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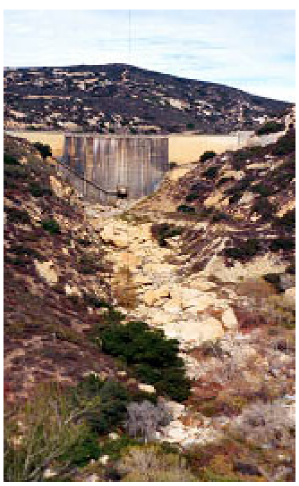
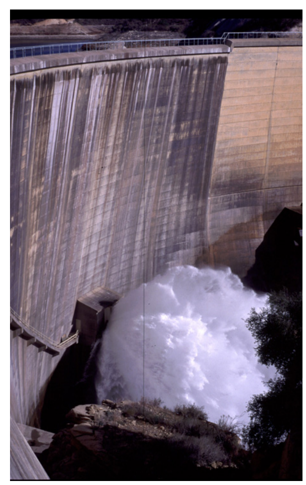
Final Report





Prepared for:

Sweetwater Authority

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Assessing the Risk of Loveland Dam Operations to the Arroyo Toad (*Bufo californicus*) in the Sweetwater River Channel, San Diego County, California

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Abstract

The purpose of this study was to provide a risk assessment of the short-term and long-term effects of Loveland Dam operations on arroyo toad (*Bufo californicus*) reproductive success and population viability. Results of this study will be used in the development of the Sweetwater Authority Subarea Plan of the Joint Water Agencies Subregional Natural Community Conservation Planning (NCCP) program and will be used in the process of gaining scientific justification for the United States Fish and Wildlife Service (USFWS) and California Department of Fish and Game (CDFG) incidental take permits associated with the Sweetwater Authority Subarea Plan (Fleury 2001). The goal is for Sweetwater Authority to maintain flexibility in the management of their reservoirs while sustaining arroyo toad populations within the system (Fleury 2001). Historical arroyo toad breeding, weather, hydrological, and Loveland Dam release data were used to examine the risk associated with the short-term and long-term effects of Loveland Dam operations on arroyo toad reproductive success and population viability. Dam releases during the arroyo toad breeding season are the biggest concern for reproductive success and the focus of this risk assessment. Using historical breeding occurrence data, rough upper and lower bounds for arroyo toad cohort loss due to controlled dam releases during the arroyo toad breeding season were estimated. In the analysis, risk due to dam releases was found to be the highest in early March to late July when the greatest loss of egg masses, larvae and metamorphs was estimated to occur, with the upper bound ranging from 28% to 63% of the entire year's cohort. Over time, repeated loss of cohorts due to dam releases can decrease population viability, but further study is required to determine the exact risk. Simply avoiding controlled releases during the arroyo toad breeding season, especially from March to late July, will greatly reduce the risk to arroyo toad reproductive success and population viability. In addition, several other possible risks to arroyo toad reproductive success as a result of dam operations were qualitatively examined. These included the effects of dam releases concurrent with rain or spill events, the effects of dam releases during wet and dry years, the effects of the intensification and lengthening of drought periods and the effects of the degradation of arroyo toad breeding habitat from the increase in vegetative cover and the loss of coarse sediments. Due to the lack of specific data for this system, the exact effects of these stressors on arroyo toad reproductive success and population viability are unknown and will require further study, however qualitative assessments were possible. With little refinement, this risk assessment may be used as a framework for other agencies studying the impacts of dams on amphibians and other riparian dependent species.

Introduction

Throughout the world, riparian ecosystems have been substantially altered by the construction and operation of dams. An estimated two-thirds of the fresh water flowing to the world's oceans is obstructed by dams (Nilsson & Berggren 2000) and approximately 193,500 square miles is inundated by the reservoirs associated with these dams (Collier et al. 2000). In the United States, nearly every river is regulated by dams, locks, or diversions (Collier et al. 2000). In California there are 1395 dams within the jurisdiction of the State of California's Department of Water Resources (CDWR 1993). Three hundred and forty of these dams occur in southern California and 56 of these are found in San Diego County (Figure 1) (CDWR 1993).

Besides the initial destruction and degradation of habitat resulting from the construction of dams, some of the most important effects of dams are: 1) altered flow regime, 2) reduced sediment and nutrient load, 3) increase in riparian vegetation cover and 4) invasion by exotic species (Baxter 1977; Williams & Wolman 1984; Ligon et al. 1995; Cole & Landres 1996; Lind et al. 1996; Richter et al. 1996; Collier et al. 2000; Nilsson & Berggren 2000). Alteration of flow regime can result in a reduction of discharges, a decrease of flood peaks and a reduction in the frequency of over bank flooding (Baxter 1977; Williams & Wolman 1984; Ligon et al. 1995; Collier et al. 2000; Nilsson & Berggren 2000). Sediments and inorganic nutrients are trapped by the reservoir and then restored downstream by the erosion of shores and streambed, resulting in channel simplification or widening, reduced geomorphic activity (e.g., lack of point bar deposition), and an increase in the particle size of the bed material (Baxter 1977; Nilsson et al. 1991; Ligon et al. 1995; Richter et al. 1996; Trimble 1997; Collier et al. 2000; Nilsson & Berggren 2000). Alteration or collapse of the stream's food web may result from the loss of inorganic and organic nutrients to the reservoir and/or the absence of scouring floods (Baxter 1977; Ligon et al. 1995; Richter et al. 1996; Wooten et al. 1996; Nilsson & Berggren 2000). Additionally, a decrease in peak flows can result in increased vegetation below the dam, usually by encroachment of the active channel (Williams & Wolman 1984; Ligon et al. 1995; Lind et al. 1996; Collier et al. 2000). Riparian habitats are vulnerable to invasion by exotic species as a result of recurrent disturbance and dams may contribute to this vulnerability by providing a year round source of water and by preventing winter scouring floods that may flush exotics from the system (Lind et al. 1996; Nilsson & Berggren 2000). Other downstream effects of dams include changes in oxygen content, water chemistry, and water temperature (Baxter 1977; Ligon et al. 1995; Cole & Landres 1996; Richter et al. 1996) and a decrease in species richness (Nilsson et al. 1991).

The alteration of hydrologic regimes associated with dam operations is one of the leading threats to freshwater fauna in the United States and is especially predominant in the West (Richter et al. 1996). Alteration of the hydrologic regime along with direct habitat destruction and degradation from the construction of dams is considered one of the leading causes of amphibian decline. In southern California alone, there are eight species of amphibians that are considered at risk from hydrologic modifications: western toad (*Bufo boreas*), Pacific treefrog (*Hyla regilla*), California treefrog (*Hyla cadaverina*), California newt (*Taricha torosa*), western spadefoot toad (*Spea hammondii*), mountain yellow-legged frog (*Rana muscosa*), California red-legged frog (*Rana aurora*) and arroyo toad (*Bufo californicus*) (Hunter 1999). Several of these species have some level of protection. The arroyo toad is federally endangered, the mountain yellow-legged frog is federally endangered, the California red-legged frog is federally threatened and the western spadefoot toad is a California species of special concern. The focal species of this study, the arroyo toad, was listed as an endangered species under the Federal Endangered Species Act on December 16, 1994 (USFWS 1994).

The arroyo toad, a small (55-82 millimeters snout to urostyle), dark-spotted toad of the family Bufonidae, (Figure 2) is a mostly upland species that primarily uses streams during the breeding season, January to September (these dates range depending on precipitation and location)(USFWS 1999). Arroyo toads are breeding habitat specialists, breeding only in shallow, slow-moving riparian habitats that are typically disturbed naturally on a regular basis by flooding (USFWS 1999) (Figure 3). Sweet (1992) describes the major characteristics of arroyo toad breeding pools as: “proximity to sandy terrace habitat; minimal current; majority of pool < 1 inch deep; substrate of sand, gravel, or pebbles; gently sloping shoreline, or central bar; and bordering vegetation low or set back such that most of the pool is open to the sky.” Unlike most western species of *Bufo* that will initiate breeding after rain events and often breed in ponds and standing water, the arroyo toad waits to initiate breeding until the above conditions exist (Sweet 1992; USFWS 1999). Because the arroyo toad is specialized in such a stochastically fluctuating habitat, the additional stress of habitat degradation and loss from manmade factors and predation by exotic species has lead to its disappearance in 75 percent of the previously occupied habitat in California (Jennings & Hayes 1994).

The decline of the arroyo toad is considered largely due to the degradation and destruction of breeding habitat as a result of dam construction and operation (Sweet 1992; USFWS 1994). Approximately 40% of the estimated original range of the toad has been lost to dam construction, including at least 25 large reservoirs that have inundated over 190 km (120 miles) of suitable upland and breeding habitat (USFWS 1994, 1996 & 1999). In addition, arroyo toad habitat downstream from reservoirs is affected by the alteration of the hydrologic regime, the reduction in coarse sediment, the increase in vegetation and the persistence of exotic predatory species. The reduction of peak flows prevents the movement and deposition of sediments required to create and maintain arroyo toad habitat. Additionally, arroyo toad habitat is further degraded as coarse sediments are stripped away and not replaced below dams (Campbell et al. 1996; USFWS 1999). This is a function of the sediment load being trapped by the dam and then restored by the erosion of the channel below the dam (Baxter 1977; Nilsson et al. 1991; Ligon et al. 1995; Richter et al. 1996; Trimble 1997; Collier et al. 2000; Nilsson & Berggren 2000). A balance of scouring flows and sufficient sediment supply is required to maintain arroyo toad breeding habitat. Elimination of flow, which is common for storage reservoirs, reduces summer water levels and can lead to early drying of arroyo toad breeding pools, resulting in failure of reproductive effort (Campbell et al. 1996; USFWS 1999). Unseasonable releases may prevent successful arroyo toad recruitment by altering breeding pools or by displacing arroyo toad eggs and larvae (Sweet 1992; USFWS 1994, 1996 & 1999). Arroyo toad egg and larvae loss to dam releases has been documented at Cottonwood Creek as a result of water releases of several million gallons per day from Barrett Dam (Campbell et al. 1996) and by Sweet (1992) in Piru Creek due a to month long release averaging 120 cubic-feet-per-second from Pyramid Lake in 1991. Similarly, Lind et al. (1996) found complete loss of foothill yellow-legged frog (*Rana boylii*) egg masses due to dam releases in the Trinity River. Furthermore, persistent water releases throughout the year encourage overgrowth of riparian vegetation and the change from an ephemeral water supply to a permanent supply maintains exotic predators. These effects are worsened by the reduction of peak flows and lack of scouring needed to prevent the overgrowth of riparian vegetation in arroyo toad breeding habitat and to flush exotic predators such as bullfrogs, green sunfish and African clawed frogs from the system (Campbell et al. 1996). Viability of arroyo toad populations affected by dams is a concern throughout southern California.

In San Diego County, the possible downstream effects of Loveland Dam are a concern for the viability of arroyo toad populations found in the Sweetwater River between Loveland and Sweetwater Reservoirs. The Sweetwater Dam was constructed in 1886-1888 to create a drinking water reservoir and due to “water shortage and the large amount of storage required to obtain the full safe yield of the Sweetwater River” (Fowler 1952) the Loveland Dam was built in 1943-

1945 approximately 16 miles upstream on the Sweetwater River to capture water that would have spilled from Sweetwater Reservoir (Fowler 1952; Kasner 2002). Sweetwater Authority took over operations of the reservoirs in 1977 and since then has carefully managed the levels of the two reservoirs in a way that maximizes water capture so they can continue to provide a reliable local water supply to their customers (Fleury 2001; Kasner 2002). The "rules of thumb" Sweetwater Authority uses for its transfer operations are included in Appendix 1 (Kasner 2002). The "rule of thumb" that may benefit the arroyo toad the most states, "releases should begin after we have had significant rainfall to saturate the river channel to maximize the volume recovered at Sweetwater" (Kasner 2002). According to this rule, controlled releases will occur during the typically wetter months of the year, November through March (according to NOAA weather data 1971-2001, Table 1), and either in conjunction or immediately after a rain event, thus mimicking the natural flow of the system. Flushing winter flows prior to breeding may be beneficial to arroyo toads by improving water quality and removing exotic species from breeding pools. Since 1977, Sweetwater Authority's management scheme has resulted in fewer controlled releases during the arroyo toad breeding season, with most releases occurring in November through February (67%) (Kasner 2002). Before 1977, more controlled releases occurred during the arroyo toad breeding season with only 24% of controlled releases occurring in November through February and 81% of the releases occurring during the arroyo toad breeding season, February through August (Figure 4).

In 2001, USFWS designated the Sweetwater River basin (Southern Unit, Unit 18) (Figure 5) and twenty-one other riparian land units as critical habitat for the arroyo toad. Critical habitat is considered to be essential to the conservation of the species and has "one or more of the following characteristics: (1) supports a substantial core population of arroyo toads; (2) supports at least a small toad population and possesses favorable habitat conditions for population expansion and persistence; (3) suitable habitat situated in a location that appears to be crucial for maintaining the viability of a larger metapopulation; (4) occupied habitat on the periphery of the arroyo toad's geographic range; and (5) occupied habitat in atypical or underrepresented ecological environments" (USFWS 2001). The 16 miles of Sweetwater River between Loveland Dam and Sweetwater Reservoir, critical habitat subunit 18c, consists of characteristics (1), (2), and (3) described above. Subunit 18c falls within the San Diego Multiple Species Conservation Program (MSCP) Subregion of the Natural Community Conservation Planning (NCCP) Act. In Conjunction with two other regional water agencies, Sweetwater Authority is in the process of developing its own NCCP known as the Joint Water Agencies (JWA) Subregional Plan. As part of the Sweetwater Authority Subarea Plan for the JWA Subregional Plan, Sweetwater Authority must gain issuance of United States Fish and Wildlife Service (USFWS) and California Department of Fish and Game (CDFG) incidental take permits, because incidental take of arroyo toads may occur as a result of current operations or future projects. Most notably, the water transfer operations between Loveland and Sweetwater Reservoirs have the potential to affect arroyo toads. The purpose of this risk assessment is to examine the potential short-term and long-term effects of Loveland Dam operations on arroyo toad reproductive success and population viability. The findings of this risk assessment will be used in the development of the Sweetwater Authority Subarea Plan of the JWA Subregional Plan and in the process of gaining scientific justification for the associated incidental take permits, and as a basis for any adaptive management necessary to maintain arroyo toad reproductive success and population viability.

Based on the United States Environmental Protection Agency's (USEPA) Guidelines for Ecological Risk Assessment (1998), data on arroyo toad biology, hydrology of the Sweetwater

River, Loveland Reservoir release and weather data were used to estimate risk to arroyo toads from Loveland Dam operations. A summary of the USEPA Guidelines for Ecological Risk Assessment and a description of how these guidelines fit into the framework of a traditional scientific paper, like this report, can be found in Appendix 2. The following hypotheses, derived from the above-mentioned data and based on the potential short-term and long-term effects of Loveland Dam operations, were examined in this risk assessment:

Hypothesis 1: The effect of controlled releases on arroyo toad reproductive success varies depending on timing relative to the breeding season;

Hypothesis 2: Releases concurrent with a spill event or rain event with flow volume greater than or equal to 350 cubic-feet-per-second (the maximum flow volume for a Loveland Dam controlled release is 350 cubic-feet-per-second) will have no additional effect on arroyo toad reproductive success;

Hypothesis 3: Controlled releases during dry years will have less of an effect on arroyo toad reproductive success than releases during wet years when more breeding is assumed to be occurring;

Hypothesis 4: Changes in the patterns of wet and dry years due to dam operations will have a negative effect on reproductive success and population viability;

Hypothesis 5: Reduction in the amount of coarse sediment supply due to entrapment by the reservoir and loss of sediment below the dam by erosion of banks and streambed will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat; and

Hypothesis 6: Increased vegetation cover due to changes in amount of peak flows (scouring flows to remove vegetation and to maintain or create breeding habitat) will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat.

Methods

Study Area

The study area is approximately 26 kilometers (16 miles) of Sweetwater River between Loveland and Sweetwater Reservoir (Figure 6). The Sweetwater River originates in the coastal mountains of eastern San Diego County, flows through Loveland and Sweetwater Reservoirs, and discharges into San Diego Bay (Figure 7). Loveland Reservoir is located in deeply incised, crystalline rock, and has a capacity of approximately 25,000 acre-feet. Water in this upper reservoir is composed primarily of runoff from precipitation on the surrounding hills and mountains. Water importation to Loveland Reservoir is currently under consideration. Where the water will come from, how it will be transferred and managed and when the importation will begin is still to be decided. Water importation and the possible changes in dam operations were not considered in this risk assessment. Sweetwater Reservoir is located in more gently sloping, sedimentary rock, downstream from Loveland Reservoir, and has a capacity of approximately 28,000 acre feet. Water in Sweetwater Reservoir is composed of both local runoff and water imported from northern California or the Colorado River. Although both reservoirs have similar capacities, the topographic setting of Sweetwater Reservoir causes it to be broader, shallower and have greater evaporative loss than Loveland Reservoir. As a result, Sweetwater Authority tends to keep water in Loveland Reservoir in order to minimize evaporative loss. In order to minimize transit loss, Sweetwater Authority tries to release water after precipitation and local runoff has saturated the river channel (Kasner 2002). Despite these efforts at conserving local water, the highly variable local precipitation combined with the relatively small capacity of each reservoir restricts management flexibility of the two-reservoir system. Precipitation less than the annual average of 17.3 inches- per-year produces little runoff into Loveland Reservoir (Figure 8). In years with above-average precipitation, local runoff often exceeds the storage capacity of Loveland Reservoir and results in spill (uncontrolled) releases from the reservoir. The frequency of uncontrolled releases results primarily because of the relatively small storage capacity of the reservoir (25,000 acre-feet) compared to runoff, which can exceed 30,000 acre-feet (Figure 9). The small storage capacity of Loveland Reservoir limits the ability to use the reservoir to carry over runoff from an above-average runoff year to next year. Most often, an above-average runoff year results in a spill event, much as if the reservoir were not present. However, this is dependant on the volume of inflow necessary for the dam to overflow. The relationships between weather, inflow and releases from Loveland Reservoir may have short-term and long-term effects on arroyo toad reproductive success and population viability.

Data Collection

Arroyo Toad

Historical breeding data from locations throughout the toad's range (Santa Barbara County, California to Baja California) were used to develop the conceptual models, to estimate the percent risk of dam releases on arroyo toad reproductive success and to address Hypothesis 1, 3 and 4. To simplify the models and analyses, we assumed adult arroyo toads were at no risk due to dam releases. We only assumed risk to life stages dependent on the breeding pools for survival, (i.e., eggs, larvae and metamorphs). A combined total of 199 egg, larva and metamorph records were collected from 36 sources. Data were compiled into a breeding occurrence database (breeding records per year) and a life stage occurrence database (egg, larva, or metamorph records per month). Sources included databases from museums (University of California Berkeley Museum of Vertebrate Zoology, California Academy of Sciences and Los Angeles County Museum of Natural History), government agencies (United States Geological Survey, United States Fish and Wildlife Service, United States Forest Service- Los Padres National Forest and Marine Corps Base Camp Pendleton); published studies (Cunningham 1961; Griffin & Case 2001; Mahrdt, et al. 2002); unpublished reports (Sweet 1992 & 1993; Beaman et al. 1995; Campbell et al. 1996; Haas 1997; Haas & Famolaro 1998; Famolaro 1999; Griffin et al. 1999; Zimmitti & Mahrdt 1999; Brown, et al. 2000 & 2001; Haas 2001; Holland et al. 2001; Holland & Sisk 2001a & 2001b; Brown & Fisher 2002; Famolaro 2002b; Ramirez 2002); and personal communication or field notes (Beaman 2003; Copp 2003; Ervin 2003; Haas 2003; Lovich 2003; Ortega 2003; Stephenson 2003; Warburton 2003). Records were managed in two

Microsoft Excel databases, one for breeding occurrences per year and one for life stage occurrences per month. Regrettably, little historical data was obtainable for arroyo toad populations within the study area. Potentially useful data from the largest population in Sloan Canyon, which has apparently been monitored from 1995-2002 by William Haas of URS/Varanus Biological Services, was not available (Haas in lit. & Haas pers. comm. 2003). In risk assessment, when data are few and new data cannot be collected, extrapolation from existing data may be possible (USEPA 1998; Cech, et al. 1998). Extrapolation was necessary in this study due to the lack of site-specific data and made possible by the breadth of data obtained for the arroyo toad throughout its range.

Hydrology

Hydrologic, weather and release data for the Sweetwater River reservoir system were summarized to develop the hydrologic model, to determine any patterns in Loveland Dam operations that may affect arroyo toad breeding and to address Hypothesis 1 – 4, and 6. Data from 1970 to 2002 were used, but the focus was on data collected since Sweetwater Authority took control of the reservoir system in 1977. Sweetwater Authority provided the data on Loveland Dam operations as well as precipitation data for Loveland Reservoir. Additional weather data came from the National Oceanic and Atmospheric Administration (NOAA). Gaged inflow data came from the USGS gaging station #1101500 above Loveland Reservoir in Descanso.

Analysis

Conceptual Models

Operations of Loveland Dam have the potential for short-term and long-term effects on arroyo toad reproductive success and population viability. The first part of the analysis required gaining a better understanding of the relationships between Loveland Dam operations and the arroyo toad in the Sweetwater River. This was accomplished by developing three conceptual models based on a combination of historical arroyo toad breeding data, historical weather data, hydrologic data for the Sweetwater River, and Loveland Dam release data: 1) a biologic model of the arroyo toad life cycle, 2) a hydrologic model of the Sweetwater River system and 3) a model diagramming the different effects of Loveland Dam operations on arroyo toad breeding. The conceptual model for arroyo toads in Sweetwater River below Loveland Dam (Appendix 3) describes the arroyo toad life cycle and the possible risk factors associated with each life stage, including risk factors associated with Loveland Dam. This unpublished model is based on the best available data for the arroyo toad life cycle, Sweet (1992), USFWS (1999) and Atkinson, et al. (2003), and incorporates the hypotheses and possible management actions for this assessment. The hydrologic conceptual model (Figure 10) describes the relation between inflow to and outflow from Loveland Reservoir as well as the overall management of the Sweetwater River system, including the operations of Loveland Dam. The biologic and hydrologic models were integrated to form the conceptual model of the different effects of Loveland Dam operations on arroyo toad breeding (Figure 11). This model presents the presumed short-term and long-term effects of Sweetwater Authority’s water management practices on the arroyo toads below

Loveland Dam. The most important effect, and the focus of this risk assessment, is the short-term effect of loss of eggs, larvae, and metamorphs due to dam releases, which may result in lower reproductive success of the arroyo toad. Possible long-term effects include the effects of the altered hydrologic regime on the arroyo toad and arroyo toad breeding habitat through the increase of vegetation cover and the reduction of coarse sediment (sand and fine gravel) below the dam.

Analysis of Short-term Effects

Timing of Releases

The life stage occurrence database was used to examine the timing of occurrence for the arroyo toad egg, larval, and metamorph life stages throughout the breeding season and then address Hypothesis 1 which states that the effect of controlled releases on arroyo toad reproductive success varies depending on timing relative to the breeding season. The purpose was to bound the risk associated with controlled dam releases during different months of the year. This database included every available record of breeding (eggs, larvae, and metamorphs) for 55 sites and a total of 145 records (34 egg records, 65 larvae records and 46 metamorph records) (Table 2). Each site varied in survey effort and negative data were disregarded. The number of egg, larva and metamorph records was tallied for each month of the year. Each record was scored as one rather than the number of egg strings, larvae or metamorphs reported per record. For example, a record of 5 egg strings would be counted as one occurrence. This was done to simplify our analysis and because of the inconsistency in reporting (some researchers reported numbers, while others reported as "several," "numerous," "many," "hundreds", etc.). The tallies per month of each of the three life stages were then converted into percentages of the total number of occurrences in all months. The percentages of occurrence were then used to estimate the percent risk of cohort loss per month as a result of a dam release. The following paragraph explains the analysis that resulted in the risk estimates.

The overall strategy was to bound the risk to arroyo toad reproductive success as a result of dam releases. This was done by using the life stage percent occurrence data along with several assumptions to estimate a range of cohort loss per month due to a dam release. Cohort was defined as the total amount of offspring in the study area in a given year. The following assumptions were made:

Assumption 1: Only the egg, larval and metamorph life stages will be affected by dam releases (no loss of adults was assumed due to their ability to escape from the streambed).

Assumption 2: Based on expert knowledge (Robert Fisher and Ed Ervin pers. comm. 2003), eggs, larvae and metamorphs should have varying ranges of percent loss due to their placement or mobility. Eggs are assumed to be at greatest risk with 80-100% estimated to be lost as a result of a dam release. Because of their immobility and the fact that egg strings are usually laid in pools free of vegetation, eggs have a greater risk of being displaced to unsuitable habitat or being stranded on the shore or in quickly drying pools. Due to their mobility, larvae are assumed to have a greater chance of surviving a release event with 50-100% estimated to be lost as a result of a dam release. Larvae can possibly swim to safety or track the rising and falling water levels to avoid getting displaced or stranded. Due to their mobility and ability to leave the streambed, metamorphs were assumed to have the greatest chance of surviving a release event with 0-50% estimated to be lost as a result of a dam release. It is necessary to take metamorphs into consideration for our analysis of loss, because they can remain around the margins of the breeding pools for up to 6 months, depending on the conditions. It is important to emphasize that the estimates of loss are only assumptions. It could be that dam releases result in 100% or 0% loss of eggs, larvae and metamorphs, but without data on loss due to Loveland Dam releases it is not certain.

Assumption 3: The distribution through time of sightings of egg masses, larvae and metamorphs from throughout the arroyo toads range reflect the timing of these life stages in the study area.

Assumption 4: The egg to larval stage and larval to metamorph stage were simplified to 30 day periods (arroyo toad egg to larval stage is approximately 12-20 days and the larval to metamorph stage is approximately 65-85 days).

The basic equation used to determine cohort loss was:

$$\begin{aligned}\text{Total Cohort Loss} &= (\text{Loss of Eggs}) + (\text{Loss of Larvae}) + (\text{Loss of Metamorphs})\\ &= (\%\ \text{Egg Mass Occurrence})(\%\ \text{Egg Mass Loss}) +\\ &\quad (\%\ \text{Larvae Occurrence})(\%\ \text{Larvae Loss}) +\\ &\quad (\%\ \text{Metamorph Occurrence})(\%\ \text{Metamorph Loss})\end{aligned}$$

Figure 12 is a diagram illustrating how this formula was calculated. An upper and lower limit of total cohort loss was calculated using the assumed range of loss for each life stage as a result of a dam release.

Releases Concurrent with a Spill Event or Rain Event

The analysis of Hypothesis 2, releases concurrent with a spill event or rain event with flow volume greater than or equal to 350 cubic-feet-per-second (the maximum flow volume for a Loveland Dam controlled release is 350 cubic-feet-per-second) will have no additional effect on arroyo toad reproductive success, relied on literature and personal communication (Haas pers. comm. 2003; Lind et al. 1996; Sweet 1992). Data on flow volumes capable of washing away arroyo toad eggs, larvae, and metamorphs in Sweetwater River below Loveland Dam were not available.

Controlled Releases During Dry Years

The breeding occurrence database was used to examine arroyo toad breeding in relation to annual weather conditions. The purpose of this was to address Hypothesis 3 which states that controlled releases during dry years will have less of an effect on arroyo toad reproductive success than releases during wet years when more breeding is assumed to be occurring. The database included yearly occurrence of breeding (where arroyo toads bred) at 59 different sites for a total of 120 records when summed. Each site varied in survey effort and negative data were disregarded because they were not always available. The number of sites where breeding was recorded was tallied for each year that data were available. The tallies were then converted into percentages and compared to precipitation records for the corresponding year. Normal precipitation values came from NOAA weather data based on 30-year averages (1971-2000) (Table 1). The normal values were then compared to yearly values to distinguish between wet and dry years.

Analysis of Long-term Effects

Changes in the Patterns of Wet and Dry Years

Precipitation, inflow and release data were used to address Hypothesis 4 which states that changes in the patterns of wet and dry years due to dam operations will have a negative effect on reproductive success and population viability. The purpose of examining the relationship between precipitation and Loveland Dam releases (uncontrolled spill and controlled) and inflow and Loveland Dam releases was to determine patterns that may have an effect on arroyo toad reproductive success, specifically to determine if periods of drought below Loveland Dam are intensified or lengthened by the presence of the dam. Lengthening of drought periods refers to the reduction in flow below Loveland Dam in years of normal rainfall immediately following a period of low rainfall or drought due to the water being trapped in Loveland Reservoir. Increased intensity of drought refers to periods of low rainfall that are intensified by a reduction in the flow of Sweetwater River due to Loveland Dam. Release and weather data (Figure 9) provided by Sweetwater Authority for Loveland Reservoir were graphed using Microsoft Excel. Data from the 1977-2002 fiscal years of Sweetwater Authority were used. Sweetwater Authority's fiscal years are the equivalent of rain years, July-June. Data from the only active gage on the Sweetwater River, the USGS gaging station #1101500 above Loveland Reservoir in Descanso (Figure 7), were used to estimate the gaged inflow into Loveland Reservoir. Gaged inflow data were in cubic-feet-per-second-per-day and were converted into acre-feet (cubic-feet-per-second = .5042 acre-feet-per-day), to compare to release data in acre-feet. There is a small reservoir, Palo Verde Lake, which falls between gage #1101500 and Loveland Reservoir. Data from this private reservoir was not available for this analysis. According to Sweetwater Authority (Famolaro pers. comm. 2003), inflow from Sweetwater River into Loveland Reservoir may be delayed up to several months if Palo Verde Lake is low. However, precipitation and gaged inflow data were compared to verify that flow through the Descanso gage is a good indicator of inflow into Loveland Reservoir (precipitation and flow through the gage are related as shown in Figure 8). In addition, data from the Descanso gage approximates flow that would have occurred downstream from Loveland Dam if the dam did not exist. According to Williams & Wolman (1984), a gaging station upstream from a dam "reflects to a significant degree the flows that would have occurred downstream from the dam if no dam had been built" and that "a control station is most useful located as close as possible to the dam as long as it is not within the backwater of the dam." Ungaged flow into Loveland Reservoir was estimated using a mass-balance equation for Loveland Reservoir:

Change in storage = Gaged Inflow + Ungaged Inflow – Evapotranspiration

+/- Groundwater – Outflow

The mass-balance equation is related to the hydrologic conceptual model of the Sweetwater River system (Figure 10) and is illustrated in Figure 13. Loveland Dam controlled and uncontrolled spill release data from Sweetwater Authority were then graphed in calendar years with the gaged and ungaged inflow data using Microsoft Excel and Adobe Pagemaker.

Reduction in the Amount of Coarse Sediment

The analysis of Hypothesis 5, reduction in the amount of coarse sediment supply due to entrapment by the reservoir and loss of sediment below the dam by erosion of banks and streambed will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat, relied on literature on the relationship between dams and sediment loss (Baxter 1977; Williams & Wolman 1994; Ligon et al. 1995; Trimble 1997; Collier et al. 2000; Nilsson & Berggren 2000), photographs and site visits. Quantitative data on sediment loss in Sweetwater River below Loveland Dam were not available.

Increased Vegetation Cover

The analysis of Hypothesis 6, increased vegetation cover due to changes in amount of peak flows (scouring flows to remove vegetation and to maintain or create breeding habitat) will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat, relied on literature on the relationship between dams and vegetation cover increase (Williams & Wolman 1984; Ligon et al. 1995; Lind et al. 1996; Collier et al. 2000), Loveland Dam release data, Sweetwater River inflow data, photographs and site visits. Quantitative data on the increase in vegetation cover in Sweetwater River below Loveland Dam were not available. Because data on increased vegetation were not available, Loveland Dam release data and Sweetwater River inflow data were compared to determine whether peak flows below Loveland Dam have been reduced or are fewer in number, resulting in fewer scouring events to remove vegetation. Again, data from the USGS gaging station #1101500 above Loveland Reservoir in Descanso (Figure 7), were used to estimate the gaged inflow into Loveland Reservoir and gaged inflow data were converted into acre-feet (cubic-feet-per-second = .5042 acre-feet-per-day), to compare to release data in acre-feet. Loveland Dam controlled and uncontrolled spill release data from Sweetwater Authority were graphed in calendar years with the gaged and ungaged inflow data using Microsoft Excel and Adobe Pagemaker.

Results

Results of Analysis of Short-term Effects

Timing of Releases

The hypothesis is that the effect of controlled releases on arroyo toad reproductive success varies depending on timing relative to the breeding season. According to the life stage occurrence data, the highest percent occurrence of egg strings occurs in March to May, the highest percent occurrence of larvae occurs in April to June, and the highest percent occurrence of metamorphs occurs in May to August (Figure 14). The graph in Figure 14 resembles the expected overlapping bell curves for the occurrence of these 3 life stages. The egg string monthly percent occurrence values were used for all analyses of percent monthly loss to cohorts from dam releases. Using the equation described in Figure 12, the estimated ranges of loss to each life stage and the egg string monthly percent occurrence values, it is estimated that dam releases from March to July will result in the greatest loss of arroyo toad eggs, larvae and metamorphs (Table 2, Figure 15). April, May and June were estimated to have the highest possible loss with 31-52%, 33-63% and 23-51% loss to cohorts, respectively. By extrapolating these data to the Loveland Dam and Sweetwater River system, it can be assumed that avoiding controlled releases in March to July will greatly reduce the risk of loss of arroyo toad eggs, larvae and metamorphs and in turn increase the toad's reproductive success and long-term population viability. Sweetwater Authority's current water transfer management has resulted in only 30% of controlled releases occurring during the months of greatest risk, March through July. Additionally, only 21% of Sweetwater Authority's controlled releases have occurred during the months of most risk, April through June. Additionally, since 1989 all controlled releases have occurred during November (0% risk of cohort loss), December (0% risk of cohort loss), January (1-2% risk of cohort loss) and February (7-9% risk of cohort loss). Thus in trying to optimize releases for water management, Sweetwater Authority has been managing the reservoir system in a way that should have less short-term effect on arroyo toad reproductive success than the previous management. Additionally, when a controlled release does not coincide with arroyo toad breeding, the assumption is that there is no risk to arroyo toad breeding or a positive effect on arroyo toad breeding. The arroyo toad is a mostly terrestrial species, only using the shallow, slow-moving, sandy pools of the river to breed. Again, if no loss of adults is assumed due to their ability to escape the streambed, eggs, larvae, and metamorphs are the only life stages that will be lost due to a controlled release from Loveland Dam. If a release does not coincide with the arroyo toad breeding season there will be no risk of losing eggs, larvae, or metamorphs and thus there will be no risk to arroyo toad reproductive success. Finally, controlled releases during the winter months prior to the arroyo toad breeding season may have an indirect positive effect on arroyo toad reproductive success by improving water quality (Warburton unpublished data) and flushing exotic predators, such as green sunfish, bullfrogs and African clawed frogs from breeding pools.

Releases Concurrent with a Spill Event or Rain Event

The hypothesis is that releases concurrent with a spill event or rain event with flow volume greater than or equal to 350 cubic-feet-per-second (the maximum flow volume for a Loveland Dam controlled release is 350 cubic-feet-per-second)will have no additional effect on arroyo toad reproductive success. The flow volume of 350 cubic-feet-per-second was used because it is the maximum flow of a controlled release from Loveland Dam, however flow volumes less than 350 cubic-feet-per-second have been known to displace eggs, larvae and metamorphs. Sweet (1992) reported that releases of 120 cubic-feet-per-second or more have the potential to displace eggs and larvae. Additionally, eggs and larvae were displaced in Cottonwood Creek as a result of water releases of several million gallons-per-day (average of approximately 4.6 cubic-feet-per-second) from Barrett Dam (Campbell et al. 1996). As a result, a controlled release, an uncontrolled spill release or a rain event of 350 cubic-feet-per-second or more occurring during the arroyo toad breeding season are all assumed to displace eggs, larvae, and metamorphs and thus are assumed to have a negative effect on reproductive success. In 1998, Loveland Reservoir spilled during most of arroyo toad breeding season and water levels and flows (from February to June flows ranged from an average of 33-196 cubic-feet-per-second) were too great for arroyo toad breeding in most breeding locations in Sloan Canyon (Haas pers. comm. 2003).

When controlled releases are coupled with rain or spill events, they are assumed to more closely mimic the natural hydrology of the system and depending on the timing may have either a positive or negative effect on arroyo toad reproductive success. Dam releases outside of the arroyo toad breeding season may help to improve water quality, flush out exotic species, and scour vegetation from breeding pools, while dam releases during the arroyo toad breeding season may wash away eggs, larvae and metamorphs. According to Lind et al. (1996), an appropriate dam release strategy for species that have evolved in stochastic riverine environments may "be to base real-time changes in flow releases on current environmental conditions (e.g., if it is raining, release more water)." Sweetwater Authority has already been using a similar strategy to maximize the water recovered at Sweetwater Reservoir by releasing from Loveland Reservoir when there has been significant precipitation to saturate the river channel and reduce infiltration. Since Sweetwater Authority started managing Sweetwater and Loveland Reservoir in 1977, there has been a shift from releasing in the drier months to releasing in the wetter months, largely because of this management strategy (Figure 4). In sum, Loveland Dam releases concurrent with spill events or rain events more closely mimic the natural hydrology of Sweetwater River and those releases concurrent with spill events or rain events of flow volume greater than or equal to the maximum flow volume for a controlled release (350 cubic-feet-per-second) may have a negative or positive effect depending on timing, but should pose no additional threat to arroyo toad reproductive success. Furthermore, collection of data on flow volumes required to displace arroyo toad eggs, larvae, and metamorphs in Sweetwater River might allow better refinement of this analysis.

Controlled Releases During Dry Years

The hypothesis is that less breeding occurs during dry years and that controlled releases during these conditions would have little impact on arroyo toad reproductive success. It has been documented at some sites that arroyo toad breeding is absent or greatly reduced during years of below average precipitation (Sweet 1992; Jennings & Hayes 1994; Haas 2001; Holland et al. 2001; USFS 2002; Copp pers. comm. 2003; Ervin pers. comm. 2003). Sweet (1992) attributes this to the time it takes females to eat sufficient prey for vitellogenesis (egg formation) to complete. Due to the scarcity of prey during years of drought, vitellogenesis may not complete until males have ceased calling and have left the breeding pools (Sweet 1992). However, the collected breeding occurrence data did not show that less breeding occurred during dry years (Figure 16). In fact, the data showed that some arroyo toad breeding could occur in all years. Thus the only conclusions that can be drawn are that changes in breeding during dry years may be a site-specific issue or that the coarse quality of our data and the lack of negative data make it difficult to separate out this effect. Collection of breeding information data during drier years might allow better refinement of this analysis.

Results of Analysis of Long-term Effects

Changes in the Patterns of Wet and Dry Years

The hypothesis is that changes in the patterns of wet and dry years due to dam operations will have a negative effect on reproductive success and population viability. Comparison of total inflow (gaged and ungaged) into Loveland Reservoir with discharge from the reservoir indicates that operation of Loveland Reservoir over the past 30 years has lead to increased intensity of drought periods and the lengthening of drought periods due to storage needs (Figure 17). This is a result of Sweetwater Authority's water storage requirements and is apparent by the lack of outflow during the dry periods of 1973-1978 and 1988-1991 (Figure 17). Over the past 30 years there have been two periods, 1973-1978 and 1988-1991 (Figure 18), where the only water flowing below Loveland Dam was due to rain events (zero outflow from Loveland Dam occurred). During 1973-1978 and 1988-1991, modest inflow resulted in essentially zero outflow from the reservoir (Figure 17) and it is unlikely that optimal breeding conditions were present in Sweetwater River below Loveland Dam due to the limited amount of water in the system. An additional effect of the drought periods may be the lengthening of the dry periods by a year or more for the area between Loveland and Sweetwater Reservoir while Loveland Reservoir refills. These effects could potentially reduce the number of good breeding years and result in reduced reproductive effort over time, but the overall effect on population viability as a result of reduced reproductive effort is not known. Presently this pattern of intensification and lengthening of drought appears to be repeating. There has not been a release from Loveland Reservoir since February 2000 (Figure 9) and Loveland Reservoir is approximately 18 meters (60 feet) below its maximum level (Figure 19). As in 1973-1978 and 1988-1991, a release may not occur until the reservoir fills and spills (Figure 18). Additionally, the last time Loveland Reservoir was this low (1968) it took approximately 10 years for the reservoir to sufficiently fill and a spill to occur (Famolaro pers. comm. 2003). Arroyo toads have been monitored in Sloan Canyon during 2000-2002; (Haas pers. comm. 2003); however, access to these data was unavailable and it is unknown if successful recruitment occurred. Because most arroyo toads are thought to live about 5-8 years and take 2-3 years to reach sexual maturity (male 2 years, females 2-3 years) (Sweet 1992 & 1993), altering the number and pattern of good breeding years could mean that arroyo toads in Sweetwater River below Loveland Dam may have fewer years of successful breeding due to their short lifespan and number of years to mature. The overall effect on population viability as a result of reduced opportunity for reproduction (fewer breeding years) over time is unknown and would require further study.

Reduction in the Amount of Coarse Sediment

The hypothesis is that reduction in the amount of coarse sediment supply due to entrapment by the reservoir and loss of sediment below the dam by erosion of banks and streambed will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat. It is evident that loss of sediments is occurring in Sweetwater River below Loveland Dam, but the extent is unknown. In order to create and maintain arroyo toad breeding pools and open sandy terraces, peak flows are necessary for the scouring and deposition of sediments (Campbell et al. 1996; USFWS 1999). However, in dammed systems peak flows can wash away coarse sediments and destroy arroyo toad breeding habitat. Sediments are trapped by reservoirs and then restored downstream by the erosion of shores and streambeds (Baxter 1977; Williams & Wolman 1994; Ligon et al. 1995; Trimble 1997; Collier et al. 2000; Nilsson & Berggren 2000). Because coarse sediments are being removed and not replaced in the riverbed below Loveland Dam, arroyo toad habitat has been degraded or destroyed over time (Figure 20). Sediments from the Sweetwater River above Loveland Reservoir are deposited into the reservoir and are trapped, reducing its capacity. The exact amount of sedimentation in Loveland is unknown, but sedimentation is apparent. Below Loveland Dam, whatever sediment is picked up along the way is then deposited in the sand and gravel ponds at Lake Emma and mined by Vulcan Materials Company. Below Lake Emma sediment loads are removed as part of existing sand extraction permits at Cottonwood Golf Course. Consequently, negligible sediment loads from Sweetwater River are received downstream at Sweetwater Reservoir. Long-term reservoir maintenance could be designed to benefit arroyo toads while restoring and maintaining reservoir capacity. Sand and fine gravel must be replaced below Loveland Dam in order to restore and maintain arroyo toad breeding habitat, while at the same time, sediments must be removed from the reservoirs to restore and maintain storage capacity. A possible solution is to supplement the sediment supply below Loveland Dam, similar to gravel supplementation methods used for restoration of salmon spawning habitat (USDOI 2000; BC Hydro 2003). A suggestion may be to remove sand and fine gravel from the upstream end of Loveland or Palo Verde Reservoir (where coarser sediments are deposited) and then deposit the sand and fine gravel in the Sweetwater River channel below Loveland Dam. It's important to note that only coarse sediments, such as sand and fine gravel, are important to arroyo toads. Fine sediments and silts actually decrease the quality of arroyo toad breeding habitat because they can suffocate eggs and larvae. This possible management action needs to be examined further, because the possible consequences of translocating coarse sediments are unknown. Furthermore, the exact effect of loss of sediments on arroyo toad reproductive success and population viability is unknown and would require further study. However, it can be assumed that reproductive success will decrease as arroyo toad breeding habitat is reduced.

Increased Vegetation Cover

The hypothesis is that increased vegetation cover due to changes in amount of peak flows (scouring flows to remove vegetation and to maintain or create breeding habitat) will have a negative effect on arroyo toad reproductive success and population viability due to loss of breeding habitat. Arroyo toads require open shallow pools of water with sand or fine gravel bottoms for breeding. In order to create and maintain arroyo toad habitat, peak flows are necessary for the removal of vegetation (Campbell et al. 1996; USFWS 1999). Alteration of the hydrologic regime, specifically the reduction of peak flows caused by dam operations, can result in increased vegetation (Williams & Wolman 1984; Ligon et al. 1995; Lind et al. 1996; Collier et al. 2000). Removal of vegetation may also be important to prevent increased water loss from the evapotranspiration of the plants (Williams & Wolman 1984). It is unclear how reduced the peak flows have become in the Sweetwater River due to the operation of Loveland Dam, but it is apparent that an increase in vegetation has occurred. However, the extent of vegetation increase is unknown. An example of increased vegetation in Sweetwater River between Loveland and Sweetwater Reservoir is shown in Figure 21. In Figure 21, high quality arroyo toad breeding habitat located approximately 1 kilometer (0.6 mile) upstream from Sweetwater Reservoir became unsuitable due to an increase in vegetative cover. Arroyo toads were present in 1997 when photograph A of Figure 21 was taken (Haas 1997; Haas & Famolaro 1998) and have not been detected in the vicinity since then (Haas & Famolaro 1998; Famolaro 1999 & 2000; Famolaro & Tikkanen Reising 2001; Famolaro 2002a & 2002b; Famolaro pers. comm. 2003). The increase in vegetation seen in photograph B of Figure 21 is likely due to the cumulative reduction in flow caused by Loveland Dam and other impedances. Although the increase in vegetation shown in Figure 21 was not due to Loveland Dam alone, it does demonstrate the increase in vegetation that can occur with the reduction of scouring flows and how it negatively affects arroyo toad populations.

Below Loveland Reservoir peak flows have most likely been reduced and are fewer in number, resulting in fewer scouring events to remove vegetation. As illustrated in Figure 9, total outflow from Loveland Reservoir ranges from zero in some years, to less than about 10,000 acre-feet in most years, to as much as 70,000 acre-feet in an unusually wet year—more than twice the capacity of either Loveland or Sweetwater Reservoir. Additionally, total outflow from Loveland Reservoir is less than total inflow in most years (Figure 17), but large volume releases do still occur as uncontrolled spill events. Due to its small capacity, most of the outflow from Loveland Reservoir is the result of uncontrolled spill releases (Figure 17). Two example of flows greater than the maximum controlled release (350 cubic-feet-per-second) occurred in 1980 and 1983. In February 1980, approximately 34,616 acre-feet (17,453 cubic-feet-per-second) or an average of 600 cubic-feet-per-second per day spilled from Loveland Dam. In March 1983, approximately 27,463 acre-feet (13,846 cubic-feet-per-second) or an average of 446 cubic-feet-per-second per day spilled from Loveland Dam. Because the Loveland Dam release data from Sweetwater Authority is recorded as total spilled from the dam per month and not a daily acre-feet or cubic-feet-per-second value, it is only possible to give flow in monthly or daily average values and it is impossible to determine the intensity of the spill releases. Although peak flows have most likely been reduced and are fewer in number, maintaining higher volume spill releases, ones that allow the scouring of vegetation to occur, may benefit the arroyo toad in this system. The exact effect of increased vegetation on arroyo toad reproductive success and population viability is unknown and would require further study. Again, it can be assumed that reproductive effort will decrease as arroyo toad breeding habitat is reduced.

Discussion

Summary of Risk Assessment Results

Releases from Loveland Reservoir during the breeding season show the greatest evidence of risk to arroyo toad reproductive success and long-term population viability in Sweetwater River below Loveland Dam (Figure 15). Even though few breeding data were collected for Sweetwater River arroyo toads, breeding data from the entire range of the arroyo toad were sufficient to successfully extrapolate the risk of dam releases on arroyo toad reproductive success for the Sweetwater system. It is intuitive that dam releases during the arroyo toad breeding season will cause greater risk to arroyo toad reproductive success and that the amount of risk will vary throughout the season (peaking mid-season and decreasing as the young toads move upland). The extrapolated breeding data clearly supported these assumptions, with the range of greatest risk occurring in early March to late July (the estimated upper bound of loss ranging from 28% to 63%) and risk peaking in April-June (the estimated upper bound of loss is 52% for April, 63% for May and 51% for June) (Figure 15). Coincidentally, Sweetwater Authority has managed to eliminate some risk to arroyo toad reproductive success by avoiding controlled releases from Loveland Dam during the arroyo toad breeding season due to their management policy to increase the efficiency of transfers by releasing in conjunction with rain events (when the system is already charged with water and infiltration is at a minimum). Most releases (67%) occur outside of the arroyo toad breeding season in November to February (Kasner 2002). Before Sweetwater Authority began managing Loveland Reservoir in 1977, most releases occurred during the arroyo toad breeding season with only 24% of Loveland Dam releases occurring outside of the arroyo toad breeding season. Releasing with rain events mimics the natural flow regime, which may be beneficial to the arroyo toad and other riparian species.

Management Suggestions Related to Water Transfer Operations

Below are management suggestions or best management practices (BMP's) that could contribute to the maintenance or increase of arroyo toad populations in Sweetwater River below Loveland Dam. Some of the recommendations are based on Kasner (2002) (Appendix 1), and may be reiterations of current management practices.

1) To the maximum extent feasible, avoid controlled releases during the arroyo toad breeding season, especially March to late July;

2) Release during rain or spill events in order to mimic the natural flow of the system;

3) Continue to step up controlled releases (Sweetwater Authority currently ramps releases starting with 100 cubic-feet-per-second on day one, 200 cubic-feet-per-second on day two and 300-350 cubic-feet-per-second on day three) to allow larvae and metamorphs to adjust or escape the rising water levels and increasing flow, but also step down controlled releases to allow larvae to follow the falling water and reduce stranding;

4) When controlled releases during arroyo toad breeding cannot be avoided, survey for egg masses, larvae and metamorphs prior to and immediately following releases to see if egg masses, larvae or metamorphs are in fact present and determine the actual number displaced by releases. Significant losses could necessitate the need to relocate or temporarily captive house egg masses, larvae or metamorphs (needs further evaluation);

5) Maintain peak spill releases prior to the arroyo toad breeding season to allow scouring of vegetation, the removal of exotics and the improvement of water quality in arroyo toad breeding habitat.

An inventory and baseline monitoring was conducted during the 2003 arroyo toad breeding season (data in preparation) consisting of habitat assessment and nocturnal surveys to detect the presence of breeding adult arroyo toads. The habitat assessment included: percent vegetative cover, streambed and bank vegetation type, substrate type, hydrologic descriptions including stream width, depth, and qualitative estimates of flow. As part of these surveys, management concerns (e.g., presence of bullfrogs or other exotic predators, obstructive vegetative growth [native and non-native], etc.) were also identified. The nighttime adult presence/absence surveys were conducted in any potential habitat identified from the habitat assessment. Survey techniques were in accordance with the recommended US Fish and Wildlife Service Protocol (1999) with some modification by USGS. Surveys were performed during six nights to determine absence. Surveys were performed on all lands where access was secured. For inaccessible areas, available arroyo toad abundance and distribution data will be used to fill in where current information is lacking.

Additional Suggestions for Monitoring and Long-term Management of Arroyo Toad Populations Between Loveland and Sweetwater Reservoirs

The following suggestions are proposed as means to sustain and improve the overall arroyo toad population within the Sweetwater River between Loveland and Sweetwater Reservoirs. Currently there is only one location in Sweetwater River between Loveland and Sweetwater Reservoirs with a viable population, Sloan Canyon. Increasing this population or expanding the population into other suitable areas should be a part of the management goal and may be achieved by increasing habitat quality and having a more natural hydrologic regime in Sweetwater River below Loveland Dam. The following suggestions should benefit the arroyo toad and improve the understanding of this declining species within the study area.

1) Periodically assess the extent and quality of arroyo toad breeding habitat between Loveland and Sweetwater Reservoir and track habitat availability and quality through the system to determine if it is increasing or decreasing (every 5-8 years);

2) Conduct surveys and monitor for egg masses and/or larvae annually. Egg masses and larvae are hypothesized to be an easier life stage to monitor than adults and provide a direct measure of reproduction, which is what is most strongly affected by Loveland Dam operations (Atkinson, et al. 2003; USFS 2002);

3) Monitor presence of exotic plant species and their effects on arroyo toad breeding habitat. Where necessary, remove exotic species, monitor removal effectiveness and measure benefits to arroyo toad. Early removal of known problem species can be more cost effective than delaying removal until an impact on the toads is clearly detectable;

4) Control invasive predator species, especially during drier years when they are concentrated in the limited number of pools and easier to eradicate. Monitor the effectiveness of eradication techniques and measure benefits to arroyo toads. Again, early removal of known problem species can be more cost effective than delaying removal until an impact on the toads is clearly detectable;

5) Replace and maintain the coarse sediments required for arroyo toad breeding habitat. Sediment could be deposited below Loveland Dam to offset the current sediment depletion downstream. The quality and quantity of material required needs to be identified. Possible sources for materials include the upper limits of Loveland or Palo Verde Reservoirs;

6) Expand the abundance and range of the Sloan Canyon arroyo toad population through restoration of breeding habitat and restoration of the natural hydrologic regime in the system.

7) Explore the possibility of reestablishing arroyo toad populations at sites where arroyo toads no longer exist or occur in very low numbers by translocating tadpoles or metamorphs from more robust populations (e.g., Sloan Canyon). Detailed studies investigating the cause of decline or extirpation of the arroyo toad populations must first be conducted at sites considered for population reestablishment. Additionally, any causes for decline (e.g., loss of breeding habitat, presence of invasive predatory species, etc.) must be remedied before arroyo toads populations can be reestablished.

Uncertainties and Opportunities for Improving the Assessment

There are several opportunities for improving this risk assessment, most of which can be fulfilled by the monitoring suggestions above. A better understanding of the short-term effects on arroyo toad reproductive success due to Loveland Dam operations can be established by collecting life stage occurrence data for the Sloan Canyon population and by determining the actual numbers of eggs and larvae being displaced by Loveland Dam releases. These data could be used to improve the calculations for the percentages of cohorts lost to Loveland Dam controlled releases by giving an actual range of loss of eggs, larvae and metamorphs as a result of release events. Long-term effects on arroyo toad reproductive success and population viability may be better understood by surveying and monitoring eggs and larvae in Sweetwater River. A better understanding of the long-term effects of Loveland Dam operations on arroyo toad habitat can be gained by monitoring the changes in coarse sediment and vegetative cover in arroyo toad habitat and comparing these data with historic habitat information for the watershed. In addition, to strengthen the results of this risk assessment and possibly provide more flexibility to water transfer operations, historical breeding data (1995-present) for the largest arroyo toad population in Sweetwater River below Loveland Dam (Sloan Canyon) and access to the site should continue to be pursued. With some refinement this risk assessment could be used by other agencies as a framework for estimating risk to amphibians and other riparian dependent species in systems regulated by dams.

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References

Atkinson, A.J., B.S. Yang, R.N. Fisher, E. Ervin, T.J. Case, N. Scott and H.B. Shaffer. 2003. MCB Camp Pendleton arroyo toad monitoring protocol: 1. Summary of results from a workshop on August 27, 2002; 2. Monitoring protocol and targeted studies. USGS Technical Report. Prepared for Marine Corp Base Camp Pendleton, Camp Pendleton, California.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Annual Review of Ecological Systems. 8:25-83.

Beaman, K.T., S.J. Meyers and C. McGaugh. 1995. Report on surveys for arroyo toads on Deep Creek. Technical Report. Prepared for the U.S. Forest Service, San Bernardino National Forest, California.

Beaman, K.T. 2003. Personal Communication. Natural History Museum of Los Angeles, 900 Exposition Blvd., Los Angeles, CA 90007.

BC Hydro. 2003. Cheakamus River gravel recruitment project 2002, final report. Prepared for the Government of Canada Fisheries and Oceans, the North Vancouver Outdoor School and the BC Hydro Bridge Coastal Fish and Wildlife Restoration Program.

Brown, C., E. Ervin, and L. Lyren. 2000. Arroyo toad, *Bufo californicus*, 2000 USGS/USFS survey data. Angeles, Cleveland, and San Bernardino National Forests, California: Year 2000. USGS Technical Report (Compact Disk). Prepared for the U.S. Forest Service, Angeles, Cleveland, and San Bernardino National Forests, California.

Brown, C., L. Lyren and R.N. Fisher. 2001. Summary of arroyo toad surveys in the Angeles and San Bernardino National Forests. USGS Technical Report. Prepared for the U.S. Forest Service, Angeles and San Bernardino National Forests, California.

Brown, C. and R.N. Fisher. 2002. Survey results for the arroyo toad (*Bufo californicus*) in the San Bernardino National Forest, 2001. USGS Technical Report. Prepared for the U.S. Forest Service, San Bernardino National Forests, California.

California Department of Water Resources. 1993. Dams within the jurisdiction of the state of California.

Campbell, L.A., T.B. Graham, L.P. Thibault and P.A. Stine. 1996. The arroyo toad (*Bufo microscaphus californicus*), ecology, threats, and research needs. California Science Center of the National Biological ServiceTechnical Report NBS/CSC-96-01. Prepared for the U.S. Fish and Wildlife Service, Ventura Field Office, California.

Cech, J.J., B.W. Wilson and D.G. Crosby. 1998. Multiple stresses in ecosystems. Lewis Publishers, CRC Press LLC. Boca Raton, Florida.

Cole, D.N. and P.B. Landres. 1996. Threats to wilderness ecosystems: impacts and research needs. Ecological Applications. 6(1):168-184.

Collier, M., R.H. Webb and J.C. Schmidt. 2000. Dams and rivers, a primer on the downstream effects of dams. U.S. Geological Survey Circular 1126.

Copp, J.F. 2003. Personal communication and field notes. 1441 Muirlands Dr., La Jolla, CA 92037.

Cunningham, J.D. 1961. Observations on the natural history of the California toad, *Bufo californicus*. Herpetologica. 17(4):255-260.

Ervin, E. 2003. Personal communication. United States Geological Survey, 5745 Kearny Villa Rd, Suite M, San Diego, CA 92123.

Famolaro, P. 1999. Arroyo toad excerpts from 1998 endangered/threatened species monitoring report. Technical Report. Prepared by Sweetwater Authority, Spring Valley, California.

Famolaro, P. 2000. Arroyo toad excerpts from 1999 endangered/threatened species monitoring report. Technical Report. Prepared by Sweetwater Authority, Spring Valley, California.

Famolaro, P. and L. Tikkanen Reising. 2001. Arroyo toad excerpts from endangered species monitoring report for the Sweetwater Reservoir habitat management program and urban runoff diversion system, phase II (Year 2000). Technical Report. Prepared by Sweetwater Authority, Spring Valley, California.

Famolaro, P. 2002a. Arroyo toad excerpts from endangered species monitoring report for the Sweetwater Reservoir habitat management program and urban runoff diversion system, phase II (Year 2001). Technical Report. Prepared by Sweetwater Authority, Spring Valley, California.

---------. 2002b. Upper Loveland Reservoir arroyo toad notes (Year 2001). Technical Report. Prepared by Sweetwater Authority, Spring Valley, California.

Famolaro, P. 2003. Personal communication. Sweetwater Authority, 100 Lakeview Ave, Spring Valley, CA 91977.

Fleury, S.A. 2001. Adaptive management research protocol to determine the effects of water releases from Loveland Reservoir on the arroyo southwestern toad (*Bufo californicus*). Draft Report. Prepared for Sweetwater Authority, Spring Valley, California.

Fowler, L.C. 1952. A History of the dams and water supply of western San Diego County. Master's Thesis, University of California.

Griffin, P.C., T.J. Case and R.N. Fisher. 1999. Radio telemetry study of *Bufo californicus*, arroyo toad movement patterns and habitat preferences. Technical Report. Prepared for the California Department of Transportation.

Griffin, P.C. and T.J. Case. 2001. Terrestrial habitat preferences of adult arroyo southwestern toads. Journal of Wildlife Management. 65(4):633-644.

Haas, W.E. 1997. Summary of the findings of surveys to detect arroyo toad (*Bufo microscaphus californicus*) in the vicinity of the Sweetwater Reservoir, surveys conducted March – June 1997. TechnicalReport. Prepared for Sweetwater Authority, Spring Valley, California.

Haas, W.E. and P. Famolaro. 1998. Summary status of the arroyo toad within the Sweetwater River watershed. TechnicalReport. Prepared for Sweetwater Authority, Spring Valley, California.

Haas, W.E. 2001. Rincon arroyo toad summary. Technical Report. Prepared for the Rincon Indian Tribe, Valley Center, California.

Haas, W.E. 2003. Personal communication. Varanus Biological Services, Inc., 7920 Silverton Ave., Suite D, San Diego, CA 92126.

Holland, D.C., N.R. Sisk and R.H. Goodman. 2001. Linear transect censusing of the arroyo toad (*Bufo californicus*) from 1996-2000 on MCB Camp Pendleton, San Diego County, California. Technical Report. Prepared for AC/S Environmental Security, MCB Camp Pendleton, Camp Pendleton, California.

Holland, D.C. and N.R. Sisk. 2001a. Habitat use and population demographics of the arroyo toad (*Bufo californicus*) on MCB Camp Pendleton, San Diego County, California 1998-2000. Technical Report. Prepared for AC/S Environmental Security, MCB Camp Pendleton, Camp Pendleton, California.

---------. 2001b. Linear transect censusing of the arroyo toad (*Bufo californicus*) on two streams on the Cleveland National Forest, San Diego County, California 1998-1999. Technical Report. Prepared for the U.S. Forest Service, Cleveland National Forest, California.

Hunter, R. 1999. California Wildlands Project: A vision for wild California. Technical Report. Prepared for the California Wilderness Coalition, Davis, California.

Jennings, M.R. and M.P. Hayes. 1994. Amphibian and reptile species of special concern in California. Technical Report. Prepared for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova, California.

Kasner, K. 2002. Historical (1977-2002) Loveland releases and projections. Interoffice memorandum, first revision, to P. Famolaro, Sweetwater Authority, Spring Valley, California.

Ligon, F.K., W.E. Dietrich and W.J. Trush. 1995. Downstream ecological effects of dams, a geomorphic perspective. BioScience. 45(3):183-192.

Lind, A.J., H.H. Welsh, and R.J. Wilson. 1996. The effects of a dam on breeding habitat and egg survival of the foothill yellow-legged frog (*Rana boylii*) in northwestern California. Herpetological Review. 27(2):62-67.

Lovich, R.E. 2003. Personal communication. AC/S Environmental Security, Box 555008, Marine Corps Base, Camp Pendleton, CA 92055.

Mahrdt, C.R., R.E. Lovich and S.J. Zimmitti. 2002. *Bufo californicus* (California arroyo toad) habitat and population status. Herpetological Review. 33(2):123-125.

Nilsson, C., A. Elblad, M. Gardfjell and B. Carlberg. 1991. Long-term effects of river regulation on river margin vegetation. Journal of Applied Ecology. 28(3):963-987.

Nilsson, C. and K. Berggren. 2000. Alteration of riparian ecosystems caused by river regulation. BioScience. 50(9):783-792.

Ortega, B. 2003. Personal communication. Dudek & Associates, Inc., 605 Third St., Encinitas, CA 92024.

Ramirez, R.S. 2002. Arroyo toad (*Bufo californicus*) radio telemetry study, Little Rock Creek, Los Angeles, California. Technical Report. Prepared for the U.S. Forest Service, Angeles National Forest, California.

Richter, B.D., J.V. Baumgartner, J. Powell and D.P. Braun. 1996. A method for assessing alteration within ecosystems. Conservation Biology. 10(4):11163-1174.

Stephenson, J. 2003. Personal communication. United States Fish and Wildlife Service, 20310 Empire Ave., Suite A100, Bend, OR 97701

Sweet, S.S. 1992. Initial report on the ecology and status of the arroyo toad (*Bufo microscaphus californicus*) on the Los Padres National Forest of southern California, with management recommendations. Technical Report. Prepared for the U.S. Forest Service, Los Padres National Forest, California. Revised 1992.

Sweet, S.S. 1993. Second report on the biology and status of the arroyo toad (*Bufo microscaphus californicus*) on the Los Padres National Forest of southern California. Technical Report. Prepared for the U.S. Forest Service, Los Padres National Forest, California.

Trimble, S.W. 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. Science. 278(5342):1442-1444.

U.S. Department of the Interior. 2000. Record of decision, Trinity River main stem fishery restoration, final environmental impact statement/environmental impact report, December 19, 2000.

U.S. Environmental Protection Agency. 1998. Guidelines for ecological risk assessment. Federal Register 63(93):2686-26924.

U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants; determination of endangered status for the arroyo toad; final rule. Federal Register. 59(241): 64859-64867.

U.S. Fish and Wildlife Service. 1999. Recovery plan for the arroyo southwestern toad.

U.S. Fish and Wildlife Service Protocol. 1999. Survey protocol for the arroyo toad. Prepared by the Ventura Fish and Wildlife Office, California.

U.S. Fish and Wildlife Service. 2001. Endangered and threatened wildlife and plants; final designation of critical habitat for the arroyo toad; final rule. Federal Register. 66(26):9414-9474.

U.S. Forest Service. 2002. Los Padres National Forest, draft population monitoring plan for amphibians.

Warburton, M. 2003. Personal communication. United States Geological Survey, 5745 Kearny Villa Rd, Suite M, San Diego, CA 92123.

Williams, G.P. and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. U.S. Geological Survey Professional Paper 1286.

Wooten, J.T., M.S. Parker and M.E. Power. 1996. Effects of disturbance on river food webs. Science. 273(5281):1558-1561.

Zimmitti, S.J. and C.R. Mahrdt. 1999. Report on surveys for arroyo toads (*Bufo californicus*) in Boden Canyon. Technical Report. Prepared for the U.S. Fish and Wildlife Service, Carlsbad, California and Boden Canyon Management Team, City of San Diego, Environmental Services Department, San Diego, California.

NORMALS 1971-2000	YRS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
LONG BEACH, CA	30	2.95	3.01	2.43	0.6	0.23	0.08	0.02	0.1	0.24	0.4	1.12	1.76	12.94
LOS ANGELES AP, CA	30	2.98	3.11	2.4	0.63	0.24	0.08	0.03	0.14	0.26	0.36	1.13	1.79	13.15
LOS ANGELES C.O., CA	30	3.33	3.68	3.14	0.83	0.31	0.06	0.01	0.13	0.32	0.37	1.05	1.91	15.14
SAN DIEGO, CA	30	2.28	2.04	2.26	0.75	0.2	0.09	0.03	0.09	0.21	0.44	1.07	1.31	10.77
SANTA BARBARA, CA	30	3.57	4.28	3.51	0.63	0.23	0.05	0.03	0.11	0.42	0.52	1.32	2.26	16.93
	Sums:	15.11	16.12	13.74	3.44	1.21	0.36	0.12	0.57	1.45	2.09	5.69	9.03	68.93
	Means:	3.022	3.224	2.748	0.688	0.242	0.072	0.024	0.114	0.29	0.418	1.138	1.806	13.786

Table 1. NOAA normal precipitation data for southern California 1971-2000. Normal precipitation is the arithmetic mean for each month over the 30-year period, adjusted as necessary, and includes the liquid water equivalent of snowfall. NOAA Precipitation data was used to examine arroyo toad breeding in relation to weather.

	# Sightings per month			Percentages of total sightings of each life stage			Estimated occurrence rate of life stages			Estimated % cohort loss due to dam release	
	Egg Mass	Larvae	Metamorphs	% of total egg mass sightings	% of total Larval sightings	% of total metamorph sightings	Egg Mass	Larvae	Meta-morphs	Lower Bound	Upper Bound
Jan				0%	0%	0%	1.8%	0%	0%	1.4%	1.8%
Feb	1	2		2.9%	3.1%	0%	7.5%	1.8%	0%	6.9%	9.2%
Mar	13	7	1	38.2%	10.8%	2.2%	24.9%	7.5%	1.8%	23.7%	33.3%
Apr	8	11	4	23.5%	16.9%	8.7%	23.5%	24.9%	7.5%	31.3%	52.1%
May	10	15	9	29.4%	23.1%	19.6%	27.0%	23.5%	24.9%	33.4%	63.0%
Jun	2	18	11	5.9%	27.7%	23.9%	11.3%	27.0%	23.5%	22.6%	50.1%
Jul		7	11	0%	10.8%	23.9%	2.8%	11.3%	27.0%	7.9%	27.6%
Aug		4	8	0%	6.2%	17.4%	1.2%	2.8%	11.3%	2.4%	9.7%
Sep		1	1	0%	1.5%	2.2%	0%	1.2%	2.8%	0.6%	2.6%
Oct			1	0%	0%	2.2%	0%	0%	1.2%	0%	0.6%
Nov				0%	0%	0%	0%	0%	0%	0%	0%
Dec				0%	0%	0%	0%	0%	0%	0%	0%
Totals	34	65	46	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		

Table 2. Life stage occurrence by month and estimated percent cohort loss due to a controlled dam release. The number of sightings of egg masses, larvae, and metamorphs, the percentage of total sightings and the calculated % cohort loss due to dam releases are given. Estimated loss of egg masses due to a controlled release is 80-100%, estimated loss for larvae is 50-100%, estimated loss for metamorphs is 0-50%.

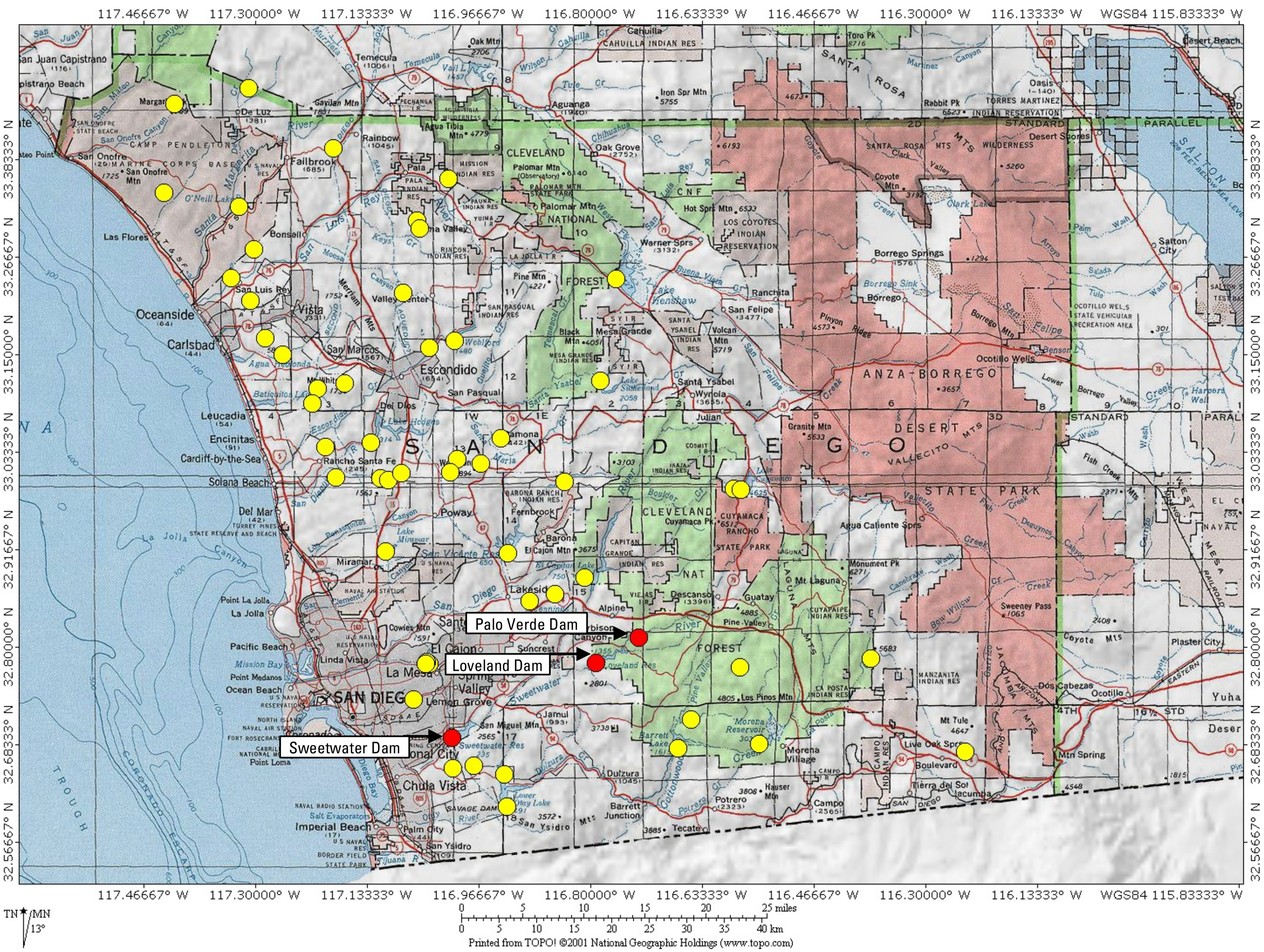


Figure 1. Dam locations in San Diego County. Red dots represent dams on Sweetwater River.

Figure 2. Adult arroyo toad.

Figure 3. Example of high quality arroyo toad breeding habitat.

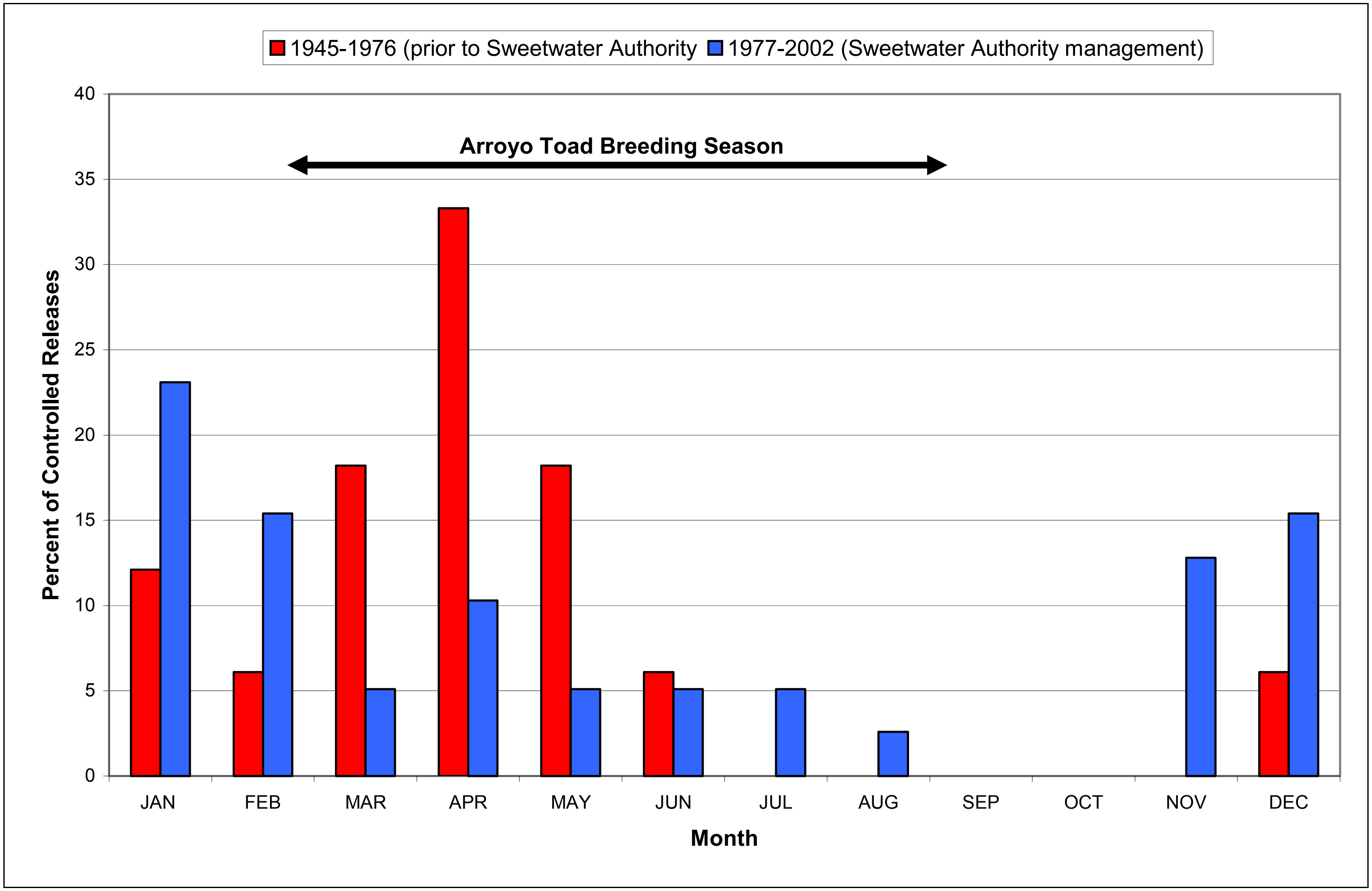


Figure 4. Loveland Dam controlled releases 1945-1976 and 1977-2002. Since Sweetwater Authority has managed Loveland, fewer releases have occurred during the arroyo toad breeding season.

Figure 5. Arroyo toad Critical Habitat Unit 18 from USFWS 2001. The study site lies within section 18C.

Figure 6. Aerial photograph of study area, approximately 16 miles between Loveland and Sweetwater Reservoirs.

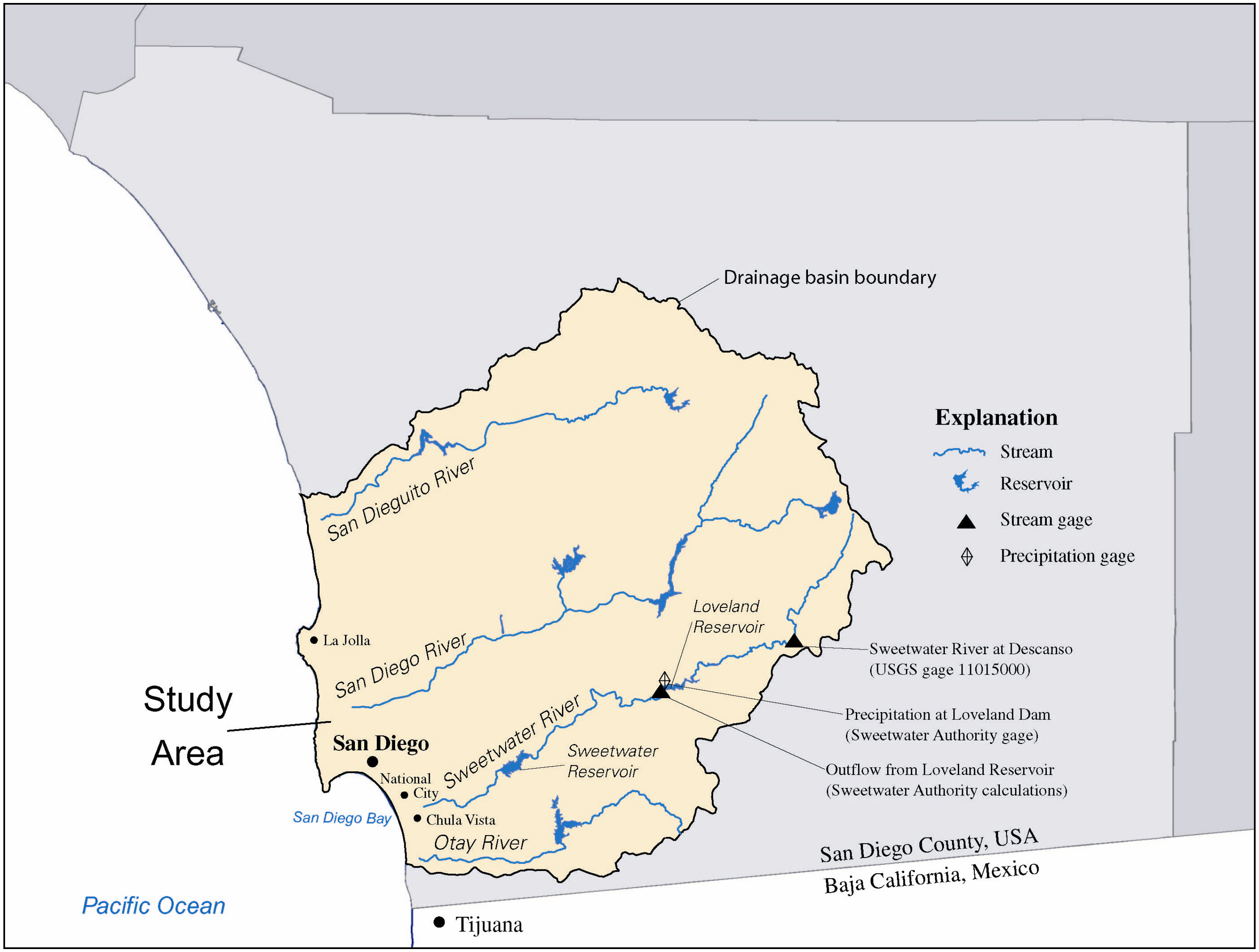


Figure 7. Sweetwater River and surrounding rivers. The USGS gage in Descanso is the only active gage on Sweetwater River.

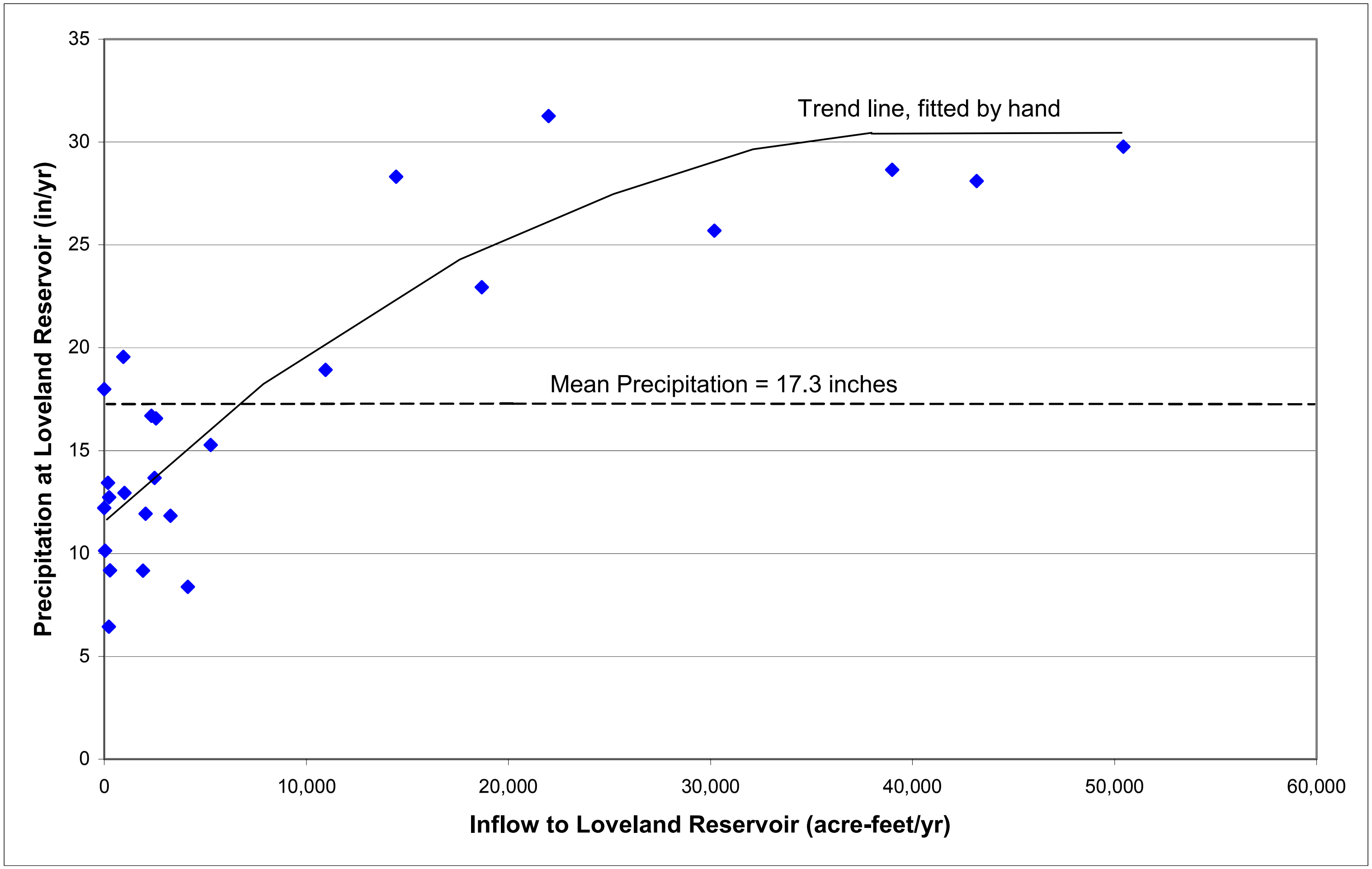


Figure 8. Comparison of annual precipitation and inflow to Loveland Reservoir, 1976-2000. Mean precipitation for Loveland Reservoir 1976-2000 is 17.3 inches.

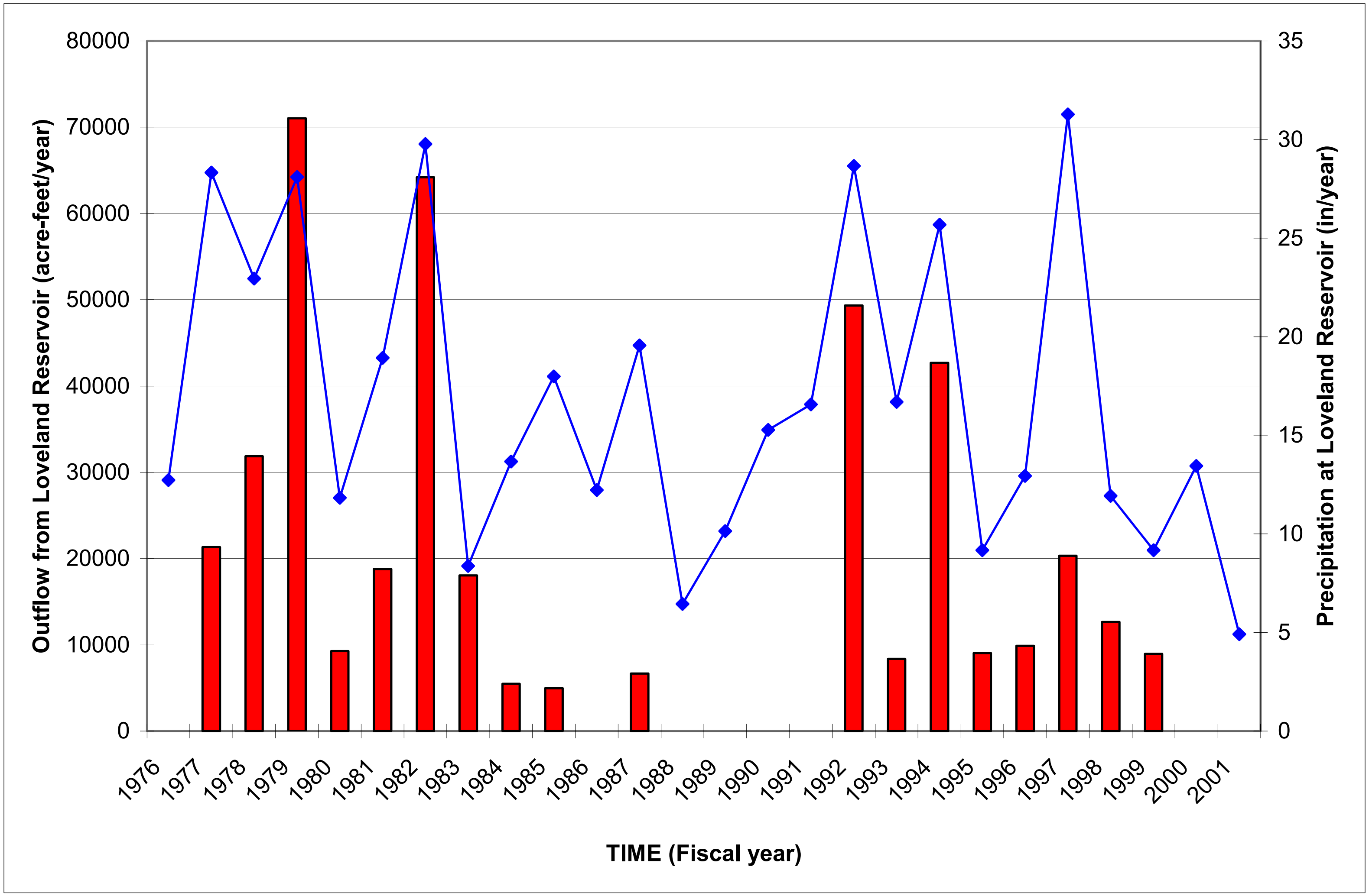


Figure 9. Comparison of annual precipitation in fiscal years (July-June) and outflow from Loveland Reservoir, 1976-2001. Red bars represent total releases from Loveland Dam and blue lines represent precipitation at Loveland Reservoir gage.

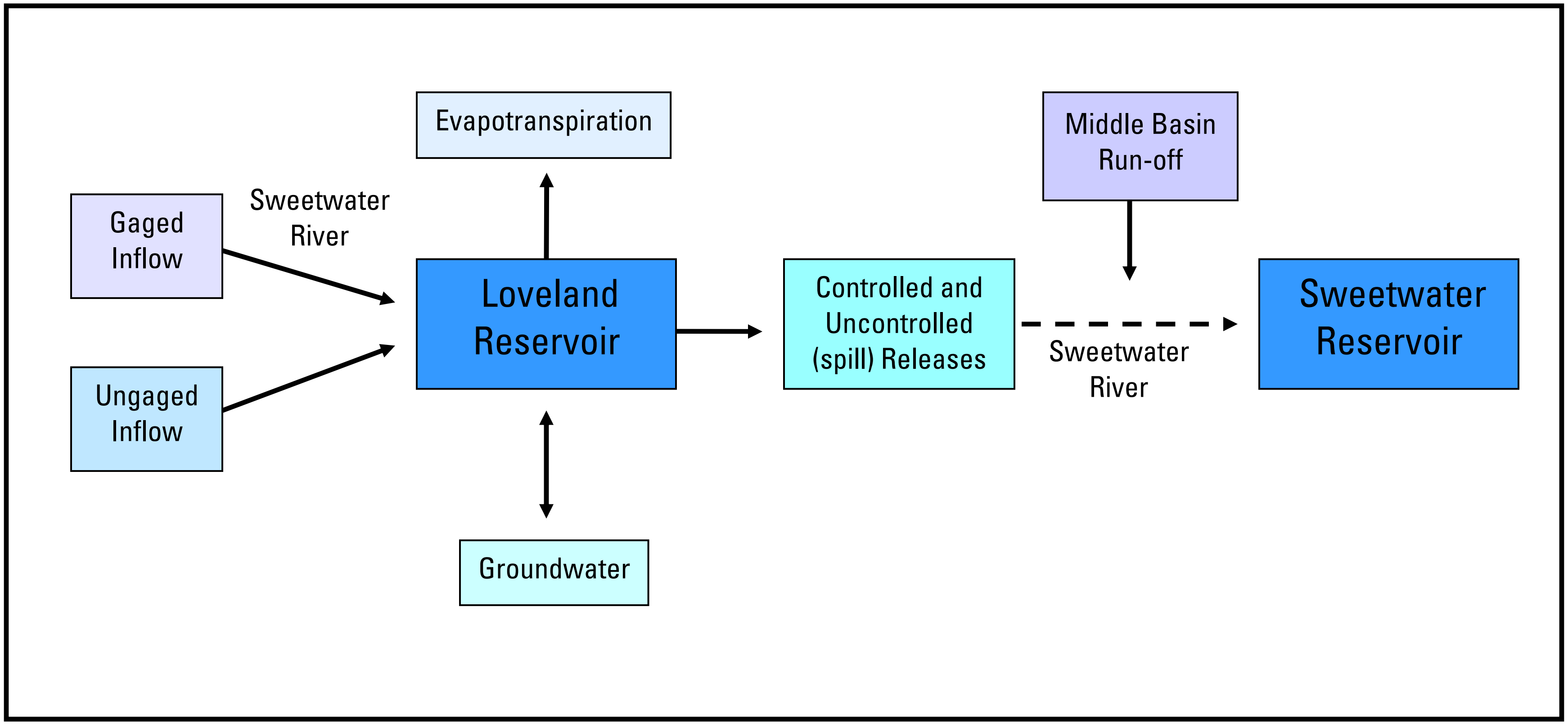


Figure 10. Hydrologic conceptual model of the Sweetwater River system. Ungaged inflow includes direct precipitation at the reservoir.

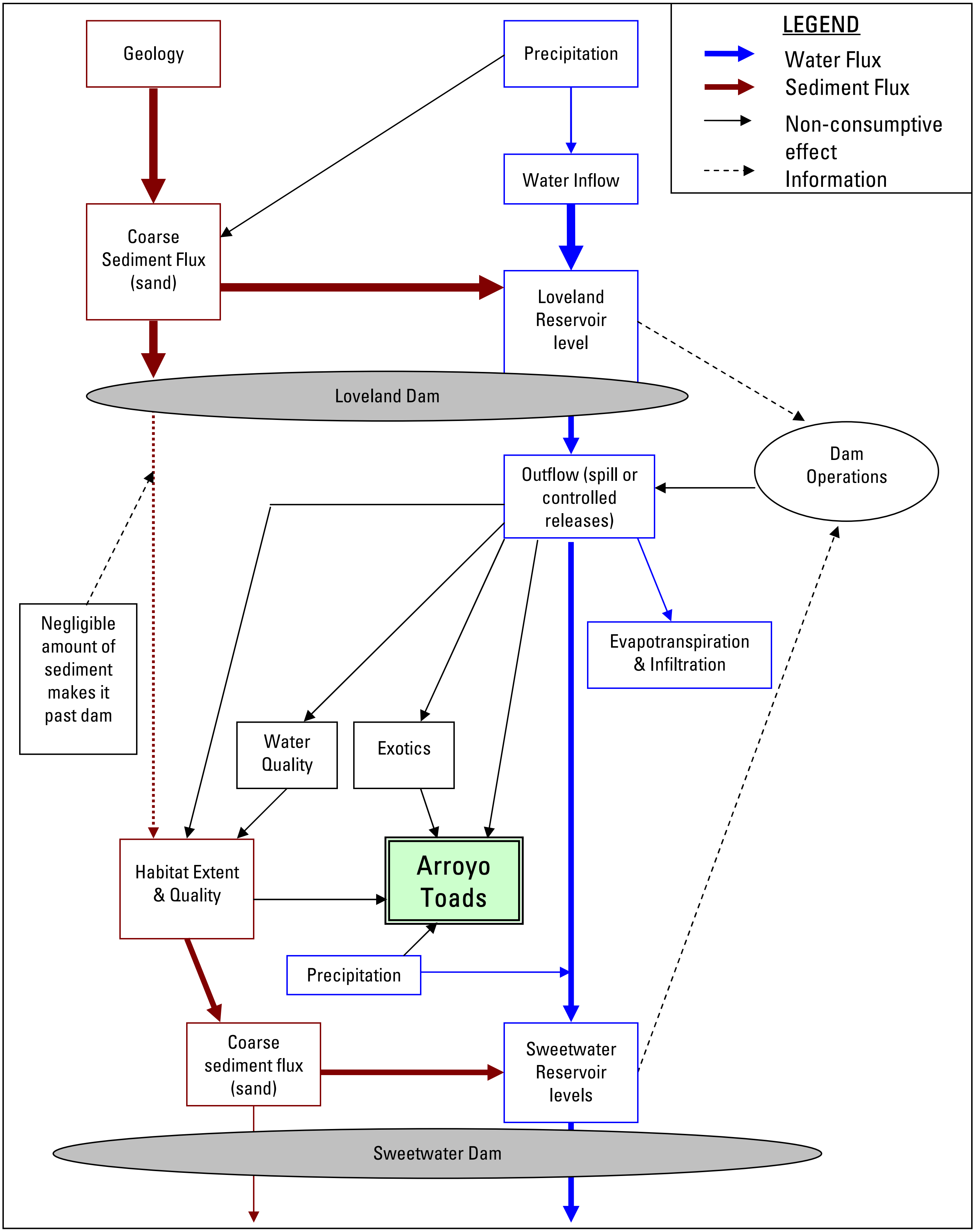


Figure 11. Conceptual model of different effects of Loveland Dam operations on arroyo toad breeding: altered flow amount and timing, altered coarse sediment supply, water quality, and flushing out of exotics.

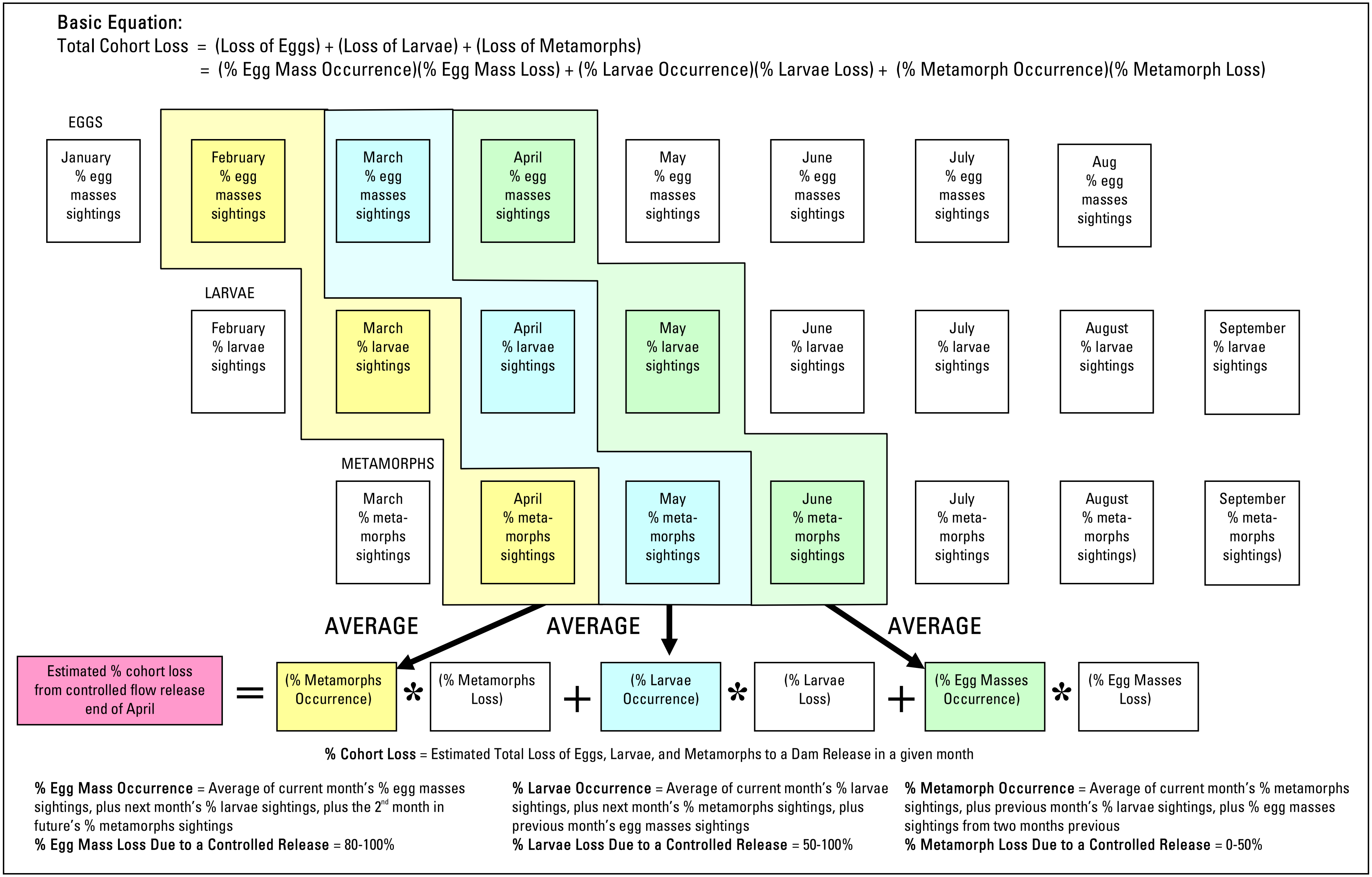
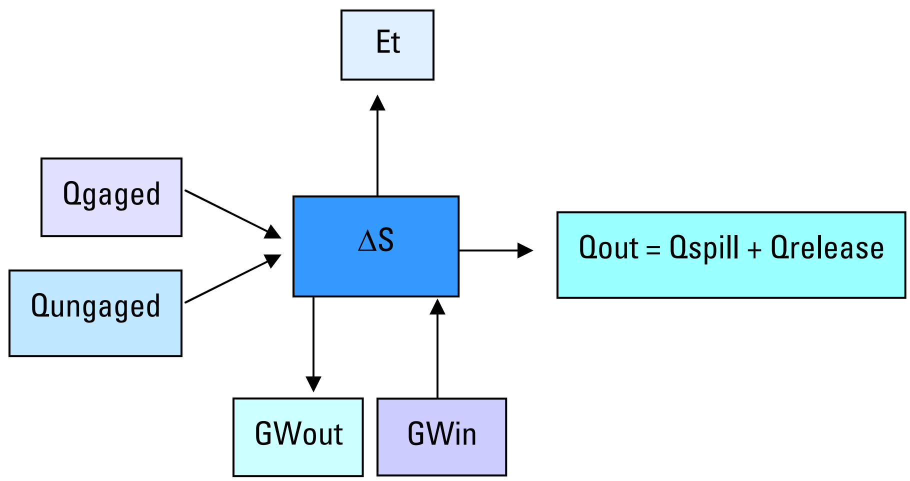


Figure 12. Calculation of estimated cohort loss due to a controlled dam release in a specific month (e.g., April) based upon the distribution of the percent of sightings of egg masses, larvae, and metamorphs in each month. It is assumed for the basis of these calculations that egg masses in a given month (e.g., April) become larvae in the next month (e.g., May) and then metamorphs in two months (e.g., June). Thus an average of the percentage of sightings in each of these months will give an overall average estimate of the egg masses present in April at the time of the flow release.

Change in storage = Gaged Inflow + Ungaged Inflow + Groundwater –
Evapotranspiration +/- Groundwater - Outlfow



ΔS = Qgaged + Qungaged + GWin - Et - Qout - Gwout

ΔS = change in storage, in acre-feet/year
Qgaged = Sweetwater River near Dehesa (gage 11015000), in acre-feet/year
Qungaged = all surface water flow into Loveland except drainage area at gage 11015000
(includes direct precipitation onto reservoir, in acre-feet/year)
Qout = Outlfow (controlled release or spill) from Loveland Reservoir, in acre-feet/year
Et = evapotranspiration, in acre-feet/year
GWin = groundwater into reservoir, assumed negligible
GWout = groundwater recharge out of reservoir, assumed negligible

Figure 13. Illustration of the Loveland Reservoir mass-balance equation. The mass-balance equation is related to the hydrologic conceptual model of the Sweetwater River system in Figure 10.

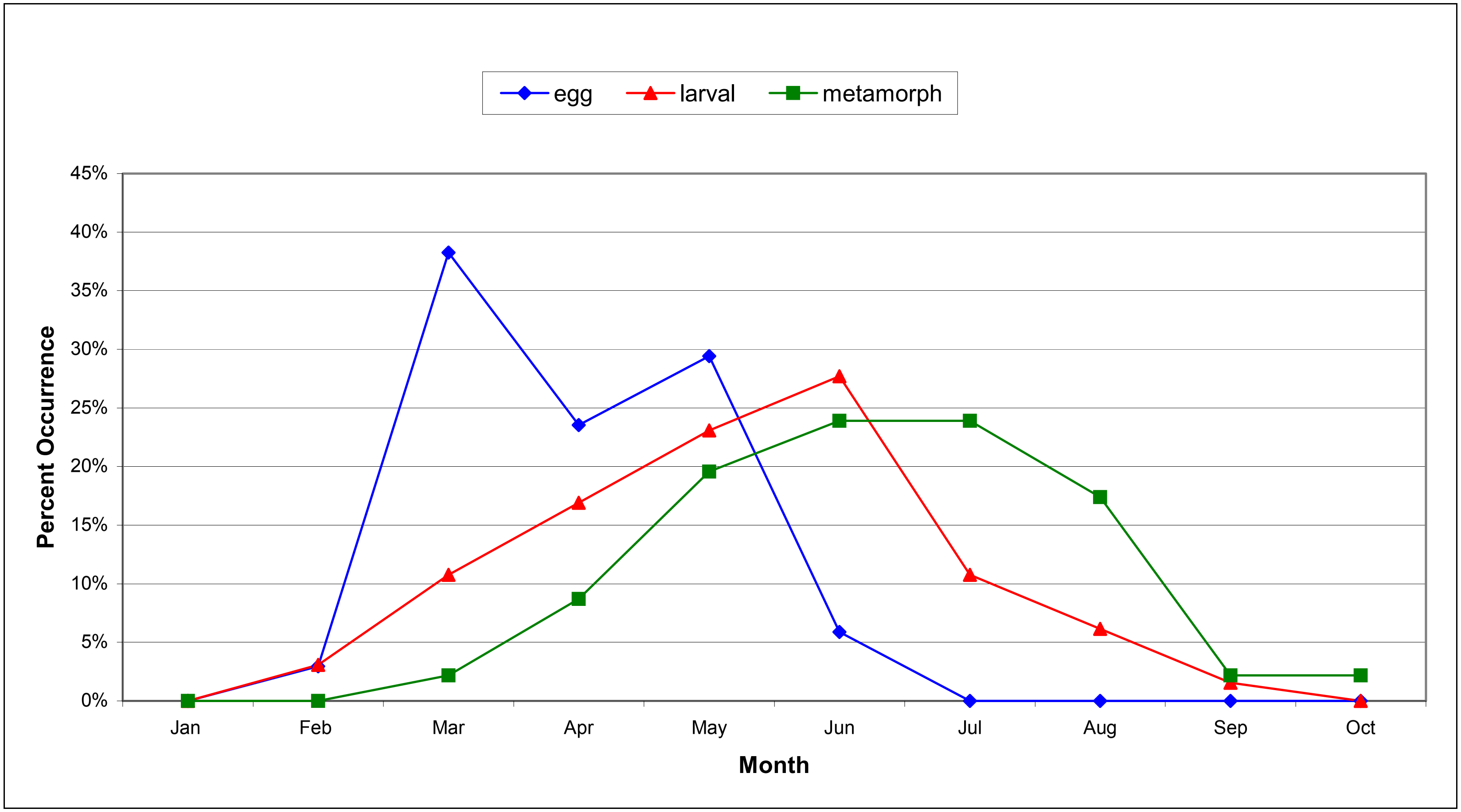


Figure 14. Graph of overlapping life stage occurrence curves from raw life stage occurrence data.

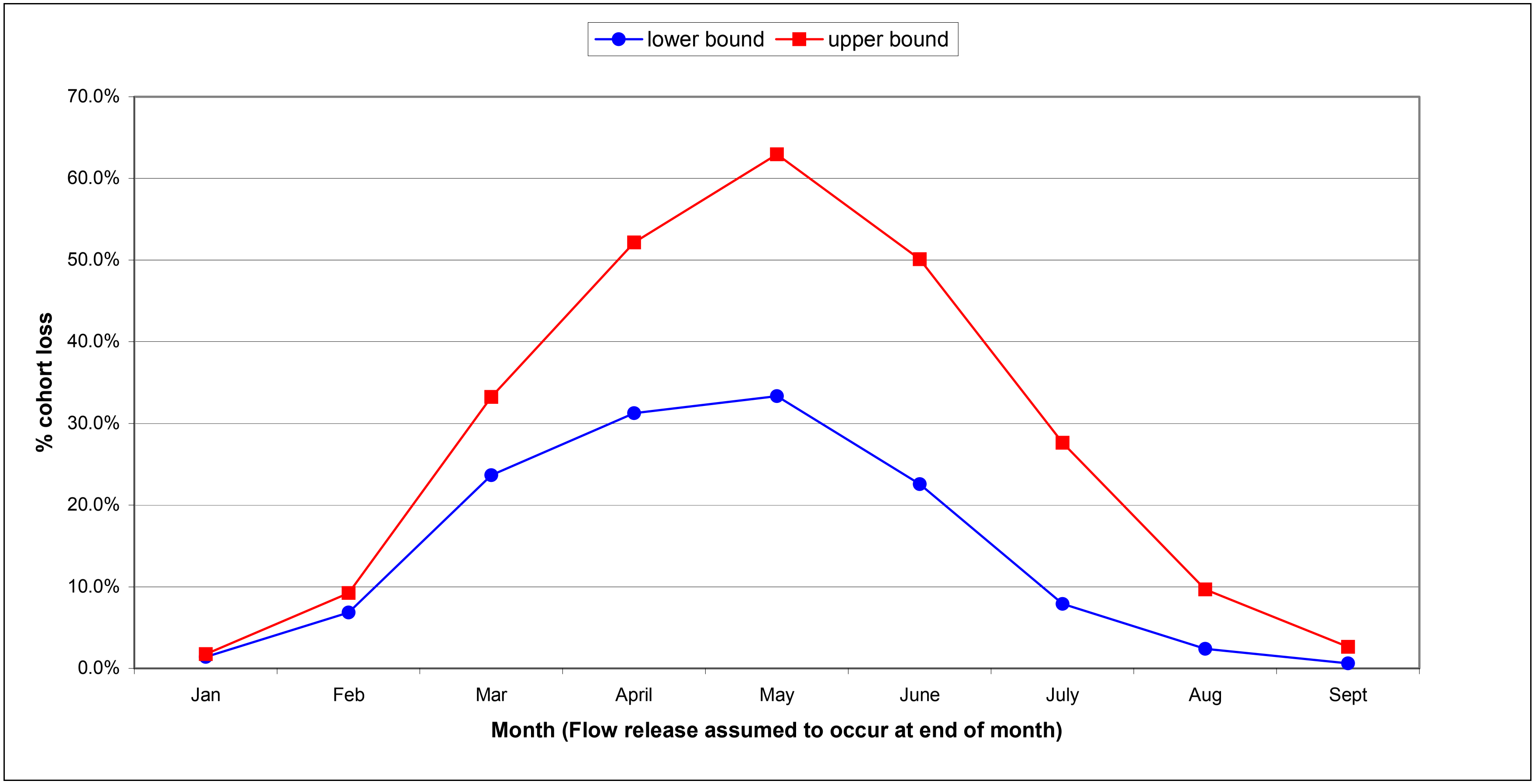


Figure 15. Upper and lower limits of estimated percent loss of breeding effort (cohort) per month due to a controlled dam release at the end of the month. March -July is the period of highest estimated risk.

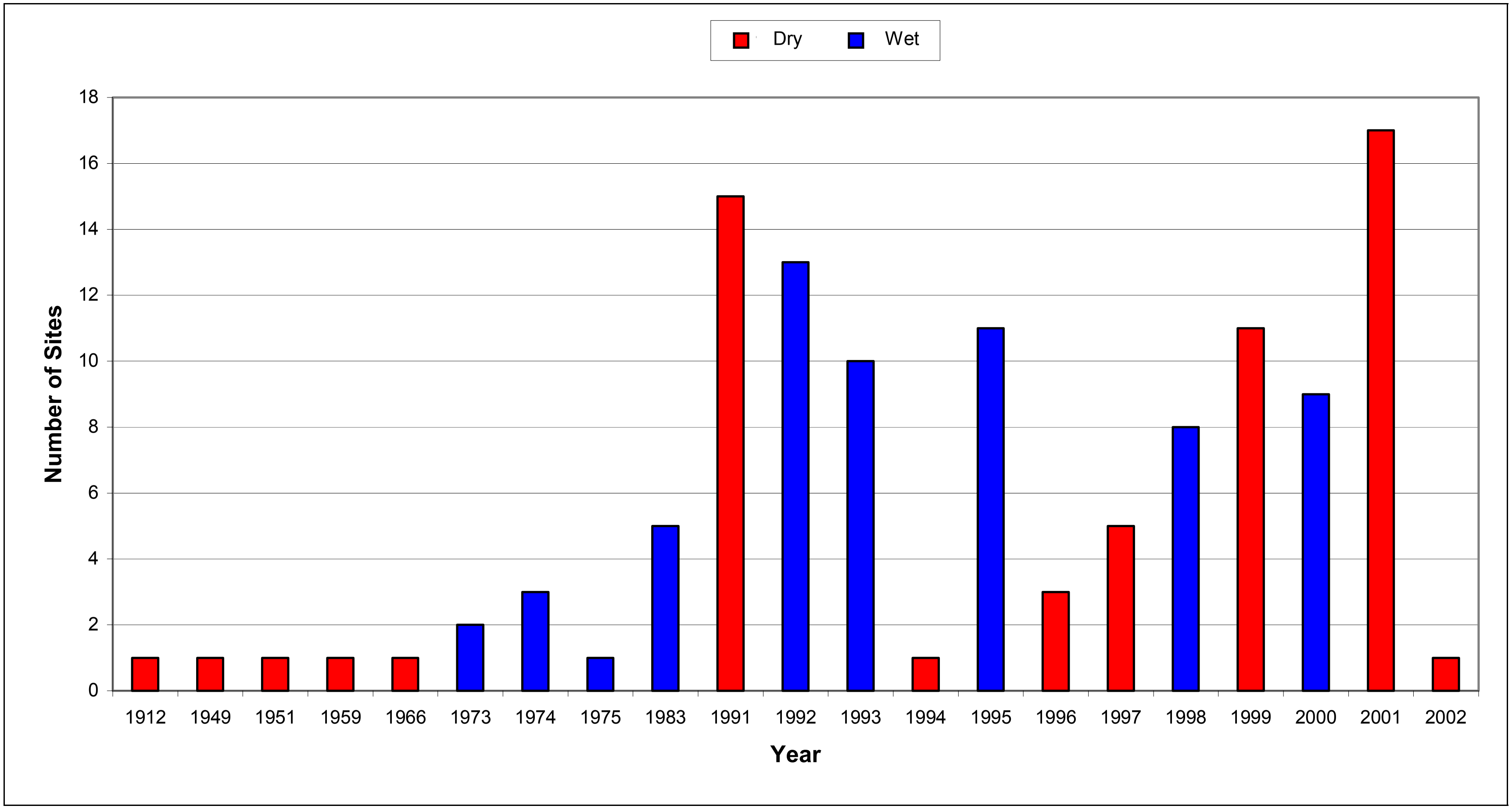


Figure 16. Number of sites with arroyo toad breeding records per year (from the collected historical data). Blue bars represent years of normal to above normal precipitation (approximately 52%) and red bars represent years of below normal precipitation (approximately 48%).

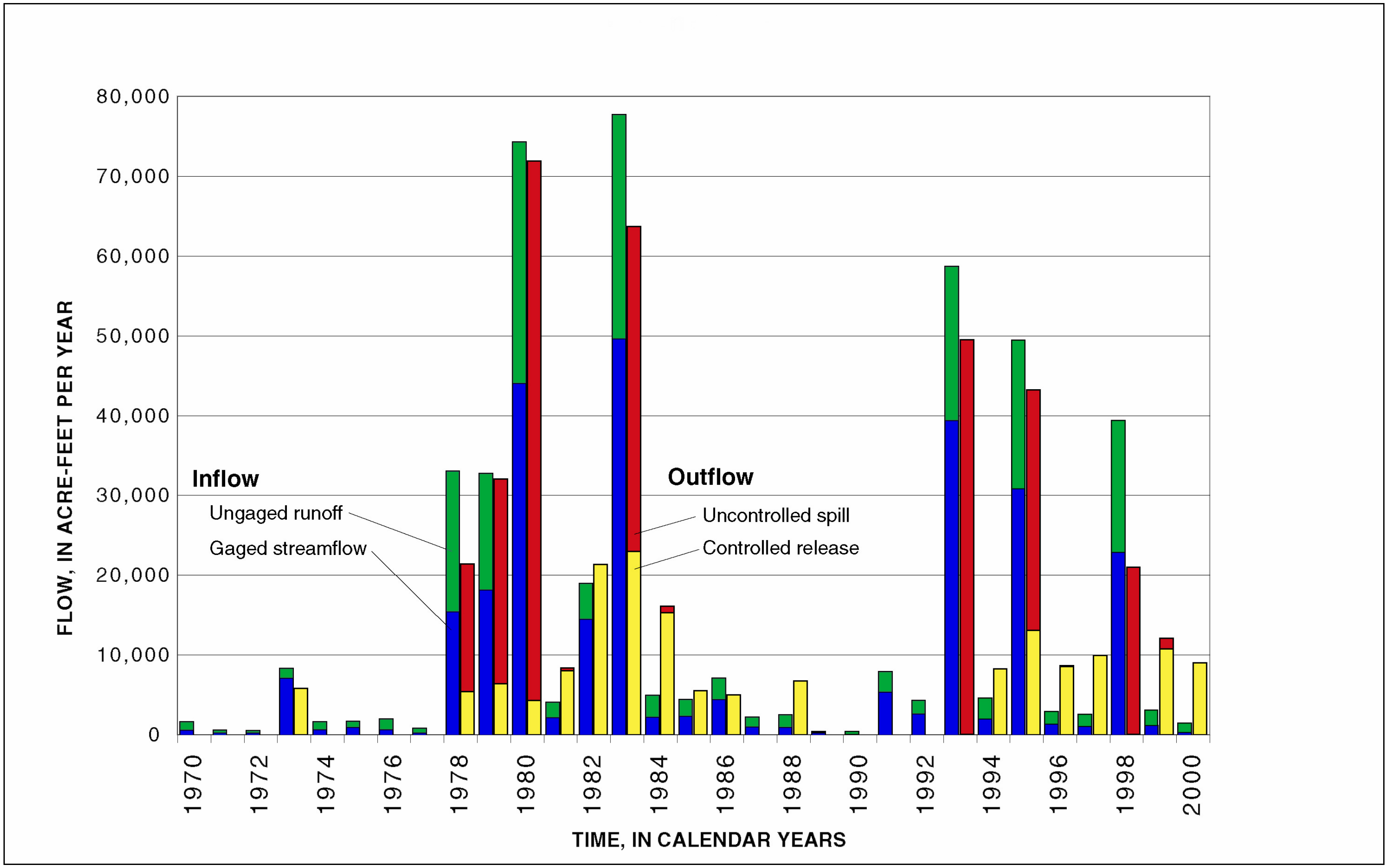
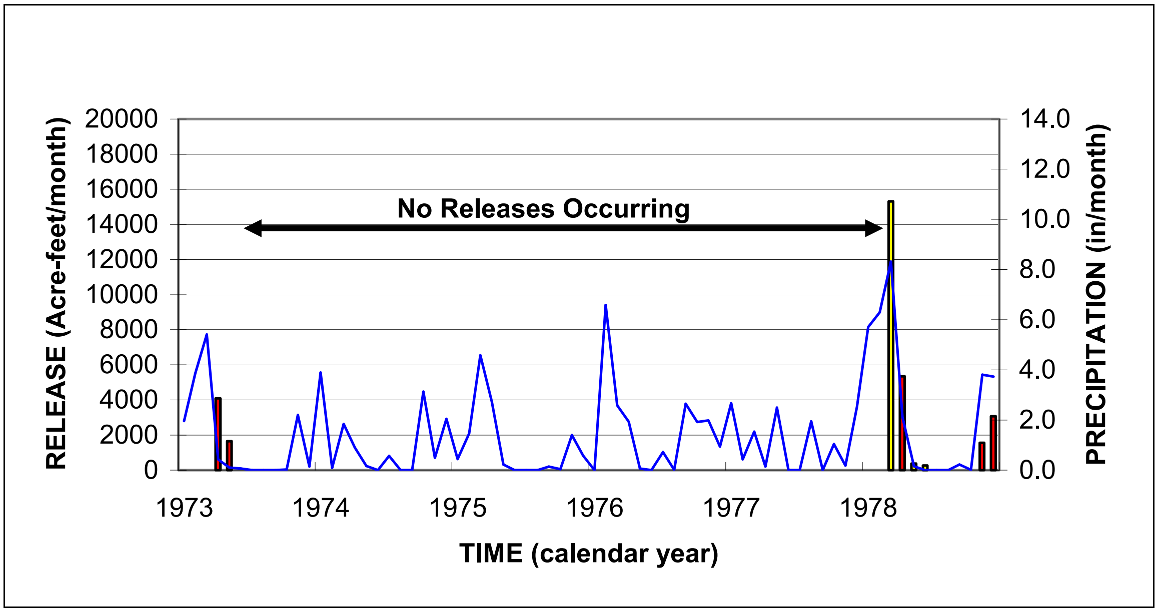


Figure 17. Inflow to and outflow from Loveland Reservoir, 1970-2000. Capacity of the reservoir is approximately 25,000 acre-feet.

A.



B.

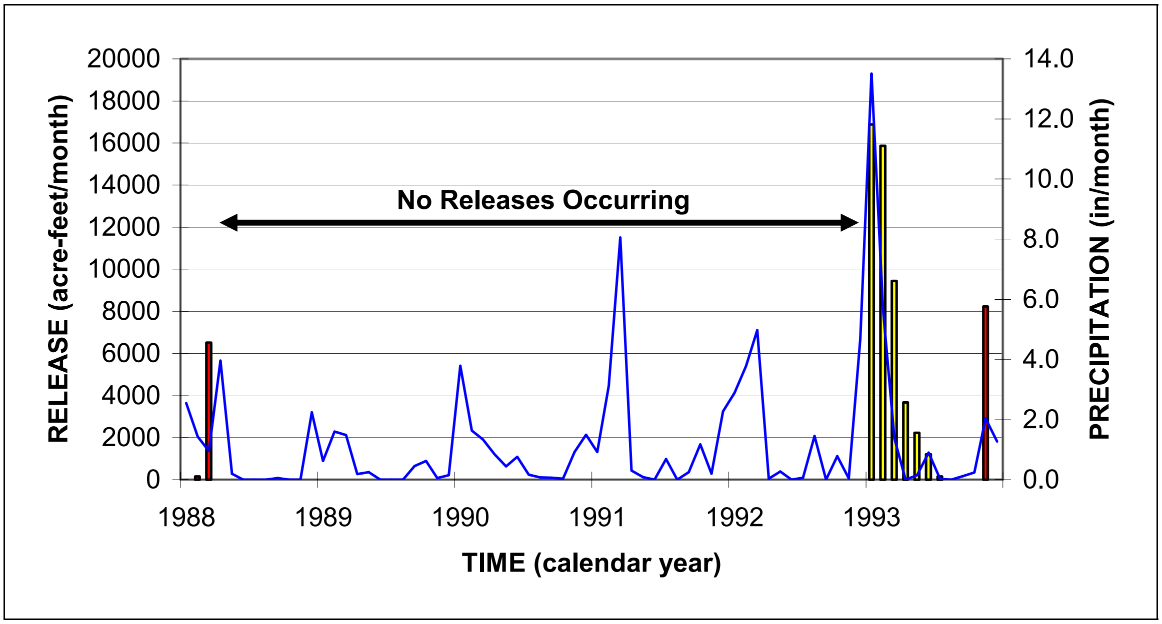


Figure 18. Periods of drought in Sweetwater River between Loveland Reservoir and Sweetwater Reservoir. Red bars represent controlled releases, yellow bars represent spill releases and blue line represents precipitation at Loveland Reservoir. Although precipitation is occurring during these dry periods (the amount of precipitation is related to the amount of inflow to Loveland Reservoir, see Figure 8), water is not being released from the reservoir. Drought periods do not end until water is released from Loveland Reservoir, typically after it fills and spills.

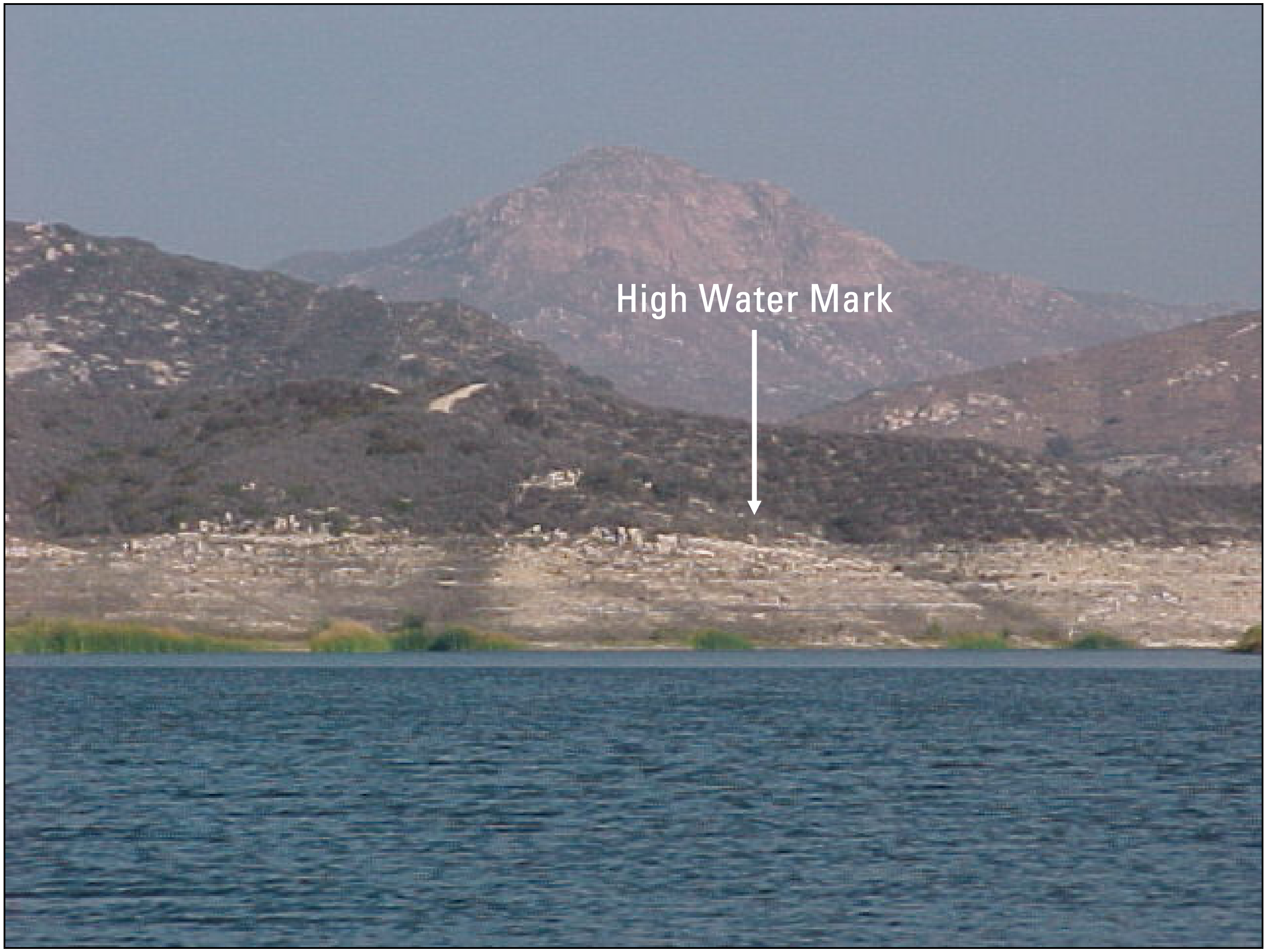


Figure 19. Photograph demonstrating the low water level at Loveland Reservoir in 2002.

A.

B.

Figure 20. Photographs demonstrating loss of sediments below Loveland Dam.

A.

B.

Figure 21. Photographs demonstrating an increase in vegetation cover between Loveland and Sweetwater Reservoir. Photographs taken of the same arroyo toad habitat located approximately 1 kilometer (0.6 miles) upstream from Sweetwater Reservoir in 1997 (A) and 2002 (B).

Appendix 1. Sweetwater Authority Interoffice Memorandum

S W E E T W A T E R   A U T H O R I T Y

INTEROFFICE MEMORANDUM

TO: PETE FAMOLARO

FROM: KEVIN KASNER

SUBJECT: HISTORICAL (1977-2002) LOVELAND RELEASES AND PROJECTIONS

DATE: NOVEMBER 14, 2002 – REVISION 1

CC: DB, JLS, MG, SWA GEN FILE: WATER RESOURCES

Background

Loveland reservoir was constructed in 1945 to store water on the Sweetwater River that would have otherwise spilled from Sweetwater Main Dam.

Historically, water has been released through the dam to “move” water from Loveland to Sweetwater through the middle Sweetwater River where it can be treated and served to our customers. Historically, these transfers have occurred in every month of the year, but typically occur at the beginning or end of the winter. Since Sweetwater took over operation of the system in 1977, the transfers have occurred mostly (66% of releases) in November through February.

Current conditions for transfer:

There are a couple of “Rules of thumb” that have been applied to transfers since 1977: (1) When feasible, the quantity of the release is based on proportioning the amount of available space for water capture to 1/3 of the total available space at Sweetwater and 2/3 of the total space available at Loveland. The intent of this split is to try and ensure that Sweetwater only spills after Loveland begins spilling; (2) releases should begin after we have had significant rainfall to saturate the river channel to maximize the volume recovered at Sweetwater; and (3) since evaporation rates at Sweetwater are considerably greater than Loveland, only transfer enough water from Loveland to Sweetwater to supply the upcoming summer and fall.

Predictions of weather patterns might dictate preference of (1) over (3), or vice-versa. For example, if the year is expected to be very wet, proportioning available space to maximize capture is probably the controlling factor. However, in dry years, minimizing evaporation by only transferring enough to meet rule (3) would be the controlling factor.

Late season transfers, such as April – August typically occur in years when Loveland spilled but Sweetwater did not. The release is initiated as the reservoir stops spilling to increase the amount of water that reaches Sweetwater. This is usually done to meet rule of thumb (3) above.

Depending upon the volumes to be transferred, releases can be as short as a couple of weeks, or as long as a couple of months.

Winds of Change:

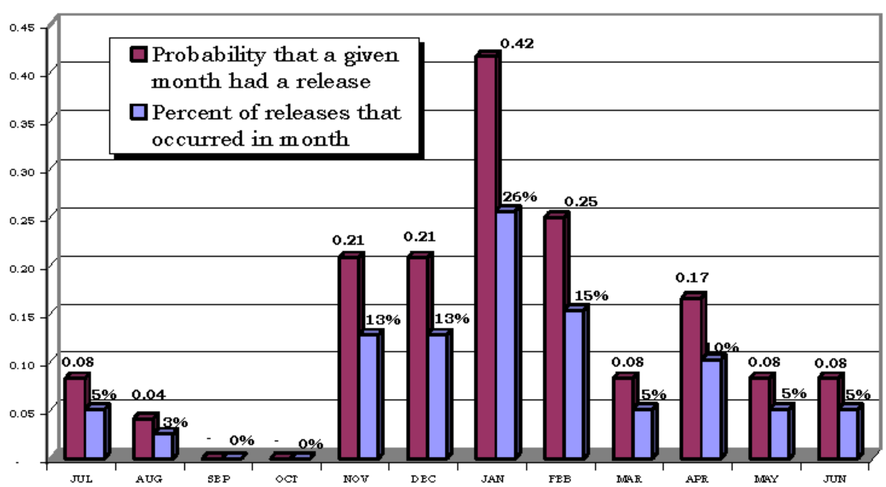
Several external factors could likely influence the decision process for future transfers and their influence has yet to be fully explored. These include: A new rate structure in place at both MWD and CWA considers "time of use" of imported water during the peak summer months, as well as several other factors; A five-year program with MWD and CWA will facilitate placement of imported water into Sweetwater Reservoir during the winter months without exposing Sweetwater Authority to the costs associated with evaporation and the potential for spilling water if the winter suddenly turns "wet".

Additionally, the water resources group is constantly looking to refine the operation of both reservoirs to maximize their benefits to our ratepayers. This includes exploring new sources of water, better uses of existing resources, and balance of the use of our existing sources of supply.

Probability of release occurring in a given month:

Based on the above discussion, the best estimation of when transfers are likely to occur is from our historical record, since Sweetwater Authority was formed in 1977. In the 25 years since 1977, there have been 39 months where releases have taken place.

The likelihood of a release occurring in each month is shown on the graph below. Note that the "zero" probabilities do not mean that a release will not occur, only that they are not probable to occur based on historical practices.



The first column for each month shows the probability of a controlled release occurring. This probability is based on the number of times that a release is expected to occur in that month. For example, January has a probability of about 0.42. This means that, on average, we will release in January 4 times in ten years. The probabilities shown do not add up to 1.0, because each month is compared only to its own history.

Percentage of releases occurring in a given month:

The second column for each month shows the percentage of releases that occurred in a given month. This percentage is based on the number of times a release occurred in a given month, and the number of months where releases occurred. For example, controlled releases occurred in 39 months since 1977, and of the 39 months 10 were January so the percentage is 26%.

Appendix 2. Summary of USEPA Guidelines for Ecological Risk Assessment

According to the USEPA Guidelines for Ecological Risk Assessment (1998), there are four steps in ecological risk assessment: (1) problem formulation, (2) analysis phase, (3) risk characterization and (4) relating ecological information to risk management decisions. A traditional scientific format was chosen for "Assessing the Risk of Loveland Dam Operations on the Arroyo Toad (*Bufo californicus*) in the Sweetwater River Channel, San Diego County, California." In the summary below there are descriptions of how the USEPA Guidelines for Ecological Risk Assessment fit into the framework of a traditional scientific paper. The framework of a traditional scientific paper includes: (1) introduction, (2) materials and methods, (3) results and (4) discussion.

Problem Formulation

The first step of risk assessment, problem formulation, involves developing assessment endpoints, conceptual models, and an analysis plan. Components of problem formulation fall within the "Introduction" and/or "Materials and Methods" sections of a traditionally formatted scientific paper. The assessment endpoint is the ecological entity and the attributes of the ecological entity that are of concern for the risk assessment. Conceptual models are a written and visual representation of the predicted relationship between the ecological entity and the stressor(s). Developing assessment endpoints and conceptual models involves the formation of risk hypotheses which can be found in the "Introduction" or "Materials and Methods" section. The final component of problem formulation is the analysis plan, which involves analyzing the risk hypotheses developed with the conceptual models to help determine how they will be assessed using the available data. The conceptual models and the analysis plan are components of the analysis portion of the "Materials and Methods" section.

Analysis Phase

The analysis phase, the second step of risk assessment, has two components: characterization of exposure and characterization of ecological effects. Characterization of exposure is simply a description of the potential or actual contact that occurs between a stressor and a receptor. The characterization of ecological effects is a description of the effects caused by the stressor that links and evaluates the effects to the assessment endpoints. The two steps of the analysis phase fall within the "Results" section of a traditionally formatted scientific paper.

Risk Characterization

The third step of risk assessment is risk characterization, which includes an estimate of ecological risks, indication of the overall degree of confidence in the risk estimates, citing evidence to support the risk estimates, and interpreting the adversity of ecological effects. Components of this step can be found in the “Results” and “Discussion” sections of a traditional scientific paper.

Relating Ecological Information to Risk Management Decisions

The last component of an ecological risk assessment involves relating the ecological information gathered in the risk assessment to possible risk management decisions. This step falls within the “Discussion” section of a traditional scientific paper.

Appendix 3. Conceptual Model for Arroyo Toads in Sweetwater River Below Loveland Dam

A general conceptual model based on Sweet 1992, USFWS 1999, and Atkinson, et al. 2003 is described below and shown in the last page of this Appendix. The conceptual model is broken down into the 6 major life stages of the arroyo toad (breeding adult, egg, larva, metamorph, juvenile and adult) and gives characteristics, habitat requirements, risk factors associated with dams and non-dam risk factors for each life stage. Additionally it incorporates the risk hypotheses and possible management actions from the risk assessment.

RISK HYPOTHESES

1) The effect of controlled releases on arroyo toad reproductive success varies depending on timing relative to the breeding season;
2) Controlled releases concurrent with a spill event or rain event with flow volume greater than or equal to 350 cubic-feet-per-second (the maximum flow volume for a controlled release is 350 cubic-feet-per-second) will have no additional effect on arroyo toad reproductive success;
3) Controlled releases during dry years will have less of an effect on arroyo toad reproductive success than releases during wet years when more breeding is assumed to be occurring;
4) Changes in the patterns of wet and dry years due to dam operations will have a negative effect on reproductive success and population viability;
5) Reduction in the amount of coarse sediment supply due to entrapment by the reservoir and loss of sediment below the dam by erosion of banks and streambed will have a negative effect on arroyo toad reproductive success due to loss of breeding habitat; and
6) Increased vegetation cover due to changes in amount of peak flows (scouring flows to remove vegetation and to maintain or create breeding habitat) will have a negative effect on arroyo toad reproductive success due to loss of breeding habitat.

BREEDING ADULT STAGE:

Characteristics

- Breeding is nocturnal in spring after water temperatures reach at least 14°C and water levels (<30cm deep) and speed (<5cm/sec) are appropriate for breeding
- Females are assumed to lay one egg mass per season
- Males may mate with multiple females
- Adults prefer darker nights

Habitat Requirements

- Clear still to slow-moving water (generally flow rates less than 5 cm per second) with shallow, exposed clean, sandy bottom and open canopy (see influencing factors)

Influencing Factors

- Episodic flushing flows and floods are needed to naturally disturb habitat, clear vegetation on sandy terraces and maintain toad habitat
- Variability in climate, amount of precipitation, and timing of precipitation strongly affect available habitat and breeding- breeding may not occur during drier years

Dam Risk Factors

- Dams alter the amount and timing of flushing flows and sediment supply- lack of flushing flows and sediment supply causes loss of breeding habitat
- Lack of water in breeding pools due to water impoundment and reduced releases due to storage needs
- Possible flushing of adults from breeding pools during releases (but assumed to be negligible)
- Mild winters with low to moderate flood scouring and water impoundment enable exotic species to persist in or near most breeding pools- predation by bullfrogs
- Periods of drought in the system may be extended due to storage needs, resulting in fewer years with optimal breeding conditions

Other Risk Factors

- In drought years, females may find insufficient insect prey to produce eggs before males cease their calling, resulting in no reproduction
- Lack of water in pools due to low annual precipitation, water diversions, and ground water pumping
- Predation by bullfrogs, raccoons and crows
- Disturbance from mining or road noise- noise pollution does not appear to affect males, but may affect female response
- Breeding habitat degradation and loss due to exotic plants (Arundo, Tamarisk) or to native plants (water cress)
- Urban runoff can contain contaminants
- Erosion after fires can cause siltation of breeding habitat

EGG STAGE

Characteristics

- (12-20 days)
- Strings of 2000-10000 on sand, gravel, cobble or mud along pool margins away from vegetation

Habitat Requirements

- Same as breeding habitat

- Require lack of sediment/turbidity (can tolerate for a few days)

Dam Risk Factors
- Eggs stranded or washed away to unsuitable habitat during dam releases
- Desiccation due to lack of water in pools due to water impoundment, including reduced releases due to storage needs
- Mild winters with low to moderate flood scouring and water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes, crayfish

Other Risk Factors
- Eggs stranded or swept away due to flood events
- Crushing, disturbance or siltation due to humans, sand/gravel mining, floods, runoff, fires
- Desiccation due to lack of precipitation, water diversions and ground water pumping
- Contaminants- pesticides, etc.

LARVAL STAGE

Characteristics
- 65-85 days
- Diurnal
- Very cryptic
- Highly specialized foragers- feed on loose organic material in substrate

Habitat Requirements
- Similar to breeding habitat
- Also need detritus, interstitial algae, bacteria, and diatoms

Dam Risk Factors
- Larvae stranded or washed away to unsuitable habitat during dam releases
- Desiccation due to lack of water in pools due to water impoundment and reduced releases due to storage needs
- Mild winters with low to moderate flood scouring and water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes (green sunfish) bullfrogs

Other Risk Factors
- Predation by garter snakes, birds (killdeer, herons), etc
- Desiccation due to lack of precipitation, water diversions and ground water pumping
- Crushing, disturbance or siltation due to humans, sand/gravel mining, floods, runoff, fires
- Contaminants- pesticides, etc.

METAMORPH STAGE

Characteristics

- 10-17 mm
- Metamorphosis peaks late April to mid May
- Diurnal
- Subsist largely on native ants
- Found clustered
- Remain in saturated soil around the margins of the breeding pool for the first 1-3 weeks, usually until the grow to be 15-16 mm
- Lack mass needed to dig into the surface until they reach 16-17 mm when they can dig shallow pockets in loose sand

Habitat Requirements

- Soft, exposed sand and moist sandy benches with partial shading adjacent to pools

Dam Risk Factors

- Metamorphs can be washed away to less suitable habitat during dam releases
- Mild winters with low to moderate flood scouring and water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes (green sunfish) bullfrogs

Other Risk Factors

- Predation from garter snakes, bullfrogs, birds (killdeer, herons)
- Contaminants- pesticides, etc
- Native ants displaced by fire ants and Argentine ants
- Crushing or disturbance from sand/gravel mining, vehicles and humans (especially vulnerable when still clustered)

JUVENILE STAGE

Characteristics

- Toads 17-23 mm are able to dig burrows and change to a nocturnal activity pattern
- If conditions permit they may remain along margins of breeding pools for up to 6 months
- Forage for nocturnal ants and beetles
- At 28-30 mm they begin to disperse to uplands (dispersal affected by local drying conditions and suitable microhabitat)
- Can be found in dense concentrations

Habitat Requirements

- Exposed portions of bars bordering breeding pools until sand begins to harden and they begin to disperse to nearby stands of willows and mulefat thickets
- Take refuge underground within the riparian zone and disperses farther with dampening of stream terraces

Dam Risk Factors

- Assume no risk to juveniles once they have moved upland
- Smaller juveniles remaining near breeding pools can be washed away to less suitable habitat during dam releases

Other Risk Factors

- Many toads are often exposed and lost to predation by native and exotic predators
- Native ants displaced by fire ants and Argentine ants
- Contaminants- pesticides, etc.

ADULT STAGE

Characteristics (limited knowledge)

- Lifespan about 5 years
- Males reach adulthood in 1- 2 years, females in 2-3 years
- Nocturnal, burrow in sand during the day; many sub adult and some adult males move 0.5-1 km perpendicular from streams, but may travel up to 2 km
- Very dispersed
- Subsist on native ants and other invertebrates

Habitat Requirements

- Coastal sage scrub, chaparral, or oak woodland, but not grasslands (may travel through)
- Require friable soils and permeable plant understory for burrowing

Dam Risk Factors

- Assume no risk to non-breeding adults in uplands

Other Risk Factors

- Predation by native and exotic predators
- Native ants displaced by fire ants and Argentine ants
- Fire
- Drought
- Contaminants- pesticides, etc.

POSSIBLE MANAGEMENT ACTIONS RELATED TO LOVELAND DAM OPERATIONS

1) Avoid controlled releases during the arroyo toad breeding season, especially March to September;
2) Release during rain or spill events in order to mimic the natural flow of the system;

3) Continue to step up controlled releases (Sweetwater Authority currently ramps releases starting with 100 cubic-feet-per-second on day one, 200 cubic-feet-per-second on day two and 300-350 cubic-feet-per-second on day three) to allow larvae and metamorphs to adjust or escape the rising water levels and increasing flow, but also step down controlled releases to allow larvae to follow the falling water;
4) When controlled releases during the arroyo toad breeding cannot be avoided, survey for egg masses and tadpoles prior to the releases to see if eggs, larvae or metamorphs are present and consider relocating or temporarily captive housing (needs further evaluation);
5) Replace and maintain the coarse sediments required for arroyo toad breeding habitat by dredging sand and fine gravel from the reservoirs and depositing it in Sweetwater River below Loveland Dam;
6) Maintain peak spill releases to allow scouring of vegetation, the removal of exotics and the improvement of water quality in arroyo toad breeding habitat; and
7) Control invasive predator species, especially during drier years when they are concentrated in the limited number of pools and easier to eradicate.

Conceptual Model for Arroyo Toads in Sweetwater River Below Loveland Dam *

Risk Hypotheses: The effect of controlled releases on arroyo toad reproductive success varies depending on timing relative to the breeding season; 2) Controlled releases concurrent with a spill event or rain event with flow volume greater than or equal to 350 cubic-feet-per-second (the maximum flow volume for a controlled release is 350 cubic-feet-per-second) will have no additional effect on arroyo toad reproductive success, 3) Controlled releases during dry years will have less of an effect on arroyo toad reproductive success than releases during wet years when more breeding is assumed to be occurring, 4) Changes in the patterns of wet and dry years due to dam operations will have a negative effect on reproductive success and population viability, 5) Reduction in the amount of coarse sediment supply due to entrapment by the reservoir and loss of sediment below the dam by erosion of banks and streambed will have a negative effect on arroyo toad reproductive success due to loss of breeding habitat and 6) Increased vegetation cover due to changes in amount of peak flows (scouring flows to remove vegetation and to maintain or create breeding habitat) will have a negative effect on arroyo toad reproductive success due to loss of breeding habitat.

Possible Management Actions Related to Loveland Dam Operations: 1) Avoid controlled releases during the arroyo toad breeding season, especially March to September; 2) Release during rain or spill events in order to mimic the natural flow of the system; 3) Continue to step up controlled releases (Sweetwater Authority currently ramps releases starting with 100 cubic-feet-per-second on day one, 200 cubic-feet-per-second on day two and 300-350 cubic-feet-per-second on day three) to allow larvae and metamorphs to adjust or escape the rising water levels and increasing flow, but also step down controlled releases to allow larvae to follow the falling water; 4) When controlled releases during the arroyo toad breeding cannot be avoided, survey for egg masses and tadpoles prior to the releases to see if eggs, larvae or metamorphs are present and consider relocating or temporarily captive housing (needs further evaluation); 5) Replace and maintain the coarse sediments required for arroyo toad breeding habitat by dredging sand and fine gravel from the reservoirs and depositing it in Sweetwater River below Loveland Dam; 6) Maintain peak spill releases to allow scouring of vegetation, the removal of exotics and the improvement of water quality in arroyo toad breeding habitat; 7) Control invasive predator species, especially during drier years when they are concentrated in the limited number of pools and easier to eradicate.

Breeding Adult Stage: Breeding is nocturnal in spring after water temperatures reach at least 14°C and water levels (<30cm deep) and speed (<5cm/sec) are appropriate for breeding; females are assumed to lay one egg mass per season, males may mate with multiple females; adults prefer darker nights
Habitat Requirements: Clear still to slow-moving water (generally flow rates less than 5 cm per second) with shallow, exposed clean, sandy bottom and open canopy (see influencing factors)
Influencing Factors: Episodic flushing flows & floods are needed to naturally disturb habitat, clear vegetation on sandy terraces and maintain toad habitat; variability in climate, amount of precipitation, & timing of precipitation strongly affect available habitat & breeding- breeding may not occur during drier years.
Dam Risk Factors: Dams alter the amount & timing of flushing flows and sediment supply- lack of flushing flows & sediment supply causes loss of breeding habitat; lack of water in breeding pools due to water impoundment & reduced releases due to storage needs; possible flushing of adults from breeding pools during releases (but assumed to be negligible) ; mild winters with low to moderate flood scouring & water impoundment enable exotic species to persist in or near most breeding pools- predation by bullfrogs; periods of drought in the system may be extended due to storage needs, resulting in fewer years with optimal breeding conditions.
Other Risk Factors: In drought years, females may find insufficient insect prey to produce eggs before males cease their calling, resulting in no reproduction; lack of water in pools due to low annual precipitation, water diversions, & ground water pumping; predation by bullfrogs, raccoons and crows; disturbance from mining or road noise- noise pollution does not appear to affect males, but may affect female response; breeding habitat degradation and loss due to exotic plants (Arundo, Tamarisk) or to native plants (water cress); urban runoff can contain contaminants; erosion after fires can cause siltation of breeding habitat.

Adult Stage (limited knowledge): Lifespan about 5 years; males reach adulthood in 1- 2 years, females in 2-3 years; nocturnal, burrow in sand during the day; many sub adult and some adult males move 0.5-1 km perpendicular from streams, but may travel up to 2 km; very dispersed; subsist on native ants and other invertebrates.
Habitat Requirements: Coastal sage scrub, chaparral, or oak woodland, but not grasslands (may travel through); require friable soils and permeable plant understory for burrowing.
Dam Risk Factors: Assume no risk to non-breeding adults in uplands.
Other Risk Factors: Predation by native and exotic predators; native ants displaced by fire ants and Argentine ants; fire; drought; contaminants- pesticides, etc.

Juvenile Stage: Toads 17-23 mm are able to dig burrows and change to a nocturnal activity pattern; if conditions permit they may remain along margins of breeding pools for up to 6 months; forage for nocturnal ants and beetles; at 28-30 mm they begin to disperse to uplands (dispersal affected by local drying conditions and suitable microhabitat); can be found in dense concentrations.
Habitat Requirements: Exposed portions of bars bordering breeding pools until sand begins to harden & they begin to disperse to nearby stands of willows and mulefat thickets; take refuge underground within the riparian zone and disperses farther with dampening of stream terraces.
Dam Risk Factors: Assume no risk to juveniles once they have moved upland; smaller juveniles remaining near breeding pools can be washed away to less suitable habitat during dam releases.
Other Risk Factors: Many toads are often exposed and lost to predation by native and exotic predators; native ants displaced by fire ants and Argentine ants; contaminants- pesticides, etc.

BREEDING
Jan – Early July**

ADULTS
Uplands

EGGS
Feb – Early July**

12-20 days

JUVENILES
Uplands

LARVAE
Mar-Early Sept**

65-85 days

METAMORPHS
April-Early Sept**

Egg Stage (12-20 days): Strings of 2000-10000 on sand, gravel, cobble or mud along pool margins away from vegetation
Habitat Requirements: Same as breeding habitat; require lack of sediment/turbidity (can tolerate for a few days)
Dam Risk Factors: Eggs stranded or washed away to unsuitable habitat during dam releases; desiccation due to lack of water in pools due to water impoundment, including reduced releases due to storage needs; mild winters with low to moderate flood scouring & water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes, crayfish.
Other Risk Factors: Eggs stranded or swept away due to flood events; crushing, disturbance or siltation due to humans, sand/gravel mining, floods, runoff, fires; desiccation due to lack of precipitation, water diversions & ground water pumping; contaminants- pesticides, etc.

Larval Stage (65-85 days): Diurnal; very cryptic; highly specialized foragers- feed on loose organic material in substrate
Habitat Requirements: Similar to breeding habitat, also need detritus, interstitial algae, bacteria, and diatoms
Dam Risk Factors: Larvae stranded or washed away to unsuitable habitat during dam releases; desiccation due to lack of water in pools due to water impoundment & reduced releases due to storage needs; mild winters with low to moderate flood scouring & water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes (green sunfish) bullfrogs.
Other Risk Factors: Predation by garter snakes, birds (killdeer, herons), etc; desiccation due to lack of precipitation, water diversions & ground water pumping; crushing, disturbance or siltation due to humans, sand/gravel mining, floods, runoff, fires; contaminants- pesticides, etc.

Metamorph Stage (10-17 mm): Metamorphosis peaks late April to mid May; diurnal; subsist largely on native ants; found clustered; remain in saturated soil around the margins of the breeding pool for the first 1-3 weeks, usually until the grow to be 15-16 mm; lack mass needed to dig into the surface until they reach 16-17 mm when they can dig shallow pockets in loose sand
Habitat Requirements: Soft, exposed sand and moist sandy benches with partial shading adjacent to pools
Dam Risk Factors: Metamorphs can be washed away to less suitable habitat during dam releases; mild winters with low to moderate flood scouring & water impoundment enable exotic species to persist in or near most breeding pools- predation by exotic fishes (green sunfish) bullfrogs.
Other Risk Factors: Predation from garter snakes, bullfrogs, birds (killdeer, herons); contaminants- pesticides, etc; native ants displaced by fire ants and Argentine ants; crushing or disturbance from

*Based on Atkinson et al. 2003; USFWS 1999 and Sweet 1992.
**These dates may shift in some years depending on precipitation.