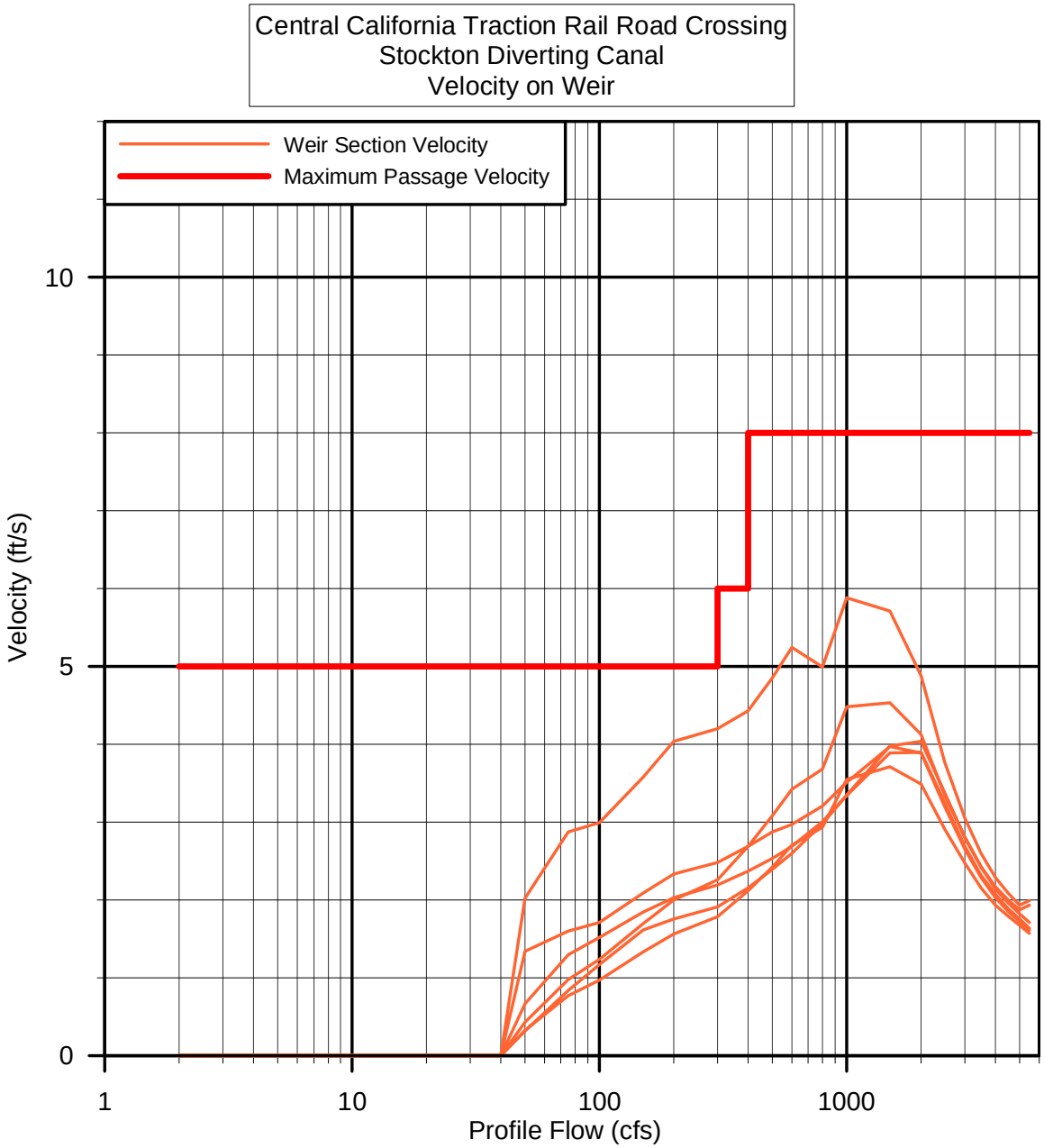


**Figure D-4. Central California Traction Railroad Bridge – Depth rating curves for the weir**

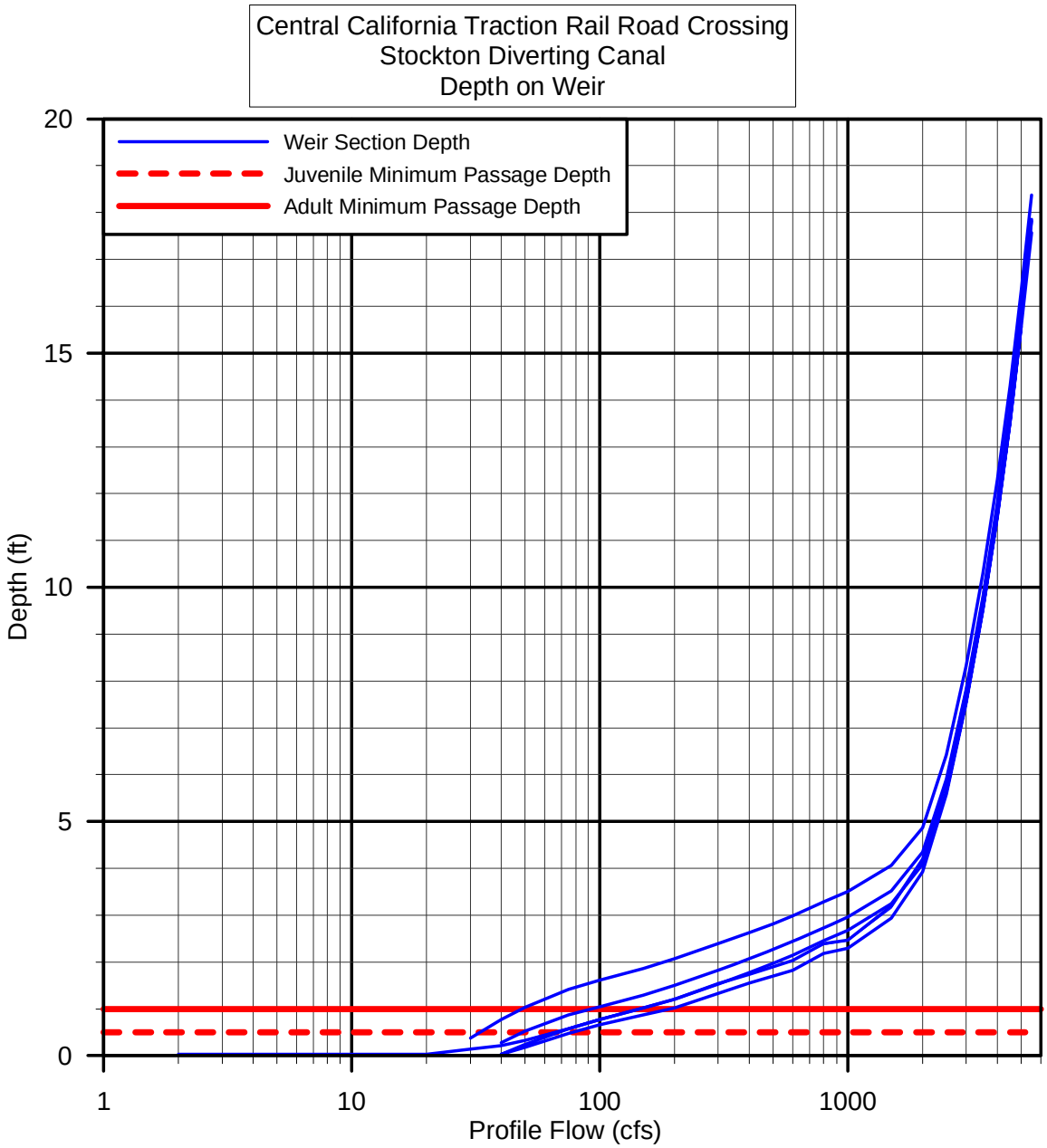


**Figure D-5. Central California Traction Railroad Bridge – Velocity rating curves for the flume**

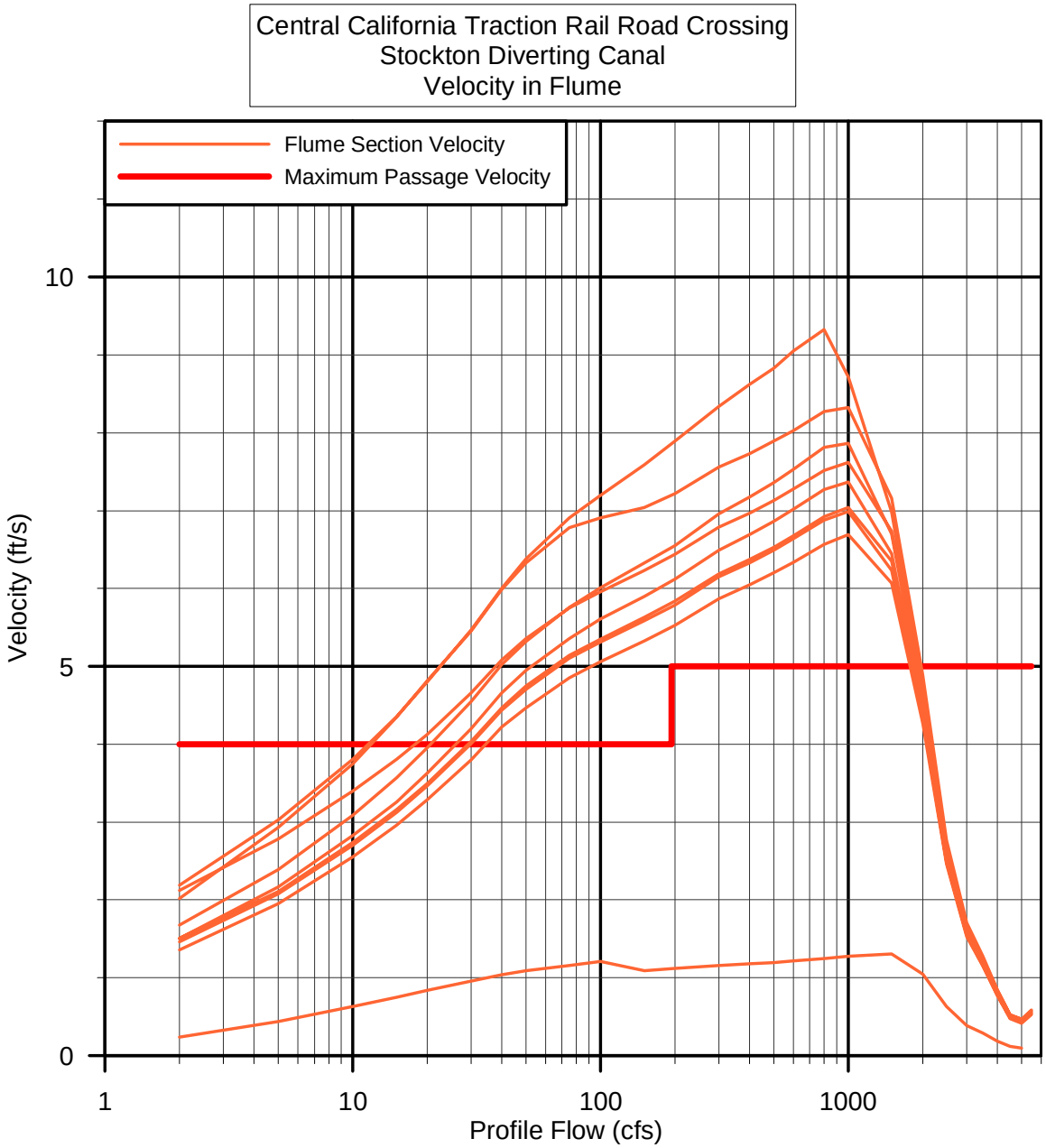


**Figure D-6. Central California Traction Railroad Bridge – Depth rating curves for the flume**

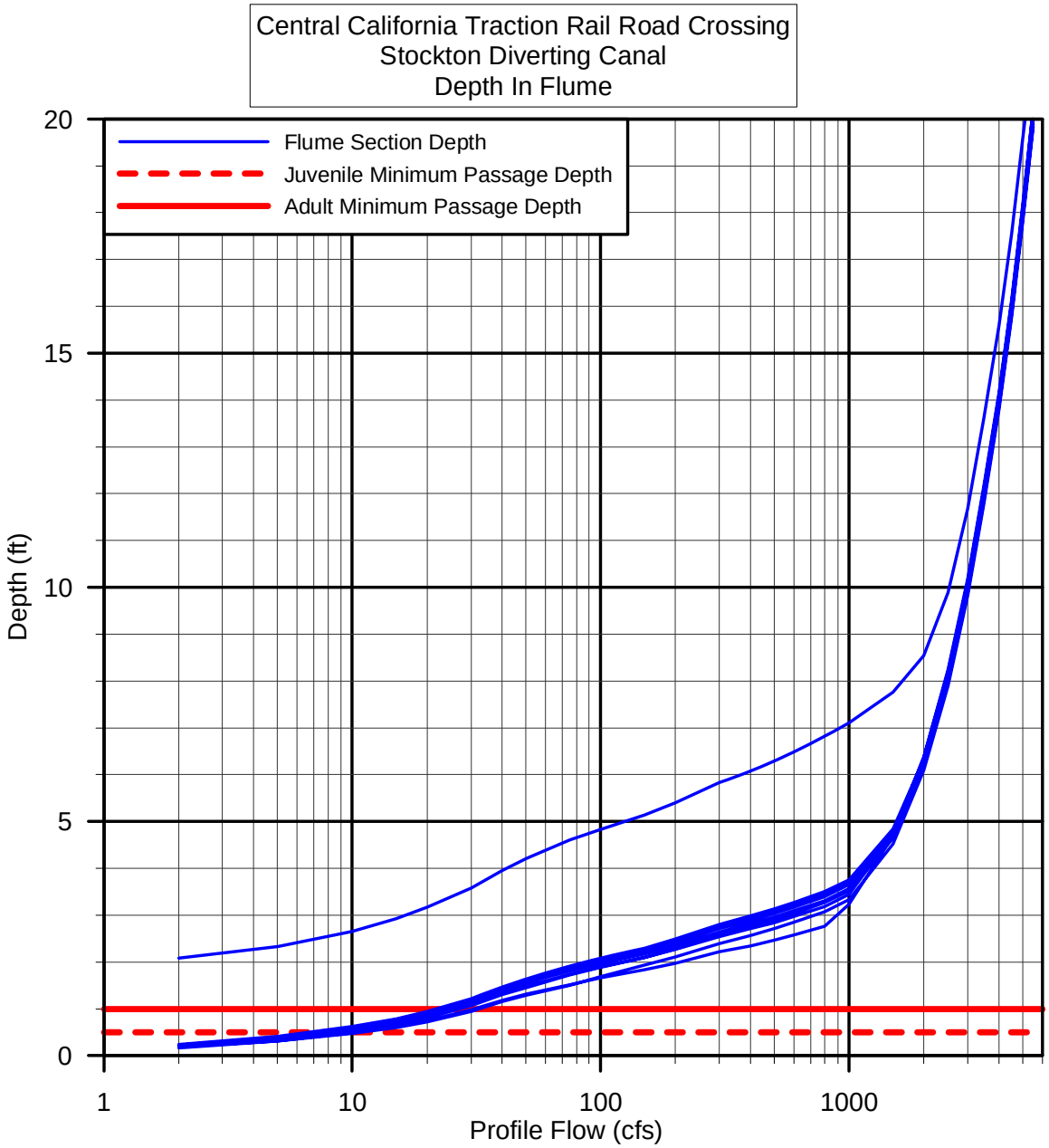


**Figure D-7. Central California Traction Railroad Bridge – Velocity rating curves for the riprap**

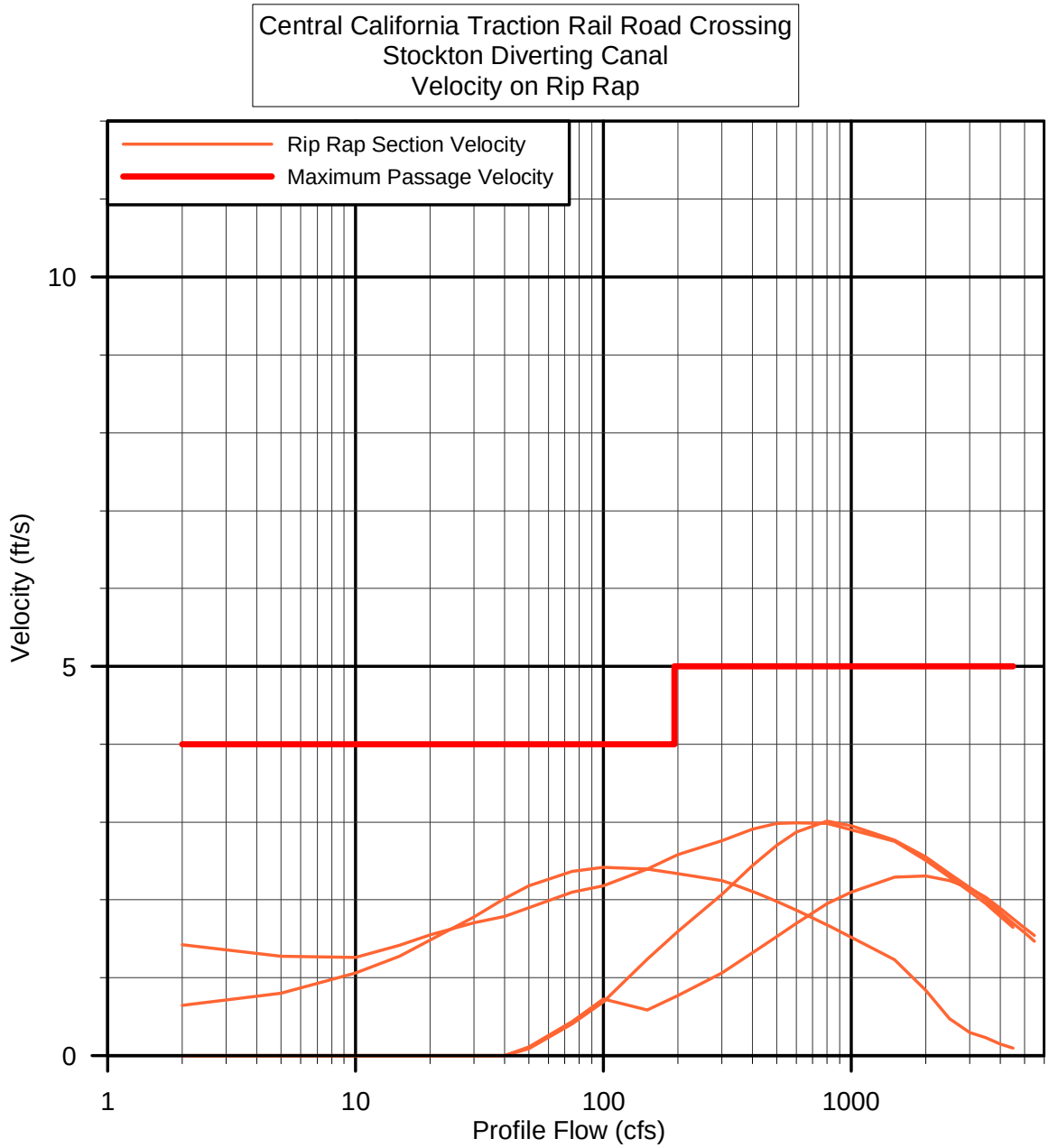


**Figure D-8. Central California Traction Railroad Bridge – Depth rating curves for the riprap**

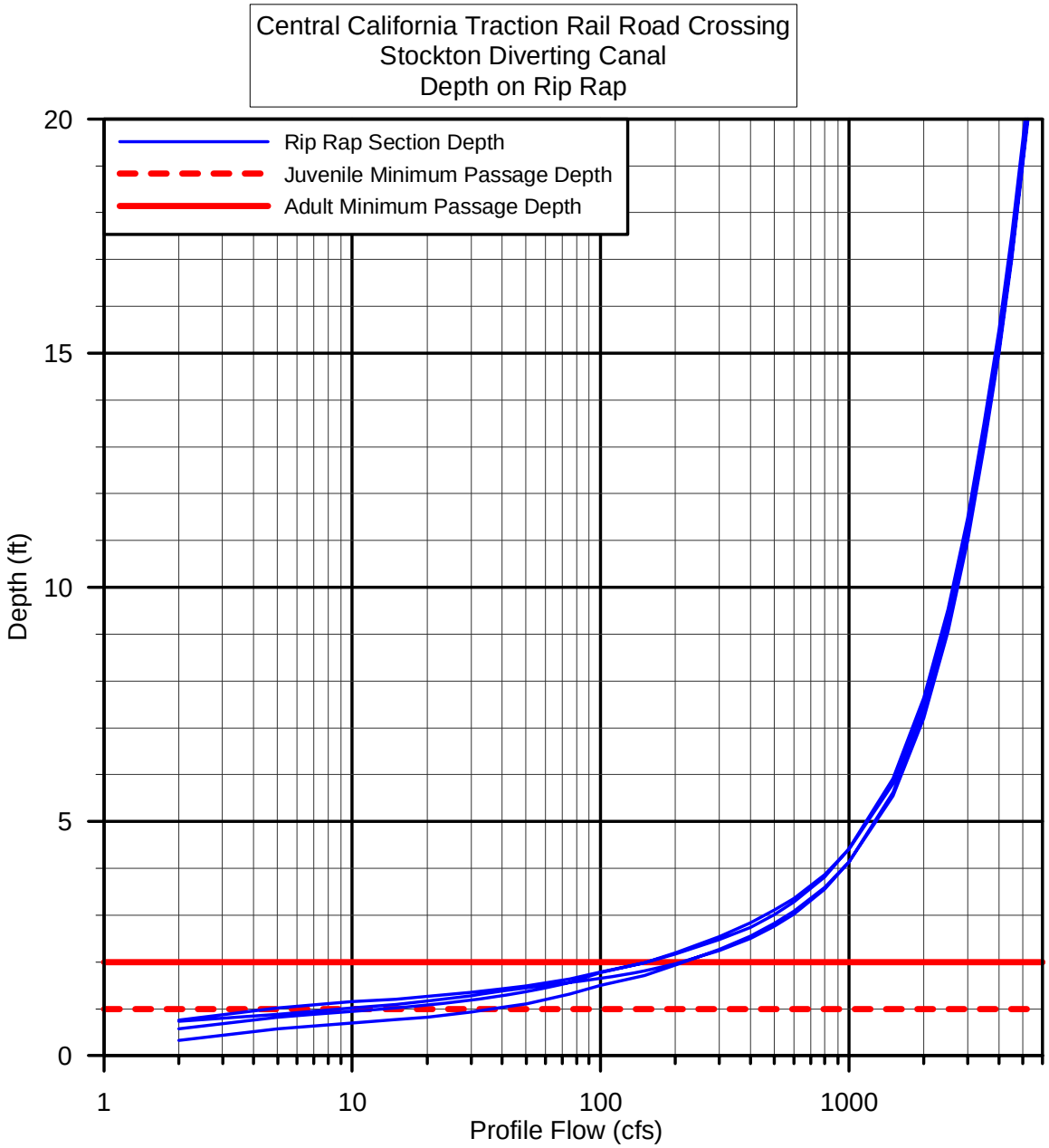


**Figure D-9. Central California Traction Railroad Bridge – Velocity rating curves for the channel**

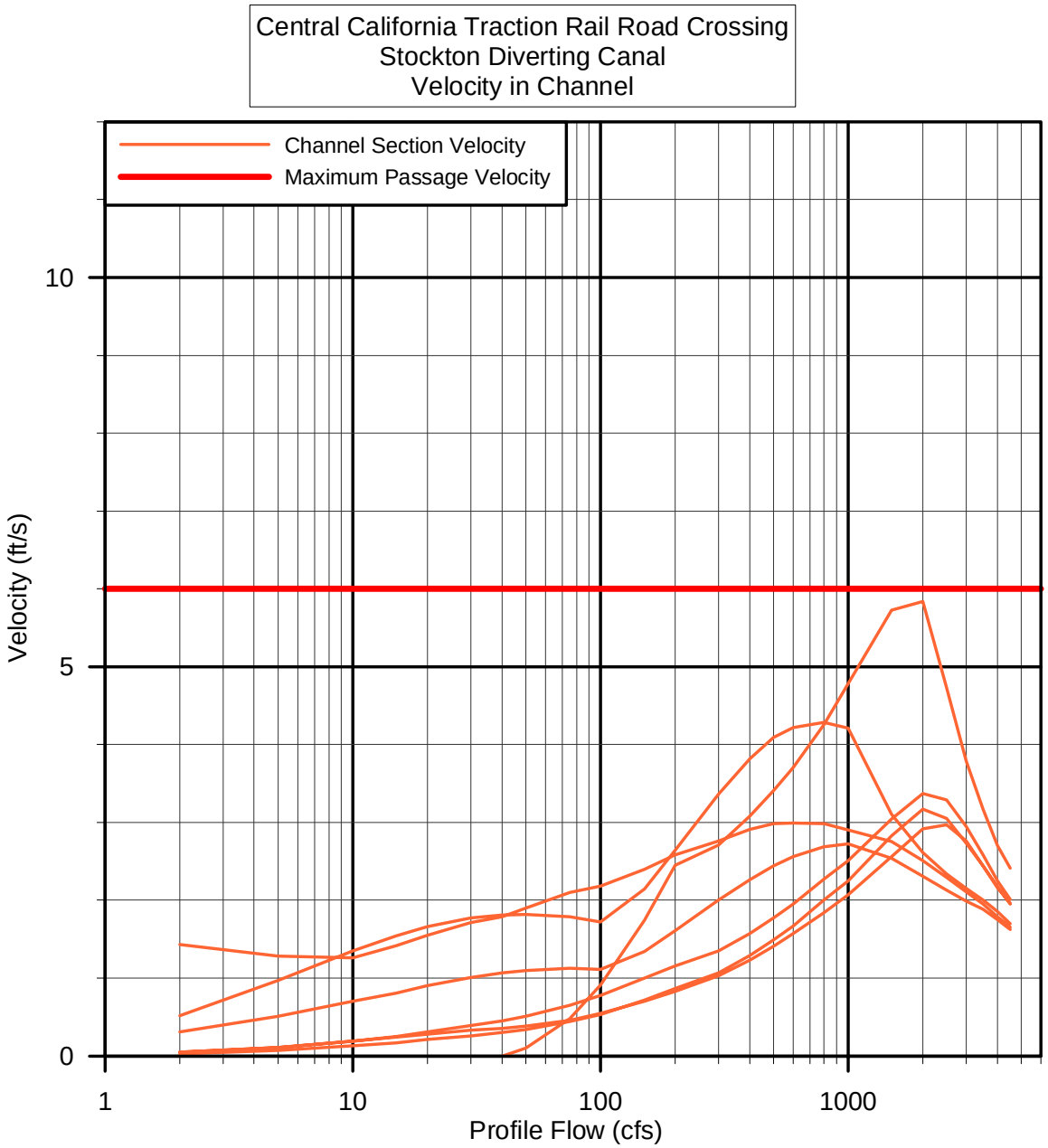
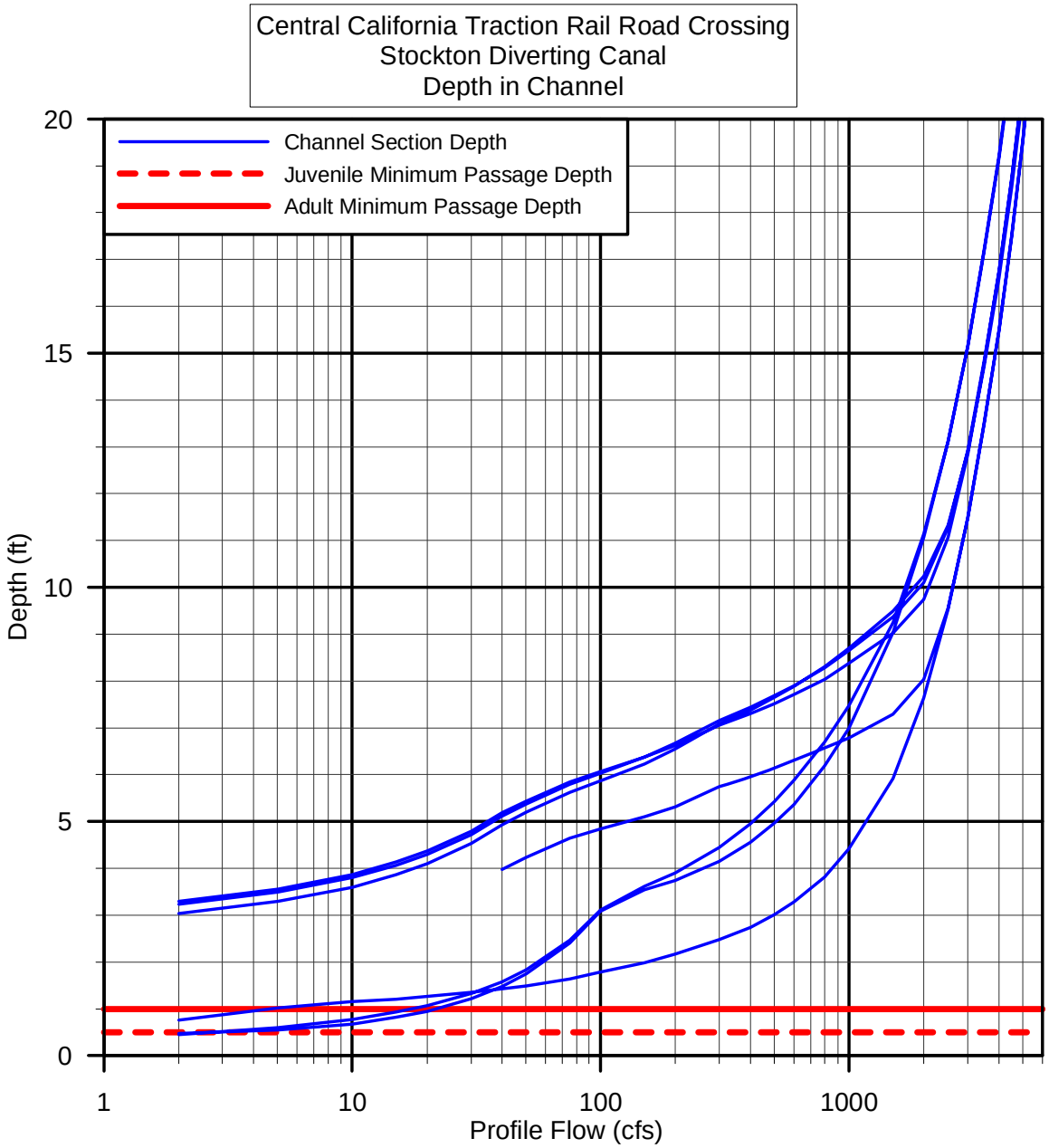


**Figure D-10. Central California Traction Railroad Bridge – Depth rating curves for the channel**



## *Budiselich Flashboard Dam*

**Photo D-3. Budiselich Flashboard Dam – Photo includes dam and downstream channel**

**Photo D-4. Budiselich Flashboard Dam – Photo is looking upstream at dam and channel**

## Structure Details

| | | | |
|---|---|---|---|
| Name of structure: | Budiselich Flashboard Dam | | |
| Type of structure: | Flashboard Dam | | |
| Tributary: | Stockton Diverting Canal | | |
| Number of sections: | upstream: 2 | downstream: 3 | structure: 4 |
| Length of model: | upstream: 375 ft | | downstream: 300 ft |

*Description of Structure.* A flashboard dam aligned perpendicular to the stream flow with riprap placed in the channel on the downstream end.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.03-0.07 |
| Side slopes and banks: | 0.04-0.05 |
| Concrete Structure: | 0.02-0.04 |
| Riprap: | 0.05-0.07 |

*Calibration*

Number of flows: 3

1. Flow: 116 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site. All points taken on left bank. Complex flow immediately downstream of structure over riprap.
2. Flow: 267 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site. All points taken on left bank. Complex flow immediately downstream of structure over riprap.
3. Flow: 2,240 cfs Survey method: Total Station
Comments: Flow estimated based on site observation and Bellota Weir hydrograph. All points taken on left bank.

*Starting conditions used for the model.* The model was run with mixed flow conditions for all three flows, so boundary conditions for downstream and upstream were specified. For all three flows, the downstream boundary was based on observed water surface elevation.

*Assumptions.* Primary assumptions include similar side slope and bank topography (one set of survey data used for all sections near structure above abutments); roughness was reduced slightly on riprap covered with vegetation to account for increased conveyance where the roughness of the riprap was diminished.

*Comments.* This structure was relatively simple to model. However, problems encountered with calibration included some deviations just downstream of the main structure in the riprap. Two observed surfaces matched the model, but one was off slightly. In this case we believe the discrepancies were due to insufficiently placed water surface marks resulting from the complex flow patterns of the channel immediately downstream of the structure, particularly at those lower flows. An additional discrepancy between modeled and observed upstream water elevations was found at lower flows, but was deemed insignificant because that section of channel does not pose a fish passage problem.

### Performance Summary

The velocities across the structure for adults remain below the maximum due to the width of the structure. For the same reason, the depths across the downstream edge are below minimum depths for all flows up to about 190 cfs. The riprap exceeds maximum velocities from about 45 to 85 cfs but is ok on all others but minimum depth requirements are not met until flows reach around 570 cfs. The channel has no serious problems as expected except for depths when flows are low. This leaves the structure with unimpeded passage for flows above 570 cfs.

Juveniles have depth problems across the riprap for flows up to 170 cfs. There are also problems on the structure until flows exceed 80 cfs. This leaves unimpeded juvenile passage for flows above 170 cfs.

**Figure D-11. Cross section locations for Budiselich Flashboard Dam HEC-RAS model**

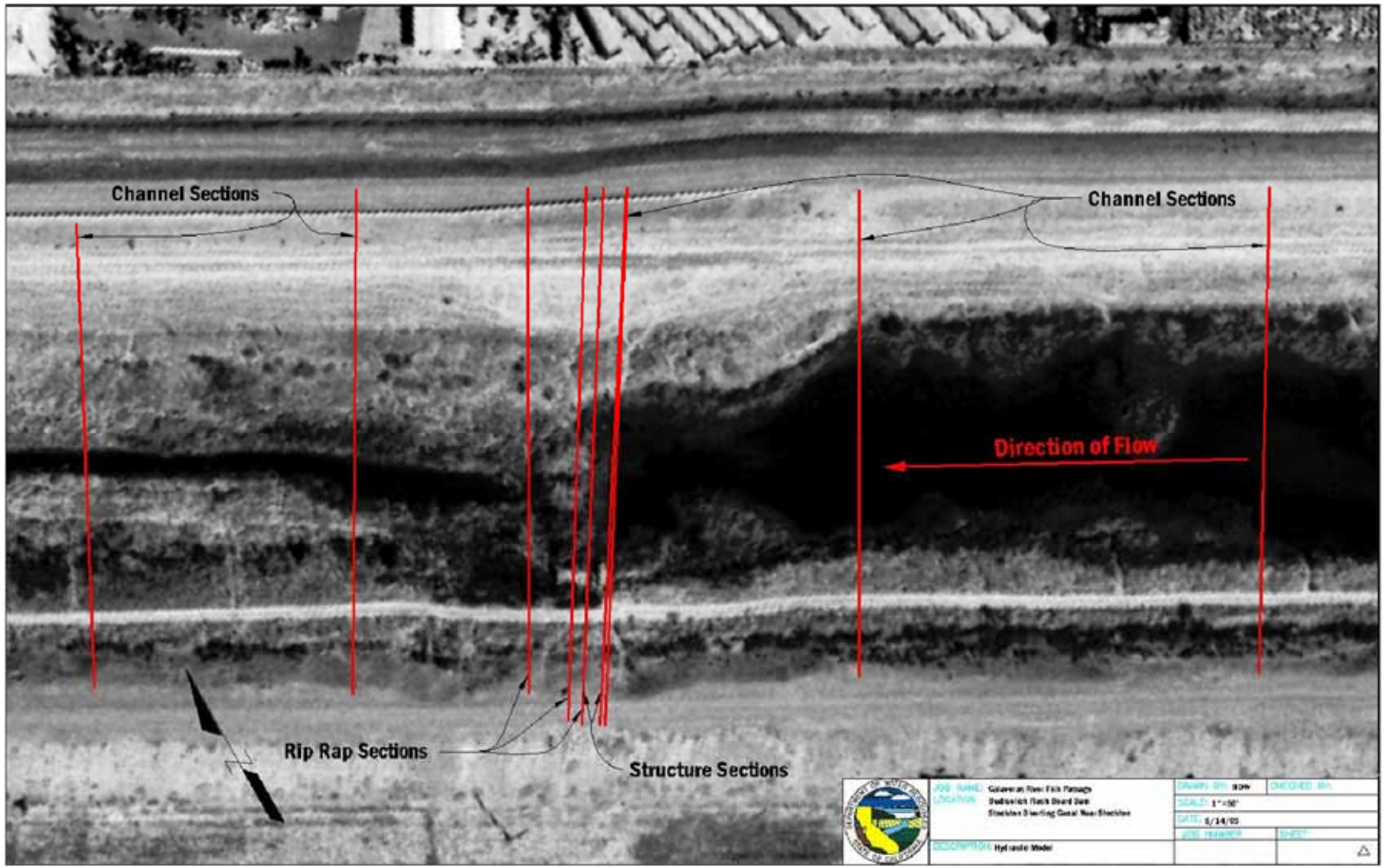


**Figure D-12. Budiselich Flashboard Dam – Relationship of length to maximum velocity**

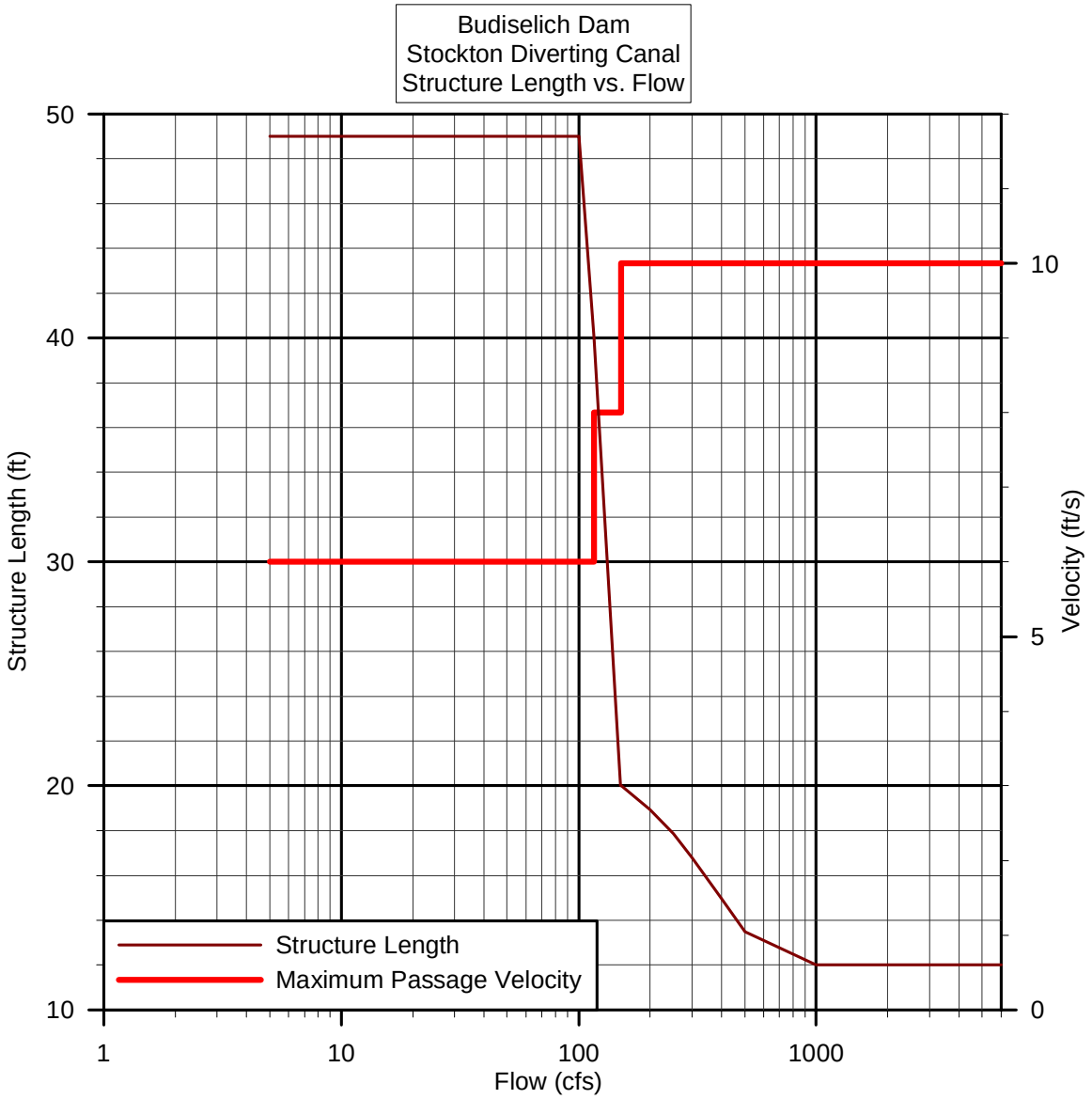


**Figure D-13. Budiselich Flashboard Dam – Velocity rating curves for the structure**

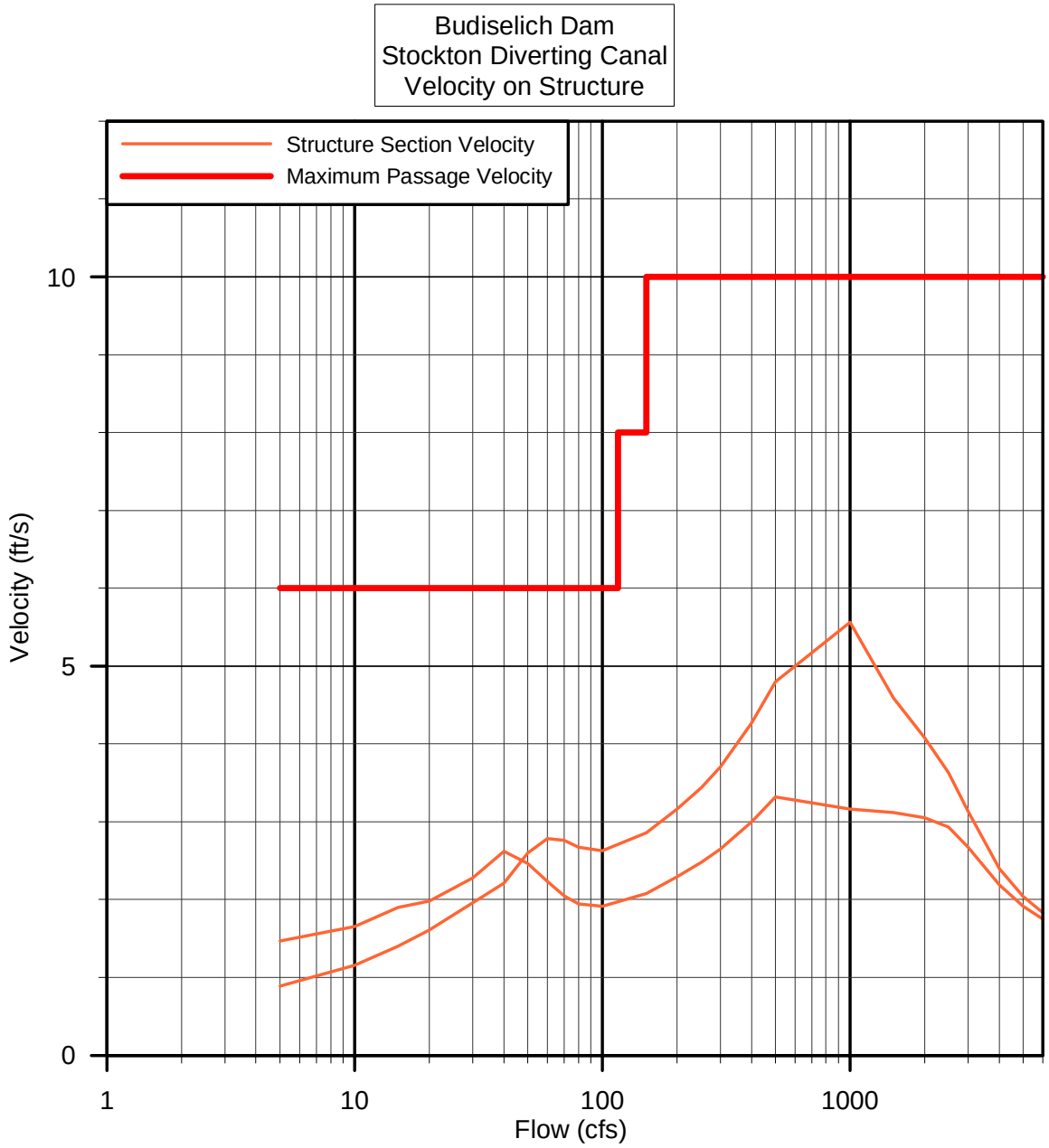


**Figure D-14. Budiselich Flashboard Dam – Depth rating curves for the structure**

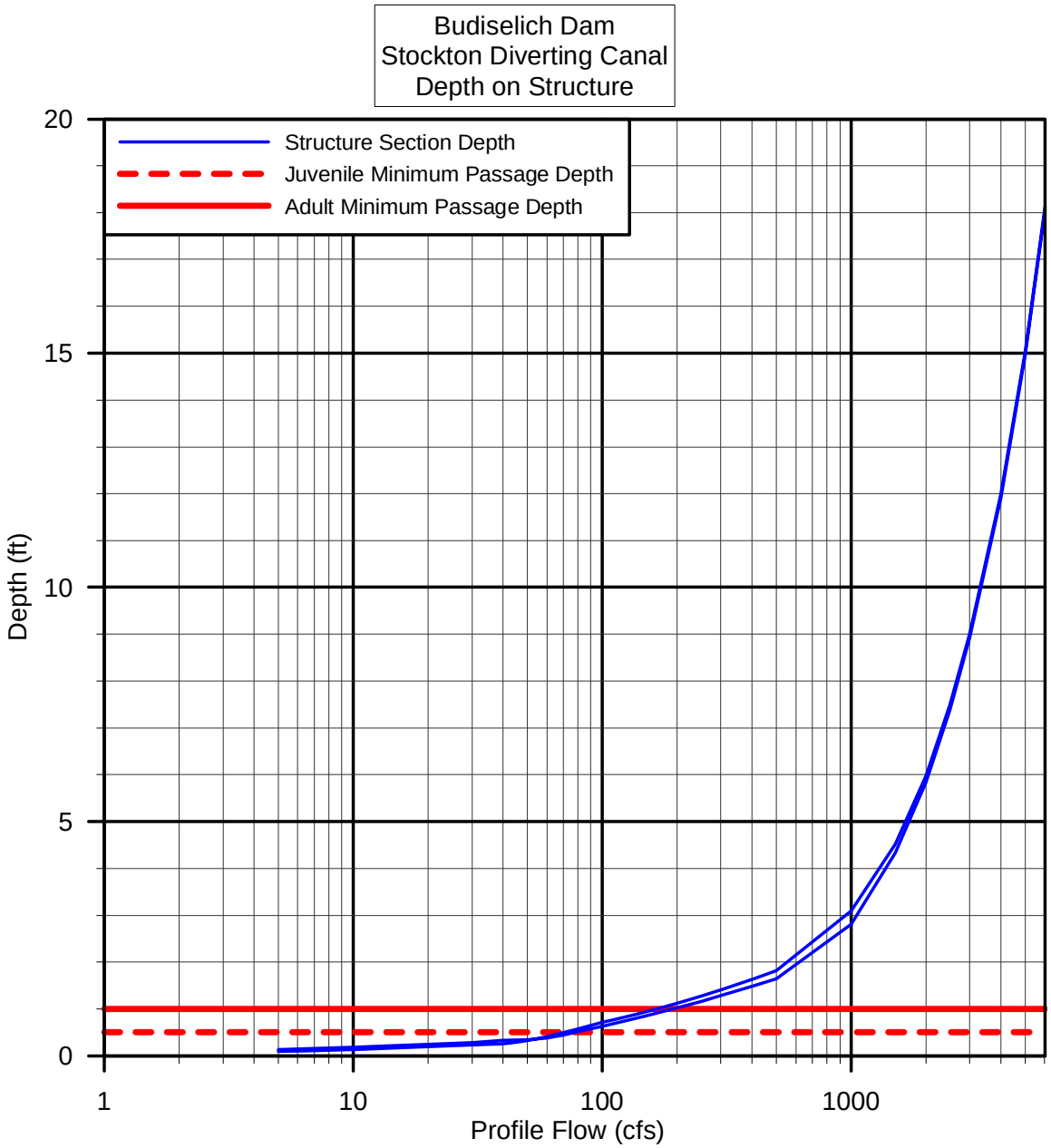


**Figure D-15. Budiselich Flashboard Dam – Velocity rating curves for the riprap**

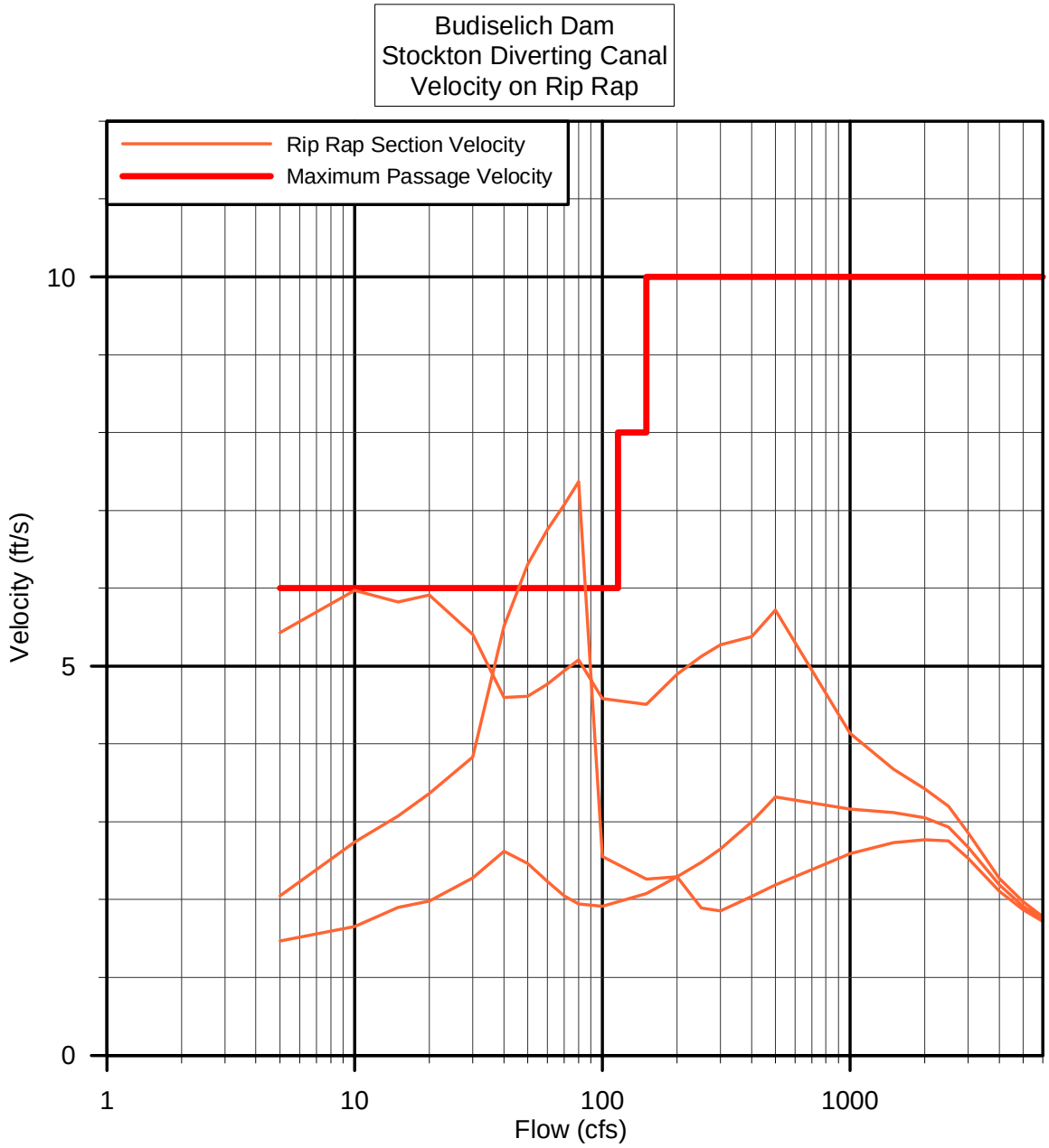


**Figure D-16. Budiselich Flashboard Dam – Depth rating curves for the riprap**

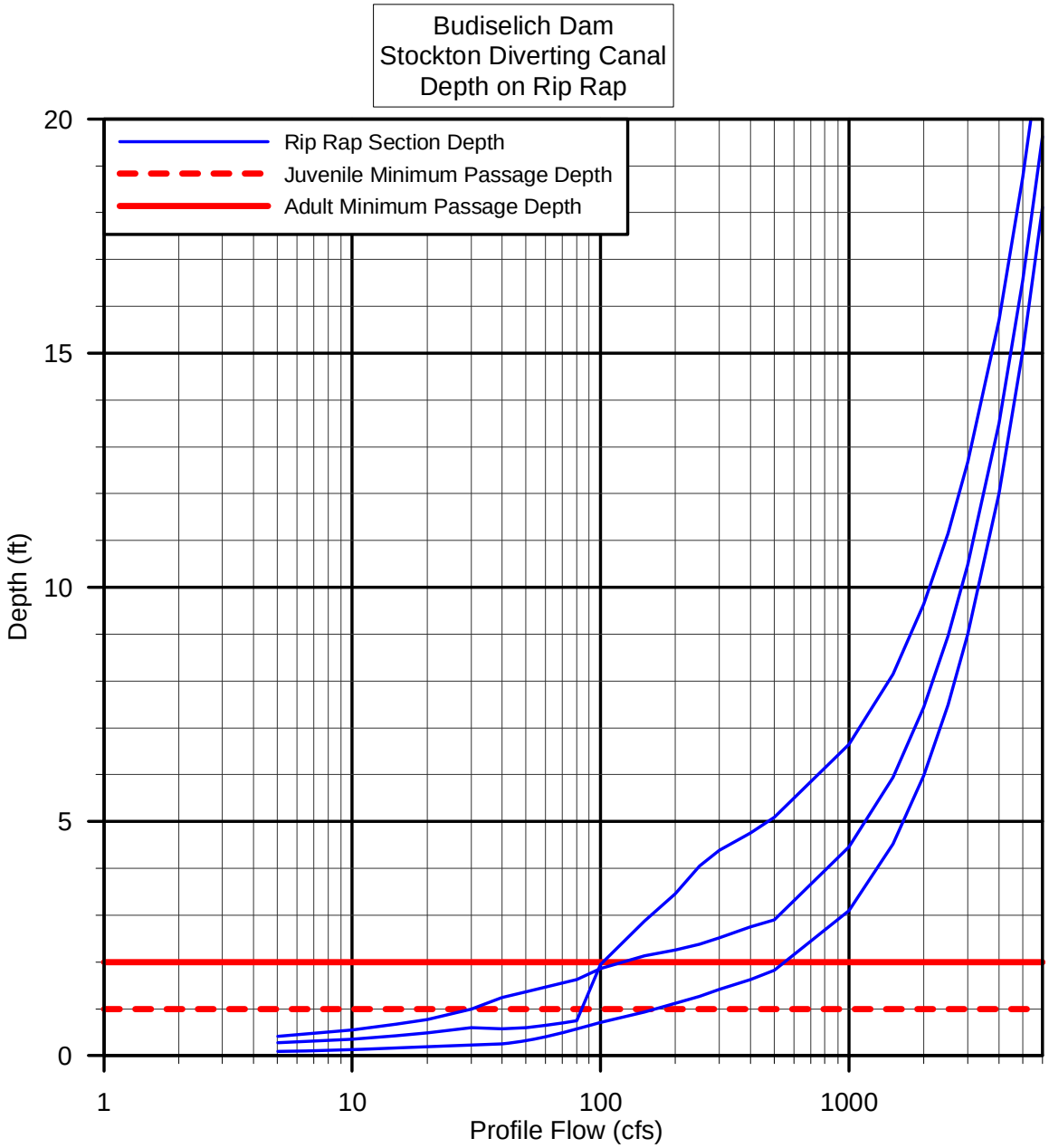


**Figure D-17. Budiselich Flashboard Dam – Velocity rating curves for the channel**

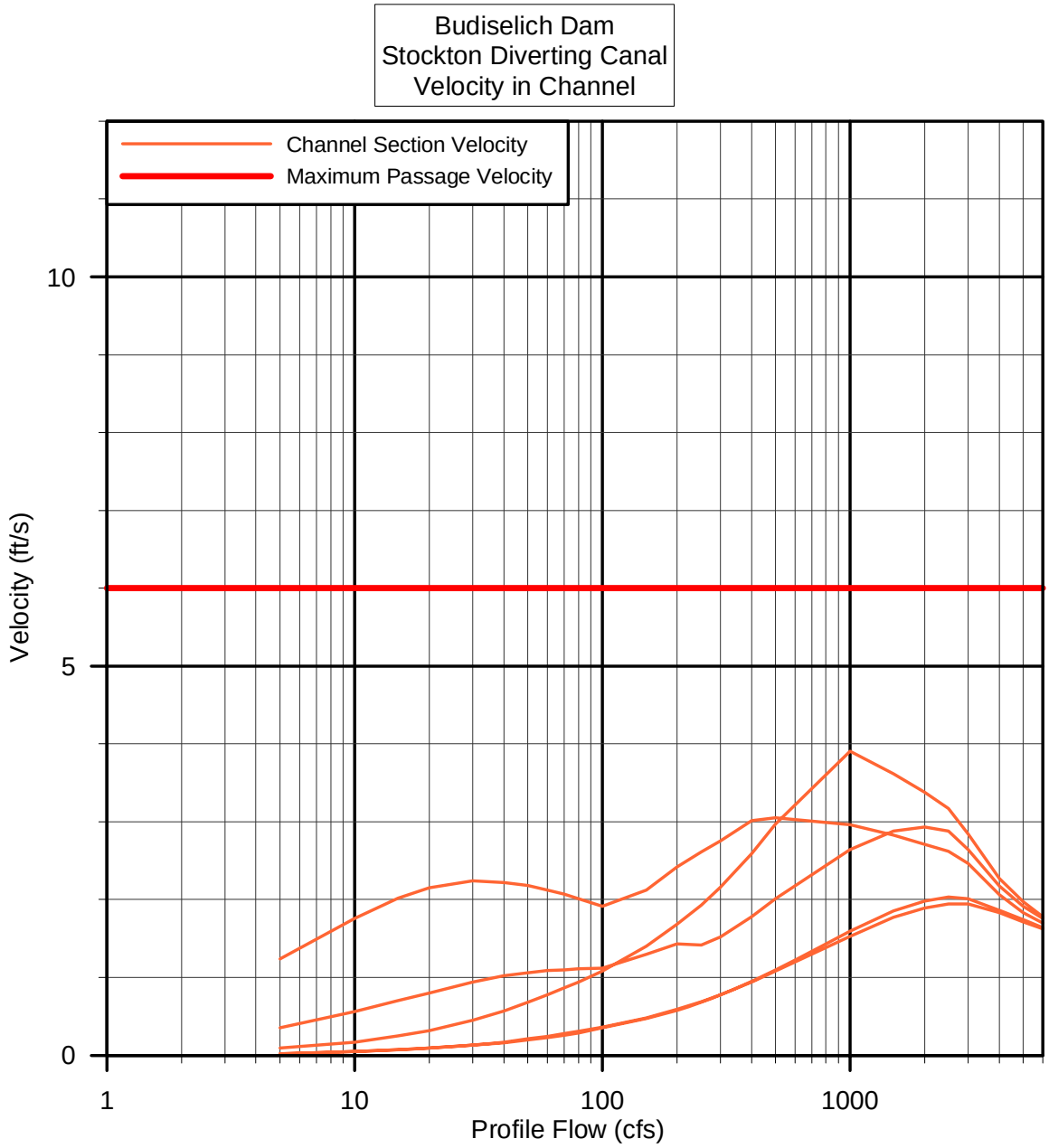
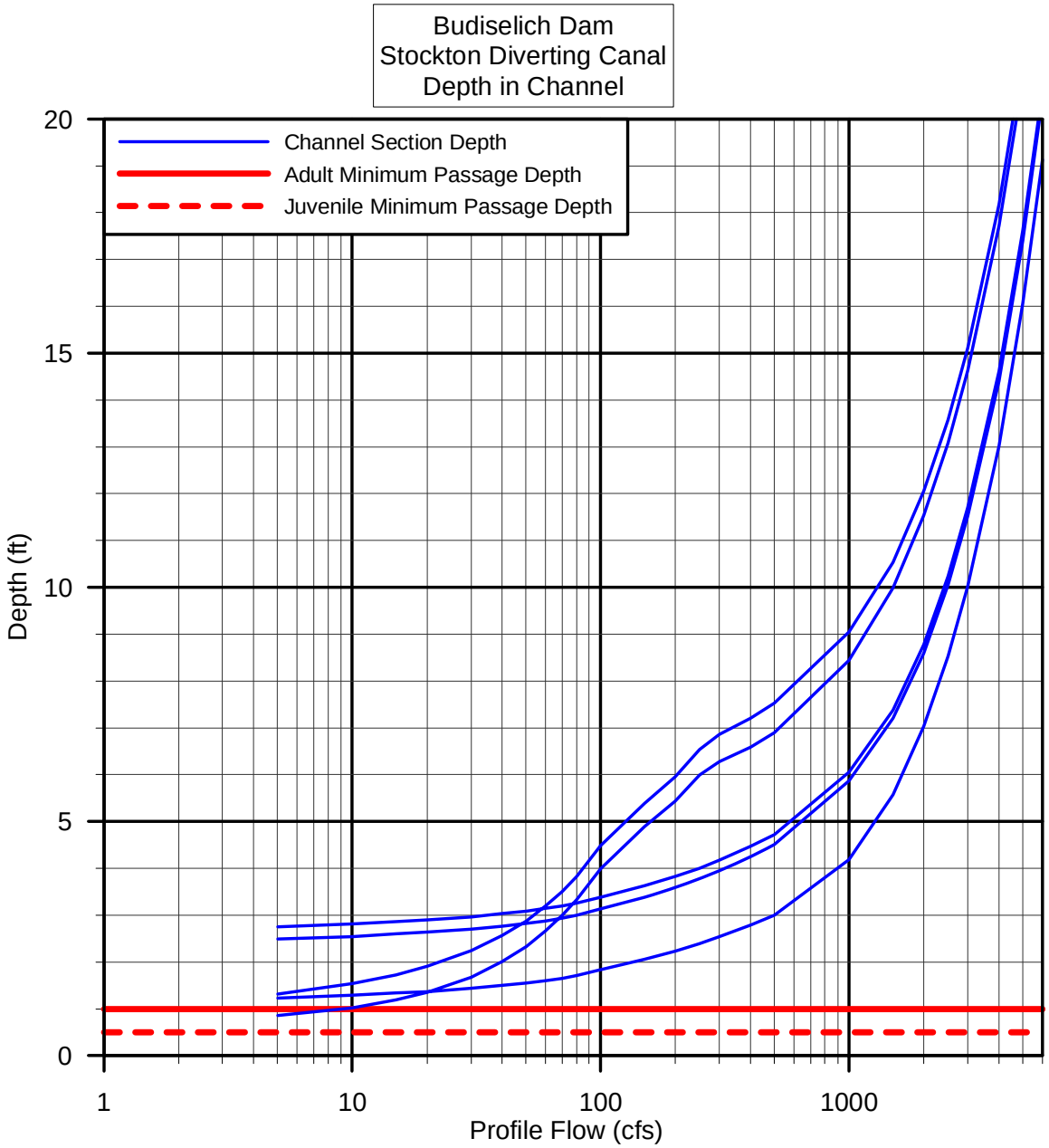


**Figure D-18. Budiselich Flashboard Dam – Depth rating curves for the channel**



## *Caprini Low-flow Road Crossing*

**Photo D-5. Caprini Low-flow Road Crossing – Structure during high flow event**

**Photo D-6. Caprini Low-flow Road Crossing – Downstream during low flow condition**

**Photo D-7. Caprini Low-flow Road Crossing – Upstream during low flow condition**

## Structure Details

| | | | |
|---|---|---|---|
| Name of structure: | Caprini Low-flow Road Crossing | | |
| Type of structure: | Weir with Culvert | | |
| Tributary: | Mormon Slough | | |
| Number of sections: | upstream: 5 | downstream: 5 | structure: 2 |
| Length of model: | upstream: 275 ft | | downstream: 236 ft |

*Description of Structure.* The structure is a low flow crossing with 3 parallel identical culverts built into the structure.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.032-0.035 |
| Side slopes and banks: | 0.035-0.1 |
| Concrete Structure: | 0.02 |
| Riprap: | 06-0.08 |
| Culverts: | 0.03 |

*Calibration*

Number of flows: 2
1. Flow: 208 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site.
2. Flow: 1,900 cfs Survey method: Total Station
Comments: Estimated flow using a combination of velocity measurements and gauge readings. All points taken on right bank.

*Starting conditions used for the model.*

Starting Condition on Flow 1: Normal Depth was used on upstream boundary due to no known elevation. Slope used was determined from EG slope of section after previous run. First run used critical depth for upstream boundary.

Starting conditions on Flow 2: Known water surface elevation for flow 2 at the downstream boundary was determined by trial and error starting with the observed elevation. Both flows were run as mixed flow.

*Assumptions.* Bank stations are located at the top of the channel banks at the point where flow would overtop and flow on the floodplains.

*Comments.* Upstream boundary was used to determine supercritical flow at sections where profile does not yield a subcritical answer. Once subcritical flow was reestablished, the normal bottom up procedure was resumed, yielding an analytical profile at this boundary. The weir has no flow over it until around 150 cfs and indicates zero velocity and depth until it is overtopped.

### Performance Summary

In general all flow in the channel is handled by the culverts until 150 cfs, at which point water begins to flow over the roadway or weir. For adults the culverts show velocity and depth problems until 450 cfs. Juveniles however have impeded passage for flows below 9 cfs. The weir doesn't have any velocity problems, but does not meet minimum depths up to 350 cfs for adults and 230 cfs for juveniles. The riprap sections have intermittent velocity problems up to 730 cfs but depth is a bigger problem and is an issue up with flows up to 400 cfs. Juveniles have depth problems across the riprap for flows up to 120 cfs. The channel velocities are acceptable but depths are a problem at low flows. In summary the structure does not have unimpaired passage until flows exceed 730 cfs for adults and 120 cfs for juveniles.

**Figure D-19. Cross section locations for Caprini Low-flow Road Crossing HEC-RAS model**

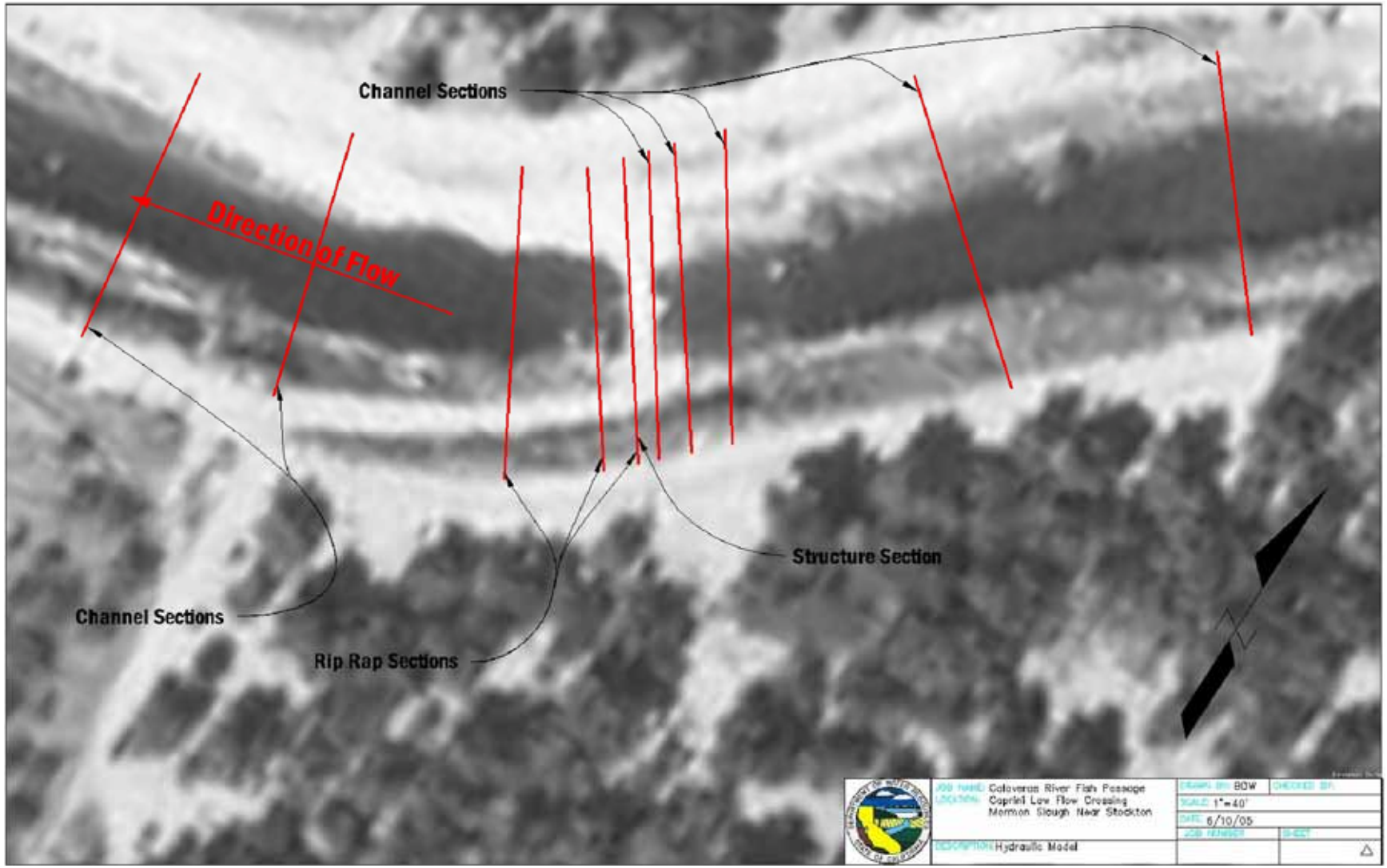


**Figure D-20. Caprini Low-flow Road Crossing - Relationship of length to maximum velocity**

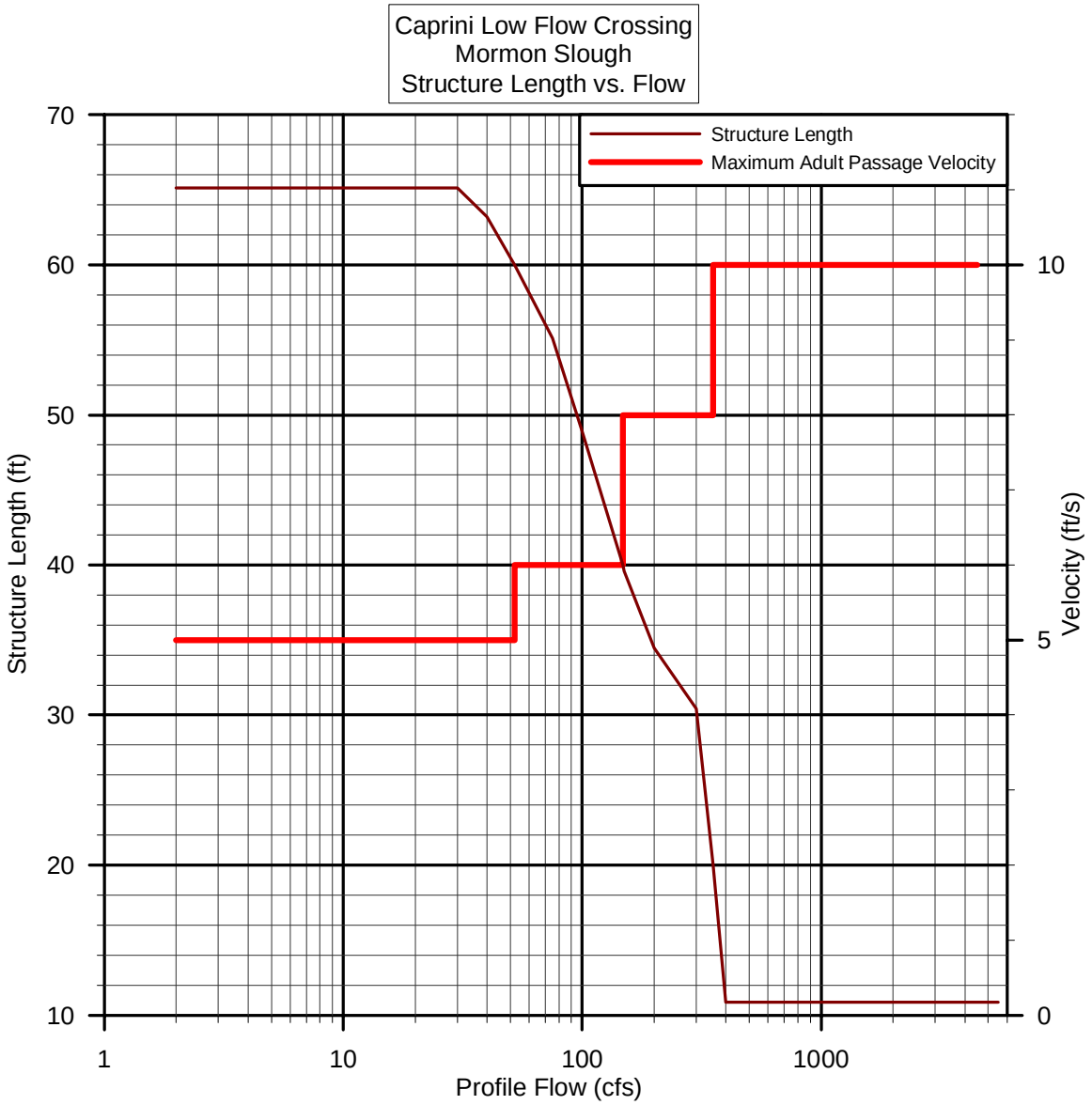


**Figure D-21. Caprini Low-flow Road Crossing – Velocity rating curves for the weir and culverts**

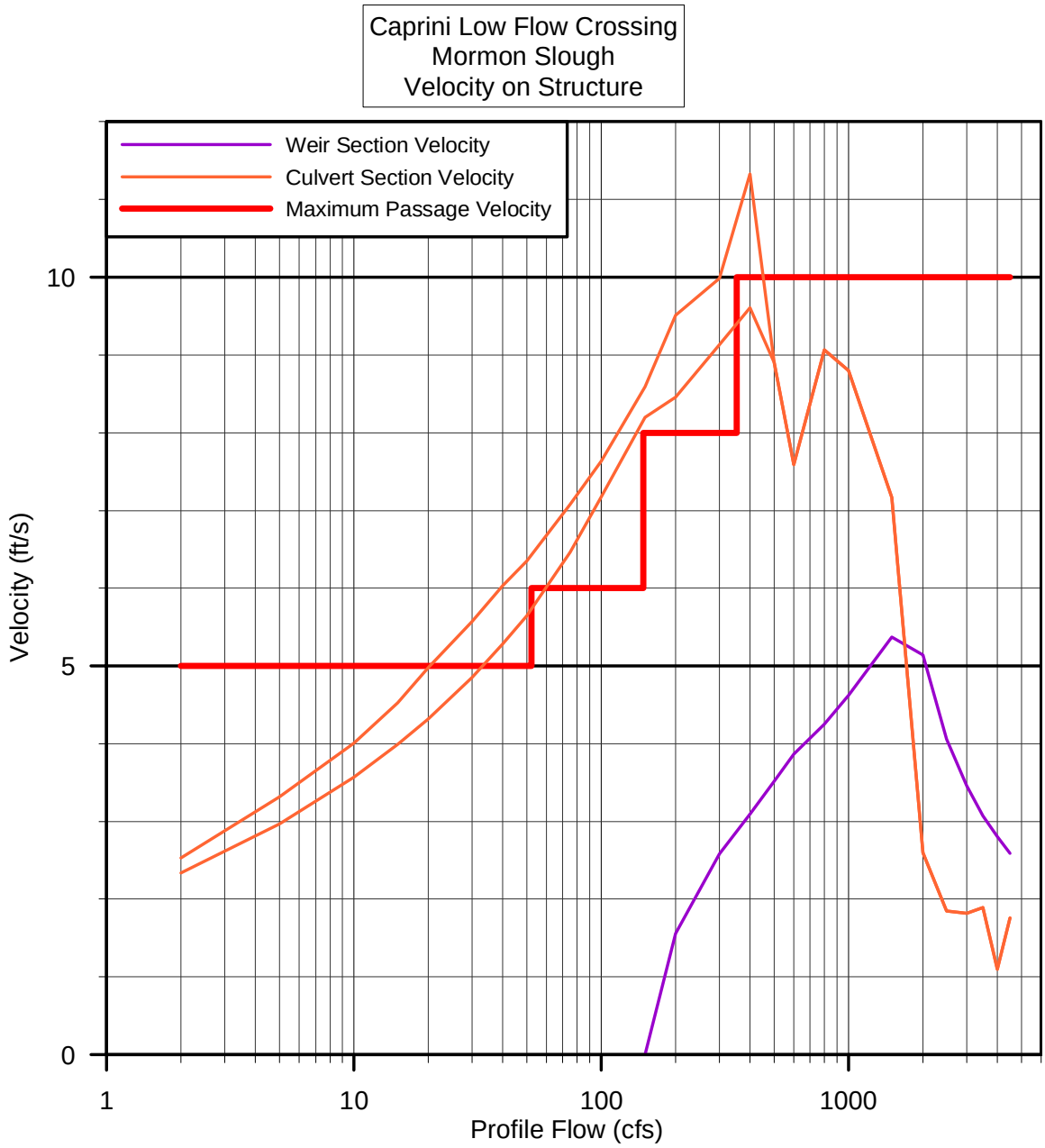


**Figure D-22. Caprini Low-flow Road Crossing – Depth rating curves for the weir and culverts**

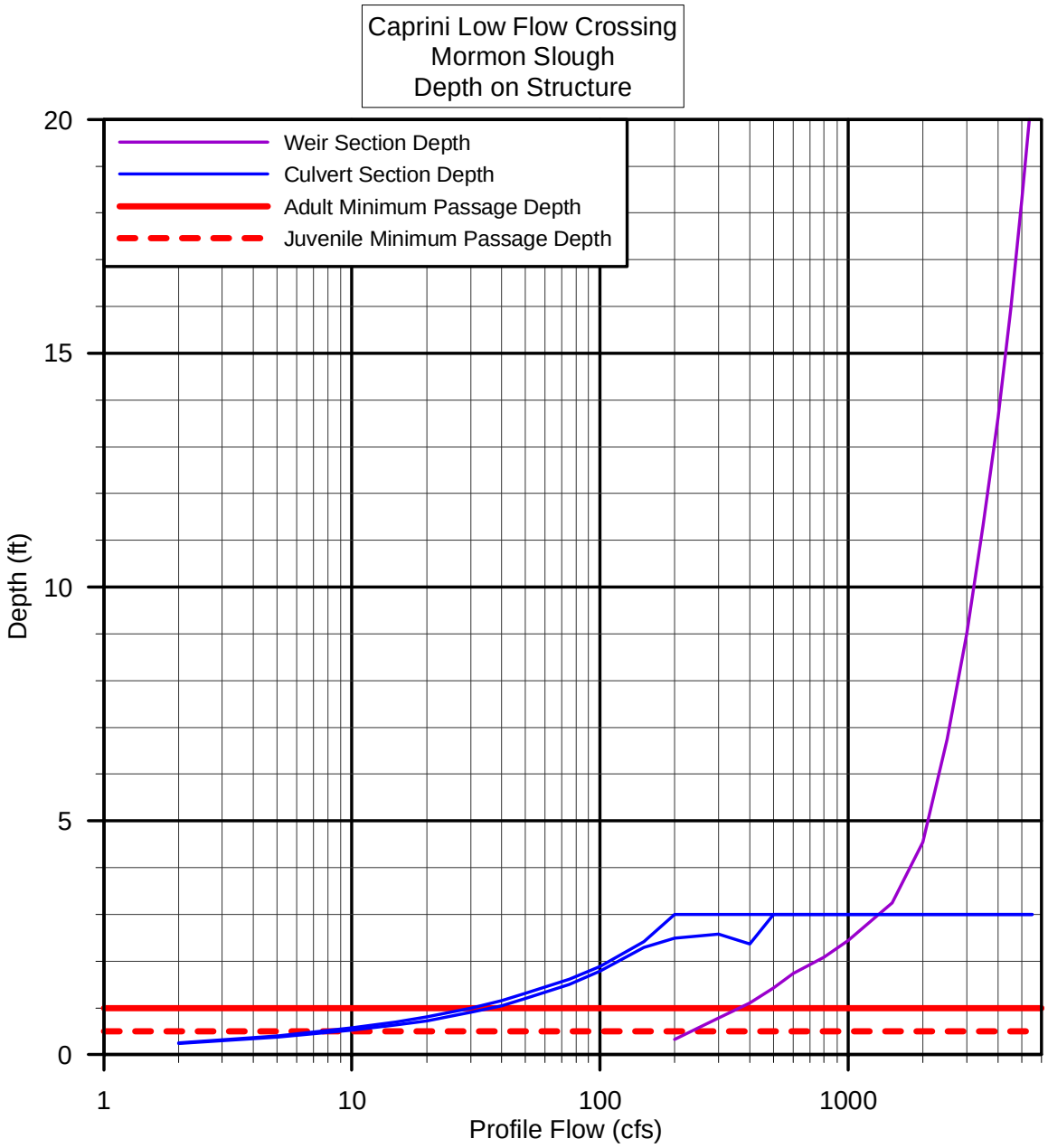


**Figure D-23. Caprini Low-flow Road Crossing – Velocity rating curves for the riprap**

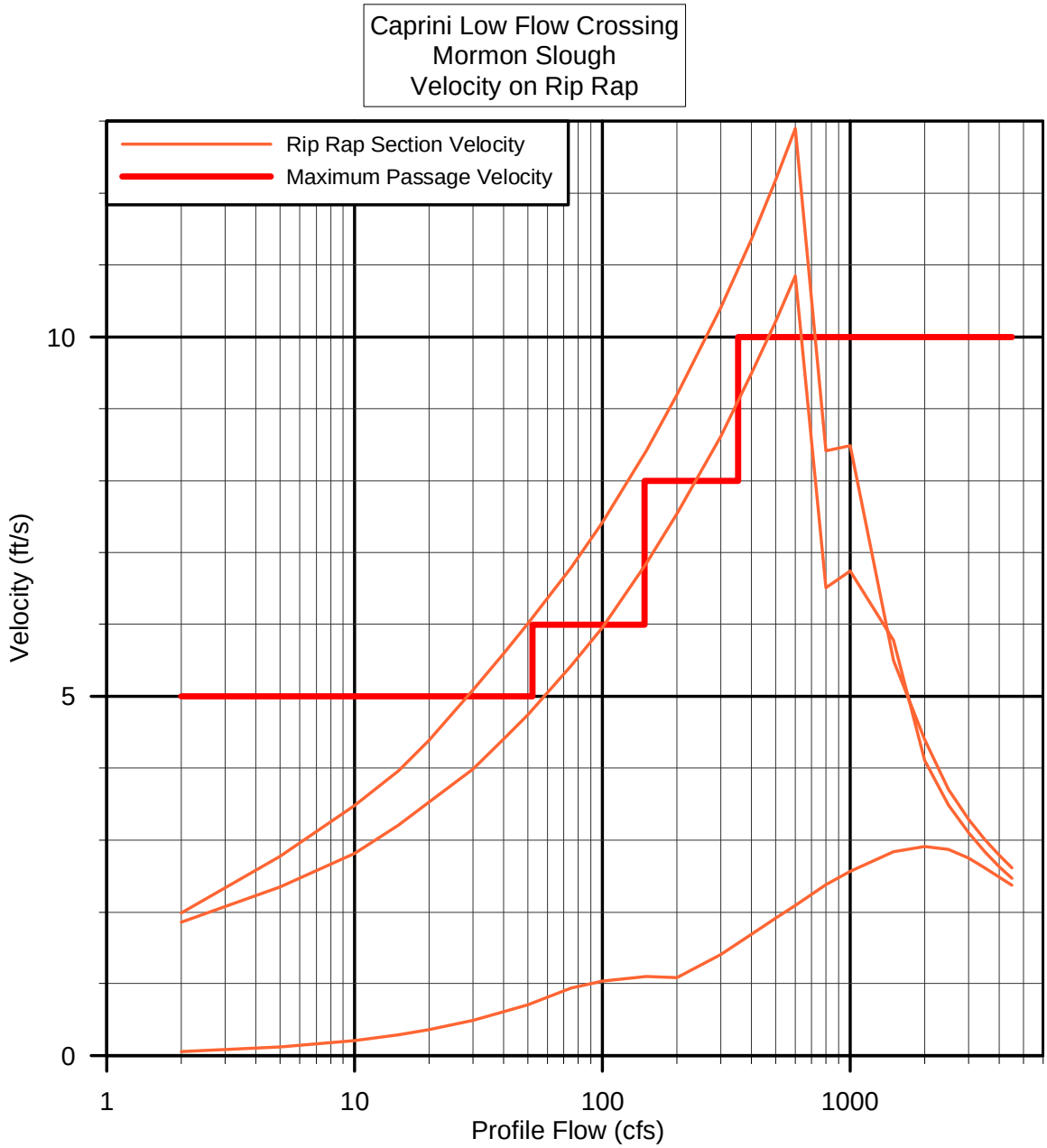


**Figure D-24. Caprini Low-flow Road Crossing – Depth rating curves for the riprap**

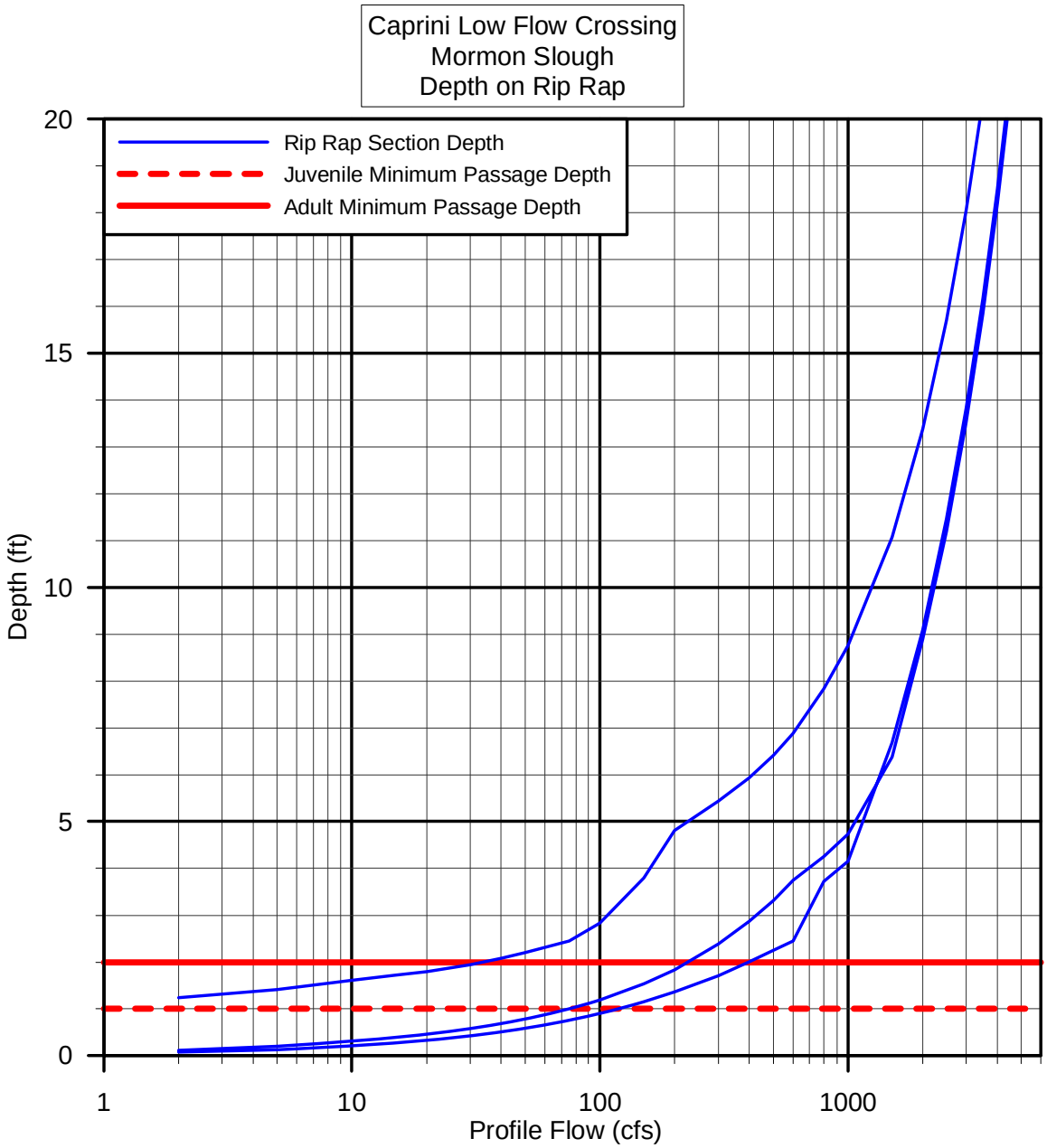


**Figure D-25. Caprini Low-flow Road Crossing – Velocity rating curves in the channel**

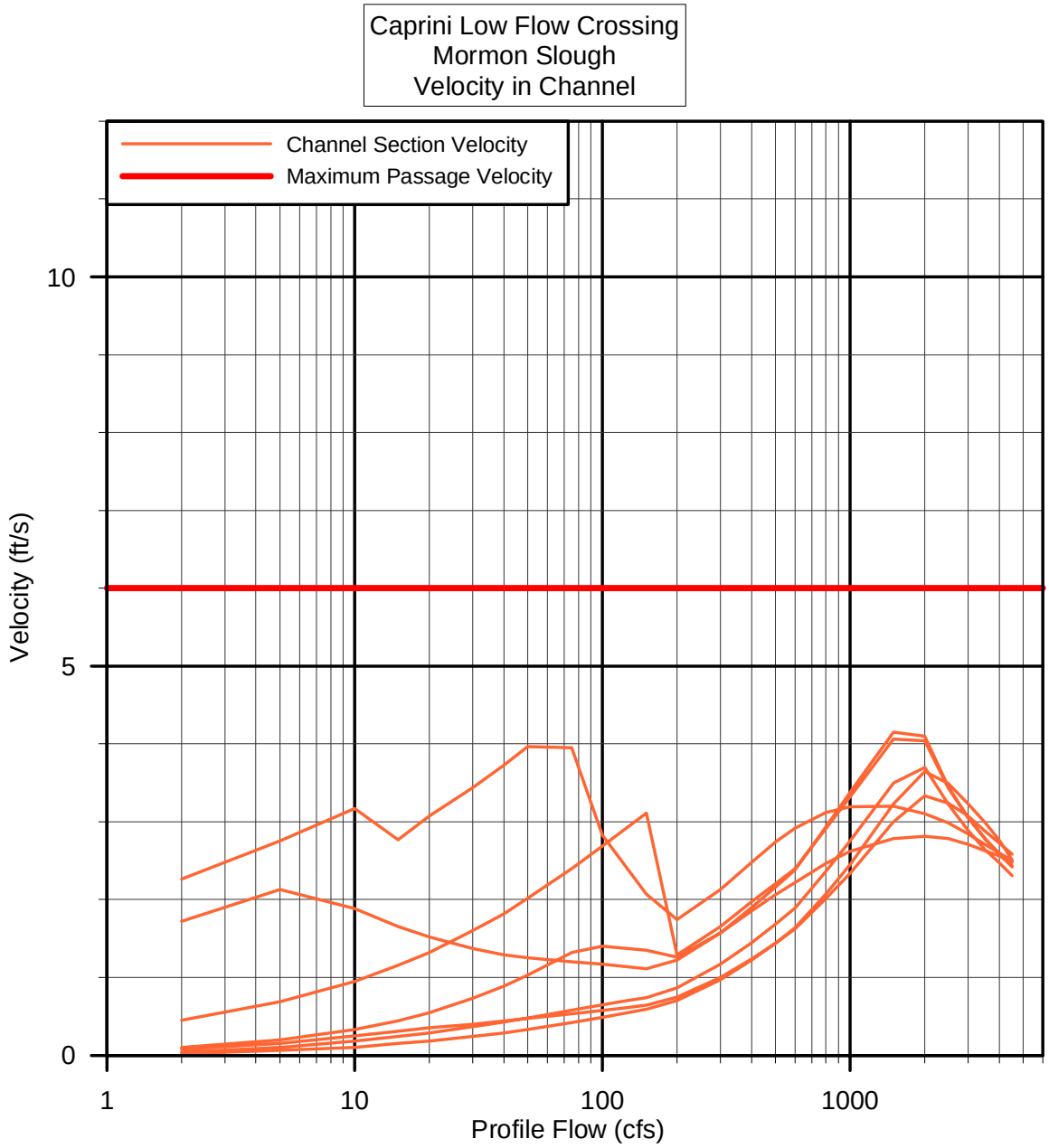
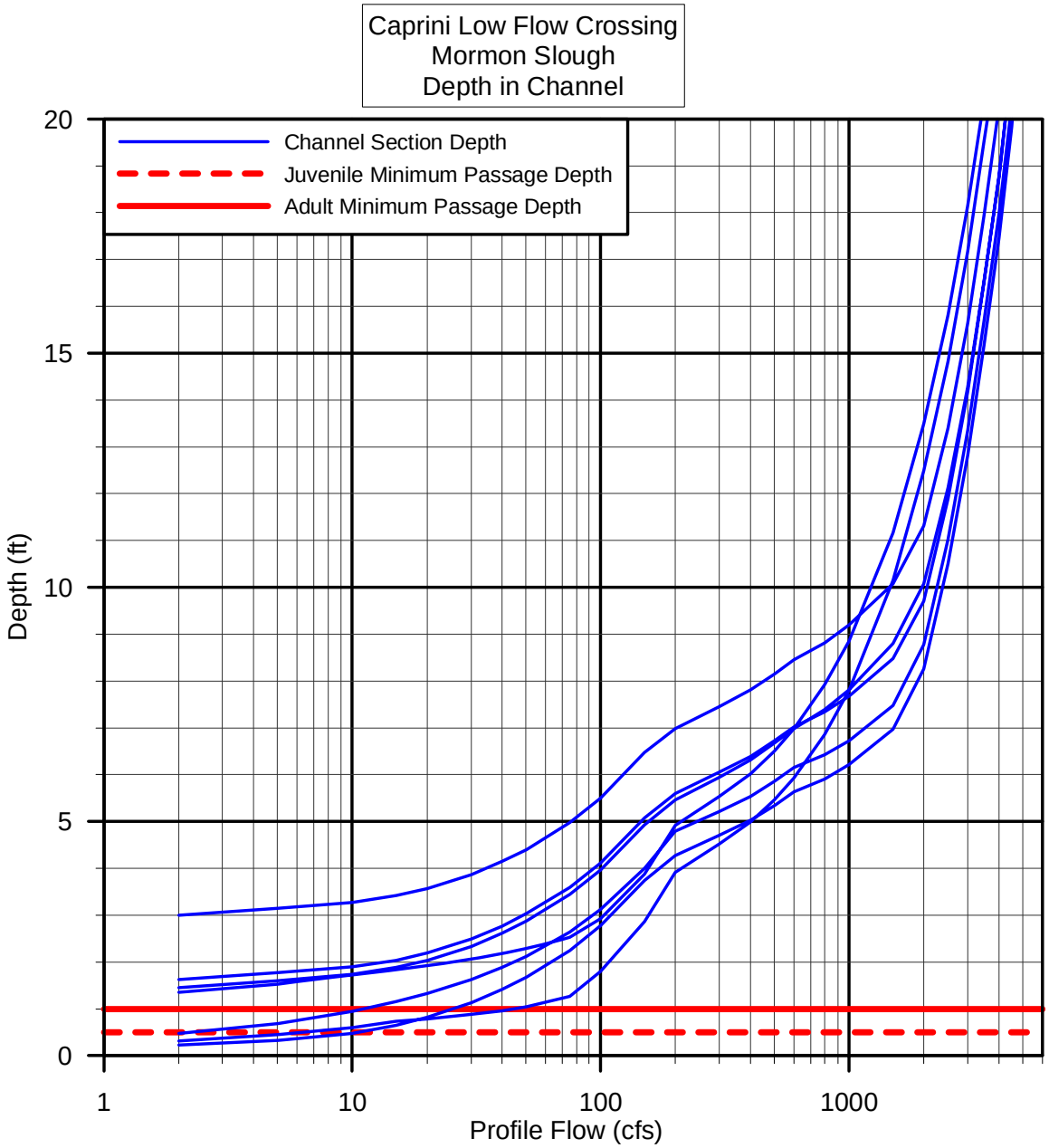


**Figure D-26. Caprini Low-flow Road Crossing – Depth rating curves in the channel**



## *Hogan Low-flow Road Crossing*

**Photo D-8. Hogan Low-flow Road Crossing – Photo taken downstream during low flow condition**

**Photo D-9. Hogan Low-flow Road Crossing – Photo taken upstream during low flow condition**

## Structure Details

| | |
|---|---|
| Name of structure: | Hogan Low-flow Road Crossing |
| Type of structure: | Weir with Culverts |
| Tributary: | Mormon Slough |
| Number of sections: | upstream: 3 downstream: 4 structure: 2 |
| Length of model: | upstream: 258 ft downstream: 232 ft |

*Description of Structure.* The structure is a low flow crossing with 3 culverts placed within the crossing. The culverts are various sizes and lengths, and are placed at different elevations and orientations with respect to the flow line of the channel and each other.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.035 |
| Side slopes and banks: | 0.08 |
| Concrete structure: | 0.025 |
| Riprap: | 0.06 |
| Culverts: | 0.012 |

*Calibration*

Number of flows: 2

1. Flow: 208 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site with a high level of accuracy.

2. Flow: 1,980 cfs Survey method: Total Station

Comments: Estimated flow using velocity measurement approximately 5 ft from waters edge and Bellota Weir gauge readings with a moderate level of accuracy. All points taken on right bank.

*Starting conditions used for the model.* Both profiles were modeled using the observed water surface elevations and was modeled mix flow.

*Assumptions.* Structure was modeled as a weir and 3 culverts. An interpolated section was included in the model, where field observations indicated riprap on the downstream end of the model that was hidden by ponding during the cross sectional survey, which creates a tail water control point in the channel below the structure. The irregular shape of the structure also causes a lower conveyance of the flow that overtops the structure.

*Comments.* Culverts in the structure required individual modeling due to multiple sizes, multiple inverts, and multiple lengths of extension beyond the structure. There are two 2.5ft diameter culverts and one 3.5ft diameter culvert, one culvert sloped downstream, one level culvert, and one sloped upstream. The bell end of all three culverts faces downstream. The structure appears to be constructed in phases without using forms or concrete finishing or smoothing. There are many irregularities in the surface, including incomplete coverage of the culverts.

### Performance Summary

Culverts on the structure show problems with velocity from 69 to 1100 cfs, and do not meet depth requirements up to 40 cfs for adults. Juvenile passage through the culverts is also limited for flows below 6 cfs. The weir, or road surface, does not begin to be overtopped until about 100 cfs, and exhibits depth problems until flows reach 250 cfs for adults and 160 cfs for juveniles. Velocities through the riprap remain within acceptable ranges, while depth problems occur on the riprap up to 20 cfs. Once again, channel velocities are acceptable with depth problems in the lower flow range. In summary the structure has unimpeded passage for flows above 250 cfs with a small window between 37 and 69 cfs. Juveniles have unimpeded passage for flows above 6 cfs.

**Figure D-27. Cross section locations for Hogan Low-flow road crossing HEC-RAS model**

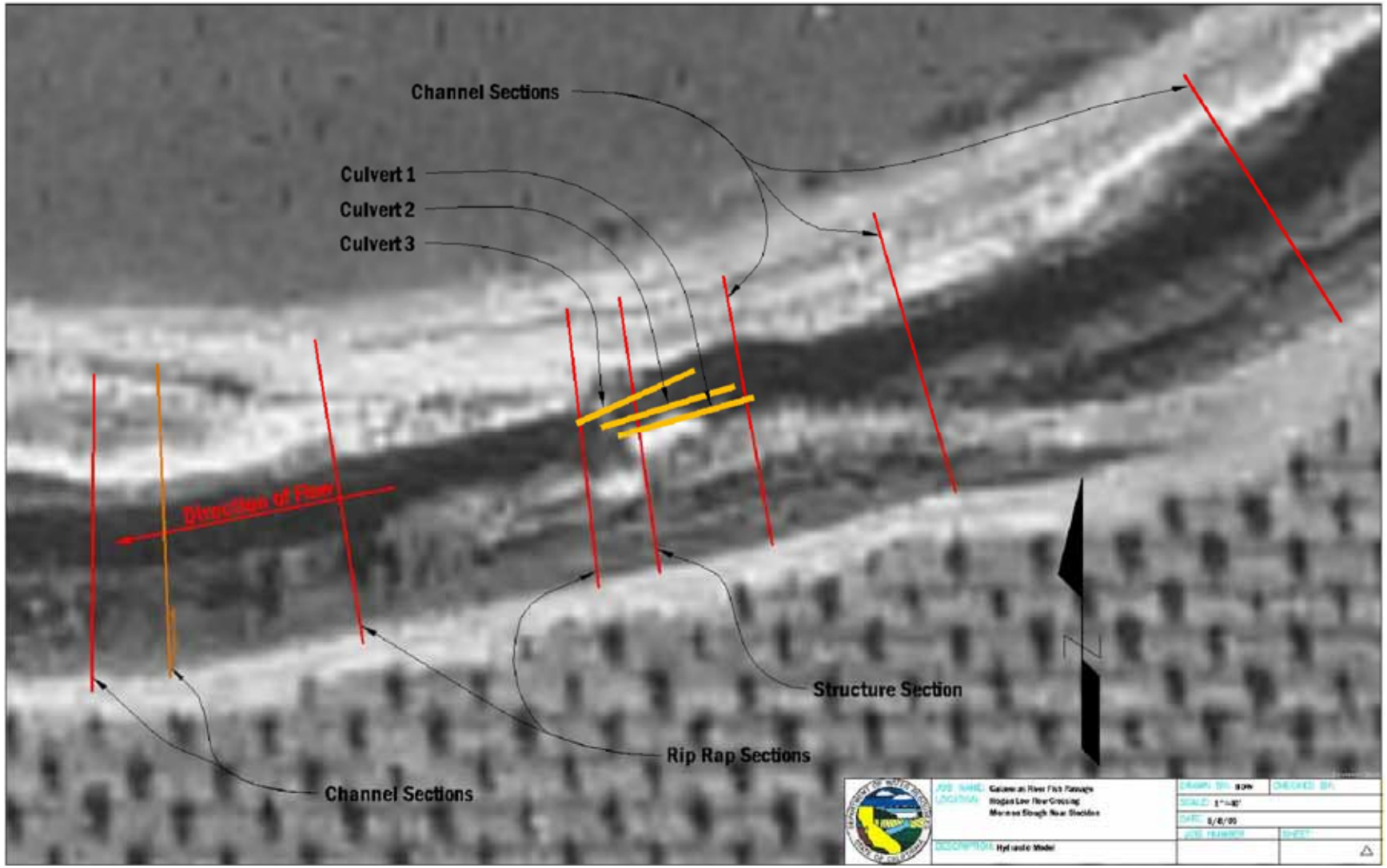


**Figure D-28. Hogan Low-flow Road Crossing – Relationship of length to maximum velocity**

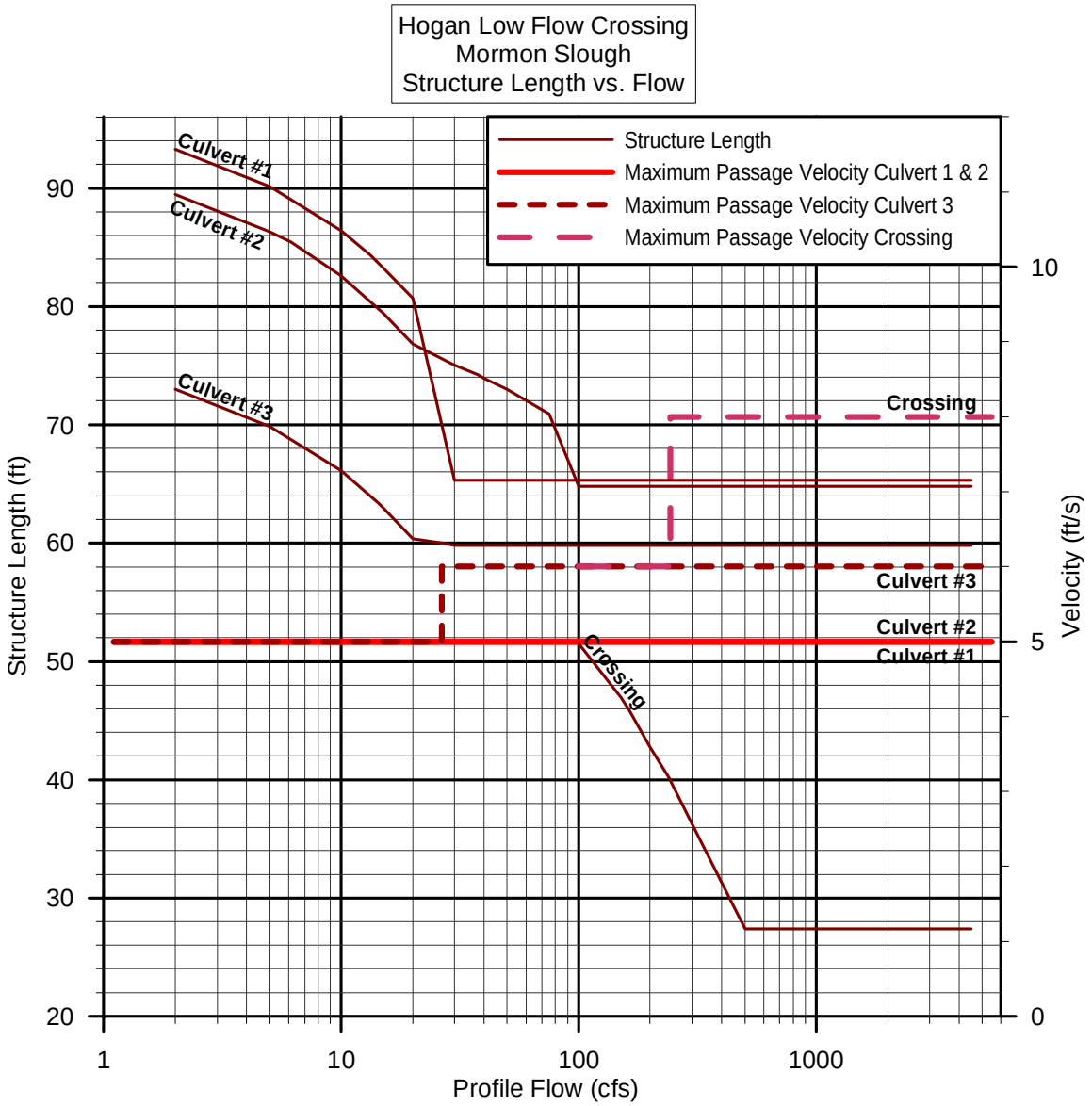


**Figure D-29. Hogan Low-flow Road Crossing – Velocity rating curves for the structure**

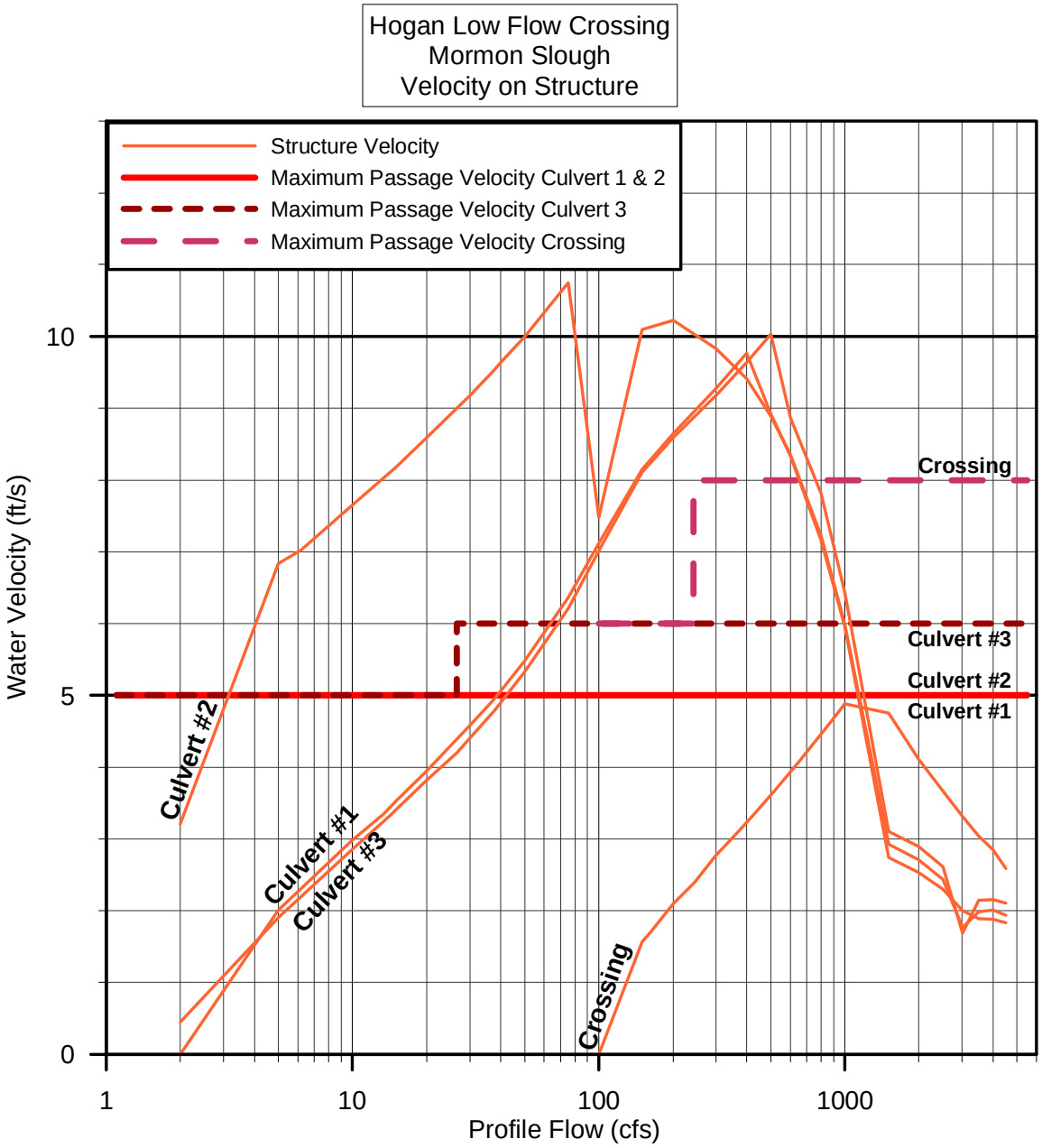


**Figure D-30. Hogan Low-flow Road Crossing – Depth rating curves for the structure**

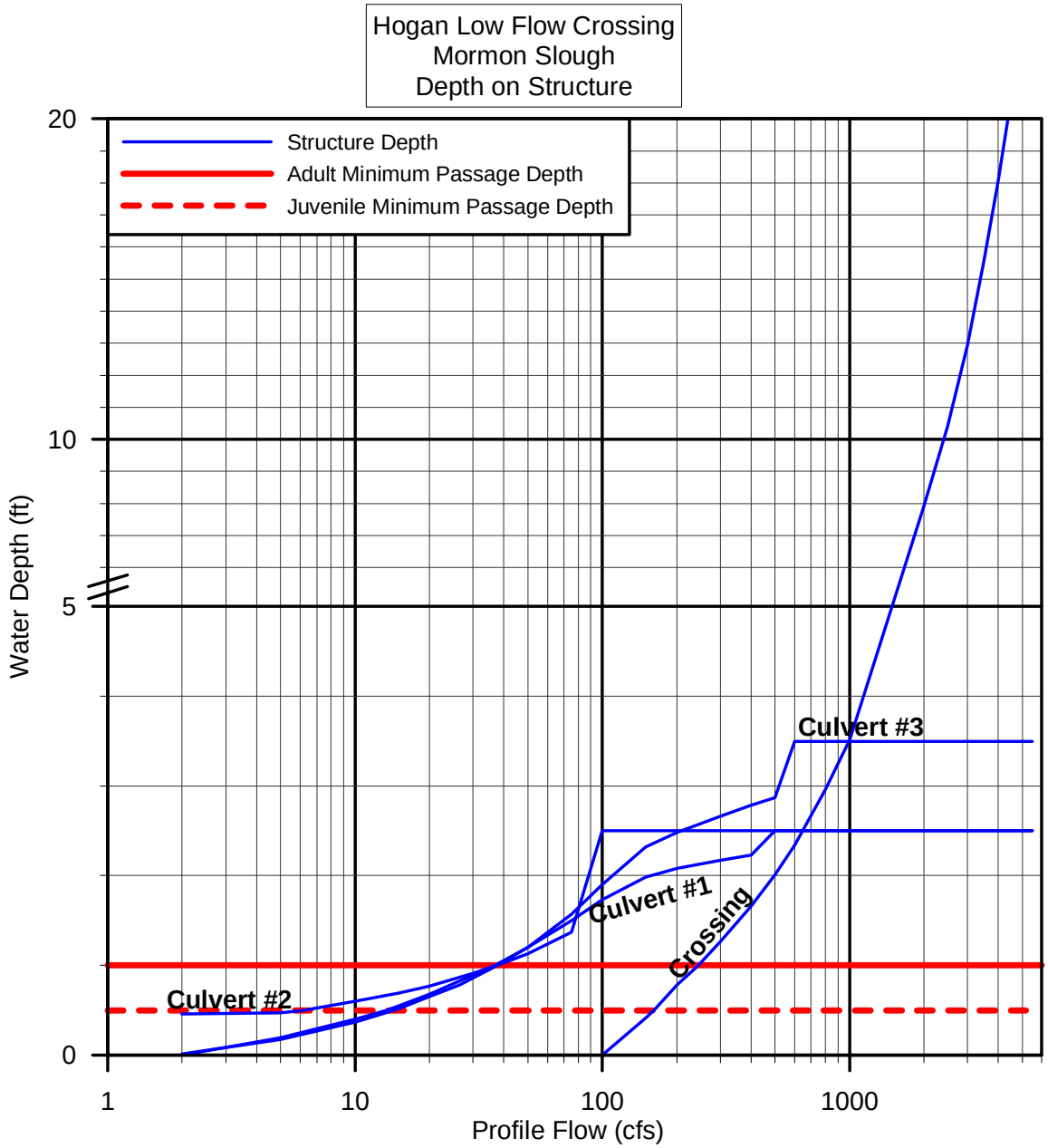


**Figure D-31. Hogan Low-flow Road Crossing – Velocity rating curves for the channel**

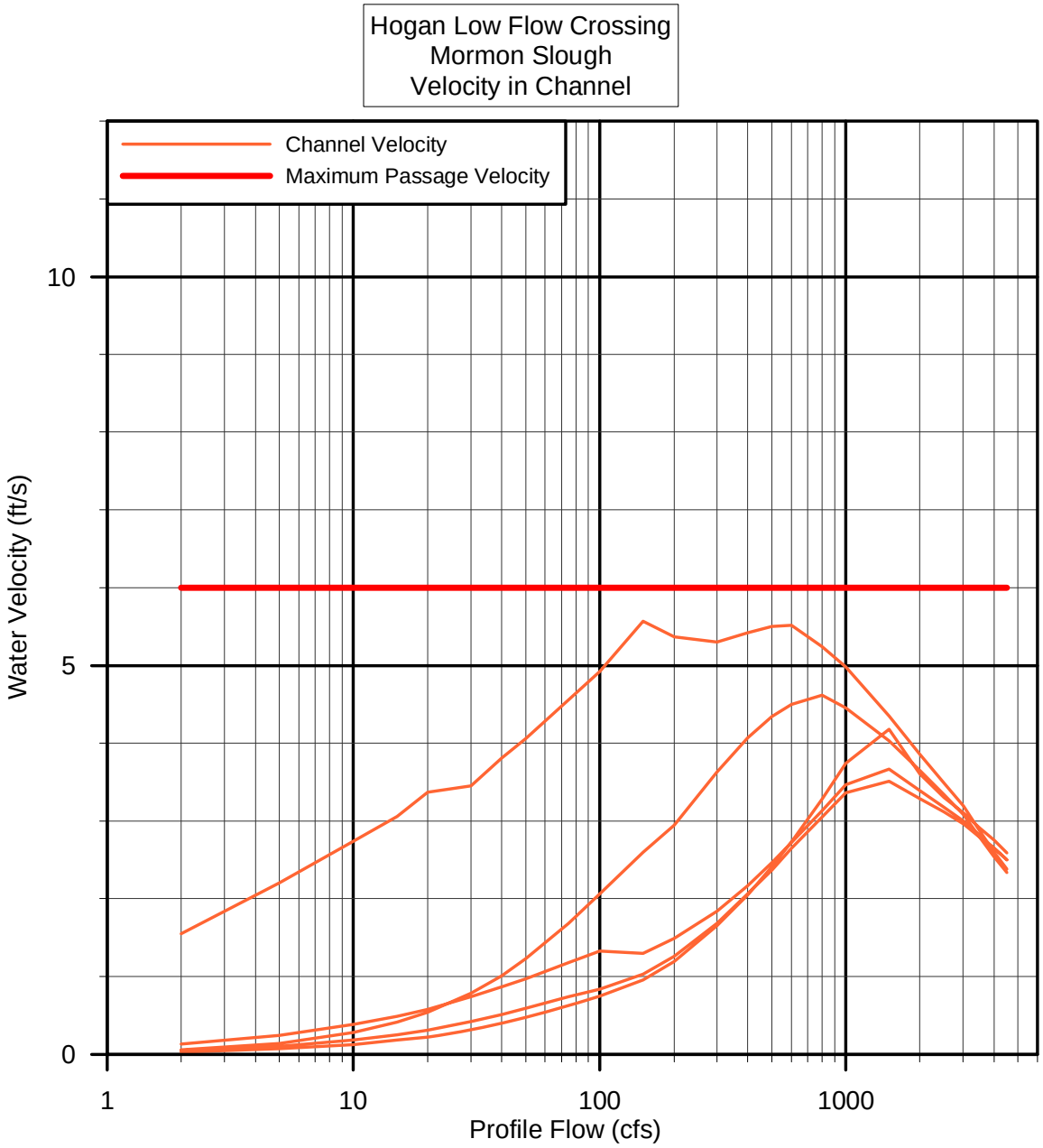


**Figure D-32. Hogan Low-flow Road Crossing – Depth rating curves for the channel**

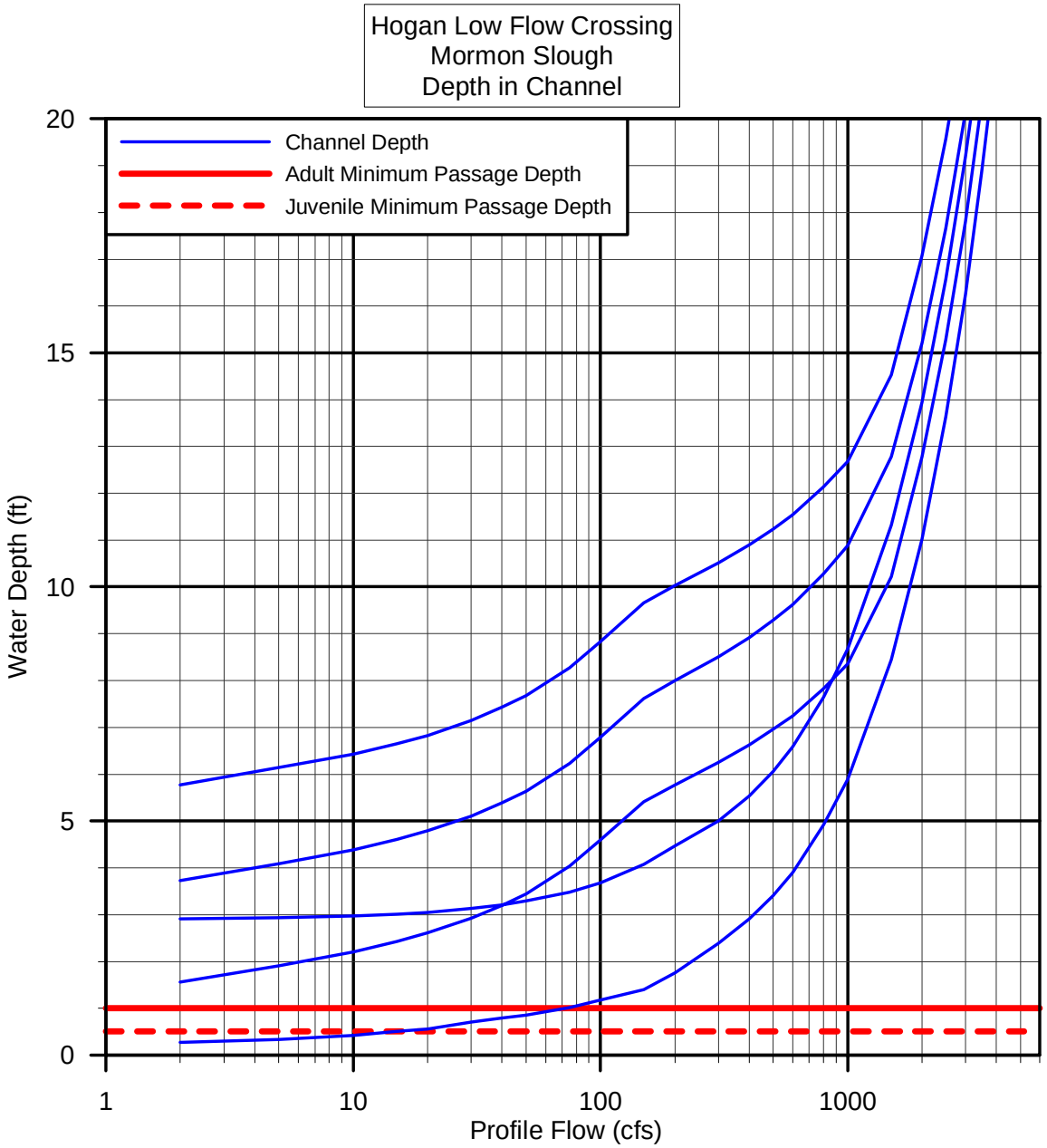


**Figure D-33. Hogan Low-flow Road Crossing – Velocity rating curves for the riprap**

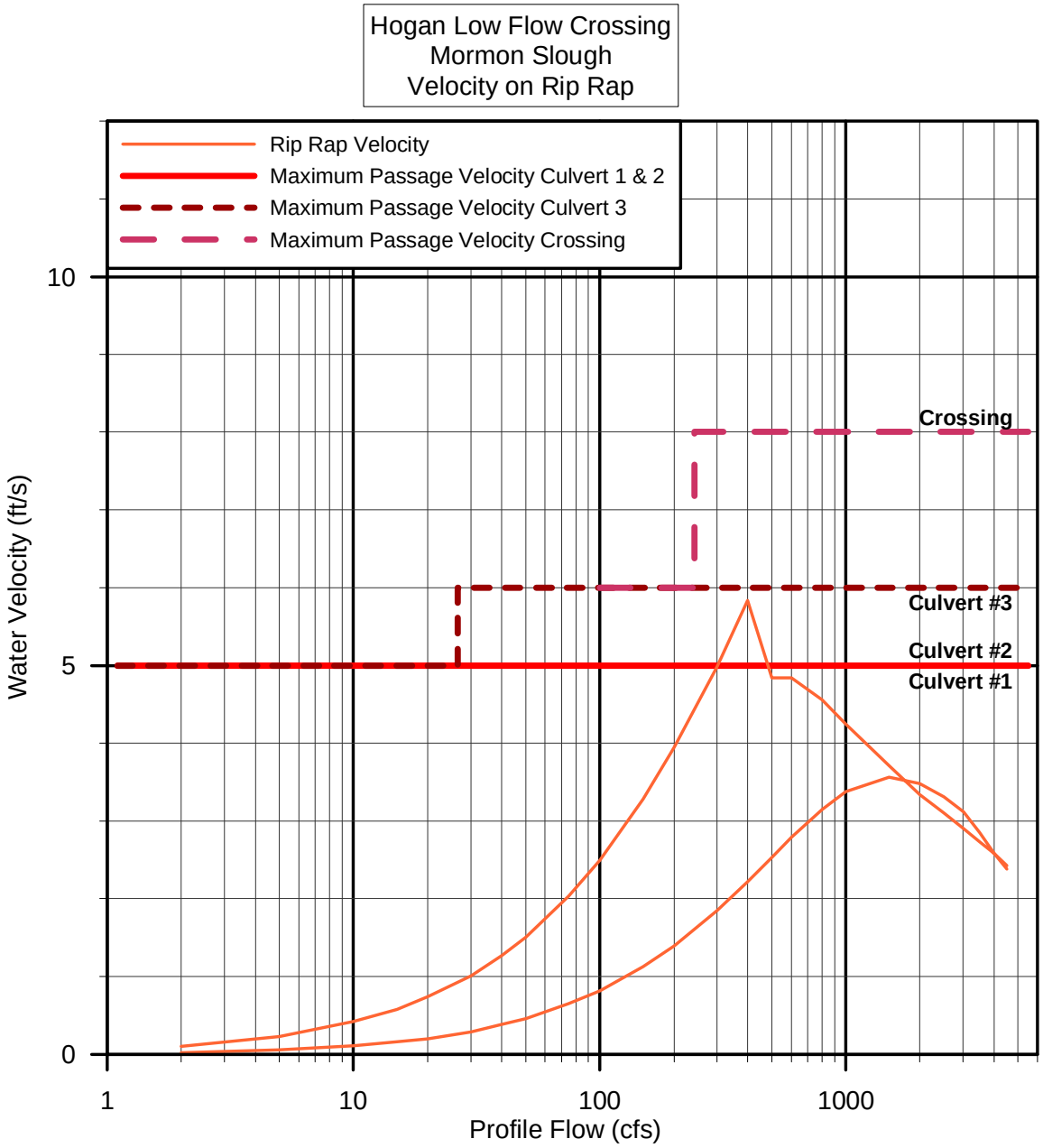
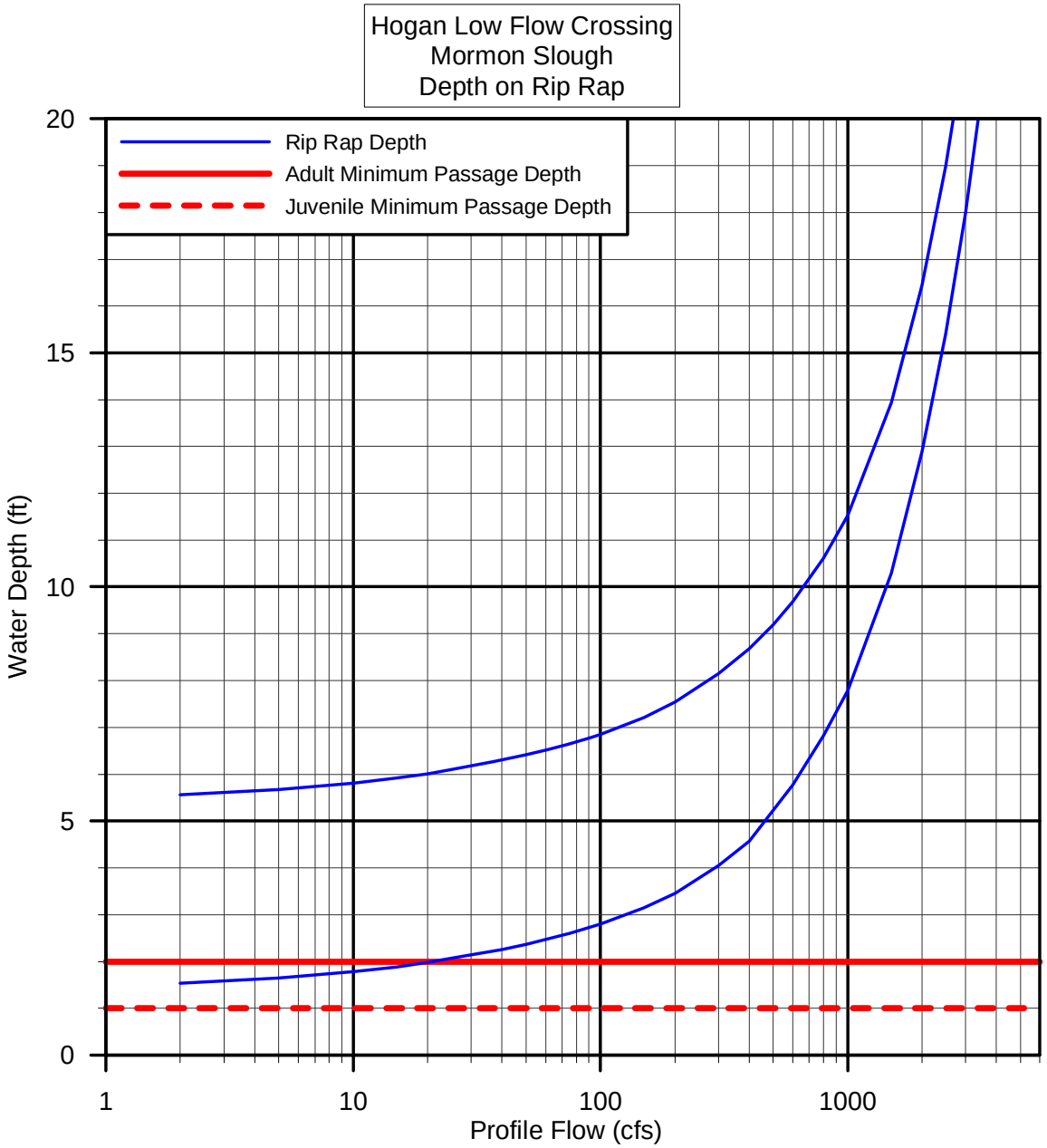


**Figure D-34. Hogan Low-flow Road Crossing – Depth rating curves for the riprap**



## *Hosie Low-flow Road Crossing*

**Photo D-10. Hosie Low-flow Road Crossing – Photo of the upstream channel and structure during no flow condition**

**Photo D-11. Hosie Low-flow Road Crossing – Photo of the structure during flow condition**

## Structure Details

| | |
|---|---|
| Name of structure: | Hosie Low-flow Road Crossing |
| Type of structure: | Low flow crossing |
| Tributary: | Mormon Slough |
| Number of sections: | upstream: 3 downstream: 3 structure: 6 |
| Length of model: | upstream: 400 ft downstream: 600 ft |

*Description of Structure.* Low flow crossing set askew from the flowline of the channel. Downstream of the structure is covered in riprap.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.03-0.035 |
| Side slopes and banks: | 0.1 |
| Concrete Structure: | 0.02 |
| Riprap: | 0.06-0.08 |
| Culverts: | N/A |

*Calibration*

Number of flows: 3

1. Flow: 112 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. All points taken on right bank or center of structure. Skew of structure and complex flow immediately downstream of structure caused difficulty in lining up observed water surface points with model cross-sections.

2. Flow: 162 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. All points taken on right bank or center of structure. Skew of structure and complex flow immediately downstream of structure caused difficulty in lining up observed water surface points with model cross-sections.

3. Flow: 1,800 cfs Survey method: Total Station

Comments: Flow estimated based velocity measurement, on site observations and Bellota Weir hydrograph. All points taken on right bank.

*Starting conditions used for the model.* The model was run with mixed flow conditions for all three flows, so boundary conditions for downstream and upstream were specified. For the lower two flows, no observed water surface existed for the downstream end, so a water surface was derived based on water surface slope and the next upstream section observation. At the highest flow, an observation existed and was used.

*Assumptions.* Primary assumptions include skewing the sections on or near the structure because the structure is at an angle to the channel.

*Comments.* Problems encountered with calibration included some deviations just downstream of the main structure. Several observed elevations at the lower two flows on sections going through the riprap downstream of the structure were likely taken a few feet off of the sections. Based on the photos at those flows, it appears that a small deviation from the cross-section could make a large difference in elevation in that area. Again, these problems are associated with the details in modeling riprap.

### Performance Summary

The structure and channel performed well relative to staying below maximum velocities but the riprap exceeded velocities between 100 and 190 cfs. Minimum depths across the crossing impeded passage for juveniles for flows up to 100 cfs. The crossing had problems with depth for adults up to 320 cfs. Riprap shows problems up to 460 cfs for adults. In summary the structure has impaired passage for flows up to 460 cfs for adults and 100 cfs for juveniles.

**Figure D-35. Cross section locations for Hosie Low-flow Road Crossing HEC-RAS model**

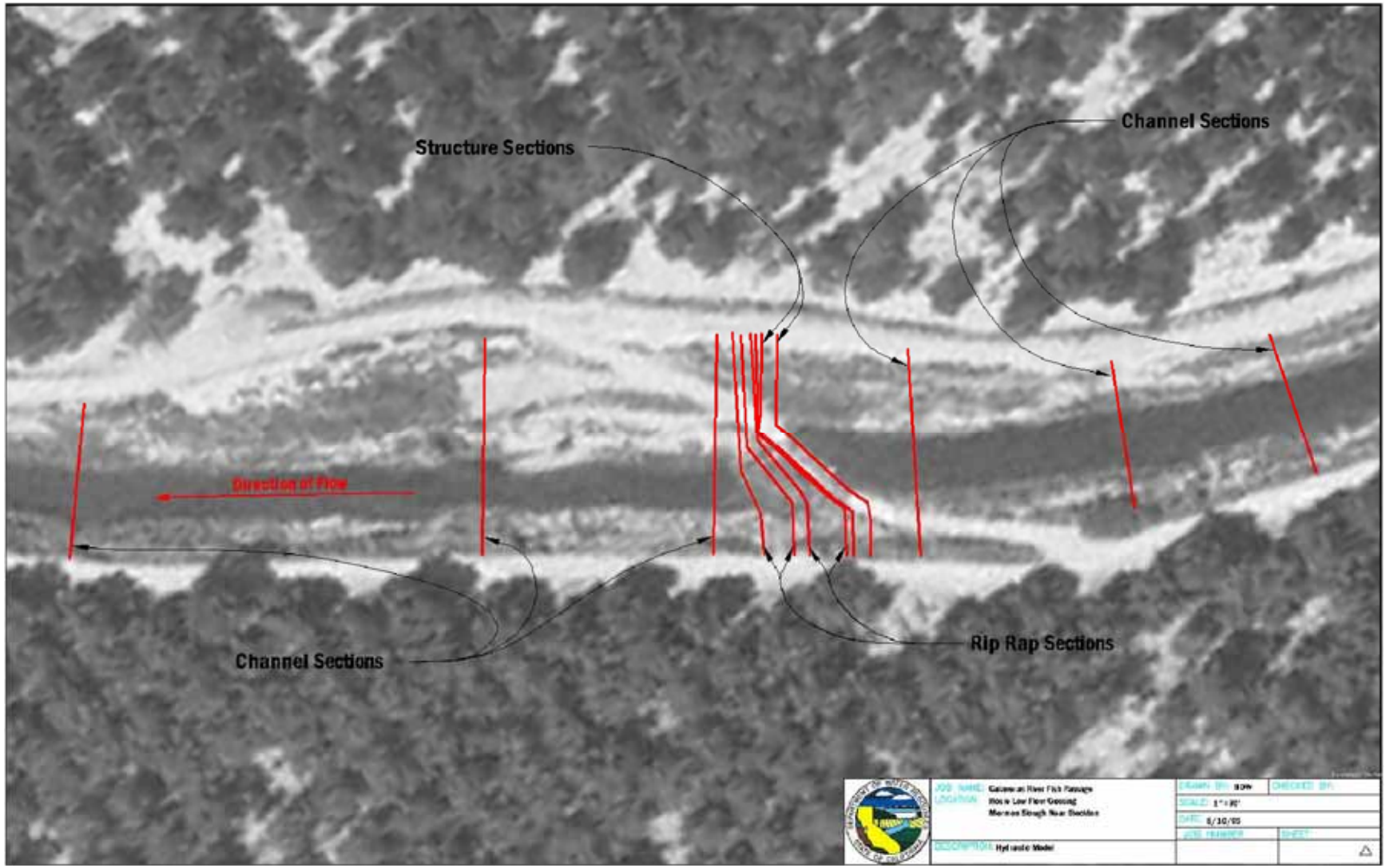


**Figure D-36. Hosie Low-flow Road Crossing – Relationship of length to maximum velocity**

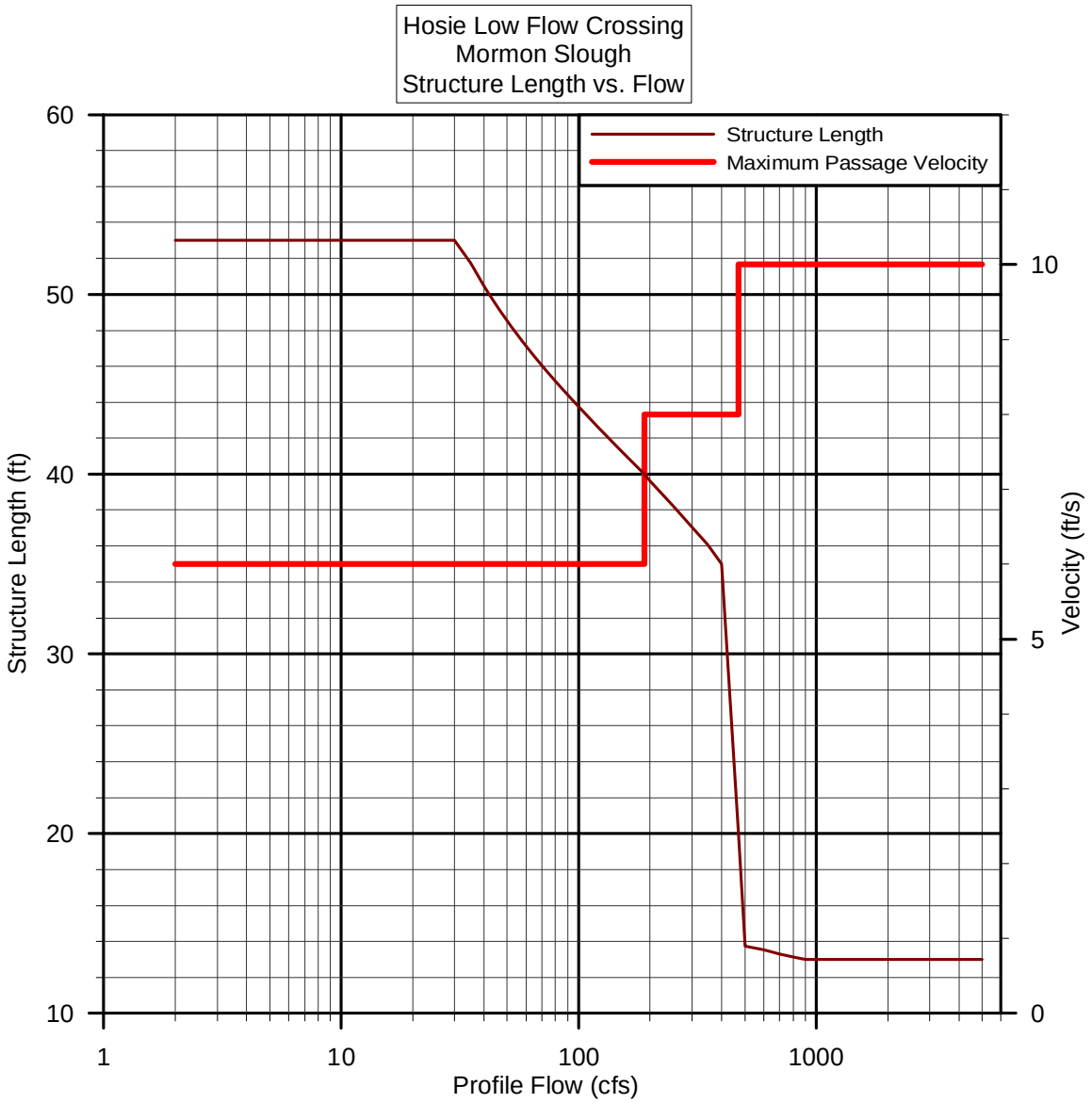


**Figure D-37. Hosie Low-flow Road Crossing – Velocity rating curves for the structure**

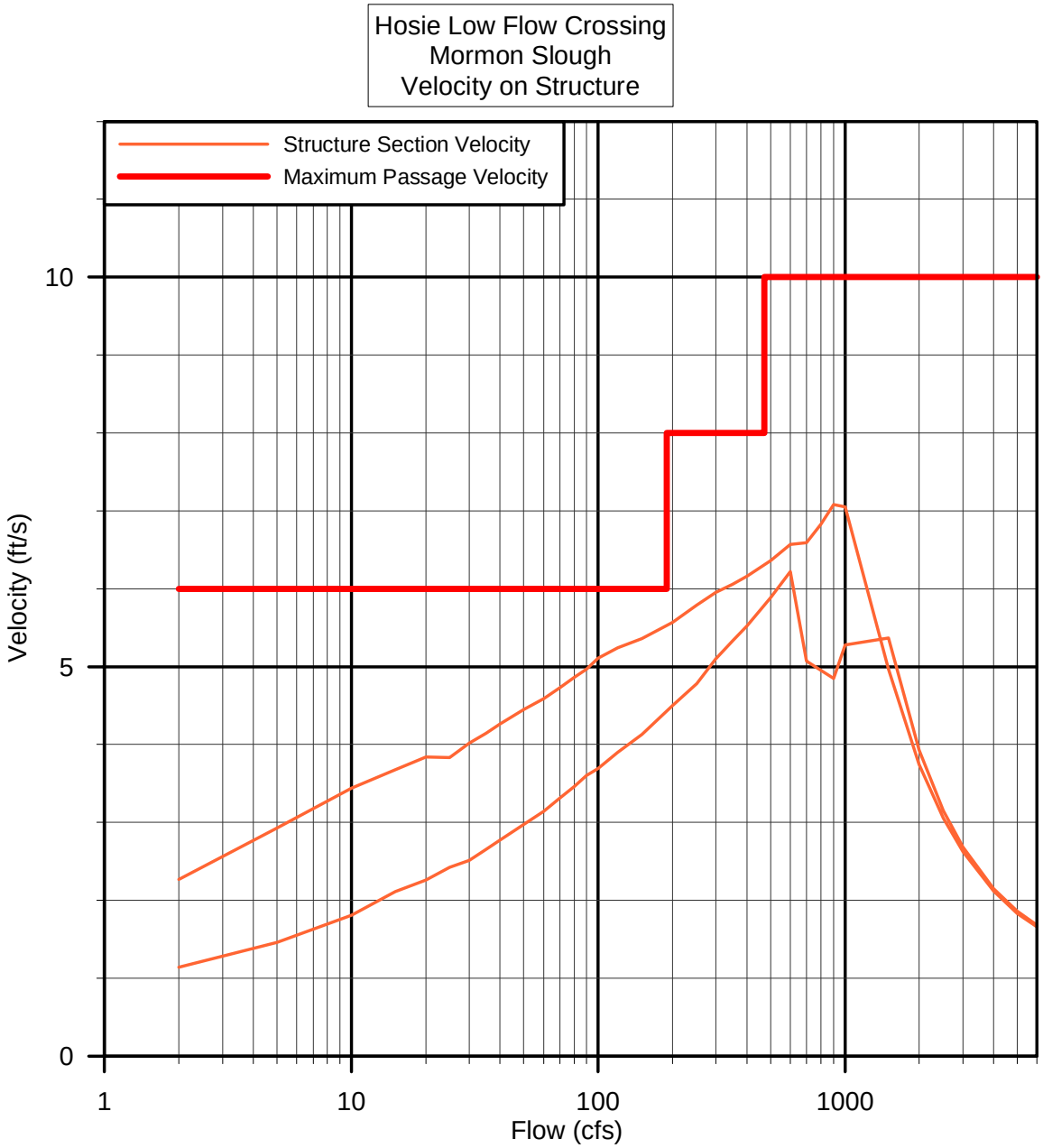


**Figure D-38. Hosie Low-flow Road Crossing – Depth rating curves for the structure**

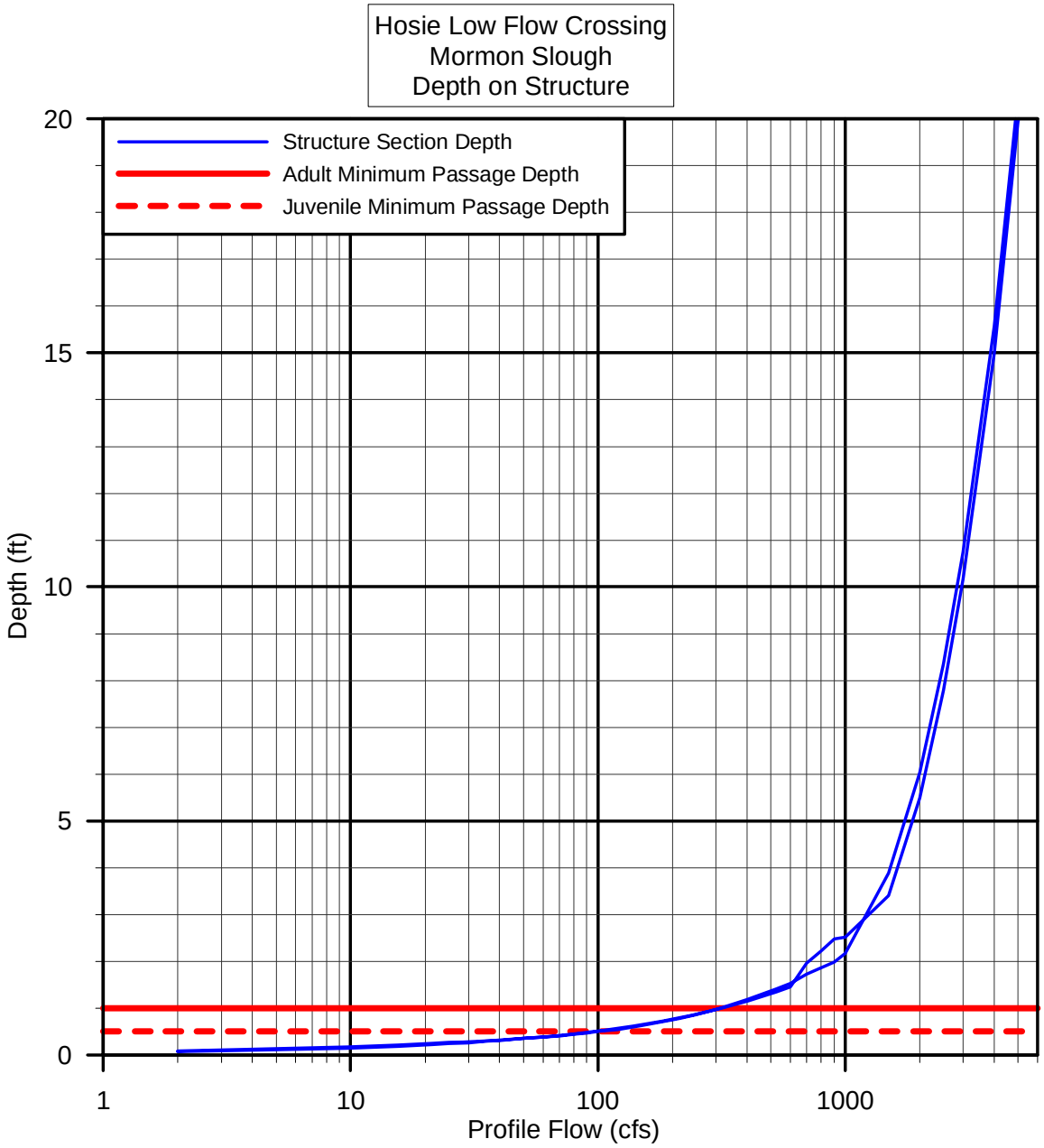


**Figure D-39. Hosie Low-flow Road Crossing – Velocity rating curves for the riprap**

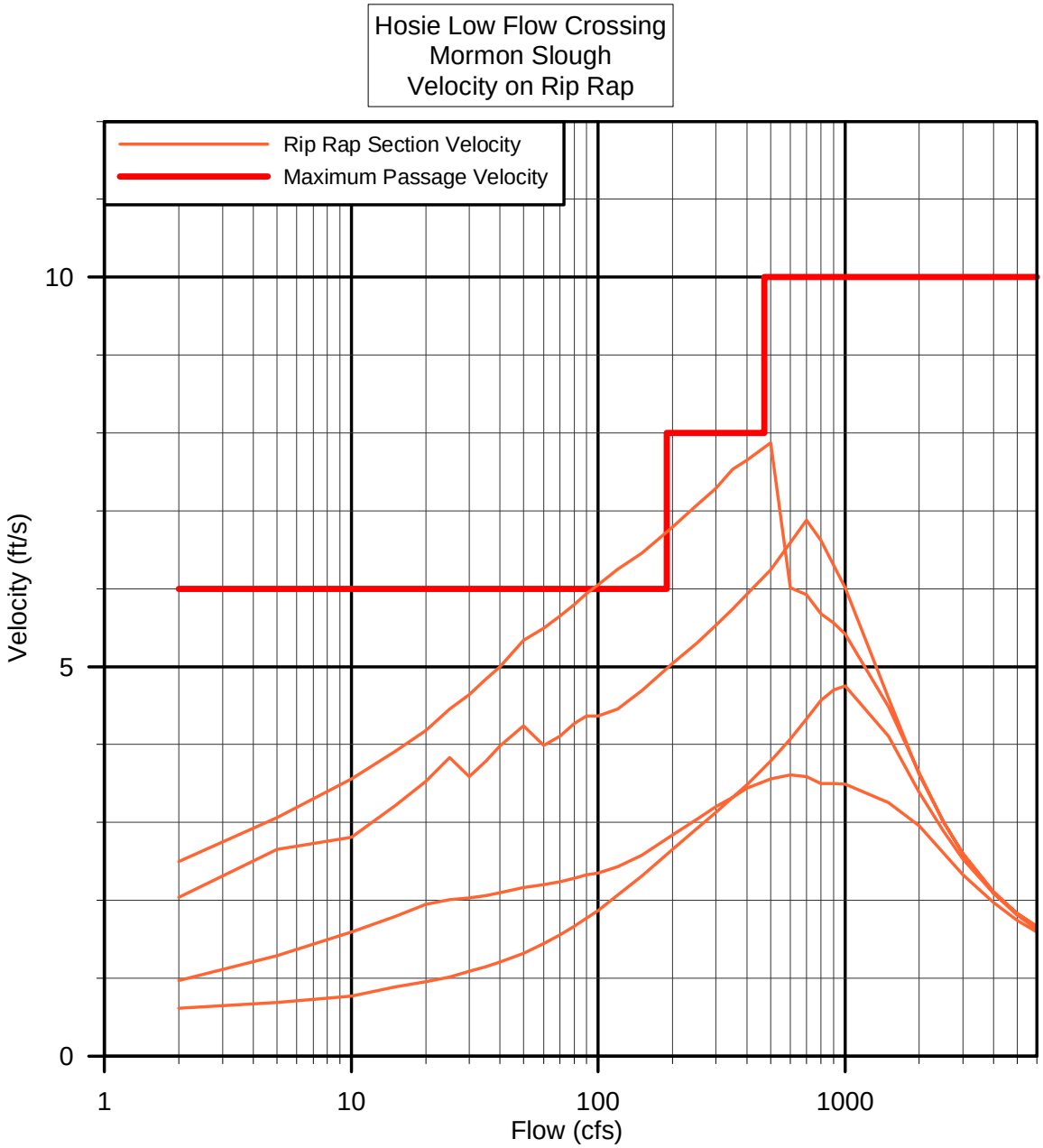


**Figure D-40. Hosie Low-flow Road Crossing – Depth rating curves for the riprap**

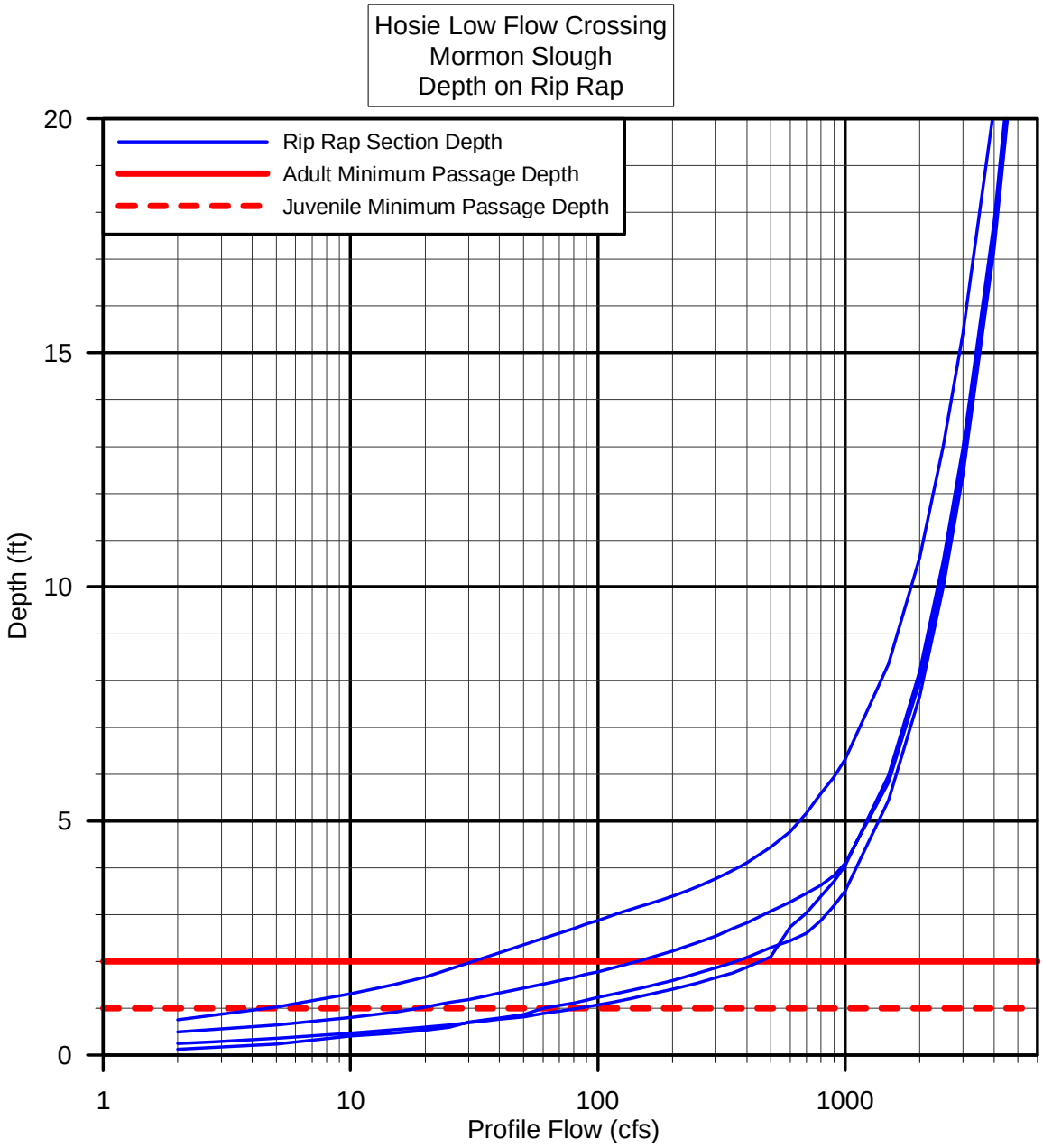


**Figure D-41. Hosie Low-flow Road Crossing – Velocity rating curves for the channel**

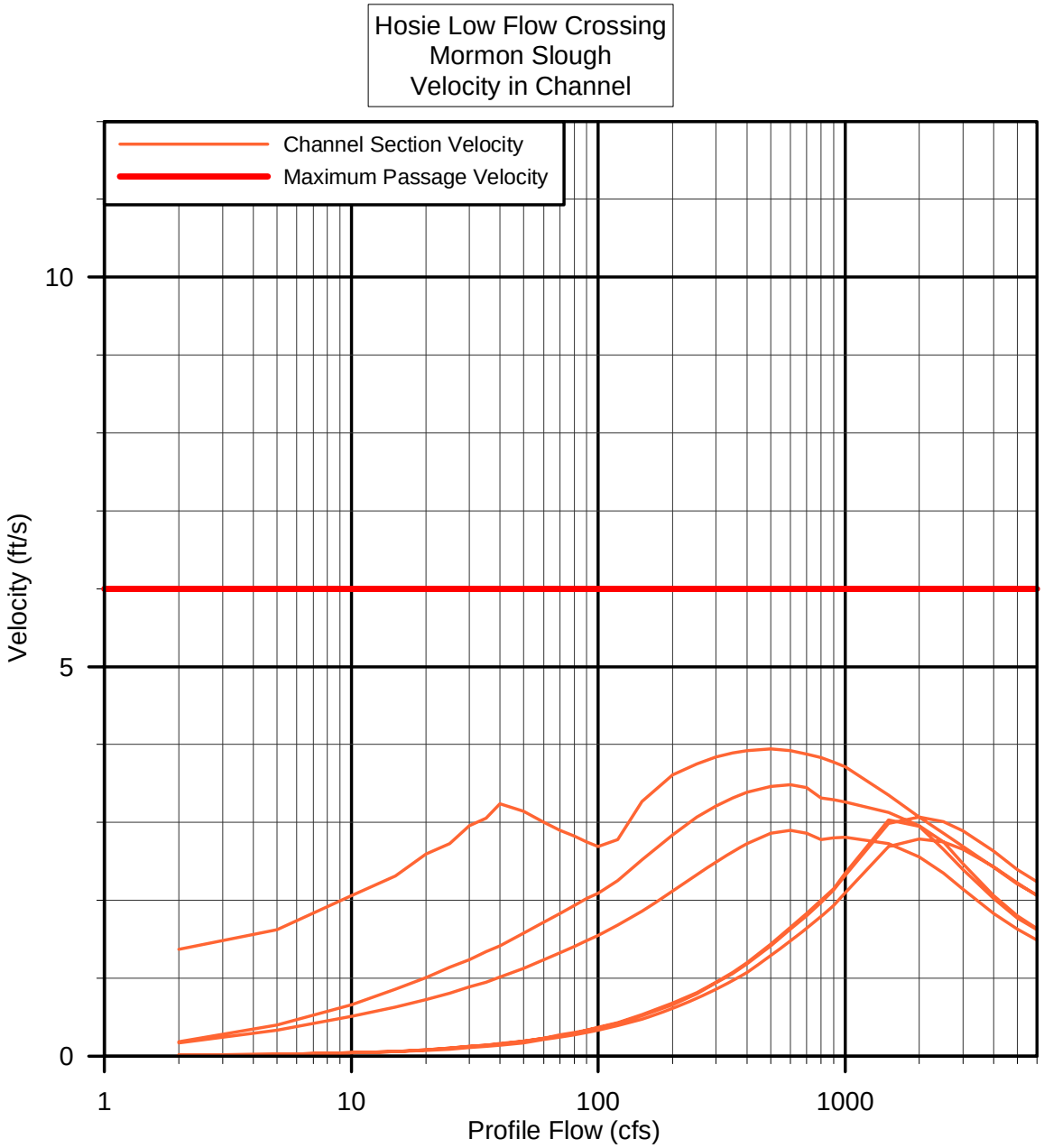
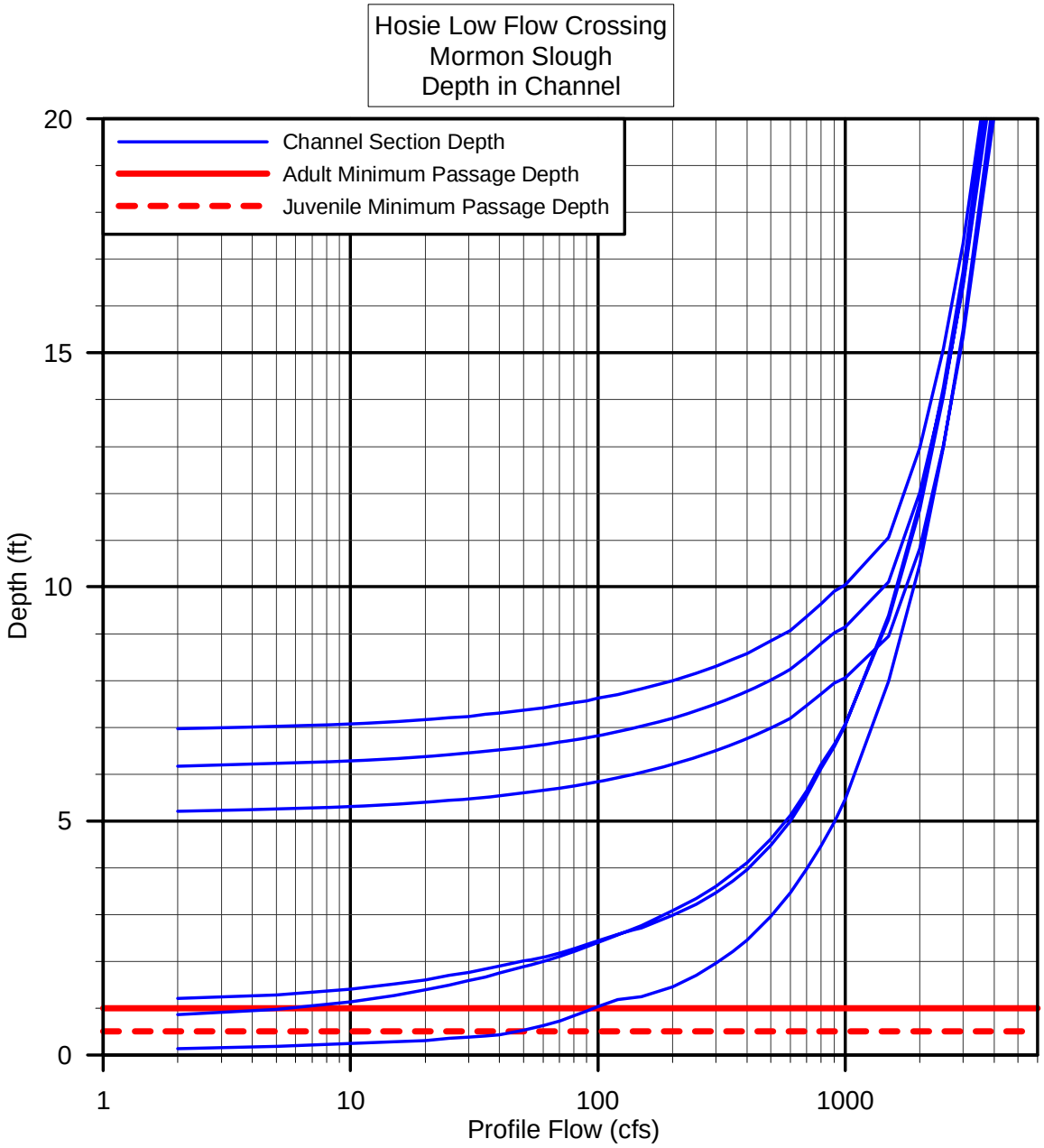


**Figure D-42. Hosie Low-flow Road Crossing – Depth rating curves for the channel**



## *Watkins Low-flow Road Crossing*

**Photo D-12. Watkins Low-flow Road Crossing – Structure during high flow event**

**Photo D-13. Watkins Low-flow Road Crossing – Structure during no flow condition**

## Structure Details

| | |
|---|---|
| Name of structure: | Watkins Low-flow Road Crossing |
| Type of structure: | Weir |
| Tributary: | Mormon Slough |
| Number of sections: | upstream: 2 downstream: 5 structure: 4 |
| Length of model: | upstream: 420 ft downstream: 442 ft |

*Description of structure.* A low flow crossing set askew of channel flowline. The structure is heavily riprapped on the downstream end. Structure also contains a culvert that was assumed inoperable because it was full of riprap and sediment.

## Model Summary

*Mannings 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.032-0.035 |
| Side slopes and banks: | 0.1 |
| Concrete structure: | 0.01 |
| Riprap: | 0.05-0.08 |
| Culverts: | N/A |

*Calibration*

Number of flows: 4

1. Flow: 129 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. Upstream and furthest downstream points were taken on right bank, Structure points were taken in middle of channel, bottom of riprap point was taken on left bank.

2. Flow 168 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. Upstream and furthest downstream points were taken on right bank, Structure points were taken in middle of channel, bottom of riprap point was taken on left bank.

3. Flow: 42 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site.

4. Flow: 1520 Survey method: Total Station

Comments: Flow estimated using a combination of field measurements and Bellota Weir gage data. All points taken on right bank.

*Starting conditions used for the model.* The model was run using the mixed flow regime using known up and downstream water elevations.

*Assumptions.* Since culvert in structure was completely covered, it was assumed that flow through the culvert is negligible and was not included in the model. The direction of flow across a structure that is skewed to the flow will not be constant at all flow depths but it is assumed it will remain constant for all flows. High flow path and low flow path will be effected the same by the angle of the cross sections.

*Comments.* The model calibrates well for low flows except in riprap slope below the structure where a significant part of the flow may be through riprap, below the measured bed. To increase accuracy in the riprap at low flows, the riprap area below the structure would require a considerable increase in detail by measuring more sections and obtaining a better understanding of flow paths through the riprap.

### Performance Summary

Flow across the structure meets the velocity requirements even on the downstream edge of the structure; however, the wide structure does not meet depth requirements for flows up to 380 cfs for adults and 120 cfs for juveniles. Adults experience depth problems over riprap for flows below 310 cfs. Juveniles experience similar problems across the riprap for flows up to 70 cfs. The channel does not appear to have any velocity problems, but has depth problem at flows less than 30 cfs. In summary, the structure has impeded passage for flows up to 380 cfs for adults and 120 cfs for juveniles.

**Figure D-43. Cross section locations for Watkins Low-flow Road Crossing HEC-RAS model**

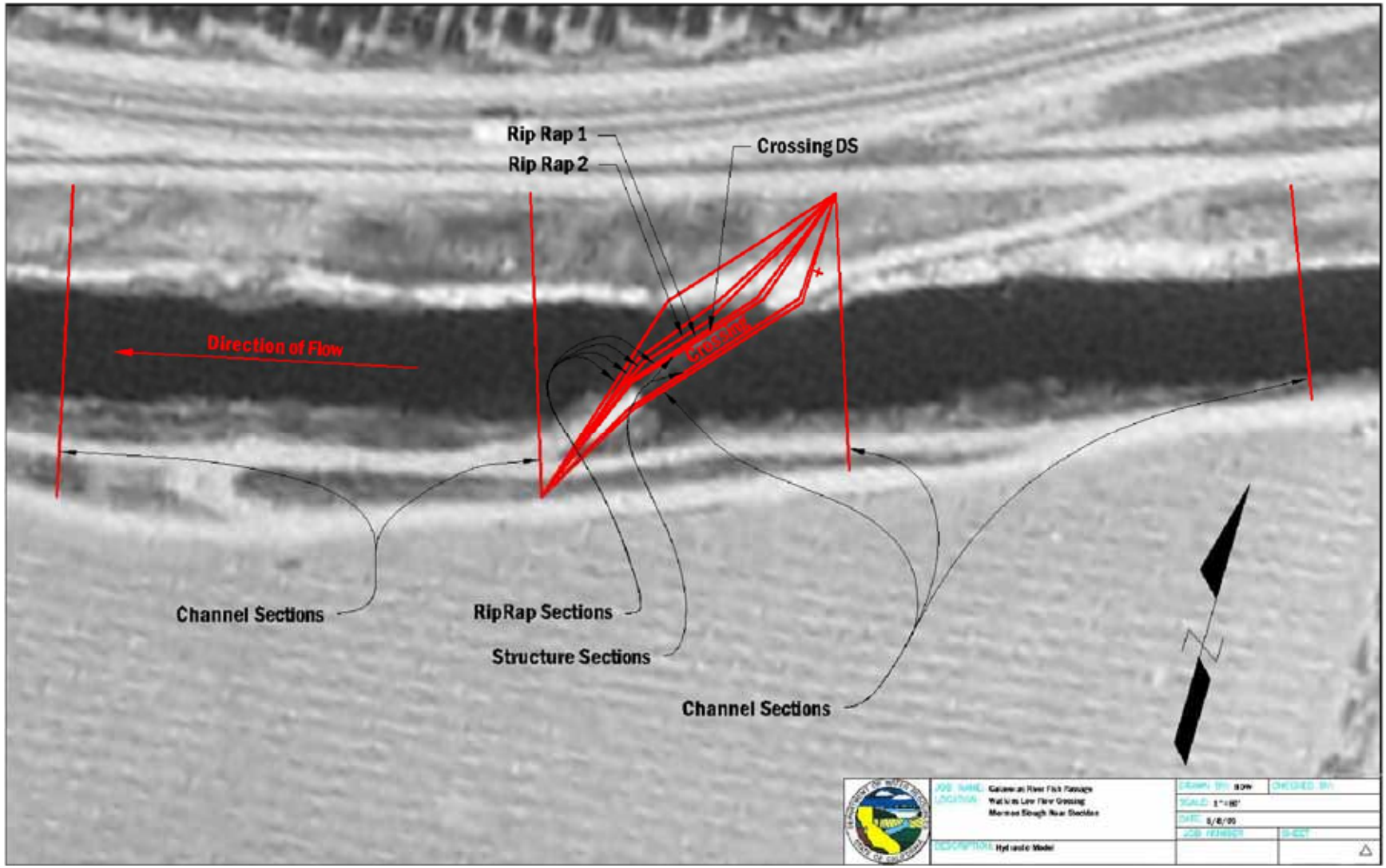


**Figure D-44. Watkins Low-flow Road Crossings – Relationship of length to maximum velocity**

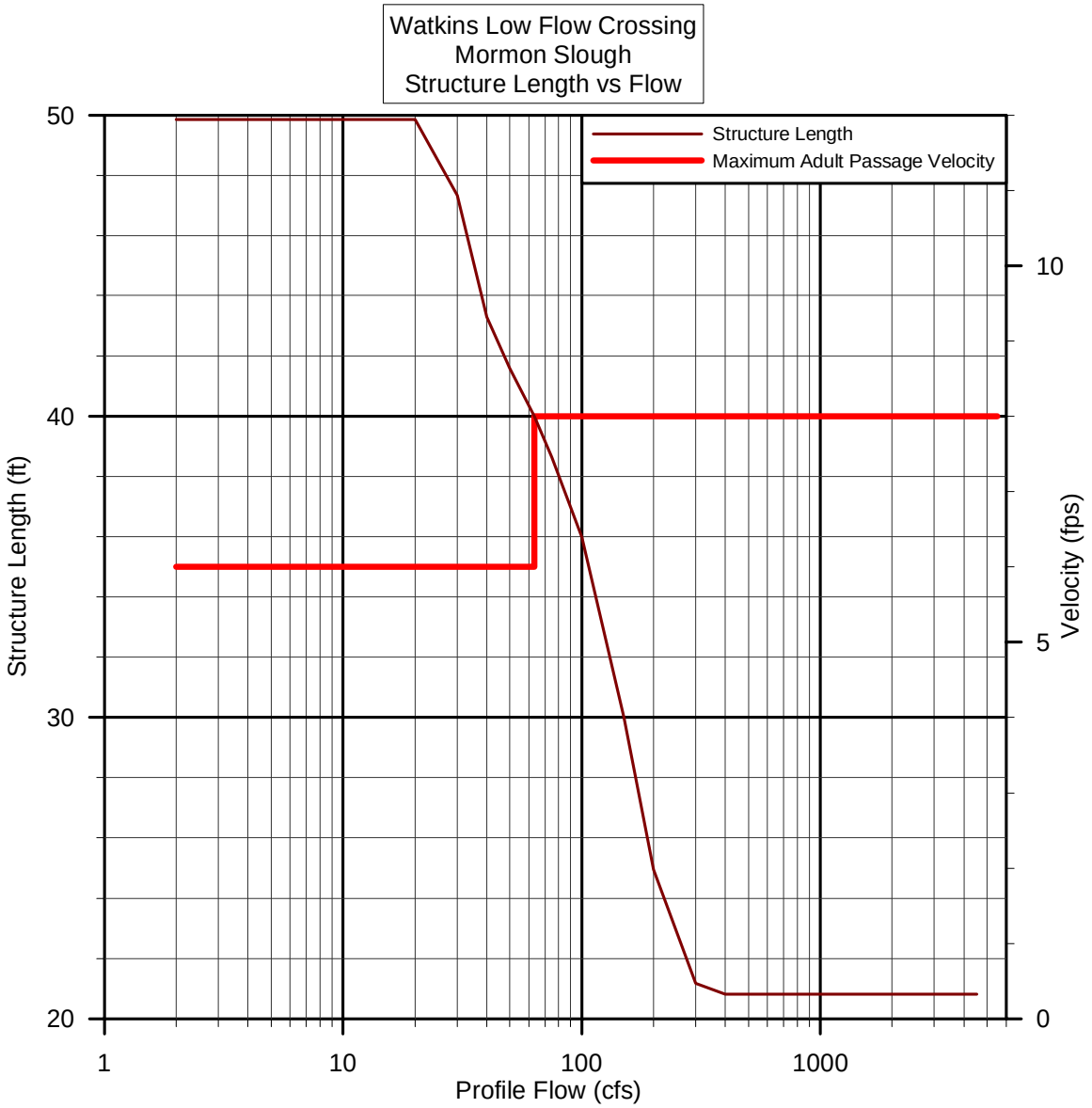


**Figure D-45. Watkins Low-flow Road Crossing – Velocity rating curves for the structure**

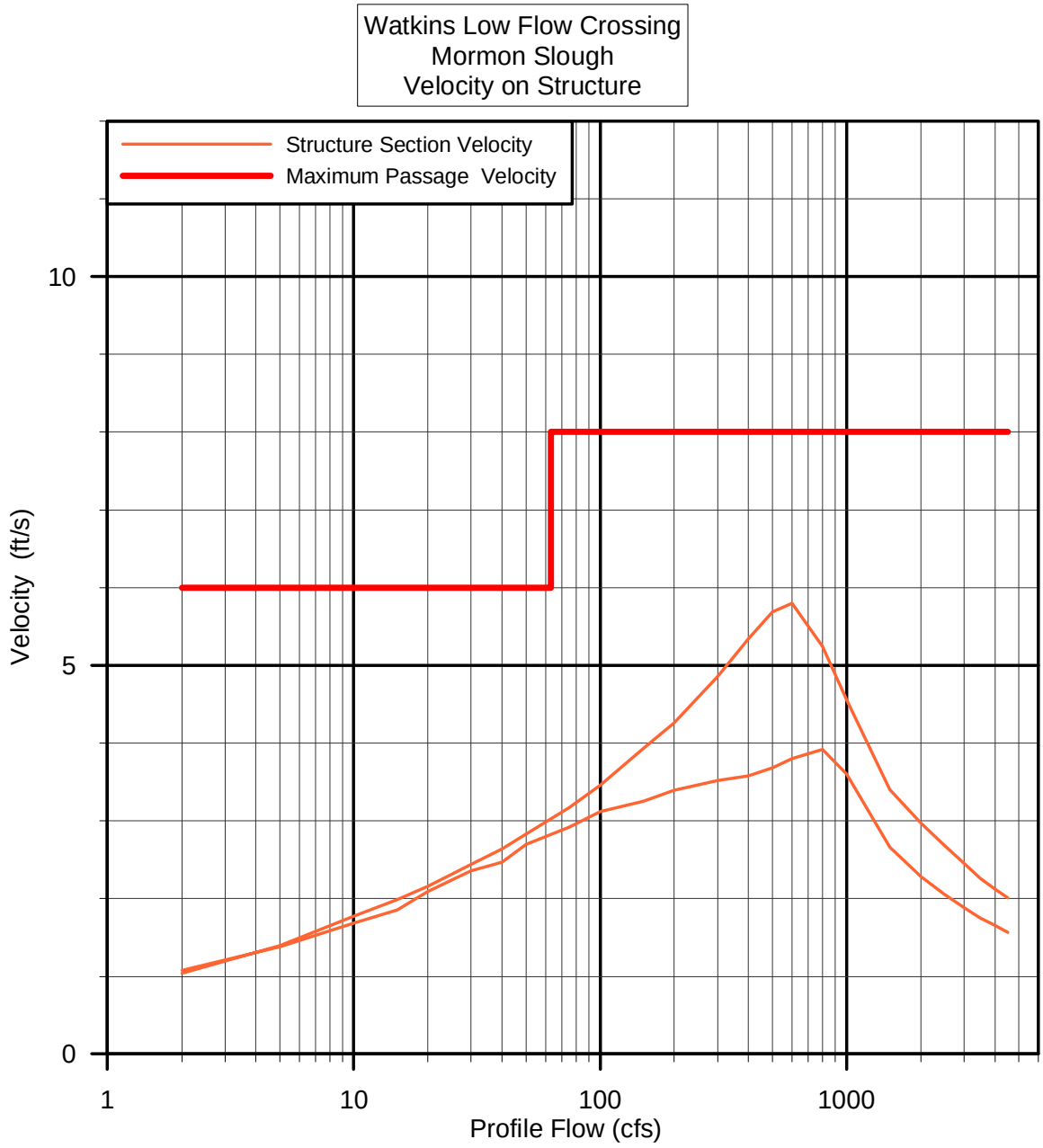


**Figure D-46. Watkins Low-flow Road Crossing – Depth rating curves for the structure**

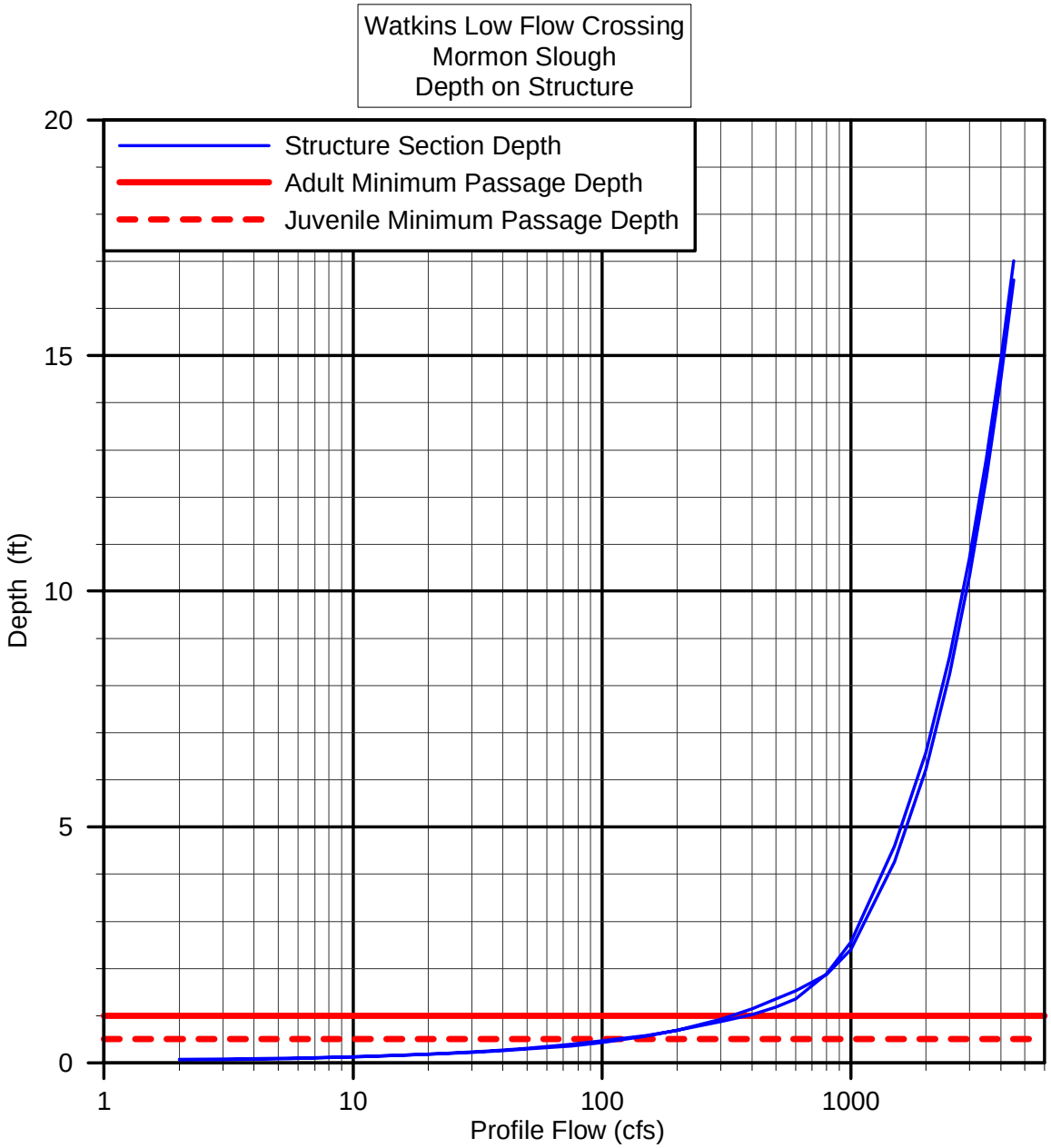


**Figure D-47. Watkins Low-flow Road Crossing – Velocity rating curves for the riprap**

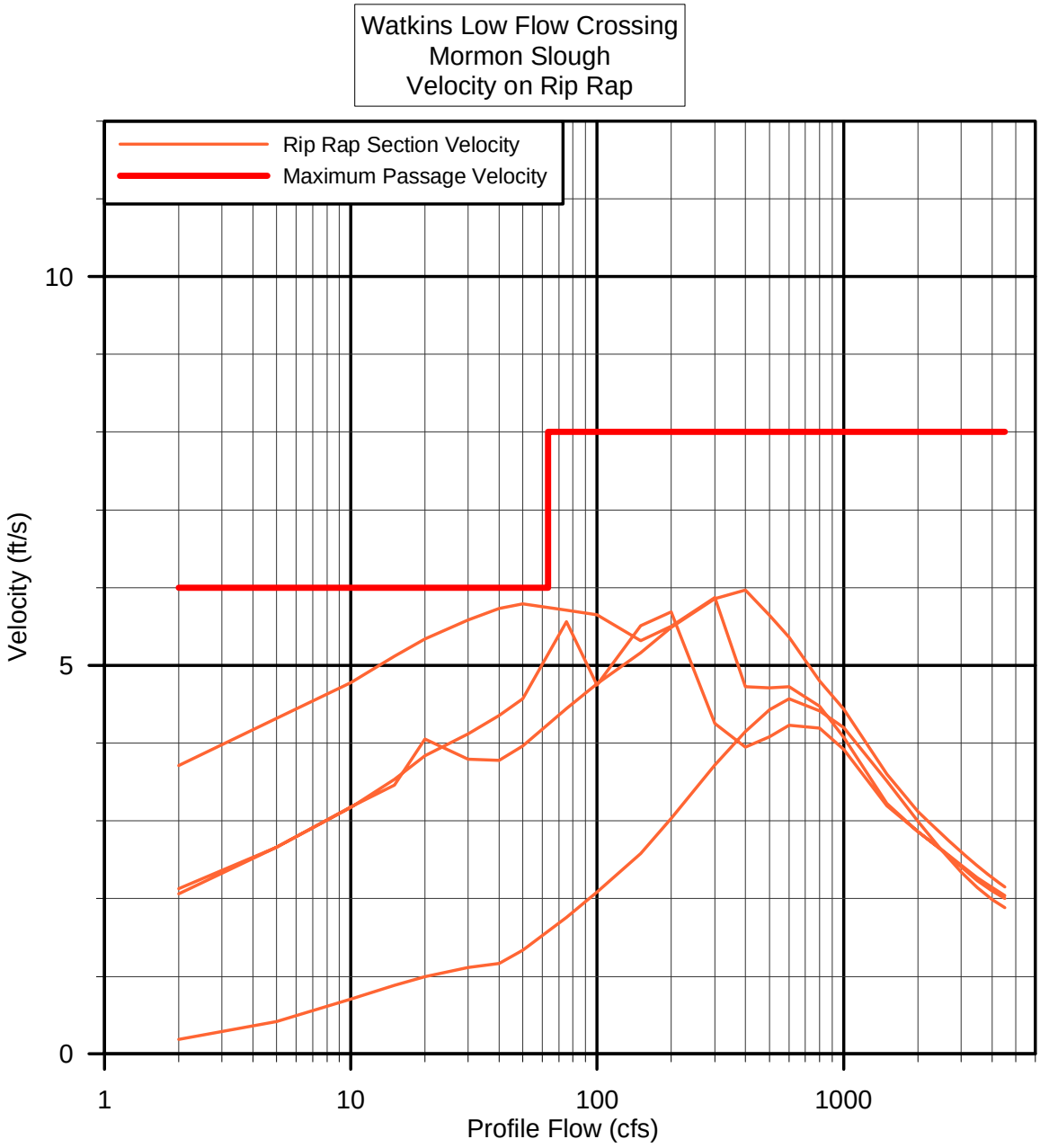


**Figure D-48. Watkins Low-flow Road Crossing – Depth rating curves for the riprap**

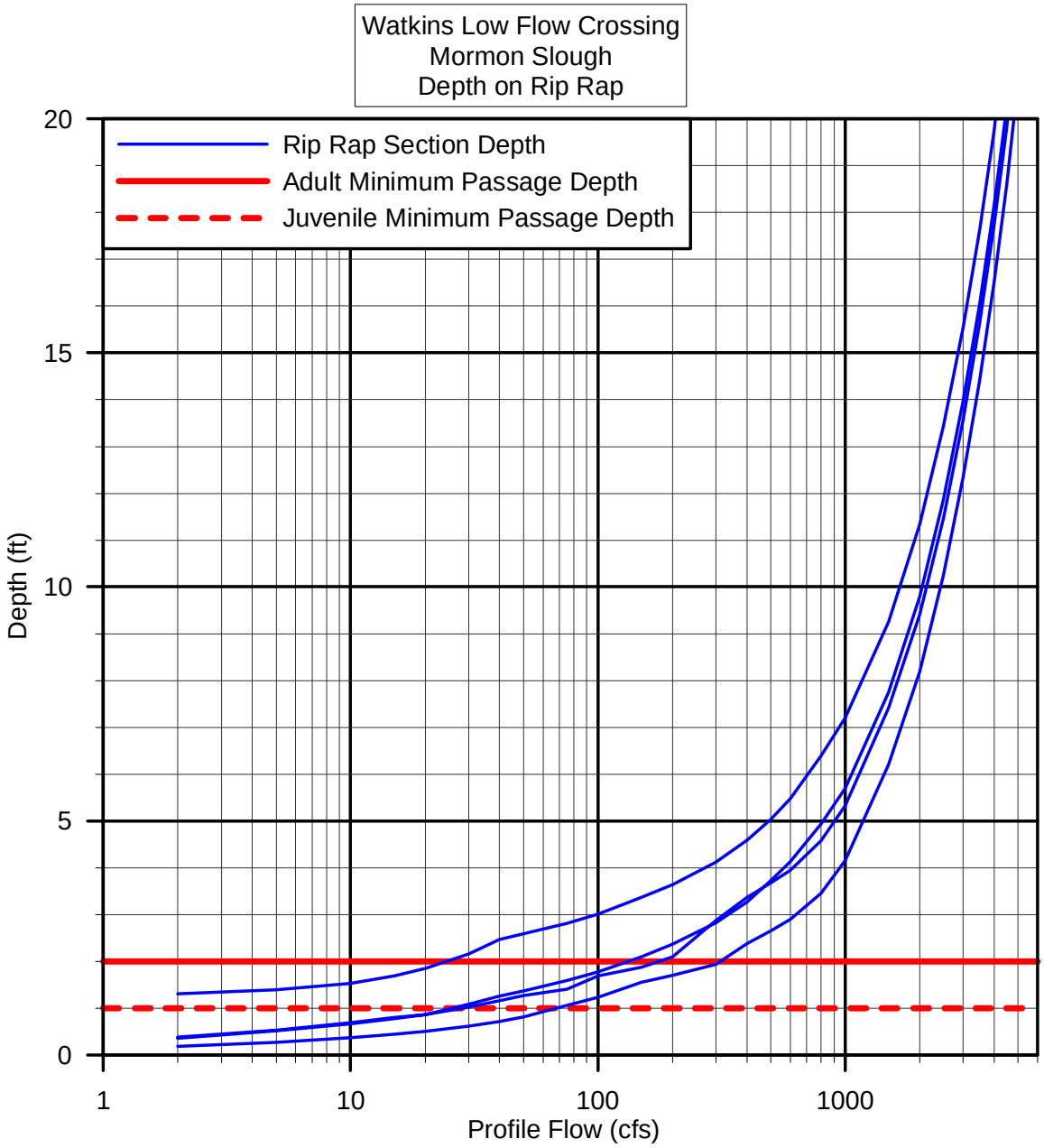


**Figure D-49. Watkins Low-flow Road Crossing – Velocity rating curves for the channel**

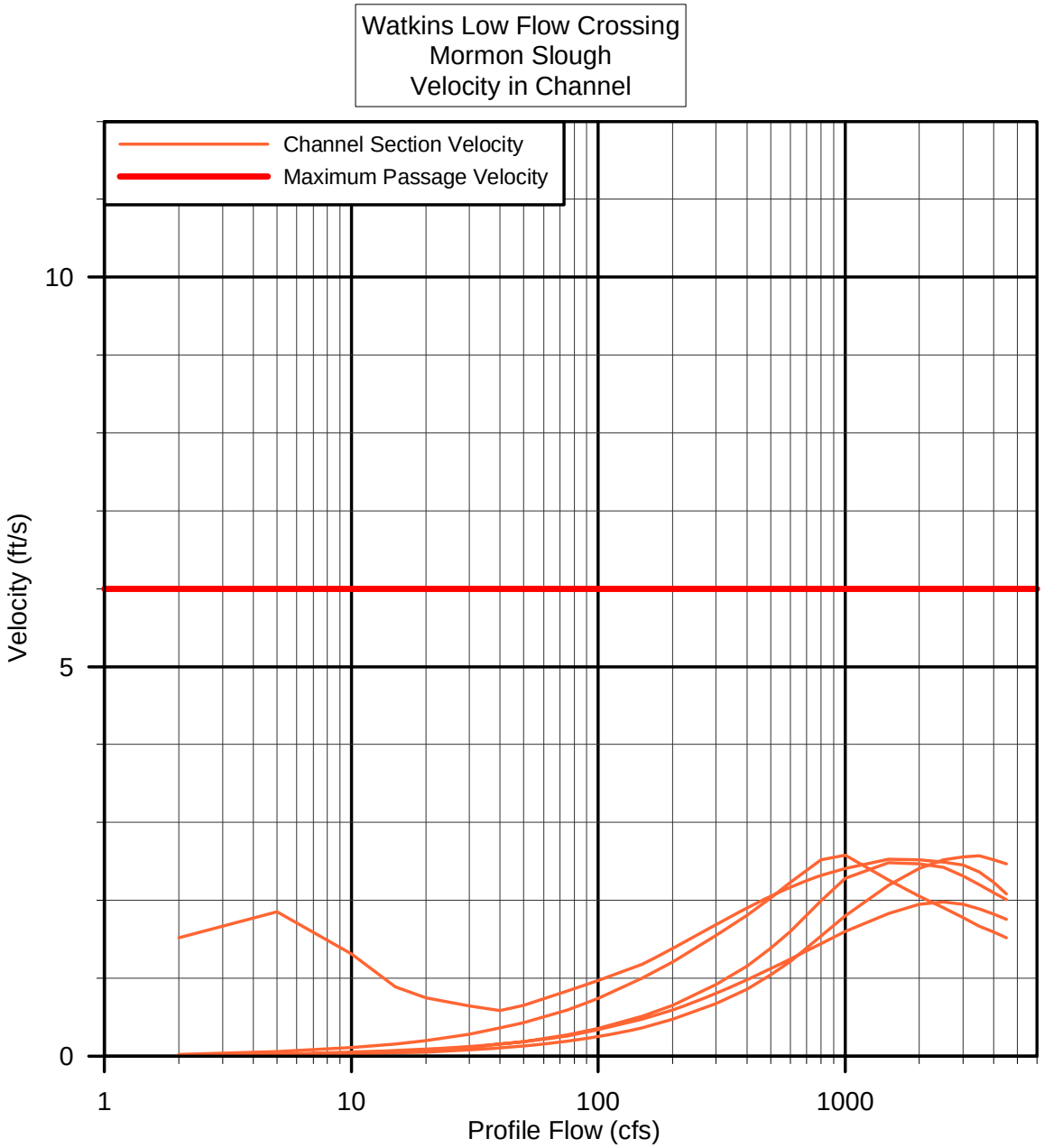
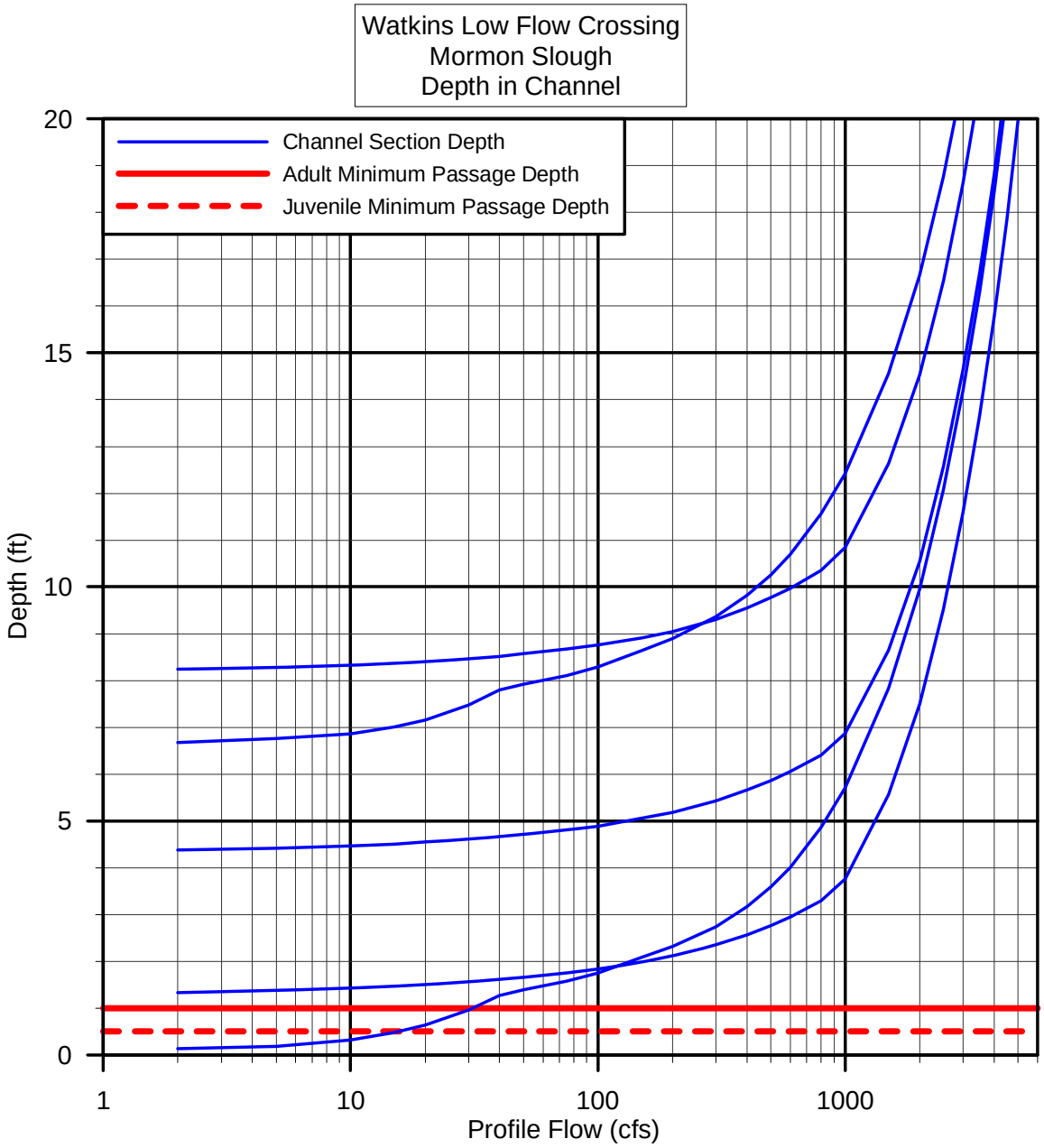


**Figure D-50. Watkins Low-flow Road Crossing – Depth rating curves for the channel**



## *Murphy Flashboard Dam*

**Photo D-14. Murphy Flashboard Dam – Downstream side of structure during flow**

**Photo D-15. Murphy Flashboard Dam – Upstream side of dam during flow condition**

## Structure Details

| | | | |
|---|---|---|---|
| Name of structure: | Murphy Flashboard Dam | | |
| Type of structure: | Flashboard dam | | |
| Tributary: | Calaveras River | | |
| Number sections: | upstream: 3 | downstream: 4 | structure: 2 |
| Length of model: | upstream: 115 ft | downstream: 174 ft | |

*Description of structure*. A concrete flashboard dam with four bays.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel bottom: | 0.03-0.10 |
| Side slopes and banks: | 0.10 |
| Concrete structure: | 0.02 |
| Concrete wingwalls & sandy bottom: | 0.03 |

*Calibration*

1. Feb. 20, 2004
Flow: 15 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site.
2. Feb 27, 2004
Flow: 48 cfs Survey method: Total station
Comments: Flow measurement using current meter at site.

*Starting conditions used for the model*. The model was run subcritical, so boundary conditions were set on the downstream section.

*Assumptions.* The Dam has several flashboards that were in during our surveys. For modeling purposes, the flashboards were assumed permanent, not likely to ever be removed. The blocked feature was used (as opposed to the ineffective flow areas) to represent the boards. The model showed a lower (0.1 feet for 15 cfs and 0.3 to 0.4 feet for 48 cfs flow) water surface elevation upstream of the dam than was observed. Since calibration was good downstream of the structure, and differences were uniform upstream of the structure, flow and survey errors were assumed not to be the cause. However, after viewing photos of the 15 cfs flow and after discussions with surveyors during the 48 cfs flow, it was assumed that debris was causing the lack of calibration. Debris can be seen in photos of the 15 cfs flow. To allow for the added energy loss at the structure due to debris, the additional EG loss option was used. The loss was kept for flows above 50 cfs.

*Comments.* The model calibrates fairly well for the two flow events, although energy losses were added at the structure (mostly for the 3/27 flow). Based on the limited photos, the added energy loss (mainly due to debris) is reasonable.

## Performance summary

The structure and channel performed well from the standpoint of velocity but had problems with depth for flows up to 26 cfs for adults and 8 cfs for juveniles. This is due to the crest fall of the water over the board dam.

**Figure D-51. Cross section locations for Murphy Flashboard Dam HEC-RAS model**

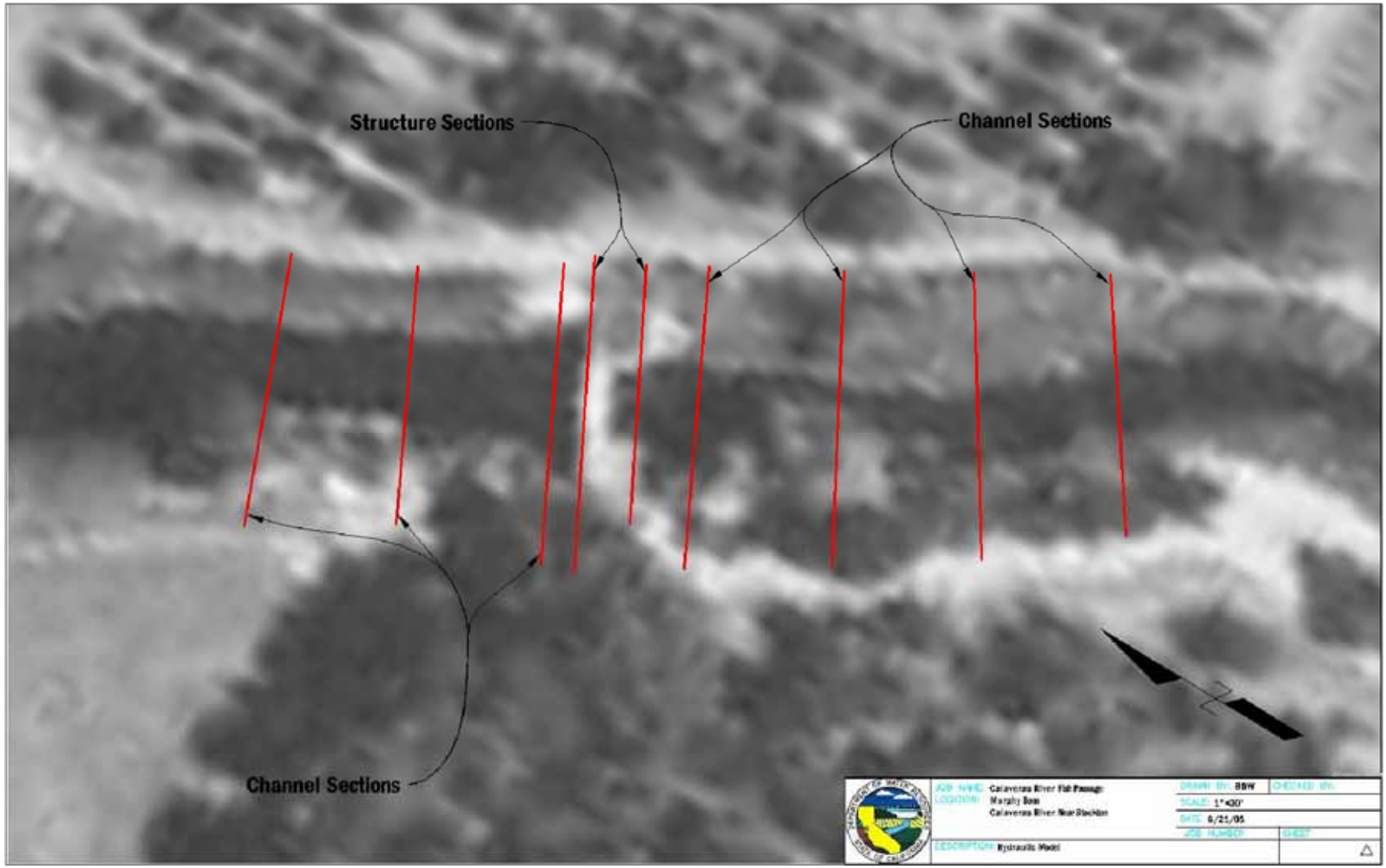


**Figure D-52. Murphy Flashboard Dam – Relationship of length to maximum velocity**

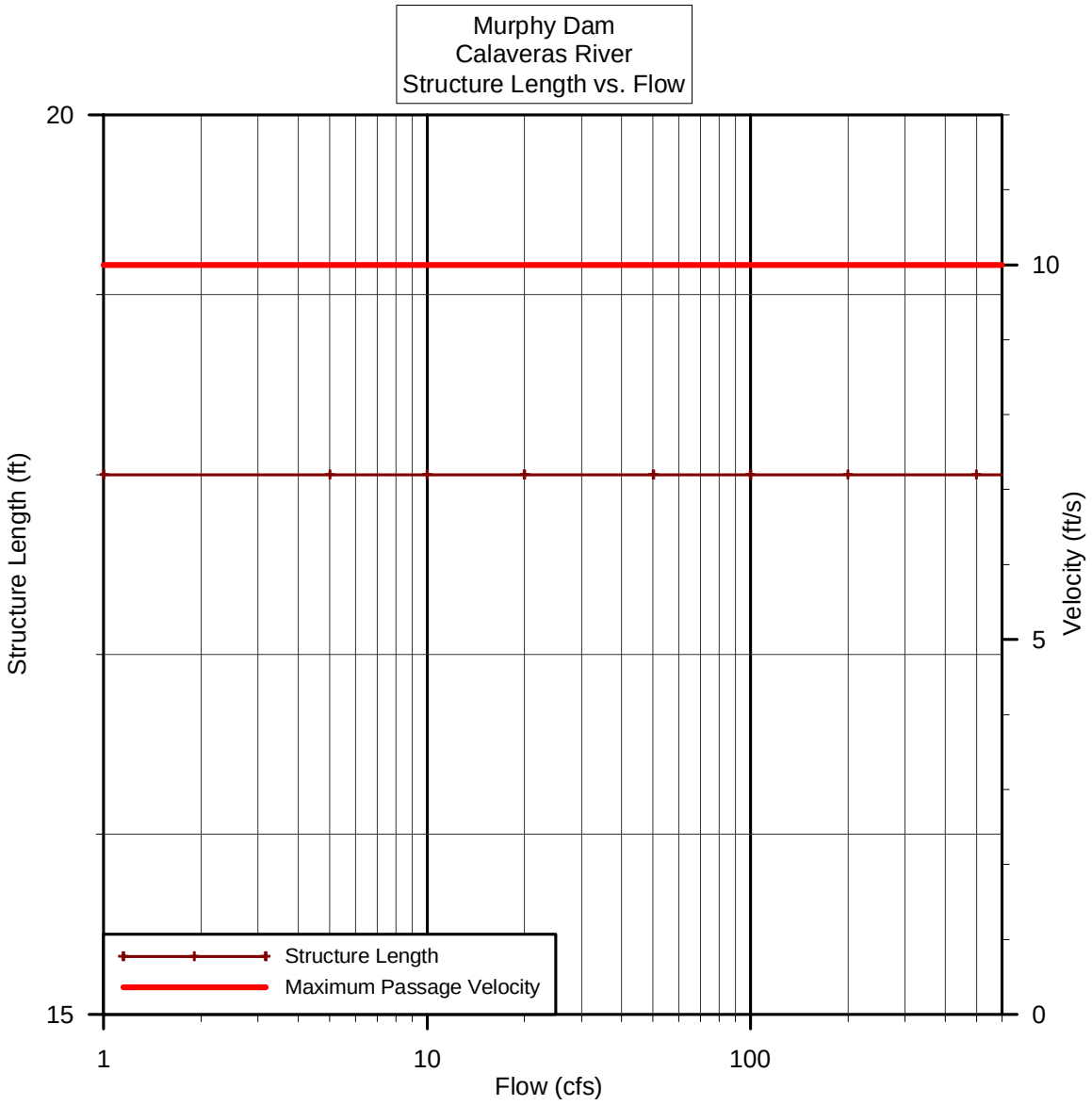


**Figure D-53. Murphy Flashboard Dam – Velocity rating curves for the structure**

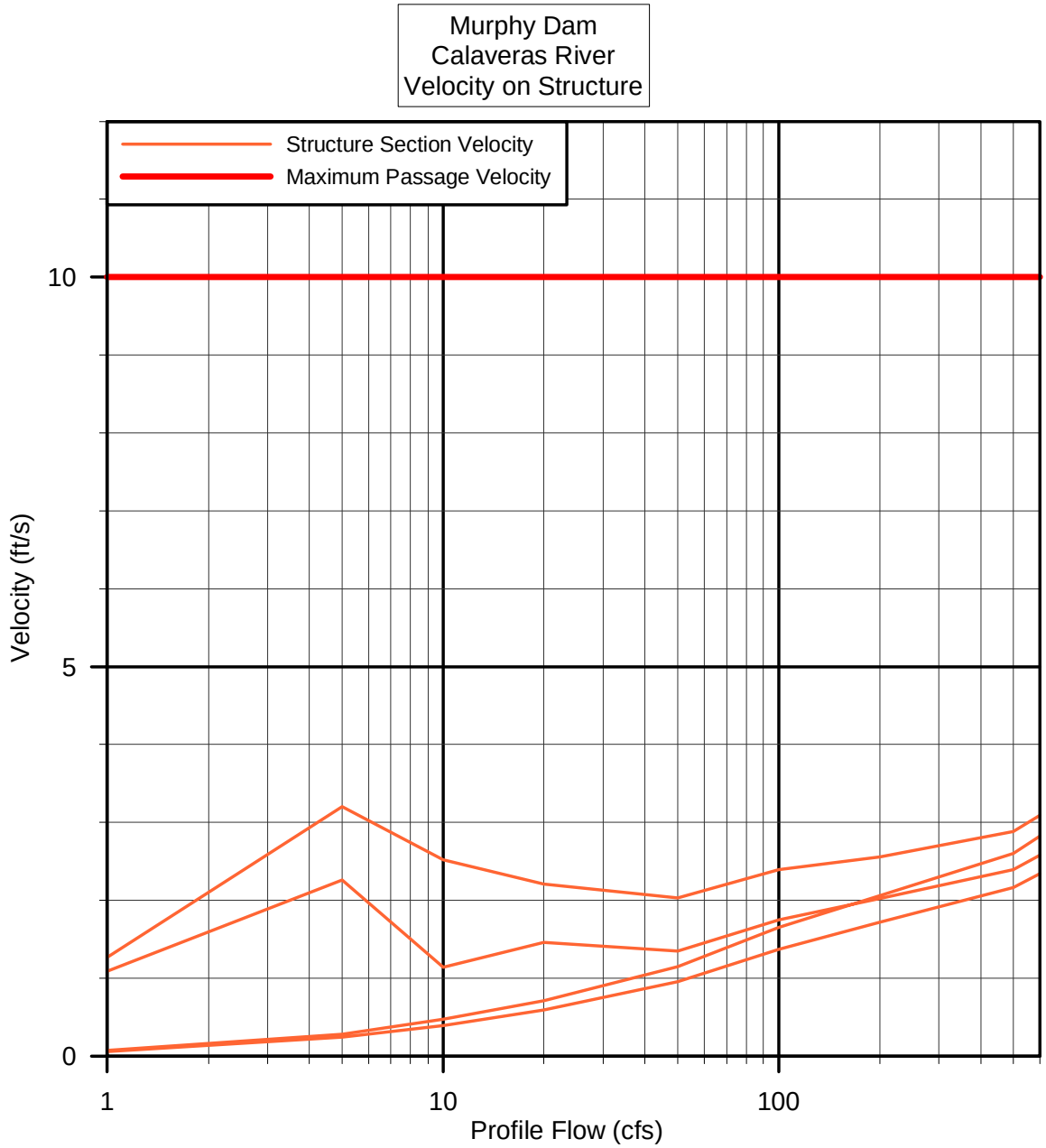


**Figure D-54. Murphy Flashboard Dam – Depth rating curves for the structure**

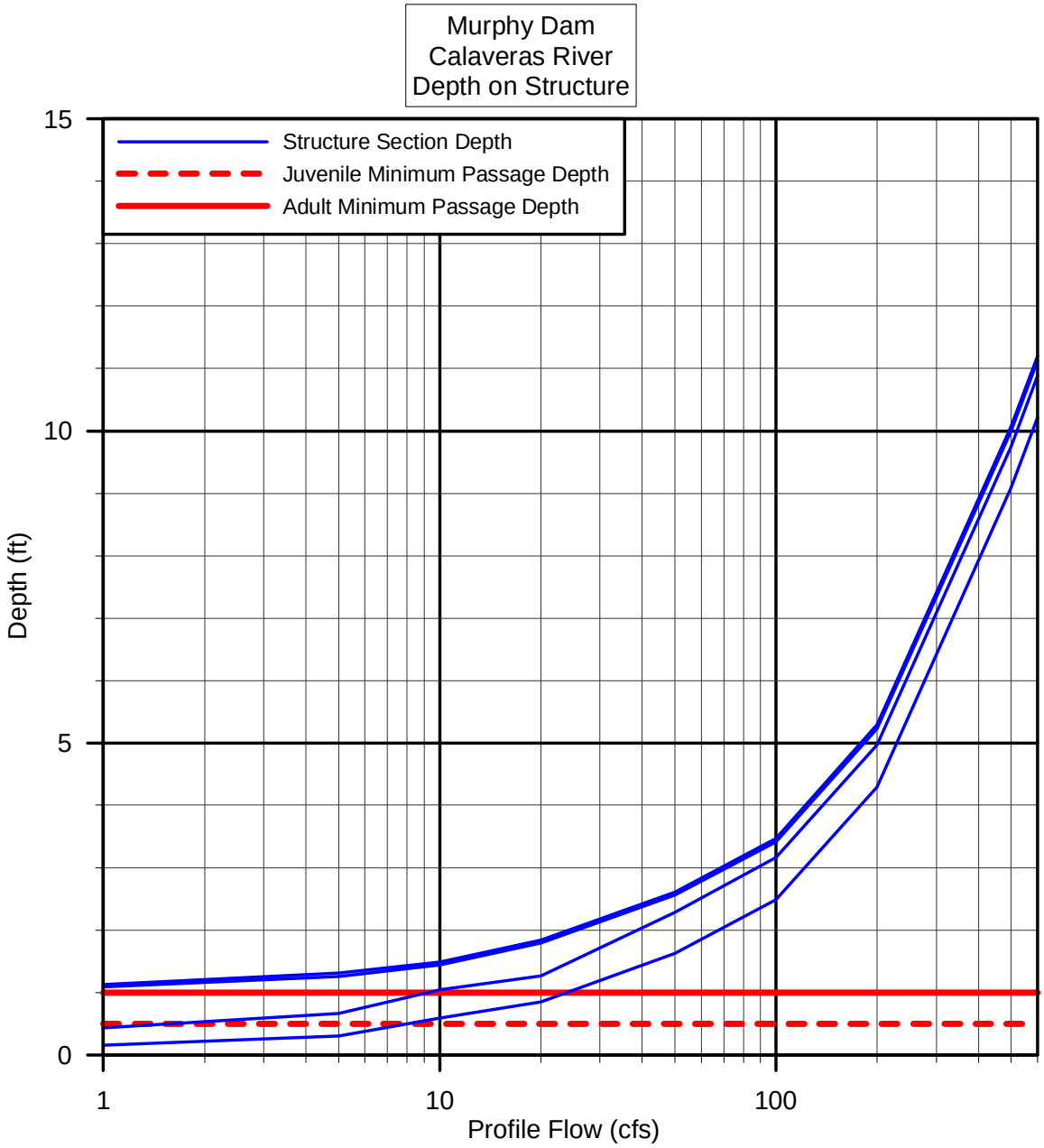


**Figure D-55. Murphy Flashboard Dam - Velocity rating curves for the channel**

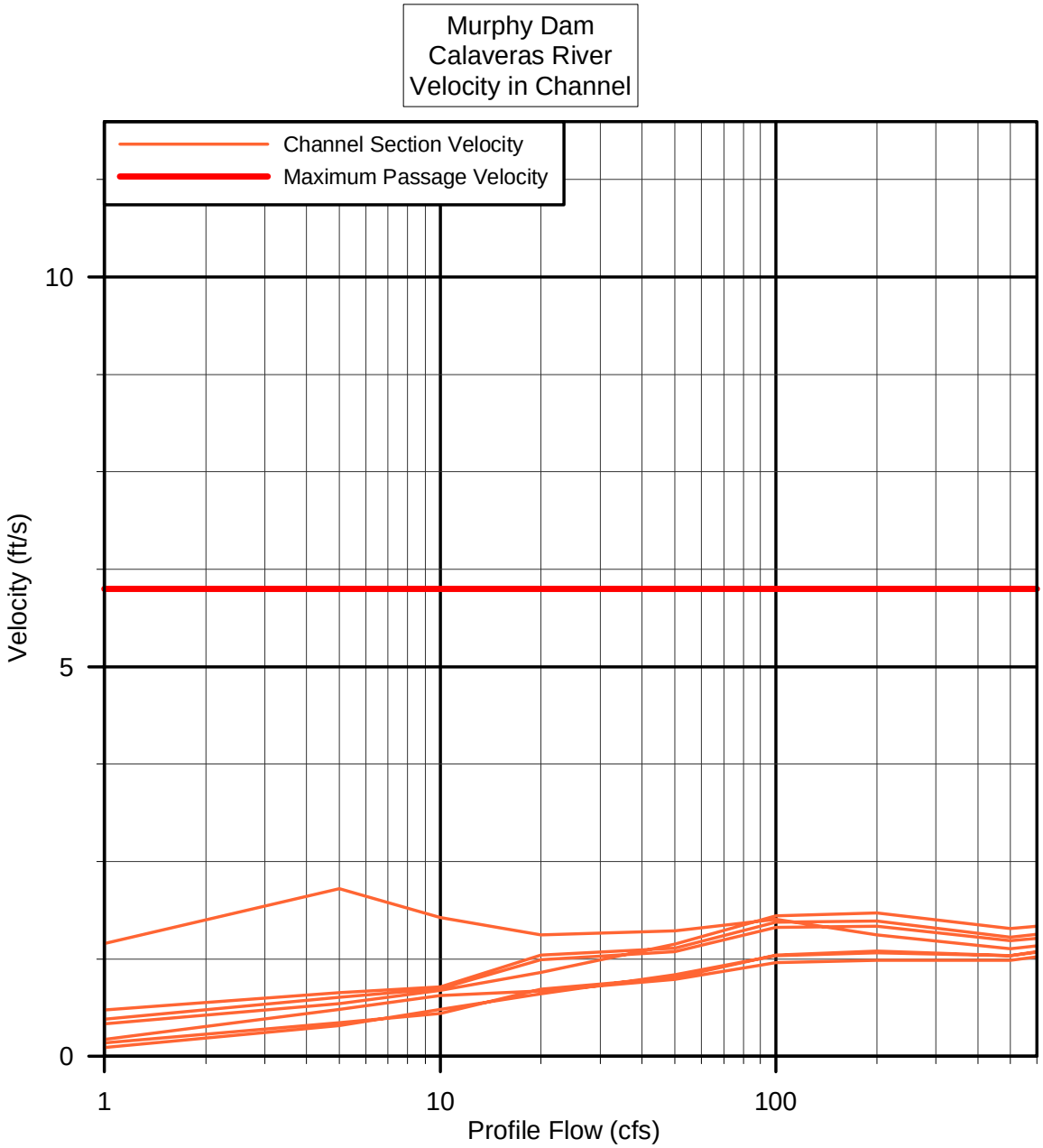
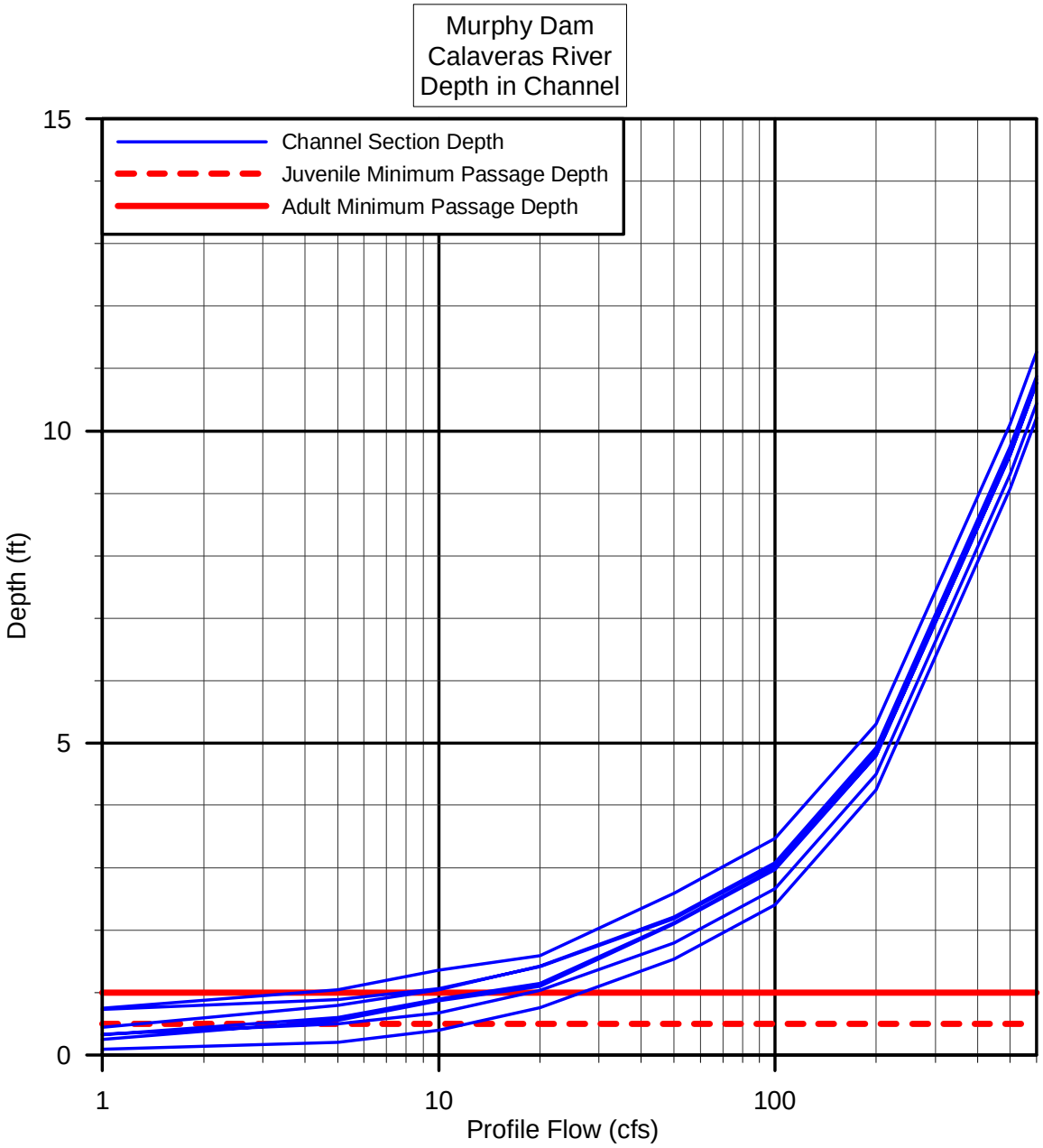


**Figure D-56. Murphy Flashboard Dam – Depth rating curves for the channel**



## *Clements Road Flashboard Dam*

**Photo D-16. Clements Road Flashboard Dam – Photo of downstream during high flow condition**

**Photo D-17. Clements Road Flashboard Dam - Photo taken from downstream during no flow condition**

## Structure Details

| | |
|---|---|
| Name of structure: | Clements Road Flashboard Dam |
| Type of structure: | Bridge |
| Tributary: | Calaveras River |
| Number of sections: | upstream: 4 downstream: 9 structure: 2 |
| Length of model: | upstream: 197 ft downstream: 193 ft |

## Model Summary

### Manning's 'n' values

| | |
|---|---|
| Channel bottom: | 0.035 |
| Side slopes and banks: | 0.08-0.1 |
| Concrete structure: | 0.013 |
| Riprap: 0.08 | |

### Calibration Flows

Number of flows: 2

1. Flow: 48 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. All points taken on left bank. Note debris on bridge pier as shown in photo associated with bridge in debris plan.

2. Flow: 18 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site. All points taken on left bank.

*Starting conditions used for the model.* Both profiles were modeled in the subcritical flow regime and used known water surface elevations.

*Assumptions.* Expansion losses are greater in sections below structure due to drop and highly turbulent region of riprap. Bank stations are located at the top of the banks, where water begins to flow out of the channel. Debris on the pier causes ponding upstream of the structure at the 48 cfs calibration flow. The debris is equally distributed on both openings, allowing the same flow on either side.

*Comments.* Two geometries are used to calibrate this model. One geometry has debris on the structure causing a partially blocked flow (48 cfs), and the other geometry (18 cfs) is without any debris on the pier. The amount of debris is estimated from the photo corresponding to the 2/27/04 event and is entered in the model as a centered, floating obstruction on the pier.

## Performance Summary

The structure performs well with respect to velocity but has problems with depth for adults up to 50 cfs primarily due to the lowest section where flows crest over the riprap. Depths on the structure limits juvenile passage for flows under 22 cfs. While the riprap sections have no velocity problems, depth is a problem until flows approach 67 cfs for adults and 30 cfs for juveniles. This is the point when backwater begins to inundate the structure. Passage in the channel also has some depth problems in the low flows up to 9 cfs. In summary the structure has impaired passage for flow up to 67 cfs for adults and 30 cfs for juveniles.

**Figure D-57. Cross section locations for Clements Road Flashboard Dam HEC-RAS model**

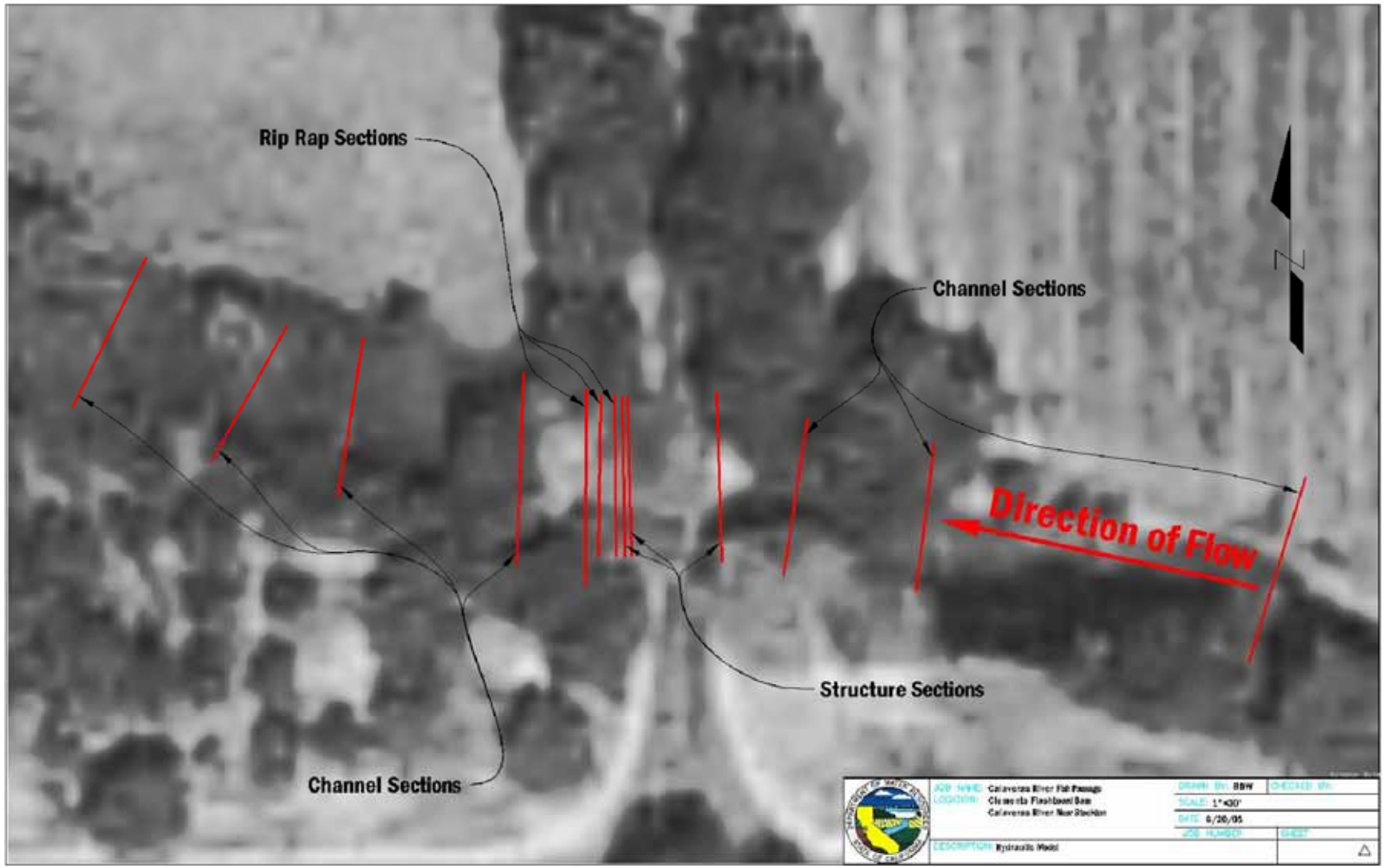


**Figure D-58. Clements Road Flashboard Dam – Relationship of length to maximum velocity**

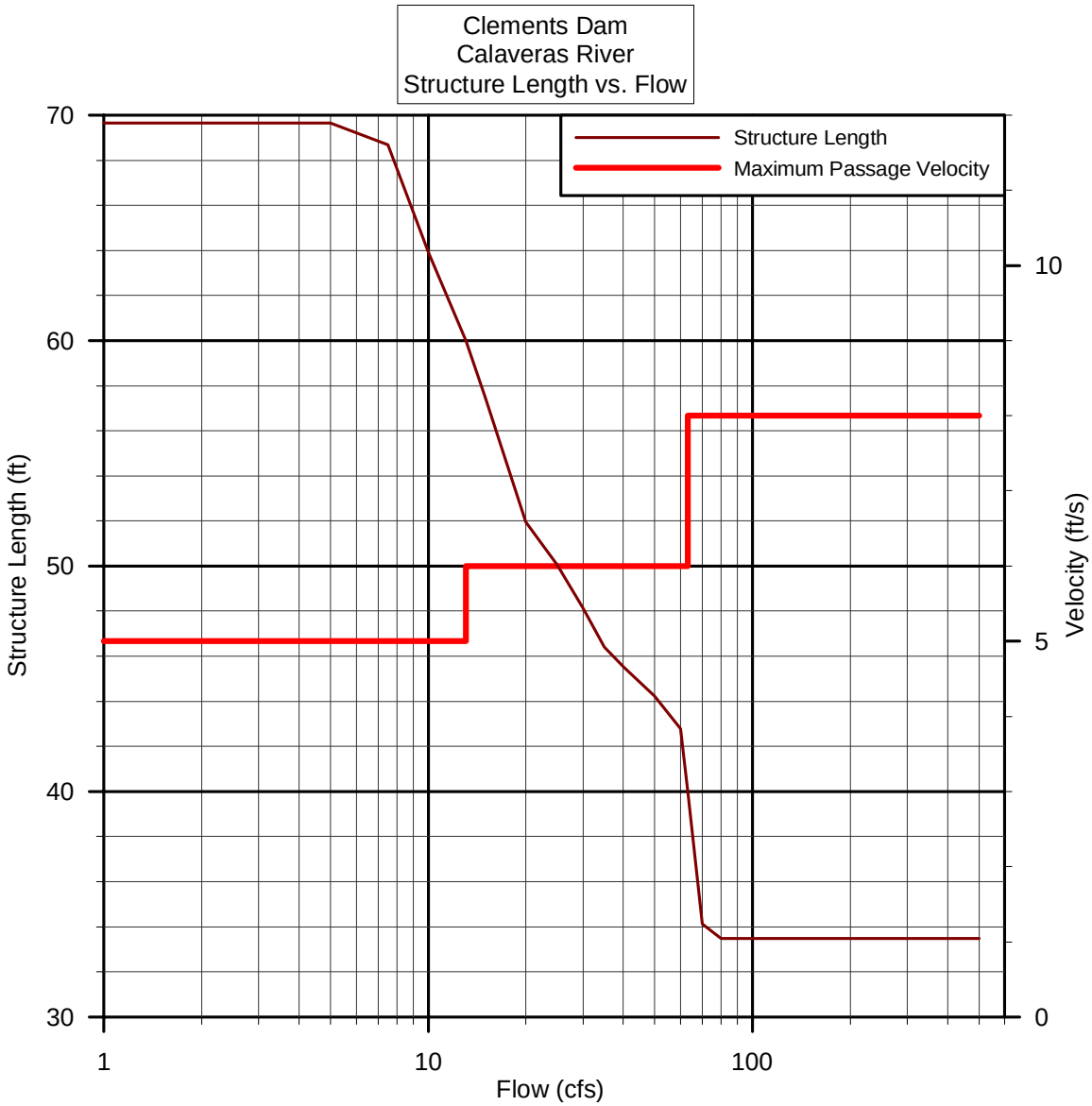


**Figure D-59. Clements Road Flashboard Dam - Velocity rating curves for the structure**

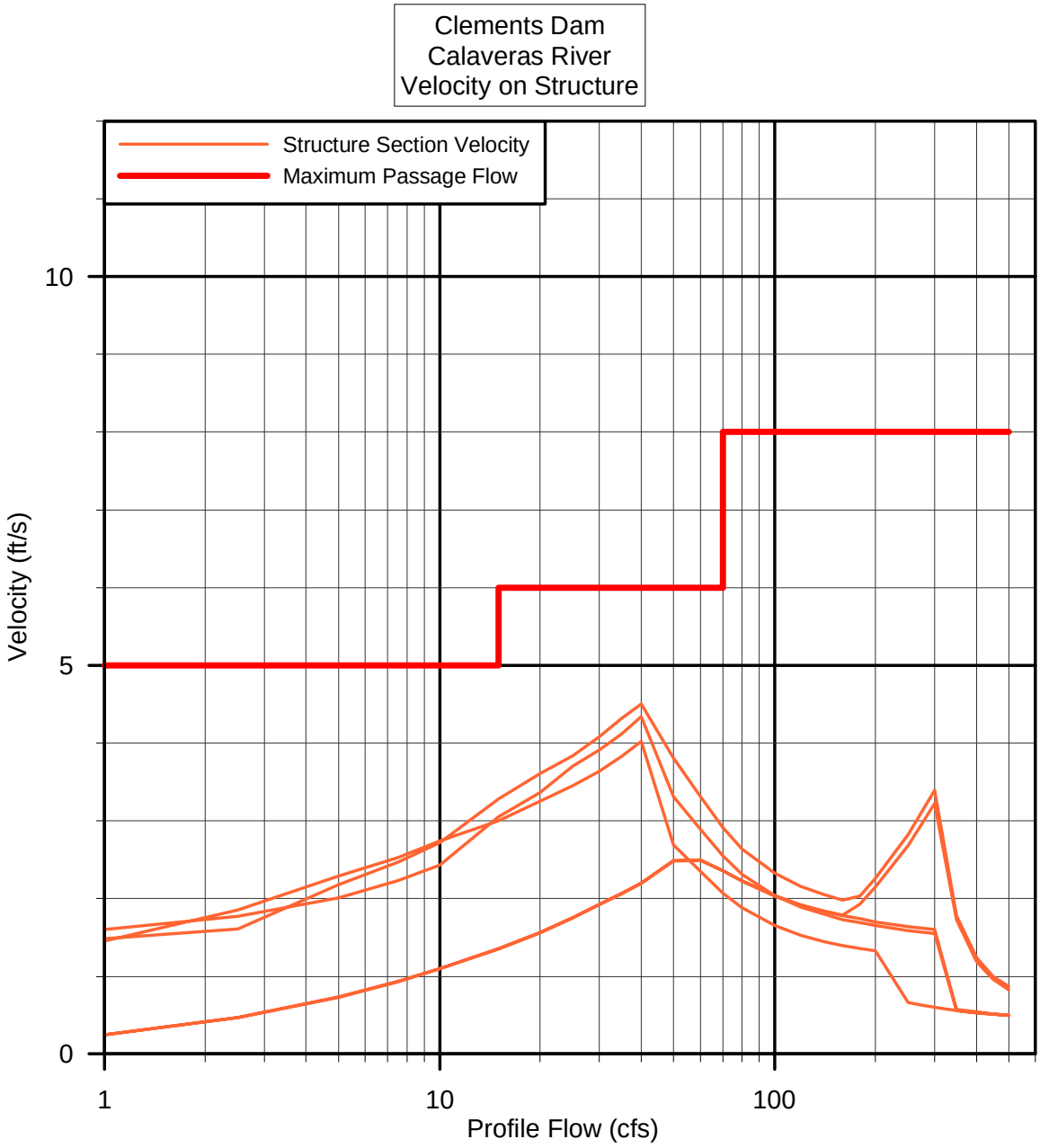


**Figure D-60. Clements Road Flashboard Dam – Depth rating curves for the structure**

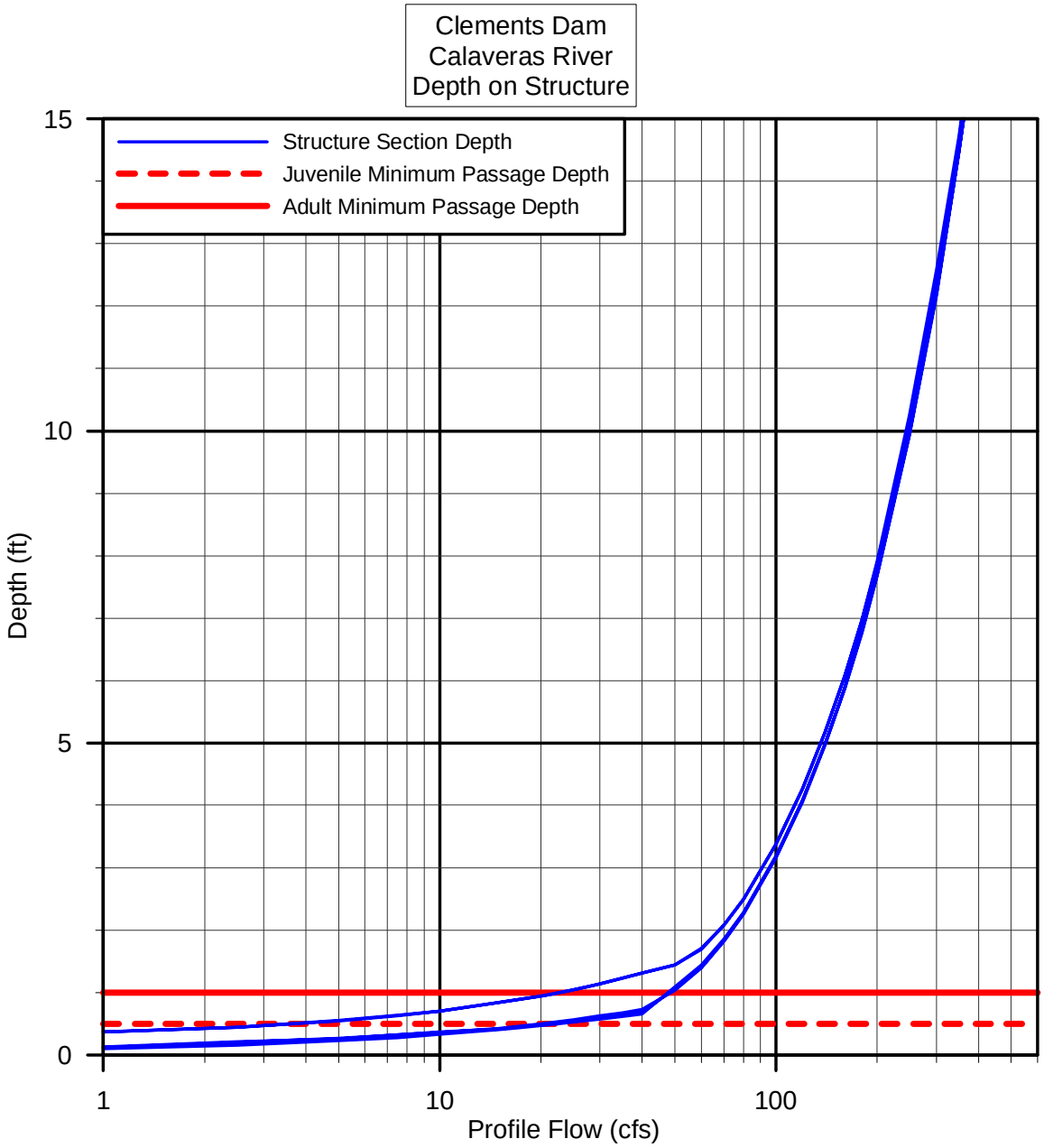


**Figure D-61. Clements Road Flashboard Dam – Velocity rating curves for the channel**

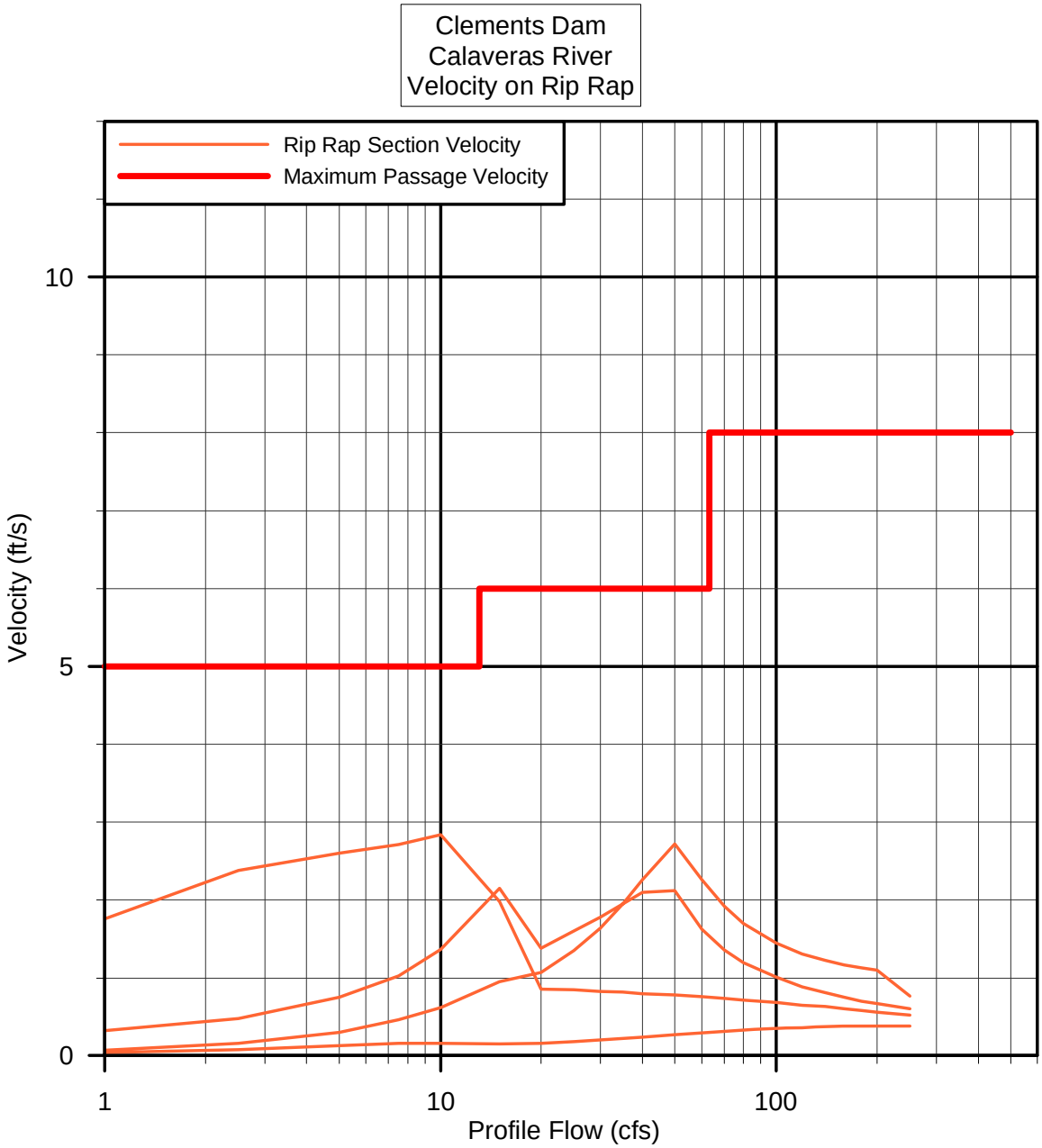


**Figure D-62. Clements Road Flashboard Dam – Depth rating curves for the riprap**

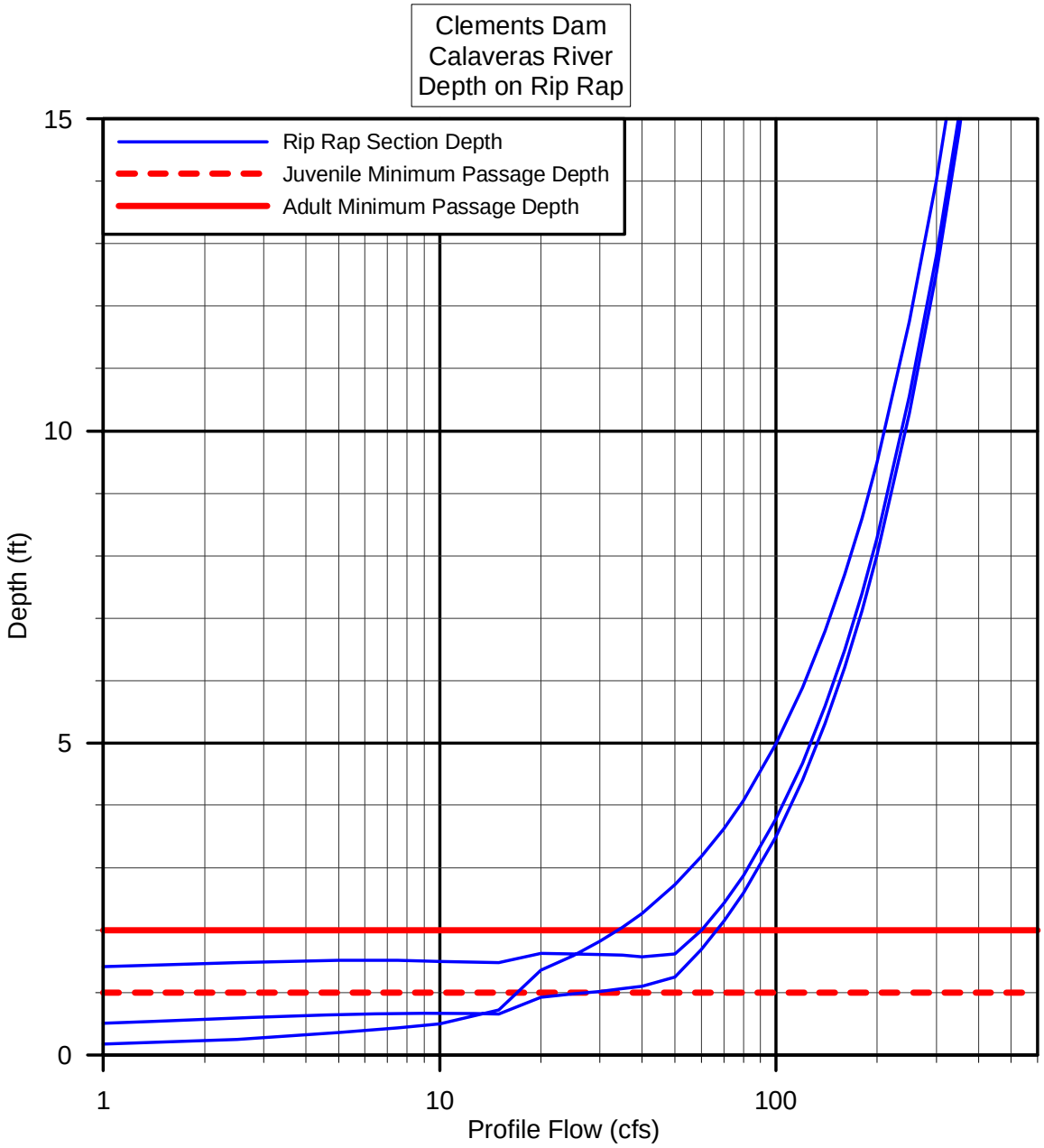


**Figure D-63. Clements Road Flashboard Dam – Velocity rating curves for the channel**

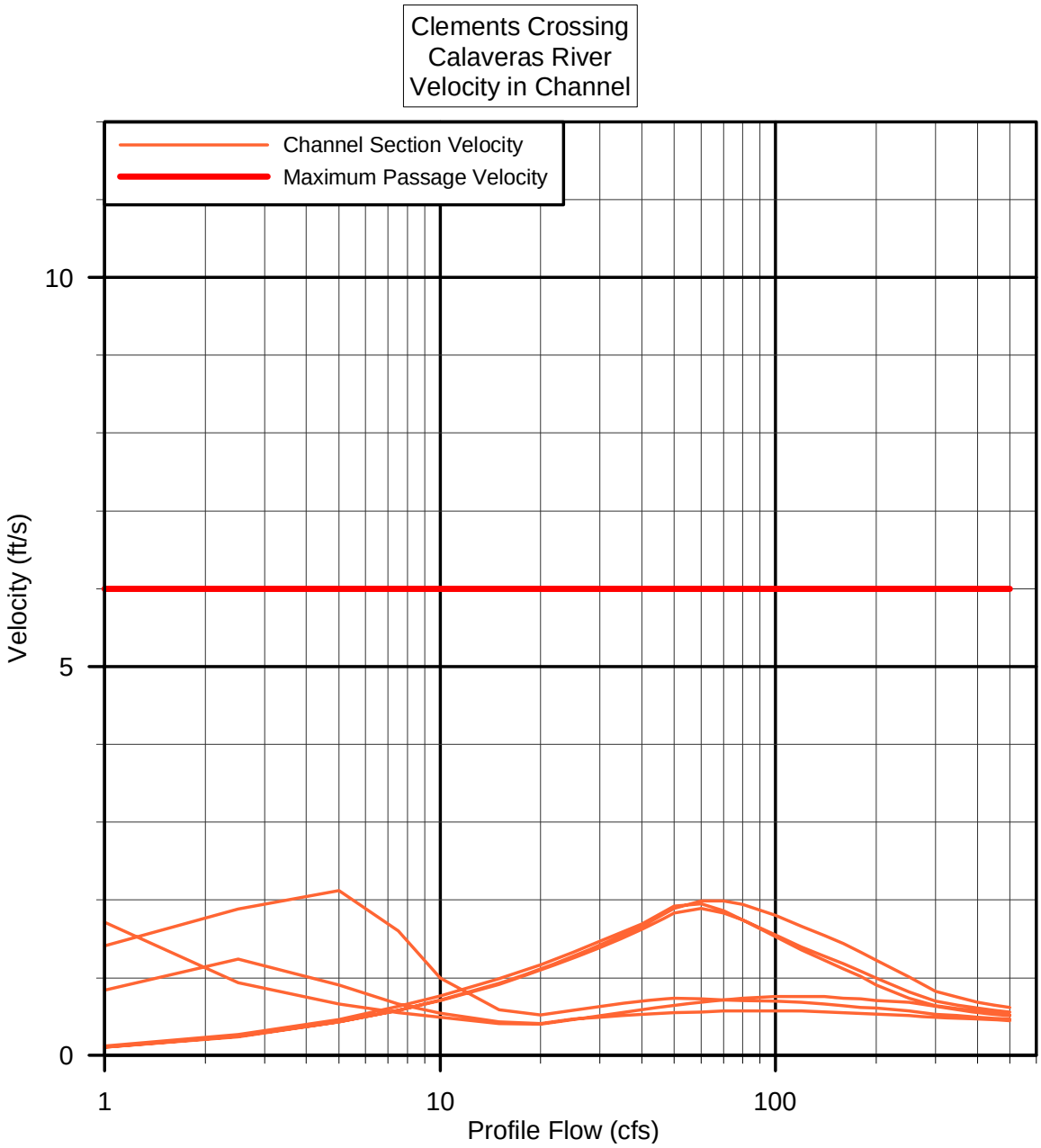
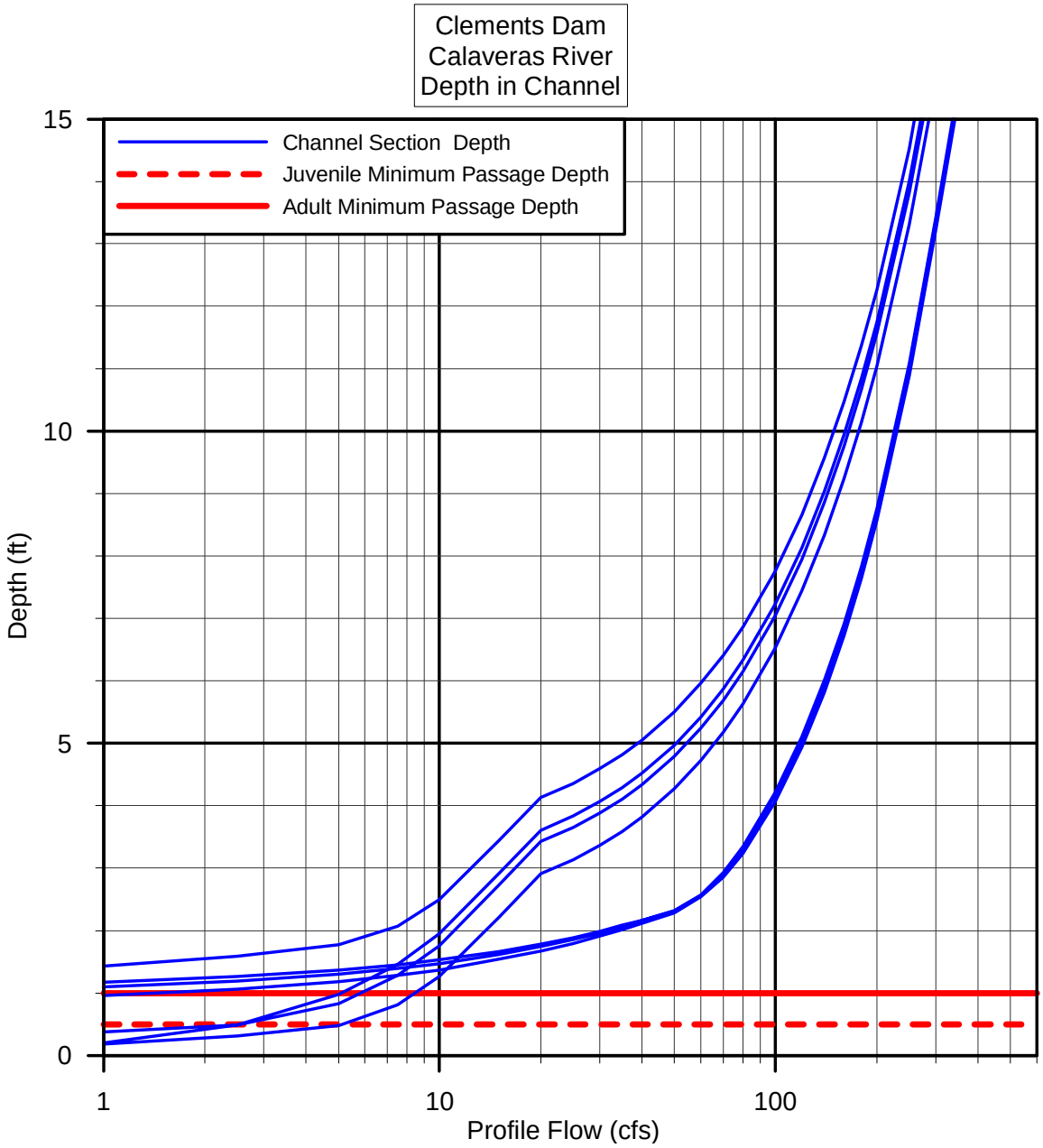


**Figure D-64. Clements Road Flashboard Dam – Depth rating curves for the channel**



# 2005 Modeled Structures

## *Lavaggi Flashboard Dam*

**Photo D-18. Lavaggi Flashboard Dam with flashboards**

**Photo D-19. Lavaggi Flashboard Dam - downstream riprap in channel**

## Structure Details

| | | | |
|---|---|---|---|
| Name of structure: | Lavaggi Flashboard Dam | | |
| Type of Structure: | Flashboard Dam | | |
| Tributary: | Mormon Slough | | |
| Number of sections: | upstream-4 | downstream-4 | structure-3 |
| Length of model: | upstream-220 ft | downstream-220 ft | |

*Description of structure.* Lavaggi Flashboard Dam consists of a concrete apron and abutments with a seasonally maintained flashboard dam. The channel downstream of the dam is lined with riprap for a distance of approximately 60 feet.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel bottom: | 0.02-0.06 |
| Side slopes and banks: | 0.04-0.1 |
| Structure: | 0.025-0.06 |
| Riprap: | 0.06-0.1 |

*Calibration*

Number of flows: 3

1. Flow: 47 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site.

2. Flow: 220 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site.

3. Flow: 1,980 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at Hogan low flow crossing and verification from Bellota weir gauge.

*Starting conditions used for the model.*

Starting Condition on Flow 1: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 2: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 3: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

### Performance Summary

Adult passage velocities on the structure are below maximums at all flow conditions. However, acceptable depths of 1 ft for non-rip rapped sections are not realized until flow is above 35 cfs. The riprap sections velocities are below the maximums and the depth exceeds the 2 feet minimum for flows above 60 cfs. Channel section velocities remain below maximum velocities at all flows and channel depths become greater than the 1 ft requirement for non-rip rapped sections for flows above 15 cfs. These constraints indicate Lavaggi Flashboard Dam has impeded passage, for adults, at flows less than 60 cfs.

Juvenile passage constraints limit water depths to 0.5 feet, which occurs above at flows greater than 10 cfs. Passage constraints on riprap sections are 1 ft of depth and are exceeded when flows rise above 25 cfs. Channel sections exhibit greater than 0.5-foot depths for all modeled flows. These constraints indicate juveniles have unimpaired passage for flows greater than 25 cfs.

**Figure D-65. Cross section locations for Lavaggi Flashboard Dam HEC-RAS model**

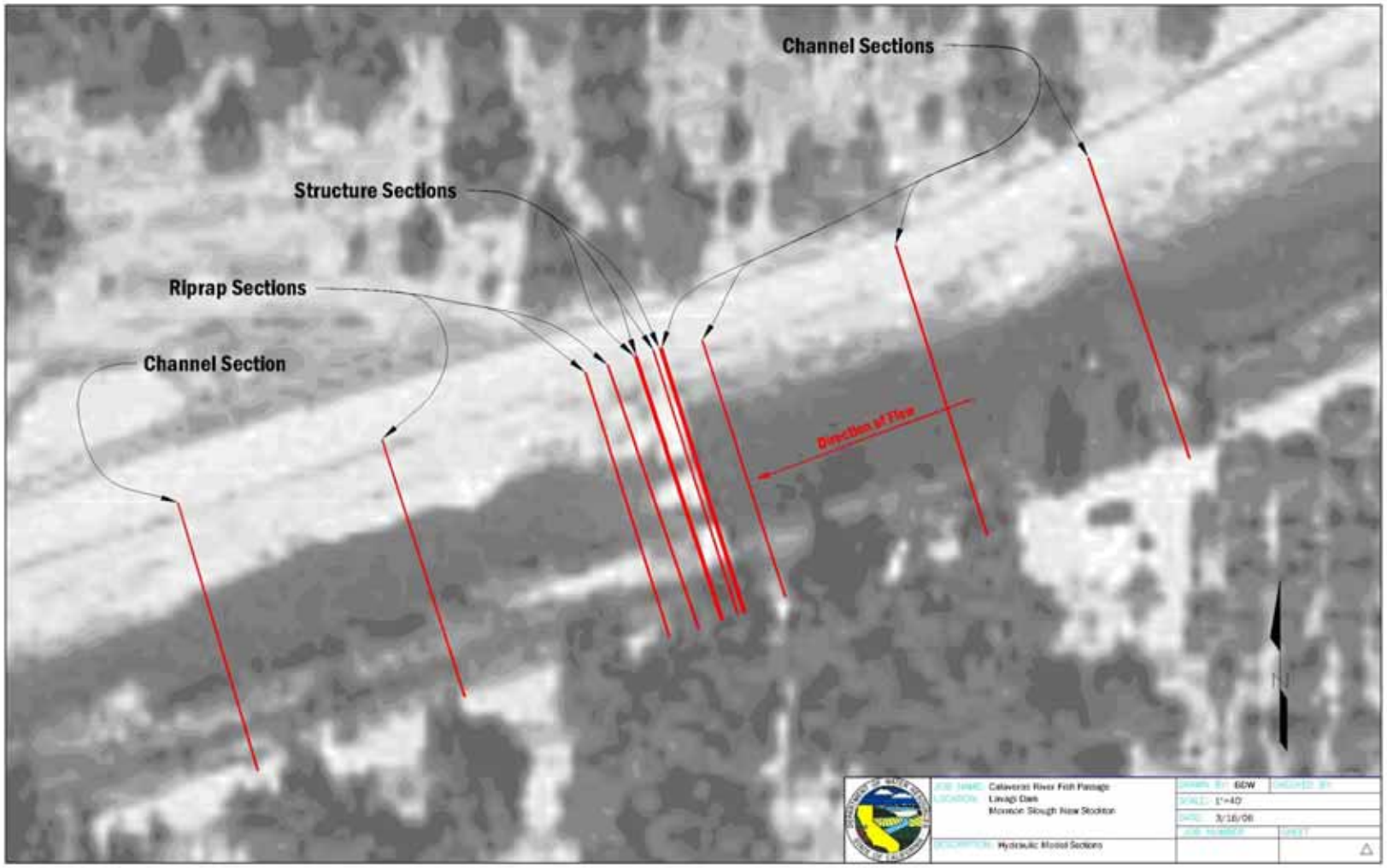


**Figure D-66. Lavaggi Flashboard Dam – Relationship of length to maximum velocity**

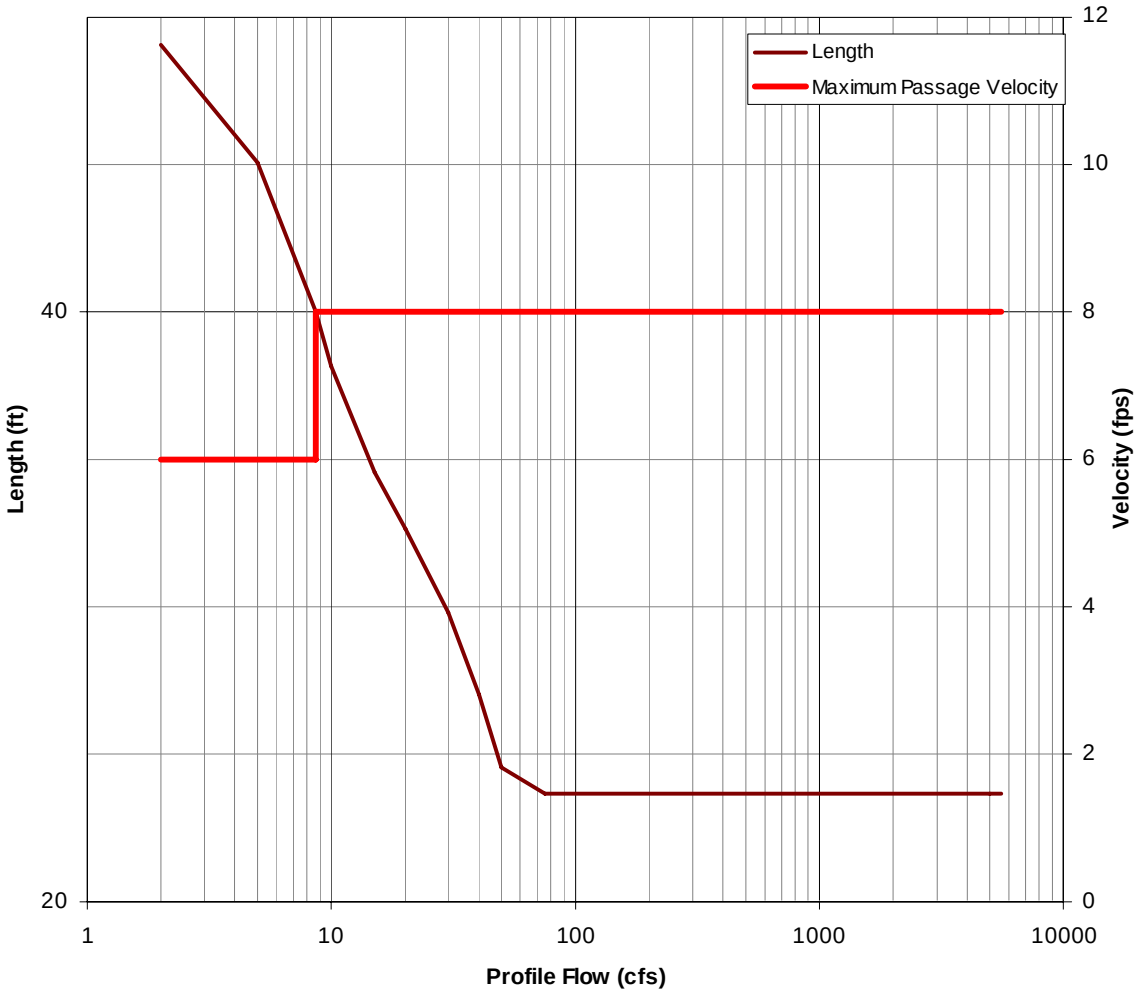


**Figure D-67. Lavaggi Flashboard Dam – Velocity rating curves for structure sections**

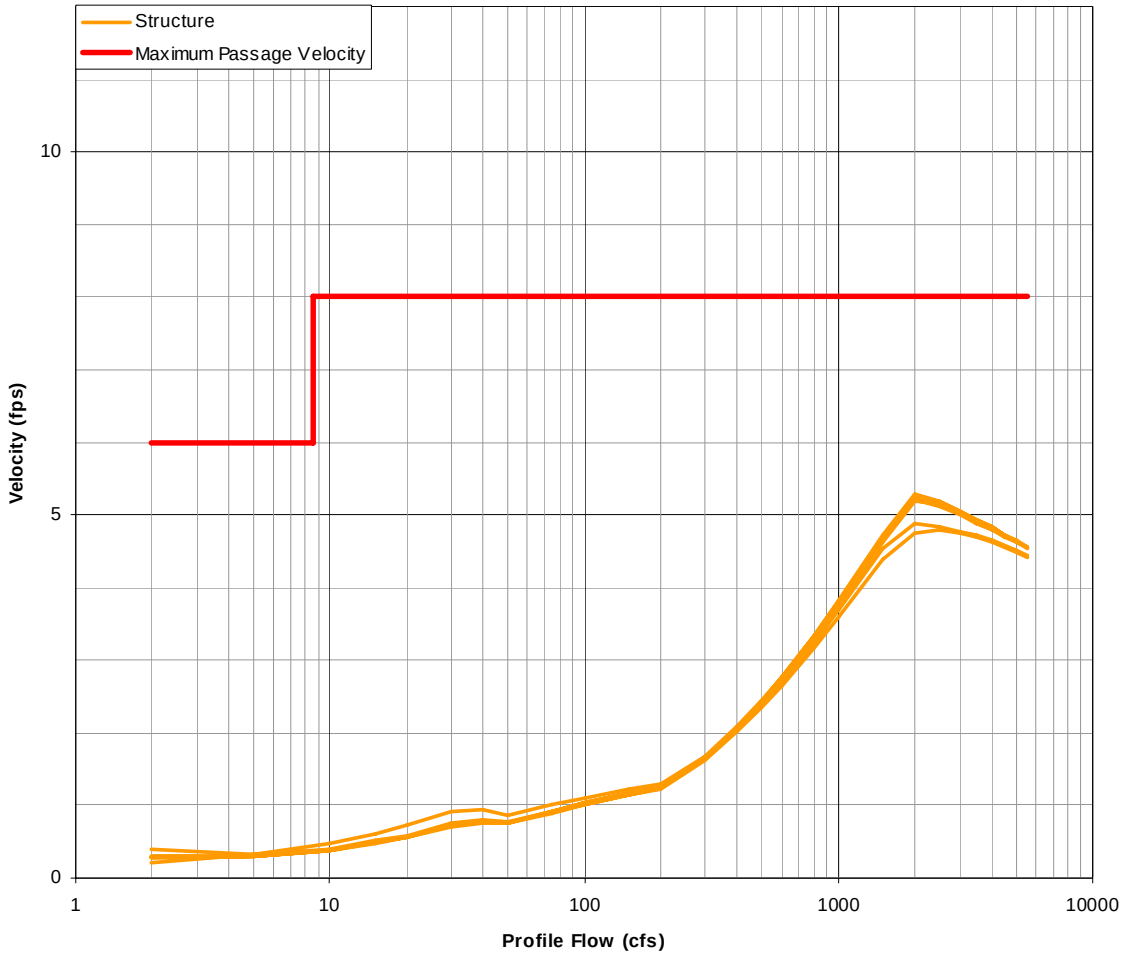


**Figure D-68. Lavaggi Flashboard Dam – Depth rating curves for structure sections**

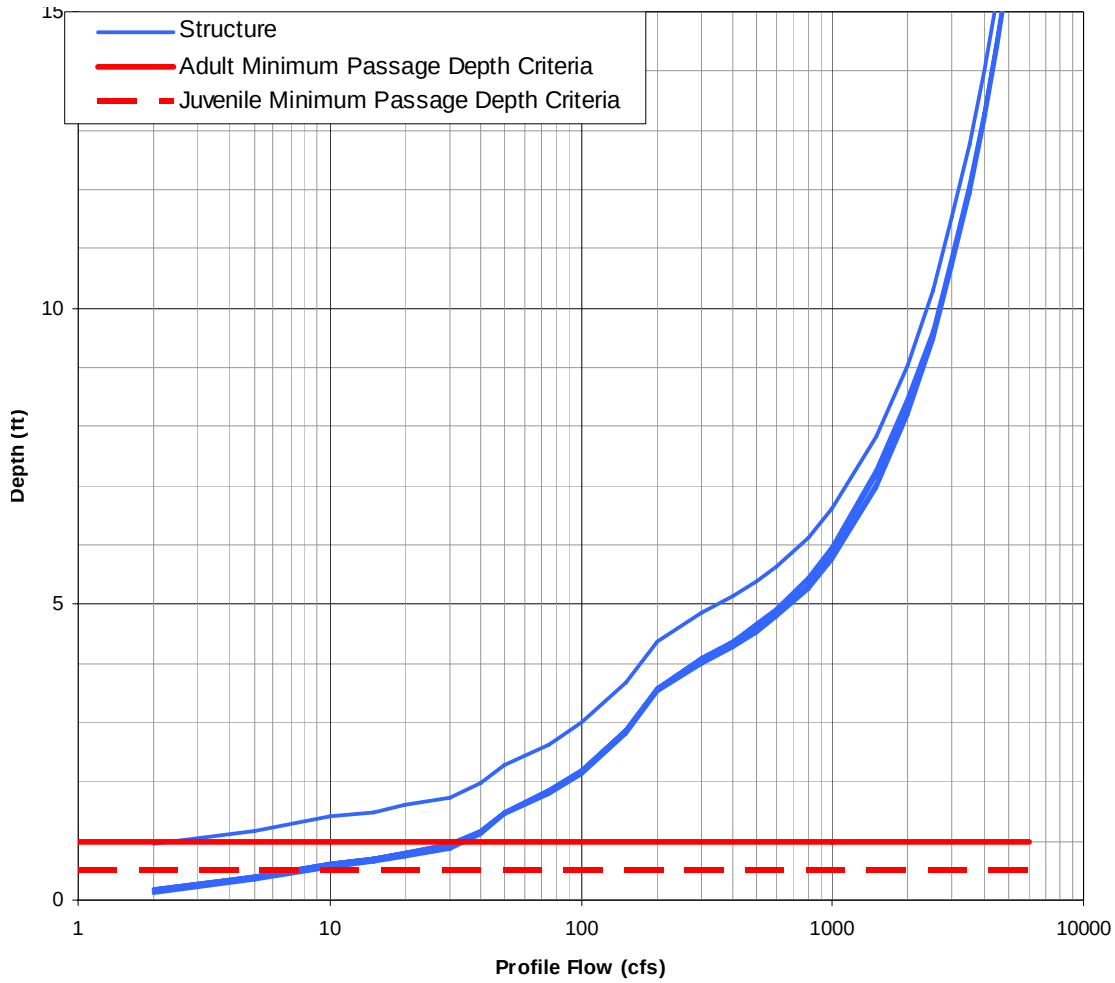


**Figure D-69. Lavaggi Flashboard Dam – Velocity rating curves for the channel**

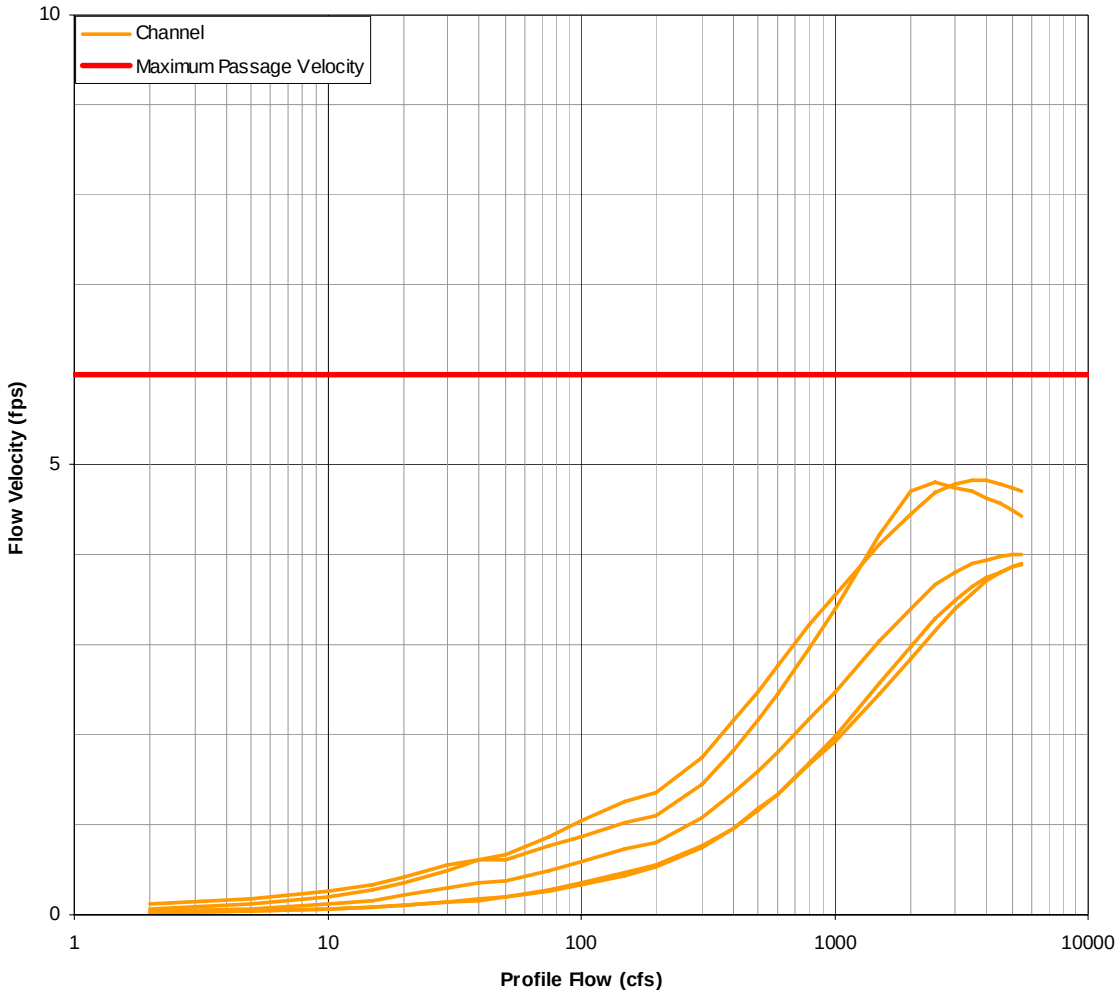


**Figure D-70. Lavaggi Flashboard Dam – Depth rating curves for the channel**

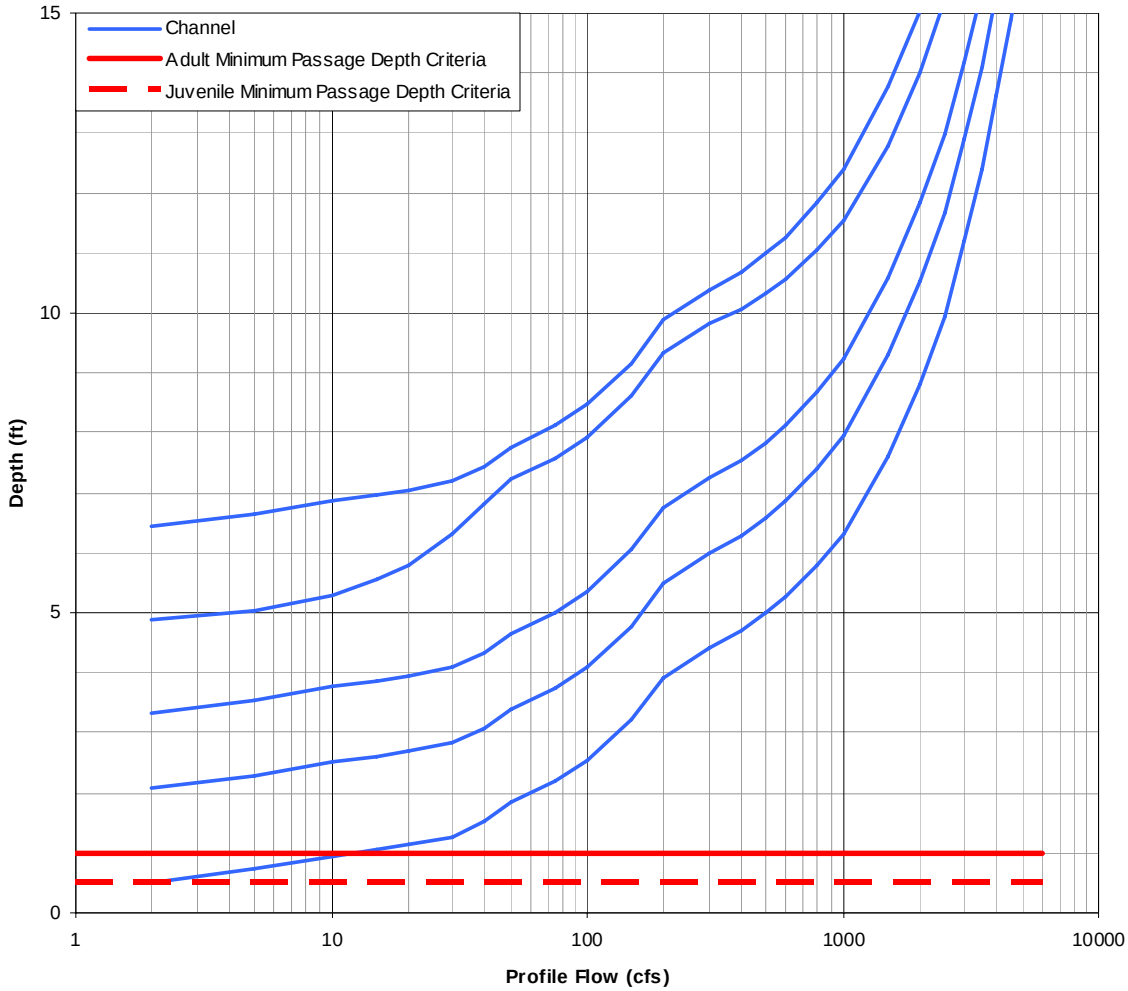


**Figure D-71. Lavaggi Flashboard Dam –Velocity rating curves for the riprap**

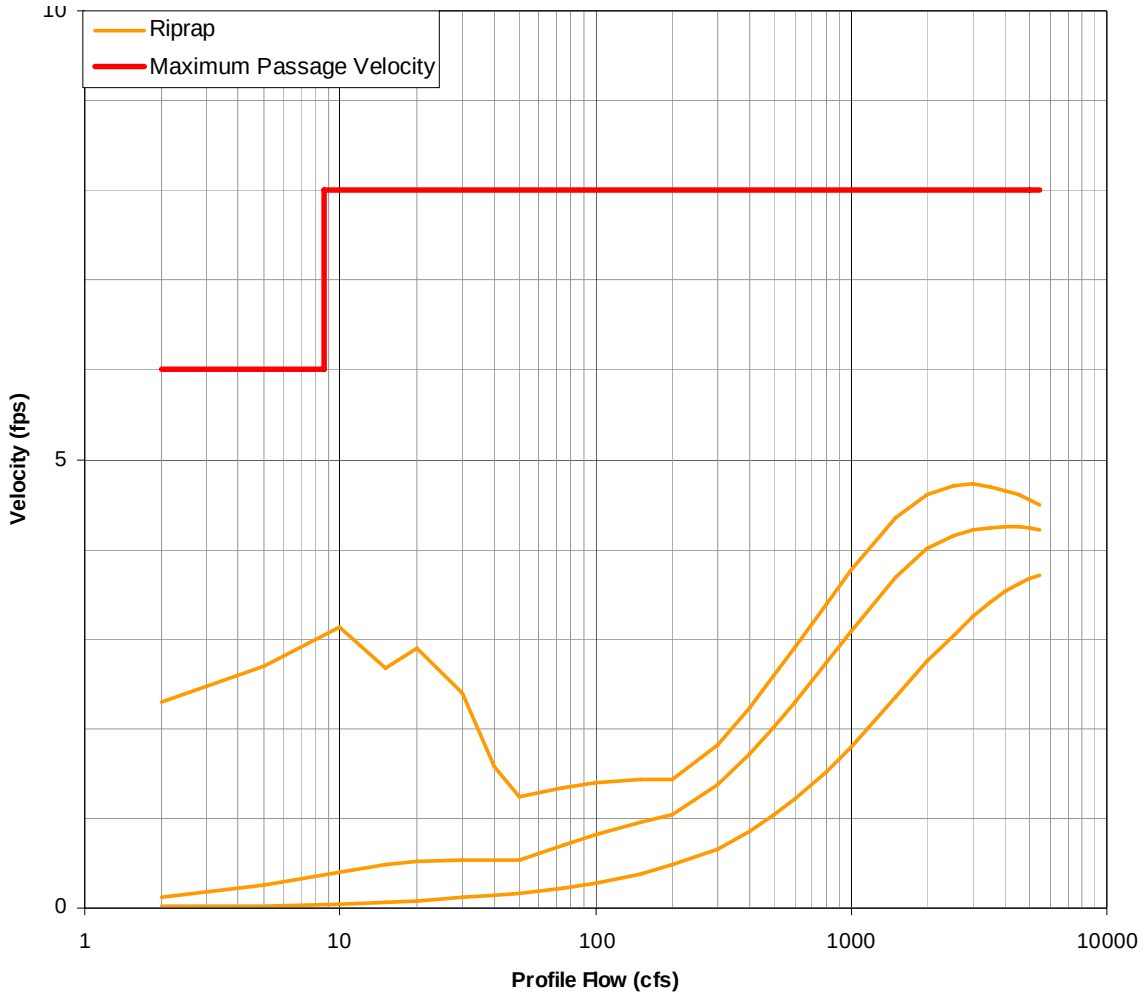
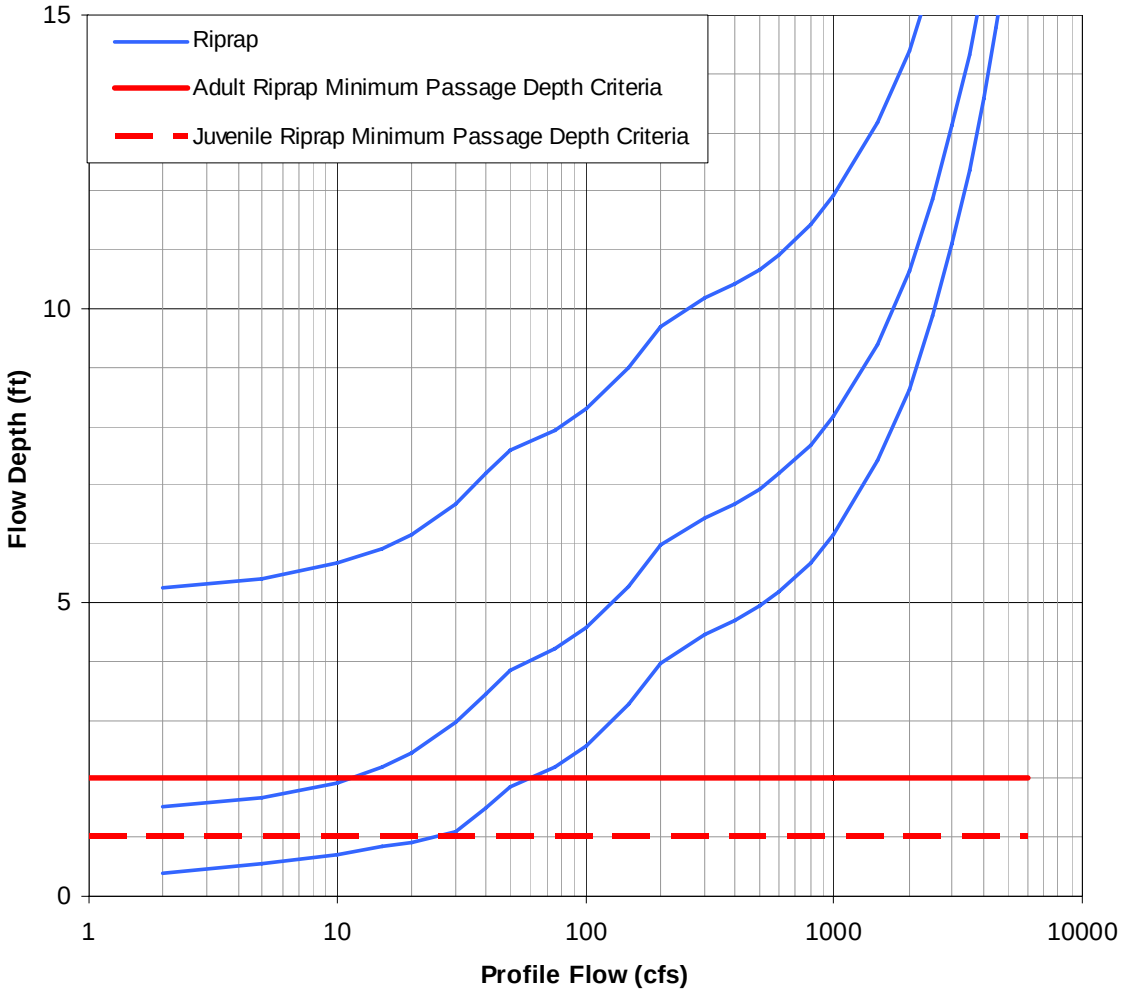


**Figure D-72. Lavaggi Flashboard Dam – Depth rating curves for the riprap**



## *Fujinaka Low-flow Road Crossing*

**Photo D-20. Fujinaka Low-flow Road Crossing with flow**

**Photo D-21. Fujinaka Low-flow Road Crossing without flow**

## Structure Details

| | | | |
|---|---|---|---|
| Name of Structure: | Fujinaka Low-flow Road Crossing | | |
| Type of Structure: | Low-flow road crossing with culverts | | |
| Tributary: | Mormon Slough | | |
| Number of sections: | upstream-3 | downstream-5 | structure-1 |
| Length of model: | upstream-256 ft | downstream-313 ft | |

*Description of structure.* A low-flow road crossing consisting of 3 culverts of varying diameter, slope, and elevation overlaid by a rough concrete road prism. Riprap has been placed on the downstream side of the structure.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.025 |
| Side Slopes and Banks: | 0.04 |
| Concrete Structure: | 0.015 |
| Rip-rap: | 0.04 |

*Calibration*

| | |
|---|---|
| Number of flows: | 1 |
| 1. Flow: 90 cfs | Survey method: Autolevel |
| Comments: | Flow measurement using current meter at site. |

*Starting conditions used for the model*. The calibration flow was modeled in the subcritical flow regime and used a measured water surface elevation at the downstream boundary.

*Assumptions.* Normal depth was used as the starting water surface elevation at the downstream end for the range of model flows. For flows 200 cfs and less, the energy slope used for the normal depth calculation was 0.0018, which matches the energy slope of the 90 cfs calibration profile. For flows greater than 200 cfs, the energy slope used for the normal depth calculations was 0.0008, which is the channel slope measured on Mormon Slough in the vicinity of the structure from the USGS 7.5-minute quad map.

## Performance Summary

The 1 foot depth criterion for adult salmonid passage is met in the channel downstream of the structure at 22 cfs. The 1 foot depth criterion is met in at least 1 of the 3 culverts at all modeled flows. Over the crossing, the 1 foot depth criterion is met at flows of 367 cfs and above. Over the riprap, the 2 foot depth criterion for adult salmonid passage is met at all modeled flows.

The 0.5 foot depth criterion for juvenile passage is met in the channel downstream of the structure at 4 cfs. This depth criterion is met in at least one of the culverts at all modeled flows. The 1 foot depth criterion for juveniles over riprap is also met at all modeled flows.

Since the riprap has at least 2 feet of depth over it for all modeled flows, the velocity criterion is dependent only on culvert length and remains constant throughout the flow range. The 8 fps velocity criterion is met in the channel, over the riprap, and in at least 1 of the 3 culverts at all modeled flows. The 8 fps velocity criterion is met over the crossing at all flows that pass over the top of the crossing.

In summary, adults have unimpaired passage at Fujinaka at flows of 22 cfs and higher. Juveniles have unimpaired passage at flows of 4 cfs and higher.

**Figure D-73. Cross section locations for Fujinaka Low-flow Road Crossing HEC-RAS model**

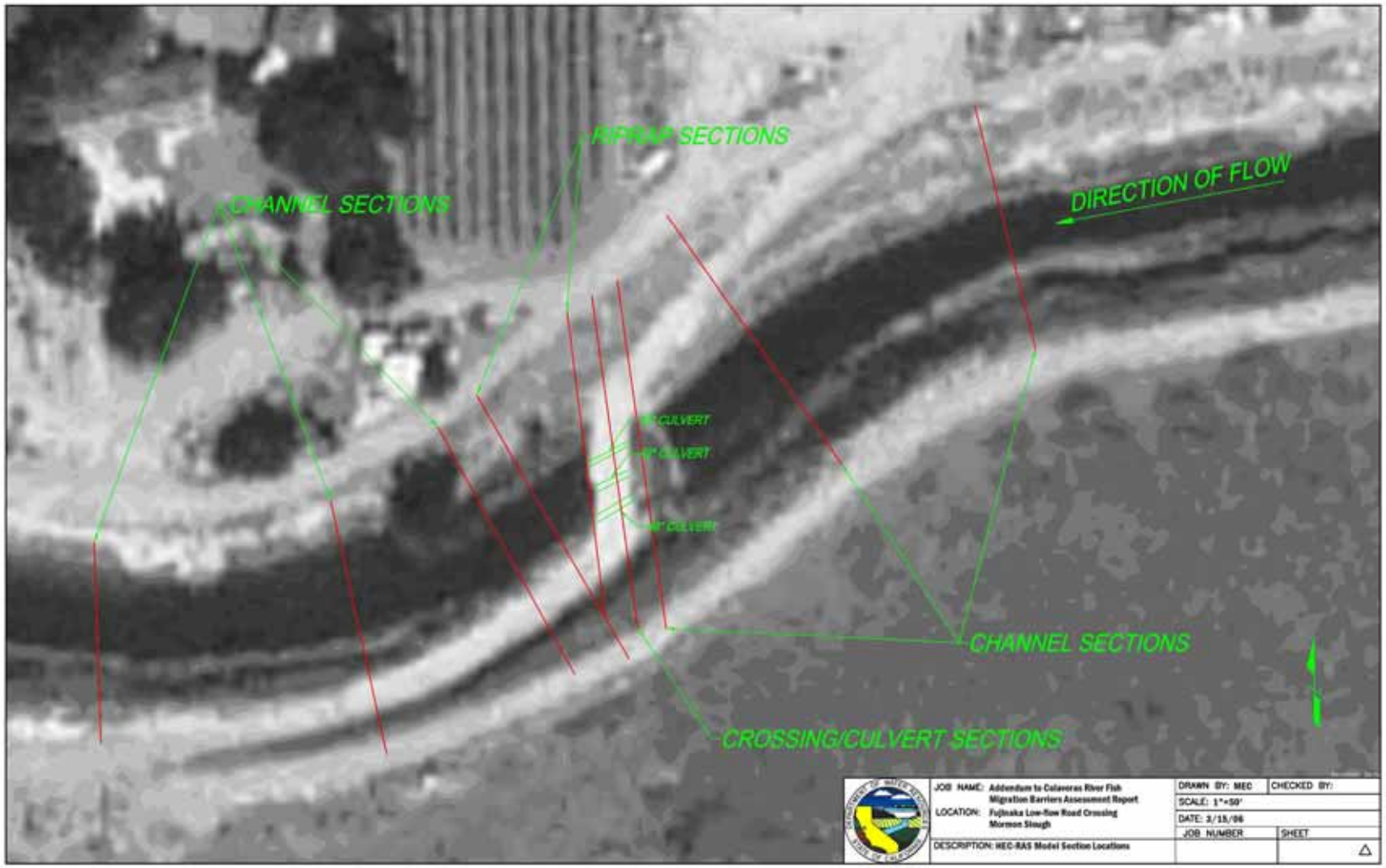


**Figure D-74. Fujinaka Low-flow Road Crossing – Relationship of length to maximum velocity**

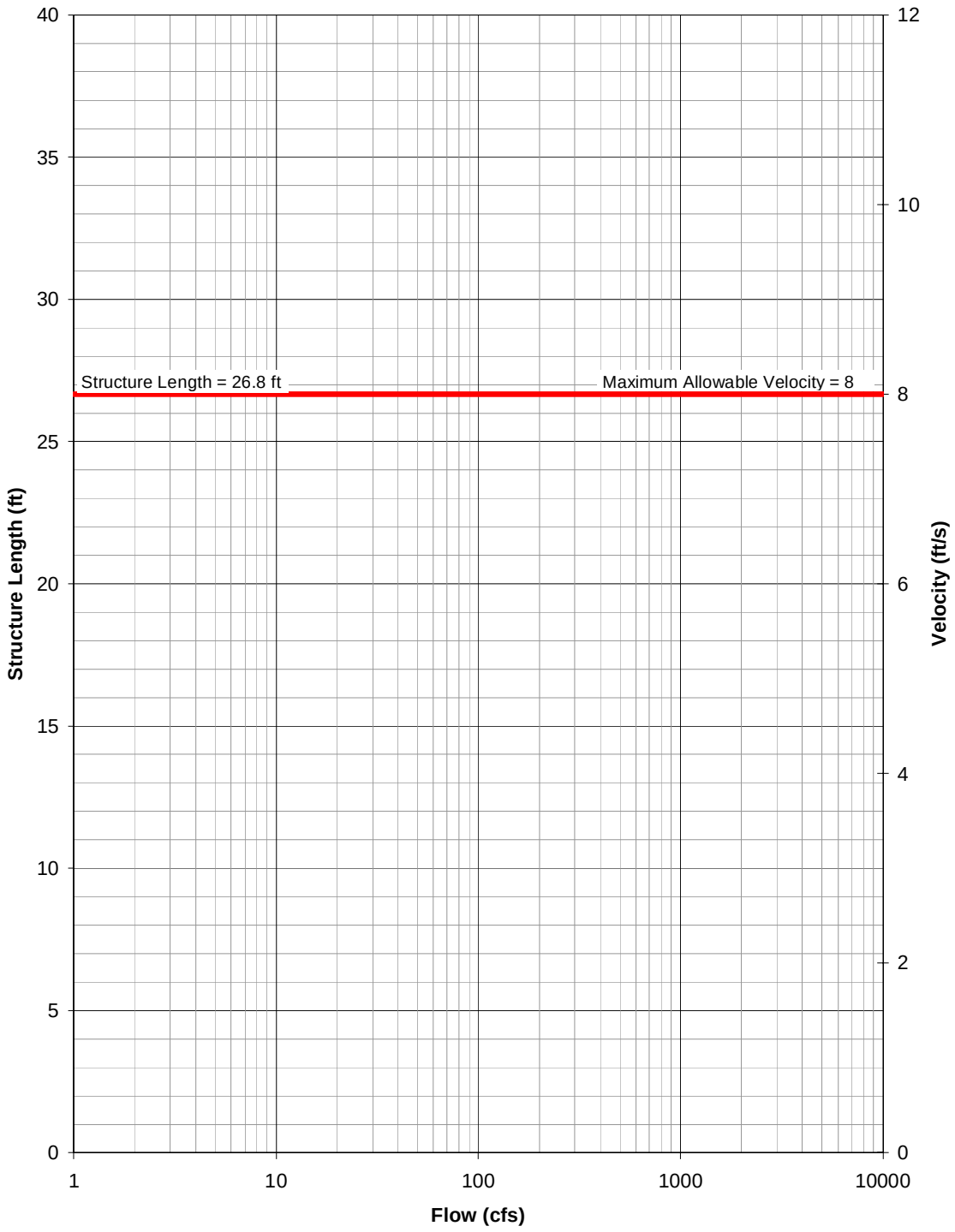


**Figure D-75. Fujinaka Low-flow Road Crossing – Velocity rating curves for channel sections**

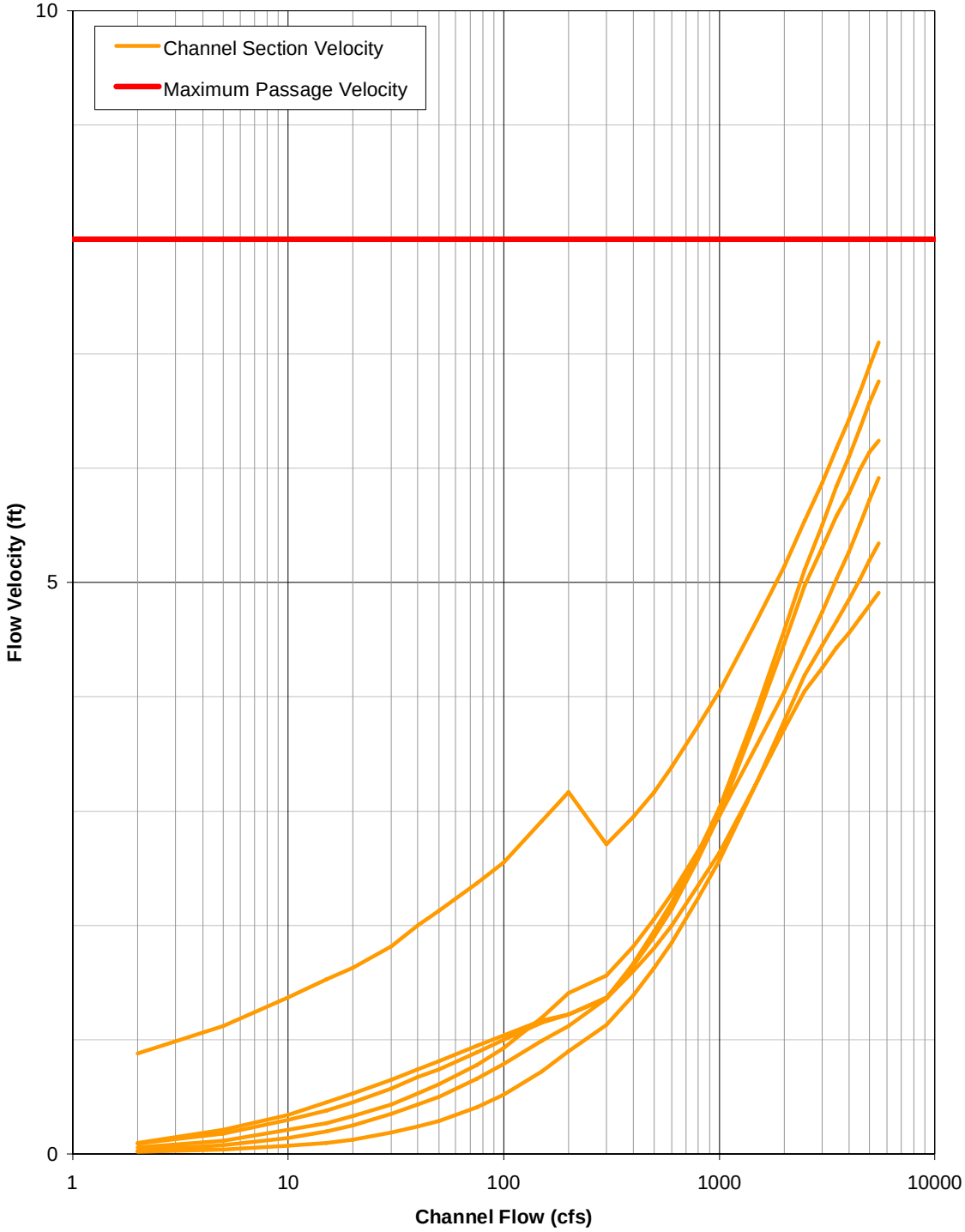


**Figure D-76. Fujinaka Low-flow Road Crossing – Depth rating curves for channel sections**

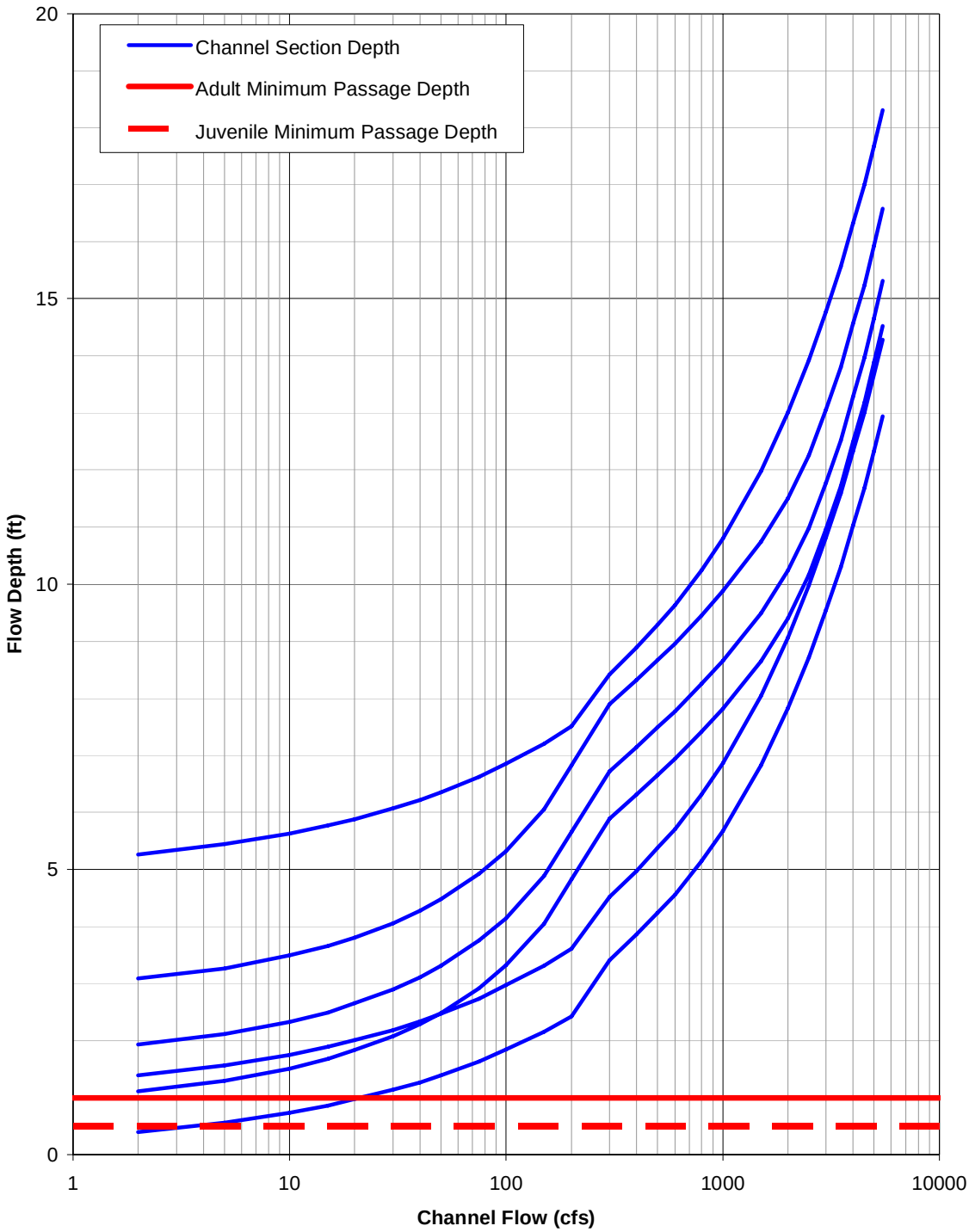


**Figure D-77. Fujinaka Low-flow Road Crossing – Velocity rating curves for the riprap**

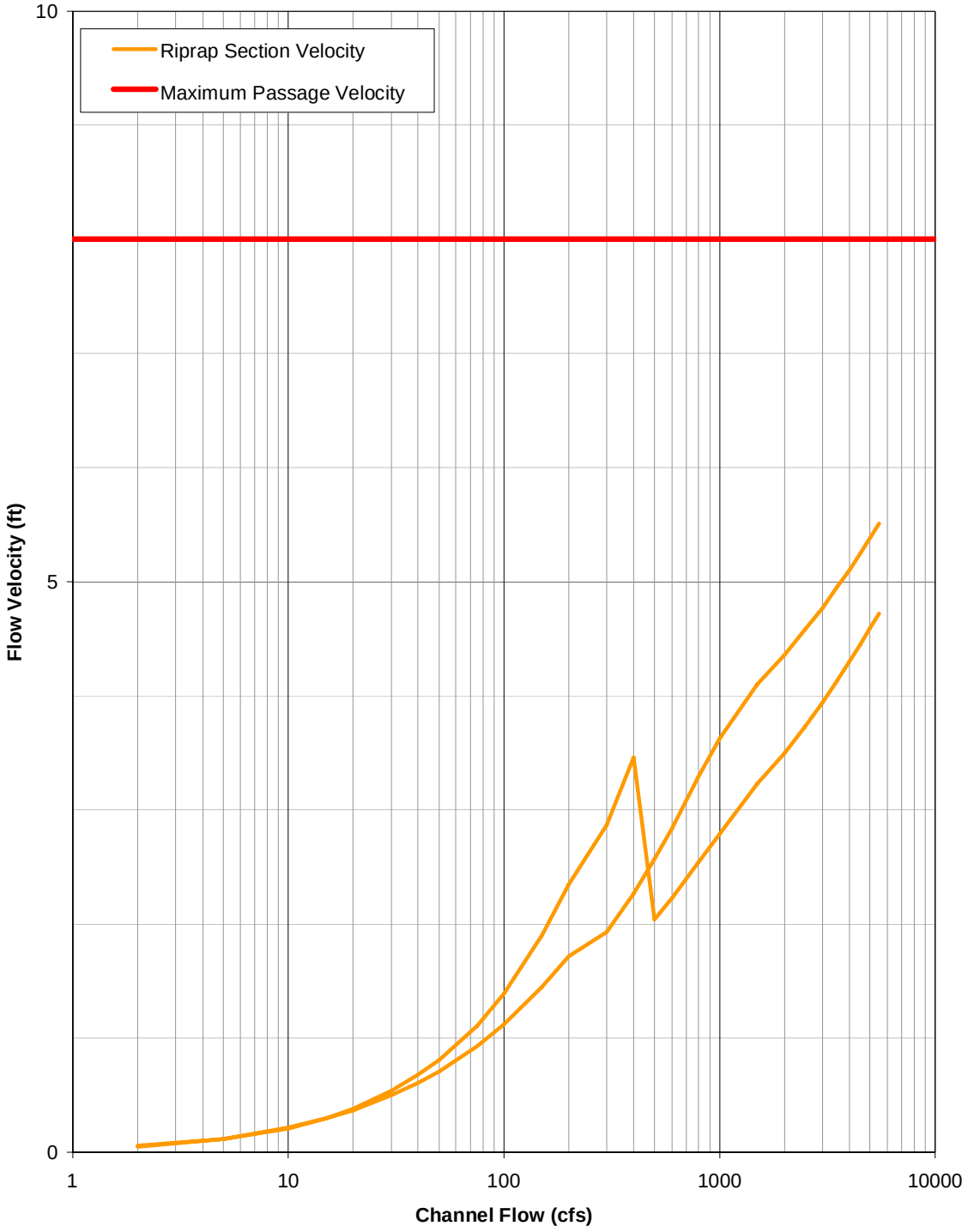


**Figure D-78. Fujinaka Low-flow Road Crossing – Depth rating curves for the riprap**

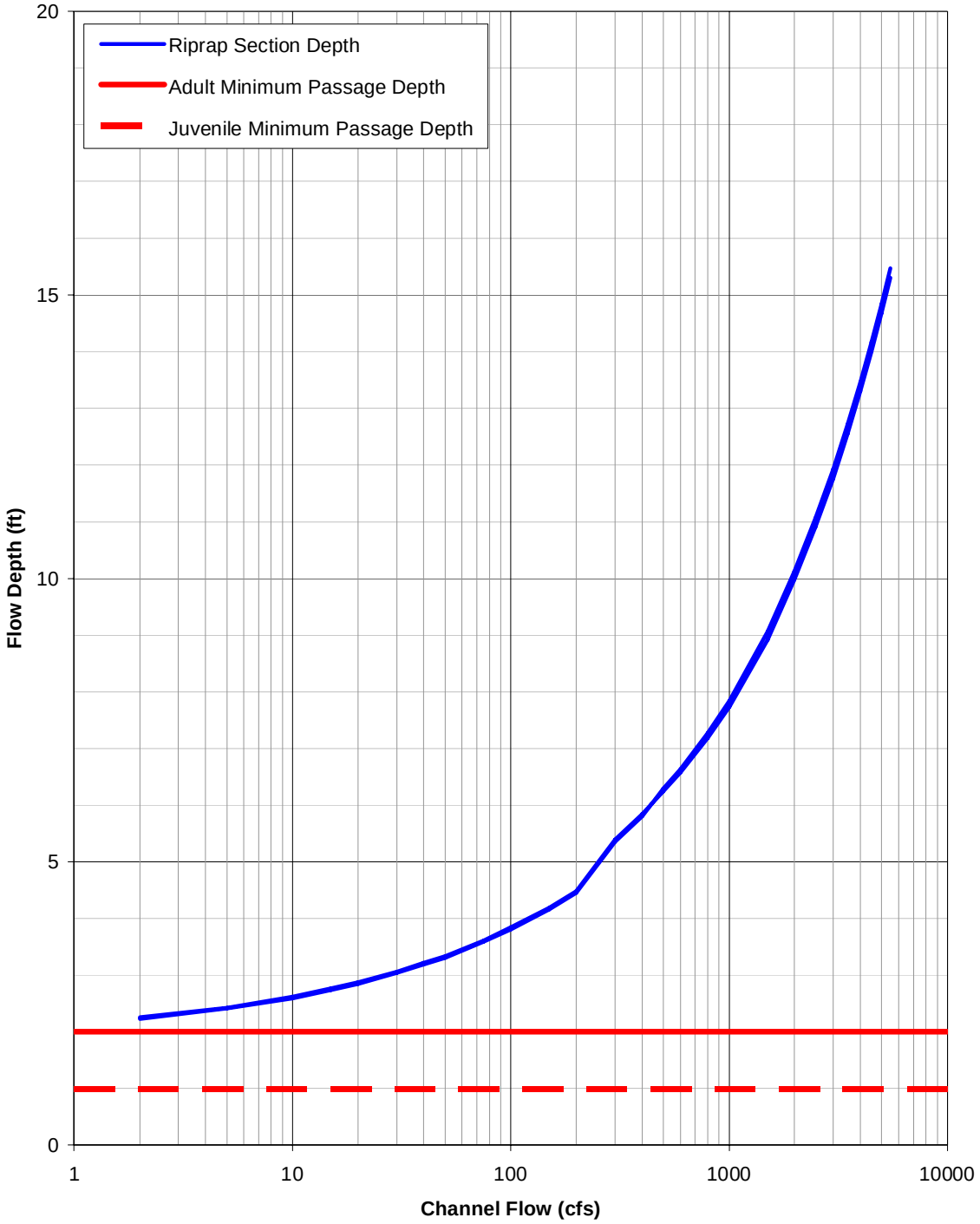


**Figure D-79. Fujinaka Low-flow Road Crossing – Velocity rating curves for structure components**

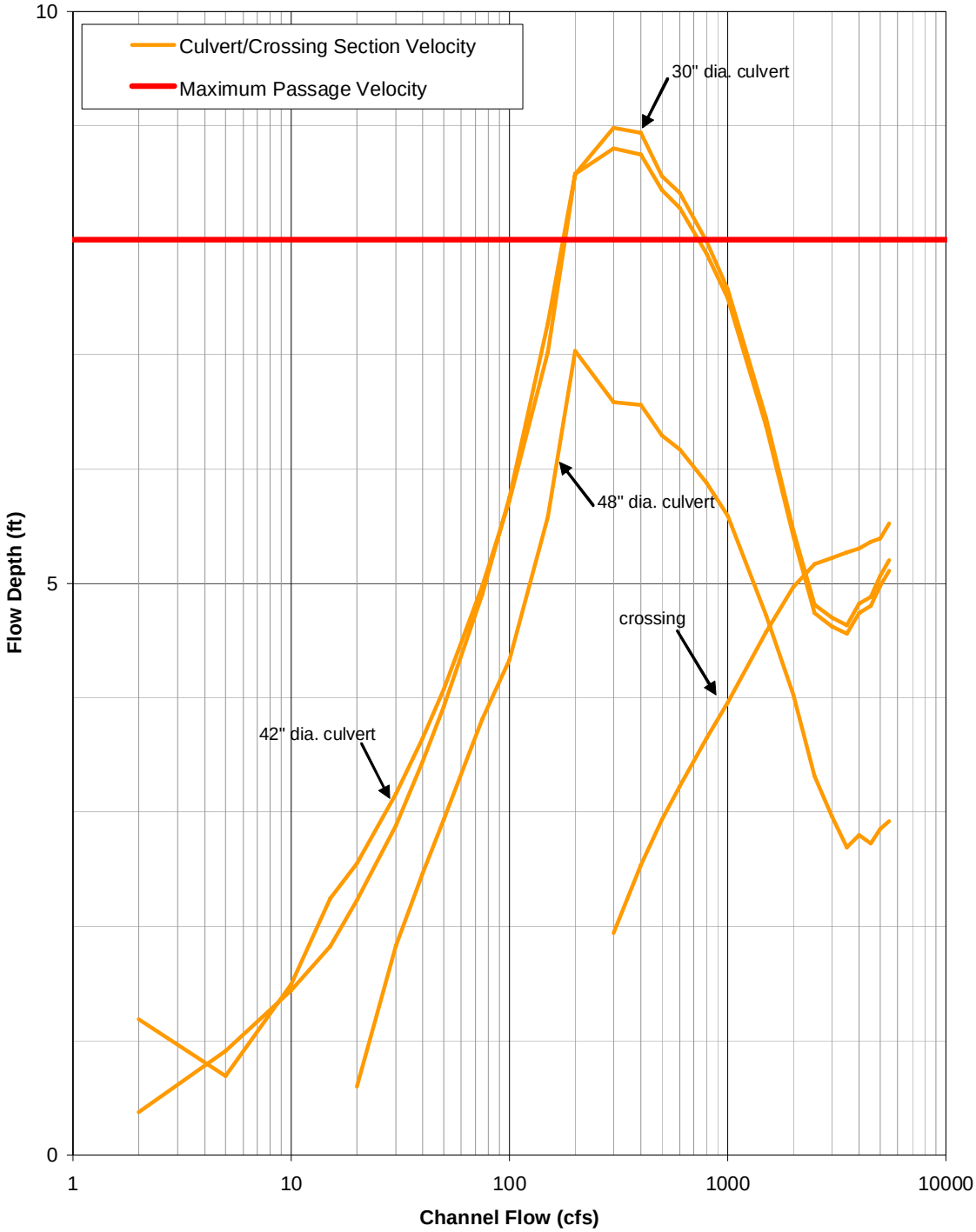
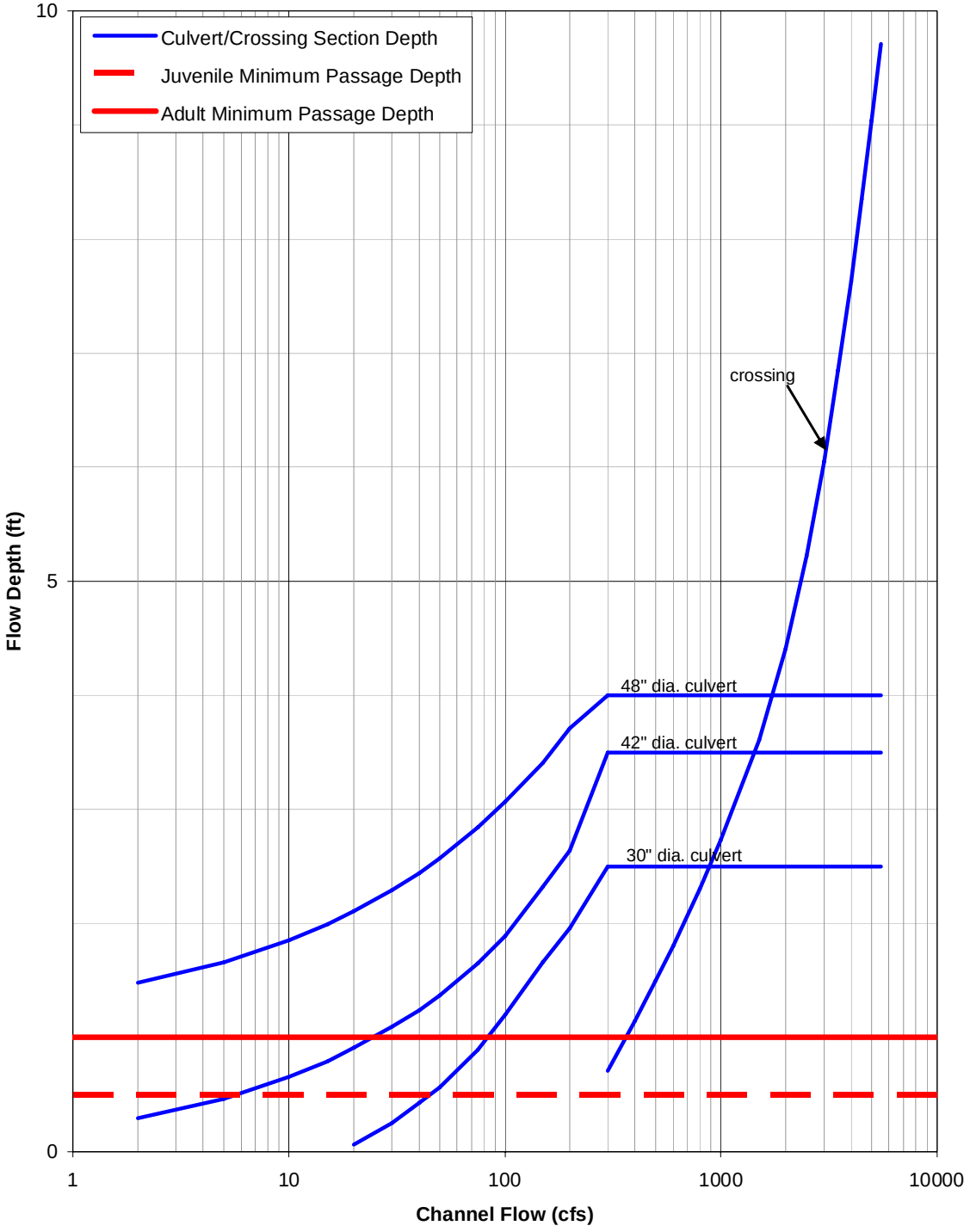


**Figure D-80. Fujinaka Low-flow Road Crossing – Depth rating curves for structure components**



## *Mormon Slough Railroad Bridge*

**Photo D-22. Mormon Slough Railroad Bridge – Upstream side**

**Photo D-23. Mormon Slough Railroad Bridge – Downstream side**

## Structure Details

| | |
|---|---|
| Name of Structure: | Mormon Slough Railroad Bridge |
| Type of Structure: | Bridge |
| Tributary: | Mormon Slough |
| Number of sections: | upstream-6 downstream-6 structure-4 |
| Length of model: | upstream-640 ft downstream-500 ft |

*Description of structure.* Mormon Slough Railroad Bridge is supported on concrete piers and a concrete apron approximately 50 ft in channel length. The apron has five, approximately 40 ft wide, openings between four, approximately 7 ft wide piers, and abutments for an overall width of approximately 250 ft. The structure alignment is askew from the channel alignment. The piers are parallel to the structure not the channel.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.03-0.08 |
| Side slopes and banks: | 0.04-0.08 |
| Structure: | 0.012-0.04 |
| Riprap: | 0.06-0.08 |

*Calibration*

Number of flows: 3

1. Flow: 27.6 cfs Survey method: Autolevel
Comments: Flow measurements using current meter at site. Flow determined from deducting Potter Creek flow, 17.7 cfs, from downstream flow, 45.3 cfs.
2. Flow: 161 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site. Flow determined from deducting Potter Creek flow, 47.9 cfs, from downstream flow, 208.9 cfs. Calibration points on structure and upstream of structure.
3. Flow: 241 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site. Flow determined from deducting Potter Creek flow, 48.7 cfs, from downstream flow, 290 cfs. Calibration points downstream of structure and on structure

*Starting conditions used for the model.*

Starting Condition on Flow 1: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 2: Known WS was used on both boundaries. Surveyed downstream starting elevation was not available and critical depth elevation was used. US elevation was determined from survey measurements in the field.

Starting conditions on Flow 3: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

*Comments.* The skewed alignment of the structure is by nature difficult to model at both low and high flows. However, 2 sets of surveyed water surface profiles were used to validate model performance at

higher flows. Validations flows were estimated from a combination of observed field conditions, Bellota Weir gauge readings and flow elevations determined from water surface profile surveys.

### Performance Summary

Velocities on the structure do not exceed adult maximum passage velocities in bay 1, exceed passage velocities in bay 2 from 1,200 to 3,400 cfs, bay 3 from 180 to 3,000 cfs, bay 4 from 500 to 2,900 cfs and from 3,700 to 4,700 cfs, and do not exceed maximum velocities in bay 5. The apron exhibits velocities greater than the maximum adult velocities for flows from 800 to 2,900 cfs. Acceptable depths, for adults, of 1 ft are not exceeded in bay 1 until flow is above 3,100 cfs, in bay 2 until flow exceeds 200 cfs, in bay 3 when flow exceeds 30 cfs, in bay 4 when flows exceed 70 cfs and in bay 5 when flows exceed 2,200 cfs. The apron exceeds 1 ft depth for flows greater than 30 cfs. Channel section velocities just exceed maximum velocities at flows between 1,000 and 1,300 cfs while channel depths become greater than the 1 ft requirement for flows above 230 cfs. The model indicates that Mormon Slough Railroad Bridge provides unimpeded passage for adults when flows exceed 32 cfs.

Juvenile criteria require that depths must exceed 0.5 ft, which occurs in bay 1 above 2,700 cfs, bay 2 above 100 cfs, bay 3 above 6 cfs, bay 4 above 25 cfs, and bay 5 above 1,800 cfs. The apron exceeds 0.5 ft in depth for flows greater then 5 cfs. Channel sections exhibit greater than 0.5-ft depths for flows greater than 70 cfs. These constraints indicate unimpaired juvenile passage through the structure for flows greater than 6 cfs.

**Figure D-81. Cross-section locations for Mormon Slough Railroad Bridge HEC-RAS model**

**Figure D-82. Mormon Slough Railroad Bridge – Relationship of length to maximum velocity**

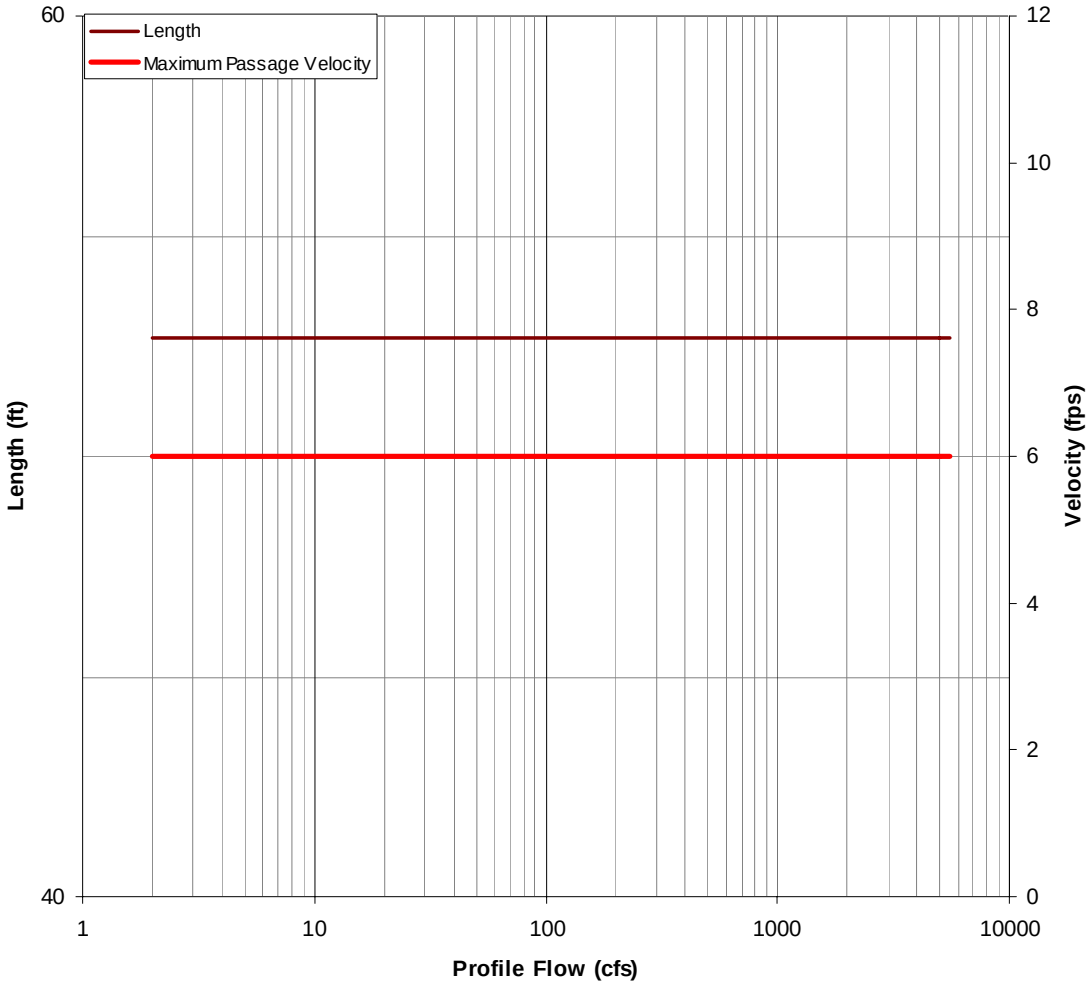


**Figure D-83. Mormon Slough Railroad Bridge – Velocity rating curves for structure components**

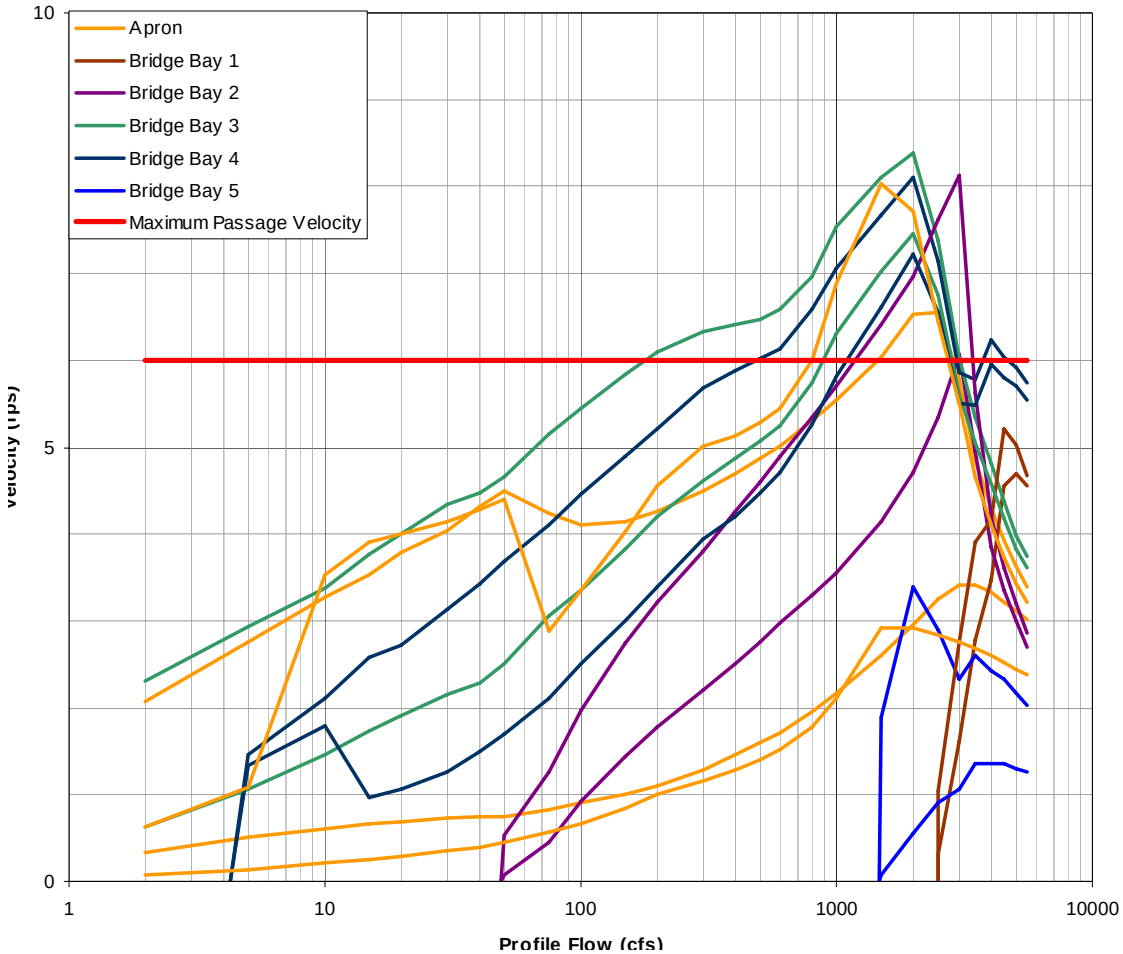


**Figure D-84. Mormon Slough Railroad Bridge – Depth rating curves for structure components**

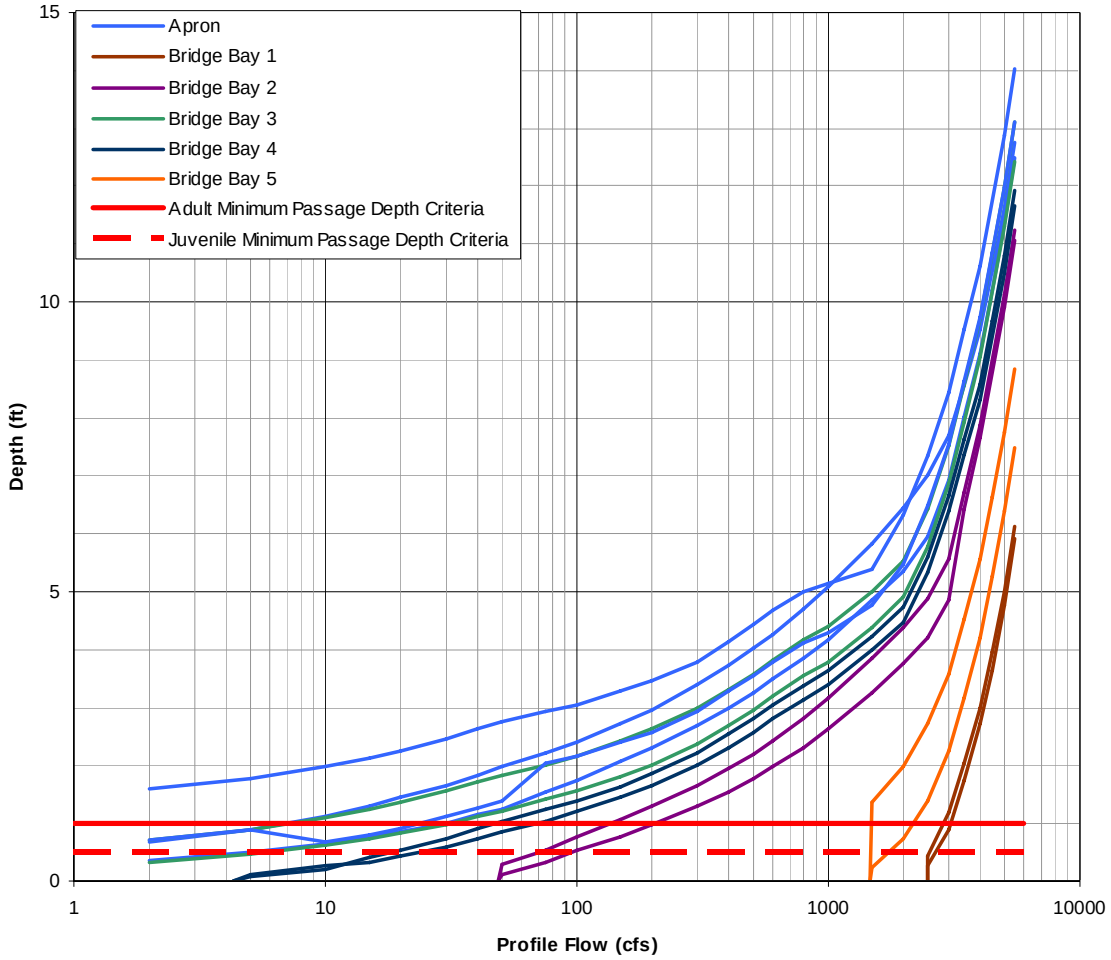


**Figure D-85. Mormon Slough Railroad Bridge – Velocity rating curves for channel sections**

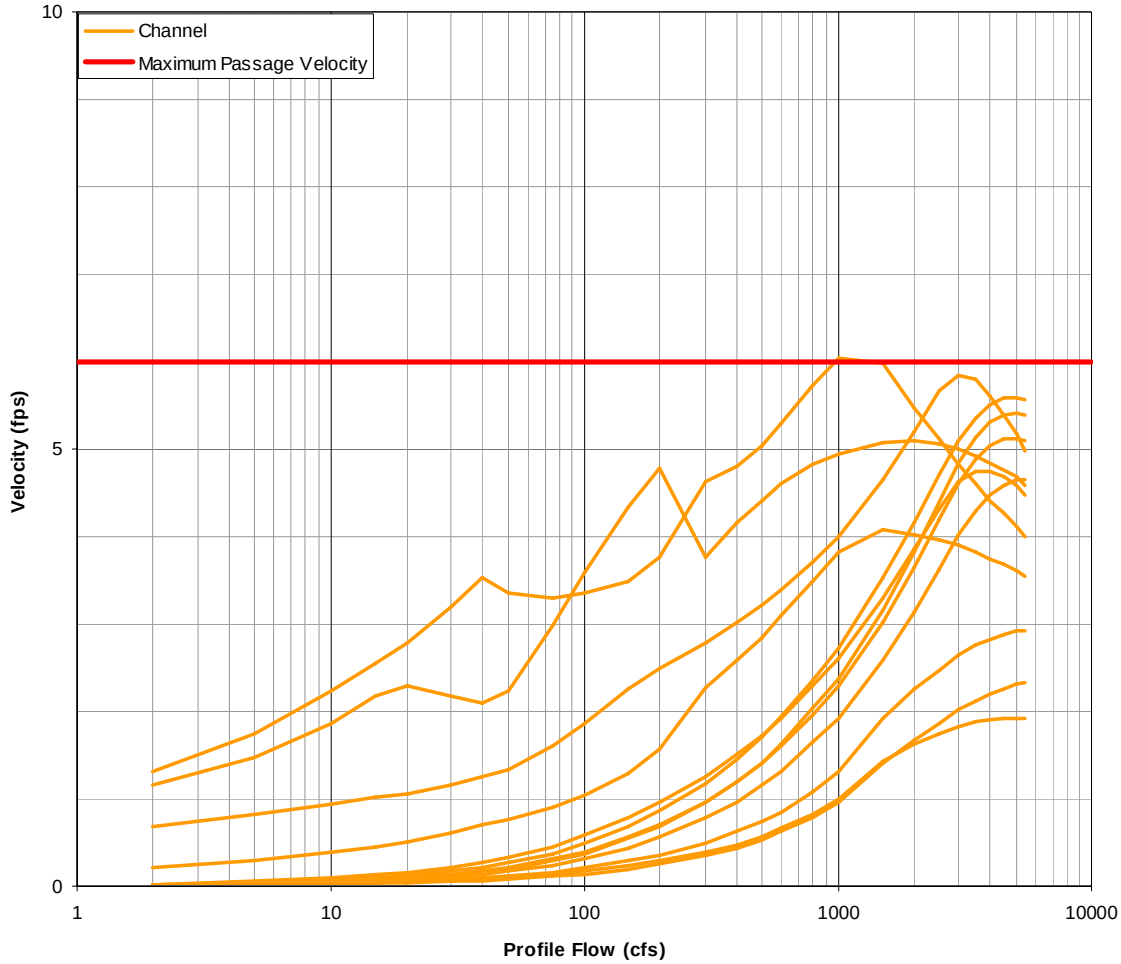
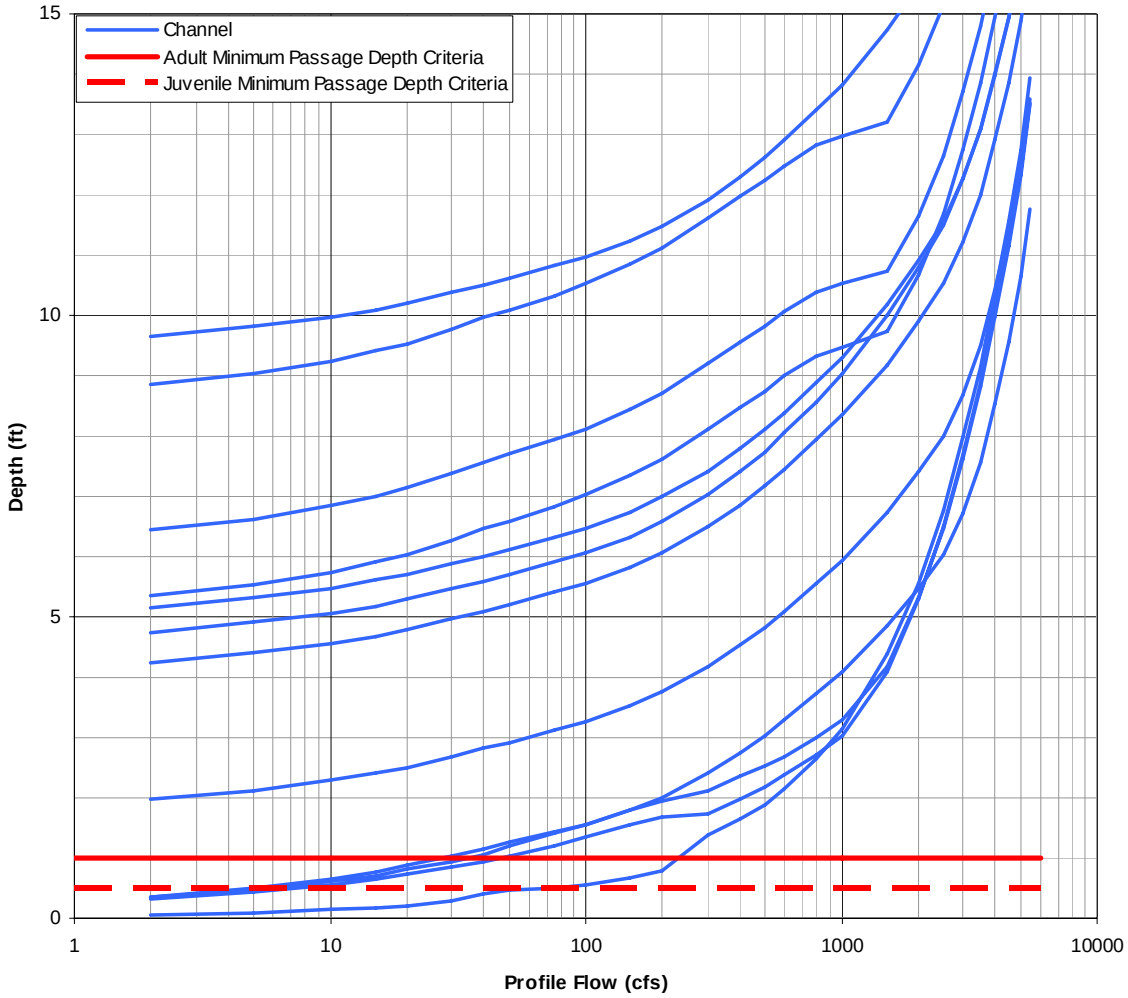


**Figure D-86. Mormon Slough Railroad Bridge – Depth rating curves for channel sections**



## *Piazza Flashboard Dam*

**Photo D-24. Piazza Flashboard Dam base at a low flow**

**Photo D-25. Piazza Flashboard Dam base at a high flow**

## Structure Details

| | | | |
|---|---|---|---|
| Name of Structure: | Piazza Flashboard Dam | | |
| Type of Structure: | flashboard dam base | | |
| Tributary: | Mormon Slough | | |
| Number of sections: | upstream-4 | downstream-5 | structure-1 |
| Length of model: | upstream-354 ft | downstream-350 ft | |

*Description of structure.* A flashboard dam base consisting of a concrete apron between two 8-ft high concrete abutments. Riprap has been placed on the upstream and downstream sides of the structure.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.04 |
| Side Slopes and Banks: | 0.04 |
| Riprap: | 0.06 - 0.08 |

*Calibration*

Number of flows: 2

1. Flow: 70 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site.

2. Flow: 260 cfs Survey method: Autolevel

Comments: Flow measurement using current meter at site.

*Starting conditions used for the model.* The calibration flows were modeled in the subcritical flow regime and used measured water surface elevations at the downstream boundary.

*Assumptions.* The flashboard dam base was modeled as an inline weir with a weir coefficient of 2.0. The weir coefficient was adjusted such that the calculated water surface profile match the measured water surface profile closely at both calibration flows. For flows less than or equal to 200 cfs, the starting water surface elevation was set to produce water surface profile slopes that were the same as the slope of the water surface profile of the 70 cfs calibration flow. Normal depth was used as the starting water surface elevation at the downstream end for flows greater than 200 cfs. The energy slope used for the normal depth calculations was 0.00056, which was used in order to match the water surface profile of the 260 cfs calibration flow.

## Performance Summary

For adult salmonids, the 1 foot depth criterion is met in the channel at flows of 100 cfs and higher. It is met over the dam base at 75 cfs. The 2 foot depth criterion for adults over riprap is met at flows of 330 cfs and higher. The 0.5 foot depth criterion for juveniles is met in the channel at 10 cfs and higher. Over the dam base, the 0.5 foot criterion is met at 25 cfs and higher. The 1 foot depth criterion for juveniles over riprap is met at 170 cfs.

The 6 fps velocity criterion in the channel and over the riprap is met at all modeled flows. The velocity criterion changes with flow over the dam base. It ranges between 5 fps at low flows up to 10 fps at higher flows. The velocity criterion is met over the dam base at all modeled flows.

In summary, adults have unimpaired passage at Piazza at flows of 330 cfs and higher. Juveniles have unimpaired passage at flows of 170 cfs and higher.

**Figure D-87. Cross-section locations for Piazza Flashboard Dam HEC-RAS model**

**Figure D-88. Piazza Flashboard Dam – Relationship of length to maximum velocity**

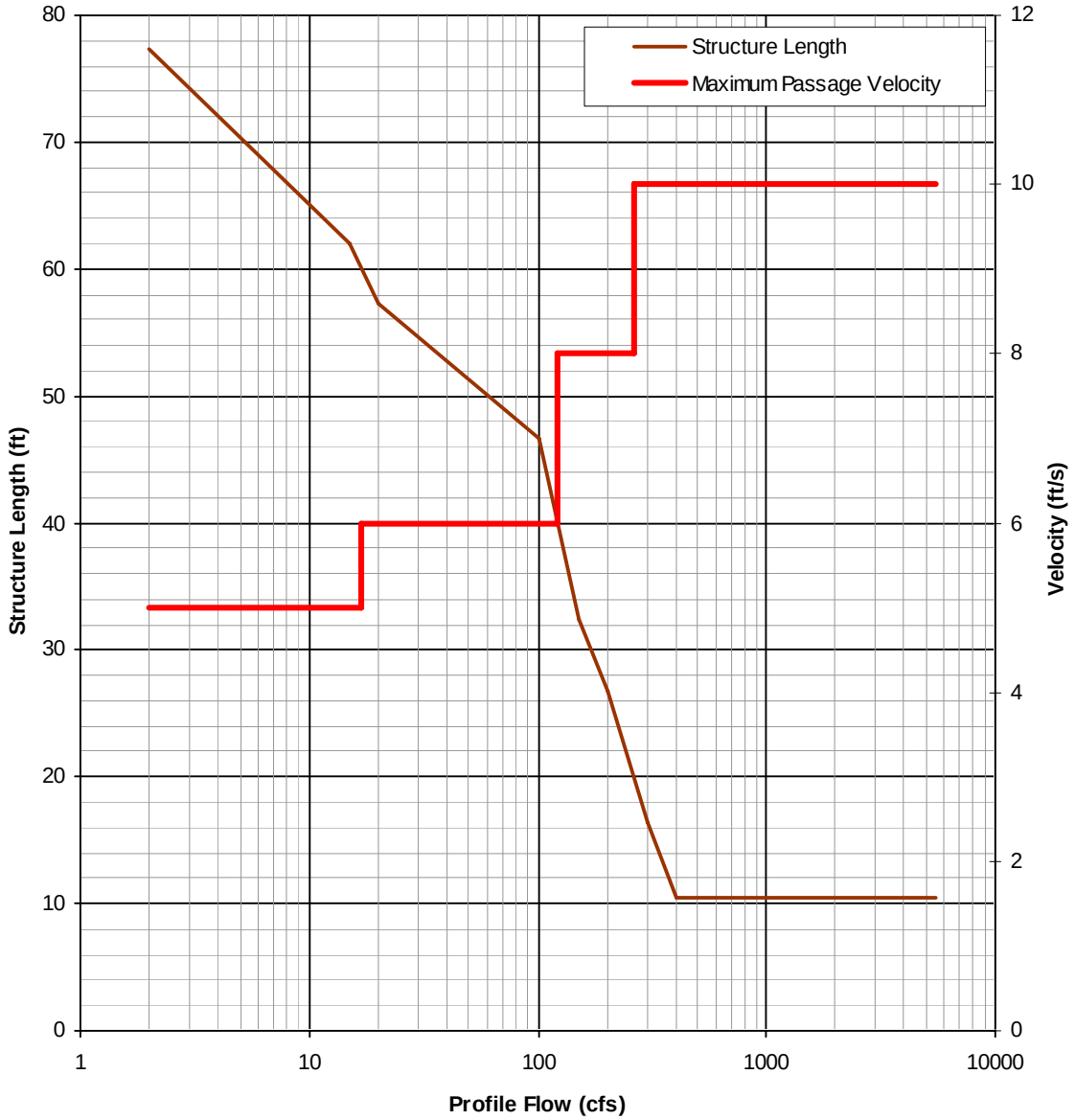


**Figure D-89. Piazza Flashboard Dam – Velocity rating curves for channel sections**

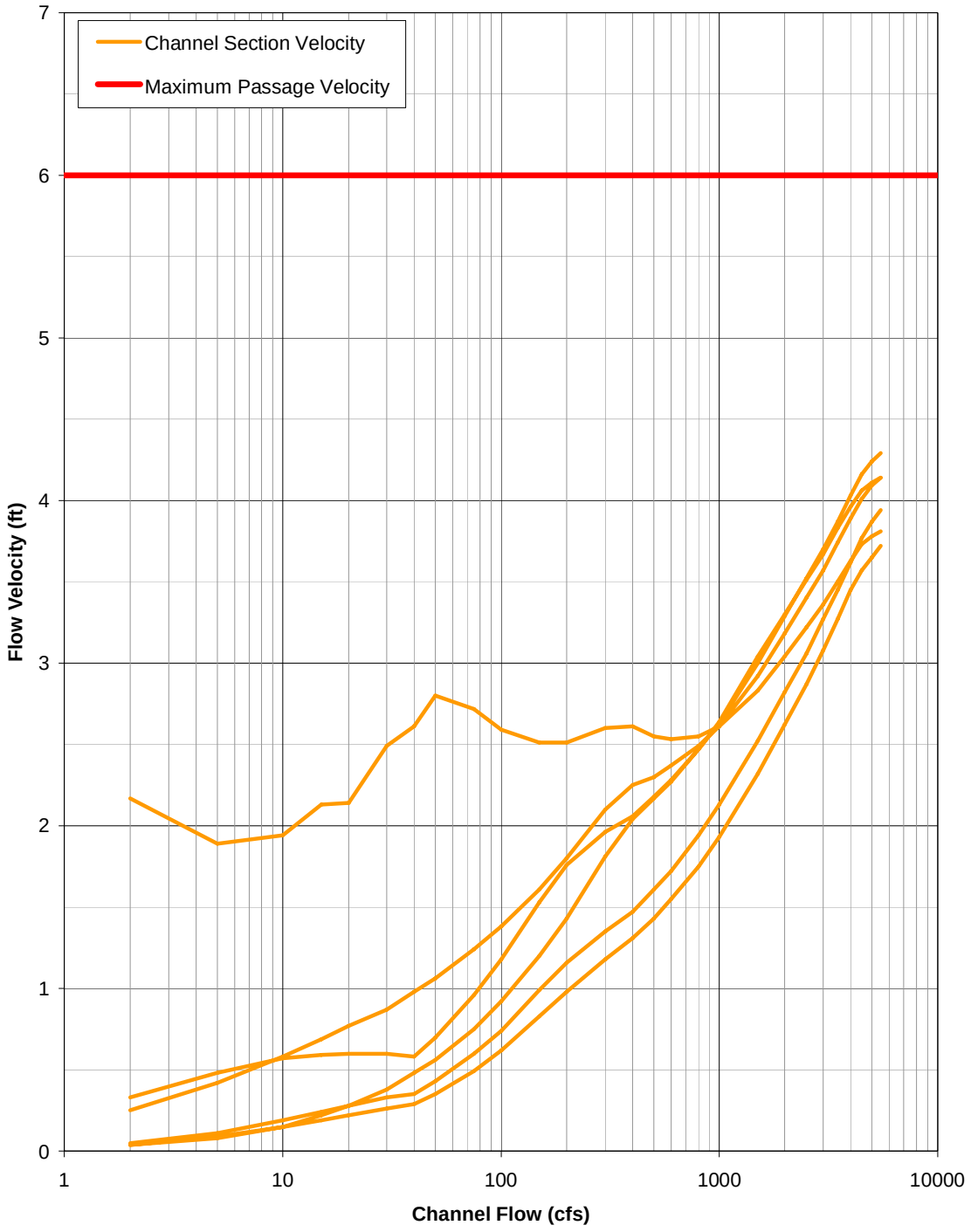


**Figure D-90. Piazza Flashboard Dam – Depth rating curves for channel sections**

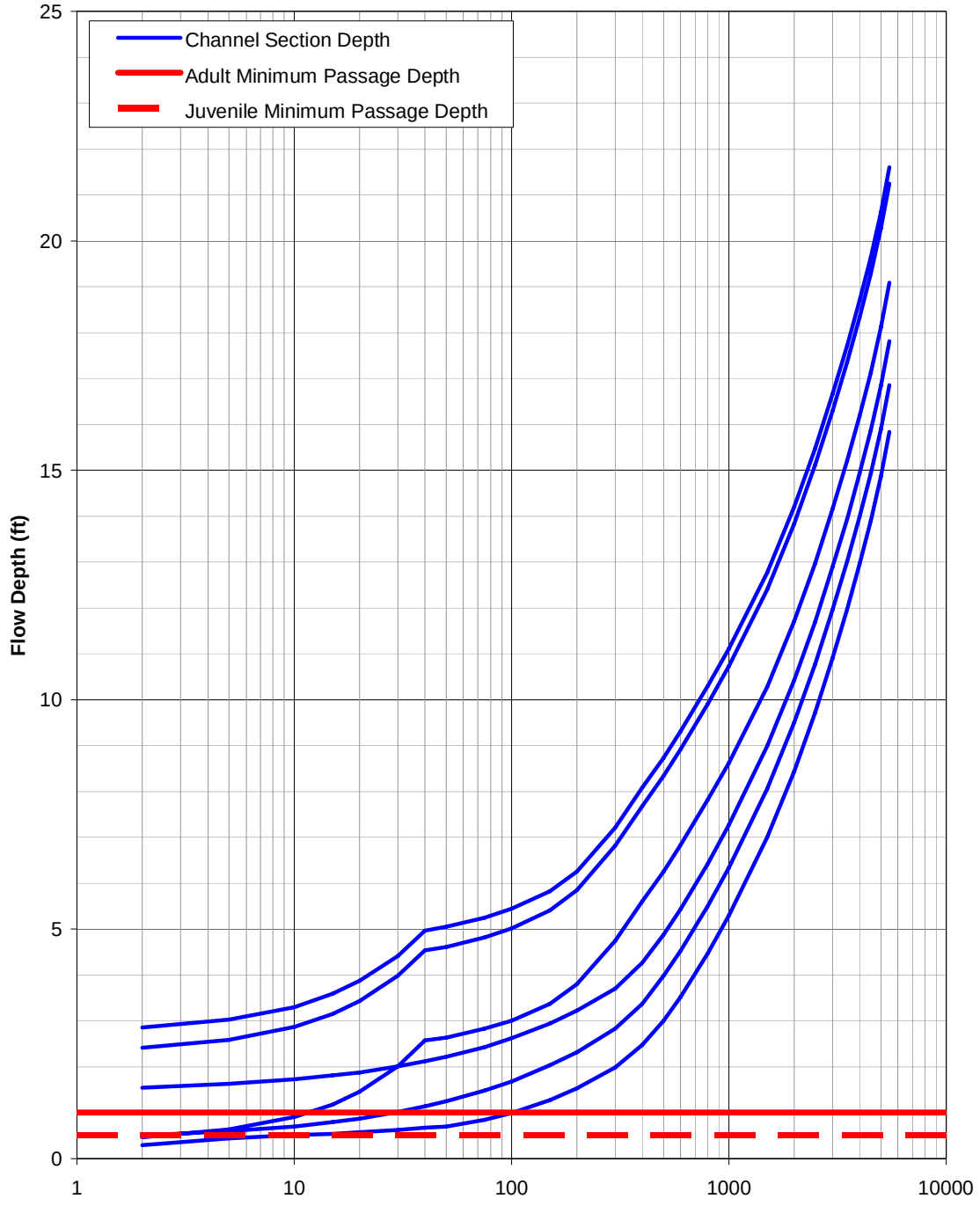


**Figure D-91. Piazza Flashboard Dam – Velocity rating curves for riprap**

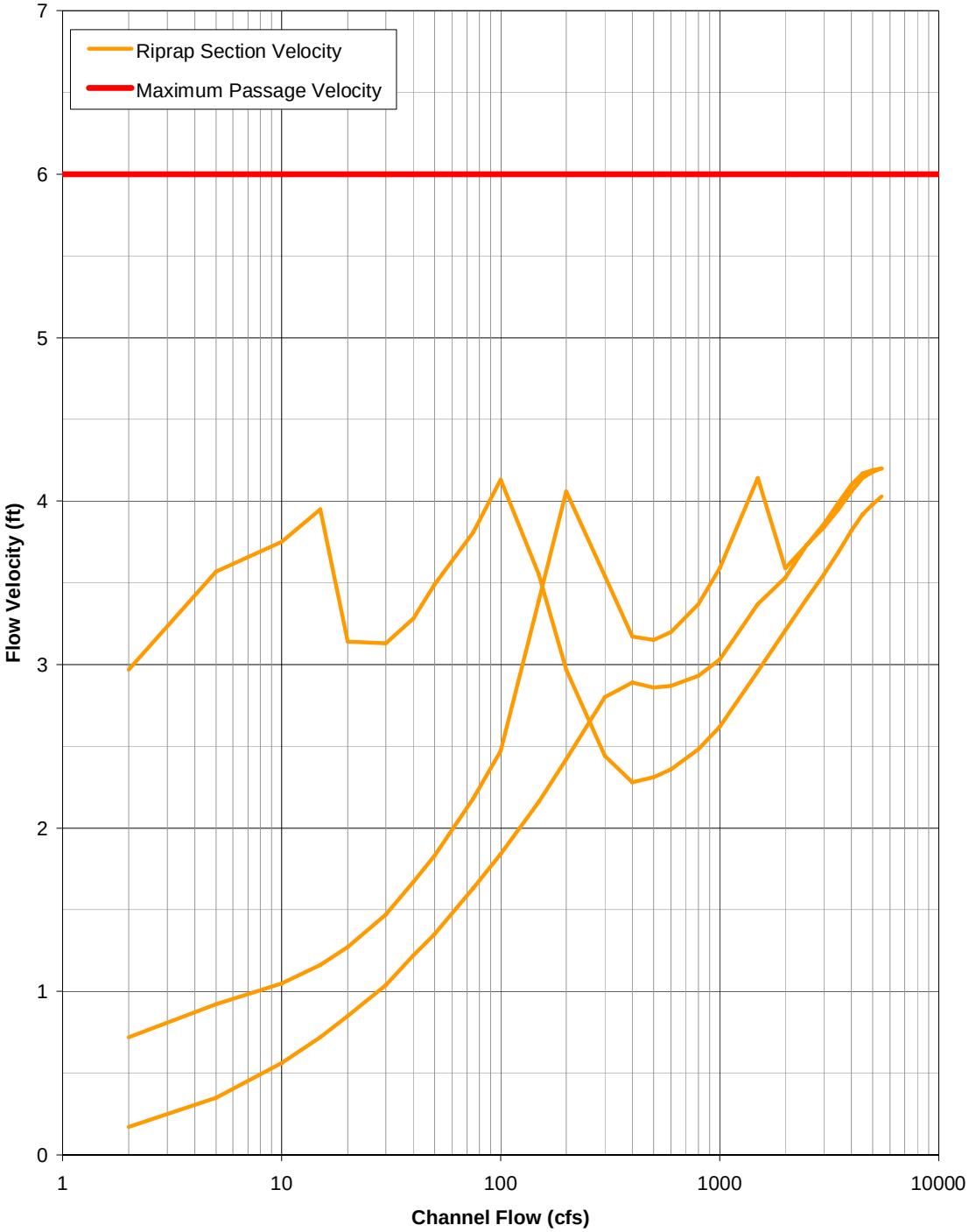


**Figure D-92. Piazza Flashboard Dam – Depth rating curves for riprap**

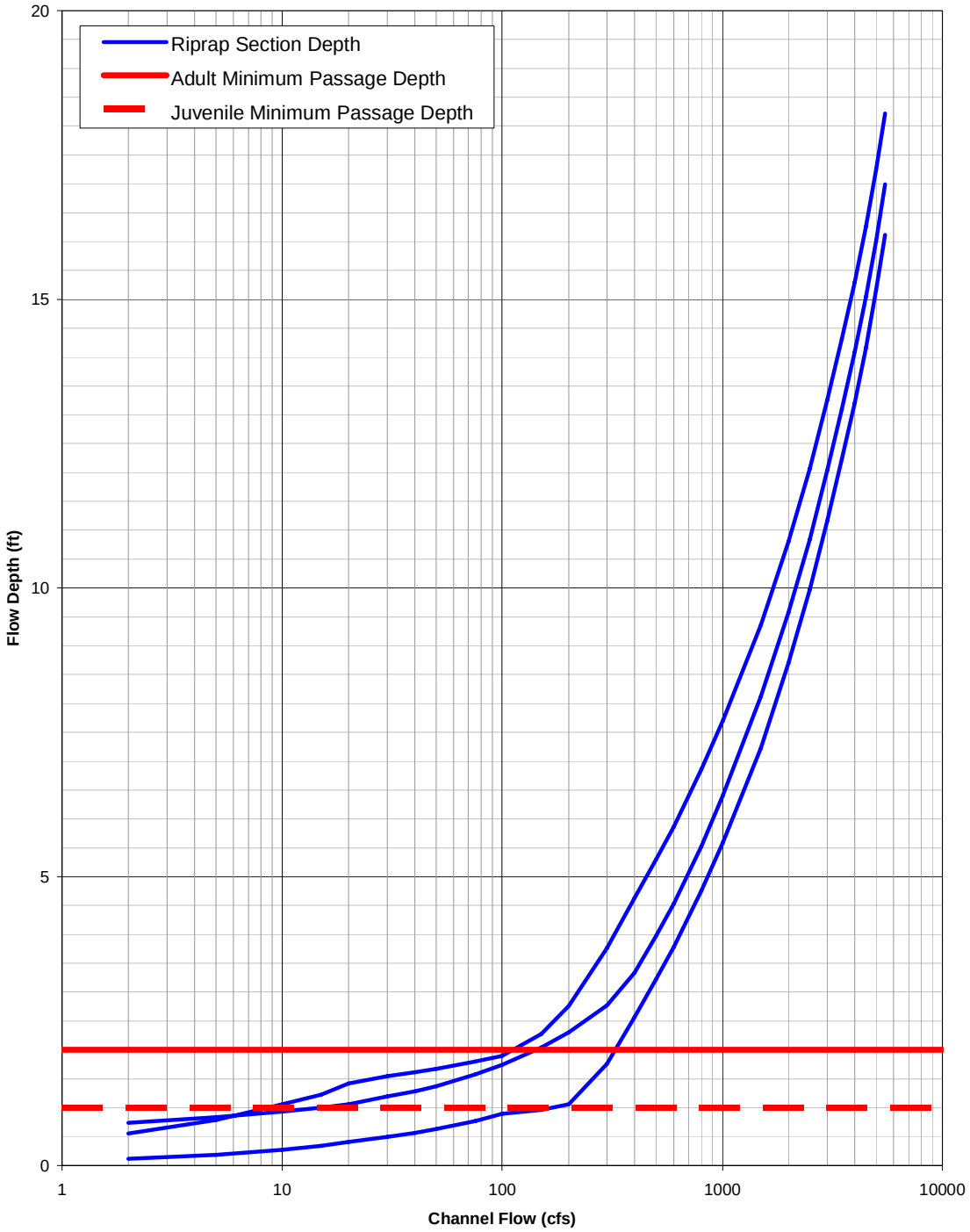


**Figure D-93. Piazza Flashboard Dam – Velocity rating curves for structure sections**

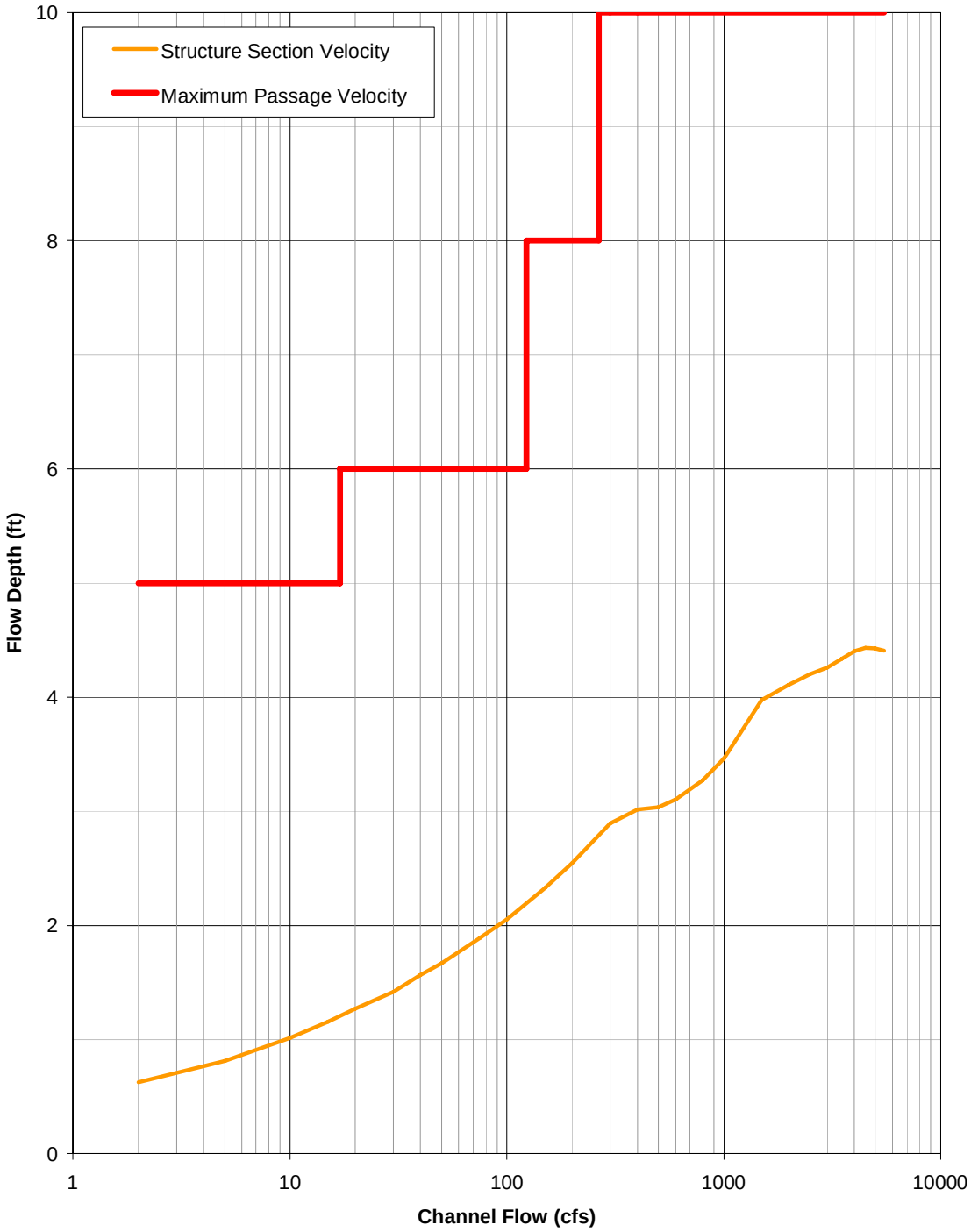
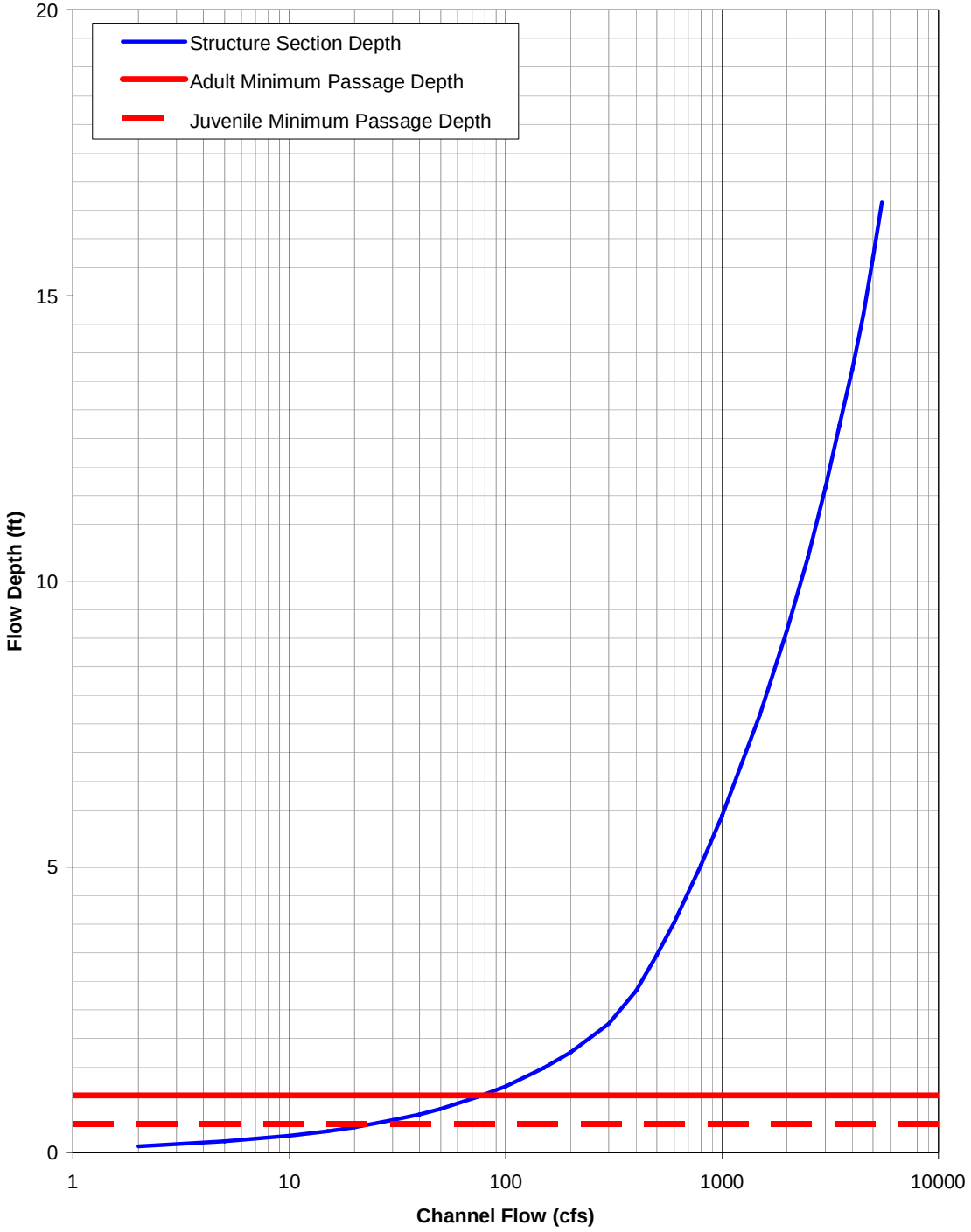


**Figure D-94. Piazza Flashboard Dam – Depth rating curves for structure sections**



## *Fine Road Bridge*

**Photo D-26. Fine Road Bridge**

**Photo D-27. Fine Road Bridge with no flow**

## Structure Details

| | | | |
|---|---|---|---|
| Name of Structure: | Fine Road Bridge | | |
| Type of Structure: | bridge | | |
| Tributary: | Mormon Slough | | |
| Number of sections: | upstream-4 | downstream-4 | structures-2 |
| Length of model: | upstream-350 ft | downstream-380 ft | |

*Description of structure.* A concrete road bridge with 2 piers. The piers are located near the toe of the channel banks. They are concrete, elongated piers oriented along the direction of flow. There is riprap scour protection at the base of each pier.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel bottom: | 0.03 |
| Side slopes and banks: | 0.05 - 0.06 |
| Riprap: | 0.06 - 0.07 |

*Calibration*

Number of flows: 2

1. Flow: 92 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site.
2. Flow: 270 cfs Survey method: Autolevel
Comments: Flow measurement using current meter at site.

*Starting conditions used for the model.* The calibration flows were modeled in the subcritical flow regime and used measured water surface elevations at the downstream boundary.

*Assumptions.* An additional energy loss of 0.07 feet was used at cross-section 4. A change in the slope of the water surface profile was measured downstream of the bridge at both calibration flows, but could not be reproduced in the model by adjusting Manning's n values or expansion/contraction coefficients. Thus, the additional energy loss was used to reproduce the change in water surface slope. Normal depth was used as the downstream boundary condition for the range of modeled flows. The slope used in the normal depth calculations was 0.001 in order to match the water surface profiles of the calibration flows.

## Performance Summary

The 1 foot depth criterion for adult salmonids is met at flows of 28 cfs and higher in the channel and at all modeled flows at the structure sections. The 0.5 foot depth criterion for juveniles is met at flows of 7.5 cfs and higher.

Since the channel bed at Fine Road Bridge is not interrupted by an apron or riprap, the model sections at the bridge were treated as regular channel sections. Thus, the velocity criterion at the structure sections was 6 fps, the same as the velocity criterion in the channel sections. The velocity criterion is met below 3,750 cfs in the channel and at all modeled flows at the structure sections.

In summary, adults have unimpaired passage at Fine Road Bridge at flows of 28 cfs and higher. Juveniles have unimpaired passage at flows of 7.5 cfs and higher.

**Figure D-95. Cross section locations for Fine Road Bridge HEC-RAS model**

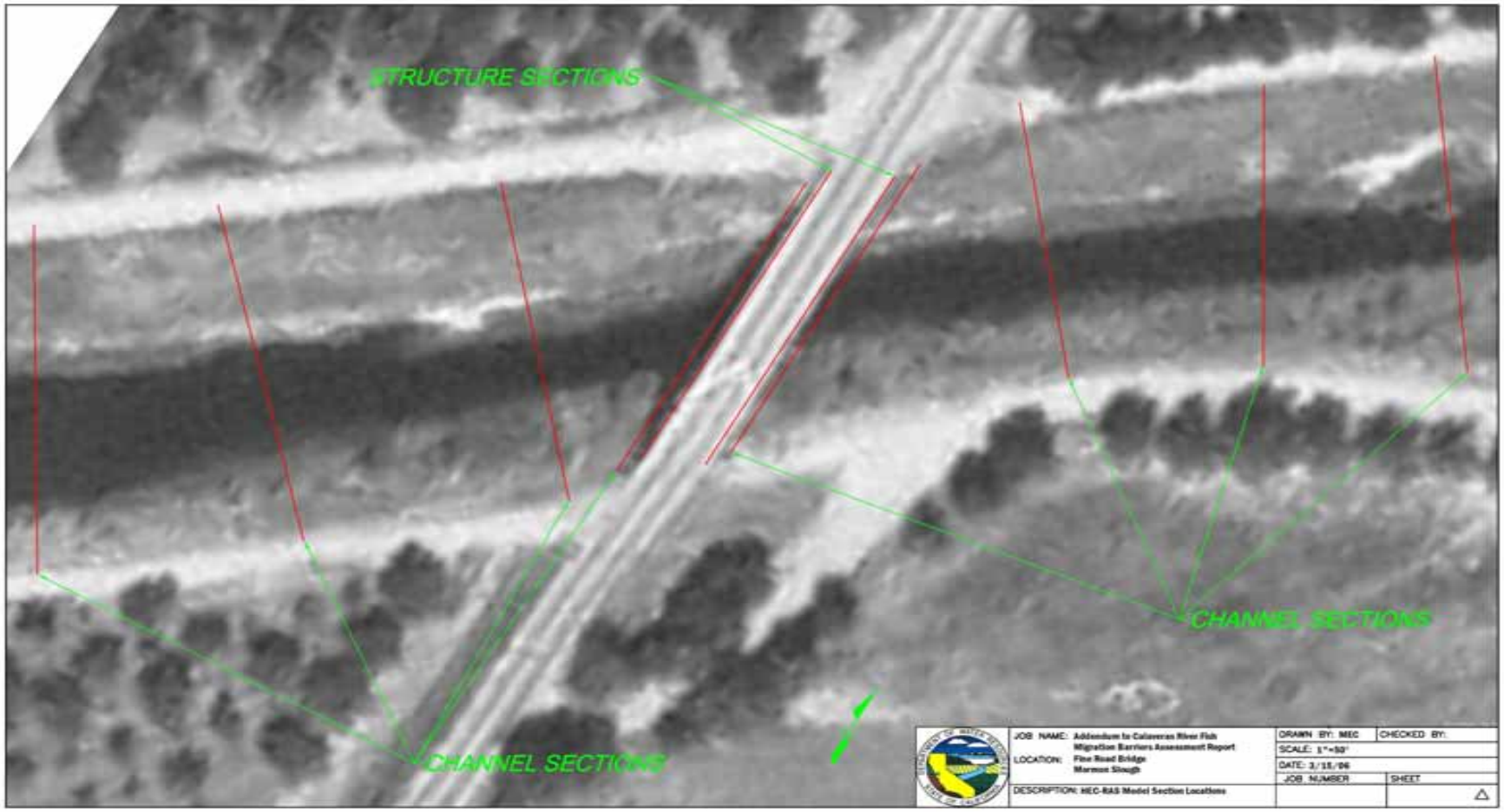


**Figure D-96. Fine Road Bridge – Velocity rating curves for channel sections**

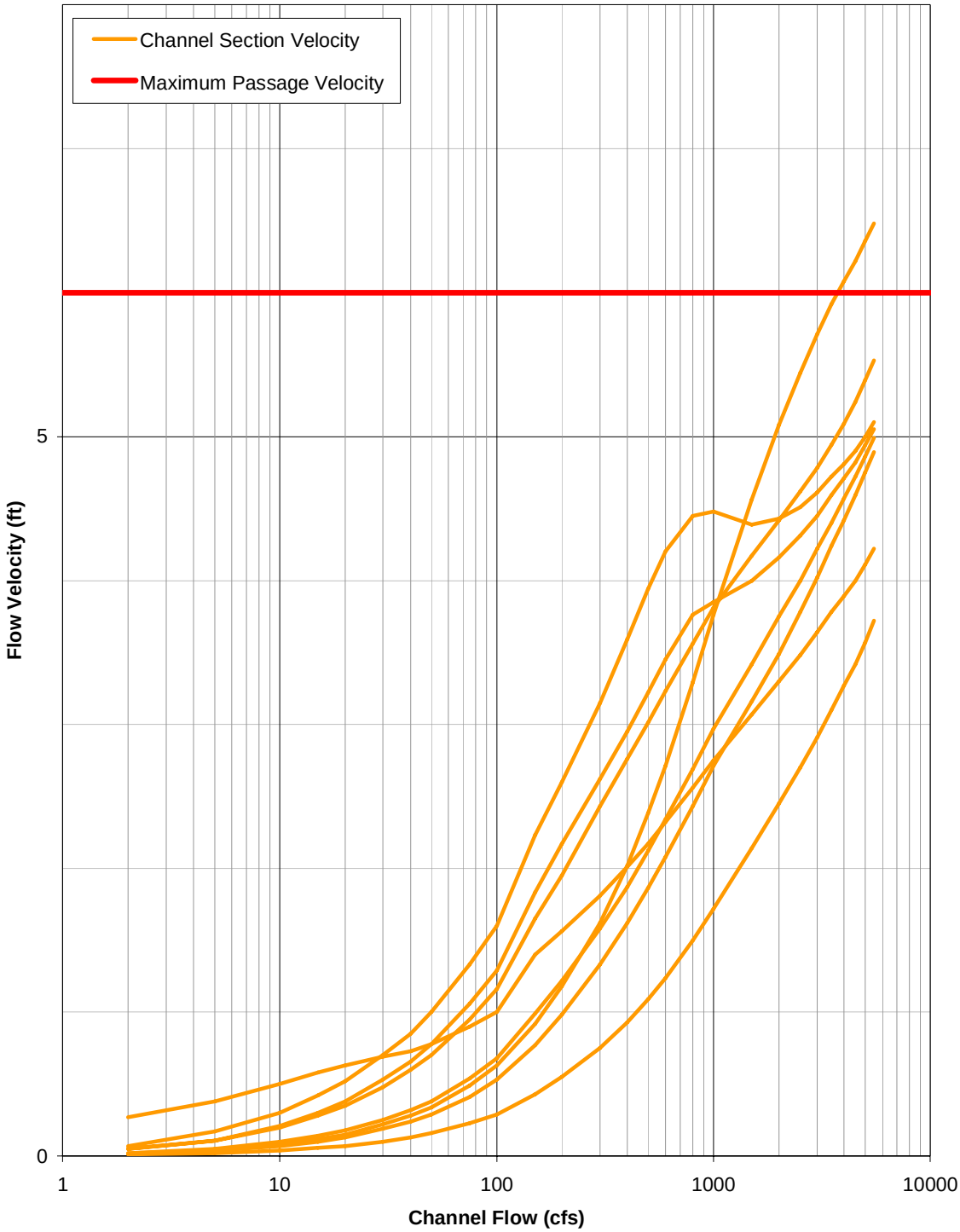


**Figure D-97. Fine Road Bridge – Depth rating curves for channel sections**

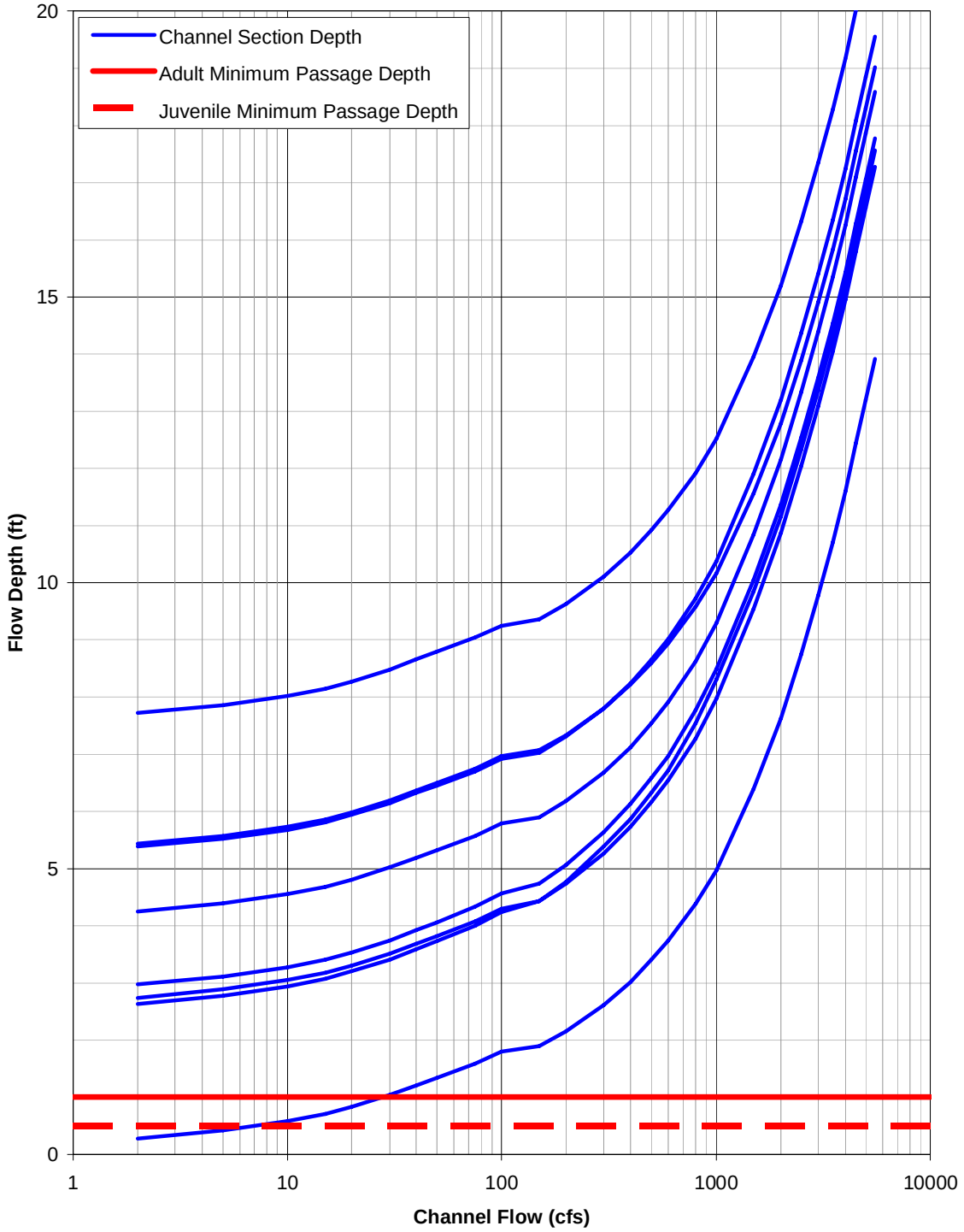


**Figure D-98. Fine Road Bridge – Velocity rating curves for structure sections**

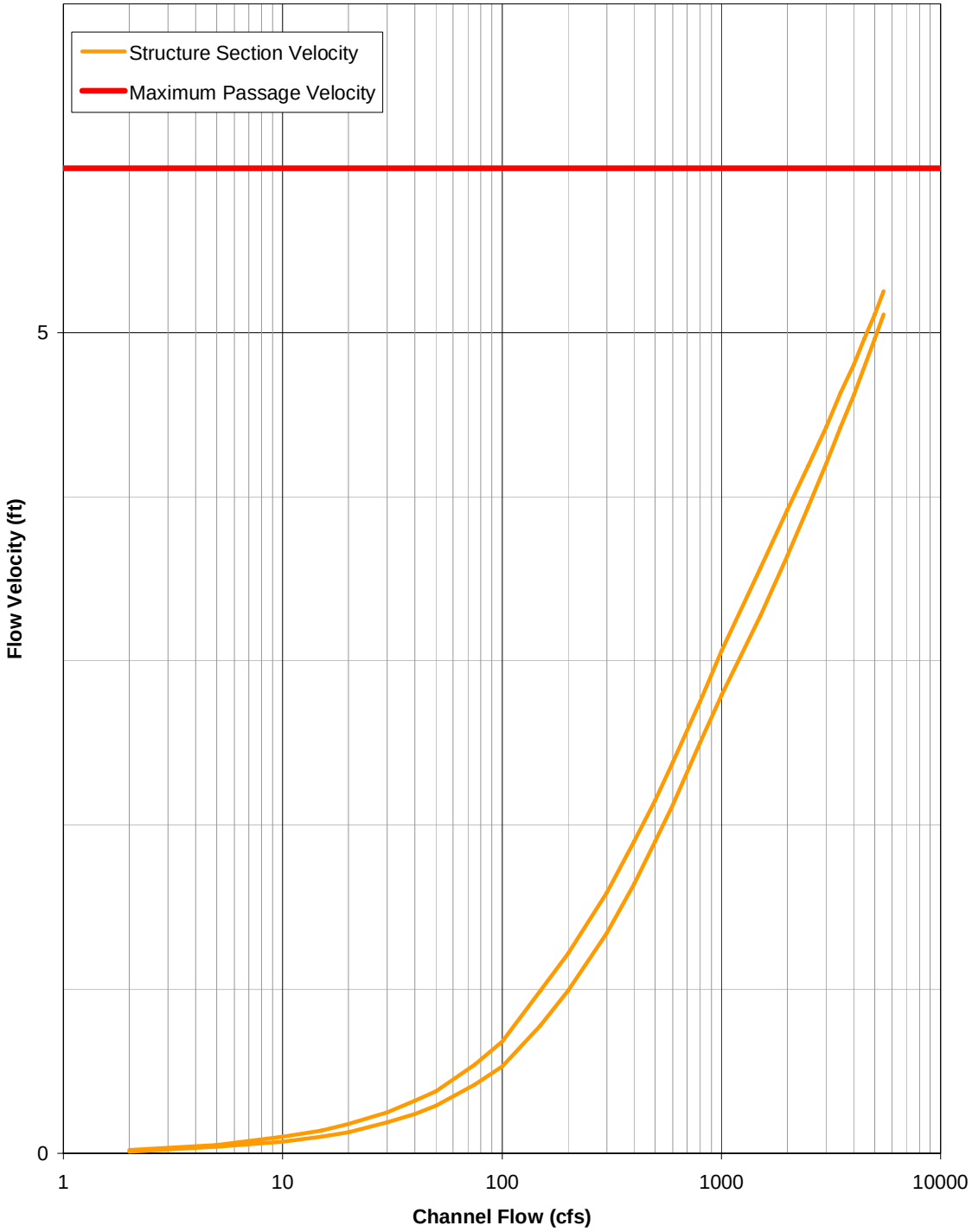
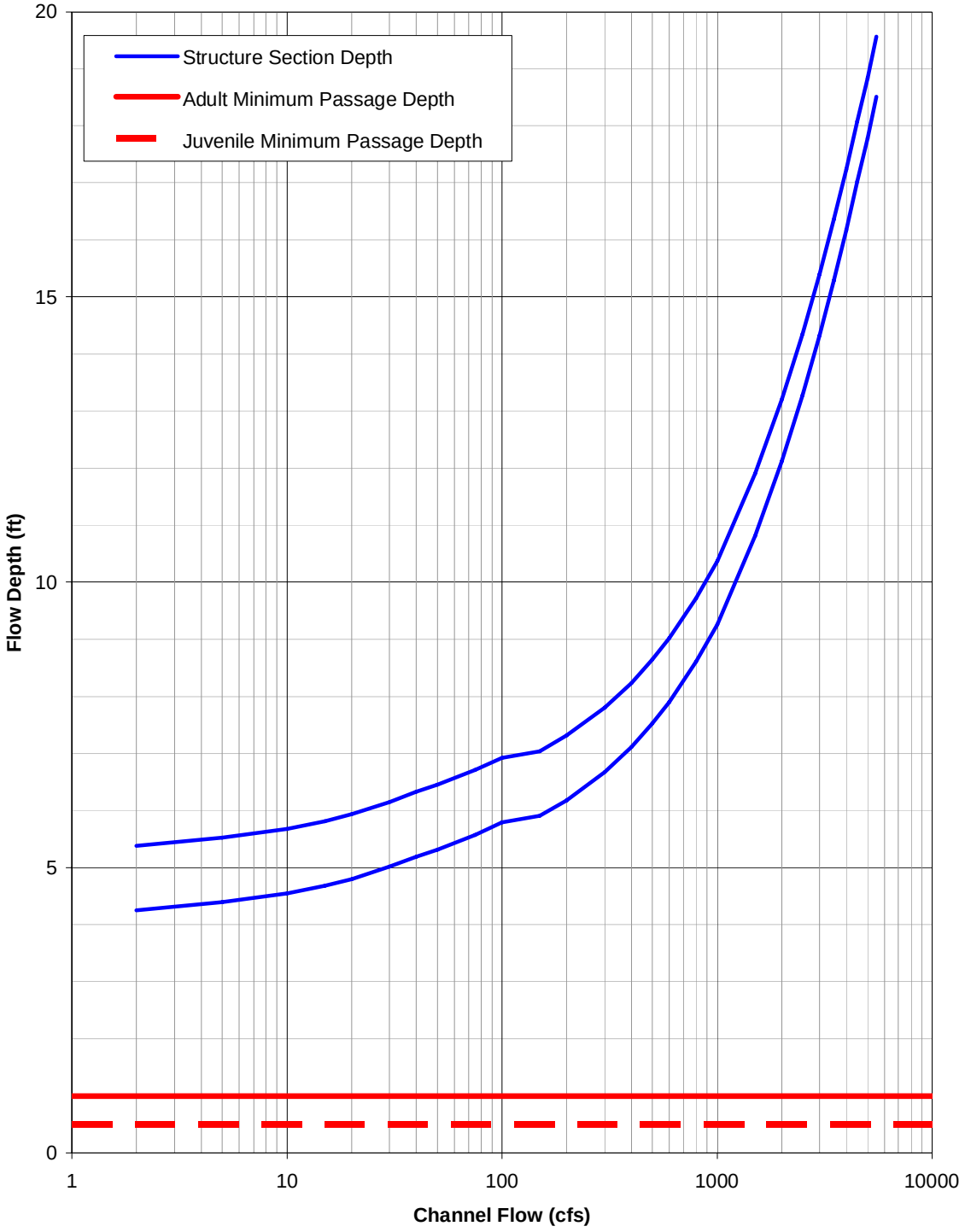


**Figure D-99. Fine Road Bridge – Depth rating curves for structure sections**



## *Gotelli Low-flow Road Crossing*

**Photo D-28. Gotelli Low-flow Road Crossing**

**Photo D-29. Gotelli Low-flow Road Crossing – Riprap at inlet**

**Photo D-30. Gotelli Low-flow Road Crossing – Riprap at outlet**

## Structure Details

| | |
|---|---|
| Name of Structure: | Gotelli Low-flow Road Crossing |
| Type of Structure: | Low-flow road crossing with culvert |
| Tributary: | Calaveras River |
| Number of sections: | upstream-4 downstream-7 structures-3 |
| Length of model: | upstream-195 ft downstream-265 ft |

## Description of Structure

A low flow crossing perpendicular to flow with a four foot CMP culvert placed at the channel invert. The channel is riprapped both up and downstream of the crossing with broken concrete. Not far downstream is a old bridge crossing with concrete apron that is also causing passage problems in the reach and backwatering the crossing.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.03-0.1 |
| Side slopes and banks: | 0.025-0.04 |
| Structure: | 0.025-0.03 |
| Riprap: | 0.05-0.1 |
| Culvert: | 0.03 |

*Calibration.* No calibration points exist for this model. It was determined that this simple structure could use similar model parameters from the calibrated McAllen Dam and Bridge, just upstream. Additionally, the surveyed and uncalibrated waterline, from the cross sectional survey used to build the model geometry, was used, with an estimated flow, to validate the model.

*Starting conditions used for the model.* The model was run with mixed flow conditions for all modeled flows, so boundary conditions for downstream and upstream were specified. For the water line flow the measured water surface was used at both boundaries. For all other flows, the upstream boundary was defined as normal depth slope of 0.001 and downstream boundary was based a normal depth slope between 0.000029 and 0.0003.

*Assumptions.* Primary assumptions include channel roughness that is characteristic of published values and experience in similar reaches. Using normal depth slope for boundary conditions converges to a realistic profile before and through the structure.

*Comments.* An abandoned bridge downstream of the culvert is likely causing an impediment to passage due to the slope of the apron and the channel slope below the apron.

## Performance Summary

Adult passage requires velocities ranging from 0 to 10 fps dependant on the length of the obstacle, and flow depths greater than 2 ft on riprap sections and 1 ft on the concrete structure or in typical channel sections. Velocities through the culvert remain below the maximum due to the culvert being backwatered by riprap. For the same reason, the depths in the culvert are above minimum depths for all flows. Velocities over the crossing also remain below the maximum. This is due to flows spreading out, above the low flow channel. Depths over the crossing stay below minimum depths until flows reach about 100 cfs. The riprap exhibits acceptable velocities throughout the range of flows however depths are only met above about 35cfs. The channel has no serious problems as expected except for depths when flows are low. Due to multiple flow paths through and over the structure, unimpeded passage can be found for flows above 35cfs.

Juvenile passage downstream does not present any velocity problems, however, minimum depths are 1/2 ft on the concrete structure or typical channel sections, and 1 ft on the riprap. Depths in the culvert exceed 0.5 ft for all flows while depths on the crossing exceed 0.5 ft for flows greater than 70 cfs. Riprap depths exceed 1ft for flows greater than 10 cfs. Channel depths become greater than 0.5 ft for flows greater than 10 cfs. Unimpeded juvenile passage for the Gotelli Low-flow Crossing are realized for flows greater than 10 cfs.

**Figure D-100. Cross section locations for Gotelli Low-flow Road Crossing HEC-RAS model**

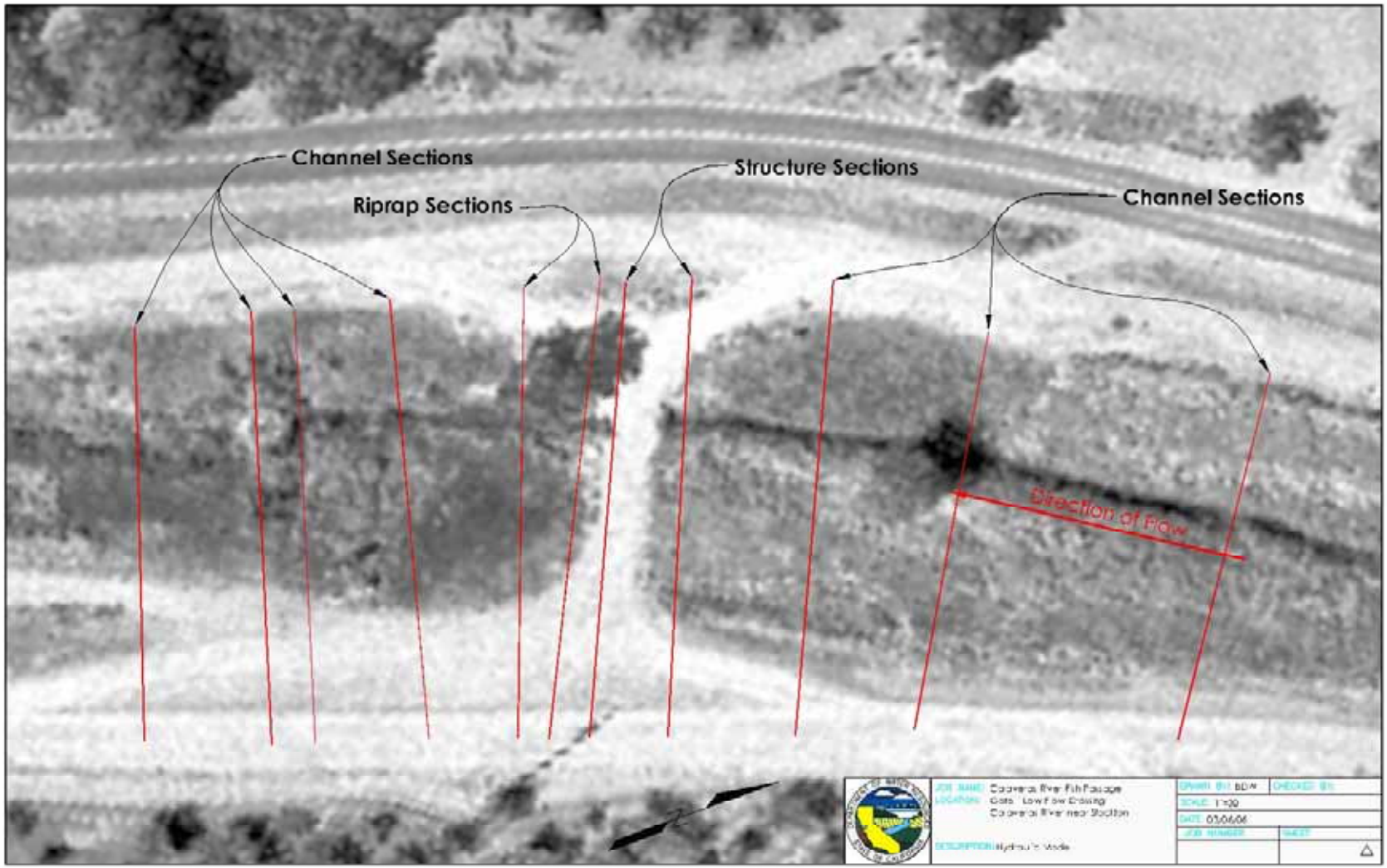


**Figure D-101. Gotelli Low-flow Road Crossing – Relationship of length to maximum velocity**

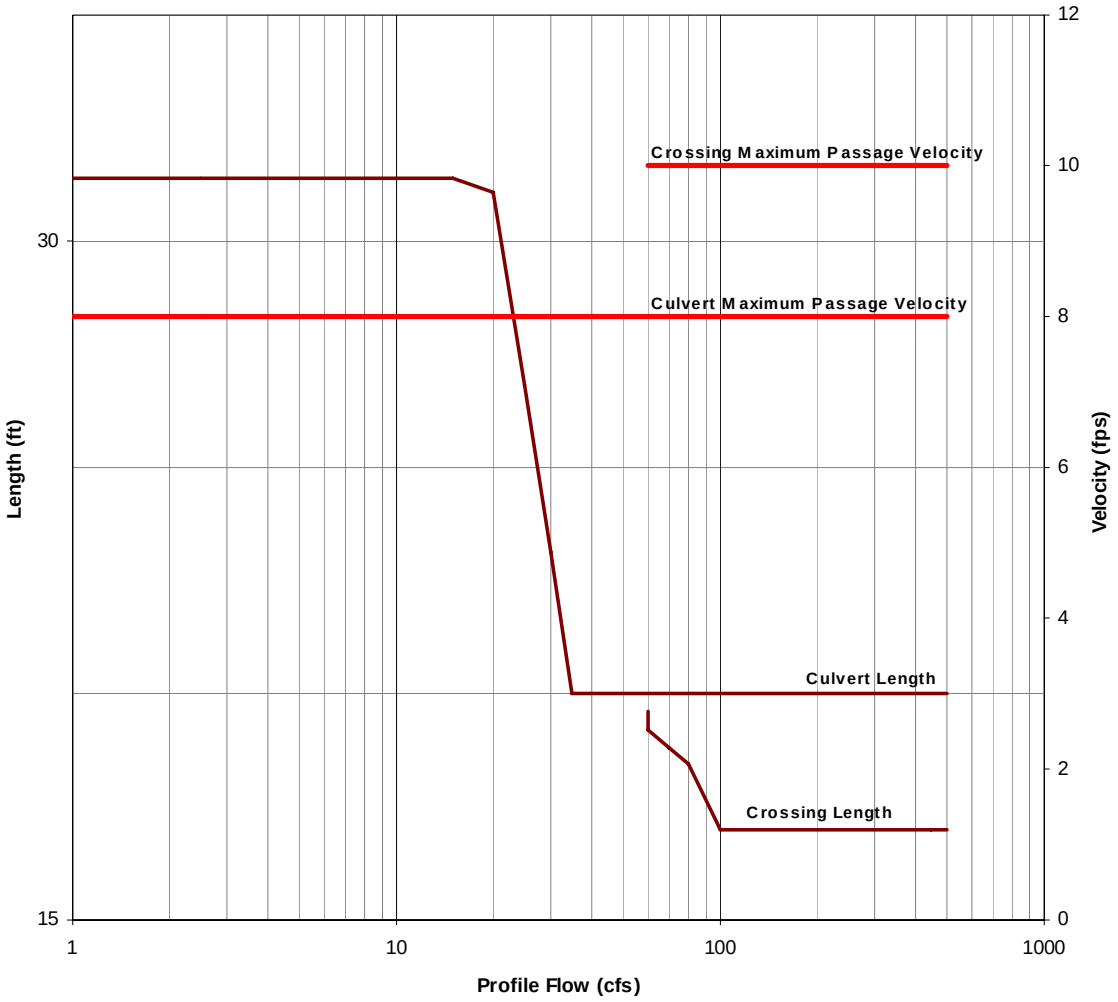


**Figure D-102. Gotelli Low-flow Road Crossing – Velocity rating curves for channel sections**

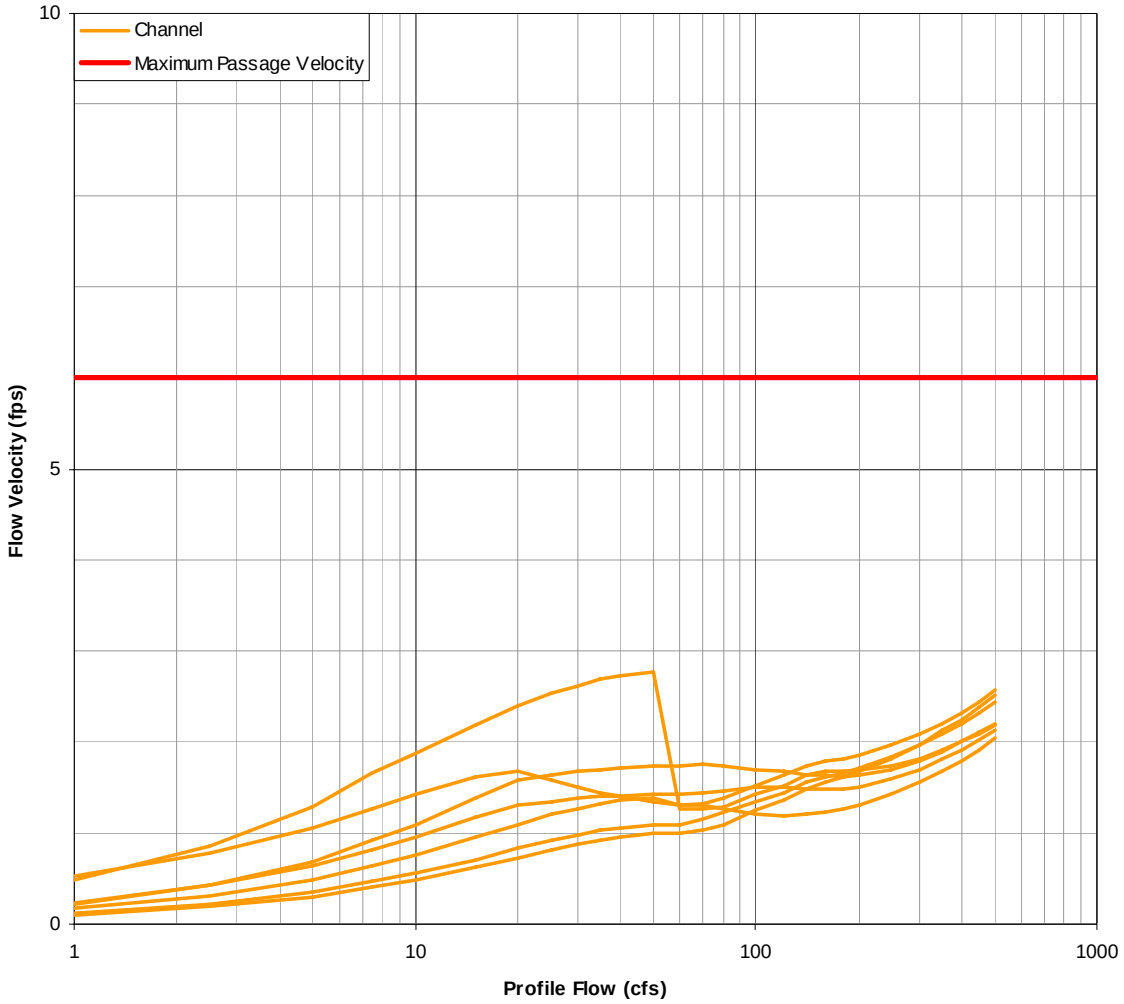


**Figure D-103. Gotelli Low-flow Road Crossing – Depth rating curves for channel sections**

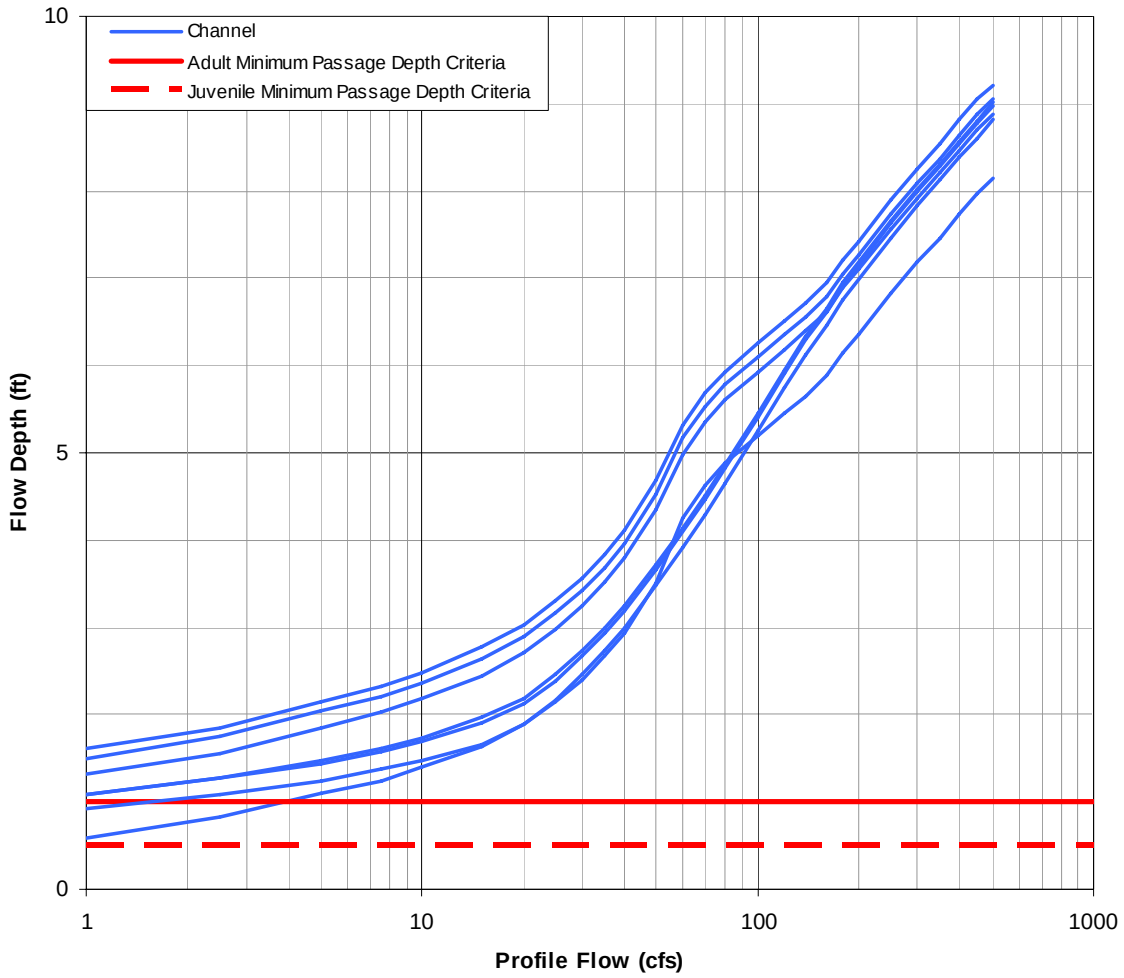


**Figure D-104. Gotelli Low-flow Road Crossing – Velocity rating curves for riprap**

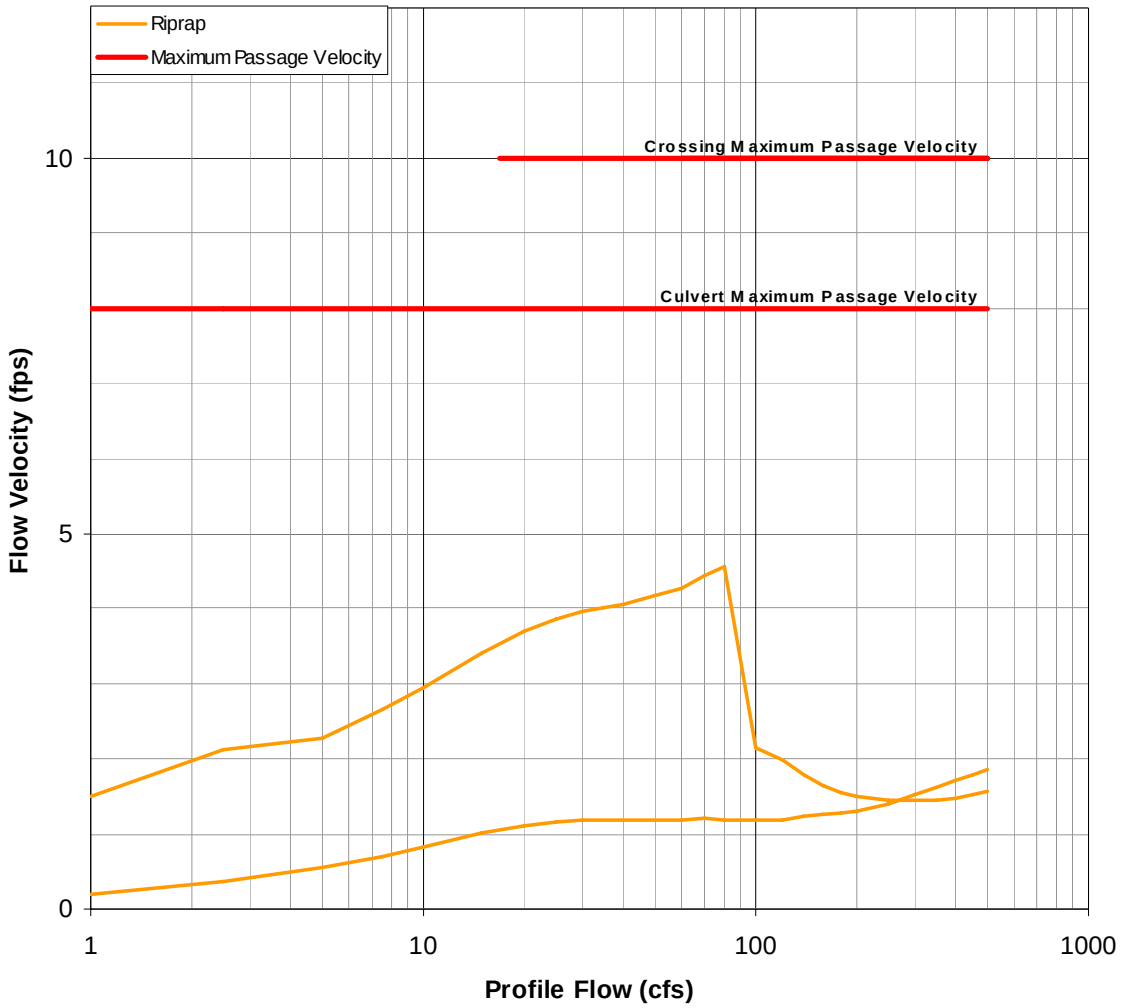


**Figure D-105. Gotelli Low-flow Road Crossing – Depth rating curves for riprap**

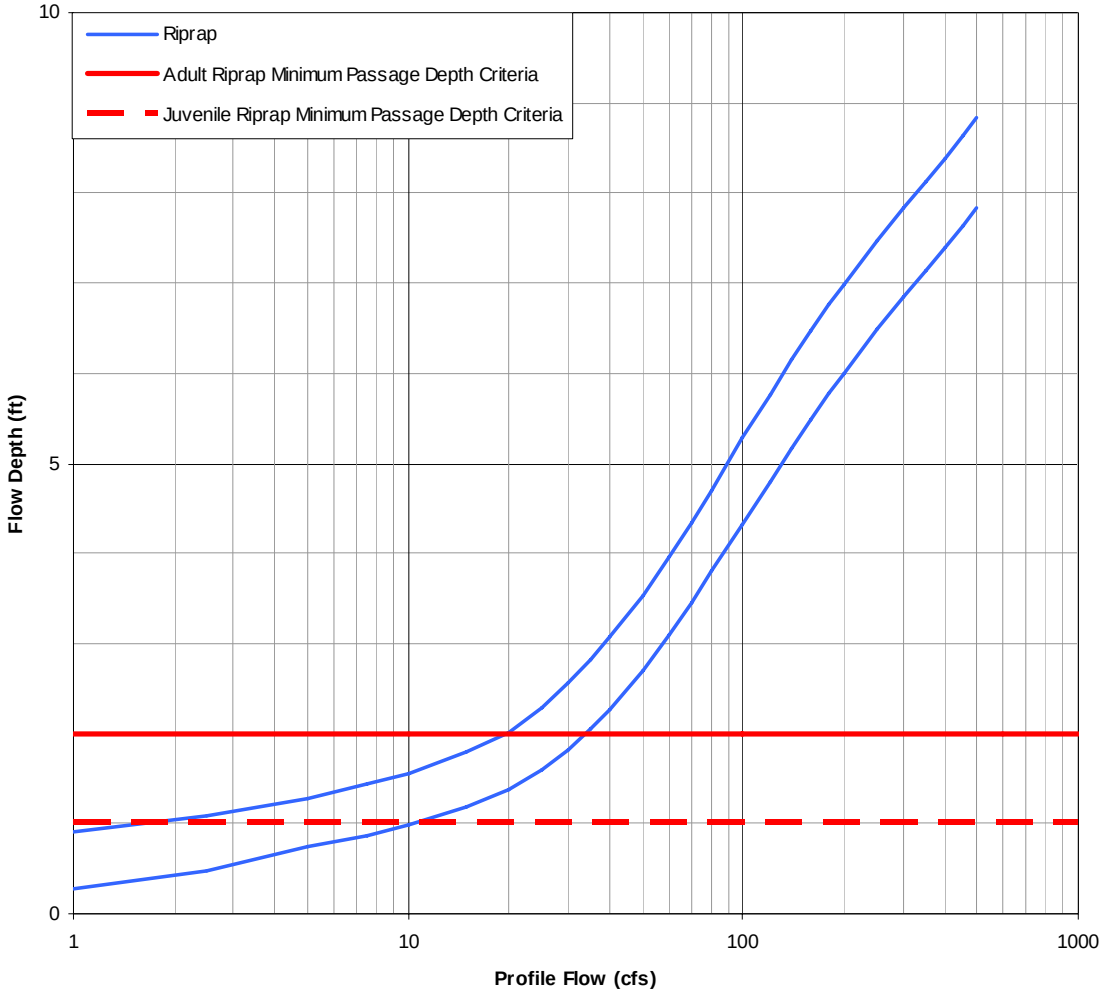


**Figure D-106. Gotelli Low-flow Road Crossing – Velocity rating curves for structure components**

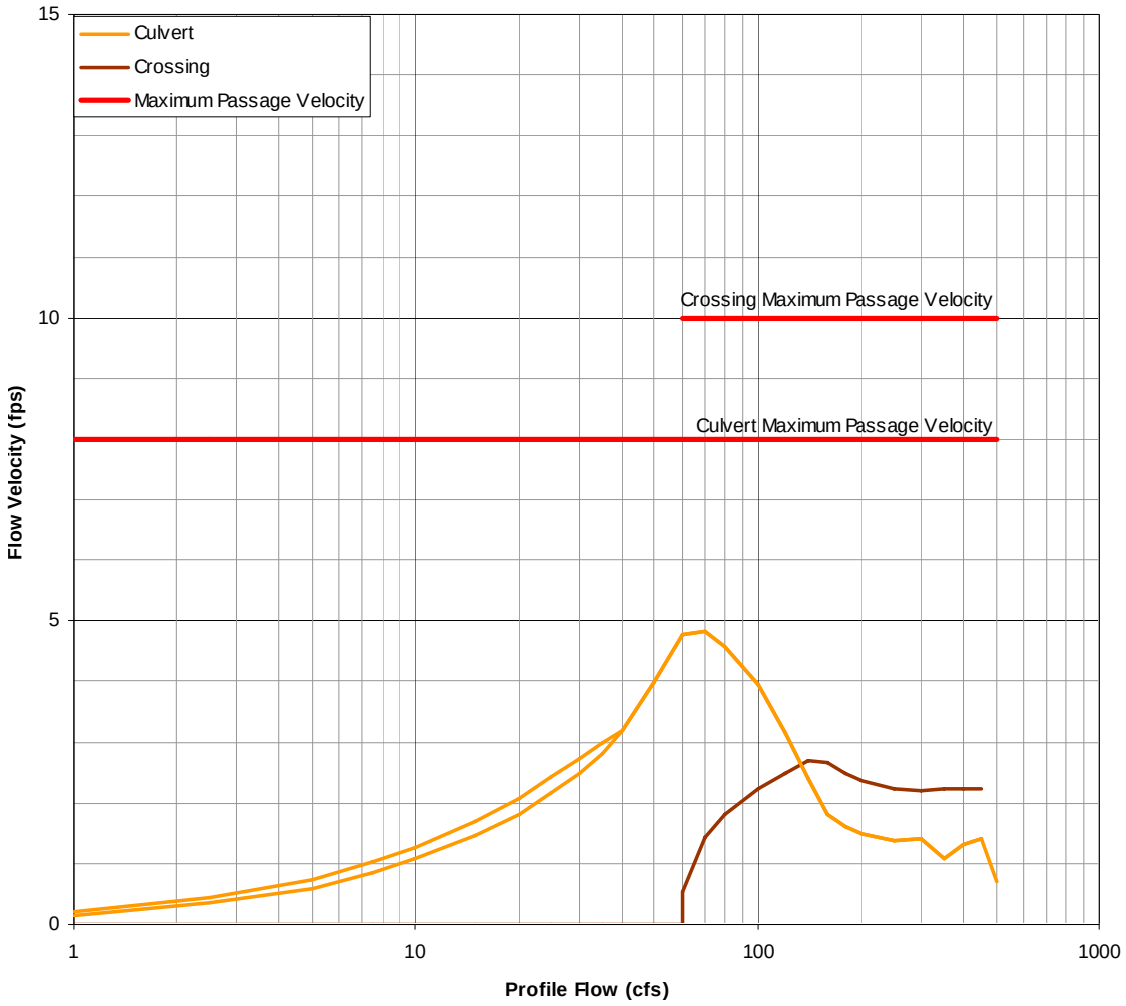
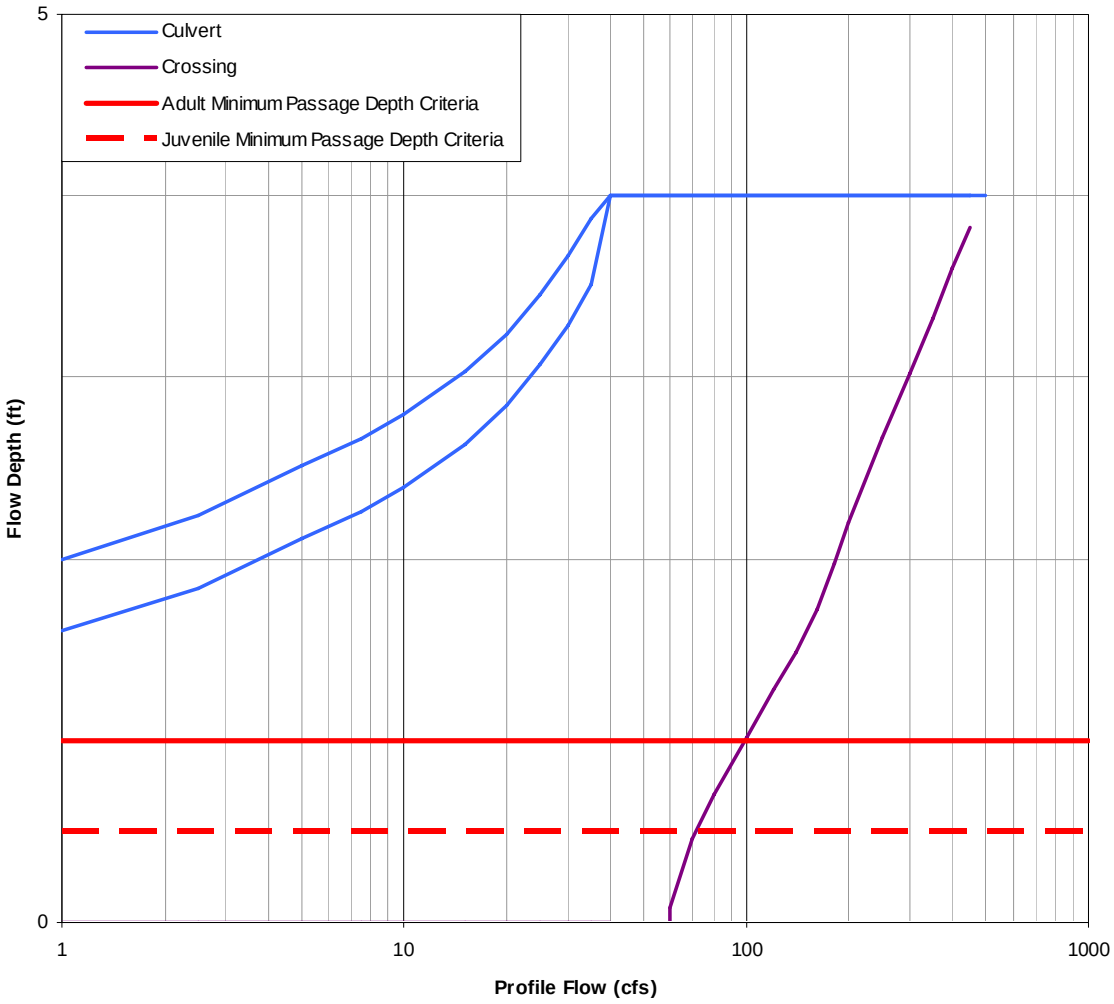


**Figure D-107. Gotelli Low-flow Road Crossing – Depth rating curves for structure component**



## *McAllen Road Bridge*

**Photo D-31. McAllen Road Bridge from the upstream side**

**Photo D-32. McAllen Road Bridge channel under and downstream of bridge**

## Structure Details

| | | | |
|---|---|---|---|
| Name of Structure: | McAllen Road Bridge | | |
| Type of Structure: | Bridge | | |
| Tributary: | Calaveras River | | |
| Number of sections: | upstream-3 | downstream-4 | structures-2 |
| Length of model: | upstream-295 ft | downstream-235 ft | |

*Description of structure.* The structure is a 2 lane road bridge spanning bank to bank and resting on eight cylindrical piers located in two sets of 4, making 3 spans. The low flow channel under the bridge consists of natural substrate entirely covered in riprap. Upstream of the bridge the riprap continues over the next 15 ft to McAllen flashboard dam.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.025-0.12 |
| Side Slopes and Banks: | 0.03-0.06 |
| Rip-rap: | 0.06-0.12 |

*Calibration*

| | | | |
|---|---|---|---|
| Number of flows: | 2 | | |
| 1. Flow: | 12.6 cfs | Survey method: | Autolevel |
| Comments: Flow measurement using current meter at site. | | | |
| 2. Flow: | 24.5 cfs | Survey method: | Autolevel |
| Comments: | Flow measurement using current meter at site. | | |

*Starting conditions used for the model.*

Starting Condition on Flow 1: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 2: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

*Assumptions.* Bridge deck dimensions were approximated from photographic analysis and bridge deck elevations were extrapolated from survey data. Structure starts upstream just below the flashboard dam and continues under the bridge to below the riprap.

## Performance Summary

Riprap in the channel through this reach is extensive, requiring using riprap depth criteria for bridge sections. Channel sections upstream of the bridge also have riprap lining and are considered as part of the bridge structure included in the riprap curves.

Adult requirements indicate velocities at the bridge are below maximums at all flow conditions however, due to riprap lining under the bridge, acceptable depths are met at flows above 35 cfs. Riprap sections both up and downstream of the bridge don't show problems with velocity but show problems with depth at flows below 40 cfs. Channel section velocities remain below maximum velocities at all flows and channel depths are above minimum depths for flows above 5 cfs. These constraints indicate that adult passage is unimpaired at flows greater than 40 cfs.

Juvenile requirements show depths greater than 1 ft on the bridge sections with flows greater than 8 cfs, while other riprap sections indicate 1 ft depth is exceeded for flows greater than 9 cfs. Channel depths exceed ½ ft for flows greater than 1 cfs indicating the greatest obstacle for McAllen Bridge is the riprap, requiring 9 cfs for unimpaired juvenile passage.

**Figure D-108. Cross section locations for McAllen Road Bridge HEC-RAS model**

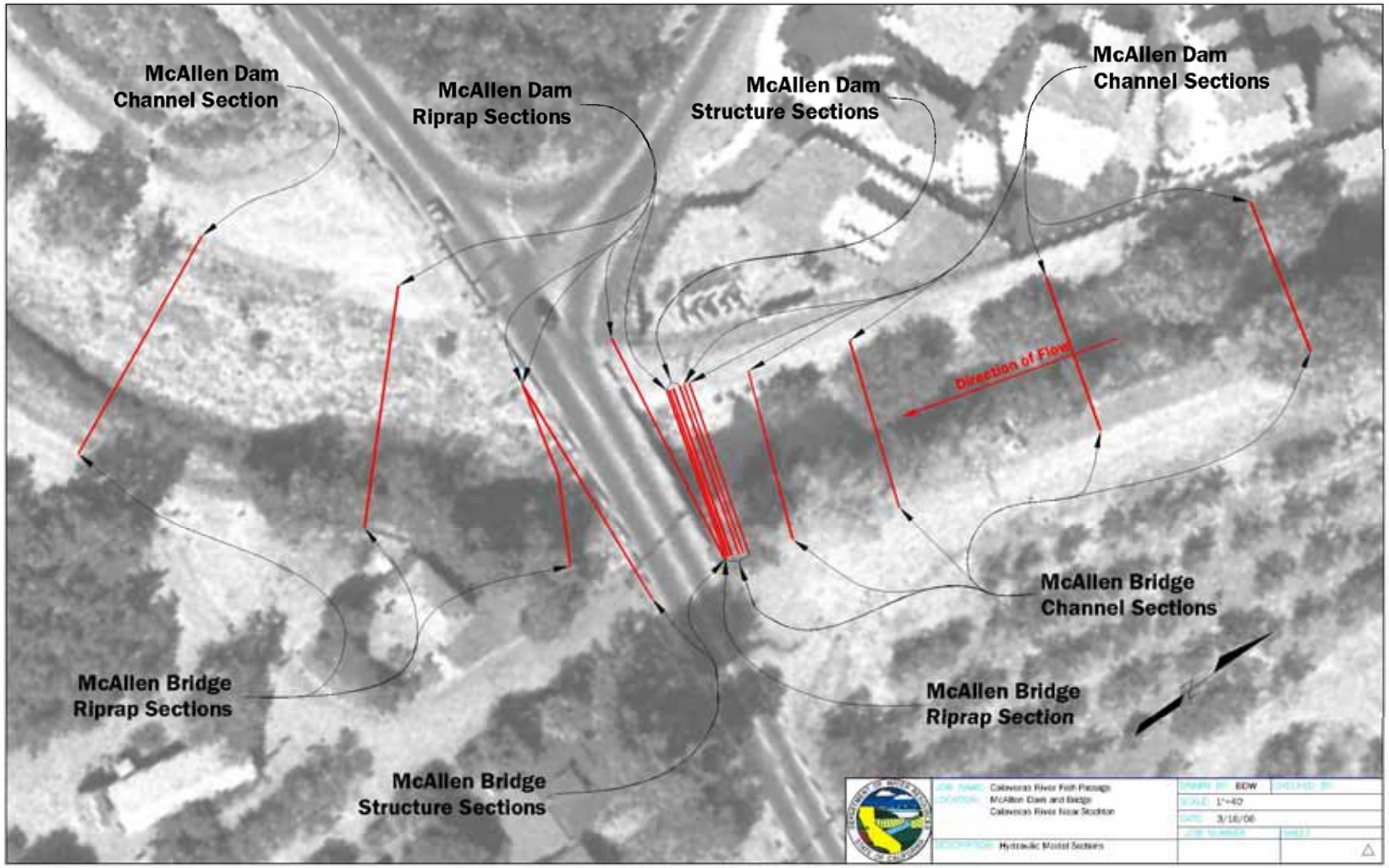


**Figure D-109. McAllen Road Bridge – Relationship of length to maximum velocity**

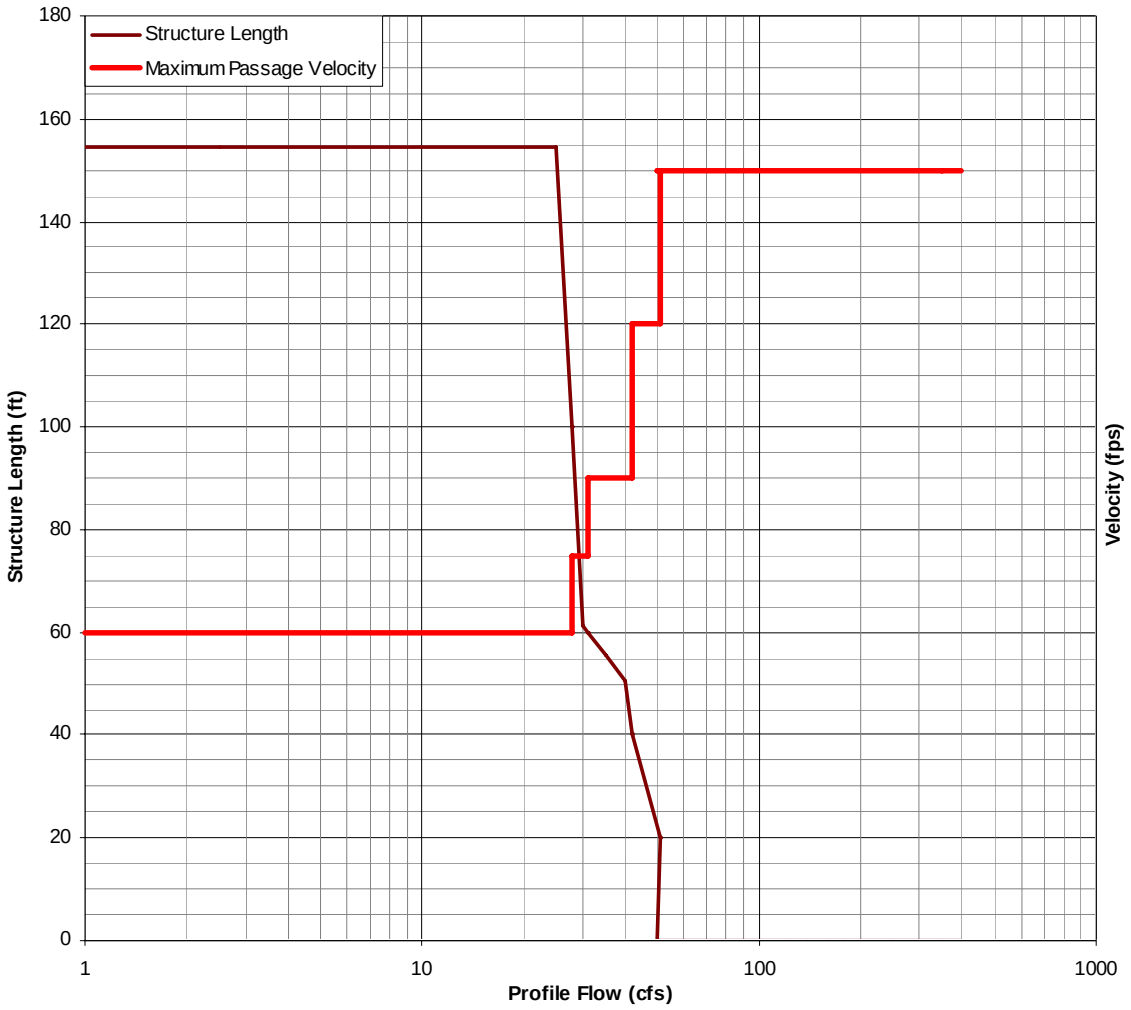


**Figure D-110. McAllen Road Bridge – Velocity rating curves for channel sections**

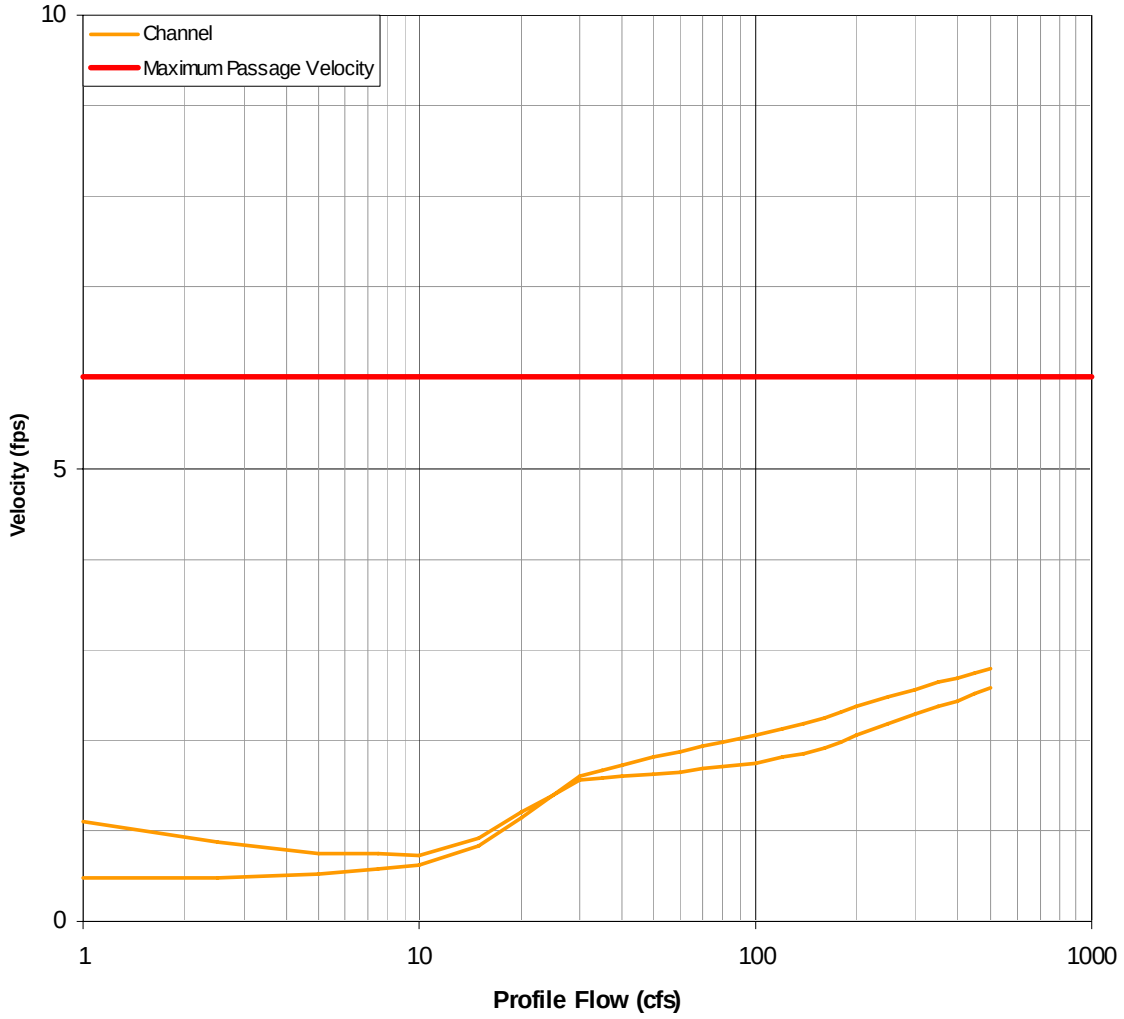


**Figure D-111. McAllen Road Bridge – Depth rating curves for channel sections**

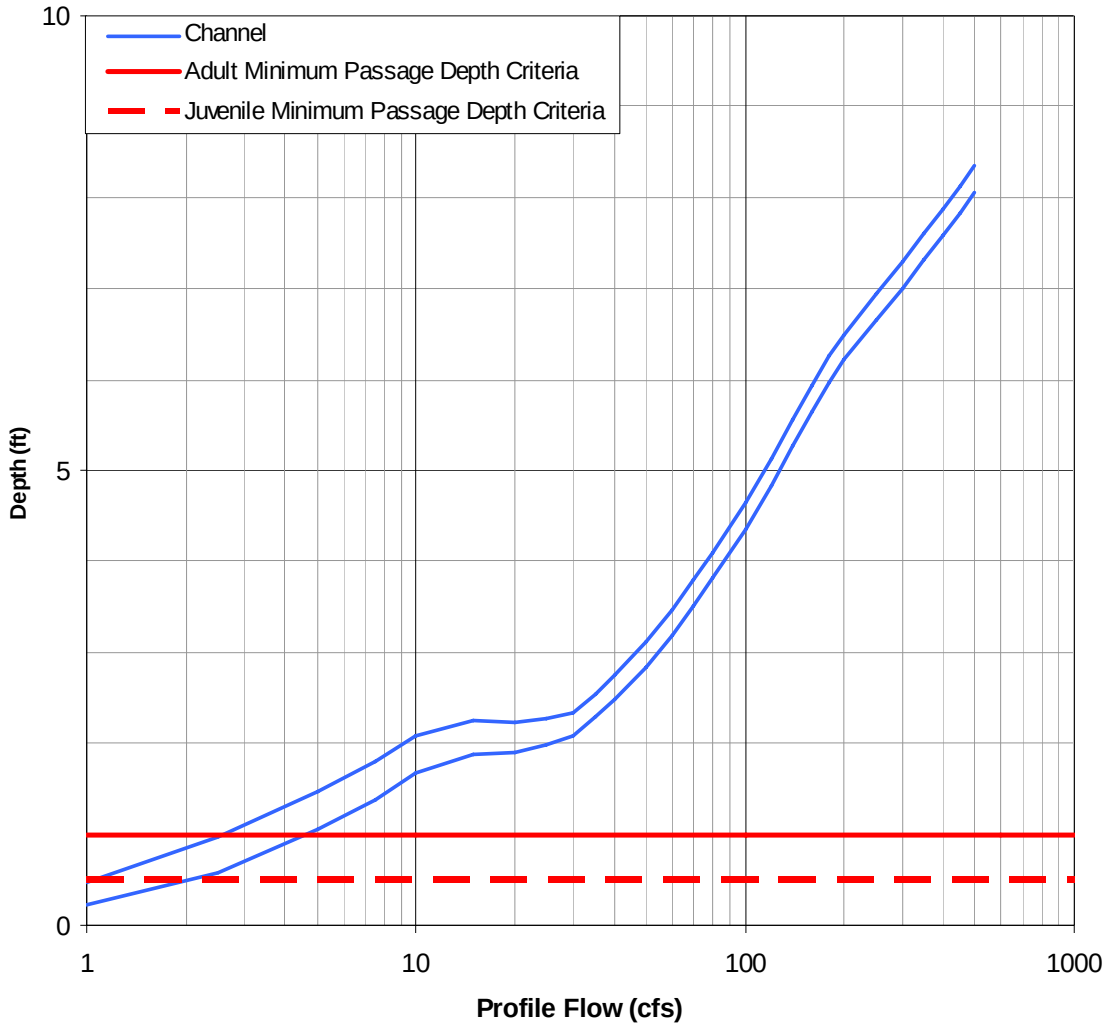


**Figure D-112. McAllen Road Bridge – Velocity rating curves for riprap sections**

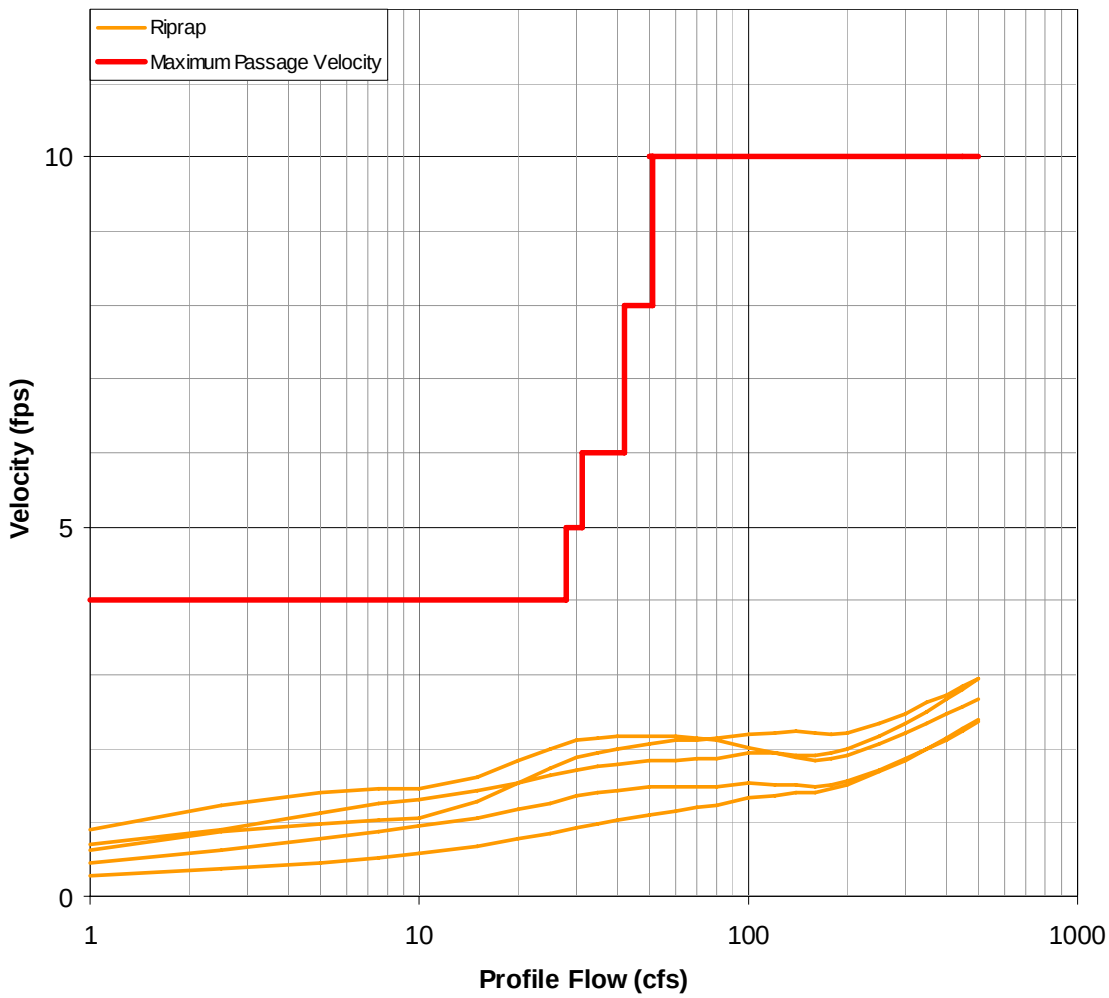


**Figure D-113. McAllen Road Bridge – Depth rating curves for riprap sections**

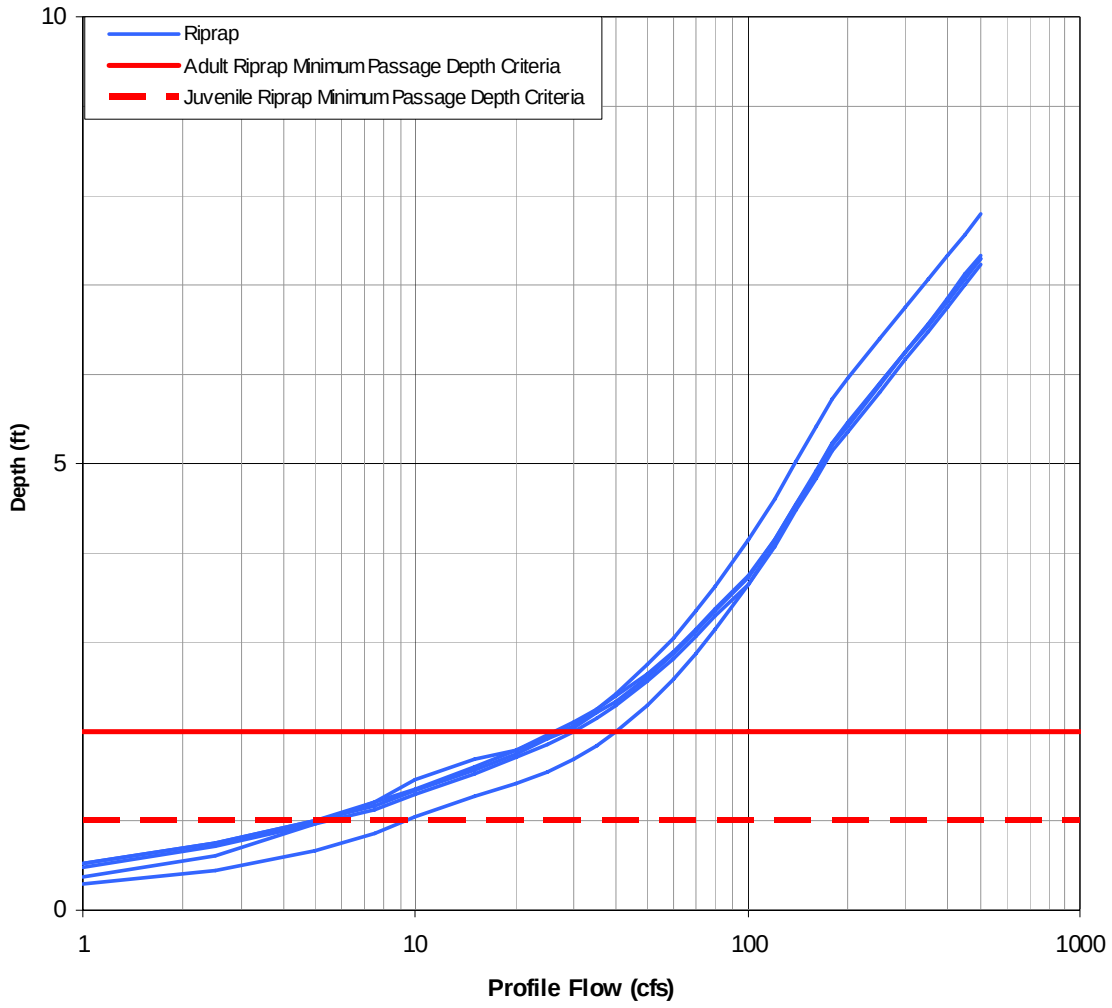


**Figure D-114. McAllen Road Bridge – Velocity rating curves for structure sections**

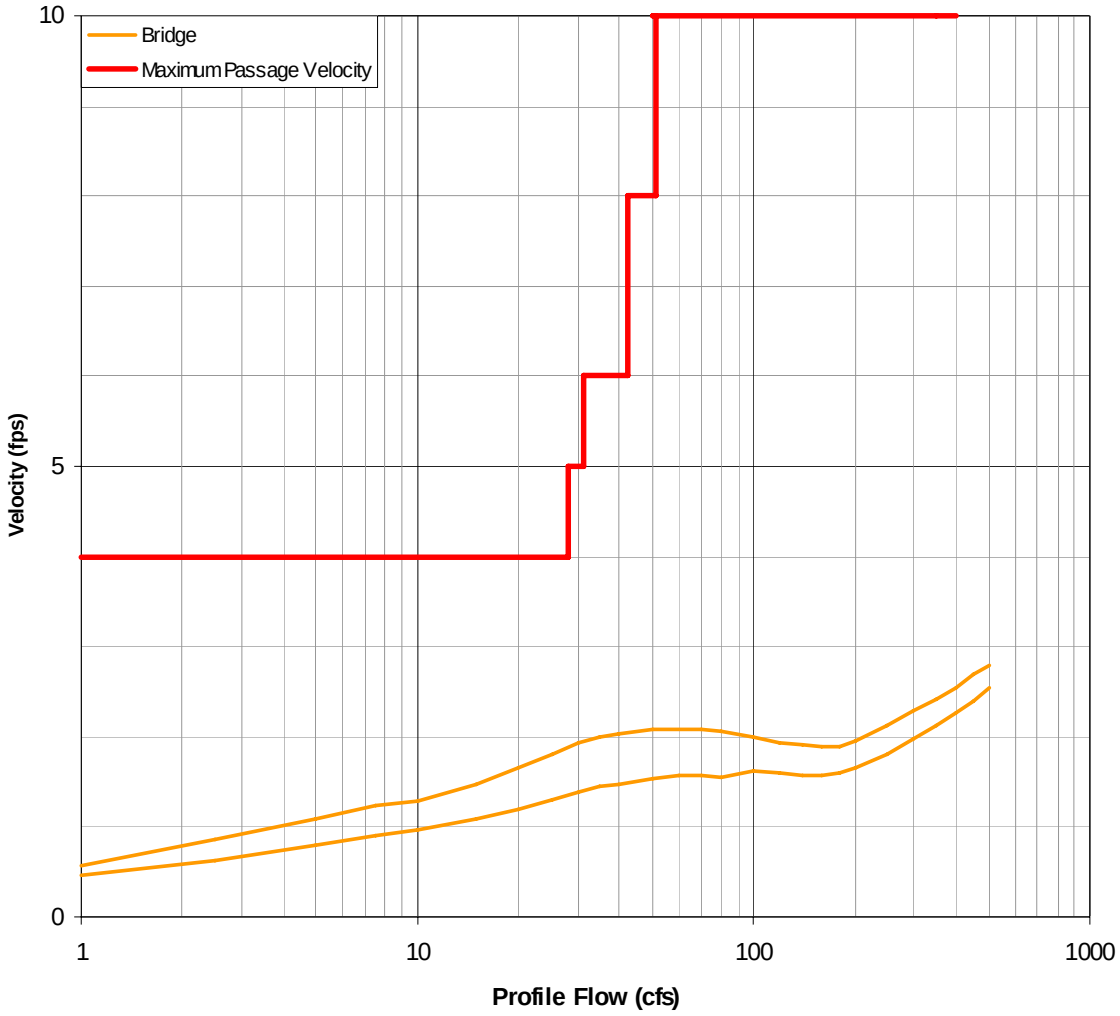
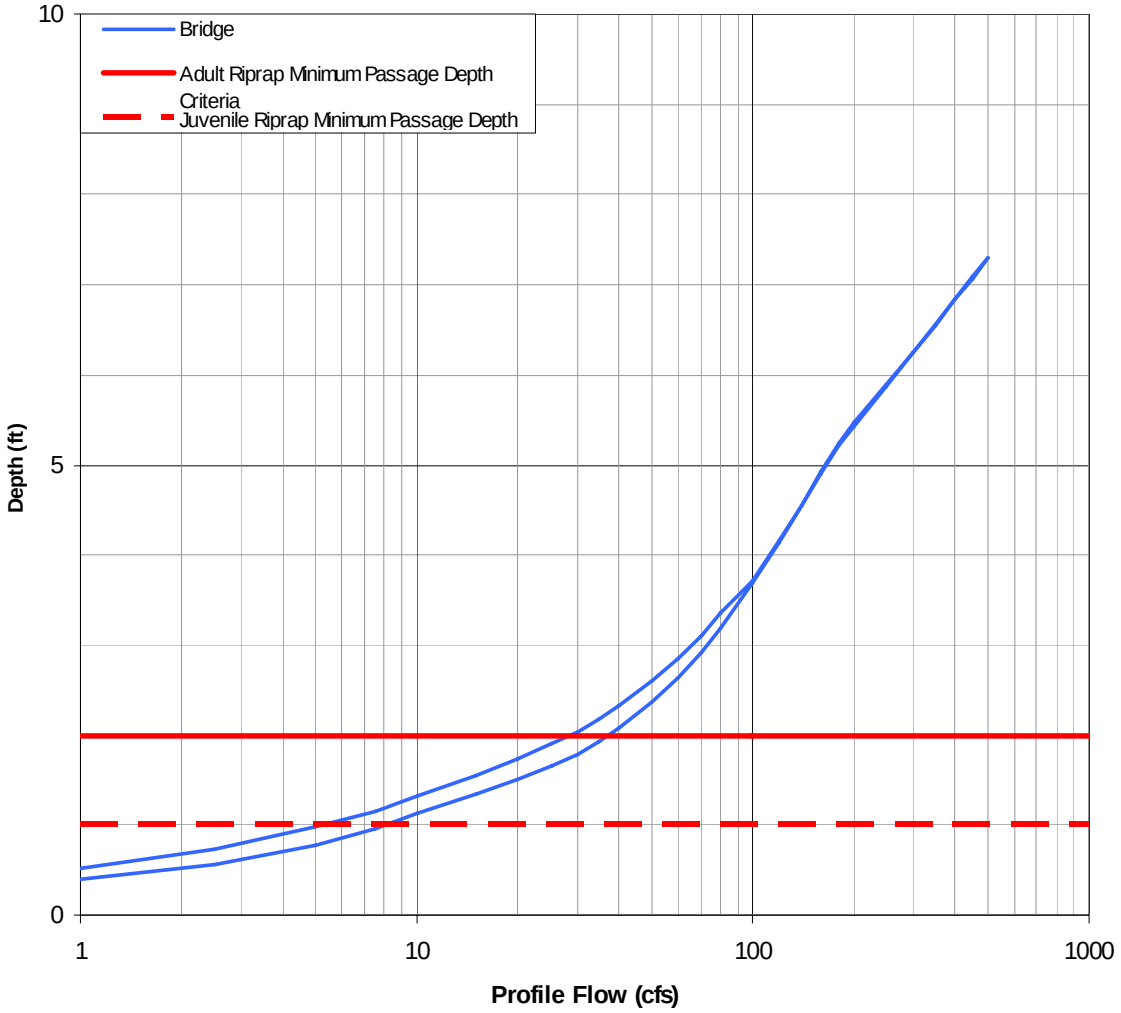


**Figure D-115. McAllen Road Bridge – Depth rating curves for structure sections**



## *McAllen Flashboard Dam*

**Photo D-33. McAllen Bridge and flashboard dam apron without flashboards**

**Photo D-34. McAllen Flashboard Dam without boards in place**

**Photo D-35. McAllen Flashboard Dam - Upstream side proximity of bridge and culverts**

## Structure Details

| | |
|---|---|
| Name of structure: | McAllen Flashboard Dam |
| Type of structure: | Flashboard Dam |
| Tributary: | Calaveras River |
| Number of sections: | upstream-6 downstream-6 structures-4 |
| Length of model: | upstream-280 ft downstream-280 ft |

*Description of structure:* McAllen Flashboard Dam consists of a concrete apron that is covered with riprap and seasonally maintained flashboard dam. The channel downstream of the dam is lined with riprap for a distance of approximately 150 ft. Riprap also lines the channel upstream of the dam providing scour protection from four, 3 ft culverts that empty into the channel.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.025-0.12 |
| Side Slopes and Banks: | 0.03-0.06 |
| Structure: | 0.015-0.06 |
| Rip-rap: | 0.06-0.12 |

*Calibration*

| | |
|---|---|
| Number of flows: | 2 |
| 1. Flow: 12.6 cfs | Survey method: Autolevel |
| Comments: Flow measurement using current meter at site. | |
| 2. Flow: 24.5 cfs | Survey method: Autolevel |
| Comments: | Flow measurement using current meter at site. |

*Starting conditions used for the model.*

Starting Condition on Flow 1: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 2: Known WS was used on both boundaries. Elevations were determined from survey measurements in the field.

*Assumptions.* 24.5 cfs flow takes into account some flow entering the channel at a small side culvert, estimated to be 1 cfs or less. Rip rapped channel under the bridge is part of the riprap run out of the dam adding to the length of the structure.

*Comments.* Riprap lining upstream of apron is cemented in place and lines the right side up to the three ft culverts. The apron and riprap partially obscuring the apron is above the channel invert and causes a backwater condition upstream of the structure.

### Performance Summary

Adult passage velocities on the structure are below maximums at all flow conditions however, acceptable depths of 1 ft for non-riprapped sections are not met until flow is above 25 cfs. The riprap sections indicate velocities stay well below the maximum velocity. Depth is passable with values above 2 ft or when flows rise above 40 cfs. Channel section velocities remain below maximum velocities at all flows and channel depths become greater than the 1 ft requirement for flows above 20 cfs. The models indicate McAllen Flashboard Dam allows for adult unimpaired passage for flows greater than 40 cfs.

Juvenile passage depths greater than 1 ft on the structure are realized for flows greater than 15 cfs. Depths on the riprap exceed 1 ft for flows greater than 9 cfs. Typical channel sections exhibit depths greater than 12 ft for flows in excess of 5 cfs. Therefore unimpaired passage for juveniles on McAllen Flashboard Dam will require flows greater than 15 cfs.

**Figure D-116. Cross section locations for McAllen Flashboard Dam HEC-RAS model**

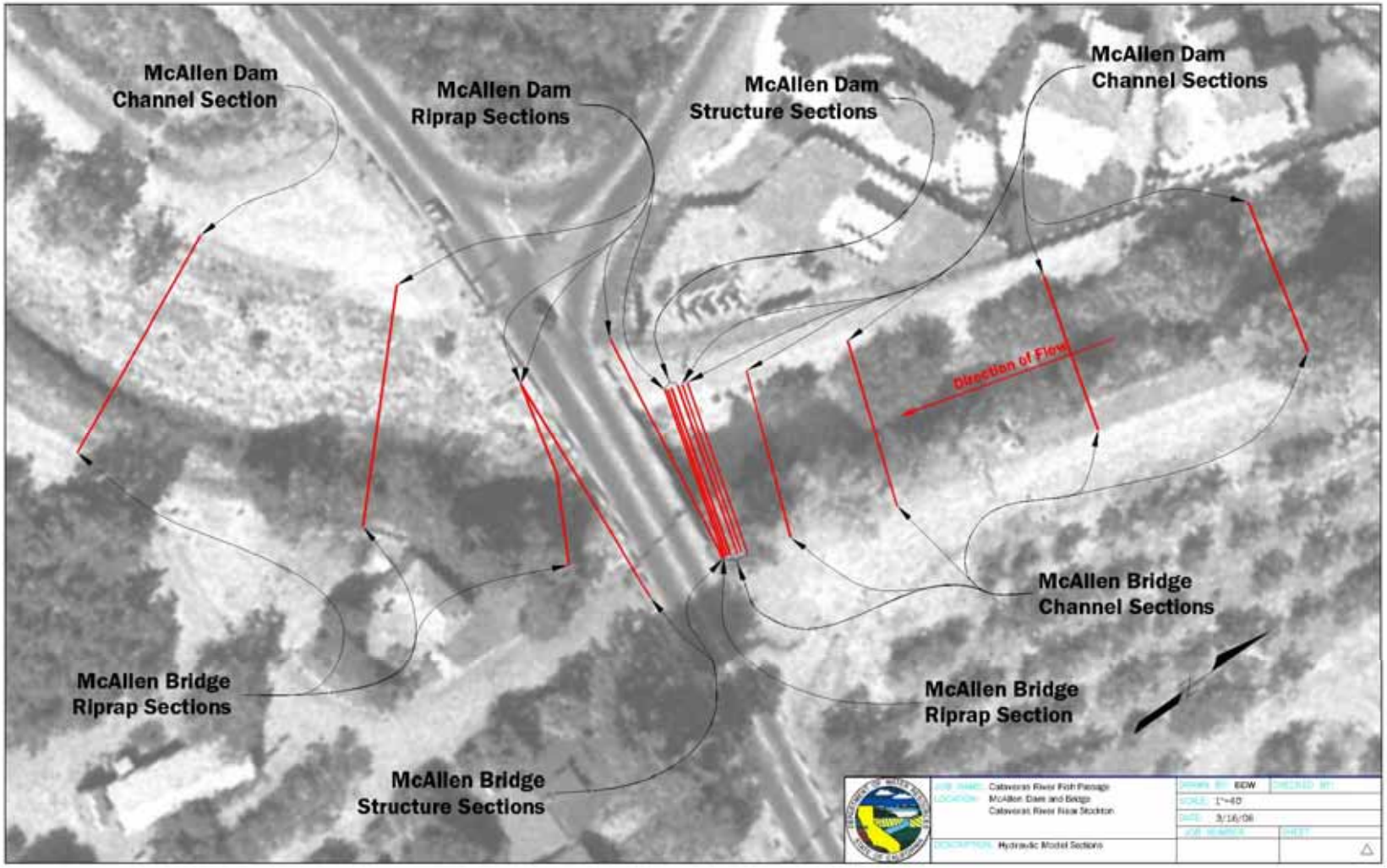


**Figure D-117. McAllen Flashboard Dam – Relationship of length to maximum velocity**

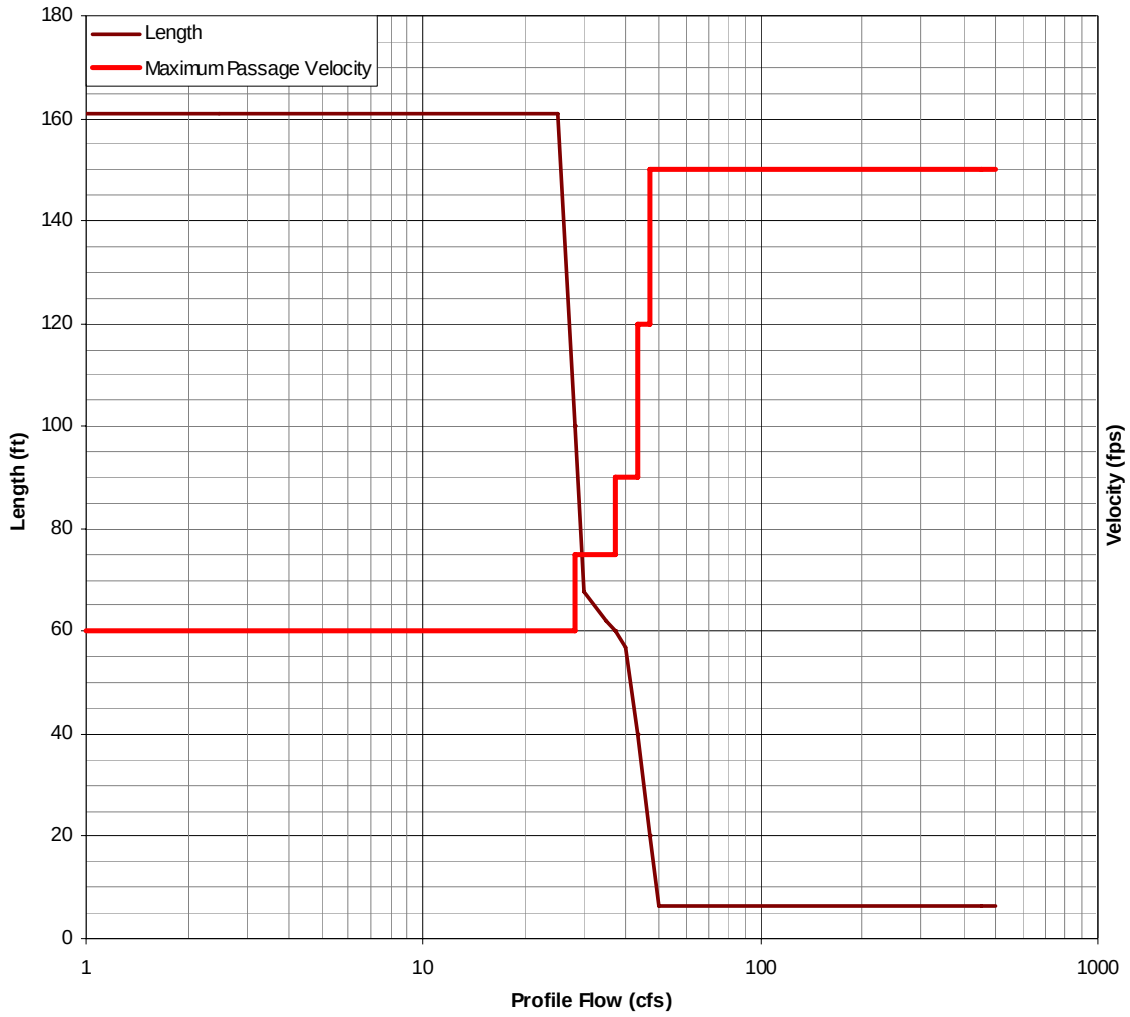


**Figure D-118. McAllen Flashboard Dam – Velocity rating curves for channel sections**

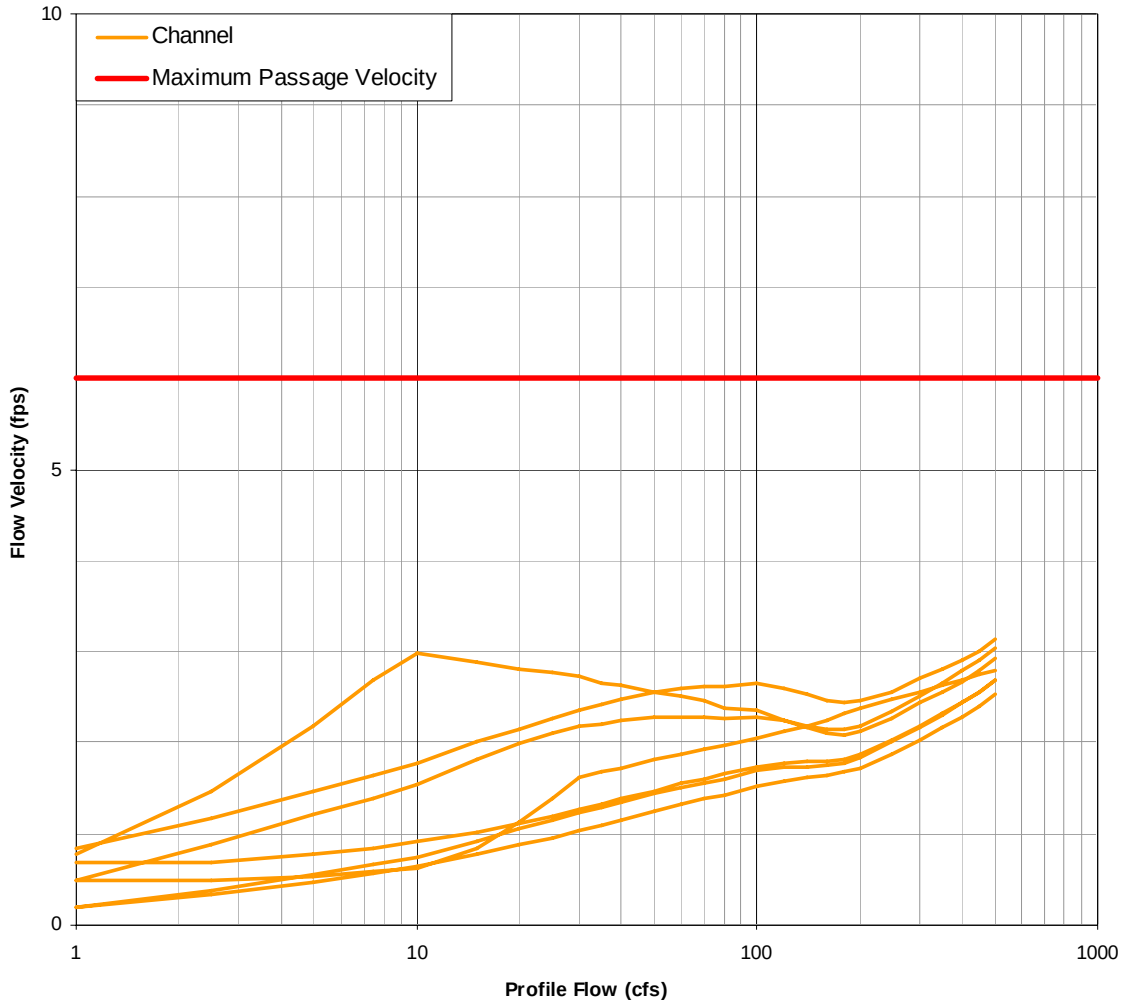


**Figure D-119. McAllen Flashboard Dam – Depth rating curves for channel sections**

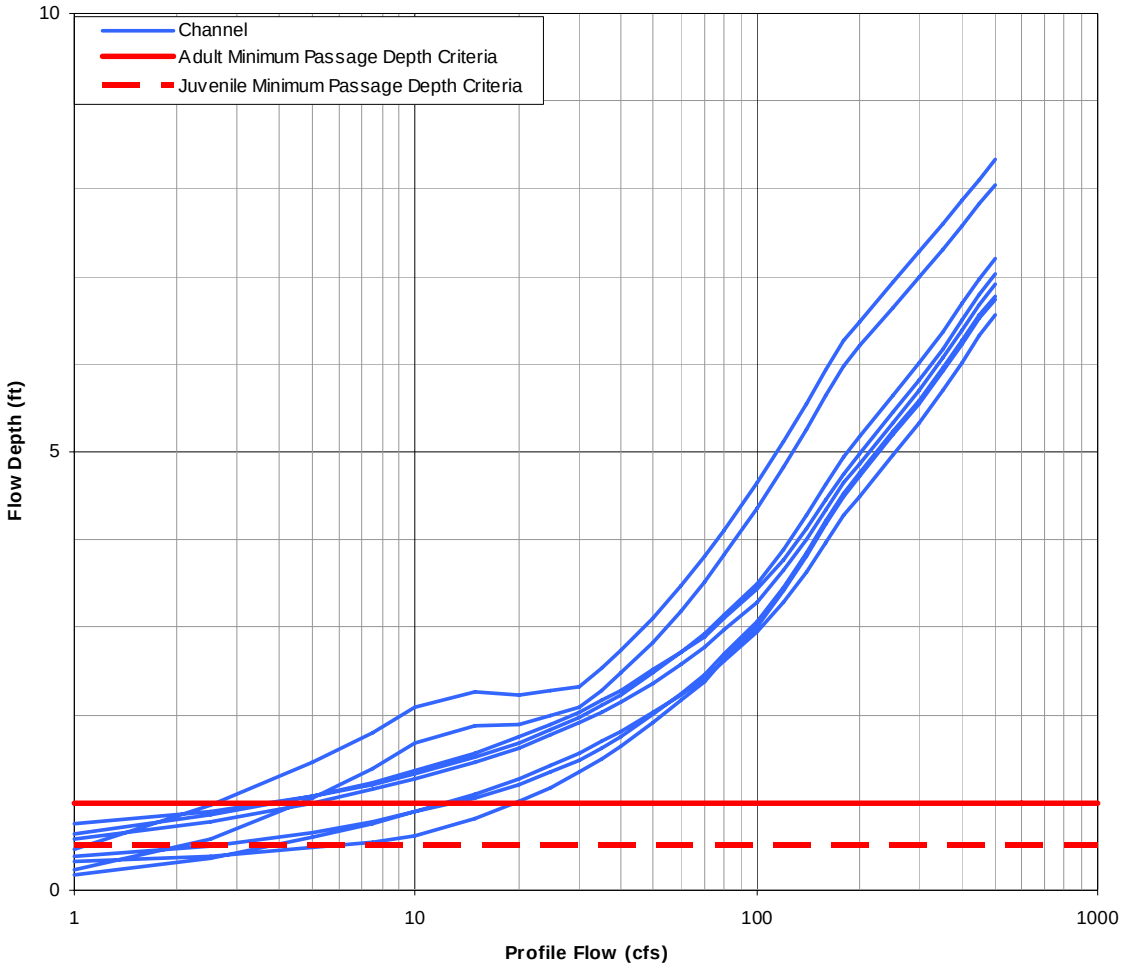


**Figure D-120. McAllen Flashboard Dam – Velocity rating curves for riprap sections**

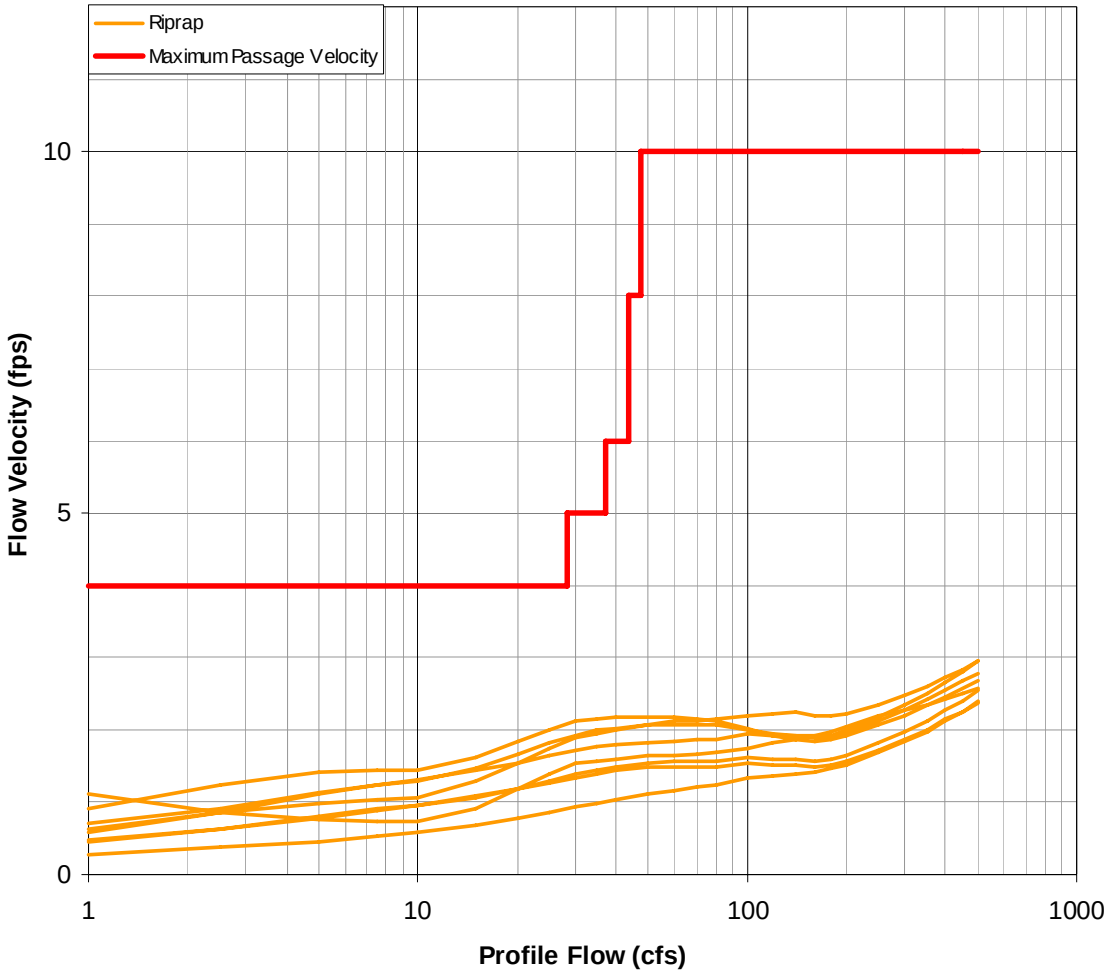


**Figure D-121. McAllen Flashboard Dam – Depth rating curves for riprap sections**

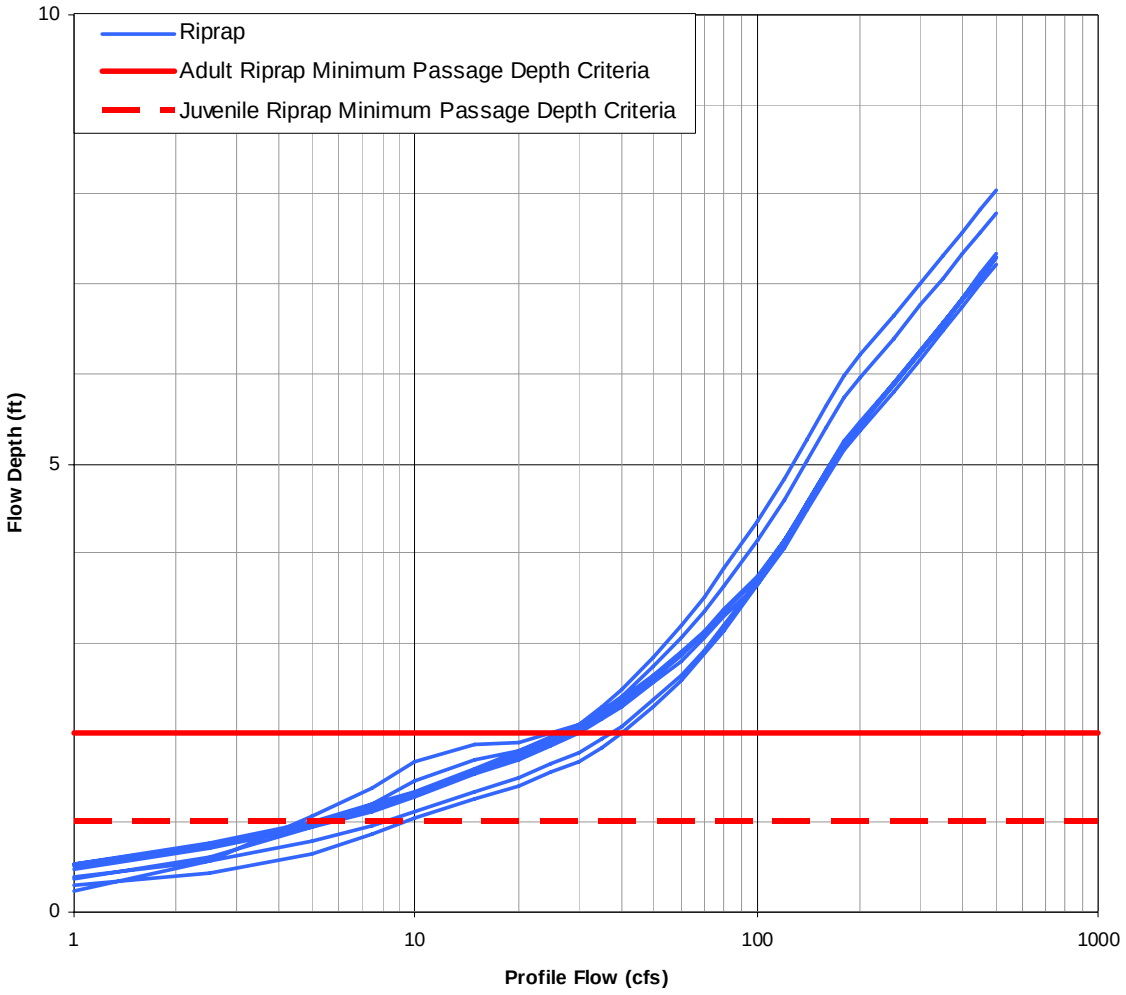


**Figure D-122. McAllen Flashboard Dam – Velocity rating curves for structure components**

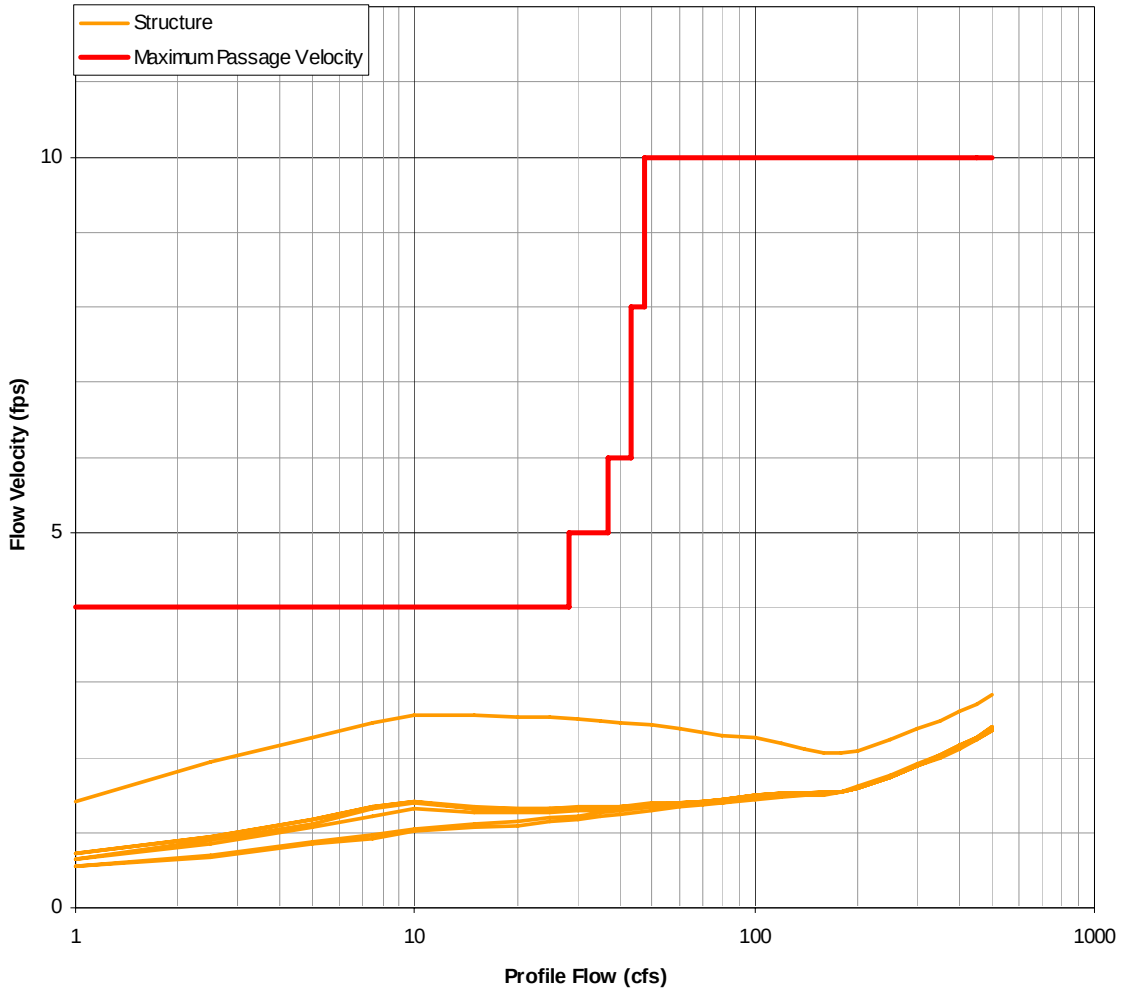
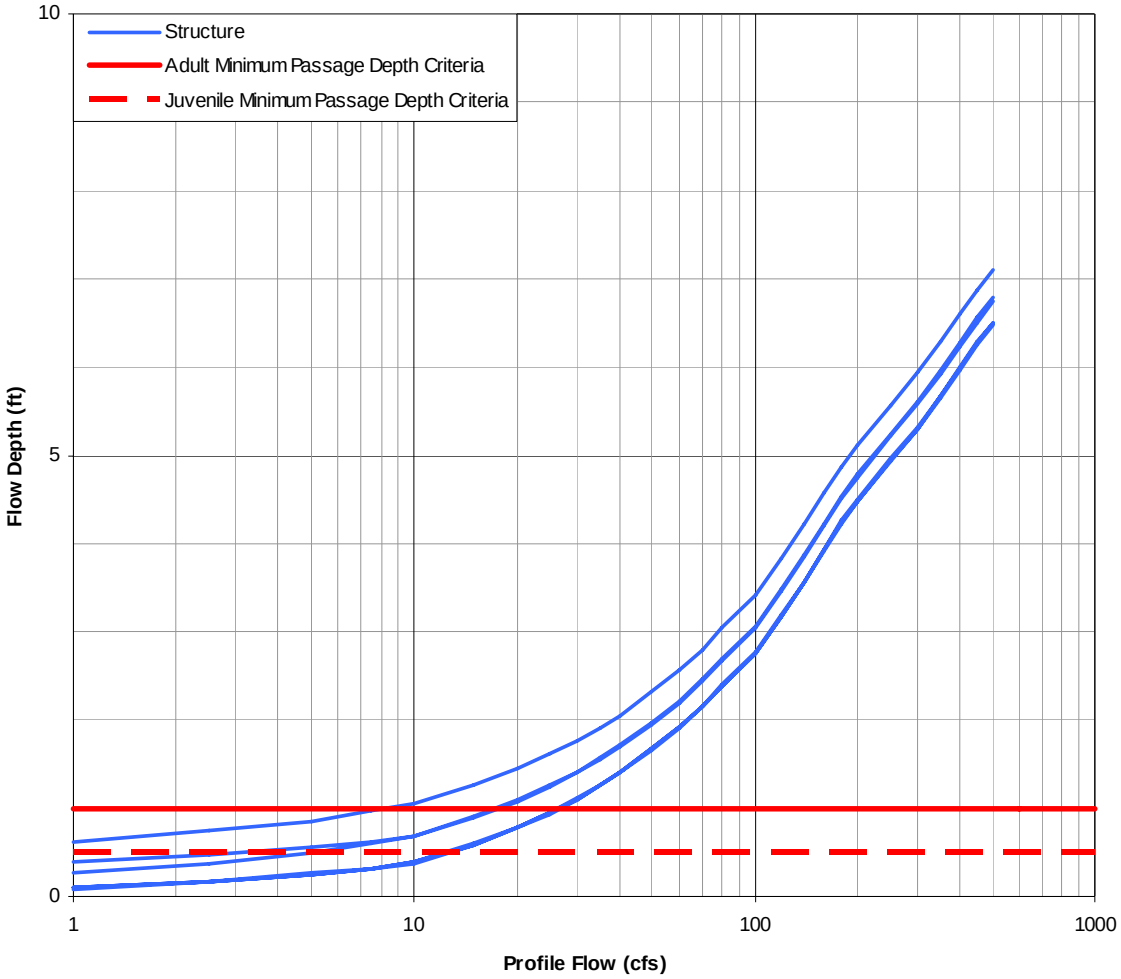


**Figure D-123. McAllen Flashboard Dam – Depth rating curves for structure components**



## *Cherryland Flashboard Dam*

**Photo D-36. Cherryland Flashboard Dam without boards in place**

**Photo D-37. Cherryland Flashboard Dam - 25 cfs**

## Structure Details

| | | | |
|---|---|---|---|
| Name of Structure: | Cherryland Flashboard Dam | | |
| Type of Structure: | Flashboard Dam | | |
| Tributary: | Calaveras River | | |
| Number of sections: | upstream-5 | downstream-7 | structures-5 |
| Length of model: | upstream-440 ft | downstream-350 ft | |

*Description of structure:* Cherryland Flashboard Dam consists of a concrete lined section of channel and a sloping, stepped apron that is seasonally fitted with a flashboard dam. Approximately 100 ft of channel downstream of the apron is lined with riprap.

## Model Summary

*Manning's 'n' values*

| | |
|---|---|
| Channel Bottom: | 0.025-0.03 |
| Side slopes and banks: | 0.027-0.08 |
| Structure: | 0.02-0.05 |
| Riprap: | 0.08-0.11 |

*Calibration*

| | | | |
|---|---|---|---|
| Number of flows: | 2 | | |
| 1. Flow: | 12.37 cfs | Survey method: | Autolevel |
| Comments: Flow measurement using current meter at site. | | | |
| 2. Flow: | 25.11 cfs | Survey method: | Autolevel |
| Comments: Flow measurement using current meter at site. | | | |

*Starting conditions used for the model*:

Starting Condition on Flow 1: Known WS elevation was used on both boundaries. Elevations were determined from survey measurements in the field.

Starting conditions on Flow 2: Known WS elevation was used on both boundaries. Elevations were determined from survey measurements in the field.

*Comments.* Low flow on the structure go sub grade on the downstream end of the structure. This is possible because of cracks and holes in the concrete invert in the structure and the riprap just below it.

### Performance Summary

Velocities on the structure are below maximums for adults, at all flows less than 15 cfs and greater than 30 cfs. Depths on the structure exceed 1 ft for flows above 40 cfs. The riprap curves indicate velocities are below the maximum velocity for all flows and the depth is greater than 2 ft for flows above 60 cfs. Channel section velocities remain below maximum velocities at all flows and channel depths become greater than 1 ft for flows above 20 cfs. In summary unimpaired passage to adults occurs at flows greater than 60 cfs.

Juvenile minimum passage depths on the structure exceed ½ foot with flows greater than 15 cfs. One foot minimum depth on riprap is also exceeded for flows 15 cfs. Channel depths exceed ½ ft for flows greater than 5 cfs. Juvenile unimpaired passage is indicated at Cherryland Flashboard Dam for flows greater than 15 cfs when depths on the riprap and structure are above minimums.

**Figure D-124. Cross section locations for Cherryland Flashboard Dam HEC-RAS model**

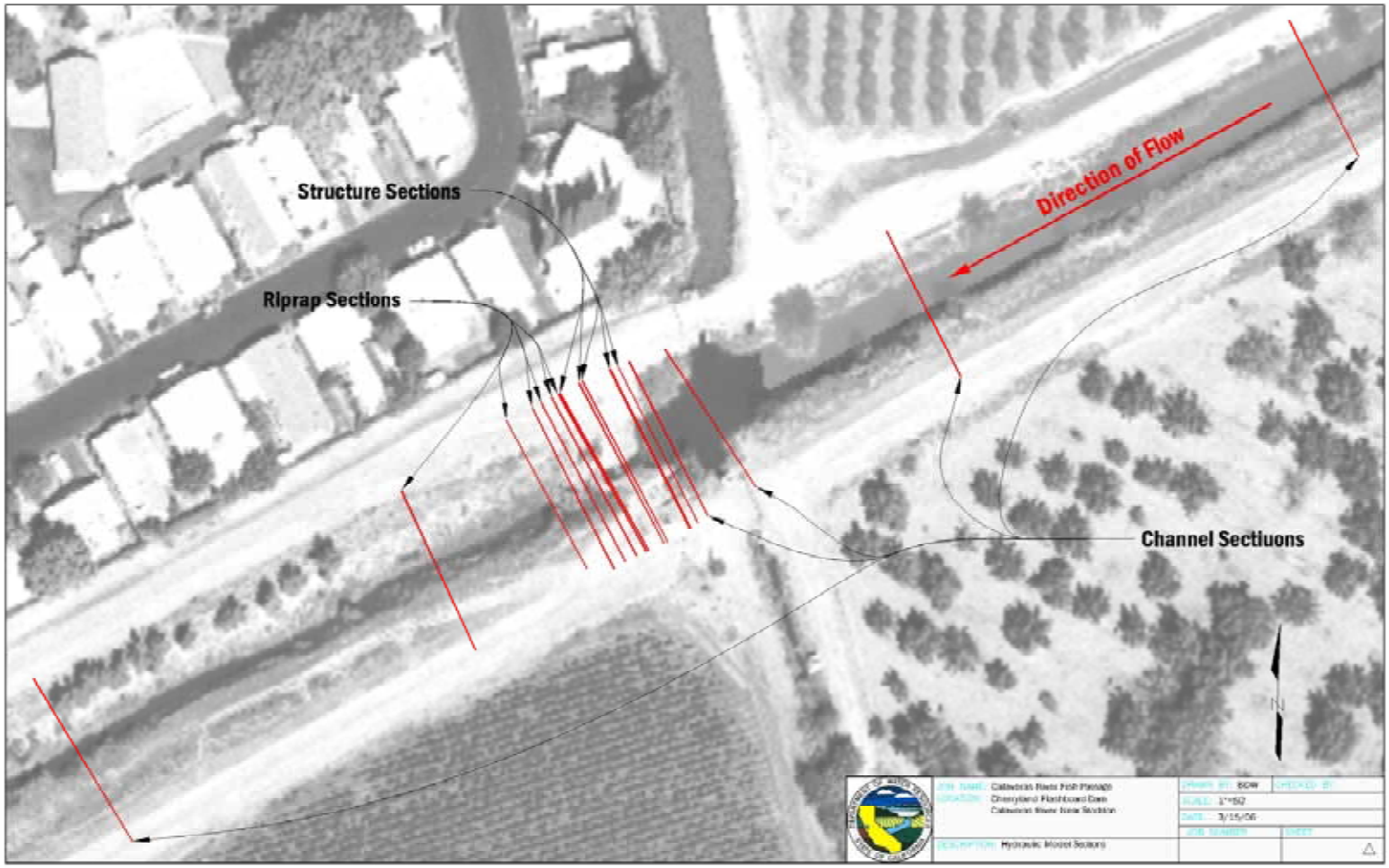


**Figure D-125. Cherryland Flashboard Dam – Relationship of length to maximum velocity**

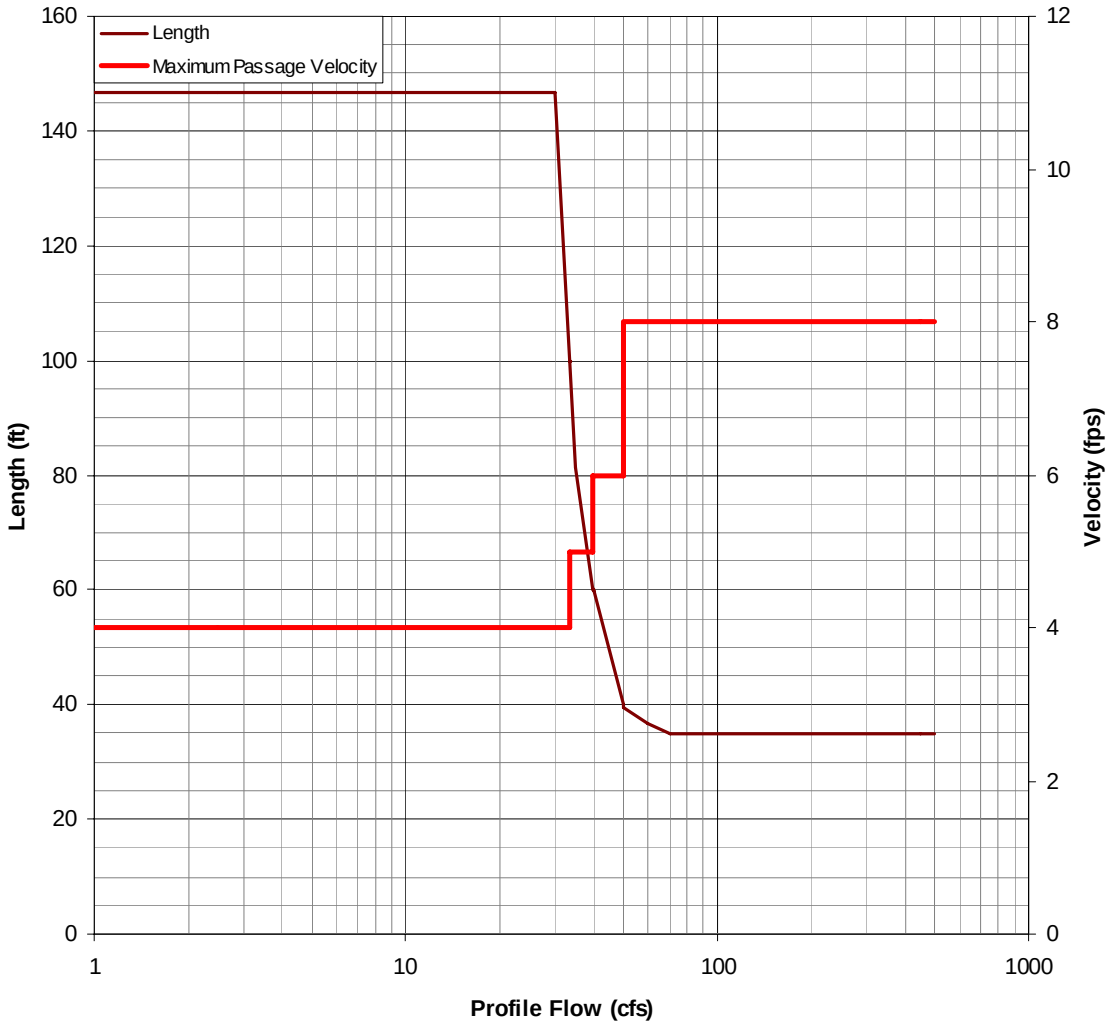


**Figure D-126. Cherryland Flashboard Dam – Velocity rating curves for channel sections**

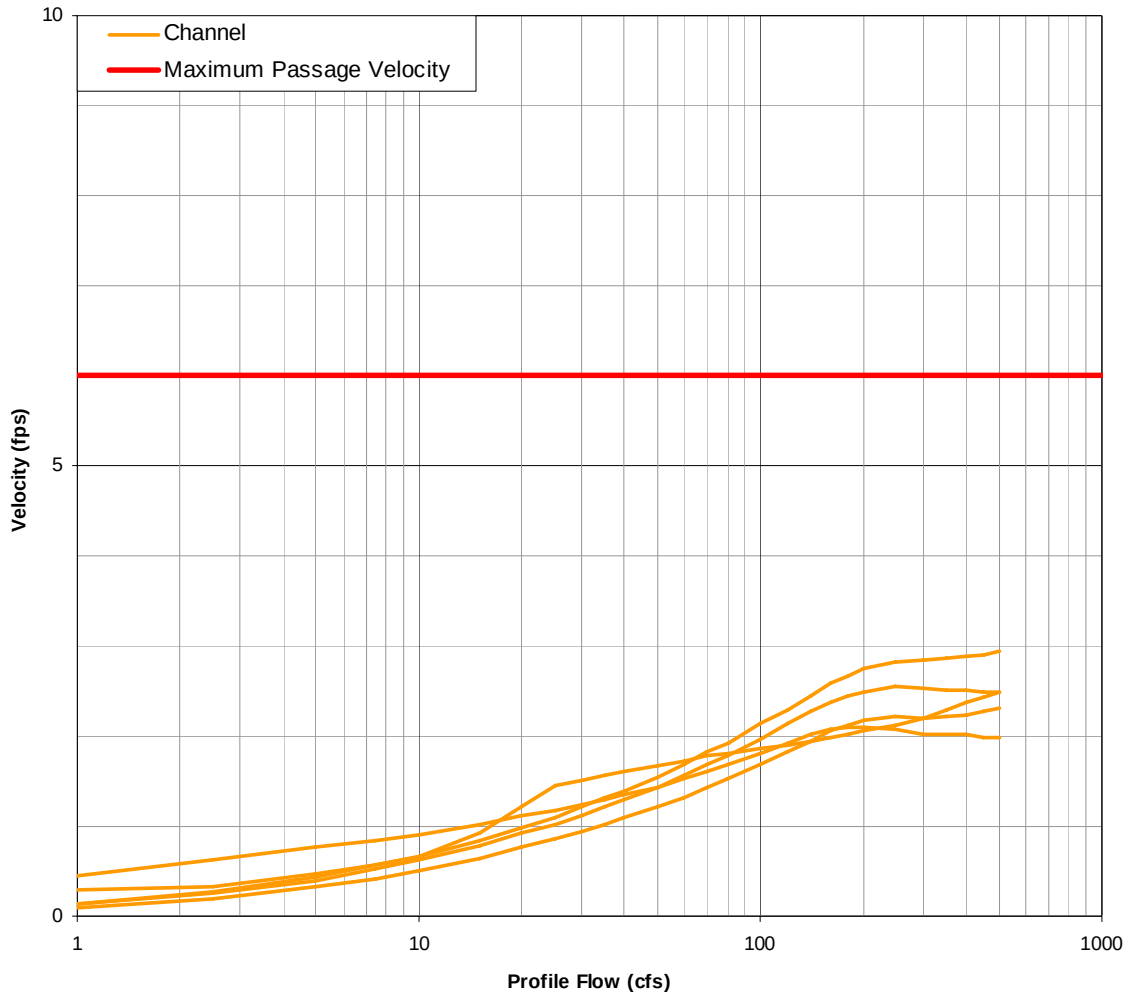


**Figure D-127. Cherryland Flashboard Dam – Depth rating curves for channel sections**

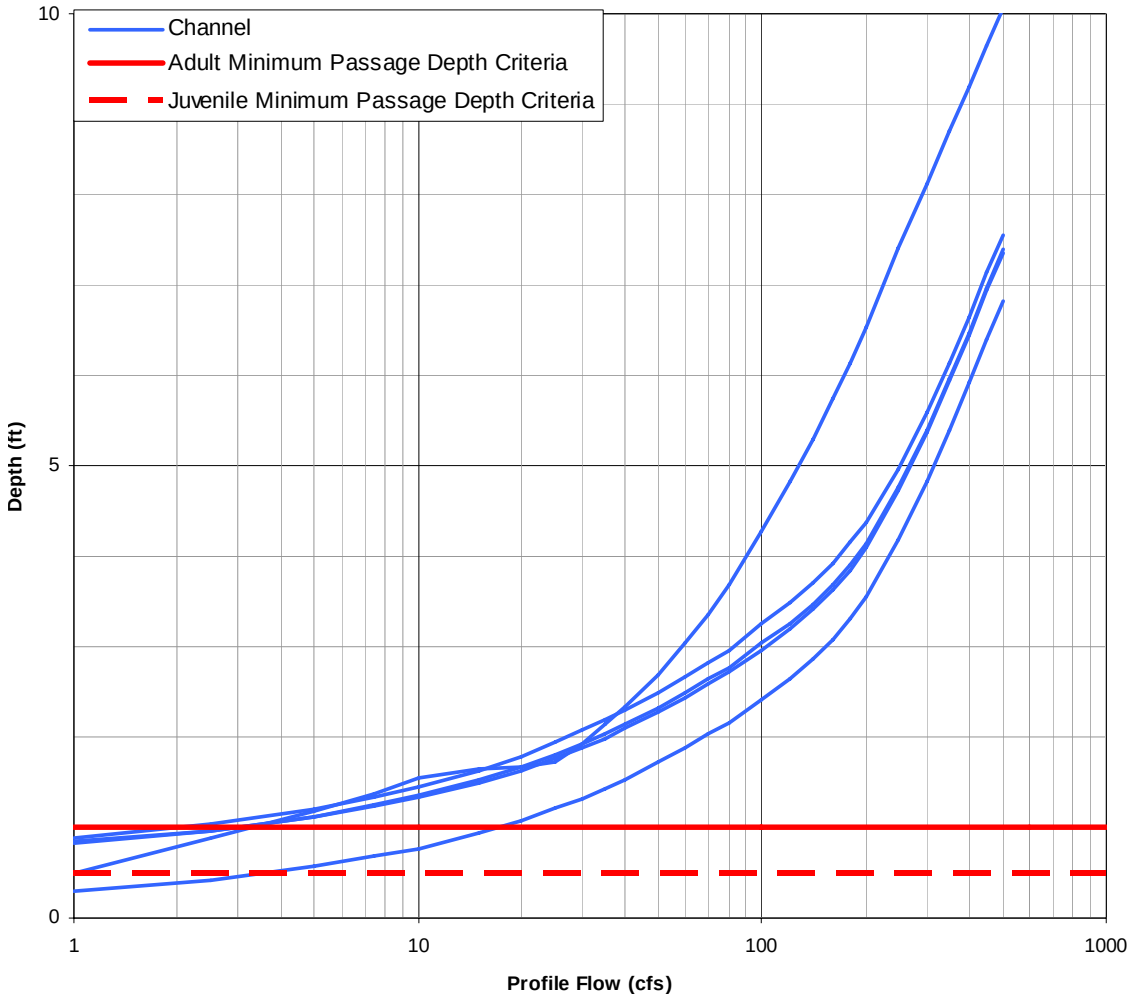


**Figure D-128. Cherryland Flashboard Dam – Velocity rating curves for riprap sections**

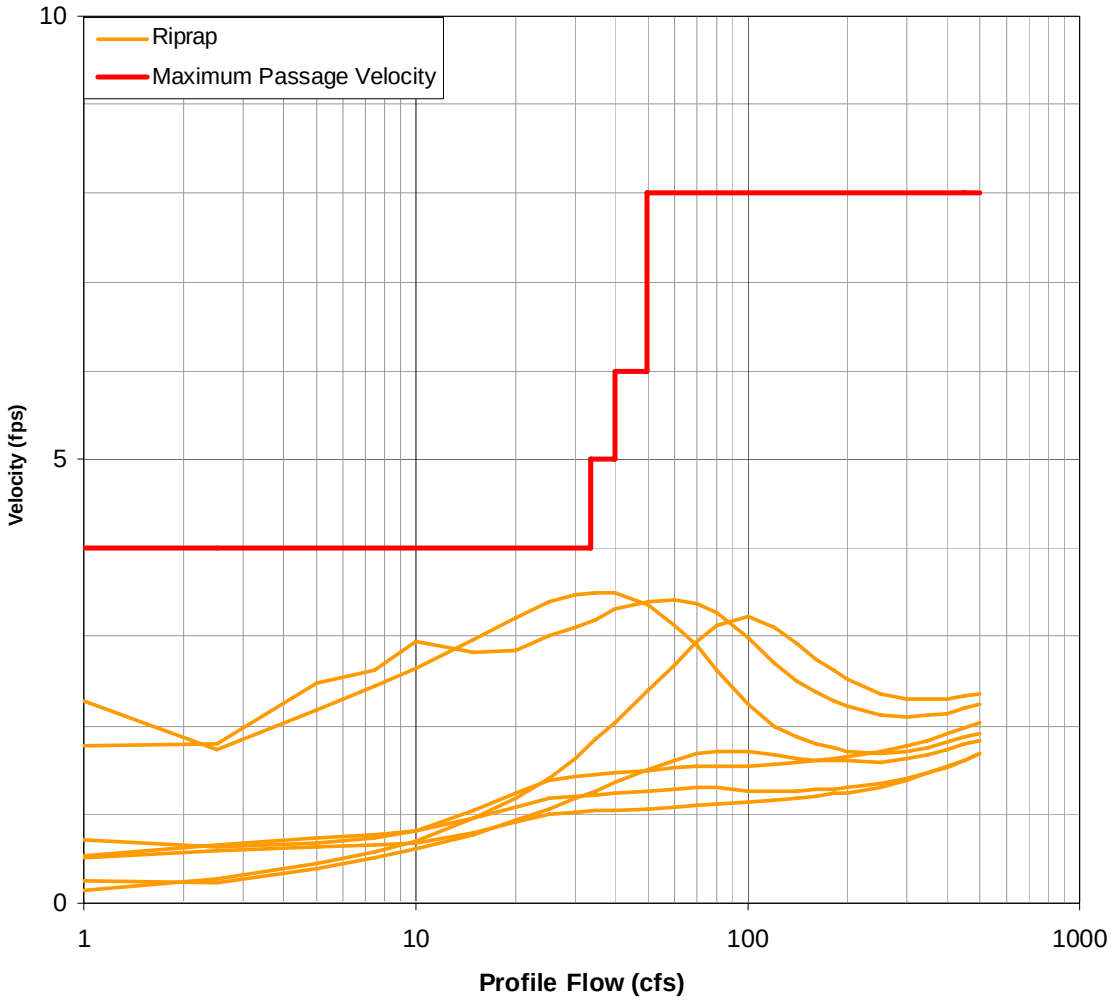


**Figure D-129. Cherryland Flashboard Dam – Depth rating curves for riprap sections**

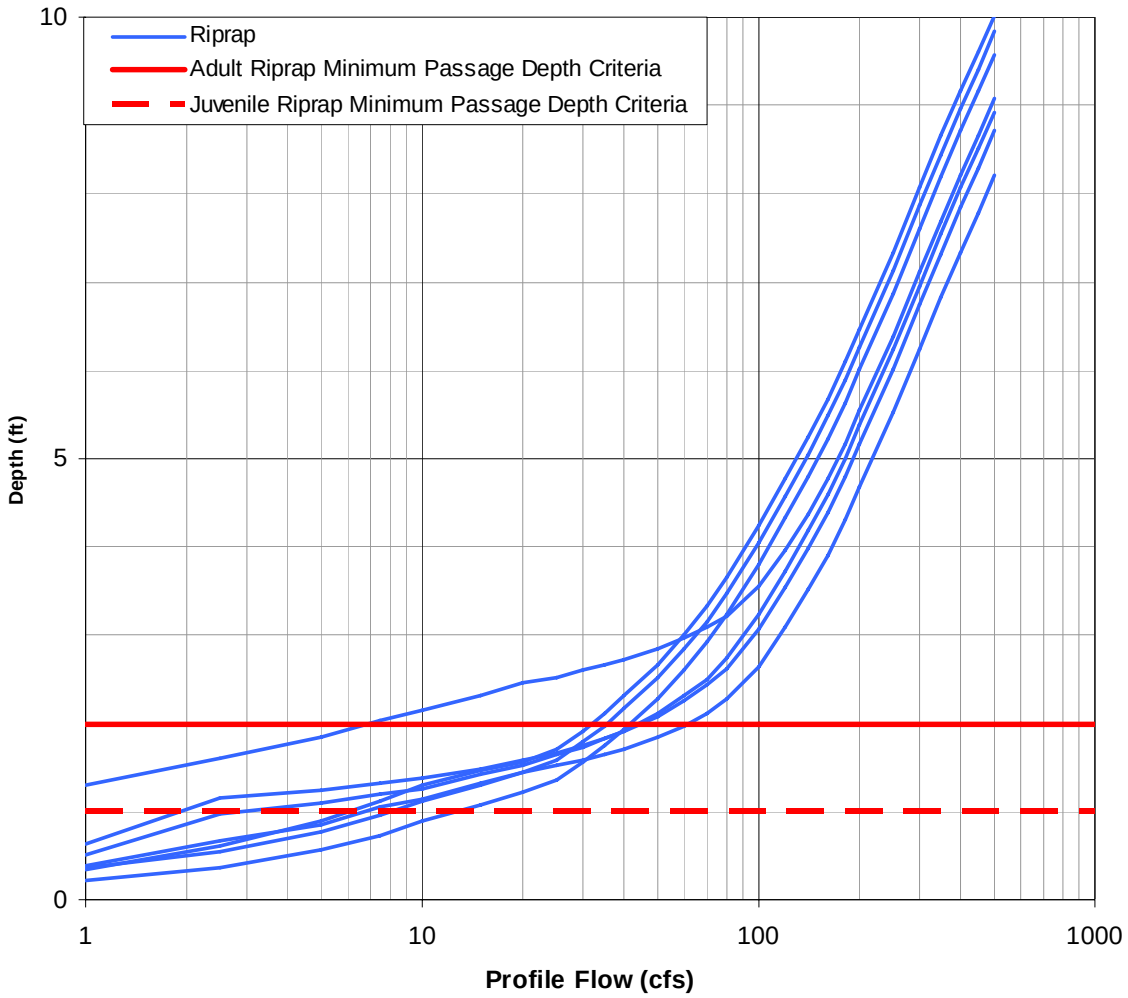


**Figure D-130. Cherryland Flashboard Dam – Velocity rating curves for structure sections**

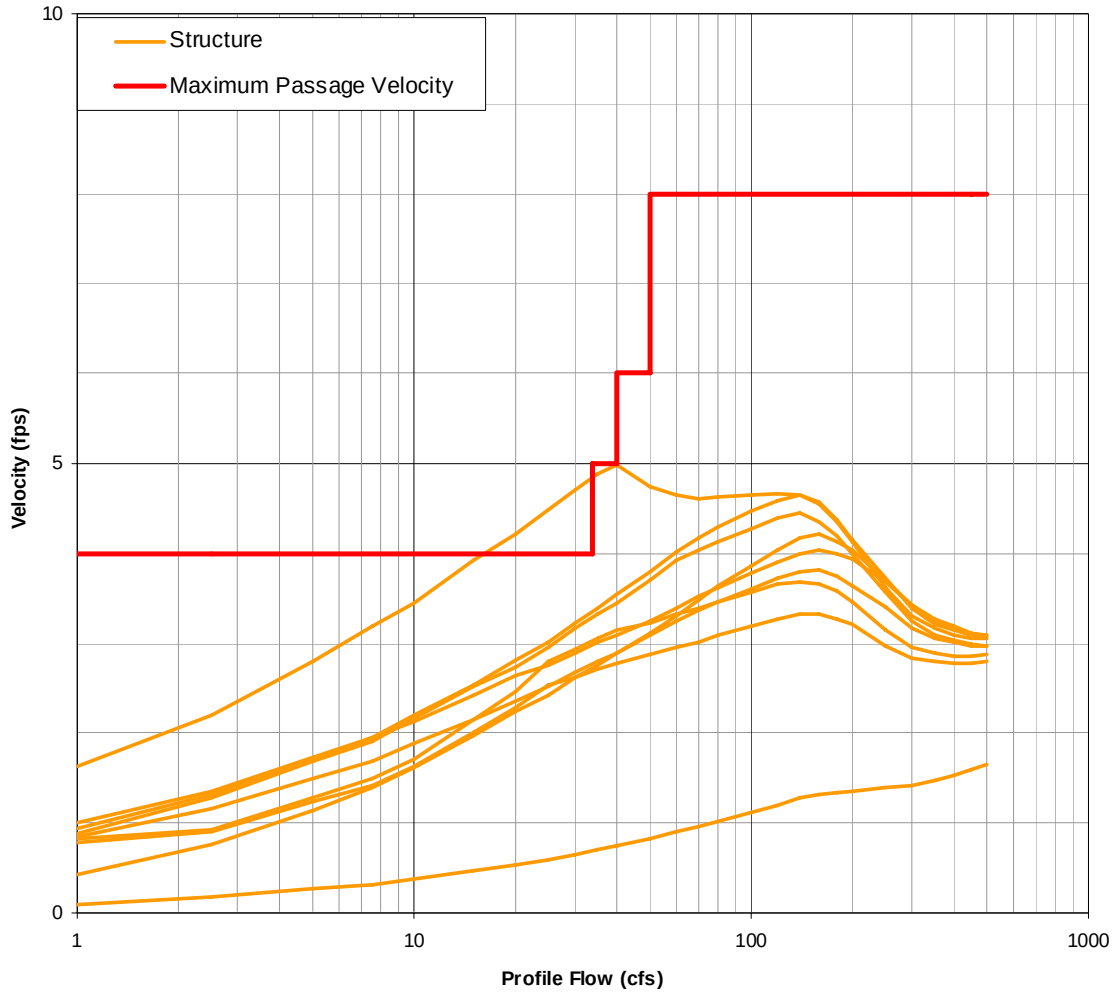
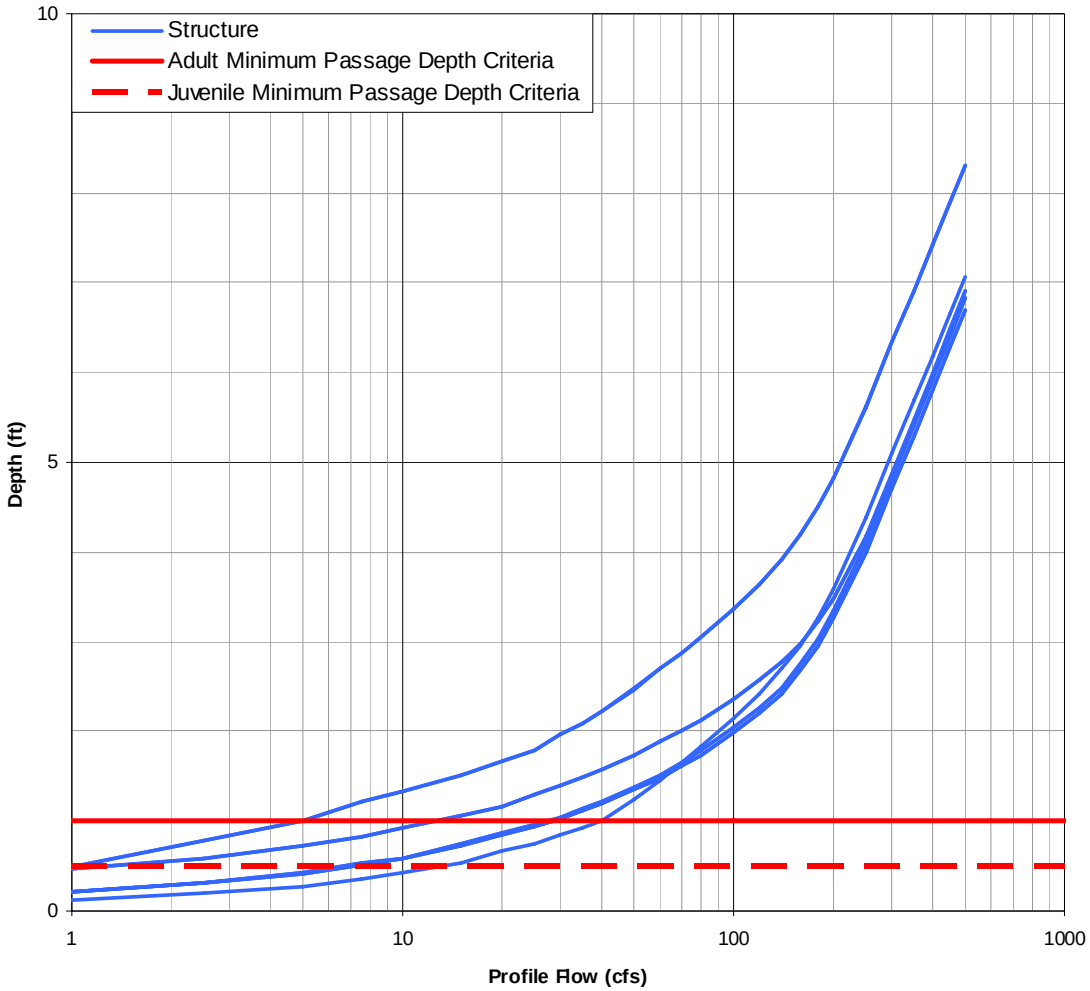


**Figure D-131. Cherryland Flashboard Dam – Depth rating curves for structure sections**



# References

[DFG] California Department of Fish and Game. 2003. California Salmonid Stream Habitat Restoration Manual (Table IX-6).

[DWR] California Department of Water Resources. 2004a. *Draft Report: Water Line Surveys for the Purpose of Hydraulic Model Calibration for the Calaveras River, Mormon Slough and the Stockton Diverting Canal*. 12 April.

[DWR] California Department of Water Resources. 2004b. *Draft Report: Fish Passage Criteria Used to Evaluate Structures on the Calaveras River, Mormon Slough and Stockton Diverting Canal.*