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June 29, 2009

Via Federal Express

Arizona Department of Water Resources
Attn: Adjudications
3550 N. Central Ave, 4th Floor
Phoenix, AZ 85012

Re: United States' comments on the Preliminary Hydrographic Survey Report for the Hopi Indian Reservation

Dear Sir or Madam,

Pursuant to A.R.S. § 45-256(H) and in accordance with the Court's Pretrial Order No. 6 re: Notice of Hydrographic Survey Reports, dated July 26, 2000, the United States of America ("United States") respectfully submits its comments on the Preliminary Hydrographic Survey Report for the Hopi Indian Reservation ("Preliminary HSR"). The comments are provided below by section consistent with the presentation in the Preliminary HSR. Language presented in italics below reflects the United States' proposed revisions to the Preliminary HSR.

Chapter 1: Introduction and Scope

1.1: Introduction

p. 1-2, footnote 1 – The information regarding the San Juan Southern Paiute Tribe should be clarified to note that they are a federally recognized tribe although they do not currently have a land base. It should be noted that the San Juan Southern Paiute lands are located generally northwest of Moenkopi village. The proposed revision would replace Section 1.1, footnote 1:

"The lands occupied by the San Juan Southern Paiute Tribe are not depicted on Figure 1-1. The San Juan Southern Paiute Tribe is a federally recognized Indian Tribe but does not currently have a reservation. The lands occupied by the San Juan Southern Paiute Tribe are generally located northwest of Moenkopi Village and may form the basis of a future San Juan Southern Paiute Reservation."

1.3: Scope

p. 1-4, ¶ 2– The *Gila V* statement of law should recognize that "[t]he method utilized in arriving at such an amount, however, must satisfy both present and future needs of the reservation as a livable homeland." *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 201 Ariz. 307, 35 P.3d 68, 77 (2001). The proposed revision for Section 1.3, ¶ 2, 2nd Sent. follows:

"Under Gila V, the water rights for the Hopi Reservation are to be quantified by determining the amount necessary to satisfy both the present and future needs that serve the purpose of the reservation, i.e. as a permanent home and abiding place, also referred to as homeland purposes. Gila V, 35 P.3d at 76-77."

Chapter 2: Summary of Adjudication Claims

As a general matter, the United States intends to file a Second Amended Statement of Claimant on behalf of the Hopi Tribe that will set out revised water right claims.

2.3.4: Past and Present Irrigation Use

p. 2-5, ¶ 1, last sentence – The maximum amount of water available is claimed in order to provide any available water to lands that have been irrigated in the past and present. The proposed revision for Section 2.3.4, ¶ 1 follows:

"However, the Hopi claim a maximum quantity for irrigation of the past and presently irrigated acreage in order to provide water in years when water is available. In other words, for those years with higher than average water availability, the maximum quantity claim ensures that the Hopi will be able to increase their farming acreage at the times that increased water is available. Such an approach is consistent with Hopi historic practice.

2.5: 1994 United States Claim

p. 2-12,– The summary of the 1994 United States Amended Claim needs to clarify that the numbers provided in the HSR are for Hopi only. The proposed revision for Section 2.5, ¶ 1 follows:

"On November 22, 1994, pursuant to court order, the United States, on its own behalf and as trustee for the Navajo Nation, the Hopi Tribe, the White Mountain Apache Tribe and the Zuni Pueblo, filed amended SOCs on behalf of Indian Lands in the Little Colorado River Basin, including SOC No. 39-91441 (See Appendix A-2). The 1994 United States Amendment separated the water claimed by tribe. The claimed water uses for the Hopi Tribe set forth in the amendment are set forth below, and are based on 'current or recent' (as of 1994) as well as 'future additional' uses, which respective amounts are indicated parenthetically after the total."

2.6.4: Past and Present Irrigation Use

p. 2-15, ¶ 1 on this page, last sentence – The maximum amount of water available is claimed in order to provide any available water to lands that have been irrigated in the past and present. The proposed revision for Section 2.6.4, ¶ 1 follows:

"This information is presented in Table 2 of the United States claim, which includes an average irrigation diversion of 28,489 AFA. The United States claims the maximum diversion amount in order to provide irrigation on larger areas of historically irrigated land in years when water is available. (see also Sec. 2.3.4)"

2.8: Summary and Comparison of Hopi and United States 2004 Claims and 2005 Supplemental Information for Past and Present Uses

p. 2-18,– HSR Table 2-1 claims to compare the Hopi and United States claims but does not compare them accurately. The Hopi and United States' domestic, commercial, municipal and industrial ("DCMI") claims included past, present and future DCMI claims as one 11,211 AF claim. ADWR's breakdown of the springs, wells and stockponds does not accurately reflect past and present DCMI quantities as claimed. The proposed revision for Table 2-1 is to _delete_ the DCMI entry and simply note that the US and Hopi Tribe claim a DCMI amount that includes past, present and future and that the separation of the time-dependant components of the DCMI claim has not been performed.

2.12: Other Water Uses

p. 2-26, - The first sentence of Section 2.12 may create some confusion as it does not specify that it is addressing non-Hopi uses. The proposed revision for Section 2.12, 1st Sent. follows:

"The Department is aware of two parcels of land that may lie within the Hopi Reservation on which water may have been claimed or used by persons or groups other than the Hopi Tribe or its members."

Chapter 3: Hopi Reservation Lands

3.1.5: Hopi Agency (1850-1882)

pp. 3-6 through 3-7,– This Section 3.1.5 charts generally the administrative history of Hopis under American authority, but glosses over much of the background behind the issuance of the 1882 Executive Order which set aside the "Moqui," i.e. Hopi reservation. The proposed revision is to add the following paragraph, to be inserted after the fourth paragraph of this section:

"Efforts to set aside a reservation for the Hopi spanned the careers of all of these Indian agents. Prior to 1882, these agents' concern focused on the lack of a reservation to protect the Hopis from threat of encroachments by non-Indian cattlemen, the proximity of the Mormons at Moenkopi, the presence of the Navajos and the resulting competition over land and water. All of these issues led periodically to recommendations by some Indian agents to move the Hopis from their villages to the Little Colorado River in order to secure a reliable water source"

3.2: 1882 Executive Order Reservation Lands

p. 3-8, , ¶ 1 – This Section provides an instructive description of Jesse Fleming's depiction of proposed Hopi Reservation boundaries but lacks the underlying reasoning for his decision to exclude Moenkopi and fails to mention another government official's recommendation that Moenkopi be included as part of the Hopi Reservation. The proposed revision is to substitute the following text in lieu of the 5th sentence beginning "*As instructed…*":

"His proposal did not include the Moenkopi area, occupied by approximately 100 Hopi in 1882, because Fleming felt that the inclusion of the non-Indians at Moenkopi could complicate the administration of the reservation. It should be noted that contemporary to Fleming's survey of the land was the work of another government official, Charles H. Howard. Inspector Howard was in the process of making his own reservation proposal, one to include the Moenkopi area within a Hopi reservation, when the 1882 Executive Order was issued."

p. 3-8, ¶ 2 – Historical evidence does not support the statement that Navajos settled on the Hopi Mesas, but rather that the Navajo occupied lands between the Hopi mesas at times. The proposed revision is to substitute the following sentence for the third sentence in Sec. 3.2, ¶ 2:

"Some Navajo used lands between the Hopi Mesas and within the boundaries of the 1882 Executive Order Reservation for raising livestock and building homes."

3.3: 1934 Act Reservation Lands (Moenkopi)

pp. 3-14 through 3-15, ¶ 1 – The description of the 1900 Executive Order lands as opposed to the 1934 Navajo Boundary Extension Act should be clarified. The proposed revision is to redraft Sec. 3.3, ¶ 1 & the first sentence of ¶ 2 as follows:

"*In addition to lands within the 1882 Executive Order Reservation, there are Hopi lands within the surrounding Navajo Reservation. The Navajo Reservation was initially created by Treaty of June 1, 1868, 15 Stat. 667, and was expanded through various executive orders. For example, the Executive Order, dated January 8, 1900, incorporated the lands immediately west of the 1882 Executive Order Reservation extending to the Little Colorado River and Colorado River into the Navajo Reservation, including Upper and Lower Moenkopi villages as well as surrounding areas to which the Hopi claimed an exclusive interest. This land is often referred to as the 1900 Extension. See Figure 3-2.* (keep footnote 13 the same) *The 1900 Executive Order did not mention the Navajo or any other Indians, but the consensus of the government officials was that the lands were withdrawn in anticipation of the areas being allotted to the Indians. Certain Moenkopi lands were allotted and occupied by both Hopis and Navajos prior to the issuance of the 1900 Executive Order.*

In 1934, Congress passed legislation that confirmed the boundaries of the Navajo Reservation resulting from the additions made by the prior executive orders. Act of June 14, 1934, Ch. 521, 48 Stat. 960. In addition to confirming the boundaries of the Navajo Reservation, the 1934 Act permanently ..."

3.4: Allotted Lands

pp. 3-17 through 3-18,– This Section needs some additional information to clarify that the Dawes Act authorized allotment of lands from the unappropriated public domain as well as from reservation lands. This is important because the Hopi allotments were withdrawn from the public domain, not from the 1882 Executive Order Reservation, and allotted to Hopi individuals. This clarification is important because the Hopi allotments occurred prior to the 1900 Executive Order but were part of the lands covered by the 1900 Executive Order that were added to the Navajo Reservation as a result of the passage of the 1934 Navajo boundary extension bill. The proposed revision is to substitute the following text in lieu of ¶ 1 and 1st Sent of ¶ 2 :

"*Under the Indian General Allotment Act of 1887, also known as Dawes Severalty Act, the President was authorized to allot reservation lands to individual Indians when advantageous for "agricultural and grazing purposes." Act of February 8, 1887, ch. 119, § 1, 24 Stat. 338. The Act authorized the allotment of lands within the boundaries of Indian reservations as well as from lands on unappropriated public domain to Indians not residing upon a reservation or for those with no tribal reservation. The allotment program ended in 1934 as part of the Indian Reorganization Act. 48 Stat. at 984.*

The allotments to Hopi Tribal members were established in the late 1800s and were allotted from the public domain at Moenkopi, located outside the exterior boundaries of the 1882 Hopi Reservation. The surrounding area was subsequently *withdrawn by the January 8, 1900 Executive Order. This withdrawal became a permanent addition to the Navajo reservation as the result of the passage of the 1934 Navajo boundary extension bill. These allotted lands are depicted on Figure 1-2 ..."*

Chapter 4: Physical Setting

The United States has no comments on this section.

Chapter 5: Culture

The United States has no comments on this section.

Chapter 6: Economic Base

6.1.1: Arable Land

p. 6-2, Sec. ¶ 4 – The use of the term "irrigated" in the last sentence appears to be an error and should be changed to "arable" as follows:

"The other 37% of Reservation lands or approximately 597,758 acres had soil types that were not found to be arable during the NRCS survey and, therefore, were not given an Irrigated Capability Class by NRCS."

6.4: Human Resources

As a general matter, the United States intends to update its population projections for the Hopi Tribe in its Second Amended Statement of Claimant.

The United States finds that Section 6.4 reveals a number of data gaps and, with some data, a level of inter-year variation that on its face puts to question the data's accuracy. While the United States understands that accurate and consistent data on Reservation demography, employment and general economics is sometimes unavailable, we feel that this section demands closer examination of data and explanation of possible sources of error. Given the number and specificity of the United States' concerns, proposed revisions for Section 6.4 have been made in the table below.

Data	Location in Report	Issue	Proposed Revision
"approximately 12,000"	6.4.1., p. 6-22, Population, ¶ 1	The SWCA study cites a 2006 Tetra Tech study that estimates the population at 13,000. Therefore, the basis of "approximately 12,000" is not clear. Perhaps it is due to the discrepancies in population numbers discussed in the SWCA document (including the Tetra Tech study) or from another source. Regardless, this discrepancy should be corrected or explained.	*Include a footnote citing the source(s) of the "12,000" estimate or change the estimate to "13,000" to reflect the Tetra Tech data referenced in the SWCA document.*
"In 2000, about 94% of the Reservation population was determined to be American Indian with Whites making up most of the remainder."	6.4.1., p. 6-22, Population, ¶ 2	This sentence requires two changes. First, the current wording suggests that someone other than the census respondent had a role in determining the race of the respondent when the census is actually a self identification process. Second, the source of the 94% American Indian appears to be based on incorrect numbers. Table 6-7 reports a Reservation population of 6,315 in 2000 based on Census data. However, according to the US Census file, the Reservation and off-reservation trust land population in 2000 was 6,946, of which 6,633 identified themselves as American Indian alone or American Indian in combination with other races.	*Change "was determined to be..." to "identified themselves as..."* *Change 94% to 95%* *Change Table 6-7 entry of 6,315 to accurately reflect the Census 2000 population of Indians on the Reservation as 6,633.*
"This equates to an annual growth rate of up to 2.2%"	6.4.1., p. 6-22, Population, ¶ 3	The growth rate is incorrect because it should be based on the correct Census data and should go through the entire 175 year period. Using the correct initial 2000 population of 6,946, the annual growth rate is 1.26 percent for the full 175 year period and 2.05 percent for the first 100 years. Even based on an initial population of 6,315 cited in Table 6-7, which the US believes to be incorrect, the respective annual growth rates would only be 2.14 percent for 100 years and 1.32 percent for the 175 year time.	*Change to "This equates to an annual growth rate of 2.1% over 100 years and 1.3% over 175 years."*

"Average persons per household on the Reservation have dropped from nearly 4 in 1990 to about 2 in 2007"	6.4.1., p. 6-24, ¶ 2	Combining the data from Tables 6-7 and 6-8 demonstrates that if anything the average persons per household on the Reservation has increased and certainly has not decreased by half. For example, these tables show that the number of housing units during this time frame went from 2,476 to 3,061 while the population went from approximately 8,000 to approximately 12,000. The estimate of 4 persons per household is rightly calculated using the 1990 statistics and the occupancy rate of 75% given in Table 6-8. Even if we were to assume 100% occupancy for 2007, we should still have an average number of persons per household in excess of 3.9. Furthermore, the claim of a dramatic decrease in average number of persons per household is puzzling as the rest of the paragraph focuses on the difficulties in overcrowding. It should be noted that the SWCA report discards the lower number and adopts 4 persons per domestic unit as its basis for estimating future housing needs.	*Change to "The average number of persons per household on the Reservation is estimated to have remained around 4 from 1990 to 2007."*
"The unemployment rate over this period varied from 10.9% in 2006 to 62% in 1999. Hopi unemployment is relatively high and variable compared to Arizona as a whole, where rates since 1990 have remained at or below 6.2%."	6.4.2., <u>Employment</u>, p. 6-24, ¶ 1 and Table 6-9	The statement that the unemployment rate varied from 62% to 10.9% between 1999 and 2006 suggests a wildly varying status of employment on the Reservation. In fact this variation seems to be a result of relying on multiple sources that calculate unemployment differently.	*Change to "Reservation unemployment data vary tremendously based on the source of data. For example, estimates range from 10% to 62% between 1999 and 2007. In 2008, the TDR and Hopi tribe reported the unemployment rate as 29.8% and 35.6% respectively. Despite disagreement on precise statistics, all sources agree that Hopi unemployment is relatively high and variable compared to Arizona as a whole, where rates since 1990 have remained at or below 6.2%."*

"Outlying communities such as Flagstaff, Page, Winslow, Holbrook, and Gallup will probably continue to provide only limited employment opportunities for Reservation residents."	6.4.2., Employment, p. 6-25, ¶ 1	This statement should be clarified as many Hopi live in these outlying communities during the week precisely for employment reasons and then return to the Reservation on weekends and for ceremonies. This sentence appears to be taken directly from the SWCA report, only the HSR added the word "only." It should be noted that the SWCA Report states that the Hopi Tribe has purchased land in Holbrook, Winslow, Flagstaff, and Sedona to create "economic enterprises." This seems to imply that the Tribe intends for these areas to offer greater employment opportunities in the future.	*Change to "Outlying communities such as Flagstaff, Page, Winslow, Holbrook, and Gallup will continue providing limited employment opportunities for Reservation residents, however, these opportunities may increase due to the Hopi Tribe's purchase of property in those communities with plans for economic enterprises."*
"The median family income on the Reservation has increased from $15,875 in 1999 to as much as $41,250 in 2007."	6.4.2., Income, ¶ 2 and Table 6-9	This suggests that there has been a tremendous and unexplained infusion of wealth on the Reservation during this period. Furthermore, the footnote on Table 6-9 addressing the median income in 2007 indicates that while the projected median family income is $41,250, "households that were queried were found to have a median income of only $9,600." Given the lack of verification of this data and the inexplicable nature of the dramatic increase, the United States is opposed to it inclusion in the Report. Finally, the difference in income data from the Reservation and Moenkopi should be included in the Report in order to capture key socioeconomic issues.	*Change to "The median family income in 1999 was $15,875. More current estimates have indicated an increase but remain unconfirmed. The income for residents living in Moenkopi in 2005 was substantially higher than for those living on the Reservation, likely due to the larger job market and better income opportunities."*

Chapter 7: Water Resources

7.1.1: Hopi Washes, Flow Conditions and Regional Flow Analysis

pp. 7-1 through 7-4,– This discussion is a summary of the information presented in *Streamflow Characteristics of the Hopi Indian Reservation* (ADWR, 2008b) ("ADWR Streamflow Report"). Accordingly, the United State's provides detailed comments on the ADWR Streamflow Report in **Attachment 1**. As a general matter and for purposes of commenting on the Preliminary HSR rather than its supporting documentation, there are three primary shortfalls with the methods described in the ADWR Streamflow Report. First, the methods used to determine perennial streams are too restrictive and result in misclassifications. Second, the filling/extension of annual streamflows uses models built from either too short of periods (as short as four data points) or with inadequate explanation of the variance to use for record extension. Third, these filled annual data are used to produce models of ungaged locations using questionable statistical techniques including correlated predictor variables from a non-representative period. The result is a compounding of errors in the final results. *For all of these reasons, the United States requests that ADWR reevaluate their methodology for estimation of undepleted wash flows consistent with the United States' comments in* ***Attachment 1.***

7.2: Impoundments

pp. 7-7,– As a general matter, the impoundment information presented by the Preliminary HSR has some errors which the United States will address when it files its amended statement of claimant on behalf of the Hopi Tribe. For example, the difference in the number and/or size of each individual impoundment and verification of the 4 impoundments that ADWR could not verify will be addressed in the amended statement of claimant rather than through these comments.

7.2.1: Condition

pp. 7-7 through 7-8 – ADWR identified breached and silted-in impoundments, but either did not include a storage quantity or included a limited storage quantity for such impoundments. The claim submitted by the United State is based on past and present use and thus includes impoundments that are breached and silted-in. The breached and silted-in impoundments can be repaired and/or the silt removed, therefore, the United States will claim the storage quantities based on original construction capacities. It should be noted that the United States' Second Amended Statement of Claimant will include updated storage quantities for these impoundments.

7.3: Springs

pp. 7-10– As a general matter, the springs information presented by the Preliminary HSR has some errors which the United States will correct when it files its Second Amended Statement of Claimant on behalf of the Hopi Tribe. For example, the difference in the number and /or size of each individual spring will be addressed in the amended statement of claimant rather than through these comments.

7.3.1: Characteristics

p. 7-11– This section states that ADWR verified the location of 328 of the overall 360 springs claimed. Therefore, ADWR was unable to verify 32 springs. In its amended claim, the United States will provide verification data for many of the 32 springs plus additional unclaimed springs.

7.4: Aquifers

As a general matter, the information about wells presented by the Preliminary HSR has some errors which the United States will correct when it files its Second Amended Statement of Claimant on behalf of the Hopi Tribe. For example, the difference in the number and/or size of each individual well will be addressed in the amended statement of claimant rather than through these comments.

On p. 7-14 this section also states that ADWR was unable to verify 14 of the claimed wells. In its amended claim, the United States will provide verification data for many of these claimed wells.

7.4.2: Aquivers, Alluvial/Coluvial Aquifer

Colluvial water may be entirely distinct from alluvial water, as suggested by the mapped occurrence of landslide debris by Cooley et al (1969, their Plate 2), which is different than the alluvium mapped in Figure 7-16. Calling it a single aquifer appears inappropriate.

This section expands on the limited concept of alluvial water provided by Cooley et al (1969, Plate 2) to nearly the entire area mapped as Quaternary alluvium (Figure 7-16). Truini and Longsworth (2003) and Richards et al (2000) did not indicate that additional information existed regarding the saturated conditions of this mapped unit. *Therefore, the map should be limited to the alluvial areas that Cooley et al identified as being water bearing unless ADWR has additional information not cited that would justify including the larger areas shown.*

p. 7-16, ¶ 3 – The reference to Section 8.6 should instead be to Section 8.8.

7.4.3: Bidahochi Aquifer

This section refers to the "underlying T Aquifer" which insinuates that the T Aquifer underlies the entire Bidahochi Aquifer. On the contrary, much of the Hopi Buttes portion of the Bidahochi directly overlies Mancos Shale, lower Jurassic rocks, and Triassic rocks. It appears that only the northeast area of the Bidahochi Aquifer directly overlies the T aquifer in the Roberts Mesa area. (Plate 1, Sheet 4 in Cooley et al, 1969).

The United States proposes that the following sentences be added to the end of the "Occurrence" paragraph on p. 7-17:

"In many places, the Bidahochi Aquifer directly overlies Mancos Shale, lower Jurassic rocks, and Triassic rocks. It overlies the T Aquifer in the northeast area near Roberts Mesa."

7.4.6: N Aquifer, __Occurrence__

The last paragraph on page 7-22 states that water is obtained from sandstones in the Kayenta Formation. This is incorrect. As shown in Figure 4-9, the Kayenta Formation is non-water bearing, a fact which is evident where the Kayenta Formation outcrops in the Dinnebito, Polacca and Moenkopi Washes in the form of springs emanating from the top of the Kayenta/base of Navajo Sandstone. The United States proposes that reference to the Kayenta Formation be deleted from the 2nd sentence, last ¶, p. 7-22 and be revised as follows:

"The Navajo Sandstone is the primary water-bearing unit, with water also obtained from underlying sandstones in the Lukachukai Member of the Wingate Sandstone. (Figure 4-9)"

7.4.6: N Aquifer, __Natural Recharge and Discharge__

p. 7-23,– The 1st sentence states that the N Aquifer has a median recharge of 13,000 AFA. The range of recharge listed includes estimates based on different N aquifer model areas and differences over time. The "median" of these estimates is not informative and could be misleading. The United States proposes deleting the reference to a median and revising the 1st sentence of this section as follows:

"Recharge to the N Aquifer is estimated to range from 2,600 and 20,248 AFA."

p. 7-24, 2nd ¶ – The 1st sentence of this paragraph states that the Jeddito Wash, among others, is fed by the N Aquifer. This is incorrect because there is no indication that Jeddito Wash receives water fed by the N aquifer. The perennial reach mapped by Hack (1942), and by Cooley et al (1969, their Plate 2) lies mostly adjacent to D aquifer rocks or Mancos Shale. The USGS N aquifer model boundary runs north of Jeddito Wash because the Navajo Sandstone thins to extinction along that boundary. The United States proposes deleting Jeddito Wash and revising the sentence as follows:

"Perennial and intermittent stream reaches historically and currently observed along Moenkopi, Dinnebito, Oraibi and Polacca Washes are also believed to have been fed by the N Aquifer (Figure 7-5)."

7.4.6: N Aquifer, Water in Storage

pp. 7-25 through 7-26¶ – The calculated ratio of total N aquifer pumping to total volume in storage (0.1%, page 7-26) is misleading because it infers that existing pumping has a negligible impact on N aquifer groundwater resources. As the various groundwater modeling results have shown, this inference is incorrect because the ratio is neither a measure of groundwater availability nor is it an indicator that pumping impacts on the groundwater resources are negligible. *The United States proposes deletion of the last sentence of this section.*

7.4.6: N Aquifer, Well Development

p. 7-26 – The Truini and Macy (2007) report provides N aquifer pumping totals through year 2005, not 2002. The United States proposes that 2002 be changed to 2005 in the 3rd sentence, 3rd ¶ as follows:

"*Over 218,000 acre-feet of water have been pumped from the N Aquifer over the period from 1965 to 2005 and, since 1972, annual withdrawals have steadily risen from 4,300 acre-feet in 1972 to 8,000 acre-feet in 2005 (Truini and Macy, 2007).*"

7.4.6: N Aquifer, Measured Hydrologic Impacts from Development

p. 7-27¶ – The United States proposes that the last sentence, 1st ¶, be revised to change "municipal well" to "Hopi Reservation boundary" as follows:
"*A municipal well (PM2) near Keams Canyon showed a water-level decline of 196.2 feet, a USGS monitoring well (BM2) northeast of the leasehold showed a change of -87.8 feet, and a USGS monitoring well (BM6) between the leasehold and the Hopi Reservation boundary showed a change of -161.7 feet.*"

7.4.6: N Aquifer, Future Hydrologic Impacts from Development

pp. 7-28 through 7-29¶ – The HSR recognizes its limitations as to future uses on p. 1-5. Based on these limitations, the United States proposes that this section be renamed and changed to simply list the models that exist rather than recommending the use of one model over another for calculating future uses. Comparing various models and recommending one over others was not an objective of the HSR and is not appropriate in light of the specific limitations imposed on ADWR in opining on future uses. Such recommendations should be left to the hyrdologists that will present evidence regarding future uses without prejudicing the court and parties regarding which model is preferred by ADWR for simplistic reasons listed on p. 7-28. For example, although the PWCC model is indeed more complex than the others listed, predictions made by that model did not significantly differ from the much simpler USGS N aquifer model, given the uncertainties in modeled hydrologic properties. Increased model accuracy is not a natural result of model complexity. The United States proposes that this section be changed as follows:

"*Available Models to Evaluate Future Hydrologic Impacts from Development*
Three numeric groundwater flow models have been developed to simulate existing hydrologic impacts from well development in the N Aquifer and predict future impacts. A detailed review and comparison of the models is presented in ADWR (2008h). (delete remainder of this section)"

Moreover, any discussion of the HDR model developed by the Western Navajo-Hopi Water Supply Study, 2004, should be deleted pursuant to the Protective Order, dated January 3, 2002, which states the following:

> IT IS ORDERED that the Hopi/Western Navajo Water Supply Study shall not be used in any judicial proceeding in this Adjudication by any party to this Adjudication or by any representative of a party to this Adjudication.

Chapter 8: Water Demands

8.1.1: Agriculture, Quantification

The United States' approach to quantification of the historic and present irrigation claim on behalf of the Hopi Tribe has significant differences from ADWR's approach to quantification in this section of the HSR. A detailed explanation of these differences, including suggested changes to ADWR's approach, is provided below in **Attachment 2 - United States' Comments on HSR Appendix F: *Consumptive Use of Crops Grown on the Hopi Indian Reservation* (ADWR, Dec. 2007).** A summary of comments and proposed revisions is provided here.

ADWR summarizes its approach to quantification by stating that it "estimated agricultural water demands on the Reservation utilizing the following commonly used factors: 1) the type of crops being grown; 2) the net irrigation requirement of the crops (i.e., the amount of water needed to supplement local precipitation); 3) the efficiency of the irrigation system; and 4) the cropped average." HSR, p. 8-2. The United States provides comments on this section according to each subject outlined above:

1. Type of crops being grown – The United States generally agrees with ADWR's conclusion that corn has been the most common crop, followed by orchards, beans, melons and squash, among other items.

2. Net irrigation requirement of crops in traditional agriculture/native irrigation – ADWR provided a range from 0.35 to 0.86 acre-feet per acre for crop water irrigation demands. This estimate is lower than the United States' claimed depletion of 0.61 to 0.99 acre-feet per acre. Some of the difference between the net irrigation requirements for crops can be explained by the different approaches, i.e., the United States' claim is based on modeling of the water supply to simulate the quantity of surface water depleted by irrigation whereas ADWR did not analyze water supply. However, even under ADWR's approach, a number of important factors such as climate data, crop spacing, growing

season, soil moisture accounting, crop coefficients, and effective precipitation were not properly addressed and need to be considered in any final analysis. *The United States' proposed changes to ADWR's analysis on these topics are outlined in detail in* ***Attachment 2***. It should be noted that this discussion of the net irrigation of crops refers to crops under traditional farming methods rather than project irrigation systems.

3. Efficiency of the irrigation system – ADWR's treatment of irrigation efficiency, on p. 8-3, ¶ 2, is inconclusive and unhelpful. The United States estimated conveyance seepage and evaporation water uses for seasonal and range pasture irrigation as 16% of irrigation diversion. Generally, seasonal and range pasture irrigation have structures that convey water a short distance to the parcels. Since native farming uses few structures, and irrigated parcels are very near the water source, it is reasonable to assume that conveyance and distribution water uses are small. These values are appropriate based on diversion into dry unlined canals (ditches). The intermittent use of the ditches does not allow for steady-state seepage conditions, which would result in less loss. ADWR could adopt the United States' estimate of 16% of the irrigation diversion going to inefficiency losses composed of deep percolation and evaporation from conveyance facilities or provide support for other conveyance efficiency value. The field level (on-farm) efficiency estimated by the United States is from the irrigation model output based on irrigation water entering the field through the diversion, deep percolation in the soil moisture budget, and a runoff estimate. ADWR should also include estimates of field-level efficiencies to determine irrigation diversion requirements.

The last sentence on p. 8-3, "[c]omparison of the depletion and diversion rates indicates an irrigation efficiency of 90%," should be deleted because it is incorrect. The 90 percent is actually the percentage of diverted water that does not return to the surface flows. To the extent that this 90% may be based on NRCE's October 29, 2007 memorandum, it does not represent the irrigation efficiency. There, the 90% represents the fact that the full water requirements of crops irrigated with a perennial water supply would not be met on an annual basis because even perennial flows are not constant from year to year. Thus, the claim was reduced to 90 percent of crop irrigation requirement to account for water supply shortages. It was also assumed that with well irrigation 95 percent of the irrigation requirement would be met on an average annual basis. The reduction in this irrigation requirement is to account for typical irrigation management and cropping conditions.

4. Cropped Acreage – On pp. 8-4 and 8-10, ADWR concludes that the maximum cropped acreage in one year on the Hopi Reservation has been 9,330 acres but has typically ranged between 3,500 and 6,500 acres. In its Second Amended Statement of Claimant, the United States intends to provide an updated photo interpretation analysis that will improve its estimate of the irrigated acreage on the Hopi Reservation in a certain time period.

It should be noted that ADWR's estimate of a maximum of 9,330 acres irrigated at one time is likely an underestimate for several reasons. First, to the extent that the estimate is based on the Anderson Report and historical documents relied on therein, those historical documents represent a sporadic collection of materials gathered over a large period of time and cannot accurately reflect a single irrigated acreage. While the historical documents are helpful in generally identifying irrigated lands, they should not be viewed as a comprehensive inventory of all irrigated lands.

The second reason that ADWR's estimate likely undercounts acreage is the flaws associated with ADWR's photo interpretation outlined in HSR Appendix C. ADWR's photo analysis is flawed for the following reasons: 1) it was based on images scanned from aerial photos rather than negatives of the photos; 2) it lacks stereoscopic analysis; 3) it incorrectly assumes "digitizing errors" in its evaluation of United States' interpretation; 4) it is based on a misleading classification scheme; 5) it inappropriately collapses small fields into larger fields; and 6) it failed to identify clear categories of irrigation such as orchards and range pasture. **Attachment 3** provides a detailed critique of the ADWR photo interpretation.

Despite the flaws in ADWR's photo interpretation effort, the United States supports the premise that photo interpretation methodology is the most important source of information necessary to estimate irrigated acreage during a certain time period, particularly when used in conjunction with historical documents such as those cited in the Anderson Report. For these reasons, the United States' Second Amended Statement of Claimant will provide an updated photo interpretation of irrigated acreage for a certain time period.

8.1.2: Historic (Pre-1985)

The last paragraph observes that Hopi farming in the number of acres per person has decreased. While this is true in a general sense, the end of this paragraph speculates as to what the current ratio of acreage per person may be. Such speculation is unnecessary and misleading because it is based on certain assumptions that lack a basis, i.e.: 8,000 Hopis on the Reservation farming 5,000 acres. The HSR does not provide sufficient information to support these population and acreage numbers; therefore, the United States proposes deletion of the final two sentences which currently read as follows:

"*If it were assumed that 8,000 Hopi were living on the Reservation in 2005 and they successfully cropped 5,000 acres that year, the ratio now would be less than 1. The ratio would be even lower if the entire population of the Reservation at the time (about 12,000) were assumed.*"

8.1.2: Historic (Pre-1985), <u>Irrigation Projects</u>

p. 8-6 and Table 8-3 – The list of historical irrigation projects is incomplete because historic reports and interpretation of aerial photos document several other historic irrigation projects as well as a much larger historic project irrigated acreage. Some of the projects omitted from the Preliminary HSR list include Begashibito 2, Upper

Kerley Valley (joint Hopi/Navajo), Dinnebito Wash (DW)10, Oraibi Delta (joint Hopi/Navajo), Polacca Wash (PW) 1, Polacca Wash 35, and Polacca Delta (joint Hopi/Navajo). A comprehensive list and map locating the historic projects will be provided in the upcoming Second Amended Statement of Claimant.

8.1.2: Historic (Pre-1985), Claims

pp. 8-7 through 8-8 – As mentioned above, the maximum amount of water diverted and total acreage claimed by the United States and Hopi Tribe will be updated when the amended statements of claimant are filed in the future with updated information. Therefore, the number of AFA (49,200) and amount of acreage (37,514) listed in the 1st ¶ will change.

ADWR's photographic analysis of irrigated acres, Preliminary HSR Appendix G-1, is inaccurate in many instances for two primary reasons. First, ADWR used scanned photos rather than prints from original negatives. Second, ADWR did not employ stereoscopic analysis of the photos. For these reasons, ADWR's conclusions that 11% of acreage had complete evidence of agriculture, 55% of acreage had partial evidence of agriculture, and 34% of acres were questionable or lacked evidence of agriculture is incorrect and wholly unreliable. Moreover, ADWR's classification scheme listed at the bottom of p. 8-7 is misleading. For example, based the explanation in Appendix G-1, the "Questionable" category should be labeled "Cannot be Determined." A complete set of comments regarding HSR Appendix G-1 is provided herewith in **Attachment 3**. *In light of the United States' view that ADWR's photographic analysis underestimates the number of irrigated acres, the United States proposes that ADWR not rely on this photo interpretation and rely on the acreage provided in the United States' amended claim that will be filed in the near future.*

Sec. 8.1.3 Recent

The Preliminary HSR indicates that the Pasture Canyon Reservoir Irrigation Project serves 179 acres. There are some minor differences between the tracts in Figure 8-3 and the GIS coverage for the ADWR 2005 inspected field study. For example, Fig.8-3 shows some tracts between Highway 160 and Pasture Canyon Reservoir, while the GIS coverage does not. The United States requests that ADWR clarify the basis for Figure 8-3. The United States intends to update the acreage for the Pasture Canyon Reservoir Irrigation Project in its Second Amended Statement of Claimant because it appears that ADWR's approach underestimates the total acreage under irrigation.

The Preliminary HSR on page 8-9 and on Figure 8-3 indicates that there are 55 acres of recent irrigation of traditional farming in the Moenkopi area not served from Pasture Canyon. The United States believes there are more than the 55 acres of non-Pasture Canyon system irrigation. Some of this acreage is on the Hopi south side of Moenkopi Wash within the Upper Kerley Valley Irrigation Project downstream of the Pasture Canyon project. The Upper Kerley Valley Irrigation Project is a modern system of a diversion dam and canals. There are two major siphons which serve two distinct service areas. One of the siphons is currently not in operation but could be repaired. Another part of this acreage is in isolated tracts which are either served by pumping from Moenkopi Wash or are "traditional farm tracts" served from springs and small side tributaries of Moenkopi Wash upstream of the Pasture Canyon project area. In addition, some of the Pasture Canyon service area adjacent to Moenkopi Wash receives supplemental water pumped from Moenkopi Wash. 8.2.4, Domestic, Commercial, Municipal and Light Industrial, Future

p. 8-15 – The 2nd sentence states that the growth rate is 2.2%. The 2.2% growth rate reflects the first 100 years only. The growth rate to the stable population of 62,512 in 2175 is actually 1.26%. The United States proposed the following revision:

"This claim assumes that the population of the Reservation grows annually at 1.26% and stabilizes in 2175 at 62,512."

Sec. 8.4.1, Livestock, Quantification

p. 8-19 – The United States' claim for livestock is referenced as a use in the wells, springs, and impoundments claim and quantification. The United States does not have a specific identifiable quantity of water use for livestock. However, ADWR calculated upper and lower limit quantifications for livestock use. ADWR assumes that a cow or horse need 12 gallons per day (gpd) and sheep need 1.5 gpd. The livestock water used by Daniel B. Stephens and Associates in the Hopi Drought Plan of 19.5 gpd per animal unit is a more suitable number because it includes the losses and other inefficiencies associated with livestock water. *For these reasons, the United States proposes that ADWR use the 19.5 gpd instead of 6-12 gpd.*

8.8, Riparian Evapotransporation

The discussion of riparian evapotranspiration (ET) is not necessary as it is not part of either the Hopi or US claims. Moreover, the analysis appears to have significant flaws as explained below.

ADWR calculated ET by multiplying 14,000 acres of riparian vegetation times a demand of 2.3 to 4.4 acre-feet per acre, and subtracting a portion provided by local precipitation. The total ranges between 23,100 and 56,400 AFA. Both values are extraordinarily large, up to 7 times greater than total modeled ET in the USGS N aquifer model, more than 5 times greater than the total aquifer discharge to streams on the Hopi Reservation, and between 2 and 4 times as much as the average yearly streamflow in the five Hopi Washes (Section 7.1.1).

It is likely that the supply of water to the alluvium is grossly inadequate for this amount of ET to occur. Additionally, winter periods, when ET is negligible, should show a cumulative increase in base flow in washes of between 32 and 78 cubic feet per second during a winter month (or a large rise in the alluvial aquifer water table), if this calculation was correct. However, the wintertime increase in base flow in these washes is only a small fraction of this amount, and there is no evidence that alluvial storage could increase by this amount. For these reasons, this amount of ET is not justified based on alluvial aquifer water balance considerations.

Likely errors are in how the acreage was calculated, and in the assumption that the riparian vegetation evapotranspires at its potential rate. The measured 14,000 acres is undoubtedly not at 100 percent plant density, and probably not even half that, on average. Lower plant density, for example 20 percent, would reduce this ET calculation by a factor of 5. Equally as important is that riparian vegetation may be significantly water stressed over most of the year, and actual ET over a year may be much less than the demand listed above.

For these reasons, the United States proposes that ADWR delete this section.

Chapter 9: Analysis

Chapter 9 provides a summary of the information presented in prior chapters in the Preliminary HSR. Accordingly, the United States comments on previous chapters are incorporated into Chapter 9 and should be applied to the relevant issues below. In addition, the United States summarizes certain comments for Chapter 9 below.

9.1.1, Agriculture

p. 9-2, and Table 9-1 – ADWR underestimates the water amounts used by the Hopi Tribe for traditional irrigation (350 to 7,921 AFY) and project irrigation (0 to 1,582 AFY) for several reasons that were explained in detail above and are summarized below. The United States intends to provide updated acreage amounts in its Second Amended Statement of Claimant and requests that ADWR consider adopting that updated acreage at that time. The primary reasons that ADWR's methodology underestimates the water use for historic and present agriculture are:

1. ADWR's estimate of traditional irrigation cropped acreage is too low because:
    a. Historical documents in the Anderson Report are helpful but do not represent a comprehensive record of irrigated acreage;
    b. ADWR's photo interpretation underestimates irrigated acreage because it was based on images scanned from aerial photos rather than negatives of the photos and lacks stereoscopic analysis; and
    c. ADWR's photo interpretation failed to identify clear categories of irrigation such as orchards and range pasture.

2. ADWR's estimate of crop water demand for traditional irrigation is low because:
    a. it does not acknowledge the importance of water availability, as calculated through the United States PRMS model, to estimate water diversions; and
    b. it does not include critical data components in its analysis including, but not limited to, climate data analysis, proper crop spacing, appropriate crop growing season estimates, soil moisture accounting, crop coefficients,

realistic effective precipitation, accurate cropped area and crop evapotransporation, deep percolation and conveyance losses measurements.

3. ADWR underestimates the acreage irrigated from historic and recent projects. The United States intends to provide an updated estimate of cropped acreage within projects in its Second Amended Statement of Claimant.

9.1.2: DCMI

The United States' claim includes past, present and future use within the DCMI category as a single claim. It did not separate the time-dependant components of the claim nor did it present a past and present use portion of the claim distinct from the future use portion of the claim. *Therefore, the United States does not provide comments on ADWR's attempt to separate the claim in this manner other than to note that such an approach is inconsistent with the claims as filed in the adjudication.*

9.1.3: Heavy Industrial

The United States intends to provide an updated mining claim in its Second Amended Statement of Claimant.

9.1.4: Livestock

The United States intends to provide an updated livestock claim in its Second Amended Statement of Claimant.

9.2: Comparison of Quantities of Water for Past and Present Uses Claimed by the Hopi and United States to Quantities of Water Determined by ADWR

Overall, ADWR accurately describes the differences between the 2004 claims and ADWR's determination. It should be noted that the United States intends to file a Second Amended Statement of Claimant which will update certain categories of information, such as providing an updated agricultural acreage for a single period rather than just a composite of acreage. The comparison presented in this Section will necessarily change in light of the amended claims.

9.3.2: ADWR's Recommended Water Right Attributes, Quantity of Use

p. 9-12, Water Source – The second sentence in the second paragraph is unnecessary and should be *deleted.* For convenience, the sentence proposed for deletion reads "Because the Court has not yet determined whether the Hopi are entitled to use surface water sources that do not cross the Reservation, and because the Court has not yet analyzed or quantified proposed future uses, ADWR cannot make a recommendation regarding whether the Hopi federal reserved water right extends to groundwater."

p. 9-12, Quantity of Use - For the reasons explained above, the United States comments that ADWR underestimates the quantity of water used for past and present purposes by the Hopi Tribe.

Please do not hesitate to contact either Vanessa Willard at (303) 844-1353 or Guss Guarino at (303) 844-1343 if you have questions regarding these comments and enclosures.

Sincerely,

Vanessa Boyd Williard
Andrew "Guss" Guarino

Enclosures

cc (w/enclosures) via US Mail:

Chris Banet, BIA
Grant Vaughn, Solicitor's Office
Colin Hampson, Counsel for Hopi Tribe
Scott McElroy, Counsel for Navajo Nation

ATTACHMENT 1 – United States' Comments on *Streamflow Characteristics of the Hopi Indian Reservation* (ADWR, 2008b) ("ADWR Streamflow Report")

ADWR (2008b) was examined in detail; it reviews four general attributes of streamflows on the Hopi Reservation: Streamflows at Gaging Stations, Temporal Streamflow Patterns, and Spatial Streamflow Patterns. Each is described in further detail below.

Streamflows at Gaging Stations

ADWR attempted to characterize streamflows by their magnitude and frequency and categorize them as perennial, intermittent, or ephemeral. This categorization was based upon Meinzer (1923) which listed perennial flows as 100% of days showing flows, intermittent as 10%-90%, and ephemeral as below 10%. There are many attempted categorizations of streamflows between perennial, intermittent, and ephemeral. For example, the State of Idaho defines intermittent streams as such (Rea and Skinner, 2009):

> Intermittent Waters. A stream, reach, or water body which naturally has a period of zero (0) flow for at least one (1) week during most years. Where flow records are available, a stream with a $7Q_2$ hydrologically-based unregulated flow of less than one-tenth (0.1) cubic feet per second (cfs) is considered intermittent. Streams with natural perennial pools containing significant aquatic life uses are not intermittent. (IDAPA 58.01.02.010.45)

Hedman and Oesterkamp (1982) define the break between intermittent and perennial as 80% and Hewlett (1982) defines it at 90%. Clearly, the Meinzer definition of "intermittent" would misidentify a number of perennial stream reaches, including on Moenkopi Wash and the Little Colorado River.

A comparison of some of the gages between calculated values and reported (ADWR) reveals slight differences in streamflows (see Table 1 below).

Table 1: Comparison of gage flow summaries between NRCE and ADWR.

Gage	Number	9400568	9400583	9401110	9401260	9401400
	Name	Polacca	Jadito	Dinnebito	Moenkopi	Moenkopi Near Tuba City
Minimum (acre-feet/year)	ADWR (2008g)	--	--	--	--	--
	ADWR HSR	194	14	312	1,376	2,181
	NRCE	194	13	311	1,373	2,188
Mean (acre-feet/year)	ADWR (2008g)	2,320	298	2,790	7,290	11,200
	ADWR HSR	2,319	298	2,787	7,292	11,165
	NRCE	2,312	298	2,787	7,282	11,167
Median (acre-feet/year)	ADWR (2008g)	2,130	145	2,300	7,470	8,830

	ADWR HSR	2,126	145	2,297	7,462	8,838
	NRCE	2,128	145	2,294	7,471	8,845
Maximum (acre-feet/year)	**ADWR (2008g)**	--	--	--	--	--
	ADWR HSR	6,151	1,427	6,687	14,779	44,482
	NRCE	6, 070	1,425	6,703	14,739	44,580

Temporal Streamflow Patterns

The temporal streamflow pattern section attempted to identify likely trends in streamflows over a long period. ADWR used maintenance of variance extension (MOVE) to extend annual streamflows through 1926. Comments on individual analyses are listed below.

USGS 9402000

ADWR lists a 13-year record as the calibration period for this model. It is not clear whether this period is long enough to develop a robust model. The periods in question may not contain representative dry, normal, and wet periods that are required to properly calibrate a model.

USGS 9401260

ADWR correlated annual rainfall and runoff between Tuba City and the streamflow gage on Moenkopi Wash. The reported correlation coefficient was 0.17 for the model used to extend this gage for annual flows. Because of the extremely low amount of variance explained by this model, it is unlikely that it represents the annual streamflows well. Similarly, they use a model reconstruction for the period 1940 through 1973 based on four overlapping annual streamflows. While the reported correlation coefficient is relatively high, this is clearly not a robust model. The period of overlap was also from 1974-1977, so most likely represents only a small portion of hydrologic conditions.

USGS 9400562 Oraibi Wash, 9400568 Polacca Wash, 9401110 Dinnebito Wash, 941400 Moenkopi Wash

These gages use relationships built from between four and six years of data. Again, they are unlikely to represent a range of hydrologic conditions and are not robust models.

9400583 Jeddito Wash

Over an 11-year concurrent period, the model explained only 25% of the variance in annual streamflows. This is not adequate to use for filling and extension of gage records.

Peabody Coal Company records

Similar problems exist with the models developed for the Peabody gages. These either show a short period of record, inadequate explanation of variability, or both.

Long-term flow variability

ADWR uses Meko et al. (2007) and Meko and St. George (in prep.) to examine the long-term variability of flow in the Colorado and Little Colorado River basins. NRCE was unable to obtain a copy of Meko and St. George, so these data were not reviewed.

Meko et al. use tree ring data from various locations in the Colorado River basin to synthesize an annual hydrograph to 762 at the Lee's Ferry gage. However, none of these tree rings were contained within the Little Colorado basin, so this provides little insight into the streamflows in the Hopi Reservation. In fact, examination of Figure 7-11 shows little correlation between the extended Moenkopi Wash data and the extended Lee's Ferry record for the period beginning in 1927.

It should be also noted that tree ring reconstructions tend to underestimate years of high streamflows, so it is possible that comparisons with tree ring reconstructions are biased toward lower streamflows.

Spatial Streamflow Patterns

In the spatial streamflow patterns section, ADWR attempted to estimate mean and median annual runoff at various points throughout the Hopi Indian Reservation. ADWR used multiple regression analysis to create models between their extended gage records described in the Temporal Streamflow Patterns section and various basin characteristics. These models were then transferred to other ungaged points in the basin and runoff was estimated.

The ADWR models used a calibration period of 1981-2006. These data were filled at 13 gages and measured at one gage. As mentioned previously by ADWR, the Colorado River basin may see significant persistence of trends including drought or wet periods. It is quite possible that this 25-year period is not representative of the total record. If their trend analysis is correct, the runoff on the Reservation has recently been declining. This could indicate that the most recent period represents a relatively dry period.

The model was developed using a number of basin characteristics including drainage area, stream gage elevation, stream length, stream slope, forested area, barren area, mined area, Quaternary deposit area, and mean annual precipitation. They point out that there is a significant correlation between variables, which promotes error in multivariate models. ADWR used a multivariate model using stream gage elevation, forested area, and barren area to predict mean and median annual runoff.

Three potential problems arise from the use of these models. First, while there may be a significant correlation between gage elevation and runoff, it is not clear that this is a causal link that can be explained through any physical reasoning. Similar problems can be seen with the other variables used.

The second problem arises with the multivariate regression method used. As mentioned previously, there is substantial correlation between predictor variables used. A common method of removing collinearity is to use principal components analysis (PCA). PCA transforms related variables into orthogonal components (Haan, 1977) and would have been appropriate in this situation.

Finally, the model was produced using depleted streamflows. The model represents undepleted streamflows at the Reservation boundary but does not take into account the fact that the predictive model was built using gaged (depleted) streamflows. Hence, this is not a viable model of undepleted flows available for irrigation at the Reservation boundary.

Attachment 1 References

ADWR, 2008a. Streamflow Characteristics of the Hopi Indian Reservation. Internal report prepared in support of Preliminary Hopi HSR, January 2008.

ADWR, 2008b. Surface Water Quality of the Hopi Indian Reservation. Internal report prepared in support of Preliminary Hopi HSR, March 2008.

Haan, C.T. 1977. *Statistical Methods in Hydrology.* The Iowa State University Press, Ames, IA.

Hedman, E.R., and W.R. Osterkamp. 1982. Streamflow Characteristics Related to Channel Geometry of Streams in Western United States. USGS Water-Supply Paper 2193. 17 p.

Hewlett,J.D. 1982. Principles of Forest Hydrology. University of Georgia Press. 183p.

Meko, D.M. and St. George, S., in preparation. Tree-ring reconstruction of Little Colorado River Annual Flows. University of Arizona, Tree Ring Laboratory.

Meko, D.M., Woodhouse, C.A., Baisan, C.A., Knight, T., Lukas, J.J., Hughes, M.K., and Slazer, M.W., 2007. Medieval Drought in the Upper Colorado River Basin. Geophysical Research Letters, v. 34, L10705.

Rea, Alan, and Skinner, K.D., 2009, Estimated perennial streams of Idaho and related geospatial datasets: U.S. Geological Survey Data Series 412, p. 32.

ATTACHMENT 2 - United States' Comments on HSR Appendix F: *Consumptive Use of Crops Grown on the Hopi Indian Reservation* (ADWR, Dec. 2007)

The differences between the analysis of irrigation conducted by the United States in support of its irrigation claim on behalf of the Hopi Tribe and the agricultural analysis conducted by ADWR for the HSR are substantial. A large portion of the difference results from the difference in irrigated acreage and a smaller portion results from the different methodologies of estimating crop irrigation water requirements.

The United States' approach is superior because it is more thorough and includes a number of important factors that the HSR analysis ignored. Therefore, the United States recommends that ADWR revise its report, *Consumptive Use of Crops Grown on the Hopi Indian Reservation* (ADWR, Dec. 2007), to account for the following factors:

1) **Climate data analysis** should include all available data (not just two stations), adjust for location, utilize the method that best estimates solar radiation in the region, and perform an exceedance probability analysis based on daily ET (rather than using mean climatic data);
2) Proper **Crop Spacing** measurements;
3) **Crop Growing Season** should be tailored to subbasins and elevations (rather than simply using high and low values of 170 and 115 days for corn);
4) **Soil Moisture Accounting** should be included;
5) **Crop Coefficients** should be determined using the proper method to estimate water use when adjusting for non-standard conditions where crops do not reach effective cover;
6) Realistic **Effective Precipitation** estimates;
7) **Calculation of overall consumptive use should include:**

   a) *Cropped Area* ***with all historic acres cropped because Indian water rights are not lost through non-use; and***

   b) revised *Cropped ET* ***calculation;***
8) **Deep Percolation Losses** should be included;
9) **Conveyance Losses**, such as evaporation and seepage, should be included;
10) Acknowledge the importance of **Water Availability**, such as calculated through the PRMS model, to estimate diversions.

These factors are discussed in detail below. The following analysis compares and comments on the methods used by ADWR versus those used by the United States in estimating irrigation water use on the Hopi Reservation.

Differences in Treatment of Climate Data

ADWR's climate analysis is inadequate for two reasons. First, the HSR uses limited climate data and does not attempt to adjust these data for location. This is an important process and calculations are easily performed. ADWR did not use the full climate record available at the Keams Canyon station. As Shown in Figure 1 below, ADWR's method of radiation calculation is not the best method available for the region, overestimating measured radiation at the Flagstaff station.

Second, ADWR uses only mean climatic data to calculate evapotranspiration. Irrigation requirements will be highest during drought seasons that have higher than average temperatures and lower than average precipitation. A more comprehensive analysis should be performed by estimating daily ET and performing an exceedence probability analysis. The United States analysis rectifies these two inadequacies as explained below.

Temperature and Precipitation Records

The United States used nine stations in the generation of climatic data for calculations of depletions. These stations are shown below in Table 1. The selection of stations was based upon climate record and proximity to the basin. The closest station was used and lapsed to each hydrologic response unit (HRU) in the PRMS model, developing refined precipitation and temperature records for the ET analysis.

Table 1: Summary of climate stations used in the hydrologic modeling.

Station ID	Station Name	County	State	Latitude	Longitude	Elevation (feet)	Period
1169	Cameron 1 NNE	Coconino	AZ	N35:53:00	W111:24:00	4,165	1962-1992
3103*	Flagstaff Pulliam AP	Coconino	AZ	N35:09:00	W111:40:00	7003	1950-2006
3303	Ganado	Apache	AZ	N35:42:59	W109:33:58	6,340	1929-2006
3420	Gallup 5 E	McKinley	NM	N35:32:00	W108:39:00	6,604	1918-1979
4586	Keams Canyon	Navajo	AZ	N35:48:40	W110:11:30	6,205	1894-2006
4872	Leupp	Coconino	AZ	N35:17:00	W110:58:00	4,705	1914-1981
6468	Bellemont NWFO	Coconino	AZ	N35:13:48	W111:49:17	7,152	1999-2006
7488	Sanders	Apache	AZ	N35:13:26	W109:19:20	5,853	1949-2006
7496	Sanders 11 ESE	Apache	AZ	N35:10:00	W109:10:00	6,250	1961-1986
9410	Window Rock 4 SW	Apache	AZ	N35:37:01	W109:07:28	6,920	1937-1999

*Station was used only for solar radiation data; not included in precipitation or temperature calculation.

Table 1 (Continued): Summary of climate stations used in the hydrologic modeling.

Station ID	Station Name	Elev. (ft)	Annual Avg. Prcp (in)	Annual Avg. Tmax (F)	Annual Avg. Tmin (F)	State	USGS HUC	USGS HUC Name
1169	Cameron 1 NNE	4164	5.59	73.9	42.0	AZ	15020016	Lower Little Colorado
3303	Ganado	6340	12.32	64.9	33.7	AZ	15020011	Cottonwood Wash
3420	Gallup 5 E	6604	9.18	66.9	31.7	NM	15020012	Cottonwood Wash
4586	Keams Canyon	6205	10.60	66.4	34.6	AZ	15020013	Polacca Wash
4872	Leupp	4705	6.49	72.2	35.2	AZ		
6468	Petrified Forest	5444	9.37	70.7	39.0	AZ	15020007	Lower Puerco
7488	Sanders	5853	11.26	68.9	35.2	AZ		
7496	Sanders 11 ESE	6250	12.37	67.3	31.3	AZ		
9410	Window Rock 4 SW	6920	11.67	64.0	32.6	AZ	15020006	Upper Puerco

ADWR used only two stations: 8792 Tuba City and 4586 Keams Canyon. ADWR used a period of record from 1900 to 2006 for Tuba City and 1948-2006 for Keams Canyon. However, the record extends to 1894 for both stations. Using the entire set of data would provide better average data. Precipitation and temperature were assumed to be relatively uniform across cropped areas and these records were not refined for geographical location. ADWR states that:

> "data from additional met stations on the Reservation with a significant period of record may improve ET estimates". (Appendix F to the HSR, page 3-1)

The United States used the daily data over the period of analysis which accounts for differences in temperature that occur over time. The United States then filled missing data using a regression analysis between weather stations. ADWR methodology relied only on mean data. The ADWR methodology does not take into account the temperature and precipitation differences that result from the elevation changes across the Reservation. Since mean data was used by ADWR the missing data was not filled.

Solar Radiation

Daily solar radiation was calculated by the United States as a function of day of the year, the dew point temperature (*Tdew*), and the total sky cover (*Tskc*), using equations from Dingman (1994). These values were adjusted within PRMS for aspect, elevation, and slope. ADWR used the Hargreaves Method. The United States compared measured radiation at Flagstaff to the Dingman and Hargreaves method as presented in Figure 1. The Hargreaves method overestimates radiation in this comparison.

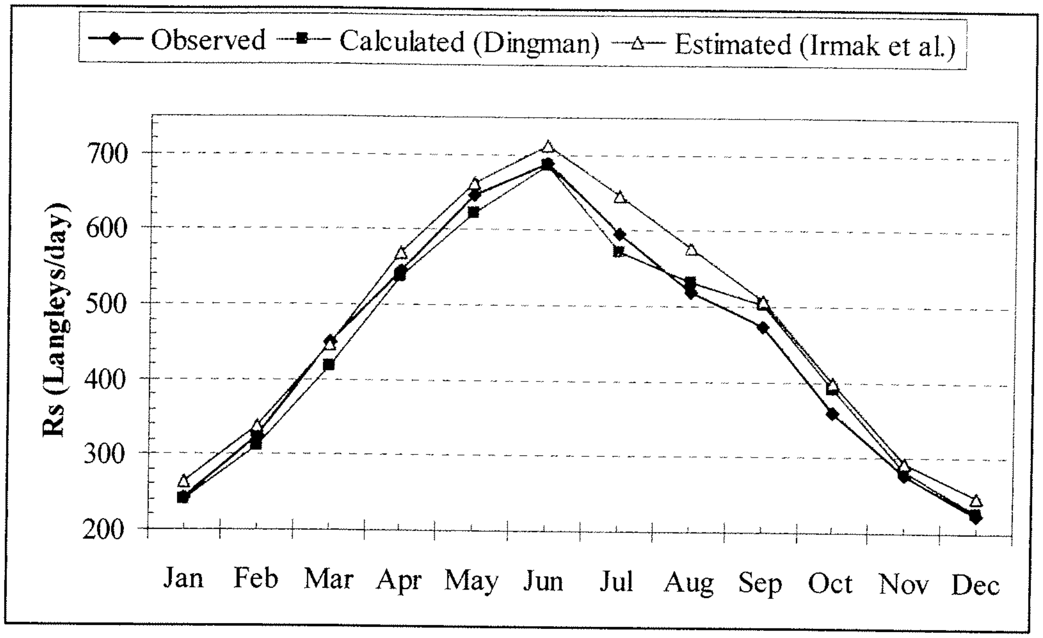

Figure 1: Average monthly solar radiation based on data from NCDC SA station 3103.

Wind Speed

Wind speed was not considered by the United States, as the method of ET calculation did not require wind speed data. ADWR estimated the wind speed to be between 3 and 5 meters per second.

Differences in Crop Evapotranspiration and Consumptive Use Determinations

The largest differences in crop ET between the HSR and the United States' claim are due to crop coefficient estimates. For example, the United States used very different peak crop coefficient estimates than the HSR. It should be noted that Table 2.1 of Appendix F the HSR is incorrect; the growing season should be April 7-September 24 for a 170-day growing season.

As listed in Table 2, the HSR peak coefficient is considerably lower than the already-reduced estimates by the United States. ADWR justifies this by estimating crop spacings at a minimum of 8-12 feet and a maximum of 15-20 feet. However, ADWR's own photos show this spacing to be unreasonable (see photo figures in Appendix F in ADWR Hopi HSR). Figure 2 shows a typical field; for scale the tire tracks at the left of the photo should be no more than 12" wide. Clearly crop spacing is not 8-12 feet.

Table 2: Comparison of U.S. and ADWR cropping dates and coefficients.

	Crop Type	Cropping Dates[a]				Crop Coefficient[b]			
		A	B	C	E	Kc1	Kc2	Kc3	%
U.S.	Corn	1-Jun	18-Jun	27-Jul	28-Sep	0.16	0.95	0.33	90
U.S.	Native Range	1-Apr	20-Apr	15-May	15-Sep	.30	.68	.40	77
ADWR (Upper)	Corn	7-Apr	7-May	26-Jun	24-Sep	0.12	0.36	0.19	
ADWR (Lower)	Corn	15-May	4-Jun	9-Jul	7-Sep	0.12	0.36	0.19	

[a] *Cropping Dates*: A = planting, B = 10% ground shading, C = 75% ground shading, E = transpiration ceases or harvest. Date D (not listed) is a calculated date at which Kc begins to decrease linearly to Kc3.
[b] *Crop Coefficients*: Kc1 = crop coefficient from date A to B, Kc2 = crop coefficient from C to D, and Kc3 = crop coefficient at date E, % = percent of growing season from A to D. The crop coefficients between dates B and C are a linear interpolation between Kc1 and Kc2, and the crop coefficients between dates D and E are a linear interpolation between Kc2 and Kc3.

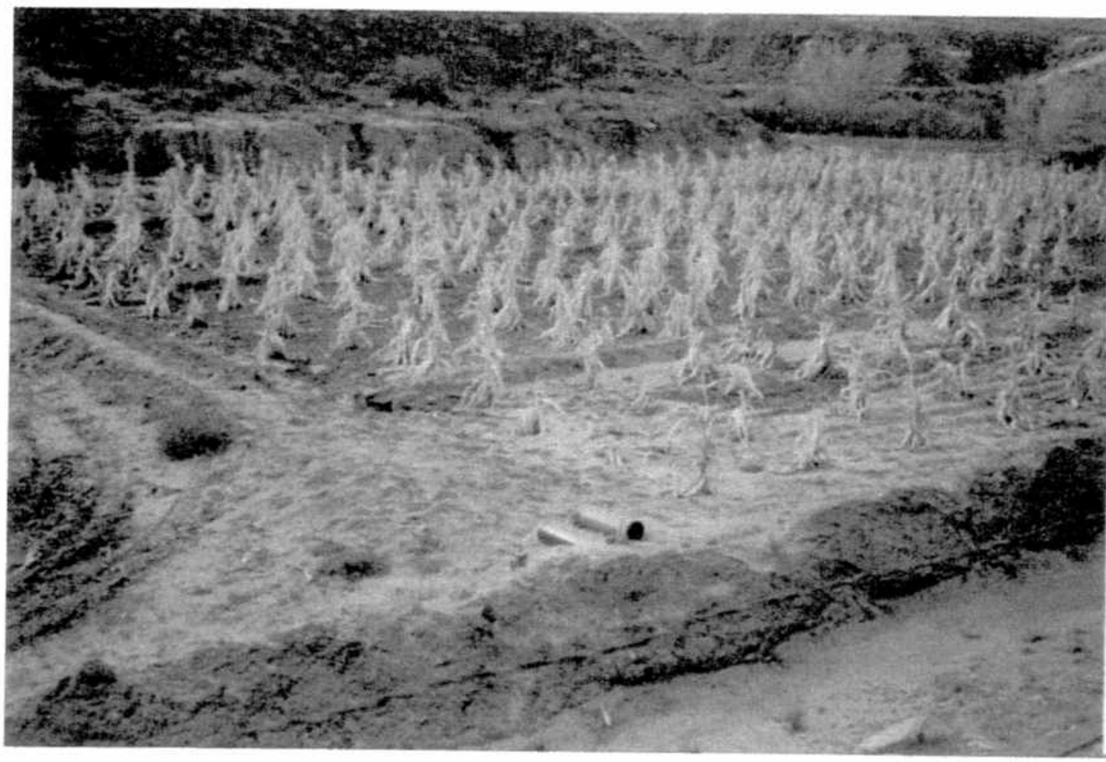

Figure 2: Example of corn spacing on the Hopi Reservation.

Crop Growing Season

The United States used different cropping dates for individual subbasins based upon elevation. While cropping dates vary from year to year, the cropping dates were estimated by one set of cropping dates for each subbasin. The cropping dates provide adequate results due to the soil moisture budget accounting which allows irrigation before planting. ADWR used cropping dates to produce a high and low value of 170 and 115 days, respectively for corn.

Soil Moisture Accounting

ADWR did not use a soil moisture accounting approach to account for reductions in crop water use due to low soil moisture. The United States used a daily soil moisture accounting model. ADWR recognized the need for this:

> "To model actual growing conditions on the Hopi Reservation (DRY), a daily soil moisture budget would be helpful to ETc estimations. Due to infrequent watering, readily available water within the soil declines to the point of zero which causes the ETc to also approach zero. In other words, when there is no moisture in the soil, the plant does not transpire. To correct Kc for such conditions, soil moisture needs to be quantified. Because these data could not be obtained, an alternative approach to correcting Kc was used.". (2008 ADWR HSR, Appendix F page 2-8).

Crop Coefficients (Detail)

Both the United States and ADWR used the methods outlined in Food and Agriculture Organization of the United Nations, Publication 56 (FAO, 1998) to estimate crop coefficients. Both claims adjusted the crop coefficients (Kc) to represent the less than ideal growing conditions observed on the Hopi Reservation. ADWR estimated the plant spacing at 8-12 feet between rows and clumps of plants. ADWR estimated the peak crop coefficient for corn at 0.36, using a method described in FAO 56. However, the methodology is applicable to adjustments in the basal crop coefficients, not the Kc mean. Kc basal only includes plant transpiration and evaporation beneath the vegetation canopy; therefore, if effective cover is never obtained the soil evaporation component needs to be included. Additional water use or demands are needed to account for the evaporation from the soil surface during and after a precipitation events or irrigations. The combined or average (evaporation and transpiration) Kc for the crop is 1.0 for the day of a rain decreases over the following days depending on the soil type. Similarly, upon irrigation the Kc combined is also increased to account for soil evaporation. For crops with a small percentage of effective cover the soil evaporation is a significant contributor to crop ET.

The proper method for estimation of water use when adjusting for non-standard conditions is described in the FAO 56 manual and Part 623 Irrigation of the National Engineering Handbook (NEH, 1993). Figure 3 is an illustration from the National Engineering Handbook Part 623, Chapter 2, page 2-90. If the crop coefficient is less than 1.0 due to less than 100 percent effective cover than the average coefficient is greater that the basal crop coefficient. This is particularly important because most crops grown on the Hopi Reservation never reach effective cover due to the crop spacing.

Figure 2-23 Comparison of basal and average crop coefficients for the average crop coefficient example

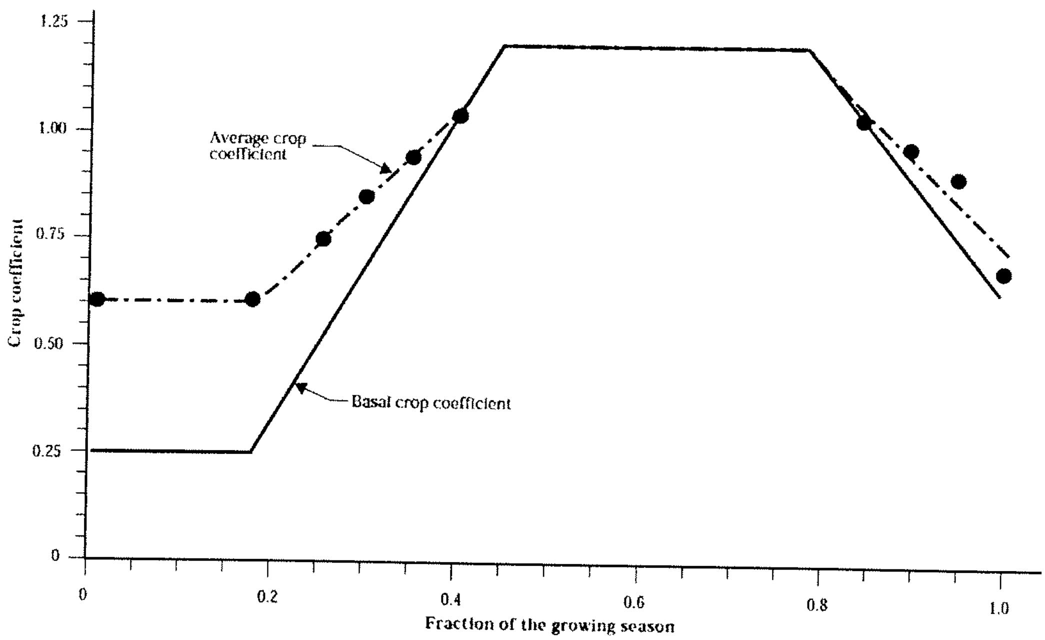

Figure 3. Example of Basal and Average Crop Coefficients from National Engineering Handbook.

ADWR made an adjustment for "DRY" referred to as dry land, based primarily on the crop spacing of corn. ADWR's definition of dry land is crops grown without irrigation. While precipitation farming was a land use category, the United States did not estimate a water requirement for the precipitation farming.

The United States made an adjustment in the Kc for crops irrigated from seasonal water supplies based on a variety of non-quantified conditions. It used the water use of corn for lands with seasonal and native irrigation. The United States's peak crop coefficient was 0.95 (vs. 0.36 as determined by ADWR). The United States estimated plant spacing at 4-5 feet between rows and 3 feet between clumps of plants based on photographs taken during a field visit. In addition to the Kc adjustment, the soil water budget reduces the crop ET further when the soil water limits crop ET.

Reference Evapotranspiration

The United States estimated reference ET using the Jensen-Haise method (1963). This method uses mean daily air temperature and solar radiation to estimate ET. Temperature and radiation are adjusted within the model by HRU, representing elevation, slope, and aspect. The United States estimates ET on a daily basis using climatic data.

ADWR used the Penman-Monteith method described in FAO (1998) via the Ref-ET program to calculate reference ET. ET is calculated based upon mean long-term daily data rather than actual year-to-year daily data.

The Jensen-Haise method is used in the PRMS model. The United States conducted analysis to determine the sensitivity of reference ET to irrigation depletion. It was found that the estimated water supply was the most significant factor in the determination of crop water use. Under the deficit irrigation conditions the reference ET methodology made little difference in irrigation depletion.

Potential Crop ET

Both the United States and ADWR calculated potential crop ET as reference ET multiplied by the crop coefficient. As stated in the discussion on crop coefficients, it appears that ADWR neglected to consider the evaporation portion of the crop ET when adjusting the Kc for crops grown in non-standard conditions.

Effective Precipitation

Effective precipitation is calculated by the United States using daily time step and a soil moisture accounting model. The daily precipitation was based upon recorded precipitation adjusted based on location and elevation. The United States also neglected precipitation events less than 0.05 inches, these small precipitation events do not provide a significant source of water for plants and the storms as often accompanied by winds that increase ET. Additionally, the United States used only 67 percent of winter moisture as being available for soil moisture storage. During the winter there is evaporation from wet soil surfaces and snow which was not modeled for the fields. On an annual basis, the United States estimated that effective precipitation ranges from about 55 to 60 percent of total precipitation.

ADWR estimated that 81 and 85 percent of the long-term annual average precipitation is effective for Keams Canyon and Tuba City, respectively. ADWR estimated that over 90 percent of the growing season precipitation is effective. These estimates were applied to both dry land farmed and non-deficit irrigated lands. In addition to the high effective percentages, the long-term average precipitation the irrigation water claim would be insufficient over 50 percent of the years.

Consumptive Use and Irrigation Requirement

Two main differences result in the large discrepancy between the United States' Claim and the HSR: cropped area and the crop ET. Tables 3-5 provide summaries of the United States' irrigation claim and the ADWR's estimate of net irrigation requirements. The HSR cropped area is considerably lower, at a maximum of 9,853 acres and a minimum of 1,000 acres, compared to a total cropped area in the United States' Claim of 37,514 acres.

Likewise, for net irrigation requirements, ADWR estimates a low end of 4.2 inches per year and a high end of 10.32 inches per year for traditional farming (dry land), and low end of 20.64 inches per year and a high end of 29.52 inches per year for irrigation projects (non-deficit irrigation). The United States did not provide estimate of net irrigation requirements in their Hopi claim. However, the weighted irrigation averaged 7.33 inches per year with a maximum of 11.87 inches per year and the irrigation diversion averaged 9.11 inches per year with a maximum diversion of 15.72 inches per year. ADWR's maximum net irrigation requirement is 9,502 acre-feet per year verses the United State's maximum irrigation depletion claim of 37,110 acre-feet per year. ADWR's minimum net irrigation requirement is 305 acre-feet per year. The United States' claim did not report a minimum irrigation depletion. ADWR's only estimated net irrigation which does not include irrigation efficiencies or losses.

Table 3: United States Estimates of Acreage, Irrigation Depletion, and Irriagtion Diversion.

Wash	Acreage	Irrigation Depletion		Irrigation Diversion	
		Average (ac-ft/yr)	Maximum (ac-ft/yr)	Average (ac-ft/yr)	Maximum (ac-ft/yr)
Moenkopi Main Reservation	2,496	2,084	2,440	2,772	3,246
Moenkopi Island	989	1,310	1,535	1,468	1,795
Dinnebito	6,938	3,961	6,552	5,280	8,714
Oraibi	10,615	5,384	9,865	5,384	13,120
Polacca	12,297	7,218	11,869	9,622	15,786
Jadito	4,126	2,936	4,790	3,914	6,371
Minor Tributaries	53	37	59	49	104
TOTAL	**37,514**	**22,930**	**37,110**	**28,489**	**49,136**

Table 4: United States' Esitmate of Irrigation Depletion and Diversion Rate.

Wash	Irrigation Depletion		Irrigation Diversion	
	Average (in/yr)	Maximum (in/yr)	Average (in/yr)	Maximum (in/yr)
Moenkopi Main Reservation	10.02	11.73	13.33	15.60
Moenkopi Island	15.90	18.62	17.81	21.79
Dinnebito	6.85	11.33	9.13	15.07
Oraibi	6.09	11.15	6.09	14.83
Polacca	7.04	11.58	9.39	15.40
Jadito	8.54	13.93	11.38	18.53
Minor Tributaries	8.31	13.45	11.06	23.51
Weighted Average	**7.33**	**11.87**	**9.11**	**15.72**

Table 5: Summary of ADWR's Cropped Acreage and Net Irrigation Demand.

Irrigation Practice	Area Type	Acreage	Lower Limit Net Irrigation CU (in/yr)	Upper Limit Net Irrigation CU (in/yr)	Total Net Irrigation CU (Lower Limit) (ac-ft/yr)	Total Net Irrigation CU (Upper Limit) (ac-ft/yr)
Traditional Farms Dry Land	Maximum	9,210	4.2	10.32	3,224	7,921
	Minimum	1,000	4.2	10.32	350	860
Irrigation Projects Non-Deficit	Maximum	643	20.64	29.52	1,106	1,582
	Minimum	0	20.64	29.52	0	0
Total	Maximum	9,853			4,329	**9,502**
	Minimum	1,000			**350**	860

Table Notes: Acreage from Table 9-1 ADWR HSR 2008
Irrigation CU from Appendix F, ADWR HSR 2008, Table 2.13 and 2.14

Other Factors Governing Water Use

Deep Percolation Losses from Irrigation Applications

The United States uses the daily soil moisture accounting to calculate deep percolation losses. Deep percolation occurs after a field's soil moisture reaches field capacity. ADWR does not account for any deep percolation.

Conveyance inefficiency—Evaporation and Deep Percolation Losses

The United States estimates 16% of the irrigation diversion goes to conveyance inefficiency losses. These losses include deep percolation and evaporation from conveyance facilities that do not return to the surface flows. ADWR ignores these losses.

Water availability

The United States conducted a detailed accounting of available flow. This is performed by estimating streamflows in the washes using the PRMS hydrologic model, routing them through the channel network, and estimating diversions on a daily basis. ADWR does not estimate water availability; instead they reduce crop coefficients to limit the claim.

Attachment 2 References

(FAO, 1998) Food and Agriculture Organization of the United Nations (FAO), *Crop Evapotranspiration, Guidelines for computing crop water requirements,* FAO Irrigation ad Drainage Paper No. 56, Rome, Italy, 1998.

(Jensen and Haise, 1963) *Estimating Evapotranspiration From Solar Radiation* by Jensen, M.E. and Haise, H.R. In Proceedings of the American Society of Civil Engineers, Journal of Irrigation and Drainage, vol. 89, no. IR4.

(NEH, 1993) U.S. Department of Agriculture, Soil Conservation Service (SCS), *National Engineering Handbook*, Chapter 2, Irrigation Water Requirements, 1993.

ATTACHMENT 3 - United States' Comments on HSR Appendix G-1: Verification of Claimed Agricultural Lands on the Hopi Indian Reservation (Dianne Yunker)

The United States provides the following detailed comments regarding ADWR's photographic review of irrigated acres. These comments can be divided in the following categories and are addressed in detail below:

1) ADWR's aerial photo data is faulty because it consists of digital images scanned from aerial photos rather than images created from negatives;

2) ADWR's analysis erred because it did not employ stereoscopic analysis;

3) "Digitizing errors" identified by ADWR are not errors but results of the unioning process that are removed once a Dissolve function is applied to the data;

4) ADWR's classification scheme is misleading and ambiguous;

5) ADWR's decision to collapse small fields into larger fields for random review leads to errors; and

6) ADWR's analysis overlooks critical irrigated lands such as orchards and range lands.

Aerial Photographic Data and Process used by ADWR

The aerial photographic data used by ADWR as the basis for their critique are not comparable to the aerial photos used by the United States. The photo analyses which support the United States' claim were accomplished using stereo aerial chemical photographic contact prints and enlargements made from original negatives, while ADWR used only digital images scanned from aerial photos and did not employ stereo photo analysis.

Stereoscopic analysis is vitally important in mapping agricultural fields and determining their water uses for many reasons. Stereoscopic photo analysis allows the topography of the landscape and therefore the sources of water supplied to fields to be identified and classified by the photo analyst.

In addition, things on the ground are often expressed very differently on the left vs. the right frames of a stereo pair because of variation in photographic exposure due to vignetting, and because of the effects of lens aberration in photos, which depends largely on an objects' distance from the principal point (the point in the middle of an aerial photo, directly below the central lens axis). By viewing the stereo pair with a stereoscope, the photo analyst sees entities on the land surface on both of the frames of the pair, with clarity and definition almost always unattainable by viewing a monoscopic image.

There are other problems associated with relying solely on digital images scanned from aerial photos to identify ground features such as those important in identifying agricultural water use. When images are scanned there is a fundamental tradeoff between spatial resolution and file size. If, for instance, a 10" x 10" black-and-white contact print is scanned at 3200 dpi resolution, which is a common maximum optical resolution for many recent flat-bed scanner models, a file about 1 gigabyte in size results, much too large to be used without difficulty in ArcGIS. A scan of the same print at 800 dpi produces a file about 70 megabytes in size, much more reasonable for use in ArcGIS. There is no indication in ADWR's report of what file sizes they used for viewing scanned aerial data in ArcGIS, but depending upon the scale of the images they had scanned for them, files of workable size were clearly of too low resolution to show some features clearly. The quality of scans produced by different scanners, even at the same dpi resolution, can vary significantly as well. The fact that about 15% of the "joined fields" ADWR inspected were classified as "questionable," indicating the images were of poor quality, show ADWR had significant concerns regarding the usefulness of their digital images.

Viewing images with magnifying, optical stereoscopes as well as digitally on a computer, infers many advantages over digital viewing alone.

Photographic data from the mid-1930's are especially important in the Hopi water claim because they are the only source from which maps of early Twentieth Century Hopi agricultural water use can be made.

The 1930's aerial photographic data ADWR used were obtained from the Arizona State University Library's Map Collection. This collection contains monoscopic mosaics of most of the state of Arizona, which were created by overlaying portions of 10" x 10" contact prints made from negatives flown at an approximate scale of 1:28,000 by Fairchild Aerial Surveys in 1935-1937. At the time these mosaics were made, the aerial contact prints were manually overlain using a network of metal aerotriangulation templets and pasted together, then rephotographed and printed. They were then printed on paper from the third-generation photographic negatives, making them a fourth-generation photographic product (the original negatives are the first generation, and contact prints made from them are the second generation). Each time another photographic generation is made, contrast increases (i.e. the light-to-dark range of the photographic image is decreased), and spatial definition of details in the photo product is decreased. The fourth-generation mosaics were printed at a reduced scale of 1:62,500 so they would cover the same area, at the same scale, as a USGS 15-minute quad sheet. These mosaics were scanned for ADWR at the ASU Library.

The United States worked with 1:28,000 scale contact prints from the 1930's Fairchild aerial photographs, many of them originals printed at that time by Fairchild and archived by the BIA. The lower resolution of the scanned versions of the 4th, or perhaps later, generation mosaics, reduced in scale to 1:62,500, is probably responsible for ADWR's inability to identify fields from these images, and classifying so many areas with agricultural fields as "No."

Comments on "Digitizing Errors"

The GIS shapefile analyzed by ADWR is the first generation of a fields database created with a unioning process. This unioned fields shapefile can be thought of simply as comprising three different years of field shapes superimposed and collapsed upon one another. The boundaries of all original fields are retained in this data. It is, therefore, not surprising that myriad small polygons, or slivers of the original field shapes, occur in the database. These are not "very small claimed fields" or " residual errors from digitizing" as described on page 3 of Appendix G-1, but are instead artifacts of the unioning process that are removed once a Dissolve function is applied to the data. This is, in fact, the process ADWR used in beginning to evaluate the data.

The ADWR's Classification Scheme and Decision Flow

Two categories in the ADWR's classification scheme are markedly ambiguous. The "Questionable" category has a name which is misleadingly and conveys an unwarranted connotation. The "Questionable" classification is given to a "joined field" if, "...due to poor image quality, it was difficult to determine if agriculture had actually occurred in an area (Yunker, page 8)." A better name for this class would be "Cannot be Determined," or "We Can't Tell Due to the Quality of the Digital Data We're Using." If a determination cannot be made, it apparently means a conclusion cannot be reached as to whether the joined field they are inspecting is "Complete," or "Partial," or "No."

The "Partial" category is also ambiguous and misleading. No mention is made in the report of any mapping being done to determine how much of a "joined field" classified as "Partial" is devoid of agricultural activity or not, "in a given year." The "Partial" class and the enumeration of the acreages defined as being "Partial," purposefully or not, conveys the connotation that since the whole unioned area wasn't being farmed on a single photo date, the United States interpretations are incorrect. Since the GIS data *is* unioned, it would be expected that one would find some places in a unioned field area that are not being farmed in any single year.

The "Fields Selected for Review" Procedure used by ADWR

One of the first steps in reviewing the GIS database criticized by ADWR was to dissolve the boundaries of individual agricultural fields, reducing "... the number of claimed fields to verify from 8,121 to 2,214 (Yunker, page 3)." The new "fields," as they are referred to in Appendix G-1, are actually collections of contiguous agricultural fields. After this was done, "... ADWR randomly reviewed about 25% of the resulting fields, which covered between 0 and 10 acres, about 50% of the fields that covered between 10 and 100 acres, and 100% of the fields that covered more than 100 acres (Yunker, page 6). No mention is given in appendix G-1 as to how the fields were selected randomly, and it needs to be determined how the "random" selection was made. "Randomly" is just as likely, in our opinion, to actually mean "arbitrarily" in this context, and the method of doing so is not explicated in the report.

The rationale behind this selection was probably that ADWR did not want to have to find and look at many small fields, but rather fewer, larger ones. Such a selection process biases ADWR's results; however, when individual photo years are selected for inspection rather than unioning all photo years by type. It is far more likely that in the large "field" areas created by the unioning process there will be areas that are not being farmed in single years, than in smaller field areas, resulting in ADWR's classification of them as "partial." This is evidenced by the fact that the average acreage of "joined fields" they classify as "Complete" is 21.71 acres, while the average size classified as "Partial" is 72.36 acres.

ADWR's Approach Misidentifies Irrigated Acreages in the "No" Category such as Orchards and Range Pasture

ADWR review classified acres in one of four classes: Complete, Partial, Questionable and No. The United States' contractor reviewed a sampling of the fields classified by ADWR as "No" and concluded that ADWR's approach overlooked both orchards and irrigated pasture lands. For example, several of the "No" fields are unequivocally orchards. Most others are characterized by rectilinear outlines, cleared level surfaces some of which are bordered by heavy vegetation. Indeed, a large portion of acreage is a waterspreading area within the Polacca Irrigation Project. This area is irrigated pasture in the BIA classification. A simple visual inspection of the topographic maps in the ADWR Appendix B allows an estimate of about 3,250 acres of areas classed as irrigated pasture (Type 3) reviewed as "No" by ADWR. The irrigated pasture in the United States' inventory appears to have been overlooked by the ADWR review, its recognition dependent more on a definition of what uses of surface water distributed by means of waterspreading structures comprise irrigation than on its photographic signature.

The poor quality of imagery used in the ADWR effort is probably the cause for lack of field recognition in the case of photos taken in 1934. The inability to recognize orchards could be due to inexperience or the small scale of 1954 photos. Even with these problems, fields in this "No" class that were reexamined on digital and hard copy imagery are fully recognizable.

It was not possible to review a large enough sample of the ADWR "Questionable" field. However, field areas identified as "Questionable" by ADWR that were seen during the above described inspection of "No" fields also appear to be good candidates for classification as cultivated fields.