SACRAMENTO MUNICIPAL UTILITY DISTRICT
UPPER AMERICAN RIVER PROJECT
(FERC NO. 2101)

AMPHIBIAN HABITAT TEST FLOW TECHNICAL REPORT

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4.15 Amphibian Habitat Test Flow Study Plan

This study is designed to provide information relating to special status amphibian and aquatic reptile species in stream reaches associated with Sacramento Municipal Utility District's (SMUD's) Upper American River Project (UARP) and Pacific Gas and Electric Company's (PG&E's) Chili Bar Project. Changes in habitat quality and structure used by target special status amphibian species will be qualitatively evaluated during various flow release scenarios to assess potential effects that may be associated with SMUD and PG&E project operations. The overall approach is to assess habitat conditions under various flow regimes at sites where target special status amphibian species are documented during the 2003 Visual Encounter Surveys (VES).

4.15.1 Pertinent Issue Questions

This Test Flow Study Plan addresses the following Aquatic/Water Issue Questions:

1. Does the Project affect special-status species? If so, where and how?

This test flow study plan only addresses effects of flows on amphibians and amphibian habitat. The survey methods for determining the presence, distribution, and abundance of amphibians and aquatic reptiles are outlined in the Amphibian and Aquatic Reptile Study Plan, approved May 1, 2002. Other aquatic species and resources are addressed in the Fish Survey Study Plan and the Aquatic Bioassessment Study Plan (benthic macroinvertebrates).

4.15.2 Background

SMUD's Initial Information Package lists 18 amphibians and aquatic reptiles that have a potential to occur in the vicinity of the UARP and/or Chili Bar projects based on SMUD's review of existing information (SMUD 2001, pp. E3-6 through E3-11). As described in the Amphibian and Aquatic Reptile Study Plan, nine of these are special status species, four of which have a very low likelihood of being affected by either project: California tiger salamander (*Ambystoma californiense*), western spadefoot toad (*Scaphiopus hamondii*), northern leopard frog (*Rana pipiens*), and Mt. Lyell salamander (*Hydromantes platycephalus*). Also, the project area is beyond the documented range of Yosemite toad (*Bufo canorus*), so specific VES are not proposed for this species. Likewise, because habitat requirements for western pond turtle (*Clemmys marmorata*) are encompassed by the remaining special status species that could occur within the project area, species-specific VES for western pond turtle will not be conducted during 2003 surveys. Thus, the following species will be targeted for test flow studies, if they are documented to occur at VES sites based on the results of the 2003 surveys: California red-legged frog (*R. aurora*) (CRLF), foothill yellow-legged frog (*R. boylii*) (FYLF), and mountain yellow-legged frog (*R. muscosa*) (MYLF). All three species are targeted for the UARP. Only FYLF will be targeted for the reach downstream of Chili Bar, as all sites targeting CRLF in this reach occur upslope of the main channel. Habitat characteristics generally associated with the target amphibian species in lotic areas are summarized in Table 1.

4.15.3 Study Objectives

The objective of this study effort will focus on identifying suitable habitat that exists under variable flow releases at known locations of frogs. The focus and goal of this study is to further our understanding of the correlation between flow and habitat for various species and life stages of amphibians.

4.15.4 Study Area

The general study area will include the mainstem of all Project stream reaches as identified by the Aquatics TWG, including the reach downstream of Chili Bar Dam. The study area will not include Project reservoirs nor tributary streams flowing into Project-affected reaches since the Project cannot affect flow in these reaches. Test flow studies will be conducted at all sites where Visual Encounter Surveys (VES) determine target amphibian species and stages (egg/tadpole) presence (FYLF, CRLF, and MYLF).

Table 1. Habitat characteristics generally associated with the target amphibian species in lotic areas.

Habitat characteristics in lotic areas for the different life stages of the target species*			
Habitat parameter	**CRLF**	**FYLF**	**MYLF**
basic habitat type (all life stages)	Wetlands, wet meadows, ponds, lakes, pools, & low-gradient, slow-moving stream reaches below 5,000 feet	Streams below 5,000 feet	Streams, lakes, pools, & low-gradient, slow-moving stream reaches above 4,500 feet
depth and velocity	▪ adults associated with deep (>0.7 m [USFWS Recovery Plan citation]), still, or slow-moving water ▪ Tadpoles found in greater numbers at depths of 0.26–0.5 m (Reis 1999, as cited in USFWS 2002)	▪ eggs typically laid in <40 cm water depth, <10 cm/sec water velocity (Seltenrich and Pool 2002) ▪ adult females prefer plunge pools in a small stream (Van Wagner 1996) ▪ on the South Yuba River deep, channelized stream habitats were used by adults (Yarnell 2000, as cited in Seltenrich and Pool 2002) ▪ The depth at which eggs were laid in the South Fork Eel study varied from 4 to 43 cm, with an average depth 19.7 cm (Kupferberg 1996a). Average velocities at oviposition sites were 0.1 ft/s (3.2 cm/s). ▪ Metamorph and post-metamorph R. boylii were associated with water that had a low flow velocity of 0.04 m/s (0.14f/s) ± 0.09 m/s (0.28 f/s) that was adjacent to water of intermediate to fast flow velocities (Borisenko and Hayes 1999)	▪ gently sloping margins along open streams, typically 5-8 cm water depth for refuge from predators (tadpoles) and for suitable water temperatures for development (egg-laying)
water temperature		▪ majority of egg laying follows high flow discharge in spring (March – early June) at water temperatures of approx. 12-15°C ▪ On the South Fork Eel River, oviposition commenced when water temperatures reached approximately 54o F (12 °C) (Kupferberg 1996a)	▪ can overwinter in lakes that are not completely frozen (Fed Reg. Vol. 68 p. 2285) ▪ breeding typically begins as snow begins to melt
gradient	▪ < or equal to 2% gradient for adult habitat	▪ eggs and tadpoles typically found along gently-sloping banks (Kupferberg 1996a, Borisenko and Hayes 1999)	▪
substrate composition	▪ eggs often laid on submerged large woody debris such as root wads of fallen trees or submerged parts of living willows/other vegetation	▪ cobble and boulder substrates most common for egg laying, but also uses bedrock and pebbles eggs usually laid on bare/clean rock surfaces; females will scrape rocks clean if necessary	▪ silt or mud substrates ▪ eggs are attached to rocks, gravel, vegetation, or undercut banks ▪ adults can be found on fine sand, rubble, and boulder substrates
distance from shore	▪ variable	▪ eggs are laid relatively close to shore – typically < 5 m from the water's edge (Kupferberg 1996a)	▪ adults are found relatively close to shore

Table 1 (continued)

Habitat characteristics in lotic areas for the different life stages of the target species*

Habitat parameter	CRLF	FYLF	MYLF
emergent vegetation cover	▪ egg masses are typically attached to emergent vegetation; juvenile frogs prefer this habitat, along with organic debris for food and cover.	▪ tadpoles require aquatic cover to escape predation	▪ emergent vegetation required for egg mass attachment
adjacent riparian vegetation	▪ Arroyo willow, cattails, and bulrushes provide the most structurally suitable shrubby vegetation (Jennings 1988)	▪ low to moderate shade for adult and juvenile habitats ▪ breeding habitats located away from overhead cover (Seltenrich and Pool 2002) along open, sunny stream margins	▪ aquatic/riparian vegetation for cover
presence/abundance of algae, macroinvertebrates, and predators	▪ bullfrogs, garter snakes, and introduced fishes are known predators ▪ tadpoles rely on algae for food; adults rely on invertebrates	▪ algae and/or diatoms required for tadpoles, juveniles; adult diet includes aquatic and terrestrial invertebrates (Kupferberg 1996a, b) ▪ introduced bullfrogs, crayfish and fishes are significant egg and tadpole predators (Kupferberg 1997)	▪ non-native fishes thought to exclude MYLF from certain habitats (V. Vrendenberg, pers. comm., 2003)

* Primary source: Jennings and Hayes 1994.

4.15.5 Information Needed From Other Studies

Information from other studies will assist in identifying the distribution, quality, and quantity of available habitat for amphibians. The needed information will include: 1) results from the Amphibian and Aquatic Reptiles Study on amphibian presence and habitat characteristics at sites where targeted amphibians are documented to occur during 2003 VES; and 2) results from the Hydrology Study on stream flow, ramping rates and reservoir elevations.

As information becomes available, additional data from the following studies may also be used to interpret test flow study results, including: 1) results from the Channel Morphology Study on coarse sediment supply dynamics as it relates to suitable substrates/habitats for amphibian breeding locations; 2) results from the Water Temperature Study on how hydroelectric project facilities and operations affect temperatures in project-affected reaches; 3) results from the Fish Survey Study on the distribution of potential predators on amphibians; 4) results from the Aquatic Bioassessment Study on the distribution of suitable prey taxa, particularly for FYLF adults (of the three target species, FYLF rely most heavily on macroinvertebrates for prey [S. Kupferberg, pers. comm., 2003]), and the potential effects of project operations on prey abundance; and 5) results from the Riparian Vegetation Study on the extent of riparian vegetation in providing cover for adult habitats, and on vegetation encroachment onto cobble bars and other surfaces suitable for egg laying.

4.15.6 Study Methods And Schedule

Phase 1 – Identify study sites and train field crew

As mentioned above, test flow study sites will be selected based on presence of the target amphibian species as documented during VES. These sites will be selected to cover a range of habitat types, if possible, and particular importance will be given to known breeding localities. The extent of each study site will depend on the extent of contiguous suitable habitat and may include areas farther upstream and/or downstream of the original VES site, if suitable habitat is present. Test flow releases will be conducted after the breeding stage has been completed for the above-mentioned species, so as to limit any potential negative effects on amphibian populations in the study area. Since the test flow studies will be conducted after the breeding season, habitat conditions (particularly vegetation and water temperature) are likely to be different than during the breeding period. Field crews will bring photographs of test flow study sites taken during the breeding season VES and compare the conditions with those observed in the field during test flow surveys, so as to account for changes when conducting the habitat suitability assessment.

Breeding site locations will be marked with semi-permanent monuments to allow for photographic comparisons between seasons and/or flow conditions.

Because there is a degree of subjective data collection for this study, all field crew members will be trained together, so that the collected data can be analyzed and compared collaboratively among sites. Measurements and estimations will be made for the habitat parameters listed below, using consistent methods. Datasheets will be reviewed and used during the field training session.

Phase 2 – Collect data
Because the methodology and data collection efforts will necessarily be different for the three target species, protocols for data collection efforts are described by species below. Since much of the previous work on test flow releases and the effects of flow on habitat have been conducted for FYLF, the most detail has been provided for this species. Should evidence of breeding and/or adult habitat be found for the other two target species (CRLF and MYLF) within the Project-affected reaches, a subgroup of the Aquatics TWG will convene to develop an approach, with the help of expert amphibian biologists, for assessing effects of flows on habitat for these species.

In general, data collection will focus on providing information for the following specific study questions:

(1) Where and how much suitable habitat occurs at the lowest test flow release, and how do the characteristics of that habitat change at each subsequent (increased) flow release?
(2) Where and how much suitable habitat occurs at each of the test flows under consideration?

Foothill yellow-legged frog
For FYLF, the focus of data collection will be on the effects of flows on breeding habitat (egg-laying and tadpole-rearing), as adults typically summer and overwinter in tributaries. One two-person team will collect the data at a given site for each of the test flows to ensure continuity in data collection efforts. Data collection will focus on measurable habitat variables known to be important to FYLF. If available, data collected during the VES will be used for comparison purposes, and data collected during the test flow study will use the same methods employed during the VES. Data collection will focus on egg deposition and tadpole rearing locations, but will also consider adult habitat. To answer questions regarding location and extent of suitable habitat, we will map polygons (whenever possible) at all test flows onto digital, ortho-rectified aerial photographs and characterize habitat parameters. It is understood that these are site-specific studies, and that the results should be interpreted accordingly.

For this analysis of the effect of flows on the location and extent of suitable habitat, suitable habitats for breeding will be initially identified at the lowest flow (Flow A), based on criteria presented in the table above. Suitable habitat areas will be sketched as polygons onto aerial photographs of the site. Polygons will be sequentially numbered from downstream to upstream directly onto the aerial photograph. The following parameters will be measured/estimated for each polygon and recorded onto a standardized datasheet ("Polygon Parameters"):

1. Shape (oval, square, triangle, etc.)
2. Length and width (to later calculate area)
3. Average depth and velocity
4. Water temperature
5. Site gradient
6. Substrate composition (percent sand, gravel, cobble, boulder, and bedrock)
7. Distance from shore (perpendicular distance from center of polygon)
8. Emergent vegetation cover (percentage)
9. Adjacent riparian vegetation (species composition, percent overhead cover, and distance between suitable aquatic habitat and shaded cover), particularly areas that could provide cover for ambush predators
10. Presence/abundance of algae, macroinvertebrates, and predators (on a site-scale)

The shape, length, and width measurements of the polygon coupled with the aerial photographs will be used to estimate the area of the polygon. Depth will be measured at several locations throughout the polygon. Velocity measurements will be taken in the water column, at 60% of the total depth (or 20% and 80% of total depth at depths equal or greater than 2.5 feet), and at the surface, at several locations (e.g., across transects or along velocity isopleths) throughout the polygon. Because of the possibility of differing temperatures in edgewater and main channel habitats, water temperature will also be measured in each polygon. The gradient of the site will be measured using an auto level and stadia rod. Substrate composition within the polygon will be estimated according to the modified Wentworth (1922) scale. Distance from shore will be measured from the center of the polygon to the nearest water's edge. Percent cover of emergent vegetation will be estimated within each polygon. Emergent vegetation will be grouped, and will not necessarily be identified to genus/species. The species composition of nearby or adjacent riparian vegetation will be noted, and percent overhead cover will be estimated for each polygon. Because adults may depend on terrestrial shade cover, distance between the polygon and adjacent riparian cover will also be measured.

Observations related to algal cover, macroinvertebrate presence (qualitative observations), and predator presence will be made at the site-scale only, under the lowest flow (Flow A). If significant changes occur under higher test flows (e.g., algae becomes dislodged under highest test flow), additional observations will also be recorded.

Photographs of each site will be taken under each flow from the upstream and downstream ends as well as from the middle of the site. Photographs of each polygon under various test flows will also be taken.

Mapping and data collection at polygons will be conducted at each of the test flows. Each subsequent mapping effort after the lowest baseflow (Flow A) will involve both (1) taking measurements at the habitat polygons mapped at the previous (and lower) test flow, and (2) identifying habitat polygons that become available under the new test flow.

Table 2. Data to be collected under each test flow release.

Test Flow	Location of data collection	Factors to be assessed[1]
Flow A (lowest flow)	suitable habitat (polygons) under Flow A	Polygon Parameters
Flow B	polygons considered suitable habitat during Flow A	subset of Polygon Parameters[2]
	suitable habitat (polygons) under Flow B	Polygon Parameters
Flow C (highest flow)	polygons considered suitable habitat during Flow A, and B	subset of Polygon Parameters[2]
	suitable habitat under Flow C	Polygon Parameters

[1]See explanation for each of these factors in text descriptions above (in this section)
[2]The subset of parameters to be measured will include average depth and velocity and distance from shore. The subset will NOT include shape, length and width, water temperature, substrate composition, emergent vegetation cover, and adjacent riparian vegetation measurements because these will not change for the polygon with increased flows.

As outlined in Table 2, three or four test flows are proposed for release to quantify the availability of amphibian habitat at sites where amphibians are observed during the VES. Actual flow releases are specified in Table 3, and will be based on the natural hydrograph, project facility (valve) and operational limitations. Target flows and locations are specified in Table 3.

Table 3. Sites and target flows for amphibian habitat test flow studies.

Site	Target Study Flows
Camino Reach	Three flows similar to PHABSIM: 10, 30, and 100 cfs
Slab Creek	Three flows similar to PHABSIM: 40, 75, and 150 cfs, plus the lowest boating study flow (~500+ cfs)

California red-legged frog

For CRLF, the focus of the data collection will be to determine effects of flow on breeding habitat, including backwater and slow-water habitats with suitable substrates for oviposition, such as emergent vegetation and other plant material. Because CRLF is state and federally listed, efforts to document effects of flows on habitat for metamorphs and adults will also be included in the survey effort. A detailed methodology will be developed in coordination with Aquatics TWG members and CDFG and USFWS biologists if CRLF egg masses, tadpoles, and/or subadults/adults are found in Project-affected reaches.

Mountain yellow-legged frog
MYLF use of the Project area is not well known. Both stream-breeding populations and lake- or pond-breeding populations exist within the vicinity of the project area. As such, the study approach for MYLF will depend on what life stages are found within Project-affected reaches during the VES. If breeding is documented in stream reaches within the Project area, data collection efforts will focus on the effects of flows on breeding habitat within these streams. If only adults are documented in the stream reaches, data collection efforts will focus on the effects of flows on adult overwintering habitat (i.e., deep pools). A detailed methodology will be developed in coordination with Aquatics TWG members and CDFG and USFWS biologists if MYLF egg masses, tadpoles, and/or subadults/adults are found in Project-affected reaches.

Phase 3 – Analyze Data
- See Analysis Section below.

Test Flow surveys will be conducted in fall 2003.

4.15.7 Analysis
Data analysis will include evaluating the location and extent of suitable habitat areas at each site under various test flows, and as compared among test flows. Data analysis will be largely qualitative, with some quantitative data to compare extent of suitable habitat at each site. Analysis of photographs (both aerial and on-the-ground), and comparisons with site photographs taken during VES, will provide more insight into the distribution of suitable habitats during the breeding season, and professional judgment will be used to analyze the potential benefits of increased flows to amphibian populations.

4.15.8 Study Output

A written report including the issues addressed, objectives, description of study area and sampling locations (e.g., maps and photos), methods, results, discussion and conclusions will be prepared after field visits and analyses are complete. The report will be prepared in a format that can easily be incorporated into SMUD's and PG&E's draft environmental assessment that will be submitted to FERC with SMUD's/PG&E's application for a new license.

4.15.9 Preliminary Estimated Study Cost

A preliminary cost estimate will be prepared after the Plenary Group approves this study plan.

4.15.10 TWG Endorsement

This study plan was approved on August 26, 2003 by the following participants of the Aquatic TWG: USFS, USBLM, Camp Lotus, PG&E, SWRCB, SMUD and CDFG. No participant said they could not "live with" the study plan. The Plenary Group approved the plan on September 9, 2003. The participants a the meeting who said they could "live with" this study plan were USFS, SWRCB, NPS, CDFG, El Dorado County, Taxpayers Association of El Dorado County, Teichert Materials, ARRA/Camp Lotus, El Dorado Irrigation District, SMUD, PCWA, City of Sacramento, FOR, and PG&E. None of the participants at the meeting said they could not "live with" this study plan.

4.15.11 Literature Cited

Borisenko, A. N. and M. P. Hayes. 1999. Status of the Foothill yellow-legged frog (Rana boylii) in Oregon. Final report prepared for The Nature Conservancy under contract to the U.S. Fish and Wildlife Service. 38 pp. + appendices.

Jennings, M. R. 1988. Natural history and decline of native ranids in California. Pages 61-72 *in* H. F. DeLisle, P. R. Brown, B. Kaufman and B. M. McGurty, editor. Proceedings of the conference on California herpetology. Special Publication 4. Southwest Herpetological Society, Van Nuys, California.

Jennings, M. R., and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final Report. Prepared by California Academy of Sciences, Department of Herpetology, San Francisco and Portland State University, Department of Biology, Portland, Oregon for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Kupferberg, S. J. 1996a. Hydrologic and geomorphic factors affecting conservation of a river-breeding frog (Rana boylii). Ecological Applications 6: 1332-1344.

Kupferberg, S. J. 1996b. The ecology of native tadpoles (Rana boylii and Hyla regilla) and the impact of invading bullfrogs (Rana catesbeiana) in a northern California river. Doctoral dissertation. University of California, Berkeley.

Kupferberg, S. J. 1997. Bullfrog (Rana catesbeiana) invasion of a California river: the role of larval competition. Ecology 78: 1736-1751.

Kupferberg, S. 2003. Personal communication with Sarah Kupferberg, private consultant and expert on foothill yellow-legged frogs, by S. Khandwala and C. Champe, Stillwater Sciences, Berkeley, CA.

Reis, D.K. 1999. Habitat characteristics of California red-legged frogs (Rana aurora draytonii): Ecological differences between eggs, tadpoles, and adults in a coastal brackish and freshwater system. M.S. Thesis. San Jose State University. 58 pp.

Seltenrich, C. and A. Pool. 2002. A standardized approach for habitat assessments and visual encounter surveys for the foothill yellow-legged frog (*Rana boylii*). Pacific Gas and Electric Company.

SMUD (Sacramento Municipal Utility District). 2001. Initial Information Package for Relicensing of the Upper American River Project (FERC Project No. 2101). Sacramento, CA.

Van Wagner, T. J. 1996. Selected life-history and ecological aspects of a population of foothill yellow-legged frogs (Rana boylii) from Clear Creek, Nevada County, California. Master’s Thesis, Department of Biological Sciences, California State University, Chico. 143 pp.

Vredenberg, V. 2003. Personal communication with Vance Vredenberg, Post-doctoral student and expert on mountain yellow-legged frogs, UC Berkeley by S. Khandwala, Stillwater Sciences, Berkeley, CA.

Wentworth, C. K., 1922. A scale of grade and class terms for clastic sediments; Journal of Geology, 30: 377-392.

Wolman, G. M. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35: 951-956.

Yarnell, S. M. 2000. The influence of sediment supply and transport capacity on foothill yellow-legged frog habitat, South Yuba River, California. Masters Thesis, Department of Geology, University of California, Davis.

USFWS (U.S. Fish and Wildlife Service). 2002. Recovery Plan for the California Red-legged Frog (Rana aurora draytonii). U.S. Fish and Wildlife Service, Portland, Oregon. viii + 173 pp.

AMPHIBIAN HABITAT TEST FLOW TECHNICAL REPORT

SUMMARY

Three test flows (20, 50, and 100 cfs) were released in the Camino Dam Reach of the Upper American River Project (UARP) to assess habitat suitability and availability for foothill yellow-legged frogs. Flow levels and patterns can affect the quality of habitat for various life history stages, particularly eggs and tadpoles of this species.

The two study sites on the Camino Dam Reach had different responses to increased discharges. The Camino adit site, approximately halfway down the reach from Camino Dam, is located in a bedrock-confined portion of Silver Creek with a narrow floodplain. The SFAR confluence site is located at the mouth of Silver Creek where it joins the South Fork American River. The channel morphology at the SFAR confluence site is open, with a number of braided channels and mid-channel islands and a wide floodplain. Potentially suitable habitats were identified at the two sites as polygons, marked, and characterized under each test flow. Habitat polygon suitability was evaluated both quantitatively and qualitatively to assess: 1) changes in habitat suitability among flow levels, and 2) suitable habitat area at each discharge. Under the quantitative analysis, suitable polygons had mean depths less than 1.6 ft and mean velocities of less than 0.328 ft/s. Under the qualitative analysis (based on the professional judgment of biologists in the field), moderate and high quality polygons met the depth and velocity criteria, as well as other published habitat associations linked to foothill yellow-legged frogs, such as substrate, overhead vegetation, and emergent vegetation characteristics.

At the Camino adit site, most habitat polygons met quantitative suitability criteria under all three test flows, but qualitative assessments of the habitat suggested that potential habitat for egg deposition and tadpole rearing, while relatively similar and of moderate or high quality at 20 cfs and 50 cfs, became of low quality or unsuitable at 100 cfs. In general, depth was more responsible than velocity for the change in habitat conditions. Habitat area meeting quantitative criteria for egg deposition habitat ranged from 1,634 ft^2 to 1,943 ft^2, for discharges of 20 cfs and 100 cfs, respectively. Habitat area meeting qualitative criteria for egg deposition habitat ranged from 1,517 ft^2 to 92 ft^2, for discharges of 20 cfs and 100 cfs, respectively.

At the SFAR confluence site, quantitative and qualitative assessments of egg deposition habitat were similar and indicated that habitat area decreased with increased discharge. While it was evident that new potential habitats were created under the higher test flows, habitat area meeting suitability criteria (both quantitative and qualitative) decreased. This result suggests that while new potential habitats were being created at higher discharges (for example, previously dry side channels became inundated at 100 cfs at this site), habitats identified at 20 cfs were losing their suitability at these higher discharges.

Observations of egg deposition and tadpole rearing during 2003 visual encounter surveys occurred under flows of approximately 23 cfs. Points of observed egg masses and tadpoles during those surveys were also measured during the test flow releases, to assess how conditions at oviposition sites change under higher flows. In general, quantitative criteria at these points and other points identified as potential ovipositon and tadpole rearing locations were met at 20 cfs and 50 cfs, while flows of 100 cfs rendered those sites unsuitable for eggs and/or tadpoles, suggesting that high discharges could impact the success of egg masses that were laid at lower flows.

1.0 INTRODUCTION

This technical report is one in a series of reports prepared by Devine Tarbell & Associates, Inc., (DTA) for the Sacramento Municipal Utility District (SMUD) as an appendix to SMUD's application to the Federal Energy Regulatory Commission (FERC) for a new license for the Upper American River Project (UARP or Project). This study examines the relationship between flow and habitat suitability in the one Project Reach (Camino Dam Reach) where confirmed sightings of foothill yellow-legged frog (FYLF) have been recorded. The report includes the following sections:

- **BACKGROUND** – Summarizes the applicable study plan approved by the UARP Relicensing Plenary Group; a brief description of the issue questions addressed, in part, by the study plan; the objectives of the study plan; the study area, and agency information requests.
- **METHODS** – A description of the methods used in the study, including a listing of study sites.
- **RESULTS** – A description of the most important data results.
- **ANALYSIS** – A brief analysis of the results, where appropriate.
- **LITERATURE CITED** – A listing of all literature cited in the report.

This technical report does not include a detailed description of the UARP Alternative Licensing Process (ALP) or the Project, which can be found in the following sections of the Licensee's application for a new license: The UARP Relicensing Process, Exhibit A (Project Description), Exhibit B (Project Operations), and Exhibit C (Construction).

In addition, this technical report does not include a discussion regarding the effects of the Project on amphibians or aquatic reptiles or their habitat, nor does the report include a discussion of appropriate protection, mitigation, and enhancement (PM&E) measures. Project effects and PM&E discussions will take place within collaborative settlement group dialogues. An impacts discussion regarding the UARP is included in the applicant-prepared preliminary draft environmental assessment (PDEA) document, which is part of the Licensee's application for a new license. Development of resource measures will occur in settlement discussions, which will commence in 2004, and will be reported on in the PDEA.

The final Amphibian Habitat Test Flow Study Plan included revisions in response to review comments received from Sarah Kupferberg, a consulting amphibian specialist from U.C. Berkeley.

2.0 BACKGROUND

The UARP Aquatic Technical Working Group (TWG) developed two study plans that pertain specifically to amphibians and aquatic reptiles: (1) the Amphibians and Aquatic Reptiles Study Plan; and (2) the Amphibian Habitat Test Flow Study Plan. This report addresses the Amphibian Habitat Test Flow Study. The Amphibians and Aquatic Reptiles Study is addressed in the *Amphibians and Aquatic Reptiles Technical Report*.

2.1 Amphibian Habitat Test Flow Study Plan

On September 9, 2003, the Plenary Group approved the Amphibian Habitat Test Flow Study Plan that was developed and approved by the Aquatic Technical Working Group (TWG) on

August 26, 2003. The study plan was designed to address, in part, the following issue question developed by the Plenary Group:

Issue Question 1: Does the Project affect special-status species? If so, where and how?

Specifically, the objectives of the study were to:

- Determine where and how much suitable habitat occurs at the lowest test flow release, and how do the characteristics of that habitat change at each subsequent (increased) flow release; and
- Determine where and how much suitable habitat occurs at each of the test flows under consideration.

The study plan specified that the study area for test flow studies would be reaches in which target species (mountain yellow-legged frog, foothill yellow-legged frog, or California red-legged frog) were observed. Only FYLF were found during the Visual Encounter Surveys (VES) for amphibians and aquatic reptiles during the 2003 study season (See *Amphibians and Aquatic Reptiles Technical Report*).

2.2 Water Year Type During Study

The information in this subsection is provided in response to a request by the agencies. The derivation of water year types is described in the Water Quality Report. Table 2.1-1 presents water year types, including the period (October-November 2003) when the Amphibian Habitat Test Flow was conducted; additional information is provided for comparison.

Table 2.2-1. Water year types applied to individual months of years 2001-2004.*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2001	AN	D	D	D	D	D	D	D	D	D	D	D
2002	D	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN	BN
2003	BN	BN	BN	D	BN	BN	BN	BN	BN	BN	BN	BN
2004	BN	BN	BN	-	-	-	-	-	-	-	-	-

*CD=Critically Dry; D=Dry; BN=Below Normal; AN=Above Normal; W=Wet

2.3 Agency Requested Information

In a letter dated December 17, 2003 to the Licensee regarding content of technical reports, the agencies did not specifically address the *Amphibian Habitat Test Flows Technical Report*.

3.0 METHODS

3.1 Field Methods

3.1.1 Site Selection

As described in the study plan, the test flow study was conducted at all sites where FYLF eggs or tadpoles were observed during VES conducted within the study area, and where flow was or could be controlled by the Project. Thus, the study was conducted in the Camino Dam Reach (on Silver Creek), and specific evaluations were made at the two sites where FYLF had been observed: 1) the Camino adit site (Site C-3 of the VES); and 2) the SFAR confluence site (Site SFA-4 of the VES) (Figure 3.1-1). Although FYLF were found in the South Fork American River Reach during the 2003 VES (See *Amphibian and Aquatic Reptiles Technical Report*), no test flow study sites were selected in this reach because both El Dorado Irrigation District and SMUD impact flow and operations within this reach, and there is a relatively large influence from uncontrolled runoff. No sites were selected in the Reach Downstream of Chili Bar because FYLF were not observed at any of the study sites in that reach. Basic characteristics of the study sites are described in Table 3.1-1 below.

Table 3.1-1. Study site characteristics for Amphibian Test Flow Study in 2003.

Site name	Location	GPS coordinates*		Habitat description
		Upstream end	Downstream end	
Camino adit	Silver Creek, downslope from an adit of the Camino Powerhouse Tunnel	0710153 E 4298592 N	0710244 E 4298645 N	Mostly bedrock and boulder, with some seeps and widening of channel along right bank. Left bank steep and vegetated, with very little suitable habitat for FYLF. Data were collected along right bank.
SFAR confluence	Silver Creek, 300 m upstream of confluence with SF American River	0709896 E 4296012 N	0709456 E 4296024 N	Open area near mouth with multiple channels, and a large mid-channel island. Substrate cobble, boulder, and bedrock. Data collection effort was focused along the right and left banks upstream of split channel, with only cursory observations along island margins, where habitat was generally of lower quality.

**Datum = NAD27*

Discharge conditions experienced by FYLF during the past water year in the Camino Dam Reach are depicted in Figure 3.1-2. Because the dataset for the Camino Dam Reach is incomplete, discharge conditions in the South Fork American River Reach are presented in Figure 3.1-3. Approximate timing of egg-laying, tadpole rearing, and metamorphosis are shown in the figures to illustrate timing and corresponding discharge, based on observations in 2003.

3.1.2 Field Crew Training

Datasheets (See Appendix A) were developed and reviewed by Jann Williams of the Forest Service and Dr. Sarah Kupferberg, a consultant to the Forest Service, prior to a field crew training session. Because there was a degree of subjective data collection for this study, all field crew members were trained together at a single site, so that the collected data could be analyzed and compared between sites. Datasheets were explained and used during the field training session. Ms. Williams and Dr. Kupferberg were in attendance at the field training session and provided input to the field methods and completion of datasheets.

3.1.3 Data Collection

Three flows (20 cfs, 50 cfs, and 100 cfs) were released from Camino Dam on October 28–30, 2003, and November 19, 2003. The survey of 100 cfs at the SFAR confluence site had to be postponed until November because of site access difficulties. Round Tent Creek enters Silver Creek just below Camino Dam and six ephemeral streams enter Silver Creek upstream of the Camino adit site; one additional ephemeral tributary enters before the SFAR confluence site. Accretion in this reach was minimal during the time of study. Water releases from Camino Dam began approximately four hours prior to beginning fieldwork to ensure that consistent and stable flows were present at both sites. Flow releases were conducted after the breeding stage of FYLF was completed, to limit any potential negative effects on amphibian populations in the study area.

Data collection focused on the effects of flows on breeding habitat (egg-laying and tadpole-rearing), as adults typically summer and overwinter in tributaries. Data collection focused on measurable habitat variables known to be important to FYLF, as described in Table 3.1-2 below. If available, data collected during the VES were used for comparison purposes, and data collected during the test flow study used the same methods of collection employed during the VES. Data were also collected for juvenile and adult habitat. The same survey team collected the data at a given site for each of the test flows to ensure continuity in data collection efforts.

3.1.3.1 Polygon Measurements

Suitable habitat polygons were identified based on previous experience and observations of egg deposition and tadpole rearing locations at the site, literature review, expert opinion, and professional judgment (see Table 3.1-2).

Table 3.1-2. Habitat characteristics generally associated with foothill yellow-legged frog.	
Habitat parameter	**FYLF habitat associations**
depth and velocity	▪ eggs typically laid in <40 cm water depth, <10 cm/sec water velocity (Seltenrich and Pool 2002) ▪ adult females prefer plunge pools in a small stream (Van Wagner 1996) ▪ on the South Yuba River deep, channelized stream habitats were used by adults (Yarnell 2000, as cited in Seltenrich and Pool 2002) ▪ eggs laid in the South Fork Eel River varied in depth from 4 to 43 cm, with an average depth 19.7 cm (Kupferberg 1996a); average velocities at oviposition sites were 0.1 ft/s (3.2 cm/s) ▪ metamorph and post-metamorphs were associated with a low flow water velocity of 0.04 m/s (0.14f/s) ± 0.09 m/s (0.28 f/s) that was adjacent to water of intermediate to fast flow velocities (Borisenko and Hayes 1999)
water temperature	▪ majority of egg laying follows high flow discharge in spring (March – early June) at water temperatures of approximately 12-15°C (Seltenrich and Pool 2002) ▪ oviposition commenced when water temperatures reached approximately 54° F (12 °C) on South Fork Eel River (Kupferberg 1996a)
gradient	▪ eggs and tadpoles typically found along gently-sloping banks (Kupferberg 1996a, Borisenko and Hayes 1999)
substrate composition	▪ cobble and boulder substrates most common for egg laying, but also use bedrock and pebbles; eggs usually laid on bare/clean rock surfaces; females will scrape rocks clean if necessary (Jennings and Hayes 1994, Kupferberg, pers. comm., 2003)
distance from shore	▪ eggs are laid relatively close to shore – typically < 5 m from the water's edge (Kupferberg 1996a)
emergent vegetation cover	▪ tadpoles require aquatic cover to escape predation (Jennings and Hayes 1994)
adjacent riparian vegetation	▪ low to moderate shade for adult and juvenile habitats ▪ breeding habitats located away from overhead cover (Seltenrich and Pool 2002) along open, sunny stream margins
presence/abundance of algae, macroinvertebrates, and predators	▪ algae and/or diatoms required for tadpoles, juveniles; adult diet includes aquatic and terrestrial invertebrates (Kupferberg 1996a, b) ▪ introduced bullfrogs, crayfish and fishes are significant egg and tadpole predators (Kupferberg 1997)

There was no minimum size that determined a polygon. Once a suitable habitat polygon was identified, markers (colored plastic flagging tied around metal weights or rocks) were placed to delineate its boundaries and the polygon was given a unique number. Photographs were taken from various angles and logged. Representative photographs of the sites can be found in Appendix B. Physical habitat within each polygon was characterized by the parameters described in Table 3.1-3. In addition, each polygon was assigned a qualitative rating of high, moderate, or low for suitability by life stage (egg, tadpole, and juvenile/adult) under each flow. High quality habitats met criteria for depth and velocity described in Table 3.1-2, and contained suitable substrates and vegetation cover and were generally close to shore. Moderate quality habitats met the depth and velocity criteria but did not have suitable substrates or vegetation cover, and/or were not close to shore. Low quality habitats met either the depth or velocity criteria and may or may not have met substrate or overhead vegetation criteria.

Table 3.1-3. Physical habitat parameters measured/estimated for each polygon.	
Parameter	**Method of measurement**
shape of polygon	--
length, width and diameter measurements	meter tape
average depth and velocity	3 measurements of depth and velocity (60% depth and surface) were obtained using a Marsh McBirney Flo-Mate meter at randomly selected locations within the polygon
water temperature	thermometer
substrate composition	percent sand, gravel, cobble, boulder, and bedrock were estimated using a Wentworth scale
distance from shore	perpendicular distance from center of polygon to shore was measured with a meter tape
distance to riparian vegetation	perpendicular distance from center of polygon to riparian vegetation was measured using a meter tape
riparian vegetation cover composition	percent open, tree (>2 m height), shrub (<2 m height), grass/sedge, and woody debris cover were estimated visually
emergent vegetation cover	percent emergent vegetation (grouped, not by species) within the polygon was estimated visually
presence of overhangs and interstices	noted as present or not present based on visual inspection

The shape of the polygon and the length and width measurements were later used to estimate the area encompassed within the polygon. Distance from shore was used to assess the position of the polygon within the channel and distance to riparian vegetation was used to assess potential access to basking and cover sites for adults and juveniles. Emergent and overhanging vegetation was evaluated as it existed during the study period, and did not necessarily represent the condition: 1) during the spring season when egg-laying generally occurs; or 2) under a sustained higher flow regime that would likely cause some dieback of rooted vegetation. Relevant notes on these conditions were made in the field and considered during the analysis. For example, at 100 cfs, many near-bank surfaces previously dry became inundated. Polygons identified in this newly inundated area often included large trees or shrubs. The habitat quality was evaluated based on the assumption that some dieback of vegetation would occur before the habitat would be useable.

Polygons of suitable habitat were identified under the lowest flow (20 cfs) and characterized according to the habitat parameters described in Table 3.1-2. At each subsequently higher flow, depth, velocity, and distance from shore were re-measured to later compare change in habitats identified under 20 cfs flows. For example, if Polygon 1 was identified under 20 cfs, depth and velocity and distance from shore data would be collected for this same polygon under 50 and 100 cfs as well. Repeat measurements at 100 cfs of polygons identified at 50 cfs flow were also conducted.

In addition, new polygons of suitable habitat were identified under 50 cfs and 100 cfs test flows. These new polygons were also characterized according to the habitat parameters described in Table 3.1-2. In some cases, these new polygons overlapped with a polygon identified the previous day (i.e., the previously-identified polygon became unsuitable in a portion of its delineated habitat area). In other cases, new habitat became available (i.e., when dry areas become inundated) under the higher flow, and these habitat patches were identified as new polygons.

Thus, each subsequent mapping effort after the lowest baseflow (20 cfs) involved both: 1) taking measurements at the habitat polygons mapped at the previous (and lower) test flow; and 2) identifying habitat polygons that became available under the new test flow. This concept is summarized below in Table 3.1-4.

Table 3.1-4. Data collected under each test flow release.

Test Flow	**Location of data collection**	**Factors to be assessed**[1]
20 cfs	suitable habitat (polygons) at 20 cfs release	Polygon Parameters (Table 3)
50 cfs	polygons considered suitable habitat at 20 cfs release	subset of Polygon Parameters[1]
	new suitable habitat (polygons) at 50 cfs release	Polygon Parameters (Table 3)
100 cfs	polygons considered suitable habitat during 20 cfs and 50 cfs release	subset of Polygon Parameters[1]
	new suitable habitat at 100 cfs	Polygon Parameters (Table 3)

1 The subset of parameters measured included depth and velocity and distance from shore. The subset did NOT include shape, length and width, water temperature, substrate composition, emergent vegetation cover, and adjacent riparian vegetation measurements because these did not change for the polygon with increased flows.

At the site level, the gradient was measured using an auto level and stadia rod at the SFAR confluence site. The Camino adit site coincides with a geomorphology study site (see *Geomorphic Study Technical Report*) and more specific estimates of gradient were obtained from that study. Presence and abundance of algae and potential predators (fish, birds, and reptiles) were also noted.

3.1.3.2 Oviposition and Tadpole Rearing Point Measurements

Known egg mass deposition and tadpole rearing points based on observations during the VES earlier in the season (Table 3.1-5), as well as potential egg mass deposition points, were identified at the 20 cfs baseflow. Potential egg mass deposition points were identified using data collected during the VES study, data available from the scientific literature, and professional judgment of the biologists in the field. The sites were typically located under bedrock and boulder overhangs. Depth and velocity measurements were made at each of these points and the point was marked. Repeat measurements of depth and velocity at these points were made at each subsequent flow. Potential oviposition sites were identified at the 20 cfs flow only. The purpose of this study was not to determine suitable points for oviposition or tadpole rearing at each flow, but rather to document how points identified at the baseflow change at higher flows.

Table 3.1-5. Egg masses and tadpoles at test flow study sites observed during VES.

Site	Survey date	Discharge[1] (cfs)	Comments
EGG MASSES			
Camino adit (C-3)	6/11/03	22	• Underneath a large boulder in a small backwater pool. • Predominantly bedrock substrate.
TADPOLES			
Camino adit (C-3)	8/7/03	22	• Five separate locations of tadpoles, ranging from 2 to 10 individuals
SFAR confluence (SFA-4)	8/16/03	23	• Two separate groups of tadpoles, ranging from 2 to 36 individuals

[1] As reported at USGS gage 11441900 at Camino Dam for the survey date.

3.2 Analytical Methods

As described in the study plan, data analysis entailed evaluating the location and extent of suitable habitat areas at each site under various test flows, and comparing test flows. To more fully capture the concept of habitat suitability for FYLF, suitable habitat was defined in the analysis in two different ways: quantitatively and qualitatively.

- In the quantitative assessment, a polygon was defined as suitable if it met the following depth and velocity criteria: depth less than 1.6 ft and velocity less than 0.328 ft/s. These criteria encompass a wide range of conditions, based on liberal estimates of measured depth and velocity at egg deposition and tadpole rearing locations (i.e., the values are considerably greater than the highest measured value at the site and/or in the scientific literature) (Seltenrich and Pool 2001, Kupferberg 1996a). In the quantitative assessment, a polygon was defined as either suitable (if it met both the velocity and depth criteria) or unsuitable (if it did not meet one or both criteria).

- In the qualitative assessment, each polygon was evaluated based on the professional judgment of the biologists in the field (2–4 people, depending on the day) considering the various habitat parameters listed in Table 3.1-2, such as substrate characteristics, distance from shore, and adjacent riparian vegetation. In the qualitative assessment, a polygon was defined as high, medium, or low quality, or unsuitable. The criteria used to give these designations are summarized in Section 3.1.3.1.

Quantitative measurements of depth and velocity taken at each test flow at polygons identified under the lowest test flow were compared using a single factor analysis of variance (ANOVA) to test whether mean depth and velocity evaluated over the three discharges differed significantly within a polygon.

Observed and potential oviposition and tadpole rearing points were evaluated based on the quantitative criteria listed above (depth less than 1.6 ft and velocity less than 0.328 ft/s). Points out of this range were considered unsuitable.

In order to estimate area of each polygon, simple geometric formulas for the area of circles, squares, ovals, and triangles were applied to each polygon. In some cases, estimates of the degree of overlap were made to prevent underestimating area for polygons identified under the 50 or 100 cfs flows.

4.0 RESULTS

The relationships among discharge volume and the variables measured in this flow study are extremely site specific. The effect of discharge fluctuation on near-shore current velocity and direction, depth, and vegetation inundation, are determined by a complex set of factors including the site's cross-sectional and longitudinal geometries, substrate, and vegetation. Additionally, FYLF are known to utilize breeding sites where the suitability variables are less sensitive to changes in discharge relative to surrounding reaches of river. Therefore, data from the two sites on Camino Dam Reach cannot be extrapolated to the whole reach or other sections of river. The results are presented in four sections below: 1) site and habitat characteristics; 2) changes in habitat suitability from the lowest flow to each higher flow; 3) oviposition and tadpole rearing point analysis; and 4) habitat area available at each of the test flows.

4.1 Site and Habitat Characteristics

Site characteristics are summarized in Table 4.1-1 below. Similar areas and bank lengths were evaluated at the two sites.

Table 4.1-1. Site habitat characteristics.

Site	Reach length (ft)	Average site width (ft)	Gradient (percent)	Habitat area identified during 20 cfs flow (square feet)
Camino adit	325	17	1.59	1,979
SFAR confluence	94 (left bank) 246 (right bank)	LB 10 RB 25	2.45	2,236

In general, habitat polygons were contiguous along the study reach. The distribution of polygons is summarized in Figures 4.1-1 and 4.1-2 and Table 4.1-2. Photographs of representative polygons from each site are given in Appendix B.

Table 4.1-2. Number of polygons evaluated at each flow.

Site	20 cfs	50 cfs	100 cfs
Camino adit	17 polygons	30 polygons (13 additional polygons identified at this flow)	35 polygons (5 additional polygons identified at this flow)
SFAR confluence	14 polygons	26 polygons (12 additional polygons identified at this flow)	34 polygons (8 additional polygons identified at this flow)

Habitat characteristics of the polygon are summarized in Appendix C. Mean values are summarized in Tables 4.1-3 and 4.1-4. Polygons identified at the Camino adit site were mostly comprised of bedrock substrate, with some boulder and cobble. Polygons identified at the SFAR confluence site were mostly (approximately 50 percent) comprised of boulder, with some cobble (approximately 17 percent). Polygons identified at 20 and 50 cfs contained approximately 10 to 15 percent more bedrock than those identified at 100 cfs. Polygons at both sites were mostly (over 60 percent) open, with little overhead cover. If cover was present, it was provided by trees and grasses. Emergent vegetation was present in many of the polygons, but generally comprised less than 15 percent of the polygon. In general, overhead vegetation and emergent vegetation were greater during the test flow study than during VES conducted earlier in the season.

Table 4.1-3. Site habitat substrate characteristics.

Site	Mean percentage of substrate type[1]				
	Sand	Gravel	Cobble	Boulder	Bedrock
Camino adit overall	3	3	17	27	50
polygons identified at 20 cfs	3	3	16	24	54
polygons identified at 50 cfs	5	5	16	28	46
polygons identified at 100 cfs	0	0	21	34	45
SFAR confluence overall	2	4	21	62	11
polygons identified at 20 cfs	0	4	16	63	16
polygons identified at 50 cfs	0	3	13	74	10
polygons identified at 100 cfs	8	6	43	43	1

[1] sand <2 mm; gravel 2-64 mm (approx. up to 2.5 inches); cobble 65-256 mm (approx. up to 10 inches); boulder >256 mm

Table 4.1-4. Site habitat vegetation characteristics.

Site	Mean percentage of overhead cover[1]						Percent emergent vegetation
	Open	Tree	Shrub	Grass	Woody	Other	
Camino adit overall	**68**	**21**	**2**	**8**	**0**	**1**	**14**
polygons identified at 20 cfs	83	12	0	2	0	2	5
polygons identified at 50 cfs	50	33	5	13	0	0	27
polygons identified at 100 cfs	54	28	2	16	0	0	14
SFAR confluence overall	**62**	**14**	**7**	**13**	**0**	**4**	**9**
polygons identified at 20 cfs	70	6	4	16	0	5	7
polygons identified at 50 cfs	66	5	9	13	0	7	8
polygons identified at 100 cfs	42	41	9	8	1	0	16

[1] tree = vegetation > 2 m, shrub = vegetation < 2 m, grass = grasses and sedges, woody = woody debris, and other = bedrock overhang, or boulders

4.2 Changes in Habitat Suitability From the Lowest Flow to Each Higher Flow

This section evaluates the suitability of habitat polygons identified at the 20 cfs flow, and how these polygons changed under the higher flow releases (Study Objective 1, Section 2.1).

Depth and velocity were measured at three randomly selected points in each polygon identified as potentially suitable for egg deposition or tadpole rearing (Table 4.2-1). Some polygons were excluded from this table because depth and velocity measurements were not taken at 20 cfs because of time constraints. These excluded polygons are treated below in the qualitative analysis. At the Camino adit site, only two polygons (from a total of 11 polygons) exhibited a significant difference ($p<0.05$) among depth or velocity measurements taken under each test flow based on ANOVA tests. At the SFAR confluence site, three polygons (from a total of 11 polygons) exhibited significantly different ($p<0.05$) water velocities and two different polygons exhibited significant differences in mean depth. In general, depths and velocities at polygons identified under 20 cfs increased under the 50 and 100 cfs flows at both sites, but in most cases the increases were not statistically significant, due in part to the variation among the three measurements taken under a given flow (i.e., there was frequently more variation within polygons than between flows).

Table 4.2-1a. Mean depth and velocity of polygons identified at the 20-cfs flow at the Camino adit site.

Polygon	n	Mean Depth (ft)				Mean Velocity (ft/s)			
		20 cfs	50 cfs	100 cfs	sig.[1]	20 cfs	50 cfs	100 cfs	sig.[1]
1	3	0.880	1.500	1.300		0.146	0.237	0.013	
2	3	0.340	0.667	1.033	**	0.000	0.000	0.030	
3	3	0.600	0.600	1.067		0.060	1.050	0.393	
4	3	0.600	1.333	1.433		0.097	0.193	0.203	
8	3	1.525	2.067	2.075		0.000	0.037	0.020	
10	3	0.700	1.300	1.067		0.000	0.020	0.003	
11	3	1.250	2.033	1.833		0.000	0.013	0.080	
12	3	0.350	1.100	0.733		0.003	0.073	0.113	**
14	3	1.075	1.133	1.533		0.215	0.757	0.130	
18	3	0.980	1.300	0.700		0.138	0.137	0.080	
21	3	0.500	0.467	0.733		0.037	0.047	0.070	

[1] * = significant difference between flows at $p\leq0.10$; **=significant difference between flows at $p<0.05$

Table 4.2-1b. Mean depth and velocity of polygons identified at the 20-cfs flow at the SFAR confluence site.

Polygon	n	Mean Depth (ft)				Mean Velocity (ft/s)			
		20 cfs	50 cfs	100 cfs	sig.[1]	20 cfs	50 cfs	100 cfs	sig.[1]
1	3	0.720	1.200	1.500	*	0.142	0.461	0.633	
2	3	0.880	0.900	1.233		0.309	0.333	0.719	
4	3	0.680	0.933	1.500	**	0.032	0.161	1.963	*
6	3	0.780	0.967	1.133		-0.026	0.193	1.813	
8	3	1.060	2.500	1.100	**	0.013	0.000	0.193	
9	3	0.580	0.967	1.733		0.135	0.215	1.845	**
10	3	1.320	1.533	1.800		0.077	0.064	1.137	**
12	3	0.680	0.867	1.300		0.019	0.290	1.394	
13	3	1.040	1.367	1.533		0.071	0.150	1.448	**
14	3	0.900	1.500	1.300		0.019	0.086	0.268	*
15	3	1.060	0.833	1.400		0.006	0.247	1.888	

[1] * = significant difference between flows at $p\leq0.10$; **=significant difference between flows at $p<0.05$

The suitability of polygons identified at 20 cfs was also assessed, using both quantitative and qualitative measures (see Section 3.2 above). Table 4.2-2 lists the polygons identified at the 20 cfs flow that supported breeding or tadpole rearing habitat and indicates whether the polygon met the quantitative criteria (depth less than 1.6 ft and velocity less than 0.328 ft/s), and how they were rated qualitatively as egg and tadpole habitat. Only polygons identified as potentially supporting egg and/or tadpole habitat are presented in Table 4.2-2, because this was the focus of the data collection efforts (there were no quantitative suitability criteria identified for juvenile and adult habitat).

Table 4.2-2a. Habitat suitability for egg deposition and tadpole rearing for polygons identified at the 20-cfs flow at the Camino adit site.

	Quantitative criteria (depth and velocity)[1]			Qualitative rating[2]					
				Egg			Tadpole		
Polygon	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs
1	*	*	*	M	L	N	M	L	N
2	*	*	*	N	M	N	N	M	N
3	*	-	-	L	M	N	L	M	N
4	*	*	*	M	M	N	M	M	N
8	*	-	-	H	N	N	H	H	N
10	*	*	*	H	N	N	H	M	M
11	*	-	-	H	H	N	H	H	M
12	*	*	*	H	M	N	H	M	N
14	*	-	*	H	M	N	H	N	N
18	*	*	*	H	M	N	H	N	N
21	*	*	*	L	N	N	H	L	L
TOTAL[3]	**11**	**7**	**8**	**8**	**7**	**0**	**9**	**7**	**2**

[1] * = meets criteria of depth < 1.6 ft and velocity < 0.328 ft/s
- = velocity and/or depth do not meet criteria

[2] H = high quality habitat and meets most of the criteria in Table 3.1-2 for this life stage; M = moderate quality habitat and meets some of the criteria in Table 1 for this life stage; L = low quality habitat and meets few of the criteria in Table 3.1-2 for this life stage; and N = not useable by this life stage.

[3] Total number of polygons meeting the quantitative criteria or are of moderate or high quality for the qualitative rating.

Using the quantitative (depth/velocity) criteria, the suitability of most polygons identified under the 20 cfs flow either remained constant or became unsuitable under an increased flow (i.e., a polygon deemed suitable at 20 cfs, and then unsuitable at 50 cfs, remained unsuitable at 100 cfs). In some cases, however, a polygon "re-gained" suitability at the highest test flow. This is true of Polygon 14 at the Camino adit site and Polygon 8 at the SFAR confluence site (Table 4.2-2). Polygon 14 at the Camino adit site did not meet the velocity criteria under the 50 cfs flow. Microscale flow patterns can affect velocity and may explain this result. Likewise, at the SFAR confluence site, Polygon 8 did not meet the depth criteria under the 50 cfs flow. Notes on the datasheet indicate that randomly selected points for this polygon under the 50 cfs flow over-represented the deeper and less suitable portions of the polygon.

Table 4.2-2b. Habitat suitability for egg deposition and tadpole rearing for polygons identified at the 20-cfs flow at the SFAR confluence site.

	Quantitative criteria (depth and velocity)[1]			Qualitative rating[2]					
				Eggs			Tadpoles		
Polygon	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs
1	*	-	-	H	L	L	H	L	L
2	*	-	-	M	M	L	M	M	L
4	*	*	-	M	M	L	M	M	L

Table 4.2-2b. Habitat suitability for egg deposition and tadpole rearing for polygons identified at the 20-cfs flow at the SFAR confluence site.

	Quantitative criteria (depth and velocity) [1]			Qualitative rating[2]					
				Eggs			Tadpoles		
Polygon	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs	20 cfs	50 cfs	100 cfs
6	*	*	-	H	H	L	H	H	L
8	*	-	*	H	M	M	H	M	M
9	*	*	-	L	L	N	L	L	N
10	*	*	-	H	L	L	H	L	L
12	*	*	-	M	L	N	M	L	N
13	*	*	-	M	L	L	M	L	L
14	*	*	*	M	L	L	M	L	L
15	*	*	-	M	M	L	M	M	L
TOTAL[3]	**11**	**8**	**2**	**10**	**5**	**1**	**10**	**5**	**1**

1 * = meets criteria of depth < 1.6 ft and velocity < 0.328 ft/s
- = velocity and/or depth do not meet criteria

2 H = high quality habitat and meets most of the criteria in Table 3.1-2 for this life stage; M = moderate quality habitat and meets some of the criteria in Table 1 for this life stage; L = low quality habitat and meets few of the criteria in Table 3.1-2 for this life stage; and N = not useable by this life stage.

3 Total polygons meeting the quantitative criteria or are of moderate or high quality for the qualitative rating.

4.3 Oviposition and Tadpole Rearing Point Analysis

VES conducted in spring and summer 2003 documented egg mass and tadpole rearing locations at both sites, as summarized in Table 3.1-5 above. Actual locations where egg masses or tadpoles were observed during VES were marked and measured under the various test flows, although no egg masses had been documented at the SFAR confluence site.

The point analysis was used to supplement the polygon analysis described in Section 4.2. Because oviposition and tadpole rearing points were only identified under the lowest test flow, the results presented here do not reflect the number or distribution of oviposition or tadpole rearing points under the three flow levels. Instead, this analysis demonstrates how the habitat characteristics of points selected at 20 cfs can change as discharge increases. The identification of these points was not exhaustive. Priority was placed on observed oviposition and tadpole rearing points from earlier surveys, as well as identifying potential points in the highest quality polygons.

Table 4.3-1a. Depth and velocity at each flow at observed and potential egg mass and tadpole rearing locations at the Camino adit site.

Point[1]	Depth (ft)				Velocity (ft/s)			
	20 cfs	50 cfs	100 cfs	spring 2003	20 cfs	50 cfs	100 cfs	spring 2003
A (t)	0.6	0.9	1.5	0.7	0.00	0.00	0.07	0.00
B (t)	0.6	1.2	1.5	1.0	0.00	0.00	0.00	0.00
C (t)	1.5	1.8	2.0	1.5	0.00	0.00	0.00	0.00
D (t)	0.8	1.4	1.8	0.7	0.00	0.08	0.46	0.00
12*	0.6	1.0	1.5	-	0.00	0.15	0.00	-
14*	0.7	1.6	1.7	-	0.01	0.50	1.08	-
16*	1.1	1.2	1.5	-	0.03	0.05	0.00	-

Table 4.3-1a. Depth and velocity at each flow at observed and potential egg mass and tadpole rearing locations at the Camino adit site.

Point[1]	Depth (ft)				Velocity (ft/s)			
	20 cfs	50 cfs	100 cfs	spring 2003	20 cfs	50 cfs	100 cfs	spring 2003
E (e)	1.5	1.9	2.5	0.9	0.00	0.11	0.16	0.05
F (t)	0.5	0.8	1.3	1.5	0.00	0.03	0.20	0.00

[1] Points marked with an asterisk (*) were identified as potential ovipositon points by the field biologists at 20 cfs. Point without an asterisk are points at which egg masses (e) or tadpoles (t) were observed during VES in spring 2003.

Table 4.3-1b. Depth and velocity at each flow at observed and potential egg mass and tadpole rearing locations at the SFAR confluence site.

Point[1]	Depth (ft)				Velocity (ft/s)			
	20 cfs	50 cfs	100 cfs	spring 2003	20 cfs	50 cfs	100 cfs	spring 2003
1A*	0.8	0.8	1.5	-	0.36	0.43	3.61	-
1B*	0.8	1.1	1.5	-	0.10	0.10	0.07	-
1C*	1.2	1.4	1.8	-	0.10	0.20	0.03	-
2A*	1.1	1.2	1.7	-	0.03	0.39	1.54	-
2B*	1.1	0.9	1.6	-	0.13	0.07	0.07	-
2C*	1.3	1.4	1.9	-	0.16	0.07	0.23	-
4A*	1.1	1.2	1.8	-	0.07	0.13	1.97	-
4B*[2]	1.2	1.5	-	-	0.07	0.03	-	-
6A*	0.9	1.3	1.6	-	0.00	0.00	0.03	-
6B*	1.0	0.9	1.8	-	0.00	0.03	1.31	-
6C*	0.7	1.3	1.6	-	0.00	0.00	0.30	-
8A*	0.7	0.3	1.5	-	0.00	0.07	0.00	-
8B (t)	0.6	1.6	2.0	0.6	0.00	0.03	0.00	0.00
10A (t)	1.1	2.7	2.4	1.3	0.00	0.07	0.66	0.00
10B*	1.5	2.0	2.3	-	0.00	0.16	0.49	-

[1] Points marked with an asterisk (*) were identified as potential ovipositon points by the field biologists at 20 cfs. Points without an asterisk are points at which egg masses (e) or tadpoles (t) were observed during VES in spring 2003.
[2] The marker at Point 4B washed away at 100 cfs and thus no measurement was taken under this flow.

Figures 4.3-1 and 4.3-2 depict the depth-velocity relationship of these oviposition and tadpole rearing points under each test flow. Nine points were identified during the 20 cfs flow at the Camino adit site, six of which were actual oviposition or tadpole rearing locations, and 15 points were identified at the SFAR confluence site, two of which were actual tadpole rearing locations.

Of the nine points identified at the Camino adit site, four points became unsuitable (on the basis of depth/velocity criteria) at either the 50 cfs or the 100 cfs flow (Figure 4.3-1). In general, water velocity remained relatively consistent over the various test flows, but water depth increased at higher discharges. Of the 15 points identified at the SFAR confluence site, nine became unsuitable (on the basis of the depth/velocity criteria) at either the 50 cfs or the 100 cfs flow (Figure 4.3-2). In general, most of the points remain within "suitable" depth and velocity at 20 cfs and 50 cfs, but became unsuitable at 100 cfs, although some points remained suitable at 100 cfs.

4.4 Habitat Area Available at Each Test Flow

This section evaluates the differences in amount and suitability of habitat area among the three test flow levels (Study Objective 2, Section 2.1). Habitat area was assessed for each site based on suitability of the polygons at the site for each life history stage under each test flow. Habitat area was analyzed quantitatively and qualitatively. Each polygon was first identified as having egg, tadpole, and/or juvenile/adult habitats present in the polygon.

4.4.1 Quantitative Assessment

The total area meeting quantitative criteria (average depth less than 1.6 ft and average velocity less than 0.328 ft/s) under each of the test flows is presented in Table 4.4-1. This analysis includes only polygons that were identified as having egg and tadpole habitats. The habitat area totals presented in Table 4.4-1 are cumulative (i.e., the habitat area at 50 cfs includes polygons identified at 20 cfs still meeting the quantitative criteria, in addition to polygons identified at 50 cfs also meeting the quantitative criteria).

Table 4.4-1a. Habitat area meeting quantitative criteria at the Camino adit site.

Flow (cfs)	No. of polygons evaluated	Total area (ft^2) of polygons with egg and/or tadpole habitat	Area meeting quantitative criteria[1] (ft^2)
20	11	1,634	1,634
50	24	2,359	1,592
100	29	2,375	1,943

[1] Meets criteria of depth < 1.6 ft and velocity < 0.328 ft/s

Table 4.4-1b. Habitat area meeting quantitative criteria at the SFAR confluence site.

Flow (cfs)	No. of polygons evaluated	Total area (ft^2) of polygons with egg and/or tadpole habitat	Area meeting quantitative criteria[1] (ft^2)
20	11	1,877	1,877
50	21	1,608	1,486
100	27	2,325	1,324

[1] Meets criteria of depth < 1.6 ft and velocity < 0.328 ft/s

At the Camino adit site, habitat area meeting the quantitative criteria for egg deposition and tadpole rearing habitat decreased from 1,634 ft^2 at 20 cfs to 1,592 ft^2 at 50 cfs, and then increased to 1,943 ft^2 at 100 cfs. At the SFAR confluence site, habitat area meeting the quantitative criteria for egg deposition and tadpole rearing habitat decreased from 1,877 ft^2 at 20 cfs to 1,324 ft^2 at 100 cfs.

Mean depth and velocity for polygons identified at each of the flows is presented in Figures 4.4-1 and 4.4-2. At the Camino adit site, mean depth changes more dramatically than mean velocity. At the SFAR confluence site, mean velocity increases at a faster rate than mean depth, although both show an increasing trend as discharge increases.

4.4.2 Qualitative Assessment

Table 4.4-2 summarizes the total area of moderate or high quality habitat for egg deposition, tadpole rearing, and juveniles and adults. Many polygons demonstrated potential habitat for multiple life history stages, and therefore habitat area values presented in Table 4.4-2 are not mutually exclusive in the egg, tadpole, and juvenile/adult categories.

Table 4.4-2a. Habitat area meeting qualitative criteria for each life history stage at the Camino adit site.

Flow (cfs)	No. of polygons evaluated	Total area (ft^2) of polygons with egg, tadpole, and/or juvenile/adult habitat	Area (ft^2) meeting qualitative criteria [1]		
			Egg	Tadpole	Juv/Adult
20	17	1,979	1,517	1,675	1,683
50	30	2,601	1,646	1,369	2,035
100	35	2,720	92	562	478

[1] Includes moderate and high quality habitats identified during field studies

Table 4.4-2b. Habitat area meeting qualitative criteria for each life history stage at the SFAR confluence site.

Flow (cfs)	No. of polygons evaluated	Total area (ft^2) of polygons with egg, tadpole, and/or juvenile/adult habitat	Area (ft^2) meeting qualitative criteria [1]		
			Egg	Tadpole	Juv/Adult
20	14	2,236	1,673	1,673	358
50	26	2,908	1,481	1,249	1,300
100	34	4,069	1,247	1,563	1,718

[1] Includes moderate and high quality habitats identified during field studies

Note that the total possible area (third column of Tables 4.4-1 and 4.4-2) presented in the tables above is different for the quantitative and qualitative assessments at any given site. During the 20 cfs flow, only qualitative assessments of some polygons were obtained (i.e., no depth or velocity measurements were taken) due to time constraints at the Camino adit site. Thus, these polygons are not included in the quantitative analysis, but are included here in the qualitative analysis, resulting in separate amounts of total possible area analyzed.

Juvenile and adult habitat is included only in the qualitative analysis. Because depth and velocity criteria (quantitative criteria) were based on suitability for egg deposition and tadpole rearing, habitat polygons that were deemed suitable for only juvenile and adult frogs were not considered in the quantitative analysis. In addition, the focus of the data collection effort was on egg deposition and tadpole rearing habitats, and juvenile and adult habitats were identified only when they were part of the contiguous reach being assessed. For example, at the SFAR confluence site, the mid-channel island was ignored because it supported little habitat for egg-laying or tadpole rearing. Although not mapped or evaluated, this habitat was suitable for juveniles and adults. Thus, the habitat area for juveniles and adults is comprehensive for the reach surveyed (Figures 4.1-1 and 4.1-2), but not for the site as a whole.

At the Camino adit site, the total area of habitat meeting qualitative criteria for egg deposition and tadpole rearing was similar at 20 and 50 cfs (Table 4.4-2a), but decreased substantially at 100 cfs. Habitat area of moderate and high quality for juveniles and adults increased by approximately 300 ft^2 at 50 cfs, and then decreased substantially at 100 cfs.

At the SFAR confluence site, the qualitative assessment indicated that total habitat area for egg deposition decreased as flow increased. Total habitat area for tadpoles decreased at 50 cfs, and then increased at 100 cfs to a level similar to that at 20 cfs. Juvenile and adult habitat increased as flows increased.

5.0 ANALYSIS

This study focuses on the effect of flow on area of suitable habitat. Suitability was defined as: 1) quantitatively by depth and velocity criteria, and 2) qualitatively by assessing factors such as substrate, and emergent and overhead vegetation, in addition to depth and velocity. Because the understanding of Sierran populations of FYLF is still growing, the definition of habitat suitability is evolving. The results below are therefore not only site-specific, but also specific to the criteria used in this evaluation.

It might be assumed that the area of suitable habitat is positively related to FYLF population levels—that is, that habitat, particularly breeding and tadpole rearing habitat, is limited or perhaps limiting the population. However, relationships between FYLF populations and suitable habitat area are particularly unclear when populations are small. For example, there were a number of VES study sites that appeared to have suitable habitat, but no FYLF were observed. Our observations of juveniles and adults at these two study sites numbered less than 9 on any given visit (both sites were surveyed three times). The VES study and other studies in the vicinity (*Amphibian and Aquatic Reptiles Technical Report*; S. Hoover, pers. comm., 2003) suggest that FYLF population sizes in the area are small, and study results should be interpreted accordingly. Another consideration when interpreting the results of this study is that there are a number of potential indirect influences of flow that could affect FYLF populations, which have not been tested in this or other flow studies, including effects of flow on algal growth and on habitat suitability for predators of FYLF eggs and tadpoles, such as fish, crayfish, and bullfrogs.

The analysis presented below is divided into two sections: 1) changes in habitat suitability from the lowest flow to each higher flow; and 2) habitat area available at each of the test flows.

5.1 Changes in Habitat Suitability From the Lowest Flow to Each Higher Flow

Depth and velocity were measured at three randomly selected points under each test flow. Because these points were different each day, a linear relationship between depth and discharge and velocity and discharge does not always exist. Two of the 11 polygons identified at 20 cfs at the Camino adit site and five of the 11 polygons identified at 20 cfs at the SFAR confluence site demonstrated significant (p<0.05) differences in mean depth or velocity for the three discharges. This suggests that habitats at the SFAR confluence site are more closely influenced by discharge than at the Camino adit site.

At the Camino adit site, the quantitative assessment suggested polygons tended to remain suitable at higher flows, but the qualitative assessment indicated a steeper decline in habitat suitability as flows increased (Table 4.2-2a). All of the polygons identified for potential oviposition and nearly all identified for tadpole rearing become low quality or not useable at 100 cfs. These data indicate that while suitable depths and velocities are present at this site (and remain present, as the ANOVA test suggests) over all three test flows, other qualitative habitat attributes tend to decrease in quality of habitat for egg deposition and tadpole rearing at 100 cfs.

At the SFAR confluence site, habitat of low suitability (and some of moderate suitability) for eggs and tadpoles was available at 100 cfs (of the polygons identified at 20 cfs). The number of polygons remaining suitable as flows increased are similar in both the quantitative and qualitative assessments at this site. In general, the number of suitable polygons of those identified at 20 cfs decreased as discharge increased. These data indicate that not only is there a statistically significant difference in depth and velocity at approximately 50 percent of the polygons evaluated for this analysis (i.e., polygons with egg deposition or tadpole rearing habitat identified at 20 cfs), but the difference is high enough to make polygons unsuitable, both quantitatively and qualitatively, at higher discharges.

5.1.1 Oviposition and Tadpole Rearing Point Analysis

For observed oviposition and tadpole rearing points, measurements made during the spring breeding season were similar implied that habitat area meeting the depth/velocity criteria remained fairly consistent across the three test flows (ranging from 1,634 ft^2 at 20 cfs to 1,943 ft^2 at 100 cfs) (Table 4.4-1a), the qualitative assessment showed a dramatic decrease in habitat area (of moderate or high quality) for eggs, tadpoles, and juveniles and adults at the 100 cfs flow (Table 4.4-2a). This decrease occurs despite a general increase in the total area evaluated with potential habitat (Table 4.4-2a).

The data also suggest that while mean velocity remains fairly consistent as discharge increases (regardless of which flow the polygon was identified at), mean depth increases with increased discharge (Figure 4.4-1), i.e., flow has a greater influence on depth than on velocity at this site. Thus, flows of 20 and 50 cfs appear to maintain some near-shore, low velocity, shallow habitat, but higher flows of 100 cfs inundate these areas sufficiently to be classified as lower quality.

5.1.2 Comparison of Polygon and Point Approach

Both the polygon and point analyses described above assess changes in habitat conditions from 20 cfs to each of the higher test flows. At the Camino adit site, the quantitative analysis of polygons was relatively consistent with the quantitative analysis of the points. The polygon analysis indicated only seven polygons (of a total of 11 identified at 20 cfs) remained suitable when discharge increased to 50 cfs (Table 4.2-2a), and remained relatively consistent from 50 to 100 cfs. The point analysis indicated that conditions remained generally suitable when discharges increased from 20 to 50 cfs, and four of the 15 identified points became unsuitable when discharges increased from 50 to 100 cfs (Figure 4.3-1).

At the SFAR confluence site, the quantitative analysis of polygons and the quantitative analysis of points indicated that suitable habitat identified at 20 cfs remains suitable at 50 cfs (although with some decrease in habitat polygons and some points becoming unsuitable at 50 cfs), but these habitats (both polygons and points) decrease dramatically at 100 cfs (mostly due to increased velocity; see Figure 4.4-2).

5.2 Habitat Area Available at Each Test Flow

5.2.1 Camino Adit Site

The habitat areas that meet quantitative and qualitative criteria differ (Tables 4.4-1a and 4.4-2a). While the quantitative assessment implied that habitat area meeting the depth/velocity criteria remained fairly consistent across the three test flows (ranging from 1,634 ft^2 at 20 cfs to 1,943 ft^2 at 100 cfs) (Table 4.4-1a), the qualitative assessment showed a dramatic decrease in habitat area (of moderate or high quality) for eggs, tadpoles, and juveniles and adults at the 100 cfs flow (Table 4.4-2a). This decrease occurs despite a general increase in the total area evaluated with potential habitat (Table 4.4-2a).

The data also suggest that while mean velocity remains fairly consistent as discharge increases (regardless of which flow the polygon was identified at), mean depth increases with increased discharge (Figure 4.4-1), i.e., flow has a greater influence on depth than on velocity at this site. Thus, flows of 20 and 50 cfs appear to maintain some near-shore, low velocity, shallow habitat, but higher flows of 100 cfs inundate these areas sufficiently to be classified as lower quality.

5.2.2 SFAR confluence site

The habitat area meeting both the quantitative and qualitative criteria for egg habitat is consistent at this site. Both analyses suggest that suitable habitat area for egg deposition decreases as flows increase (by approximately 500 ft^2 under both analyses). Mean velocity increased much more rapidly at higher discharges at this site (Figure 4.4-2), and polygons identified at 20 cfs were mostly not suitable at 100 cfs (Table 4.2-2b). Previously dry side channels or side pockets with stagnant water became inundated at the highest flow examined (see SFAR confluence site, Polygon 24, Appendix A), adding approximately 1,160 ft^2 of "new" habitat under the 100 cfs flow (Table 4.4-2b). Thus, the area meeting quantitative criteria in Table 4.4-1b is mostly due to "new" habitat polygons identified at 100 cfs.

Juvenile and adult habitat increased as flows increased, but it should be noted that much of that "increase" is habitat that switched from being egg deposition or tadpole rearing habitat at lower flows to juvenile and adult habitat at higher flows.

The channel morphology at this site is much more open than at the Camino adit site, with a wide mouth, multiple channels and mid-channel islands, increasing the complexity of habitat and the potential increase in wetted perimeter at high discharges. As a result of the wider floodplain, side channels previously dry became inundated at the highest test flow. Thus, while habitats identified at 20 cfs often became low quality at 100 cfs, new habitats of moderate to high quality were created in newly inundated areas at 100 cfs. The qualitative assessment also supports this conclusion; habitat area remains fairly consistent for eggs and tadpoles at each test flow.

6.0 LITERATURE CITED

Borisenko, A. N. and M. P. Hayes. 1999. Status of the Foothill yellow-legged frog (*Rana boylii*) in Oregon. Final report prepared for The Nature Conservancy under contract to the U.S. Fish and Wildlife Service. 38 pp. + appendices.

Jennings, M. R., and M. P. Hayes. 1994. Amphibian and reptile species of special concern in California. Final Report. Prepared by California Academy of Sciences, Department of Herpetology, San Francisco and Portland State University, Department of Biology, Portland, Oregon for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Hoover, S. 2003. Personal communication with S. Hoover, Biologist, ECORP Inc., Roseville, CA with R. Peek, Wildlife Biologist, Stillwater Sciences, Davis, CA.

Kupferberg, S. J. 1996a. Hydrologic and geomorphic factors affecting conservation of a river-breeding frog (*Rana boylii*). Ecological Applications 6: 1332-1344.

Kupferberg, S. J. 1996b. The ecology of native tadpoles (*Rana boylii* and *Hyla regilla*) and the impact of invading bullfrogs (*Rana catesbeiana*) in a northern California river. Doctoral dissertation. University of California, Berkeley.

Kupferberg, S. J. 1997. Bullfrog (*Rana catesbeiana*) invasion of a California river: the role of larval competition. Ecology 78: 1736-1751.

Kupferberg, S. 2003. Personal communication with Sarah Kupferberg, private consultant and expert on foothill yellow-legged frogs, by S. Khandwala and C. Champe, Stillwater Sciences, Berkeley, CA. October.

Seltenrich, C. and A. Pool. 2002. A standardized approach for habitat assessments and visual encounter surveys for the foothill yellow-legged frog (*Rana boylii*). Pacific Gas and Electric Company. Technical and Ecological Services Division. San Ramon, CA.

Van Wagner, T. J. 1996. Selected life-history and ecological aspects of a population of foothill yellow-legged frogs (*Rana boylii*) from Clear Creek, Nevada County, California. Master's Thesis, Department of Biological Sciences, California State University, Chico. 143 pp.

Yarnell, S. M. 2000. The influence of sediment supply and transport capacity on foothill yellow-legged frog habitat, South Yuba River, California. Masters Thesis, Department of Geology, University of California, Davis.

FIGURES

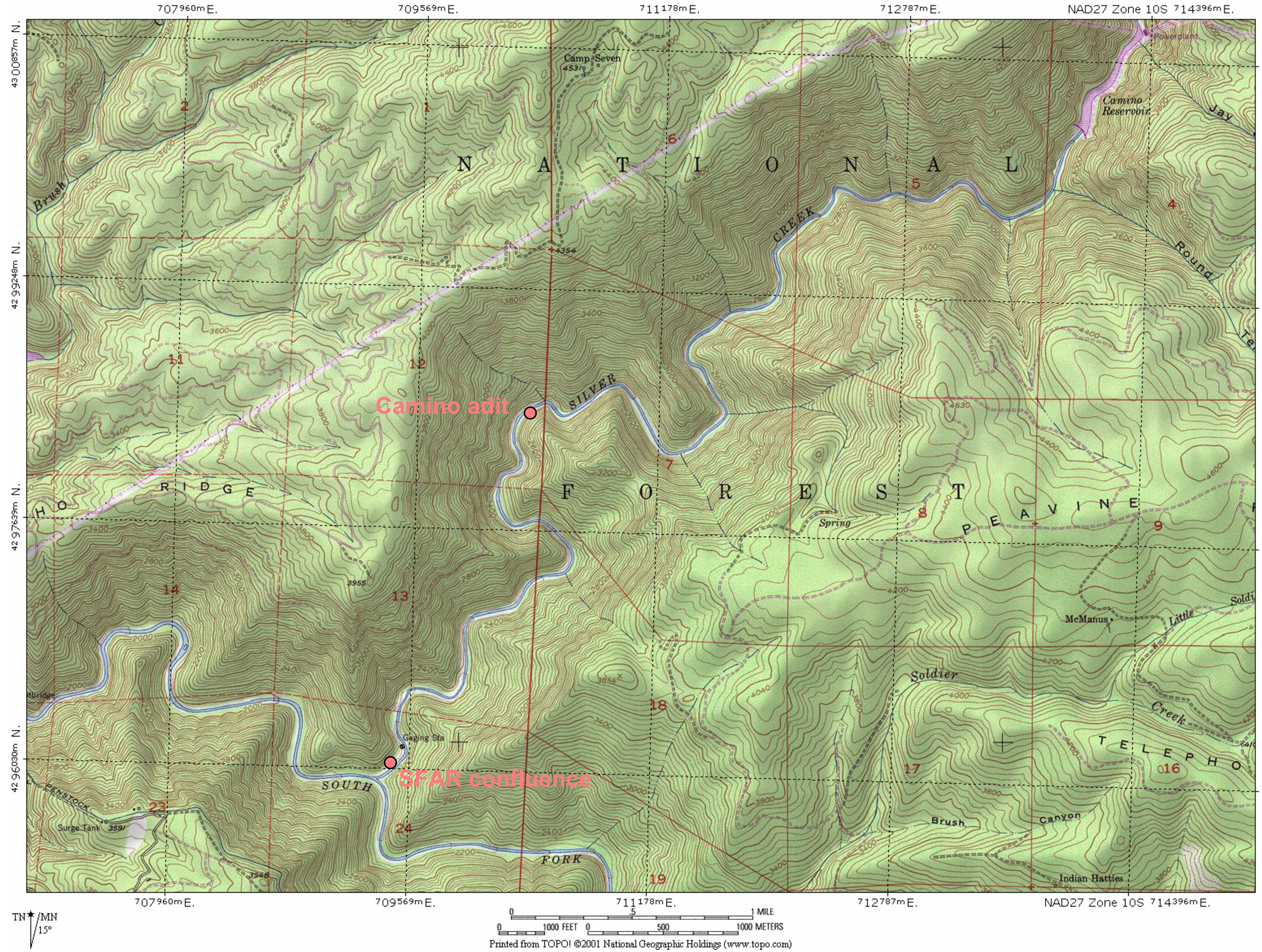


Figure 3.1-1. Study site vicinity map. C-3 is the Camino adit site and SFA-4 is the SFAR confluence site.

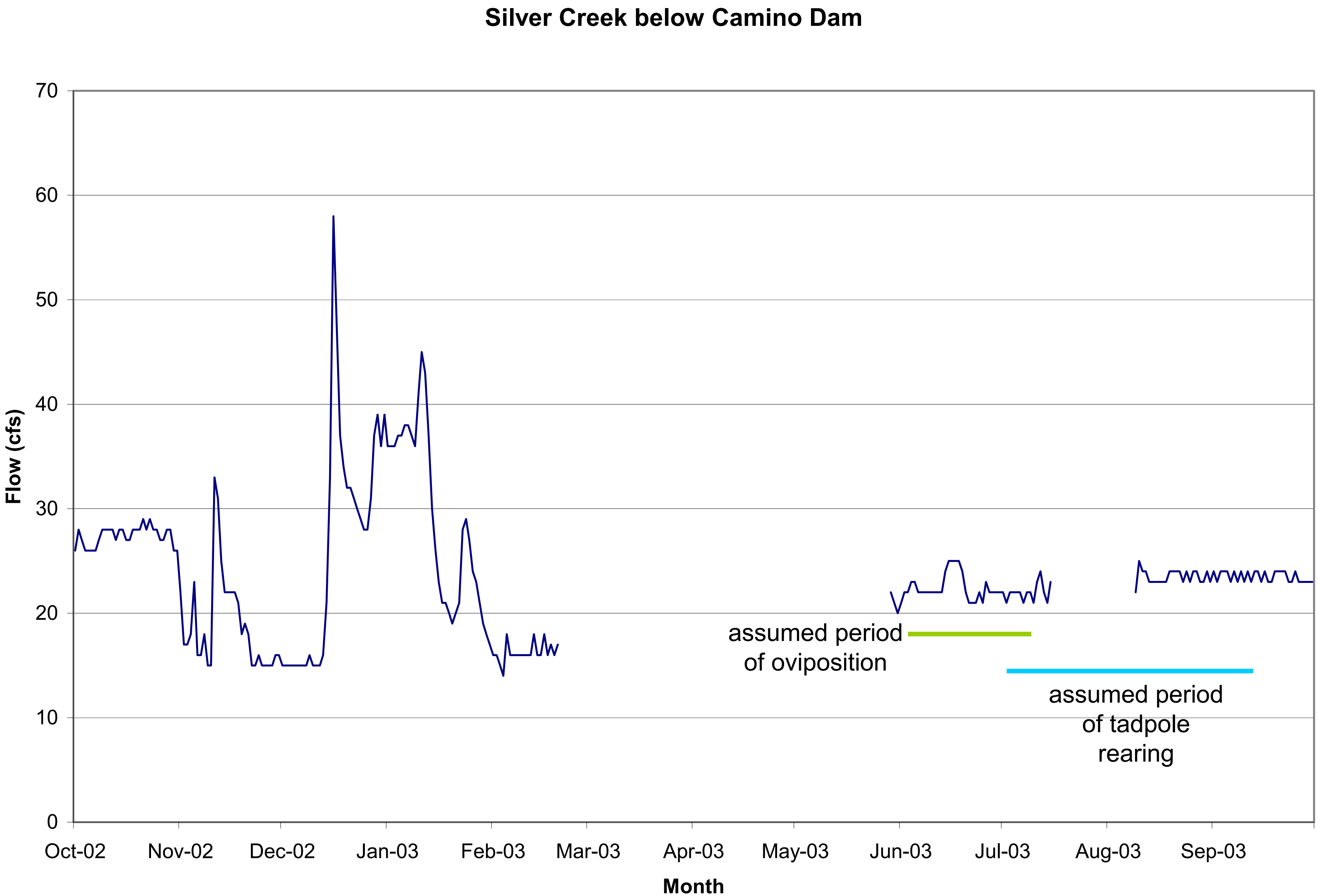


Figure 3.1-2. Flow in Camino Dam Reach for water year 2002 (USGS gauge 11441900). (Data are provisional and subject to change. Problems with data recording related to water leakage into power terminals explain the gaps in data.) Assumed period of oviposition and tadpole rearing is based on observations during VES at Site C-3.

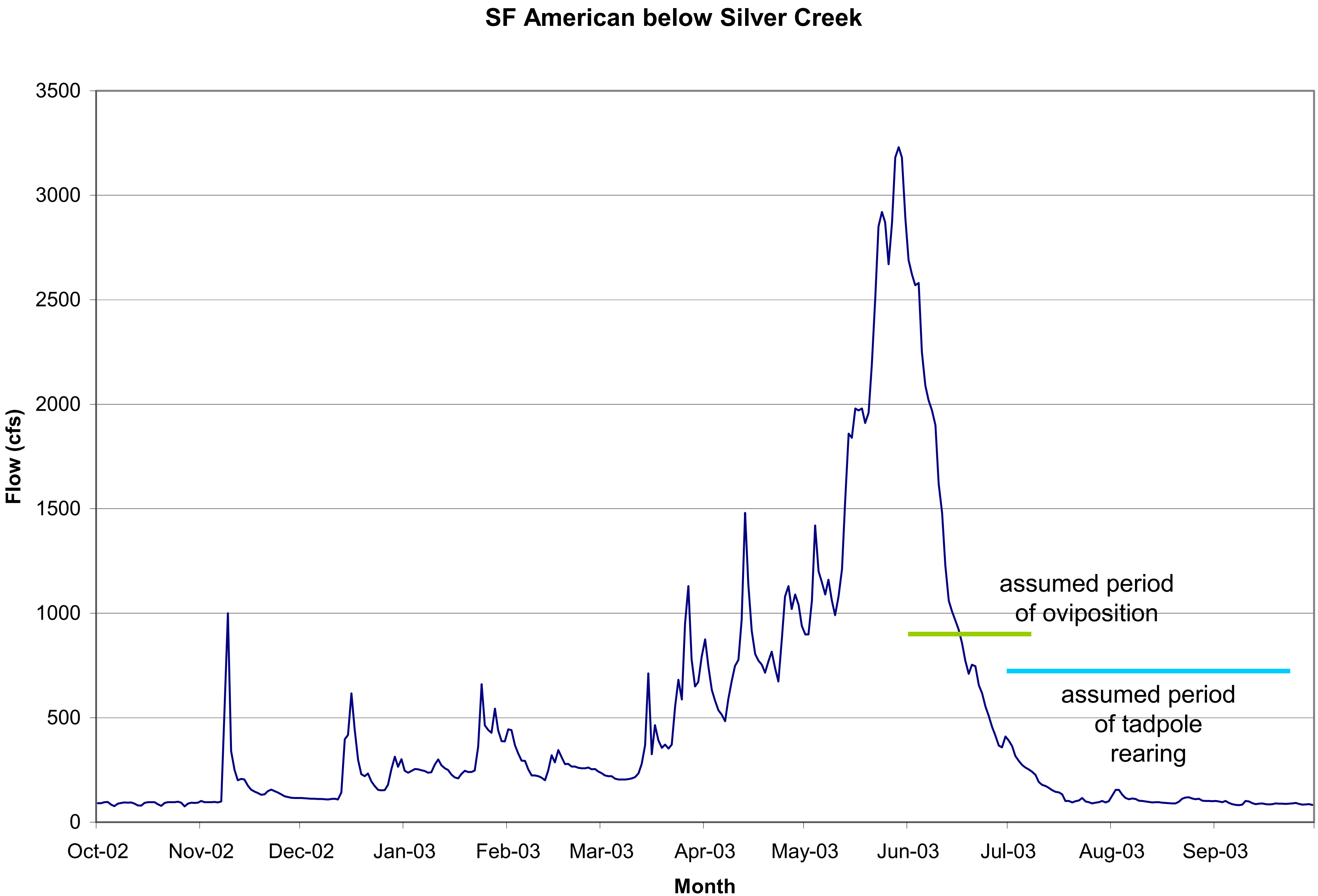


Figure 3.1-3. Flow in SF American River Reach for water year 2002 (USGS gauge 11442500). (Data are provisional and subject to change.) Assumed period of oviposition and tadpole rearing based on observations during VES at Site SFA-3.

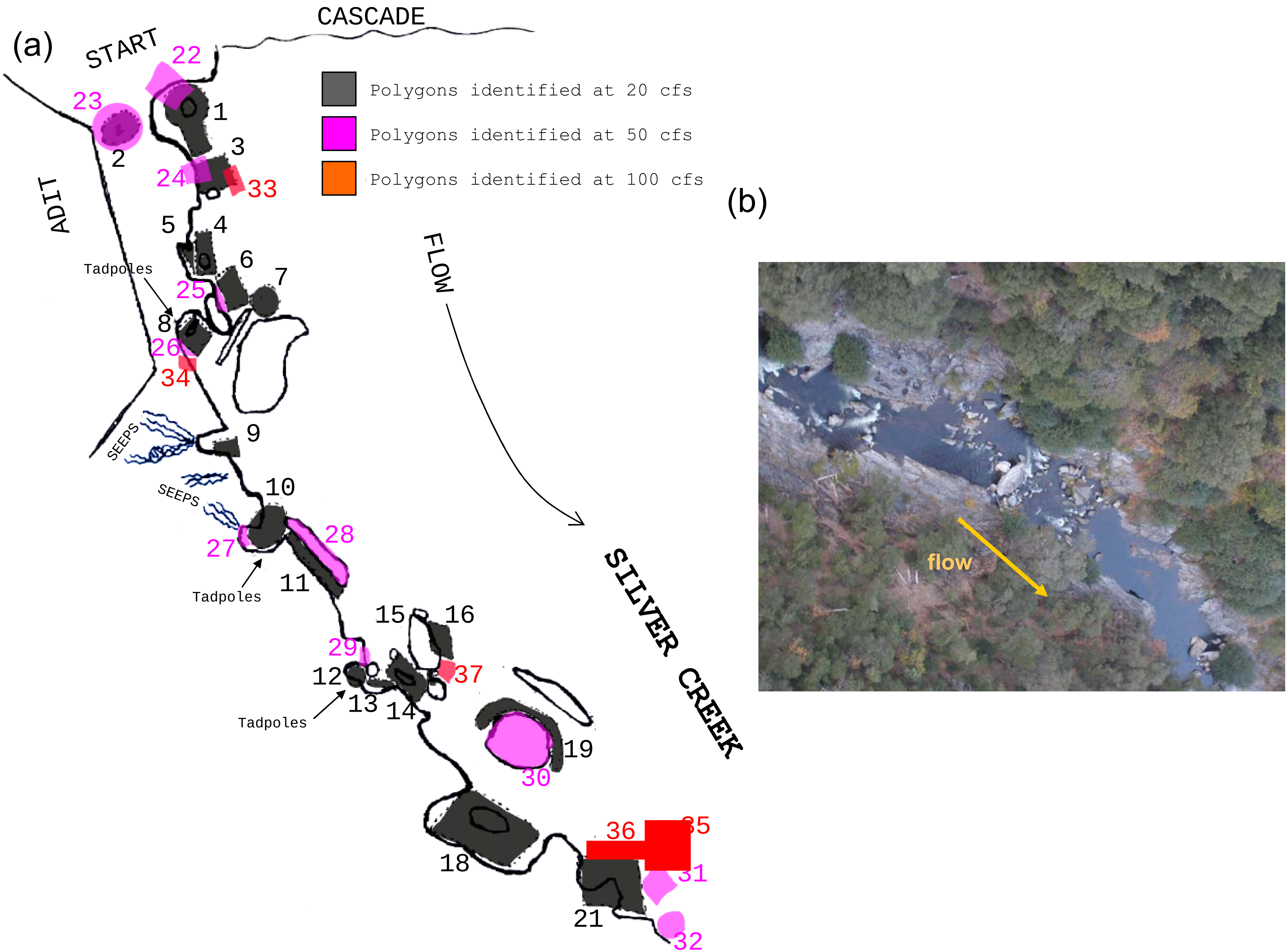


Figure 4.1-1. Camino adit site (a) habitat sketch (not necessarily to scale), (b) aerial photo (looking downstream).

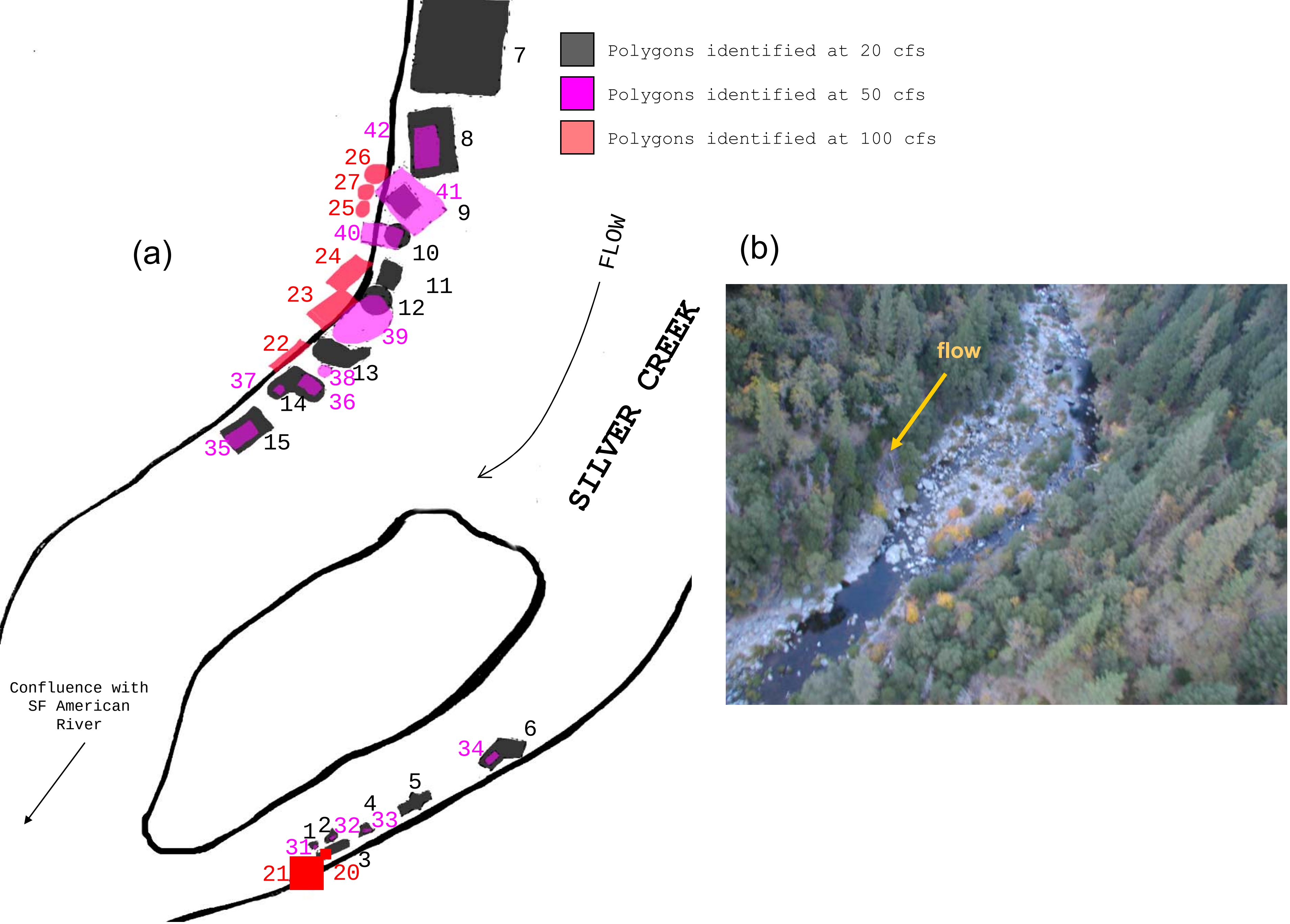


Figure 4.1-2. SFAR confluence site (a) habitat sketch (not necessarily to scale), (b) aerial photo (looking upstream).

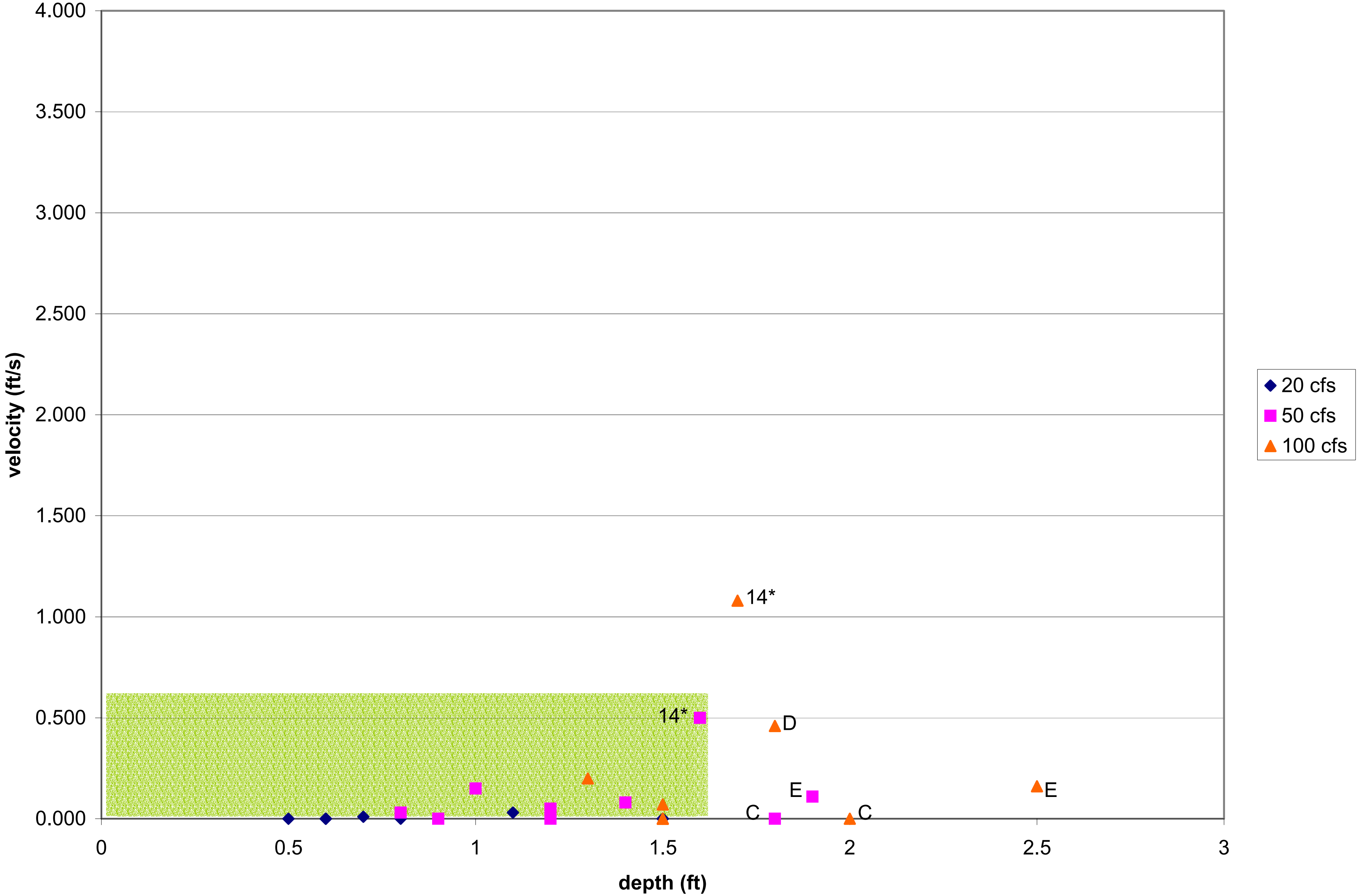


Figure 4.3-1. Depths and velocities at oviposition and tadpole rearing sites located at the Camino adit site. Suitable range (depth < 1.6 ft, velocity < 0.328 ft/s) shaded in green.

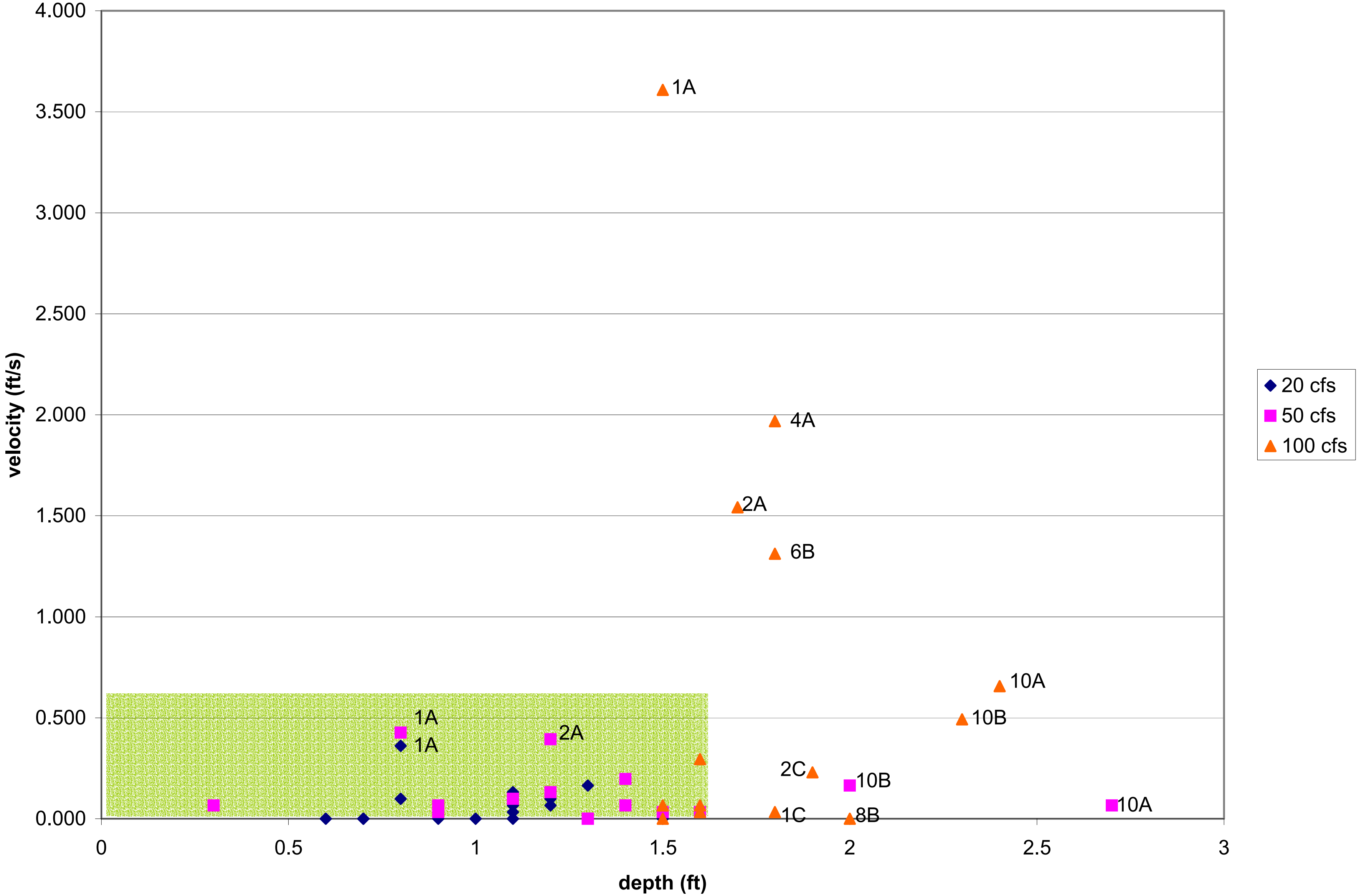
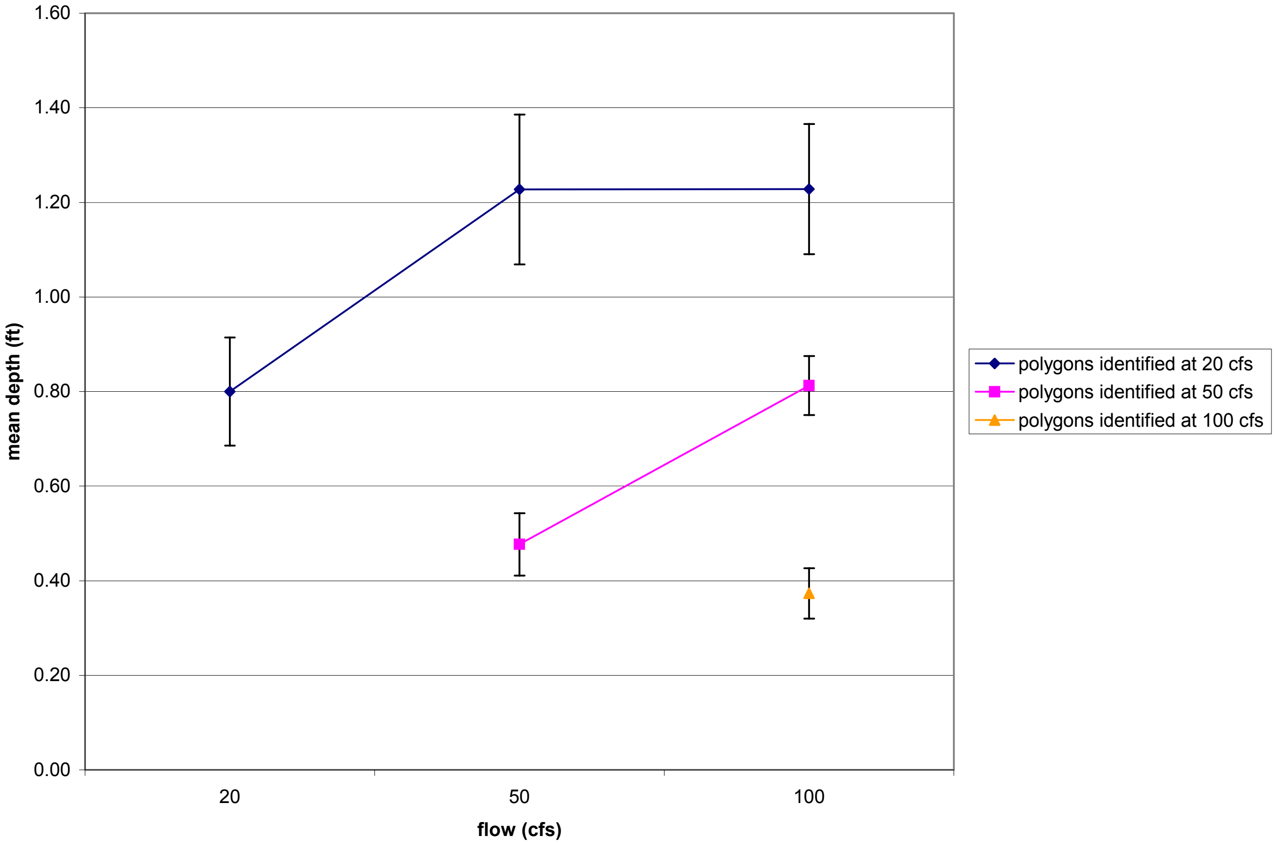


Figure 4.3-2. Depths and velocities at oviposition and tadpole rearing sites located at the SFAR confluence site. Suitable range (depth < 1.6 ft, velocity < 0.328 ft/s) shaded in green.



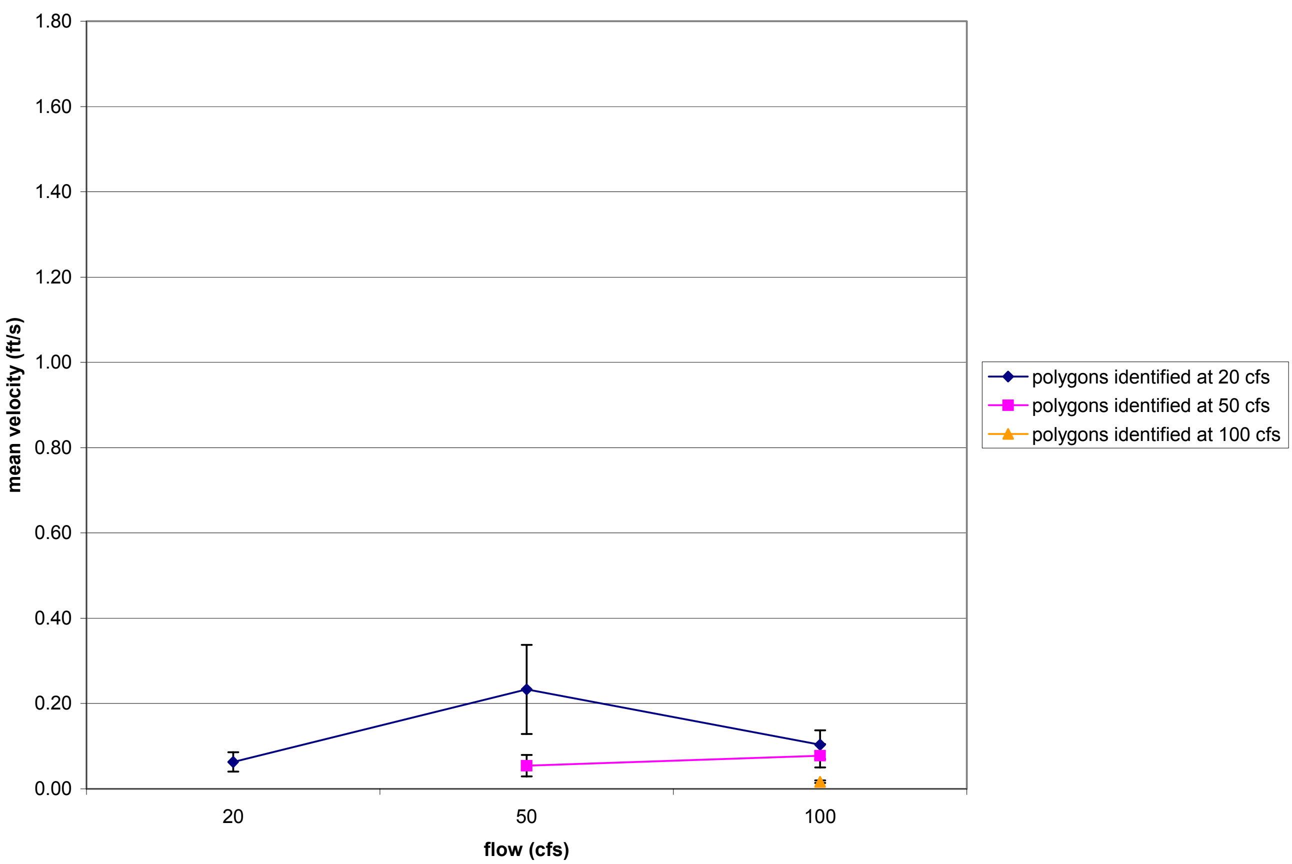
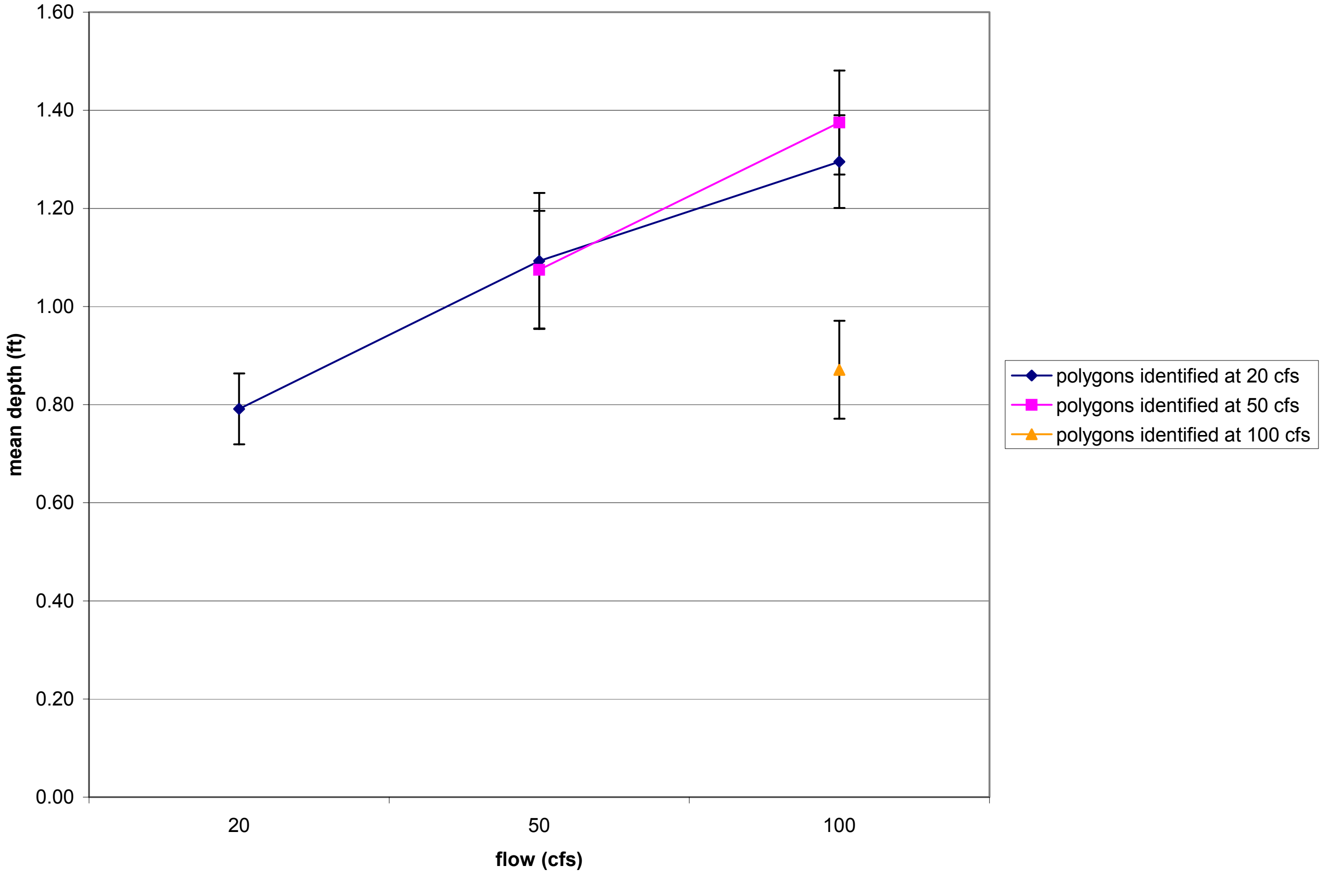


Figure 4.4-1. Mean depths and velocities at polygons identified at each discharge level at the Camino adit site. Error bars represent one standard error.



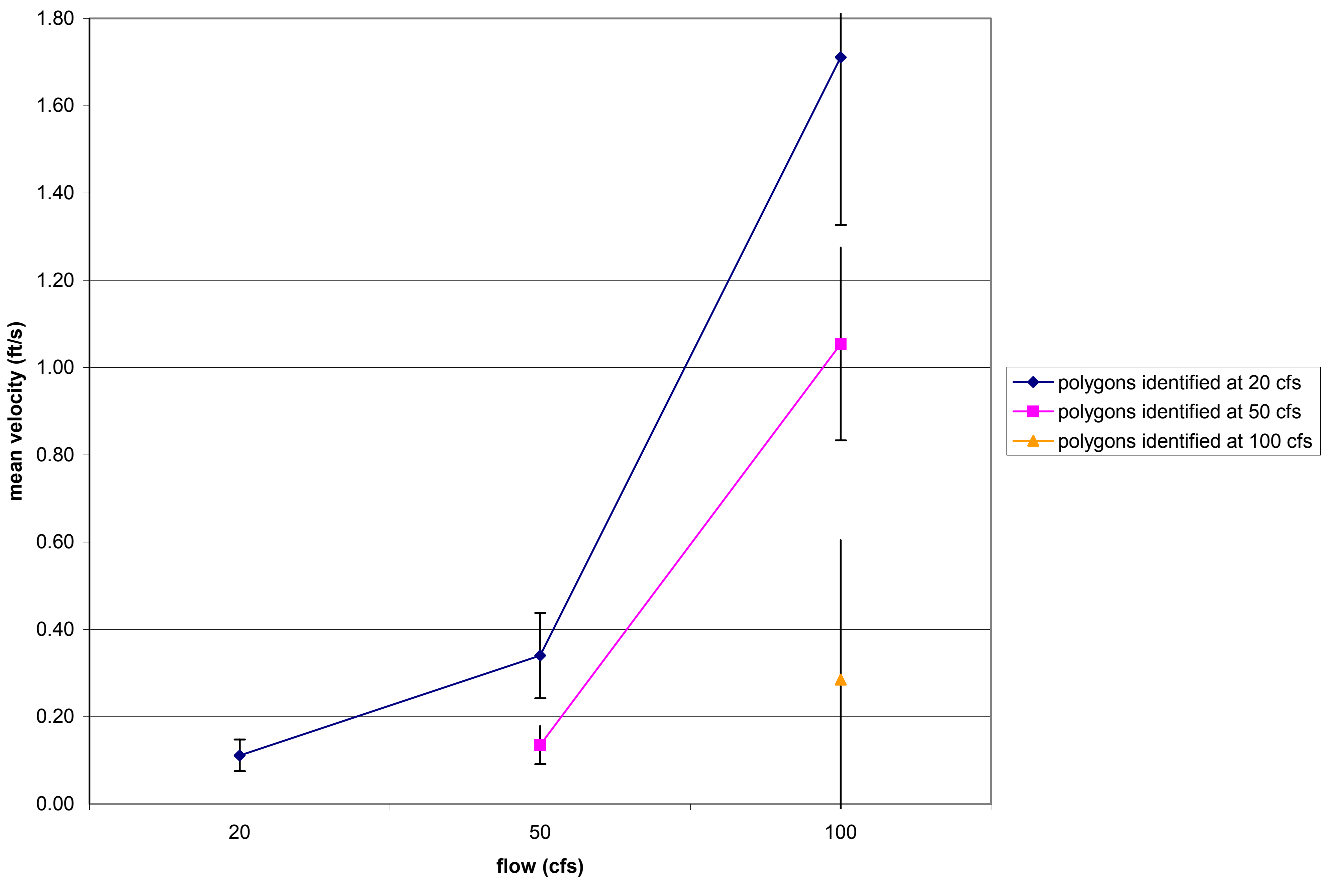


Figure 4.4-2. Mean depths and velocities at polygons identified at each discharge level at the SFAR confluence site. Error bars represent one standard error.

APPENDIX A

DATASHEETS USED IN FIELD DATA COLLECTION

Test Flow Release
Habitat Evaluation for Amphibians

Target Species: Foothill Yellow-Legged Frog

Date: mm_________ dd________ yy _________ Start time: __________ End time: _________

Site: Camino Adit Silver/SFAR confluence

Observers: __________ ___________ Total site length (m): _______________

Map of Site

Draw a map/sketch of the site, indicating habitat units, vegetation, direction of flow, extent of site, and river bank. Indicate previous sightings of FYLF.

Qualitative Biological Assessment

Fish observed? Y N
Species: Salmonid Centrarchid Cyprinid Other:_______________

Crayfish observed? Y N

Amphibians/aquatic reptiles observed? Y N
Species and life stage (A J T): FYLF ______ CRLF _______ HYLA _______ bullfrog _______ toad _______ turtle _______ garter snake __________

Other species observed:
____
____
____

Algal cover (%) within site: __________ Riparian vegetation species composition: ____

Site gradient: height of observer (m) __________ height on stadia rod (m) ___________ distance (m) ___________

Additional comments:
____
____
____

Test Flow Release
Initial polygon measurements

Target Species: Foothill Yellow-Legged Frog

Observers: __________ ___________

Date: mm_________ dd________ yy _________ Start time: __________ End time: _________

Flow: baseflow (20cfs) mid-flow (50cfs) high flow (100cfs) Avg Site Width (m): ___________ Avg Channel Width (m): __________

Site: Camino Adit Silver/SFAR confluence

Measure any polygons <<50 cm deep and <<10 cm/s velocity.

POLYGON # ____________ **Egg/Tadpole** **Juvenile/Adult** **Is Polygon wet? Y N**

Shape:
(draw general shape below and indicate measurements taken)

Right bank Left bank

Temperature (°C)

____

Substrate composition*

%

_______ sand
_______ gravel
_______ cobble
_______ boulder
_______ bedrock
100%

Overhangs and interstices present

Y N

Distance (m)
(from center of polygon)

A (to water's edge) __________
B (to riparian cover) __________
C (to top of site) __________

Depth and Velocity
(taken at randomly selected points)

	Depth (m)	Velocity (m/s) Surface	Velocity (m/s) 60%	vector
1	________	__________	________	
2	________	__________	________	
3	________	__________	________	
4	________	__________	________	
5	________	__________	________	

Overhead cover
(% of total polygon)

type	**%**
open	_______
tree (>2 m)	_______
shrub (<2 m)	_______
grass/sedge	_______
woody debris	_______
other _________	_______
	100%

Emergent veg cover
(% of total polygon) _______%

POLYGON # ____________ **Egg/Tadpole** **Juvenile/Adult** **Is Polygon wet? Y N**

Shape:
(draw general shape below and indicate measurements taken)

Right bank Left bank

Temperature (°C)

____

Substrate composition*

%

_______ sand
_______ gravel
_______ cobble
_______ boulder
_______ bedrock
100%

Overhangs and interstices present

Y N

Distance (m)
(from center of polygon)

A (to water's edge) __________
B (to riparian cover) __________
C (to top of site) __________

Depth and Velocity
(taken at randomly selected points)

	Depth (m)	Velocity (m/s) Surface	Velocity (m/s) 60%	vector
1	________	__________	________	
2	________	__________	________	
3	________	__________	________	
4	________	__________	________	
5	________	__________	________	

Overhead cover
(% of total polygon)

type	**%**
open	_______
tree (>2 m)	_______
shrub (<2 m)	_______
grass/sedge	_______
woody debris	_______
other _________	_______
	100%

Emergent veg cover
(% of total polygon) _______%

Test Flow Release
Follow-up polygon measurements

Target Species: Foothill Yellow-Legged Frog Page _____ of _____

Date: mm_________ dd________ yy _________ Start time: __________ End time: _________

Site: Camino Adit Silver/SFAR confluence

Observers: __________ ___________ Flow: mid-flow (50cfs) high flow (100cfs)

Flow	Polygon #	Distance to water's edge (m) (from center of polygon)	Comments (wet or dry at previous flows? Part of another polygon?)	Depth (m)	Velocity (m/s) – 60% depth	Velocity (m/s) - surface	Vector

Test Flow Release
Point measurements at known egg/tadpole sites

Target Species: Foothill Yellow-Legged Frog

Page _____ of _____

Observers: __________ ___________

Date: mm_________ dd________ yy _________ Start time: __________ End time: _________

Flow: baseflow (20cfs) mid-flow (50cfs) high flow (100cfs)

Site: Camino Adit Silver/SFAR confluence

Site A:
Comments:

sampling period	date	depth (m)	velocity (m/s)
spring/summer 2003			
20 cfs			
50 cfs			
100 cfs			

Site B:
Comments:

sampling period	date	depth (m)	velocity (m/s)
spring/summer 2003			
20 cfs			
50 cfs			
100 cfs			

Site C:
Comments:

sampling period	date	depth (m)	velocity (m/s)
spring/summer 2003			
20 cfs			
50 cfs			
100 cfs			

Site D:
Comments:

sampling period	date	depth (m)	velocity (m/s)
spring/summer 2003			
20 cfs			
50 cfs			
100 cfs			

Site E:
Comments:

sampling period	date	depth (m)	velocity (m/s)
spring/summer 2003			
20 cfs			
50 cfs			
100 cfs			

APPENDIX B

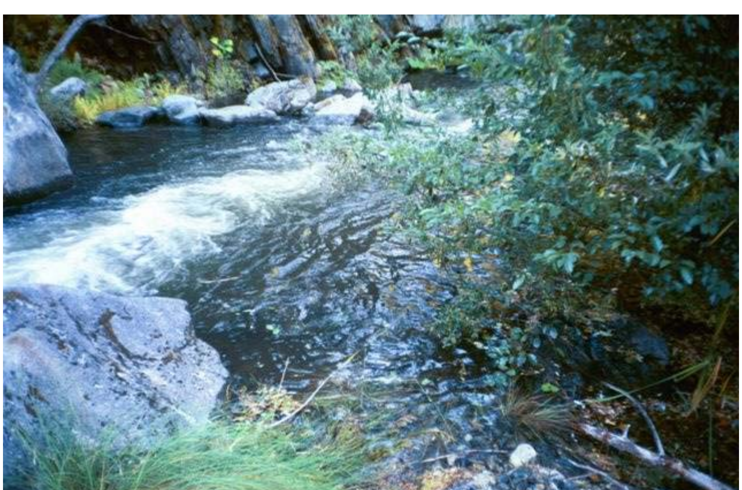
PHOTOGRAPHS OF REPRESENTATIVE POLYGONS

POLYGON 1

Polygon 1, looking upstream from right bank.

20 cfs

50 cfs



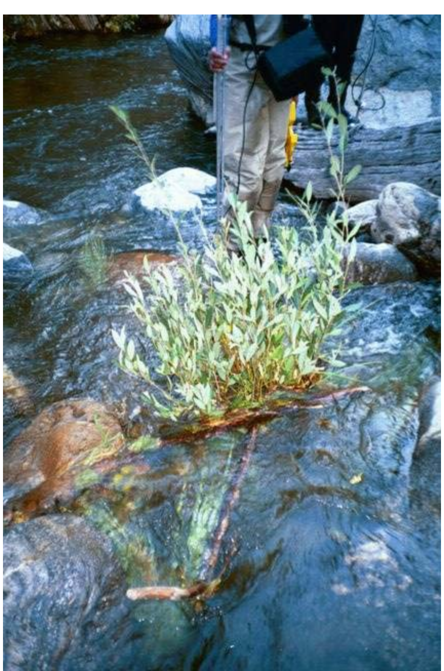
100 cfs

POLYGON 7

Polygon 7, looking downstream from right bank.

20 cfs

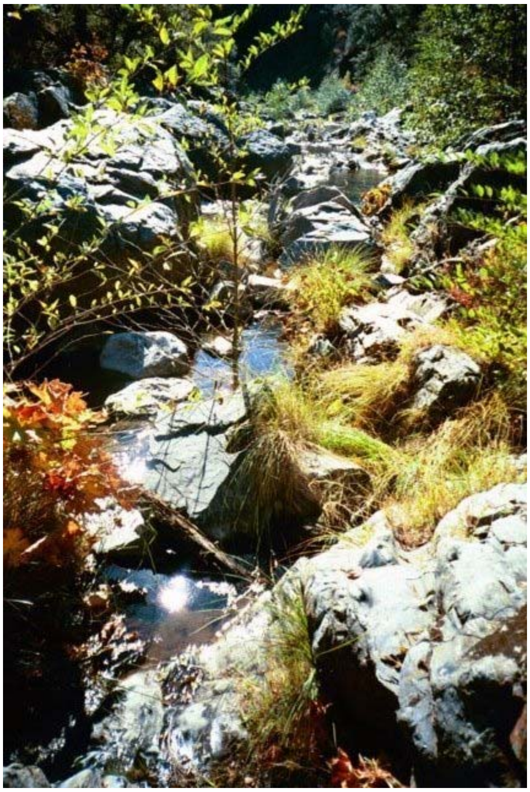
50 cfs



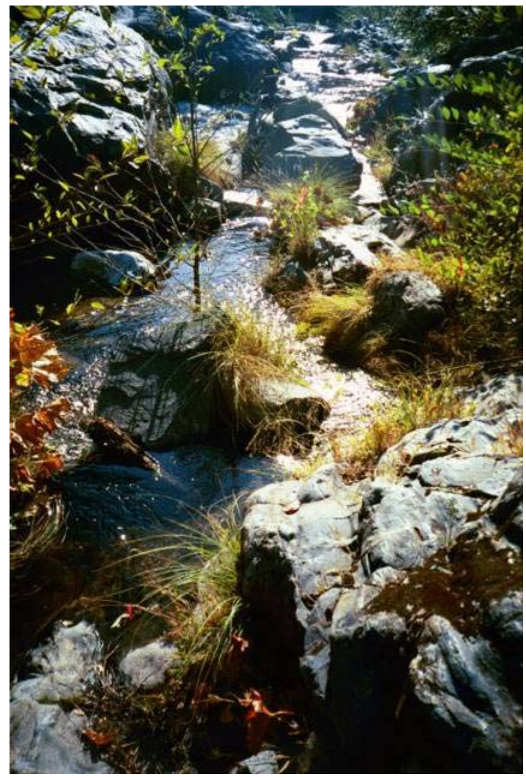
100 cfs

POLYGON 13

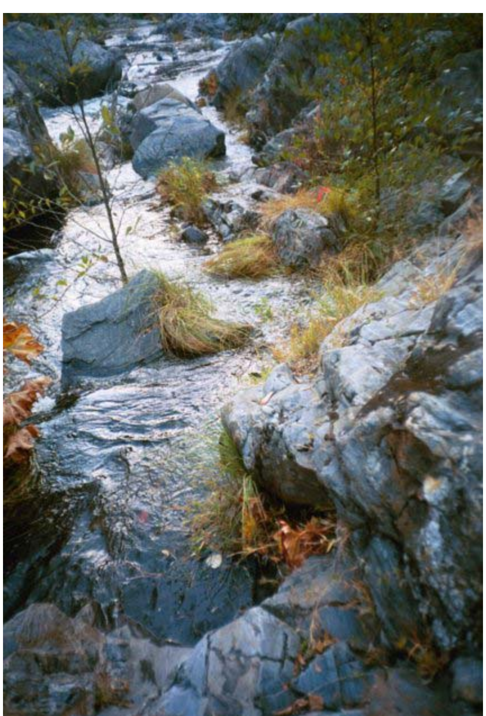
Polygon 13, looking downstream from right bank.



20 cfs



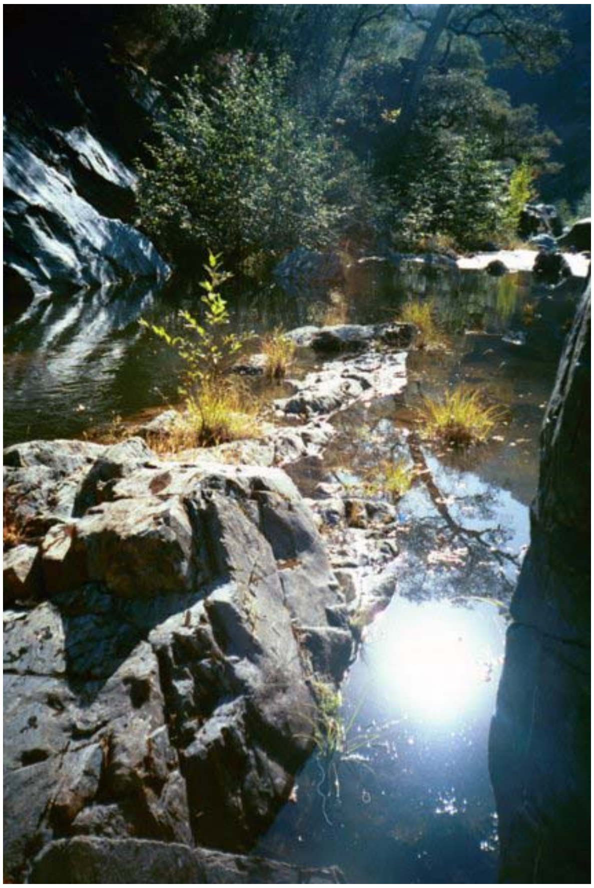
50 cfs



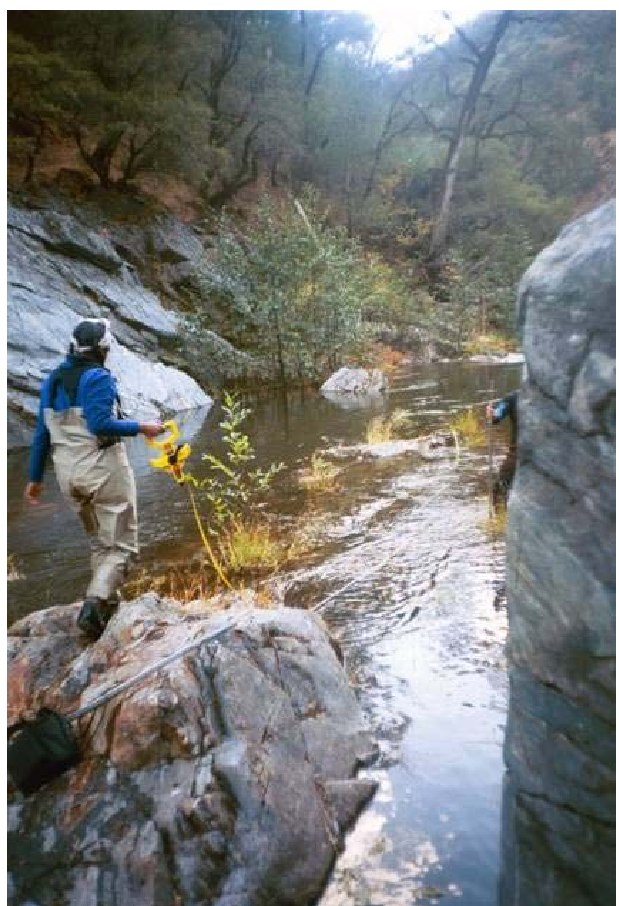
100 cfs

POLYGON 28

Polygon 28, looking downstream from right bank.



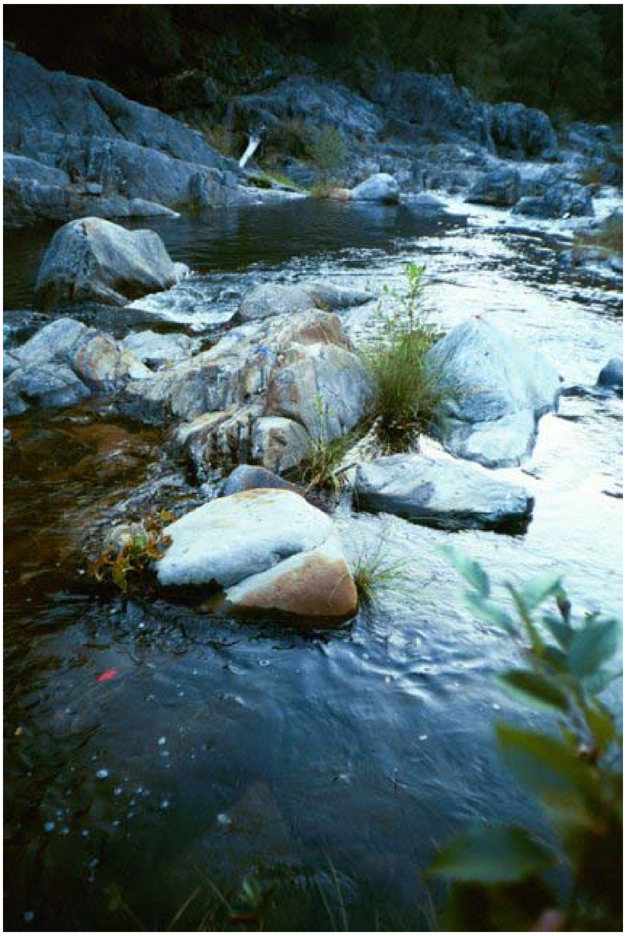
50 cfs



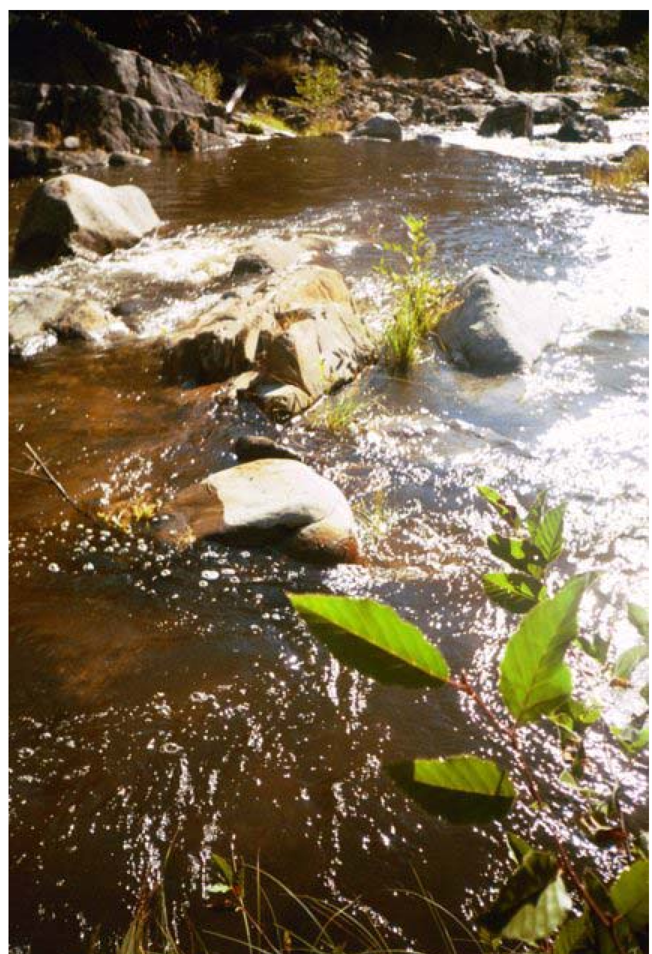
100 cfs

POLYGON 30

Polygon 30, looking downstream from right bank.



50 cfs



100 cfs

POLYGON 1

Polygon 1, looking downstream from left bank.

20 cfs

50 cfs

100 cfs

POLYGON 4

Polygon 4, looking downstream and towards left bank.

20 cfs

50 cfs

100 cfs

POLYGON 12

Polygon 12, looking across river channel from right bank.

20 cfs

50 cfs

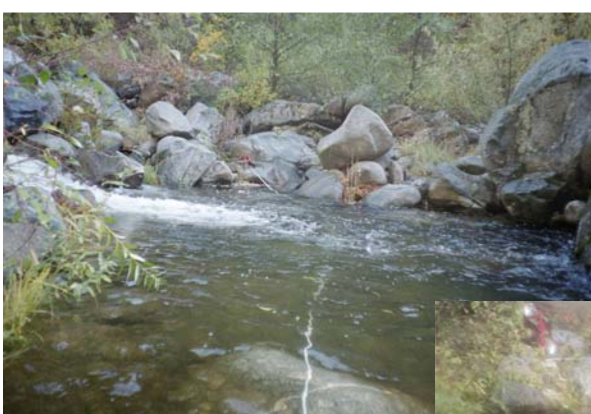
100 cfs

POLYGON 13

Polygon 13, looking upstream on right bank.

20 cfs

50 cfs



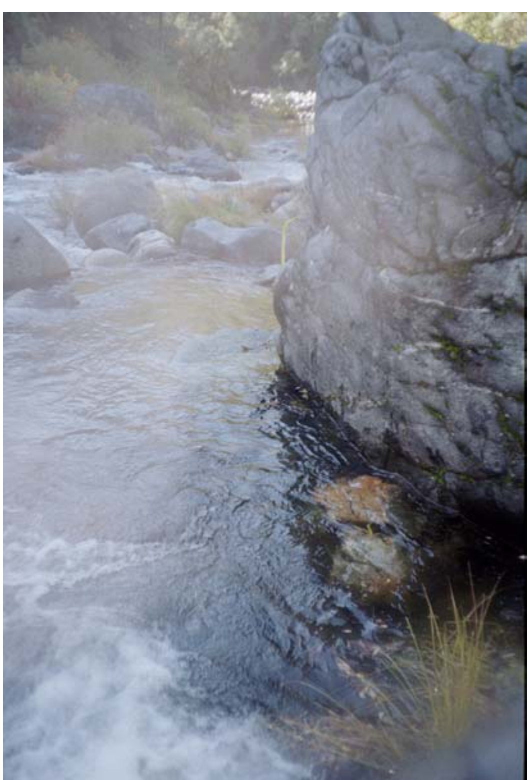
100 cfs

POLYGON 14

Polygon 14, looking downstream from right bank.

20 cfs

50 cfs



100 cfs

POLYGON 24

Polygon 24, looking towards right bank. New polygon identified at 100 cfs.

100 cfs

APPENDIX C

HABITAT CHARACTERISTICS OF POLYGONS AND QUANTITATIVE MEASUREMENTS

Substrate composition at SFAR Confluence site

polygon #	sand	gravel	cobble	boulder	bedrock	overhang or interstices present?	distance to water's edge (m)
	substrate compostion (percent)						
1	0	0	5	95	0	Yes	2
2	0	0	10	70	20	Yes	13.83
3	0	0	5	60	35	No	1
4	0	0	15	70	15	Yes	1
5	0	0	5	65	30	No	4.25
6	0	0	10	45	45	Yes	1
7	0	0	10	65	25	Yes	
8	0	15	30	40	15	Yes	6.08
9	0	5	15	65	15	Yes	4
10	0	15	25	50	10	Yes	4.5
11	0	10	30	55	5	No	3.5
12	0	10	45	45	0	Yes	8.33
13	0	5	10	70	15	Yes	2.67
14	0	0	10	85	5	Yes	3.67
15	0	0	20	70	10	Yes	5.5
MEAN for polygons identified at 20 cfs	**0**	**4**	**16**	**63**	**16**		**4**
31	0	0	5	95	0	Yes	2.42
32	0	0	5	80	15	Yes	3
33	0	5	10	80	5	Yes	0.5
34	0	5	10	55	30	Yes	1.9
35	0	10	10	70	10	Yes	10.8
36	0	0	15	80	5	Yes	4.6
37	0	0	5	90	5	No	2.5
38	0	0	5	90	5	Yes	9
39	0	5	30	60	5	No	9.5
40	0	0	30	50	20	Yes	6
41	0	5	25	60	10	No	6.4
42	0	0	10	80	10	Yes	5.2
MEAN for polygons identified at 50 cfs	**0**	**3**	**13**	**74**	**10**		**5**
20	0	0	30	70	0	Yes	6
21	30	0	70	0	0	No	4.5
22	0	0	15	85	0	Yes	4
23	0	20	70	10	0	Yes	6
24	10	10	40	40	0	Yes	2.8
25	0	5	45	50	0	Yes	3.5
26	10	5	20	65	0	Yes	3
27	10	10	50	20	10	Yes	3.8
MEAN for polygons identified at 100 cfs	**8**	**6**	**43**	**43**	**1**		**4**
OVERALL MEAN	**2**	**4**	**21**	**62**	**11**		**5**

Substrate composition at Camino adit site

polygon #	sand	gravel	cobble	boulder	bedrock	overhang or interstices present?	distance to water's edge (m)
	substrate compostion (percent)						
1	0	35	35	30	0	Yes	5.4
2	35	0	65	0	0	No	
3	0	5	10	85	0	Yes	2.5
4	10	10	30	50	0	Yes	4
6	0	0	60	40	0	Yes	3
8	5	0	15	20	60	Yes	6.5
9	0	0	0	0	100	No	3
10	0	0	0	0	100	No	4
11	0	0	0	0	100	Yes	3
12	0	0	0	0	100	Yes	3
13	0	0	0	0	100	No	1
14	0	0	30	70	0	No	12
15	0	0	0	50	50	Yes	7
16	0	0	10	0	90	Yes	20
18	0	0	20	60	20	Yes	9
19	0	0	0	0	100	Yes	20
21	0	0	0	0	100	Yes	5
MEAN for polygons identified at 20 cfs	**3**	**3**	**16**	**24**	**54**		**7**
22	0	35	35	30	0	Yes	7
23	35	0	65	0	0	Yes	0
24	0	5	10	85	0	Yes	4
25	0	0	60	40	0	No	1.5
26	15	10	10	40	25	No	3
27	0	5	0	5	90	No	1
28	0	0	0	0	100	No	2.5
29	0	0	0	80	20	Yes	3
30	0	0	0	30	70	No	25
31	0	0	0	0	100	No	1.5
32	0	0	0	0	100	Yes	2
MEAN for polygons identified at 50 cfs	**5**	**5**	**16**	**28**	**46**		**5**
33	0	0	75	25	0	No	1.9
34	0	0	30	70	0	Yes	3.5
35	0	0	0	0	100	No	0.7
36	0	0	0	0	100	No	0.7
37	0	0	0	75	25	Yes	12.5
MEAN for polygons identified at 100 cfs	**0**	**0**	**21**	**34**	**45**		**4**
OVERALL MEAN	**3**	**3**	**17**	**27**	**50**		**6**

Vegetation cover at SFAR Confluence site

	overhead cover (percent)						
polygon #	open	tree	shrub	grass	woody	other	emergent vegetation (percent)
1	80	0	0	20	0	0	5
2	75	0	10	15	0	0	5
3	10	20	0	70	0	0	25
4	80	0	0	15	0	5	5
5	78	0	0	20	2	0	10
6	63	0	0	2	0	35	2
7	35	15	10	40	0	0	20
8	85	0	5	10	0	0	2
9	90	0	5	5	0	0	2
10	80	10	5	5	0	0	5
11	60	20	10	10	0	0	5
12	80	15	5	0	0	0	5
13	85	5	2	8	0	0	2
14	60	0	5	5	0	30	2
15	85	0	5	10	0	0	10
MEAN for polygons identified at 20 cfs	**70**	**6**	**4**	**16**	**0**	**5**	**7**
31	80	0	0	20	0	0	10
32	50	0	10	40	0	0	5
33	50	0	0	20	0	30	5
34	59	0	0	1	0	40	5
35	55	10	5	25	0	5	15
36	70	0	5	15	0	10	5
37	100	0	0	0	0	0	2
38	45	0	50	5	5	0	30
39	35	40	15	10	0	0	10
40	75	10	10	5	0	0	5
41	75	5	10	10	0	0	5
42	95	0	0	5	0	0	2
MEAN for polygons identified at 50 cfs	**66**	**5**	**9**	**13**	**0**	**7**	**8**
20	30	40	10	20	0	0	20
21	0	100	0	0	0	0	25
22	50	0	50	0	0	0	5
23	20	75	0	5	0	0	10
24	0	100	0	0	0	0	25
25	80	0	0	20	0	0	5
26	80	5	5	10	0	0	30
27	75	10	5	5	5	0	5
MEAN for polygons identified at 100 cfs	**42**	**41**	**9**	**8**	**1**	**0**	**16**
OVERALL MEAN	**62**	**14**	**7**	**13**	**0**	**4**	**9**

Vegetation cover at Camino adit site							
	overhead cover (percent)						
polygon #	open	tree	shrub	grass	woody	other	emergent vegetation (percent)
1	50	50	0	0	0	0	5
2	5	95	0	0	0	0	5
3	90	10	0	0	0	0	15
4	95	0	5	0	0	0	5
6	75	25	0	0	0	0	10
8	90	5	0	5	0	0	5
9	95	0	0	5	0	0	5
10	100	0	0	0	0	0	0
11	100	0	0	0	0	0	5
12	90	5	0	5	0	0	5
13	85	5	0	10	0	0	10
14	90	5	0	0	0	0	5
15	95	0	0	5	0	0	0
16	70	0	0	0	0	30	0
18	90	5	0	5	0	0	5
19	100	0	0	0	0	0	0
21	95	0	0	5	0	0	0
MEAN for polygons identified at 20 cfs	**83**	**12**	**0**	**2**	**0**	**2**	**5**
22	50	35	0	15	0	0	15
23	5	95	0	0	0	0	10
24	30	55	15	0	0	0	70
25	0	80	10	10	0	0	80
26	15	70	10	5	0	0	10
27	100	0	0	0	0	0	5
28	95	0	0	5	0	0	2
29	40	15	0	45	0	0	45
30	95	0	5	0	0	0	0
31	85	10	0	5	0	0	0
32	30	0	10	60	0	0	65
MEAN for polygons identified at 50 cfs	**50**	**33**	**5**	**13**	**0**	**0**	**27**
33	10	65	0	25	0	0	30
34	5	75	5	15	0	0	5
35	100	0	0	0	0	0	0
36	90	0	0	10	0	0	5
37	65	0	5	30	0	0	30
MEAN for polygons identified at 100 cfs	**54**	**28**	**2**	**16**	**0**	**0**	**14**
OVERALL MEAN	**68**	**21**	**2**	**8**	**0**	**1**	**14**

Camino adit
depth and velocity measurments

		velocity (ft/s)					depth (ft)	
site	polygon #	20 cfs	50 cfs	100 cfs		20 cfs	50 cfs	100 cfs
Camino Adit	1	0.03	0.14	0		0.9	0.9	1.5
Camino Adit	1	0.02	0.53	0		0.5	1.8	1.4
Camino Adit	1	0.13	0.04	0.04		1.7	1.2	1.6
Camino Adit	2	0	0	0.03		0.2	0.7	1.4
Camino Adit	2	0	0	0.06		0.4	0.7	0.9
Camino Adit	2	0	0	0		0.2	0.6	0.8
Camino Adit	3		0.1	0.38			0.7	1
Camino Adit	3	0.06	0.47	0.14		0.6	0.3	0.8
Camino Adit	3		2.58	0.66			0.8	1.4
Camino Adit	4	0.28	0.23	0.12		0.6	1.2	2.3
Camino Adit	4	0.01	0.14	0.48		0.6	1.3	0.6
Camino Adit	4	0	0.21	0.01		0.6	1.5	1.4
Camino Adit	8	0	0	0.02		0.6	0.5	1.5
Camino Adit	8	0	0.06	0		1.9	2.9	2.6
Camino Adit	8	0	0.05	0.01		1.6	2.8	1.4
Camino Adit	10	0	0.03	0.01		0.2	2.1	1.5
Camino Adit	10	0	0.03	0		1.1	1.4	1.4
Camino Adit	10	0	0	0		0.8	0.4	0.3
Camino Adit	11	0	0.01	0.1		1.5	0.5	1.1
Camino Adit	11	0	0	0		1	1.8	3.2
Camino Adit	11	0	0.03	0.14			3.8	1.2
Camino Adit	12	0	0.08	0.17		0.1	1.4	0.6
Camino Adit	12	0	0.04	0.06		0.5	1	1.1
Camino Adit	12	0.01	0.1	0.11		0.8	0.9	0.5
Camino Adit	14	0.03	0.5	0.07		1.5	1.6	1.5
Camino Adit	14	0.03	1.75	0.1		1.2	0.5	1.2
Camino Adit	14	0.3	0.02	0.22		0.6	1.3	1.9
Camino Adit	18	0.01	0.11	0.03		1.2	1.9	0.4
Camino Adit	18	0.15	0.12	0.08		0.9	0.7	0.2
Camino Adit	18	0.07	0.18	0.13		1.2	1.3	1.5
Camino Adit	21	0.09	0.03	0		0.6	0.8	0.8
Camino Adit	21	0.02	0.11	0		0.7	0.4	1
Camino Adit	21	0	0	0.21		0.2	0.2	0.4
Camino Adit	5		0.14	0.01			1.3	1.4
Camino Adit	5		0.05	0.01			0.9	0.3
Camino Adit	5		0.04	0.75			0.5	0.9
Camino Adit	9		0.02	0.06			0.3	0.4
Camino Adit	9		0.03	0.07			0.4	1.5
Camino Adit	9		0.02	0.14			0.5	1.5
Camino Adit	22		0.02	0			0.2	0.9
Camino Adit	22		0.05	0.01			1.3	0.2
Camino Adit	22		0.1	0.01			0.5	0.7
Camino Adit	23		0	0			0.7	0.8
Camino Adit	23		0	0.06			0.7	0.9
Camino Adit	23		0	0.03			0.6	1.4

Camino adit
depth and velocity measurments

			velocity (ft/s)				depth (ft)	
site	**polygon #**	**20 cfs**	**50 cfs**	**100 cfs**		**20 cfs**	**50 cfs**	**100 cfs**
Camino Adit	24		0.1	0.66			0.7	1.4
Camino Adit	24		0.47	0.14			0.3	0.8
Camino Adit	24		0.19	0.03			0.3	0.7
Camino Adit	25		0.02	0.03			0.6	0.5
Camino Adit	25		0.01	0.04			0.5	0.9
Camino Adit	25		0.01	0.01			0.3	0.6
Camino Adit	26		0	0.01			0.2	0.6
Camino Adit	26		0	0			0.5	1
Camino Adit	26		0	0			0.3	0.9
Camino Adit	27		0	0			0.1	0.5
Camino Adit	27		0	0.03			0.2	0.5
Camino Adit	27		0	0.1			0.3	0.1
Camino Adit	28		0	0.02			0.1	0.3
Camino Adit	28		0	0			0.1	1.4
Camino Adit	28		0.03	0.03			0.6	0.9
Camino Adit	29		0	0.03			0.5	2
Camino Adit	29		0.03	0.01			0.4	0.6
Camino Adit	29		0	0.11			0.2	0.7
Camino Adit	30		0.15	0.15			0.5	0.5
Camino Adit	30		0.53	0.41			0.4	0.4
Camino Adit	30		0.06	0.02			0.3	1.2
Camino Adit	31		0	0			0.2	0.5
Camino Adit	31		0	0.02			0.1	0.6
Camino Adit	31		0	0.01			0.3	0.6
Camino Adit	32		0.01	0.01			0.9	1
Camino Adit	32		0.03	0			0.9	0.7
Camino Adit	32		0	0.01			0.9	0.9
Camino Adit	33			0				0.4
Camino Adit	33			0.03				0.6
Camino Adit	33			0				0.4
Camino Adit	34			0				0.2
Camino Adit	34			0.06				0.2
Camino Adit	34			0.01				0.2
Camino Adit	35			0				0.1
Camino Adit	35			0.02				0.1
Camino Adit	35			0.05				0.7
Camino Adit	36			0.01				0.9
Camino Adit	36			0				0.4
Camino Adit	36			0.03				0.1
Camino Adit	37			0.02				0.8
Camino Adit	37			0.02				0.4
Camino Adit	37			0				0.1

SFAR confluence
depth and velocty measurements

		velocity (ft/s)					depth (ft)	
site	polygon #	20 cfs	50 cfs	100 cfs		20 cfs	50 cfs	100 cfs
Silver/SFAR	1	0.02	0.22	0.12		1	1.3	1.2
Silver/SFAR	1	0.04	0.18	0.14		0.8	1.3	2
Silver/SFAR	1	0.08	0.03	0.33		0.8	1	1.3
Silver/SFAR	2	0.05	0.08	0.49		1.1	1	0.8
Silver/SFAR	2	0.01	0.04	0.17		0.9	0.9	1.5
Silver/SFAR	2	0.08	0.19	0.01		0.8	0.8	1.4
Silver/SFAR	3	0.01	0.03	0.11		0.4	0.3	1.3
Silver/SFAR	3	0.01	0.35	1		0.8	0.7	1.6
Silver/SFAR	3	0.15	0.04	0.29		0.3	0.8	1
Silver/SFAR	4	0	0.05	0.5		0.5	0.7	1.3
Silver/SFAR	4	0.01	0.08	0.13		0.9	0.9	1.7
Silver/SFAR	4	0.02	0.02	1.2		0.5	1.2	1.5
Silver/SFAR	5	0.1	0.98	0.5		0.5	0.2	0.6
Silver/SFAR	5	0.08	0.13	1.8		0.2	0.5	0.4
Silver/SFAR	5	0.15	0.24	0.78		0.3	0.5	0.2
Silver/SFAR	6	0	0.14	1.6		1	0.2	0.6
Silver/SFAR	6	0	0.04	0.05		0.5	1.2	1.4
Silver/SFAR	6	-0.01	0	0.04		0.5	1.5	1.4
Silver/SFAR	8	0.02	0	0		1.8	2.1	0.7
Silver/SFAR	8	0	0	0.08		0.8	2.5	1.1
Silver/SFAR	8	0	0	0.1		1.1	2.9	1.5
Silver/SFAR	9	0.03	0.17	0.3		0.6	0.6	2.8
Silver/SFAR	9	0.07	0.03	0.92		0.3	1.6	0.8
Silver/SFAR	9	0.09	0	0.5		0.9	0.7	1.6
Silver/SFAR	10	0	-0.01	0.4		1	1.1	1.8
Silver/SFAR	10	0.07	-0.01	0.24		1.9	2	2.1
Silver/SFAR	10	0	0.08	0.42		2.3	1.5	1.5
Silver/SFAR	11	0.06	0.03	1.45		0.4	1.3	1
Silver/SFAR	11	0.08	0.56	3.6		0.7	0.5	0.7
Silver/SFAR	11	0.06	0.03	0.4		0.3	0.4	1
Silver/SFAR	12	0	0.03	1		0.8	0.4	1.7
Silver/SFAR	12	0.02	0.01	0.05		0.7	1.2	1.6
Silver/SFAR	12	0	0.23	0.25		0.6	1	0.6
Silver/SFAR	13	0	-0.01	0.26		0.6	0.6	1.5
Silver/SFAR	13	0.08	0.13	0.39		1.2	2.2	1.1
Silver/SFAR	13	0.02	0.02	0.7		1.3	1.3	2
Silver/SFAR	14	0.03	0	0.12		1.1	1.5	1.4
Silver/SFAR	14	0	0.03	0.1		0.9	1.8	0.9
Silver/SFAR	14	0	0.05	0.03		0.9	1.2	1.6
Silver/SFAR	15	0	0.14	1.2		1	0.3	1.1
Silver/SFAR	15	0	0.11	0.5		1.5	0.6	0.5
Silver/SFAR	15	0	-0.02	0.06		1.2	1.6	2.6
Silver/SFAR	31		0.06	0.11			0.8	1.5
Silver/SFAR	31		-0.02	0.8			1.3	1.7
Silver/SFAR	31		0.15	0.36			0.9	0.9
Silver/SFAR	32		0.06	0.42			0.6	1.3
Silver/SFAR	32		-0.01	0.05			0.7	1.5
Silver/SFAR	32		0.02	0.3			0.2	1.1
Silver/SFAR	33		0.03	0.13			1.3	1.7
Silver/SFAR	33		0.16	1.2			0.7	1.5

SFAR confluence
depth and velocty measurements

		velocity (ft/s)					depth (ft)	
site	polygon #	20 cfs	50 cfs	100 cfs		20 cfs	50 cfs	100 cfs
Silver/SFAR	33		-0.02	0.5			1	0.9
Silver/SFAR	34		-0.02	1.6			1	0.6
Silver/SFAR	34		0.02	0.05			1.1	1.4
Silver/SFAR	34		0.09	0.09			1.3	1.6
Silver/SFAR	35		-0.02	0.06			1.6	0.9
Silver/SFAR	35		-0.01	0.09			1.3	1.1
Silver/SFAR	35		-0.01	0			0.4	0.5
Silver/SFAR	36		0.04	0.12			0.1	1.4
Silver/SFAR	36		0.02	0.1			1.1	0.9
Silver/SFAR	36		0.01	0.04			0.5	1.4
Silver/SFAR	37		0.05	0.04			1.5	2.7
Silver/SFAR	37		-0.01	0.06			2.3	2.4
Silver/SFAR	37		0.05	0.06			1.6	2
Silver/SFAR	38		0.1	0.58			1.1	1
Silver/SFAR	38		0.01	0.85			1	1.2
Silver/SFAR	38		0.02	0.5			0.8	1.6
Silver/SFAR	39		0	0.3			1.3	1.5
Silver/SFAR	39		0.28	1			1.6	1.7
Silver/SFAR	39		0.06	0.25			1.1	0.6
Silver/SFAR	40		0.06	0.4			1.1	1.8
Silver/SFAR	40		-0.03	0.42			0.2	1.5
Silver/SFAR	40		-0.03	0.02			1.1	1.2
Silver/SFAR	41		0.17	0.45			0.6	0.7
Silver/SFAR	41		0.23	0.75			0.7	0.7
Silver/SFAR	41		0.03	0.08			1.3	3.5
Silver/SFAR	42		0	0			2.1	0.7
Silver/SFAR	42		-0.02	0			1.8	2
Silver/SFAR	42		-0.01	0.01			1.6	0.8
Silver/SFAR	20			0.1				1.5
Silver/SFAR	20			0.03				0.8
Silver/SFAR	20			0.3				1.5
Silver/SFAR	21			0.02				0.9
Silver/SFAR	21			0.05				0.8
Silver/SFAR	21			0.03				1.2
Silver/SFAR	22			0.12				1.4
Silver/SFAR	22			0.6				1.2
Silver/SFAR	22			0.03				0.9
Silver/SFAR	23			0.01				0.8
Silver/SFAR	23			0.19				0.7
Silver/SFAR	23			0.03				0.2
Silver/SFAR	24			0.18				0.7
Silver/SFAR	24			0				1
Silver/SFAR	24			0.01				1.2
Silver/SFAR	25			0.09				1
Silver/SFAR	25			0.92				0.8
Silver/SFAR	25			1.55				0.6
Silver/SFAR	26			0				0.2
Silver/SFAR	26			0.04				0.5
Silver/SFAR	26			0.02				0.6
Silver/SFAR	27			0.08				0.7
Silver/SFAR	27			0.02				1.2
Silver/SFAR	27			0				0.5

APPENDIX D

S. KUPFERBERG CORRESPONDENCE ON STUDY PLAN

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From: Sarah Kupferberg
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re: Foothill yellow legged frog flow study in Upper South Fork American River / Silver Creek

Jan. 26, 2004

Dear Jann,

This letter report summarizes my involvement in the Foothill Yellow legged frog flow studies conducted Oct. 28-30, 2003 at Silver Ck. / South Fork American River. In the week prior to attending the test flows, I reviewed the study plan and sample data collecting sheets. I provided my comments to Sapna Khandwala of Stillwater Sciences. In general, the literature review was comprehensive and the study plan was well thought out. It did not require major changes. Sapna was receptive to my suggestions and working out the details was a collaborative process. During my field visit I observed that most of the suggestions were included. From my perspective, accompanying the team (Christine Chamf and Ryan Peek) who collected data at the Camino Adit site, the work went mostly according to plan and the only modifications made to the methods in the field were minor and due to time constraints. For example, it was decided at a breakfast meeting on Oct. 29th that taking fewer replicate flow measurements per polygon would be acceptable. In general I thought the field teams were quite competent, thorough, and professional. I have confidence that the data collected were accurate. My specific comments follow below.

With respect to the objective of the study I suggested that there needed to be more clarity about what the goal of the study was. I thought that the goal should not necessarily be to determine which flow provided the maximum habitat for each life stage of FYLF, given that the population numbers are small and that we do not know whether the frogs are limited by space *per se*. The more appropriate question should be: Do flows that provide adequate habitat area, for current and future populations, have survivable conditions over a range of flows? Because FYLF breed in the spring when flows can fluctuate up or down due either to flow regulation or due to natural occurrences, such as rain on snow events or the end of snow melt, it is important to consider how stable the conditions are within habitat patches over the range of test flows.

To better understand the relevance of the three test flow discharges to FYLF and the kinds of flow conditions experienced by breeding FYLF under the *status quo*, I requested that Stillwater Sciences provide spring / early summer hydrographs for the reaches of the S. Fork American River with FYLF present. Although there are only data from 2003 regarding the timing of FYLF breeding, larval development, and metamorphosis in this system, background information of many years of hydrographs will be helpful in determining whether the incidence and frequency of large fluctuations across the range of the test flows should be a management concern to the Forest Service and SMUD. Fluctuation could occur in the form of rapid channel de-watering after the peak of spring run-off, and might lead to stranding of eggs and/or young larvae. For example, data gathered in the flow study will tell us whether eggs laid in patches that are appropriate at 50 cfs are dry at 20 cfs. Alternatively, a spill event after breeding has begun might lead to loss of recruitment of new individuals if velocities became lethal. Repeated "at a point" velocity measurements taken at the known breeding sites will indicate whether eggs/larvae in a patch appropriate at 20 cfs would likely be washed downstream at 50 or 100 cfs.

With respect to the planned analysis of data, I suggested that in addition to comparing the extent of suitable habitat areas under each of the test flows that, the repeated measures of average conditions within polygons also be included. Information gathered from the flow study should help us understand what magnitude of discharge fluctuation, and from which base flow, may lead to changes in conditions beyond the observed tolerances of FYLF. In addition to measuring how flow velocities and depth change in a polygon among 20, 50, and100 cfs, I suggested that flow direction also be included as a measurement. Because FYLF often lay their eggs on the lee sides or under sides of rocks, changes in the vector of the current can be just as, or more, important than increases in velocity. If a clutch of eggs is no longer protected behind a rock because the current changes its angle at a higher flow, it is more likely to be dislodged.

To refine the definition and ranking of "suitable" habitat, which would determine which patches would be measured during the flow study, I suggested that the boundaries of suitability be tailored in part by on-site observations of FYLF made during the 2003 field season. With respect to substrate for breeding, I suggested that the focus should be on rocks of appropriate size, with large enough interstices or overhangs, given the observations from the 2003 season that most clutches were placed up underneath rocks. Assigning suitability of a patch for larval and adult life stages need not be limited by this constraint. Making distinctions / observer value judgments of suitability ranking in the field did not appear to be too difficult, and there was generally agreement among the observers and consistency during the day. The one grey area in determining suitability of patches at 50 and 100 cfs had to do with anticipated vegetation change at the margins should a higher base flow regime be in place. At these higher flows vegetated margins were inundated, and observers had to make assumptions that the vegetation which was covering the substrates would die back.

On the first day of the test flow at the Camino Adit site, we did not observe any FYLF in the river proper. It appeared that most frogs had already moved to their over-wintering site at the opening of the adit tunnel. We observed at least 6 adult FYLF, and many recent metamorphs of the Pacific treefrog (*Hyla regilla*) basking in the early morning sun there. It may be that the maintenance of the population that breeds in the section of river surveyed is determined by proximity to this protected tunnel as much as it is by the particular geomorphic and habitat traits of the test flow study site. Fortuitously, the Camino Adit test flow study site was also a site in the geomorphology study. It will be interesting to find out if this reach is unique with respect to its combination of channel geometry and longitudinal gradient. The other team did observe frogs in the river. It is possible that frogs over-winter there closer to the channel. Perhaps the springs and seeps at that site are important refugia.

Another important aspect of evaluating the habitat has to do with the presence or absence of FYLF predators. The signal crayfish, *Pacifastacus leniusculus*, was not observed at the Camino Adit site, but was observed at the Aiken Powerhouse. I believe that crayfish were not found at the downstream study site. These non-native crayfish are amphibian egg and tadpole predators. Preventing the spread of this species, which is sensitive to hydrologic disturbance, should be one of the goals in developing recommendations for the relicensed flow regime.

Thank you very much for the opportunity to work with you. If you have any questions regarding this letter report please feel free to contact me.

Respectfully,

Sarah Kupferberg