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INUNDATION AND SUBSTRATE STABILITY STUDY TO SUPPORT VERDE RIVER VEGETATION ANALYSIS

Prepared for:

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(8.6–year RI), and (4) chute channels that are inundated at about 16,000 cfs. The slope of the river at the site is 0.0027, and the median (D_{50}) sizes of the sediments that comprise the main channel, low bars, high bars, and chute channels are 81, 73, 73, and 73 mm, respectively. The critical discharge (discharge at which sediment begins to be mobilized) in the main channel, the edges of which support a fringe of riparian vegetation, ranges from 4,600 to 28,000 cfs, which has corresponding RI of 1.3 to 3.5 years. Significant bed mobilization occurs at a range of discharges between 10,000 and 60,000 cfs (1.6 to 7-year RI). The critical discharge range for the low bar surfaces that tend to be associated with the riparian vegetation is 35,000 to 60,000 cfs (4 to 7-year RI), and significant sediment mobilization occurs at a range of discharges between 50,000 and 110,000 cfs (6 to >30-year RI). The critical discharge range for the high bar surfaces that tend to be associated with mesquite and other non-riparian vegetation species, is about 170,000 cfs (>50-year RI), and significant sediment mobilization occurs at discharges of >200,000 cfs (>100-year RI). The chute channel that extends for much of the length of the site is inundated at about 16,000 cfs, but because of the presence of very coarse bed material, the critical discharge and significant sediment mobilization occur at flows in excess of 200,000 cfs. Frequent flows within the chute channel remove any fine sediment.

Review of the time-sequential aerial photographs of the site confirms the findings of the hydraulic and sediment-transport analyses. Between large floods, vegetation tends to establish on the lower bar surfaces, but the vegetation is stripped off during large floods. The high bar surfaces tend to remain vegetated even when there have been large floods because the flow depths, and therefore, shear stresses are low.

6.1.2. Site 2: Downstream of Horseshoe Dam Near the KA Ranch

Site 2 is located about two miles downstream of Horseshoe Dam near the KA Ranch (Figure 1.1). The site is located within a wider reach of the Verde River valley that is controlled at the downstream end by a narrower valley constriction. The downstream constriction, and the locally wider reach of the valley that is confined between old alluvial fans to the west and Tertiary-age basin-fill sediments to the east, has created a net depositional reach of the river that has a braided planform. Davenport Wash on the east, and a large unnamed arroyo on the west, episodically deliver sediment to the reach, and this sediment at least partially compensates for the loss of the upstream sediment supply. Sedimentation rates in Horseshoe Reservoir (Table 5.2) suggest that the Verde River transports significantly less sediment than many other rivers in the southwestern US, and this may explain why there have been few reservoir-related morphological changes to the river below the dam.

Within the site, the following geomorphic surfaces were identified: (1) main channel with a capacity of about 20,000 cfs (4-year RI), (2) low bar surfaces inundated at flows between 10,000 and 20,000 cfs (2.5- to 4-year RI), (3) high bar surfaces inundated at about 55,000 cfs (10-year RI), and (4) chute channels that are inundated at flows between 30,000 and 55,000 cfs (6 to 10-year RI). If the Tangle Creek gage flood frequencies, which are representative of the pre-dam hydrology at all three study sites, are applied to the discharges that are associated with the geomorphic surfaces at Site 2, they are very similar to those at Site 1, which indicates that there has been little, if any, morphological adjustment of the Horseshoe and Bartlett Dams. The differences in the associated flow frequencies are due to the changes in hydrology.

The slope of the river at the site is 0.0047, and the median (D_{50}) sizes of the sediments that comprise the main channel, low bars, high bars, and chute channels are 146, 73, 105 and 105 mm, respectively, which are somewhat coarser than those at Site 1, probably because of the steeper slope and local delivery of sediment by both Davenport Wash and the unnamed arroyo.

The critical discharge in the main channel, the edges of which support a fringe of riparian vegetation, ranges from 2,400 to 55,000 cfs which have corresponding RI's of 1.1 to 10 years. Significant bed mobilization occurs at a range of discharges between 3,200 and 120,000 cfs (1.3 to >57-year RI). The critical discharge range for the low bar surfaces that tend to be associated with the riparian vegetation is 32,000 to 50,000 cfs (6- to 8-year RI), and significant sediment mobilization occurs at a range of discharges between 42,000 and 170,000 cfs (7 to >57-year RI). The RI's of the critical discharges and discharges for substantial sediment transport in the main channel and low bars from the Tangle Creek (i.e., pre-dam) flood-frequency curve are similar to those at Site 1, further indicating that there has been little, if any, morphologic adjustment of the channel between Horseshoe and Bartlett Dams. The critical discharge range for the high bar surfaces that tend to be associated with mesquite and other non-riparian vegetation species is above 200,000 cfs. The critical discharges for the chute channels that are located primarily in the downstream portions of the site, are between 120,000 and 170,000 cfs (>50-year RI), and significant sediment transport occurs at flows in excess of 200,000 cfs.

Review of the time-sequential aerial photographs of the site confirms the findings of the hydraulic and sediment-transport analyses. Between large floods, vegetation tends to establish on the lower bar surfaces, but the vegetation is stripped off during large floods. The high bar surfaces tend to remain vegetated even when there have been large floods because the flow depths, and therefore, shear stresses are low. Chute channels are formed during the infrequent large floods and remain stable for long periods of time. They appear to be the preferred sites for cottonwood establishment following the large infrequent floods.

6.1.3. Site 3: Downstream of Bartlett Dam near the Box Bar Ranch

Site 3 is located about 6.5 miles downstream of Bartlett Dam near the Box Bar Ranch (Figure 1.1). The site is located within a much wider reach of the Verde River valley that is located upstream of a narrower valley constriction that makes Site 3 a net depositional area. The braided river is confined between heavily vegetated alluvial terraces to the east and alluvial terraces and old, relatively erosion-resistant, alluvial deposits to the west, and there is no well-developed floodplain. The younger flanking terraces are inundated by large infrequent flows (Skotnicki, 1996).

Within the site, the following geomorphic surfaces were identified: (1) main channel with a capacity of about 20,000 cfs (8.4-year RI), (2) low bar surfaces inundated at flows between 10,000 and 20,000 cfs (4.8 to 8.4-year RI), (3) high bar surfaces inundated at about 50,000 cfs (12-year RI), and 4) chute channels that are inundated at flows between 10,000 and 50,000 cfs (4.8 to 12-year RI). If the Tangle Creek (i.e., pre-dam) flood frequencies are applied to the discharges that are associated with the geomorphic surfaces at Site 3, they are very similar to those at Site 1, which indicates that there has been little, if any, morphological adjustment of the channel downstream of both dams. The differences in the associated flow frequencies are due to the changes in hydrology.

The slope of the river at the site is 0.0023, and the median (D_{50}) sizes of the sediments that comprise the main channel, low bars, high bars, and chute channels are 95, 61, 61 and 61 mm, respectively, which are somewhat finer than those at Site 2, probably because of the flatter slope. The critical discharge in the main channel, the edges of which support a fringe of riparian vegetation, ranges from 2,200 to 16,000 cfs, which have corresponding RI's of 1.9 to 7.7 years. Significant bed mobilization occurs at a range of discharges between 5,000 and 90,000 cfs (3.5 to 22-year RI). The critical discharge range for the low bar surfaces that tend to be associated with the riparian vegetation is 20,000 to 100,000 cfs (8.4 to >50-year RI), and significant sediment mobilization occurs at a range of discharges between 40,000 and 190,000 cfs (9 to >57-year RI). The RI's of the critical discharge and discharge for substantial sediment transport in the main channel and low bars from the Tangle Creek (i.e., pre-dam) flood-frequency curves are similar to those at Site 1, further indicating that there has been little, if ay, morphologic adjustment of the channel downstream from both dams. The critical discharge range for the high bar surfaces that tend to be associated with mesquite and other non-riparian vegetation species, is about 160,000 cfs, but significant sediment transport does not occur at flows under 200,000 cfs. The critical discharges for the chute channels that are located primarily in the downstream portions of the site, are between 40,000 and 180,000 cfs (9 to >50-year RI), and significant sediment transport occurs at flows between 55,000 and 150,000 cfs (13 to >50-year RI).

The vegetation and morphological changes that were observed on the time-sequential aerial photography may be related to the effects of the upstream dam on the frequency of morphogenetically significant events (Figure 2. 7), as well as by the fact that the earlier part of the 20th century was wetter than the later part. Prior to construction of Bartlett Dam, inundation of portions of the younger Lehi terrace probably occurred with a frequency of about 2.5 to 3 years at a discharge of about 20,000 cfs. In the post-Bartlett period, the same flow has a recurrence interval of about 7 years. Review of the flow records at the Bartlett gage indicates that between 1942 and 1965 the largest peak flow was less than 10,000 cfs. The aerial photography shows that vegetation became well established during this 23-year period in areas of the site that were obviously disturbed in the 1934 photographs. In contrast, at the Tangle Creek gage, there were six floods in excess of 20,000 cfs in the same time period. Between 1965 and 1977, there were no flows in excess of 15,000 cfs below Bartlett Dam. Cumulatively, the three floods of 1978, 1979 and 1980 caused significant morphological and vegetation changes at the site, but these flood magnitudes ranged between 75,800 and 101,000 cfs (15 to 50-year RI). Hydraulic modeling of the site indicates that, at a discharge of 100,000 cfs, about 20 percent of the total flow is being conveyed in the left overbank area and this magnitude of flow is, therefore, capable of effecting change. In contrast, at a discharge of 50,000 cfs, less than 10 percent of the total flow is being conveyed in the left overbank area, and hence there is a much lower potential to effect change. The large floods of the late 1970s were again followed by a period of 12 years (1981 through 1992) when the maximum flow was less than 17,000 cfs below Bartlett Dam, but six events exceeded 20,000 cfs at the upstream gage in the same time period. The 1993 (84,700 cfs) and 1995 (64,100 cfs) floods with RI's of 11 and 18 years, respectively, caused very little change in the left overbank area at the site, probably because of the extent of the vegetation that has become established since the dam was constructed due to the infrequent disturbance of the site in the post-dam period.

6.2. Conclusions

This study was conducted to determine whether re-operation of the dams could significantly improve conditions for establishment and maintenance of woody riparian vegetation. The following general conclusions can be drawn from the results of the investigation:

1. The magnitudes of the discharges that inundate the channels and bars, and that mobilize the sediments that comprise these geomorphic features at all of the sites are similar, which indicates that there has been little, if any, morphological or sedimentological adjustment of the Verde River in response to the dams.

2. The reduced frequencies of inundation of the channels and bars, and mobilization of their constituent sediments downstream of the dams are due to the changes in hydrology imposed by the dams. Because of the smaller capacity of Horseshoe Reservoir, the frequency reductions at Site 2 are less than those at Site 3 that is located below Bartlett Reservoir and has a much larger storage capacity.

3. Reduction in the frequency of morphogenetically significant events below Bartlett Dam has enabled primarily mesquite vegetation to become better established in the left overbank area, and this reduces the erodibility of the low terrace during the less frequent, higher magnitude events that are not significantly affected by the upstream dams.

4. The reservoir re-operation scenarios that were considered in this analysis would have an insignificant effect on the frequency and duration at which geomorphic surfaces along the margins of the Verde River are inundated and mobilized. These processes are part of the disturbance regime that is important for establishing and maintaining riparian vegetation; thus, implementation of the scenarios would also have an insignificant effect on the health of the riparian corridor.

5. Comparison of the below Bartlett Dam flow-duration curve with the Tangle Creek gage flow-duration curve (Figure 3.6) shows that the durations of flows in the 200- to 1,400-cfs range have been increased by the dams, and these increased flows occur during the May through October period (Figure 3.7). The increased flows may well be responsible for supporting the relatively low-elevation channel margin riparian vegetation (Appendix A).