DIGITAL GEOLOGIC MAP DGM-71

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Surficial Geologic Map and Flood Hazard Assessment, Rainbow Valley, Maricopa County, Arizona, version 1.0

February 2009

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by

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Introduction

Geomorphologic analyses and surficial geologic mapping provide information about the age and type of alluvial deposits on piedmonts that is critical in assessing the character of piedmont landforms and the nature and extent of piedmont flood hazards. Piedmonts in Maricopa County are covered by complex mosaics of surficial deposits with different physical characteristics related to the ages of the deposits. Surficial geologic maps differentiate alluvial deposits based on physical characteristics of the deposits (sediment size and character) and geomorphic characteristics of the upper surfaces of the deposits. Differences in the primary physical characteristics of surficial deposits result from differences in rock types in drainage basins and differences in the size and character of the stream system that transported the sediment. Surficial deposits are subsequently altered by processes including weathering, soil development, and local erosion, so the character of the surface and near-surface portion of the deposits is related to the length of time that the deposits have been exposed at the surface. Simply stated, active fluvial systems leave behind evidence of their activity in the form of young deposits. Thus, surficial geologic maps are very useful in defining the physical framework of active fluvial systems on piedmonts.

The primary purpose of the geomorphologic analyses and mapping conducted in Rainbow Valley is to provide a preliminary assessment of the character and extent of piedmont flood hazards in areas not assessed through detailed hydrologic and hydraulic analyses. This mapping covers the entire Waterman Wash watershed except most of the area within the boundaries of the Sonoran Desert National Monument, which presumably will not be developed. Surficial geologic units in active agricultural areas in the axis of the valley were mapped in a generalized fashion. Approximate flood hazard interpretations are provided for all areas except those that have been altered by agricultural activities. We utilized color aerial photographs flown in the late 1970's, high-resolution black-and-white orthophotos flown in 2002 and 2003, the statewide NAIP orthophotography from 2007, and 10-foot topographic contours provided by the Flood Control District of Maricopa County (FCDMC) to map surficial geologic units. Surficial geologic mapping in the northernmost part of the map area is modified from Skotnicki (2002a; 2002b). Spot field investigations were conducted to document surface and soil characteristics and check unit boundaries. Surficial geologic units were differentiated by age based on geomorphic criteria that have been used to map surficial deposits in many areas in central and southern Arizona and elsewhere in the Southwest. In addition, we developed a unit to depict potentially active alluvial fans in middle and upper piedmont areas. This unit integrates evidence of recent fan activity in the form of extensive, fan-shaped areas of young deposits, distributary drainage networks, minimal channel incision, and topographic contours that are convex downslope.

The resulting geologic /geomorphic map depicts the approximate extents of active fluvial systems on the piedmonts of Rainbow Valley, and also provides information that can be used to delineate potentially active, inactive and relict alluvial fans. The general criteria used to differentiate and map surficial geologic units in this area are described below, followed by descriptions of the various surficial geologic / geomorphic units that were mapped. Finally, we present a brief discussion of the character and extent of piedmont flood hazards based on our interpretation of piedmont geology and geomorphology.

Criteria Used to Define and Delineate Surficial Geologic Map Units

Surficial geologic maps are constructed based on the physical characteristics of alluvial surfaces, with emphasis on the characteristics that reflect relative surface age. Alluvial surfaces of similar age have a distinctive appearance and soil characteristics because they have undergone similar post-depositional modifications. Alluvial fans, floodplains, and low terraces that are less than a few thousand years old still retain clear evidence of the original depositional topography, such as bars of coarse deposits, finer-grained swales (trough-like depressions) where low flows passed between bars, and braided or distributary channel networks. Young alluvial surfaces have little rock varnish on surface clasts, weak or no desert pavement development, minimal soil development, and channels typically are incised a few feet or less below adjacent terrace or fan surfaces. Young alluvial surfaces tend to be found in proximity to modern channel systems, although in some areas channels may be small and discontinuous. Very old alluvial surfaces, in contrast, have been isolated from substantial fluvial deposition or reworking for hundreds of thousands of years. These surfaces have been strongly modified by processes of erosion and soil formation since they were deposited, and thus look substantially different from young deposits as seen in the field, on aerial photographs, and on topographic maps. Old alluvial surfaces are characterized by strongly developed soils, well-developed tributary stream networks that are entrenched 3 or more feet below the fan surface, and strongly developed varnish on surface rocks. The ages of alluvial surfaces in the southwestern United States may be roughly estimated based on these characteristics, especially soil development (Gile et al, 1981; Bull, 1991).

Several characteristics evident on aerial photographs and on the ground were used to differentiate and map various alluvial surfaces. The color or tone of alluvial surfaces depicted on aerial photographs is primarily controlled by soil color, and to a lesser extent, rock varnish. Significant soil development begins on an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile et al., 1981; Birkeland, 1999). Over thousands of years, distinct soil horizons develop. Two typical soil horizons in Pleistocene alluvial sediments of Arizona are reddish brown argillic horizons and white calcic horizons. As a result, on color aerial photographs older alluvial surfaces characteristically appear redder or whiter (on more eroded surfaces) than younger surfaces. Gradual accumulation of dark varnish on rocks that remain at or near the surface over thousands of years gives older surfaces a dark brown color where desert pavements are well preserved. Differences in the drainage patterns between surfaces also provide clues to surface age. Young alluvial surfaces that have been subject to relatively recent flooding commonly display distributary (branching downstream) or braided channel patterns, although young surfaces may have very little developed drainage if shallow sheetflooding predominates. Dendritic tributary drainage patterns are characteristic of older surfaces that are not subject to extensive flooding. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young flood-prone surfaces appear nearly flat on aerial photographs and are less than 1 m above channel bottoms. Active channels are typically entrenched 3 to 30 feet below older, inactive alluvial surfaces. Comparisons of calcic horizon development in Rainbow Valley with other soil sequences in the western United States provide one of the few methods of estimating the ages of the different alluvial surfaces (Gile et al, 1981; Machette, 1985). Calcic horizon development varies from fine white filaments of calcium carbonate in young soils to soil horizons completely plugged with calcium carbonate (caliche) in very old soils.

The physical characteristics of alluvial surfaces evident on aerial photographs and verified in the field were used to differentiate their associated deposits by age. The original mapping was done on overlays over color aerial photos. This mapping was checked against the digital orthophoto base from 2002 and 2003 provided by the Flood Control District of Maricopa County. Final mapping was compiled in a GIS format. Digital mapping was commonly done at scales ranging from 1:5,000 to 1:10,000, so lines are located fairly accurately. Three types of lines are used to designate the relative clarity of relationships between adjacent surfaces of different ages or sources. Solid lines depict contacts that are quite well-defined and can be accurately located on the digital photo base; we estimate a horizontal accuracy of less than about 30 feet for these contacts. Contacts that are less clear or more gradual are depicted with dashed lines; we estimate a horizontal accuracy of about 100 feet for dashed contacts. Finally, we use gradual contacts for the downstream margins of potentially active alluvial fan areas because they are not discrete and their locations are relatively uncertain. The horizontal position uncertainty for these contacts is less clear, but must be hundreds of feet at least.

Surficial Geologic Units

The various geomorphic units we differentiated in Rainbow Valley are described in some detail in this section. Geomorphic units are grouped together based on their relative flood hazards, and in each group the areas of highest hazard presented first. Our assessment of the types of flood flows that likely occur on these units (i.e., channel flow, sheetflooding, potential for lateral bank erosion or channel change) are included in these descriptions. Flood hazard categories and limitations on this analysis are considered after the unit descriptions.

Deposit descriptions are arranged by unit label (e.g., Qycr), landform type (e.g., modern river channels), and summary of the physical characteristics of the unit.

Deposits of Waterman Wash

Qycr Modern river channels – This unit includes active river channel deposits of Waterman Wash and West Prong. These deposits are composed mainly of unconsolidated, moderately-sorted sand, gravel, and pebbles. There is no soil development in this dynamic environment, and little vegetation grows within the channels.

Qy2r Modern river terraces and bars – This unit consists of young terrace and bar deposits in and along the active channels of Waterman Wash and West Prong. These deposits typically are composed of moderately-sorted sand and pebbles, but in many areas are capped with finer floodplain sediment composed mainly of silt and sand. Channel scouring, bar deposition and lateral bank erosion may occur during flooding. Deposits in this active unit have no to weak soil development, and soil color (yellow brown, 10YR) is not altered from the original deposits. Qy_2r surfaces are slightly higher than channels and are commonly vegetated with shrubs, mesquite, and palo verde trees.

Qy1r River terraces – This unit consists of relatively young river terraces deposited by Waterman Wash and West Prong. The deposits are fine grained and composed primarily of well- to moderately-sorted silt and sand with lenses of gravel and pebbles. In southern Waterman Wash this unit may still be part of the active floodplain in moderate to large floods, but from the southern end of the agricultural fields northward, this unit is typically isolated from the active system and is likely rarely inundated. Soil development associated with these deposits is typically weak with some soil structure but no clay accumulation. Carbonate is dispersed throughout the soil profile, ranging from weak to strong stage I (Machette, 1985). Yellow brown (10YR 6/4) soil color is similar to original fluvial deposits. This unit, where not disturbed by agriculture, is vegetated with shrubs, mesquite and palo verde trees.

Piedmont Deposits

Qyc Channels of large tributary washes – This unit includes active, open channels and low, lightly vegetated terraces of tributary washes on the piedmonts. This unit is composed of moderately-sorted sand and silt, with common pebbles and some cobbles in the lower piedmont areas to poorly-sorted sand, pebbles, cobbles and small boulders in the upper piedmont areas. Channels are typically incised less than 3 ft below adjacent Holocene terraces and alluvial fans. Channel morphologies generally consist of a single-thread, deep, high-flow channel or multi-threaded, shallow, low-flow channels with adjacent gravel bars. There is no soil development in these deposits, and little vegetation grows within the channels.

Qy3 Smaller active channels, bars and low terraces – This unit includes smaller active channels, and low bars and terraces along tributary washes. In upper piedmont areas, channel sediment is generally poorly-sorted to very poorly-sorted sand and pebbles, but may include cobbles and boulders. Terrace and fan surfaces commonly are mantled with silt and sand. On lower piedmont areas, young deposits consist predominantly of moderately-sorted silt, sand, and fine gravel, including some pebbles and cobbles in channels. Channels typically are incised less than 3 ft below adjacent terraces and fans, but locally incision may be as much as 6 ft. Channel morphologies generally consist of a single, moderately deep high-flow channel or multi-threaded, shallow, low-flow channels with adjacent gravel bars and finer floodplain deposits. Terraces have planar surfaces and are covered primarily with fine-grained deposits; small channels, slightly incised channels are common. Deposits in this active unit have no to weak soil development, with a yellow brown (10YR 6/4) color that is similar to unaltered stream deposits. Shrubs, mesquite, and palo verde trees are found along active channels and on bars and terraces, and vegetation tends to be relatively dense compared with surrounding older surfaces.

Qy2 Swales, sheetflood areas, and minor channels – This unit includes young deposits found in broad swales, sheetflood areas and active drainageways, and is associated with potentially active alluvial fans in some areas. Qy2 surfaces are generally planar with local relief less than one foot. Channels are small with complex branching and rejoining patterns (anastomosing), and commonly are discontinuous. Deposits are moderately-sorted to well-sorted silt and sand with some pebbles and cobbles. Surfaces typically are covered with silt and sand with a scattered, unvarnished gravel lag. Most are these areas likely are inundated in moderate to large flow events. Inundation is deepest adjacent to channels, and is broad and shallow on surfaces between channels. Soil development associated with Qy2 deposits is weak with no clay accumulation and no to stage I carbonate accumulation. Yellow brown (10YR 6/4) color is similar to unaltered stream deposits. Vegetation on Qy2 surfaces is mainly creosote bush with mesquite, palo verde and ironwood trees along channels. This unit contains inclusions of units Qy1 and Qyi, described below.

Qyaf Potentially active alluvial fans – This unit includes very poorly-sorted sand, pebbles, cobbles and silt, with some boulders associated with young alluvial fans in middle and upper piedmont areas. Young alluvial fans are minimally incised and have downstream-branching, weakly integrated distributary channel networks. Channels are typically small and commonly are not continuous downslope. Soil development associated with Qyaf deposits is weak with no clay accumulation and no to stage I carbonate accumulation. Yellow brown (10YR 6/4) color is similar to original deposits. Vegetation on Qyaf surfaces is predominantly creosote bushes and other shrubs, but mesquite, palo verde and ironwood trees are also fairly common. Portions of these active fans are inundated in moderate to large floods, but inundation is infrequent to rare and typically broad and shallow. The greatest flood hazard associated with active fans is the potential for dramatic shifts in channel positions on the fans during floods (e.g., Pearthree et al, 2004). Most commonly, Qyaf deposits commonly grade downslope into mixed Holocene and Pleistocene deposits (unit Qyi). The downslope margins of potentially active alluvial fans are never clearly defined, however, and all such contacts are shown as gradational on the map sheet.

Qy1 Inactive Holocene alluvial fans and terraces – This unit consists of older Holocene terrace and alluvial fan deposits. Qy1 deposits are generally moderately- to well-sorted silt, sand, pebbles and cobbles, locally with unvarnished open to moderately packed pebble surface lag. Qy1 surfaces are generally planar with local surface relief up to two feet where gravel bars are present. Qy1 surfaces are slightly higher and less subject to inundation than adjacent Qy2 surfaces. Relatively low portions of Qy1 surfaces may be inundated during large flood events, but inundation is typically broad and shallow. Carbonate is dispersed throughout the soil profile, due to parent material, with accumulation up to stage I at approximately two feet depth. Yellow brown (10YR 5/4) soil color is similar to original fluvial deposits. This surface is dominated by creosote and small herbaceous plants. Units Qy1 and Qyi (described below) are commonly intermixed, with the designated unit dominant.

Qye Mixed Holocene alluvial and eolian deposits over inactive alluvial fans on lower piedmont slopes – This unit consists of intricately mixed small-scale eolian deposits over older Holocene alluvial deposits. The juxtaposition of these different types of deposits results in a distinctive, crudely striped pattern in aerial photographs that is very difficult to see on the ground. Unit Qye is composed of structureless to weakly bedded sandy loam deposited by wind over older piedmont alluvium (primarily units Qy1 and Qyi). Drainage networks are very weakly developed and discontinuous unless flow has been concentrated along roads or tracks. Extensive, small-scale eolian landforms indicate that these areas have not been subjected to substantial flooding for hundreds to thousands of years. Qye surfaces are generally planar with local relief less than one foot where channels are present. Soil development is weak with little clay or carbonate accumulation. Soil color is typically yellow brown (10YR). This surface is dominated by creosote and small herbaceous plants.

Qy Holocene sheetflood areas and terraces, undivided – This unit is mapped where it is not feasible to subdivide Holocene alluvium at 1:24,000 scale, and in areas where the surficial geology has been obscured by agricultural activity. Potential flood hazards are low to high depending on local conditions.

Qyi Holocene and Pleistocene alluvium in sheetflood areas on piedmont slopes– This unit is composed of fine-grained Holocene alluvium deposited over late to middle Pleistocene alluvium (units Qi2 and Qi1) by sheetflooding. The late Holocene alluvium is thin, typically less than a few feet, and is composed of silt and sand with some fine gravel. Pleistocene alluvium is exposed in patches and in gullies throughout this unit. Qyi surfaces are generally planar with local surface relief up to two feet where small channels are slightly incised into the surface. Unit

Qyi is mapped primarily downslope from and adjacent to active alluvial fans (unit Qyaf), and represents the transition between active fan processes and more stable shallow sheetflooding. Some areas mapped as Qyi are inundated during large flow events, but inundation is generally shallow sheetflooding. Soil development of the Holocene alluvium is weak with little clay or carbonate accumulation. Soil color is typically yellow brown (10YR 6/4). This surface is dominated by creosote and small herbaceous plants.

Qiy Pleistocene and Holocene alluvium on inactive alluvial fans and piedmont slopes – This unit consists of Pleistocene alluvial fan and piedmont slope deposits (units Qi2 and Qi1, described below), with Holocene alluvium deposited in swales and other topographically low areas. Exposed Pleistocene alluvium typically consists of moderately to strongly varnished pebble and cobble bar deposits. Holocene alluvium is silt and sand deposited in the swales and relict channels of the fan deposits. These inactive alluvial fans are weakly to moderately dissected. Swales and channels in this unit have been subject to inundation during the past 10 ka, however, and may be subject to inundation during large flood events. Higher areas between channels and swales are isolated from flow. Soil development is variable. In the finer-grained Holocene alluvium there is typically some soil structure and weak carbonate accumulation. In the coarser Pleistocene deposits, stage I to II carbonate accumulation is common. Soil color varies from yellow brown (10YR 6/4) to brown (7.5YR 5/4). This surface is dominated by creosote and small herbaceous plants.

Qi2 Late Pleistocene alluvial fans and terraces – This unit consists of late Pleistocene alluvial fan and terrace deposits with weak to moderate soil development. Near the mountains Qi2 surfaces may be up to 10 feet above active channels. These surfaces are generally isolated from flow. On the lower piedmont, Qi2 surfaces are typically less than 1-2 feet above active channels. In large floods parts of Qi2 surfaces on the lower piedmonts where topographic relief is minimal may be subject to inundation, especially on the lower piedmonts where topographic relief is minimal. Inundation on these surfaces will probably be broad and shallow. Soils are brown (7.5YR 6/4), weakly developed sandy loams with carbonate filaments to friable nodules (stage I to II). Creosote and small herbaceous plants dominate this unit on the lower piedmonts, with diverse Sonoran upland species on the upper piedmonts.

Qi1 Middle Pleistocene alluvial fans – This unit consists of moderately to deeply dissected relict alluvial fans. These deposits are moderately-sorted, moderately to very strongly varnished cobble, pebble and boulder lags. Near the mountains active channels are incised up to 20 feet into these surfaces. On the lower piedmont Qi1 surfaces are 3 to 6 feet above active channels. Flooding on these surfaces is confined to channels and immediately adjacent overbank areas. Soils are yellowish red to red (5 to 2.5YR), well-developed loams with carbonate accumulation up to stage IV. In the western and southern portions of the valley, creosote and small herbaceous plants dominate Qi1 surfaces. Near the mountains in the east side of the valley Qi1 surfaces have diverse Sonoran upland species.

Qi Pleistocene alluvial fans and terraces, undivided – This unit is mapped where the land surface has been altered by agricultural activity and it is not feasible to subdivide Pleistocene alluvium, and in areas within the Sonoran Desert National Monument that were not field-checked. Mapping is based on interpretation of soil survey maps (Hartman, 1977) and aerial photo imagery.

Qo **Early Pleistocene alluvial fans –** This unit consists of deeply dissected relict alluvial fans. These surfaces are preserved only in or near the mountain fronts. These deposits are poorly-sorted to moderately-sorted. Surface clasts on preserved in gravel and boulder pavements are very strongly varnished. Flooding on these surfaces is confined to channels and immediately adjacent overbank areas. Soils are yellowish red to red (5 to 2.5YR), well-developed loams with laminar carbonate accumulation exposed at the surface in some areas (stage IV to V). Vegetation on unit Qo includes creosote, ocotillo, mesquite and palo verde.

QTa **Late Tertiary to early Quaternary deposits –** This unit is composed of interbedded conglomerates and sandstones to unsorted, structureless conglomerates and breccias. Deposits are indurated with a reddish hematite and carbonate matrix. This unit is only found in or near the mountains. Flooding on these surfaces is confined to channels and immediately adjacent overbank areas. Soil development is variable due to erosion. This surface is dominated by saguaro, prickly pear, palo verde trees, and cholla.

Other Units

Qtc **Colluvium and talus –** This unit mantles bedrock hillslopes. It is composed of very poorly-sorted, weakly bedded, angular clasts on hillslopes mantling bedrock. Colluvium is only mapped in a few areas, but undoubtedly is common on slopes shown as undifferentiated bedrock.

d **profoundly disturbed areas –** Areas where human excavations have completely disturbed and altered the land surface for aggregate operations or landfills. This designation does not apply to agricultural areas, where the surface is altered but surficial units may be generally inferred from soil survey maps and historical and modern aerial photographs.

dt **ditches and tanks –** This unit includes ditches and tanks associated with agricultural activities. They are part of the active fluvial system and have high flood hazards.

R **Bedrock, undivided –** This unit includes several different types of bedrock, including granitic rocks and basalt. It also includes extensive areas of hillslope colluvium and talus that are not subdivided from the bedrock.

Flood Hazard Assessment

This is a general assessment of the character and severity of flood hazards associated with the various surficial geologic units depicted on these maps. In each category, flood hazards generally decrease from the first unit listed to the last unit listed. For example, in the category "Flood Hazard High", the frequency of flooding is much greater for units Qycr and Qyc than for unit Qyaf.

Flood Hazard High

The surfaces and deposits described in this section are associated with the most active portions of the fluvial systems that drain the Waterman Wash watershed.

Qycr Modern channels of Waterman Wash –This unit is extremely flood prone and subject to deep, high velocity flow in moderate to large events. Channels are subject to scouring and bar deposition. Banks are unprotected and may be subject to lateral erosion. Flood flows may significantly change channel morphology and flow paths.

Qyc Channels of large tributary washes – Channels are flood prone and are subject to deep, high velocity flow during moderate to large flood events. Channels are subject to scouring and bar deposition. Banks are subject to lateral erosion. Flood flows may significantly change channel morphology and flow paths.

Qy2r Modern terraces and bars of Waterman Wash – Bars and terraces of Waterman Wash are extremely flood prone and is subject to deep, high velocity flow in moderate to large events. Channel scouring, bar deposition and lateral bank erosion may occur during flooding.

Qy3 Active channels, bars and low terraces –Channels are flood prone and may be subject to deep, high velocity flows in moderate to large flow events. Channels are subject to scouring and bar deposition, banks are subject to lateral erosion, and flood flows may significantly change channel morphology and flow paths. Terraces are subject to occasional sheetflooding and deeper flow in swales.

Qy2 Active swales, small channels and sheetflood areas Most of these areas likely are inundated in moderate to large events. Inundation is deepest adjacent to channels, and is broad and shallow on surfaces between channels.

Qyaf Potentially active alluvial fans –Portions of these active fans are inundated in moderate to large floods, but inundation is infrequent to rare and typically broad and shallow. The greatest flood hazard associated with active fans is the potential for dramatic shifts in channel positions on the fans during floods

Flood Hazard Intermediate

Flood hazards in the areas described in this section are moderate to low and consist primarily of inundation in and along small channels and shallow sheetflooding.

Qy1r Terraces of Waterman Wash and West Prong – Along southern Waterman Wash this unit may still be part of the active floodplain in moderate to large events. From the southern end of the agricultural fields northward, this unit is typically isolated from the active system and is probably rarely inundated. During flooding, channel banks in this unit may be subject to lateral erosion.

Qyi Holocene and Pleistocene alluvium on piedmont slopes–Unit Qyi is mapped primarily downslope from, and adjacent to, active alluvial fans (unit Qyaf), and represents the transition between active fan processes and more stable shallow sheetflooding. This unit may be flood prone during large events, but inundation is generally shallow sheetflooding confined to topographically low areas.

Qy1 Inactive Holocene alluvial fans and terraces – Relatively low portions Qy1 surfaces may be inundated during large flood events, but inundation is typically broad and shallow.

Qy Holocene alluvium, undivided – Potential flood hazards are intermediate to high depending on local conditions.

Qye Mixed Holocene alluvial and eolian deposits on lower piedmont slopes –Drainage networks are very weakly developed and discontinuous unless flow has been concentrated along roads or tracks. Extensive, small-scale eolian landforms indicate that these areas have not been subjected to substantial flooding for hundreds to thousands of years.

Qiy Pleistocene and Holocene deposits on inactive alluvial fans and piedmont slopes – Swales and channels in this unit have been subject to inundation during the past 10,000 years and may be subject to inundation during large flood events. Areas between channels and swales are isolated from flow.

Flood Hazard Low

Flood hazards in the areas described in this section are generally low and are restricted to fairly well-defined washes and adjacent floodplains.

Qi2 Late Pleistocene alluvium – Near the mountains Qi_2 surfaces may be up to 10 feet above active channels. These surfaces are probably isolated from flow. On the lower piedmont, Qi_2 surfaces are typically less than 1-2 feet above active channels. In large floods parts of Qi_2 surfaces on the lower piedmonts where topographic relief is minimal may be subject to inundation, especially on the lower piedmonts where topographic relief is minimal. Inundation on these surfaces will probably be broad and shallow.

Qi1 Middle Pleistocene alluvium – Near the mountains active channels are incised up to 20 feet into these surfaces. On the lower piedmont Qi_1 surfaces are 3 to 6 feet above active channels. Flooding on these surfaces is confined to channels and immediately adjacent overbank areas.

Qi Pleistocene alluvium, undivided – This unit is mapped only in disturbed agricultural areas. Topographic relief is extremely low, but typically these areas are surrounded by ditches that divert streamflow away from the fields.

Qo Early Pleistocene alluvium – Flooding on these surfaces is confined to channels and immediately adjacent overbank areas.

QTa late Tertiary to early Quaternary sediment –Flooding on these surfaces is confined to channels and immediately adjacent overbank areas.

Implications for fluvial behavior and potentially unstable stream reaches

We have used a hierarchical structure for the description of surficial geologic units in an attempt to depict the relative flood hazards across the Waterman Wash watershed. The potential for widespread shallow inundation and changes in channel position exists in many places because of the minimal topographic relief and the complex distributary and anastomosing flow networks that characterize much of the watershed. The potential for inundation and significant changes in channel patterns is much greater in some areas than in others, however. Units described in the first group comprise various elements of the active fluvial systems on the piedmonts of the area. These obviously include larger channels (units Qycr and Qyc), but channels are a very small part of the active fluvial systems on the piedmonts. Unit Qy3 includes many channels that are too small to adequately depict at a reasonable map scale, but most of this unit consists of bars, low terraces, and other overbank areas that are subject to sheetflooding. Typically, channel networks within the areas mapped as Qy3 are discontinuous, with obvious confined channel reaches and expansion reaches where channels diverge and in many areas disappear completely. Unit Qy2 depicts portions of the active system that are covered with very young fine-grained deposits indicative of sheetflooding. Channels are small and discontinuous or nonexistent in these areas.

Potentially unstable alluvial fan areas in the middle and upper piedmont areas are depicted by units Qyaf and Qy2. Areas mapped as Qy2 are part of the active drainage network and flood hazards are relatively high in these areas, similar to areas mapped as Qy3 and Qy2 elsewhere in the study area. Areas identified as potentially active alluvial fans (Qyaf) may be partially inundated in large floods, but the greatest concern for floodplain management in these areas is the potential for significant changes in the active drainage network. The deposits of unit Qyaf are relatively young (less than 10,000 years) and topographic relief between these areas and adjacent active channels and sheetflood areas is minimal, typically a few feet or less. Therefore, the potential exists for substantial changes in position in these areas, which may result in their incorporation into the active fluvial system.

Several other units have been subject to at least partial inundation during the Holocene, and these are grouped together in the intermediate flood hazard category. Channels in these areas typically are quite small and discontinuous, and most flood inundation that does occur is shallow sheetflooding. Sheetflooding is probably more common in areas designated as Qyi and less likely in areas designated as Qiy or Qy1. The eolian overprint of alluvial deposits that characterizes unit Qye indicates that fluvial processes have not shaped the surface during the recent past. Topographic relief between all of these areas and adjacent active fluvial systems is not great, however, and human modifications such as roads can dramatically alter drainage patterns.

Flood hazards are generally low in areas covered by Pleistocene or older alluvial deposits (units Qi_2, Qi_1, Qo, and QTa) and bedrock hillslopes (units R and Qtc). Drainage systems in these areas typically are tributary in nature and topographic confinement is sufficient to contain flood flows to channels and immediately adjacent terraces. Isolated areas of Pleistocene deposits surrounded by younger deposits may be flood prone, however, if topographic relief between the younger and older deposits is minimal (i.e., Pearthree et al, 2004).

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