Hydrology | Hydraulics | Geomorphology | Design | Field Services

TECHNICAL MEMORANDUM

Date:	7/1/2022
To:	Gary Estes, California Extreme Precipitation Symposium (CEPSYM); Gary Bardini, Sacramento Area Flood Control Agency (SAFCA)
From:	Matthew Weber, PE and Chris Bowles, PhD, PE – cbec, inc., eco engineering (cbec)
Project:	21-1009 – Flood of 1862 HEC-RAS Modeling
Subject:	Estimate of 1862 flood event

1 INTRODUCTION

From December 5th, 1861, to January 31st, 1862, heavy rains fell over the Sierra Nevada mountains. The most intense periods of rain occurred from January 9-10 and January 14-18, resulting in widespread flooding throughout the Sacramento River watershed and within the City of Sacramento itself. Due to the flooding, the newly elected governor, Leland Stanford, was forced to travel to his inauguration by boat and the California State Legislature was temporarily moved to San Francisco. The magnitude of the 1862 flooding (i.e., peak discharge and 3-day runoff volume) is uncertain, as these floods occurred prior to well-documented stage-discharge relationships. The purpose of this effort was to evaluate the size of the 1862 peak discharge and 3-day runoff volume for the American River based on newly compiled historical information by Gary Estes, founder and program coordinator of the California Extreme Precipitation Symposium.

1.1 PROJECT BACKGROUND

The area of interest for this work is Folsom Canyon within the American River (Slide 4). Folsom Canyon is a narrow bedrock-dominated stretch of the American River from present day Folsom Dam at U.S. Army Corps of Engineers (USACE) river mile (RM) 29.2 to the Rainbow Bridge at RM 26.9. Due to the bedrock composition, this portion of river has been the focus of prior peak flood estimates because it is less likely to have experienced significant topographic change between flood events (more discussion on this in Section 1.1.2). High-water marks (HWMs) have been recorded within Folsom Canyon for various peak flood events and, prior to the construction of Folsom Dam, a topo-bathymetric survey of Folsom Canyon was completed by the U.S. Bureau of Reclamation (USBR) in 1950. The HWMs and the 1950 Folsom Canyon survey were the crucial inputs for re-assessing the peak flood estimate for the 1862 event.

2544 Industrial Blvd, West Sacramento, CA 95691 USA
T/F 916.231.6052
www.cbecoeng.com

1.1.1 PRIOR FLOOD ESTIMATES

In the 160 years since the January 1862 flood, several attempts have been made to estimate the peak discharge for the American River. Below is a summary of prior efforts that were reviewed.

On May 13, 1862, two engineers, B.F. Leet and George H. Goddard, delivered a report (Leet and Goddard, 1862) to the Board of Swamp Land Commissioners that included three cross-sections along the American River and peak flow estimates for the 1862 flood at each cross-section. Unfortunately, the cross-sections have not been recovered, but the report was published in the Sacramento Daily Union and was accessed online at the California Digital Newspaper Collection. Leet and Goddard (1862) calculated that, for the 1862 event, the cross-sectional conveyance area at the Folsom railroad bridge (near the present-day Rainbow Bridge) was 10,782 sq. ft. and the water surface elevation (WSE) slope was 35.05 ft/mile (i.e., 0.0066 ft/ft). Based on this information, Leet and Goddard (1862) estimated (through unknown methods) that the resulting discharge was 501,294 cubic feet per second (cfs).

In 1912, A. Givan (engineer for the City of Sacramento) and C.E. Grunsky (consulting engineer) submitted a report (Givan and Grunsky, 1912) to the California Debris Commission (composed of three USACE officers) and the California State Board of Reclamation. The report provides detailed information on the 1862 and 1907 floods, including precipitation data, newspaper and personal accounts, HWMs, and longitudinal flood profiles. The Givan and Grunsky (1912) report stated that the 1862 flood was 11.5 ft higher than the 1907 flood at the Stockton and Coover stone stable (Slide 13). An attachment to the report shows the cross-section at the Stockton and Coover stone stable with the 1862 HWM listed as 183 ft (U.S.G.S. Datum) and the 1907 HWM listed as 171.54 ft (U.S.G.S. Datum, Slides 14 & 15). The river in this section was described as having "a permanent bottom" (i.e., bedrock), and a slope of 0.63% was listed on the cross-section (i.e., 0.0063 ft/ft). At the time of this report, the 1907 flood was estimated at 128,000 cfs (present day estimate is 156,000 cfs); therefore, Givan and Grunsky (1912) reasoned that, through increased conveyance area alone (i.e., without accounting for increased velocities), the 1862 flood should be greater than 188,850 cfs. Applying that same logic to the present day estimate for the 1907 event yields an 1862 flood discharge of greater than 230,000 cfs.

From 1941 to 1943, Leslie E. Bossen (assistant engineer) of USACE developed a brief set of documents that compiled flood estimates, gage heights, and HWMs at four sites within the American River from 1862 to 1942. Bossen used this data to extrapolate and estimate the 1862 flood peak. Bossen (1941) estimated that, based on the assumed 1928 flood peak of 150,000 – 160,000 cfs (present day estimate is 163,000 cfs), the 1862 flood peak would be approximately 254,000 to 352,000 cfs depending on the location used for the comparison. Based on the best comparison locations, Bossen (1941) concluded that "the 1862 flood crest flows at Folsom and Fair Oaks must have been about 280,000 and 265,000 cfs, respectively."

In 1951, Howard F. Matthai of the U.S. Geological Survey (USGS) developed an internal paper that revisited the information that Bossen presented. The focus of the paper was to incorporate the revised estimate of the 1928 peak discharge event based on subsequent data and analysis that came after the Bossen (1941) document. Matthai (1951) compiled data for 11 flood events with HWMs at the Stockton and Coover stone stable and their corresponding discharge estimates. Matthai (1951) used this data to extend the rating curve by logarithmic plotting to estimate the 1862 flood peak, which yielded an estimate of 340,000 cfs (note that the rating curve was not available for review).

In 2009, Chuck Parrett of the USGS revisited the Matthai (1951) report and, since the rating relationship was not available for review, reconstructed the rating curve. Parrett (2009) concluded that the plausible range for the 1862 peak discharge was between 289,000 to 318,000 cfs. Parrett (2009) recommended using the higher estimate because "floods and flood frequency is a major concern" (i.e., public safety concern) on the American River.

1.1.2 TOPO-BATHYMETRIC CHANGES

Significant topo-bathymetric changes have occurred within the American River watershed from pre-1862 to present, and this can present a significant challenge when comparing flood discharge estimates to HWMs. Hydraulic mining began in the Sierra Nevada mountains in the 1850s. Gilbert (1917) estimated that over 1.1 billion m^3 of sediment was eroded through hydraulic mining in the Sierra Nevada mountains from 1853 to 1884. Within the American River watershed, Gilbert (1917) estimated a volume of 197 million m^3 hydraulic mining sediment was eroded from the upper watershed. In reference to the subsequent waves of hydraulic mining sediment that moved through the watersheds, Mendell (1881) stated that prior to the 1862 flood, "No one appears to have observed any considerable change in the bed or slopes of the streams until the great flood of 1862 had receded". Therefore, it is assumed that hydraulic mining debris hadn't reached Folsom Canyon in large quantities until after the 1862 flood event. After the 1862 flood event, waves of hydraulic mining sediment were washed into the American River channel and floodplain, which exacerbated flooding and disrupted stage-discharge relationships (Gilbert 1907, James 1997 & 1999).

The extent to which the waves of hydraulic mining sediment affected Folsom Canyon is unknown. Aerial photographs from 1928 and 1937 show significant alluvial deposits upstream of the Old Folsom Dam near RM 28.45 and downstream of Rainbow Bridge near RM 26.9. However, from the Old Folsom Dam to Rainbow Bridge (i.e., Folsom Canyon), the river still appears to be bedrock-dominated with little to no alluvial deposits. A 1906 longitudinal profile of the American River from the California Debris Commission (CDC 1907) shows a similar pattern with hydraulic mining sediment stored upstream of Old Folsom Dam and below Rainbow Bridge but not within Folsom Canyon. The Givan and Grunsky (1912) report stated that the river channel adjacent to the Stockton and Coover stone stable had "a permanent bottom" and did not discuss significant deposition of hydraulic mining sediment within that cross-section or within Folsom Canyon.

Folsom Dam construction was completed in 1955, but earthwork to blast the tailrace channel (i.e., the channel downstream of the dam) began in 1951. The tailrace channel was blasted through the Folsom Canyon bedrock, lowering the elevation of the streambed by as much as 100 ft and greatly reducing the flow resistance within this section of river (Slides 9-11). Prior the construction of the tailrace channel, the United States Bureau of Reclamation (USBR) surveyed Folsom Canyon and produced a set of plates with 5-ft contour lines and sonar soundings within the channel. The 1950s bathymetric elevations next to the Stockton and Coover stone stable are similar to the bathymetric elevations shown in the Givan and

Grunsky (1912) report, further strengthening the conclusion that the bedrock topography in this area remained largely unchanged from 1862 to 1950 without significant deposition from hydraulic mining sediment.

1.2 STUDY OBJECTIVES

The study objective is to estimate the 1862 peak flood discharge by calibrating / validation a 1D HEC-RAS model to estimated peak discharge events during the pre-Folsom Dam era and apply those parameters to estimate the peak 1862 flood discharge.

1.3 ASSUMPTIONS AND LIMITATIONS

- **Channel change:** Hydraulic mining sediment greatly affected streambed and floodplain elevations upstream of Old Folsom Dam and downstream of Rainbow Bridge. This is documented in the stage-discharge relationships at the USGS Fair Oaks gage (James 1997 & 1999), the 1928 and 1937 aerial photographs, and the California Debris Commission maps (CDC 1907). For Folsom Canyon, which is composed primarily of boulders and bedrock, it is assumed that sediment was routed through the canyon without significant alluvial deposition and storage.
- **Vertical datums:** The HWMs listed in Givan and Grunsky (1912), Bossen (1941), and Matthai (1951) were reported with respect to the "U.S.G.S. datum". It is unknown how the U.S.G.S. vertical datum compares to the modern North American Vertical Datum of 1988 (NAVD88) or the prior National Geodetic Vertical Datum of 1929 (NGVD29). The Given and Grunsky (1912) report pre-dates NGVD29, but the Bossen (1941) report refers to the U.S.G.S. datum as "U.S.G.S. datum (1929 adjustment)". Therefore, it is assumed that the USGS datum is the same as NGVD29. NGVD29 was previously referred to as the "Sea Level Datum of 1929" but was renamed to NGVD29 in 1973. All data in this analysis were converted from NGVD29 to NAVD88 using the North American Vertical Datum Conversion (VERTCON) for a shift of +2.55 ft to convert NGVD29 elevations to NAVD88 elevations.
- **Discharge estimates:** Discharge estimates for the 1907 to 1950 events are assumed to have a +/- 15-20% error estimate based on the Meyer (1998) USGS report for gage uncertainty within the American River watershed.
- **High water marks (HWMs):** The HWMs are assumed to have a vertical uncertainty of approximately +/- 1 ft.

2 MODEL DEVELOPMENT

To conduct this study, a one-dimensional (1D) HEC-RAS model developed by USACE (2006) was reviewed and adapted to model pre-Folsom Dam flood events. The USACE 1D HEC-RAS model was developed to analyze the 35% design of Folsom Bridge (at approximately river mile 28.7, just downstream of Folsom Dam) and evaluate the tailwater conditions for the Folsom Dam auxiliary spillway. This model covered the stretch of the American River from downstream of Folsom Dam to Nimbus Dam (approximately RM 29 to 22.5) and was developed using topography from 2003 and bathymetry from 2005. The applicability of this model to simulate pre-Folsom Dam flood events was limited due to the topo-bathymetric changes that occurred during construction of the Folsom Dam tailrace channel. In addition, the cross-section spacing and orientation were not necessarily well suited to represent pre-Folsom Dam flow patterns. Therefore, entirely new geometry files were developed within the HEC-RAS model to conduct the analysis for the pre-Folsom Dam floods (i.e., pre-1951 floods).

2.1 MODEL DOMAIN

The new model domain developed to simulate the pre-Folsom Dam floods begins downstream of old Folsom Dam (also known as the old PG&E Dam, near RM 28.4) that was deconstructed during the construction of Folsom Dam. The model ends after the Rainbow Bridge, near river mile 26.8. The area near Rainbow Bridge is a natural topographic constriction and is the last section of heavily bedrock-controlled canyon walls. After Rainbow Bridge, the valley widens and there are significant alluvial deposits on the floodplains. The Stockton and Coover stone stable is located near RM 27.7. Its location was confirmed on the USBR (1950) survey plates (Slide 19).

2.2 BATHYMETRY AND TOPOGRAPHY

The USBR 1950s plates were digitized from the PDFs using the software tool R2V (Able Software Corp, Massachusetts, USA). The results were georeferenced in Civil 3D (Autodesk, San Rafael, CA), and then manually edited to re-assign the elevations associated with the contours, include the soundings, and develop three-dimensional (3D) breaklines. This surface was converted to NAVD88 by applying a shift of +2.55 ft (from VERTCON), and then merged with the 2008 Central Valley Floodplain Evaluation and Delineation (CVFED) Program LiDAR surface (Slide 20).

2.3 CROSS-SECTIONS

Cross-sections were drawn perpendicular to flow paths using the 1950s USBR survey lines and the 1937 aerial photographs to interpret the historical channel alignment (Slide 20). Cross-selections were drawn to match locations with sonar data to limit the amount of bathymetric interpolation error. The approximate cross-section spacing was 150-200 ft; however, two gaps with poor channel bathymetry exist and cross-sections were not included in those locations. Cross-sections were adjusted, as needed, to capture areas that would provide topographic controls (i.e., lateral and vertical bedrock constrictions).

For the cross-section at the Stockton and Coover stone table, two versions were created: a version that uses the elevations provided by the USBR (1950) survey, and a version that uses the Givan and Grunsky (1912) cross-section (Slide 21).

2.4 BOUNDARY CONDITIONS AND OBSERVED DATA

The 1D HEC-RAS model simulates steady flows using the USGS estimated flows for the 1907, 1928, 1943, and 1950 peak floods as inputs. Table 1 shows the dates of the peak floods, the USGS flow estimates at the American River Fair Oaks gage (AFO, gage #11446500), and the HWM elevations reported by Bossen (1941 & 1943) and Matthai (1951). For the 1862 flood, steady flows in 10,000 cfs intervals were run from

240,000 to 330,000 cfs. All simulations used the critical depth for the downstream boundary condition. This downstream boundary condition is located downstream of the modern Rainbow Bridge cross-section, which is a natural constriction where the flows are supercritical (Slide 23). Due to this super-critical cross-section upstream of the boundary condition, sensitivity tests show that the results at the Stockton and Coover stone stable are not sensitive to the choice of the downstream boundary condition (i.e., critical depth or normal depth based on the average energy grade slope).

Table 1. Boundary Conditions and Observed High Water Marks

Date	USGS gage (AFO, cfs)	[1]Stone Stable HWM (USGS, ft)	[2]Stone Stable HWM (NAVD88, ft)	Downstream Boundary Condition
1/10/1862	Unknown	183.0	185.6	Critical depth
3/19/1907	156,000	171.5	174.1	Critical depth
3/25/1928	163,000	174.5 to 175.0	177.3	Critical depth
1/22/1943	152,000	172.9	175.5	Critical depth
11/21/1950	180,000	175.5 to 175.8	178.2	Critical depth

[1]HWM elevations shown were reported by Bossen (1941 & 1943) and Matthai (1951) according to the "U.S.G.S. Datum", which is assumed to be equivalent to NGVD29.

[2]HWM elevations were shifted to NAVD88 from the USGS / NGVD29 datum elevations by adding +2.55 ft, according to North American Vertical Datum Conversion (VERTCON).

2.5 MODEL CALIBRATION

The HEC-RAS model was calibrated to best-match the HWMs from the 1907, 1928, 1943, and 1950 events (Slide 24). Table 2 shows the results for the model with the Stockton and Coover stone stable cross-section included. The model is within +/- 1.2 ft of the HWMs with an average difference (i.e., model WSE minus HWM elevation) of -0.18 ft. The Manning's n for this scenario was 0.065 for the channel and 0.08 for the overbank.

Table 2. Givan and Grunsky (1912) Stockton and Coover stone stable cross-section with channel Manning's n of 0.065 and overbank Manning's n of 0.08

Date	Peak Flow (cfs)	Stone Stable HWM (NAVD88, ft)	Water Surface Elevation (WSE, ft)	Difference (ft, WSE – HWM)
3/19/1907	156,000	174.1	175.27	1.2
3/25/1928	163,000	177.3	176.17	-1.1
1/22/1943	152,000	175.5	174.74	-0.7
11/21/1950	180,000	178.2	178.03	-0.2
Average Difference				**-0.18**

Table 3 shows the results for the model with the USBR (1950) survey data at the Stockton and Coover stone stable location. The calibrated model is within +/- 1.0 ft of the HWMs with an average difference of 0.01 ft. The Manning's n for this scenario was 0.07 for the channel and 0.09 for the overbank.

Table 3. USBR (1950) Stockton and Coover stone stable with channel Manning's n of 0.07 and overbank Manning's n of 0.09

Date	Peak Flow (cfs)	Stone Stable HWM (NAVD88, ft)	Water Surface Elevation (WSE, ft)	Difference (ft, WSE – HWM)
3/19/1907	156,000	174.1	175.27	1.0
3/25/1928	163,000	177.3	176.17	-0.7
1/22/1943	152,000	175.5	174.74	-0.9
11/21/1950	180,000	178.2	178.03	0.4
Average Difference				**0.01**

The calibration results show that the model is matching the HWM elevations to within the expected uncertainty for the HWMs (i.e., +/- 1 ft). The calibrated Manning's n values are higher for the USBR (1950) survey data at the Stockton and Coover stone stable. This is due to a larger cross-sectional area represented by that survey. The Manning's n values for the two scenarios are similar and high, but within the range of guidance for higher-gradient and bedrock/boulder dominated rivers (Yochum 2017). Slides 5-7 show pictures of Folsom Canyon at low flow and Slides 16-18 show flood flows at the Stockton and Coover stone stable. These pictures show a rough channel with high turbulent mixing, which would indicate the need for high Manning's n values.

3 1862 MODEL RUNS

For the 1862 flood, steady flows from 240,000 cfs to 330,000 cfs, in 10,000 cfs intervals, were run for the two calibrated geometry and roughness conditions. In both cases, the discharge that best fit the 1862 HWM elevation was 260,000 cfs. Table 4 shows the results for the two scenarios and the resulting WSEs and differences from the HWM.

Table 4. USBR (1950) Stockton and Coover stone stable with channel Manning's n of 0.07 and overbank Manning's n of 0.09

Scenario	Peak Flow (cfs)	Stone Stable HWM (NAVD88, ft)	Water Surface Elevation (WSE, ft)	Difference (ft, WSE – HWM)
Givan and Grunsky (1912)	260,000	185.6	185.51	-0.09
USBR (1950)	260,000	185.6	185.78	0.18

The energy-grade slope at the Stockton and Coover stone stable was 0.0064 ft/ft, which is similar to the slope listed on the Givan and Grunsky (1912) cross-section of 0.0063 ft/ft. In addition, the slope used by

Leet and Goddard (1862) was 0.0066 ft/ft. This further validates that the hydraulics in the model are representative of the observed 1862 flood conditions.

4 3-DAY VOLUME ESTIMATE

The National Research Council (NRC 1999) estimated the 3-day mean discharge for the 1862 flood by developing a log-log regression of 3-day mean discharges to peak discharges on the American River. NRC (1999) used the Bossen (1941) peak flow estimate of 265,000 cfs at the Fair Oaks USGS gage. This resulted in an estimated 3-day mean discharge of 147,000 cfs for the 1862 event. Since the peak flow used in the NRC (1999) analysis is comparable to the HEC-RAS model prediction of 260,000 cfs, the 3-day mean discharge estimate of 147,000 cfs remains as the best estimate. Table 5 shows the 1862 peak flow estimate from the HEC-RAS model and the 1862 3-day mean estimate from NRC (1999) in comparison to the top 10 peak flood events on the American River (Slide 26). Based on the top 10 peak flood events, the average 3-day mean/peak discharge ratio is 0.548 (i.e., 54.8 %) with a standard deviation of 0.077. Therefore, the 95% confidence limit for the 1862 3-day mean estimate is 103,100 cfs to 181,800 cfs (612,500 acre-ft to 1,081,600 acre-ft).

Table 5. Comparison of peak flow to 3-day mean flows for the 1862 event and 10 largest American River floods

Event	[1]Peak Flow (cfs)	1-Day Mean (cfs)	3-Day Mean (cfs)	3-Day Mean / Peak (%)
1862	260,000	-	147,000	56.54%
1997	300,000	252,400	165,900	55.30%
1964	260,000	183,200	140,400	54.00%
1986	255,000	171,000	165,700	64.98%
1963	240,000	152,600	93,900	39.13%
1955	219,000	189,100	127,500	58.22%
2005	190,100	136,300	83,400	43.87%
1950	180,000	132,000	107,500	59.72%
1980	175,000	124,900	97,800	55.89%
1928	163,000	119,000	98,200	60.25%
1907	156,000	105,000	87,800	56.28%

[1]Peak flows from 1955 and on are based on estimated unimpaired flows; All 1907 –2005 numbers are from USACE-SPK (2017)

5 SUMMARY

This analysis used a HEC-RAS model to estimate the 1862 peak flood flow. A USBR (1950) survey of Folsom Canyon was digitized to provide the topo-bathymetric data for the HEC-RAS model. The HEC-RAS model was calibrated to HWMs at the Stockton and Coover stone stable for the 1907, 1928, 1943, and 1950 peak flood events. The calibrated model was used to estimate the 1862 flood peak by matching the HWM elevation at the Stockton and Coover stone stable. This resulted in an estimated 1862 peak flow of 260,000 cfs (+/- 10-20 %, based on pre-1950s USGS peak discharge uncertainties) and an estimated 3-day mean flow of 147,000 cfs (95% confidence limit of 109,100 cfs to 178,400 cfs). These estimates put the 1862 event as comparable in size to the 1964, 1986, and 1997 peak flood events.

6 REFERENCES

Bossen, L.E., 1941a. The 1862 Flood on the American River, California. U.S. Army Corps of Engineers, Sacramento District. August 1941.

Bossen, L.E., 1941b. Discharge Rating Curves of American River at Fair Oaks and at Folsom. U.S. Army Corps of Engineers, Sacramento District. August 1941.

Bossen, L.E., 1943. The Flood Crest of January 1943 on the American River. U.S. Army Corps of Engineers, Sacramento District. February 1943.

California Debris Commission (CDC), 1907. Map of American River, California, from its mouth in the Sacramento River to the South Fork. U.S. Army Corps of Engineers; Tower, M.I., Jr. Engineer, 7 sheets plus cross-sections scale 1:9600

Gilbert, G.K., 1917. Hydraulic-mining Debris in the Sierra Nevada. U.S. Geological Survey Professional Paper 105. https://doi.org/10.3133/pp105

Givan, A., and Grunsky, C.E., 1912. Statement Relating to the Flood Discharge of the American River. Submitted on behalf of the City of Sacramento to the U.S. Army Corps of Engineers and the California State Board of Reclamation. October 17, 1912.

James, L. A., 1997. Channel incision on the lower American River, California, from streamflow gage records. Water Resources Research 33: 485-490. https://doi.org/10.1029/96WR03685

James, L. A., 1999. Time and the persistence of alluvium: River engineering, fluvial geomorphology, and mining sediment in California. Geomorphology 31: 265-290. https://doi.org/10.1016/S0169-555X(99)00084-7

James, L. A., 2006. Bed waves at the basin scale: implications to river management and restoration. Earth Surface Processes and Landforms. 31: 1692-1706. https://doi.org/10.1002/esp.1432

Leet, B.F., and Goddard, G.H., 1862. Engineers' Report of the Northern Boundary of Swamp Land District No. 2. Report to the Board of Swamp Land Commissioners. May 13, 1862.

Matthai, H.F., 1951. Revision of Peak Discharge of American River at Fair Oaks, California, March 25, 1928. U.S. Geological Service, California Water Science Center, Sacramento, CA. December 14, 1951.

Mendell G.H., 1881. Report upon a Project to Protect the Navigable Waters of California from the Effects of Hydraulic Mining. House Doc. 98, 47th Congress, 1st session.

Meyer, R.W., 1998, Assessment of peak discharge uncertainty in the American River Basin, California: U.S. Geological Survey Open-File Report 97-668, 9 p. https://doi.org/10.3133/ofr97668

National Research Council (NRC), 1995. Flood Risk Management and the American River Basin: An Evaluation. NRC Committee on Flood Control Alternatives in the American River Basin. Washington, D.C., The National Academies Press. https://doi.org/10.17226/4969

National Research Council (NRC), 1999. Improving American River Flood Frequency Analyses. Washington, D.C., The National Academies Press. https://doi.org/10.17226/6483

Parret, C., Internal USGS memo on 1862 flood peak at Fair Oaks gage location. U.S. Geological Survey, California Water Science Center, Sacramento, CA. December 31, 2009.

U.S. Army Corps of Engineers (USACE), 2006. American River HEC-RAS Model Folsom Dam to Nimbus Dam. U.S. Army Corps of Engineers, Sacramento District Hydraulic Design Section. March 1, 2006.

U.S. Army Corps of Engineers (USACE), 2017. Appendix 8 to Master Water Control Manual –Folsom Dam and Lake. U.S. Army Corps of Engineers, Sacramento District. September 2017.

U.S. Bureau of Reclamation (USBR), 1950. Design Data for Preparation of Designs and Estimates for Specification Purposes for Excavation of Tailrace Channel Downstream from the PG&E Diversion Dam and Excavation for Powerplant to Elevation 210 feet. Prepared by the U.S. Bureau of Reclamation Folsom Unit, American River Division, Central Valley Project. December 1950.

Yochum, S.E., Flow Resistance Coefficient Selection in Natural Channels: A Spreadsheet Tool. U.S. Forest Service Technical Summary TS-103.2. February 2018.