Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

California Red-Legged Frog

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate
Exposure	Moderate
Adaptive Capacity	Moderate
Vulnerability	**Low-moderate**

Overall vulnerability of California red-legged frogs was scored as low-moderate. The overall scores is the result of moderate sensitivity, moderate future exposure, and moderate adaptive capacity scores.

Precipitation amount is a key climate factor affecting the California red-legged frog. More precipitation contributes to increased reproductive opportunities, habitat availability, and dispersal opportunities, and low precipitation depresses reproduction, reduces habitat availability and quality, and potentially contributes to adult mortality.

Key non-climate factors for California red-legged frogs include invasive and problematic species and agricultural and rangeland practices. Invasive predators (e.g., bullfrogs, bass) prey upon red-legged frogs, disrupt breeding, and can cause population extirpation from remnant habitat, while invasive plants can reduce habitat quality. Agricultural and rangeland practices have destroyed large portions of wetland habitat in the Central Valley, and continue to modify habitat quality and availability through water diversions, topography alterations, and pesticide/herbicide use. However, stock and other artificial ponds created by this sector do provide potential habitat.

Key disturbance regimes for the California red-legged frog include flooding, grazing, and disease. Flooding can scour or strand and desiccate eggs and larvae, as well as facilitate downstream invasive species introductions. Grazing can reduce riparian vegetation cover,

contributing to warmer stream temperatures, and can also increase erosion, which may smother eggs and larvae, fill pools, and reduce aquatic invertebrate prey.

California red-legged frogs display a mostly R-selected reproductive strategy; they take 2-3 years to reach reproductive maturity, and egg clutches usually consist of 2000-5000 eggs, although larval mortality is often high (>99%). California red-legged frogs are habitat specialists and prey generalists; they rely on an aquatic habitat for reproduction, and a combination of aquatic, riparian, and upland habitat for foraging, resting, and aestivation.

Declining California red-legged frog populations are patchy, and this species has a moderate dispersal ability, which limits gene flow and increases vulnerability to extirpation during extreme events or human disturbance. Several landscape barriers, including agricultural and rangeland practices, urban development, roads, highways, and trails, and invasive species further undermine red-legged frog dispersal.

This species has low-moderate intraspecific species diversity, although it may exhibit slight life history diversity in response to variable environmental conditions. This species is resistant to some degree of climate variability, but more research is needed on its resistance to human-induced stresses, since existing information is either limited or derived from other amphibian studies.

Management potential for California red-legged frogs was scored as moderate. Management options may include regulatory support from the Endangered Species Act and as a listed Species of Special Concern in California, managing stock ponds to provide habitat, and mitigating negative impacts from flood control projects.

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Introduction

Description of Priority Natural Resource

The California red-legged frog (*Rana draytonii*) is endemic to California and Baja California, and is the largest native frog in western North America (U.S. Fish and Wildlife Service 2010). It has aquatic egg and larval stages, while adults utilize a combination of aquatic, riparian, and upland habitat (U.S. Fish and Wildlife Service 1996, 2002, 2010).

As part of the Central Valley Landscape Conservation Project, workshop participants identified red-legged frog as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species group's management importance as indicated by its priority in existing conservation plans and lists and, 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the red-legged frog as a Priority Natural Resource included the following: the species group has high management importance, and the species group's conservation needs are not entirely represented within a single priority habitat. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source1. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Extreme events: drought	Moderate	Moderate-high
Increased flooding	-	Low-moderate
Precipitation (amount)	Moderate-high	Low-moderate
Precipitation (timing)	Moderate	Low-moderate
Soil moisture	Low-moderate	-
Water temperature	Low-moderate	Moderate-high
Overall Scores	**Moderate**	**Moderate**

Precipitation (amount)

Sensitivity: *Moderate-high (high confidence)*

Future exposure: *Low-moderate (low confidence)*

Potential refugia: *Stock ponds maintained to hold water for cattle.*

Shifts in rainfall are likely to impact California red-legged frog population numbers and distribution (U.S. Fish and Wildlife Service 2010). Reproduction is tied with rainfall; most adults lay eggs during or after large rainfall events in early spring or late winter (Hayes & Miyamoto 1984). Larger rainfall years may coincide with population increases and new habitat colonization via enhanced reproductive opportunities and dispersal, while reduced precipitation may depress reproduction and/or contribute to adult and sub-adult mortality by temporarily reducing or degrading existing habitat (U.S. Fish and Wildlife Service 1996, 2010). For example, low pond water levels can increase predation (Jennings et al. 1992). However, low precipitation may also help control invasive species populations (U.S. Fish and Wildlife Service 2002).

Reduced rainfall may also affect adult dispersal (U.S. Fish and Wildlife Service 2002, 2010), which typically occurs during wet periods (Fellers & Kleeman 2007). Reduced precipitation and moisture availability will likely increase red-legged frog dependence on and utilization of moist microrefugia, including areas with high cover (e.g., riparian vegetation), shade, and moisture retention (e.g., under boulders/debris, pond bottom cracks; U.S. Fish and Wildlife Service 2002). Conversely, periods of high rainfall may increase habitat suitability in both aquatic, riparian, and upland systems (U.S. Fish and Wildlife Service 2010).

Drought

Sensitivity: *Moderate (moderate confidence)*

Future exposure: *Moderate-high (moderate confidence)*

Potential refugia: *Stock ponds maintained to hold water for cattle.*

Drought may help mitigate invasive species that affect red-legged frogs (U.S. Fish and Wildlife Service 2002), but prolonged drought may depress red-legged frog reproduction and/or lead to adult and sub-adult mortality by temporarily eliminating or degrading existing habitat (U.S. Fish and Wildlife Service 1996, 2010). For example, state-wide populations of red-legged frogs declined during the multi-year drought from 1986-1992 (Jennings et al. 1992). Additionally, increasing human populations and associated increases in water demand may interact with drought to reduce water supply, natural habitat availability, and habitat quality for red-legged frog populations (U.S. Fish and Wildlife Service 2002; Medellín-Azuara et al. 2007; U.S. Fish and Wildlife Service 2010).

Precipitation (timing)

Sensitivity: *Moderate (moderate confidence)*

Future exposure: *Low-moderate (low confidence)*

Potential refugia: *Manually filled stock ponds (low confidence in effectiveness).*

Breeding is triggered by rainfall, but red-legged frogs exhibit breeding timing flexibility; breeding can occur as long as rain starts anywhere between December-April[1].

Water temperature

Sensitivity: *Low-moderate (moderate confidence)*

Future exposure: *Moderate-high (high confidence)*

Potential refugia: *Shaded ponds, maybe higher elevations.*

Water temperature accelerates larval development rates (eggs and tadpoles; Jennings 1988; Jennings & Hayes 1994; U.S. Fish and Wildlife Service 1996).

Soil moisture

Workshop participants did not further discuss this factor beyond assigning scores.

Sensitivity: *Low-moderate (low confidence)*

Climatic changes that may benefit the species:

- Warmer water temperature leads to faster larval development.
- Shorter hydroperiods will help with invasive species pressure (bullfrogs).

In general, climate change is likely to alter habitat suitability for the California red-legged frog (U.S. Fish and Wildlife Service 2010). Statewide, 1% or less of the current area of freshwater marsh will remain suitable by the end of the century, and the small areas of marsh that are still suitable will likely occur as vegetation refugia (Thorne et al. 2016). Higher elevations and moist areas will likely become important refugia for the red-legged frog, and habitat and population distribution may shift northward (U.S. Fish and Wildlife Service 2010).

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	Moderate-high	High
Groundwater overdraft	Low-moderate	Low
Invasive & other problematic species	Moderate-high	High
Pollution & poisons	Moderate	Moderate-high
Urban/suburban development	Low-moderate	Moderate
Overall Scores	**Moderate**	**Moderate-high**

Agricultural & rangeland practices

Sensitivity: *Moderate-high (high confidence)*

Current exposure: *High (high confidence)*

Pattern of exposure: *Consistent across the landscape.*

The removal of wetland habitat for agricultural development has contributed to a 90% loss of historic wetlands in the Central Valley (Frayer et al. 1989), significantly reducing available habitat for California red-legged frogs (U.S. Fish and Wildlife Service 1996). Agricultural and rangeland practices can also impact the quality of remnant habitat; practices such as vegetation removal or alteration, topography alterations, and water diversions may render remnant habitats unusable (U.S. Fish and Wildlife Service 1996). For example, drawdown of ponds for spring and summer irrigation can expose and desiccate egg masses and/or increase predation risk (U.S. Fish and Wildlife Service 2002). In addition, agricultural pesticide or herbicide use can increase frog mortality (Relyea 2009) and/or contribute to increased disease and injury (U.S. Fish and Wildlife Service 2002); populations adjacent to or upwind of intensive agricultural areas have been declining at the fastest rates (Sparling et al. 2001). Comparatively, stock ponds provide critical breeding habitat for red-legged frogs (U.S. Fish and Wildlife Service 2002).

Invasive & other problematic species

Sensitivity: *Moderate-high (high confidence)*

Current exposure: *High (high confidence)*

Pattern of exposure: *Consistent across the landscape.*

California red-legged frogs are sensitive to several invasive predators, including bullfrogs (*Rana catesbeiana*), bass (*Micropterus* spp.), sunfish (*Lepomis* spp.), mosquito fish (*Gambusia affinis*), catfish (*Ictalurus* spp.), red swamp crayfish (*Procambarus clarkii*), and signal crayfish (*Pacifastacus leniusculus*) (U.S. Fish and Wildlife Service 1996). These invasive predators have been intentionally and accidentally introduced across most of the red-legged frog range (U.S. Fish and Wildlife Service 2002); for example, there are only a few red-legged frog sites that do not have bullfrogs[1]. Future invasive predator spread is likely. These predators can spread to downstream locations during reservoir releases for flood control, and may expand where stream reaches shift from ephemeral to perennial water bodies due to human-driven shifts in flow regimes (U.S. Fish and Wildlife Service 2002).

Invasive species enhance red-legged frog mortality, depress reproduction, and extirpate frogs from suitable habitat, particularly when multiple invasive predators inhabit the same area (U.S. Fish and Wildlife Service 2002). For example, bullfrogs prey directly on red-legged frogs, interfere with red-legged frog reproduction, and compete for available resources (U.S. Fish and Wildlife Service 1996). Because bullfrogs have a higher reproductive capacity than red-legged frogs and are favored by human-induced habitat modifications, they contribute to extirpations of red-legged frog populations (U.S. Fish and Wildlife Service 1996). Similarly, introduced fish prey directly on red-legged frog larvae and/or compete with frogs for aquatic invertebrate prey,

depressing or preventing recruitment and contributing to declining red-legged frog populations (U.S. Fish and Wildlife Service 1996).

Invasive plants may also reduce habitat quality by outcompeting native vegetation, altering riparian vegetation structure and/or water availability and chemistry. Although links between invasive plants and red-legged frogs have not been fully investigated, plants of concern include tamarisk (*Tamarix* spp.), arundo (*Arundo donax*), eucalyptus (*Eucalyptus* spp.) and cape ivy (*Delaria odorata*) (U.S. Fish and Wildlife Service 2002).

Pollution & poisons

Sensitivity: *Moderate (moderate confidence)*

Current exposure: *Moderate-high (high confidence)*

Pattern of exposure: *Consistent across the landscape; pesticides are used across the landscape, but exposure may be higher for Sierra Nevada foothill populations relative to Coast Range populations.*

Urban/suburban development

Sensitivity: *Low-moderate (moderate confidence)*

Current exposure: *Moderate (high confidence)*

Pattern of exposure: *Localized; developed/developing areas where suburban sprawl is converting rural land (e.g., Stockton, Fresno,), especially along Valley edges.*

Groundwater overdraft

Sensitivity: *Low-moderate (moderate confidence)*

Current exposure: *Low (low confidence)*

Pattern of exposure: *Localized; only in habitat areas that are groundwater fed.*

Most of red-legged frog breeding habitat is fed by surface water rather than groundwater[1].

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

Overall sensitivity to disturbance regimes: *Low-moderate (moderate confidence)*

Flooding

Future exposure: *Low-moderate (moderate confidence)*

Potential refugia: *Ponds that are raised out of floodplains.*

Seasonal flooding can scour, wash away, or strand and desiccate tadpoles and eggs laid in stream reaches, undermining reproductive success (U.S. Fish and Wildlife Service 2002). Flooding can also indirectly affect red-legged frogs by driving shifts in human management behavior; for example, reservoir releases for flood control can increase downstream exposure to invasive species (e.g., fish introductions or increases in ponds; U.S. Fish and Wildlife Service 1996), and bank, channel, and vegetation treatments can reduce viable habitat (U.S. Fish and Wildlife Service 2002).

Disease

Although pathogens and parasites have been linked to declines of other amphibian species, disease in red-legged frogs has not been well-studied (U.S. Fish and Wildlife Service 2002). Spread of parasites between bullfrogs and red-legged frogs has emerged as a recent concern (U.S. Fish and Wildlife Service 2002). Additionally, red-legged frogs are susceptible to Chytrid fungus (*Batrachochytrium dendrobatidis*) infection, and although direct mortality hasn't been documented, this fungus likely has sub-lethal effects (Padgett-Flohr 2008).

Grazing

Grazing can have a variety of negative impacts on red-legged frogs. High cattle utilization of riparian areas, particularly during dry periods, reduces emergent and riparian vegetation, increases erosion, crushes exposed eggs and larvae, and can contribute to bank and stream alterations (U.S. Fish and Wildlife Service 1996, 2002). Lower plant cover can reduce foraging opportunities and increase water temperatures, leading to higher bullfrog reproductive rates (U.S. Fish and Wildlife Service 1996). Increased erosion and sedimentation can smother eggs and larvae, kill aquatic invertebrates utilized as prey, and contribute to pool filling, reducing available habitat (reviewed in U.S. Fish and Wildlife Service 1996). However, the creation of stock ponds for cattle grazing operations may also help maintain red-legged frog habitat across the landscape (U.S. Fish and Wildlife Service 2002).

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

Overall degree of specialization*: Moderate (high confidence)*

Dependency on one or more sensitive habitat types: *Moderate-high (high confidence)*

Description of habitat: *Semi-permanent ponds, vernal pools, stock ponds.*

Dependency on specific prey or forage species: *Low-moderate (high confidence)*

California red-legged frogs require aquatic areas for breeding, typically laying eggs on emergent vegetation in pools, artificial impoundments (e.g., stock ponds), and still/slow-moving areas of creeks, streams, ponds, marshes, and springs (U.S. Fish and Wildlife Service 1996, 2002, 2010). Adult red-legged frogs also require access to well-vegetated riparian and upland areas (Fellers & Kleeman 2007), particularly during dry periods when standing water may not be available (U.S. Fish and Wildlife Service 1996, 2002). Within this habitat matrix, red-legged frogs rely on aestivation habitat (moist, cool areas with cover) during the dry season, which can be provided by a variety of structures, including boulders, downed trees, and industrial or agricultural infrastructure such as watering troughs, sheds, or drains (U.S. Fish and Wildlife Service 1996).

Red-legged frogs are prey generalists; larvae are thought to graze algae, while adults consume a variety of aquatic invertebrates (U.S. Fish and Wildlife Service 1996). Red-legged frogs forage on the water surface, adjacent banks, and sometimes in riparian vegetation (U.S. Fish and Wildlife Service 2002).

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Status, and Dispersal Ability	Moderate
Landscape Permeability	Moderate-high
Intraspecific Species Diversity	Low-moderate
Resistance	Moderate
Overall Score	**Moderate**

Extent, status, and dispersal ability

Overall degree of extent, integrity, connectivity, and dispersal ability: *Moderate (high confidence)*

Geographic extent: *Transboundary (high confidence)*

Health and functional integrity: *Declining (high confidence)*

Population connectivity: *Patchy with connectivity between patches (high confidence)*

Dispersal ability: *Moderate (moderate confidence)*

Maximum annual dispersal distance of species: *1-5 km (high confidence)*

Within the Central Valley hydrogeological basin, California red-legged frog occurrences declined 77% over the course of the 20th century; paired with additional population losses in southern California, this led to a formal listing of the California red-legged frog in 1996 as a threatened species under the Endangered Species Act (U.S. Fish and Wildlife Service 1996). A combination of habitat loss and alteration, invasive species introductions, frog harvest, drought, grazing, reservoir construction, and other factors led to complete extirpation of populations on the Valley floor, and significantly reduced populations in adjacent foothills (U.S. Fish and Wildlife Service 1996). Fourteen remnant populations remain in the foothills of the Coast Range adjacent to the San Joaquin Valley, in addition to one population in the Sierra Nevada foothills (U.S. Fish and Wildlife Service 1996, 2002). There are some California red-legged frog populations in southern California, and a genetically distinct red-legged frog species (Northern red-legged frog, *R. aurora*; Conlon et al. 2006) can be found from northern California through British Columbia (U.S. Fish and Wildlife Service 1996).

Most red-legged frog populations have few individuals and are fairly fragmented, existing as isolated patches along stream courses (U.S. Fish and Wildlife Service 1996, 2002). Small and isolated populations increase the vulnerability of this species to local extirpation due to extreme events, climate change, or human activity (U.S. Fish and Wildlife Service 1996), and also decrease gene flow and increase predation risk during seasonal migration attempts (U.S. Fish and Wildlife Service 2002). California red-legged frogs have been documented to move anywhere from a few meters to 2 miles from their natal habitat, provided that the landscape and environmental conditions permit movement (U.S. Fish and Wildlife Service 2002; Fellers & Kleeman 2007). However, most dispersal distances are small (<500m; Fellers & Kleeman 2007).

Landscape permeability

Overall landscape permeability: *Moderate-high (moderate confidence)*

Impact of various factors on landscape permeability:

Urban/suburban development: *High (high confidence)*

Roads, highways, & trails: *Low-moderate (moderate confidence)*

Agricultural & rangeland practices *Low-moderate (moderate confidence)*

Invasive & other problematic species: *Low-moderate (moderate confidence)*

Urban/suburban development can restrict dispersal and gene flow amongst fragmented red-legged frog populations (U.S. Fish and Wildlife Service 2002). Roads and highways also act as barriers to dispersal, particularly roads without modifications to permit passage (e.g., culverts, underpasses; U.S. Fish and Wildlife Service 2010) and roads with heavy traffic, which increase vehicle strikes (Glista et al. 2008). Invasive species (e.g., bullfrogs, introduced fish) can preclude red-legged frog occupancy following dispersal (U.S. Fish and Wildlife Service 2002).

Resistance

Resistance to stresses/maladaptive human responses: *Moderate (moderate confidence)*

Adult red-legged frogs may be somewhat resistant to short-term perturbations in water availability, although resistance is affected by habitat availability, habitat and population connectivity, and the availability of moisture refugia (U.S. Fish and Wildlife Service 2002). This species has not been heavily studied, so knowledge regarding its resistance or tolerance of several stresses (e.g., grazing, disease, mosquito fish) is largely derived from studies on other amphibians or general knowledge of habitat impacts (U.S. Fish and Wildlife Service 2002).

Species diversity

Overall species diversity: *Low-moderate (moderate confidence)*

Diversity of life history strategies: *Low-moderate (moderate confidence)*

Genetic diversity: *Low-moderate (moderate confidence)*

Behavioral plasticity: *Moderate (high confidence)*

Phenotypic plasticity: *Low-moderate (low confidence)*

Although the majority of tadpoles hatch and develop in the same year eggs are laid, there is emerging evidence that this species may be able to over-winter in the egg or larval stage (Bobzien & DiDonato 2007). Large numbers of eggs/larvae may facilitate rapid adaptation to environmental change (Padgett-Flohr 2008).

Life history and reproductive strategy

Species reproductive strategy, representing generation length and number of offspring*: Displays mainly R-selected characteristics (high confidence)*

Average length of time to reproductive maturity: *2 years*

California red-legged frog egg clutches are typically large (2000-5000 eggs; Jennings et al. 1992). Eggs hatch in 6-14 days depending on water temperature (Jennings 1988), and larvae undergo metamorphosis 3.5-7 months later, although larval mortality is often very high (>99%; Jennings et al. 1992). Red-legged frogs reach sexual maturity between 2-3 years of age, with males maturing fastest (Jennings & Hayes 1985), and can live between 8-10 years on average (Jennings et al. 1992).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Species value	Moderate
Societal support	Moderate-high
Agriculture & rangeland practices	High
Extreme events	Low-moderate
Converting retired land	Low
Managing climate change impacts	Moderate-high
Overall Score	**Moderate**

Value to people

Value to people: *Moderate (high confidence)*

Description of value: *Frogs are somewhat charismatic species.*

Support for conservation

Degree of societal support for management and conservation: *Moderate-high (high confidence)*

Description of support: *The California red-legged frog is a listed species.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *High (high confidence)*

Description of support: *Red-legged frogs breed in stock ponds, so agricultural/rangelands with stock ponds are beneficial.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low-moderate (moderate confidence)*

Description of events: *It is unlikely that these events will convince the public that water should be allocated to save frogs.*

Likelihood of converting land to support species

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species: *Low (high confidence)*

Description of events: *Retiring rangelands – unless they are currently heavily overgrazed – does not garner large benefits for red-legged frogs. Working rangelands actually benefit frogs due to related stock pond maintenance/habitat provisioning.*

Likelihood of managing or alleviating climate change impacts: *Moderate-high (high confidence)*

Description of likelihood: *Ponds that dry up in the late summer and fall are actually better for red-legged frogs than ponds that always hold water, because the dry-down helps control invasive species. Managing stock ponds for this ephemeral hydroperiod type is feasible even in a drier future, if there is will to do it.*

There is some regulatory support provided for management of California red-legged frog populations via their listing as a threatened species under the Endangered Species Act (U.S. Fish and Wildlife Service 1996), and as a Species of Special Concern in California (Steinhart 1990). Although natural water sources may decline, private landowners could be engaged to provide artificial habitat (e.g., stock ponds); these impoundments could be managed to maintain suitable breeding and foraging habitat for red-legged frogs now and in the future, with specific attention paid to managing hydroperiod, vegetation structure and type, pond structure, and invasive species (U.S. Fish and Wildlife Service 2002). Species-specific management guidance could be created to help mitigate the negative impacts of flood control projects, including reservoir releases, vegetation treatments, and bank alterations. This guidance will become more important if the need for flood control increases as a result of shifting snow and precipitation regimes (U.S. Fish and Wildlife Service 2002).

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