Ecosystem Flow Workshop
Bill Williams River Corridor, Arizona
March 16-18, 2005

Workshop Summary

I. Workshop Agenda and Purpose

The Bill Williams River Ecosystem Flow Workshop was held in Tempe, AZ, March 16-18, 2005, with the purpose of defining a set of flow requirements for sustaining the long-term ecological health of the Bill Williams River corridor. The workshop was sponsored by the Bill Williams River Corridor Steering Committee (BWRCSC) and was attended by over fifty scientists and water and natural resource managers, representing no less than twenty agencies and institutions. The workshop participants (listed in Appendix A) included experts with specialties in hydrology, geomorphology, water quality, riparian vegetation, ornithology, fisheries biology, macroinvertebrates, amphibians and reptiles. The flow requirements defined during the workshop built on over fifteen years of flow-related work on the river system and are designed to support adaptive management of Alamo Dam and the broader Bill Williams River watershed.

The workshop agenda is presented in Appendix B. The workshop began with presentations by Andrew Hautzinger (U.S. Fish and Wildlife Service), Joe Evelyn (U.S. Army Corps of Engineers), and Andy Warner (The Nature Conservancy) that covered the purpose and structure of the workshop, expected products, and how the products will be used to guide management decisions. These opening remarks provided the opportunity to supply the workshop participants with their two-part charge: 1) that they focus their efforts on defining flow requirements designed to maximize native biodiversity, and 2) that their deliberations be as unaffected as possible by existing constraints (e.g., dam outlet capacity). This document's primary intent is to accurately capture the participants' efforts spent towards achievement of this two-part charge.

The workshop's opening remarks were followed by five presentations highlighting key sections of the Summary Report (in press 2006) that was disseminated to all participants prior to the workshop. The order of discussion was: executive summary (Pat Shafroth, U.S. Geological Survey), hydrology and geomorphology (Kyle House, University of Nevada), fishes and aquatic macroinvertebrates (Dave Lytle, University of Oregon), riparian vegetation (Pat Shafroth), and terrestrial fauna (Doug Andersen and Charles van Ripper III, U.S. Geological Survey). [Note: Vanessa Beauchamp (U.S. Geological Survey) and Charles Paradzick (Arizona Game and Fish Department) were instrumental contributors to the Summary Report, and at the workshop, but did not present]

Following the overview presentations, workshop participants were split into three groups according to their specialties and each group was tasked with drafting flow requirements. The three groups were:

- "Aquatics" -- including coverage on fishes and aquatic macroinvert's and amphibians;
- "Riparian Vegetation and Birds" (hereafter: *Riparian-Birds*);
- "Riparian Veg. and Terrestrial Fauna Other than Birds" (hereafter: *Riparian Non-Birds*).

Both of the riparian groups considered vegetation because of its central role in supporting fauna.

Recognizing that natural flows in the Bill Williams River reflect regional weather patterns that are distinctly seasonal, the following flow and seasonal break-downs were used for the workshop. Base flows (0 to 100 cubic feet per second)(cfs) and flood flows (greater than 100 cfs) were defined for the Monsoon (July 1 – September 15), Tropical (September 16 – November 15), Winter-Spring (November 16 – April 30), and Dry (May 1 – June 30) Seasons.

At a minimum, the flow requirements defined by each group addressed baseflows and floods and defined the *magnitude, timing, duration*, and *frequency* of these events, as well as *rates of change* between different flow conditions. Some groups provided additional resolution, characterizing *low*, *moderate*, and *high baseflows* and *small*, *moderate*, and *large floods*. After the three group's flow requirements were developed, each was presented in a plenary session. The participants were then divided into two new working groups tasked with *unifying* the requirements for *baseflows* and *floods*, respectively. These "*Baseflow*" and "*Flood*" groups were formed by way of a remix of the scientists from the three previous biologically-based groups. The process used to define a unified set of flow requirements for the Bill Williams River corridor is illustrated in Figure 1.

The remaining sections of this workshop summary present:

- ✓ the unified flow requirements (Section II),
- ✓ details on what the biological-based groups considered in defining flow requirements (Section III),
- ✓ details on how these flow requirements were unified (Section IV),
- ✓ a synthesis of priority monitoring and research needs in the Bill Williams River corridor (Section V),
- ✓ workshop conclusions (Section VI).

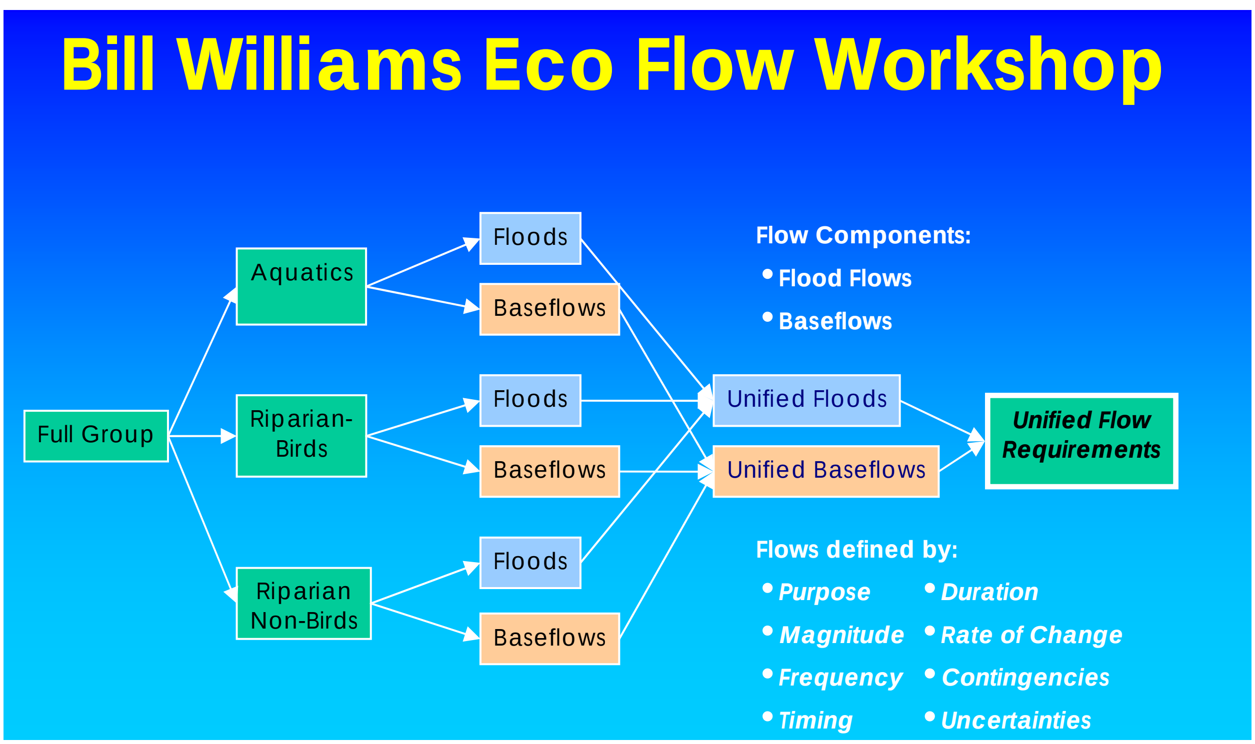

Figure 1. WORKSHOP FLOWCHART

II. Summary of Unified Ecosystem Flow Requirements for the Bill Williams River Corridor

The unified flow requirements defined for the Bill Williams River corridor below Alamo Dam are presented in Figure 2. Each of the "building blocks" portrayed in this figure represents an ecological outcome that would be expected if the associated flow conditions are attained. The flow requirements in the figure consist of baseflows and floods, both of which are further delineated as low/moderate/high (for baseflows) and small/moderate/large (for floods) as denoted in the key. In addition to the magnitude of flow, the requirements define the necessary timing and duration of the events, and rates of change between event types. The frequency of specific event types – for example, once every five years – is also included and captures the importance of inter-annual variability in flow conditions.

The recommended river flows denoted in Figure 2 would be generated by water releases from Alamo Dam and are targets for release from the reservoir recognizing flow attenuation downstream. It should be noted that the moderate and large flood flows suggested in Figure 2 could not be attained unless structural modifications were made to Alamo Dam, which has a current maximum outlet capacity of roughly 7,000 cfs. It should also be noted that these flow requirements – and especially the flood components – are presented assuming (realistically or not) that commensurate changes are made to the sediment regime below Alamo Dam. Tasks needed to identify and implement appropriate sediment management options associated with larger flow events are discussed further under both "Priority Monitoring and Research" and "Conclusions".

This workshop was conducted within the context of Alamo Dam and Reservoir being one of ten facilities managed by the U.S. Army Corps of Engineers that are within the **Sustainable Rivers Project**, which is collaboration between the Corps and The Nature Conservancy. The Sustainable Rivers Project is designed to evaluate, and if necessary, recommend changes to dam operations to restore and protect the health of rivers and surrounding natural areas while continuing to meet human needs for services such as flood control and power generation. The definition of ecological flow requirements is the first step in a methodology, known as the *Ecologically Sustainable Water Management* (ESWM), which guides decision-making at those Corps dam sites across the country that participate in the Sustainable Rivers Project. For more details regarding the Sustainable Rivers Project, the reader is directed to this link: http://nature.org/success/dams.html.

Ecosystem Flow Requirements -- Unified

Bill Williams River Corridor, below Alamo Dam

BUILDING BLOCKS (linking ecology to dam releases)

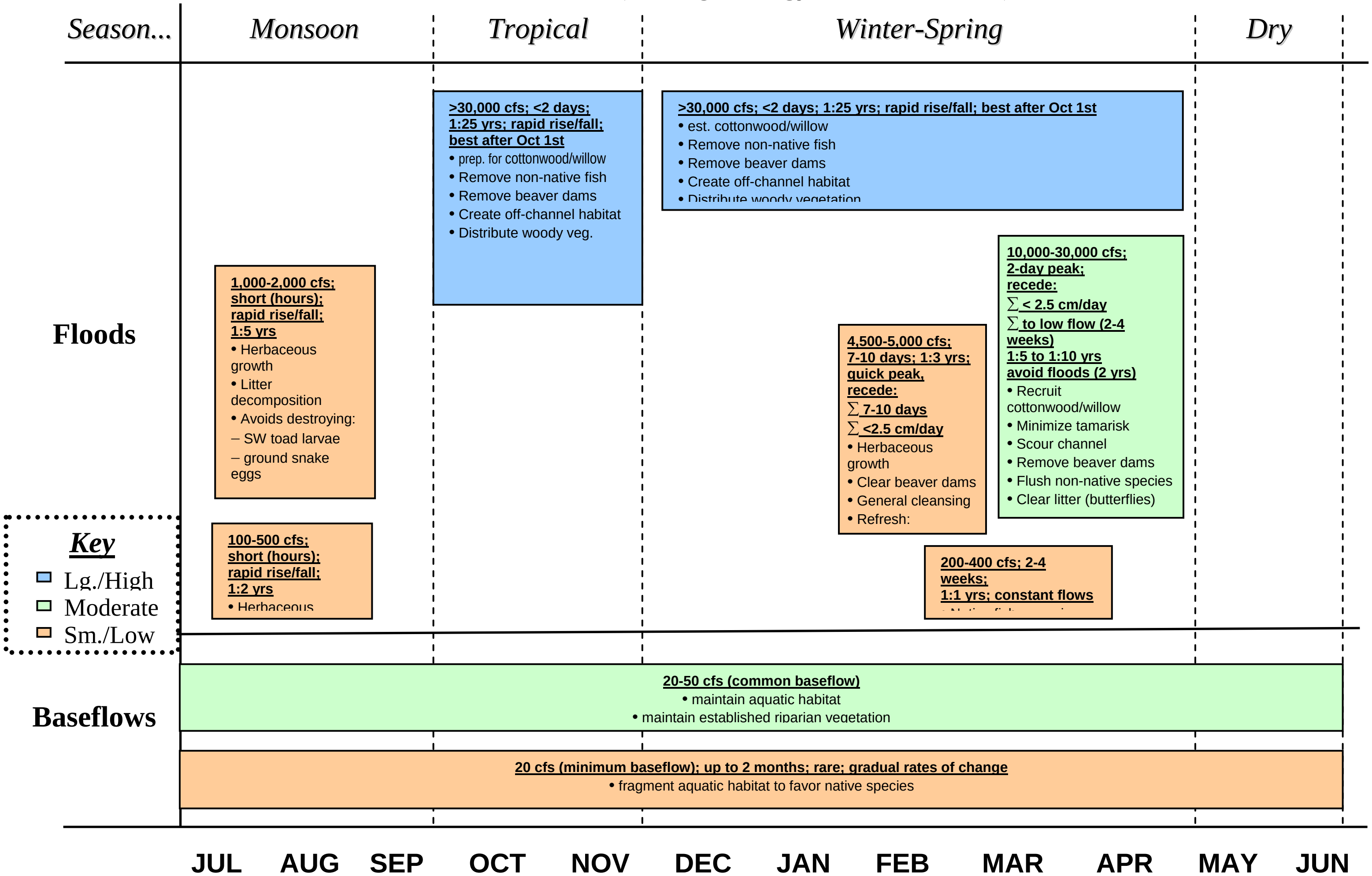

Figure 2. Unified Flow Requirements for the Bill Williams River

III. Flow Requirements by Biological Group

The following sections describe flow requirements developed by the workshop's three biological groups (*aquatics, riparian-birds,* and *riparian non-birds*). Each section describes the approach followed by a group to develop flow requirements, as well as presents the flow requirements themselves, and any supporting information used to justify the flow requirements. As the text shows, each group's approach was unique and each group's section bears distinctive marks in both format and content. The three groups all focused discussion on knowledge gaps and uncertainties (Appendix C), which is summarized collectively in Section V.

A. Aquatics Group

1. Approach (*Aquatics Group*)

The Aquatics Group accepted the workshop's general objective of maximizing native biodiversity on the Bill Williams River below Alamo Dam and agreed that natural flow patterns may be important for maximizing some native biodiversity (e.g., fishes, aquatic invertebrates, and a few reptiles and amphibians). Currently, the Bill Williams River below Alamo Dam is not occupied by any native fish, but there are good prospects for re-establishing them in this reach: flow needs were specified in part to support the possible re-establishment of these native species.

The group then divided native biodiversity into several representative classes outlined below and reviewed the life histories and flow needs of each group over the monsoon, tropical, winter/spring, and dry seasons of any year. The flow needs of each species group were assessed qualitatively using the flow components and their wide ranges from the Shafroth et al Summary Report (Table 1).

The group secondarily considered the natural flow patterns for any year as percentages of exceedances of average daily, pre-dam flows, which confirmed a consistent seasonal pattern. Moreover, it was agreed that very high flow "bricks" – the characteristic shape of post-dam high flows – would have significant negative effects on aquatic life and that flow "spikes" – the natural shape of pre-dam high flows – and variability are important.

Finally the group consolidated the flow needs for each species group into a few hydrographs, showing baseflow needs for wet and dry years, and boxes for flood needs. The flood flow boxes indicated a range of flow magnitude, whether the flood should be spiked or bricked, the months within which that magnitude and duration of flood should occur within any year, and the frequency with which the flood should occur over a number of years.

There was firm group consensus that a monitoring program must be developed to test all flow needs.

2. Flow Requirements and Justifications (*Aquatics Group*)

Baseflow Requirements:

Tropical and winter/spring baseflows should be elevated, and dry season baseflows should be depressed for a kind of "cook-down", which is consistent with the pre-dam hydrograph. For dry years, the dry season baseflows should be 5 cfs, which was thought to fragment stream habitat into isolated pools and allow side channel pools to dry, to the disadvantage of non-native fish and to the benefit of aquatic invertebrates. For the monsoon and tropical season in dry years, the baseflows should be elevated to 20 cfs, to improve native fish habitat and provide cooler temperatures and better water chemistry. Winter/spring baseflows should be further elevated to 50 cfs for greater fish habitat and favorable riffle conditions for some aquatic invertebrates. For wet years, this whole seasonal pattern should be maintained but with increased magnitudes, as follows: dry – 10 cfs, monsoon/tropical – 50 cfs, and winter/spring – 80 cfs. As a rare event, if native fish are absent, baseflows should be dropped to 0 cfs for up to 2 months to eliminate non-native fish.

Table 1. **Baseflow Requirements for the *Aquatics Group***

	Extremely Low Baseflows	*Low Baseflows*	*Moderate Baseflows*	*High Baseflows*
Name	'Cook-Down'	Maintenance (low end)	Winter/ Spring Maintenance	Winter/ Spring Maintenance2
Purpose	Hyper-dry conditions to fragment habitat in favor of natives	Dry conditions to fragment habitat in favor of natives	Facilitate fish habitat and favorable riffle conditions for inverts	Facilitate fish habitat and favorable riffle conditions for inverts
Timing	Variable	Variable	Variable	Variable
Magnitude *1) Dry Year* *2) Wet Year*	1) 5 cfs 2) 10 cfs	1) 0 to 10 cfs 2) 0 to 10 cfs	1)10 to 50 cfs 2) n/a (wet year)	1) n/a (dry year) 2)50 to 80 cfs
Frequency	Rare	Common	Common	Less Common
Duration	< 2 Months	Months	Months	Months
Rate of change	Gradual	Gradual	Gradual	Gradual
Contingency	Natives present?	Wet or dry year?	Wet or dry year?	Wet or dry year?

Flood Flow Requirements:

A principal rational for flood flow needs was to maximize habitat diversity by occasionally removing beaver dams and scouring off channel habitats. Another consideration was to discourage non-native fish and bullfrogs. Smaller, more frequent floods would support native fish spawning. Wet and dry years were not specified for floods, instead return intervals were. For the dry season, no floods are recommended, because flooding would interfere with leopard frog and lentic invertebrate reproduction. No large floods were considered necessary for the monsoon season, consistent with the pre-dam hydrograph. For the tropical season, 1 to 2 spiked floods between 5,000 to 30,000 cfs were recommended, with a return interval of 5 years, mainly to blow out beaver dams and to create some off-channel habitats (an objective that could be achieved with spring floods). For early winter/spring (mid-Nov to mid-February), a moderate, single spike flood between 1,000 to 2,500 cfs was recommended with a return interval of 1 to 2 years, for refreshing the riffle habitat after the beaver dams have been removed, and to re-fill side and off-channel pools. For late winter/spring (late February-early April), yearly "bricked" or relatively constant, small floods between 200 to 400 cfs are recommended to enhance native fish spawning. A large flood exceeding 50,000 cfs during either the tropical or winter/spring season with a return interval of 10 years is recommended to flush out non-native fish and to create off-channel habitats.

Table 2. Small Floods for the *Aquatics Group*

Name	Habitat Establishment	Native Fish Spawning
Purpose	Refresh riffle habitat and refill side and off-channel pools	Enhancement of native fish spawning
Timing	Mid-November to Mid-February	Late February to early April
Magnitude	1,000 to 2,500-cfs	200 to 400-cfs
Frequency	1:1-2	1:1
Duration	3 to 4 days	2 to 4-weeks
Rate of change	None	Elevated flows should be held relatively constant for the full duration
Contingencies	None	None
Uncertainties	None cited.	

Table 3. Moderate Floods for the *Aquatics Group*

Name	Tropical Season Cleansing
Purpose	Removal of beaver dams and creation of off-channel habitat
Timing	September 15 to November 14
Magnitude	5,000 to 30,000-cfs
Frequency	1:5
Duration	2 separate peaks both sharp, spiked events
Rate of change	None
Contingencies	None
Uncertainties	Magnitude needed to redistribute woody vegetation. Spatial extent of vegetation removal. Relationship with other reset factors (drought, fire, and infestation).

Table 4. Large Floods for the *Aquatics Group*

Name	Tropical Season Non-native Fish Flush	Winter/Spring Season Non-native Fish Flush
Purpose	Blowout non-native fishes and creation of off-channel habitat	Blowout non-native fishes and creation of off-channel habitat
Timing	September 15 to November 14	November 15 to April 30
Magnitude	> 50,000-cfs	> 50,000-cfs
Frequency	1:10	1:10
Duration	1 peak, spiked	1 peak, spiked
Rate of change	None	None
Contingencies	Ok to occur in the Winter-Spring Season with a combined frequency of 1:10	Ok to occur in the Tropical Season with a combined frequency of 1:10
Uncertainties	Actions other than flow management may be needed to control/eradicate non-natives. There are important connections between release temperature and fish stranding	

3. **Aquatic Species Analysis** (*Aquatics Group*)

Macroinvertebrates

Lotic

Fast life cycle: Baetid mayflies- best with moderate base flows throughout year, but life cycle responds to flows received. Robust populations, can quickly recolonize. Don't need floods in short term, but moderate flood on approx 3 yr return interval would remove some beaver dams, restore lotic habitat, provide pulse of nutrients. Smaller floods more frequently would be good to provide nutrients. Seasonality of floods not important. Two-day adult life stage – sustained high flow (i.e. "brick" flow) deemed NOT beneficial. Adults are always present in summer, few in winter.

Slow life cycle: Gomphid dragonflies- prefer slow but flowing water. Fairly mobile. Larvae take several years to mature, need relatively clear water (visual predators). Low base flow during dry season (beneficial for feeding as predators); moderate base flow rest of year. Zero flows bad. Floods are bad in short-term, necessary for long-term to remove or refresh beaver dams. Best if floods happen during summer (monsoon or tropical season) when adults can easily recolonize. Extended flood bad because adults start dying off. Probably a 5-year return interval, short duration, moderate floods would be best.

Lentic

Long adult life span: Aquatic beetles and Bugs. Need ponded water. Base flow low during dry season, low-moderate remainder of year. Floods should occur during the dry season. Okay to have small floods remainder of year. A 7-yr moderate flood, tropical or winter season, to maintain off-channel pools is desirable. Total dry-down every 5 to 10 years beneficial to provide fish-free habitat. They fly at end of summer. Recolonize quickly.

Short adult life span: Callibaetis mayflies, dipterans. Consistent moderate base flows year round. Prefer fish-free water. Off-channel pools, side channels should dry at times to eliminate predators. 7 year return interval for moderate floods, yearly small floods.

Fish

Longfin dace, speckled dace, Gila topminnow. Need moderate base flows throughout year, but can tolerate occasional low flows. Diversity of habitat is good. Species can withstand flooding. Moderate floods okay in monsoon, tropical, winter seasons. Ecological justification: support variety of habitats for spawning; provide connectivity longitudinally/laterally; fill pools for refugia.

Roundtail chub. Prefer high base flows throughout year to provide plenty of flowing habitat, but can tolerate occasional low flows. Best habitat likely in reach just below the dam. Small flood good in Feb-Apr, every year, prolonged. Moderate flood, short duration, good in monsoon, tropical, winter seasons, 3-yr return interval, for geomorphic work, break beaver dams, knock back non-natives. Ecological justification: Need pools; connectivity throughout stream; spike in December before spawning to knock out beaver dams.

Flannel-mouth sucker. Marginal habitat present, only in 4-mile reach just below dam. Tolerates cold water, bass. High base flows year-round. Small flood (400 cfs) prolonged duration, good in Feb-Apr, every year. Moderate flood, short duration, good in monsoon, tropical, winter seasons, 3-yr return interval, for geomorphic work.

Amphibian

Lowland leopard frog. Does well in lentic or lotic habitat, but needs slow or still water for breeding. Eggs present March-May, Oct. Tadpoles present Jan-July, Oct-Dec. Need low base flows or permanent pools year-round. No moderate or high floods during spring, dry summer.

Reptile

Sonoran mud turtle. Low baseflows year-round.

Non-natives

Crayfish: Not enough information to know how flow regulation might limit populations.

Bullfrog: Tadpoles require >1 year before metamorphosis and vulnerable to being flushed out of system. Eggs present Jun – August. Annual moderate flood during monsoon season would wash out eggs and tadpoles, but flood large enough to break beaver dams would reduce populations any time of year.

Fish (green sunfish, bass, bullhead catfish, red shiner, mosquitofish):
Occasional (5-10 yr) short-duration large (50,000 cfs) flood would physically remove many individuals, depressing population. Occasional (3 yr) low base flows during dry summer would make hostile habitat (high temp, low dissolved oxygen).

B. Riparian–Birds Group

1. Approach (*Riparian-Birds*)

This section describes the approach taken to define ecological flow requirements by the Riparian Vegetation and Bird Group, including explicit identification of species/species groupings considered. The group started with the groupings of bird guilds that were identified in the Summary Report and modified the groupings based on participant expertise. The major changes from the Summary Report consisted of splitting the shallow-water birds into shore and marsh birds and identifying forest birds as passerines.

The following list of key bird groups and representative species provides those biological elements that the group considered in terms of defining flow requirements:

- Deep water

- Shallow water
    - –Shore
    - –Marsh
- Predators/scavengers
- Game birds
- Passerine birds
- Southwestern willow flycatcher (*Empidonax traillii extimus*)
- Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*)

For each element above, the group identified aspects of life history as they related to seasonal rainfall patterns: monsoon, tropical, winter/spring, and dry. This included aspects about when breeding, nesting, rearing/fledgling, and migration occurred, as applicable. When possible, the group also identified how different birds use the different habitats associated with the Bill Williams River corridor, with an emphasis on the habitat requirements of the southwestern willow flycatcher and western yellow-billed cuckoo.

Key habitats that were identified and considered include:

- Open water
- Exposed substrates
- Herbaceous
    - –Floodplain
    - –Marsh
- Woody/shrub understory
    - –Young Fremont cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*)
    - –Seep-willow (*Baccharis salicifolia*)
    - –Tamarisk or salt cedar (*Tamarix ramosissima*)
- Midstory
    - –Mature tamarisk
    - –Pole cottonwoods and willows
- Mature cottonwood
- Mesquite (bosque) (*Prosopis* spp.)

The group discussed which birds use the above habitats and the season(s) of use. It then discussed the life history requirements of each of the bird groups/species and habitats in relation to seasons. The findings from this discussion are summarized in Table 5 (birds) and Table 6 (habitats). Table 6 includes not only habitat life history information but also identifies which bird groups or species may depend on such habitats to meet specific needs as well as in some cases a particular habitat's specific role in meeting such needs. With this information in-hand, the group then **linked flow requirements to the bird and vegetation life history requirements.** To create one prescription for the *Riparian-Bird Group*, the group then resolved any conflicts in the proposed prescriptions (see next section).

Table 5. **Bird Species Life History Requirements by Season**

Bird Group or Species	Season			
	Monsoon	**Tropical**	**Winter/Spring**	**Dry**
Deep Water			Overwinter, migrate, breed	
Shore	Fall migration commences Sep. 1; forage exposed sandbars		Spring migration occurs Feb. 1 to May 1; peaks about Apr. 1; forage on exposed sandbars; sandpipers overwinter	
Marsh	Foraging; flow fluctuations okay; black rails and clapper rails may have different needs	Forage	Forage; breeding occurs late March to April; limit floods during breeding season	Fledging occurs mid-May; forage
Predators			Overwintering	
Game Birds	Forage (seeds and herbaceous plants); for juvenile survival need standing water near upland edges	Forage	Forage	Breed end of May, early Jun.; forage
Passerines	Migrants depart	Residents forage and overwinter	Residents forage and overwinter; migrants arrive/breed Feb through Mar.	Same as winter through Jun. 1; rearing through Jun. 30
Southwestern willow Flycatcher	Fledging and depart			Arrive about May 1; breed, nest, rear nestlings; require saturated soils, standing water, and early successional cottonwood-willow
Western yellow-billed cuckoo	Rear nestlings, fledging, depart; require mature cottonwood with understory (patch size > 15 ha) and soil moisture			Arrive about Jun. 1 or later; breed, nest

Table 6. Habitat Life History Requirements or Relationship to Bird Use by Season

Habitat	Associated Bird Group or Species	Season				Notes
		Monsoon	Tropical	Winter/Spring	Dry	
Open Water					Need to maintain during dry season	
Exposed Substrates	Shorebirds					
Herbaceous: Floodplain	Gamebirds, sparrows	Germination, est.& dispers.		Germination, est.& dispersal	Forage is critical	
Marsh	Rails, yellowthroats					
Woody/Shrub Understory: Young cottonwood	Southwestern willow flycatchers, yellow warblers, vireos, song sparrows		Dormant by Oct. 15: low flows okay, but susceptible to adverse impacts by high flows	Same as for tropical season up to Jan. 15; seed dispersal/ establishment occurs Feb. 15 to Apr. 15	Survival and growth	Both need bare, moist soil to germinate. Wet conditions throughout the year are best, but are responsive to moisture any time. Higher base flows lead to increased survival of obligate plants near channel.
Willow				Seed dispersal/ establishment commences about Mar. 15	Same as winter/spring up to Jun. 1; survival and growth thereafter	
Seep-willow						
Tamarisk		Germination, est.& dispers.	Germination, est.& dispersal		Germination, est.& dispersal	
Midstory: Mature tamarisk	Southwestern willow flycatchers					Growth; water availability affects general plant health.
Pole CW's & willows						
Mature cottonwood	W. yellow-billed cuckoos, cavity nesters, raptors			Growth	Growth	
Mesquite	Passerines	Germination		Wet substrate after Feb. 1, dry by Apr. 1		Creates favorable growth and recruitment conditions

2. Flow Requirements and Justifications (*Riparian-Birds*)

The next two sections summarize flow requirements, by baseflows and flood flows, for riparian vegetation and birds. The ecological purpose (justification) for each flow component also is identified.

Baseflow Requirements:

Baseflows were designed to account for year-to-year climatic variability. Transitions in required flows generally occurred in accordance with the seasons as defined by rainfall patterns, with some exceptions. It is important that these transitions (from one max-min range to another) are made over the course of two to three days, when actual flow changes are involved, to avoid abrupt changes in flows as experienced by the biota. Table 7 provides the maximum and minimum baseflows for each time period (season) and their ecological purpose. With especially low flows, the effect of the aquifer underlying Planet Ranch and its hydrologic status creates significant uncertainties regarding the ecological effects of the flows in Table 7 within and downstream of Planet Ranch.

Table 7. **Baseflow Requirements for the *Riparian-Bird Group***

Time Period (Season)	Min Low Flow (cfs)	Max Low Flow (cfs)	Ecological Purpose (Baseflows)
July 1 – Sept 15 (Monsoon season)	20	50	Elevated baseflows are needed to mediate vegetation water stress during the hot, unpredictable monsoon season, augment microclimate humidity for nesting birds, and increase/maintain aquatic insect forage base.
Sept 16 – Dec 31 (Tropical season and winter/spring season in part)	10	25	Reduced baseflows are adequate to meet vegetation maintenance needs during a generally low water stress period.
Jan 1 – Apr 30 (Remainder of winter/spring season)	10	40	Increased baseflows during favorable climatic periods are needed to support new vegetation growth.
May 1 – Jun 30 (Dry season)	20	50	Elevated baseflows are needed to mediate vegetation water stress during the hot, dry season, augment microclimate humidity for nesting birds, and increase/maintain aquatic insect forage base.

Flood Flow Requirements:

This section details each of the flood flows recommended by the Riparian Vegetation and Bird Group. Small, Moderate, and Large Flood requirements are tabulated separately in the following three tables (Tables 8 to 10).

Table 8. Small Flood Flow Requirements for the *Riparian-Bird Group*

Flow Components and Additional Information	Description (Small Floods)		
	Monsoon Forage (small magnitude)	Monsoon Forage (intermediate magnitude)	Winter Forage
Purpose	Stimulate herbaceous plant growth for forage and provide standing water for insect production.	Stimulate herbaceous plant growth for forage and provide standing water for insect production.	Stimulate herbaceous plant growth for forage, provide bird cover, support flowering and seeding, boost insect productivity, provide maintenance flow for cottonwood and willow, and saturate soils.
Timing	Mid-July to mid-Aug.	Mid-July to mid-Aug.	February 1 to February 28
Magnitude	100 to 500 cfs	500 to 1,000 cfs	500 to 5,000 cfs
Frequency	1:2 years	1:6 years	1:3 years
Duration	Short, on the order of hours. Drop rapidly. Can have multiple small spikes.	Short, on the order of hours. One peak. Drop rapidly.	7 days sustained small flood.
Rate of change	None specified, but event is sharp and brief to limit tamarisk recruitment.	None specified, but event is sharp and brief to limit tamarisk recruitment.	Taper lower receding limb at 2.5 cm/day.
Contingencies	None	Time with El Nino or prevailing wet hydrologic cycle. Try to time peak with a rainfall event to boost downstream flows.	None
Uncertainties	Spatial extent of surface flows, and as a consequence the ecological benefit, needs to be determined for these flows.	Spatial extent of surface flows, and as a consequence the ecological benefit, needs to be determined for these flows.	Even at the upper range, it is uncertain whether the flows will be high enough to benefit Mesquite bosque community.

Table 9. Moderate Flood Flow Requirements for the *Riparian–Bird Group*

Flow Components and Additional Information	Description (Moderate Floods)	
	Cottonwood-Willow Recruitment Primer	Cottonwood-Willow Recruitment
Purpose	Set the stage for spring season recruitment of cottonwoods and willows by scouring (removing) the vegetation, reworking the floodplain, redistributing sediment, and establishing bare soil sites.	Stimulate recruitment catered to the requirements of cottonwood and willow (may result in limited recruitment of tamarisk).
Timing	Tropical season (9/16 to 11/15), preferably after October 1 to limit tamarisk recruitment.	Mid-March to end of April

Magnitude	10,000 to 30,000 cfs	10,000 to 30,000 cfs
Frequency	1:15 to 30 years	1:5 to 10 years
Duration	1 peak, spiked. Up and down within 1 to 2 days.	2-day duration peak with a multi-day tail that blends into the desired baseflow.
Rate of change	Steep. A specific rate of change is not important. More important that the event simply occur quickly (in mimicry of natural hydrograph).	Lower portion of the receding limb should not exceed a stage (water level) change of more than 2.5 cm/day. This rate of change should be maintained down to the desired base or low flow condition and held at this flow for 2 to 4 weeks to encourage deep root growth before any additional flow adjustments are made.
Contingencies	Try to couple this with a cottonwood-willow recruitment flood in the following spring.	Avoid floods for two years after this event. Start small with respect to flood magnitude to gauge effects on vegetation and geomorphic change.
Uncertainties	Magnitude needed to remove vegetation and rework the floodplain is unknown.	Transition point from peak to start of 2.5 cm/day recession during the receding limb may not be one set value depending on channel/floodplain condition. The time to hold at a low base flow after recession to encourage root growth is uncertain.

Table 10. **Large Flood Flow Requirements for the *Riparian–Bird Group***

Flow Components and Additional Information	Description (Large Floods)
Purpose	Remove vegetation, scour and create new channels, set stage for establishment of new vegetation.
Timing	November 16 to April 30 (winter/spring season)
Magnitude	> 30,000 cfs
Frequency	1:100 years
Duration	1 peak, maintain 2 to 6 days.
Rate of change	Steep. If event occurs in mid-February through mid-April, then the lower portion of the receding limb should not exceed a stage (water level) change of more than 2.5 cm/day. This rate of change should be maintained down to the desired base or low flow condition and held at this flow for 2 to 4 weeks to encourage deep root growth before any additional flow adjustments are made.
Contingencies	In a cottonwood-willow recruitment scenario, avoid floods for two years after the event. Start with relatively small, large flood events to gauge the effects on vegetation and channel/floodplain geomorphic change.
Uncertainties	Magnitude of flood needed to remove woody vegetation is unknown. Relationship of spatial extent of vegetation removal with flood discharge amount is yet to be quantified. Relationships with other ecological processes, such as drought, fire, and infestation, are unknown. See other uncertainties described for moderate floods.

C. Riparian Non-Birds

1. **Approach** (*Riparian Non-Birds*)

The group started by identifying a suite of riparian obligate mammals, reptiles, amphibians, and invertebrates native to the Bill Williams for which the life history was fairly well known. We chose the Viceroy Butterfly, Beaver, Ground Snake, Desert Shrew, Southwestern Toad, Cotton Rat and Hoary Bat and identified critical times in their life history such as dormancy, reproductive periods and foraging needs which may be dependent on or could be impacted by the flow regime. The majority of these species were directly or indirectly dependent on cottonwood-willow habitat or mesquite for habitat or forage. For example, the desert shrew and ground snake forage on invertebrates found in cottonwood-willow litter, the hoary bat roots in cottonwood and willow trees and viceroy butterfly caterpillars feed on willow trees. The cotton rat is an exception in that it forages in grassy herbaceous areas rather than in the cottonwood understory. Given the importance of these types of forest and open floodplain habitats we then defined flow requirements to provide these habitats, particularly cottonwood-willow forests and mesquite bosques. We then adjusted these flow requirements or added to them as necessary to accommodate the mammals and herptofauna discussed, with an emphasis on avoiding stressful conditions (large floods or low baseflows) during vulnerable life stages.

2. **Flow Requirements and Justifications** (*Riparian Non-Birds*)

The *Riparian Non-Birds Group* flow requirements are provided in the following tables (Table 11 and Table 12). The justification for these recommended flows (the link between the flows and ecological needs) is included within each table (e.g., "*purpose*"). The *Riparian Non-Birds Group* emphasized the need to monitor and experiment to further the strength and accuracy of these linkages between Alamo Dam releases and flow dependent flora and fauna.

Baseflow Requirements:

Table 11. **Baseflow Requirements for the *Riparian Non-Bird Group***

Name	Wet Year-- Low Flow	Dry Year-- Low Flow
Purpose	Maintain water levels for plant growth	Maintain water levels for plant growth
Timing	all year	all year
Magnitude	10 to 50 cfs	10 to 100 cfs
Frequency	Continuous	Continuous
Duration	Continuous	Continuous
Rate of change	flows should vary between high and low magnitude	Flows should vary between high and low magnitude
Contingen.	no scouring floods of over 500 cfs after the first year and 500-1,000 cfs floods permissible in the 2nd year	Raise baseflow overall during the driest part of year to reduce stress (10-100 cfs)

Flood Flow Requirements:

Table 12. **Flood Flow Requirements for the *Riparian Non-Bird Group***

Name	Wet Year Flood	Dry Year—Winter Flood	Dry Year—Summer Flood
Purpose	Scouring of channel and floodplain for reestablishment of cottonwood and willow. Timing in accord with seeding of these trees, but before salt cedar max. seeding	Scouring of channel and for reestablishment of cottonwood and willow. Timing in accord with seeding of these trees, but before salt cedar seeding and to avoid dormancy and breeding of animals earlier in the year. To breakout beaver dams, to elevate water table for herbaceous plants, to clear out litter for Viceroy butterflies, and to wash out exotic species	To help herbaceous plant growth and litter decomposition. Timing is to avoid destruction of ground snake eggs and southwestern toad larvae
Timing	Late Feb. to Apr.-1st	Late Feb. to Apr.-1st	July 15-Sept. 15
Magnitude	>7,000 cfs	2,000 cfs	1,000 to 2,000 cfs
Frequency	1:10	Once every 2-3 years	Once every 2-3 years
Duration	2-7 days	2-3 days (@ Lake Havasu)	Hours
Rate of change	Quick start up and gradual recession – about 2.5 cm/day (change in water level)	Quick start up and gradual recession – about 2.5 cm/day (change in water level)	Quick start up and shut down
Contingen.	No further scouring floods afterwards for 2 years - maintain high baseflows	Raise baseflow overall during the driest part of year to reduce stress (10-100 cfs)	Flooding will likely depend upon seasonal weather conditions

IV. Unification of Biological Group Flow Requirements

A. Unified Baseflows

Baseflow recommendations, developed independently by the *Aquatics*, *Riparian-Birds*, and *Riparian Non-Birds* groups, were merged into one set of recommendations referred to herein as **Unified Baseflows**. "Baseflows" were typically defined by *name, purpose, timing, magnitude, frequency, duration, rates of change, contingencies*, and *uncertainties*. For the purpose of the workshop, baseflows included releases from Alamo Dam between 0 and 100 cfs.

1. Process – Unified Baseflows

The unification process involved pulling different recommended baseflow recommendations into a unified flow request, while striving to not sacrifice any of the purposes associated with the originally identified baseflows. In the instance where a flow's purpose was not reconcilable between the groups, a discrete flow component was added to the **Unified Baseflow** recommendation

The **Unified Baseflows** group began by comparing the recommended baseflows made by each of the three biotic groups. Of all the flow characteristics reviewed, there was significant agreement between the three groups, especially as related to flow magnitudes. A constant theme in the **Unified Baseflows** discussions dealt with the recognition that the Bill Williams exhibited great longitudinal variability, so that at a given baseflow release out of Alamo Dam, many different flows would likely be expressed over the project area. While this spatial variation certainly complicated the analysis, it was also considered a factor likely to provide a range of appropriate flows for a wide suite of the biota via the anticipated constant baseflow releases from the dam.

One point of difference between the groups related to varying degrees of interest in the seasonal timing of flow changes. The *Aquatics Group* was interested in an increase in the winter baseflows, while the riparian groups saw a buffering benefit via higher baseflows during the heat of the summer. Similarly, the *Aquatics Group*'s typical flow recommendations were more static than the riparian groups, who recommended more frequent intra- and inter-season variations in baseflows (e.g., to facilitate root development). The Aquatics people indicated that there were fairly high levels of uncertainties associated with the recommended flow magnitudes, while their group had an appreciably higher level of confidence in regards to the "shape" of a recommended hydrograph.

All three biotic groups identified the need to have different baseflows based on antecedent conditions (e.g., in the event of floods that recruit new growth, higher baseflows would be desirable for a period of time afterwards to support the newly established seedlings). The *Aquatics Group* especially focused on differing baseflow regimes being a function of either being in a "dry year" or a "wet year".

The most pronounced difference between the three groups' recommendations was that the *Aquatics Group* emphasized the need for a period of extremely low baseflows / no flows, in essence a "cook-down" event that would tend to favor natives over non-natives. It was pointed out that while the native species have mechanisms to survive periods of extreme drought, the issue of recolonization by the natives is of concern because of the current lack of refugia. Neither of the riparian groups articulated this "cook-down" element as a beneficial flow component.

2. Results - Unified Baseflows

This section details the desired baseflows that were originally identified by the three groups and the resulting baseflows called for in the **Unified Baseflows** recommendations. Because purposes did not change from the independent recommendations, the uncertainties for the **Unified Baseflows** are a composite of uncertainties noted by the biotic groups for each of the baseflows being merged and are not listed here (see Section V & Appendix C).

<u>Extremely Low Baseflows (~0 to 5 cfs)</u>:

As noted above, this type of event was only advocated by the *Aquatics Group* and was not explicitly carried forward into the **Unified Baseflows**. The need for a rare "cook-down" event was tied to the desire to fragment stream habitat into isolated pools to the anticipated advantage of the native species. Such an event was also seen as a relict of the pre-dam hydrograph. The two riparian groups were concerned with the risks to the riparian vegetation associated with severely depressed water levels.

The unification process forged a compromise where there would be no releases below 20-cfs, somewhat based on the longitudinal variation (described above), which it was thought would likely create "cook-down" conditions in some limited areas along the river during periods of lower baseflow releases. It was agreed by all that it is crucial that appropriate monitoring be conducted to better understand how the lowest flows manifest throughout the project area.

Table 13. **Extremely Low Baseflows (0 to 5 cfs) – UNIFIED BASEFLOWS**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Baseflows*
Name	"cook-down"	n/a	n/a	n/a
Purpose	Fragment habitat: favor natives			n/a
				n/a
Magnitude	0 to 10 cfs			20 cfs
Frequency	Rare			No flows<20
Duration	Up to 2 months			No flows<20
Rate of change	Gradual			n/a
Contingen.	Monitor & evaluate			Monitor & evaluate

<u>Low Baseflows (0 to 10 cfs)</u>:

Again, the **Unified Baseflows** group recommended that there be no baseflows below the 20-cfs level. Hence, the 0-10 cfs **Extremely Low Baseflow** recommendation was essentially the same as the *Aquatic Group*'s "cook-down" recommendation captured above.

<u>Moderate Baseflows (10 to 50 cfs)</u>:

All three groups saw important benefits associated with moderate baseflows, especially in acknowledgement that these moderate baseflows will probably be the system's most common flows. Both riparian groups advocated flows in this category to range from 20 cfs to 50 cfs, with a major advantage being the recharging of the groundwater to reduce the depth to water for vegetative benefit. The *Riparian Non-Birds Group* also saw a possible benefit as related to decomposition of plant materials (processes that require some degree of moisture), although there exists uncertainty as to what level of flows would be needed to support this function. The *Aquatics Group* saw benefit in keeping flow levels consistently elevated during the Sept.15-thru-April 30th period of time. The Aquatics folk also viewed different prescriptions as being tied to different flow years (wet year vs. dry year) – refer to Section 3 above for more details.

Generally speaking, the three groups agreed upon the broad design for this flow category. While the groups expressed appreciation that water availability will often be a strongly limiting factor, all three groups saw distinct advantages for baseflows to be more typically higher vs. lower. Aquatically, higher baseflows would improve water quality conditions (e.g., lower temperatures, higher DO) and would thus tend to reduce the biologic stressors during the heat of the summer. That said, though, long-term high-baseflows were not advocated by the *Aquatics Group* to be included in the reconciled baseflow requirement. Vegetatively, higher baseflows would typically translate into higher water table elevations, which would be advantageous for riparian plants.

All three groups also saw advantages from occasional baseflows on the lower end of this range. As described above, the *Aquatic Group* advocated the "cook-down" concept. Both riparian groups indicated an interest in occasional short-duration lowering of water levels to facilitate more extensive root development. This was especially of interest in those periods of time following establishment events.

Table 14. **Moderate Baseflows (10 cfs to 50 cfs) – UNIFIED BASEFLOWS**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Baseflows*
Name	Maintenance	Maintenance	Maintenance	Maintenance
Purpose	Habitat Maintenance	Maintain established veg. & (contingency) stimulate root development with younger plants	Maintain established veg. & (contingency) stimulate root development with younger plants	Habitat Maintenance & (contingency) stimulate root development with younger plants
Timing	~ year-long	~ year-long	~ year-long	~ year-long
Magnitude	10 to 50 cfs	10 to 50 cfs	10 to 50 cfs	10 to 50 cfs
Frequency	Common	Common	Common	Common
Duration	Weeks/Months	Weeks/Months	Weeks/Months	Weeks/Months
Rate of change	Gradual	Gradual	Gradual	Gradual
Contingency	Wet or Dry Year?	Post-Establish. Event?	Post-Establish. Event?	???

<u>High Baseflows</u> (50 to 100 cfs):

There was little expressed interest in baseflows falling in the 50 to 100 cfs range. Group discussion focused on how this type of flow was not a common part of the natural hydrograph, except typically on the declining limb of a flood, and therefore flow recommendations for these types of flows would more logically be left to the **Unified Floods** group.

That said, it is likely that the goals associated with the higher end of the Moderate Baseflows (up to 50 cfs) also would apply to this flow category. With the uncertainties associated with how a given low flow will manifest in a given reach, the group consensus was to not explicitly call for baseflows in the 50 to 100 cfs range.

3. Summary – **Unified Baseflows**

Most of the baseflows recommended by the three biotic groups had significant overlap with each other and were easily unified. The **Unified Baseflow Group**'s discussions centered primarily on issues related to uncertainties on how baseflows would be expressed across the project area. This inability to route / model baseflows through the project area, especially through the Planet Ranch reach, was a constant touch-stone during the **Unified Baseflow Group**'s discussion. The resolution of this issue was reached by a consensus that resources need to be prioritized to attend to flow routing questions.

It was viewed as a critical objective that the Bill Williams system be sufficiently understood such that physical goals (tied to ecological objectives) be rendered in terms of quantifiable flows levels. Further, there emerged a philosophical consensus that these goals and objectives not be "hardwired", but that they rather have built in ranges and variations such that they more closely mimic natural dynamics. This mimicry of the natural dynamics was thought to be especially critical in transition zones of the hydrograph, as typified by the declining limb of a flood hydrograph.

B. Unified Floods

Flood flow recommendations, developed independently by the *Aquatics*, *Riparian-Birds*, and *Riparian Non-Birds* groups, were merged into one set of recommendations referred to herein as **Unified Floods**. Floods were defined by *name, purpose, timing, magnitude, frequency, duration, rates of change, contingencies*, and *uncertainties*.

1. Process – **Unified Floods**

The **Unified Floods** group began by comparing floods recommended by each of the three groups. In general, the independent recommendations were more similar than dissimilar. The Riparian groups lined up especially well for their winter/spring moderate floods designed to regenerate cottonwood/willow riparian areas and their monsoon small floods to stimulate growth of herbaceous plants. The biggest difference was for the frequency and magnitude of the highest of the large floods. The Aquatics group recommended both the highest and most frequent large flood events calling for floods of greater than 50,000-cfs with a return period of 1:10 years. The Riparian-Birds group recommended smaller and less frequent events calling for floods of greater than 30,000-cfs with a return period of 1:100 years. The *Riparian Non-Birds* group did not request any floods near those magnitudes.

The unification process involved pulling different recommended floods into single events without sacrificing any purposes of the original flood events. When the group was worried that an original purpose might not be accomplished by the flood event after merging, it was discussed and if that did not resolve the concerns, it was treated as a separate flood event in the **Unified Floods** recommendations.

2. Results – Unified Floods

This section details the floods that were merged and the resulting flood events called for in the **Unified Floods** recommendations. Because purposes did not change from the independent recommendations, the uncertainties for the **Unified Floods** are a composite of uncertainties noted by the biotic groups for each of the floods being merged and are not listed here.

Unified Small Floods (100 to 5,000 cfs):

This flood was unique to the Riparian-Birds Subgroup and was incorporated nearly verbatim into **Unified Floods**.

Table 15. **Unified Small Floods, 1 of 4.**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Floods*
Name		Monsoon Forage (low)		Monsoon Forage (low)
Purpose		Stimulate herbaceous growth for forage		Stimulate herbaceous growth for forage
Timing		Mid-July to Mid-August		Mid-July to Mid-August
Magnitude		100 to 500 cfs		100 to 500 cfs
Frequency		1:2		1:2
Duration		Very short, rapid drop (ours). Can have multiple short spikes		Very short & rapid. 1 to 3 spikes at 2 to 3 times base flow.
Rate of change		None, but event is sharp and brief to limit Tamarisk recruitment		None, but event is sharp and brief to limit Tamarisk recruitment
Contingency		None		None

Both Riparian groups recommended a small flood in the monsoon season to support herbaceous plant growth, which is an important source of forage for insects, birds, and animals. The reduction in frequency recommended by the *Riparian Non-Birds Group* (1:2-3 changed to 1:5) was partially offset by inclusion of the smaller "Monsoon Forage (low)" in **Unified Floods**. The *Riparian-Birds Group* did not object to the change in frequency or the increased magnitude.

Table 16. **Unified Small Floods, 2 of 4.**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Floods*
Name		Monsoon Forage (high)		Monsoon Forage (high)
Purpose		Stimulate herbaceous growth for forage	Herbaceous plant growth and litter decomposition. Timed to avoid destruction of ground snake eggs and southwestern toad larvae	Herbaceous plant growth and litter decomposition
Timing		Mid-July to Mid-August	Mid-July to September	Mid-July to Mid-August
Magnitude		500 to 1,000 cfs	1,000 to 2,000 cfs	1,000 to 2,000 cfs
Frequency		1:6	1:2-3	1:5
Duration		Very short, rapid (hours). One peak.	Hours	Very short, rapid (hours). One peak.
Rate of change		None, but event is sharp and brief to limit Tamarisk recruitment	Quick start up and shut off	Quick start up and shut off
Contingency		El Nino Driven	Flooding may depend upon seasonal weather conditions	Look for link to regional climactic conditions

The following Table 17 shows a flood designed to facilitate fish spawning conditions, and was unique to the *Aquatics Group* and was incorporated verbatim into **Unified Floods**.

Table 17. **Unified Small Floods, 3 of 4.**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Floods*
Name	Native Fish Spawning			Native Fish Spawning
Purpose	Enhancement of native fish spawning			Enhancement of native fish spawning
Timing	Late February to early April			Late February to early April
Magnitude	200 to 400 cfs			200 to 400 cfs
Frequency	1:1			1:1
Duration	2 to 4 weeks			2 to 4 weeks
Rate of change	Elevated flows should be held relatively constant for the full duration			Elevated flows should be held relatively constant for the full duration
Contingency	None			None

Table 18 displays the forth type of "small flood", and was called for by the biotic groups to emphasize winter foraging and cleansing affects. The magnitude was set at the upper end of the range, while the timing was set according to the recommendations of the *Riparian-Birds Group* to encourage an advantageous creation of seasonal forage for passerines and upland game birds.

Table 18. **Unified Small Floods, 4 of 4.**

	Aquatics	*Riparian-Birds*	*Riparian Non-Birds*	*Unified Floods*
Name		Winter Forage		Winter Forage and Cleansing
Purpose	Refresh riffle habitat and refill side and off-channel pools	Stimulate herbaceous growth for forage		Herbaceous growth, beaver dam removal, general cleansing
Timing	Mid-November to Mid-February	February 1 to February 28		February 1 to February 28
Magnitude	1,000 to 2,500 cfs	500 to 5,000 cfs		4,500 to 5,000 cfs
Frequency	1:1-2	1:3		1:3
Duration	3 to 4 days	7-days sustained small flood		Peak quickly then recede for 7 to 10-days
Rate of change	None	Taper lower receding limb at 2.5 cm/day		Taper lower receding limb at 2.5 cm/day
Contingency	None	None		None

<u>Unified Moderate Flood (5,000 to 30,000 cfs)</u>:

The *Riparian Non-Birds Group* had two flood events that were merged into this unified flood. Some purposes of their Cottonwood and Willow Recruitment (low) event (scouring, removal of beaver dams, litter, and exotics) were also partially taken care of by the "Winter Forage and Cleansing" flood discussed above. An important contingency for this flood is incorporation of the annual native fish spawn. To accommodate the spawn, when the recession limb is between 200 and 400 cfs, flows should hold relatively steady for 2-4 weeks before continuing to gradually recede.

Table 19. **Unified Moderate Flood, 1 of 1.**

	Riparian-Birds	*Riparian Non-Birds1*	*Riparian Non-Birds2*	*Unified Floods*
Name	Cottonwood and Willow Recruitment	Cottonwood and Willow Recr.(low)	Cottonwood and Willow Recr. (high)	Cottonwood and Willow Recruitment
Purpose	Stimulate mixed recruitment catered to Cottonwood and Willow (with a little Tamarisk)	Scour channel, break beaver dams, wash out exotic species, elevate water table, clear litter for Viceroy butterflies, and recruit C&W	Scouring of channel and floodplain for reestablishment of Cottonwood and Willow	Stimulate mixed recruitment of Cottonwood and Willow (with a little Tamarisk)
Timing	Mar.15 to Apr.30	Late Feb. to Apr.1	Late Feb. to Apr.1	March 15 to April 30
Magnitude	10,000-30,000 cfs	2,000 cfs	> 7,000 cfs	10,000-30,000 cfs
Frequency	1:5-10	1:2-3	1:10	1:5-10
Duration	2-day spike with a multi-day tail that blends into recession	2 to 3-days at Lake Havasu	2 to 7-days	2-day spike with a multi-day tail that blends into recession
Rate of change	Lower receding limb should not exceed stage change more than 2.5 cm/day and recede down to a low base flow and hold at the low base for 2-4 weeks to encourage deep root growth	Quick start up and gradual recession – about 2.5 cm/day	Quick start up and gradual recession – about 2.5 cm/day	Lower receding limb should not fall more than 2.5 cm/day. Recede down to a low base flow and hold at the low base for 2-4 weeks to encourage deep root growth
Contingen	Avoid floods for two years after this event. Start small to gage effects on vegetation and geomorphic change	Timed in accord with seeding of these trees, but before Tamarisk seeding and to avoid dormancy and breeding of animals earlier in the year.	Timed in accord with seeding of these trees, but before Tamarisk seeding. No further scouring floods for 2 years after event and maintain high baseflows	Avoid floods for two years after this event. Start small, but be aggressive in terms of increasing magnitude of peak within specified range. Accommodate annual Native Fish Spawning flood as part of recession.

Unified Large Flood (Greater than 30,000 cfs):

The *Aquatics Group* had two flood events that were merged into this unified flood event. Purposes of their "Tropical Season Cleansing" event (removal of beaver dams and creation of off-channel habitat) were also partially taken care of by the unified "*Cottonwood and Willow Recruitment*" flood discussed above.

The combined frequency (1:10) recommended by the *Aquatics Group* for blowing out non-native fishes in the Tropical and Winter/Spring seasons was decreased during unification (1:25), but this reduction in frequency was offset by decoupling their blowout floods in the Tropical and Winter/Spring seasons. In other words, **Unified Floods** calls for two independent high flood events, whose purposes include blowing out non-native fishes, each with a frequency of 1:25.

The increase in magnitude during unification was acceptable to the *Riparian-Birds Group*, though it was reinforced that the value of this flood (in terms of setting the stage for renewal of riparian habitat) is maximized when it is coupled with a Cottonwood-Willow recruitment flood in the following spring.

Table 20. **Unified Large Floods, 1 of 2.**

	Aquatics(#1)	*Aquatics (#2)*	*Riparian-Birds*	*Unified Floods*
Name	Tropical Season Cleansing	Tropical Season Non-native Fish Flush	Cottonwood and Willow recruitment primer flood	Non-native Fish Flush and Riparian Rework (Tropical season)
Purpose	Removal of beaver dams and creation of off-channel habitat	Blowout non-native fishes and creation of off-channel habitat	Set the stage for Spring season recruitment of Cottonwoods and Willows	Non-native fish blowouts, Manipulate distribution of woody vegetation
Timing	September 15 to November 14	September 15 to November 14	Tropical Season (9/15-11/14), preferably after October 1 to limit Tamarisk recruitment	September 15 to November 14 preferably after October 1 to limit Tamarisk recruitment
Magnitude	5,000-30,000 cfs	> 50,000 cfs	10,000-30,000 cfs	>30,000 cfs
Frequency	1:5	1:10	1:15-30	1:25
Duration	2 separate peaks both sharp, spiked events	1 peak, spiked	1 peak, spiked. Up and down within 1 to 2 days	1 peak, spiked. Up and down within 2 days
Rate of change	None	None	Steep. Rates not key, important to be quick	Steep. Rates not key, important to be quick
Contingency	None	Ok to occur in the Winter-Spring Season with a combined frequency of 1:10	Try to couple this with a Cottonwood Willow recruitment flood in the following Spring	Try to couple this with a Cottonwood Willow recruitment flood in the following Spring

The second "Large Floods" recommendation came from the *Aquatics* and *Riparian-Birds* groups, and aligned quite well. The increase in frequency from the *Riparian-Birds Group*'s recommendations (1:100 to 1:25) was acceptable, but representatives from that group <u>stressed that the Bill Williams is a critical resource for migratory birds</u> and that these large floods should start near the bottom of the specified flow ranges to allow scientists to gage the effects on bird habitat before progressing to higher flows.

As discussed above, the combined frequency (1:10) recommended by the *Aquatics Group* for blowing out non-native fishes in the Tropical and Winter/Spring seasons was decreased during unification (1:25), but this reduction in frequency was offset by decoupling the Tropical and Winter/Spring seasons.

Table 21. **Unified Large Floods, 2 of 2.**

	Aquatics(#1)	*Aquatics (#2)*	*Riparian-Birds*	*Unified*
Name	Winter/Spring Season Non-native Fish Flush	Ecological Reset		Non-native Fish Flush and Riparian Rework (winter /spring season)
Purpose	Blowout non-native fishes and creation of off-channel habitat	Remove vegetation, scour and create new channels, set stage for est. of new vegetation		Non-native fish blowouts, Manipulate distribution of woody vegetation
Timing	November 15 to April 30	November 15 to April 30		November 15 to April 30
Magnitude	> 50,000 cfs	> 30,000 cfs		> 30,000 cfs
Frequency	1:10	1:100		1:25
Duration	1 peak, spiked	1 peak, 2 to 6 days		1 peak, 3 to 6 days
Rate of change	None	Steep. If occurs in mid-February through mid-April then lower receding limb should not exceed stage change of > than 2.5 cm/day		Steep. Hit 2.5 cm/day recession on lower limb of timing is right for recruitment
Contingency	Ok to occur in the Tropical Season with a combined frequency of 1:10	In a recruitment scenario, avoid floods for two years after the event. Start small to gage the effects on vegetation and geomorphic change		In a recruitment scenario, avoid floods for two years after the event

3. Summary – Unified Floods

Most floods recommended by the biotic groups had significant overlap with each other and were easily unified. Debate within the **Unified Floods** group focused mainly on 1) the degree of flexibility in timing floods designed to cleanse the system - which was agreed to be quite high; 2) the frequency of large floods – which boiled down to striking a balance between protecting the current ecological value of the Bill Williams by cautiously exploring high flows and a need to reestablish those high flows as a powerful disruptive force that encourages more dynamic and natural behavior of the ecosystem, and 3) the philosophical relationship between the Cottonwood-Willow recruitment flood and the higher and less frequent floods designed to rework the riparian areas and blow out the non-native fishes – this was describe by the group as an analogy of the recruitment floods being used to manage crop rotation for the Cottonwood and Willow while the higher floods were used to clear the fields.

The single most important caveat for the **Unified Floods** is that these recommendations assume that changes to the flood regime will be implemented with commensurate changes to the sediment budget of the Bill Williams River below Alamo Dam. This is of critical importance. If any of the moderate or large floods (peak flows greater than or equal to 10,000 cfs) were implemented without an accompanying sediment adjustment, the effects downstream are expected to be quite negative.

V. Priority Monitoring and Research Needs

Each of the biotic groups noted uncertainties and knowledge gaps identified while formulating their flow requirements. Several knowledge gaps were echoed by multiple biotic groups and by the subsequent flow-based groups. The following list is a synthesis (roughly prioritized) of key knowledge gaps from all of the workshop's groups:

<u>Sediment budget and transport dynamics.</u> The sediment budget of the Bill Williams River has been very much altered by the presence of Alamo Dam, which is effectively a sink for all coarse sediment mobilized upstream of the lake. Below the dam, unregulated tributaries remain productive sediment sources, but the ability of flows in the Bill Williams below Alamo to redistribute this sediment has been greatly reduced by decreases in large flood flows. There are unresolved questions about 1) the sustainability and evolution of the current channel and riparian forest since Alamo was constructed, 2) potential negative effects resulting from implementation of the ecological flow requirements – the flood flows in particular – without commensurate adjustments to the sediment budget, and 3) gradation of sediment deposited in floodplain areas and whether these materials are conducive to plant growth.

<u>Magnitude and duration of flows required to achieve the purposes of the ecological flow requirements, especially for the prescribed floods.</u> There was a general uncertainty in whether the different components of the ecological flow requirements would achieve their designed purposes, especially with respect to the flood flows. This was mentioned by all the groups in ways that implied 1) that the groups anticipate thresholds of flood magnitude that will need to be met or exceeded to accomplish specific actions, 2) that the flood flow requirements formulated in this workshop reflected the biotic groups' best estimates of these thresholds, and 3) that there is a need to better define these thresholds through experimentation and adaptive management. Specific uncertainties listed by the groups related to this topic included flow magnitudes needed to remove beaver dams, mobilize sediment, remove vegetation, stimulate decomposition, rework floodplain areas, and depress non-native fishes.

<u>Connections between surface water, groundwater, and related biotic communities.</u> The Bill Williams below Alamo Dam courses through a series of narrow canyon and alluvial valleys. The valleys tend to have a moderating effect on stream flows where surface flows recharge underlying aquifers in times of high flow and those aquifers later augment surface flows in times of low flow. There was a general uncertainty regarding connections between stream flow and the underlying aquifers, <u>especially in regard to Planet Ranch</u>. This uncertainty was spatial and seasonal in nature (how do surface water releases from Alamo Dam translate downstream to Lake Havasu and what are the groundwater responses?) and was a concern for baseflows and, to a lesser extent, small and moderate floods. These questions were related back to rooting dynamics and the sustainability of riparian vegetation as a function of ground water levels. A need to better understand the impacts of (and to develop contingencies for changes in) groundwater pumping in the basin was also noted.

<u>Role of floods in the Tropical and Monsoon Seasons.</u> Tropical and Monsoon floods occur less frequently and tend to be of shorter duration and lower magnitude than those in the Winter-Spring Season, which is the wettest season for the Bill Williams, but can still be powerful flood events. Also, as Tropical and Monsoon Seasons follow the Dry Season, where any flows above minimal baseflows are quite rare, flow fluctuations in those seasons may be important hydrologic stimuli from an ecological perspective. There was a general uncertainty regarding the ecological roles of high flows in the Tropical and Monsoon Seasons, including whether Tropical floods

were important precursors for successful recruitment of Cottonwoods and Willows during Winter-Spring Floods, effects of Monsoon Floods on tamarisk, and whether there would be ecological consequences if Tropical Floods were not prescribed.

<u>Nutrient cycling, decomposition, and the role of fire.</u> There was a general uncertainty regarding connections between flow, decomposition, nutrient cycling, and fire. Knowledge gaps noted by the groups created an interrelated sequence of uncertainties beginning with fundamental questions about the drivers of decomposition and how nutrients cycle within the system. These questions led to recognition of uncertainties about the balance of litter production and decomposition and the potential increase in fire frequency in situations where production outpaces decomposition. This, is turn, led to the question of the role of fire as a disturbance mechanism for riparian forests.

VI. Conclusions

The Bill Williams River Ecosystem Flow Workshop was held with the purpose of defining a set of flow requirements for sustaining the long-term ecological health of the Bill Williams River corridor. The workshop (sponsored by the Bill Williams River Corridor Steering Committee and attended by over fifty scientists and water and natural resource managers) tasked participants with formulating flow requirements that would maximize native biodiversity, without being constrained by current conditions (such as the dam's current outlet capacity of 7,000 cfs). The workshop participants successfully articulated a <u>set of flow requirements</u>, which are summarized in this document (see Figure 2).

The flow formulation process entailed two stages. During the first stage, three biologically-based groups were convened to construct relationships between flow and species needs. The three groups were: 1) "Aquatics" (including coverage on fishes and aquatic macroinvertebrates and amphibians); 2) "Riparian Vegetation and Birds" (*Riparian-Birds*); and 3) "Riparian Vegetation and Terrestrial Fauna Other than Birds"(*Riparian Non-Birds*). The second stage involved reorganizing workshop participants into two groups defined by flow ("*Baseflows* "& "*Floods*"). These two flow-based groups were charged with reconciling the flow requirements defined by the first three biologically-based groups, to produce a single set of unified flow requirements that account for the flow needs of a wide suite of species of interest.

The results from this workshop will be used to further the commitment of the U.S. Army Corps of Engineers and the other members of the Bill Williams River Corridor Steering Committee to make science-based management decisions in regards to the operation of Alamo Dam and the affected environment. This redoubled commitment on the part of member agencies builds upon over fifteen years of flow-related work on the Bill Williams river system. The history on the Bill Williams provides a body of work that has consistently acknowledged the central need to meaningfully apply the concept of *adaptive management*.

The implementation of an effective adaptive management scheme is of high priority to the Bill Williams River Corridor Steering Committee, and it is clear to the committee that with complicated systems like the Bill Williams, the ability to *adaptively manage* is proportional to the commitment to monitoring and experimentation. The workshop's defined flow requirements will be evaluated to identify which components can be immediately implemented and those that will need further study. The knowledge and research gaps that were identified will be used to develop a strategic monitoring plan and priority research agenda, and opportunities will be identified to better link reservoir operations with scientific research.

Appendix A

Workshop Participants

Table 22. **List of Workshop Participants.**

	Name	Affiliation	Area of expertise
1	Susan Fitch	ADEQ	Water Quality
2	Bill Werner	ADWR	Aquatic Biologist
3	Kim Mitchell	ADWR	Hydrologist
4	Brad Jacobson	AGFD	Fishery Biologist
5	Chris Cantrell	AGFD	Fishery Biologist
6	Charles Paradzick	AGFD	Avian (Chuck-of-all-trades)
7	Larry Voyles	AGFD	Biologist / Management
8	Lin Piest	AGFD	Biologist
9	Scott Blackman	AGFD	Research Biologist
10	Phil Pearthree	Arizona Geological Survey	Geomorphology / Geology
11	Bob Ohmart	Arizona State University	Avian
12	Mark Dixon	Arizona State University	Riparian Ecologist
13	Bob Sejkora	ASP (Parks)	Hydrologist
14	Doyle Wilson	Mohave Comm.College	Hydrogeologist
15	Dave Lytle	Oregon State University	Aquatic Ecologist
16	Mike Bogan	Oregon State University	Aquatic Ecologist
17	Bertin Anderson	Private	Birds, Soils, Restoration
18	Mark Briggs	Private	Riparian Ecologist
19	Marshall Brown	Scottsdale (City)	Hydrogeologist
20	Andy Warner	TNC	Biohydrologist
21	Dale Turner	TNC	Biology
22	Jeanmarie Haney	TNC	Hydrologist
23	John Hall	TNC	Biologist
24	Robert Wigington	TNC	Law
25	Tom Fitzhugh	TNC	Biologist
26	Mary Harner	University of New Mexico	Ecologist
27	David Walker	University of Ariz. (WQC)	Aquatic Ecologist
28	Kyle House	University of Nevada-Reno	Fluvial Geomorphologist
29	Carvel Bass	USACE	Biologist
30	Joe Evelyn	USACE	Hydraulics / Management
31	John Hickey	USACE	Hydraulic Engineer
32	Phyllis Traboldt	USACE	Biologist
33	William Miller	USACE	Biologist
34	Kirk Koch	USBLM	Biologist
35	Barbara Raulston	USBR	Biologist / Avian
36	Bruce Williams	USBR	Hydraulic Engineer
37	Diane Laush	USBR	Avian
38	John Swett	USBR	Wildlife Biologist
39	Mark Nelson	USBR	Biologist (Invertebrates)
40	Andrew Hautzinger	USFWS	Hydrologist
41	Dave Smith	USFWS	Biologist
42	Jeff Whitney	USFWS	Biologist / Management
43	Jim Rorabaugh	USFWS	Herpetologist
44	Kathleen Blair	USFWS	Refuge Ecologst
45	Ted Rentmeister	USFWS	Biologist / Management
46	Charles van Riper	USGS	Avian Biologist
47	Doug Andersen	USGS	Vertebrate/Riparian Ecologist
48	Greg Auble	USGS	Riparian Ecologist
49	Jamie Myers	USGS	Biologist
50	Jeanette Carpenter	USGS	Aquatic Ecologist

	Name	Affiliation	Area of expertise
51	Pat Shafroth	USGS	Riparian Ecologist
52	Vanessa Beauchamp	USGS	Riparian Ecologist
53	Bill Hansen	USNPS	Hydrologist
54	Mark Wondzell	USNPS	Hydrologist

Figure 3. Workshop Participants

Appendix B

Workshop Agenda

Agenda
Bill Williams River
Ecosystem Flows Workshop
March 16-18, 2005

March 16, 2005

10:30 Introductions, review of process, define meeting outcomes – Andrew Hautzinger, Joe Evelyn, Andy Warner

11:15 Executive Summary – Pat Shafroth

Overview of the approach taken in assessing studies related to the development of ecosystem flow requirements for the Bill Williams River below Alamo Dam. The project scope will be introduced (hydrology/geomorphology; riparian vegetation; fish and aquatic macroinvertebrates; birds; and mammals, reptiles, amphibians, and floodplain invertebrates) and key findings will be summarized.

12:00 Lunch (provided on site)

12:45 Project Section Reports

- 12:45 River Hydrologic Regime, Geomorphology and Inundation Patterns – House
- 1:10 Flow Regime Relationships to Fishes and Aquatic Macroinvertebrates – Lytle
- 1:35 Flow Regime Relationships to Riparian Vegetation – Shafroth
- 2:00 Flow Regime Relationships to Terrestrial Fauna – Andersen, van Riper, and Beauchamp

2:30 Break

2:45 Breakout I- Assignments and Work Session

Breakout groups, organized around two terrestrial categories and one aquatic category are tasked with drafting flow requirements for the *Dry Season* ***(May 1 – June 30) and*** *Monsoon Season* ***(July 1 – September 14), characterizing low flows and flood flows, as well as identifying knowledge gaps***

5:00 Happy Hour (*The Vine*)

6:30 Dinner on your own

March 17, 2005

8:30 Breakout I - Work Session continued

In same groups as above, tasked with drafting flow requirements for the **Tropical Storm Season** (September 15 – November 14) and the **Winter Storm Season** (November 15 – April 30), characterizing low flows and flood flows

12:30 Lunch (provided on site)

1:30 Breakout groups wrap-up and preparation for presenting on draft flow requirements, including summarizing primary knowledge gaps and research needs.

2:30 Presentation by breakout groups (20 minutes each)

3:30 Breakout II - Developing a Unified Flow Requirement

Groups will be assigned to develop a unified ecological requirement for low flows and flood flows

5:30 Adjourn

6:30 Cash Bar and Group Dinner (*Holiday Inn*)

March 18, 2005

8:00 Breakout II - Developing a Unified Flow Requirement, continued

9:30 Presentations by Breakout II small groups (20 minutes)

10:30 Break

10:45 Facilitated whole group discussion and next steps

12:30 Adjourn (lunch on your own)

Appendix C

Lost of Uncertainties and Knowledge Gaps

(by each of the **Three Biologic Groups)**

***AQUATICS GROUP*: Uncertainties and Knowledge Gaps**

Listing and prioritization of uncertainties and knowledge gaps identified by the group.

- What is the sediment budget? How is channel evolving in absence of upstream sediment inputs? How do releases at the dam route through downstream reaches? Need transects and hydraulic modeling.
- What is the impact of groundwater pumping along BW River? Develop contingency if they increase groundwater pumping or surface diversions.
- Can re-colonization of fish or invertebrates be expected after flood events? What is connectivity of upstream and downstream populations of fish or invertebrates? What is overlap of lotic and lentic habitats below Alamo Dam?
- Is there significant entrainment of non-native fish in water from dam during cool-season releases, and is there less during times when lake is stratified?
- What is the feasibility of establishing native fish populations below dam, given current presence of non-natives? How can non-natives be eradicated? Are there other management actions needed besides flow management?
- Water quality varies by season – released water in summer is especially different. Lots of water quality issues for meeting our aquatic diversity objectives.
- What is the status of native mud turtles and garter snakes?
- How is sediment moving through the system?

***RIPARIAN-BIRDS GROUP*: Uncertainties and Knowledge Gaps**

Listing and prioritization of uncertainties and knowledge gaps identified by the group.

- How is sediment moving through the system?

Without replenishing sediment, prescribed flood flows may mine the sediment out of the system. A key knowledge gap is a sediment budget for the Bill Williams River that accounts for sediment movement and transport by flood discharge stqage and geographic location. With a sediment budget in-hand, plans can be developed for how to augment sediment input into the system. To develop a sediment budget, the following tasks are recommended:

- Install permanent sediment monitoring cross-sections for individual reaches. Use these for particle tracking to determine residence time and suspended sediment loads.
- Use annual aerial photos to reconstruct sediment budgets. Re-fly flight lines every year.

Associated uncertainties include:

- What type of sediment is being deposited on floodplain? Are these particle sizes conducive to plant growth? That is, is deposition of fine particles occurring that can form confining layers?

We need a **better understanding of stream flow and aquifer connections** at the reach and sub-reach scale. To address this need, the following task is recommended:

- Install and monitor-well networks and piezometers in critical reaches. Compare water table dynamics at different discharges and between wet and dry years (that is, full aquifer compared to depleted aquifer).

Associated uncertainties include:

- What is the hydraulic effect of a base flow of 20 to 50 cfs between reaches and at different positions within a particular reach?
- What are the magnitude and duration of **small**, moderate, and large flood flows necessary to accomplish presumed purposes? The priority here is on small flood flows because at least in the near-term we can empirically test the effect of these flows. Stage-discharge data can be used to make initial predictions.
- What flows are necessary to maintain adequate pool habitat?

Models and geospatial analytical tools can be used to predict where pool habitats are located.

- What are the roles of monsoon/tropical-storm generated flood flows in the ecosystem?

Associated uncertainties include:

- Do tropical storm-related floods occurring as precursors to winter/spring floods facilitate cottonwood regeneration following winter/spring floods (some evidence of this from work by J. Stromberg)? This would make a good adaptive management study—compare regeneration success of cottonwoods and willows after a sequence of tropical storm-related floods and winter/spring storm-related floods versus no tropical floods.
- Does a tropical storm-related flood affect patch dynamics, turnover, number of successful recruits?
- What should the receding limb be for cottonwood regeneration following winter/spring floods? Specifically, when should the recession start? Why was the 500 cfs flow magnitude chosen for the start of recession? Will this number change over time if channel morphology changes?
- How do roots grow in different sediments and with different availability of water? Roots will need to be mapped under different soil and moisture conditions to address this question.
- How are nutrients cycling in the system? What are controls on decomposition? How are nutrients moving downstream and vertically in the system?
- What are links between decomposition rates/litter accumulation and fire frequency? How can we balance artificially high production with adequate decomposition to prevent fuel accumulations conducive to fire?
- **Do mesquite bosque communities respond to river flow regimes or are they independent of flows, such that they rely on local precipitation patterns instead of river flows?** With flood pulses, do we get areas with a lot of mesquite? How do you manage mesquite that is already present?
- What do we know about N-fixation in mesquite? Are they actually nodulating?

RIPARIAN NON-BIRDS GROUP: Uncertainties and Knowledge Gaps

Listing and prioritization of uncertainties and knowledge gaps identified by the group.

1. Flows needed to clear existing vegetation (at differing size) and mobilize sediment movement?
2. Sustainability of large floods and current fluvial with current sediment budget?
3. Depth of groundwater, laterally and longitudinally and surface discharge in relation to pulses (depth and rate of drawdown) and baseflows as a function of discharge at Alamo? Ability to route released flows?

As the previous three were all geomorphic, we felt a more biologically oriented priority gap follows:

4. Monitor effects of groundwater level on cottonwood and willow sustainability?
5. Flows to remove beaver dams at Alamo?
6. Potential for invasion by exotics (sub-tropical plants, the bull frog)?
7. Ground snake life history and nesting period?
8. Effectiveness of refugia/recolonization processes of spp (especially regionally rare spp.)?
9. Consequences of not prescribing tropical floods?
10. Southwestern toads; are they above Plant Ranch? Period of estivation? Life history?
11. Monitor effect of monsoon floods on tamarisk?
12. Effect of moderate flows (1-2K) on decomposition?
13. Rate of beaver dam rebuilding?
14. Knowledge of floodplain elevation? – e.g., Brown's crossing (system wide (D.T.M.))
15. Long-term succession in bottomland in the absence of destructive floods? How does the use of fire as destructive forest compare?
16. Importance of gap-phase CW regeneration?
17. When, to what extant and how does decomposition really occur?