RECLAMATION

Managing Water in the West

North Central Arizona Water Supply Study

Report of Findings

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

October 2006

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Disclaimer

The water demand assumptions and resulting future conditions described in this Report of Findings reflect the position of the study's partners and stakeholder groups.

The use of these assumptions and resulting future conditions in the Report of Findings does not reflect any agreement by the Bureau of Reclamation and has no bearing on the position the Department of the Interior may take with respect to the Indian water rights settlement negotiations or litigation.

Executive Summary

Study Purpose

As the result of ongoing drought conditions in the Coconino Plateau region and the findings of the North Central Arizona Regional Water Study Phase One Report, stakeholders in the region requested that the Bureau of Reclamation conduct a regional water study to:

- Determine if water demand in the demand areas is unmet (projected to the year 2050)
- If the demand is unmet, determine if there is at least one regional alternative to meet future demands
- Determine if there is a Federal objective in which there exists at least one regional plan that can be recommended to be carried forward into a Feasibility Study.

The Study Team

In conjunction with a Technical Advisory Group assembled from representatives of interested stakeholder groups including the Navajo Nation, the Hopi Tribe, the Havasupai Tribe, the Grand Canyon Trust, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the City of Flagstaff, the City of Page, the City of Williams, Coconino County, and the Arizona Department of Water Resources, Reclamation developed a Plan of Study to address the above identified objectives. With additional team members provided by Reclamation, an appraisal level study was performed as outlined by the Plan of Study.

Tasks Performed

The study team estimated population growth for the study area through the year 2050, and based on that projected population growth, estimated water demands for the year 2050. The team then compared those projected demands to available resources to determine if there were unmet demands in the study area. After concluding that unmet water demands in the region are likely, even if additional conservation methods are implemented, the team identified potential sources of additional supply and matrixed those sources to regional demand centers which could potentially be supplied from those sources. The sources of supply considered included: surface water from the mainstem of the Colorado River (diverted both from the Lake Powell area and Lake Mead area), surface water from the tributaries to the Little Colorado River off the Mogollon Mesa, the Little Colorado River alluvium, Roaring Springs off the North Rim of the Grand Canyon (for supplying the Grand Canyon and Tusayan demand centers only), C-Aquifer (from both high water quality and low water quality areas), and the R-Aquifer. Subsequent iterations of plan formulation resulted in the identification of four plans which could address all of the identified unmet demands in the region. These plans include:

- Alternative 1 delivers water to the Navajo Nation and Hopi Tribe from Lake Powell. Flagstaff receives water from the C-Aquifer. Williams receives water from the Redwall-Muav (RM) aquifer, and the Grand Canyon and Tusayan receive water from a Bright Angel Creek infiltration gallery located at Phantom Ranch in the Grand Canyon.

- Alternative 2 delivers water to the Navajo Nation, Hopi Tribe, and Flagstaff from Lake Powell. Williams receives water from the R-M Aquifer, and the Grand Canyon and Tusayan receive water from a Bright Angel Creek infiltration gallery located at Phantom Ranch in the Grand Canyon.

- Alternative 3 delivers water to the Navajo Nation, Hopi Tribe, Flagstaff, Williams, the Grand Canyon, and Tusayan from Lake Powell.

- Alternative 4 delivers water to the Navajo Nation and Hopi Tribe from Lake Powell. Flagstaff and Williams receive water from the R-M Aquifer, and the Grand Canyon and Tusayan receive water from a Bright Angel Creek infiltration gallery located at Phantom Ranch in the Grand Canyon.

Prior to the evaluation of these complete plans, Alternative 4 was dropped from further consideration due to the large uncertainties associated with the yields and impacts of R-M Aquifer well fields (this was the only feature that distinguished Alternative 4 from Alternative 2; hence, its elimination). Appraisal level cost estimates were developed for the remaining three alternatives and are displayed below.

Item	Alternative No. 1	Alternative No. 2	Alternative No. 3
Field cost	$471,000,000	$621,000,000	$650,000,000
Present worth operation and maintenance	$81,700,000	$170,000,000	$196,000,000
Project total present worth	$553,000,000	$791,000,000	$846,000,000

Present worth values were based on a 50-year project life and an interest rate of 5.125 percent.

The alternatives were further evaluated relative to their economic, environmental, and social impacts.

For the most part, the projected response to unmet demands in lieu of a Federal response would be to further develop ground water sources. However, as identified in this study and several other recent studies, such as the Hopi Western Navajo Water Supply Study, under some demand assumptions, continued development of the C-Aquifer and N-Aquifer could become unsustainable in portions of these aquifers within the next few decades. These aquifers are the most heavily utilized, dependable water supply sources for current and future generations of the Navajo and Hopi people. From the perspective of these tribes, it is essential to protect these resources from unsustainable development. In addition, the primary reason for the Havasupai Tribe's participation in this study has been to ensure protection of R-M Aquifer springs, considered the "life-blood of the earth and the Havasupai." Further development of wells into the R-M Aquifer which result in a decrease in R-M Aquifer spring flows is not acceptable to the Havasupai Tribe.

Conclusions

Relative to the three objectives outlined in the "Study Purpose" section above, the study determined:

- There are unmet demands in the study area which will develop by the year 2050
- Three alternatives were identified as potential solutions that could meet these future unmet demands in the region
- There are Federal objectives that exist in all of these regional plans, and justification therefore exists for recommending any or all of these alternatives to be carried forward into a Feasibility Study.

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Glossary

Alternative: A set of water resource components that can meet all of the unmet demands in the demand area, without causing unacceptable impacts in the Study Area.

Component: A water resource feature that can meet some of the unmet demands within the demand area.

Demand Area: A subset of the study area that includes all of the residents with identified unmet demands.

Demand Center: A subset of the demand area. Current and future water use was estimated for each demand center and aggregated to identify the estimated current and future water use for the demand area.

Regional Stakeholders: Stakeholders include representatives from the Navajo Nation, Hopi Tribe, City of Page, City of Flagstaff, City of Williams, Grand Canyon National Park, Tusayan, Coconino County, Northern Arizona University, Grand Canyon Trust, The Nature Conservancy, Forest Service, U.S. Fish and Wildlife Service, Arizona Department of Water Resources, private citizens, and various small communities and private water providers.

Study Area: The geographic area for which the study team either desired to evaluate the water needs of the residents and develop alternatives to meet any identified unmet water needs, and/or identify existing water resources that need to be protected as the study area develops additional water supplies. The Study Area does not include all areas of potential impact which may need to be considered for environmental compliance evaluations.

Sustainable Yield: The yield of an aquifer that can be sustained over a period of time without any significant detrimental effects.

Acronyms

ACHP	Advisory Council on Historic Preservation
ADES	Arizona Department of Economic Security
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AF	acre-feet
AFY	acre-feet per year
AMA	Active Management Area
BIA	Bureau of Indian Affairs
BLS	Bureau of Labor Statistics
CCD	Census County Division
CDP	Census Designated Place
cfs	cubic feet per second
CPWAC	Coconino Plateau Water Advisory Council (the acronym CWAC has also been used to refer to this group, but this report uses CPWAC)
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FWCA	Fish and Wildlife Coordination Act
GCNP	Grand Canyon National Park
gpcd	gallons per capita per day
gpm	gallons per minute
HDPE	high density polyethylene pipe
hp	horsepower
HWNSS	Hopi Western Navajo Water Supply Study
IHS	Indian Health Service
INA	irrigation nonexpansion area
kW	kilowatt
LCR	Little Colorado River
LLC	Bellemont Truck Stop and Utility Source Limited Liability Company
MGY	million gallons per year
M&I	municipal and industrial
MY	million years

MYA	million years ago
NCAWSS	North Central Arizona Water Supply Study
NEPA	National Environmental Policy Act
NESL	Navajo Endangered Species List
NIIP	Navajo Indian Irrigation Project
NNHPD	Navajo Nation Historic Preservation Department
NPS	National Park Service
NTUA	Navajo Tribal Utility Authority
OM&R	Operations, Maintenance, and Replacement
PDO	Pacific Decadal Oscillation
Phase One Report	ADWR North Central Arizona Regional Water Study, Phase One Report
POS	Plan of Study
psi	pounds per square inch
PVC	Polyvinyl Chloride
Reclamation	Bureau of Reclamation (move under "R")
ROF	North Central Arizona Water Supply Study Report of Findings
R-M	Redwall-Mauv
RMI	Rocky Mountain Institute
RMI Demand Study	North Central Arizona Water Demand Study, Phase One Report
SCADA	Supervisory Control and Data Acquisition
Service	U.S. Fish and Wildlife Service
SHPO	State Historic Preservation Officer
SRP	Salt River Project
TAG	(Coconino Water Advisory Council) Technical Advisory Group (the acronym TAC has also been used to refer to this group, but this report uses TAG)
TCP	Traditional Cultural Property
TSC	Bureau of Reclamation, Technical Service Center
THPO	Tribal Historic Preservation Officer
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Chapter I
Introduction

In 1998, the Arizona Department of Water Resources (ADWR) organized a regional study (ADWR, 1998) to evaluate future municipal water demands for communities within the western range of the Navajo Nation, City of Flagstaff, City of Williams, Tusayan and the Grand Canyon National Park (GCNP). These communities were the initial study area. This study resulted in the publication of findings in a report titled, "North Central Arizona Regional Water Study Phase One – Arizona Department of Water Resources," (Phase I Report). ADWR requested technical assistance from the Bureau of Reclamation (Reclamation) to evaluate the engineering hydraulics of the conceptual water conveyance infrastructure detailed in the Phase I report. Reclamation interviewed water managers and stakeholder representatives who participated in the ADWR Rural Water Program planning process and contributed to the Phase I Report publication. The Bureau of Reclamation published a peer review (Reclamation, 1999) and presented the findings to a water advisory group organized by Coconino County. Reclamation recommended that other alternatives be considered and identified uncertainties regarding the continued and future development of the ground water aquifers currently used by the majority of the northern Arizona communities.

As a result of the finding in these reports, and the onset of drought conditions in the Coconino Plateau region, stakeholders requested that Reclamation conduct a regional water study to:

- Determine if water demand in the demand areas is unmet (projected to the year 2050)

- If the demand is unmet, determine if there is at least one regional alternative to meet future demands

- Determine if there is a Federal objective where there exists at least one regional plan that can be recommended to be carried forward into a feasibility study.

In October 2000, the United States Congress allocated funding to Reclamation to conduct an appraisal level regional water study as authorized by the Reclamation Act (Act of June 17, 1902, ch. 1093, 32 Stat. 388), as amended, titled "North Central Arizona Water Supply Study (NCAWSS)." Reclamation and ADWR executed a cost-share agreement establishing terms to jointly fund the regional study. Reclamation organized a Technical Advisory Group (TAG) enlisting representatives from the demand areas, Grand Canyon Trust, U.S. Geological Survey (USGS), Northern Arizona University, Coconino County, Navajo Nation, Hopi Tribe, Havasupai Tribe, and interested local citizens. In 2005, the Coconino Plateau Water Advisory Council (CPWAC) was formed, incorporating several members of the 1998 water advisory group, formalizing the role of *regional stakeholders* within the context of the ADWR Rural Water Program. The Havasupai Tribe and the Hopi Village of Moenkopi was added to the study area. The CPWAC and TAG participated in numerous meetings to scope and complete various study elements. Although Reclamation Appraisal Studies typically are only 2 years in duration, the study team recognized that there were a number of ongoing and related studies that could benefit from the analysis of this region. Throughout the past 5 years, several related studies have been completed which provide important information and modeling tools, many of which have been incorporated by reference in this NCWSS Report of Findings (Report of Findings).

I.1 Plan of Study

The TAG developed a comprehensive Plan of Study (POS), establishing the goals, objectives, assumptions, roles, and responsibilities necessary to complete the study. The TAG modified the POS as details associated with study elements were refined.

I.2 Study Area

Figure I.2-1 shows the study area. The study area is defined as the area including specific communities that are the subject of the future water needs analysis. Also included in the study area are the areas defining water resources that are either currently being used to meet water needs or have been identified as alternatives to meet future water needs.

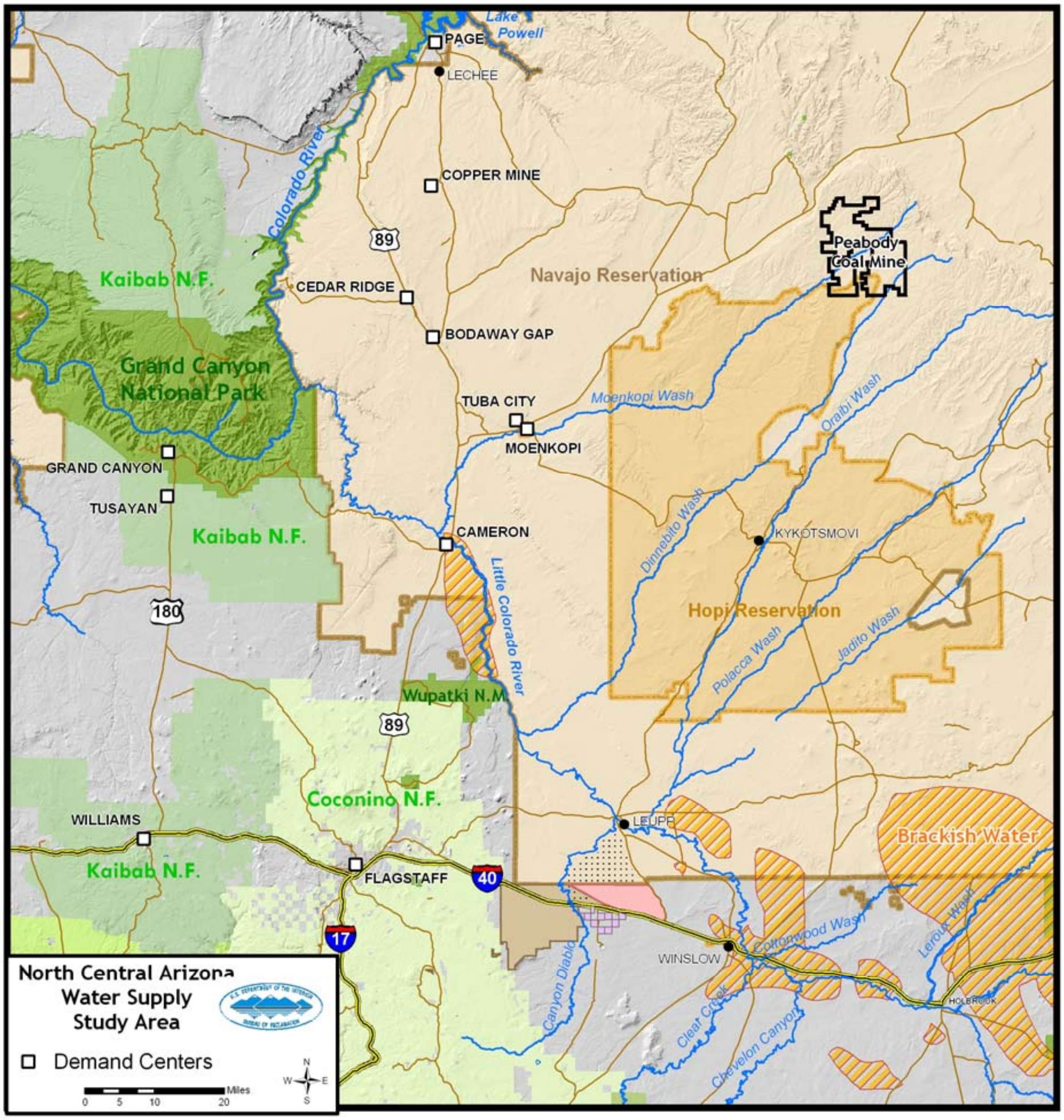

Figure I.2-1 North Central Arizona Water Supply Study area.

I.3 Study Team

Reclamation assigned an interdisciplinary team composed of a study manager, resource management specialists, civil engineers, hydrologists, biologists, archaeologists, social factors analysts, cost estimators, policy specialists, and economists to work with the CPWAC and TAG to complete this Report of Findings.

I.4 Reclamation General Investigation Program – Appraisal Study

Reclamation's Phoenix Area Office is located within the Lower Colorado Region, one of five regions covering the 17 Western States in which Congress authorized Reclamation's mission "to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." The General Investigation Program was established to help organizations and groups identify and formulate a plan to develop new water supplies from traditional sources (such as surface water and ground water) and ways to deliver existing supplies to new service areas. An appraisal study is typically a brief investigation to determine whether to proceed to a feasibility study. An appraisal study uses existing data and information and identifies plans to meet current and projected objectives. Appraisal studies present an array of options that have been screened and evaluated to justify potential Federal involvement and they identify at least one potential solution. This appraisal level study does not result in a commitment of the U.S. to fund any subsequent level of investigation or construction. Assumptions found in the record and deemed reasonable in this study are not necessarily assumed in water rights negotiations.

I.5 Related Studies

North central Arizona water needs have been the subject of numerous studies dating back to early non-Indian settlements in the region. Private parties, as well as Federal, county, State, and tribal governments have conducted numerous investigations to identify potential water sources to meet future water demands and evaluations of claims in the Little Colorado River (LCR) adjudication. The Reclamation study team conducted an inventory of water and water-related studies as the initial task of the NCAWSS. The various water supply studies and modeling tools have been incorporated, where applicable, throughout this Report of Findings.

Chapter II
Current Conditions in the Study Area

II.1 Communities and Population

A relatively diverse group of communities and rural areas are located within the study area on the Coconino Plateau, including tribal and nontribal communities, highly dispersed communities, small towns, and Flagstaff, a small city that is the dominant community in the study area. Many residents in the rural unincorporated areas of Coconino County rely on hauled water and local water companies to access water.

II.1.1 Tribal Communities

The tribal communities in the study area are the Havasupai Tribe, Hopi Tribe's Village of Upper Moenkopi and Lower Village of Lower Moencopi, and the western portion of the Navajo Nation.

The Havasupai reservation is in the western portion of the study area, within the Havasu Canyon south of Grand Canyon National Park. Most of the tribal population is concentrated within Havasu Canyon, within the village of Supai, or on the rim above Havasu Canyon. The tribe's estimated population of enrolled members is 650 (year 2000), of which 450 live in the village of Supai (Havasupai Tribe, 2006).

The Hopi Reservation is located in northeastern Arizona, on a parcel of land surrounded by the Navajo Reservation. Hopi is comprised of two noncontiguous parcels: lands within the Hopi 1882 Reservation and lands in and around the Moenkopi Villages, which are within the area of the Navajo Reservation created by the Act of June 14, 1934, 48 Stat. 960 (1934), commonly referred to as "the 1934 Act" and "the 1934 Act Reservation." Only the Moenkopi District of the Hopi Reservation is within the study area. In 1992, after years of litigation initiated by the Hopi Tribe to determine its rights and interests in the 1934 Act Reservation, the Moenkopi Administrative Area was transferred to the jurisdiction of the Hopi Tribe.[1] (Lynelle Hartway, personal communication). The Moenkopi District is an island consisting of two villages, Upper Moenkopi and Lower Moencopi, located 45 miles from the Hopi Reservation. The two villages of Moenkopi currently use the Navajo (N) Aquifer water for both domestic and community needs. The Hopi Villages, both the Upper Village of Moenkopi and Lower Village of Moencopi, have a current (year 2006) population of 1500. For the purposes of this study, the population of the Hopi Tribe within the study area (year 2000) was estimated to be 749. "U.S. Census-based estimates of Tribal populations are uncertain and probably undercount the actual Reservation population" (Hopi Western Navajo Water Supply Study (HWNSS) (HDR, 2004). The 2000 population data cited for the Hopi Tribe (above) and for the Navajo Nation (below) were developed by the HWNSS, which addressed this perceived undercount by increasing year 2000 census data by 7.9 percent (HDR, 2004).[2] The two distinct villages are residential and agricultural year round. Future expansion for the two villages of the Moenkopi District will include residential and economic development, both north/south of the Moenkopi Wash.

The Navajo Nation encompasses most of the northeastern corner of Arizona, as well as portions of Utah and New Mexico. However, only the western portion of the reservation is included within the study area. The Chapters within the study area located generally along U.S. Highway 89 include Cameron, Tuba City, Bodaway Gap, Coppermine, and LeChee.[3] The tribal population is highly dispersed within the Chapters. The population of the Navajo Nation within the study area (year 2000) is estimated to be 15,588 (HDR, 2004).

The tribal populations are summarized in table II.1-1.

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[1] This land transfer also affected the local and area Bureau of Indian Affairs (BIA) offices that had Federal oversight jurisdiction over the lands. Before the transfer of jurisdiction, the management responsibility for the landfill resided with the BIA Navajo Regional Office. After 1992, that responsibility was transferred to the BIA Western Regional Office.

[2] Further rationale for why an undercount of tribal populations is thought to occur is provided in HDR (2004), volume 2, task 4.1, "Water Demand."

[3] The communities of Bitter Springs and Cedar Ridge are located within the Bodaway Gap Chapter, and the community of Gray Mountain is within the Cameron Chapter.

Table II.1-1. Population of Tribal Communities (Year 2000)[1]

Community	Population
Hopi Tribe	
Moenkopi	749
Lower Moencopi (a new future village site)	0
Navajo Nation Chapters	
Coppermine	726
LeChee	2,126
Bodaway Gap[2]	1,982
Tuba City	9,426
Cameron[3]	1,328
Havasupai Tribe	650
Total	16,987

[1] Hopi and Navajo midrange estimates from HWNSS (HDR, 2004).
[2] Population for Bitter Springs Chapter includes the communities of Bitter Springs and Cedar Ridge.
[3] Population for Cameron Chapter includes the community of Gray Mountain.

II.1.2 Nontribal Communities

Nontribal[4] communities in the study area include the City of Flagstaff and its surrounding communities, such as Doney Park/Timberline and Fort Valley; Kachina Village and Mountainaire to the south of Flagstaff along I-17; Parks and Williams to the west of Flagstaff along I-40; Valle, Tusayan, and Grand Canyon Village in the western portion of the study area; and the City of Page at the northern edge of the study area. The current populations (year 2000) of these communities are shown in table II.1-2.

In addition to the populations of the nontribal communities, there are populations of smaller communities (e.g., Flagstaff Ranch; Bellemont; Arizona National Guard, Camp Navajo; Red Lake; Forest Highlands; Mountain Dell; Lockett Ranch; Cedar Valley; Saskan Ranch, etc.) for which specific population data are not available. In addition, some residents are highly dispersed on private properties in rural portions of the Coconino County within the study area. This population was estimated by subtracting the known populations of the study area communities and the known populations of county communities outside the study area (e.g., Sedona, Oak Creek Canyon) from the total county population. This method resulted in an estimated study area population for smaller communities and dispersed residents of 4,050 (as of 2002) unaccounted for in table II.1-3

[4] Although these communities are called "nontribal," many members of different tribes reside in these communities.

(Reclamation, 2004a).[5] For the purposes of this study, 50 percent of this dispersed population (or 2,025 people) were considered to reside in the area between Williams and Tusayan, 25 percent (1,013 people) were considered to reside in the area between Flagstaff and Williams), and 25 percent (1,013 people) were considered to reside in smaller communities surrounding Flagstaff.[6]

Table II.1-2. Population of Nontribal Communities (Year 2000)

Community	Population
City of Flagstaff	62,710
Doney Park/Black Bill	5,794
Timberline/Fernwood	2,185
Fort Valley	660
Grand Canyon Village	1,460
Kachina Village	2,664
Mountainaire	1,014
Page	9,570
Parks[1]	1,137
Tusayan	562
Valle	534
Williams	2,905
Total	**91,285**

[1] The Parks CDP includes the communities of Pitman Valley and Garland Prairie.
Source: Reclamation (2003)

Table II.1-3. Dispersed Nontribal Communities (Year 2002)

Community	Population
Williams to Tusayan	2,025
Flagstaff to Williams	1,013
Surrounding Flagstaff	1,013
Total	4,051

Source: Reclamation (2003a)

[5] For complete methodology, see *Updated Historical and Project Population for N.AZ Water Supply Study Demand Areas: Accounting for "Rural" Areas in Population Projection,* Reclamation (2004a). Subsequent analysis has determined that this calculation inadvertently also subtracted out the populations of Munds Park/Pinewood and "County Islands." The estimates of the dispersed population are therefore considered underestimated by 1,600 in the year 2002 and 3,400 in the year 2050. This underestimate is somewhat countered by the use of 2002 data rather than 2000 data to estimate the dispersed population.

[6] It is recognized that these assigned percentages do not represent a precise representation of the dispersed populations in each of the identified area. However, for the purposes of this study, given the many other uncertainties associated with demand estimating and project sizing, these values are considered reasonable.

II.2 Current Economic and Social Conditions

The study area does not include all of Coconino County. However, the study area is completely encompassed by the county. The Census Bureau collects demographic data by census tract and city, but not all data are available at that level. For appraisal level studies, it is typical to use county-level data to represent a study area when data for specific smaller areas are not available.

Coconino County is 18,661 square miles, making it the second largest county in the U.S. and the largest county in Arizona. The county is very sparsely populated. Indian reservations comprise 38 percent of the land and are home to the Navajo, Hopi, Paiute, Havasupi, and Hualapai Tribes. The U.S. Forest Service, National Park Service (NPS), and Bureau of Land Management control 40 percent of the land; the State of Arizona owns 9 percent; and the remaining 13 percent is owned by individuals or corporations (Sue Pratt, personal communication, 2006).

II.2.1 Current Regional Economic and Social Conditions

Employment

According to a factsheet put together by the U.S. Department of Labor, the Bureau of Labor Statistics (BLS), and the State of Arizona Economic Security Research Administration, Coconino County was occupied by approximately 129,570 people in 2004. This publication reports that in 2000, 63.1 percent of these individuals were white, 28.5 percent were Native American, and 10.9 percent were of Hispanic heritage. In 2004, Coconino County's unemployment rate was 6.1 percent, up from 4.8 percent in 2000. The U.S. Bureau of the Census, 2003 County Business Patterns reports that these people are employed mostly by the accommodation and food services industry, as well as by the retail trade industry. Figure II.2-1 presents the census estimates for the number of employees that represent the respective industries for the week including March 12, 2003.[7]

As illustrated in figure II.2-2, the majority of employed people in Coconino County work as *managers and professionals*, as well as in *sales and office occupations* within the industries shown in figure II.2-1.

[7] Census information does not provide a statistic for government workers for the breakdowns shown in figures II.2-1 and II.2-2. However, in an evaluation of "Class of Worker," census data indicate that 28 percent of all the workers in Coconino County worked for some level of government.

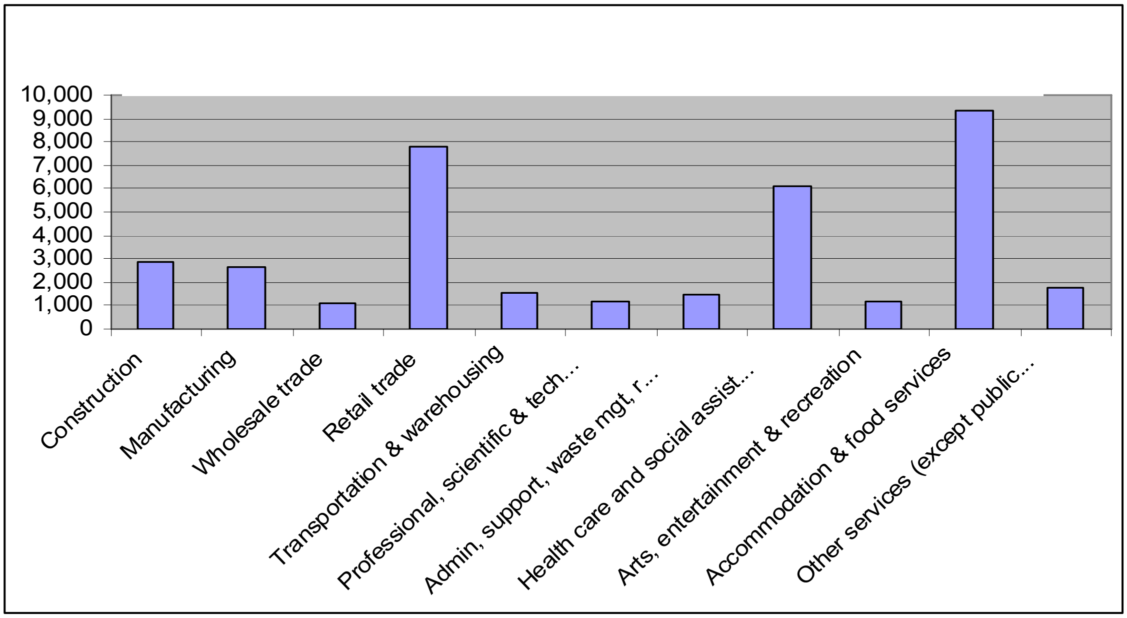

Figure II.2-1. Representative number of employees in Coconino County by industry code description, 2003.

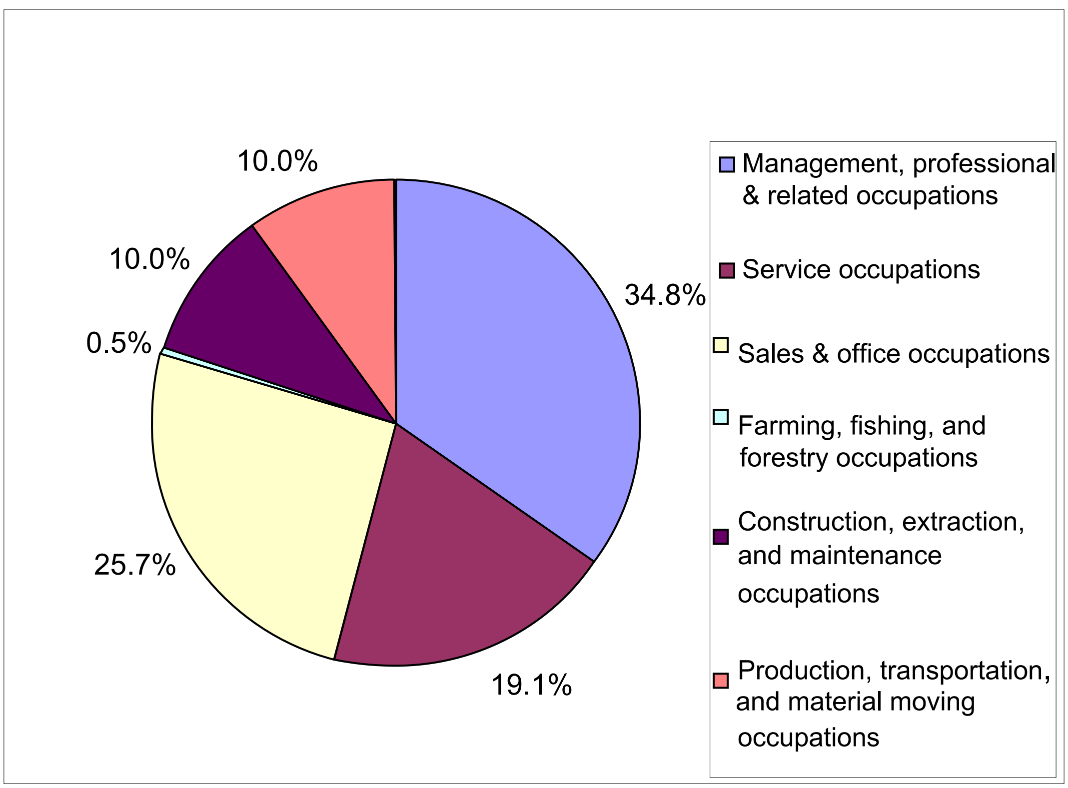

Figure II.2-2. Occupation of employed civilian population in Coconino County, 2000.

Income

The U.S. Bureau of Census reported that the 2000 annual median household income was approximately $38,000 and the annual per capita income was approximately $17,000, as illustrated in figure II.2-3.

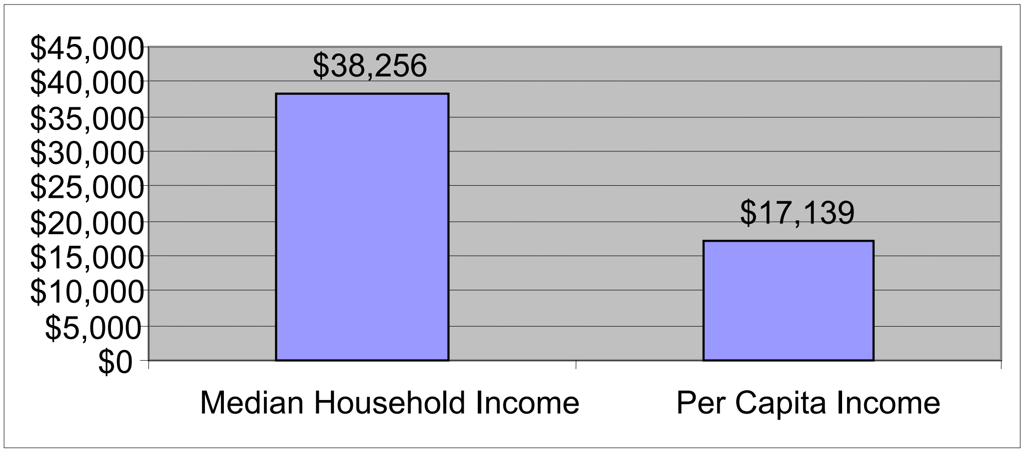

Figure II.2-3. Coconino County 2000 median household and per capita income.

Sales

The U.S. Bureau of the Census, 2002 Economic Census reports the amount of sales, shipments, receipts, or revenue for counties. *Retail trade* leads Coconino County in the amount of sales generated. *Manufacturing* and *wholesale trade* are second and third, respectively, in the amount of sales reported.

The numbers of establishments located in Coconino County are illustrated in figure II.2-5. The top three industries in Coconino County are *retail trade* establishments, *construction* establishments, and *accommodation and food services* establishments, respectively. According to the U.S. Bureau of the Census, County Business Patterns, these are the three industries with the most establishments in Coconino County.

Race and Ethnicity

Population data from the 2000 census for the State of Arizona, Coconino County, and local communities were shown earlier in the report in tables II.1-1 and II.1-2. Table A-1 in appendix A provides a breakdown of population for seven racial categories: White, Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, Some Other Race, and Two or More Races. The percentages of total racial minority population and the Hispanic or Latino population, a minority ethnic group, are also shown.

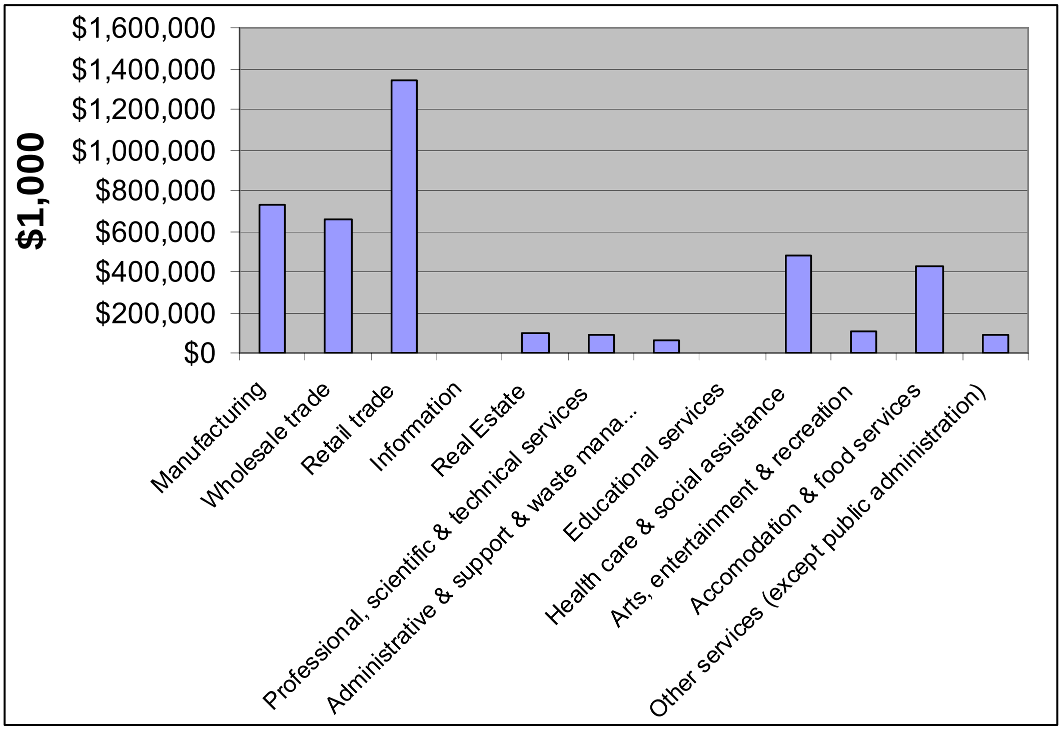

Figure II.2-4. 2002 Coconino County sales by major economic sector.

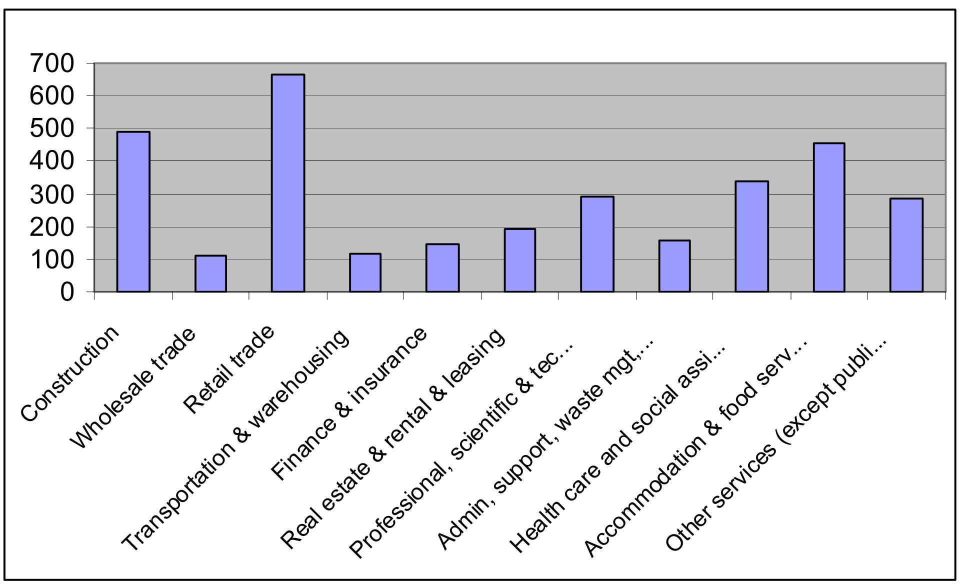

Figure II.2-5. Number of establishments by industry code description in Coconino County, 2003

All of the areas (except the Coconino census county division (CCD), Kachina Village census designated place (CDP), and Flagstaff) have a greater percentage of total racial minority populations than the State of Arizona as a whole. Only

Williams and Tusayan have greater ethnic (Hispanic or Latino) populations than the State. The racial minority population of each of the three reservations is over 90 percent.

Low-Income Populations

Low-income populations in the area are identified by several socioeconomic characteristics. As categorized by the 2000 census, specific characteristics used in this description of the current conditions are income (per capita and median family), the percentage of the population living below poverty level (all persons and families), substandard housing, and unemployment rates.

The per capita incomes for all areas (except Mountainaire CDP and Munds Park CDP) are less than the State. The median family incomes for the nontribal communities are generally greater than the State median, while the median family income for several of the tribal communities is less than one-half of the State median. Coconino County as a whole and all of the tribal areas have an equal or greater percentage of persons and families living below the poverty level. For most of the tribal areas, the percentages of persons living below the poverty level are more than two times the State rate, with the levels for the Havasupai Reservation and some areas of the Navajo Reservation nearly three times greater. Table A-2 in appendix A includes data showing 1999 income as reported in the 2000 census,

Other measures of low income, such as substandard housing and employment, also characterize demographic data in relation to environmental justice. Substandard housing units are those that are overcrowded and those that are lacking complete plumbing facilities. The percentage of occupied housing units in the areas with 1.01 or more occupants per room and the percentage of those lacking complete plumbing facilities for all of the tribal areas were significantly greater than for the State. The 2000 unemployment rates for the local areas ranged from zero percent to 25 percent, compared to the State unemployment rate of 5.6 percent. These data are summarized in table A-3 of appendix A.

II.2.2 Current Community Economic and Social Conditions

Tribal Communities

"Despite more than 200 years of Federal trusteeship, on-reservation Native American Indians remain the poorest ethnic group in the Nation and suffer from some of the most acute poverty-related socioeconomic maladies" (Kalt et al., 1999; BIA, 1999).

"The social and economic deficits of Indian Country are significant and are not subject to simple or quick remedy" (Cornell et al., 1992). "The consequence of this history of privation is a legacy of severe and overwhelming social and economic neglect. The backlog of the problems and deficits are particularly relevant when determining and evaluating the needs and living conditions of Indian communities" (BIA, 1999; Kalt et al., 1999).[8]

Western Navajo Nation

Employment, income, and poverty statistics clearly demonstrate that the Navajo are experiencing living conditions considerably worse than the rest of the U.S. Unemployment in Western Navajo communities ranges from 14 percent to 26 percent (www.city-data.com, 2006). Per capita income for the Navajo Nation is currently $7,000, compared to per capita income values of $20,000 in Arizona and $22,000 in the United States. Over 40 percent of the Navajo population lives below the poverty line, and over 50 percent of children live below the poverty line. Over 30 percent of the Navajo tribal members live without plumbing, approximately 28 percent are without kitchens, and 60 percent are without phones (Kirk, 2005). Municipal systems within the Navajo Reservation are developed by the Indian Health Services (IHS). Based on the identified need for municipal systems within the reservation, it will take 15 years at the current rate of funding to provide the necessary municipal systems to meet the current existing demand. Median housing values are significantly below median values for the State of Arizona, and the percentages of individuals with high school degrees and college degrees are significantly lower than for other communities in Arizona (City-Data.com, 2006).

Of those without plumbing, households that haul water are subjected to a total economic cost for hauling the water that has been estimated at nearly $37,000 per acre-foot ($113 per 1,000 gallons). The total economic cost includes the costs to purchase the water for the container, for the transportation, and for the opportunity cost of time (Merchant, 2005). Many of the water haulers rely on nonpotable water sources for their supply and/or unsanitary tanks for the transport and storage of the water. These sources and tanks are susceptible to microbial contamination (U.S. EPA, 2001; Ecosystems Management, Inc., 2004). For those residents with running water, estimated usage rates are 75 to 100 gallons per capita per day (gpcd), but for those without plumbing, estimated usage is 10 to 15 gpcd (Robert Kirk, personal communication). This per capita per day water usage is below the average among the demand areas within the study area.

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[8] According to BIA (1999), "Based upon a range of socio-economic indicators, Indian people remain severely disadvantaged compared to the U.S. population as a whole." In addition to that finding, BIA concluded that, "preliminary indications are the current funding meets only one-third of identified need."

As noted in the HWNSS, "Although significant economic development in the Little Colorado River Basin portion of the Navajo Nation probably will not occur without improvements in water supply, water infrastructure, and wastewater infrastructure, there is no assurance that development will occur if the water supply projects are constructed. Many communities in the Southwest are competing for future economic development, such as St. George, Utah; Flagstaff, Arizona; and communities in the Phoenix, Arizona area. Many of these competitors currently have better water and transportation infrastructure, as well as an adequate workforce to meet emerging labor demand. Although the 17 Tribes have the workforce, they have not yet fully developed the remaining infrastructure. Economic development on the Reservation is more likely to be in the form of tribal enterprises, such as the value-added enterprises associated with the Navajo Indian Irrigation Project (NIIP). Development of tribal enterprises may reduce out migration by encouraging tribal members to remain on the Reservation" (HDR, 2004, vol. 2, Task 4.1, "Water Demand"). The tribe is actively addressing economic development constraints through major investments in housing, communication systems, electric utility service, and new and improved roads.

Springs emanating from the Navajo (N) Aquifer are of major cultural significance to the Navajo Nation. Navajo Nation Water Quality Standards, enacted through the Resources Committee of the Navajo Nation Council, contain an antidegradation policy for the protection and maintenance of "unique waters." Included within the definition of unique waters are ground water sources that have exceptional cultural, ecological, and/or recreational significance due to the nature of their flora, fauna, water quality, aesthetic value, or wilderness characteristics. The N-Aquifer is this type of an exceptional water source. As a result, any decrease in flow levels of N-Aquifer springs is of concern to the tribe.

Hopi Community of Moenkopi

The Hopi Villages represent some of the oldest continuously occupied areas in the U.S. Archaeological studies have shown that indigenous peoples have inhabited this area (what is now northeastern Arizona) since at least 1150 B.C. The importance of springs to the Hopi Tribe is indicated by the Hopi Prophecy, "When the sacred springs at Moenkopi are no longer able to support life, and the last person leaves the old village, it marks the beginning of the end times for all peoples." Hopi Tribal members' observance of their ancient culture and ceremonial cycle, of which water is an important part, is of fundamental importance to the Hopi people. In Hopi philosophy, the health and safety of the Hopi people are indistinguishable from the health and safety of the environment.

Both of the Villages at Moenkopi obtain their water supply from the Navajo sandstone and Kayenta formation members of the N-Aquifer. The N-Aquifer is the main source of drinking water for the area, and it discharges water at numerous springs, seeps, and wells across the Hopi Reservation and, most notably, at several springs within the Villages at Moenkopi. Due to the exceptional nature of the N-Aquifer's water quality and its importance to the Hopi people, the Hopi Tribal Council specifically addressed the N-Aquifer in the tribe's water quality standards, giving it a special designation by tribal resolution.[9] In a very real sense, the N-Aquifer water provides a basis for their subsistence and livelihood, as well as constituting a central ingredient to their cultural and religious practice.

Economic development designed to build a stable local economy is desperately needed on the Hopi Reservation and in Moenkopi. According to the last census data, 13.9 percent of Moenkopi households live under the poverty level. In 2002, the Arizona Department of Economic Security determined that the average unemployment rate for the Hopi Reservation was 22.6 percent; in Moenkopi, it was 17 percent (City-Data.com, 2006).[10] This is over four times the Arizona and nationwide unemployment rates. There is currently little or no private sector economy within the Hopi Reservation, and the potential for economic development is minimal. Many tribal members are without running water and use is only 10-35 gpcd. Furthermore, the shutdown of the Black Mesa Mine means the loss of up to approximately $2 million per week in direct economic benefits to the tribe (Peabody Energy, 2006).

Havasupai[11]

The Havasupai Tribe has lived on the banks of Havasu Creek in the Grand Canyon for over 1,000 years. Historically, the Havasupai occupied a territory from the Aubrey Cliffs on the west to the LCR on the east, and from the Colorado River on the north to the vicinity of Bill Williams Mountain on the south (Kaibab National Forest, 1999). While traditionally relying on hunting and gathering in the canyon and upper Coconino Plateau surrounding the canyon, since the creation of the reservation in 1882, the tribe has become more dependent upon

[9] Hopi Tribal Council Resolution H-107-97 classified certain Hopi ground water, including the ground water supplying the drinking water needs of the Hopi Villages at Moenkopi, as a "unique water" of the Tribe. This classification includes, "The N-Aquifer and all areas recharging the N-Aquifer. The N-Aquifer includes water bearing units of the Navajo Sandstone, the Kayenta Formation, the Wingate Sandstone, and all springs emanating from these units."

[10] The unemployment level at the date of this report may be higher due to the closure of the Black Mesa Coal Mine as a result of the shut down of the Mohave Generating Station.

[11] Information provided from NRCE (2005) and Havasupai Tribe (2006).

farming within the bottom of the canyon and seeking wage labor outside of the reservation. More recently, tourism has developed into a primary economic base for the tribe.

Much of the native flora and fauna of Havasu Canyon and the adjacent Coconino Plateau have traditionally been important to the Havasupai for both religious and economic purposes. National forest land and private in-holdings in the area contain a variety of medicinal, ceremonial, and subsistence plants that have been, and continue to be, important to tribal members (Kaibab National Forest, 1999).

Until recently, most tribal residents have lived in the village of Supai, which is only accessible by an 8-mile trail from Hilltop, or by helicopter. However, Supai has reached its maximum capacity and planning for new housing development on the rim/hilltop region of the reservation is underway.

Ground water circulating within the Coconino Plateau is considered the "life-blood of the earth and the Havasupai." Ninety-eight percent of the Redwall-Mauv (R-M) Aquifer discharge occurs at Havasu Springs. In addition, over three dozen other springs and seeps are present on the 185,000-acre reservation. These springs and seeps serve as the municipal and agricultural water supply for the tribe, are of paramount importance for cultural and religious purposes, and are the source of the waterfalls and pools which are the primary draw for tourism and are critical to the recreation-based economy of the tribe. The Havasupai's primary reason for participating in this study is to ensure protection of these R-M Aquifer springs and seeps as the region develops plans for future water use. Any withdrawal from the R-M Aquifer is considered by the tribe to have an impact on its water rights and water resources. The tribe has stated that they "cannot tolerate any decrease in the natural flow of Havasu Springs and other canyon springs and seeps" (Shiel, 2002).

Nontribal Communities

Page

The City of Page is located at the northern edge of the study area, approximately 140 miles north of Flagstaff on U.S. Highway 89. The city is on the south shore of Lake Powell and is near Glen Canyon Dam. The city was established during the construction of Glen Canyon Dam and has since developed into a community supported largely by seasonal tourism. The community includes several hotel/motel complexes, gas stations, restaurants, airport, golf course, and other visitor associated facilities. An additional significant employer is the nearby Navajo Generating Station. Although not on the Navajo Reservation, 23 percent of Page's population in 2000 was Navajo Indians and approximately 70 percent of the city's high school students were Navajos (TetraTech RMC, 2003). Page is the business hub of the local economy and provides numerous jobs to residents of the community of LeChee."

Flagstaff and Outlying Areas

Bellemont

Bellemont is an unincorporated community located along Interstate 40 approximately 7 to 8 miles west of the City of Flagstaff. The Bellemont community includes a relatively small, but recently increasing, number of residences, some commercial development in proximity to a truck stop complex, and some light industrial development. In addition, the Arizona National Guard, Camp Navajo (Camp Navajo) is the site of the Arizona National Guard training and munitions storage facility, and the National Weather Service Office is located on the south side of I-40. A new residential community, Flagstaff Meadows, is under development on the north side of I-40. Flagstaff Meadows Units 1 and 2 consist of 221 single family lots, and the Townhomes at Flagstaff Meadows include 105 attached units. Plans for Unit 3, with an additional 276 units, are being processed by Coconino County as of the date of this report (summer 2006).

The Southern San Juan Paiute Tribe has recently purchased land for a potential casino in the Bellemont area. Development of this casino would require a change of status to trust land. Should this change be implemented as sovereign tribal land, it would not be subject to county zoning or building codes.

Doney Park/Timberline/Fernwood

The Doney Park/Timberline/Fernwood area is the largest unincorporated community in Coconino County. It is located to the northeast of Flagstaff and mostly east of U.S. Highway 89. It is an agricultural/residential area with some limited commercial uses that primarily serve area residents. As represented in the county area plans for this community (most recently updated in 2001), the residents' desire is to maintain the large lot rural character and predominantly residential land uses. Doney Park Water, an owner cooperative, provides water service to most of the property within this area.

City of Flagstaff

The City of Flagstaff is the largest community in the study area, is the regional business center, and has the most diverse economy in the region. The major employers include Northern Arizona University, a regional hospital, several industrial facilities, and all levels of government and many retail and service businesses. Flagstaff is a hub for regional tourist activities and is associated with the many attractions on the Coconino Plateau and Verde Valley.

Fort Valley

Fort Valley is primarily a rural residential community, with few commercial businesses, spread out in an unincorporated area to the north and west of Flagstaff. The area has a "rural character," and the Fort Valley Area Plan approved by Coconino County in 1990 sets forth policies to maintain that character (Rocky Mountain Institute, 2002).

Flagstaff Ranch

The Flagstaff Ranch community is located to the west of Flagstaff, primarily to the south of Interstate 40. The community includes the private Flagstaff Ranch Golf Club, a residential community, the Westwood residential subdivision, and the Flagstaff Ranch Business Park. The latter includes a Coca-Cola distributing Center, and a waste management facility. There is room for further commercial and industrial development. The residential communities are recently developed and relatively upscale for the area.

Forest Highlands

The gated community of Forest Highlands is located several miles to the south of Flagstaff and immediately to the east of Highway 89A. The community is oriented around a private golf course and is relatively upscale. Less than 20 percent of the homes are occupied year round.

Kachina Village

Kachina Village is an unincorporated community located several miles south of Flagstaff and immediately south of Forest Highlands. The community is west of Interstate 17 and is primarily residential, but it does include a convenience store, real estate office, church, utility facilities, and two fire stations. Primarily, the community was originally developed as second homes, but over 80 percent of the homes are now occupied year round. The homes range from mobile homes to modular homes to site-built homes (RMI, 2002).

Mountainaire

Mountainaire is a residential community located several miles south of Flagstaff and east of Interstate 17, to the east of Kachina Village. The Mountainaire subdivision was first developed in the 1960s for seasonal occupancy; however, most homes are presently occupied year round. The homes are concentrated on relatively small lots.

Munds Park/Pinewood

Munds Park/Pinewood is an unincorporated residential community located approximately 17 miles south of Flagstaff. It was developed in the late 1960s early 1970s for seasonal occupation and has approximately 25 percent year-around residents. The residential community is located on the east side of I-17 and includes a golf course, fire station, several convenience stores, and gas stations. A commercial area is located on the west side of I-17 and includes an RV park, church, and mini storage.

Other Small Communities

In addition to the above communities, many additional small communities, for which little existing information was available for the Reclamation study team, are present in the study area. For example, these include such communities as Red Lake, Pitman Valley, Garland Prairie, Mountain Dell, Lockett Ranch, Cedar Valley, and Saskan Ranch.

Parks

The community of Parks is located in the Kaibab National Forest along both sides of Interstate 40, about 20 miles west of Flagstaff and west of Bellemont. The community is primarily residential but includes a small number of commercial businesses. The homes are widely scattered, and the Rocky Mountain Institute (RMI) found that most Parks residents found the prospect of growth undesirable. The Parks Area Plan, adopted by Coconino County in 2001, noted that the lack of water in the Parks area is a "serious constraint on future development" that could maintain the rural character of the area (RMI, 2002).

Williams

Williams is a small city located approximately 30 miles west of Flagstaff along Interstate 40. It is close to the junction of State Route 64 with Interstate 40. Williams' economy is oriented towards providing services to tourists traveling to GCNP and other attractions in the Coconino Plateau area. Services include many hotel/motel complexes, restaurants, gift shops, gas stations/convenience stores, a golf course, and the Grand Canyon railway that runs from Williams to Grand Canyon National Park. In addition, Williams' economy is also supported by local agriculture, ranching, rock quarrying, an office of the Kaibab National Forest, and a limited amount of industry. In 2005, the Governor of Arizona signed a bill to create an amusement park district in Williams for a proposed 1,000-acre park. There are also plans for a 160-acre territorial Arizona theme park (*The Arizona Republic*, 2005).

Valle

Valle is an unincorporated community located at the junction of State Route 64 and U.S. Highway 180, approximately 30 miles south of the south entrance to Grand Canyon National Park. The community's economy is therefore oriented towards providing services to tourists visiting the Grand Canyon and other regional attractions. Businesses include a campground, airplane museum, lodging, gift shops, gas station/convenience stores, and a small amusement park.

Tusayan

Tusayan is an unincorporated community located 1 mile south of the south entrance to Grand Canyon National Park on State Route 64. Tusayan serves as the gateway community to Grand Canyon National Park, and most residences and businesses are oriented around tourism associated with the park. Approximately 80 percent of the visitors to the south rim enter through the south entrance to Grand Canyon National Park, and therefore, Tusayan (National Park Service, 2006b). The community includes several hotel/motel complexes, an IMAX theater, a gas station, restaurants, an airport, and other visitor associated facilities. The Kaibab National Forest also has an office in the community. Few concessionaire or NPS staff reside in Tusayan. NPS plans to continue moving as many as 135 staff positions to Flagstaff in the coming years. However, the number of community residents in Tusayan significantly increases during the summer tourist season (Grand Canyon National Park, 2006).

Grand Canyon Village

Visitor and residential facilities supporting Grand Canyon National Park on the south rim of the Grand Canyon are concentrated in Grand Canyon Village. In addition to the lodging facilities, campground, and gift shops oriented to the park visitors, the village includes the NPS administrative and maintenance facilities, concessionaire administrative facilities, residential housing for Grand Canyon National Park and concessionaire staff, a public school, bank, medical clinic, and a shopping area. A concessionaire operates all of the lodging facilities, restaurants, and gift shops.

Total visitation to the south rim reached nearly 3.7 million by the year 2000 and then decreased sharply as a result of the events of September 11, 2001. In 2002, visitation to the south rim was approximately 2,700,000. However, visitation has since rebounded, reaching over 3,700,000 in 2004, the last year for which data are currently available (National Park Service, 2006b).

II.3 Ground Water/Geology Overview

II.3.1 Previous Studies

Victor and Montgomery (1999) conducted hydrogeologic and ground water flow modeling investigations for the Tusayan Growth Environmental Impact Statement (EIS) to project the potential impacts of pumping from the R-M Aquifer system in the Coconino Plateau area. Results indicated that long-term pumping from the

R-M Aquifer system will result in decreased flows from Havasu Springs and smaller springs under the south rim of the Grand Canyon. Projected impacts are largest for pumping centers located nearest the south rim and/or Havasu Springs and less for pumping centers furthest from the south rim. Presumably, the same criteria would apply to the sizes of the withdrawals as well.

Bills et al. (2000) evaluated the regional aquifer in the Flagstaff area. It is a complex regional aquifer that has become increasingly important as a source of water for domestic, municipal, and recreational uses. The ground water flow in the regional aquifer is poorly understood in this area because: (1) depth of the aquifer limits exploratory drilling and testing, and (2) the geologic structure increases the complexity of the aquifer characteristics and the ground water flow system. The investigators used four methods to improve the understanding of the hydrogeology of the regional aquifer near Flagstaff:

(1) Remote sensing techniques and geologic mapping

(2) Data from surface-geophysical techniques that included ground-penetrating radar, seismic reflection and seismic refraction, and square-array resistivity

(3) A well and spring inventory, borehole-geophysical methods, and well and aquifer tests

(4) Water-chemistry data, which included major ion, nutrient, trace element, and radioactive and stable-isotope analyses.

The investigators estimated the annual average recharge to the regional aquifer in the study area at about 290,000 acre-feet (AF). Ground water flows laterally and vertically through pore spaces in the rock and along faults and other fractures from high-altitude areas in the southern part of the study area, to regional drains north of the study area along the Little Colorado and Colorado Rivers, and to drains south of the study area along Oak Creek and the Verde Valley. Ground water discharge in these areas (about 400,000 acre-feet per year (AFY)) exceeds the annual recharge to the aquifer in the Flagstaff area, but ground water from areas outside the study area contributes to this discharge as well. The saturated thickness of the regional aquifer averages about 1,200 feet, and the amount of water in storage could be as much as 4,800,000 AF, or about 10 percent of the total volume of the aquifer. The regional aquifer is heterogeneous and anisotrophic and has a complex ground water flow system.

Hydro Geo Chem, Inc. (2001) prepared a series of "white papers" that summarized the previous works and studies for the N-, C-, and Alluvial Aquifers as part of the Western Navajo-Hopi Water Supply Needs, Alternatives, and Impacts Plan of Study prepared by the Bureau of Reclamation.

Pierce (2001) conducted a structural evaluation of ground water conditions in the Bill Williams Mountain area near Williams, Arizona. The regional northwest trending Cataract Creek Fault system and the regional northeast trending Mesa Butte Fault system intersect in the study area. Additionally, local north-south fault systems cut through the area. The faults are nearly vertical in the study area. These fault systems provide near-vertical flow paths for water to enter the regional aquifer system (R-M Aquifer), and the radial nature of the intersecting fault systems provides a pathway for waters to travel away from the area. Migration of water through the R-M Aquifer may be enhanced by solution features along fractures in the limestone.

Bills and Flynn (2002) compiled data for the Coconino Plateau between October 2000 and September 2001 consisting of geology, topography, hydrology, climate, land use, and vegetation patterns. They briefly describe the occurrence of ground water in a series of perched water-bearing zones, a regionally extensive aquifer, and a limestone aquifer. The perched water-bearing zones are of limited extent and only yield small amounts of water. The regionally extensive aquifer (Coconino Aquifer) consists of hydraulically connected, water-bearing zones in the Kaibab Formation, Coconino Sandstone, Schnebly Hill Formation, and sandstone units in the Upper and Middle Supai Formation. Other studies suggest that this aquifer drains into an underlying limestone aquifer along fractures and faults. The limestone aquifer consists of water-bearing zones in the Redwall and Mauv Limestones and the Temple Butte Formation. Water-bearing zones in the Devonian Limestones, where present, are also a part of this limestone aquifer.

Flynn and Bills (2002) put together USGS Factsheet 113-02, which briefly describes the geology and hydrology of the Coconino Plateau west of the LCR and north of the Verde River. They state that ground water is known to exist in several perched water-bearing zones and in two regional-flow systems. They further state that these water-bearing zones are not well defined and that the flow between them is not well documented. Highly fractured rocks in the regional-flow systems can be either conduits or barriers to the general flow of ground water, and their relation to the occurrence and movement of water in the regional-flow systems in not well understood (Bills, 2006).

Hart et al. (2002) evaluated the C-Aquifer that underlies the Little Colorado River Basin and parts of the Verde and Salt River. They stated that the areal extent of this aquifer is more than 27,000 square miles. More than 1,000 well and spring sites were identified in the USGS database for the C Aquifer in Arizona and New Mexico. The C Aquifer is the most productive aquifer in the Little Colorado River Basin. The LCR is the primary surface water feature in the area, and it has a direct hydraulic connection with the C Aquifer in some areas. Ground water discharge as base flow from the C Aquifer to the LCR occurs from Salado Spring near St. Johns to Joseph City. C Aquifer springs also occur in Silver Creek and the lower reaches of Chevelon and Clear Creeks. R-M Aquifer springs that discharge in the lower 13 miles of the LCR maintain the base flow of this reach of the river and represent a regional drain for much of the north flowing ground water in the LCR Basin. Ground water mounds or divides exist along the southern and northeastern boundaries of the LCR Basin. The ground water divides are significant boundaries of the C Aquifer; however, the location and persistence of the divides potentially can be affected by ground water withdrawals. Ground water development in the C Aquifer has increased steadily since the 1940s because population growth has produced an increased need for agricultural, industrial, and public water supply. Ground water pumpage from the C Aquifer during 1995 was about 140,000 AF. Hart et al. (2002) evaluated the ground water budget components for the C Aquifer using measured or estimated discharge values. The system was assumed to be in a steady-state condition with respect to natural recharge and discharge, and the stability of discharge from major springs during the past several decades supported the steady-state assumption. Downward leakage to the Redwall-Mauv Limestone Aquifer is a major discharge component for the ground water budget. Discharge from the C Aquifer was estimated to be 319,000 AFY.

Kessler (2002) conducted a modeling study of the R-M Aquifer of the Coconino Plateau sub-basin and of the Grand Canyon area. The three-dimensional model was based on the USGS MODFLOW2000 code and calibrated to the few known head measurements in the R-M Aquifer and to the springs below the south rim of the Grand Canyon. Modeling results indicated that Havasu Springs captures the vast majority of the regional R-M flows and that smaller springs below the south rim have smaller capture zones that are limited to the region near the south rim.

Ward (2002) wrote an article for Southwest Hydrology based on the Hart et al. (2002) report, in which he stated that the C-Aquifer underlies 27,000 square miles of the LCR Basin in northeastern Arizona and northwestern New Mexico. The amount of storage in the C Aquifer has been estimated to range up to 400 million acre-feet (Cooley et al., 1969, McGavock et al., 1986, and Hart et al. 2002).[12] In 2002, withdrawals from the C-Aquifer exceeded 140,000 AFY and were growing

[12] Some have theorized there may be as much as 1 billion acre-feet in storage in the C-Aquifer (Ward, 2002).

at a rate of 3 to 4 percent per year. The C-Aquifer is recharged along its southern flanks from Flagstaff to the White Mountains, on the eastern side of Arizona along the Defiance Uplift, and in western New Mexico along the Zuni Uplift. Ground water diverges from these recharge zones, and most of it flows westward to discharge in the LCR and the Grand Canyon. Annually, about 200,000 to 300,000 AF of water discharges into the upper LCR and its tributaries; however, the largest discharge is at Blue Springs above the confluence with the Colorado River at more than 160,000 AF. About 130,000 AF flows southerly into the Salt and Verde watersheds.

HDR Engineering, Inc. (2004) conducted an extended assessment of the Western Navajo and Hopi Reservations' water supply needs, alternatives, and impacts. They evaluated existing conditions for the N-Aquifer, the C-Aquifer, and the Alluvial Aquifer along the LCR. They also assessed potential/probable growth within the study area, evaluated the potential for the aquifer systems to support the growth, and evaluated the potential impacts of the growth on the aquifer systems. During the assessment, they evaluated previous ground water models, developed new ground water models, and used the models to evaluate a number of potential alternative projects to meet the needs of the projected growth.

Kobor (2004) used a coupled surface water/ground water model to evaluate the impacts on woody riparian vegetation within the Cottonwood Springs and Indian Gardens Springs systems. Decreased flows could be the result of increased pumping from the regional aquifer or from decreased recharge due to climatic conditions. The model accurately simulated measured values between March 2003 and January 2004. Based on statistically significant trends at these two spring systems since 1994, the model suggested that with increased pumping and continuation of climatic conditions (i.e., drought conditions), there is a potential for alteration of spring-fed ecosystems of the south rim over relatively short timespans.

Monroe et al. (2004) completed a geochemical study of ground water discharges along the south rim of the Grand Canyon. They evaluated 20 sampling locations in springs and creeks issuing from the Redwall-Mauv Limestone over a 17-month period from May 2000 to September 2001. The chemistry of each spring and creek did not vary over the period of the study, but the chemistry of each site varied considerably between sites, indicating spatial variability in the ground water composition. Most sites had a calcium magnesium bicarbonate composition, a few had a substantial sulfate composition. Isotope analysis indicated that residence times for the ground water discharges (the time between when the water percolates into the aquifer and the time it discharges from the aquifer) varied from 50 years to over 3,400 years. Younger waters were absent from several sites, and most sites were a mixture of young and old waters. This suggests that the water discharging from the R-M Aquifer follows multiple flow paths and has multiple recharge areas.

Hoffmann et al. (2005) collected and analyzed water quality samples from an aquifer testing program near Leupp, Arizona, in support of the Bureau of Reclamation's testing program in that area (Black et al., 2006). They also collected and summarized the geologic and hydrologic data for the C-Aquifer in the area of Leupp, Arizona.

Leake et al. (2005) developed a numerical ground water model to evaluate the impacts of pumping withdrawals from the C-Aquifer on selected reaches of Clear Creek, Chevelon Creek, and the LCR. The perennial flows in these three streams are maintained by discharges from the C-Aquifer. The study evaluated the potential depletions in streamflows from withdrawals from the C-Aquifer in the vicinity of Leupp, Arizona, to meet the needs of the Black Mesa Mine, along with municipal needs of the Navajo and Hopi Reservations. Maximum withdrawal rates produced a maximum depletion on all stream reaches of less than 0.6 cubic feet per second (cfs), or about 6 percent of the ultimate volume of water produced.

S.S. Papadopulos & Associates, Inc. (2005) developed a ground water flow model of the C-Aquifer in northeastern Arizona and northwestern New Mexico. The purpose of this model was to evaluate the potential impact of a proposed well field south of Leupp, Arizona. Specific areas of cultural and environmental interest addressed by the model were Chevelon Creek, Clear Creek, and Blue Springs. Estimates of water use in the basin over the period 1950-2000 were compiled, and values for transmissivity, storage coefficient, and recharge were varied to achieve a good correlation between observed and calculated values. Calibration targets included historical water levels, water level changes, and streamflows. The calibrated model is consistent with observed historical water level trends, baseflows in Chevelon and Clear Creeks, and transmissivity values derived from recent long-term aquifer tests in the vicinity of the proposed well field. The results indicate that under all potential project scenarios there is an adequate water supply for the proposed well field. The project pumping has a relatively small impact on wells outside of the well field and virtually no impact on the annual discharge rate at Blue Springs. The greatest impact on baseflow in the lower, perennial reaches of both Chevelon and Clear Creeks is due to future regional pumping under either baseline scenario. The increased stream depletion due to project pumping is a small fraction of the total impact; it is also a small fraction of the total flow in these streams. Evaluation of water quality data from within the area of probable capture suggested that the water obtained from the potential well field would be of adequate quality for public and industrial use.

Black et al. (2006) conducted an exploratory drilling and aquifer evaluation program to evaluate the potential water supplies in the C-Aquifer for supplying water to the Black Mesa Mine in lieu of the mine using waters from the N-Aquifer. As part of the study, hydrologic data collected as part of the drilling program was used in a numerical model to simulate the impacts on the C-Aquifer from pumping 6,500 AFY and 11,600 AFY at a site in the vicinity of Leupp, Arizona. The study concluded that there are waters of sufficient quantity and quality for the identified purpose. Additionally, the impacts of the proposed pumping are minimal and consistent with findings of C-Aquifer ground water models developed previously by Federal agencies and private interests.

II.3.2 Geologic Framework

The following section summarizes the geology of the Coconino Plateau and the local surrounding region associated with the study area. Because the aquifers of interest in the study area are the Permian aged Coconino Aquifer and the Mississippian aged Redwall Aquifer (and, possibly, the Cambrian aged Mauv Limestone where it is in contact with the Redwall Limestone), the summary only looks at the stratigraphy from the Precambrian through the Permian. Descriptions of the formations and units are based primarily on exposures in the Grand Canyon as described by Beus and Morales (1990). Correlation of the formations and units across the Coconino Plateau are based on exposures in the Grand Canyon and interpretations from drill-hole logs.

The Grand Canyon presents a unique window onto the stratigraphy and geologic history of the rocks comprising the Coconino Plateau of the study area. Because the Grand Canyon presents over 200 miles of continuous exposures of the stratigraphic sequence of rocks making up the adjacent Coconino Plateau, a unique opportunity is available to understand and interpret the geologic history of the area—an opportunity that is seldom available from limited and scattered drill-hole data.

Within the extent of the Grand Canyon and its many tributary canyons, there are exposures of rocks dating back to the late-early Proterozoic Eon 1700 million years ago (MYA) and extending up to the middle Permian Period of the late Paleozoic Era, a mere 260 MYA. The many plateaus adjacent to the Grand Canyon continue the stratigraphic sequence of geologic history from the middle Permian Period to the current Holocene Epoch. There are many gaps in the geologic history, to be sure, but within the Grand Canyon and the surrounding plateaus, there is a unique record of the geologic history of the region. This history allows for a unique perspective of the hydrologic resources and properties of the Coconino Plateau region.

Figure II.3-1 represents a generalized section of the formations and units in the Grand Canyon column, including delineation of the major water-bearing horizons that comprise the two major aquifers in the study area. Figure II-3.2 relates the formations and units of the Grand Canyon column to the Geologic Time Scale. Figure II.3-3 is a fence diagram of representative geologic sections throughout the Grand Canyon.

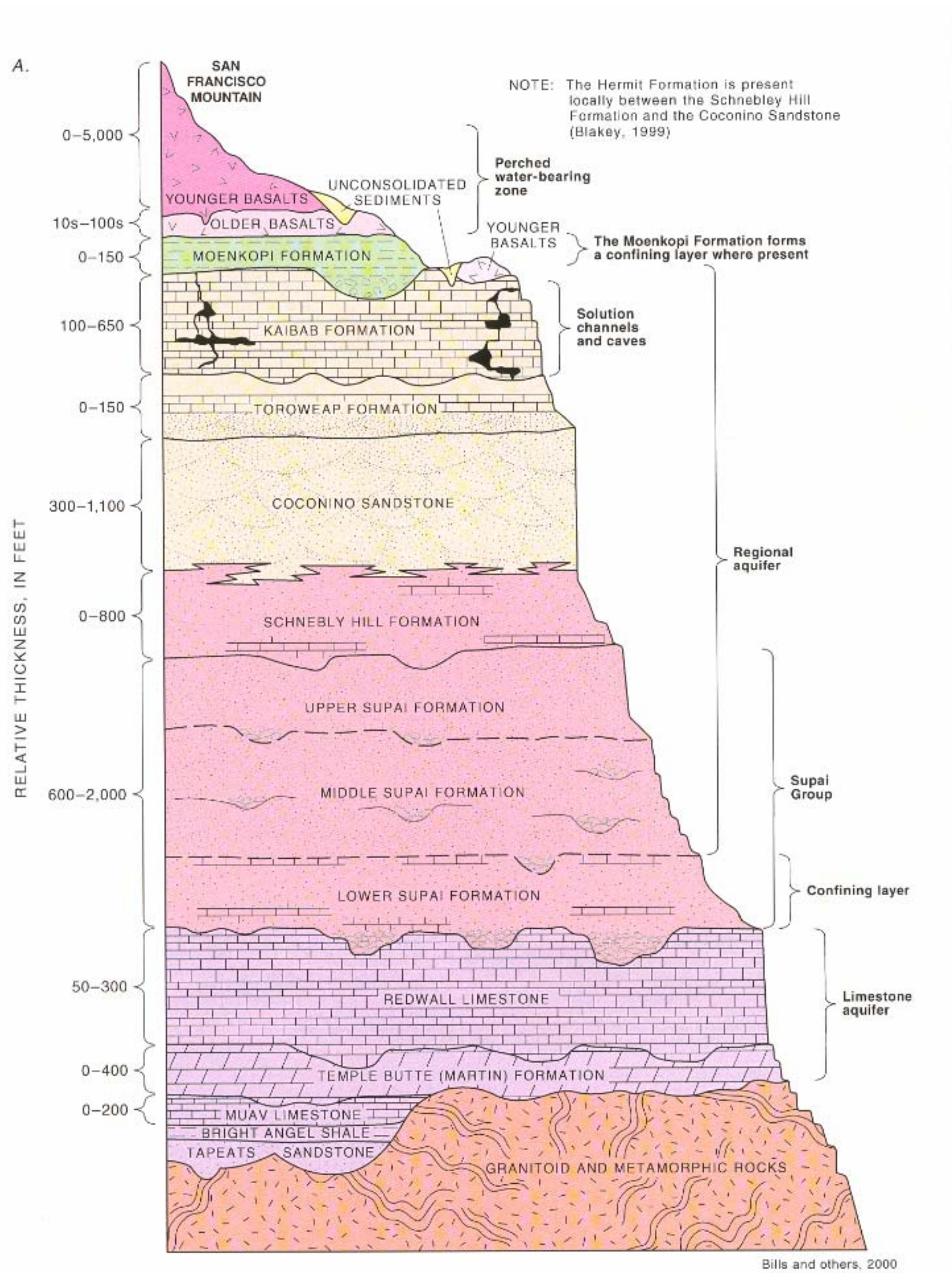

Figure II.3-1. Generalized stratigraphic section of the Coconino Plateau, Arizona, with regional aquifer (C-Aquifer) and Limestone Aquifer (R-M Aquifer) delineated (figure 3 from Bills and Flynn, 2002).

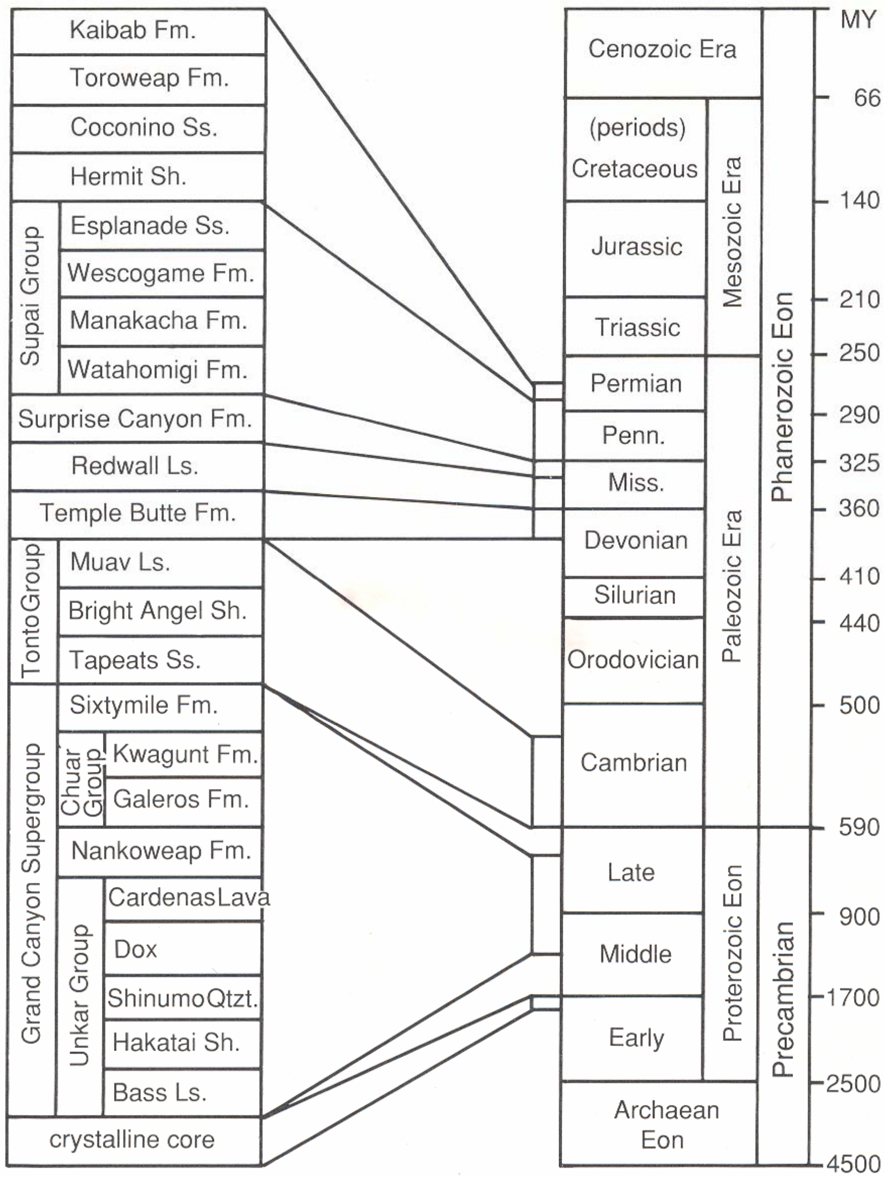

Figure II.3-2. Formations in the Grand Canyon in relation to the Geologic Time Scale (Beus and Morales, 1990).

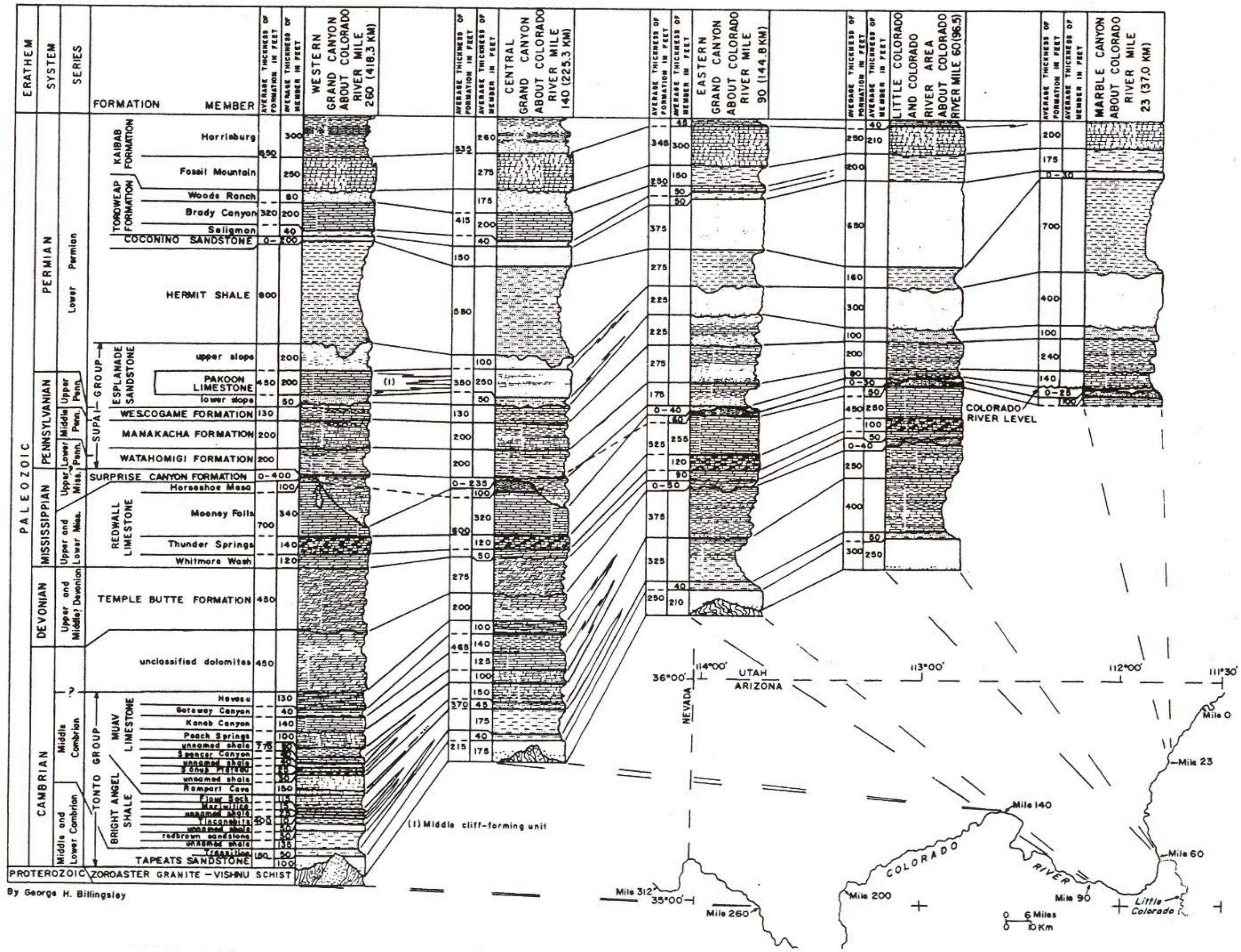

Figure II.3-3. Stratigraphic sections through the Grand Canyon, from west to east, showing the thickening and facies changes in Paleozoic rocks in the Grand Canyon area (after Beus and Billingsley, 1989).

To date, all of the boreholes that penetrate the Precambrian basement rocks underlying the southern Colorado Plateau in North Central Arizona encounter granite or granite rubble (Bills and others, in press).

The Cambrian sediments consist of the Tonto Group (figures II-3.1, II.3-2, and II.3-3)**,** which is comprised of the Tapeats Sandstone, Bright Angel Shale, and Mauv Limestone of early to middle Cambrian age, respectively. The Tonto Group is essentially horizontal and lies unconformably on the tilted and eroded Grand Canyon Supergroup at the Grand Canyon and on Precambrian Granites in the rest of the study area. The contacts between the units of the Tonto Group are gradational. The units represent a generally transgressive shoreline—again transgressing from west to east—with minor fluctuations in sea level. Like the underlying sediments of the Grand Canyon Supergroup, the units of the Cambrian Tonto Group get thicker to the west and thin to the south and east.

The contact between the Cambrian formations and the overlying middle to late Devonian Temple Butte Formation represents an unconformity consisting of the late Cambrian, Ordovician, Silurian, and early to middle Devonian periods—a time period of more than 100 million years (figure II.3-2). The Temple Butte Formation is predominantly a dolomite or sandy dolomite with minor sandstone and limestone beds. The Temple Butte Formation is encountered at both the south rim of the Grand Canyon and at the Mogollon Rim, where it interfingers with and grades into the Martin Formation. South of the Grand Canyon, the Temple Butte and Martin Formations are used interchangeably. Neither the Temple Butte nor Martin Formation has been encountered by wells on the Coconino Plateau (Bills et al., in press).

The overlying early to late-early Mississippian Redwall Limestone (figures II.3-1, II.3-2, and II.3-3) lies unconformably on the Temple Butte Formation in the central and western parts of the Grand Canyon and on the Cambrian in the eastern parts where the Temple Butte is missing. The Redwall is thickest in the west and thins to the east, representing a west-to-east transgression of the seas across the region. The upper surface of the Redwall Limestone consists of an unconformity representing the late-middle to early-late Mississippian period. This surface represents the development of a karstic topography with several hundreds of feet of relief. The late Mississippian Surprise Canyon Formation occurs as isolated, lens-shaped exposures of clastic and carbonate rocks filling erosional valleys, karsted topography, and caves in the top of the Redwall Limestone. The erosional valley fill becomes thinner and wider to the east.

The Supai Group and Hermit Formation of Pennsylvanian and early Permian age represent continental, shoreline, and shallow marine sediments composed of sandstones, mudstones, limestones, conglomerates, and gypsum. The basal formation consists of lower and upper mudstone/siltstone units separated by a middle limestone/dolomite unit. The basal unit thickens from about 100 feet in the eastern part of the Grand Canyon to 300 feet in the western part. Locally, the basal formation thins and pinches out against topographic highs on the Redwall Limestone erosional surface.

The remaining three formations of the Supai Group represent a distinct change in the depositional environment of the Grand Canyon region. Prior to the Mississippian Period, the lithology of the sediments in the region were dominated by carbonates, mudstones, and siltstones. With the Mississippian Supai Group, the dominant lithologies are sandstones deposited in eolian and shallow subaqueous environments. However, like previous formations, these units also thin to the east and thicken to the west. East of the Grand Canyon region, the Supai Group is dominated by mudstones; west of the Grand Canyon region, the Supai Group is dominated by carbonates.

Overlying the Supai Group is the Hermit Formation of early Permian age. The Hermit Formation consists of interbedded silty sandstones and sandy mudstones. The Hermit Formation is thinnest to the east and thickens to the west. The upper contact of the Hermit Formation probably represents a regional disconformity and often displays mud cracks up to 20 feet deep that are filled in with the overlying Coconino Sandstone.

The Schnebly Hill Formation was formally named based on work by Blakely (1990) Blakely and Knepp (1989), and Elston and DiPaolo (1979). The Schnebly Hill Formation is distinct from the Hermit Shale of the Grand Canyon and represents a transition phase between the Coconino Sandstone and the Supai Group. The contact between the Schnebly Hill and the Coconino Sandstone is gradational, and the contact between the Schnebly Hill and the Supai Group is erosional. In some areas near Flagstaff, and to the south and west of Flagstaff, the Schnebly Hill Formation is the principal water-bearing zone of the C-Aquifer.

The Permian aged Coconino Sandstone is an eolian sandstone with a wide range of thicknesses across the region. Generally, it is thickest in the central part of the Grand Canyon and thins to the west, north, and northeast, where it pinches out in southwestern Utah and in the Monument Valley area. Eastward, it transitions into the Glorieta Sandstone in New Mexico. In contrast, it appears to thicken to the south towards the Mogollon Rim in the region of the Sedona Arch, but some of the thickening may be a facies change in the overlying Toroweap Formation that resembles the Coconino Sandstone. The Coconino Sandstone is conformably overlain by the Toroweap Formation, or where the Toroweap is absent or undergoes a facies change in the underlying Schnebly Hill Formation that resembles the Coconino sandstone. The Coconino Sandstone is conformably overlain by the Toroweap Formation to the west. To the east, the Coconino Sandstone is unconformably overlain by the Kaibab Formation.

The Toroweap Formation is a highly variable formation that exhibits major facies changes across the region. In the western and northwestern portion of the region, it consists of interbedded gypsum, carbonate, and irregularly bedded sandstone members. Towards the east and south, the gypsum and carbonates are phased out, and the irregularly bedded sandstones dominate the formation. These sandstones are virtually indistinguishable from the underlying Coconino Sandstone. The Toroweap Formation also thins to extension to the east and south of Flagstaff.

The Kaibab Formation rests unconformably on the Toroweap Formation or the Coconino Sandstone and is exposed at land surface along the Grand Canyon and much of the adjacent Kaibab and Coconino Plateaus. The Kaibab Formation is divided into two members representing a complex sedimentary system composed of a variety of lithologies. However, because of mixing of carbonate siliciclastic sediments during deposition, and postdepositional alterations (diagenesis) involving silicification and dolomitization, the Kaibab has a very uniform look throughout the region. The Kaibab is up to 500 feet thick under the Kaibab Plateau, 400 feet thick in the Grand Canyon, and pinches out against the Defiance and Monument uplifts east of Page, Arizona, and southeast of Holbrook, Arizona (figure II.3-4). The lower member is predominantly cherty limestone in the western portion of the region but becomes more siliciclastic to the east and southeast with sandstones, sandy carbonates, and dolomite predominating.

The geologic history of the region, as recorded in the stratigraphic sections of the Grand Canyon (figure II.3-3), shows an almost uniform history of west/northwest to east/southeast transgressions of the seas onto the margin of the North American Craton from the Precambrian through the Permian, a time period of over 1,400 million years (MY). Figure II.3-4 is a map of Arizona with outlines of paleo-physiographic provinces and more recent structural regions. The Grand Canyon Embayment and associated syncline represent the general area over which the west/northwest to east/southeast transgressions occurred. The maximum extent of transgression varied throughout time, and there were extended periods of erosion between subsequent formations. This results in the extent of the formations in Northern Arizona being variable, in that some formations extend across most of Northern Arizona in fairly thick and uniform layers, while other formations are thin or nonexistent just to the east of the Grand Canyon region. Regional and local tectonic events, not discussed herein, have also contributed to the variability of the presence and thickness of individual formations at any given location.

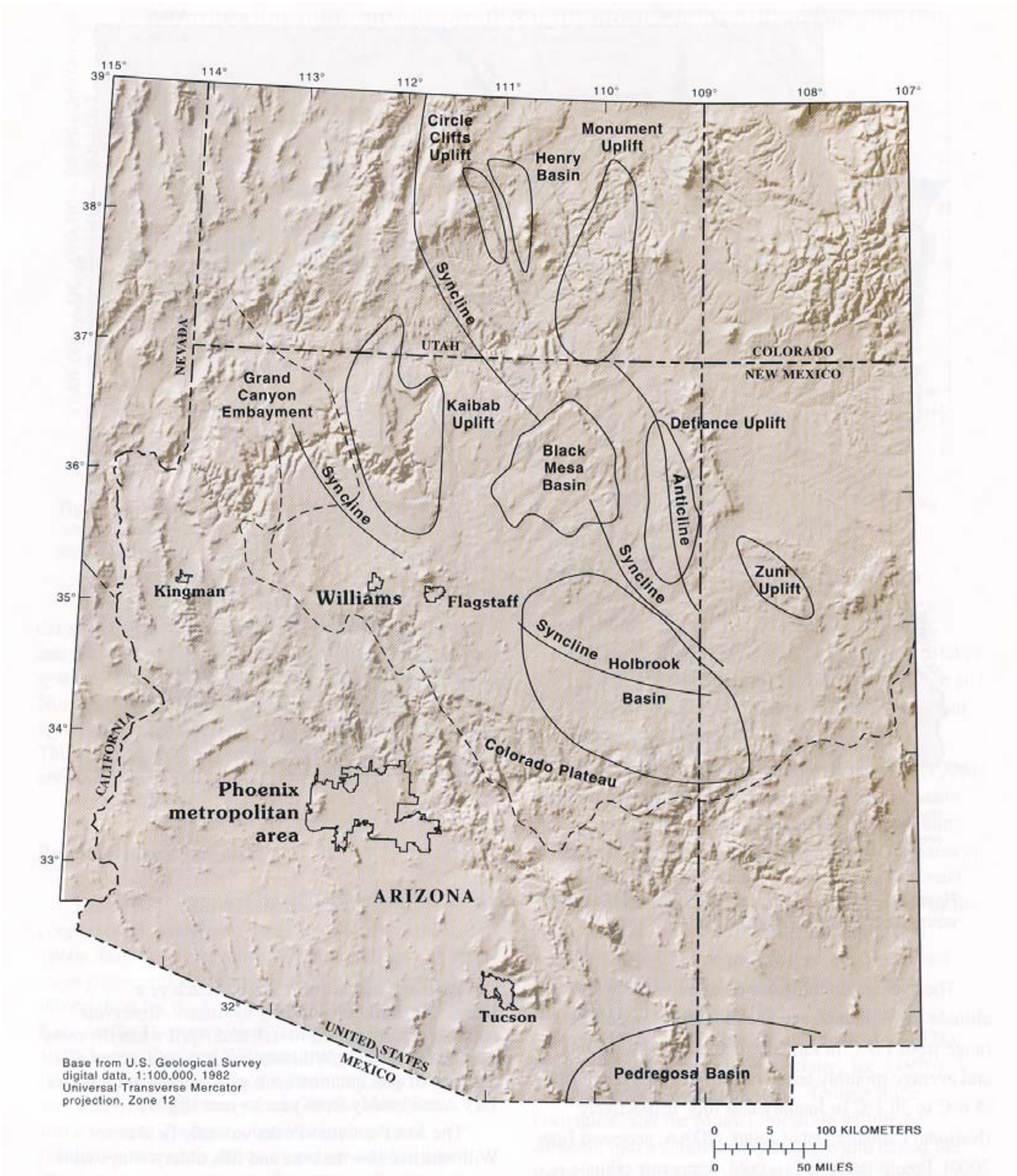

Figure II.3-4. Structural map of Arizona and the Four Corners area (figure 2 from Pierce, 2001).

The majority of the sequence from the Precambrian through the early Pennsylvanian Period, nearly 1,385 MY, is dominated by siltstones, mudstones, and carbonates. During the deposition of the early Pennsylvanian aged Supai Group, the dominant lithologies were eolian sandstones, siliciclastics, silty sandstones, sandy carbonates, and evaporites. The Supai Formation was followed by four Permian aged formations, the Hermit Formation (interbedded silty sandstones and mudstones), the Coconino Sandstone (thick eolian sandstones), the Toroweap Formation (widespread facies changes between evaporites, sandy limestones, irregularly-bedded sandstones, and thick eolian sandstones), and, finally, the Kaibab Formation (cherty limestones transitioning to siliciclastic dolostone, sandstones, redbeds, and evaporites). The more clastic sequence of the early Pennsylvanian through Permian in the Grand Canyon region represents about 50 MY of deposition and erosion.

Figure II.3-3 represents the overall trends in the geologic column in the Grand Canyon region. In general (there are some localized exceptions to the general trends along the Grand Canyon), the marine units thicken and contain more carbonate units to the west and north. The clastic formations and units associated with continental deposition become thicker and contain fewer and thinner carbonate units to the south and east. Other trends to note are: (1) the younger rocks (higher in the geologic column) tend to be dominated by continental depositional units, whereas the older rocks (lower in the geologic column) tend to be dominated by marine units, and (2) marine and continental shelf deposits prominent at the Grand Canyon thin and interfinger south and eastward as these units encounter the continental margin. Both of these trends suggest that the early depositional history of the area was dominated by island-arc and continental margin processes at the edge of the young North American Craton. Over time, as the Craton grew and the continental margin expanded, the shoreline migrated to the west and the area was dominated by continental and erosional processes.

II.4 Surface Water and Ground Water Supply Sources Overview

Flynn and Bills (2002) provide a synopsis of hydrology for the Coconino Plateau. The following paragraphs are excerpts from their USGS factsheet.

Surface drainages on the Coconino Plateau can be divided into three general categories: (1) young, (2) mature, and (3) internal. Most of the young drainages are at the margins of the Coconino Plateau, drain north toward the Colorado River or south toward the Verde River, and are short and steep. These young drainages tend to be deeply incised into the sedimentary rocks, and springs can occur where the drainages intersect the ground water flow systems. The only drainages that have the appearance of mature river valleys are the LCR, Cataract Creek, and the Verde River. These drainages are well developed and reach most parts of the Coconino Plateau. There are internal drainages on the Coconino Plateau, the result of continuing extensional process and quaternary volcanic activity, flow where surface water infiltration recharges the ground water systems locally.

Ground water resources in the Coconino Plateau region are contained in two main aquifer systems – the C-Aquifer and the R-M Aquifer. A third aquifer system, the

N-Aquifer, is higher in the stratigraphic section than the C-Aquifer or the R-M Aquifer and only occurs in regions to the east of the study area. Minor ground water resources exist in the form of alluvial channel aquifers, primarily along the LCR and perched water-bearing zones in the volcanic rocks and the Kaibab Formation.

II.4.1 Alluvial Aquifer and Other Perched Water-Bearing Zones

The alluvial channel aquifers are associated with the perennial and intermittent streams in the study area. Most of these streams exist in incised canyons. As such, these aquifers would be of limited extent and capacity and would be highly dependent upon flow conditions in the associated streams. Water resources from these aquifers would be suitable for alternative supplies as backups to other supplies, emergency drought supplies, or small individual or community systems.

Perched water-bearing zones are also encountered in volcanic rocks and the Kaibab Formation to the north, west, and south of Flagstaff. These water-bearing zones are relatively small and discontinuous in the subsurface with yields to wells of a few, to a few 10's of gallons per minute (gpm) (Bills et al., 2000). Recharge to these water-bearing zones is by infiltration from the surface and is entirely dependant on annual precipitation. As a result, the availability of water from these zones can be highly variable from year to year. Water resources from these units are only suited for limited low-volume uses, such as local domestic and livestock use. The one exception to these conditions is the Inner Basin Aquifer of San Francisco Mountain. This water-bearing zone is contained in glacial outwash and volcanic rocks of San Francisco Mountain, can yield up to several hundred gpm to wells, but has been fully developed by the City of Flagstaff as one of its sources of water supply.

The Little Colorado River Alluvial Aquifer Basin parallels the river for about 25 river miles. It ranges in width from about ½ mile to 3 miles and has a maximum thickness of 150 feet. Recharge is from direct infiltration of precipitation, infiltration from surface flows in the river, and, possibly, from upward leakage from the underlying C-Aquifer at the middle and upstream end of the drainage. Precipitation in the area is only about 7 inches per year, so direct infiltration of precipitation would only be a minor component of the recharge. Flows in the alluvium are to the northwest, generally in the downstream direction. Discharge from the alluvial aquifer is through evapotranspiration, downward leakage, and discharge to the surface or underflow at the downstream aquifer boundary. Model estimates by HDR (2004) suggested that the LCR Alluvial Aquifer could produce about 1,700 AF on an every-other-year basis.

II.4.2 N-Aquifer

The N-Aquifer consists of water-bearing sandstone units of the Glen Canyon Group and is named for the primary sandstone unit: the Navajo Sandstone. The N-Aquifer underlies approximately 5,400 square miles of the Little Colorado River Basin, primarily beneath the Navajo and Hopi Reservations, but it does extend outside of the Little Colorado River Basin to the north into Utah. The aquifer is thickest to the northwest and thins to extinction on the southern and southeastern boundaries. Yields from the N-Aquifer are generally dependable, range from tens to more than 1,000 gpm, and the quality of the water is good. Recharge occurs in the Shonto and Granado areas, and on the Kaibito Plateau, flows to the southwestern and southeastern portions of the aquifer discharging to: Moenkopi Wash, springs in incised southwest trending drainages, along the Echo Cliffs at the western margin of the Black Mesa Basin, and in Chinle Creek. Recharge and storage volumes of the N-Aquifer are based mostly on modeling results. Estimates of recharge range from 2,500 to 13,000 AFY, depending on the size of the area assumed for the N-Aquifer and the model used (results of previous studies summarized in HDR, 2004, volume II, appendix A-1). Measured discharges from the N-Aquifer are a minimum of 7,000 AFY; however, not all of the smaller springs were included in all of the measurements, so these estimates would tend to be conservatively low. Estimates of the volume of water stored in the N-Aquifer vary from 180 to 400 million AF, again, depending upon what model is being used and what values are assumed for porosity, specific yield, and/or size of the aquifer.

A number of issues are associated with the N-Aquifer as it relates to meeting the water needs in the study area of the NCAWSS. These are:

- The N-Aquifer does not underlie the study area.
- The N-Aquifer is the sole source of water for many communities on the Navajo and Hopi Reservations.
- Many, if not most, of the N-Aquifer springs have cultural and/or religious significance to the Navajo and Hopi peoples.
- While the N-Aquifer is estimated to hold 180 to 400 million acre-feet in storage, its extent is considered limited by the areas' Native American tribes that feel ground water withdrawal in the future should remain within sustainable limits to ensure an adequate supply of water, in perpetuity, for future generations of tribal members.

These issues would make pumping and piping N-Aquifer waters to the study area expensive, both in terms of initial capital costs and long-term operation, maintenance, and replacement (OM&R) costs. Additionally, increased pumping from the N-Aquifer would impact the flows from many of the springs and would not be acceptable to the Navajo and Hopi Tribes.

II.4.3 C-Aquifer

The C-Aquifer, or the Coconino Aquifer, is comprised of a number of sedimentary units from the middle Permian aged Kaibab Formation (where present) down to the early middle Pennsylvanian aged middle Supai Group (variously called the Manakacha Formation or the middle Supai Formation). The primary aquifer unit is the Coconino Sandstone (and the laterally equivalent DeChelly and Glorieta Sandstones in New Mexico), but the overlying Toroweap and Kaibab Formations, where present, and the underlying upper and middle parts of the Supai Group can be locally significant water-producing units. Within the study area, the Toroweap Formation is generally absent in the eastern and northern parts of the Little Colorado River Basin and the Kaibab Formation thins to extension to the east.

The C-Aquifer is dry to the west of Flagstaff coincident with the northeast-southwest trending Mesa Butte Fault (Bills et al., in press). Springs in the Grand Canyon that issue from the Pennsylvanian and Permian Supai Group, the Permian Coconino Sandstone, and the Permian Kaibab Formation are related to localized or limited perched water-bearing zones. Figure II.4-1 is a generalized illustration of the localized flow regime near the Grand Canyon. Figure II.4-2 is an idealized illustration of a more regional flow system.

Precipitation that infiltrates volcanic rocks and the Kaibab Formation is the primary source of recharge for the water-bearing units of the C-Aquifer. Ground water movement through the water-bearing units is probably dominated by secondary permeability created by faults and fractures, and is enhanced by widening of the cracks through dissolution (Bill et al., 2002; Monroe et al., 2004). While these processes are evident in the Grand Canyon, by inference, these processes are probably active throughout most of the study area. Hereford et al. (2002) suggest that "Recent trends in Colorado Plateau precipitation and the Pacific Decadal Oscillation (PDO) suggest that the climate of the region may become drier for the next 2 to 3 decades in a pattern that could resemble the drought of 1942-1977. . . Water resources were heavily affected during the early part of the 1942-1977 drought . . . population of the region has increased fourfold since the mid-1950s, substantially increasing the demand for water in a region without abundant supplies and creating the possibility of severe or catastrophic consequences if such a drought were repeated."

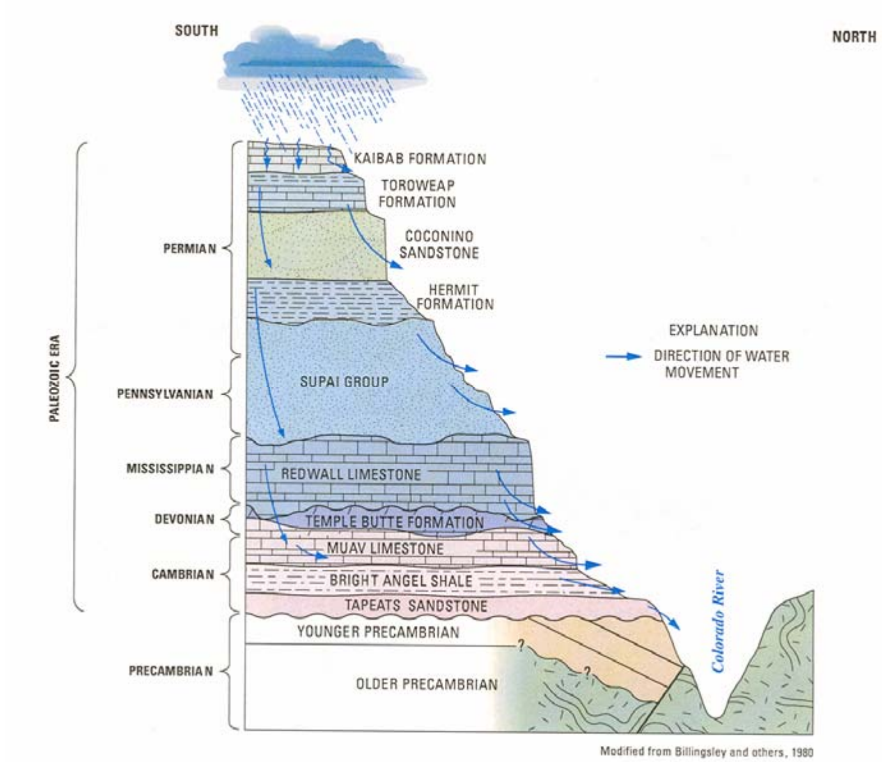

Figure II.4-1. Idealized illustration of local flow regime on the south rim of the Grand Canyon, showing local recharge from precipitation events and discharge at springs in the different formations of the Grand Canyon. Additional spring discharge may be due to a regional flow regime in the R-M Aquifer (Redwall Limestone through Tapeats Sandstone (after Monroe, et al., 2004).

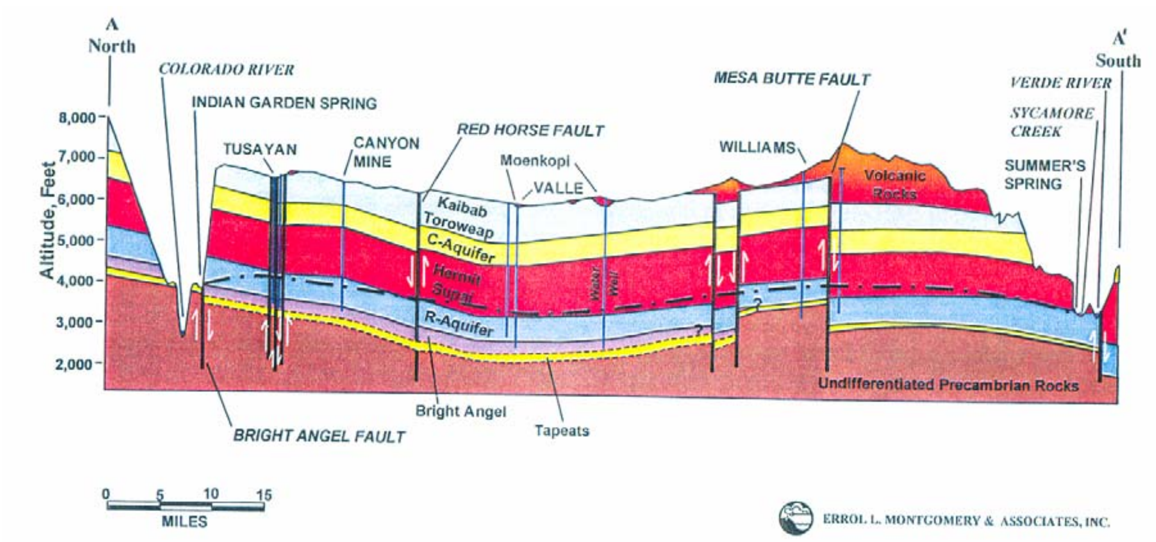

Figure II.4-2. Idealized cross section of the Coconino Plateau from the Verde River valley to the Grand Canyon, showing the regional flow systems in the C-Aquifer and the R-M Aquifer, along with the fault zones that are thought to be the main conduits for transmitting R-M Aquifer recharge from the C-Aquifer (after Victor and Montgomery, 2000).

Water quality in the upper and middle parts of the C-Aquifer (in the Kaibab Formation, the Coconino Sandstone, and the upper parts of the upper Supai Group) is generally reported as good to excellent. Because of the evaporite deposits in the middle Supai Group (the lower parts of the C-Aquifer where saturated), waters from this part of the C-Aquifer can often be salty and of poor quality.

The C-Aquifer has been extensively developed in localized areas, and the reported well yields range from a few gpm to as much as 1,000 gpm. Some of this variability is a function of the intended use of the well (domestic or stock wells do not generally require high yields). However, the yields probably do vary somewhat within the C-Aquifer, depending upon the size of the well, how much of the formation is penetrated by the well, the primary and secondary permeabilities, and other factors. Very few wells have been completed in the R-M Aquifer, so the range of potential yields is uncertain. Based on the wells that have been completed, the yields could range from as little as 30 gpm to as much as 250 to 500 gpm. (Victor and Montgomery, 2000; Bills et al., in press), depending upon the degree of secondary permeability (fracturing, faulting, solution cavities, etc.) encountered at any given location.

The hydraulic conductivity of the C-Aquifer generally varies between 4 to 5 feet per day and 6 to 7 feet per day, although locally it can be greater, depending upon the degree of secondary permeability developed in areas of faulting and/or fracturing (Cooley et al., 1969; McGavock et al., 1986; and Bills et al., 2000).

The C-Aquifer is partly to fully saturated east of the Mesa Butte Fault and unsaturated west of the fault, as shown in Figure II.4-3. The C-Aquifer outcrops to the south along the Mogollon Rim and in the Defiance Uplift area to the east. These two areas are major recharge areas for the C-Aquifer, although some localized recharge also occurs in other areas where the C-Aquifer is at or near ground surface. Estimates of total average annual recharge to the Little Colorado River Basin C-Aquifer system range from 170,000 to 190,000 AFY (HDR, 2004; Hart et al., 2002). Current potable demand on the C-Aquifer system is estimated to be in the range of 140,000 AFY.

On the face of it, there would appear to be adequate supplies of water available in the C-Aquifer to meet the demands of the study area. However, several issues are involved with using the C-Aquifer to meet the needs of the users within study area of the NCAWSS. These are:

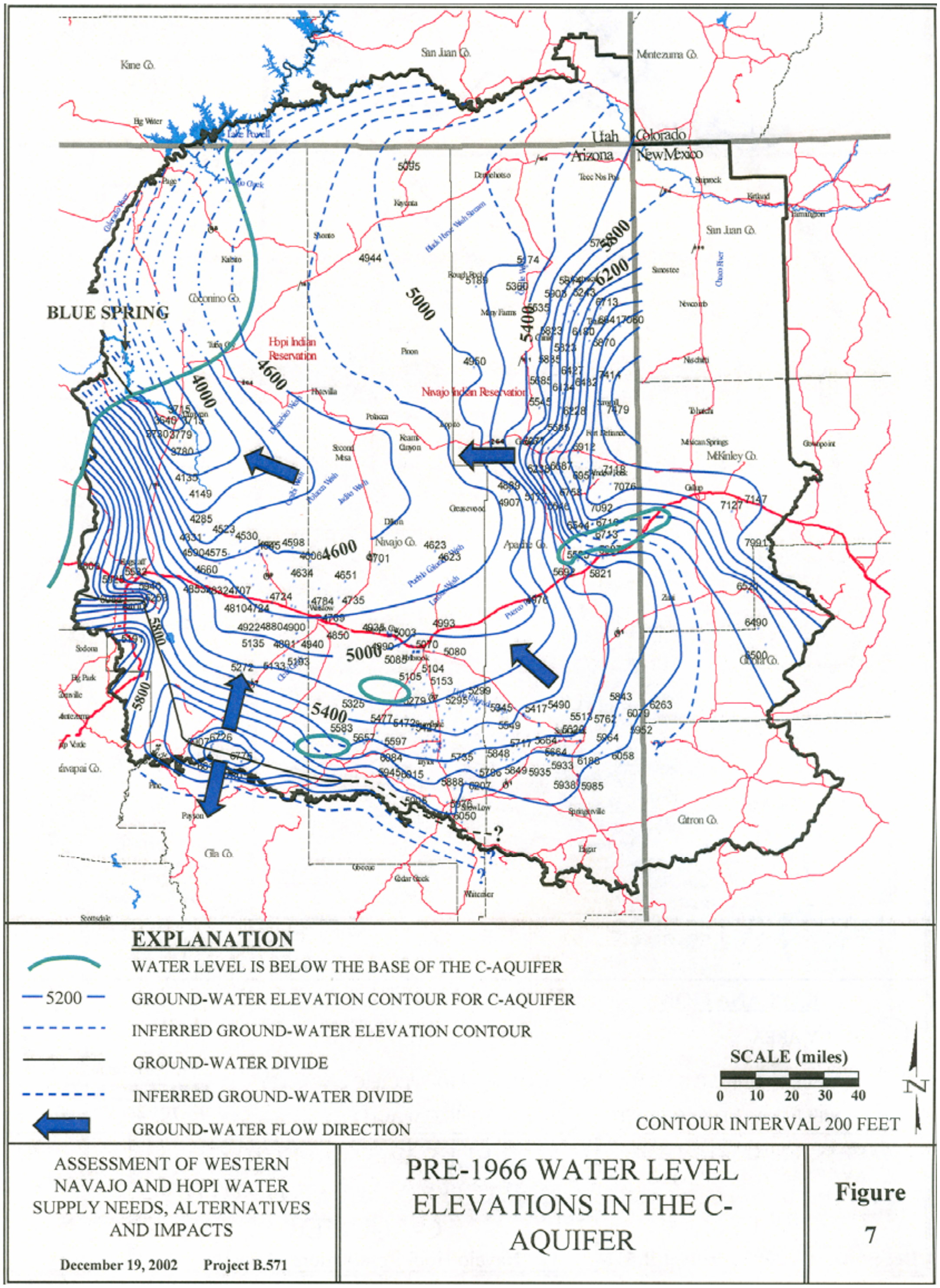

Figure II.4-3. Pre-1966 water levels in the C-Aquifer. Note that the green line on the northwest side of the study area indicates the point at which water levels drop below the bottom of the C-Aquifer. Within the NCAWSS area, the C-Aquifer is dry north of Cameron and west of Flagstaff (figure 7, volume 2, task 4.3 of HDR, 2004).

- The C-Aquifer is assumed to be in a transient state (condition under which parameters change over time) with current uses and spring discharges (Bills et al., in press).

- Current withdrawals have already impacted base flow of the LCR. Additional pumping from the C-Aquifer will likely impact flows from the springs.

- Flow from springs will also be impacted by precipitation and recharge.

- The C-Aquifer underlying the study area is mostly unsaturated.

- Pumping and piping water to the study area from the C-Aquifer will likely be costly in terms of capital costs and long-term OM&R costs.

- Not all the recharge to the C-Aquifer occurs near the study area.

- The water quality of the C-Aquifer degrades with increasing distance from the recharge areas and at increasing depths.

- The study area is at the downstream end of the C-Aquifer flow system, and increasing uses and demands upon the C-Aquifer from upgradient users will affect the water availability in the C-Aquifer closest to the study area.

- There are unquantified water rights and potential conflicts among competing ground water users resulting from unadjudicated claims in the Little Colorado River Basin.

II.4.4 R-M Aquifer

The primary water-bearing units of the Coconino Plateau in the vicinity of the Grand Canyon consist of the lower Paleozoic carbonate formations, commonly called the Redwall-Mauv Aquifer (R-M Aquifer). The R-M Aquifer is comprised of the mostly carbonate units of the Mississippian aged Redwall Limestone, the late Devonian aged Temple Butte/Martin Formation, and the Cambrian aged Mauv Limestone. Locally, where present, the basal Cambrian aged Tapeats Sandstone can also be a water producing unit. The primary water producing units are the Redwall Limestones to the north and the Redwall Limestone and Temple Butte/Martin Formation to the south.

The hydrogeology of the R-M Aquifer and the degree of connection with water-bearing zones in the overlying formations are not well understood. Few wells have been completed in the R-M Aquifer on the Coconino Plateau, and subsurface information is limited (Monroe, et al., 2004; Bills and Flynn, 2002). Modeling studies suggest that the regional flow in the R-M Aquifer is towards the Grand Canyon, and, in particular, Havasu Springs, as illustrated in figure II.4-4 (Springer and Kessler, 2000; Kessler, 2002). Recent regional studies indicate a local ground water mound coincident with the south rim of the Grand Canyon and trending east-west. This ground water mound affects recharge and flows of many of the small south rim springs and seeps that issue from the R-M Aquifer. Regional structure, the Cataract Syncline and the Mesa Butte Fault, control and direct most of the regional ground water flow in the R-M Aquifer to major discharge areas on the lower LCR and in Cataract Canyon to the north, and in the upper reaches of the Verde River to the south (Bills et al., in press; Wirt et al., 2005).

The regional water quality trends in the R-M Aquifer are less well known since very few wells have been completed in the R-M Aquifer. However, based on the few wells completed in the R-M Aquifer, and based on springs issuing from the R-M Aquifer in the Grand Canyon (Monroe et al., 2004; Bills et al., in press), water quality is generally good to poor. The poor quality waters of the R-M Aquifer appear to be the result of leakage from overlying units, solution of limestones within the flow system, and upwelling of ancient water from underlying units (Bills et al., in press; Dr. Laura Crossey, personal communication, n.d.).

The hydraulic conductivities of the R-M Aquifer are mostly unknown because of the relatively few number of wells completed in the formation. Modeling studies have estimated transmissivities for the R-M Aquifer that range from 0.3 feet per day to 320 feet per day (Springer and Kessler, 2000) to 0.1 feet per day to 742 feet per day (Victor and Montgomery, 2000). These estimates vary considerably with the lower values in zones of primary permeability and higher values in zones of secondary permeability developed from fractures, faulting, and/or solution cavities. The hydraulic conductivities of the R-M Aquifer would vary considerably since the thickness of the R-M Aquifer can vary from as little as 50 feet to as much as 900 feet, depending upon the area and whether or not the water-bearing zones consist of one or more of the Redwall Limestone, Temple Butte/Martin Formation, Mauv Limestone, and Tapeats Sandstone units. Hydraulic conductivity is related to transmissivity by the equation $K = T * b$ where K is hydraulic conductivity, T is transmissivity, and b is saturated thickness.

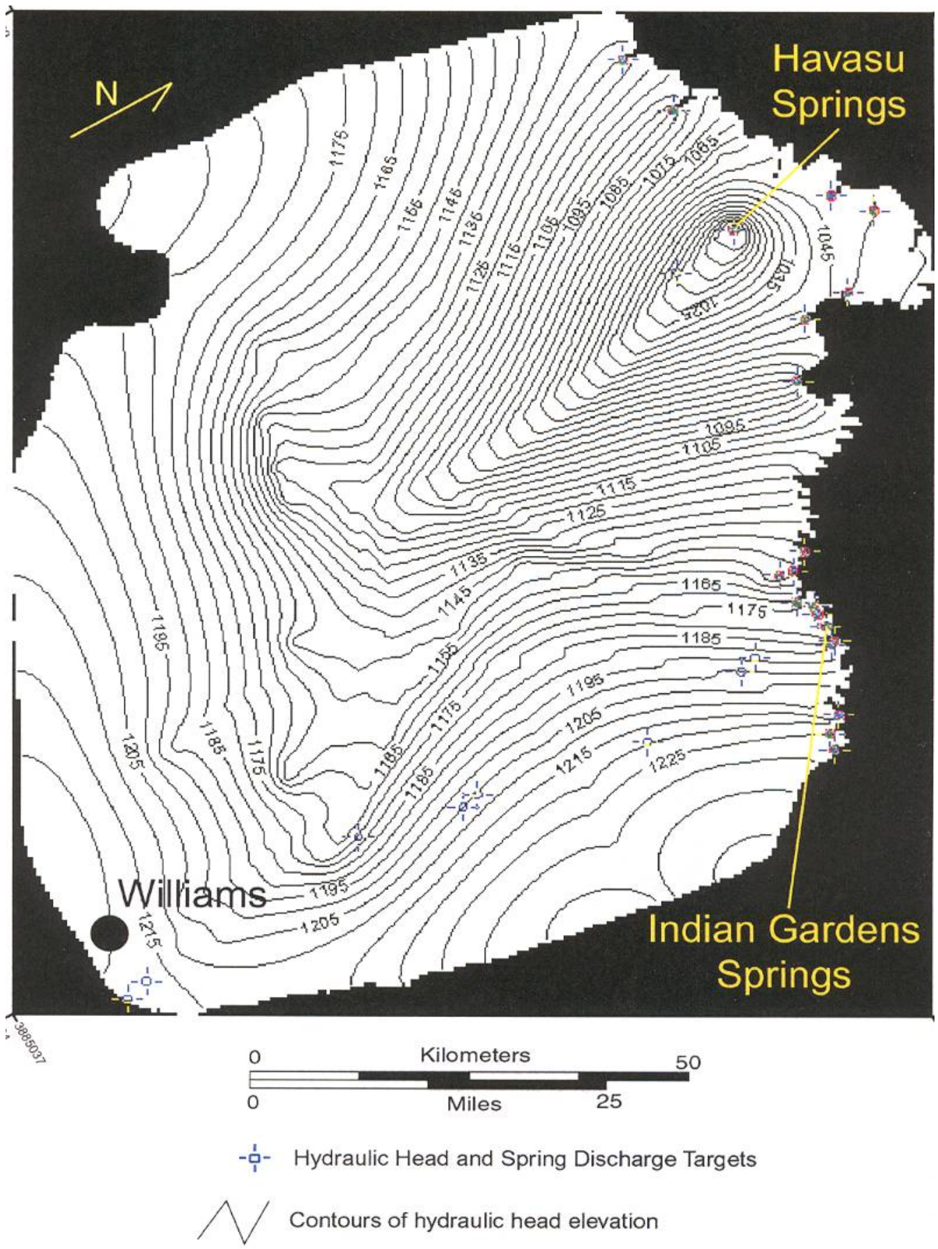

Figure II.4-4. Simulated potentiometric surface in the R-M Aquifer, showing major discharge point at Havasu Springs (after Kessler, 2002).

The R-M Aquifer is generally fully saturated and confined on both sides of the Mesa Butte Fault. It does not outcrop within the Coconino Plateau, so it is thought that the main source of recharge for the R-M Aquifer is downward leakage from the C-Aquifer along fault zones, particularly the Mesa Butte Fault zone. So, ultimately, the recharge to the R-M Aquifer would come from the same source as the C-Aquifer.

Demands and Impacts on the Aquifers

The N-Aquifer underlies the northern portion of the study area and contains both confined and unconfined portions (figure II.4-5). The confined portion underlies the Hopi Mesas, the Black Mesa Mine, and areas in between. It is characterized by deep saturated thickness and relatively high water quality, but little recharge. The unconfined portions are around the edges of the aquifer, whose western and southern edges underlie the communities of Tuba City and Dilkon. The N-Aquifer is not only a water supply source for the Tribes, but it also has religious significance, particularly through the many springs and critical stream reaches that it feeds. Pumping of the aquifer for any purpose, including irrigation, pumping plant cooling water, or municipal and industrial (M&I) supply, will eventually impact these springs and reaches. Accordingly, the issues of whether there is sufficient M&I water supply potential in the N-Aquifer, and how the use of the N-Aquifer will impact nearby springs and critical reaches, are of equal importance.

Estimated values for recharge, evapotranspiration, and stream gains/losses are almost entirely based on modeling results. The HWNSS evaluated previous modeling results. Two overriding problems are encountered in comparing the results of previous modeling studies: (1) the models typically do not have the same extent or cover the same areas, and (2) the boundary conditions, number of layers, and other basic parameters of the models vary significantly from one model to the next. Even so, the HWNSS presented a comparison of the various results as shown in tables II.4-1 through II.4-5 from the HWNSS (HDR, 2004).

Table II.4-1. Previous Recharge Estimates for HWNSS Model Area

Investigator	Procedure for Estimating Recharge	Percent of Average Annual Precipitation that Infiltrates and Becomes Recharge	Recharge on the N-Outcrop Area (AFY)
Lopes and Hoffman (1997)	Geochemical (^{14}C)	0.68	8,108
PWCC (1999)	% of precipitation	0.92	10,894
Geotrans (1987)	% of precipitation	1.04	12,381
Eychaner (1983)	% of precipitation	1.11	12,930
Brown and Eychaner (1988)	% of precipitation	1.11	13,380
Zhu (2000)	Geochemical (^{14}C)	1.46	17,400
HydroGeoChem (1991)	% of precipitation	1.62	25,800

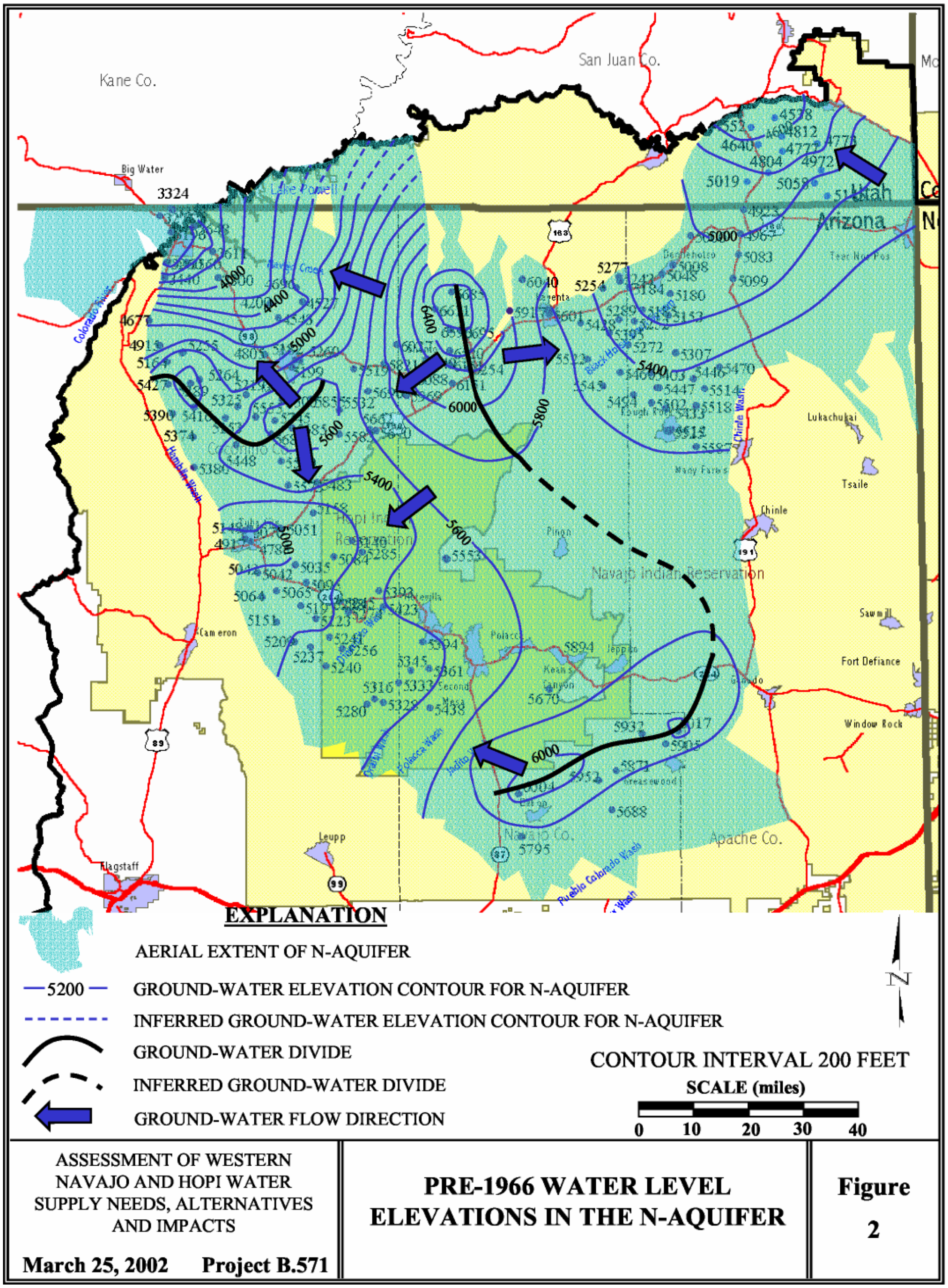

Figure II.4-5. Pre-1996 water level elevations in the N-Aquifer (HDR, 2004).

Table II.4-2. Model Diffuse Recharge Comparison

Model	Diffuse Recharge (AFY)
HWNSS Model (HDR, 2002)	12,000 on D, 48,600 on N (10,400 on Shonto Plateau)
HGC Model (HGC, 1991)	27,000 (2,000 on D, 24,900 to 27,200 on N; 14,900 to 16,200 on Shonto Plateau) – recharge is net: reduced by diffuse evaporation
USGS Black Mesa Model (Brown and Echnayer, 1988)	13,400 (all N; 5,800 on south half of Shonto Plateau)
USGS Four Corners Model (Thomas, 1989)	14,560 (7,250 on N, 7,040 on D)
PWCC Black Mesa Model (PWCC, Inc., 1999)	17,700 (5,400 on D, 1,400 on Carmel; 10,900 on N; amount on Shonto not given)

Table II.4-3. Model Concentrated Evaporation Comparison

Model	Evaporation (AFY)
HWNSS Model (HDR, 2002)	20,600 (N) [6,900 in USGS BM area], 730 (D)
HGC Model (HGC, 1991)	16,400 to 28,600 (major washes – rates not given)
USGS Black Mesa Model (Brown and Echnayer, 1988)	7,000
USGS Four Corners Model (Thomas, 1989)	2,910 in Chinle Wash and Laguna Creek
PWCC Black Mesa Model (PWCC, Inc., 1999)	13,400

Table II.4-4. Model Diffuse Evaporation Comparison

Model	Evaporation (AFY)
HWNSS Model (HDR, 2002)	20,700 (N) [10,000 in USGS BM Area], 9,500 (D)
HGC Model (HGC, 1991)	Not known; simulated as reduction in diffuse recharge
USGS Black Mesa Model (Brown and Echnayer, 1988)	6,600
USGS Four Corners Model (Thomas, 1989)	4,550
PWCC Black Mesa Model (PWCC, Inc., 1999)	4,100

Table II.4-5. Model River Interaction Comparison

Model	Flow To/From Rivers (AFY)
HWNSS Model (HDR, 2002)	8,800 inflow, 200 outflow during steady-state to San Juan/Colorado Rivers (south sides only), calculated by calibrated model
HGC Model (HGC, 1991)	4,300 to 5,800 to Colorado River below Navajo Creek
USGS Black Mesa Model (1988) (Brown and Echnayer, 1988)	No river connections
USGS Four Corners Model (Thomas, 1989)	13,560 to San Juan River (north and south sides)
PWCC Black Mesa Model (PWCC, Inc., 1999)	No river connections

The HWNSS evaluated a number of different scenarios for meeting the projected demands in the study area out to Year 2100. Scenario 2 was the “all ground water” scenario, in which an attempt would be made to meet all the demands exclusively with ground water supplies, which included developing projects in the N-Aquifer.

Figure II.4-6 is from the HWNSS Report of Findings for the impacts to the N-Aquifer under midrange demands for Scenario 2. As can be seen from the table, a number of areas served by the N-Aquifer begin to have significant impacts to the N-Aquifer as early as the year 2020, and many areas have significant to unsustainable impacts by the year 2060.

The North Central Arizona Water Demand Study, Phase I Report by the Rocky Mountain Institute and Planning and Management Consultants, Ltd., estimated that in the year 2000, the total demand in the study area was17,930 AFY, or roughly 10 percent of the estimated average annual recharge to the entire C-Aquifer. Some of this estimated demand is met from surface water resources, particularly for the cities of Flagstaff and Williams, so the estimated demands on the C-Aquifer would be reduced by the amount of demands that are met from surface water resources.

Estimates for the total demand on the C-Aquifer in the year 2000 were on the order of 140,000 AFY and were growing by 3 to 4 percent per year (Hart, et al., 2002). Estimates performed as part of the HWNSS (HDR, 2004) indicated that demand projections in the year 2100 for the entire area underlain by the C-Aquifer would be around 310,000 AFY, or roughly twice the average annual recharge to the C-Aquifer, indicating that the C-Aquifer would only be able to meet half of the area’s demands, at best, without mining of the aquifer storage. Part of the HWNSS was to evaluate the impacts on the C-Aquifer from several different water supply alternatives. Alternative 2a was the alternative that relied solely on the C-Aquifer to meet the demands of the Navajo and Hopi Reservations.

Aquifer Dewatering Impacts: N-Aquifer Service Area, Alternative 2, Midrange

Impact in Percent	
Insignificant	<30%
Significant	30%-50%
Unsustainable	>50%
Water level at bottom of aquifer	Dry
No Pumping	"-"

ECONOMIC CENTER	PUMPING CENTER	Threshold 30%	Threshold 50%	Base of Aquifer	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
KAIBETO	Kaibeto	4770	4579	4100	5058	5053	5043	5028	5010	4988	4961	4937	4909	4879	4844
	Coppermine	4864	4817	4700	4934	4920	4907	4889	4865	4835	4799	4754	Dry	Dry	Dry
	LeChee	3225	3075	2700	3450	3442	3435	3426	3413	3400	3387	3373	3364	3354	3343
	Tonalea	5155	4854	4100	5607	5597	5586	5567	5550	5536	5518	5498	5483	5469	5454
	Inscription House	5677	5455	4900	6009	6004	5998	5990	5979	5964	5949	5931	5921	5910	5898
	Shonto	5959	5800	5400	6199	6198	6192	6184	6174	6164	6154	6143	6134	6125	6111
	Navajo Mountain	5846	5747	5500	5994	5988	5979	5963	5940	5910	5875	5833	5782	5719	5638
TUBA CITY	Tuba City	4603	4402	3900	4904	4929	4929	4929	4911	4863	4796	4748	4697	4645	4592
PINON	Pinon	4265	4075	3600	5436	5370	5228	4853	4647	4505	4408	4333	4271	4203	4124
	Black Mesa	4525	4375	4000	5430	5368	5250	5084	5085	5024	4978	4935	4890	4836	4775
	Forest Lake	4065	3875	3400	5379	5317	5201	4915	4958	4891	4843	4801	4760	4715	4671
	Hard Rock	3955	3625	2800	5403	5352	5195	4880	4786	4718	4662	4609	4554	4494	4439
	Tachee/Blue Gap	4720	4600	4300	5511	5360	5162	4894	4794	4659	4499	Dry	Dry	Dry	Dry
	Whipporwill Spring	4705	4575	4250	5542	5390	5194	4921	4826	4706	4567	4402	Dry	Dry	Dry
DILKON	Dilkon	5806	5761	5650	5876	5876	5876	5876	5867	5832	5768	5717	5679	Dry	Dry
	Indian Wells	5755	5725	5650	5847	5847	5847	5847	5840	5814	Dry	Dry	Dry	Dry	Dry
	Jeddito	4925	4775	4400	5527	5563	5499	5407	5301	5177	5081	5031	5012	4994	4973
	Low Mountain	4825	4675	4300	5552	5470	5324	5107	5037	4968	4906	4836	4742	4621	4406
	Teestoh	5716	5669	5550	5787	5787	5787	5787	5781	5760	5724	5674	5614	Dry	Dry
	White Cone	5355	5325	5250	5791	5792	5772	5750	5610	Dry	Dry	Dry	Dry	Dry	Dry
	Lower Greasewood	5751	5722	5650	5759	5781	5757	5738	Dry	Dry	Dry	Dry	Dry	Dry	Dry
KAYENTA	Kayenta	5039	4714	3900	5536	5531	5489	5440	5388	5329	5260	5197	5132	5063	4905
	Chilchenbito	4735	4525	4000	5400	5340	5266	5165	5176	5117	5073	5043	5020	5000	4979
	Dennehotso	4873	4767	4500	5033	5018	5003	4982	4957	4925	4891	4852	4808	4768	4665
TEEC NOS POS	Teec Nos Pos	4963	4803	4400	5205	5200	5191	5179	5165	5144	5118	5092	5067	5034	5001
	Mexican Water	4589	4421	4000	4842	4832	4823	4813	4799	4789	4777	4763	4745	4723	4706
	Red Mesa	4959	4842	4550	5134	5136	5136	5136	5135	5134	5134	5133	5132	5131	5130
	Rock Point	4910	4850	4700	5001	4977	4942	4884	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	Sweetwater	5106	4990	4700	5279	5254	5214	5161	5086	4992	4945	4906	4874	4837	4798
THIRD MESA	Moenkopi	4445	4275	3850	4794	4801	4801	4801	4790	4771	4749	4724	4698	4677	4654
	Bacavi	4510	4250	3600	5349	5358	5301	5213	5167	5114	5061	5006	4955	4899	4853
	Hotevilla	4580	4300	3600	5342	5350	5298	5227	5185	5134	5083	5035	4993	4957	4927
	Kykotsmovi	4555	4325	3750	5343	5358	5329	5280	5249	5215	5182	5150	5120	5090	5064
	Howell Mesa	4888	4620	3950	5289	5290	5289	5288	5286	5284	5279	5272	5263	5250	5243
	Lower Moenkopi	4533	4324	3800	4847	4847	4847	4847	4845	4839	4829	4814	4800	4792	4781
SECOND MESA	Cultural Center	4710	4450	3800	5375	5391	5370	5330	5294	5250	5206	5172	5143	5122	5104
FIRST MESA	Polacca	4700	4500	4000	5424	5454	5400	5303	5226	5143	5067	5035	5006	4985	4966
	Keams Canyon	4765	4575	4100	5515	5532	5463	5356	5261	5169	5097	5074	5066	5058	5047
OTHER HOPI AREAS	Tuquoise	3965	3675	2950	5400	5388	5274	5018	4942	4875	4814	4762	4706	4645	4584
	Spider Mound	5015	4925	4700	5592	5601	5537	5456	5367	5285	5203	5175	5135	5109	5089
	South Orabi	5020	5000	4950	5097	5093	5084	5069	5049	5018	4972	Dry	Dry	Dry	Dry
	Side Rock	5005	4775	4200	5415	5413	5409	5405	5398	5388	5375	5369	5362	5352	5338

Figure II.4-6. Aquifer dewatering impacts: N-Aquifer service area, Alternative 2a, midrange (HDR, 2004).

Figure II.4-7 is a table from the HDR report that shows the effects on the C-Aquifer from Alternative 2a for low, medium, and high demand scenarios.[13] The HDR study area only overlapped the NCAWSS study area in the vicinity of Cameron, Tuba City, and Kaibito. Figure II.4-7 shows that although there are significant impacts to areas east of the NCAWSS study area in the C-Aquifer, there are minimal impacts around Cameron and points west—mainly because the C-Aquifer is unsaturated west and north of Cameron. Relying on the C-Aquifer to meet the needs of the NCAWSS study area would require well fields to the east of Flagstaff and south of Cameron and would require extensive distribution pipelines.

USGS estimates for the storage capacity/volume of the C-Aquifer is on the order of 300 million acre-feet (Hart and others, 2002). Other estimates range from 400 million acre-feet (Cooley et al., 1969; McGavock et al., 1986) to maybe 1 billion acre-feet (Ward, 2002). Although the estimates of the water in storage in the C-Aquifer are large, mining of the waters of the C-Aquifer (withdrawing water from storage that is not replaced) would have significant impacts on stream baseflows and spring discharges.

Estimated average annual water-budget components for the Coconino Plateau with the C Aquifer and the R-M Aquifer assumed to be in a state of dynamic equilibrium would be:

Total precipitation	8,700,000 AFY
Inflows Natural recharge to the regional ground water flow system (C Aquifer and R-M Aquifer combined)	300,000 AFY
Underflow from the east	7,000 AFY
Total inflow	307,000 AFY
Outflows Ground water discharge	300,000 AFY
Evapotranspiration from ground water flow systems	7,000 AFY
Runoff from the watershed	200,000 AFY
Estimated evaporation from the watershed	8,200,000 AFY

Bills and others, in press

[13] The results shown in figure II.4-7 are derived from HWNSS analyses, which assumed a population growth rate of 2.48 percent for the midrange scenario and a ramped up water usage of 160 gpcd.

Aquifer Drawdown Impacts: C-Aquifer Service Area, Alternative 2a

Impact in percent	
Insignificant	<30%
Significant	30%-50%
Unsustainable	>50%
Water level at bottom of aquifer	Dry

M&I Demand Center	Drawdown Threshold-30%	Drawdown Threshold - 50%	Maximum Drawdown	Drawdown(ft) 2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low Demand Scenario													
C-Aquifer Service Area													
Many Farms	800	900	1150	66	98	123	147	170	194	220	249	279	317
Chinle	400	500	750	145	210	268	330	383	436	490	547	610	677
Ft Defiance	205	305	555	36	54	68	83	109	134	159	183	208	240
Ganado	132	220	440	6	28	48	69	95	120	151	180	214	255
Leupp	228	380	760	21	34	44	53	60	67	73	79	88	100
Cameron	545	705	1105	3	4	5	7	8	9	11	12	14	16
I-40 Wellfield	195	325	650	70	89	101	111	119	133	150	169	184	196
Midrange Demand Scenario													
C-Aquifer Service Area													
Many Farms	800	900	1150	67	110	147	188	232	284	339	400	471	560
Chinle	400	500	750	145	214	294	378	463	560	666	Dry	Dry	Dry
Ft Defiance	205	305	555	36	55	81	108	136	169	207	251	307	394
Ganado	132	220	440	6	35	58	98	133	177	233	310	Dry	Dry
Leupp	228	380	760	21	60	84	102	119	142	165	187	213	241
Cameron	545	705	1105	3	5	7	9	12	16	20	25	31	39
I-40 Wellfield	195	325	650	76	98	113	129	154	172	186	199	212	223
High Demand Scenario													
C-Aquifer Service Area													
Many Farms	800	900	1150	68	113	152	199	251	306	368	438	524	624
Chinle	400	500	750	145	215	300	390	483	591	707	Dry	Dry	Dry
Ft Defiance	205	305	555	36	55	81	107	137	172	210	255	315	412
Ganado	132	220	440	6	37	64	104	143	194	259	355	Dry	Dry
Leupp	228	380	760	21	60	84	103	126	156	184	220	259	305
Cameron	545	705	1105	3	5	7	10	14	18	23	29	37	46
I-40 Wellfield	195	325	650	77	100	114	134	158	176	193	210	227	245

Figure II.4-7. Aquifer drawdown impacts: C-Aquifer service area, Alternative 2a (table 2a-8, volume 4, HDR, 2004). The first, second, and third blocks of numbers are for the low, midrange, and high demand scenarios, respectively.

II.5 Ground Water and Surface Water Legal Overview

Two bodies of law define Arizona water law and its effects on water management in the State. Laws that govern the use of surface water and the use of percolating ground water are distinct. However, wastewater effluent is not comprehensively regulated by either of these doctrines.

II.5.1 Regional Water Law

The primary water source for this project is surface water. The States of Arizona and New Mexico have adopted a "prior appropriation" system of water law whereby a water user ("appropriator") has a right to take and use for a beneficial purpose a necessary amount of water. Water rights are administered during times of shortage, based on the priority of the water right. The first priority right goes to the appropriator who has the earliest priority date, which is the date when the water was first put to beneficial use by that appropriator. The appropriator does not own the water but has the right to divert or impound water for beneficial use. In addition, the right is subject to forfeiture or abandonment for nonuse. In Arizona, unlike New Mexico, ground water is not administered based on priority. Under State law in Arizona, there are no limits to the amount that a user can pump, outside of Active Management Areas (AMAs), so long as the ground water is put to a "reasonable use" and there is no impairment to other water users.

The water rights held by an Indian tribe differ significantly from that described above. Indian water rights are largely governed by Federal law and were first defined in the U.S. Supreme Court case of *Winters* v. *United States*, 207 U.S. 564 (1908). In *Winters,* the Supreme Court held that when Indian reservations were established, the tribes and the United States implicitly reserved, along with the land, sufficient water to fulfill the purposes of the reservation. Unlike State water rights, these reserved water rights are not subject to forfeiture or abandonment for nonuse. In addition, these reserved water rights are perfected by the creation of the reservation and not by putting the water to beneficial use. This Federal reserved rights doctrine can be difficult to reconcile with the State system of water law.

In *Arizona* v. *California*, 373 U.S. 546 (1963), the U.S. Supreme Court defined a standard for the quantification of reserved water rights. The Court held that "enough water was reserved to irrigate all the practicably irrigable acreage on the reservations" (*Id.* At 600). The practicably irrigable acreage standard has been subject to interpretation and dispute.

In *In re the General Adjudication of All Rights to Use Water in the Gila River System and Source*, 201 Ariz. 307 (2001), the Arizona Supreme Court held that the practicably irrigable acreage standard is not the only quantification measure for determining water rights on Indian lands. The Court held that tribal reservation should be allocated water necessary to achieve their purpose as permanent homelands. As such, the standard for determining quantification under the permanent homeland purpose is a fact-intensive inquiry that must be made on a reservation-by-reservation basis based upon actual and proposed uses, accompanied by the parties' recommendations regarding feasibility and the amount of water necessary to accomplish the homeland purpose.

The Arizona Supreme Court also recently held that Indian tribes may have reserved rights to ground water where the surface water supplies are inadequate to supply the water necessary to meet the needs of the reservation as a permanent homeland. The Court also held that such rights are governed by Federal law and are entitled to greater protection than ground water appropriations made under State law. The courts in Arizona have yet to decide how to protect such federally reserved ground water rights

A water rights adjudication is a legal process whereby the ownership and extent of all water rights in a particular stream system are determined. The adjudication is a lawsuit filed by the State Attorney General, the United States, or by water users. A court must then determine the amount, type, and priority date of every water right associated with a particular water source.

The official caption of the Little Colorado Adjudication is *In re the General Adjudication of All Rights to Use Water in the Little Colorado River System and Source,* No. 6417. The Adjudication was filed in 1978 and remains ongoing. Currently, the Navajo Nation is actively challenging the water rights arising out of Show Low Reservoir, which involves a diversion of water out of the basin by the Phelps Dodge Corporation for use in mining operations in Morenci. The parties to the litigation are also briefing issues relating to claims made by the Arizona State Land Department. The Zuni Pueblo entered into a settlement agreement in 2003 to settle rights for and to restore Zuni Heaven. The Court has not yet issued a settlement decree for Zuni Heaven. The Navajo Nation was close to settling its water rights in the Adjudication, but in 1999, the Navajo Nation sued Peabody Western Coal Company, the Salt River Project, and Southern California Edison, which stalled settlement negotiations. The Nation and the State have recently convened discussions to determine if a settlement is possible.

In June 1980, the Arizona Legislature passed the Ground Water Management Act. The Act was primarily designed to stop the overdrafting of ground water within several critical ground water areas. The Ground Water Management Act established three levels of water management to respond to different ground water conditions. The most general level of ground water management applies throughout Arizona and is applicable to the entire study area. The Statewide ground water management provisions include designation of ground water basins, restrictions on transporting ground water from one ground water basin to another, mandatory well registration, and requirements for land developers to evaluate and report water availability.

The other two levels of water management are Irrigation Nonexpansion Areas (INAs) and AMAs. INAs add one more level of management than the general Statewide provisions. The Ground Water Management Act restricts irrigation in designated INAs to land that was irrigated in the 5 years prior to designation as an INA. There are currently three INAs in the State; none of them are located in the study area.

The most extensive level of management occurs in AMAs where ground water overdraft has been the most severe. In addition to the Statewide and INA management provisions, the right to use ground water in an AMA is exercised through "grandfathered rights" for irrigation and nonirrigation purposes or by application to ADWR for a ground water withdrawal permit for nonirrigation purposes. Cities, towns, and water companies have "service area rights" to pump ground water as needed for the residents of their legally defined serve areas. Annual uses are required by law to be within the limitations of each management period's mandated conservation requirements. Land developers are required to demonstrate the physical and legal availability of an assured water supply for 100 years in order to obtain approval to develop. There are five AMAs currently in existence in the State; none of them are located within the study area.

II.6 LCR General Stream Adjudication

A general stream adjudication is a judicial proceeding to determine or establish the extent and priority of water rights in a river basin. Since 1979, an adjudication has been ongoing to resolve water right claims in the LCR (*In re: The General Adjudication of all Rights to Use Water in the Little Colorado River System and Source*, Civil No. CV 6417 (Supreme Court, Apache County). Over 13,000 claims have been filed by the nearly 5,000 parties involved in the adjudication, which includes municipalities, ranches, irrigation companies, Indian tribes, and other interests. Those with claims, or on whose behalf claims to surface and/or ground water have been made include, among others, the Hopi Tribe, Navajo Nation, State of Arizona, the Salt River Project, Arizona Public Service, and the City of Flagstaff.

An effort to reach a negotiated settlement that would resolve tribal water rights and many other issues commenced around 1991. Water sources of interest in the adjudication and/or the associated negotiations have included the C-Aquifer, N-Aquifer, the LCR and its major tributaries, and Colorado River water diverted from Lake Powell. Over the years, the negotiations have progressed at varying levels of intensity. In 2005, the LCR Indian water rights settlement negotiations were linked to the settlement negotiations concerning the 2003 Navajo claims against the United States. Regarding the latter negotiations, the Navajo Tribe asserted that the United States breached its trust obligation to the tribe by its failure to consider Navajo rights to Colorado River water and unmet water needs when taking, or failing to take, various actions. While some of the discussions in the negotiations are subject to confidentiality agreements, some of the publicly available information can be found on the Arizona Supreme Court website: http://www.supreme.state.az.us/wm/.

II.7 Current Water Supply

Based on data in the *North Central Arizona Demand Study, Phase 1 Report,* completed in 2002 by RMI, the HWNSS**,** and more recent supplemental information provided by representatives of individual communities participating in the study, the following sections of this report summarize the current water supply and water use for each community in the study area.

Flynn and Bills (2002) note, "Ground water is the major source of public water supply in the study area. Surface water resources are small and unreliable, and surface water rights either are appropriated fully or under adjudication. High-yield wells are desired for public supply because of the high cost associated with drilling and developing wells that reach the regional aquifers. Municipal and commercial water suppliers delivered about 14,000 AF of ground water from the regional aquifers to public and commercial customers in the study area in 1999 and 2000, almost 60 percent more than in 1990 (Arizona Department of Water Resources, 1999). Hundreds of private wells exist throughout the study area. However, the City of Flagstaff accounts for more than half of the region's ground water use."

The HWNSS (HDR, 2004) reviewed and summarized previous studies of the availability of surface water supplies within and adjacent to the HWNSS area, which included parts of the NCAWSS study area. That study concluded: "Overall, opportunities for developing new surface water resources in the Little Colorado River Basin for M&I supply are limited. This analysis concludes that only two main sources of surface water are viable for a reliable future M&I supply: the Three Canyons watershed and importation of Colorado River supply.

. . The surface water sources considered in this study include the main stem Colorado River, the LCR, and sources associated with the Three Canyons Project."

The HWNSS broke the potential surface water supply areas down to: 1—the upper LCR Basin; 2—the mainstem LCR with the associated Three Canyons Watershed and the Northern Washes Watershed; and 3—the mainstem Colorado River. The Upper LCR Basin is southwest of the Navajo Nation's southern boundary and is bound by the Mogollon Rim and the White Mountains of Arizona. Headwaters generated from the east along the Continental Divide in New Mexico enter Arizona through several watersheds, of which the Puerco River, Silver Creek, and Upper LCR generate the primary contributions to the mainstem LCR. The majority of the diversions and impoundments throughout the basin are located nearer the headwaters, and local runoff and excess storm waters comprise the basic flow in the mainstem LCR. Significant upstream depletions leave no water for further practical development.

Considerable analysis of this upper portion of the watershed has been conducted by the Arizona Department of Water Resources (ADWR) and summarized in a 1989 report, entitled *Hydrology of the Little Colorado River System, Special Report to the Settlement Committee.* An overall evaluation of the surface water resources in this region was based on stream gage outflow data, where it was available, during a base period of record from October 1927 to September 1987. The median flow, according to the ADWR report, entering the southwestern portion of the Navajo Nation near Winslow, Arizona, was 162,900 AF annually. While this is a significant amount of flow, the LCR remains essentially an intermittent stream for all but reaches between Woodruff and Winslow and below Blue Springs.

The mainstem LCR between Woodruff and the southern boundary of the Navajo Nation north of Winslow includes the contributions made from the Upper LCR Basin in addition to Cottonwood Wash to the north and Jacks Canyon, Clear Creek, and Chevelon Creek to the southwest.

While median flows on the lower mainstem LCR are shown by ADWR to be on the order of 54,420 AFY, that flow contains high concentrations of sediment, making it difficult to use. The Three Canyons watershed contributions to the mainstem furnish an additional water supply near Winslow, contributing to an estimated annual median flow of approximately 162,900 AF entering the Navajo Reservation at the south end. The HWNSS estimated that surface water in the Clear Creek and Chevelon Creek Basins, in addition to Jacks Canyon flow, could be collected to serve a range of demands from nearly 4,000 to 20,000 AF on an average annual basis. Drainage of the northern washes across the northern region of the LCR Basin accounts for much of the streamflow in the LCR that intermittently reaches Cameron, Arizona. These washes, flowing across much of the Hopi and Navajo Reservations, include Moenkopi Wash, Shonto Wash, Dinnebito Wash, Oraibi Wash, Polacca Wash, Wepo Wash, and Jeddito Wash.

The Natural Resources Consulting Engineering, Inc. (NRCE) 1995 report, entitled *Revised Draft Conceptual Plan—Tucker Flat Water Delivery Project for Settlement of the Reserved Water Rights of the Navajo Nation in the Little Colorado River Basin,* indicated that “average annual flow from these washes is 67,000 acre-feet.” That estimated flow would account for about 40 percent of the total flow in the LCR measured at Cameron. However, this average figure is skewed by intense storm runoff. Baseflows, where they do exist in perennial stream reaches, are about 5 cfs or less and account for less than 20 percent of the annual streamflow. The streamflow is highly variable from day to day, month to month, and year to year, and the surface runoff carries a high sediment flow. Currently, much of the storm runoff that truly characterizes the flow in these ephemeral washes has been used for irrigation projects.

Article III of the 1948 Upper Colorado River Basin Compact apportions to the State of Arizona the consumptive use of 50,000 AF of Colorado River water from the Upper Colorado River System. Approximately 30,000 AFY of Arizona’s Upper Basin apportionment is used at the Navajo electrical generating plant near Page, Arizona. The majority of the remaining Upper Basin apportionment to Arizona is being used on the Navajo Reservation. The Boulder Canyon Project Act of 1928 apportioned to the State of Arizona the consumptive use of 2.8 million acre-feet of Colorado River water from the Lower Colorado River System below Lees Ferry. Approximately 1.6 to 1.8 million acre-feet of Arizona’s Lower Basin water apportionment is diverted into the Central Arizona Project canal near Lake Havasu. Arizona’s remaining Lower Basin allocation is used by senior water right holders in southern and western Arizona.

After evaluating issues of diversion points, priority of water rights, and how shortages are apportioned, the HWNSS concluded that, “The acquisition of long-term imported mainstem Colorado River water contracts represents an uncertainty in the Colorado River supply analysis. The diversion of water from Lake Powell must be addressed, but it appears that viable, long-term reliable sources of good quality Colorado River supplies exist for use in the potential Hopi Tribe and Navajo Nation Indian water rights settlement.” However, as addressed in the HWNSS, system shortages and/or prolonged droughts could potentially have severe impacts on the amount of Colorado River water that is available and on the reliability of the delivery of that water.

During the year 2000, total water use in the study area was estimated by the RMI to amount to roughly 5.84 billion gallons, or 17,930 AF. This includes potable and nonpotable use, but it does not include Valle, and the rural households supplied by standpipes in Valle (for which data were not available), and other small communities such as Red Lake and Parks for which specific data were not cited. Table II.7-1 summarizes this estimated usage (the "greater than or equal to" figure (≥) to indicate where the slight underestimation occurs). Nonpotable use includes two components: raw water use and use of reclaimed wastewater effluent. Total use as estimated by RMI (not including tribal areas) in the study area in 2000 breaks down as shown in table II.7-1 (RMI, 2002).

Table II.7-1. Total Water Use in the Study Area in 2000

	Millions of Gallons	Acre-Feet	Portion of Total Use
Potable use	≥ 4,660	≥ 14,300	80%
Nonpotable use			
Raw water	248	760	4%
Reclaimed wastewater	929	2,850	16%
Total use	5,840	17,910	100%

II.7.1 Tribal Communities

Western Navajo Nation

This portion of the study area includes the demand areas of LeChee, Coppermine, Cedar Ridge, Bodaway Gap, Tuba City, and Cameron. Water use in these chapters (year 2000) is estimated to be 1,470 AFY (based on 53 gpcd usage) (HDR, 2004). These communities are served primarily by ground water in the regional N-Aquifer, alluvial wells in the LCR (Cameron) and, to a smaller extent, in the C-Aquifer. With the exception of Tuba City, most residents haul water. For those hauling water, water use rates are estimated to be 10 to 15 gpcd (Robert Kirk, personal communication). Many livestock wells are used for culinary purposes during periods of drought. LeChee is currently receiving 100,000 gallons per day through Page's pumping, treatment, and delivery system out of Lake Powell (Plummer, 2005). Water is distributed within LeChee via a Navajo Tribal Utility Authority (NTUA) system. There are small NTUA systems in Cameron and Bodaway Gap (John Leeper, personal communication). Table II.7-2 illustrates the percentage of households without access to public water systems. NTUA has a progressive rate structure implemented for all water delivered through its systems.

Table II.7-2 Households Without Access to Public Water Systems

Demand Area	Percentage of Households without Access
LeChee	22%
Coppermine	91%
Bodaway Gap	44%
Tuba City	14%
Cameron	53%

Source: LSR Innovations (2004)

Hopi Community of Moenkopi

Like the Navajo communities, communities of the Hopi Tribe, including Moenkopi, currently rely on the N-Aquifer. Recharge to the entire N-Aquifer has been estimated by a number of investigators based on percentage of precipitation and geochemical techniques. The recharge estimates range from 10,894 to 25,800 AFY (HDR Engineering Inc., 2003). Springs associated with the N-Aquifer are of major religious and cultural significance to the Hopi Tribe; therefore, the sustainability of continued reliance on the N-Aquifer is a significant concern. It is of vital importance for the two villages of Moenkopi to secure a future, long-term, self-sustaining source of drinking water for the local communities. Surface water flow in Moenkopi Wash at Moenkopi is almost entirely agricultural return flow and effluent released to the stream from the Tuba City/Moenkopi treatment facility. All of the water used for irrigation in the Moenkopi area comes from springs that discharge at or above the village (Don Bills, personal communication).

Many tribal members haul water. As a result, the current per capita use rate of water generally ranges from 10 to 35 gpcd (Hopi Tribe, 2005). The village of Moenkopi has a municipal system; based on a per capita use rate of 50 gpcd, it currently consumes an estimated 43 AF of water per year (HDR, 2004). The two Moenkopi villages have current contamination threats on the local drinking water sources, emanating from sources upgradient of the Moenkopi area. These sources of contamination include a leaking underground storage tank located under the Tuuvi Café (formerly known as the Tuba City Truck Stop Café)[14] and the Tuba City Landfill (The Hopi Tribe's preferred alternative is Clean Closure of the 28 acres of the landfill). In addition, the Davis Chevrolet underground storage tank is currently being addressed by the Navajo Nation Underground Storage Tank program. These areas of contamination are a threat to the current drinking water, to N-Aquifer wells and springs, and for the members of both the Upper and

[14] Current cleanup efforts are being performed under an EPA Administrative Order at the two gas stations associated with the site.

Lower Villages of Moenkopi. There is evidence of contamination in Moenkopi's water system, which may be the result of these contamination sources (Stephens and Associates, Inc., 1999)

The water supply for the Lower Village of Moencopi comes from a local spring that goes through a chlorination system before domestic use. There are five watering points within the village, from which the village members haul water to their homes.

The Hopi Tribe recently purchased 6,000 AFY of water rights out of the Colorado River (lower basin) from the Cibola Irrigation District (*Federal Register*, 2004). However, there is no current means to deliver this water to the reservation.

Havasupai Tribe

The Havasupai Tribe currently relies on surface water flow in Havasu Creek that emerges from R-M Aquifer springs. Water is also obtained from ground water wells in shallow stream alluvium. The tribe is planning a development in the Hilltop area, on the rim above the canyon, which is projected to include a visitor's center, gas station, convenience store, campground, and, possibly, some housing. A new, 3,000-foot well in the Hilltop area is being put into production to provide water for this development. The water quality from this well differs from the water quality in the Havasu springs, which leads the tribe to suspect that a different recharge mechanism for this aquifer may possibly exist (Havasupai Tribe, 2005). The religious and cultural importance of ground water to the Havasupai tribe was discussed above in section II.2.2, subsection entitled "Tribal Communities." "The tribe is opposed to any importation of outside surface water into the study area **unless** it brings meaningful protections for permanent ground water limitations and management" (NRCE, 2005)

II.7.2 Nontribal Communities

City of Page

The City of Page has a Secretarial contract to consumptively use 2,740 AF of water annually allocated under the Upper Basin Compact for use within the Upper Basin of Arizona. When credited with return flows to the river, the City of Page estimates they can divert as much as 4,500 AFY without exceeding the 2,740 AF consumptive use limit (Plummer, 2005). The return flow credit indicates that the portion of the water diverted by the City of Page returns to the river above Lees Ferry. The community of LeChee (also in the Upper Basin) is also using surface water that is accounted for as an Upper Basin water depletion. Water for the City of Page is pumped directly out of Lake Powell. The city is working with the

Navajo Nation and NPS to complete an EIS to determine whether a new intake at Lake Powell, as well as a pipeline that would serve Page and the LeChee, is feasible.

City of Flagstaff and Outlying Areas

This demand area incorporates the M&I water service area of the city, as well as outlying communities such as Bellemont, Doney Park, Flagstaff Ranch, Forest Highlands, Fort Valley, Kachina Village, and Mountainaire.

Bellemont

Current water usage for Bellemont was estimated at 109 AFY (Pratt, 2005).[15] The Bellemont area currently relies on ground water as its sole source of water supply. There was one pre-existing well drilled into the C-Aquifer by the U.S. Army on the depot when it was taken over by the Arizona National Guard. This pre-existing well has not been used for several decades. The Arizona National Guard recently (2002) completed a second deep well into the C-Aquifer on Camp Navajo that is currently used to supplement its water supply (Wilkerson, personal communication). The Bellemont Truck Stop and Utility Source Limited Liability Company (LLC) have recently (2002 to 2006) completed four deep wells into the C-Aquifer: three at the Truck Stop and one to the east of Flagstaff Meadows. Two of these wells are currently in use, with the shallow wells owned by Utility Source LLC to supply the Bellemont Truck Stop and Flagstaff Meadows. One deep well is currently unused, and another well is currently being developed and plumbed as a 300-gpm supply (McCleve, personal communication). The shallow water-bearing zones are highly drought sensitive, and most shallow wells have experienced substantial declines in water levels during the ongoing drought.

Bellemont has not experienced much in standpipe sales (in recent years) because the one well south of I-40 has not been reliable.

Doney Park

Current water usage for potable water in Doney Park is estimated to be 786 AFY. Doney Park Water (a member owned, not for profit, private domestic water cooperative) serves the Black Bill/Doney Park area. There are 3,300 members. Doney Park Water relies on six ground water wells into the C-Aquifer that range in depth from 1581 feet to 1746 feet (Doney Park Water, 2005). There is one well at a standpipe site that is currently not in use. To a limited extent, some individual residents also collect rainwater for their use.

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[15] This value is per ADWR and only for the area served by Utility Source LLC, the public water supply for Flagstaff Meadows, and the truck stop on the north side of I-40.

While Doney Park's wells dropped during the ongoing drought, the wells appeared to recover fairly rapidly (Bills, personal communication) in 2004, when precipitation levels were closer to long-term averages. Doney Park has a water distribution system, but no wastewater collection system. Because of the expense of extending lines to remote locations, which is borne by the property owners served, some property owners choose to haul water (RMI, 2002). However, there is limited potential in the foreseeable future for collection of wastewater for potential reuse because the area is relatively dispersed, making systemwide improvements (such as for a wastewater collection system) relatively costly. In addition, the TAG speculated that natural recharge from individual residential septic tanks is likely to be as efficient as a wastewater collection system anyway.

Doney Park has a progressive rate structure and water conservation program in place.

City of Flagstaff

Flagstaff is by far the largest user of water in the study area. The City of Flagstaff relies upon a diversified system of surface water, ground water, and water reuse facilities. Primary sources of supply are discussed below (Doba, 2005a).

Lake Mary Surface Supply

Lake Mary has had a 30-year median inflow of 5,000 AF of water for January to May; however, due to evaporation and seepage losses, the average availability for the past 18 years was only 2,252 AF of water. Production from this source is extremely variable. In 1990, 2000, and 2002, Lake Mary experienced little or no inflow. In these types of hydrographic cycles, Flagstaff is much more dependent on the ground water supply.

Woody Mountain Well Field

Based on withdrawals and water levels since 1998, this well has an estimated "sustainable yield"[16] of 3,500 AFY.

Lake Mary Well Field

Based on withdrawals and water levels since 1998, this well has an estimated "safe yield" of 2,500 AFY.

Inner City Wells Water Supply

With 3 years of experience to date (summer of 2005), Flagstaff has drawn a maximum of 1,300 AFY of water from this source and observed little water level

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[16] "Sustainable yield" is defined as the yield of an aquifer that can be sustained over a period of time without any detrimental effects.

drawdown. There is the potential to pump as much as 2,800 AFY from this source, but more history is needed to determine a "safe-yield."

Inner Basin of the San Francisco Peaks Water Supply

Over an 18-year period, this source produced an average of 542 AFY of water. However, production from this source is highly variable and in 2002, it only produced 25 AF due to drought conditions that resulted in little snow and snowmelt to recharge the system.

In total, Flagstaff estimates that the above "water portfolio" can produce 8,825 to 11,594 AFY. For a 2005 population of 62,718 and a per capita use rate of 120 gpcd, Flagstaff estimates current water use at about 8,470 AFY (Doba, 2005a). While the per capita use rate value may be skewed by the transient student population, it is also skewed by the tourists who are not counted in the City of Flagstaff population. It was not used to size the infrastructure for the alternatives.

During the drought that began in 1996 and prior to the more normal precipitation levels observed in 2004, records indicate ground water level declines of approximately 50 feet in the Woody Mountain and 140 feet in the Lake Mary areas, respectively (ADWR, 2005).

Flagstaff has an extensive and expanding water reuse program. All water made available by the program is fully utilized, and there is demand for more. In June 2005, the Regional Forester affirmed the Coconino National Forest supervisor's decision for the Snowbowl Facilities Improvement Project. This project includes developing snowmaking at the Snowbowl ski area. The Record of Decision (Coconino National Forest, 2005) allows for use of up to 1.5 million gallons per day of reclaimed water from the City of Flagstaff, from November 1st to February 28th of each ski season. This equates to approximately 178 million gallons (548 AF) per season. However, annual water use for snowmaking will vary according to natural conditions.

Flagstaff has a progressive water conservation program and water rate structure. Water conservation and residential rainwater collection is encouraged. During the ongoing drought, demand management techniques, principally municipal ordinances which increase the cost of water as the severity of drought increases, proved successful in reducing demand.

Flagstaff Ranch

Flagstaff Ranch relies 100 percent on ground water from wells developed into the C-Aquifer and on water reuse provided for a community golf course. As the community is built out and more effluent becomes available, it is expected that the water will be used to water the golf course (Don Bills, personal communication). The Flagstaff Ranch Golf Club gets their water from a private water company, which is not affiliated with the development. Flagstaff Ranch Water Company serves Flagstaff Ranch Golf Club, Westwood Estates, and the Flagstaff Ranch Business Park between I-40 and Route 66, and has recently added a standpipe for water sales.

Forest Highlands

Forest Highland relies 100 percent on ground water from wells developed into the C-Aquifer, and on water reuse provided from Kachina Village wetland for a community golf course. Forest Highlands also applies its effluent to the golf course.

Fort Valley

Fort Valley relies on shallow alluvial wells developed by individual land owners and on some water hauling from adjacent community water supplies. The wells are highly sensitive to drought, and during the ongoing drought, water levels in most wells have declined or gone dry (Don Bills, personal communication). Because residents in the area are highly dispersed, it is probably not cost effective to develop water delivery systems in the community. There is a Domestic Water Improvement District (DWID) being formed to serve two new small subdivisions. Other developers are looking at the possibility of developing more wells to incorporate into the DWID. The DWID is using the old Canyon Squire Well.

Kachina Village

Kachina Village relies 100 percent on ground water from wells developed in the C-Aquifer. A constructed wetlands habitat was developed with the new wastewater plant in 1988. As noted above, some of this reused water is also provided to Forest Highlands. Kachina Village uses a conservation based rate structure.

Mountainaire

Mountainaire relies 100 percent on ground water from wells developed in the C-Aquifer. Mountainaire has relatively small lot sizes and no wastewater treatment collection system, which requires a reliance on individual septic systems. This presents some water quality concern to downgradient water users in Oak Creek.

Munds Park/Pinewood

Munds Park/Pinewood relies 100 percent on ground water provided by Arizona Water Company from wells developed in the C-Aquifer. Treated effluent is used for a golf course (Don Bills, personal communication).

Other Small Communities

In addition to the above communities, many additional small communities, for which little existing information was available for Reclamation's study team, are present in the study area. Some of these communities include Red Lake, Pitman Valley, Garland Prairie, Mountain Dell, Lockett Ranch, Cedar Valley, and Saskan Ranch. Most of these areas are dependent on water from shallow wells developed in perched water-bearing zones. A few of these areas, such as Lockett Ranch, Cedar Valley, and Saskan Ranch, have developed wells into the C-Aquifer as a source of water supply.

Parks

Residents in Parks are widely dispersed, and they rely on shallow wells and water hauling. Rainwater collection systems are also common in the area. The shallow wells are highly susceptible to drought, and water levels are in decline. There is no community water or wastewater system in the area. There have been some community discussions regarding the development of a deep well to supplement the supply. RMI noted in its report that most residents of Parks consider an increase in high-density development undesirable. As a result, support for development of a water distribution system in conjunction with new supply sources would likely be limited.

City of Williams

The City of Williams (Cornwall, 2005) currently relies on surface water and is becoming increasingly dependent upon newly developed deep R-M Aquifer wells. In addition, the city uses reclaimed wastewater to supply water to the community golf course(s).

The development of the R-M Aquifer wells is an expensive and uncertain proposition. The cost to develop Williams' most recent well was $2,500,000, and the wells have often produced disappointing yields. The city and the Havasupai Tribe have entered into an agreement regarding regional ground water management and water conservation. Based on this agreement, the Havasupai Tribe has concluded that the "City of Williams supports the principle that there should be no decrease in the natural flow of Havasu Springs" (Shiel, 2002). The 2002 RMI Report, appendix A provides more detail on the content of the City/Tribe agreement.

Current water use in the city averages 900,000 gallons per day (2.76 AF per day), with a low value of 450,000 gallons per day (1.38 AF per day).

Williams has initiated the development of a water strategy and has adopted impact fees of $17,000 to $20,000 for new house permits. The city is supporting an education program to teach conservation, starting at the grade school level.

As of summer 2005, Williams had 71 homes under development and over 1,000 lots were approved for development. Williams also announced plans for a potential large amusement park and a “territorial Arizona” theme park. Williams expects these theme parks to develop their own water resources, but such development would likely focus on additional wells in the R-M Aquifer.

Scattered subdivisions in surrounding areas present a significant concern to the city since these residents have frequently used Williams standpipes for a hauled water supply. During the ongoing drought, Williams has restricted the use of its standpipes by nonresidents.

South Rim Grand Canyon – Tusayan

Tusayan

The unincorporated community of Tusayan relies on deep R-M Aquifer wells, an extensive conservation reuse program, a large rainwater collection facility at the local airport, hauled water, and progressive water management.

The depth to water in the R-M Aquifer is estimated to be about 3,000 feet. Studies of springs in the Grand Canyon suggest that there has been no noticeable decline to date in spring flow of monitored sites related to these ground water withdrawals (Monroe et al., 2005). However, Northern Arizona University has published a thesis wherein a three-dimensional ground water simulation has suggested that spring impacts will occur in the future as a result of continued ground water use (Don Bills, personal communication). In addition, one site in the Canyon, Cottonwood Creek, has seen noticeable declines in base flow and supporting spring flow, but it is unclear whether the decline is due to nearby ground water withdrawals or the continuing drought conditions (USGS and NPS streamflow data published and unpublished) (Bills, personal communication).

South Rim Grand Canyon National Park

The NPS currently relies on spring water from the Roaring Spring transported through the transcanyon pipeline to meet the water demand of the south rim. The NPS Grand Canyon Facilities Management Division reports this system to be viable, with the spring and pipeline having the capacity to meet current and future water demand for the park (NPS, 2006a). Whether or not capacity of the system is adequate to provide water for Tusayan and for future growth in the south rim area of Grand Canyon National Park is unknown. The pipeline is nearing the end of its “life-cycle” (Reclamation, 2002a).

The existing configuration and operation of the transcanyon pipeline presents two significant problems to the NPS:

(1) Bright Angel Creek is artificially impacted by the reduction of flows caused by the diversion of water into the pipeline and by the continual maintenance of the pipeline in areas adjacent to the creek.

(2) Current operation of the pipeline results in an overflow at Indian Gardens, which has led to the development of an unnatural and undesirable riparian habitat.

In addition, the south rim of the GCNP only has a 14-day supply in the summer and a 30-day supply in the winter when the pipeline is down for maintenance. A catastrophic failure of the transcanyon pipeline during the summer season could be highly disruptive.

Natural springs below the south rim of the Grand Canyon are a significant and critical water resource for visitors (hikers) to the inner canyon. It is the only water supply available between the rim and the Colorado River for nearly all the trails into the canyon. These springs also support much of the biodiversity found below the rims of the Grand Canyon (Stevens et al., 2002). Protection of these springs is a priority for GCNP management.

Valle

Up until 1994, there was no local water supply for the unincorporated community of Valle. Water was hauled primarily from standpipes in Williams and Bellemont. In 1994, two local wells were developed, one in conjunction with the development of the Valle Airport, and the other for the Grand Canyon Inn hotel complex. These deep wells are in the R-M Aquifer. In addition to serving their primary users, they both have incorporated standpipes for sales for commercial haulers and local residents. This practice will continue without a regional solution.

Although the Valle area is sparsely populated, there are over 7,000 lots in older subdivisions platted in the 1960s and 1970s. There are conflicting issues related to bringing a water pipeline into this and other unincorporated areas along the Highway 64 corridor. On the one hand, a pipeline delivering water to an area with so many undeveloped but platted lots could open a door to significant growth in an area where other services are not available. Alternatively, to develop a regional solution that delivers water to demand centers adjacent to these dispersed areas, but doesn't provide a means of delivering the water into the dispersed areas (other than the hauling currently being done), could result in other undesirable results, such as the residents in these dispersed areas pooling their resources to develop additional local wells in the R-M Aquifer. Several large ranches in the vicinity of Valle have been sold for development through the unsubdivided lands process, for which no formal development process is required. As these lands are developed, there will be increasing pressure for a local water supply.

Other Dispersed Population

Not included in the above discussion are Coconino County residents dispersed in very small communities or in rural areas scattered throughout the study area.[17] In almost all cases, these residents haul water from standpipes in a nearby community, collect rainwater, have shallow wells, or use some combination of these sources of water supply. This water hauling can place an additional strain on the water supplies of the communities providing the water through standpipes. In 2005, the City of Flagstaff measured 26,515,882 gallons (81 AF) of potable water hauled from system standpipes (Ronald Doba, personal communication). Much of that was presumably hauled outside of the City of Flagstaff.

Through the County Comprehensive Plan, and local area plans, the Coconino County has adopted policies that encourage water reuse and low-water consumptive uses. The county has adopted a Landscape Ordinance, which emphasizes drought resistant and native vegetation. Coconino County's Sustainable Building Program includes a water conservation element, including recommendations for the use of grey water and collection of rainwater (Sue Pratt, personal communication).

II.8 Current Water Rates

RMI's North Central Arizona Water Demand Study Phase I Report presents the current (2002) water rates for nontribal communities in the study area, as illustrated in table II.8-1.

[17] For example, this includes such communities as Red Lake, Pitman Valley, Garland Prairie, Mountain Dell, Lockett Ranch, Cedar Valley, and Saskan Ranch.

Table II.8-1. Nontribal Communities Summary of Water and Sewer Rates

Utility	Water	Sewer
Bellemont Water Company	$25.00 per month service charge $ 5.25 per 1,000 gallons *Standpipe: $4.00-$5.25 per 1,000 gallons*	Not applicable; onsite systems
Doney Park (residential/ general noncommercial)	$18.75 per month, 5/8inch meter; includes first 1,000 gallons $ 4.30 per 1,000 gallons for 1,001-5,000 gallons $ 6.90 per 1,000 gallons in excess of 5,000 (winter) $ 8.63 per 1,000 gallons in excess of 5,000 (summer) *Standpipe: $6.90 per 1,000 gallons (winter):* $ 8.63 per 1,000 gallons (summer)	Not applicable; onsite systems
Flagstaff (residential)	$6.48 per month, 3/4" meter $2.83 per 1,000 gallons, up to 5,000 $3.32 per 1,000 gallons, 5,001-15,000 $4.71 per 1,000 gallons, over 15,000 *Standpipe: $5.25 per 1,000 gallons*	$2.73 per 1,000 gallons, flat fee based on winter quarter average water use
Forest Highlands	$25.00 per month $ 2.00 per 1,000 gallons	$30.00 per month; $2.00 per 1,000 gallons
GCNP	$14.43 per 1,000 gallons	$14.49 per 1,000 gallons
Kachina Village	$14.05 per month $1.04 per 1,000 gallons, up to 3000 $1.56 per 1,000 gallons, 3,001-6,000 $3.12 per 1,000 gallons, 6,001-9,000 $6.24 per 1,000 gallons, 9,001-12,000 $10.40 per 1,000 gallons, 12,001-50,000 $16.64 per 1,000 gallons, over 50,000	$18.73 per month; $2.60 per 1,000 gallons up to 3,000; $4.16 per 1,000 gallons, 3,001 to 6,000; no charge over 6,000 gallons
Mountainaire (Ponderosa Utility Corp.)	$21.00 per month 5/8"-3/4" meter $ 3.30 per 1,000 gallons *Standpipe: $5.70 per 1,000 gallons*	Not applicable; onsite systems
Page	$4.00 base rate, includes first 3,000 gallons $1.25 per 1,000 gallons, 3,001 to winter average $1.35 per 1,000 gallons, over winter average	$2.52 per 1,000 gallons
Tusayan	$50.00 per 1,000 gallons, Airport system $45.00 per 1,000 gallons, Anasazi Water Co. $18.50 per 1,000 gallons, Hydro Resources $1.00 per 1,000 gallons, reclaimed water	$13.59 per 1,000 gallons
Valle - Grand Canyon Inn	$10.00 per 1,000 gallons *Standpipe: $12.50-$20.00 per 1,000 gallons*	Not obtained
Williams (residential)	$6.72 per month, includes first 1,000 gallons $3.37 per 1,000 gallons; 1,001 to 10,000 $3.54 per 1,000 gallons; 10,001 to 20,000 $3.72 per 1,000 gallons; 20,001+ *Standpipe: $7.33-$12.52 per 1,000 gallons*	$13.00 flat rate

Current water rates for tribal communities are shown in table II.8-2.

Table II.8-2 Tribal Communities Current Water Rates

Navajo Nation (NTUA system)[1]	Monthly service charge of $7.43 for a 1.0-inch or smaller meter and $21.51 for a 2.0-inch or larger meter $2.93 per 1,000 gallons for first 3,000 gallons per month $4.54 per 1,000 gallons for additional use
Navajo Nation – hauled water	Varies from zero for water obtained from local wells to $250 per 1,000 gallons for water from vended sources. Average price (2003) was $32 per 1,000 gallons.
Hopi Tribe[2]	Upper Village of Moenkopi rates are $35 per month for 3-inch meter, and Moenkopi Day School rates are $500 per month for 4-inch meter The rates of other businesses are $100 per month for 2-inch meter Upper Moenkopi Village pays $2,632 per month for wastewater disposal.

[1] Rates effective March 1, 2006 (NTUA, 2006).
[2] (Hopi Tribe, 2006)

The above rates will be referenced again later in this report for comparison to the incremental costs associated with project alternatives.

Chapter III
Projected Demands and Future Without a Federal Project in the Study Area

Substantial population growth in the study area is forecasted for the next 50 years. Accompanying that growth is the potential for a significant increase in the demand for water. This chapter will outline the projected population increases identified by the Bureau of Reclamation team, the expected water demands associated with the projected populations, the projected unmet demand, and the likely future without scenario should there be no federally developed project in the area.

III.1 Projected Population in the Study Area

A Population Subgroup was formed to develop the study area population estimates. Actively participating in the subgroup were representatives from Reclamation, ADWR, Navajo Department of Water Resources, Grand Canyon Trust, and the City of Flagstaff. The City of Williams and Grand Canyon National Park initially expressed an interest in participating in the group, and although they were not actively involved, they were kept informed of the issues and subgroup discussions. The complete findings of the Population Subgroup are summarized in the document *Northern Arizona Water Supply Study Population Sub-group Report of Findings,* March 6, 2003.

For nontribal areas, existing data regarding population and population projections for the study area were collected by contacting the Arizona Department of Economic Security (ADES), Northern Arizona Council of Governments, and the U.S. Census Bureau. For the Navajo and Hopi Tribes, the study adopted the midrange population and population projections identified for the midrange scenario in the HWNSS. This study assumed an annual population growth rate of 2.48 percent for both tribes (Leeper, 2006).[18] These tribal population projections

[18] The 2.48 percent growth rate was the midrange value determined by HDR in the HWNSS and represented the 50th percentile of exceedance in a Monte Carlo simulation developed to estimate the range of growth rates. For planning purposes, higher percentiles of exceedance could have justifiably been used to ensure that projected demands were not underestimated. Potentially driving population growth, the Navajo Nation notes that 100,000 tribal members live off of the reservation; with adequate infrastructure development and a sustainable economy, it is assumed that a significant portion of that off-reservation population would be inclined to return to the reservation. Furthermore, the BIA has a $60-million-per-year road building program ongoing, the Department of Energy has a $15-million-dollar rural electrification program, IHS is building

are shown in table III.1-1. For the Havasupai Tribe, population projections were not developed on a 10-year interval, as the tribe's participation in the study was based on their concern that their existing water resources be protected; it was not based on a desire to be provided with a future water supply from a regional project.

For the nontribal communities, much of the subgroup effort focused on identifying the population projections for the City of Flagstaff. The population subgroup determined that two data points (a high and low value) should be developed to characterize the potential range of population growth for Flagstaff. Five alternate methodologies were considered to look at Flagstaff's population. These methodologies included:

- 1997 ADES Arizona Demographic Cohort-Survival Projections Model
- Adjusted 1997 ADES
- Modified trend analysis
- City of Flagstaff buildout model
- Historical growth rate (1992-2002)

The range of potential population growth for the City of Flagstaff by these methodologies is shown in table III.1-2

After discussions about the methodologies, the Population Subgroup endorsed the 1997 ADES ***Arizona Demographic Cohort-Survival Projections Model*** as the best method for Flagstaff's low-end population projection, and it endorsed the City of Flagstaff's Buildout Models as the best method to adopt for the high-end projection. In addition, the 1997 ADES ***Arizona Demographic Cohort-Survival Projections Model*** was adopted for all nontribal areas outside of Flagstaff within the study area.

Table III.1-3 shows the historical population, as well as the initial population projections for the study area. The table includes the low and high estimates for Flagstaff.

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hospitals and clinics, various school districts are building new schools, and NHA is spending about $80 million per year on primarily new housing.

Table III.1-1. Tribal Population Projections

Navajo Nation[1]

Economic Center	Chapter	1980 Census	1990 Census (adj)	1996 (Chapter Images, 1997)	2000 Census	2000 Population Adjusted Upward 7.9%	2010	2020	2030	2040	2050
Kaibeto/Page	Coppermine	684	423	443	673	726	853	1,090	1,392	1,779	2,273
	LeChee	1,060	1,561	1,728	1,890	2,039	2,396	3,061	3,910	4,995	6,382
Tuba City	Bodaway Gap[2]	1,238	1,649	1,814	1,837	1,982	2,328	2,975	3,800	4,855	6,203
	Tuba City	5,416	7,305	8,041	8,736	9,426	11,073	14,146	18,073	23,090	29,500
Cameron	Cameron[3]	901	1,011	1,100	1,231	1,328	1,560	1,993	2,547	3,254	4,157

Hopi Tribe[4]

Region	Village	2000	2010	2020	2030	2040	2050
	Moenkopi	749	1,119	1,267	1,435	1,625	1,840
	Lower Moencopi	0	889	1,195	1,606	2,158	2,901

Havasupai Tribe[5]

	2000	2050
Population	650	1800 to 2900

[1] From HWNSS (HDR, 2004), volume 2, table 6.
[2] The population of the study area communities of Cedar Ridge and Bitter Springs are included in the Bodaway Gap Chapter.
[3] The population of the study area community of Gray Mountain is included in the Cameron Chapter.
[4] From HWNSS (HDR, 2004), volume 2, table 7.
[5] Year 2000 estimate from Havasupai Tribe (2006); year 2050 estimate from Copfer

Table III.1-2. Projected Population of Flagstaff Based on Different Methodologies

Methodology	Population 2002	Population 2050	Average Annual Growth Rate
City of Flagstaff buildout	59,158	124,840	1.57%
Historical growth rate (1992-2002)	59,158	156,099	2.04%
Adjusted ADES	59,158	106,570	1.22%
Trend analysis using 1980-2000 historic population	59,158	120,044	1.46%
1997 ADES Demographic Cohort-survival Projections Model	63,107	113,684	1.23%

Table III.1-3. Updated Historical and Projected Population for NCAWSS Demand Areas[1]

	1970	1980	1990	2000	2010	2020	2030	2040	2050	2000-2050
Coconino County	48,326	75,008	96,591	124,575	147,352	169,343	189,868	211,616	235,707	89%
Doney Park/Timberline	n/a	3,550	5,504	7,979	9,737	11,734	13,608	15,605	17,831	123%
Fort Valley	n/a	350	534	660	754	863	964	1068	1,182	79%
Grand Canyon Village	1,011	1,348	1,499	1,460	1,888	2,048	2,214	2,406	2,639	81%
Kachina Village	n/a	1,250	1,711	2,664	2,683	3,120	3,522	3,941	4,397	65%
Mountainaire	n/a	500	738	1,014	1,046	1,199	1,340	1,486	1,646	62%
Page	1,409	4,907	6,598	9,570	11,128	13,057	14,841	16,714	18,770	96%
Parks	n/a	950	603	1,137	1,335	1,604	1,898	2,256	2,701	138%
Tusayan	n/a	500	555	562	819	890	996	1152	1,372	144%
Valle	n/a	n/a	123	534	632	726	814	907	1,010	89%
Williams	2,386	2,266	2,532	2,905	3,310	3,601	3,925	4,323	4,826	66%
				2002						2002-2050
Flagstaff	26,117	34,845	45,990	63,107	71,981	81,972	91,529	101,907	113,684	80%
				59,158	67,024	78,299	91,471	106,859	124,840	111%
Total population range										
Low				91,592	105,313	120,814	135,651	151,765	170,058	86%
High				87,643	100,356	117,141	135,593	156,717	181,214	107%
Total CCD remainder in study area*				4,051	6,026	7,760	9,242	10,674	12,099	
Total population range				**2002**						2002-2050
Low				95,643	111,338	128,574	144,893	162,439	182,157	90%
High				91,694	106,381	124,901	144,835	167,391	193,313	111%

* See narrative for explanation and methodology

Sources: U.S. Census Bureau, Arizona Department of Economic Security, and City of Flagstaff

[1] This table includes data for specific communities when such population data were available for that community. No population data were available for many of the smaller communities in the project area; as described in section II.1.2 above, the population of these communities is considered accounted for in the "Total CCD remainder in study area" in table III.1-3.

III.2 Projected Demands

Future water demand is tied to future population in this study. This analysis provides an estimate of the potential growth in water demand based upon population growth predictions for both tribal and nontribal communities in the study area for the NCAWSS.

III.2.1 Tribal Demands

For the Navajo and Hopi Tribes, the study adopted the per capita use projections (table III.2-1) identified in the HWNSS for municipal, commercial, and light industrial water demands (HDR, 2004).

Table III.2-1. Estimated Rates of Water Usage (gpcd)[1]

Chapter	Population Projection	2000	2000 Adjusted	2007	2010	2020	2030	2040	2050
Navajo									
Coppermine	Midrange	50	50	69.6	78	105	133	160	160
LeChee	Midrange	50	50	69.6	78	105	133	160	160
Bodaway Gap[2]	Midrange	50	50	69.6	78	105	133	160	160
Cameron[3]	Midrange	100	100	121	130	160	160	160	160
Tuba City	Midrange	100	100	121	130	160	160	160	160
Hopi									
Moenkopi	Midrange	50	50	88.5	105	160	160	160	160
Lower Moencopi	Midrange	50	50	88.5	105	160	160	160	160

Note: The 2050 use rate, 160 gpcd, includes system losses.[19] The volume of these losses may vary from about 5 to 15 percent of total system usage, depending on the age of the system, pipe materials, local geology, the treatment process, and other variables. As one would expect, losses associated with newer systems tend to be less than losses for older systems. System losses are explicitly considered here as a component of the 160-gpcd usage estimate.

[1] Source: HDR (2004), Task 4.1, Summary of Water Demand, table 9 - Navajo and table 10 – Hopi.

[2] The population of the study area communities of Cedar Ridge and Bitter Springs are included in the Bodaway Gap Chapter.

[3] The population of the study area community of Gray Mountain is included in the Cameron Chapter

Using the per capita use rates from table III.2-1 and the population data from table III.1-1 for the Navajo and Hopi Tribes, estimated water demands for these tribal communities can be developed. These estimates are shown in table III.2-2 in units of million gallons per year and acre-feet per year.

[19] The reasonableness of the 160-gpcd value was determined by the HWNSS, as was the reasonableness of the 2.48 percent population growth rate that determined the population values in these analyses.

Table III.2-2. Estimate of Annual Navajo and Hopi M&I Water Demand, Midrange Rates of Population Growth, Assuming Growth Towards Population Centers, and Ramped-Up Water Uses

Chapter	Population Projection	Units	2000	2000 Adj.	2007	2010	2020	2030	2040	2050
Coppermine	Midrange	MGY	12	13	20	23	36	53	75	90
		AFY	37	40	62	70	110	163	230	275
LeChee	Midrange	MGY	34	37	57	66	101	149	211	251
		AFY	104	114	175	203	310	457	[1] 946	946
Bodaway Gap[2]	Midrange	MGY	34	36	55	64	98	145	205	244
		AFY	104	110	169	196	301	445	629	750
Cameron[3]	Midrange	MGY	45	48	64	75	121	158	206	267
		AFY	138	147	196	230	371	485	632	819
Tuba City	Midrange	MGY	319	344	454	529	850	1,103	1,427	1,841
		AFY	979	1,056	1,393	1,623	2,609	3,385	4,379	5,648
Total Navajo	Midrange	MGY	444	479	650	757	1,207	1,608	2,124	2,693
		AFY	1,363	1470	1,995	2,323	3,704	4,935	6,518	8,263
Moenkopi	Midrange	MGY		14	26	34	70	94	126	169
		AFY		43	80	104	215	288	387	519
Lower Moencopi	Midrange	MGY				6	14	20	30	45
		AFY				18	43	61	92	138
Total Hopi	Midrange	MGY		14	26	40	84	114	156	214
		AFY		43	80	122	258	249	479	658

[1] The municipal demand value for 2040 was obtained from TetraTech RMC (2003). The HWNSS estimated LeChee demands as 648 AF in 2040 and 771 AF in 2050. The TetraTech report did not estimate 2050 demands. The Navajo Nation prefers the TetraTech value be used for the 2040 demands.

[2] The population of the study area communities of Cedar Ridge and Bitter Springs are included in the Bodaway Gap Chapter.

[3] The population of the study area community of Gray Mountain is included in the Cameron Chapter.

Total tribal demands are estimated to be about 2,907 MGY (8,921 AFY) in 2050.

III.2.2 Nontribal Demands

For this study, current production estimates for each community were applied to the population data reported by the NCAWSS Population Subgroup to estimate per capita rates of production across the study area. The information collected and presented in the Phase 1 Report, North Central Arizona Water Demand Study (Rocky Mountain Institute, 2002) was used in developing table III.2-3.

Table III.2-3. Estimates of M&I Per Capita Water Use (gpcd) for Nontribal Communities[1]

	2000	2050
Doney Park/Timberline	88	88
Fort Valley	162	162
Grand Canyon Village	366	[2]
Kachina Village	81	81
Mountainaire	73	73
Page	351	326
Parks	162	162
Tusayan	276	276
Valle	162	162
Williams	198	198
Coconino County CCD[3]	50	120
Flagstaff (Reclamation estimate)	[4]132	132
Flagstaff (City of Flagstaff 2005 estimate)	120	120

[1] This table includes data for the specific communities where population data were found to be available and where water usage could therefore be estimated based on multiplying population by the estimated per capita use rates for the community.

[2] NPS anticipates water use in 2050 will be 20 gallons per visitor for the South Rim Village.

[3] For 1995, the USGS reported a per capita use rate of 162 gpcd for Coconino County. Population in the portions of the Coconino County census areas outside of incorporated communities, but included in the study area, was assigned a per capita use of 50 gpcd as described by the USGS for 1995.

[4] Population data from 2002 were used in the development of Flagstaff demand.

Flagstaff, GCNP, Williams, and Page were contacted by the Demand and Conservation Subgroup for additional clarification and additional data relative to recent trends in water demand in these areas.

It is important to distinguish these rates as per capita rates relative to water production, rather than estimates of water usage. In some areas, water production facilities may serve a much larger population than the estimate provided by the Population Subgroup for this study. In these cases, per capita rates could over-represent individual use rates by a wide margin.

These per capita production rates, in gallons per capita per day, and the projected community population estimates were adopted as a means of computing future water production by community for the 2050 demand estimate.

Table III.2-4 shows the historic, current, and future demand estimates based upon the population data that were presented in the Report of Findings for nontribal population as prepared by the Population Subgroup of the NCAWSS and the per capita use rates shown in table III.2-3. These demand estimates will be used in the study to describe future demand within the nontribal communities. For Flagstaff, Reclamation originally estimated demand rates using a per capita use rate of 132 gpcd, which reflected Flagstaff use rates in 2002, including conservation efforts. Subsequently, in large part due to the continuing drought conditions, Flagstaff has seen use rates fall to 120 gpcd based on 2005 estimates.[20]

Table III.2-4. Estimates of M&I Water Demands (MGY and AFY) for Nontribal Communities[1]

	2000		2050	
	MGY	AFY	MGY	AFY
Doney Park/Timberline	256	786	572	1,755
Fort Valley	39	120	70	215
Grand Canyon Village	195	598	[2] 257	789
Kachina Village	79	242	130	399
Mountainaire	27	83	44	135
Page	1,226	3,762	2,233	6,853
Parks	67	206	160	491
Tusayan	57	175	138	424
Valle	32	98	60	184
Williams	210	644	349	1,071
Coconino County CCD	76	233	532	1,635
Flagstaff (Reclamation estimate)	[3] 3,040	9,329	5,477	16,810
Flagstaff (City of Flagstaff 2005 estimate)	2,760	8470	5,020	15,400
Total nontribal demand	5,300	16,280	10,020	30,760

[1] This table includes data for the specific communities where population data were found to be available and where water usage could therefore be estimated based on multiplying population by the estimated per capita use rates for the community. No population data were available for many of the smaller communities in the project area, as described in section II.1.2 above, and specific demands for these communities could not be estimated. As explained further in the text below, the demands for these communities are considered accounted for in the “dispersed” values included in table III.2-5 (i.e., Flagstaff surrounding communities – 25 percent total Coconino County CCD remaining, Flagstaff to Williams – 25 percent total Coconino County CCD remaining, and Williams to GCNP – 50 percent total Coconino County CCD remaining).

[2] 20 gallons per visitor in 2050, for an estimated 9,200,000 visitors in 2050, plus 2,689 residents in Grand Canyon Village using 75 gpcd.

[3] Flagstaff data are from 2002.

[20] As noted earlier, while this value may be skewed by the transient student population, it is also skewed by the tourists who are not counted in the City of Flagstaff population. It was not used to size the infrastructure for the alternatives.

Table III.2-5 Estimated Unmet 2050 Demands for the Study Area

Demand Center[1]	Water Use and Projected Demands (AFY)		
	Current Use (2000)	2050 Projected Demand	Unmet Demand to be Met by Project
Navajo	1,472	8,263	8,263
Hopi	42	658	658
Page	3,762	6,853	3,091
City of Flagstaff			
Reclamation	9,329	16,808	8,027
Flagstaff	8,500	15,400	8,027
Flagstaff surrounding communities			
Doney Park	785	1,755	970
Ft. Valley	120	215	95
Kachina	240	400	160
Mountainaire	85	135	50
25% total Coconino CCD remaining	60	410	350
Total for Flagstaff surrounding communities	1,290	2,915	1,625
Williams	650	1,070	420
Flagstaff to Williams			
Parks	200	490	290
25% total Coconino CCD remaining	60	410	350
Total for Flagstaff to Williams	260	900	640
Williams to GCNP			
Valle	100	185	85
50% total Coconino CCD remaining			
Total for Williams to GCNP	115	815	700
	215	1,000	785
GCNP	600	790	790
Tusayan	175	425	425
TOTALS	17,000	[1] 39,700	24,700

This table includes data for the specific communities where population data were found to be available and where water usage could therefore be estimated based on multiplying population by the estimated per capita use rates for the community. No population data were available for many of the smaller communities in the project area, as described in section II.1.2 above, and specific demands for these communities could not be estimated. As explained further in the text above, the demands for these communities are considered accounted for in the "dispersed" values included in table III.2-5 (i.e., Flagstaff surrounding communities – 25 percent total Coconino CCD remaining, Flagstaff to Williams – 25 percent total Coconino CCD remaining, and Williams to GCNP – 50 percent total Coconino CCD remaining).

[1] Using Reclamation estimate for Flagstaff.

Combining tribal and nontribal demand estimates for 2050 yields a regional 2050 water demand estimate of 12,930 MGY (39,680 AFY).

Three areas of dispersed population within the nontribal portion of the study were identified: (1) other communities surrounding Flagstaff, (2) Flagstaff to Williams dispersed, and 3) Williams to GCNP dispersed. Per capita use estimates of 50 gpcd in 2000 and 120 gpcd in 2050 were applied to these areas. Further, rural population within the study area and Coconino County census tract, but not accounted for by incorporated towns and communities, was estimated to be 4,050 in 2000 and 12,100 in 2050.[21] The associated estimated demand for this rural population (denoted as Coconino County CCD in tables III.2-3 and III.2-4) was distributed across these three areas as follows: (1) Other communities surrounding Flagstaff: 25 percent of Coconino County CCD demand; (2) Flagstaff to Williams dispersed: 25 percent of Coconino County CCD demand; and (3) Williams to GCNP dispersed: 50 percent of Coconino County CCD demand.

Based on the estimated demands shown in table III.2-3 and III.2-4, the Reclamation team then estimated the unmet demand for 2050 that should be addressed by the project. For the tribal demands, it was assumed that each alternative formulated should be sized to meet the full 2050 demand, since the current water supply sources (ground water) are unsustainable. Total unmet demands for the Navajo Nation in the study area were estimated at 8,263 AFY. Total unmet demands for the Hopi Tribe in the study area were estimated at 658 AFY. For the nontribal areas, or exceptions as further discussed below, it was generally assumed that the current sources of supply would be maintained into the future; therefore, the unmet demand was the incremental difference between the 2050 and the 2000 demands. For the City of Flagstaff demands, city staff performed an analysis to determine the "sustainable yield" from the existing water supply sources, as discussed in detail in section II.7.2, "Nontribal Communities." Based on this estimated sustainable yield, staff at the City of Flagstaff determined that an appropriate unmet demand to be met by the project should be 8,027 AFY (Ron Doba, personal communication, 2005b). Because of the suspected adverse impacts associated with the pumping of the Tusayan R-M Aquifer wells on Grand Canyon springs, it was assumed that any formulated alternative should meet the Tusayan's full demand for 2050, thereby allowing for discontinuation of well pumping. Because the current water supply system for the south rim of the Grand Canyon is prone to maintenance problems that could result in extended shutdowns, it was assumed that any formulated alternative should meet the full demand for 2050 for the south rim, thereby eliminating the existing problems with the system. Estimated unmet demands for GCNP and Tusayan were therefore 790 AFY and 425 AFY, respectively.

Prior to finalizing the unmet demands resulting from the above analyses, the Reclamation team was asked by the Coconino Plateau Water Advisory Council to

[21] Updated historical and projected population for NCAWSS demand areas: accounting for "Rural" areas in population projections (Reclamation, 2004a).

evaluate whether an escalated conservation effort would eliminate unmet City of Flagstaff demand in 2050 (Doba, 2006). For the purposes of this analysis, it was assumed that an escalated conservation effort might be able to reduce 2050 demands by 20 percent. The results of this analysis indicated that there would still be an unmet demand of 3,370 AF in 2050. Because the City of Flagstaff has already established a strong water conservation program, a 20-percent reduction would be difficult to achieve without eliminating industrial uses and initiating stronger regulations that would likely generate public opposition.[22] However, a 20-percent reduction could be easy to achieve in communities that are relatively wasteful in their water use habits.

III.2.3 Water Conservation

During the scoping phase of the NCAWSS, stakeholders emphasized the importance of water conservation and the extent to which it should apply to the analysis and recommendations to meet future water demands. Hopi and Navajo representatives expressed concern that their conservation practices were an imposition of limited water availability, citing the lack of economic development to produce the economies of scale necessary to develop regional supplies and a dispersed water demand. Stakeholders from the non-Indian demand areas had contrasting views with regard to the use of conservation to meet future demand. Some felt that conservation was an essential alternative to meet future water demand. Others felt conservation was a management tool used to sustain the current supply. The TAG recommended that a comprehensive examination of water use, water conservation, and alternative water supplies be conducted and incorporated by reference in the NCAWSS Report of Findings.

The Coconino Plateau Water Advisory Council agreed to commission an inventory of the current conservation practices with an option to evaluate how conservation could be used to meet future demands. The RMI completed an inventory of conservation practices within the study area under contract with the Grand Canyon Trust. The study was jointly funded by the Grand Canyon Trust and the City of Flagstaff. NCAWSS Technical Advisory Group members participated in the scoping, interviews, and review of the final report of findings titled, *North Central Arizona Water Demand Study – Phase One Report* (RMI, 2002).

[22] The request to reduce by 20 percent was not specific to Flagstaff. The Reclamation study team concluded that it would be most efficient and illustrative to select Flagstaff given its significance as a large current and future water user in the region. By illustrating the balance of unmet demands in Flagstaff, it was not necessarily significant to apply this same analysis to the other non-Indian demand areas.

The objectives of RMI Demand Study were to:

- Compile existing data and information on current water demand, water efficiency, and conservation activities and alternative supplies in the region

- Develop qualitative evaluations of current levels of conservation/ alternative supply effort and the potential for further gains

- Develop a recommended methodology and work plan for demand forecasting and estimation of potential contributions of alternative supplies to meeting future demand.

Current Condition

The RMI Demand Study evaluated the non-Indian water demands and conservation practices within the study area. Interviews were conducted with water providers to asses the extent to which conservation was applied to both water management and the need to meet future water demand. Demand areas with limited or drought-sensitive water supplies reported extensive conservation practices to meet current demand. Water reuse and conservation incentives integrated water management tools applied in a manner considered contemporary by conservation standards. Demand areas with more reliable or diverse water supplies also applied conservation incentives, many of which were elevated and in practice due to onset of drought conditions, which have substantially reduced the availability of surface water supplies. Coconino County's Comprehensive Plan encourages future growth in the county in clustered development within existing populated areas to enhance water use efficiency.

The demand areas within the Hopi Tribe and Navajo Nation experience severe drought impacts to surface water impoundments and shallow ground water supplies. Current per capita per day water use is less than half of the non-Indian sector of the study area. Many water users within the tribal demand areas haul their potable water from potable and nonpotable sources. Conservation is also considered a culturally significant practice, owing to the respect for water as a life-way observed in many Hopi and Navajo religious ceremonies.

Future Without Project

The research indicates that demand areas included in the study area will continue to develop cost-effective conservation practices as a means to extend their current water supply. Municipalities and communities within the study area recognize the values of conservation and, as a practical matter, will seek to implement conservation technologies as the cost benefits allow.

Future With Project

Members of the Coconino Plateau Water Advisory Council asked the study team to conduct an analysis that would include a reduction of future unmet demands, as discussed in Section III.2.2, by 20 percent to represent future conservation practices. The Reclamation study team agreed to analyze the 20-percent reduction using the City of Flagstaff's future water demand. Table III.2-6 includes an analysis of "safe-yield" from a 10-year period of record between 1995 and 2004. The City of Flagstaff, the largest water user within the study area, considered this 10-year period of record to include normal and less than normal precipitation.

Table III.2-6. Potential Unmet Demands With Assumed 20-Percent Conservation

City of Flagstaff Water Demand (AFY)	
	1995 to 2004
Average surface water	1,977
Average ground water	6,381
Maximum surface water	4,151
Maximum ground water	8,649

Location	2010	2020	2030	2040	2050	2060	Notes
Surface water	2,252						Safe yield (Doba, 2005a)
Ground water	8,800						Safe yield (Doba, 2005a)
Sustainable yield total	11,052	11,052	11,052	11,052	11,052	11,052	
Water demand					16,809		NCAWSS estimated demands (2003 – 132-gpcd population 113,684)
Imported supply					5,757		Incremental demand to be served by imported water supply
20% reduction					1,151		
Unmet demand					4,606		Incremental demand to be served by imported water supply
					15,393		See Doba (2005a)
Imported supply					4,341		Incremental demand to be served by imported water supply
20% reduction					868		
Unmet demand					3,472		

Summary

Conservation is both an effective water management tool and a culturally significant practice within the study area. The results of the analysis to reduce projected water demand for the City of Flagstaff identify an unmet demand of approximately 3,500 AFY.[23] The effects of ground water pumping to meet existing and future supply are not well known and are beyond the scope of the appraisal study.

III.3 Projected Response to Demands In Lieu of a Federal Response

This scenario projects a future without project that essentially considers the alternatives each demand area will likely implement in the absence of a regional plan—essentially, a "no Federal action" plan. Formulated alternatives will then be compared to this scenario.

III.3.1 Tribal Communities

Western Navajo Nation

Along with Page, the LeChee Chapter would be expected to pursue development of the new intake and pipeline out of Lake Powell. The Navajo communities of Bitter Springs, Coppermine, Cedar Ridge, Bodaway Gap, Tuba City, and Cameron would be expected to continue to rely on ground water wells in the Navajo Aquifer and in alluvial aquifers. The use of many livestock wells for culinary use would continue. There is some possibility for limited wastewater reuse. There would be continued development of IHS and NTUA municipal water projects, but the IHS has more than $3 million worth of sanitation deficiencies listed, which amounts to more than a 15-year backlog of projects (Kirk, 2005).

Impacts to ground water use in the majority of these communities are estimated to be significant, based on their current water use projected to the year 2100, particularly in the Coppermine area.[24] Continued reliance on ground water in the future is considered unsustainable by the tribe based on the projections of ground water depletions reported in the HWNSS for the N-Aquifer, the primary water source for this region.

Continued outmigration of tribal members from chapters to off-reservation communities would be likely. Health problems due to a lack of running water and

[23] As noted above, achieving a 20-percent reduction in the City of Flagstaff's demands may be difficult to achieve due to its already strong conservation program; however, for communities with relatively wasteful water use habits, such a reduction could be easy to achieve.
[24] HWNSS (HDR 2004) "low range", "mid-range", and "high range" estimates of population growth and water demands.

poor water quality would continue, particularly in those areas relying on hauling of water and livestock wells. The ongoing lack of economic development and modern housing development would continue.

Hopi Community of Moenkopi

This demand area is in proximity to Tuba City, where there are conflicting reports about the viability of continued use of the N-Aquifer. The Hopi Tribe currently projects a need for additional water supply by the year 2015 and considers continued reliance on ground water to be unsustainable (Roberson, personal communication, 2005). The HWNSS analysis of the demand area indicated that no additional supply would be required to the year 2100; however, unless a supplemental supply was available, significant aquifer dewatering and impacts to the local springs and critical reaches were projected (HDR, 2004). However, ground water yield versus demand is not the only issue determining sustainability of ground water as a water resource for the Moenkopi Villages. As noted earlier in this report, the villages' ground water sources are threatened by existing sources of contamination and leave the villages vulnerable if their sole source of water supply is from ground water. This threat is significant, and the Hopi Tribe has therefore been attempting to secure other sources of drinking water.

Without an imported supply, dependence on the N-Aquifer will continue with its associated reliance on water hauling. This dependence is likely to continue the substandard living conditions of the tribal members and inhibit any future economic growth on the reservation. Continued use of the N-Aquifer will continue to strain the sustainability of the aquifer and potentially impact the springs that are of cultural and religious importance to the tribe, as well as critical reaches.

It is unlikely that the tribe will be able to import the newly acquired Colorado River water without Federal assistance.

In the future, the tribe will probably consider development of C-Aquifer wells, primarily for industrial use. Municipal use may be considered from this source (Hopi Tribe, 2005).

Havasupai Tribe

Of importance to the Havasupai Tribe, with or without a Federal regional project, is the introduction of ground water management regulation. Such regulation could occur with or without a Federal project, but would be more likely to be introduced in conjunction with a water importation plan that could reduce both the current demands placed on the R-M Aquifer and the potential for future demands on the R-M Aquifer.

III.3.2 Nontribal Communities

City of Page

Currently, the city is working with the Navajo Nation and NPS conducting an EA to determine whether a new intake at Lake Powell, and a pipeline that would serve Page and LeChee, is feasible. Page can proceed ahead with this proposal without a Federally developed regional plan.

City of Flagstaff & Outlying Areas

Bellemont

Bellemont would be expected to continue to rely on ground water, perhaps drilling additional wells into the C-Aquifer if drought conditions persist and further dry up the shallow aquifers. This will place additional strain on the C-Aquifer. The City of Flagstaff projects that increased pumping from its nearby Woody Mountain well field would likely result in a decline in water levels, and such declines might also be expected should Bellemont increase withdrawals from the C-Aquifer. Should unacceptable declines in the C-Aquifer develop, then the water providers for the area may need to increase rates and/or impose water restrictions that limit use. There could also be increases in hauling water from water stands outside of this area's jurisdiction. The Navajo Army Depot may have some opportunities to install more water efficient plumbing or restrict landscape irritation.

Doney Park

Doney Park would be expected to continue to rely on ground water wells in the C-Aquifer. Potential future well sites have been identified and would likely be developed. This will place additional strain on the C-Aquifer in the Flagstaff area, which could contribute to a decline in water levels if all communities in the area continue to heavily rely on this source and/or the ongoing drought continues. Doney Park wells are located in an area of the aquifer that has historically been recharged by wastewater effluent releases into Rio de Flag by the City of Flagstaff. As Flagstaff increases its efficiency in utilizing wastewater, recharge to some Doney Park wells may decline.

Additional actions by Doney Park could include restricting standpipe usage by customers outside of the area, increasing rates further, developing a rainwater/storm water collection system, and imposing water restrictions that limit use.

City of Flagstaff

In the near term, the City of Flagstaff would be expected to continue to draw on its existing surface water and ground water resources. More water would be pumped from some of the newly developed inner city wells, and new C-Aquifer wells would be developed as needed. However, more history is needed to develop an understanding of what would be a sustainable level of pumping from these wells. Flagstaff projects that increased pumping from its Woody Mountain and Lake Mary well fields would likely cause a decline in water levels in those well fields. If ground water levels start to decline, Flagstaff's ADWR Adequate Water Supply designation may be at risk.

It is also assumed that conservation efforts will continue to keep pace with the current level of effort and that all additional water that becomes available for reuse will be used. Flagstaff assumes that no new "big water users" will appear. If the ongoing drought continues, well levels decline, and surface water sources become depleted, city ordinances mandating increasing levels of water restrictions and water rates will probably be implemented.

In May 2004, Flagstaff voters approved a $15-million bond for the city to purchase water rights and to investigate potential new sources of water to meet the expected future growth of the city. Using that funding, Flagstaff recently purchased lands in the Red Gap Ranch and is negotiating to purchase the same in the Bar T Bar Ranch with the intent of developing the C-Aquifer ground water lying below the ranches. To meet midterm growth, it would be expected that Flagstaff would pursue development of the well field and pipeline system infrastructure needed to deliver water from this source to the city. City of Flagstaff voters also approved a second $8,500,000 bond for the drilling and development of up to six new water wells in the Flagstaff area to supplement the current water supply. One of these wells is proposed to be a test well to the R-M Aquifer in the Flagstaff area to develop additional information about the R-M Aquifer as a source of water supply for Flagstaff.

Flagstaff Ranch

Flagstaff Ranch would be expected to continue to rely on ground water wells in the C-Aquifer. This will place additional strain on the C-Aquifer in the Flagstaff area, which could contribute to a decline in water levels if all communities in the area continue to heavily rely on this source and/or the ongoing drought continues. The community would likely have the resources to continue pumping, even as water levels declined, and to invest in water conservation technologies and water reuse should those opportunities become available.

Forest Highlands

Forest Highlands would be expected to continue to rely on ground water wells in the C-Aquifer. This will continue to strain the C-Aquifer in the Flagstaff area and potentially contribute to a decline in water levels if all communities in the area continue to heavily rely on this source and/or the ongoing drought continues. The community would likely have the resources to continue pumping, even as water levels declined, and to invest in water conservation technologies and extend their water reuse should those opportunities become available.

Fort Valley

Fort Valley would be expected to continue to rely on shallow alluvial wells and water hauling. These resources would be extremely sensitive should the ongoing drought continue. In June 2005, the Regional Forester affirmed the Coconino National Forest Supervisor's decision for the Snowbowl Facilities Improvement Project. This project includes developing snowmaking at the Snowbowl ski area, using reclaimed water from the City of Flagstaff. The supply pipeline for the Snowbowl development would go through Fort Valley and potentially offer the opportunity to tie in and use reclaimed water should excess reclaimed water be available.

Kachina Village

Kachina Village would be expected to continue its reliance on ground water and its water reuse in the wetland. This will continue to strain the C-Aquifer in the Flagstaff area and potentially contribute to a decline in water levels if all communities in the area continue to heavily rely on this source and/or the ongoing drought continues. Dropping water levels and the resulting increased pumping costs could present an economic hardship for some members of the Kachina Village community.

Mountainaire

Mountainaire would be expected to continue its reliance on ground water. This will continue to strain the C-Aquifer in the Flagstaff area and potentially contribute to a decline in water levels if all communities in the area continue to heavily rely on this source and/or the ongoing drought continues. Dropping water levels and the resulting increased pumping costs could present an economic hardship for some members of the Mountainaire community.

Other Small Communities

In addition to the above communities, many additional small communities, for which little existing information was available for the Reclamation study team, are present in the outlying Flagstaff area. These include such communities as Red Lake, Pitman Valley, Garland Prairie, Mountain Dell, Lockett Ranch, Cedar Valley, and Saskan Ranch.

Parks

Since the community of Parks is widely dispersed, residents will likely remain dependent on individual shallow wells, water hauling, and rainwater collection. Ongoing discussions could lead to the development of a community well into the C-Aquifer or R-M Aquifer. However, should Parks pursue a C-Aquifer well, in lieu of a Federal project, most of the communities in the surrounding areas would remain dependent on the C-Aquifer, and declining water levels would be likely. Development of an R-M Aquifer well would be risky since the depth to the aquifer is significant, the cost of development is high, and the probability of obtaining a usable yield from such a well is potentially low.

City of Williams

The City of Williams would be expected to continue to rely on its existing surface water facilities and wells in the R-M Aquifer. Maintenance of the existing dam structures could be a problem, as was seen during the summer of 2005 with the problems at the City Reservoir Dam.

Williams could look into expanding its surface water reservoirs' capacities by dredging out and lining the reservoirs. There may be Reclamation programs available to assist in this effort.

The projected future growth of Williams (theme park and residences) would likely need to be supported by additional wells drilled into the R-M Aquifer. If drawdown of the R-Aquifer or impacts to springs associated with the R-M Aquifer were projected to occur, the projected future growth may need to be curtailed.

Valle

Valle would be expected to continue to rely on wells into the R-M Aquifer. Future increases in water supply may be limited without drilling additional wells into the R-M Aquifer. Additional drilling, however, would be controversial from the perspectives of the GCNP, environmental community, and the Havasupai Tribe.

South Rim Grand Canyon – Tusayan

Tusayan

Tusayan would be expected to continue to rely on deep R-M Aquifer wells, the airport rainwater collection system, and their progressive conservation and water reuse program. Future increases in water supply may be limited without drilling additional wells into the R-M Aquifer. Additional drilling, however, would be controversial from the perspectives of the GCNP, environmental community, and the Havasupai Tribe.

South Rim Grand Canyon

As noted above, the pipeline from Roaring Springs to the south rim is nearing the end of its "life-cycle" (Reclamation, 2002a). In the absence of the implementation of a regional solution that would import water to the south rim, the NPS currently has two primary options:

(1) Continue the maintenance and replacement of the existing system

(2) Independent of any regional Federal project, develop an infiltration gallery in Bright Angel Creek to collect water for diversion to the south rim. In conjunction with a new pumping plant in the Phantom Ranch area, this would alleviate the two problems associated with the operation of the existing system. The technical feasibility of this alternative will be considered in a recently initiated feasibility study being performed by Reclamation and NPS.

GCNP has the statutory authority to sell water to the town of Tusayan, and the Park is willing to consider implementation of an agreement to do so, as one method to help reduce the town's reliance on the pumping of the R-M Aquifer.

Coconino County

Residents in the dispersed portions of Coconino County would be expected to continue to haul water or to operate individual wells. Should water levels begin to decline in localized aquifers, water haulers from these dispersed areas would likely find they need to pay increasing prices at standpipes or even be prohibited from utilizing standpipes that had previously been available for use by non-residents of the operating municipalities. Additionally, residents in these dispersed areas could pool economic resources to develop new wells into the R-M or C-Aquifers.

III.4 Summary

All listed demand areas will likely continue the practice of developing ground water and increasing conservation and reuse, while seeking alternative water supplies. The consequence of this practice is varied throughout the study area. Continued use of existing ground water wells within the C, N, and R-M Aquifers may have impacts on seeps, springs, and perennial reaches of some streams. Some studies suggest there could be impacts on the base flows of Havasu Spring, the Verde River, and the Blue Spring reach of the LCR. Regional ground water studies have suggested that continued pumping of the ground water in proximity to the south rim of the Grand Canyon may adversely affect the flows of springs below the south rim of the Grand Canyon. R-M Aquifer development is very expensive, and drawdowns of C-Aquifer wells have been recorded in the majority of study areas over the past 10 years.

All stakeholders within the study area have concerns about their future water supply alternatives if they continue their current water supply and demand practices.

Chapter IV
Plan Formulation

IV.1 Potential Sources Considered for Demand Centers

To begin the development of plans that would address the identified objectives of the appraisal study, Bureau of Reclamation identified the range of potential sources of water supply within the study area. Sources considered included:

- Surface water from the mainstem Colorado River above Grand Canyon
- Surface water from the mainstem Colorado River below Grand Canyon
- Surface water from the LCR tributaries
- Ground water from the alluvium of the LCR
- High-quality ground water from the C-Aquifer
- Low-quality ground water from the C-Aquifer
- Ground water from the R-M Aquifer
- Roaring Springs on the North Rim of the Grand Canyon

The Reclamation team then arrayed these potential sources against the identified demand centers in the study area. The team then evaluated which of these sources could potentially provide water to each demand center. This evaluation is summarized below and in table IV.1-1. Based on table IV.1-1, for each demand center considered to be servable by a supply source, the Reclamation team then formulated the conceptual infrastructure necessary to deliver the water from the supply source to the demand center. Preliminary costing of this infrastructure was performed to assist the Reclamation team in deciding which concepts merited further consideration. While it is recognized that optimization analyses could ultimately provide more efficient alignments and systems, this level of detail is not considered appropriate for an appraisal level of study. These preliminary costs are for capital costs only (no OM&R costs were estimated) and are shown in table IV.1-2.[25]

[25] Subsequent evaluation of the cost estimates revealed an error in the tribal demands used to size the Lake Powell pipeline alternatives.

IV.1.1 Lake Powell

While the Reclamation team refers to this supply source as "Lake Powell," this title is actually a placeholder for the concept of diverting water into a pipeline delivery system out of the mainstem Colorado River above the Grand Canyon. Potential diversion points fall into three distinct categories: out of Lake Powell itself (as is being done by the City of Page now), out of the Colorado River between Lees Ferry and the bottom of Glen Canyon Dam, and out of the Colorado River below Lees Ferry. Each of these diversion points has different significant issues associated. For the purposes of managing the flows in the Colorado River, the river is split into a lower basin and upper basin, with the dividing point at Lees Ferry. Each State under the Colorado River Compact is apportioned a quantity of water that can be diverted from the river. In the case of the State of Arizona, a certain amount of water can be diverted for use from the upper basin and used in that basin, and a certain amount can be diverted from the lower basin for use in the Lower Basin. Since any diversion out of Lake Powell itself would be from the upper basin, while the vast majority of uses of this water in a North Central Arizona study area would be in the lower basin, the diversion of any water which would be counted against the Upper Basin apportionment is a matter of interpretation of the law of the river and the subject of negotiations that would have to occur between the upper and lower basin States. Diversion points which would not have these issues would be from points below the basin dividing line at Lees Ferry. This is possible at Lees Ferry itself, but developing a diversion in this area would present potential impacts to existing recreational and historical resources in the Lees Ferry area. Lees Ferry is within the Glen Canyon National Recreation Area and is the launching point for all GCNP river trips. Downstream of Lees Ferry, the potential diversion points are technically limited by the steep-walled topography of Marble Canyon, and by the potential impacts to environmental, cultural, wilderness, and recreational resources within GCNP and the Navajo Nation. This type of diversion at Jackass Canyon was evaluated by Reclamation as part of the Peabody Coal Black Mesa Mine Water Supply Appraisal Study (Reclamation, 2002b), and substantial negative public comment resulted from this proposal. For the purpose of costing alternatives for this study, the Reclamation team therefore assumed that the point of diversion would be at Lake Powell and would generally be representative of the cost of a system using one of the other diversion points. While a cost for the other diversion point variations will not be developed, the technical evaluation of alternatives discussed below that include a Lake Powell component will address the issues associated with these alternative diversion points.

As seen in table IV.1-1, Lake Powell was considered a potential source of supply for the entire list of demand centers in the study area. However, a Lake Powell component to a regional alternative could range from a pipeline which meets the demands of just the Navajo Nation and, possibly, the Hopi Tribe, to a pipeline which provides water to the furthest demand centers in the study area and all the demand centers in between. In addition, there are several possible ways to align and split a system to deliver water to all of the nodes. Reclamation therefore identified a set of alternatives that incrementally add demand centers and represent a logical range of ways to deliver the water to the most outlying demand centers. These include:

- A trunk line to Cameron, with spur lines to Tuba City/Moenkopi and to Bitter Springs. See figure IV.1-1 (map of this iteration). This iteration would meet just tribal demands.

- A trunk line to Flagstaff, via Cameron, with spur lines to Tuba City/Moenkopi and to Bitter Springs. See figure IV.1-2 (map of this iteration). This iteration would meet the demands of the Flagstaff demand center and the tribal demands.

- A trunk line to Williams via Flagstaff and Cameron, with spur lines to Tuba City/Moenkopi and to Bitter Springs. See figure IV.1-3 (map of this iteration). This iteration would meet the demands of the Williams demand center, Flagstaff demand center, and the tribal demands.

- A trunk line that would loop through the entire study area, passing sequentially through Cameron, Flagstaff, Williams, and Tusayan, and ending at the Grand Canyon. Spur lines would go to Tuba City/Moenkopi and to Bitter Springs. See figure IV.1-4 (map of this iteration). This iteration would provide for the demands of the entire study area.

- A trunk line that would deliver water to Cameron and then split into two primary spur lines. The first would branch off to the northwest and deliver water to meet demands of the Grand Canyon/Tusayan area, while the second would continue south to Flagstaff and then continue west to Williams, where it would terminate. Smaller spurs would deliver water off the main trunk line to Tuba City/Moenkopi and to Bitter Springs. See figure IV.1-5 (map of this iteration). This iteration would also provide for the demands of the entire study area, but it is distinguished from the iteration shown on figure IV.1-4 by avoiding the placement of a pipeline through the Williams to Grand Canyon corridor.

IV.1.2 Lake Mead

While this supply source is identified as "Lake Mead" in this study, it is actually a placeholder for the concept of a diversion point somewhere below the Grand Canyon. The primary thought behind using this type of supply source is that it would avoid the upper basin/lower basin issues and/or environmental and recreational issues associated with the "Lake Powell" diversion options discussed above. The Reclamation team considered several possible points of diversion, ranging from Lake Mead to Lake Mohave, but settled upon Lake Mead as the point of diversion. While having a similar length to a Lake Mohave diversion, this option would require less pumping than a Lake Mohave option. As discussed further below, a pipeline from Lake Mead could be developed in areas already disturbed by existing roadways.

While the Lake Mead supply source could theoretically provide as much water as a Lake Powell supply source, it likewise could potentially deliver water to all of the demand centers within the study area. However, the Reclamation team speculated that a pipeline system from this source was likely to be relatively expensive due to the additional distance (approximately 120 miles from Lake Mead to Flagstaff) and additional lift (over 8,500 feet of total pumping head) associated with a Lake Mead source; while the Reclamation team felt that at least a preliminary cost estimate should be made for a pipeline system from this source, it was not considered worthwhile to expend a lot of resource time evaluating the same number of iterations considered for the Lake Powell supply source unless and until the early evaluations indicated this option was more viable than expected. Therefore, the team only evaluated a system capable of delivering water to Williams and Flagstaff. From the area of the Hoover Dam at Lake Mead, a pipeline would be developed along existing road alignments to Williams and then to Flagstaff. See figure IV.1-6 (map of this alignment).

IV.I.3 Little Colorado River Surface Water Tributaries Off the Mogollon Mesa

In December 1977, Reclamation completed a study of potential water supply sources on tributaries flowing off of the Mogollon Mesa with the release of the Mogollon Mesa Project concluding report. This study considered the development of surface water storage on Clear Creek in a proposed Wilkins Dam. For the purposes of the North Central Arizona Project evaluation, Reclamation assumed that a similar type of storage structure could be developed on Mogollon Mesa tributaries, such as Clear Creek, and potentially provide up to 11,900 AF of water. See figure IV.1-7 (map of this alignment).

The western range communities of the Navajo Nation and Hopi Tribe in the study area currently rely upon the N- and/or C-Aquifers for their water supplies. The Navajo Nation maintains that it has rights to surface water in the mainstem Colorado River and LCR, that it needs such surface water to provide for the future of the tribe, and that it will not accept continued sole reliance on the C- and N-Aquifers for communities in the study area. The Navajo Nation has claims on surface water flowing off of the Mogollon Rim and would challenge the use of this water by any of the other demand centers in the study area. The tributaries of the LCR are currently being adjudicated. It is therefore uncertain as to what water would be available to meet future demands in the NCWSS study area. Furthermore, in a review of the availability of water in the LCR tributaries, the Reclamation team determined that there was only sufficient water from this source, for the purposes of this study, to address the unmet demands of the two closest demand centers, Flagstaff and Williams.[26]

IV.1.4 Little Colorado River Alluvium

The HWNSS identified the possibility of collecting alluvial flow in the LCR in the Cameron area. Up to 17,000 AF of water over a 2-year period was considered potentially available from this source.[27] However, long-term use of this alluvial source may not be possible, particularly under drought conditions when water would be most needed. The Navajo Nation currently is reliant upon the N- and C-Aquifers for its water supplies, maintains that it has a right to surface water in the mainstem Colorado River and LCR, that it needs such surface water to provide for the future of the tribe, and that it will not accept continued reliance on the N- and C-Aquifers. Since the Navajo Nation has claims on water flowing in the alluvium of the LCR, and would challenge the use of this water by any of the other demand centers in the study, the Reclamation team initially concluded that this supply source could be used to meet the demands of the Navajo Nation, but for only tribal communities outside of the study area. Furthermore, there are water quality concerns with water in the LCR alluvium, it would require an estimated 70 to 140 wells to produce 17,000 AF of water, and there are potential impacts to riparian habitats that are dependent upon this resource. Based on all of the issues cited above, the Reclamation team determined the LCR alluvium was not a supply source to be considered as a component in a regional solution.

[26] As described further below, the Reclamation team subsequently decided that this source was not a viable source for any demand center in the study area.

[27] This value was derived by the HWNSS from an analysis of the alluvial aquifer in the Leupp area.

IV.1.5 Roaring Springs Off the North Rim of the Grand Canyon

Water for facilities within GCNP is supplied by Roaring Springs. Roaring Springs is located below the north rim and is tributary to Bright Angel Creek. Eight water supply alternatives associated with the GCNP were evaluated in 2001 under an interagency agreement between Reclamation and NPS. The results of this evaluation were documented in the Grand Canyon Water Supply Appraisal Study (Reclamation, 2002a). This study concluded that the most attractive alternative to meet future demands of the park would still involve the use of Roaring Springs as a supply source. However, under this alternative, the section of the existing transcanyon pipeline from Roaring Springs Pump Station to Phantom Ranch would be abandoned, flows would be returned to Bright Angel Creek, and water diversion into the remaining portion of the transcanyon pipeline would instead be accomplished through an infiltration gallery system located near Phantom Ranch. While the 2001 appraisal study only considered meeting the needs of the NPS, the Reclamation team identified an opportunity to evaluate the potential for this supply source to meet the future demands of the Tusayan area (essentially the Grand Canyon/Tusayan Demand Center as defined in this study) and even the Williams Demand Center. However, as further discussed later in this report, subsequent to the first iteration of complete plans, GCNP provided input to the Reclamation team that the Park has no statutory authority to provide Roaring Springs water to Williams and would require Congressional authorization to provide such authority. However, GCNP was doubtful they would ever seek or obtain such authority due to potential conflicts with the Park's mission or purpose, environmental concerns, and unfavorable flow and cost protections. Therefore, providing water to Williams from Roaring Springs was determined to be unrealistic. See GCNP comments dated August 23, 2006, in appendix F.

IV.1.6 C-Aquifer – High Water Quality Areas

As discussed in section II.3, the C-Aquifer underlies much of the eastern portion of the study area. The USGS has estimated the total storage capacity/volume for the entire C-Aquifer, much of which lies outside the study area, at roughly 300 MAF. However, water quality varies significantly within the aquifer, with the better quality water being generally found in the southern portions of the aquifer. Interest in development of high water quality C-Aquifer sources has focused in areas along the I-40 corridor west of Winslow. Potential well field developments have been considered for locations on Navajo Nation lands, lands held in fee title by the Hopi Tribe, or privately held ranch lands. The City of Flagstaff has recently purchased lands within one of these privately held ranches, the Red Gap Ranch, and is negotiating to purchase lands within a second, the Bar

T Bar. The Reclamation team therefore focused on use of C-Aquifer water from a theoretical well field in this I-40 corridor. See figure IV.1-8 (map of this iteration).

The identification of a potential yield that could be utilized from this source is a complex issue. Tribal chapters in the area currently rely upon the C-Aquifer, as do several significant nontribal users.[28] Many potential future demands on the aquifer have been projected, and the potential drawdown of the aquifer is a concern to existing users and for potential impacts on endangered species in Clear Creek and Chevelon Creek and on flow, riparian habitat, and endangered species in the Blue Spring reach of the LCR. These drawdown impacts have been evaluated in several recent studies, most notably the HWNSS and two studies, one of which is ongoing, which Reclamation has conducted for the Peabody Coal Mine on Black Mesa. The potential exists for water quality in high water quality portions of the C-Aquifer to be impacted by intrusion of saline water as a result of pumping and drawdown in high water quality areas. Ground water modeling conducted for these studies has generally shown that impacts to flow in Clear Creek and Chevelon Creek will occur as future demands on the aquifer increase, but the impacts from individual well field development projects become immeasurable, as such developments are sited further to the west of the creeks. Complicating a yield analysis further is uncertainty concerning the actual timing and quantity of future demands on the aquifer, and how long those demands might be maintained. Of principal interest is the potential demand for Peabody's Black Mesa Coal Mine. The studies cited above project a potential demand of 6,500 AF of water to be provided from the C-Aquifer for the life of the Black Mesa mine, which is projected to extend to 2026. Fortuitously, whereas the principal nontribal water demands in the study area, for the City of Flagstaff, are not projected to require importation of water from an outside source until around this same time period. Based on the above considerations, the Reclamation team initially concluded that only the demands for the Flagstaff and Williams Demand Centers could be met from this supply source.[29] Water from the I-40 corridor area would therefore be delivered by a pipeline roughly following I-40 into the Flagstaff area.

The communities of the Navajo Nation and the Hopi Tribe in the study area currently rely upon the N- and C-Aquifers for their water supplies and maintain that they have rights to surface water in the mainstem Colorado River and LCR, that they need such surface water to provide for the future of the tribes, and that

[28] Among others, these users would include the City of Winslow, area ranches, irrigation districts, Joseph City, Cholla Power Plant, Forest Industries, and the City of Holbrook.

[29] As discussed further below, subsequent evaluation concluded that only the Flagstaff Demand Center could be supplied from a C-Aquifer source.

they will not accept additional reliance on the N and C-Aquifers. Therefore, for the purposes of this study, meeting the demands for the tribal demand centers from the N- and C-Aquifers was not considered.

IV.1.7 C-Aquifer – Low Water Quality (Saline) Areas

Water quality in the C-Aquifer progressively deteriorates in areas to the north of the I-40 corridor. In particular, aquifer use is limited by high salinity levels. In some areas, arsenic and uranium levels are also potential concerns. As part of the Peabody Coal Black Mesa Mine C-Aquifer Draft Appraisal Study (Reclamation, 2003b), Reclamation first considered the development of a C-Aquifer well field in the Ward Terrace area northwest of Leupp for potential use by the Black Mesa Mine. However, this part of the C-Aquifer is high in salinity and was rejected as a low water quality source that exceeded the water quality thresholds provided by the project proponents. Other potential low water quality well field locations include areas north of Flagstaff and south of Gray Mountain within the Babbitt Ranch. For the purposes of this study, the Reclamation team chose to evaluate a theoretical well field developed in the Ward Terrace area to represent the concept of developing a low water quality source in the C-Aquifer. See figure IV.1-9 (map of this iteration). As with the freshwater C-Aquifer alternative, this supply source was considered for the Flagstaff Demand Center only and was considered inappropriate for meeting the demands of tribal nodes given the potential high cost for treatment. However, future improvements in water treatment technology may enable this supply source to be developed to meet future water demands.

IV.1.8 R-M Aquifer

Development of the R-M Aquifer as a water supply source is complicated by its depth from the surface (approximately 3,000 feet), lack of geohydrological data relative to the size of the area, and potential impacts to significant water resources on the edges of the study area, principally the spring flows in Havasu Canyon, spring flows below the south rim of the Grand Canyon, Blue Springs on the LCR, and the headwaters of the Verde River above Sedona.

Potential well field development was considered by the Reclamation team in two general areas: areas to the west of the Mesa Butte Fault, and areas to the east of the Mesa Butte Fault.[30] For the former, while wells have been successfully drilled in this area (Tusayan, Verde, and on its outer edge, Williams), additional development would raise the potential for impacts to springs in Havasu Canyon and below the south rim of the Grand Canyon. For the latter, while there is minimal potential for impacting the springs in Havasu Canyon and below the south rim of the Grand Canyon, much less is known about where a well field

[30] See figure II.4-2.

could be sited that would successfully yield water to meet the identified demands. Only one well into the R-M Aquifer has been attempted in the Flagstaff area to date, and that well was able to yield only 30 gpm, much less than would be required to meet projected Flagstaff area demands. Nevertheless, two potential areas east of the Mesa Butte Fault were suggested by the USGS: north of the San Francisco Mountains and 20 miles west of Flagstaff (Don Bills, personal communication, 2005b). The former would require wells between 3,000 feet and 4,000 feet in depth, would have highly variable yield potential, could have high levels of total dissolved solids, and would be in an area likely to intercept ground water that eventually drains at Blue Springs. For the latter, wells in this area would be in a recharge zone very close to a ground water divide, with the ground water to the north of the divide draining at Blue Springs and ground water to the south of the divide draining into the Verde Valley. However, the occurrence and movement of ground water in this area is very poorly understood. Wells would likely be in the 3,000-foot to 4,000-foot depth range, and while the quantity of yield would be highly variable, good water quality would be expected.

As a result of the above considerations, the Reclamation team initially concluded that the only demands which could be met from the R-M Aquifer would be those of the Flagstaff and Williams demand centers.[31] It was assumed that such development would be sited either local to the Williams area or in some location to the east of the Mesa Butte Fault. However, any such development local to the Williams area would need to be consistent with the agreement between the Havasupai Tribe and the City of Williams. Development east of the Mesa Butte fault would need to consider impacts on the Blue Springs reach of the LCR.

Table IV.1-1. Demand Center versus Supply Source Matrix (initial iteration)

Source	Navajo Nation	Hopi Tribe	Flagstaff Area	Williams Area	Grand Canyon/ Tusayan
Lake Powell	Yes	Yes	Yes	Yes	Yes
Lake Mead	Yes	Yes	Yes	Yes	Yes
C-Aquifer – high water quality	No	No	Yes	Yes	No
C-Aquifer – low water quality	No	No	Yes	Yes	No
R-M Aquifer	No	No	Yes	Yes	No
Mogollon Rim	No	No	Yes	Yes	No
LCR Alluvium	No	No	No	No	No
Roaring Springs	No	No	No	Yes	Yes

[31] In the next iteration of analysis, the Reclamation team determined that only the demands of the Williams Demand Center could be supplied by the R-Aquifer. See further discussion below.

Table IV.1-2. Preliminary Cost Estimate of Potential Plan Components[1]

Component Number	Component Description	Field Cost (September 2005)
I.A	Lake Powell pipeline to Cameron	$49,000,000
I.B	Lake Powell pipeline to Flagstaff	$270,000,000
I.C	Lake Powell pipeline to Williams via Flagstaff	$300,000,000
I.D	Lake Powell pipeline to Grand Canyon via Flagstaff and Williams	$360,000,000
I.Ea	Lake Powell pipeline to Grand Canyon via spur from Cameron and to Williams via spur through Flagstaff	$370,000,000
II.A	Lake Mead pipeline to Williams and Flagstaff	$410,000,000
III.A	Mogollon Rim Tributaries to Williams and Flagstaff	$242,300,000
X	C-Aquifer source to Williams and Flagstaff	$140,000,000
XI	Low water quality C-Aquifer source to Williams and Flagstaff	$190,000,000

[1] These costs were very preliminary at the time they were used by the Reclamation team. As noted in the text, an error was subsequently identified in the calculation of costs for the Lake Powell pipeline. As a result of this error, and changes in the underlying assumptions used in the estimating, some differences will be noted from the costs presented in Chapter V, Section V.1, "Alternative Designs and Costing," for similar components in the complete alternatives. The costs in this table are displayed for the purpose of discussing the evolution of the plans formulated and, in all cases, are superseded by those displayed in section V.1.

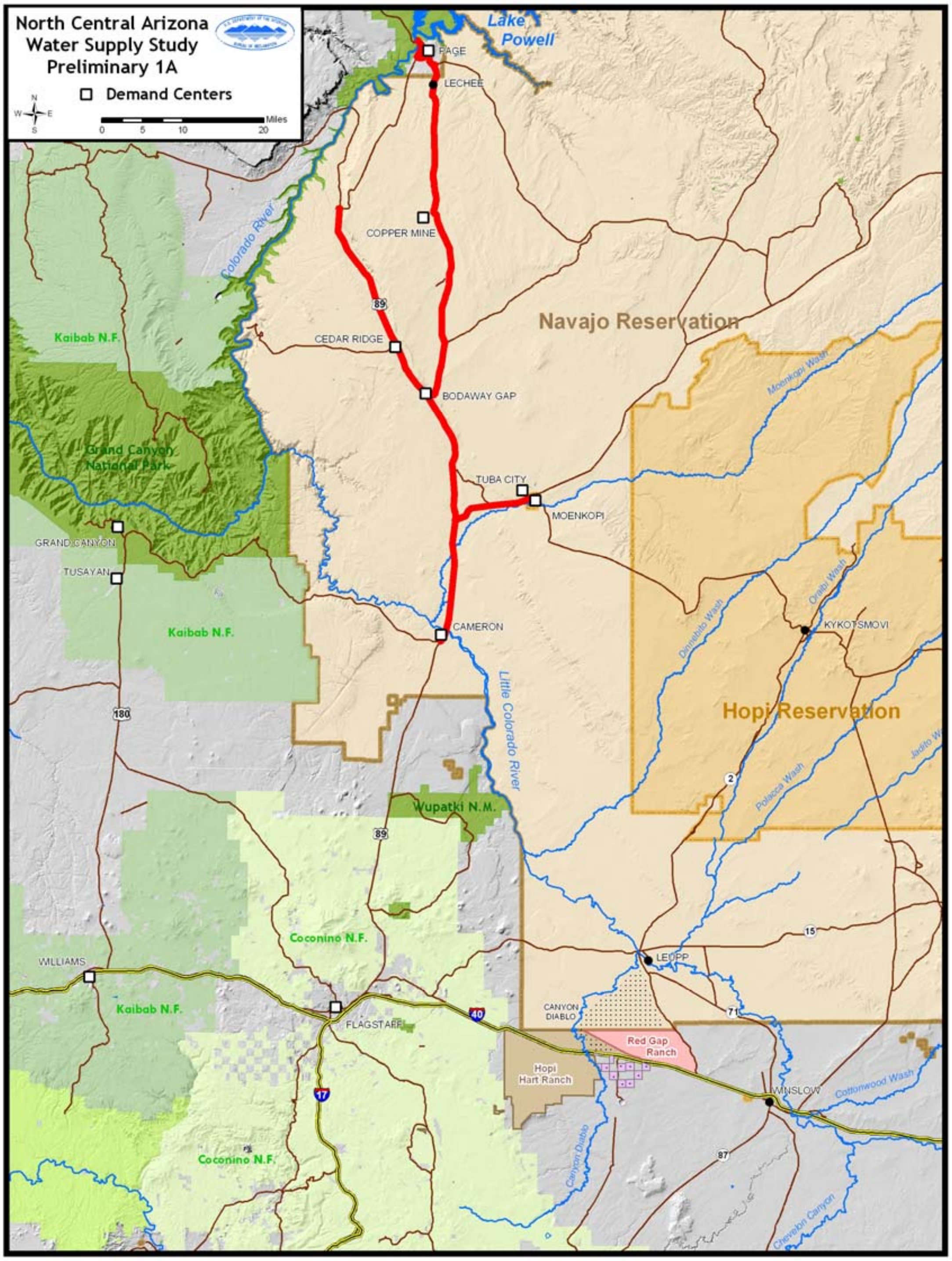

Figure IV.1-1. Lake Powell pipeline to Cameron.

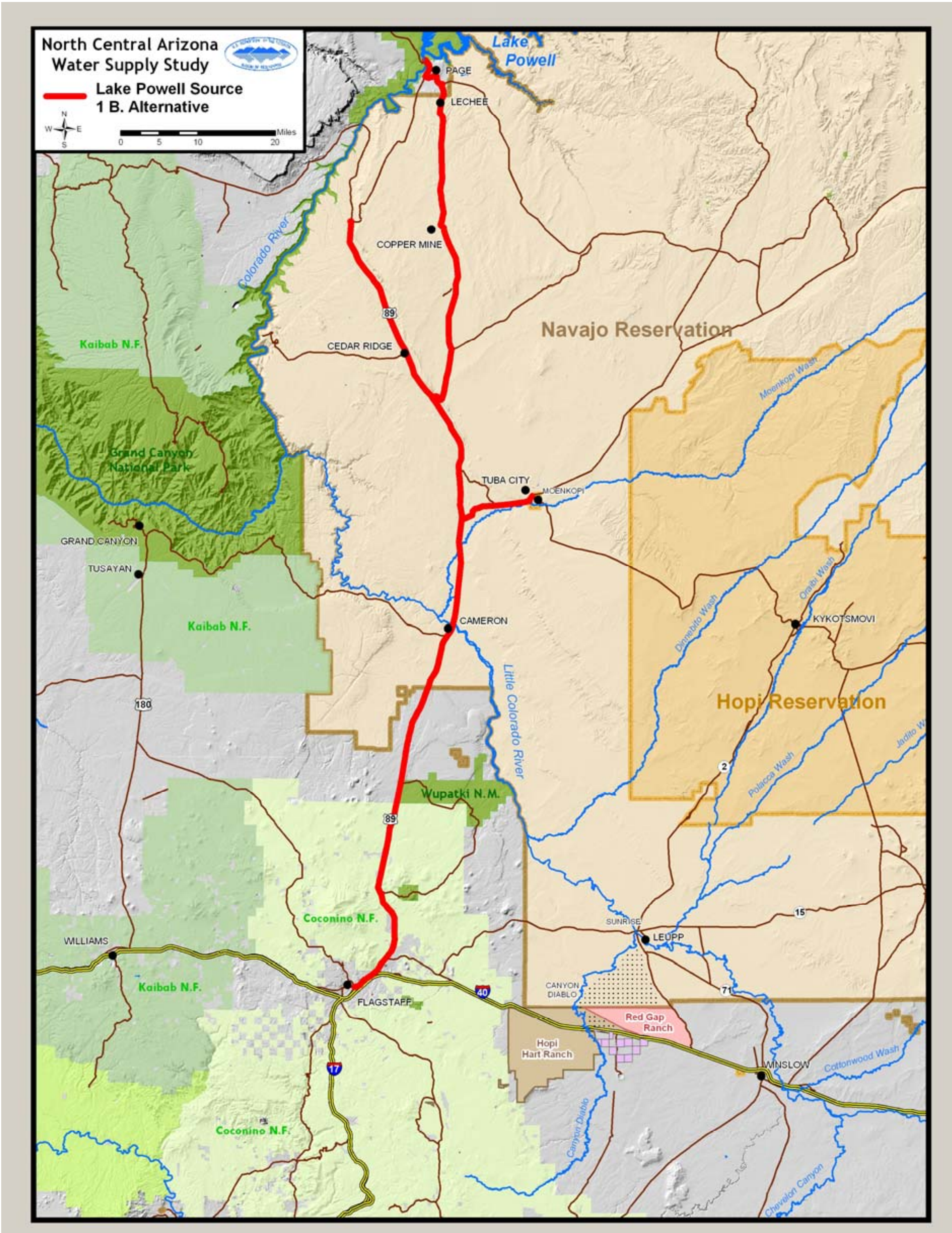

Figure IV.1-2. Lake Powell pipeline to Flagstaff.

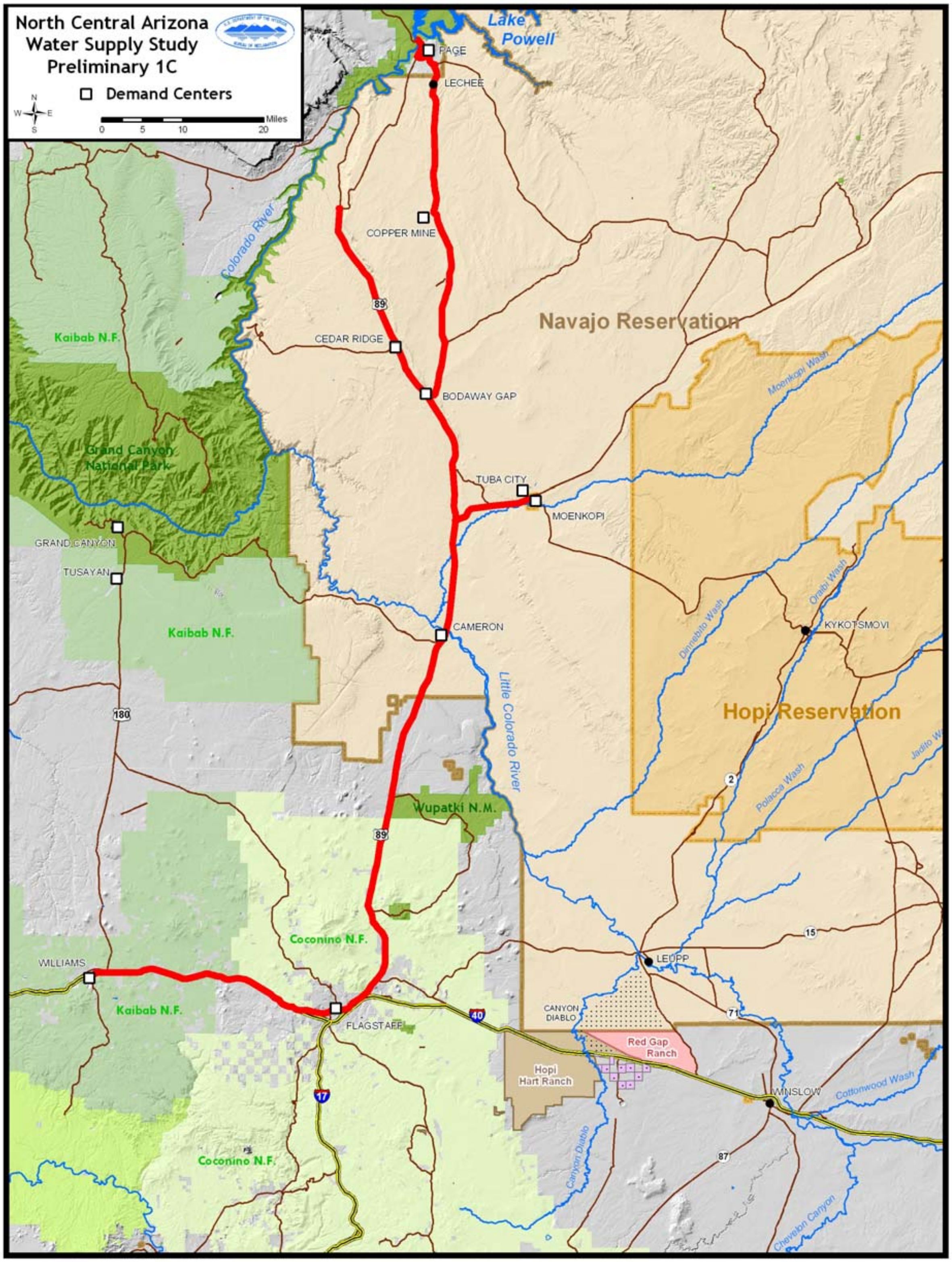

Figure IV.1-3. Lake Powell pipeline to Williams via Flagstaff.

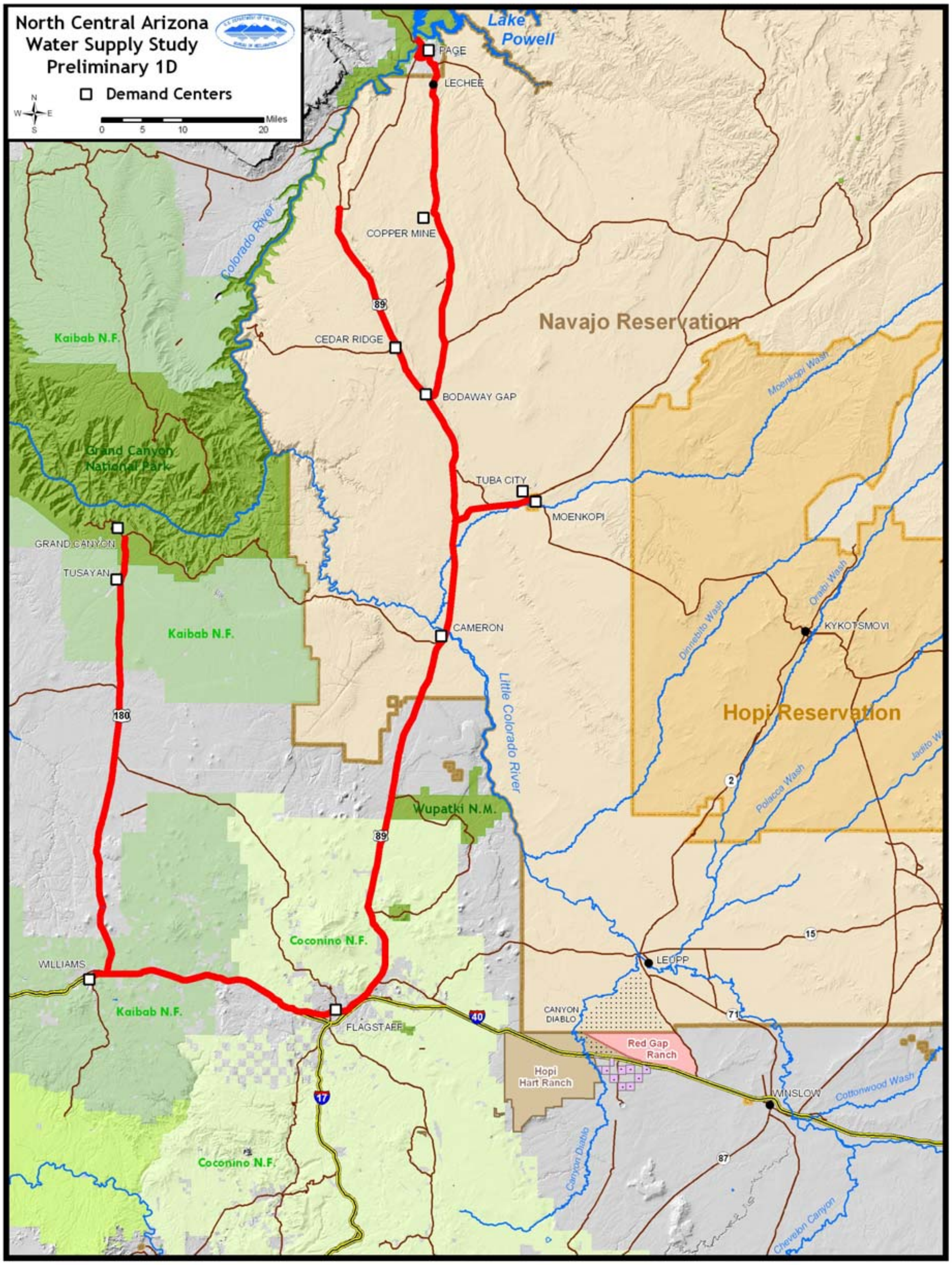

Figure IV.1-4. Lake Powell pipeline to Grand Canyon via Flagstaff and Williams.

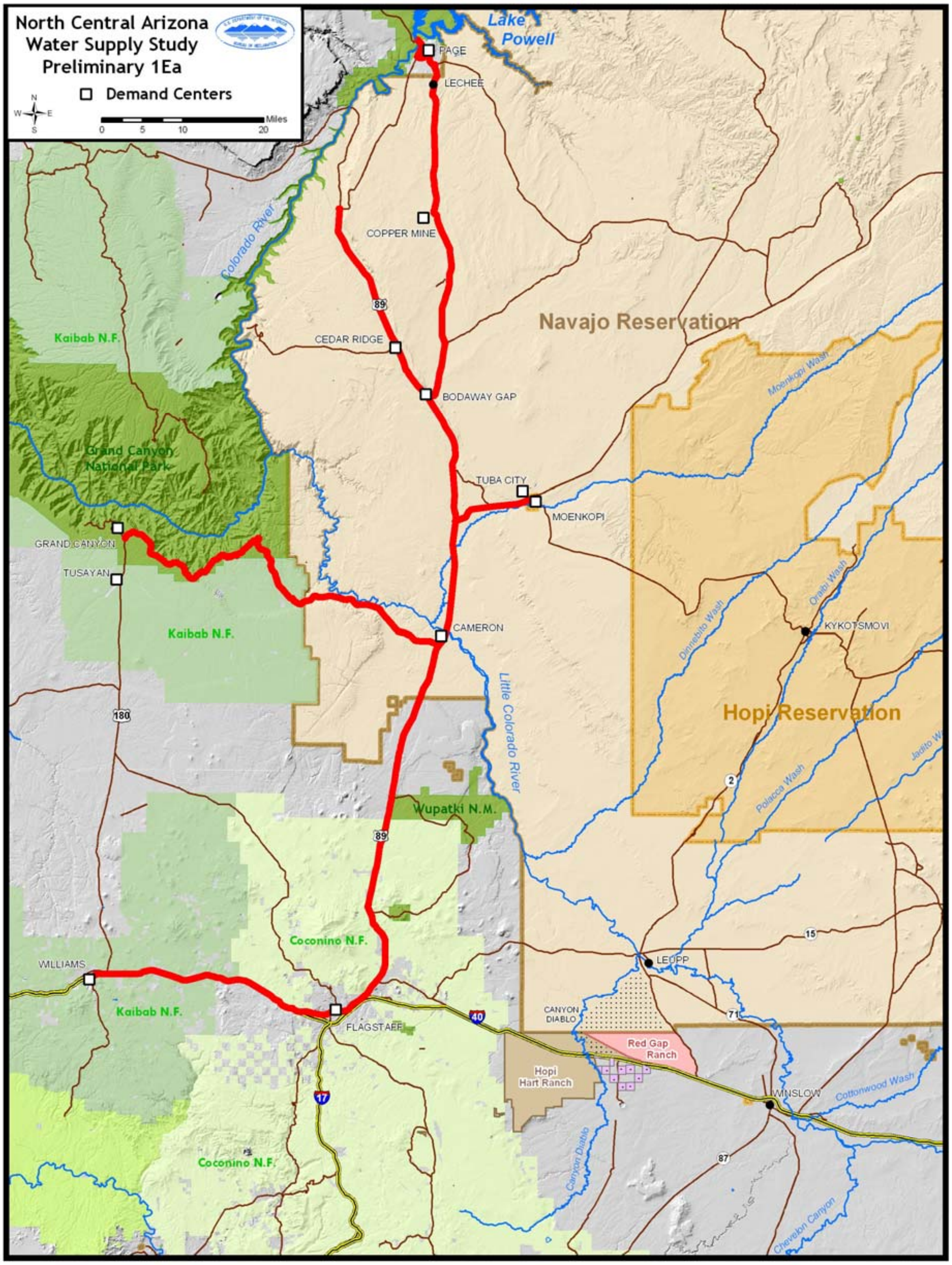

Figure IV.1-5. Lake Powell pipeline to Grand Canyon via spur from Cameron and to Williams via spur through Flagstaff.

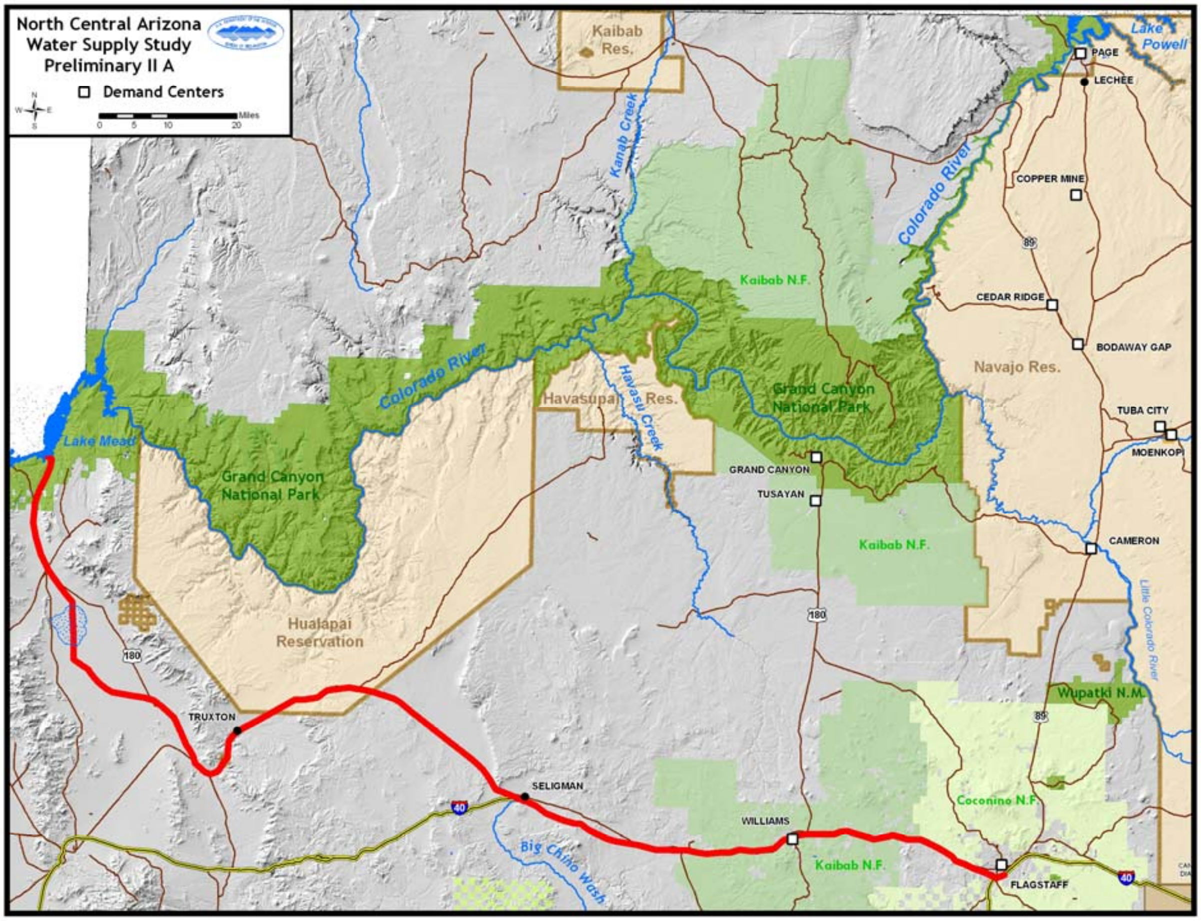

Figure IV.1-6. Lake Mead pipeline to Williams and Flagstaff.

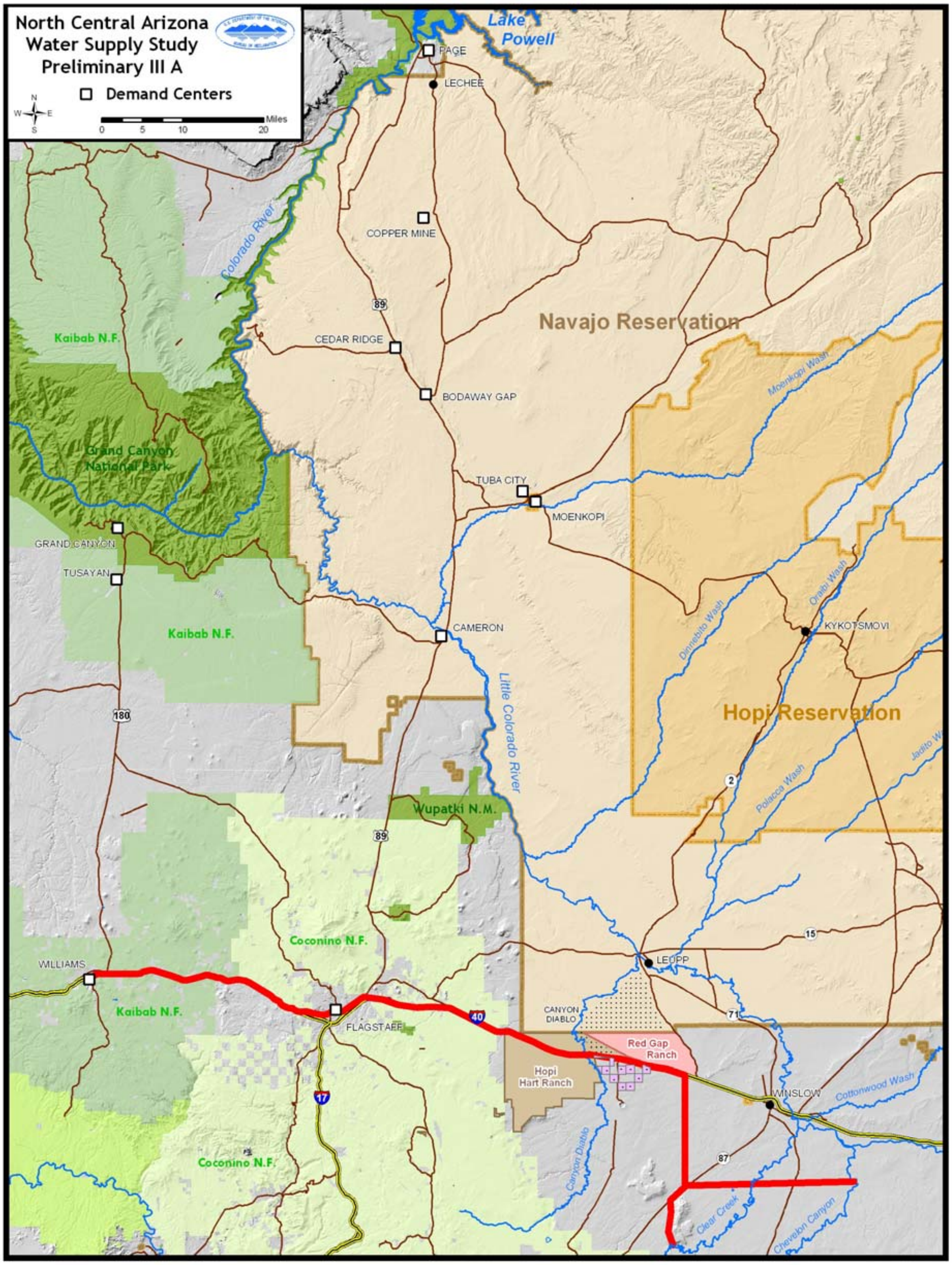

Figure IV.1-7. Mogollon Rim tributaries to Williams and Flagstaff.

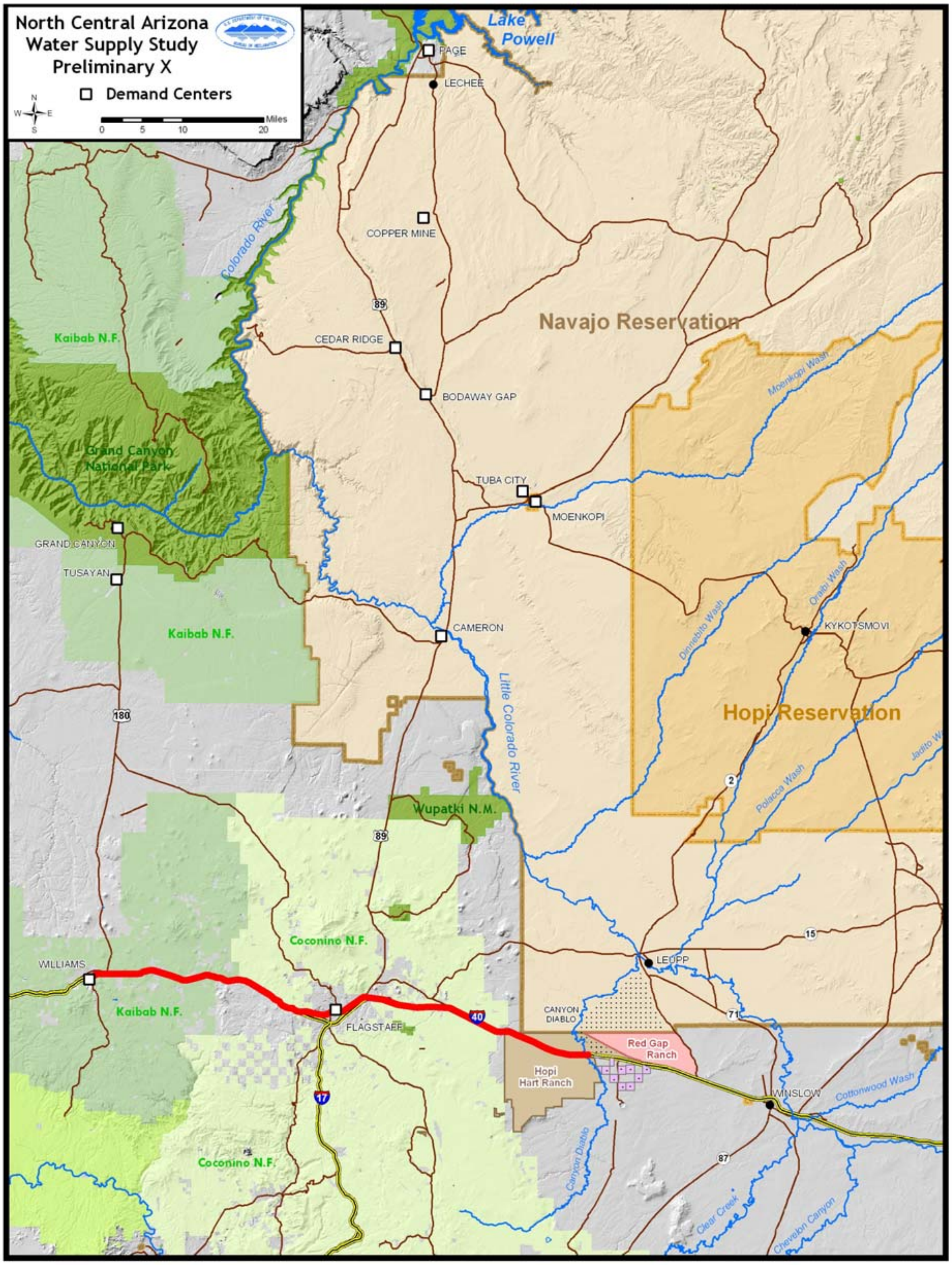

Figure IV.1-8. C-Aquifer source to Williams and Flagstaff.

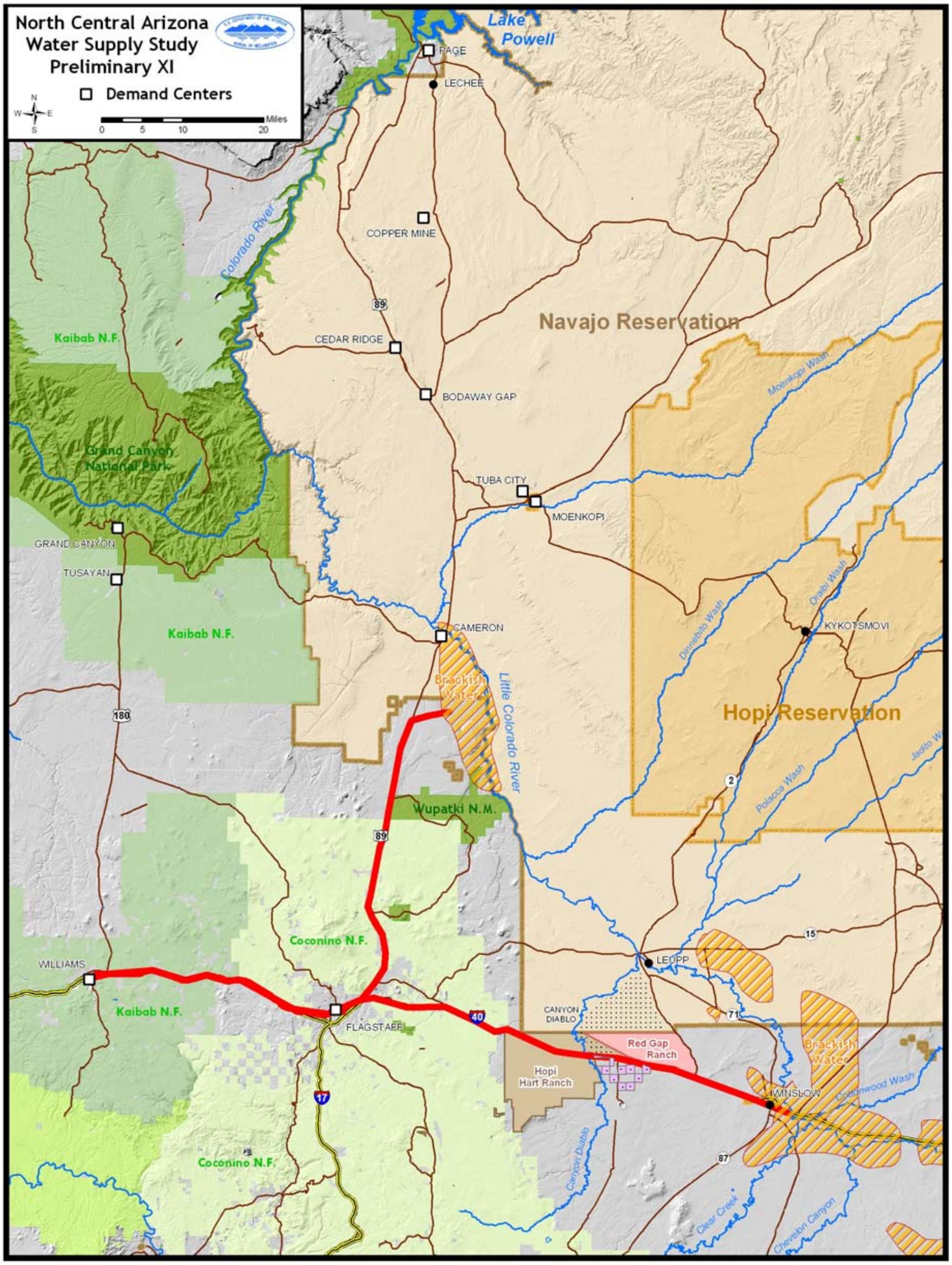

Figure IV.1-9. Low water quality C-Aquifer source to Williams and Flagstaff.

IV.2 Formulation of Alternatives to Meet Regional Demands

From the matrix shown in table IV.1-1, the Reclamation team developed alternatives that were solutions to meeting the entire regional demands identified. While many different permutations could ultimately be formulated to provide such a regional solution, the Reclamation team focused on identifying a range of alternatives that would include each component in at least one of the alternatives and, therefore, bring to the subsequent analyses any relevant issues associated with that particular source.

Prior to attempting to assemble alternatives that represented regional solutions, the Bureau of Reclamation team deleted several of the potential water supply options from further consideration:

- Use of a low water quality C-Aquifer source was dropped from further consideration because the team saw no advantages to this particular source relative to a high water quality source, and the projected cost was substantially higher.

- Use of surface water flows off of the Mogollon Rim was dropped after consideration of recent developments regarding the allocation of water from the Mogollon Rim water sources of interest. As a part of the Arizona Water Settlement Act, water rights for available yield from Blue Ridge Reservoir on Clear Creek were provided to the Salt River Project (SRP) notwithstanding the Navajo Nation's asserting a senior claim to the water (John Leeper, personal communication, 2006). The Reclamation team concluded that this source remains uncertain until adjudicated and, therefore, dropped it for consideration as a supply source for inclusion as a component in a complete regional solution.

- Yield of the C-Aquifer was determined to be insufficient to meet the demands of the Williams Demand Center, in addition to the Flagstaff Demand Center. Furthermore, delivery of water to Williams would be an out of basin transfer, and such transfer is currently prohibited by State law. Therefore, only the Flagstaff Demand Center was considered for supply from this source.

The resulting demand center versus supply source matrix was therefore revised as shown in table IV.2-1.

From the remaining identified water supply components, the Reclamation team assembled six alternatives that could meet all of the regional demands and which represented the range of possible options. These alternatives are shown in figures IV.2-1 through IV.2-6.

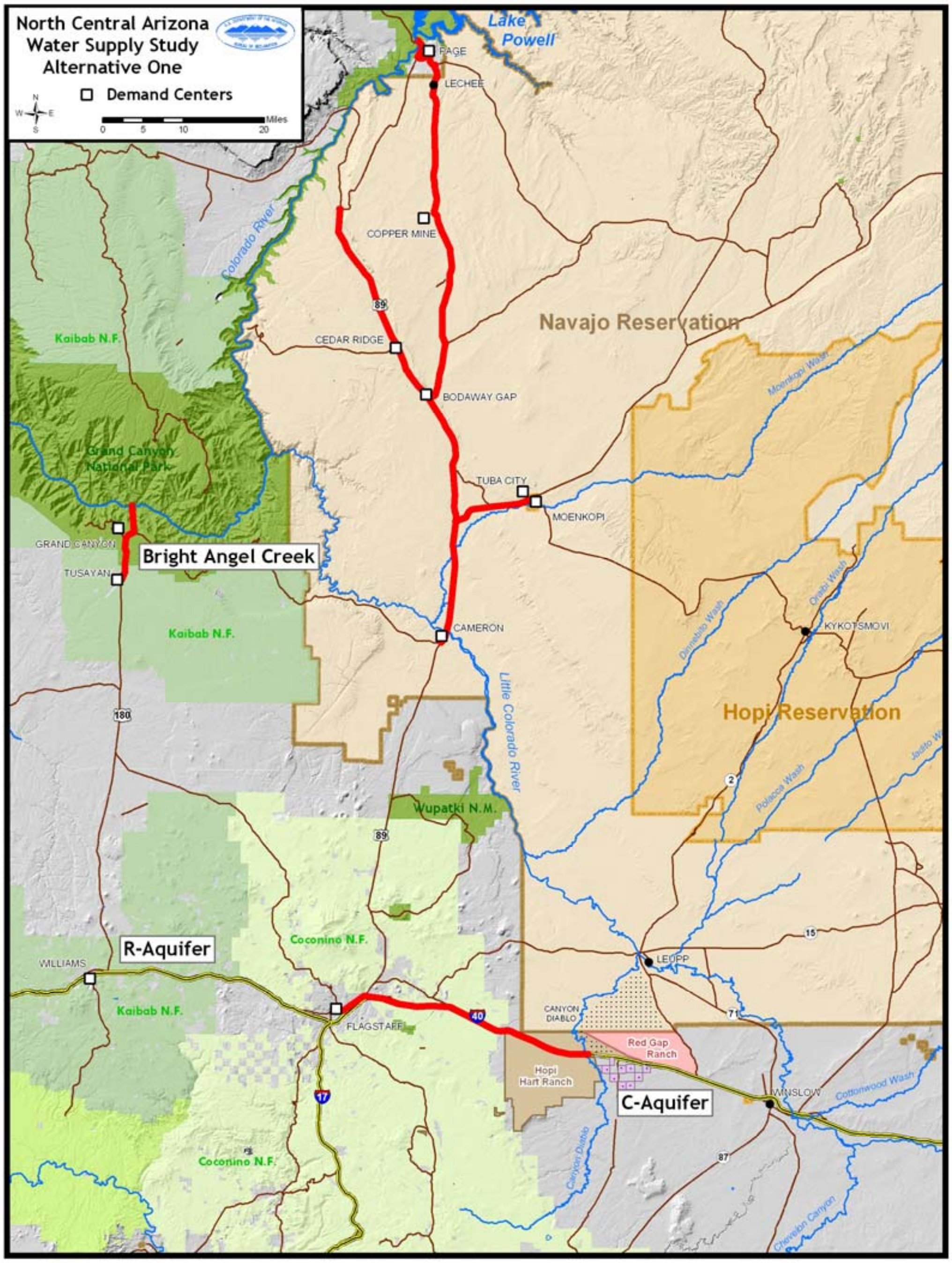

Figure IV.2-1. Alternative 1: Hopi/Navajo Demand Center – supplied via Lake Powell pipeline; Flagstaff Demand Center – supplied via pipeline from C-Aquifer pipeline; Williams Demand Center – supplied from local R-M Aquifer wells; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

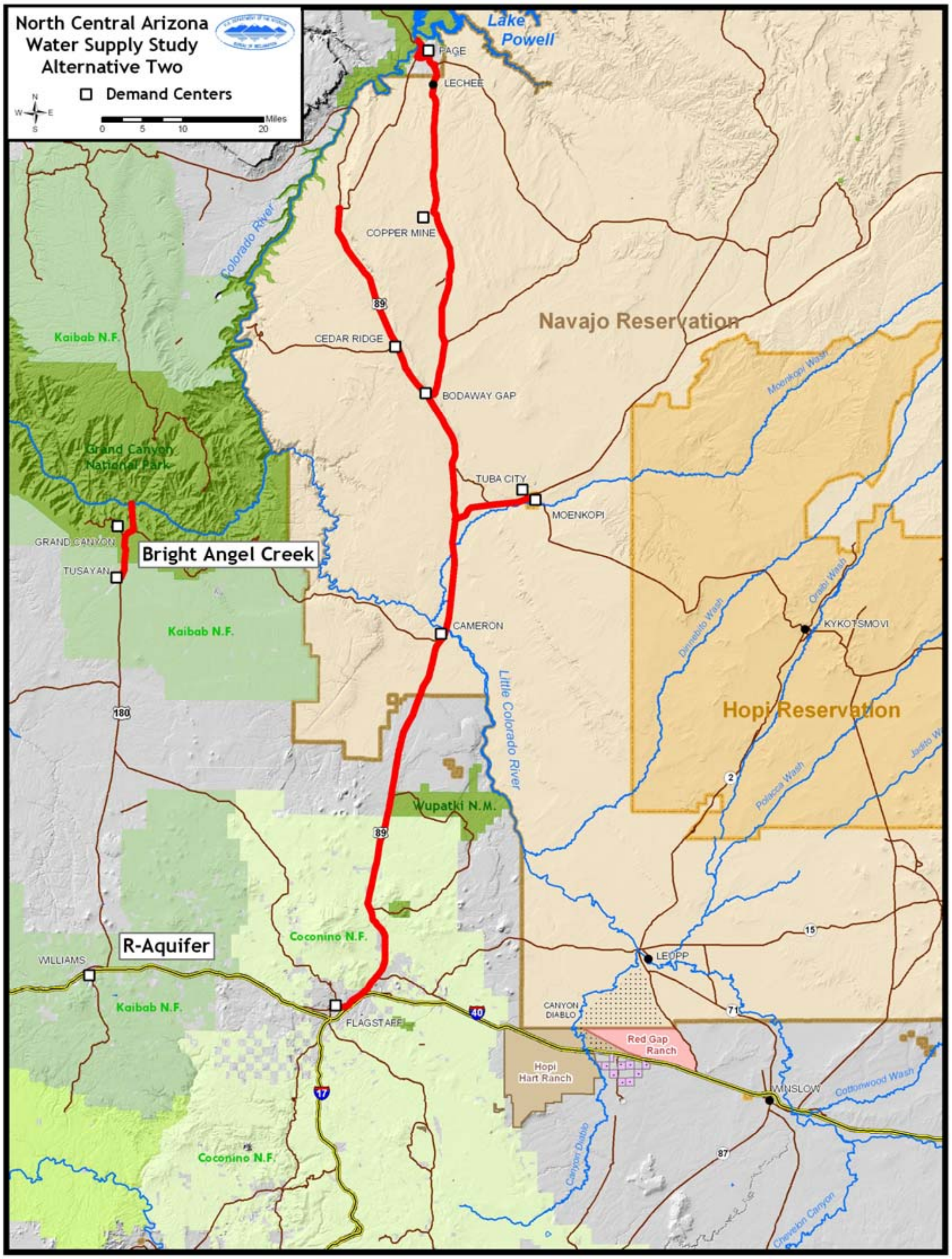

Figure IV.2-2. Alternative 2: Hopi/Navajo/Flagstaff Demand Centers – supplied via Lake Powell pipeline; Williams Demand Center – supplied from local R-M Aquifer wells; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

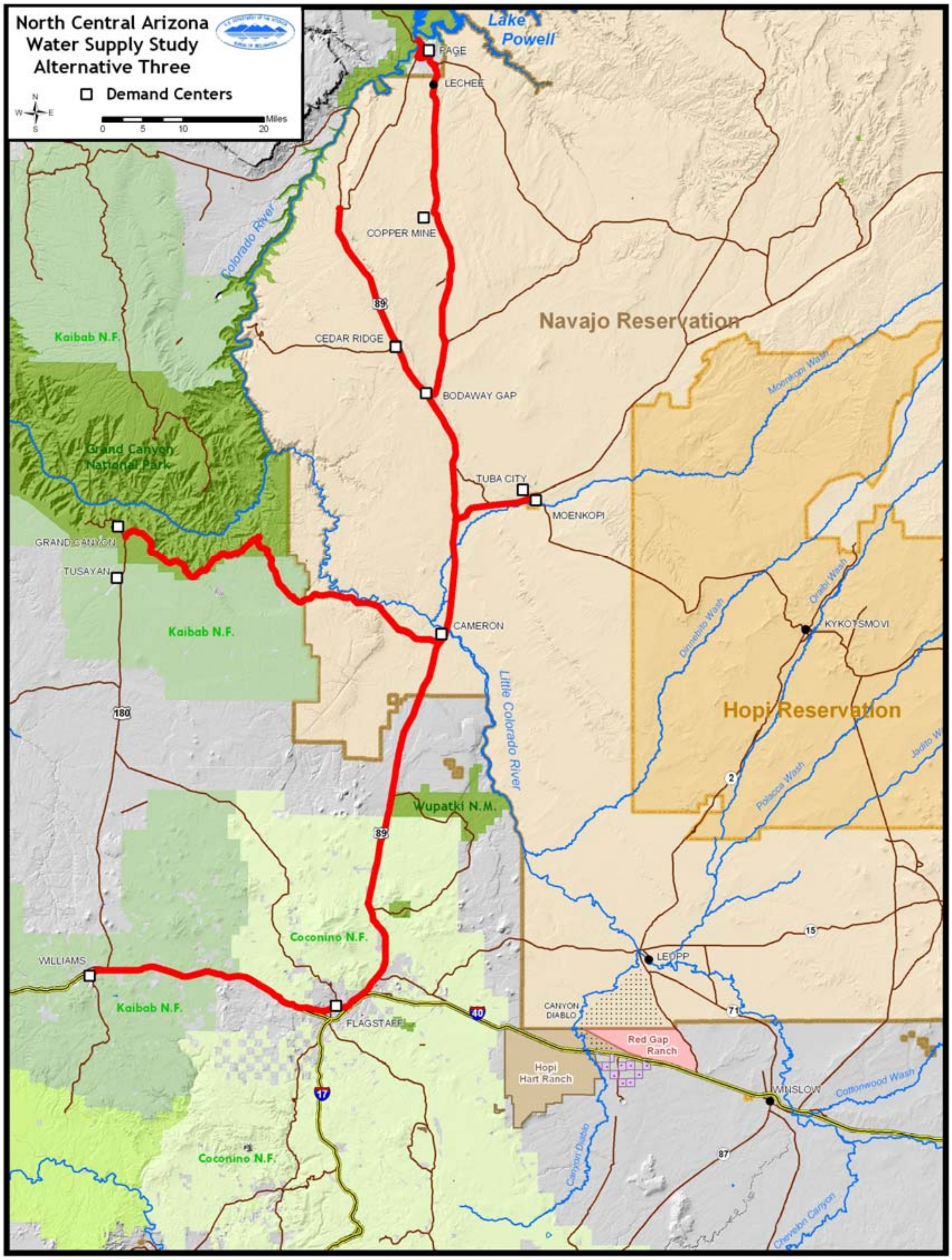

Figure IV.2-3. Alternative 3: Hopi/Navajo/Flagstaff/Williams/Grand Canyon/Tusayan Demand Centers –supplied via Lake Powell pipeline.

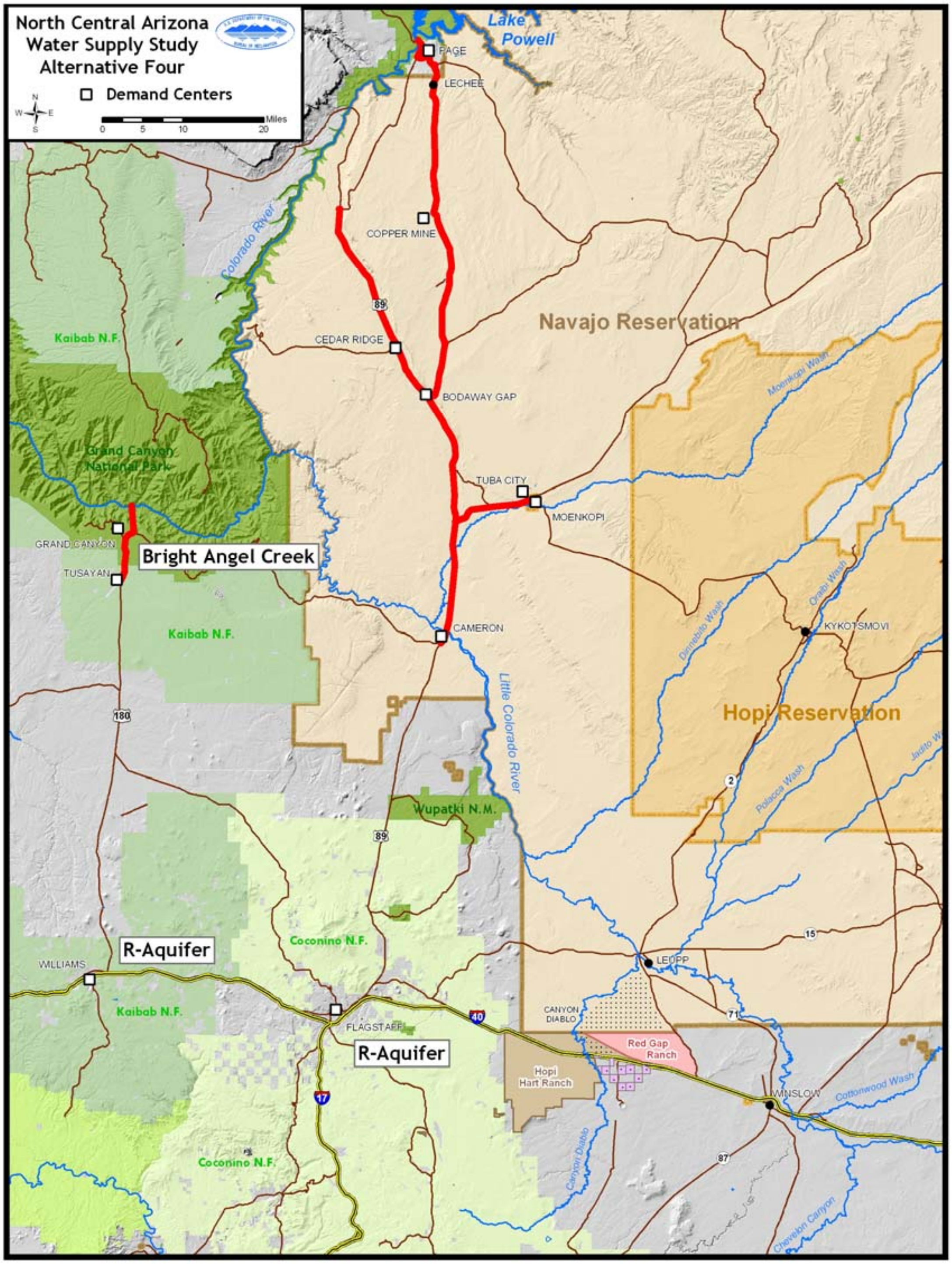

Figure IV.2-4. Alternative 4: Hopi/Navajo Demand Center – supplied via Lake Powell pipeline; Flagstaff/Williams Demand Center – supplied by pipeline from R-M Aquifer well field; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

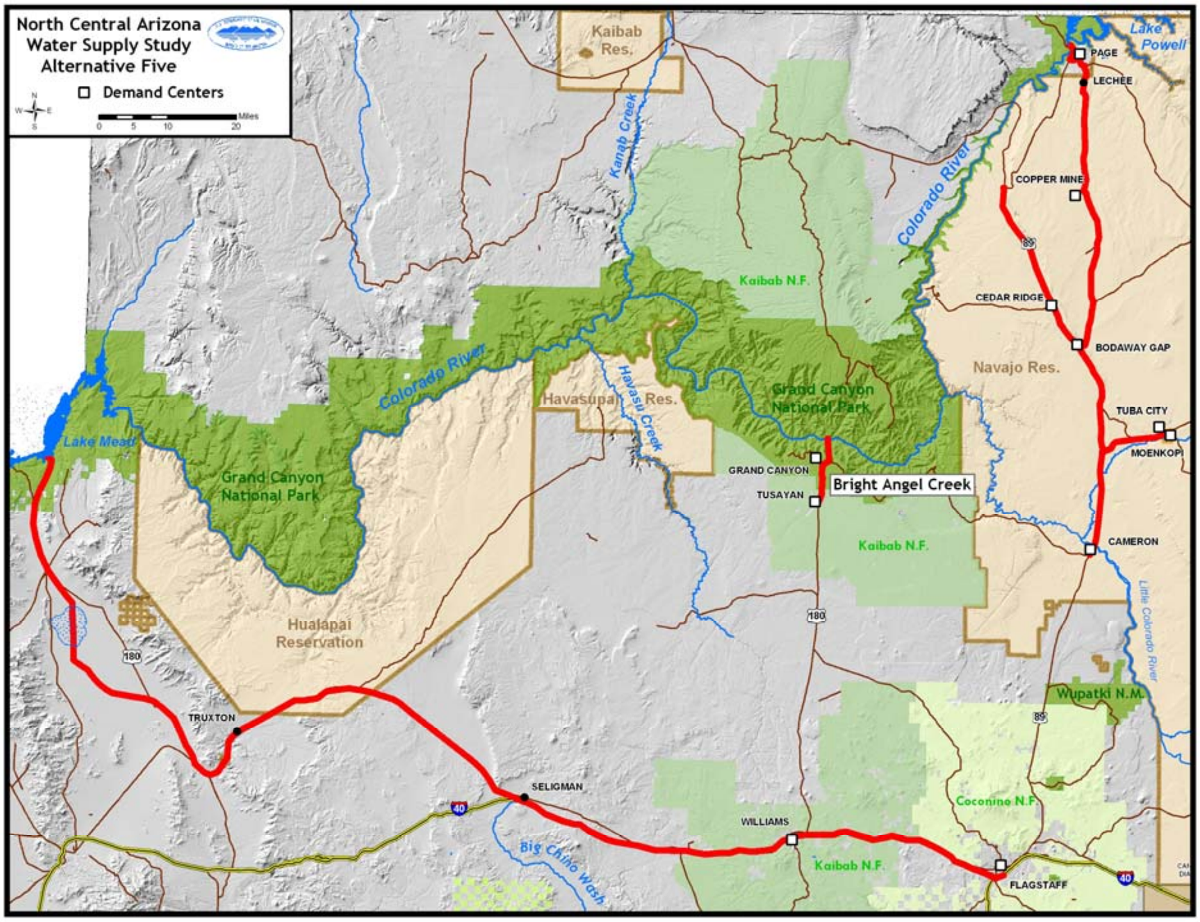

Figure IV.2-5. Alternative 5: Hopi/Navajo Demand Centers – supplied via Lake Powell pipeline; Flagstaff/Williams Demand Center – supplied by pipeline from Lake Mead; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

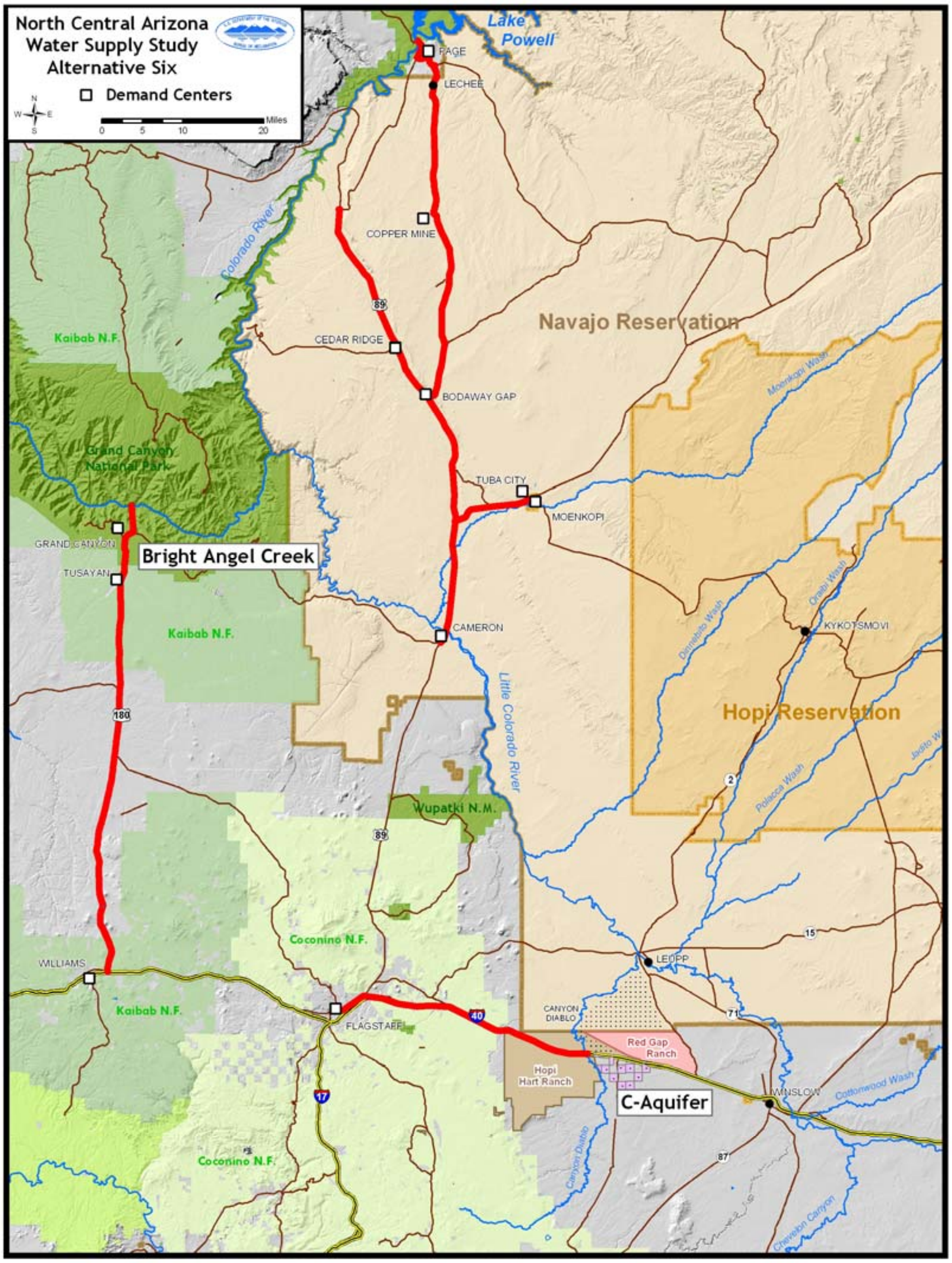

Figure IV.2-6. Alternative 6: Hopi/Navajo Demand Centers – supplied via Lake Powell pipeline; Flagstaff Demand Center – supplied via pipeline from C-Aquifer pipeline; Williams/Grand Canyon/Tusayan Demand Centers – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

Note: Based on input provided by Grand Canyon National Park subsequent to the initial phase of plan formulation described in this section, GCNP indicated that Congressional authorization would be required to provide water to Williams from Roaring Springs, and GCNP expressed doubt that they would ever find reason to seek such authority. As discussed in the following section, this alternative therefore fails the completeness test.

Table IV.2-1. Demand Center versus Supply Source Matrix (second iteration)

Source	Navajo Nation	Hopi Tribe	Flagstaff Area	Williams Area	Grand Canyon/Tusayan
Lake Powell	Yes	Yes	Yes	Yes	Yes
C-Aquifer - fresh	No	No	Yes	No	No
R-Aquifer	No	No	No	Yes	No
Roaring Springs	No	No	No	No[1]	Yes

[1] See further discussion on the next page regarding the determination late in the study that Williams Demands could not be supplied from this source.

Although none of these alternatives include a pipeline alignment that traverses the length of the Williams to Grand Canyon corridor, water of a sufficient quantity to meet the demands of the dispersed areas in this corridor is made available at the Williams demand center. The method of delivery of this water beyond the Williams demand center to water users in the dispersed areas is beyond the scope of this study, just as it is for defining the method of delivery to other relatively dispersed populations in the study, such as for portions of the Navajo Nation. Other pipeline alignments that can provide water to the entire region, such as one which would include the Williams to Grand Canyon corridor, could be considered at a subsequent level of study. There are significant potential issues with any of these options for distributing water to the dispersed populations in the Williams to Grand Canyon corridor. If a regional pipeline is extended through this area, there is potential for a boom in growth, which may not be desirable and would likely be opposed by GCNP and the environmental community. However, if a pipeline is not available, rather than continuing to haul water, residents may pool resources and attempt to develop new wells into the R-M Aquifer. As discussed earlier in this report, further development of the R-M Aquifer would be opposed by the Havasupai Tribe, GCNP, and the environmental community. These issues must be considered at the next level of study.

IV.3 Initial Evaluation of Alternatives – Four Tests

The Reclamation team evaluated these alternatives in a “four tests” framework to determine if the list could be reduced further. Originally established as guidance for conducting planning studies in the Principles and Guidelines in 1983, Reclamation has traditionally used the “four tests of viability” as a screening tool to identify plans that are appropriate for further study. These four tests are:

Acceptability: The workability and viability of the alternative with respect to acceptance by State and local entities and the public, and compatibility with existing laws, regulations, and public policies.

Effectiveness: The extent to which an alternative plan solves the specified problems and achieves the specified opportunities as stated in the study purpose and needs.

Efficiency: The extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.

Completeness: The extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other public or private plans if the other plans are crucial to realizing the objective. Each alternative will be analyzed to assess whether it would respond to the study purpose and objectives without further investments or implementation of other plans not assumed to be already in place.

This evaluation led to the conclusion that Alternatives 5 and 6 were flawed to the extent that they did not warrant further study at this time. Alternative 5 was flawed by its exceptionally high cost compared to the other alternatives and would, therefore, fail the efficiency test. For Alternative 6, a significant completeness issue was identified. While it was theorized by the study team during the initial plan formulation that sufficient water was potentially present from a Roaring Springs source to meet the demands of the Williams Demand Center, GCNP has indicated that they have no statutory authority to provide water to an entity such as Williams and are doubtful that they would ever seek or obtain such authority from Congress. This is primarily due to potential conflicts with GCNP's mission and purpose, as well as environmental concerns and unfavorable flow and cost projections. This was the only feature that distinguished Alternative 1 from Alternative 6, so there was no point in retaining Alternative 6 for further evaluation.

As further discussed in the next section, the remaining alternatives were then evaluated and compared against the future without condition.

Chapter V
Alternative Analyses

V.1 Alternative Designs and Costing

As a result of the previous formulation steps, four alternatives were identified for evaluation to determine the cost to deliver water to the study area demand areas: the Navajo communities, the Hopi village of Moenkopi, Flagstaff, Williams, and the Grand Canyon and Tusayan. For the purpose of sizing the associated delivery infrastructure of the alternatives, demands associated with the dispersed areas/communities outside of these defined demand areas were assigned to the closest demand center.

Alternative 1 delivers water to the Navajo and Hopi from Lake Powell. Flagstaff receives water from the C-Aquifer. Williams receives water from the R-M Aquifer, and the Grand Canyon and Tusayan receive water from the Bright Angel Creek Infiltration Gallery located at Phantom Ranch in the Grand Canyon.

Alternative 2 delivers water to the Navajo, Hopi, and Flagstaff from Lake Powell. Williams receives water from the R-M Aquifer, and the Grand Canyon and Tusayan receive water from the Bright Angel Creek Infiltration Gallery located at Phantom Ranch in the Grand Canyon.

Alternative 3 delivers water to the Navajo, Hopi, Flagstaff, Williams, the Grand Canyon, and Tusayan from Lake Powell.

Alternative 4 delivers water to the Navajo and Hopi from Lake Powell. Flagstaff and Williams receive water from the R-M Aquifer, and the Grand Canyon and Tusayan receive water from the Bright Angel Creek Infiltration Gallery located at Phantom Ranch in the Grand Canyon.

However, because of the large uncertainties associated with the yields and impacts of R-M Aquifer well fields, and since an R-M Aquifer water supply to Flagstaff was the only feature that distinguished Alternative 4 from Alternative 2, the cost of Alternative 4 was not estimated.

V.1.1 Lake Intakes

It was assumed that a series of sloped borings with submersible pumps would be used for all lake options. The inclined bores were assumed to be 30 inches in diameter and 330 feet long, with an 18-inch-diameter casing and a 12-inch-diameter carrier pipe. At a velocity of 10 feet per second, each 12-inch pipe could deliver approximately 8 cfs. The submersible pumps in each bore were priced at 3,600 gpm and 300 feet of lift.[32]

V.1.2 Ground Water Wells

The well field gathering systems were designed based on wells spaced 1 mile apart. For the C-Aquifer, each well would be 12 inches in diameter, 1,200 feet deep and would deliver 500 gpm with 150-horsepower (hp) submersible pumps. For the R-M Aquifer, each well would be 12 inches in diameter, 3,000 to 4,000 feet deep, and would deliver 250 gpm with 150-hp submersible pumps. Based on recent experience by the City of Williams, costs for the R-M Aquifer wells were ranging from $3 million to $6 million per well and were estimated at $5 million per well for the purposes of this study by the Reclamation project team. The R-M Aquifer wells were assumed to be located within a mile of the City of Williams.

V.1.3 Hydraulics

The Hazen-Williams equation was used to compute the loss due to friction in the pipe laterals. The Reclamation Technical Service Center followed a guideline that the design velocity should be about 5 feet per second or less and the maximum pump lift would be about 400 feet. The minimum system pressure along the pipe laterals was 15 feet. Pipe friction losses were limited to about 25 percent of the total dynamic head for the pumps. Pumping plant heads were made the same, where possible, to optimize the use of the pumps between plants.

V.1.4 Pipelines

The TSC used National Geographic Topographic Software (TOPO!), which included the area of the locations of the pipe alignments for all of the pipe laterals. The TSC used this software for the layouts of the general plans and profiles for each alternative, which were then used to determine pipe lengths and head classes. The hydraulic profiles are included in appendix C.

The pipelines were sized based on a velocity of approximately 5 feet per second, and design flows assumed a peaking factor of two at all locations.

V.1.5 Pipe Types

When computing the hydraulics, it was assumed that all of the lateral pipe would be mortar-lined steel pipe with full inside diameters. In using a Hazen-Williams Coefficient of 140 and steel pipe with full inside diameters, it is felt that the resulting friction losses are conservative. By limiting the pump lift to about

[32] The design of these intakes was based on a combination of data obtained from the 2003 Page-LeChee Project Report (TetraTech RMC, 2003) and Reclamation (2004b).

400 feet of head and adding 30 percent for an upsurge allowance, the head class (pressure class) for the pipe was generally limited to 575 feet (250 pounds per square inch (psi)). However, in areas where the topography results in large decreases in the ground surface elevations, pipe head classes may reach values higher than 575 feet. The pipe head classes, pumping plant locations, pump heads, and pipeline alignments will be more precisely defined in the next level of study.

Steel pipe can be manufactured in all of the pipe diameters and head class increments that have been estimated for this project. At the present time, some of the newer pipe types are not available in the larger diameters and higher pressure ratings. Polyvinyl Chloride (PVC) pipe is currently limited to 30 inches in diameter with a 165-psi pressure rating and 24 inches in diameter with a 235-psi pressure rating. High Density Polyethylene Pipe (HDPE) pipe is currently limited to 24 inches in diameter with a 160-psi pressure rating, 28 inches in diameter with a 128-psi pressure rating, and 30 inches in diameter with a 128-psi pressure rating. Fiberglass pipe is currently limited to 24 inches in diameter with a 250-psi pressure rating and 30 inches in diameter with a 250-psi pressure rating. In some instances, pipe manufacturers may have the capability to make larger diameters with higher pressure ratings.

Since cathodic protection is not required for these nonmetallic type pipes, they should at least be considered an option in most of the pipe diameters in the next level of design for this project. Also, every year, pipe manufacturers are making larger diameter pipes with higher pressure ratings. These nonmetallic type pipes generally have a lower coefficient of friction but, in some instances, do not have full inside diameters, requiring a larger nominal pipe size to achieve the required internal diameter. When more precise design data is available in the next level of design, all of these factors should be considered when computing the hydraulics.

Steel pipe prices were used for all lateral pipe. The appurtenant structures and mechanical equipment associated with the pipeline are covered under “unlisted items” in the cost estimates. These would include such items as air valves, blowoffs, drains, flowmeters, altitude valves, and sectionalizing valves.

All lateral pipe was assumed to be mortar-lined steel pipe. The collection pipe for the well field options was assumed to be DR25 PVC pipe.

V.1.6 Excavation and Backfill

Quantities for pipe earthwork were based on a typical trench section with 1:1 side slopes and an average depth of cover of 4 feet. This value was chosen because the majority of the pipe alignment is along existing roadways and gradual grades were anticipated. Excavation was assumed to be 60 percent rock and 40 percent common, with the exception of the pipe between the C-Aquifer and Flagstaff, which was assumed to be 100 percent rock.[33] Embedment to 3 inches over the top of the pipe was assumed to be material obtained from nearby borrow areas.

Because the embedment material is to be imported, excess waste due to the volume of both the pipe and the embedment will be substantial. For purposes of the cost estimate, it was assumed that any excavated material that cannot be used as backfill in the pipe trench can be spread in the construction right-of-way.

V.1.7 Pumping Plants

The TSC used the Reclamation computer program, "**PUMPLT,**" to estimate the field costs of the pumping plants. This program estimates costs of pumping plant construction based upon historical data for plants with similar flows, heads, and number of pumping units. The program output includes structural improvements, including the structure itself and civil site work, waterways, pumps, motors, electrical access, and miscellaneous equipment.

Pumping plants were placed in the system based on a maximum pumping lift of 400 feet. It was assumed that a forebay tank would be placed immediately upstream of each pumping plant and an air chamber would be required immediately downstream.

Forebay tanks would be required upstream from each pumping plant to supply water during startup of the pumps and during shutdown to reduce waterhammer effects. Altitude valves would be installed at most sites to prevent the forebay tanks from overtopping. For this appraisal level study, all of the forebay tanks were estimated to be 10 feet in diameter and 20 feet tall. Tank water surfaces would be the primary control for automatically stopping and starting the pumps. In the next level of study, each of these tanks would be sized on an individual basis.

The air chambers were assumed to be 20-foot-diameter spheres.

V.1.8 Power

Power transmission lines were estimated at $2 million per mile along the entire pipe alignment.

[33] These percentages were based both on regional geology maps and the interpretations and onsite experiences of Reclamation geologist Brad Prudhom in the Phoenix Area Office.

V.1.9 Storage Tanks

Tanks were sized based on 3 days of storage for the well field options and at tribal delivery nodes. It was assumed that no storage was required at other delivery nodes.

V.1.10 Pressure Reducing Stations

In-line pressure reducing stations were assumed to be required in order to limit the pipe head class to a maximum of 500 feet. These stations include an in-line pressure reducing valve and an in-line steel tank. The tanks were assumed to be 20 feet in diameter and 10 feet tall.

V.1.11 Bright Angel Creek Infiltration Gallery

The cost of the infiltration gallery was obtained from the Grand Canyon National Park Water Supply Appraisal Study (Reclamation, 2002a) estimates, factored up for the increase in flow from 2.16 cfs to 3.36 cfs.

V.1.12 Water Treatment

The cost of the water treatment plant at the south rim of the Grand Canyon was obtained from the Grand Canyon National Park Water Supply Appraisal Study (Reclamation, 2002a) estimates.

V.1.13 Operation and Maintenance

Annual operation and maintenance costs for pipelines were estimated to be 0.5 percent of the initial pipe cost. Annual OM&R costs for pumping plants were generated by a Reclamation computer program, "PMPOM." The computer program is derived from information in "Guidelines for Estimating Pumping Plant Operation and Maintenance Costs," by John Eyer; 1965, Bureau of Reclamation. Estimates of annual OM&R costs were derived from records of 174 existing electric and hydropowered pumping plants. The procedures cover direct OM&R costs for pumps, motors, accessory electrical equipment, and plant structures for plants up through 15,000 total horsepower, and consider wage rates and price levels. Price levels were updated from 1965 to 2005 levels.

V.1.14 Power Costs

It was necessary to determine the fraction of pumping at peak demand that would be necessary to deliver the design flow (peaking factor of 2).

The fraction of pumping at peak demand is given by the following equation:

$$P_k = \frac{Q_{AD}}{Q_{peak\_acft}}$$

Where: P_k is the fraction of peak pumping
Q_{AD} is the annual diversion in acre-feet per year
Q_{peak_acft} is the peak pumping rate in acre-feet per year

The cost of power consists of two components. The first component is the cost of power based on the rate charged per kilowatt-hour (kWh)of usage. The second component is the demand charge per month in kilowatt-hours.

The Peak Power Demand

The peak power demand is given by the following equation:

$$P_{pwd\_ft-lbs/s} = \frac{\gamma_w Q_{pk\_cfs} H}{e}$$

Where: $P_{pwd\_ft\text{-}lbs/s}$ is the peak power demand in foot-pounds per second
γ_W is the unit weight of water in pounds per cubic foot (62.4)
Q_{pk_cfs} is the peak pumping discharge in cubic feet per second
H is the pumping head in feet
e is the efficiency (80 percent was used, combined for both pumps and motors)

Since 1 hp is equal to 550 foot-pounds per second.

$$P_{pwd\_hp} = \frac{P_{pwd\_ft-lbs/s}}{550}$$

Where: P_{pwd_hp} is the peak power demand in horsepower

Since: 1 hp = 0.746 kW, then:

$$P_{pwd\_kW} = 0.746 P_{pwd\_HP}$$

Where: P_{pwd_kW} is the peak power demand in kilowatts

Kilowatt-Hours of Energy Consumption Per Year

The kilowatt-hours of consumption is given by the following equation:

$$E_{kwhrs} = 8760 P_K P_{pwd\_kW}$$

Where: E_{kwhrs} is the energy consumption per year in kilowatt-hours
P_k is the fraction of pumping at peak demand (as determined previously)
P_{pwd_kW} is the peak power demand in kilowatts

Cost of Power (Based on Charge per Kilowatt-Hour)

The cost of power (based on the rate per kilowatt-hour) is given by the following equation:

$$C_{p\_kwhr} = R_{kwhr} E_{kwhrs}$$

Where: C_{p_kwhr} is the cost of power based on the rate per kilowatt-hour
R_{kwhr} is the rate per kilowatt-hour

Demand Charge (Yearly)

The yearly demand charge is given by the following equation:

$$C_D = 12 P_{pwd\_KW} R_D$$

Where: C_D is the yearly demand charge
R_D is the monthly demand charge in dollars per kilowatt

The total yearly power costs (C_T) are given by the flowing equation:

$$C_T = C_{p\_kwhr} + C_D$$

The annual power costs for Arizona Public Service rates were computed for the pumping plants.

The following values were used:

Rate	Power Cost (Dollars per Kilowatt Hour)	Demand Charge (Dollars per Kilowatt per month)
Arizona Public Service	0.05634	.493*365+.43*kw*12

V.1.15 SCADA

The cost estimate includes the cost for a Supervisory Control and Data Acquisition (SCADA) system for the control of the pumping plants. The construction costs for the SCADA system were assumed to be 3 percent of the construction cost.

V.1.16 Corrosion Monitoring and Cathodic Protection

The cost estimate includes the cost for corrosion monitoring and cathodic protection of the steel pipelines where applicable. The construction costs for the corrosion monitoring and cathodic protection of the steel pipelines were assumed to be 1 percent of the construction cost.

V.1.17 Project Costs

Costs for each of the project alternatives are summarized below in table V.1-1.

Table V.1-1 . Alternative Costs

Item	Alternative 1	Alternative 2	Alternative 3
Field cost	$471,000,000	$621,000,000	$650,000,000
Pumping plants annual O&M	$1,051,973	$1,658,346	$2,023,994
Pumping plants annual energy	$3,029,771	$6,394,839	$7,276,020
Pipelines annual O&M	$480,000	$1,425,000	$1,660,000
Total annual O&M& energy	$4,561,744	$9,478,185	$10,960,014
Present worth O&M	$81,695,948	$169,744,140	$196,282,110
Project total present worth	$553,000,000	$791,000,000	$846,000,000

Present worth values were based on a 50-year project life and an interest rate of 5.125 percent.

V.2 Economic Analyses

V.2.1 Project Costs

The appraisal level costs for each of the project alternatives were developed by Reclamation's cost estimating group and were summarized in table V.1-1 above. These project costs are for comparison purposes and, thus, do not include noncontract items such as right-of-ways, geological evaluations, public involvement, mitigation, etc. These noncontract items would likely be similar across the alternatives so the relationship between the alternatives would remain the same after these costs are added at the feasibility level. The present worth values were based on a 50-year project life and an interest rate of 5.125 percent.

Table V.2-1 shows annual project costs.

Table V.2-1. Annual Project Costs

	Alternative 1	Alternative 2	Alternative 3
Total Annual O&M plus energy	$4,561,744	$9,478,185	$10,960,014
Annualized construction costs	$26,299,731	$34,675,441	$36,294,745
Total annual project costs[34]	$31,000,000	$44,000,000	$47,000,000

V.2.2 Demand

Table V.2-2 presents the estimated annual amount of water demanded by each entity in the study area in the year 2050.[35] Water demand and supply is the same for all three alternatives. Demand per 1,000 gallons is also displayed in table V.2-2. For conversion purposes, approximately 325,829 gallons are in acre-foot of water.

[34] Rounded to the nearest million dollars.

[35] The estimated demands for Page and the LeChee Chapter are not included in this table because none of the identified costs of the alternatives would be allocated to either community.

Table V.2-2. Study Area Water Demand 2050

Demand Center	AF/yr	1,000s of gallons
City of Flagstaff	8,027	2,615,606
Flagstaff to Williams - dispersed	640	208,545
Flagstaff surrounding communities	1,625	529,508
Cameron	819	266,872
Tuba City	5,648	1,840,406
Moenkopi	658	214,410
Bodaway Gap	750	244,388
Coppermine	275	89,609
Williams	1,205	392,650
GCNP	790	257,422
Tusayan	425	138,487
Total	20,862	6,797,904

V.2.3 Cost Per Acre-Foot

Under each of three alternatives, approximately 20,862 AF/yr of water is delivered to the study area. The annual cost per acre-foot to deliver 20,862 AF/yr of water to the study area is shown in table V.2-3. These costs were estimated by dividing total annual project costs by the amount of water supplied from each alternative. It should be noted that this methodology was selected at the appraisal level to provide the stakeholders with a comparison to current water rates. This methodology does not recognize special consideration for entities that would have to negotiate use of their rights-of-way, water leases, etc. Cost allocation is subject to change at the feasibility level when a more definitive plan and entities wanting to actually cost-share in the project have been identified.

Table V.2-3. Estimated Annual Cost of Water for Each Alternative

	Alternative 1	Alternative 2	Alternative 3
Cost per acre-foot	$1,479	$2,116	$2,265
Cost per 1,000 gallons	$4.54	$6.50	$6.95

Alternatives 1 and 2 contain components where different infrastructure is built to deliver water to different areas. Therefore, these components need to be identified separately to show the amount of water that they provide. Alternative 1 consists of four components that deliver water to the tribes, to Flagstaff, to Williams, and to Tusayan and GCNP. The amount of water supplied by each component, as well as its destination and annual cost, are presented in table V.2-4.

Table V.2-4. Alternative 1 Components and Estimated Costs

Component	Water Supply Location	Amount of Water Supplied (AF/yr)	Annual Cost[1]
Lake Powell pipeline	Tribes	8,150	$12,000,000
C-Aquifer	Flagstaff	10,292	$15,000,000
R-M Aquifer	Williams	1,205	$2,000,000
Infiltration gallery	GCNP/Tusayan	1,215	$2,000,000
Total		20,862	$31,000,000

[1] Rounded to the nearest million dollars.

Alternative 2 consists of three components that deliver water to the tribes and Flagstaff, to Williams, and to Tusayan and GCNP. The amount of water supplied by each component, as well as its destination and annual cost, are presented in table V.2-5.

Table V.2-5. Alternative 2 Components and Estimated Costs

Component	Water Supply Location	Amount of Water Supplied (AF/yr)	Annual Cost[1]
Lake Powell pipeline	Tribes and Flagstaff	18,442	$39,000,000
R-M Aquifer	Williams	1,205	$2,500,000
Infiltration gallery	GCNP/Tusayan	1,215	$2,500,000
Total		20,862	$44,000,000

[1] Rounded to the nearest million dollars.

As illustrated in table V.2-6, Alternative 3 has only one component: the Lake Powell pipeline that would supply water to the entire study area. The amount of water supplied by the pipeline to the various entities is the same as for Alternatives 1 and 2. The annual cost to each entity from Alternative 3 would likely be split out by the amount of water supplied (as in tables V.2-4 and V.2-5) to each entity (in acre-feet) and multiplied by $2,692 per acre-foot (or $8.26 per 1,000 gallons) per year.

Table V.2-6. Alternative 3 Components and Estimated Costs

Component	Water Supply Location	Amount of Water Supplied (AF/yr)	Annual Cost[36]
Lake Powell pipeline	Tribes, Flagstaff, Williams, GCNP, Tusayan	20,862	$47,000,000

[36] Rounded to the nearest million dollars.

As shown in tables V.2-7 and V.2-8, the three alternatives provide the same amount of water to the study area. Therefore, the least expensive alternative would be the most cost effective in terms of annual cost per acre-foot, or annual cost per 1,000 gallons of water.

For comparison purposes, see tables II.8-1 and II.8-2 under Section II.8, "Current Water Rates." The tables indicate the current rates being assessed within study area communities, are repeated below:

Table V.2-7. Annual Demand and Costs by Alternative for Study Area Demand Centers (per acre-foot)

Demand Center	Demand (AF)	Alternative 1 ($1,479/AF)	Alternative 2 ($2,116/AF)	Alternative 3 ($2,265/AF)
City of Flagstaff	8,027	$11,874,463	$16,988,839	$18,182,051
Flagstaff to Williams - dispersed	640	$946,762	$1,354,536	$1,449,671
Flagstaff surrounding communities	1,625	$2,403,887	$3,439,250	$3,680,806
Cameron	819	$1,211,559	$1,733,382	$1,855,126
Tuba City	5,648	$8,355,172	$11,953,776	$12,793,351
Moenkopi	658	$973,389	$1,392,632	$1,490,443
Bodaway Gap	750	$1,109,486	$1,587,346	$1,698,834
Coppermine	275	$406,812	$582,027	$622,906
Williams	1,205	$1,782,575	$2,550,336	$2,729,460
GCNP	790	$1,168,659	$1,672,005	$1,789,438
Tusayan	425	$628,709	$899,496	$962,672
Total	20,862	$30,861,475	$44,153,626	$47,254,759

Table V.2-8. Annual Demand and Costs by Alternative for Study Area Demand Centers (per 1,000 gallons)

Demand Center	Demand (1,000's of gallons)	Alternative 1 ($4.54/1,000 gallons)	Alternative 2 ($6.50/1,000 gallons)	Alternative 3 ($6.95/1,000 gallons)
City of Flagstaff	2,615,606	$11,874,463	$16,988,839	$18,182,051
Flagstaff to Williams - dispersed	208,545	$946,762	$1,354,536	$1,449,671
Flagstaff surrounding communities	529,508	$2,403,887	$3,439,250	$3,680,806
Cameron	266,872	$1,211,559	$1,733,382	$1,855,126
Tuba City	1,840,406	$8,355,172	$11,953,776	$12,793,351
Moenkopi	214,410	$973,389	$1,392,632	$1,490,443
Bodaway Gap	244,388	$1,109,486	$1,587,346	$1,698,834
Coppermine	89,609	$406,812	$582,027	$622,906
Williams	392,650	$1,782,575	$2,550,336	$2,729,460
GCNP	257,422	$1,168,659	$1,672,005	$1,789,438
Tusayan	138,487	$628,709	$899,496	962,672
Total	6,797,904	$30,861,475	$44,153,626	$47,254,759

Table V.2-9. Nontribal Communities Summary of Water and Sewer Rates

Utility	Water	Sewer
Bellemont Water Company	$25.00 per month service charge $ 5.25 per 1,000 gallons *Standpipe: $4.00-$5.25 per 1,000 gallons*	Not applicable; onsite systems
Doney Park (residential/ general noncommercial)	$18.75 per month, 5/8-inch meter; includes first 1,000 gallons $ 4.30 per 1,000 gallons, for 1,001-5,000 gallons $ 6.90 per 1,000 gallons in excess of 5,000 (winter) $ 8.63 per 1,000 gallons in excess of 5,000 (summer) *Standpipe: $6.90 per 1,000 gallons (winter):* $ 8.63 per 1,000 gallons (summer)	Not applicable; onsite systems
Flagstaff (residential)	$6.48 per month, ¾-inch meter $2.83 per 1,000 gallons, up to 5,000	$2.73 per 1,000 gallons; flat fee based on winter

Table V.2-9. Nontribal Communities Summary of Water and Sewer Rates

Utility	Water	Sewer
	$3.32 per 1,000 gallons, 5,001-15,000 $4.71 per 1,000 gallons, over 15,000 Standpipe: $5.25 per 1,000 gallons	quarter average water use
Forest Highlands	$25.00 per month $ 2.00 per 1,000 gallons	$30.00 per month $ 2.00 per 1,000 gallons
GCNP	$14.43 per 1,000 gallons	$14.49 per 1,000 gallons
Kachina Village	$14.05 per month $ 1.04 per 1,000 gallons, up to 3000 $ 1.56 per 1,000 gallons, 3,001 to 6,000 $ 3.12 per 1,000 gallons, 6,001 to 9,000 $ 6.24 per 1,000 gallons, 9,001 to 12,000 $10.40 per 1,000 gallons, 12,001 to 50,000 $16.64 per 1,000 gallons, over 50,000	$18.73 per month $ 2.60 per 1,000 gallons up to 3,000 $ 4.16 per 1,000 gallons, 3,001 to 6,000 No charge over 6,000 gallons
Mountainaire (Ponderosa Utility Corp.)	$21.00 per month 5/8-inch to 3/4-inch meter $ 3.30 per 1,000 gallons Standpipe: $5.70 per 1,000 gallons	Not applicable; onsite systems
Page	$4.00 base rate, includes first 3,000 gallons $1.25 per 1,000 gallons, 3,001 to winter average $1.35 per 1,000 gallons, over winter average	$2.52 per 1,000 gallons
Tusayan	$50.00 per 1,000 gallons, airport system $45.00 per 1,000 gallons, Anasazi Water Co. $18.50 per 1,000 gallons, Hydro Resources $ 1.00 per 1,000 gallons, reclaimed water	$13.59 per 1,000 gallons
Valle - Grand Canyon Inn	$10.00 per 1,000 gallons Standpipe: $12.50-$20.00 per 1,000 gallons	Not obtained
Williams (residential)	$6.72 per month, includes first 1,000 gallons $3.37 per 1,000 gallons; 1,001 to 10,000 $3.54 per 1,000 gallons; 10,001 to 20,000 $3.72 per 1,000 gallons; 20,001+ Standpipe: $7.33-$12.52 per 1,000 gallons	$13.00 flat rate

Table V.2-10 Tribal Communities Current Water Rates

Navajo Nation (NTUA system)[1]	Monthly service charge of $7.43 for 1.0-inch or smaller meter and $21.51 for 2.0-inch or larger meter $2.93 per thousand for first 3,000 gallons per month $4.54 per thousand gallons for additional use
Navajo Nation – hauled water	Varies from zero for water obtained from local wells to $250 per thousand gallons for water from vended sources. Average price (2003) was found to be $32 per 1,000 gallons.
Hopi Tribe[2]	Upper Village of Moenkopi rates are $35 per month for 3-inch meter Moenkopi Day School rates are $500 per month for 4-inch meter Other businesses rates are $100 per month for 2-inch meter Upper Moenkopi Village pays $2,632per month for wastewater disposal

[1] Rates effective March 1, 2006 (NTUA, 2006).
[2] Hopi Tribe (2006).

V.2.4 Impacts

The direct impacts from the alternatives would consist of impacts from construction expenditures in the area. Those construction expenditures would, in turn, create impacts to regional sales, income, and employment. In general, the higher the construction expenditures, the more positive impacts will be to the regional economy from new monies flowing into the region. These impacts would likely be in the form of short-term (the length of the project) sales and employment. However, the higher the construction expenditures for this project, the higher the cost of water will be for the communities in the study area. This may create negative impacts to the regional economy in the form of longer term impacts to sales and income. Additional water could support more residential and commercial growth that could share in these higher water costs and potentially contribute to the regional economy in the long term.

V.2.5 Water Use Impacts

The implementation of any one of these alternatives will bring more water into the north central Arizona study area, as well as water into some areas that currently do not have a readily available water supply. The availability of water provided by a regional water supply system may decrease the likelihood of further conservation methods being implemented compared to a future condition where there was no regional system developed. As discussed earlier, conservation technologies would be expected to be implemented as the cost/benefits allow; conservation measures might not be implemented, or implemented to a lesser extent, if another source of water is less expensive. The alternatives developed and analyzed herein are not less expensive than the current condition from a capital cost perspective. Current condition may be more expensive if ground water depletion adversely impacts endangered species and traditional cultural properties. Water availability could create an influx of people and/or businesses into the area, creating a higher demand for water and greater water use.[37] In the tribal communities, such an increase in water availability would be considered a benefit and would help meet already existing demands and decrease the potential for future aquifer drawdowns, as shown previously in figure II.4-5. More water available to the study area could result in less water available for riparian and critical habitat in natural discharge areas that support endangered species and cultural resources. Increased water availability in the study area will result in greater amounts of treated effluent for reuse, which could be used for riparian enhancement until a demand and market for effluent reallocates this supply.

V.3 Social and Environmental Justice Analysis

While all alternatives provide water to meet year 2050 demand for the Navajo Communities, the Hopi Village of Upper Moenkopi and Lower Village of Moencopi, Flagstaff, Williams, the Grand Canyon, and Tusayan, potential adverse and beneficial social impacts will vary between communities and alternatives.

As discussed in the “Traditional Cultural Properties” subsection under Section V.4.3, “”Cultural Resources,” the Grand Canyon area and the Colorado River are considered sacred by some tribes. Similarly, other waters (rivers, streams, and springs) are also considered sacred. Any alternative that could potentially affect the flow of a particular river or spring will be viewed as harmful by those tribes.

A distinguishing characteristic between alternatives is the source of the water. Potential adverse social impacts may be associated with the alternatives using water from the R-M Aquifer. The religious and cultural importance of ground water to the Havasupai Tribe was discussed above in the “Tribal Communities” subsection under Section II.2-2, “Current Community Economic and Social Conditions.” Any withdrawal from the R-M Aquifer is considered by the Havasupai Tribe to have an impact on its water rights and water resources. The tribe has stated that they “cannot tolerate any decrease in the natural flow of Havasu Springs and other canyon springs and seeps” (Michael Shiel, personal communication, 2002). “The tribe is opposed to any importation of outside surface water into the study area unless it brings meaningful protections for

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[37] However, the price of new water supplies could be significantly higher than the price some communities are now paying and could lead to an increased incentive towards implementing additional conservation practices.

permanent ground water limitations and management" (NRCE, 2005). (See the "Tribal Communities" subsection below Section II.2.2, "Current Community Economic and Social Conditions."

Springs associated with the N-Aquifer are of major religious and cultural significance to the Hopi Tribe. Therefore, any impact to those springs from this action would be of concern to the Hopi.

While most of the area appears to support an increased water supply and the potential associated increased economic activity, population increase, etc., not all do. For example, Parks, Fort Valley, and, likely, individuals within some of the larger communities as well do not support increased water supply, commercial activities, and population increase.

Provision of a reliable future water supply will enable most areas to grow and allow planned economic development to occur; however, as discussed earlier, some areas will not realize the same benefit because of physical location and other factors.

Areas without means to deliver the water will not realize benefit from the water unless or until distribution infrastructure becomes available. Some people will no longer have to haul water, while others will need to continue to do so unless or until distribution systems are in place.

Even slight increases in water rates have the potential to adversely affect the low-income and minority populations.

Construction of the project could provide limited short-term employment that could potentially benefit minority or low-income individuals, especially if local hiring provisions are included in project construction contracts.

At the next level of analysis, potential social impacts (beneficial and adverse) will need to be refined and the level of significance addressed. Information collected during public involvement activities and scoping for National Environmental Policy Act (NEPA) compliance will provide additional social issues to be addressed, assist in determining the importance of identified issues to those directly affected by the implementation and operation of the project, and identify opportunities to avoid significant adverse social impacts.

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," dated February 11, 1994, requires agencies to identify and address disproportionately high and adverse human health or environmental effects of their actions on minorities and low-income populations and communities, as well as the equity of the distribution of the benefits and risks of their decisions. Environmental justice addresses the fair treatment of people of all races and incomes. Fair treatment implies that no group of people should bear a disproportionate share of adverse effects from an environmental action.

Many of the communities potentially affected by implementation of the project have high percentages of racial minorities and persons and families below the poverty level. Consequently, the potential exists for environmental justice populations to be disproportionately and adversely affected by this project. For example, the potential exists for the environmental justice populations to be disproportionately and adversely affected by construction of the project (i.e., if more environmental justice areas than nonenvironmental justice areas are disrupted). Such areas are to be avoided; if they cannot be avoided, appropriate mitigation must be provided. However, if the "disruption" is to provide those "disrupted" with a benefit, it is adversely disproportionate in the short term, but positive in the long term. It is the disproportionate disruption of the environmental populations without benefit to them that is disproportionately adverse and to be avoided. This type of potential impact is noted here but the actual analysis is for the next level of study. Thus, it is important that the environmental justice areas be identified early so that pipeline routes and other project facilities can be designed to avoid them.

At the next level of analysis, the following are environmental justice issues to be evaluated to determine potential effects and their level of significance:

- Are affected resources used by minority or low-income populations? One example: plants used for medicinal or spiritual purposes.

- Are minority or low-income populations disproportionately subject to adverse environmental, human health, or economic effects? One example: air quality impacts associated with construction.

- Do the resources used for the project support subsistence living? One example: water supporting fish, wildlife, plants, etc., used for subsistence.

V.4 Environmental Considerations

A reconnaissance level evaluation of resources in the study area was conducted for the major pipeline alignments proposed under the alternatives being considered in this appraisal level study. This evaluation assumed the pipeline alignments would be placed within the fenced rights-of-way of major roadways. General considerations regarding the alternative component involving an infiltration gallery at Phantom Ranch and pipeline delivery system up to the Grand Canyon Village are also included; these are based upon the discussion of existing conditions and potential effects of alternatives found in the Bureau of Reclamation's *Grand Canyon National Park Water Supply Appraisal Study* (2002). Neither the C-Aquifer nor R-M Aquifer well field and related infrastructure have been sufficiently defined at this point to address either area with any specificity.

On March 29-30, 2006, a field trip was conducted to assess the general topography and landscape of the study area, and vegetation communities that might be impacted by pipeline construction associated with the various alternative components. This assessment was made on a very broad scale. Objectives did not include quantifying acreages to be disturbed, assessing habitat quality or suitability, compiling lists of specific species encountered, or performing on-the-ground surveys.

V.4.1 Vegetation

The study area affected by construction of major water distribution pipelines contains four vegetation communities. These communities are identified in Brown (1994) and discussed below.

Rocky Mountain Montane Conifer Forest

Rocky Mountain Montane Conifer Forest (Conifer Forest) and the closely related Madrean Montane Conifer Forest on the high plateaus and mountains extend southward from the Rocky Mountains to the southwest in Colorado and Utah through New Mexico and Arizona to the Sierra Madre Occidental and Sierra Madre Oriental and outlying mountains in Mexico. The Conifer Forest can be divided into two major communities or series: a ponderosa pine forest at lower elevations and a mixed conifer forest of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), and aspen (*Populus tremuloides*) where it is cooler at higher elevations and in canyons and on north slopes.

Ponderosa pine is the Southwest's most common montane tree and often grows in pure stands. While ponderosa pine is the dominant species over most of the forest, such associated trees as southwestern white pine (*Pinus strobiformis*), Douglas-fir, white fir, and aspen are frequently intermixed at middle and lower elevations. In the Rocky Mountain Conifer Forest, Gambel oak (*Quercus gambelii*) and the New Mexico locust (*Robinia neomexicana*) are locally common and may dominate some of the lower and rockier locations. Gambel oak is of great importance and affects the distribution of several species of wildlife (Brown, 1994).

Depending on soils, aspect, and elevation, the Montane Conifer Forest ranged from dense stands to more open park-like stands. Some aspen was noted between Flagstaff and Williams, and an occasional stand of Gambel oak was also noted.

Great Basin Conifer Woodland

This cold-adapted evergreen woodland is characterized by the unequal dominance of two conifers: juniper (*Juniperus* spp.) and pinyon pine (*Pinus* spp.) (Brown, 1994). Relatively short in stature, these trees are typically openly spaced, except at higher elevations and less xeric sites where interlocking crowns may develop a closed canopy aspect.

In the Great Basin, conifer woodland occurs on the mountain gradient above and within the Great Basin Desert scrub community. Big sagebrush is often the dominant understory plant. Junipers have invaded large areas of former grassland, and attempts have been made to reconvert these areas back to grasslands with various success.

Only a few vertebrates are closely tied to Great Basin Conifer Woodland. Pinyon-juniper woodlands may provide seasonal habitats for a number of montane and subalpine animals; as such, they are often of great importance as winter range for elk and mule deer.

Great Basin Grasslands

This grassland community was once an open, grass-dominated landscape in which the grasses formed a continuous or nearly uninterrupted cover, but the grassland community has been greatly altered due to overgrazing and fire suppression. Much of this vegetation has been invaded by shrubs such as snakeweed (*Gutierrezia*), saltbush (*Atriplex* spp.), and winterfat (*Ceratoides lanata*). Pronghorn is a large mammal species typically associated with this community. The list of associated smaller mammals is long, and this vegetation type can support a surprisingly diverse array of birds and herps.

Great Basin Desert Scrub

The Great Basin Desert is the most northerly of the four North America deserts. Major plant dominants in this cold-adapted community are sagebrushes

(*Artemisia*), saltbushes, and winterfat. Species diversity is characteristically low in all major communities of this biome, with a dominant shrub occurring to the virtual exclusion of other woody species.

Great Basin Desert scrub has evolved a distinct fauna. However, large ungulates are generally poorly represented. Pronghorn may occasionally be seen as an incursionary species from adjacent grasslands. Reptiles are not as well represented in the Great Basin Desert as in warmer biomes because of the desert's long, cold winters.

Riparian habitat of note occurred where Highway 89 crossed over the LCR. This community was not well developed and appeared to have only minimal wildlife value.

V.4.2 Species of Concern

The Fish and Wildlife Service (Service) lists 22 plant and animal species on its Coconino County list as either threatened, endangered, candidates, or species for which a conservation agreement is in place. Of the federally listed species, the following could be impacted or affected by pipeline construction, based upon a reconnaissance level evaluation of the existing habitat:

Common Name	Scientific Name	Status	Comment
Bald eagle	*Haliaeetus leucocephalus*	E	
Black-footed ferret	*Mustela nigripes*	E	
Brady pincushion cactus	*Pediocactus bradyi*	E	
California condor	*Gymnogyps californianus*	E	
Chiricahua leopard frog	*Rana chiricahuensis*	T	
Mexican spotted owl	*Strix occidentalis lucida*	T	
Navajo sedge	*Carex specuicola*	T	
Sentry milk vetch	*Astragalus cremnophylax* var. *cremnophylax*	E	
Siler pincushion cactus	*Pediocactus sileri*	T	
Southwestern willow flycatcher	*Empidonax traillii extimus*	E	
Welsh's milkweed	*Asclepias weshii*	T	
Arizona bugbane*	*Cimicifuga arizonica*	CA	

Common Name	Scientific Name	Status	Comment
Paradine (Kaibab) plains cactus*	*Pediocactus paradinei*	CA	
Razorback sucker	*Xyrauchen texanus*	E	May be impacted by upstream water diversions in the Colorado River
Humpback chub	*Gila cypha*	E	May be impacted by upstream water diversions in the Colorado River

Note: E = endangered; T = threatened; CA = conservation agreement among applicable land and resource management agencies

Critical habitat for both species of fish is designated within the Grand Canyon downstream of Glen Canyon Dam.

The species of concern list is very conservative. A more detailed description and location of the various components would facilitate more in-depth analyses, including discussion with the Service and other resource biologists, to determine the potential occurrence of a species within the study area, which may likely result in the removal of some species from this list. This level of analysis could also be expected to identify the need and recommended survey period for a species of concern, especially plants.

Reclamation also requested a list of imperiled or species of concern from the Navajo Nation, Bureau of Land Management, U.S. Forest Service, and the NPS. These species are identified in appendix D, "Environmental." As with the federally listed species, it is likely that the list of species in need of analysis, discussion with the appropriate land management agency, and possibly the development of mitigation would require a more specific and detailed alignment configuration. It is anticipated that a separate biological analysis and consultation will be needed with each of these agencies to address sensitive wildlife and plants. A Fish and Wildlife Coordination Act Report (FWCA) would need to be developed in consultation with the respective land management agency, the Arizona Game and Fish Department, and the Service to address these impacts, as well as impacts to species of economic concern such as deer, elk, turkey, and others. The FWCA report would also identify recommended mitigation measures to reduce project impacts.

The response from the Navajo Nation indicates 34 species on the Navajo Endangered Species List (NESL) that are known to occur, or have the potential to occur, near the proposed alignments on the Navajo Nation. The following species are known to occur "on or near" or within 3 miles of the proposed alignments:

Common Name	**Scientific Name**	**NESL Status**
Golden eagle	*Aquila chrysaetos*	G3
Beath milk-vetch	*Astragalus beathii*	G4
Ferruginous hawk	*Buteo regalis*	G3
Parish's alkali grass	*Puccinella parishii*	G4
Peeble's blue-star	*Amsonia peeblesii*	G4
Northern leopard frog	*Rana pipiens*	G2
Wupatki pocket mouse	*Perognathus amplus cineris*	G4
Milk snake	*Lampropeltis triangulum*	G4
Fickeisen plains cactus	*Pediocactus peeblesianus* var. *fickeiseniae*	G3
Peregrine falcon	*Falco peregrinus*	G4
The following species are G2 or G3 listed species with the **potential** to occur within the study area:		
Pronghorn	*Antilocapra americana*	G3
Rocky mountain elk	*Cervus elaphus*	Economic
American dipper	*Cinclus mexicanus*	G3
Roundtail chub	*Gila robusta*	G2
Bighorn sheep	*Ovis canadensis*	G3
Colorado pikeminnow	*Ptychocheilus lucius*	G2
Razorback sucker	*Xyrauchen texanus*	G2
Marble Canyon milk-vetch	*Astragalus cremnophylax* var. *hevroni*	G3
Brady pincushion cactus	*Pediocactus bradyi*	G2

G2 = species or subspecies whose prospects of survival or recruitment are in jeopardy
G3 = species or subspecies whose prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future
G4 = species or subspecies which may be endangered but for which the Nation Lacks sufficient information to support listing
Economic = species having economic significance to the Tribe

The Navajo Nation also states that the potential for the black-footed ferret (*Mustela nigripes*) should also be evaluated if prairie dog towns of sufficient size (per Navajo Nation Fish and Wildlife Department guidelines) occur in the study area.

Biological surveys for listed species need to be conducted during the appropriate season to ensure that they are complete and accurate. Surveyors must be permitted by the Director, Navajo Fish and Wildlife Department. Potential impacts to wetlands should also be evaluated.

Once a proposed pipeline alignment is determined, it is recommended that a survey be conducted to determine the presence and proximity of prairie dog towns to the pipeline. If the prairie dog towns are within ¼ mile of the alignment, surveys may be needed to determine the presence of black-footed ferrets.

For northern leopard frog, the Navajo Nation provides the following guidance to avoid impacts: no surface disturbance within 60 meters of lakes, 15-60 meters of streams, or 60 meters of wetlands; and avoid upstream activities that impact water quantity and chemistry.

In discussion with the Navajo Nation Environmental Review staff, it was determined that a separate biological assessment would need to be submitted to the Nation (White Horse-Larson, personal communication, 2006). Only G2 and G3 species would need to be addressed. Incidental occurrence of G4 species would be noted during any required surveys for G2 and G3 species (personal communication with Daniela Roth, April 12, 2006) but would not need to be specifically addressed during preparation of a biological assessment.

V.4.3 Cultural Resources

Information was gathered, consistent with an appraisal level effort, regarding known cultural resources within the major pipeline alignment corridors that are associated with the various alternative components evaluated in this study. Data for the appraisal level study were taken from site location maps at the Navajo Nation Historic Preservation Department (NNHPD) and the Phoenix Area Office of the Bureau of Reclamation. The AZSITE electronic data base was also searched for the portions of the various alternatives located off the Navajo Reservation. Archaeologists from the Coconino National Forest and Desert Archaeology were also contacted for information.[38] An intensive Class I records check was not undertaken, and specific information about recorded archaeological sites and surveys has not been analyzed.

For portions of the study area discussed below, survey data are sometimes limited and are confined primarily to sections of highways and road rights-of-way that are proposed as pipeline corridors. Selected areas such as the Phantom Ranch and the Bright Angel Trail up to the south rim of the Grand Canyon, SR-89 from the

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[38] Acknowledgment is given to Coconino National Forest archaeologist Peter Pilles and Dr. William H. Doelle of Desert Archaeology, who provided information and insight on survey and data recovery on recent archaeological work along SR-89.

eastern end of Flagstaff to at least Cameron, and major portions of I-40 within the study area have good survey data, especially within the last decade. Some archaeological data recovery has also been completed in portions of SR 89 and I-40 prior to road improvement projects by the Arizona Department of Transportation (ADOT). Nonetheless, especially for ADOT projects, data recovery is often confined within a narrow construction corridor, and many sites extend beyond the ADOT construction zone into the rights-of-way and beyond.

Cultural resource data from related reports such as the HWNSS and the Grand Canyon Water Supply Study were used when they overlapped with the study area. An in-depth search for information on Traditional Cultural Properties (TCPs) was not undertaken. Such information was included when it was available from previous studies, such as those cited above.

Pipeline Corridors

As indicated above, the following discussions assume that proposed pipeline alignments follow roads and highways and would be confined within the respective, fenced rights-of-way. Proposed alignments for the formulated alternatives were previously shown on figures IV.2-1 to figure IV.2-6. References to highways and roads that have been surveyed for cultural resources are based solely on how these surveys were identified in AZSITE and drawn on the maps that were consulted. Because of the general nature of the available data, it is assumed that these surveys were confined to the road right-of-way, although it is possible that areas outside of and paralleling the right-of-way were surveyed. In some cases, only one side of the right-of-way may have been surveyed.

Pipeline Corridor Segment	General Overview of Existing Survey Information
Lake Powell to Cameron	There have been some surveys in and around Page, including the road from Antelope Point to the powerplant; 21 sites were recorded along this road. Portions of both SR 89 and IR 20 have been surveyed. Most of these surveys were done in the late 1990s. The most recent survey was in 2004. Along IR 20, probably less than 20 archaeological sites have been recorded. From the junction with SR 160, SR 89 heading south to Cameron was surveyed most recently in 2003, except for the first 9 or 10 miles south of the SR 160 junction. Only three sites were noted on NNHP maps within or adjacent to the highway right-of-way.
From Cameron to Grand Canyon Village	Based on site maps at NNHPD, only a portion of SR 64 that crosses the Navajo Reservation has been surveyed, and only four sites were found. Survey in the area around SR 64 on the reservation is very limited. AZSITE shows that where SR 64 crosses into Kaibab National Forest, site density picks up, although there has been no survey of SR 64. AZSITE shows numerous sites located in the general vicinity of SR 64, but survey coverage is

Pipeline Corridor Segment	General Overview of Existing Survey Information
	apparently not consistent in the area, and there are areas with few or no sites recorded. Generally speaking, numerous sites can be expected on the Kaibab National Forest. Within GCNP, the majority of cultural resources recorded on the south rim tends to be along the rim and is associated with surveys conducted for infrastructure, such as roads and utility corridors. Further away from the rim, cultural resource survey coverage generally is less intense and data are fewer. The pipeline alignment following SR 64 right-of-way from Cameron to GCNP facilities at the south rim would likely reduce impacts to cultural resources.
From Cameron to Flagstaff	From Cameron south, AZSITE indicates that most of SR 89 has been surveyed to the east end of Flagstaff. The earliest survey was in 1975; the latest survey was in 2000. In general, archaeological sites are not common in and along the SR 89 right-of-way until higher elevations are reached (piñon and juniper habitat), beginning around Wupatki National Monument. From here to the outskirts of Flagstaff, site density increases noticeably, and sites are numerous along SR 89 and immediately surrounding it. Site density decreases somewhat in the more developed areas of east Flagstaff.
From The Gap to Bitter Springs	From The Gap to Bitter Springs, portions of SR 89 have been surveyed and around 24 archaeological sites have been recorded. The surveys appear related to road improvements.
From SR 89 to Tuba City/Moenkopi	From its junction with SR 89 to its junction with SR 264, SR 160 has been surveyed. There are a number of sites recorded along SR 160; the number increases significantly as the road approaches SR 264 and the community of Moenkopi.
Flagstaff to Williams	According to AZSITE, I-40 through Flagstaff has not been surveyed, although there are several surveys that were conducted adjacent to it. Site density is generally low in areas adjacent to I-40 through Flagstaff. West from the junction with I-17 to Williams, I-40 is not surveyed until around Bellemont Flat. From here to Williams, the I-40 was surveyed in 1997, and scattered sites were recorded within and adjacent to the right-of-way.

Well Field Components

For purposes of this analysis, it was assumed that the C-Aquifer well field would be developed on Hopi Tribal lands (Hart and Red Gap ranches) and on Navajo Nation tribal land southwest of Leupp (figure IV.2-1). Cultural resource data for the potential well fields are limited; however, several cultural resource surveys have been done nearby for a proposed well field near Leupp, Arizona. These include a portion of SR 99 that cuts through the area (Breen, 2002), a home site parcel survey (Benalie, 1987), and surveys of five test well sites (approximately 500 acres) (Jolly and Aguila, 2004). The latter survey recorded 13 sites. Five sites were determined to be eligible for listing in the *National Register of Historic Places,* four sites require testing to determine their eligibility, and four sites were determined not to be eligible. All the sites were prehistoric limited activity artifact scatters or recent historic sites associated with the railroad that runs through the area or with ranching. Isolated artifacts (prehistoric and historic) were also relatively abundant. Additional survey of the well fields will undoubtedly identify additional similar sites.

AZSITE shows that since the year 2000, at least three archaeological surveys were conducted along the I-40 right-of-way, and possibly outside it, from Padre Canyon east of Flagstaff to Winslow. Archaeological sites were scattered in and adjacent to the right-of-way, occasionally increasing in numbers where I-40 crossed large drainages. From Padre Canyon west into Flagstaff, AZSITE showed no survey of the I-40 right-of-way, although archaeological sites have been recorded adjacent to the I-40 corridor. AZSITE did show a number of surveys that included small portions of I-40; these surveys are more prevalent as one gets closer to Flagstaff.

Well site and pipeline information regarding the proposed R-M Aquifer well field to serve Williams, Arizona, are not available to allow any assessment of known or anticipated cultural resources for this portion of the study area.

Phantom Ranch Infiltration Gallery

GCNP archaeological site maps indicate a cluster of sites in the Phantom Ranch area. Along the Bright Angel Trail from the south rim to the Colorado River, there are no recorded sites until Indian Gardens, where 19 sites were recorded during a 1980 survey (Coulam, 1980). Many of these sites contained masonry foundations, although exact room counts were difficult to make because of the poor preservation of many of the sites.

Generally, prehistoric site types found within the pipeline corridor include sherd and lithic scatters, storage cists, small pueblos, cliff dwellings, rock shelters, petroglyphs, and rock alignments. Human burials have been noted at some sites. Historic sites are related to mining, tourism, and the development of the Bright Angel Trail (Coulam, 1980). Some of the prehistoric sites in the Phantom Ranch area have been identified as TCPs; other TCPs may be located along the trail. A thorough review of existing TCP data, combined with additional consultation with affected or interested Indian tribes, can address specific issues for these resources.

Summary Discussion of Cultural Resources Considerations

Suffice it to say**,** portions of the study area that would be impacted by various alternative components are rich in prehistoric and historic cultural resources going back perhaps as far as 10,000 years. A project of this magnitude would have an adverse effect on cultural resources, even if the majority of the construction can be limited to existing road rights-of way. Until reasonably reliable maps are available that show specific locations of proposed land disturbance, any attempt to try to quantify what is currently known about cultural resources in the study area is not recommended. Once reasonably reliable maps are available, a site records check can be undertaken to determine what is known about the cultural resources within those areas, as well as a better idea of potential cultural resource issues. Further steps that need to be undertaken at that time to comply with the National Historic Preservation Act and other related Federal, State, and tribal requirements are enumerated below.

Traditional Cultural Properties

For many Native American tribes, certain landforms, areas, and water sources play significant and sacred roles in their cultures. The term "culture" includes, among other things, traditions, beliefs, practices, arts, and lifeways of a particular group of people. Sometimes, an area, location, landform, or some other natural or cultural feature may hold special traditional cultural significance for a community or group of people. Traditional refers to, "those beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice." (Parker and King, 1990:2). Two examples of places that can hold traditional significance for a Native American group are a location associated with traditional beliefs about a group's origin and cultural history, and a location that Native American religious practitioners have used historically, and still use today, to perform traditional ceremonial activities (Parker and King, 1990:2).

Because the traditional cultural value placed on a particular place or feature can assume great significance and importance to a group of people (not necessarily only Native Americans), damage to or infringement upon the place or feature can be deeply offensive to, perhaps even destructive to, the group that values it. "As a result, it is extremely important that traditional cultural properties [traditional cultural places (TCPs)] be considered carefully in planning." (Parker and King, 1990:2).

Some generalities regarding TCPs and sacred sites can be made. Occasionally, tribal consultation results in the identification of specific TCPs; however, in many cases, specific locational information is not provided. The Grand Canyon area and the Colorado River are considered sacred by some tribes. Water (rivers, streams, and springs) is considered sacred by some tribes. Any action that could potentially affect the flow of a particular river or spring will be viewed as harmful by tribes. Certain landforms and features, such as the San Francisco Peaks, are sacred. Prehistoric archaeological sites (for example, the Bright Angel Site east of the confluence of Bright Angel Creek and the Colorado River), petroglyphs (engravings on rocks or boulders), and pictographs (painted designs on rocks) are considered to be TCPs by some tribes.

For the NCAWSS, a considerable amount of information on TCPs has been gathered in conjunction with the Bureau of Reclamation's Glen Canyon Dam EIS. TCP consultation was conducted with the Hopi, Zuni, Hualapai, Southern Paiute, Paiute Indian of Utah, Kaibab-Paiute, Havasupai, and the Navajo Nation. Similarly, tribal consultations were undertaken by Coconino National Forest for road improvements along portions of SR 89. Analysis of these data was not part of the appraisal study, but it may be useful in identifying TCP issues and concerns for future studies related to the project. If the decision is made to go forward to a feasibility study, it is important that consultations with these tribes be initiated as soon as possible.

Future Work/Next Steps

The foregoing assessment is intended solely to provide decisionmakers with preliminary data on potential resources issues associated with the proposed project.

Once a preferred alternative is selected, a more intensive cultural resources review can identify specific issues for that alternative. There are, however, a number of issues that apply to most, if not all, of the four alternatives and need to be considered.

- Cultural resources need to be considered early in the planning process. An archaeologist(s) should be included on any planning team to ensure that cultural resource issues and problems are identified early and appropriate actions are taken in a timely manner.

- Consultation should be initiated with the State Historic Preservation Officer (SHPO), Tribal Historic Preservation Officer (THPO), Advisory Council on Historic Preservation (ACHP), and appropriate Indian tribes as soon as possible. Consultation for the Glen Canyon EIS and other projects has already established points of contact and relationships with tribal cultural resource specialists that should make new consultation easier. Through tribal consultations, TCPs can be addressed early in the planning process, thereby avoiding future potentially timely and costly delays resulting from a lack of consultation and communication.

- Significant cultural resources are finite and nonrenewable. Whenever possible, avoidance or preservation, or both, of cultural resources is recommended. This strategy reduces project costs by avoiding data recovery, as well as by reducing other costs associated with data recovery, such as the level of consultation (that can often be time consuming and involved) and curation costs.

- There are no **apparent** archaeological resources that could adversely affect any of the four alternatives. Through consultation with the SHPO, affected tribes, and other agencies, adequate data recovery plans can be developed to mitigate the loss of significant cultural resources through construction.

- If mitigative data recovery is necessary, a treatment plan for dealing with prehistoric human remains is required. This treatment plan must be developed in consultation with the SHPO, TPHO, and ACHP, as well as with all Indian tribes that claim affiliation to the remains.

A public education component should be part of any mitigation project to inform visitors as to why the project is being undertaken, what was discovered, and why it is important to GCNP prehistory. This is an ideal opportunity to educate the visitors to GCNP not only about the prehistory of the area, but also about the need to protect the fragile cultural resources in GCNP.

V.4.4. Other Environmental Considerations

A cursory field trip that mainly involved driving most of the affected roadway corridors within the study area indicates that using the highway and road rights-of-way will likely present many significant challenges due to physical constraints and other geographic, geologic, regulatory, and jurisdictional considerations. In many places along I-40 from Flagstaff to Williams, there appears to be an insufficient amount of space to locate a pipeline between the pavement and the right-of-way fence. Some of these rights-of-way consist of rock cliffs and deep ravines. Along all routes, there are numerous washes—some of which are shallow but many of which are deeply incised—as well as high-voltage and low-voltage power lines and low hanging telephone wires. In one or two places, there are indications of buried gas pipelines crossing the highway. There are also numerous areas where scattered residences and small commercial sites are located adjacent to the roadways.

It is recommended that all affected Federal, State, tribal, and local agencies be offered an opportunity to comment upon this appraisal level study, prior to finalization, to ensure that any major concerns they may have are addressed. If or when it is determined that a feasibility study will be take place, it is recommended that coordination with these same entities be initiated as early in the process as possible, so that their respective interests and requirements are taken into consideration in the early design phase of the project.

The planners and designers should also carefully consider alternatives (in terms of delivery routes, facility designs, and construction methods) that would reduce the amount of discharges of fill material into waters of the U.S. These considerations will need to be documented in any section 404 permit application that is prepared for the project.

V.5 Summary Report of Findings

The materials presented in this study adequately support a recommendation to advance three alternatives to feasibility level investigations. The appraisal ROF concludes that additional water supplies, beyond the developed and available supplies which provide for the municipal and small industrial demands, will be needed to meet 2050 water demand for the communities and cities included in this analysis. The research indicates that conservation remains a principal water management tool and may not adequately provide for future water demands. Aquifer protection for long-term reliability and environmental resource protection has created uncertainties for individual water providers who have projected water demands that exceed their current supply. Federal trust assets and obligations are implicated in both future and future without alternatives. Opportunities exist among stakeholders in the study area to develop reliable long-term water supplies through economic regional solutions containing Federal objectives.

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