ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

December 18, 2002

Scott Shewbridge
El Dorado Irrigation District
2890 Mosquito Rd.
Placerville, Ca 95667

Re: FERC Project 184, Geomorphology

As part of the relicensing of the El Dorado Hydroelectric Project, FERC 184-065 (Project 184), the El Dorado Irrigation District (EID) has contracted with ECORP Consulting, Inc. (ECORP) to complete a set of study elements as listed in the original scope of work. ECORP subcontracted the Geomorphology task to ENTRIX, who prepared the attached the Geomorphic Site Assessment report. This study addresses Section 5.0 of the Scope of Work dated September 24, 2001, and amended on October 19, 2001.

Please find enclosed the Geomorphology Site Assessment report for El Dorado Hydroelectric Project, FERC 184-065 (Project 184). If you have any questions, please call me at (916) 782-9100.

Sincerely,

Tom Keegan, B.S.
Senior Fisheries Scientist / Project Manager

CC: Richard Floch / Richard Floch and Associates

Attachment

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EID Project 184 Geomorphic Sites Assessment

Prepared for

El Dorado Irrigation District

Under Contract to
ECORP Consulting Inc.
2260 Douglas Blvd
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Prepared by

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December, 2002

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EID Project 184 Geomorphic Sites Assessment

1.0 INTRODUCTION

ENTRIX, Inc. Purpose and Scope

ENTRIX, Inc. (ENTRIX) under contract to Ecorp, Inc., has performed a geomorphic study in support of the El Dorado Irrigation District (EID) application for relicensing of the El Dorado Hydroelectric Project (FERC No. 184) (Project). The ENTRIX study focused on conducting a Rosgen level III (Rosgen 1996) analysis of Project study sites that had been selected through agency/stakeholder consultation. Previous consultants have collected Rosgen level I, II, and III data (Douglas Parkinson & Associates, 1999; Lydgate, 2002), and provided initial interpretation of results relative to the Project. ENTRIX was scoped to review and summarize data from the prior assessments conducted by other consultants, to provide comment and verification, and to develop and present conclusions.

2.0 SUMMARY OF ROSGEN LEVEL I ASSESSMENT

Rosgen level I classification identifies channels as one of eight (8) types, based on morphometric parameters, including: gradient, bedforms, cross-section shape, sinuosity (channel length/valley length), and entrenchment (Table 1).

Table 1. Morphological characteristics of the Rosgen Level I stream types

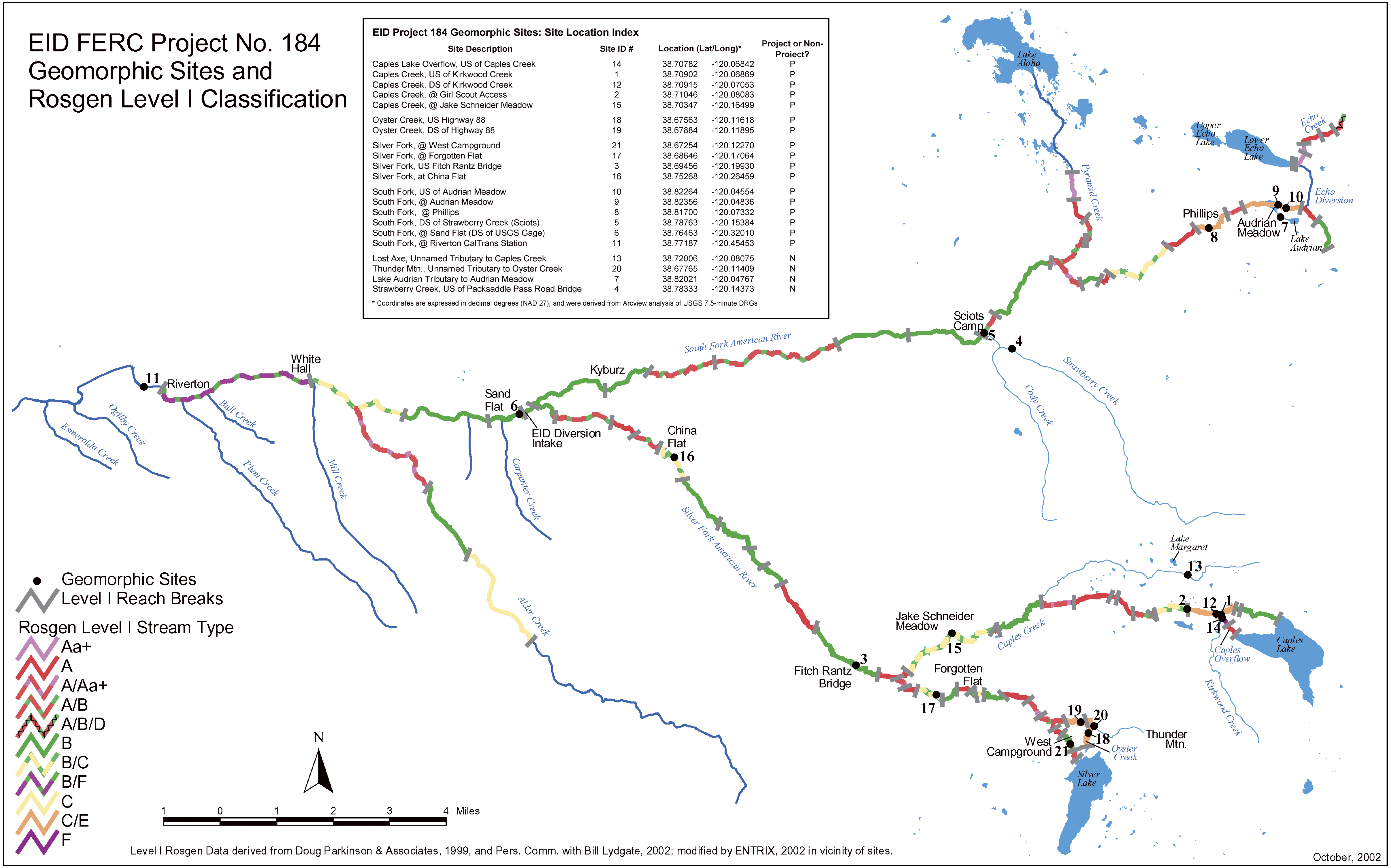
Stream Type	Morphological Characteristics
A	Step-pool or cascading; plunge and scour pools, high gradient and high energy, low sediment storage, entrenched, narrow and deep channel, low sinuosity
B	Riffles and rapids; some scour pools, bars occur but infrequent, moderate gradient, moderately entrenched, moderate width-depth ratio and sinuosity
C	Pool-riffle; meandering, point bars, floodplain, wide and shallow channel, slightly entrenched, high sinuosity, low to moderate gradient, banks can be stable or unstable
D	Braided; multiple channels, shifting bars, deposition, high sediment supply, bank erosion, not entrenched, wide and shallow channel, low sinuosity, and low gradient
DA	Anastomsing; multiple stable channels, pool-riffle, vegetated floodplain and bars, stable banks, wide and shallow channel, no entrenchment, low sinuosity, and low gradient
E	Meadow meanders; well-developed floodplain, pool-riffle, high sediment transport, narrow and deep channel, slightly entrenched, low to moderate gradient, high sinuosity
F	Valley/Canyon meanders; incised into valleys, small or no floodplain, pool-riffle, banks can be either stable or unstable, highly entrenched, moderate to wide, shallow channel, moderate to high sinuosity, moderate slope
G	Gully; incised into hillslopes, alluvial fans, and meadows, high sediment supply, unstable banks, step-pool, entrenched, narrow and deep channel, moderate sinuosity, moderate gradient

Source: Rosgen, 1996

Douglas Parkinson & Associates (1999) performed a Rosgen level I classification for the entire South Fork study area using USGS 7.5 minute topographic map interpretation. The Rosgen level I channel type classification identified 82 distinct stream reaches within the 250 square mile study area.

ENTRIX reviewed the tabled Rosgen level I data and hand-drawn map segments, and produced a GIS overlay of the Rosgen level I designations (Figure 1). ENTRIX resolved discrepancies between the tabled reach lengths (hand measured on paper map copies) and the GIS topographic information with the help of Bill Lydgate (personal communication, 2002), who had participated in the prior study.

ENTRIX was not scoped to perform a comprehensive review of the level I designations. However, ENTRIX did observe channel types during field visit travels to, and in the vicinity of, all level II and III study sites. Based on these observations, ENTRIX adjusted some of the level I designations. At the level-of-detail visible on Figure 1, the only



EID Project 184 Geomorphic Sites: Site Location Index

Site Description	Site ID #	Location (Lat/Long)*		Project or Non-Project?
Caples Lake Overflow, US of Caples Creek	14	38.70782	-120.06842	P
Caples Creek, US of Kirkwood Creek	1	38.70902	-120.06869	P
Caples Creek, DS of Kirkwood Creek	12	38.70915	-120.07053	P
Caples Creek, @ Girl Scout Access	2	38.71046	-120.08083	P
Caples Creek, @ Jake Schneider Meadow	15	38.70347	-120.16499	P
Oyster Creek, US Highway 88	18	38.67563	-120.11618	P
Oyster Creek, DS of Highway 88	19	38.67884	-120.11895	P
Silver Fork, @ West Campground	21	38.67254	-120.12270	P
Silver Fork, @ Forgotten Flat	17	38.68646	-120.17064	P
Silver Fork, US Fitch Rantz Bridge	3	38.69456	-120.19930	P
Silver Fork, at China Flat	16	38.75268	-120.26459	P
South Fork, US of Audrian Meadow	10	38.82264	-120.04554	P
South Fork, @ Audrian Meadow	9	38.82356	-120.04836	P
South Fork, @ Phillips	8	38.81700	-120.07332	P
South Fork, DS of Strawberry Creek (Sciots)	5	38.78763	-120.15384	P
South Fork, @ Sand Flat (DS of USGS Gage)	6	38.76463	-120.32010	P
South Fork, @ Riverton CalTrans Station	11	38.77187	-120.45453	P
Lost Axe, Unnamed Tributary to Caples Creek	13	38.72006	-120.08075	N
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	38.67765	-120.11409	N
Lake Audrian Tributary to Audrian Meadow	7	38.82021	-120.04767	N
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	38.78333	-120.14373	N

* Coordinates are expressed in decimal degrees (NAD 27), and were derived from Arcview analysis of USGS 7.5-minute DRGs

Figure 1. Rosgen Level I Map for the FERC Project No. 184 Study Area

changes ENTRIX has made are: the C/B designation downstream of Kyburz on the South Fork is now B/F; the C reach on the South Fork at Phillips is now C/E; the section of the Caples Lake Overflow from C/E to F; and, a B reach on Oyster Creek upstream of Highway 88 ia now C/E.

3.0 DETAILED STUDY SITES

A total of 21 detailed study sites within the South Fork American River watershed are included in the Rosgen level II and III analysis (Figure 1). These sites were selected through agency/stakeholder consultation using the interim information available from the previous consultants' Rosgen level I analysis. Douglas Parkinson & Associates (1999) recommended that sensitive sites selected for further study focus on Rosgen type B, F, C, and E channels, and not include:

1. Channels classified as Rosgen A or Aa+; or,
2. Streams with bedrock or large caliber bedload (boulders and large cobble).

The seventeen (17) study sites on Project reaches were selected based on their potential sensitivity to Project operations and the Rosgen level I screening described above (Table 1). The Project reach study sites are downstream of one of the four Project water storage reservoirs: Caples Lake , Silver Lake, lower Echo Lake, and Lake Aloha, and/or downstream of the EID diversion dam near Kyburz on the South Fork of the American River (South Fork) (Figure 1). Six sites are located on the South Fork, three are on Caples Creek, one is on the Caples Lake overflow channel, four are on the Silver Fork American River (Silver Fork), and two are located on Oyster Creek. The Oyster Creek sites, while not affected by direct releases or spills, are influenced by leakage from Silver Lake through the natural geologic materials along the northwest margin of the reservoir.

The remaining four study sites are not affected by the Project, but were identified by the U.S. Forest Service (USFS) and included in the geomorphic assessment because of potential value as reference reaches (Table 2). The sites include: an unnamed tributary to Caples Creek (hereafter referred to as Lost Axe); an unnamed tributary to Oyster Creek (hereafter referred to as Thunder Mountain); the Audrian Lake tributary to Audrian Meadow; and, Strawberry Creek (upstream of Packsaddle Ridge Road) (Figure 1).

Table 2. Geomorphic Site Location Index table

Site Description	Site ID #	Location (Lat/Long)*		Project or Non-Project?
Caples Lake Overflow, US of Caples Creek	14	38.70782	-120.06842	P
Caples Creek, US of Kirkwood Creek	1	38.70902	-120.06869	P
Caples Creek, DS of Kirkwood Creek	12	38.70915	-120.07053	P
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* Coordinates are expressed in decimal degrees (NAD 27), and were derived from Arcview analysis of USGS 7.5-minute DRGs

4.0 ROSGEN LEVEL II ASSESSMENT

Methods

Field surveys by previous consultants were undertaken at the 21 study sites to measure the morphometric parameters that form the basis of Rosgen level II designations. In general, standard level II survey procedures were employed, although the particular techniques and equipment used varied. For detailed descriptions of the prior studies' methods, the reader is referred to Douglas Parkinson & Associates (1999) and Bill Lydgate (2002). Previous level II survey data (Appendix A) and Bill Lydgate's (2002) level II and level III data and text discussion of the 21 sites are attached (Appendix B). The following overview of Rosgen level II methods by ENTRIX provides context for ENTRIX's verification and the later discussion of specific parameters and stream condition.

Rosgen level II analysis (Rosgen, 1996) requires the collection of a series of quantitative field measurements of channel morphology at a specific stream reach for the purpose of classifying the stream reach in its existing condition according to one of 41 possible stream types. The Rosgen method relies on taking documented, quantifiable and replicable field measurements to reduce subjectivity in interpretations of the mechanisms involved in channel form and stream departure. If these measurements are properly collected, it is assumed that various individuals conducting separate surveys would derive the same stream type for a reach of channel. Although the Rosgen method does effectively standardize field protocols, experience has shown that not all subjectivity is eliminated, and that different investigators can assign different stream types.

This point especially holds true in the variability that can arise in the selection of the bankfull elevation, which has a prominent role in Rosgen level II channel classification. Furthermore, in many cases not all of the level II parameter measurements will coincide with one particular stream type category. Ultimately it is up to the practitioner to make a judgement on final stream type.

The level II field survey of study sites conducted by prior consultants measured channel cross-section topography, slope, and bed material, and made observations at the site and on aerial photos to determine the following five essential parameters for Rosgen level II classification:

- ◊ Entrenchment ratio;
- ◊ Width-to-depth ratio;
- ◊ Sinuosity;
- ◊ Water surface slope; and,
- ◊ Bed particle size

Entrenchment describes the degree of vertical containment of the channel in its valley. The entrenchment ratio is computed as the width of the flood prone area at an elevation twice the maximum bankfull depth divided by the top width of the bankfull channel. Low values of the entrenchment ratio indicate that the channel is constrained, whereas high entrenchment ratios indicate that the 'active' channel can greatly enlarge its width during high flow events.

Width-depth ratio is an indicator of the channel cross section shape, and is computed as the ratio of the bankfull width/mean bankfull depth. High values indicate the channel is relatively broad and shallow, whereas low values indicate that the channel is narrow and deep. The channel shape affects distribution of energy within the channel. Channels with high width-depth ratios tend to develop shear stress near the banks, while low width-depth ratios indicate shear stress is more distributed on the bed. Width-depth ratio is an indicator for sensitivity to changes in the flow and sediment regime.

Sinuosity characterizes the planform of the channel, and is calculated as stream length/valley length. Higher sinuosity is associated with a meandering channel planform, and lower sinuosity is associated with straighter channels. While useful as a description, sinuosity carries the least weight of the five morphologic parameters in the Rosgen system.

Water surface slope (i.e., gradient) is determined along the longitudinal profile of the channel by measuring the difference in water surface elevation over a length of stream. The gradient is a significant factor as it represents the energy environment and is directly related to hydraulic parameters.

Bed particle size influences the planform, cross section shape, and longitudinal profile of the channel. Bed particle size also affects the rate of sediment transport and the vertical or lateral channel stability. The Rosgen level II classification identifies the channel as one of six sub-categories on the basis of dominant bed material size. Bed particle size is potentially sensitive to, and reflective of, changes in the flow and sediment regime.

ENTRIX geomorphologists made site visits to all 21 study sites to verify Rosgen level II stream typing and make level III observations of channel stability. ENTRIX did not duplicate the prior level II quantitative measurements. ENTRIX reviewed the field data sheets and photographs, and descriptive text regarding the level II channel typing available (Douglas Parkinson & Associates, 1999; Lydgate, 2002) (Appendix B).

The discussion of Rosgen level II results at the Project sites is preceded by a short overview of some challenges presented when applying this classification system to regulated streams.

Rosgen Classification Challenges

Determining the bankfull elevation is crucial to the Rosgen level II and level III stream classification method. From it, entrenchment ratios, channel stability indicies, and bankfull discharge can be calculated. The bankfull discharge is commonly expressed as the "dominant" or "channel-forming" discharge, and it is the discharge that fills the channel to the top of the banks (Williams, 1978). The importance of the bankfull discharge for performing geomorphic work is described by Dunne and Leopold (1978, pp. 608-609) as:

> The discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels.

Alteration of the hydrologic regime changes the magnitude and frequency of flows affecting a channel. Downstream of flow-regulating facilities, natural processes responsible for the formation and maintenance of the channel morphology may be interrupted, discontinuing renewal of prior bankful indicators. However, when the flow regime is modified for a period of time long enough to allow channel adjustment, new indicators of bankfull discharge are formed.

Application of the Rosgen entrenchment ratio in a regulated river system is also challenging. The standard Rosgen method measures floodprone width at an elevation twice the maximum bankfull depth. This elevation is considered to be an approximation of the 50-year return period flood (Rosgen, 1996). The problem with applying this concept is that a 50-year return period is a standard statistical calculation (Thomas et al., 1998) developed for natural, unregulated streams. Flows of the same magnitude as an unregulated 50-year event may not ever occur, or may not occur on the same statistical frequency under a regulated condition (details vary based on individual river system and facilities). Generally, the change in large peak flow frequencies and magnitudes on regulated rivers would be expected to decrease the 'actual' floodprone height above bankfull and floodprone width. However, the Rosgen standard method still looks at the higher level, which can produce entrenchment ratios that are misleading relative to topographic, soils, vegetation, or similar field indicators of the floodprone area. The Rosgen methodology does not include a specific protocol change for regulated rivers. Therefore, the standard protocol was applied in this study. On a site-by-site basis, we discuss how this limitation affects interpretation of the channel condition and project effects, as needed.

Finally, aside from the general difficulty in classifying regulated streams, geomorphic observations made following major floods, such as the historic January 1997 floods in the study area, are difficult. The channel may display temporary flood signatures for several years. Major floods can produce effects that may be appear to be, or may obliterate, bankfull indicators developed over many years of channel adjustment.

Results

Table 3 lists the Rosgen level II determination for each of the 21 sites, based on ENTRIX's review and verification process. In a few instances, ENTRIX's identified channel type differs from the prior two studies. Such conclusions were based on review of the reported measurements for parameters, prior studies' field photographs, field observation by ENTRIX, and our professional judgement and experience on similar river systems. Differences in final Rosgen level II type do not generally influence impact assessment conclusions. However, the following text discussion specifically mentions classification differences between ENTRIX's work and prior consultants, where appropriate.

Table 3. Rosgen Level II Stream Type Results by Site

Site Description	Site ID #	Rosgen Stream Type
Caples Lake Overflow, US of Caples Creek	14	F4
Caples Creek, US of Kirkwood Creek	1	C4
Caples Creek, DS of Kirkwood Creek	12	C4
Caples Creek, @ Girl Scout Access	2	C4
Caples Creek, @ Jake Schneider Meadow	15	F4
Oyster Creek, US Highway 88	18	E4
Oyster Creek, DS of Highway 88	19	F4/C4
Silver Fork, @ West Campground	21	B4c
Silver Fork, @ Forgotten Flat	17	B4c
Silver Fork, US Fitch Rantz Bridge	3	B3
Silver Fork, at China Flat	16	B4c
South Fork, US of Audrian Meadow	10	F4/C4
South Fork, @ Audrian Meadow	9	E6
South Fork, @ Phillips	8	C5 *
South Fork, DS of Strawberry Creek (Sciots)	5	B2
South Fork, @ Sand Flat (DS of USGS Gage)	6	B3
South Fork, @ Riverton CalTrans Station	11	F3
Lost Axe, Unnamed Tributary to Caples Creek	13	C4
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	E4b
Lake Audrian Tributary to Audrian Meadow	7	E3
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	C3

* Sampling site is not typical of reach, which is dominantly an-E5 channel.

Caples Creek

Caples Lake Overflow, Upstream of Caples Creek

The Caples Lake overflow channel, upstream of Caples Creek (site #14), is an F4 channel (Figure 2). Slope, entrenchment ratio, and width/depth ratio are typical for an F channel, although sinuosity is low. Cross section 1 has characteristics more like a B channel, but is less representative of the local reach than the other two cross sections.

Caples Creek, Upstream of Kirkwood Creek

Caples Creek, upstream of Kirkwood Creek (site #1) is a C4 channel (Figure 3). Sinuosity, slope, entrenchment ratio, and width/depth ratio are typical for a C channel.

Caples Creek, Downstream of Kirkwood Creek

Caples Creek, downstream of Kirkwood Creek (site #12) is a C4 channel (Figure 4). Sinuosity, slope, entrenchment ratio, and width/depth ratio are typical for a C channel.

Caples Creek at the Girl Scout Access

Caples Creek at the Girl Scout Access (site #2) is a C4 channel (Figure 5). Slope, entrenchment ratio, and width/depth ratio are typical for a C channel, although sinuosity is low (attributed to bedrock/boulder control). Cross section 3 has characteristics more like an E channel, but is less representative of the local reach than the other two cross sections.

Caples Creek at Jake Schneider Meadow

Caples Creek at Jake Schneider Meadow (site #15) is an F4 channel (Figure 6). Sinuosity, slope, entrenchment ratio, and width/depth ratio are typical for an F channel.

Oyster Creek

Oyster Creek, Upstream of Highway 88

Oyster Creek, upstream of Highway 88 (site #18) is an E4 channel (Figure 7). Slope and entrenchment are typical for an E channel, although sinuosity is low and width/depth ratio is high for an E channel.

Oyster Creek, Downstream of Highway 88

Oyster Creek, downstream of Highway 88 (site #19) is characterized as an F4 with incipient C4 channel development (Figure 8). The cross sections have a large range of entrenchment ratios, controlled by variations in the width of the incised meander belt. The sinuosity, slope, width/depth ratio are all suitable for C, F, or E channels, but the position within the incised channel creates entrenchment values more indicative of an F or C channel, consistent with bank erosion conditions.

Figure 2: Caples Overflow channel (site #14), Upstream view, August 2002

Figure 3: Caples Creek upstream of Kirkwood Creek (site #1), downstream view, August 2002

Figure 4: Caples Creek downstream of Kirkwood Creek (site #12), downstream view, August 2002

Figure 5: Caples Creek at the Girl Scout access (site #2), downstream view, August 2002

Figure 6: Caples Creek at Jake Schneider Meadow (site #15), upstream view, August 2002

Figure 7: Oyster Creek upstream of Highway 88 (site #18), downstream view, August 2002

Figure 8: Oyster Creek downstream of Highway 99 (site #19), upstream view, August 2002

Silver Fork American River

Silver Fork, at West Campground

The Silver Fork, at West Campground (site #21) is a B4c channel (Figure 9). Entrenchment, slope, width/depth are typical for Bc channels, although sinuosity is low (attributed to bedrock control).

Silver Fork at Forgotten Flat

The Silver Fork at Forgotten Flat (site #17) is a B4c channel (Figure 10). Sinuosity, slope entrenchment, and width/depth are all typical for Bc channels.

Silver Fork, Upstream of Fitch Rantz Bridge

The Silver Fork, upstream of Fitch Rantz bridge (site #3) is a B3 channel (Figure 11). Sinuosity, slope entrenchment, and width/depth are all typical for B3 channels.

Silver Fork at China Flat

The Silver Fork at China Flat (site #16) is a B4c channel (Figure 12). Slope, entrenchment, and width/depth are typical for Bc channels, although sinuosity is low.

South Fork American River

South Fork, Upstream of Audrian Meadow

The South Fork, upstream of Audrian Meadow (site #10) is an F4 with incipient C4 characteristics (Figure 13). The cross sections have a large range of entrenchment ratios, controlled by variations in the width of the incised meander belt. Entrenchment ranges from F to C and E channel types, sinuosity is typical of C or F channels, and width/depth is most like an E channel. The position within the incised meanders, bank erosion characteristics, and sedimentation indicators favor an F or C designation.

South Fork at Audrian Meadow

The South Fork at Audrian Meadow (site #9) is an E6 channel (Figure 14). The sinuosity, slope, and entrenchment ratio are typical of E channels, although some areas have low width/depth ratio. Figure 9

South Fork at Phillips

The South Fork at Phillips (site #8) is a C5 channel (Figure 15). Slope, sinuosity, and width/depth ratio are typical for C channels, although the entrenchment ratio is low. The upstream cross section is highly influenced by the culvert outfall hydraulics, and the site is atypical of the local reach, which is an E channel.

South Fork, Downstream of Strawberry Creek

The South Fork, downstream of Strawberry Creek (site #5, at Sciots) is a B2 channel (Figure 16). Slope, sinuosity, and entrenchment ratio are typical of B channels, although the width/depth ratio is low. Some areas have bedrock substrate (B1), but the local reach is dominantly a B2 channel.

Figure 9: Silver Fork American River at West Campground (site #21), downstream view, October 2002

Figure 10: Silver Fork at Forgotten Flat (site #17), upstream view, September 2002

Figure 11: Silver Fork upstream of Fitch Rantz Bridge (site #3), dowstream view, August 2002

Figure 12: Silver Fork at China Flat (site #16), downstream view, August 2002

Figure 13: South Fork upstream of Audrian Meadow (site #10), upstream view, August 2002

Figure 14: South Fork at Audrian Meadow (site #9), downstream view, August 2002

Figure 15: South Fork at Phillips (site #8), US view, September 2002

Figure 16: South Fork, downstream of Strawberry Creek (site #5), upstream view, September 2002

South Fork at Sand Flat

The South Fork at Sand Flat (site #6) is a B3 channel (Figure 17). Slope, sinuosity, entrenchment ratio, and width/depth ratio are typical for B channels

.South Fork at Riverton CalTrans Station

The South Fork at Riverton CalTrans Station (site #11) is an F3 channel (Figure 18). Slope, entrenchment ratio, and width/depth ratio are typical for an F channel, although sinuosity is low.

Non-Project Reaches

Lost Axe, Unnamed Tributary to Caples Creek

Lost Axe, on the unnamed tributary to Caples Creek near Lake Margaret (site #13) is a C4 channel (Figure 19). Slope, sinuosity, entrenchment ratio, and width/depth ratio are all typical for a C channel, although the natural flow regime appears to be intermittent rather than perennial.

Thunder Mountain, Unnamed Tributary to Oyster Creek

The Thunder Mountain unnamed tributary to Oyster Creek upstream of Highway 88 (site #20) is an E4b channel (Figure 20). Slope, entrenchment ratio, and width/depth ratio are typical for an Eb channel, although sinuosity is low.

Lake Audrian Tributary to Audrian Meadow

The Lake Audrian tributary to Audrian Meadow (site #7) is an E3 channel (Figure 21). Slope, sinuosity, entrenchment ratio and width/depth ratio are typical of an E channel. The substrate includes regular cobble and small boulder components, although the material in transport is finer size classes.

Strawberry Creek, Upstream of Packsaddle Pass Road

Strawberry Creek, upstream of Packsaddle Pass Road bridge (site #4) is a C3 channel (Figure 22). Slope, sinuosity, entrenchment ratio, and width/depth ratio are typical for C channels.

Figure 17: South Fork at Sand Flat (site #6), upstream view, August 2002

Figure 18: South Fork at Riverton Caltrans Station (site #11), upstream view, September 2002

Figure 19: Lost Axe, unnamed tributary to Caples Creek (site #13), downstream view, August 2002

Figure 20: Thunder Mountain, Unnamed tributary to Oyster Creek (site #20), upstream view, August 2002

Figure 21: Lake Audrian Tributary to Audrian Meadow (site #7), upstream view, August 2002

Figure 22: Strawberry Creek upstream of Packsaddle Pass Road (site #4), upstream view, September 2002

5.0 ROSGEN LEVEL III AND PROJECT EFFECTS ASSESSMENT

Introduction

A Rosgen level III analysis incorporates hydrologic, biological, ecological, and human impacts assessment with the results of a level II classification to further evaluate the stream condition or stability (Rosgen, 1996). Defining exactly what it means for a stream to be in a "stable condition" can be open to many interpretations. However, geomorphologists typically refer to stable stream as a graded stream. Mackin (1948, p. 471) defined a graded stream as:

> One in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transportation of the load supplied from the drainage basin. The graded stream is a system in equilibrium; its diagnostic characteristic is that any change in any of the controlling factors will cause a displacement of the equilibrium in a direction that will tend to absorb the effect of the change.

A channel in equilibrium is able to adjust to changes in independent variables, namely sediment load and discharge, while maintaining stability of form and profile (Leopold et al., 1964). A channel in equilibrium may still undergo episodes of scour, fill, and lateral migration. However, these episodes are short-term variations over geologic time scales. A stream in equilibrium is neither aggrading nor degrading, it maintains its form and local gradient by striking a balance between sediment load and transport capacity.

A series of parameters are included in level III analysis because of their combined ability to indicate the level of channel stability or instability for a particular reach. They are interrelated to fluvial form and process, whereby they can both influence and be influenced by channel dynamics. Through an evaluation of these parameters at a stream reach, an assessment can be made on the channel's condition and potential departure from its current state and evolution into a new stream type.

Numerous factors throughout the watershed and direct disturbance to the stream channel itself can alter the discharge and sediment load supplied to a stream reach. Likewise, the form and magnitude of adjustment to changes in flow regime and sediment load will vary with stream channel type. For example, a lower gradient channel with alluvial banks and gravel substrate will be more sensitive to increased peak flows than will a steeper, bedrock controlled channel with a boulder bed. In the case of the latter, the channel will likely respond to greater flows primarily through an increase in stage, while it is quite possible that the former will scour, incise, and widen to compensate for the extra energy. Field observations of the level III parameters offer a means of determining the type of adjustment a stream is undertaking in response to a disturbance(s).

Methods

ENTRIX has reviewed and incorporated verified results of Lydgate's level III observations (Appendix B), and independently assessed all 21 geomorphic sites for stream bank characteristics and channel stability conditions.

Level III Parameters

Lydgate (2002) recorded twenty-four descriptive parameters in the field for level III analysis. These parameters can be grouped in six broad categories representing Rosgen's (1996) riparian and in-channel level III parameters (Table 4). ENTRIX has provided a text description of the parameters, by category, to illustrate their relationship to stream condition assessment.

Table 4. Level III Parameters and Categories

Descriptive parameters (Lydgate, 2002)	Broad Category	Rosgen level III parameter
Vegetation Type Tree Structure Downscaling	Riparian Vegetation	Riparian Vegetation
Cover Roots Vigor Streambank Composition Bank Height Bank Erosion Bank Angle	Streambank Characteristics	Streambank Erosion Potential
Occurrence Influence Landslides Aquatic Vegetation	Debris	Debris
Pattern Width Mobility	Bars	Depositional Pattern Aggradation/Degradation
Condition Imbrication Shape Riffles Pools	Substrate	Depositional Pattern Aggradation/Degradation
Meander Sinuosity	Channel Pattern	Channel Pattern

<u>Riparian Vegetation</u>

Analysis of riparian vegetation species type and age structure serves as an indicator of flood frequency and channel evolution in the form of vertical incision and lateral channel migration. It is often possible to make estimates of flooding frequency from the age and type of species occupying the channel margins. Riparian zones that are dominated by woody, upland perennial species are a sign of infrequent overbank flooding; resulting in the successful growth of plants that are less tolerant of mesic soil conditions. A comparison of species types from one bank to the other will suggest the direction of possible channel migration. The age of the species living along the banks also offers an indication of the frequency of larger flood events. Downscaling refers to the encroachment of perennial vegetation into the channel and onto bars. It is another indication of higher flows that are not of a great enough magnitude to periodically scour vegetative growth. Channel incision can also promote downscaling by lowering the elevation of the bed and creating terraces out of abandoned floodplains, thus altering the vegetation structure. Meadows containing non-woody vegetation with shallow rooting depths are especially impacted by channel incision that has the effect of lowering the water table – leading to a decrease in soil moisture.

Streambank Characteristics

Vegetation cover, rooting characteristics, and vigor are all related to bank erosion. In general, the greater the plant cover along the banks, the greater the rooting density to bind soil together and resist erosion from shear stresses exerted by the flow. Exposure of roots along both streambanks can be evidence of channel downcutting. Roots that are exposed at cut banks indicate active lateral migration of the channel. The vigor parameter is closely related to cover, and it refers to the overall level of healthiness apparent in the vegetation community.

Debris

Debris includes various obstacles to flow that may be present in the channel and their frequency of occurrence. Debris can vary widely in scale, from large woody debris (LWD) and landslide relics to beaver dams and debris from human influences. Aquatic vegetation characteristics are also included. The level and types of debris in the channel will have an influence on the stream morphology by altering the hydrodynamics of the flow, which has implications for bank erosion, sediment retention, and scour and fill of the bed. High or low quantities of LWD can be an indication of the role that channel flow has on recruiting wood into the channel. Landslides can also deliver LWD to the channel, as well as large influxes of sediment.

Bars

Sediment depositional features in the channel can take on many forms, and occur in various in-channel positions. Stream sedimentation can be associated with loss of transport capacity brought on by any factors that decrease flow volume and velocity relative to sediment load. Increases in sediment supply through upstream (and up-watershed) processes can also initiate channel aggradation. Bar forms that extend across much of the channel are typically related to assumed inability of flow to sort, transport, or scour depositional features. Bar mobility is controlled by particle size, armoring, and vegetation stabilization relative to flows. Bars void of vegetation, or at least free of older, perennial plants, indicate more frequent scour, mobilization, and/or fresh sediment deposition. The absence of bars and the presence of channel bed armour or scour features are indicators of degradation.

Substrate

Substrate variables pertain to the particles on the streambed as well as the bed forms. The condition parameter recorded by Lydgate (2002) is posed as an indicator of geologic parent material and frequency of mobility of the streambed particles. Substrate with a brighter appearance is considered to be more mobile than particles that have darker colors. Imbrication refers to the packing of particles of similar sizes in an overlapping, shingle-like structure. It is a form of bed surface structure that develops in response to local hydraulic conditions. Imbrication is commonly associated with armoring of the bed, which is a surface coarsening of the substrate. Armoring is typical in high mountain streams where high transport capacities exceed sediment supplies. In such a scenario, fine sediment is winnowed away; leaving behind an erosion pavement that is only mobilized under the highest of flows. Armored beds are also commonly found downstream of dams since the reservoirs cut off upstream sediment supplies, creating a flow with high erosive capacity. Particle shape refers to a particle's degree of angularity, ranging from being flat to fully round in all dimensions. Particle angularity is an indication of mobility and of parent geologic material. High angularity is evidence that a particle has not been transported a long distance by fluvial processes. Particles that are more round are generally assumed to be more mobile under fluvial processes.

Geologic properties of the parent material play a role in rock angularity. Granite becomes rounded relatively quicker with downstream transport distance compared to schist, which tends to remain as a layered disc-shaped particle, and basalt, which is apt to chip away as small-elongated particles (Bunte and Abt, 2001). Riffles were examined for the extent of sediment accumulations forming. Similarly, pools were observed to determine the pattern and degree of sedimentation.

Channel Pattern

In alluvial river systems (with adjustable bed and banks), channel pattern can provide an indication of stream response to lateral confinement, or changes in flow and sediment load. However, in non-alluvial situations, such as mountain stream reaches with high proportion of vertical or lateral bedrock control, channel pattern is less informative.

Bank Erosion Hazard

ENTRIX made field observations of streambank characteristics using a modified version of the Rosgen (1996) Bank Erosion Hazard Index at each of the 21 geomorphic sites. The following four parameters were evaluated along the total bank length (both sides) of the channel at each site:

Ratio of Bank Height to Bankfull Height

The lowest risk to erosion rating has a ratio of 1.0, meaning the bankfull and top of bank indicators are at the same elevation. Higher ratios indicate that a stream channel is more entrenched, confining flows within the channel and causing more of the erosive shear stress to be directed toward the banks.

Ratio of Root Depth to Bank Height

The mechanical and hydrological properties of riparian vegetation are most often quite beneficial to increasing streambank stability. Positive benefits of riparian root systems include reinforcement of the soil, which reduces hydraulic scour, and increases in bank shear strength from a reduction in soil moisture content through transpiration (Simon and Collison, 2002). A ratio value of 1.0 corresponds to the strongest level of protection by roots, while ratios of less than 0.05 indicate a very shallow rooting depth that affords little shear strength to the banks. When possible, exposed root depths were evaluated along areas of bank scour. In cases where rooting depths were not readily observed, estimates were made based off of the plant species and level of maturity.

Bank Angle (degrees)

Estimates of this parameter relate to the steepness of the bank from the channel bed to the top of the bank, which depending on the stream reach, can equal or exceed the bankfull elevation. As bank angle increases, the risk of erosion is assumed to increase. In cases of bank undercutting, angle measurements can surpass 90 degrees and the potential for sloughing or mass failure is classified as extreme.

Surface Protection (%)

This parameter considers vegetation or geologic material protection of the streambanks, both below and above bankfull. Vegetation protection from all rooted, live plants is included, both non-woody and woody species.

The field index values for all four parameters are totaled for each site and adjusted to account for bank material composition and stratification. Hazard rating is assigned one of six categories. The lowest values correspond to a “Very Low” risk of bank erosion.

As values become greater, the bank erosion hazard increase is reflected by category, with the highest possible rating of "Extreme."

Channel Stability Rating

ENTRIX conducted field evaluations of channel stability using the Pfankuch method, as modified by Rosgen (1996) at each of the 21 geomorphic sites. A series of descriptive conditions for the 'upper banks', 'lower banks', and channel 'bottom' are matched to the field condition to place the channel into one of four level of stability: Excellent, Good, Fair, or Poor. Supplemental observations about sediment supply bed stability, and width/depth condition are recorded in the field for use in qualitative discussion. The Pfankuch rating values increase with increasing risk of instability. Rosgen level II stream type is used to convert stability values to the categories. This conversion is intended to help judge stability relative to the assumed stable stream type (Rosgen, 2001). However, ENTRIX has found that in situations lacking adequate reference channel conditions, comparing to the appropriate stream type is difficult and the numeric ratings retain significance.

ENTRIX reviewed the results of all three above-described evaluations to prepare the level III assessment of channel condition for the Project Sites. All of the level III field observations require identification of bankfull indicators. However, as discussed under the level II methods, there are difficulties with assigning bankfull levels in regulated rivers. In addition, several of the project sites do not have an obvious floodplain because they are either naturally, or through land use and water system regulation, entrenched. Finally, recent major flood damage affects the bankfull indicator characteristics. A discussion of these challenges precedes the level III results.

<u>Bankfull Indicator Challenges</u>

The bankfull discharge represents the flow responsible for making adjustments to the dimensions of a stable alluvial channel (i.e., a stream that is neither aggrading nor degrading and has the ability to change its shape). In channels with an active floodplain, the bankfull indicator is readily identified by the elevation of incipient flooding over the banks. It is often the case, though, that certain channel types are confined in a narrower valley floor, are entrenched, or are non-alluvial, and thus do not have a well-defined or connected floodplain. In such cases, the top of bank is not coincident with the bankfull flow, and identifying the elevation that represents the channel-forming discharge becomes much more subjective. Several proxy indicators of the bankfull stage in channels without an obvious floodplain include:

- the elevation of the low bench (middle bench if three or more)
- the rooting level the lower limit of well-established perennial vegetation, usually trees
- the elevation of the top of depositional features in the active channel, such as unvegetated bars
- the upper extent of sand-sized particles in the boundary sediment
- significant changes in particle size of bank material
- undercut banks, and
- stain lines or the lower extent of lichens on boulders and bedrock valley walls.

As needed, all of these morphological features were considered to help identify the bankfull level at all 21 sites.

In many cases, multiple bankfull indicators may be present, and identifying the "true" elevation is often not possible. At best, a range of possible bankfull elevations can be recorded. The existence of multiple bankfull indicators, and the difficulty of identifying one representative bankfull elevation is exacerbated in flow regulated systems such as the Project reaches. Defining a single channel-forming flow that the channel has adjusted to maybe further complicated by historical or continuing land use activities, such as roads residential development, logging, and livestock grazing, and the impact that recent (1997) flood flows have had on the channel condition. The tremendous flows of 1997 scoured bed and banks and left behind new depositional features. Remnants of this large magnitude, low frequency event, however, are temporary, and should not be mistaken as indicators of the channels' response to long term conditions.

The relatively short time period since the 1997 flood has not allowed for channels in a temporarily unstable condition to recover to a new equilibrium state or return to the prior state before field surveys were conducted. This is particularly true for the Project site observations by Douglas Parkinson & Associates (1999), but also relevant for the 2000 through 2002 observations. In degrading and non-alluvial reaches, sediment transport capacity normally exceeds sediment supply, and bar forms are often missing or underdeveloped. Using recent flood deposits as bankfull indicators in these areas will result in too low an estimate of a bankfull discharge (or the assumption of inadequate sediment transport). Conversely, a reliance on deposits left behind by an extreme flood event outside an active channel will yield a bankfull discharge that is too high (or the assumption that the channel is aggrading). In channel reaches that are experiencing long-term aggradation, in-channel deposits or floodplain topography may both be incorrect bankfull indicators, even without recent flood damage (Copeland et al., 2000).

ENTRIX geomorphologists used professional judgement and experience to make field determinations of approximate bankfull elevations that can represent modern channel conditions, despite recent flood impacts and post-flood adjustments.

Results

A summary table of the 2002 level III observations by Lydgate is included in Appendix B. ENTRIX bank erosion hazard and channel stability ratings for each Project site are listed in Tables 5 and 6 respectively. The following text descriptions provide ENTRIX's conclusions about each site, including sensitivity to flow and sediment changes, present stability, and type/degree of departure from a stable channel form. Project effects, and important non-Project influences on the geomorphology are described for each site. The Project sites are described first, organized by sub-basin, followed by the potential reference sites.

Table 5. Bank Erosion Hazard

Site ID	Reach Location:	Rosgen Level III: Bank Erosion Hazard Index Bank Height	Root Depth	Bank Angle (Degrees)	Surface Protection (%)	Overall Bank Erosion* Rank
14	Caples Lake Overflow, US of Caples Creek	Very High	Extreme	High	Extreme	Extreme
1	Caples Creek, US of Kirkwood Creek	Very Low	Low	High	Very Low	Very Low
12	Caples Creek, DS of Kirkwood Creek	High	Very High	High	High	High
2	Caples Creek, @ Girl Scout Access	High	Low	Very High	Very Low	Moderate
15	Caples Creek, @ Jake Schneider Meadow	Extreme	High	High	Very High	Very High
18	Oyster Creek, US Highway 88	Low	Very Low	High	Very Low	Very Low
19	Oyster Creek, DS of Highway 88	Extreme	Low	Moderate	Very Low	High
21	Silver Fork, @ West Campground	High	Low	Low	Very Low	Very Low
17	Silver Fork, @ Forgotten Flat	Extreme	High	Low	High	Moderate
3	Silver Fork, US Fitch Rantz Bridge	Low	Low	Low	Low	Low
16	Silver Fork, at China Flat	Extreme	Low	Low	low	Low
10	South Fork, US of Audrian Meadow	Very High	Moderate	High	Very Low	Very High
9	South Fork, @ Audrian Meadow	Low	Moderate	Very High	Very Low	Low
8	South Fork, @ Phillips	Moderate	Low	Very Low	Very Low	Low
5	South Fork, DS of Strawberry Creek (Sciots)	Extreme	Extreme	Low	Very Low	Very Low
6	South Fork, @ Sand Flat (DS of USGS Gage)	Extreme	Moderate	Low	Moderate	Low
11	South Fork, @ Riverton CalTrans Station	Extreme	High	Low	Low	Low
13	Lost Axe, Unnamed Tributary to Caples Creek	Low	Low	High	Very Low	Low
20	Thunder Mtn., Unnamed Tributary to Oyster Creek	Very High	Low	Moderate	Low	Moderate
7	Lake Audrian Tributary to Audrian Meadow	Very High	Very Low	High	Very Low	Low
4	Strawberry Creek, US of Packsaddle Pass Road Bridge	High	High	Low	High	High

Notes: * Adjusted to reflect bank materials and/or stratification, as needed

Table 6. Channel Stability Rating

			Channel Stability (Pfankuch) Evaluation, Categories[1] and Resulting Stream Condition Rating																	
			Upper Banks				Lower Banks					Bottom						Pfankuch Rating		
Site ID	Site Description	Stream Type	1: Landform Slope	2: Mass Wasting	3: Debris Jam Potential	4: Vegetative Bank Protection	5: Channel Capacity	6: Bank Rock Content	7: Obstructions to Flow	8: Cutting	9: Deposition	10: Rock Angularity	11: Brightness	12: Consolidation of Particles	13: Bottom Size Distribution	14: Scouring and Deposition	15: Aquatic Vegetation	Value	Category	ENTRIX Stability Rating
14	Caples Lake Overflow, US of Caples Creek	F4	P	E	F	P	E	P	F	F	F	F	F	P	P	F	P	118	Fair	Fair
1	Caples Creek, US of Kirkwood Creek	C4	E	E	G	E	F	F	E	G	F	F	E	G	G	F	G	76	Good	Fair
12	Caples Creek, DS of Kirkwood Creek	C4	E	E	F	F	F	P	G	F	F	G	G	P	F	P	G	107	Fair	Fair
2	Caples Creek, @ Girl Scout Access	C4	E	E	F	E	G	P	F	F	F	G	E	F	P	F	G	98	Fair	Fair
15	Caples Creek, @ Jake Schneider Meadow	F4	E	E	P	P	E	P	F	P	F	G	F	P	F	P	P	119	Fair	Poor
18	Oyster Creek, US Highway 88	E4	E	E	E	E	G	P	E	G	E	G	G	G	G	G	F	63	Good	Good
19	Oyster Creek, DS of Highway 88	F4/C4	E	E	F	E	E	P	F	G/P	E	E	F	G	P	G	F	78	Good	Fair
21	Silver Fork, @ West Campground	B4c	G	E	E	G	F	G	E	E	E	G	E	E	F	E	P	59	Good	Good
17	Silver Fork, @ Forgotten Flat	B4c	G	G	G	P	G	F	G	G	E	G	G	G	F	G	F	83	Fair	Fair
3	Silver Fork, US Fitch Rantz Bridge	B3	G	G	F	F	G	G	F	E	G	G	F	G	F	G	P	86	Poor	Fair
16	Silver Fork, at China Flat	B4c	G	G	G	G	G	G	E	G	E	G	G	G	F	G	F	81	Fair	Fair
10	South Fork, US of Audrian Meadow	F4/C4	E	E	F	E	G	P	F	F	G	E	G	P	G	F	G	87	Good	Fair
9	South Fork, @ Audrian Meadow	E6	G	G	E	E	G	P	E	G	E	*	E	E	E	E	G	52	Good	Good
8	South Fork, @ Phillips	C5	E	E	G	G	F	P	P	G	F	P	F	P	P*	P	G	107	Fair	Fair
5	South Fork, DS of Strawberry Creek (Sciots)	B2	P	G	G	P	E	E	G	E	E	G	G	G	G	G	F	76	Poor	Good
6	South Fork, @ Sand Flat (DS of USGS Gage)	B3	F	G	G	F	G	E	G	G	E	G	G	G	F	F	F	90	Poor	Good
11	South Fork, @ Riverton CalTrans Station	F3	F	G	E	F	E	G	E	E	E	G	G	G	F	G	P	70	Good	Good
13	Lost Axe, Unnamed Tributary to Caples Creek	C4	E	E	F	G	F	P	F	F	F	G	F	G	P	F	P	105	Fair	Good
20	Thunder Mtn., Unnamed Tributary to Oyster Creek	E4b	E	E	F	G	G	P	E	G	F	E	G	P	F	F	G	88	Fair	Fair
7	Lake Audrian Tributary to Audrian Meadow	E3	E	E	F	E	G	E	E	E	E	E	E	P	G	F	G	64	Good	Good
4	Strawberry Creek, US of Packsaddle Pass Road Bridge	C3	F	G	F	F	F	F	G	F	F	G	P	F	P	F	G	112	Poor	Poor

Notes: 1: Channel stability categories: E=Excellent, G=Good, F=Fair, P=Poor
*: Fines/Silt

Caples Creek

Caples Lake Overflow, Upstream of Caples Creek

Caples Lake Overflow, upstream of Caples Creek is a sensitive site that has an extreme bank erosion hazard and fair channel stability. The site displays indications of prior incision, lateral bank erosion, and local aggradation (Figure 2). The site is at a transition point between the steeper upstream channel types (A and B) and the low gradient meadow along the main stem Caples Creek. Based on topography, geology, valley type, it seems likely that a channel type change would naturally occur at this location. Evidence of 1997 flood damage includes excess fine sediment (from local bank erosion) and large woody debris (LWD). The modern channel is within an incised meander belt, but is not actively downcutting. The confluence with Caples Creek provides local base elevation control. Given the high bank instability and local sediment supply, it is likely that further channel adjustments will be through lateral migration. This could allow room for a more stable C channel to develop within the meander belt. However, the likelihood and timeframe for this recovery process under the regulated flow regime is uncertain (due to the small base flows and extreme, infrequent spills).

At this location, the upstream Project reservoir (Caples Lake) controls 100 percent of the less than one square mile contributing natural watershed area.

Present non-Project influences include the Lake Margaret trail upslope to the southwest and the trail crossing near the downstream end of the site. Surface erosion and bank degradation along the trail contribute to the excessive local sediment supply.

Caples Creek, Upstream of Kirkwood Creek

Caples Creek, upstream of Kirkwood Creek is a sensitive site that has a very low bank erosion hazard and fair channel stability. The site exhibits blocked side channels and bar deposits that indicate excess sediment supply, although the main channel remains functional and stable (Figure 3). Recent field observations alone cannot determine whether the excess sediment is a result of long-term conditions or the 1997 flood event. The site is in the upstream half of the first large low gradient area downstream of Caples Lake Dam. The reach between the site and the dam is dominated by B channel type, more transport efficient than in the site vicinity. The site would naturally experience overbank flows and sediment deposition, with some combination of C and E channels. The modern channel is a single-thread C channel, but there are field indicators (e.g., meander scars, abandoned channel segments) of either a more dynamic channel or a multiple channel system in the past. The modern channel is stable, with side and mid-channel gravel bars producing a shallower and narrower active channel than would be expected naturally. There is limited evidence of active lateral migration (i.e., few point bar deposits and cut banks). Sediment transport is limited relative to supply and channel hydraulics; this may have resulted from a combination of Project peak flow reduction and high local sediment supply. The sediment relations do not indicate that the project reservoir has seriously interrupted natural sediment delivery.

At this location, the upstream Project reservoir (Caples Lake) controls over 90 percent of the approximately 13 square mile contributing watershed area.

Present non-Project related influences in the vicinity include trail crossings of the meadow and stream and beaver activity; however, they do not exert obvious effects at the site.

Caples Creek, Downstream of Kirkwood Creek

Caples Creek, downstream of Kirkwood Creek is a sensitive site that has high bank erosion hazard and fair channel stability. The site includes large point bar and side channel deposits (Figure 23), and some mid-channel bars. The site is immediately downstream of the confluence with Kirkwood Creek and the Caples Lake overflow channel, within a large low gradient meadow. Recent field observations alone cannot determine whether the excess sediment is a result of long-term conditions or the 1997 flood event. The site vicinity would naturally experience frequent overbank flows and sediment deposition, with some combination of C and E channels. The modern channel is a single-thread C channel, but there are field indicators (e.g., meander scars, abandoned small E channel segments,) of lateral channel dynamics and/or a previous multiple thread system. The modern channel has some side and mid-channel gravel bars, but includes distinct, large point bars, evidence of active lateral migration. Evidence of minor (0.5 ft) incision includes undercut banks and a topographic break between point bar deposits and the floodplain. Bank erosion is primarily along outer channel bends and may reflect normal lateral migration processes, as well as recent 1997 flood effects. There are some indications of excess sedimentation, but not of woody vegetation stabilizing bars. Therefore, sediment deposits may reflect the exposure of this site to the unregulated peak flows and sediment load from the Kirkwood Creek drainage during the 1997 event. Sediment transport is limited relative to supply and channel hydraulics; this may have resulted from a combination of Project peak flow reduction and high local sediment supply.

At this location, the upstream Project reservoir (Caples Lake) controls about three-quarters of the approximately 18 square mile contributing watershed area.

Present non-Project influences at the site, aside from beaver activity, are not readily visible, but the land use history information for the site and the Kirkwood Creek drainage is unavailable.

Caples Creek at the Girl Scout Access

Caples Creek at the Girl Scout Access is a sensitive site that has moderate bank erosion hazard and fair channel stability. The channel exhibits aggradation and non-woody vegetation encroachment (Figure 24). The site is located at the downstream end of a large meadow, near the transition to the downstream B channel reach. The valley is more confined and has more bedrock outcrops near the site than at the two upstream meadow sites. Due to the gradient, confinement and bedrock influences, it seems likely that the natural channel would be a C channel, perhaps with low sinuosity. Numerous side channel gravel bars, partially buried LWD, sand deposits in poorly developed pools, and cut banks may reflect on-going trends and/or the effects of the 1997 flood. The sediment deposits may reflect the exposure of this site to the unregulated peak flows and sediment load from the Kirkwood Creek drainage during the 1997 event. Sediment transport is limited relative to supply and channel hydraulics; this may have resulted from a combination of Project peak flow reduction and high local sediment supply.

At this location, the upstream Project reservoir (Caples Lake) controls about three-quarters of the approximately 18 square mile contributing watershed area.

Present non-Project influences at the site, aside from beaver activity, are not readily visible, but the land use history information for the site and the Kirkwood Creek drainage is unavailable.

Figure 23: Caples Creek downstream of Kirkwood Creek (site #12), upstream view, August 2002

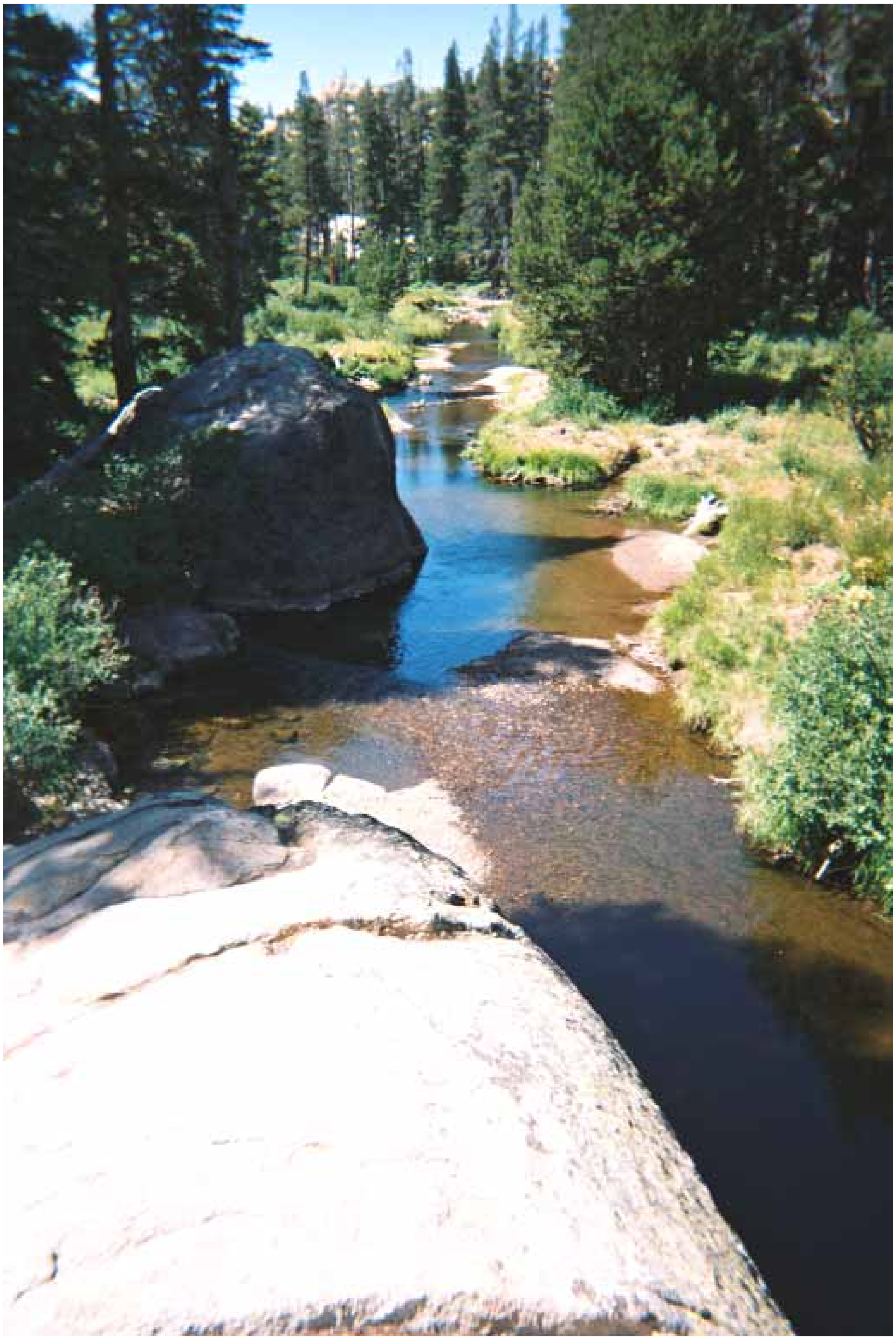

Figure 24: Caples Creek at the Girl Scout access (site #2), downstream view, August 2002

Figure 25: Caples Creek at Jake Schneider Meadow (site 15), downstream view, August 2002

Caples Creek at Jake Schneider Meadow

Caples Creek at Jake Schneider Meadow is a sensitive site that has very high bank erosion hazard and poor channel stability. The site exhibits indicators of prior incision, lateral instability, and distinct 1997 flood damage (Figure 25). The site is along a narrow sloping meadow, with abandoned meander scars about two feet above the present channel grade. These indicators, along with the local valley gradient and anecdotal accounts of historic dairy pastures in wet floodplain meadows, suggest that the natural stream type was a C channel. Evidence of the 1997 flood is abundant, in the form of extensive bank erosion, channel widening/rooted tree falls, LWD debris jams, fine sediment in pools, and records that the downstream trail bridge washed out. The modern channel is within an incised meander belt, but is not actively downcutting. Overall, incision in the range of two to four feet has occurred in modern times. However, the timing and relative contributions of grazing, the Project's flow regulation, and other watershed land use(s) prior to downcutting are unclear. Given the very high bank instability, local sediment supply, and in-channel debris (forming hydraulic restrictions), it is likely that lateral migration will occur in response to future high flows. This could allow room for a more stable C channel to develop within the meander belt. However, the likelihood and timeframe for this recovery process under continuing grazing pressure, upstream watershed land use change (i.e., Kirkwood Creek), and the regulated flow regime is uncertain.

At this location, the upstream Project reservoir (Caples Lake) controls about half of the approximately 30 square mile contributing watershed area.

Present non-Project influences at the site include hiking trails and continued grazing lease activity. Written land use history information is unavailable, but anecdotal information indicates that there was a dairy on-site and local grazing for over 100 years, although little or no logging.

Oyster Creek

Oyster Creek, Upstream of Highway 88

Oyster Creek, upstream of Highway 88 is a sensitive site that has very low bank erosion hazard and good channel stability. The minor gravel bar deposits within the channel are vegetated with non-woody vegetation (Figure 7). The site is downslope and north of Silver Lake and Oyster Lake, in an area of volcanic rock, mudflow deposits and moraine deposits that support natural springs and seeps. A small E channel, or multiple small E channels could have occurred naturally. Hydraulic head in the Project reservoir (Silver Lake) creates seepage rates ranging from a base flow of 2 cfs, to a high of 17 cfs when at the normal maximum lake level (Hydrologics, 2002). No specific evidence of 1997 flood impacts were noticed at this site. The modern channel appears to be a stable functioning meadow channel, but has larger dimensions than might be expected for the small topographic watershed area. The channel is transporting gravel and sand efficiently, but does not appear to be actively downcutting or widening in this vicinity.

At this location, the Project reservoir (Silver Lake) is not within the surface watershed, but affects subsurface hydrology.

Present non-Project effects include recreational meadow use that does not appear to impact the channel. Written land use history information is unavailable, but extends over 100 years. Direct channel modifications for the purpose of site drainage or water conveyance could have occurred, but are unverified.

Figure 26: Oyster Creek Downstream of Highway 88 (site #19), upstream view at bedrock knickpoint, August 2002

Figure 27: Oyster Creek downstream of Highway 88 (site #19) upstream view from RB to LB, August 2002

Oyster Creek, Downstream of Highway 88

Oyster Creek, downstream of Highway 88 is a sensitive site that has high bank erosion hazard and fair channel stability. The site displays evidence of prior incision and lateral erosion (Figure 8). Downstream of the site, a bedrock knickpoint provides local grade control (Figure 26), although channel incision is also evident further downstream. The local valley width and gradient suggest that the natural channel type would likely be an E or C channel, with E and B channel areas upstream, and steeper A and B channels downstream. No specific indicators of 1997 flood damage were noted. Immediately downstream of the highway culvert, the channel is slightly incised, with two to three foot banks and one-foot bank undercuts (Figure 27). However, the bed was somewhat armored and the channel remained connected to a floodplain. At the study site, the active channel is about 10 to 15 feet below the meadow surface at top-of-bank. The channel has a small, inset floodplain that is best developed immediately upstream of the bedrock knickpoint. Downstream of the knickpoint, the channel is also deeply incised, but the area is not within the detailed study site.

Given the high bank instability and sediment supply, downstream bedrock grade control, and Project base flow augmentation, it is likely that lateral migration will continue to occur at the site. This could allow room for C channel development to continue within the F channel meander belt.

At this location, the Project reservoir (Silver Lake) is not within the surface watershed, but affects subsurface hydrology.

Present non-Project effects include Highway 88 runoff and sediment loading, and associated hydraulics from the upstream highway culvert. Written land use history information is unavailable, but extends over 100 years. Several activities could have occurred on site, but are unverified, including: meadow use for pasture or grazing, various upstream roadbed/culvert configurations, and direct channel modifications for site drainage or water conveyance.

The factors initiating and contributing to the total historical incision are uncertain. The timing and relative impact of historical meadow grazing, possible channel modifications for drainage or conveyance, upstream road fill and culvert flow concentration, and the Project base flow increases have not been documented.

Silver Fork American River

Silver Fork, at West Campground

The Silver Fork is a non-sensitive site that has very low bank erosion hazard and good channel stability. Bedrock and boulder control provides lateral and vertical control (Figure 28), with limited gravel and cobble deposits. This riffle-run reach is in the reach closest to, and downstream of, Silver Lake dam. Based on topography, geology, and valley type, it seems likely that the natural channel was a B channel. The high sediment transport capacity is evident from the armored bed of small cobble to large gravel and the lack of bar deposits. No signs of active aggradation or degradation are evident at the site. Small overbank floodplain areas exist between bedrock outcrops and confining valley walls. Hydraulic scour pools occur, but there is little specific evidence (either scour or debris) of the 1997 flood. Long-term Project releases of sediment-free water may have led to a coarsening of the bed substrate and lack of fine sediment.

Figure 28: Silver Fork American River at west campground (site #21), upstream view, October 2002

At this location, the upstream Project reservoir (Silver Lake) controls nearly 100 percent of the approximately 16 square mile contributing watershed area.

Present non-Project effects include potential increased runoff and sediment delivery from the Silver Lake West Campground. However, the lack of fines in the channel bed indicates any sediment loading in the reach has not exceeded transport capacity. Written land use history information is unavailable. Several activities could have occurred on site, but are unverified. On-going construction of a new Highway 88 bridge at Silver Lake dam may produce short-term changes in runoff or sedimentation, but would be expected to be controlled through mitigation measures.

Silver Fork at Forgotten Flat

The Silver Fork at Forgotten Flat is a non-sensitive site that has moderate bank erosion hazard and fair channel stability. Based on valley type, topography, and geologic materials, a B channel would have occurred naturally. An inactive cobble bar and multiple bankfull indicator levels at the site suggest that channel dimensions have decreased (Figure 29), although channel type has not changed. Flood damage from 1997 is still apparent, particularly downstream of the site where accumulations of LWD have formed large jams (Figure 30). Sands likely deposited from the 1997 flood on side channel bars have young alders and willows on them, suggesting that they are stabilizing.

At this location, the upstream Project reservoir (Silver Lake) controls about 70 percent of the approximately 22 square mile contributing watershed area.

Present non-Project influences at the site include a small trail crossing. Written land use history information is unavailable. Several activities could have occurred in the watershed (between Silver Lake and Forgotten Flat), including logging, grazing and road networks, but are unverified.

Silver Fork, Upstream of Fitch Rantz Bridge

The Silver Fork, upstream of Fitch Rantz Bridge is a non-sensitive site that has low bank erosion hazard and fair channel stability. Flood damage from 1997 is still apparent, particularly LWD debris and sand deposits near the downstream end of the site by the bridge (Figure 11). Based on valley type, topography, and geologic materials, a B channel would have occurred naturally. The reach is a transition area from higher gradient large boulder controlled cascades to riffle-run bedforms of cobbles and large gravel. Bars are few or absent, but pools have sand and gravel substrate. Channel grade has bedrock and boulder control, while channel banks on the campground side (north east) have higher proportion of soil materials.

At this location, the upstream Project reservoirs (Caples Lake and Silver Lake) control about 40 percent of the approximately 73 square mile contributing watershed area.

Present non-Project influences at the site include an informal campground, trailhead, and off-road vehicle access with highly compacted soils and little vegetation on the northeast bank, and the Silver Fork Road bridge crossing downstream of the site. Written land use history information is unavailable. Several activities could have occurred on site and in the watershed (of both Caples Creek and the Silver Fork), including logging, grazing and road networks, but are unverified.

Figure 29: Silver Fork at Forgotten Flat (site #17), downstream view, September 2002

Figure 30: Silver Fork downstream of Forgotten Flat, downstream view of LWD jam, September 2002

Silver Fork at China Flat

The Silver Fork at China Flat is a sensitive site that has low bank erosion hazard and fair channel stability. Disturbance due to the 1997 flood and related clean-up, and the on-going bridge construction (Figure 31) limit interpretations of natural processes or Project effects. There are large, extensive overbank gravel and sand flood deposits on top of the terrace with mature conifers. However, it is unclear if these materials were deposited by the 1997 flood, or reworked as part of flood clean-up. Based on valley gradient and width, topography, and geologic materials, a B channel likely occurred under natural conditions. Upstream of the bridge reconstruction site, the channel was over-wide and degraded in the vicinity of the low-water crossing. The furthest upstream section was more stable, with valley side slopes and bedrock controls confining the meander belt width. Downstream of the bridge construction site, the channel is confined between old river terraces and the Silver Fork Road, but appears laterally and vertically stable.

At this location, the upstream Project reservoirs (Caples Lake and Silver Lake) control about 27 percent of the approximately 105 square mile contributing watershed area.

Present non-Project influences include: Silver Fork Road drainage, the Middle Creek culvert outfall, recreational cabins upslope on the west bank, a USFS fire access road and low water crossing, and bridge reconstruction (including staging and dewatering areas and activities). Written land use history information is unavailable. Several activities could have occurred on site (e.g., gold mining and exploration, various road and bridge configurations) and in the watershed (e.g., logging, grazing and road networks), but are unverified.

South Fork American River

South Fork, Upstream of Audrian Meadow

The South Fork, upstream of Audrian Meadow is a sensitive site that has very high bank erosion hazard and fair channel stability. The site has indications of prior incision and lateral instability (Figure 13), and on-going aggradation (Figure 32). The site is an area of transition between the steeper watershed crest slopes along and northeast of Highway 50 and the low gradient area at Audrian Meadow. Topography, valley type, and geologic materials suggest that a small C channel, or one or more E channel(s) could have occurred naturally.

Evidence of the 1997 flood includes bank erosion, channel widening/rooted tree falls, LWD debris jams and abundant fine sediment. At the study site, the active channel is about six feet below the forested top-of-bank. The channel has a discontinuous small, inset floodplain that is densely vegetated. Prior vertical incision appears to have been supplanted by lateral instability. Stream banks at outer bends are actively eroding and often undercut. The channel has distinct and relatively deep pools, with gravel and sand riffles and large point bar deposits. Sand and other fine deposits are not only within the channel, but on the floodplain in LWD debris. The origin of the excess sediment is uncertain, but likely includes local bank material and may include upslope sources along the Echo Lake conduit and Highway 50 roadway (including non-local sands used for snow and ice maintenance). Given the very high bank instability, high sediment supply, and in-channel debris (forming hydraulic restrictions), it is likely that lateral migration will continue, particularly in response to future high flows. This could allow room for a more stable C channel to develop within the meander belt. However, the likelihood and timeframe for this recovery process under continuing effects of upstream land use (i.e.,

Figure 31: Silver Fork at China Flat (site #16), upstream view of bridge replacement construction, August 2002

Figure 32: South Fork upstream of Audrian Meadow (site #10), upstream view, September 2002

residential uses and access roads, highway drainage and road maintenance practices) and the regulated flow regime is uncertain.

An inner-basin Project diversion of up to a maximum of 30 cfs from Lower Echo Lake is routed through the Echo Conduit that empties into the South Fork upstream of this geomorphic site (EID, 2001). No historic records documenting the seasonal flow regime of the Echo Conduit are available. Simulated historic flows for the Echo Conduit were modeled by Hydrologics (2002) for the years 1923 to 1996. Reported as mean monthly data, the average flow in cfs for all years modeled is one cfs in October, zero cfs for the months November through August, and 27 cfs in September. These results indicate that from 1923 – 1996, for about one month in late summer a continuous flow of 27 cfs was released from Lower Echo Lake and discharged into the South Fork upstream of Audrian Meadow.

The natural contributing drainage area to this location is only approximately one square mile in the headwaters of the South Fork. Under non-Project conditions, the channel would likely have experienced a small base level flow for most of the year, probably less than 5 cfs. Peak flows would have occurred during the maximum snowmelt months of May and June, at uncertain magnitudes. Under non-Project conditions, September flows would have been limited to a very small base flow and limited, periodic thunderstorm runoff events.

The present geomorphology has been used by prior consultants (Appendix D) to esimate bankfull discharge at about 22 cfs at this site. Although ENTRIX did not calculate its own bankfull discharge estimates, field observations of channel dimension--------prior surveys suggest that the present channel forming flows are on the order of 20 to 30 cfs. The Project's late summer releases of 27 cfs, sustained for over 75 years, has had an inverse impact on the channel condition at this site.

Present non-Project effects include potential increased runoff and sediment delivery from Highway 50 and the upslope residential developments. Written land use history information is unavailable. Several activities could have occurred on site as suggested by the abandoned shack, but are unverified, including: grazing and various upslope roadbed/culvert configurations.

<u>South Fork at Audrian Meadow</u>

The South Fork at Audrian Meadow is a sensitive site that has low bank erosion hazard and good channel stability (Figure 14). The site is near the margin of a large low gradient meadow with a multiple thread channel network. Upstream of the site on the side closest to Highway 50 (northeast), the South Fork has a discontinuous channel, including abandoned former channels with small natural levees indicating deltaic/alluvial fan processes. Along the southwest side of the meadow, a continuous channel leads from Lake Audrian to the meadow. Topography, valley type, and geologic materials suggest that one or more E channel(s) could have occurred naturally in the meadow.

Evidence of the 1997 flood is not obvious, but may include sand and fine sediment overbank deposits along the eastern margin of the meadow. The origin of the excess sediment is uncertain, but likely includes bank material from the upstream forested reach and may include upslope sources along the Echo Lake conduit and Highway 50 roadway (including non-local sands used for maintenance). The modern channel has thickly vegetated, fine-textured banks with some undercutting, but no distinct indications of active incision or aggradation. The channel cross-section shape is simple and hydraulically efficient; bed forms are limited and substrate is fine mineral sediment and organic.

An inner-basin transfer from the Upper Truckee River through the Echo Conduit introduces up to a maximum of 30 cfs upstream of the South Fork in Audrian Meadow (EID, 2001). The effect of this flow augmentation on the seasonal hydrologic regime of the channel in Audrian Meadow is nearly the same as previously discussed for site 10, the South Fork upstream of Audrian Meadow. The channel in Audrian Meadow that would be naturally dominated by snowmelt hydrology in early summer has experienced a longer duration of high magnitude flows, late in the season under Project operations that is out of balance with the pre-Project flow regime.

The contributing drainage area to this location is approximately two square miles and includes the headwaters of the South Fork and the drainage of Lake Audrian. A bankfull discharge estimate of about 2 cfs was made at this site by prior consultants (Appendix D). This reported value is an estimate of the bankfull flow for one channel of the multi-thread system of the South Fork in Audrian Meadow, and is clearly an underestimate of the total channel forming discharge flowing through the meadow. Although the contributing drainage area at this location has nearly doubled compared to site 10, the project flows input of about 30 cfs for the entire month of September, in what is still a relatively small drainage basin, has likely led to adjustments in the channel form.

Present non-Project effects include potential increased runoff and sediment delivery from Highway 50 and the upslope residential developments. Written land use history information is unavailable. Several activities could have occurred on site, but are unverified, including: grazing and various upslope roadbed/culvert configurations.

South Fork at Phillips

The South Fork at Phillips is a sensitive site that has low bank erosion hazard and fair channel stability. The upstream portion of the site near the road crossing and culvert is less stable that the main sampling site, while the channel is stable both downstream of the site (Figure 33) and upstream of the site and road crossing (Figure 34). Based on valley gradient and width, surface topography, and geologic materials, an E channel likely occurred under natural conditions (as exists downstream of the site and upstream of the road). The site is just upstream of the confluence with Phillips Creek, which crosses the forested floodplain in a slightly entrenched E channel. No obvious 1997 flood damage was noted, but the flood may have contributed to the bank erosion immediately downstream of the road culvert and to the moderately high sediment load still in transport within the reach. However, it is also possible that the bank erosion and high sediment conditions may have developed over a long period of time. The channel appears to have undergone minor lateral and vertical erosion for about 300 feet downstream of the road crossing (including some of the sampling site). The channel does not appear to be actively incising or aggrading, but lateral instability is still likely in the reach nearest the culvert outfall. However, the channel is wider and shallower than the upstream and downstream reaches, which have more dense riparian vegetation and LWD spanning and anchored within the channel. At the site, there is some bank undercutting and sloughing, with sand and fines in pools and riffles and as side bars and small point bars. The channel is well-connected to an active floodplain with riparian vegetation on the north side of the channel.

About two miles upstream of this site, a Project facility (Echo Lake conduit) introduces a small inter-basin transfer from the Upper Truckee River basin to the nearly seven square mile local contributing watershed. Previous consultants estimated a bankfull discharge from channel geometry of about 200 cfs at Phillips (Appendix D). The input of Echo Conduit's average historic flow augmentation of approximately 30 cfs for the month of September (see previous discussion of site 10, South Fork upstream of Audrian

Meadow) are not expected to be substantial. As contributing drainage area and natural bankfull flow increase

Figure 33: South Fork at Phillips, downstream of (site #8), September 2002

Figure 34: South Fork at Phillips, upstream of site and Sierra at Tahoe Road, September 2002

with distance downstream from the confluence of the South Fork and the conduit, the relative importance of an additional input of 30 cfs diminishes. However, base flow Project releases may have increased.

Given the localized nature of the channel bed and bank disturbance, their position relative to the road crossing, and the stable E channel downstream, the site does not appear to have experienced Project-related effects.

Present non-Project effects include the floodplain-crossing road fill and upstream culvert, potential increased runoff and sediment delivery from Highway 50, local residential use and septic systems. Written land use history information is unavailable. Several activities could have occurred on site, but are unverified: grazing, dispersed recreation, and various roadbed/culvert configurations.

South Fork, Downstream of Strawberry Creek

The South Fork downstream of Strawberry Creek is a non-sensitive site that has very low bank erosion hazard and good channel stability. The site has local bedrock and boulder outcrops that provide lateral and vertical stability (Figure 35). Evidence of 1997 flood damage includes soils scour near the top-of bank (above boulder and bedrock toe-of-slope (Figure 36), and anecdotal information regarding damage to the south bridge abutment/support that has been replaced. Based on valley gradient and width, topography, and geologic materials, a B channel would likely occur under natural conditions. Bed materials reflect the valley and side slopes and local bedrock conditions. There are no bar deposits, but cobble, gravel and sand materials are common in pools, bedrock scour holes, and pocket water. There is no indication of excessive sediment transport.

The upstream Project reservoir (Lake Aloha) controls about seven percent of the 48 square mile contributing watershed. Additionally, an upstream Project facility (Echo Lake conduit) introduces a small inter-basin transfer from the Upper Truckee River basin. Given the distance downstream from the conduit, and the substrate conditions and bank materials, the small magnitude of Project releases during September have not adversely affected channel type, dimension, riparian vegetation, bank erosion, or channel stability. However, base flow levels may have increased.

Present non-Project effects include potential increased runoff and sediment delivery from Highway 50 and the recreational cabin lots and access roads along the banks and upslope, and dispersed recreation. Written land use history information is unavailable. Several activities could have occurred on site, directly upslope, and in the local watershed (i.e., Strawberry Creek), but are unverified: logging, grazing, road building and modifications, recreation access and use.

South Fork at Sand Flat

The South Fork at Sand Flat is a non-sensitive site that has low bank erosion hazard and good channel stability. Based on valley gradient and width, topography, and geologic materials, a B channel would likely occur under natural conditions. This reach is highly confined by valley walls that impede lateral migration of the channel. The south bank is armored with large boulders and bedrock that protect the El Dorado Diversion Canal upslope and the north bank has bedrock, boulders and riprap along the Highway 50 roadway. Channel substrate includes cobble and large boulder providing vertical stability. Evidence of 1997 flood damage includes bank scour that exposed tree roots (Figure 37), and several fresh sand bars and sand deposits within deep pools (Figure 38). Bed materials are dominantly large boulders and cobble, with abundant sand in runs and pools. However, there are no distinct indications of channel aggradation or

Figure 35: South Fork at mouth of Strawberry Creek, upstream view, September 2002

Figure 36: South Fork downstream of Strawberry Creek (site #5), downstream view, September 2002

Figure 37: South Fork at Sand Flat (site #6), view of right bank, August 2002

Figure 38: South Fork at Sand Flat (site 6), downstream view of bedrock confined pool, August 2002

narrowing. The site is less than 0.5 miles downstream of the EID diversion dam, which washed out in the 1997 flood and has recently been replaced. Sediment that had historically accumulated behind the dam may not yet have fully processed through this reach.

At this location, the four upstream Project reservoirs together control less than 17 percent of the 193 square mile contributing watershed area. Overall, the Project has little or no effect on major peak flow hydrology in this reach. Project hydrology effects are limited to diversions at the EID diversion dam about 0.5 miles upstream. The El Dorado Canal, which conveys water diverted by the EID diversion dam to the Powerhouse, has a maximum transport capacity of about 165 cfs (EID, 2001). Hydrologic modeling by Hydrologics (2002) estimated historic flow diversions at Kyburz for the years 1923 to 1996. Average simulated monthly flows for the period of record during the months of October through January range from 71 to 107 cfs. The largest average diversions range from 139 to 163 cfs in the months of February to June, and decrease again to below 130 cfs for the remainder of the water year. No bankfull discharge estimates are available for this site. Based on field observation alone, and also on a calculation that was made for the Riverton site further downstream by prior consultants (Appendix D), it is likely that the channel forming flow at Sand Flat is on the order of 1,000 cfs. This is not a calculated value, but rather one based roughly on channel width and depth to observed bankfull indicators. Average modeled diversions during the typical peak flow months of May through July range from 114 to 163 cfs (Hydrologics 2002). Based on an approximate bankfull discharge of 1,000 cfs, this flow reduction is about 15 percent of the bankfull flow. In relation to the large magnitude flows that are necessary for channel maintenance at Sand Flat, it is not likely that the river has adjusted to a new form because of the flow diversions at Kyburz. However, other aspects of channel morphology may have been impacted by historic flow diversions such as bar formation and mobility, and pool scour. Project diversions at Kyburz are likely lowering base flow levels, particularly in the months of August, September, and October.

In addition to the diversion of flow, the dam at Kyburz has historically altered bedload transport by retaining sediment. The extent that the EID dam has trapped sediment is not known. It is also not known whether this sediment has been dredged and hauled off site, or reintroduced to the channel at a downstream location. The reconstructed diversion dam will pass sediment again (the mechanism for passing sediment is not known). The geomorphic response of the channel to the new dam will depend on the type, magnitude and timing of the sediment that passes through. It will also depend on whether or not over the years trapped sediment has been regularly reintroduced to the river downstream of the dam. A channel that has only been receiving sediment free water since the river was dammed is likely to have a more pronounced reaction to the return of sediment transport.

Present non-Project effects include potential increased runoff and sediment delivery from Highway 50 and the recreational cabin lots and access roads along the banks and upslope, the campground along the low terrace, and dispersed recreation. Written land use history information is unavailable. Several activities could have occurred on site and directly upslope, but are unverified: logging, grazing, road building and modifications, recreation access and use.

South Fork at Riverton CalTrans Station

The South Fork at Riverton CalTrans Station is a non-sensitive site that has low bank erosion hazard and good channel stability. Evidence of 1997 flood damage was limited, but includes sand deposits on side and mid-channel boulder bars that are vegetated with non-woody species (Figure 39). Based on valley gradient and width, high valley side

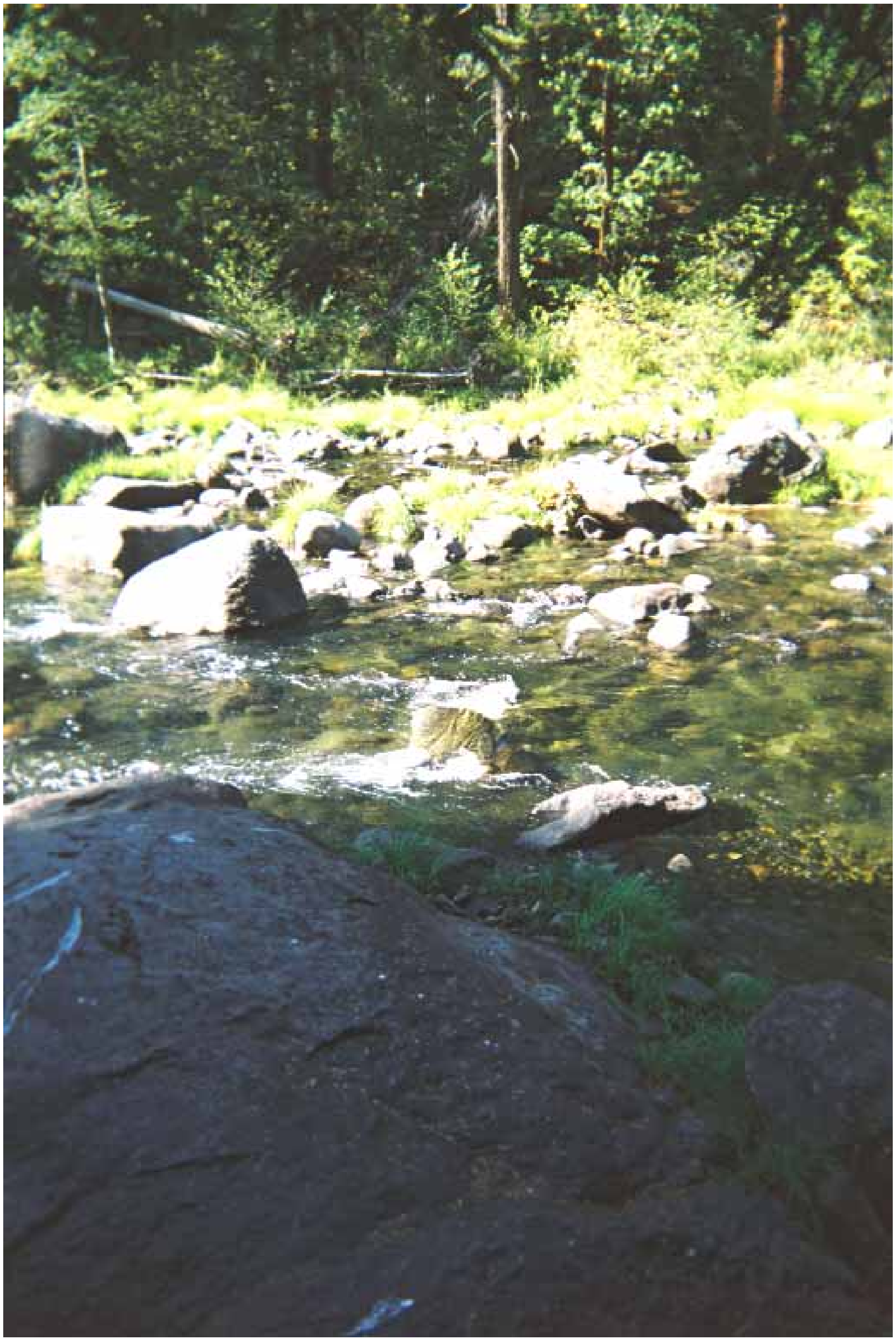

Figure 39: South Fork at Riverton Caltrans Station (site #11), cross section view from LB to RB, September 2002

slope angles, and valley sinuosity, an F channel may occur under natural conditions, with short B channel sections in steeper, bedrock controlled areas. The banks are generally well-armored with boulder and cobble or vegetated with mature trees. The reach is dominantly riffle-run, with scattered scour pools. Channel substrate is cobble and boulder, with sands in low velocity areas and gravel in bars.

At this location, the upstream Project reservoirs together control about 15 percent of the approximately 250 square mile contributing watershed area. Therefore, the Project has little or no effect on peak flow hydrology in this reach. Project hydrology effects are limited to the EID diversions at Kyburz. Prior consultants estimated a bankfull discharge at Riverton of approximately 1,300 cfs. Based on the simulated mean monthly flow values (see previous discussion of site 6, South Fork at Sand Flat) (Hydrologics 2002), diversions at Kyburz account for about 10 percent of the estimated bankfull flow at Riverton. A decrease in channel forming flows of this magnitude is not expected to influence channel morphology. The dynamics of bar formation and mobility and pool scour may have been altered to some extent because of the diversions at Kyburz. A reduction in late summer base flows has also likely occurred.

Non-Project effects are not highly evident, although the steep side slopes have transmission line corridors, maintenance and fire roads, and the Highway 50 roadway, which may produce local changes in drainage and sedimentation. In addition, the site is downstream of the Whitehall section of the South Fork, that has experienced repeated episodes of fire, landslide, and flood damage over more than twenty years.

Non-Project Reaches

<u>Lost Axe, Unnamed Tributary to Caples Creek</u>

The Lost Axe unnamed tributary to Caples Creek is a sensitive site that has low bank erosion hazard and good channel stability. This alluvial C4 channel has pool-riffle morphology and a sinuous planform (sinuosity increases in downstream section) that is free to make lateral and vertical adjustments. The floodplain is well connected to the channel at this site and the structure of the riparian vegetation indicates frequent overbank flooding. There was no flow in the channel at the time of the site visit in late August, which suggests that this is an intermittent stream dominated by snowmelt and storm hydrology. Evidence of the 1997 flood is limited to isolated areas of bank undercutting, particularly at one scour pool along the north bank (Figure 40), and deposition of fresh gravel on point bars. No sediment deposition onto the floodplain from the flood was observed. This stream reach has a bed substrate composed of gravel and sand that is well sorted. Channel spanning LWD is firmly embedded and functions to alter hydraulics that causes sediment retention and the formation of local plunge pools (Figure 41).

The site is near Lake Margaret and has a local watershed area of about three square miles.

This site is located in a remote area of the Caples Creek Watershed, and present watershed effects are not evident at the site. The Lake Margaret trail traverses near the site, but its impacts are negligible. Written land use history within the Lost Axe watershed is unavailable.

Thunder Mountain, Unnamed Tributary to Oyster Creek

Thunder Mountain unnamed tributary to Oyster Creek is a sensitive site that has moderate bank erosion hazard and fair channel stability. This E channel runs through the densely forested drainage of the northwest face of Thunder Mountain, north of Silver Lake, before emptying into Oyster Creek (Figure 42). Only a small trickle of flow originating from a seep approximately 10 feet upstream of the reach's most upstream extent was in the channel at the time of the field visit in late August. No remnants of the 1997 flood were observed at this site. Erosion is limited to isolated areas of undercutting into banks of fine composition. Localized bank erosion appears to be the source of fine deposition in the channel. The channel bed has a diverse substrate that ranges from fines to large cobbles and small boulders. These coarser bed elements alter local hydrodynamics and create small, unvegetated side and mid-channel bars that are not well defined. No signs of aggradation or degradation were present in the channel.

The site has a local watershed area of less than one square mile.

Present watershed effects are not evident at the site. Written land use history within the Thunder Mountain drainage to Oyster Creek is unavailable.

Lake Audrian Tributary to Audrian Meadow

Lake Audrian tributary to Audrian Meadow is a sensitive site that has low bank erosion hazard and good channel stability. This creek flows from Lake Audrian approximately 0.25 miles upstream, and joins the South Fork in Audrian Meadow. No indications of active channel adjustments to changes in flow or sediment were evident. Large boulders in the bed armor much of the banks and impede channel lateral migration (Figure 43). Effects from the 1997 flood are not apparent, but high flows may have contributed to the large amount of downed trees of varying diameter that form LWD in the channel. At the time of the field visit to the site in late August, no flow was observed

Figure 40: Lost Axe, unnamed tributary of Caples Creek (site #13), cross -section view of right bank, August 2002

Figure 41: Lost Axe, unnamed tributary of Caples Creek (site #13), upstream view, August 2002

Figure 42: Thunder Mountain unnamed tributary to Oyster Creek, (site #20), downstream view, August 2002

Figure 43: Lake Audrian tributary to Audrian Meadow, (site #7), downstream view, August 2002

in the channel. Dense riparian vegetation of both woody and non-woody types exists along both banks of the channel. Conifer trees are generally set back a few feet from the channel margins. The bed substrate is composed of sand, fines, and some small gravel. Although large boulders are numerous throughout the reach, they are not a part of the active bed load and function as hydraulic roughness elements. Bars forms chiefly composed of sand develop in association with LWD and the local hydraulics created by the large boulders on the bed.

The site has a local watershed area of about one square mile.

Potential watershed effects at this site include runoff and erosion from Forest Service logging road 11N06Y, which crosses over the stream just upstream of the site, and hydraulic effects of the culvert at this road crossing. Field observations of relic stumps suggests that logging may have occurred within this watershed. Written land use history within the Lake Audrian drainage is unavailable.

<u>Strawberry Creek, Upstream of Packsaddle Pass Road</u>

Strawberry Creek upstream of Packsaddle Pass Road is a sensitive site that has high bank erosion hazard and poor channel stability. This C channel has riffle-run with intermittent pool morphology that is still adjusting to a period of channel incision that has downcut about 2 feet throughout this reach (Figure 44). Downstream of the site and upstream of the Packsaddle Pass Road bridge, channel downcutting is even more pronounced where nearly vertical banks are approximately 10 feet in height. The channel has cobble point bars with fresh sand deposits, likely from the 1997 flood. Plant growth on these bars suggests that they are not actively mobilized. The potential for floodplain connection and lateral migration exists in local flat areas where the valley walls are not confining. However, encroachment of woody vegetation onto the floodplain suggests less frequent overbank flows, which is possibly related to the channel incision (Figure 22). Boulders in the channel are not a part of the active bed load but do affect hydrodynamics and bed topography.

The site has a local watershed are of approximately 12 square miles.

Potential watershed impacts to this site include runoff and erosion from Forest Service road 11N19 that parallels the creek just upslope to the north. Written land use history within the Strawberry Creek basin is unavailable. The presence of logging roads, however, does suggest that timber harvesting has occurred at some point in time.

Figure 44: Strawberry Creek upstream of Pack Saddle Pass Road (site #4), downstream view, September 2002

6.0 DISCUSSION

Reservoir Sedimentation

A potential influence that the Project has had on stream condition is a disruption of the sediment supply to downstream reaches due to sediment trapping in the reservoirs. ENTRIX analyzed bathymetric maps and area-capacity curves for each of the four Project reservoirs in an attempt to investigate the degree to which reservoirs may have altered the sediment balance.

Bathymetric surveys and associated area-capacity curves of Caples Lake, Silver Lake, Echo Lake, and Forebay Lake were completed by the Pacific Gas and Electric Company in 1970, and then again in July 1999, by Sea Surveyor, Inc. The 1999 survey is reported in data files from the Resource Insights EID Project 184 EID CD #1, December 2000, and was plotted by ECORP Consulting, Inc. Resource Insights conducted a comparison of the area-capacity curves that were generated from both surveys (Appendix C). These curves plot surface area (acres) and usable capacity (acre-feet) in relation to the reservoir gage height elevation (feet). Evidence of gains or losses in storage capacity from the 1999 survey could potentially serve as indicators of reservoir dredging or sediment aggradation, respectively.

Maximum depths are reported for each reservoir in both surveys. Caples Lake and Silver Lake show respective increases of eight (60 to 68 ft) and eleven ft (60 to 71 ft) maximum depths, whereas Echo Lake has a slight decrease of two feet, changing from 152 ft in 1970 to 150 ft in 1999. The increase in maximum depth may be indicative of dredging (Caples/Silver), or decrease in depth may indicate sedimentation (Echo). However, it is also quite possible that they can be attributed to the different surveying methods used between 1970 and 1999, and the accuracy of their results.

The analysis of the capacity curves to estimate the rate of sedimentation behind the dams within the Caples, Silver, and Echo reservoirs is also impaired by the structure of the capacity curves. A certain estimate of dredging or sediment in-fill volume was not possible, because the curves display usable capacity of the reservoirs in reference to the bottom of outlet elevation, as opposed to capacity based on the maximum depth of the lake. Streams flowing into the reservoirs' pools would deposit sediment load on the bottom of the lakebed, which lies below the bottom of outlet elevation. Area-capacity curves of this type would not reflect sedimentation until aggradation has exceeded a level above that of the outlet. The only conclusion that can be made is that if sediment has accumulated, it is not to a degree that has reached the elevation of the outlet.

A review of generalized surface geology in the study area (Figure 45) also supports the conclusion that Project reservoirs have not trapped considerable amounts of sediment. This conclusion is partially due to the reservoirs' high elevation position within the glaciated landscape. All four reservoirs are near their watershed crests, with small, but highly productive runoff conditions. Lake Aloha and lower Echo Lake have contributing drainage areas deninated by eroded granite bedrock (Figure 45). Caples Lake has a contributing drainage basin with primarily eroded granite bedrock, a side from the small percentage of area (near the reservoir) in volcanic pyrodastic deposits and some ridge top moraines (Figure 45). Silver Lake likewise is fed by natural runoff within a basin almost entirely of eroded granite bedrock, with minor extent of volcanic and glacial depnts (Figure 45). There is a significant difference between the Caples Lake and Silver Lakes drainage basin from that of the un-regulated Kirkwood Creek basin (Figure 45); Kirkwood Creek local geology is almost entirely volcanic pyrodastics and mudflow units.

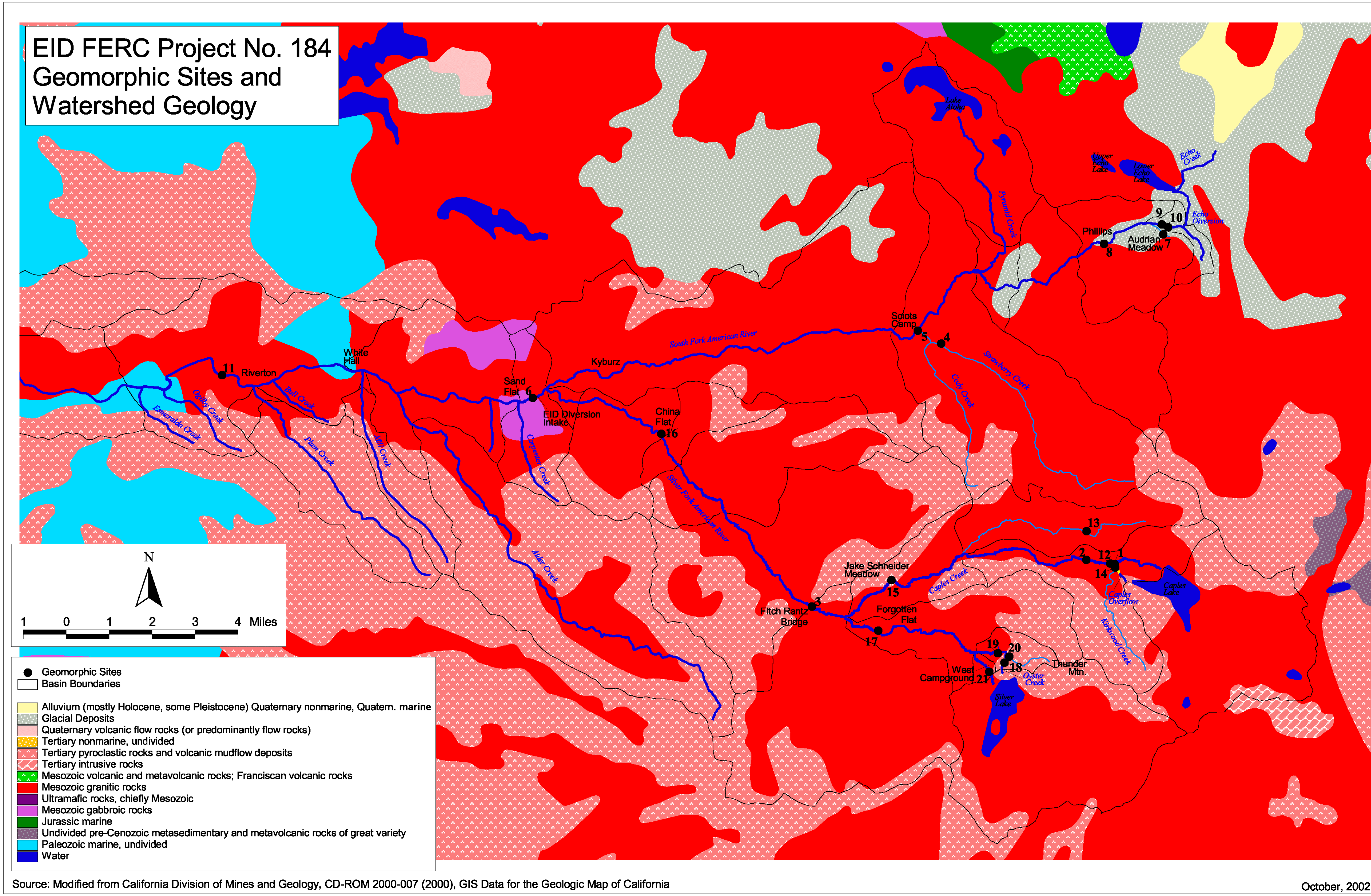

Figure 45. South Fork of the American River Watershed Geology

A final consideration that also limits the likely sediment retention impact is that the reservoirs are all in areas of natural lakes. The locations functioned as sediment traps under natural conditions, even if less complete than if dammed. It seems unlikely that the reservoirs have had a large impact, if any, on sediment availability beyond pre-Project conditions. Construction of the reservoirs did enlarge the capacity of the lakes and therefore altered the spatial pattern of sediment deposited by streams feeding the lakes, but this would not have substantially affected the quantity of sediment transported downstream through their outlets. Since sediment delivery was naturally limited downstream of the lakes, potential channel adjustments related to Project operations are more likely due to the altered flow regime.

Project Reservoirs and Flow Regulation

The general downstream effects of dams on rivers have been well-documented (Williams and Wolman, 1984). Reservoirs with a relatively small storage capacity that do not substantially reduce flood peaks, yet release sediment-free water, can cause coarsening of the bedload (development of an armor layer) and possibly channel incision of downstream reaches that are composed of finer-grained bed material capable of being mobilized (Kondolf, 1997). Reservoirs with a large capacity relative to river inflow and have a greater impact on reducing peak flood events, or that divert flows from a reach, have a tendency to cause channel narrowing and encroachment of riparian vegetation downstream (Kondolf, 1997). Channel narrowing develops when flow releases are not great enough to scour and transport the fine sediment that is delivered and deposited in the stream by downstream unregulated tributaries. The stream response to reservoir releases is most pronounced closest to the dam and progressively decreases in intensity with increasing distance downstream and the inflow of other tributaries.

Occurrences of armoring, incision, and channel narrowing at the Project sites are noted in the individual reach discussion of Rosgen level III results (see Section 5).

For nearly a hundred years, reservoirs in the Project area have regulated flow in a fairly consistent manner. Water is stored in the reservoirs throughout the spring snowmelt season and then released during the summer, fall, and early winter to meet downstream water demands (Borcalli & Associates, 1999). Reservoir operations also meet minimum flow requirements that can vary annually depending on the water year type (see Borcalli & Associates, 1999).

No data is available to document peak flows under pre-Project conditions. There are peak flow records at a few gage stations for the historic period, which includes Project operations. However, there are no simulated peak flows to represent the no-Project condition during the historical record. Based on hydrologic modeling of unimpaired and impaired mean daily flows in the Project area done by Borcalli & Associates (1999) and Hydrologics (2002), reservoirs tend to reduce mean daily flows in the months of March, April, and May as they capture snowmelt runoff and increase water storage. During the remainder of the summer and on into fall and the early winter, reservoir stage is gradually lowered as water is released for generating hydropower. This has the effect of increasing base flows above what they would have been under no-Project conditions in the conveyance Project reaches, upstream of the EID diversion dam.

The ability of the Project reservoirs to attenuate peak flows varies between reservoirs in relation to their storage capacity relative to runoff, which can be expressed by annual runoff. Caples Lake has the greatest capacity to store average annual inflow (78 percent), followed by Lake Aloha (45 percent), Silver Lake (28 percent), and Echo Lake (14 percent). Therefore, their ability to modify peak flows would be expected to vary widely, too. Modeling of mean daily flow illustrates the range in respective abilities of the reservoirs to contain the higher flows during the snowmelt months (Borcalli & Associates, 1999, and Hydrologics, 2002). More of the higher flows on Caples Creek are contained than on the Silver Fork. Peak flows from Echo Lake are released to the natural drainage, in the Upper Truckee River Basin. A maximum of 30 cfs can be released via the Echo Lake Conduit to the South Fork near Phillips. Lake Aloha peak flow attenuation may modify peak events within the Pyramid Creek sub-basin but rapidly diminish as a percent of downstream along the South Fork.

None of the reservoirs can control major peak flow events (e.g. 1950, 1964, 1986, and 1997). With increasing distance downstream from the reservoirs, any regulatoring effects on flows are diminished. This is also apparent in the modeling of mean daily flow of the South Fork at the El Dorado Diversion Dam (Borcalli & Associates, 1999). At this location, the difference in magnitude of mean daily flows between impaired and unimpaired conditions is less substantial than comparisons of Project or unimpaired flows at or near the reservoirs. Despite the lack of specific simulated information on peak flows, we can assume that geomorphic sites closer to the dams have had a greater change in peak flows than those sites further downstream.

Non-Project Reference Conditions

Many factors can potentially disrupt equilibrium balance between the hydrologic regime, sediment production and sediment transport within watersheds. Direct channel modifications and impoundment infrastructure, rerouting and transfer of water, and flow regulation associated with hydroelectric generation can alter flow and sediment relationships. Several land-use activities, including: roadways, logging, grazing and other agricultural activities, residential and commercial development, and various forms of recreation use can also create direct and indirect hydrologic and sediment process changes in watersheds. In addition to human alterations, watersheds often have substantial natural disturbance events, trends, and cycles affecting the geomorphic condition of the stream system. Regardless of the origin, changes in the driving hydrologic and sediment processes can produce shifts that result in channel morphology changes. Such changes may take the form of aggradation or degradation of the channel bed, vertical instability, lateral instability, bank erosion, accelerated sediment production, or changes in riparian vegetation associated with altered soil moisture conditions and/or channel dynamics. Therefore, reference conditions that control for similar non-Project effects are often used in impact assessments.

The task of interpreting a potential Project stream condition departure from its “stable” condition is problematic without adequate reference reaches for comparison. The four geomorphic sites selected for inclusion in this study as reference reaches represent streams that are unaffected by Project flow regulation. However, without knowledge of land use history within the watersheds of both the Project and non-Project streams, making comparisons of channel condition from one stream to another for the purpose of drawing conclusions on Project effects will be misleading. Furthermore, ENTRIX is unaware of any standard protocol that was undertaken by the stakeholders to select the four reference sites. No comparisons of non-Project controls such as drainage area, valley type, geology, landform slope, and similarity in natural bankfull discharge between Project and potential reference streams were made available to ENTRIX.

Based on field observations, and stemming from a lack of information on the above-mentioned parameters, ENTRIX does not believe that any of the proposed reference reaches are suitable for comparison to Project sites. The stream characteristics of Thunder Mountain tributary and the Audrian Lake tributary to Audrian Meadow are unlike any other of the sites. Lost Axe’s intermittent nature impedes its comparison to any of the perennial geomorphic sites on Caples Creek. Finally, Strawberry Creek is an “unstable” stream that is currently adjusting to some non-Project disturbance within its watershed, thereby reducing its value as a reference reach.

Without a reliance on reference streams for comparison, ENTRIX’s level III assessment and conclusions about Project effects were based solely on the physical condition of the geomorphic sites, our understanding and interpretation of likely natural conditions, and processes observed that indicated stream channel instability. Only generalizations about potential effects from flow regulation or land use alteration could be made.

7.0 BANKFULL DISCHARGE CALCULATION FOR PROJECT REACHES

To provide additional context to our assessment of possible Project effects, ENTRIX analyzed the frequency at which estimated bankfull discharges occur. Presented below are the methods that were undertaken to make estimates of bankfull flows for selected locations throughout the EID project area with available data. The significance of these results is then interpreted relative to channel-forming flows in a regulated system.

Methods

Previous fluvial geomorphology studies for the Project utilized three different methods to make estimates of bankfull flows at various locations throughout the Project area. At 14 of the 21 geomorphic sites, bankfull discharge calculations were based off of channel geometry measurements. In addition, bankfull discharges were estimated from both flood frequency recurrence intervals and drainage area at five US Geological Survey (USGS) gaging stations.

Channel Geometry

Bankfull discharge estimates for the existing channel configurations provide an indication of "with Project" morphology that may be reviewed in relation to gaged "with Project" hydrology. Previous consultants employed channel geometry relationships to estimate bankfull flows at 14 of the 21 geomorphic sites (Appendix D). At each of these sites, three cross-sections were surveyed to determine channel dimensions, including width, cross-sectional area, wetted perimeter, and the hydraulic radius. Additionally, the bed surface slope was surveyed, and the median particle size (d_{50}) was determined. From these measurements and the identification of the bankfull channel elevation, the Manning's equation was used to calculate the expected discharge at a bankfull flow. It is not known how the "implied water surface," as referred to in the previous consultants survey data, was determined for use in the Manning's calculations. Two methods were used to estimate an appropriate channel roughness "n" value in the equation. One calculation of roughness was taken from the "Handbook of Hydrology" (1993), by David R. Maidment; pg. 8.22, equation 8.3.3a, and is a function of the bed slope and the hydraulic radius. In the second method, roughness values were estimated using guidelines outlined for mountain streams with boulders, in the "Handbook of Hydrology" (1993, Table 12.2.1). The calculated bankfull discharges displayed in Appendix D rely on the second method that estimates channel roughness from observation.

Flood Frequency Recurrence Interval

Flood frequency-derived bankfull discharge estimates from the historical record indicate the "with Project" peak flow hydrology for comparison to estimates made using "with Project" morphology (above). Peak annual flow data from five USGS gaging stations was used in the flood frequency analysis. The location and period of record for these gaging stations (Table 7) cover specific Project reaches and occur within Project operation records. Peak annual data for these gaging stations is plotted in Appendix E. Annual peak flow data from the gages were ranked by magnitude and plotted as recurrence intervals (*T*), whereby the return period is calculated from:

$$T = \frac{n+1}{m}$$

where n is the number of years on record, and m is the rank. Appendix D displays the plots of the recurrence intervals for the peak flow data. The recurrence interval is the average length of time (in years) between events equaling or exceeding a given magnitude.

Based on empirical analysis of recurrence interval regressions, the bankfull discharge of a stream generally corresponds to a return period of 1 to 2.5 years, with a 1.5-year flood common for many streams (Wolman and Miller, 1960). It should be noted that the 1.5-year flood is based on a best-fit regression, and that the scatter of points about the line can lead to wide variability in this value. Furthermore, regressions developed for streams in one region are not always applicable to streams operating under different variables in another region. Previous studies have found variability of bankfull recurrence intervals from 1.01 to 32 years (Williams, 1978), and in another study, ranging from 4 to 10 years (Pickup and Warner, 1976). Due to the large discrepancies amongst these values, many researchers have determined that the recurrence interval approach can yield poor estimates of the bankfull discharge, and that field verification should be undertaken (Copeland et al., 2000).

Results listed in Table 8 show the estimated bankfull discharge, based off of the 1.5-year recurrence interval, for stream reaches adjacent to the gaging stations. Three gaging sites (11437000, Caples Lake Outlet near Kirkwood; 11436000, Silver Lake Outlet near Kirkwood; and 11439500 South Fork American River near Kyburz) have records dating from 1922 to the present or near present. The other gages that only have 30 years on record or are discontinued are much less statistically significant in a flood-frequency calculation, and their results should be interpreted with caution. Furthermore, none of these gaging locations corresponds exactly to any of the 21 geomorphic sites, although some are closer in proximity than others.

Drainage Area

In the absence of valid "non-Project" peak flow hydrology data or simulation, a regional curve comparison using drainage basin at a site is one approximation of potential bankfull discharge. The bankfull method based off of drainage areas for the five gaging stations is similar to the recurrence interval method. Researchers have developed various regional regression curves correlating drainage area and bankfull discharge (Dunne and Leopold, 1978). Regression curves have been developed for several regions throughout the United States (Dunne and Leopold, 1978). The regression equation used in this study is one that was developed for streams in the San Francisco Bay region (Dunne and Leopold, 1978):

$$Q_{bkf} = 53 D_A^{0.93}$$

where D_A is drainage area. Results from the application of this relationship to the drainage areas of the gaging stations are also displayed in Table 8. The equation used in this calculation was chosen because average annual runoff in the Bay Area is more similar to that of the northern Sierra Nevada than are the other regression formulas. However, streams in the Project area have snowmelt driven hydrology, unlike those in the Bay Area. This difference alone may limit any usefulness gained from applying the regression to Project drainage areas. Ideally, a regional regression curve that has been

Table 7. USGS Gage Station Information Summary

Station Number	Site Name	County	Elevation (Feet Above Sea level)	Drainage Area Mi^2	Gage range		Site Description
					Start Date	End Date	
11437000	Caples Lake Outlet Near Kirkwood CA	Alpine	--	13.5	10/01/1922	09/30/1992	Daily Stream Flow Data
11436999	Caples Creek Release Below Caples Dam Near Kirkwood CA	Alpine	--	13.5	10/01/1970	09/30/2002	Daily Stream Flow Data
11436000	Sliver Lake Outlet Near Kirkwood CA	Amador	7,200	15.2	10/01/1922	09/30/2001	Daily Stream Flow Data
11438000	Sliver Fork of South Fork American River Near Kyburz CA	El Dorado	--	107	10/01/1924	09/30/1944	Daily Stream Flow Data
11439500	South Fork American River Near Kyburz (River Only)	El Dorado	--	193	10/01/1922	09/30/2002	Daily Stream Flow Data and Water Quality Samples (5/31/1979-8/28/1980)
11435000	Pyramid Creek Near Phillips CA	El Dorado	8,050	3.73	10/01/1960	09/30/1970	Daily Stream Flow Data
11435100	Pyramid Creek at Twin Bridges CA	El Dorado	--	8.76	10/01/1970	09/30/2001	Daily Stream Flow Data

Table 8. Bankful Flow Estimates based on Fluvial Frequency Data and Regional Regressions and Drainage Area

Station No.	Station Name:	Drainage Area	ENTRIX Derived 1.5-year Recurrence Interval	Prior Consultants 1.5-year Recurrence Interval	$Qbkf=53D_A^{0.93}$
		Mi^2	CFS	CFS	CFS
11437000	Caples Lake Outlet Near Kirkwood	13.5	143	140	596
11436999	Caples Creek Release Below Caples Dam Near Kirkwood CA	13.5	166	--	596
11436000	Silver Lake Outlet Near Kirkwood	15.2	265	260	666
11438000	Sliver Fork American River Near Kyburz (River Only)	107	1,230	--	4,089
11439500	South Fork American River Near Kyburz (River Only)	193	2,340	2,300	7,077
11435000	Pyramid Creek Nr Phillips	3.73	83	80	180
11435100	Pyramid Creek at Twin Bridges	8.76	237	210	399

Notes:
(--): No data for category

developed for unregulated streams near the Project area in the northern Sierra Nevada would be used, but none are known to exist. Researchers have also warned of the risk in using drainage area regressions for determining bankfull discharges, stating that drainage area is only a single parameter of many affecting runoff (Copeland et al., 2000). Even in physiographically similar watersheds, differences in snowmelt patterns, geology, and the responsiveness of hydrographs will directly alter bankfull discharge values. Natural variation in drainage area throughout the same watershed can also lead to wide scatter of points about the regression line.

Bankfull Discharge Estimates

Gaging records (11437000 and 11436999) on the Caples Lake Outlet near Kirkwood produce a 1.5-year flood flow of 143 cfs to 166 cfs (Table 8). The nearest study site to these gages with a bankfull discharge calculated from channel geometry is approximately 1.25 miles downstream at Site #12, Caples Creek downstream of Kirkwood Creek, with a channel geometry estimated discharge of 129 cfs (Table 7). These values are 10 to 25 percent different from each other. The channel geometry estimate is less than the flood frequency estimate. Since the geomorphic site is located downstream of the gaging site, and receives inflow from Kirkwood Creek and intervening area, the actual bankfull flow experienced at the site over the gage period would be higher than the flood flow estimate. This suggests that the channel geometry estimate is low. Bankfull discharge determined from drainage area at the two gaging stations is 596 cfs (Table 8). This is over 3.5 to four times greater than the estimate from flood frequency.

The Silver Fork at Silver Lake West Campground, Site #21, provides a good comparison to gaging station 11436000, Silver Lake Outlet near Kirkwood. Due to their close proximity, bankfull flows at the two sites should be very similar. The channel geometry estimate of 310 cfs (Table 4) is higher than the 1.5-year flood frequency value of 265 cfs (Table 8). The drainage area estimate of 666 cfs (Table 8) is substantially higher than the two methods reflecting Project conditions.

The Silver Fork near Kyburz gaging station (11438000) is approximately 1.25 miles downstream of Site #16 at China Flat. No tributaries enter the Silver Fork between the two locations, but some additional flow may be reflected at the gage from intervening runoff. The 1.5-year flood has a discharge of 1,230 cfs (Table 8), which is less than the 1,864 cfs calculated from the cross-section surveys at China Flat (Table 7). These values have a 41 percent difference. The drainage area relationship for the Silver Fork gage produces a flow over three times greater, of 4,089 cfs (Table 8).

The gaging station on the South Fork American River near Kyburz (River Only) (11439500), is at the upstream extent of Site #6, Sand Flat, yet no comparisons can be made since cross-sectional surveys of channel geometry and related hydraulic data are not available from this site.

Discussion of Bankfull Discharge Estimates

The channel geometry method should provide a useful estimate of channel-forming flows under Project conditions if high quality field data hydraulic calculation is used. The limitations of flood frequency regressions to correlate recurrence intervals with bankfull flows are compounded for stream reaches in regulated streams. Nearly a hundred years of flow impoundment and land use alterations have key changed the flood hydrology of the Project area. Progressive changes over time, with streams adjusting to periods of increased and decreased runoff due to natural and human-intervened reasons may create a flow record less likely to have a strong statistical significance. Recurrence intervals are calculated from an entire gaging record of regulated flow to attempt to achieve the “best statistics”, while bankfull elevations may be adjusted to historical flows in certain sub-periods (say only the last 30 years).

The reported values in Appendix D of bankfull discharges calculated through channel geometry measurements and estimates of roughness values do have limitations and quality concerns. The accuracy of these data relies on how well: 1) appropriate indicators were selected that reflect the current bankfull elevation as adjusted to the current flow and sediment regime; 2) correct Manning’s “n” values represent channel roughness; and, 3) adequately measured slope values. ENTRIX’s review of the Rosgen II data sets (Appendix A and field data) indicates that the valves should not be assumed “accurate”, but require a consideration as “approximations” of bankfull flows.

Because no record exists of unregulated peak flow data, it is not possible to determine how frequently bankfull floods occurred prior to the Project. Drainage area calculations are based solely on the upstream contributing area, and do not account for changes to the watershed hydrology either from the Project of other non-natural influences. Bearing in mind that the regional regression has not been calibrated for the Project area, they provide only an order of magnitude estimate on what bankfull flows might be under natural runoff conditions. The bankfull estimates produced from drainage area regressions may be useful for some gross comparison to estimates determined from channel geometry and flood frequency for the purpose of showing how channel forming flows have changed under a non-natural flow regime. However, comparing bankfull flows estimated from drainage area regressions to bankfull flow estimates derived from channel geometry or flood frequency analysis does not sort Project effects from other non-Project reasons as causal factors for the differences between the values.

8.0 NON-PROJECT IMPACTS TO CHANNEL CONDITION

River reaches are closely linked with hillslopes and upstream reaches. Changes to land use throughout a watershed can indirectly affect downstream channel conditions. In the case of the Project area, land use changes have been widespread over the past 150 years and have occurred at different periods and at varying intensity. These land use alterations have come in the form of gold mining, logging, grazing, transportation and residential development, and miscellaneous water supply infrastructure. The potential impacts that these watershed changes have had on the channel condition of the Project streams are interrelated, meaning it is often not possible to correlate one single disturbance with a particular channel adjustment. It is very likely that a several activities have contributed to stream type departure(s) in several of the geomorphic sites. No specific information of historic land use activity within the South Fork watershed was made available to ENTRIX. Based upon previous experience working in this region of the Sierra Nevada and from direct observations made during site visits, it can be stated that the watersheds in the study area have had a complex land use history. Impacts from logging, cattle grazing, roads, and land development were apparent in the course of the fieldwork, but not always at site-specific level of detail.

Logging was extensive in the Sierra Nevada. Relics tree stumps of the timber harvesting were evident at many of the geomorphic sites. Deforestation leads to increased peak runoff and sediment delivery to the channel. The type of response to clearing of the forests depends on the rate and type of sediment supplied to the streams (Knighton, 1998). Channel adjustments of widening, aggradation, decreased sinuosity, bar instability, and a general decrease in streambed complexity are common responses to deforestation. On the other hand, reforestation can also initiate channel adjustments as streams respond to decreases in runoff and sediment supply. The potential reduction in sediment supply will lead many stream channels to adjust to reforestation by actively eroding its bed (Knighton, 1998).

Livestock cattle grazed practically everywhere in the Sierra Nevada from the nineteenth century through 1930 (Kondolf et al., 1996), and continues to be prevalent in many high-elevation meadows today (Dudley and Embury, 1995). Livestock grazing has been so widespread throughout the Sierra Nevada that it is thought that no unaffected "reference" reaches are available for comparison, and that what may be regarded as a stream reach in a "natural" condition has in fact been affected by historical, and potentially current, grazing (Kondolf et al., 1996). Cattle are fond of congregating along riparian zones so that they can lounge in the shade and take advantage of drinking water and more succulent riparian vegetation (Armour et al., 1991). The negative effects of grazing on riparian vegetation and stream morphology have been well documented. Excessive foraging and trampling in meadow areas causes a reduction in both plant biomass and development of young woody plants, and compaction of the soil; all of which contribute to increased runoff into the stream and streambank instability. Along the streambanks, cattle create paths to enter and exit the water, effectively destabilizing banks and establishing new channels for overland runoff to the stream. Additionally, the impact of hooves chiseling the banks often promotes the collapse of overhanging banks and input of fine sediment into the channel. In terms of impacts to stream geomorphology, grazing is generally associated with channel widening, decreased sinuosity, decreased heterogeneity of the streambed, and channel incision from the increased runoff (Magilligan and McDowell, 1997).

Land development for roads and residential use in the Project watershed may have changed the water and sediment deliveries to study reaches; a flashier hydrograph with an increased frequency of higher flows can cause channel widening and incision, and initial increases in sediment delivery to the stream during construction phases. Likewise, roads throughout the watersheds also have the ability to accelerate runoff concentrate plans, and induce localized erosion. Major highways may have additional sediment inputs in high elevation zones related to snow and ice safety practices.

These comments are provided as context regarding the nature of potential non-project influences mentioned in some of the specific study site analyses within section 4.0. The data available regarding non-project effects at particular study sites is not quantitative enough to permit distinguishing Project versus non-project effects, aside from the qualitative conclusions stated herein.

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APPENDIX A

Doug Parkinson & Associates (1999) and Bill Lydgate (2002)

Rosgen Level II Classification Data

Doug Parkinson & Associates (1999) and Bill Lydgate (2002) Rosgen Level II Classification Data*

Site	Site ID #	Responsible Party	Cross Section	Bankfull Width (ft)	Maximum Bankfull Depth (ft)	Average Bankfull Depth (ft)	Floodprone Width (ft)	Entrenchment Ratio	Width / Depth Ratio	d50 (mm)	Slope	Sinuosity	Rosgen classification
Caples Lake Overflow, US of Caples Creek	14	DPA	XS 1	20.5	2.7	2.1	29.0	1.4	9.7	35	0.005		
Caples Lake Overflow, US of Caples Creek	14	DPA	XS 2	30.7	3.4	2.3	41.5	1.4	13.3	15	0.006		
Caples Lake Overflow, US of Caples Creek	14	DPA	XS 3	33.0	2.6	1.9	40.6	1.2	17.3	9	0.005		
Caples Lake Overflow, US of Caples Creek	14	DPA	Reach	28.1	2.9	2.1	37.0	1.3	13.3	20	0.005		F4
Caples Lake Overflow, US of Caples Creek	14	BL	XS 1	20.5	2.7	1.9	29.0	1.4	11.3				
Caples Lake Overflow, US of Caples Creek	14	BL	XS 2	30.7	3.4	2.3	41.5	1.4	13.6				
Caples Lake Overflow, US of Caples Creek	14	BL	XS 3	33.0	3.1	2.0	40.6	1.2	16.1				
Caples Lake Overflow, US of Caples Creek	14	BL	Reach	28.1	3.1	2.0	37.0	1.3	13.8		0.005	1.1	F4
Silver Fork, at China Flat	16	DPA	XS 1	103.0	5.0	2.9	154.0	1.5	35.2	28			
Silver Fork, at China Flat	16	DPA	XS 2	153.0	4.9	2.5	175.0	1.1	61.0	15			
Silver Fork, at China Flat	16	DPA	XS 3	84.0	5.8	3.8	160.0	1.9	22.2	18			
Silver Fork, at China Flat	16	DPA	Reach	113.3	5.3	3.1	163.0	1.4	36.8	20	0.005		B4c
Silver Fork, at China Flat	16	BL	XS 1										
Silver Fork, at China Flat	16	BL	XS 2										
Silver Fork, at China Flat	16	BL	XS 3										
Silver Fork, at China Flat	16	BL	Reach							16	0.005	1.1	B4c
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	DPA	XS 1	4.3	1.0	0.6	16.0	3.7	7.2	5	0.048		
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	DPA	XS 2	4.0	1.7	1.3	32.0	8.0	3.2	16	0.070		
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	DPA	XS 3	1.9	0.5	0.4	3.4	1.8	5.4	10	0.056		
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	DPA	Reach	3.4	1.1	0.7	17.1	5.0	4.6	10	0.056		E4b
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	BL	XS 1										
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	BL	XS 2										
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	BL	XS 3										
Thunder Mtn., Unnamed Tributary to Oyster Creek	20	BL	Reach	3.4	1.1	0.7	17.0	5.0	4.9	16	0.053	1.2	E4b
Oyster Creek, US Highway 88	18	DPA	XS 1	11.5	1.5	1.3	60.0	5.2	9.0	45	0.013		
Oyster Creek, US Highway 88	18	DPA	XS 2	9.0	1.0	0.7	12.0	1.3	12.2	65	0.013		
Oyster Creek, US Highway 88	18	DPA	XS 3	12.0	1.3	0.8	21.0	1.8	16.0	45	0.013		
Oyster Creek, US Highway 88	18	DPA	Reach	10.8	1.3	0.9	31.0	2.9	11.7	52	0.013		E4
Oyster Creek, US Highway 88	18	BL	XS 1										
Oyster Creek, US Highway 88	18	BL	XS 2										
Oyster Creek, US Highway 88	18	BL	XS 3										
Oyster Creek, US Highway 88	18	BL	Reach					2.9	11.7	16	0.004	1.2	E4
Silver Fork, @ West Campground	21	DPA	XS 1	31.0	2.2	1.4	57.5	1.9	21.9	45	0.014		
Silver Fork, @ West Campground	21	DPA	XS 2	51.5	2.8	1.3	80.0	1.6	40.6	65	0.023		
Silver Fork, @ West Campground	21	DPA	XS 3	33.5	2.7	1.6	55.0	1.6	21.3	45	0.017		
Silver Fork, @ West Campground	21	DPA	Reach	38.7	2.6	1.4	64.2	1.7	27.2	52	0.017		B4c
Silver Fork, @ West Campground	21	BL	XS 1										
Silver Fork, @ West Campground	21	BL	XS 2										
Silver Fork, @ West Campground	21	BL	XS 3										
Silver Fork, @ West Campground	21	BL	Reach					1.7	27.2	64	0.018	1.0	B4c
Caples Creek, @ Jake Schneider Meadow	15	DPA	XS 1	56.4	3.5	2.6	69.0	1.2	21.6	28	0.003		
Caples Creek, @ Jake Schneider Meadow	15	DPA	XS 2	41.0	2.7	1.6	55.0	1.3	26.5	54	0.001		
Caples Creek, @ Jake Schneider Meadow	15	DPA	XS 3	49.6	2.7	1.9	67.3	1.4	26.7	14	0.002		
Caples Creek, @ Jake Schneider Meadow	15	DPA	Reach	49.0	3.0	2.0	63.8	1.3	24.4	32	0.002		F4
Caples Creek, @ Jake Schneider Meadow	15	BL	XS 1										
Caples Creek, @ Jake Schneider Meadow	15	BL	XS 2										
Caples Creek, @ Jake Schneider Meadow	15	BL	XS 3										
Caples Creek, @ Jake Schneider Meadow	15	BL	Reach				1.3		24.4		0.002	1.5	F4

* Shaded cells indicate missing survey data

Doug Parkinson & Associates (1999) and Bill Lydgate (2002) Rosgen Level II Classification Data*

Lost Axe, Unnamed Tributary to Caples Creek	13	DPA	XS 1	32.0	2.4	1.5	85.0	2.7	20.8	8	0.009		
Lost Axe, Unnamed Tributary to Caples Creek	13	DPA	XS 2	24.0	1.9	1.2	46.0	1.9	20.7	13	0.011		
Lost Axe, Unnamed Tributary to Caples Creek	13	DPA	XS 3	22.0	2.0	1.0	49.5	2.3	21.2	4	0.010		
Lost Axe, Unnamed Tributary to Caples Creek	13	DPA	Reach	26.0	2.1	1.2	60.2	2.3	20.9	8	0.010		C4c
Lost Axe, Unnamed Tributary to Caples Creek	13	BL	XS 1	32.0	2.4		85.0	2.7					
Lost Axe, Unnamed Tributary to Caples Creek	13	BL	XS 2	24.0	1.8		100.0	4.2					
Lost Axe, Unnamed Tributary to Caples Creek	13	BL	XS 3	22.0	2.0		49.5	2.3					
Lost Axe, Unnamed Tributary to Caples Creek	13	BL	Reach	26.0	2.0		78.2	3.0	21.0		0.008	1.3	C4c
Oyster Creek, DS of Highway 88	19	DPA	XS 1	10.5	1.5	0.9	48.0	4.6	12.4	11	0.007		
Oyster Creek, DS of Highway 88	19	DPA	XS 2	11.5	1.7	0.9	66.0	5.7	13.1	10	0.016		
Oyster Creek, DS of Highway 88	19	DPA	XS 3	13.0	1.1	0.8	16.0	1.2	17.1	11	0.011		
Oyster Creek, DS of Highway 88	19	DPA	Reach	11.7	1.4	0.8	43.3	3.7	14.1	11	0.011		C4
Oyster Creek, DS of Highway 88	19	BL	XS 1	10.5	1.5	0.9	47.5	4.5	12.4				
Oyster Creek, DS of Highway 88	19	BL	XS 2	11.5	1.7	0.8	66.0	5.7	13.7				
Oyster Creek, DS of Highway 88	19	BL	XS 3	11.2	2.0	0.8	16.0	1.4	13.3				
Oyster Creek, DS of Highway 88	19	BL	Reach	11.1	1.7	0.8	43.2	3.9	13.1	8	0.011	1.8	E4
Caples Creek, DS of Kirkwood Creek	12	DPA	XS 1	43.8	2.2	1.1	200.0	4.6	39.1	11	0.004		
Caples Creek, DS of Kirkwood Creek	12	DPA	XS 2	57.5	1.8	0.8	200.0	3.5	73.7	17	0.002		
Caples Creek, DS of Kirkwood Creek	12	DPA	XS 3	59.4	2.3	0.9	200.0	3.4	69.9	9	0.003		
Caples Creek, DS of Kirkwood Creek	12	DPA	Reach	53.6	2.1	0.9	200.0	3.7	58.4	12	0.003		C4c
Caples Creek, DS of Kirkwood Creek	12	BL	XS 1										
Caples Creek, DS of Kirkwood Creek	12	BL	XS 2										
Caples Creek, DS of Kirkwood Creek	12	BL	XS 3										
Caples Creek, DS of Kirkwood Creek	12	BL	Reach								0.002	1.4	C4
Silver Fork, @ Forgotten Flat	17	DPA	XS 1	44.0	2.2	1.0	51.5	1.2	45.8	21	0.005		
Silver Fork, @ Forgotten Flat	17	DPA	XS 2	43.5	2.3	1.6	56.5	1.3	26.7	35	0.005		
Silver Fork, @ Forgotten Flat	17	DPA	XS 3	30.3	3.4	2.0	61.0	2.0	15.2	17	0.005		
Silver Fork, @ Forgotten Flat	17	DPA	Reach	39.3	2.6	1.5	56.3	1.4	25.7	24	0.007		B4c
Silver Fork, @ Forgotten Flat	17	BL	XS 1	39.3	2.6	1.5	56.3	1.4	26.2	32	0.007		
Silver Fork, @ Forgotten Flat	17	BL	XS 2										
Silver Fork, @ Forgotten Flat	17	BL	XS 3										
Silver Fork, @ Forgotten Flat	17	BL	Reach									1.2	B4c
South Fork, @ Riverton CalTrans Station	11	DPA	XS 1	85.0	3.8	1.2	155.0	1.8	72.6	170	0.013		
South Fork, @ Riverton CalTrans Station	11	DPA	XS 2	125.0	3.7	2.2	144.0	1.2	57.3	150	0.012		
South Fork, @ Riverton CalTrans Station	11	DPA	XS 3	142.5	4.6	2.2	167.0	1.2	63.9	50	0.012		
South Fork, @ Riverton CalTrans Station	11	DPA	Reach	117.5	4.1	1.9	155.3	1.3	63.2	123	0.012		F3
South Fork, @ Riverton CalTrans Station	11	BL	XS 1	130.0	3.8	1.2	155.0	1.2	111.1				
South Fork, @ Riverton CalTrans Station	11	BL	XS 2	134.8	3.7	2.2	144.0	1.1	61.8				
South Fork, @ Riverton CalTrans Station	11	BL	XS 3	142.5	1.7	2.2	167.0	1.2	63.9				
South Fork, @ Riverton CalTrans Station	11	BL	Reach	135.8	3.1	1.9	155.3	1.1	73.0	128	0.012	1.1	F3
South Fork, @ Audrian Meadow	9	DPA	XS 1	2.2	1.2	0.6	83.5	38.0	3.5	silt	0.004		
South Fork, @ Audrian Meadow	9	DPA	XS 2	4.5	0.9	0.5	155.0	34.4	9.8	silt	0.003		
South Fork, @ Audrian Meadow	9	DPA	XS 3	5.0	0.4	0.2	125.0	25.0	31.3	silt	0.004		
South Fork, @ Audrian Meadow	9	DPA	Reach	3.9	0.8	0.4	121.2	31.1	9.4	silt	0.004		E6
South Fork, @ Audrian Meadow	9	BL	XS 1	2.2	0.4	0.6	121.0	55.0	3.6				
South Fork, @ Audrian Meadow	9	BL	XS 2			0.5			9.8				
South Fork, @ Audrian Meadow	9	BL	XS 3			0.2			31.3				
South Fork, @ Audrian Meadow	9	BL	Reach	0.7	0.1	0.4	40.3	55.0	9.4	<2	0.002	1.5	E6

* Shaded cells indicate missing survey data

Doug Parkinson & Associates (1999) and Bill Lydgate (2002) Rosgen Level II Classification Data*

South Fork, US of Audrian Meadow	10	DPA	XS 1	5.5	3.8	0.8	45.0	8.2	7.1	3	0.007		
South Fork, US of Audrian Meadow	10	DPA	XS 2	9.8	1.7	1.2	26.0	2.7	8.2	5	0.007		
South Fork, US of Audrian Meadow	10	DPA	XS 3	8.0	1.5	1.2	13.5	1.7	6.8	2	0.007		
South Fork, US of Audrian Meadow	10	DPA	Reach	7.8	2.4	1.1	28.2	3.6	7.4	3	0.007		E4
South Fork, US of Audrian Meadow	10	BL	XS 1	5.5	3.8	0.8	44.0	8.0	7.1				
South Fork, US of Audrian Meadow	10	BL	XS 2	9.7	1.7	1.2	26.0	2.7	8.1				
South Fork, US of Audrian Meadow	10	BL	XS 3	8.0	1.8	1.2	21.0	2.6	6.8				
South Fork, US of Audrian Meadow	10	BL	Reach	7.7	2.5	1.1	30.3	3.9	7.4	4	0.007	1.3	E5
South Fork, @ Phillips	8	DPA	XS 1	29.0	2.3	1.6	47.0	1.6	17.9	2	0.010		
South Fork, @ Phillips	8	DPA	XS 2	12.5	2.0	1.5	30.0	2.4	8.4	3	0.001		
South Fork, @ Phillips	8	DPA	XS 3	23.0	1.3	0.9	24.0	1.0	26.7	2	0.004		
South Fork, @ Phillips	8	DPA	Reach	21.5	1.9	1.3	33.7	1.6	16.2	2	0.004		B5c
South Fork, @ Phillips	8	BL	XS 1	29.0	2.3	1.6	47.0	1.6	17.9				
South Fork, @ Phillips	8	BL	XS 2	12.5	2.0	1.5	30.0	2.4	8.4				
South Fork, @ Phillips	8	BL	XS 3	23.0	0.1	0.9	28.0	1.2	26.7				
South Fork, @ Phillips	8	BL	Reach	21.5	1.5	1.3	35.0	1.8	17.7	2	0.004	1.2	B5c
Caples Creek, US of Kirkwood Creek	1	BL	XS 1	30.8	8.6	4.3	328.1	10.6	7.2				
Caples Creek, US of Kirkwood Creek	1	BL	XS 2	15.4	9.6	4.8	188.6	12.2	3.2				
Caples Creek, US of Kirkwood Creek	1	BL	XS 3	24.9	6.9	3.5	193.6	7.8	7.2				
Caples Creek, US of Kirkwood Creek	1	BL	Reach	23.7	8.4	4.2	236.8	10.0	5.7	16	0.002	1.9	E4
Caples Creek, @ Girl Scout Access	2	BL	XS 1	43.6	9.5	4.8	121.7	2.8	9.2				
Caples Creek, @ Girl Scout Access	2	BL	XS 2	28.2	11.3	5.6	170.3	6.0	5.0				
Caples Creek, @ Girl Scout Access	2	BL	XS 3	34.8	26.2	13.1	37.7	1.1	2.7				
Caples Creek, @ Girl Scout Access	2	BL	Reach	35.5	15.7	7.8	109.9	3.1	4.5	8	0.017	1.6	E4
Silver Fork, US Fitch Rantz Bridge	3	BL	XS 1	48.6	15.2	7.6	90.2	1.9	6.4				
Silver Fork, US Fitch Rantz Bridge	3	BL	XS 2	35.8	18.0	9.0	113.8	3.2	4.0				
Silver Fork, US Fitch Rantz Bridge	3	BL	XS 3	57.7	8.2	4.1	200.1	3.5	14.1				
Silver Fork, US Fitch Rantz Bridge	3	BL	Reach	47.4	13.8	6.9	134.7	2.8	6.9	512	0.030	1.3	B3
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	BL	XS 1	39.7	1.8	0.9	110.1	2.8	44.6				
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	BL	XS 2	20.0	3.4	1.7	89.6	4.5	11.8				
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	BL	XS 3										
Strawberry Creek, US of Packsaddle Pass Road Bridge	4	BL	Reach	29.9	2.6	1.3	99.8	3.6	28.2	128	0.030	1.3	C3
South Fork, DS of Strawberry Creek (Sciots)	5	BL	XS 1	51.5	13.4	6.7	78.7	1.5	7.7				
South Fork, DS of Strawberry Creek (Sciots)	5	BL	XS 2	49.9	14.6	7.3	76.4	1.5	6.8				
South Fork, DS of Strawberry Creek (Sciots)	5	BL	XS 3	43.3	11.7	5.8	96.3	2.2	7.4				
South Fork, DS of Strawberry Creek (Sciots)	5	BL	Reach	48.2	13.2	6.6	83.8	1.8	7.3	>4096	0.030	1.3	B2
South Fork, @ Sand Flat (DS of USGS Gage)	6	BL	XS 1	139.8	17.6	8.8	200.1	1.4	15.9				
South Fork, @ Sand Flat (DS of USGS Gage)	6	BL	XS 2	103.7	16.6	8.3	141.1	1.4	12.5				
South Fork, @ Sand Flat (DS of USGS Gage)	6	BL	XS 3	89.0	13.6	6.8	172.7	1.9	13.0				
South Fork, @ Sand Flat (DS of USGS Gage)	6	BL	Reach	110.8	15.9	8.0	171.3	1.6	13.8	128	0.025	1.2	B3
Lake Audrian Tributary to Audrian Meadow	7	BL	XS 1	6.2	7.0	2.3	55.1	8.8	2.7				
Lake Audrian Tributary to Audrian Meadow	7	BL	XS 2	6.6	9.1	3.0	101.7	15.5	2.2				
Lake Audrian Tributary to Audrian Meadow	7	BL	XS 3	3.4	7.1	2.4	105.0	30.5	1.5				
Lake Audrian Tributary to Audrian Meadow	7	BL	Reach	5.4	7.7	2.6	87.3	16.1	2.1	4	<.02	>1.5	E4

* Shaded cells indicate missing survey data

APPENDIX B

Bill Lydgate (2002)

Rosgen Level III Analysis and Data

- **Individual Reach Discussions**
- **Rosgen Level III Field Survey – Key**
- **Rosgen Level III Field Survey – Results**

SFAR FERC #184 GEOMORPHOLOGY INVESTIGATION

INDIVIDUAL REACH DISCUSSIONS

This discussion is based on the field observation and measurements recorded by Bill Lydgate, Smokey Pittman, Doug Parkinson and Dick LaVen in 1999, 2000 and 2002. The following parameters are used to frame a discussion of the 21 Level III reaches studied:

- Paired/unpaired with control and evaluation of suitability of control.
- Potential impacts from project operations and evaluation of significance to geomorphology.
- Level II analysis results:
    - entrenchment ratio,
    - width-to-depth ratio,
    - sinuosity,
    - channel slope and
    - channel bed materials
- Level III analysis results:
    - riparian vegetation,
    - channel stability rating,
    - channel composition,
    - erosion potential,
    - debris occurrence and influence,
    - particle characteristics,
    - sediment measures
    - depositional patterns/bars,
    - channel bedform,
    - channel pattern,
    - longitudinal profile,
- Unique site characteristics.
- Sensitivity.
- Suitability for further study.
- Possible mitigation measures.

Caples Creek Reaches

Caples Creek Above Kirkwood Creek, Y2K #1. Rosgen Channel Type E4.

The Caples Creek Above Kirkwood Creek reach lies downstream of the confined, high gradient portion of the channel below Caples Lake. This is the first opportunity for the stream to develop alluvial bed and banks and overtop the banks. The reach was potentially affected from flow regulation and interruption of sediment and debris transport. The maximum release from Caples Lake is 350cfs (C. Mulder, personal communication), possibly inhibiting natural channel evolution by flattening out the peak flows. The excess flow is sent to the Overflow Channel (Y2K Reach #14). The abundance of oxbow lakes and old meander scars on the flood plain suggest a dynamic system that would continue to evolve through lateral migration if undisturbed. The potential controls for this reach are Lost Axe Creek, (which has a steeper gradient, more sediment, lower sinuosity and a smaller drainage area), and Audrian Lake Creek, (which has a finer bedload and a smaller drainage area).

Level II analysis results: The entrenchment ratio, width-to-depth ratio, sinuosity and channel slope all support classifying this reach as an E type. The dominant particles are gravels, giving the reach an E4 classification.

Level III analysis results: The presence of riparian vegetation on the floodplain and terraces suggests that the water table rises seasonally and that the entire meadow is saturated during snow melt. The primary sediment depositional pattern is in the form of point and mid channel bars and the abundance of sediment generally increased in a downstream direction. The Average S* for the reach was 40%, which is relatively high. The longitudinal profile illustrates that 44% of the reach length was occupied by pools, some of which have residual depths greater than 3 feet. The channel stability rating was high and the erosion potential was low. There was no obvious signs of riparian encroachment. The occurrence of large wood was low but debris still has a profound influence on scour and habitat variability. The channel pattern consists of irregular, truncated, and distorted meander loops.

There was algae covering the bed in late Autumn. This could be from elevated temperature, solar radiation or nutrient inputs. This could pose a problem if the algae dies without being accompanied with a discharge sufficient to prevent anaerobic conditions. Trampling from recreational use and livestock was evident but not overwhelming and the livestock and hiking crossings do not pose significant problems.

The site is sensitive and therefore there are merits for inclusion in a long term monitoring plan. Possible mitigation measures could include increasing the maximum release from Caples Lake, mimicking the unimpaired daily hydrograph to the degree possible and restoration of the Overflow channel.

Caples Creek Overflow Channel, Y2K #14. Rosgen Channel Type F4.

This reach is in a stream channel that receives augmented discharge or “overflow” from Caples Lake. This short forested reach is located at the gradient break after the steep, confined section below the Caples Lake overflow spillway. The channel is currently adjusting and developing a flood plain within the entrenched channel. The lower part of this reach above the confluence with Caples Creek is seasonally a backwater environment. This channel was significantly impacted by the high flows of January, 1997. Failing banks and downed trees are common. The log jams in the steeper channel immediately above this reach meters the movement of bedload. The Lake Margaret trail near cross section #3 exasperates bank erosion in this reach and should be armored. There are no controls for this F type channel.

The slope, entrenchment and W:D ratios place the reach as an F type, but the sinuosity was on the low end of the spectrum for this type. Medium gravel was the dominant particle size. Riparian vegetation was predominantly sparse but also consisted of shrubs and grasses. The channel stability rating was low, the erosion potential was high and erosion was prevalent (from the 1997 flood). There was a moderate to high occurrence of debris which had a strong influence on channel geometry. The upper end of the reach exhibited a pool riffle morphology with the channel meandering between exposed and calving banks, while the lower end of the reach was a long glide to Caples Creek. The particles were bright, loose, sub-angular medium sized gravels in low quantities. V* measures were not possible due to the dry nature of the channel during the study period.

There were fish stranded in pools isolated by dry riffles during the Fall 2000 survey. If habitat is created by project operations, then consideration should be given to maintaining this habitat throughout the season by releasing minimal flows in the Overflow channel to sustain a flowing channel.

The site is sensitive and impacted and should be included in a long term monitoring plan. Possible mitigation measures could include a modification of the release schedule and restoration of the Overflow channel (riparian planting, placement of woody debris against failing banks, rescaling a flood plain within the entrenched banks).

Caples Creek Below Kirkwood Creek, Y2K #12. Rosgen Channel Type C4.

After reviewing the slope data, I reclassified this reach as a C4 from the 1999 designation as a C4c. The reach has many of the characteristics of an E type, but due to the low sinuosity and unusually high width to depth ratio, a C type is more appropriate. During snow melt and high flows, the water table probably rises to the top of bank elevation. The presence of abandoned channels and riparian vegetation on the flood plain are more akin to E than C channel types. The potential controls for this reach are Lost Axe Creek, (which has a steeper gradient, lower sinuosity and a smaller drainage area), and Audrian Lake Creek, (which has a different Rosgen classification, finer bedload and a smaller drainage area). Potential impacts from project operations include flow and sediment regulation and a change in the sediment transport from excess flows eroding the bed and banks of the Overflow channel.

The dominant particle size was medium gravel, the average S* was 39%, which was moderately high, the particles were loose, sub-rounded and covered with algae. The presence and width of island and mid channel bars concurs with the moderately high sediment load (perhaps from erosion in the Overflow channel). The bed and banks have an interesting mixed origin of clay with embedded gravels, moraine and colluvium, suggesting a history of lateral migration. The riparian vegetation don't exhibit any signs of downscaling from regulated flows and all life stages are present. The channel stability rating was moderately high but the natural process of lateral migration should be expected. Erosion from the 1997 flood was restricted to the outside of bends and channel roughness features. There was an infrequent occurrence of debris in this reach. The longitudinal profile identified nine pools in 1500' of channel length. Fish were present in this reach and had reasonably good habitat.

Unique site characteristics include prevalent beaver activity, abundant algae (possibly from nutrient enrichment from Kirkwood or other human development, the horse stables, migratory bird use of Caples Lake, excess temperature or solar radiation). This site is suitable for future V* investigation as part of a Level IV analysis. The site is sensitive and warrants inclusion in a long term monitoring plan.

Caples Creek Girl Scouts of America, Y2K #2. Rosgen Channel Type E4.

This sensitive reach lies at the end of the Caples Valley where the channel begins to have constrictions from the valley walls necking down. The name comes from the access to the reach from the Girl Scouts of America camp. Alternate access is from the Lake Margaret trail and then hiking downstream. The potential controls for this reach are Lost Axe Creek, (which has a different Rosgen classification, gentler gradient, more sediment and a smaller drainage area), and Audrian Lake Creek, (which has a finer bedload and a smaller drainage area). Potential impacts from project operations include flow and sediment regulation and a change in the sediment transport from excess flows eroding the bed and banks of the Overflow channel.

The lack of entrenchment, generally shallow and deep channel, sinuous nature and gentle slope caused the classification of this channel as an E type. Fine gravels were the dominant and average sized particles, were loose, covered with algae and were rounded to sub-rounded. Fine sediment was abundant in riffles and pools with an average S* of 52%, a relatively high value. A V* analysis is appropriate in this reach. The channel had confined meander scrolls and a moderate to high sinuosity. Erosion was prevalent, the banks were generally steep, often undercut and collapsed and the channel stability rating was moderate. Unique site characteristics include lack of human presence, prevalent beaver activity, abundant algae and good fish habitat.

Lost Axe Creek, Y2K # 13. Rosgen Channel Type C4.

This sensitive site was included as a control. The channel has no diversions or impediments to sediment transport and runs through a narrow meadow. In both the 1999 and the 2000 field season, the channel was dry during the sample period but measurements were still performed. The system appeared to be dominated by snow melt in a valley formed by glacial action. Bankfull indicators were difficult to determine and may have been buried by bedload. The abundance of sediment in this control reach suggests there was naturally occurring high bedload in this region.

After reviewing the slope data, I reclassified this reach as a C4 from the 1999 designation as a C4c. The reach has many of the characteristics of an E type, but due to the moderate sinuosity and moderate width to depth ratio, a C type designation is more appropriate. Fine to very fine particles were the dominant channel bed materials, and were being transported through the reach as a 1 meter thick convex wave that tapered down to the channel edges. The particles were bright, loose, rounded and abundant. The channel pattern was predominantly unconfined meander scrolls. The riparian vegetation was predominantly grasses and shrubs with mature conifers outside of the riparian zone. The occurrence of debris was moderate, the recruitment potential was good and the retention potential was also good. Debris had a strong influence on channel morphology and habitat in this reach. The banks comprised of material finer than the bed. Erosion was variable and probably from the 1997 flood. The channel stability rating was moderate.

Caples Cr., Jake Schneider Meadow, Y2K # 15. Rosgen Channel Type F4.

The potential controls for this sensitive reach are Lost Axe Creek, (which has a different Rosgen classification, finer bedload and a smaller drainage area), Audrian Lake Creek, (which also has a different Rosgen classification, finer bedload and a smaller drainage area) and Strawberry Creek (which is steeper, has a different Rosgen classification, coarser bedload and a smaller drainage area). Potential impacts from project operations decrease with distance downstream from regulation, but are still potentially significant and include flow regulation with an altered hydrograph and reduction in sediment and debris transport.

The entrenchment and width-to-depth ratios place this reach as a F type, the sinuosity straddles C, B, F, G, and E types and the slope falls into a C, E, or F type. The top of bank elevation was much greater than bankfull elevation and to the reach was considered entrenched. Riffle pool morphology has developed within the tall banks. There was a bimodal particle distribution in this reach of gravel and sand with an average size of coarse gravel.

The Level III analysis results indicate that the riparian vegetation does not show any signs of downscaling or impacts to the age structure from project operations. Trees, grasses and bare ground are the dominant bank cover. The top of bank elevation was higher than the rooting depth of most of the vegetation next to the channel, and there was no strong influence of the channel on species composition, structure or vigor. The channel stability rating was low to moderate and the banks were steep, tall, exposed and finer than the bed material. The erosion potential was high and erosion from the 1997 flood was prevalent to continuous and more significant than in the Forgotten Flat reach in the Silver Fork. Debris was frequent and had a strong influence on channel morphology. The 1997 flood served to introduce large amounts of wood into the channel. Streambed particles were moderately embedded, sub-rounded and covered with algae despite the over-story canopy. The average S* for the reach was 79%, which was a high value. The width and length of the bars also support the notion of abundance of sediment in this reach. The prevalent bank erosion was probably the source of the abundant sediment. This site is sensitive and has moderate suitability for further study or inclusion in long term monitoring. There is no reason for mitigation measures at this site beyond attempting to mimic the unimpaired daily hydrograph.

Silver Fork Reaches

Silver Fork below Silver Lake at Silver Lake West Campground, Y2K # 21. Rosgen Channel Type B4c.

This reach was formed in shallow glacial moraine of mixed composition overlying granitic bedrock. Large pyroclastic boulders showing little or no water rounding were lying in the channel but were not part of the active bedload. Channel widening has eroded the material surrounding and supporting these boulders, causing them to drop into the active channel. This was particularly evident at the second cross-section. Potential controls for this reach are Lost Axe Creek, (which has a different Rosgen classification, gentler gradient, more sediment and a smaller drainage area), Audrian Lake Creek, (which has a finer bedload, a different Rosgen classification, and a smaller drainage area) and Strawberry Creek (which is steeper, has a different Rosgen classification, coarser bedload and a larger drainage area). Potential impacts from project operations are restricted to flow regulation and the impediment of debris transport. Silver Lake was a natural feature before the lake level was raised in the 1870's, so bedload transport through the lake and into the study reach has probably always been restricted.

The moderate entrenchment ratio along with the gentle slope and low sinuosity cause the Rosgen classification to fall in to a Bc channel type. There was little differentiation between upland and riparian vegetation with the exception of shrubby alders clinging to the stream margin. All seral stages of trees were present and there was no evidence of downscaling or vegetation encroachment into the channel. The channel stability rating was relatively high and the erosion potential was low. Debris occurrence was infrequent and the influence of debris was moderate. Particles were dark, embedded and angular. Small cobble was the most common size, while the D50 was between coarse and very coarse gravel. The reach was sediment starved in both the riffle and pools and S* was not measured. The lack of sediment led to the impoverishment of bars, the winnowing of material from banks and the embedded nature of the remaining bedload.

Unlike the reaches in Caples valley, there was not an abundance of algae. This site is not particularly sensitive due to the lack of alluvial features. The only possible mitigation would be to adopt a release schedule that mimics the unimpaired daily hydrograph and perhaps introducing large woody debris into the channel. This reach has low to moderate suitability for further geomorphic study due to the low sensitivity.

Thunder Mountain Creek, Y2K # 20. Rosgen Channel Type E4b.

This channel was surveyed in order to provide a control reach for Oyster Creek. However, Thunder Mountain Creek is much smaller, steeper, less sinuous, has a lower width to depth ratio and has a more forested canopy than the other two Oyster Creek reaches. The study reach flows on the North lateral edges of an ancient earth flow. The channel classification was delineated as an **E4b** type because of the low width-to-depth ratio and lack of entrenchment, despite the steep channel gradient and relatively low sinuosity.

The channel stability rating indicated a moderately stable system, the banks were finer than the bed and colluvial in nature, erosion was intermittent and the erosion potential was moderately low. There was little differentiation between upland and riparian vegetation. There were moderate quantities of large organic debris in this reach and it had a strong influence on channel morphology. Bars were mostly mid channel, narrow and comprised of mossy, embedded, sub-angular particles. Medium gravels were the most common size class and the d50 was 10mm. S* sediment measures were not performed due to the steep gradient and lack of depositional environment in the pools.

This reach has low suitability for further geomorphic study due to its unique nature and lack of similarities to reaches affected by project operations.

Oyster Creek Above Hwy 88, Y2K # 18. Rosgen Channel Type E4.

This reach is impacted from project operations in that it receives leakage or sub surface flow from Silver Lake. At a stage height of 22.7 feet (normal operating maximum), an estimated leakage to Oyster Creek is 17cfs (Resource Insights, 1999). This can potentially cause an adjustment in the channel geometry as the additional discharge has the capacity to transport sediment and contribute to bank erosion and accelerate channel evolution. The influence of leakage wanes during lower Silver Lake stage heights. The potential control for this reach is Thunder Mountain Creek which is smaller, steeper, less sinuous, has a lower width to depth ratio, greater entrenchment and a forested canopy.

Oyster Creek Above Hwy 88 was classified as an E4 due to the moderate entrenchment ratio and low width-to-depth ratio despite the low sinuosity. There was little difference between upland and riparian vegetation , grass was the dominant cover and the banks were lacking over-story canopy. Large organic debris was infrequent in this reach. Bars were mostly submerged, deprived of surface fines and had an abundance of algae. Medium gravels were the most common size class and the d50 was 12mm (not 52mm as reported by Parkinson in 1999). S* sediment measures were not performed due to the lack of pools and depositional environments. The channel stability rating was moderately high and the erosion potential was low to moderate and signs of recent erosion were notably less than other reaches studied.

Unique site characteristics include a lack of pool habitat and finer material under laying the gravel bed. this reach is sensitive and could be included in future studies. Surface and sub-surface particle measure may be revealing here. Possible mitigation could include riparian planting and encouraging the natural development of meandering with carefully placed debris structures.

Oyster Creek Below Hwy 88, Y2K # 19. Rosgen Channel Type E4.

This reach is also impacted from project operations in that it receives leakage or sub surface flow from Silver Lake. At a stage height of 22.7 feet (normal operating maximum), an estimated leakage to Oyster Creek is 17cfs (Resource Insights, 1999). This can potentially cause an adjustment in the channel geometry as the additional discharge has the capacity to transport sediment and contribute to bank erosion and accelerate channel evolution. The influence of leakage wanes during lower Silver Lake stage heights. The potential control for this reach is Thunder Mountain Creek which is smaller, steeper, less sinuous, has a lower width to depth ratio, greater entrenchment and a forested canopy.

Oyster Creek Below Hwy 88 is classified as an E4 due to the low entrenchment and very high sinuosity. The moderate width-to-depth ratio are usually associated with C types. The channel was laterally confined by the tall banks at the upper terrace elevation and the channel has developed flood plain characteristics within these wide banks, and has F type characteristics. Grass was the dominant cover and the banks were lacking over-story canopy. Shrubby alders and young conifers were found on the inside of meander bends and on the terrace, probably sustained by the snow melt dominated water table. Large organic debris was infrequent in this reach. The upstream culvert under Hwy. 88 inhibits the passage of debris and recruitment potential was low despite the radical meandering. Medium gravels were the most common size class and the d50 was 9mm. S* sediment measures of 66% indicate a high mobile fraction of fines. The channel stability rating was low and the erosion potential was high. Recent bank erosion on the outside of bends was prevalent and in contrast to both upstream reaches.

Unique site characteristics include very high sinuosity and resulting bank erosion. The reach has elevation controls upstream at the culvert and downstream at a bedrock outcrop, so self adjustment of channel length by lateral migration was the only available response to changes in sediment or discharge. This reach is sensitive and could be included in future studies. V* is possible and appropriate. Possible mitigation could include riparian planting and fencing off the creek and banks from grazing pressures.

Forgotten Flat, Silver Fork, Y2K # 17. Rosgen Channel Type B4c.

The potential controls for this sensitive reach are Lost Axe Creek, Audrian Lake Creek and Strawberry Creek (all of which have different Rosgen classifications and significantly smaller drainage areas). Potential impacts from project operations decrease with distance downstream from regulation and were difficult to determine at this site with the exception of higher discharge during the growing season. This forested reach showed less evidence of recent flood damage than the Jake Schneider Meadow reach on Caples Creek. Trees had been washed from the channel banks and many banks were eroded. A large log jam is located upstream from the study section.

The channel is classified as a **B4c** type due to the moderate entrenchment and width-to-depth ratios, low sinuosity and very low slope. There was a bimodal particle distribution in this reach of very coarse gravel and sand with a D50 of 24mm. The Level III analysis results indicate that riparian vegetation does not show any signs of downscaling or impacts to the age structure. Trees, grasses and bare ground are the dominant bank cover. Upland forest vegetation seemingly unaffected by influence of channel and riparian vegetation restricted to shrubby alders and willows. The channel stability rating was high to moderate. The banks were often undercut, had moderate amounts of debris cover and were generally finer than the bed material. The erosion potential was moderate and erosion from the 1997 flood was localized to intermittent. Debris and debris recruitment was frequent and has a strong influence on channel morphology, particularly when it accumulated in jams. The 1997 flood served to introduce large amounts of wood into the channel. Streambed particles were bright, loose and well-rounded. The average S* for the reach was 43%, which was a moderately high value but was less than the Jake Schneider Meadow reach on Caples Creek. Bank erosion was probably the source of the sediment. This site has good fish habitat, is sensitive and has low to moderate suitability for further study or inclusion in long term monitoring. There is no reason for mitigation measures at this site beyond attempting to mimic the unimpaired daily hydrograph.

Fitch Rantz, Silver Fork, Y2K # 3. Rosgen Channel Type B3.

This reach lies upstream of the confluence with Sherman Canyon/North Tragedy Creek. The reach is not particularly sensitive, but still retains alluvial features in a system constrained by prevalent bedrock. This is a lower gradient section of a long transport portion of the channel. Potential control for this reach is Strawberry Creek (which is steeper, has a different Rosgen classification, greater width to depth ratio, finer bedload and smaller drainage area). Potential impacts from project operations are sediment and flow regulation and the impediment of debris transport, but the influence of project operations wanes with distance downstream and become ameliorated as unregulated tributaries contribute a greater percentage of drainage area.

This reach falls into a B type based on the moderate entrenchment and 3% slope despite the low width-to-depth ratio. Bright, embedded well rounded large cobbles were the most common size class of channel bed materials, and the D50 also fell into this size class. S* sediment measures were not performed due to the lack of a fine mobile fraction. Depositional patterns such as bars were absent and the reach was starved for sediment but more likely due to the gradient and not as a result of regulation. There was no evidence of downscaling of the channel or of regulation affecting tree structure. There was no strong influence of the channel on species composition, structure or vigor. The channel stability rating was high and the erosion potential was low. Woody debris was absent and channel structure was controlled by bedrock and boulders. This site has low sensitivity and little utility in long term monitoring but is representative of many miles of channel in the South Fork American Basin.

China Flat, Silver Fork, Y2K # 16. Rosgen Channel Type B4c.

China Flat is the first opportunity for sediment deposition after an extensive transport reach in both Caples Creek and the Silver Fork. The Flat is probably a combination of glacial and alluvial deposits, plus colluvial deposits from landslides off Eagle Rock to the North. Anthropogenic change of this flat from modern day recreation as well as turn of the century mining confounds geomorphic investigation. The left bank of this reach showed extensive sand deposits and evidence of out-of-channel high flow over the large point bar. Indicators of bankfull conditions were few and unreliable. The channel segment was classified as a **B4c** type based on the moderate entrenchment and moderate width-to-depth ratio and low gradient. The sinuosity was low for a B type and fell below the Rosgen range. B4 channel types are considered relatively stable and are common in low sediment supply systems. The potential control for this reach is Strawberry Creek (which is steeper, has a different Rosgen classification, finer bedload and considerably smaller drainage area). Potential impacts from project operations are sediment and flow regulation and the impediment of debris transport, but the influence of project operations wanes with distance downstream and become ameliorated as unregulated tributaries contribute a greater percentage of drainage area.

The riparian vegetation was severely affected from the 1997 flood, shows no signs of downscaling, and judging by its age structure, seems to be regularly reset by floods. Large woody debris was infrequent and had low retention potential. The channel stability rating is moderate and the erosion potential is moderately low. Erosion from the 1997 flood was prevalent, and the flood flowed over the “Flat” sweeping it clean. The channel bed was comprised of loose, bright, sub-rounded gravels and cobbles in a bimodal distribution with sand. The d50 was 16mm. Bars were small and mobile fine sediment was restricted to small local accumulations.

The most notable unique site characteristic here is the low gradient "Flat." The site has low to moderate sensitivity and low to moderate suitability for further study. Possible mitigation measures could include mimicking the unimpaired daily hydrograph to the degree possible and possibly the introduction of large woody debris to the channel.

South Fork American River Reaches

South Fork American River above Audrian Meadow, Y2K #10. Rosgen Channel Type C4.

After reviewing the Level II data, I reclassified this reach as a **C4** from the 1999 designation as an E4. The channel has a very low gradient and a high sinuosity. The reach has many of the characteristics of an E type, but I feel that a C type is a more appropriate designation due to the lateral entrenchment within the stream banks and the inability of the channel to spill onto the flood terraces. The low width to depth ratio is misleading because the small size of the channel allows it to develop the necessary width within the banks to delineate as an E type despite its entrenched nature. The only effect of project operations in this reach is the 2cfs augmented flow from the Echo Lake Diversion. The potential control for this reach is Audrian Lake Creek, which is reasonably appropriate. The channel is formed in shallow deposits and flows through mixed federal (USFS) and private ownership. Bank failures were common.

The principal material transported through this reach was coarse sand of both granitic and basaltic origin. There may not be any basaltic outcrops within the upstream basin. This material may have been transported to the fluvial system through road maintenance. There was a bimodal particle distribution in this reach of large boulders and sand with a d50 of 3mm. Particles were bright, loose, sub-angular and abundant but despite fine sediment being the dominant material, the deposits were shallow and the S* was only 3%. The meander pattern was regular and the sinuosity was high, undercutting the forested stream banks and causing bank erosion on the outside of the bends. Fallen trees spanning the narrow channel were common. Recruitment, retention and occurrence of debris was high with a strong influence on channel morphology. The riparian vegetation was shrubby, vigorous, and showed no signs of downscaling. The channel stability rating and erosion potential were moderate and erosion was intermittent to prevalent on the outside of bends. This reach is sensitive and warrants consideration for inclusion in future studies, particularly to discern the source of the bedload.

South Fork American River in Audrian Meadow, Y2K #9. Rosgen Channel Type E6.

This reach is a classic E type meadow channel with a sinuous, narrow, deep channel lacking entrenchment. The bed was comprised primarily of silt with a lesser fraction of fine sand at the upper end of the study reach. The SFAR channel was discontinuous at the upstream end of the meadow. A continuous channel leads from the outflow from Lake Audrian, but not from the South Fork "mainstem" stream paralleling Hwy. 50.

The South Fork American River channel entered the wetland and deposited its sand bedload into the marsh as a deltaic fan. Several naturally formed small-scale levees followed the present and abandoned former channels entering the marsh. These levees and other over-bank deposits covered approximately the upper one third of the marsh area. There is a pronounced change in the marsh vegetation between the eastern end presently receiving the sand deposits and the western end where a natural drainage channel has evolved. A representative section was established in the natural channel draining the western end of the marsh.

The only effect of project operations in this reach is the 2cfs augmented flow from the Echo Lake Diversion. This could serve to elevate the water table during the usually dry summer and fall growing period. It could also potentially increase bedload transport and stream bank erosion. The potential control for this reach is Audrian Lake Creek, which is reasonably similar, but has a forested over-story, coarser bed load and more structural elements influencing channel morphology.

According to Rosgen, E6 stream types are hydraulically efficient because they require the least cross-sectional area per unit of discharge. Channels in this classification are considered very stable unless there is a significant change in sediment supply and/or discharge, both of which may be the case here!

There was no association of vegetation type or vigor with proximity to the channel. Vegetation on the meadow can reach the water table and is probably influenced by the seasonal snow-pack. The dominant vegetation was grass with a notable absence of trees. The channel stability rating was high and the erosion potential was low. The banks were generally steep and mildly undercut. Debris was absent from the reach and the recruitment potential was zero.

S* sediment measures were not performed due to the lack of measurable deposits. The reach was lacking in bars and appeared not to have the capacity to transport particles larger than silt. Algae was present but not overwhelming.

By definition, meadow reaches are considered sensitive. Suitability for further study is restricted to investigating the origin of the bedload and perhaps performing a sediment budget. Possible mitigation measures could include working with Cal Trans to establish sediment catchment basins at strategic locations to abate road related sediment from entering the wetland environment .

Audrian Creek, Y2K #7. Rosgen Channel Type E4.

This reach was included as a potential control reach. The upstream Lake Audrian may function as an impediment to bedload transport, but the system is unregulated and has no upstream diversions. This reach was classified as an E type due to the sinuous, narrow, deep channel lacking entrenchment. The bed was comprised primarily of granitic fine gravel with the presence of boulders functioning as roughness elements. The boulders were not included in the calculation of the D50 since they are not part of the mobile bedload.

According to Rosgen, E4 stream types are hydraulically efficient and maintain a high sediment transport capacity. Channels in this classification are considered very stable.

There was no association of vegetation type or vigor with proximity to the channel. Vegetation included grasses, shrubs and trees and the cover was high. Unlike other stream channels investigated, there were no signs of recent bank erosion. The channel stability rating was high and the erosion potential was low. The banks were generally steep and typically undercut. Debris was numerous and influential in the reach and the recruitment potential was high.

The average S* sediment value was 38%.   Particles were loose, mossy, dark, sub-angular and abundant. Bars were vegetated with moss and overlaid the silt bed. The sinuosity was moderate and the meander pattern was irregular with unconfined scrolls. The swale on the right floodplain was below the bankfull elevation. Eastern Brook trout were numerous and surprisingly large for such a small channel.

South Fork American River at Phillips Creek, Y2K # 8. Rosgen Channel Type B5c.

This reach was classified as a **B5c** because of the low slope, moderate entrenchment, moderate width to depth ratio, moderate sinuosity and fine particle size. The potential controls for this sensitive reach include Audrian Lake Creek, Strawberry Creek and Lost Axe Creek (all of which have different Rosgen classifications). Potential impacts from project operations were difficult to discern in the field, but would be limited to higher discharge during the growing season and a potentially elevated capacity for bedload transport and erosion. During the field investigation in September, the bars appeared submerged and the stage seemed high.

Level III analysis indicates that the riparian vegetation was vigorous, had a high density and was comprised of trees, grasses and shrubs. There were no indications of downscaling or absent tree age-classes. Riparian vegetation was strongly associated with the channel, suggesting that the water table gradient was steep. The banks were well vegetated, finer than the bedload, did not contribute to entrenchment and were often undercut at meander bends. The channel stability rating was high, the erosion potential low and erosion from the 1997 flood was negligible and constrained to the outside of bends and roughness elements. Woody debris was numerous to prevalent and had a significant influence on channel morphology. There was significantly more algae and moss in this reach than the upstream control. The flood plain above this reach is used for grazing and there are homes with septic tanks in the vicinity. Particles were loose, covered with both moss and algae, sub-rounded, and in relative abundance in both riffles and pools. The mean S* value was 38% but had high variability and ranged from 0-100%. This reach is suitable for V* analysis if a Level IV is required.

This site has moderate sensitivity to alteration from project operations but the impacts are not apparent. This site has moderate suitability for further study.

South Fork American River at Sciots Camp, Y2K # 5. Rosgen Channel Type B2.

This reach was classified as a **B2** because of the steep slope, moderate entrenchment and prevalence of bedrock. Cross section #3 had a lower entrenchment than the other cross sections and could be classified as a C type. The width to depth ratio is more akin to A types. The potential control for this non-sensitive reach was Strawberry Creek which was not as steep, had a smaller bedload and smaller drainage area. Potential impacts from project operations are relatively negligible at this site and would be limited to slightly higher discharge during the growing season.

Level III analysis indicates that the riparian vegetation was mostly absent and the banks were bedrock dominated and precluded the development of streamside vegetation. The upland trees near the channel showed no indications of downscaling and were not missing any tree age-classes. The channel stability rating was high, the erosion potential low and erosion from the 1997 flood was negligible. Woody debris was absent and retention was low. There were large conifers adjacent to the channel, so recruitment of future debris was possible. There was significantly more algae and moss in this reach than the upstream control. Multiple homes with septic tanks were in the vicinity of this reach. Bars were lacking in this reach due to the steeper slope. Particles were loose, covered with algae, well-rounded, and in low abundance in both riffles and pools. The mean S* value was a low 17% and accumulations of mobile fine sediment were infrequent and limited to back eddies behind boulders. The D50 of the bedload was 25mm but the overall average size of the stream bed material fell into the category of very large boulder (3230mm). There was a bimodal distribution of channel materials with bedrock and very fine gravel being the most numerous.

Unique site characteristics include an atypical well developed flat or terrace on river right at cross section #3. This site is not sensitive but is representative of many miles of the South Fork. There is no need to continue studies at this location or for mitigation. I recommend that the US Forest Service require the removal or adjustment of cables that are currently girdling the mature trees in the tract, particularly the large pine on river left above the flat. The Forest Service should also remove all the dysfunctional and abandoned cable and pipe currently in the stream channel.

Strawberry Creek, Y2K # 5. Rosgen Channel Type C3.

This reach was included as a potential control. There are no water diversions nor regulation above this study reach. Bedload and debris transport are assumed to be natural. This reach was classified as C type due to the moderate entrenchment, 3% slope, moderate sinuosity, and moderate average width to depth ratio. There were only two cross sections in this reach. The first was wider and shallower than the second and the average width to depth ratio did not represent either cross section. The third cross section was dropped due to the backwater depositional environment created by a logjam. The bedload had a bimodal distribution of cobbles and silt. The D50 was calculated as 75mm, which falls into the Rosgen 3 class. If the silt fraction is removed from the calculation, the Rosgen type does not change.

Riparian vegetation had a strong association with proximity to the channel. Vegetation included grasses, shrubs and trees and the cover was moderate to high. The channel stability rating was moderately high and the erosion potential was moderately low. This channel can accommodate large flows without damage, and erosion from the 1997 flood was localized. Beaver activity was noticed in the reach, but the potential for beaver dams and influence on the channel morphology was low. Debris was infrequent above the log jam and the recruitment potential was high. The log jam had been in place long enough for sediment to aggrade almost 2 meters deep upstream and flatten the local gradient. Cedar tress on the stream banks were dying due to their lower trunks being inundated with sediment and the elevation of the water table.

The average S* sediment value above the log jam was 92%. S* was dramatically lower above and below the influence of the jam and this value should be considered a spatial and temporal anomaly. The S* value is unusually high, and in combination with the high silt load, suggests that there may be some sort of sediment producing disturbance in the upstream watershed. There is un-rocked and dusty low slope road paralleling the creek which could also be contributing sediment. Particles were moderately embedded, bright, sub-rounded and swept clean. The sinuosity was low and the channel was not meandering. Algae was present, but to a lesser degree in comparison to other reaches.

South Fork American River at Sand Flat, Y2K # 6. Rosgen Channel Type B3.

This reach was classified as a **B3** because of the moderate slope, moderate entrenchment, low sinuosity, moderate width to depth ratio and predominantly cobble bed. The potential control for this non-sensitive reach was Strawberry Creek which had a different Rosgen classification and a significantly smaller drainage area. Potential impacts from project operations include the Eldorado diversion immediately above the reach, augmented flow from the Echo diversion, and flow regulation in Caples Creek and Silver Fork. Sediment transport and flood flows are probably not significantly affected by project operations, but the duration of the effective discharge might be altered when project reservoirs are being filled.

Level III analysis indicates that the banks were often bare, but also had shrub and tree cover. The banks were influenced to some degree by human activities on both sides of the river. On the left bank, the diversion had been armored in places and had also failed between cross sections 2 and 3. On the right bank, armoring for Highway 50 was in the flood prone channel. The riparian vegetation and upland trees near the channel showed no indications of downscaling and were not missing any tree age-classes. The channel stability rating was high, the erosion potential low and erosion from the 1997 flood was intermittent. Woody debris was absent and retention potential was low. The new diversion upstream may inhibit the transport of debris into the reach reducing potential recruitment. There was more algae in this reach than the upstream control.

Bars were lacking in this reach with the exception of a well developed cobble bar at the forced bend above the campground bridge. Particles were imbricated, embedded, bright when not covered with algae, rounded, and fines were in relatively low abundance in both riffles and pools. Accumulations of mobile fine sediment were infrequent and limited to back eddies behind boulders. The single S* value was 100%. This value was high because in the one measurable pool, the accumulation of fine sediment was higher than the riffle crest elevation. This caused the maximum residual depth to be 100% occupied with fines. The name “Sand Flat” seems anomalous due to the lack of sand at the flat. Cobble Flat would be more appropriate, or perhaps the name refers to the campground area and not the river bar. The D50 of the bedload was 119 mm and fell into the category of small cobble. There was a bimodal distribution of channel materials with bedrock and very fine gravel being the most numerous.

Unique site characteristics include the forced bend at the campground bridge. This bend could be the cause of the elevated terrace or flat on river right. This site has low to moderate sensitivity and low to moderate utility for further study. Possible mitigation measures could include mimicking the unimpaired daily hydrograph to the degree possible.

South Fork American River at Riverton, Y2K # 11. Rosgen Channel Type F3.

This reach was classified as an **F3** because of the strong entrenchment, low slope, low sinuosity, very high width to depth ratio and predominantly cobble bed. The potential control for this non-sensitive reach was Strawberry Creek which had a different Rosgen classification and a significantly smaller drainage area. Potential impacts from project operations include the Eldorado and various tributary diversions, augmented flow from the Echo diversion, and flow regulation in Caples Creek and Silver Fork. Sediment transport and flood flows are probably not significantly affected by project operations, but the duration of the effective discharge might be altered as project reservoirs are filled during the snowmelt season.

Level III analysis indicates that the banks were well armored, coarser than the bed material, provided significant roughness during flood flows allowing trees to establish and persist within the flood prone channel. Riparian tree species included dogwood, alder, willow, and maple. Upland species close to the channel included cedar, oak, Douglas fir and pine. The riparian vegetation and upland trees near the channel showed no indications of downscaling and were not missing any tree age-classes. Woody debris was infrequent and had no influence on channel morphology. Debris retention potential was low with the exception of the channel margins where debris had settled out and desiccated above the bankfull elevation. Recruitment potential of debris was high due to the steep and forested nature of the valley walls. The new diversion upstream may inhibit the transport of debris into the reach reducing potential recruitment. The channel stability rating was high, the erosion potential low and erosion from the 1997 flood was intermittent. There was more algae in this reach than the upstream control.

Bars were lacking in this reach with the exception of a well developed cobble bar at the forced bend above the campground bridge. Particles were embedded, bright, well-rounded, and fines were in relatively low abundance in both riffles and pools and were limited to eddy deposits behind boulders. S* was not performed due to the lack of well defined pools and lack of significant deposits in the reach. The D50 of the bedload was 91 mm and fell into the category of small cobble. There was a bimodal distribution of channel materials with small boulders and sand being the most frequently occurring classes of bedload.

Unique site characteristics include a particularly wide and shallow channel without a well defined thalweg. The high width to depth ratio may account for the tendency of the channel to form large mid channel bars and islands in the vicinity. In a site visit in 2002, the reach appeared to have an increase in fines since the 1999 particle count. The reach is downstream of the large 1997 landslide near Whitehall which may be contributing to this observation. This site has low sensitivity and low utility for further study, but it is representative of large portions of the South Fork channel. Possible mitigation measures could include mimicking the unimpaired daily hydrograph to the degree possible.

Bill Lydgate (2002) Rosgen Level III Analysis - Key

Riparian Vegetation and Bank Channel Rating

		Notes
Vegetation	0 = Bare, 1 = Tree, 2 = Shrub, 3 = Grass, 4 = Herb	Includes dominant and subdominant vegetation types within floodprone width
Tree Structure	0 = None, 1 = Seedling, 2 = Sapling, 3 = Pole, 4 = Tree, 5 = Senescent, 6 = Battered by floods, 7 = Desiccated	
Downscaling	Evidence of downscaling of the channel/riparian corridor? (Y/N)	
Cover	Density of vegetated area 1 = Low, 2 = Moderate, 3 = High	Includes dominant and subdominant vegetation types within floodprone width
Roots	Exposed root depth on banks as a % of total bank height.	
Vigor	Riparian vigor ratings: 1 = Low, 2 = Moderate, 3 = High	
Stream Banks	1 = Bedrock, 2 = Alluvial, smaller than bed, 3 = Alluvial, same as bed, 4 = Alluvial, larger than bed, 5 = Colluvial, 6 = HWY 50	
Bank Height	1 = <Bankfull, 2 = 1.5-2x BF, 3 = >2x Bankfull	
Erosion	1 = None, 2 = Local, forced, 3 = Intermittent, 4 = Prevalent, 5 = Continuous	
Bank Angle	1 = <20, 2 = 20-60, 3 = 60-80, 4 = 80-90, 5 = >90 Degrees	

Debris

		Notes
Occurrence	1 = None, 2 = Infrequent, 3 = Moderate <10%, 4 = 10-30%, 5 = 30-50%, 6 = >50%, 7 = Beaver/Few, 8 = Beaver/Frequent, 9 = Beaver/Abandoned, 10 = Human Influences	Percentages expressed as a ratio of bankfull elevation
Influence on Channel Geomorphology	1 = Low, 2 = Moderate, 3 = High	
Landslides	1 = None, 2 = Minor, 3 = Significant	Left and right banks
Aquatic Vegetation	1 = None, 2 = Moss, 3 = Algae, 4 = Other	

Bar Forms (dominant and subdominant)

		Notes
Pattern	0 = None, 1 = Point, 2 = Point with few Mid-Channel, 3 = Mid-Channel, 4 = Side Channel, 5 = Diagonal, 6 = Islands and Mid-Channel, 7 = Side and Mid-Channel >2x channel width in length, 8 = Delta	
Width	1 = <20%, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 = >80%, 6 = Variable	Percentages expressed as ratio of bankfull width
Mobility	1 = Bare, 2 = Some Vegetation, 3 = Vegetation Encroachment, 4= Vegetation Established	

Substrate (dominant and subdominant)

		Notes
Condition	1 = Mossy, 2 = Dark, 3 = Bright, 4 = Algae	
Imbrication	1 = Low (loose), 2 = Moderate, 3 = High (tightly packed)	
Shape	1 = Flat, 2 = Angular, 3 = Subangular, 4 = Subrounded, 5 = Rounded	
Riffles	1= Sediment starved (<10%), 2 = Local accumulations (10-25%), 3 = Behind ptx (25-50%), 4 = Over most of the riffle (>50%), 5 = Thin covering over coarser bed	Percentages expressed as ratio of riffle area
Pools	1 = Sediment starved (<10%), 2 = Local accumulations (10-25%), 3 = Outside of thalweg (25-50%), 4 = Over most of the bed (>50%), 5 = Fine sediment is dominant material	

Channel Pattern

		Notes
Meander Pattern	1 = Regular, 2 = Tortuous, 3 = Irregular, 4 = Truncated, 5 = Unconfined Scrolls, 6 = Confined Scrolls, 7 = Distorted Loops, 8 = Irregular with Oxbows, 9 = Not	
Sinuosity	0 = Straight, 1 = Low, 2 = Moderate, 3 = High	

Bill Lydgate (2002) Rosgen Level III Analysis

Site ID			Riparian Vegetation, Channel Stability Rating, Composition & Erosion										Debris				Bars			Particles Characteristics					Channel Patterns	
			Vegetation Type	Tree Structure	Downscaling	Cover	Roots	Vigor	Streambank Composition	Bank Height	Bank Erosion	Bank Angle	Occurrence	Influence	Landslides	Aquatic Vegetation	Pattern	Width	Mobility	Condition	Imbrication	Shape	Riffles	Pools	Meander	Sinuosity
14	Caples Creek - Caples Lake Overflow																									
	XS 1	LB	0	All	No	1	0.2	1	2	3	5	4	6	3	1	dry,1	5,1	6	1	3	1	3	1	1	3	2
		RB	2	All	No	2	0.4	1	1	3	5	3														
	XS 2	LB	0	All	No	1	0.2	1	2	2	4	4	3	3	1	dry,1	2	2	1	3	1	3	2	1	1	2
		RB	0,2	4	No	1	0.2	1	2	3	5	4														
	XS 3	LB	3	All	No	1	0.5	1	2	3	3	4	3	3	1	dry,1	4	3	2	3	2	4	2	1	3	2
		RB	2	All	No	1	1	1	2	2	3	4														
12	Caples Creek - Below Kirkwood Creek																									
	XS1	LB	3,1	4	No	3	2%	3	2	2	2	4														
		RB	0,1	All	No	2	2%	2	2	1	2	1	2	3	0	3	6	3	1	4	1	4	4	4	3, 4?	2
	XS2	LB	3,2	2	No	3	2	3	2	1	1	1														
		RB	3,1	All	No	3	2	3	2	2	4	5	2	3	0	3	6	3	2	4	1	4	4	3	3	2
	XS3	LB	3	All	No	3	2	3	2	2	1	2														
		RB	0,3	2,4	No	1	2	1	2	3	5	5	2	3	0	3	6	3	1	4	1	3	4	3	3	2
1	Caples Creek - Above Kirkwood																									
	XS1	LB	3	All	No	3	90%	3	2	2	3	2	2	3	0	3	1,3	2	1	3,4,	1	3	1	1	4,8	2
		RB	3,2	2	No	3	100%	3	2	2	2	4														
	XS2	LB	3	All	No	3	100%	2	1,2	2	2		2	2	0	3	0,3	1	3,4, algae	4	1	3	3	2	3	3
		RB	3,2	All	No	3	100%	3	2	1	2	5														
	XS3	LB	3	All	No	3	100%	3	2	2	4	5	2	2+	0	3	0	1	1,4	4	1	3	2	2	3	2
		RB	3	All	No	3	100%	3	2	2	2	5														
2	Caples Creek - Girl Scouts of America																									
	XS1	LB	0,3	All	No	2	20%	1	2	3	5	4,5	3	3	0	3	2	4	1	4	1	5	4	4	6	2
		RB	0,2	All	No	3	100%	3	2	2	3	2														
	XS2	LB	3,2	All	No	3	20%	2	2	2	4	4	3	3	0	3	4	4	2, algae	4	1	4	4	4	6	2,3
		RB	2,3	All	No	3	100%	2	2	2	3	4														
	XS3	LB	3,1	All	No	3	100%	2	2	2	4	4	3	3	0	3	3	4	2	4	1	5	4	4	6	2
		RB	3,2	All	No	3	40%	2	2	2	5	5														
15	Caples Creek - Jake Schneider Meadow																									
	XS 1	LB	1,1	All	No	2	80%	1	2	2	5		5	3	1	3	3	4	1	4,2	2	4	4	5	3	2
		RB	0,1	All	No	1	50%	1	2	3	5															
	XS 2	LB	3,1	All	No	1	40%	1	2,6	3	5		5	3	NA	3	2	4	1	4,2	2	5	4	5	3	2
		RB	0,1	All	No	2	60%	1	2,6	3	5															
	XS 3	LB	0,3	All	No	1	0%	1	6,2	2	4		5	3	NA	3	1	3	1	4,2	2	4	4	5	3	2
		RB	3,1	All	No	2	50%	1	6,2	2	4															
18	Oyster Creek - Above Hwy 88																									
	XS 1	LB	3	0		No	3%	100	3	2	2		1	0	1	3	drowned	1	1,2	4	2	2	2	no pools	3	1
		RB	3	0		No	3%	100	3	2	2															
	XS 2	LB	3	0		No	3%	100	3	2	2	3	2	1	1	3	drowned	1	1	4	2	3	2	no pools	3	1
		RB	3	0		No	3%	100	3	2	2	4														
	XS 3	LB	3			No	3%	No	3	2	2	2	3	3	1	3	drowned	1	1	4	3	3	2	no pools	9	2
		RB	0,3			No	3%	20	2	3	4	5														
19	Oyster Creek - Below Hwy 88																									
	XS 1	LB	0,3	0	No	1	10%	1	2	3	5	4	2	1	1	1	0	1	1	2	3	3	3	4	2	3
		RB	3	0	No	3	NA	3	2	1	1	1														
	XS 2	LB	3	2	No	3	NA	3	2	1	1	1	2	1	1	1	2	2	1	2	3	3	4	4	2	3
		RB	3	0	No	3	10	3	2	3	5	4														
	XS 3	LB	3	0	No	2	30	1		3	5	4	1	0	1	1	1,4	1	1	2	3	4	4	4	2	3
		RB	3	3	No	2	n	2		1	1	2														

Bill Lydgate (2002) Rosgen Level III Analysis

Site ID			Riparian Vegetation, Channel Stability Rating, Composition & Erosion										Debris				Bars			Particles Characteristics					Channel Patterns	
			Vegetation Type	Tree Structure	Downscaling	Cover	Roots	Vigor	Streambank Composition	Bank Height	Bank Erosion	Bank Angle	Occurrence	Influence	Landslides	Aquatic Vegetation	Pattern	Width	Mobility	Condition	Imbrication	Shape	Riffles	Pools	Meander	Sinuosity
21	Siver Fork - Silver Lake West Campground																									
	XS 1	LB	1	All	No	3	100%	3	2	3	2	1	2	2	0	1	0	1	1	2	3	2	1	1	9	0
		RB	1,2	All		2	50%	2	2	2	2	2														
	XS 2	LB	0,1	All		1	40%	1	3	3	3	3	2	2	0	1	0	1	1	2	3	3	1	1	9	0
		RB	0,2	All		1		1	1	2	3	2														
	XS 3	LB	2	All		3	100%	3	2	2	2	2	2	2	0	1	0	0	1	2	3	3	1	1	9	0
		RB	2	All		2	100%	2	2	3	2	3														
17	Silver Fork - Forgotten Flat																									
	XS 1	LB	1	All	No	3	100%	1	2	2	2	5														
		RB	1,2	All	No	3	100%	1	4	3	2	2														
	XS 2	LB	0,1	All	No	1	50%	1	2	2	2	2														
		RB	2,0	All	No	2	100%	1	2	2	2	5														
	XS 3	LB	0,1	All	No	1	100%	1	2	1	3	5														
		RB	3,2	All	No	3	75%	3	2	2	2	5														
3	Silver Fork - Fitch Rantz																									
	XS1	LB	0,1	All	No	1	0%	3	3,2	2	2	2	1	1	0	1	0	1	1	3	3	5	1	1	9	1
		RB	0,1	All	No	1	0%	1	1,4	3	1	3														
	XS2	LB	0,2	All	No	2	0%	2	2,3	2	2	5	1	1	0	1	0	1	1	3	3	5	1	1	9	2
		RB	0	All	No	1	0%	1	1	3	1	3														
	XS3	LB	0,1	All	No	1	0%	2	1	3	1	3	1	1	0	1		1	1	3	3	5	1	1	9	1
		RB	0,1	All	No	1	0%	2	2	2	2	1														
16	Silver Fork - China Flat																									
	XS 1	LB	0, 1	2	No	1	100%	2	2, 6	2	4	4	2, 10	1	1	1	1, 4	2	2	3	2	4	2	2	9	1
		RB	2, 1	2	No	3	100%	3	6	3	3	4														
	XS 2	LB	0	6	No	2	50%	2	4	2	3	2	1	1	2 (road related)	1	4	3	1	3	1	4	2	2	9	1
		RB	2	2	No	2	50%	2	6	3	4	4														
	XS 3	LB	0, 1	4	No	1	30%	2	6, 2	3	4	3	2	1	1	1	4	3	1	3	1	4	2	2	9	1
		RB	0, 1	2	No	1	40%	2	6, 2	3	4	4														
10	SFAR - Above Audrian Meadow																									
	XS1	LB	1,3	All	No	3	100%	3	2	3	3	5			bank failure from root throw											
		RB	1,3	All	No	3	100%	3	2	3	3	4	5,4	3		1	1	3,4	1	3	1	3	4	5	1,2	3
	XS2	LB	1,3	All	No	3	100%	3	2	3	3	5														
		RB	1,3	All	No	3	100%	3	2	3	3	4	5,4	3		1	1	3,4	1	3	1	3	4	5	1,2	3
	XS3	LB	1,3	All	No	3	100%	3	2	3	3	5														
		RB	1,3	All	No	3	100%	3	2	3	3	4	5,4	3		1	1	3,4	1	3	1	3	4	5	1,2	3
9	SFAR - Audrian Meadow																									
	XS1	LB	3	0	No	3	100%	3	2	1	3	3														
		RB	3	0	No	3	100%	3	2	2	3	4	1	1	1	3	0	1	NA	4	3	NA	NA	silt	3	3
	XS2	LB	3	0	No	3	100%	3	2	2	3	5														
		RB	3	0	No	3	100%	3	2	2	2	4	1	1	1	3	0	1	NA	NA	NA		silt		3	3
	XS3	LB	3	0	No	3	100%	3	2	2	2	3														
		RB	3	0	No	3	100%	3	2	1	3	2	1	1	1	3	0	1	NA	silt	silt	silt	silt	silt	3,1	3
8	SFAR - Phillips																									
	XS1	LB	1,3	4	No	3	100%	3	2	2	2	4			1											
		RB	1,3	4	No	3	100%	3	2	2	1	3	5	3	1	3,2	1	3	1	1,4	1	4,3	4	5	3	2
	XS2	LB	1,3	2,3,4	No	3	100%	3	2	2	2	5			1											
		RB	3,2	3	No	3	100%	3	2	2	1	4	3	2	1	3,2	0,3	3,4	1	1,3,4	1	4	4	5	3	2
	XS3	LB	1,2	3,4,5	No	2	80%	2	2	2	2	1			1											
		RB	3,2	NA	No	3	NA	3	2	2	1	4	4	3	1	3,2	2,3	3	1	1,3,4	1	4	4	5	3	2

Bill Lydgate (2002) Rosgen Level III Analysis

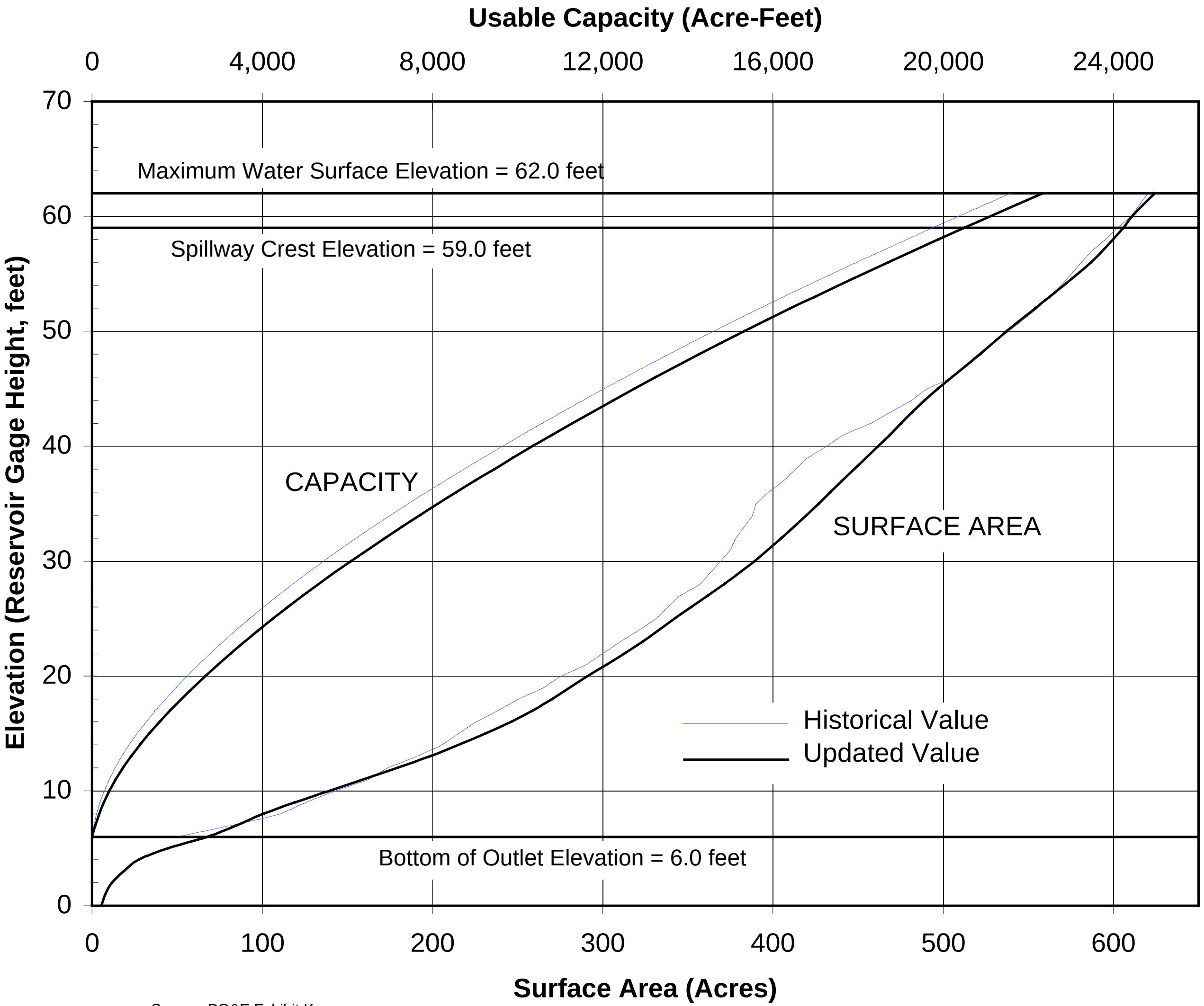
Site ID			Riparian Vegetation, Channel Stability Rating, Composition & Erosion										Debris				Bars			Particles Characteristics					Channel Patterns	
			Vegetation Type	Tree Structure	Downscaling	Cover	Roots	Vigor	Streambank Composition	Bank Height	Bank Erosion	Bank Angle	Occurrence	Influence	Landslides	Aquatic Vegetation	Pattern	Width	Mobility	Condition	Imbrication	Shape	Riffles	Pools	Meander	Sinuosity
5	SFAR - Sciots Camp																									
	XS1	LB	0	All	No	1	0%	1	1, 2	3	1	3	1	1	3	3	0	1	1	4	1	4	1	1,2	9	0
		RB	0	All	No	1	0%	1	1	3	1	3														
	XS2	LB	0	All	No	1	0%	1	1	3	1	3	1	1	3	3	0	1	1	4	1	5	1,2	1	9	0
		RB	2	All	No	1	0%	1	3	2	1	3														
	XS3	LB	0,2	All	No	2	0%	1	3	3	1	3	1	1	3	3	0	1	1	4	1	5	1,2	1,2	9	2
		RB	0,1	All	No	1	20%	1	1	2	1	4														
6	SFAR - Sand Flat																									
	XS1	LB	0,1	All	No	1	100%	2	2	1	3	2	1	1	1	3	0	1	1	4	1	4	2	2	9	1
		RB	0,2	All	No	2	75%	3	3, 6	3	2	2														
	XS2	LB	2,1	All	No	1	100%	1	2	3	3	2	1	1	1	3	1	4	1	3	3	5	2	1	9	2
		RB	0,1	All	No	2	75%	1	2	2	4	3														
11	SFAR - Riverton																									
	XS1	LB	3	All	No	3	50%	1	5	3	3	3														
		RB	0	All	No	3	50%	3	4	3	3	3	2	1	1	1	0, 3	1, 2	3	3	3	5	1, 2	1, 2	9	0
	XS2	LB	0 1	All	No	2	NA	1	4, 5, 1	3	3	3														
		RB	4	All	No	1	100%	3	5, 4	3	3	2	2	1	1	1	0, 3	1	3	3	3	5	1, 2	1, 2	9	0
	XS3	LB	0 3	All	No	1	NA	1	1 4	3	2	2														
		RB	2	All	No	3	100%	3	4	3	2	2	1	1	1	1	0, 3	2	3	3	3	5	1, 2	1, 2	9	0
13	Caples Creek - Lost Axe																									
	XS1	LB	0,3	All	No	1	bdrk	1	1	2	1	2														
		RB	3,4	All	No	3	100%	3	2	2	2	5	3	3	0	dry	2	5	1	3	1	5	4	5	5	2
	XS2	LB	3,4	All	No	3	50%	3	2	2	3	5														
		RB	3,4	All	No	2	50%	2	2	2	3	5	2	3	0	dry	2	5	1	3	1	5	4	5	5	2
	XS3	LB	0,3	All	No	2	50%	2	2	2	4	4														
		RB	3	All	No	2	100%	2	2	2	3	2	2	3	0	dry	2	4	1	3	1	5	4	5	4	3
20	Thunder Mountain Creek																									
	XS 1	LB	4,1	1,2,3,4,5	No	1	40%	2	2	2	2	3	3	3	1	2	3	2	3, mossy	1	3	2	2	2	3	3
		RB	4,1	1,2,3,4,5	No	2	100%	2	2	2	2	3														
	XS 2	LB	0,1	1,2,3,4,5	No	2	10	2	2	3	2	4	3	3	1	2	3	3	3	1	3	3	2	2	3	3
		RB	1,0	1,2,3,4,5	No	2	20	2	2	2	2	4														
	XS 3	LB	1,0	1,2,3,4,5	No	1	40	2	2	3	2	5	3	3	1	2	3	2	3	1	3	3	2	2	3	3
		RB	0,4	1,2,3,4,5	No	1	30	2	2	3	2	4														
7	Audrian Creek																									
	XS1	LB	1,2	All	No	3	100%	3	2	2	1	4	4	3	1	2	2	5	5	1,2	1	3	4	4	3	2
		RB	1,2	All	No	3	100%	3	2	2	1	5														
	XS2	LB	3	All	No	3	100%	3	2	1	1	4	4	3	1	2	2	1	1	1,2	1	3	4	4	3	2
		RB	3,1	All	No	3	100%	3	2,1	2	1	4														
	XS3	LB	3	All	No	3	100%	3	2	1	1	5	4	3	1	2	2	1	4	1,2	1	2	4	4	5	3
		RB	3	All	No	3	100%	3	2	1	1	5														
4	Strawberry Creek																									
	XS1	LB	1,2	2	No	3	NA	3	2	2	2	1	2	1	1	1,3	1	2	1	3	3	4	1	2	9	0
		RB	3,1	1	No	2	NA	3	2	2	2	2			1											
	XS2	LB	1	4,3	No	2	100%	2	2	3	2	4	7,2	1	1	3	1	2	1	3	2	4	1	2	9	1
		RB	1	4,2	No	3	NA	3	2	2	2	2			1											

APPENDIX C

Reservoir Area – Capacity Curves

- **Caples Lake**
- **Silver Lake**
- **Echo Lake**

CAPLES LAKE
AREA - CAPACITY CURVES



Source: PG&E Exhibit K
Carlton Engineering, Inc.

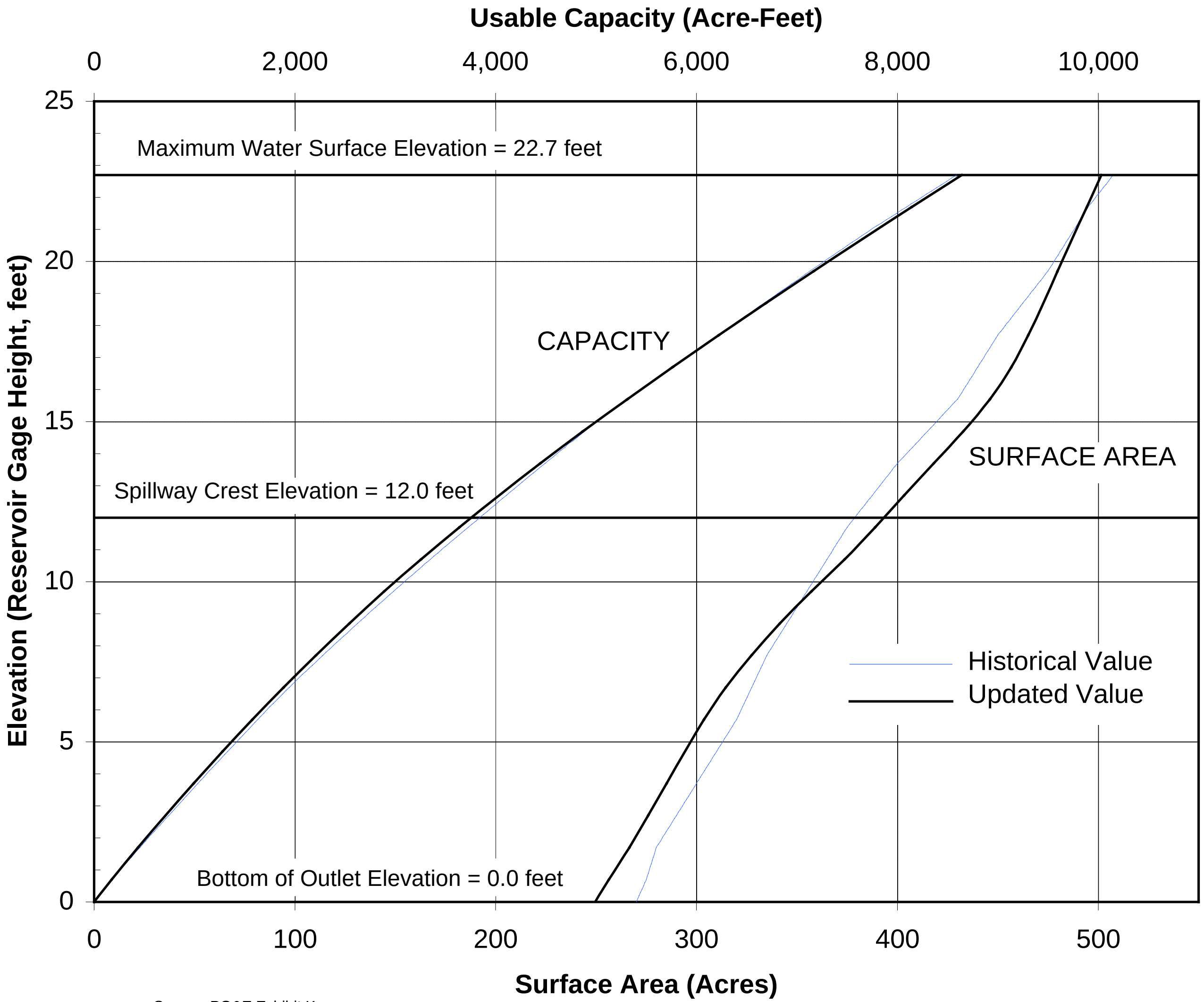
CAPLES LAKE

	Historical Value	Updated Value
Elevation at full pool (USGS Datum), msl	7,800.9	7,797.7
Usable Capacity, af	21,581	22,338
Total Capacity, af	21,781	22,490
Storage at zero usable capacity, af	200	152
Surface area at full pool, acres	620	624
Surface area at draw-down (usable capacity of 2,000 af), acres	250	266
Surface area at zero usable capactiy, acres	50	68
Maximum depth, ft	60	68

Historical Value: Values used prior to bathymetric surveys conducted in 1999.
Updated Value: Determined using bathymetric survey information collected in 1999.

Resource Insights (2000)

SILVER LAKE
AREA - CAPACITY CURVES



Source: PG&E Exhibit K
Carlton Engineering, Inc.

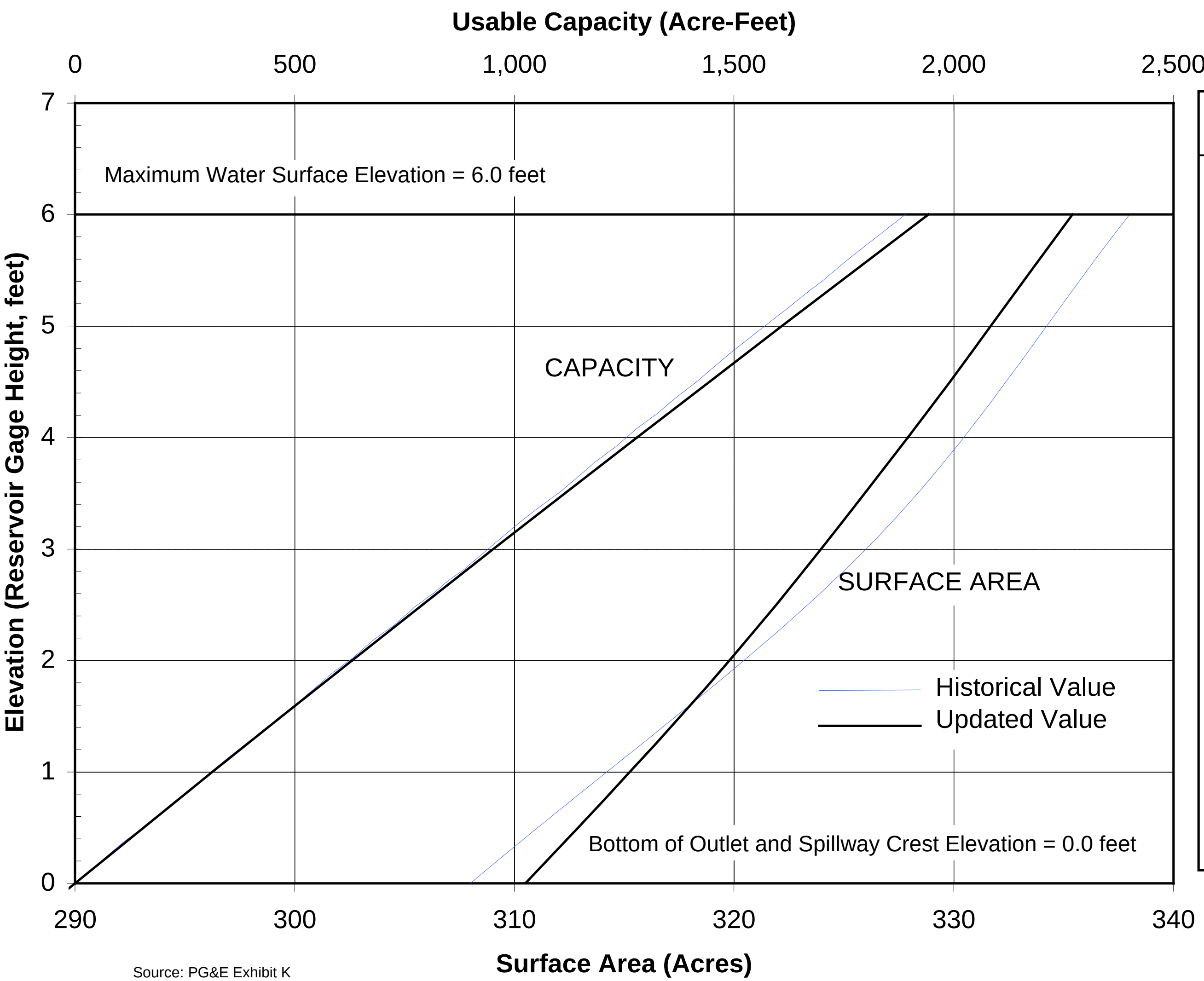
SILVER LAKE

	Historical Value	Updated Value
Elevation at full pool (USGS Datum), msl	7,261.1	7,261.1
Usable Capacity, af	8,590	8,640
Total Capacity, af	13,958	13,280
Storage at zero usable capacity, af	5,368	4,640
Surface area at full pool, acres	510	502
Surface area at zero usable capactiy, acres	260	250
Maximum depth, ft	60	71

Historical Value: Values used prior to bathymetric surveys conducted in 1999.
Updated Value: Determined using bathymetric survey information collected in 1999.

Resource Insights (2000)

ECHO LAKE
AREA - CAPACITY CURVES



Source: PG&E Exhibit K
Carlton Engineering, Inc.

ECHO LAKE

	Historical Value	Updated Value
Elevation at full pool (USGS Datum), msl	7,411.5	7,411.5
Usable Capacity, af	1,890	1,943
Total Capacity, af	15,389	15,749
Storage at zero usable capacity, af	13,499	13,806
Surface area at full pool, acres	338	335
Surface area at zero usable capactiy, acres	308	311
Maximum depth, ft	152	150

Historical Value: Values used prior to bathymetric surveys conducted in 1999.
Updated Value: Determined using bathymetric survey information collected in 1999.

Resource Insights (2000)

APPENDIX D

Doug Parkinson & Associates (1999), Resource Insights (1999) and Bill Lydgate (2002)

Bankfull Flow Estimates from Channel Geometry

SUMMARY OF BANKFULL FLOW ESTIMATES FROM CHANNEL GEOMETRY
Doug Parkinson & Associates (1999), Bill Lydgate (1999) and Resource Insights (1999)

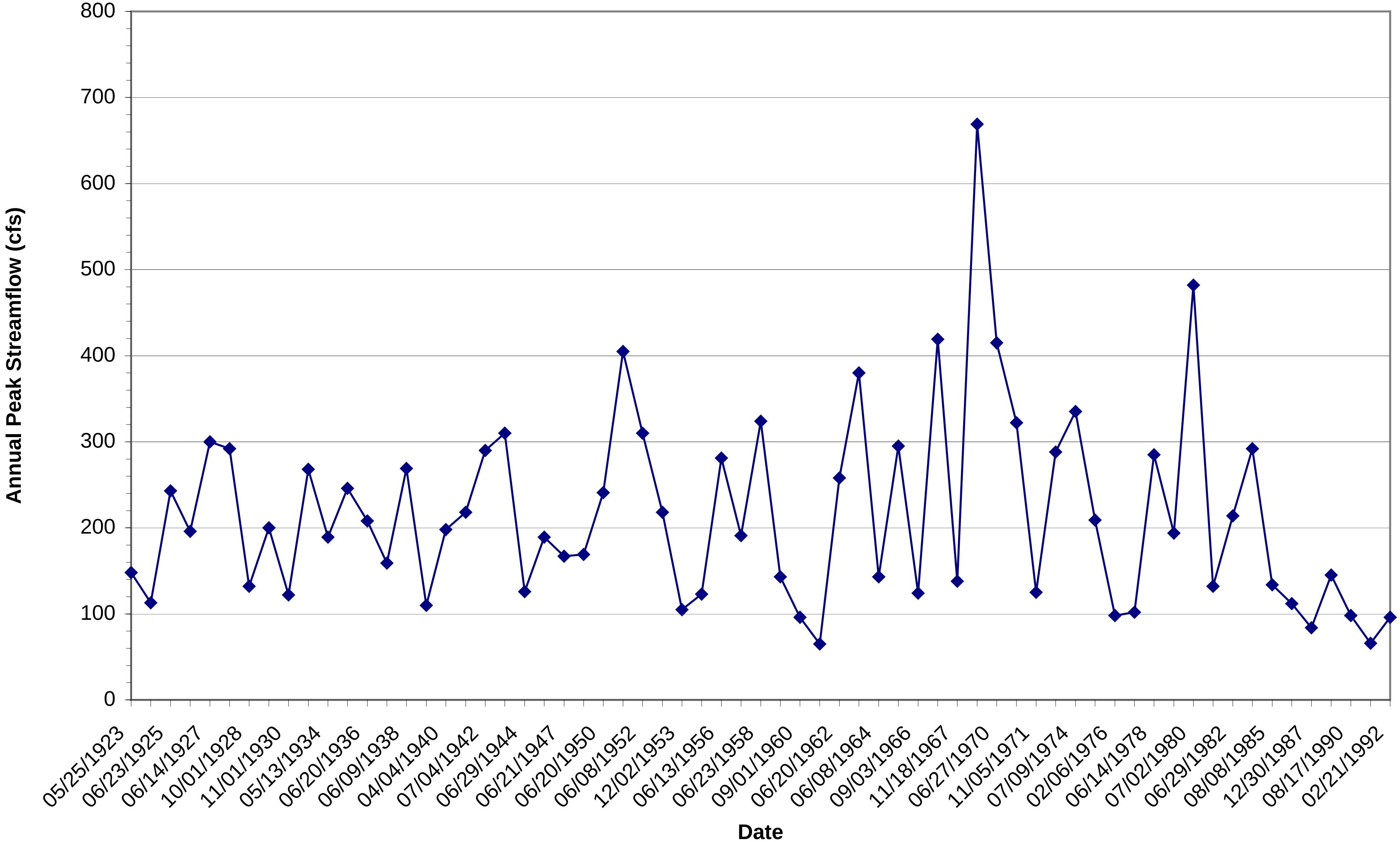
Site ID	Site Description	CALC "n"	d_{50} (mm)	Final "n"*	Bankfull Flow (cfs)
10	South Fork, US of Audrian Meadow	0.067	3.3	0.040	21.8
9	South Fork, @ Audrian Meadow	0.047	silt	0.040	1.8**
8	South Fork, @ Phillips	0.025	2.3	0.045	198.2
11	South Fork, @ Riverton CalTrans Station	0.070	123	0.040	1285.9
21	Silver Fork, @ West Campground	0.081	52	0.040	311.9
17	Silver Fork, @ Forgotten Flat	0.056	24	0.040	203.8
16	Silver Fork, at China Flat	0.044	20	0.040	1876.1
14	Caples Lake Overflow, US of Caples Creek	0.048	20	0.035	252.1
12	Caples Creek, DS of Kirkwood Creek	0.039	12	0.030	133.7
15	Caples Creek, @ Jake Schneider Meadow	0.027	32	0.035	299.9
13	Lost Axe, Unnamed Tributary to Caples Creek	0.060	8	0.030	180.4
19	Oyster Creek, DS of Highway 88	0.076	11	0.035	27.0
18	Oyster Creek, US Highway 88	0.048	52	0.035	39.2
20	Thunder Mtn., Unnamed Tributary to Oyster Creek	0.143	10	0.035	15.5

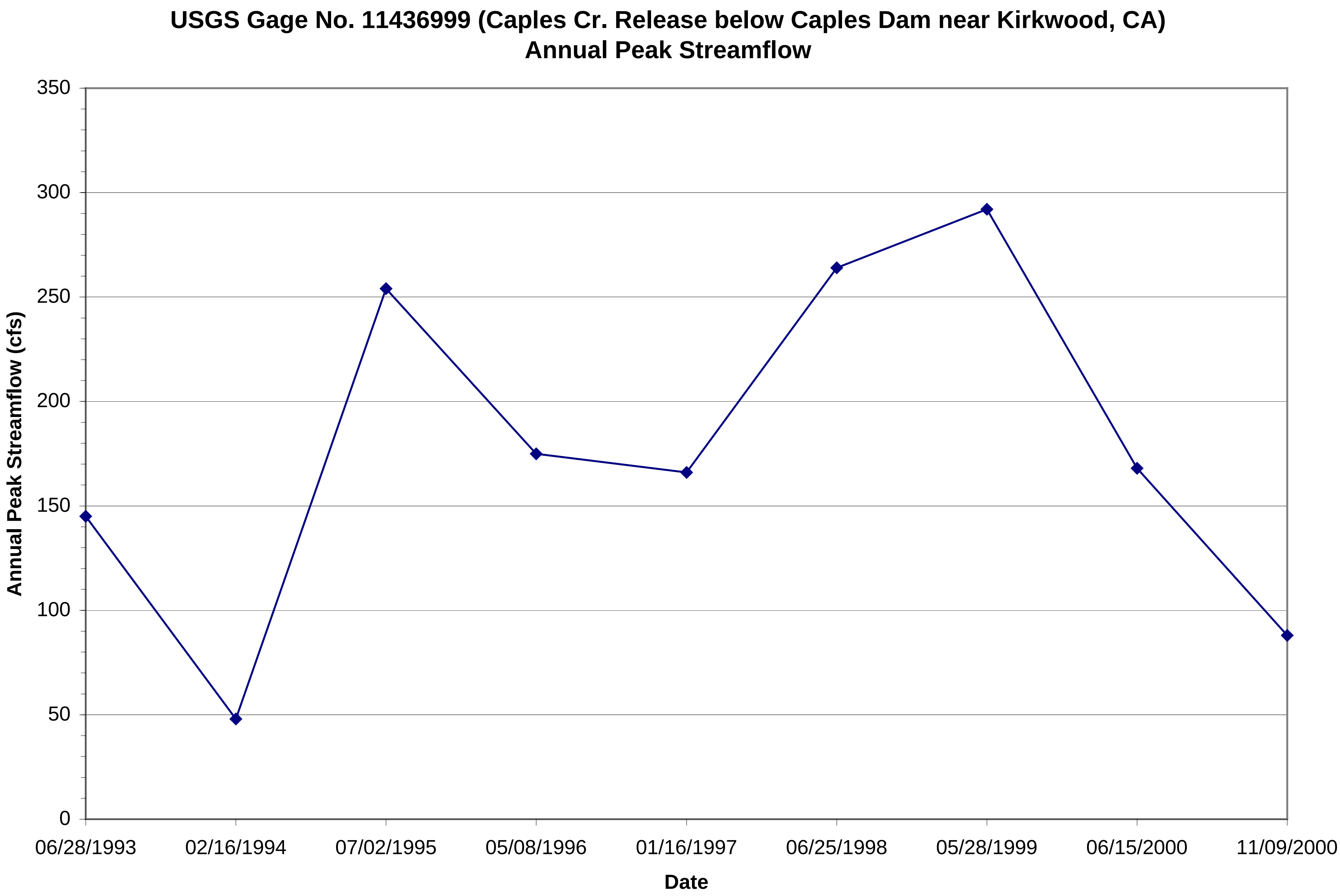
* "n" should be between 0.04 and 0.10 for mountain streams with boulders, per "Handbook of Hydrology" pg 12.5,
** calculated for a single channel of a multi-channel system in Audrian Meadow

APPENDIX E

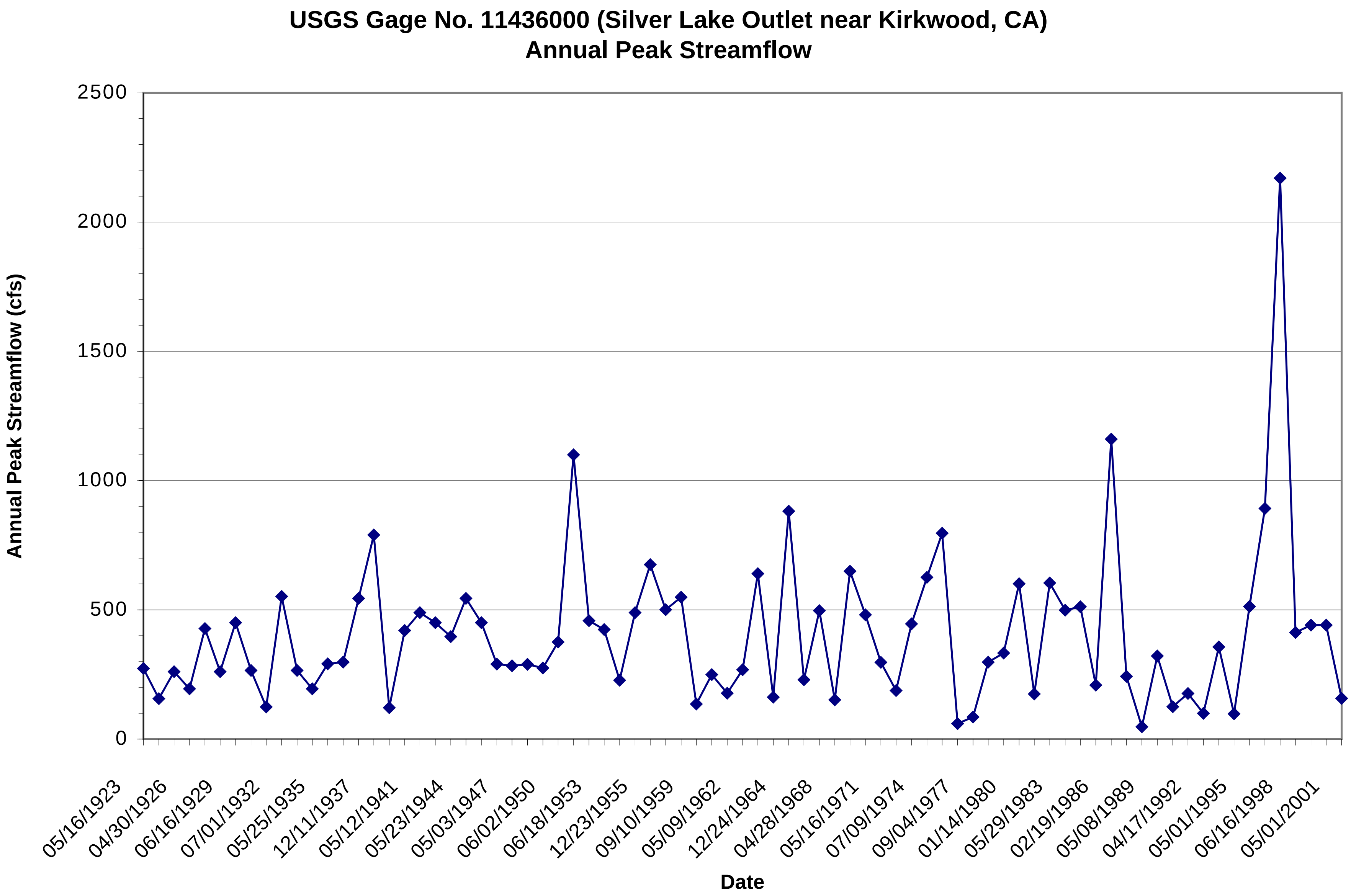
Annual Peak Streamflow and Flood Frequency Graphs

USGS Gage No. 11437000 (Caples Lake Outlet near Kirkwood, CA)
Annual Peak Streamflow

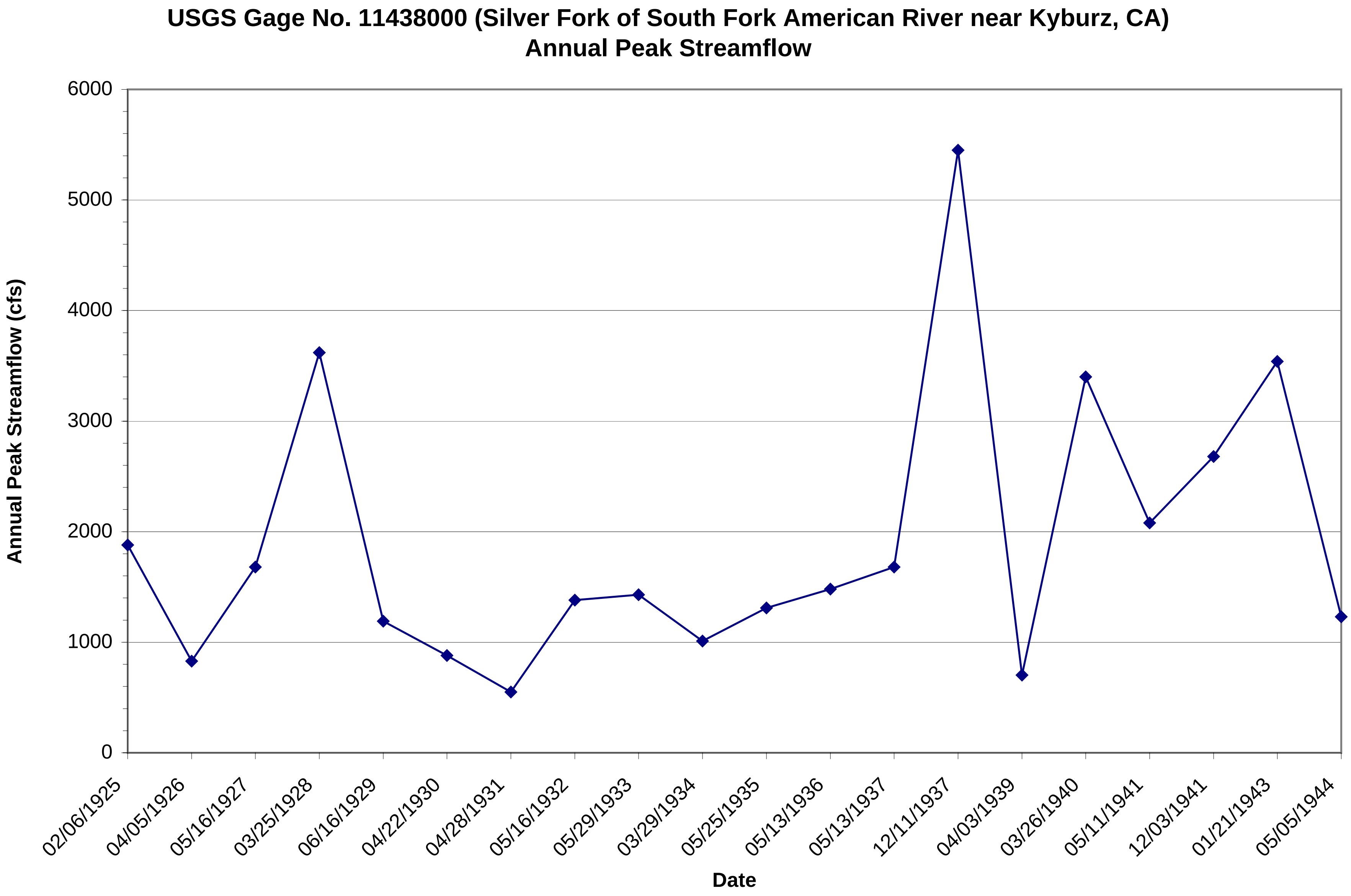




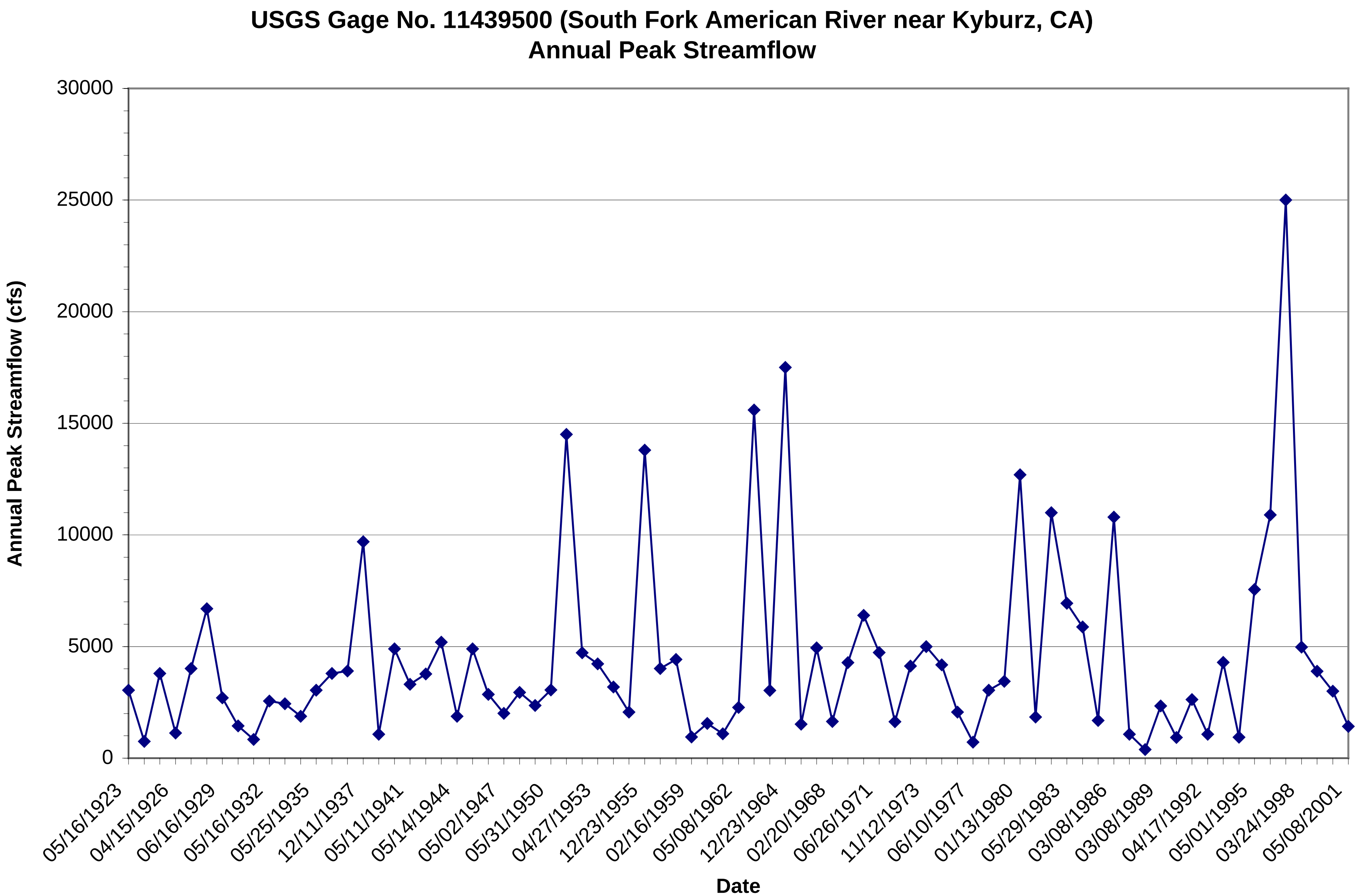
USGS Gage No. 11436999 (Caples Cr. Release below Caples Dam near Kirkwood, CA)
Annual Peak Streamflow
Annual Peak Streamflow (cfs)
350
300
250
200
150
100
50
0
06/28/1993
02/16/1994
07/02/1995
05/08/1996
01/16/1997
06/25/1998
05/28/1999
06/15/2000
11/09/2000
Date



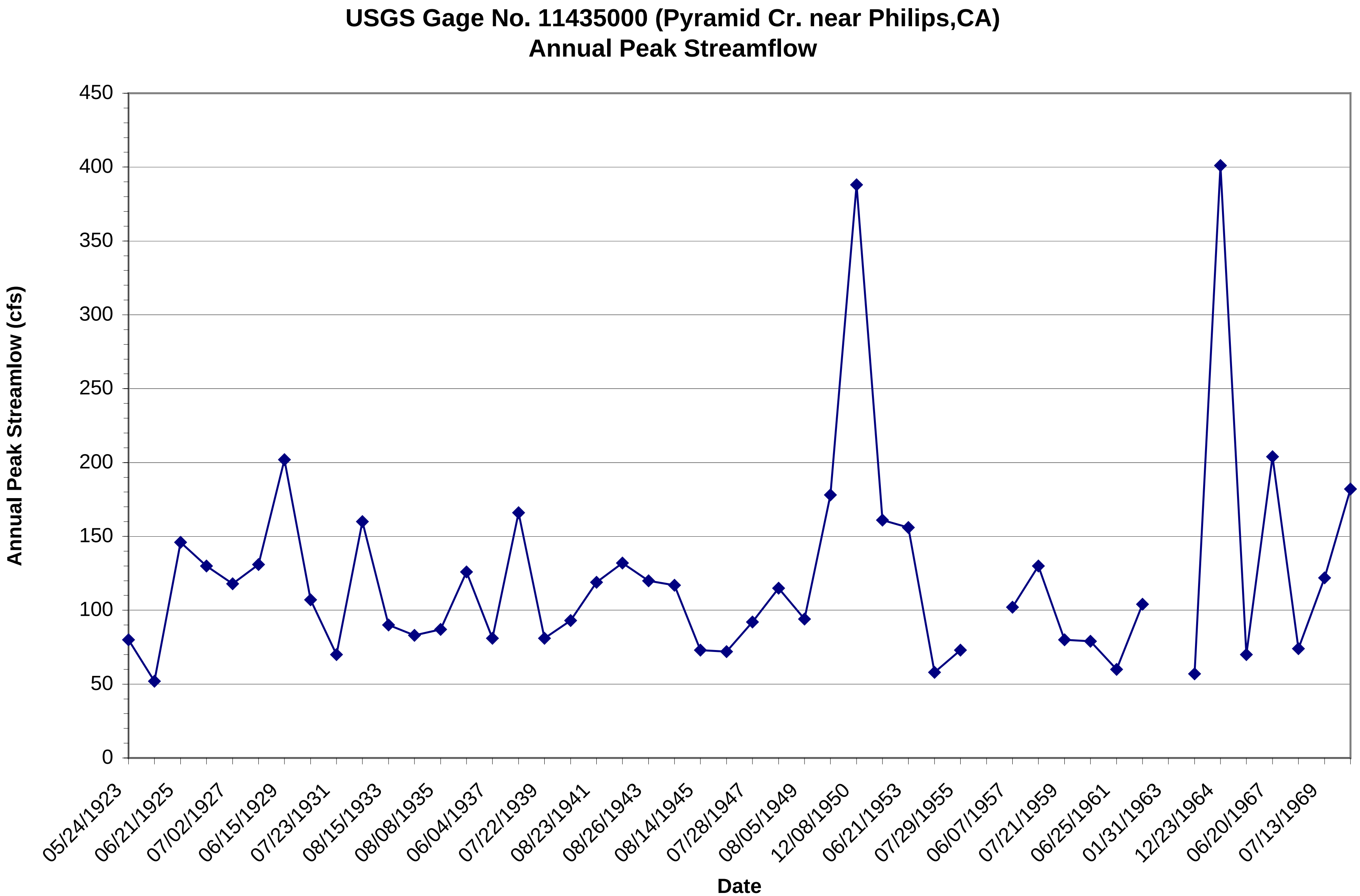
USGS Gage No. 11436000 (Silver Lake Outlet near Kirkwood, CA)
Annual Peak Streamflow
Annual Peak Streamflow (cfs)
2500
2000
1500
1000
500
0
05/16/1923
04/30/1926
06/16/1929
07/01/1932
05/25/1935
12/11/1937
05/12/1941
05/23/1944
05/03/1947
06/02/1950
06/18/1953
12/23/1955
09/10/1959
05/09/1962
12/24/1964
04/28/1968
05/16/1971
07/09/1974
09/04/1977
01/14/1980
05/29/1983
02/19/1986
05/08/1989
04/17/1992
05/01/1995
06/16/1998
05/01/2001
Date

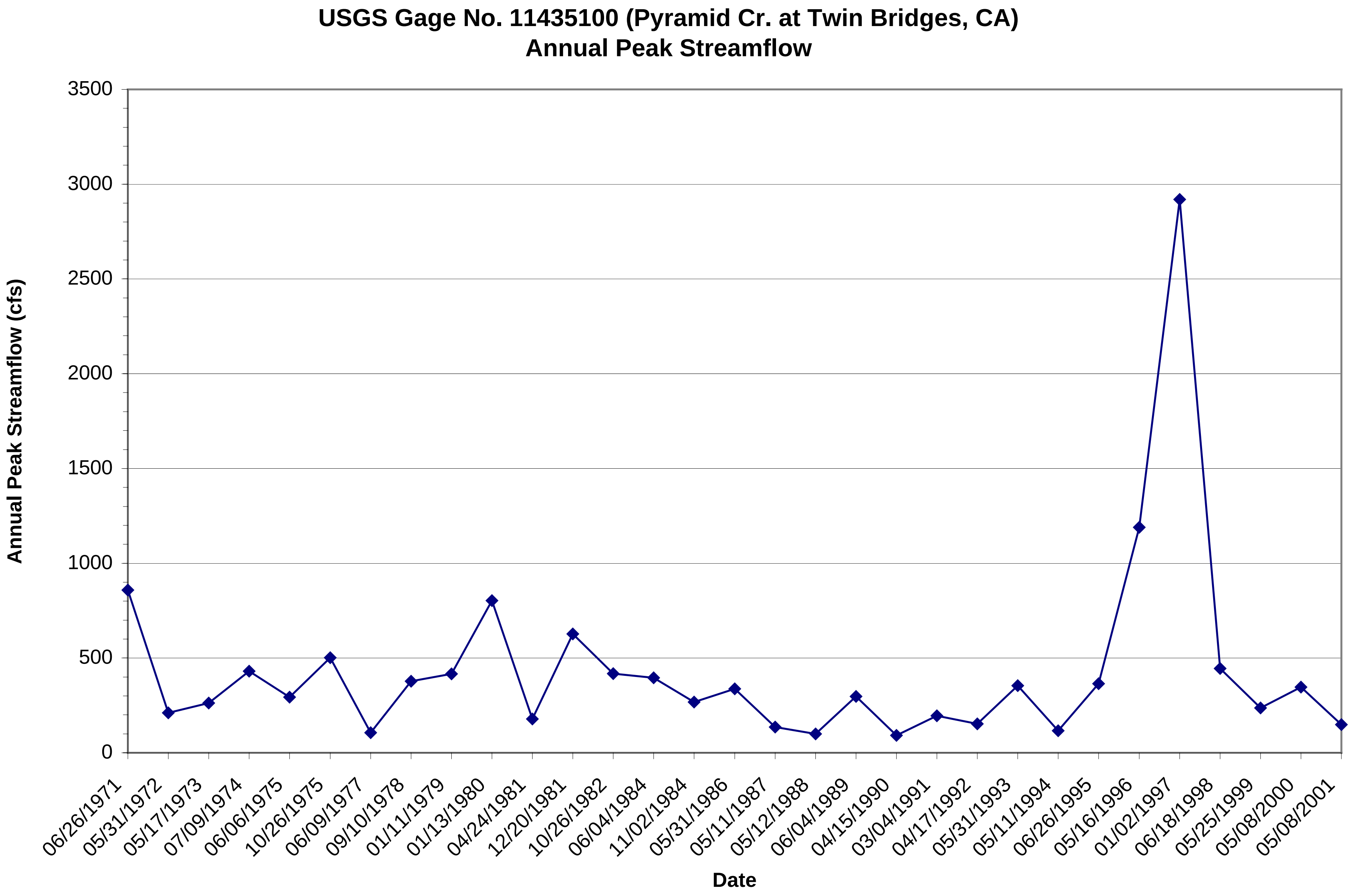


USGS Gage No. 11438000 (Silver Fork of South Fork American River near Kyburz, CA)
Annual Peak Streamflow
Annual Peak Streamflow (cfs)
6000
5000
4000
3000
2000
1000
0
02/06/1925
04/05/1926
05/16/1927
03/25/1928
06/16/1929
04/22/1930
04/28/1931
05/16/1932
05/29/1933
03/29/1934
05/25/1935
05/13/1936
05/13/1937
12/11/1937
04/03/1939
03/26/1940
05/11/1941
12/03/1941
01/21/1943
05/05/1944
Date

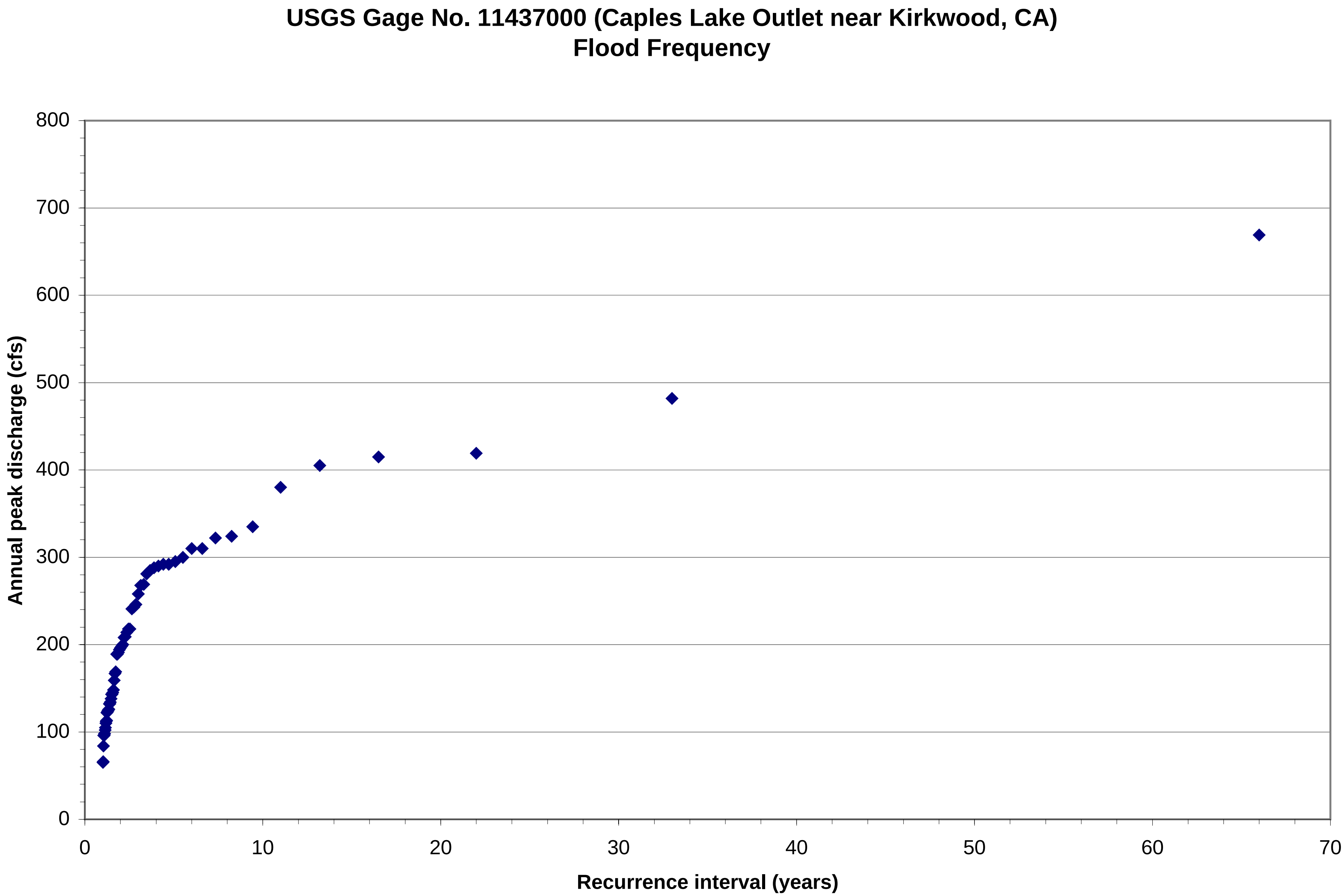


USGS Gage No. 11439500 (South Fork American River near Kyburz, CA)
Annual Peak Streamflow
Annual Peak Streamflow (cfs)
30000
25000
20000
15000
10000
5000
0
05/16/1923
04/15/1926
06/16/1929
05/16/1932
05/25/1935
12/11/1937
05/11/1941
05/14/1944
05/02/1947
05/31/1950
04/27/1953
12/23/1955
02/16/1959
05/08/1962
12/23/1964
02/20/1968
06/26/1971
11/12/1973
06/10/1977
01/13/1980
05/29/1983
03/08/1986
03/08/1989
04/17/1992
05/01/1995
03/24/1998
05/08/2001
Date

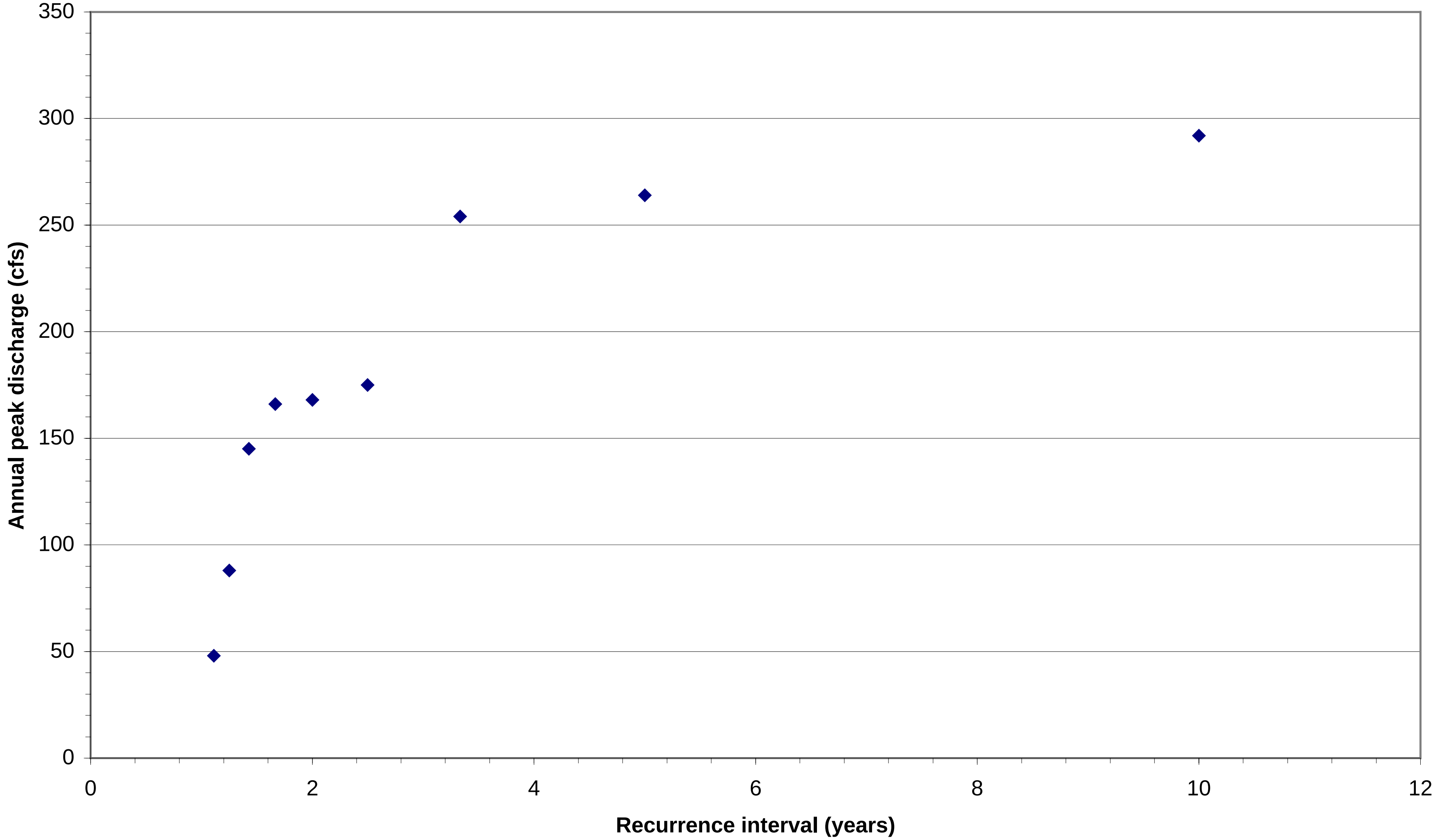

USGS Gage No. 11435000 (Pyramid Cr. near Philips,CA)
Annual Peak Streamflow
Annual Peak Streamlow (cfs)
450
400
350
300
250
200
150
100
50
0
05/24/1923
06/21/1925
07/02/1927
06/15/1929
07/23/1931
08/15/1933
08/08/1935
06/04/1937
07/22/1939
08/23/1941
08/26/1943
08/14/1945
07/28/1947
08/05/1949
12/08/1950
06/21/1953
07/29/1955
06/07/1957
07/21/1959
06/25/1961
01/31/1963
12/23/1964
06/20/1967
07/13/1969
Date

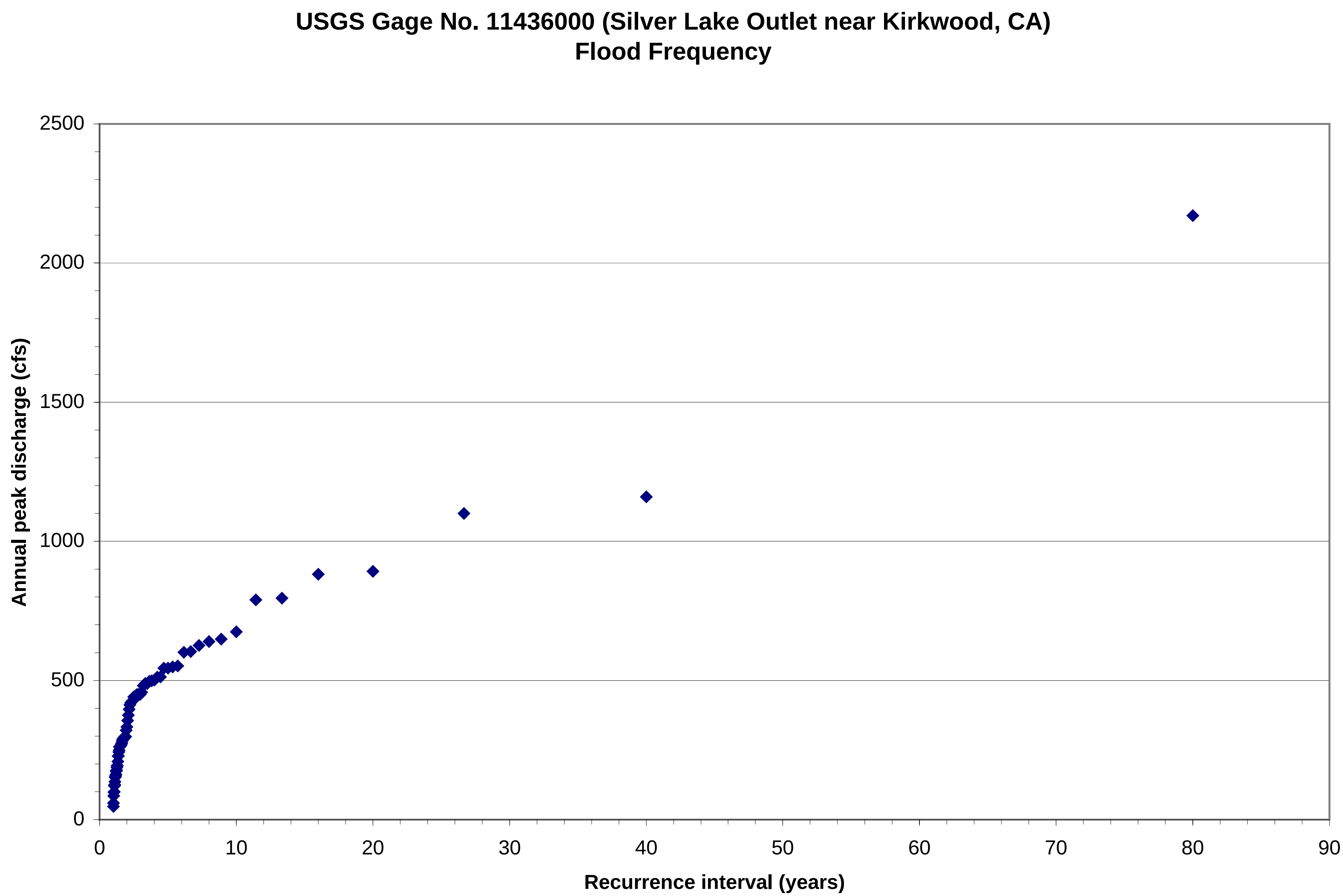


USGS Gage No. 11435100 (Pyramid Cr. at Twin Bridges, CA)
Annual Peak Streamflow
Annual Peak Streamflow (cfs)
3500
3000
2500
2000
1500
1000
500
0
06/26/1971
05/31/1972
05/17/1973
07/09/1974
06/06/1975
10/26/1975
06/09/1977
09/10/1978
01/11/1979
01/13/1980
04/24/1981
12/20/1981
10/26/1982
06/04/1984
11/02/1984
05/31/1986
05/11/1987
05/12/1988
06/04/1989
04/15/1990
03/04/1991
04/17/1992
05/31/1993
05/11/1994
06/26/1995
05/16/1996
01/02/1997
06/18/1998
05/25/1999
05/08/2000
05/08/2001
Date

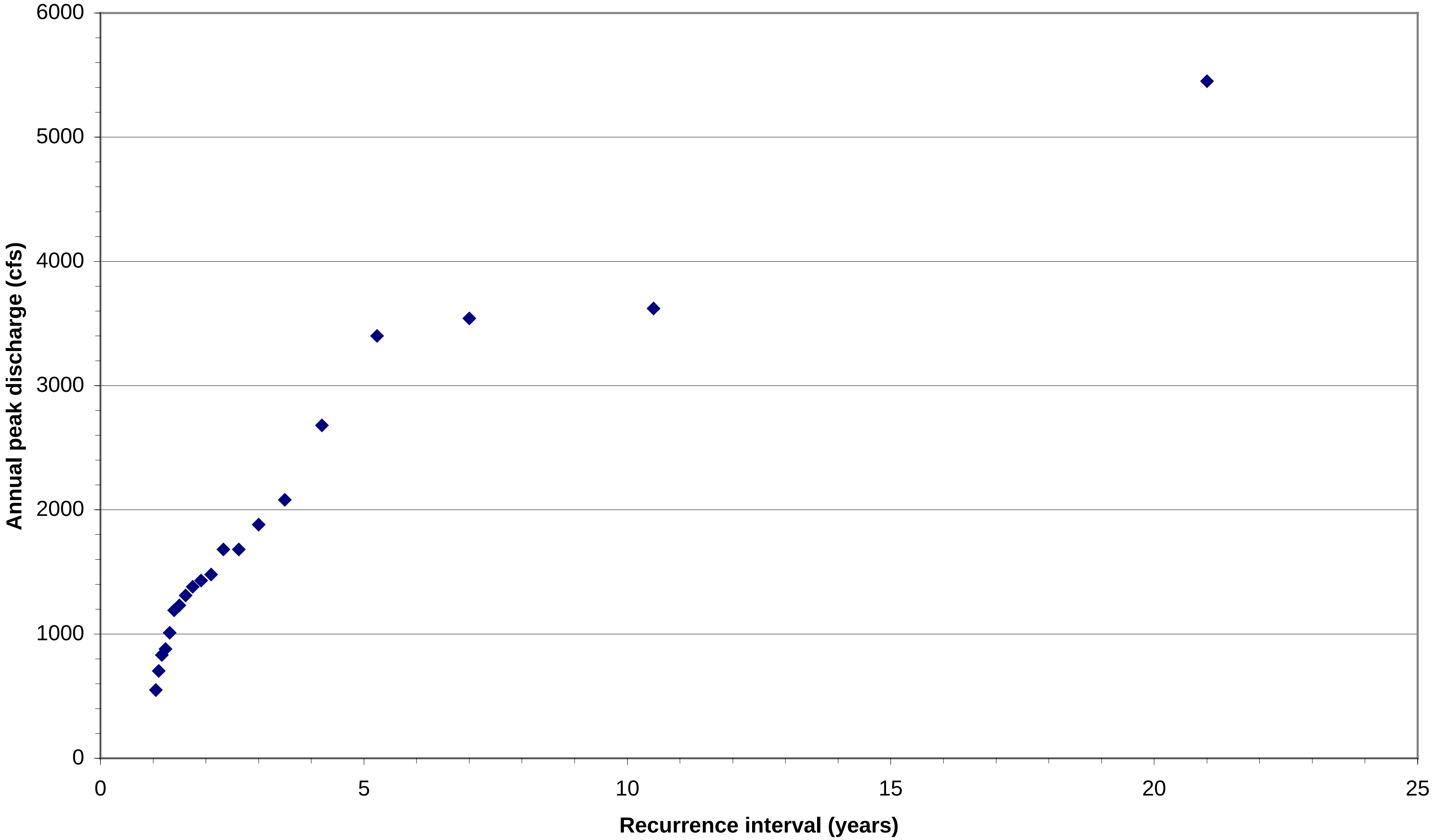

USGS Gage No. 11437000 (Caples Lake Outlet near Kirkwood, CA)
Flood Frequency
Annual peak discharge (cfs)
0
100
200
300
400
500
600
700
800
Recurrence interval (years)
0
10
20
30
40
50
60
70

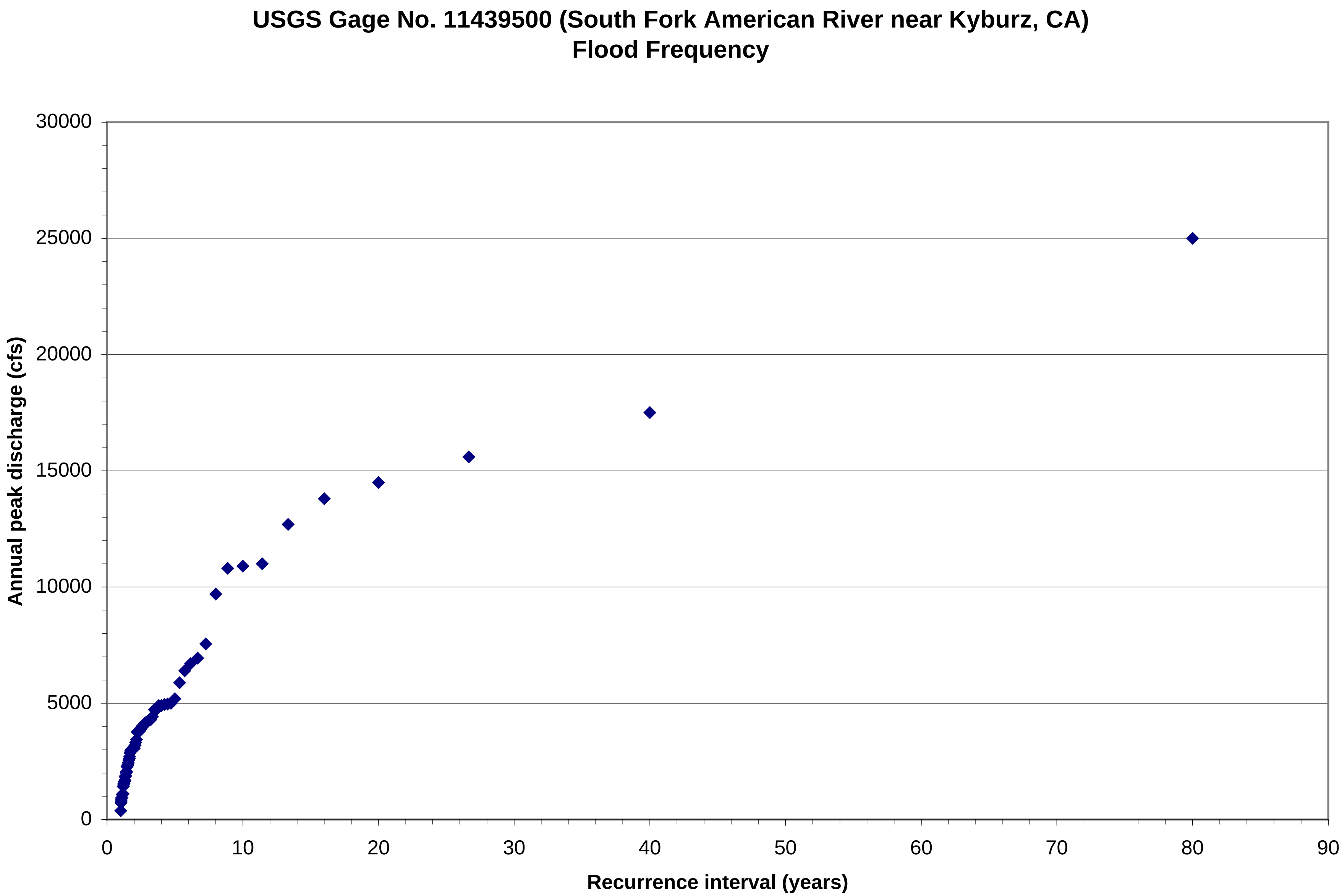
USGS Gage No. 11436999 (Caples Cr. Release below Caples Dam near Kirkwood, CA)
Flood Frequency

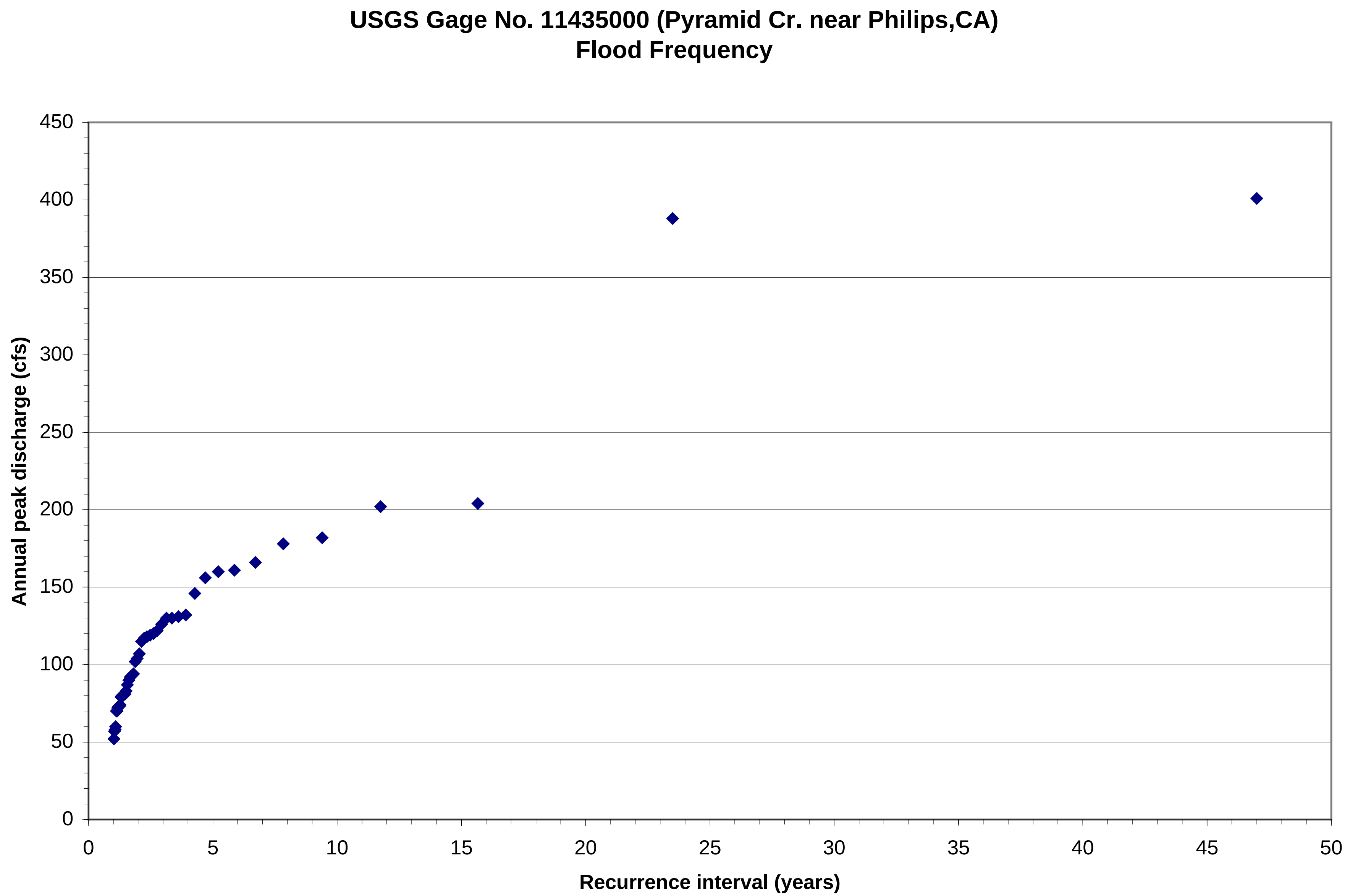


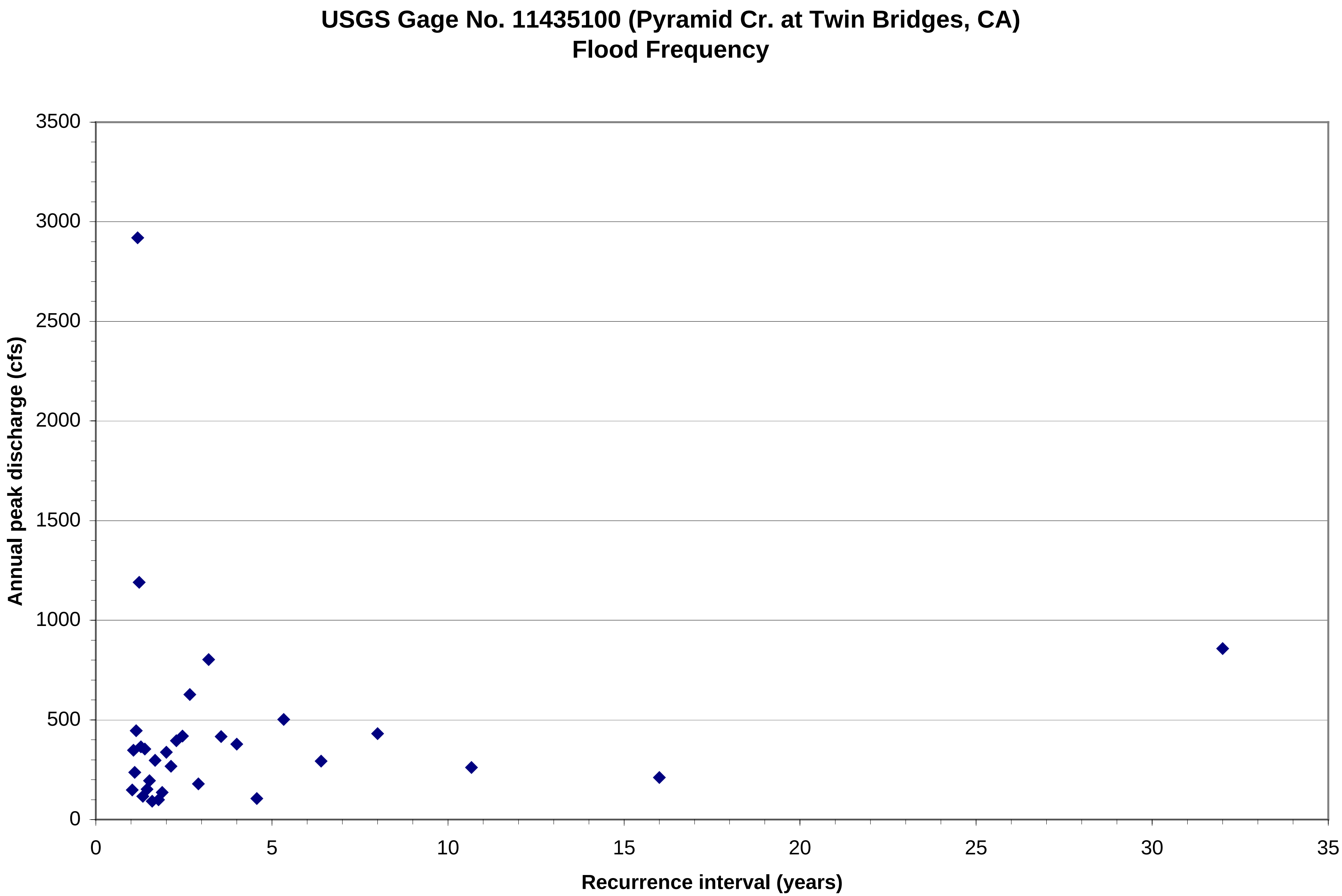

USGS Gage No. 11436000 (Silver Lake Outlet near Kirkwood, CA)
Flood Frequency
2500
2000
1500
1000
500
0
Annual peak discharge (cfs)
0
10
20
30
40
50
60
70
80
90
Recurrence interval (years)

USGS Gage No. 11438000 (Silver Fork of South Fork American River near Kyburz, CA)
Flood Frequency




USGS Gage No. 11439500 (South Fork American River near Kyburz, CA)
Flood Frequency
Annual peak discharge (cfs)
30000
25000
20000
15000
10000
5000
0
0
10
20
30
40
50
60
70
80
90
Recurrence interval (years)


USGS Gage No. 11435000 (Pyramid Cr. near Philips,CA)
Flood Frequency
Annual peak discharge (cfs)
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
Recurrence interval (years)


USGS Gage No. 11435100 (Pyramid Cr. at Twin Bridges, CA)
Flood Frequency
Annual peak discharge (cfs)
Recurrence interval (years)
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35