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.

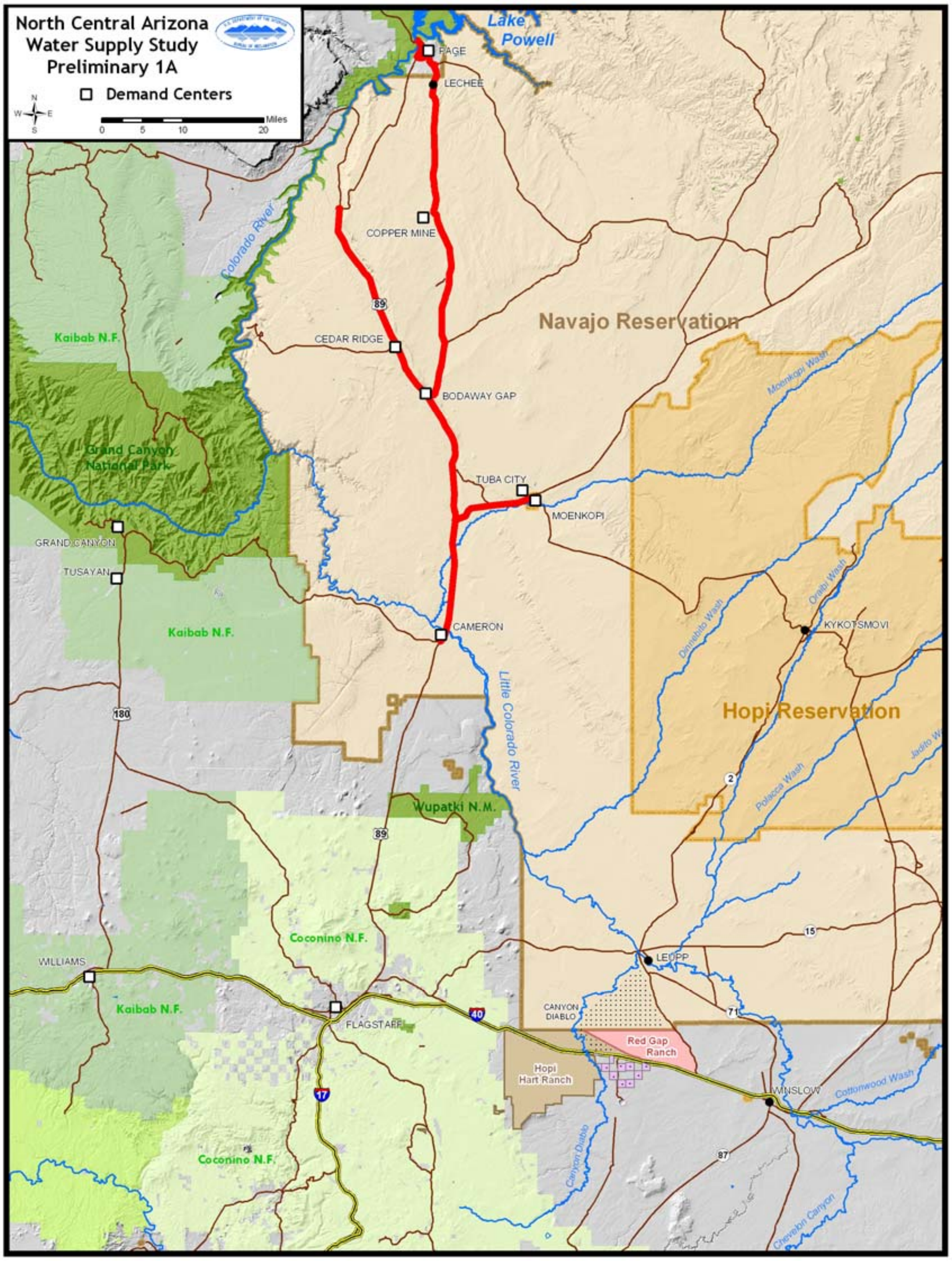

Figure IV.1-1. Lake Powell pipeline to Cameron.

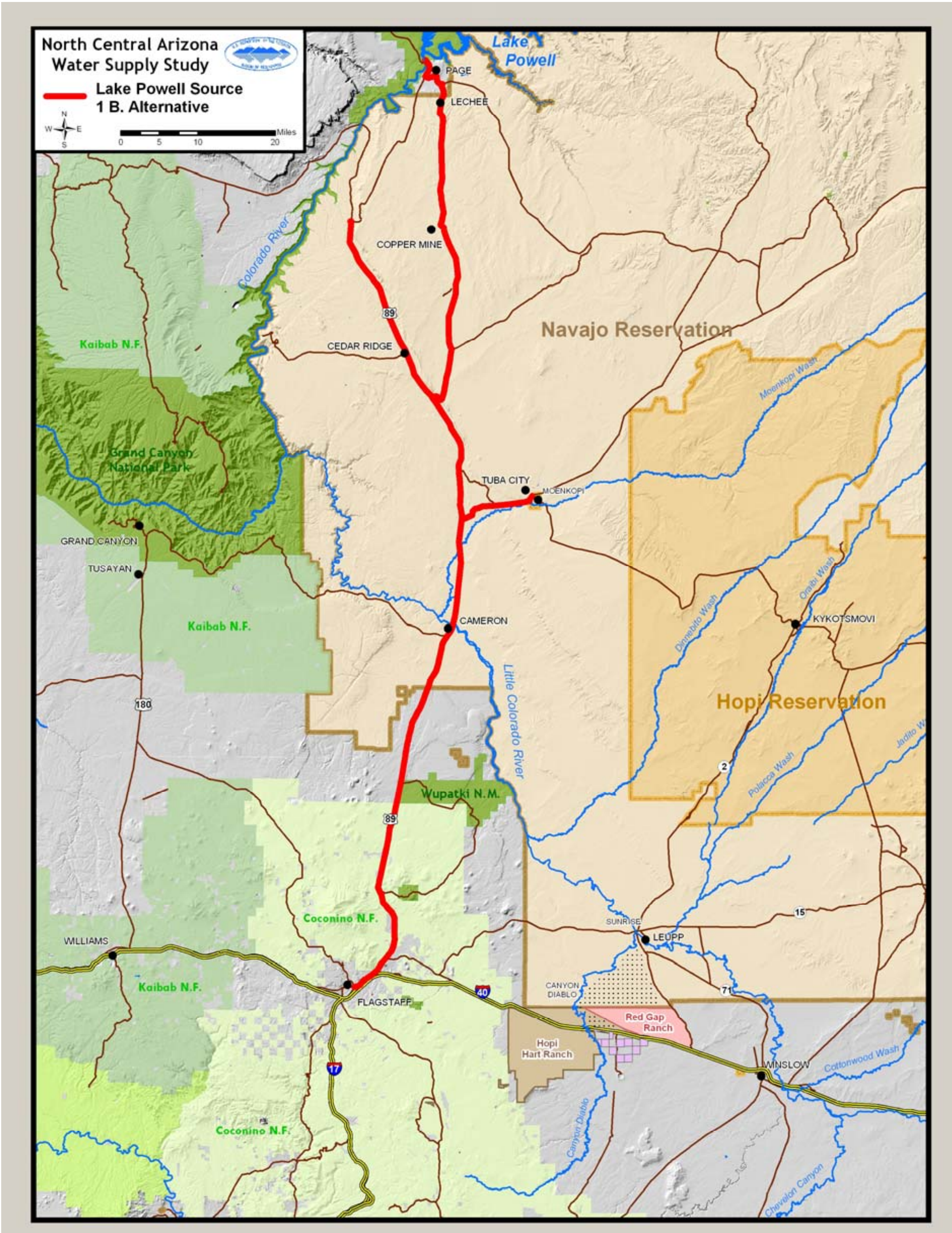

Figure IV.1-2. Lake Powell pipeline to Flagstaff.

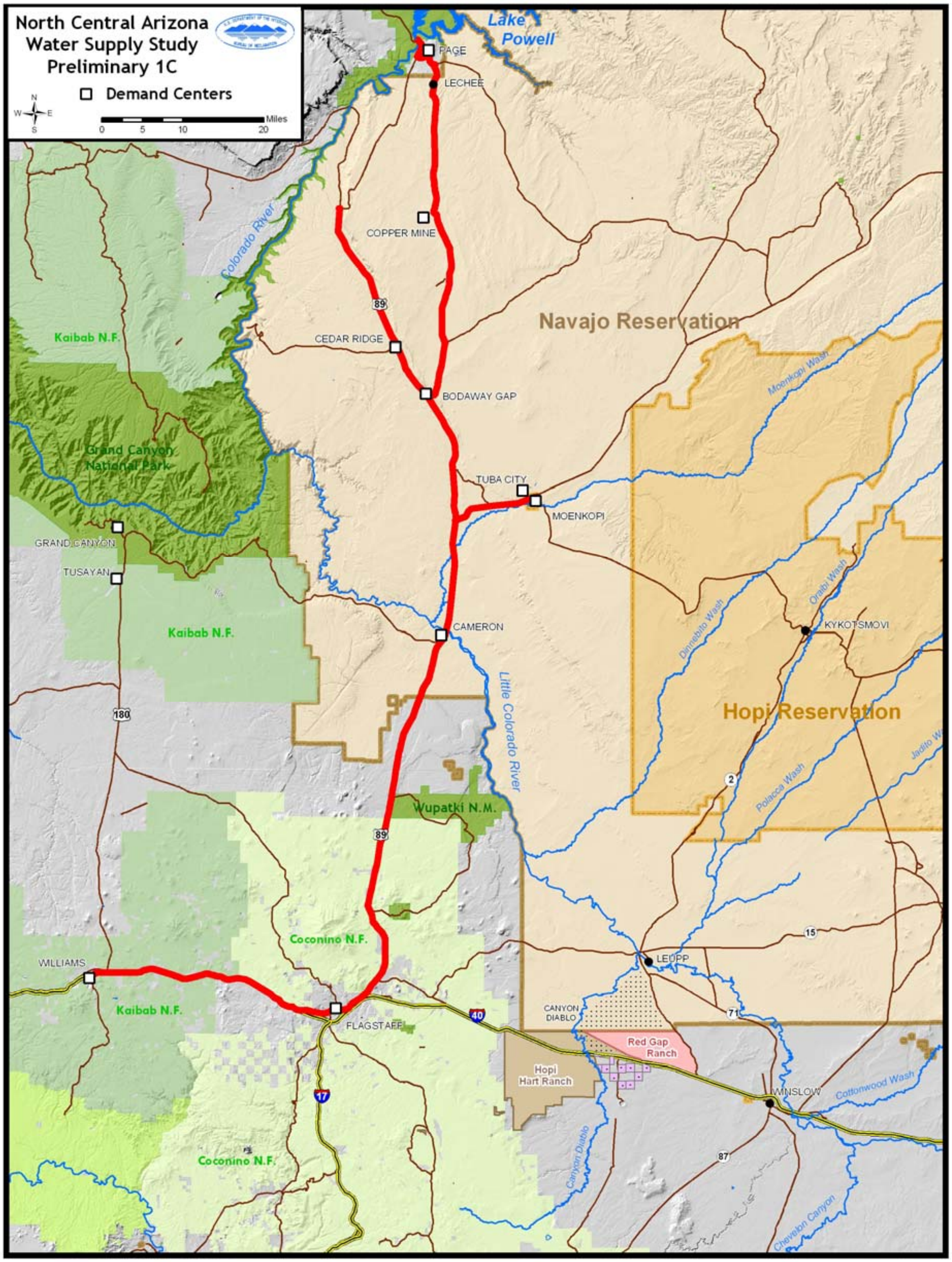

Figure IV.1-3. Lake Powell pipeline to Williams via Flagstaff.

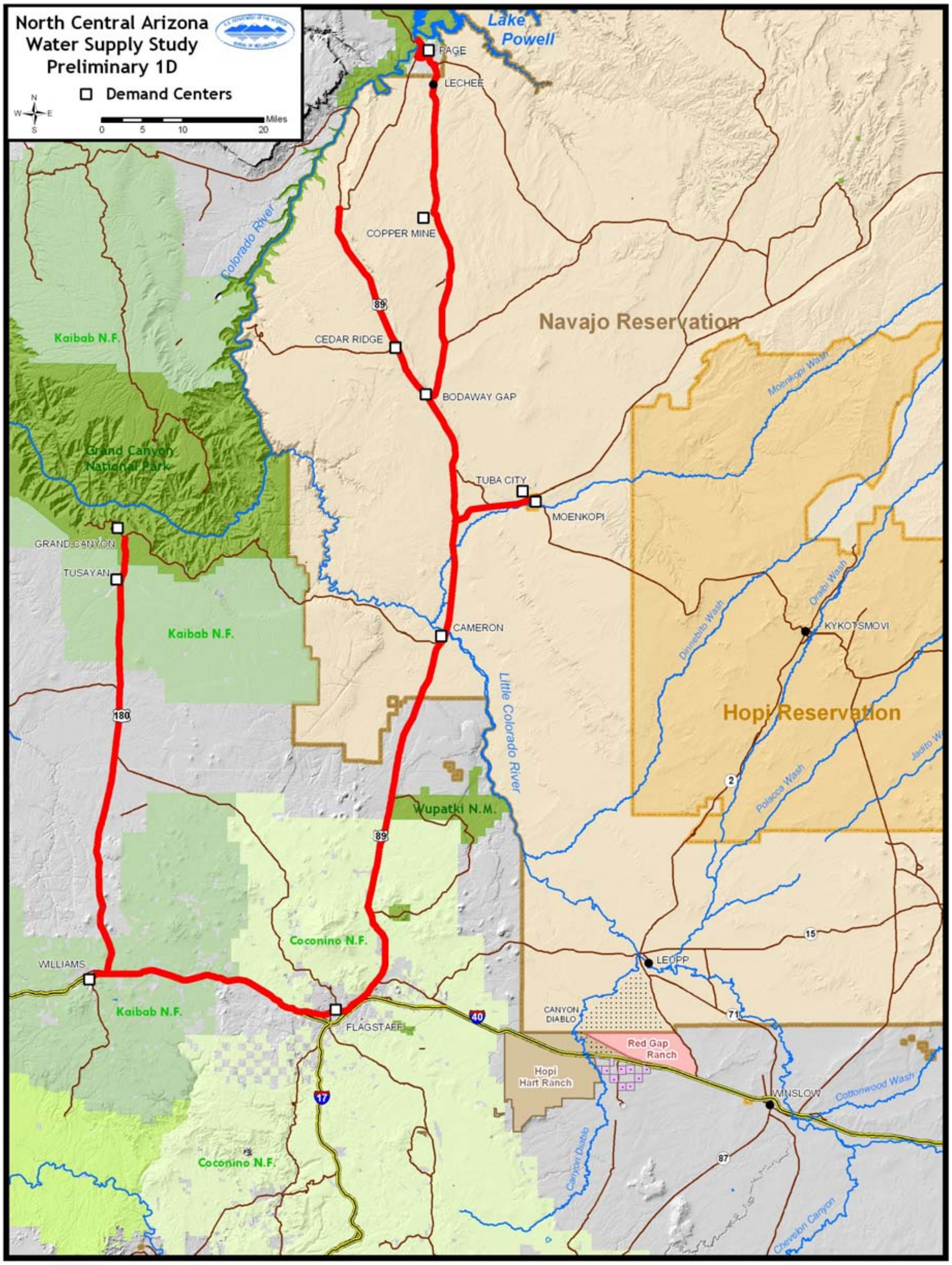

Figure IV.1-4. Lake Powell pipeline to Grand Canyon via Flagstaff and Williams.

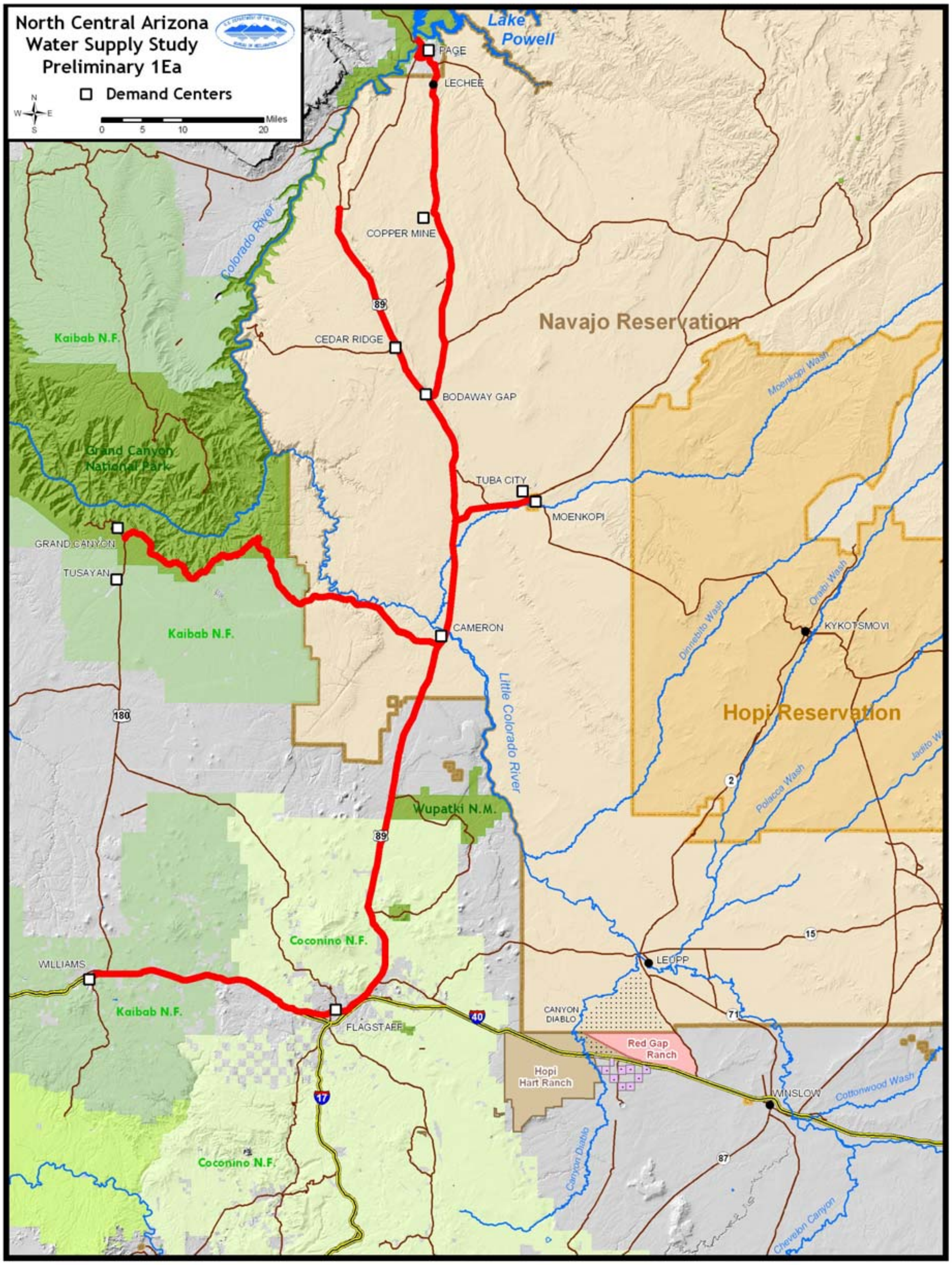

Figure IV.1-5. Lake Powell pipeline to Grand Canyon via spur from Cameron and to Williams via spur through Flagstaff.

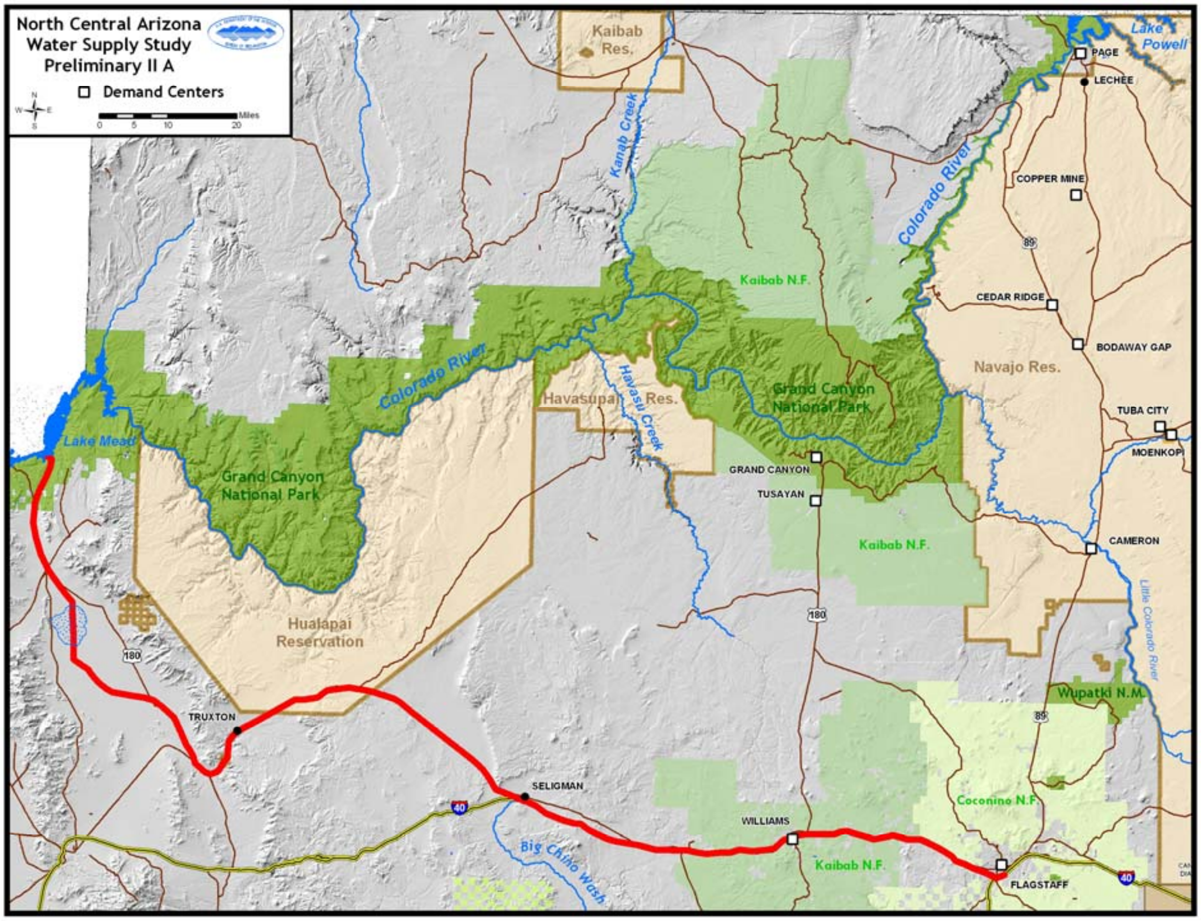

Figure IV.1-6. Lake Mead pipeline to Williams and Flagstaff.

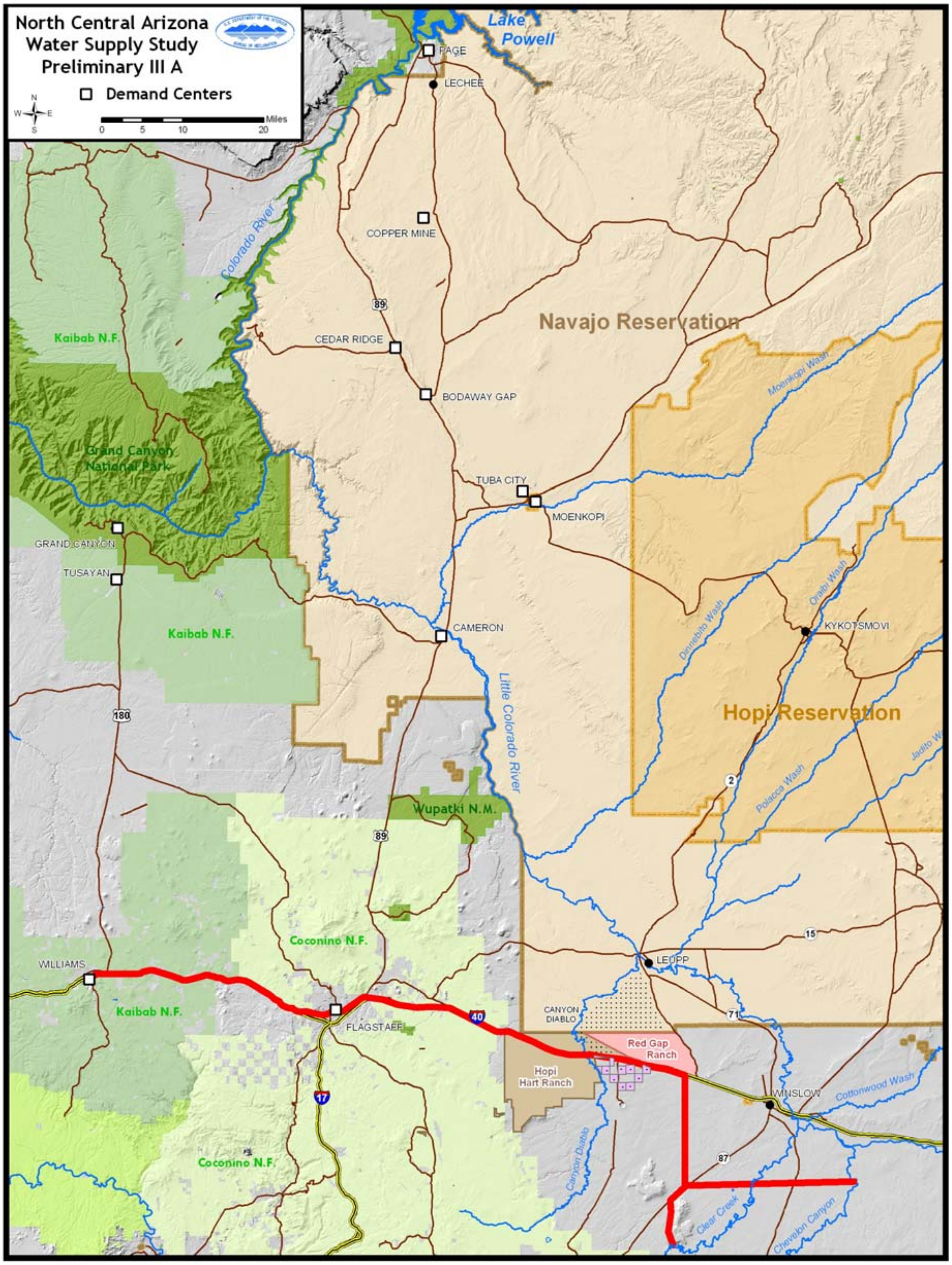

Figure IV.1-7. Mogollon Rim tributaries to Williams and Flagstaff.

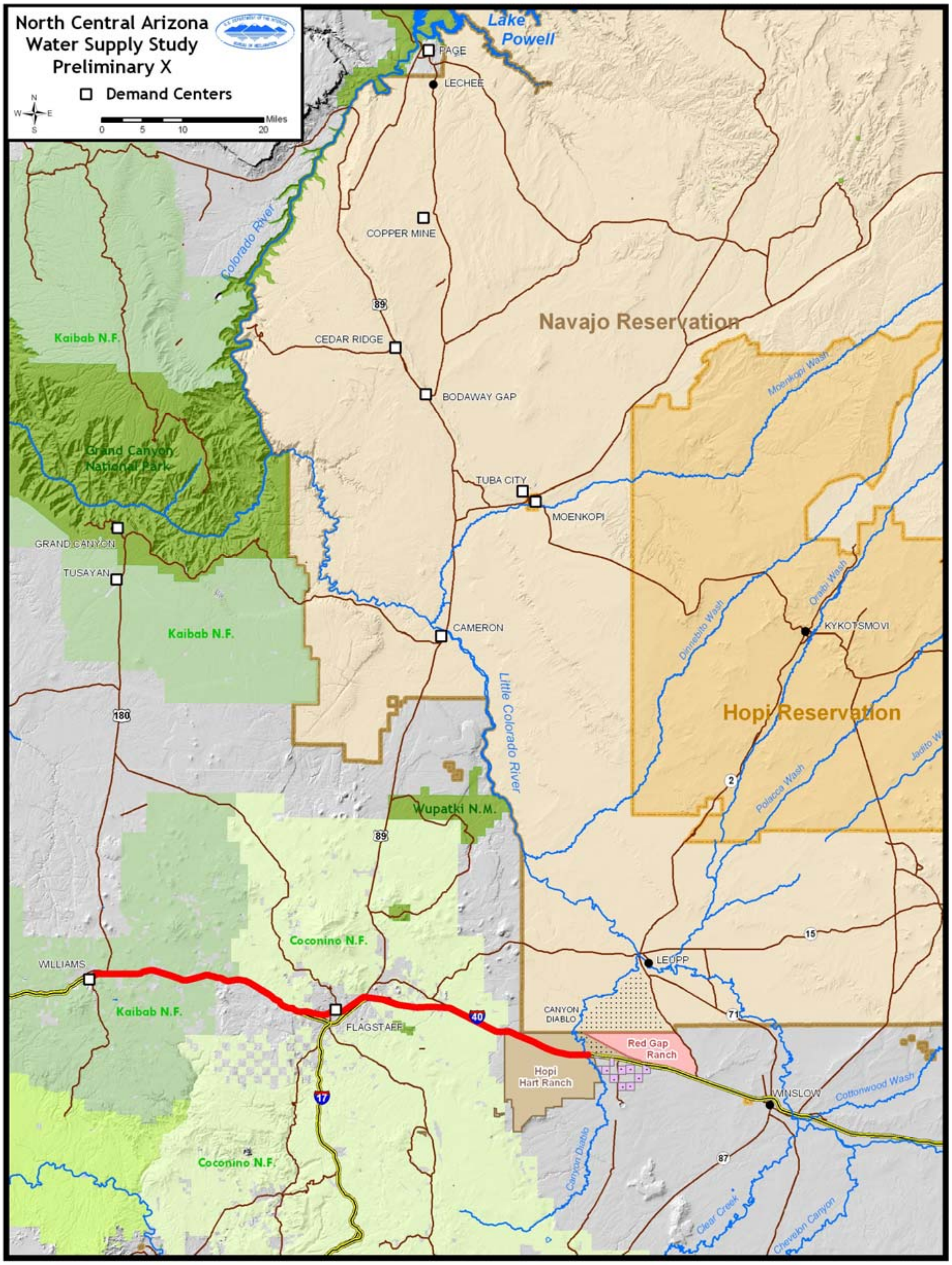

Figure IV.1-8. C-Aquifer source to Williams and Flagstaff.

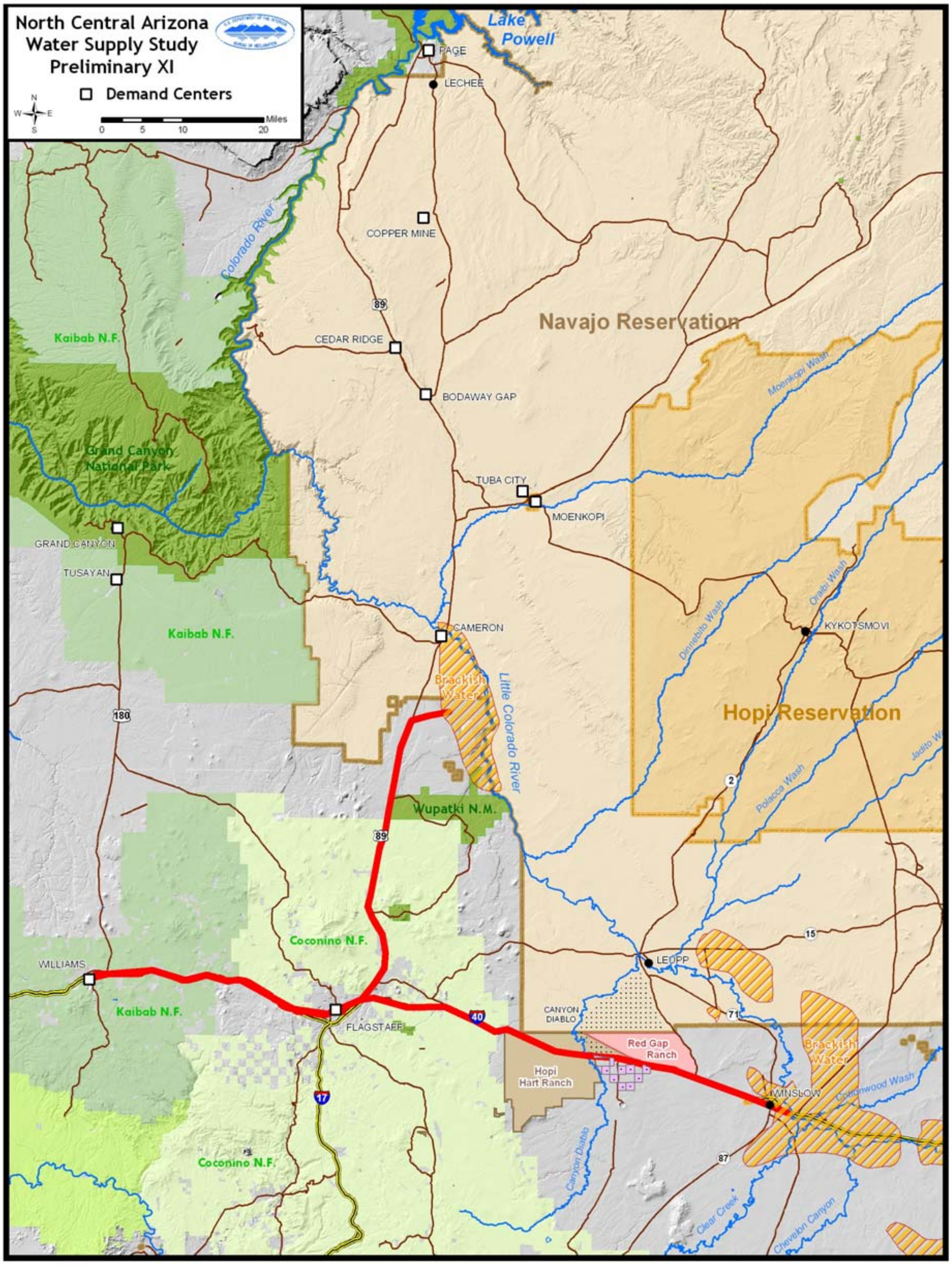

Figure IV.1-9. Low water quality C-Aquifer source to Williams and Flagstaff.

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.

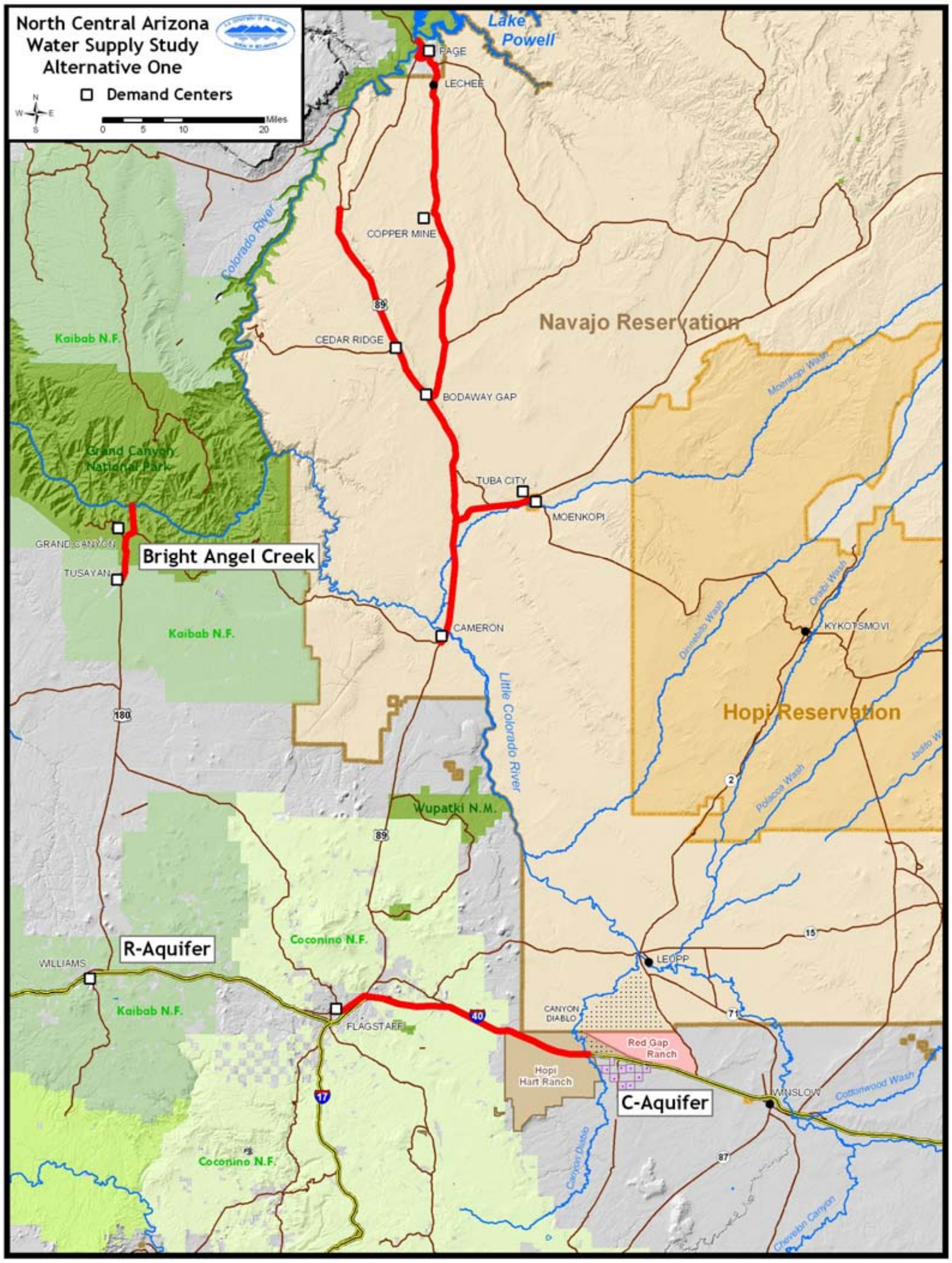

Figure IV.2-1. Alternative 1: Hopi/Navajo Demand Center – supplied via Lake Powell pipeline; Flagstaff Demand Center – supplied via pipeline from C-Aquifer pipeline; Williams Demand Center – supplied from local R-M Aquifer wells; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via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

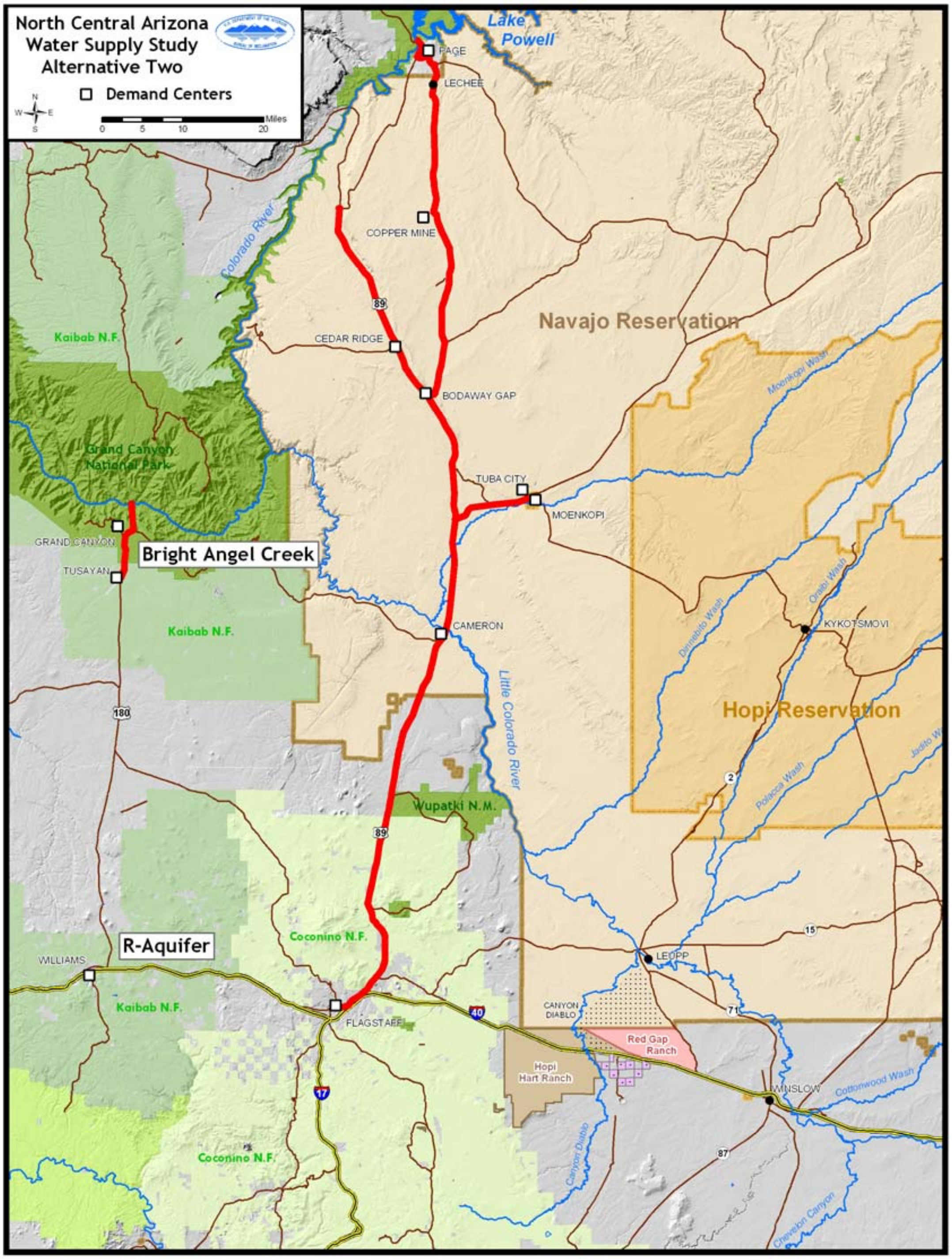

Figure IV.2-2. Alternative 2: Hopi/Navajo/Flagstaff Demand Centers – supplied via Lake Powell pipeline; Williams Demand Center – supplied from local R-M Aquifer wells; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

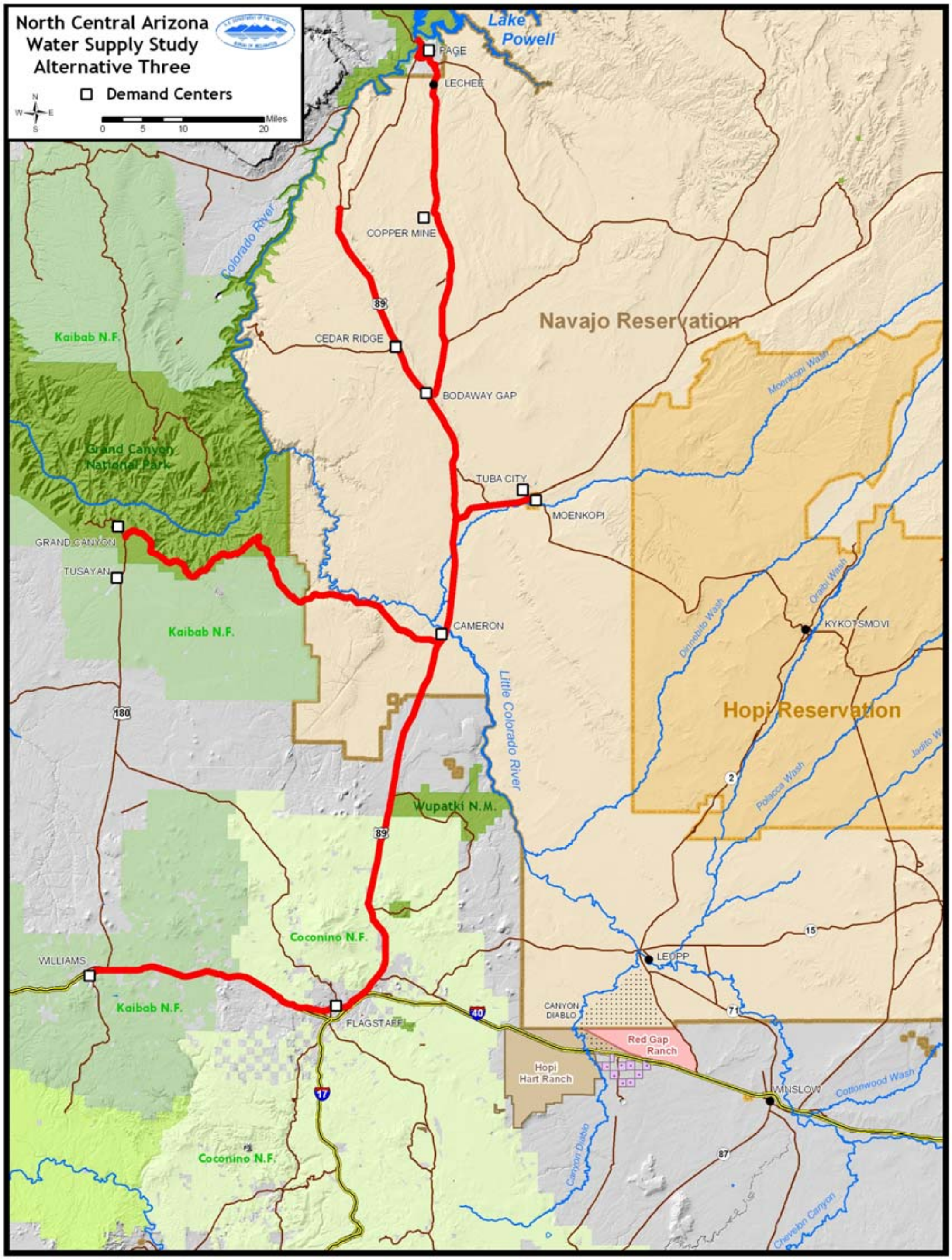

Figure IV.2-3. Alternative 3: Hopi/Navajo/Flagstaff/Williams/Grand Canyon/Tusayan Demand Centers –supplied via Lake Powell pipeline.

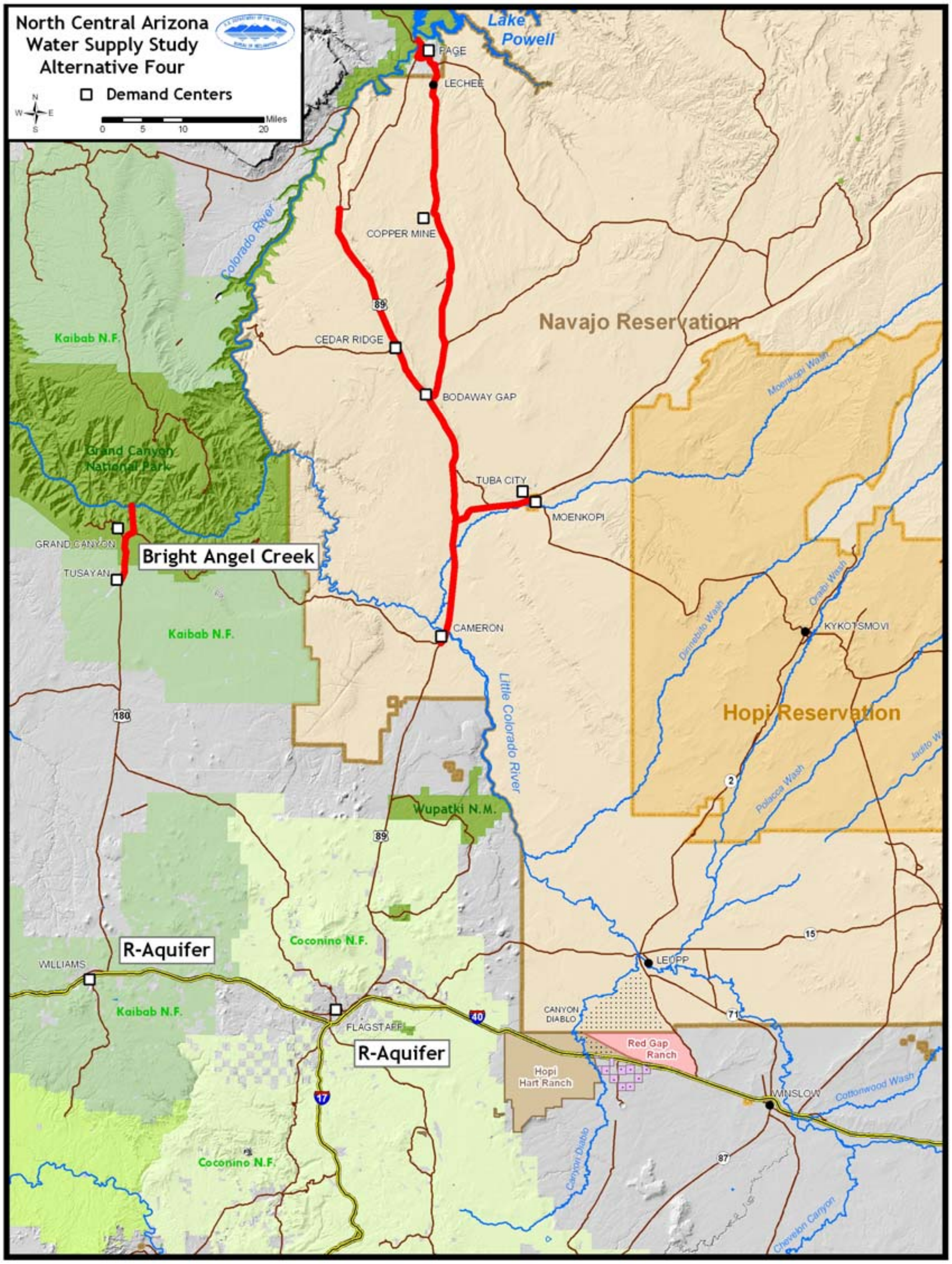

Figure IV.2-4. Alternative 4: Hopi/Navajo Demand Center – supplied via Lake Powell pipeline; Flagstaff/Williams Demand Center – supplied by pipeline from R-M Aquifer well field; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

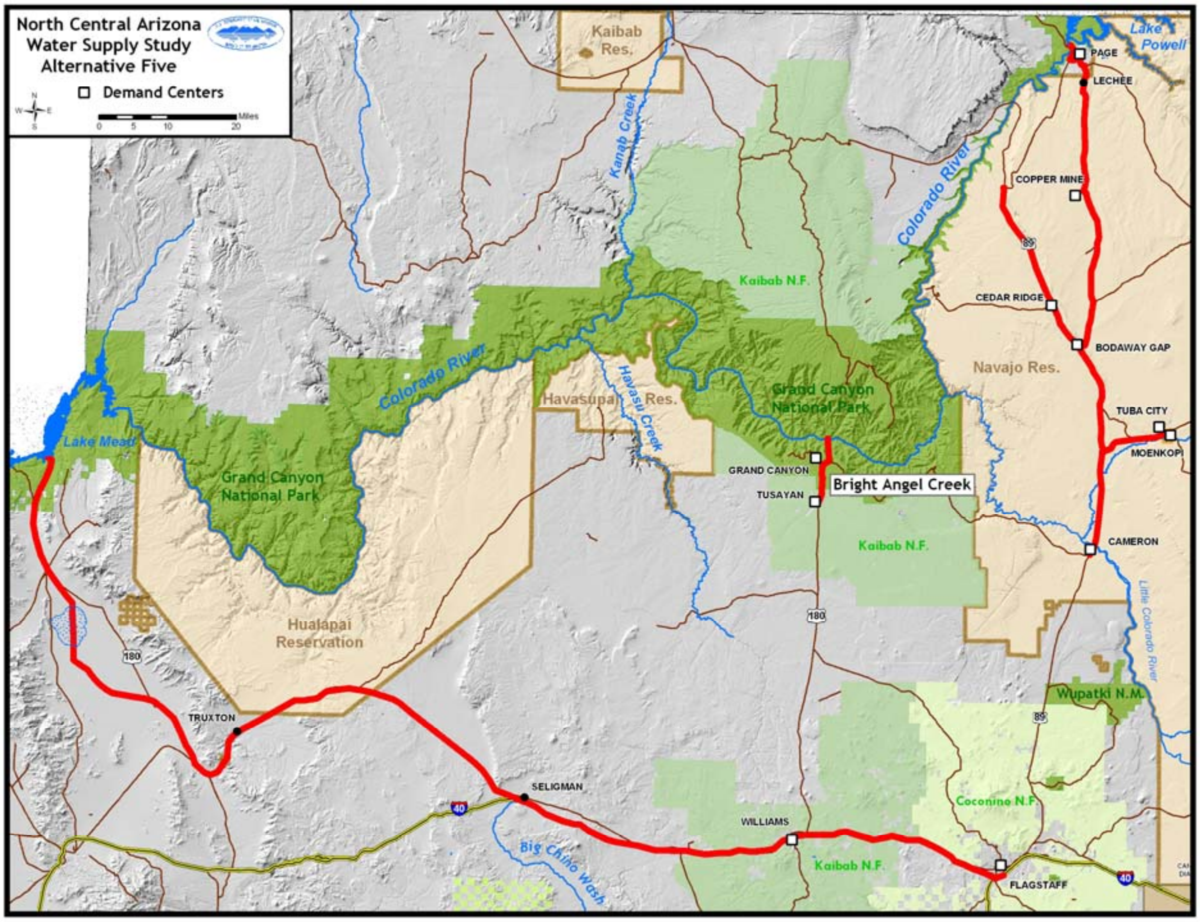

Figure IV.2-5. Alternative 5: Hopi/Navajo Demand Centers – supplied via Lake Powell pipeline; Flagstaff/Williams Demand Center – supplied by pipeline from Lake Mead; Grand Canyon/Tusayan Demand Center – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

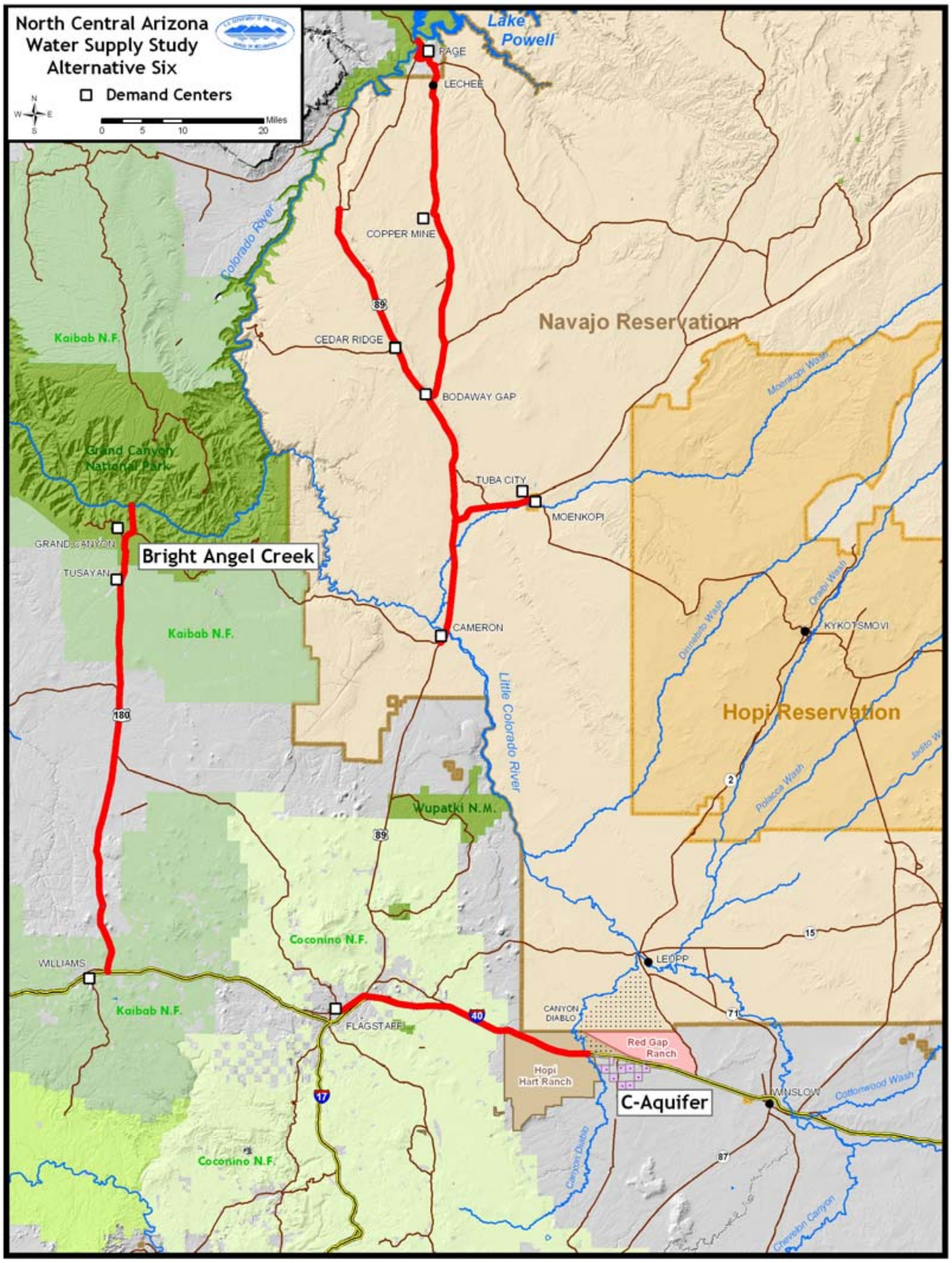

Figure IV.2-6. Alternative 6: Hopi/Navajo Demand Centers – supplied via Lake Powell pipeline; Flagstaff Demand Center – supplied via pipeline from C-Aquifer pipeline; Williams/Grand Canyon/Tusayan Demand Centers – supplied from Roaring Springs via pipeline diverting from Phantom Ranch infiltration gallery.

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

---

[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

---

[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.

This page intentionally left blank.

References

Arizona Department of Water Resources (ADWR). 2005. Comments on draft "Current Conditions" document. January.

_____. 1999. North Central Arizona Regional Water Study – Phase One. ADWR Administrative Report, 85 p.

_____. 1998. North Central Arizona Water Supply Study – Phase One.

_____. 1989. Hydrology of the Little Colorado River System. Special Report to the Settlement Committee.

Arizona Supreme Court. 2006. Arizona Supreme Court Web site: http://www.supreme.state.az.us/wm/.

Benallie, Larry. 1987. An Archaeological Inventory of the Albert George and Mariette Littleman Relocation Homesite near Leupp, Arizona (CF#01764). Unpublished manuscript on file at Navajo Nation Historic Preservation Department, Window Rock, Arizona.

Beus, Stanley S., and Michael Morales (eds.). 1990. Grand Canyon Geology, Oxford University Press, New York.

Beus, S.S., and G.H. Billingsley. 1989. Paleozoic strata of the Grand Canyon, Arizona. In: D.P. Elston, G.H. Billingsley, and R.A. Young (eds.) Geology of Grand Canyon, northern Arizona, with Colorado River guides, Lees Ferry to Pierce Ferry, Arizona, pp. 122-127. 28th International Geological Congress Field Trips T115/315. American Geophysical Union, Washington DC.

Bills, Donald. 2006. Personal communication by Donald Bills, hydrologist, U.S. Geological Survey, to the Reclamation study team.

_____. 2005a. Personal communication by Donald Bills, comments on draft "Current Conditions" document, January 2005.

_____. 2005b. Personal communication via email by Donald Bills, hydrologist, U.S. Geological Survey, to Robert Talbot, Bureau of Reclamation. December 14.

Bills, Donald J., and Marilyn E. Flynn. 2002. Hydrogeologic Data for the Coconino Plateau and Adjacent Areas, Coconino and Yavapai Counties, Arizona. USGS Open-File Report 02-265, U.S. Geological Survey Informational Services, Denver, Colorado.

Bills, D.J., Margot Truini, M.E. Flynn, H.A. Pierce, R.D. Catchings, and M.J. Rymer. 2000. Hydrogeology of the regional aquifer near Flagstaff, Arizona, 1994–97: USGS Water-Resources Investigations Report 00-4122, 143 p., 4 plates.

Black, Kevin, Bradley Prudhom, and Michael Miller. 2006. C Aquifer Water Supply Study – Report of Findings. Bureau of Reclamation, Phoenix Area Office, Phoenix, Arizona.

Blakely, R.C. 1990. Stratigraphy and Geologic History of Pennsylvanian and Permian Rocks, Mogollon Rim Region, Central Arizona and Vicinity. Geological Society of America Bulletin 102, No. 9: 1189-1217.

Blakely, R.C., and R. Knepp. 1989 and 1979. Pennsylvanian and Permian Geology of Arizona. In: Geologic Evolution of Arizona. Jenney, J.P., and S.J. Reynolds (eds.), Vol. Digest 17. Tucson, Arizona, Arizona Geological Society, pp. 313-347.

Breen, Judith. 2002. A Cultural Resources Survey of 11.02 Miles of SR 99 Right-of-Way Between Mileposts 61.20 and 72.22, South of Leupp, Coconino County, Arizona. Unpublished manuscript on file at Logan, Simpson Design, Inc., Tempe, Arizona.

Brown. D. 1994. Biotic Communities of the American Southwest-United States and Mexico. University of Utah Press, Salt Lake City, Utah, 342 p.

Brown, J.G., and J.H. Eychaner. 1988. Simulation of Five Ground-Water Withdrawal Projections for the Black Mesa Area, Navajo and Hopi Indian Reservations, Arizona. U.S. Geological Survey Water-Resources Investigations Report 88-4000, 51 p.

Bureau of Indian Affairs (BIA). 1999. Report on Tribal Priority Allocations. July 1999.

City-Data.com. 2006. Employment, income, and poverty statistics in Western Navajo communities. Accessed February 1, 2006.

Coconino County. 2006. Comments on North Central Arizona Water Supply Study Draft Report of Findings. July 7.

Coconino National Forest. 2005. Record of Decision, Arizona Snowbowl Facilities Improvement Final Environmental Impact Statement and Forest Plan Amendment No. 21. U.S. Department of Agriculture, Forest Service, Peaks Ranger District, Coconino National Forest, February 2005.

Cooley, M.E. 1976. Spring Flow from Pre-Pennsylvanian Rocks in the Southwestern Part of the Navajo Indian Reservation, Arizona. U.S. Geological Survey, Professional Paper 521-F, U.S. Government Printing Office, Washington, DC.

Cooley, M.E., J.W. Harshbarger, J.P. Akers, and W.F. Hardt. 1969. Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; with a section on vegetation by O.N. Hicks. U.S. Geological Survey Professional Paper 521-A, 61 p., 9 plates.

Copfer, Torrey. 2005. Personal communication. Natural Resources Consulting Engineering, Inc., August 10.

Cornell, S., and J.P. Kalt. 1992. What Can Tribes Do? Strategies and Institutions in American Indian Economic Development, University of California.

Cornwall, Glenn. 2005. Presentation made to the Coconino Plateau Water Advisory Council, July 29.

Coulam, Nancy J. 1980. An Archaeological Survey of Indian Gardens, Grand Canyon National Park, Arizona. Unpublished manuscript on file at Grand Canyon National Park, National Park Service.

Crossey, Laura. n.d. Personal communication from Dr. Laura Crossey, Professor, University of New Mexico.

Doba, Ron. 2006. Personal communication. Comments on NCAWSS Draft Report of Findings.

Doba, Ron. 2005a. Flagstaff Water: To import or not to import. A presentation by Ron Doba, City of Flagstaff, to the Coconino Plateau Water Advisory Council, May 27.

_____. 2005b. Personal communication from Ron Doba, City of Flagstaff, regarding City of Flagstaff. August 11.

_____. n.d. Personal communication by Ron Doba, City of Flagstaff, to the Reclamation study team.

Doney Park Water. 2005. Presentation made to the Coconino Plateau Water Advisory Council, December.

Ecosystems Management, Inc. 2004. Sanitary Assessment of Drinking Water Used by Navajo Residents Not Connected to Public Water Systems, November.

Elston and DiPaolo. 1979.

Eychaner, J.H. 1983. Geohydrology and Effects of Water Use in the Black Mesa Area, Navajo and Hopi Indian Reservations, Arizona. U.S. Geological Survey Water-Supply Paper 2201, 26 p.

Federal Register. 2004. Quarterly Status Report of Water Service, Repayment, and Other Water-Related Contract Negotiations. Volume 69, No. 39, pp. 9370-9378. Website: <http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/2004/04-4355.htm>

Flynn, Marilyn E., and Donald J. Bills. 2002. Investigation of the Geology and Hydrology of the Coconino Plateau of Northern Arizona: A Project of the Arizona Rural Watershed Initiative. USGS Fact Sheet 113-02, U.S. Geological Survey, U.S. Government Printing Office.

Foos, Annabelle. 1999. Geology of the Grand Canyon National Park, North Rim. University of Akron, Geology Department.

Geotrans, Inc. 1987. A Two-Dimensional Finite-Difference Flow Model Simulating the Effects of Withdrawals to the N-Aquifer, Black Mesa Area, Arizona. Consultants report for Peabody Coal Company.

Grand Canyon National Park (GCNP). 2006. Comments on the Draft Report of Findings submitted to the Bureau of Reclamation. July 10, 2006.

Hart, R.J., J.J. Ward, D.J. Bills, and M.E. Flynn. 2002. Generalized hydrogeology and ground-water budget for the C aquifer, Little Colorado River Basin and parts of the Verde and Salt River Basins, Arizona and New Mexico. Water-Resources Investigations Report 02-4026, 47 p., 1 plate.

Havasupai Tribe. 2006. Economic and social conditions of tribal communities. Website: <www.havasupaitribe.com>, accessed January 26.

Havasupai Tribe. 2005. Havasupai Tribe response to draft "Current Conditions" document.

HDR Engineering, Inc. (HDR). 2004. Report of Findings for the Assessment of Western Navajo-Hopi Water Supply Needs, Alternatives, and Impacts," HDR Engineering, Inc., Omaha, Nebraska.

______. 2002. Hopi Western Navajo WNH3C Groundwater Flow Model. December.

Hereford, Richard, Robert H. Webb, and Scott Graham. 2002. Precipitation History of the Colorado Plateau Region, 1900-2000. USGS Fact Sheet 119-02, U.S. Geological Survey, U.S. Government Printing Office.

Hoffmann, J.P., D.J. Bills, J.V. Phillips, and K.J. Halford. 2005. Geologic, Hydrologic, and Chemical Data from the C Aquifer near Leupp, Arizona. USGS Scientific Investigations Report 2005-5280, 42 p.

Hopi Tribe. 2006. Comments on Draft Report of Findings. June 16.

Hopi Tribe. 2005. The Hopi Tribe, North Central Arizona Water Supply Study, Hopi Water Supply and Demands. A presentation made to the Coconino Plateau Water Advisory Council. May 27.

HydroGeoChem, Inc. 2001. White Papers: Western Navajo-Hopi Water Supply Needs, Alternatives, and Impacts. Bureau of Reclamation Plan of Study.

HydroGeoChem, Inc. 1991. Results of Hydrogeologic and Geochemical Investigation for the Little Colorado River Basin, Vol. 1. Consulting Report prepared for the U.S. Bureau of Indian Affairs, June 4.

Jeffernon, Rick and Mark Muro. 2001. Growth on the Coconino Plateau. Morrison Institute, March.

Jolly, Donald W., and Aguila Lourdes. 2004. Class III (Intensive) Cultural Resources Survey of Five Well Sites on Navajo Nation and Hopi Tribe lands, near Leupp, Navajo County, Arizona. Archaeological Consulting Services, Ltd., Tempe, Arizona.

Kaibab National Forest. 1999. Final Environmental Impact Statement for Tusayan Growth.

Kalt, Joseph P., Taylor, and Grant. 1999. The Costs, Benefits, and Public Policy Merits of the Proposed Western Navajo-Hopi Lake Powell Pipeline.

Kessler, James A. 2002. Grand Canyon Springs and the Redwall-Mauv Aquifer: Comparison of Geologic Framework and Groundwater Flow Models. Northern Arizona University, Master of Science Thesis.

Kirk, Robert. 2005. Western Navajo Water Supply and Demands, A Navajo Perspective. A presentation made to the Coconino Plateau Water Advisory Council.

Kirk, Robert, 2006. Personal communication to the Reclamation study team.

Kobor, Jeremiah S. 2004. Simulating Water Availability in a Spring-Fed Aquifer with Surface/Groundwater Flow Models, Grand Canyon, Arizona. Northern Arizona University, Master of Science Thesis.

Leake, S.A., J.P. Hoffmann, and Jesse E. Dickinson. 2005. Numerical ground-water change model of the C Aquifer and effects of ground water withdrawals on stream depletion in selected reaches of Clear Creek, Chevelon Creek, and the Little Colorado River, in northeastern Arizona. USGS Scientific Investigations Report 2005-5277, 29 p.

Leeper, John. 2006. Personal communication via email from John Leeper, Navajo Tribe, to Kevin Black. July 18.

Leeper, John. 2006. Personal communication to Bob McCaig, March 30.

Lopes, T.J., and J.P. Hoffman. 1997. Geochemical Analysis of Ground-Water Ages, Recharge Rates, and Hydraulic Conductivity of the N Aquifer, Black Mesa Area, Arizona. U.S. Department of the Interior, U.S. Geological Survey Water-Resources Investigations Report 96-4190, 1967.

LSR Innovations. 2004. Chapter Images: 2004 Edition, Profiles of 110 Navajo Nation Chapters. Research and Planning Division of Community Development, The Navajo Nation, April.

McCleve, Ron. 2005. Personal communication from Ron McCleve, owner, Utility Source LLC to Don Bills.

McGavock, T.W. Anderson, O. Moosburger. 1986. Water Resources of Southern Coconino County.

Merchant, James P. 2005. Economic Benefit/Cost Analysis Navajo-Gallup Water Supply Project (Draft). Dornbusch Associates, Berkeley, California, and Tucson, Arizona, October 4.

Monroe, Stephen A., Ronald C. Antweiler, Robert J. Hart, Howard E. Taylor, Margot Truini, John R. Rihs, and Tracey J. Felger. 2005. Chemical Characteristics of Ground-Water Discharge along the South Rim of Grand Canyon in Grand Canyon National Park, Arizona, 2000-2001. USGS Scientific Investigations Report 2004-5146, U.S. Government Printing Office, Washington, DC.

National Park Service (NPS). 2006a. Presentation to John Beshears, GCP Engineer, Coconino Plateau Water Advisory Council.

NPS. 2006b. Grand Canyon National Park Web site. www.nps.gov/grca/facts/index.htm, accessed January 31.

Natural Resource Consulting Engineering (NRCE). 2005. Havasu Baaja: The People of the Blue-Green Waters.

NRCE. 1995. 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.

Navajo Tribal Utility Authority (NTUA). 2006. Tribal community current water rates. Website: http://www.ntua.com/Utility%20Rates/water.htm, accessed May 30.

Parker, Patricia L., and Thomas F. King. 1990. Guidelines for Evaluating and Documenting Traditional Cultural Properties. National Register Bulletin 38, Washington, DC, National Park Service.

Peabody Energy. 2006. http://www.peabodyenergy.com/Operations/CoalOperations-Southwest.asp, accessed April 17, 2006.

Pierce, Herbert A. 2001. Structural Controls on Ground-Water Conditions and Estimated Aquifer Properties near Bill Williams Mountain, Williams, Arizona. U.S. Geological Survey, U.S. Government Printing Office, Washington, DC.

Pilles, Peter, and Dr. William H. Doelle. n.d. Personal communication by Pilles and Doelle, Desert Archaeology.

Pinkham, Richard, and Bill Davis. 2002. North Central Arizona Water Demand Study: Phase 1 Report; an examination of water use, water conservation and alternative supplies in non-reservation communities on the Coconino Plateau. Rocky Mountain Institute, Snowmass, Colorado; and Planning and Management Consultants, LTD., Carbondale, Illinois.

Plummer, Bill. 2005. Representative of the City of Page. Comments on the draft “Current Conditions” document, January.

Pratt, Sue. 2006. Personal communication to Reclamation team regarding Coconino County economic and social conditions.

Pratt, Sue. 2005. Comments on draft “Current Conditions” document, January.

PWCC, Inc. 1999. A Three-Dimensional Flow Model of the D and N Aquifers, Black Mesa Basin, Arizona. Consulting Report prepared for by HIS. Geotrans, Inc. and Waterstone Engineering, Inc. for Peabody Western Coal Company, three volumes, September.

Bureau of Reclamation. 2004a. TAG subgroup. Personal communication from subgroup team leader. Updated historical and projected population for NCAWSS demand areas: accounting for “rural” areas in population projections. July 1.

_____. 2004b. Page-LeChee Water Supply Project. June.

_____. 2003a. TAG subgroup. North Central Arizona Water Supply Study Population Subgroup Report of Findings. March 6.

_____. 2003b. Peabody Coal Black Mesa Mine C-Aquifer Water Supply Appraisal Study, July.

_____. 2002a. Grand Canyon National Park Water Supply Appraisal Study, January.

_____. 2002b. Peabody Coal Black Mesa Mine Water Supply Appraisal Study, October.

_____. 2000. Appraisal Level Peer Review Study of the Arizona Department of Water Resources Phase I – North Central Arizona Regional Water Study, September.

_____. 1999. Peer review of North Central Arizona Water Supply Study Phase One.

_____. 1996. Western Navajo Water Supply Project, August 1996.

_____. 1977. Mogollon Mesa Concluding Report.

Reed, Kristen E. n.d. Renegotiating Urban Water Management in Flagstaff.

Roberson, Joelynn. 2005. Personal communication from Joelynn Roberson of the Hopi Tribe.

Roberson, Joelynn, 2004. Personal communication from Roberson of the Hopi Tribe, February 14.

Rocky Mountain Institute (RMI). 2002. North Central Arizona Water Demand Study, Phase One Report, Draft.

S.S. Papadopulos & Associates. 2005. Groundwater Flow Model of the C Aquifer in Arizona and New Mexico. Southern California Edison, Salt River Project, Nevada Power Company.

Shiel, Michael. 2002. Letter from Michael Shiel, attorney representing the Havasupai Tribe, to Kevin Black, May 3.

Springer, A.E., and J.A. Kessler. 2000. Seeps, Springs, and Capture Zones of the Coconino Plateau: In a Context of Sustainability. In Proceedings of the First Coconino Plateau Hydrology Workshop, October 26 and 27, 2000, Northern Arizona University, Flagstaff, Arizona.

Stephens, Daniel B. and Associates, Inc. 1999. Water System Feasibility Study: Upper and Lower Moenkopi.

Stevens, L.E., and T.J. Ayers. 2002. The biodiversity and distribution of alien vascular plant and animals in the Grand Canyon region. In: B. Tellman (editor), Invasive Exotic Species in the Sonoran Region, University of Arizona Press, Tucson, pp. 241-265.

TetraTech RMC. 2003. Summary Report – Page LeChee Water Supply Project Alternatives, January.

The Arizona Republic. 2005. Canyon Gateway Rides Amusement Park Plan. June 2.

Thomas, B.E. 1989. Simulation Analysis of the Ground-Water System in Mesozoic Rocks in the Four Corners Area, Utah, Colorado, Arizona, and New Mexico. USGS Water-Resources Investigations Report 88-4086, 89 p.

U.S. Bureau of the Census, 2003. Arizona Department of Economic Security, and the City of Flagstaff. Updated historical and projected population for North Central Arizona Water Supply Study Demand Areas.

_____. 2003. Economic Census and County Business Patterns, Coconino County, Arizona.

_____. 2002. Economic Census and County Business Patterns, Coconino County, Arizona.

_____. 2000. Economic Census and County Business Patterns, Coconino County, Arizona.

U.S. Environmental Protection Agency (EPA). 2001. Drinking Water Infrastructure Needs Survey, American Indian and Alaska Native Village Water Systems Survey, EPA 816-R-01-006, February.

Victor, William R., and Errol L. Montgomery. 2000. Groundwater Flow Model for the Tusayan Growth Environmental Impact Statement. In: Proceedings of the First Coconino Plateau Hydrology Workshop, October 26 and 27, Northern Arizona University, Flagstaff, Arizona.

Ward, John. 2002. Groundwater on the Plateau. Southwest Hydrology, Vol. 1, No. 4, November and December.

White Horse-Larson, Rita. 2006. Personal communication. April 13.

Wilkerson, Randy. 2006. Hydrologist, Camp Navajo, personal communication to Don Bills.

Wirt et al. 2005.

Zhu, C. 2000. Estimate of Recharge from Radiocarbon Dating of Groundwater and Numerical Flow and Transport Modeling. American Geophysical Union, Water Resources Research, Vol. 36, No. 9, pp. 2607-2620, September.