# ESTIMATING CHANGES IN RIPARIAN AND CHANNEL FEATURES ALONG THE TRINITY RIVER DOWNSTREAM OF LEWISTON DAM, CALIFORNIA, 1980 TO 2011

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**Abstract:** The Trinity River Restoration Program, one of the nation's largest adaptively managed river restoration programs, requires periodic assessments to determine the effectiveness of management actions in restoring channel dynamics and habitat features. This study documents the evolution of the intensively managed 65-km restoration reach downstream of Lewiston Dam, California during the period spanning 1980 to 2011. The nature and extent of riparian and channel changes were characterized using a series of geomorphic feature maps constructed from orthorectified photography acquired at low flow conditions in 1980, 1997, 2001, 2006, 2009, and 2011. Since 1980 there has been a general conversion of riparian to channel features and expansion of the active channel area. The primary mechanism for expansion of the active channel area was bank erosion from 1980 to 1997 with channel widening being well distributed longitudinally throughout the study reach. The primary period of bar accretion occurred from 1997 to 2001 and was followed by slightly higher rates of bar scour from 2001 to 2006. In comparison, post-2006 bank and bar changes were spatially limited to reaches with sufficient local transport capacity or sediment supply supported by gravel augmentation, mechanical channel rehabilitation, and tributary contributions to flow and sediment supply. A series of tributary floods in 1997, 1998 and 2006 were the primary factors leading to documented increases in channel complexity and floodplain connectivity. During the post-2006 period managed flow releases, gravel augmentation and mechanical restoration caused localized increases in sediment supply and transport capacity, which led to small but measurable increases in channel complexity and floodplain connectivity. Significant channel widening and muted geomorphic response of channel rehabilitation sites to post-2006 management highlights the need for continued monitoring and assessment of the magnitude, duration, and timing of prescriptive gravel augmentation, flow releases, and associated geomorphic objectives.

## INTRODUCTION

Completion of the Trinity River Diversion in 1964 enabled the transfer of 75 to 90 percent of the upper Trinity River flows into the upper Sacramento River. Subsequent declines in salmon and steelhead populations prompted a series of studies (Trinity River Taskforce, 1970; USFWS, 1980; USFWS and HVT, 1999) that culminated in the Record of Decision (USDOI, 2000) and organization of the multi-agency Trinity River Restoration Program (TRRP). The Record of Decision (ROD) authorized management actions to restore salmon and steelhead populations to pre-dam levels downstream of Lewiston Dam, California. The TRRP, a collaborative partnership, is responsible for implementing ROD-mandated restoration and adaptive management for one of the largest river restoration programs in the nation.

The Trinity River is the largest tributary to Northern California's Klamath River. The study reach extends 65 kilometers along the upper main stem from Lewiston Dam downstream to the confluence with the North Fork Trinity River (Figure 1). The restoration reach is a partially confined gravel-bed river with a nearly constant bedrock-controlled slope of 0.002. The channel pattern is primarily single-thread and the dominant channel type is pool-riffle with intermittent

plane-bed and bedrock-controlled canyon reaches. Restoration efforts began in the 1970s and included: construction of spawning beds, side channels and channel complexity features, as well as riparian berm removal and re-contouring of channel margins, pool dredging, bridge replacement, installation of engineered log dams, and prescriptive gravel augmentation and flow releases.

The goal of this study was to quantify ecologically significant measures of geomorphic change, relevant to Trinity River fisheries restoration, and to evaluate the cumulative effects of natural and managed drivers of change during the period spanning 1980 to 2011.

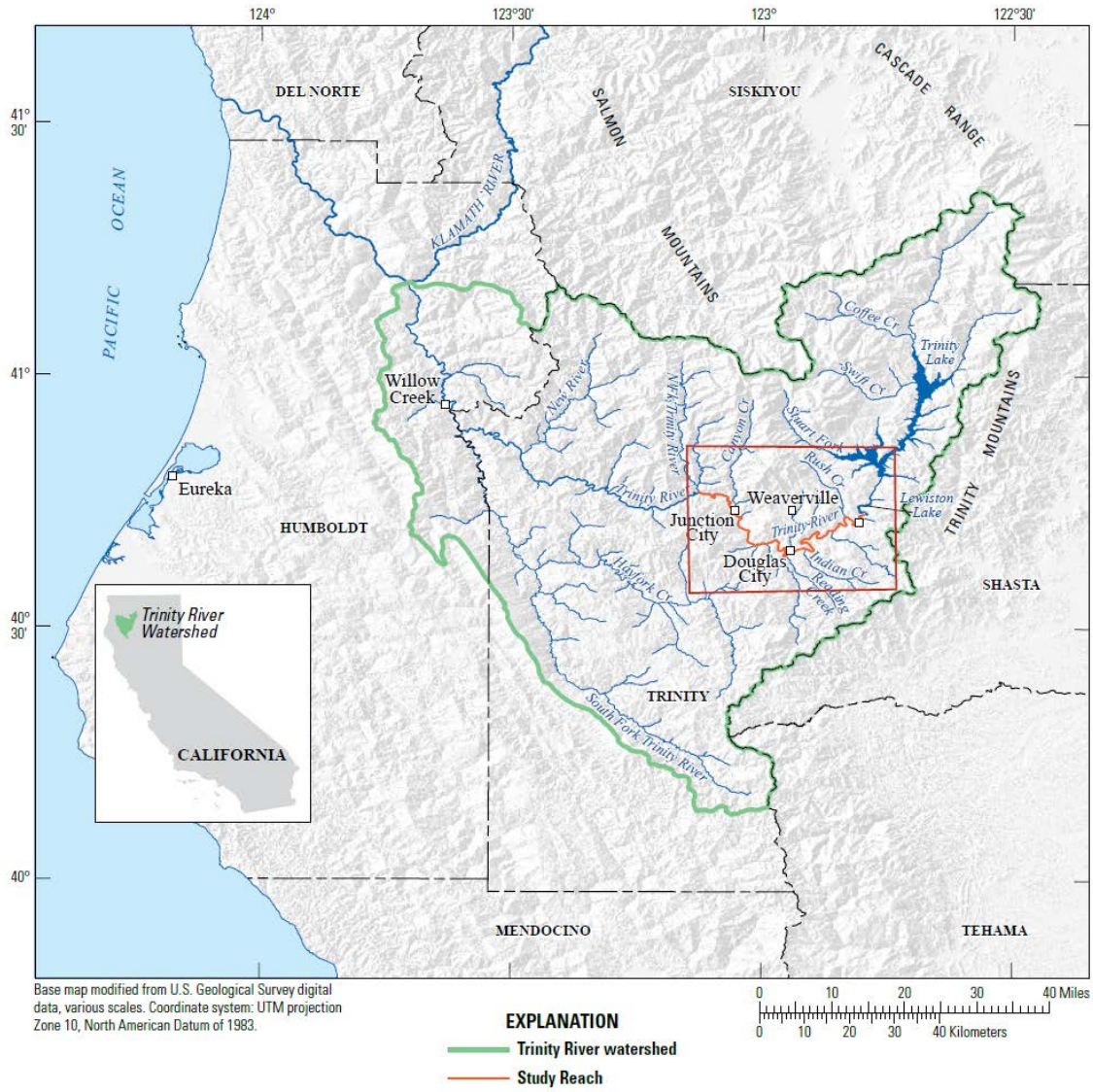


Figure 1. Map showing study area with the 65-km study reach shown in red located along the Trinity River downstream of Lewiston Dam, California.

## METHODS

Six discrete geomorphic maps were created from rectified orthophotographs (1980, 1997, 2001, 2006, 2009, and 2011). Riparian and channel features larger than 30 $m^2$ were digitized at a scale of 1:1,000 into an ARCMap (v.10.0) geodatabase (Curtis and Guerrero, pending approval). Channel features included: the primary baseflow wetted channel, secondary water features (alcoves, wetlands, side-channels and split-flow channels), active and stable alluvial bars, and bedrock outcrops. Riparian features included: islands, wetlands and three floodplain types. Floodplain types included: a relatively continuous high-elevation pre-dam floodplain, a series of mid-elevation floodplains constructed by mechanical surface lowering, and lower elevation post-dam topographic benches composed of coalesced bars that were stabilized by 1975. The geomorphic maps were used to estimate spatial and temporal changes in ecologically significant riparian and channel features relevant to Trinity River fisheries restoration (Curtis and others, pending approval). The study reach is divided into upper, central, and lower river segments and sub-divided further into thirteen geomorphic reaches for the presentation of results. The upper river includes geomorphic reaches 1 to 5, the central river includes reaches 6 to 8, and the lower river includes reaches 9 to 13.

## RESULTS

Since 1980 the general trajectory of change within the study area has been the conversion of riparian to channel features and expansion of the active channel area, which includes the baseflow wetted channel and morphologically active channel margins characterized by bedload transport. The primary mechanism for active channel area expansion was bank erosion from 1980 to 1997 (Figure 2B). The primary period of bar accretion from 1997 to 2001 was followed by slightly higher cumulative bar scour from 2001 to 2006 (Figure 3A). In comparison, smaller post-2006 bank and bar changes were spatially limited to reaches with sufficient local transport capacity or sediment supply supported by post-ROD gravel augmentation (upper river only), mechanical channel rehabilitation, and tributary contributions to flow and sediment supply (Figures 2 and 3).

Scour and deposition produced by tributary floods in 1997, 1998 and 2006 (Figure 4) were the primary factors leading to increases in the active channel area, channel complexity and floodplain connectivity. Channel complexity was characterized by the areal extent of secondary water features (alcoves, side-channels, split-flow channels and wetlands) and active alluvial bars. Increases in floodplain connectivity were characterized by the areal extent of constructed floodplains. Managed flow releases after 2006, in the absence of tributary flooding, combined with gravel augmentation and mechanical restoration caused localized increases in sediment supply and transport capacity. This led to additional increases in the active channel area, channel complexity and floodplain connectivity.

In 1980 the diversity of channel features was greatest in the upper and central river (Figure 5) where channel complexity features (active alluvial bars and secondary water features) represented approximately 12 percent of the active channel area. From 1980 to 2001 the active channel area increased by 20 percent. By 2001 channel complexity features comprised 17 percent of the active channel area. From 2001 to 2011 the active channel area increased by about

5 percent and in 2011 channel complexity features again occupied 17 percent of the active channel area.

In 1980 post-dam topographic benches comprised 94 percent of the riparian environment (Figure 6). By 2001 floodplain construction had increased riparian diversity and the proportion of post-dam benches declined to 86 percent. By the end of the study period in 2011, the relative proportions of post-dam benches, constructed floodplains, and stabilized bars were 60, 27, and 10 percent respectively.

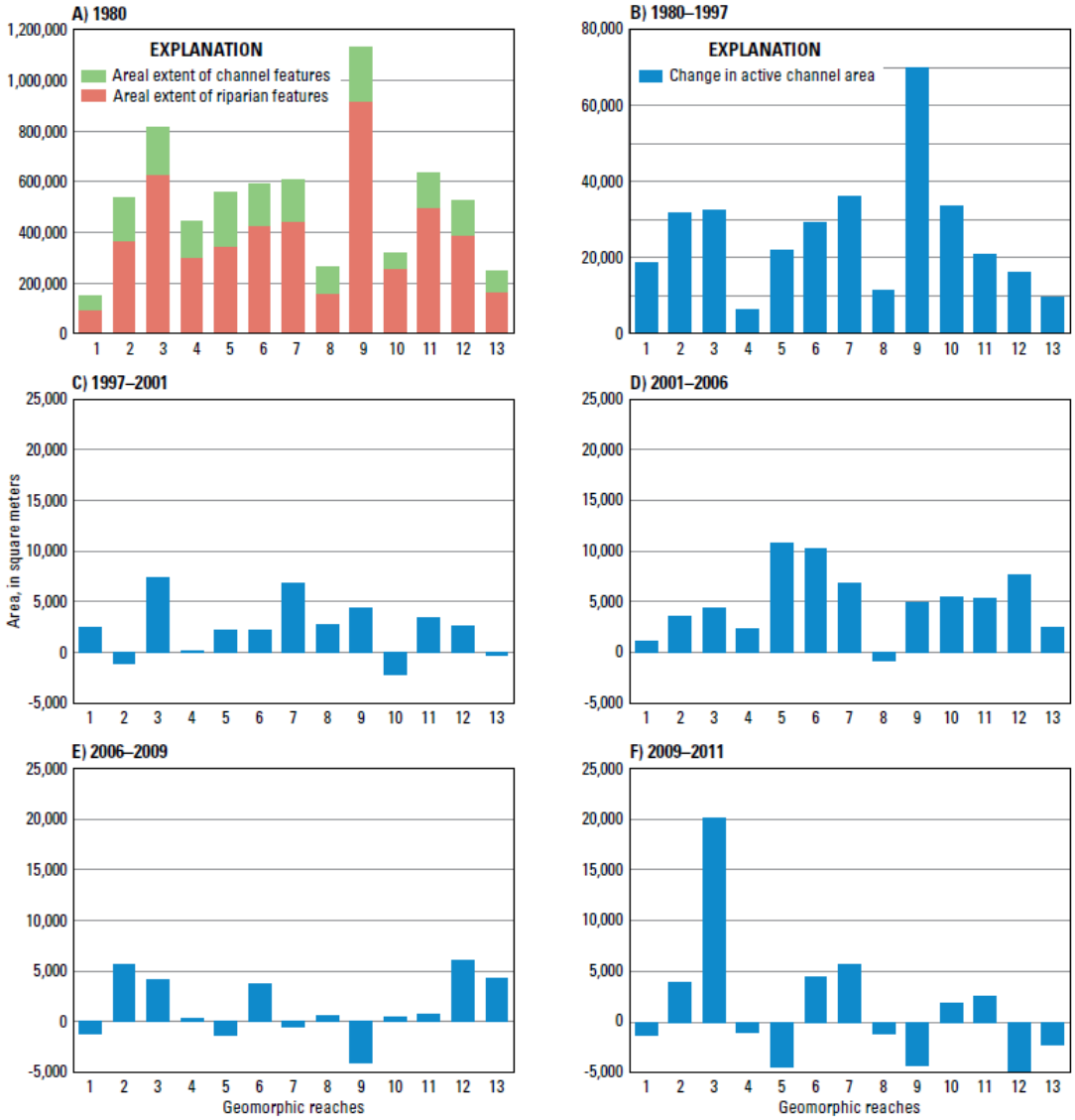


Figure 2. Graphs showing areal extent of riparian and channel features within thirteen geomorphic reaches along the Trinity River downstream from Lewiston Dam, California, A) in 1980, and change in active channel area for five periods from B) 1980 to 1997, C) 1997 to 2001, D) 2001 to 2006, E) 2006 to 2009, F) 2009 to 2011. Note the change in scale.

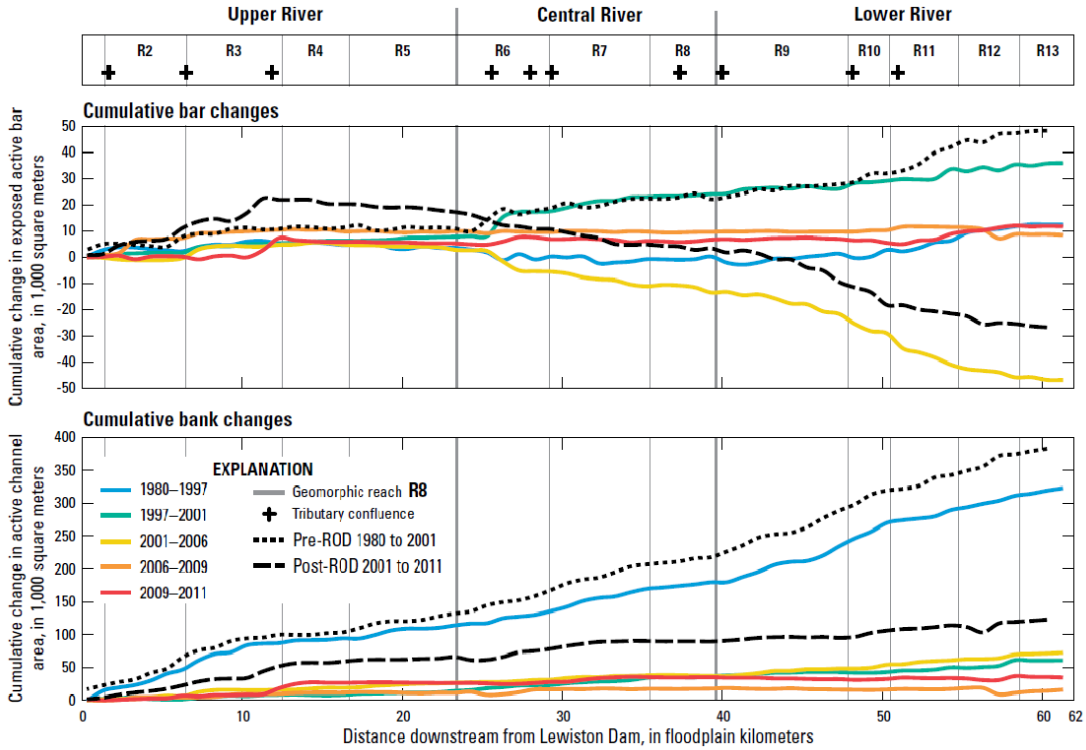


Figure 3. Cumulative longitudinal changes in A) exposed active bar area and B) active channel area estimated for five time periods spanning 1980 to 2011 along the Trinity River downstream of Lewiston Dam, California.

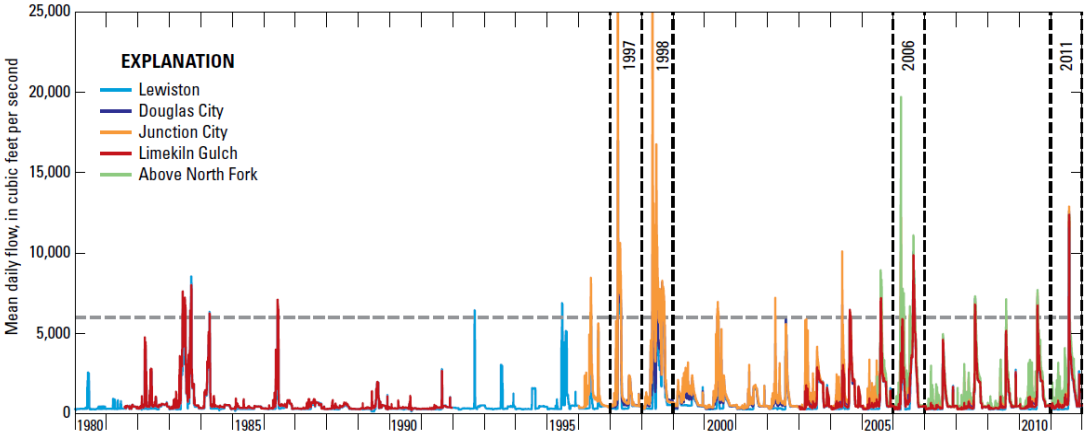


Figure 4. Mean daily flows measured at five mainstem gaging stations located along the Trinity River downstream of Lewiston Dam, California. Comparison of Lewiston flows with downstream gage data indicates tributary contributions to mainstem flow. The largest mean daily flows occurred at Junction City gage in 1997 (27,150 $ft^3/s$) and 1998 (25,150 $ft^3/s$). Dashed horizontal line denotes a managed flow release threshold of 6,000 $ft^3/s$

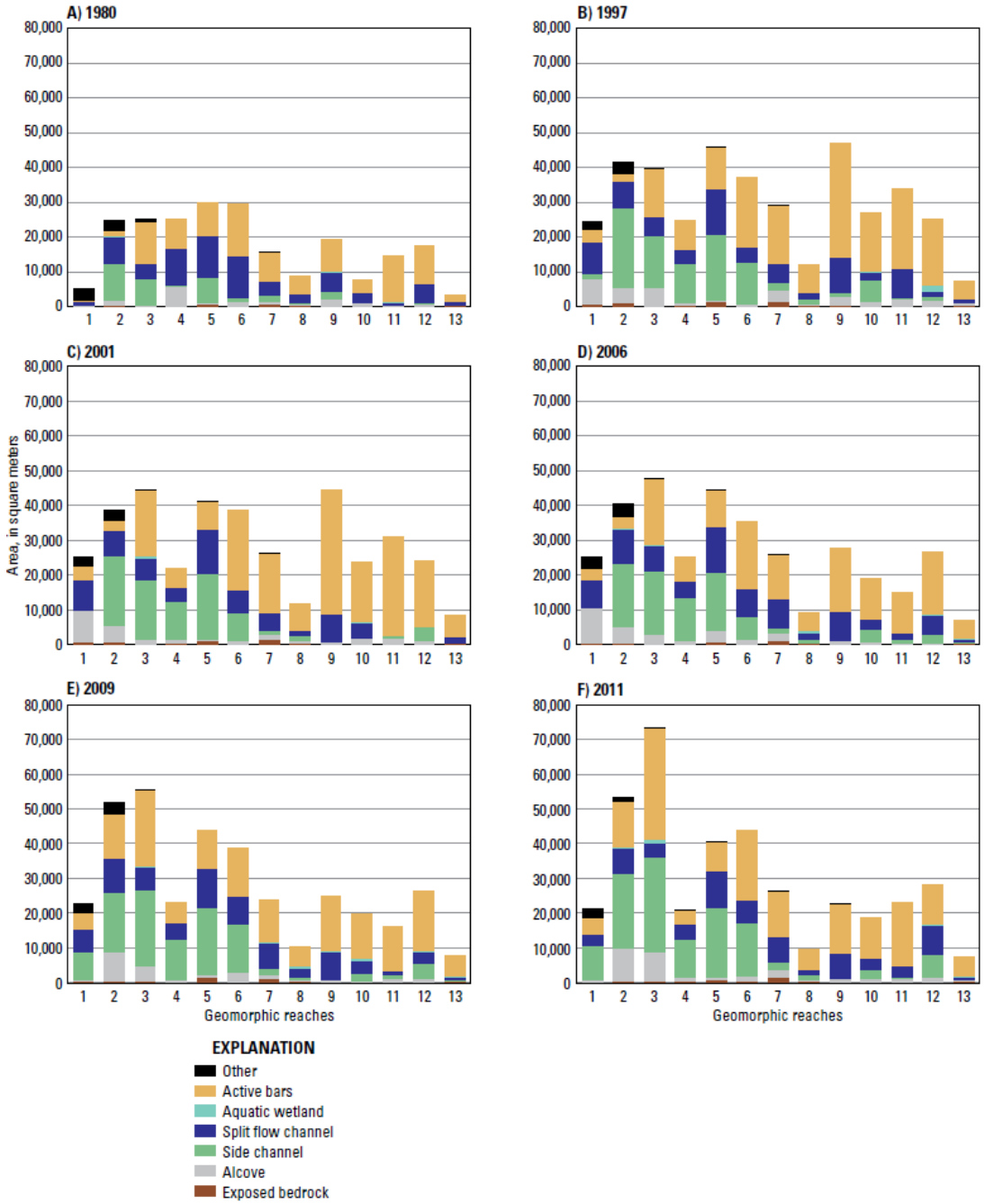


Figure 5. Areal extent of channel complexity features within thirteen geomorphic reaches located along the Trinity River downstream of Lewiston Dam, California in A) 1980 B) 1997 C) 2001 D) 2006 E) 2009 F) 2011.

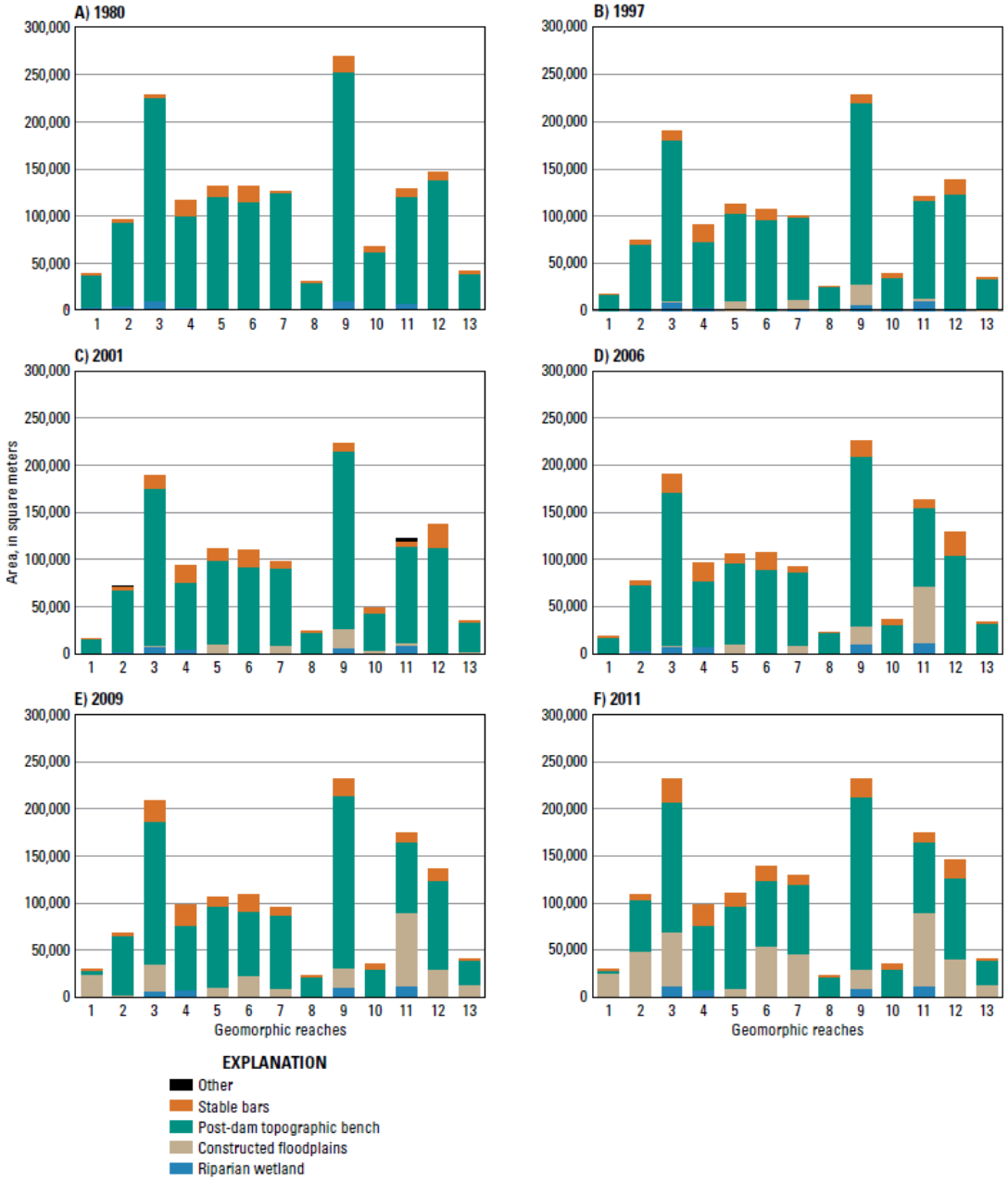


Figure 6. Areal extent of lower elevation riparian features within thirteen geomorphic reaches located along the Trinity River below Lewiston Dam, California in A) 1980 B) 1997 C) 2001 D) 2006 E) 2009 F) 2011.

## CONCLUSIONS

Intrinsically the upper river has a low potential for change because dam construction and flow diversions decreased the transport capacity and sediment supply. Numerous management actions were implemented during the study period to resolve the lack of capacity for maintaining a

dynamic alluvial river with desirable habitat features. These management actions included channel rehabilitation, gravel augmentation and alterations in the size and timing of prescriptive flow releases.

In 1980 the study reach possessed a static channel form but the tendency toward stable alluvial features was disrupted by the 1997, 1998, and 2006 tributary floods. Channel widening from 1980 to 1997 represented a system-wide threshold disturbance that was followed by bar accretion (1997 to 2001) and bar scour (2001 to 2006). The geomorphic effectiveness of the post-2006 prescriptive flows and gravel augmentation was small in comparison to pre-2006 precipitation-driven tributary flows that generated higher and longer duration main stream flows (Curtis and others, pending approval). Pre-1997 studies determined that 80 percent of the low-flow channel margin was mobilized during a peak flow release of 6,000 $ft^3/s$ (TRA, 1993; Wilcock and others, 1995; MT, 1997). More recent studies (HVT and others, 2011) indicate prescriptive flows did not produce expected scour, mobility, or channel maintenance targets at many rehabilitated sites. These observations suggest that channel widening could have altered local hydraulics such that prescriptive flows may need to be increased to achieve the TRRP's restoration goals. The muted geomorphic response of channel rehabilitation sites to the post-2006 flows highlights the need for continued monitoring and assessment of the magnitude, duration, and timing of prescriptive gravel augmentation, flow releases and associated objective for channel scour, mobility, and maintenance. Achieving the TRRP goal of a downscaled dynamic river may come with the unexpected consequence of a larger active channel area that requires larger maintenance flows.

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