WITTMANN AREA DRAINAGE MASTER STUDY UPDATE (ADMSU)

GEOMORPHIC AND SEDIMENTATION ANALYSIS REPORT

VOLUME GR

FINAL REPORT

Contract FCD 2002C029

April, 2005

Prepared by:

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Flood Control District of Maricopa County

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ARIZONA, U.S.A.

Wittmann Area Drainage Master Study Update
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SECTION GR-1: INTRODUCTION

This geomorphology report is a chapter in the Wittmann Area Drainage Master Study Update (ADMSU). The goal of the ADMSU is to identify flood hazard areas and drainage problems as well as to identify potential cost-effective solutions to alleviate or manage flooding in the Wittmann study area.

The main portion of the geomorphic analysis is a piedmont assessment of the Wittmann study area. In the course of this piedmont assessment, the Wittmann study area was broken down into three distinct areas. These areas are 1) the area south of the Sun Valley Parkway to the study boundaries (i.e., the White Tank Mountains area), 2) the area north of the Central Arizona Project (CAP) canal and east of Grand Avenue, and 3) the area between the Sun Valley Parkway and the CAP/Grand Avenue boundary. All three of these areas were studied at a different level of detail as explained in the report. Most of the effort was concentrated on the White Tank Mountains area and the area north of the CAP canal and east of Grand Avenue. In addition to the piedmont assessment, a 100-year sediment yield analysis was performed for McMicken Dam. Also, a sedimentation and erosion hazard analysis was performed for the Wittmann study area. Finally, an erosion hazard zone analysis was performed on four (4) washes in the Wittmann study area: the Trilby Wash, the Iona East Wash, the Iona West Wash, and the CAP-1 West Wash.

SECTION GR-2: STAGE 1 AND 2 PIEDMONT ASSESSMENT OF THE WHITE TANK MOUNTAINS AREA

2.1. Introduction

Stage 1 and stage 2 piedmont assessments were performed on the area south of the Sun Valley Parkway and north of the White Tank Mountains. McMicken Dam forms the boundary for the eastern side of the study area. The southern and western boundaries of the study area are defined by the edge of the watershed that flows into McMicken Dam. The location and approximate shape of the study area is shown in the lower left hand portion of Figure GR-1.

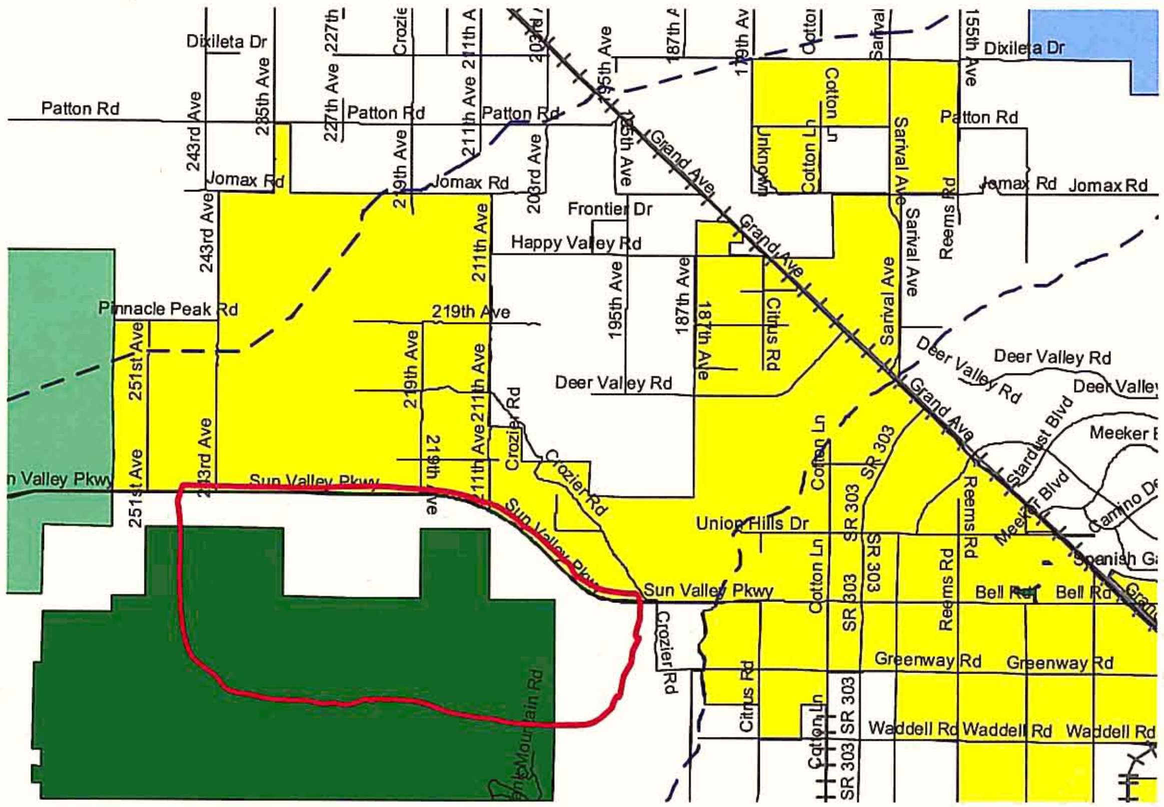

Figure GR-1. White Tank Mountains study area. Study area is outlined in red south of Sun Valley Parkway and west of McMicken Dam.

2.2. Landforms of Maricopa County

According to Hjalmarson (2003), there are four major landforms in Maricopa County: pediments (P), relict fans (RF), alluvial fans (AF), and alluvial plains (AP). A fifth landform, other old alluvium (OOA), is also an acceptable landform to the Flood Control District of Maricopa County (FCDMC). Hjalmarson (2003) gives the following definitions for the first four landforms.

2.2.1. Pediment

A pediment is a broad, flat or gently sloping, rock-floored erosion surface located at the base of an abrupt mountain front or plateau escarpment. Pediments are underlain by bedrock that may be bare but more often are partly mantled with a thin and discontinuous veneer of alluvium derived from the upland masses and in transit across the surface.

2.2.2. Relict Fan

A relict fan is an erosion remnant of an old alluvial fan that was formed in the past geologic epoch and hardened by cementation. The original fan surface has been strongly modified by erosion. In some cases, the original fan shape has not survived disintegration or burial.

2.2.3. Alluvial Fan

An alluvial fan is a sedimentary deposit located at a topographic break, such as the base of a mountain front, escarpment, or valley side, that is composed of streamflow and/or debris flow sediments and has the shape of a fan, either fully or partially extended.

2.2.4. Alluvial Plain

An alluvial plain is a nearly level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium. It may be situated on a flood plain, a delta, or at the toe of an alluvial fan.

2.2.5. Other Old Alluvium

There is no formal definition for other old alluvium. Essentially, these are old embayed valleys near the toe of hill slopes that do not meet the criteria to be either a relict fan or a pediment.

2.3. Identification of Landforms

2.3.1. Methodology

The methodology for a stage 1 analysis as outlined in the draft version of *Piedmont Flood Hazard Assessment for Flood Plain Management for Maricopa County, Arizona* (Hjalmarson 2003) was used to identify the landforms in the White Tank Mountains area. The landforms in this area were classified as pediments, relict fans, alluvial fans, alluvial plains, or other old alluvium. Hjalmarson (2003) lists several indicators that can be used to identify the landforms. A summary of the indicators that were used in this study along with a description of the data sources used follows.

2.3.1.1. Soil Type

Soil type was one of the prime indicators used to identify the landforms in the White Tank Mountains area. Hjalmarson (2003) provides a list of typical soils found in each of the landforms. National Resource Conservation Service (NRCS) soil survey reports by Camp (1986) and Hartman (1977) were used to identify the soil types in the White Tank Mountains area.

2.3.1.2. Surficial Geology

Maps that show the surficial geology of the area can be used to help identify the landforms. Typically, older surfaces are associated with pediments and relict fans while younger surfaces are associated with alluvial fans and alluvial plains.

Geological Consultants, Inc. provided a detailed geologic map of the study area.

2.3.1.3. Flood Hazard Potential

An Arizona Geological Survey report by Field and Pearthree (1992) reports the potential flood hazards in the White Tank Mountains. Field and Pearthree (1992) used topographic maps, aerial photographs, and ground surveys to estimate the degree of flood hazard. Field and Pearthree's (1992) flood hazard map and the surficial geologic map are similar because older surfaces typically have a low flood hazard while younger surfaces have a higher flood hazard.

2.3.1.4. Slope

Slope can be an indicator of landform type. Hjalmarson (2003) lists typical slopes for the various landforms. Average slopes of the landforms were estimated from detailed contour data provided by the FCDMC.

2.3.1.5. Surface Texture

The surface texture of the landforms can be categorized from aerial photographs and topographic maps. A large variety of data sources were used to help identify the surface texture of the landforms. These data sources included United States Geological Survey (USGS) 7.5 minute topographic maps, FCDMC's detailed contour data, black and white aerial photographs (1940, 1958, and 2003), natural color aerial photographs (1979), and color infrared aerial photographs (1982). The oldest black and white photographs were from the Fairchild Project. The 1958 aerial photographs were taken by the United States Department of Agriculture (USDA), and the most recent black and white photographs were provided by the FCDMC. The natural color aerial photographs were taken by the United States Bureau of Land Management (BLM) and the color infrared photographs were taken by the USGS. A list of the surface texture characteristics that were used to identify the landforms follows.

Pediments

1. Low topographic relief.
2. Large vegetation along the banks of the larger channels.
3. Exposed bedrock along incised channels.
4. Drainage pattern is tributary on the upper slopes of the pediment.
5. Drainage pattern may be tributary, distributary, or anastomosing on the lower slopes of the pediment.
6. Drainage pattern increases upslope.
7. There are many first-order channels.

Relict Fans

1. May have a light appearance with boundaries that can be easily seen on aerial photographs (due to lack of vegetation).
2. May have a dark appearance due to desert varnish.
3. Larger channels are separated by wide interfluves that are cut by small tributary channels.
4. Crenulations are distinct with an alternating ridge-valley-ridge appearance.
5. Large vegetation along the banks of the larger channels.
6. Hill slopes are cut into numerous short noses or long spurs by side slope drainage ways.

7. Drainage pattern decreases upslope.

<u>Alluvial Fans</u>

1. Crenulations are flat and slightly rounded.
2. May have a light appearance with boundaries that can be easily seen on aerial photographs (due to lack of vegetation).
3. May have a dark appearance due to desert varnish.
4. Drainage pattern is uniform in the upslope direction (inactive alluvial fans).
5. Undulating and parallel ridges and valleys of small channels (inactive alluvial fans).
6. Smaller channels than relict fans (inactive alluvial fans).
7. Surface texture is a result of tributary channels (inactive alluvial fans).
8. Braided-stippled appearance (active alluvial fans).
9. Surface texture is a result of many braided channels, the movement of sediment, and scattered growth of vegetation (active alluvial fans).

<u>Alluvial Plains</u>

1. Low topographic relief.
2. Smooth, nearly level surface.
3. Widely spaced, small washes.

2.3.1.6. Surface Color

A light surface color can indicate that the surface is young and has been recently eroded or subjected to sediment deposition. A dark surface usually indicates an older surface that is covered with desert varnish. As mentioned in the Surface

Texture section, an older relict fan may also have a light appearance due to the sparse vegetation. The aerial photographs provided by the FCDMC were used to get an estimate of the surface color of the landforms.

2.3.1.7. Channel Size

Older landforms such as pediments and relict fans have a greater amount of channel incision than younger surfaces. Aerial photographs, FCDMC's contour data, and the 7.5 minute USGS topographic maps were used to get a qualitative estimate of the amount of channel incision.

2.3.1.8. Drainage Pattern

The drainage patterns of the various landforms were briefly mentioned in the Surface Texture section. The various aerial photographs were used to determine the characteristic drainage pattern of each landform.

2.3.1.9. Contour Shape

The contour shape of the landform was already used to get an estimate of the surface texture and the amount of channel incision. Typically, rounded, smooth contours may depict an alluvial fan. Contours with large crenulations may depict older surfaces such as relict fans and pediments. FCDMC's contour data and the 7.5 minute USGS topographic maps were used to determine the contour shape of the landforms.

2.3.1.10. Desert Pavement

Typically, older surfaces have desert pavement while younger surfaces do not. The aerial photographs and Field and Pearthree's (1992) report on flood hazards were used to get an estimate of the amount of desert pavement on the landform.

Field surveys were performed at selected sites to verify the amount of desert pavement reported by Field and Pearthree (1992).

2.3.1.11. Desert Varnish

Like desert pavement, desert varnish is indicative of older landforms. Again, the aerial photographs and Field and Pearthree's (1992) report were used to determine if a landform had desert varnish. Their conclusions were checked during field visits of selected sites.

2.3.1.12. Vegetation

Vegetation type and distribution are good methods for identifying landforms. FCDMC's aerial photographs were used to identify the distribution of the vegetation. The field visits were used to verify the vegetation type.

2.4. Identification of Stable and Unstable Areas

2.4.1. Methodology

The methodology for a stage 2 analysis as outlined in the draft version of the *Piedmont Flood Hazard Assessment for Flood Plain Management for Maricopa County, Arizona* (Hjalmarson 2003) was used to identify stable and unstable areas of the landforms in the White Tank Mountains area. Hjalmarson (2003) lists several indicators that can be used to identify the stable and unstable portions of the landforms. Many of these indicators overlap with those used to classify the landform during the stage 1 analysis. A summary of the indicators that were used in this study along with a description of the data sources used follows.

2.4.1.1. Definitions

Hjalmarson (2003) gives the follow definitions of stable and unstable.

- Stable – the relative state of the location, geometry, and roughness of a channel, network or channels, or landform where any changes of flow path, geometry, and roughness during floods are likely to be minor and can be set aside in realistic assessments of flood risk.
- Unstable – the relative state of the location, geometry, and roughness of a channel, network of channels or landform where major changes of flow path, geometry, and roughness are possible during floods and cannot be set aside in realistic assessments of flood risk.

2.4.1.2. Flow Path Movement

If there has been no channel movement, then the landform should be classified as stable. Conversely, if there has been channel movement, then the landform should be classified as unstable. *Comparing recent and historic aerial photographs is a* good way of determining whether there has been any flow path movement. The 2003 aerial photographs from the FCDMC, the 1958 aerial photographs from the USDA, and the 1940 Fairchild photographs were used to determine the amount of flow path movement on the landforms.

2.4.1.3. Soils

In general, Eba-Pinaleno, Laveen, Gran-Wickenburg complex, and Anthony soils are associated with stable areas. Carrizo, Gilman, Brios, Estrella, and Torrifluvents are associated with unstable areas. The NRCS soil survey reports by Camp (1986) *and Hartman (1977)* were used to identify the soil types in the White Tank Mountains area.

Visible calcium carbonate development along the banks of the stream channels strongly suggests the channel is stable and has not been subject to substantial erosion or deposition for at least 10,000 years (Hjalmarson 2003). Lack of calcium carbonate development suggests the surface is young and may be unstable. Field and Pearthree (1991 and 1992) indicate the calcium carbonate levels for the various areas in the White Tank Mountains. This information, along with field verification of several sites, was used to estimate the calcium carbonate development for each landform.

2.4.1.4. Surficial Geology

Maps that show the surficial geology of the area can also be used to help identify the areas that are stable or unstable. Typically, older surfaces from the Pleistocene era are stable (M2 and M1b) while younger surfaces from the Holocene era may be unstable (Y1 and Y2). Geological Consultants, Inc. provided a detailed geologic map of the study area.

2.4.1.5. Flood Hazard Potential

Field and Pearthree's (1992) flood hazard rating is also an indicator of the stability of a landform. Surfaces with a low flood hazard potential are probably stable while surfaces with a high flood hazard potential are probably unstable.

2.4.1.6. Desert Pavement and Desert Varnish

Desert pavement is not always a reliable indicator of stability. However, desert pavement accompanied by a dark desert varnish is a strong indicator that the landform is stable. Lack of desert pavement or desert varnish suggests the landform is unstable. Field and Pearthree (1991 and 1992) indicate the amount of desert pavement and desert varnish for the various areas in the White Tank Mountains. This information, along with field verification of several sites, was used to estimate the amount of desert pavement and desert varnish.

2.4.1.7. Drainage Pattern

Tributary drainage patterns typically indicate that the landform is stable. Unstable areas will typically have distributary drainage patterns. The aerial photographs provided by the FDCMC were used to identify the drainage patterns of the various landforms.

2.4.1.8. Vegetation

Stable landforms are characteristically sparsely covered with scattered large trees except along the banks of through flow channels where large paloverde, ironwood, and mesquite trees are abundant (Hjalmarson 2003). Stable areas are commonly dominated by creosote bush and saltbush because they like to grow in areas with high amounts of calcium carbonate. Jumping cholla is abundant only on old stable surfaces (Field and Pearthree 1992). Unstable areas are characterized by the lack of large trees along the banks of the through flow channels. The aerial photographs from the FDCMC were used to get a rough estimate of the amount of vegetation on a landform and whether or not the channels were lined with thick vegetation. The type of vegetation was noted for a few of the landforms during field visits.

2.5. Maps of the White Tank Mountains Study Area

A small map of the various landforms that were identified using the stage 1 techniques outlined by Hjalmarson (2003) appears in Figure GR-2. The landforms are not labeled on Figure GR-2. A larger map is attached to this report. On the larger map, all of the landforms are labeled. On the larger map, the labels shown in Table GR-1 were used. Each landform has its own landform ID. The landform IDs for each landform are shown in Figure GR-3.

The scope of work indicated that two examples of each landform type need to be field verified. Two relict fans, pediments, and alluvial fans were selected for field verification. However, only one alluvial plain was identified in the study area, so it was not possible to select two alluvial plains to field verify. The seven landforms that were field inspected are colored red in Figure GR-4.

A small map of the stable and unstable areas identified using the stage 2 techniques outlined by Hjalmarson (2003) appears in Figure GR-5. The stable landforms are colored green while the unstable landforms are colored red. A larger map of the stable and unstable landforms is also attached to the report in Appendix A.

Table GR-1. Labels used on the large landform map

RF	Relict fan
P	Pediment
AF	Alluvial fan
AP	Alluvial plain
TC	Through flow channel
OOA	Other old alluvium
RO	Rock outcrop

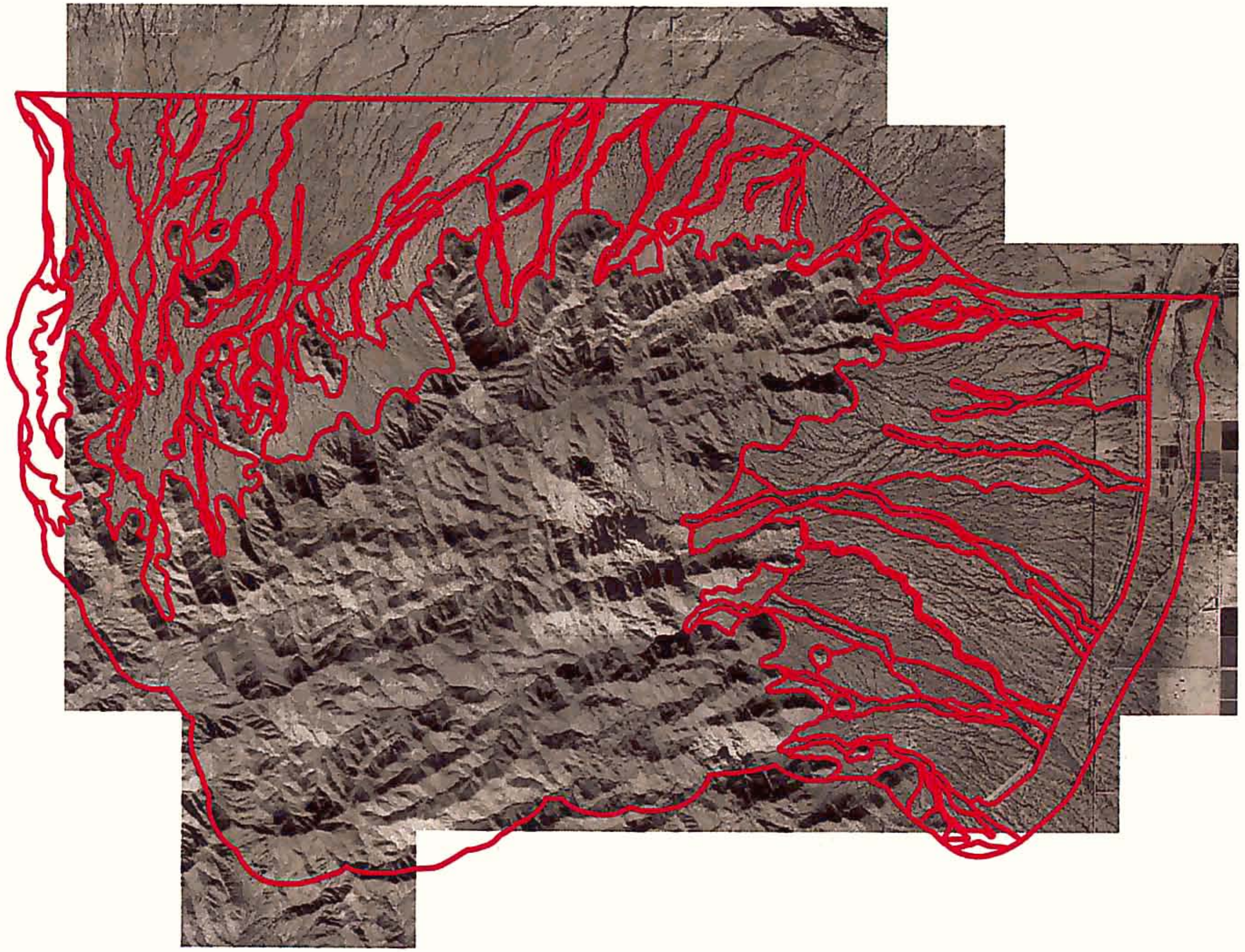

Figure GR-2. Map of landforms in the White Tank Mountains study area

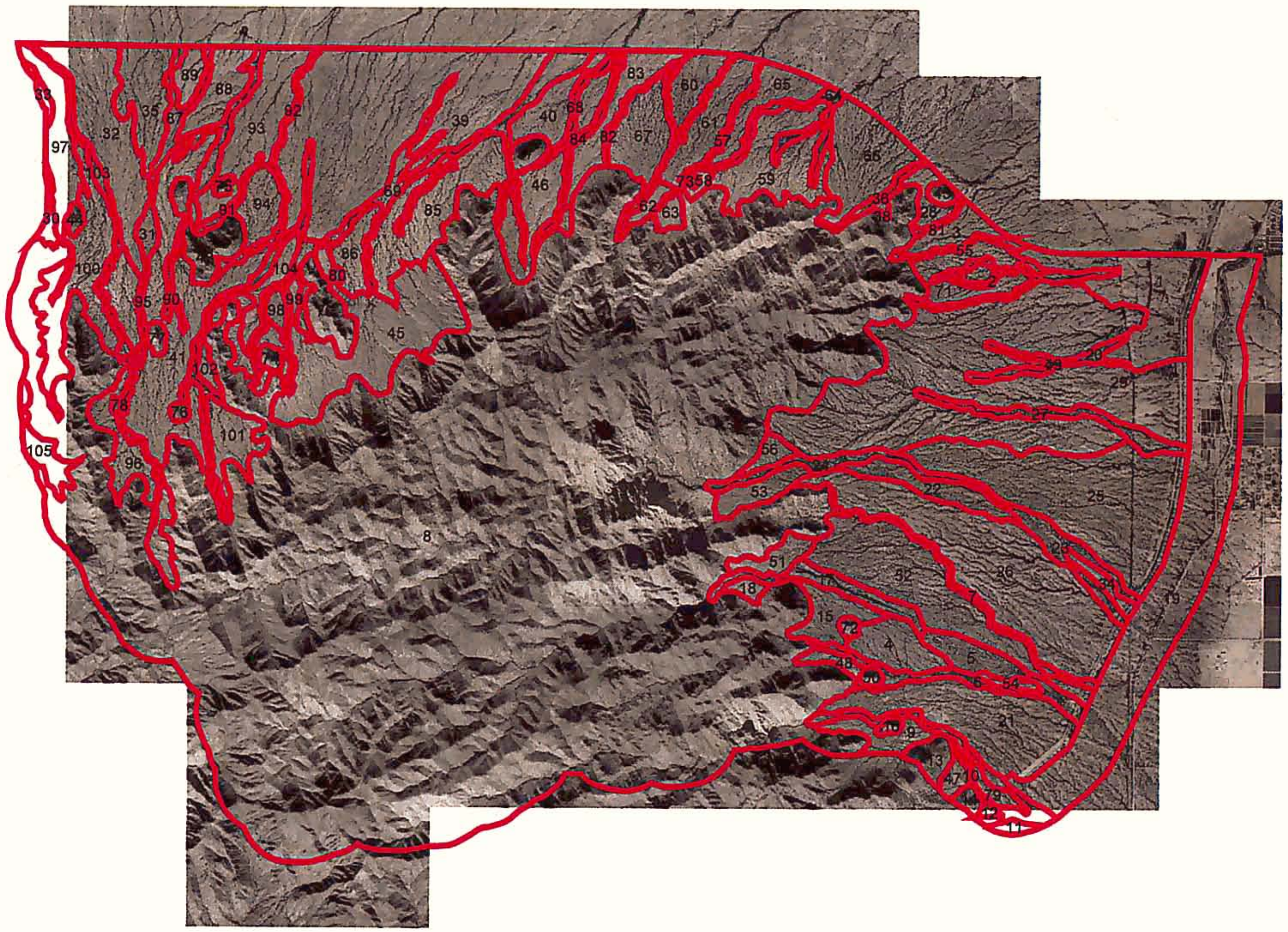

Figure GR-3. Landform IDs for the White Tank Mountains study area

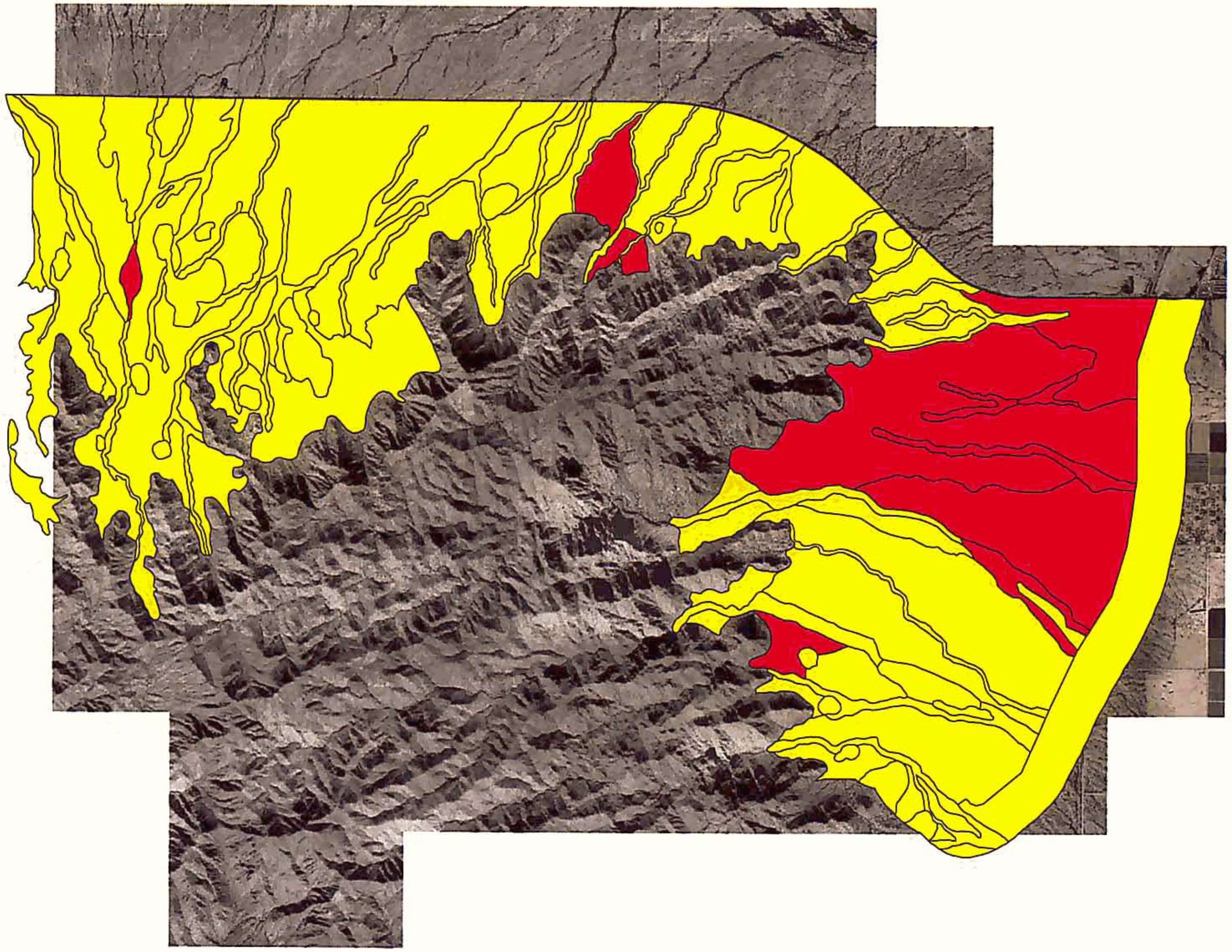

Figure GR-4. Detailed field inspections were performed at the landforms colored red

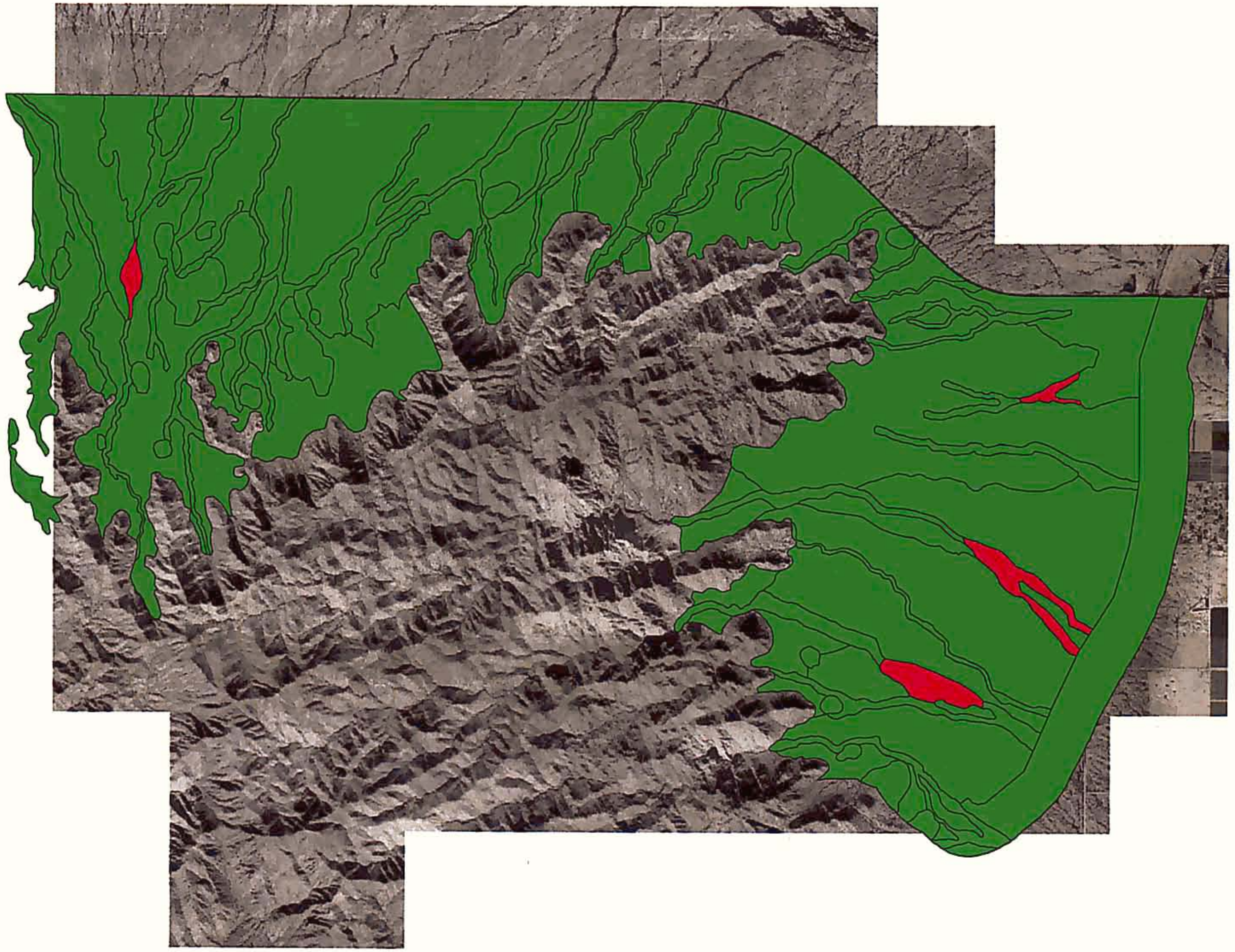

Figure GR-5. Map of stable (green) and unstable (red) landforms in the White Tank Mountains area

2.6. Summary of Landforms

A stage 1 and stage 2 analyses were performed on the White Tank Mountains study area. The landforms were identified and their relative stability was classified using the techniques discussed earlier. The landforms that had the characteristics of active alluvial fans (AAF) and were classified as unstable are landforms 5, 20, 23, and 31 (see Figure GR-3). The landforms that had the characteristics of inactive alluvial fans (IAF) are landforms 4, 9, 11, 21, 22, 25, 32, 39, 60, 93, 97, 98, 99, and 104 (see Figure GR-3). All of these landforms were classified as stable. Only one landform was identified as an alluvial plain (AP) and this landform (ID1) was classified as stable. The landforms that were identified as relict fans (RF) are landforms 3, 26, 28, 29, 33, 34, 35, 40, 41, 46, 52, 54, 59, 61, 65, 66, 67, 71, 79, 83, 86, 88, 89, 94, 96, 100, 101, and 102 (see Figure GR-3). These landforms were also classified as stable. The landforms that exhibited characteristics common to pediments (P) were landforms 12, 15, 30, 38, 45, 47, 48, 58, 62, and 63 (see Figure GR-3). These landforms are stable. Five areas were classified as other old alluvium. These areas were landforms 18, 51, 53, 56, and 105. All of these areas were classified as stable. The remaining landforms were identified as either through flow channels (TC), rock outcrops (RO), or mountains (M). These landforms were all classified as stable landforms. In summary, there were 23 through flow channels, 29 relict fans, 14 inactive alluvial fans, 4 active alluvial fans, 10 pediments, 5 areas classified as other old alluvium, 18 rock outcrops, and 1 alluvial plain.

Appendix B consists of a table that presents detailed information that was developed during the stage 1 analysis used to identify the landforms. Appendix C consists of a table that lists the information used to classify the stability of the landforms. This information was developed during the stage 2 analysis. A more detailed verbal description of the stage 1 and stage 2 analyses for selected landforms follows.

2.7. Landform ID 31 – Active Alluvial Fan

2.7.1. Introduction

The first landform studied in detail is an active alluvial fan located on the far west side of the study area. The ID for this landform is 31 (see Figure GR-3). An aerial photograph of the landform can be seen in Figure GR-6. The same aerial photograph with 4-foot contour mapping is shown in Figure GR-7. The various indicators that were used to identify the landform are listed in Table GR-2. Landform 31 is the small shaded landform on the far left hand side of Figure GR-2.

Figure GR-6. Landform 31 – alluvial fan

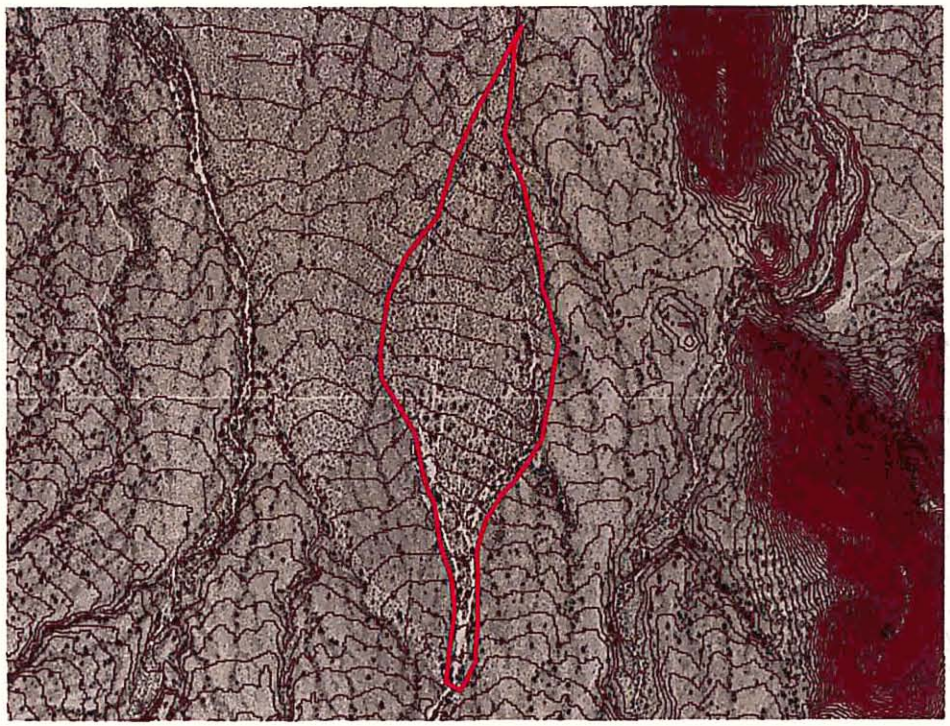

Figure GR-7. Contour mapping (4-foot) for landform 31

Table GR-2. Indicators used to classify landform 31

Landform Number	31
Landform Name	Active alluvial fan
Soil Type	Antho-Carrizo-Maripo complex
Surficial Geology	Y2 – late Holocene
Flood Hazard Potential	H1 – highest flood hazard potential
Average Slope	1.8%
Surface Texture	Stippled appearance
Surface Color	Medium light
Channel Size	Small channels
Drainage Pattern	Braided system
Contour Shape	Rounded, flat
Desert Pavement	No
Desert Varnish	No
Vegetation	Sparse

2.7.2. Stage 1 Analysis

The Natural Research Council's (NRC) definition of an alluvial fan is that it 1) is composed of deposits of alluvial sediments, 2) has the shape of a fan, and 3) is located at a topographic break (NRC 1996). Landform 31 meets all of these requirements.

2.7.2.1. Composition

The soil of this landform is an Antho-Carrizo-Maripo complex. All three of these soils were formed from recently deposited alluvium. The surficial geology maps indicate that this landform has a Y2 classification, which implies that this landform has a very young surface and is from the late Holocene period. The flood hazard maps give this landform an H1 classification, which indicates that the area is highly susceptible to flooding. The H1 classification indicates that this area has the potential for localized, high-velocity, relatively deep, channelized flow as well as sheetflooding (Field and Pearthree 1992).

An inspection of this site showed that the channels were composed of unconsolidated alluvium (Figure GR-8). The banks of the streams are shallow and consist of loosely consolidated cobbles (Figure GR-9). Also, there is no desert pavement or desert varnish on this landform.

The vegetation on landform 1 consists of creosote bush, bursage, and a few paloverde trees. This vegetation is scattered along the banks of the channels and across the interfluves. There are a few large saguaro cacti on landform 31, which is not typical of active alluvial fans. These saguaro cacti appear near the boundaries of the landform towards the apex.

Figure GR-8. Bed material of landform 31

Figure GR-9. The banks of landform 31 consist of loosely consolidated cobbles

2.7.2.2. Morphology

This landform consists of small braided channels with flat bottoms that branch out in a fan-like manner on the upper portion. On the lower portion of the landform, the distributary channels reconnect into one through flow channel. The braided channels and the scattered vegetation give this landform a braided-stippled appearance and a relatively light surface color. The topographic contours are rounded, or fan-shaped, and relatively smooth (small crenulations). The smooth contours indicate that the channels are not incised very much, which is typical of alluvial fans. A field inspection verified that there was little incision in the channels (Figure GR-10).

Figure GR-10. Typical channel in landform 31

2.7.2.3. Location

Landform 31 is located at topographic break, which is typical for active alluvial fans. It is north of the White Tank Mountains about halfway between the Sun Valley Parkway and the mountain front. This landform is located at a break in grade and the average slope of the landform is about 1.8%.

2.7.2.4. Boundaries

The toe of this active alluvial fan was defined where the braided channel system reconnected into one, single channel. The lateral extents of this landform were identified by examining the aerial photographs as well as surficial geology maps, the flood hazard maps, and the soils maps. Figure GR-6 shows that this landform is bounded on the east by a much older surface, which is light colored due to lack of vegetation. On the west, landform 31 is bounded by an inactive alluvial fan. The boundaries are clearly distinguishable from Figure GR-6. The surficial geology maps, the flood hazard maps, and the soils maps also support the lateral boundaries as shown in Figure GR-6.

2.7.3. Stage 2 Analysis

The indicators used to assess the stability of landform 31 are shown in Table GR-3. In comparing the recent aerial photographs to the historic Fairchild photographs (Figure GR-11), some movement of the channel system could be observed. Comparing Figure GR-6 to Figure GR-11 shows that there has been some channel movement in the southern portion of landform 31. Field and Pearthree (1992) indicate that there is no calcium carbonate development on this landform, and the lack of calcium carbonate development was verified during the field visit. This landform has a distributary drainage system and has no desert pavement or desert varnish. All of the indicators shown in Table GR-3 suggest that landform 31 is unstable. The large saguaro cacti that appear along the edges of landform 31 suggest that even though landform 31 is unstable, flows have been contained within landform 31 for a very long time.

Table GR-3. Indicators used to assess the stability of landform 31

Landform Number	31
Landform Name	Active alluvial fan
Flow Path Movement	Yes
Calcium Carbonate	None
Soil Type	Antho-Carrizo-Maripo complex
Surficial Geology	Y2 – late Holocene
Flood Hazard Potential	H1 – highest flood hazard potential
Desert Pavement	No
Desert Varnish	No
Drainage Pattern	Braided system
Vegetation	Sparse – scattered along the landform
Vegetation Type	Creosote bush, bursage, paloverde

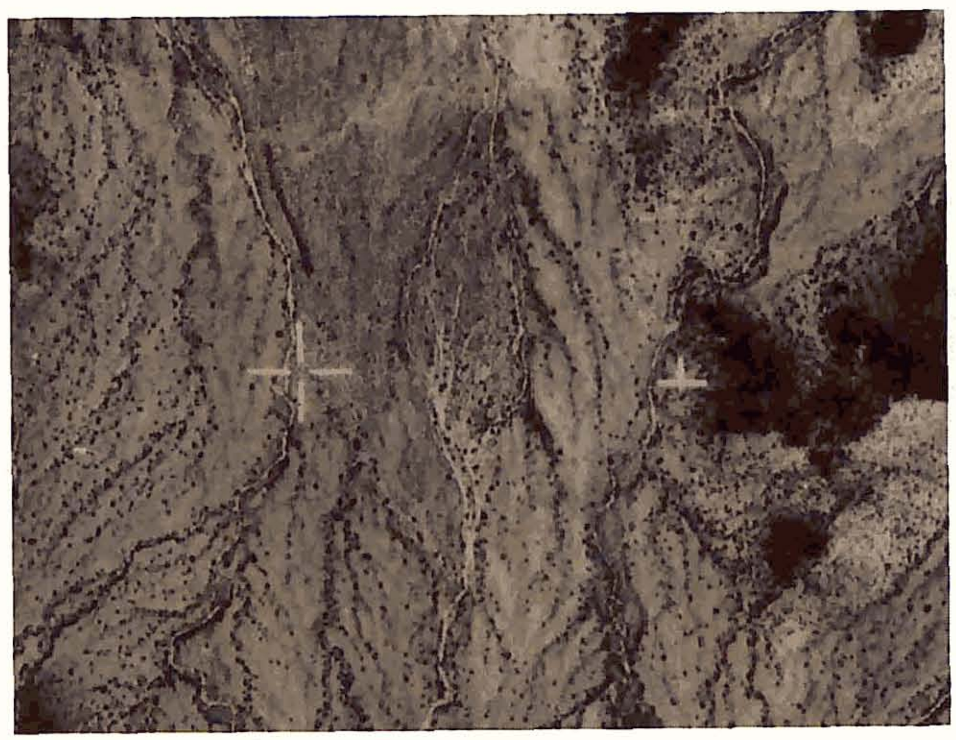

Figure GR-11. Historic aerial photograph of landform 31 (Fairchild, 1940)

2.8. Landform ID 67 – Relict Fan

2.8.1. Introduction

The second landform examined is just north of the White Tank Mountains and just south of the Sun Valley Parkway, close to the eastern edge of the White Tank Mountains. Landform 67 is near the area where the Sun Valley Parkway straightens out after it curves around the White Tank Mountains (see Figure GR-3). An aerial photograph of the landform with and without 4-foot contours appears in Figure GR-13 and Figure GR-12, respectively.

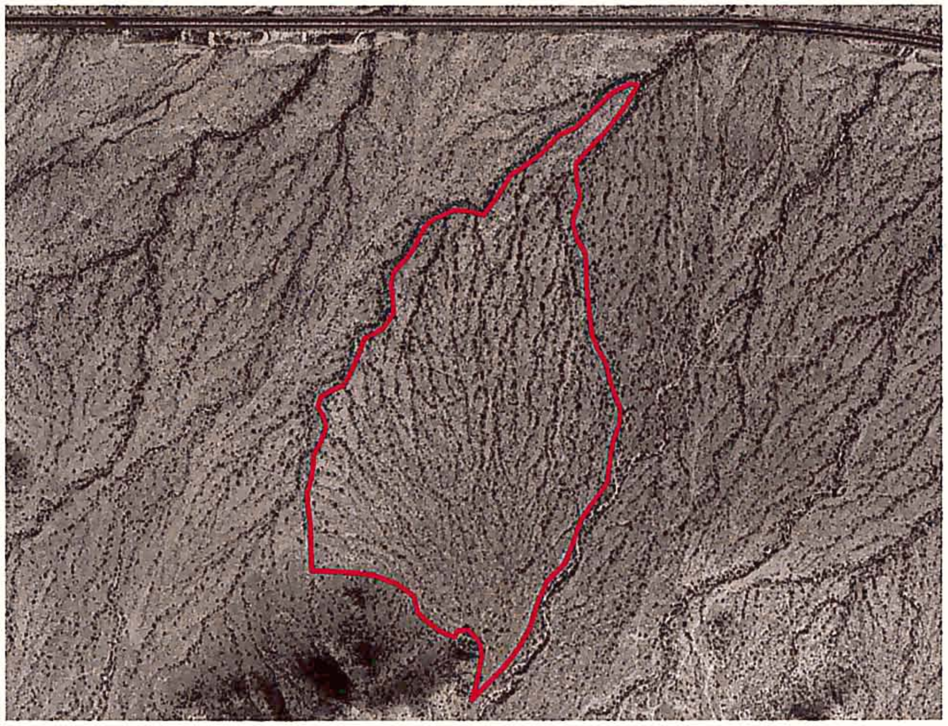

Figure GR-12. Landform 67 – relict fan

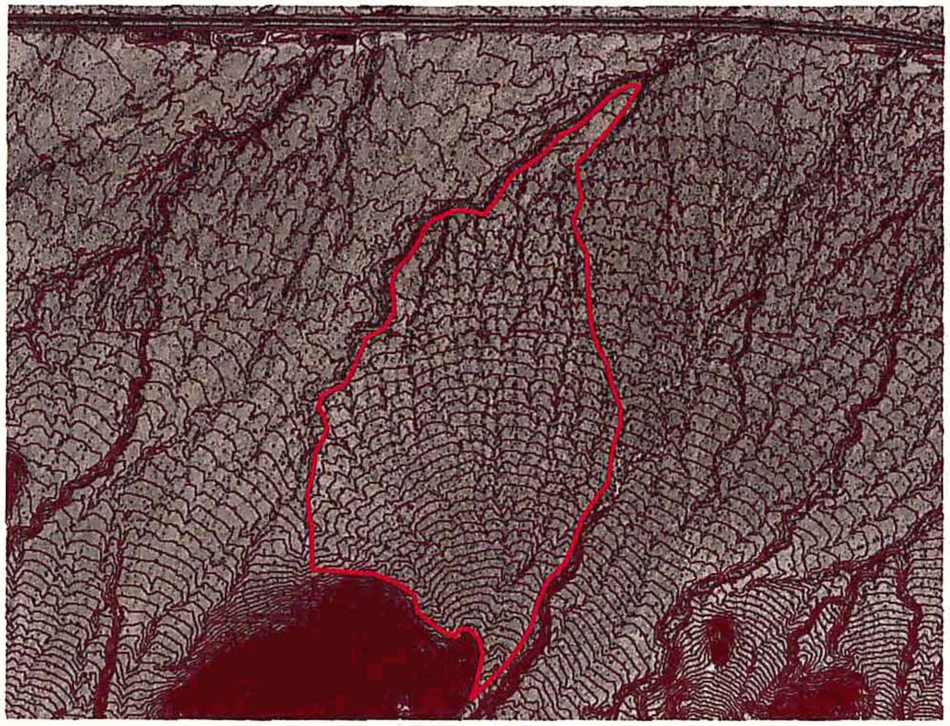

Figure GR-13. Contour mapping (4-foot) for landform 67

2.8.2. Stage 1 Analysis

The various indicators used to identify this landform are shown in Table GR-4. These indicators suggest that landform 67 is a relict fan. A field survey was done to verify this classification.

2.8.2.1. Composition

Landform 67 consists of the Ebon-Pinamt complex soil, which is common in relict fans. The surficial geology maps places this landform in the middle to late Pleistocene era (M1b). This area also has the lowest flood hazard rating (L2), which indicates that the landform has not experienced flooding in at least 10,000 years. The flood prone areas are limited to the existing channels.

The vegetation is scattered across the interfluves. It is also concentrated along the banks and inside the channel system of the landform. The channels are lined with large saguaro cacti, paloverde trees, and ironwood trees. Bursage and creosote clutter the banks and bed of the channels (Figure GR-14). The vegetation present on the banks and beds of the channels are also present on the interfluves with the addition of cholla cacti.

Table GR-4. Indicators used to classify landform 67

Landform Number	67
Landform Name	Relict fan
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Average Slope	3.1%
Surface Texture	Smooth, bar and swale topography
Surface Color	Medium
Channel Size	Heavily incised
Drainage Pattern	Tributary pattern decreasing upslope
Contour Shape	Rounded, ridge-valley appearance
Desert Pavement	Yes, closely packed
Desert Varnish	Moderate amount
Vegetation	Scattered vegetation, large trees concentrated along banks of channels

Figure GR-14. The channel beds on landform 67 are cluttered with vegetation

2.8.2.2. Morphology

The average slope of landform 67 is about 3.1%. This is typical for relict fans. The interior of the landform consists of wide, flat interfluves that are cut by numerous small drainage channels (Figure GR-15). This tributary channel system is incised about 3 to 4 feet. The channels are cluttered with vegetation, implying that a large flow has not passed through in a long time (Figure GR-14). The large storm events of August 2003 were not enough to remove the vegetation in the channel beds (Figure GR-14). In addition, the high water marks were only about half way up the channel banks after these large storms. The channel beds do not contain fine material and are mostly composed of gravel and cobbles (Figure GR-16).

The entire area has a ridge-valley-ridge appearance which can be seen on the aerial photographs and the topographic maps. The crenulations on the topographic maps are distinct and they are rounded downslope (Figure GR-13). Most of this landform has some desert pavement (Figure GR-15). The surface is medium dark on the south and east side and relatively light on the north and west side. The surface color of the entire landform was classified as medium. The lighter surfaces indicate a closely packed desert pavement with very little vegetation. The darker surfaces indicate areas with desert varnish.

Figure GR-15. The interfluves in landform 67 are wide and flat

Figure GR-16. The channel beds in landform 67 are composed mostly of gravel and cobbles

2.8.2.3. Location

As mentioned earlier, landform 67 is at the base of the north portion of the White Tank Mountains. It is just south of the Sun Valley Parkway, close to the north-eastern corner of the White Tank Mountains. Landform 67 is adjacent to the White Tank Mountains (see Figure GR-3).

2.8.2.4. Boundaries

This relict fan is surrounded on the east and the west by deeply incised channels. The channel on the east is about 13 feet deep on the upper portion of the landform. Towards the bottom of the landform (near Sun Valley Parkway), the east channel becomes less incised (about 4 feet). The channel on the west border of this relict fan runs approximately at a depth of 8 feet.

2.8.3. Stage 2 Analysis

The indicators used to assess the stability of landform 2 are shown in Table GR-5. No channel movement could be observed when comparing the recent aerial photographs with the historic ones. Field and Pearthree (1992) indicate that this landform has a calcic horizon greater than stage II. This calcium carbonate development was noticeable in the cemented walls of the deeply incised channels that frame landform 67 (Figure GR-17). This landform is covered with a closely packed desert pavement (Figure GR-15) and there is a moderate amount of desert varnish. Landform 67 has a tributary drainage pattern with large amounts of vegetation concentrated along the channel banks. There are large saguaro cacti, paloverde trees, and ironwood trees along the channels banks, which indicate that the landform is stable. This landform also has abundant jumping cholla, which is a good indicator that the landform is stable. All of the indicators listed in Table GR-5 imply that this relict fan is stable.

Table GR-5. Indicators used to assess the stability of landform 67

Landform Number	67
Landform Name	Relict fan
Flow Path Movement	No
Calcium Carbonate	Greater than a stage II calcic horizon
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Desert Pavement	Yes, closely packed
Desert Varnish	Moderate amount
Drainage Pattern	Tributary pattern decreasing upslope
Vegetation	Scattered vegetation, large trees concentrated along banks of channels
Vegetation Type	Saguaro, paloverde, ironwood, bursage, creosote bush, cholla

Figure GR-17. Calcium carbonate development was apparent in the large channels that surround landform 67

2.9. Landform ID 62 and 63 – Pediment

2.9.1. Introduction

Landforms 62 and 63 are located just south and a little bit east of landform 67 (Figure GR-3). They are at the base of the northeast corner of the White Tank Mountains. These landforms are separated by a through flow channel (landform 57). Aerial photographs on landforms 62 and 63 both with and without contours can be seen in Figure GR-19 and Figure GR-18, respectively.

2.9.2. Stage 1 Analysis

Based on the indictors presented in Table GR-6, Landforms 62 and 63 were classified as pediments. Although these landforms have many characteristics of relict fans, they were classified as pediments because of their location on the piedmont.

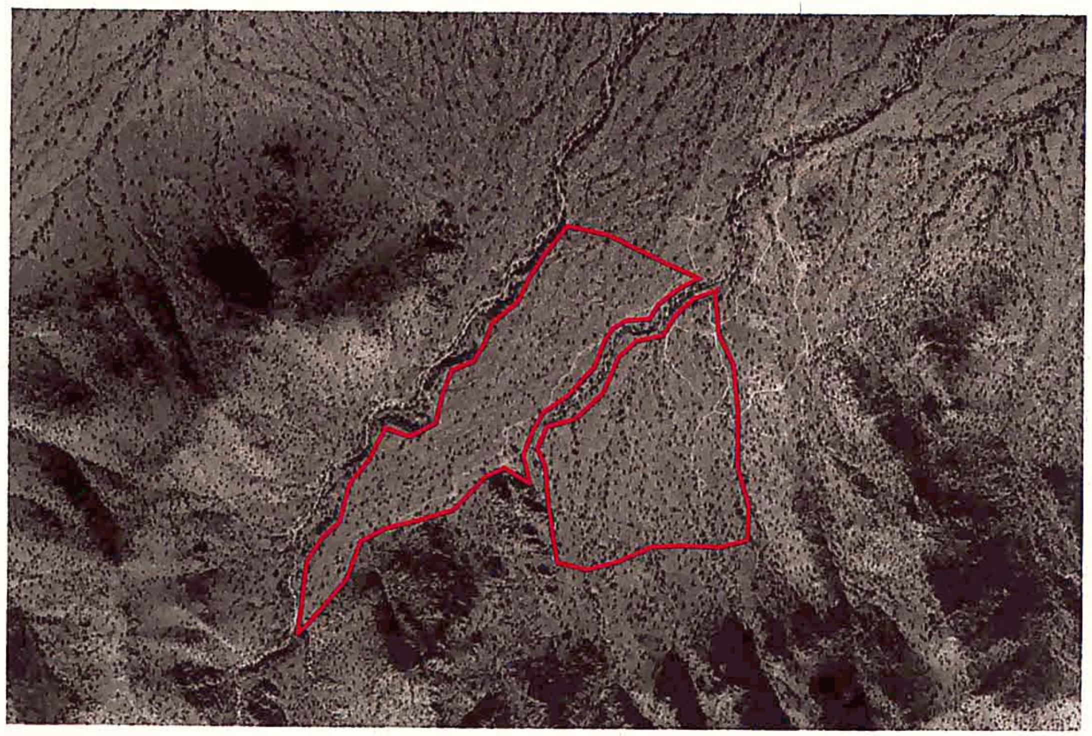

Figure GR-18. Landforms 62 and 63 – pediment

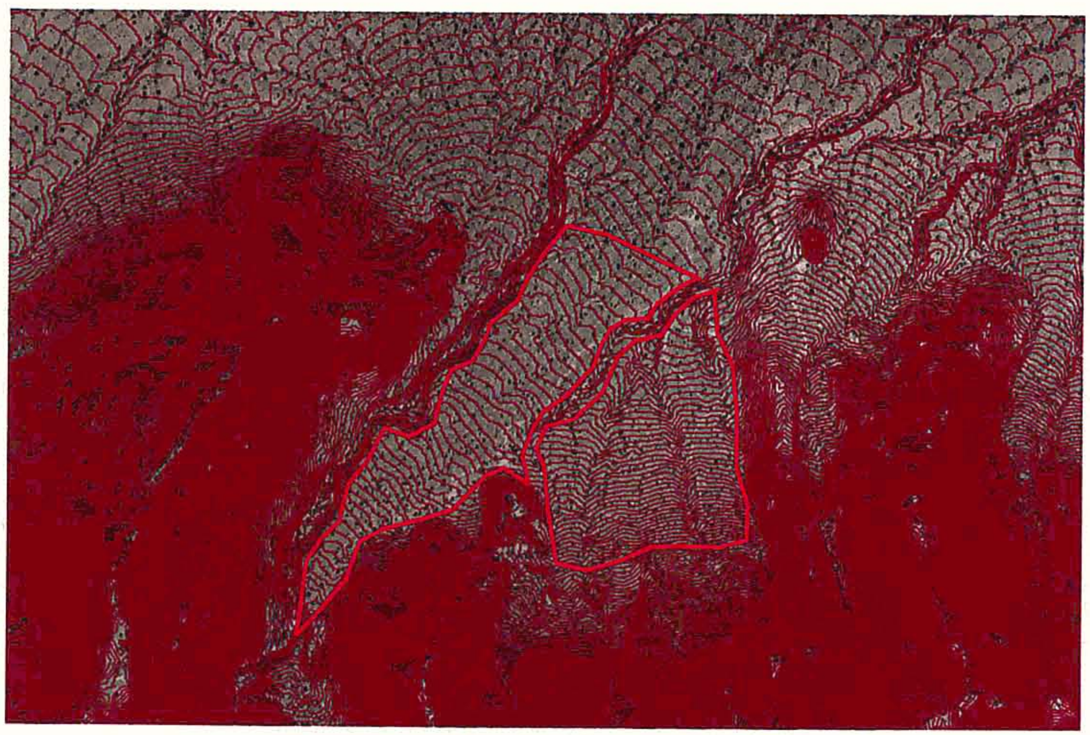

Figure GR-19. Contour mapping (4-foot) for landforms 62 and 63

Table GR-6. Indicators used to classify landforms 62 and 63

Landform Number	62 and 63
Landform Name	Pediment
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Average Slope	3.9%
Surface Texture	Smooth, low topographic relief
Surface Color	Light to medium light
Channel Size	Small, first-order channels
Drainage Pattern	Tributary
Contour Shape	Rounded, flat
Desert Pavement	Yes
Desert Varnish	Moderate amount
Vegetation	Sparse

2.9.2.1. Composition

These landforms are composed of Ebon-Pinamt complex soil, which is common in relict fans. They are located at the base of the mountain front. Like landform 67, landforms 62 and 63 are from the middle to late Pleistocene era (M1b) and have the lowest flood hazard (L2). In fact, flood damage and high water marks were not apparent even after the large storms of August 2003. Both landforms are littered with granite cobbles (Figure GR-20).

Ironwood and paloverde trees line the small channels and the overbanks on this pediment. There are also large saguaro cacti scattered across the overbanks. Bursage is abundant on the overbanks, banks, and channel bottoms. Creosote bush is almost nonexistent on landforms 62 and 63. Overall, the vegetation on landforms 62 and 63 is sparse. This may be the reason for the relatively light color of this landform.

Figure GR-20. Granite cobbles litter the surface of landforms 62 and 63

2.9.2.2. Morphology

The average slope of landforms 62 and 63 is about 3.9%. The surface is smooth and it has very low topographic relief (Figure GR-21). As shown in Figure GR-19, the elevation contours are bowed downslope and are very smooth (i.e., the crenulations are not distinct). The landform has very small, first-order channels that form a tributary network, which is typical on pediments. Like landform 67, these small channels are cluttered with bursage (Figure GR-22). The channel beds are a mixture of cobbles and sand. The area is covered with desert pavement and has a moderate amount of desert varnish.

Figure GR-21. Landforms 62 and 63 have very little topographic relief

Figure GR-22. Landforms 62 and 63 have small, first order channels that are cluttered with vegetation

2.9.2.3. Location

Landforms 62 and 63 are nestled in a small valley on the north-eastern corner of the White Tank Mountains. These landforms are located high up on the piedmont and are right next to the base of the mountains. There is a through flow channel (landform 57) that separates these two landforms.

2.9.2.4. Boundaries

The western, southern, and eastern boundaries of these landforms are the White Tank Mountains. The northern boundary was drawn where it appears that the first-order channels become more incised and the granite cobbles disappear. At this point, the landform was reclassified as a relict fan (landform 61).

2.9.3. Stage 2 Analysis

The indicators used to assess the stability of landforms 62 and 63 are shown in Table GR-7. No flow path movement was observed when comparing the recent aerial photographs to the historic ones. Field and Pearthree classify this area as having a calcic horizon greater than stage II; however, the field survey of this area did not yield a good indication as to the amount of calcium carbonate development. Landforms 62 and 63 have a tributary drainage system, an old surficial geology (M1b), a low flood hazard potential (L2), desert pavement, and a moderate amount of desert varnish. The area is sparsely populated with large ironwood trees, paloverde trees, and saguaro cacti. It is also populated with bursage, but there is a surprising lack of creosote bush on this landform. This is surprising because creosote bush is common on soils with a highly developed calcic horizon. Most of the indicators shown in Table GR-7 imply that landforms 62 and 63 are stable.

Table GR-7. Indicators used to assess the stability of landforms 62 and 63

Landform Number	62 and 63
Landform Name	Pediment
Flow Path Movement	No
Calcium Carbonate	Greater than a stage II calcic horizon
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Desert Pavement	Yes
Desert Varnish	Moderate amount
Drainage Pattern	Tributary
Vegetation	Sparse
Vegetation Type	Bursage, ironwood, paloverde, saguaro

2.10. Landform ID 29 – Relict Fan

2.10.1. Introduction

Landform 29 is on the east side of the White Tank Mountains immediately south of the Sun Valley Parkway. The landform starts at the base of the White Tank Mountains and ends near McMicken Dam. An aerial photo of the landform is shown in Figure GR-23. The 4-foot topographic mapping of the area is shown in Figure GR-24.

2.10.2. Stage 1 Analysis

Landform 29 was classified as a relict fan because of its soil type and deeply incised channels. Also, this landform was not classified as an inactive alluvial fan because it no longer has a fan shape. The various indicators used to identify this landform are listed in Table GR-8.

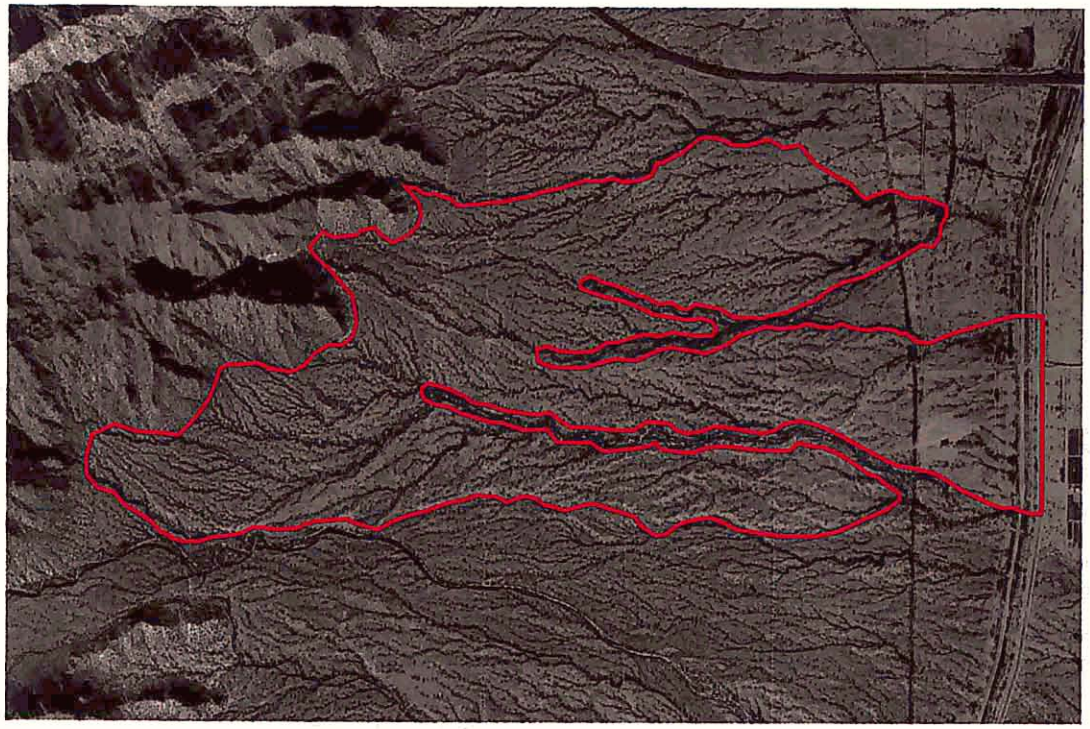

Figure GR-23. Landform 29 – relict fan

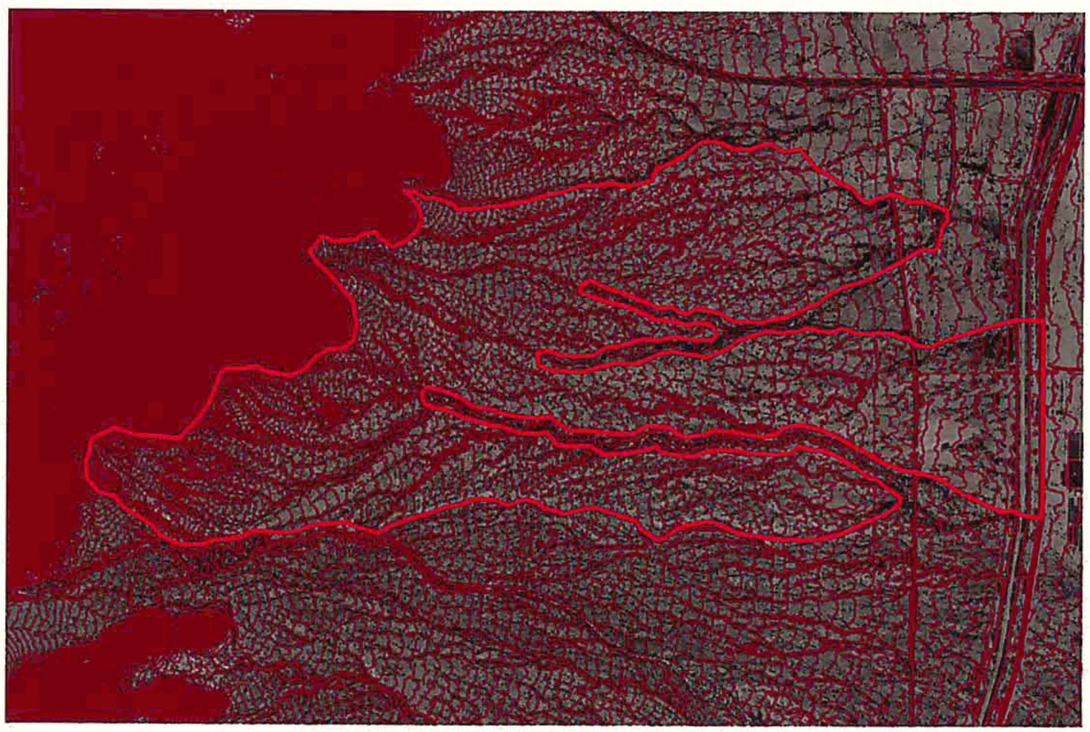

Figure GR-24. Contour mapping (4-foot) for landform 29

Table GR-8. Indicators used to classify landform 29

Landform Number	29
Landform Name	Relict fan
Soil Type	Ebon-Pinamt upper, Antho-Tremant lower
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Average Slope	3.1%
Surface Texture	Smooth, bar and swale topography
Surface Color	Medium
Channel Size	Heavily incised
Drainage Pattern	Tributary
Contour Shape	Ridge-valley appearance
Desert Pavement	Yes
Desert Varnish	Moderate amount
Vegetation	Scattered vegetation, large trees concentrated along banks of channels

2.10.2.1. Composition

The upper portion of landform 29 consists of Ebon-Pinamt complex soil while the lower portion is made up of Antho-Tremant complex soil. The Ebon, Pinamt, and Tremant soils are associated with relict fans. The surficial geology indicates that the landform is from the middle to late Pleistocene era (M1b), with a few of the through flow streams given a very young classification (Y2). The flood hazard maps report findings similar to the surficial geology. Most of the landform is given the lowest flood potential (L2) with a few of the through flow channels given a higher flood potential (H1 or H2). The channel beds are sandy with some 6 to 18 inch cobbles and boulders (Figure GR-25).

The vegetation on the overbanks is sparse (Figure GR-26). Most of the vegetation on landform 29 is concentrated along the banks of the tributary drainage channels (Figure GR-25).

Along the banks there are large saguaro cacti, paloverde trees, acacia trees, and ironwood trees. The banks are also covered with creosote bush, saltbush, and bursage.

Figure GR-25. Typical channel in landform 29

Figure GR-26. The interfluves on landform 29 are wide and flat

2.10.2.2. Morphology

The average slope of the landform is around 3.1%. The topographic contours have distinct crenulations with an alternating ridge-valley appearance. The contours are only slightly rounded and the landform does not have a fan shape (Figure GR-24). The distinct crenulations imply that the channels in this landform are deeply incised. A field investigation revealed that the channels have about a 6 to 8 foot flat bottom and are incised 6 to 10 feet (Figure GR-25). The banks are lined with large, thick vegetation (Figure GR-25). The interfluves on this landform are wide and flat (Figure GR-26). Some portions of the larger channels have banks that are almost vertical (Figure GR-27). These vertical walls have been cut into extremely hard soil that has significant calcium carbonate development. The landform also has many areas of desert pavement and desert varnish.

The largest of the channels on this landform are labeled as through flow channels. In general, the drainage into the through flow channels is tributary; however, the beds of the through flow channels themselves may be braided. There may be some slight shifting of the beds of the through flow channels, but the overall position of the through flow channels is stable because they are deeply incised into the landform. Thus, the through flow channels are typically considered stable even through there may be some slight bed movement over time.

Figure GR-27. Some portions of the channels in landform 29 have vertical walls and a highly developed calcic horizon

2.10.2.3. Location

Landform 29 is on the east side of the White Tank Mountains immediately south of the Sun Valley Parkway. The landform starts at the base of the White Tank Mountains and ends near McMicken Dam. It is located high up on the piedmont.

2.10.2.4. Boundaries

The western boundary of landform 29 is the eastern edge of the White Tank Mountains. This landform is bounded on the north and the south by large through flow channels. The eastern boundary consists of either McMicken Dam or an alluvial plain (landform 1). There are some rather large and deeply incised through flow channels that cut through landform 29. These through flow channels can be seen in Figure GR-23.

At the end of the northern through flow channel (landform 49 on Figure GR-3) is a small inset active alluvial fan (landform

20 on Figure GR-3). This inset alluvial fan is sandwiched between landform 29 (relict fan) and landform 1 (alluvial plain). The shape, location, and composition of landform 20 all suggest that it is an active alluvial fan. For more detailed information on this landform, please examine the entry for landform 20 in the tables located in Appendices B and C.

2.10.3. Stage 2 Analysis

The indicators used to assess the stability of landform 29 are shown in Table GR-9. No flow path movement was observed when comparing the recent aerial photographs to the historic ones. Field and Pearthree (1992) classify this area as having a calcic horizon greater than stage II, and a highly developed calcic horizon was observed in some places on this landform (Figure GR-27). Landform 29 has a tributary drainage system, an old surficial geology (M1b), a low flood hazard potential (L2), desert pavement, and a moderate amount of desert varnish. The overbanks are sparsely populated with vegetation. The banks of the channels are heavily populated with large ironwood trees, paloverde trees, acacia trees, and saguaro cacti. Creosote bush, bursage, and saltbush also heavily populate the channels banks. Most of the indicators shown in Table GR-9 imply that landform 29 is stable.

Table GR-9. Indicators used to assess the stability of landform 29

Landform Number	29
Landform Name	Relict fan
Flow Path Movement	No
Calcium Carbonate	Greater than a stage II calcic horizon
Soil Type	Ebon-Pinamt upper, Antho-Tremant lower
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Desert Pavement	Yes
Desert Varnish	Moderate amount
Drainage Pattern	Tributary
Vegetation	Scattered vegetation, large trees concentrated along banks of channels
Vegetation Type	Creosote bush, bursage, saltbush, ironwood, paloverde, saguaro, acacia

2.11. Landform ID 1 – Alluvial Plain

2.11.1. Introduction

Landform 1 is located immediately south of the Sun Valley Parkway. It is sandwiched between landform 29 and McMicken Dam. Aerial photographs of landform 1 with and without contour mapping are shown in Figure GR-29 and Figure GR-28, respectively.

2.11.2. Stage 1 Analysis

This landform was classified as an alluvial plain. It is very flat and has an average slope of only 1.7%. This was the only alluvial plain found in the study area. The indicators used to identify this landform are shown in Table GR-10.

Figure GR-28. Landform 1 – alluvial plain

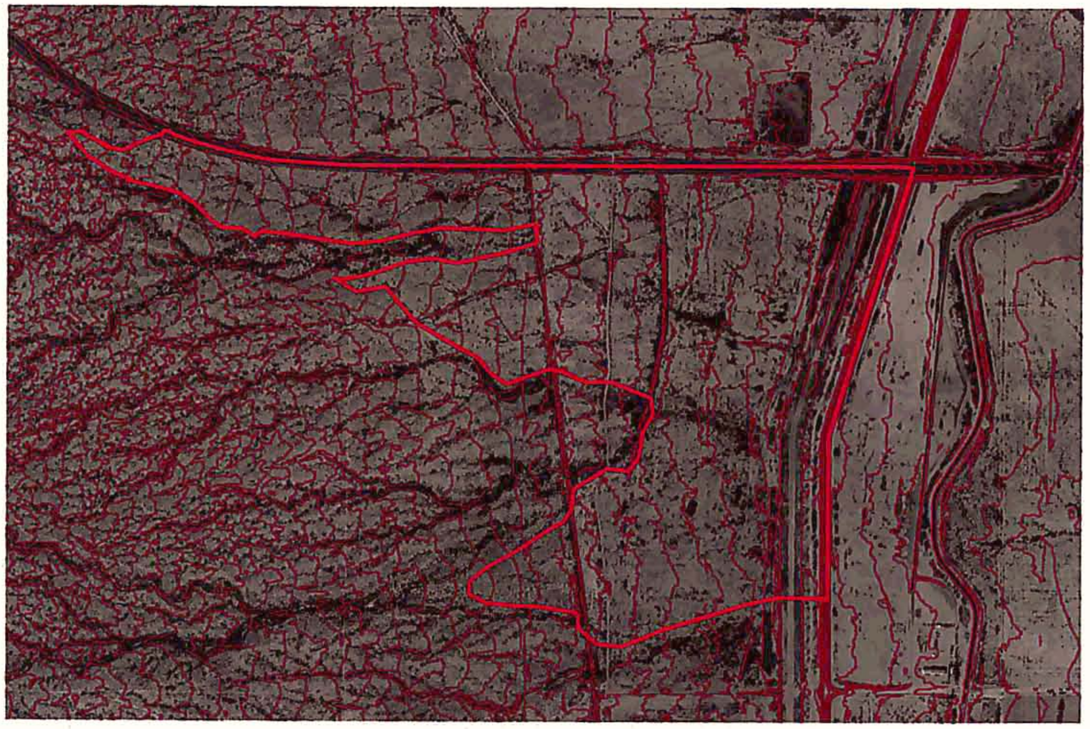

Figure GR-29. Contouring mapping (4-foot) for landform 1

Table GR-10. Indicators used to classify landform 1

Landform Number	1
Landform Name	Alluvial plain
Soil Type	Antho, Gilman soils plus others
Surficial Geology	Y2 – late Holocene
Flood Hazard Potential	H2 – moderately high flood hazard potential
Average Slope	1.7%
Surface Texture	Flat, smooth
Surface Color	Medium
Channel Size	Very small
Drainage Pattern	Tributary
Contour Shape	Flat
Desert Pavement	No
Desert Varnish	No
Vegetation	Sparse

2.11.2.1. Composition

Landform 1 is composed mostly of Antho and Gilman soils, which are common to alluvial plains. This landform also has small pockets of Mohall, Laveen, Brios, and Tremant soils. The upper portion of this landform is composed of Antho-Tremant complex. The surficial geology maps indicate that the lower portion of this landform is very young (Y2) while the upper portion is older (M1b). The flood hazard maps label this area mostly as a moderately high flood hazard (H2). The upper portion of landform 1 is classified as a low flow hazard (L2). The flood hazard in this area is predominately from sheetflow. Creosote bush and saltbush populate the banks of the channels as well as the overbanks (Figure GR-30). A few paloverde trees line the channels.

Figure GR-30. Overbanks of the channels in landform 1

2.11.2.2. Morphology

This landform is very flat with an average slope of 1.7%. This small slope is common in alluvial plains. As shown in Figure GR-29, the surface texture is smooth and the topographic contours are relatively flat (i.e., the crenulations are not distinct). Most of the channels are very small and tributary in nature (Figure GR-31). The channel shown in Figure GR-31 has a 3 foot bottom width and is only incised a little over 2 feet. The channels are sandy with some cobbles (Figure GR-32). The left and right overbanks of these small channels are very flat and sheet flooding would occur if the banks were overtopped. There is sparse vegetation and no desert pavement or desert varnish.

2.11.2.3. Location

Landform 1 is located immediately south of the Sun Valley Parkway. It is sandwiched between landform 29 and

McMicken Dam. This landform is located very low on the piedmont.

Figure GR-31. Typical channel on landform 1

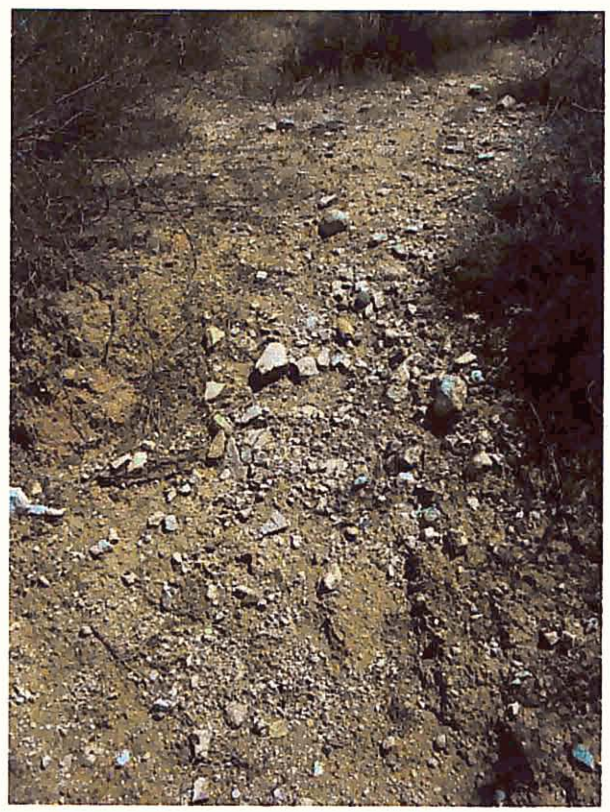

Figure GR-32. Typical channel bottom material in landform 1

2.11.2.4. *Boundaries*

The eastern boundary on landform 1 is McMicken Dam while the northern border is the Sun Valley Parkway. Landform 1 is bounded on the east and south by landform 29. Sandwiched in between landform 1 and landform 29 is a small inset alluvial fan that appears to be active (landform 20 on Figure GR-3). Details of the various indicators for landform 20 appear in the tables listed in Appendix B and C. It was difficult to determine the exact boundary between landform 29 (relict fan) and landform 1 (alluvial plain). The heavily incised channels of the relict fan slowly disappear into very small channels, lightly incised channels of the alluvial plain. From the aerial photographs, it is not clear exactly where the boundary should be. Hjalmarson (2003) recommends that alluvial plains be defined based on soils and surficial geology. However, the soils and surficial geology maps place the alluvial plain too low on the piedmont. In other words, the aerial photographs suggest that the alluvial plain extends closer to the White Tank Mountains than the soils and geology maps suggest. Thus, it was decided that the boundary between the relict fan and the alluvial plain would occur where ever there was a significant break in grade. Using the contour data provided by the FCDMC, it was possible to approximately determine where the break in grade occurred. Using this method, the boundary for the alluvial plain is further up the piedmont than indicated by the soils maps or the surficial geology. However, the boundaries for this landform essentially run parallel to the surficial geology boundaries.

2.11.3. Stage 2 Analysis

The indicators used to assess the stability of landform 1 are shown in Table GR-11. In comparing the recent aerial photographs to the historic photographs, no channel movement was detected in the tributary channel system. Field and Pearthree (1992) indicate that there is no calcium carbonate development on this landform, and the lack of calcium carbonate development was verified during the field visit. Part of landform 1 is composed of soils that are associated with unstable areas (Gilman and Brios). This landform has a young surficial geology, a moderately high flood hazard potential, no desert pavement, and no desert varnish. The sparse desert brush suggests the absence of stable flow paths. Despite several indicators which suggest that landform 1 is unstable, this landform was classified as stable because no flow path movement could be detected.

Table GR-11. Indicators used to assess the stability of landform 1

Landform Number	1
Landform Name	Alluvial plain
Flow Path Movement	No
Calcium Carbonate	None
Soil Type	Antho, Gilman soils plus others
Surficial Geology	Y2 – late Holocene
Flood Hazard Potential	H2 – moderately high flood hazard potential
Desert Pavement	No
Desert Varnish	No
Drainage Pattern	Tributary
Vegetation	Sparse
Vegetation Type	Creosote bush, saltbush, paloverde

2.12. *Landform ID 25* – Inactive Alluvial Fan

2.12.1. Introduction

Landform 25 is located just south of landforms 1 and 29 (see Figure GR-3). It heads on the east side of the White Tank Mountains and it ends at McMicken Dam. Figure GR-34 and Figure GR-33 show aerial views of the landform with and without contours, respectively.

2.12.2. Stage 1 Analysis

Landform 25 was classified as an inactive alluvial fan. The various indicators used to classify this landform are shown in Table GR-12.

2.12.2.1. Composition

This landform is composed of Ebon-Pinamt and Antho-Carrizo complexes. There are also patches of Antho-Tremant complex and various other Antho associations. This landform is bounded by a large through flow stream that is composed of Torrifluvents. The surficial geology classifies most of this landform as M2 with some M1b. This area appears to be covered with a thin film of alluvium that was deposited when the landform was active (Figure GR-35). This is seen as a thin, light gray layer on top of the orangey-brown native soil. Most of this landform also has an L2 flood hazard classification.

Landform 25 is also covered with scattered small shrubs and bushes. The main channel is lined with large paloverde and ironwood trees. There is abundant creosote bush, bursage, and saltbush throughout landform 25.

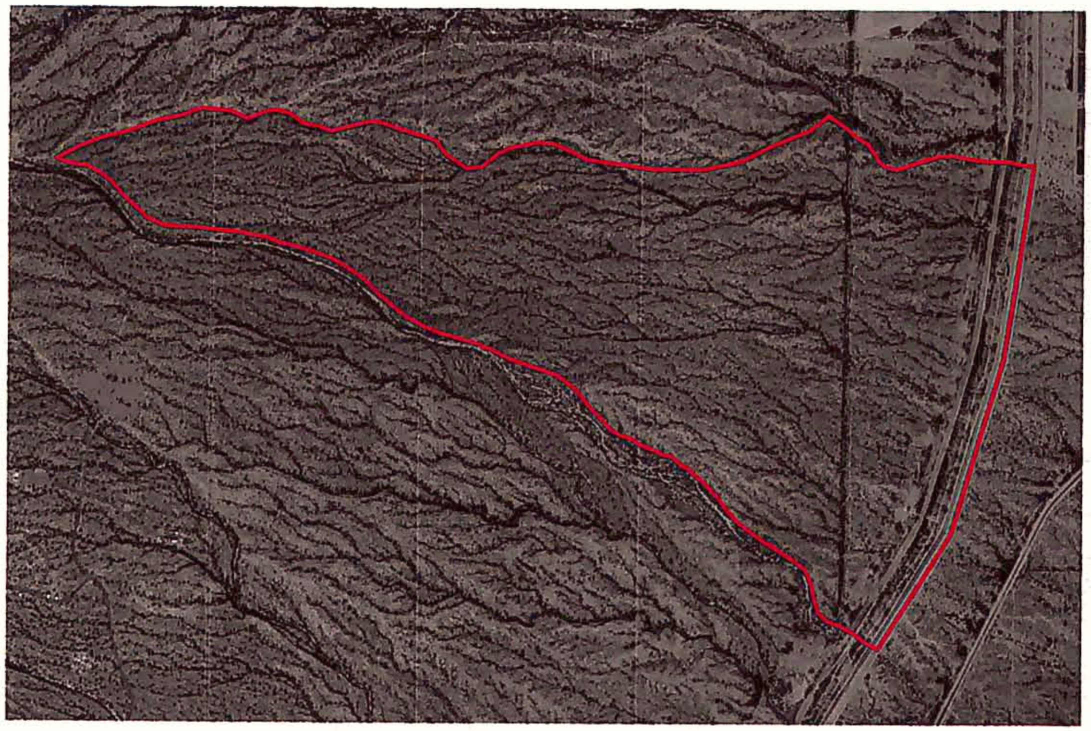

Figure GR-33. Landform 25 – inactive alluvial fan

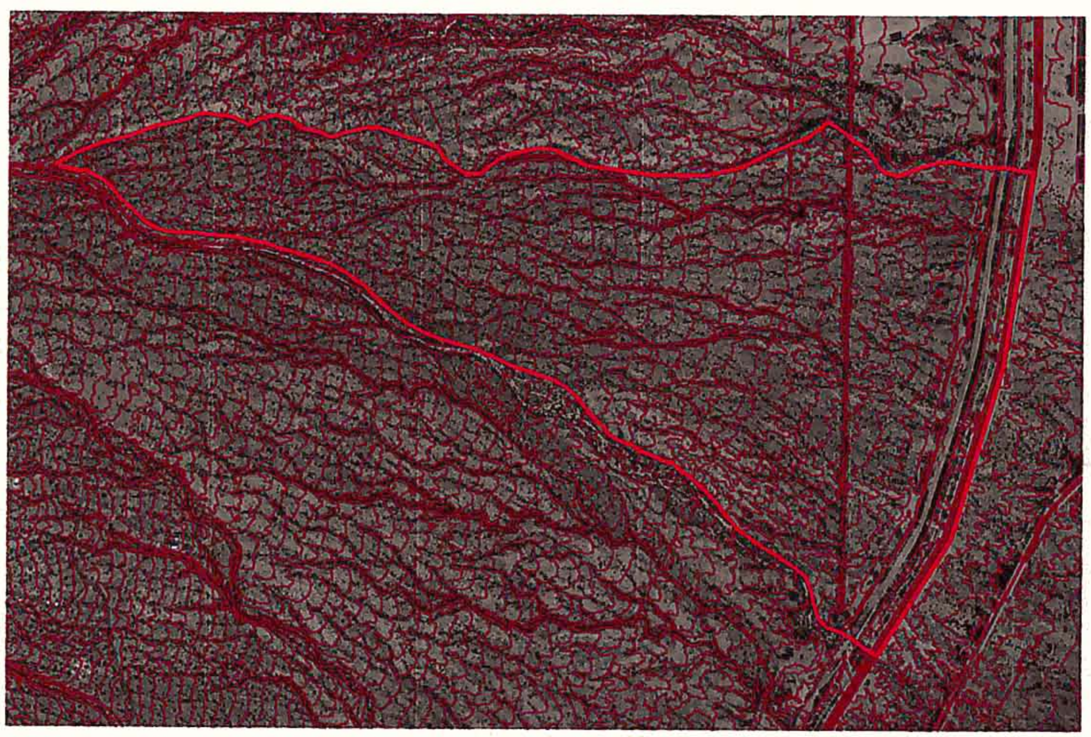

Figure GR-34. Contour mapping (4-foot) for landform 25

Table GR-12. Indicators used to classify landform 25

Landform Number	25
Landform Name	Inactive alluvial fan
Soil Type	Ebon-Pinamt and Antho-Carrizo complexes
Surficial Geology	M2 with some M1b
Flood Hazard Potential	L2
Average Slope	4.9%
Surface Texture	Smooth, bar and swale topography
Surface Color	Medium dark
Channel Size	Small at head, incised at toe
Drainage Pattern	Tributary
Contour Shape	Ridge-valley appearance, rounded downslope
Desert Pavement	Yes
Desert Varnish	Moderate amount
Vegetation	Scattered small bushes with large trees concentrated along banks of the channels

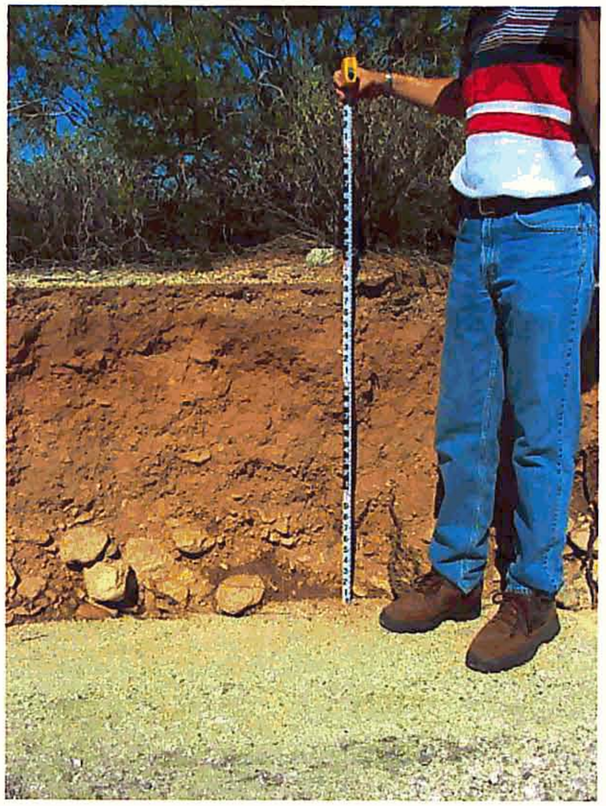

Figure GR-35. A thin layer of alluvium (light gray) lies on top of the native soil (orangey-brown color) of landform 25

2.12.2.2. Morphology

The average slope of the landform is 4.9%. There is a large through flow channel (ID 24) that travels the southern length of this landform. This through flow channel is incised over 30 feet near the mountain front (Figure GR-36). In places, the channel has cut tall vertical banks in very hard soil with significant calcium carbonate development (Figure GR-37). The channel bottom is flat, sandy, and about 75 feet wide. It is interesting to note that even after the large storm events of August 2003, the high water marks in the upper portion of the main channel were only about one foot deep. About half way between the mountain front and McMicken Dam, landform 24 breaks into small area of braided channels (landform 23). These braided channels form where there is a slight break in grade and this area was classified as an active inset alluvial fan (Figure GR-38). The braided channel system has sandy channel beds that are flat.

The channels located on landform 25 are small drainage channels that cut across the landform and drain into the through flow channel (Figure GR-39). These channels are about 2 to 3 feet deep and have beds that are a mixture of sand and cobbles. The topographic contours are slightly rounded downslope and have a ridge-valley appearance. The area has some desert pavement and a moderate amount of desert varnish.

Figure GR-36. The through flow channel (ID 24) bounding landform 25 is deeply incised

Figure GR-37. Some places along the through flow channel (ID 24) have vertical wall

Figure GR-38. Inset alluvial fan (ID 23) located just south of landform 25

Figure GR-39. Typical small drainage channel in landform 25

2.12.2.3. Location

Landform 25 is located just south of landforms 1 and 29 (see Figure GR-3). It heads on the east side of the White Tank Mountains and it ends at McMicken Dam.

2.12.2.4. Boundaries

Landform 25 is bounded by the White Tank Mountains on the west, McMicken Dam on the east, and a relict fan (landform 29) on the north. This landform is bounded on the south by a large through flow channel (landform 24). As landform 24 approaches McMicken Dam, there is a change in grade and a small inset alluvial fan (landform 23) is formed. This landform forms the southern border of landform 25 near its eastern edge.

2.12.3. Stage 2 Analysis

The indicators used to assess the stability of landform 25 are shown in Table GR-13. No flow path movement was observed when comparing the recent aerial photographs to the historic ones. Field and Pearthree (1991) classify this area as having a calcic horizon greater than stage I or II. Near the head of this landform, the through flow channel (landform 24) is deeply incised and a highly developed calcic horizon was observed (Figure GR-37). Landform 25 has a tributary drainage system. This landform also has an old surficial geology (M2 and M1b), a low flood hazard potential (L2), desert pavement, and a moderate amount of desert varnish. The overbanks are populated with desert shrubs and bushes. The banks of the channels are heavily populated with large paloverde and ironwood trees. The banks are also crowded with creosote bush, bursage, and saltbush. Most of the indicators shown in Table GR-13 imply that landform 25 is stable.

Table GR-13. Indicators used to assess the stability of landform 25

Landform Number	25
Landform Name	Inactive alluvial fan
Flow Path Movement	No
Calcium Carbonate	Greater than a stage I or II calcic horizon
Soil Type	Ebon-Pinamt and Antho-Carrizo complexes
Surficial Geology	M2 with some M1b
Flood Hazard Potential	L2
Desert Pavement	Yes
Desert Varnish	Moderate amount
Drainage Pattern	Tributary
Vegetation	Scattered small bushes with large trees concentrated along banks of the channels
Vegetation Type	Creosote bush, bursage, saltbush, paloverde, ironwood

2.13. Landform ID 15 – Pediment

2.13.1. Introduction

An aerial view of landform 15 can be seen in Figure GR-40 and Figure GR-2. The 4-foot contour mapping for this landform is shown in Figure GR-41. This landform is located at the far south end of the study area and is adjacent to the east mountain front of the White Tank Mountains. It is located within Maricopa County's White Tank Mountains Park.

2.13.2. Stage 1 Analysis

Landform 15 was classified as a pediment. Although this landform has many characteristics of a relict fan, it was classified as a pediment because of its location and the large number of small, first-order channels. The various indicators used to classify this landform appear in Table GR-14.

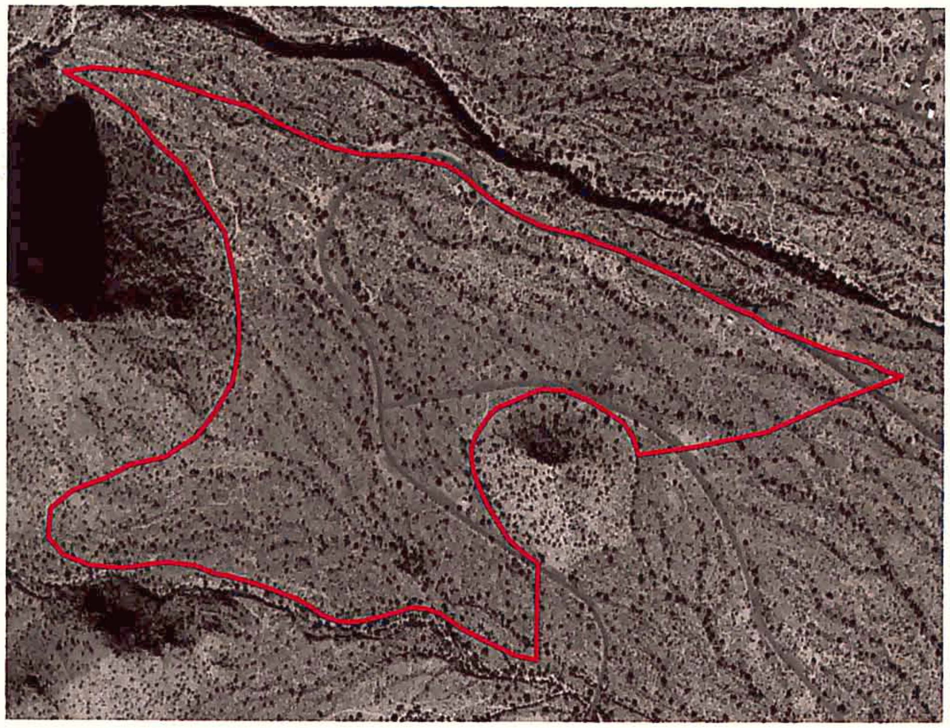

Figure GR-40. Landform 15 – pediment

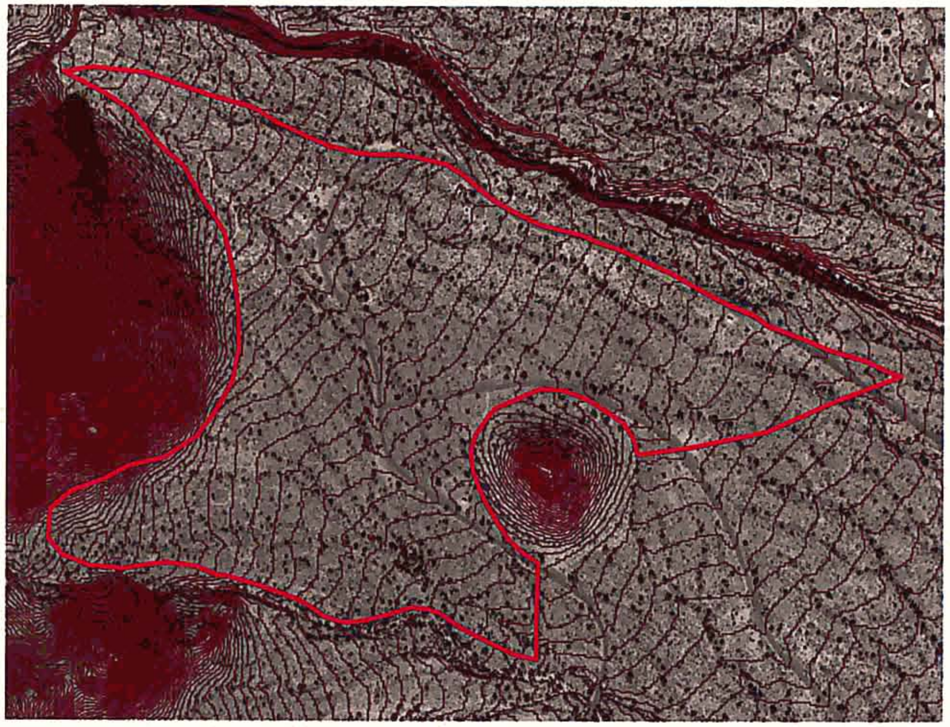

Figure GR-41. Contour mapping (4-foot) for landform 15

Table GR-14. Indicators used to classify landform 15

Landform Number	15
Landform Name	Pediment
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Average Slope	1.7%
Surface Texture	Low topographic relief
Surface Color	Medium dark
Channel Size	Small, first-order channels
Drainage Pattern	Tributary
Contour Shape	Rounded, flat
Desert Pavement	Yes
Desert Varnish	Moderate amount
Vegetation	Dense covering of bushes and trees

2.13.2.1. Composition

Landform 15 is composed of the Ebon-Pinamt complex soil. The surficial geology maps classify it as an M1b surface and the flood hazard maps give it the lowest flood potential (L2).

This landform has a fairly dense covering of bursage, creosote bush, saguaro cacti, cholla cacti, and paloverde trees.

2.13.2.2. Morphology

The area is relatively flat, with an average slope of 1.7%. The area has very low topographic relief and topographic contours are slightly rounded and flat (see Figure GR-41). The crenulations on the contours are not distinct. The drainage system on the landform consists of a tributary system of small, first-order channels that are full of vegetation (Figure GR-42). In fact, it is difficult to make out the channels on this landform because of the thick amounts of vegetation. There is some desert pavement and desert varnish, which gives the landform its darker color. The amount of vegetation may also attribute to its darker color.

2.13.2.3. Location

Landform 15 is located at the far south end of the study area and is adjacent to the east mountain front of the White Tank Mountains. It is located within Maricopa County's White Tank Mountains Park. It is also located high up on the piedmont, right at the base of the White Tank Mountains.

Figure GR-42. Channels on landform 15 are very small and full of vegetation

2.13.2.4. Boundaries

The western border of landform 15 is the White Tank Mountains. Landform 15 is bounded on the north and south by through flow channels (landforms 17 and 6, respectively). The eastern boundary of this landform consists of a rock outcrop (landform 72) and an inactive alluvial fan (landform 4).

2.13.3. Stage 2 Analysis

The indicators used to assess the stability of landform 15 are shown in Table GR-15. No flow path movement was observed when comparing the recent aerial photographs to the historic ones. Field and Pearthree (1991) classify this area as having a calcic horizon greater than stage II; however, the field survey of this area did not yield a good indication as to the amount of calcium carbonate development. Landform 15 has a tributary drainage system, an old surficial geology (M1b), a low flood hazard potential (L2), desert pavement, and a moderate amount of desert varnish. The area is densely populated with large paloverde trees and saguaro cacti. It is also densely populated with bursage, creosote bush, and cholla cacti. The indicators shown in Table GR-15 imply that landform 15 is stable.

Table GR-15. Indicators used to assess the stability of landform 15

Landform Number	15
Landform Name	Pediment
Flow Path Movement	No
Calcium Carbonate	Greater than a stage II calcic horizon
Soil Type	Ebon-Pinamt complex
Surficial Geology	M1b – middle to late Pleistocene
Flood Hazard Potential	L2 – lowest flood hazard potential
Desert Pavement	Yes
Desert Varnish	Moderate amount
Drainage Pattern	Tributary
Vegetation	Dense covering of bushes and trees
Vegetation Type	Bursage, creosote bush, saguaro, cholla, and paloverde

2.14. Summary and Conclusions

The White Tanks Mountains study area is dominated by the steep and rocky White Tank Mountains. The majority of the area that is not mountainous consists of either relict fans or inactive alluvial fan landforms. The area does contain areas that are active, however. Several large through channels convey water from the mountains to the fans and alluvial plain. Several of the channels reach McMicken dam while others disappear into braided alluvial fan areas. Development in these areas should be aware of the active areas and braided channel areas. Considerable thought and effort should be given to either avoid or protect against future instabilities in these areas.

The most useful tool for performing this stage 1 analysis was the high resolution aerial photographs provided by the FCDMC. The other aerial photographs were useful, but did not provide nearly the amount of detail that the FCDMC's aerial photographs did. The natural color photographs from the BLM were useful in picking out shading differences that were not apparent in the black and white photographs from the FCDMC. The color infrared photographs from the USGS were not as useful because the scale was too large and the photographs did not provide enough detail to help classify the landforms.

The soils maps, surficial geology maps, and the pre-existent flood hazard maps were also extremely important tools in performing this stage 1 analysis. For the most part, all three of these resources agreed with each other. In additions, the field surveys added further credence to the various maps completed earlier. This agreement gives a high level of confidence in the results of this stage 1 analysis. The detailed contour data from the FCDMC were also very valuable to the analysis. These data facilitated the identification of incised channels in the White Tank Mountains study area.

SECTION GR-3: STABILITY ANALYSIS FOR THE AREA NORTH OF THE CAP AND EAST OF GRAND AVENUE

3.1. Introduction

A stability analysis was performed on the northern portion of the Wittmann study area. Specifically, this area is located north of the Central Arizona Project (CAP) canal and east of Grand Avenue.

3.1.1. Scope of Work

The analysis performed on the northern portion of the Wittmann study area was not a complete stage 1 or 2 piedmont assessment as outlined in the draft version of *Piedmont Flood Hazard Assessment for Flood Plain Management for Maricopa County, Arizona* (Hjalmarson 2003). In this manual, three stages are presented for assessing the flood hazard on piedmonts. Stage 1 consists of identifying the landforms on the piedmont. Stage 2 consists of classifying each landform as either stable or unstable. Finally, stage 3 consists of identifying the areas that would be affected by the 100-year flood. In this study, only portions of a stage 1 and 2 analysis were performed. This study was only designed to identify possibly active alluvial fans and to assess where channel instabilities occur. In addition, this area was examined for areas of probable two-dimensional flow. Areas immediately adjacent to the CAP canal were not included in this analysis but are discussed in Section GR.6.

3.1.2. Methodology

The methodology used to identify areas where channel instabilities exist was outlined earlier for the White Tanks Area. The indicators used to identify unstable areas were channel path movement, soil type, surficial geology, drainage pattern, and vegetation pattern. To identify areas where channel instabilities occur, the entire study area was carefully examined for areas that had indicators common to unstable landforms. These areas were roughly drawn out. Next, the areas that were initially identified as unstable were analyzed in more detail. A careful examination of the various landform indicators helped refine the shape of the unstable portions of the study area. Topographic maps and soils maps were used to help identify areas of possible two-dimensional flow.

3.1.3. Sources of Data

Sources of data were not as abundant for the northern portion of the Wittmann study area as they were for the White Tank Mountains area. Aerial photographs were limited to the Flood Control District of Maricopa County's (FCDMC) detailed 2003 aerial photographs and the 1940 Fairchild photographs. The 2003 photos were used as the basis for this delineation with comparisons to the 1940 photos to determine historical movement and stability. The National Resource Conservation Service (NRCS) soil survey report by Camp (1986) was used to identify the soil types in this area. Geological Consultants, Inc. provided a detailed geologic map of the study area. This map, along with the Arizona Geological Survey's Open-File Report on the surficial geology of the Wittmann and Hieroglyphic Mountains Southwest quadrangles (Huckleberry 1994), were used to identify the approximate age of the landforms on the northern portion of the Wittmann study area. Finally, the United States Geological Survey's (USGS) 7.5 minute topographic maps and the FCDMC's detailed contour data were also used.

3.2. Mapping of Potential Active Alluvial Fans - Northern Area

Four alluvial fans were identified in the study area and can be seen in Figure GR-43. In addition, there are numerous small alluvial fans that have formed upstream of the CAP canal as shown in Figure GR-43. These fans were identified based on shape, soils, geomorphology, and topography. Two of the fans are small and further study may be warranted before final classification as active alluvial fans. These areas may be simply part of an unstable channel system that gives the appearance of active alluvial fans. The two western fans are located directly in the unstable channel areas and as such they should be protected from development by the unstable channel classification.

A review of the aerial photos for the area gives the impression that the entire northern area is a series of alluvial fans. Several of these fans cover tens of square miles but the upper areas of the fans are deeply incised and show no recent indication of activity. These stable geologic fans were not identified in this study since these relict fans appear to be extremely stable. The goal of this analysis was to identify unstable areas rather than the various landforms as was done for the White Tanks area.

Figure GR-43. Alluvial fans in the northern portion of the Wittmann study area

3.2.1. Alluvial Fan 1 – Padelford Fan

Four alluvial fans were identified in the study area and can be seen in Figure GR-43. All four of these landforms have a fan shape and are composed of numerous braided channels. One of the fans is located on the Padelford Wash on the far eastern side of the study area. Whether this fan is one continuous fan or two fans joined by an unstable portion of channel can be debated. The two portions of the fan are described separately here but are considered one continuous fan and GIS coverage developed as a part of this study show the area as one continuous fan. The Padelford alluvial fan is discussed in two parts as the upper fan and lower fan in this report primarily to allow the upper portion of the fan to be seen in the figures and covered in the discussion since the lower portion of the fan is so much larger.

3.2.1.1. Upper Portion of Padelford Alluvial Fan

The small northern portion of the fan on the Padelford Wash appears to be an inset alluvial fan. Aerial photographs with and without 4-foot contour mapping appear in Figure GR-45 and Figure GR-44, respectively. This alluvial fan has a surficial geology that was classified as Ya2 and is composed of Antho-Carrizo-Maripo complex. When the recent aerial photographs were compared to the historic Fairchild photographs, some channel movement was observed (compare Figure GR-44 to Figure GR-46). This landform has a very stippled appearance which also suggests that the surface is very young. All of these indicators suggest that this landform is an active alluvial fan.

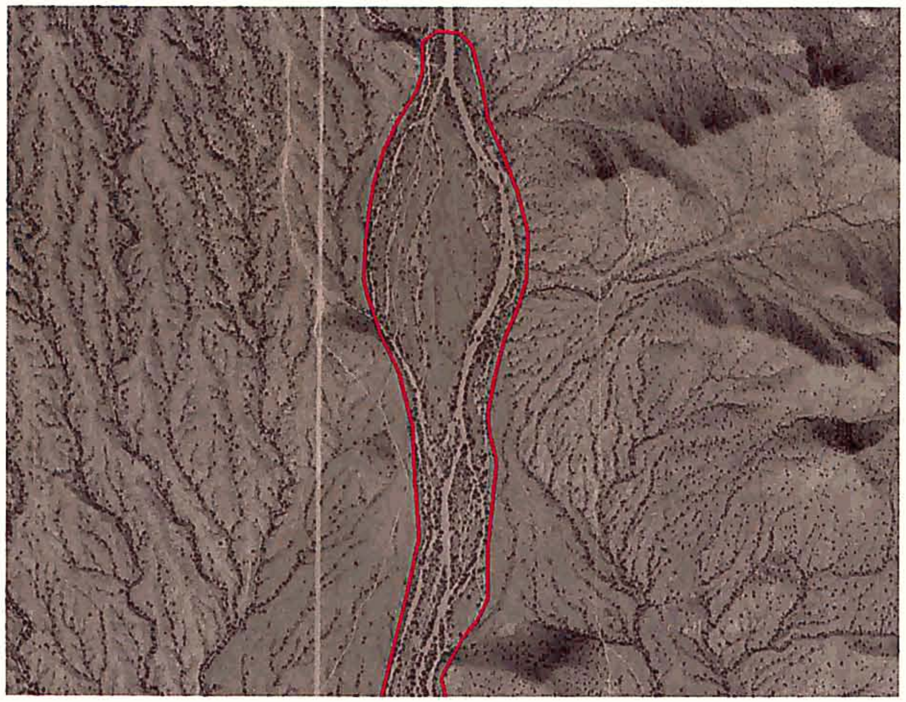

Figure GR-44. Northern alluvial fan on Padelford Wash

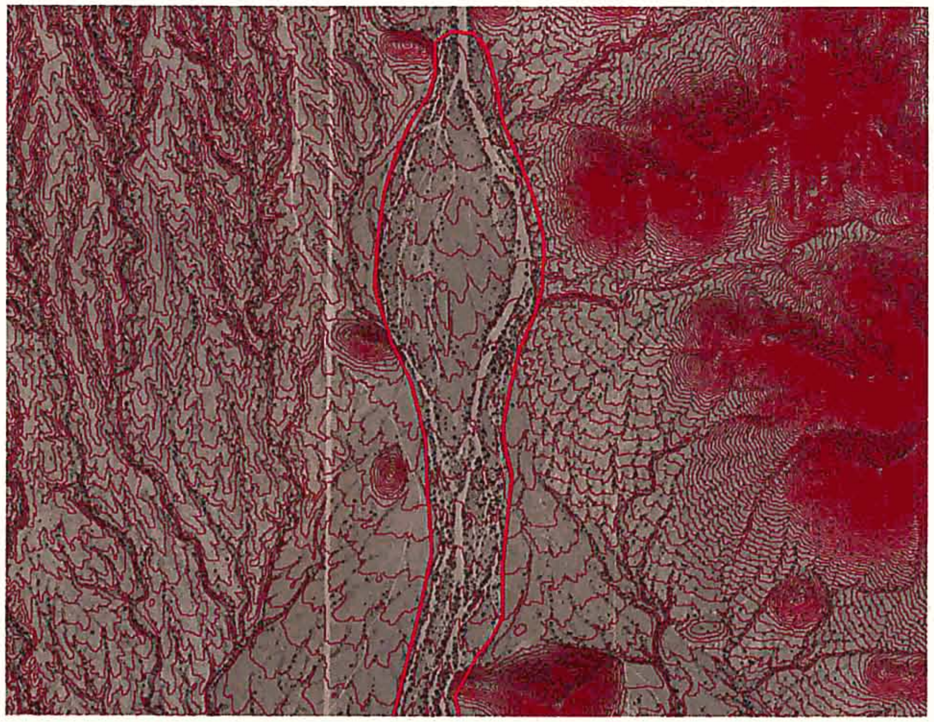

Figure GR-45. Contour mapping (4-foot) of the northern alluvial fan on Padelford Wash

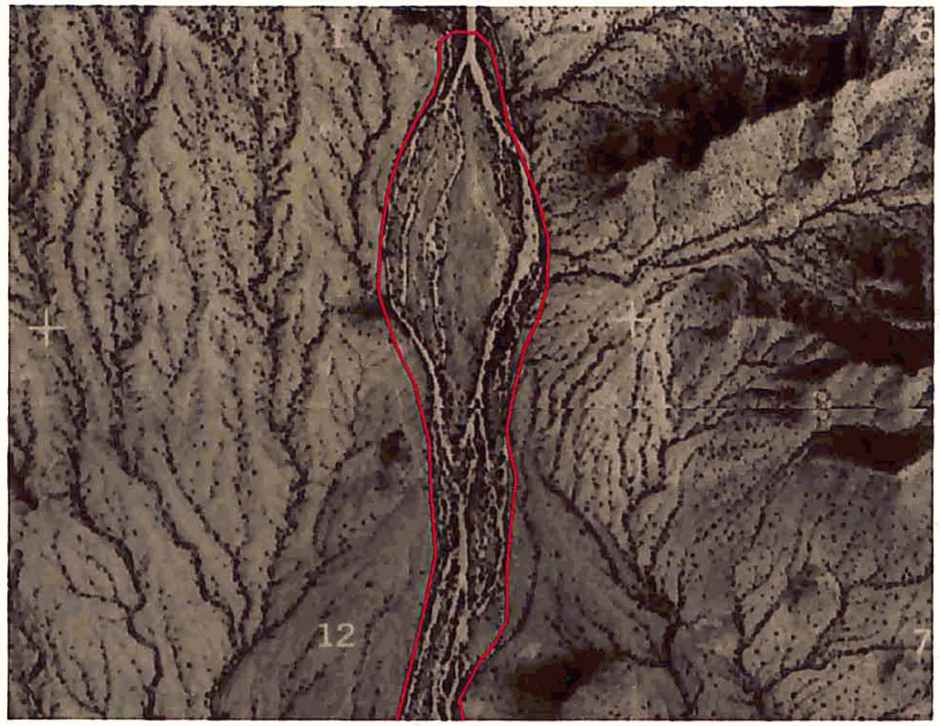

Figure GR-46. Historic aerial photographs of the northern alluvial fan on Padelford Wash

3.2.1.2. Lower Portion of Padelford Alluvial Fan

The lower portion of the fan on the Padelford Wash continues south from the northern portion of the fan and ends at the CAP canal (see Figure GR-47.). Four-foot contour mapping for this landform is shown in Figure GR-48. The southern portion of the fan is composed of Antho-Carrizo-Maripo Complex (northern section of lower portion) and Pinamt-Tremant Complex (southern section). It should also be noted that the Antho-Carrizo-Maripo Complex is typically associated with active alluvial fans while the Pinamt-Tremant Complex is typically associated with relict fans. The surficial geology of this landform contains both Ya2 and Ma2. Most of the landform is classified as Ya2 (a very young surface), but there are many streaks of Ma2 (an older surface) running through the landform (see Figure GR-49). Some channel movement was observed when the current aerial photographs were compared with the historic Fairchild photographs and the entire area has a stippled appearance. For example, a recent aerial photograph of the top portion of this alluvial fan is shown in Figure GR-50. Noticeable channel movement can be observed when this photograph is compared to a historic photograph of the same area (Figure GR-51). Most of the indicators suggest that this is an active alluvial fan. However, there appears to be patches of older surfaces that are not active within this alluvial fan. It appears, however, that the active portion of the fan may be covering older surfaces that have been inactive for long periods of time.

Figure GR-47. Southern alluvial fan on Padelford Wash

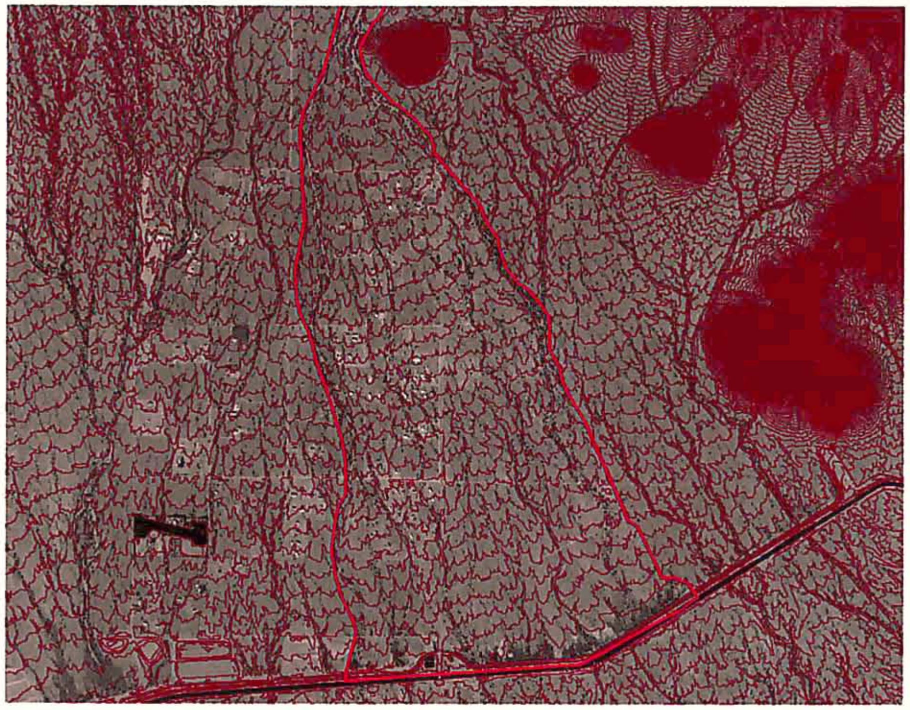

Figure GR-48. Contour mapping (4-foot) of the southern alluvial fan on Padelford Wash

Figure GR-49. The southern alluvial fan on Padelford Wash is streaked with older surfaces

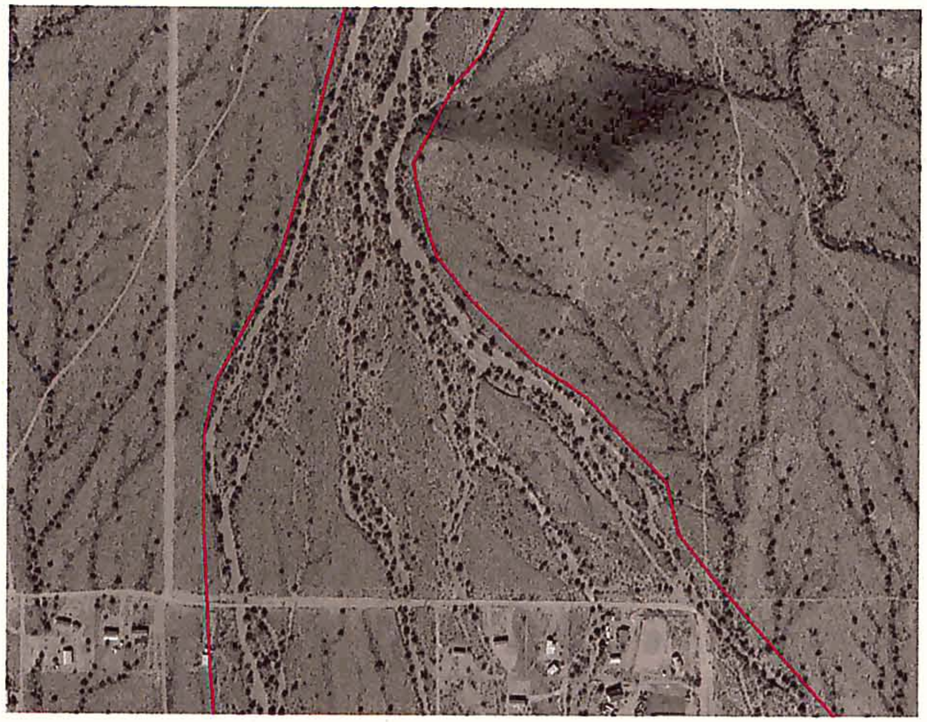

Figure GR-50. Close up view of the top portion of the southern alluvial fan on Padelford Wash

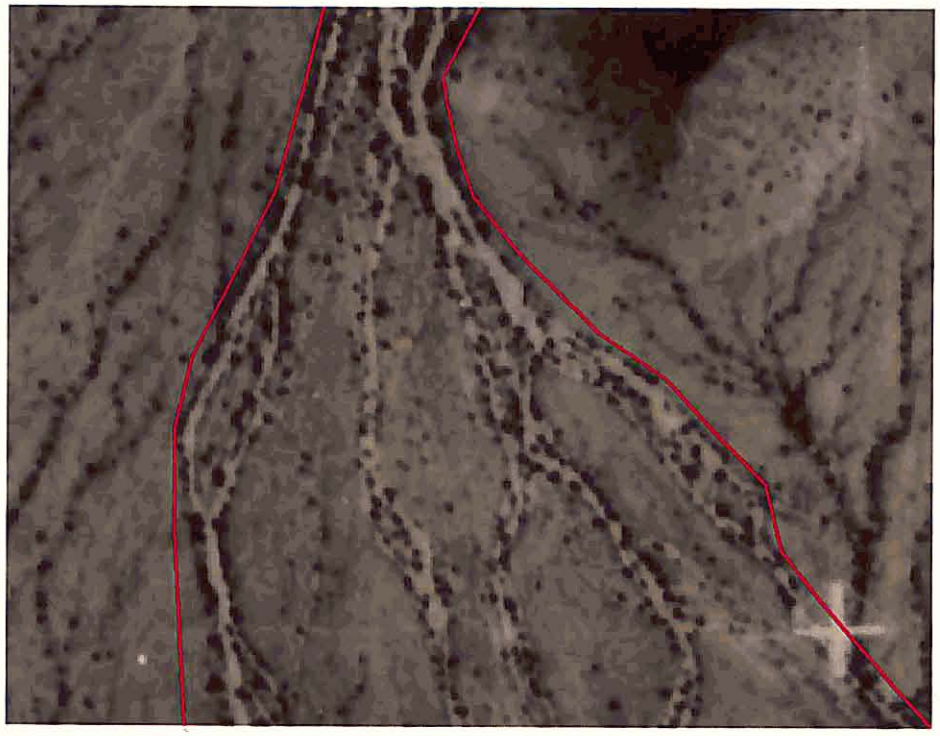

Figure GR-51. Historical aerial view of the top portion of the southern alluvial fan on Padelford Wash

3.2.2. Alluvial Fan 2

The second alluvial fan is west of the fan on the Padelford Wash; it is located near the east boundary of the Chrysler Proving Grounds. A recent aerial photograph of this alluvial fan is shown in Figure GR-52 while the 4-foot contour mapping of this landform is shown in Figure GR-53. The head of this fan begins at break in grade. The fan spreads out and eventually turns into an alluvial plain. Because of this, it was difficult to determine the exact location of the toe of this alluvial fan. After examining the detailed contour data provided by FCDMC, it was determined that there is a distinct grade break to a much flatter slope about 1.5 to 2 miles from the head of the fan. The toe of the alluvial fan was placed at this break in grade. The soil types in this landform are either Denure-Momoli-Carrizo complex or Gilman loams, both of which are common in active alluvial fans. Huckleberry (1994) classified this alluvial fan as having both Ya2 and Ya1 surfaces. Some channel movement was observed when the current aerial photographs were compared with the historic Fairchild photographs and the entire area has a stippled appearance. A recent and historic close up aerial view of the lower portion of this alluvial fan is shown in Figure GR-54 and Figure GR-55, respectively. Some channel movement can be observed by comparing these two photographs.

Figure GR-52. Alluvial fan located near the Chrysler Proving Grounds

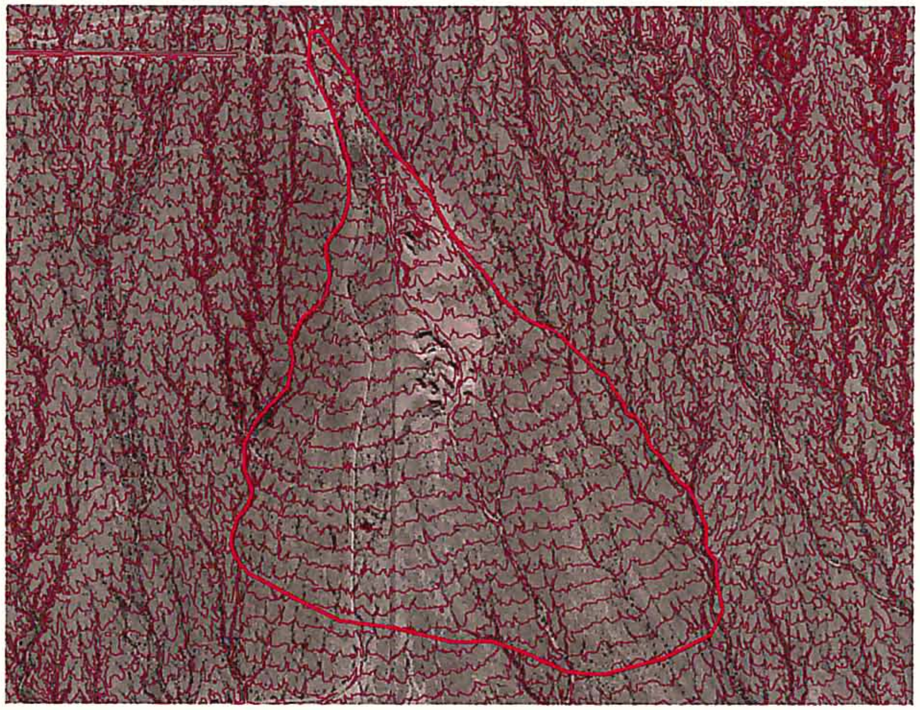

Figure GR-53. Contour mapping (4-foot) of the alluvial fan located near the Chrysler Proving Grounds

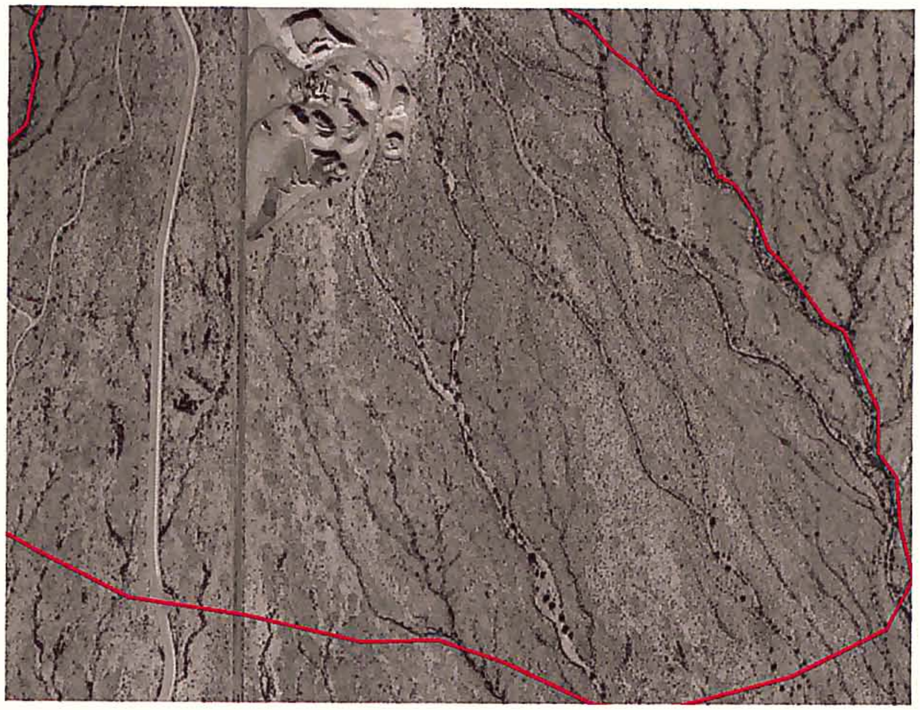

Figure GR-54. Close up view of the lower portion of the alluvial fan located near the Chrysler Proving Grounds

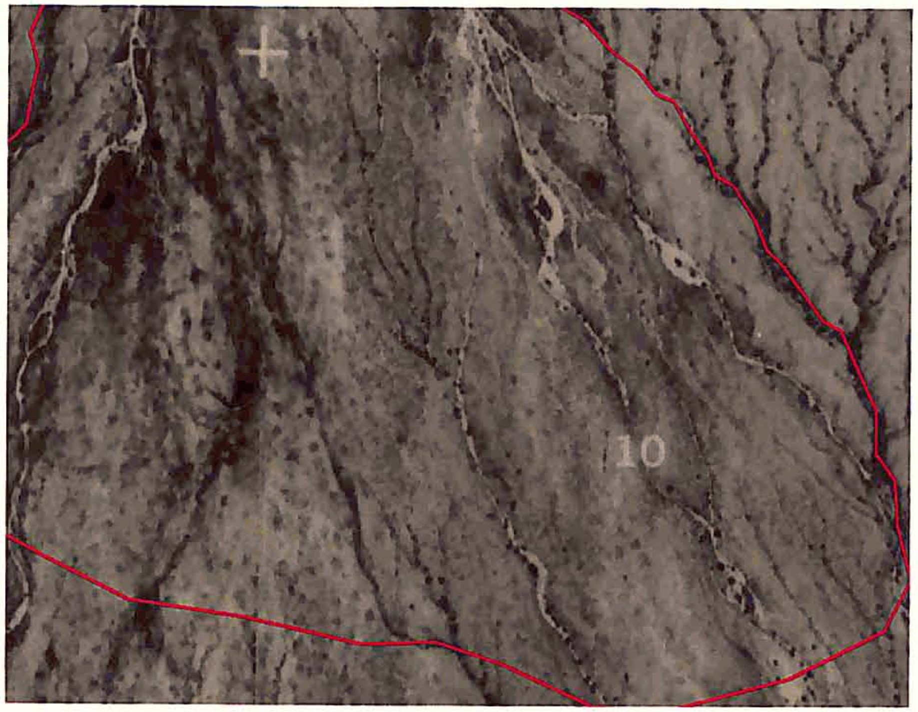

Figure GR-55. Historic aerial view of the lower portion of the alluvial fan located near the Chrysler Proving Grounds

3.2.3. Small Alluvial Fans (Fans 3 and 4)

Two small alluvial fans were located in the western portion of the study area as shown in Figure GR-43. These fans are shown in more detail in Figure GR-56 and Figure GR-57. The fans are both within the unstable channel classification and were thus not analyzed in detail. The fans are small in extent and have visual features consistent with alluvial fans. The upper fan (see Figure GR-56) consists of Antho-Carrizo-Maripo complex (indicative of active alluvial fans) and bordered by Ebon soils which are indicative of relict alluvial fans. A grade break is also found at the apex of the northern fan. This is indicative that this is an inset alluvial fan and given its location in the channel it is most likely active.

The lower (or southern small) fan (see Figure GR-57) does not have a grade break associated with it that is necessary to be classified as an alluvial fan but is identified as needing additional study prior to channelization or other improvements in the area. The soil type of this lower fan (or unstable area) consists of Antho-Carrizo-Maripo complex which is an indicator of instability and is associated with active alluvial fans.

Figure GR-56. Northern small fan immediately upstream from Highway 74

Figure GR-57. Small southern potential alluvial fan or unstable area (note proximity to homes in the area)

3.3. Map of Potentially Unstable Areas in the Northern Portion

A map of the potentially unstable areas in the northern portion of the Wittmann study area appears in Figure GR-59. A summary of the indicators used to assess the stability of the landforms is shown in Table GR-16. Figure GR-61 indicates where the landforms identified in Table GR-16 are located. Most of the potentially unstable areas that were identified consisted of braided through flow channels. Figure GR-58 shows an aerial photograph of a typical braided through flow channel in the study area. These wide channels have flat bottoms and are deeply incised. All of the braided through flow channels are around 30 to 150 feet wide and are incised to a depth of 10 to 30 feet. The largest of these channels are over 150 feet wide and are incised over 30 feet. These channels have a braided flow pattern and flow path movement was noticeable when the recent aerial photographs were compared with the historic Fairchild photographs. Many of these channels have wide overbanks that are covered with scattered vegetation that gives the landform a stippled appearance, as shown in Figure GR-58. The stippled appearance indicates that the overbanks are also unstable and subject to at least occasional flooding. There is not a significant amount of large vegetation along the banks, which also suggests that the overbanks are subject to flooding as well as channel movement. The braided conveyance corridor channels are composed mostly of Brios-Carrizo complex, Antho-Carrizo-Maripo complex, or Anthony-Arizo complex. All of these soil types also suggest that the braided through flow channels are unstable. Finally, all of the identified braided through flow channels were labeled as Ya2 by Huckleberry (1994), which indicates that these landforms are very young.

It should be noted that many of these through flow channels pass through old landforms. In these portions, the through flow channels are not braided, but consist of a single, straight channel with thick vegetation lining the banks. Although these portions are more than likely stable, they are still part of the same channel that has potentially unstable portions upstream and downstream.

Thus, the entire through flow channel was labeled potentially unstable even though portions of the channel may actually be stable.

Figure GR-58. Typical potentially unstable through flow channel

There is a large, potentially unstable area in the southern portion of the study area, near where the CAP canal meets Grand Avenue. In this area, many individual through flow channels combine to form one relatively undissected alluvial plain. This flat area is covered with small channels that are 1 to 2 feet deep. There are also a large number of medium-sized channels that are incised to a depth of 4 to 5 feet. The larger through flow channels in this area are incised to about 10 to 12 feet. The small and medium channels form a tributary drainage pattern and are composed of single channels. The larger through flow channels are typically braided. In a portion of this landform, the larger through flow channels form a braided drainage pattern. This area was classified as an alluvial fan (i.e., the alluvial fan immediately east of the Chrysler Proving

Grounds). The larger through flow channels form a tributary system on the rest of this landform. The soil in this area consists of Gilman-Momoli-Denure complex, Denure-Momoli-Carrizo complex, Mohall loams, and Gilman loams. All of these soil types are common in unstable alluvial plains. The entire area is sparsely vegetated except along the banks of the medium-sized streams. Huckleberry (1994) classifies the surficial geology in this area as either Ya2 or Ya1. Flow path movement was detected only in the large through flow channels and not in the small or medium-sized channels. This landform has characteristics of both stable and unstable landforms. However, it appears that more of indicators suggest the landform is unstable.

3.4. Map of the Areas Requiring Two-Dimensional Modeling

A map showing five areas that were identified in the northern portion of the Wittmann study area that may require two-dimensional modeling is shown in Figure GR-60. Two of these areas correspond to the alluvial fans shown in Figure GR-43 but other areas do not appear to be unstable but rather lack identifiable drainage patterns making one-dimensional modeling difficult. The areas identified for two-dimensional flow are very flat areas that are covered with either braided channels or no channels at all. The soils in these areas are soils that are typically associated with active alluvial fans or alluvial plains. The areas shown in Figure GR-60 would be best modeled using two-dimensional techniques. A larger version showing all of the possible two-dimensional areas is found in Appendix E.

Although there are many pockets of braided channels along the numerous unstable through flow channels, these areas do not require two-dimensional modeling because at high flows (e.g., the 100-year flood) the braided channels will probably be overtopped and the entire wash will be flowing as a single reach.

3.5. Summary and Conclusions

The northern area of the Wittmann study area has only two large potentially active alluvial fans as shown in Figure GR-43 and two possible small fans. In addition, the area has numerous unstable wash corridors. There is also a large unstable area just north of where the CAP canal and Grand Avenue meet. The various indicators (e.g., soil type, surficial geology, flow path movement) indicate that these areas are unstable. The remaining areas of the northern portion of the Wittmann study area appear to be stable with the exception of some small areas immediately upstream of the CAP canal as will be discussed in Section GR.6. A larger version showing all of the possible areas is found in Appendix E.

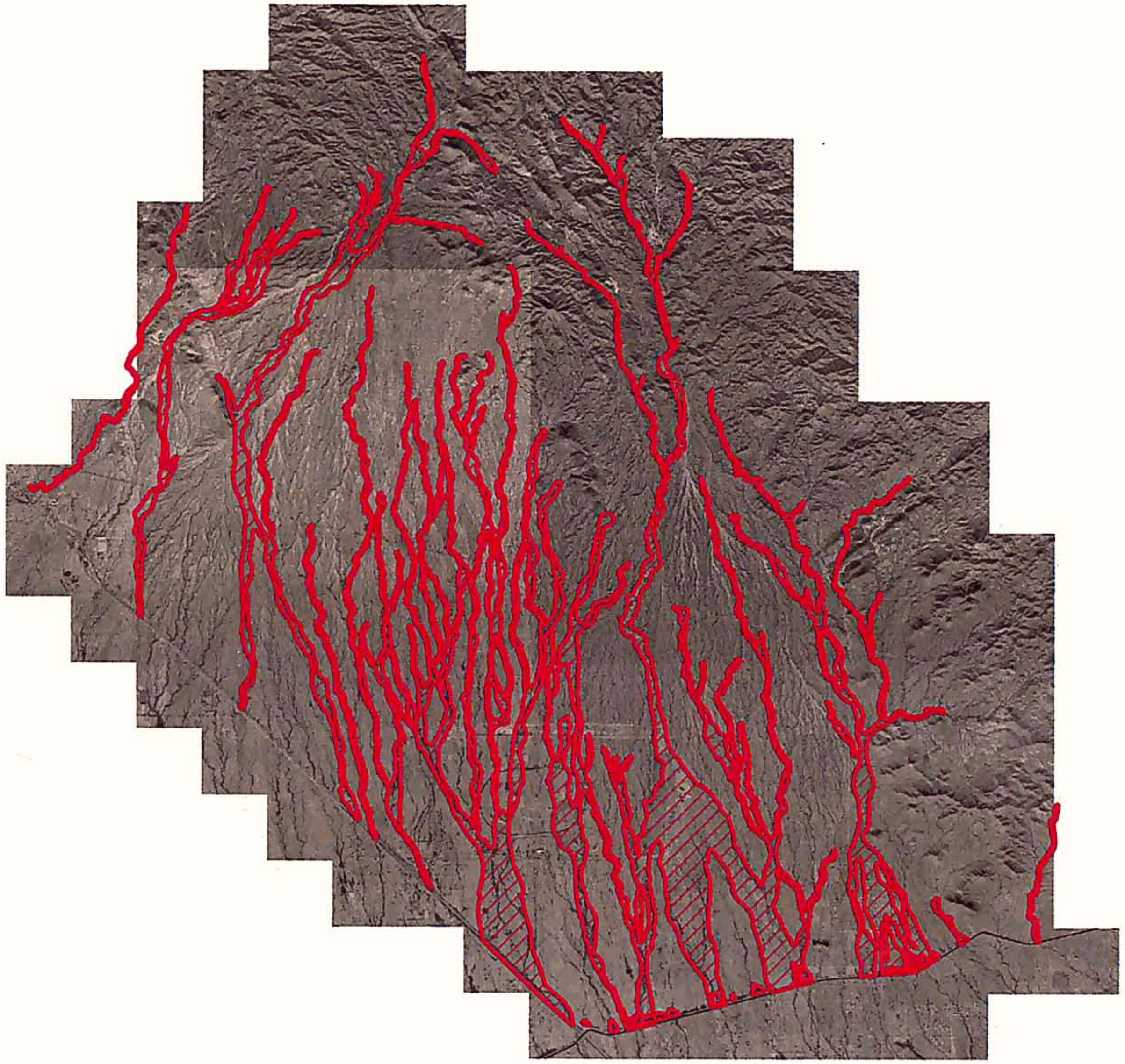

Figure GR-59. Potentially unstable areas in the northern portion of the Wittmann study area

Figure GR-60. Areas in the northern portion of the Wittmann study area possibly requiring two-dimensional modeling

Table GR-16. Summary of indicators used to assess the stability on the northern portion of the Wittmann study area

Landform ID	Stability	Channel movement	Drainage Pattern	Vegetation Pattern	Surficial Geology	Soil Types	Surface Texture
106	Unstable	Slight	Some Braided	Heavy along banks	Ya2	Pinamt-Tremant*	Stippled
107	Unstable	No photos	Some Braided	Heavy along banks	Ya2	Brios-Carrizo	Stippled
108	Unstable	Slight	Some Braided	Heavy along banks	Ya2	Gunsight-Cipriano* Ebon-Gunsigh-Cipriano*	Stippled
109	Unstable	Slight	Some Braided	Heavy along banks	Ya2	Pinamt-Tremant* Eba-Pinaleno* Ebon*	Stippled
110	Unstable	Slight	Some Braided	Heavy along banks	Ya2	Pinamt-Tremant* Ebon*	Stippled
111	Unstable	No photos	Some Braided	Heavy along banks	Ya2	Lehmans-Rock Outcrop* Greyeagle-Suncity*	Stippled
112	Unstable	Yes	Braided	Scattered along banks	Ya2	Antho-Carrizo-Maripo Pinamt-Tremant*	Stippled
113	Unstable	Yes	Braided	Scattered along banks	Ya2	Antho-Carrizo-Maripo Anthony-Arizo	Stippled
114	Unstable	Yes	Braided	Scattered along banks	Ya2	Antho-Carrizo-Maripo Anthony-Arizo	Stippled
115	Unstable	Slight	Some Braided	Scattered along banks	Ya2 Ya1	Gilman-Momoli-Denure Denure-Momoli-Carrizo Gilman Mohall Loams Brios-Carrizo	Stippled
116	Unstable	Slight	Some Braided	Scattered along banks	Ya2 Ya1	Gilman-Momoli-Denure Denure-Momoli-Carrizo Gilman Mohall Loams Brios-Carrizo	Stippled
117	Unstable	Slight	Some Braided	Scattered	Ya2 Ya1	Denure-Momoli-Carrizo	Stippled
118	Unstable	Slight	Braided	Heavy along banks	Ya2	Gilman-Momoli-Denure Gilman Loams	Stippled

* Indicates soil type is from the surrounding area and not from the channel itself.

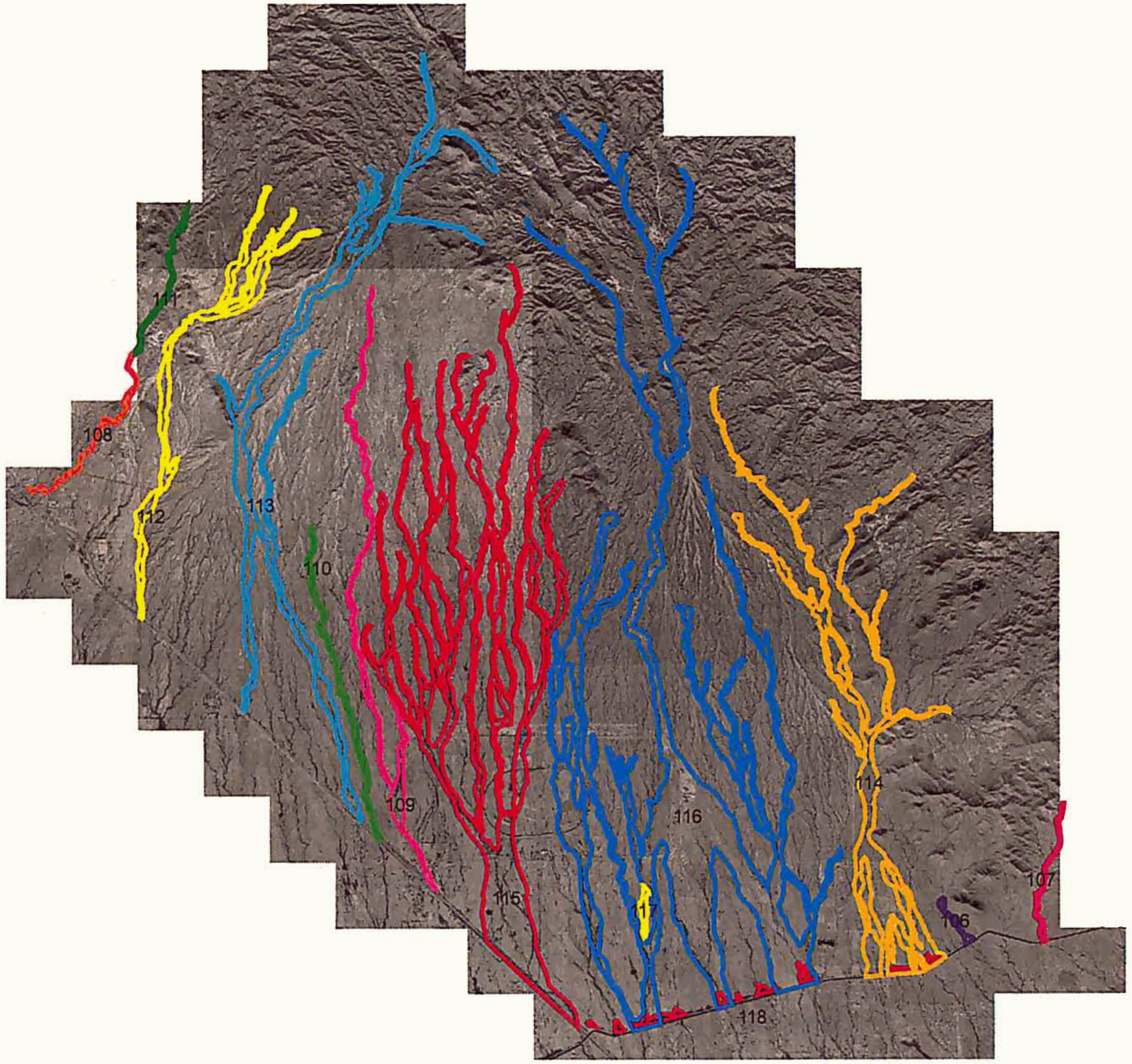

Figure GR-61. Potentially unstable areas keyed to Table GR-16

SECTION GR-4: CURSORY REVIEW OF THE PORTIONS OF THE STUDY AREA NOT STUDIED IN DETAIL

A cursory review of the remaining study area was done for the area not studied in more detail to ensure that areas of two-dimensional flow were not overlooked in the hydraulic effort. The area included in this cursory review is the area that is between the Sun Valley Parkway and the CAP as well as the area west of Grand Avenue and north of the CAP canal. The aerial photographs, the soils maps, and the topographic maps were used to identify areas of possible two-dimensional flow. Areas with soils commonly associated with alluvial plains and active alluvial fans and areas with very little topographic relief were tagged as areas of possible two-dimensional flow. These areas were then adjusted primarily based on observed topography. The areas identified in this manner are shown in Figure GR-62.

The areas shown in Figure GR-62 are designated as two-dimensional areas for modeling. These areas, if channelized, could be modeled using one-dimensional analysis. If the areas are modeled for flow paths or flood elevations without channelization it would be extremely advisable to use some type of two-dimensional model in these areas. These areas tend to be very flat with little relief and one-dimensional modeling will present very difficult challenges in the accurate modeling of flows in the area.

Flow patterns in this area vary widely depending on location in the watershed. Areas immediately downstream of the CAP and east of Grand Avenue tend to have incised channels without significant lateral movement. Areas above the CAP and west of Grand Avenue typically exhibit braided, distributary, and other complex flow types. Areas south of Grand and south of the CAP also exhibit complex flow patterns. All of the areas indicated in Figure GR-62 are also associated with the features that indicate two-dimensional modeling approaches. The various drainage patterns and types are discussed further in Section GR-6.

The areas that are not highlighted as two-dimensional areas in Figure GR-62 can be modeled using standard one-dimensional models, or in combination with geomorphic analyses. Larger versions of this figure can be found in Appendix E.

Figure GR-62. Possible areas of two-dimensional flow in the area north of the White Tank Mountains and South of Grand Avenue

SECTION GR-5: SEDIMENT YIELD ANALYSIS

Numerous methods are available to estimate sediment yield or production. Each method takes a different approach, and there is uncertainty associated with each method. It is prudent to calculate sediment yield using a variety of methods. The results of the various methods can then be compared to establish a range of possible sediment yields.

Of the methods available to estimate sediment production, some give average annual sediment yield, while others provide estimates of sediment yield for a given storm hydrograph. The results of all methods were converted to average annual sediment to make them comparable. One method estimated sediment production by storm event. For that method, the sediment yield was computed for six frequency floods (2-, 5-, 10-, 25-, 50- and 100-years) and integrated over a probability graph to get the average annual sediment yield.

For comparison purposes, all methods were converted to acre-ft/square mile/year. Two methods produced results in tons/year, which were converted to acre-ft/square mile/year using an estimated soil density of 87.4 lbs/cubic foot.

The methods used to estimate sediment yield from the study area are:

1. Revised Universal Soil Loss Equation (RUSLE).
2. Pacific Southwest Inter-Agency Committee (PSIAC) method.
3. Los Angeles Corps of Engineers Debris Method.

RUSLE and PSIAC allow for the analysis of any region in the watershed, and for those methods charts and tables are presented showing the sediment yield by sub-basin of the watershed. The Los Angeles Corps of Engineers Debris Method can only estimate sediment yield for the basin as a whole. The following sections explain the applicability of each method, how the sediment yield was calculated, and the results for each method. A section follows which presents other sources of sediment yield information for this basin, including previous studies, regional averages, and approximate methods. A summary of the results of the three methods follows. Finally, there is a section on expected future conditions and their impact on sediment yield.

5.1. Revised Soil Loss Equation (RUSLE)

5.1.1. Overview of Method

The Revised Universal Soil Loss Equation (RUSLE) is a revision and update of the widely used Universal Soil Loss Equation (USLE). USLE is an empirical equation designed for the computation of average soil loss in agricultural fields (Mitasova and Mitas 1999). RUSLE retains the factors of USLE to calculate annual sheet and rill erosion from a hillslope; however changes have been made for each factor. The application of RUSLE is based primarily on a USDA NRCS document explaining the use of the RUSLE equation in Arizona (NRCS 2000).

5.1.2. Limitations

The primary limitation of RUSLE is that it is a prediction of erosion, and not sediment yield. RUSLE does not subtract the sediment that is deposited after it is eroded (NRCS 2000). Therefore, the RUSLE results should theoretically be higher than the sediment yield. The application of a sediment delivery ratio (a factor less than one) would be required to correctly predict the sediment yield based on erosion.

5.1.3. Calculation

RUSLE uses the same factorial approach employed by the USLE, and is as follows:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

where

A = annual soil loss from sheet and rill erosion in tons/acre

R = Rainfall erosivity factor

K = soil erodibility factor

LS = slope length and steepness factor

C = cover and management factor

P = support practice factor

The RUSLE method predicts tons per acre per year rather than acre-feet per year of sediment yield. To enable comparison to other sediment yield methods, the RUSLE results were converted to volumes. Examination of the soil surveys for the study area shows that the average soil density is about 1.4 g/cc, or 87.4 lb/cubic foot, and therefore this density was used for the conversion.

For each of the subfactors, a GIS coverage was created, then converted to a grid. The spatial multiplication of all the subfactor grids resulted in an "annual soil loss" grid, a coverage which shows the predicted soil loss rate at each point in the watershed. The average RUSLE soil loss for the study area is an average value of this "annual soil loss" grid.

5.1.4. Determination of *R*

An NRCS map (NRCS 2000) shows that *R* is 15 for lower part of the watershed and 25 for upper mountain area.

5.1.5. Determination of *C*

The *C* values were calculated based on the table *"C" Values for Permanent Pasture, Rangeland, and Idle Land* (NRCS 1976). The use of that table required selection of the following parameters:

- The type and height of the raised canopy (no appreciable cover, 0.5 m, 2 m, 4 m)

- The percentage of canopy cover if canopy exists (25%, 50%, 75%)
- The percentage of ground cover (from zero to 100%)
- Whether the cover at the surface is grass-like (code G), at least 2 inches deep, or mostly broadleaf herbaceous plants (such as weeds) (code W).

It was determined based on field reconnaissance that the cover type of the watershed was closer to code W (broadleaf herbaceous). The type and height of raised canopy, the percentage of canopy cover, and percentage of ground cover were all visually estimated based on aerial photographs.

5.1.6. Determination of *K*

The K (erosion) factors came from two soil surveys. The Soil Survey of the Aguila-Carefree Area (Camp 1986), Table J-1 provided the *K* factors for the soils the northern part of the watershed.

The southern part of the watershed was covered by the Maricopa County, Arizona Soils Survey. Table J-1 from this survey was generated by downloading the SSURGO tables (in a plain text format) (NRCS 9/25/2002) from the Internet, then using a utility provided by the NRCS to generate Table J-1. A PDF version of the table was created and is included with the files for this report. Similarly, a PDF version of the most recent Aguila-Carefree Soil Survey's survey Table J-1 was generated (NRCS 12/9/2002). However the actual *K* values used for the RUSLE calculation were taken from the earlier 1986 soil survey (Camp 1986).

Each of the J-1 tables provided two values for K: K_w and K_f. Factor K_w considers the whole soil, and factor K_f considers only the fine-earth fraction, which is the material less than 2.0 mm in diameter. (NRCS National Soil Survey Handbook 2002, Section 618.55).

The method to select the *K* value was based on a conversation with Mr. Robert Wilson of NRCS (Chandler-Higley Service Center (480) 988-1078, 18256 E Williams Field Rd, Higley, AZ 85236) (personal communication, 8/27/03). Mr. Wilson instructed that K_w should be used for gravelly loam or very gravelly loam, and K_f should be used for sandy loam. Many of the map symbols contained different soils. In these cases the *K* for the predominant soil was used. Some map symbols included rock outcrops. For these map symbols, the *K* factor was reduced by the percentage of rock outcrops, since rock outcrops are assumed to have no erodibility.

5.1.7. Determination of *LS*

A general equation to calculate *LS* from digital elevation models is (Mitasova and Brown undated):

$$LS(\mathbf{r}) = (m+1)\ [A(\mathbf{r}) / a_0]^m\ [\sin b(\mathbf{r}) / b_0]^n$$

where *A* is upslope contributing area per unit contour width, *b* is the slope, a_0 = 22.1m, b_0 = 0.09, *m* is 0.4-0.6 and *n* is 1-1.4. The **r** variable appears to refer to the spatial location where *LS* is being calculated. In the reference, two specific forms of this equation appear, using different combinations of *m* and *n*. The two forms are:

Form 1 (m = 0.6, n = 1.3):

$$LS = 1.6 * (flowacc * resolution/22.1)^{0.6} * (sin(slope) /0.09)^{1.3}$$

Form 2 (m = 0.4, n = 1.4) :

$$LS = 1.4 * (flowacc * resolution/22.1)^{0.4} * (\sin(slope)/0.09)^{1.4}$$

Each form of the equation was calculated for each grid cell. In these equations, *flowacc* is the flow accumulation at each grid cell (this gives the number of grid cells upstream), *resolution* is the grid cell size in meters, and *slope* is the terrain slope in radians at each grid cell (in ArcGIS the slope is in degrees and must be multiplied by 0.01745 to convert it to radians). These expressions provide a value of *LS* for each grid cell. An average over the watershed is then calculated to determine *LS* for use in the RUSLE equation.

5.1.8. Determination of *P*

The support practices factor *P* is, according to NRCS documents, almost always 1.0 (NRCS August 2000). Therefore 1.0 was used for *P*.

5.1.9. Results

Table GR-17 summarizes the different factors that were used, and the soil loss predictions using RUSLE. Table GR-18 summarizes the RUSLE results.

Table GR-17. RUSLE method inputs

	Using equation Form 1 for calculating *LS*	Using equation Form 2 for calculating *LS*
R factor (rainfall erosivity)	15 for lower part, 25 for upper mountain area, Average = 16.68	
K factor (soil erodibility)	Average = 0.189	
LS factor (length-slope)	Average = 7.62	Average = 3.94
C factor (cover and management)	Values ranged from 0.0525 to 0.45, Average = 0.241	
P factor (support practice)	1.0	

Table GR-18. RUSLE results

RUSLE soil loss in tons / acre / year*	2.161	0.989
RUSLE soil loss in acre-ft / square mile /year (assuming soil density of 87.4 pcf)	0.726	0.332

* The RUSLE soil loss is not the product of the average of each factor shown in the previous table. The product of the factors was computed at each 10x10 foot grid cell. These products were then averaged across the grid cells to get the study area's soil loss.

Charts showing the variation in the RUSLE predictions of soil loss by region are presented in Appendix D-1.

5.2. Pacific Southwest Inter-Agency Committee (PSIAC) Method

5.2.1. Overview of Method

The application of PSIAC is based on the documentation provided in the "Design Manual for Engineering Analysis of Fluvial Systems" (Simons, Li, and Associates 1985). PSIAC is used by developing a numerical rating of nine factors affecting sediment production in a watershed. This rating, in turn, is correlated with ranges of annual sediment yield in acre-feet per square mile. The nine factors are surface geology, soil, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and transport.

5.2.2. Limitations

The method relies on estimates of numerous parameters. The estimation of parameters is subjective.

5.2.3. Calculations and Results

Because of the subjective nature of the estimates of PSIAC parameters, the sensitivity of results to variations in parameters was checked. Three sets of estimates were made: Case 1, Case 2 and Case 3. The middle case, Case 2, has the best estimates for each parameter. Cases 1 and 3 show how sensitive the results are to different assumptions. Case 1 has parameters at the lower end of the expected range – leading to lower sediment yields. Case 3 has parameters at the higher end of the expected range – leading to higher sediment yields.

The PSIAC method includes a table which converts the PSIAC rating in a sediment yield, shown in Table GR-19. Although the table translates ranges of ratings into ranges of sediment yields, it is possible through interpolation to generate a specific value of sediment yield from a particular rating.

The estimates used for each of the nine factors are shown in Table GR-20. The sediment yield characteristic of each factor is assigned a numerical value. The yield rating is the sum of values for the appropriate characteristics for each of the nine factors (Simons, Li, and Associates 1985, Appendix A.2). The yield rating is translated into a predicted sediment yield using a table.

GIS was used to model the spatial variation of the factors over the study area. The product of the factors was calculated at each 10x10 foot grid cell in the watershed. Then, an average PSIAC value across the watershed was calculated. The ranges of factors used, as well as the weighted averages for each factor over the study area, are shown in Table GR-20.

Table GR-19. Sediment yield from PSIAC rating

Classification	Rating	Sediment Yield (acre-feet/square mile)
1	> 100	3.0
2	75 – 100	1.0 – 3.0
3	50 – 75	0.5 – 1.0
4	25 – 50	0.2 – 0.5
5	0 -25	< 0.2

Table GR-20. PSIAC factors and results

	CASE 1 (lower yield)	CASE 2 (best estimate)	CASE 3 (higher yield)
Surface Geology (*A*)	5 (moderate) for flat area, and 3 (between moderate and low) for rocky sites (average = 4.601)		
Soils (*B*)	Based on description of erosion hazard of each soil group in soil survey. Values used were 2 (slight), 3 (slight to moderate), 5 (moderate), 7 (moderate to severe) and 10 (severe) (average = 2.901)		
Climate (*C*)	5 (moderate)		
Runoff (*D*)	5 (moderate)	5 (moderate) for most areas or 8 (between moderate and high) for mountain areas (average = 5.790)	
Topography (*E*)	0 (0-5%) slope, 5 (5-12%), 10 (12-20%), 15 (20-30%), and 20 (more than 30%) (average = 2.968)		
Ground Cover (*F*)	Ranging from -5 (between moderate and medium) to 5 (moderate) (average=2.480)		
Land Use (*G*)	0 (moderate) for roads, -6 (between moderate and low) for residential and industrial. -7 (between moderate and low) for open space and vacant space, -8 (between moderate and low) for agriculture and -10 (low) for water. (average = -6.875) (see Table GR-23 for details)		
Upland Erosion (*H*)	5 (between moderate and low)	10 (moderate)	15 (between moderate and high)
Channel Erosion and Sediment Transport (*I*)	5 (between moderate to low)	10 (moderate)	10 (moderate)
Weighted average PSIAC rating, existing conditions	25.8376	36.5675	41.5675
PSIAC sediment yield, existing conditions, acre-feet/square mile / year	0.2101	0.3388	0.3988

Charts and tables showing the variation in the PSIAC predictions of sediment yield by region are presented in Appendix D-2 for existing conditions and in Appendix D-3 for Future Conditions.

5.3. Los Angeles Corps of Engineers Debris Method

5.3.1. Overview of Method

The application of this method is based on the Debris Method manual (USACE 1992). This method was developed to assist in the design of debris basins. It predicts the debris yield resulting from a single flood event. It was primarily designed based on data from coastal draining, mountainous, Southern California watersheds. The definition of "debris" according the Corps of Engineers is "silt, sand, clay, gravel, boulders, and organic materials" (USACE 1992). Since it is expected that most of the "debris" would in fact be sediment, the results of this method are comparable to methods that predict sediment yield.

5.3.2. Limitations

The application of the L.A. Corps method to the study area has the following limitations:

1. The L.A. Corps method is designed to predict debris yield for a single event. However, the desired result is an average annual yield. The average annual yield can be estimated by providing a weighted average of a number of flood events (e.g., the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events), assigning probabilities for each event for a particular year. The conversion to an average annual yield based on a weighted average from various events increases the uncertainty of the results.
2. The various flood events used to calculate the weighted average are not known since the watershed is ungaged. They can be estimated using the USGS Flood Frequency regression equations; however, these equations are in fact only supposed to be used for watersheds of 200 square miles or less. The study watershed is 246.4 square miles.
3. The L.A. Corps method is designed for watersheds not greater than 200 square miles in size. The study watershed is 246.4 square miles.
4. The L.A. Corps method is designed primarily for use in Southern California, west of the coastal desert drainage divide. Its

applicability to other watersheds requires the application of uncertain correction factors.

5.3.3. Calculation

The L.A. Corps method requires the following inputs:

Q = the unit peak runoff (cfs / square mile)

RR = the relief ratio (feet / mile)

A = drainage area (acres)

FF = non-dimensional fire factor

Additionally, because the watershed is not in the San Gabriel Mountains area, the equations also require the application of an Adjustment-Transposition (*A-T*) factor.

5.3.4. Unit Peak Runoff

The unit peak runoff was estimated using the USGS National Flood Frequency equations for the region (USGS January 1999). These equations are designed for watersheds of 200 square miles or less. The study watershed, at 246.4 square miles, is larger than this, and is therefore beyond the recommended limit for the application of these equations.

Per the USGS NFF charts, the watershed was in Arizona Region 12. The equations for peak flow for the 2, 5, 10, 25, 50, and 100-year runoff events are:

$$Q_2 = 41.1 * AREA^{0.629}$$

$$Q_5 = 238 * AREA^{0.687} * (ELEV / 1000)^{-0.358}$$

$$Q_{10} = 479 * AREA^{0.661} * (ELEV / 1000)^{-0.398}$$

$$Q_{25} = 942 * AREA^{0.630} * (ELEV / 1000)^{-.383}$$
$$Q_{50} = 10^{(7.36 - 4.17 * AREA^{-0.08})} * (ELEV / 1000)^{-0.440}$$
$$Q_{100} = 10^{(6.55 - 3.17 * AREA^{-0.11})} * (ELEV / 1000)^{-0.454}$$

where

AREA = drainage area in square miles, and
ELEV = mean basin elevation in feet.

Using the elevation grid in the area where it overlaps the watershed, it was found using ArcView GIS that the average elevation was 1937.8 feet. However, the elevation grid does not overlap a small portion of the Northern limit of the watershed. The area without elevation information is 1,411 acres. The area of the watershed that overlaps the grid is about 156,289 acres. Examination of the USGS quadrangle contours in the area without digital elevation data indicate that the average elevation in this region is roughly 3,800 feet.

The estimated weighted average elevation of the study area is therefore:

*(1,411 acres * 3,800 feet + 156,289 acres * 1937.8 feet) / (1,411 acres + 156,289 acres) = 1954 feet*

and

AREA = 246.4 square miles

Using these factors, the following values were obtained for peak runoff:

$Q_2 = 1,313$ *cfs*

$Q_5 = 8{,}232\ cfs$

$Q_{10} = 13{,}977\ cfs$

$Q_{25} = 23{,}408\ cfs$

$Q_{50} = 35{,}307\ cfs$

$Q_{100} = 48{,}775\ cfs$

The unit peak runoffs, in cfs per square mile, for application in the L.A. Corps equations, are:

$Q_2 = 5.33\ cfs / sq\ mile$

$Q_5 = 33.41\ cfs / sq\ mile$

$Q_{10} = 56.73\ cfs / sq\ mile$

$Q_{25} = 95.00\ cfs / sq\ mile$

$Q_{50} = 143.29\ cfs / sq\ mile$

$Q_{100} = 197.94\ cfs / sq\ mile$

5.3.5. Relief Ratio

The relief ratio is defined as the "the difference in elevation (feet) between the highest point in the watershed (measured at the end of the longest stream) and the lowest point (at the debris collection site). The longest stream path was measured by overlaying a GIS coverage of Arizona rivers and streams onto the watershed. The highest point of the stream was slightly north (by about 2 miles) of the limits of the elevation grid. The elevation at that point was instead read from a USGS quadrangle. The highest point in the watershed, at the upstream limit of the longest stream, is about 4,100 feet.

For this reach, the stream path from down to the dam measured 29.64 miles (51,400 meters). The elevation difference is 4,100 – 1,353 feet = 2,747 feet. Therefore:

$RR = 2{,}747\ feet / 29.64\ miles = 92.7\ feet / mile$

5.3.6. Drainage Area

The drainage area is 157,700 acres.

5.3.7. Non-dimensional Fire Factor

This factor depends on the number of years since the last wildfire. This data is not known for the watershed. However, the watershed is considerably less vegetated than the California watershed on which the Corp's model was based. The highest fire-factor used in California, 6.0, was chosen, representing a "recent fire" or in the case of the study basin, sparse vegetation. Thus, *FF* was set equal to 6.0.

5.3.8. Adjustment-Transposition (*A-T*) Factors

The *A-T* factor was not known for this watershed. The L.A. Corps debris method requires, to calculate the *A-T* factor, one of the following:

(1) Sediment records for the basin, or
(2) Sediment records for nearby basins, or
(3) The use of adjustment-transposition factors based on subfactors including parent materials, soils, channel morphology, and hill slope morphology.

The first two methods were not used because no sediment records were available. The final method, using the subfactors, is based on watersheds in Southern California, and may not be applicable for this watershed. It was assumed for lack of better information that each of the subfactors was equal to the middle value of the range provided (from Table B-1, USACE 1992). This assumption resulted in an *A-T* factor of 0.6.

5.3.9. Results

The L.A. Corps Debris method equation for watersheds of 50 to 200 square miles was used to calculate the yield:

$$\log_{10} Dy = 1.02 \log_{10} Q + 0.23 \log_{10} RR + 0.16 \log_{10} A + 0.13\, FF$$

This debris yield must be calculated for each return period. Applying a probability equation, the average annual sediment yield is estimated by:

$$Y_{average\ annual} = 0.01 * Y_{100} + 0.005 * (Y_{100} + Y_{50}) + 0.01 * (Y_{50} + Y_{25}) + 0.03 * (Y_{25} + Y_{10}) + 0.05 * (Y_{10} + Y_{5}) + 0.15 * (Y_{5} + Y_{2}) + 0.25\, Y_{2}$$

When all the variables were entered in a spreadsheet, and converted to acre-ft/year, the result is:

$$Y_{average\ annual} = 1.73 \text{ acre-ft/year/sq mile (without A/T factor)}$$

This is without application of the A-T factor. Incorporating the estimated A/T factor of 0.6 results in:

$$Y_{average\ annual} = 1.04 \text{ acre-ft/year/sq mile}$$

5.4. Regional Averages, Previous Studies, and Approximate Methods

This section summarizes additional sources of sediment yield information for this basin.

5.4.1. Sediment Yield for Particular Basins in the Southwest

The Draft Drainage Design Manual (FCDMC, 2003) presents the sediment yield at assorted locations in Arizona, California, and New

Mexico. The median sediment yield for the Arizona sites is 0.24 acre-ft/square mile/year, while the average is 0.32 acre-ft/square mile/year.

5.4.2. Relationship between Precipitation and Sediment Yield

The Draft Drainage Design Manual (FCDMC, 2003) also discusses the relationship between precipitation and sediment yield. The Manual notes that maximum sediment yield occurs with precipitation in the 10 to 15 inch range. Overlaying an annual precipitation map of Arizona (from the Spatial Climate Analysis Service) over the watershed area reveals that over half the watershed is in the 10-15 inch range of precipitation, which would indicate a high sediment yield for this basin.

5.4.3. Regional Sediment Yield by Drainage Area

The Draft Drainage Design Manual (FCDMC, 2003) presents a graph showing a scatter plot of sediment yields by drainage area for basins in Arizona and New Mexico (from Glyph, 1951). This plot only goes to 200 square miles, while the study area is about 246 square miles. At the 200 square mile limit, however, the envelope curve shows that the upper and lower limits of the sediment yield are 0.04 to 1.57 acre-feet/square mile/year. Averaging the log of these values (i.e. the middle point between 0.04 and 1.57 on the log scale shown in the graph), results in a sediment yield of 0.25 acre-feet/square mile/year.

5.4.4. 1953 US Army Corps of Engineers Study

A 1953 Corps of Engineers Study says that: *"On the basis of sedimentation studies of the area by the Soil Conservation Service, the assumption that the drainage-area conditions would not deteriorate over the next 50 years was considered reasonable and a sedimentation rate of 0.2 acre-foot per square mile per year was considered adequate"* (Corps of Engineers, 1953).

5.4.5. Langbein and Schumm Sediment Yield

The Draft Drainage Design Manual (FCDMC, 2003) also presents a graph (from Langbein and Schumm, 1958) which provides a relationship between annual precipitation and sediment yield. This method is used to illustrate the trend of sediment yield versus precipitation, and is not included in the "analytical methods" section of Draft Drainage Design Manual. As part of our examination of approximate methods, however, we calculate the sediment yield using this method.

The Langbein and Schumm graph has two curves, one for small basins, and another for large basins—the large basin curve is applicable here. The graph shows that sediment yield tends to peak at a precipitation of about 12 inches per year. Where precipitation exceeds this, vegetation growth is promoted which increases surface protection, reducing sediment production into fluvial systems (North, Colin P.). In drier areas, although vegetation is further reduced, potentially increasing sediment availability, the available energy for erosion and transport is limited (North, Colin P.). Table GR-21 shows the calculation of the weighted average sediment yield using the Langbein and Schumm method.

Table GR-21. Weighted average sediment yield by Langbein and Schumm method

Range of Annual Precipitation / Center of range	Percentage of Basin area with given annual precipitation	Langbein and Schumm annual sediment yield in tons / square mile / year (at center of precipitation range)
8-10 inches / avg. 9 inches	14%	730
10-12 inches / avg. 11 inches	47%	810
12-14 inches / avg. 13 inches	18%	800
14-16 inches / avg. 15 inches	9%	750
16-18 inches / avg. 17 inches	12%	700
All precipitation ranges	*100% (sum)*	*778 (weighted average)*

The weighted average using the Langbein and Schumm method is 778 tons per square mile per year. Using a soil density of 87.4 lbs/cubic foot, this translates to 0.41 acre-ft/square mile/year.

5.5. Summary: Existing Conditions

The sediment yields obtained by the different methods are summarized in Table GR-22. The values are in acre-feet/square mile/year, and have been rounded to two decimal places.

Table GR-22. Summary of predicted sediment yields in acre-ft/square mile/year, existing / historical conditions

Method	Low Estimate	Middle Estimate	High Estimate
L.A. Corps Debris Method	-	1.04	-
RUSLE (soil loss)	0.33	-	0.73
PSIAC	0.21	0.34	0.40

The L.A. Corps Debris method gives the highest sediment yield. However, due to the numerous uncertainties associated with the application of this method to the study area, the results should not be given undue weight. The RUSLE method, which would be expected to over-predict sediment yield since it is a measure of erosion, provides the next highest estimates. The PSIAC method's estimates are slightly lower. The PSIAC method, having detailed inputs, and not having as many limitations as the L.A. Corps method and RUSLE, is probably the most applicable of the yield methods.

A reasonable range of estimates for sediment yield would be from the lowest PSIAC value of 0.21 acre-ft/square mile/year (which is also approximately the highest estimate from the topographic measurement), to the average of the RUSLE estimates, 0.53 acre-ft/square mile/year. We can probably conclude, based on the yields calculated, that a reasonable estimate is in the 0.4 acre-ft/square mile/year range—which is approximately the mean of the average PSIAC value of 0.32 ([0.21 + 0.34 + 0.40]/3) and the average RUSLE value of 0.53 ([0.33 + 0.73] / 2.

On the subbasin level, conservative estimates (i.e., probably not underestimates) of the sediment yield would be given by either Case 3 of PSIAC (average value of 0.40 acre-ft/year/square mile) or *LS* Equation form 1 of RUSLE (average value of 0.73 acre-ft/year/square mile). The sediment yields for these two methods are illustrated in Figure GR-63 and Figure GR-64.

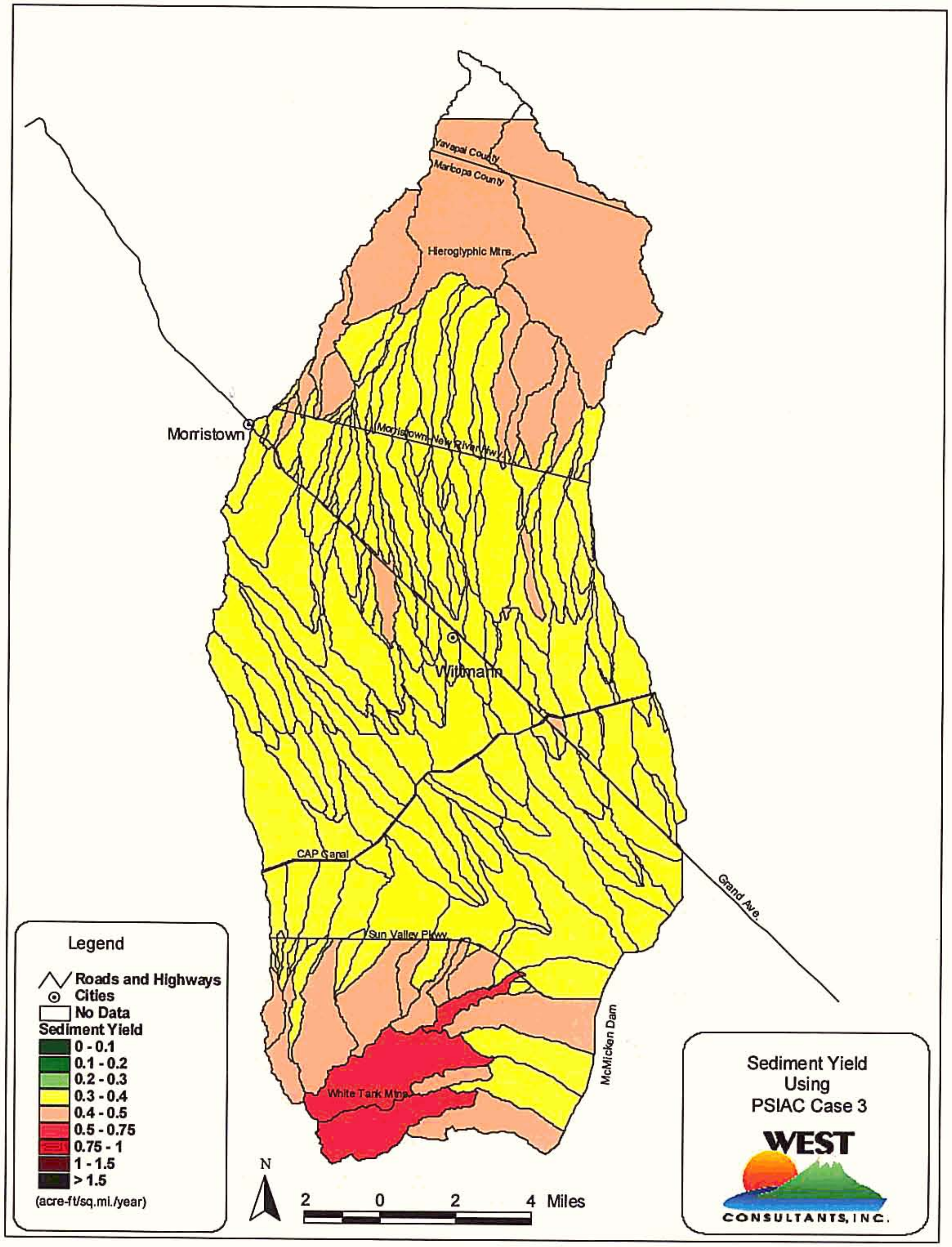

Figure GR-63. PSIAC results by subbasin for Case 3.

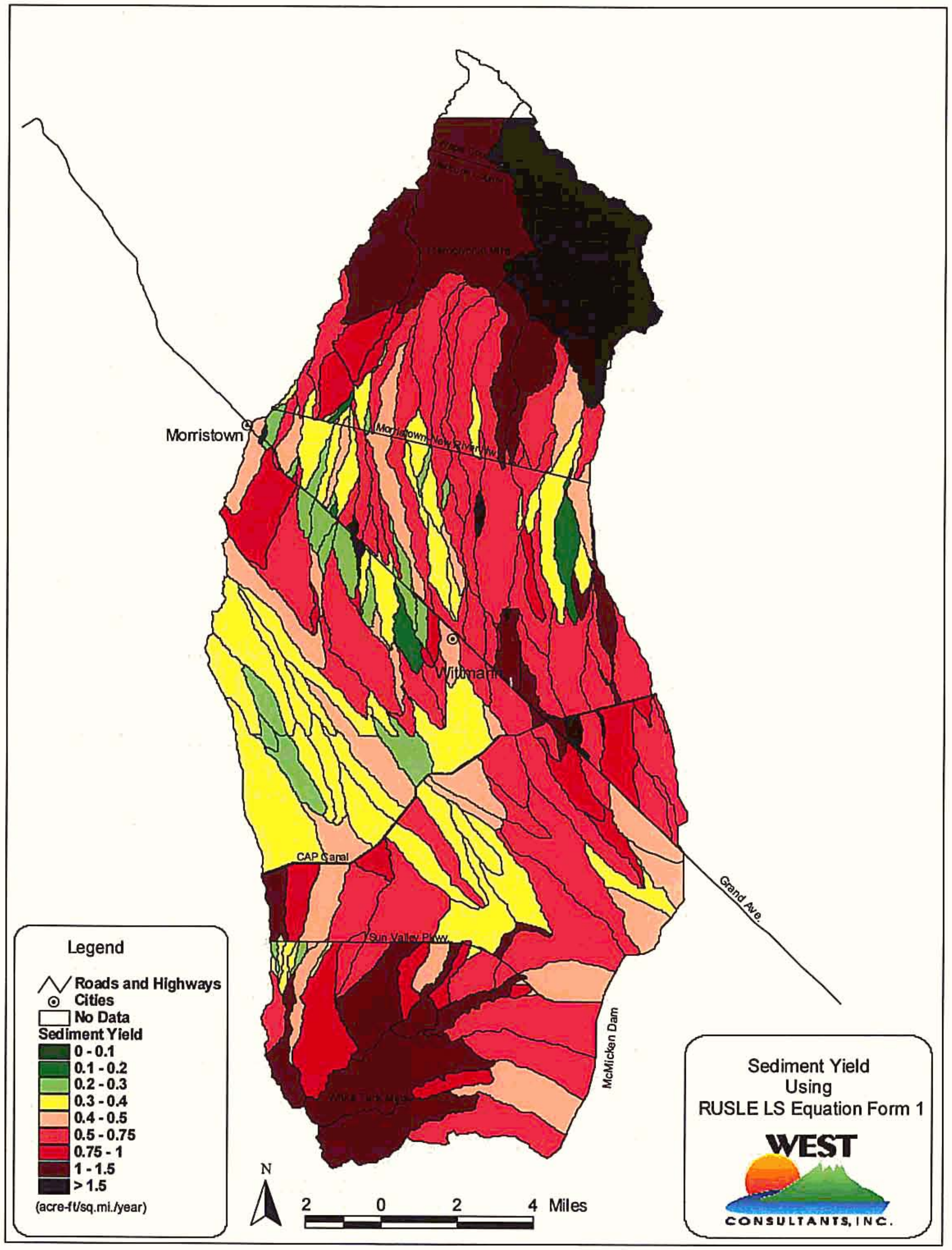

Figure GR-64. RUSLE results by subbasin using *LS* Equation Form 1.

5.6. Future Conditions

Of the four methods, only PSIAC had inputs that could be modified to reflect future conditions. In PSIAC, the Land Use (*G*) Factor can be adjusted to reflect changing land use. In order to compare the effect of the Land Use Factor in present versus future conditions, a detailed analysis was done of the existing and proposed land use. A summary of the existing conditions land use, and the Land Use factor used for each type, is shown in Table GR-23.

Table GR-23. Existing conditions Land Use Factors (*G*)

Land Use	PSIAC Land Use (*G*) Factor	Square Miles
Active Open Space	-7	26.828
Agriculture	-8	1.494
Airports	-6	1.043
Business Park	0	0.037
Community Commercial	-6	0.080
Educational	0	0.041
Estate Residential	-6	0.834
Industrial	-6	0.076
Institutional	0	0.004
Large Lot Residential	-6	1.713
Medium Lot Residential	-6	0.243
Neighborhood Commercial	-6	0.146
Other Employment - low	-6	6.974
Public Facilities	-6	0.007
Roads	0	1.929
Rural Residential	-6	2.169
Small Lot Residential	-6	0.195
Specialty Commercial	0	0.008
Tourist and Visitor Accommodations	-6	0.012
Vacant	-7	200.577
Very Small Lot Residential -	0	0.015
Warehouse/Distribution Centers	-6	0.061
Water	-10	0.327
Water (dry)	-7	1.594
TOTAL		*246.407*

For the future conditions land use, most roads could not be digitized, since they do not yet exist. Instead, existing sample lots of each residential type were examined from aerial photographs. The percentage of roads for each residential type was quantified. Then, a weighted average of the PSIAC *G* for the lots (-6) and the PSIAC *G* for the roads (0) was calculated to obtain a PSIAC *G* value for each residential type including the roads. These are shown in Table GR-24.

The residential types of very high, high, and medium density do not currently exist in the study area. The PSIAC *G* value for these residential types was estimated at –5. Table GR-25 summarizes the PSIAC *G* factors for future conditions.

Table GR-24. Future conditions PSIAC Land Use Factors (*G*) for regions including roads

	Percentage of lots	PSIAC G for lots	Percentage of roads	PSIAC G for roads	Weighted Average PSIAC G	Adopted PSIAC G (including roads)
Rural Residential	96.4%	-6	3.6%	0	-5.788	-5.7
Estate Residential	93.7%	-6	6.3%	0	-5.622	-5.6
Large Lot Residential	91.1%	-6	8.9%	0	-5.469	-5.4
Medium Lot Residential	83.9%	-6	16.1%	0	-5.036	-5.4*
Small Lot Residential	89.4%	-6	10.6%	0	-5.368	-5.3

* The sample of medium lot residential examined had a greater percentage of roads than small lot residential. This was considered to be an anomaly. The PSIAC *G* adopted was the same as large lot residential.

Table GR-27 shows how the future conditions PSIAC *G* affect the PSIAC sediment yield, and a comparison with the existing conditions sediment yield is presented. Table GR-26 shows the existing and future conditions land use side-by-side. Note than in Table GR-26, some of the residential use categories do not include roads as in Table GR-25. For example, "Estate Residential" is 70.477 square miles, which equals the future condition's 75.216 squares miles of "Estate Residential (with roads)" reduced by the estimated area of roads.

Table GR-25. Future conditions land use

Land Use	PSIAC Land Use (G) Factor	Square Miles
Active Open Space	-7	70.025
Estate Residential (with roads)	-5.6	74.656
General Commercial	-6	1.058
High Density Residential (with roads)	-5	1.108
Large Lot Residential (with roads)	-5.4	4.106
Medium Density Residential (with roads)	-5	5.590
Medium Lot Residential (with roads)	-5.4	0.855
Other Employment - low	-6	11.710
Other Employment - medium	-6	1.529
Passive Open Space	-7	4.242
Public Facilities	-6	11.865
Roads	0	1.377
Rural Residential (with roads)	-5.7	21.503
Small Lot Residential (with roads)	-5.3	24.191
Tourist and Visitor Accommodations	-6	0.389
Vacant	-7	11.462
Very High Density Residential (with roads)	-5	0.415
Water	-10	0.327
TOTAL		*246.407*

Table GR-26. Comparison of existing and future conditions land use

Type	Existing Conditions, Square Miles	Future Conditions, Square Miles
Active Open Space	26.828	70.025
Agriculture	1.494	
Airports	1.043	
Business Park	0.037	
Community Commercial	0.080	
Educational	0.041	
Estate Residential	0.834	69.953
General Commercial		1.058
High Density Residential (with roads)		1.108
Industrial	0.076	
Institutional	0.004	
Large Lot Residential	1.713	3.741
Medium Density Residential (with roads)		5.590
Medium Lot Residential	0.243	0.769
Neighborhood Commercial	0.146	
Other Employment - low	6.974	11.710
Other Employment - medium		1.529
Passive Open Space		4.242
Public Facilities	0.007	11.865
Roads	1.929	9.870
Rural Residential	2.169	20.729
Small Lot Residential	0.195	21.627
Specialty Commercial	0.008	
Tourist and Visitor Accommodations	0.012	0.389
Vacant	200.577	11.462
Very High Density Residential (with roads)		0.415
Very Small Lot Residential	0.015	
Warehouse/Distribution Centers	0.061	
Water	0.327	0.327
Water (dry)	1.594	

* The future condition square miles in these categories has been reduced by the estimated percentage of roads from Table GR-24 to make them comparable to the existing conditions category. The estimated road area was then added to the future condition "Roads" category shown in this table.

5.6.1. Results

Table GR-27 summarizes the PSIAC-predicted yield for existing and future conditions. The increase in sediment yield due to the future conditions is very small. The land use moves from predominantly vacant and open spaces (which have PSIAC land use factors of –7), to predominantly residential (which have PSIAC land use factors of –6 to –

5). This small change in the PSIAC land use factor does not have a significant impact on the sediment yield.

Table GR-27. PSIAC predicted sediment yield, existing and future conditions

	CASE 1 (lower yield)	CASE 2 (best estimate)	CASE 3 (higher yield)
PSIAC rating, existing conditions	25.8376	36.5675	41.5675
PSIAC sediment yield, existing conditions (acre-ft / sq mi / year)	0.2101	0.3388	0.3988
PSIAC rating, future conditions	26.6796	37.4095	42.4095
PSIAC sediment yield, future conditions	0.2202	0.3489	0.4089
Increase in Sediment yield, future versus existing conditions (acre-ft / sq mi / year)	0.101	0.101	0.101
Increase in sediment yield, entire watershed (acre-feet / year)	2.5	2.5	2.5

SECTION GR-6: WITTMANN STUDY AREA SEDIMENT ANALYSIS

Sediment Transport in the study area is complex and is significantly impacted by infrastructure in the watershed. Local roads have minor impacts which are primarily localized to the immediate area surrounding the roads unless flows are concentrated by bridges and culverts. Several man-made features do, however, impact sediment transport on a large scale. These features have large impacts primarily due to their length and the fact that nearly all of the water and sediment must cross these features. The large features include the CAP canal, U.S. 60 (Grand Avenue) and the BNSF railroad embankment. These long features have significant impacts on sediment transport in the area. Highway 74 which crosses the watershed higher may have some local impacts but for the most part has a more limited impact due to higher slopes and velocities and more constrained and channelized flow paths.

The impacts of the various infrastructure features will be discussed individually below. The area's infrastructure includes both major infrastructure and more minor features such as local roads.

Sediment transport is related directly to the flow of water. As water velocities slow, sediment is deposited. As the velocity increases transport capacity increases and, if sediment is available, the transport volume increases. If no sediment is available due to hardened channels or sediment sizes being too large to transport, the water retains its capacity to transport sediment and as soon as possible will erode enough sediment to again achieve equilibrium between its capacity to transport sediment and its sediment load.

With these general principles in mind the basin can be analyzed to review the interaction between sediment transport and the various manmade features that exist in the area.

6.1. The Central Arizona Project Canal (CAP)

Water and sediment are passed over or under the CAP via over-chutes, pipes, and culverts. These features pass water and sediment with varying degrees of efficiency. The over-chutes tend to pass more sediment simply because of their size while the pipes appear to pass the least quantity of sediment over the canal. The culverts that pass under the canal are limited in number and are generally in areas with significant relief. The culverts were not reviewed because they are not within the boundaries of the study area. Site visits were made to each pipe and over-chute within the project area. CAP personnel provided access to the various sites and explained problems they had noticed at the various sites. Their assistance was extremely valuable.

6.1.1. CAP Pipe Over-Chutes

The pipe over-chutes for the most part are not passing significant quantities of sediment but force the areas upstream of the canal to act as detention basins. The detention of the flood flows captures nearly all of the sediment coming from the upper basin. The only exception to this general rule was the pipe overflow immediately east of where 163rd Avenue crosses the CAP. The area upstream of this pipe over-chute has filled with sediment to the point that low flows pass directly into the pipe over-chute. Only when the flow exceeds the capacity of the pipe at a particular water surface elevation does water begin to pond in the area upstream. This has resulted in the passing of gravel sized sediment through the pipe. These conditions are illustrated in Figure GR-65 and Figure GR-66. The channel downstream of this pipe over-chute, however, has not received enough sediment to recover and it continues to degrade. This indicates that sufficient sediment is not passing through the pipe over-chute to preserve the continuity of sediment transport even at the lower flow rates. This particular pipe over-chute shows the greatest geomorphic development and will likely continue to build banks along the main channel until a more clearly defined main channel is defined into the pipe over-chute or the channel avulses to a lower flow path. Water surfaces upstream from the pipe over-chute inlet will continue to rise as the wash approaches equilibrium. The flood elevations in the upper reaches of what was a pool will increase as water begins to flow over the delta/alluvial fan to the pipe over-chute inlet raising water surface elevations upstream of the pool area. This is normal delta/fan behavior and can be expected over time at all of the pipe over-chute inlets.

Figure GR-65. CAP pipe over-chute carries sediment during flow events

All of the other pipe over-chutes trap nearly all of the sediment upstream from the pipe over-chute inlets. This capture of sediment has resulted in the development of small alluvial fans at just upstream of the CAP. While these small fans were not identified as such in this study since they are immediately upstream of the canal and (hopefully) within the 100 year floodplain, they can readily be noted in any aerial photo of the area. A series of these fans near 163rd Avenue is highlighted in Figure GR-67 and those along the entire CAP are shown in Figure GR-68. Nearly every wash will develop a fan just upstream of the point where it meets the canal.

Figure GR-66. Pipe over-chute outlet showing some sediment passing from upstream (local material is light brown and upstream material is grey – note downstream channel is approximately 5.5 ft lower than pipe invert and approximately 4 feet lower than the energy dissipater outlet)

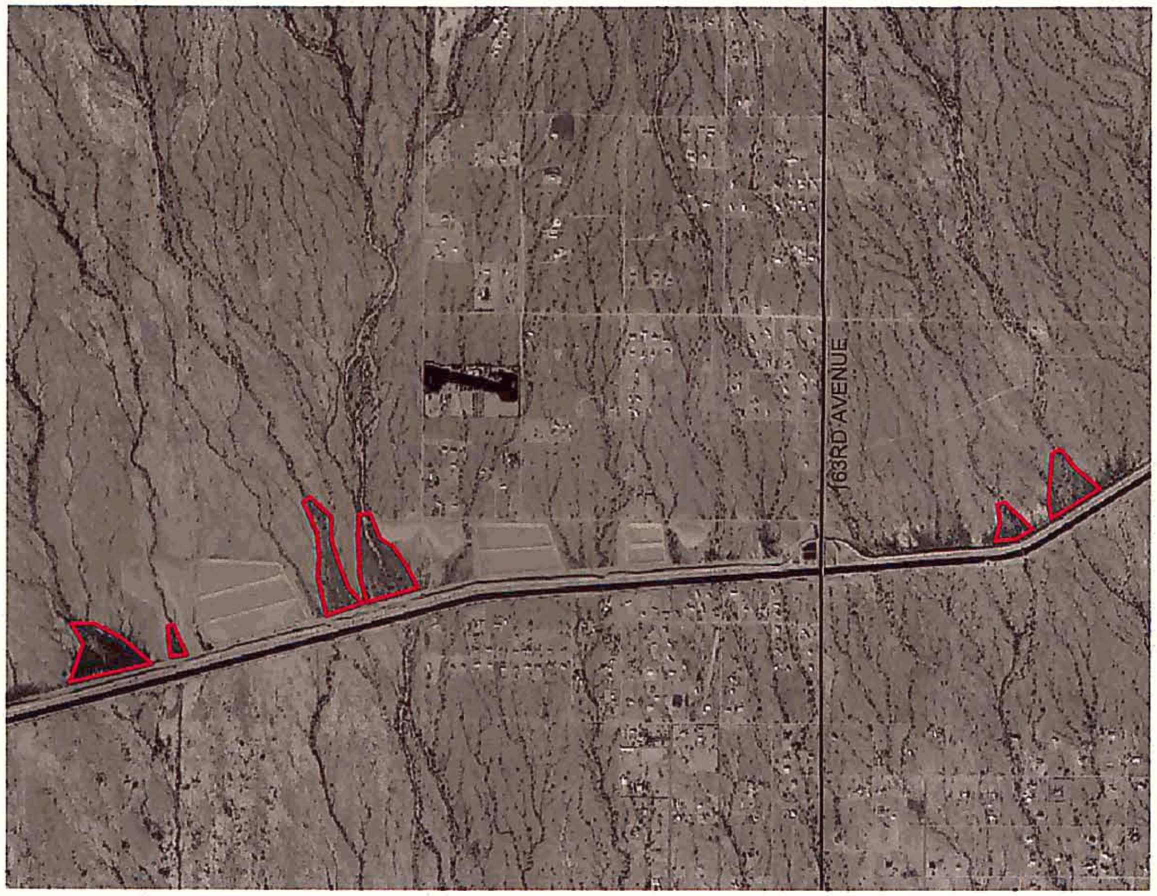

Figure GR-67. Small alluvial fans upstream of CAP Canal near 163rd Avenue

6.1.2. CAP Concrete Over-Chutes

In addition to the pipe over-chutes, there is also a series of concrete over-chutes to pass larger washes over the canal. These over-chutes are located along the CAP canal west of Grand Avenue. The over-chutes also vary widely in the amount of sediment they transport across the CAP canal.

The over-chute immediately west of Grand Avenue, for example, carries nearly its entire sediment load across the canal and deposits the majority of it downstream of the canal (see Figure GR-69 and Figure GR-70) This over-chute contained a sand bar on the over-chute prior to its cleaning in 2004. This was due to the sharp approach angle upstream from the over-chute (See Figure GR-69). One of the main reasons this over-chute passes its sediment load is because the upstream channel is constrained from the Grand Avenue crossing to the over-chute. The flow in this area overtopped a low berm and flowed into the CAP canal during one of the 2003 flood events. The channel was subsequently realigned and the east bank was raised to prevent this from occurring in the future.

The area downstream from this concrete over-chute acts like a delta since the wash loses its channel definition immediately downstream. The wash spreads rapidly and exhibits depositional characteristics in this area. A small channel exists but is much smaller than the channel between Grand Avenue and the CAP canal. This sudden expansion allows the wash to deposit most of its coarser sediment load. This process fills the energy dissipater with sediment. The dissipater was cleaned but is located below grade and will refill with sediment during the next flood event.

The other concrete over-chutes carry significantly less sediment and the downstream channels show significant scour below the canal. The over-chute just west of 219th Avenue has experienced large flow events but the downstream channel is clearly erosional. This indicates that the majority of sediment is still being trapped above the canal. A limited investigation of the upstream channel indicates that this area is depositional and, while not as completely depositional as the areas upstream from the pipe overflows, a significant amount of sediment is being deposited upstream from the over-chute. This channel area is shown in Figure GR-71.

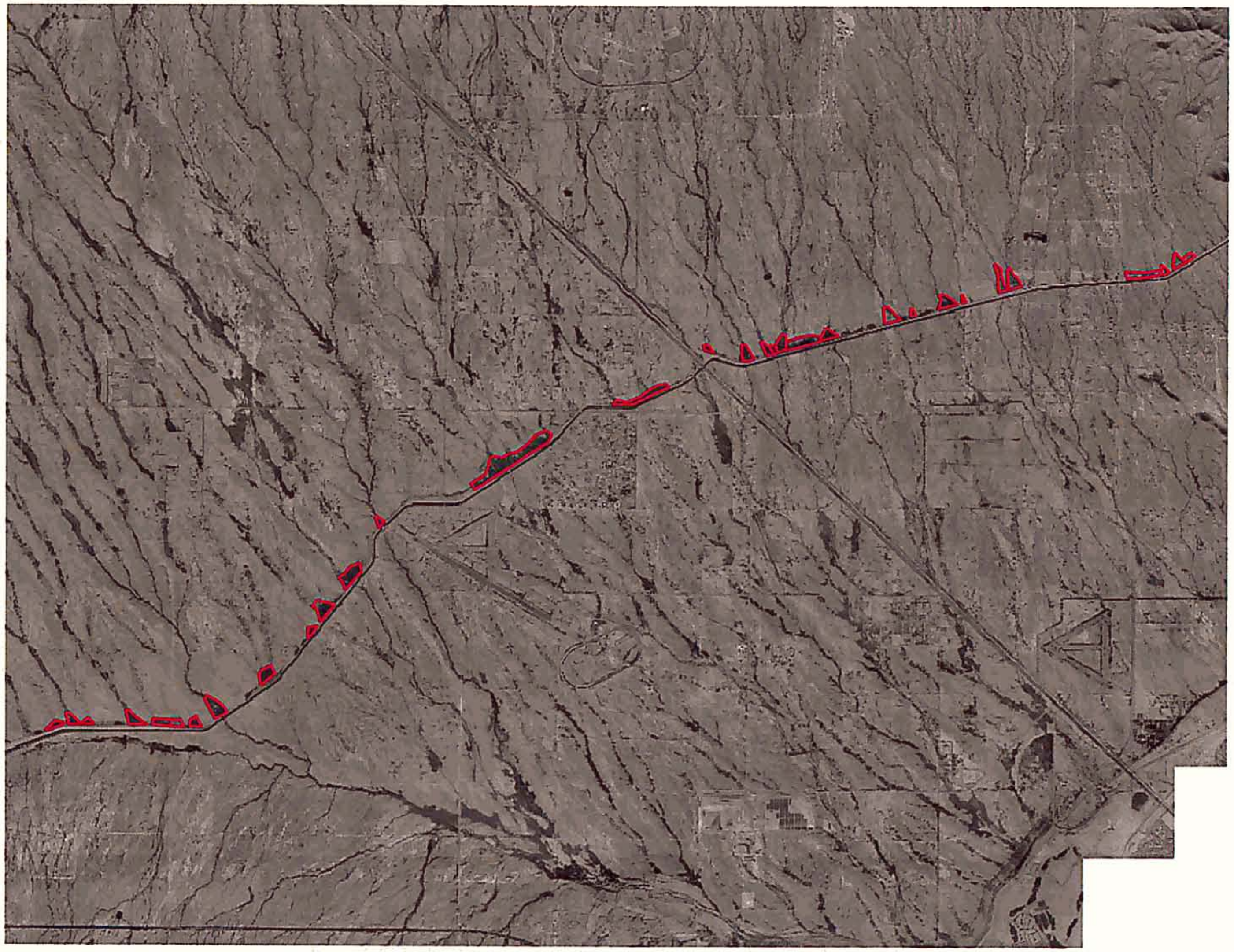

Figure GR-68. Existing unstable areas upstream of the CAP Canal (the entire 100 year floodplain should be taken to be unstable due to the potential deposition of sediment)

Figure GR-69. CAP concrete over-chute at Grand Avenue looking downstream (photos courtesy of CAP)

Figure GR-70. CAP concrete over-chute at Grand Avenue (flow is from upper middle to lower right – photos courtesy of CAP)

One of the over-chutes appears to have seldom passed significant flows and during the large flood events of 2003 did not experience any flow. This over-chute (east of 219th Avenue) appears to be set higher than the other over-chutes and will provide relief flows during large floods but any low flows arriving from upstream of this over-chute will either be forced to flow laterally along the canal to an over-chute either east or west of this site or simply pond and infiltrate or evaporate from behind the canal. From the aerial photos it appears that flows tend to pond in this area and may flow laterally along the canal prior to flowing over the next to the west over-chute. This area is shown in Figure GR-72.

The washes above the concrete over-chutes, with the exception of the one near Grand Avenue and the one east of 219th Avenue, have developed small deltas / fans similar to those noted for the pipe over-chutes but to a smaller degree. The concrete over-chutes pass sufficient water to cause erosion upstream and keep a channel open through the delta area. This was not the case for most of the pipe over-chutes - there the wash channels were, for the most part, completely lost upstream of the pipe over-chutes.

All of the areas above the CAP within the 100-year floodplain should be considered to be depositional hazard areas. This is especially true near washes. Further analysis should be performed in these areas prior to any development. These areas can be found by looking for areas of vegetation above the CAP as can be seen in Figure GR-67 and Figure GR-72. The dark area indicates dense vegetation which here indicates areas of deposition. These conditions will tend to worsen over time as the lower areas fill and water is forced to flow over prior deposits.

Figure GR-71. Wash looking upstream from concrete over-chute west of 219th Avenue (note that channel exists although it is narrowed substantially and that the area shows significant evidence of deposition)

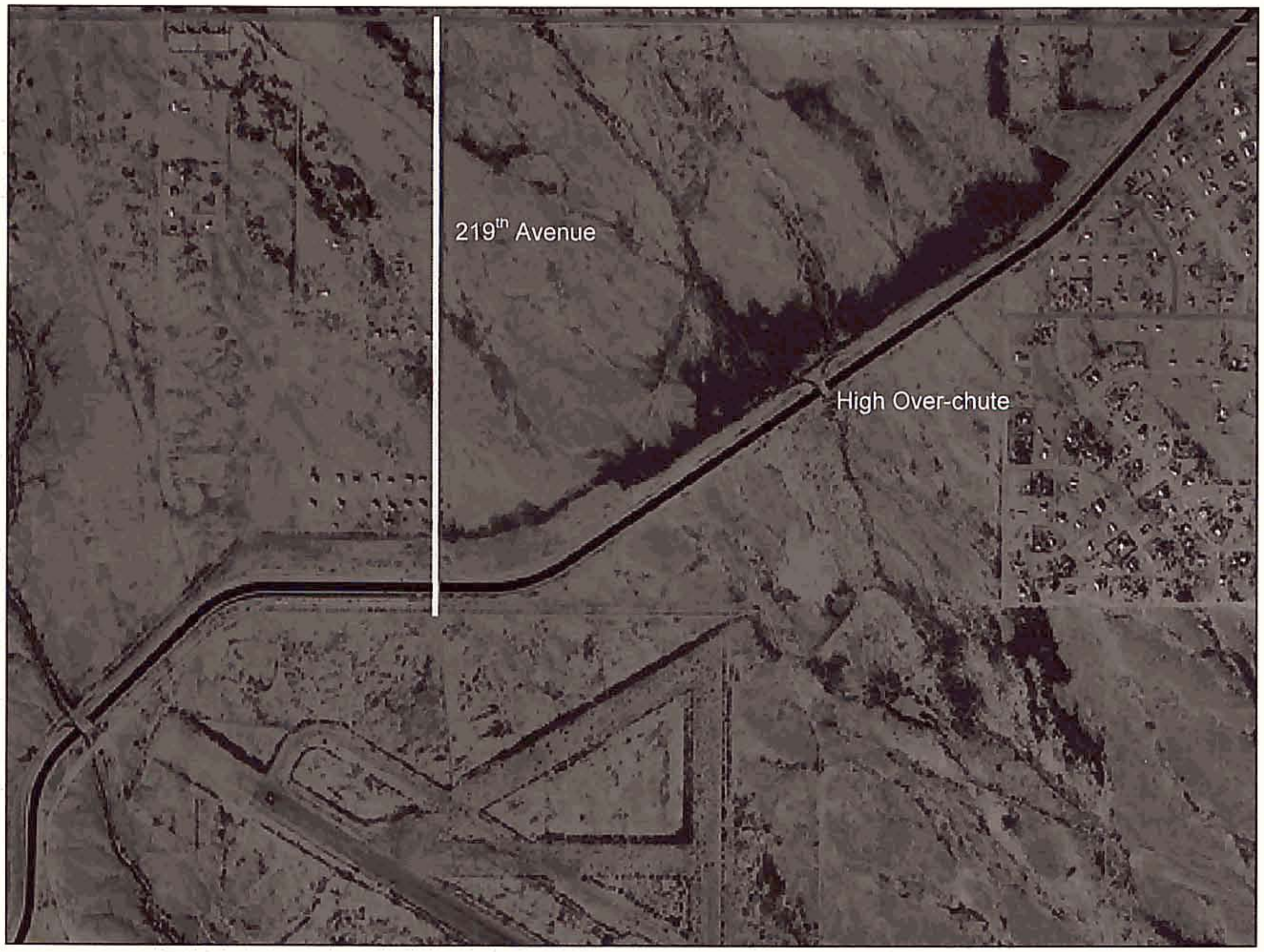

Figure GR-72. Location of high concrete over-chute showing ponding area upstream and possible flow path to west to next over-chute

6.2. BNSF Railroad

The Burlington Northern and Santa Fe (BNSF) rail embankment cuts across nearly the entire watershed. Only a small portion of the watershed at the very eastern portion of the study area reaches the McMicken Outlet Channel prior to crossing the rail embankment.

The rail embankment contains numerous culverts and bridges to allow drainage and floodwaters to pass under the rail embankment. The larger washes have bridges that appear to be adequately sized for most flood events. The bridges are either standard wooden trestle or concrete and steel pier bridges with numerous piles. These piles do, however, tend to collect debris (See Figure GR-73) and require cleaning after large events. The culverts are primarily for local drainage or to pass overbank flows from larger events. These culverts likely cause some minor deposition of sediment upstream and possible minor scour downstream. No major problems with the passage of water or sediment were noted along the rail embankment other than those resulting from trapped debris.

Figure GR-73. BNSF Railroad Bridge at Grand Avenue following flood event (the majority of the main channel opening was filled with debris)

6.3. Grand Avenue – U.S. 60

U.S. Highway 60 or Grand Avenue cuts across nearly the entire watershed and parallels the BNSF Railroad embankment. The rail embankment is located immediately upstream (northeast) of the highway and gathers flows which are not in wash channels to discharge points of either wash bridges or culverts. These culverts tend to concentrate flows into defined drainage areas downstream. This concentration of flows would need to occur at the highway if the rail embankment did not exist.

Figure GR-74. New bridges on wash at Grand Avenue and CAP (note misalignment between wash and protection and avulsion into CAP canal – CAP is just off bottom of photo – photo courtesy of CAP)

The highway was widened to four lanes with a median during 2002 to 2003. This widening replaced bridges and extended the distance the washes are concentrated under the highway. The new bridges appear to be sized adequately and tend to pass the flows. The bridges may be a little wide for some of the lower flows and portions of the channels under the bridges may tend to fill with sediment until the channels reach equilibrium. Overall the highway appears to have the capacity to pass sediment and flow to the lower portion of the watershed.

A few problems were noted during the flood events of 2003. The right descending bank below the eastbound bridge just west of the CAP canal was protected downstream with a gabion mattress protection. This bank was aligned to bring the water back into the former wash channel. The problem is that the bank is aligned such that the water is not aimed down the wash but rather across the wash towards the CAP canal. This caused the wash to overtop the left descending bank and flow into the CAP canal during one of the large events of 2003. The situation is depicted in Figure GR-74. The channel downstream of the protection was subsequently widened and the bank was raised to prevent further overtopping but the alignment of the bank protection was not modified nor was the left descending bank protected against erosion.

New bridges were also constructed across Trilby Wash. These bridges also appear to be adequately sized to pass flows. The bridges are estimated to be approximately 120 ft in width but the bank protection downstream is narrowed to a base width of approximately 20-30 ft to match the downstream channel. This will concentrate flows down the channel and cause extreme erosion downstream as well as exacerbate deposition in the contraction area immediately downstream of the bridge. This feature is shown in Figure GR-75.

Additional areas were noted where riprap-scour protection at culvert outlets was not working properly and significant erosion was occurring. It should be noted that repairs will likely be made and long term the erosion will likely be arrested. It was also noted not all of the culverts under the rail embankment were matched with culverts under the highway. This tends to further channelize the water downstream of Grand Avenue. This channelization reduces flood hazards away from the washes but tends to increase flow and erosion in the washes below Grand Avenue. The extent of this increase could require modeling and further analysis but is probably not significant for the 100 year flood flows.

Figure GR-75. Trilby Wash Bridge and downstream protection (note semi-truck on bridge and width of outlet to wash – stone size in baskets is approximately 6 inches in diameter – also the erosion of the channel downstream of the gabion basket protection)

6.4. Local Features

Local features such as roads, fences, low water crossings and other disturbances to the drainage network in the basin can have serious consequences depending on the location in the watershed. The Padelford Wash alluvial fan area, for example, could be seriously impacted if water from one of the distributaries were to be inadvertently rerouted down another wash. This rerouting could easily occur if flow follows one of the numerous roads or is diverted by a block wall fence. The diversion can cause ponding upstream and erosion downstream. These changes can impact areas several miles from the diversion point due to the large distributary network. The re-regulation of the flows by the CAP pipe over-chutes tends to reduce the impacts immediately downstream of the CAP but areas upstream and further downstream could suffer significant impacts from inadvertent or intentional rerouting of flows.

6.4.1. Roads

Numerous roads create a network that has the potential to disrupt the flow of water and sediment across the entire study area. As development occurs more and more roads and crossings can be expected to occur. Wash Crossings consisting of dip crossing cause the least disruption of the movement of sediment down the various washes. Often these dip crossings are improved by the installation of culverts to pass low water flows. These culverts often clog and create what becomes a drop structure during low to intermediate flows. This causes increased scour immediately downstream and increased deposition and loss of channel capacity further downstream.

Another problem is the use of undersized culverts or bridges. These create the problems described in the above section on the CAP pipe over-chutes. Significant deposition occurs upstream of the culverts and erosion occurs downstream. It is recommended that if where all weather crossings are required that they be sized to pass large events (such as the 50 year flood) without causing significant backwater. This will allow the flows to pass readily through the bridges without deposition of sediment upstream and scour downstream. While the impacts to sediment transport are normally somewhat localized, the impacts of gathering numerous washes into a single wash to reduce bridge construction costs can have major impacts downstream.

At the moment the local (i.e., city and county) road system does not cause major impacts on sedimentation in the region. Local instances of erosion and sedimentation were, however, observed in the study area. At one location the installation of undersized low flow culverts encased on concrete had resulted in the redirection of a wash such that the wash bank was retreating towards an adjoining home. An aerial photograph of this site is shown in Figure GR-76, which is located south of Jomax

Road and west of 157th Avenue. This illustrates the problems that can be created locally by the improvement of low water crossings. The problems are normally relatively easy to fix unless the wash gets too near adjoining improvements or switches washes downstream.

Figure GR-76. Local instance of erosion problem (site is located south of Jomax Road and west of 157th Avenue)

6.4.2. Fences

The construction of concrete block fences was observed to have obstructed smaller washes and caused diversion of flows out of former wash channels. The practice of enclosing the entire property in block walls must be carefully reviewed in terms of flood passage and local flow patterns. While the diversion of water from a local drainage channel may not seem to be important locally it may have significant impacts downstream, especially if it is diverting flow from one wash distributary to another as well as in the local vicinity of the wall.

Although water diversion due to fences can cause problems downstream, most of the problems created by individual block fences in the Wittmann study area were local problems. Although these small water diversions will not impact an area far distant from the change, the proliferation of walls and block fences across the entire watershed may cause channelization of flows and serious erosion and deposition problems across significant portions of the watershed.

6.4.3. Low Water Crossings

Most of the roads in the area have low water crossings for the smaller (and sometimes larger) washes. These are the most efficient at passing sediment through an area since flow across the road is unregulated and unhindered. Public pressure for access during flood events tends to move low water crossings towards overtopping culvert sections (combination culverts and high water overflow sections) or bridges. These features can have significant impacts on flow and sediment if not properly sized. The trapping of debris can also play a significant role in the behavior and possible failure of these structures. Several sets of culverts were noted to be almost entirely plugged in the area after the 2003 summer storms. Several culverts sets were more than half plugged prior to the storms indicating that maintenance in the area could be improved. One of the culvert sets is shown in Figure GR-77.

The major problem to be faced if these crossings are not properly sized will be in terms of sediment deposition upstream and erosion downstream rather than water flow or ponding.

Figure GR-77. Culverts on 219th Avenue below CAP before and after 2003 storms showing debris capture

6.5. Sediment Sample Analysis

Sediment samples were collected from 11 representative sites within the study area. The locations where the sediment samples were collected in the northern portion of the study area can be seen in Figure GR-78 while the location of the sediment samples in the southern portion of the study area can be seen in Figure GR-79. The results of the sieve analysis can be seen in Table GR-28. Graphical plots of the grain size distributions can be found in Figure GR-80 (for the northern portion) and Figure GR-81 (for the southern portion). All of the sediment samples fall in the range of fine sands to coarse gravel. Generally, the coarser samples appear higher on the watershed although this is not always the case. In the few places where the sediment samples were taken both on the upstream and downstream side of a culvert or over-chute, the samples tended to be coarser upstream of the culvert or over-chute and finer on the downstream side. This can attributed to ponding which occurs upstream of the culvert or over-chute. The ponding slows the water down and allows the coarser material to be deposited while the finer materials are passed downstream.

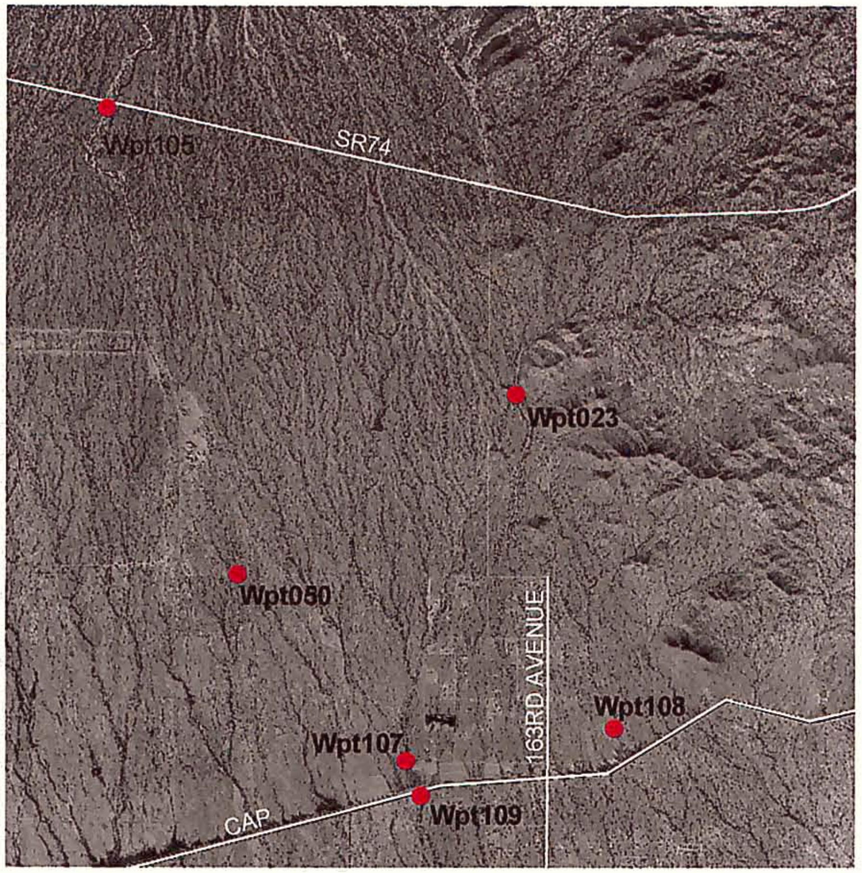

Figure GR-78. Locations of the various sediment samples taken in the northern portion of the study area

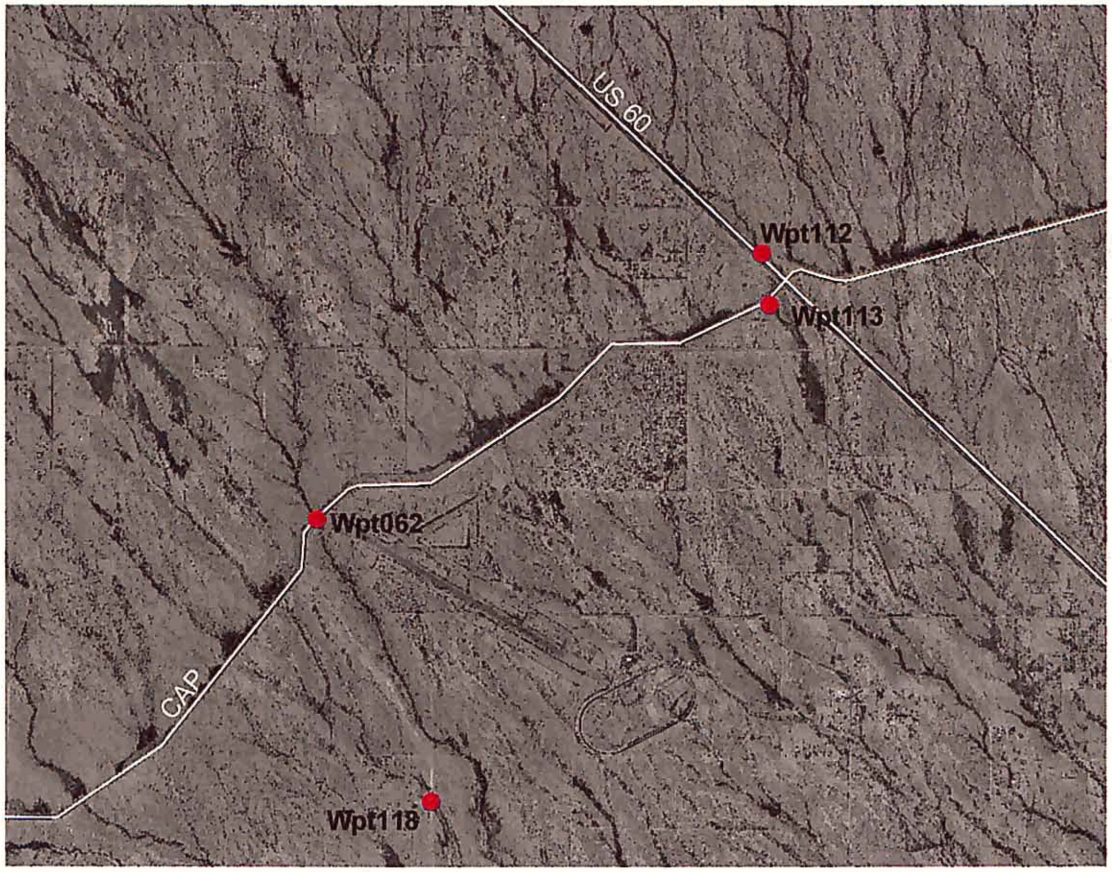

Figure GR-79. Locations of the various sediment samples taken in the southern portion of the study area

Table GR-28. Sieve analysis results

	Percent Passing										
Sieve Size	**WPT 105**	**WPT 023**	**WPT 050**	**WPT 108**	**WPT 107**	**WPT 109**	**WPT 112**	**WPT 113**	**WPT 62 U/S**	**WPT 62 D/S**	**WPT 118**
6"	100	100	100	100	100	100	100	100	100	100	100
4"	100	100	100	100	100	100	100	100	100	100	100
3"	100	100	100	100	100	100	100	100	100	100	100
2"	100	100	100	100	100	100	100	100	100	100	100
1-1/2"	100	100	92.2	100	100	100	100	100	94.2	100	100
1"	100	98.0	78.8	92.5	96.8	100	100	98.0	90.0	100	100
3/4"	97.9	89.6	65.5	83.7	89.6	96.9	100	95.2	79.8	97.9	98.5
1/2"	85.3	80.4	45.7	67.4	82.1	95.4	99.4	91.1	69.6	89.6	92.8
3/8"	77.1	75.7	38.3	61.7	75.9	93.0	95.2	87.2	62.4	81.2	90.3
1/4"	63.9	63.7	32.4	54.1	63.0	88.6	89.1	81.7	52.7	73.7	87.8
#4	56.5	56.2	29.0	50.2	55.2	85.3	85.1	77.5	46.5	68.5	85.1
#8	40.2	40.0	22.6	41.5	34.3	73.4	69.5	61.5	35.1	50.1	78.0
#10	37.6	36.9	21.3	39.7	30.5	69.3	64.6	56.8	32.5	44.9	75.9
#16	30.4	27.0	17.1	33.9	19.8	55.1	48.0	39.6	24.1	27.8	66.0
#30	21.7	15.9	12.5	24.5	10.8	39.0	28.3	21.4	14.2	10.6	48.4
#40	16.6	11.2	10.3	17.9	7.4	33.1	19.9	14.8	10.2	5.8	36.5
#50	11.8	7.6	8.4	11.2	4.8	28.6	12.8	9.7	7.4	3.6	23.9
#100	3.9	3.0	4.6	3.6	1.4	21.3	4.4	3.6	4.7	2.6	7.5
#200	1.2	1.8	2.4	1.9	0.2	15.0	2.3	2.1	3.4	2.1	3.7

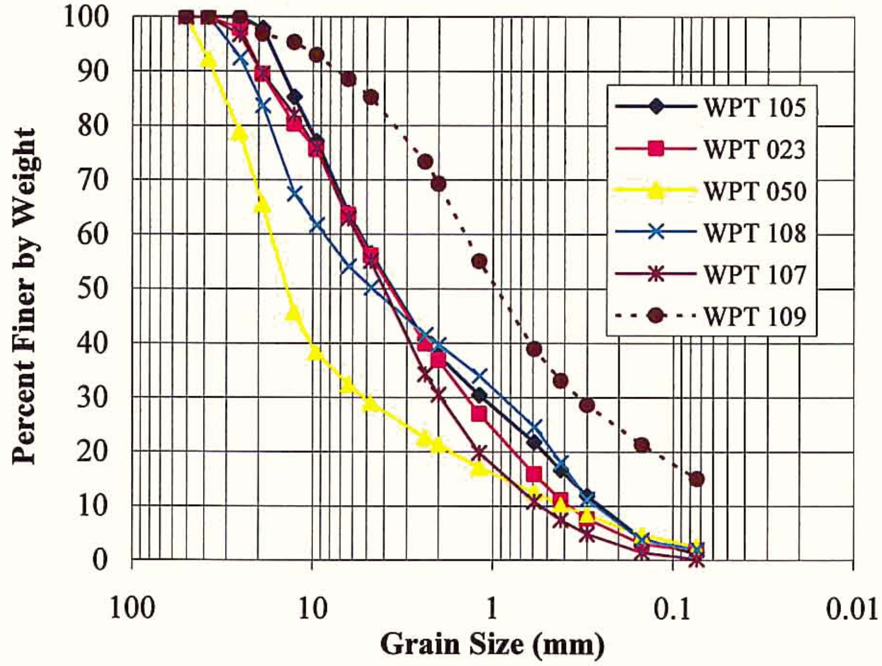

Figure GR-80. Grain size distribution of sediment samples taken in the northern portion of the study area

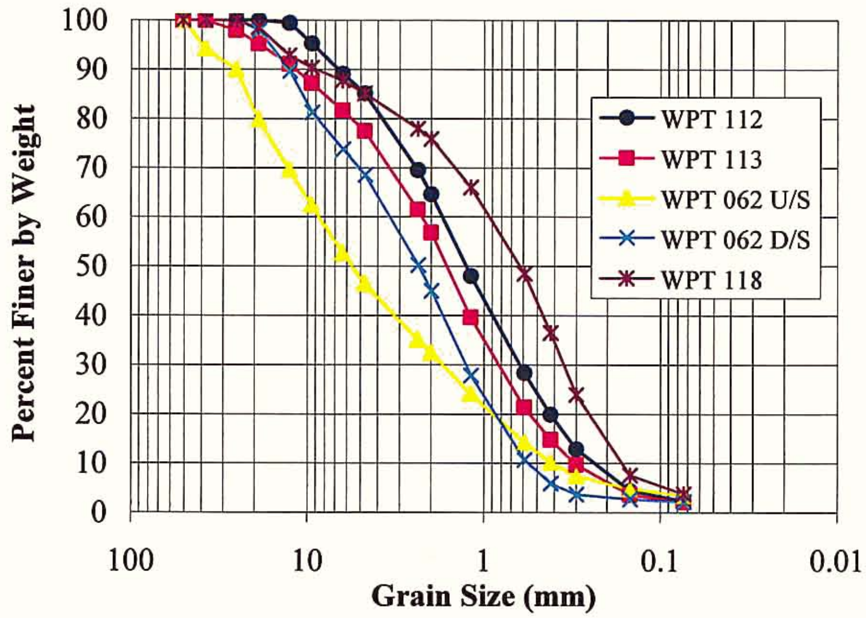

Figure GR-81. Grain size distribution of sediment samples taken in the southern portion of the study area

SECTION GR-7: EROSION HAZARD ZONE DELINEATION FOR THE WITTMANN AREA

The Federal Emergency Management Agency (FEMA) has specifically noted that the washes in Maricopa County have significant and well-documented erosion problems (Fuller 2003). To address the many erosion hazard problems found in Maricopa County, the FCDMC has developed a set of draft guidelines for delineating erosion hazard zones. This draft report was prepared by JE Fuller Hydrology and Geomorphology, Inc. and is titled *Erosion Hazard Zone Delineation and Development Guidelines* (Fuller 2003). The goals of these guidelines can be summarized as follows:

1. To protect the health, safety, and property of the citizens of Maricopa County.
2. To minimize the expenditure of public funds for erosion hazard mitigation.
3. To assure consistent floodplain management policies and review procedures.
4. To inform the public of regulatory standards for development in erosion hazard zones.
5. To provide guidelines for development and design to landowners, developers, and development engineers.
6. To assure that development in stream corridors is consistent with the recommendations of watercourse master plans.

7.1. Study Area

The study area consists of four (4) washes in the Wittmann area as shown in Figure GR-82. In general, the study area is bounded by the CAP canal on the north and by McMicken Dam on the south. The four (4) washes studied are:

1. Trilby Wash from the CAP canal to McMicken Dam,
2. Iona East Wash from the CAP canal to where it intersects Trilby Wash,
3. Iona West Wash from where it breaks off from the Iona East Wash to where it intersects Trilby Wash, and

4. CAP-1 West Wash from the CAP canal to McMicken Dam.

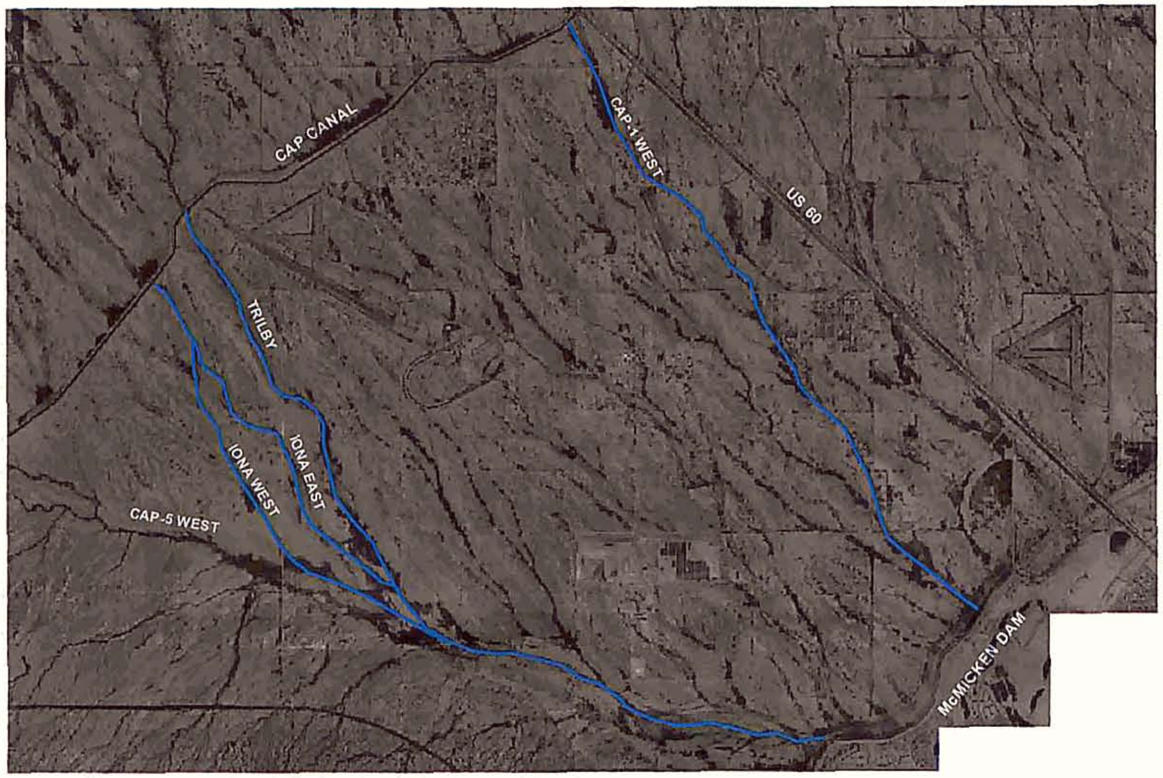

Figure GR-82. Study area showing the four washes that were examined

7.2. Methodology

A Limited Scope Level 3 Analysis was performed on the four (4) reaches of interest. This methodology is outlined in detail in a report prepared for the FCDMC entitled *Erosion Hazard Zone Delineation and Development Guidelines* (Fuller 2003). A Level 3 erosion hazard delineation analysis is an in-depth evaluation of the potential for lateral erosion that considers historic information regarding past channel behavior, past changes in the watercourse outside the project reach, the local geology and geomorphology of the river corridor, hydraulic modeling of the channel and floodplain, and interpretation of field observations (Fuller 2003). A Limited Scope Level 3 Analysis includes the following five (5) components:

1. Geomorphic and geologic mapping,
2. Field investigation,
3. Hydraulic modeling,
4. Delineate erosion hazard zone, and
5. Report.

A summary of the five (5) components of a Limited Scope Level 3 Analysis follows. These descriptions are taken directly from Fuller's (2003) guidelines.

7.3. Geomorphic and Geologic Mapping

Mapping of the Holocene and Pleistocene landforms and geomorphic surfaces as well as mapping of the locations of bedrock outcrops is required. The surficial geology reported by Geological Consultants, Inc. in *Volume SU – Land Subsidence and Earth Fissure Investigation Report* of the Wittmann Area Drainage Master Study Update was used in this study. In this report, the younger Holocene surfaces are designated by Y2, Y2r, Y1, and Y while the older Pleistocene surfaces are designated by M2, M1b, M12, M1a, M1, and O. These geologic units are summarized in Table GR-29. For more details on the various geologic units, refer to *Volume SU* of the Wittmann Area Drainage Master Study Update. A plot of the surficial geology of the study area can be seen in Figure GR-83.

Table GR-29. Summary of geologic units

Geologic Unit	Description	Age
Y2	Late Holocene alluvial fans, low terraces, and active stream deposits	< 3 ka
Y2r	Active channels and low terraces along axial drainages	< 3 ka
Y1	Late to early Holocene alluvial fans and terraces	1 to 10 ka
Y	Undifferentiated Holocene alluvial fans	0 to 10 ka
M2	Latest to late Pleistocene alluvial fans	10 to 150 ka
M1b	Middle to late Pleistocene alluvial fans	150 to 300 ka
M12	Middle or late Pleistocene distal alluvial fans	10 to 300 ka
M1a	Middle to early Pleistocene alluvial fans	300 to 1,000 ka
M1	Middle Pleistocene alluvial fans	150 to 1,000 ka
O	Early Pleistocene to late Pleistocene alluvial fans, undifferentiated	> 10 ka

7.4. Field Investigation

Fuller (2003) outlines many goals of the field investigation. These goals include:

1. Describe and document channel and bank conditions in each reach, at a minimum using the Level 2 site characteristics.
2. Identify and document stream characteristics indicative of active or recent lateral erosion.
3. Identify and document stream characteristics indicative of resistance to lateral erosion.
4. Identify and document stream and floodplain characteristics indicative of potential, historical, or active channel avulsions.
5. Identify evidence of long-term degradation or aggradation in each reach.

During the field investigation, the entire length of all four (4) of the washes was walked. Many photographs and notes were taken in an attempt to identify and document the physical characteristics of the washes. The various photographs and notes that were taken at each waypoint shown in Figure GR-84 can be seen in the attached CD.

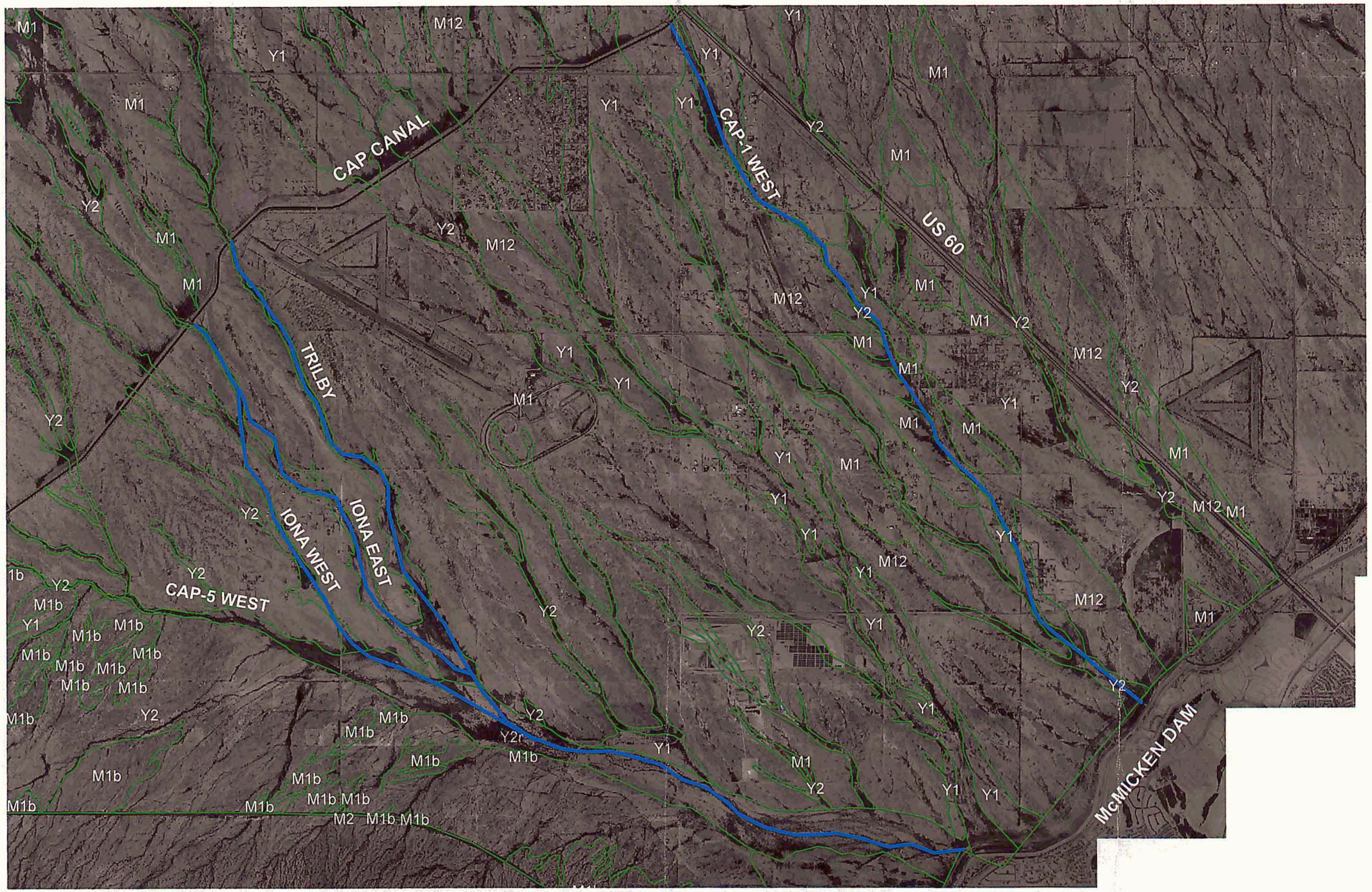

Figure GR-83. Surficial geology of the study area

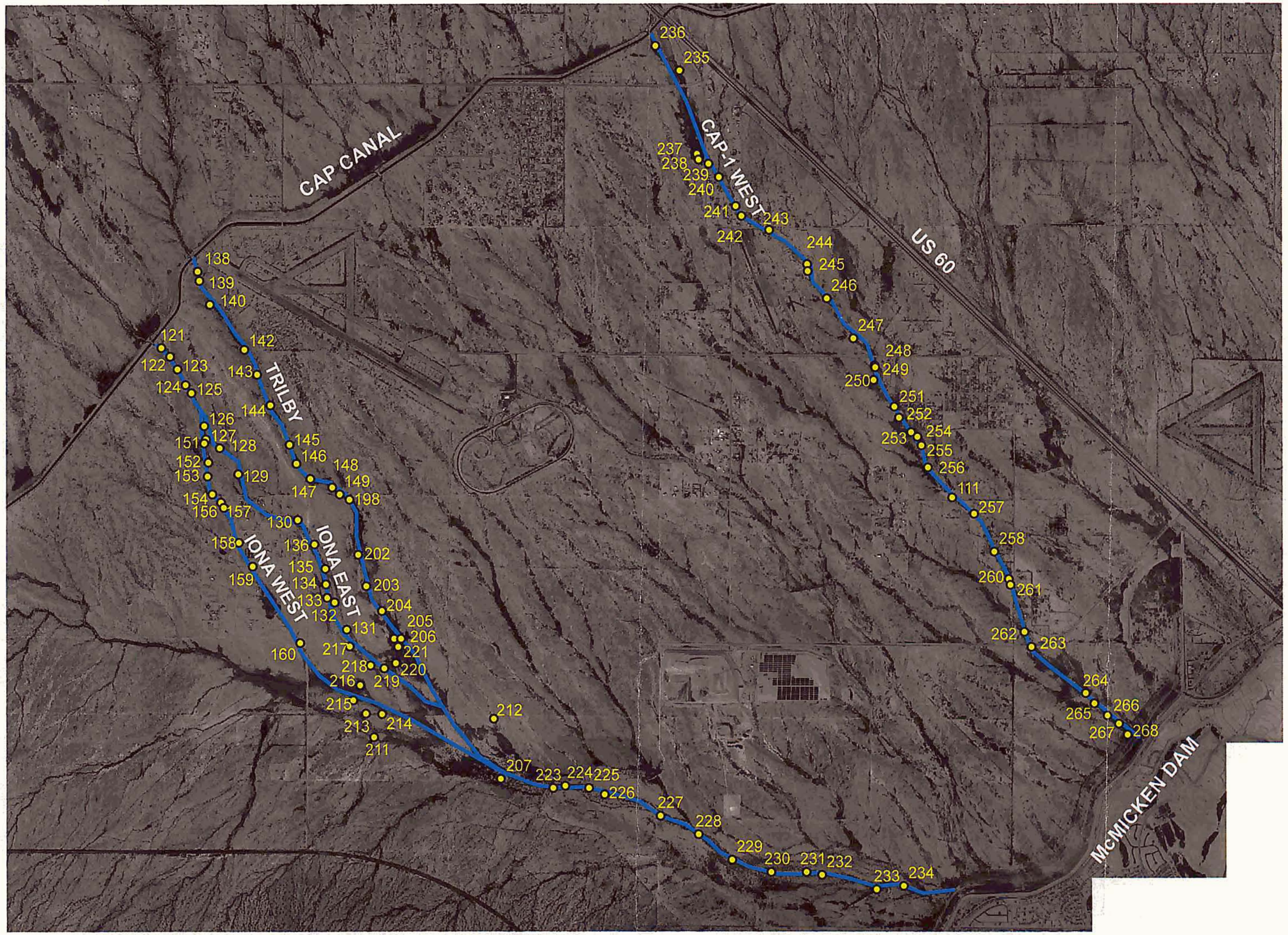

Figure GR-84. Locations and corresponding waypoint numbers where field data were collected

To assist in organizing the field investigation, the parameters used in a Level 2 erosion hazard zone delineation were identified and categorized during the field investigation. A Level 2 erosion hazard zone delineation analysis uses an equation to calculate the width of the erosion hazard zone from the channel bank. This equation is a function of the 100-year peak discharge as well as number of factors that are determined from field investigations, aerial photographs, and hydraulic models. There are 12 of these factors and a summary of each factor as well as some of the techniques used in identifying the factors follows.

7.4.1. Channel Bend Angle Factor

Sinuous stream reaches and channels with sharp bends are subject to higher rates of lateral erosion and more frequent avulsions than straight channels. Bend angles were determined from aerial photographs of the region. Areas of the washes that bent were noted on the aerial photographs and measured using the procedure outlined by Fuller (2003). Only areas on the outside of the bends were considered.

7.4.2. Channel Velocity Factor

Channels with high velocities are subject to higher rates of lateral erosion than channels with low velocities. The maximum channel velocity needs to be examined instead of the average channel velocity. The maximum channel velocity was estimated from hydraulic models of the various washes. When examining areas for avulsion hazard, the maximum overbank velocity needs to be examined.

7.4.3. Bankfull Width/Depth Ratio

Streams with high width to depth ratios are subject to higher rates of lateral erosion than streams with low width to depth ratios. The hydraulic models of the washes were used to estimate the bankfull width to depth ratios. The bankfull width to depth ratios were verified during the field visits.

7.4.4. Bank Materials Factor

Bank materials provide resistance to lateral erosion through a variety of properties such as cohesion, armoring, angle of repose, ability to transmit and store water, susceptibility to piping, stratigraphy, and the ability to promote and prevent root growth. Banks composed of silts and sands will provide less resistance to lateral erosion than banks composed of clays and loams. Information on the bank materials was collected during the field visits. Fuller (2003) indicates that in the case where a bank is composed of more than one material (e.g., many of the banks in the Wittmann area are composed of silts, sands, and gravels), the material with the least amount of resistance should be chosen as the representative bank material. Doing this will give a conservative estimate of the erosion hazard zones. It was observed in the field that most of the banks consisted of a combination of sand, gravel, and silt as shown in Figure GR-85. To be on the conservative side, the most erosive bank material (i.e., sand) was used to characterize the banks of the washes.

Figure GR-85. Typical bank material of washes in the Wittmann area (from WPT223)

7.4.5. Bank Cementation Factor

Accumulation of calcium carbonate in the bank materials can significantly increase resistance to bank erosion. Descriptions of the various carbonate stages can be found in Birkeland et al. (1991). The carbonate stage of the banks was estimated from field observations and by observing its reaction to acid. There was very little calcium carbonate accumulation in the four (4) washes that were examined (i.e., the highest calcium carbonate stage observed in the field was Stage II).

7.4.6. Bank Vegetation Density Factor

Bank vegetation can reduce the rate of lateral erosion by increasing the hydraulic roughness, anchoring soil material, and decreasing the amount of soil to water contact. The amount of bank vegetation was estimated during the field investigations of the washes. In addition, recent aerial photographs of the area were used as verification of the vegetation densities observed in the field. An example of dense bank vegetation can be seen in Figure GR-86, while an example of very sparse vegetation can be seen in Figure GR-87.

Figure GR-86. Dense bank vegetation (from WPT144 on Trilby Wash)

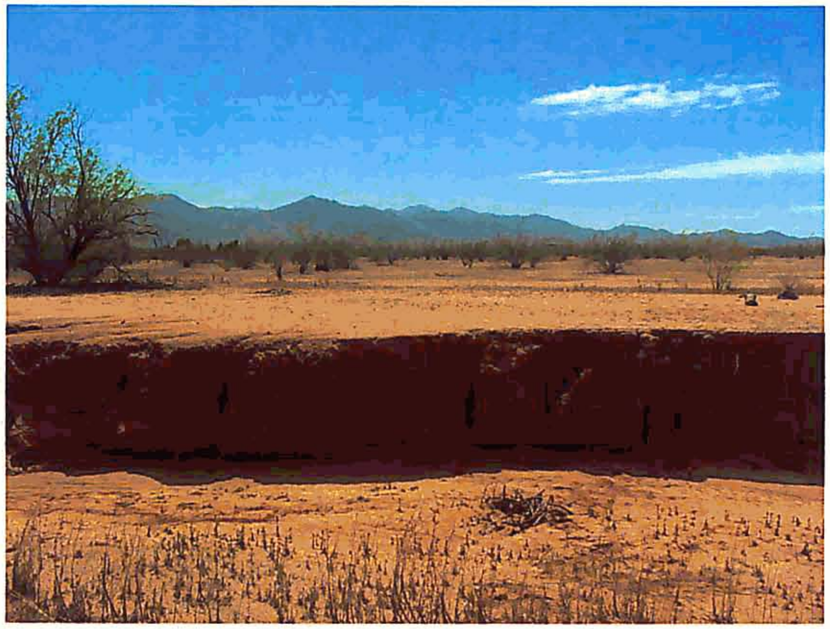

Figure GR-87. Sparse bank vegetation (from WPT157 on Iona West Wash)

7.4.7. Bank Vegetation Type Factor

Different plant species provide different levels of bank stability and resistance to erosion. Fuller (2003) defines three (3) different vegetation types: woody species, shrubs, and grasses. Woody species are those that consist of a well-defined trunk and leaf canopy. Shrubs consist of a narrow stem, are generally less than six (6) feet high, and include plants that tend to bend downstream when submerged in flowing water. Grasses are annual species that grow low to the ground, lack a trunk, and tend to lie flat when submerged by flowing water. In general, the denser and larger the vegetation coverage along the banks, the more resistant the banks are to lateral erosion. Exposed roots along the banks, sparse vegetation, and small-sized vegetation are all evidence that the banks are more prone to lateral movement. Fuller (2003) identifies three (3) vegetation type conditions that are found in the field:

1. Condition 1
    a. Deep rooting woody species
        i. No woody plants or isolated emergent woody plants
        ii. Woody plants perched above the channel bottom
    b. Shrub and grass cover
        i. Sparse cover (< 25% cover)
        ii. Bare ground between plants
2. Condition 2
    a. Deep rooting woody species
        i. Isolated woody plants separated by greater than one (1) canopy width
        ii. Small diameter emergent woody species
        iii. Some roots of large plants near the banks exposed by erosion

b. Shrub and grass cover
    i. Moderate cover (25% – 50% cover)
    ii. Bare ground between plants
3. Condition 3
    a. Deep rooting woody species
        i. Root mass extends below the channel invert
        ii. Trunk diameter of most woody plants greater than four (4) inches
        iii. No roots exposed by bank erosion
        iv. Interlocking root masses and continuous canopy
    b. Shrub and grass cover
        i. Banks have greater than 50% cover

Notes and ground photographs were taken during the field investigations of the washes in an attempt to define the condition number of the bank vegetation. Example photographs for the three (3) bank vegetation type conditions are shown in Figure GR-88 through Figure GR-90.

Figure GR-88. Bank vegetation type condition #1 (from WPT239 on CAP-1 West Wash)

Figure GR-89. Bank vegetation type condition #2 (from WPT261 on CAP-1 West Wash)

Figure GR-90. Bank vegetation type condition #3 (from WPT198 on Trilby Wash)

7.4.8. Bank Conditions Factor

The physical condition of the stream banks provides evidence of whether or not the stream has been subject to recent lateral erosion or may be subject to future bank erosion. Fuller (2003) identifies three (3) indicators of the physical condition of the stream banks: percent of the cutbanks, freshness of the cutbanks, and thalweg proximity. If a high percentage of the reach has cutbanks, a high rate of future lateral erosion should be expected. In arid regions like Arizona, cutbanks may persist for long periods after they form due to infrequency of channel forming flows, resistant bank materials, and/or slow rates of slope processes and vegetative growth. Fresh cutbanks are the most diagnostic of significant erosion hazard. The banks closest to the thalweg are most likely to experience lateral erosion. An example of a very recent cutbank with vertical walls can be seen in Figure GR-91, while an example of an older cutbank that is starting to exhibit some basal control is shown in Figure GR-92.

Figure GR-91. Fresh, vertical cutbanks (from WPT156 on Iona West Wash)

Figure GR-92. Older cutbanks exhibiting some basal control (from WPT154 on Iona West Wash)

7.4.9. Flow Conditions Factor

Ephemeral streams tend to be poorly vegetated, subject to erosive flash floods, experience slow recovery from flood damage, and are more likely to be braided or exist in a state of non-equilibrium. Perennial and intermittent streams tend to be better vegetated, have more stable stream patterns, and be more resistive to lateral erosion than ephemeral streams.

7.4.10. Watershed Development Factor

Urbanization often causes changes in the natural hydrology of a watershed that result in erosive changes such as long-term degradation, increased flooding, or depletion of sediment supply. Fuller (2003) identifies four (4) watershed development categories: natural watershed, undeveloped watershed, partially developed watershed, and urbanized watershed. The watershed basins provided by Entellus estimated the percent of each basin that was urbanized. For all of the washes under consideration, the watershed development factor fell under the "partially developed" category.

7.4.11. Manmade Channel Disturbance Factor

Manmade disturbances of the natural channel such as floodplain encroachment, in-stream sand and gravel mining, highway encroachments, construction of bank protection, or channelization often leads to accelerated rates of lateral erosion in adjacent reaches. Areas of manmade disturbances were identified during the field investigations of the washes. Several areas of manmade disturbances were noted such as the old berm at the beginning of the Iona West Wash (see Figure GR-93) and the dirt bike race track along the CAP-1 West Wash near Jomax

Road (see Figure GR-94). An aerial view of the manmade berm can be seen in Figure GR-101.

Figure GR-93. Manmade berm (right hand side of photo) at the head of the Iona West Wash (from WPT151)

Figure GR-94. Looking across the dirt bike race track located at CAP-1 West Wash and Jomax Road (from WPT244)

7.4.12. Vertical Channel Stability Factor

Channel degradation is closely linked to increased lateral erosion of the incised channel. Conversely, long-term aggradation leads to channel widening and/or avulsive channel change. During the field investigations, the washes were examined to see if they appeared to have long-term degradation or aggradation tendencies.

7.5. Hydraulic Modeling

Hydraulic modeling is an important part of a Limited Scope Level 3 Analysis. Hydraulic modeling can be used to develop inundation mapping, determine channel and floodplain hydraulic data such as velocity and depth, and help identify areas of high avulsion potential.

One goal of the Wittmann Area Drainage Master Study Update was to develop new HEC-RAS models of the Iona East Wash, the Iona West Wash, and the CAP-1 West Wash. A new model for the Trilby Wash south of the CAP canal was not developed. At the time the erosion hazard zone study was undertaken, the new HEC-RAS models were not finished. Thus, the old HEC-2 models of the various washes were used, along with the 100-year peak discharges listed in Table GR-30, to estimate the maximum velocity at each cross-section in the wash. These HEC-2 models were obtained from the FCDMC, and they were converted into HEC-RAS models. The maximum channel velocity was approximated by using the Flow Distribution option in HEC-RAS. The HEC-RAS models were run in subcritical mode first. The model was then checked to see if the flow approached critical depth in any of the cross sections. If it did, then the model was re-run in mixed mode. This procedure was done to be conservative and to guarantee that the HEC-RAS model produced the highest maximum velocity possible. In addition, the geometries of the HEC-RAS models were slightly modified so that the bank stations agreed with the bank stations identified for the erosion hazard study. This was done so that the left overbank (LOB) and the right overbank (ROB) of the hydraulic models would match the left and right overbanks used in the erosion hazard study.

7.5.1. 100-Year Peak Discharge

The 100-year peak discharge was determined from the new hydrology that was developed for the Wittmann Area Drainage Master Study Update for all of the washes except Iona West Wash, which was not included in the new hydrology. The new hydrology for the washes lists four (4) separate 100-year peak discharges: the 24-hour peak discharge for existing conditions, the 24-hour peak discharge for future conditions, the 6-hour peak discharge for existing conditions, and the 6-hour peak discharge for future conditions. As per the FCDMC, the existing conditions peak discharges were used instead of the future conditions peak discharges. The 100-year peak discharge used in this study was the maximum of the 6-hour and 24-hour existing conditions peak discharges. For the Iona West Wash, the 100-year peak discharge was determined from an existing HEC-1 hydrologic model that was obtained from the FCDMC. The 100-year peak discharges for the various washes used for this study are shown in Table GR-30.

Table GR-30. 100-year peak discharges for the various washes

Wash	Approximate Starting River Station	Approximate Ending River Station	100-Year Peak Discharge (cfs)
Iona West	2.145	2.145	152
Iona West	2.100	1.912	150
Iona West	1.806	1.393	145
Iona West	1.285	0.976	142
Iona West	0.919	0.534	140
Iona West	0.402	0.114	6,200
Iona West	0.000	0.000	12,400
Iona East	3.027	0.000	6,992
Trilby	10.444	6.787	5,060
Trilby	6.645	5.645	10,637
Trilby	5.579	4.679	14,045
Trilby	4.539	2.737	13,989
CAP-1 West	6.229	5.181	4,832
CAP-1 West	5.118	3.096	4,939
CAP-1 West	2.955	0.987	5,173
CAP-1 West	0.944	0.000	4,215

7.5.2. Floodplain/Floodway Delineation

The floodplain/floodway delineation determined from hydraulic modeling can give an indication as to the maximum extent of the lateral erosion of a wash as well as help identify areas of high avulsion potential. The existing floodplain and floodway delineation was obtained from FCDMC and is shown in Figure GR-95. All of the defined active channel banks fall within a Zone AE, Zone A, or Zone FW floodplain.

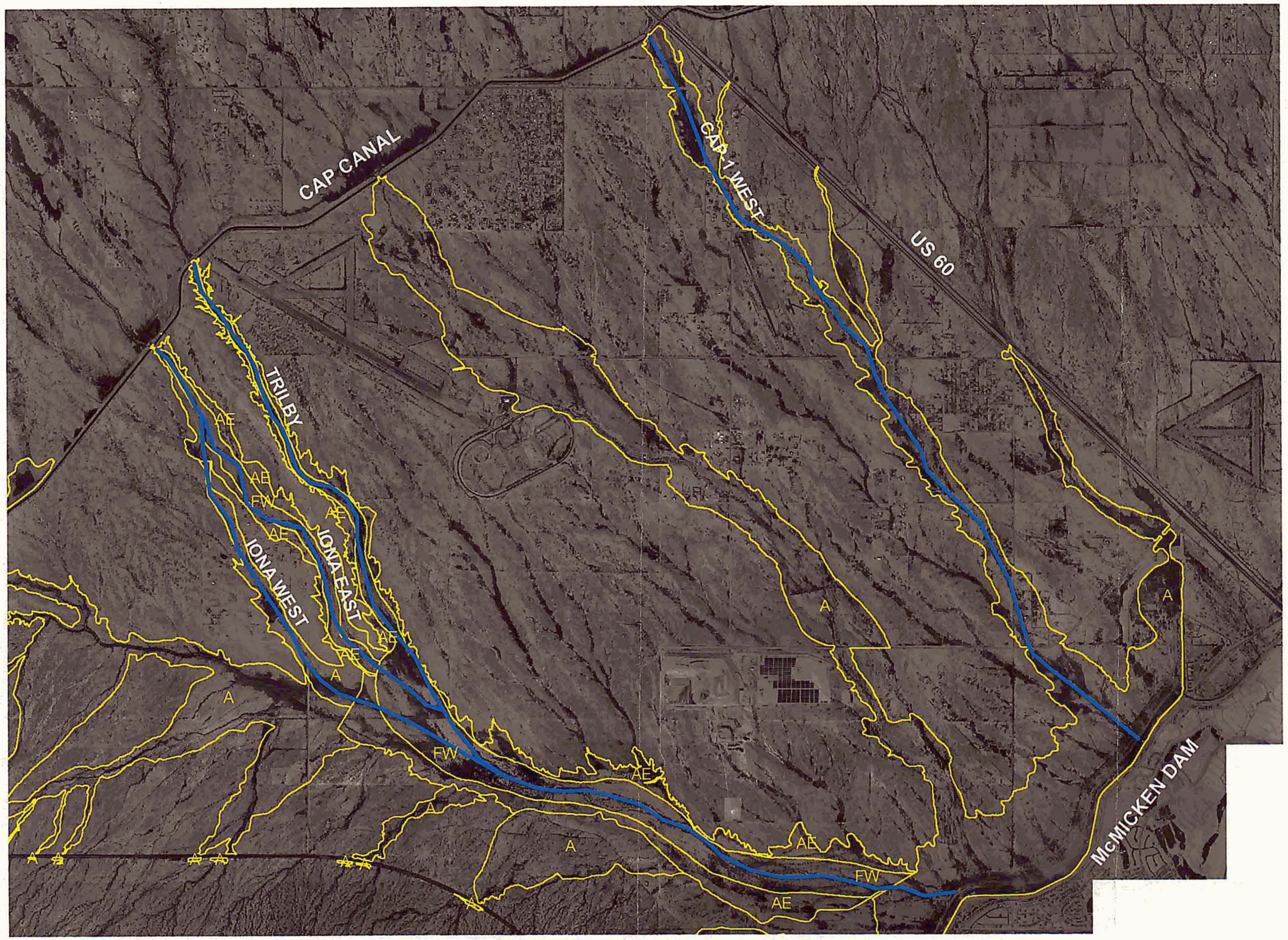

Figure GR-95. Existing floodplains for the Wittmann area

7.5.3. Identifying Channel Avulsion Areas

Channel avulsions are responsible for some of the largest magnitudes of known lateral channel movement in Arizona. An avulsion occurs when a new channel forms in an area that was formerly part of the floodplain, leaving an island of relatively high ground between the former and current channel locations. The potential for avulsive channel change increases as the frequency of inundation, depth of inundation, and duration of inundation increases. In order for an avulsion to occur, the floodplain must be subject to inundation for along enough duration for erosion of a new channel to occur. Therefore, to be avulsive, a floodplain must be flooded at a great enough depth, velocity, and frequency to cause formation of a new channel.

Floodplain and channel characteristics that are often indicative of avulsive conditions on many Arizona stream systems are listed below. No single characteristic should be considered solely diagnostic of avulsive conditions. Where several of the avulsive characteristics listed below are observed, the stream corridor should be considered subject to avulsions. The following characteristics are indicative of avulsion potential (Fuller 2003):

1. The 100-year maximum (not average) flow depth in the floodplain is greater than two (2) feet.
2. The 100-year maximum velocity in the floodplain is greater than four (4) feet per second, or the product of the 100-year floodplain depth (*d*) and maximum velocity (*v*) squared is greater than 18 ft^3/s^2.
3. The 10-year floodplain is not contained in the main channel.

4. Lack of, or minimal, topographic relief between main channel invert and floodplain elevation.
5. Evidence of frequent overbank flooding such as flood damage records and high water marks.
6. Perched channels and swales observed in the overbanks and floodplain created by concentration of floodplain flow, tributary inflow to the floodplain, or physical modification of the floodplain.
7. Meander cutoff channels present in stream reaches located upstream or downstream.
8. The overbank topography indicates continuous flow paths have formed in the floodplain (the floodplain contours bend in the upstream direction).
9. Lack of upland or mature vegetation in the floodplain.
10. Lack of bank vegetation along the main channel and/or minimal differences between the channel, channel banks, and floodplain vegetation.
11. Hummocky bar and swale terrain in the floodplain caused by sculpting of floodplain surface by flooding, sediment transport, and scour.
12. Fresh gravel and coarse sand deposits in continuous swales located within the floodplain or in overbank channels.
13. Alignment of large trees (living or dead) in the floodplain of similar species to bank vegetation that identify former or forming avulsive flow paths.
14. Islands of older geomorphic surfaces of low relief inset within younger floodplain deposits that indicated former incision of the floodplain.
15. Tributary channels flowing parallel to the main channel across the floodplain that may become conduits for future avulsive flow.

16. Rapid and significant changes in main channel geometry and capacity, particularly alternating single and highly braided reaches.

An example where an avulsion has already taken place occurs in the area near where the Iona West Wash, the CAP-5 West Wash and the Trilby Wash converge. In this area, an access road for power lines wash was captured by the CAP-5 West Wash. This road converted into a channel has steep, vertical cutbanks as shown in Figure GR-96. For a short distance, the CAP-5 West Wash changes its flow path as it follows this access road. Historically, the CAP-5 West Wash flowed in a southeastern direction in this area. Now, the wash flows directly east along this road before it heads south. The new and historic flow paths are clearly visible in the aerial photograph shown in Figure GR-97.

Figure GR-96. Access road that was captured by the channel (from WPT213 near the where the Iona West Wash, the CAP-5 West Wash, and the Trilby Wash converge)

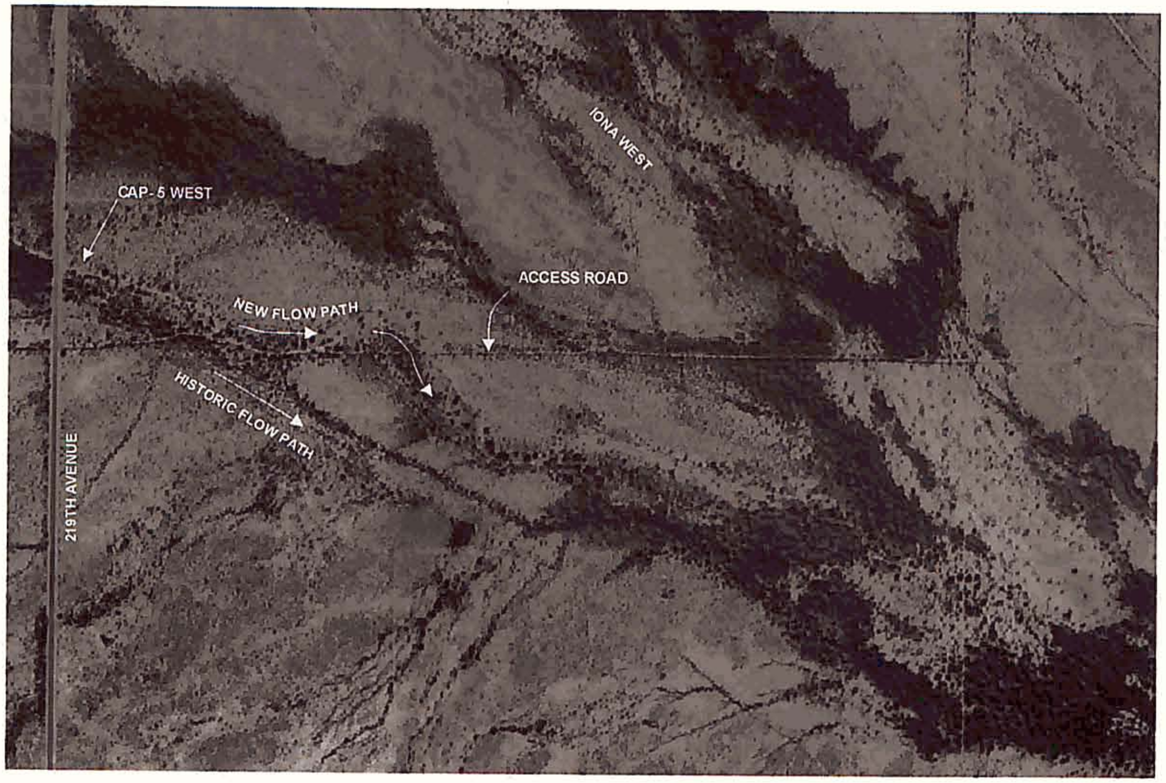

Figure GR-97. The CAP-5 West Wash has captured the power line access road and changes its flow path

To identify areas with high avulsion potential, the parameter dv^2 was calculated for the overbanks using the HEC-RAS hydraulic models. The necessary hydraulic parameters for Trilby Wash, Iona East Wash, Iona West Wash, and CAP-1 West Wash are shown in Table GR-31, Table GR-32, Table GR-33, and Table GR-34, respectively. The overbanks of the various washes were examined for areas in which the dv^2 parameter was greater than 18 ft^3/s^2. These areas were flagged as areas of high avulsion potential. The dv^2 parameter was not the only thing considered when identifying areas of high avulsion potential; the other 15 indicative characteristics listed from above were also considered. Using these characteristics, areas of high avulsion potential were identified as shown in Figure GR-111 for the Trilby/Iona system and in

Figure GR-112 for the CAP-1 West Wash. The areas highlighted in these two figures typically had the following characteristics:

1. The 100-year maximum (not average) flow depth in the floodplain is greater than two (2) feet.
2. The 100-year maximum velocity in the floodplain is greater than four (4) feet per second, or the product of the 100-year floodplain depth (*d*) and maximum velocity (*v*) squared is greater than 18 ft^3/s^2.
3. Lack of, or minimal, topographic relief between main channel invert and floodplain elevation.
4. Evidence of frequent overbank flooding such as flood damage records and high water marks.
5. The overbank topography indicates continuous flow paths have formed in the floodplain (the floodplain contours bend in the upstream direction).
6. Lack of bank vegetation along the main channel and/or minimal differences between the channel, channel banks, and floodplain vegetation.
7. Alignment of large trees (living or dead) in the floodplain of similar species to bank vegetation that identify former or forming avulsive flow paths.
8. Tributary channels that flow parallel to the main channel across the floodplain that may become conduits for future avulsive flows.

Table GR-31. Hydraulic parameters used to determine avulsion potential on Trilby Wash

River Station	Flow Rate (cfs)	Maximum Channel Velocity (ft/s)	Maximum LOB Velocity (ft/s)	Maximum ROB Velocity (ft/s)	Maximum LOB Depth (ft)	Maximum ROB Depth (ft)	dv^2 for LOB (ft^3/s^2)	dv^2 for ROB (ft^3/s^2)
10.444	5,060	3.93	1.12	1.13	2.96	2.96	3.7	3.8
10.382	5,060	7.74	2.66	2.72	5.89	7.89	41.7	58.4
10.283	5,060	7.83	2.60	2.91	5.05	5.55	34.1	47.0
10.179	5,060	7.60	2.91	2.53	6.01	6.01	50.9	38.5
10.137	5,060	10.23	1.70	3.70	2.80	4.80	8.1	65.7
10.077	5,060	8.50	2.69	1.93	5.15	5.15	37.3	19.2
10.020	5,060	10.67	3.49	1.98	3.76	2.93	45.8	11.5
9.980	5,060	8.08	2.89	2.14	4.19	2.69	35.0	12.3
9.899	5,060	7.76	1.86	2.51	3.26	4.21	11.3	26.5
9.791	5,060	7.90	2.50	1.40	4.29	3.79	26.8	7.4
9.726	5,060	10.78	3.27	1.97	4.09	1.59	43.7	6.2
9.649	5,060	6.27	1.81	1.71	5.42	3.32	17.8	9.7
9.567	5,060	7.77	2.15	2.21	4.03	4.03	18.6	19.7
9.473	5,060	7.79	2.69	2.63	4.03	4.03	29.2	27.9
9.402	5,060	9.73	2.87	2.56	3.66	4.16	30.1	27.3
9.317	5,060	8.18	2.15	2.42	4.85	4.85	22.4	28.4
9.211	5,060	9.36	2.71	2.66	3.84	3.84	28.2	27.2
9.113	5,060	6.74	1.65	2.01	3.62	3.62	9.9	14.6
9.043	5,060	7.62	1.36	1.97	4.15	3.65	7.7	14.2
8.950	5,060	7.61	2.15	2.63	5.04	4.04	23.3	27.9
8.851	5,060	7.81	2.73	2.62	5.35	3.35	39.9	23.0
8.736	5,060	7.63	2.14	2.83	2.75	5.25	12.6	42.0
8.639	5,060	6.65	2.51	1.28	3.61	1.81	22.7	3.0
8.535	5,060	7.25	2.65	3.16	5.28	5.28	37.1	52.7
8.421	5,060	6.28	2.13	1.48	3.47	3.47	15.7	7.6
8.298	5,060	8.63	2.36	2.59	4.66	3.66	26.0	24.6
8.173	5,060	4.74	1.50	1.71	2.64	2.94	5.9	8.6
8.073	5,060	6.39	2.50	2.99	3.69	3.69	23.1	33.0
7.969	5,060	4.58	1.73	1.95	3.09	3.09	9.2	11.7
7.868	5,060	7.74	2.87	2.66	3.67	3.67	30.2	26.0
7.764	5,060	7.83	2.34	2.35	2.96	2.96	16.2	16.3
7.643	5,060	6.47	2.33	2.16	3.79	3.79	20.6	17.7
7.520	5,060	2.79	2.39	2.32	4.67	4.67	26.7	25.1
7.410	5,060	3.16	2.42	1.73	5.28	2.28	30.9	6.8
7.262	5,060	3.87	2.15	2.55	3.09	4.09	14.3	26.6
7.134	5,060	2.27	1.28	1.98	1.45	2.45	2.4	9.6
7.020	5,060	1.56	0.43	1.83	0.55	4.15	0.1	13.9
6.906	5,060	2.01	0.94	2.17	0.97	3.97	0.9	18.7
6.787	5,060	1.03	0.50	1.47	1.03	4.03	0.3	8.7
6.645	10,637	1.83	1.27	2.18	1.77	4.20	2.9	20.0
6.520	10,637	2.11	1.87	1.92	3.29	3.29	11.5	12.1
6.395	10,637	2.32	1.81	2.34	3.44	3.54	11.3	19.4
6.293	10,637	2.36	2.34	1.93	3.43	2.93	18.8	10.9

6.200	10,637	2.99	2.83	2.83	3.00	3.50	24.0	28.0
6.082	10,637	3.15	3.06	1.88	3.37	1.87	31.6	6.6
5.961	10,637	4.34	3.48	1.67	2.63	2.63	31.9	7.3
5.840	10,637	5.03	2.82	1.93	6.21	1.71	49.4	6.4
5.777	10,637	6.49	5.53	2.29	5.12	6.62	156.6	34.7
5.717	10,637	7.91	4.76	1.42	3.93	1.73	89.0	3.5
5.645	10,637	4.42	1.80	1.11	9.72	4.72	31.5	5.8
5.579	14,045	11.04	2.16	0.45	3.90	0.40	18.2	0.1
5.544	14,045	8.17	2.82	4.18	3.74	5.74	29.7	100.3
5.490	14,045	9.48	2.65	2.45	4.43	4.43	31.1	26.6
5.346	14,045	7.51	2.71	1.48	3.36	1.66	24.7	3.6
5.217	14,045	5.70	4.84	0.76	3.89	0.89	91.1	0.5
5.099	14,045	6.28	2.85	1.07	3.66	1.46	29.7	1.7
4.974	14,045	6.89	2.56	1.64	3.46	2.46	22.7	6.6
4.810	14,045	7.07	3.00	1.71	5.32	3.82	47.9	11.2
4.679	14,045	6.19	3.27	1.67	9.92	3.42	106.1	9.5
4.539	13,989	6.92	2.34	2.55	3.80	3.80	20.8	24.7
4.405	13,989	7.52	3.33	2.57	4.70	4.20	52.1	27.7
4.275	13,989	5.10	2.85	2.23	4.89	3.39	39.7	16.9
4.157	13,989	3.21	3.44	2.26	6.69	2.69	79.2	13.7
4.053	13,989	2.88	3.33	2.56	4.72	3.22	52.3	21.1
3.958	13,989	4.28	2.35	2.69	2.59	3.59	14.3	26.0
3.797	13,989	3.96	3.66	2.81	4.82	2.82	64.6	22.3
3.636	13,989	6.42	2.13	2.04	4.56	5.06	20.7	21.1
3.521	13,989	8.43	2.74	2.55	3.52	5.52	26.4	35.9
3.360	13,989	7.02	2.66	2.39	5.28	8.28	37.4	47.3
3.199	13,989	9.02	2.59	3.15	4.99	6.49	33.5	64.4
3.023	13,989	6.43	2.09	2.68	7.70	6.70	33.6	48.1
2.890	13,989	4.42	1.71	2.07	5.67	7.17	16.6	30.7
2.811	13,989	5.31	2.10	1.99	8.04	6.54	35.5	25.9
2.737	13,989	5.78	1.76	2.55	7.79	9.39	24.1	61.1

Table GR-32. Hydraulic parameters used to determine avulsion potential on Iona East Wash

River Station	Flow Rate (cfs)	Maximum Channel Velocity (ft/s)	Maximum LOB Velocity (ft/s)	Maximum ROB Velocity (ft/s)	Maximum LOB Depth (ft)	Maximum ROB Depth (ft)	dv^2 for LOB (ft^3/s^2)	dv^2 for ROB (ft^3/s^2)
3.027	6,992	6.02	2.59	2.33	3.86	3.86	25.9	21.0
2.942	6,992	5.74	2.32	2.15	6.02	6.02	32.4	27.8
2.843	6,992	7.57	2.36	2.37	3.81	3.81	21.2	21.4
2.762	6,992	7.86	2.73	3.01	5.77	5.77	43.0	52.3
2.626	6,992	9.54	3.69	3.76	5.28	5.28	71.9	74.6
2.525	6,992	7.12	3.11	1.86	5.30	2.30	51.3	8.0
2.412	6,992	5.00	2.46	1.46	3.00	1.50	18.2	3.2
2.296	6,992	4.62	3.21	1.21	3.95	0.95	40.7	1.4
2.145	6,992	5.99	2.50	1.32	2.87	1.87	17.9	3.3
2.035	6,992	6.27	2.55	2.64	2.89	2.89	18.8	20.1
1.921	6,992	5.62	2.60	2.89	3.83	3.83	25.9	32.0
1.826	6,992	6.32	2.97	2.39	2.99	1.99	26.4	11.4
1.747	6,992	4.82	2.55	2.28	3.21	2.71	20.9	14.1
1.664	6,992	5.27	2.97	2.03	3.89	2.39	34.3	9.8
1.577	6,992	4.46	3.26	2.07	3.65	2.65	38.8	11.4
1.480	6,992	5.41	2.62	2.42	4.47	4.47	30.7	26.2
1.393	6,992	6.73	2.91	2.67	2.60	2.10	22.0	15.0
1.310	6,992	5.67	2.19	2.73	3.47	3.47	16.6	25.9
1.230	6,992	5.18	2.66	2.09	4.38	4.19	31.0	18.3
1.147	6,992	5.95	2.97	2.60	3.93	4.43	34.7	29.9
1.056	6,992	7.15	3.35	2.78	4.31	4.25	48.4	32.8
0.956	6,992	4.83	2.59	3.02	4.09	4.59	27.4	41.9
0.850	6,992	5.02	3.14	2.81	3.94	3.94	38.8	31.1
0.752	6,992	5.52	2.56	2.87	3.41	4.01	22.3	33.0
0.636	6,992	3.06	1.90	2.30	4.65	5.15	16.8	27.2
0.516	6,992	3.09	2.41	2.34	2.78	2.77	16.1	15.2
0.421	6,992	2.49	1.88	2.08	2.90	3.40	10.2	14.7
0.201	6,992	4.70	3.15	3.70	3.30	3.27	32.7	44.8
0.114	6,992	2.54	1.66	2.23	2.37	3.87	6.5	19.2
0.000	6,992	1.32	0.86	1.37	1.93	4.93	1.4	9.3

Table GR-33. Hydraulic parameters used to determine avulsion potential on Iona West Wash

River Station	Flow Rate (cfs)	Maximum Channel Velocity (ft/s)	Maximum LOB Velocity (ft/s)	Maximum ROB Velocity (ft/s)	Maximum LOB Depth (ft)	Maximum ROB Depth (ft)	dv^2 for LOB (ft^3/s^2)	dv^2 for ROB (ft^3/s^2)
2.145	152	0.35	0.74	0.00	1.60	N/A	0.9	0.0
2.100	150	2.64	0.82	0.78	0.52	0.52	0.3	0.3
2.002	150	1.78	1.08	0.88	0.87	0.87	1.0	0.7
1.912	150	2.40	1.37	1.28	1.07	1.07	2.0	1.8
1.806	145	2.02	0.88	0.81	0.84	0.84	0.7	0.6
1.702	145	1.33	0.00	0.00	N/A	N/A	0.0	0.0
1.592	145	1.67	0.10	0.07	0.04	0.02	0.0	0.0
1.476	145	1.67	0.99	0.87	1.07	1.06	1.0	0.8
1.393	145	1.80	1.05	1.14	1.06	1.06	1.2	1.4
1.285	142	1.04	0.00	0.95	N/A	0.84	0.0	0.8
1.207	142	1.33	0.53	0.73	0.53	0.53	0.1	0.3
1.133	142	1.29	0.55	0.60	0.49	0.51	0.1	0.2
1.046	142	0.69	0.27	0.61	0.43	0.93	0.0	0.3
0.976	142	3.64	1.56	1.51	0.53	0.53	1.3	1.2
0.919	140	1.13	0.85	0.55	0.95	0.95	0.7	0.3
0.796	140	2.37	1.06	1.11	0.84	0.89	0.9	1.1
0.663	140	1.43	0.55	0.51	0.74	0.66	0.2	0.2
0.534	140	0.64	0.22	0.30	0.80	0.90	0.0	0.1
0.402	6,200	2.49	1.70	1.79	2.81	2.81	8.1	9.0
0.201	6,200	2.58	2.15	1.97	2.30	2.80	10.6	10.9
0.114	6,200	2.00	1.32	1.37	2.62	4.12	4.6	7.7
0.000	12,400	2.33	1.52	2.43	1.93	4.93	4.5	29.1

Table GR-34. Hydraulic parameters used to determine avulsion potential on CAP-1 West Wash

River Station	Flow Rate (cfs)	Maximum Channel Velocity (ft/s)	Maximum LOB Velocity (ft/s)	Maximum ROB Velocity (ft/s)	Maximum LOB Depth (ft)	Maximum ROB Depth (ft)	dv^2 for LOB (ft^3/s^2)	dv^2 for ROB (ft^3/s^2)
6.229	4,832	13.77	0.00	0.00	N/A	N/A	0.0	0.0
6.150	4,832	7.15	2.39	3.37	2.69	2.69	15.4	30.6
6.040	4,832	6.72	2.97	2.48	2.85	1.85	25.1	11.4
5.908	4,832	7.03	4.72	4.13	2.35	1.85	52.4	31.6
5.747	4,832	5.47	2.88	3.51	2.16	2.16	17.9	26.6
5.630	4,832	5.97	2.76	2.90	2.79	2.79	21.3	23.5
5.455	4,832	4.00	2.10	2.19	2.62	2.69	11.6	12.9
5.249	4,832	5.88	3.74	3.25	2.66	2.66	37.2	28.1
5.181	4,832	13.21	5.89	4.55	3.66	3.66	127.0	75.8
5.118	4,939	6.96	3.14	1.33	6.44	1.94	63.5	3.4
4.948	4,939	13.48	1.47	4.98	4.15	4.15	9.0	102.9
4.782	4,939	11.85	2.55	2.47	2.67	2.67	17.4	16.3
4.600	4,939	16.46	5.51	5.11	6.90	6.90	209.5	180.2
4.431	4,939	10.37	3.22	2.60	5.87	5.87	60.9	39.7
4.270	4,939	9.60	2.47	2.40	4.62	4.62	28.2	26.6
4.115	4,939	7.05	2.02	2.32	4.57	4.57	18.6	24.6
3.969	4,939	7.72	3.32	2.53	5.46	5.46	60.2	34.9
3.795	4,939	9.98	3.21	3.13	3.55	3.55	36.6	34.8
3.656	4,939	6.16	2.37	2.33	4.30	4.30	24.2	23.3
3.494	4,939	12.65	3.84	3.56	2.38	2.38	35.1	30.2
3.337	4,939	4.49	2.14	2.12	3.85	3.85	17.6	17.3
3.216	4,939	6.68	3.18	3.56	3.19	4.19	32.3	53.1
3.096	4,939	5.25	2.79	2.51	4.51	4.51	35.1	28.4
2.955	5,173	10.36	4.50	5.12	3.47	3.47	70.3	91.0
2.776	5,173	4.16	2.25	1.82	2.98	2.91	15.1	9.6
2.584	5,173	8.96	3.50	3.45	2.08	2.08	25.5	24.8
2.427	5,173	7.99	2.58	1.88	6.68	2.68	44.5	9.5
2.254	5,173	12.83	3.15	1.79	4.78	4.78	47.4	15.3
2.023	5,173	10.44	2.75	2.78	6.24	6.24	47.2	48.2
1.845	5,173	10.77	3.54	2.08	4.79	4.79	60.0	20.7
1.671	5,173	9.95	3.03	2.64	3.15	3.15	28.9	22.0
1.519	5,173	10.74	1.60	1.37	1.32	1.32	3.4	2.5
1.330	5,173	8.74	2.67	2.80	3.25	3.25	23.2	25.5
1.129	5,173	9.09	1.39	2.58	0.69	2.39	1.3	15.9
0.987	5,173	4.48	1.25	0.95	2.82	1.32	4.4	1.2
0.944	4,215	2.12	1.05	0.73	4.03	2.23	4.4	1.2
0.901	4,215	7.32	0.00	0.00	N/A	N/A	0.0	0.0
0.892	4,215	10.70	0.00	0.00	N/A	N/A	0.0	0.0
0.604	4,215	3.82	1.93	2.23	2.31	2.81	8.6	14.0
0.441	4,215	5.41	1.28	2.69	0.92	2.42	1.5	17.5
0.238	4,215	5.93	2.43	1.99	4.29	4.79	25.3	19.0
0.000	4,215	6.94	2.15	1.77	2.08	2.08	9.6	6.5

7.5.4. Identifying Channel Banks

One of the most important aspects of defining the erosion hazard zones is to carefully define where the channel banks occur. Identification of the channel banks is important because the channel banks define the areas that are considered the overbanks. Thus, the velocity in the overbanks, which is an important indicator in identifying avulsion potential, is highly dependent on the location of the channel bank stations. Fuller (2003) outlines a procedure which can be used to identify the channel banks. In the *Erosion Hazard Zone Delineation and Development Guidelines*, Fuller (2003) presents three methods that can be used to identify channel banks:

1. Ordinary high water marks,
2. Flood frequency, and
3. Hydraulic criteria.

In this report, the ordinary high water marks method was used to define the channel banks. This method is based on the U.S. Army Corps of Engineers' (USACE) criteria for identifying channel banks. This method depends on three characteristics: vegetation, soils, and topography. A brief summary of these three characteristics follows. For this study, topography was used most extensively in defining the channel banks. The topography was observed from the aerial photographs. In addition, notes from the field investigations as well as the surficial geology aided in the identification of the channel banks. Typically, the channel banks should lie within the younger Holocene surfaces and they should not cross into the older Pleistocene surfaces unless there has been some significant lateral erosion.

7.5.4.1. Vegetation

The ordinary high water mark is located at the point where the vegetation along the stream corridor changes from terrestrial to aquatic species, or the point where permanent, terrestrial vegetation begins.

7.5.4.2. Soils

The ordinary high water mark is located at the point where soil characteristics changes from undifferentiated, poorly developed, layered, fluvial deposits subject to scour and deposition to more well developed soils with distinct soil horizons. The change in soil characteristics is caused by channel processes that prevent soil formation from occurring in the portions of the stream corridor subject to erosion and deposition.

7.5.4.3. Topography

The ordinary high water mark is located at a break in slope or at the point where the top of the channel bank transitions to the more planar floodplain.

7.5.4.4. Examples of Bank Definition for Specific Channel Types

Fuller (2003) presents several graphical examples of defining channels. Figure GR-98 shows the recommended bank station positions for a single channel cross section. Bank stations are located at the top of the bank at the slope break between the bank and the floodplain. Figure GR-99 shows the recommended location of the channel banks for a multiple channel with shallow islands that are inundated by the 100-year flood. Low islands are subject to frequent erosion, deposition, and channel processes. In this case, bank stations are located at the top of the bank at the slope break between the bank and the floodplain. Figure GR-100 shows the recommended location for the bank stations for braided or multiple channels with shallow or small islands that are not inundated by the 100-year flood. In this case, the bank stations are located at the top of the bank that separates the outermost braided channel from the floodplain or unflooded area. Fuller (2003) presents a few additional examples for the location of the channel banks; however, these additional examples were not encountered in the Wittmann area. Thus, the additional examples are not discussed here.

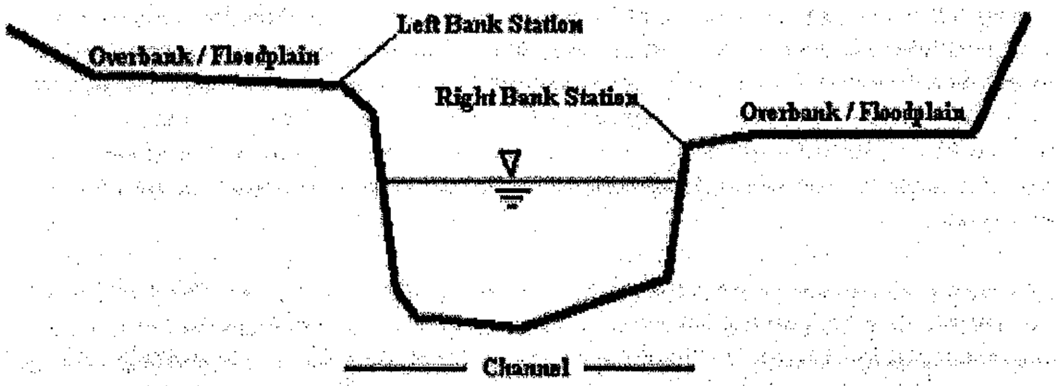

Figure GR-98. Recommended bank stations for a single channel cross section (from Fuller (2003))

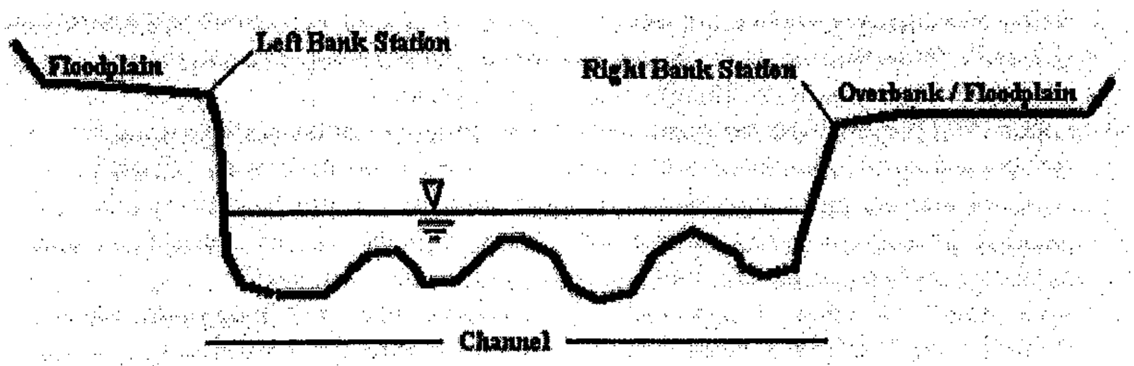

Figure GR-99. Recommended bank stations for a multiple channel with shallow islands or bars inundated by the 100-year flood (from Fuller (2003))

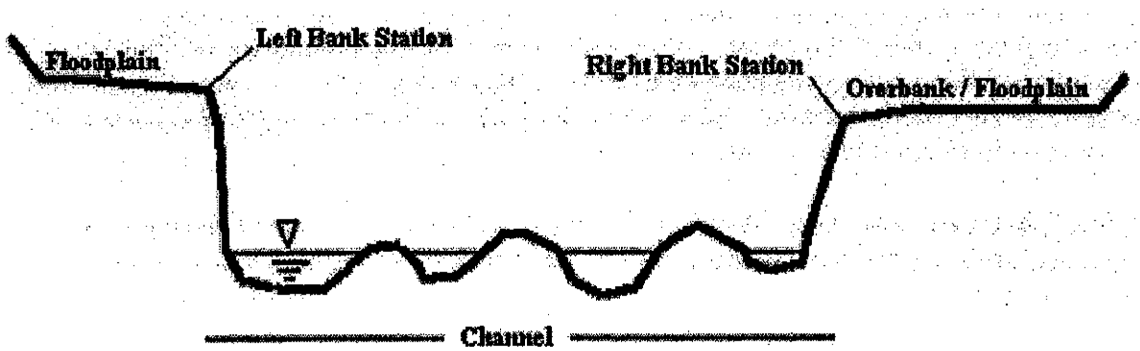

Figure GR-100. Recommended bank stations for braided or multiple channels with shallow, insignificant, or small islands near the 100-year water surface but not inundated by the 100-year flood (from Fuller (2003))

7.5.4.5. Examples for the Wittmann Study Area

The active channel banks were defined using the procedures outlined above. In general, most of the defined active channel banks were completely within younger Holocene surfaces and did not directly abut the older Pleistocene surfaces. There were a few instances in which the active channel banks did abut or cross over into a Pleistocene surface. However, in these cases, the surficial geology does not appear to be a fine enough scale to isolate all the younger channel surfaces. An example of where this occurs is at the head of the Iona West Wash as shown in Figure GR-101. At this location, there is a small manmade berm that runs directly south. This berm was constructed some time after 1964 (it does not appear in the 1964 aerial photographs, but it shows up in all newer aerial photographs). From Figure GR-101, it is obvious that Iona West and Iona East cuts through an apparent older M1 surface, which implies that the Iona East Wash cuts through the older Pleistocene surface after the manmade berm was constructed. However, by examining historical aerial photographs, it became obvious that the Iona East Wash was always in this location and had not moved due to the berm. Thus, it appears from the aerial photograph shown in Figure GR-101 that the surficial geology is not detailed enough to reflect the actual conditions.

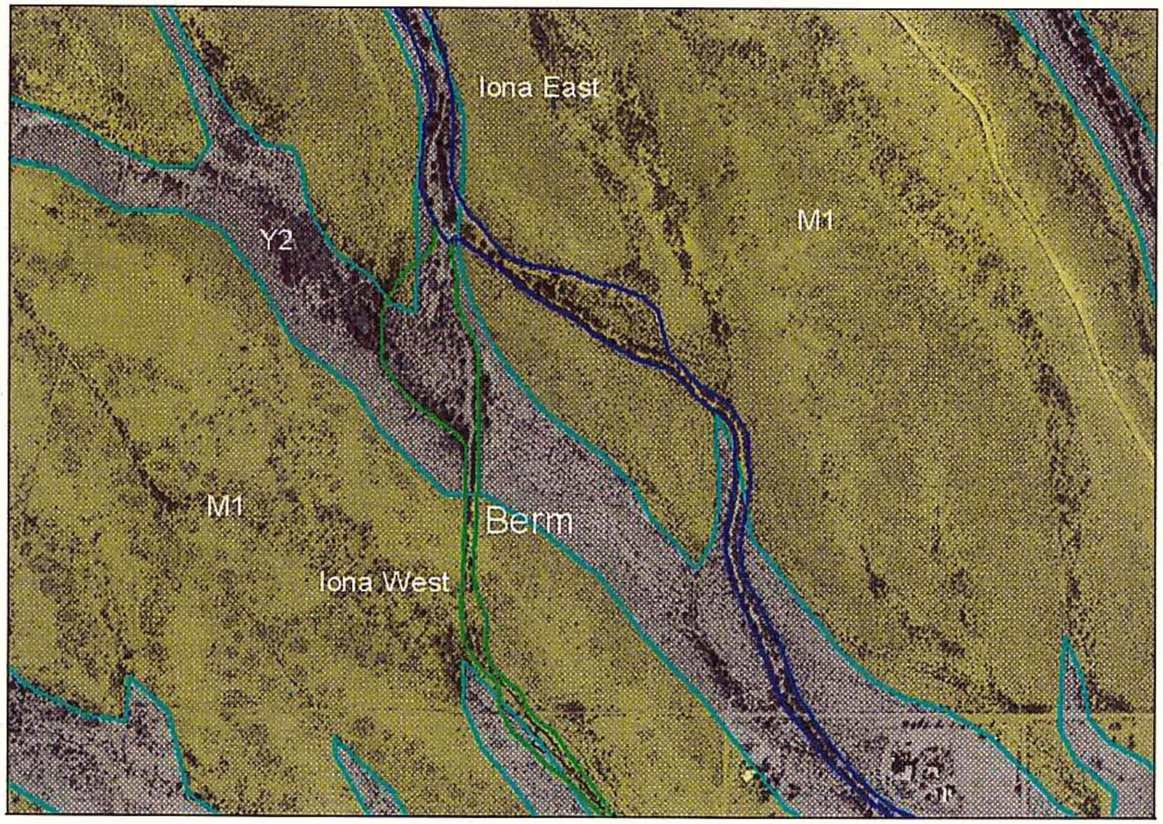

Figure GR-101. Channels banks and surficial geology near the head of the Iona West Wash

Another example where the surficial geology is not at a fine enough scale to isolate all the younger surfaces can be found on the CAP-1 West Wash near the CAP canal. When the CAP canal was built, many of the washes were slightly re-routed where they crossed the canals. The CAP-1 West Wash was moved approximately 500 feet to the southwest just upstream of the CAP canal. After the wash crosses the canal, it takes approximately 1,100 feet before the re-routed wash joins the historic channel just north of Patton Road. The remains of the original wash just downstream from the CAP canal can still be seen; however, it is quite obvious that no water has flowed there in quite some time. Despite this, the surficial geology still indicates that the main channel (i.e., the youngest surface) still follows the historic channel path and not the re-routed channel path (see Figure GR-102).

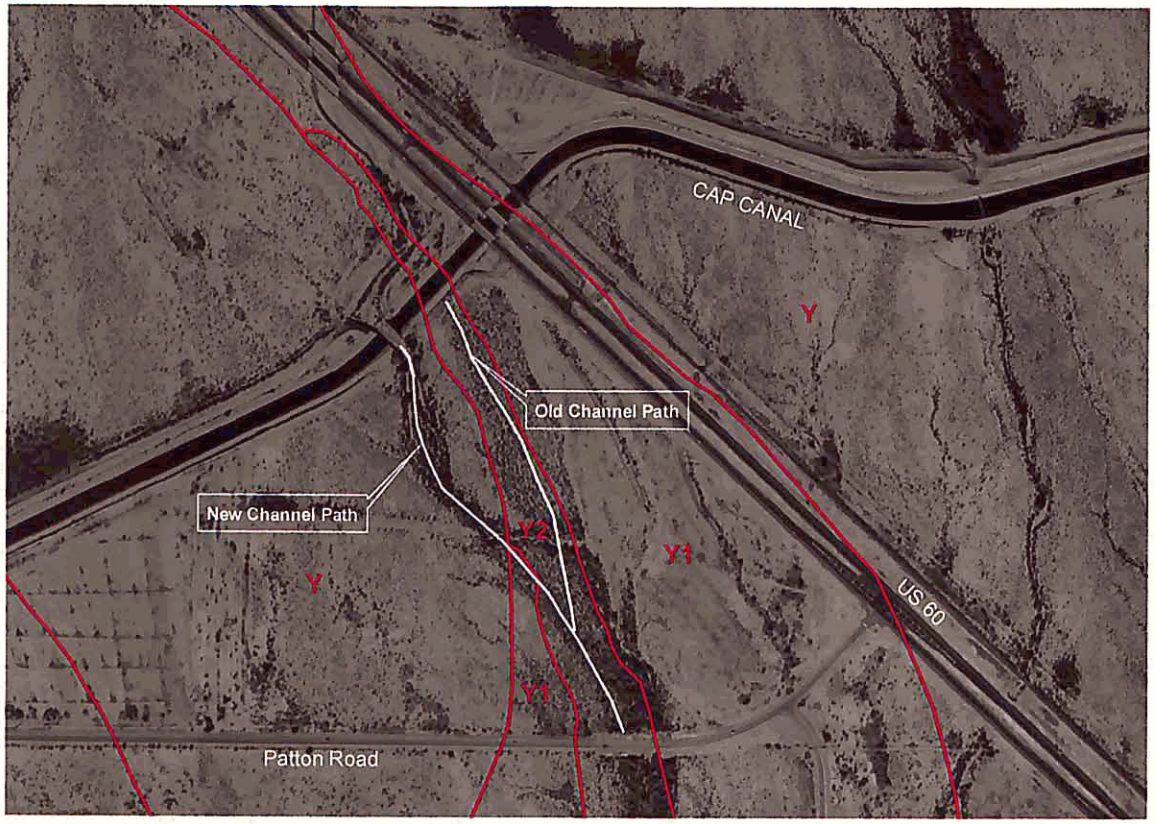

Figure GR-102. New and historic channel paths on the CAP-1 West Wash just south of the CAP canal

7.6. Delineate Erosion Hazard Zone

An erosion hazard zone should be delineated based on the results of the methodologies and analyses outlined above. The recommended erosion hazard zones can be seen in Figure GR-109 and Figure GR-110. Large scale plots of these figures can be found in Appendix F.

7.7. Recommended Erosion Hazard Zone

Using the procedures and methodologies outlined above, a recommended erosion hazard zone was determined for the four washes under consideration. One ArcView shape file was created to define the erosion hazard zone for the Trilby/Iona Wash system. A second ArcView shape file was created to define the erosion hazard zone for CAP-1 West Wash. The recommended erosion hazard zone for the Trilby/Iona Wash system is shown in Figure GR-109 while the recommended erosion hazard zone for the CAP-1 West Wash is shown in Figure GR-110.

On Trilby Wash, the erosion hazard potential appears to become more severe in the area between Pinnacle Peak Road and Deer Valley Road. In this area, there are many small side channels that are flowing parallel to the main Trilby Wash. In addition, the aerial photographs suggest that flows have breached the main banks of Trilby Wash in the recent past.

On the Iona East Wash, the erosion hazard potential appears to be high near the head of the Iona West Wash. Just north of the Iona West Wash is a fairly large channel that runs parallel to the Iona East Wash (see Figure GR-101). The hydraulics in this area indicate that the avulsion potential is high, so it is possible that the Iona East Wash may avulse into this side channel. In addition, if the man-made berm shown in Figure GR-101 fails, the area downstream of that will be subject to high erosion hazard potential.

On the Iona West Wash, the area from about Pinnacle Peak Road to Patrick Lane appears to have a high erosion hazard potential. In this area, the banks of the channel are vertical and there is almost no vegetation (see Figure GR-91). There are also numerous head cuts in this area of the Iona West Wash (see Figure GR-103).

Figure GR-103. Head cuts on the Iona West Wash (located between Pinnacle Peak Road and Patrick Lane)

The confluence of the Trilby Wash, Iona East Wash, and the Iona West Wash also appears to be an area of high erosion hazard potential. This area starts around Pinnacle Peak Road on the Trilby, Iona East, and Iona West washes and continues down to where the Trilby finally forms into a large single channel around Crozier Road. In the area south of Pinnacle Peak Road and west of 211th Avenue, the main channel in all three of the washes becomes quite small. There are numerous side channels and it is actually difficult to tell which of these channels are the "main" channels for the Trilby, Iona East, and Iona West Wash. The aerial photographs also suggest that flows have breached the banks of the "main" channel in this area in the recent past. Downstream from 211th Avenue, the three washes are beginning to combine into one. This area is populated by numerous, large head cuts with vertical banks (see Figure GR-104). The large amount of exposed roots in this area is another indication that the erosion hazard potential is high (see Figure GR-105).

Figure GR-104. Head cuts on the Trilby Wash (located downstream from 211th Avenue)

Figure GR-105. Exposed roots on the Trilby Wash (located downstream from 211th Avenue)

The erosion hazard potential also appears to be high on the Trilby Wash from about river mile 4.405 down to McMicken Dam. In this area, there are many small side channels that are flowing parallel to the main Trilby Wash. In addition, the aerial photographs suggest that flows have breached the main banks of Trilby Wash in the recent past. The hydraulics also indicate that the avulsion potential is high in this area.

On the CAP-1 West Wash, the area between the CAP canal and 195th Avenue appears to have a high potential for erosion hazard. This area includes the section of the wash just downstream from the CAP canal that was re-routed with the CAP canal was built. This area has a high avulsion potential because the wash may want to recapture its historical flow path. In the area between Patton Road and 195th Avenue, the channel is not well defined and there are numerous, small, deeply incised channels (see Figure GR-106).

Figure GR-106. Small, deeply incised channel on the CAP-1 West Wash (located near 195th Avenue)

The erosion hazard potential also appears to be high on the CAP-1 West Wash between Happy Valley Road and Pinnacle Peak Road. The aerial photographs indicate that flow has breached the banks of the CAP-1 West Wash in this area in the recent past. In addition, there are numerous, large head cuts in this area (see Figure GR-107). In this area, there is also a house that was abandoned due to the frequent flood problems in this area.

Figure GR-107. Large head cut on the CAP-1 West Wash (located between Happy Valley Road and Pinnacle Peak Road)

Another area on the CAP-1 West Wash that has a high erosion hazard potential is the area from Deer Valley Road to McMicken Dam. In this area, the main channel is not well defined and there are many small side channels that are flowing parallel to the main CAP-1 West Wash. In addition, the aerial photographs suggest that flows have breached the main banks of CAP-1 West Wash in the recent past. The hydraulics also indicate that the avulsion potential is high in this area. There are also some newly formed head cuts in this area (see Figure GR-108).

Figure GR-108. Head cuts on the CAP-1 West Wash (located between Deer Valley Road and McMicken Dam)

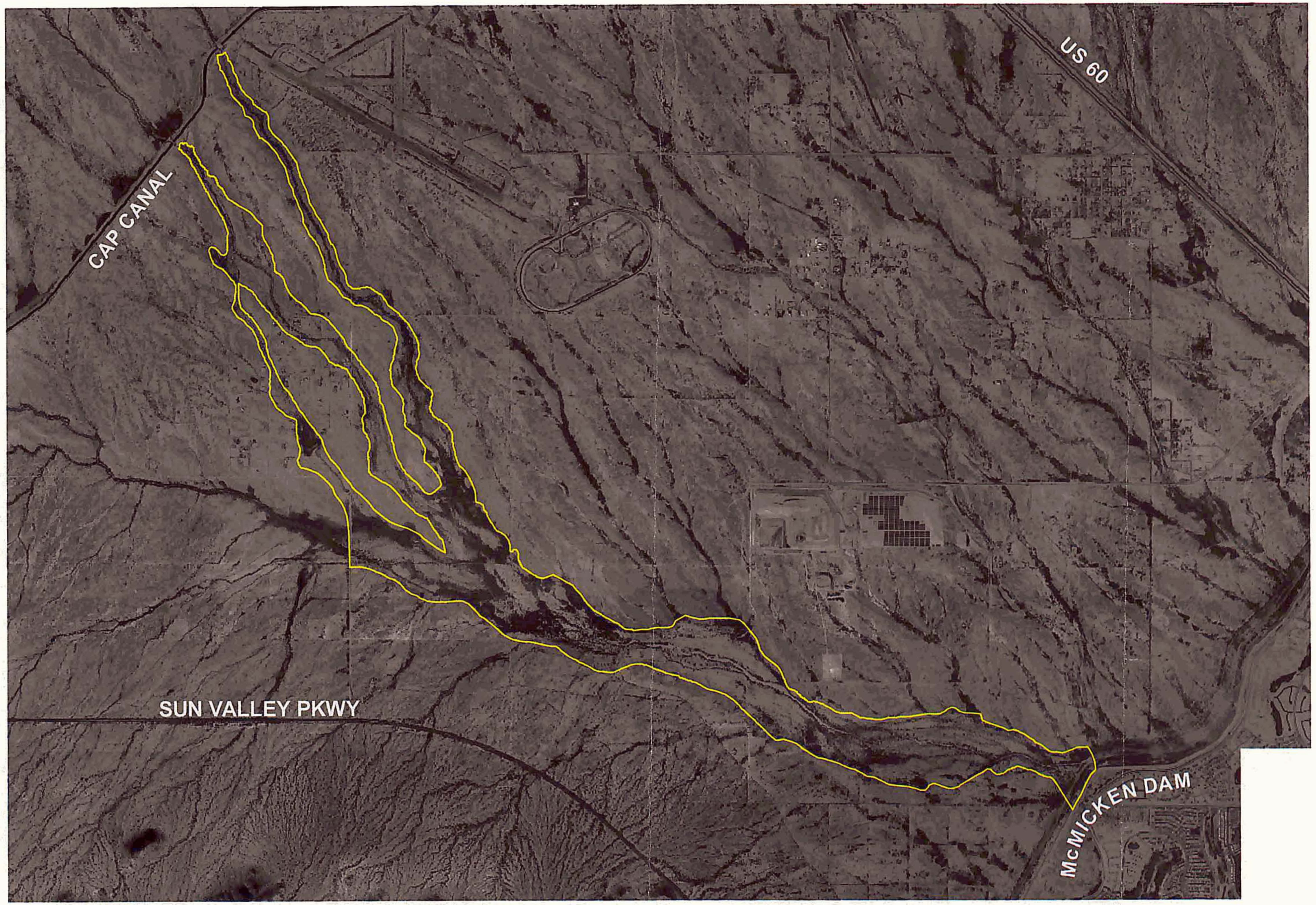

Figure GR-109. Recommended erosion hazard zone for the Trilby Wash, the Iona East Wash, and the Iona West Wash

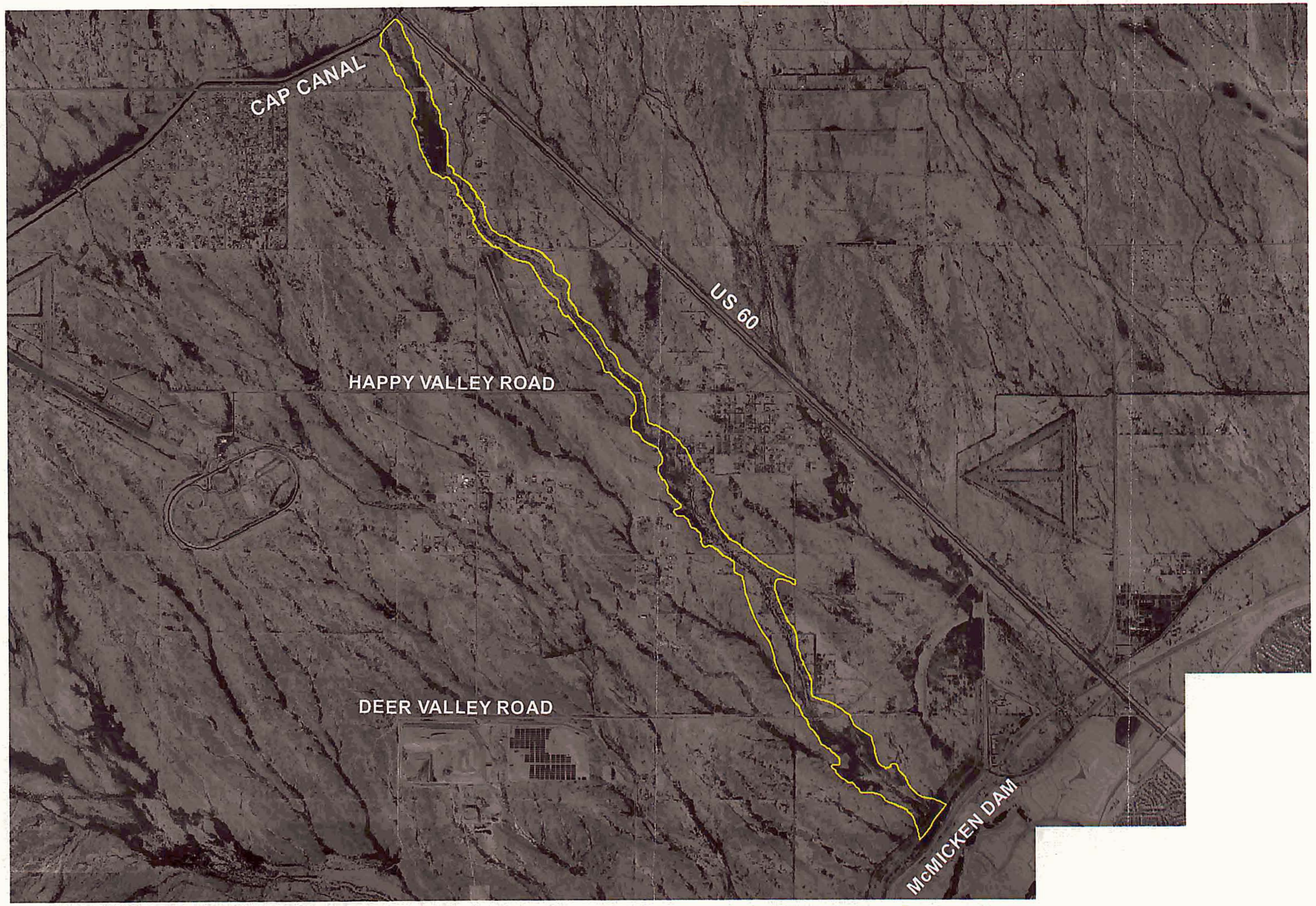

Figure GR-110. Recommended erosion hazard zone for the CAP-1 West Wash

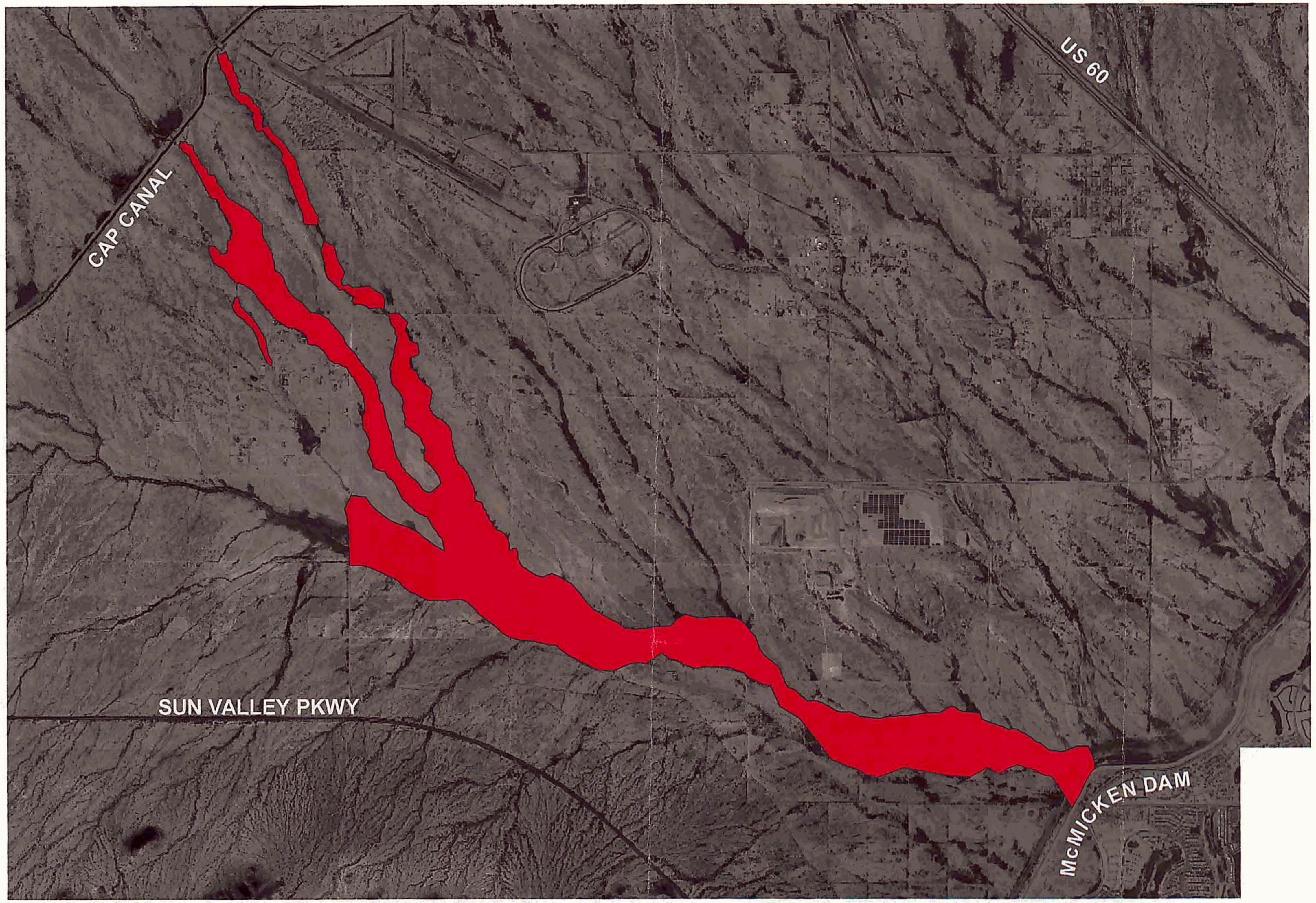

Figure GR-111. Areas with a high avulsion potential on the Trilby Wash, the Iona East Wash, and the Iona West Wash

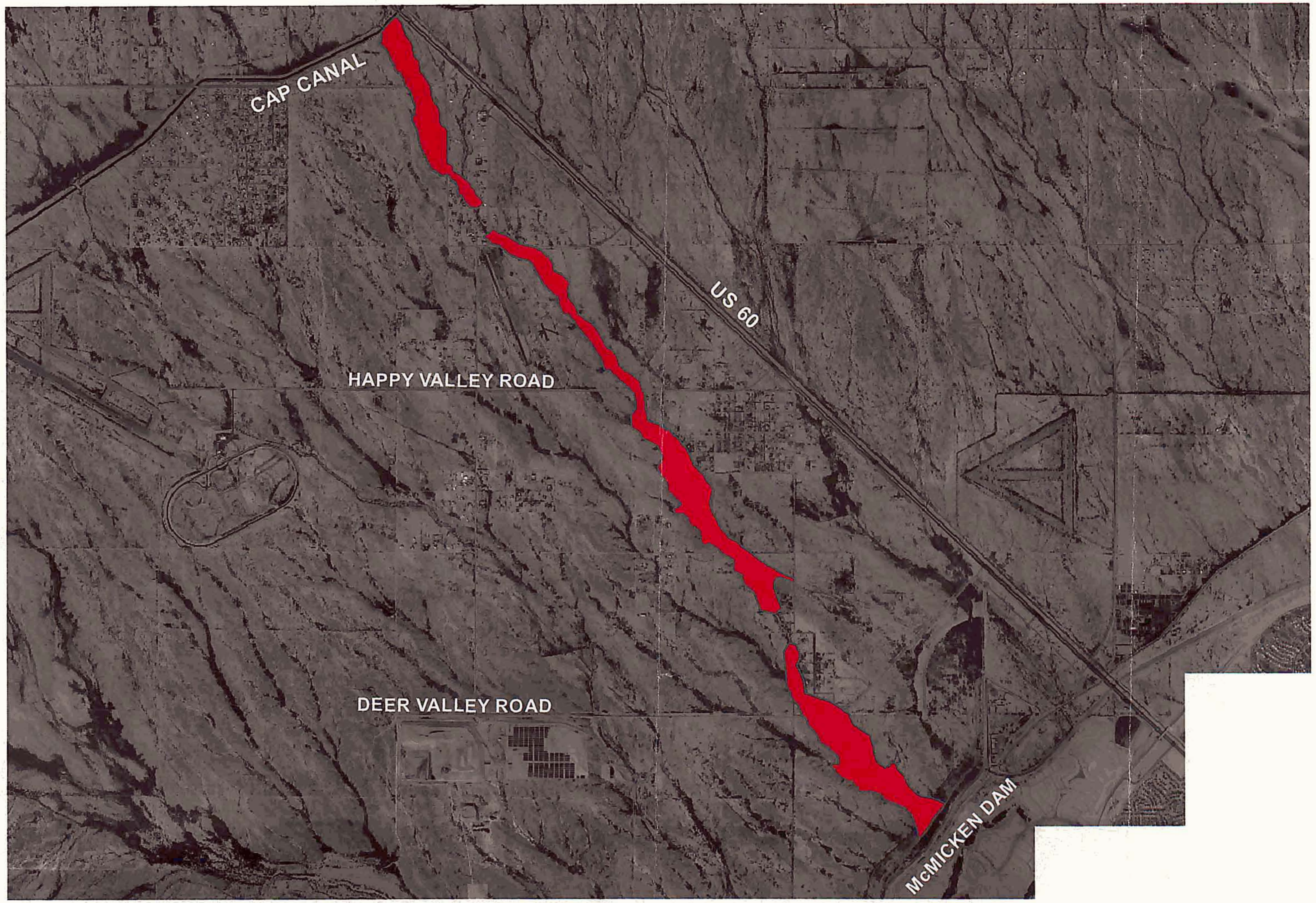

Figure GR-112. Areas with high avulsion potential on the CAP-1 West Wash

SECTION GR-8: SUMMARY

The Wittmann Study Area has numerous areas that are classified as unstable and areas that would require modeling with two-dimensional models to accurately determine flood hazards. A detailed review of the area south of the Sun Valley Parkway was performed and found most areas to be stable. Several areas were found where a geomorphic assessment indicated unstable land forms.

A limited stage 1 analysis was performed for the area north of the CAP canal and east of Grand Avenue. This study indicated that current development along Padelford Wash is occurring on lands that may not be stable. The development is occurring in areas where the geomorphic features would indicate possible active alluvial fans. Another large fan that is possibly active was noted just east of the Chrysler Proving Grounds. Other areas appear to be stable with the exception of a two minor fans and areas immediately adjacent to major washes that were classified as unstable. These areas need further analysis to determine which areas are stable and what the proper erosion setbacks are for the areas along the washes. Areas immediately upstream of the CAP canal are also considered unstable areas due to deposition of sediment and the continuing development of alluvial fans.

A very limited analysis was performed for the balance of the study area to identify areas of possible two-dimensional flow. These areas were highlighted for further analysis in the future.

As a result of the study it appears that most of the study area is geomorphically stable but extreme care should be taken to insure the passage of flood waters and sediment through the various washes from the upper watershed north of Highway 74 through the point where the washes reach the McMicken Dam pool area.

A sediment yield study was also conducted to predict the volume of sediment that can be expected to flow into McMicken Dam. A number of methods were applied, some of which have not been applied in this area previously. The various methods agreed relatively well with very approximate estimates of the historical sediment delivery to the dam.

Finally, an erosion hazard zone analysis was performed on four (4) washes in the Wittmann area: Trilby Wash, Iona East Wash, Iona West Wash, and the CAP-1 West Wash. There are many areas along these washes that have a high erosion hazard potential due to the lack of vegetation and large number of vertical head cuts. The hydraulics of the area also indicate that there are many areas with a high avulsion potential along these washes.

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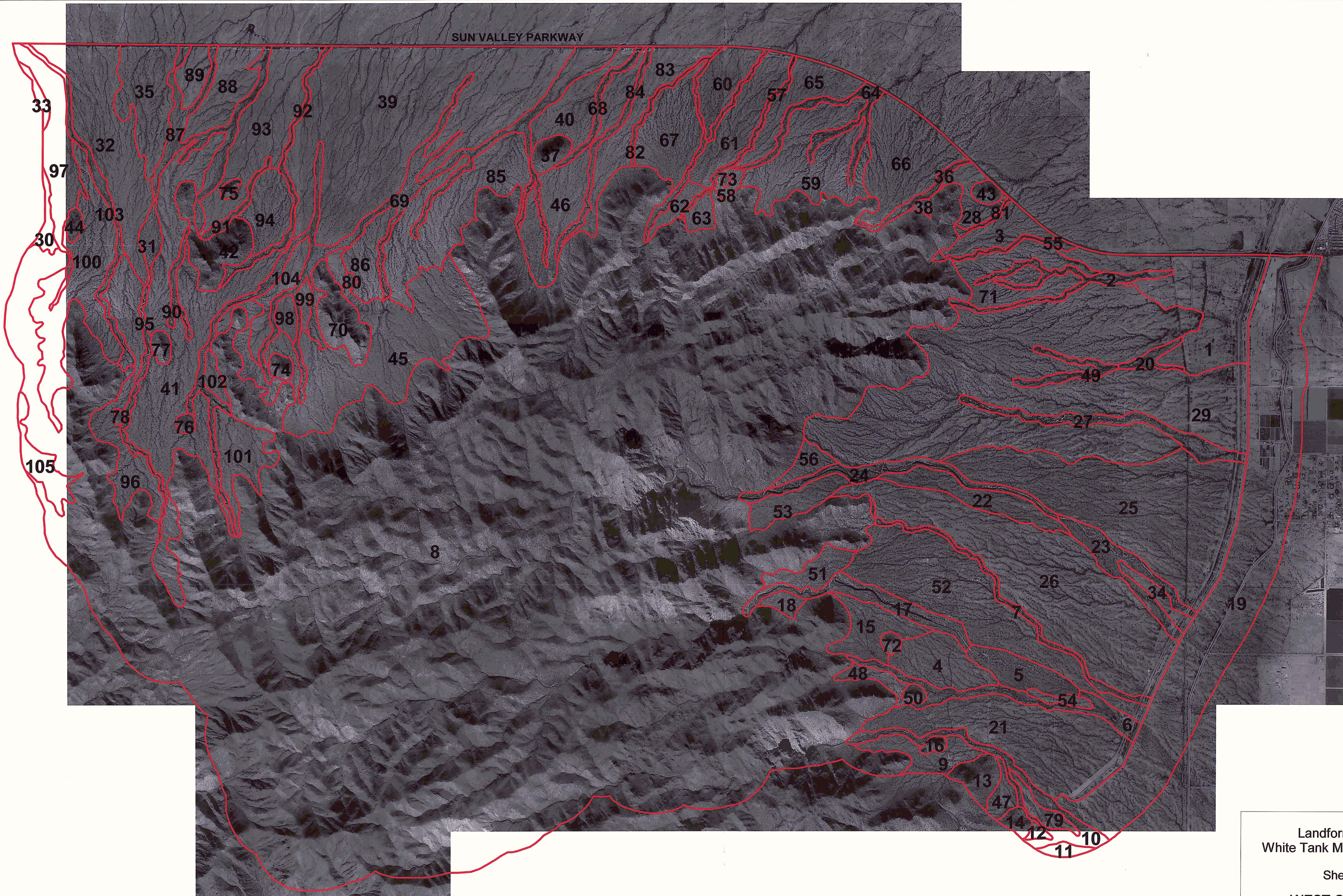
APPENDIX A

Large Scale Exhibits of Stable and Unstable Areas In the White Tanks Portion of Study Area

Sheet 1. Landform IDs for the White Tanks Mountains Study Area
Sheet 2. Map of Stable and Unstable Landforms in the White Tank Mountains Study Area

WEST CONSULTANTS, INC.



Aerial Photography: 2003

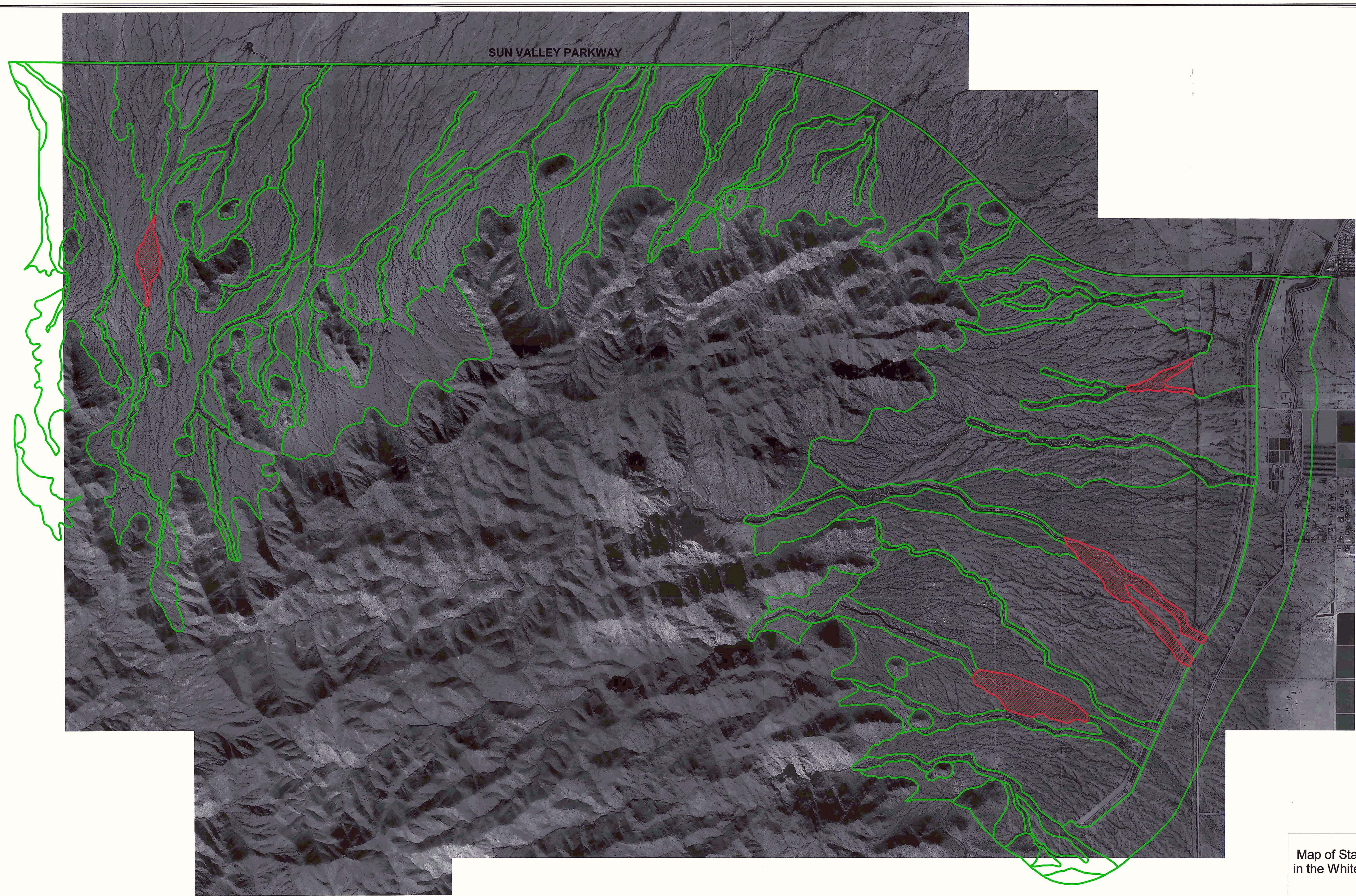
0 2000 4000 6000 8000 10000 Feet

N E S W

Landform IDs for the White Tank Mountains Study Area

Sheet 1 of 7

WEST Consultants, Inc.



Legend

Unstable Landforms

Stable Landforms

Aerial Photography: 2003

0 2000 4000 6000 8000 10000 Feet

Map of Stable and Unstable Landforms in the White Tank Mountains Study Area

Sheet 2 of 7

WEST Consultants, Inc.

APPENDIX B

Detailed Information Developed During
Stage 1 Analysis

WEST
CONSULTANTS, INC.

Classification Data for Wittman Study - White Tanks Area

Landform ID	Landform Classification	Soil Type	Surficial Geology	Flood Hazard Potential	Surface Texture	Surface Color	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern	Fan Shaped
1	Alluvial plain	Antho association (AAF, AP) Gilman Loam (AP)	Y2 (AAF, AP)	H2 (AAF, AP)	Very flat (AP)	Medium (N/A)	Tributary (IAF, P, RF)	No (AAF, AP)	No (AAF, AP)	Sparse (N/A)	No (AP, P, RF)
2	Throughflow channel	Antho-Carrizo complex Antho association	M1b	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
3	Relict fan	Ebon-Pinamt complex (IAF, RF) Antho-Carrizo complex (AF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Channels incised > 10 ft (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
4	Inactive alluvial fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Dense (IAF, P, RF)	Yes (AF)
5	Active alluvial fan	Torrifluvents	Y (AAF)	H1 (AAF)	Braided, stippled	Channel is light	Braided	No	No	Along channel	Yes (AF)
6	Throughflow channel	Torrifluvents	M2	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
7	Throughflow channel	Torrifluvents	M2	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
9	Inactive alluvial fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Small channels (IAF)	Dark (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Dense (IAF, P, RF)	No (P, RF)
10	Throughflow channel	Torrifluvents	M2	L2	Stippled	Light channel, dark banks	Braided	No	No	Along channel	No
11	Inactive alluvial fan	Antho-Carrizo complex (AF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Light (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	Yes (AF)
12	Pediment	Ebon-Pinamt complex (IAF, RF)	TK (P)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Light (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
15	Pediment	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Dense (IAF, P, RF)	No (P, RF)
17	Throughflow channel	Torrifluvents	M2	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
18	Other old alluvium	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
20	Active alluvial fan	Antho association (AAF, AP)	Y2 (AAF, AP)	H1 (AAF)	Braided, stippled (AAF)	Light (AAF)	Distributary (AAF)	No (AAF, AP)	No (AAF, AP)	Sparse (N/A)	Yes (AF)
21	Inactive alluvial fan	Ebon-Pinamt complex (IAF, RF) Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF) M2 (IAF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
22	Inactive alluvial fan	Ebon-Pinamt complex (IAF, RF)	M2 (IAF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
23	Active alluvial fan	Torrifluvents (AAF)	Y (AAF)	H1 (AAF)	Braided, stippled (AAF)	Light (AAF)	Distributary (AAF)	No (AAF, AP)	No (AAF, AP)	Scattered (AAF)	Yes (AF)
24	Throughflow channel	Torrifluvents	M2	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
25	Inactive alluvial fan	Ebon-Pinamt complex (IAF, RF) Antho-Carrizo complex (AF)	M2 (IAF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
26	Relict fan	Ebon-Pinamt complex (IAF, RF) Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Channels incised > 10 ft (RF) Drainage pattern decreases upslope (RF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
27	Throughflow channel	Torrifluvents	Y	H1	Stippled	Light channel, dark banks	Braided	No	No	Along channel	No
28	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
29	Relict fan	Ebon-Pinamt complex (IAF, RF) Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Channels incised > 10 ft (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
30	Pediment	Suncity-Cipriano complex (N/A)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
31	Active alluvial fan	Antho-Carrizo-Maripo complex (AAF)	Y2 (AAF, AP)	H1 (AAF)	Braided, stippled	Medium light (AAF)	Distributary (AAF)	No (AAF, AP)	No (AAF, AP)	Scattered (AAF)	Yes (AF)
32	Inactive alluvial fan	Antho-Carrizo-Maripo complex (AAF) Tremant Loams (RF)	Y2 (AAF, AP)	H2 (AAF, AP)	Stippled (AF)	Medium light (AAF)	Pockets of distributary (AF)	Yes (IAF, P, RF)	No (AAF, AP)	Scattered (AAF)	Yes (AF)
33	Relict fan	Antho-Carrizo-Maripo complex (AAF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
34	Relict fan	Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
35	Relict fan	Tremant Loams (RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	Yes (AF)
36	Throughtflow channel	Torrifluvents	M1b and Y1	L2 and I	Stippled (AF)	Channel is light	Braided	No	No	Along channel	No

Classification Data for Wittman Study - White Tanks Area

Landform ID	Landform Classification	Soil Type	Surficial Geology	Flood Hazard Potential	Surface Texture	Surface Color	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern	Fan Shaped
38	Pediment	Cheriono-Rock outcrop (P)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
39	Inactive alluvial fan	Denure-Momoli-Carrizo complex (AP)	Y1 (AAF, AP) Y2 (AAF, AP)	H2 (AAF, AP) I (IAF)	Ridge-valley (IAF, RF) Stippled (AF)	Medium light (AAF)	Pockets of distributary (AF)	Yes (IAF, P, RF)	No (AAF, AP)	Sparse (N/A)	Yes (AF)
40	Relict fan	Ebon-Pinamt complex (IAF, RF) Gunsight-Rillito (RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Drainage pattern decreases upslope (RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
41	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
45	Pediment	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
46	Relict fan	Ebon-Pinamt complex (IAF, RF) Tremant Loams (RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
47	Pediment	Ebon-Pinamt complex (IAF, RF)	M2 (IAF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Fairly dense (IAF, P, RF)	No (P, RF)
48	Pediment	Ebon-Pinamt complex (IAF, RF)	M2 (IAF) M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Dense (IAF, P, RF)	No (P, RF)
49	Throughflow channel	Antho-Tremant complex (IAF, RF)	Y2	H1	Braided, stippled	Channel is light	Pockets of distributary	No	No	Along channel	No
51	Other old alluvium	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Light (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
52	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Drainage pattern decreases upslope (RF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Fairly dense (IAF, P, RF)	No (P, RF)
53	Other old alluvium	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Fairly dense (IAF, P, RF)	No (P, RF)
54	Relict fan	Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF)	L1 (IAF, P, RF)	Ridge-valley (IAF, RF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
55	Throughflow channel	Ebon-Pinamt complex (IAF, RF) Antho-Carrizo complex (AF)	M1b (IAF, P, RF) Y2 (AAF, AP)	H2 (AAF, AP)	Stippled	Channel is light	Braided	No	No	Along channel	No
56	Other old alluvium	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
57	Throughflow channel	Torrifluvents	Y2	L1	Stippled	Channel is light	Braided	No	No	Along channel	No
58	Pediment	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Stippled (AF) Many first-order channels (P)	Light (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Very sparse (N/A)	No (P, RF)
59	Relict fan	Ebon-Pinamt complex (IAF, RF) Antho-Tremant complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Channels incised > 10 ft (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
60	Inactive alluvial fan	Antho-Carrizo-Maripo complex (AAF) Tremant Loams (RF)	M2 (IAF)	L1 (IAF, P, RF)	Ridge-valley (IAF, RF) Small channels (IAF)	Medium dark (N/A)	Pocket of distributary (AF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
61	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Drainage pattern decreases upslope (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
62	Pediment	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
63	Pediment	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first-order channels (P)	Light (IAF, P, RF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Very sparse (N/A)	No (P, RF)
64	Throughflow channel	Torrifluvents	Y2	H2	Stippled	Channel is light	Braided	No	No	Along channel	No
65	Relict fan	Ebon-Pinamt complex (IAF, RF) Tremant Loams (RF)	M1b (IAF, P, RF) Y (AAF)	L2 (IAF, P, RF) H2 (AAF, AP)	Ridge-valley (IAF, RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
66	Relict fan	Ebon-Pinamt complex (IAF, RF) Antho-Carrizo complex (AF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Drainage pattern decreases upslope (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)
67	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF) Drainage pattern decreases upslope (RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	Yes (AF)
68	Throughflow channel	Torrifluvents	M1b	L2	Stippled	Channel is light	Braided	No	No	Along channel	No
69	Throughflow channel	Torrifluvents	Y2	H2	Stippled	Channel is light	Braided	No	No	Along channel	No
71	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)

Classification Data for Wittman Study - White Tanks Area

Landform ID	Landform Classification	Soil Type	Surficial Geology	Flood Hazard Potential	Surface Texture	Surface Color	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern	Fan Shaped
					Channels incised > 10 ft (RF)						
79	Relict fan	Ebon-Pinamt complex (IAF, RF)	M2 (IAF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF)	Medium dark (N/A)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Fairly dense (IAF, P, RF)	No (P, RF)
81	Throughflow channel	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Stippled	Channel is light	Braided	No	No	Along channels	No
82	Throughflow channel	Antho-Carrizo-Maripo complex (AAF)	M2 (IAF)	L1 (IAF, P, RF)	Stippled	Channel is light	Braided	No	No	Along channels	No
83	Relict fan	Ebon-Pinamt complex (IAF, RF) Tremant Loams (RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
84	Throughflow channel	Ebon-Pinamt complex (IAF, RF) Tremant Loams (RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Stippled	Channel is light	Braided	No	No	Along channels	No
85	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
86	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Large vegetation along banks (IAF, RF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
87	Throughflow channel	Ebon-Pinamt complex Denure-Momoli-Carrizo complex	Y2 M1b	H2	Stippled	Channel is light	Braided	No	No	Along channels	No
88	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
89	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
90	Throughflow channel	Ebon-Pinamt complex	M1b	L2	Stippled	Channel is light	Braided	No	No	Along channels	No
91	Throughflow channel	Denure-Momoli-Carrizo complex	Y2 M1b	H2	Stippled	Channel is light	Braided	No	No	Along channels	No
92	Throughflow channel	Denure-Momoli-Carrizo complex	Y2 M1b	H2	Stippled	Channel is light	Braided	No	No	Along channels	No
93	Inactive alluvial fan	Denure-Momoli-Carrizo complex (AP)	Y2 (AAF, AP)	H2 (AAF, AP)	Ridge-valley (IAF, RF) Stippled (AF)	Medium light (AAF)	Pockets of distributary (AF)	Yes (IAF, P, RF)	No (AAF, AP)	Sparse (N/A)	Yes (AF)
94	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
95	Throughflow channel	Ebon-Pinamt complex	M1b	L2	Stippled	Channel is light	Braided	No	No	Along channels	No
96	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
97	Inactive alluvial fan	Antho-Carrizo-Maripo complex (AAF) Tremant Loams (RF)	Y2 (AAF, AP)	H2 (AAF, AP)	Stippled (AF)	Medium light (AAF)	Pockets of distributary (AF)	Yes (IAF, P, RF)	No (AAF, AP)	Scattered (AAF)	Yes (AF)
98	Inactive alluvial fan	Denure-Momoli-Carrizo complex (AP) Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Stippled (AF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	Yes (AF)
99	Inactive alluvial fan	Denure-Momoli-Carrizo complex (AP) Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Stippled (AF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	Yes (AF)
100	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
101	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
102	Relict fan	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	No (P, RF)
103	Throughflow channel	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Stippled	Channel is light	Braided	No	No	Along channels	No
104	Inactive alluvial fan	Denure-Momoli-Carrizo complex (AP)	M1b (IAF, P, RF) Y2 (AAF, AP)	L2 (IAF, P, RF)	Ridge-valley (IAF, RF) Stippled (AF)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Sparse (N/A)	Yes (AF)
105	Other old alluvium	Ebon-Pinamt complex (IAF, RF)	M1b (IAF, P, RF)	L2 (IAF, P, RF)	Low topo relief (P) Many first order channels (P)	Medium light (AAF)	Tributary (IAF, P, RF)	Yes (IAF, P, RF)	Moderate (IAF, P, RF)	Scattered (AAF)	No (P, RF)

APPENDIX C

Information Used to Classify Landform Stability

WEST CONSULTANTS, INC.

Stability Classification Data for Wittmann Study - White Tanks Area

Landform ID	Landform Classification	Stability Classification	Stream Movement	Calcium Carbonate	Soil Type	Surficial Geology	Flood Hazard Potential	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern
1	Alluvial plain	Stable	No (S)	None (U)	Antho association (U) Gilman Loam (U)	Y2 (U)	H2 (U)	Tributary (S)	No (U)	No (U)	Sparse (N/A)
2	Throughflow channel	Stable	Slight (U)	None (U)	Antho-Carrizo complex (U) Antho association (U)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
3	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Carrizo complex (U)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
4	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Dense (S)
5	Active alluvial fan	Unstable	Yes (U)	None (U)	Torrifluvents (U)	Y (U)	H1 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
6	Throughflow channel	Stable	Yes (U)	None (U)	Torrifluvents (U)	M2 (S) Y (U)	L2 (S) H1 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
7	Throughflow channel	Stable	Yes (U)	None (U)	Torrifluvents (U)	M2 (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
9	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Dense (S)
10	Throughflow channel	Stable	Slight (U)	None (U)	Torrifluvents (U)	M2 (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
11	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Antho-Carrizo complex (U)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
12	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	TK (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
15	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Dense (S)
17	Throughflow channel	Stable	Slight (U)	None (U)	Torrifluvents (U)	M2 (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
18	Other old alluvium	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
20	Active alluvial fan	Unstable	Slight (U)	None (U)	Antho association (U)	Y2 (U)	H1 (U)	Distributary (U)	No (U)	No (U)	Sparse (N/A)
21	Inactive alluvial fan	Stable	No (S)	> Stage I or II (S)	Ebon-Pinamt complex (S) Antho-Tremant complex (S)	M1b (S) M2 (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
22	Inactive alluvial fan	Stable	No (S)	> Stage I or II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
23	Active alluvial fan	Unstable	Yes (U)	None (U)	Torrifluvents (U)	Y (U)	H1 (U)	Distributary (U)	No (U)	No (U)	Scattered (N/A)
24	Throughflow channel	Stable	No (S)	None (U)	Torrifluvents (U)	M2 (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
25	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Tremant complex (S)	M2 (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
26	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Tremant complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
27	Throughflow channel	Stable	Yes (U)	None (U)	Torrifluvents (U)	Y (U)	H1 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
28	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
29	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Tremant complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
30	Pediment	Stable	No (S)	> Stage II (S)	Suncity-Cipriano complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
31	Active alluvial fan	Unstable	Yes (U)	None (U)	Antho-Carrizo-Maripo complex (U)	Y2 (U)	H1 (U)	Distributary (U)	No (U)	No (U)	Scattered (N/A)
32	Inactive alluvial fan	Stable	Slight (U)	None (U)	Antho-Carrizo-Maripo complex (U) Tremant loams (S)	Y2 (U)	H2 (U)	Some Distributary (U)	Yes (S)	No (U)	Scattered (N/A)
33	Relict fan	Stable	No (S)	> Stage II (S)	Antho-Carrizo-Maripo complex (U)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
34	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
35	Relict fan	Stable	No (S)	> Stage II (S)	Tremant loams (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
36	Throughtflow channel	Stable	No (S)	None (U)	Torrifluvents (U)	M1b (S) Y (U)	L2 (S) I (S)	Braided (U)	No (U)	No (U)	Along channels (S)
38	Pediment	Stable	No (S)	> Stage II (S)	Cheriono-Rock outcrop (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
39	Inactive alluvial fan	Stable	Slight (U)	None (U)	Denure-Momoli-Carrizo complex (U)	Y1 (U) Y2 (U)	H2 (U) I (S)	Some Distributary (U)	Yes (S)	No (U)	Sparse (N/A)
40	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Gunsight-Rillito (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
41	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
45	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
46	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Tremant loams (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)

Stability Classification Data for Wittmann Study - White Tanks Area

Landform ID	Landform Classification	Stability Classification	Stream Movement	Calcium Carbonate	Soil Type	Surficial Geology	Flood Hazard Potential	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern
47	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M2 (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Fairly dense (S)
48	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M2 (S) M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Dense (S)
49	Throughflow channel	Stable	Slight (U)	None (U)	Antho-Tremant complex (S)	Y2 (U)	H1 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
51	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
52	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Fairly dense (S)
53	Other old alluvium	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Fairly dense (S)
54	Relict fan	Stable	No (S)	> Stage II (S)	Antho-Tremant complex (S)	M1b (S)	L1 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
55	Throughflow channel	Stable	Slight (U)	None (U)	Ebon-Pinamt complex (S) Antho-Carrizo complex (U)	M1b (S) Y2 (U)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
56	Other old alluvium	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
57	Throughflow channel	Stable	No (S)	None (U)	Torrifluvents (U)	Y2 (U)	L1 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
58	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Very sparse (N/A)
59	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Tremant complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
60	Inactive alluvial fan	Stable	No (S)	> Stage I or II (S)	Antho-Carrizo-Maripo complex (U)	M2 (S)	L1 (S)	Some Distributary (U)	Yes (S)	Moderate (S)	Scattered (N/A)
61	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
62	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
63	Pediment	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Very sparse (N/A)
64	Throughflow channel	Stable	Slight (U)	None (U)	Torrifluvents (U)	Y2 (U)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
65	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Tremant loams (S)	M1b (S) Y2 (U)	L2 (S) H2 (U)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
66	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Antho-Carrizo complex (U)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
67	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
68	Throughflow channel	Stable	No (S)	None (U)	Torrifluvents (U)	M1b (S)	L2 (S)	Tributary (S)	No (U)	No (U)	Along channels (S)
69	Throughflow channel	Stable	Yes (U)	None (U)	Torrifluvents (U)	Y2 (U)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
71	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)
79	Relict fan	Stable	No (S)	> Stage I or II (S)	Ebon-Pinamt complex (S)	M2 (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Fairly dense (S)
81	Throughflow channel	Stable	No (S)	None (U)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
82	Throughflow channel	Stable	No (S)	None (U)	Antho-Carrizo-Maripo complex (U)	M2 (S)	L1 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
83	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S) Tremant loams (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
84	Throughflow channel	Stable	No (S)	None (U)	Ebon-Pinamt complex (S) Tremant loams (S)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
85	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
86	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
87	Throughflow channel	Stable	Slight (U)	None (U)	Ebon-Pinamt complex (S) Denure-Momoli-Carrizo complex (U)	Y2 (U) M1b (S)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
88	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
89	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
90	Throughflow channel	Stable	No (S)	None (U)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
91	Throughflow channel	Stable	Slight (U)	None (U)	Denure-Momoli-Carrizo complex (U)	Y1 (U) M1b (S)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
92	Throughflow channel	Stable	Slight (U)	None (U)	Denure-Momoli-Carrizo complex (U)	Y1 (U) M1b (S)	H2 (U)	Braided (U)	No (U)	No (U)	Along channels (S)
93	Inactive alluvial fan	Stable	Slight (U)	None (U)	Denure-Momoli-Carrizo complex (U)	Y2 (U)	H2 (U)	Some Distributary (U)	Yes (S)	No (U)	Sparse (N/A)

Stability Classification Data for Wittmann Study - White Tanks Area

Landform ID	Landform Classification	Stability Classification	Stream Movement	Calcium Carbonate	Soil Type	Surficial Geology	Flood Hazard Potential	Drainage Pattern	Desert Pavement	Desert Varnish	Vegetation Pattern
94	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
95	Throughflow channel	Stable	No (S)	None (U)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
96	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
97	Inactive alluvial fan	Stable	Slight (U)	None (U)	Antho-Carrizo-Maripo complex (U) Tremant loams (S)	Y2 (U)	H2 (U)	Some Distributary (U)	Yes (S)	No (U)	Scattered (N/A)
98	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Denure-Momoli-Carrizo complex (U) Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
99	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Denure-Momoli-Carrizo complex (U) Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
100	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
101	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
102	Relict fan	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
103	Throughflow channel	Stable	No (S)	None (U)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Braided (U)	No (U)	No (U)	Along channels (S)
104	Inactive alluvial fan	Stable	No (S)	> Stage II (S)	Denure-Momoli-Carrizo complex (U)	M1b (S) Y2 (U)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Sparse (N/A)
105	Other old alluvium	Stable	No (S)	> Stage II (S)	Ebon-Pinamt complex (S)	M1b (S)	L2 (S)	Tributary (S)	Yes (S)	Moderate (S)	Scattered (N/A)

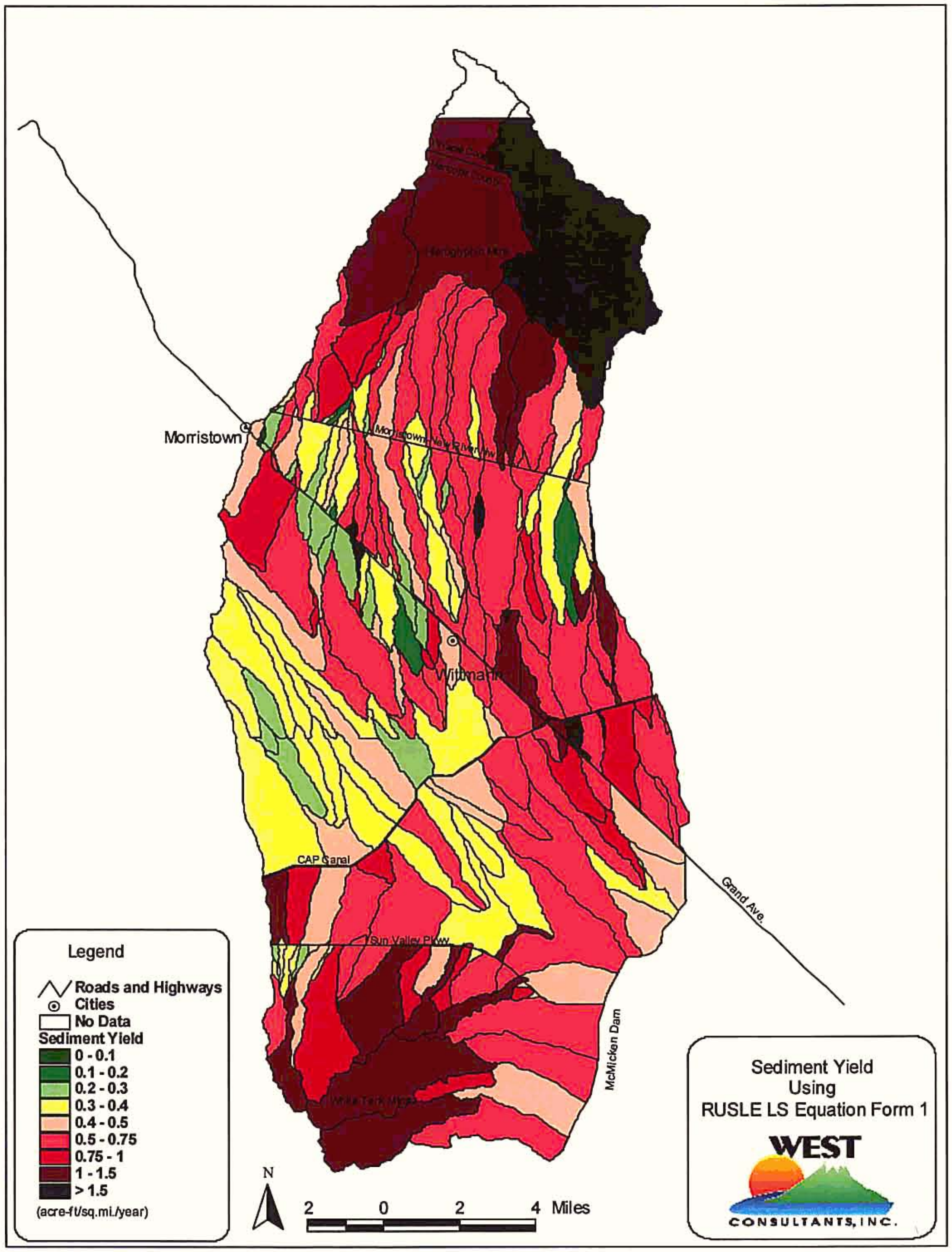
APPENDIX D

Sediment Yield Analysis Figures and Data

D-1. Variation in RUSLE and PSIAC Predictions by Sub-Watershed
D-2. PSIAC and RUSLE Variables and Values by Sub-Watershed for Existing Conditions
D-3. PSIAC Values by Sub-Watersheds for Future Conditions

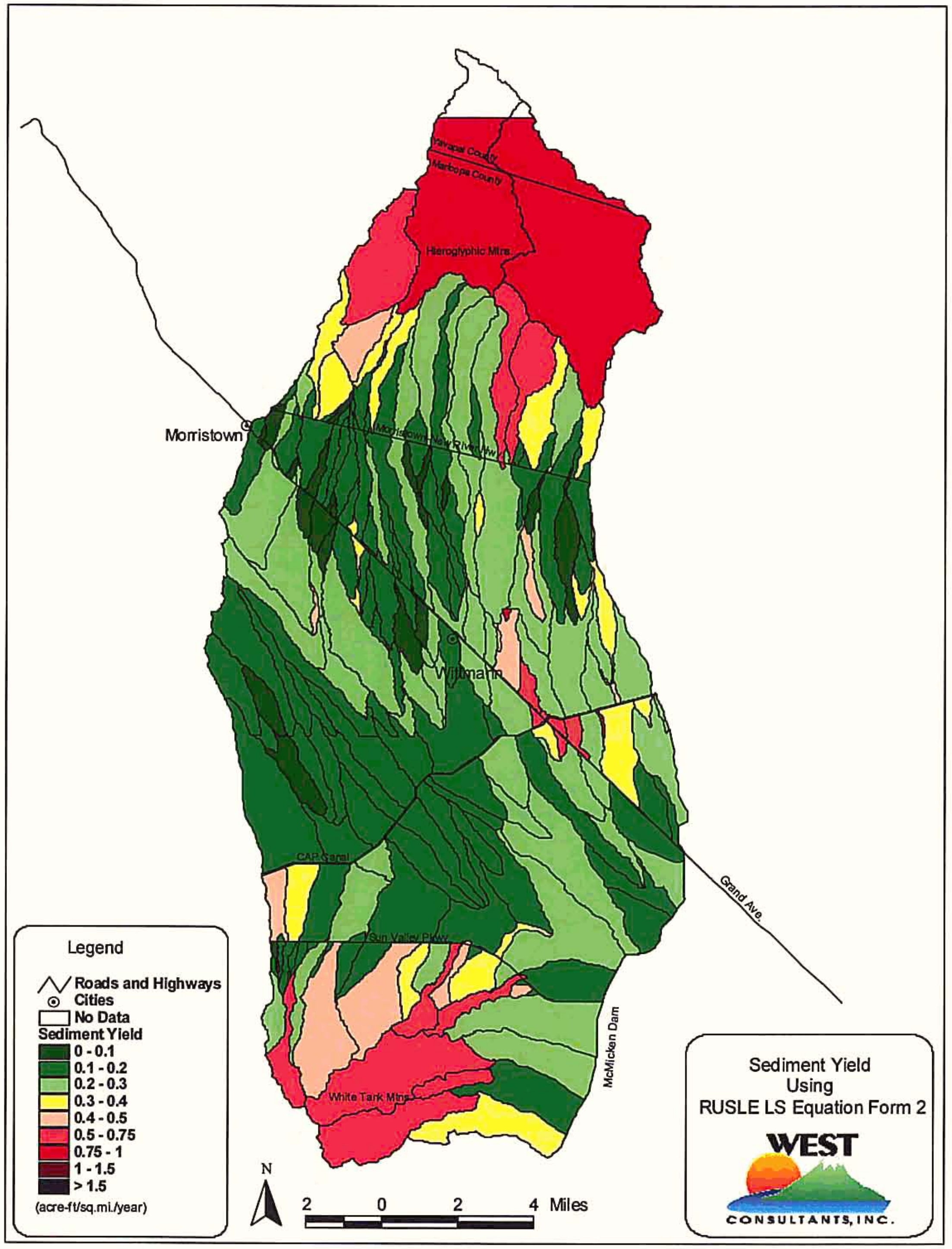
APPENDIX D-1

Variation in RUSLE and PSIAC Predictions by Sub-Watershed

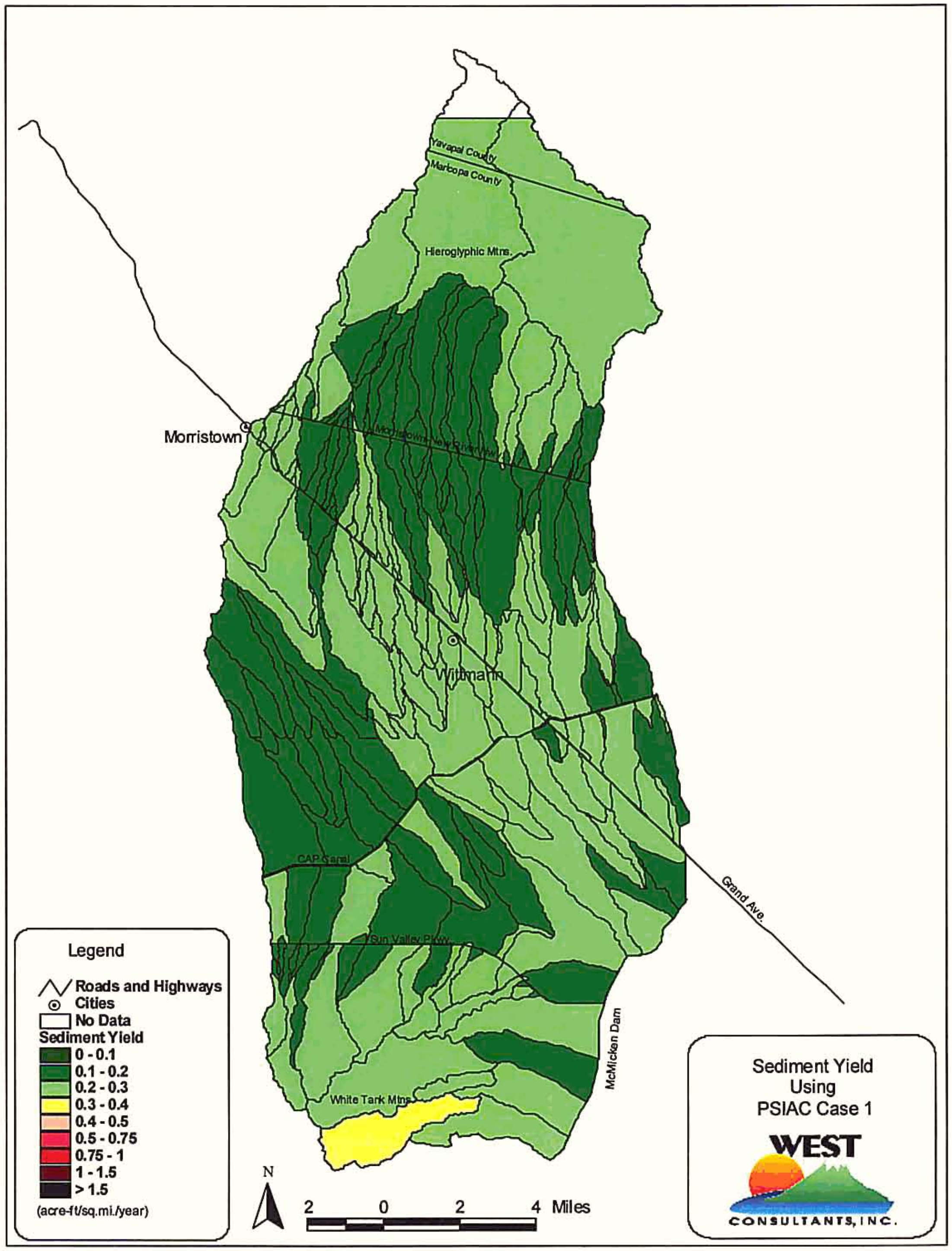


WEST CONSULTANTS, INC.

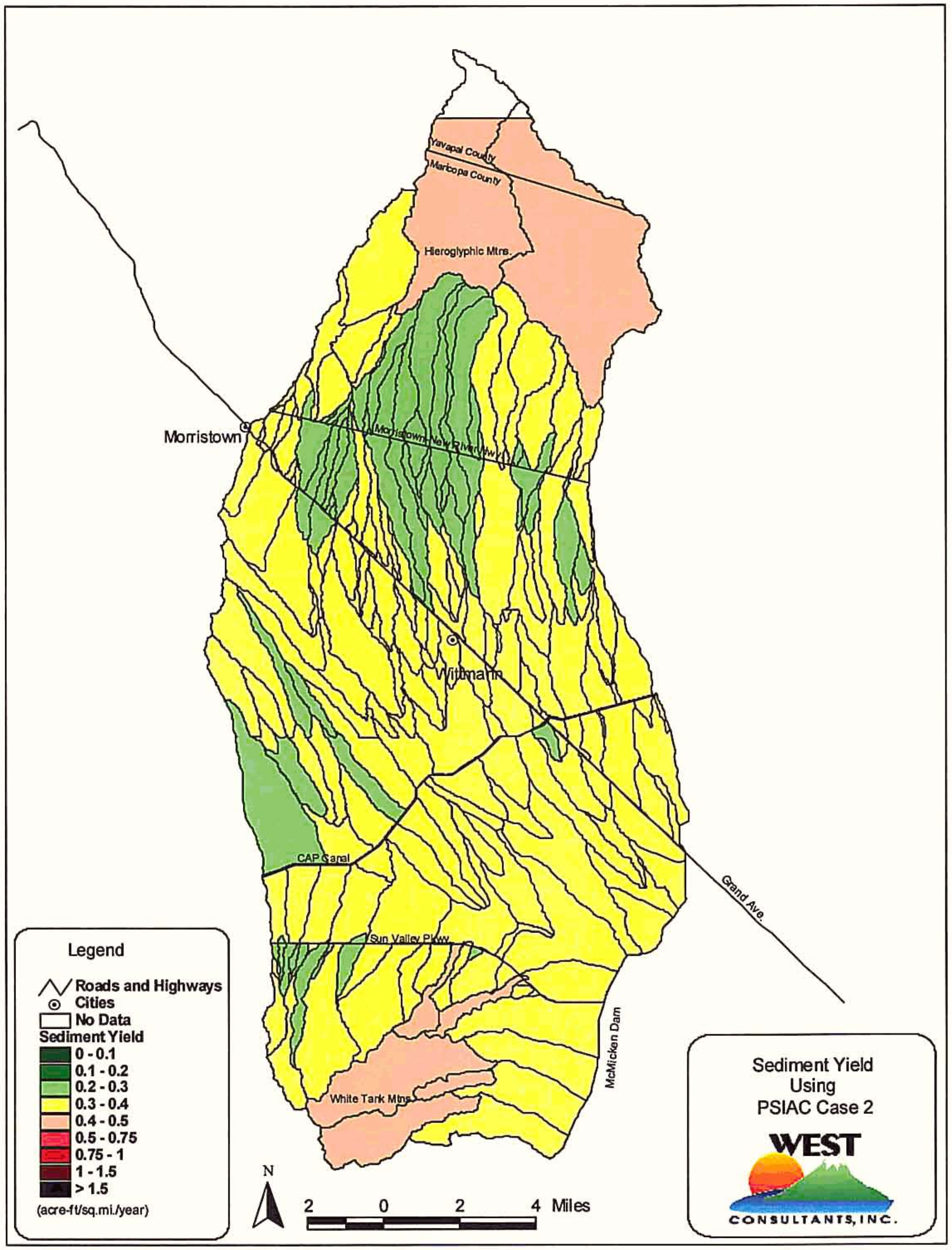
Flood Control District of Maricopa County

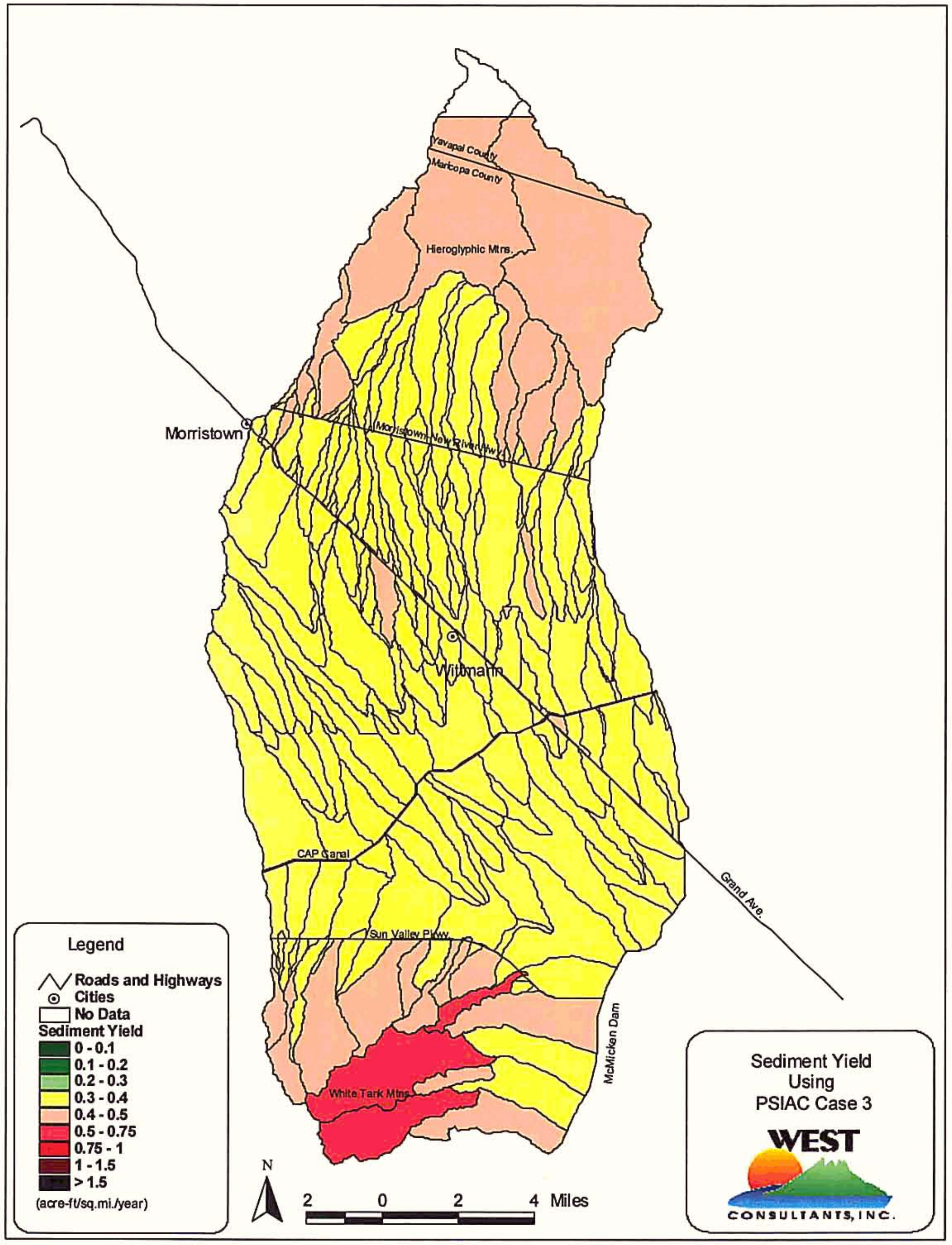


Hieroglyphic Mtns
Morristown
Wittmann
CAP Canal
Sun Valley Pkwy
White Tank Mtns
McMicken Dam
Grand Ave.
Legend
Roads and Highways
Cities
No Data
Sediment Yield
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
> 1.5
(acre-ft/sq.mi./year)
N
2 0 2 4 Miles
Sediment Yield
Using
RUSLE LS Equation Form 2
WEST
CONSULTANTS, INC.



Yavapai County
Maricopa County
Hieroglyphic Mtns.
Morristown
Wittmann
CAP Canal
Sun Valley Pkwy.
Grand Ave.
McMicken Dam
White Tank Mtns.
Legend
Roads and Highways
Cities
No Data
Sediment Yield
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
> 1.5
(acre-ft/sq.mi./year)
N
2 0 2 4 Miles
Sediment Yield
Using
PSIAC Case 1
WEST
CONSULTANTS, INC.


Yavapai County
Maricopa County
Hieroglyphic Mtns.
Morristown
Morristown New River Hwy
Wittmann
CAP Canal
Grand Ave.
Sun Valley Pkwy
McMicken Dam
White Tank Mtns
Legend
Roads and Highways
Cities
No Data
Sediment Yield
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
> 1.5
(acre-ft/sq.mi./year)
N
2 0 2 4 Miles
Sediment Yield
Using
PSIAC Case 2
WEST
CONSULTANTS, INC.


Yavapai County
Maricopa County
Hieroglyphic Mtns.
Morristown
Morristown New River Hwy
Wittmann
CAP Canal
Grand Ave.
Sun Valley Pkwy
McMicken Dam
White Tank Mtns.
Legend
Roads and Highways
Cities
No Data
Sediment Yield
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
> 1.5
(acre-ft/sq.mi./year)
N
2 0 2 4 Miles
Sediment Yield
Using
PSIAC Case 3
WEST
CONSULTANTS, INC.

APPENDIX D-2

PSIAC and RUSLE Variables and Values by Sub-Watershed
Existing Conditions

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Appendix D-2: Existing Conditions by Sub-Watersheds

Source Shapefile	Basinid	Full_basin	Basin name	Area, square feet	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	PSIAC Case 1 rating	PSIAC Case 2 rating	PSIAC Case 3 rating	PSIAC Case 1 Yield, af/ sm /yr	PSIAC Case 2 Yield, af/ sq mi /yr	PSIAC Case 3 Yield, af/ sq mi/ yr
Southeast_poly.shp	35	yes	WI529	4,642,257	4.1801	2.0770	1.40535	0.69829	26.7311	36.7311	41.7311	0.2208	0.3408 \	
Southeast_poly.shp	1	yes	WI528	9,996,470	4.9817	1.8132	1.67485	0.60960	26.088	36.0880	41.0880	0.2131	0.3331	0.3931
Southeast_poly.shp	98	yes	WI527	19,773,933	1.8582	0.7103	0.62473	0.23880	25.2771	35.2771	40.2771	0.2033	0.3233	0.3833
Southeast_poly.shp	31	yes	WI526	1,358,117	4.5287	1.6934	1.52255	0.56932	25.6225	35.6225	40.6225	0.2075	0.3275	0.3875
Southeast_poly.shp	99	yes	WI525	54,098,352	2.8470	1.0175	0.95716	0.34208	25.4654	35.4654	40.4654	0.2056	0.3256	0.3856
Southeast_poly.shp	12	yes	PI630	6,305,091	2.3609	1.1674	0.79373	0.39248	25.413	35.4130	40.4130	0.2050	0.3250	0.3850
Southeast_poly.shp	23	no	PI624	52,977,277	1.9568	0.7397	0.65788	0.24869	25.032	35.0320	40.0320	0.2004	0.3204	0.3804
Southeast_poly.shp	136	yes	WI524	26,446,831	1.5383	0.5076	0.51718	0.17066	26.4204	36.4204	41.4204	0.2170	0.3370	0.3970
Southeast_poly.shp	37	no	PI639	8,864,440	1.5506	0.5417	0.52131	0.18212	26.3974	36.3974	41.3974	0.2168	0.3368	0.3968
Southeast_poly.shp	13	no	PI627	2,742,953	1.5453	0.6677	0.51953	0.22448	25.1041	35.1041	40.1041	0.2013	0.3213	0.3813
Northwest_poly.shp	86	yes	SV286	42,876,018	1.1185	0.4192	0.37604	0.14094	24.2706	34.2706	39.2706	0.1942	0.3113	0.3713
Northwest_poly.shp	84	yes	SV294	73,780,974	1.1416	0.4196	0.38381	0.14107	24.1461	34.1461	39.1461	0.1932	0.3098	0.3698
Northwest_poly.shp	307	yes	IW359	81,181,960	2.2500	0.6592	0.75645	0.22162	25.2093	35.2093	40.2093	0.2025	0.3225	0.3825
Northwest_poly.shp	89	yes	IW350	57,631,024	1.4586	0.6004	0.49038	0.20185	25.2703	35.2703	40.2703	0.2032	0.3232	0.3832
Northwest_poly.shp	78	yes	IW366	29,434,285	1.2128	0.3171	0.40774	0.10661	25.1736	35.1736	40.1736	0.2021	0.3221	0.3821
Northwest_poly.shp	82	yes	SV264	134,265,197	0.9230	0.3119	0.31031	0.10486	23.3493	33.3493	38.3493	0.1868	0.3002	0.3602
Northwest_poly.shp	23	yes	IW322	51,591,155	1.0826	0.4228	0.36397	0.14215	24.0454	34.0454	39.0454	0.1924	0.3085	0.3685
Northwest_poly.shp	83	yes	SV298	30,023,592	0.9043	0.3107	0.30403	0.10446	21.6408	31.6408	36.6408	0.1731	0.2797	0.3397
Northwest_poly.shp	85	yes	SV290	22,684,364	0.7437	0.2579	0.25003	0.08671	23.4934	33.4934	38.4934	0.1880	0.3019	0.3619
Northwest_poly.shp	309	yes	IW353	78,145,730	1.6133	0.6017	0.54239	0.20229	25.0434	35.0434	40.0434	0.2005	0.3205	0.3805
Northwest_poly.shp	90	yes	SV284	7,900,408	0.8355	0.3012	0.28090	0.10126	23.9417	33.9417	38.9417	0.1915	0.3073	0.3673
Northwest_poly.shp	305	yes	IW371	1,475,350	0.2336	0.0890	0.07854	0.02992	25.837	35.8370	40.8370	0.2100	0.3300	0.3900
Northwest_poly.shp	92	yes	IW374	10,801,862	0.6557	0.2265	0.22045	0.07615	25.6538	35.6538	40.6538	0.2079	0.3279	0.3879
Northwest_poly.shp	53	yes	SV272	33,481,902	0.7434	0.2795	0.24993	0.09397	23.3507	33.3507	38.3507	0.1868	0.3002	0.3602
Northwest_poly.shp	311	yes	IW381	10,708,804	1.5242	0.7313	0.51244	0.24586	26.9997	36.9997	41.9997	0.2240	0.3440	0.4040
Northwest_poly.shp	93	yes	IW377	3,138,086	1.1340	0.5610	0.38125	0.18861	26.3273	36.3273	41.3273	0.2159	0.3359	0.3959
Northwest_poly.shp	79	yes	IW382	17,274,603	1.4476	0.5489	0.48668	0.18454	25.5214	35.5214	40.5214	0.2063	0.3263	0.3863
Northwest_poly.shp	94	yes	IW384	2,301,362	0.7148	0.2986	0.24032	0.10039	25.2935	35.2935	40.2935	0.2035	0.3235	0.3835
Northwest_poly.shp	24	yes	IW318	16,257,263	1.0676	0.3382	0.35893	0.11370	23.334	33.3340	38.3340	0.1867	0.3000	0.3600
Northwest_poly.shp	50	yes	SV276	25,739,138	1.1107	0.4077	0.37342	0.13707	23.9247	33.9247	38.9247	0.1914	0.3071	0.3671
Northwest_poly.shp	95	yes	IW386	10,403,945	1.6288	0.7988	0.54760	0.26856	26.8522	37.4476	42.4476	0.2222	0.3494	0.4094
Northwest_poly.shp	49	yes	SV260	35,167,982	1.2418	0.4153	0.41749	0.13962	24.4577	34.4577	39.4577	0.1957	0.3135	0.3735
Northwest_poly.shp	21	yes	IW314	60,647,507	1.2572	0.4573	0.42267	0.15374	23.7042	33.7042	38.7042	0.1896	0.3045	0.3645
Northwest_poly.shp	10	yes	IW390	33,769,304	2.1013	1.0535	0.70646	0.35419	26.6962	38.5107	43.5107	0.2204	0.3621	0.4221
Northwest_poly.shp	47	yes	SV280	29,402,014	1.0996	0.3692	0.36969	0.12413	24.4974	34.4974	39.4974	0.1960	0.3140	0.3740
Northwest_poly.shp	28	yes	IW361	9,959,208	1.4390	0.6017	0.48379	0.20229	24.2751	34.2751	39.2751	0.1942	0.3113	0.3713
Northwest_poly.shp	27	yes	IW358	4,574,871	2.6847	1.2834	0.90260	0.43148	25.6469	35.6469	40.6469	0.2078	0.3278	0.3878
Northwest_poly.shp	71	yes	IW392	31,043,714	2.2893	1.1165	0.76966	0.37537	26.4668	37.2329	42.2329	0.2176	0.3468	0.4068
Northwest_poly.shp	15	yes	IW357	20,788,595	0.6929	0.2622	0.23295	0.08815	22.5092	32.5092	37.5092	0.1801	0.2901	0.3501
Northwest_poly.shp	96	yes	IW330	32,631,125	1.5035	0.6056	0.50548	0.20360	23.6986	33.6986	38.6986	0.1896	0.3044	0.3644
Northwest_poly.shp	75	yes	IW351	8,040,882	0.6039	0.2602	0.20303	0.08748	25.0083	35.0083	40.0083	0.2001	0.3201	0.3801
Northwest_poly.shp	97	yes	IW346	95,991,383	1.6995	0.7183	0.57137	0.24149	25.1889	35.1889	40.1889	0.2023	0.3223	0.3823

Appendix D-2: Existing Conditions by Sub-Watersheds

Source Shapefile	Basinid	Full_basin	Basin name	Area, square feet	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	PSIAC Case 1 rating	PSIAC Case 2 rating	PSIAC Case 3 rating	PSIAC Case 1 Yield, af/ sm /yr	PSIAC Case 2 Yield, af/ sq mi /yr	PSIAC Case 3 Yield, af/ sq mi/ yr
Northwest_poly.shp	81	yes	IW310	32,538,793	0.9702	0.3441	0.32618	0.11569	23.0196	33.0196	38.0196	0.1842	0.2962	0.3562
Northwest_poly.shp	77	yes	IW387	37,660,668	2.5206	1.2950	0.84743	0.43538	24.2092	34.6332	39.6332	0.1937	0.3156	0.3756
Northwest_poly.shp	150	yes	IW360	23,155,852	0.7460	0.3347	0.25081	0.11253	25.9335	35.9335	40.9335	0.2112	0.3312	0.3912
Northwest_poly.shp	227	yes	IW368	8,103,140	1.7241	0.5367	0.57964	0.18044	25.236	35.2360	40.2360	0.2028	0.3228	0.3828
Northwest_poly.shp	99	yes	SV268	38,348,245	1.0888	0.3622	0.36605	0.12177	24.8962	34.8962	39.8962	0.1992	0.3188	0.3788
Northwest_poly.shp	8	yes	IW394	116,340,712	3.0672	1.7289	1.03119	0.58126	26.2129	38.0961	43.0961	0.2146	0.3572	0.4172
Northwest_poly.shp	38	yes	IW349	6,964,960	5.9608	1.1782	2.00402	0.39611	25.997	35.9970	40.9970	0.2120	0.3320	0.3920
Northwest_poly.shp	228	yes	IW352	2,678,035	2.4290	1.0683	0.81663	0.35916	25.8164	35.8164	40.8164	0.2098	0.3298	0.3898
Northwest_poly.shp	33	yes	IW396	16,343,885	2.2353	1.1388	0.75151	0.38286	24.3674	34.4284	39.4284	0.1949	0.3131	0.3731
Northwest_poly.shp	312	yes	IW380	13,934,776	1.1056	0.5173	0.37170	0.17392	22.355	32.4108	37.4108	0.1788	0.2889	0.3489
Northwest_poly.shp	1	yes	IW356	8,229,992	1.0068	0.4741	0.33849	0.15939	25.8671	35.8671	40.8671	0.2104	0.3304	0.3904
Northwest_poly.shp	310	yes	IW354	10,051,022	0.8522	0.3352	0.28651	0.11269	25.312	35.3120	40.3120	0.2037	0.3237	0.3837
Northwest_poly.shp	73	yes	IW372	8,401,547	1.6947	0.5880	0.56976	0.19769	25.7087	35.7087	40.7087	0.2085	0.3285	0.3885
Northwest_poly.shp	101	yes	TW462	2,227,101	0.7184	0.3034	0.24153	0.10200	21.1074	31.1074	36.1074	0.1689	0.2733	0.3333
Northwest_poly.shp	102	yes	TW450	70,781,600	1.3454	0.4739	0.45232	0.15933	23.3536	33.3536	38.3536	0.1868	0.3002	0.3602
Northwest_poly.shp	76	yes	IW375	18,349,786	2.1015	0.6102	0.70652	0.20515	25.7145	35.7145	40.7145	0.2086	0.3286	0.3886
Northwest_poly.shp	103	yes	IW326	9,285,198	1.1849	0.4684	0.39836	0.15748	25.0604	35.0604	40.0604	0.2007	0.3207	0.3807
Northwest_poly.shp	104	yes	TW459	29,131,950	1.8526	0.9708	0.62284	0.32638	23.2946	33.2946	38.2946	0.1864	0.2995	0.3595
Northwest_poly.shp	9	yes	IW364	32,120,283	0.9865	0.5288	0.33166	0.17778	26.7317	36.7317	41.7317	0.2208	0.3408	0.4008
Northwest_poly.shp	308	yes	IW362	5,000,872	1.4653	0.5705	0.49263	0.19180	25.4291	35.4291	40.4291	0.2052	0.3252	0.3852
Northwest_poly.shp	105	yes	IW334	36,207,440	0.8732	0.3655	0.29357	0.12288	25.617	35.6170	40.6170	0.2074	0.3274	0.3874
Northwest_poly.shp	80	yes	TW448	9,670,376	1.5824	0.5237	0.53200	0.17607	26.1784	36.1784	41.1784	0.2141	0.3341	0.3941
Northwest_poly.shp	106	yes	TW452	71,634,061	1.6131	0.6770	0.54232	0.22761	23.1061	33.1061	38.1061	0.1849	0.2973	0.3573
Northwest_poly.shp	30	yes	IW338	9,452,145	1.6513	0.6577	0.55517	0.22112	25.7362	35.7362	40.7362	0.2088	0.3288	0.3888
Northwest_poly.shp	473	yes	TW446	19,277,076	0.7563	0.3953	0.25427	0.13290	26.4946	36.4946	41.4946	0.2179	0.3379	0.3979
Northwest_poly.shp	45	yes	IW342	9,854,960	1.4040	0.5576	0.47202	0.18747	25.5387	35.5387	40.5387	0.2065	0.3265	0.3865
Northwest_poly.shp	474	yes	TW432	22,962,245	0.5067	0.2115	0.17035	0.07111	25.2986	35.2986	40.2986	0.2036	0.3236	0.3836
Northwest_poly.shp	107	no	IW395	296,451,882	4.0865	2.3239	1.37388	0.78130	29.721	42.6174	47.6174	0.2567	0.4114	0.4714
Northwest_poly.shp	472	yes	TW431	25,008,405	1.6454	0.6448	0.55318	0.21678	25.2834	35.2834	40.2834	0.2034	0.3234	0.3834
Northwest_poly.shp	61	yes	TW454	9,917,426	0.9319	0.2465	0.31330	0.08287	20.9748	30.9748	35.9748	0.1678	0.2717	0.3317
Northwest_poly.shp	63	yes	TW458	18,670,119	1.0469	0.4253	0.35197	0.14299	21.5159	31.5159	36.5159	0.1721	0.2782	0.3382
Northwest_poly.shp	392	yes	TW430	84,960,352	1.1877	0.4884	0.39930	0.16420	25.0722	35.0722	40.0722	0.2009	0.3209	0.3809
Northwest_poly.shp	108	yes	TW460	64,544,671	1.6827	0.8295	0.56572	0.27888	22.8025	32.9925	37.9925	0.1824	0.2959	0.3559
Northwest_poly.shp	109	yes	TW444	10,062,694	0.6948	0.2504	0.23359	0.08418	25.9931	35.9931	40.9931	0.2119	0.3319	0.3919
Northwest_poly.shp	62	yes	TW456	4,917,107	0.7266	0.2035	0.24428	0.06842	20.3094	30.3094	35.3094	0.1625	0.2637	0.3237
Northwest_poly.shp	69	yes	TW440	3,017,985	2.4863	0.7761	0.83589	0.26092	25.4609	35.4609	40.4609	0.2055	0.3255	0.3855
Northwest_poly.shp	389	yes	TW434	15,858,241	2.2247	0.8075	0.74794	0.27148	25.6227	35.6227	40.6227	0.2075	0.3275	0.3875
Northwest_poly.shp	110	yes	TW442	10,514,278	2.8742	0.7782	0.96631	0.26163	25.6584	35.6584	40.6584	0.2079	0.3279	0.3879
Northwest_poly.shp	111	yes	TW436	18,798,758	1.4390	0.5650	0.48379	0.18995	25.8688	35.8688	40.8688	0.2104	0.3304	0.3904
Northwest_poly.shp	112	yes	IW388	34,169,785	1.0664	0.3846	0.35852	0.12930	22.4416	32.4416	37.4416	0.1795	0.2893	0.3493
Northwest_poly.shp	476	yes	IW363	17,501,281	0.8365	0.2677	0.28123	0.09000	21.5647	31.5647	36.5647	0.1725	0.2788	0.3388
Northwest_poly.shp	475	yes	IW312	15,840,134	1.0310	0.3686	0.34662	0.12392	20.9687	30.9687	35.9687	0.1678	0.2716	0.3316

Appendix D-2: Existing Conditions by Sub-Watersheds

Source Shapefile	Basinid	Full_basin	Basin name	Area, square feet	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	PSIAC Case 1 rating	PSIAC Case 2 rating	PSIAC Case 3 rating	PSIAC Case 1 Yield, af/ sm /yr	PSIAC Case 2 Yield, af/ sq mi /yr	PSIAC Case 3 Yield, af/ sq mi/ yr
Northwest_poly.shp	113	yes	IW365	13,183,462	1.3211	0.3970	0.44415	0.13347	20.9545	30.9545	35.9545	0.1676	0.2715	0.3315
Northwest_poly.shp	14	yes	IW389	3,658,881	0.5922	0.2429	0.19910	0.08166	20.4271	30.4271	35.4271	0.1634	0.2651	0.3251
Northwest_poly.shp	72	yes	IW367	1,426,656	0.4893	0.2305	0.16450	0.07749	21.4392	31.4392	36.4392	0.1715	0.2773	0.3373
Northwest_poly.shp	114	yes	IW369	22,160,895	1.1231	0.3849	0.37759	0.12940	21.1926	31.1926	36.1926	0.1695	0.2743	0.3343
Northwest_poly.shp	306	yes	IW370	24,517,615	2.2020	0.5644	0.74031	0.18975	25.1975	35.1975	40.1975	0.2024	0.3224	0.3824
Southwest_poly.shp	22	yes	SV219	25,006,926	3.7562	1.3601	1.26283	0.45727	25.5823	35.5823	40.5823	0.2070	0.3270	0.3870
Southwest_poly.shp	18	yes	SV258	20,516,783	1.8249	0.8697	0.61353	0.29239	25.5519	36.7460	41.7460	0.2066	0.3410	0.4010
Southwest_poly.shp	16	yes	SV256	1,683,918	1.1141	0.3480	0.37456	0.11700	24.4492	34.4492	39.4492	0.1956	0.3134	0.3734
Southwest_poly.shp	48	yes	SV252	4,106,185	1.0792	0.4462	0.36283	0.15001	22.2964	32.2964	37.2964	0.1784	0.2876	0.3476
Southwest_poly.shp	121	yes	SV251	7,456,899	0.9769	0.3955	0.32843	0.13297	21.0044	31.0044	36.0044	0.1680	0.2721	0.3321
Southwest_poly.shp	122	yes	SV218	35,863,497	2.2590	0.9422	0.75948	0.31677	24.9996	34.9996	39.9996	0.2000	0.3200	0.3800
Southwest_poly.shp	8	yes	SV244	26,376,162	1.4097	0.6395	0.47394	0.21500	22.247	32.2616	37.2616	0.1780	0.2871	0.3471
Southwest_poly.shp	20	yes	SV240	102,179,073	2.5935	1.2086	0.87193	0.40633	26.9139	38.4045	43.4045	0.2230	0.3609	0.4209
Southwest_poly.shp	119	yes	SV216	45,395,623	1.2745	0.5243	0.42849	0.17627	24.801	34.8009	39.8009	0.1984	0.3176	0.3776
Southwest_poly.shp	36	yes	WT150	162,655,369	3.3226	1.6891	1.11706	0.56788	32.6059	45.4806	50.4806	0.2913	0.4458	0.5096
Southwest_poly.shp	17	yes	SV242	2,618,618	1.0462	0.4478	0.35173	0.15055	20.2477	30.2477	35.2477	0.1620	0.2630	0.3230
Southwest_poly.shp	38	yes	WT140	105,640,674	3.8030	2.0060	1.27857	0.67442	34.1502	47.0997	52.0997	0.3098	0.4652	0.5420
Southwest_poly.shp	120	yes	SV214	52,127,348	2.1317	0.7482	0.71668	0.25154	25.1326	35.1326	40.1326	0.2016	0.3216	0.3816
Southwest_poly.shp	25	yes	SV236	16,326,175	1.5712	0.5547	0.52824	0.18649	21.0273	31.0273	36.0273	0.1682	0.2723	0.3323
Southwest_poly.shp	24	yes	SV212	112,675,793	1.6043	0.5777	0.53937	0.19422	23.8931	33.8936	38.8936	0.1911	0.3067	0.3667
Southwest_poly.shp	23	yes	SV232	85,304,014	3.4994	1.4877	1.17650	0.50016	27.0951	38.7267	43.7267	0.2251	0.3647	0.4247
Southwest_poly.shp	27	yes	SV220	16,737,423	2.5144	0.8534	0.84534	0.28691	25.2628	35.2628	40.2628	0.2032	0.3232	0.3832
Southwest_poly.shp	29	yes	SV208	29,726,987	3.9902	1.8759	1.34151	0.63068	32.1488	44.4473	49.4473	0.2858	0.4334	0.4934
Southwest_poly.shp	35	yes	IW300	41,255,995	1.7147	0.5322	0.57648	0.17893	25.4388	35.4388	40.4388	0.2053	0.3253	0.3853
Southwest_poly.shp	31	yes	SV230	23,733,336	2.3155	1.0638	0.77847	0.35765	25.7309	36.7706	41.7706	0.2088	0.3413	0.4013
Southwest_poly.shp	115	yes	WT130	81,975,079	2.1187	1.0804	0.71231	0.36323	27.2062	38.4647	43.4647	0.2265	0.3616	0.4216
Southwest_poly.shp	30	yes	SV210	20,028,989	1.4860	0.6431	0.49959	0.21621	23.6812	34.3139	39.3139	0.1895	0.3118	0.3718
Southwest_poly.shp	37	yes	WT160	22,656,489	2.8848	1.5419	0.96987	0.51839	31.2905	43.6873	48.6873	0.2755	0.4243	0.4843
Southwest_poly.shp	34	yes	IW302	36,979,432	1.1211	0.4022	0.37691	0.13522	24.8753	34.8753	39.8753	0.1990	0.3185	0.3785
Southwest_poly.shp	44	yes	TW408	25,371,761	3.3835	1.8052	1.13753	0.60691	32.5422	45.2022	50.2022	0.2905	0.4424	0.5040
Southwest_poly.shp	109	yes	TW418	38,140,691	1.3842	0.5824	0.46537	0.19580	25.713	35.7130	40.7130	0.2086	0.3286	0.3886
Southwest_poly.shp	32	yes	SV205	14,642,889	2.7570	1.2684	0.92690	0.42644	26.755	38.2346	43.2346	0.2211	0.3588	0.4188
Southwest_poly.shp	39	yes	WT100	107,359,761	1.7617	0.8779	0.59228	0.29515	26.7963	37.7260	42.7260	0.2216	0.3527	0.4127
Southwest_poly.shp	42	yes	TW420	22,518,827	0.8996	0.3026	0.30245	0.10173	24.5791	34.5791	39.5791	0.1966	0.3150	0.3750
Southwest_poly.shp	41	yes	TW414	32,574,350	2.2136	1.0393	0.74421	0.34941	25.9306	36.9724	41.9724	0.2112	0.3437	0.4037
Southwest_poly.shp	116	yes	WT120	78,157,022	1.2713	0.5479	0.42741	0.18420	25.7387	35.8952	40.8952	0.2089	0.3307	0.3907
Southwest_poly.shp	117	yes	TW412	57,532,013	1.0155	0.4188	0.34141	0.14080	24.7845	34.7845	39.7845	0.1983	0.3174	0.3774
Southwest_poly.shp	40	yes	WT110	80,729,483	1.7727	0.8148	0.59598	0.27394	24.8013	35.1911	40.1911	0.1984	0.3223	0.3823
Southwest_poly.shp	33	yes	SV203	2,117,579	1.0249	0.3561	0.34457	0.11972	20.7551	30.7551	35.7551	0.1660	0.2691	0.3291
Southwest_poly.shp	10	yes	TW424	41,720,370	1.6975	0.6547	0.57070	0.22011	25.9228	35.9228	40.9228	0.2111	0.3311	0.3911
Southwest_poly.shp	110	yes	TW422	19,603,900	2.1291	0.7724	0.71580	0.25968	25.8549	35.8549	40.8549	0.2103	0.3303	0.3903
Southwest_poly.shp	46	yes	TW410	8,585,572	3.0171	0.9668	1.01435	0.32504	25.61	35.6100	40.6100	0.2073	0.3273	0.3873

Appendix D-2: Existing Conditions by Sub-Watersheds

Source Shapefile	Basinid	Full_basin	Basin name	Area, square feet	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	PSIAC Case 1 rating	PSIAC Case 2 rating	PSIAC Case 3 rating	PSIAC Case 1 Yield, af/ sm /yr	PSIAC Case 2 Yield, af/ sq mi /yr	PSIAC Case 3 Yield, af/ sq mi/ yr
Southwest_poly.shp	113	yes	TW400	119,064,540	1.6755	0.6682	0.56330	0.22465	25.9382	35.9382	40.9382	0.2113	0.3313	0.3913
Southwest_poly.shp	45	yes	TW406	4,551,115	2.8058	1.4614	0.94331	0.49132	25.603	36.5694	41.5694	0.2072	0.3388	0.3988
Southwest_poly.shp	11	yes	WI510	65,693,386	1.6477	0.5963	0.55396	0.20048	25.4461	35.4461	40.4461	0.2054	0.3254	0.3854
Southwest_poly.shp	43	yes	TW404	58,340,627	1.3538	0.5501	0.45515	0.18494	24.3036	34.3061	39.3061	0.1944	0.3117	0.3717
Southwest_poly.shp	6	yes	WI512	37,781,334	2.3900	0.8924	0.80352	0.30002	25.8813	35.8813	40.8813	0.2106	0.3306	0.3906
Southwest_poly.shp	50	yes	WI508	19,487,607	2.7581	0.8747	0.92727	0.29407	26.1247	36.1247	41.1247	0.2135	0.3335	0.3935
Southwest_poly.shp	15	yes	WI502	33,689,907	1.1604	0.4632	0.39013	0.15573	23.9644	33.9644	38.9644	0.1917	0.3076	0.3676
Southwest_poly.shp	114	yes	WI504	37,621,112	1.2536	0.5778	0.42146	0.19426	25.3905	35.3905	40.3905	0.2047	0.3247	0.3847
Southwest_poly.shp	28	yes	SV202	40,116,247	1.0656	0.3921	0.35825	0.13182	24.4833	34.4833	39.4833	0.1959	0.3138	0.3738
Southwest_poly.shp	7	yes	SV200	65,926,181	1.1253	0.4389	0.37833	0.14756	24.5522	34.5522	39.5522	0.1964	0.3146	0.3746
Southwest_poly.shp	21	yes	SV254	2,708,859	0.7007	0.2887	0.23558	0.09706	20.884	30.8840	35.8840	0.1671	0.2706	0.3306
Southwest_poly.shp	49	yes	WI518	14,833,272	1.8829	0.7311	0.63303	0.24580	25.5967	35.5967	40.5967	0.2072	0.3272	0.3872
Southwest_poly.shp	19	yes	SV248	35,456,763	3.0154	1.5265	1.01378	0.51321	29.6026	41.6371	46.6371	0.2552	0.3997	0.4597
Southwest_poly.shp	52	yes	SV246	4,369,420	0.7966	0.3605	0.26782	0.12120	21.1608	31.1608	36.1608	0.1693	0.2739	0.3339
Southwest_poly.shp	51	yes	SV250	3,380,729	1.0857	0.4379	0.36501	0.14722	20.7374	30.7374	35.7374	0.1659	0.2689	0.3289
Southwest_poly.shp	56	yes	TW416	16,401,418	1.2607	0.4580	0.42385	0.15398	26.0495	36.0495	41.0495	0.2126	0.3326	0.3926
Southwest_poly.shp	118	yes	TW402	137,004,267	1.6851	0.7152	0.56653	0.24045	25.1542	35.1544	40.1544	0.2019	0.3219	0.3819
Southwest_poly.shp	13	yes	WI516	3,994,075	3.9672	1.6304	1.33377	0.54814	26.0345	36.0345	41.0345	0.2124	0.3324	0.3924
Southwest_poly.shp	12	yes	WI514	9,824,990	2.2132	0.9221	0.74408	0.31001	21.8903	31.8903	36.8903	0.1751	0.2827	0.3427
Southwest_poly.shp	54	yes	WI500	29,876,093	1.2576	0.6047	0.42281	0.20330	24.8114	34.8114	39.8114	0.1985	0.3177	0.3777
Southwest_poly.shp	55	yes	WI506	43,287,691	1.4068	0.5218	0.47297	0.17543	25.0872	35.0872	40.0872	0.2011	0.3211	0.3811
Northeast_poly.shp	113	yes	TW496	15,272,003	1.0371	0.3234	0.34867	0.10873	21.6188	31.6188	36.6188	0.1730	0.2794	0.3394
Northeast_poly.shp	110	yes	TW494	26,552,322	1.0577	0.3890	0.35560	0.13078	25.2666	35.2666	40.2666	0.2032	0.3232	0.3832
Northeast_poly.shp	108	yes	TW484	15,659,748	1.6793	0.6275	0.56458	0.21097	25.8988	35.8988	40.8988	0.2108	0.3308	0.3908
Northeast_poly.shp	109	yes	TW490	64,023,615	1.5020	0.4600	0.50497	0.15465	21.2952	31.3407	36.3407	0.1704	0.2761	0.3361
Northeast_poly.shp	103	yes	WI580	47,125,319	2.0127	0.8467	0.67667	0.28466	22.2215	32.7570	37.7570	0.1778	0.2931	0.3531
Northeast_poly.shp	112	yes	TW488	10,071,323	1.3902	0.4274	0.46739	0.14369	25.033	35.0330	40.0330	0.2004	0.3204	0.3804
Northeast_poly.shp	237	yes	TW492	3,269,535	0.6400	0.1340	0.21517	0.04505	20.176	30.1760	35.1760	0.1614	0.2621	0.3221
Northeast_poly.shp	101	yes	WI576	99,578,425	2.2164	0.7950	0.74515	0.26728	22.2414	32.5057	37.5057	0.1779	0.2901	0.3501
Northeast_poly.shp	111	yes	TW486	8,630,113	1.1546	0.5418	0.38818	0.18215	25.3065	35.3065	40.3065	0.2037	0.3237	0.3837
Northeast_poly.shp	106	yes	TW480	21,007,704	1.5809	0.6432	0.53150	0.21624	25.883	35.8830	40.8830	0.2106	0.3306	0.3906
Northeast_poly.shp	107	yes	TW482	21,089,143	1.6256	0.6353	0.54653	0.21359	25.6985	35.6985	40.6985	0.2084	0.3284	0.3884
Northeast_poly.shp	102	yes	WI578	11,042,306	0.9334	0.3218	0.31381	0.10819	20.6202	30.6202	35.6202	0.1650	0.2674	0.3274
Northeast_poly.shp	94	yes	WI560	156,116,594	1.8824	0.6486	0.63286	0.21806	23.3283	33.6209	38.6209	0.1866	0.3035	0.3635
Northeast_poly.shp	100	yes	WI574	6,105,162	4.6936	0.9583	1.57799	0.32218	24.9698	34.9698	39.9698	0.1998	0.3196	0.3796
Northeast_poly.shp	76	no	PI687	467,361,378	5.0706	2.8931	1.70474	0.97266	31.0076	44.0073	49.0073	0.2721	0.4281	0.4881
Southwest_poly.shp	56	yes	TW478	7,323,624	1.3944	0.5421	0.46880	0.18225	25.3949	35.3949	40.3949	0.2047	0.3247	0.3847
Northeast_poly.shp	104	yes	WI582	10,461,624	1.5880	0.6793	0.53389	0.22838	25.5943	35.5943	40.5943	0.2071	0.3271	0.3871
Northeast_poly.shp	105	yes	WI584	35,040,668	2.0310	0.7189	0.68282	0.24169	25.7126	35.7126	40.7126	0.2086	0.3286	0.3886
Northeast_poly.shp	99	yes	WI572	57,446,357	3.4953	1.7092	1.17512	0.57463	25.7137	37.2421	42.2421	0.2086	0.3469	0.4069
Northeast_poly.shp	91	yes	WI554	28,536,705	3.1632	1.2979	1.06347	0.43635	25.8453	35.8453	40.8453	0.2101	0.3301	0.3901
Northeast_poly.shp	93	yes	WI558	1,564,111	2.5404	1.0855	0.85408	0.36495	25.4827	35.4827	40.4827	0.2058	0.3258	0.3858

Appendix D-2: Existing Conditions by Sub-Watersheds

Source Shapefile	Basinid	Full_basin	Basin name	Area, square feet	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	RUSLE LS Equation 1, tons/ acre/ yr	RUSLE LS Equation 2, tons/ acre/ yr	PSIAC Case 1 rating	PSIAC Case 2 rating	PSIAC Case 3 rating	PSIAC Case 1 Yield, af/ sm /yr	PSIAC Case 2 Yield, af/ sq mi /yr	PSIAC Case 3 Yield, af/ sq mi/ yr
Northeast_poly.shp	92	yes	WI556	1,102,668	5.4945	2.4027	1.84725	0.80779	27.6421	37.6421	42.6421	0.2317	0.3517	0.4117
Northeast_poly.shp	98	yes	WI570	62,382,965	3.1147	1.6755	1.04716	0.56330	26.7639	39.1496	44.1496	0.2212	0.3698	0.4298
Northeast_poly.shp	86	yes	WI544	50,009,041	1.7525	0.7489	0.58919	0.25178	26.2026	36.2026	41.2026	0.2144	0.3344	0.3944
Northeast_poly.shp	95	yes	WI562	24,313,666	1.7772	0.5917	0.59749	0.19893	21.6701	32.5938	37.5938	0.1734	0.2911	0.3511
Northeast_poly.shp	37	yes	WI566	3,093,065	1.5251	0.5905	0.51274	0.19853	20.6244	30.6244	35.6244	0.1650	0.2675	0.3275
Northeast_poly.shp	11	yes	WI542	32,725,356	2.1242	0.8635	0.71416	0.29031	25.0637	35.0637	40.0637	0.2008	0.3208	0.3808
Northeast_poly.shp	97	yes	WI568	2,754,837	1.0725	0.3338	0.36057	0.11222	20.5024	30.5024	35.5024	0.1640	0.2660	0.3260
Northeast_poly.shp	96	yes	WI564	50,339,902	1.6240	0.9242	0.54599	0.31072	25.8173	38.5592	43.5592	0.2098	0.3627	0.4227
Northeast_poly.shp	175	yes	WI552	11,518,895	4.3927	1.6839	1.47683	0.56613	26.2057	36.2057	41.2057	0.2145	0.3345	0.3945
Northeast_poly.shp	87	yes	WI546	16,869,628	2.9075	1.2023	0.97750	0.40421	26.7944	36.7944	41.7944	0.2215	0.3415	0.4015
Northeast_poly.shp	88	yes	WI548	8,595,820	1.0581	0.2307	0.35573	0.07756	22.845	32.8471	37.8471	0.1828	0.2942	0.3542
Northeast_poly.shp	35	yes	WI550	3,989,813	3.0805	1.5044	1.03566	0.50578	26.1689	36.1689	41.1689	0.2140	0.3340	0.3940
Northeast_poly.shp	84	yes	WI538	61,518,828	1.0490	0.3865	0.35267	0.12994	23.4654	34.2189	39.2189	0.1877	0.3106	0.3706
Northeast_poly.shp	85	yes	WI540	34,728,620	1.4387	0.8575	0.48369	0.28829	26.02	39.0200	44.0200	0.2122	0.3682	0.4282
Northeast_poly.shp	80	yes	WI530	66,225,395	2.1742	0.8748	0.73097	0.29411	25.377	35.3770	40.3770	0.2045	0.3245	0.3845
Northeast_poly.shp	83	yes	WI536	38,194,477	0.5874	0.2306	0.19748	0.07753	22.0074	32.0074	37.0074	0.1761	0.2841	0.3441
Northeast_poly.shp	74	yes	PI681	27,773,319	1.2592	0.4817	0.42334	0.16195	23.3795	33.4295	38.4295	0.1870	0.3012	0.3612
Northeast_poly.shp	81	yes	WI532	8,999,782	3.9336	1.1408	1.32248	0.38354	26.6813	36.6813	41.6813	0.2202	0.3402	0.4002
Northeast_poly.shp	82	yes	WI534	12,099,146	0.9178	0.4246	0.30856	0.14275	23.3149	33.3149	38.3149	0.1865	0.2998	0.3598
Northeast_poly.shp	75	yes	PI684	21,481,040	2.0234	0.9551	0.68027	0.32110	24.8912	35.6820	40.6820	0.1991	0.3282	0.3882
Northeast_poly.shp	34	yes	PI693	23,309,199	1.7549	0.7639	0.59000	0.25682	24.7695	34.7695	39.7695	0.1982	0.3172	0.3772
Northeast_poly.shp	77	yes	PI690	16,816,656	2.1190	0.8435	0.71241	0.28358	25.4799	35.4799	40.4799	0.2058	0.3258	0.3858
Northeast_poly.shp	176	no	PI678	26,034,073	3.6881	1.1655	1.23994	0.39184	25.3913	35.3913	40.3913	0.2047	0.3247	0.3847
Northeast_poly.shp	72	yes	PI675	2,596,845	3.7686	1.2512	1.26700	0.42065	24.7543	34.7543	39.7543	0.1980	0.3171	0.3771
Northeast_poly.shp	70	no	PI672	41,513,760	1.8020	0.8266	0.60583	0.27790	25.0191	35.0191	40.0191	0.2002	0.3202	0.3802
					2.1608	0.9887	0.72647	0.33241						
					Weighted Average, PSIAC rating				25.83762	36.5675	41.5675			
					PSIAC Sediment Yield, tons/acre/year				0.2101	0.3388	0.3988			

APPENDIX D-3

PSIAC Values by Sub-Watersheds
Future Conditions

WEST
CONSULTANTS, INC.

Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Southeast_poly.shp	35	WI529	yes	4,642,257	28.8296	38.8296	43.8296	0.24596	0.36596	0.42596
Southeast_poly.shp	1	WI528	yes	9,996,470	27.8359	37.8359	42.8359	0.23403	0.35403	0.41403
Southeast_poly.shp	98	WI527	yes	19,773,933	26.7866	36.7866	41.7866	0.22144	0.34144	0.40144
Southeast_poly.shp	31	WI526	yes	1,358,117	27.5264	37.5264	42.5264	0.23032	0.35032	0.41032
Southeast_poly.shp	99	WI525	yes	54,098,352	27.1492	37.1492	42.1492	0.22579	0.34579	0.40579
Southeast_poly.shp	12	PI630	yes	6,305,091	26.7287	36.7287	41.7287	0.22074	0.34074	0.40074
Southeast_poly.shp	23	PI624	no	52,977,277	26.9825	36.9825	41.9825	0.22379	0.34379	0.40379
Southeast_poly.shp	136	WI524	yes	26,446,831	28.2695	38.2695	43.2695	0.23923	0.35923	0.41923
Southeast_poly.shp	37	PI639	no	8,864,440	28.1596	38.1596	43.1596	0.23792	0.35792	0.41792
Southeast_poly.shp	13	PI627	no	2,742,953	26.4437	36.4437	41.4437	0.21732	0.33732	0.39732
Northwest_poly.shp	86	SV286	yes	42,876,018	24.2714	34.2714	39.2714	0.19417	0.31126	0.37126
Northwest_poly.shp	84	SV294	yes	73,780,974	24.4058	34.4058	39.4058	0.19525	0.31287	0.37287
Northwest_poly.shp	307	IW359	yes	81,181,960	26.3702	36.3702	41.3702	0.21644	0.33644	0.39644
Northwest_poly.shp	89	IW350	yes	57,631,024	26.0371	36.0371	41.0371	0.21245	0.33245	0.39245
Northwest_poly.shp	78	IW366	yes	29,434,285	26.4103	36.4103	41.4103	0.21692	0.33692	0.39692
Northwest_poly.shp	82	SV264	yes	134,265,197	23.8565	33.8565	38.8565	0.19085	0.30628	0.36628
Northwest_poly.shp	23	IW322	yes	51,591,155	25.1548	35.1548	40.1548	0.20186	0.32186	0.38186
Northwest_poly.shp	83	SV298	yes	30,023,592	22.5007	32.5007	37.5007	0.18001	0.29001	0.35001
Northwest_poly.shp	85	SV290	yes	22,684,364	23.8725	33.8725	38.8725	0.19098	0.30647	0.36647
Northwest_poly.shp	309	IW353	yes	78,145,730	26.4608	36.4608	41.4608	0.21753	0.33753	0.39753
Northwest_poly.shp	90	SV284	yes	7,900,408	23.6082	33.6082	38.6082	0.18887	0.30330	0.36330
Northwest_poly.shp	305	IW371	yes	1,475,350	26.7849	36.7849	41.7849	0.22142	0.34142	0.40142
Northwest_poly.shp	92	IW374	yes	10,801,862	26.7161	36.7161	41.7161	0.22059	0.34059	0.40059
Northwest_poly.shp	53	SV272	yes	33,481,902	24.5960	34.5960	39.5960	0.19677	0.31515	0.37515
Northwest_poly.shp	311	IW381	yes	10,708,804	28.0437	38.0437	43.0437	0.23652	0.35652	0.41652
Northwest_poly.shp	93	IW377	yes	3,138,086	26.4241	36.4241	41.4241	0.21709	0.33709	0.39709
Northwest_poly.shp	79	IW382	yes	17,274,603	27.0388	37.0388	42.0388	0.22447	0.34447	0.40447
Northwest_poly.shp	94	IW384	yes	2,301,362	27.9441	37.9441	42.9441	0.23533	0.35533	0.41533
Northwest_poly.shp	24	IW318	yes	16,257,263	24.4697	34.4697	39.4697	0.19576	0.31364	0.37364
Northwest_poly.shp	50	SV276	yes	25,739,138	25.3618	35.3618	40.3618	0.20434	0.32434	0.38434
Northwest_poly.shp	95	IW386	yes	10,403,945	27.7827	38.3781	43.3781	0.23339	0.36054	0.42054
Northwest_poly.shp	49	SV260	yes	35,167,982	26.0320	36.0320	41.0320	0.21238	0.33238	0.39238
Northwest_poly.shp	21	IW314	yes	60,647,507	24.8417	34.8417	39.8417	0.19873	0.31810	0.37810

Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Northwest_poly.shp	10	IW390	yes	33,769,304	27.5103	39.3249	44.3249	0.23012	0.37190	0.43190
Northwest_poly.shp	47	SV280	yes	29,402,014	25.7072	35.7072	40.7072	0.20849	0.32849	0.38849
Northwest_poly.shp	28	IW361	yes	9,959,208	25.8480	35.8480	40.8480	0.21018	0.33018	0.39018
Northwest_poly.shp	27	IW358	yes	4,574,871	27.0501	37.0501	42.0501	0.22460	0.34460	0.40460
Northwest_poly.shp	71	IW392	yes	31,043,714	27.7670	38.5331	43.5331	0.23320	0.36240	0.42240
Northwest_poly.shp	15	IW357	yes	20,788,595	23.9439	33.9439	38.9439	0.19155	0.30733	0.36733
Northwest_poly.shp	96	IW330	yes	32,631,125	25.0986	35.0986	40.0986	0.20118	0.32118	0.38118
Northwest_poly.shp	75	IW351	yes	8,040,882	26.3755	36.3755	41.3755	0.21651	0.33651	0.39651
Northwest_poly.shp	97	IW346	yes	95,991,383	26.5839	36.5839	41.5839	0.21901	0.33901	0.39901
Northwest_poly.shp	81	IW310	yes	32,538,793	24.3945	34.3945	39.3945	0.19516	0.31273	0.37273
Northwest_poly.shp	77	IW387	yes	37,660,668	24.4128	34.8368	39.8368	0.19530	0.31804	0.37804
Northwest_poly.shp	150	IW360	yes	23,155,852	27.0816	37.0816	42.0816	0.22498	0.34498	0.40498
Northwest_poly.shp	227	IW368	yes	8,103,140	26.7350	36.7350	41.7350	0.22082	0.34082	0.40082
Northwest_poly.shp	99	SV268	yes	38,348,245	26.5474	36.5474	41.5474	0.21857	0.33857	0.39857
Northwest_poly.shp	8	IW394	yes	116,340,712	26.6545	38.5377	43.5377	0.21985	0.36245	0.42245
Northwest_poly.shp	38	IW349	yes	6,964,960	27.3773	37.3773	42.3773	0.22853	0.34853	0.40853
Northwest_poly.shp	228	IW352	yes	2,678,035	27.2164	37.2164	42.2164	0.22660	0.34660	0.40660
Northwest_poly.shp	33	IW396	yes	16,343,885	24.4776	34.5386	39.5386	0.19582	0.31446	0.37446
Northwest_poly.shp	312	IW380	yes	13,934,776	23.5049	33.5607	38.5607	0.18804	0.30273	0.36273
Northwest_poly.shp	1	IW356	yes	8,229,992	27.3861	37.3861	42.3861	0.22863	0.34863	0.40863
Northwest_poly.shp	310	IW354	yes	10,051,022	26.7120	36.7120	41.7120	0.22054	0.34054	0.40054
Northwest_poly.shp	73	IW372	yes	8,401,547	26.9627	36.9627	41.9627	0.22355	0.34355	0.40355
Northwest_poly.shp	101	TW462	yes	2,227,101	22.3962	32.3962	37.3962	0.17917	0.28875	0.34875
Northwest_poly.shp	102	TW450	yes	70,781,600	24.4132	34.4132	39.4132	0.19531	0.31296	0.37296
Northwest_poly.shp	76	IW375	yes	18,349,786	27.0312	37.0312	42.0312	0.22437	0.34437	0.40437
Northwest_poly.shp	103	IW326	yes	9,285,198	26.4531	36.4531	41.4531	0.21744	0.33744	0.39744
Northwest_poly.shp	104	TW459	yes	29,131,950	24.2638	34.2638	39.2638	0.19411	0.31117	0.37117
Northwest_poly.shp	9	IW364	yes	32,120,283	28.2147	38.2147	43.2147	0.23858	0.35858	0.41858
Northwest_poly.shp	308	IW362	yes	5,000,872	26.8291	36.8291	41.8291	0.22195	0.34195	0.40195
Northwest_poly.shp	105	IW334	yes	36,207,440	26.7105	36.7105	41.7105	0.22053	0.34053	0.40053
Northwest_poly.shp	80	TW448	yes	9,670,376	27.6052	37.6052	42.6052	0.23126	0.35126	0.41126
Northwest_poly.shp	106	TW452	yes	71,634,061	23.9463	33.9463	38.9463	0.19157	0.30736	0.36736
Northwest_poly.shp	30	IW338	yes	9,452,145	26.8636	36.8636	41.8636	0.22236	0.34236	0.40236

Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Northwest_poly.shp	473	TW446	yes	19,277,076	27.9635	37.9635	42.9635	0.23556	0.35556	0.41556
Northwest_poly.shp	45	IW342	yes	9,854,960	26.8911	36.8911	41.8911	0.22269	0.34269	0.40269
Northwest_poly.shp	474	TW432	yes	22,962,245	26.5206	36.5206	41.5206	0.21825	0.33825	0.39825
Northwest_poly.shp	107	IW395	no	296,451,882	29.8268	42.7232	47.7232	0.25792	0.41268	0.47268
Northwest_poly.shp	472	TW431	yes	25,008,405	26.6165	36.6165	41.6165	0.21940	0.33940	0.39940
Northwest_poly.shp	61	TW454	yes	9,917,426	22.3748	32.3748	37.3748	0.17900	0.28850	0.34850
Northwest_poly.shp	63	TW458	yes	18,670,119	22.2333	32.2333	37.2333	0.17787	0.28680	0.34680
Northwest_poly.shp	392	TW430	yes	84,960,352	26.3336	36.3336	41.3336	0.21600	0.33600	0.39600
Northwest_poly.shp	108	TW460	yes	64,544,671	23.2867	33.4767	38.4767	0.18629	0.30172	0.36172
Northwest_poly.shp	109	TW444	yes	10,062,694	27.0169	37.0169	42.0169	0.22420	0.34420	0.40420
Northwest_poly.shp	62	TW456	yes	4,917,107	21.7094	31.7094	36.7094	0.17368	0.28051	0.34051
Northwest_poly.shp	69	TW440	yes	3,017,985	26.7245	36.7245	41.7245	0.22069	0.34069	0.40069
Northwest_poly.shp	389	TW434	yes	15,858,241	26.7573	36.7573	41.7573	0.22109	0.34109	0.40109
Northwest_poly.shp	110	TW442	yes	10,514,278	26.9100	36.9100	41.9100	0.22292	0.34292	0.40292
Northwest_poly.shp	111	TW436	yes	18,798,758	26.6354	36.6354	41.6354	0.21962	0.33962	0.39962
Northwest_poly.shp	112	IW388	yes	34,169,785	23.8313	33.8313	38.8313	0.19065	0.30598	0.36598
Northwest_poly.shp	476	IW363	yes	17,501,281	22.7413	32.7413	37.7413	0.18193	0.29290	0.35290
Northwest_poly.shp	475	IW312	yes	15,840,134	22.3650	32.3650	37.3650	0.17892	0.28838	0.34838
Northwest_poly.shp	113	IW365	yes	13,183,462	22.3731	32.3731	37.3731	0.17898	0.28848	0.34848
Northwest_poly.shp	14	IW389	yes	3,658,881	21.7275	31.7275	36.7275	0.17382	0.28073	0.34073
Northwest_poly.shp	72	IW367	yes	1,426,656	23.0012	33.0012	38.0012	0.18401	0.29601	0.35601
Northwest_poly.shp	114	IW369	yes	22,160,895	22.5942	32.5942	37.5942	0.18075	0.29113	0.35113
Northwest_poly.shp	306	IW370	yes	24,517,615	26.4740	36.4740	41.4740	0.21769	0.33769	0.39769
Southwest_poly.shp	22	SV219	yes	25,006,926	26.0786	36.0786	41.0786	0.21294	0.33294	0.39294
Southwest_poly.shp	18	SV258	yes	20,516,783	25.5822	36.7763	41.7763	0.20699	0.34132	0.40132
Southwest_poly.shp	16	SV256	yes	1,683,918	24.4492	34.4492	39.4492	0.19559	0.31339	0.37339
Southwest_poly.shp	48	SV252	yes	4,106,185	23.4067	33.4067	38.4067	0.18725	0.30088	0.36088
Southwest_poly.shp	121	SV251	yes	7,456,899	22.3814	32.3814	37.3814	0.17905	0.28858	0.34858
Southwest_poly.shp	122	SV218	yes	35,863,497	26.3557	36.3557	41.3557	0.21627	0.33627	0.39627
Southwest_poly.shp	8	SV244	yes	26,376,162	22.6157	32.6303	37.6303	0.18093	0.29156	0.35156
Southwest_poly.shp	20	SV240	yes	102,179,073	26.9676	38.4581	43.4581	0.22361	0.36150	0.42150
Southwest_poly.shp	119	SV216	yes	45,395,623	26.2387	36.2387	41.2387	0.21486	0.33486	0.39486
Southwest_poly.shp	36	WT150	yes	162,655,369	32.6059	45.4806	50.4806	0.29127	0.44577	0.50961

Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Southwest_poly.shp	17	SV242	yes	2,618,618	20.9531	30.9531	35.9531	0.16762	0.27144	0.33144
Southwest_poly.shp	38	WT140	yes	105,640,674	34.1502	47.0997	52.0997	0.30980	0.46520	0.54199
Southwest_poly.shp	120	SV214	yes	52,127,348	26.6625	36.6625	41.6625	0.21995	0.33995	0.39995
Southwest_poly.shp	25	SV236	yes	16,326,175	21.8013	31.8013	36.8013	0.17441	0.28162	0.34162
Southwest_poly.shp	24	SV212	yes	112,675,793	25.3873	35.3878	40.3878	0.20465	0.32465	0.38465
Southwest_poly.shp	23	SV232	yes	85,304,014	27.3745	39.0061	44.0061	0.22849	0.36807	0.42807
Southwest_poly.shp	27	SV220	yes	16,737,423	26.9110	36.9110	41.9110	0.22293	0.34293	0.40293
Southwest_poly.shp	29	SV208	yes	29,726,987	32.4008	44.6993	49.6993	0.28881	0.43639	0.49639
Southwest_poly.shp	35	IW300	yes	41,255,995	26.8873	36.8873	41.8873	0.22265	0.34265	0.40265
Southwest_poly.shp	31	SV230	yes	23,733,336	26.4350	37.4747	42.4747	0.21722	0.34970	0.40970
Southwest_poly.shp	115	WT130	yes	81,975,079	27.6036	38.8621	43.8621	0.23124	0.36635	0.42635
Southwest_poly.shp	30	SV210	yes	20,028,989	24.6004	35.2331	40.2331	0.19680	0.32280	0.38280
Southwest_poly.shp	37	WT160	yes	22,656,489	31.2905	43.6873	48.6873	0.27549	0.42425	0.48425
Southwest_poly.shp	34	IW302	yes	36,979,432	26.0182	36.0182	41.0182	0.21222	0.33222	0.39222
Southwest_poly.shp	44	TW408	yes	25,371,761	32.7146	45.3746	50.3746	0.29258	0.44450	0.50749
Southwest_poly.shp	109	TW418	yes	38,140,691	26.5021	36.5021	41.5021	0.21803	0.33803	0.39803
Southwest_poly.shp	32	SV205	yes	14,642,889	26.9771	38.4567	43.4567	0.22373	0.36148	0.42148
Southwest_poly.shp	39	WT100	yes	107,359,761	27.6601	38.5897	43.5897	0.23192	0.36308	0.42308
Southwest_poly.shp	42	TW420	yes	22,518,827	25.6812	35.6812	40.6812	0.20817	0.32817	0.38817
Southwest_poly.shp	41	TW414	yes	32,574,350	26.1367	37.1784	42.1784	0.21364	0.34614	0.40614
Southwest_poly.shp	116	WT120	yes	78,157,022	26.5291	36.6856	41.6856	0.21835	0.34023	0.40023
Southwest_poly.shp	117	TW412	yes	57,532,013	26.0355	36.0355	41.0355	0.21243	0.33243	0.39243
Southwest_poly.shp	40	WT110	yes	80,729,483	25.6892	36.0790	41.0790	0.20827	0.33295	0.39295
Southwest_poly.shp	33	SV203	yes	2,117,579	20.7264	30.7264	35.7264	0.16581	0.26872	0.32872
Southwest_poly.shp	10	TW424	yes	41,720,370	26.8202	36.8202	41.8202	0.22184	0.34184	0.40184
Southwest_poly.shp	110	TW422	yes	19,603,900	26.8354	36.8354	41.8354	0.22202	0.34202	0.40202
Southwest_poly.shp	46	TW410	yes	8,585,572	27.0984	37.0984	42.0984	0.22518	0.34518	0.40518
Southwest_poly.shp	113	TW400	yes	119,064,540	26.7057	36.7057	41.7057	0.22047	0.34047	0.40047
Southwest_poly.shp	45	TW406	yes	4,551,115	26.9810	37.9474	42.9474	0.22377	0.35537	0.41537
Southwest_poly.shp	11	WI510	yes	65,693,386	26.8577	36.8577	41.8577	0.22229	0.34229	0.40229
Southwest_poly.shp	43	TW404	yes	58,340,627	25.6156	35.6181	40.6181	0.20739	0.32742	0.38742
Southwest_poly.shp	6	WI512	yes	37,781,334	26.9659	36.9659	41.9659	0.22359	0.34359	0.40359
Southwest_poly.shp	50	WI508	yes	19,487,607	27.3093	37.3093	42.3093	0.22771	0.34771	0.40771

Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Southwest_poly.shp	15	WI502	yes	33,689,907	24.9627	34.9627	39.9627	0.19970	0.31955	0.37955
Southwest_poly.shp	114	WI504	yes	37,621,112	26.1191	36.1191	41.1191	0.21343	0.33343	0.39343
Southwest_poly.shp	28	SV202	yes	40,116,247	25.9558	35.9558	40.9558	0.21147	0.33147	0.39147
Southwest_poly.shp	7	SV200	yes	65,926,181	26.3354	36.3354	41.3354	0.21602	0.33602	0.39602
Southwest_poly.shp	21	SV254	yes	2,708,859	20.9102	30.9102	35.9102	0.16728	0.27092	0.33092
Southwest_poly.shp	49	WI518	yes	14,833,272	26.9662	36.9662	41.9662	0.22359	0.34359	0.40359
Southwest_poly.shp	19	SV248	yes	35,456,763	29.7413	41.7758	46.7758	0.25690	0.40131	0.46131
Southwest_poly.shp	52	SV246	yes	4,369,420	22.4309	32.4309	37.4309	0.17945	0.28917	0.34917
Southwest_poly.shp	51	SV250	yes	3,380,729	22.1308	32.1308	37.1308	0.17705	0.28557	0.34557
Southwest_poly.shp	56	TW416	yes	16,401,418	26.1481	36.1481	41.1481	0.21378	0.33378	0.39378
Southwest_poly.shp	118	TW402	yes	137,004,267	26.2007	36.2009	41.2009	0.21441	0.33441	0.39441
Southwest_poly.shp	13	WI516	yes	3,994,075	27.6481	37.6481	42.6481	0.23178	0.35178	0.41178
Southwest_poly.shp	12	WI514	yes	9,824,990	23.4435	33.4435	38.4435	0.18755	0.30132	0.36132
Southwest_poly.shp	54	WI500	yes	29,876,093	25.7535	35.7535	40.7535	0.20904	0.32904	0.38904
Southwest_poly.shp	55	WI506	yes	43,287,691	26.2002	36.2002	41.2002	0.21440	0.33440	0.39440
Northeast_poly.shp	113	TW496	yes	15,272,003	23.0188	33.0188	38.0188	0.18415	0.29623	0.35623
Northeast_poly.shp	110	TW494	yes	26,552,322	26.6350	36.6350	41.6350	0.21962	0.33962	0.39962
Northeast_poly.shp	108	TW484	yes	15,659,748	27.0774	37.0774	42.0774	0.22493	0.34493	0.40493
Northeast_poly.shp	109	TW490	yes	64,023,615	22.3619	32.4074	37.4074	0.17890	0.28889	0.34889
Northeast_poly.shp	103	WI580	yes	47,125,319	23.4957	34.0312	39.0312	0.18797	0.30837	0.36837
Northeast_poly.shp	112	TW488	yes	10,071,323	26.4330	36.4330	41.4330	0.21720	0.33720	0.39720
Northeast_poly.shp	237	TW492	yes	3,269,535	21.5760	31.5760	36.5760	0.17261	0.27891	0.33891
Northeast_poly.shp	101	WI576	yes	99,578,425	23.5306	33.7949	38.7949	0.18824	0.30554	0.36554
Northeast_poly.shp	111	TW486	yes	8,630,113	26.6021	36.6021	41.6021	0.21923	0.33923	0.39923
Northeast_poly.shp	106	TW480	yes	21,007,704	26.7842	36.7842	41.7842	0.22141	0.34141	0.40141
Northeast_poly.shp	107	TW482	yes	21,089,143	26.5937	36.5937	41.5937	0.21912	0.33912	0.39912
Northeast_poly.shp	102	WI578	yes	11,042,306	21.9129	31.9129	36.9129	0.17530	0.28295	0.34295
Northeast_poly.shp	94	WI560	yes	156,116,594	24.1673	34.4598	39.4598	0.19334	0.31352	0.37352
Northeast_poly.shp	100	WI574	yes	6,105,162	26.3394	36.3394	41.3394	0.21607	0.33607	0.39607
Northeast_poly.shp	76	PI687	no	467,361,378	31.0083	44.0080	49.0080	0.27210	0.42810	0.48810
Southwest_poly.shp	56	TW478	yes	7,323,624	26.5905	36.5905	41.5905	0.21909	0.33909	0.39909
Northeast_poly.shp	104	WI582	yes	10,461,624	26.8851	36.8851	41.8851	0.22262	0.34262	0.40262
Northeast_poly.shp	105	WI584	yes	35,040,668	26.5349	36.5349	41.5349	0.21842	0.33842	0.39842

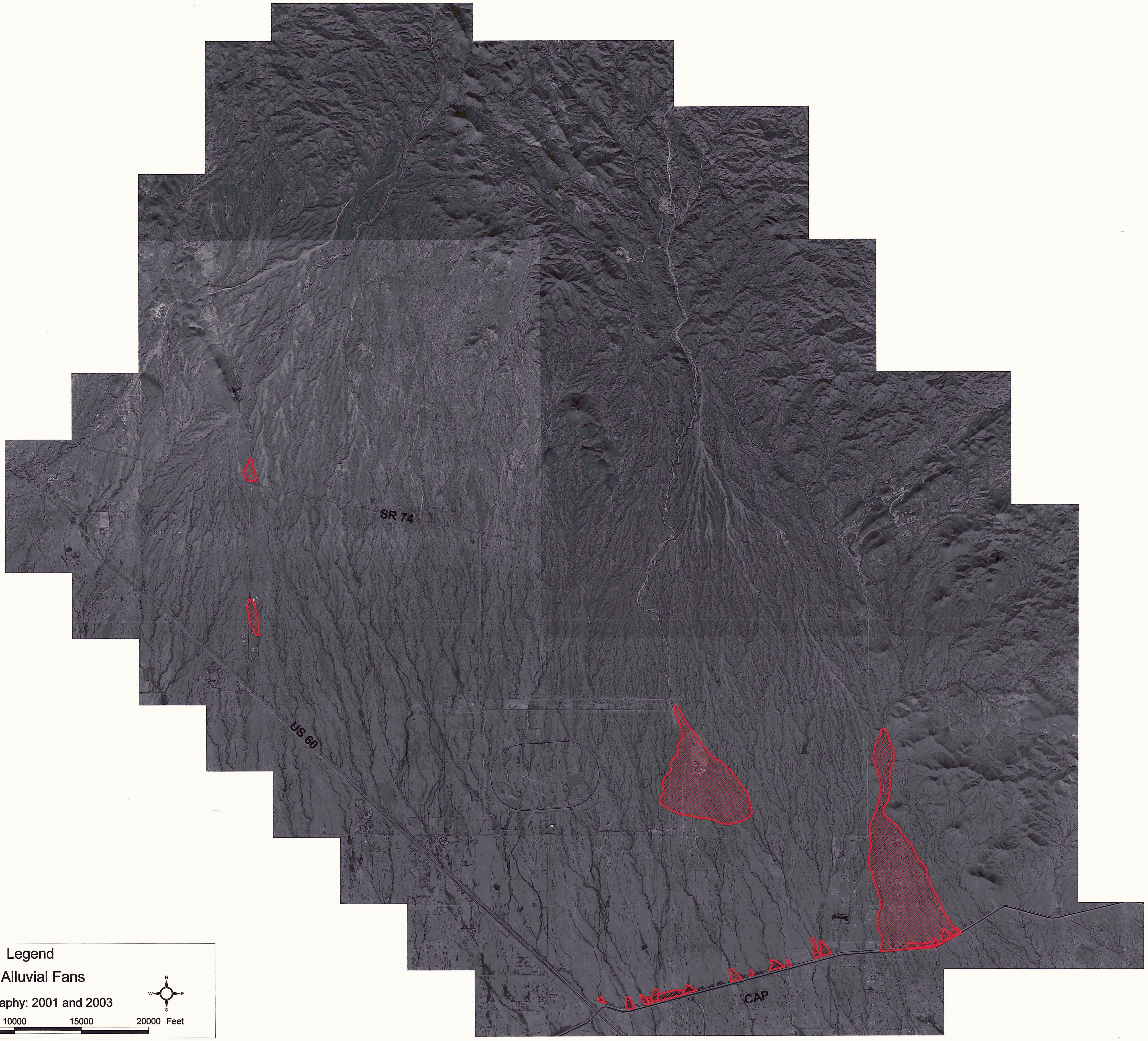
Appendix D-3: Future Conditions by Sub-Watersheds

Source Shapefile	Basinid	Basinname	Full_basin	Area, square feet	PSIAC Case 1 Rating	PSIAC Case 2 Rating	PSIAC Case 3 Rating	PSIAC Case 1 Yield, af/ sq mi/yr	PSIAC Case 2 Yield, af/ sq mi/ yr	PSIAC Case 3 Yield, af/sm/yr
Northeast_poly.shp	99	WI572	yes	57,446,357	26.7787	38.3071	43.3071	0.22134	0.35969	0.41969
Northeast_poly.shp	91	WI554	yes	28,536,705	27.3114	37.3114	42.3114	0.22774	0.34774	0.40774
Northeast_poly.shp	93	WI558	yes	1,564,111	26.7374	36.7374	41.7374	0.22085	0.34085	0.40085
Northeast_poly.shp	92	WI556	yes	1,102,668	27.1829	37.1829	42.1829	0.22619	0.34619	0.40619
Northeast_poly.shp	98	WI570	yes	62,382,965	27.6206	40.0063	45.0063	0.23145	0.38008	0.44008
Northeast_poly.shp	86	WI544	yes	50,009,041	26.5959	36.5959	41.5959	0.21915	0.33915	0.39915
Northeast_poly.shp	95	WI562	yes	24,313,666	22.7991	33.7228	38.7228	0.18239	0.30467	0.36467
Northeast_poly.shp	37	WI566	yes	3,093,065	21.9246	31.9246	36.9246	0.17540	0.28310	0.34310
Northeast_poly.shp	11	WI542	yes	32,725,356	26.6313	36.6313	41.6313	0.21958	0.33958	0.39958
Northeast_poly.shp	97	WI568	yes	2,754,837	21.8857	31.8857	36.8857	0.17509	0.28263	0.34263
Northeast_poly.shp	96	WI564	yes	50,339,902	26.3173	39.0593	44.0593	0.21581	0.36871	0.42871
Northeast_poly.shp	175	WI552	yes	11,518,895	27.9800	37.9800	42.9800	0.23576	0.35576	0.41576
Northeast_poly.shp	87	WI546	yes	16,869,628	26.9537	36.9537	41.9537	0.22344	0.34344	0.40344
Northeast_poly.shp	88	WI548	yes	8,595,820	24.2450	34.2471	39.2471	0.19396	0.31097	0.37097
Northeast_poly.shp	35	WI550	yes	3,989,813	27.3873	37.3873	42.3873	0.22865	0.34865	0.40865
Northeast_poly.shp	84	WI538	yes	61,518,828	24.0554	34.8089	39.8089	0.19244	0.31771	0.37771
Northeast_poly.shp	85	WI540	yes	34,728,620	26.0202	39.0202	44.0202	0.21224	0.36824	0.42824
Northeast_poly.shp	80	WI530	yes	66,225,395	26.5652	36.5652	41.5652	0.21878	0.33878	0.39878
Northeast_poly.shp	83	WI536	yes	38,194,477	22.5599	32.5599	37.5599	0.18048	0.29072	0.35072
Northeast_poly.shp	74	PI681	yes	27,773,319	24.2854	34.3354	39.3354	0.19428	0.31202	0.37202
Northeast_poly.shp	81	WI532	yes	8,999,782	26.5424	36.5424	41.5424	0.21851	0.33851	0.39851
Northeast_poly.shp	82	WI534	yes	12,099,146	23.2473	33.2473	38.2473	0.18598	0.29897	0.35897
Northeast_poly.shp	75	PI684	yes	21,481,040	24.9332	35.7241	40.7241	0.19947	0.32869	0.38869
Northeast_poly.shp	34	PI693	yes	23,309,199	26.1695	36.1695	41.1695	0.21403	0.33403	0.39403
Northeast_poly.shp	77	PI690	yes	16,816,656	26.5785	36.5785	41.5785	0.21894	0.33894	0.39894
Northeast_poly.shp	176	PI678	no	26,034,073	26.3496	36.3496	41.3496	0.21620	0.33620	0.39620
Northeast_poly.shp	72	PI675	yes	2,596,845	26.1543	36.1543	41.1543	0.21385	0.33385	0.39385
Northeast_poly.shp	70	PI672	no	41,513,760	26.4163	36.4163	41.4163	0.21700	0.33700	0.39700
Weighted Average, PSIAC rating					26.6796	37.4095	42.4095			
PSIAC Sediment Yield, tons/acre/year					0.2202	0.3489	0.4089			

APPENDIX E

Large Scale Maps of Alluvial Fans, Potential Unstable Areas and Two-Dimensional Areas For Wittmann Study Area North of the Sun Valley Parkway

Sheet 3. Alluvial Fans in the Northern Portion of the Wittmann Study Area
Sheet 4. Potential Unstable Areas in the Northern Portion of the Wittmann Study Area with Landform IDs
Sheet 5. Possible Areas of Two-Dimensional Flow



Legend

Alluvial Fans

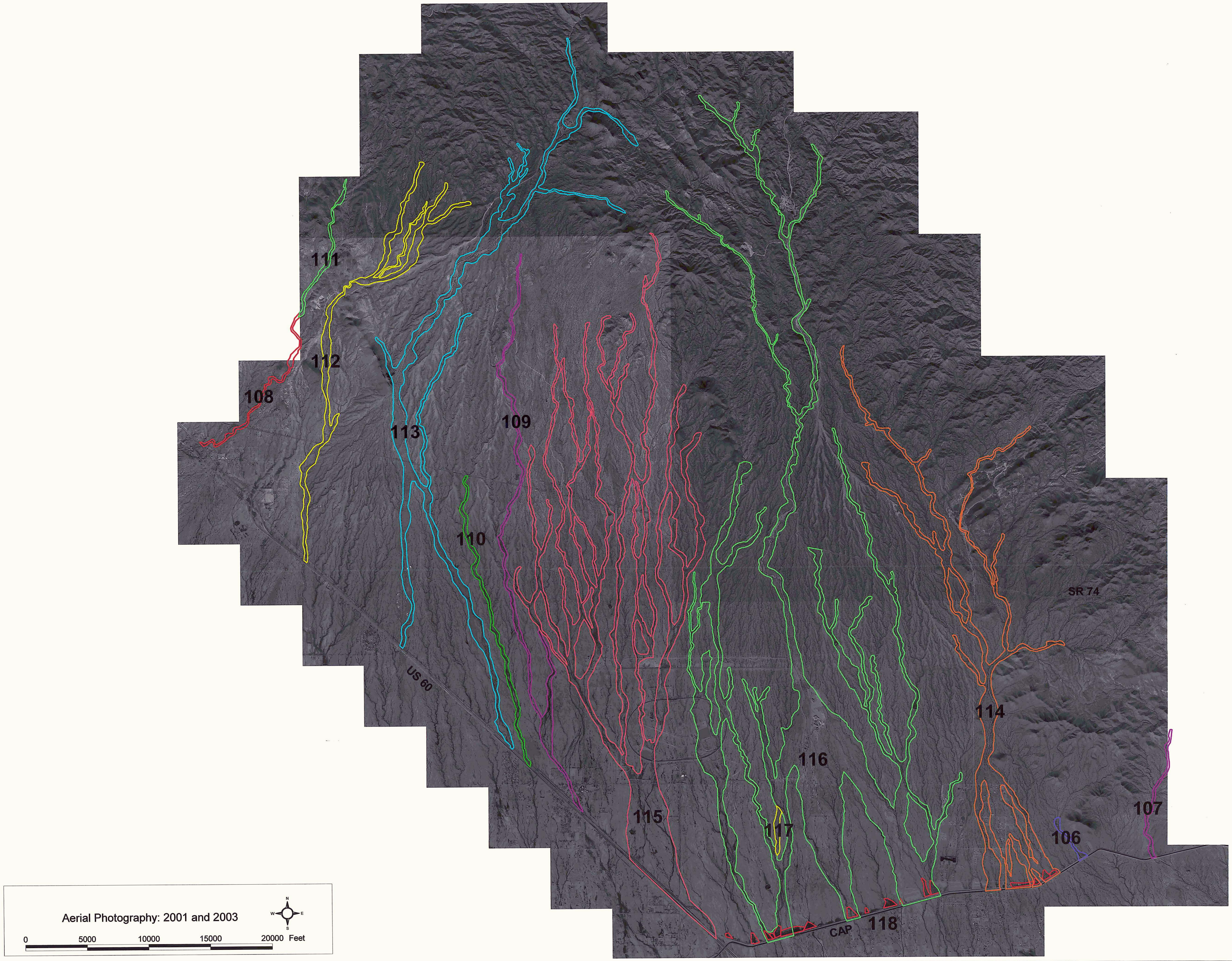
Aerial Photography: 2001 and 2003

0 5000 10000 15000 20000 Feet

Alluvial Fans in the Northern Portion of the Wittmann Study Area

Sheet 3 of 7

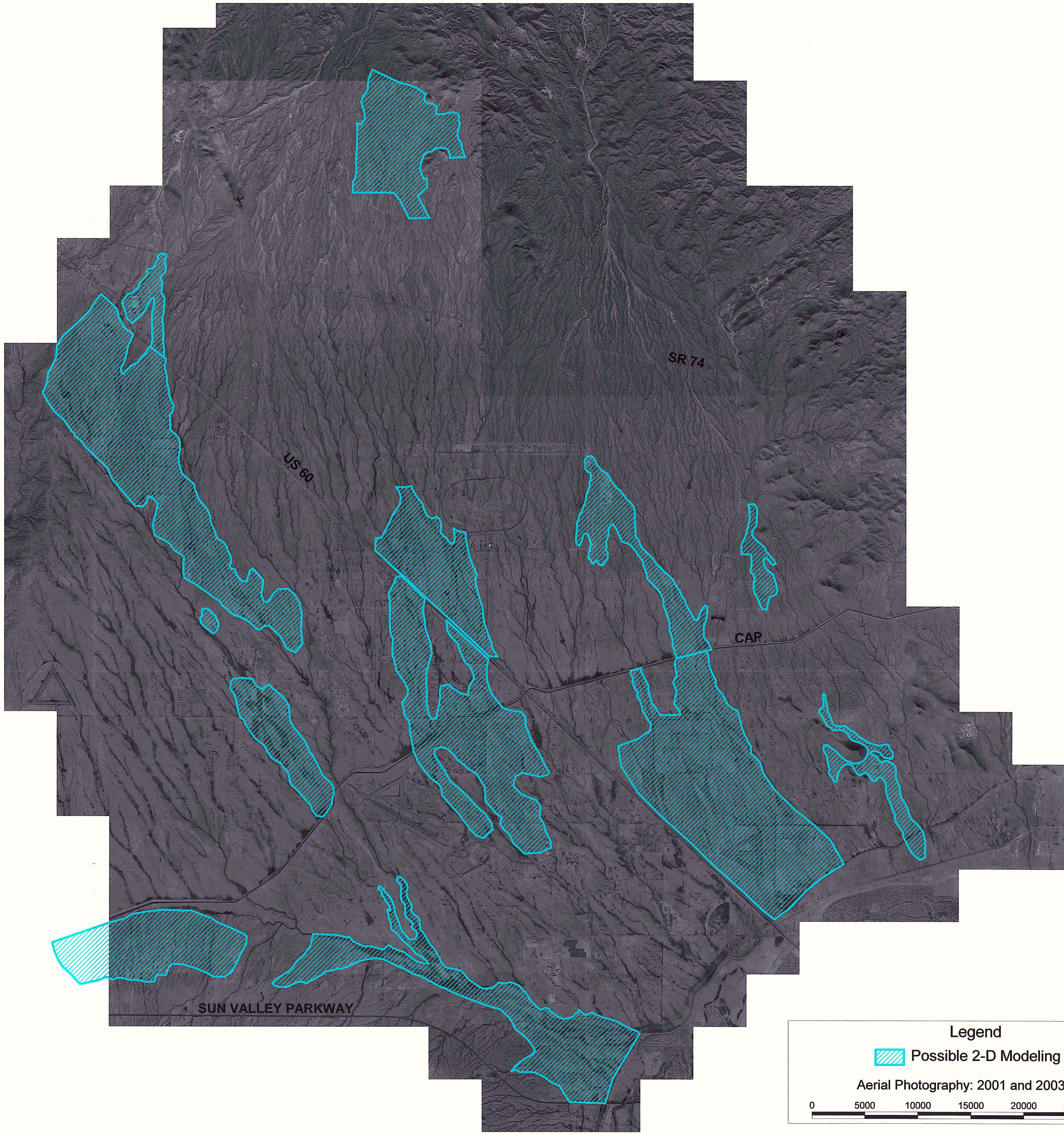
WEST Consultants, Inc.



Potential Unstable Areas in the Northern Portion of the Wittmann Study Area with Landform IDs

Sheet 4 of 7

WEST Consultants, Inc.



Legend

Possible 2-D Modeling Areas

Aerial Photography: 2001 and 2003

0 5000 10000 15000 20000 25000 30000 Feet

Possible Areas of
Two-Dimensional Flow

Sheet 5 of 7

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APPENDIX F

Large Scale Maps of Erosion Hazard Zones for the Wittmann Area

Sheet 6. Erosion Hazard Zones for the Trilby, Iona East, and Iona West Washes

Sheet 7. Erosion Hazard Zones for the CAP-1 West Wash

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Erosion Hazard Zones for the Trilby, Iona East, and Iona West Washes

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Erosion Hazard Zones for the CAP-1 West Wash

Sheet 7 of 7

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