Appendix A-2

The effects of flow regime on Rana boylii, the Foothill Yellow-Legged Frog (FYLF) in the Pit 3, 4 and 5 reaches

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re: The effects of flow regime on *Rana boylii*, the Foothill Yellow Legged Frog (FYLF) in the Pit 3, 4, and 5 reaches.

Dear Kathy,

Please find below my comments on three reports pertaining to FYLF in the Pit River. At the date of this correspondence, May 4, 2003, I have received: FERC's DEIS, March 2003; Spring Rivers Ecological Sciences (Spring Rivers) revised report, dated May 12, 2003; and R2 Resource Consultants, Inc. (R2) vegetation report, dated March 17, 2003. I would like to commend Spring Rivers for the comprehensive reporting of the results and thorough presentation of background information. Data were presented clearly in the tables and figures of the report. Although I may have some disagreements with respect to interpretation, the work of conducting the study and compiling the results was well done and represents considerable effort.

Decision Making Criteria

There are two main questions that should frame the discussion regarding how the flow regime affects FYLF in the Pit River. First, will FYLF be limited by the space available for breeding under the various flow regimes proposed by PG&E, FS, Interior and CDFG? Second, how does flow regime influence survival? That is, we want to find a flow regime in which there is sufficient habitat area for the current and future populations to breed, and in which eggs, embryos, and larvae survive to become new recruits to the population. Although we do not want to choose a minimum discharge that would make habitat scarce, we should pay more attention to selecting a flow regime that will have optimal impacts on survival and recruitment rather than a regime that maximizes breeding habitat area. Basing a decision primarily on which discharge maximizes oviposition habitat area is not prudent, because it ignores the resilience of the conditions within a given habitat patch to fluctuations in discharge. In other words, eggs are more likely to survive changes in discharge from 400-600 cfs to peaks in the 1000-2000 cfs range, than from 150 cfs to peaks in the 1000-2000 cfs range. The maximum oviposition

habitat area decision criterion also ignores the rest of the life cycle of the frog, and should thus be one of several decision making criteria.

The data gathered at the Upper Deep Creek breeding site in 2002 support my hypothesis that FYLF are more limited by the effects of a) unnatural flow fluctuation, and b) non-native predators, whose invasion is facilitated by the impaired flow regime, than they are limited by space, per se. The May 2002 test flow conditions, imposed on eggs laid at the minimum flow, caused 50% mortality of embryos prior to hatching. After hatching there was almost 100% disappearance of the remaining tadpoles, due either to spills, or crayfish predation, or a combination of the two. At upper Deep Creek, FYLF are using only 25% of the available habitat (see section 1.1.2) for egg laying. Even though there is sufficient space for eggs at 150 cfs, the eggs are vulnerable to the effects of flow fluctuation when laid at the status quo minimum discharge. As discharge approaches 400 cfs, the river jumps the low flow banks. When the water begins to inundate the large bench/cobble bar, the vector of the current shifts 45°, and the clutches of eggs are no longer protected in the low velocity shadow on the lee side of their substrate. The data regarding flow velocities and direction, and habitat patch area collected by Spring Rivers shows that if the spring discharges were in the range of 400-600 cfs, the effects of spills would be mitigated and there would be adequate habitat patch area to accommodate the current population as well as a future recovery of a larger population. I have examined the spring hydrographs for the years 1970-1999 and determined that during the likely months for FYLF breeding, April–June, the discharges proposed under the FS "shaped flow" plan would both mitigate the potential impacts of spills and also provide breeding habitat sufficient for present populations and future recoveries of FYLF.

1. Breeding Habitat Area.

Based on the Spring Rivers draft report, FERC concluded that "the higher flows recommended by the FS, Interior, and CDFG would not be likely to benefit the FYLF" (p. 189, DEIS). This conclusion is erroneously based on using habitat area as a sole decision criterion and a misinterpretation of the habitat area data. The conclusion is based on changes in only the first of the three categories of breeding habitat, and lumping together data from sites currently occupied by frogs with data from unoccupied sites. However, I recommend that conclusions be based on only occupied sites (see section 1.1) and that all three vegetation categories of habitat be considered (see section 1.2).

1.1. Data from occupied and non-occupied sites are not equivalent

I recommend that the heaviest weight should be given to consideration of how habitat area changes in relation to discharge at known breeding locations. Spring Rivers states in its conclusions (p. 57) that "Given the likelihood that the Pit 4 Reach has more breeding sites than the two known sites in the Deep Creek area, total habitat from all sites combined should be used to assess what flows would maximize other shallow low-velocity areas of potential foothill yellow-legged frog breeding habitat in the Pit 4 Reach." I agree that there must be other breeding sites, *but we (meaning myself, Spring Rivers, Forest Service, and USFWS biologists) didn't locate them.* Some likely candidate sites (like Canyon Creek delta) were inaccessible at high test flows, and our site selection was limited by the small amount of time in the spring spent searching for egg masses.

Based on the dissimilarity of the responses of the two sets of sites, the un-occupied sites we chose are not appropriate surrogates for the occupied sites we didn't find. I recommend that the data from the known breeding locations, upper and lower Deep Creek, and the Bedrock Tadpole site, be used for decision making purposes. If any assumptions *are* to be made, it would be more prudent to assume that the unknown occupied sites respond to discharge in a manner more similar to the known occupied sites than the known un-occupied sites. The results of this study have shown that it is difficult, even for well-trained biologists (myself included) and geomorphologists, to determine visually how channel morphology interacts with discharge to create the near shore stage and velocity conditions that are conducive to frogs. In retrospect, we can say that it is likely that there were not frogs at the unoccupied sites because the channel morphology was "wrong". Only the empirical data, showing the response to change in discharge, revealed that these were not appropriate candidate sites (Fig. 1).

For the occupied sites, appropriate depth and velocity conditions existed across the range of 150 to 600 cfs (Fig. 1). For the occupied sites, total habitat area fluctuated within the narrow range of 74 to 112 square meters. These differences are not statistically or biologically significant. The un-occupied sites were relatively wider and shallower than the surrounding reaches and hence we expected that stage and velocity would be insensitive to discharge fluctuation in a manner similar to the occupied sites. Our expectation that appropriate depth and velocity habitats would be available at a range of river stages, as occurs at FYLF occupied breeding sites, was not borne out. Relative to the breeding sites, Category 1 habitat area summed for all un-occupied sites was not stable as discharge increased, fluctuating between 60 and 300 square meters. These data reveal that un-occupied sites do not have the same properties as breeding sites. These results confirm the findings of Kupferberg (1996) that FYLF breeding sites have unique geomorphic properties that create stage to discharge and velocity to discharge relationships conducive for long term occupation of a site over the range of historic variability in discharge.

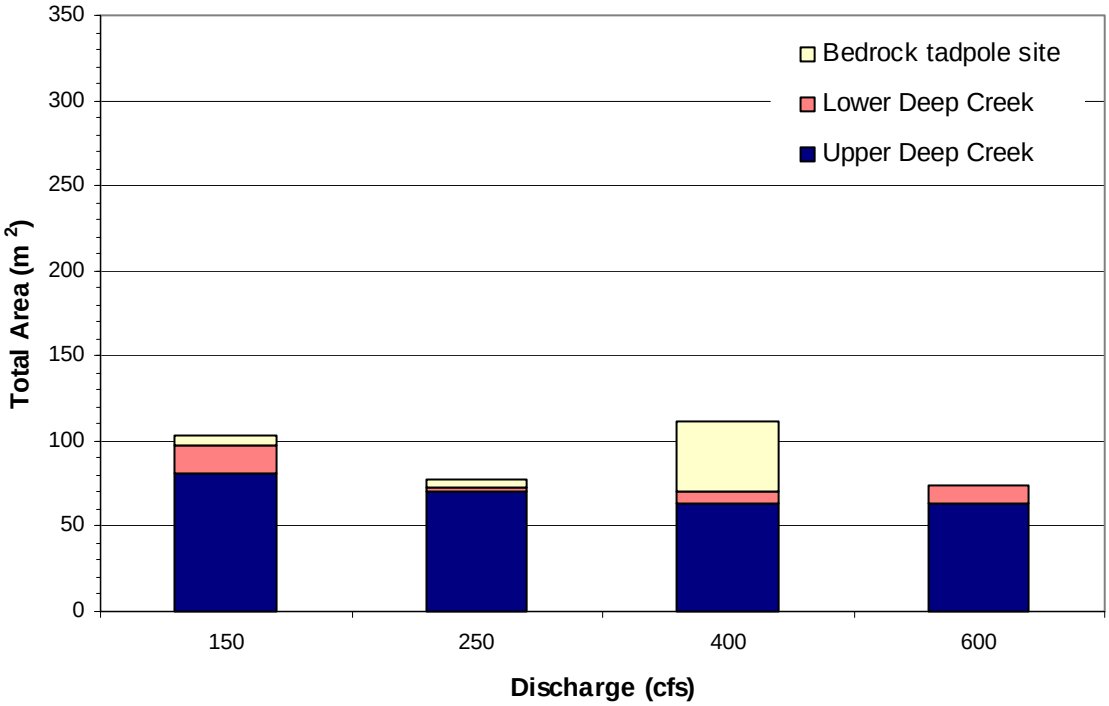
Spring Rivers further states (p. 56) that because of the Pit River's extensive spring system, FYLF did not historically face the same degree of variability in spring flows as in other northern California locations: "Assuming that breeding primarily occurs at or near the base flow (either unimpaired or post-project) in the Pit River, there is little change in discharge over the breeding, hatching, and tadpole rearing season, with the exception of relatively low-occurrence events such as late-season storms (both pre- and post-project) and post-project spills." This is a large assumption and not warranted. There are no data, or temperature modeling predictions, to support the assertion that appropriate breeding temperatures are not reached until all spills have ended. We have only one year of breeding observation, and in 2002 breeding extended from mid-April to mid-May. For that time period there is a large range of historic flows. The selective pressure for frogs to utilize sites in which appropriate habitat is available at a range of flows, exists at the Pit River similar to other populations of FYLF in the South Fork Eel River as well as the rest of its range. See the hydrographs in Figures 5 and 6 for examples, and section 5.1. for fuller treatment of the subject.

These differences in response between occupied and unoccupied sites also illustrate the limitations of visual assessments of habitat quality. The lesson to be learned here is that in order to understand how the frogs use the habitat, there is no substitute for walking and/or paddling the margins and islands of the entire study reach during the breeding season in order to locate the important centers of reproduction.

Because the upper Deep Creek site appears to be the breeding center for the Pit 4 FYLF population (27 of 30 known clutches laid there), the most weight with regard to decision making with respect to FYLF should be given to improving flow conditions at this site. At 600 cfs, the sum of connected categories 1, 2, and 3 is maximized at approximately 175 sq meters (the stacked blue, tan, and red solid bars in Fig. 2).

If the effects of discharge on habitat area at un-occupied sites are to be considered, the data indicate that the range of minimum flows proposed by FS, Interior, and CDFG would lead to increases in breeding habitat area (Fig. 4). Under a best case scenario, we can hope that under improved conditions, the population may expand to breed at the currently un-occupied locations. Although there is variation in the channel morphology along the length of Pit 4 reach, there is a degree of congruence among sites showing that total suitable habitat area (summing categories 1, 2) at the other potentially usable sites is also highest at 600 cfs (See Tables 1, 2).

Figure 1. Total area of canopy-1 habitat for the three known breeding or tadpole rearing sites (top) and the three non-breeding or tadpole rearing sites (bottom) at the four lowest test releases. (Source, Springrivers 2003, Fig. 18)



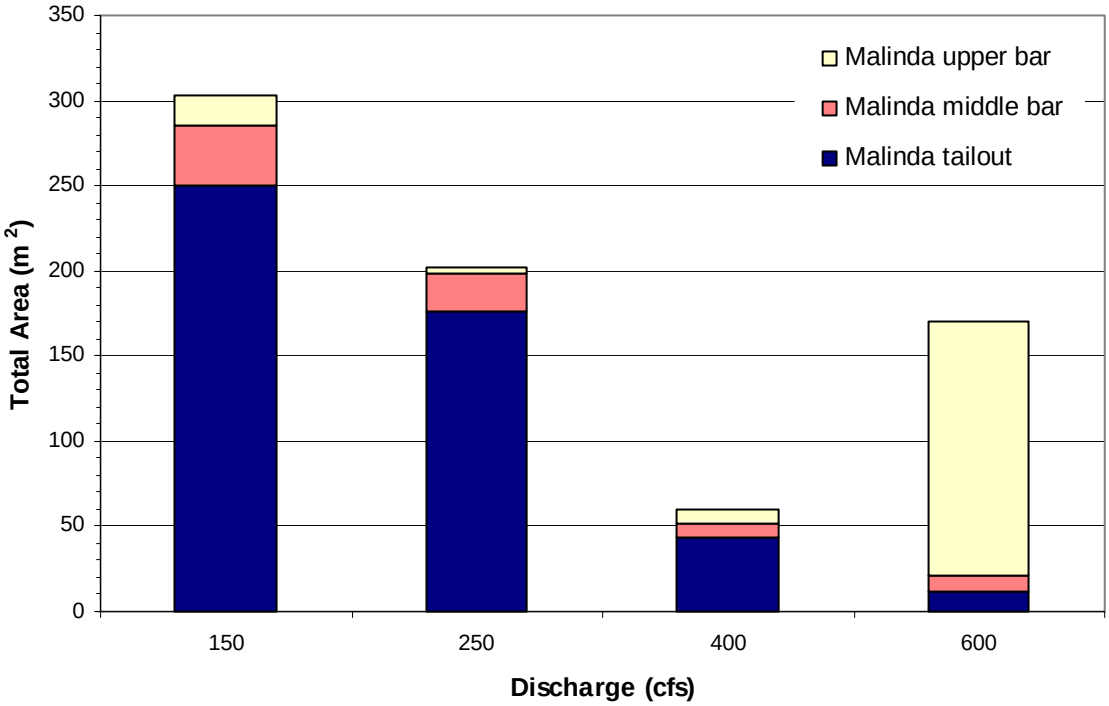


Figure 2. Total area of connected and disconnected canopy-1, -2, and -3 habitat for upper Deep Creek at each discharge (Source, Spring Rivers 2003, Fig. 16, p. 37).

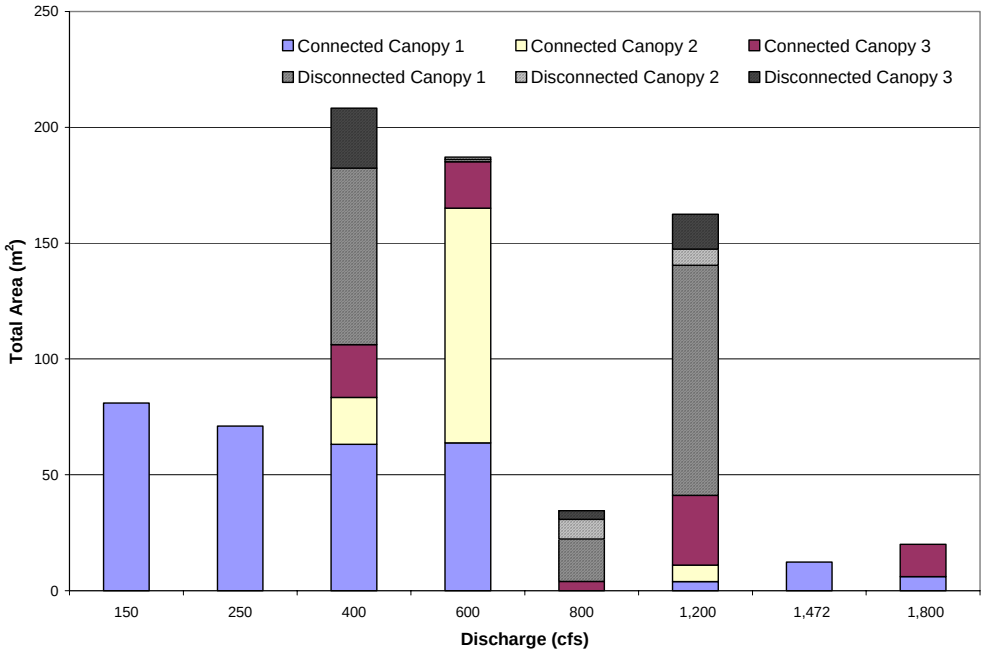


Table 1. The change in the total area of canopy-1 and 2 habitat combined for sites with known breeding and tadpole rearing (n=3) as compared to other sites (n=5) if the current base flow of 150 cfs were changed to 400 cfs or 600 cfs. (Source Spring Rivers, Table 14, p. 43)

Discharge	Breeding & Tadpole Sites				Non-Breeding Sites			
	Total Area (m^2)	Number of Areas	Mean Area (m^2)	Maximum Area (m^2)	Total Area (m^2)	Number of Areas	Mean Area (m^2)	Maximum Area (m^2)
150 to 400	+30%	+225%	-60%	-53%	-65%	+5%	-67%	-83%
150 to 600	+71%	+188%	-41%	+9%	+60%	+68%	-5%	-63%

Table 2. Number and size of foothill yellow-legged frog habitat patches, summing both vegetation categories one and two, at various test flows. Comparison of number of patches and mean patch size between occupied and unoccupied sites could not be deduced from the figures in Spring Rivers report (Source, Spring Rivers 2003, and FERC Table 33, modified by S. Kupferberg)

Test flows (cfs)	Number of patches	Mean Patch Size (square meters)	Total Area of Patches (square meters)	
			Occupied	Unoccupied
150	27	15.0	103	303
250	15	18.6	77	202
400	46	4.8	134	105
600	55	7.7	176	483

It would be a misinterpretation of the data to conclude that increased base flows pose a risk of losing cohorts because frogs will not have usable habitat at their current breeding sites. The important question is whether the fluctuation in category 1, immediately occupiable habitat, at 400 and 600 cfs, is biologically significant? The only way such changes could be biologically significant is if: 1) the frogs are currently using more than 66% of the category 1 habitat available now; 2) the anticipated vegetation change which would make category 2 habitat usable never occurs; and 3) frogs are philopatric at the scale of individual rocks. *None* of these three conditions are true.

1.1.2 Availability of oviposition habitat as a limiting factor.

We can estimate whether breeding habitat area is currently a limiting factor at the pit River, by estimating what percent of the currently available suitable habitat is occupied. At 150 cfs, there were two elliptically shaped patches of habitat at the upper Deep Creek site. One patch was 4.5 by 10 meters, and the second patch was 4 by 9 meters, for a total of 81 square meters. Twenty five egg masses were found in the first patch, and 2 clutches were found in the second patch. A polygon drawn around clutches in patch 1 would cover 20.1 square meters, and a polygon drawn around the two clutches in patch 2 would cover 0.68 square meters. Thus a total of 20.78 square meters of habitat was used. This represents 25.7% of the available habitat. Thus, at the current population size, there is not compelling evidence that space, in terms of total area, is a limiting factor.

I do not wish to invalidate the basic premise that restoration of breeding habitat area is unimportant for the recovery of the Pit River population. In fact there are data to suggest that there is a positive correlation between oviposition habitat area and the number of clutches laid at breeding site. For example, there is the example from Lind et al. at the Trinity River, showing rapid recolonization by frogs after vegetation removal (see section 1.2.1).

1.2 Reasons for summing the three vegetation categories

1.2.1 Conversion of Category 2 to 1.

Both categories represent suitable depth, velocity and substrate, patches, but vary in terms of the time scale of their availability (immediate vs. post vegetation change).

Because the term of the license is thirty years, it would be shortsighted to focus solely on the transition period while vegetation responds to the new flow regime. Although there is uncertainty regarding the rate at which small willows will die off with inundation, it is more a question of when they will die rather than if. If the rate of die off is not sufficiently quick, active vegetation management at sites of concern may be called for, see the "Vegetation Management Plan" and Amphibian and Reptile Monitoring" components of the "Land and Habitat Management Plan 4(e) license condition in Enclosure 1, and the plan detail in Enclosure 3, Appendix C. Since the speed of vegetation change is only a concern at the known breeding sites, which are relatively small in areal extent, chain-sawing the saplings down, would not be a large effort. In fact, similar habitat restoration projects on the Trinity River resulted in rapid colonization of bars by breeding FYLF immediately after woody vegetation was cleared (Lind, et al. 1996).

FERC asserts that the success of this Trinity River habitat restoration example is not relevant to the Pit River (p. 187, DEIS) because manipulation of discharge at the Pit did not increase the area of vegetation free, category one, patches. This reasoning is faulty. Habitat at the Trinity was created by removing woody vegetation instantaneously with a chainsaw, which in the terminology of the Pit River flow study is conversion of category two patches to category one patches. In the Pit River, this conversion could similarly be accomplished either instantaneously with a chain-saw, or over time as vegetation responds to inundation. So the data from the Pit R. that are analogous to the Trinity River data is the amount of category 1 and 2 habitat areas summed together, which are maximized at 600 cfs for the breeding sites currently occupied by FYLF (see Tables 1 and 2 above).

The habitat mapping done by R2 corroborates that, given the channel morphology of the Deep Creek delta / debris fan, the discharge which maximizes FYLF breeding habitat is around 600 cfs. There is a steep increase in the area of slow shallow microhabitats from 400 to 600 and 800 cfs (fig. 3-25, p. 3-35, R2 2003). The shoreline / margin of this habitat, which was identified with respect to eagle foraging, contains within it the areas which are suitable for FYLF breeding and tadpole rearing. The cumulative inundation plots in the vegetation study also indicate that a similar range of flows, 400-700 cfs, would almost completely inundate willows, a condition necessary for die-off (conversion of category 2 patches to category 1 patches).

The R2 authors assert that complete inundation, although necessary, may not be sufficient to maintain the desired changes in riparian vegetation because the riparian zone would just shift to a higher elevation. This prediction is based on an assumption that recruitment processes and outcomes under the new license conditions will be identical to the recruitment processes which have created the current distribution of *Carex* and woody vegetation. Specifically, the current plant populations recruited as seedlings under the conditions of a constant, unfluctuating discharge after spills cease in the late spring /early summer. In a flat-line hydrograph state, soil moisture would be similarly stable. Under unimpaired hydrologic conditions, or if the hydrograph mimics the shape of the unimpaired hydrograph, seedlings would be faced with

entirely different soil moisture conditions. As the discharge would decline along the receding limb of the hydrograph, the depth to moist soil would steadily increase. A seedling, or vegetative propagule, would only survive if its root growth could outpace the rate at which depth to moist soil increased. Jonathon Levine, the plant ecologist with the most expertise on torrent sedge, found that the dominance of torrent sedge in the streamside plant community of the SF Eel River was greatly diminished in reaches where stage dropped more steeply during the summer months relative to headwater reaches where stage was more stable (pers. comm. to S. Kupferberg). Therefore, if the license conditions requested by the Forest Service are in place, which mimic the shape of the unimpaired hydrograph, one would *not* expect a pattern of "one for one" replacement, which the R2 researchers predict.

Determination of whether the new conditions (specifically the slope of the receding limb of the hydrograph and concomitant rate of near shore soil drying) will be sufficient to prevent rapid re-colonization of newly wetted margins could be determined by observations of natural seedling recruitment and adaptive management of flow conditions during the early years of the license agreement. Alternatively, seeds and / or willow stakes could be planted in test plots on bars. Soil moisture depths could be measured and sequential destructive sampling of subsets of the seedlings could be done to measure root length. Adjustments to the rate of stage decrease over time could then be made to manipulate recruitment to a desired level.

It is important to note that *Carex* and woody vegetation at the river margin are not necessarily detrimental to *R. boylii* over the entire course of its life history, because each life stage has different habitat requirements. The adults in the summer require shade from the canopy trees above inundated areas to provide refuge from high summer temperatures. Field observations in August prior to the test flows were that adults occurred in wet side channels with mature alder canopy (S. Kupferberg pers. obs.). Inundation near mature trees that likely would not likely die back under higher base flow conditions, i.e. canopy category 3 habitat, although infrequently used by adults for breeding, would be usable by adult frogs in the summer. Sedge clumps also provide necessary cover. After storms, Van Wagner (1996) found juveniles and adults hiding in the bases of sedge clumps.

1.2.2 Canopy-3 habitat should be included.

Patches shaded by tall trees are not entirely unsuitable breeding habitat for FYLF; such patches are just less commonly used. At the South Fork Eel River, a well studied FYLF population is known to utilize some breeding sites where shading from tall trees occurs. Percent open canopy ranges from 26% to 88% (Fig. 3, Kupferberg unpublished data). The median value is 62% open and the, mid range of canopy values is 55-80% open. Furthermore the sites with less percent open canopy did not necessarily have fewer egg masses deposited there, and there was no correlation between degree of shading and the mean number of clutches laid at a site over an eleven year monitoring period (R^2=.03). If one accepts PG&E's argument that all sites, regardless of occupancy be considered, and canopy category three habitat is

included, it is clear from examining Fig. 4 (below) that the maximum amount of breeding habitat is created at 600 cfs (i.e. adding the solid, blue, tan and red bars).

Figure 3. The number of clutches at a breeding site did not correlate with the percent open canopy (n=15 breeding sites). Numbers of FYLF clutches at each site was monitored from 1992 to 2002 and a mean number of clutches laid at that site was calculated. Canopy was measured using a spherical densitometer in 1994, with four measurements taken at each breeding site.

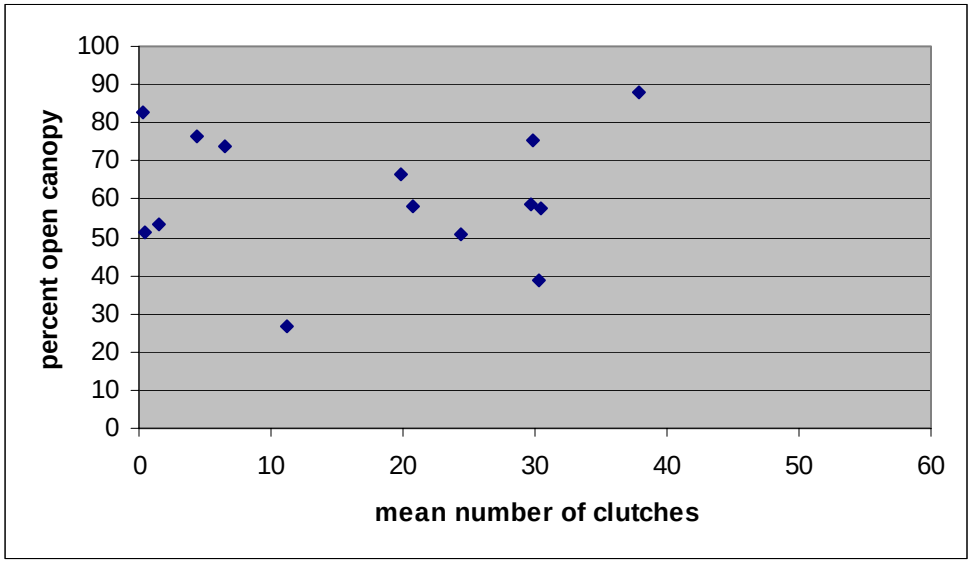
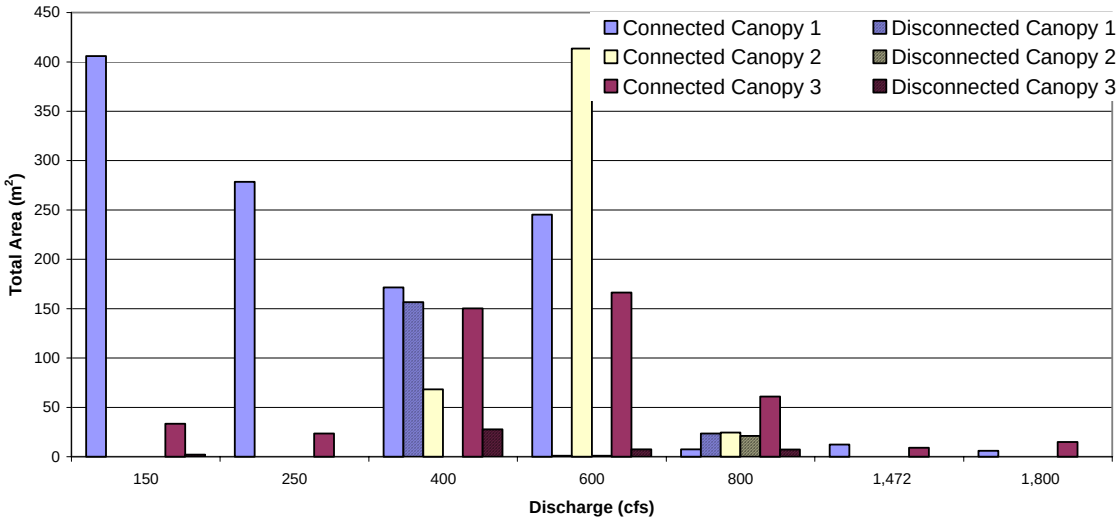


Figure 4. Total area of connected and disconnected canopy-1, -2, and -3 habitat for all eight sites combined at each discharge (Source Spring Rivers / PG&E 2003, Fig. 15, p. 35)



1.2.3. Vegetation status of category 1 patches is not static.
Spring Rivers states that total category 1 habitat should be the considered metric "because no changes are necessary in order for canopy-1 areas to provide suitable breeding habitat for foothill yellow-legged frogs… (Spring Rivers p.58)." No changes in vegetation are not only *necessary*, but also *required* in order for canopy-1 areas to continue to provide suitable breeding habitat. Spring Rivers acknowledges that vegetation is not currently static, because much riparian vegetation was scoured by the 40,000 cfs floods in 1997. Under the status quo flow conditions we are witnessing the rapid recolonization of bars. It is unknown whether or not the category one patches will persist over the term of the license under PG&E's proposed flow regime.

1.3 Habitat Fragmentation
Spring Rivers presents data that there will be changes in patch number, mean patch size, and inter-patch distance as discharge increases. Determining the biological significance of more numerous but smaller patches is conjecture, because there is simply not enough known about breeding behavior, movement, and territoriality in FYLF in general. Educated guesses should be based on what is known about this species rather than an assumption that smaller patches will have negative effects.

1.3.1 Inter-patch distance. Frogs are philopatric with respect to a breeding site, which is at the scale of geomorphic unit, i.e. a certain cobble bar or pool tail out, not necessarily with respect to an oviposition site. The assumption that discontinuity and shifts in the distribution of patches within a breeding site is harmful, overstates the spatial and time scales of site fidelity. Oviposition sites vary within a given breeding site both within a given breeding season and among years. Individuals select specific depths and velocities and are not necessarily wedded to specific rocks. It is true that the same rocks are reused in years when discharge conditions are similar, but in years when discharge is naturally higher or lower, different microsites/rocks are chosen.

In a multiple year study of *R. boylii* oviposition site selection, with sample sizes an order of magnitude larger than the Pit River data (both with respect to numbers of clutches and numbers of breeding sites), depth and velocity at egg mass did not vary significantly inter-annually, but distance from shore (and hence which rock was used) did vary significantly (Kupferberg 1996). Over twelve years of monitoring egg laying (Kupferberg, unpublished data) there have been several seasons in which the stage drops during the course of the breeding season. Some years the breeding season can be 6 weeks long. Eggs laid toward the end of the breeding season are laid further into the channel, on rocks where the velocities and depths would have been outside the preference range a month earlier. New patches are thus found on the time scale of days to weeks within a given bar or pool tail out. Another anecdote of how frogs can find new oviposition sites within the same geomorphic unit comes from a situation where a large old growth Douglas Fir crossed the entire width of the SF Eel channel (approx. 30 m) changing the velocities in a run that had many clumps of sedges and emergent boulders. Frogs had a historic breeding site on the banks of a point bar near the upstream end of the run, within 1-2 m of shore. In the one year when the tree was

altering the flows, they used boulders 12 m downstream and 8 m further towards the thalweg for oviposition.

Data regarding the distances between existing and potential new patches at upper Deep Creek would be helpful in evaluating whether the distances are greater than their typical rates of movement. The only study conducted on movement of individuals was conducted by VanWagner (1996) on a small stream in the Sierra Nevada Foothills using mark recapture techniques. Granted movement patterns may be different through the Pit River landscape, but he observed mean maximum linear distance traveled along the study reach during the pre-spawning and spawning season to be 54 m (±SE 85.5; range = 0-413 m). From my field observations on the days I accompanied Spring Rivers during the test flow, the newly inundated patches were within the range of these known frog movements.

Also the direction from which the frogs are approaching the Upper Deep Creek breeding site supports the guess that they would find the newly inundated patches. One thing to consider here is the direction from which the frogs are approaching the breeding site in the spring. Spring Rivers asserts that "the change from essentially one large breeding area to multiple smaller breeding areas separated from the old breeding site by tens of meters, faster velocity water, and dense vegetation is likely to have some negative impact on the reproductive success…"(Spring Rivers p. 58). Frogs are most likely coming from overwintering sites in Deep Creek, not from the 2002 egg sites which is toward the thalweg of the Pit River. The newly inundated patches at higher discharges are in the path of travel from Deep Creek to the 2002 egg sites. The assertion that the frogs must traverse the high velocity patches does not make sense and it is not known that adult frogs are incapable of moving through high velocity patches. In fact, in my many years of observing this species I have often seen adult frogs jump into fast moving riffles and move along the bottom when startled by my footfalls.

During the flow study we did observe males staying close to the previously laid clutches despite the changes in depth and velocity. This observation may be interpreted as males not moving from, or defending, a territory in which they had successful matings. It could also be interpreted as males guarding eggs. Since the females choose the actual oviposition site (males are carried by the females during amplexus), there is no reason to assume that any new eggs would be laid at inappropriate or "risky" depths and velocities.

1.3.2. Patch number. Given that males defend a territory from which they call to attract females, perhaps an increase in the number of patches within a breeding site could influence levels of male-male aggression, competition for mates, and male territory size. But it is unknown whether or not the females (who are carrying the males on their backs) choose oviposition sites only within the males' calling territories or how far amplecting pairs travel. Making a value judgment as to how changes in patch number within a breeding site might affect total reproductive success over-reaches the current state of knowledge. Research regarding these

intricacies of breeding behavior is being conducted by Ph.D. candidate Clara Wheeler, and member of the Redwood Sciences Laboratory, USFS, PSW.

1.3.2 Mean Patch Size. There are no data in the Spring Rivers/PG&E report to support the assertion that smaller mean patch size is detrimental. In fact, re-examination of previously unpublished analyses of the spatial patterns of site use at the SF Eel (n=4 breeding sites, 104 clutches), reveals three reasons why small mean patch size is not necessarily detrimental (Kupferberg, unpublished data). First, there is often clumping of clutches within a breeding site. Three of the four breeding sites had clumped distribution, one had random distribution, using the Campbell and Clarke Test (Krebs 1989, p133-135) Second, nearest neighbor distances are quite small, with 69% (8.6% SE) of clutches being laid less than 30 cm from the nearest neighboring clutch. And third, the most populous breeding site (n= 47.7 ± 4.1 clutches laid per year 1993-2002) is characterized by numerous small patches (approx 1-3 m^2) of appropriate depth and velocity spread along 133 m of the river.

1.4 Habitat at high flows

There is habitat at the higher flows that was not explicitly mapped during the flow study. At higher flows, 1800 cfs, there would be a vast increase in breeding habitat within what is at lower base flows (150 to 1200 cfs) Deep Creek proper. When water washes over the Deep Creek Delta and there is mixing of the cold Deep Ck water with warmer Pit River water, the temperatures in Deep Creek become suitable for breeding. This point is illustrated by the temperature logs from Deep Creek during the unplanned spill of 4/19/02. Temperatures went from diel cycling between 6 and 8 °C to a peak of 11.3 °C, a temperature at which breeding could occur. The margins of the channel of Deep Creek from the cascade / footbridge crossing all the way to the 150 cfs confluence, a distance of approx 200-300 m, has continuous potentially suitable breeding habitat, i.e. the correct range of depth and velocities and substrates, and is not overly shaded with canopy, but the temperatures are too cold. Essentially the confluence of Deep Ck with the Pit shifts further up the Deep Creek channel and a whole new reach of the Pit River becomes available for breeding. Thermal mixing may start at about 1200 cfs; there was a slight increase in temperature at that discharge in May, but mixing is not complete until the range of historical base flows is approached at 1800 cfs. Thus, the current low base flows have caused a loss of historic breeding habitat. Because Deep Creek is appropriate adult habitat, the project has also caused breeding and rearing habitat to become disjunct from adult habitat at Deep Creek.

2. Non-native Predators (p. 188 of DEIS)

2.1 Bullfrogs.

FERC does not recognize that FYLF have been observed in Pit 5 (See p. 1 of Spring Rivers' report FYLF found in 1999, but not since). Thus, the control of bullfrogs in Pit 5 is not to mitigate the "potential for adverse interactions (paragraph 2, p. 188)" but to mitigate for the current situation. FERC states that flooding alone is insufficient to prevent persistence of bullfrogs in a river, as evidenced by the continued presence of bullfrogs after large flooding in 1997 and 1998. I agree that flooding alone will not

eliminate bullfrogs from the Pit 5 reach. Bullfrogs are highly vagile and fecund. Although flooding will prevent successful reproduction in the river, and decrease the density of the population, immediately after high intensity, but low frequency, flooding. Recovery in the absence of disturbance, however, is quite rapid. Populations will be sustained by immigration of adult bullfrogs from the surrounding ponds and reservoirs, and one female lays 10,000 eggs. Because the project creates more habitat, i.e. reservoirs, and creates conditions more suitable for bullfrogs, i.e. changes in temperature and decreased frequency of flooding, bullfrog control should be included as mitigation for the project's impact on FYLF. Control efforts must be multifaceted, including manipulation of physical conditions, temperature and freshet frequency/magnitude/ and duration, as well as direct eradication of adults and egg mass removal. Because Pit 5 reach was not surveyed during the FYLF spawning season in 2002, I recommend that the monitoring of FYLF populations that FERC supports in Pit 4 be extended to Pit 5.

2.2 Crayfish.

FERC does not mention another very important non-native predator, the signal crayfish. In the Pit River, signal crayfish (*Pacifastacus leniusculatus*) invasion has progressed during the years of flow alteration (Light et al. 1995). In smaller unregulated Sierran streams, signal crayfish invasion is constrained by high intensity (bankfull and higher) flood events (Light 2002). Similar observations of susceptibility to high intensity flow events have been made for other species of crayfish as well (Gamradt and Kats 1996, Robinson, et al 2000). Crayfish are known predators of amphibian eggs and larvae (Axelsson et al. 1997) and interfere with newt breeding (Gamradt et al. 1997). Signal crayfish may pose a significant threat to FYLF at the Pit River. The rapid disappearance of tadpoles at the Deep Creek site during May 2002 was suspected to have been caused by the abundant crayfish seen near eggs and tadpoles (Spring Rivers 2003, p. 49). This disappearance occurred after the May test flows and prior to the first of the emergency spills that could have provided alternative explanations. I recommend that the density of crayfish be monitored to see if the proposed freshet flows and shaped flow regime have any impact on signal crayfish density. I also recommend that some predator exclusion trials be conducted to verify that tadpole survival would be within expected levels in the absence of crayfish.

3. Effects of discharge fluctuation on velocity, depth, and FYLF survival

The results of the study confirm what is already known about FYLF breeding site preferences from other populations in California, that females select microsites within a narrow range of depths and velocities for attaching their eggs to rocks. Clutches can withstand a moderate degree of increase in velocity but are susceptible to dislodging after prolonged exposure to higher velocity flows. In part, the risk of an egg mass fraying and separating from its rock is a function of egg mass age, because the adhesive and cohesive properties of the jelly deteriorates with age. The conditions of the test flow, continual increases in velocities over the course of a week, resulted in a loss of approximately half of the clutches, a significant impact on survival. It is reasonable to assume that a similar and if not higher percentage of the egg masses that were moved to Deep Creek would have also been scoured. The clutches that were relocated were chosen because it appeared that they were beginning to fray or detach.

The increases in discharge also caused biologically significant changes in the direction of the current. The flow vectors changed as discharge approached 400 cfs and above, i.e. when the water jumped the low flow banks. When water began to flow over the cobble bar, there was a 45° change in the direction of flow, such that the micro eddies on the lee sides of boulder/ cobbles where eggs had been deposited shifted. It was at the higher discharges that parts of the egg masses were caught by the current and began to fray and detach.

The management implications of these findings are twofold with respect to flow regime. First, the minimum discharge should be sufficiently high such that spills and powerhouse outages during the spawning season will not be lethal to eggs, embryos, and recently hatched tadpoles which are poor swimmers. I believe a breeding season base flow of 600 cfs would provide a buffer from changes in the magnitude of velocity change as well as changes in the direction of the water current when spills occur during the spawning season. The magnitude of spills caused by operational and emergency outages vary widely (from 1,500 cfs to 5,600 cfs as per PG&E reports discussed in reference to Page 128-131 of the DEIS in Enclosure 2) but due to their significant magnitude difference from the 150 cfs base flow, they induce changes in flow vectors at the breeding site. Second, the velocity study results reinforce the reasoning used to develop the "freshet flow" component of the "Flow Regime for Affected NFSL" Revised Preliminary 4(e) condition. The timing of freshet flows and planned outages should not coincide with the spawning season. In addition to avoiding spawning season by not having freshets if water temperature has reached 11 degrees C, a spot check for eggs at the Deep Creek site would be prudent, prior to initiating the freshet flows.

4. Whitewater Boating (WWB)

FERC does not include the effects of high flows on dislodging egg masses, washing tadpoles downstream into inappropriate habitats, stranding of tadpoles during the ramp down following potential WWB flows. I agree with the FERC regarding the negative impacts on dislodgement of algae. Although this food web effect of exportation of primary production to the downstream reservoirs is detrimental for tadpoles and the entire benthic macroinvertebrate community, the direct effects of un-seasonal pulse flows should be considered.

5. Status Quo Risks

Spring Rivers and FERC assert that there would be risk associated with changing to a new flow regime. The reasoning presented in the sections above, shows that FYLF have adaptations, namely vagility, and opportunism, for dealing with environmental variability. There are no data from the flow study to indicate that the spatial shifts in habitat patch distribution would be outside FYLF adaptive abilities. Additionally, the risk of change must be weighed against the following risks of continuing the status quo flow regime.

5.1 Spills

The velocity data and outcome of the dislodging study show that clutches are at risk of dislodgement during extended flow fluctuations/spills. Higher winter and early spring base flows would act as a buffer, moderating the stage and velocity fluctuations that now occur in breeding habitats when, in many years, spills are abruptly superimposed on low (150 cfs) minimum flows.

I examined the hydrographs prepared by Craig Addley and Matt Smeltzer, to determine how frequently spills occur during the FYLF breeding season. Unfortunately, we only have one year of data regarding the timing and length of the breeding season, so we do not know exactly which calendar dates bracket the breeding season. If the temperature model were run for all the years of record, 1970-1999, it might be possible to estimate a start date based on an initiation temperature in the 9 to 12 °C range, however this simulation has not been run by PG& E to my knowledge. In the absence of such information, I estimated that the breeding season would likely fall in the months of April-June. We do not know if FYLF at the Pit River delay breeding until spills cease or if they lay eggs at higher flows. Given these unknowns, I counted the number of years in which spills occurred, and whether the peaks were superimposed over the current minimum discharge of approximately 150 cfs. There were spring / early summer spills in the 15 of the 29 years. From 1992 to 2002 there were also seven emergency shutdown spills.

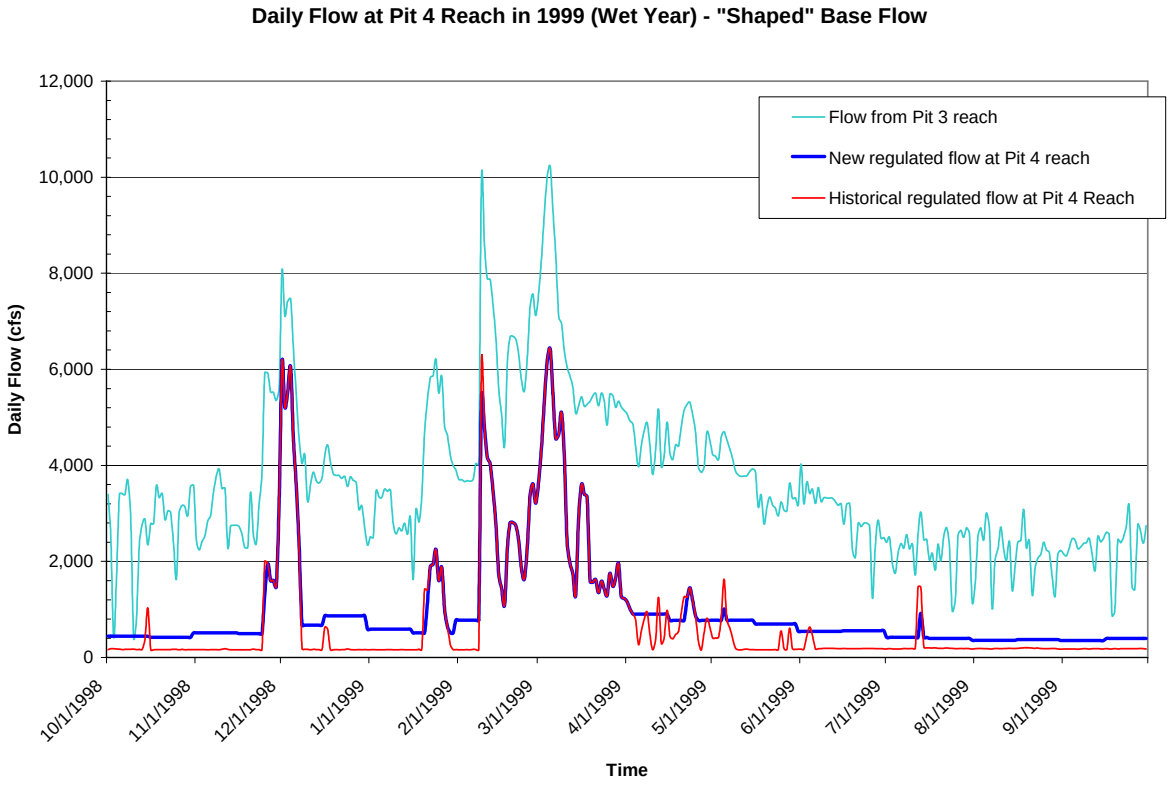
Below are some examples of the wet years in which the variability in discharge would likely have been detrimental to FYLF (Fig. 5). In the spring of 1999 (Fig. 5 top), there were 9 peaks (red line) during the probable breeding season, each of which crossed the approximately 400 cfs boundary in which flows change direction at the upper Deep Creek breeding site. The proposed shaped hydrograph in which minimum discharge (dark blue line in Fig. 5) would be a percentage of the previous two weeks' inflow, mimics the descending limb of the unimpaired Pit River hydrograph (light blue line). This would be benefit FYLF by buffering the effects of spills above the minimum discharge, and dampen or eliminate the peaks. About half of the spill years are comparable to 1999 with respect to this pattern (1978, 1984, 1986, 1991, 1996, and 1997).

Under unimpaired conditions, there would have been good and bad years for FYLF recruitment. Increases in minimum discharge would not be a panacea that eliminates the effects of large magnitude spills that continue late into the spring. In 1982, for example, (Fig. 5 bottom), there is little difference between the proposed and the historical regulated hydrograph. About half of the spill years have similar patterns (1971, 1975, 1975, 1993, 1995, 1998). Only future monitoring of FYLF breeding behavior will answer the outstanding questions regarding whether frogs delay breeding in such years because water temperatures are still too cool during these lager magnitude spills or whether the portions of Deep Creek that have mixing with Pit River water above 1800 cfs would be used for breeding.

Perhaps, abundant reproductive success during dry years when discharge variability was low has sustained the population (e.g. 1970 and 1971, Fig. 6). But even among such dry

years, discharge during the breeding season varied. In 1970, (top graph, Fig. 6) April – May discharge varied between 3,000 and 4,000 cfs, in 1971 , (bottom graph, Fig. 6) discharge varied between 2,000 and 2,300. Therefore, the selective pressure for frogs to utilize sites in which appropriate habitat is available at a range of flows exists at the Pit River similar to other populations of FYLF in northern California.

Figure 5. Historical regulated and proposed flows from two examples of wet years, 1999, and 1982. In 1999 there was also an emergency spill in July.



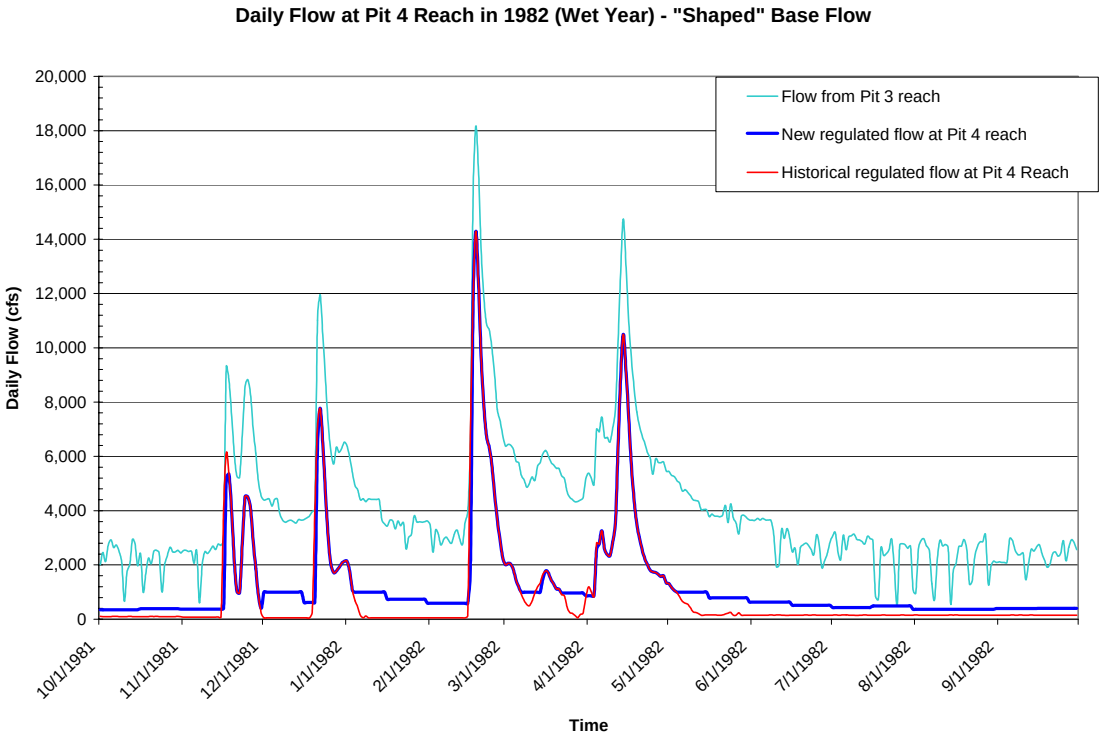
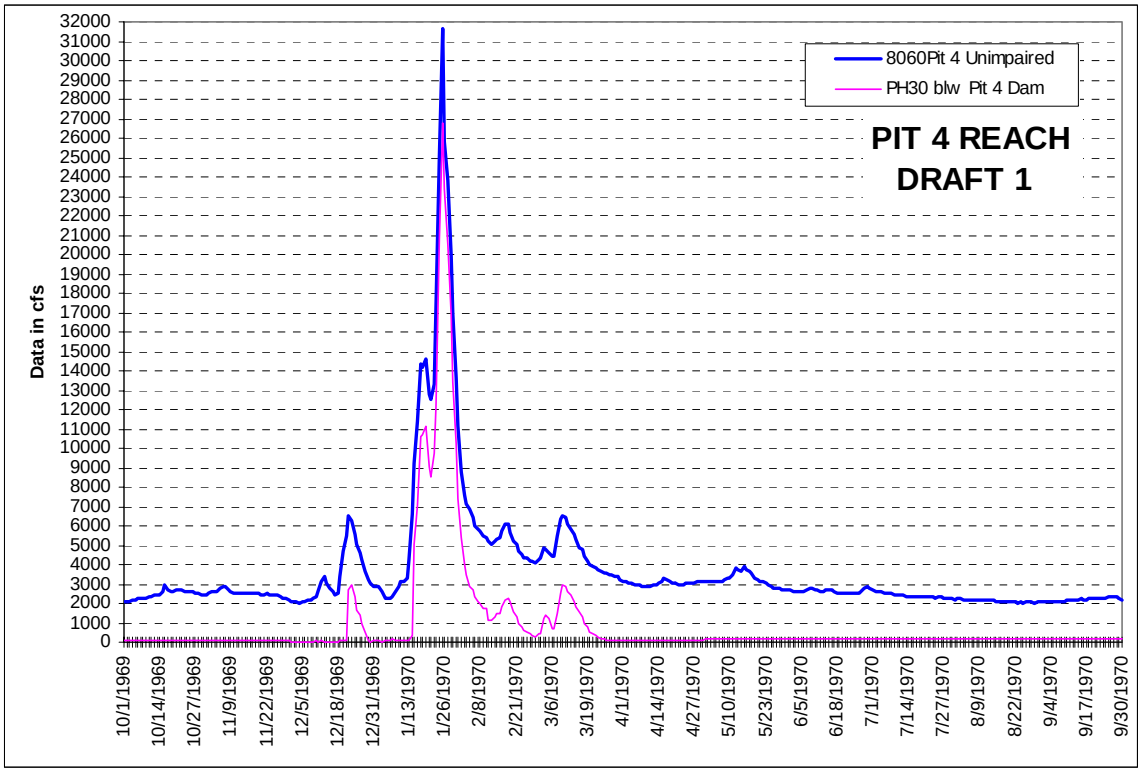
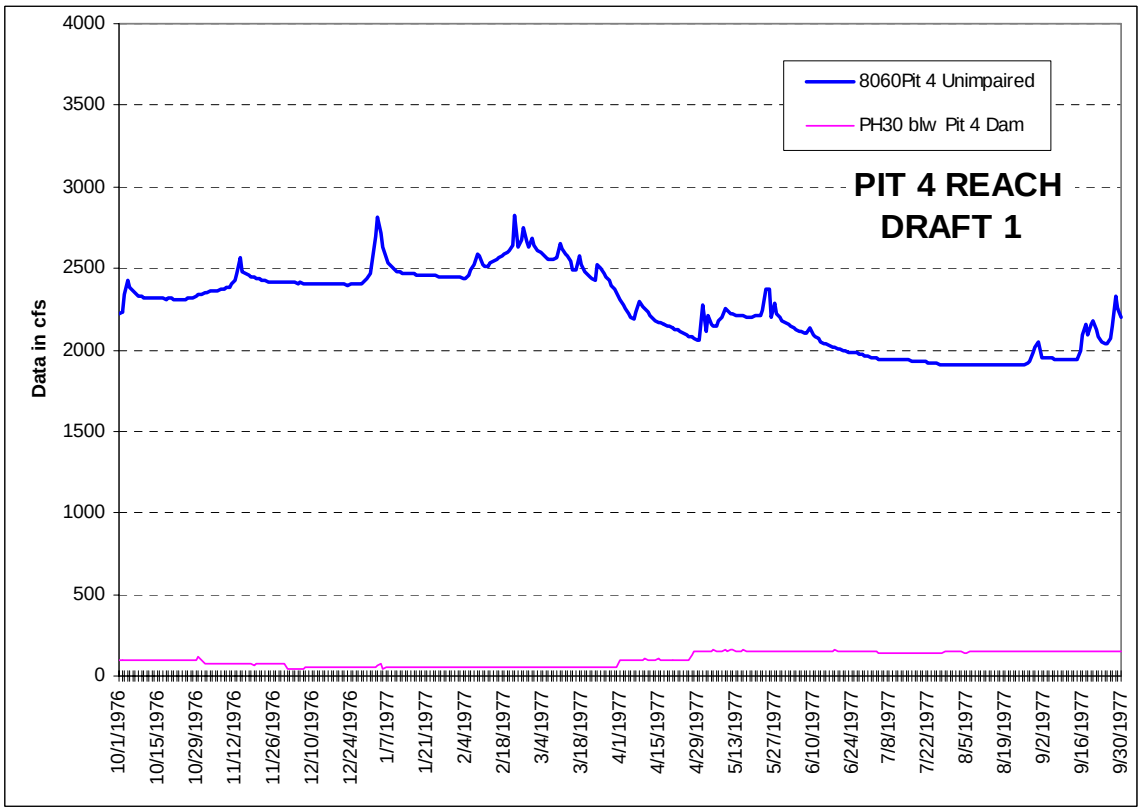


Figure 6. Flow variability during the breeding season in two examples of dry years, 1970-1971.





5.2 Time to hatching.

The 2002 hatching times upwards of 30 days for some clutches, were extremely long relative to other populations. In other populations I have observed in the San Francisco Bay Area, the North Coast, and the Sierra, hatching takes two-three weeks. The current flow regime in which stage is constant from egg laying to egg hatching promotes slow embryo development. Under the shaped flow proposal, stage would be declining such that eggs will be in shallower water that warms, and in water with lower levels of dissolved oxygen, two factors known to shorten the time to hatching. The extended time spent as embryos increases the risk of predation, especially by crayfish.

5.3 Continued overgrowth of point bars by willows and *Carex*.

It is not known how long the current "category one" habitat patches will remain bare. The vegetation at the present time is in a state of recovery from the 1997 floods, and in the process of re-colonizing the bars. In the absence of change of the flow regime there is a risk that current "category one" patches may become less suitable for use.

6. Conclusions: Mitigation for Loss of Historical Habitat and Increased Variability in Discharge.

The Spring Rivers report hypothesizes (p. 50) that the widest reaches of the channel and canyon, such as the present-day reservoir sites, Deep Creek delta, and the lower Pit 5 Reach, contained some of the best historical breeding habitat. The current best potential breeding habitat is no different from these best historical habitats, excepting the reservoirs of course, which have been eliminated by inundation. After all, spill flows still occur in many (>50%) years, up to, and sometimes well above the former 2,000 cfs base flow, and may persist until late May or early June. However, frogs breeding today face more extreme challenges with respect to fluctuations in discharge. As under historical conditions, and like other populations of FYLF which evolved under the same wet winter /dry summer climate regime, Pit River FYLF breed during the transition between the wet and dry season and must utilize places where stage and velocity change slowly as a function of discharge. In the pre-project era breeding season, discharge could range from 2,000 cfs up to thousands more. Today discharge ranges from 150 cfs up to thousands more. In either case, the frogs must endure the "thousands more" conditions. The shaped flow proposal should help to mitigate the effects of the project induced increased variability in discharge.

This point about historical habitat, made by Spring Rivers / PG&E, underscores the huge amount of lost FYLF habitat due to inundation of reservoirs and lack of thermal mixing in the tributaries near their confluences with the Pit. Appropriate mitigation for this lost habitat may include funding for chainsaw / vegetation removal work, and bullfrog control in the Pit 5 reach. We did not have time to search for FYLF breeding sites in Pit 5, and the monitoring which FERC recommends that PG&E conduct, should include more thorough searches of that area.

It is also not known if Pit 3 historically may have had FYLF. Because Pit 3 only received accretion flows for many years it is possible that FYLF were extirpated from that reach, and the dam and reservoir may represent barriers to upstream recolonization from Pit 4. Once more is learned about how FYLF behave in Pit 4 and 5, and how to manage this resource, I recommend that the question of what factors are limiting to FYLF in Pit 3 be revisited. Transplant experiments may be warranted to determine if dispersal is the limiting factor.

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