APPENDIX D.

RIPARIAN SUBCOMMITTEE REPORT

BILL WILLIAMS RIVER CORRIDOR RIPARIAN SUBCOMMITTEE

Flow Recommendations for Riparian Resources

January 1994

BWRC Riparian Subcommittee

Bill Werner, AZ Game and Fish Department (Region IV)
Bob Posey, AZ Game and Fish Department (Region III)
Dave Busch, U.S. Bureau of Reclamation
Ron Hooper, U.S. Bureau of Land Management
Carvel Bass, U.S. Army Corps of Engineers
Nancy Gilbertson, U.S. Fish and Wildlife Service
Paul Tashjian, U.S. Fish and Wildlife Service

Chairperson: Sarah Hooper, U.S. Bureau of Land Management

BILL WILLIAMS RIVER CORRIDOR RIPARIAN SUBCOMMITTEE
Flow Recommendations for Riparian Resources

I. GOAL AND OBJECTIVES

A. CURRENT STATUS OF MANAGEMENT AREA

The riparian resources along the Bill Williams River have been subjected to several unnatural stresses in the past few decades, severely impacting the native vegetation growing in the riparian corridor (Fenner et al. 1985, Hunter et al. 1987). Although the corridor contains a few remnant cottonwood stands, these native riparian forests have been greatly reduced and are being replaced extensively by non-native salt cedar. Construction of Alamo Dam in 1969 altered the water regime in the river that sustained the riparian vegetation. Restricted flows of sediment-poor water during much of the year, combined with occasional moderately high flows (2,000-3,000 cfs) for extended periods (>60 days) for flood control, have been the primary contributors to the degradation of this riparian system. These altered flows have prevented most natural recruitment of cottonwoods, leaving stands of decadent riparian forests being replaced by more drought-tolerant salt cedar or not replaced at all. Any recruitment of native trees that does occur during high flow years is generally lost when flood flows are quickly scaled back to base flows of 10 cfs or less, and the water table drops too deeply too quickly. Extensive pumping at Planet Ranch has compounded these problems by draining the subsurface hydrologic basin, restricting even more the water available to riparian resources downstream from the ranch. Wildfires in the riparian corridor may also contribute to replacement of cottonwoods and willows by shrubby species such as salt cedar and arrowweed (Busch and Smith 1993). These fires destroy mature native riparian forests, and the lack of subsequent flood flows and sufficient base flows prevents natural recruitment of native trees to replace those lost to fire. The Wildlife Subcommittee report (July 1993) and the letter from Julie Stromberg, President, Arizona Riparian Council (4/21/93) detail the stresses and subsequent degradation of riparian resources along the Bill Williams River corridor. A properly functioning riparian ecosystem could be restored by implementing a flow regime that mimics the pattern of historic (pre-dam) flows.

Properly functioning riparian ecosystems are dynamic, with suitable sites for recruitment and sustained growth varying naturally with each season's water regimes. Through time, the location of specific forest sites may change within a corridor, but the overall health and function of the ecosystem remains. Managing Alamo Dam for riparian resources provides the opportunity to create hydroperiods, including both sufficient base flows and flushing flows, to stabilize and restore a healthy riparian system in the Bill Williams River corridor. While the Riparian Subcommittee emphasized natural variation in recruitment sites for key riparian species, some reaches of the river should receive special consideration for hydrologic concerns. Flows in the Bill Williams National Wildlife Refuge depend largely upon the amount of pumping at Planet Ranch and subsequent depletion of the subsurface hydrologic basin. With pumping at the Ranch, higher releases from Alamo Dam are necessary to provide sufficient base flows to the Refuge. Conversely, sustained high base flows could detrimentally impact resources at sites upstream from the ranch. In addition, the sediment deficiency experienced by, particularly, Banded Canyon (just downstream from the dam) is also of concern. The recommendations provided by the Riparian Subcommittee are designed to balance these concerns, providing longterm recovery goal for riparian resources in the Bill Williams River corridor.

B. RIPARIAN RESOURCES GOAL

The Riparian Subcommittee's goal is to enhance the riparian vegetation at Alamo Lake and the Bill Williams River, using pre-dam flow patterns (timing and shape of Spring and monsoon flows) to promote a healthy, self-sustaining riparian-wetland ecosystem in the Bill Williams River-Alamo Lake corridor.

The Subcommittee decided to focus on restoring riparian resources downstream from Alamo Dam and maintaining the cottonwood gallery forest at the upper end of Alamo Lake (Santa Maria River arm). We decided riparian resources at the reservoir itself were not substantial enough to warrant indepth discussion. Priorities for using water for riparian resources are:

1. ***Maintenance (base) flows***, to stabilize and maintain existing riparian stands;
2. ***Spring flushing flows***, to promote seed bed establishment, recruitment, and germination of key riparian species.
3. ***Fall flushing flows***, to recharge the aquifer and promote additional riparian species.

C. RIPARIAN RESOURCES OBJECTIVES

1. Maintain both <u>area</u> (acreage) and <u>structural diversity</u> of existing vegetation stands dominated by native riparian species, particularly cottonwood/willow stands.

2. Expand coverage and diversity of native riparian stands through natural recruitment.

3. To the extent possible, reduce the dominance of non-native tree species through flow releases and lake levels.

II. <u>ASSUMPTIONS FOR RECOMMENDATIONS</u>

A. HYDROLOGY

1. Dam operation includes the flexibility to store water in times of "surplus" for future (within 12 months) releases that would benefit riparian resources. Water years would be based on those established by the Corps of Engineers, October 1 - September 30.

2. Maximum flows down the river are not constrained by socio-economic factors. The joint resolution by the United States Government and the State of Arizona, dated 15 March 1963, declared that the floodplain below Alamo Dam would be maintained free of encroachment for discharges up to 7,000 cfs.

3. Pumping at Planet Ranch will continue as long as the ranch is privately owned. If Planet Ranch is transferred to Federal ownership, pumping will be significantly reduced. Figure 1 illustrates the effects of pumping at Planet Ranch with releases of 35 cfs from Alamo Dam.

4. A minimum of 18 cfs (measured at the Bill Williams Refuge gauge just below Planet Ranch) is needed to sustain riparian resources within the Refuge. This flow would provide surface flows of at least 1 cfs to Lake Havasu. The Rivers West, Inc. study for the USFWS estimated that a 35 cfs release from Alamo Dam provides flows of 18-20 cfs at the refuge gauge without pumping at Planet Ranch, and 5-10 cfs at the refuge with maximum pumping at Planet Ranch. These estimates are being supported by the USFWS model being developed for this system (Harshman and Maddock, unpubl. report; Harshman, unpubl. report) (see Figure 1).

5. A sustained surface flow in the channel indicates a saturated alluvium (water table is near the floodplain surface).

6. All recommendations by the Riparian Subcommittee assume Alamo Lake is at normal operating range within the water conservation pool (lake elevation ≥1,100 ft. & ≤1,172 ft.), and, therefore, most of the water volume from incoming flows during storm events would be available for release downstream.

B. VEGETATION

1. Cottonwood and willow are key indicator species for riparian systems (e.g. healthy cottonwood-willow stands = healthy riparian system).

2. Cottonwood and willow trees are dormant between approximately December 1 and January 31.

3. Of the key riparian species, cottonwood trees (*Populus fremontii*) are the least tolerant of inundation (sustained flows ≥1,000 cfs). During the growing season (March-October), cottonwood trees may be able to sustain ≤30 days of inundation. From November-February, cottonwood trees may be able to sustain up to 60 days of inundation (Walters et al. 1980, Kozlowski 1984, Kozlowski et al. 1991).

Because of the extreme environment along the Bill Williams River compared to the locales where cottonwoods (*Populus* spp.) have been studied, these inundation tolerances may need refinement through further study. Thus, these tolerance levels should be noted with some degree of uncertainty.

4. Cottonwoods and willows are phreatophytes (Busch et al. 1992), thus, maintaining high water tables is essential for cottonwood and willow vigor during the growing season. Minimum requirements include:

-- any drop in water table should be *≤2 cm/day* (McBride et al. 1988, Mahoney and Rood 1991, Scott and Segelquist 1992);

-- total drop in water table should be ***≤0.5-1 m/growing season*** (J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93);

-- maximum water table depth should be ≤2 m
(Stromberg 1993b; D. Busch, BOR, 1993, pers. comm.).

5. Peak seed dispersal for key riparian species (Ohmart and Anderson 1984):

Cottonwood - March/April (1x/yr)
Willow - April/May (1x/yr)
Salt Cedar - April - late October (June peak) (prolonged/yr)

6. Peak flows in February to early April are good for cottonwood-willow regeneration (based on their seed dispersal). Cottonwoods need flushing flows to prepare seed beds for natural regeneration. Cottonwood regeneration occurs naturally every 5-10 years (Stromberg et al. 1991, 1993; Stromberg 1993a).

7. Flows approximating the pattern of pre-dam conditions are good for maintaining sustainable riparian ecosystems in the desert southwest.

III. WATER OPERATION RECOMMENDATIONS FOR RIPARIAN RESOURCES

A. ALAMO LAKE

1. Purpose:

This recommendation serves to maintain the cottonwood stands at the upper end of Alamo Lake in the Santa Maria River arm. The primary purpose is to prevent salt cedar from further invading cottonwood stands at this site, and from interfering with the natural recruitment of these cottonwoods. This recommendation also proposes minimum lake levels for retaining sufficient water volume to maintain minimum base flows for riparian resources downstream.

2. Recommendation

Maintain Alamo Lake levels between 1,100-1,200 foot msl.

	Optimum	Acceptable	Adverse
Lake level:	1,115-1,171	1,110-1,171	<1,100, >1,200
Months:	Oct. - Sept.	March - Oct.	

3. Limitations

A "bathtub ring" in the Santa Maria Arm depicts the highest historic lake levels at approximately 1,200 feet. Below this line, thick "doghair" stands of salt cedar have invaded and established, creating a solid understory in the cottonwood gallery. Above this line, natural cottonwood recruitment is occurring in the stands, and salt cedar is a minor component. Lake levels above 1,200 feet would detrimentally impact these cottonwood galleries by allowing further displacement of native cottonwood trees with non-native salt cedar.

For downstream riparian resources, minimum lake levels are provided to ensure a sufficient volume of water required to meet at least the *minimum* maintenance flows throughout the year (minimum annual volume = 32,500 ac-ft for Optimum lake level; 14,870 ac-ft. for Acceptable lake level -- see recommendations following). Lake levels ≤1,100 msl mandate maximum releases of 10 cfs. These low flows are not sufficient to sustain riparian resources during the hot Summer months. However, trees may survive these low flows during the cooler Winter months.

B. BILL WILLIAMS RIVER

1. Adverse (accept some impacts to riparian resources)

a. Purpose

This flow regime provides *minimum* base flows to minimally support riparian resources on the river. Base flows *below* this rate, including current dam operations, are considered *adverse* in supporting riparian resources in the Bill Williams River corridor, and would continue to degrade the riparian resources. The recommended flows under this scenario would not restore this corridor to a properly functioning riparian ecosystem, as they do not provide for establishing natural recruitment of native vegetation.

b. Recommendation

Table 1.

Month	No. Days	Flow (cfs/day)	Volume (total Ac Ft)
January	31	10	620
February - September	242	25	12,100
October	31	15	930
November - December	61	10	1,220
TOTAL			14,870 AF/year

c. Limitations

The 10 cfs for winter may not provide sufficient water to the refuge, unless the Planet Ranch aquifer is full. However, during winter the trees are dormant, and may not require as much water. This recommendation provides higher flows in the Summer to account for the high Summer temperatures and increased evapotranspiration, but April-August are also the heaviest times of year for pumping at Planet Ranch (Harshman, unpubl. report). Therefore, these minimum flows may not provide sufficient water to the Bill Williams National Wildlife Refuge, although resources above the ranch could still be supported.

Any flows less than those recommended under this alternative would continue to degrade the existing riparian vegetation in the Bill Williams River corridor. Continued flows over time (> 5 years) under this recommendation would still prevent natural recruitment of cottonwood and willow trees; would continue to subject mature cottonwood and willow trees to water stress; and would allow salt cedar to continue to increase in dominance along the corridor.

2. Acceptable

a. Purpose

This flow regime would provide sufficient base flows to stabilize the current riparian system as is in the Bill Williams River. Essentially, it would allow what is existing to survive, and would permit stable and predictable conditions for any (mechanical) revegetation projects. These flows would not restore this corridor to a properly functioning riparian ecosystem, as they do not provide for establishing natural recruitment of native vegetation.

b. Recommendation

Table 2.

Month	No. Days	Flow (cfs/day)	Volume (total Ac Ft)
January	31	25 - 50	1,550 - 3,100
February - April	89	40 - 500[a]	7,120 - 35,600
May - September	183	50 - 100	18,300 - 36,600
October	31	40 - 60	2,480 - 3,720
November - December	61	25 - 50	3,050 - 6,100
TOTAL			32,500 - 85,120 AF/yr

[a] Flows between 40-200 cfs can be sustained throughout the 2-month period. Flows between 200-500 cfs should be provided in short pulses of 3-5 days.

Sustaining at least the minimum releases provided in this scenario is most critical for stabilizing riparian resources in the Bill Williams River corridor. Therefore, reserving water in Alamo Lake to sustain these minimum flows during the critical release times (hot Summer months) should take priority. The upper limits provided can be flexible up to approximately 200 cfs, or 500 cfs during the early Spring (as noted in the footnote), after which conditions for innundation need to be avoided.

c. Limitations

Recommended flows in this regime may provide greater base flows than occurred historically (pre-dam) during certain times of the year. However, an artificial hydroperiod may be required to sustain the remaining riparian resources in this corridor, even in its current state of degradation Construction of Alamo and Parker Dams inundated large stands of native riparian vegetation, and significantly altered flows supporting the remaining stands in the Bill Williams River corridor. These riparian resources have continued to degrade from altered flows from Alamo Dam, pumping at Planet Ranch, and other factors. The recommended flows would partially compensate for riparian habitat losses that have occurred from the various impacts.

The ranges presented in the table are designed to provide flexibility in the dam operations for sustaining riparian resources. Using these recommendations as *guidelines* (most particularly the *minimum* flows), the Corps of Engineers would determine appropriate releases based on current (at the time of the decision) and predicted lake elevations, season, and other operational factors. The Corps would have the flexibility to revise the flows within and among months, seasons, and years based on these recommended ranges. In fact, this may be desirable for the resources to ensure sufficient water in the lake for sustained releases, to vary the water table depth (prevent a "bathtub ring"), and to minimize potential impacts to resources above Planet Ranch (e.g. soil erosion, sustained inundation of plants in the lowest floodplain or river banks) during extended flows at the high end of the range (180-500 cfs).

The minimum 25 cfs in winter allows sufficient water through Planet Ranch to the Bill Williams Refuge, when pumping at the ranch is minimal. In March, higher minimum flows are needed as temperatures start increasing, but also the system can experience higher flows and small pulse flows, as this is the usual time for Spring rains and flowering of cottonwoods. The 50-100 cfs during Summer accounts for high Summer temperatures and increased evapotranspiration in the riparian system, and extensive pumping at Planet Ranch. These figures are based on studies conducted by the Bureau of Land Management (1988), Rivers West, Inc. (1990), and the hydrology model being developed by the USFWS and University of Arizona (Harshman and Maddock, unpubl. report). The Rivers West, Inc. study for the USFWS estimated that a 35 cfs release from Alamo Dam provides flows of 18-20 cfs at the refuge gauge without pumping at Planet Ranch, and 5-10 cfs at the refuge with pumping at Planet Ranch. These figures have been supported by the USFWS model (Harshman and Maddock, unpubl. report; Harshman, unpubl. report) (see Figure 1).

Flows less than the minimums recommended under this alternative may not provide sufficient water to stabilize and maintain current riparian resources, especially with maximum pumping at Planet Ranch. Also, implementing only this recommendation over time (> 5 years) without adding sufficiently high pulse flows to stimulate cottonwood recruitment would prevent increases in diversity or acreage of cottonwood stands. As the mature trees grow older and become decadent, they would eventually be replaced by salt cedar.

3. Optimal

a. Rationale

Periodic "flood" events mimic the pattern of natural flows in the Bill Williams River before the dam. Spring floods would prepare the seed bed (through aggradation and degradation of the banks and terraces), and stimulate natural cottonwood and willow regeneration. Summer monsoon floods would scour the channel, recharge the Planet Ranch aquifer, and possibly flush salts associated with salt cedar. This semiannual pattern also provides for other natural processes adapted to these flushing flow systems that we may not know about.

This recommendation would use natural storm events in the Spring and monsoon to provide the water necessary for these large downstream flushes, with high pulse releases being timed to best benefit the key riparian species (according to their phenology). The higher base flows would take advantage of the ability of the dam to retain water for future (within the year) releases at unnatural rates or at times of the year when water would not have been available prior to the dam.

b. Purpose

This flow regime would 1) stimulate natural recruitment of cottonwood and willow trees on a periodic basis; and 2) provide sufficient base flows to maintain riparian resources on the river. Again, our subcommittee stresses that imitating the *pattern* of pre-dam flows is more important than absolute numbers (cfs) for dam releases, *as long as at least the **minimum** (maintenance) flows are being sustained.*

c. Recommendation

1. *Base flows.*-- Optimum flows for riparian resources along the Bill Williams River would combine base flows provided in the Acceptable recommendation with large "pulse" flows resulting from Spring (January-May) and Summer (August-September) storm events.

2. *Spring flows.*--During the Spring flood season, the Corps of Engineers would determine when water is considered "surplus" in Alamo Lake and in need of releasing. This determination would be based on inflow from storm events and subsequent increases in lake elevation above a target elevation. The decision to release or store water from storm events should be made in the broad context of flow patterns over previous years' storm events. For example, if large releases have not been made in several years (particularly ≥3,000 cfs), and sufficient water is available in the current year, large releases for downstream resources would be implemented. Pulse releases should be timed to best accomodate the phenology (leafing out, flowering, and growing season) of the trees, taking into consideration natural variation from year to year (generally late February to early April). The Corps could revise release schedules, as needed, within a flood season as natural storm events dictate.

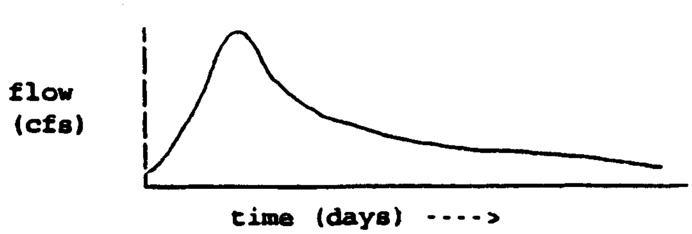
The following guidelines would be used to determine peak flows during natural Spring storm events:

Table 3.

Approx. Interval (years)[a]	Volume H_2O to Flush (000's AF)[b]	Peak Flow (cfs)	Peak Duration[c]	Recession[d]
±3	5-30	1,000-2,000	1-7 days	500->45 cfs over 6 days
±5	30-50	3,000-4,000	5-8 days	500->45 cfs over 20 days
±7	50-75	4,000-5,000	8-10 days	"
±10	75-100	6,000-7,000 (or max cfs)	10-14 days	"
>10	100+	7,000 (or max cfs)	14-30 days	"

[a] "Approximate Interval" reflects the approximate yearly interval we may be able to expect these levels of flows based on U.S. Geological Survey data from the Alamo Dam gauge during 1940-1969 (pre-dam). See Figures 1 and 2.
[b] "Volume H_2O to Flush" denotes the amount of surplus water available in Alamo Lake that the U.S. Army Corps of Engineers needs to remove from the reservoir.
[c] "Peak Duration" includes time necessary to increase flows from base flows to peak flow and return to 500 cfs at approximately 1,000-2,000 cfs per day.
[d] "Recession" refers to the back side of the peak -- that is, drawing out the decrease in flows back to base flows rather than quickly reducing flows back down to base flows (see graph below).

The general idea of this recommendation is to get flows up to the peak flow as quickly as possible (without undo hardship on downstream users), and then draw out the decrease in flows. This simulates, based on pre-dam data, the shape (hydrograph) of these Spring events in a naturally functioning desert riparian system. The hydrograph refers to the way a volume of water is released, including the increase to peak flows, duration at peak flow, and return to base flow. The desired hydrograph is to increase to peak flow as quickly as possible, hold at peak flow as long as recommended, and return slowly to base flow with drawn-out decreases in flow (recession of curve). The hypothetical hydrograph would be as follows:



Drawing out the decrease in flows prevents the water table from dropping too rapidly, which would result in higher mortality of cottonwood seedlings. Sample flow regimes for different water volumes are attached in Appendix A.

Pulse flows would be timed to the natural processes of riparian plants in the corridor, using natural storm events to supply the necessary water, rather than holding to a rigid schedule. The Corps of Engineers would determine at what volume water was considered surplus and in need of discharge.

3. ***Monsoon flows.***--Generally, the Spring events comprise storms with greater volumes of water and longer duration than the Summer monsoon events, although there are years when the Summer monsoon events are larger. Typically, monsoon storms are much flashier, of shorter duration, and lower volumes. To accommodate Fall (August-September) storm events, the following guidelines are recommended:

(a) Ensure sufficient water is stored in the system to ***maintain base flows*** until the following Spring storms, and possibly through the following Summer (in case Spring flows are extremely low). Minimum volume needed = 14,870 ac-ft. per year (see Adverse recommendation). Minimum lake level should be ≥1,110 foot msl, if the lake is to remain ≥1,100 foot msl during the year. This would be determined at the time the decision is being made on whether or not to release a Fall pulse.

(b) Provide a ***monsoon pulse*** approximately *every 3-6 years*, based on natural storm events, but a *at least every 6-7 years*.

(c) Monsoon pulses should occur in *≤7 days, with peak flows ≥1,000 cfs*. Exact peak flows and duration of flows would be determined by the Corps of Engineers, depending on the volume of water to be released. Only a short recession, if any, would be necessary for these flows.

(d) Timing of a monsoon pulse would generally occur in late August - early September, depending on the timing of natural storm events.

c. **Limitations**

The yearly intervals listed in the recommendations table represent approximate intervals of (natural) large Spring storm events based on analyses of pre-dam data (average monthly volumes) at the Alamo gauge from 1940-1969 (see Figures 2 and 3). These intervals also correspond to the timing of natural cottonwood regeneration (Stromberg et al. 1991, 1993; Stromberg 1993a). We recommend the Corps of Engineers use these natural storm events to provide various high-volume releases downstream to promote cottonwood recruitment, timing the pulses to the phenology of the plants (late February - early April). We would expect these large volume releases in approximately the same yearly intervals as suggested by the pre-dam data, but again, it would depend on the timing of natural storm events. *We do not expect these volumes to be released every year, or necessarily at exactly these yearly intervals.* In fact, high volume releases (>3,000) may not be desirable every year, as recruitment in the lower terraces from each previous year may not have a chance to establish. We do, however, request large-volume releases *at least once in every 5-10 years* to rehabilitate the downstream riparian resources. If the Corps does not take advantage of these large-volume Spring releases, cottonwoods cannot naturally regenerate, and the riparian resources downstream will continue to degrade.

The various peak releases relative to volume of water to be discharged should lead to germination sites at varying levels above the base water table, with optimum recruitment zones approximately 0.5-1.0 m above the base water table (J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93). Although at this time, the base water table is unknown for the Bill Williams River, the recommended flow patterns, including the recession, should promote natural regeneration of cottonwoods at acceptable floodplain levels.

If releases are cut off too quickly from peak flows to base flows, the water table supporting the riparian corridor would drop too quickly for cottonwood roots to keep up. This would lead to high mortality of the seedlings, which cannot tolerate a water table dropping at ≥2-3 cm per day (McBride et al. 1988, Mahoney and Rood 1991; Scott and Segelquist 1992). Not only are the flood flows necessary to lay seed beds for germination, but a slowly declining water table is necessary to sustain the seedlings (as well as saplings and mature trees). The recommended 20-day recession is an estimate, made with limited quantitative information on the rate of groundwater decline, and may need to be refined through further study.

According to the literature, the Riparian Subcommittee determined that cottonwoods (*Populus fremontii*) along the Bill Williams River may be "intermediately tolerant" to inundation (Walters et al. 1980, Kozlowski 1984, Koslowski et al. 1991). For these recommendations, we defined inundation as sustained flows ≥1,000 cfs. To prevent stress or death of cottonwoods from extremely high flows, the following guidelines are recommended when releasing ≥1,000 cfs:

Cottonwood Inundation Duration (maximum days)

Dates	Optimum	Acceptable	Adverse
November 1 - February 28	30	60	>80
March 1 - October 31	14	30	>50

Extended inundation (>50 or >80 days, depending on season) should not occur >2 years in a row.

If water must be released for >30 days during the growing season or >60 days during the non-growing season to remove surplus water, a "dry-out" period of ≤300 cfs for ≥30 days should be maintained. The high release/dry-out pattern could be repeated as much as necessary until all surplus water is released.

The monsoon releases do not need to occur every year, although they should be maintained at least every 6-7 years, according to analysis of pre-dam data (see table below). They should not occur in the same years as high Spring releases, unless natural storm events dictate so. If monsoon pulses are completely eliminated, or occur at intervals >6-7 years, many riparian plants that are adapted to these monsoon rains, such as mesquite, may suffer (B. Anderson, 1993, pers. comm.; J. Stromberg, AZ Riparian Council, letter to AGFD dated 4/21/93). These pulses are included to maintain the historic (pre-dam) pattern of flows, thereby providing for the many unknown riparian values that these southwestern riparian ecosystems are adapted to.

Fall Flow Frequencies from 1940-1969 (pre-dam)
Months = August-September
Data Source = U.S.G.S. flow data from Alamo Dam gauge (monthly averages)

Volume of Water (Ac-ft)	Frequency (n/30 yrs)	Approx. Yearly Interval
<1,000	9	<3 yrs.
1,000-2,000	9	±3 yrs.
2,000-3,000	3	±10 yrs.
3,000-5,000	2	±15 yrs.
5,000-10,000	2	±15 yrs.
>10,000	5	±6 yrs.

**All volumes >10,000 ac-ft measured >20,000 ac-ft.

C. **DAM MAINTENANCE**

The Riparian Subcommittee acknowledges the need to conduct periodic inspections of the dam approximately every 5 years. We recommend drawdown for the bulkhead occur in *April-September, with sustained flows not exceeding 300 cfs* during this time frame. This would maintain sufficient water for the riparian vegetation during the hottest time of the year. Drawdown should be particularly targeted for *June 1-September 30, maintaining flows from 45-300 cfs*, depending on the volume of water that needed to be removed from the lake. The guidelines provided under the Acceptable recommendation could be used to maintain "average" releases between 26-180 cfs. However, since no releases can be made while the bulkhead is in place, we recommend that the actual maintenance begin in *early November*, when temperatures have dropped sufficiently to lower evapotranspiration stress on the trees. Thus, the trees should survive better in the cooler temperatures (and approaching dormancy) with no flows from the dam supporting them.

Maintaining flows at 300 cfs for June-September would flush approximately 73,200 acre-feet from the reservoir. Maintaining flows at 300 cfs for April-September would flush approximately 109,800 acre-feet of water from the reservoir. If >100,000 acre-feet of water needed to be flushed from the reservoir for this maintenance, a pulse in March or April accommodating the excess volume should be provided, then flows should be dropped to 300 cfs for the remainder of the Summer. The peak flow and duration of the pulse should follow the guidelines provided in the "Optimum" recommendation for Spring pulses, extending the recession as long as necessary to remove the water.

D. MONITORING

A *long-term, repeatable* monitoring system should be developed to provide information on the success of the final flow regimes in meeting the resource objectives. Future feedback through monitoring should be used to refine water management prescriptions and flow regimes. The approved final flow regimes should be flexible enough to revise as needed based on resource results. Monitoring methods should include:

1. Establishing *gauges* (including the current Refuge gauge, and others as needed) to monitor downstream flow and groundwater;
2. Monitoring acreage and structural diversity of riparian vegetation with low-elevation (approx. 3,000 ft AGL or ≤1" = 800') *aerial photographs, photo points, and permanent transects* at least every 3 years;
3. Establishing *permanent cross sections* to monitor channel morphology and sediment depletion, aggradation, and degradation;
4. Monitoring *depth to ground water and percent soil moisture* during different releases;
5. Determining *groundwater discharge rates* for the Bill Williams River;
6. Monitoring *plant condition and stress* in low and high water situations, using fluorescence, growth measurements, and other established techniques;
7. Verify the *timing of flowering and seed dispersal* in cottonwoods in this system, including the degree of variation in these processes associated with annual variations in precipitation; and
8. Determining *inundation periods* for cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) trees in the arid southwest. Data are available for the genera *Populus* and *Salix* from more mesic environments, but little hard data is available on these species in highly arid locales.

Several methods and sources could be used to monitor the riparian system. Local agency (BLM, AGFD, BOR, and USFWS) personnel could use established inventory techniques (e.g. AZ Riparian Inventory, Ecological Site Inventory, etc.) to determine "baseline" data, and monitoring would occur during regular, pre-determined intervals thereafter (min. 3-5 years). In addition, graduate students, senior wildlife students, SCA volunteers, or the Water Research Institute may be available to conduct studies along the Bill Williams River, through grants or contracts from the managing agencies. The primary researcher would depend on the technical expertise needed for each research or monitoring project. The agency (or agencies) letting each contract or grant would be responsible for ensuring adequate results from the research project. Monitoring would occur at key areas along the entire river length (e.g. Banded Canyon, Lincoln Ranch, Pitrat Ranch, Planet Ranch, and the Refuge), with inherent flexibility to modify key areas as natural recruitment sites dictate.

E. RESOURCE OUTCOMES

The following outcomes are expected for riparian resources if the Optimum recommendations are implemented:

1. Maintain current acreage of riparian vegetation, particularly cottonwood-willow stands (although stands may not necessarily always be located in the same place, due to the dynamic nature of riparian ecosystems);
2. Promote natural regeneration of cottonwood and willow, thereby increasing acreage and structural diversity (natural age class and size distributions) of cottonwood-willow stands;
3. Provide for aquifer recharge and channel maintenance to support riparian resources at various floodplain levels; and
4. Provide for vegetation species keyed to monsoon flows.

F. BENEFITS

1. Natural cottonwood and willow regeneration will maintain existing stands and expand acreage and structural diversity of riparian vegetation
2. Channel restoration and maintenance
3. Recharge of Planet Ranch aquifer
4. Reduced fire hazard by increasing fuel moisture and humidity
5. Potentially reduced salt cedar encroachment
6. Structurally diverse cottonwood-willow gallery forests
7. Improved habitat for wildlife (especially neotropical migrants)
8. Regular flushing of salts associated with salt cedar
9. Aesthetically better recreation experience
10. Restoration of a self-sustaining, *dynamic* system
11. Provide a physical setting for artificial restoration/revegetation efforts

G. ADVERSE IMPACTS

1. Possible undesirable lake level fluctuations
2. Damage to access and utility facilities
3. Flooding of some farms may occur with high flows
4. Some wetland/marshes may be altered
5. During extended drought periods, riparian resources downstream may need to temporarily pre-empt reservoir resources
6. Construction of Alamo Dam has left the Bill Williams River corridor without a system for replacing sediments. Erosion of sediments without replacement has occurred since operation of the dam began, and will continue no matter what operational tactics are used. Recommending flushing flows higher than those previously released from the dam may accelerate erosion in some locations, particularly the Banded Canyon (immediately below the dam). Conversely, sites downstream from the canyon may not be in such a predicament Prior to the dam, flows through the Bill Williams River reached ≥25,000 cfs during some storm events. These flows, depending on duration, likely scoured large amounts of sediment in the Bill Williams River corridor. Because the releases from the dam cannot exceed 7,000 cfs, some down-canyon sites may actually be experiencing a <u>reduction</u> in sediment loss from these reduced flows. The hydrologic basin under Planet Ranch may also buffer scouring and sediment loss in the Refuge as it buffers downstream flows. Monitoring

channel morphology, particularly the Banded Canyon, will be important as these recommendations are implemented to assess the impacts these flows have on sediment loss.

H. OPERATIONAL CONSTRAINTS

The following operational constraints for Alamo Dam were identified within the riparian resources recommendations:

1. No instantaneous releases between approximately 70-150 cfs due to structure of dam gates
2. Minimum lake level at 1,100 foot msl for bald eagles
3. Need to try to maintain lake level within water conservation pool (≤1,172 foot msl)
4. No discharges >7,000 cfs, unless the dam is modified
5. No storage of water within the reservoir for >1 year
6. Required inspection and maintenance approximately every 5 years
7. For large releases (>1,000 cfs), increases in releases to peak flows should be ≤1,000 cfs per day to reduce downstream property damage and maintain public safety (J. Evelyn, U.S. Army Corps of Engineers, pers. comm.)

All operational constraints were incorporated into the riparian resource recommendations.

IV. <u>INFORMATION NEEDS AND DEFICIENCIES</u>

A. For informed recommendations:

1. With no inflows into the Planet Ranch aquifer, how long can an outflow (into the Refuge) be maintained (assuming the aquifer is full to begin with)? Without pumping at Planet Ranch? With pumping at Planet Ranch?

2. Lag time between dam release and downstream effects/flow (e.g. If you release water from the dam on Day 1, how long does it take for the water to reach the Pitrat Ranch? Planet Ranch? The Refuge?).

3. What does a release at the dam mean at select downstream points (e.g. If you release 25 cfs from the dam, what is the flow at Pitrat Ranch? Above Planet Ranch? At the Refuge gauging station?)?

4. How far in advance does the Corps of Engineers know about their exact maintenance schedules? How much flexibility is there in when they are scheduled?

**Questions #1-3 may be answered at least in part by the hydrology model being developed by the USFWS and University of Arizona.

B. Monitoring and future research needs

As identified in the Monitoring section of the recommendations, the following research and monitoring efforts are needed to better understand riparian resources along the Bill Williams River corridor:

1. Are we meeting the minimum needs of the resources?
2. Is there excess water in the system (downstream? in the lake?) from our flow regimes?
3. Monitor channel morphology, soil moisture, and riparian vegetation (area, structural diversity, and plant condition) changes based on our flows.
4. Research the relationship between adequate soil moisture, ground water, and surface flow in this system. Determine groundwater discharge relationship using aerial photographs taken during various dam releases (known available = 1987, 300 cfs; 1993, 1500 cfs, 1993, 7000 cfs), and other appropriate techniques (**This is an important one**).
5. Determine the inundation tolerance of cottonwood, willow, and possibly salt cedar trees in the Bill Williams River corridor (**This is also an important one**).
6. Is there a way to pass sediments from above the dam to the system below the dam to reduce sediment deficiency in the long term?

Use this resource information to evaluate the success of the flow regimes and, if necessary, to modify the dam operations/releases. This is to ensure that we (as management agencies) are meeting the resource objectives agreed upon by the Technical Committee, subcommittees, and agencies.

V. ISSUES, CONCERNS, AND OPPORTUNITIES

The Riparian Subcommittee believes the Technical Committee has an opportunity to restore valuable riparian resources within the Bill Williams River corridor. Although during some extreme years, the reservoir resources may have to suffer at the expense of the downstream resources, we believe this is an acceptable trade-off, considering the amount of degradation that has occurred in the riparian corridor during the last 20 years. We view it as a type of mitigation for the riparian resources that have been lost or severely impacted since the dam was constructed and efforts began focusing on reservoir opportunities.

Because of the extent of the degradation, it may take a few "cycles" of these recommendations to bring the system back into some resemblance of a properly functioning riparian ecosystem. Any perceived losses or detrimental impacts will be offset by the benefits of natural recruitment of cottonwoods, higher water tables and recharge of the aquifer, channel scouring and maintenance, and a healthier, dynamic riparian ecosystem. Using varying peak flows ranging from 1,000-7,000 cfs should promote regeneration at various levels within the floodplain. Under sustained low flows, recruitment occurs in the river channel and gets wiped out with the subsequent year's floods. With only the highest flows, recruitment occurs in the highest floodplains that quickly dry up with a (rapidly) receding water table. Observations from the high flows of Winter 1993 indicate the river channel can sustain the 7,000 cfs flows without undue degradation of the resources, and that, in fact, these high flows actually benefitted the downstream resources. Combining the high flows with retaining a higher water table should provide positive results in a relatively short time frame.

Our subcommittee was concerned that the final flow regimes agreed upon by the Technical Committee would be "set in stone", regardless of the resulting impacts to the resources at Alamo Lake and the Bill Williams River. We did not want to the see the recommendations to the Corps of Engineers for operating the dam to be absolute, especially as these flows are, for the most part, predicted ranges of what will be good for the resources. *The pattern of the flows is more important than the actual numbers, as long as at least the* ***minimum*** *(maintenance) flows are being sustained.* The recommended minimim flows (cfs) are most critical for stabilizing the riparian corridor, and maintaining the riparian resources in the longterm. We realize flow schedules such as those we recommended will require greater coordination and flexibility in how the dam is operated. However, we believe these flows are necessary to stabilize and improve the valuable riparian resources that have been so heavily impacted in past years.

Flushing flows should be timed to the natural processes of the riparian plants, using natural storm events to provide the water, rather than holding to a rigid schedule. For example, the excessive rain we had in January-February 1993 caused the trees to leaf out in early February, rather than March. Not only did they break dormancy early, they also flowered early. Flushing flows should be timed to account for these natural variations. We hope the Corps of Engineers understands the flexibility inherent in our recommendations, provided the minimum flows are maintained.

Along with this, our subcommittee emphasized monitoring the resources, after the system has been implemented, to evaluate the success of our recommendations. We felt a strong need for some flexibility in the dam operations to modify flows, if necessary, as indicated by the changes in the resources.

VI. REFERENCES AND DATA SOURCES

Anderson, B.W. and R.D. Ohmart. 1984. Vegetation Management Study for the Enhancement of Wildlife along the Lower Colorado River. For U.S. Bureau of Reclamation, Lower Colorado River Region, Boulder City, NV (Contract No. 7-07-30-V009).

Busch, D.E., N. L. Ingraham, and S.D. Smith. 1992. Water uptake in woody riparian phreatophytes of the southwestern United States: A stable isotope study. Ecological Applications 2(4):450-459.

Busch, D.E. and S.D. Smith. 1993. Effects of fire on water and salinity relations of riparian woody taxa. Oecologia 94:186-194.

Fenner, P., W.W. Brady, and D.R. Patton. 1985. Effects of regulated water flows on regeneration of Fremont cottonwood. Journal of Range Management 38:135-138.

Harshman, C. Unpublished Report. Interim Report Detailing the Model Simulation of the Bill Williams River, August 1993. 6 pp.

Harshman, C. and T. Maddock. Unpublished Report. Quarterly update on the finite groundwater model of the Bill Williams River being developed at the University of Arizona, May 1992. 4 pp.

Hunter, W.C., B.W. Anderson, and R.D. Ohmart. 1987. Avian community structure changes in a mature floodplain forest after extensive flooding. Journal of Wildlife Management 51:495-502.

Kozlowski, T.T. 1984. Response of woody plants to flooding. Pages 129-164 *in* T.T. Kozlowski (ed.) Flooding and Plant Growth. Academic Press, Orlando, Florida.

Kozlowski, T.T., P.J. Kramer, and S.G. Pallardy. 1991. The Physiological Ecology of Woody Plants. Academic Press, San Diego, California.

Mahoney, J.M. and S.B. Rood. 1991. A device for studying the influence of declining water table on poplar growth and survival. Tree Physiology 8:305-314.

McBride, J.R., N. Sugihara, and E. Nordberg. 1988. Growth and survival of three riparian woodland species in relation to simulated water table dynamics. Unpublished report to Pacific Gas and Electric Co., San Ramon, California.

Rivers West, Inc. and Water and Environmental Systems Technology, Inc. 1990. Water Resources Assessment: Bill Williams Unit, Havasu National Wildlife Refuge, Final Report. For U.S. Fish and Wildlife Service, Region 2, Albuquerque, NM.

Scott, M.L. and C.A. Segelquist. 1992. Establishment and growth of Plains cottonwood under varying rates of groundwater decline. Abstracts, Society of Wetland Scientists, New Orleans, Louisiana.

Stromberg, J.C., D.T. Patten, and B.D. Richter. 1991. Flood flows and dynamics of Sonoran riparian forests. Rivers 2:221-235.

Stromberg, J.C., B.D. Richter, D.T. Patten, and L.G. Wolden. 1993. Response of a Sonoran riparian forest to a 10-year return flood. Great Basin Naturalist: in press.

Stromberg, J.C. 1993a. Dynamics of Fremont cottonwood (*Populus fremontii*) along Sonoita Creek. Unpublished report to the Arizona Nature Conservancy, Tucson, AZ.

Stromberg, J.C. 1993b. Fremont cottonwood-Goodding willow riparian forests: A review of their ecology, threats, and recovery potential. Journal of the Arizona-Nevada Academy of Science: in press.

U.S. Army Corps of Engineers. 1990. Alamo Lake, Arizona Reconnaissance Study, Final Report. U.S. Army Corps of Engineers, Los Angeles District, Planning Division, Water Resources Branch, CA.

U.S. Bureau of Land Management. 1988. Assessment of Water Resource Conditions in Support of Instream Flow Water Rights, Bill Williams River, Arizona. Bureau of Land Management, Phoenix District, AZ.

U. S. Bureau of Land Management. 1989. Bill Williams River Riparian Management Area Plan. Bureau of Land Management, Yuma District and Phoenix District, AZ.

U.S. Geological Survey. Arizona Hydrological Data Base for historical water discharge at Alamo Dam gauging station - mean monthly flows (1940-1992).

U.S. Geological Survey. Water discharge record for Bill Williams Refuge gauging station below Planet Ranch - mean daily flows (October 1991 - July 1992).

Walters, M.A., R.O. Teskey, and T.M. Hinckley. 1980. Impact of water level changes on woody riparian and wetland communities, Vol. VII, Mediterranean Region, Western Arid and Semi-arid Region. U.S. Fish and Wildlife Service report FWS/OBS-78/93. Kearneysville, West Virginia.

APPENDIX A

Spring Flow Recommendations:
Sample Calculations

APPENDIX A

Spring Flow Recommendations: Sample Calculations

Table 3 (see page 8). Recommendations for release of surplus water during Spring (January-May) storm events.

AF to flush	Peak Flow (cfs)	(includes stepping up & down) Peak Duration	Recession
5-30k	1,000-2,000	1-7 days	500->45 cfs over 6 days
30-50k	3,000-4,000	5-8 days	500->45 cfs over 20 days
50-75k	4,000-5,000	8-10 days	"
75-100k	6,000-7,000 (or max cfs)	10-14 days	"
100k+	7,000 (or max cfs)	14-30 days	"

Table A-1. Volume of water needed for recession (back side of hydrograph), using the conversion factor of 1 cfs/day = 2 ac-ft.

1 cfs/day = 2 ac-ft

Long recession:

Flow (cfs)	No. days	Ac-Ft
500	1	1,000
480	1	960
460	1	920
440	1	880
420	1	840
400	1	800
380	1	760
360	1	720
340	1	680
320	1	640
300	1	600
280	1	560
260	1	520
240	1	480
220	1	440
200	1	400
180	1	360
160	1	320
150	1	300
50	1	100
TOTAL:	20	12,280 AF

Short recession:

Flow (cfs)	No. days	Ac-Ft
500	1	1,000
400	1	800
300	1	600
200	1	400
150	1	300
50	1	100
TOTAL:	6	3,200 AF

The following tables (A-2 through A-6) illustrate sample flow regimes for flushing various volumes of water according to the guidelines provided above. They are not meant to be "written in stone" release patterns, only *examples* on how to implement the guidelines. These estimated volumes of water do not account for the effects of evaporation.

Table A-2. 5-30k to release, peak flow 1,000-2,000 cfs, short recession.

Sample Calculation #1a:

Flow (cfs)	No. days	Ac-Ft	
1,000	1	2,000	
(then begin recession)	1 day	2,000 AF	
		+ 3,200 AF	(recession)
		5,200 AF	

Sample Calculation #1b:

Flow (cfs)	No. days	Ac-Ft	
1000	1	2,000	
2000	2	8,000	
1000	1	2,000	
(then begin recession)	4 days	12,000 AF	
		+ 3,200 AF	(recession)
		15,200 AF	

Sample Calculation #1c:

Flow (cfs)	No. days	Ac-Ft	
1000	1	2,000	
2000	5	20,000	
1000	1	2,000	
(then begin recession)	7 days	24,000 AF	
		+ 3,200 AF	(recession)
		27,200 AF	

Table A-3. 30-50k to release, peak flow 3,000-4,000 cfs, long recession.

Sample Calculation #2a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	5 days	18,000 AF
		+ 12,280 AF (recession)
		30,280 AF

Sample Calculation #2b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	4	24,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	36,000 AF
		+ 12,280 AF (recession)
		48,280 AF

Sample Calculation #2c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	7 days	32,000 AF
		+ 12,280 AF (recession)
		44,280 AF

Appendix A (continued)

Table A-4. 50-75k to release, peak flow 5,000 cfs, long recession.

Sample Calculation #3a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	2	16,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	40,000 AF
		+ 12,280 AF (recession)
		52,280 AF

Sample Calculation #3b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	8 days	50,000 AF
		+ 12,280 AF (recession)
		62,280 AF

Sample Calculation #3c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	2	20,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	10 days	60,000 AF
		+ 12,280 AF (recession)
		72,280 AF

Appendix A (continued)

Table A-5. 75-100k to release, peak flow 6,000-7,000 cfs, long recession.

Sample Calculation #4a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	10 days	64,000 AF
		+ 12,280 AF (recession)
		76,280 AF

Sample Calculation #4b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	72,000 AF
		+ 12,280 AF (recession)
		84,280 AF

Sample Calculation #4c:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
7,000	1	14,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	78,000 AF
		+ 12,280 AF (recession)
		90,280 AF

Table A-6. 100k+ to release, peak flow 7,000 cfs, long recession.

Sample Calculation #5a:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
4,000	1	8,000
5,000	1	10,000
6,000	1	12,000
7,000	1	14,000
6,000	1	12,000
5,000	1	10,000
4,000	1	8,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	11 days	98,000 AF
		+ 12,280 AF (recession)
		110,280 AF

Sample Calculation #5b:

Flow (cfs)	No. days	Ac-Ft
1,000	1	2,000
2,000	1	4,000
3,000	1	6,000
5,000	1	10,000
7,000	6	84,000
5,000	1	10,000
3,000	1	6,000
2,000	1	4,000
1,000	1	2,000
(then begin recession)	14 days	128,000 AF
		+ 12,280 AF (recession)
		140,280 AF