T E C H N I C A L S E R V I C E C E N T E R
D E N V E R , C O L O R A D O

UPPER GILA RIVER FLUVIAL GEOMORPHOLOGY STUDY

GEOMORPHIC MAP
ARIZONA

US Department of the Interior
Bureau of Reclamation

R E V I S E D M A R C H 4 , 2 0 0 4

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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GRAHAM COUNTY, ARIZONA

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Graham County, Arizona, and Reclamation are Cost Share Partners in the Upper Gila River Fluvial Geomorphology Study. The views or findings of Reclamation presented in this deliverable do not necessarily represent those of Graham County.

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The Fluvial Hydraulics & Geomorphology Team from the Technical Service Center is leading the Upper Gila Fluvial Geomorphology Study. The team consists of geomorphologists, engineers, and biologists. The members have expertise in water resources management, fluvial geomorphology, paleohydrology, hydraulics, and sedimentation.

The team members are:

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INTRODUCTION

A geomorphic map portrays surficial features or landforms that record geologic processes on the earth's surface. In fluvial geomorphology, these processes include erosion and deposition of sediment. Geomorphic landforms such as stream terraces and alluvial fans record sedimentary processes in a river system and are the basis for the delineations on the Geomorphic Map. For the Upper Gila River Fluvial Geomorphology Study, the Geomorphic Map will illustrate geomorphic features that will aid in understanding recent channel changes of the Gila River.

The objective of the geomorphic map is to provide a picture of long-term river behavior in the Safford Valley and the Duncan Valley. Understanding long-term river behavior is useful for providing a comprehensive picture of river processes, placing recent channel changes into a long-term context, identifying causes of channel change and property loss in the historical period, and defining limits of channel migration. The accompanying maps present basic geomorphic data on black and white orthophotographs. The Geomorphic Map, along with the Catalog of Historical Changes (Task 7C), fieldwork, and laboratory analyses, will be combined in the Geomorphic Analysis (Task 10), a compilation of all geomorphic data developed in the Upper Gila River Fluvial Geomorphology Study.

Existing geologic maps and reports (e.g., Aldridge, 1970; Culler and others, 1970; Davidson, 1961; Fair, 1961; Heindl, 1958; Houser, et al 1985; Knechtel, 1938; Weist, 1971) provide detailed information on bedrock, faults, mineral resources, Tertiary/Pleistocene geology, ground water, and hydrology, but do not provide the detailed geomorphic data necessary to meet the objectives of this project. The emphasis in this task was on defining limits to lateral channel migration and assessing channel stability. Geomorphic features that provide information on lateral migration and channel stability include flood-modified surfaces, bedrock, alluvial fans, and older floodplain surfaces. Infrastructure is also a major factor in channel position and behavior of the Upper Gila River (Klawon, 2001). Thus, the maps include levees, diversion dams, and bridges.

METHODS

Methods used to produce the geomorphic map of Safford Valley and Duncan Valley include a combination of aerial photograph interpretation, field mapping of geomorphic features, soil/stratigraphic descriptions, laboratory analyses, and use of previously published soil surveys. Ground leveling of agricultural fields made some geomorphic features difficult to observe on recent photography and during field mapping. Historical aerial photography and soil surveys are instrumental in mapping those features obscured by recent land use. Aerial photography spanning 1935 to 2000 with various scales and the Catalog of Historical Changes (Klawon, 2001) was used to identify recent channel change during large floods. The photography was also used to map prominent levees built during the historical period. Soil maps developed by Poulson and Youngs (1938) and Poulson and Stromberg (1950) for Safford Valley and Duncan Valley, respectively, provided critical information for obscured areas and for checking those areas mapped by aerial photo interpretation and fieldwork. The soils for Safford Valley are mapped at a

1:63,360 scale, while the soils of Duncan Valley are mapped at a 1:15,840 scale. Although more recent soil surveys were available (DeWall, 1981; Gelderman, 1970), they did not accurately reflect fluvial geomorphic processes and therefore were not used. Approximately 30 soil/stratigraphic descriptions of bank exposures provide detailed information about areas that are currently being eroded. Soil and sedimentologic characteristics of bank exposures were described following USDA guidelines and standard sedimentary terminology (Tucker, 1981; Soil Survey Staff, 1993; Birkeland, 1999). The degree of soil development provides important information on the relative age of soils developed on alluvial surfaces in the study area. Characteristics such as carbonate and clay accumulations and soil structure develop with time and can be used as indicators of soil age (Birkeland, 1999; Machette, 1985). Radiocarbon analysis provides quantitative estimates of the age of surfaces. Radiocarbon analysis relies on the decay rate of radiocarbon that was incorporated into the tissue of a once living organism (Trumbore, 2000). There are numerous problems associated with ages derived using this methodology, but there are precautions that when followed can provide accurate age estimates for the sediments that comprise the terrace. The most common materials found in fluvial sediments that are collected for radiocarbon analysis are charcoal and mollusk shell. Both types of materials are identified to the species level if possible prior to radiocarbon analysis in order to minimize some of the potential problems. These descriptions and associated lab analyses will be discussed further in the geomorphic analysis. Features were initially mapped on 9 X 9" contact prints of aerial photography and then were transposed onto paper versions of the orthophotographs developed in Task 5 of the Upper Gila River Fluvial Geomorphology Study (Arizona). Delineations were then transferred onto the digital orthophotographs. The coordinate system was re-projected from an arbitrary projection to state plane coordinates.

DESCRIPTION OF MAP UNITS

The accompanying geomorphic maps depict the Gila River from the San Carlos Indian Reservation boundary to the mouth of Gila Box in Safford Valley and from the head of Gila Box to the Arizona-New Mexico boundary in Duncan Valley (Figure 1).

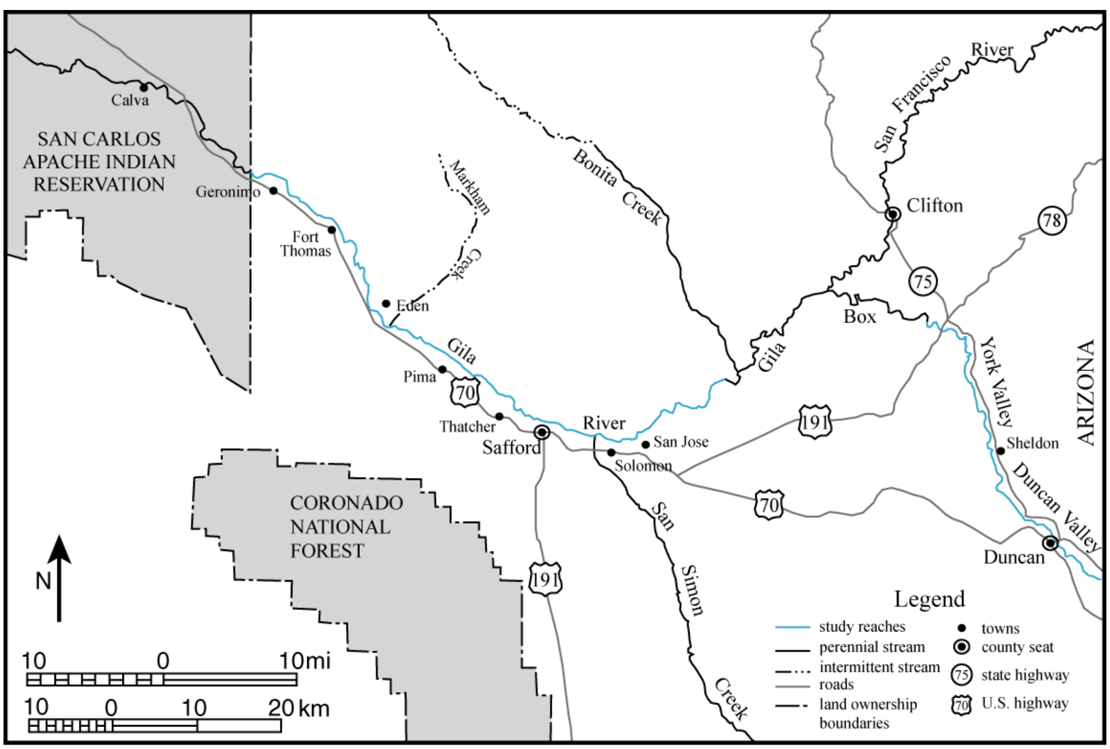

Figure 1. Location of geomorphic mapping, Upper Gila River, Arizona.

The geomorphic map defines four major features: the Pima Soil boundary, geomorphic limit of flood evidence, levees of various ages from 1953 to 1992, and historical property loss along the river. All delineations of features are visible on the Geomorphic Map. Features that follow the same alignment are shown side by side on the map. Delineations are terminated at the edges of the photography or at the ends of features. In many cases, the Pima Soil Boundary terminates at the geomorphic limit. Labels indicate diversion dams and bridges. The following paragraphs describe the geomorphic features shown on the orthophotographs.

PIMA SOIL BOUNDARY

This boundary defines the extent of the Pima Soil as shown on soil surveys and as identified in soil descriptions of bank exposures and observations of corresponding stream terraces. The Pima Soil Boundary is an important boundary because it provides a limit to lateral channel migration for the past several hundred years and is an indicator of channel instability where significant areas of this soil have been eroded. Surfaces with the Pima Soil are generally elevated above the active channel by 5 to 10 ft and appear to be formed on alluvium that is several hundred years old. The Pima Soil Series generally runs parallel to the river and is a deep, dark-colored soil formed on level to 2% slopes. Although there is no salt concentration in any particular layer, the soil is generally rich in salts. Stratified materials are present in the subsoil, which is lighter in color below a depth of 2-3 ft (Poulson, 1950). A typical soil consists of 15 inches of brownish gray granular silty clay loam underlain by brownish gray silty clay loam with irregular fine blocky structure to a depth of 24 inches. From 24 to 40 inches, the profile consists of stratified or laminated layers of pale brown to weak brown friable silty clay loam, loam, and clay loam with occasional sandy and silty seams. From 40 to 70 inches, the soil consists of friable stratified pale brown material ranging from fine sandy loam to silty clay loam. Coarser material is present below 70 inches (Poulson and Youngs, 1938). Surfaces with Pima soils are accessed by the river during flood flows and may be substantially modified in some cases. These soils are currently being eroded along the river in some locations where the active channel is adjacent to the Pima Soil.

In some areas, the boundary between the Pima Soil and younger alluvium along the river was well defined and could be drawn with an accuracy of ± 40 ft. In other areas, ground leveling obscured the boundary so that it could only be drawn with an accuracy of ± 200 ft. The two levels of uncertainty are depicted on the Geomorphic Map by a solid and dashed line, respectively.

GEOMORPHIC LIMIT OF FLOOD EVIDENCE

The geomorphic limit of flood evidence defines the boundary for surface modification by floods of the Gila River and provides a limit to lateral channel migration for at least the past 1,000 years. Within the geomorphic limit, surfaces are channelized or have tonal signatures on aerial photography that suggest flooding in agricultural fields. Soils developed on surfaces within the geomorphic limit are poorly developed and labeled as the Gila Soil (see Poulson and Stromberg, 1950; Poulson and Youngs, 1938) or are moderately developed soils in the Pima Soil Series. Beyond the geomorphic limit, soils may be eroded along bank exposures, but are eroded much slower than other banks due to their consolidated nature. Geomorphic units beyond the geomorphic limit include bedrock, colluvium, high stream terraces, alluvial fans derived from a single tributary, and alluvial fan complexes on gently sloping piedmonts. These units provide a constraint on the lateral movement along the Gila River because they are difficult to erode. Although several soil series are included in this unit, the soils generally contain higher percentages of gravel and are more sloping than soils of the Pima Series. The soils also typically have carbonate accumulations in a particular horizon in the form of coatings on gravels in gravelly sediments or nodules and filaments in fine-grained sediments. In many cases, these soils have a greater amount of clay when compared to the Pima soil (Poulson and Youngs, 1938). They are also further removed from the active channel where the Pima soil is present and occupy positions of higher elevation than the Pima soil. As with the Pima Soil Boundary, in some areas the geomorphic limit was easily observed and could be depicted with an accuracy of ± 40 ft. In other cases where the boundary was not readily observed and had to be transferred from soils information, it could only be depicted with an accuracy of ± 200 ft. The two levels of accuracy are shown on the Geomorphic Map as solid and dashed lines, respectively.

LEVEES

Levees from 1953 to 1992 were mapped that appeared to be important factors in property loss during large floods. Although many levees have been built that are not portrayed on the Geomorphic Map, they were not mapped because they did not appear to be catalysts for channel change on the Gila River. Table 1 lists the aerial photographs that were used in mapping levees from various years.

Table 1. Source data for mapped levees

DATE	SOURCE	SCALE	FILM TYPE
1953	Army Map Service	1:54,000	Black & White
1967	U.S. Department of Agriculture	1:20,000	Black & White
1978	Bureau of Land Management	1:24,000	Color
1981	U.S. Geological Survey	1:32,800 to 1:34,000	Color Infrared
1992	U.S. Geological Survey	1:40,000	Black & White

PROPERTY LOSS

Property loss is defined as agricultural land eroded during large floods. Aerial photography from 1935-2000 was examined to determine property loss. Since the majority of land in Safford Valley was eroded between 1967 and 2000, 1967 was set as an arbitrary datum. The majority of erosion in Duncan Valley occurred between 1978 and 2000, so that pre-flood 1978 photography was used as the datum. Once the eroded property was identified, it was then outlined on the 2000 aerial photography.

PRELIMINARY ANALYSIS

Geomorphic boundaries shown on the Geomorphic Map provide evidence for lateral stability of the Gila River prior to the historical period. The Gila River has migrated laterally within the Pima alluvium for the last several hundred years and within the geomorphic limit for greater than 1,000 years. During the historical period, property loss especially of older alluvium is an indicator of lateral instability. Areas of lateral instability in Duncan Valley as indicated by property loss are located in two separate reaches upstream of Duncan Bridge, near Whitefield Wash, and near Kaywood Wash. With the exception of the mentioned reaches, Duncan Valley appears to be laterally stable in most reaches; however, there appears to be some vertical fluctuations upstream of the Duncan Bridge as well as in Sheldon and York Valleys. These fluctuations may be caused by the construction of Duncan Bridge and levees in upstream Duncan Valley, by natural constrictions such as alluvial fans and bedrock, and by the process of vertical accretion. Lateral instability in Safford Valley is most prevalent in reaches near San Jose Diversion, Smithville Diversion, Tilley Wash, Pima, Curtis Canal, north of Eden Bridge, Fort Thomas, and Geronimo. Other reaches with minor instability are near the head of Safford Valley, Graham Diversion, and Fort Thomas Diversion. Property loss appears to be associated primarily with levees and diversion dams. Downstream of Pima, Arizona, vegetation and alluvial fans also appear to play an important role. Vertical channel changes in Safford Valley appear to be more localized than Duncan Valley, and are mostly caused by shifts in channel position and in limited cases by the construction of levees.

SUMMARY

The Geomorphic Map combines aerial photo interpretation, field mapping of geomorphic features, soil/stratigraphic descriptions, laboratory analyses, and use of previously published soil surveys to provide a long-term picture of river behavior. The maps are produced on 1:4800 scale digital orthophotographs and display geomorphic features and infrastructure important in the recent lateral movement of the Gila River channel. The Geomorphic Analysis will include a more detailed interpretation and discussion of the Geomorphic Map.

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