

**CHAPTER 4:
DESCRIPTION AND ANALYSIS OF
CLAIMED WATER USES**

CHAPTER 4: DESCRIPTION AND ANALYSIS OF CLAIMED WATER USES

The Hopi and United States Third Amended SOCs claim the following categories of water uses, as described in **Chapter 3**:

- Domestic, Commercial, Municipal, and Industrial (DCMI);
- Agricultural (Irrigation);
- Evaporation from Irrigation Storage;
- Livestock and Water Storage for Stock (Stockponds);
- Ceremonial and Subsistence Irrigation;
- Mining;
- Energy Resources Development;
- Tourism;
- Recreation;
- Subsurface Mineral Rights; and
- Aesthetic, Cultural and Ecological Flows (Riparian and Wetlands Habitat).

This chapter provides a description and background information for each category of water use, followed by a description of the claims and supporting information for those claims provided by both the Hopi Tribe and the United States. The findings of ADWR's review of the claims are then presented. Based on these findings, ADWR's proposed attributes for past and present uses are discussed and presented in **Chapter 5**.

4.1 DOMESTIC, COMMERCIAL, MUNICIPAL AND INDUSTRIAL USE

4.1.1 Description and Background

Domestic, commercial, municipal and industrial (DCMI) water use incorporates multiple types of non-irrigation water demands that can be supplied by individual wells or springs, or through public water systems. Generally, domestic or residential use includes water used indoors (bathing, cooking, cleaning, etc.) and water used outdoors (watering plants, swimming pools,



washing cars, etc.) (ADWR, 2015a). Commercial water use generally incorporates use within commercial or office buildings, hospitals, and schools. Industrial uses are generally quite diverse and include turf-related facilities, sand and gravel operations, large-scale power plants and cooling facilities, dairy operations, cattle feed lots, and large landscape users (ADWR, 2015b). Municipal water use includes government buildings, parks, and other public service related facilities. Municipal water systems can be used to supply domestic, commercial, and light industrial uses.

One method for determining DCMI water use is by directly measuring water deliveries from the various providers. However, not all water providers are regulated or required to report water use (e.g. domestic well owners), so directly measuring DCMI water use can be difficult. Where there are no direct measurements of DCMI water use, such as on the Reservation, DCMI water use is often estimated based on an assumed usage per person. The per person usage is represented as the number of gallons used per capita per day (gpcd) for a population within a selected geographical area or municipality. Both estimated and calculated gpcd values vary widely throughout Arizona. Because large water users such as golf courses may be served by a municipal system, gpcd rates within towns serving such large uses may be significantly higher than in towns without large water users. Some examples of calculated gpcd values within Arizona are provided below.

ADWR stated in the 2008 Preliminary HSR that in 2000, the cities of Williams and Page had an estimated per capita water use of 198 and 351 gpcd, respectively. For Flagstaff, per capita water usage was estimated at 120 gpcd in 2005 and 132 gpcd in 2002 (BOR, 2006).

The U.S. Geological Survey's (USGS) National Water-Use Information Program compiles and publishes water-use data by state and national basis every five years. The USGS works in cooperation with local, state, and federal environmental agencies to collect water-use information. According to the USGS, the total domestic per capita use in Arizona for 2010 was 147 gpcd. The USGS domestic per capita use includes self-supplied domestic and public supply uses (USGS, 2015).



4.1.2 Claimed Use and Basis

4.1.2.1 Hopi Third Amended SOC (DCMI)

In its Third Amended SOC, the Hopi claim a future DCMI water use of 9,348 AFA. The total future use claim is based on tribal-wide DCMI demands, rather than village-by-village water demands, using a per capita estimated water use.

The per capita approach used by the Hopi consists of multiplying a stable reservation population projection for the year 2175 and an assumed per capita usage rate. Hopi population projections rely on the work of experts retained by the United States, which has been updated since the Tribe filed its Second Amended SOC. The Hopi used a stable population projection of 52,016 in 2175 for the 1882 Executive Order Reservation and Moenkopi Island. This population projection does not include the Hopi Industrial Park, which is located outside of the Reservation. The population projection figure was obtained from a table identified in the claim as “Appendix 3 – Distribution of Hopi Reservation Population Projection” from an unnamed report prepared for the United States by the consulting firm, Ramboll Environ. The table lists population estimates from 2010 through 2120, with a stable population estimate in 2175 for each of 11 tribal villages and a “Total Rural Population” category.

The Hopi use a per capita usage rate of 160 gpcd, which includes residential indoor use, residential outdoor use, commercial use, light industrial use, public uses and system losses. The Hopi did not provide any documentation or information to support the 160 gpcd usage figure, although it was requested by ADWR.

4.1.2.2 United States Third Amended SOC (DCMI)

In its Third Amended SOC, the United States claim a present and future DCMI water use of 8,746 AFA. Like the Hopi, the United States also utilized a per capita approach, based on current population and a future stable population projection of 52,016 for 2175 determined by Ramboll Environ.

The claim states that the population forecast is based on the 2010 Census, demographic methodology and data, information collected from Hopi tribal reports, interviews with Hopi tribal members and employees, and other sources. According to the United States, the population



projection is based on current and future geographic distribution of villages and other population centers on the Reservation.

In support of its Third Amended SOC, the United States provided two documents: 1) “Brief Summary of Little Colorado River Basin Hopi Reservation Population Projection for Arizona Department of Water Resources,” dated August 20, 2015, from Ramboll Environ; and 2) an excerpt from the Ramboll Environ demographic report, updated in July 2015, entitled “Current Hopi Reservation Population.” ADWR requested the complete Ramboll Environ report from the United States but it was not provided.

The United States utilized a slightly lower per capita usage rate of 150 gpcd than the Hopi. The 150 gpcd rate represents several components including: residential indoor use; residential outdoor use including irrigation for landscape and gardens; commercial use; light industrial use; public use and system losses. The United States stated that this rate is based on comparisons with local area water use and state averages. ADWR requested supporting documentation, information, or data to support the 150 gpcd figure, but it was not provided.

4.1.3 ADWR Review and Findings (DCMI)

4.1.3.1 Review of Hopi Third Amended SOC (DCMI)

The Hopi claim of 9,348 AFA for DCMI water use is presented as a future use only, and is based on a future per capita use rate of approximately 160 gpcd. The Hopi stated in 2009 in their written comments to the 2008 Preliminary HSR (Hopi, 2009) that the per capita water use in Tuba City, AZ was 146 gpcd at that time. The Hopi did not provide any direct evidence or data in support of their 160 gpcd estimate, although it was requested by ADWR.

In 2009, the Community Water System Program at ADWR produced a summary report that included annual water use reporting from 2006 through 2008. The summary report included annual water demands and annual gpcd use rates for systems in the Little Colorado River Plateau Basin in Navajo County. There were four community water systems included in the summary report for this area which are in close proximity to the Hopi Reservation: City of Winslow, City of Holbrook, Sun Valley Utilities Corp. (Holbrook area), and Joseph City Utility. **Table 4-1** summarizes the gpcd values for these systems which range from 135 to 213 gpcd (ADWR, 2009). The 160 gpcd value used by the Hopi is within this range.



The Tribe's population projections relied upon the work of Ramboll Environ that included a total population estimate on the Reservation in 2015 of 8,853. Assuming a per capita use rate of 160 gpcd, and a current (2015) estimated population of 8,853, ADWR calculated that the current DCMI use would be 1,591 AFA. ADWR also calculated that the future DCMI use for the Reservation would be 7,757 AFA (9,348 AFA – 1,591 AFA).

4.1.3.2 Review of United States Third Amended SOC (DCMI)

The United States claim a present and future DCMI water use of 8,746 AFA. Although the United States describes the DCMI use as present and future, the present and future uses are not provided separately in its Third Amended SOC. The United States included irrigation for landscape and gardens in the DCMI use category while the Hopi did not. The Hopi and United States both have a separate use claim for Ceremonial and Subsistence Irrigation, which is discussed below in this chapter.

The United States Third Amended SOC is based on a per capita demand of 150 gpcd. Assuming a per capita demand of 150 gpcd, and a current estimated population of 8,853 based on the work done by Ramboll Environ, ADWR calculated that the estimated current DCMI use would be 1,489 AFA. ADWR also calculated that the future DCMI use for the Reservation would be 7,257 AFA (8,746 AFA – 1,489 AFA). In its claim, the United States indicates that it based the 150 gpcd rate on comparisons with local area water use and state averages, but it did not provide any additional information or data in support of its 150 gpcd rate and did not provide copies of the reports prepared by Ramboll Environ, although that information was requested by ADWR.

4.2 AGRICULTURAL USE (IRRIGATION)

4.2.1 Description and Background

The Hopi have a long history of farming in the region, and their water right claims in the adjudication reflect this history. The largest claims for water on the Reservation are for irrigation of agricultural lands. About 63% of the Reservation, or over 1 million acres, have been determined to have soils that could potentially grow crops if irrigated (ADWR, 2008p).

Use of Reservation land for farming has, and apparently continues to be, bound by land ownership rules (Andersen, 2008). Hopi villages reportedly have claims to the best farmland, and



clans within the villages have their own claims based on tenure. Within clans, Hopi families may own individual farm tracts and may try to have two or more fields located on different streams and/or in different areas to improve their chances for a successful crop.

Traditional and more modern (recent) farming practices have been in the past and are presently still being used by the Tribe to grow crops on the Reservation. Both farming practices are further described below.

Traditional Farming

The Hopi have a long history of growing crops in the region and have developed traditional farming practices to adapt to a limited water supply and relatively harsh climate. The latter is characterized by strong winds, early and late frosts, and a semi-arid climate. Hopi cultivation methods include, but are not limited to, diverting surface water flows onto the floodplains and terraces of large washes, placing fields at the mouth of smaller washes (ak-chin farming), and constructing check dams along small washes (Trinchera fields). Springs also have historically been developed to convey water to terrace gardens at and near the Hopi villages and to sand dunes on the sides and tops of mesas for cultivation.

Historic accounts suggest the Hopi have used these farming practices for centuries (Andersen, 2008). The Spanish reported Hopi growing a surplus of beans, corn, cotton, squash, and other vegetables as early as 1583 near the Hopi Mesas, and as early as 1604 in the Moenkopi area. Several crops including fruits (apples, apricots, and peaches), onions, peppers, and wheat were introduced by the Spanish and later adopted by the Hopi. In an early survey of the District 6 area, Mayhugh (1892) identified 12 springs and pools that he reported were being used by the Hopi to water gardens and peach orchards. Archeological evidence suggests the Hopi may have farmed other areas as far east as Canyon De Chelly, as far south as the LCR, as far west as the Kerley Valley, and the Coal Mine Mesa and Moenkopi Plateau region that currently lies on Navajo land between the Hopi Partitioned Land and Moenkopi area. The Hopi reportedly have travelled long distances to tend to individual fields. Such long distance farming included fields in the Sand Spring, Burro Spring, Coyote Spring, and Talahogan areas (Hopi, 2009).

Although traditional farming practices have been modified somewhat to incorporate new tools, similar techniques are generally still being employed (Andersen, 2008). For example, rather than using hoes to cultivate fields by hand, horses and tractors have been employed to plow or disk



fields in the spring prior to planting, during the growing season to control weeds, and in the fall after harvest.

Cultivated fields are still harvested and largely planted by hand and pesticides are generally not used. In her study of Hopi farms, Manolescu (1995) found that up to one-third of crops grown on the Reservation were lost to pests. She also found that the best fields were still those less than three acres large, located along or near streams, and hand planted. Cultivation of sand dunes is also a prevalent practice, as observed in the field by ADWR in 2005. On sand dunes, tin cans and tires have replaced rock and brush fences as wind breaks. Approximately 5,000 acres of active traditional farming were identified by ADWR during its 2005 survey.

Modern (Recent) Farming

The first attempt at more modern farming methods on the Reservation appears to be the efforts of Mormon settlers in the Moenkopi area (Andersen, 2008). Mormons were established in the area by 1875 and afterward, the Hopi began to return to fields they had previously farmed. The Hopi reportedly used traditional farming practices in and around Moenkopi, including lands that are now on the Navajo Reservation, using the relatively abundant spring water along Pasture Canyon.

Sometime before 1903, the Mormons built an upper dam and middle dam along Pasture Canyon that were raised in 1908 (Andersen, 2008). The middle dam was later abandoned, and the upper dam rebuilt by the Federal government in the 1920s and 1930s, and raised again in the 1970s to form present day Pasture Canyon Reservoir. It is unclear whether a third dam presently located along lower Pasture Canyon (Lower Lagoon Reservoir) was built by the Mormons prior to 1912 or afterward by the Federal government. Either way, by 1914, crops including corn, wheat, melons, squash, and fruit were being grown using the Pasture Canyon irrigation system. The number of acres cropped by the Hopi in the area increased from 385 in 1907 to between 600 and 860 in the 1930s, and 550 in 1963. However, it is not clear to ADWR what portions of these lands were being irrigated from Pasture Canyon Reservoir. In 1958, it was reported that the Pasture Canyon irrigation system was serving an area of approximately 300 acres, presumably below the dam, but only 40% of this area (120 acres) was being cropped at that time (Chambers & Campbell, 1962).



Agricultural lands in the Moenkopi area were surveyed by ADWR during 2005, 2006, and 2008 (ADWR, 2008p, Appendix G). Water for most fields was observed to originate as spring discharge along upper Pasture Canyon and stored downstream in Pasture Canyon Reservoir. Below the reservoir, the water is piped both below and above ground surface to a main canal that feeds a series of unlined lateral ditches. Abandoned instream pumps were also observed along Moenkopi Wash that may have previously been used to irrigate some fields in the area. A new wastewater treatment plant was being completed in 2008 near the western boundary of the Moenkopi area. According to Hopi guides, reclaimed water from the plant was planned to be used to irrigate Hopi and adjoining Navajo lands. The Tribe claims the wastewater treatment plant has been releasing water for irrigation use.

The Federal government constructed other irrigation projects on the Hopi Indian Reservation, but none have been as successful as Pasture Canyon. ADWR described several historic irrigation projects including their general location, date of completion, system components, annual acreage cropped, years in operation, and status (ADWR, 2008p). According to the Tribe, other irrigation projects that were developed, but not listed in ADWR (2008p) included Begashibito 2, Upper Kerley Valley, (joint Hopi/Navajo), Oraibi Delta (joint Hopi/Navajo), Polacca Wash 1, Polacca Wash 35, and Polacca Delta (joint Hopi/Navajo). The irrigation projects were generally completed between the 1890s and 1940 and all appear to have been lost by 1960, either through flooding, abandonment, or both. More recently (circa 2000) an irrigation system was completed along Dinnebito Wash (near Sand Springs), referenced in the Hopi Third Amended SOC as “historic project DW 10,” consisting of an instream pump and drip lines. The current acreage claimed to be served by this project is approximately 70 acres.

4.2.2 Claimed Use and Basis

Claims in the Hopi Third Amended SOC and Supplement and United States Third Amended SOC for past and present irrigation represent a composite of all lands the Hopi and United States determined, through analysis of historic aerial photographs and field surveys, to have been farmed on at least one occasion. The acreage claimed represents the total acreage of all the fields that show visible evidence of cultivation.



4.2.2.1 Supplement to Hopi Third Amended SOC (Agricultural Use)

Acreage

In the 2015 supplement to the Hopi Third Amended SOC (Hopi Tribe Supplement), the Hopi claim the right to annually irrigate a composite total of 26,921.9 acres of land. The past and present claimed acreage information is presented in Table 2 of the Hopi Tribe Supplement and includes an additional 311 acres not identified in the Hopi Third Amended SOC. Table 2 references acreage described in the United States Third Amended SOC and identified by ADWR in the 2008 Preliminary Hopi HSR (ADWR, 2008p). Table 2 lists six categories of irrigated lands and corresponding acreages as described below:

- **13,031.6 acres** –described in the United States Third Amended Claim;
- **1,853.3 acres** - identified by ADWR (2008p) as having “Complete Evidence” and not included in the United States claim;
- **11,658.5 acres** - identified by ADWR (2008p) as having “Partial Evidence” and not included in the United States claim;
- **67.5 acres** - “Historic project DW10” acreage on Dinnebito Wash and not included in the above categories or previously verified by ADWR;
- **172.7 acres** - “Additional Historic Irrigated Acreage (HIA) from New Aerial Imagery, Current Irrigation;” and
- **138.3 acres** - “Additional Historic Irrigated Acreage (HIA) from New Aerial Imagery, Recent Irrigation.”

The Tribe provided ADWR with GIS shapefiles depicting the irrigated acreage for each category listed above. The Hopi Third Amended SOC did not include any historical aerial imagery data associated with the claim, instead relying on supporting data in the United States claim and on the Preliminary Hopi HSR classification system and imagery analysis determinations.¹

The Hopi Tribe Supplement explains how the Tribe digitized additional historic irrigated acreage from 2010 Bing aerial imagery obtained by using GIS software. This imagery is shown in Appendix 1 to the Hopi Tribe Supplement. (See Hopi, 2015 (Supplement) at p. 6, n. 5)

¹ The Preliminary Hopi HSR contains Appendix G-1, Verification of Claimed Agricultural Lands on the Hopi Indian Reservation.



Quantity of Use

As described in **Chapter 3**, the Hopi claim a diversion volume of 102,303 AFA, based on a claimed water duty of 3.80 acre-feet per acre of surface and groundwater to irrigate the 26,921.9 acres of agricultural lands described above.² To ADWR's knowledge, the quantity of irrigation water applied to cultivated fields, in any of the categories claimed, has not been measured directly by the Tribe.

4.2.2.2 United States Third Amended SOC (Agricultural Use)

Acreage

The United States' agricultural claims represent a composite of all lands that they determined, through analysis of aerial photographs, had at one time been farmed on the Reservation. The United States claims the right to annually irrigate a total of 13,032 acres of land. The past and present claimed acreage information is presented in Table 1 of the United States Third Amended SOC. Table 1 presents information for six classes of irrigation, which are based on water source and crop, in the five main washes and minor tributaries on the Reservation. The six classes of irrigation and corresponding acreages listed in the United States claim are as follows:

- **Perennial Irrigation (264 acres)** - irrigation with perennial spring water conveyed and stored in permanent structures;
- **Seasonal Irrigation (4,294 acres)** – irrigation with seasonal surface water conveyed by permanent or temporary structures or by pumping;
- **Range / Pasture Irrigation (3,483 acres)** – irrigation with seasonal surface water to improve range for pasture conveyed by permanent or temporary structures;
- **Native Irrigation (4,791 acres)** – irrigation with seasonal surface water with minimal or no conveyance structures to cropped areas, which are strategically placed;
- **Well Irrigation (17 acres)** – irrigation with water from a well conveyed through a system of pipes and/or open ditches; and

² See Table 2, Hopi, 2015 (Supplement).



- **Spring Irrigation (183 acres)** – irrigation from “perennial” groundwater, obtained and distributed from a spring.

The United States provided ADWR with GIS shapefiles (digitized irrigated acreage coverages) containing polygons of historic and/or currently irrigated agricultural fields and aerial imagery used as the basis for determining agricultural activity. Appendix 8 to the United States claim contains a series of maps depicting the irrigated acreage on the Hopi Reservation, based on the United States’ aerial photo interpretations.

Digital ortho-rectified aerial photography datasets spanning eight decades, from the mid-1930s through the 2010s, used in support of the United States claim, were made available to ADWR for analysis. The photography was prepared and georeferenced and indexed by National Resources Consulting Engineers, Inc. (NRCE). The United States aerial photography datasets include the following coverage dates:

- 1934-1935 SCS (Soil Conservation Service) images;
- 1952 GS-WG images³
- 1954-1955 Army Map Services (AMS) images;
- 1974 Joint Use Area (JUA) images;
- 1980 National High Altitude Photography (NHAP), precursor to National Agriculture Imagery Program (NAIP) images; and
- 2010 and 2013 NAIP images.

The United States Third Amended SOC states that “use of aerial photos from 1952, 1954, and 1955 provided for delineation of the native irrigation fields, while use of photos from 1934, 1952, 1954, 1955, 1974, 1980, 2010 and 2013 allowed delineation of fields in the five other irrigation classes.”

Quantity of Use

Estimated irrigation depletion and diversion amounts from the five washes and other minor tributaries are presented in Table 2 of the United States Third Amended SOC. Table 2 lists

³ ADWR was unable to determine the originator of these images.



irrigation depletions and diversion amounts for the five washes and tributaries in both average and maximum years. The United States claims the maximum diversion amount “in order to provide a water supply for the maximum irrigated acreage in years that the water is available.”

Table 2 of the United States Third Amended SOC lists average and maximum irrigation depletion amounts for the five washes and minor tributaries totaling 14,148 AFA and 20,626 AFA, respectively. The table also lists average and maximum irrigation diversion amounts for the five washes and minor tributaries totaling 19,440 AFA and 28,417 AFA, respectively. The United States claims the maximum irrigation diversion total of 28,417 AFA for past and present irrigation on the Reservation.

4.2.3 ADWR Review and Findings (Agricultural Use)

4.2.3.1 Review of Supplement to Hopi Third Amended SOC (Agricultural Use)

Acreage

The past and present irrigated acreage claims listed in the Hopi Third Amended SOC and Supplement were verified by ADWR via an office GIS aerial photo interpretation evaluation (ADWR 2015 GIS Verification). The ADWR 2015 GIS Verification evaluated the GIS polygons for claimed agricultural fields associated with the six categories of irrigated lands described in **Section 4.2.2.1**, in conjunction with the multiple years of aerial photography provided by the United States as described in Section 4.2.2.2. ADWR’s findings are presented below and summarized in **Table 4-2** provides claim acreage not verified by ADWR.

(1) United States Third Amended Claim Acreage (13,031.6 acres)

Approximately 13,022 acres or 99.9% of lands claimed by the United States, and referenced by the Hopi Tribe, have evidence of previous agricultural activity. Approximately 10 acres of land (or roughly 0.1%) show no evidence of historic agricultural activity as observed in the provided aerial imagery.

(2) ADWR (2008) Complete Evidence Acreage (1,853.3 acres)

All of the 1,853.3 acres claimed by the Hopi, and previously classified by ADWR in the Preliminary Hopi HSR as irrigated based on ‘Complete Evidence,’ are re-verified as having evidence of previous agricultural activity.



(3) ADWR (2008) Partial Evidence Acreage (11,658.5 acres)

Approximately 11,007.8 acres or 94% of lands claimed by the Hopi, and previously classified by ADWR in the Preliminary Hopi HSR as irrigated based on ‘Partial Evidence’, are re-verified as having evidence of previous agricultural activity. Approximately 650.7 acres were found to have either less than 50% agricultural activity observable in the provided aerial images, or were identified by ADWR as non-agricultural uses.

(4) Historic Project DW 10 Acreage (67.5 acres)

All 67.5 acres claimed by the Hopi were verified as having evidence of previous agricultural activity.

(5) Additional Historic Irrigated Acreage (HIA) – Current Irrigation (172.7 acres)

All 172.7 acres claimed by the Hopi were verified as having evidence of previous agricultural activity.

(6) Additional Historic Irrigated Acreage (HIA) – Recent Irrigation (138.3 acres)

All 138.3 acres claimed by the Hopi were verified as having evidence of previous agricultural activity.

The Hopi claimed, and ADWR evaluated, a composite total of all lands that were believed to have been irrigated at any time during the last approximately 80 years. The maximum total acreage that is believed to have been irrigated in any one period is 9,553 acres in the 1954-1955 timeframe, as claimed by both the Hopi and the United States in their 2009 Second Amended SOCs. That number of acres is consistent with the historical research conducted by Andersen (2008) who found that the maximum acreage irrigated in any one year was approximately 9,300 acres.

Quantity of Use

The Hopi claim a total of 26,921.9 acres of irrigated acreage within the six categories of irrigated lands described in **Section 4.2.2.1**. The total corresponding annual diversion volume claimed is 102,303 acre-feet based on a 3.80 acre-foot per acre water duty that is derived from



ADWRs findings in the Preliminary Hopi HSR. That report estimated agricultural water demands on the Reservation utilizing the following factors:

- the type of crops being grown;
- the net irrigation requirement of the crops (*i.e.*, the amount of water needed to supplement local precipitation);
- the efficiency of the irrigation system; and
- the cropped acreage.

Recent and historic surveys of Hopi fields indicate that corn has typically been the most common crop grown on the Reservation, followed by orchards, beans, melons, and squash. Using local climate data and accounting for the traditional farming practices of the Hopi, (ADWR, 20081) estimated the water demands for these crops. Results were summarized in Table 8-1 of the Preliminary Hopi HSR, which included a range of values that accounted for variations in climate across the Reservation and whether the crops were grown using traditional Hopi farming practices or through more modern agricultural methods. Table 8-1 also included composite and net irrigation requirements based on a typical crop mix for the Reservation and accounted for the effective precipitation in the area.

The composite irrigation requirement was defined in the Preliminary Hopi HSR as the irrigation requirement of different crop types weighted by their percentage in the crop mix. Net irrigation requirement (NIR) was calculated by reducing the composite irrigation requirement by the annual effective precipitation.

ADWR determined in the Preliminary HSR that crops grown following traditional Hopi farming practices had an NIR of 0.35 to 0.86 acre-feet per acre. If the same crop mix were grown using more modern agricultural methods, the NIR would increase to between 1.72 and 2.46 acre-feet per acre. The lower NIR calculated for traditional farming practices reflected the Hopi's ability to adapt to a limited, local water supply using a variety of strategies. A copy of ADWR's crop water demand study was provided in Appendix F of the Preliminary Hopi HSR.

DOWL, a water resources consultant to the Hopi Tribe, calculated the "full-supply" water duty per acre based on the following: 1) calculation of an average NIR value; 2) calculation of overall irrigation efficiency; and 3) calculation of a water duty to be applied Reservation-wide, on



a per-acre basis, to all past and present irrigation categories described in the claim. DOWL's quantification methodology is summarized below.

- 1) DOWL's quantification relies on use of the lower and upper NIR estimates for modern farming listed in Table 8-1 of the Preliminary Hopi HSR in order to calculate an average NIR value as follows:

$$\text{AVERAGE NIR} = 1.72 \text{ (lower)} + 2.46 \text{ (upper)} / 2 = 2.09^4$$

- 2) DOWL's overall irrigation efficiency calculation for the Reservation is as follows:

$$\text{OVERALL IRRIGATION EFFICIENCY} = 0.85 \text{ (irrigation conveyance efficiency)} \times 0.65 \text{ (on-farm efficiency)} = 0.55$$

- 3) DOWL's water duty calculation is as follows:

$$\text{WATER DUTY} = 2.09 \text{ ac-ft./acre (NIR)} / 0.55 \text{ (overall irrigation efficiency)} = 3.80 \text{ ac-ft./acre}$$

Once the water duty is determined, it is multiplied by the total number of irrigated acres for all of the irrigated lands listed in Table 2 in the Hopi Tribe Supplement in order to determine the total claimed annual diversion volume. The total claimed irrigated acreage from all six irrigation categories is 26,921.9 acres. The Hopi calculated total corresponding annual diversion volume of 102,303 AF as follows:

$$\text{AVERAGE ANNUAL DIVERSION VOLUME} = 3.80 \text{ ac-ft./acre} \times 26,921.9 \text{ acres} = 102,303 \text{ acre-feet}$$

The Hopi Third Amended SOC does not utilize or reference the range of NIR values for traditional Hopi farming practices (between 0.35 to 0.86 acre-feet per acre) from the Preliminary Hopi HSR. In its comments on the Preliminary Hopi HSR, the Tribe states "historic irrigation on the Hopi Reservation has included both traditional farming as well as irrigation projects which have higher NIR values and depletions" (Hopi, 2009 p.20) .

⁴. See Hopi Third Amendment at p. 32, n. 12; Table 2, Hopi Supplement at p. 7.



In 2010 ADWR received an updated consumptive use report, prepared under contract, in support of its work to finalize the Hopi HSR at that time. This report, entitled *Response to Comments on the Preliminary Hopi HSR Related to Consumptive Use of Water by Crops*, is provided as **Appendix D**. The original Appendix F of the Preliminary Hopi HSR is included as an appendix to the 2010 report.

The 2010 report responds to comments received by ADWR on the Preliminary Hopi HSR related to consumptive use (CU) of water by crops. In response to the comments received, the updated report describes changes made to ADWR's original CU calculation methods and provides revised results for Supplemental Irrigation Demand (SID), defined as the CU less the effective precipitation. These revised numbers are provided in **Table 4-3**.

As described above, the Hopi water resources consultant calculated an overall irrigation efficiency of 0.55 for all irrigated acres claimed by the Hopi. ADWR believes that this value is not unreasonable for modern irrigation, but that it should not be applied to acres irrigated using traditional farming practices. ADWR considers modern irrigation as equivalent to the perennial and spring classes and traditional irrigation as equivalent to the seasonal, range, and native classes, as described in the United States Second Amended SOC. ADWR is using the irrigation classes from the United States Second Amended SOC because those classes were used to describe the maximum acreage believed to have been irrigated in any one period.

As noted by DOWL, the overall irrigation efficiency is comprised of the irrigation conveyance efficiency and the on-farm efficiency, with the conveyance efficiency very much dependent on the length of the canal (FAO, 1989). The majority of traditionally farmed acres claimed in the Second Amended SOC have no conveyance systems and are instead strategically placed to intercept flowing water. Traditionally farmed acres have virtually no conveyance losses and their conveyance efficiency would be equal to 100%. ADWR believes that the conveyance efficiency that should be applied to traditional acres in aggregate should not be less than 90% (0.90).

Hopi traditional farming methods “have resulted in an agricultural efficiency known in few other places on earth.” (Wall and Masayeva, 2004.) For more than 1,000 years the Hopi have adapted their farming practices and their crops, most notably corn, to make the best use of a limited amount of moisture. Hopi corn can be planted at depths exceeding 10-inches in order to access residual moisture from winter rains (Collins, 1914). Corn roots are reported to reach depths of



greater than 10 feet (Brew, 1979) and may extend horizontally up to three feet from the stalk (Benson, 2010). Through the spacing of their plantings, the Hopi take full advantage of the adaptations of their crop. Much of the water that would be considered “lost” because it percolated too deeply into the soil, or too far from the plant, in a modern field, is captured in a traditional field. ADWR believes that the on-farm efficiency that should be applied to traditional acres in aggregate should not be less than 80% (0.80).

Based on the discussion above and using the updated SID values from Crowley (2010), ADWR believes that the water duty for modern acres and traditional acres should be 4.33 and 0.93 acre-feet per acre, respectively. The calculations are summarized in Table 4-4.

4.2.3.2 Review of United States Third Amended SOC (Agricultural Use)

Acreage

The United States claims a composite total of 13,032 acres of agricultural land. As described in **Section 4.2.3.1** above, ADWR determined that approximately 13,022 of the 13,032 acres, or 99.9% of the lands claimed by the United States, had evidence of agricultural activity.

Quantity of Use

ADWR requested supporting documentation for the volume of water claimed by the United States for past and present irrigation. ADWR was supplied with a draft memorandum that provided “...a summary of a draft report...” The draft memorandum was marked “Attorney-Client Communication, Confidential, Privileged Information.” ADWR is unable to assess or rely on the information provided in the draft memorandum and therefore presents no findings.

4.3 EVAPORATION FROM IRRIGATION STORAGE

4.3.1 Description and Background

Irrigation reservoirs are used to capture stream runoff and baseflow throughout the year so that greater volumes are available for irrigation use during the growing season. Water evaporates from the surface of such reservoirs resulting in a net loss to the system.



4.3.2 Claimed Use and Basis

4.3.2.1 Hopi Third Amended SOC (Irrigation Storage Evaporation)

The Hopi claim the right to store 333 AF of water flowing from springs and surface runoff in two irrigation reservoirs above Pasture Canyon in Moenkopi Island. The two reservoirs are identified in the claim as Pasture Canyon and Lower Lagoon, with claimed surface areas of 32 acres and 16 acres, respectively. The Hopi Tribe claims 192 AFA for evaporation losses from these two reservoirs calculated using a net evaporation rate of 4 feet per year.

4.3.2.2 United States Third Amended SOC (Irrigation Storage Evaporation)

The United States does not claim evaporative losses from irrigation reservoirs on behalf of the Hopi Tribe.

4.3.3 ADWR Review and Findings (Irrigation Storage Evaporation)

Pasture Canyon Reservoir, readily visible on Google Earth® imagery, appears at least 50% full in five different images between 1997 and 2014, and is approximately 32 acres in size. Lower Lagoon, also visible on Google Earth® imagery, has less than one acre of water visible in the 1997 image and no water visible in the 2007, 2010, 2012, or 2014 images, and appears to be approximately 10 acres in size.

In the Preliminary HSR, ADWR estimated the gross monthly rates of surface water evaporation on the Reservation using the Penman method and measured or estimated values for wind speed, dew point, temperature, and minimum and maximum air temperature. Evaporation rates were calculated for the Tuba City and Keams Canyon areas and are listed in **Appendix B (Table B-2)**. These calculations indicate that the gross annual rates of surface water evaporation on the Reservation ranges from 63.5 inches (5.3 feet) to 80.2 inches (6.7 feet) (ADWR, 2008p).

Mean annual precipitation in the vicinity of the Reservation is shown in **Figure B-4** for the period 1971-2000 and **Appendix B (Table B-1)** lists precipitation and snowfall data from the Tuba City and Keams Canyon meteorological stations. In Keams Canyon, annual precipitation has averaged 9.94 inches since 1948, with the average monthly precipitation ranging from 0.30 inches in June to 1.61 inches in August. In Tuba City, annual precipitation has averaged 6.47 inches since



1900, with the average monthly precipitation ranging from 0.24 inches in June to 0.85 inches in August (ADWR, 2008p).

ADWR calculated the net annual evaporation in inches based on the following formula:

$$\text{Net Annual Evaporation} = \text{Gross Mean Annual Surface Evaporation} - \text{Mean Annual Precipitation}$$

Using the above formula, ADWR calculated lower and upper bound net annual evaporation at Tuba City and Keams Canyon. The calculations indicate that net annual rates of surface water evaporation on the Reservation range from 53.56 inches (4.5 feet) to 73.73 inches (6.1 feet) (**Table 4-5**). The Hopi claim an annual net evaporation rate of 48 inches (4.0 feet) related to the Pasture Canyon and Lower Lagoon reservoirs, which is supported by ADWR's calculations.

4.4 LIVESTOCK AND WATER STORAGE FOR STOCK (STOCKPONDS)

4.4.1 Description and Background

The Hopi Land Use and Development Plan (Hopi, 2001) indicated that grazing is the “principal activity” on approximately 1,565,590 acres of Reservation land used for agriculture and range. NRCS (1996) reported that about 85% of the 1882 Reservation land base is used throughout the year for grazing. Based on reservation boundary data from NRCE (2005), this equals about 1,326,000 acres of rangeland (ADWR, 2008b).

For the purpose of range management, Reservation lands have been divided into 53 tracts known as range units (Hopi, 1998). Fifteen range units are located in District 6 and 38 range units are located in the Hopi Partitioned Lands (**Figure B-15**). Characteristics of the units are listed in **Table B-5** including their name and number, acreage, and percentage of area useable as forage. To ADWR's knowledge, separate range units have not been established in the Moenkopi area. However, the Hopi claim that stock were in the Moenkopi area based on water uses from ponds, wells and springs (ADWR, 2008p).

Regulation of livestock on the Reservation is described in *Tribal Ordinance 43–Control of Livestock and Grazing on the Hopi Reservation*. The ordinance governs “the allocation of grazing and accommodation permits to, and the use of the Hopi Reservation for grazing purposes by tribal members and Accommodation Agreement (Navajo) signatories, and shall otherwise control the



presence of livestock on the Hopi Reservation” (Hopi, 1998). Provisions of the ordinance are carried out by staff of the Hopi Tribal Office of Range Management (ORM) and Hopi Resources Enforcement Services (HRES) (ADWR, 2008p). The Hopi Tribe enforces grazing regulations on the Reservation pursuant to a contract with the U.S. Department of the Interior (Hopi, 2009).

Available data indicate that the Hopi have grazed livestock since at least 1775 and the number of Hopi livestock has varied substantially over time. Livestock water demands are expected to have varied as well, but were probably greater in the past than recent demands due to reported greater numbers of Hopi livestock in the past (ADWR, 2008p).

Other than domestication of turkey, the raising of livestock was not an aboriginal activity of the Hopi. With the Spanish introduction of sheep, goats, cattle, horses, and burros, herding of livestock, particularly sheep, became an important part of Hopi subsistence. Livestock eventually replaced hunting as the main source of dietary protein, while wool became a preferred weaving material (ADWR, 2008p).

4.4.2 Claimed Use and Basis

4.4.2.1 Hopi Third Amended SOC (Livestock and Stockponds)

Livestock Watering (Hopi)

The Hopi Tribe claims 1,000 AFA of water use to support the maximum carrying capacity of livestock within the 1882 Reservation and Moenkopi Island. The primary source of water for the livestock demand is groundwater from existing and future wells, with additional water from springs. The Hopi claim references Appendices 4 and 5 to the United States claim, which list the wells and springs.

The Tribe states that rangeland covers 1,622,455 acres of land with a maximum carrying capacity of 44,486 animal units (AU). The Hopi claim includes a consumptive use rate for cattle of 12 gallons per animal unit per day (gpAUD) that is based on ADWR’s revised Standard Water Use Quantities, dated January 2006 (described further in **Section 4.4.3.1**). Further, the Hopi claim a diversion rate of 20 gpAUD based on a 60% water use efficiency to account for evaporation, spills and other losses from wells. The 60% efficiency assumes the use of metal drinker tanks to store stock well water, although such water also is stored in earthen facilities. If earthen facilities



continue to be used for livestock storage in the future, the Tribe asserts the right to use more than the 20 gpaud rate and more than 1,000 AFA due to decreased efficiency. As discussed further in **Section 4.4.3.1**, this claim appears to be for future uses.

Water Storage for Stock (Hopi)

Additionally, the Hopi claim the right to divert and deplete 4,883 AFA for livestock consumption based on water stored in past and present stockponds served by surface flows. The Hopi claim the right to maintain each water storage facility at its described location and dimensions and fill each facility to its full capacity when the stated source of supply is available. The Hopi Tribe also claims the right to construct future stockponds as needed to satisfy the claimed livestock consumption demand.

The Hopi Third Amended SOC includes a list and mapped locations of 608 livestock water storage impoundments. The information provided also includes the claimed capacity for each impoundment, location coordinates, and ArcGIS shapefiles with impoundment locations as points.

Appendix 3 of the Hopi 2015 amended claim includes a report prepared for the Hopi Tribe titled *Hopi Indian Reservation Livestock Impoundments* dated May 29, 2015 that was prepared by DOWL of Billings, Montana. This report, among other things, describes the methodology used in 1991 and 1992 to identify and analyze impoundments. The following information is a brief synopsis of the methodology discussion in the DOWL report.

For the DOWL report, black and white 1991 aerial photography prints at a scale of 1:24,000 were examined under stereoscope. The historic maximum controlled water level, corresponding surface area, and depth were determined. Color infrared imagery from 1980 was used to supplement this information. A field investigation of sample impoundments was conducted in July 1991 to obtain ground-verified information. The field information was used to calibrate the physical parameters identified in the aerial photography interpretation.

The capacity of each impoundment was calculated using the following formula:

$$C = A \times D \times 0.4$$

Where:

C = Capacity

A = Area

D = Depth



0.4 = Volume conversion factor for water impoundments utilized by the Soil Conservation Service (now Natural Resources Conservation Service) and the Montana Water Rights Claim Examination Manual.

The only exception to the use of the 0.4 volume conversion factor was where the pit was cone-shaped. In those cases, a factor of 0.33 was used. The claim does not specify which impoundments had capacity calculations based on the 0.33 instead of the 0.4 factor.

The number of impoundments for use by livestock claimed by the Hopi in its Third Amended SOC (608) was less than the number of impoundments claimed by the United States (1,001). The impoundments claimed by the United States are described in **Section 4.4.2.2**. The Tribe submitted supplemental information to ADWR on August 31, 2015 that revised the number of impoundments and storage capacities. The Hopi Tribe Supplement states:

The Tribe and the United States worked cooperatively to explain the discrepancy in the number of impoundments claimed. The Tribe and the United States determined that the discrepancy arose because their respective experts had slightly different definitions of impoundments. For example, Hopi experts only claimed impoundments used for stockwater whereas United States experts claimed any impoundment verified, even if the use was for purposes other than stockwater. Therefore, the Hopi claim for stockwater impoundments is generally a subset of the United States claim as approximately 600 of the Hopi impoundments claimed are also part of the United States claim for impoundments for stockwater use. The approximately 400 remaining federal claims for impoundments are additional impoundments comprised of 180 impoundments found by ADWR in 2008 during field work and the remainder identified by the United States during field work from 2007 – 2015.

Based on the impoundments claimed by the United States, the Hopi revised its Third Amended SOC by: (1) correcting locations of previously identified impoundments; (2) adding impoundments claimed by the United States but not previously claimed by the Hopi Tribe; and (3) adding impoundments previously unclaimed by either party. The corrections and additions are summarized below:

- 40 impoundments had incorrect locations due to GIS projection issues, with no additional volume added to the Hopi claim;



- 396⁵ impoundments were added that were previously claimed by United States but not by the Hopi, which resulted in an increase of 1,289 AF of storage capacity;
- 8 new impoundments identified by the Hopi based on more recent aerial photography, which resulted in an increase of 12 AF of storage capacity.

The Hopi submitted a revised list and printed maps that corrected the locations for 40 impoundments, and identified the additional 404 impoundments with capacities and coordinates. ADWR received GIS shapefiles for the eight (8) new impoundments identified by the Tribe but did not receive GIS shapefiles for the 396 impoundments previously claimed by the United States but not by the Hopi.

As indicated above, the addition of the 404 impoundments increased the Hopi water storage claimed amount by 1,301 AF (1,289 AF + 12 AF). The Hopi Third Amended SOC as supplemented includes 1,012 impoundments with capacities that total 6,184 AF (4,883 + 1,301) for past and present livestock consumption. The Hopi claim the right to divert surface flows in the amount of 6,184 AFA to fill livestock impoundments to their stated capacities whenever the source of supply is available.

4.4.2.2 United States Third Amended SOC (Livestock and Stockponds)

Livestock Watering (United States)

The United States claims the right to divert and deplete 997 AFA for livestock purposes from existing wells and/or future wells that will be drilled on the Reservation, springs, and stockponds. The wells, stockponds and springs are identified in Appendices 4, 5, and 6 to the claim. The livestock watering claim is based on 1,622,455 acres of rangeland with a maximum carrying capacity of 44,486 AU, which are the same numbers used by the Hopi for its claim. Like the Hopi claim, in addition, the United States claim is based on a 12 gpaud cattle consumption rate, and a diversion rate of 20 gpaud based on a 60% water use efficiency to account for evaporation, spills and other losses. As with the Hopi claim, the United States claim for livestock watering appears to be for future use as described in **Section 4.4.3.2**.

⁵The Hopi claim nine impoundments not claimed by the United States and the United States claim six different impoundments not claimed by the Hopi. The net result is three additional impoundments thus making the total additional impoundments count 396 instead of 393.



Water Storage for Stock (United States)

In their 2015 amended claim, the United States claims 3,388 AF to fill each impoundment to its full capacity when the water supply is available. The majority of impoundments are utilized for livestock. However, a few impoundments have additional reported uses such as recreation and irrigation. The United States also claims the right to repair, maintain, and replace existing impoundments, and the claim is not intended to prevent the construction of new impoundments in the future.

In Appendix 6 of the United States 2015 amended claim, the United States provided a list of 1,001 total impoundments that included the U.S. Label ID, Plate Number, location coordinates, area in acres, capacity in acre-feet, and water use. The United States also provided ArcGIS shapefiles for the 1,001 impoundments with locations as polygons.

4.4.3 ADWR Review and Findings (Livestock and Stockponds)

4.4.3.1 Review of Hopi Third Amended SOC (Livestock and Stockponds)

Review of Livestock Watering (Hopi)

The Hopi claim of 1,000 AFA for stockwatering appears to be for future use due to the following: (1) the Tribe's assertion that 1,000 AFA is based on a maximum future carrying capacity of 44,486 AU, rather than the current or maximum past number of AU; and (2) the Tribe's statement that this claim is for well water stored in metal tanks which are not reported to be in wide use at this time on the Reservation. ADWR recognizes that livestock are currently being watered on the Reservation by means of stockponds.

The Hopi state in their 2015 amended claim that the Reservation contains 1,622,455 acres of rangeland. The Hopi claim did not contain any documentation or information to support their stated rangeland acreage.

In the Hopi Strategic Land Use and Development Plan (Hopi, 2001), the Tribe stated that grazing occurred on 1,565,590 acres of Reservation lands. NRCS (1996) reported approximately 1,326,000 acres of rangeland within the Reservation. In the 2008 Preliminary HSR, ADWR estimated that between 819,000 and 1,326,000 acres of the 1882 Executive Order Reservation were useable as range (ADWR, 2008b).



The Hopi claim a maximum carrying capacity of livestock within the 1882 Reservation and Moenkopi Island of 44,486 AU. The Hopi 2015 amended claim did not contain any documentation, data, or information to support their stated maximum carrying capacity.

Table B-5 provides the carrying capacity of each range unit based on a 1996 range survey. Carrying capacity has been defined by the Hopi (1998) as “the maximum stocking rate possible without inducing damage to vegetation or related resources.” Carrying capacity is expressed in the table as the number of animal units that can be grazed on an area of range over a year, or Animal Units Year Long (AUYL). To account for the forage needs of different livestock, the Hopi assumed the following factors when calculating AUYL on the Reservation:

- 0.8 Horse or Burro = 1 AUYL
- 1 Cow = 1 AUYL
- 4 Sheep or Goats = 1 AUYL.

Carrying capacity can vary from year to year due to overgrazing by livestock and/or from natural factors such as drought, fire, and grazing by native animals. Since 1984, actual carrying capacities on the 1882 Executive Order Reservation have ranged from 5,000 to 12,250 AUYL and potential carrying capacities have ranged from 10,000 to 24,529 AUYL (ADWR, 2008b). Carrying capacity data for the Moenkopi area are currently not available to ADWR (ADWR, 2008p).

The Hopi do not provide any current or historic counts or estimates of animal units for the Reservation in their Third Amended SOC, which appears instead to be based on future uses. **Table 4-6** lists historic accounts of the number and type of livestock grazed on the Reservation (ADWR, 2008p). These accounts were summarized from Andersen (2008). Based on these accounts, the estimated historic maximum number of animal units on the Reservation was approximately 21,500 AU in 1887.

Recent inventories of Hopi livestock are listed in **Table 4-7** (ADWR, 2008p). Between 1984 and 2006, the maximum reported number of animal units on the Reservation was approximately 6,900 AU in 1984. These numbers are all much less than the 44,486 AU claimed by the Hopi apparently for future uses.

The Hopi claim includes a consumptive use for cattle of 12 gpaud that is based on ADWR’s revised Standard Water Use Quantities, January 2006, which is a document that ADWR provides



to assist applicants seeking to appropriate surface water pursuant to state law. This document sets forth quantities of water that ADWR considers reasonable for certain beneficial uses in most cases. For stockwatering use, ADWR considers 12 gpaud to be reasonable consumptive use rate for cattle and horses.

The Hopi Tribe claims a diversion rate of 20 gpaud based on a 60% water use efficiency to account for evaporation, spills and other losses from wells. The Tribe did not provide any additional documentation or information in support of this diversion rate.

Review of Water Storage for Stock (Hopi)

The Hopi claim the right to divert and deplete 6,184 AFA for livestock consumption from surface sources that have been stored in past and present stockponds. The underlying premise associated with water storage claims is that the water is stored temporarily for an associated beneficial use. Water storage itself is not the use of this water. The consumption of water by stock is the actual water use associated with storage in stockponds. ADWR believes that there is an overlap between the claimed amounts for livestock watering and the claimed amounts for water storage for stock.

In its Third Amended SOC and its Supplement, the Hopi claimed a total of 1,012 water storage impoundments. ADWR conducted a review of claimed impoundments using ArcGIS. No field verification was conducted as part of this review process.

ADWR's review consisted of determining the presence of impoundments, either constructed or natural, on the land surface. ADWR staff looked for evidence of water storage on GIS-based aerial imagery and topographic maps at the identified location. Evidence generally consisted of a visible water surface, pronounced vegetation, presence of berms, earthen dams or other water retention structures, and visible scarring, discoloration or depressions resulting from standing water. ADWR did not attempt to verify the surface area or the depth of each impoundment as both the Hopi and United States claimed the right to repair, maintain and fill each impoundment to its stated claimed capacity. Impoundments identified to be wastewater sewage ponds were eliminated from consideration as a livestock related impoundment.

ADWR used the following GIS-based imagery and topographic maps for the review of impoundments:

- 2007 Color NAIP imagery



- ESRI World Imagery
- ESRI USA Topo Maps

ADWR's review determined that seven of the 1,012 total impoundments that were reviewed did not have visible evidence to be classified as a water storage impoundment. The total capacity for these seven impoundments without visible evidence of a water storage impoundment is 9.015 AF. This represents a reduction in water storage capacity of approximately 0.15% (9.015 AF/ 6,184 AF). **Table 4-8** lists the claimed impoundments without visible evidence of water storage.

ADWR's review determined that the volume for a reservoir in the Pasture Canyon area reservoir was double-counted. In the Hopi Tribe Supplement, the Hopi stated that, "FC I0411, an impoundment claimed in the Pasture Canyon area, appears to duplicate amounts previously claimed by the Tribe in its 3rd Amended SOC." The stated capacity for the Pasture Canyon reservoir is 212 AF. A reduction of 212 AF is approximately 3.4% of the total storage capacity (212 AF/ 6,184 AF).

ADWR's review of the Hopi claimed use for water storage for stock (stockponds) identified a lack of evidence to support 9.015 AF of claimed capacity and double counting of 212 AF for impoundment FC-I0411 (Pasture Canyon reservoir) for a total reduction of 221.015 AF. This is 3.6 % of the total claimed capacity of 6,184 AF, which the Hopi claim on an annual basis.

4.4.3.2 Review of United States Third Amended SOC (Livestock and Stockponds)

Review of Livestock Watering (United States)

The United States relied upon the same information and data as the Hopi for its 2015 amended claim for livestock watering use. The United States claim on behalf of the Hopi is only 3 AFA less than the Hopi for livestock use. ADWR's review and findings discussed for the Hopi claim in the previous section are the same for the United States claim.

Review of Water Storage for Stock (United States)

The United States claimed a total of 1,001 water storage impoundments with a storage capacity of 3,388 AF. ADWR completed a review of the unique polygons for the 1,001



impoundments submitted by the United States using GIS-based imagery and topographic maps and the methods described above in **Section 4.4.3.1** for determining the presence of impoundments. ADWR's review determined seven of the 1,001 total impoundments did not have visible evidence of water storage. The total volume of water claimed for these seven impoundments was 9.015 AF, which resulted in a reduction in capacity claimed by the United States of approximately 0.27% (9.015 AF/ 3,388 AF). **Table 4-8** lists the claimed impoundments without visible evidence of water storage.

There is a large difference in the total claimed stockpond impoundment capacity between the Hopi at 6,184 AFA and the United States at 3,388 AFA, despite generally similar stockpond impoundment counts of 1,012 for the Hopi and 1,001 for the United States and nearly complete overlapping of the claimed locations. ADWR evaluated the Hopi and United States claims for the 608 impoundments claimed by both parties and found that the average of the impoundment capacities claimed by the Hopi was approximately 8.0 AF while the average of the impoundment capacities claimed by the United States was approximately 3.5 AF.

The United States provided both areas and capacities for each of the 608 impoundments so ADWR was able to determine an average depth for each impoundment. These average depths ranged from 1.0 to 7.2 feet with an overall average depth of 1.86 feet.

The Hopi Tribe only provided the capacity of each impoundment. ADWR attempted to assess the average depth of the impoundments as claimed by the Hopi by assuming that the surface area provided by the United States was approximately correct. Based on this assumption, ADWR determined the average depths ranged from 0.023 feet to 167.9 feet with an overall average depth of 5.6 feet. Because the Hopi did not provide the surface areas of their claimed impoundments, ADWR cannot conclusively resolve the discrepancy in the total claimed capacities of the two datasets.

4.5 CEREMONIAL AND SUBSISTENCE IRRIGATION USE

4.5.1 Description and Background

The Hopi people have a long agricultural history. Although subsistence agriculture is not as prevalent as it was in the past, traditional agricultural practices still exist at many Hopi households. The Hopi state almost 40% of households farm crops for ceremonial and subsistence



use. Further, 78% of people not currently cultivating crops reported that they would like to have a garden plot or a field for farming. According to the Hopi, drought and lack of land are the principal reasons for not farming.

4.5.2 Claimed Use and Basis

4.5.2.1 Hopi Third Amended SOC (Ceremonial and Subsistence Irrigation)

In their Third Amended SOC, the Hopi Tribe claims 7,385 AFA of groundwater use for future irrigation of small garden plots for ceremonial and subsistence purposes, in addition to past and present agriculture water use discussed in **Section 4.2**. The claimed use is based on stable population and total number of households projected for the Hopi villages with 25% of the households carrying out ceremonial and subsistence farming and each participating household requiring 0.8 acres. Additionally, the Tribe relied on a CIR⁶ of 25.08 inches and efficiency of 75%.

Information provided by the Hopi in support of its claim indicates that the estimates of households carrying out ceremonial and subsistence farming is based on information gathered in a household survey conducted between 2005 and 2006. Experts retained by the Tribe surveyed households on the Hopi Reservation during the summers of 2005 and 2006. The survey included households in 12 villages.

The survey broke down the Hopi population into three categories. Group 1 included those currently engaged in farming dryland or irrigated gardens away from their home. Group 2 included those Hopi households engaged in irrigated gardens near their homes. Group 3 included those Hopi households not engaged in subsistence farming at the time of the survey.

The Tribe's claim related to ceremonial and subsistence farming is for new water use to irrigate garden plots not adjacent to people's homes. The household survey responses indicated that 80% of Group 1 households would want an additional garden plot if it were available. Further, 10% of Group 2 households would want such a garden plot if it were available. Finally, 78% of the Group 3 households indicated that they would like to engage in ceremonial and subsistence farming away from their homes, but a large majority of the Group 3 households wanted only very

⁶ The Hopi claim did not define "CIR". ADWR believes that "CIR" is composite irrigation requirement.



small plots. The Tribe, therefore, estimated that only 10% of the Group 3 households would irrigate a larger ceremonial and subsistence garden plot.

The estimate of 25% of households relied upon by the Tribe for new ceremonial and subsistence irrigation is a combination of the above percentages from households in Groups 1, 2 and 3. The Tribe based its stable population number on the United States' population projections as described previously in **Section 4.1**. The Hopi did not provide any additional documentation or information related to ceremonial or subsistence irrigation use.

4.5.2.2 United States Third Amended SOC (Ceremonial and Subsistence Irrigation)

In its Third Amended SOC, the United States claims 4,977 AFA of groundwater use for future irrigation of small family garden plots near the villages for subsistence and cultural purposes. The United States indicates that its claim is identical to its Second Amended SOC filed in 2009 which did not include any supporting documentation. The United States did not provide any additional documentation or information related to ceremonial or subsistence irrigation use in its Third Amended SOC.

4.5.3 ADWR Review and Findings (Ceremonial and Subsistence Irrigation)

ADWR believes that there potentially may be some overlap between the volumes claimed for future DCMI and the volumes claimed for future ceremonial or subsistence gardening. The claimed gpcd rate for DCMI, as stated by both the Hopi and the United States, includes outdoor residential water use.

4.6 MINING USE

4.6.1 Description and Background

As noted in **Appendix B**, coal deposits beneath upper Black Mesa have been leased and commercially developed on a large scale by Peabody Western Coal Company (PWCC). Known as the Black Mesa Complex, the operation consisted of the Black Mesa and Kayenta Mines (**Figure B-16**). The Black Mesa Mine began operations in 1970 and produced about 4.8 million tons of coal annually until operations ceased in December 2005. The coal from this mine was crushed and piped as slurry to the Mohave Generating Station (MGS) near Laughlin, Nevada. MGS was



closed in December 2005 due to air quality concerns. The Kayenta Mine opened in 1973 and has produced about 7.5 million tons of coal annually. This coal has been transported 100 miles by conveyor belt and electric train to the Navajo Generating Station (NGS) near Page, Arizona.

The Black Mesa region contains the most extensive coal reserves in Arizona. Stated estimates of coal resources within the Black Mesa area range from 3.6 to 20 billion tons. The Tribe is currently only leasing a small portion of these extensive coal resources and as a result, additional coal resources are available for future mining.

4.6.2 Claimed Use and Basis

4.6.2.1 Hopi Third Amended SOC (Mining)

In its 2015 amended claim, the Hopi Tribe claims 1,255 AFA of groundwater use for past and present coal mining needs at the Peabody coal mine at Black Mesa. The amount of water claimed is based on the “latest records available for current use.”

In support of the present mining use claim, the Hopi relied on information reported in a USGS report, “Groundwater, Surface-Water, and Water Chemistry Data, Black Mesa Area, Northeastern Arizona 2011-2012.” The 1,255 AFA figure is an annual average of the Industrial pumping category from 2006–2011 on page 5, Table 1 of the report. The Industrial category represents metered pumping from the confined part of the aquifer by PWCC.

In its 2015 amended claim, the Hopi Tribe also claims 500 AFA of water use for activities related to a possible future coal mine. Details regarding the specific water needs or uses related to a future mine were not known at the time the Hopi 2015 amended claim was filed.

4.6.2.2 United States Third Amended SOC (Mining)

Like the Hopi, in its 2015 amended claim, the United States claims 1,255 AFA for past and present mining operations at the Black Mesa Complex. The United States, as the Hopi, indicated that the amount claimed is based on the “latest records available for current use.” The United States also claims 6,500 AFA to support a future coal mine and mine mouth power plant located at the future mine site.



4.6.3 ADWR Review and Findings (Mining)

4.6.3.1 Review of Hopi Third Amended SOC (Mining)

ADWR reviewed the USGS report “Groundwater, Surface-Water, and Water Chemistry Data, Black Mesa Area, Northeastern Arizona 2011-2012” submitted by the Hopi and verified that the annual average of the Industrial pumping figure of 1,255 AFA was accurate for the 2006–2011 reported usage. The Hopi did not provide details describing the quantification of its claimed future use.

4.6.3.2 Review of United States Third Amended SOC (Mining)

The United States’ claim is the same as the Hopi for past and present mining use, and ADWR’s review and findings discussed for the Hopi claim immediately above are the same for the United States claim. The United States quantified its claimed future use, which also included a power plant, but did not provide any supporting documentation.

4.7 ENERGY RESOURCES DEVELOPMENT USE

4.7.1 Description and Background

The Hopi claim describes two potential future energy development projects and estimated water use for each. The two future projects are: (1) a solar/thermal power plant, and (2) a coal liquefaction/gasification facility and related secondary manufacturing.

4.7.2 Claimed Use and Basis

4.7.2.1 Hopi Third Amended SOC (Energy Resources Development)

The Hopi claim a total of 27,100 AFA for future energy resources development. The Hopi claim 6,500 AFA of water use related to development and operation of a 1,500 megawatt solar power plant. The anticipated water use is associated with wet cooling of a concentrated solar facility. The Hopi estimate that the wet cooling process would require from 800 to 1,000 gallons of water per megawatt hour.



The Hopi also claim 20,600 AFA of water use from groundwater and other water sources related to the development and operation of a no-liquid-discharge coal liquefaction/gasification facility (CLG) and secondary manufacturing. The Hopi state that CLG facility would require 12,600 AFA, which may also be used to produce primary products such as natural gas, liquid fuels, and naphtha. In addition, the Hopi estimate that the development of businesses related to secondary manufacturing from these primary products would require between 6,000 to 8,000 AFA.

4.7.2.2 United States Third Amended SOC (Energy Resource Development)

The United States did not claim a use for future energy resource development.

4.7.3 ADWR Review and Findings (Energy Resource Development)

The Hopi did not provide documentation to support the quantity claimed for energy resource development.

4.8 TOURISM USE

4.8.1 Description and Background

According to the Hopi Comprehensive Economic Development Strategy, revised July 31, 2014, tourism is important to the regional economy. The presence of many natural wonders, including the Grand Canyon, Petrified Forest, and Meteor Crater bring visitors to the region, as well as US Highway I-40. In addition, there are 26 Hopi and 3 non-Hopi companies located in northern Arizona that conduct tours in the region.

The Hopi Cultural Center Hotel and restaurant and the Moenkopi Legacy Inn and Suites are locations for visitor information and education, and a place for the Hopi artisans to gain greater exposure for their work. State Route 264 between Moenkopi and Keams Canyon has been designated as the Hopi Arts Trail with a brochure identifying all businesses along the route.

The Moenkopi Legacy Inn was completed in 2011 and it features a conference center and an outdoor swimming pool. The intent is to make the hotel a gateway to the villages and mesas with guided tours.



4.8.2 Claimed Use and Basis

4.8.2.1 Hopi Third Amended SOC (Tourism)

According to the Hopi Third Amended SOC, “[t]ourism is the most important non-industrial, non-governmental source of income in northern Arizona.” In its Third Amended SOC, the Hopi Tribe claims 1,022 AFA for a future destination resort with the potential for a recreational vehicle (RV) park, golf course and other destination resort amenities, possibly at Keams Canyon, and for the expansion of the Hopi Tribal Cultural Center. The claim does not include the possible hotel, casino, golf course and RV park at the Hopi Industrial Park in Winslow due to the limited scope of the Final HSR.

4.8.2.2 United States Third Amended SOC (Tourism)

The United States Third Amended SOC did not include a claim for water use related to tourism.

4.8.3 ADWR Review and Findings (Tourism)

ADWR believes that potentially there may be some overlap in the volumes claimed for future DCMI and the volumes claimed for tourism. The claimed gpcd rate for DCMI includes commercial water uses that could be associated with tourism related facilities or activities, such as a hotel or RV park.

4.9 RECREATION USE

4.9.1 Description and Background

Keams Canyon is located in the southeastern portion of the Hopi Reservation and is within the Polacca Wash watershed. Keams Lake is located within Keams Canyon in the northwest portion of Section 28, Township 28 North, Range 20 East. Keams Lake is used for recreational purposes such as camping and fishing.



4.9.2 Claimed Use and Basis

4.9.2.1 Hopi Third Amended SOC (Recreation)

In its Third Amended SOC, the Hopi Tribe claims 41 AFA of water use for recreational purposes at Keams Lake. The Hopi claim the right to continuously fill Keams Lake to its maximum capacity of 27.8 AF and also claim evaporative losses of 12.8 AFA.

To determine annual evaporative losses, the Hopi provided a surface area of 3.2 acres for Keams Lake and a net evaporation rate of 4 feet per year. No information was provided regarding how the capacity of Keams Lake was determined.

4.9.2.2 United States Third Amended SOC (Recreation)

The United States Third Amended SOC did not include a claim on behalf of the Hopi Tribe for recreation water use.

4.9.3 ADWR Review and Findings (Recreation)

ADWR reviewed ESRI World Imagery to verify the existence of Keams Lake. Review of the 2013 imagery verified the existence of a feature with a visible water surface at the location listed by the Hopi. Google Earth[®] imagery shows an impoundment of varying size at this location in 1997, 2007, 2010, and 2013. Based on ADWR's review of the ESRI World Imagery and Google Earth[®], the stated surface area of Keams Lake of 3.2 acres appears reasonable.

The Hopi claim the same annual net evaporation rate of 4 feet for Keams Lake as listed in the Hopi claim for evaporation from irrigation storage. ADWR's review and associated analysis of the net annual evaporation rate is presented in **Section 4.3**. In summary, the analysis indicates that net annual rates of surface water evaporation on the Reservation may range from 53.56 inches (4.5 feet) to 73.73 inches (6.1 feet). The evaporation rate of 4 feet used by the Hopi is less than this range.

Although the United States did not include a claim on behalf of the Hopi for recreation water use, ADWR's review of impoundments claimed by the United States indicates the presence of an impoundment in the same location as Keams Lake. The United States' ID number for this



impoundment is I1130. Associated information provided by the United States for this impoundment indicates that the surface area is 2.94 acres and the capacity is 6.065 AF.

The Hopi state in their Third Amended SOC that Keams Lake is not included in the livestock water storage claim. ADWR confirmed that this statement was correct when the Third Amended SOC was filed. However, when the Hopi supplemented their water storage claim by adding 396 additional impoundments that were previously claimed by the United States but not by the Hopi (see **Section 4.4**), impoundment I-1130 was included as one of the additional impoundments added to the Hopi water storage claim. The Hopi supplemental claim included 6.065 AFA for this impoundment, as compared to the fill-volume of 27.8 AF claimed in the Hopi Third Amended SOC.

4.10 SUBSURFACE MINERAL RIGHTS USE

4.10.1 Description and Background

The Little Colorado River flows southeast to northwest in northeastern Arizona to its confluence with the Colorado River in Grand Canyon National Park. The Little Colorado River does not cross Hopi Reservation lands; however, the river does cross Navajo Nation lands in the southwestern and western portions of the Navajo Reservation.

The base flow of the Little Colorado River near its confluence with the Colorado River is sustained by the C aquifer (see **Section 2.1.7**) which discharges into the underlying Redwall-Muav aquifer and ultimately into the Little Colorado River. Blue Spring is the largest of several springs that discharge into the Little Colorado River and is located approximately 13 miles upstream from the confluence with the Colorado River on Navajo Nation land. The series of springs are often referred to as “Blue Springs” (Leake, 2005).

4.10.2 Claimed Use and Basis

4.10.2.1 Hopi Third Amended SOC (Subsurface Mineral Rights)

In its 2015 amended SOC, the Hopi claim 40,295 AFA of water for the Tribe’s proportional share of the Blue Springs complex. The Tribe’s claim is for both instream flows and consumptive use and it asserts the right to transfer this claimed use for consumptive or non-consumptive



purposes. The Hopi cited three USGS reports that provide information in support of their Third Amended SOC related to water use associated with subsurface mineral rights. The reports are Hart (2002), Leake (2005) and Bills (2007).

These USGS reports indicate that groundwater that discharges from Blue Springs is derived from the Redwall-Muav aquifer, which underlies the C aquifer. All of the groundwater in the Redwall-Muav aquifer occurs from downward leakage from overlying formations through faults, fractures, or other geologic structures. Groundwater migrates laterally and vertically through the aquifer to reach the discharge area for these springs. One USGS report lists the flow of Blue Spring at about 95 cubic feet per second (cfs) or 68,777 AFA with a combined flow from all springs in this lower reach of the Little Colorado River of about 237 cfs or 171,580 AFA (Bills, 2007). The other two USGS report estimates the discharge from Blue Spring and other springs in the area to be 164,000 AFA (Leake, 2005, Hart, 2002).

The Hopi state in their 2015 amended claim that, “Water, like oil and gas, is a mineral in the broader sense of the word.” The Hopi cite several legal references in support of this statement. The Hopi claim that water is a mineral under the Navajo Hopi Land Dispute Settlement Act of 1974 (1974 Settlement Act) and they are therefore entitled to a proportional share of that mineral resource. The Hopi define their proportional share as 25% based on the Hopi Tribe’s land area in the LCR basin compared to the land area of the Navajo Nation in the LCR basin.

4.10.2.2 United States Third Amended SOC (Subsurface Mineral Rights)

The United States Third Amended SOC did not include a claim related to subsurface mineral rights water use.

4.10.3 ADWR Review and Findings (Subsurface Mineral Rights)

The Hopi Third Amended SOC is based on its proportional share of the “Blue Springs complex.” The Hopi did not provide information or documentation to define or describe which springs constitute this complex.

ADWR’s review and interpretation of the USGS reports cited by the Hopi indicate that the Blue Springs complex likely refers to all springs in the lower reach of the Little Colorado River that are in the vicinity of Blue Spring. As stated above, the USGS estimates discharge from Blue Springs and other springs in the area (the Blue Springs complex) to range from 164,000 AFA to



171,580 AFA. Using these USGS estimates of flows, the Hopi claimed proportional share of 25% of the total discharge would be 41,000 AFA to 42,895 AFA. The Hopi claim of 40,295 AFA falls below this range.

4.11 AESTHETIC, CULTURAL, AND ECOLOGICAL USE

4.11.1 Description and Background

Water flows in the lower Little Colorado River have long held tremendous cultural and religious significance for the Hopi people. In addition, the Pasture Canyon and White Ruin Canyon Wash areas provide continuing ecological, spiritual and cultural significance to the Tribe. The wetlands in these areas are important sources of fish, wildlife and plant materials for Hopi ceremonial, cultural, and everyday uses, and for the Hopi arts and crafts industry.

Riparian vegetative species identified on the Reservation include cottonwood, willow, Russian olive, and salt cedar. The latter two are invasive species that are not native to the area (ADWR, 2008p). In comments to the Preliminary HSR, the Hopi identified alkali sacaton and camelthorn as other vegetative species that are found in riparian areas on the Reservation (Hopi, 2009). Riparian vegetation relies on water from both precipitation and underlying alluvial aquifers (ADWR, 2008p).

4.11.2 Claimed Use and Basis

4.11.2.1 Hopi Third Amended SOC (Aesthetic, Cultural and Ecological Flows)

In its Third Amended SOC, the Hopi Tribe claims 294 AFA of water use for riparian and wetland habitat in Pasture Canyon, which is located in Moenkopi Island. The Hopi state that Pasture Canyon is a unique ecosystem that has great historic and present significance to the Hopi Tribe. The Hopi also assert a non-diversionary claim to protect the aesthetic, cultural and ecological flows of Pasture Canyon and White Ruin Canyon Wash.

The Hopi state that the average annual depletion within Pasture Canyon is 267 AFA for riparian vegetation and wetlands. However, the Hopi claim a maximum of 294 AFA for riparian and wetland habitat when such water is available. The Hopi did not provide documentation or information in support of their claimed volume for depletion within Pasture Canyon. The Hopi



Tribe did clarify, however, that the wetland and riparian areas of Pasture Canyon are separate and apart from certain nearby agricultural fields that are subject to irrigation, and the Hopi 2015 amended claim referenced maps found in Appendices 9 and 10 to the United States Third Amended SOC.

The Hopi Tribe also claim a non-diversionary right to protect White Ruin Canyon Wash, which is located near the headwaters of Moenkopi Wash. In the Hopi Tribe Supplement, the Hopi claim 16 AFA (rounded) for flows in White Canyon Ruin Wash and cite a report, *White Ruin Canyon Discharge Reconnaissance 14 August 2015: Preliminary Draft Report*, submitted by Stevens Ecological Consulting. This report briefly discusses flow measurements taken on August 14, 2015, summarizes findings, and estimates total annual discharge.

The Hopi Tribe claims a non-diversionary right for instream flows in the lower Little Colorado River. The Hopi state that this area holds tremendous cultural and religious significance for the Hopi people. The quantity of water claimed by the Hopi was not known at the time the 2015 amended claim was filed.

4.11.2.2 United States Third Amended SOC (Aesthetic, Cultural and Ecological Flows)

In its Third Amended SOC, the United States claims 294 AFA of water use for riparian and wetland habitat in Pasture Canyon. The United States provides a map of Pasture Canyon in Appendix 9 to its claim, and another map that also delineates nearby agricultural lands in Appendix 10 to its claim. Like the Hopi, the United States notes that the average annual depletion within Pasture Canyon is 267 AFA, and claims a maximum of 294 AFA for riparian vegetation when such water is available. The United States did not provide documentation or information in support of its claimed volume for depletion within Pasture Canyon.

However, the United States clarifies that springs that are located in Pasture Canyon are part of the water supply calculated for its past and present irrigation claim, and that reservoirs within Pasture Canyon are included in the United States list of impoundments in Appendix 6 to its claim. According to the United States, these springs and reservoirs are not included twice in its claim.



4.11.3 ADWR Review and Findings (Aesthetic, Cultural and Ecological Flows)

4.11.3.1 Review of Hopi Third Amended SOC (Aesthetic, Cultural and Ecological Flows)

As stated above, the Hopi did not provide any documentation, data, or calculations to demonstrate how the annual depletion of 267 AFA or a maximum of 294 AFA for riparian and wetland habitat in Pasture Canyon was determined. ADWR evaluated this claimed water use utilizing riparian area acreage values referenced in the Hopi 2015 amended claim and estimates of water use by riparian vegetation as described below.

In its 2015 amended claim, the Hopi reference a map of Pasture Canyon, identified as Appendix 10 of the United States 2015 amended claim, which delineates the areas that serve as the basis for the Hopi riparian and wetland habitat. The United States provided ArcGIS shapefiles that depict approximately 72.1 acres riparian areas and associated vegetation.

ADWR estimated the water demand of riparian vegetation to range from 2.3 to 4.4 AFA (ADWR, 2008p). This estimate is based on an evapotranspiration study conducted in New Mexico under similar climatic conditions (Cleverly and others, 2006 and Shafike and Cleverly, 2007).

ADWR calculated the estimated riparian vegetation water use by multiplying the number of acres of riparian vegetation by the lower and upper range of the estimated water demand per acre. Based on these calculations, ADWR determined that estimated water use for the Pasture Canyon riparian area would be 165.7 AFA to 317.0 AFA. The maximum Hopi claim of 294 AFA for riparian vegetation falls within the ADWR calculated range.

The report cited by the Hopi to support their claim to a non-diversionary right to protect White Ruin Canyon Wash is labeled “Preliminary Draft.” ADWR is unable to rely on the information provided in the draft report and therefore presents no findings with regard to that claim.

As stated above, the Hopi did not provide any flow volumes claimed for the lower Little Colorado River for aesthetic, cultural, and ecological water use. Nor did they provide any documentation, data, or calculations. As a result, ADWR was unable to conduct a review or present any findings related to the lower Little Colorado River.



4.11.3.2 Review of United States Third Amended SOC (Aesthetic, Cultural and Ecological Flows)

As stated above, the United States also did not provide any documentation, data, or calculations to demonstrate how the annual depletion of 267 AFA or a maximum of 294 AFA for riparian and wetland habitat in Pasture Canyon was determined. Since the United States claim is identical to the Hopi claim for riparian and wetland habitat in Pasture Canyon, ADWR utilized the same review and findings as provided in **Section 4.11.3.1**.

