RESPONSE TO COMMENTS AND OBJECTIONS FILED ON ADWR'S JUNE 2009 SUBFLOW ZONE DELINEATION REPORT FOR THE SAN PEDRO RIVER WATERSHED

In re The General Adjudication of the

Gila River System and Source

Arizona Department of Water Resources

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TABLE OF CONTENTS

TABLE OF CONTENTS

PAGE

TABLES ii
FIGURES ii
REFERENCES iii
APPENDICES iii

CHAPTER 1: INTRODUCTION 1
1.1 BACKGROUND 1
1.2 OBJECTIONS AND COMMENTS 1
1.3 SCOPE OF REPORT 2

CHAPTER 2: TECHNICAL COMMENTS AND OBJECTIONS 3
2.1 CATEGORIES 3
2.2 SUMMARY OF TECHNICAL COMMENTS AND OBJECTIONS 3

CHAPTER 3: PREDEVELOPMENT STREAMFLOW CONDITIONS 5
3.1 MULTIPLE YEARS OF EVIDENCE 5
3.2 WEIGHTING LINES OF EVIDENCE 6
3.3 CONFLICTING EVIDENCE 7
3.4 HISTORIC AERIAL PHOTOGRAPHY 7
3.5 HISTORIC DIVERSION RECORDS 8
3.6 USE OF NRCS SOIL SURVEY MAPS 8

CHAPTER 4: AZGS GEOLOGIC MAPS 9
4.1 UNIT LABELS AND COLORS 9
4.2 DISTURBED AREAS 10
4.3 DATA TRANSFER TO ADWR 10
4.4 CROSS SECTIONS 11
4.5 UNIT CONTACTS 12
4.6 MAP SCALE 12
4.7 ADWR GROUPING OF UNITS 13

CHAPTER 5: EXTENT OF FLOODPLAIN HOLOCENE ALLUVIUM 15
5.1 FAN DEPOSITS AND ACTIVE FLOODPLAIN ANALYSIS 15
5.2 RIPARIAN VEGETATION 17
5.3 BOREHOLE GEOLOGIC LOGS AND AQUIFER DATA 19
5.4 TOPOGRAPHIC SLOPE CHANGE 21
5.5 DISTRIBUTION OF SURFICIAL GEOLOGIC UNITS 24
5.6 ALTERNATIVES 26

PAGE

CHAPTER 6: SETBACKS FOR SIDE RECHARGE 27
6.1 PRESCRIBED SETBACKS 27
6.2 EFFECT OF TRIBUTARY SIZE 28
6.3 LOCAL GROUNDWATER FLOW CONDITIONS 29
6.4 CONCLUSION 30

CHAPTER 7: DELINEATION OF SUBFLOW ZONES 31
7.1 COMBINED EFFECT OF FAN DEPOSITS AND SETBACKS 31
7.2 ALTERNATIVE SUBFLOW ZONE MAPS 32
7.3 MOUNTAIN-FRONT STREAMS 33

TABLES

(follow tab)

TABLE 1-1: Parties Who Filed Comments and Objections
TABLE 2-1: Summary of Technical Comments and Objections Which Disagree with Subflow Zone Delineation Report
TABLE 2-2: Summary of Technical Comments Which Agree with Subflow Zone Delineation Report
TABLE 5-1: Alternatives for Delineating the Full Extent of Floodplain Holocene Alluvium

FIGURES

(follow tab)

FIGURE 4-1: Comparison of Generalized Geologic Cross Sections along the San Pedro River
FIGURE 5-1: Examples Where the Historic Active Floodplain Is Currently Covered by Fan Deposits
FIGURE 5-2: Use of Riparian Vegetation as an Indicator of Subsurface Floodplain Holocene Alluvium
FIGURE 5-3a: Example Cross Sections of the San Pedro River
FIGURE 5-3b: Example Cross Sections of the Babocomari River
FIGURE 5-3c: Example Cross Sections of Aravaipa Creek
FIGURE 5-4: Use of Geologic Outcrop Patterns to Map Fan Deposits Potentially Underlain by Floodplain Holocene Alluvium

REFERENCES
(follow tab)

APPENDICES
(follow tab)

APPENDIX A: Court Orders
APPENDIX B: Comments and Objections
APPENDIX C: Historic Aerial Photography
APPENDIX D: Analysis of Active Floodplain Migration
APPENDIX E: Distribution of Current Riparian Vegetation
APPENDIX F: Floodplain Cross Sections

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CHAPTERS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

On June 30, 2009, the Arizona Department of Water Resources ("Department" or "ADWR") published a report entitled "Subflow Zone Delineation Report for the San Pedro River Watershed" ("Sublow Zone Delineation Report"). Pursuant to Court order dated September 28, 2005 ("2005 Order"), ADWR filed this report in a judicial proceeding known as the Gila River Adjudication, which is pending in the Maricopa County Superior Court.[1] Using criteria and procedures set forth in the 2005 Order, the Subflow Zone Delineation Report presents a series of hydrogeologic maps that delineate the subflow zones for the San Pedro River, Babocomari River, and Aravaipa Creek, together with related information.[2]

1.2 OBJECTIONS AND COMMENTS

Upon filing the Subflow Zone Delineation Report with the Court, ADWR sent a notice to all water users who had filed claims to water rights ("claimants") in the San Pedro River Watershed, and claimants listed on the Gila River Adjudication Court-Approved Mailing List. The notice informed the claimants of the scope and availability of the report, as well as the right to file written objections to the report by December 28, 2009. Under the 2005 Order, objections were to be limited to ADWR's findings regarding the lateral extent of the subflow zone. Twenty-five objections or comments were filed on or before December 28, 2009, and one set of comments was filed after that date.[3]

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[1] *In re the General Adjudication of all Rights to Use Water in the Gila River System and Source,* W-1, W-2, W-3, W-4 (Consolidated).

[2] A copy of the September 28, 2005 order is included in Appendix A-4 to the Subflow Zone Delineation Report.

[3] Freeport-McMoRan filed comments on December 31, 2009.

By Court order entered August 24, 2010, the Honorable Judge Eddward P. Ballinger, Jr. scheduled a March 15, 2011 hearing on the objections and comments that raised "substantive legal and technical issues," and referred the remaining objections and comments to the Special Master, George A. Schade, Jr., for determination. August 24, 2010 Order at 1. Judge Ballinger directed ADWR to submit a report that describes the objections or comments "with which ADWR agrees or does not take issue and providing information in response to a specific objection or comment." *Id.* at 2. At the request of ADWR, the original December 31, 2010 deadline for submitting this report was extended to January 31, 2011 by Court order dated December 8, 2010.

Table 1-1 lists the objectors whose comments and objections are addressed in this report and those objectors whose comments and objections are before the Special Master.[4] See August 24, 2010, December 8, 2010 and December 20, 2010 Orders, which are included in **Appendix A**. Copies of the comments and objections addressed in this report are included in **Appendix B**.

1.3 SCOPE OF REPORT

The comments and objections addressed in this report raise both technical and legal issues. The technical issues are summarized in Chapter 2 of this report, and ADWR's responses to those issues are set forth in subsequent chapters. The legal issues generally consist of challenges to the Court's 2005 Order, which directed ADWR to use certain criteria and procedures to determine the subflow zones within the San Pedro River Watershed. Two of the objectors asserted that the 2005 Order does not comply with certain decisions of the Arizona Supreme Court, and consequently the Subflow Zone Delineation Report should be rejected.[5] This report does not address those legal issues.

[4] In the Special Master's December 20, 2010 Minute Entry and Order, the Special Master also granted the December 1, 2010 motion to intervene filed by the San Carlos Apache Tribe.
[5] *See* objections and comments filed by ASARCO and Bella Vista Water Co. *et al*.

CHAPTER 2: TECHNICAL COMMENTS AND OBJECTIONS

2.1 CATEGORIES

Several technical comments and objections were filed to the Subflow Zone Delineation Report. These comments and objections generally address five categories of issues concerning the following:

- Predevelopment streamflow conditions;
- Geologic maps prepared by the Arizona Geological Survey (AZGS);
- Extent of the floodplain Holocene alluvium;
- Setbacks for side recharge; and
- Delineation of subflow zones.

Each of these categories is addressed below in separate chapters of the report.

2.2 SUMMARY OF TECHNICAL COMMENTS AND OBJECTIONS

The following seven parties filed substantive technical comments and objections to the Subflow Zone Delineation Report:

- ASARCO
- Bella Vista Water Co. *et al* (Sierra Vista Parties)
- Freeport McMoRan Corporation (Freeport)
- Gila River Indian Community (GRIC)
- Salt River Project (SRP)
- The Nature Conservancy (TNC)
- United States (US).

In addition, the City of Phoenix and the City of Tempe joined in SRP's objections.

The technical comments and objections filed by these parties are summarized in two tables. **Table 2-1** includes those comments and objections that disagree with certain

parts of the Subflow Zone Delineation Report, the party that filed the comment or objection, and the section of the report where the comment or objection is addressed. **Table 2-2** includes those comments that agree with certain parts of the Subflow Zone Delineation Report and the parties that filed the comments.

CHAPTER 3: PREDEVELOPMENT STREAMFLOW CONDITIONS

In this chapter, ADWR responds to comments from five parties who disagree with ADWR's analysis of predevelopment streamflow conditions. ADWR grouped their comments into six categories and addresses each category below:

- Multiple Years of Evidence (**Section 3.1**)
- Weighting Lines of Evidence (**Section 3.2**)
- Conflicting Evidence (**Section 3.3**)
- Historic Aerial Photography (**Section 3.4**)
- Historic Diversion Records (**Section 3.5**)
- Use of NRCS Soil Survey Maps (**Section 3.6**).

Table 2-2 summarizes areas where the parties agree with ADWR's predevelopment streamflow analysis, which are not discussed further here.

3.1 MULTIPLE YEARS OF EVIDENCE

In accordance with the 2005 Order, ASARCO (p. 12, n. 8) and the Sierra Vista Parties (p. 3) state that ADWR should have identified a single year or range of years to represent predevelopment streamflow rather than using multiple years, although neither party specified which years should have been used. The Sierra Vista Parties (p. 4) believe that ADWR's streamflow analysis overstates the subflow zone since looking at water uses over longer periods tends to make a water source appear more reliable and ignores the impacts of years where precipitation and snowmelt is unavailable.

In its 2005 Order, the Court directed ADWR to use predevelopment streamflow conditions to determine the lateral extent of the subflow zone within the San Pedro River Watershed. The Court defined predevelopment conditions as those that existed immediately prior to regular, discernable diversions or depletions by human activity and recognized that predevelopment periods may differ across the watershed due to the quality and availability of data. Although ADWR was directed to use predevelopment

streamflow conditions that existed during an identifiable chronological year or range of years, ADWR was also instructed to take a practical approach using the best available data while doing so with as much accuracy and reliability as possible.

Based on its review of available data, ADWR was unable to identify a specific year or range of years that would characterize predevelopment streamflows throughout the watershed. However, it did identify several independent lines of evidence that taken together were used to infer whether stream reaches likely had ephemeral or perennial/intermittent flow prior to development. ADWR only concluded that a stream reach had perennial or intermittent flow prior to development where at least two independent lines of evidence were found in its favor:

- Historic accounts
- Historic irrigation ditch diversions and ore mills
- Early streamflow data
- 1935 aerial photographs
- Recent streamflow data.

These lines of evidence take advantage of the best available data for several different time frames.

3.2 WEIGHTING LINES OF EVIDENCE

Freeport (pp. 7-8, 10) notes that the lines of evidence ADWR used to infer predevelopment streamflow conditions were not necessarily of equal value and should be weighted according to uncertainty. They specifically question the reliability of historic accounts and the use of March 1899 and March 1921 seepage runs.

ADWR understands that the lines of evidence it used to assess predevelopment streamflows are based on varying types of data. However, it believes its approach was reasonable and that attempting to weight each line of evidence would add more subjectivity to the analysis.

3.3 CONFLICTING EVIDENCE

Both ASARCO (p. 13, n. 9) and Freeport (p. 8) note that some of ADWR's evidence of predevelopment streamflow conflicts. Freeport suggests that ADWR address conflicting lines of evidence and assume that predevelopment flows were ephemeral where it was unable to reconcile differences clearly in favor of perennial or intermittent flows.

ADWR recognized that some historic accounts differed and other lines of evidence were inconclusive. ADWR only concluded that a stream reach had perennial or intermittent flow prior to development if *at least two* independent lines of evidence support that conclusion.

3.4 HISTORIC AERIAL PHOTOGRAPHY

Freeport (pp. 9-11) suggests that ADWR provide additional information on the 1935 aerial photographs used to infer predevelopment streamflows. Since some of ADWR's interpretations of this photography appear questionable, ADWR should not consider it a sole line of evidence.

Freeport's comments are based on Figure 3-14 of the Subflow Zone Delineation Report which shows examples of streamflow conditions inferred from the historic photographs. Better quality copies of the photographs are provided in **Appendix C** in digital format.[6] For comparison to ADWR's interpretation of the photographs (see Figure 3-21 of the Subflow Zone Delineation Report), river miles are plotted on these images. As stated above, ADWR only inferred that predevelopment streamflows were perennial or intermittent if at least two, independent lines of evidence were available. Analysis of historic aerial photography was not used as a sole line of evidence of streamflow conditions.

[6] For its analysis, ADWR reviewed both digital versions and hard copy prints of the aerial photographs.

3.5 HISTORIC DIVERSION RECORDS

SRP (p. 15) indicates that historic diversion records should be used to extend the predevelopment perennial/intermittent reach of Aravaipa Creek upstream of stream mile 36, where ADWR terminated it.

ADWR agrees that 1921 records from the Arizona Water Commissioner indicate that four diversions were located on Aravaipa Creek upstream of stream mile 36. However, ADWR's other lines of evidence do not support the conclusion that this reach of Aravaipa Creek was previously perennial or intermittent. Lacking other supporting evidence, ADWR concluded the reach above stream mile 36 was probably ephemeral.

3.6 USE OF NRCS SOIL SURVEY MAPS

GRIC (p. 5) states it is unclear that the Natural Resources Conservation Service (NRCS) has expertise in streamflow duration analysis superior to ADWR and questioned whether ADWR should defer to NRCS on this issue. In its 2005 Order, the Court instructed ADWR to exclude ephemeral streams shown on NRCS soil survey maps when delineating subflow zones in the watershed.

ADWR did not rely on NRCS soil survey maps in its analysis of predevelopment streamflow conditions. As described in **Section 3.1,** other independent lines of evidence were used for this analysis. AZGS did, however, review the NRCS soil maps during preparation of the surficial geology maps that ADWR utilized in the Subflow Zone Delineation Report. Comments on the AZGS maps are described in the next section.

CHAPTER 4: AZGS GEOLOGIC MAPS

In this chapter, ADWR responds to comments from four parties who disagree with the AZGS (2009) surficial geology maps that ADWR used to delineate floodplain Holocene alluvium (FHA) in the watershed. ADWR grouped their comments into seven categories and addresses each category below:

- Unit Labels and Colors (**Section 4.1**)
- Disturbed Areas (**Section 4.2**)
- Data Transfer to ADWR (**Section 4.3**)
- Cross Sections (**Section 4.4**)
- Unit Contacts (**Section 4.5**)
- Map Scale (**Section 4.6**)
- ADWR Grouping of Units (**Section 4.7**).

Table 2-2 summarizes areas where the parties agree with the AZGS geologic maps, which are not discussed further here.

4.1 UNIT LABELS AND COLORS

Freeport (p. 12) observes that map unit boundaries and labels are not always clear on the AZGS maps and the colors used for map units are sometimes inconsistent with map legends.

ADWR agrees that some minor deficiencies exist in the appearance of the final AZGS maps, but it does not believe that these had an affect on its delineation of subflow zones. ADWR used a Geographic Information System (GIS) database from AZGS for its analysis. Each geologic unit mapped by AZGS was stored in the database with a unique unit code. ADWR therefore avoided any ambiguity that may appear on hard copies of the AZGS maps.

4.2 DISTURBED AREAS

Two parties commented on the delineation of disturbed areas by AZGS. AZGS (2009, p. 42) defines disturbed areas as "heavily disturbed ground due to agriculture, extensive excavation or construction of earth dams." AZGS groups disturbed areas with "Other Units" that include plowed areas, colluvium, and Quaternary hillslope talus and colluvium. GRIC (p. 5) agrees that AZGS should have mapped these areas but should not have identified them as geologic units.

While ADWR agrees that disturbed areas are not geologic units per se, it followed the convention used by AZGS. Appendix D-2 of the Subflow Zone Delineation Report shows where AZGS mapped disturbed areas within and bordering FHA and which geologic units ADWR assumed originally underlay these areas for purposes of subflow zone delineation.

In Attachment 7 of its comments, SRP presents photographs of a man-made berm that extends into the floodplain of lower Aravaipa Creek. They note that AZGS incorrectly mapped this berm as late Holocene alluvium. ADWR agrees that the berm should have been mapped as a disturbed area and is likely underlain by FHA.

4.3 DATA TRANSFER TO ADWR

Freeport (pp. 11-12) asks ADWR to describe how geologic data from AZGS were transferred and used in the Subflow Zone Delineation Report.

ADWR relied on the same GIS database that AZGS used to produce its final surficial geology maps.[7] AZGS created the database by digitizing its delineation of geologic units compiled on 1:24,000 scale topographic maps. ADWR only modified these data by grouping geologic units of similar origin (*e.g.*, FHA vs. basin fill). No manual tracing was performed or electronic smoothing functions applied by ADWR.

[7] AZGS provided ADWR a personal geodatabase dated March 20, 2009 that was developed using ESRI ArcMap version 9.2 and stored in Microsoft Access 2003.

4.4 CROSS SECTIONS

SRP (p. 16) indicates that the geologic cross section prepared by AZGS and presented in the Subflow Zone Delineation Report does not represent actual surface and subsurface conditions in the watershed. According to SRP, the AZGS cross section erroneously shows basin fill exposed at ground surface between FHA units and does not properly depict the relationship between subsurface units.

ADWR brought this comment to AZGS' attention, which agreed that its original cross section inadvertently showed basin fill exposed at ground surface between certain FHA units. It has since provided ADWR with a revised cross section that both corrects this error and adds question marks at the base of the FHA units to depict their uncertainty with the subsurface conditions. However, neither AZGS nor ADWR agree that the original AZGS cross section improperly depicts the relationship between subsurface units.

For comparison, **Figure 4-1** shows the revised AZGS cross section and two alternatives:

- SRP's modification of the original AZGS cross section (Att. 2, fig. A) and
- A geologic cross section prepared by Hereford (1993) in the Lewis Springs area.

Hereford's study of the entrenchment and widening of the upper San Pedro River was recognized by Judge Goodfarb in his 1994 Subflow Order,[8] and Hereford's cross section depicts subsurface conditions that are more in line with the original and revised AZGS cross sections. It appears to ADWR that SRP used the cross sections it developed in the vicinity of TNC's San Pedro Preserve (Att. 2, fig. B) and near Hereford (Att. 2, fig, C) to modify the AZGS cross section. However, ADWR's review of the SRP cross sections suggests that SRP has either misinterpreted or overinterpreted subsurface conditions based on the limited geologic data it was able to derive from well driller logs. In several cases, the driller log data shown on SRP's cross sections do not support the relationships shown between subsurface units. In other cases, subsurface conditions are depicted on

[8] A copy of Judge Goodfarb's Subflow Order is included in Appendix A-1 to the Subflow Zone Delineation Report.

the SRP cross sections with no supporting driller log data and no indication of their uncertainty.

4.5 UNIT CONTACTS

The Sierra Vista Parties (p. 5) comment that the FHA boundary varies in accuracy causing the width of the subflow zone to be overstated. AZGS identified three levels of accuracy when mapping the contact between surficial geologic units:

- Well defined (± 25 feet accuracy)
- Subtle or gradational (± 50 feet accuracy)
- Approximate (± 250 feet accuracy).

On its generalized surficial geology maps, ADWR used solid, dashed and dotted lines, respectively, to depict these levels of accuracy at the contact between FHA and other mapping units. However, it did not carry these contact lines forward onto its subflow zone delineation maps. As such, the actual width of the subflow zones may be overstated (or understated) due to mapping uncertainty. As appropriate, ADWR recommends that the final subflow zone delineation maps for the watershed include various contact lines to reflect differing levels of accuracy.

4.6 MAP SCALE

Freeport (p. 12) notes that ADWR's reduction in the original scale of the AZGS maps from 1:24,000 to approximately 1:52,000 results in less accurate maps and is an odd scale to use.

The original scale of the AZGS maps was reduced so that the U.S. Geological Survey (USGS) quadrangles utilized by ADWR as base maps could readily be copied on 11-inch x 17-inch paper. The map scale ADWR used for display and printing did not affect its analysis and results. ADWR relied on GIS data from AZGS that are scalable and did not alter original units or their contact lines. However, future ADWR maps will

be drafted so that they can be reproduced at the original AZGS mapping scale of 1:24,000.

4.7 ADWR GROUPING OF UNITS

GRIC (p. 5) believes that ADWR's grouping of surficial geologic units into FHA, tributary Holocene alluvium, basin fill and bedrock is too simplistic since part of the tributary Holocene alluvium is FHA at depth. GRIC did not provide an alternative grouping of geologic units but indicated that at "some point the current surface Tributary Holocene Alluvium crosses the edge of the Holocene Trough and drapes over some area of the Trough."

ADWR addresses GRIC's assertion that a "Holocene Trough" exists and its use in delineating the full extent of FHA in **Section 5.4**. Also, as further described in Section 5.1, ADWR divided its basin fill unit into two subunits – Holocene basin fill and older basin fill to assist in determining the full extent of FHA.

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CHAPTER 5: EXTENT OF FLOODPLAIN HOLOCENE ALLUVIUM

In this chapter, ADWR responds to comments from four parties who disagree with its delineation of the extent of FHA since ADWR relied on surficial geologic maps that do not depict subsurface FHA. ADWR grouped their comments into five categories and addresses each category below:

- Fan Deposits and Active Floodplain Analysis (**Section 5.1**)
- Riparian Vegetation (**Section 5.2**)
- Borehole Geologic Logs and Aquifer Data (**Section 5.3**)
- Topographic Slope Change (**Section 5.4**)
- Distribution of Surficial Geologic Units (**Section 5.5**).

Based on these comments, **Section 5.6** describes two alternatives that ADWR recommends be considered to further delineate the full extent of FHA.

5.1 FAN DEPOSITS AND ACTIVE FLOODPLAIN ANALYSIS

Four parties comment that ADWR did not properly map the full (surface and subsurface) extent of FHA since it relied on surficial geology maps. GRIC (pp. 2-4), SRP (pp. 16-19), TNC (Exh. 2, p. 3) and the US (p. 4) state that areas exist where recent fan deposits (also referred to as alluvial fans, tributary Holocene alluvium and tributary surficial deposits) overly FHA and these areas should have been included by ADWR in its subflow zone. SRP (p. 18) and the US (p. 5) also believe that ADWR misinterpreted Goodfarb's 1994 Subflow Order regarding exclusion of floodplain alluvium of ephemeral streams from the subflow zone. GRIC (p. 4), SRP (pp. 27-28; Att. 2, fig. J) and the US (pp. 8-9) comment that ADWR's proposed methodology to address overlapping fan deposits (Appendix D-4 of the Subflow Zone Delineation Report) is arbitrary and speculative. Finally, GRIC (pp. 3-4), SRP (pp. 20-22), TNC (Exh. 2, p. 2) and the US (pp. 9-10) note that the boundary between FHA and fan deposits is subject to flood events

and channel migration so current outcrops of FHA are not a stable geologic unit, which is a key factor set forth in the 1994 Subflow Order and the 2005 Order.

SRP (p. 25) asserts that, "By definition, the active river channel contains saturated floodplain alluvium, which must be part of the subflow zone." In their objections, SRP (Att. 2, figs. D through I; Att. 3) and TNC (Exh. 2, figs. 11, 12) provide examples where the active channel of the San Pedro River has migrated overtime, is currently eroding fan deposits and is outside of ADWR's subflow zone. SRP (p. 24) also provides evidence that FHA underlying fan deposits can be saturated. In Attachment 6 of its comments, subsurface water level data from TNC's San Pedro River Reserve are contoured and plotted on AZGS surficial geology. Review of the contours suggests that subsurface water is flowing beneath fan deposits on the preserve in a direction parallel to the river.

ADWR understands that fan deposits likely overlie FHA where they border the floodplain or form fingers of material that extend out into the floodplain. The generalized geologic cross sections in **Figure 4-1** illustrate how fan deposits can overlap FHA near the floodplain boundary. ADWR agrees with the parties that its proposed methodology to address overlapping fan deposits has limitations, but ADWR does not agree with SRP (p. 29) that areas where FHA underlies fan deposits can be mapped with "little difficulty" or with SRP's suggested mapping methodology.

ADWR believes that one possible approach for better delineating the full extent of FHA is to map how the location of the active floodplain has changed over time. In areas where the active floodplain is now covered by fan deposits, the extent of FHA could be extended to include the areas of overlap. In order to locate where the active floodplain is now covered by fan deposits, ADWR conducted a systematic analysis of the active floodplains of the San Pedro and Babocomari Rivers and Aravaipa Creek.

ADWR's active floodplain analysis is described in **Appendix D** and was based on review of aerial imagery taken during 1935, the 1950s, the 1980s/1990s and 2007. As observed by SRP, along some stream reaches the active floodplain has been relatively dynamic and its location has migrated across the floodplain and/or changed appreciably in width since 1935. Along other reaches, the active floodplain has been more stable and its location has varied little over the period (**App. D, Att. 1**). For use in delineating subsurface FHA, ADWR prepared a series of quadrangle maps covering the stream

reaches that it determined had predevelopment perennial or intermittent flows. On these maps, the composite active floodplain boundary delineated from the aerial imagery was plotted on top of the generalized surficial geology that ADWR based on AZGS mapping (**App. D, Att. 2**). Review of the composite maps shows several areas where the historic (1930s to 2007) active floodplain is currently covered by fan deposits and other Holocene basin fill.[9] **Figure 5-1** provides examples of these areas of overlap where it is likely that FHA occurs in the subsurface. However, in many other areas, the fan deposits and Holocene basin fill remain outside of the historic active floodplain.

Other approaches were offered by the parties to better delineate the full extent of FHA and these are described below along with ADWR's confidence in their application.

5.2 RIPARIAN VEGETATION

Two parties suggest that the current distribution of riparian vegetation can be used to delineate FHA in the subsurface. SRP (p. 23, Att. 5) notes that ADWR ignored dense communities of riparian vegetation located outside of its mapped subflow zone, and TNC (Exh. 2, p. 8) indicates that the pattern of riparian vegetation together with the distribution of pre-Holocene outcrops and local topography is a strong indicator of subsurface FHA. In his 1994 Subflow Order (p. 56), Judge Goodfarb noted that:

> To the extent that phreatophication exists or can be documented in the areas adjacent to the principal channel, it does mark that portion of the area of the 'subflow' zone. If it extends to the lateral edge of the saturated floodplain Holocene alluvium, then it is a vital marker. However, even phreatophytes cannot tell the difference between floodplain alluvium and tributary aquifer alluvium and, therefore, can be a false marker. The boundaries of riparian zones are helpful and certainly within the 'subflow' zone if they do not extend over the top of tributary aquifer or basin fill.

Judge Goodfarb further notes that delineating riparian areas in their predevelopment state would not be an easy task.

[9] ADWR revised its generalized surficial geology maps by dividing the basin fill unit into two subunits - Holocene basin fill and older basin fill. This revision was made to account for younger basin fill that is potentially also underlain by FHA. The other generalized units (FHA, tributary Holocene alluvium, bedrock, and disturbed areas) were unchanged from the Subflow Zone Delineation Report.

To test the approach suggested by SRP and TNC, ADWR plotted riparian areas and wetlands recently mapped by the U.S. Fish and Wildlife Service (USFWS) on top of ADWR's generalized surficial geology maps. USFWS (2009, pp. 7, 24) defines riparian areas and wetlands as follows:[10]

> Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes or drainage ways). Riparian areas have one or both of the following characteristics: 1) distinctly different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland.
>
> Wetlands (are) lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.

ADWR downloaded GIS data for riparian areas and wetlands in the San Pedro River Watershed from the USFWS National Wetlands Mapper website (http://www.fws.gov/wetlands/Data/DataDownload.html). Metadata on the website indicate that USFWS based its mapping on 1:24,000-scale aerial photographs primarily taken in 2001. The last four miles of the lower San Pedro River and about five miles in the middle Babocomari River were mapped using 2005 and 1996 aerial photographs, respectively.

Appendix E presents a series of quadrangle maps that show the relationship between the riparian areas and wetlands mapped by USFWS and AZGS surficial geology.[11] **Figure 5-2** provides examples where riparian vegetation may or may not be a useful indicator of subsurface FHA. Ideally, if riparian vegetation were a useful tool in delineating subsurface FHA, it should primarily grow on outcrops of FHA as well as fan deposits and Holocene basin fill near the floodplain potentially underlain by FHA.

[10] This definition is consistent with the definition of "riparian area" in A.R.S. § 45-101(b) relied upon by Judge Goodfarb (1994 Subflow Order, p. 54).

[11] For comparison to SRP's riparian vegetation maps, which only show dense cottonwood-willow and mesquite woodland, ADWR used USFWS data to differentiate cottonwood-willow and mesquite forest from wetlands and other riparian areas. The latter include salt cedar, sacaton grass and riparian scrub-shrub.

Review of the maps in **Appendix E** shows that this is indeed the case along the lower San Pedro River, particularly below approximately river mile 60. In this area, the cottonwood-willow and mesquite forest is relatively wide and occurs on outcrops of both FHA and adjacent tributary Holocene alluvium and Holocene basin fill. However, above approximately river mile 60, the cottonwood-willow and mesquite forest is relatively narrow and typically confined to existing FHA outcrops. SRP's approach would not assist in identifying subsurface FHA in this area. Along the middle and upper San Pedro River, other riparian vegetation is frequently found growing along tributaries far outside of the floodplain and in some places directly on older (pre-Holocene) basin fill. Since FHA cannot underlie pre-Holocene deposits, the growth of riparian vegetation in these areas suggests it may not be as clear an indicator of subsurface geology as suggested by SRP and TNC.

Growth of riparian vegetation on fan deposits and Holocene basin fill does not necessarily indicate the presence of subsurface FHA, as recognized by Judge Goodfarb. Even if it did, the maps in **Appendix E** show that along the middle and upper San Pedro River, current riparian areas and wetlands are often highly irregular in shape with vegetation occurring in patches and strips and sometimes only on one side of the river. Areas currently covered by riparian vegetation would have to be used to infer areas that may have previously had this vegetation, which would add more uncertainty to the analysis. Based on these factors, ADWR has *low confidence* in using riparian vegetation to delineate subsurface FHA.

5.3 BOREHOLE GEOLOGIC LOGS AND AQUIFER DATA

Two parties suggest that borehole geologic logs and/or aquifer data could be used to infer where FHA occurs in the subsurface. TNC (Exh. 2, p. 3) states that geologic logs and pumping tests allow the true extent of FHA to be delineated. The US (p. 6; Exh. 1, Att. B) believes that where the boundary of FHA is in doubt, the general direction of groundwater flow should be determined, either by measurement or inferred from existing data and experience in similar areas.

Although ADWR agrees that reliable borehole and aquifer data are valuable in understanding hydrogeologic conditions, such site specific data are lacking along most stream reaches in the watershed and are impractical to collect considering the extent of the watershed. The data most readily available (well driller logs) are often incomplete and/or inconclusive.

It is instructive to review the well driller logs that TNC (Exh. 2, Tables 1-3) presents to infer subsurface geologic conditions in the vicinity of three properties it owns along the San Pedro River north of Benson – the San Pedro River Preserve, H&E Farm and Three Links Farm properties (Exh. 2, fig. 2). On 24 of these well driller logs, TNC highlights where clay was encountered during drilling to indicate where it believes that older basin fill is first encountered in the subsurface. On the other 27 well driller logs, TNC does not provide an indication of the older basin fill contact even though at least nine of these logs show substantial clay layers were encountered and several others logs indicate an excess of 100 feet of coarser material. In summarizing their findings, TNC (Exh. 2, p. 7) states "data from geologic and drillers logs from wells on and near the three Conservancy properties described in this report indicates that the floodplain Holocene alluvium is on the order of 100 feet thick and extends beneath the thin veneer of surficial tributary alluvium…" TNC provides no other interpretation of these logs to substantiate the potential subsurface contact between overlying fan deposits and underlying FHA. It is unclear to ADWR how these logs would be used to verify the extent of FHA underlying fan deposits and Holocene basin fill.

TNC also provides maps (Exh. 2, figs. 3, 7 and 9) which show where numerous monitor wells have been drilled on their San Pedro River properties in addition to existing production wells. ADWR does not understand why the geologic logs for these monitoring wells were not included in TNC's comments and compared to their interpretation of well driller logs described above. In Figures 4 and 5 of Exhibit 2, TNC does provide detailed (2-foot contour interval) water level altitude maps for the south and north parcels of its San Pedro River Preserve that appear to have been drawn using data from over 30 wells and piezometers. SRP presents a similar figure in Attachment 6 of its comments for the south parcel of the preserve showing how the water level contours compare to the SRP and ADWR subflow zone delineations. As described above, ADWR

agrees that such aquifer data are valuable in evaluating hydrogeologic conditions. However, this level of data is typically not available throughout the watershed and would be impractical for ADWR and most parties to collect.

5.4 TOPOGRAPHIC SLOPE CHANGE

Three parties suggest that topographic maps and aerial photographs can be used to identify changes in topographic slope which would better define the boundary of FHA deposition. GRIC (p. 3) believes that topographic breaks occur at the edge of what GRIC terms a "Holocene Trough" that laterally confines FHA in the subsurface and forms a stable boundary for sediment movement along major streams in the watershed. SRP (p. 28) and TNC (Exh. 2, pp. 3, 8) believe that topographic breaks, together with the distribution of surficial geologic units, can be used to delineate the edge of subsurface FHA.

As described by GRIC, the Holocene Trough is analogous to the ancestral floodplain of a river. ADWR attempted to identify this feature by constructing a series of cross sections along the major streams in the watershed. Each cross section was oriented perpendicular to the active floodplain and displays the generalized surficial geologic units mapped by AZGS.[12] If this were a viable means of delineating subsurface FHA, the cross sections should show a distinct change in slope where the edge of the Holocene Trough is crossed and tributary Holocene alluvium or Holocene basin fill occurs at ground surface. The cross sections would not be helpful where older basin fill and bedrock border FHA outcrops since FHA cannot occur beneath these geologic units. **Figure 4-1** shows the potential relationship between topographic slope and the surface and subsurface extent of geologic units in the watershed, and **Appendix F** presents ADWR's cross sections.

ADWR constructed its cross sections using 10-meter digital elevation model (DEM) data downloaded from the USGS National Elevation Dataset (http://ned.usgs.gov/). More detailed (1-meter) topography was available from the

[12] For ease of viewing, cross sections for the San Pedro and Babocomari Rivers were generated looking downstream while the Aravaipa Creek cross sections look up upstream.

University of Arizona based on 2003 Light Detection and Ranging (LIDAR) imagery, but only for the portion of the watershed covered by the San Pedro Riparian Conservation Area. ADWR compared the DEM and LIDAR topography and found good agreement in the areas outside of the active floodplain where the edge of the Holocene Trough should be located.[13] Based on this comparison, ADWR used DEM data for generating representative cross sections throughout the watershed.

ADWR generated a separate cross section along each mile of the San Pedro River (157 miles), Babocomari River (29 miles) and Aravaipa Creek (53 miles).[14] To allow slope changes such as a Holocene Trough to be more easily identified, the cross sections were plotted at a vertical exaggeration of 15 times. For comparison, the cross sections also display ADWR's composite active floodplain boundary (**Section 5.1**) and the riparian areas and wetlands mapped by the USFWS (**Section 5.2**).

Using the cross sections in **Appendix F**, ADWR attempted to identify slope breaks that could signify the edge of a Holocene Trough and subsurface FHA. The following observations were made.

<u>San Pedro River</u>

- Only 5 of the 158 San Pedro River cross sections show FHA outcrops bordered on both sides of the floodplain by older basin fill or bedrock. These cross sections are located along the upper reach of the river, at and above river mile 116. Since FHA cannot underlay older basin fill and bedrock, identification of potential subsurface FHA is not required in such areas.
- All of the remaining San Pedro River cross sections show FHA outcrops bordered on at least one side by tributary Holocene alluvium or Holocene basin fill. In these areas, FHA could occur in the subsurface.
- Many of the cross sections below river mile 80 show a distinct change in slope on both sides of the floodplain which may indicate a Holocene Trough (*e.g.*, river

[13] The 10-meter DEM data were derived from 1:24,000-scale USGS topographic maps and consist of a grid of elevation values posted every 10 meters. The 1-meter DEM data were collected by an aircraft-mounted laser and consist of a grid of elevation values posted every one meter.
[14] Cross sections were also generated at the mouths of these three streams (river mile 0) for a total of 242 cross sections.

miles 8, 39 and 71). The topographic breaks typically occur where outcrops of older basin fill border outcrops of tributary Holocene alluvium or Holocene basin fill. Although less frequent, some cross sections along this reach of the river only show a clear topographic break on one side of the floodplain (*e.g.*, river miles 18 and 48).

- Above river mile 80, topographic breaks are generally less obvious in the cross sections and more often occur on only one side of the river (*e.g.*, river miles 88 and 115) or sometimes on neither side (*e.g.*, river miles 93 and 153).

Babocomari River

- About one third of the 30 Babocomari River cross sections show FHA outcrops bordered on both sides of the floodplain by older basin fill or bedrock. These cross sections cover portions of the lower and upper reaches of the river. Subsurface FHA is not present in such areas.
- The other Babocomari River cross sections show FHA outcrops bordered on at least one side by tributary Holocene alluvium or Holocene basin fill, so subsurface FHA may exist. However, about half of these cross sections show little or no clear indication of topographic breaks that would indicate a Holocene Trough (*e.g.*, river miles 5 and 22). The remaining cross sections show some evidence of a topographic break typically at or near the surface contact between older basin fill and tributary Holocene alluvium or Holocene basin fill (*e.g.*, river miles 10 and 23).

Aravaipa Creek

- The 54 Aravaipa Creek cross sections show that along most of the creek's lower reach (below river mile 28), FHA outcrops are bordered by older basin fill or relatively steep bedrock canyon walls so subsurface FHA is not expected to be present.
- Along the upper reach of the creek, tributary Holocene alluvium or Holocene basin fill typically border FHA outcrops on at least one side of the floodplain. About one-third of the cross sections in this area show little or no evidence of a

Holocene Trough (*e.g.*, river miles 38 and 50). The remaining cross sections do show a topographic break that may indicate a Holocene Trough on one or both sides of the creek (*e.g.*, river miles 30 and 44, respectively). These topographic breaks typically occur at or near the surface contact between older basin fill and tributary Holocene alluvium or Holocene basin fill.

As described above, several cross sections along the major streams in the watershed either do not show clear changes in slope that could signify a Holocene Trough and subsurface FHA, or the topographic breaks occur only on one side of the floodplain. Where slope changes are observed, they typically occur at or near the surface contact between older basin fill and tributary Holocene alluvium or Holocene basin fill. **Figures 5-3a, 5-3b and 5-3c** provide examples where the cross sections may or may not indicate the presence of a Holocene Trough along the San Pedro River, Babocomari River and Aravaipa Creek, respectively. ADWR has *low confidence* in using slope change by itself to identify subsurface FHA and believes that the distribution of surficial geologic units, discussed in **Section 5.5**, could be more useful.

5.5 DISTRIBUTION OF SURFICIAL GEOLOGIC UNITS

Three parties comment that the distribution of surficial geologic units along the floodplain could also be used to better delineate the full extent of FHA. GRIC (p. 4) suggests the relatively simple approach of drawing a smooth line connecting outcrops of geologic units clearly older than Holocene where they occur closest to the stream of interest. During the proceedings before Judge Goodfarb, these outcrops were termed "inliers."[15] SRP (pp. 28-29; Att. 2, fig. L) and TNC (pp. 3, 8; Exh. 2, fig. 13) believe that the patterns of pre-Holocene outcrops together with topographic breaks (**Section 5.4**) are a good indicator of the subsurface edge of FHA.

[15] Stetson Engineers, Inc. (1993), consultant for the US, used the term inlier to describe "where basin fill is exposed within the floodplain alluvium" (p. 15) and presented a map (fig. 6) showing how its proposed subflow zone for the St. David to Pomerene area takes inliers into account. In his 1994 Subflow Order (p. 36), Judge Goodfarb indicated that the subflow zone "must be outside of and not include those tributary alluvial deposits known as "inliers" as indicated in figure 6 of the Stetson Report."

ADWR evaluated this approach by selecting two reaches of the San Pedro River where distinct outcrops of older basin fill border the floodplain and then attempted to draw a smooth line connecting the outcrops. **Figure 5-4** presents the results for the Benson and Mammoth/Dudleyville areas. In each area, ADWR delineated the potential extent of FHA based on the presence of inliers as well as the general shape of fan deposits covering the floodplain. ADWR used three line types to indicate its relative level of confidence in these delineations:

- Solid line (*high confidence*) - where fingers of fan deposits clearly overlie the floodplain and where outcrops of older basin fill or bedrock border outcrops of FHA;
- Dashed line (*moderate confidence*) – where inliers are relatively close to the floodplain and occur in a frequent and consistent pattern; and
- Dotted line (*low confidence*) – where inliers are relatively far from the floodplain and occur infrequently and in an inconsistent pattern.

ADWR understands that the use of inliers to delineate the subsurface extent of FHA presumes there is no subsurface older basin fill between the inlier and exposed FHA. It follows that the further away from the floodplain one goes before encountering an inlier, the greater the possibility that older basin fill is simply covered by fan deposits and not exposed at ground surface. In some areas, tributary Holocene alluvium extends to the edge of the area AZGS mapped with no inliers in between for guidance. However, to assume that no FHA underlies fan deposits outside of the active floodplain is unreasonable and inconsistent with water level data TNC collected at its San Pedro River Preserve (SRP, Att. 6). The latter clearly show that subsurface water is flowing beneath some fan deposits in a direction parallel to the river. Moreover, the fact that outcrops of older basin fill often form patterns that parallel the floodplain suggests they were previously eroded by the river, and areas between the inliers and the active floodplain may contain subsurface FHA. The distribution of surficial geologic units alone is not dispositive.

5.6 ALTERNATIVES

This chapter describes five approaches for better delineating the full extent of FHA in the watershed based on comments received by the parties. ADWR has the *highest confidence* in mapping areas where the historic active floodplain is now covered by fan deposits (**Section 5.1**) and identifying where fingers of fan deposits clearly overlie the floodplain (**Section 5.5**). It has *moderate confidence* in extending the FHA outward to inliers that are relatively close to the floodplain and occur in a frequent and consistent pattern, and *lower confidence* in using inliers which are farther from the floodplain and occur infrequently and in an inconsistent pattern (**Section 5.5**). ADWR has *lowest confidence* in using riparian vegetation (**Section 5.2**) or topographic slope changes (**Section 5.4**). Reliable subsurface geologic and aquifer data would provide the greatest confidence in delineating the full extent of FHA, but these data are not readily available and would be impractical to collect on a watershed scale (**Section 5.3**).

ADWR suggests two alternatives that the Court can consider for delineating the full extent of FHA in the watershed. As indicated in **Table 5-1,** each alternative has tradeoffs and different levels of relative confidence. In Alternative A, the extent of FHA would be constrained to current outcrops of FHA combined with areas where the historic active floodplain is now covered by fan deposits and where fingers of fan deposits clearly overlie the floodplain. Under this alternative, confidence is high that only FHA deposits would be delineated, but confidence is low that all FHA deposits would be included. Confidence is also low that the FHA delineated would represent a stable geologic unit. It is likely under this alternative that some subsurface FHA would be excluded.

In Alternative B, the extent of FHA would be expanded from Alternative A to include potential subsurface FHA deposits located between the active floodplain and inliers. Under this alternative, confidence is high that no FHA would be excluded and the FHA delineated would represent a stable geologic unit. However, confidence is low that only FHA deposits would be included. In this case, it is possible that non-FHA deposits would be included.

CHAPTER 6: SETBACKS FOR SIDE RECHARGE

In its 2005 Order, the Court directed ADWR to exclude tributary aquifers, areas of basin fill recharge and the alluvial plains of ephemeral streams. In this chapter, ADWR responds to comments from three parties who disagree with ADWR's application of setbacks to account for side recharge from tributary and basin fill aquifers. ADWR grouped their comments into three categories and addresses each category below:

- Prescribed Setbacks (**Section 6.1**)
- Effect of Tributary Size (**Section 6.2**)
- Local Groundwater Flow Conditions (**Section 6.3**).

ADWR's conclusion regarding the use of setbacks is presented in **Section 6.4**.

6.1 PRESCRIBED SETBACKS

To delineate subflow zones in the watershed, ADWR applied a 100-foot setback where FHA was bordered by basin fill and a 200-foot setback where it was bordered by tributary Holocene alluvium. Judge Goodfarb prescribed these setbacks in his 1994 Subflow Order (pp. 57-58, 65):

> [W]here there are connecting tributary aquifers or floodplain alluvium of ephemeral streams, the boundary of the "subflow" zone must be at least 200 feet inside of that connecting zone so that the hydrostatic pressure effect of the side recharge of this tributary aquifer is negligible and the dominant direction of flow is the stream direction…[W]here there is a basin-fill connection between saturated zones of the floodplain Holocene alluvium and a saturated zone of basin fill, the boundary of the "subflow" zone must be 100 feet inside of the connecting zone so that the hydrostatic pressure effect of the basin-fill's side discharge is overcome and the predominant direction of flow of all of the "subflow" zone is the same as the stream's directional flow.
>
> * * *

> That part of the floodplain alluvium which qualifies as a "subflow" zone must also be where the pressure of side recharge from adjacent tributary aquifers or basin fill is so reduced that it has no significant effect on the flow direction of the floodplain alluvium. (i.e., a 200-foot setback from connecting tributary aquifers and a 100-foot setback from the basin-fill deposits).

Judge Goodfarb did not prescribe setbacks where FHA was bordered by bedrock but his 1994 Subflow Order (p. 30) recognized the existence of bedrock canyon streams which were defined as "perennial or intermittent streams located in canyons bounded by consolidated tributary aquifers or impermeable bedrock."

SRP (pp. 22-23) and the US (Exh. 1, p. 2) note that ADWR routinely applied 200-foot setbacks in numerous locations where a tributary aquifer or inflow from ephemeral stream alluvium do not exist. The US (Exh. 1, p. 4) also notes that ADWR should not have applied setbacks where the San Pedro River flows through two bedrock areas in the northern part of the Lewis Springs quadrangle map since it reduced the width of the subflow zone or eliminated it entirely.

The 100- and 200-foot setbacks required by Judge Goodfarb were based on the testimony of Stephen G. Erb, the former ADWR adjudications manager, together with evidence of different rates of permeability and transmissivity of different geologic units, as well as certain exhibits received at trial (1994 Subflow Order, p. 58). ADWR applied 100-foot setbacks where basin fill borders FHA and 200-foot setbacks where tributary Holocene alluvium borders it. ADWR considered outcrops of tributary Holocene alluvium a practical marker of where connecting tributary aquifers and floodplain alluvium of ephemeral streams may contribute side recharge. ADWR agrees with the US that it should not have applied setbacks in the two bedrock areas within the Lewis Springs quadrangle map as these stream reaches could be viewed as flowing through bedrock canyons.

6.2 EFFECT OF TRIBUTARY SIZE

Both SRP (p. 23) and the US (Exh. 1, pp. 2-4) believe that different setbacks should be applied for large and small tributaries bordering the floodplain. A 200-foot

setback would be appropriate at the mouths of large tributaries, but for small tributaries and where basin fill borders the floodplain, the setback should be 100-feet. To distinguish large from small tributaries, SRP's consultant did the following (p. 30):

> Identified named washes from topographic maps and determined how far their alluvial fans extended upstream and downstream on the floodplain along the saturated floodplain line. The [AZGS] mapping and topography were used to make this determination. In many places, alluvial fans overlap and, in those cases, professional judgment was used to make the determination.

SRP (pp. 30-31) indicates that further adjustment of these setbacks may be necessary where their application causes "the river channel, as identified by [AZGS], to be outside of the subflow zone." The US (Exh. 4, p. 4) indicates that the 200-foot setback "should only apply for large tributaries that have groundwater flow in the tributary Holocene alluvium at the edge of the San Pedro River floodplain year round. It is only in these areas that the groundwater flow in the tributary alluvium is expected to be perpendicular to that of the San Pedro River subflow as defined by the Court." Unlike SRP, the US does not offer a ready means of identifying these large tributaries.

While ADWR agrees that larger setbacks may be hydrologically reasonable for larger tributaries, neither SRP nor the US provide hydrogeologic evidence that supports their suggested use of 200-foot setbacks only for large tributaries and 100-foot setbacks for the other washes. In addition, Judge Goodfarb does not discuss such an approach in his 1994 Subflow Order.

6.3 LOCAL GROUNDWATER FLOW CONDITIONS

TNC (Exh. 2, p. 4) suggests that more appropriate setbacks could be developed based on local water level data and subsurface flow directions. Based on its water level contour maps for the San Pedro River Preserve (Exh. 2, fig. 4 and 5), TNC (Exh. 2, p. 7) concludes that subsurface flow within the FHA is in the same approximate direction, and side recharge has no significant affect on flow direction.

ADWR does not understand how TNC uses Figures 4 and 5 in its comments to conclude that side recharge has no significant affect on flow direction beneath its preserve, since the contact between tributary and basin fill aquifers and saturated FHA are not delineated on their contour maps. ADWR agrees that more appropriate setbacks could be developed based on detailed subsurface water level data, however, these data are not readily available throughout the watershed. What are more readily available are regional water level contour maps as SRP presents for the Upper San Pedro Basin in Attachment 6 of their comments. However, the relatively small scale of such regional water level maps would not be useful in developing site specific setbacks.

6.4 CONCLUSION

Based on its review of the SRP, TNC and US comments regarding setbacks and upon further consideration, ADWR concludes that there are currently insufficient data to support application of site specific setbacks in the watershed. ADWR applied the setbacks presented by the 1994 Subflow Order.

CHAPTER 7: DELINEATION OF SUBFLOW ZONES

In this chapter, ADWR responds to comments from four parties who disagree with its delineation of subflow zones in the watershed. ADWR grouped their comments into three categories and addresses each category below:

- Combined Effect of Fan Deposits and Setbacks (**Section 7.1**)
- Alternative Subflow Zone Maps (**Section 7.2**)
- Mountain-Front Streams (**Section 7.3**).

Table 2-2 summarizes areas where the parties agree with ADWR's subflow zone delineations, which are not discussed further here.

7.1 COMBINED EFFECT OF FAN DEPOSITS AND SETBACKS

Three parties state that ADWR's failure to map the full extent of FHA together with its routine application of prescribed setbacks results in delineation of overly narrow and discontinuous subflow zones. The US (pp. 4, 6) believes it is unreasonable to allow temporary fan deposits to narrow the subflow zone, particularly where application of setbacks causes the subflow zone to disappear entirely and leaves large gaps along streams that ADWR determined had predevelopment perennial or intermittent flow. TNC (Exh. 2, p. 7) observes that by applying setbacks and only considering surface exposures of FHA, ADWR's subflow zone has several gaps and areas where the current river channel lies outside of it. SRP (pp. 15, 25-26) identified nearly 500 areas where the current river channel is excluded from ADWR's delineation of saturated FHA including a half mile reach of lower Aravaipa Creek where AZGS incorrectly mapped a man-made berm as late Holocene alluvium (**Section 4.2**).

ADWR understands that fan deposits likely overlie FHA where they border the floodplain or form fingers of material that extend out into the floodplain. As described in **Section 5.6**, ADWR evaluated five approaches for better delineating the full extent of

FHA and suggested two alternatives that could be considered by the Court. One of these methodologies could be used to revise ADWR's FHA maps.

ADWR concludes in **Section 6.4** that there are currently insufficient data to support application of site specific setbacks in the watershed and that application of the prescribed setbacks leads to anomalous results. Application of setbacks under Alternative A would further limit the width of the subflow zone and potentially create even more anomalies. Application of setbacks under Alternative B would eliminate the anomalies, but would potentially include non-FHA deposits.

7.2 ALTERNATIVE SUBFLOW ZONE MAPS

Three parties offer alternative subflow zone maps to those ADWR presents in Appendix E of the Subflow Zone Delineation Report. On Sheets 1 through 6 of Attachment 10, SRP's consultant (Leonard Rice Engineers or LRE) plots the lateral extent of both surface *and* subsurface FHA directly onto the AZGS surficial geology maps based on their interpretation of the geology maps and "aerial photography, topographic map analysis, drillers logs and field observation." On these same sheets, LRE then applies 100- and 200-foot setbacks to the lateral extent of FHA, as described in **Section 6.2,** and derives a final subflow zone. In Attachment 8 of their comments, SRP compares the LRE subflow zone for the San Pedro River to ADWR's 2009 subflow zone and the post-1880 subflow zone that Errol Montgomery, consultant for the groundwater users, presented as Exhibits 209-216 at trial in 1994. SRP makes a similar comparison between the LRE and ADWR subflow zones in Attachments 9 and 11, but this time it also includes the Babocomari River and Aravaipa Creek, and in Attachment 9 it also shows the location of large wells.[16] In Figure K of Attachment 2, LRE compares its current interpretation of the subflow zone to its 1994 interpretation and notes how well they agree.

In Figures 6, 8 and 10 of Exhibit 2, TNC's expert (Haney) delineates subflow zones for their three properties along the lower San Pedro River based chiefly on

[16] SRP (p. 27) points out that many large wells are located outside of ADWR's proposed subflow zone but within LRE's subflow zone. These wells would likely be subject to cone of depression tests and "require enormous amounts of additional time and money to be spent by ADWR, the parties and the Court."

"geologic logs, AZGS geologic mapping units, NRCS soil units, topography, and hydrogeologic data obtained during investigations and regular monitoring." Haney then compares these to ADWR's 2009 subflow zones.

Finally, in Attachment B of Exhibit 1, the US consultant (Stetson Engineers) proposes an alternative subflow zone for the San Pedro River along the northern portion of the Hereford USGS quadrangle map "based primarily on geology and topography" with "setbacks of 100 feet for basin fill and 200 feet for large tributaries…added to the floodplain Holocene alluvium boundary to create a new subflow boundary." Where the subflow zone is uncertain, the US consultant (Exh. 1, p. 3) suggests applying a "simple field test" involving "driving three well points or piezometers into the Holocene alluvium and carefully measuring the water levels and measurement point elevation." This test would be very costly and time consuming.

All of the alternative maps show continuous subflow zones that are considerably wider than those ADWR delineated in the Subflow Zone Delineation Report. This is not unexpected since ADWR applied uniform setbacks and did not attempt to delineate subsurface FHA. ADWR agrees with the US (Exh. 1, p. 4) that the "boundary of Holocene alluvium in the San Pedro River floodplain may be more difficult to define in some places rather than others due to limited basin fill or bedrock outcrops, and low topography." Final subflow zones would therefore be delineated with more confidence in some areas of the watershed than others.

7.3 MOUNTAIN-FRONT STREAMS

Two parties comment that ADWR should have mapped subflow zones along mountain-front streams in the watershed. SRP (pp. 14-15) disagrees with ADWR's criteria for excluding mountain-front streams noting that "streams may be excluded only if the stream is ephemeral under predevelopment conditions and there is not a connection of saturated floodplain Holocene alluvium between the ephemeral stream and a perennial or intermittent stream." SRP also asks that ADWR explain why it excluded at least two specific reaches (Redfield and Buehman canyons) from the Subflow Zone Delineation Report and suggests that whether there are appropriative rights to the isolated intermittent

or perennial reach of the stream should be a consideration (pp. 4, 15). GRIC (p. 4) believes that ADWR should have considered all streams in its analysis and notes that the Babocomari River and Aravaipa Creek, which ADWR did analyze, could also be viewed as mountain-front streams.

ADWR did not consider mountain-front streams in the Subflow Zone Delineation Report, noting the following factors:

- The reaches are relatively short and often isolated from major streams in the alluvial valleys;
- Access is often difficult or restricted due to their location within and/or at the base of mountains;
- Significant resources would be required to research and map their locations; and
- AZGS did not include these streams in its surficial geologic mapping.[17]

ADWR recognizes that subflow zones may exist along some mountain-front streams in the watershed and could develop a strategy for identifying and delineating these zones. However, in light of the resources that would be required, ADWR requests that the Court consider how this work should be prioritized with other ADWR efforts in the watershed.

[17] AZGS' contract with ADWR was limited to mapping surficial geologic units along the San Pedro and Babocomari Rivers and Aravaipa Creek.

TABLES

TABLE 1-1. PARTIES WHO FILED COMMENTS AND OBJECTIONS

PARTIES RAISING SUBSTANTIVE LEGAL AND TECHNICAL COMMENTS	OTHER PARTIES[1]
ASARCO	Apache Powder Company
Bella Vista Water Company, Pueblo Del Sol Water Company, and the City of Sierra Vista (Sierra Vista Parties)	Richard Donahue
	Howard L. Ludd
Freeport-McMoRan Corporation (Freeport)	Paul Kartchner
Gila River Indian Community (GRIC)	Miller Brothers' Ranch [3]
City of Phoenix [2]	Miller Family Trust
Salt River Valley Water Users Association and Salt River Project Agricultural Improvement and Power District (SRP)	Quentin Miller [3]
	William Miller
City of Tempe [2]	Marsha Thompson [4]
The Nature Conservancy (TNC)	Kevin Trejo [4]
United States (US)	George L. White

Notes:

[1] Comments referred to the Special Master.
[2] Joined in SRP's comments.
[3] Filed three separate objection forms.
[4] Filed two separate objection forms.

TABLE 2-1. SUMMARY OF TECHNICAL COMMENTS AND OBJECTIONS WHICH DISAGREE WITH SUBFLOW ZONE DELINEATION REPORT

SECTION ADDRESSED IN REPORT	COMMENT	PARTIES[1]
3.0	***Predevelopment Streamflow Conditions***	
3.1	A single year or range of years should have been identified to represent predevelopment streamflows rather than multiple years.	ASARCO, Sierra Vista Parties
3.2	ADWR's lines of evidence for predevelopment streamflows were not necessarily of equal value and should be weighted according to uncertainty.	Freeport
3.3	Conflicting lines of evidence should be addressed.	ASARCO, Freeport
3.4	Additional information on the 1935 aerial photography used by ADWR should be provided and this imagery should not be considered a sole line of evidence.	Freeport
3.5	Historic diversion records should be used to extend the perennial/intermittent reach of Aravaipa Creek further upstream.	SRP
3.6	NRCS soil survey maps should not be relied on to exclude ephemeral reaches.	GRIC
4.0	***AZGS Geologic Maps***	
4.1	Map unit boundaries and labels are not always clear and colors used for map units are sometimes inconsistent with map legends.	Freeport
4.2	Disturbed areas should not be identified as geologic units.	GRIC, SRP
4.3	ADWR should describe how geologic data were transferred from AZGS.	Freeport
4.4	The AZGS geologic cross section used by ADWR does not represent actual surface and subsurface conditions in the watershed.	SRP
4.5	The varying accuracy of geologic contacts mapped by AZGS overstates the width of the subflow zone.	Sierra Vista Parties
4.6	ADWR's reduction in the scale of AZGS maps results in less accurate mapping of subflow zones and is an odd scale to use.	Freeport
4.7	ADWR's generalized grouping of AZGS geologic units is too simplistic.	GRIC
5.0	***Extent of Floodplain Holocene Alluvium***	
5.1	ADWR did not properly map the full extent of floodplain Holocene alluvium (FHA) since it relied on recent surficial geology, which is not stable, and its proposed methodology to address overlapping tributary Holocene alluvium (fan deposits) is flawed.	GRIC, SRP, TNC, US
5.2	The current distribution of riparian vegetation can be used to delineate FHA in the subsurface.	SRP and TNC
5.3	Borehole geologic logs and/or aquifer data can also be used to infer where FHA occurs in the subsurface.	TNC, US
5.4	Topographic maps and aerial photographs can be used to identify changes in topographic slope ("Holocene Trough") which define the boundaries of FHA deposition.	GRIC, SRP, TNC
5.5	Distribution of surficial geologic units along the floodplain could also be used to delineate the full extent of FHA.	GRIC, SRP, TNC
6.0	***Setbacks for Side Recharge***	
6.1	ADWR should not have routinely applied prescribed setbacks to account for side recharge from tributary and basin fill aquifers.	SRP, US
6.2.	Different setbacks should be applied for large and small tributaries.	SRP
6.3	More appropriate setbacks could be developed based on local water level data and subsurface flow directions.	TNC
7.0	***Delineation of Subflow Zones***	
7.1	ADWR's failure to map the full extent of FHA together with its routine application of prescribed setbacks for side recharge resulted in delineation of overly narrow and discontinuous subflow zones.	SRP, TNC, US
7.2	Alternative subflow zones were delineated and compared to ADWR's maps.	SRP, TNC
7.3	Subflow zones should have been mapped along mountain-front streams.	GRIC, SRP

Note:

[1] The cities of Phoenix and Tempe joined in the comments filed by SRP.

TABLE 2-2. SUMMARY OF TECHNICAL COMMENTS WHICH AGREE WITH SUBFLOW ZONE DELINEATION REPORT[1]

COMMENTS	PARTIES [2]
Predevelopment Streamflow Conditions	
Predevelopment conditions should be used to delineate the subflow zone.	SRP, US
Hydrologic criteria and procedures described in Chapter 2 are appropriate.	SRP, TNC
The description of hydrologic conditions in the San Pedro Watershed presented in Chapter 3 was thorough and accurate.	TNC
The general magnitude of phreatophyte evapotranspiration was properly estimated in Chapter 3.	SRP
Cultural depletions were properly summarized in Chapter 3.	SRP
ADWR properly concluded that the San Pedro River was perennial or intermittent during predevelopment times from the International Border to its confluence with the Gila River.	TNC, US
ADWR properly concluded that Aravaipa Creek and Babocomari River were perennial or intermittent during predevelopment times.	TNC, US
Predevelopment flows and water levels were properly analyzed in Chapter 3.	SRP
The delineation of predevelopment conditions is thorough, accurate and reliable.	US
AZGS Geologic Maps	
AZGS appropriately mapped the surficial geology along the San Pedro and Babocomari Rivers and Aravaipa Creek.	GRIC, SRP, TNC
Delineation of Subflow Zones	
Saturated floodplain Holocene alluvium should be used to delineate the subflow zone.	SRP, TNC
It is appropriate to assume that the entire lateral extent of floodplain Holocene alluvium is saturated.	SRP, TNC
Tributary aquifers, areas of basin fill recharge, and the alluvial plains of ephemeral streams should be excluded from the subflow zones.	SRP, TNC, US

Notes:

[1] This summary includes only those parties who explicitly agree with certain portions of the report.

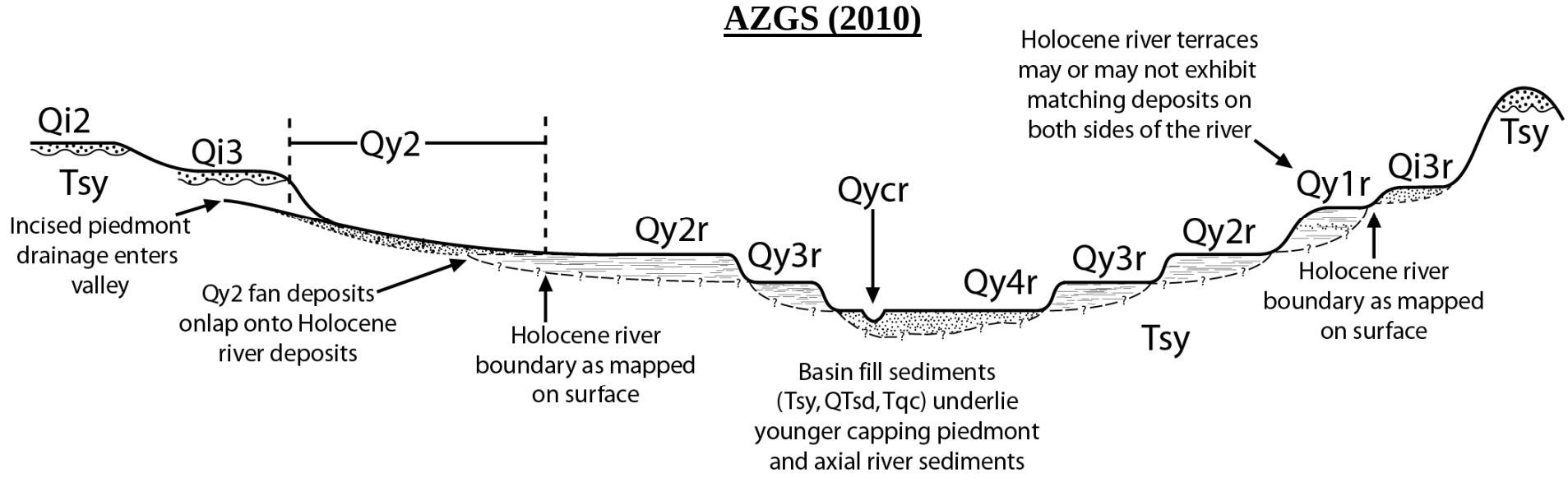
[2] The cities of Phoenix and Tempe joined in the comments filed by SRP.

TABLE 5-1. ALTERNATIVES FOR DELINEATING THE FULL EXTENT OF FLOODPLAIN HOLOCENE ALLUVIUM (FHA)

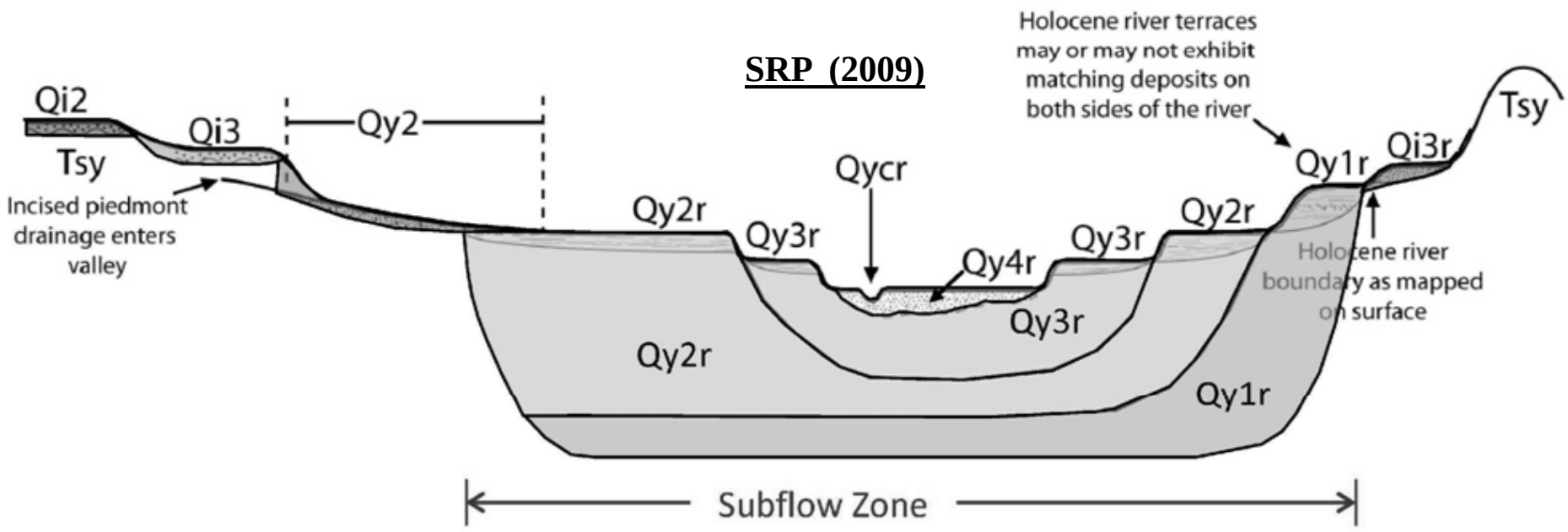
ALTERNATIVE	BASIS FOR DELINEATION	RELATIVE LEVELS OF CONFIDENCE		
		Delineation Only Includes FHA	Delineation Includes All Subsurface FHA	Delineation Represents a Stable Geologic Unit
A	Current outcrops of FHA combined with areas where fan deposits cover the historic active floodplain and form obvious fingers in the floodplain	High	Low	Low
B	Same as Alternative A plus potentially buried FHA located between the current floodplain and inliers	Low	High	High

FIGURES

AZGS (2010)



SRP (2009)



Key to AZGS and SRP Cross Sections

GEOLOGIC UNIT	UNIT NAME	AGE
Active\Modern Channel Deposits	Qycr	Holocene (10,000 years ago to present)
Stream Terraces	Qy4r (youngest)	Holocene
	Qy3r	
	Qy2r	
	Qy1r	
	Qi3r (oldest)	Pleistocene (2 million to 10,000 years ago)
Piedmont Deposits (Tributary Alluvium and Younger Basin Fill)	Qy2 (youngest)	Holocene
	Qi3	Pleistocene
	Qi2 (oldest)	
Older Basin Fill	QTsd (youngest)	Tertiary (2 million years ago and before)
	Tqc	
	Tsy (oldest)	

Hereford (1993)

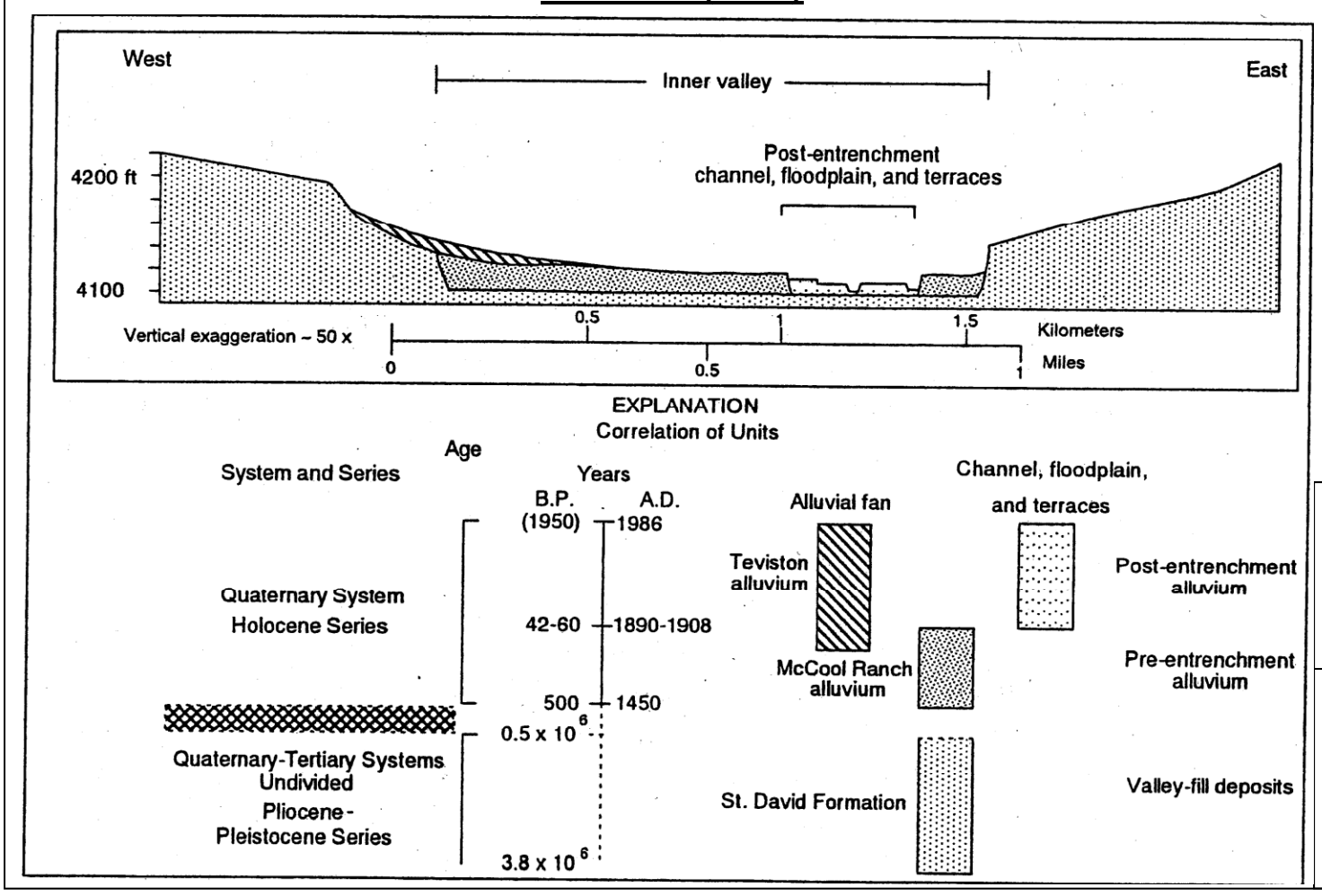


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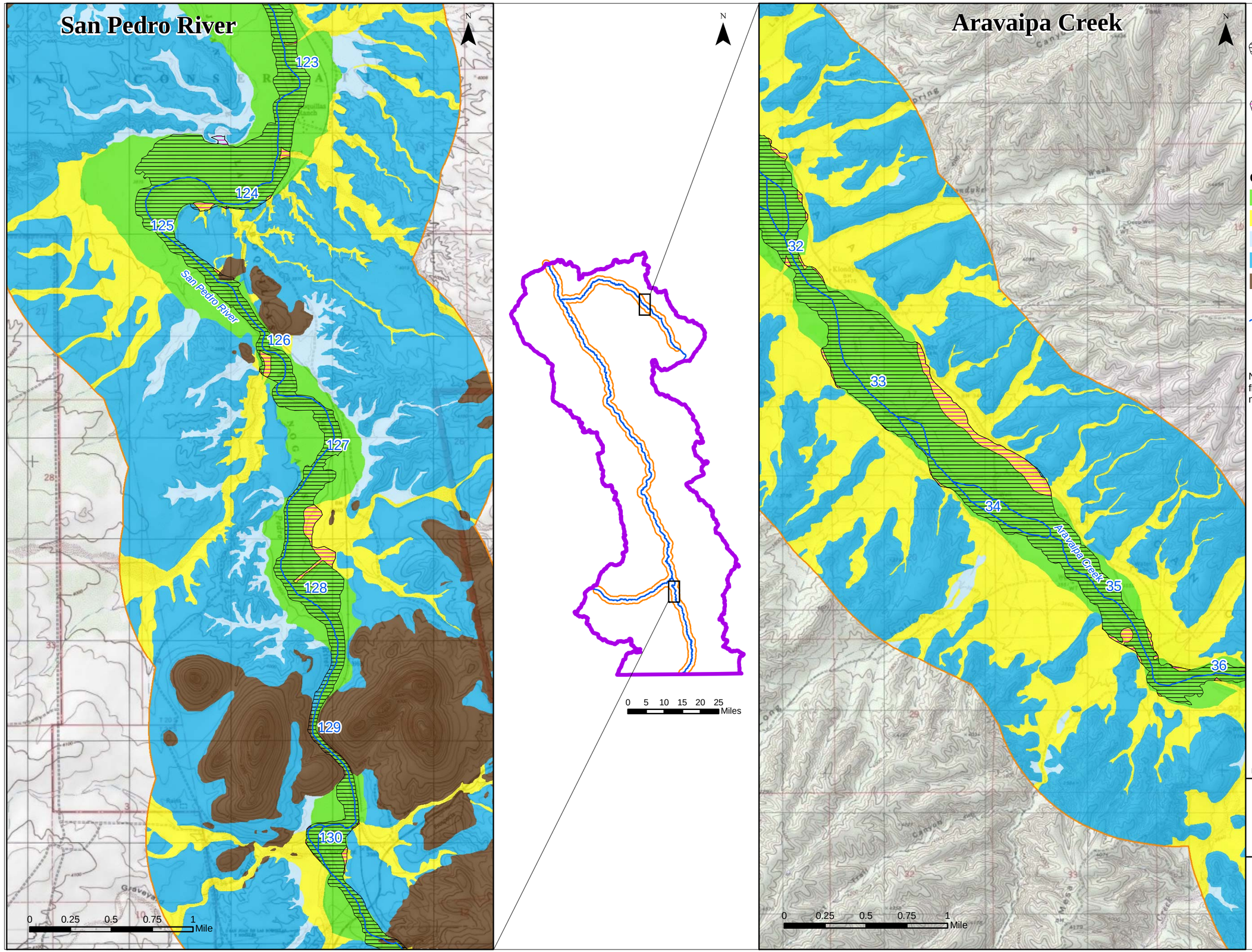
Figure 4-1

Comparison of Generalized Geologic Cross Sections along the San Pedro River

Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed



Legend

- Historical (1930s to 2007) Composite Active Floodplain Boundary
- Portion of Historic Composite Active Floodplain Boundary Currently Covered by Fan Deposits
- Area Mapped by AZGS (2009)

Generalized Geologic Units

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock

- Major Stream and River Mile Locations
- San Pedro Watershed

Note: Appendix D describes ADWR's active floodplain analysis and presents a series of maps that cover major streams in the watershed.

Base Map: USGS 1:24,000 Topo

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Figure 5-1
Examples Where the Historic Active Floodplain Is Currently Covered by Fan Deposits

Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed

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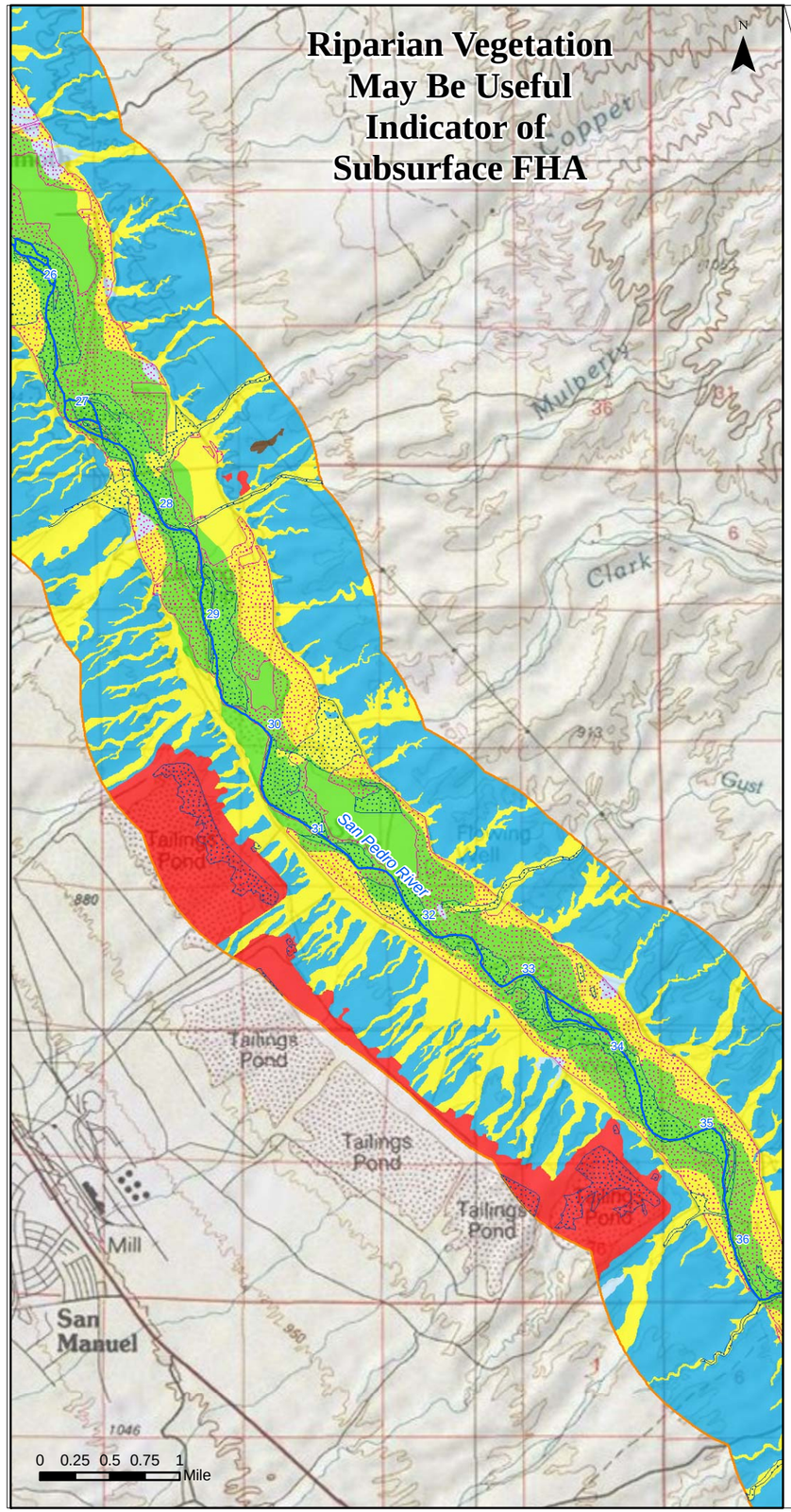

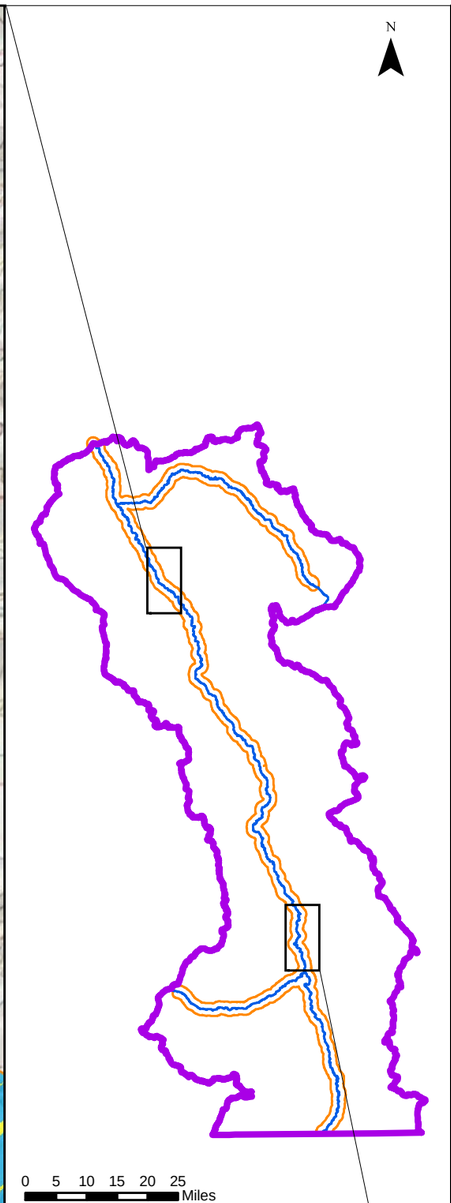

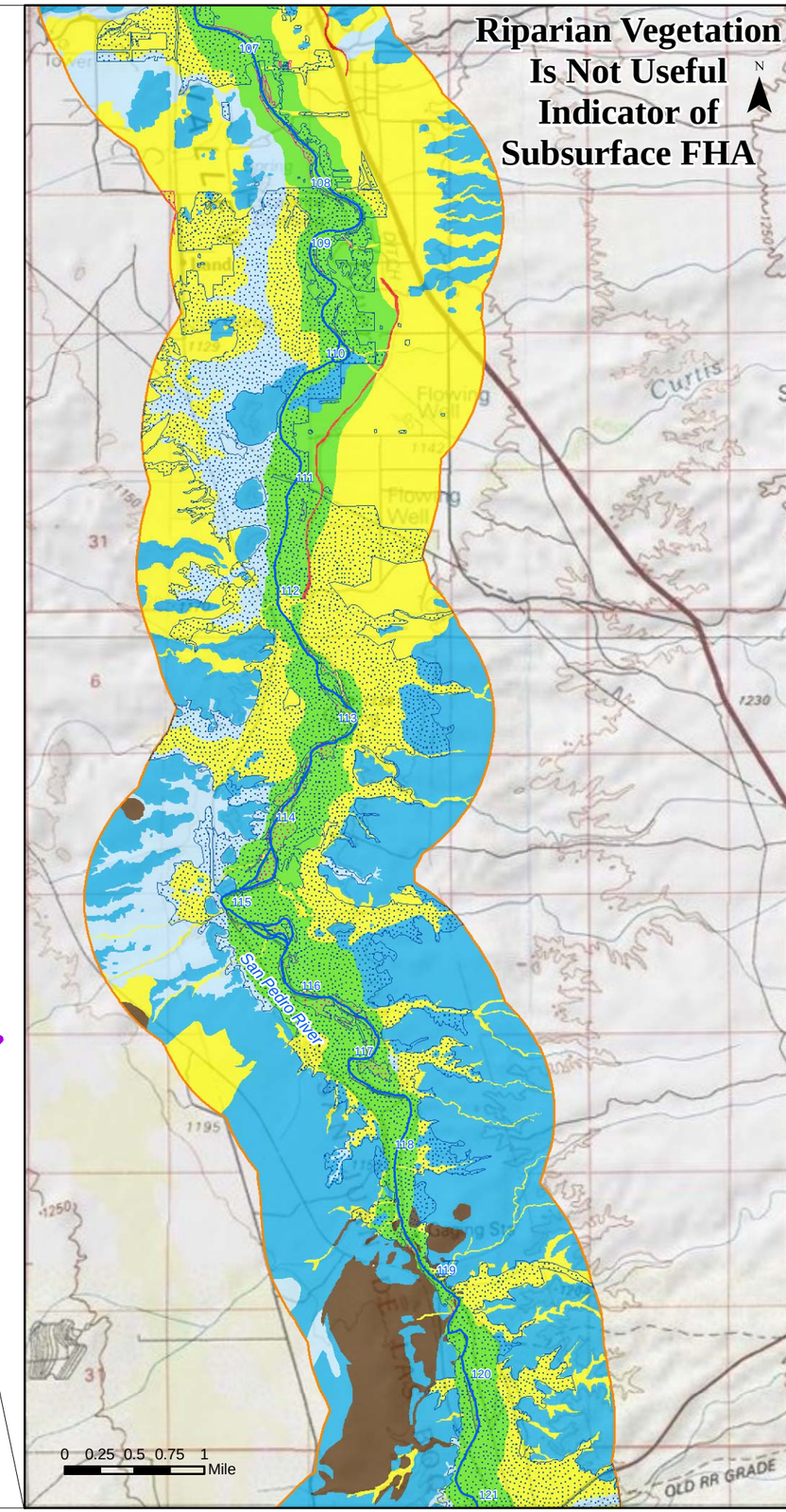

Legend

- 2001 Cottonwood-Willow and Mesquite Forest
- 2001 Wetlands and Other Riparian Areas*
  *Includes salt cedar forest, sacaton grass, and riparian scrub-shrub.
- Area Mapped by AZGS (2009)

Generalized Geologic Units

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock
- Disturbed (unit not determined)

- Major Stream and River Mile Locations
- San Pedro Watershed

Note: Appendix E presents a series of riparian vegetation maps that cover the San Pedro River and lower reaches of the Babocomari River and Aravaipa Creek. Vegetation mapping completed by U.S. Fish and Wildlife Service.

Base Map: USGS 1:24,000 Topo

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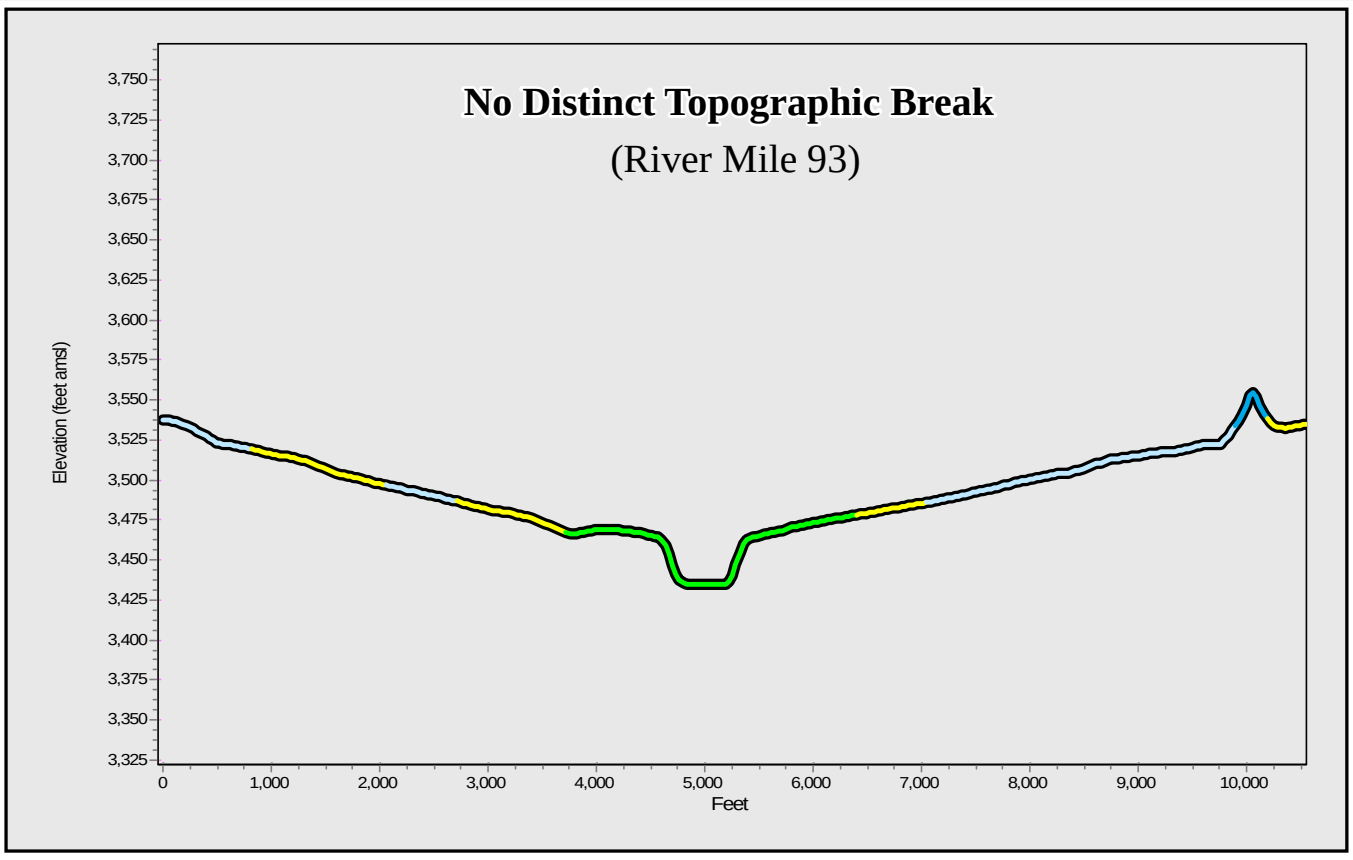
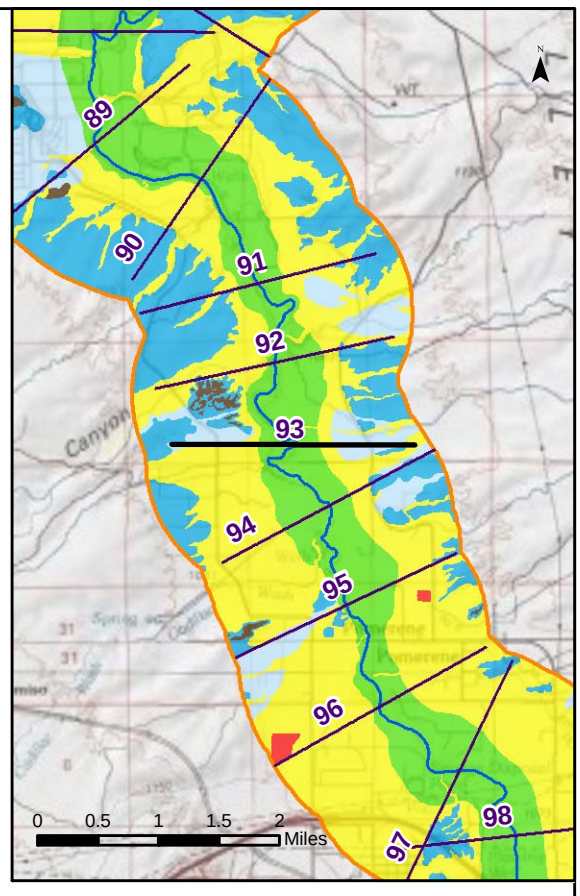
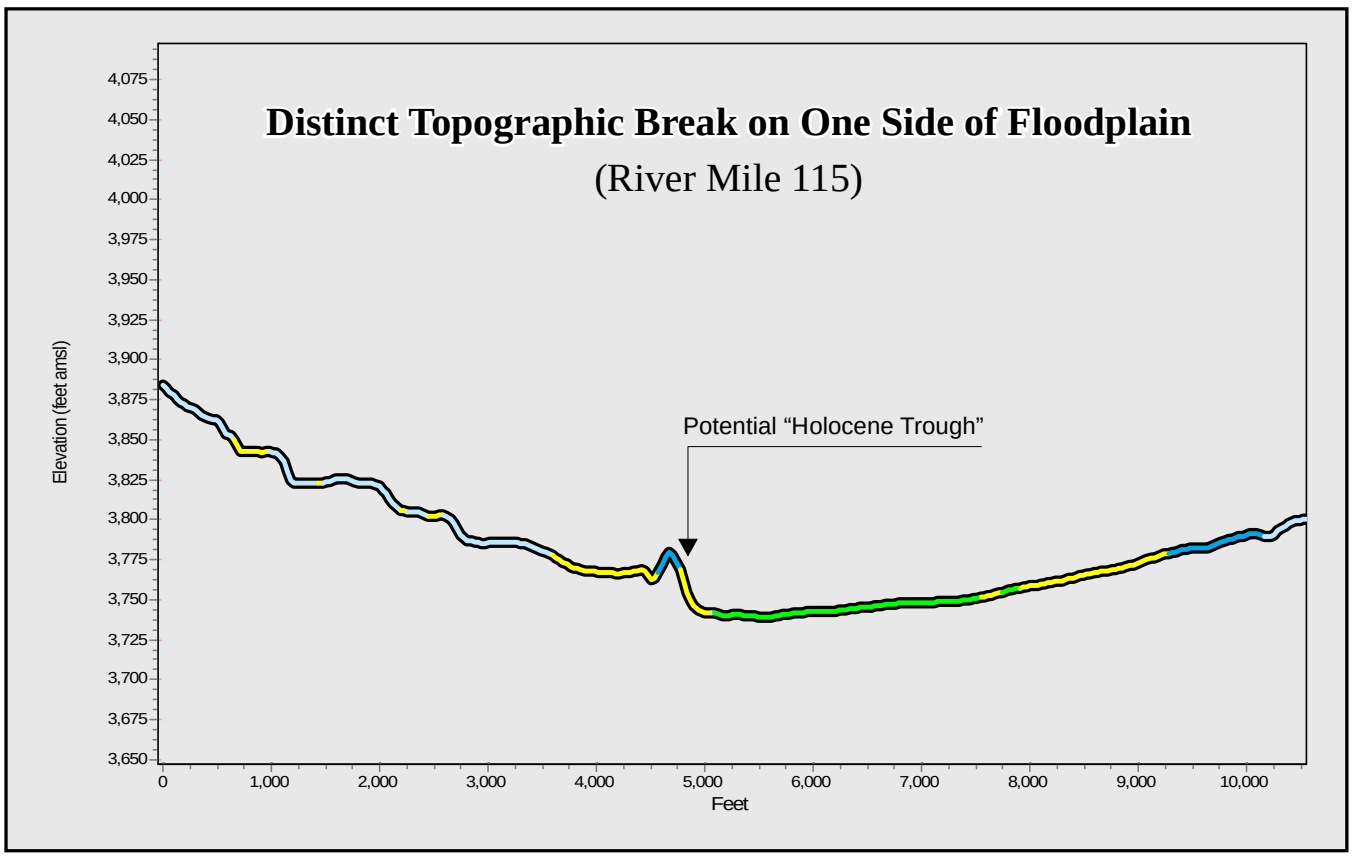
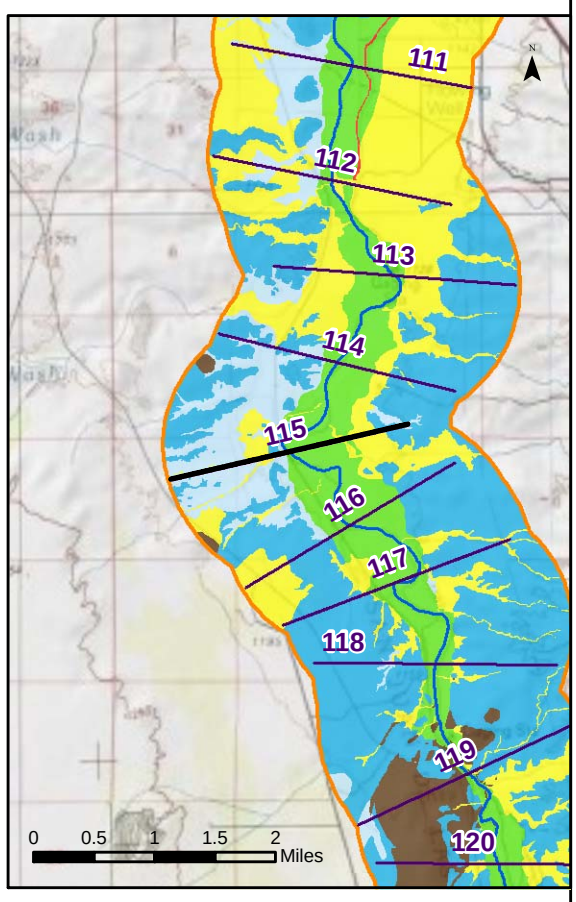
Figure 5-2
Use of Riparian Vegetation as an Indicator of Subsurface Floodplain Holocene Alluvium

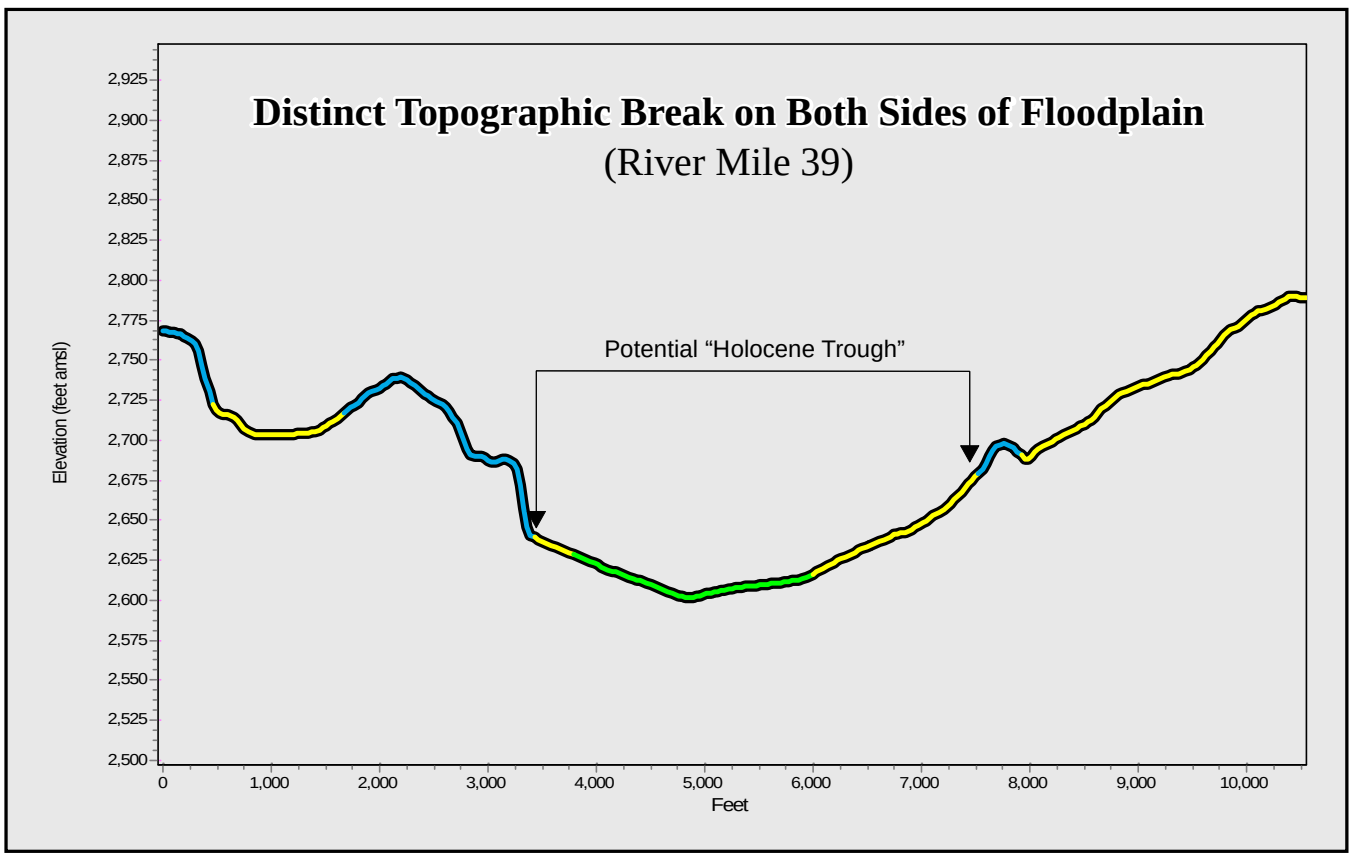
Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed

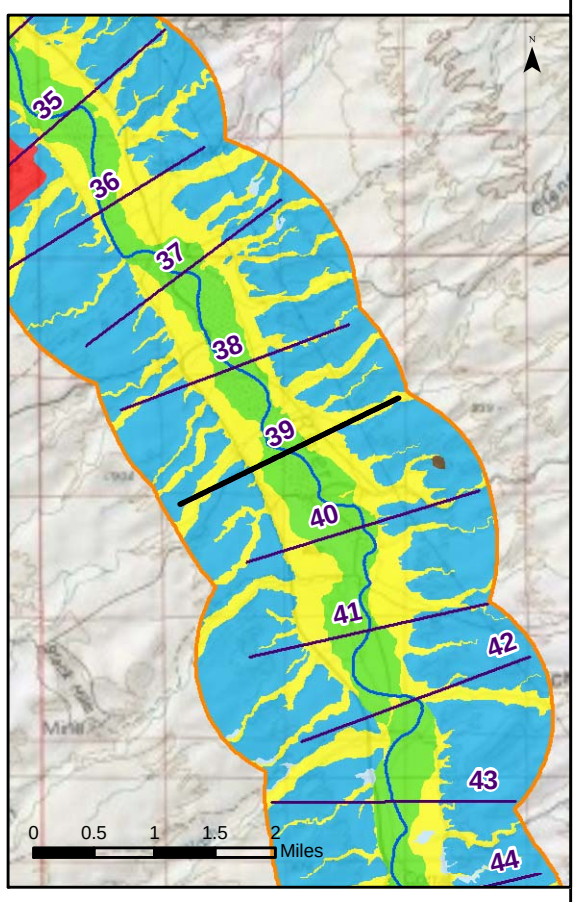


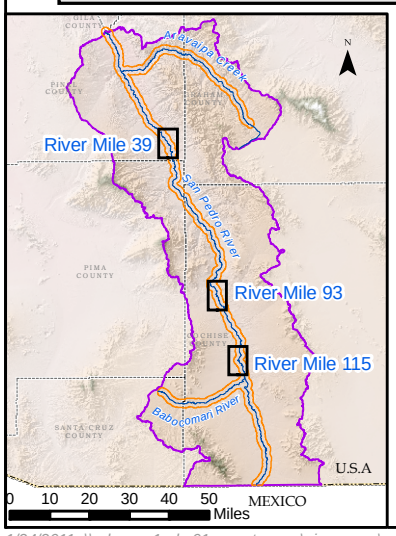












All Cross Sections at 15 X Vertical Exaggeration

Legend

Generalized Surficial Geology

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock
- Disturbed (unit not determined)

- Cross Section
- Surficial Geology Mapped by AZGS (2009)
- Major Stream and River Mile Location
- San Pedro River Watershed

Note: Appendix F includes a separate cross section along each mile of the San Pedro River (158 total)

Base Map: USGS 1:24,000 Topo

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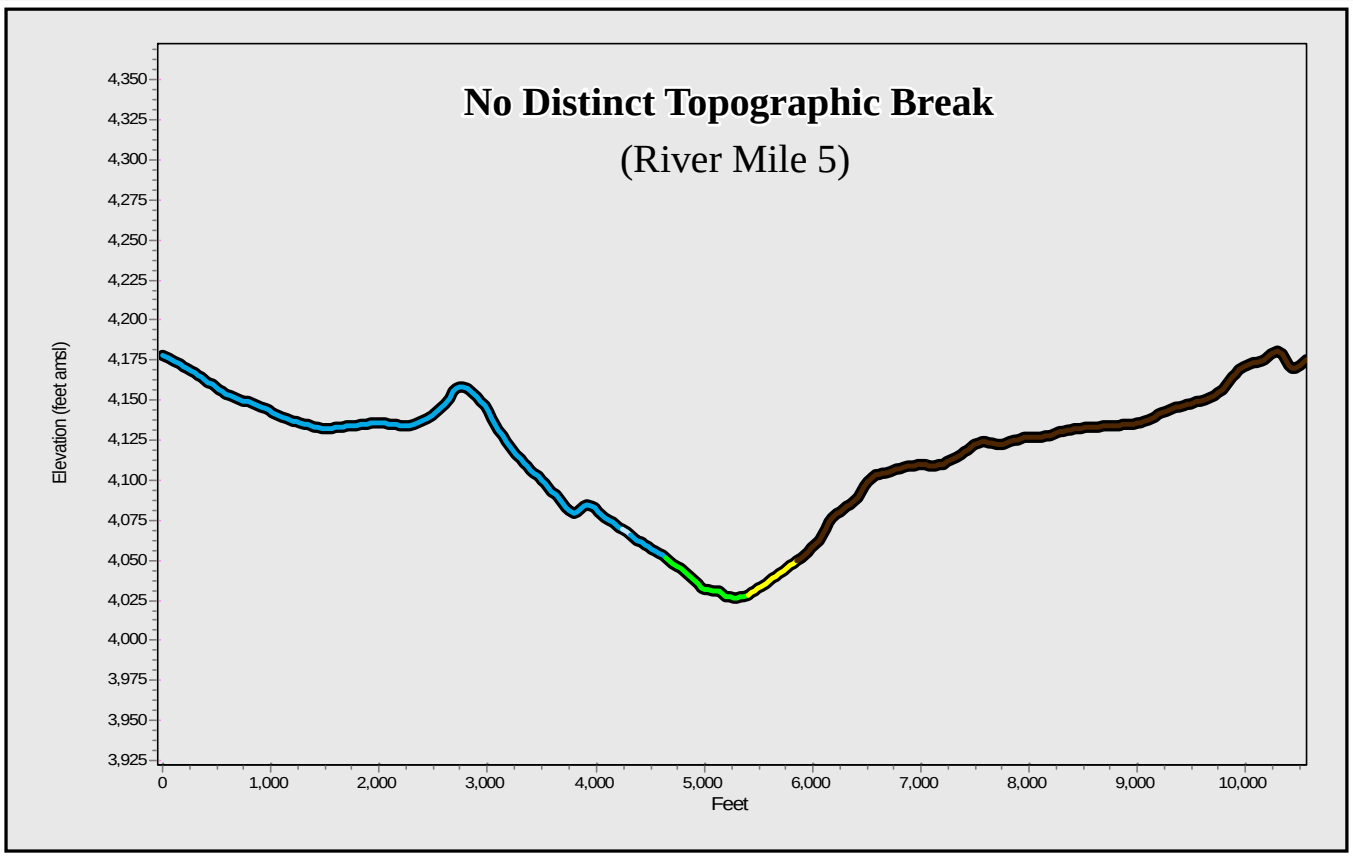
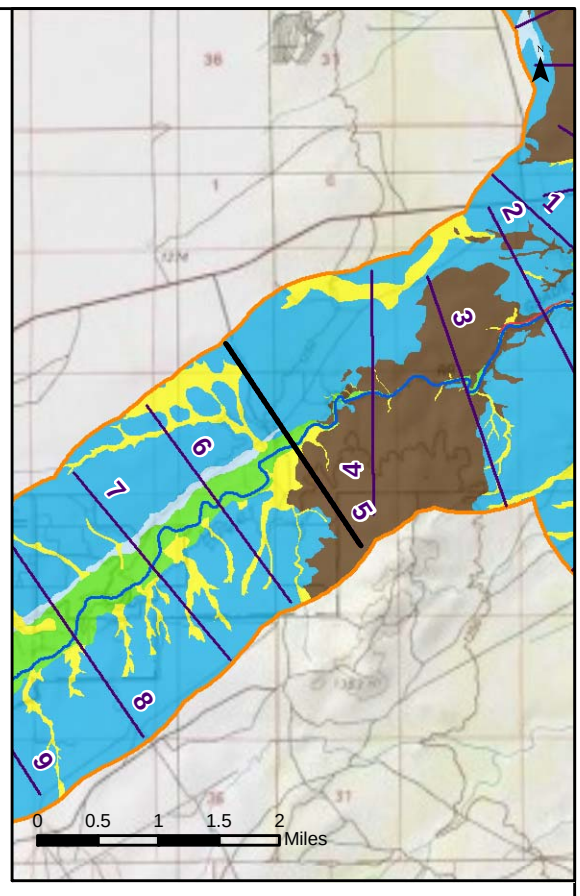
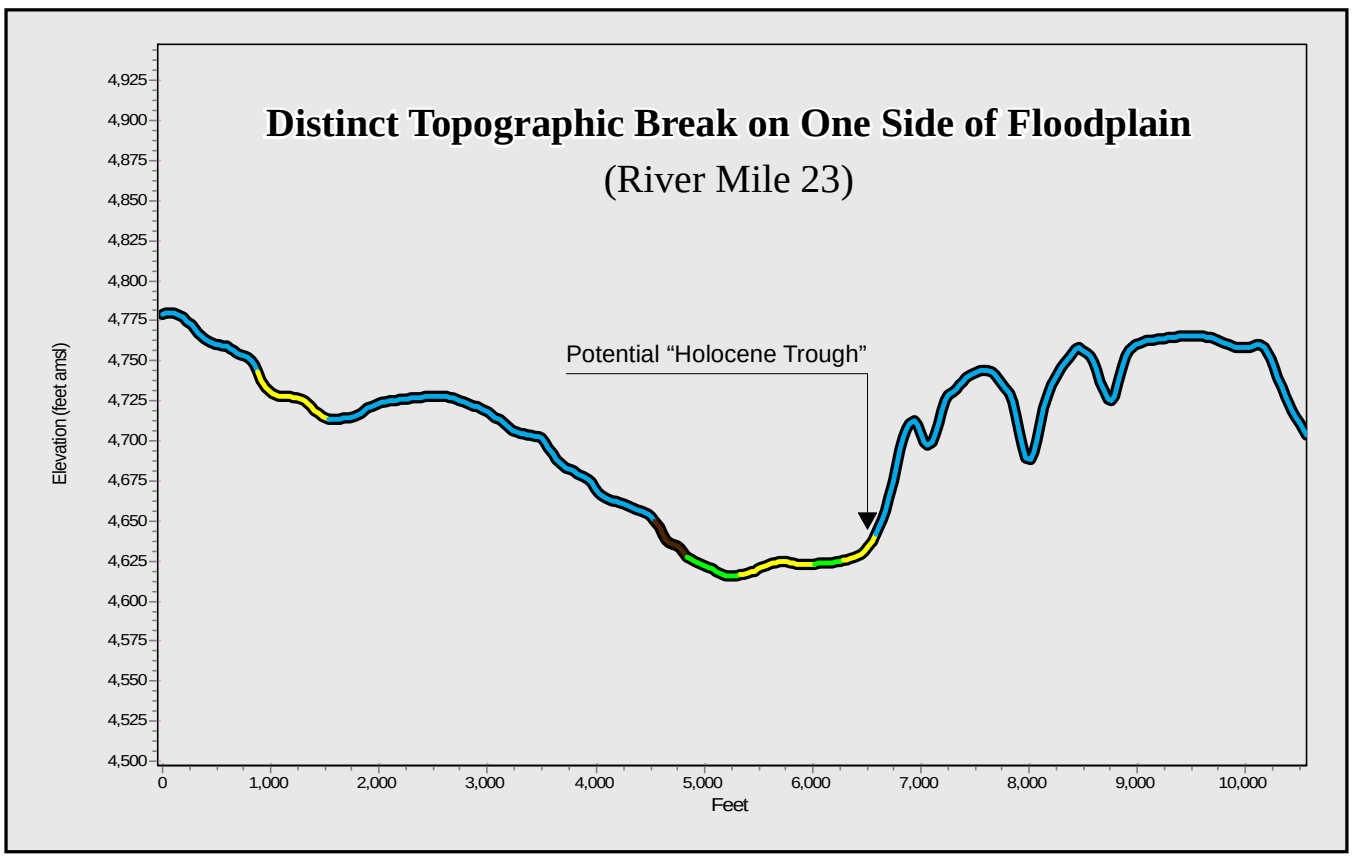
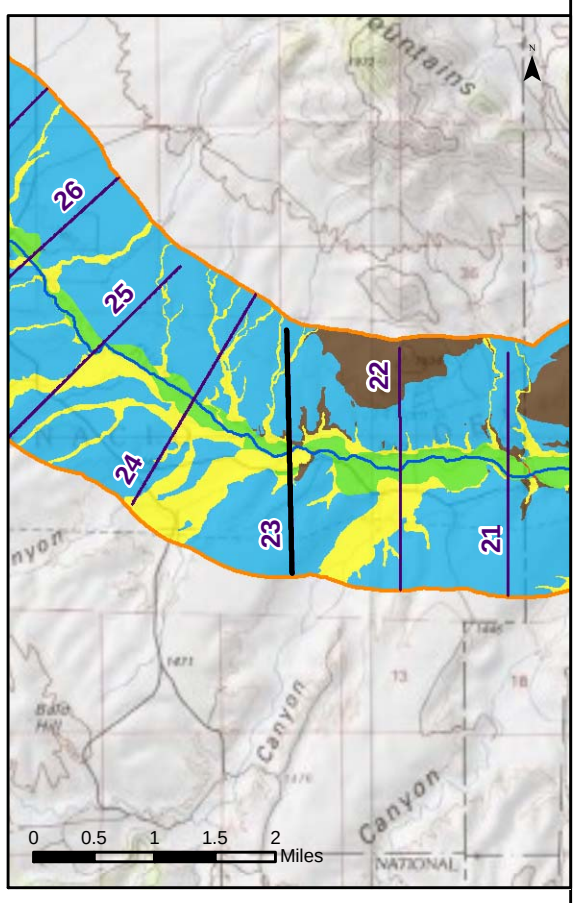
Figure 5-3a
Example Cross Sections of the San Pedro River

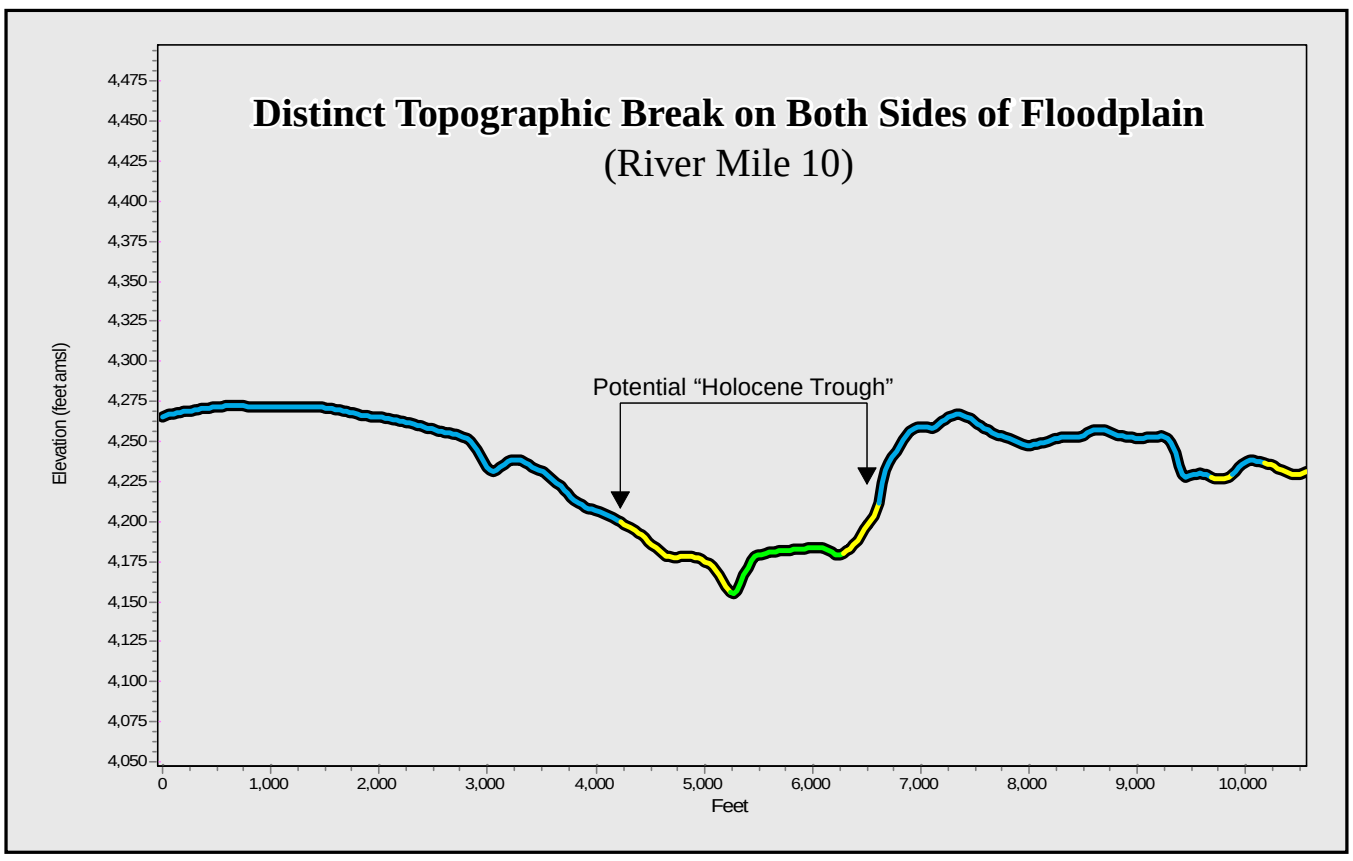
Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed

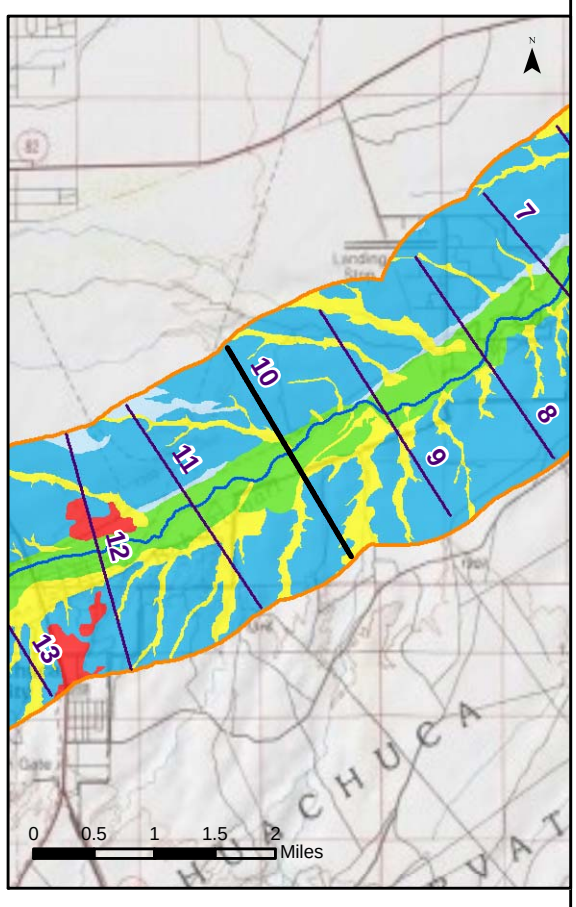


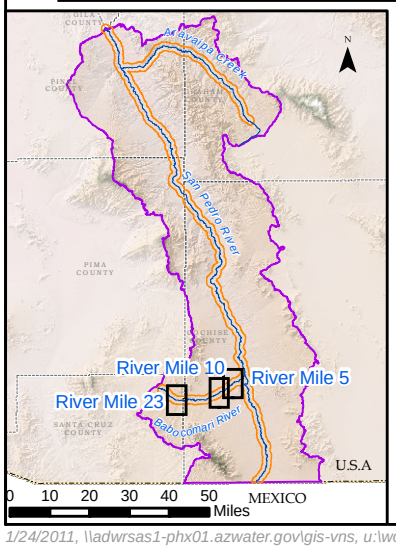












All Cross Sections at 15 X Vertical Exaggeration

Legend

Generalized Surficial Geology

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock
- Disturbed (unit not determined)
- Cross Section
- Surficial Geology Mapped by AZGS (2009)
- Major Stream and River Mile Location
- San Pedro River Watershed

Note: Appendix F includes a separate cross section along each mile of the Babocomari River (30 total)

Base Map: USGS 1:24,000 Topo

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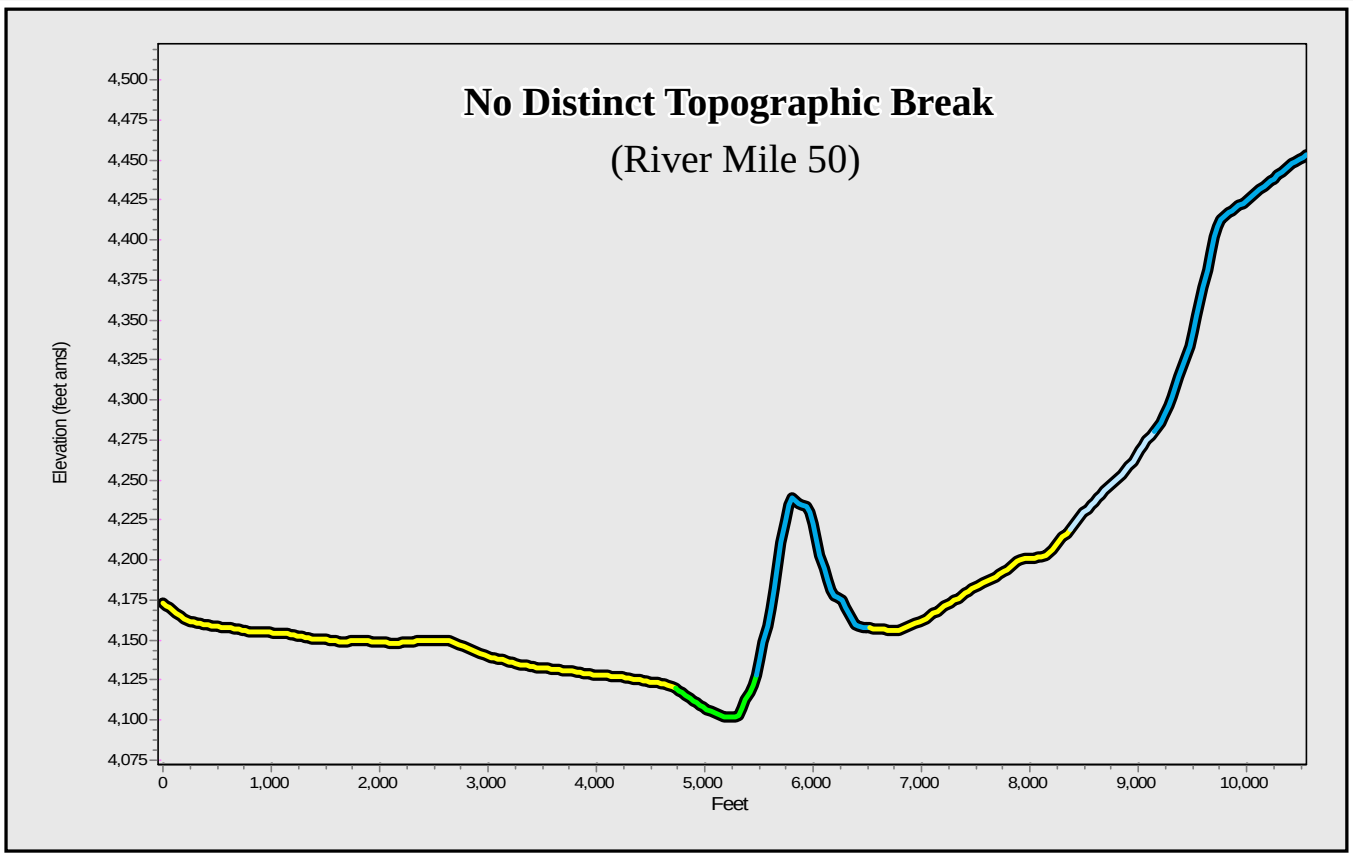
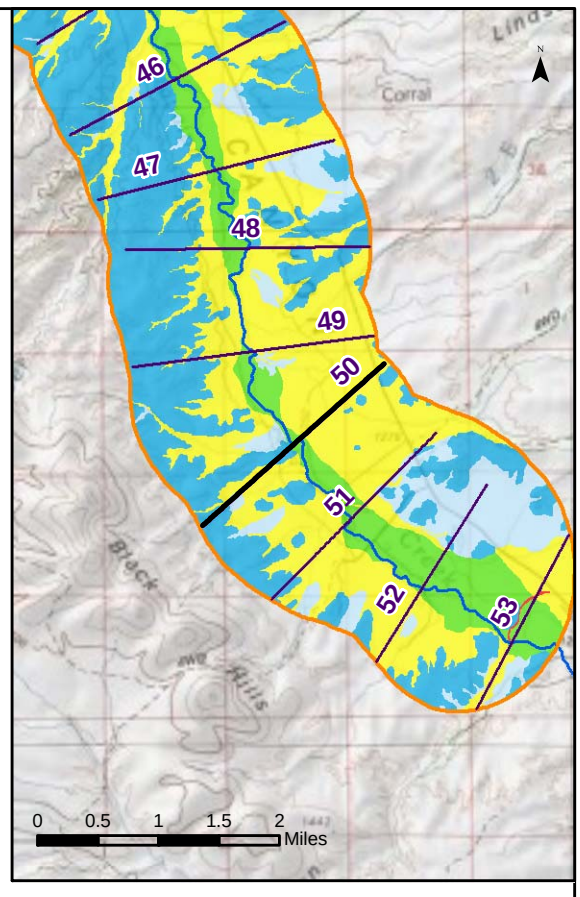
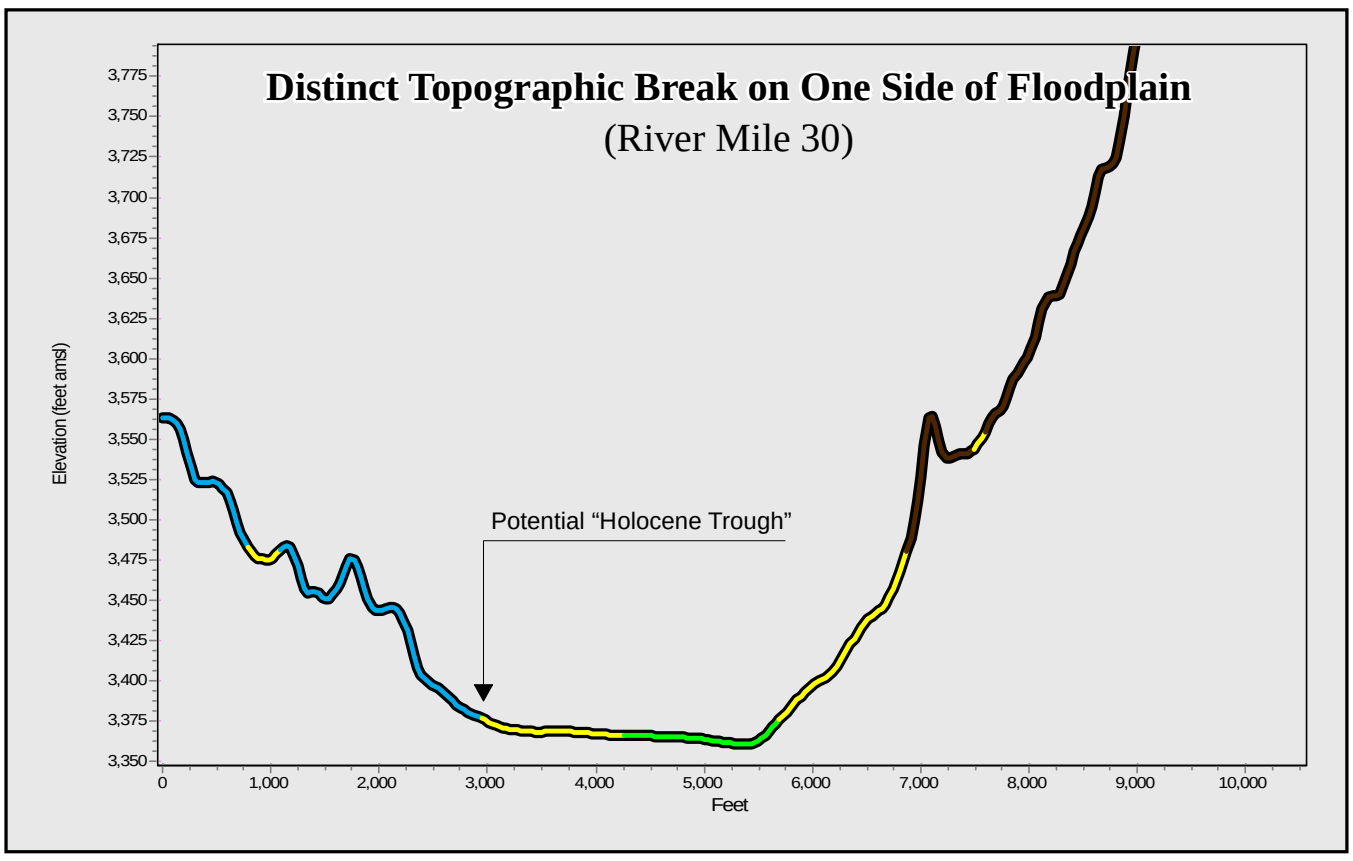
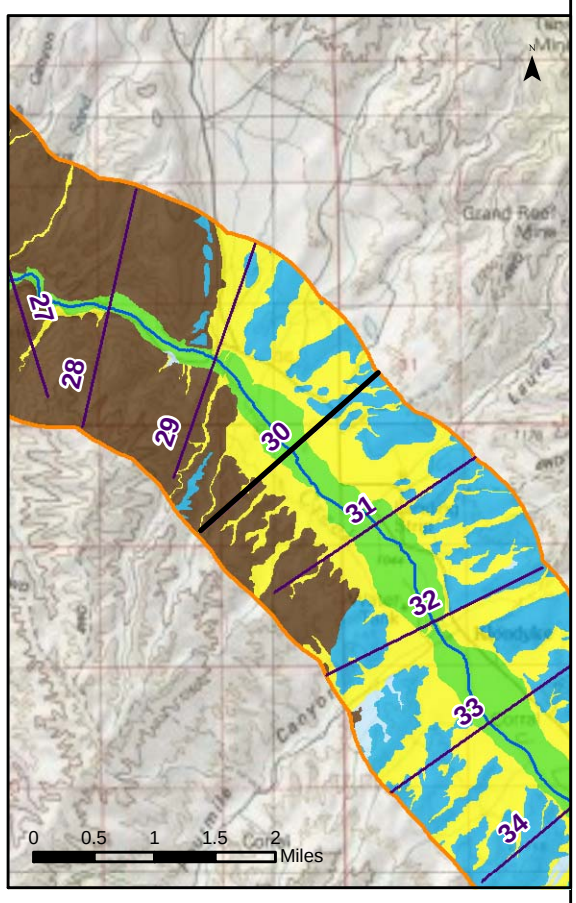
Figure 5-3b
Example Cross Sections of the Babocomari River

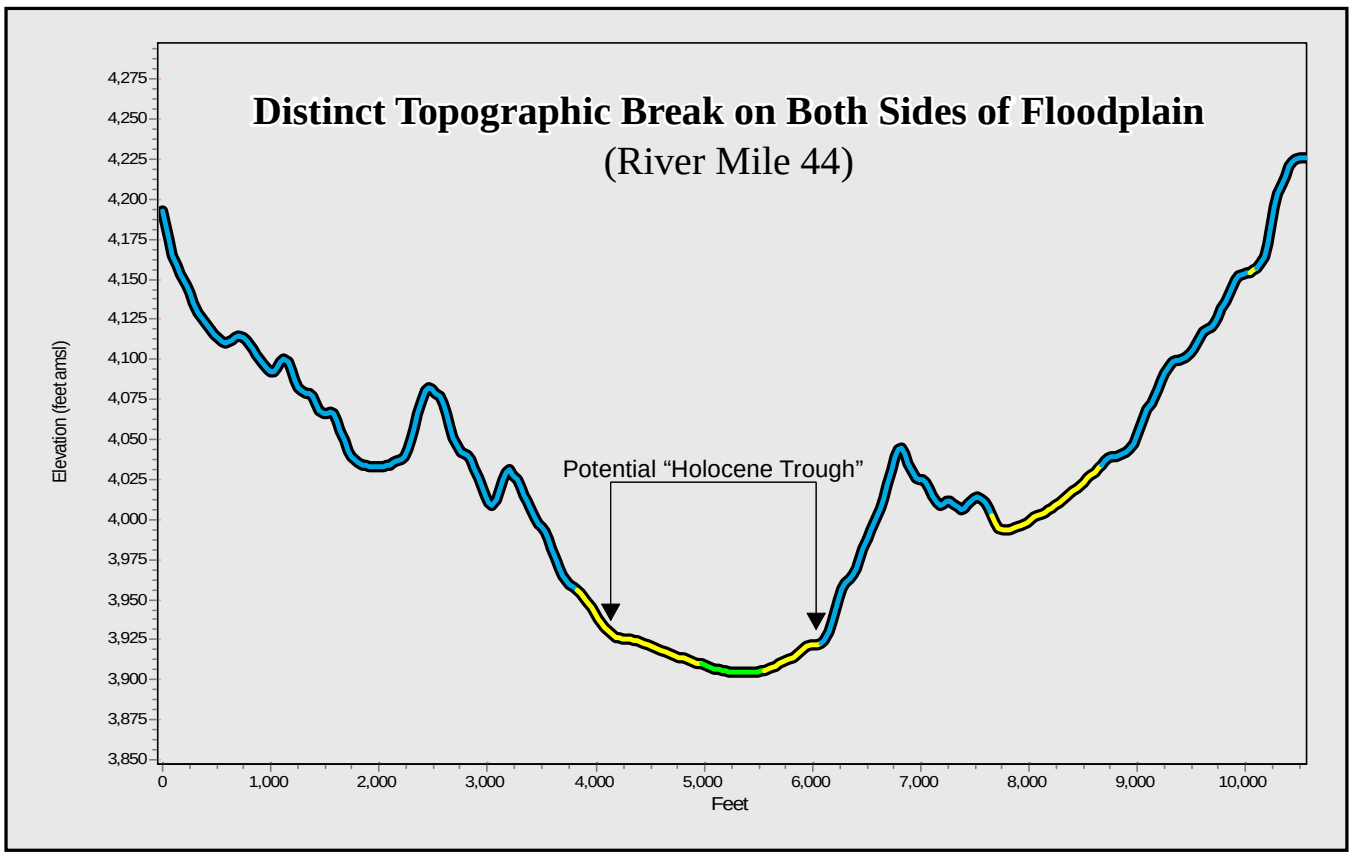
Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed

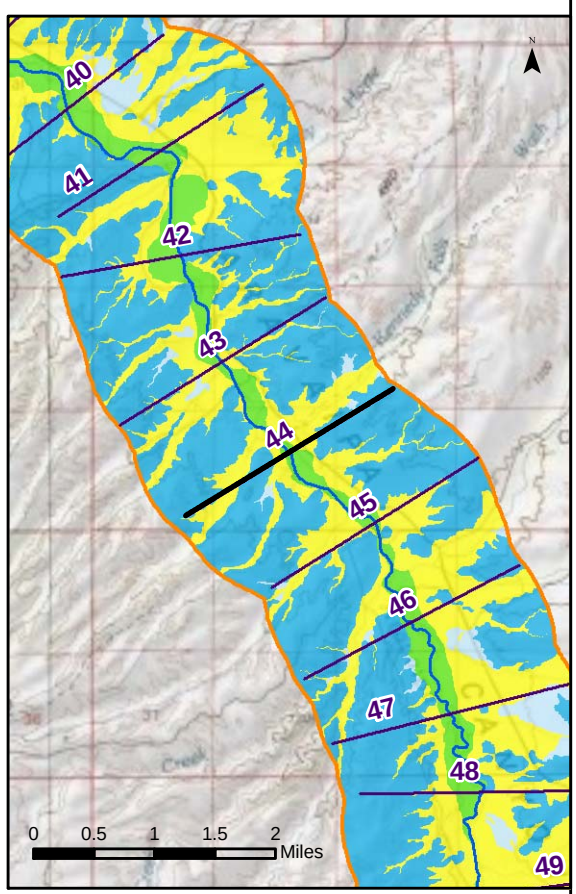


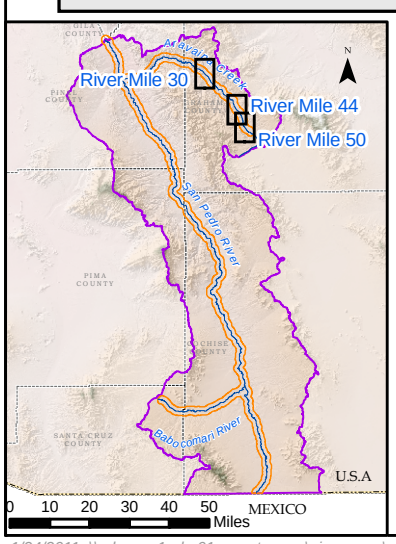












All Cross Sections at 15 X Vertical Exaggeration

Legend

Generalized Surficial Geology

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock
- Disturbed (unit not determined)

- Cross Section
- Surficial Geology Mapped by AZGS (2009)
- Major Stream and River Mile Location
- San Pedro River Watershed

Note: Appendix F includes a separate cross section along each mile of Aravaipa Creek (54 total)

Base Map: USGS 1:24,000 Topo

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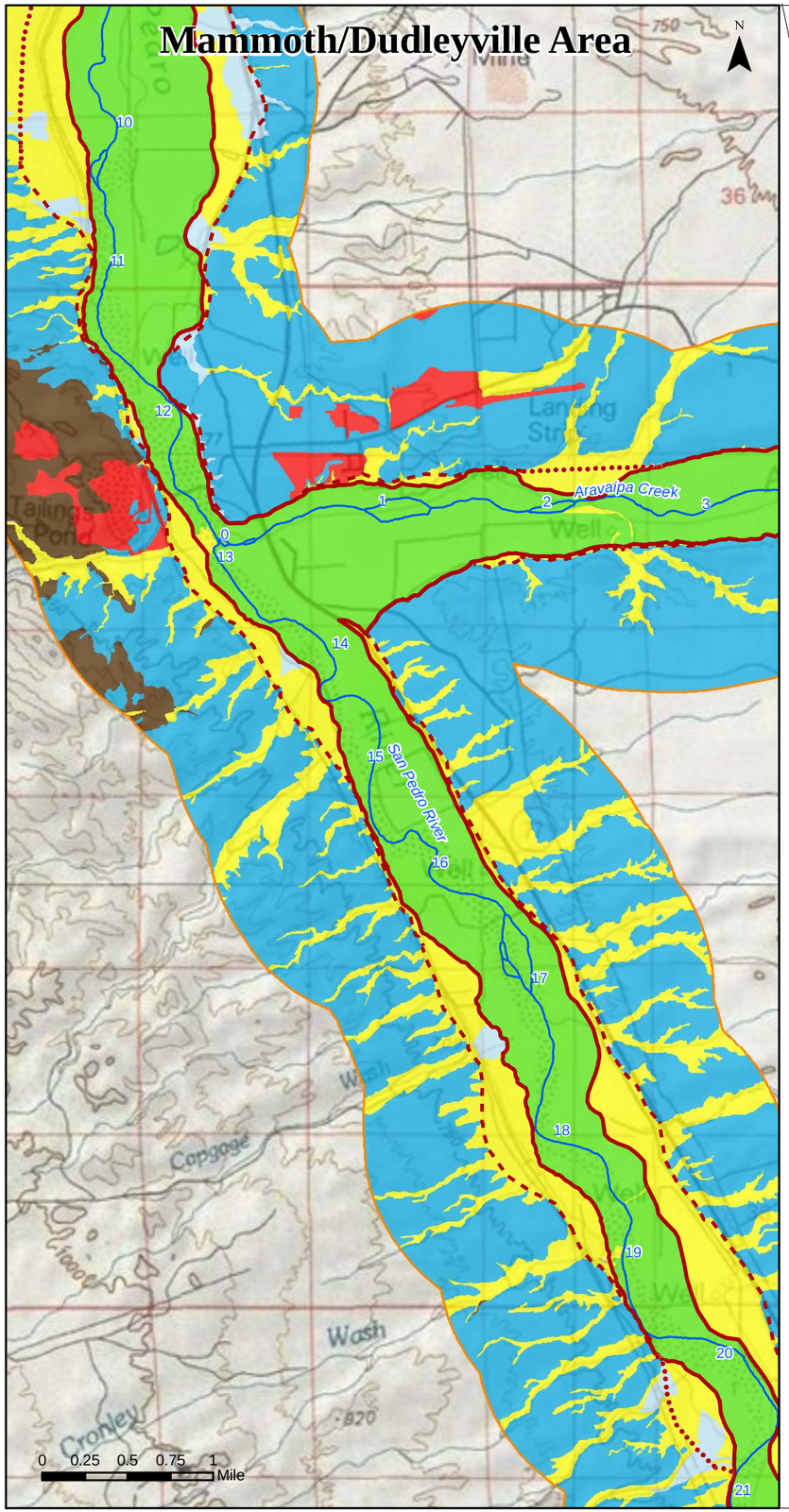
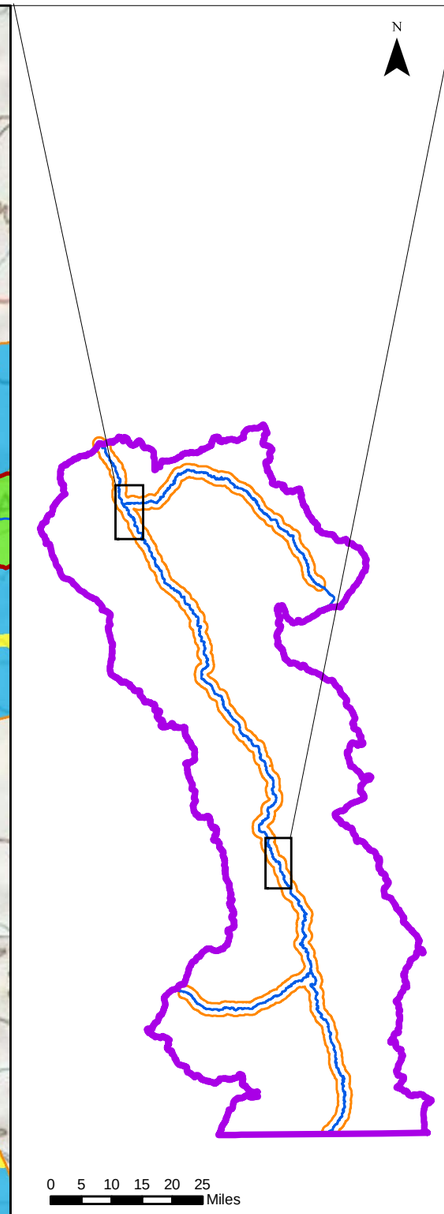
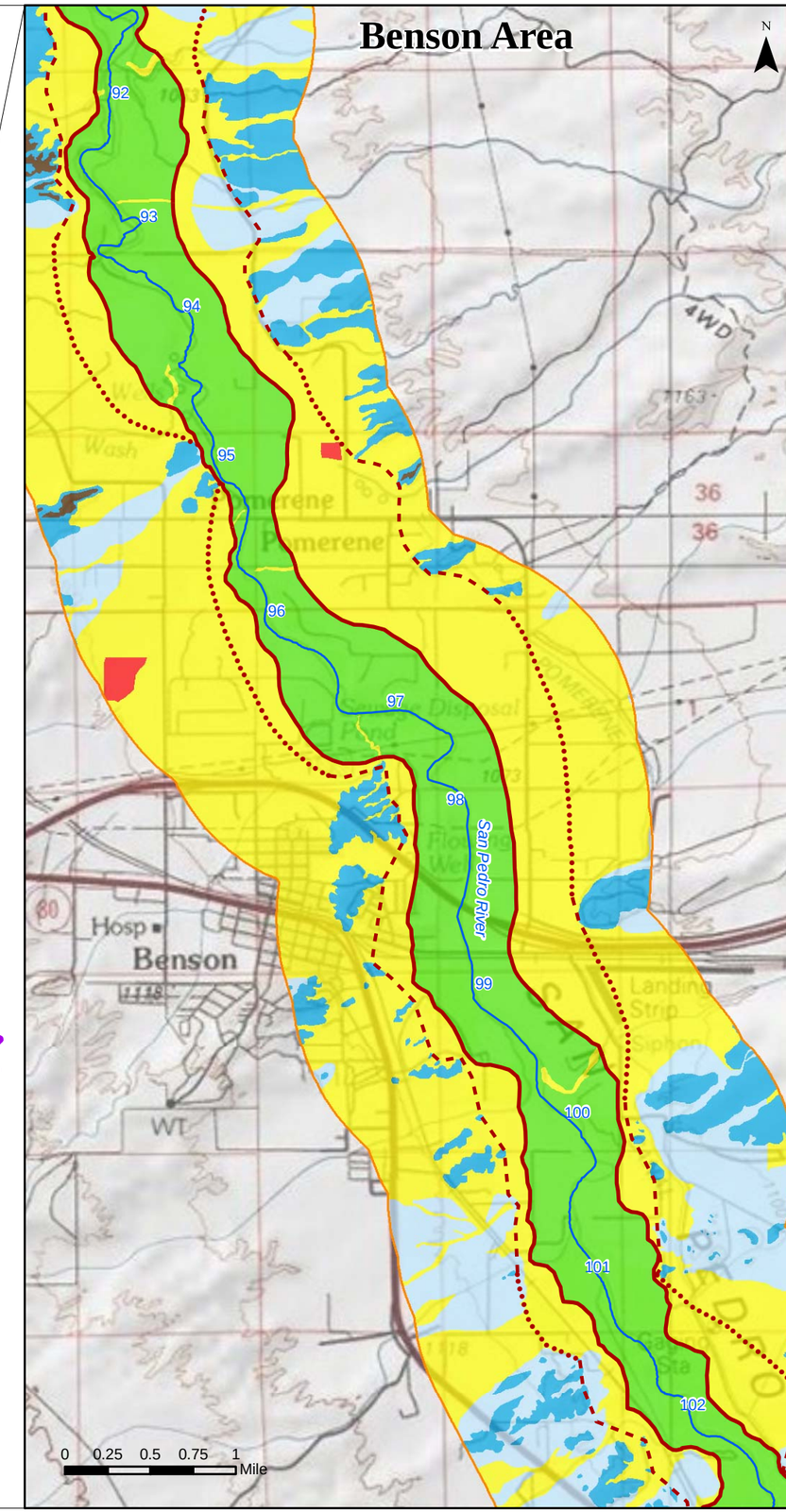
Figure 5-3c
Example Cross Sections of the Aravaipa Creek

Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed







Legend

- Area Mapped by AZGS (2009)

Generalized Geologic Units

- Floodplain Holocene Alluvium (FHA)
- Tributary Holocene Alluvium
- Holocene Basin Fill
- Older Basin Fill
- Bedrock
- Disturbed (unit not determined)

Potential Extent of FHA (Relative Levels of Confidence)

- High Confidence
- Moderate Confidence
- Low Confidence

- Major Stream and River Mile Locations
- San Pedro Watershed

Base Map: USGS 1:24,000 Topo

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Figure 5-4
Use of Geologic Outcrop Patterns to Map Fan Deposits Potentially Underlain by Floodplain Holocene Alluvium

Response to Comments and Objections Filed on ADWR's June 2009 Subflow Zone Delineation Report for the San Pedro River Watershed

REFERENCES

REFERENCES

Arizona Department of Water Resources (ADWR), 2009. *Subflow Zone Delineation Report for the San Pedro River Watershed*. In re The General Adjudication of the Gila River System and Source, June 2009.

Arizona Geologic Survey (AZGS), 2010. *Revision to Figure 3 from 2009 Holocene Mapping Report*. Attachment to December 13, 2010 email from Joe Cook (AZGS) to Rich Burtell (ADWR).

_____, 2009. Mapping *of Holocene River Alluvium along the San Pedro River, Aravaipa Creek, and Babocomari River, Southeastern Arizona*. Report prepared for the Adjudication and Technical Support Section of ADWR.

Hereford, R., 1993. *Entrenchment and Widening of the Upper San Pedro River, Arizona.* Geological Society of America Special Paper 282. 44 pp.

Pandy, S.N., 1987. *Principles and Applications of Photogeology*. New Age International. 366 pp.

Ray, R.G., 1984. *Aerial Photographs in Geologic Interpretation and Mapping.* U.S. Geological Survey Professional Paper 373.

Stetson Engineers, Inc. (Stetson), 1993. *The Delineation of Subflow in the San Pedro River Basin, Arizona, The General Adjudication of the Gila River System and Source.* Report to the United States Department of Justice. 25 pp.

U.S. Fish and Wildlife Service (USFWS), 2009. *A System for Mapping Riparian Areas in the Western United States.* Division of Habitat and Resource Conservation, Branch of Resource and Mapping Support, November 2009.

Van Zuidam, R.A., 1986. *Aerial Photo-interpretation in Terrain Analysis and Geomorphologic Mapping.* Smits Publishers. 442 pp.

Way, D.S., 1973. *Terrain Analysis: A Guide to Site Selection Using Aerial Photographic Interpretation*. Dowden, Hutchinson & Ross, Inc. 400 pp.