SURFICIAL GEOLOGY AND FLOOD HAZARDS ON THE WESTERN PIEDMONT OF THE MARICOPA MOUNTAINS AND THE SOUTHERN PIEDMONT OF THE BUCKEYE HILLS, MARICOPA COUNTY, ARIZONA

Philip A. Pearthree, Jeri J. Young and Joseph P. Cook
Arizona Geological Survey

Gravel lag on Buckeye Hills piedmont.

OPEN-FILE REPORT OFR-12-07
June 2012

Arizona Geological Survey

www.azgs.az.gov | repository.azgs.az.gov
Surficial Geology and Flood Hazards on the Western Piedmont of the Maricopa Mountains and the Southern Piedmont of the Buckeye Hills, Maricopa County, Arizona

by

Philip A. Peartree, Jeri J. Young, and Joseph P. Cook

Arizona Geological Survey Open-File Report 12-07

August 2012

This report accompanies Arizona Geological Survey Digital Geologic Map DGM-75

Funding provided by the Flood Control District of Maricopa County and the Arizona Geological Survey. Work done in cooperation with Stantech.
Table of Contents

Introduction 2

Mapping Criteria 3

Surficial Geologic Map Units 5

Implications of Surficial Geology and Geomorphology for Piedmont Flood Hazards 16

Acknowledgments 22

References 22

List of Figures

Figure 1. Location of the mapped area in western Maricopa County. 3
Figure 2. Moderately large open channel (unit Qyc). 6
Figure 3. Smaller channels, gravel bars, and fine-grained overbank areas of unit Qy3. 7
Figure 4. Gravelly Qy2 deposits adjacent to an active channel. 8
Figure 5. Cobbles and small boulders at the apex of a young alluvial fan (Qyag). 9
Figure 6. Qya surface on the Buckeye Hills piedmont. 10
Figure 7. Bouldery debris flow deposits along a small drainage in the Maricopa Mountains. 11
Figure 8. Aerial photo showing debris flow deposits in the northern Maricopa Mountains. 11
Figure 9. Fine, moderately tight gravel lag is characteristic of Qy1 surfaces. 12
Figure 10. Aerial photo showing examples of Qiy. 13
Figure 11. Qi2 surfaces mantled by gravel with variable rock varnish. 14
Figure 12. Qi1 deposits are more incised and have strong calcic horizon development. 15
Figure 13. Locations of the example areas discussed later in this section. 16
Figure 14. Complex depositional patterns associated with distributary flow systems on the Buckeye Hills piedmont. 19
Figure 15. Distributary drainage networks, very extensive Qya deposits, and extensive Qiy deposits on the low-relief northern piedmont of the Maricopa Mountains. 20
Figure 16. Large alluvial fan complexes associated with 2 washes on the western Maricopa Mountains piedmont. 21
Figure 17. The upper portion of the northern large distributary system on the west side of the Maricopa Mountains. 22
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 surface characteristics associated with the deposits. Differences in the primary physical characteristics of surficial deposits result from differences in rock types in drainage basins, distance from uplands, and differences in the size and character of the stream system that transported the sediment. Surficial deposits are subsequently altered by processes of weathering, inputs of fine dust from the atmosphere, 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. Geologically young deposits on piedmonts record relatively recent activity of piedmont fluvial systems; laterally extensive young deposits are indicative of widespread flood inundation, shifts in flooding patterns, or both, in the past few thousand years. Thus, surficial geologic maps are very useful in defining the physical framework of active fluvial systems on piedmonts, and in particular are critical in evaluating the potential for alluvial fan flooding.

The primary purpose of this surficial geologic mapping conducted on the Buckeye Hills and Maricopa Mountains piedmonts (Figure 1) is to provide a geologic / geomorphologic basis for assessing the character and extent of piedmont flood hazards that can (1) be compared with the results of hydrologic and hydraulic analyses, and (2) provide basic data for alluvial fan flooding assessments. The map area within the Gillespie Area Drainage Master Study [ADMS] of the Flood Control District of Maricopa County [FCDMC] was delineated specifically to encompass the areas of distributary (downstream-branching) drainage networks and sheetfloodling associated with fluvial systems draining the south side of the Buckeye Hills and the west side of the Maricopa Mountains. The extent of the map area was initially inferred from a reconnaissance assessment of aerial photographs, but the boundaries were expanded slightly to assure coverage of all critical areas of distributary flow. The lower limits of both map areas are defined by areas that have been altered for agricultural activity or major facilities such as landfills and prison complexes. We primarily utilized color aerial photographs flown in 1978 for the Bureau of Land Management and color orthophotographs produced in 2007 and 2010 as part of the statewide National Agricultural Inventory Program (NAIP). We also used several generations of georectified aerial photo coverage available through Google Earth. Most of the map area was covered by 2-foot topographic contours provided by the FCDMC, and these were used to discriminate map units based on detailed topography. 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 (e.g., Pearthree et al., 2009). Mapping was compiled digitally using ESRI ArcGIS software.
Geologic units estimated to be a few thousand years old or less depict the approximate extents of active or recently active fluvial systems on the piedmonts of the Gillespie ADMS. The distribution of these young deposits across the piedmonts also provides information that can be help to understand the behavior of distributary drainage systems and 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.

**Mapping Criteria**

Surficial geologic maps are constructed based on the physical characteristics of alluvial surfaces and deposits, 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 surfaces 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 evidence of braided or distributary channel networks. Young alluvial surfaces have little rock varnish on surface gravel, weak or no desert pavement development, minimal soil
development, and channels typically are incised a few feet or less below these alluvial surfaces. Older alluvial surfaces, in contrast, have been isolated from substantial fluvial deposition or reworking for tens to hundreds of thousands of years. These surfaces have been strongly modified by processes of erosion and soil formation, 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 carbonate- or clay-rich soils, well-developed tributary stream networks that are entrenched 3 or more feet below the fan surface, and moderately to strongly developed varnish on surface rocks that may form tightly interlocking pavements. Vegetation assemblages typically are quite different between younger and older alluvial surfaces, reflecting differences in soil development, coarseness of deposits, and water availability and distribution in the subsurface.

Several characteristics evident on aerial photographs and on the ground were used to differentiate and map various alluvial surfaces in the Gillespie ADMS. The color or tone of alluvial surfaces on aerial photographs is primarily controlled by soil color, rock varnish and desert pavement, and vegetation type and density. 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, clay-enriched cambic and argillic horizons and white, calcium-carbonate-rich calcic horizons. As a result, on color aerial photographs older alluvial surfaces characteristically appear reddish, whitish (on more eroded surfaces) or mottled. 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. Younger surfaces typically are gray or brown in color. 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 or braided channel patterns, although young surfaces may have very little developed drainage if shallow sheetfloodling predominates. Dendritic tributary drainage systems incised well below the surrounding landscape are characteristic of older surfaces. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be evaluated using stereo-paired aerial photographs and topographic maps. Young flood-prone surfaces are nearly flat or gently undulating and are less than 3 feet above channel bottoms. Active channels are entrenched 3 to 30 feet below older, inactive alluvial surfaces, and these surfaces typically are more or less rounded by erosion depending on surface age and the amount of local incision.

Ages of all map units were roughly estimated through correlations to deposits and alluvial surfaces with similar characteristics in the southwestern U.S. (e.g., Gile et al., 1981; Machette, 1985; Bull, 1991). Few numerical age constraints exist for these deposits in Maricopa County (Huckleberry, 1997; Young, 2010), numerical dating techniques for piedmont deposits are fairly expensive, and no funding was allocated for new dating in this project. Soil development does provide a basis for crudely estimating ages of surficial deposits. For example, in soils less than a few thousand years old, calcic horizon development consists of fine white filaments of calcium
carbonate (typical of Qy2 and Qya deposits). Soil horizons closer to the surface may exhibit a bit of soil structure, but no detectable increase in clay content. Somewhat older soils have thin but obvious calcium carbonate coatings on pebbles and cobbles and slight clay increase in shallow soil horizons (typical of Qy1 and Qi3 deposits). Older deposits may have soil horizons partially or completely cemented with calcium carbonate (caliche; typical of Qi1 deposits) and distinctly reddened horizons with some increase in clay content immediately beneath the surface. Published soil survey maps for this area (Hartmann, 1977) provide information on soil development in various parts of these piedmonts, but the maps are much more generalized than this surficial mapping so attributing the characteristics of particular soil map units to our surficial geologic units is problematic.

**Surficial Geologic Map Units**

**Qyc** – Active channel deposits; light gray, moderately to poorly sorted, unconsolidated sand, pebbles and cobbles, locally with small boulders in channels and bars of larger washes; lightly vegetated except along channel margins; both tributary and distributary channels are mapped separately from surrounding deposits where large enough to delineate at mapping scale.

*Surface roughness: low to moderate; generally low vegetation size and density except along margins, channels relatively smooth, but bed roughness varies with particle size.*

*Infiltration potential: moderate to high.*

*Flood hazard is high, with frequent inundation and deep, high velocity flow.*

Figure 2. Moderately large open channel (unit Qyc). Coarser bed load on the margins of the channel is likely transported in larger floods. Finer gravel and sand in the channel bottom may have been deposited in the later stages of floods or in smaller events.
**Qy3** – Smaller channel, bar, and low terrace deposits that are part of the active drainage system; channel and bar deposits typically consist of light gray, poorly sorted sand and pebbles, with some cobbles and boulders; terraces typically are less than 3 feet above adjacent active channels and consist of similar deposits, but typically are partially or totally mantled by sand and silt; deposits of this unit have essentially no soil development and the associated vegetation consists of bursage, creosote, palo verde, iron wood, and mesquite.

*Surface roughness: moderate to high; relatively high vegetation density outside channels; variable local topography.*

*Infiltration potential: moderate to high.*

*Flood hazard is high, with frequent inundation; areas of deep, high velocity flow and more extensive sheetflood inundation.*

Figure 3. Smaller channels, gravel bars, and fine-grained overbank areas typical of unit Qy3. Areas mapped as Qy3 typically have relatively abundant vegetation, including desert riparian trees and shrubs.
**Qy2** – Low terrace deposits along larger channels; typically at least 3 feet above active channels and not laterally extensive. Deposits consist of moderately sorted sand, pebbles and cobbles, and are commonly capped by sand and silt deposits. Surface gravel is not varnished and soil development is very weak, with no clay accumulation and thin carbonate filaments and incipient gravel carbonate coatings. Associated vegetation includes mostly creosote with some palo verde, iron wood and mesquite.

*Surface roughness: moderate; vegetation generally small, medium density; variable particle size Infiltration potential: moderate to high.*

*Flood hazard is moderate, with infrequent sheetflood inundation and generally shallow flow*
**Qyag** – Coarse-grained proximal young alluvial fan deposits; surface color is light gray; deposits are very poorly sorted, consisting of sand to small boulders; coarse cobbly and boulder deposits form distinct bars up to 3 feet higher than adjacent channels; mapped only in a few areas on the Buckeye Hills piedmont where deposits consist of a large proportion of cobbles and boulders. No soil exposures in this unit were observed.

*Surface roughness: high; medium vegetation density, surface gravel common and relatively large caliber; variable local topography*

*Infiltration potential: high.*

*Flood hazard is moderate, with infrequent inundation but potential for high velocity flow and dramatic changes in channel positions during floods.*

Figure 5. Cobbles and small boulders deposited at the apex of a young alluvial fan are typical of Qyag. Light-colored, unvegetated area in the foreground and toward the right side of the photo is mapped as Qyc, but is clearly part of the young alluvial fan system.
**Qya** – Laterally extensive, sandy to gravelly young alluvial fan or sheetflood deposits. Qya surfaces are light gray to brown in color. Deposits are very poorly to poorly sorted sand, fine gravel, with granules, pebbles, cobbles and rare boulders; channels are incised less than 5 feet and typically much less than that. Surfaces are typically drained by weakly integrated networks of very small distributary channels. Soil development is weak with minimal structure, no clay accumulation and carbonate filaments and incipient gravel coatings. Qya units are dominated by creosote with some small shrubs and desert trees such as palo verde and mesquite.

*Surface roughness: moderate; vegetation generally small, low to medium density, coppice mounds around bushes; variable particle size, but surface gravel generally limited.*

*Infiltration potential: moderate.*

*Flood hazard is moderate to low, with infrequent to rare sheetflood inundation; some potential for changes in channel linkages or development of new channels during floods.*

---

Figure 6. Fine gravel lag mantles a Qya surface on the Buckeye Hills piedmont. Topographic relief is very low and the surface is gently undulating, although active distributary channels may be incise up to 4 ft below Qya surfaces.
Qyd – Holocene to late Pleistocene debris flow deposits. This unit consists of very coarse, very poorly sorted deposits along drainages on steep hillslopes, on adjacent alluvial fans, and along washes within and near the mountains. Deposits consist primarily of small to medium boulders, cobbles, pebbles and sand. Typically, the coarse deposits form curvilinear levees paralleling small washes or irregularly shaped piles representing debris flow snouts. Most of these deposits have moderate rock varnish, but some deposits are obviously less varnished and relatively young. This unit also includes areas of erosion (debris flow scars) on hillslopes that are spatially associated with debris flow deposits.

Surface roughness: high; vegetation small to moderately large, medium density, coarse particle size.

Infiltration potential: moderate to high.

Flood hazard is moderate to high, with frequent inundation in channels and rare inundation in adjacent boulder berms and snouts; high potential for changes in channel positions during debris flows, which are almost certainly rare events along individual washes.

Figure 7. Bouldery debris flow deposits along a small tributary drainage in the Maricopa Mountains. Light-colored (unvarnished), medium to large boulders in the foreground and in the channel in the middle distance were deposited by a recent debris flow. Darker (varnished) boulders lining the channel were deposited by older and larger debris flows.
Figure 8. Aerial photograph showing debris flow scars and deposits in the northern Maricopa Mountains. White arrows point to darkly varnished boulder trains along drainages, and a wider area of debris flow deposits at the head of an alluvial fan. Dashed lines show approximate downslope limit of debris flow deposition. Solid white line represents 1500 ft.
Qy1 – Intermediate terrace deposits along channels and inactive portions of alluvial fans. Qy1 surfaces are at least 3 feet above adjacent channels. Deposits consist of poorly to moderately sorted silt, sand, pebbles, and cobbles, with some small boulders. Gravel clasts on Qy1 surfaces are generally unvarnished or weakly varnished; gravel bar and swale deposits are about 1 foot high; soil development is weak, with incipient calcium carbonate accumulation. Vegetation on Qy1 surfaces is predominantly creosote.

Surface roughness: medium; vegetation generally small, medium density; variable particle size; smooth to gently undulating local topography
Infiltration potential: moderate.
Flood hazard is low, with rare shallow inundation possible in some areas.

Figure 9. Fine, moderately tight gravel lag is characteristic of Qy1 surfaces. These surfaces typically are not subject to inundation in floods, and vegetation is sparse.
**Qi** – Pleistocene alluvial fan deposits that have been substantially eroded or partially buried by younger deposits. Some areas retain characteristics of Pleistocene relict surfaces, such as gravel surface lags and moderate soil development, but in other areas these characteristics have been modified by erosion or partially obscured by younger deposits. This unit designation is applied to areas where the spatial relationships between Pleistocene and younger deposits are complex, and topographic relief between surfaces of different ages is a few feet or less.

*Surface roughness: medium; vegetation generally small, low density; areas partially covered by gravel; gently undulating local topography.*

*Infiltration potential: moderated to low.*

*Flood hazard is low, with shallow inundation possible in some areas.*

---

Figure 10. Aerial photo image of part of the northern Maricopa Mountains piedmont showing examples of Qi. In this area, Qi is probably eroded Qi2 that is partially covered by younger deposits. Horizontal white line is 1500 feet.

---

**Qi3** – Lightly to moderately dissected relict alluvial fan and terrace deposits; deposits consist of poorly sorted sand, pebbles, cobbles, and silt, with some small boulders. Gravel clasts on Qi3 surfaces are weakly to moderately varnished; pavements, where present, vary from weak to moderate; surfaces are generally fairly smooth between incised drainages, which are up to about 6 ft deep; soil development is weak to moderate, with visible calcium carbonate accumulation; Qi3 surfaces are typically lightly vegetated, with small trees along incised drainages and sparse creosote bushes on planar surfaces. Qi3 deposits are mapped in only a few areas; equivalent are grouped with Qi2 deposits in most of the map area.
Surface roughness: medium; vegetation generally small, low density; surfaces typically partially covered by gravel; smooth local topography
Infiltration potential: low.
Flood hazard is low; deposits generally subject only to local sheetflow or inundation immediately adjacent to incised washes.

Qi2 – Moderately dissected relict alluvial fan and terrace deposits; deposits consist of poorly sorted sand, pebbles, cobbles, and silt, with some small boulders and clay. Gravel clasts on Qi2 surfaces are vary from darkly to lightly varnished; pavements vary from weak to moderately strong; surfaces are generally fairly smooth between incised drainages, which are up to about 10 ft deep; soil development is moderate, with visible calcium carbonate accumulation. Qi2 surfaces are typically lightly vegetated, with small trees along incised drainages and sparse creosote bushes on planar surfaces.
Surface roughness: medium; vegetation generally small, low density; surfaces typically partially covered by gravel; smooth local topography
Infiltration potential: low.
Flood hazard is low; deposits generally subject only to shallow inundation immediately adjacent to incised small washes.

Figure 11. Qi2 surfaces characteristically are mantled by gravel with variable, but in some cases fairly dark, rock varnish. Locally, gravel mantles form moderate to tight gravel pavements. Soils are slightly reddened, but clay accumulation is not impressive.
Qi1 – Eroded relict alluvial fans; deposits consist of poorly sorted pebbles, cobbles, sand and silt, with some small boulders and clay. Varnish on gravel clasts is variable, from darkly varnished to weakly varnished; pavements vary from weak to strong depending on preservation. Surfaces are generally rounded, and planar remnants between incised drainages up to 30 ft deep. Soil development is strong, with abundant calcium carbonate accumulation and some cementation; carbonate fragments are fairly common on surfaces. Qi1 surfaces are typically lightly vegetated, with small trees along incised drainages and sparse creosote bushes on rounded surfaces.

Surface roughness: medium; vegetation generally small, low density; surfaces typically covered by gravel

Infiltration potential: low.

Flood hazard is low; deposits generally subject only to local inundation immediately adjacent to small, incised washes.

Figure 12. Qi1 deposits are typically 6 ft or more above active washes and have strong calcic horizon development. Surface at the top of the bank in the left photo is Qi1. The close-up photo on the right shows a calcium-carbonate-cemented petrocalcic horizon.

Qi – Undifferentiated Pleistocene alluvial fan and terrace deposits; used where we are not confident whether deposits should be designated Qi1 or Qi2, generally in areas of relatively low topographic relief.

QTa – Highly eroded relict alluvial fans deposits. Depth of dissection depends on the local setting, but typically is 20 feet or more, and QTa surfaces typically consist of rounded ridges and adjacent valleys. Deposits consist of moderately cohesive sand and gravel, and surfaces are mantled with gravel. Locally, ridges formed primarily in QTa deposits are capped by younger Qi1 alluvial surfaces. Soil development is variable as a result of erosion.

pCg – Primarily granite and metamorphic rocks such as gneiss; also includes areas covered by colluvium.
Qtc – Hillslope colluvium; designated only near bedrock hills.
d – Profoundly disturbed by human activity; primarily highways.

**Implications of Surficial Geology and Geomorphology for Piedmont Flood Hazards**

In this section, we discuss the geologic and geomorphic framework of the area and how it affects the nature of modern fluvial behavior and the distribution of potential flooding on the piedmonts. We then generally assess the flood hazards associated with each of the surficial geologic units. Using the distribution of these units on the piedmonts, we discuss the variations in fluvial behavior across the piedmonts. Finally, we consider three particular areas (see Figure 13) that illustrate quite different flood hazards associated with distributary drainage systems.

Figure 13. Locations of the example areas discussed later in this section.
**Landscape evolution and climate change.** The distribution of flood-prone areas and the character of flood hazards in various parts of the Buckeye Hills and Maricopa Mountains piedmonts are the product of millions of years of geologic and geomorphic evolution of this region. Taking a very long view, fluvial systems move material from topographically high areas (hills and mountains) onto adjacent piedmonts. Some of this sediment is transported to larger trunk streams (like the Gila River), and eventually at least some of that sediment reaches the sea. Most of the coarse material that is eroded from the mountains is deposited on adjacent piedmonts as alluvial fans, however, and much of this sediment remains on the piedmont for thousands to millions of years.

Global and regional climate changes that occurred during the Quaternary period (the past 2.6 million years) have resulted in changes in sediment supply from the mountains and the ability of fluvial systems to transport sediment. This has in turn resulted in periods of net aggradation and net incision on desert piedmonts (Bull, 1991). Alluvial fan deposits of different ages on piedmonts of Maricopa County record periods of net aggradation that undoubtedly lasted for thousands of years. Older alluvial fan deposits are exposed (not buried) in some areas of the piedmont because of subsequent stream incision and partial erosion of the older deposits. In addition, areas of major deposition have varied, at times being adjacent to the mountains and at other times well down on the piedmont. During periods of net aggradation, deposits initially fill in existing erosional topography. If deposition is sufficient to fill in this topography on parts of the piedmont, opportunities arise for floodwater to spread widely and for loci of deposition to shift positions, the processes that form active alluvial fans.

**Piedmont geomorphology and the extent and character of flooding.** The distribution of young deposits on these piedmonts provides a cumulative record of many large floods over the past few thousand years. This assertion is based on a simple premise – that fluvial systems erode, deposit, or rework existing deposits during floods. The spatial distribution of young deposits across piedmonts and the character of the modern channel networks together record recent fluvial behavior, and thus provide important clues regarding the potential for flooding. In addition, the character of deposits provides clues to the nature of the fluvial processes (channel flow, sheetflooding, debris flows) that emplaced them. Areas of very young deposits (Qyc, Qy3) compose the most active parts of the modern fluvial systems and are most prone to flooding. Not coincidentally, these are almost always in local topographic lows. These are also areas of relatively deep and high-velocity flow, and this is reflected in the relatively large caliber of the deposits. Adjacent young geologic units that are slightly higher in the landscape or farther removed from the most active parts of the fluvial system (Qy2, Qyag, Qya) are likely prone to inundation in large floods. Sheetflooding probably occurs during large floods in some in areas designated as Qiy and Qy1, where topographic relief between younger and older surfaces is minimal (e.g., Pearthree et al, 2004). Areas of the youngest Pleistocene deposits (Qi3) are moderately incised and generally are not subject to inundation. In areas covered by older Pleistocene deposits (units Qi2, Qi1, Qi, and QTa) and bedrock hillslopes (units pCg and Qtc), flood inundation is confined to areas immediately adjacent to small washes. 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.

In mountain canyons and upper piedmont areas where flood flows are confined by local topography, corridors of young deposits are quite thin. The typical set of surficial deposits includes Qyc or Qy3 in the lowest areas, fringed by slightly higher, relatively narrow Qy2 or Qy1 terraces. Lateral topographic confinement is provided by bedrock hillslopes or incised Pleistocene (Qi1, Qi2, Qi) alluvial fan or terrace deposits. Distributary channel networks and laterally extensive suites of young deposits characterize piedmont areas where lateral topographic constraints decrease or widen dramatically. Channels that are large enough to depict at the map scale are a very small part of the active fluvial systems in the distributary portions of the piedmonts. More extensive Qy3 deposits include many smaller channels, but mostly consist of bars, low terraces, and other overbank areas that are subject to shallow flooding. Adjacent areas that have been subject to shallow inundation, and possibly changes in channel position, during large floods in the past few thousand years are mapped as Qya and locally Qyag. Typically, channel networks within the areas mapped as Qy3 and Qya are discontinuous, with obvious narrow channel reaches and expansion reaches where channels diverge and in some areas disappear completely. It is not uncommon for areas of young deposition to narrow again downslope along distributary drainageways that are incised into Pleistocene alluvial fan deposits. Obviously, patterns of young deposition on piedmonts are complex and are not necessarily consistent with simple models of alluvial fan flooding (e.g., FEMA, 1990).

**Examples from the Buckeye Hills and Maricopa Mountains piedmonts.** Within the map area, all of the fluvial systems that drain the Buckeye Hills have distributary reaches somewhere on the adjacent piedmont. Washes are incised well below Pleistocene alluvial fan deposits in all upper piedmont areas, but in middle and lower piedmont areas laterally extensive Qya and younger deposits are common (see Figure 14). Because of the low topographic relief across most of the Qya surfaces, broad sheetflooding certainly occurs during large floods. Gravel bars are fairly common in Qya deposits, and they are indicative of deeper flow in or adjacent to relict channel systems that have not been active for some time. Thus, there have been changes in channel positions in these areas over the past few thousand years. Along several of the distributary systems, active fluvial systems and the young deposits associated with them become reconfined by Pleistocene fan deposits farther downslope, and in some areas, young deposits become laterally extensive again as the systems grade to the Gila River floodplain (Figure 14).
Figure 14. Complex depositional patterns associated with distributary flow systems on the Buckeye Hills piedmont. Young, laterally extensive deposits (Qya) cover much of this part of the piedmont. Low to moderately large flood flows are likely conveyed through these areas in many small channels, but sheetflooding is almost certainly an important in larger floods (see Pearthree et al., 2004). The approximate lateral extent of the sheetflood areas is shown with the dashed line. Relict gravel bars indicate that channel locations have shifted in these areas as well. Numerous separate washes (shown with blue arrows) contribute flow to broad Qya areas. Sheetflooding becomes reconfined along incised drainageways in several of the distributary systems (shown with white arrows), and then spreads widely again as the systems grade to the Gila River floodplain in the lowermost left part of the image. The solid white line represents 1500 ft.
Drainage networks and patterns of young deposition imply different patterns of fluvial behavior and flooding on various parts of the Maricopa Mountains piedmont. On much of the piedmont fringing the northern Maricopa Mountains, young deposits are very extensive and typical topographic relief between numerous active channels and adjacent young alluvial surfaces is a few feet or less. Qya deposits in this area are generally fine gravel and finer except in the upper portions of the distributary systems. Topographic relief is also very minor in adjacent areas mapped as Qiy, and as is noted in the unit description, these areas are partially covered by young deposits. The character of the deposits and the broad extent of the Qya and Qiy deposits strongly suggest that sheetflooding is the dominant fluvial process on this piedmont. Changes in channel position may occur in large floods, particularly in the upper parts of the distributary systems, and these may change the distribution of floodwater farther down the piedmont. Relatively minor differences in local topographic relief may direct sheetflooding into different parts of the lower piedmont, and inundation in large floods may well be discontinuous across broad swaths of the piedmont.

Figure 15. Distributary drainage networks, very extensive Qya deposits, and extensive Qiy deposits on the low-relief northern piedmont of the Maricopa Mountains. Channels are incised 5-10 ft below Pleistocene alluvial fan deposits near the mountains in the lower part of the photo. Relief between channels and adjacent Qya and Qiy deposits is typically 3 ft or less in the upper 2/3 of the photo. Solid white line represents 1500 ft.
Two watersheds that drain much of the northern Maricopa Mountains have large distributary channel networks and have formed large alluvial fan complexes on the western piedmont of the range (Figure 16). Unlike the areas discussed previously, however, most of the area within these fans consists of incised Pleistocene fan deposits, which are generally not prone to flooding. Distributary channel networks of these systems are very complex - in fact, a small distributary channel branch from the northern wash links to the southern wash through an intramontane valley roughly 2 miles east of the main distributary split on the upper piedmont (Figure 16). Flood flows through these distributary systems must be quite complex, but over the past few thousand years, and in many areas for much longer than that, flow has been restricted to valleys and has not spread widely on the fan surfaces downslope from major distributary channel splits. This is particularly true of the southern fan complex, where deeply incised, very old deposits (units QTa and Qi1) make up the majority of the fan and young deposits are very limited in lateral extent.

Figure 16. Large alluvial fan complexes associated with 2 washes on the western Maricopa Mountains piedmont. These large washes drain much of the northern Maricopa Mountains. Blue arrows depict principal flow paths leading to the major distributary systems; white areas illustrate some of the distributary flow paths. Dashed lines show the approximate lateral extents of the fan complexes, which consist primarily of Pleistocene fan deposits. Distributary drainage patterns are very complex, especially on the northern fan complex – some drainage paths are depicted with white arrows. In addition, a minor distributary channel links the northern and southern systems via a valley about 2 miles east of the mountain front.
The northern fan complex is less deeply incised and consists of generally younger Pleistocene fan deposits (Figure 17). The “tributary” or moderately confined drainage that feeds the primary distributary system is characterized by complex, anastomosing channels and broad areas of young deposits between them. At the head of the primary distributary system, several relatively small channels diverge downstream, and the lateral extent of young deposits (Qiy and younger) is quite wide. Just downslope, flood flow splits into multiple flow paths separated by Pleistocene deposits that are typically 5-10 feet above the active washes. Some of these flow paths are very narrow, implying that they do not carry much flood flow, have developed fairly recently, or both. Given that topographic relief between surfaces of different ages at the top of the distributary system is minimal, the potential for slightly different flow paths to develop in floods cannot be discounted. Farther downslope in the distributary system, somewhat more extensive young deposits indicative of sheetfloodings exist in both the southern and northern portions of the complex. The central portion of the fan complex consists mostly of late Pleistocene deposits (unit Qi2) and is primarily drained by small tributary washes that head on the fan.

Figure 17. The upper portion of the northern large distributary system on the west side of the Maricopa Mountains. Flood flows exit the mountain in a broad valley, with anastomosing channels (large blue arrow). The system transitions to distributary flow near the valley mouth (1st dashed line). Distributary drainages downslope from there are quite complex (white arrows). Most of the area within the distributary network is covered by Pleistocene deposits and is not active, but there are areas of sheetfloodings farther down in the system (dashed lines near the left edge of the photo).
Acknowledgments

Pat Ellison and Mike Gerlach of Stantech provided logistical support for our project and helpful feedback for our mapping. Jennifer Pokorski and Kathryn Gross of the Flood Control District of Maricopa County provided encouragement for and review of our mapping. Ryan Clark and Janel Day of the AZGS provided GIS support and map layout. We are grateful to Jon Fuller for many useful and interesting discussions regarding the geomorphology and flood hazards of piedmonts in central Arizona.

References


