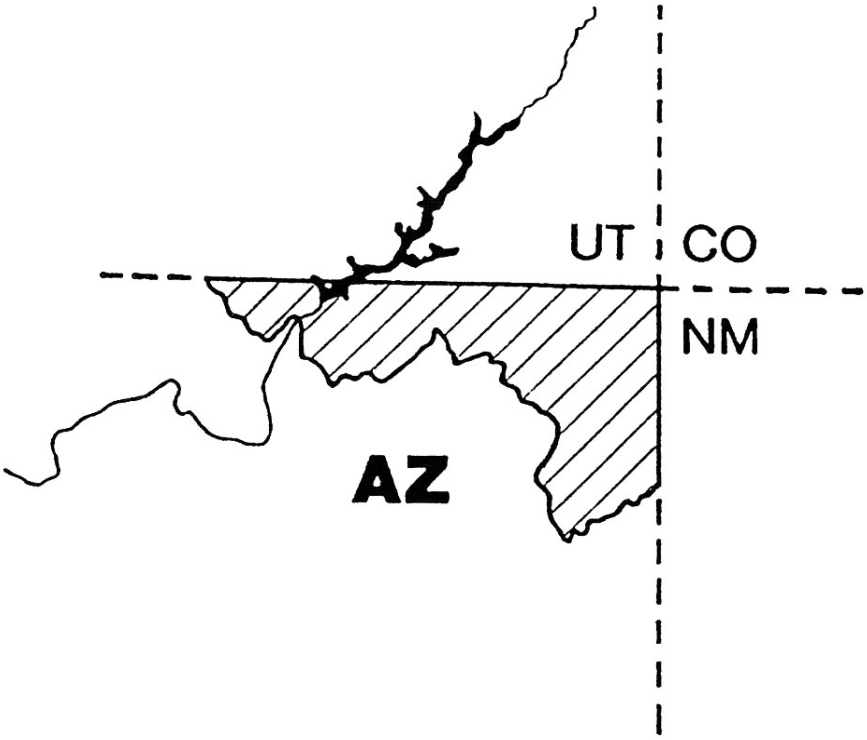
RECLAMATION

Managing Water in the West

Consumptive Uses and Losses: Provisional Estimate

Arizona Portion of the Upper Colorado River Basin Calendar Year 2011

Provisional Version revision dated: September 24, 2014



U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

November 2013
Revised September 2014

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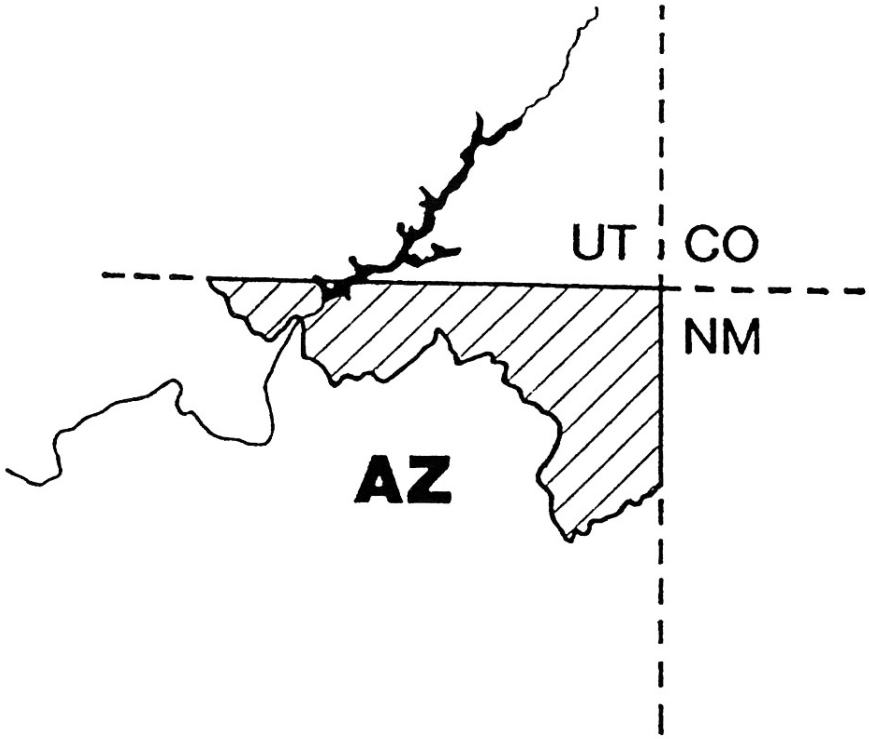

Prepared by: Alan Harrison – November 4, 2013
Revised by: Alan Harrison – September 24, 2014

U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

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CONSUMPTIVE USES AND LOSSES
Provisional Estimates (9/14)

ARIZONA PORTION
OF THE
UPPER COLORADO RIVER BASIN

CALENDAR YEAR
2011

AUTHORITY

This report was prepared in compliance with Public Law 90-537, Section 601 (b)(1), dated September 30, 1968, which directs the Secretary of the Interior to "make reports as to the annual consumptive uses and losses of water from the Colorado River System. . . starting on October 1, 1970. Such reports shall include a detailed breakdown of the beneficial consumptive use of water on a state-by-state basis." Additionally, this report is in compliance with Section 49 of the Navajo Project Participation Agreement dated September 30, 1969, which states in part: "The Secretary of the Interior further agrees to make the reports required by Section 601 (b)(1) of Public Law 90-537 as they pertain to Arizona's Upper Basin uses annually rather than every five years. Within fifteen days following the completion of said reports, the Secretary of the Interior shall furnish copies of such reports to the Co-Tenants, the Navajo Tribe, each of the Upper Basin States, and the Upper Colorado River Commission."

SUMMARY

Based upon data made available for preparation of this document. the total consumptive use and loss value for the Arizona portion of the Upper Colorado River Basin for calendar year 2011 was 34,878 (±1,253) acre-feet. Reclamation prepares this estimate annually, final annual values for consumptive uses and losses for the northern Arizona portion of the Colorado River basin are published in the 5-year summary documents for the Upper Colorado River Basin

STUDY AREA DESCRIPTION

The Arizona portion of the Upper Colorado River Basin covers approximately 6,900 square miles in the north-east corner of Arizona, as shown on the location maps shown on pages 19 and 20 (Drawings 1246-406-1, 1246-406-2). The climate of the 5,900 square mile area to the west of the Chuska and Carrizo Mountains is largely arid to semiarid, with mean annual precipitation ranging from 6 to 12 inches and with summertime temperatures often reaching 100 degrees Fahrenheit (^{o}F). The potential

evaporation rate is high and exceeds mean annual precipitation, with gross lake evaporation values of up to 55 inches per year or more. Elevations in the western portion range from 3200 feet on the Colorado River at Lees Ferry to over 8000 feet on the northern edge of the Black Mesa and across the Zilnez and Skeleton Mesas, back down to 5280 feet in the Chinle Valley, and back up to about 6500 feet on the western edge of the Chuska Mountains. Much of the western part of the study area is starkly beautiful southwestern desert country with mesas and canyons intertwined across a pastoral landscape. By contrast, the eastern 1,000 square miles is largely mountainous, with elevations rising to nearly 10,000 feet and mean annual precipitation reaching 30 inches. The mountainous land responds with grass meadows interspersed with conifer forest of mostly ponderosa pine.

Except for Page, Arizona; a small area around Lees Ferry; and a portion of the Paria Plateau administered by the Bureau of Land Management; the study area lies entirely within the Navajo Nation. Based on straight-line interpolation of 2000 and 2010 census data for the area, it is estimated that approximately 47,054 persons were living within the study area in 2011, and of these an estimated 39,763 resided on the Navajo Nation.

The largest cities are Page and Kayenta, with 2010 populations of 7,247 and 5,189, respectively. Other major communities and their populations include Dennehotso (746), Kaibeto (1,522), Chinle (4,518), LeChee (1,443), Lukachukai (1,701), Many Farms (1,348), Rock Point (642), Teec Nos Pos (730), and Tsaile (1,205). Subsistence in the region is derived principally from livestock grazing, farming, tourist-related industries, employment at the Navajo Generating Station (NGS), which consumes approximately 69 percent of the water used or lost in the study area every year. Agriculture accounted for about 7 percent of the total water use; municipal and industrial (including the Navajo Generating Station) about 82 percent; recreation, fish and wildlife, about 4 percent; and reservoir evaporation, about 7 percent.

AGRICULTURAL CONSUMPTIVE USE

Agricultural consumptive use is divided into three categories: irrigation, stock pond, and livestock. Irrigation use includes all use related to irrigating crops including the incidental losses. Stock pond use is the evaporation that occurs from stock ponds and livestock use is the water consumed by livestock.

IRRIGATION USES

Within the Arizona portion of the Upper Colorado River Basin, historically 23 irrigated areas were scattered across the Navajo Nation plus a small amount of land near Lees Ferry irrigated by the National Park Service. Currently, only 16 irrigated areas are in production. An accurate assessment of consumptive use on the irrigated land is difficult due to poor quality of information, such as the exact number of acres under irrigation, the cropping pattern for each irrigated area, site climatological conditions, and the amount s of water actually diverted. In many cases, during the latter part of the irrigation season, farmers have to rely on dry land farming since there is little water available in the streams. This means that the crops do not receive their full water requirement.

For this report, the U.S. Department of Agriculture, Soil Conservation Service's (SCS) Modified Blaney-Criddle ET estimation model was used for computing irrigated crop consumptive use. This model, along with appropriate crop-growth stage coefficients and the method for computing effective precipitation, is described in SCS's *Irrigation Water Requirements Technical Release No. 21* (TR 21). Information required for applying this model includes mean monthly temperature and precipitation values, growing season data for each crop type, and the total number of acres planted by crop at each site. With the exception of Teec Nos Pos, Canyon de Chelly, Lukachukai, and Lees Ferry, no climatological data exist for the irrigation sites, and site values must be generated from data collected at surrounding established weather stations. Growing season dates depend largely on the judgment of the local inhabitants and are, therefore, not known. Although several reports are available with published values for irrigated acres, it is unclear if these values are meant to represent potential irrigated acres, acres irrigated in the past, acres for which farming permits have been issued, or actual acres currently under irrigation.

The crop acreage used to estimate consumptive use by irrigated crops for the year 2011 is shown in table 1. These values were estimated from previous direct field examination by a party composed of representatives from the State of Arizona and the Navajo Nation.

Table 1.—Total irrigated acreage, 2011

PROJECT	CORN (ACRES)	ALFALFA (ACRES)	GRASS PASTURE (ACRES)	SPRING GRAINS (ACRES)	SMALL VEGETABLES (ACRES)	ORCHARD (ACRES)	TOTAL (ACRES)
CHINLE AGENCY							
Canyon de Chelly	0.36	0.00	0.00	3.03	2.26	0.00	5.65
Lukachukai	39.09	7.69	0.00	7.50	5.98	2.07	62.33
Many Farms	138.96	23.18	85.81	2.26	23.18	0.00	273.40
Nazlini	0.00	0.00	0.00	0.00	1.79	0.74	2.53
Rough Rock	30.00	0.00	11.87	0.00	12.43	0.00	54.30
Tsaile	23.72	5.27	15.67	5.73	5.42	0.00	55.81
Wheatfields	0.00	60.80	0.00	0.00	0.00	0.00	60.80
TOTAL	232.13	96.94	113.35	18.52	51.06	2.81	514.82
SHIPROCK AGENCY							
Red Rock Valley	26.22	0.00	10.19	5.12	10.22	0.00	51.75
Teec Nos Pos	20.00	0.00	0.00	0.00	3.67	0.00	23.67
Toh Chin Lini	0.00	0.00	0.00	0.00	3.90	13.67	17.57
Totacon	0.00	0.00	0.00	0.00	1.00	0.00	1.00
TOTAL	46.22	0.00	10.19	5.12	18.79	13.67	93.99
WESTERN NAVAJO AGENCY							
Dennehotso	1.82	0.00	38.70	0.00	0.00	0.00	40.52
Lees Ferry	0.00	0.00	1.00	0.00	0.00	2.00	3.00
Marsh Pass	7.02	3.31	0.00	0.00	1.99	0.00	12.32
Navajo Canyon	0.00	0.00	0.00	0.00	0.00	3.50	3.50
Paiute Canyon	2.64	0.00	0.00	0.00	3.86	0.00	6.50
TOTAL	11.48	3.31	39.70	0.00	5.85	5.50	65.84
GRAND TOTAL	289.83	100.25	163.24	23.64	75.70	21.98	674.65

Several factors complicated the modeling of irrigation consumptive use. For example, the computer program used to model consumptive use assumes a full water supply; if shortages exist, as they often do in this semiarid study area, adjustments must be made. These adjustments are complicated because some of the projects have no storage water and may only have a reliable irrigation water supply during spring runoff. After spring runoff, farming becomes essentially dry land until rains in July and August provide intermittent flows for irrigation. Finally, no ditch diversion records are available to help estimate irrigation water supplies and shortages.

A full irrigation supply seldom exists at many of the projects. Generally, a full supply is available for Lees Ferry, Navajo Canyon, Tsaile, and Wheatfields projects because of adequate stream flows or because of available storage water. In years with average precipitation, it is estimated that Chinle Wash provides approximately 75 percent of the irrigation requirement. Precipitation in the area averages approximately 9.5 inches per year. Based on this information, it would require approximately 12.67 inches of precipitation to provide 100 percent of the irrigation requirement. The percent of crop water requirement met was computed as a ratio of annual precipitation to 12.67 inches. These values are found in table 2.

The percentage of crop water requirement met was multiplied by the total net crop water requirement to come up with the amount of crop consumptive use. Incidental irrigation losses, evaporation, and phreatophyte consumptive use along supply canals are estimated to be 5 percent of the consumptive use of the irrigated area and are added to the crop consumptive use value to develop a total consumptive use value.

A portion of the water used for irrigation at these sites may not be contributing to the Colorado River System since evaporation rates in the area are high and the nature of most of the drainage enhances evapotranspiration. A good example of such a drainage is Chinle Wash, which after it leaves Canyon de Chelly, becomes wide and sandy and is lined with willows, cottonwoods, and other phreatophytes.

The uncertainties in the irrigation consumptive use values displayed in table 2 are very large and are estimated as 40 percent of the total consumptive use. This estimate of possible error only reflects the uncertainty of consumptive use and does not account for any possible errors in the acreage estimates. The effective consumptive use for irrigation for 2011 was estimated to equal 966 acre-feet. Including the 5 percent for incidental losses, the irrigation related consumptive use is 1,014 (±406) acre-feet.

Table 2.—Net consumptive use values, 2011

PROJECT	CROP WATER REQUIREMENT (INCHES)	TOTAL IRRIGATED (ACRES)	TOTAL WATER REQUIRED (ACRE-FEET)	CROP WATER REQUIREMENT MET (%)	CROP WATER REQUIREMENT MET (ACRE-FEET)	TOTAL CONSUMPTIVE USE (ACRE-FEET)[1]
CHINLE AGENCY						
Canyon de Chelly	26.09	5.65	12	73%	9	9.4
Lukachukai	20.47	62.33	106	73%	77	81.1
Many Farms	26.26	273.40	598	73%	435	456.2
Nazlini	18.36	2.53	4	73%	3	3.0
Rough Rock	20.50	54.3	93	81%	75	78.5
Tsaile	21.12	55.81	98	73%	71	74.9
Wheatfields	27.68	60.80	140	73%	102	107.0
TOTAL	160.48	514.82	1,052		771	810.0
SHIPROCK AGENCY						
Red Rock Valley	24.06	51.75	104	65%	67	70.9
Teec Nos Pos	27.99	23.67	55	57%	32	33.3
Toh Chin Lini	37.18	17.57	54	29%	16	16.4
Totacon	24.93	1.00	2	29%	1	0.6
TOTAL	114.16	93.99	215		115	121.2
WESTERN NAVAJO AGENCY						
Dennehotso	36.88	40.52	125	36%	45	47.5
Lees Ferry	40.88	3.00	10	100%	10	10.7
Marsh Pass	18.72	12.32	19	66%	13	13.4
Navajo Canyon	35.48	3.50	10	53%	5	5.7
Paiute Canyon	23.01	6.50	12	44%	6	5.8
TOTAL	154.97	65.84	177		79	83.2
GRAND TOTAL	429.61	674.65	1,444		966	1,014.5

[1] Total includes 5% addition for incidental losses.

STOCK POND EVAPORATION

Stock pond consumptive use is assumed to be the evaporation from the stock pond. It is also assumed that any consumptive use by natural vegetation prior to the construction of the stock ponds is limited to precipitation which is subtracted from the evaporation losses.

A compilation of the stock ponds in the study area, including their locations and the water surface areas when ponds are full, was obtained from a previous BIA report entitled "1985 Survey of Irrigated Land in the Arizona Portion of the Upper Colorado River" and are shown in table 3. For an average year conditions, the stock pond evaporative surface area was estimated as one-third the water surface area that occurs when the ponds are full. The surface area used was computed by multiplying the percentage of water supply available (the ratio of the current year precipitation to the average annual precipitation) by the average water surface area. These values are found in table 3.

Table 3.—Stock pond evaporation, 2011

COUNTY	SURFACE AREA FULL (ACRES)	SURFACE AREA USED (ACRES)	WATER SUPPLY AVAILABLE (%)	LAKE EVAPORATION (INCHES)	PRECIPITATION (INCHES)	NET EVAPORATION (INCHES)	NET EVAPORATION (ACRE-FEET)
Coconino	80	25	92	57	6.21	50.79	104
Navajo	40	11	82	55	7.97	47.04	42.7
Apache	646	202	94	53	8.24	44.76	751.7
TOTAL	766	237					898

This method of evaporation estimation was used because continuous useful water level records for all stock ponds from which surface area could be accurately computed were not available. Another factor complicating the estimating procedure is that evaporation rates are not known at the individual stock ponds. For this report, the NOAA Technical Report NWS 33 "Evaporation Atlas for the Contiguous 48 United States," June 1982, was used to determine the amount of lake evaporation. It was assumed that any consumptive use by natural vegetation prior to construction of the stock ponds is limited to precipitation which is subtracted from reservoir evaporation losses.

The computed values for stock pond evaporation for calendar year 2011 are shown in table 3. The total evaporative losses in 2011 are 898 (±270) acre-feet with the stock pond evaporation uncertainty being estimated as 30 percent.

LIVESTOCK WATER

The source of most livestock water in the study area is from wells, with windmill-operated pumps developed and maintained by Navajo Water Operations and Maintenance, and water collected in small surface ponds. The estimated number of

livestock in the area was estimated based on previous livestock tallies. It was estimated that horses and cattle consume 12 gallons per day; sheep and goats consume 2 gallons per day.

The number of animals for the Upper Colorado portion of each district is shown in table 4. The computed value for livestock consumptive use is 638 acre-feet. The uncertainty in this number is estimated as 30 percent of the total or ±192 acre-feet.

Table 4.—Number of livestock, 2011

AGENCY	CATTLE	HORSES	SHEEP	GOATS
Western Navajo District No. 1	784	45	1,676	760
Western Navajo District No. 2	946	247	1,264	1,037
Western Navajo District No. 8	7,147	5,319	8,943	7,231
Shiprock District No. 9	2,542	1,473	3,269	3,469
Chinle District No. 10	3,051	2,412	4,083	2,919
Chinle District No. 11	1,543	1,232	1,631	1,310
Shiprock District No. 12	5,795	4,793	6,579	5,472
Fort Defiance District No. 17	346	63	1,766	450
Fort Defiance District No. 18	721	164	1,152	237
TOTAL	22,877	15,749	30,364	22,884

TOTAL AGRICULTURAL CONSUMPTIVE USE

The total agricultural consumptive use, displayed in table 5, is the sum of the individual components discussed in the previous sections. Agricultural water consumption represents approximately 8 percent of the total use in the study area. Total degree of uncertainty was computed by taking the square root of the sum of the individual uncertainties squared; known as the quadratic sum. This method and nomenclature is used throughout this report. This method was used because a simple sum does not account for the partial cancellation of errors occurring when calculating the total uncertainty derived from individual values that are random and independent of each other. As previously discussed, the individual uncertainties were set as a percent of the consumptive use value.

Table 5.—Total agricultural consumptive use, 2011

CATEGORY	CONSUMPTIVE USE (ACRE-FEET)	ESTIMATED UNCERTAINTY (ACRE-FEET)
Irrigation	1,014	406
Stock Ponds	898	270
Livestock	638	192
TOTAL	2,551	523

MUNICIPAL AND INDUSTRIAL CONSUMPTIVE USE

Municipal and industrial consumptive use is divided into three categories: mineral resources, thermal electric power, and other. Mineral resources consumptive use includes water used for mineral production. No mineral resources consumptive use is reported in the study area. Thermal electric power consumptive use includes the water used at the power plants, and that used to transport material to the power plant (such as a coal slurry pipeline). Other consumptive use includes urban, rural, and industrial uses.

THERMAL ELECTRIC POWER

Thermal electric power consumptive use includes the water used in the power plant and the water used to transport material to the plant.

Navajo Generating Station

The water used by the NGS is pumped directly from Lake Powell and comprises over half of the total consumption in the study area. Since all NGS water use is metered, this quantity is among those most precisely known, with the maximum uncertainty in the metered quantities believed to be less than 3 percent. The actual quantity consumed, along with the estimated uncertainty for the calendar year 2011, was 24,221 (±727) acre-feet.

OTHER

The other consumptive use category includes the remaining use by urban, rural, and industries.

Page, AZ and Vicinity

City of Page, AZ. – The city of Page pumps its domestic water directly from Lake Powell. The water pumped is metered, and the uncertainty of the pumped quantities was assumed to be less than 3 percent. A portion of the water pumped and treated by the City

of Page, is supplied to the community of Le Chee on the Navajo Nation and is accounted for separately. The quantity supplied to the City of Page and its associated uncertainty for the calendar year 2011 was 2,219 (±67) acre-feet. Water returning to the waste water treatment plant is metered as well. The waste water for the City of Page is treated and is either evaporated from lined ponds or applied to the golf course, with a portion being returned to the Colorado River. The return flow is estimated to be 1,446 acre-feet. The net consumptive use is estimated to be 773 acre-feet (±79).

Le Chee – The community of Le Chee is supplied and metered by the City of Page. Total water supplied for 2011 was 94 (±3) acre-feet. The uncertainty was estimated to be 3 percent.

Greenhaven Water Company – The Greenhaven Water Company derives its domestic water supply from wells. Well pumping records are available. According to these records, the total water pumped for 2011 was 121 (±8) acre-feet. The uncertainty was estimated to be 7 percent.

Arizona Department of Transportation Housing – The Arizona Department of Transportation operates a housing, maintenance, and administrative facility located on US Hwy 89, north of Page, AZ. This facility is supplied from wells that have no meters installed. It is estimated that the total water pumped for 2011 was 7 acre-feet with an uncertainty of 30 percent of this value or ±2 acre-feet.

Navajo Nation

Community Water Systems – 1980 statistics from the Division of Community Development of the Navajo Nation reveal that various community water systems served 26,086, or about 83 percent of the 31,429 people residing within the study area at that time. Since additional estimates have not been repeated, this same percentage was used for 2011 resulting in 33,003 out of 39,763 people being served. These systems include those operated by the Navajo Tribal Utility Authority (NTUA), the BIA, and the Water Operations and Maintenance Department of the Navajo Nation, and some privately developed community water systems.

Table 6 shows the source of water and estimated population served by each source of water for people living on the Navajo Nation during 2011. All of the communities obtain their water supply from ground water.

Table 6.—Domestic water sources, 2011

SOURCE	PERCENTAGE OF POPULATION SERVED	NUMBER OF POPULATION SERVED[1]
Community Water Systems	83	33,003
NTUA	[2](60)	19,802
BIA	[2](25)	8,251
Navajo WOM	[2](13)	4,290
Private	[2](2)	660
Individual Wells	17	6,760
TOTAL	100	39,763

[1] Total population within the Upper Colorado River Basin portion of the Navajo Nation, estimated from 2010 US Census.
[2] These numbers are a percentage of the Community Water Systems.

NTUA Water Systems – The cities and surrounding communities of Oak Springs, Red Valley, Sweetwater, Chinle , Rough Rock, Round Rock, Rock Point, Wheatfields, Lukachukai, Kayenta, Chilchinbeto, Dennehotso, and Kaibeto derive most of their domestic water supply from wells operated by NTUA. Well pumping records are available. According to these records, the total water pumped for 2011 was 1,619 acre-feet with an uncertainty estimated to be 7 percent of this value or ±113 acre-feet.

The NTUA manages the raw waste water; portions of which flow to individual septic tanks, some to evaporation ponds, and some, such as for the cities of Chinle and Kayenta, flow to waste water treatment plants. Very little water, if any, is returned to the ground water system through leakage from the evaporation ponds, but there are losses from the main collection system. Effluent from the Chinle and Kayenta waste water treatment plants is metered. Under normal conditions, the effluent returns to the Colorado River System and is subtracted from the pumping totals to determine a net consumptive use. For 2011, Chinle's treatment plant effluent was 13.6 (±1.0) acre-feet, and Kayenta's effluent was 9.7 (±0.7) acre-feet. An estimated uncertainty of 7 percent was used for the effluent of these two plants. The total effluent of 23 acre-feet is subtracted from the NTUA pumping total of 1,619 acre-feet to arrive at a net consumptive use of 1,596 (±113) acre-feet.

BIA Water Systems – Wells developed and operated by the BIA serve numerous Navajo communities. These systems also serve BIA schools, hospitals, agency offices, and some housing on the Navajo Nation. Metered records for total amounts of water pumped from BIA wells were available for a portion of the Shiprock Agency, the Western Navajo Agency, and the Chinle Agency. Drawing 1246-406-2 shows the agency boundaries within the Upper Colorado River Basin. The uncertainty was estimated to be about 7 percent for all three agencies.

The BIA systems include sewage disposal units terminating in lined evaporation ponds with very little or no return water returning to the ground water system. Undoubtedly, some losses occur in distribution, but insufficient data currently exist to estimate these losses. The losses are probably less than the uncertainties for each of the reported values.

The BIA well data available for the Shiprock Agency include: Cove, Red Rock, and Teec Nos Pos. Total consumptive use values are 11 (±1) acre-feet.

Pumping records for the Western Navajo Agency include data for the following schools: Chilchinbeto Day School, Dennehotso Boarding School, Kaibeto Boarding School, and Kayenta Boarding School. Total consumptive use for the Western Navajo Agency was 172 (±12) acre-feet.

Well pumping records for the Chinle Agency include data for the following schools: Cottonwood Day School, Lukachukai School, and Rock Point School. Rough Rock School maintains its own records, but the data was included with the Chinle Agency data. Total consumptive use for the Chinle Agency was 69 (±5) acre-feet.

Navajo WOM Water Systems – Water use in 2011 by the Navajo WOM service areas was based on an assumed consumption rate of 110 gallons per capita per day (gpcd). For a 2011 estimated service area population of 4,290, the estimated annual water use was 529 (±159) acre-feet. The uncertainty is estimated as 30 percent of the total.

Private Water Systems – The estimated 2011 population served by private water systems on the Navajo Nation was 660. Assuming a consumptive use rate of 110 gcpd, the annual water use for 2011 was 81 (±24) acre-feet. The uncertainty is estimated as 30 percent of the total.

Individual Wells – According to census data from the Division of Community Development of the Navajo Nation, approximately 17 percent of the study area's population on the reservation (about 6,760 persons in 2011) receives a domestic water supply from individual wells. A consumptive use of 110 gpcd was derived as being a reasonable water use rate. Based on these figures, the annual consumptive use was 833 (±250) acre-feet for 2011.

TOTAL MUNICIPAL AND INDUSTRIAL CONSUMPTIVE USE

The total municipal and industrial consumptive use, displayed in table 7, is the sum of the individual components discussed in the previous sections. Municipal and industrial water consumption represents approximately 82 percent of the total use in the study area.

Table 7.—Total municipal and industrial consumptive use, 2011

USER	CONSUMPTIVE USE (ACRE-FEET)	ESTIMATED UNCERTAINTY (ACRE-FEET)
THERMAL ELECTRIC POWER		
Navajo Generating Station	24,221	727
OTHER		
Page, AZ and Vicinity		
City of Page	773	79
Le Chee	94	3
Greenhaven Water Company	121	8
Arizona Department of Transportation	7	2
Navajo Indian Reservation		
Community Water Systems		
NTUA Water Systems	1,596	113
BIA Water Systems	252	13
Navajo WOM	529	159
Private Water Systems	81	24
Individual Wells	833	250
TOTAL	28,506	797

It is questionable whether all the water pumped from wells should be considered a depletion to the Colorado River System; however, it is assumed that 100 percent of the water pumped is considered lost to the system. It is proposed that a future joint study be completed by Reclamation, the State of Arizona, and the Navajo Nation to estimate what percentage of water pumped could actually be attributed to the Colorado River System and would have affected the river flows for a particular year.

RECREATION, FISH AND WILDLIFE

The recreation, fish and wildlife consumptive uses include evaporation from reservoirs used exclusively for fish & wildlife purposes as well as acreages irrigated for wildlife feeding. Consumptive use related to recreation at National parks is also addressed.

GLEN CANYON NATIONAL RECREATION AREA

Colorado River water is used by the Glen Canyon National Recreation Area (GCNRA) at Wahweap and Lees Ferry. The recreational area at Wahweap gets its water supply from a series of wells on the shore of Lake Powell. Pumping records for both Wahweap Marina, and Lees Ferry show 257 (±8) acre-feet of water withdrawn during 2011. The uncertainty is estimated at 3 percent. This water was used for domestic purposes at the

campgrounds, picnic areas, and trailer parks. It was also used to irrigate approximately 60 acres of Bermuda grass and cottonwood trees. The domestic waste water is treated and the effluent is allowed to evaporate from two lined evaporation ponds with a total surface area of 16.7 acres.

Based on estimates of evaporation and consumptive use by the plants, there is some water which is unaccounted for and is assumed to be leakage from the delivery system, the evaporation pond, or deep percolation from irrigation application. However, since these water losses are difficult to quantify and verify, the losses were charged as consumptive uses. Therefore, net consumptive use of water is estimated to be equal to the quantity of water pumped.

RESERVOIR EVAPORATION

A listing of the reservoirs in the study area, including their locations and normal water surface areas, was obtained from a previous BIA report entitled "1985 Survey of Irrigated Land in the Arizona Portion of the Upper Colorado River" and are shown in table 8.

Table 8. —Recreation, fish and wildlife reservoir evaporation, 2011

RESERVOIR	SURFACE ACRES FULL (ACRES)	SURFACE AREA USED (ACRES)	LAKE EVAPORATION (INCHES)	NET PRECIPITATION (INCHES)	NET EVAPORATION (INCHES)	NET EVAPORATION (ACRE-FEET)
Tsaile	260	260	35	9.20	25.8	559.0
Wheatfields	272	272	32	9.20	22.8	516.8
TOTAL	532	532				1,076

Efforts are made to maintain a nearly full condition and to minimize water surface fluctuations in reservoirs managed for a fishery. Under average operating conditions, the water surface area of a reservoir used primarily for fishing is assumed to be equal to a normal water surface area. It is assumed that, in 2011, these reservoirs filled in the spring and were maintained at the normal pool level.

This method of evaporation estimation was used because continuous useful water level records for all reservoirs from which surface area could be accurately computed were not available. Another factor complicating the estimating procedure is that evaporation rates are not known at the individual reservoirs.

For this report, the NOAA Technical Report NWS 33 "Evaporation Atlas for the Contiguous 48 United States," June 1982, was used to determine the amount of lake evaporation at each reservoir location. It was assumed that any consumptive use by natural vegetation prior to construction of the reservoirs is limited to precipitation which is subtracted from reservoir evaporation losses.

The computed values for reservoir evaporation for calendar year 2011 are shown in table 8. The total evaporative losses in 2011 are 1,076 (±323) acre-feet with the reservoir evaporation uncertainty being estimated as 30 percent.

TOTAL RECREATION, FISH AND WILDLIFE

The total recreation, fish and wildlife consumptive use, displayed in table 9, is the sum of the individual components discussed in the previous sections. Recreation, fish and wildlife water consumption represents approximately 4 percent of the total use in the study area.

Table 9.—Total recreation, fish and wildlife consumptive use, 2011

USER	CONSUMPTIVE USE (ACRE-FEET)	ESTIMATED UNCERTAINTY (ACRE-FEET)
Glen Canyon National Recreation Area	257	8
Reservoir Evaporation	1,076	323
TOTAL	1,332	323

RESERVOIR EVAPORATION

Reservoir evaporation losses make up about 7 percent of the total water uses and losses in the study area. A listing of the reservoirs in the study area, including their locations and normal water surface areas, was obtained from a previous BIA report entitled “1985 Survey of Irrigated Land in the Arizona Portion of the Upper Colorado River” and are shown in table 10. These reservoirs are used primarily for irrigation.

Table 10.—Reservoir evaporation, 2011

RESERVOIR	SURFACE ACRES FULL (ACRES)	SURFACE ACRES USED (ACRES)	WATER SUPPLY AVAILABLE (%)	LAKE EVAPORATION (INCHES)	NET PRECIPITATION (INCHES)	NET EVAPORATION (INCHES)	NET EVAPORATION (ACRE-FEET)
Many Farms	1,800	554	100	56	9.20	46.80	2163
Marsh Pass	40	17	100	40	9.60	30.40	43
Round Rock	83	39	100	57	8.24	48.76	158
Walker Creek	30	14	100	59	7.28	51.72	58
Others	38	17	100	55	9.24	45.76	66
TOTAL	1,991	641					2,488

Reservoirs used primarily for irrigation experience large fluctuations in water levels and, correspondingly, large variations in surface area. Reservoir level records and elevation – area curves were available at Many Farms, but not for the remaining reservoirs in table 10. For the reservoirs with no records from which surface area could be accurately computed, the average evaporative surface area was estimated as one-half the water

surface area of a full reservoir. The surface area used was computed by multiplying the percentage of water supply available (the ratio of the current year precipitation to the average annual precipitation) by the average evaporative surface area.

Another factor complicating the estimating procedure is that evaporation rates are not known at the individual reservoirs. For this report, the NOAA Technical Report NWS 33 "Evaporation Atlas for the Contiguous 48 United States," June 1982, was used to determine the amount of lake evaporation at each reservoir location. It was assumed that any consumptive use by natural vegetation prior to construction of the reservoirs is limited to precipitation which is subtracted from reservoir evaporation losses. The computed values for reservoir evaporation for 2011 are shown in table 10. The total evaporative losses in 2011 are 2,488 (±746) acre-feet with the reservoir evaporation uncertainty being estimated as 30 percent of the total evaporation.

CONCLUSIONS

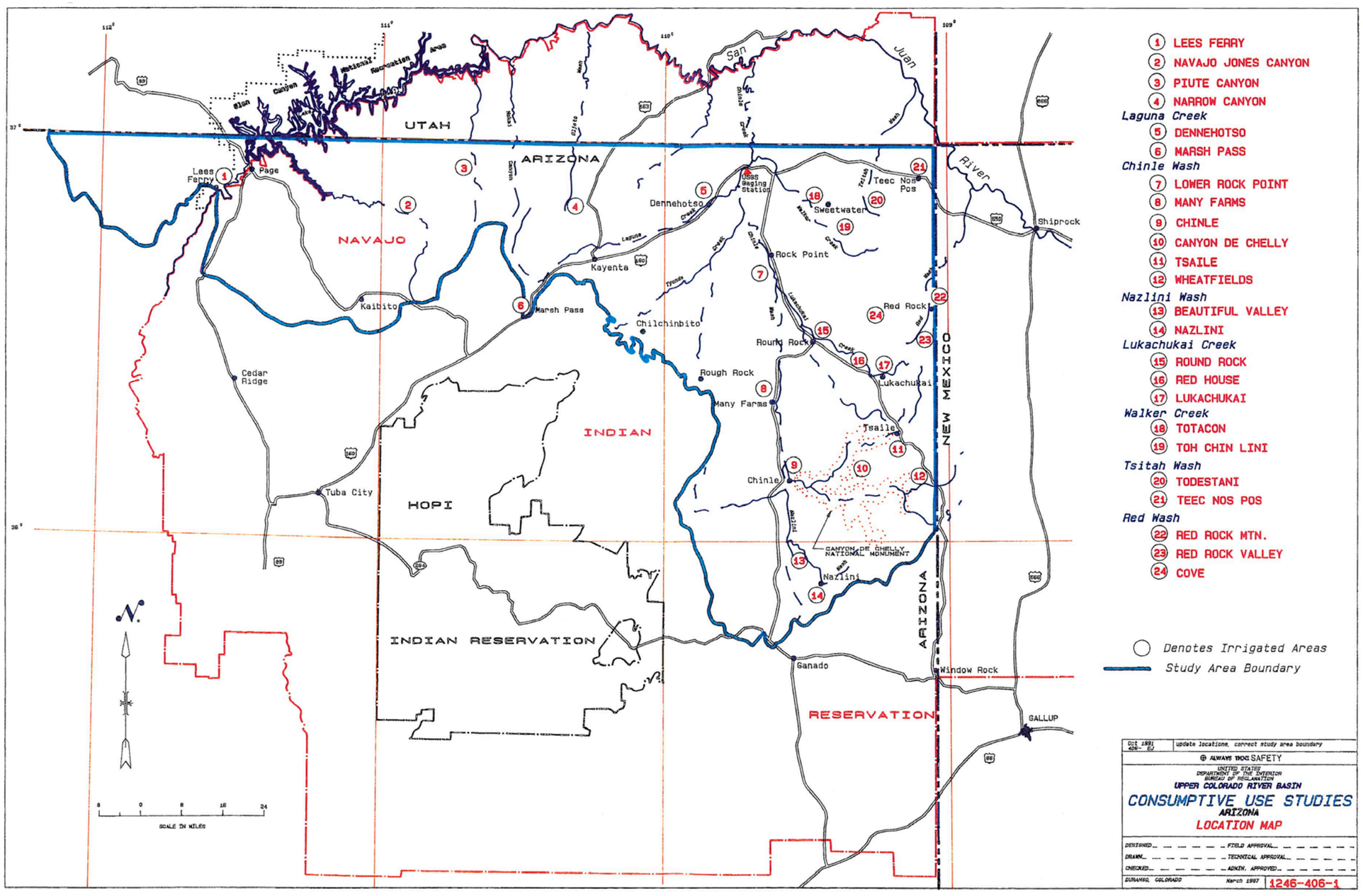
This report assesses the total consumptive use of the Arizona portion of the Upper Colorado River surface water systems, depletion of ground water, and evaporative losses. Clearly, the amounts of water used by the Navajo Generating Station, City of Page, and Wahweap and Lees Ferry recreation areas are direct depletions of water from the Upper Colorado River System, but the situation is not as clear for other consumptive uses and losses occurring in other sections of the study area. For example, the source of water used by the Navajo Nation for domestic and municipal purposes is from wells, some exceeding 1,000 feet in depth. For our purposes here, it is considered to be consumed and a depletion to the Colorado River System. But this may not actually result in a reduction of Colorado River stream flows in the same year that the withdrawal occurs, or at all. Little knowledge and information exists of ground water movement and subsurface flow rates in the study area that are accurate descriptions of the effects on river flows.

Although the water diverted for agricultural purposes is considered as consumptive use in this report, a portion of the remaining surface water on the Navajo Nation, excess to needs, does evaporate before reaching the Colorado River. No attempt has been made for this report to quantify these losses.

Uncertainties in estimating uses and losses exist, and the degree of variation in the figures is presented. Fortunately, the areas with the highest degree of uncertainty account for only a small percentage of the total consumptive use. The largest component, use by the Navajo Generating Station, is also the most accurately monitored. The total annual value for estimated consumptive use of water within the Arizona portion of the Upper Colorado River Basin for 2011 was 34,878 acre-feet, as shown in table 11.

Table 11.—Consumptive use for Arizona portion of Upper Colorado River Basin for 2011

USE CATEGORY	TOTAL CONSUMPTIVE USE (ACRE-FEET)	UNCERTAINTY	PERCENT OF TOTAL
Agriculture	2,551	523	7.3
Municipal & Industrial	28,506	797	81.7
Recreation, Fish & Wildlife	1,332	323	3.8
Reservoir Evaporation	2,488	746	7.1
TOTAL	34,878	1,253	100


UTAH
ARIZONA
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RESERVATION
NEW MEXICO
ARIZONA
Lees Ferry
Page
Kaibito
Cedar Ridge
Tuba City
Marsh Pass
Kayenta
Dennehotso
Chilchinbito
Rough Rock
Many Farms
Chinle
Rock Point
Sweetwater
Round Rock
Lukachukai
Tsaile
Red Rock
Teec Nos Pos
Shiprock
Ganado
Window Rock
GALLUP
CANYON DE CHELLY NATIONAL MONUMENT
Nazlini
San Juan River
Laguna Creek
Chinle Wash
Nazlini Wash
Lukachukai Creek
Walker Creek
Tsitah Wash
Red Wash
1 LEES FERRY
2 NAVAJO JONES CANYON
3 PIUTE CANYON
4 NARROW CANYON
Laguna Creek
5 DENNEHOTSO
6 MARSH PASS
Chinle Wash
7 LOWER ROCK POINT
8 MANY FARMS
9 CHINLE
10 CANYON DE CHELLY
11 TSAILE
12 WHEATFIELDS
Nazlini Wash
13 BEAUTIFUL VALLEY
14 NAZLINI
Lukachukai Creek
15 ROUND ROCK
16 RED HOUSE
17 LUKACHUKAI
Walker Creek
18 TOTACON
19 TOH CHIN LINI
Tsitah Wash
20 TODESTANI
21 TEEC NOS POS
Red Wash
22 RED ROCK MTN.
23 RED ROCK VALLEY
24 COVE
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UPPER COLORADO RIVER BASIN
CONSUMPTIVE USE STUDIES
ARIZONA
LOCATION MAP
DENVER, COLORADO
March 1987
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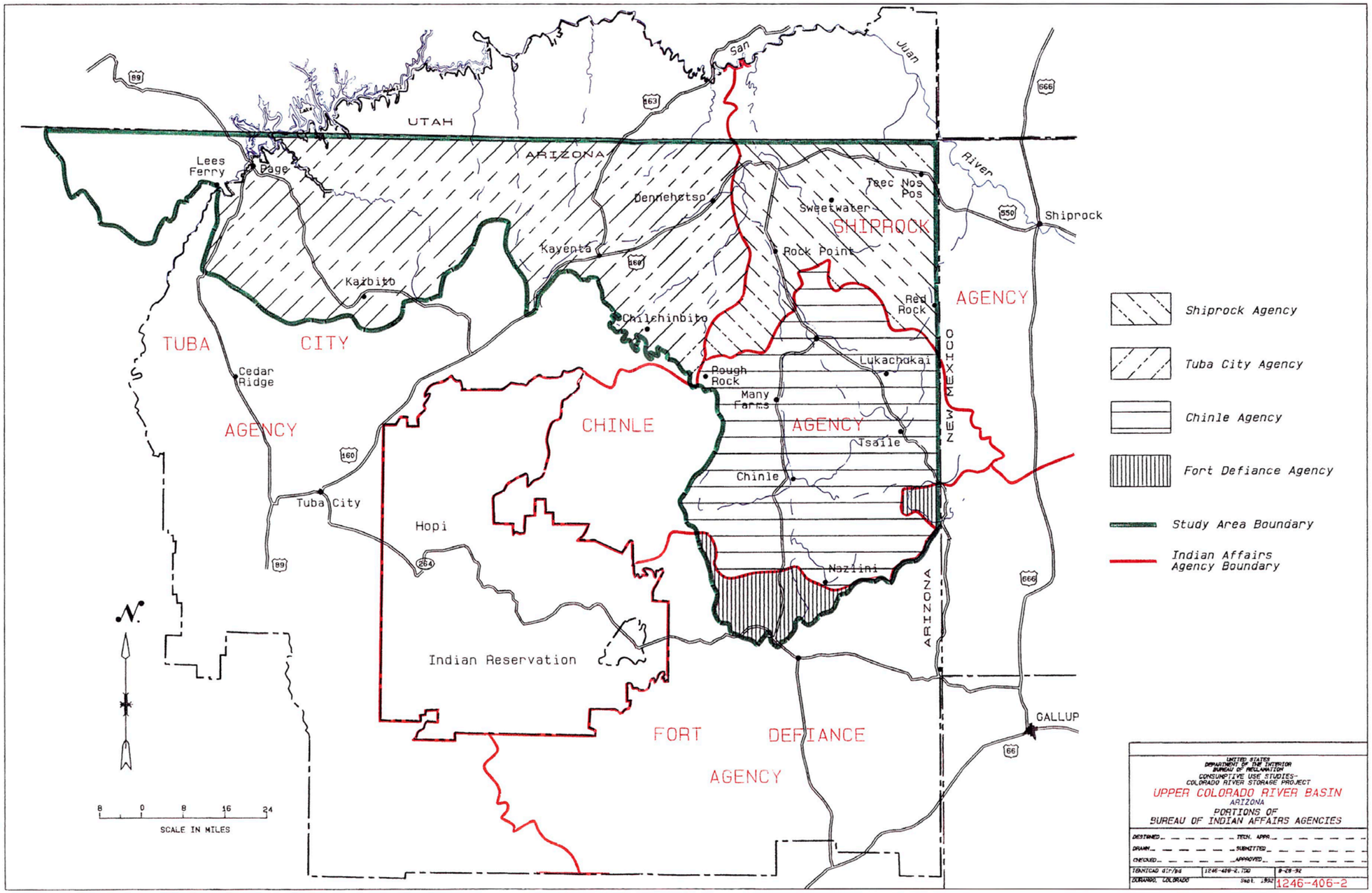
UTAH
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Rock Point
Red Rock
AGENCY
Shiprock
Lukachukai
Rough Rock
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Nazlini
TUBA
CITY
Cedar Ridge
AGENCY
Tuba City
Hopi
Indian Reservation
FORT
DEFIANCE
AGENCY
GALLUP
San
Juan
River
Shiprock Agency
Tuba City Agency
Chinle Agency
Fort Defiance Agency
Study Area Boundary
Indian Affairs Agency Boundary
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BUREAU OF RECLAMATION
CONSUMPTIVE USE STUDIES-
COLORADO RIVER STORAGE PROJECT
UPPER COLORADO RIVER BASIN
ARIZONA
PORTIONS OF
BUREAU OF INDIAN AFFAIRS AGENCIES
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