TUOLUMNE RIVER CHINOOK SALMON FRY AND JUVENILE STRANDING ASSESSMENT

Prepared for
The Tuolumne River Technical Advisory Committee

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Table of Contents

1 Introduction 2
1.1 Approach 3
2 Methods and Results 4
2.1 Task 1: Catalogue Sites Surveyed in Previous Studies 4
2.2 Task 2: Identify Potential Stranding Sites from the Existing GIS Database 6
2.3 Task 3: Field Assessment of Site Conditions 6
2.4 Task 4: Stranding and Entrapment Field Surveys 7
2.4.1 Stranding Survey Methods 8
2.4.2 Distance Sampling Methods 8
2.4.3 Stranding Survey Results 8
2.5 Task 5: Data Analysis and Site Prioritization 15
2.5.1 Effects of Flow and Ramping Rates on Stranding Frequency 15
2.5.2 Geomorphic Characteristics of Stranding Sites 16
2.5.3 Prioritization of Stranding Sites for Potential Restoration 16
3 Conclusions and Recommendations 17
3.1 Factors Contributing to Stranding Risk in the Lower Tuolumne River 17
3.2 Recommendations for Restoration Projects 18
3.3 Recommendations for Future Stranding Surveys 18
4 References 19

List of Tables

Table 1. Maximum Flow Reduction Rates under FERC Settlement Agreement at La Grange - October 16 through March 15
Table 2. Summary of 1986–1992 and 1994–1996 Juvenile Standing Surveys
Table 3. 1999 Tuolumne River Stranding (May)
Table 4. 1999 Tuolumne River Entrapment (May)
Table 5. 2000 Tuolumne River Stranding (March)
Table 6. 2000 Tuolumne River Entrapment (March)
Table 7. Number Of Stranding Transects Surveyed by Slope and Substrate Type

List of Figures

Figure 1. Stranded Juvenile Salmon by Site for the 1986–1992 and 1994–1996 Surveys
Figure 2. Stranding Occurrence by Location and Flow (1986–1992 and 1994–1996 Surveys)
Figure 3. Stranding Occurrence by Location and Date (1986–1992 and 1994–1996 Surveys)
Figure 4. Tuolumne River Flow and Ramping Rate at La Grange During 1999 Stranding Surveys
Figure 5. Tuolumne River Flow and Ramping Rate at La Grange During 2000 Stranding Surveys

List of Appendices

Appendix A. Tuolumne River Fry and Juvenile Stranding Assessment - 1986–1989 and 1990–1996 Surveys
Appendix B. Tuolumne River Fry and Juvenile Stranding Assessment – Inundation Areas and Stranding Survey Locations
Appendix C. Potential Stranding Sites Based Upon Geomorphic Characteristics

1 Introduction

Flow fluctuations can result in stranding or entrapment of fry and juvenile salmon in dewatered or isolated areas of gravel bars and floodplains when flows recede as a result of natural flow events or as a result of water project operations (during downramping). Vulnerability of salmonids to stranding appears to be greatest for coho (*Oncorhynchus kisutch*) and chum (*O. keta*), followed by chinook (*O. tshawytscha*) and steelhead trout (*O. mykiss*) (Beck and Associates 1987, Bradford 1995, Page 1976, Prewitt 1986). The effects are dependent on many variables such as flow change rate, amplitude, frequency, location, channel and floodplain features, and fish behavior.

Stranding and entrapment of chinook salmon have been documented on the Tuolumne River and on many rivers in the Pacific Northwest (Bauersfield 1978, Becker et al. 1981, Phinney 1974, Woodin et al. 1984, and Beck and Associates 1989). Stranding occurs when fish are trapped in rapidly dewatered areas, resulting in asphyxiation or desiccation. Because salmonid fry are poor swimmers, they generally prefer inshore areas near gravel for daytime refuge and are considered more vulnerable to stranding during daytime downramping (Groot and Margolis 1991).

Entrapment occurs when fish are isolated in potholes or side channels. These entrapped fish may subsequently become stranded if flows continue to recede. They may also be subject to increased predation and physiological stress (due to high temperatures and oxygen deficit) in the entrapment area. If flows increase and again inundate the side channel or pothole, the entrapped fish may return to the river; however, they may be in poorer condition than fish that did not experience a period of entrapment (Beck and Associates 1989).

Generally, stranding studies have been conducted opportunistically, due to the time, expense and protection of in-river fish populations. On the Tuolumne River, stranding of chinook salmon has been documented on a limited basis by field surveys conducted since 1986. The Turlock and Modesto Irrigation Districts (the Districts) have conducted two series of surveys to document stranding and entrapment resulting from flow fluctuation. From 1986 through 1989, stranding was surveyed at locations from La Grange Dam (River Mile [RM] 52) downstream to Lakewood (RM 21.9), although specific reaches and locations surveyed varied among study years. Since 1989, less extensive surveys have been conducted annually in conjunction with annual seining studies or flow opportunities.

In water years 1987 through 1989, the Districts conducted surveys to examine the potential for stranding losses from flow reductions by searching in locations expected to have a high potential for stranding (TID/MID 1991, Appendix 14). Areas to be surveyed were identified based on bar gradient and substrate. The timing and frequency of surveys depended on the pattern of flow reductions that occurred each year.

From 1990 through 1997, the Districts conducted occasional stranding and entrapment surveys each year (with the exception 1993) (TID/MID 1997, Report 96-2; TID/MID 1998, Report 97-2). In general, survey locations were chosen based on the magnitude and rate of flow reduction, flow volume, and channel/floodplain topography. However, survey sites were generally chosen in areas known to have high stranding potential. The study plan for the current (1998–2000) stranding assessment conducted for this study was developed by the TRTAC in 1998 to use random survey site selection within the inundation areas exposed during specific flow reductions. The study plan sought to identify the potential for fry and juvenile salmon stranding throughout the Tuolumne River corridor from Old La Grange Bridge (RM 52) downstream to Empire (RM

21) based on floodplain geomorphic characteristics. Random site selection would allow extrapolation of river wide stranding estimates based upon the distribution of specific slope-substrate categories.

The 1995 FERC Settlement Agreement (FSA) Section 13(d) specified assessing fry distribution and survival (fluctuation) as a component of "Flow Fluctuation" monitoring. Section 16 of the FSA contained restrictions on flow ramping rates (Table 1) that were intended to reduce the impacts to spawning, incubation and fry rearing (Appendix I, FERC 1996) because stranding had been documented during previous surveys and was a potentially important source of mortality. In addition, the Don Pedro Project flood manual (USACE 1972) limits flow reductions for flood management to 1000 cfs over two hour periods except for certain emergency spillway operations. The current stranding assessment will help to evaluate the effectiveness of the FSA ramping rates, further document conditions under which stranding may occur, and identify potential areas for floodplain improvements.

Table 1.
Maximum Flow Reduction Rates under FERC Settlement Agreement at La Grange - October 16 through March 15

Flow at La Grange (cfs)	Ramping Rate (cfs/hr)
< 2,000	500
2,000–2,700	700
2,700–4,500	900

1.1 Approach

For the years 1998–2000, we identified and prioritized sites where stranding could be reduced through floodplain restoration or other management actions. This included the following tasks:

Task 1. Catalogue Sites Surveyed in Previous Studies: From existing reports, identify sites surveyed during the Districts' 1987–89 study and subsequent 1990–96 surveys. Using ArcInfo, plot these sites on existing GIS base maps. Review stranding data associated with each of these sites.

Task 2. Identify Potential Stranding Sites from the Existing GIS Database: Based on the Districts' existing GIS mapping of the wetted area at various flows, identify areas with high potential for stranding based on the horizontal extent of flooding.

Task 3. Field Assessment of Site Conditions: In the field, determine slope, substrate, and entrapment area of all sites identified in Task 2. From these sites, select a sample of sites for future surveys representing the full range of physical characteristics at stranding sites.

Task 4. Stranding and Entrapment Field Surveys: Conduct surveys to document whether stranding and entrapment are occurring at the study sites identified under Task 3 under typical flow schedules and ramping rates or flood control flow changes.

Task 5. Data Analysis and Site Prioritization: Based on site conditions (slope and substrate) and the occurrence of stranding and entrapment documented at the sample sites, determine the risk of stranding and entrapment at all potential stranding and entrapment sites in the river corridor. From these results, develop a prioritized list of stranding sites to be addressed by floodplain reconstruction or other methods and indicate preliminary assessment of most appropriate method(s) of reducing stranding.

This report provides results of Tasks 1 through 5. Tasks 1 and 2 were completed and presented to the TRTAC in 1998. The field component of Task 3 was completed in November and December 1998. The initial results of Task 4 were presented to the TRTAC subgroup on May 21, 1999 and on April 11, 2000.

2 Methods and Results

2.1 Task 1: Catalogue Sites Surveyed in Previous Studies

Tasks 1 and 2 included compiling and reviewing existing survey data, mapping existing survey sites, and identifying potential stranding sites from the existing GIS database. Sites previously surveyed by the Districts and the results of these surveys were identified from review of the Districts' 1991 and 1996 reports to FERC and from data files provided by Turlock Irrigation District. However, these reports often provided only general information on survey locations. To clarify the specific areas surveyed at each site, we interviewed Steve Kirihara (EA Engineering), who conducted many of the original surveys. All survey results were entered into a spreadsheet, and all survey locations were entered as a point coverage in an ArcInfo GIS database.

A total of 22 sites were surveyed in the 1986–1992 and 1994–1996 surveys. The results of these surveys are included in Appendix A. Flow conditions varied among years, with fluctuations ranging from 57 to 7,600 cfs in magnitude (Table 2). In water year (WY) 1987, a "normal flow schedule" year, flow fluctuations occurred from December through the beginning of June. Water years 1988 and 1989 were relatively dry years and flow fluctuations were minor. In WY 1988, power peaking flows ranged from 100 to 200 cfs; the highest flow was 550 cfs. In WY 1989, no winter power peaking flows were released. Flows were consistently 100 cfs or less, except for two pulse flows occurring in April.

Due to dry conditions, flow fluctuations in 1990 through 1994 were limited to pulse flows to aid in downstream migration of salmon (no power peaking flows occurred). Salmonid stranding was observed in 1990 following flow reductions from approximately 250 to 150 cfs. No salmonid stranding was observed in 1991, 1992, or 1994, although other fish species were observed stranded. Lack of documented salmonid stranding in these years may have been due to extremely low salmon densities in the river (no survey was conducted in 1993). In 1995, three surveys were conducted in March and one in June following flow reductions from 3,000 to 1,200 cfs, 7,700 to 4,700 cfs, 4,700 to 1,900 cfs, and 8,600 to 1,000 cfs, respectively.

The greatest numbers of stranded juvenile salmon were documented after flows were reduced from 5,000 to 3,000 cfs (February 1996), from 2,900 to 1,200 cfs (March 1995), from 1,050 to 400 cfs (April 1989), from 550 to 200 cfs (May 1987), and from 230 to 10 cfs (June 1987). In years of high juvenile salmon density, stranded salmon were generally found on gently sloping stream banks and gravel bars on a wide range of substrates in the upper reaches of the river. Of the sites that were surveyed, most stranding occurred at Riffles A3, A4, 2, 4B, and 5, and at Old La Grange Bridge (Figure 1). No stranded salmon were found when densities were low, as in 1991, 1992, and 1994. However, other species, including riffle sculpin (*Cottus gulosus*), Sacramento squawfish (*Ptychocheilus grandis*), Pacific lamprey (*Lampetra tridentate*), Sacramento sucker (*Catostomus occidentalis*), mosquitofish (*Gambusia affinis*), and several centrarchid species, were found stranded.

Table 2. Summary of 1986–1992 and 1994–1996 Juvenile Standing Surveys

Year	Month	Beginning Flow (cfs)	Ending Flow (cfs)	Change in Flow (cfs)	No. of sites surveyed	No. of stranded salmon
1986	Dec	4,700	500	4,200	3	16
1986	Dec	4,000	200	3,800	6	16
1987	Jan	2,600	200	2,400	7	25
1987	Jan	1,200	500	700	5	20
1987	May	550	200	350	1	52
1987	Jun	200	3	197	6	403
1988	Jan	550	125	425	3	9
1988	Feb	300	120	180	7	18
1988	Apr	550	115	435	11	17
1988	Apr	550	100	450	9	5
1988	May	67	10	57	4	53
1989	Apr	730	120	610	7	0
1989	Apr	1,050	400	650	7	52
1990	Mar	167*			5	12
1990	Mar	162*			6	34
1990	Mar	174*			3	17
1990	Mar	180*			8	30
1990	Mar	220	120	100	6	11
1990	May	560	280	280	7	5
1991	May	1,120	667	453	7	0
1991	May	667	284	383	3	0
1992	May	1,000	550	450	6	0
1992	May	160	50	110	10	0
1994	Apr	1,100	550	550	5	0
1995	Mar	2,900	1,200	1,700	4	98
1995	Mar	7,700	4,700	3,000	5	2
1995	Mar	4,700	1,900	2,800	4	2
1995	Jun	8,600	1,000	7,600	2	0
1996	Feb	5,000	3,000	2,000	6	54

*These figures are mean daily flows reported by the USGS for the Tuolumne River below La Grange Dam, near La Grange (Gauge No. 11289650). Instantaneous flows and flow fluctuations were not reported in the FERC documents for these surveys.

In 1997, limited stranding surveys were conducted following flood conditions that included peak daily flows of 55,900 cfs on January 3rd. The first survey conducted corresponded to flow reductions from 9,500 to 5,700 cfs, few fish were observed stranded and in-river densities were low at this time (TID/MID 1998, Report 97-2). A late season flow reduction and survey was also conducted on May 15, 1997; few stranded fish were observed and salmon density in the Tuolumne River was also low.

From review of the previous surveys, we concluded that several factors contribute to the magnitude of juvenile stranding caused by flow fluctuations, including: (1) salmon density, (2) the magnitude of flow reduction and the minimum flow in the fluctuation cycle (which determines the amount of potential stranding area exposed), (3) ramping rate, and (4) antecedent flow level prior to reduction. For instance, in May and June 1987, the density of salmon was relatively high (5 – 15 fish/1,000 ft^2); flow reduction was in the range at which many bank areas and side channels became exposed; flow reduction was rapid; and a long period of stable, higher flows preceded the flow reduction, which may have increased use of marginal areas by juvenile salmon prior to flow reduction. These conditions likely contributed to the high rates of stranding that were observed in 1987.

2.2 Task 2: Identify Potential Stranding Sites from the Existing GIS Database

Inundation areas were assessed along the lower Tuolumne River using GIS files obtained from the Districts. Inundation area at 620, 1,000, 3,100, 5,300, and 8,400 cfs was plotted. Channel features at 620 cfs (including riffles, special run-pools, run-pools, bedrock chutes, side channels, backwaters, tailraces, and gravel pits) were also plotted. High priority survey areas were identified from this map.

Increases in flow from 620 to 1,100 cfs results in a relatively minor increase in the area of inundation, except at the following locations (where broad areas are inundated): Riffle 23D to Riffle 23C2, Riffle 22N to Riffle 18, and Riffle 17B to SRP 2. Increase in flow from 1,100 to 3,100 cfs substantially increases the width of inundated floodplain throughout the river corridor from Old La Grange Bridge to the Ruddy Gravel Mine. The broadest incremental increases in inundated area occur from Riffle 17A1 to Riffle 11, from Riffle 9A to Riffle 5A, and from Riffle 4B to New La Grange Bridge. Increase in flow from 3,100 to 5,300 cfs generally results in only a small incremental increase in the width of the inundated floodplain, except at the following locations (where broad areas are inundated): Riffle A1A to Riffle A5A, Riffle 5B, and Riffle 17 (Appendix B).

2.3 Task 3: Field Assessment of Site Conditions

The working hypothesis for the assessment of field conditions was that the stranding locations (Task 2) and stranding densities are not random with respect to geomorphic characteristics, specifically surface slope and substrate size. Field assessment of site conditions documented the slope and substrate characteristics of the inundation areas identified above. These surveys were conducted on foot and were subject to private property access. Once the physical parameters of each site were surveyed, a subsample of sites to be surveyed for stranded salmon was identified for Task 4.

The field assessment of site conditions on the Tuolumne River was conducted from November 16–20 and November 30–December 2, 1998. The assessment included the delineation and description of bar and floodplain characteristics inundated at flows ranging from 300 cfs to 5300 cfs. Surveys extended from approximately 800 meters below La Grange Dam (RM 51.8) to the bridge near Empire (RM 21.6). Streamflow releases during the surveys averaged 300 cfs.

Bar and floodplain areas were characterized using slope and substrate particle size. Bar slope was measured using a hand level and stadia rod or estimated using a clinometer or visual estimation. The slope categories used to describe stranding potential were <4%, 4–8%, and >8%. Slope measurements were used to characterize the slope of the bar along the fall line (i.e., slope of the path water is expected to flow). Slope and substrate particle size were generalized to characterize overall bar characteristics. Using relatively coarse slope and substrate categories helped to reduce the time necessary for conducting field surveys and facilitate the use of GIS in the analysis while maintaining a level of detail that is thought to be functionally important to stranding vulnerability.

Bar and floodplain characteristics were delineated on enlarged color photocopies of aerial photographs (1997). In addition to aerial photographs, the GIS database was used to develop plots that display expected inundation of bar and floodplain features over a range of flows (i.e., 620 cfs, 1,100 cfs, 3,100 cfs, 5,300 cfs, and 8,400 cfs) and that corresponded to the size and scale of the aerial photograph reproductions. The plots and photos were used to determine the spatial extent of bar and floodplain areas to characterize for stranding potential.

Facies maps of substrate particle size were developed for bar and floodplain areas within the critical inundation range (300–5,300 cfs). The substrate grain size categories used were bedrock, boulder, cobble, coarse gravel, fine gravel, and sand. For this assessment, fine gravel ranges from 2–16 mm (d_{50}) and coarse gravel ranges from 16–64 mm. Particle-size characterization was difficult where vegetation was present due to the visual obstruction created by the vegetation. Substrate particle size and bar slope had to be estimated where dense vegetation was present within the inundation range. Although densely vegetated areas may be significant stranding locations, quantifying stranding in these areas is more difficult due to limited access and visibility.

A list of potential survey sites was identified by comparing maps of substrate grain size and slope with the GIS mapped information on the wetted perimeter of the Tuolumne River at different discharges (Appendix C). Based on flows expected to occur during the fry and juvenile rearing period in early 1999, only sites that would be exposed at discharges between 1,100 and 3,100 cfs were selected. Survey sites for Task 4 were randomly selected from this pool of all potential sites within each unique slope and substrate category. Selected sites were discarded if they did not meet predetermined selection criteria. Selection criteria included the following: (1) vegetation at the site would not preclude effective sampling, (2) sites were able to be accurately located in the field, and (3) sites had a minimum area of 3,200 m^2 (to reduce bias resulting from edge effects). Up to five sites were selected within each slope-substrate category.

2.4 Task 4: Stranding and Entrapment Field Surveys

The goal of the stranding surveys was to document stranding occurrence at each target flow and then calculate the stranding density in each slope/substrate category and determine how these characteristics affect stranding susceptibility. Using the list of stranding sites identified in Task 3 above, sites from Basso Bridge (RM 47.3) upstream to La Grange Dam (RM 52) were selected because seining results indicated the total density of chinook salmon juvenile and fry upstream of Empire (RM 21) were greatest in these upstream locations. Further, the clumped location of study sites within fairly close distance of each other was intended to reduce bias that would result from sites being sampled at different times of day during a period when flows may be changing and also reduce the probability that fry density in the river was significantly different among selected sites.

2.4.1 Stranding Survey Methods

The stranding surveys were conducted for two consecutive days. During this period, flow in the Tuolumne River was downramped from approximately 3,500 cfs to approximately 500 cfs in the 1999 surveys, and from approximately 7,000 cfs to below 4,000 cfs in the 2000 surveys. At each site, the field crew established a temporary (unmonumented) transect using a field tape in an orientation that adequately characterized an area of homogenous slope and substrate. On-site determination of survey (transect) locations was necessary due to uncertainties in the level and extent of flow inundation. If the slope or substrate characteristics appeared different from earlier surveys, a more thorough site characterization was performed using a hand level and stadia rod (for slope) or cursory d_{50} estimate (for substrate). Concurrently with the stranding survey, a field crew (EA/S.P. Cramer/Stillwater Science) seined in the river channel to document presence or absence of chinook salmon (not density) and also in floodplain potholes at the stranding survey sites to document density of entrapped juvenile salmon.

2.4.2 Distance Sampling Methods

Distance sampling (Buckland et al. 1993) was used to estimate the abundances and densities of stranded fry and juveniles within homogeneous slope substrate categories of the recently dewatered floodplain. This approach differs from finite population sampling methods in that finite sampling relies on obtaining a complete census of all individuals within spatially defined and randomly placed sampling plots or along transects and extrapolating information collected at these sites to the total area of interest. Distance sampling, however, relies on observing the location of an individual relative to fixed transects or points. Using this method, the observer surveys transects or points and records the location of any individual organism observed in terms of distance from the observer along the transect or point and perpendicular distance from the transect or point. This approach can compensate for poorly delineated sampling areas in which some or many of the organisms may go undetected because of vegetative cover or lack of visibility.

After establishing the transect tape, field crew members walked each transect, observing and documenting on standardized data sheets all stranded fish within three feet of each side of the transect (6 feet total width). The field crew recorded distance from the transect (to the nearest foot), and the fish were collected and measured at the completion of each transect survey. Any fish observed outside the transect were documented as well, with location along the transect and distance from transect estimated to the nearest foot. Fish found in groups were noted as such on the data sheets. The field crew sketched and photographed the site and noted presence of topographic features such as potholes, hummocks, and vegetation patches where dead and live fish were observed, counting the fish and measuring length to the best accuracy possible.

2.4.3 Stranding Survey Results

1999 Stranding Surveys. The first field survey was conducted May 16–17 in coordination with planned flow reductions from La Grange Dam from 3,500 cfs to 500 cfs (Figure 4). On May 17, EA/Cramer personnel seined in the river channel at the stranding survey sites to document juvenile salmon density. Potential stranding areas were selected by comparing floodplain geomorphic character data (slope and substrate grain size) collected in 1998 (Task 3), with GIS maps showing changes in wetted perimeter between 500 and 3,500 cfs. Sites were chosen based on accessibility and variability in substrate characteristics. Sampling each day focused on freshly dewatered areas that had been inundated the previous day. For this reason, some sites sampled on

May 17 were contiguous with sites sampled the previous day. The crew did not sample the same areas both days. In addition, the field crew surveyed an area on the left bank of Riffle 4B where stranded fish have been documented in the past.

The stranding survey identified 14 stranded salmon, approximately 400 sculpin, and 2 lamprey (Table 3). This corresponds to approximately one salmon (34 fish total) per 1,000 ft^2 of riffle surveyed. An additional 7 salmon and 250 sculpin were found off-transect in the surveys. Most of these off-transect fish were found in groups stranded in newly dewatered depressions or entrapped in shallow potholes. Distance sampling results were inconclusive. The results indicated the expected decline in observed fish with increasing distance from the tape, but these results were limited to three sites with low-gradient, sand substrates (Table 3). Extrapolation of the stranding density within these two slope-substrate categories, bounded by the floodplain exposed between 3,500 and 500 cfs, requires additional survey data to reduce the confidence intervals.

A field crew conducted seining surveys in the river channel (primarily on May 17) to determine potential numbers of fish vulnerable to stranding. Juvenile chinook salmon were observed in the river at two of the five locations surveyed, although density varied (Table 3). District seining surveys of the lower Tuolumne River on May 5 and May 19 indicated a low average density of 0.2–0.4 salmon per 1,000 ft^2 for upper (RM 50.5 to RM 42.3) and middle (RM 31.6 to RM 17.2) reaches, respectively. Though numerous Sacramento sucker fry and mosquitofish were caught in seining efforts in the main channel, no fish of these species were found among the stranded (Table 3) or entrapped fish (Table 4).

Lastly, a number of potholes, backwaters and side-channel habitats were seined for entrapped fish that may have become stranded upon further flow reduction. For each seining haul, the area covered was estimated, and depth and substrate were noted. All fish were alive when caught and were released back into the river after recording species and length. Seining revealed three locations (Riffles 1A, 4A and 4B) where juvenile chinook salmon were entrapped in potholes on the floodplain (Table 4). However, other than one location with a large number of sculpin, very few fish were found entrapped in these potholes (Table 4).

<u>2000 Stranding Surveys</u>. The second year of field surveys was conducted on March 18 and 20, 2000 coinciding with planned flow reductions at from 7,000 cfs to 5,400 cfs on March 17 and from 7,000 cfs to 4,000 cfs on March 19 (Figure 5). Surveys were conducted at 8 sites extending from Riffle 1B downstream to Riffle 17B. Potential stranding areas were selected by comparing floodplain geomorphic character data (slope and substrate grain size) collected in 1998 (Task 3) with maps of expected wetted perimeter at 5,300 and 3,100 cfs (near the expected lowest flow for both days). Sites were chosen based on accessibility and variability in substrate characteristics.

Of all areas surveyed, only one fish (a sculpin) was found stranded (Table 5). The surveys consisted of 51 transects that covered approximately 25,000 ft^2 of potential stranding area along mainstem and side channel habitat of the lower Tuolumne River. The field crew also found no fish in observations away from the transect tape and stranding density could not be assessed using distance sampling techniques.

A field crew conducted seining surveys in the river channel to determine potential numbers of fish vulnerable to stranding. Juvenile chinook salmon were observed at all of the locations sampled on both days in the river except two (Riffles 1B and 4A) where salmon were captured on only one of the two days of river seining (Table 5). District seining surveys of the lower

Tuolumne River on March 7 and March 21 indicated an average density of 4 and 13–40 salmon per 1,000 ft^2 for upper and middle reaches, respectively.

Lastly, a number of potholes, backwaters and side-channel habitats were seined for entrapped fish that may have become stranded upon further flow reduction. These surveys revealed only one location where juvenile chinook salmon were found entrapped in potholes on the floodplain (Table 6). However, a large number of salmon were found in backwater and side-channel habitats that may have become stranded if flows had receded further.

Table 3 - 1999 Tuolumne River Stranding (May 16-17, 1999)

Location Riffle #	Slope (%)	Substrate class[1]	Total Time (min)	Total Transect length (ft)	Total Transect area (ft^2)	Salmon/ 10^3 ft^2 in Channel	Fish Found on Transect: Stranded Chinook	Fish Found on Transect: Avg. Length (mm)	Fish Found on Transect: Other sp. Stranded	Fish Found on Transect: Avg. Length (mm)	Fish Found Off Transect: Chinook	Fish Found Off Transect: Other sp.	Other Species Found
Surveyed, May 16, 1999 Following Flow Reduction from 3,500 cfs to 500 cfs at La Grange Dam													
R3B	4-8	S	7	84	504	0[2]	0		0				
R3B	<4	S	7	70	420	0[2]	0		0				
R4A	<4	S	7	221	1,326	No Seine[2]	0		0				
R4A	<4	C	7	106	636	No Seine[2]	0		0				
R4A	4-8	S	7	110	660	No Seine[2]	0		0				
R4B	<4	C,G	7	245	1,470	No Seine[2]	0		0				
R4B	<4	S	7	249	1,494	No Seine[2]	0		0				
R5B	4-8	C,G	7	275	1,650	No Seine[2]	0		0				
R5B	<4	S	7	119	714	No Seine[2]	0		0				
R5B	4-8	S	7	263	1,578	No Seine[2]	0		0				
R5B	>8	S	7	21	126	No Seine[2]	0		0				
Surveyed, May 17, 1999 Following Flow Reduction from 3,500 cfs to 500 cfs at La Grange Dam													
R1A	<4	S	8	82	164	No Seine[2]	4	32	>400	15	4	>200	Sculpin
R1A	<4	C,G	7	51	102	No Seine[2]	0		0				
R3B	>8	S	7	81	486	0	0		0				
R4A	<4	S	7	123	738	0	0		0				
R4A	<4	C,G	7	103	618	0	0		0				
R4A	4-8	S	7	96	576	0	0		0				
R4B	<4	C	7	174	1,044	33	0		0				
R4B	<4	S	7	181	1,086	33	1	50	2	79			Sculpin
R4B	4-8	S	19	357	2,142	33	9	47	9	57			Sculpin, Lamprey
R4B	>8	C,G	7	83	498	33	0		0				
R5B	<4	S	14	220	1,320	1	0		0		3	50	Sculpin
		Totals:	**181**	**3,467**	**19,658**		**14**		**411**		**7**	**250**	

Notes
1. Substrate Class: C=Cobble, G=Gravel, S=Sand
2. District seining surveys on 5/5/19 and 5/19/99 indicate average density of 0.2-0.4 salmon per 1,000 ft^2 for Upper and Middle Tuolumne River Reaches.

Table 4 - 1999 Tuolumne River Entrapment
Following 3,500 cfs to 500 cfs Flow Reduction at La Grange Dam (May 16-17, 1999)

Location Riffle #	Habitat	Substrate class[2]	Seine Hauls	Area Seined (ft^2)	Depth Seined	Number of Salmon Captured	Avg. Length (mm)	Entrap. Density per 10^3 ft^2	No. of Other Fish	Other spp. (avg. FL)
R1A	Pothole	S	NA[1]	NA	NA	4	32	NA	327	Sculpin (15mm)
4A	Pothole	S,G	2	180	2.75	3	87	17	0	
4B	Pothole	S	3	690	4.2	0		0	0	
		Totals:	**5**	**870**		**7**			**327**	

Notes:

1. Direct Count, no seining
2. Substrate Class: C=Cobble, G=Gravel, S=Sand

Table 5 - 2000 Tuolumne River Stranding (March 18-20, 2000)

Location Riffle #	Slope (%)	Substrate class[1]	Transects	Time (min)	Transect length (ft)	Transect area (ft^2)	Salmon/ 10^3 ft^2 in Channel	Stranded Chinook	Avg. FL (mm)	Other spp. Stranded	Length (mm)	Other sp.
Surveyed, March 18, 2000 Following Flow Reduction from 7,000 cfs to 5,400 cfs at La Grange Dam												
IB	<4	C,G	3	15	316.2	1,897	6 [3]	0		1	38.1	Sculpin[2]
IB	<4	S	4	10	380	2,280	6 [3]	0		0		
3A	<4	C,G	3	12	241	1,446	1 [3]	0		0		
3A	>8	C,G	1	3	100	600	1 [3]	0		0		
4A	<4	S	1	3	100	600	0 [3]	0		0		
4A	4-8	S	2	5	168	1,008	0 [3]	0		0		
4A	>8	S	1	2	90	540	0 [3]	0		0		
13B	<4	S	3	8	232	1,392	0 [3]	0		0		
14	<4	S,C	2	7	150	900	0 [3]	0		0		
17B	<4	S,G	1	4	100	600	2 [3]	0		0		
17B	<4	C,G	1	3	100	600	1 [3]	0		0		
Surveyed, March 20, 2000 Following Flow Reduction from 7,000 cfs to 4,000 cfs at La Grange Dam												
IB	<4	S	4	12	349	2,094	0 [3,4]	0		0		
IB	4-8	S,G	1	3	75	450	0 [3,4]	0		0		
3A	<4	S,G	2	4	123	738	2 [3]	0		0		
4A	<4	S,C	1	3	100	600	2 [3,4]	0		0		
4A	4-8	S	2	5	163	978	2 [3,4]	0		0		
4A	4-8	C,G	1	2	49	294	2 [3,4]	0		0		
4A	4-8	G	1	2	69	414	2 [3,4]	0		0		
4A	>8	S,G	2	5	91	546	2 [3,4]	0		0		
5B	<4	S	1	3	80	480	1 [3,4]	0		0		
5B	<4	S,C	2	6	200	1,200	1 [3,4]	0		0		
5B	4-8	S	1	3	100	600	1 [3,4]	0		0		
5B	>8	S	1	1	73	438	1 [3,4]	0		0		
13B	<4	S	2	6	200	1,200	2 [3,4]	0		0		
14	<4	S,C	1	3	56	336	2 [3,4]	0		0		
17B	<4	S	1	4	100	600	2 [3]	0		0		
17B	<4	S,G	2	5	162	972	2 [3]	0		0		
17B	4-8	C,G	2	6	160	960	2 [3]	0		0		
17B	>8	S,G	1	3	44	264	2 [3]	0		0		
		Totals:	**50**	**148**	**4,171**	**25,027**		**0**		**1**		

Notes:
1. Substrate Class: C=Cobble, G=Gravel, S=Sand
2. One stranded fish found in 2000, none found off-transect
3. District seining surveys on 3/7/00 and 3/21/00 indicate average density of 4 and 13–40 salmon per 1,000 ft^2 for Upper and Middle Reaches, respectively.
4. Results from Off-Channel Seining (Table 6).

Table 6 - 2000 Tuolumne River Entrapment Following Flow Reductions at La Grange Dam on March 17 and March 19, 2000

Location Riffle #	Habitat	Substrate class[2]	Seine Hauls	Area Seined (ft^2)	Depth Seined	Number of Salmon Captured[2]	Avg. Fork Length (mm)	Entrap. Density per 10^3 ft^2	No. of Other Fish	Other spp. (avg. Fork Length)
Surveyed March 18, 2000 Following Flow Reduction from 7,000 cfs to 5,400 cfs at La Grange Dam										
1B	Backwater	S	6	1,640	2.5	0		0	1	Sculpin (32mm)
3A	side channel	S,G	3	2,310	2.5	2	32	1	3	Gambusia, Sucker (29mm)
13B	side channel	S	3	1,860	2.5	11	52	6	1	Bullfrog (55mm)
14	backwater	C	2	450	0.75	1	55	2	0	
14	backwater	S	2	750	1.5	0		0	3	Gambusia (26mm)
17B	side channel	C	1	600	1	2	43	2	0	
			17	**7,610**		**16**			8	
Surveyed, March 20, 2000 Following Flow Reduction from 7,000 cfs to 4,000 cfs at La Grange Dam										
1B	side channel	S,G	9	5,580	1.8	0		0	0	
1B	pothole	S	2	280	1.3	0		0	0	
1B	backwater	C	4	850	0.5	0		0	0	
3B	backwater	S,G	1	840	1	0		0	0	
3B	pothole	S,G	1	480	3	3	44	6	9	Gambusia (25mm)
3B	side channel	S,G	6	3,250	1.8	4	56	1	0	
4A	side channel	S,G	3	1,980	1.2	4	52	2	2	Sucker, Shiner (57mm)
5B	side channel	G	5	4,425	1.4	4	50	1	0	
13B	side channel	G	4	3,550	1.4	9	49	3	0	
13B	backwater	G	1	300	1	0		3	1	Gambusia (28mm)
14	side channel	G	3	1,140	0.8	1	69	1	28	Gambusia (35mm)
17B	side channel	G,C	6	4,470	2	10	44	2	3	Gambusia, Sucker (31mm)
17B	backwater	S,G	2	1,095	1.8	46	54	42	0	
		Totals:	**31**	**20,690**		**81**			**43**	

Notes:

1. Substrate Class: C=Cobble, G=Gravel, S=Sand
2. Only fish found in potholes were considered entrapped. Depending upon drainage to the main channel other side channel and backwater habitats may become stranding or entrapment areas upon further flow reduction.

2.5 Task 5: Data Analysis and Site Prioritization

The current stranding surveys were intended to supplement the stranding surveys conducted between 1986–1992 and 1994–1996. Earlier survey data were analyzed to determine the effects of contributing factors in juvenile stranding caused by flow fluctuations, including: salmon density in the river, the magnitude of flow reductions, ramping rates, and flows prior to reduction. For the most recent surveys conducted between November 1998 and March 2000, geomorphic observations were included to identify any relationship between stranding locations (Task 2) and stranding densities with respect to characteristics such as surface slope and substrate size. In the two years of stranding surveys, the combination of low fish presence in the river and high Tuolumne River flows resulted in low stranding totals across a range of sites with similar geomorphic characteristics. Although this prevented statistical comparison, a number of observations relate to the stranding risk factors discussed above.

2.5.1 Effects of Flow and Ramping Rates on Stranding Frequency

Between 1986–1992 and 1994–1996, the Districts surveyed approximately one-third to one-half of the twenty-two survey sites shown in Appendix A in any one year (Figure 3). Although no survey period encompassed all the sites (i.e., synoptic stranding surveys), Figures 2 and 3 show that stranding occurrence is clustered by location and flow across all years. Prior to 1988 the riffle areas near La Grange Dam have the highest stranding occurrence at flows below 350 cfs. The broader floodplain from Riffle 4A (RM 48.8) downstream to Zanker Farm (RM 45.9) has a higher stranding occurrence at intermediate flows (2,500–5,000 cfs) across all years surveyed (Figures 2 and 3). Figure 1 also shows this reach as having the highest historical observations of stranding occurrence relative to the number of surveys taken.

Although the stranding frequency in 1999 and 2000 was low, the observed stranding locations (Riffles 1A, 1B and 4B) are consistent with prior observations of stranding (Figures 1–3). Although flow reductions from 3,500 to 500 cfs in 1999 would be expected to result in higher stranding occurrence, not all stranding sites were seined concurrently in the main river channel to demonstrate potential salmon available for stranding (Table 3). However, the observed strandings at Riffle 4B were associated with high salmon density in the river channel and separate District seining indicated salmon presence in the upper river reach on May 19.

Historically, less stranding has been documented at flow reductions beginning above 5,000 cfs (Table 2 and Figure 2) and the 2000 surveys resulted in only one fish (riffle sculpin) found stranded despite the documented presence of salmon in the river (Table 5). A total of three salmon and nine mosquitofish were found entrapped in a single exposed floodplain pothole at Riffle 3B (Table 6). Although the higher flows observed during the 2000 surveys would be expected to result in lower stranding and entrapment, a total of 94 salmon and 42 other fish were found in seining of backwater and side channels across nearly all sites surveyed. Depending upon the local drainage, some of these fish may have been expected to become stranded or entrapped upon further flow reduction.

The maximum ramping rate schedule contained in the 1995 FSA (FERC 1995) ranges from 500 cfs/hr to 900 cfs/hr (Table 1). The flow reductions for the most recent stranding surveys ranged from 3,500–500 cfs in 1999 to reductions of about 6,500–4,000 cfs and 4,000–1,000 cfs in 2000 (Figures 4 and 5). The ramping rates for these surveys ranged from 63 cfs/hr in 1999 to over 400 cfs/hr in 2000 (Figures 4 and 5).

2.5.2 Geomorphic Characteristics of Stranding Sites

Other than the magnitude of flow and ramping rate, the primary hypotheses for the stranding surveys was that the stranding locations and stranding densities are not random with respect to geomorphic characteristics, specifically surface slope and substrate size. Because the prior stranding surveys reviewed in Tasks 1 and 2 (see Appendix A) did not record slope or substrate, comparatively little data is available to associate the stranding occurrence with geomorphic characteristics. For the surveys conducted in 1999 and 2000, most of the transects were concentrated in low gradient (< 4%) sand (Table 7).

Table 7. Number of stranding transects surveyed, by slope and substrate type.

Slope	Sand	Sand/fine gravel	Sand/ coarse gravel	Sand/ cobble	Coarse gravel	Coarse gravel/ cobble
1999 Stranding Surveys						
<4 %	11	-	-	1	3	2
4-8 %	5	-	-	-	1	-
>8 %	2	-	-	-	1	-
2000 Stranding Surveys						
<4 %	17	-	6	5	3	4
4-8 %	5	1	1	-	1	2
>8 %	2	-	3	-	-	1

Fish were found stranded (Table 3) primarily on low gradient (<4%) sand substrates in 1999 (Riffles 1A, 4B and 5B), with only one stranded fish found in 2000 (Table 5) on low gradient coarse gravel. Fish were found in entrapped in potholes, side channels and backwater areas in predominantly sand and gravel substrates on low gradient bars and floodplains (Tables 3 and 5). Although these fish are sensitive to potential stranding if water levels recede faster due to high ramping rates (Section 2.5.1), entrapment areas appear to be widely distributed in the river (Riffles 3A–5B, 13B, 14, 17B).

2.5.3 Prioritization of Stranding Sites for Potential Restoration

Based upon the relative stranding occurrence in the historical survey data (Figures 1–3), sites with the greatest stranding risk extend from Riffle A3/A4 (RM 51.6) to Old La Grange Bridge (RM 50.5) to Riffle 5 (RM 48). Although only a limited number of stranding surveys were available to develop stranding associations with geomorphic characteristics, the most recent surveys indicate that the areas located downstream of Riffle 1A (RM 50.5) to Riffle 5B (RM 48.2) continue to be associated with stranding (Tables 2 and 4) and entrapment (Tables 3 and 5) of juvenile salmon.

In general, the historical and current stranding sites correspond to the conceptual Basso Spawning Reach floodplain restoration project, which calls for regrading floodway surfaces outside the low flow channel so that they are inundated at 4,000–5,000 cfs (McBain & Trush 2000). More specifically, these stranding and entrapment sites correspond to areas shown to be inundated at the 3,100 cfs and 5,000 cfs wetted perimeter on the right bank from Riffle 3B (RM 49.1) downstream to the left bank at Riffle 5B (RM 47.8) and also at Riffle 17B (RM 44.3). Additional stranding and entrapment areas are located in the Dredger Tailing Reach, including Riffles 13B (RM 45.5), 14 (RM 44.8) and Riffle 17B (RM 44.3).

3 Conclusions and Recommendations

Based upon our review of recent stranding surveys carried out by the Districts between 1986–1992 and 1994–1996 (Tasks 1 and 2) and surveys of field conditions, a number of stranding sites were initially prioritized based upon their geomorphic characteristics and relative exposure at the flows anticipated for the 1999 and 2000 surveys (Tasks 3 and 4). As stated previously, several factors contribute to the magnitude of juvenile stranding and entrapment caused by flow fluctuations, including: salmon density in the river, the magnitude of flow reductions and ramping rates and geomorphic characteristics of the sites.

3.1 Factors Contributing to Stranding Risk in the Lower Tuolumne River

Salmon Density in the River. To adequately assess stranding risk that may be attributed to other factors, both the historical (1990–1992, 1994–1996) and most recent (1999–2000) stranding surveys demonstrated that for the flows tested, fish were present in the river at a number of locations where no stranding occurred. Although there were some surveys in this period which found no fish stranded despite high in-river density, this may be attributed to flow levels and low ramp rates. Concurrent river seining is a good method to show fish presence/absence and density and also to relate changes in stranding risk to future restoration projects and changes in river flow management.

Location. Limited stranding events continue to occur in the lower Tuolumne River at sites that have been documented beginning in 1986. In prior surveys, most stranding occurred at Riffles A3, A4, 2, 4B, and 5, and at Old La Grange Bridge. Although the stranding frequency in 1999 and 2000 was low, the observed stranding locations (Riffles 1A, 1B and 4B) are consistent with prior observations of stranding in the upper reach (RM 50.5 to RM 42.3). Although there was limited entrapment in floodplain potholes in the most recent surveys, fish were found in seining of backwater and side channels across nearly all sites. Although these fish may return to the main channel, some of these fish may become stranded or entrapped upon further flow reduction.

Flow/Ramping Rates. The current surveys have not encompassed a wide range of flow conditions. However the majority of stranding sites identified in this analysis are exposed at intermediate river flows and limited stranding has continued to occur downstream of Riffle 4A (RM 48.8 to RM 45.9) at flows between 1,100–3,100 cfs. Further, while recent flow reductions in the Tuolumne River have been at rates below the current FSA ramping rate schedule, these ramp rates may still be high enough to cause some stranding events in some cases.

Geomorphology. The GIS floodplain maps developed from aerial photography document floodplain exposure at differing flows throughout the lower Tuolumne River corridor from La Grange Dam (RM 52) to Empire (RM 22). The geomorphic surveys conducted in this study document slope and substrate from La Grange Dam (RM 52) to Basso Bridge (RM 47.3). Unfortunately, the most recent stranding surveys have not encompassed a sufficient number of specific flow fluctuation events since the development of the slope-substrate maps to allow site prioritization or river-wide stranding risk estimates on a geomorphic basis. The current surveys do confirm higher stranding risk on low gradient sand and gravel substrates in the primary spawning reach (RM 49.1 to 47.8) of the Tuolumne River. However, the limited number of events makes these observations inconclusive and the downward movement of fry in response to receding water levels further complicates accurate stranding observations on coarse gravel and cobble substrates.

3.2 Recommendations for Restoration Projects

Current restoration project plans include constructed channels for drainage of floodplain backwaters along the Gravel Mining Reach identified in the Tuolumne River Corridor Restoration Plan (McBain & Trush 2000). In addition, the results of this study suggest that stranding and entrapment may be reduced by floodplain restoration projects along the Primary Spawning Reach (RM 49.1 to 47.8). Although stranding may also be reduced by further limits of the current ramping rates at specific river flows, some stranding may be practically unavoidable.

Currently, the flow range that represents the greatest stranding risk in the lower Tuolumne River falls between 1,100–3,100 cfs. The currently proposed restoration projects (McBain & Trush 2000) call for the filling of floodplain potholes, channel modifications and floodplain regrading to increase the bankfull carrying capacity to about 4,000 cfs. This may have the consequence of shifting the greatest stranding risk to flows above 4,000 cfs, which will represent the flow range that exposes the greatest proportion of potential low-gradient stranding area in the future, but would occur much less frequently than lower flows. This suggests that some regrading of the higher floodplain may be necessary to improve side-channel and backwater drainage to the main channel at higher flows. In addition to the reassessment of the locations of high stranding risk, both the flow ranges and ramping rates that pose the greatest risk could be reassessed upon completion of the proposed restoration projects.

3.3 Recommendations for Future Stranding Surveys

The current study plan included random survey site selection within the inundation areas exposed during flow reduction. Fundamentally, this random site selection method differs from surveys conducted prior to 1999 to permit extrapolation of river wide stranding estimates based upon the distribution of specific slope-substrate categories. However, the GIS-derived geomorphic maps are more complex than initially anticipated, with some reaches having more than fifty slope-substrate polygons per river mile. Although the study design in 1999–2000 used pre-selected survey locations by slope-substrate category, surveys often encompassed several slope-substrate categories that were difficult to locate in the field.

In order to improve the data quality of future stranding surveys using this methodology, survey locations should be selected at random in the field within general areas that capture both a predominant slope-substrate category and that will be dewatered by the planned flow reduction. Transects within these general areas should be located at random in the field within homogenous slope-substrate areas and located with GPS. Because geomorphic characteristics change over time, slope and substrate at stranding sites should be characterized directly in the field and location should be documented by the transect GPS location and/or aerial photographs.

Future surveys should be conducted during planned flow reductions between 3,100–1,100 cfs. Surveys should be conducted in conjunction with District seining efforts in the Lower Tuolumne River to ensure surveys are conducted at a time when juveniles are present in the river channel. Future surveys would include concurrent seining to document salmon density in the main river channel and in any floodplain potholes.

The differences in methods used in prior stranding surveys limit the comparability of the data with the most recent surveys conducted for this study both in terms of the total number of fish found after specific flow reductions and in their suitability for developing river-wide stranding estimates. However, it may be possible to increase the power of the existing or future analyses by associating many of the historical stranding sites (Appendix A) with known or inferred slope-substrate characteristics. Lastly, conversion of (cfs/hr) ramping rates documented for future surveys to changes in river stage per unit time (*i.e.,* in/hr) will improve the comparability with stranding studies conducted in other rivers.

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FIGURES

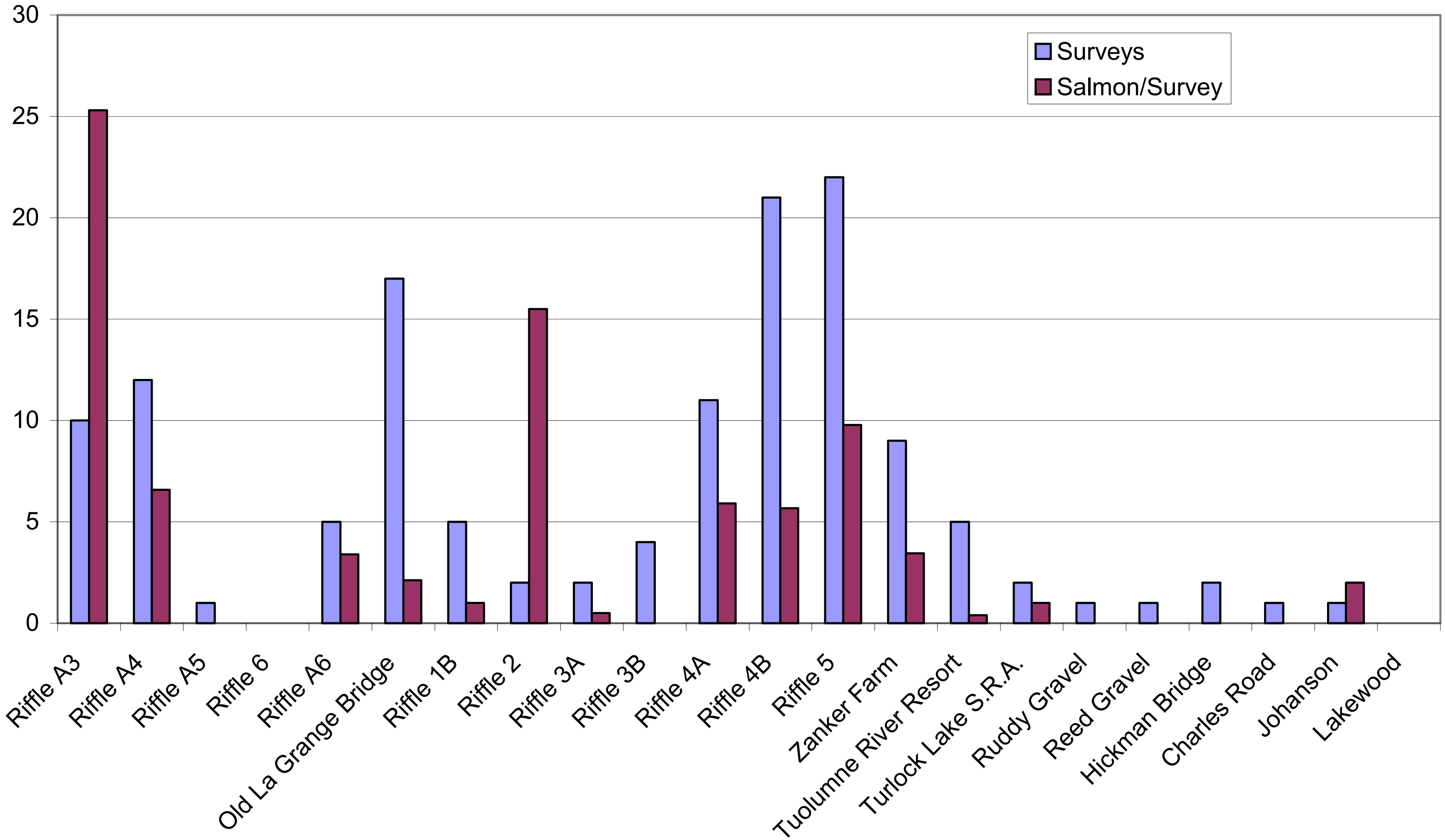
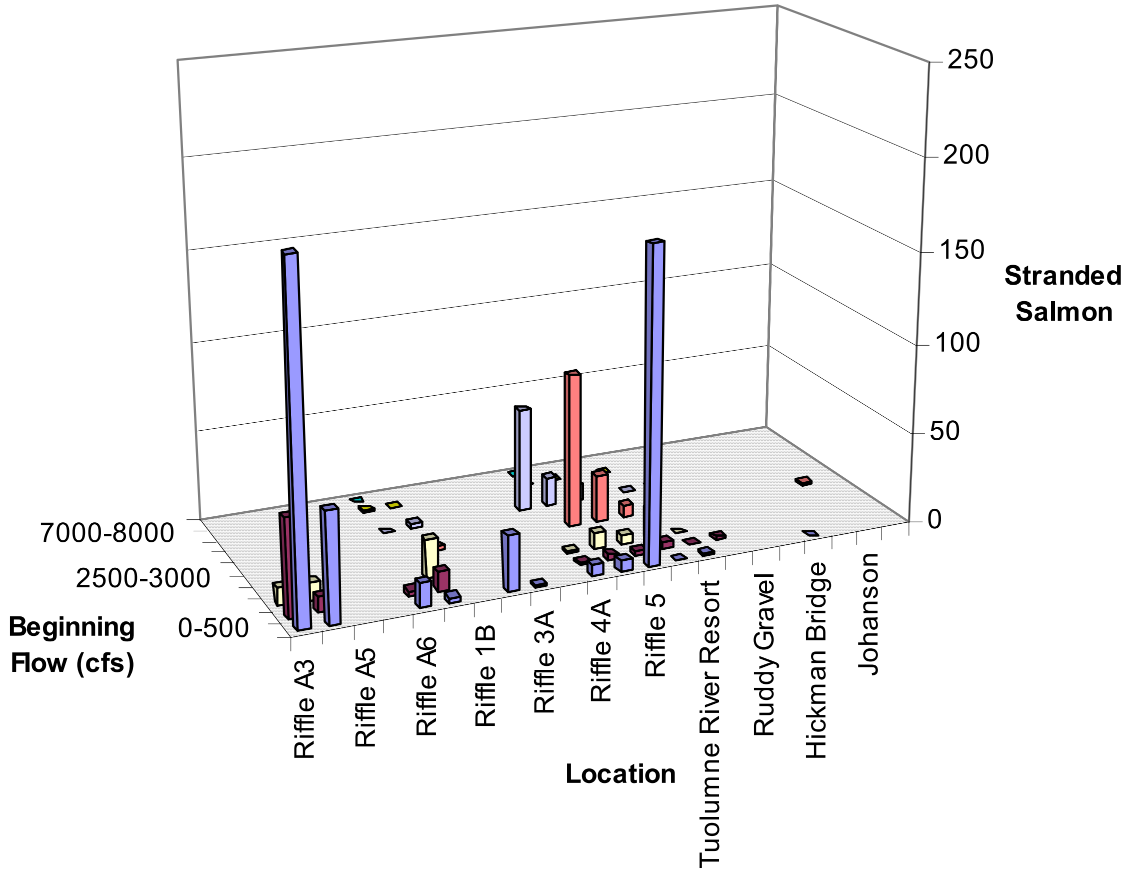


Figure 1. Stranded juvenile salmon by site for the 1986–1989 and 1990–1996 surveys.



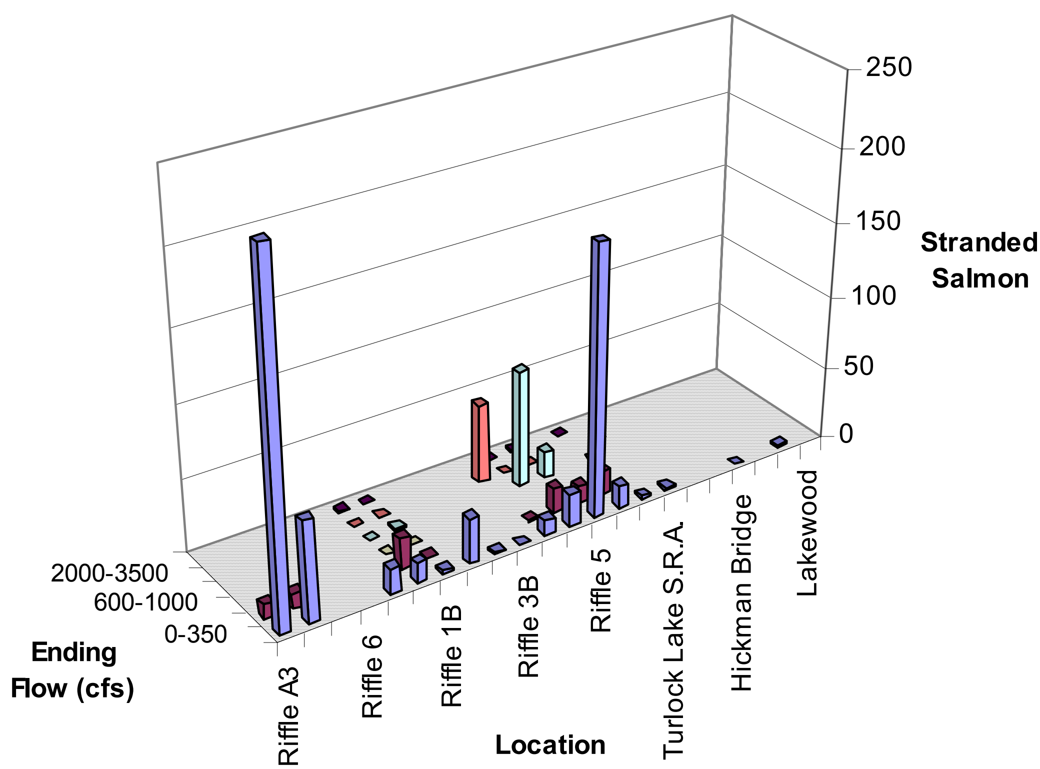


Figure 2. Stranding occurrence by location and flow (1986-1992 and 1994-1996 Surveys). Note: zero's indicate fish found in river but no fish found stranded.

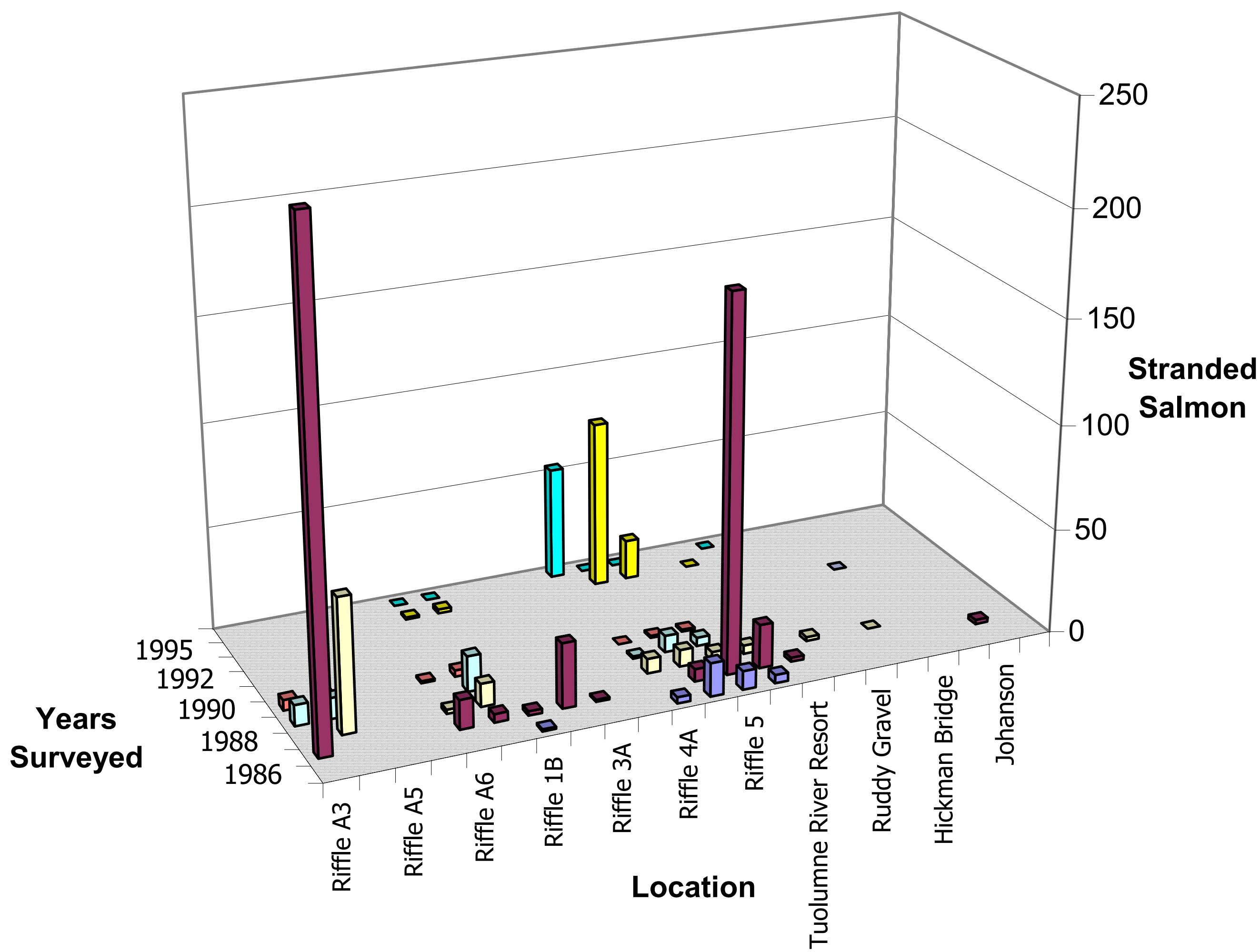
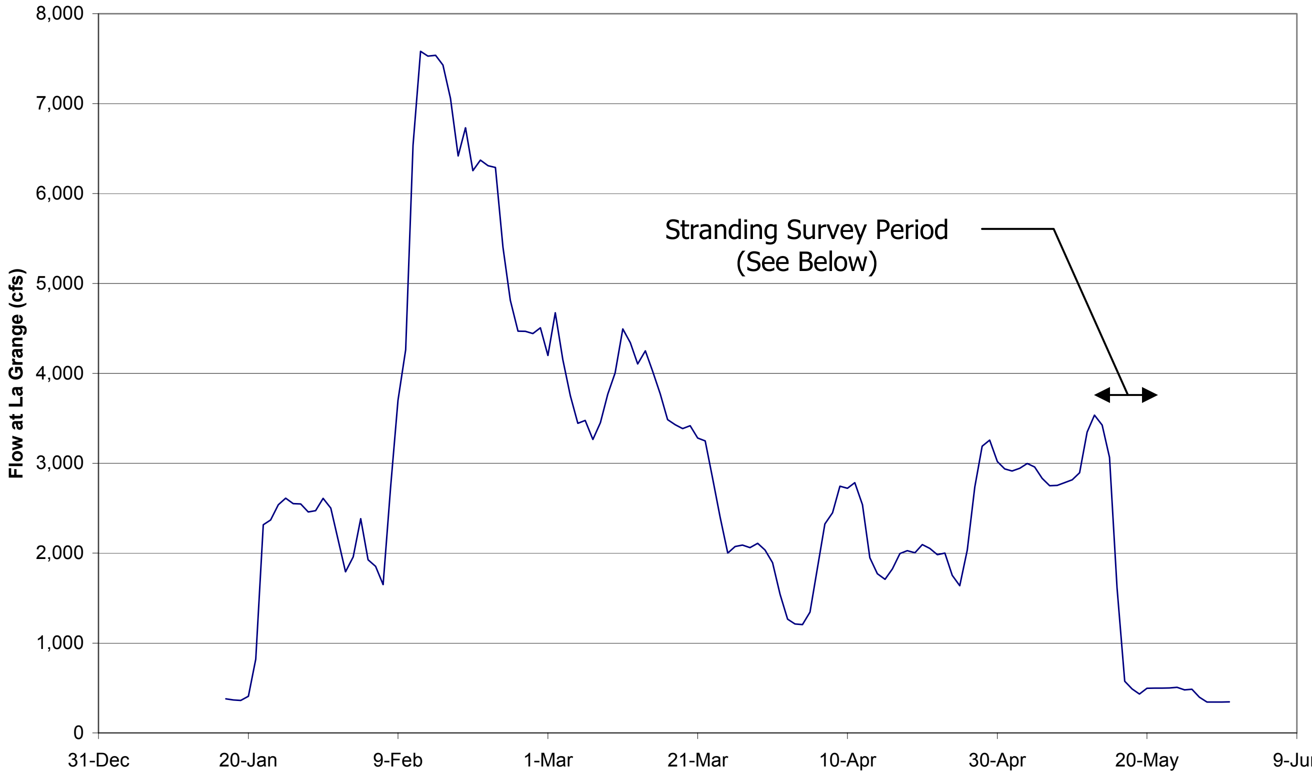


Figure 3. Stranding occurrence by location and date (1986-1992 and 1994-1996 surveys). Note: Zero's indicate fish found in river but no fish found stranded.



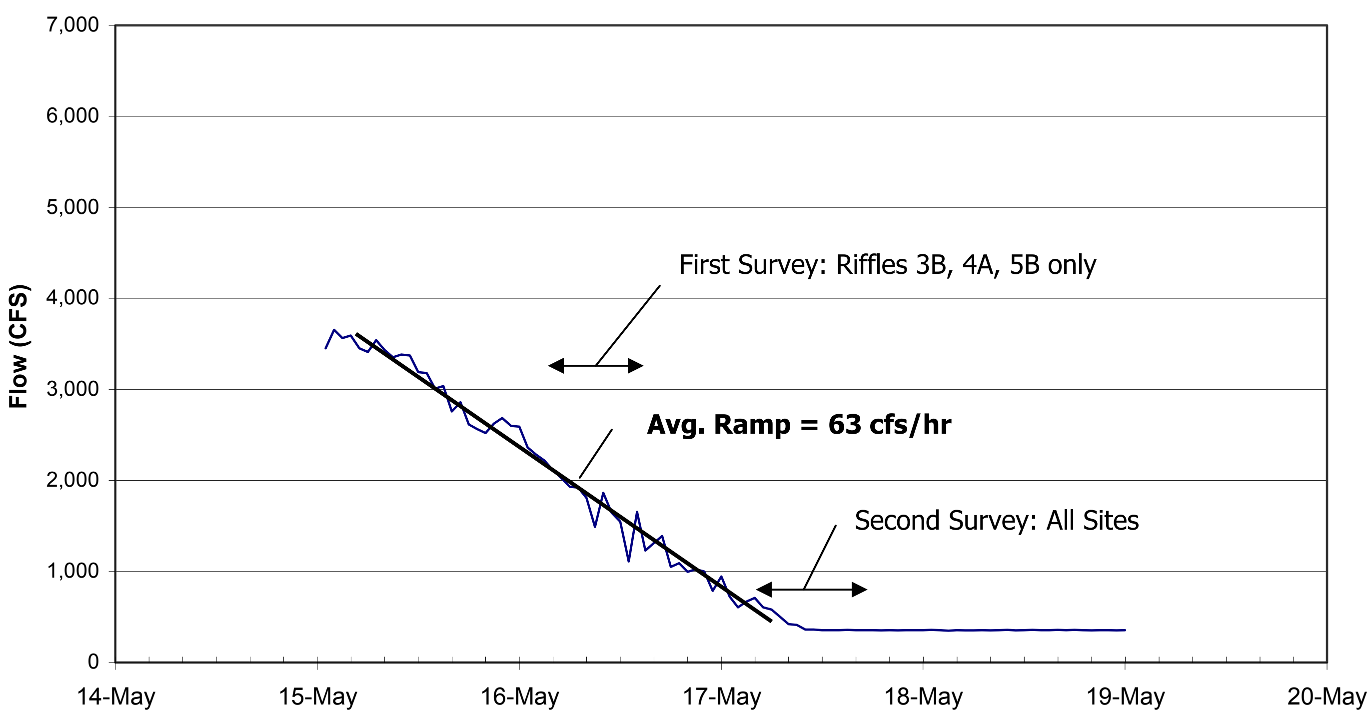


Figure 4. Tuolumne River flow and ramping rate at La Grange during 1999 stranding surveys.

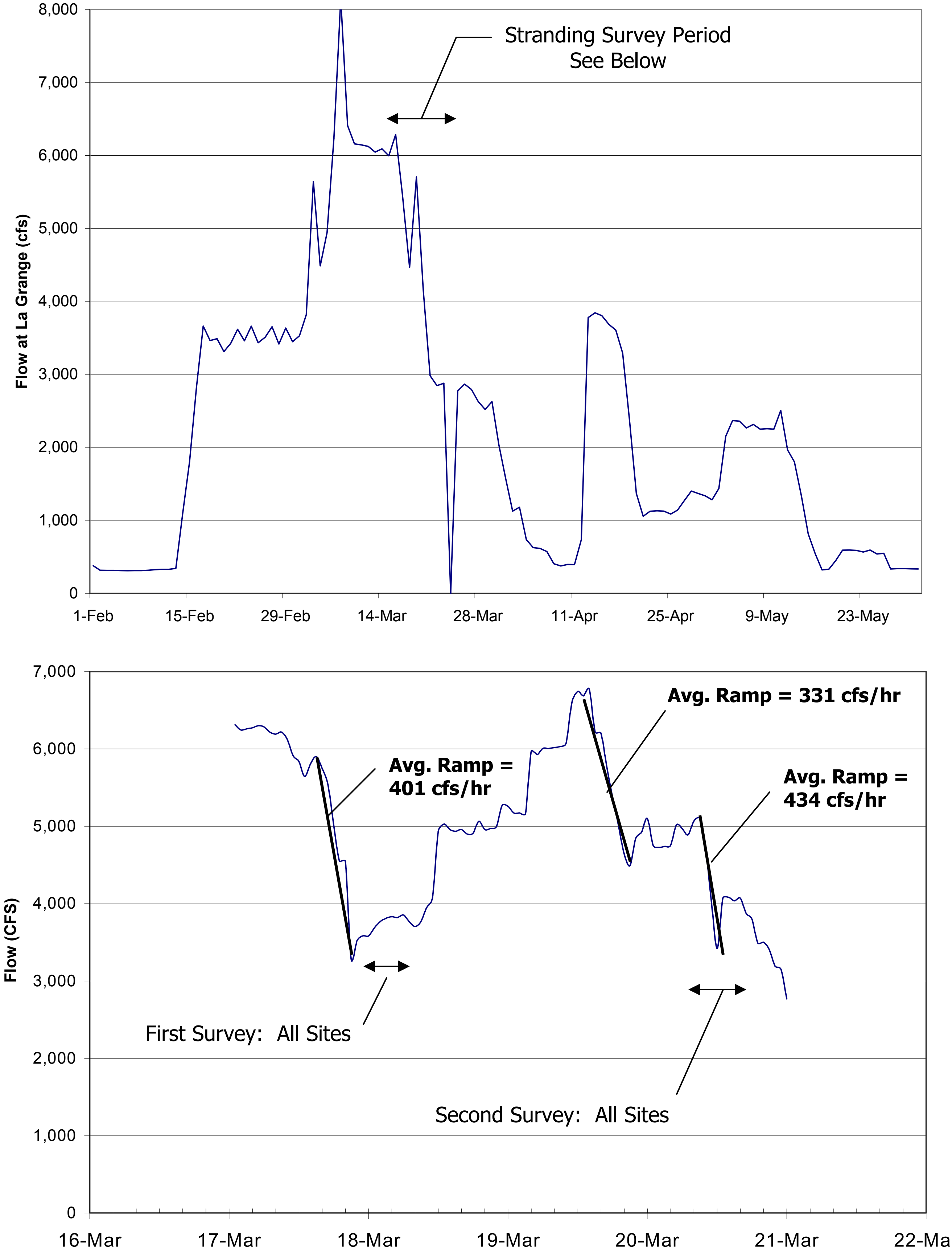


Figure 5. Tuolumne River flow and ramping rate at La Grange during 2000 stranding surveys.

APPENDICES

Survey Date	Beginning Flow (cfs)	Ending Flow (cfs)	Change in Flow (cfs)	Location Name	River Mile	Number of salmon found	Comments
14-16 Dec 86	4700	500	4200	Riffle 5	48	7	flows estimated from Figure 3, Appendix 14
14-16 Dec 86	4700	500	4200	Riffle 4B	48.4	8	flows estimated from Figure 3, Appendix 14
14-16 Dec 86	4700	500	4200	Riffle 1B	50.1	1	flows estimated from Figure 3, Appendix 14
22-Dec-86	4000	200	3800	Riffle 5	48	1	flows estimated from Figure 3, Appendix 14
22-Dec-86	4000	200	3800	Riffle 4B	48.4	3	flows estimated from Figure 3, Appendix 14
22-Dec-86	4000	200	3800	Riffle 4A	48.8	2	flows estimated from Figure 3, Appendix 14
28-Dec-86	4000	200	3800	Zanker Farm	45.9	4	flows estimated from Figure 3, Appendix 14
28-Dec-86	4000	200	3800	Riffle 4B	48.4	5	flows estimated from Figure 3, Appendix 14
28-Dec-86	4000	200	3800	Riffle 4A	48.8	1	flows estimated from Figure 3, Appendix 14
1-Jan-87	2600	200	2400	Riffle 5	48	1	flows estimated from Figure 3, Appendix 14
1-Jan-87	2600	200	2400	Riffle 4B	48.4	1	flows estimated from Figure 3, Appendix 14
7-Jan-87	2600	200	2400	Johanson	23.7	2	flows estimated from Figure 3, Appendix 14
9-Jan-87	2600	200	2400	Zanker Farm	45.9	7	flows estimated from Figure 3, Appendix 14
9-Jan-87	2600	200	2400	Riffle 5	48	7	flows estimated from Figure 3, Appendix 14
9-Jan-87	2600	200	2400	Riffle 4B	48.4	5	flows estimated from Figure 3, Appendix 14
9-Jan-87	2600	200	2400	Riffle 1B	50.1	2	flows estimated from Figure 3, Appendix 14
13-Jan-87	1200	500	700	Riffle 5	48	1	flows estimated from Figure 3, Appendix 14
13-Jan-87	1200	500	700	Riffle 4B	48.4	1	flows estimated from Figure 3, Appendix 14
13-Jan-87	1200	500	700	Old La Grange Bridge	50.5	3	flows estimated from Figure 3, Appendix 14
22-23 Jan 87	1200	500	700	Zanker Farm	45.9	14	flows estimated from Figure 3, Appendix 14
22-23 Jan 87	1200	500	700	Old La Grange Bridge	50.5	1	flows estimated from Figure 3, Appendix 14
5-Feb-87	200	200	0	Zanker Farm	45.9	1	no daily flow fluctuations (except for storm run-off); average flow for Feb approx 200 cfs
27-Mar-87	349	349	0	Lakewood	21.9	41	isolated pool; no daily flow fluctuations (except for storm run-off); average flow for Mar approx 349 cfs
1-May-87	550	200	350	Riffle A3	51.6	52	no daily flow fluctuations (except for storm run-off); average flow for May approx 230 cfs
4-May-87	230	230	0	Turlock Lake S.R.A.	42	14	no daily flow fluctuations (except for storm run-off); average flow for May approx 230 cfs
1-2 Jun 87	200	3	197	Tuolumne River Resort	42.4	2	no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
1-2 Jun 87	200	3	197	Riffle 5	48	169	1 possible CWT 71mm 02Jun87, 168 or 169 were measured; no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
1-2 Jun 87	200	3	197	Riffle 3A	49.5	1	no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
1-2 Jun 87	200	3	197	Riffle 2	49.9	31	no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
1-2 Jun 87	200	3	197	Riffle A6	51.1	14	no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
1-2 Jun 87	200	3	197	Riffle A3	51.6	186	no daily flow fluctuations (except for storm run-off); average flow for Jun approx 15 cfs
14-Jan-88	550	125	425	Zanker Farm	45.9	3	
14-Jan-88	550	125	425	Riffle 4B	48.4	1	
14-Jan-88	550	125	425	Old La Grange Bridge	50.5	5	
1-Feb-88	300	120	180	Zanker Farm	45.9	0	
1-Feb-88	300	120	180	Riffle 5	48	2	
1-Feb-88	300	120	180	Riffle 4B	48.4	5	
1-Feb-88	300	120	180	Riffle 4A	48.8	6	
1-Feb-88	300	120	180	Old La Grange Bridge	50.5	2	
1-Feb-88	300	120	180	Riffle A6	51.1	0	
1-Feb-88	300	120	180	Riffle A4	51.6	3	
16-Apr-88	550	115	435	Turlock Lake S.R.A.	42	2	
16-Apr-88	550	115	435	Zanker Farm	45.9	1	
16-Apr-88	550	115	435	Riffle 5	48	2	
16-Apr-88	550	115	435	Riffle 4B	48.2	1	
16-Apr-88	550	115	435	Riffle 4A	48.8	0	
16-Apr-88	550	115	435	Riffle 3B	49.1	0	
16-Apr-88	550	115	435	Riffle 2	49.9	0	
16-Apr-88	550	115	435	Old La Grange Bridge	50.5	4	
16-Apr-88	550	115	435	Riffle A6	51.1	0	
16-Apr-88	550	115	435	Riffle A5	51.4	0	
16-Apr-88	550	115	435	Riffle A4	51.6	7	
27-Apr-88	550	100	450	Reed Gravel	34	0	
27-Apr-88	550	100	450	Tuolumne River Resort	42.4	0	
27-Apr-88	550	100	450	Riffle 5	48	0	
27-Apr-88	550	100	450	Riffle 4B	48.2	1	
27-Apr-88	550	100	450	Riffle 4A	48.8	1	
27-Apr-88	550	100	450	Riffle 3B	49.1	0	
27-Apr-88	550	100	450	Old La Grange Bridge	50.5	0	
27-Apr-88	550	100	450	Riffle A6	51.1	2	
27-Apr-88	550	100	450	Riffle A4	51.6	1	
4-May-88	67	10	57	Riffle 5	48	0	
4-May-88	67	10	57	Riffle 4B	48.2	0	
4-May-88	67	10	57	Riffle 4A	48.8	0	
4-May-88	67	10	57	Riffle A4	51.6	53	
18-Apr-89	730	120	610	Zanker Farm	45.9	0	
18-Apr-89	730	120	610	Riffle 5	48	0	
18-Apr-89	730	120	610	Riffle 4B	48.4	0	
18-Apr-89	730	120	610	Riffle 4A	48.8	0	
18-Apr-89	730	120	610	Riffle 3A	49.5	0	
18-Apr-89	730	120	610	Old La Grange Bridge	50.5	0	
18-Apr-89	730	120	610	Riffle A3/A4	51.6	0	
29-Apr-89	1050	400	650	Tuolumne River Resort	42.4	0	
29-Apr-89	1050	400	650	Zanker Farm	45.9	2	
29-Apr-89	1050	400	650	Riffle 5	48	4	
29-Apr-89	1050	400	650	Riffle 4B	48.4	8	
29-Apr-89	1050	400	650	Riffle 4A	48.8	1	
29-Apr-89	1050	400	650	Old La Grange Bridge	50.5	17	
29-Apr-89	1050	400	650	Riffle A3/A4	51.6	20	
3-Mar-90				Riffle 5	48	1	
3-Mar-90				Riffle 4B	48.4	2	
3-Mar-90				Riffle 4A	48.8	0	
3-Mar-90				Old La Grange Bridge	50.5	1	
3-Mar-90				Riffle A3/A4	51.6	8	5 live
4-Mar-90				Zanker Farm	45.8	0	
4-Mar-90				Riffle 5	48	3	1not fresh, 1 live
4-Mar-90				Riffle 4B	48.4	15	3 not fresh
4-Mar-90				Riffle 4A	48.8	5	
4-Mar-90				Old La Grange Bridge	50.5	1	
4-Mar-90				Riffle A3/A4	51.6	10	1 not fresh
8-Mar-90				Riffle 4A	48.8	0	
8-Mar-90				Old La Grange Bridge	50.5	2	1 live
8-Mar-90				Riffle A3/A4	51.6	15	
12-Mar-90				Tuolumne River Resort	42.2	0	
12-Mar-90				Zanker Farm	45.8	0	
12-Mar-90				Riffle 5	48	2	1 not fresh (39 mm)
12-Mar-90				Riffle 4B	48.4	19	
12-Mar-90				Riffle 4A	48.8	3	
12-Mar-90				Old La Grange Bridge	50.5	5	
12-Mar-90				Riffle 6	51.1	0	

12-Mar-90				Riffle A3/A4	51.6	1	
15-Mar-90	220	120	100	Zanker Farm	45.8	0	
15-Mar-90	220	120	100	Riffle 5	48	1	1 not fresh (52 mm)
15-Mar-90	220	120	100	Riffle 4B	48.4	1	
15-Mar-90	220	120	100	Riffle 4A	48.8	0	
15-Mar-90	220	120	100	Old La Grange Bridge	50.5	1	
15-Mar-90	220	120	100	Riffle A3/A4	51.6	8	
4-May-90	560	280	280	Zanker Farm	45.8	0	
4-May-90	560	280	280	Riffle 5	48	0	
4-May-90	560	280	280	Riffle 4B	48.4	0	
4-May-90	560	280	280	Riffle 4A	48.8	0	
4-May-90	560	280	280	Old La Grange Bridge	50.5	2	1 not fresh (76 mm); dead cwt smolt from release group at bridge
4-May-90	560	280	280	Riffle 6	51.1	1	
4-May-90	560	280	280	Riffle A3/A4	51.6	2	
2-May-91	1120	667	453	Riffle 5	47.8	0	
2-May-91	1120	667	453	Riffle 5	47.8	0	
2-May-91	1120	667	453	Riffle 5	47.8	0	
2-May-91	1120	667	453	Riffle 4B	48.2	0	
2-May-91	1120	667	453	Old La Grange Bridge	50.5	0	
2-May-91	1120	667	453	Old La Grange Bridge	50.5	0	
2-May-91	1120	667	453	Riffle A3/A4	51.6	0	
3-May-91	667	284	383	Charles Road	25	0	
3-May-91	667	284	383	Hickman Bridge	31.7	0	
3-May-91	667	284	383	Ruddy Gravel	36.7	0	
4-May-92	1000	550	450	Riffle 5	47.8	0	gravel bar
4-May-92	1000	550	450	Riffle 3B	49.1	0	north bank, lower
4-May-92	1000	550	450	Riffle 3B	49.1	0	north bank, upper, GAM(35mm), SKR(YOY)
4-May-92	1000	550	450	Old La Grange Bridge	50.5	0	south bank, upper
4-May-92	1000	550	450	Old La Grange Bridge	50.5	0	south bank. Lower, LMB(28mm)
4-May-92	1000	550	450	Riffle A3/A4	51.6	0	south bank/tall veg.
12-May-92	160	50	110	Hickman Bridge	31.7	0	S gravel bar
12-May-92	160	50	110	Riffle 5	47.8	0	gravel bar, perimeter, SKR,GAM,SCP, 500 testing peak
12-May-92	160	50	110	Riffle 4B	48.2	0	south, SKR(YOY), 500 testing peak
12-May-92	160	50	110	Riffle 4B	48.2	0	N gravel bar, river side, 500 testing peak
12-May-92	160	50	110	Riffle 4B	48.2	0	N gravel bar, side channel, SKR,GAM, 500 testing peak
12-May-92	160	50	110	Old La Grange Bridge	50.5	0	north, SKR(YOY), 500 testing peak
12-May-92	160	50	110	Old La Grange Bridge	50.5	0	south, SKR(YOY), 500 testing peak
12-May-92	160	50	110	Riffle A3/A4	51.6	0	top of island, 500 testing peak
12-May-92	160	50	110	Riffle A4	51.6	0	north side, side chan., GAM(19,26), 500 testing peak
12-May-92	160	50	110	Riffle A4	51.6	0	south side, side chan., 500 testing peak
28-Apr-94	1100	550	550	Riffle 5	47.8	0	GRAVEL BAR
28-Apr-94	1100	550	550	Riffle 5	47.8	0	SOUTH BANK
28-Apr-94	1100	550	550	Old La Grange Bridge	50.5	0	SOUTH BANK, upper
28-Apr-94	1100	550	550	Old La Grange Bridge	50.5	0	SOUTH BANK, lower
28-Apr-94	1100	550	550	Riffle A3/A4	51.6	0	SOUTH BANK, tall veg.
2-Mar-95	2900	1200	1700	Riffle 5	47.8	18	SOUTH BANK, GAM,SKR
2-Mar-95	2900	1200	1700	Riffle 4B	48.2	7	SOUTH BANK, NONE
2-Mar-95	2900	1200	1700	Riffle 4B	48.2	73	SOUTH BANK, GAM
2-Mar-95	2900	1200	1700	Old La Grange Bridge	50.5	0	SOUTH BANK, SQ,SCP,LP,SKR
21-Mar-95	7700	4700	3000	Tuolumne River Resort	42.5	0	(quick walk-through of low areas was made ~12000 sq.ft.)
21-Mar-95	7700	4700	3000	Riffle 5	47.8	1	
21-Mar-95	7700	4700	3000	Riffle 4B	48.3	0	
21-Mar-95	7700	4700	3000	Riffle 1B	50.2	0	
21-Mar-95	7700	4700	3000	Old La Grange Bridge	50.5	1	
23-Mar-95	4700	1900	2800	Tuolumne River Resort	42.5	0	(quick walk-through of low areas was made ~12000 sq.ft.)
23-Mar-95	4700	1900	2800	Riffle 5	47.8	0	
23-Mar-95	4700	1900	2800	Riffle 4B	48.3	0	
23-Mar-95	4700	1900	2800	Riffle 1B	50.2	2	
23-Mar-95	4700	1900	2800	Old La Grange Bridge	50.5	(not searched)	
27-Jun-95	8600	1000	7600	Riffle 4B	48.3	0	
27-Jun-95	8600	1000	7600	Old La Grange Bridge	50.5	0	
22-Feb-96	5000	3000	2000	Turlock Lake S.R.A.	42	0	The south bank in the campground area adjacent to the river was searched from 12:45 to 13:00 pm. Many low areas still had standing water and the dense undergrowth was difficult to search.
22-Feb-96	5000	3000	2000	Riffle 5	47.8	0	The floodplain on the south bank was searched from 12:15 to 12:27 pm. No fish were found. However, if salmon were scattered in low densities, they would be difficult to detect. Most of this area does not appear to be ideal habitat for young salmon at the 5000 cfs flow level.
22-Feb-96	5000	3000	2000	Riffle 4B	48.2	0	At 12:04 pm the area along the south bank was looked at. The area has good drainage characteristics with adequate slope at this flow change.
22-Feb-96	5000	3000	2000	Riffle 4A	48.8	54	Searched the south bank gravel bar floodplain area along the riffle from 11:03 to 11:33 am. At the top of the overflow area is a depression ~40' X 40' which is a typical stranding area. There is little opportunity for salmon to escape this area as the flow recedes. All stranded salmon were found here (N=54 Ave.=41.6 mm FL), plus three Gambusia. The area immediately downstream of the stranding problem area was also searched. An area ~ 160' X 20' was searched. This area has adequate drainage at this flow change.
22-Feb-96	5000	3000	2000	Riffle 1B	50.1	0	Searched the north bank area downstream of Gasburg Creek between 10:15 and 10:45 am. There is a fairly flat floodplain which has limited stranding area potential. The search was focused on depressions within 100 ft. of the main channel edge.
22-Feb-96	5000	3000	2000	Old La Grange Bridge	50.5	0	Searched the south bank downstream of the old La Grange Bridge. There does not appear to be any stranding problem at this flow reduction. There is a good slope in the effected area and a quick 5 minute walk-through was made.

Sequence #	PRIM5000-ID	PRIM3000-ID	SLOPE	SUBSTRATE	SLP_SUBS2-ID	area	Old Site #	New Site #	Accept/Reject	Location	RB/LB (looking d/s)	Comments
3	1	1	0-4	Bedrock	1295	6148	3		A	RA7A	RB	
5	1	0	0-4	Cobble	556	3897	5		A	RA1A	RB	d/s, narrow band along channel
6	1	1	0-4	Cobble	569	13275	6		A	R1B	RB	narrow band along channel / at stranding site 6
44	1	1	0-4	Coarse Gravel	1016	31323	9		A	R1A	LB	at stranding site 5
31	1	1	0-4	Coarse Gravel	2821	12166	10		A	R4A	LB	d/s, at stranding site 10
48	1	1	0-4	Coarse Gravel	2769	43053	11		A	R4A	RB	d/s, Ingalls Property
39	1	1	0-4	Coarse Gravel	3059	22492	17		A	R4B	LB	at stranding site 11
49	1	1	0-4	Coarse Gravel	599	45179	20		A	R2	LB	at stranding site 7
51	1	1	0-4	Coarse Gravel	2963	48636	26		A	R4B	RB	Ingalls Property
56	1	1	0-4	Coarse Gravel	3427	119450	27		A	R5B	LB	d/s
41	1	1	0-4	Coarse Gravel	344	23567	24		?	R2	RB	vegetation and potholes
			0-4	Coarse Gravel			B1		A	SRP2	RB	Rairden Property
			0-4	Coarse Gravel			A7		A	R17B	RB	Hall Property
			0-4	Coarse Gravel			A5		A	R16C	LB	Hall Property
			0-4	Coarse Gravel			A3		A	R16C	LB	Hall Property
			0-4	Fine Gravel			A8		A	R17B	RB	Hall Property
			0-4	Fine Gravel			A1		A	R16C	LB	Hall Property
			0-4	Fine Gravel			62		A	RA5	LB	at stranding site 12
			0-4	Fine Gravel			63		A	R5B	LB	d/s
			0-4	Sand			A2		A	R16C	LB	Hall Property
82	1	1	0-4	Sand	281	38871	28		A	R2	RB	Varain Property
77	1	1	0-4	Sand	1590	23432	29		A	SRP1	LB	d/s
87	1	1	0-4	Sand	2542	73792	30		A	R4A	RB	Ingalls Property
83	1	1	0-4	Sand	685	42541	31		A	R2	LB	at stranding site 7
86	1	1	0-4	Sand	3314	72358	33		A	R5B	LB	at stranding site 12
89	1	1	0-4	Sand	2700	158504	34		A	R4A	RB	d/s, Ingalls Property
75	1	1	0-4	Sand	1557	22424	35		A	R3A	LB	d/s
95	1	1	4-8%	Coarse Gravel	1664	6453	37		A	R3B	RB	Ingalls Property
93	1	1	4-8%	Coarse Gravel	3298	3878	36		A?	RA5	LB	at stranding site 12
			4-8%	Coarse Gravel			C1		A	R57	LB	d/s Hickman Bridge
			4-8%	Coarse Gravel			C4		A	R57	LB	d/s Hickman Bridge
			4-8%	Fine Gravel			A6		A	R17B	RB	Hall Property
			4-8%	Fine Gravel			A9		A	R17B	RB	Hall Property
99	44	52	4-8%	Sand	2587	6971	39		A	RA4	RB	combine with site #40, Ingalls Property
104	1	1	4-8%	Sand	2560	16074	40		A	R4A	RB	combine with site #39, Ingalls Property
120	1	1	over_8	Bedrock	1142	19374	41		A	RA7A	RB	
116	1	1	over_8	Bedrock	1078	6221	42		A	RA7B	RB	
115	1	1	over_8	Bedrock	1288	5550	43		A	R2A	LB	d/s
113	1	1	over_8	Bedrock	1824	4555	44		A	RA3B	LB	d/s, at stranding site 3
111	1	1	over_8	Bedrock	1056	3954	45		A	RA7B	RB	d/s
110	1	1	over_8	Bedrock	1290	3235	46		A	RA4A	RB	
124	1	1	over_8	Cobble	1943	9711	47		A	SRP1	LB	
125	1	1	over_8	Cobble	2303	11568	48		A	RA6	RB	at stranding site 4
131	1	1	over_8	Coarse Gravel	1197	16221	49		A	RA7B	LB	
			over_8	Coarse Gravel			C2		A	R57	LB	d/s Hickman Bridge
			over_8	Coarse Gravel			C3		A	R57	LB	d/s Hickman Bridge
130	1	1	over_8	Coarse Gravel	1254	8905	50		A	RA7B	LB	
132	1	1	over_8	Coarse Gravel	428	43380	54		A	R3A	RB	Varain Property
127	1	1	over_8	Coarse Gravel	700	4617	55		A	R1A	RB	
133	1	1	over_8	Coarse Gravel	364	56275	52		?	R1C	RB	d/s, dependent on flow, Varain Property
147	1	1	over_8	Sand	1962	10421	57		A	RA6	RB	at stranding site 4
141	1	1	over_8	Sand	3039	5360	58		A	R4B	RB	d/s, Ingalls Property
153	1	1	over_8	Sand	604	21256	59		A	R3A	LB	
150	1	1	over_8	Sand	1577	13784	60		A	SRP1	RB	
149	1	1	over_8	Sand	961	12653	61		A	RA7B	RB	d/s