Appendix 4

Floodplain Inundation Mapping

MEMORANDUM

Date:	October 19, 2010
To:	Michele Palmer (FISHBIO), Tom Payne (TRPA)
From:	Chris Campbell, John Stofleth, April Sawyer
Project:	10-1035 – San Joaquin River Technical Support
Subject:	Floodplain Inundation Mapping

1 BACKGROUND AND APPROACH

cbec, inc. were requested by FISHBIO to develop a 1D unsteady hydraulic model for the San Joaquin River between the Merced River and the Mossdale Bridge as a means to characterize the relationship between floodplain inundation and flow. To do this, a HEC-RAS (RAS) model was developed for the 60 miles of river using readily available data. Model development was facilitated by using HEC-GeoRAS, which is a GIS interface for pre-processing model inputs (i.e., cross sections) and post-processing model outputs (i.e., inundation maps). The results of this analysis, including details on model development, are described in the following sections.

Note: all tabular and graphical data presented within this technical memorandum were prepared in California State Plane (CASP) 1983 Zone 3 (feet) and NVGD29 (feet).

2 MODEL DEVELOPMENT

Given time and budget limitations, the RAS model was developed from readily available information, which primarily consisted of Comprehensive Study (USACE, 2002) topography and DWR and USGS rating and flow data. This information is further described in the sections below.

2.1 TOPOGRAPHY

Topography for the entire model domain relied upon the Comprehensive Study (USACE, 2002). The topographic information included hydrographic surveys below the waterline and photogrammetric surveys above the waterline, all collected in the summer of 1998. The topography was collected and processed to an accuracy suitable to develop 2-foot contours. The data was prepared in California State Plane (CASP) 1983 Zone 3 (feet) and NVGD29 (feet).

In addition to topography, the Comprehensive Study (USACE, 2002) was also used as a source for bridge geometry. Bridges that were incorporated into the model included Crows Landing Rd, E Las Palmas Ave, W Grayson Rd, Maze Blvd, and Airport Way. Bridges that were not included in the model due to their locations at model boundaries included Hills Ferry Rd near the Merced River and the I5 crossing near Mossdale.

On a cross section basis, levee markers and ineffective flow markers were used in the RAS model. Levee markers were typically used if multiple or setback levees were encountered. Ineffective flow markers were used to allow inundation of large oxbows on the floodplain without significant conveyance through these features.

2.2 HYDRAULIC ROUGHNESS

Hydraulic roughness or Manning's n-values for the channel and floodplain were initially derived from the Comprehensive Study (USACE, 2002), which ranged from 0.040 to 0.046 for the channel and 0.046 to 0.090 for the floodplain. These initial values were fine tuned during model calibration.

2.3 OBSERVED FLOW DATA

Readily available rating curves and flow information was downloaded from the California Data Exchange Center (CDEC; http://cdec.water.ca.gov/) and US Geological Survey (USGS; http://ca.water.usgs.gov/). Table 1 below lists the available gage data, all of which are located in the vicinity of the bridges listed in Section 2.1. The rating curve information listed in Table 1 was used for calibration and at the downstream model boundary.

Table 1. List of river gages with rating curves and flow information

CDEC	USGS	Name	Lat	Long	Period	Datum	Status
NEW	**11274000**	SJR near Newman	37.3506	120.9761	04/1912 – P	NGVD29	05/2010
	11274550	SJR near Crows Landing	37.4319	121.0128	10/1995 – P	NGVD29	07/2010
SJP	11274570	SJR near Patterson	37.4940	121.0810	03/1997 – P	NGVD29	01/1997
MRB		SJR at Maze Blvd Bridge	37.6414	121.2276	11/2006 – P	NGVD29	11/2006
VNS	**11303500**	SJR near Vernalis	37.6761	121.2653	10/1923 – P	NGVD29	05/2010
MSD		SJR at Mossdale Bridge	37.7860	121.3060	12/2005 – P	NAVD88	*

* Reconstructed from gage data from January 2006 through December 2006

In addition to the data provided by Table 1, low flow discharge data collected in September 2010 at approximately 2-mile intervals was used to facilitate low flow model calibration. The low flow stage and flow data for the non-tidal reach are contained in Table 2 below.

Table 2. Low flow stage and flow data (this study)

River Station (feet)	Date	Flow	Stage (feet)	River Station (feet)	Date	Flow	Stage (feet)
307376.8	9/11/2010	1636	51.76	175231.8	9/12/2010	1871	28.65
303373.3	9/11/2010	1652	51.28	163973.7	9/12/2010	1769	26.51
296989.4	9/11/2010	1673	50.32	152485.5	9/13/2010	1978	25.09
287120.4	9/11/2010	1584	48.12	143338.0	9/13/2010	1987	23.44
276373.7	9/11/2010	1561	45.73	128607.7	9/13/2010	2442	19.43
266713.7	9/11/2010	1577	43.04	120342.7	9/13/2010	2405	17.82
256391.7	9/11/2010	1600	41.38	112216.9	9/13/2010	2380	16.87
246199.6	9/11/2010	1471	40.43	100509.5	9/13/2010	2463	15.25
237184.9	9/11/2010	1533	38.98	90174.4	9/13/2010	2338	13.77
226302.9	9/11/2010	1611	37.45	84882.7	9/13/2010	2445	12.74
215507.3	9/11/2010	1632	34.96	76886.0	9/13/2010	2560	11.61
207642.9	9/12/2010	1790	34.46	71403.4	9/13/2010	2515	10.41
205378.2	9/12/2010	1642	34.09	62326.5	9/14/2010	2605	9.12
194674.5	9/12/2010	1699	33.02	51294.5	9/14/2010	2465	7.23
185259.7	9/12/2010	1718	30.66	40475.1	9/14/2010	2723	5.42

2.4 BOUNDARY CONDITIONS

The model included an upstream boundary near Newman, just downstream of the Merced River confluence at Hills Ferry Rd, and a downstream boundary near Mossdale at the I5 crossing (see Figure 1). The upstream boundary was a flow boundary and the downstream boundary used the MSD rating curve. Since the downstream boundary is tidal, a best fit curve was fit through the data to represent a mean tidal condition with fluvial influences. Additional flow boundaries included the Toulumne River and the Stanislaus River.

2.5 CALIBRATION

Calibration of the model was performed by adjusting Manning's n-values for the channel and floodplain to achieve a satisfactory fit between model predictions and the published rating curve data in Table 1. Low flow calibration of the model was also performed by comparing the measured water surface elevations for the non-tidal reach of the river based on flow measurements collected as part of this study in September 2010.

2.6 INUNDATION MAPPING

Following calibration of the unsteady RAS model, a range of quasi steady state flows were modeled in 1,000 cfs increments. For each flow condition, inundation maps and tabular data (i.e., acreages and percentages) were generated and further delineated into four (4) reaches defined as:

Reach 1 – Newman to E Las Palmas Ave (19 miles);
Reach 2 – E Las Palmas Ave to the Toulumne River (14 miles);
Reach 3 – Toulumne River to the Stanislaus River (10 miles);
Reach 4 – Stanislaus River to Mossdale Bridge (17 miles).

3 RESULTS

3.1 CALIBRATION

Calibration of the unsteady RAS model was achieved by adjusting Manning's n-values for defined reaches as well as adjusting channel bed topography at select bridges and within select reaches. The latter was necessary considering that the Comprehensive Study (USACE, 2002) topography is twelve (12) years old. Since the Summer of 1998, there have been three (3) bankfull events (i.e., February 1999, March 2000, June 2005) and one (1) out-of-bank event (i.e., April 2006) similar in magnitude to the February 1998 flood event. Prior to the February 1998 flood event, the January 1997 flood event was particularly notable, which had a peak flow nearly twice as large as the 1998 flood event. In total, these flood events have the ability to rework this sand bed system, resulting in present day bed elevations that can differ by 2 to 5 feet from Summer 1998 conditions.

Results of the calibration are shown by Table 3 and Table 4 and Figure 3 through Figure 8. As detailed in Table 3, Manning's n-values were specified for low flow and high flow conditions. Depending on the reach, the transition from low flow to high flow ranged from 6,000 to 15,000 cfs. At low flows, a low Manning's n-value of 0.020 was used, partially to hydraulically offset the bed topography, which was generally too high as it tended to force the modeled water surfaces to be higher than the published rating curves or measured data.

Since a low Manning's n-value of 0.020 could only partially counter the effects of high bed topography (as based on Summer 1998 conditions), it was necessary to reasonably adjust the channel bed topography manually. In this instance, bed elevations for the main channel (i.e., between the bank markers) were lowered 1.5 to 2.0 feet upstream of Patterson at roughly a dozen locations where the bed topography was controlling the water surface profile.

Figure 3 through Figure 7 show the satisfactory fit between model predictions and the published rating curve data. Table 4 shows that the error between model predictions and the published rating curve data was on average 0.2 feet too high. Table 4 also shows that the standard deviation of the error generally became larger in the downstream direction, potentially indicating that the effects of outdated channel bed topography were not fully overcome. This result is further exemplified in Figure 8, showing the low flow calibration, which is generally too high by 0.9 feet on average with a standard deviation of 1.0 feet.

Table 3. Calibrated Manning's n-values

Station Start (feet)	Station Stop (feet)	Flow Change (cfs)	Manning's n-values		Roughness Factor	Manning's n-values	
			Low Flow Channel	Low Flow Floodplain		High Flow Channel	High Flow Floodplain
307376.8	228567.7	12,000	0.020	0.035	3.10	0.062	0.109
227581.2	188618.9	7,000	0.020	0.044	2.00	0.040	0.088
187609.6	129139.3	11,500	0.020	0.044	2.00	0.040	0.088
128607.7	72659.4	6,000	0.020	0.044	2.15	0.043	0.095
71975.4	3.1	15,000	0.020	0.055	1.75	0.035	0.096

Table 4. Rating curve calibration error bounds

Name	Average Error (feet)	Standard Deviation (feet)
SJR near Newman	0.1	0.1
SJR near Crows Landing	0.0	0.4
SJR near Patterson	0.2	0.2
SJR at Maze Road Bridge	0.2	0.3
SJR near Vernalis	0.1	0.5

3.2 INUNDATION MAPPING

Inundation mapping was performed by running a range of quasi steady state flows through the unsteady RAS model in increments of 1,000 cfs from 1,000 cfs up to 25,000 cfs. Figure 9 through Figure 14 and Table 5 and Table 6 show the results of the hydraulic modeling and subsequent inundation mapping. Inundation mapping for Reach 1 through Reach 4 are depicted in Figure 9 through Figure 12, respectively. Figure 13 and Figure 14 further summarize these inundation figures by presenting the results in terms of inundated channel and floodplain acres by individual reach and percent inundation within the domain (i.e., total area between levees) of an individual reach. The tabular results supporting Figure 13 and Figure 14 are contained in Table 5 and Table 6, respectively.

For Reach 1 and Reach 2:

1. Table 6 shows that bankfull conditions are in the range of 5,000 to 8,000 cfs
2. Figure 14 shows that approximately 50% of the available floodplain, or 2,800 acres over 33 miles (85 acres/mile), can be inundated between 6,000 to 12,000 cfs and that up to 60% of the available floodplain, or 3,200 acres, can be inundated up to 12,000 cfs.
3. Figure 13 shows that an additional 2,100 acres can be inundated between 12,000 to 25,000 cfs.

For Reach 3:

1. Table 6 shows that bankfull conditions are approximately 13,000 cfs.

2. Figure 14 shows that approximately 70% of the available floodplain, or 1,800 acres over 10 miles (180 acres/mile), can be inundated between 7,000 to 17,000 cfs, and that up to 80% of the available floodplain, or 2,100 acres, can be inundated up to 17,000 cfs.
3. Figure 13 shows that an additional 300 acres can be inundated between 17,000 to 25,000 cfs.

For Reach 4:

1. Table 6 shows that bankfull conditions are approximately 16,000 cfs.
2. Figure 14 shows that approximately 56% of the available floodplain, or 1,600 acres over 17 miles (94 acres/mile), can be inundated between 10,000 to 25,000 cfs, and that up to 74% of the available floodplain, or 2,100 acres, can be inundated up to 25,000 cfs.

Figure 13 and Figure 14 also demonstrate that there is minimal inundated floodplain below 5,000 cfs. The greatest availability of floodplain above 5,000 cfs occurs in Reach 1 and Reach 2, followed closely behind by Reach 3. Reach 4 by far has the least amount of readily available floodplain below 10,000 cfs.

The model results are subject to the following limitations:

1. The outdated channel topography appears to be a limiting factor in terms of model calibration.
2. The outdated channel topography cannot be used to accurately describe the availability or suitability of in-channel habitat.
3. The connectivity of the available floodplain could be over or under predicted as flows initially rise since a 1D model cannot always accurately capture the nature of the various floodplain connections due to a) the inherent limitations of a 1D model, and b) the multitude of abandoned oxbows that may or may not be well represented in the photogrammetric surface.

4 SUMMARY

An unsteady RAS model, developed for 60 miles of the San Joaquin River between the Merced River and the Mossdale Bridge, was calibrated and used as a tool to characterize the relationship between floodplain inundation and flow. A series of quasi steady state flows were run through the unsteady RAS model in increments of 1,000 cfs from 1,000 cfs up to 25,000 cfs. Based on the hydraulic analysis and subsequent inundation mapping, bankfull channel conditions ranged from 5,000 cfs in Reach 1 to 17,000 cfs in Reach 4. Floodplain inundation, partially due to a multitude of abandoned oxbows, begins to at 5,000 cfs in Reach 1 and is closer to 7,000 to 10,000 cfs in the lower reach.

cbec staff offer the following recommendations to strengthen this analysis:

1. Update the RAS model with the latest FloodSAFE LiDAR topography as and when it becomes available and redo the calibration.
2. Verify the unsteady model with the April 2006 flood event.
3. Perform sensitivity testing on the RAS model to understand the effects of key hydraulic parameters (e.g., Manning's n-values).
4. Perform a flood frequency analysis to better understand frequency of floodplain inundation based on historic flow records and overlay the frequency curves on Figure 13 and Figure 14.

5. Perform a flow duration analysis to better understand duration of floodplain inundation based on historic flow records and overlay the duration curves on Figure 13 and Figure 14.

5 REFERENCES

USACE. 2002. Sacramento and San Joaquin River Basins Comprehensive Study. US Army Corps of Engineers Sacramento District, December, 2002.

Table 5. Inundated floodplain by reach (acres)

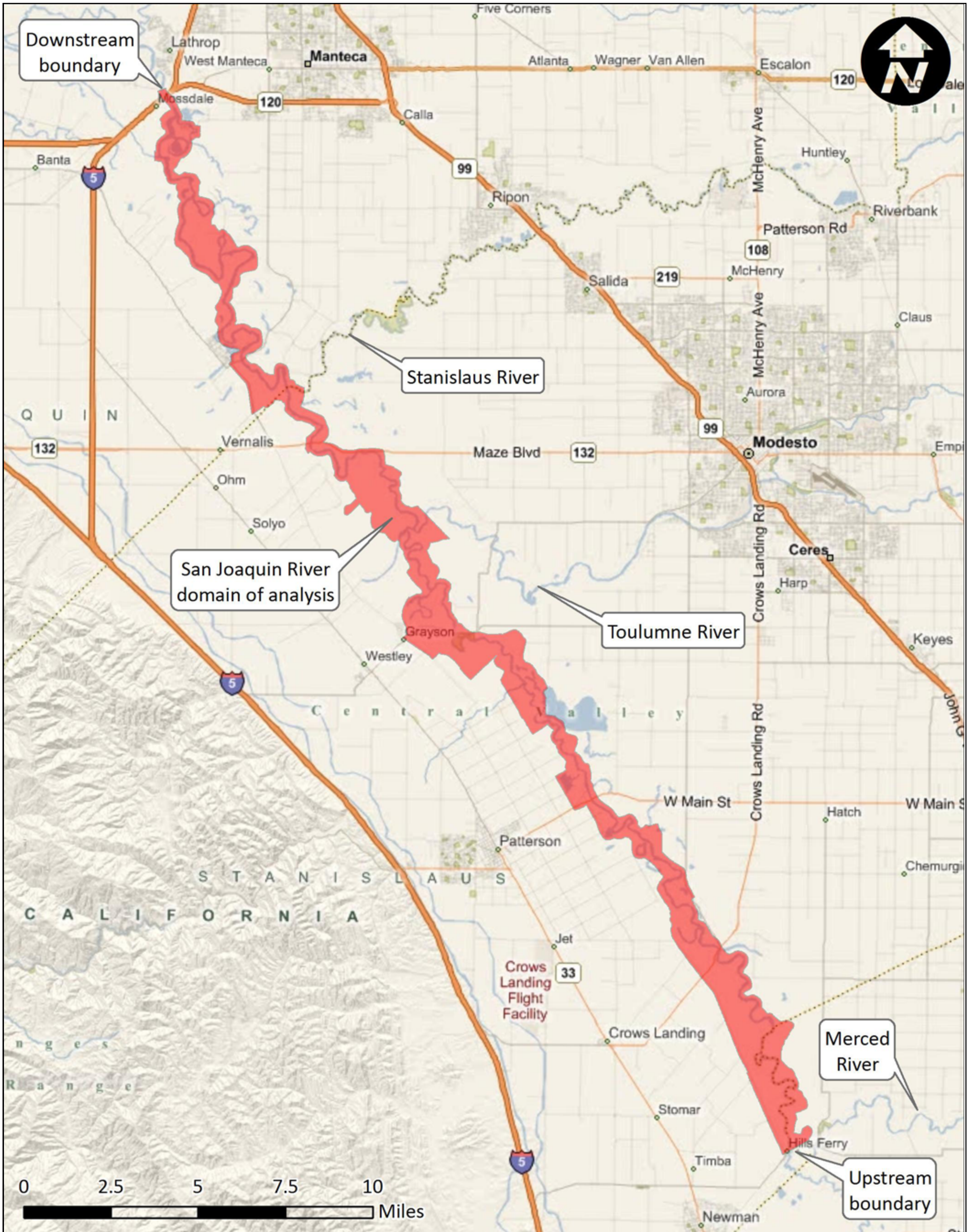
Profile	Flow	Reach1					Reach 2					Reach 3					Reach 4				
	(cfs)	CH (acres)	LFP (acres)	RFP (acres)	FP (acres)	Total (acres)	CH (acres)	LFP (acres)	RFP (acres)	FP (acres)	Total (acres)	CH (acres)	LFP (acres)	RFP (acres)	FP (acres)	Total (acres)	CH (acres)	LFP (acres)	RFP (acres)	FP (acres)	Total (acres)
1	1000	390.5	4.0	6.5	10.5	401.0	288.4	16.2	40.6	56.8	345.1	228.4	2.5	5.2	7.7	236.1	543.8	7.0	55.2	62.3	606.0
2	2000	475.2	8.0	10.8	18.9	494.0	299.5	3.7	16.4	20.1	319.6	280.5	11.1	11.4	22.5	303.0	591.9	9.1	66.4	75.4	667.3
3	3000	528.2	31.4	28.7	60.1	588.3	323.8	16.8	52.5	69.3	393.1	296.7	12.4	16.8	29.2	325.9	625.4	10.5	72.9	83.4	708.9
4	4000	570.1	93.6	70.2	163.9	734.0	343.9	36.7	86.6	123.2	467.1	312.8	17.8	22.1	39.9	352.7	642.8	12.9	77.8	90.7	733.4
5	5000	632.3	232.1	160.2	392.4	1024.6	360.2	128.0	232.6	360.6	720.9	339.4	67.2	33.2	100.4	439.8	656.9	15.4	83.1	98.5	755.4
6	6000	670.0	389.0	261.9	650.9	1320.9	374.5	229.7	405.4	635.2	1009.7	356.5	159.4	53.7	213.1	569.6	670.3	18.4	89.1	107.6	777.9
7	7000	704.0	642.0	365.9	1007.8	1711.8	385.5	437.1	575.2	1012.3	1397.8	366.8	208.1	77.4	285.5	652.3	683.2	24.8	100.6	125.3	808.5
8	8000	723.1	896.8	481.3	1378.1	2101.2	392.7	673.8	715.4	1389.2	1781.9	376.1	283.1	116.6	399.7	775.8	703.3	53.7	177.2	230.9	934.2
9	9000	735.8	1197.2	618.1	1815.3	2551.1	397.5	958.6	855.6	1814.2	2211.7	383.8	412.3	161.3	573.6	957.3	721.4	91.2	261.9	353.1	1074.5
10	10000	743.6	1501.0	772.7	2273.7	3017.3	401.1	1232.1	974.7	2206.7	2607.8	390.2	564.7	215.3	779.9	1170.1	734.0	167.3	333.0	500.3	1234.3
11	11000	749.7	1801.1	923.3	2724.3	3474.0	404.4	1467.2	1061.8	2529.0	2933.4	395.2	713.1	301.1	1014.1	1409.4	746.8	198.9	371.8	570.7	1317.5
12	12000	754.2	2042.3	1130.0	3172.3	3926.5	406.5	1624.2	1103.6	2727.8	3134.3	400.1	881.8	380.8	1262.6	1662.7	758.5	248.1	405.5	653.6	1412.1
13	13000	757.0	2178.2	1204.9	3383.1	4140.1	408.3	1731.8	1121.7	2853.6	3261.8	404.9	1050.0	443.1	1493.1	1898.0	769.5	287.8	440.6	728.4	1497.9
14	14000	758.5	2290.6	1260.8	3551.4	4309.9	409.3	1813.0	1134.8	2947.7	3357.0	408.5	1194.5	507.2	1701.7	2110.2	779.4	341.5	478.9	820.4	1599.8
15	15000	759.4	2381.4	1300.8	3682.2	4441.5	410.0	1878.5	1146.2	3024.7	3434.7	411.4	1298.2	566.6	1864.8	2276.2	788.0	388.0	519.7	907.7	1695.7
16	16000	759.9	2461.5	1333.2	3794.6	4554.5	410.6	1935.1	1155.3	3090.4	3501.0	413.8	1359.5	620.1	1979.5	2393.3	794.1	425.3	560.9	986.3	1780.3
17	17000	760.5	2533.6	1356.8	3890.4	4650.9	411.2	1988.3	1162.8	3151.1	3562.3	415.6	1396.3	681.7	2078.0	2493.6	800.2	465.1	613.1	1078.2	1878.4
18	18000	761.0	2605.3	1375.0	3980.3	4741.3	411.8	2033.5	1168.5	3202.0	3613.8	417.0	1423.5	721.0	2144.5	2561.4	805.1	508.6	673.6	1182.2	1987.3
19	19000	761.2	2670.4	1392.4	4062.8	4824.0	412.2	2074.4	1173.0	3247.4	3659.6	418.2	1447.8	750.8	2198.6	2616.9	809.1	552.9	743.7	1296.7	2105.8
20	20000	761.4	2735.0	1408.0	4142.9	4904.3	412.7	2117.4	1177.8	3295.2	3707.9	419.3	1471.2	774.9	2246.1	2665.3	813.4	613.3	821.3	1434.6	2248.0
21	21000	761.5	2799.8	1417.2	4216.9	4978.5	413.0	2161.4	1182.3	3343.7	3756.7	420.1	1494.5	793.5	2287.9	2708.0	817.2	680.5	891.5	1572.0	2389.2
22	22000	761.6	2859.9	1422.8	4282.7	5044.3	413.2	2201.6	1188.4	3390.1	3803.2	420.9	1512.6	811.4	2323.9	2744.8	820.4	748.6	956.7	1705.3	2525.7
23	23000	761.7	2911.2	1427.5	4338.7	5100.5	413.4	2242.4	1195.2	3437.6	3851.0	421.8	1528.3	826.0	2354.3	2776.2	823.2	814.8	1028.9	1843.7	2666.9
24	24000	761.8	2964.1	1433.1	4397.2	5159.1	413.6	2286.8	1202.7	3489.5	3903.1	422.6	1538.9	837.5	2376.4	2799.0	825.2	877.3	1088.7	1966.0	2791.2
25	25000	761.9	3018.9	1437.7	4456.6	5218.5	413.9	2321.6	1211.9	3533.5	3947.4	423.2	1548.8	847.5	2396.3	2819.5	827.3	938.3	1142.9	2081.2	2908.5

Table 6. Inundated floodplain by reach (percent)

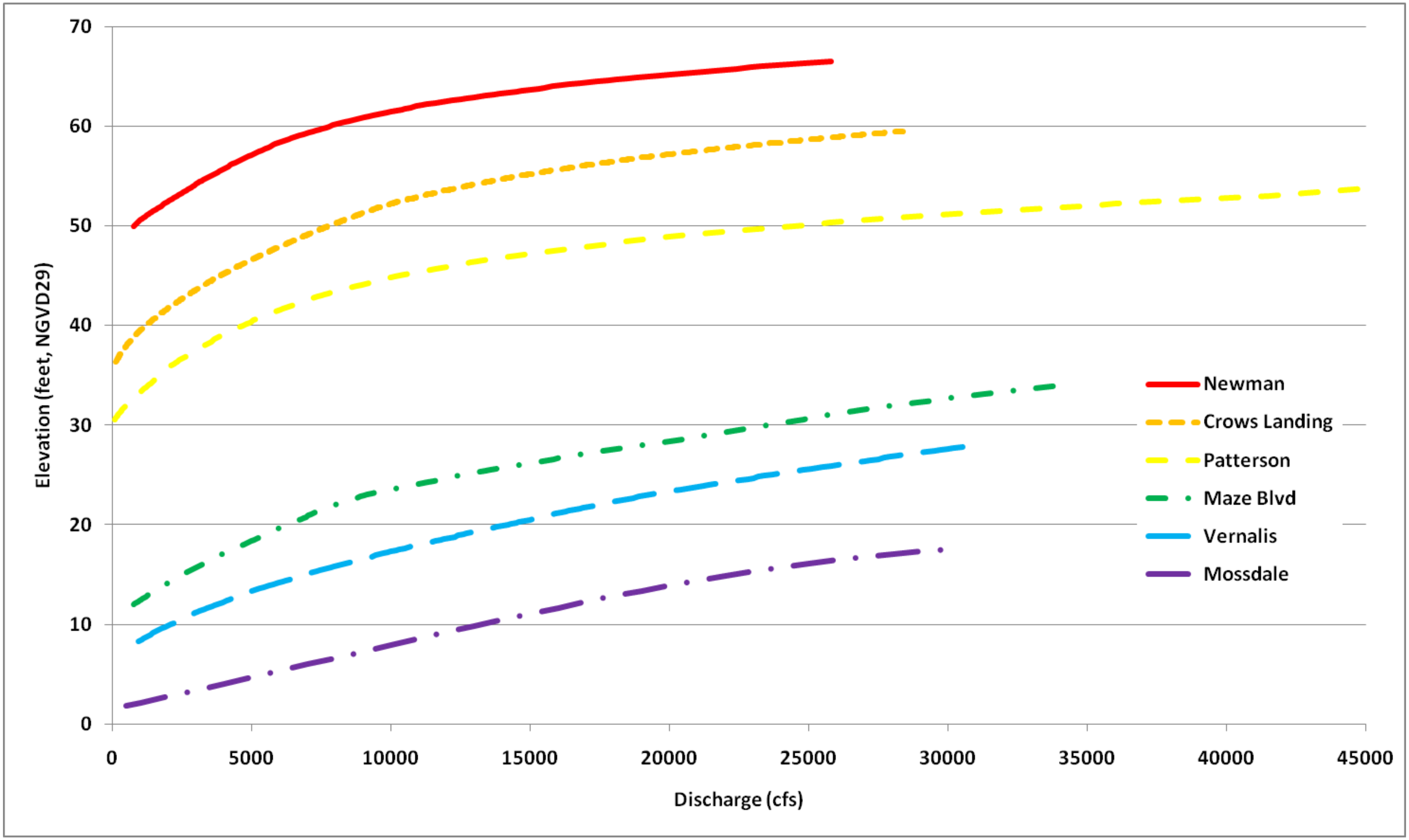
Profile	Flow	Reach1					Reach 2					Reach 3					Reach 4				
	(cfs)	CH (%)	LFP (%)	RFP (%)	FP (%)	Total (%)	CH (%)	LFP (%)	RFP (%)	FP (%)	Total (%)	CH (%)	LFP (%)	RFP (%)	FP (%)	Total (%)	CH (%)	LFP (%)	RFP (%)	FP (%)	Total (%)
1	1000	51%	0%	0%	0%	7%	69%	1%	3%	1%	7%	53%	0%	1%	0%	8%	65%	1%	4%	2%	17%
2	2000	62%	0%	1%	0%	8%	72%	0%	1%	0%	7%	66%	1%	1%	1%	10%	71%	1%	5%	3%	18%
3	3000	69%	1%	2%	1%	10%	78%	1%	4%	2%	8%	69%	1%	2%	1%	11%	75%	1%	5%	3%	19%
4	4000	75%	3%	5%	3%	12%	83%	1%	6%	3%	10%	73%	1%	2%	2%	12%	77%	1%	5%	3%	20%
5	5000	83%	6%	10%	8%	17%	87%	4%	17%	8%	15%	79%	4%	4%	4%	15%	79%	1%	6%	4%	21%
6	6000	88%	11%	17%	13%	22%	90%	8%	29%	14%	21%	83%	10%	6%	8%	19%	80%	1%	6%	4%	21%
7	7000	92%	18%	24%	20%	29%	93%	14%	42%	23%	29%	86%	13%	8%	11%	22%	82%	2%	7%	4%	22%
8	8000	95%	25%	32%	27%	35%	95%	22%	52%	32%	37%	88%	17%	13%	16%	26%	84%	4%	12%	8%	26%
9	9000	97%	33%	40%	35%	43%	96%	32%	62%	41%	46%	90%	25%	18%	22%	32%	86%	7%	18%	13%	30%
10	10000	98%	41%	51%	44%	51%	97%	41%	70%	50%	54%	91%	35%	23%	31%	39%	88%	12%	23%	18%	34%
11	11000	98%	50%	60%	53%	59%	97%	49%	77%	57%	61%	93%	44%	33%	40%	47%	89%	15%	26%	20%	36%
12	12000	99%	56%	74%	61%	66%	98%	54%	80%	62%	65%	94%	54%	41%	50%	56%	91%	18%	28%	23%	39%
13	13000	99%	60%	79%	66%	70%	98%	57%	81%	65%	68%	95%	64%	48%	59%	64%	92%	21%	31%	26%	41%
14	14000	100%	63%	83%	69%	73%	99%	60%	82%	67%	70%	96%	73%	55%	67%	71%	93%	25%	33%	29%	44%
15	15000	100%	65%	85%	71%	75%	99%	62%	83%	69%	71%	96%	80%	62%	73%	76%	94%	28%	36%	32%	47%
16	16000	100%	68%	87%	73%	77%	99%	64%	84%	70%	73%	97%	83%	67%	78%	80%	95%	31%	39%	35%	49%
17	17000	100%	70%	89%	75%	78%	99%	66%	84%	72%	74%	97%	86%	74%	81%	84%	96%	34%	43%	38%	52%
18	18000	100%	72%	90%	77%	80%	99%	67%	84%	73%	75%	98%	87%	78%	84%	86%	96%	37%	47%	42%	55%
19	19000	100%	73%	91%	79%	81%	99%	69%	85%	74%	76%	98%	89%	82%	86%	88%	97%	40%	52%	46%	58%
20	20000	100%	75%	92%	80%	83%	99%	70%	85%	75%	77%	98%	90%	84%	88%	90%	97%	45%	57%	51%	62%
21	21000	100%	77%	93%	82%	84%	99%	72%	85%	76%	78%	98%	92%	86%	90%	91%	98%	50%	62%	56%	66%
22	22000	100%	79%	93%	83%	85%	99%	73%	86%	77%	79%	99%	93%	88%	91%	92%	98%	55%	66%	61%	69%
23	23000	100%	80%	93%	84%	86%	99%	74%	86%	78%	80%	99%	94%	90%	92%	93%	98%	60%	71%	66%	73%
24	24000	100%	82%	94%	85%	87%	100%	76%	87%	79%	81%	99%	94%	91%	93%	94%	99%	64%	76%	70%	77%
25	25000	100%	83%	94%	86%	88%	100%	77%	88%	80%	82%	99%	95%	92%	94%	95%	99%	69%	79%	74%	80%

6 FIGURES

Figure	Title
1	Location map and domain of analysis
2	Published rating curves
3	Newman calibration
4	Crows Landing calibration
5	Patterson calibration
6	Maze Blvd calibration
7	Vernalis calibration
8	Low flow calibration
9	Reach 1 floodplain inundation
10	Reach 2 floodplain inundation
11	Reach 3 floodplain inundation
12	Reach 4 floodplain inundation
13	Floodplain inundation by reach (acres)
14	Floodplain inundation by reach (percent)



Notes:	cbec eco engineering	*San Joaquin River Technical Support* **Location map and domain of analysis**		
		Project No. 10-1035	Created By: CRC	**Figure 1**

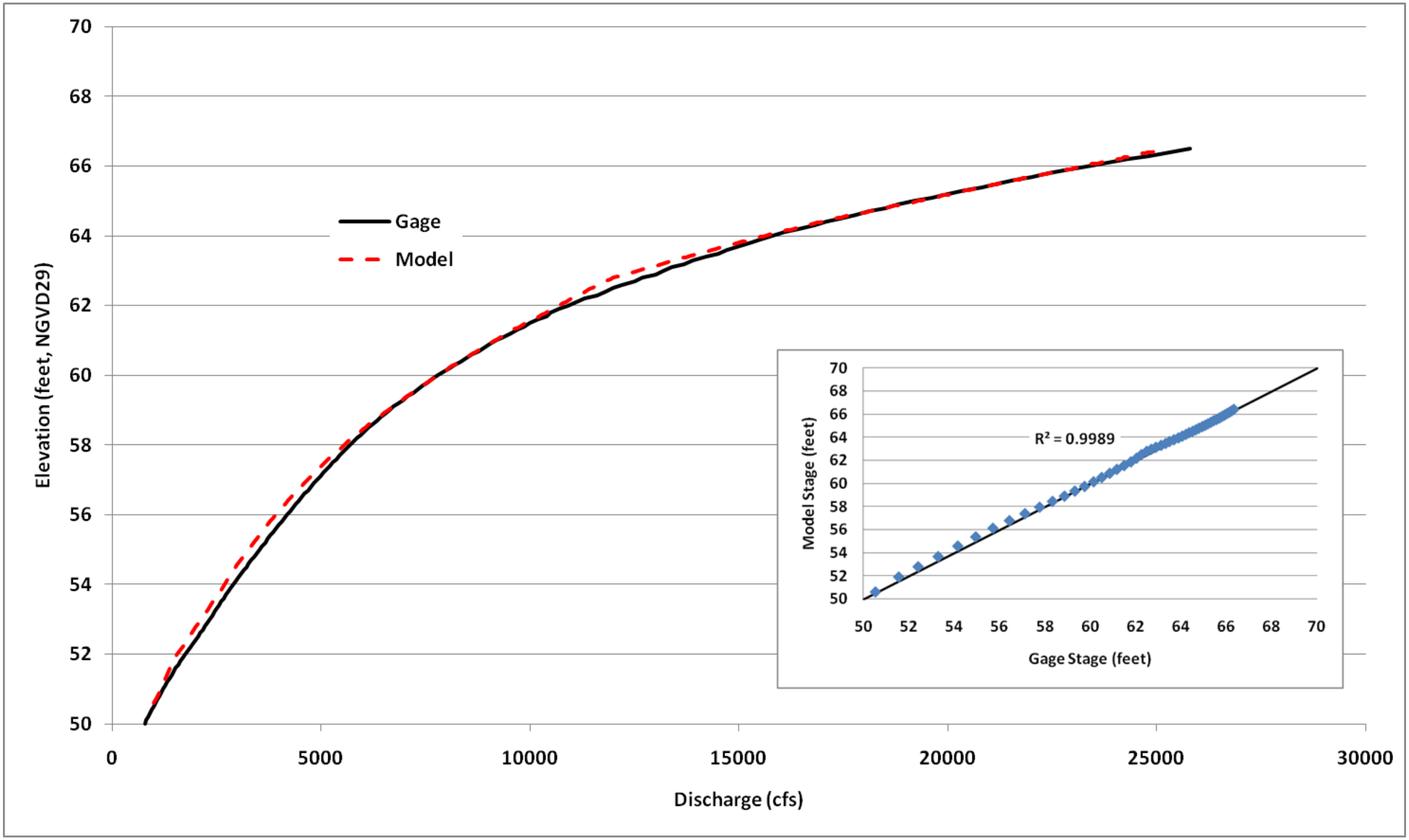


Notes:

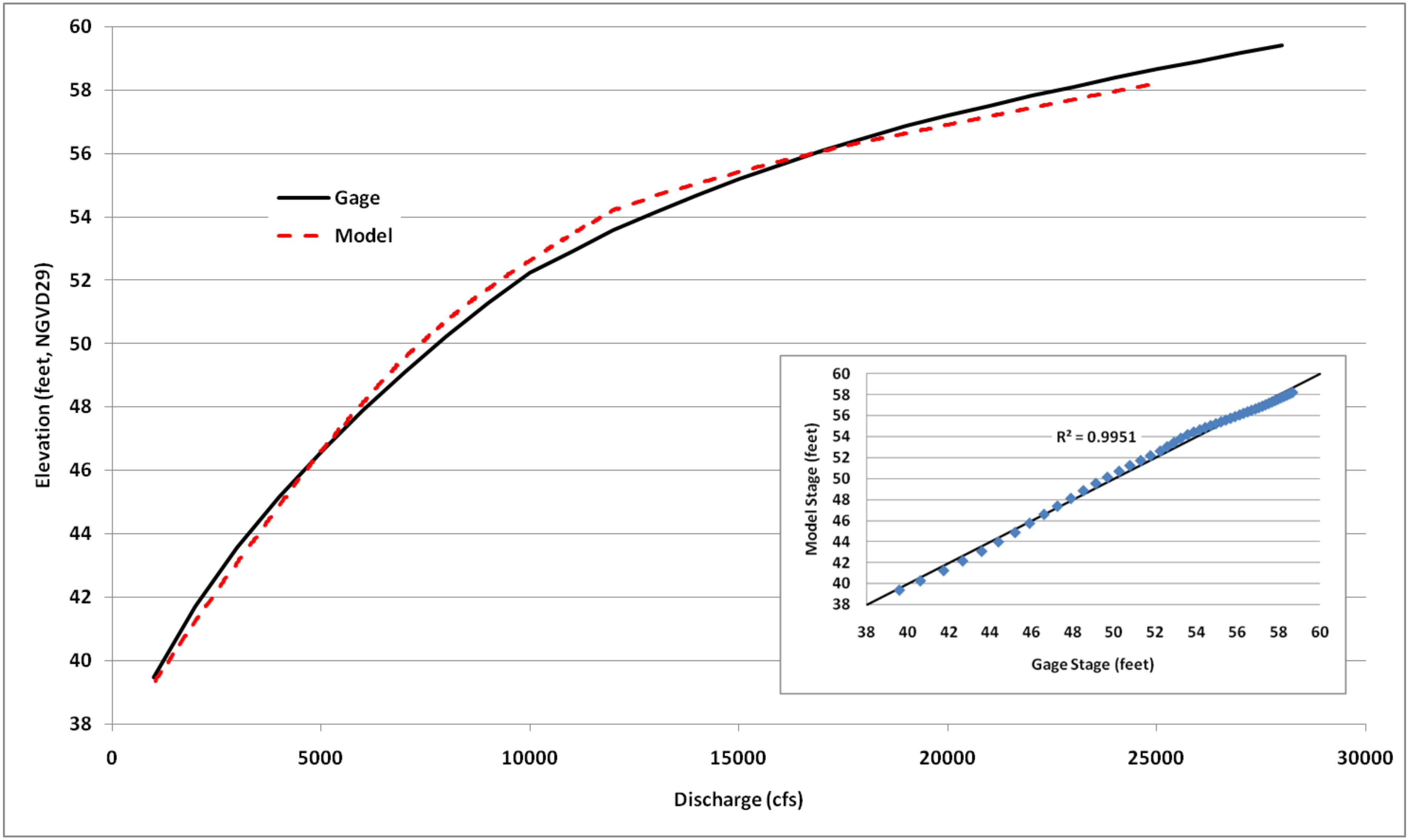
San Joaquin River Technical Support

Published rating curves

Project No. 10-1035	Created By: CRC	**Figure 2**



Notes:	cbec eco engineering	*San Joaquin River Technical Support* **Newman calibration**		
		Project No. 10-1035	Created By: CRC	**Figure 3**



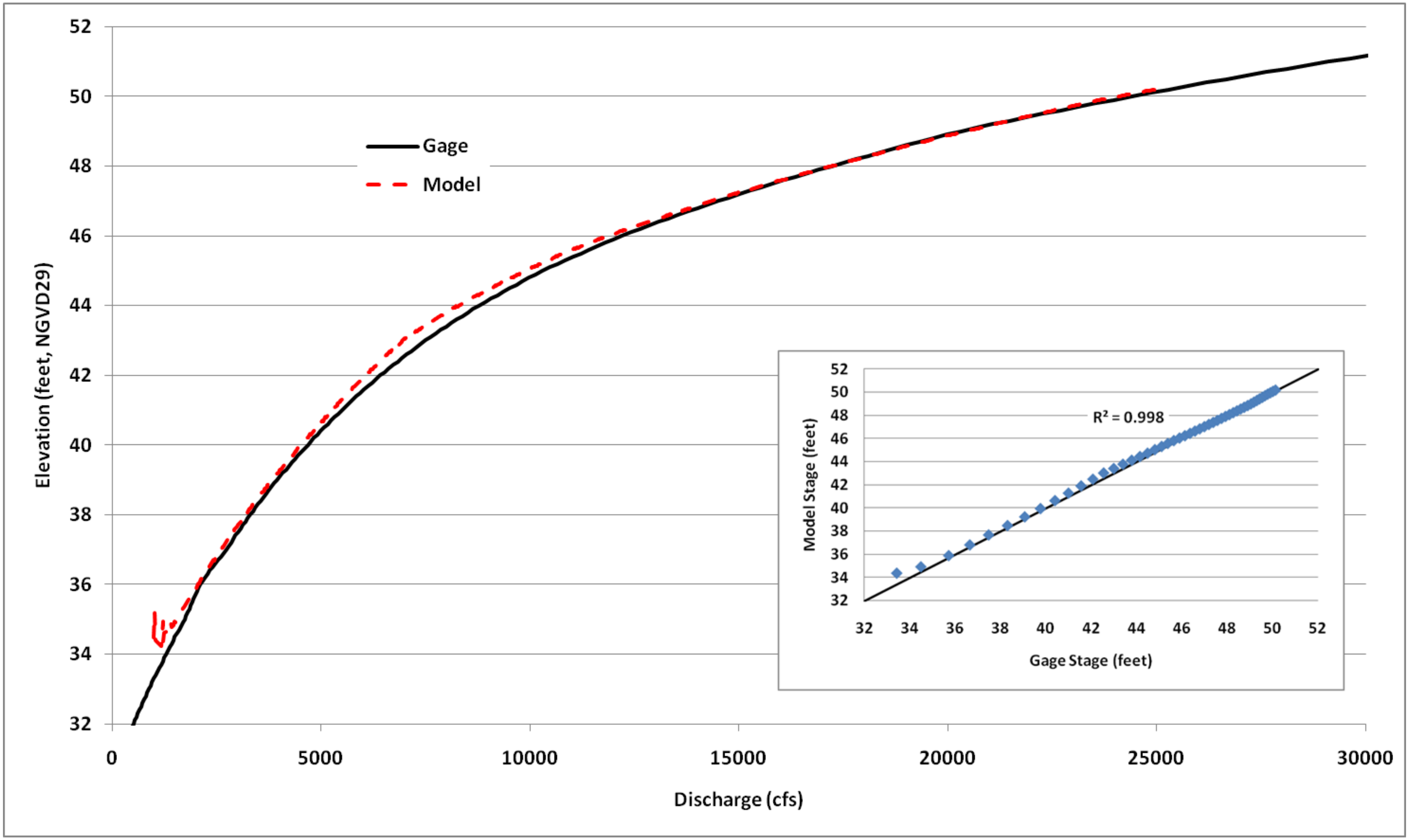
Notes:

San Joaquin River Technical Support

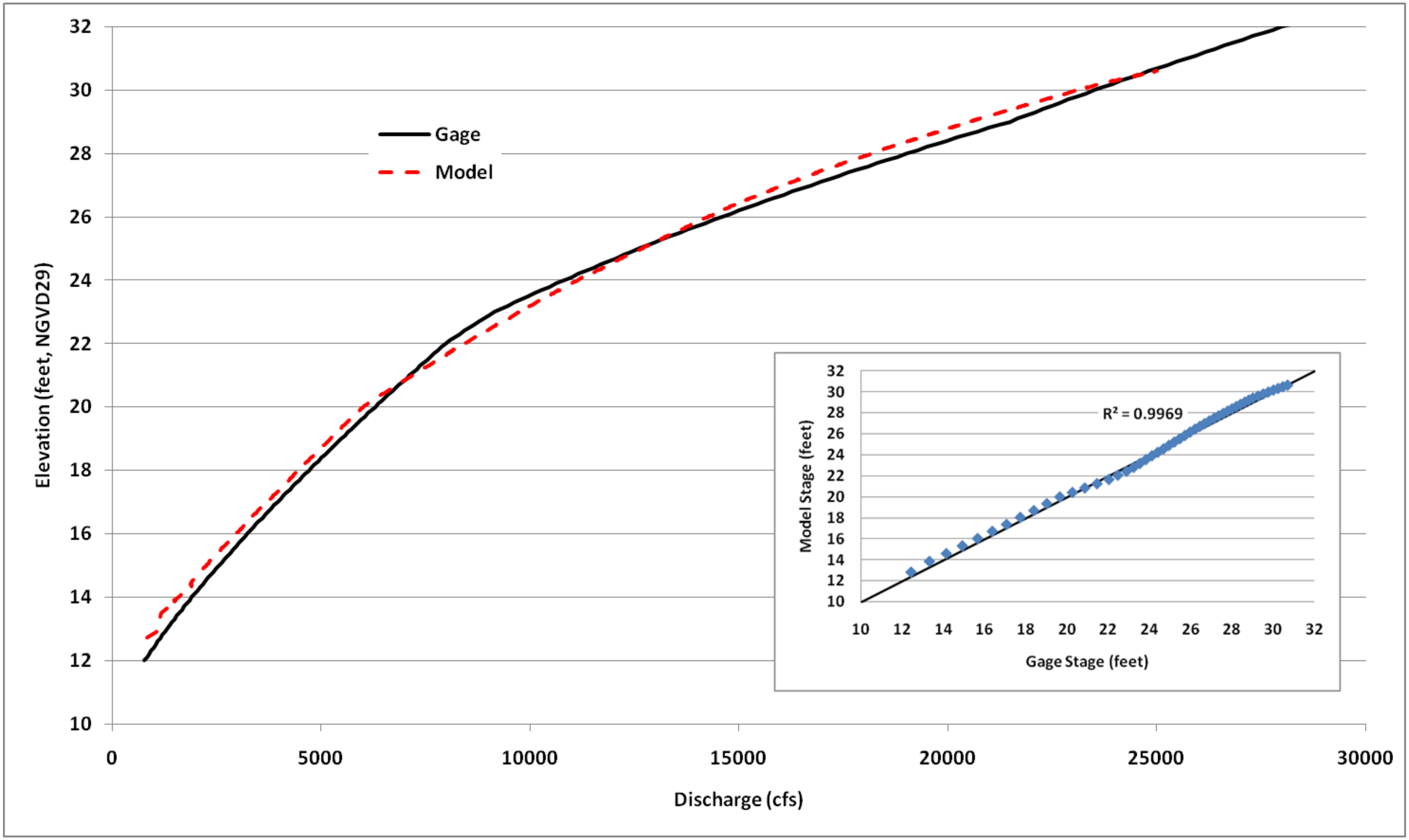
Crows Landing calibration

Project No. 10-1035	Created By: CRC	**Figure 4**

R:\Projects\10-1035_SJR_Tech_Support\Task4_Reporting\Figures\Fig4_Crows_Calib.docx
10/19/2010



Notes:	cbec eco engineering	*San Joaquin River Technical Support* **Patterson calibration**		
		Project No. 10-1035	Created By: CRC	**Figure 5**

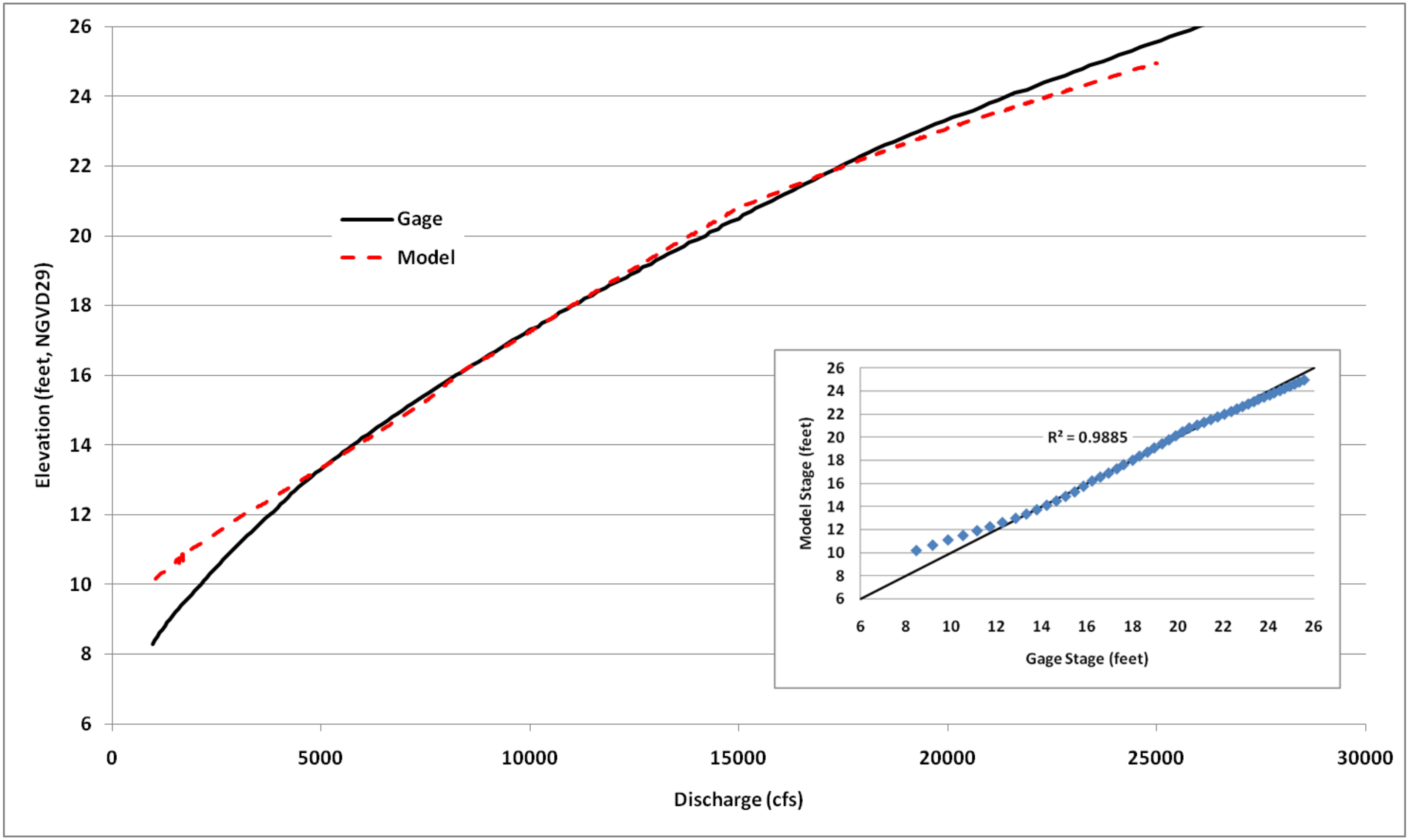


Notes:

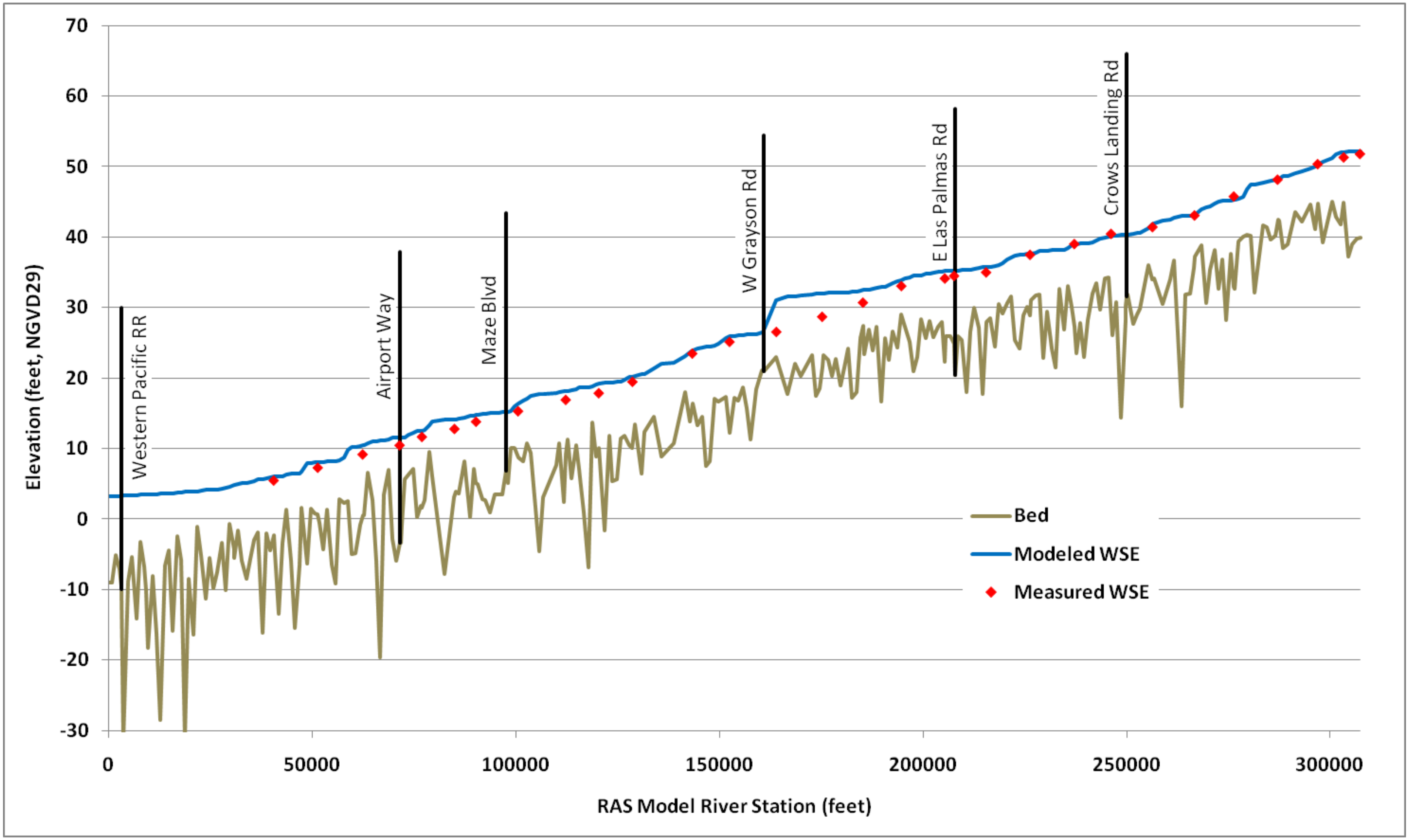
San Joaquin River Technical Support

Maze Blvd calibration

Project No. 10-1035	Created By: CRC	**Figure 6**

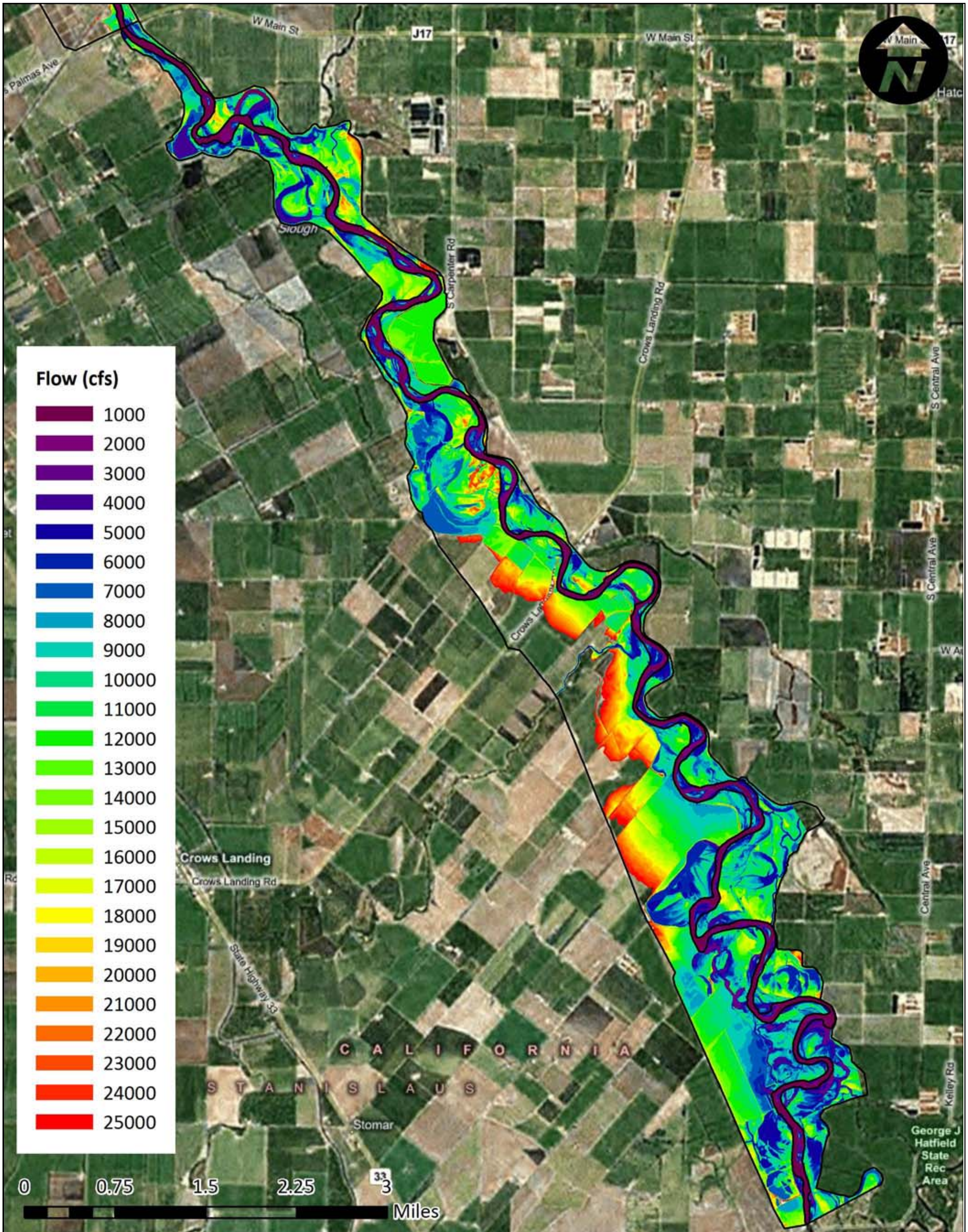


Notes:	cbec eco engineering	*San Joaquin River Technical Support* **Vernalis calibration**		
		Project No. 10-1035	Created By: CRC	**Figure 7**

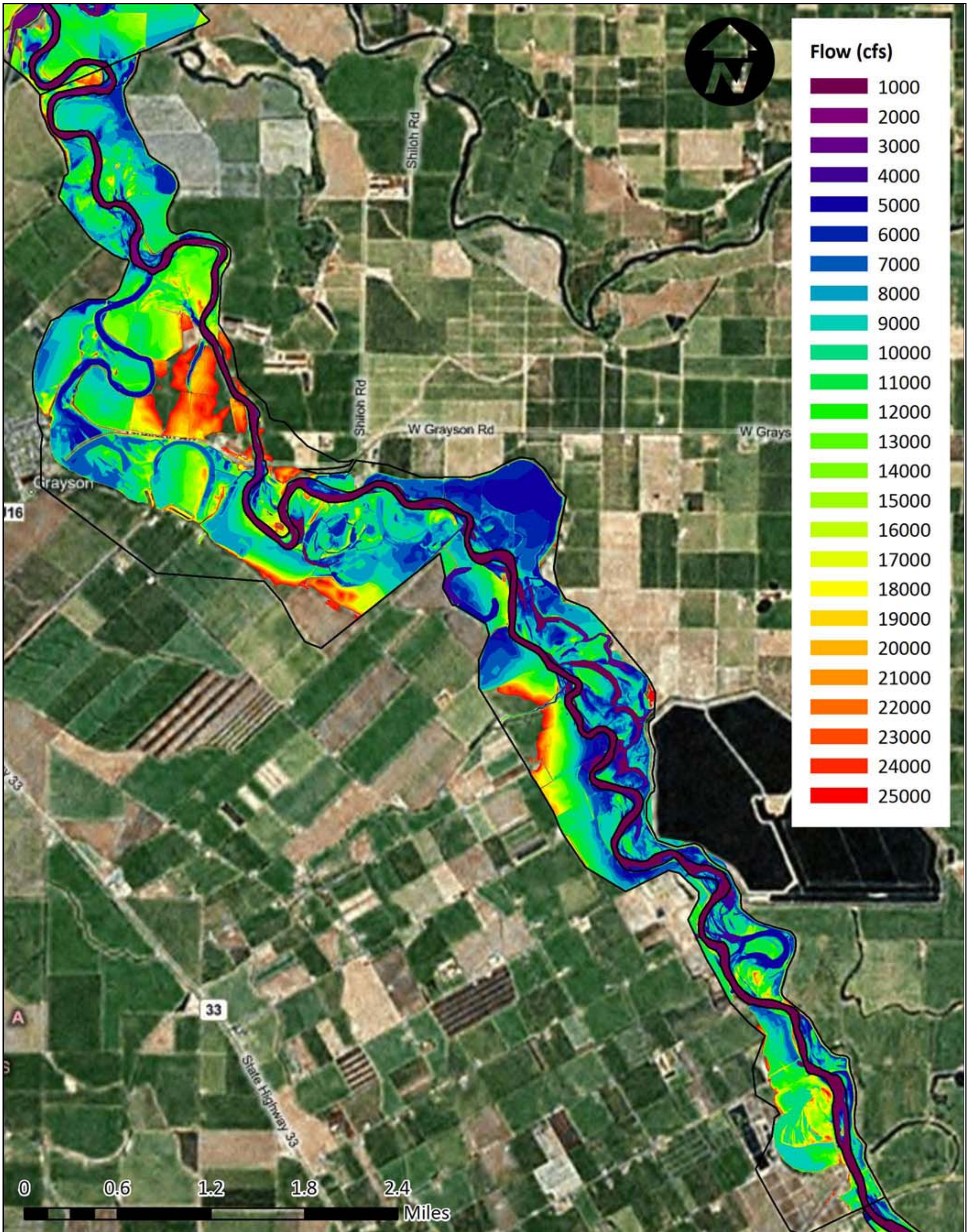


Notes:

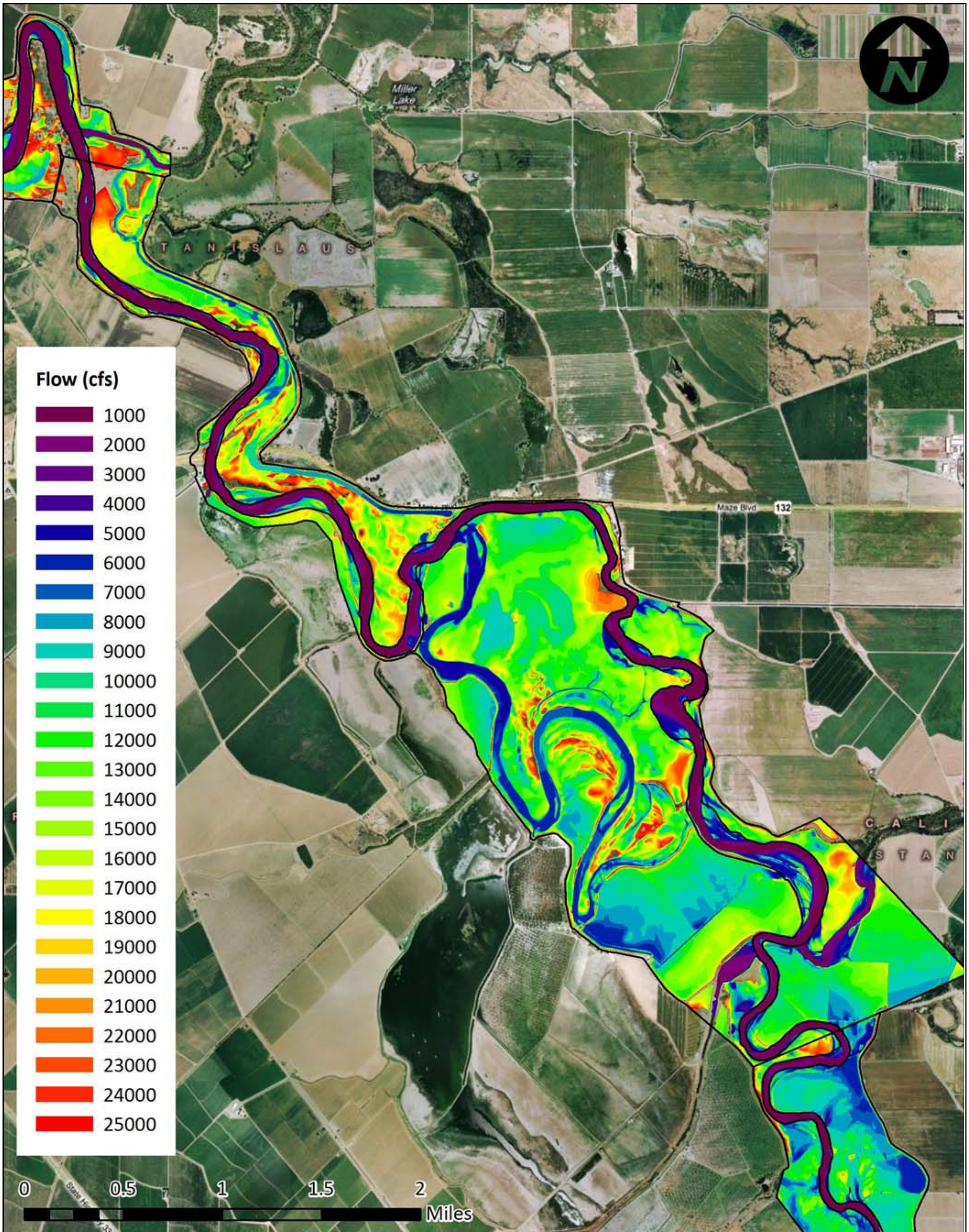
	San Joaquin River Technical Support	
	Low flow calibration	
Project No. 10-1035	Created By: CRC	**Figure 8**



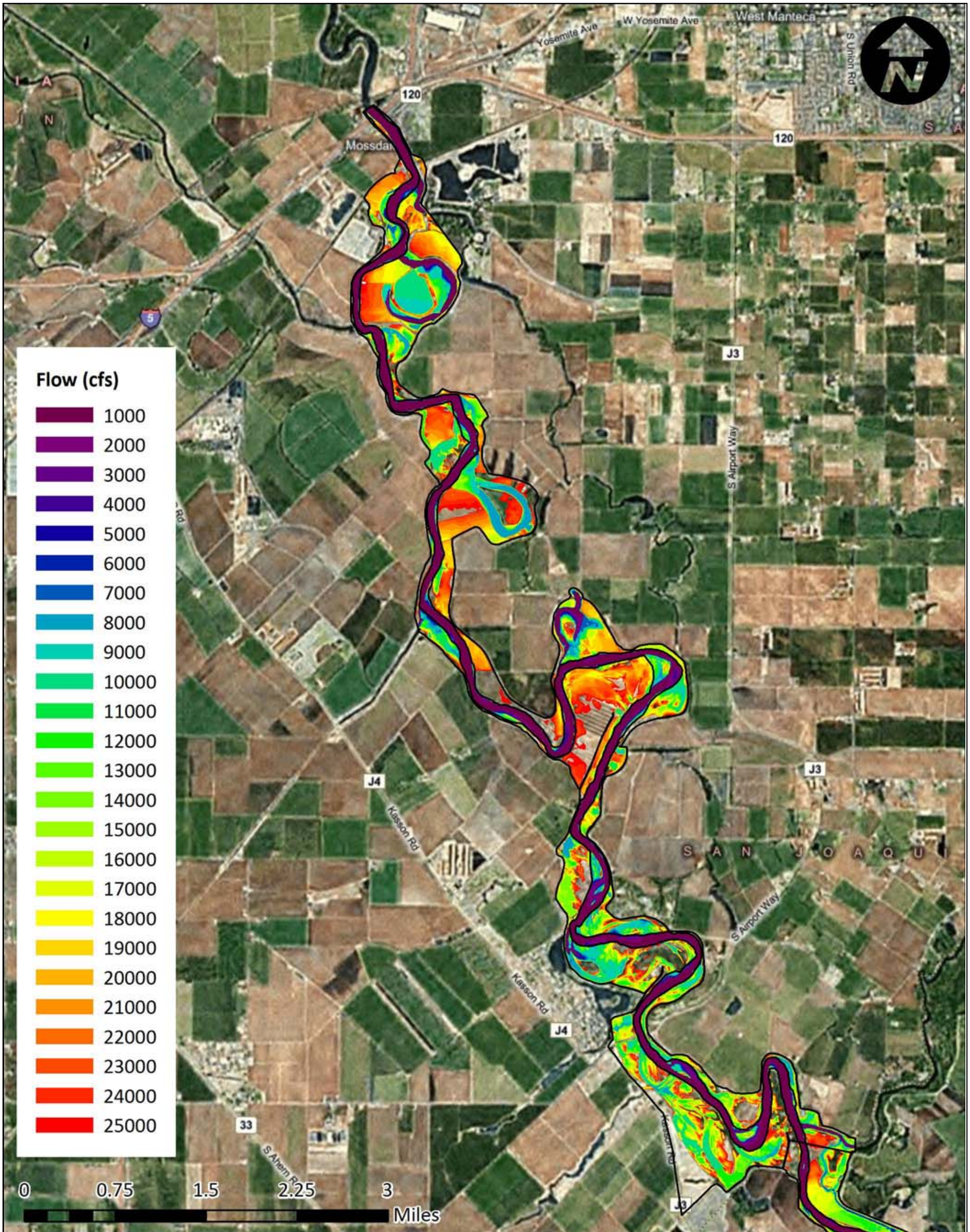
Notes: reach defined from Newman to E Las Palmas Ave	cbec eco engineering	*San Joaquin River Technical Support* **Reach 1 floodplain inundation**		
		Project No. 10-1035	Created By: CRC	**Figure 9**



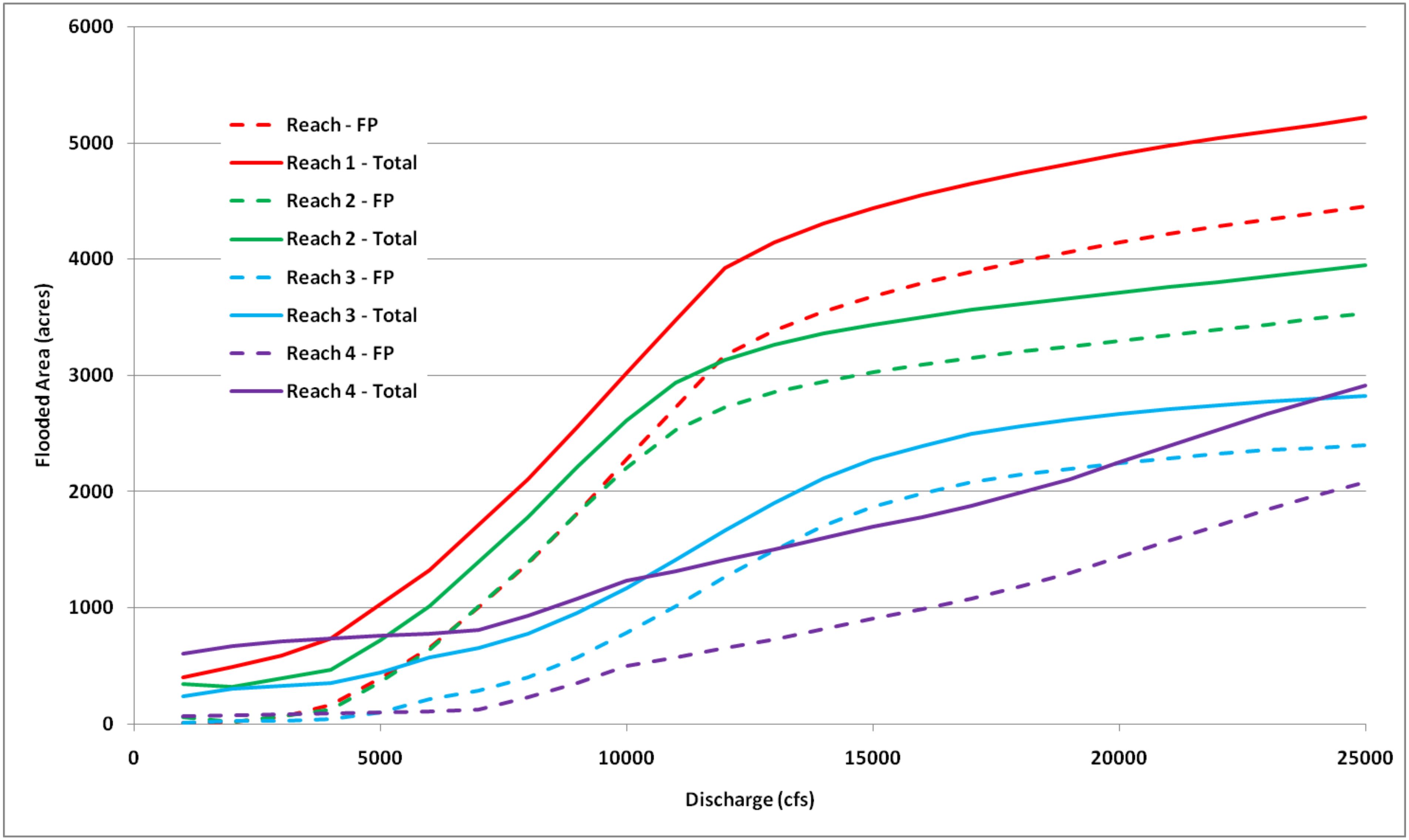
Notes: reach defined from E Las Palmas Ave to Toulumne River	cbec eco engineering	*San Joaquin River Technical Support* **Reach 2 floodplain inundation**		
		Project No. 10-1035	Created By: CRC	**Figure 10**



Notes: reach defined from the Toulumne River to the Stanislaus River		*San Joaquin River Technical Support* **Reach 3 floodplain inundation**		
		Project No. 10-1035	Created By: CRC	**Figure 11**



Notes: reach defined from the Stanislaus River to Mossdale	cbec eco engineering	*San Joaquin River Technical Support* **Reach 4 floodplain inundation**		
		Project No. 10-1035	Created By: CRC	**Figure 12**

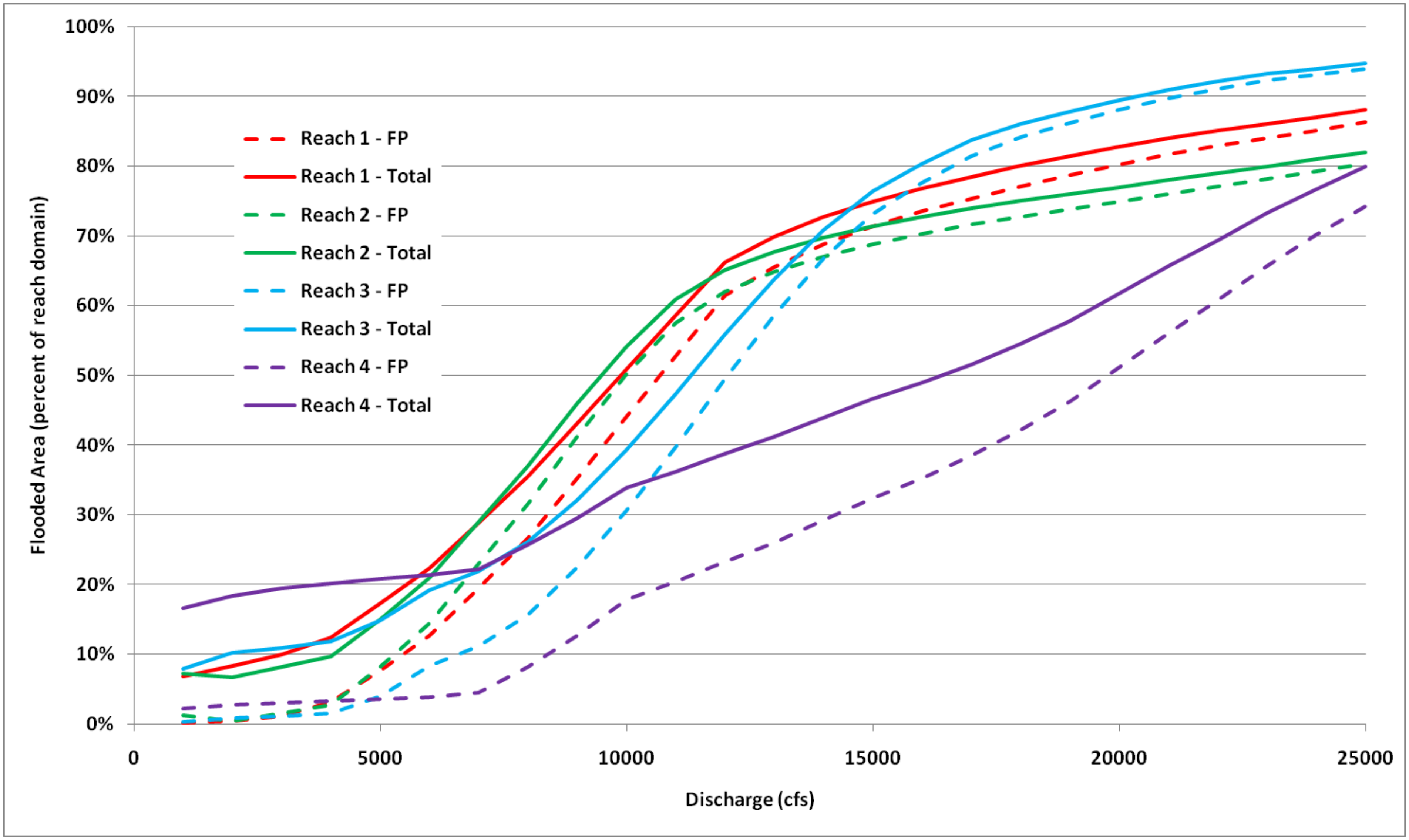


Notes: FP = floodplain only; Total = channel plus floodplain

San Joaquin River Technical Support

Floodplain inundation by reach (acres)

Project No. 10-1035	Created By: CRC	**Figure 13**



Notes: FP = floodplain only; Total = channel plus floodplain

San Joaquin River Technical Support

Floodplain inundation by reach (percent)

Project No. 10-1035	Created By: CRC	**Figure 14**