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Soils and Watershed Specialist Report

Forest Plan Revision Final Environmental Impact Statement

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Executive Summary

This Specialist Report examines the potential effects of implementation of a revised Forest Land Management Plan for the Kaibab National Forest (KNF) on watersheds and soils. This report is based on the existing conditions and the four Priority Needs for Change identified in the Analysis of the Management Situation.

A comprehensive evaluation report (CER) was completed in April of 2009 to evaluate the needs for change in the Kaibab Forest Plan as it affects trends related to social, economical and ecological sustainability (KNF 2009, KNF 2010). This report was based upon the sustainability reports (which describe the social, economic, and ecological conditions and trends) and other recent information (KNF 2008a, KNF 2008b).

An internal Management Review of the CER was conducted in December of 2008 to determine which needs for change issues would be carried forward into plan revision. The Forest Leadership Team identified four priority topics that focus the scope of the Kaibab's plan revision. These topics reflect the priority needs and potential changes in program direction that will be emphasized in the development of the Revised Forest Plan components. They are:

- Modify stand structure and density towards reference conditions and restore historic fire regimes
- Regenerate aspen to insure long-term healthy aspen populations
- Restore natural waters and wetlands to insure healthy riparian communities
- Restore historic grasslands by reducing tree encroachment and restoring fire

Overview of the Affected Environment

Analysis Area

The affected environment analysis area for soils and watersheds includes all of the 4^{th}-(HUC8), 5^{th}-(HUC10), and 6^{th}-level (HUC12) hydrologic units that contain, at least partially, Kaibab National Forest (KNF) lands. A sub-basin is a 4^{th}-level hydrologic unit, a watershed is a 5^{th}-level hydrologic unit, and a subwatershed is a 6^{th}-level hydrologic unit.

According to national direction (Chapter 40 of FSH 1909.12) and Regional guidance, Forest Plan Revision analysis should extend beyond Forest boundaries in order to understand the environmental context and ecological niche of the Forest and the opportunities and limitations of the Forest to contribute to the sustainability of ecological systems.

Figures 1 through 7 in Appendix A display the analysis area for Soils and Watersheds for the KNF Forest Plan Revision Environmental Impact Statement (EIS) and the hierarchy of the watersheds and associated Hydrologic Unit Codes (HUCs).

Watersheds

The KNF intersects eight HUC8 subbasins, occupying an average of 15% of each, with the minimum being 0.38 percent and the maximum being 28 percent of any single subbasin (Appendix A, Table 1). The Forest comprises more than ten percent of four of the subbasins. Subbasins represent the broadest level of analysis and extend well beyond KNF boundaries.

Historically subbasin conditions have been satisfactory. Overall, management of surface water resources plays the largest role in maintaining overall ecological function of subbasins where KNF lands occur; however, surface water as perennial streams on the KNF is extremely limited with only 1.5 stream miles of perennial water flow in North Canyon Creek on the North Kaibab Ranger District.

The Forest intersects 29 HUC10 watersheds. The KNF occupies approximately 33 percent of each watershed that intersects the Forest, with the maximum being 93 percent and the minimum being 0.15 percent of any single watershed. Snake Gulch and Sycamore Creek are the dominant watersheds (i.e., have the greatest number of acres) on the KNF and have some of the largest acreages extending beyond KNF boundaries. No watersheds are totally contained within the KNF. The following watersheds, in order from highest to lowest, have the greatest proportion, and are more than two-thirds contained within the KNF: Snake Gulch, Ashfork Draw-Jumbo Tank, Jumpup Canyon-Kanab Creek, Red Horse Wash and North Canyon Wash. Water resource management activities, including maintaining perennial water quality, quantity, and timing of flows contribute a very important role in overall ecological function and sustainability of these watersheds. Conversely, Bright Angel Creek, Hack Canyon, Middle Havasu Creek, Lower Partridge Creek, Grindstone Wash, Shinumu Creek and Lower Buckskin Gulch watersheds occupy less than 6 percent of KNF lands. Forest water resource management activities, including maintaining perennial waters, contribute less to overall ecological function and sustainability of these watersheds when compared to those with greater proportions occurring on the KNF.

All other watersheds occupy intermediate extent on the Forest. Management activities including maintaining surface water quality, quantity, and timing of flows play an important role in overall ecological function and sustainability of these watersheds.

The Forest intersects 126 HUC12 subwatersheds. Fifty-two occur on the North Kaibab Ranger District, 25 occur on the Tusayan Ranger District, and 49 occur on the Williams Ranger District. The KNF occupies an average of 52% of each subwatershed that the Forest intersects, with several being wholly within the KNF and the minimum occupancy of a single watershed by KNF land being less that 0.01 percent. The lands that comprise the HUC12 subwatersheds (hydrologic units generally of the scale 10,000 to 40,000 acres) consist of contiguous units of KNF lands and combinations of KNF, other federal, state, and privately owned lands.

A watershed condition assessment was recently conducted for all sixth-level hydrologic units (HUCs) as part of an initial Forest-level assessment of watershed condition. This assessment is used to: 1) prioritize watersheds for restoration, 2) identify specific on-the-ground activities and the associated costs to maintain or improve watershed condition, and 3) manage the data appropriately. Watershed condition for these watersheds was classified using a core set of national watershed condition indicators that are updated with local data and interpreted by Forest interdisciplinary (ID) teams. These indicators are grouped according to four major ecosystem process categories: (1) aquatic physical; (2) aquatic biological; (3) terrestrial physical; and (4) terrestrial biological. These categories represent terrestrial, riparian, and riverine ecosystem processes or mechanisms by which management actions can affect the condition of watersheds and associated resources. Each indicator is evaluated using a defined set of attributes whereby each attribute is scored by the Forest interdisciplinary team as GOOD (1), FAIR (2), or POOR (3) using written criteria and rule sets and the best available data and professional judgment.

Twelve core watershed condition indicators were evaluated for all sixth-level HUCs. Aquatic physical indicators included: 1) water quality condition, 2) water quantity (flow regime) condition, and 3) stream and habitat condition. Aquatic biological indicators included: 4) aquatic biota condition and 5) riparian vegetation condition. Terrestrial physical indicators included: 6) road and trail condition, and 7) soil condition. Terrestrial biological indicators included: 8) fire effect and regime condition, 9) forest cover condition, 10) rangeland, grassland and open area condition, 11) terrestrial non-native invasive species condition, and 12) forest health condition.

Attribute scores for each indicator are summed and normalized to produce an overall indicator score. The indicator scores for each ecosystem process category are then averaged to arrive at an overall category score. The Watershed Condition scores are tracked to one decimal point and reported as Watershed Condition Classes 1, 2, or 3. Class 1 = scores of 1.0 to 1.66; Class 2 = scores >1.66 and <2.33, and Class 3 = scores from 2.33 to 3.0. Class 1 watersheds are functioning properly. Class 2 watersheds are functional – at risk, and Class 3 watersheds have impaired function.

Subwatershed conditions are generally satisfactory throughout much of the KNF. However, unsatisfactory, or impaired conditions do occur within several subwatersheds, contributing to a decline in function of portions of these subwatersheds. Past livestock grazing, the exclusion of natural fire regimes, and occurrences of high severity wildfires have contributed to downward trends in soil condition in some KNF subwatersheds. Currently, vegetation departures from historic (i.e., reference) conditions pose threats to a number of subwatersheds due to decreased vegetative ground cover and increased fuels that increase the risk of high severity wildfires. Fires that have occurred in areas with excessive fuel loads have burned with high intensity, removed protective ground cover, damaged soils, and have result in the delivery of large amounts of sediment to stream channels, causing impaired function of some subwatersheds on the KNF. National Forest System Roads that are located in close proximity to drainage channels or that cross stream courses contribute to impaired watershed function through introduction of sediments and increased surface water turbidity when roads and stream crossings are used during wet weather or are inadequately maintained. Some watersheds on the KNF have high road densities that threaten watershed function by redirecting and channelizing surface water flow in roadside ditches and other road water diversion structures (i.e., road drainage features). Noxious and invasive weed infestations and insects and pathogens have also contributed to impaired or function of some watersheds.

Management of KNF lands often influences subwatershed conditions and therefore water resources conditions at larger scales (i.e., watershed and subbasin). In areas of mixed ownership, reasonable assumptions regarding the management of non-KNF lands are based on historic and current management practices and activities on those lands in the future.

Tables 1 through 3 in Appendix A summarize subbasin, watershed, and subwatershed extent and conditions within the analysis area.

Soils

Soils within the KNF include a wide variety of taxonomic classifications, reflecting the influences of several separate, but interacting soil forming factors including parent material, climate, topography, and organisms over time. As a result, soil characteristics range from shallow, weakly developed, rocky soils on plateaus, mesas, cliffs, escarpments, and ridges to deeper, more productive soils on alluvial fans, plains, and in valley bottoms. In general, soils on the KNF are fine textured and contain a wide range of rock fragment sizes within soil profiles and at the surface (Hendricks 1985). The dominant parent materials that occur in the KNF consist of sedimentary rocks, including sandstone, carbonates (primarily limestone and dolomite), mudstone, shale, and gypsum and igneous rocks, including granite, basalt, and basalt cinders.

Soils of the KNF were mapped as part of the Terrestrial Ecosystem Survey (TES) of the Kaibab National Forest (Brewer et al. 1991). This information is available at the Kaibab National Forest Headquarters or via the internet at:

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5138598.pdf.

Natural Waters

Streams, groundwater, springs, wetlands, and natural ponds are centers of high biological diversity in arid landscapes and the ecological health of these resources is important for forest ecosystem sustainability. Wildlife is more concentrated around open water sources than in the general landscape, and obligate aquatic and semi-aquatic species on the KNF are often entirely dependent on these limited and dispersed water sources. Collectively these resources contribute to connectivity for wildlife across the landscape. Springs are highly productive habitats in otherwise low-productivity arid and semi-arid landscapes. Springs are frequently more stable ecologically than surrounding upland ecosystems in arid regions, and may offer biological refugia for some species, particularly narrowly endemic species.

Natural waters provide water and food resources that are especially vital to wildlife; particularly birds, bats and invertebrates. Seeps, springs and wetlands have profound traditional cultural significance to tribes. Contemporary uses include potable local water supplies and agricultural uses such as livestock watering. These uses are vital to domestic and commercial interests in and around the KNF. In addition, springs provide recreational opportunities to KNF visitors.

Perennial Streams

The only known historic perennial streams on the KNF are North Canyon Creek and Kanab Creek. The perennial reach of North Canyon Creek is located in the Upper North Canyon Wash subwatershed (HUC12) of the North Canyon Wash watershed (HUC10) of the Lower Colorado-Marble Canyon sub-basin (HUC8). The historic flow ranged from one to six miles, depending on precipitation, before becoming subsurface flow. Current riparian conditions are thought to be near historic conditions with a wide variety of riparian species present. However, the stream contributes only 2% of the perennial stream miles in this watershed while the Forest area makes up almost 25% of the watershed.

The Forest Service, in cooperation with the Arizona Game and Fish Department recently completed repair and replacement of log drop and other fish habitat structures in North Canyon Creek. This project has helped protect a genetically pure population of Apache trout (*Oncorhynchus apache*) by rehabilitating pools that provide winter habitat and refugia in times of stream dewatering from limited precipitation. The project was completed in the lower to mid portion of North Canyon Creek below North Canyon Spring in the Saddle Mountain Wilderness. This stream channel is currently classified in good condition and is not diverted

Kanab Creek flows through the Rock Canyon-Kanab Creek (HUC12), Little Spring Canyon-Kanab Creek, and the Chamberlain Canyon-Kanab Creek subwatersheds (HUC12) of the Grama Canyon-Kanab Creek and Jumpup Canyon-Kanab Creek (HUC10) watersheds of the Kanab sub-basin (HUC8). Historically, Kanab Creek has been a perennial stream within the Forest, but with current upstream water use and diversion, perennial flow has been adversely affected within the KNF boundaries. The baseflow of Kanab Creek is, to a large degree, maintained by springs that discharge within the KNF portion of the Kanab Creek watershed. Upstream impoundments and water diversion have also altered flooding disturbance within Kanab Creek. However, localized, short-duration, high-intensity monsoon thunderstorms remain an important component of ecosystem health of Kanab Creek. Much of the Kanab Creek drainage within the KNF is infested by tamarisk (*Tamarix* sp.), which competes aggressively with the native willows and cottonwoods, often resulting in pure stands of tamarisk. Currently, Kanab Creek within the KNF and Grand Canyon National Park is infested with tamarisk leaf beetles (*Diorhabda carinulata*), which effectively defoliate tamarisk, resulting in severe tamarisk mortality. Elimination of this aggressively competing non-native species provides opportunities for restoration of native vegetation in areas where hydrologic processes are conducive to such efforts. Historic livestock grazing has adversely impacted the Kanab Creek area, but livestock have been excluded from grazing since 1996. Occasional, unauthorized use continues. Opportunities to negotiate with the towns of Kanab and Fredonia, as well as the Utah Division of Water Resource, and upstream water users are recommended to restore Kanab Creek streamflow quantity, and to limit groundwater depletion and water pollution.

Seeps and Springs

Arizona has the 2nd highest density of known springs in the U.S. with the Mogollon Rim and the North Kaibab having among the highest densities of springs in Arizona (pers. comm. Larry Stevens). According to the NHD layer, there are 709 springs and seeps in all KNF connected HUC8 sub-basins. The Forest contains approximately 167 known springs and seeps or about 23% of the total. Ninety-two of these springs occur on the North Kaibab Ranger District, 74 occur on the Williams Ranger District, and one has been identified on the Tusayan Ranger District (Table 1, Appendix C). The historic extent and flow of springs and seeps are generally unknown, but are presumed to be approximately equal to the current extent and flow. No springs exist on the Forest that flow more than 0.2 miles. Springs and seeps extent and flow have been observed to fluctuate largely as a factor of precipitation. Human impacts (i.e. livestock grazing, water diversion, and recreation) have adversely affected some springs on the KNF. Many of the springs on the KNF are known to be developed, which probably occurred after the Homestead Act of 1862. These developed springs remove water from the site and reduce riparian vegetation extent. Several springs have been observed and documented to be at risk or are nonfunctional riparian areas due to ungulate grazing, inadequate maintenance of spring infrastructure, and recreational activity. Springs and seeps can exhibit reduced flows caused by transpirational effect of increasingly dense forest vegetation encroaching on these areas, but this has not been conclusively documented on the KNF. In addition, springs and seeps located adjacent to existing wells may exhibit reduced flows caused by groundwater pumping, or drawdown.

Wetlands/Cienegas

The number and extent of historic wetlands on the KNF is largely unknown. The current number and extent of wetlands is estimated from information found in the U.S. Fish and Wildlife Service (USFWS), National Wetlands Inventory (NWI). The NWI data includes stock tanks as areas identified as wetlands. Generally, wetlands are areas where soil saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al. 1979). For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Stock tanks on the KNF rarely impound water at a sufficient frequency or duration to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Stock tanks therefore rarely meet the criteria for classification as wetlands. There are approximately 457 acres of stock tanks on the KNF.

There are four primary wetland types that occur on the KNF as identified in the NWI. These include freshwater emergent wetlands, freshwater forested/shrub wetlands, riverine wetlands, and lakes. There are approximately 295 acres of freshwater emergent wetlands, 1 acre of freshwater forested/shrub wetlands, 5 acres of riverine wetlands, and 690 acres of lakes on the KNF.

Of the wetlands recorded within the KNF, 16-18 have been modified to capture more water. Of the 88 known wetlands, 31 are in impaired condition, 45 are in functioning at risk, and 12 are in proper functioning condition. The primary causes of impaired wetland condition include livestock grazing, elk grazing, and recreational activities. Several wetlands have been fenced to exclude domestic livestock grazing in the last 10 years, which has improved wetland conditions. Another primary factor affecting wetland and riparian size and function is prolonged drought conditions.

Developed Waters

Reservoirs and Stock Tanks

There are three large reservoirs (500 acre-feet or larger) that occur on the Williams Ranger District of the KNF. These include West Cataract Creek, Dogtown Reservoir, and Kaibab Lake. Dogtown Reservoir is the largest with a maximum water storage capacity of 1390 acre-feet. Kaibab Lake has a maximum water storage capacity of approximately 967 acre-feet, and West Cataract Creek has a water storage capacity of approximately 860 acre-feet. The most common uses of these reservoirs are public water supply for the City of Williams, recreation, and fire protection. Three other reservoirs that are not on the KNF, but that have watersheds originating on the KNF include City Reservoir, Gonzales Lake, and Santa Fe Reservoir.

Approximately 90 percent of the City of Williams surface water supply originates from Dogtown Reservoir and City Reservoir. From 2005 through 2010, an annual average of 198,184,868 gallons of water (101.36 acre-feet) were withdrawn from surface waters and wells for public use by the City of Williams. The majority of this public water (xxxxxx gallons) originated from Dogtown Reservoir and water wells located near the Reservoir. The highest average monthly usage occurs from May through July, with average monthly usage for these three months totaling 21,212,271 gallons. There has been a slight increase in public water utilization reported by the City of Williams from 2005 through 2010. Average annual public water utilization was 191,745,081 gallons in 2005 and 216,090,312 gallons in 2010.

There are 492 reservoirs and stock tank claims within the 126 subwatersheds (HUC12) on the KNF, and 3,281 in the 4th code watersheds according to the Arizona Department of Water Resources. This represents 15% of the total number of structures in the analysis area sub-basins (HUC8). The KNF reservoirs and stock tanks were primarily built from the 1930-1980’s. These impoundments have reduced flow volume and duration of some ephemeral and intermittent stream channels on the KNF. However, a reduction in riparian vegetation has not been observed due to the historically short duration that water is present in these stream channels. The reservoirs and stock tanks on the KNF have increased perennial water on the Forest for livestock and wildlife as well as increased riparian vegetation surrounding them.

The only lake or wetland on the Forest that has been classified as impaired for the designated uses under EPA water quality standards is Whitehorse Lake, a man-made impoundment. Sampling occurred in varying degrees from 1993 to 2006. In 1998, the Lake was placed on the EPA 303 (d) list for exceeding the turbidly standard for Aquatic and Coldwater Fisheries designated use. From 1997-2000, the lake exceeded standards for dissolved oxygen, pH, and turbidity. In 2002, the lake exceeded the standard for dissolved oxygen. The Arizona Department of Environmental Quality (ADEQ) classified the lake as Category 5 (for high pH, fish kills in 1994, ammonia and turbidity exceedances). In 2006, ADEQ placed Whitehorse Lake into an improved class, Category 2 “Attaining Some Uses” and the lake was delisted in 2008.

Surface Water Quality

Surface water quality has generally been satisfactory on the KNF except during drought conditions and extreme flood events or immediately following high-severity wildfires. There are currently no streams or water bodies on the KNF that are classified as not meeting EPA water quality standards for their designated uses.

There is one perennial stream reach on the KNF that is approximately 1.5 miles in length. Therefore, no KNF streams are monitored by ADEQ or listed as Category 5 or "Impaired" on the 2007 EPA 303(d) list. The Forest does not contribute to any known adverse impacts to ADEQ monitored streams on or off the Forest.

Large fires, drought or extreme flood events continue to have an effect on water quality. Typically, these events only affect water quality for a short period of time (1 to 5 years) before natural stabilization and recovery occur.

Groundwater

Ground water on the KNF is primarily located within the regionally important Redwall-Muav (R-M) aquifer, which averages 1200 feet below the ground surface. The R-M aquifer is overlain by a thick sequence of lithified sedimentaries including sandstones, siltstones, shales, and limestones (Montgomery et al. 1988). Historically this aquifer was primarily charged with surface precipitation at the higher altitudes and in areas of heavily fractured rock. Shallow, perched aquifers in the water-bearing zones of volcanic rocks and the Kaibab Formation are also found within the KNF. These minor aquifers are commonly thin and discontinuous (Montgomery et al. 1988). Most wells drilled to these perched aquifers fail after a pumping period ranging from several days to several years and are then abandoned.

The ADEQ has independent statutory authority to develop and adopt Aquifer Water Quality Standards. Groundwater standards in Arizona are the Safe Drinking Water standards established for public water systems and surface water standards for the Domestic Water Source designated use. The ADEQ has established the Ambient Groundwater Monitoring Program which seeks to characterize groundwater quality in each of the 51 groundwater basins that have been designated in Arizona by state agencies (ADEQ 2010). ADEQ has completed studies and has reports available covering 15 groundwater basins in Arizona, none of which occur on the KNF. Groundwater quality on the KNF is expected to be in satisfactory condition.

The Arizona Depart of Water Resources (ADWR) wells registry (Wells 55) indicates there are 257 well occurrences on the KNF. The majority of these well sites (172) are located on the Tusayan Ranger District and have been primarily for mineral exploration purposes. There are 78 registered wells on the Williams Ranger District. Many of these wells are associated with private parties and appear to be errors in the location information for private wells. Other wells have been installed for cathodic protection of pipelines that cross the District. There are six registered wells on the North Kaibab Ranger District (NKRD). One of these wells was for mineral exploration. The remaining wells on the NKRD are associated with private parties and are believed to be errors in location information.

In recent years, cities have become more dependant on groundwater. Water use in Flagstaff and Colorado Plateau Cities increased approximately 30% from the mid-1980's to the mid-1990's (Hydrogeology of the Regional Aquifer, 1994 – 1997). Adverse effects of groundwater pumping on seeps, springs, and wetlands are possible but these effects have not been conclusively documented.

Summary of Environmental Consequences

Comparison of the environmental consequences of each alternative is summarized for each Priority Need for Change identified in the Analysis of the Management Situation.

Modify stand structure and density towards reference conditions and restore historic fire regimes

The focus of this Priority Need for Change is on the ponderosa pine and dry mixed conifer vegetation types.

Alternative B – the Proposed Action would more effectively achieve long term desired conditions for soil and watershed resources in ponderosa pine and dry mixed conifer vegetation communities by guiding stand structure and density towards reference conditions and restoring historic fire regimes, thus improving the ecological function and sustainability of soils and watersheds. Under the Proposed Action, mechanical thinning is proposed on approximately 11,000 to 19,000 acres annually in the ponderosa pine vegetation type and 2,000 to 4,000 acres annually in frequent fire mixed conifer. Initially, mechanical forest thinning treatments would increase risks of soil compaction, rutting, puddling, accelerated erosion, potential sediment delivery to surface waters, and establishment of invasive and noxious weeds through the use of heavy machinery. However, long-term improvement in herbaceous understory vegetation and forest structure and function would occur as a result of this alternative since treated areas are expected to recover rapidly (i.e., 1-3 years) following mechanical vegetation treatments.

Approximately 13,000 to 50,000 acres of wildland fire would occur annually in the ponderosa pine vegetation type under Alternative B while 1,000 to 13,000 acres of wildland fire would occur annually in the frequent fire mixed conifer vegetation type. This would include both prescribed fire and wildfire that would improve ecological function of soils and increase understory vegetation production.

Alternative A would be less effective than the proposed action in achieving desired conditions for soils and watershed resources of the ponderosa pine and mixed conifer vegetation types. Under Alternative A, the KNF would continue vegetation management practices at approximately the current rate. Mechanical vegetation treatments that have potential to improve long-term soils and watershed conditions in the ponderosa pine vegetation type would continue to occur on approximately 2,100 acres annually, much less than the acreage proposed under Alternative B. Alternative A would also continue mechanical vegetation treatments in the frequent fire mixed conifer vegetation type at a rate of approximately 200 acres annually (approximately 5 to 10 percent of the acreage proposed under Alternative B). In addition, approximately 20,000 acres of soils and watershed resources would receive fire disturbance that would improve soil nutrient cycling and increase understory herbaceous vegetation. Under Alternative A, desired conditions for soils and watersheds in ponderosa pine and frequent fire mixed conifer vegetation types would not be achieved as effectively under Alternative A as under Alternative B. With only 200 acres in the frequent fire mixed conifer vegetation type receiving mechanical thinning treatments annually, it is unlikely that Alternative A would achieve desired conditions for soils and watersheds.

Alternative C proposes to mechanically thin approximately 11,000 to 19,000 acres in ponderosa pine annually and approximately 30,000 to 60,000 acres in the frequent fire mixed conifer vegetation type over the plan period. Fire disturbance would be introduced on approximately 14,000 to 63,000 acres annually.

Alternative C approaches the same acreages as Alternative B with regard to mechanical and wildland fire treatments in ponderosa pine and frequent fire mixed conifer vegetation types. However, Alternative C would require retention of all ponderosa pine trees having yellow bark, effectively imposing a diameter limit over time in the remaining Suitable Timber Base. This Alternative would also include an additional Land Management Area (LMA) known as the "North Kaibab Wildlife Habitat Complex". This LMA would share the same boundary as the National Natural Landmark for the Kaibab squirrel. In this LMA, mechanical treatments, including commercial timber harvesting could be conducted once, to initially restore stand structure to a condition where natural disturbance processes could occur without uncharacteristic outcomes. Mechanical treatments and timber harvesting would be employed within the limitations of the large tree retention guidelines; after which mechanically treated acres would be removed from the Suitable Timber Base, and be maintained solely with natural disturbances, and prescribed fire.

While Alternative C would be expected to move some areas toward desired conditions, a diameter limit might prevent removal of sufficient number of trees in some areas to effectively reduce fire risk. Also, as treated stands regenerate and become increasingly dense, risk of high severity wildfire would return over time since crown interconnectedness could occur earlier than under a no diameter limit alternative. High severity fires can have profound negative effect to soil properties including: a) decreased soil productivity through loss of available nutrients, b) soil hydrophobicity (i.e. the inability of soils to absorb water following precipitation) resulting in increased overland flow and c) increased susceptibility of soils to erosion by both wind and rainfall.

Alternative D is the similar to Alternative C with the exception that all lands would be removed from the Suitable Timber Base once areas have been treated to achieve conditions where, initially, natural processes could be used without serious uncharacteristic results (i.e., State N).

Alternative D would be similar to Alternatives B and C with mechanical thinning of approximately 11,000 to 19,000 acres in the ponderosa pine vegetation type annually, and 30,000 to 60,000 acres in frequent fire mixed conifer vegetation type over the plan period. The number of acres treated per year would decrease over time since they would be removed from the Suitable Timber Base following mechanical treatments.

Protect and regenerate aspen

Aspen stands that are in a state of decline exhibit reduced leaf fall that leads to a decrease in soil organic matter accumulation and eventually a decline in the thickness of the mollic soil horizon (Cryer and Murray 1992). As a result, nutrients are leached from upper soil horizons leading to decreased soil water holding capacity and reduced base saturation. The result is a gradual increase in soil acidity, which provides an environment conducive to conifer encroachment into aspen stands. These processes, along with browsing of aspen by wildlife and impacts from domestic livestock grazing are occurring throughout much of the Williams and Tusayan Ranger Districts of the KNF. As a result, some of these aspen stands are trending toward late successional conifer-dominated vegetation communities.

There are no specific plan directions under Alternative A governing the removal of encroaching conifers from aspen stands and there are no Plan objectives to do so. However, the Williams and Tusayan Ranger Districts have inventoried aspen stands in the ponderosa pine vegetation type, identified aspen restoration needs and have implemented projects to protect and restore aspen, subject to available funding. There is uncertainty regarding whether these needs can be addressed within the next ten years.

The three proposed action alternatives build on current projects purposes and needs, setting an objective to establish exclosure fences on 200 acres of aspen stands, and to reduce conifer encroachment on 800 acres of aspen within 10 years of Plan approval. However, these alternatives also include large tree-retention guidelines that would prevent the removal of some large conifers from aspen stands, limiting the effectiveness of aspen restoration projects.

Overall, the amount of treatment to protect and regenerate aspen is not expected to be different between the Proposed Action, Alternative C and Alternative D, if funding is available. Effectiveness of treatments is likely to be somewhat higher for the Proposed Action or Alternative A than for Alternative C or D due to differences in large tree retention guidelines.

Construction and maintenance of the proposed wildlife and domestic livestock exclosures in aspen stands would result in short-term, minor soil compaction and trampling or removal of native vegetation in areas where fence construction occurs. Native vegetation would reestablish in these areas soon after construction is completed (i.e., 1 to 3 years). Soil stability and productivity within exclosures would improve over time through elimination of impacts to aspen regeneration by wildlife and domestic livestock (i.e., browsing and trampling). Additional benefits include reduced susceptibility of sites to invasion by noxious weeds by increasing native grass, forbs, shrubs and aspen recruitment over time. These increases in native plant cover would reduce the amount of open, ruderal sites susceptible to weed invasion.

Reduction of conifer encroachment in aspen stands would result in short-term, minor soil compaction and removal of native vegetation within treated areas. Native vegetation such as grasses, forbs, and shrubs would reestablish in treated areas over time improving soil stability and productivity. Where aspen recruitment occurs in the absence of wildlife and domestic livestock impacts, soil ecological processes common in aspen vegetation communities would return over time, contributing to sustainable aspen populations.

Restore natural waters and wetlands to insure healthy riparian communities (Or is it now "Protect Natural Waters")

Restore native vegetation and natural water flow patterns on at least 6 acres of wetlands within 5 years of plan approval, and maintain, or increase, the existing acreage of wetlands on the Forest over the life of the Plan.

The current Forest Plan offers little guidance for managing seeps, springs, wetlands, and natural lakes and ponds. Actions to protect natural waters are relatively inexpensive and easily accomplished, provide important benefits, and have a high concordance with social and economic needs.

Restore grasslands by reducing tree encroachment in grasslands and meadows

All Action Alternatives include objectives to reduce encroaching conifers in grassland vegetation types. Under Alternative A there is no specific plan direction governing the removal of encroaching conifers from grasslands, and there are no objectives in the current plan to do so. All action Alternatives have a large tree-retention guideline that would limit the removal of large encroaching conifers from grasslands and inhibit effective implementation of grassland and meadow restoration.

Treatments to reduce tree encroachment in grasslands would result in minor soil compaction and removal of native vegetation where tree removal is practiced. Soil compaction and removal of vegetative ground cover has the potential to cause accelerated erosion and degradation of surface water quality. These conditions typically occur for short period following treatment (i.e., 1 to 3 years). Implementation of Best Management Practices and appropriate design features and mitigation measures would minimize these adverse effects. Long term improvement in soil stability and productivity would occur as grasses and forbs reestablish in areas where tree canopy cover has reduced understory productivity. Soil carbon storage and nutrient cycling would return to historic levels through improved fine root turnover, organic matter accumulation, and increased soil water holding capacity.

Desired Future Condition

Watershed: Watershed conditions on the Forest will improve where impaired or functional at-risk watershed conditions currently exist. Watersheds that are currently in proper functioning condition will continue to function properly.

Water Quality: Water quality in streams, lakes and wetlands is currently meeting designated beneficial uses throughout the KNF and will continue to do so through the Plan period. Overall water quality will improve where water quality does not meet designated beneficial uses except immediately after large fires, drought conditions, or extreme flood events.

Perennial Streams: North Canyon Wash will continue to be at or near historic conditions for water flow and riparian vegetation. Wilderness conditions are expected to remain static.

Kanab Creek will continue to flow as an intermittent stream due to the high demand for surface water the upper reaches of the watershed. Tamarisk are expected to exhibit decline due to the southward expansion of the biocontrol agent known as the tamarisk beetle (*Diorhabda carinulata*). There is uncertainty regarding the long-term effect this beetle will have on plant community dynamics such as reestablishment of native cottonwood and willow in the watershed.

Seeps, Springs, Reservoirs, and Stock tanks: Springs and seeps will continue to flow at rates similar to historic levels. Developed springs will continue to be used at or near current levels. Springs will continue to be excluded from livestock grazing where conditions warrant in order to improve riparian vegetation. Where livestock grazing continues at springs, riparian conditions will remain static. Where forest canopies are reduced in watersheds above springs, it is possible that spring flow would increase, although frequency and duration of flow increases cannot be predicted with certainty. Where wells are located in watershed above springs on KNF or private ownerships, it is likely that spring flow would remain static or decrease.

Number and size of reservoirs and stock tanks will remain similar to current levels. These impoundments will continue to reduce the frequency and duration of water flow to downstream reaches of ephemeral and intermittent streams on the KNF. However, reservoirs and stock tanks will continue to increase perennial water on the KNF for domestic livestock and wildlife as well as increasing riparian vegetation surrounding them. Overall, sustainability of aquatic ecosystems on the KNF is not adversely affected because they are typically small, discontinuous, and widely distributed.

Ground Water: Ground water use by municipalities, including private wells on and off the KNF will continue to increase with increasing demand for water. This will likely have adverse effects to seeps, springs, riparian habitats, and down stream water flow on and off the KNF.

Wetlands: Wetland conditions will continue to improve on wetlands that are excluded from livestock grazing and have reduced recreational impacts. Wetlands that are not excluded from livestock grazing or recreational impacts will continue to remain in static condition or may exhibit downward trends. Precipitation will continue to affect the rate at which wetlands improve, wetland extent, and the condition of riparian habitats.

Soils: Soil conditions would reflect expected future disturbance levels and would not exhibit long-term decline in response to implementation of the Plan. Guidance included in the Plan should be designed to protect soil conditions and soil quality and maintain soil productivity.

Forest-wide: The levels of disturbance associated with timber production, vegetation restoration, prescribed fire, and other projects are expected to increase over the next 15 years as landscape restoration projects are implemented in an effort to restore forested ecosystems to their historic natural range of variability with regard to species composition, forest structure, and fire regime. Forestwide Desired Conditions would protect watershed values and conditions during forest management activities. The construction of few roads is anticipated and those already in place would be routinely maintained, improved, closed, or obliterated as they are used or deemed unnecessary for management activities. Implementation of the Travel Management Rule on each district would eliminate some forms of motorized cross country travel, decreasing soils and watershed resource damage from certain types of motorized cross-country travel in some areas. Consequently, forest-wide conditions are expected to improve over the long term under the.

Contents

Specialist Report

Introduction

This report evaluates and discloses the potential environmental consequences to soils and watershed resources that may result with the adoption of a revised land management plan (Revised Plan). It examines, in detail, three different alternatives for revising the 1988 KNF land management plan, as amended (Plan). This report is based on the existing conditions and the four Priority Needs for Change identified in the Analysis of the Management Situation.

A comprehensive evaluation report (CER) was completed in April of 2009 to evaluate the needs for change in the Kaibab Forest Plan as it affects trends related to social, economical and ecological sustainability (KNF 2009, KNF 2010). This report was based upon the sustainability reports (which describe the social, economic, and ecological conditions and trends) and other recent information (KNF 2008a, KNF 2008b).

An internal Management Review of this CER was conducted in December of 2008 to determine which needs for change issues would be carried forward into plan revision. The Forest Leadership Team identified four priority topics that focus the scope of the Kaibab's plan revision. These topics reflect the priority needs and potential changes in program direction that will be emphasized in the development of the Revised Forest Plan components. They are:

- Modify stand structure and density towards reference conditions and restore historic fire regimes.
- Regenerate aspen to insure long-term healthy aspen populations
- Restore natural waters and wetlands to insure healthy riparian communities
- Restore historic grasslands by reducing tree encroachment and restoring fire.

According to national direction (Chapter 40 of FSH 1909.12) and Regional guidance, Forest Plan Revision analysis should extend beyond Forest boundaries in order to understand the environmental context and ecological niche of the Forest and the opportunities and limitations of the Forest to contribute to the sustainability of ecological systems.

Relevant Laws, Regulations, and Policy that Apply

The following list includes applicable laws, regulations, and policies affecting soils and watershed management on the KNF, the requirements of which are incorporated by reference herein.

The U.S. Forest Service Directives System (FSM/FSH): Forest Service Manuals and Handbooks codify the agency's policy, practice, and procedure. The system serves as the primary basis for the internal management and control of all programs and the primary source of administrative direction to Forest Service employees. The Forest Service Manual (FSM) contains legal authorities, objectives, policies, responsibilities, instructions, and guidance needed on a continuing basis by Forest Service line officers and primary staff in more than one unit to plan and execute assigned programs and activities. Forest Service Handbooks (FSH) are the principal source of specialized guidance and instruction for carrying out the direction issued in the FSM.

Specialists and technicians are the primary audience of Handbook direction. Handbooks may also incorporate external directives with related USDA and Forest Service directive supplements.

Forest Service Manual – Service Wide Issuance
- Forest Service Manual 2500 – WATERSHED AND AIR MANAGEMENT

Region 3 (Southwestern Region): Regional Issuances
- Forest Service Manual 2504.3 Exhibit 01
- Forest Service Manual 2510 - WATERSHED PLANNING
- Forest Service Manual 2520 - WATERSHED PROTECTION AND MANAGEMENT
- Forest Service Manual 2530 - WATER RESOURCE MANAGEMENT
- Forest Service Manual 2540 - WATER USES AND DEVELOPMENT
- Forest Service Manual 2580 - AIR RESOURCE MANAGEMENT

Forest Service Handbook – Service Wide Issuance
- Forest Service Handbook 2500 – Watershed and Air Management

Region 3 (Southwestern Region): Regional Issuances
- 2509.13 - Burned-Area Emergency Rehabilitation Handbook
- 2509.16 - Water Resource Inventory Handbook
- 2509.21 - National Forest System Water Rights Handbook
- 2509.22 - Soil and Water Conservation Handbook
- 2509.23 - Riparian Area Handbook
- 2509.24 - National Forest System Watershed Codes Handbook
- 2509.25 - Watershed Conservation Practices Handbook

The Organic Administration Act: (at 16 U.S.C. 475, 551). States the purpose of the national forests, and directs their control and administration to be in accord with such purpose, that is, “[n]o national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States.” Authorizes the Secretary of Agriculture to “make such rules and regulations…to preserve the forests [of such reservations] from destruction.”

Weeks Law of 1911: as amended (at 16 U.S.C. 515, 552). Authorizes the Secretary of Agriculture to enter into agreements with States for the purpose of conserving forests and water supply, and, to acquire forested, cutover, or denuded lands within the watersheds of navigable streams to protect the flow of these streams or for the production of timber, with the consent of the State in which the land lies.

Knutson-Vandenberg Act of 1930 (16 U.S.C. at 576b). Specifies that the Secretary may require any purchaser of national forest timber to make deposits of money in addition to the payments for the timber, to cover the cost to the United States of planting, sowing with tree seeds, and cutting, destroying or otherwise removing undesirable trees or other growth, on the national forest land cut over by the purchaser, in order to improve the future stand of timber, or protecting and improving the future productivity of the renewable resources of the forest land on such sale area.

Anderson-Mansfield Reforestation and Revegetation Joint Resolution Act of 1949 (at 16 U.S.C. 581j and 581 j(note)). States the policy of the Congress to accelerate and provide a continuing basis for the needed reforestation and revegetation of national forest lands and other lands under Forest Service administration or control, for the purpose of obtaining stated benefits (timber, forage, watershed protection, and benefits to local communities) from the national forests.

Granger-Thye Act of 1950 (16 U.S.C. at 580g-h). Authorizes the Secretary to use a portion of grazing fees for range improvement projects on NFS lands. Specific types of projects mentioned are artificial revegetation, including the collection or purchase of necessary seed and eradication of poisonous plants and noxious weeds, in order to protect or improve the future productivity of the range. Section 11 of the act authorizes the use of funds for rangeland improvement projects outside of NFS lands under certain circumstances.

Surface Resources Act of 1955 (30 U.S.C. 611-614). Authorizes the Secretary of Agriculture to manage the surface resources of unpatented mining claims located under the authority of the 1872 Mining Law as amended, including, but not limited to, reclamation of disturbance caused by locatable mineral activities.

Surface Mining Control and Reclamation Act of August 3, 1977: Authorizes the Secretary of Agriculture to enter into agreements with landowners, providing for land stabilization, erosion, and sediment control, and reclamation through conservation treatment, including measures for the conservation and development of soil, water, woodland, wildlife, and recreation resources, and agricultural productivity of such lands.

U.S. Mining Laws (Public Domain Lands) Act of May 10, 1872 - Provides that all valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are free and open to exploration and purchase, and the lands in which they are found to occupation and purchase by citizens of the United States and those who have declared their intention to become such, under regulations prescribed by law, and according to the local customs or rules of miners, so far as the same are applicable and not inconsistent with the laws of the United States. There are a number of Acts which modify the mining laws as applied to local areas by prohibiting entry altogether or by limiting or restricting the use which may be made of the surface and the right, title, or interest which may pass through patent.

Sikes Act (Fish and Wildlife Conservation) of September 15, 1960 (16 U.S.C. at 670g). Section 201 directs the Secretary of Agriculture, in cooperation with State agencies, to plan, develop, maintain, coordinate, and implement programs for the conservation and rehabilitation of wildlife, fish and game species, including specific habitat improvement projects, and shall implement such projects on public land under their jurisdiction.

Soil and Water Resources Conservation Act of November 18, 1977 - Provides for a continuing appraisal of the United States' soil, water and related resources, including fish and wildlife habitats, and a soil and water conservation program to assist landowners and land users in furthering soil and water conservation.

Multiple-Use Sustained-Yield Act of 1960 (16 U.S.C. 528-531). States that the National Forests are to be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes, and that establishment and maintenance of wilderness areas are consistent with this Act. This Act directs the Secretary to manage these resources in the combination that will best meet the needs of the American people; providing for periodic adjustments in use to conform to changing needs and conditions; and harmonious and coordinated management of the resources without impairment of the productivity of the land. Sustained yield means achieving and maintaining in perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

Water Resources Planning Act of July 22, 1965 - Encourages the conservation, development, and utilization of water and related land resources of the United States on a comprehensive and coordinated basis by the Federal government, states, localities, and private enterprises.

Watershed Protection and Flood Prevention Act of August 4, 1954 - Establishes policy that the Federal government should cooperate with states and their political subdivisions, soil or water conservation districts, flood prevention or control districts, and other local public agencies for the purposes of preventing erosion, floodwater, and sediment damages in the watersheds of the rivers and streams of the United States; furthering the conservation, development, utilization, and disposal of water, and the conservation and utilization of land; and thereby preserving, protecting, and improving the Nation's land and water resources and the quality of the environment.

Water Quality Improvement Act of April 3, 1970 - Amends the prohibitions of oil discharges, authorizes the President to determine quantities of oil which would be harmful to the public health or welfare of the United States; to publish a National Contingency Plan to provide for coordinated action to minimize damage from oil discharges. Requires performance standards for marine sanitation device and authorizes demonstration projects to control acid or other mine pollution, and to control water pollution within the watersheds of the Great Lakes. Requires that applicants for Federal permits for activities involving discharges into navigable waters provide state certification that they will not violate applicable water quality standards

Wilderness Act of 1964 (16 U.S.C. §§1131 et seq.). Authorizes the Secretary of Agriculture to administer certain congressionally designated National Forest System lands as wilderness. The Act directs the protection and preservation of these wilderness areas in their natural state, primarily affected by nature and not man's actions. The Act allows certain management actions that would otherwise be prohibited in wilderness 'as necessary to meet minimum requirements for the administration of the area for the purpose of the Act,' and also provides that 'such measures may be taken as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable.' 16 U.S.C. 1133 (c),(d).

Wild and Scenic Rivers Act (82 Stat. 906, as amended; 16 U.S.C. 1271 (note), 1271-1287). Establishes the National Wild and Scenic Rivers System, and policy for managing designated rivers and designating additions to the system. The Act prescribes for designated rivers and their immediate environments the protection and enhancement of their free-flowing character, water quality, and outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values. Examples of management actions may include moving toward a desired range of structural vegetative conditions, increasing the amount of large in-stream wood, and improving water quality. Streams eligible for inclusion in the system must be in free-flowing condition or have been restored to this condition.

National Environmental Policy Act (NEPA) of 1969: (16 U.S.C. 4321 et seq.). Declares it is the policy of the Federal Government to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans. The Act requires agencies proposing major federal actions significantly affecting the quality of the human environment, to prepare a detailed statement on the environmental impacts of the proposed action, unavoidable adverse environmental impacts, alternatives to the action proposed, the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources which would be involved if the proposed action is implemented. The Act also provides that for any proposal which involves unresolved conflicts concerning alternative uses of available resources, an agency must study, develop, and describe appropriate alternatives to recommended courses of action.

Endangered Species Act of 1973: (P.L. 93-205, 87 Stat. 884; 16 U.S.C. 1531-1544, as amended). States its purposes are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, and provide a program for the conservation of such endangered species and threatened species. Federal agencies are to formulate and implement programs and activities to conserve threatened and endangered species and the ecosystems upon which they depend. Under the Act, conserve means the use of methods and procedures necessary to bring any endangered or threatened species to the point at which the measures provided under the Endangered Species Act are no longer necessary.

Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, as amended by National Forest Management Act (NFMA) of 1976 (16 U.S.C. 1600-1614, 472a). States that the development and administration of the renewable resources of the National Forest System are to be in full accord with the concepts for multiple use and sustained yield of products and services as set forth in the Multiple-Use Sustained-Yield Act of 1960. It sets forth the requirements for land and resource management plans for units of the National Forest System, including requiring guidelines to provide for the diversity of plant and animal communities based on the suitability and capability of the specific land area.

The Federal Water Pollution Control Act of 1972: Public Law 92-500, as amended in 1977 (Public Law 95-217) and 1987 (Public Law 100-4) (also known as the Federal Clean Water Act (CWA)): This Act provides the structure for regulating pollutant discharges to waters of the United States. The Act's objective is "…to restore and maintain the chemical, physical, and biological integrity of the Nation's waters," and is aimed at controlling both point and non-point sources of pollution. The U.S. EPA administers the Act, but many permitting, administrative, and enforcement functions are delegated to state governments. In Arizona, the designated agency for enforcement of the Clean Water Act is the Arizona Department of Environmental Quality (ADEQ).

> Relevant sections of the Clean Water Act:
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> CWA Sections 208 and 319: recognizes the need for control strategies for non-point source pollution.
>
> CWA Section 303(d): requires waterbodies with water quality determined to be either impaired (not fully meeting water quality standards for designated uses) or threatened (likely to violate standards in the near future) to be compiled by ADEQ in a separate list, which must be submitted to EPA every 2 years. These waters are targeted and scheduled for development of water quality improvement strategies on a priority basis.

Total Maximum Daily Loads (TMDLs): As of May 2006, there were no applicable TMDL requirements in effect for the KNF.

CWA Section 305(b): requires that states assess the condition of their waters and produce a biennial report summarizing the findings.

CWA Section 401: allows states and tribes to review and approve, set conditions on, or deny Federal permits (such as 404 permits) that may result in a discharge to state or tribal waters, including wetlands. Applications for Section 404 permits are often joint 404/401 permits to ensure compliance at both the Federal and state levels.

CWA Section 404: outlines the permitting process for dredging or discharging fill material into waters of the U.S., including wetlands. The U.S. Army Corps of Engineers administers the 404 Program.

Safe Drinking Water Amendments of November 18, 1977: Amended the Safe Drinking Water Act to authorize appropriations for research conducted by the Environmental Protection Agency relating to safe drinking water; Federal grants to states for public water system supervision programs and underground water source protection programs; and grants to assist special studies relating to the provision of a safe supply of drinking water.

Clean Air Act, as amended 1977 and 1990: (42 U.S.C. 7401, 7418, 7470. 7472, 7474, 7475, 7491, 7506, 7602). Establishes a national goal to prevent any future, and remedy existing, visibility impairment in certain wilderness areas the Forest Service manages. It also directs the Forest Service as a Federal land manager to protect air quality related values from man-made air pollution in these same areas. Lastly, it obligates the Forest Service to comply with the Act's many provisions regarding abatement of air pollution to the same extent as any private person.

North American Wetland Conservation Act of 1989 (16 U.S.C. 4401 (note), 4401-4413, 16 U.S.C. 669b (note)). Section 9 (U.S.C. 4408) directs Federal land managing agencies to cooperate with the Director of the U.S. Fish and Wildlife Service to restore, protect, and enhance the wetland ecosystems and other habitats for migratory birds, fish and wildlife within the lands and waters of each agency to the extent consistent with the mission of such agency and existing statutory authorities.

Stewardship End Result Contracting Projects (16 U.S.C. 2104 (note)). Grants the Bureau of Land Management (BLM) and the Forest Service ten-year authority to enter into stewardship contracts or agreements to achieve agency land management objectives and meet community needs.

Tribal Forest Protection Act of 2004 (P.L. 108-278, 118 Stat. 868; 25 U.S.C. 3115a). Authorizes the Secretary of Agriculture and the Secretary of the Interior to enter into an agreement or contract with Indian tribes meeting certain criteria to carry out projects to protect Indian forest land or rangeland, including a project to restore Federal land that borders on or is adjacent to Indian forest land or rangeland.

Executive Order 11988 (Floodplain Management (42 CFR 26951, May 25, 1977)**:** The purpose of this Order is "…to avoid to the extent possible the long and short term impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." Section 1 states: "Each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for (1) acquiring, managing, and disposing of Federal lands, and facilities; (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities."

Executive Orders relevant to ecological restoration include:

Executive Order 11514: issued March 5, 1970, as amended by E.O. 11991 issued May 24, 1977. Protection and enhancement of environmental quality (35 FR 4247, March 7, 1970). This order states that the Federal Government shall provide leadership in protecting and enhancing the quality of the nation's environment to sustain and enrich human life. This order provides for monitoring, evaluation, and control on a continuing basis of the activities of each Federal agency so as to protect and enhance the quality of the environment.

Executive Order 11644: issued February 8, 1972. Use of off-road vehicles on the public lands. (37 FR 2877, February 9, 1972). Amended by E.O. 11989 issued May 24, 1977 and E.O. 12608 issued September 9, 1987. This order requires federal agencies to develop and implement procedures that will ensure that the use of off-road vehicles on public lands will be controlled and directed so as to protect the resources of those lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands.

Executive Order 11990 (Protection of Wetlands): …"in order to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands… Section 1. (a) *Each agency shall provide leadership and shall take action to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities* for… (3) conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities. Sec. 5: In carrying out the activities described in Section I of this Order, each agency shall consider factors relevant to a proposal's effect on the survival and quality of the wetlands. Among these factors are: (b) maintenance of natural systems, including conservation and long-term productivity of existing flora and fauna, species and habitat diversity and stability, hydrologic utility, fish, wildlife, timber, and food and fiber resources; and (c) other uses of wetlands in the public interest, including recreational, scientific, and cultural uses."

Executive Order 13112 issued February 3, 1999. Invasive Species. (64 CFR 6183, February 8, 1999). This order requires federal agencies whose actions may affect the status of invasive species to, among other things, respond to and control populations of invasive species and provide for restoration of native species and habitat conditions in ecosystems that have been invaded by non-native invasive species.

Travel Management Rule: On December 9, 2005, the Forest Service published the TMR. The agency rewrote direction for motor vehicle use on National Forest Service (NFS) lands under 36 CFR, Parts 212, 251, and 261, and eliminated 36 CFR 295. The rule was written to address at least in part the issue of unmanaged recreation. The rule provides guidance to the Forest Service on how to designate and manage motorized recreation on the Forests. The rule requires each National Forest and Grassland to designate those roads, motorized trails, and Areas that are open to motor vehicle use.

Road System: 36 CFR 212.5 (b): ...the responsible official must identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System lands. ... The minimum system is the road system determined to be needed to meet resource and other management objectives adopted in the relevant land and resource management plan (36 CFR 219), to meet applicable statutory and regulatory requirements, to reflect long-term funding expectations, to ensure that the identified system minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance.

Identification of unneeded roads. Responsible officials must review the road system on each National Forest and Grassland and identify the roads on lands under Forest Service jurisdiction that are no longer needed to meet forest resource management objectives and that, therefore, should be decommissioned or considered for other uses, such as for motorized routes.

Regional Forester's direction: Roads analysis process (RAP) for all other existing roads should be completed in conjunction with implementation of the off-highway vehicle (OHV) Record of Decision, watershed analyses, other project level activities or Forest Plan revisions.

Memorandum of Agreement on Fostering Collaboration and Efficiencies to Address Water Quality Impairments on National Forest System Lands: Agreement between U.S. Forest Service and the U.S. Environmental Protection Agency signed in 2007. Purpose: to coordinate between agencies and address issues of water quality impairment regarding 303d list, as well as TMDLs. The leading cause of water quality impairments on National Forest lands includes temperature, excess sediment, and habitat modification. These issues are to be addressed via BMPs to the greatest extent possible. In terms of this project analysis area, BMPs can be applied to soil and watershed condition and are applicable everywhere on the KNF.

33 CFR 323 Permits for Discharges of Dredged or Fill Material into Waters of the United States - This regulation prescribes those special policies, practices and procedures to be followed by the Corps of Engineers in connection with the review of applications for permits to authorize the discharge of dredged or fill material into waters of the United States.

36 CFR 212.5 (b) Roads - ...the responsible official must identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System lands. ... The minimum system is the road system determined to be needed to meet resource and other management objectives adopted in the relevant land and resource management plan (36 CFR 219), to meet applicable statutory and regulatory requirements, to reflect long-term funding expectations, to ensure that the identified system minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance.

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Regional Forester's direction: Roads analysis process (RAP) for all other existing roads should be completed in conjunction with implementation of the off-highway vehicle (OHV) Record of Decision, watershed analyses, other project level activities or Forest Plan revisions.

36 CFR 219 Planning - Sets forth a process for developing, adopting, and revising land and resource management plans for the National Forest System.

36 CFR 241 Fish and Wildlife - Sets forth the rules and procedures relating to the management, conservation, and protection of fish and wildlife resources on National Forest System lands.

40 CFR 121-135 Water Programs - Sets forth the provisions for the administration of water programs including: state certification of activities requiring a Federal license or permit; EPA administered permit programs; state program requirements; procedures for decision making; criteria and standards for the National Pollutant Discharge Elimination System; toxic pollutant effluent standards; water quality planning and management; water quality standards; water quality guidance for the Great Lakes System; secondary treatment regulation; and, prior notice of citizen suits. See Title 40 (Protection of Environment), Chapter 1 (Environmental Protection Agency), subchapter D (Water Programs).

40 CFR 1500 Council on Environmental Quality - Council on Environmental Quality regulations implementing the National Environmental Policy Act.

Methodology and Analysis Process

This section describes the methodology and analysis processes used to determine the environmental consequences on soil condition from implementing the alternatives. Environmental consequences are not site-specific at the broad forest planning level and will be described with qualitative descriptions supported by past studies and observations. Much of the background information is found in the Ecological Sustainability Report (Forest Service 2008) and the supporting specialist reports.

Analyses for soils and watershed existing conditions and environmental consequences to soils and watershed resources that may result with the adoption of a revised land management plan (Revised Plan) were conducted using information contained in the Terrestrial Ecosystem Survey of the Kaibab National Forest (TES) (Brewer et al. 1991), the Kaibab National Forest Comprehensive Evaluation Report (KNF 2009), the Kaibab National Forest Supplement to the Comprehensive Evaluation Report (KNF 2010), information obtained from other KNF resource specialists, other agency reports, available literature, and input from KNF collaborators and cooperators. Geospatial analysis was used to quantitatively and qualitatively assess soils and subbasin, watershed, and subwatershed conditions using Geographic Information Systems (GIS) data obtained from a variety of sources.

Soils of the KNF were mapped as part of the Terrestrial Ecosystem Survey (TES) of the Kaibab National Forest (Brewer et al. 1991). This information is available at the Kaibab National Forest Headquarters or via the internet at:

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5138598.pdf.

The TES is the result of the systematic analysis, mapping, classification and interpretation of terrestrial ecosystems, also known as terrestrial ecological units that are delineated and numbered. A TES represents the combined influences of climate, soil and vegetation, and correlates these factors with soil temperature and moisture along an environmental gradient. It is an integrated survey and hierarchical with respect to classification levels and mapping intensities. It is the only seamless mapping of vegetation and soils available across the KNF that includes field visited, validated and correlated sites with a stringent Regional and National protocol stemming from decades of work. Major field work for the Kaibab TES was completed from 1979 through 1986. Map units are identified by numbers ranging from 3 to 683. One hundred and thirty-two soil types have been mapped and described and management interpretations developed on the KNF.

It is important to understand that differences in ecosystem properties including soil and vegetation can occur within short distances. The TES was mapped at a scale of 1:24,000 across the landscape. Generally, small vegetation types (i.e., smaller than about 40 acres) were not mapped and are included in larger TES map units. Where site-specific information is required and at a finer scale, on-site investigations should be made to validate or refine soil information.

Individual map units were based on data collected across the Forest and may or may not represent the exact same landscape existing conditions and potential plant community as depicted in the TES. Overall accuracy of mapping and information provided by the TES is considered reliable at the ecological unit or landscape level. It is estimated that over 3,000 points per Forest were visited on-site and have data documenting soil classification, vegetation type present, surface components and other site characteristics.

The TES follows National Cooperative Soil Survey Standards similar to Soil Surveys conducted by the Natural Resource Conservation Service. This is strict quality assurance including Project Leader field review, Regional Office, initial, annual progressive and final field review to approve map unit design and mapping.

There are minimum data collection requirements necessary to establish, design and map TES map units. Generally, at least 10 observations, 3 transects of 10 stops/transect and reference ecological sites per map unit are required and each Forest has more than 130 TES map units.

The Terrestrial Ecosystem Survey (TES) is used to evaluate and adjust land uses to the limitations and potentials of natural resources and the environment. It presents important properties pertaining to the natural, physical, and behavioral characteristics of the terrestrial ecosystems and provides the background for making interpretations. Interpretations based upon TES incorporate 1) soil physical and chemical properties, 2) climatic considerations, 3) topographic position and slope, 4) vegetation and anthropogenic influences as well as animal impacts, 5) productive and successional potentials, and 6) geologic influences. As such the TES can form the ecological basis for describing existing conditions for resource areas including watershed, wildlife, fire, and timber.

Soil condition is based on the primary soil functions of soil hydrology, soil stability, and nutrient cycling as described by R3 Supplement FSH 2509.18. The current soil condition rating is described in the Ecological Sustainability Report (KNF 2008a) and was based on how departed soils are from the historic range of natural variability. The projected trends in soil condition were based on estimates of vegetative ground cover, soil productivity, and organic matter. Each vegetation type (PNVT[1]) was examined to see whether soil conditions would generally trend

[1] PNVT - Potential Natural Vegetation Type

towards, away or remain static with the implementation of treatments by alternative. The analysis is based on the Vegetative Dynamics Development Tool (VDDT) modeling results for each vegetation type using the range of acres proposed to be treated by alternative and estimates of soil cover and organic matter retention.

Effects to water quality will be assessed qualitatively by alternative, by comparing projected changes to current areas of water quality impairment, and by comparing predicted indirect effects by major land disturbing activities (e.g. forest thinning, animal grazing, roads, mining, burning).

The general classification used for surface water quality by ADEQ is attaining, attaining some uses, inconclusive/not assessed, not-attaining, and impaired for the identified uses. The classification designates each waterbody in one of five categories:

- **Category 1** Surface waters assessed as "attaining all uses." All designated uses are assessed as "attaining."
- **Category 2 -** Surface waters assessed as "attaining some uses." Each designated use is assessed as either "attaining," "inconclusive," or "threatened."
- **Category 3 -** Surface waters assessed as "inconclusive." All designated uses are assessed as "inconclusive" due to insufficient data to assess any designated use (e.g., insufficient samples or core parameters). By default, this category would include waters that were "not assessed" for similar reasons
- **Category 4 -** Surface waters assessed as "not attaining." At least one designated use was assessed as "not attaining" and no uses were assessed as "impaired." A Total Maximum Daily Load[2] (TMDL) analysis will not be required at this time for one of the following reasons:
  - **4 A. -** A TMDL has already been completed and approved by EPA but the water quality standards are not yet attained;
  - **4 B. -** Other pollution control requirements are reasonably expected to result in the attainment of water quality standards by the next regularly scheduled listing cycle; or
  - **4 C. -** The impairment is not related to a "pollutant" loading but rather due to "pollution" (e.g., hydrologic modification).
- **Category 5 -** Surface waters assessed as "impaired." At least one designated use was assessed as "impaired" by a pollutant. These waters must be prioritized for TMDL development.

Water quality is assessed by comparing existing conditions (category 1 to 5) with desired conditions that are set by Arizona under authority of the Clean Water Act. Waters that are not

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[2]A TMDL is a written analysis that determines the maximum amount of a pollutant that a surface water can assimilate (the "load"), and still attain water quality standards during all conditions. The TMDL allocates the loading capacity of the surface water to point sources and nonpoint sources identified in the watershed, accounting for natural background levels and seasonal variation, with an allocation set aside as a margin of safety.

impaired (those not on 303d[3] list or in category 4 or 5) are providing for beneficial uses identified for that stream and can be considered in a desired condition until further sampling indicates impairment. Those in category 2 or higher require special attention during site specific project analysis. The Arizona Department of Environmental Quality (ADEQ) is the regulating authority for water quality in Arizona as promulgated by EPA.

The ADEQ also interprets its surface water quality standards to apply to “intermittent, non-navigable tributaries.” The ADEQ interprets the definition of “surface water” to include tributaries (“the tributary rule”) and assigns water quality standards to intermittent surface waters that are not specifically listed by name in Arizona’s surface water quality standards rules. ADEQ has determined it is necessary to regulate and protect these types of waters as “waters of the United States” because it is estimated that approximately 95 percent of the surface waters in Arizona are either intermittent or ephemeral.

Effects to water yield will be discussed qualitatively, based on comparison of current activities to projected effects of implementing alternatives. Generally, reducing canopy cover in vegetation types within higher precipitation zones will generate more runoff. Vegetation treatment types were entered into the Vegetation Digital Dynamics Tool (VDDT) model which provided changes in vegetation states (i.e., from groups of trees with closed canopy to open canopy). This change implies changes in water yield.

Effects to groundwater availability will be discussed qualitatively using regional studies and FS policies to generally predict effects to the forests. There is little difference between alternatives regarding groundwater use or groundwater quality, and slight differences predicted in groundwater recharge potential from the Forest.

Assumptions

In the analysis for these resources, the following assumptions have been made:

- The land management plan provides a programmatic framework for future site-specific actions.
- Land management plans do not have direct effects. They do not authorize or mandate any site-specific projects or activities (including ground-disturbing actions).
- Land management plans may have implications, or environmental consequences, of managing the forests under a programmatic framework.
- The plan decisions (desired conditions, objectives, standards, guidelines, management areas, monitoring) will be followed when planning or implementing site-specific projects and activities.

[3] Under section 303(d) of the 1972 Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These impaired waters do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters. (http://yosemite.epa.gov/R10/WATER.NSF/TMDLs/CWA+303d+List)

- Law, policy, and regulations will be followed when planning or implementing site-specific projects and activities.
- Monitoring will occur and the land management plan will be amended, as needed.
- We will be funded similar to past budget levels (past 5 years).
- The planning timeframe is 15 years; other timeframes may be analyzed depending on the resource (usually a discussion of anticipated trends into the future).
- For estimating the effects of alternatives at the programmatic forest plan level, the assumption has been made that the kinds of resource management activities allowed under the prescriptions will occur to the extent necessary to achieve the goals and objectives of each alternative. The actual location, design, and extent are not known at this time and will be a site specific (project by project) decision. Therefore this analysis refers to potential of the effect to occur, realizing that in many cases, these are only estimates. The effects analysis is useful in comparing and evaluating alternatives on a forest-wide basis but is not to be applied to specific locations on the forests. Some resources are not within the Agency's ability to control; these will be noted.
- The kinds of analysis completed at the project level compares existing condition to desired condition to determine the site specific need for change. The analysis contains description of how specific activities affect soil function, estimates of the degree of those effects, and the mitigation used to protect or improve soil function. As an example, erosion, compaction and displacement are common impacts to soil function as a result of mechanical treatments. Soil quality objectives (R-3 Supplement FSM 2509.18) provide thresholds of management concern based on soil hydrology, soil stability, and nutrient cycling.
- Data used in this analysis represents forest-wide conditions and may not represent soil condition at any given point on the landscape. It is important to realize that many differences in soils and related disturbances can occur within short distances. Overall accuracy of mapping and information provided by the TES (Terrestrial Ecosystem Survey) and soil condition protocol is considered reliable at the ecological unit or landscape level. However, on-site inspection should be conducted for site-specific project assessments.

Revision Topics Addressed in this Analysis

The Analysis of the Management Situation listed four primary needs for change to be addressed in the Revised Plan. Soils and watershed conditions are integral to all aspects of natural resource management and therefore directly affect and are affected by activities undertaken that modify forest conditions. The four primary needs for change are:

Modify stand structure and density towards reference conditions and restore historic fire regimes:

This need for change addresses the current condition of forest and woodland PNVTs on the KNF.

Currently, all vegetative communities, and therefore soils and watersheds are departed to some degree from desired conditions (and reference conditions) or are trending away. In many cases, greatly increased smaller tree density, increased canopy bulk density, increased canopy cover, loss of understory species diversity, and increased occurrences of invasive species have resulted in changes to soil stability, soil nutrient cycles, and soil hydrologic function (i.e., water holding capacity). Current vegetation conditions within the ponderosa pine and frequent fire mixed conifer vegetation types are contributing to increased risk of uncharacteristic disturbances, such as stand replacing fire in areas that would otherwise exhibit low severity, high frequency fire regime types. These two vegetation types cover approximately 40 percent of the KNF and constitute the second and third largest vegetation communities on the Forest.

Other large vegetation communities include the pinyon-juniper vegetation types which also occupy approximately 40 percent of the Forest and wet mixed conifer, spruce-fir, and the remaining fourteen vegetation types on the KNF which collectively occupy the other 20 percent. There are no specific objectives outlined in the alternatives for these vegetation types. This does not imply that treatments cannot be planned and implemented in these vegetation types as funding and personnel become available during the planning period. Since there are no objectives developed for these vegetation types, no meaningful comparison of alternatives is possible, and no evaluation criteria are developed. They are therefore not addressed in this report.

Evaluation criteria (based on VDDT outputs) for determining whether an alternative is addressing this need for change in ponderosa pine or frequent fire mixed conifer communities are:

- Frequency of occurrences of State K. State K is one of the 14 vegetative structural states developed for ponderosa pine and dry mixed conifer in the VDDT model. It represents the large, open, multi-storied state in the mid-scale desired conditions. These conditions are conducive to improved soils and watershed function through improved vegetative ground cover and fine litter (organic matter) accumulation. Increased soil organic matter content improves soil water holding capacity and nutrient cycling. Vegetative ground cover of grasses and forbs improves soil porosity and aggregate stability, decreasing susceptibility of soils to erosion by wind and rain.

- Interspersion creation. This is an indicator of the relative frequency of treatments required to create small-scale state interspersion, or "groups". Examples include group selection thinning in combination with matrix thinning or fire disturbance under moderate burning conditions. Where fewer treatments are required to achieve desired conditions, disturbance to soils and watersheds are minimized.

- Amount of stand replacing fire. Stand replacing fire destroys desired fine- and mid-scale interspersion, and is uncharacteristic, undesired fire behavior. It also contributes to soil hydrophobicity (i.e., water repellency) and increases the risk of soil erosion. Soil erosion can degrade surface water quality. Increased overland flow can cause downstream flooding and

- Relative understory abundance and diversity. As important indicators of proper ecological function of soils in ponderosa pine and dry mixed confer vegetation types, understory species abundance and diversity contribute to soil ecological function and resilience by providing habitat for a variety of soil micro fauna and ground cover to protect soil surfaces from erosive forces of wind and water.

- Acres planted to facilitate recovery from large, uncharacteristic high-severity fires. Tree canopies and boles intercept rainfall, preventing it from reaching soil surfaces. The result is decreased overland flow. Where tree and herbaceous vegetative cover has been removed by fire, raindrop impact directly to hydrophobic soil surfaces results in increased runoff and erosion. Replanting of trees following uncharacteristic high-severity fires accelerates soil recovery where native seed banks have been consumed by improving surface roughness to capture windborne seeds, intercepting rainfall, and providing microsites for herbaceous vegetation establishment. Planting is only to be applied to areas where high-severity stand replacing fire has occurred.

- Disturbance – This evaluation criterion examines the amount of area disturbed during mechanical thinning treatments. Disturbance is an adverse effect of mechanical treatments to restore stand structure. It is conducive to accelerated erosion through soil rutting and compaction and removal of understory vegetation. Mechanical treatments can also facilitate introduction and establishment of invasive species, which is examined in detail in the Invasive Species Report (KNF 2013x1).

- Acreage of open states (A, B, C, D, E, J, K, and N) with 30 percent canopy cover or less. This is an indicator of potential for desired fire behavior since open states promote surface fire, rather than crown fire. The effects of fire on soils are primarily a function of the heat and duration of combustion of fuels. Physical impacts of fire on soils include damage to soil structure, reduced water holding capacity and moisture retention, and development of hydrophobic soil conditions (i.e., water repellency**)**, all of which increase the susceptibility of soils to erosion. Chemical impacts to soils from fire include changes in nutrient cycles, loss of soil nutrients to the atmosphere, and loss of soil organic matter (Neary 2004).

Evaluation criteria for determining whether an alternative is addressing this need for change in Ponderosa Pine Forest/Bunchgrass (PPG) and Ponderosa Pine Forest/Oak (PPO) and frequent fire mixed conifer (DMC) PNVTs are:

- Relative frequency of occurrence of State K (i.e., large, open, multi-storied state as mid-scale desired condition).

- Relative frequency of application of treatments that lead to small-scale interspersion creation. (e.g., group selection thinning combined with matrix thinning or fire under moderate burn conditions.

- Relative understory abundance.

- Acres planted.

- Invasive species occurrences.

Regenerate aspen to insure long-term healthy aspen populations:

This need for change addresses the following current conditions:

- Aspen frequency of occurrence and regeneration is rapidly declining, and trending away from desired conditions. Current trends and successional processes, including shifts toward late successional stages dominated by mixed conifer, lack of appropriate scale patchiness, drought, fire exclusion, uncharacteristic high-severity fire, and ungulate herbivory - are causing changes in the abundance and distribution of aspen dominated landscapes. As a result, changes to soil nutrient cycles and hydrologic conditions are occurring in these areas. Aspen stands that are in a state of decline exhibit reduced leaf fall that leads to a decrease in soil organic matter accumulation and eventually a decline in the thickness of the mollic soil horizon (Cryer and Murray 1992). Consequently, nutrients are leached from upper soil horizons leading to decreased soil water holding capacity and reduced base saturation. The result is a gradual increase in soil acidity, which provides an environment conducive to conifer encroachment into aspen stands. These conditions are occurring throughout much of the Williams Ranger District.

- Aspen is an important component of forested ecosystems on the KNF, beginning with the ponderosa pine communities at lower elevations, and extending upwards in elevation into frequent fire mixed conifer, wet mixed conifer, and spruce-fur vegetation communities. The desired conditions for the aspen component of these communities shifts from smaller, more permanent assemblages at lower elevations to larger, more transitory assemblages at higher elevations. Aspen do not currently exhibit departure from desired conditions on the Kaibab Plateau to the extent that they do on the William Ranger District. Aspen responds in a positive manner to stand-replacing disturbances such as shelterwood and seed tree harvests and high-severity wildfires in ponderosa pine and frequent fire mixed conifer vegetation types on the Kaibab Plateau. The Tusayan Ranger District has only a few scattered aspen stands.

Evaluation criteria for whether an alternative is addressing this need for change are:

- Acres of aspen fenced to exclude elk and domestic livestock in ponderosa pine vegetation communities on the Williams and Tusayan Ranger Districts.
- Acres of reduced conifer encroachment on aspen stands in ponderosa pine vegetation communities.

Restore natural waters and wetlands to insure healthy riparian communities:

This need for change addresses the following current conditions:

- Lack of characteristic fire disturbance has resulted in limited soil and watershed nutrient cycling and reduced water inputs, causing departures from reference conditions of natural waters, wetlands, and riparian areas.

- Water movement and associated soil erosion from upland sources into natural waters and wetlands following high-severity wildfires can result in flooding, sedimentation, water quality degradation, and removal of protective vegetative cover in these areas.

- Development of springs, seeps, and headwaters (i.e., water capture) has reduced natural water flow to downstream wetlands and riparian areas.

- Domestic livestock grazing in ephemeral natural waters, wetlands, and riparian areas has the potential to alter water quality, vegetation cover and composition, reduce infiltration, introduce invasive and noxious weeds, and alter stream channel morphology.

- Climate change and drought threaten natural waters, wetlands, and riparian areas. Appropriate management strategies can minimize or mitigate these threats.

- Natural waters and wetlands are important ecosystem components on the KNF since they sustain biologically and culturally important plant and animal species.

Evaluation criteria of whether an alternative is addressing this need for change are:

- Acres surrounding natural waters, wetlands and riparian areas that are restored to characteristic fire disturbance regimes.
- Acres of conifer encroachment reduction treatments in areas adjacent to natural waters, wetlands and riparian areas.
- Acres of natural waters, wetlands, and riparian areas that fenced to exclude domestic livestock grazing.

Restore historic grasslands by reducing tree encroachment and restoring fire:

This need for change addresses the following current conditions:

- Many grassland vegetation types on the KNF, including montane, subalpine, Great Basin, and semi-desert PNVTs exhibit substantial encroachment of woody species that is indicative of historic livestock grazing and fire exclusion. By definition, these vegetation types should no more than 9 percent tree cover. Encroaching trees reduce vegetative ground cover and increases forest litter (i.e. duff) through accumulation of needles, twigs, limbs, etc. Tree cover also reduces available soil moisture since evapotransporation by trees tends to remove groundwater at a faster rate than grasses and forbs.

Evaluation criteria of whether an alternative is addressing this need for change are:

- Acres of grassland vegetation communities with tree canopy cover reduced below 10 percent.
- Relative frequency of occurrence of open states in montane and subalpine areas, except N, which could result in accelerated erosion and possible invasive species establishment.

Management response in the years immediately following large disturbance events.

This revision topic emerged as a priority need for change from the current Plan due to a recognized trend toward increased numbers of large, high-severity fires. Objectives and guidelines are necessary to address actions in the years immediately following large disturbance events. Large-scale, intense disturbances such as stand-replacing fires and epidemic bark beetle infestations) that occur in vegetation communities adapted to less-intense disturbances often exhibit many short- and long-term adverse effects. This has been observed in the ponderosa pine and frequent fire mixed conifer communities. It may also be the case for some pinyon-juniper shrublands, but this is less certain.

Losses have included:

- Substantial soil erosion (over two inches on the Point Fire in 1993, for example).
- Decreased soil productivity.

- Damage to water impoundments, diversions and other Forest infrastructure.
- Displacement of native understory species by non-native species
- Little or very slow recovery of native forest cover.
- Little or very slow recovery of associated large-tree forest structure.

This report addresses the first three listed losses.

Evaluation criteria for ponderosa pine (both bunchgrass - PPG and Gambel oak – PPO) and frequent fire mixed conifer communities are:

- Relative amount of State N – State N is a VDDT State representing an uncharacteristic open state with less than 10% canopy cover, which does not regenerate naturally, usually due to its large scale. Tree seed sources are so far removed from most of the disturbed area that regeneration of the pre-disturbance forest species (dominated by ponderosa pine) is delayed for an indefinite time; probably several decades to centuries. For analysis purposes, it was assumed that treeless openings of 100 acres or more (mid-scale to landscape scale) in ponderosa pine or dry mixed conifer created by fire are State N.
- Acres of tree planting
- Acres treated for presence of invasive and noxious weeds

Resources to be Addressed

Soil Resources

Soil Condition

- Soil Condition is an evaluation of soil quality based on an interpretation of factors which affect vital soil functions
    - Indicator – Projected trend of Soil Condition as measured by a change in soil function (Qualitative)

Watershed Resources

- Watershed Condition is the state of the physical and biological characteristics and processes within a watershed that affect the hydrologic and soil functions supporting aquatic ecosystems. Indicators include:
    - Water quality,
    - Water quantity (flow regime),
    - Stream and habitat condition,
    - Aquatic biological condition,
    - Riparian vegetation condition,
    - Condition of roads,
    - Soil condition,

- Fire effect and regime condition,
- Forest cover condition,
- Rangeland, grassland and open area condition,
- Terrestrial non-native invasive species condition, and
- Forest health condition (insects and diseases).

Summary of Alternatives

Four alternatives are evaluated in this analysis:

A. No Action – the (current) Plan

B. Proposed Action – the Proposed Plan

C. Habitat Complex NKRD – the Proposed Plan with less suitable timber area

D. Habitat Complex KNF – the Proposed Plan with no suitable timber area

Alternative A - No Action Alternative:

Under this alternative there would be no changes to the current Kaibab National Forest Land Management Plan (as amended), and current management practices would continue at current rates. Under Alternative A, there are approximately 450,000 acres of lands suitable for timber production. An additional 25,000 acres could have some trees removed through timber sales in order to meet objectives not related to timber production. Currently, the KNF implements mechanical treatments totaling approximately 2,100 acres per year in the ponderosa pine vegetation type and approximately 200 acres per year in the frequent fire mixed conifer vegetation type.

Currently fire personnel on the KNF are implementing prescribed burning on approximately 8,500 acres per year, and managing wildfires to achieve multiple objectives on approximately 11,700 acres per year. As a result, approximately 20,000 acres per year on the KNF receive beneficial fire disturbance. In accordance with the terms and conditions outlined in the Wildland Fire Use Amendment to the Plan in 2000, suppression action must be taken on all wildfires that occur in mixed conifer vegetation types on the North Kaibab Ranger District. This amendment also outlines prescriptive restrictions that define when wildfires must be suppressed in Mexican Spotted Owl habitat on the Williams Ranger District. Additional wildfire use restrictions in the current plan include requirements to suppress all wildfire starts within a two mile radius of North Canyon Spring in Saddle Mountain Wilderness on the North Kaibab Ranger District, and within the 145-acre Frank's Lake Geologic-Botanical Area, also on the North Kaibab Ranger District, and the 490-acre Arizona Bugbane Area on the north side of Bill Williams Mountain on the Williams Ranger District.

Alternative B - Proposed Plan:

Under this alternative the rate of mechanical forest vegetation treatments would increase over the next 10-15 years, with a shift in focus toward thinning dense stands where such treatments can be implemented effectively, and does not establish objectives for other areas, including:

- Areas (i.e., vegetation types) not listed in the Priority Needs for Change.

- Areas with lower risk of uncharacteristic disturbance.
- Areas that do not exhibit substantial departure from reference conditions, and are expected to remain so for the duration of the Revised Plan.
- Areas where risk cannot be effectively reduced due to limitations of law, regulation or policy.

This alternative would no preclude treatments from being planned and implemented in these areas as funding and personnel are available to do so.

This alternative would include the objective to mechanically thin 11,000 to 19,000 acres in ponderosa pine annually. In frequent fire mixed conifer, the objective would be to thin 30,000 to 60,000 acres over the plan period, which is assumed for the purpose of this report to be approximately 15 years. Proposed guidelines for vegetation management, under this alternative, include:

- Projects in forested communities that change stand structure should usually retain at least historic frequencies of trees, by species, across all diameter classes at the mid-scale. Exceptions would include areas near the wildland-urban interface (WUI), adjacent to electronic communication sites, developed areas, and other infrastructure.
- In frequent-fire vegetation types, spatial distributions of trees should have groups interspersed with openings, providing sufficient canopy breaks to limit crown fire spread between groups and facilitate the re-establishment and maintenance of a diverse vegetative understory.
- The location and spatial arrangement of vegetation management activities should effectively disconnect large expanses of areas at risk of active crown fire and improve habitat connectivity.
- Project design and treatment prescriptions should retain to the greatest extent possible:
    - Large, older trees. For ponderosa pine these trees are characterized as having yellow platy bark, relatively flat moderate to full crowns and large limbs (e.g. Dunning's tree class 5 and/or Keen's tree class 4 (A and B)).
    - Snags and trees with broken tops, wide lightning scars (>4" in wide) and large stick nests that are greater than 12 inches in diameter.
- In ponderosa pine and dry mixed conifer, groups of 3-5 reserve trees should be retained in management-created openings larger than 1 acre. In wet mixed conifer and spruce-fir, groups of 6 reserve trees should be retained within management-created openings greater than 0.5 acre. Reserve trees should generally be selected from older dominant or co-dominant crown classes.
- Post-settlement trees should not be retained in former openings.
- Vegetation treatments should favor the development of native understory species in areas where they have the potential to establish and grow.

- On suitable timberlands, projects should retain somewhat higher frequencies of trees across broad diameter classes to allow for future tree harvest.

- Montane meadows should not be used as staging areas for logging operations or heavy equipment.

This alternative includes wildland fire objectives in ponderosa pine and mixed conifer vegetation communities. In ponderosa pine, an average of 13,000 to 50,000 acres per year would be treated with wildland fire, whether from prescribed burns or wildfires exhibiting beneficial fire effects. In mixed conifer, an average of 1,000 – 13,000 acres would be treated. The Kanab Creek Wilderness represents the only guideline directing suppression action on wildfires to protect fire sensitive heritage resources, and limit further noxious weed invasion, particularly cheatgrass (*Bromus tectorum*). Wildfires could be allowed to function in their natural role in all other areas as a disturbance process when weather and fuel conditions are deemed appropriate, and current and expected fire behavior and effects are desirable.

Under Alternative B, approximately 9,223 acres of invaded grasslands currently deemed suitable for timber production under Alternative A would become unsuitable. These areas could have trees removed during timber sales to facilitate grassland restoration. These areas would subsequently be maintained with less than ten percent tree cover using other means – primarily fire. There are an additional 8,174 acres of isolated stands of ponderosa pine, and 1,204 acres of potential wilderness area that would be removed from the Suitable Timber Base.

Alternative C – North Kaibab Wildlife Habitat Complex:

This alternative is similar to the proposed action except it contains an additional Land Management Area (LMA) called the "North Kaibab Wildlife Habitat Complex." This LMA would be approximately 304,400 acres in size, and share the same boundary as the National Natural Landmark for the Kaibab squirrel. This alternative would contain a descriptive guideline for large tree retention. This guideline that retains all trees with yellow bark would effectively impose a diameter cap over time in the remaining suitable area.

In this LMA, mechanical treatments, including timber harvesting could be conducted once in order to initially restore stand structure to a point where natural disturbance processes could be used without uncharacteristic results (i.e., State N), and within the limitations of the large tree retention guidelines; thereafter, mechanically treated acres would be removed from the Suitable Timber Base, and be maintained solely with natural disturbances, and prescribed fire. Such treatments are not likely to fully restore the ecological integrity of the LMA . Where natural disturbances do not occur, fuel loading would recur through natural forest ingrowth and tree encroachment into openings followed by forest decadence caused by intraspecific and interspecific competition. Additionally, ingrowth of understories creates ‘ladder fuels’ which allow ground fires to ascend and spread quickly as crown fires.

Mechanical thinning objectives would be similar to Alternative B (i.e., to mechanically thin 11,000 to 19,000 acres in ponderosa pine annually, and 30,000 to 60,000 acres in frequent fire mixed conifer acres over the plan period). The number of acres treated per year would decrease over time, as treated acres are removed from the Suitable Timber Base in the LMA

Wildland fire objectives of 14,000 to 63,000 acres of wildland fire disturbance with desirable fire effects would be the same as in Alternative B.

Alternative D- Kaibab Habitat Complex:

This alternative is the same as Alternative C except that all lands would be removed from the Suitable Timber Base once vegetative structure is treated to the point where natural processes could be used without uncharacteristic results (State N).

Mechanical thinning objectives would be similar to Alternatives B and C, with the objective to mechanically thin approximately 11,000 to 19,000 acres in ponderosa pine annually, and 30,000 to 60,000 acres in frequent fire mixed conifer acres over the plan period. The number of acres treated per year would decrease to zero over time, as they are removed from the Suitable Timber Base.

Wildland fire objectives would be beneficial treatment of 14,000 to 63,000 acres as in Alternative B and C.

Description of Affected Environment (Existing Condition)

Soil Condition

Soils constitute a chemical, physical, and biological component of the environment made up of mineral particles (e.g., sand, silt, and clay), air, water, and organic matter. Soils store water, supply nutrients for plants, recycle animal wastes and other detritus, provide a medium for plant growth, and provide habitat for a diverse number of below-ground organisms. Due to their slow rate of formation, soils are essentially a non-renewable resource.

Soils within the KNF include a wide variety of taxonomic classifications, reflecting the influences of several separate, but interacting soil forming factors including parent material, climate, topography, and organisms over time. As a result, soil characteristics range from shallow, weakly developed, rocky soils on plateaus, mesas, cliffs, escarpments, and ridges to deeper, more productive soils on alluvial fans, plains, and in valley bottoms. In general, soils on the KNF are fine textured and contain a wide range of rock fragment sizes within soil profiles and at the surface. The dominant parent materials that occur on the KNF consist of sedimentary rocks, including sandstone, carbonates (primarily limestone and dolomite), mudstone, shale, and gypsum and igneous rocks, including granite, basalt, and basalt cinders.

Soil condition is primarily determined by evaluating surface soil properties. This is the critical area where plant and animal organic matter accumulate, begin to decompose and eventually become incorporated into soil. It is also the zone of maximum biological activity and nutrient release. The chemical, physical, and biological condition of this zone plays a significant role in soil stability, nutrient cycling, water infiltration and energy flows.

Soil condition is an evaluation of soil quality based on an interpretation of factors which affect three primary soil functions: soil hydrology, soil stability and nutrient cycling. It is important to understand that these functions are interrelated. On the KNF, there has been no forest-wide survey of soil condition, however, there have been project-specific studies completed for grazing and vegetation management projects that can be used to infer general conditions and trends. These studies indicate that areas having the majority of unsatisfactory soil conditions include pinyon-juniper woodlands, ponderosa pine forests, semi-desert grasslands, and desert vegetation communities, especially areas with excessive canopy cover (i.e., generally with canopy cover greater than 40 percent), due to poor distribution or lack of adequate vegetative ground cover (plant basal area and litter), and reduced soil productivity. Table 1 below displays soil condition (based on soil loss by PNVT), associated acreage, relative extent and percent contributions throughout each PNVT on the KNF.

Soil condition is categorized by three primary classes: satisfactory, unsatisfactory and unsuitable. The following definitions describe each class (R-3 FSM2509.18):

- Satisfactory: Indicators signify that soil function is being sustained and soil is functioning properly and normally. The ability of the soil to maintain resource values and sustain outputs is high.
- Unsatisfactory: Indicators signify that a loss of soil function has occurred. Degradation of vital soil functions result in the inability of the soil to maintain resource values, sustain outputs or recover from impacts. Unsatisfactory soils are candidates for improved management practices or restoration designed to recover soil functions.
- Unsuitable[4]: These soils have natural erosion rates exceeding tolerable limits. Based on the Universal Soil Loss Equation[5] (USLE) these soils are eroding faster than they are renewing themselves but are functioning properly and normally.

A review of Table 1 reveals that approximately 1,244,000 acres or 79% of the KNF has soils in satisfactory condition. About 234,000 acres or 15% of the KNF has soils in unsatisfactory condition and approximately 102,000 acres or 6% of the KNF has soils that are unsuited for most uses. The greatest areas of satisfactory soil condition are found in the Ponderosa Pine forest PNVT. More than 84% of the Ponderosa Pine Forest, Mixed Conifer, Spruce-Fire, Sagebrush Shrubland, Great Basin Grassland and Steppe, Wetland/Cienega, and Riparian Forest PNVTs are in satisfactory soil condition. This indicates that soil loss is within threshold limits and is not reducing the ability of the soil to maintain long-term soil productivity.

Conversely, the greatest areas of unsatisfactory soil conditions are found in the Pinyon-Juniper Woodland PNVT but only amount to about 21% of the KNF areal extent of this PNVT. All of the Desert Community PNVTs are in unsatisfactory soil conditions increasing the risk of loss of soil productivity and reducing the ability of these soils to contribute to ecosystem diversity and sustain those species that rely on these habitats for survival.

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[4] This class is not described within FSM2509.18. This is a category where long term soil productivity and management are not primary objectives, and management activities are avoided due to expected risk of irreprable loss of soil productivity.

[5] Universal Soil Loss Equation - an empirical mathematical model used to describe soil erosion processes. USLE has been modified from its original form to predict soil loss in forestlands and rangelands (RUSLE, 1997)

Table 1. Kaibab National Forest Soil Condition by Potential Natural Vegetation Type.

Potential Natural Vegetation Type	Soil Loss Soil Condition						Forest PNVT Total		PNVT Subsection Extent
	Satisfactory		Unsatisfactory		Unsuited				
	%	Acres	%	Acres	%	Acres	% in PNVT	Acres	% Contribution
Cottonwood Willow Riparian Forest	100.0	1,201					**0.1**	**1,201**	0.7
Desert Communities			100.0	13,747			**0.9**	**13,747**	0.1
Gambel Oak Shrubland	100.0	5,478					**0.3**	**5,478**	100
Great Basin/Colorado Plateau Grassland and Steppe	100.0	47,657					**3.0**	**47,657**	0.3
Mixed Conifer Forest	96.8	123,986	3.2	4,055			**8.1**	**128,040**	13.8
Montane / Subalpine Grassland	98.3	55,151	1.7	961			**3.6**	**56,112**	27.3
Pinyon Juniper Woodland	66.9	429,652	20.7	133,272	12.4	79,375	**40.6**	**642,299**	4.6
Ponderosa Pine Forest	84.8	464,992	13.2	72,323	2.0	10,722	**34.7**	**548,036**	9.5
Sagebrush Shrubland	85.4	68,767			14.6	11,734	**5.1**	**80,501**	3.7
Semi-Desert Grassland	60.3	15,190	39.7	9,994			**1.6**	**25,184**	0.8
Spruce Fir Forest	100.0	29,127					**1.8**	**29,127**	14.1
Water or Urban							**0.0**	**484**	0.1
Wetland / Cienega	100.0	2,738					**0.2**	**2,738**	16.2
Total		**1,243,939**		**234,351**		**101,836**	**100.0**	**1,580,610**	

Further analysis shows that much of the Semidesert Grasslands (about 40%) and a large portion of the Ponderosa Pine PNVT (72,000 acres or 13%) are in unsatisfactory soil condition. Soil erosion on some of these soils is above tolerance thresholds and these soils are at risk of losing long-term soil productivity.

Substantial portions of the Pinyon-Juniper and Sagebrush Shrubland PNVTs are in unsuited condition due to inherently erodible soils. These soils often occur on steep terrain where slopes exceed 40 percent. Geologic or natural erosion are high on these soils which precludes most management activities.

Maintaining satisfactory soil condition (currently about 79% of Forest) is important in maintaining long-term soil productivity and ecological function which is critically important to sustaining ecosystem diversity. Unsatisfactory soil loss on the KNF has resulted in reduced ability of the soil to store water, supply nutrients for plants, recycle animal wastes and other detritus, serve as a medium for plant growth, and provide habitat for a diverse number of below-ground organisms.

Fortunately, KNF PNVTs that contribute most towards Subsection PNVT sustainability (Gambel Oak Shrubland, Montane/Subalpine Grasslands, Mixed Conifer, Pinyon-Juniper Woodlands, and Wetland/Cienega) are generally in satisfactory condition. The Ponderosa Pine PNVT also contributes considerable acres toward ecological sustainability and is generally in satisfactory soil loss condition. These PNVTs contribute significant acres towards ecological sustainability and should be managed to maintain satisfactory soil conditions. However, as mentioned above, there are numerous PNVTs within the Forest that have unsatisfactory soil conditions and risk a loss of ecosystem diversity if not improved.

Historically (pre-European settlement) and without anthropogenic (man-caused) disturbances, soil loss, soil compaction and nutrient cycling would likely have been within natural range of variability necessary to sustain soil function and maintain soil productivity for most soils that are not inherently unstable. The most notable exception to this would be relatively short term effects of high severity wildfire during times of drought. Since there were no political boundaries historically, soil condition would have been comparable on soils of with similar properties throughout the range of the PNVT both within and outside of the KNF.

Current soil condition to some extent is related to past management practices. Minimal range condition information is available before 1935 (USDA, 1991). However the GES indicates from 1902 – 1987 that as more livestock numbers and acres were grazed, range condition (and therefore soil condition) declined, and as fewer livestock and acres were grazed, range condition and trend improved. Domestic livestock grazing was not present historically (i.e. before European settlement) and therefore did contribute to rangeland and soils degradation. One report described that most of the forest lands in the arid regions had been heavily overgrazed when the National Forests were established (Box, 1977). According to Gori and Bates (2007) livestock and large wildlife grazing removes fine fuels needed to carry surface and mixed-severity fires that likely maintained the more open structure and composition of pinyon-juniper savannas and shrub woodlands historically. Fire history reconstructions collected at a limited number of sites (representing these piñon-juniper types) show the virtual elimination of surface and/or mixed severity fire as a disturbance agent after 1880 when livestock numbers increased over most of Arizona and New Mexico. Merriam elk did exist but are believed to occur in relatively low populations and therefore did not appreciably affect soil loss. North American bison and elk were known to graze and were reported to denude grass in some areas, however, grasslands in Arizona are not considered to have been developed with bison as a factor in maintenance of the grasslands (Truett, 1996).

An important component that affects soil condition is organic matter which contributes to soil productivity and stability. Humus is decomposed organic matter while forest litter, or duff, consists of relatively undecomposed or partially decomposed leaves, needles, twigs that are still recognizable on the surface of soils. Coarse woody debris consists of woody stems greater than 3 inches in diameter. Decomposing coarse woody debris can supply moisture to plants and animals after soil surfaces have dried. All organic matter provides water and nutrients for soil organisms and plants. Because CWD is an important component of a functioning ecosystem, a portion of this material must be maintained (Graham et al. 1994). However, excessive accumulations of woody debris can result in fires that are extremely hot, resulting in large losses of soil organic matter (Harvey 1994).

Currently, most soils within the KNF exhibit adequate and in many cases excessive amounts of organic matter in a variety of size classes. Map units that are currently rated unsatisfactory generally exhibit less organic matter than satisfactory map units. These map units generally have steeper slopes, more rock, cobble and gravel and higher percentages of rock outcrops which limit vegetative ground cover in many areas. Additionally, dense pinyon-juniper stands and closed canopy Ponderosa pine forests prevent understory growth resulting in considerably less vegetative ground cover. In the case of dense, closed canopy Ponderosa pine stands, these conditions contribute to a build up of forest floor litter which protects soil surfaces from erosion, but contributes to increased fire hazard. Due to drier conditions in pinyon-juniper stands, dense, closed canopy structures in these woodlands results in loss of soil surface organic matter and increased erosion hazard.

Knowledge of specific fungal, bacterial, and arthropod populations is not available at sufficient scale to support this analysis. However, biological soil crusts, commonly found in arid or semi-arid environments (Johnston 1997) are known to exist on the KNF. Microbiotic crusts are the community of organisms living on soil surfaces. Major component are cyanobacteria, green algae, microfungi, mosses, liverworts and lichens (www.soilcrust.org). Biological soil crusts are commonly found in semiarid and arid environments and have been observed in coarse textured soils predominantly in Pinyon-Juniper Woodlands, Semidesert Grasslands and Desert Communities on the KNF and to a limited extent in other PNVTs dryer than Pinyon-Juniper Woodlands. Additionally, cryptogamic crusts have been identified in virtually every ecosystem in Grand Canyon National Park, from the mixed conifer forests and pinyon-juniper woodlands to the shrub deserts (Beymer and Klopatek 1992). During their study, Beymer and Klopatek also observed cryptogamic crusts at two locations in the Tusayan Ranger District near the National Park boundary.

In arid and semi-arid native communities, plants often exhibit patchy distributions that result in discontinuous fuel conditions and mosaics of fire intensities (Whisenant 1990). Biological soil crusts do not provide adequate fuel to carry a fire through interspaces, thereby serving as "refugia" to decrease the spread of fire and its intensity (Rosentreter 1986). The remaining unburned islands of vascular vegetation and biological soil crust provide propagules for reestablishment in burned areas. Johansen et al. (1993) observed that the structural matrix of soil biological crusts remained intact following low-intensity fire, indicating that lightly burned crusts still function to provide soil aggregate stability against erosive forces.

Populations of other soil organisms common throughout the KNF include mycorrhizal fungi, soil-dwelling arthropods, nematodes and bacteria. Some loss of soil organisms would likely occur in the short-term through direct destruction of habitats or substrates during tree felling, broadcast prescribed burning, pile burning, and fuelwood gathering. It is expected that areas where such losses occur would re-populate and soil chemical, physical and biological conditions would improve over time.

Soils Survey Interpretations

Soil survey interpretations predict soil behavior for specified soil uses and under specified soil management practices identified as important, or potentially important to users of the soil survey information. Limitation ratings identify the degree of limitation that restricts the use of a soil for a specific purpose while suitability ratings identify the degree that a soil is favorable for a given use. Projects and activities undertaken on the KNF should include reviews of applicable soil survey interpretations and development of appropriate Best Management Practices and other soils and watershed conservation measures during the planning process to minimize or mitigate adverse impacts to soils and watershed resources. Soil survey interpretations (i.e., suitabilities, limitations, and potentials) for common management practices and soils uses for each TES mapping unit are discussed in detail below.

Erosion hazard, as defined in the TES is based on bare ground (complete removal of vegetation and litter). A slight rating indicates that all vegetative ground cover could be removed from the site and the resulting soil loss will not exceed "tolerance" soil loss rates. A moderate rate indicates that predicted rates of soil loss will result in a reduction of site productivity if left unchecked. Conditions in moderate erosion hazard sites are such that reasonable and economically feasible mitigation measures can be applied to reduce or eliminate soil loss. A severe rating indicates that predicted rates of soil loss have a high probability of reducing site productivity before mitigation measures can be applied. The KNF has 739,663 acres of soils with slight erosion hazard, 485,154 acres of soils with moderate erosion hazard, and 335,385 acres of soils with severe erosion hazard.

Revegetation potential refers to the probable success and ease in the establishment of native grasses. This potential rating is influenced by climate, soil characteristics, and slope. The rating system is based on use of a rangeland drill, broadcast seeder (hand held), and aerial seeding with no consideration for site preparation (removal of trees, etc.). A low or moderate rating alerts the land manager to potential limitations for successful revegetation of an area. Soils associated with a "high" rating offer the best opportunity for success. The udic/frigid combination offers the optimum soil climate for establishment of vegetation. Conversely, the aridic/thermic combination offers the most limiting soil climate for the establishment of vegetation. The KNF has 83,366 acres of soils high revegetation potential, 797,991 acres of soils with moderate revegetation potential, and 680,396 acres of soils with low revegetation potential.

Timber harvest limitations are limits to be considered when evaluating the impact of timber harvest with regard to maintenance of soil productivity. Limits relate to year round or seasonal concerns and use of heavy machinery, as they relate to climate, soils characteristics, and landforms. A moderate or severe rating directs the land manager to areas that require mitigation in order to avoid impairment of soil productivity. Logging systems can be employed that will adequately overcome many limitations. Seasons of logging can often be used to mitigate soil moisture and potential compaction problems. For example, timber harvest operations conducted under frozen ground conditions minimizes soil displacement, compaction, and rutting. There are 1,154 acres of soils with slight limitations for timber harvesting, 573,717 acres of soils with moderate limitations for timber harvesting, and 70,155 acres of soils with severe limitations for timber harvesting.

Roadfill suitability pertains to the use of soils in the construction of roadfill. Roadfill consists of soil material that is excavated from its original location and used in road embankments at other locations. Compaction characteristics, moisture content, shrink-swell potential, and density of in-place fill material are common criteria used to assess roadfill suitability. There are 79,613 acres of soils with a roadfill suitability rating of “good”, 179,151 acres of soils with a rating of “fair”, 23,925 acres of soils with a rating of “moderate”, 6,066 acres of soils with a rating of low, and 1,271,447 acres with a rating of poor.

Cutbank Stability refers to the expected stability of vertical cuts. This rating assists land managers with information useful in the selection of road locations and subsequent use. An important consideration is that this rating is associated with the most limiting soil characteristic or condition. There are 331,759 acres of soils with slight limitations for cutbank stability, 601,640 acres of soils with moderate limitations for cutbank stability, and 615,670 acres of soils with severe limitations for cutbank stability.

Unsurfaced Road Limitations pertains to the use of soils in place for roads. These types of roads would be of low design standard and minimum construction cost. A moderate or severe rating alerts the land manager to problems in construction and maintenance of this type of road. These roads are usually temporary, and therefore receive minimal maintenance. This interpretive element provides resource managers the opportunity to consider alternate routes, thus avoiding potential problems or damage to the soils resource. The KNF has 40,189 acres of soils with slight limitations for unsurfaced roads, 211,342 acres of soils with moderate limitations, and 1,308,672 acres of soils with severe limitations for use as unsurfaced roads.

Trail limitations are similar to those of unsurfaced roads in that they pertain to the use of soils in place for construction of trails. Again, this category provides resource managers the opportunity to consider alternate routes, thus avoiding potential problems or damage to the soils resource. The KNF has 382,073 acres of soils with slight limitations for use as trails, 653,155 acres of soils with moderate limitations for use as trails, and 524,975 acres with severe limitations for use as trails.

Campground Limitations pertains to the use of soils in the construction and maintenance of developed campgrounds. Localized impacts to soils are usually considerable during and after construction of campgrounds until sites have stabilized. There are 43,883 acres of soils with slight limitations for campground development, 436,108 acres of soils with moderate limitations for campground development, and 1,080,211 acres of soils with severe limitations for campground development.

Wheeled Off-Road Vehicle (ORV) Limitations describe limits to this type of recreational activity on Forest soils. The KNF has 118,141 acres of soils with slight limitations for ORV use, 925,046 acres of soils with moderate ORV limitations, and 517,016 acres of soils with severe limitations for ORV use.

Natural Waters

Streams, groundwater, springs, and other natural waters are centers of high biological diversity in arid landscapes and the ecological health of those resources is important for forest ecosystem sustainability. Wildlife is more concentrated around open water sources than in the general landscape, and obligate aquatic and semi-aquatic species on the Forest are sometimes entirely dependent on these limited and dispersed water sources. Collectively these resources contribute to connectivity for wildlife across the landscape. Springs are highly productive habitats in otherwise low-productivity arid landscapes. Springs are frequently more stable ecologically than surrounding upland ecosystems in arid regions, and may offer biological refugia for some species, particularly narrowly endemic species.

Natural waters provide water and food resources that are especially vital to wildlife; particularly birds, bats and invertebrates. Seeps, springs and wetlands have profound traditional cultural significance to tribes. Contemporary uses include potable local and urban water supplies and agricultural uses such as livestock watering. These uses are vital to domestic and commercial interests in and around the Forest. In addition, springs provide cultural and recreational opportunities.

Perennial Streams

The only known historic perennial streams on the KNF are North Canyon Creek and Kanab Creek. The perennial reach of North Canyon Creek is located in the Upper North Canyon Wash subwatershed (HUC12) of the North Canyon Wash watershed (HUC10) of the Lower Colorado-Marble Canyon sub-basin (HUC8). The historic flow ranged from one to six miles, depending on precipitation, before becoming subsurface flow. Current riparian conditions are thought to be near historic conditions with a wide variety of riparian species present. However, the stream contributes only 2% of the perennial stream miles in this watershed while the Forest area makes up almost 25% of the watershed.

The Forest Service, in cooperation with the Arizona Game and Fish Department recently completed repair and replacement of log drop and other fish habitat structures in North Canyon Creek. This project has helped protect a genetically pure population of Apache trout (*Oncorhynchus apache*) by rehabilitating pools that provide winter habitat and refugia in times of stream dewatering from limited precipitation. The project was completed in the lower to mid portion of North Canyon Creek below North Canyon Spring in the Saddle Mountain Wilderness. This stream channel is currently classified in good condition and is not diverted

Kanab Creek flows through the Rock Canyon-Kanab Creek, Little Spring Canyon-Kanab Creek, and the Chamberlain Canyon-Kanab Creek subwatersheds (HUC12) of the Grama Canyon-Kanab Creek and Jumpup Canyon-Kanab Creek (HUC10) watersheds of the Kanab sub-basin (HUC8). Historically, Kanab Creek was a perennial stream within the Forest, but with current upstream water use and diversion this stream no longer exhibits perennial flow within the KNF boundaries. Flooding disturbance is therefore greatly reduced. Kanab Creek is now dominated by tamarisk (*Tamarix* sp.), which competes aggressively with the native willows and cottonwoods, often resulting in pure stands of tamarisk. Currently, much of Kanab Creek within the KNF and Grand

Canyon National Park is infested with tamarisk leaf beetles (*Diorhabda carinulata*), which effectively defoliate tamarisk, resulting in severe tamarisk mortality. Elimination of this aggressively competing non-native species provides opportunities for restoration of native vegetation in areas where hydrologic processes are conducive to such efforts. Historic livestock grazing has adversely impacted the Kanab Creek area, but livestock have been excluded from grazing since 1996. Occasional unauthorized use continues.

Seeps and Springs

Arizona has the 2nd highest density of known springs in the U.S. with the Mogollon Rim and the North Kaibab having among the highest densities of springs in Arizona (pers. comm. Larry Stevens). According to the NHD layer, there are 709 springs and seeps in all KNF connected HUC8 sub-basins. The Forest contains 167 known springs and seeps or about 23% of the total. Ninety-two of these springs occur on the North Kaibab Ranger District, 74 occur on the Williams Ranger District, and one has been identified on the Tusayan Ranger District (Appendix C, Table 1). The historic extent and flow of springs and seeps are generally unknown, but are presumed to be approximately equal to the current extent and flow. No springs exist on the Forest that flow more than 0.2 miles. Springs and seeps extent and flow have been observed to fluctuate largely as a factor of precipitation. Human impacts (i.e. livestock grazing, water diversions, and recreation) have adversely affected some springs on the KNF. Many of the springs on the KNF are known to be developed, which probably occurred after the Homestead Act of 1862. These developed springs remove water from the site and reduce riparian vegetation extent. Several springs have been observed and documented to be at risk or are nonfunctional riparian areas due to ungulate grazing, spring infrastructure maintenance, and recreational activity. Springs and seeps can exhibit reduced flows caused by transpirational effect of increasingly dense forest vegetation encroaching on these areas, but this has not been conclusively documented on the KNF. In addition, springs and seeps located adjacent to existing wells may exhibit reduced flows caused by groundwater pumping, or drawdown.

Springs ecosystems inventories and assessments are ongoing through the efforts of cooperators including the Museum of Northern Arizona, Spring Stewardship Institute, and Northern Arizona University. Data captured as a result of these inventories and asssessments will be used to guide future management of these rare ecosystems and facilitate restoration efforts.

Wetlands/Cienegas

The number and extent of historic wetlands on the KNF is largely unknown. The current number and extent of wetlands is estimated from information found in the U.S. Fish and Wildlife Service (USFWS), National Wetlands Inventory (NWI). The NWI data includes stock tanks as areas identified as wetlands. Generally, wetlands are areas where soil saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin 1979). For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Stock tanks on the KNF rarely impound water at a sufficient frequency or duration to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Stock tanks therefore rarely meet the criteria for classification as wetlands. There are approximately 457 acres of stock tanks on the KNF.

There are four primary wetland types that occur on the KNF as identified in the NWI. These include freshwater emergent wetlands, freshwater forested/shrub wetlands, riverine wetlands, and lakes. There are approximately 295 acres of freshwater emergent wetlands, 1 acre of freshwater forested/shrub wetlands, 5 acres of riverine wetlands, and 690 acres of lakes on the KNF.

Developed Waters

There are 26 waterbodies on the KNF that are identified as lakes. These lakes range in size from 145 acres to less than 6 acres. The majority of these lakes exhibit ephemeral characteristics. They do not hold water throughout most years. However, in many cases they do retain sufficient water into the growing season to function as lacustrine and palustrine wetlands. Lakes that exhibit perennial characteristics on the KNF include Cataract Lake (37.44 ac.), Coleman Lake (79.61 ac.), Kaibab Lake (70.57 ac.), Dogtown Reservoir (94.12 ac.), Steel Dam Reservoir (5.09 ac.), Stone Dam Reservoir (13.72 ac.), and White Horse Lake (42.26 ac.).

There are three large reservoirs (500 acre-feet or larger) that occur on the Williams Ranger District of the KNF. These include West Cataract Creek, Dogtown Reservoir, and Kaibab Lake. Dogtown Reservoir is the largest with a maximum water storage capacity of 1390 acre-feet. Kaibab Lake has a maximum water storage capacity of approximately 967 acre-feet, and West Cataract Creek has a water storage capacity of approximately 860 acre-feet. The most common uses of these reservoirs are public water supply for the City of Williams, recreation, and fire protection. Three other reservoirs that are not on the KNF, but that have watersheds originating on the KNF include City Reservoir, Gonzales Lake, and Santa Fe Reservoir.

Approximately 90 percent of the City of Williams surface water supply originates from Dogtown Reservoir and City Reservoir. From 2005 through 2010, an annual average of 198,184,868 gallons of water (101.36 acre-feet) were withdrawn from surface waters and wells for public use by the City of Williams. The majority of this public water originated from Dogtown Reservoir and water wells located near the Reservoir. The highest average monthly usage occurs from May through July, with average monthly usage for these three months totaling 21,212,271 gallons. There has been a slight increase in public water utilization reported by the City of Williams from 2005 through 2010. Average annual public water utilization was 191,745,081 gallons in 2005 and 216,090,312 gallons in 2010.

There are 492 reservoirs and stock tank claims within the 126 subwatersheds (HUC12) on the KNF, and 3,281 in the 4th code watersheds according to the Arizona Department of Water Resources. This represents 15% of the total number of structures in the analysis area sub-basins (HUC8). The KNF reservoirs and stock tanks were primarily built from the 1930-1980’s. These impoundments have reduced flow volume and duration of some ephemeral and intermittent stream channels on the KNF. However, a reduction in riparian vegetation has not been observed due to the historically short duration that water is present in these stream channels. The reservoirs and stock tanks on the KNF have increased perennial water on the Forest for domestic livestock and wildlife as well as increased riparian vegetation surrounding them.

Surface Water Quality

Improvements to the Nation's waters over the past three decades are largely due to the control of traditional point sources of water pollution. However, a large number of waterbodies remain impaired and the goal of eliminating pollutant discharge and attaining fishable and swimmable waters is still unrealized. Non-point sources of pollution such as agriculture, construction, forestry, and mining are responsible for much of the nation's remaining water quality impairment. The desired condition is that water quality meets or exceeds Arizona State standards[6] or Environmental Protection Agency water quality standards for designated uses, and water quality meets critical needs of aquatic species where they occur.

Currently on KNF land, the most important non-point source of pollution is from sediment generated from roads in close proximity to drainages, from residual effects of past, and in some cases, current livestock grazing and from short term impacts of ground disturbing activities such as timber harvest and high severity fire. Before widespread implementation of BMPs in the1980's, timber harvesting was widespread and was also a non-point source of pollution in the form of sediment delivery off-site and into adjacent stream courses. Currently the forests implement and monitor site-specific BMPs for all activities with the potential to pollute Arizona's waters.

Surface water quality has generally been satisfactory on the KNF except during drought conditions and extreme flood events or immediately following high-severity wildfires. There are currently no streams or water bodies on the KNF that are classified as not meeting EPA water quality standards for their designated uses.

The only lake or wetland on the Forest that has been classified as impaired (Category 5) for the designated uses under EPA water quality standards is Whitehorse Lake, a man-made impoundment. Sampling occurred in varying degrees from 1993 to 2006. In 1998, the Lake was placed on the EPA 303(d) list for exceeding the turbidly standard for Aquatic and Coldwater Fisheries designated use. From 1997-2000, the Lake exceeded standards for dissolved oxygen, pH, and turbidity. In 2002, the Lake exceeded the standard for dissolved oxygen. The Arizona Department of Environmental Quality (ADEQ) classified the Lake as Category 5 (for high pH, fish kills in 1994, ammonia and turbidity exceedances). In 2006, ADEQ placed Whitehorse Lake into an improved class, Category 2 "Attaining Some Uses" and the lake was delisted in 2008.

North Canyon Creek is the only remaining perennial stream reach on the KNF. It is approximately 1.5 miles in length. Therefore, no KNF streams are monitored by ADEQ or listed as Category 5 or "Impaired" on the 2007 EPA 303(d) list. The Forest does not contribute to any known adverse impacts to ADEQ monitored streams on or off the Forest.

Large fires, drought or extreme flood events continue to have an affect on water quality. Typically, these events only affect water quality for a short period of time (1 to 5 years) before natural stabilization and recovery occur.

[6] Arizona Administrative Code Title 18. Chapter 11 Arizona Water Quality Standards.

Water Yield and Water Rights

It is estimated that overall Forest water yield is static to slightly upward in non-forested areas to slightly downward in forested areas over the last 20 years due to analysis of streamflow water yield and the following three conditions:

- Streamflow is directly dependent on annual precipitation, including snowpack. Historically, periods of lower or higher annual precipitation has occurred, and will continue to occur. It is estimated that overall Forest water yield is static to slightly upward in non-forested areas to slightly downward in forested areas over the last 20 years due to the following three conditions:

- Greater tree and shrub basal area and canopy cover has been recorded over the last 20 years which probably results in increased evapotranspiration and decreased runoff and water yield.

- Drought conditions have prevailed in most years since about 1999 and have probably contributed to decreased precipitation and runoff and water yield. Climatic (drought) and vegetative conditions on the Lower Colorado River watersheds are similar to the Verde River watersheds and therefore, water yield trend is estimated to be similar (static to slightly downward).

- Non-forested areas have less vegetative ground cover than forested areas (pinyon-juniper and conifers) and in many areas have less vegetative ground cover than under the Potential Plant Community as identified in the Kaibab Terrestrial Ecosystem Survey. In addition, many of these areas have disturbance resulting in compacted soil surfaces. Decreased vegetative ground cover and compacted soils can result in water runoff rates and amounts more than would occur under conditions of the Potential Plant Community.

Past studies indicate vegetative treatments to increase water yield only result in short-term water yield increase (1-3 years). Today, treatments to increase water yield are not being considered on the Forest and therefore, a detailed analysis of water yield has not been done. However, it is estimated that Forest-wide, current water yield (supply) is similar to or slightly less than in the early 1980’s due to recent climatic drought conditions and greater evapotranspiration stemming from increased tree basal areas resulting in increased water consumption.

Periodic flooding is a natural disturbance that is necessary for maintenance of stream channels and many riparian plant species. Occasionally, high flows occur that cause damage to road infrastructure and other man made structures. Flooding is more common after large wildfires, where protective vegetative cover is removed and soil structure is altered. In severely burned watersheds, studies show peak flows (the highest flow rate measured after a storm event) can be slightly to thousands of times higher than the pre-fire flow rate (Neary et.al. 2005, Ffolliott and Neary 2003). Other damaging flow events have occurred during very high intensity summer rainstorms, or when a rainfall occurs over a melting snowpack.

The current trend of use of surface water by the KNF is static. The Forests’ consumptive use is expected to remain static into the future, as surface water in Arizona is considered to be fully appropriated. Water rights adjudications will dictate the amount and ownership of surface waters within the forests. According to ADWR Statement of Claim (SOC) Filings for water rights, there are 492 stocktank claims located on the Forest and there are 3,281 stocktank claims located in all affected 4th HUC watersheds. These claims include several watershed-level reserved water right claims allowing use of stockwater for fire fighting and road watering maintenance.

There are some private, duplicate stocktank claims filed on several tanks. The purpose of use, user and amount of water to be used will be determined during both Little Colorado River and Verde River adjudications.

The Forest actually has many more roadside stocktanks that are not filed for water rights as SOC's because they are not subject to appropriation. In a 1982 Letter to Forest Supervisors, and recent discussions, Forest Hydrologists summarized pertinent laws and concluded that roadside and tricktanks collect diffuse surface water that are waters that have not found their way into a natural watercourse, are not subject to appropriation in Arizona.

Groundwater

Water resources are obtained from surface water runoff, shallow perched water-bearing zones (which generally do not provide useful water source) and very deep regional aquifers. Although not well understood, groundwater is connected to surface water and where groundwater is pumped at a rate greater than recharge, connected surface water flow is reduced. Groundwater recharge occurs throughout all 4th and 5th level HUC watersheds but is greatest at higher elevations where precipitation is greater and in areas with heavily fractured rock units.

Groundwater pumping outside of designated Active Management Areas[7] is not limited by current Arizona groundwater codes. Projected growth will put higher demands on surface and groundwater resources, and therefore, more pressure to provide water could be placed on federal managers. Ground water on the KNF is primarily located within the regionally important Redwall-Muav (R-M) aquifer, which averages 1200 feet below the ground surface. The R-M aquifer is overlain by a thick sequence of lithified sedimentaries including sandstones, siltstones, shales, and limestones (Montgomery et al. 1988). Historically this aquifer was primarily charged with surface precipitation at the higher altitudes and in areas of heavily fractured rock. Shallow, perched aquifers in the water-bearing zones of volcanic rocks and the Kaibab Formation are also found within the KNF. These minor aquifers are commonly thin and discontinuous (Montgomery et al. 1988). Most wells drilled to these perched aquifers fail after a pumping period ranging from several days to several years and are then abandoned.

The ADEQ has independent statutory authority to develop and adopt Aquifer Water Quality Standards. Groundwater standards in Arizona are the Safe Drinking Water standards established for public water systems and surface water standards for the Domestic Water Source designated use. The ADEQ has established the Ambient Groundwater Monitoring Program which seeks to characterize groundwater quality in each of the 51 groundwater basins that have been designated in Arizona by state agencies (ADEQ 2010). ADEQ has completed studies and has reports

[7] The 1980 Arizona Groundwater Code recognized the need to aggressively manage the state's finite groundwater resources to support the growing economy. Areas with heavy reliance on mined groundwater were identified and designated as Active Management Areas (AMAs). There are five AMAs; Prescott, Phoenix, Pinal, Tucson, and Santa Cruz.

available covering 15 groundwater basins in Arizona, none of which occur on the KNF. Groundwater quality on the KNF is expected to be in satisfactory condition.

The Arizona Depart of Water Resources (ADWR) wells registry (Wells 55) indicates there are 257 well occurrences on the KNF. The majority of these well sites (172) are located on the Tusayan Ranger District and have been primarily for mineral exploration purposes. There are 78 registered wells on the Williams Ranger District. Many of these wells are associated with private parties and appear to be errors in the location information for private wells. Other wells have been installed for cathodic protection of pipelines that cross the District. There are six registered wells on the North Kaibab Ranger District (NKRD). One of these wells was for mineral exploration. The remaining wells on the NKRD are associated with private parties and are believed to be errors in location information.

City of Williams Municipal Watershed

The City of Williams Municipal Watershed is approximately 26,061 acres in size (Figure 8, Appendix A). Table 2 below lists the eight subwatershed (HUC12) and their associated acreages that occur within the Williams Municipal Watershed. Two of these HUC12 subwatersheds, Cataract Creek Headwaters and Dogtown Wash, encompass more than 96 percent of the total municipal watershed area.

Table 2. Subwatershed (HUC12) names, acreages, and associated percentages of each that comprise the City of Williams Municipal Watershed.

Subwatershed Name	HUC12 Number	Acres	Percent of Williams Municipal Watershed
Cataract Creek Headwaters	150100040502	14,616	56.1
Dogtown Wash	150100040501	10,627	40.8
Upper Red Lake Wash	150100040503	681	2.6
Johnson Creek	150602010302	70	<0.3
Upper Hell Canyon	150602020204	25	<0.3
Upper Cataract Creek	150100040504	23	<0.3
Big Spring Canyon	150602020307	9	<0.3
Pitman Valley-Scholz Lake	150602020305	3	<0.3

Citizens of Williams, Arizona depend on this watershed as a source of public drinking water and for other benefits that multiple use management of this watershed provide. The objective in managing the Williams Municipal Watershed is to recognize its water supply values and to provide management of its lands and resources to harmonize present and foreseeable resource uses with domestic water supply needs, protection of its water supply facilities and protection of the citizens of Williams from catastrophic floods (Elson 1972).

Runoff impounded in reservoirs serves as the primary water supply for the City of Williams. Seven primary reservoirs surrounding the City are the source of surface water for municipal uses. These reservoirs have a combined water storage capacity of 2,755 acre-feet (897 million gallons) of water. Approximately 2,026 acre-feet or 73.6 percent of the available water storage occurs in the two largest impoundments, Dogtown Reservoir and Kaibab Lake. However, the majority of the City's water supply (i.e., approximately 90 percent) originates from Dogtown Reservoir and City Dam. Groundwater from wells located near Dogtown Reservoir supplements surface water in the City municipal water supply. Table 3 below provides a list of reservoirs in the Williams Municipal Watershed and their approximate water storage capacities and percentages of total available surface water supply. Water from these reservoirs originates from snow melt and summer precipitation.

The annual water demand of the City of Williams is approximately 198,184,868 gallons or 101.37 acre-feet which includes billed water to customers, unmetered water used at city-owned facilities and landscapes, unaccounted-for water, process water used at the drinking water treatment plant, raw water used for golf course irrigation, and reclaimed water used for golf course irrigation. Process water used at the drinking water treatment plant is non-potable raw water used for filter backwash, sediment removal, and chemical feed, which amounts to approximately four percent additional water above total production (Pinkham and Davis 2002). Since the City of Williams does not recycle this water back into the water supply system, it is considered a water use. Monthly municipal water demand is highly variable. However, the months of highest water demand are typically June, July, and August of most years. Water demand is lowest during winter months and increases through spring, with highest usage occurring during summer. There has been an upward trend (11 percent) in water usage by the City of Williams between 2005 and 2010.

Table 3. Reservoirs, associated water storage capacities, and percentages of total municipal surface water in the City of Williams Municipal Watershed.

Reservoir Name	Water Storage Capacity (Million Gal.)	Water Storage Capacity (Acre-feet)	Percent of Total Water Storage Capacity
Dogtown	360	1,105	40.2
Kaibab Lake	300	921	33.4
Cataract	109	335	12.2
Santa Fe Reservoir	70	215	7.8
City Dam	36	111	4.0
Upper and Lower Saginaw	22	68	2.4

Water that enters reservoirs either remains in storage, is withdrawn for use, is lost through dam spillage, or is lost through evaporation and infiltration. Evaporation and infiltration from the reservoirs is substantial every year. These losses exceed the city's current annual water use (Pinkham and Davis 2002). When the reservoirs are full, they provide a 2.5 year water supply, given current average rates of water use. A two year drought results in significant stress on the City of Williams surface water supply. This occurred in 1996-1997, and again in 1999-2000. Most of the water lost as spillage from reservoirs is lost from the water supply system. Although Kaibab Lake is downstream from Dogtown Reservoir on the same drainage, or stream channel, it is usually filled by surface runoff at approximately the same rate as Dogtown Reservoir. Most of the water that spills from Dogtown Reservoir is therefore subsequently spilled from Kaibab Lake (Thomsen 1969).

Since the 1996-1997 drought, the City of Williams has agressively pursued development of reliable groundwater supplies. This program exemplifies the risks and costs of groundwater supply development in the region. The first well boring targeted a presumed perched aquifer at 500-600 feet deep west of the City. The well was dry. A second attempt, below the Santa Fe Dam, resulted in technical difficulties at approximately 2,000 feet of depth and was subsequently abandoned. A third attempt nearby struck water at 1,400 feet. This well is now producing at a peak flow of 110-120 gallons per minute (GPM), but only 20-25 GPM at maximum pumpage for more than 12 hours. A fourth boring on KNF Land in the vicinity of Dogtown Reservoir was also successful and now produces 220-240 GPM. The most recently developed well was drilled on the city's rodeo grounds. This well produces approximately 220-230 GPM. The Dogtown and rodeo grounds wells are over 3,000 feet deep. To date, Williams has spent roughly seven million dollars for three producing wells and three dry wells. The three successful wells produce a combined 500 GPM. Williams intends to continue well development in coming years, depending on the City's growth rate.

Some regional water stakeholders, including the Havasupai Tribe, have expressed concern regarding impacts of the City of Williams well development program on springs and seeps in the Grand Canyon area. The City of Williams and the Havasupai Tribe have entered into an agreement regarding regional ground water management and water conservation efforts by the City of Williams. The agreement includes discussions of tribal sovereignty, the significance of the Coconino Plateau to the tribe, the importance of water on the Coconino Plateau, the importance of water conservation, and the affect of drought on the water resources of the City of Williams. Specific agreement clauses address conditions under which the tribe would not contest or may contest well permits from the U.S. Forest Service and the city's right to respond to opposition, monitoring of well levels and production, restrictions on provision of water by the city to residents outside the city, city opposition to Coconino County allowing home development in areas without water supply, mutual support for development of other water supplies, mutual opposition to large-scale development proposals that rely on groundwater development, continuation of water conservation efforts by the City of Williams, and the City's support in principle for the tribe's position that any decrease to the natural flow of Havasu Creek cannot be tolerated (Pinkham and Davis 2002).

Description of Desired Future Conditions

Soil condition should be maintained or improved toward satisfactory condition. The vegetative ground cover should be adequate to protect against accelerated erosion, resulting in maintained or improved soil stability and productivity. Soil loss should be below tolerance levels with no visible signs of excessive erosion present.

- Soil hydrologic soil function is in satisfactory condition with well aggregated, granular surface soil structure and tubular pores with sufficient porosity to effectively infiltrate water.
- Soil nutrient cycling is in satisfactory condition. Vegetative ground cover, plant basal area, species composition, forage productivity and herbaceous understory approaches natural conditions in all vegetation types.

- Forests are restored or maintained at the landscape-scale in a manner that will provide for sustainable forest health, wildlife, and plant diversity while at the same time maintaining or improving long-term soil productivity.
- Water quality is maintained or improved (turbidity or suspended sediment parameter) and provides for those designated beneficial uses.
- At-risk and dysfunctional riparian areas, wetlands, and known springs conditions improve and trend towards proper functioning condition.
- Soils and water are free from pollution that derives from mining activities

Subwatersheds (HUC12) are functioning within their historic natural range of variability with regard to:

- Water quality condition,
- Water quantity (flow regime) condition,
- Stream and habitat condition,
- Aquatic biological condition,
- Riparian vegetation condition,
- Condition of roads,
- Soil condition,
- Fire effect and regime condition,
- Forest cover condition,
- Rangeland, grassland and open area condition,
- Terrestrial non-native invasive species condition, and
- Forest health condition (insects and diseases).

Environmental Consequences

The land management plan provides a programmatic framework that guides site-specific actions but does not authorize, fund, or carryout any project or activity. Because the land management plan does not authorize or mandate any site-specific projects or activities (including ground-disturbing actions) there can be no direct effects. However, there may be implications, or longer term environmental consequences, of managing the forests under this programmatic framework.

Soil Condition

In this analysis, the expected trends in soil condition are described for each alternative for comparison. The general effects to soil function of common management activities follow, such as: forest restoration activities (mechanical and burning treatments), roads, recreation, grazing, and special uses.

Table 3 summarizes the projected trends in soil condition based on estimates of vegetative ground cover, soil organic matter content and potential soil loss. Each PNVT was examined to determine whether soil conditions would generally trend towards, away or remain static with the implementation of the objectives of each alternative.

Table 3. Estimated trends in soil condition for each vegetation type by alternative.

Vegetation Type (PNVT)	Alternative A	Alternative B	Alternative C	Alternative D	Current Departure From DC*
Cottonwood / Willow Riparian	Away	Toward	Toward	Toward	None
Desert Communities	Away	Toward	Toward	Toward	High
Gamble Oak Shrublands	Static	Toward	Toward	Toward	None
Great Basin / Colorado Plateau Grassland and Steppe	Away	Towards	Towards	Towards	None
Mixed Conifer Forest	Static	Toward	Toward	Toward	Low
Montane / Subalpine Grassland	Away	Toward	Toward	Toward	Low
Pinyon Juniper Woodland	Away	Toward	Toward	Toward	High
Ponderosa Pine Forest	Static	Toward	Toward	Toward	Moderate
Sagebrush Shrubland	Static	Static	Static	Static	Low
Semi-Desert Grassland	Away	Toward	Toward	Toward	High
Spruce Fir Forest	Away	Static	Static	Static	Low
Water or Urban	Static	Static	Static	Static	-
Wetland / Cienega	Away	Toward	Toward	Toward	Low
Alternative A is based on the past 25-year average of vegetation treatments. Alternative B, C, and D are based on midpoint of the objective level of treatments. *Current departure estimates (Forest Service 2008)					

Under the action alternatives, there is more explicit plan direction to address the bison herd on the North Kaibab Ranger District. Guidelines specify that the bison herd should be managed so it is concentrated within the Buffalo Ranch Management Area, and that active management should be used to minimize impacts from bison to sensitive resources, particularly outside the Buffalo Ranch MA. Management of the bison herd under these guidelines will reduce potential damage to sensitive soil and water resources caused by the bison, and decrease the spread of non-native invasive species.

Forest Restoration Activities

Mechanical Treatments

Mechanical harvest and restoration treatments may impact soil hydrologic function, soil stability, and nutrient cycling through soil compaction and removal of ground cover.

Soil compaction, which decreases soil water infiltration and therefore nutrient inflows, can result from timber harvesting operations. Thinning operations are usually less likely to cause significant compaction than stand-removal (i.e. clearcut) harvest. The amount of soil compaction is dependent on harvest methods, amount of slash on site, operator technique, and soil conditions and properties (Page-Dumroese et al. 2010).

Project-level activities would include implementation of Best Management Practices for forestry operations (BMPs) and development of other mitigation measures that would result in minimal soil compaction. The following are examples of mitigations that reduce the effects of mechanical treatments:

- Timing activities in the early summer and late fall when soil conditions are driest and winter when soils are frozen to reduce soil compaction and surface rutting.
- Concentrating thinning operations on harvest traffic lanes to reduce the areal extent of soil compaction and other changes in soil physical properties throughout the stand (Curran et al. 2005, Moghaddas and Stephens 2008).
- Retention of thinning and harvest residues (i.e. slash) in place to minimize detrimental soil compaction and facilitate nutrient cycling. Coarse woody debris that supports macro- and micro- fauna would be available and balanced with the need to remove fuels to reduce the risk of high intensity fire. The potential effects of whole tree removal on soil fertility would be balanced with leaving needles, twigs, cones, and branches on thin, coarse-textured soils.

Ground cover is usually disturbed during mechanical treatments (including the removal of vegetation), and may, therefore, result in some exposure of mineral soil. Although direct timber harvesting operations may result in some local soil movement, soil displacement and soil erosion are expected to be minor because most harvest units are designed to have slopes that are not steep (i.e., less than 35 percent), with short slope lengths, and adequate ground cover and topsoil that would remain intact. BMPs and Soil and Water Conservation Practices (SWCP) (FSH 2509.22 R3) have been proven effective in mitigating ground disturbance and well as intercepting sediment in runoff (Fleishman and Jagow 1996, Fleishman 2005). Slash distribution in harvest units following timber harvesting helps protect exposed mineral soils from raindrop impacts and erosion.

Alternative Comparison

Alternative B proposes the most mechanical harvest treatments and thus the most risk from soil compaction and ground cover removal, followed by B and D. Table 4 describes treatment objective levels (acres) of mechanical harvest treatments in ponderosa pine while Table 5 describes treatment objective levels for frequent fire mixed conifer .

Table 4. Projected annual mechanical treatments in ponderosa pine PNVT by low and high

objective levels for each alternative.

	Alternative A	Alternative B	Alternative C	Alternative D
Low Treatment Objective Acres	2,100*	11,000	11,000	11,000
High Treatment Objective Acres		19,000	19,000	19,000
* Based on the past 25-year average of vegetation treatments.				

Table 5. Projected annual mechanical treatments in frequent fire mixed conifer PNVT by low and high objective levels for each alternative.

	Alternative A	Alternative B	Alternative C	Alternative D
Low Treatment Objective Acres	200*	2,000	2,000	2,000
High Treatment Objective Acres		4,000	4,000	4,000
* Based on the past 25-year average of vegetation treatments.				

The majority of treatments in both ponderosa pine and frequent fire mixed conifer under Alternatives B, C, and D would occur on level to moderately steep landscapes. Site specific BMPs and SWCPs would be prescribed to reduce impacts of mechanized equipment in all treatment areas. Soil disturbance monitoring (Page-Dumroese et al. 2009a and 2009b) would provide the necessary feedback for adaptive management to protect soil productivity.

Burning Treatments

Prescribed fires and wildfires used for resource benefit may also have negative effects on soil physical, chemical, and biological properties. Soil structure is the most important soil physical characteristic that affects soil hydrologic function and soil stability since the organic matter component, which improves aggregate stability, porosity, and water infiltration rates, can be lost at relatively low temperatures. The loss of soil structure increases the bulk density of the soil and reduces its porosity, thereby reducing soil productivity and making the soil more vulnerable to post-fire runoff and erosion.

The most basic soil chemical properties affected by soil heating during fires are also due to loss of organic matter (Neary et.al, 2005). Soil organic matter plays an important role in nutrient cycling and exchange, and water retention in soils. When organic matter is combusted, the stored nutrients are either lost to the atmosphere or are changed into highly available forms that can be taken up readily by microbial organisms and vegetation. Those available nutrients not immobilized are easily lost by leaching or surface runoff and erosion. Nitrogen is the most important nutrient affected by fire, and it is easily lost from the site at relatively low temperatures. The amount of change in organic matter and nitrogen is directly related to the magnitude of soil heating and the severity of the fire. High- and moderate- severity fires cause the greatest losses in soil organic matter and nitrogen. Nitrogen loss by volatilization during fires is of particular concern on low-fertility sites because nitrogen can only be replaced by nitrogen-fixing organisms.

Cations[8] are not easily volatilized and usually remain on the site in a highly available mineral form. An abundance of cations can be found in the thick ash layers (or ash-bed) remaining on the soil surface following high-severity fires. Soils that are inherently low in nutrients, and thin soils, are most impacted by high-severity fires as nutrients are lost. These fragile soils would be identified at the project level and protection measures would be prescribed.

Soil biological processes are also affected by fire. Soil microorganisms response to fire would depend on numerous factors, including fire severity, site characteristics, and pre-burn vegetation community composition. However, some generalizations can be made. First, most studies have shown strong resilience of microbial communities to fire. Re-colonization to pre-burn levels is common, with the amount of time required for recovery generally varying in proportion to fire severity. Second, the effect of fire is greatest at the forest floor (litter and duff). Fires that do not entirely consume the forest floor and soil humus are recommended. (Neary, et.al. 2005)

Alternative Comparison

Use of prescribed fire allows the manager the opportunity to control the severity of the fire and to avoid creating large areas that burn at high severity. Each alternative proposes the use of prescribed fire for fuel reduction and ecosystem restoration on the same acreage. However, Alternative D prescribes the most fire for ecosystem restoration, followed by B, C, and then A. See table 4 to compare objective treatment levels (acres) of burning for each alternative. Fire treatments range from low severity broadcast burning for ground fuel reduction, to mixed or high severity burns (in patches) that are designed to kill overstory vegetation to reduce the amount of canopy cover to a desired level. Alternative B and D propose the most acres of mixed severity and high severity burns. These generally may occur in focus watersheds that are away from urban interface areas. Alternative C and A have the fewest acres of mixed and high severity burns in forest types, however, mixed and high severity fires in woodland and grassland vegetation types are prescribed.

Table 1. Fire Severity Description and Projected Burning Treatment Acres by Fire Severity.

Burn Treatment	Low Severity Broadcast Burn	Mixed Severity	High Severity Stand Replacement
Burn Characteristics	Reduces fuel loading either for pre- or post-restoration treatment. Removes some ladder fuels Reduces risk of crown fire.	Some moderate and high severity in patches to improve structural diversity, and open canopy. Allows for regeneration of shade-intolerant species and restores ecologic condition in most vegetation types.	Some high severity in small stands to improve structural diversity and open canopy. Allows for regeneration of shade-intolerant species and restores ecologic condition in selected vegetation types.

[8] Soil cations are ions with fewer electrons than protons, giving them a positive charge. These constitute some of the most important soil nutrients. The amount of cations available for exchange between the soil and the soil solution available to plants is a measure of soil fertility. Examples of cations are ions of calcium, magnesium, phosphorous, potassium, copper, zinc and other elements.

Affect to Soil Function	Little to no effect to soil functioning condition at all scales.	Soil chemical, physical and biological function retained in greater than 85 percent of treated areas at fine and mid-scale.	Soil chemical, physical and biological functions may be adversely affected and require rehabilitation treatments. Size of treatment to remain at or below 15 percent of an area at the fine scale.

	Projected Annual Burning Treatment Acres by Fire Severity			
	Ponderosa Pine		Frequent Fire Mixed Conifer	
	Low	High	Low	High
Alternative A*	8,500	11,700	-	-
Alternative B	13,000	50,000	1,000	13,000
Alternative C	13,000	50,000	1,000	13,000
Alternative D	13,000	50,000	1,000	13,000
* Based on the past 25-year average of burning treatments. No breakdown of burn type available, however, the vast majority is estimated to be at the broadcast burn level (Fuels Specialist's Report)				

Under all alternatives, prescribed fire is allowed to burn under strict conditions and prescriptions that should not result in large areas of high burn severity that would be detrimental to soil physical, chemical, or biological properties resulting in loss of soil productivity.

Roads

The road system that is analyzed is the same for all alternatives. The road system results in a net loss of soil productivity within the road corridor, including cut and fill slopes. Roads are the dominant source of erosion and sediment in forests (Swank and Crossley 1988; MacDonald and Coe 2008). Some road locations are in areas that are more sensitive than others, such as along riparian areas, or in areas of inherently unstable soils. There is a large number of non-system roads (estimated to be hundreds of miles, Travel Management Rule Specialist's Reports) that are contributing to loss of soil productivity as well.

New road construction is generally not required for timber harvesting within planning areas, however, the re-opening of maintenance level 1 roads (i.e., those roads placed in storage, or closed between intermittent uses) dramatically increases the amount of open roads and, potentially, the amount of soil erosion that occurs during the life of a project. Temporary road use results in removal of vegetation along the road corridor, exposes mineral soil, and results in soil compaction within the travelway. Typically, there is increased erosion from roads during the first 2 years following road construction or reopening (MacDonald and Coe 2008; Megahan 1974). Slope failures and mass movement of soils may occur as a result of road construction. New roads or re-opening closed roads may also provide an environment conducive to the invasion and establishment of invasive plant species. New temporary roads would be closed, obliterated, and revegetated following use. Road design, avoidance of problem soils, appropriate design criteria, implementation of Best Management Practices for road construction and maintenance ,and road closures would be implemented in order to minimize adverse impacts to soils.

Alternative Comparison

The road system (miles, management level, and location) is the same for all alternatives, however, use of roads and the additional amount of level 1 roads are estimated to be higher under Alternative B followed by C, and D since Alternative B has the greatest percentage of timber harvest/mechanical restoration treatments and Suitable Timber Base of all alternatives. Since Alternativs C and D would include removal

Recreation Activities

Recreational uses shown to impact soils include off-road motor vehicle use, camping, hiking, mountain biking, and horseback riding. All of these activities may result in erosion and compaction. These impacts tend to be minor, and may occur on only a small percentage of the planning area. Implementing site specific BMPs and SWCPs for recreation projects would minimize adverse impacts to soils. The impacts from recreation could occur under all of the alternatives. No recreation development is specifically outlined in any alternatives. Recreation use and demand is estimated to increase proportionately for all alternatives with the increase in population growth.

Grazing Activities

Improper grazing management has the potential to reduce soil condition directly through hoof compaction, and indirectly from the removal of protective vegetative cover and subsequently, effective ground cover. The effects to soil condition include reduced soil hydrologic function in highly compacted areas where cattle congregate and trail, and reduce soil stability from loss of ground cover wherever over utilization of available forage occurs. Grazing is not considered detrimental where sufficient herbaceous material remains to protect the soils during periods of intense summer rainfall, or during spring snowmelt. Site specific BMPs and SWCPs provide protection from the effects of grazing and are prescribed in project level analysis.

Differences in soil condition as related to grazing impacts between alternatives are indirectly tied to the level of restoration treatments provided under each alternative. As noted in the Vegetation Specialist Report, the overstory canopy cover prescribed in the desired conditions provides the potential for an increase in understory vegetation as treatments are implemented and maintained. The relationship between overstory cover and herbaceous production has been validated in Arizona forests (Cooper 1960, Jameson, et.al. 1967). This increase would indirectly reduce grazing pressure as treatments progress across the forest. Increases in available forage would allow range managers flexibility in management to favor rehabilitation or rest in areas that are currently not in satisfactory soil condition, such as found in riparian, grassland and woodland vegetation types.

Since current composition and density of biological soil crusts have not be inventoried, we can only infer trends based on current and projected management impacts that have been shown in research to alter populations of biological crusts. Of most importance is the role crusts play in maintaining productivity of the semi-desert and great basin grasslands and woodland ecosystems. Some mosses and other crust forming organisms are found in wetter environments, but are less important to overall soil productivity. It is estimated that improved cattle management on the forest that is currently being implemented will benefit biological crusts. Reduction in grazing pressure due to estimated increases in forage production would benefit soil biological crusts as well.

Special Uses

Terms and conditions of special use permits would require site specific BMPs to provide for maintenance of soil productivity under all alternatives. Therefore, there are no anticipated effects to soil condition from permitted special use activities.

Climate Change

Based on current climate models, some of the climate change factors that may influence soil condition are:

- More extreme natural ecological process events, including wildfires, intense rain, flash foods, and wind events (Swetnam et al. 1997)
- Greater vulnerability to invasive species, including insects, plants, fungi, and vertebrates (Joyce et al. 2001)
- Long-term shifts in vegetation patterns (Westerling et al. 2006; Millar et al. 2007)
- Cold-tolerant vegetation moving upslope, or disappearing in some areas; migration of some plant species to the more northern portions of their existing range (Clark 1998)
- Potential decreases in overall forest productivity due to reduced precipitation (USDA Forest Service 2008)
- Lands grazed on the KNF are not irrigated and any variability in precipitation and temperature directly affects forage plant production and wildlife habitat. Changes in climate may affect the vigor and productivity of forage plants, and thus overall soil conditions. It is possible that higher temperatures and decreased precipitation described for the next century would decrease forage production and shorten the growing and grazing season, while flashfloods and increased risk of animal disease can adversely affect the livestock industry (Joyce et al. 2001) dependent upon the forage resources available on the KNF. Soil conditions may decline if adjustments to livestock numbers are not made based on allowable forage as productivity decreases due to climate change.

In light of the changes indicated above, there is a need to reduce vulnerability by maintaining and restoring resilient native ecosystems. Restoring and maintaining resilience in forest, woodland, chaparral, grassland, chaparral and riparian ecosystems are part of the basic elements of forest wide desired conditions, objectives and management approaches provided for in Alternatives B, C and D. Restoring and maintaining resilience would likely improve the potential for ecosystems to retain or return to desired conditions after being influenced by climate change related impacts and variability. Management practices (e.g. thinning for age class diversity and structure, and reclaiming and restoring native grasslands) that sustain healthy plant and animal communities, and provide adequate nutrients, soil productivity, and hydrologic function promote resilience and reduce opportunities for disturbance and damage. See Vegetation Specialist’s Report for further discussion of ecological condition trends.

Water Quality

Water quality trend is estimated to be towards desired conditions. Water quality monitoring provided by ADEQ resulted in a reduction of category 5 (impaired) lakes without the need to implement Total Maximum Daily Load (TMDL) plans. Implementation of BMPs would reduce water quality impacts on all land disturbing projects.

Forest Restoration Activities

Mechanical Treatments

Timber harvest and restoration treatment activities have the potential to adversely affect soil, water resources, and aquatic habitats. Typical anthropogenic disturbances used in timber harvesting include roads, skid trails, log landings, and stream crossings (Litzchert and MacDonald 2009). In addition to erosion and sedimentation, impacts may include potential vegetation loss in riparian areas, effective extension of the channel network through roads and skid trails that intersect streams or connect them to upstream disturbances, and impacts to water quality.

Additional impacts from timber harvest and forest restoration operations and prescribed fire include the contamination of soils, surface water or wetlands from chemical substances such as gasoline, oil, or hydraulic fluid that is leaked from harvesting machinery. There are also potential effects from chemicals used for treatment of non-native invasive plants associated with mechanical timber harvest activities.

Erosion that results from timber harvest activities is usually temporary, and erosion rates typically return to pre-harvest levels within 2 years. Implementation and effectiveness monitoring and research have shown that proper implementation of Best Management Practices (BMPs) and Soil and Water Conservation Practices (FSH 2209.23) greatly reduce soil erosion, compaction, sedimentation and other water quality impacts (Fleishman and Jagow 1996, Fleishman 2005, US EPA 2005). In addition, streamside management zones or vegetative buffers/filter strips would be prescribed for all streams, thus minimizing impacts from ground disturbing activities. The width of these filter strips vary based on stream order, type, slope, and erosion hazard of adjacent uplands.

Alternative Comparison

Although much of the effects to water quality from mechanical treatments are mitigated through BMPs and SWCPs, there may be short term sediment pulses from activity roads, skid trails, and landings. Alternative B prescribes the most mechanical treatment acres and therefore the highest risk to water quality, followed by C then D since these alternatives would remove land from the Suitable Timber Base following mechanical treatments. At the project level, site specific mitigation would reduce impacts to water quality below significant levels under all alternatives.

Burning Treatments

The magnitude of the effects of fire on water quality is primarily dependent upon fire severity and area impacted by fire. Fire severity is a qualitative term describing the immediate effects of fire on vegetation, litter or soils. Moderate to high severity fires as opposed to low severity broadcast burns consume more fuel and release more nutrients resulting in conditions conducive to soil erosion and transport of nutrients into a stream where water quality degradation can occur (Neary, et.al. 2005). BMPs are prescribed for all fires, and have shown to be effective in reducing sediment transport to streams through the use of filter strips and implementation strategies. The effects of prescribed fire on water quality vary depending on fire severity, type and amount of vegetation burned, soil moisture, proximity to streams, weather conditions and burning techniques.

Research of watershed effects from prescribed burning implemented under managed or controlled conditions have negligible effect on the physical, chemical, and biological properties of soil and soil productivity (Neary et.al. 2005). In addition, there is little evidence that sedimentation or water yield increases significantly in streams as a result of forested lands burned according to a prescribed burning plan that is designed to meet resource objectives (e.g., wildlife, recreation, watershed, vegetation, and ecology). Understory burning would consume only a small portion of the duff layer and would expose very little mineral soil. Most of the organic layer and fine roots would remain in place following fire.

Higher severity burns can result in water quality degradation. Physical change of soil cover and structure would lead to additional runoff and soil loss. Decreases in the time of concentration of flood flows typically occur in watersheds with extensive high burn severity which can increase channel erosion (downcutting) and loss of floodplains (Neary et al. 2005). High severity burning in riparian areas can remove protective vegetation and large woody debris needed to retain vertical and horizontal stability.

Alternative Comparison

Although much of the effects to water quality from fire treatments would also be mitigated through BMPs and SWCPs, there may be short term delivery of sediment and ash to water courses from higher severity burn areas within prescribed fire perimeters. Alternatives B, C, and D prescribe the most burning treatment acres and therefore the greatest risk to water quality, followed by Alternative A. At the project level, site specific BMPS and mitigation measures would reduce impacts to water quality under all action alternatives.

Roads

Numerous studies have identified unpaved roads as a major source of sediment in forested watersheds (Elliott, 2001) (Burroughs and King 1989). Sediment is produced from roadbeds, cut slopes and fill slopes and areas where concentrated flows deposit onto forest lands and flow energy is higher than the resistive forces of ground cover causing rills and gullies (Elliott, 2001). Traffic and road maintenance activities increase erosion rates, however, these rates can decline with non-use or age (Megahan, 1974). Roads near streams have the greatest impact on water quality as there is less surface area to filter sediment suspended in runoff. Increased road density (miles/unit area) increases drainage density and also can increase the volume of peak flows as it reduces the time required for flows to concentrate. This increases the proportion of sediment delivered as water at higher flows has more energy to scour and carry sediment (Wemple et al. 2001, Troendle et.al 1994).

Road erosion can be reduced native surface roads by surfacing with gravel, lining inside ditches with gravel, revegetating cut and fill slopes and minimizing blading of road surfaces and ditches (Burroughs and King 1989). Newer road designs would include vegetative filter strips, more frequent drainage, outsloping of the road surface to disperse road runoff, and narrower road surfaces to reduce the size of the road travelway, cutslopes and fillslopes. Whenever possible, roads would be realigned to upslope or ridgetop positions rather than along drainages. New temporary roads would be closed, obliterated, and revegetated following use.

Alternative Comparison

New road construction is generally not required for timber harvesting within the planning area, however, the re-opening of level 1 (those roads placed in storage between intermittent uses) dramatically increases the amount of open roads and, potentially, the amount of soil erosion and sediment delivered to a stream that occurs during the life of a project. Typically, there is a high initial erosion rate from roads during the first 2 years following road construction or reopening (MacDonald and Coe 2008; Megahan 1974). Road density, traffic levels, and maintenance all affect the volume of sediment delivered to watercourses. Alternative B provides the greatest potential for increasing sediment from roads as it has a higher proportion of mechanical treatment/harvest. Less mechanized harvesting and restoration treatment acres are proposed under Alternative A. Alternatives C and D propose the same initial acreage for timber harvesting as Alternative B. However, since both of these Alternatives proposed to remove land from the Suitable Timber Base and maintain treated areas using fire into the future, road usage for mechanical vegetation treatments would be reduced.

Recreation Activities

Recreationists are drawn to water as evidenced by the fact that forest campgrounds are often in close proximity to lakes. The forest has made great strides in protecting water quality by replacing all of the old, leaking outhouses with modern, sealed facilities, reducing off highway vehicle use, and improving road stream crossings on recreational routes. Concentrated unmanaged recreation use in close proximity to the forests' waters is rare, but can result in damage to vegetation, soil compaction and erosion, and water pollution from human and animal waste, dishwashing, trash and vehicle fluids. Managed campgrounds and picnic grounds proved a more efficient setting for managed access to water as well as human and animal waste as compared to primitive camping. All alternatives emphasize maintenance of existing developed recreation sites.

Grazing Activities

Water quality can be affected by grazing activities in many ways. Direct consumption and trampling of vegetation, and compaction and displacement from animal hooves in riparian areas reduces streambank stability and changes vegetation composition including the potential of noxious weed spread. Loss of vegetation reduces the ability of a stream to trap and hold sediment in floodplains and may reduce shading of the stream. Increased sediment can result in increased embeddedness. Defecation and urination into streams directly impacts water quality. Overgrazing can decrease upland vegetative cover, which in turn, may increase storm flows that potentially add sediment to streams reducing water quality.

All of these factors are mitigated, to some extent, with the implementation and monitoring of BMPs and SWCPs for grazing. As allotment management plans are revised and BMPs are incorporated into daily management of herbivores, degrading factors to water quality would be diminished.

Alternative Comparison

Alternatives that reduce pressure on riparian areas, such as Alternative B, C, and D, by improving upland vegetation condition, would reduce impacts to water quality from grazing. In addition, Alternatives B and D concentrate restoration efforts in focus watersheds. These alternatives would provide comprehensive restoration on a watershed basis, and have the best opportunity for improving water quality. Alternative A does not provide opportunity for improved forage conditions that would relieve grazing pressure in and around the forests' waters.

Special Uses

Terms and conditions of special use permits would require site specific BMPs to provide for protection of water quality. There are no differences in effects between alternatives for special use management as all authorized uses would require site specific mitigation.

Climate Change

Effects to water quality from climate change are similar to effects to soil condition. Reduced vulnerability to the effects of climate change is provided by returning ecosystem health to desired conditions. Alternatives B, C, and D move ecosystems towards vegetation desired conditions while Alternative A trends away from desired vegetation conditions. In addition, Alternatives B provides the greatest opportunity to restore watershed condition through increase in vegetative ground cover of native grasses and forbs, particularly in the ponderosa pine and frequent fire mixed conifer vegetation types, thus providing improved water quality within treated watersheds.

Response to Large Scale Disturbances, including Salvage Logging

Following large scale disturbances such as wildfire, insect infestations, disease outbreaks, and wind storms, decisions may be made under all alternatives to recover economic value of trees killed by such events, and to reduce hazardous fuels created. Salvage logging provides a means to offset other recovery efforts following large scale disturbances such as soil stabilization, reforestation, and Forest infrastructure repair and maintenance. The discussion that follows will primarily address the direct and indirect effects of post-fire salvage logging since other disturbances rarely damage soils and watershed resources to the level of high severity wildfires.

Post-disturbance salvage logging has been and continues to be a controversial activity on National Forest System lands. Arguments for and against post-disturbance salvage logging are well documented in the literature with regard to the effects to soils and water resources. Several white papers, opinion papers, and refereed journal articles exist that reflect opposing viewpoints and the current state of knowledge of the subject (Beschta et al. 1995; Ice et al. 2004a; Brown et al. 2003, Peterson et al. 2009, Collins et al. 2011). McIver and Starr (2000) conducted a literature review focused on the environmental effects of post-fire logging and removal of large woody structure. They found the scope and scale of immediate environmental effects of salvage logging following large-scale disturbance depend on characteristics of the area to be treated such as the number of standing dead trees per unit area, soil stability, slope characteristics, available access to treatment areas, and post-disturbance weather conditions, to name a few (McIver and Starr 2000).

Some examples of situations that should be avoided during post-fire salvage logging were provided by Beschta et al. (1995) and Karr et al. (2004). These include:

- Post wildfire logging activities on sensitive soils
- Post wildfire logging on steep slopes
- Logging induced soil disturbance on severely burned soils
- New road construction

Although research on the effects of post-disturbance salvage logging is limited (McIver and Starr 2001), Ice et al. (2004b) found that there is little evidence to indicate that a carefully planned and conducted salvage harvest cannot be implemented without significant impacts. Several studies have suggested that needles, fine fuels, and other residual debris from salvage logging can increase the percent of ground cover and surface roughness, thereby reducing overland flow velocities and surface erosion (Robichaud 1999). Poff (1989) noted that post-fire salvage logging can have benefits to soils that include: increasing ground cover that intercepts raindrop impact, breaking up hydrophobic soil layers, and reducing the future risk of high-intensity fires by decreasing fuel loading. A more recent study of post-fire logging (Chase 2006) concludes that logging slash is less of a factor in reducing sediment delivery due to the lack of ground contact it provides. Chase goes on to say that ground cover resulting from needle fall and revegetation of local plant species does provide for a reduction in sediment production.

McIver and Starr (2000) provide a list of perceived post-fire salvage logging effects. Those that benefit soils and watershed resources include: a) residual woody debris following salvage logging intercepts surface water flow, b) removal of tree boles prevents drip erosion at base of firekilled trees, c) fuels reduction decreases the intensity of subsequent fires, removal of dead trees reduces the susceptibility of future and adjacent stands to insect pests. Post-fire logging activities that have adverse effects to soils and watershed resources include: a) increase in soil erosion rates, b) damage to soil and nutrient cycling processes, c) increase in soil compaction and displacement, d) removal of nutrient sources from the ecosystem, and d) increased risk of spread of weeds.

Brown (2003) notes some important benefits that coarse woody debris (CWD) provides in forest ecosystems, depending on site conditions. On steep slopes, CWD protects surface soils from erosion caused by runoff, interrupts sheet flow through surface roughness, provides shade for seedlings, and reduces trampling by livestock, wildlife, and people. For ponderosa pine/fescue and Gambel oak (*Quercus gambelii*) habitat types in Arizona, Brown noted that that a common recommendation is to retain 5 to 13 tons of CWD per acre. Fuel loads that exceed 40 tons per acre were found to result in excessive soil heating. Finally, Brown noted that salvage logging can be used as a tool to reduce and disperse fuel concentrations.

Peterson et al. (2009) provide a discussion of the effects of relatively intense logging on severely burned landscapes. Post-fire logging was found to modify snag dynamics by lowering the density and average size of dead trees and by altering site conditions such as soil bulk density and windflow. Soil disturbance was also a common direct adverse effect to soils from salvage logging. Road construction and skidding were noted as common contributors to soil damage during post-fire logging (Beschta et al. 2004, McIver and McNeil 2006, McIver and Starr 2001). Peterson further concluded that different logging systems can have different effects on soil characteristics such as compaction and nutrient availability. Tractor logging and ground-based equipment on relatively level areas (<30 percent slope) cause the most soil compaction, although some effects can be mitigated by avoiding wet soils, logging over snow, and operating over residual woody debris rather than over areas with thin forest floors. Cable yarding systems also contribute to soil compaction, which is typically localized and can cause excessive erosion where logs are dragged upslope. Skyline yarding, which fully suspends logs above the ground, avoids most physical damage to the forest floor and mineral soil. Helicopter logging greatly reduces soil impacts by minimizing movement of logs along the ground.

In a study of the effects of the long-term post-wildfire dynamics of CWD after salvage logging , Monsanto and Agee (2008) concluded there may be long-term benefits where excessive CWD loads are reduced early following wildfire. They observed soil heating with detrimental effects under re-burn conditions where CWD exceeded 66 tons per acre.

In an overview of salvage logging as it relates to preservation of ecological processes, Lindenmayer and Noss (2006) provided several recommendations to guide project planning for post-disturbance salvage logging. These include:

- Exclude salvage logging from some areas such as nature reserves andwater catchments, extensive areas of old-growth forest, and places with few or no roads. Sensitive sites such as steep slopes and fragile or highly erodable soils also should be exempt from salvage harvesting
- Ensure that unburned or partially burned patches within the perimeter of a disturbed area are either excluded from salvage or subject to low-intensity harvesting with high levels of legacy retention.
- Ensure that certain biological legacies are retained in salvage-logged areas such as fire-damaged trees and large (damaged or undamaged) commercially valuable trees as these often have either high habitat value or a high probability of remaining standing for a prolonged period
- Modify salvage policies to limit the amounts of biological legacies that are removed from particular sorts of areas such as from burned old-growth stands within wood-production zones as currently occurs in some parts of northwestern North America
- Schedule salvage logging so that effects on natural recovery of vegetation are limited
- Ensure the future maintenance or creation of particular habitat elements for species of conservation concern within burned areas potentially subject to salvage logging, such as some woodpeckers, rare forest carnivores, cavity-using mammals, invertebrates, and plants.
- Ensure adequate riparian buffers are in place to protect aquatic ecosystems within areas where salvage harvesting occurs, and retain structures such as logs and logging slash on the ground to limit soil erosion
- The effects of ground-based logging on soil and water in post-disturbance environments can be great; thus, this type of harvesting should be limited and, whenever possible, replaced with cable or helicopter systems for removing fire-burned trees.

While there is clearly a potential for adverse direct and indirect effects to soils and watershed resources from salvage logging, most adverse effects can be minimized or mitigated through proper implementation of Best Management Practices (BMPs) and Soil and Water Conservation Practices (SWCPs). Management considerations for decreasing adverse impacts to soils and watershed resources from salvage logging following large-scale disturbance include those recommended by Lindenmayer and Noss (2006) and should also include, but are not limited to, the following:

- Minimizing the number and length of roads necessary to complete activities.
- Install necessary roads on stable, well-drained soils away from waterbodies
- Minimize the number of stream crossings necessary to complete activities
- Avoid sensitive soils and sites

- Consider harvest systems that produce the least soil disturbance in completing activities. These systems can include: logging on frozen-ground or snow-packed conditions, forwarding, full suspension cable yarding, helicopter yarding , partial suspension cable yarding, and ground-based skidding under dry conditions
- Stabilize disturbed areas upon completion of activities, including seeding with native species where warranted
- Maintain adequate residual woody debris to protect soil surfaces from erosion, provide shade and moisture to plants and organisms, and restore nutrient cycles.
- Buffer sensitive sites such as stream channels, water bodies, and springs.

Cumulative Environmental Consequences

Soils

Cumulative effects to soils are considered differently than other resources as they are considered to occur on-site and are affected by activities that occur or re-occur at the same place over time. Permanent loss of soil productivity has and would affect the level of future goods produced and beneficial uses provided by the forest in the future. The following are examples of cumulative effects to soil productivity that could occur, however they are not expected to occur with the implementation of the proposed plan:

- Excessive soil compaction caused by mechanical forest restoration treatments, grazing and recreation activities which may cause reduced productivity for decades (Paige-Dumroese et al. 2009). Repeating impacts from treatments over the same areas would result in or compound continual reduced productivity.
- Land disturbing activities causing erosion of topsoil at rates greater than the soils natural ability to replace it, commonly referred to as soil loss tolerance rate, results in permanent loss of soil productivity, as soils are considered a non-renewable resource (Renard, et al 1997).
- Soil loss through wind or water erosion leaving the forest or coming onto the forest could reduce soil productivity due to soil deposition.
- The forests' soils are currently not impacted by air quality deposition to the extent they are contributing to measureable reduction in soil productivity and are not expected to in the future (See Air Quality Specialist Report).

Activities that do contribute to permanent loss of soil productivity are kept to the minimum amount necessary to manage the forest. They include:

- Road corridors that make up the forests' road system result in loss of soil productivity. Restoration of roads may result in returning some or all of the soils productivity where implemented.
- Mineral extraction pits and mines result in permanent loss or reduction in soil productivity.
- Uncharacteristic wildfire results in erosion rates well beyond tolerance erosion rates.
- Footprints of Administration and recreation sites.

- Permanent special use sites, such as communication towers and buildings.

Water Quality

Cumulative effects to water quality are the result of impacts in both time and space. The cumulative effects from implementation of the alternatives include effects of resources management on national forest land and effects from land management on adjacent lands of other ownership (i.e. state, private, other federal agencies, county, etc.). Many of the types of impacts to water quality are similar to those on KNF lands, such as effects of roads, grazing, mining, recreation, and vegetation management. Other impacts are different from those of forest management activities, such as urbanization, manufacturing, solid waste management, military operations, power generation, and transportation. Some are considered point sources of pollution and must meet stringent requirements for release of pollutants.

Acidity in rain, snow, cloudwater, and dry deposition can affect soil pH, fertility and nutrient cycling and can result in acidification of lakes and streams through surface runoff. Sulfate deposition to sensitive watersheds results in increasing soil and surface water acidification. Deposition of nitrogen (nitrate and ammonium) in both terrestrial and aquatic systems can acidify streams, lakes and soils. Aquatic ecosystems in Arizona are generally well-buffered through the presence of base cations and not subject to episodic or chronic acidification. There are pollution sources around the KNF that are known to emit elements that form acids of sulfur and nitrogen. No KNF waters are known to be impacted by air quality deposition at levels contributing to measureable reduction in water quality and are not expected to in the future.

Water Yield and Water Rights

Trends

Water use is expected to increase slightly over the planning period. Major water uses on the KNF include: municipal water supply for the City of Williams, fire fighting, road maintenance, domestic livestock and wildlife watering, recreation, and minor amounts for administrative use. Water yields are expected to increase slightly through implementation of ecological restoration treatments that result in a more open forest, woodland and grassland condition. This reduces transpiration and interception losses. However, it cannot be predicted with certainty the amount of increase in water yield that would occur following forest restoration treatments. It is possible that anticipated changes in water yields may be negated by climate change or regional drought conditions. Administrative and municipal use of water on the KNF is estimated to be below the recharge rate, and this trend is expected to continue under all alternatives. However, alternative B is projected to provide the greatest potential for increases in both surface and groundwater over Alternatives C and D through increased snowpack in the ponderosa pine and frequent fire mixed conifer vegetation type and reduced evapotranspiration and interception by trees.

Forest Restoration Activities

Timber harvesting has the potential to increase water yields for short durations within harvest units. However, annual water yield for a watershed is usually only measurable when at least 25 percent of forest cover within a watershed is removed, especially in areas receiving more than 18 inches of precipitation per year (Troendle and Olsen 1994; Troendle et.al. 2001; Grant et.al. 2008 Brown H. E. et.al. 1974, Rich L.R. and J. R. Thompson, 1974). Generally, as vegetation reestablishes in treated areas plants uptake excess moisture and water runoff returns to pre-harvest levels. However, desired conditions for most of the forest vegetation types necessitate converting the currently dense, closed overstory conditions to more open conditions in order to reduce the risk of high-severity stand replacing wildfires and increase understory herbaceous vegetation that improves water conservation and increases available groundwater. Since these areas would be maintained at a lower canopy cover over the long term, water yield increases could remain following treatments.

Streamflow responses to prescribed fire would be smaller in magnitude than the responses to wildfire since wildfires typically burn larger areas at higher intensity than prescribed fire, effectively removing most of the protective ground cover and increasing stormwater runoff. Prescribed burning usually leaves portions of the surface organic matter intact (DeBano et. al. 1996). As a result, increases in streamflow discharges are not as severe as those resulting from high severity wildfires.

Roads

Since the road system (miles, location and maintenance level) are the same under all alternatives, there is no measureable difference among the alternatives in water yield as it relates to road infrastructure.

Recreation Activities

There are no new dams or other impoundments planned for recreation within the forests boundary under any of the proposed alternatives that would increase water use. Maintenance of existing impoundments would continue, which may include reconstruction of containment structures, spillways and sealing lakebeds. However, no additional water storage capacity is expected to be added for recreational purposes. There is therefore no measureable difference among the alternatives in water yield in relation to recreational activities.

Grazing Activities

Water accessibility is necessary for a pasture to be available for livestock grazing. Some allotments/pastures rely on developed springs, but many often utilize earth impounded stock tanks to capture snowmelt and monsoon rainfall. Stored water is then used by livestock and wildlife. During the recent droughts, many earth tanks on the KNF have become dry for much of the growing season, making some pastures unsuitable for livestock even though adequate forage may have been available. There are 457 acres of stock tanks on the KNF that have altered the free flowing character of many of the forests' ephemeral drainages that are dry except during runoff events. These drainages would provide minimal water for wildlife and domestic livestock under natural conditions. Stock tanks therefore effectively increase available water for longer durations than natural ephemeral drainages. Many of these impoundments also provide sediment capture, although maintenance of them may also release sediment to downstream ephemeral reaches.

Alternative Comparison

Alternatives B, C, and D provide an opportunity for potential increases in water yield which may provide more reliable water for livestock and wildlife use, especially in areas with greater than 18 inches of annual precipitation. Alternative A does not provide conditions that would lead to increased water yield and will therefore not effectively increase available surface water.

Alternatives C and D would not provide as much opportunity to increase water storage as Alternative B since forest restoration treatments would include a large tree retention requirement. By retaining large trees, more rainfall would be intercepted by tree foliage, limbs, and boles, effectively decreasing surface stormwater flow since this water would evaporate from tree surfaces instead of contributing to surface flow and groundwater recharge.

Special Uses

Special use permits to convey water from water sources such as springs to private or public holdings are common on the KNF. These are subject to terms and conditions that require demonstrating proof of water right ownership and monitoring of flows. There are no projected differences among alternatives for special uses.

Climate Change

The U.S. Environmental Protection Agency (EPA) has asserted that scientists know with virtual certainty that human activities are changing the composition of the Earth's atmosphere. It is also documented that "greenhouse" gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons have been increasing (EPA, 2010). The atmospheric increase of these gases is largely the result of human activities such as the burning of fossil fuels. Greenhouse gases absorb infrared energy that would otherwise be reflected from the earth. As the infrared energy is absorbed, the air surrounding the earth is heated (CARB 2007).

The Southwestern Region of the Forest Service recently released "Southwestern Region Climate Change – Trends and Forest Planning February 2010. The following information is summarized from excerpts of this publication:

"In the Southwest, climate modelers agree there is a drying trend that will continue well into the latter part of 21st century (IPCC 2007; Seager et al. 2007). Climate modelers predict increased precipitation, but believe that the overall balance between precipitation and evaporation would still likely result in an overall decrease in available moisture. Regional drying and warming trends have occurred twice during the 20th century (1930s Dust Bowl, and the 1950s Southwest Drought). Current drought conditions "may very well become the new climatology of the American Southwest within a time frame of years to decades". According to recent model results, the slight warming trend observed during the last 100 years in the Southwest may continue into the next century, with the greatest warming to occur during winter. Climate models predict temperatures to rise approximately 5 to 8 degrees Fahrenheit by the end of the century (IPCC 2007). This trend would likely increase demand on the region's already limited water supplies, as well as increase energy demand, alter fire regimes and ecosystems, create risks for human health, and affect agriculture (Sprigg et al. 2000).

Average ambient air temperatures are rising, and it is possible that continued warming will increase the temperature difference between the Southwest and the tropical Pacific Ocean, enhancing the strength of westerly winds that carry moist air from the tropics into the Southwest region during the monsoon season. This scenario may increase the monsoon's intensity, or its duration, or both, in which case floods would occur with greater frequency (Guido 2008). While the region is generally expected to dry, it is possible that extreme weather patterns leading to more frequent destructive flooding would occur. Along with monsoons of higher intensity, hurricanes and other tropical depressions are projected to become more intense overall. Arizona typically receives 10 percent or more of the annual precipitation from storms that begin as tropical depressions in the Pacific Ocean. In fact, some of the largest floods in the Southwest have occurred when remnant tropical storms intersect frontal storms from the north or northwest (Guido 2008).

Most global climate models are not yet accurate enough to apply to land management at the ecoregional or National Forest scale. This limits regional and forest-specific analysis of the potential effects of climate change.

Due to the spatial and temporal limitations of climate models, as stated above, site-specific analysis of climate change at the Forest level with regard to implementing Forest plans remains impractical. Several unknown factors further limit discussion and analysis of climate change at the Forest level. These include: lack of data regarding the effects of carbon sequestration and release as a result of forest and range management practices, limited data and knowledge of the effects of motorized travel to ecosystem resiliency at the Forest level, and limited knowledge of the contributions of surrounding areas to current and future climate impacts at the Forest level necessary to analyze cumulative effects. Impacts to the KNF from climate change are therefore discussed in a qualitative manner.

Projected future climate change could affect Arizona in a variety of ways. Public health and safety could be compromised due to an increase in extreme temperatures and severe weather events. Agriculture would vulnerable to altered temperature and rainfall patterns, increasing plant stress and susceptibility to insects and diseases. Forest ecosystems could face increased occurrences of high severity wildfires and may also be more susceptible to insects and diseases. Snowpack could decrease and snowmelt may occur earlier.

While the future of climate change and its effects across the Southwest remains uncertain, it is certain that climate variability will continue to occur across the KNF. Forest management activities should strive to promote ecosystem resilience and resistance to impacts of climate change. Implementation should focus on maintenance and restoration of resilient native ecosystems, thereby reducing the vulnerability of ecosystems to variations in climate patterns. Ecological diversity remains an integral component in native ecosystems. Projects should promote connected landscapes and endeavor to restore significantly altered biological communities, thus restoring their resilience to changes in climate.

Changes in the timing and amount of precipitation, water storage and distribution, watershed management, and human water uses may present some of the most important challenges related to climate change and national forest management in the Southwest. Terrestrial and aquatic ecosystems and human socioeconomic systems depend on water. Two scenarios are discussed; wetter/warmer and drier/warmer.

Under wetter climate scenarios, the potential for flooding could increase as a result of more intense precipitation. Even if total precipitation increases substantially, snowpack will likely be reduced because of higher overall temperatures. It is likely that more precipitation would also create additional water supplies, reduce demand, and ease some of the competition among water uses (Joyce et al. 2001; Smith, et al. 2001).

In contrast, a drier climate scenario is very likely to decrease water supplies and increase competition for limited water resources (Joyce et al. 2001). Overall, these trends would increase pressures on the already limited water supplies in the Southwest, increase energy demand, alter fire regimes and ecosystems, increase risks to human health, and affect agriculture in the region (Swetnam and Betancourt 1997; Sprigg et al. 2000).

The potential for future droughts becoming more severe as a result of climate change is a significant concern, especially since the human population continues to grow in the Southwest region. The most likely climate scenario for the Southwest is a substantially drier one. Human induced climate change could result in water shortages the region (Karl et al. 2009).

Development in the Southwest is highly dependent upon the ability to deliver water resources. The locations of most snow pack and many upland reservoirs are on national forests in the Southwest (Smith et al. 2001; State of New Mexico 2005). The KNF receives a substantial portion of Arizona’s annual snowpack.

While agriculture remains the greatest consumptive use of water resources in the Southwest, there has been a decrease in the amount of water used by agriculture as irrigation technologies improve and increasing urban populations demand more water for municipal and other uses; this has been an on-going trend and could continue to affect future agricultural water uses.

The frequency and severity of floods could increase with changes in climate. This could result in increased rates of soil erosion and stream sedimentation. In a drought of the magnitude of the worst one-year drought on record, water demand may exceed supply by as much as 60 percent. In the Southwest, debate will likely continue over water allocation.

Adaptive Management

All alternatives assume the use of adaptive management principles. Forest Service decisions are made as part of an on-going process, including planning, implementing projects, and monitoring and evaluation. The land management plan identifies a monitoring program. Monitoring the results of actions will provide a flow of information that may indicate the need to change a course of action or the land management plan. Scientific findings and the needs of society may also indicate the need to adapt resource management to new information. The Forest Supervisor annually evaluates the monitoring information displayed in the evaluation reports through a management review and determines if any changes are needed in management actions or the plan itself. In general, annual evaluations of the monitoring information consider the following questions:

- What are the effects of resource management activities on the productivity of the land?
- To what degree are resource management activities maintaining or making progress toward the desired conditions and objectives for the plan?
- What changes are needed to account for unanticipated changes in conditions?

In addition to annual monitoring and evaluation, the Forest Supervisor reviews the conditions on the land covered by the plan at least every 5 years to determine whether conditions or demands of the public have changed significantly. The forest plan is ordinarily revised on a 10-year cycle and the Forest Supervisor may amend the plan at any time.

Soil disturbance monitoring (Page-Dumroese, et al 2010) would provide the necessary feedback for adaptive management to protect soil productivity.

Unavoidable Adverse Impacts

The land management plan provides a programmatic framework that guides site-specific actions but does not authorize, fund, or carryout any project or activity. Before any ground-disturbing actions take place, they must be authorized in a subsequent site-specific environmental analysis. Therefore none of the alternatives cause unavoidable adverse impacts.

Irreversible and Irretrievable Commitment of Resources

The land management plan provides a programmatic framework that guides site-specific actions but does not authorize, fund, or carryout any project or activity. Because the land management plan does not authorize or mandate any site-specific project or activity (including ground-disturbing actions), none of the alternatives cause an irreversible or irretrievable commitment of resources.

Consistency with Law, Regulation, and Policy

All alternatives are designed to guide the Kaibab National Forest (KNF) management activities in meeting federal law, regulations, and policy.

Other Planning Efforts

The Coconino and Prescott National Forests are currently revising their Forest plans. These Forests have shared boundaries with the KNF and implement similar management practices. Forest management and planning efforts are expected to align with the KNF through cooperation and coordination throughout the Forest Plan Revision process.

The Bureau of Land Management, Arizona Strip shares a boundary with the North Kaibab Ranger District. The Arizona Strip Proposed Plan/Final EIS was completed in 2007. Land management practices on BLM lands are implemented in a similar manner as Forest Service lands under National Environmental Policy Act requirements. Coordination between the KNF and BLM, Arizona Strip is ongoing where resource management issues overlap KNF and BLM managed lands.

Grand Canyon National Park (GCNP) has shared boundaries with the Tusayan and North Kaibab Ranger Districts of the KNF. The GCNP General Management Plan was completed in 1995 in accordance with NEPA. The KNF coordinates with GCNP on natural resource management projects and planning efforts as needed.

Coconino and Yavapai Counties have implemented management plans that provide frameworks for managing land use, the natural environment, and conservation of natural resources. As populations in these counties continue to grow, increased pressure on NFS lands can be expected. Planning on the KNF would therefore require consideration of the impacts that population growth in these counties and expansion of the wildland-urban toward KNF ownership has on implementation of Forest management practices.

Camp Navajo adjoins the KNF at the eastern boundary of the Williams Ranger District. The primary purpose of Camp Navajo is to support the military missions of the Arizona Army National Guard. In July of 2009, Camp Navajo revised their Integrated Natural Resource Management (INRMP). The INRMP is designed to support and accommodate accomplishment of the military missions while providing for natural resources stewardship and management. Specific goals identified by the revised INRMP are found on page 1-2. These goals are consistent with KNF desired conditions.

- Maintain, monitor, and manage water resources for plants and wildlife.
- Restore fire to its more natural role in the ecosystem.
- Protect and sustain native plant communities.
- Protect vegetation communities from non-native, invasive species.
- Protect soils to prevent erosion and to maintain realistic training grounds for missions.
- Manage wildland fires to sustain Camp Navajo training lands.

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Appendix A

Subbasin, Watershed, and Subwatershed Extent on the KNF

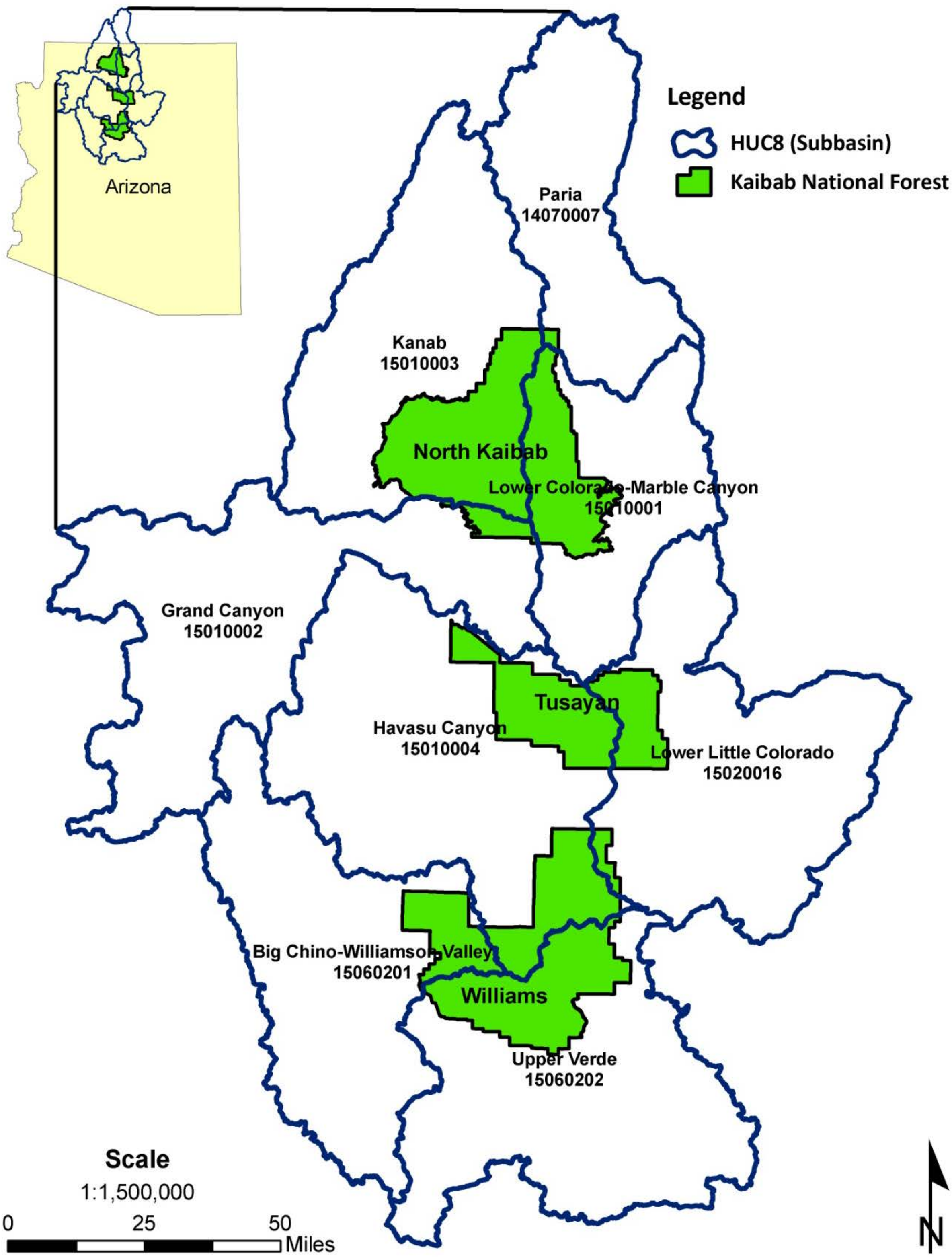

Figure 1. Subbasins (HUC8) that include Kaibab National Forest lands.

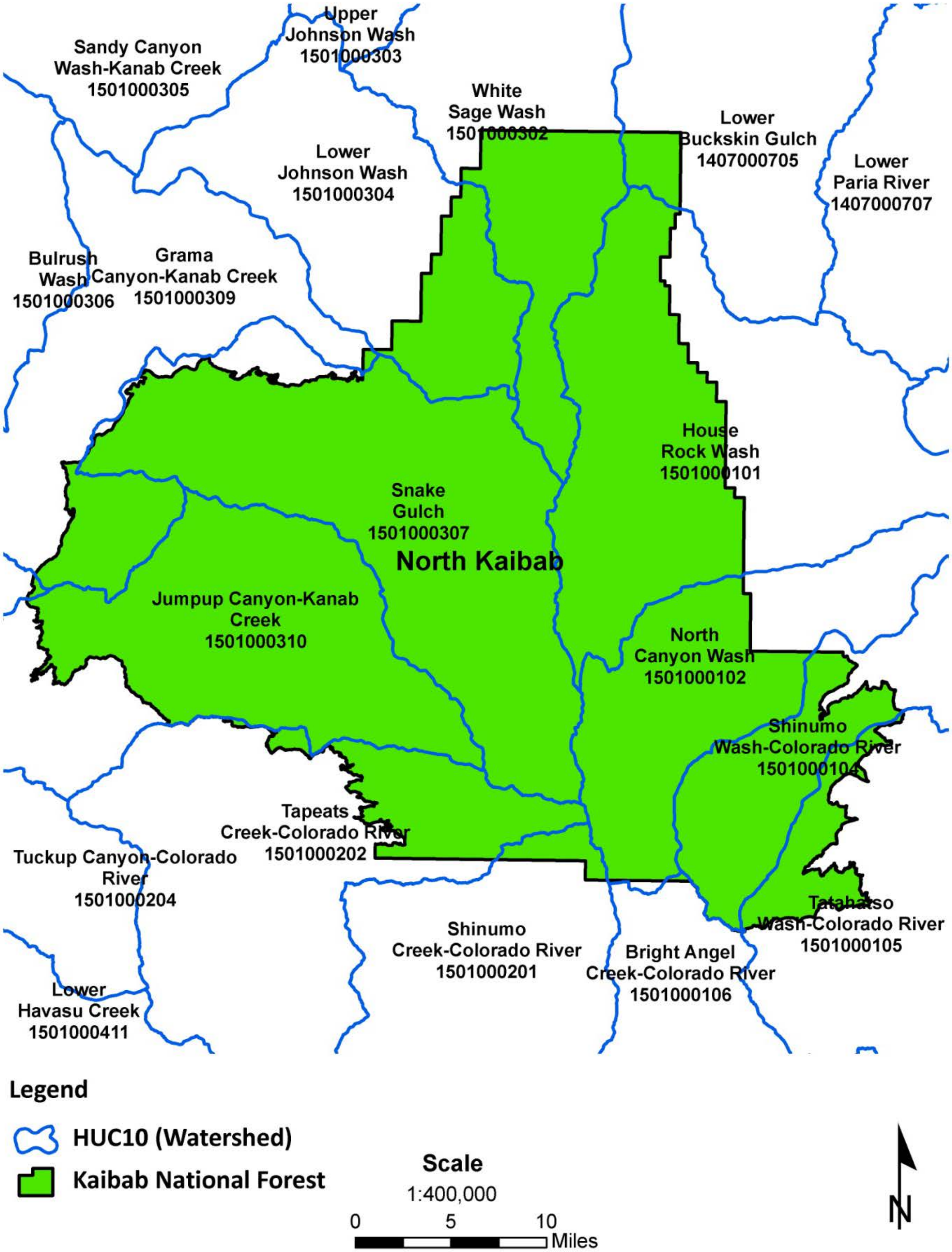

Figure 2. Watersheds (HUC10) that include North Kaibab Ranger District lands.

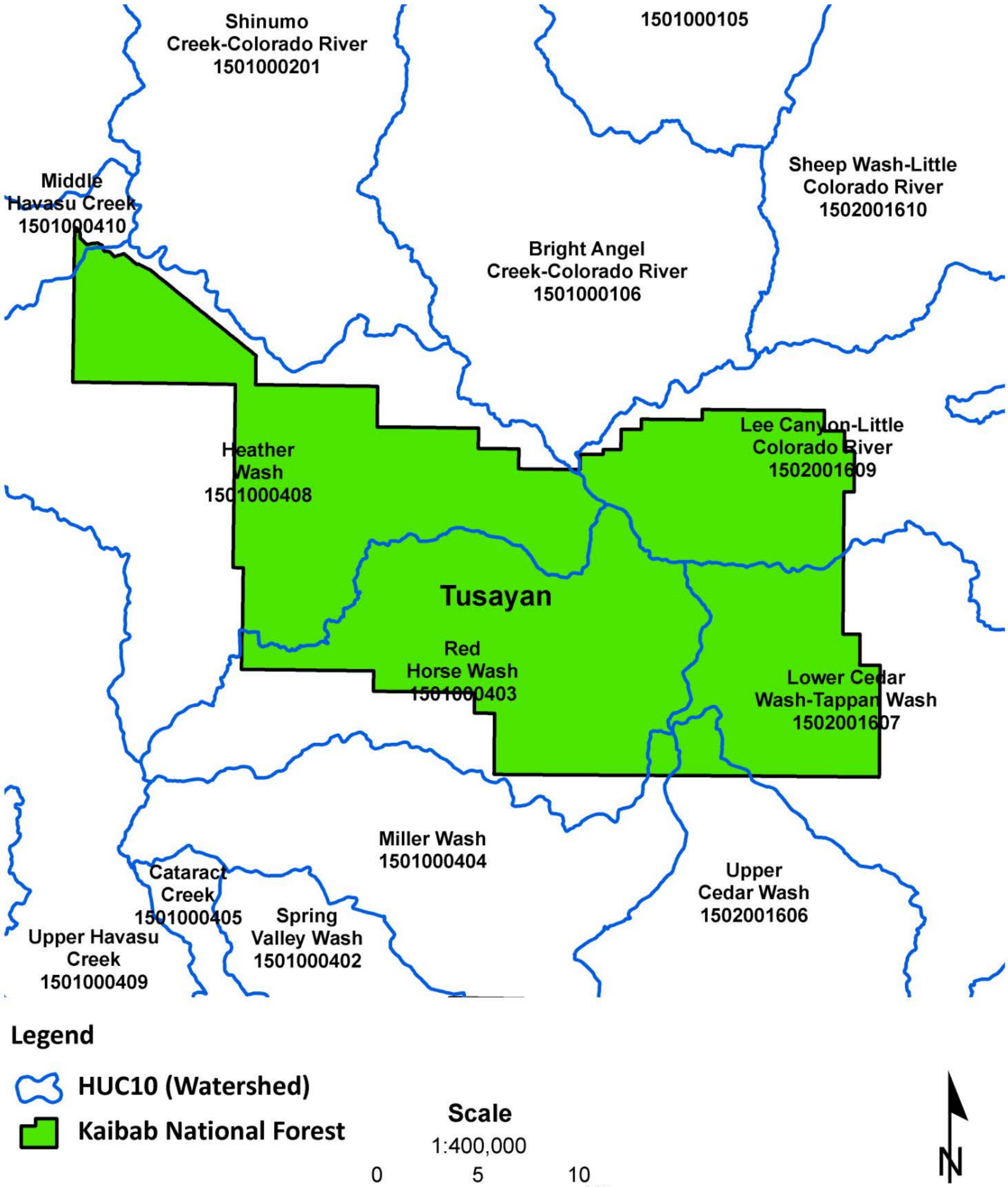

Figure 3. Watersheds (HUC10) that include Tusayan Ranger District lands.

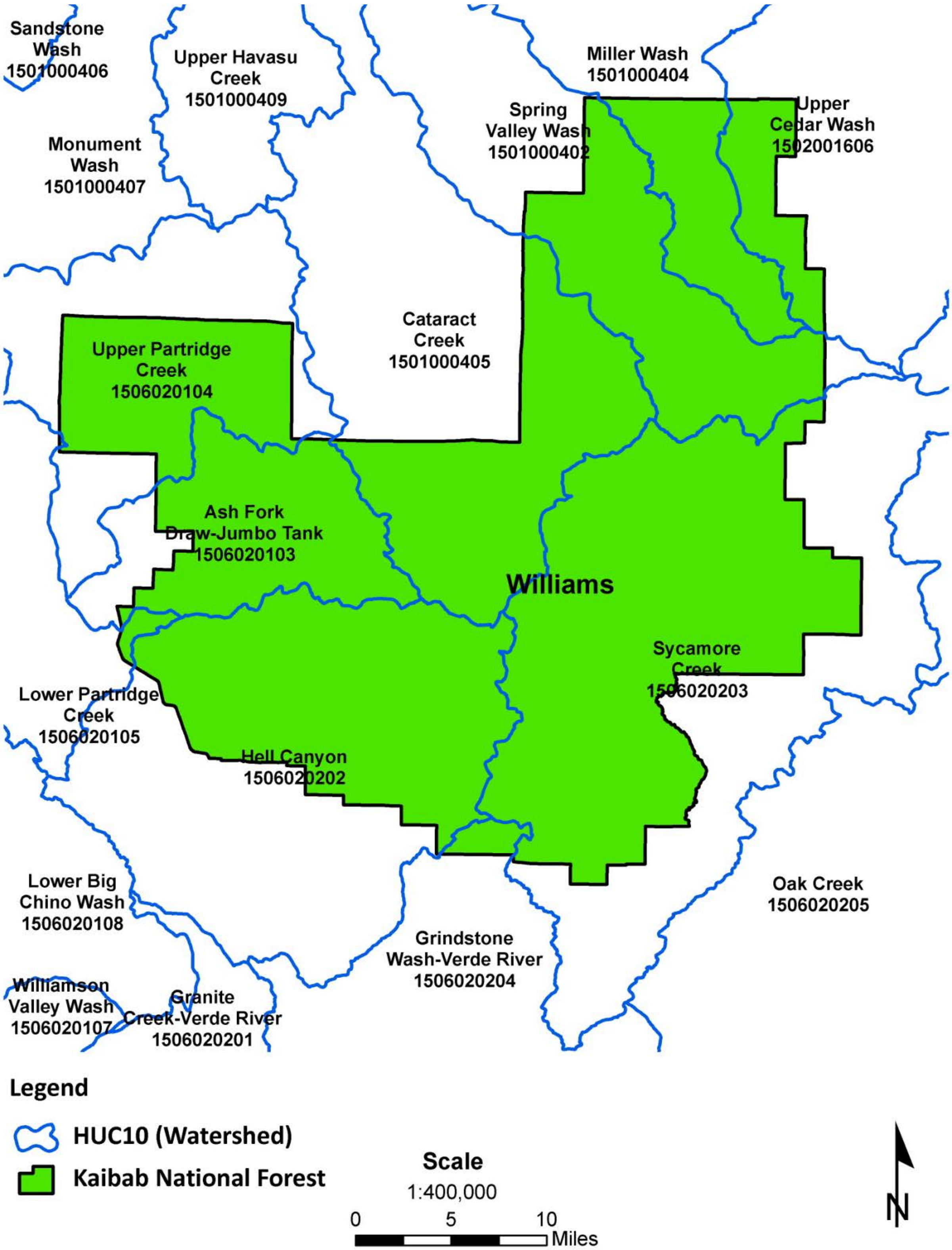

Figure 4. Watersheds (HUC10) that include Williams Ranger District lands.

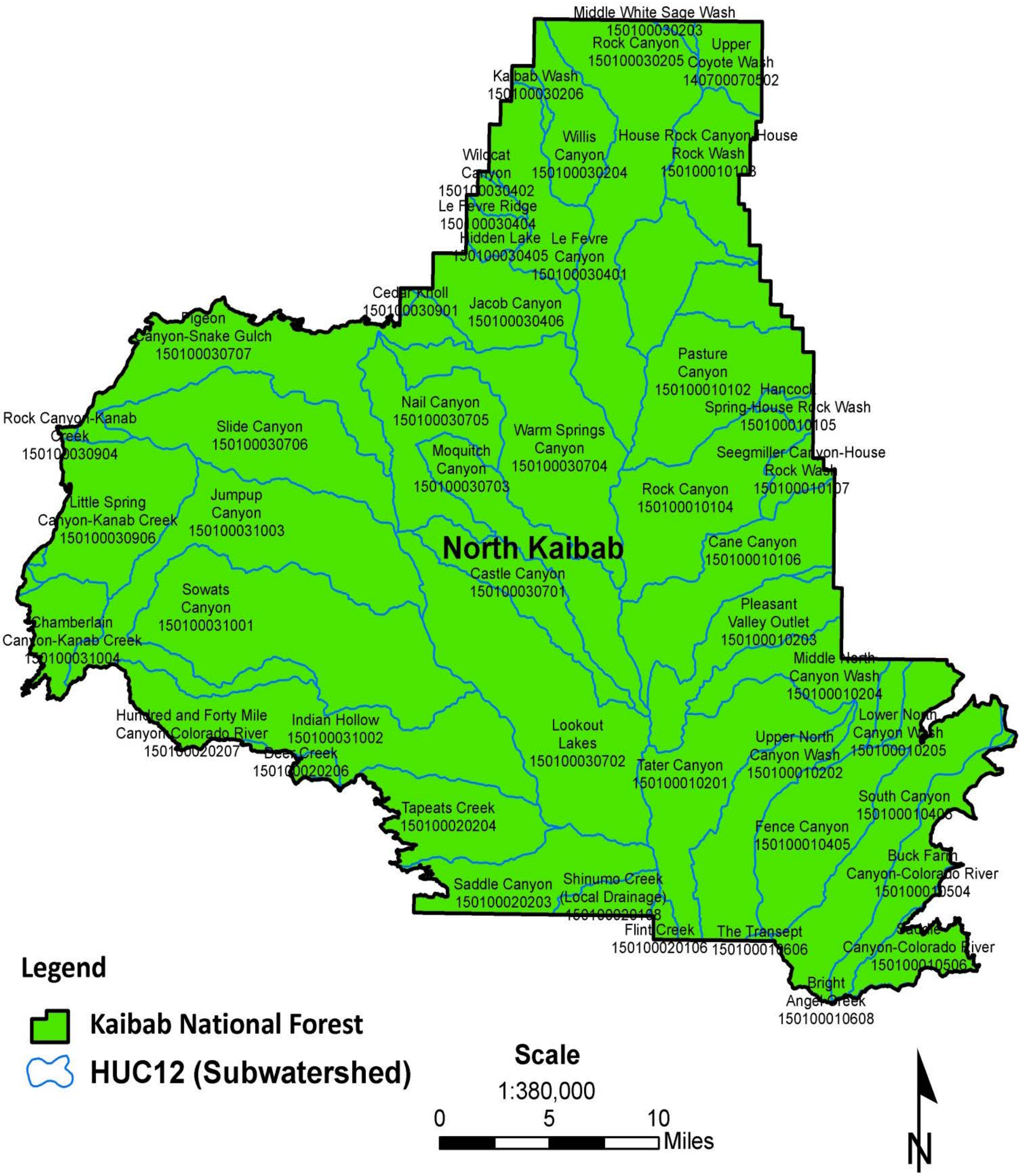

Figure 5. Subwatersheds (HUC12) of the North Kaibab Ranger District.

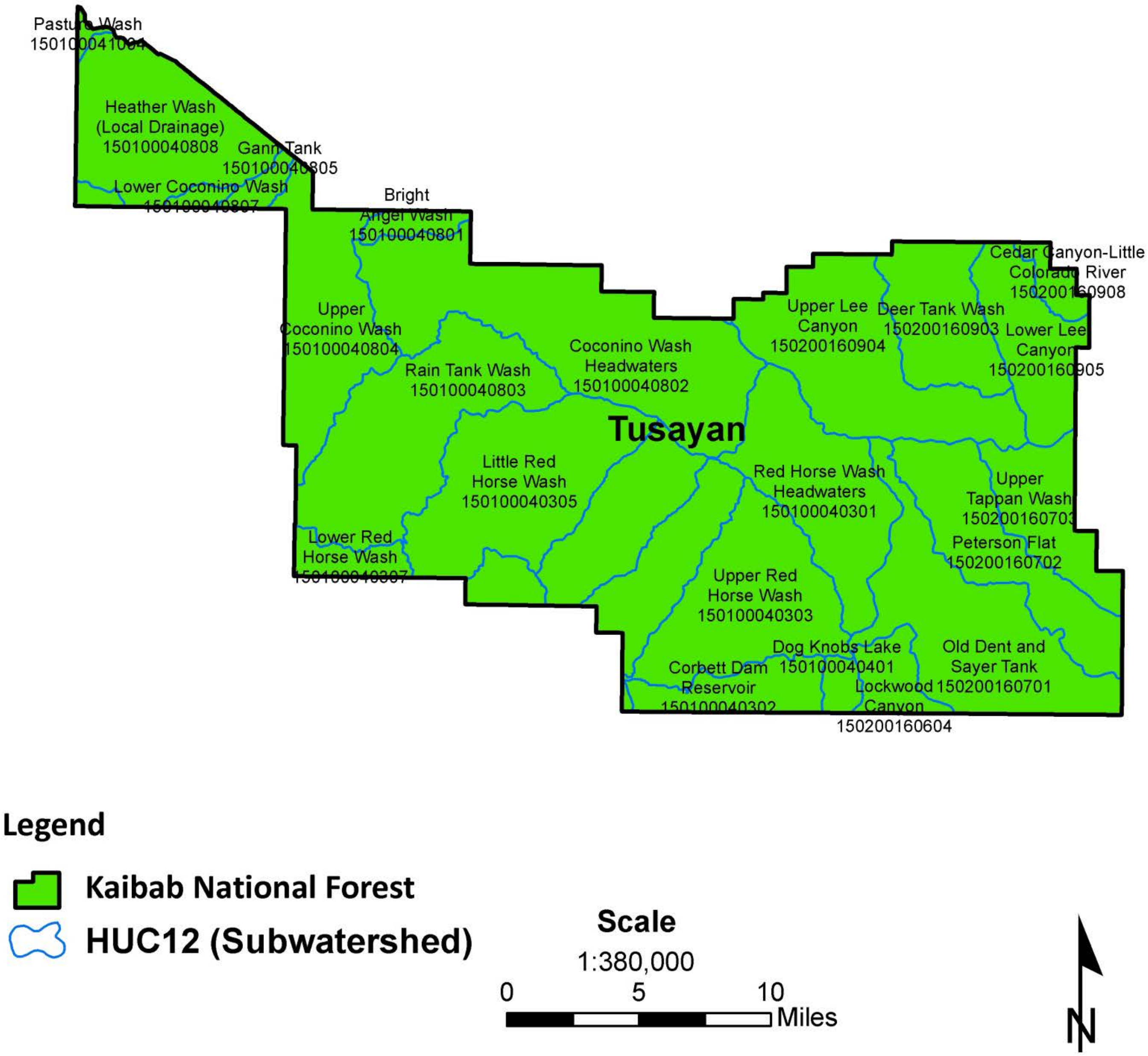

Figure 6. Subwatersheds (HUC12) of the Tusayan Ranger District.

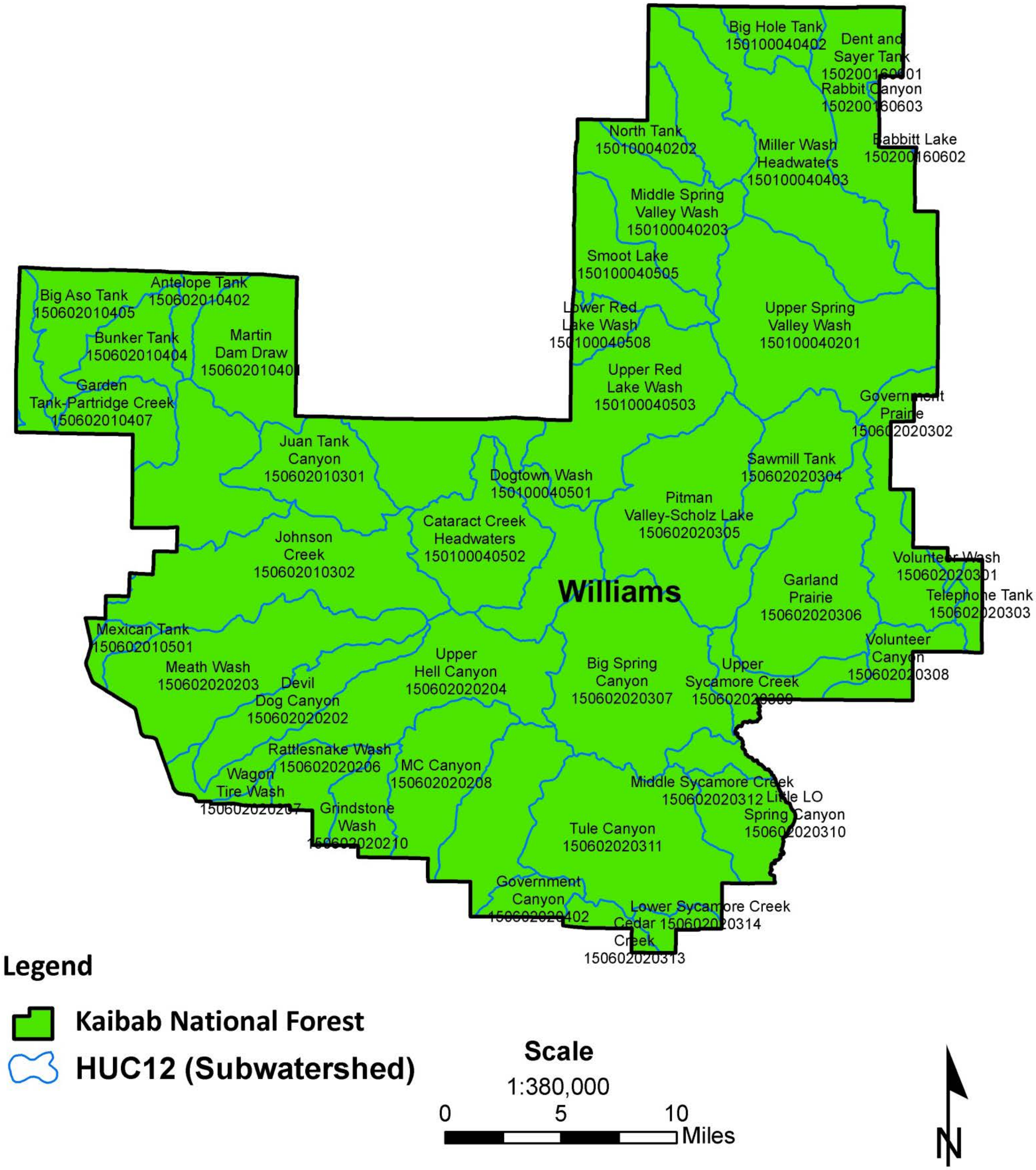

Figure 7. Subwatersheds (HUC12) of the Williams Ranger District.

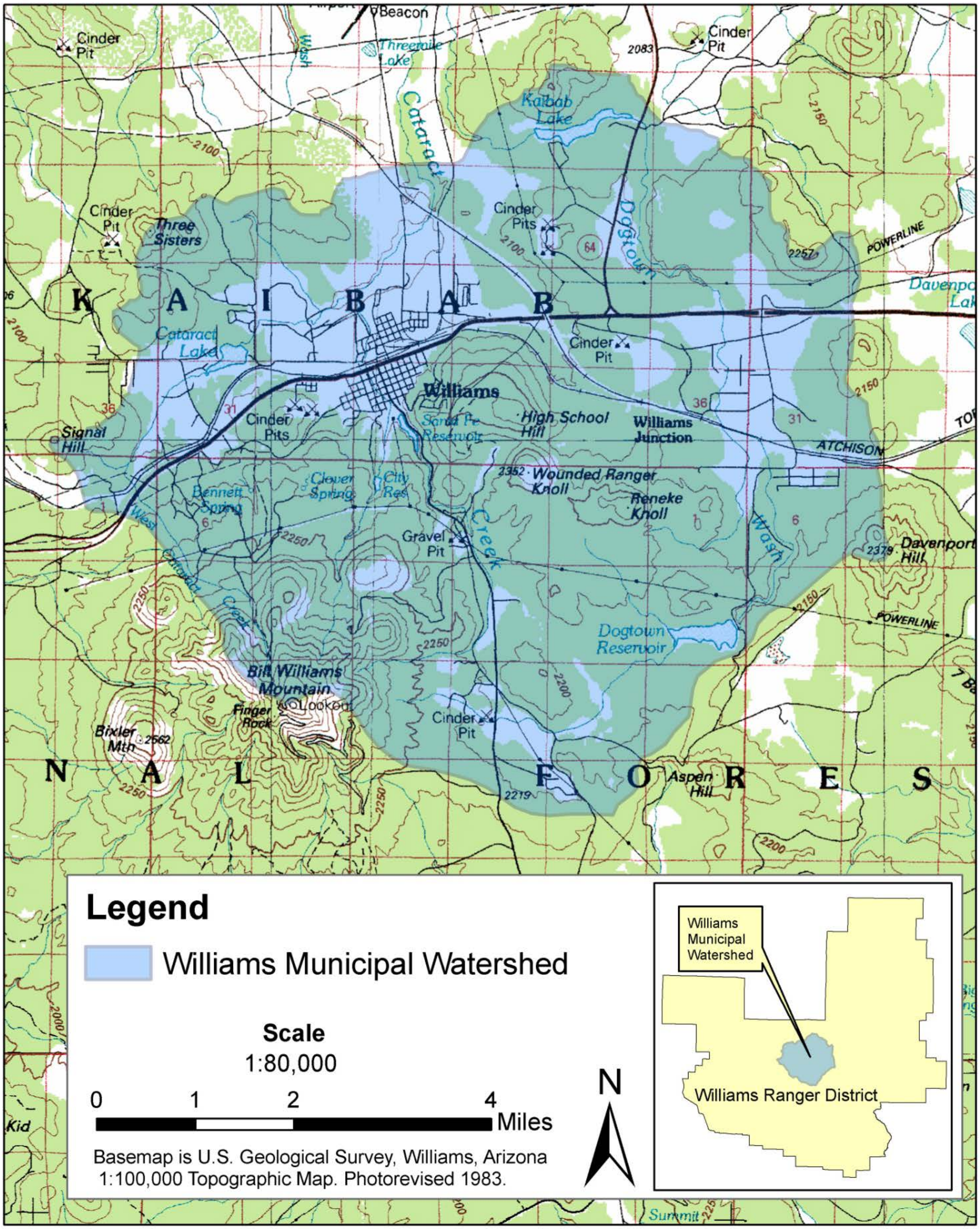

Figure 8. City of Williams Municipal Watershed.

Table 1. Subbasin (HUC4) Extent and Perennial Streams on the Kaibab National Forest. Those of which the KNF percentage exceeds 15 percent are highlighted.

Sub-basin Name	Sub-basin Area (square miles)	KNF Area (square miles)	KNF as % of Sub-basin	NHD Perennial Stream Miles in Watershed	NHD Perennial Stream Miles on KNF	Existing Perennial Stream Miles on KNF	Percent of Existing Perennial Miles on KNF Within Watershed
Big Chino-WIlliamson Valley	2153	178	8.2%	11.9	0.0	0.0	0.0%
Grand Canyon	2551	58	2.3%	69.2	[4]0.5	0.0	0.0%
Havasu Canyon	2933	607	20.7%	13.9	[2]1.4	0.0	0.0%
Kanab	1710	596	34.9%	69.8	[1]20.0	20.0	28.7%
Lower Colorado-Marble Canyon	1467	360	24.5%	67.2	1.4	1.5	2.2%
Lower Little Colorado	2393	204	8.5%	5.0	0.0	0.0	0.0%
Paria	382	10	2.6%	25.1	0.0	0.0	0.0%
Upper Verde	2507	425	17.0%	78.5	[3]9.9	0.0	0.0%
Total	**16,096**	**2,438**	**15.1%**	**340.6**	**33.2**	**1.5**	**0.5%**

Personal communication with Dr. Larry Stevens revealed that perennial flow within Kanab Creek occurs as a result of spring ecosystems that issue from within the Kanab Creek watershed. Historically, this was a perennial stream. Permanent upstream impoundments, diversions, and utilization upstream of the KNF have altered surface flow within the Kanab Creek drainage, increasing the need for communication and coordination with upstream water users, Agencies and communities to seek opportunities to improve flow in Kanab Creek. Additionally, flooding regimes caused by high intensity, short-duration monsoon storms in the Kanab Creek drainage increase the baseflow of Kanab Creek during and after the monsoon season.

[2] Personal communication with several Kaibab NF personnel (past and present), including Dave Brewer, and Bruce Higgins, as well as consultation of Forest records indicates no perennial stream exists on the KNF in this watershed.

[3] Personal communication with Kaibab NF personnel (past and present), including Bill Noble, Bruce Higgins, and Dave Brewer as well as consultation of Forest records indicates only one short reach of perennial stream occurs on the KNF in this watershed – Big Spring. Sycamore Canyon, which forms the boundary between the Coconino and Kaibab NFs may contain perennial water in its lower reach but is not covered by the Kaibab NF Plan. The Coconino NF Plan covers this area and should be addressed therein.

[4] Personal communication with several Kaibab NF personnel (past and present), including Mikcael Hannemann, Bruce Higgins, Dave Brewer, and Dustin Burger, as well as consultation of Forest records indicates no perennial stream on-Forest in this watershed.

Table 2. Watershed (HUC10) Acreage Summary and Perennial Stream Miles on the Kaibab National Forest. Highlighted watersheds have the greatest proportion, with more than two-thirds of each watershed occurring within the KNF.

Subbasin Name	Watershed Area (acres)			Watershed Perennial Streams (miles)			
	Watershed Total	Kaibab NF	Kaibab as % of Subbasin	Forest-Administered Land (Forest data)	Within Forest – Other Management (NHD)	Watershed (NHD)	Percent on Forest Within Watershed
Snake Gulch	179138	167722	94%	0.0	0.0	0.0	-
Ash Fork Draw-Jumbo Tank	74809	61727	83%	0.0	0.0	0.0	-
Jumpup Canyon-Kanab Creek	147426	113501	77%	0.0	0.0	23.0	0.0%
Red Horse Wash	152883	105354	69%	0.0	0.0	0.0	-
North Canyon Wash	100747	67912	67%	1.5	0.0	1.4	100%
Sycamore Creek	305493	177678	58%	0.0	0.0	7.6	-
House Rock Wash	192674	101112	52%	0.0	0.0	0.0	-
Spring Valley Wash	131371	68588	52%	0.0	0.0	0.0	-
Hell Canyon	213376	109239	51%	0.0	0.0	4.4	0.0%
Heather Wash	244156	112348	46%	0.0	0.0	1.9	0.0%
Cataract Creek	208324	82457	40%	0.0	0.0	0.0	-
Upper Partridge Creek	148840	52401	35%	0.0	0.0	0.0	-

Subbasin Name	Watershed Area (acres)			Watershed Perennial Streams (miles)			
	Watershed Total	Kaibab NF	Kaibab as % of Subbasin	Forest-Administered Land (Forest data)	Within Forest – Other Management (NHD)	Watershed (NHD)	Percent on Forest Within Watershed
White Sage Wash	137020	47907	35%	0.0	0.0	0.0	-
Shinumo Wash-Lower Colorado River	140302	43538	31%	0.0	0.0	0.0	-
Lee Canyon-Lower Little Colorado River	181398	53340	29%	0.0	0.0	0.5	0.0%
Lower Johnson Wash	119068	31004	26%	0.0	0.0	0.0	-
Lower Cedar Wash-Tappan Wash	205845	53234	26%	0.0	0.0	0.0	-
Miller Wash	160547	36041	22%	0.0	0.0	0.0	-
Tapeats Creek-Lower Colorado River	175669	31710	18%	0.0	0.0	11.2	0.0%
Grama Canyon-Kanab Creek	145743	21185	15%	0.0	0.0	25.8	0.0%
Upper Cedar Wash	190716	25377	13%	0.0	0.0	0.0	-
Tatahatso Wash-Lower Colorado River	153191	17487	11%	0.0	0.0	18.4	0.0%
Lower Buckskin Gulch	122060	6271	5.1%	0.0	0.0	0.0	-
Shinumo Creek-Lower Colorado River	166592	5141	3.1%	0.0	0.0	39.9	0.0%
Grindstone Wash-Upper Verde River	136099	3931	2.9%	0.0	0.0	16.0	0.0%
Lower Partridge Creek	130880	2530	1.9%	0.0	0.0	0.0	-

Subbasin Name	Watershed Area (acres)			Watershed Perennial Streams (miles)			
	Watershed Total	Kaibab NF	Kaibab as % of Subbasin	Forest-Administered Land (Forest data)	Within Forest – Other Management (NHD)	Watershed (NHD)	Percent on Forest Within Watershed
Middle Havasu Creek	140941	600	0.4%	0.0	0.0	0.0	-
Hack Canyon	135297	384	0.3%	0.0	0.0	0.0	-
Bright Angel Creek-Lower Colorado River	188248	277	0.1%	0.0	0.0	47.2	0.0%
Grand Total	**4728854**	**1599997**	**34%**	**1.5**	**0.0**	**197.3**	**0.8%**

Table 3. Subwatershed (HUC12) acreage and condition rating summary for the Kaibab National Forest

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Antelope Tank	21034	1778	19255	8	92	1.6	1.5	1	2	1.4	1.6	1.6	Unsatisfactory soils in watershed; low road maintenance; many roads near water courses.
Ash Fork Draw-Jumbo Tank (Local Drainage)	29732	8625	21107	29	71	1.7	1.5	1.3	2	1.4	1.7	1.7	Unsatisfactory soils in watershed; low road maintenance; many roads near water courses; cinder pits and quarries present.
Bear Canyon	21993	14816	7177	67	33	2.5	2.5	2.7	2.2	1.8	2.5	2.5	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (10 springs; 34 acres of riparian habitat); low road maintenance; cinder pits present; many tanks present.
Big Aso Tank	28742	7614	21128	26	74	1.7	1.5	1.7	1.8	1.6	1.7	1.7	Low road maintenance; cinder pits and quarries present.
Big Hole Tank	22001	2869	19132	13	87	1.5	1.5	1	1.8	1.6	1.5	1.5	Low road maintenance.
Big Spring Canyon	31715	20012	11703	63	37	2.5	2.5	2.7	2.3	2	2.5	2.5	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (9 springs; 155 acres of riparian habitat); high road density; low road maintenance; cinder pits present; many tanks and 9 wells present; high insect and disease risk.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Bright Angel Wash	9932	2279	7653	23	77	1.7	1.5	1.2	2.1	2	1.7	1.7	Fire regime departed from reference condition; low road maintenance; many roads near water courses; high risk of insect and disease.
Buck Farm Canyon-Colorado River	21268	10979	10289	52	48	1.7	1.5	1.3	2.3	2.4	1.7	1.7	Moderate to high burn severity - Outlet Fire 2000; fire regime departed from reference condition; high road density; low road maintenance; many roads near water courses.
Bunker Tank	8596	4152	4444	48	52	1.8	1.5	1.2	2.3	1.6	1.8	1.8	Unsatisfactory soils in watershed; high road density; low road maintenance; many roads near water courses.
Cane Canyon	33846	20689	13157	61	39	2.3	2.5	2	2.3	2.1	2.3	2.3	Reduced flows to springs and riparian areas (3 springs; 109 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance.
Castle Canyon	11176	11157	19	100	0	2.3	2.5	2.3	2.1	2.2	2.3	2.3	Fire regime departed from reference condition; high road density; low road maintenance; many tanks present; high insect and disease risk.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Cataract Creek Headwaters	16707	6405	10302	38	62	2.4	2.5	2.7	2	1.6	2.4	2.4	Reduced flows to springs and riparian areas (2 springs and 117 acres of riparian habitat); high road density; low road maintenance; septic systems present; many tanks; 4 wells; and 6 reservoirs present.
Chamberlain Canyon-Kanab Creek	38321	7847	30475	20	80	2.3	2.5	2.2	2	1.8	2.3	2.3	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (2 springs and 308 acres of riparian habitat); fire regime departed from reference condition; low road maintenance.
Coconino Wash Headwaters	51223	37079	14144	72	28	1.8	1.5	1.7	2.1	2	1.8	1.8	Low road maintenance; septic systems present.
Corbett Dam Reservoir	14960	7375	7586	49	51	1.5	1.5	1	1.9	2	1.5	1.5	Fire regime departed from reference condition; low road maintenance; many roads near water courses; high insect and disease risk.
Curley Wallace Tank	13439	12474	965	93	7	1.7	1.5	1	2.1	1.8	1.7	1.7	Low road maintenance; many roads near water courses; high insect and disease risk.
Deer Creek	10791	1675	9116	16	84	1.6	1.5	1.3	1.9	2	1.6	1.6	Fire regime departed from reference condition; low road maintenance.
Deer Tank Wash	16237	12925	3313	80	20	1.9	1.5	1.8	2.1	1.8	1.9	1.9	Low road maintenance; many roads near water courses; many tanks present; high insect and disease.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Dent and Sayer Tank	37240	17762	19478	48	52	2.1	2.5	1.7	2.1	2.2	2.1	2.1	Moderate to high burn severity - Pumpkin Fire 2000; fire regime departed from reference condition; low road maintenance; high noxious weed infestation (bull thistle).
Devil Dog Canyon	11201	5038	6163	45	55	1.8	1.5	1.7	2	1.6	1.8	1.8	Low road maintenance; many tanks present.
Dog Knobs Lake	20137	1885	18252	9	91	1.5	1.5	1	1.7	1.6	1.5	1.5	Low road maintenance; many roads near water courses.
Dogtown Wash	11669	6645	5024	57	43	2	1.5	2	2.2	2	2	2	Fire regime departed from reference condition; high road density; low road maintenance; cinder pits and septic systems present; many tanks; 3 wells; and 2 reservoirs present.
Fence Canyon	18317	18317	0	100	0	1.7	1.5	1.2	2.1	2	1.7		Low road maintenance.
Flagstone Tank-Partridge Creek	19740	2856	16885	14	86	1.6	1.5	1	1.9	1.6	1.6	1.6	Low road maintenance; many roads near water courses.
Flint Creek	16615	1124	15492	7	93	1.7	2.5	1	1.8	2	1.7	1.7	Fire regime departed from reference condition; low road maintenance; high insect and disease risk.
Gann Tank	9776	1850	7926	19	81	1.5	1.5	1	1.8	1.7	1.5	1.5	Low road maintenance; many roads near water courses.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Garden Tank-Partridge Creek	22794	3910	18884	17	83	1.8	1.5	1.3	2.1	1.6	1.8	1.8	Unsatisfactory soils in watershed; low road maintenance; cinder pits and quarries.
Garland Prairie	25070	14262	10807	57	43	2.4	2.5	2.7	1.9	1.6	2.4	2.4	educed flows to springs (5 springs); high road density; low road maintenance; septic systems present; many tanks; 8 wells present.
Government Prairie	20413	13198	7214	65	35	2.3	2.5	2.3	2	1.8	2.3	2.3	Reduced flows to springs (2 springs); high road density; low road maintenance; septic systems present; many tanks and 1 well present; high insect and disease risk.
Hancock Spring-House Rock Wash	20189	1554	18635	8	92	1.7	1.5	1.2	2	1.8	1.7	1.7	Unsatisfactory soils in watershed; low road maintenance.
Heather Wash (Local Drainage)	37933	21355	16578	56	44	1.6	1.5	1.5	1.8	1.8	1.6	1.6	Low road maintenance; many roads near water courses.
Hidden Lake	12522	3020	9502	24	76	1.9	2.5	1.3	2	2.1	1.9	1.9	Moderate to high burn severity - Hidden Fire 2001; low road maintenance.
House Rock Canyon-House Rock Wash	33010	19149	13862	58	42	2.1	2.5	1.5	2.2	1.9	2.1	2.1	Unsatisfactory soils in watershed; fire regime departed from reference condition; low road maintenance.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Indian Hollow	32686	30301	2385	93	7	2.5	2.5	2.7	2.3	2.1	2.5	2.5	Reduced flows to springs and riparian areas (4 springs; 4 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; many tanks present.
Jacob Canyon	32412	13448	18964	41	59	1.9	1.5	1.8	2.1	1.8	1.9	1.9	Fire regime departed from reference condition; high road density; low road maintenance; many tanks and 1 well present.
Johnson Creek	30870	14451	16420	47	53	2.4	2.5	2.7	1.9	1.6	2.4	2.4	Reduced flows to springs and riparian areas (2 springs and 42 acres of riparian habitat); high road density; low road maintenance; many roads near water courses; cinder pits present; many tanks; 1 well; and 4 reservoirs present.
Juan Tank Canyon	14237	6716	7522	47	53	1.8	1.5	1.7	1.8	1.4	1.8	1.8	High road density; low road maintenance; many tanks present.
Jumpup Canyon	36891	35825	1065	97	3	2.4	2.5	2.7	2.3	2.5	2.4	2.4	Moderate to high burn severity - Bridger Knoll Fire 1996; reduced flows to springs and riparian areas (4 springs; 73 acres of riparian habitat; fire regime departed from reference condition; low road maintenance; many tanks present; high noxious weeds infestation (Scotch thistle)

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Kaibab Wash	11292	984	10307	9	91	1.7	1.5	1.2	2.2	1.8	1.7	1.7	Unsatisfactory soils in watershed; fire regime departed from reference condition; low road maintenance; many roads near water courses.
Le Fevre Canyon	23149	12788	10361	55	45	1.9	1.5	1.7	2.2	1.9	1.9	1.9	Moderate to high burn severity - Hidden Fire 2001; Le Fevre Fire 2004; low road maintenance; many roads near water courses.
Le Fevre Ridge	7859	1638	6222	21	79	1.7	1.5	1.2	2.1	1.9	1.7	1.7	Unsatisfactory soils in watershed; fire regime departed from reference cond.; low road maintenance; many roads near water courses.
Little Red Horse Wash	27480	25772	1708	94	6	2	2.5	1.5	1.9	1.8	2	2	Low road maintenance; many roads near water courses; high insect and disease risk.
Little Spring Canyon-Kanab Creek	20731	20250	481	98	2	2.3	2.5	1.8	2.3	1.8	2.3	2.3	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (3 springs; 509 acres of riparian habitat; fire regime departed from reference condition; low road maintenance; many roads near water courses.
Lockwood Canyon	32183	4609	27574	14	86	1.5	1.5	1	1.8	1.8	1.5	1.5	Low road maintenance; many roads near water courses; high insect and disease risk.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Lookout Lakes	38735	38735	0	100	0	2.3	2.5	2.5	2	2	2.3		Reduced flows to springs and riparian areas (3 springs and 30 acres of riparian habitat); high road density; low road maintenance; many tanks present; high insect and disease risk.
Lower Coconino Wash	35541	1873	33668	5	95	1.5	1.5	1	1.8	1.6	1.5	1.5	Low road maintenance.
Lower Lee Canyon	15092	4870	10222	32	68	1.6	1.5	1.2	1.8	1.6	1.6	1.6	Watershed in proper functioning condition.
Lower North Canyon Wash	28592	2942	25650	10	90	1.7	1.5	1.2	2.1	2	1.7	1.7	Fire regime departed from reference condition; low road maintenance; many roads near water courses.
Lower Red Horse Wash	25926	3568	22357	14	86	1.5	1.5	1	1.7	1.6	1.5	1.5	Low road maintenance; many roads near water courses.
Lower Red Lake Wash	32725	2284	30441	7	93	1.5	1.5	1	1.8	1.6	1.5	1.5	Low road maintenance.
MC Canyon	21696	14419	7277	66	34	2.1	2.5	1.5	1.9	1.4	2.1	2.1	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (2 springs and 30 acres of riparian habitat); low level of road maintenance; many tanks present.
Martin Dam Draw	21830	7973	13857	37	63	2.4	2.5	2.5	2.2	1.8	2.4	2.4	Low road maintenance; many roads near water courses.
Meath Wash	37553	19870	17683	53	47	1.7	1.5	1.7	1.8	1.6	1.7	1.7	Low road maintenance; many tanks present.
Mexican Tank	18885	1747	17138	9	91	1.4	1.5	1	1.7	1.6	1.4	1.4	Low road maintenance.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Middle North Canyon Wash	17112	12718	4394	74	26	1.9	1.5	1.5	2.4	2.3	1.9	1.9	Low road maintenance.
Middle Red Horse Wash	29271	14029	15243	48	52	1.7	1.5	1.5	1.9	1.7	1.7	1.7	Low road maintenance.
Middle Spring Valley Wash	32690	8516	24174	26	74	1.6	1.5	1.3	2	1.9	1.6	1.6	Low road maintenance.
Miller Wash Headwaters	31239	13565	17674	43	57	1.9	1.5	2	2.2	2.3	1.9	1.9	Fire regime departed from reference condition; low road maintenance; many tanks; 1 well; and 1 reservoir present; high noxious weeds infestation (Bull thistle).
Moquitch Canyon	16283	16283	0	100	0	2.3	2.5	2.3	2.2	2.3	2.3		Moderate to high burn severity - Warm Fire 2006; Reduced flows to springs and riparian areas (1 spring and 8 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; many tanks present.
Nail Canyon	17609	17608	2	100	0	2.4	2.5	2.5	2.3	2.1	2.4	2.4	Moderate to high burn severity - Warm Fire 2006; reduced flows to springs and riparian areas (10 springs; 24 acres of riparian habitat; high road density; low road maintenance; many tanks present; high noxious weed infestation (cheatgrass).
North Tank	19857	2783	17075	14	86	1.6	1.5	1.2	1.8	1.6	1.6	1.6	Low road maintenance.

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Old Dent and Sayer Tank	36605	22224	14381	61	39	1.6	1.5	1.5	1.8	1.8	1.6	1.6	Low road maintenance; high insect and disease risk.
Pasture Canyon	23297	21525	1773	92	8	1.9	1.5	1.7	2.5	2.6	1.9	1.9	Unsatisfactory soils in watershed; fire regime departed from reference condition; low road maintenance; high insect and disease risk.
Peterson Flat	22717	13133	9585	58	42	1.7	1.5	1.3	2.1	1.8	1.7	1.7	Low road maintenance; many roads near water courses; high insect and disease risk.
Pigeon Canyon-Snake Gulch	40124	28641	11483	71	29	2.2	2.5	2	2	2	2.2	2.2	Reduced flows to springs and riparian areas (7 springs; 183 ac. of riparian habitat); fire regime departed from reference condition; low road maintenance.
Pitman Valley-Scholz Lake	28476	16121	12355	57	43	2.4	2.5	2.7	2	1.8	2.4	2.4	Reduced flows to springs and riparian areas (3 springs and 543 acres of riparian habitat); high road density; low road maintenance; cinder pits and septic systems present; many tanks and 7 wells present; high insect and disease.
Pleasant Valley Outlet	16223	14022	2201	86	14	1.7	1.5	1.2	2.2	2.1	1.7	1.7	High road density.
Rain Tank Wash	38503	26611	11892	69	31	1.9	1.5	1.7	2.1	1.7	1.9	1.9	Low road maintenance; many roads near water courses; cinder pits and septic systems present.

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Red Horse Wash Headwaters	19573	19410	163	99	1	1.6	1.5	1.2	2	1.7	1.6	1.6	Low road maintenance.
Rio Tank	22581	6096	16485	27	73	1.9	2.5	1.2	1.8	1.6	1.9	1.9	Low road maintenance.
Rock Canyon	24740	22985	1756	93	7	2.5	2.5	2.7	2.4	2.5	2.5	2.5	Moderate to high burn severity - Warm Fire 2006; reduced flows to springs and riparian areas (2 springs and 35 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; many tanks present.
Rock Canyon	41878	35625	6253	85	15	2.3	2.5	2.3	2.1	2.2	2.3	2.3	Fire regime departed from reference condition; low road maintenance; many tanks present; high insect and disease risk.
Saddle Canyon	25625	14930	10695	58	42	2.3	2.5	2.7	2	2.2	2.3	2.3	Reduced flows to springs and riparian areas (5 springs); fire regime departed from reference conition.; high road density; low road maintenance; many tanks present.
Saddle Canyon-Colorado River	20968	6573	14395	31	69	1.6	1.5	1.3	1.8	1.7	1.6	1.6	Moderate to high burn severity - Outlet Fire 2000; low road maintenance; septic systems present.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Sawmill Tank	13739	6853	6886	50	50	2.4	2.5	2.5	2.1	2	2.4	2.4	Reduced flows to springs (7 springs); fire regime departed from reference condition; high road density; low road maintenance; many tanks and 13 wells present; high insect and disease.
Seegmiller Canyon-House Rock Wash	24290	3709	20582	15	85	1.7	1.5	1.2	2.1	1.9	1.7	1.7	Unsatisfactory soils in watershed; fire regime departed from reference condition; low road maintenance.
Shinumo Creek (Local Drainage)	29017	4020	24997	14	86	1.9	2.5	1.5	1.8	1.9	1.9	1.9	Fire regime departed from reference condition; low road maintenance.
Slide Canyon	25883	25883	0	100	0	2.3	2.5	2	2.4	2.3	2.3		Moderate to high burn severity - Bridger Knoll Fire 1996; Slide Fire 2007; reduced flows to springs and riparian areas (4 springs; 84 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; high noxious weeds infestation.
Smoot Lake	21546	5638	15908	26	74	1.9	2.5	1.3	1.7	1.4	1.9	1.9	Low road maintenance.
South Canyon	28862	24807	4055	86	14	2	2.5	1.5	1.9	1.8	2	2	Fire regime departed from reference condition; low road maintenance.

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Sowats Canyon	39580	39579	2	100	0	2.5	2.5	2.7	2.3	2.3	2.5	2.5	Moderate to high burn severity - Bridger Knoll Fire 1996; reduced flows to springs and riparian areas (15 aprings; 129 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; many tanks present;
Tapeats Creek	27824	15075	12749	54	46	2.2	2.5	2.3	1.9	1.8	2.2	2.2	Reduced flows to springs (7 springs); fire regime departed from reference condition; high road density; low road maintenance; many tanks present.
Tater Canyon	23209	23123	85	100	0	2.4	2.5	2.3	2.4	2.3	2.4	2.4	Moderate to high burn severity - Point Fire 1993; reduced flows to springs and riparian areas (3 springs; 15 acres of riparian habitat); high road density; low road maintenance; many tanks; 1 well.
Trail Canyon	11607	11532	75	99	1	2	1.5	2	2.3	2.2	2	2	Moderate to high burn severity - Warm Fire 2006; fire regime departed from reference condition; high road density; low road maintenance; many tanks present.
Tule Canyon	29883	15947	13935	53	47	2.4	2.5	2.2	2.4	2	2.4	2.4	Reduced flows to springs and riparian areas (5 springs; 58 acres of riaprian habitat); high road density; low road maintenance.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Upper Cataract Creek	25024	5506	19518	22	78	1.9	1.5	1.8	2	1.6	1.9	1.9	Unsatisfactory soils in watershed; low road maintenance; many tanks present.
Upper Coconino Wash	37797	18659	19139	49	51	1.5	1.5	1	1.8	1.7	1.5	1.5	Low road maintenance.
Upper Coyote Wash	21052	6277	14774	30	70	1.6	1.5	1.2	1.8	1.4	1.6	1.6	Low road maintenance; many roads near water courses.
Upper Hell Canyon	29263	16261	13002	56	44	2.4	2.5	2.3	2.2	1.6	2.4	2.4	Unsatisfactory soils in watershed; reduced flows to springs and riparian areas (4 springs; 113 acres of riparian habitat); high road density; low road maintenance; many tanks; 1 well; and 1 reservoir present.
Upper Lee Canyon	29556	25166	4390	85	15	1.9	1.5	1.8	2.1	2	1.9	1.9	Low road maintenance; many tanks present; high noxious weeds (leafy spurge; high insect and disease risk.
Upper North Canyon Wash	15671	15060	611	96	4	2.2	2.5	2	2	1.8	2.2	2.2	Reduced flows to springs and riparian areas (3 springs; 34 acres of riparian habitat); fire regime departed from reference condition; low road maintenance.
Upper Red Horse Wash	22321	22162	159	99	1	1.7	1.5	1.7	1.9	1.8	1.7	1.7	Low road maintenance; many roads near water courses; septic systems present; many tanks; 1 wells; and 1 reservoir present; high insect and disease risk.

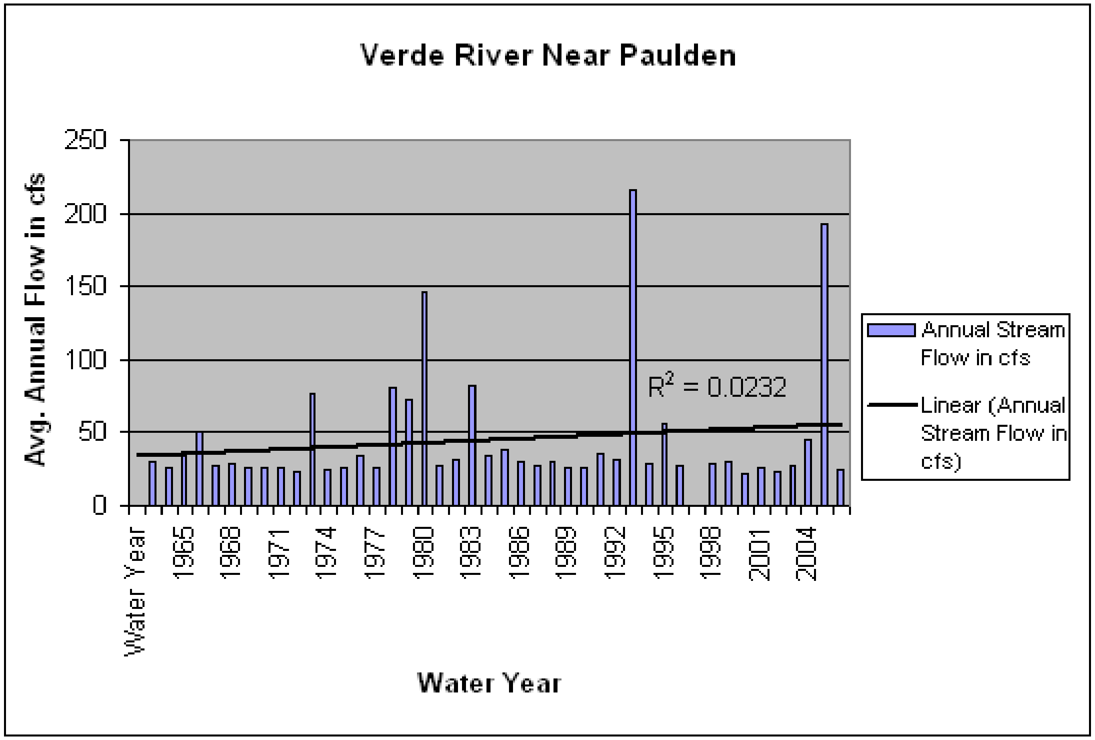
Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Upper Red Lake Wash	26945	13439	13506	50	50	2.3	2.5	2.3	2.1	1.8	2.3	2.3	High road density; low road maintenance; many roads near water courses; cinder pits and septic systems present; many tanks present; high insect and disease risk.
Upper Spring Valley Wash	38329	21080	17249	55	45	2.5	2.5	2.7	2.3	2.4	2.5	2.5	Moderate to high burn severity - Pumpkin Fire 2000; reduced flows to springs and riparian areas (5 springs; 85 acres of riparian habitat); fire regime departed from reference condition; high road density; low road maintenance; septic systems present; man
Upper Sycamore Creek	14925	10216	4709	68	32	2.3	2.5	2.5	2	1.9	2.3	2.3	Reduced flows to springs and riparian areas (2 springs; 71 acres of riparian habitat); fire regime departed from reference condition; low road maintenance; many tanks; 1 well; and 1 reservoir present.
Upper Tappan Wash	37977	6290	31687	17	83	1.6	1.5	1	2	1.7	1.6	1.6	Low road maintenance; many roads near water courses.
Warm Springs Canyon	29408	29376	32	100	0	2.4	2.5	2.7	2.2	2.3	2.4	2.4	Reduced flows to springs and riparian areas (2 springs; 17 acres of riparian habitat); fire regime departed from reference condition; many tanks present.

Subwatershed Name	Subwatershed Acres	Forest Service (FS) Acres	Non FS Acres	Percent FS Acres	Percent Non FS Acres	Overall Watershed Score	Aquatic Biological Average	Aquatic Physical Average	Terrestrial Physical Average	Terrestrial Biological Average	Watershed Score FS Average	Watershed Score Non FS Average	Watershed Condition Summary
Willis Canyon	11538	10574	964	92	8	1.8	1.5	1.3	2.2	1.8	1.8	1.8	Unsatisfactory soils in watershed; low road maintenance; many roads near water courses.

Appendix B – Streamflow Water Yield Trend

Verde River
Near Paulden
Upper Verde
River 4th HUC Latitude 34°53'42", Longitude 112°20'32" NAD27

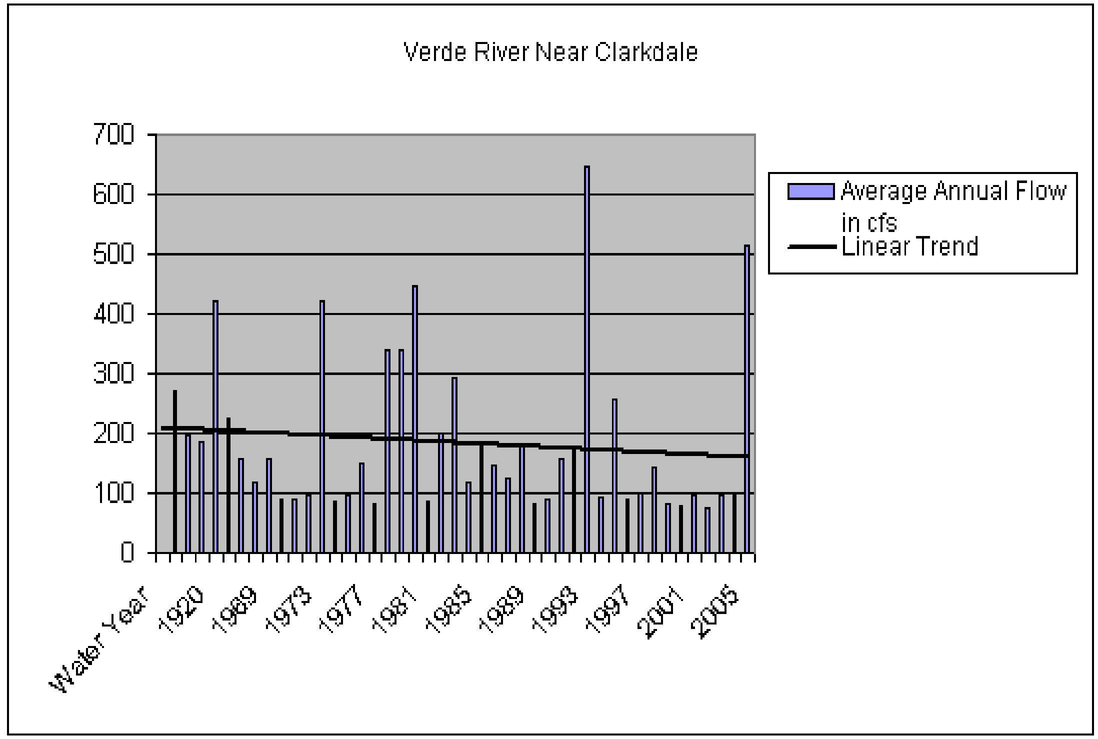
Year	Annual Stream Flow (cfs)
1963	29.6
1964	26.2
1965	33.6
1966	50.5
1967	27.8
1968	29.0
1969	26.2
1970	25.8
1971	26.2
1972	23.9
1973	76.4
1974	25.0
1975	25.5
1976	34.2
1977	25.6
1978	80.2
1979	72.1
1980	146.7



1981	26.8
1982	31.9
1983	81.4
1984	34
1985	37.6
1986	29.7
1987	28
1988	30.1
1989	26
1990	26.6
1991	35.6
1992	31.1
1993	215.2

Verde River Near Clarkdale – Upper Verde River 4th HUC

Water Year	Average Annual Flow in cfs
1917	272.8
1918	195.9
1919	186.6
1920	420.8
1966	225.4
1967	156.5
1968	116.6
1969	156.8
1970	91
1971	88.1
1972	95.9
1973	423.1
1974	84.2
1975	95.9
1976	149.5
1977	81.6
1978	339.9
1979	337.8
1980	447.6
1981	85.9
1982	199.6
1983	294.4
1984	118



1985	178
1986	145.1
1987	123.6

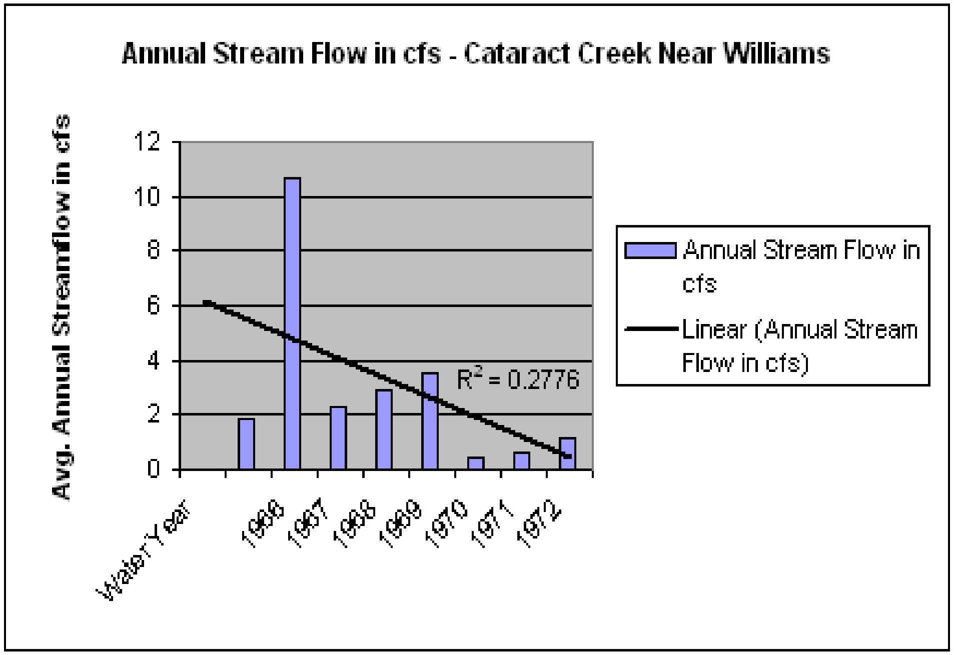
Cataract Creek Near Williams, Havasu Creek 4th HUC

Latitude 35°18'54", Longitude 112°10'42" NAD27

Annual Stream Flow in cfs

Water Year

	1.83
1966	10.7
1967	2.27
1968	2.93
1969	3.53
1970	0.474
1971	0.619
1972	1.16



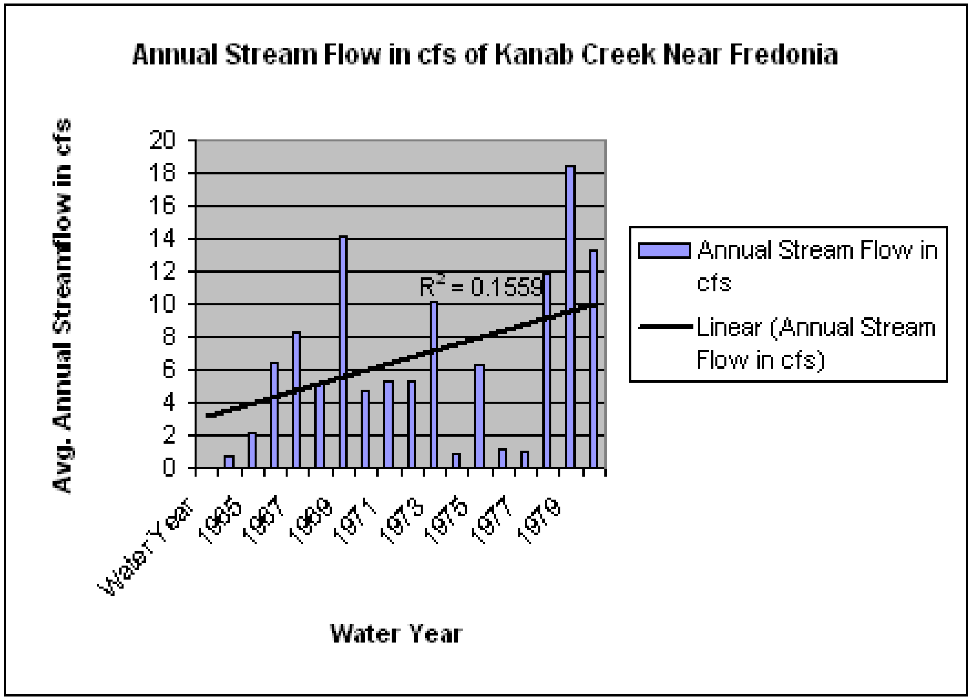
Kanab Creek Near Fredonia
Kanab Creek 4th HUC

Latitude 36°51'50", Longitude 112°34'45" NAD27

Annual Stream Flow in cfs

Water Year

	0.775
1965	2.2
1966	6.47
1967	8.27
1968	5.15
1969	14.1
1970	4.71
1971	5.35
1972	5.25
1973	10.1
1974	0.867



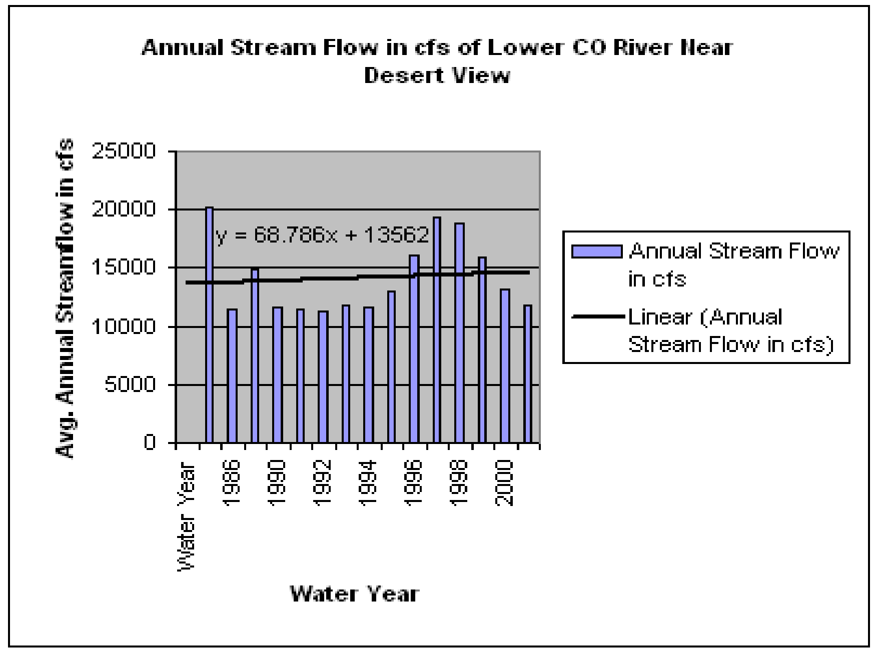
LCR Near Desert View
Lower Colorado River -
Marble Canyon 4th HUC

Latitude 36°12'08", Longitude 111°48'59" NAD27

Annual Stream Flow in cfs

Water Year

1985	20,170
1986	11,490
1989	14,940
1990	11,710
1991	11,450
1992	11,290
1993	11,770
1994	11,620
1995	13,090
1996	16,180
1997	19,330
1998	18,860
1999	15,840



2000	13,240
2001	11,730

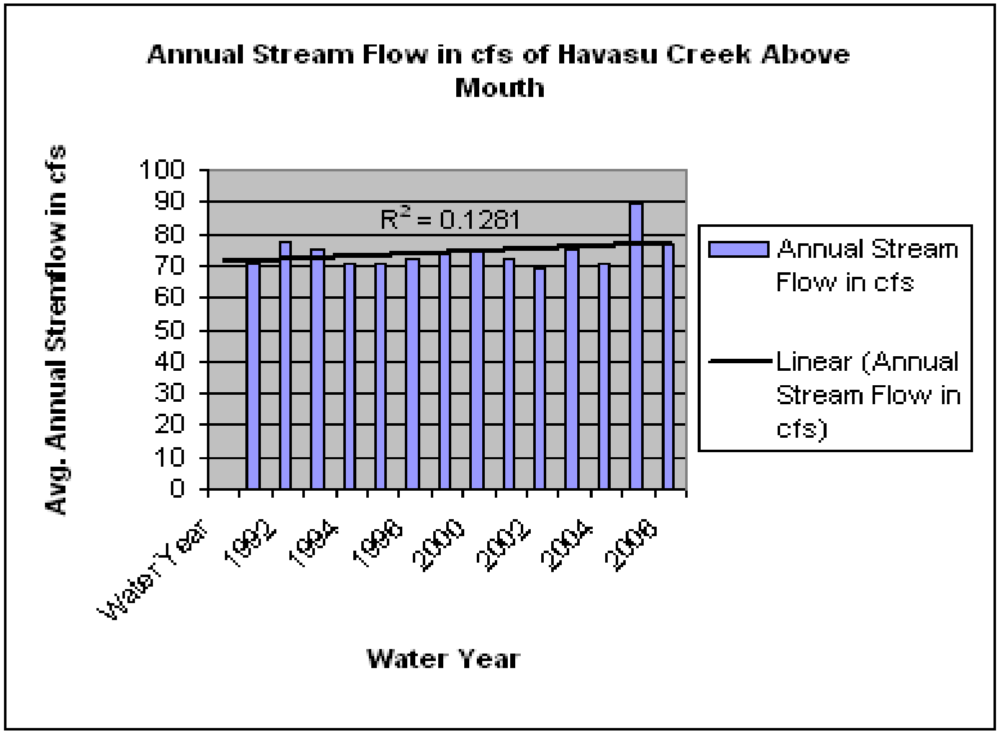
Havasu Creek above Mouth
Lower Colorado River of
Grand Canyon 4th HUC

Latitude 36°18'21", Longitude 112°45'38" NAD27

Annual Stream Flow in cfs

Water Year

1991	71
1992	77.6
1993	75
1994	70.9
1995	71
1996	72.1
1997	73.7
2000	75.2
2001	72.1
2002	69.5
2003	75.1
2004	71



Appendix C

Springs and Seeps

Table 1. Locations and conditions of known springs and seeps of the KNF. This table also presents survey/reconnaissance information regarding efforts to locate and describe sites noted as historic spring sites and sites with potential for spring occurrence where inadequate spatial information was available.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Tule north unnamed spring	NHD	-2	White Horse Lake	SKNF	403939	3879130	1911	Perennial pool in basalt tinaja with no measusrable flow. Tinaja was about 25 m long and 4-5 m wide.
Tule east unnamed spring	NHD	-2	White Horse Lake	SKNF	404225	3878249	1920	Glenn Rink explored 200 m upstream and 200 m downstream of UTMs and found no evidence of a spring.
Tule unnamed spring	NHD	-2	White Horse Lake	SKNF	403259	3878258	1891	Glenn Rink went 200 m downstream and at least 100 m upstream of UTMS and found no evidence of a spring.
Tule sw unnamed spring	NHD	-2	White Horse Lake	SKNF	402046	3878038	1893	Glenn Rink explored this canyon for 500 m upstream and 500 m downstream of the UTMS given for this spring and found no evidence of a spring.
Tule west unnamed spring	NHD	-2	White Horse Lake	SKNF	402695	3878318	1885	Glenn Rink explored the length of the short canyon where this spring is supposed to be located and found no evidence of a spring.
Lee Canyon unnamed spring	NHD	-2	White Horse Lake	SKNF	401816	3883221	2072	Glenn Rink walked from the bottom of this draw to the top and back again and found no evidence of a spring. There is an old log cabin (401692, 3882903) and a 20' steel pipe that has been washed down the draw. There are abundant elk trails, but no H_2O or H_2O improvements.
Round Mountain unnamed spring	NHD	-2	White Horse Lake	SKNF	401764	3881492	2024	Glenn Rink explored upstream and downstream 200 m both ways from UTMs given and found no evidence of a spring.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Lee Canyon unnamed spring	NHD	-2	White Horse Lake	SKNF	399470	3885608	2153	This site is depicted as two springs on the DRG, located in a meadow. During fall survey 2010, Glenn Rink found no water.
weed unnamed spring	NHD	-2	White Horse Lake	SKNF	398763	3884347	2146	There are two very large and recently built elk exclosures in this meadow. Glenn Rink found no evidence of a spring in September 2000.
Lee Canyon upper unnamed spring	NHD	-2	White Horse Lake	SKNF	398588	3884859	2139	There are two large elk exclosures in this meadow. Glenn Rink found no evidence of a spring. Two springs are depicted on the DRG, and they are included in the NHD database.
Mud Springs upper	GEO	0	May Tank Pocket	NKNF	392112	3886595	2126	This may well be a duplicate of Mud Springs that is offset.
Cane Springs south	NHD	0	Cane	NKNF	406407.9	4049349	1920	
Little Sowats lower spring	NHD	0	Sowats Spring	NKNF	369708.7	4043742.4	1806	This named spring is depicted on the DRG.
Squaw spring	LES	0	Timp Point	NKNF	384697.9	4028526.7	2443	This named spring is depicted on the DRG. Coordinates were provided by Larry Stevens.
Little Spring Canyon 1 unnamed	NHD	0	Gunsight Point	NKNF	358042.9	4055147	1391	Rheocrene spring in upper drainage of Little Spring Canyon, northwest of Little Spring.
East Rim south unnamed spring	DLG	0	Dog Point	NKNF	402853.3	4029453.3	2481	This spring is on a very steep hillslope near a footbridge.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Jumpup Canyon unnamed spring	GEO	0	Jumpup Point	NKNF	361414	4049048.2	1559	This unnamed spring is marked on the DRG and was included on the AZ State Land Office layer.
Magnum Canyon unnamed spring	NHD	0	Big Springs	NKNF	379667.9	4054100	2183	
Lower Cottonwood Spring	LES	0	Jumpup Point	NKNF	362971.7	4042837.4	1403	Coordinates for this site were provided by Larry Stevens.
Little Spring Canyon 2 unnamed	NHD	0	Gunsight Point	NKNF	358097.7	4055254.6	1401	Rheocrene spring in upper drainage of Little Spring Canyon, northwest of Little Spring.
Willow Spring	NHD	0	Gunsight Point	NKNF	363371.9	4063900.4	1462	
Indian hollow spring	LES	0	Fishtail Mesa	NKNF	361986.7	4037274.2	1496	This named rheocrene spring was visited by Larry Stevens, and is depicted on the DRG.
Little Spring S Fork unnamed	NHD	0	Gunsight Point	NKNF	357354.2	4054936.2	1410	Appears to be a small hillslope spring in a side drainage of Little Spring Canyon
Bitter Spring	NHD	0	Jumpup Point	NKNF	361045.2	4043446.9	1212	This named rheocrene spring is in a side drainage in Sowats Canyon.
Little Spring	LES	0	Gunsight Point	NKNF	358219.5	4054935.9	1470	This small named spring appears to be a rheocrene. It lies within the Kanab Creek Wilderness boundary and has a pack trail leading to it. Coordinates were provided by Larry Stevens, who visited the site in the past.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Burro Canyon unnamed spring	CFF	0	Cooper Ridge	NKNF	398360.9	4072896.3	2242	This site is at the top of a very shallow drainage. Data from Cartographic Feature File. This unnamed spring is depicted on the DRG.
Lower Two Spring	BM	0	King Arthur Castle	NKNF	382745	4025435.8	2315	This named spring is depicted on the DRG, and was included in the Brown and Moran study.
Magnum Springs 2	GEO	0	Big Bend	NKNF	380030.6	4053920.9	2181	This is one of five springs named Magnum that are depicted on the DRG.
Magnum Springs 5	DRG	0	Big Springs	NKNF	380244	4053756	2182	This is one of five Magnum Springs depicted on the DRG.
Cottonwood Spring	LES	0	Jumpup Point	NKNF	361587.7	4043445.4	1290	This site is in a wide canyon of Sowats, near Bitter Spring. It was included in Larry Stevens' survey list, but may be the wrong coordinates.
Tater Canyon Springs upper	NHD	0	Dog Point	NKNF	404131.7	4039489.6	2345	This may be a duplicate, but is shown in NHD database as a separate spring, and name indicates multiple sources.
Dry Park unnamed spring	BM	0	De Motte Park	NKNF	389417.2	4031186.2	2573	This site was included in the Brown and Moran study (1970s), but is not included on any other layer and is labeled on the DRG as "Dry Park Lakes".
Sowats Canyon upper unnamed spring	NHD	0	Jumpup Point	NKNF	363333.6	4045565.6	1414	This small unnamed rheocrene spring is in Upper Sowats Canyon.
Sowats middle unnamed	NHD	0	Sowats Spring	NKNF	369691.5	4043157.3	1816	This rheocrene spring is marked, although very lightly, on the DRG, about 330 meters upstream from Sowats Spring. It was also on the NHD database. The site was surveyed by RJ Johnson et al for Grand Canyon Wildlands Council in 2000 as Sowats B.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Lower Jumpup Spring	DRG	0	Jumpup Point	NKNF	357873.5	4044117.6	1212	This named spring is depicted on the DRG, and appears to be a rheocrene.
Table Rock Spring	LES	0	Toothpick Ridge	NKNF	369237.6	4063854.3	1617	This named spring is depicted on the DRG. Coordinates were provided by Larry Stevens.
Cane Springs north	DLG	0	Cane	NKNF	406391.8	4049420.5	1916	
Box Elder spring	LES	0	Sowats Spring	NKNF	366371.8	4045497.6	1583	This named spring is depicted on the DRG. Coordinates were provided by Larry Stevens.
Magnum Springs 3	NHD	0	Big Springs	NKNF	380045.8	4053820.7	2228	This is one of three springs named Magnum that are depicted on the DRG.
Bone Hollow unnamed hillslope	GEO	0	Jumpup Point	NKNF	365036.6	4045392	1476	This site is on the south side of the confluence of Bone Hollow and upper Sowats Canyon in the AZ State Land Office layer, but is not marked on any other layer or map.
Little Sowats upper spring	NHD	0	Sowats Spring	NKNF	369742.9	4043781.5	1822	This unnamed spring is depicted on the DRG.
Magnum Springs 1	NHD	0	Big Springs	NKNF	379949.5	4053911	2225	This is one of five springs named Magnum that are depicted on the DRG.
Upper Cottonwood Spring	LES	0	Jumpup Point	NKNF	363515.8	4042674.4	1464	Coordinates were provided by Larry Stevens.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Oak Spring	LES	0	Warm Springs Canyon	NKNF	380519.5	4059917	2053	According to the NPS, this is a perennial Spring with riparian vegetation. The coordinates were provided by Larry Stevens.
Magnum Springs 4	NHD	0	Big Springs	NKNF	380175.9	4053881.7	2183	This is one of five springs named Magnum that are depicted on the DRG.
White Spring	NHD	0	Jumpup Point	NKNF	363333.6	4045256.6	1390	This named spring is on a hillslope in upper Sowats Canyon.
Moquitch Spring	LES	0	Warm Springs Canyon	NKNF	381423.8	4054985.9	2160	This named spring appears to be a rheocrene, located in Moquitch Canyon. It is depicted on the DRG.
Andrews Spring	GEO	0	McLellan Reservoir	SKNF	385577	3891421	1997	This rheocrene spring is included in the Arizona State Land Office shapefile.
Bard Spring	GEO	0	McLellan Reservoir	SKNF	383546	3896440	2017	This spring is listed on the DRG, and included in the Arizona State Land Office shapefile.
Indian Seeps Tank	NHD	0	Sitgreaves Mountain	SKNF	400532.9	3914012.5	2045	This spring is depicted on the DRG as Indian Seeps Tank, and is included as an unnamed spring in the NHD Database.
West Elk Spring	GEO	0	Moritz Ridge	SKNF	410185.8	3915601.1	2195	This named spring is depicted on the DRG and was included in the AZ State Land Office shapefile.
Burro Spring SKNF	NHD	0	Cataract Tank	SKNF	378493.6	3918878.2	1863	This named site is depicted on the DRG.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Stewart Spring	DLG	0	May Tank Pocket	SKNF	394474.8	3885558.2	2135	This named spring is depicted on the DRG, and was included in the AZ State Land Office shapefile.
Sawmill Spring	DLG	0	Parks	SKNF	412721.6	3905386	2211	This named spring is depicted on the DRG, and was included in the AZ State Land Office shapefile.
Wild Horse Spring	DLG	0	May Tank Pocket	SKNF	393853.8	3883749.2	2048	This site is not depicted on the DRG, but was included in the AZ State Land Office shapefile.
Isham Spring	GEO	0	Davenport Hill	SKNF	405261.6	3895719.3	2079	This named site is included on the DRG, but labeled as dry.
Wade Spring	DLG	0	Sitgreaves Mountain	SKNF	405798.5	3906994.8	2148	This named spring is depicted on the DRG, and was included in the AZ State Land Office shapefile.
Verde Spring	NHD	0	May Tank Pocket	SKNF	392024.5	3877425.4	1761	This named rheocrene spring is in a main drainage in May Tank Canyon.
Clover Spring SKNF	GEO	0	Williams South	SKNF	390477.7	3899381.5	2198	This named site is depicted on the DRG.
Buck Spring	GEO	0	Davenport Hill	SKNF	404848.6	3894493.3	2087	This named site is depicted on the DRG.
Spitz Spring lower	DLG	0	Parks	SKNF	411351.7	3902378.3	2128	This spring is the lower of two named springs depicted on the DRG, and included in the AZ State Land Office layer.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Dow Spring	DLG	0	Garland Prairie	SKNF	410240.7	3890717.2	2050	This named site is located in the headwaters of Sycamore Canyon, and is depicted on the DRG.
Hat Tank lower unnamed spring	GEO	0	May Tank Pocket	SKNF	392753.9	3883968.2	2029	This unnamed site is depicted on the DRG, and is included in the NHD Database.
L O Spring	DLG	0	Garland Prairie	SKNF	410342.7	3890487.7	2041	This named site is located in the headwaters of Sycamore Canyon, and is depicted on the DRG.
Indian Spring	NHD	0	May Tank Pocket	SKNF	389996.5	3877957.5	1782	This named site is depicted on the DRG.
Laws Tank south unnamed spring	NHD	0	Squaw Mountain	SKNF	403042.2	3920665.9	2080	This site is in the NHD database, but is not depicted on the DRG, although there are several other springs in the area.
Bear Canyon upper unnamed spring	NHD	0	May Tank Pocket	SKNF	392610.5	3884714.4	2047	This unnamed spring is depicted on the DRG, and is included in the NHD database.
Lockett Spring	NHD	0	Williams South	SKNF	395020.4	3890149.2	2158	This named site is depicted on the DRG.
Ben Spring	GEO	0	May Tank Pocket	SKNF	389831.5	3878635.5	1781	This named site is depicted on the DRG.
Bennett Spring	NHD	0	Williams South	SKNF	389622.3	3899375.8	2178	This named site is depicted on the DRG.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Fues Spring	NHD	0	Williams North	SKNF	396205	3906817.8	2075	This named site is depicted on the DRG.
Klostermeyer Spring	GEO	0	Parks	SKNF	418620.5	3907146.1	2264	This named site is depicted on the DRG, on the northeast base of Klostermeyer Hill.
NE Spring	GEO	0	Parks	SKNF	410231.7	3904753.3	2184	This named spring is located near a pipeline, and is depicted on the DRG.
Mineral Spring	NHD	0	Garland Prairie	SKNF	409169.7	3900429.3	2096	Located near railroad tracks, this site is not depicted on the DRG, but is included in the NHD Database.
Pitman Valley unnamed spring	NHD	0	Davenport Hill	SKNF	405441.6	3901244.8	2098	This site is not depicted on the DRG, although there are several tanks marked in the area. It is included in the NHD Database.
Big Spring SKNF	NHD	0	Davenport Hill	SKNF	401565.6	3891102.3	2080	This named site is depicted on the DRG.
Newman Spring	GEO	0	Kendrick Peak	SKNF	421518.7	3918267.1	2581	Located at the base of the west side of Kendrick Peak, this named site is depicted on the DRG.
Laws tank north unnamed spring	NHD	0	Squaw Mountain	SKNF	403067.3	3921067.1	2092	This site is in the NHD database, but is not depicted on the DRG, although there are several other springs in the area.
Rock Spring	GEO	0	House Rock	SKNF	406376.9	4056589.6	1795	This named spring is depicted on the DRG. Coordinates were provided by the AZ State Land Office.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Campbell Spring SKNF	NHD	0	Williams South	SKNF	387432.9	3890384.5	1999	This named spring is depicted on the DRG.
McDermit Spring	DLG	0	Parks	SKNF	416944.4	3903258.2	2204	This named site is depicted on the DRG and included in the AZ State Land Office shapefile.
Beale Spring	DLG	0	Parks	SKNF	417162	3913613.1	2255	This named spring is in a shallow drainage south of Beale Mountain, near a road. It is depicted on the DRG.
Hausman Spring	GEO	0	Parks	SKNF	412462.7	3907881.2	2250	This site is not listed on the DRG, but was included in the AZ State Land Office layer.
Garland Spring	DLG	0	Garland Prairie	SKNF	409149.5	3894350.8	2052	This named site is depicted on the DRG.
Laws upper spring	NHD	0	Squaw Mountain	SKNF	403245.8	3920826.4	2073	This unnamed site is labeled on the DRG, and is one of two springs that appear to provide water to Laws Natural Tank.
Laws lower spring	NHD	0	Squaw Mountain	SKNF	403214.9	3920839.1	2072	This unnamed site is labeled on the DRG, and is one of two springs that appear to provide water to Laws Natural Tank.
Lost Spring	GEO	0	Moritz Ridge	SKNF	419995.9	3925679.1	2198	This site is included in the AZ Land Office springs layer, and is depicted as a water tank on the DRG.
Bill Williams Loop unnamed spring	NHD	0	May Tank Pocket	SKNF	387544.5	3885836.5	1982	This site is located toward the head of a canyon, is marked on the DRG, and is included on the NHD Database.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Sowats side canyon unnamed spring	NHD	0	Sowats Spring	SKNF	368015.3	4044982.2	1762	This unnamed rheocrene spring is depicted on the DRG, and is included in the NHD Database.
Holloway Spring	DLG	0	White Horse Lake	SKNF	400846.8	3886007.1	2100	This named site is depicted on the DRG.
Triangle Spring	NHD	0	Garland Prairie	SKNF	412722.6	3892376.1	2059	This site is not shown on the DRG.
Ross Spring	GEO	0	Davenport Hill	SKNF	407214.7	3896187.3	2081	This named spring is depicted on the DRG, and labeled as dry.
Twin Springs Rd unnamed spring	DLG	0	Williams South	SKNF	389262.9	3892428.5	2149	This unnamed spring is depicted on the DRG, and was included in the AZ State Land Office shapefile.
Stage Tank spring	GEO	0	Matterhorn	SKNF	384322.1	3884370.5	1969	This spring is included in the AZ State Land Office layer, and is depicted as Stage Tank on the DRG.
Hat Tank upper unnamed spring	NHD	0	May Tank Pocket	SKNF	393294.6	3884260.2	2059	This unnamed site is depicted on the DRG, and is included in the NHD Database.
Kaufman Spring	DLG	0	Parks	SKNF	410192.6	3907411.5	2229	This named spring is depicted on the DRG.
Summitt Spring	NHD	0	May Tank Pocket	SKNF	395945.6	3887395.4	2214	This named site is depicted on the DRG, and may merge from more than one source.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Spitz Spring upper	NHD	0	Parks	SKNF	411371.7	3902461.2	2130	This spring is the lower of two named springs depicted on the DRG, and included in the AZ State Land Office layer.
Twin Springs	GEO	0	Williams South	SKNF	388449.5	3892395.5	2129	This named site is depicted on the DRG, and is included in the AZ State Land Office layer.
Mud Springs	NHD	0	May Tank Pocket	SKNF	391853	3886434	2115	This named site is depicted on the DRG.
Miller Seep Tank	NHD	0	Tusayan East	TKNF	403599	3971917	2009	This named site is depicted on the DRG.
Tilton Springs	LES	1	Warm Springs Canyon	NKNF	380168	4057883		
Horse Spring	LES	1	Gunsight Point	NKNF	359593	4057192		
North Canyon Spring upper	BM	1	Dog Point	NKNF	402735.2	4028586.6	2513	Uppermost of three springs in the North Canyon drainage. This is a small hillslope spring emerging from a steep colluvial slope and flowing about 4 m into North Canyon Creek at base of Coconino formation.
East Rim south lower unnamed	BM	1	Dog Point	NKNF	403034.2	4029664.1	2349	This spring is on a very steep hillslope near a footbridge. This may be a duplicate of East Rim South.
Slide Spring west unnamed	NHD	1	Gunsight Point	NKNF	360063.1	4058089.4	1396	

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Pigeon Spring	NHD	1	Gunsight Point	NKNF	365212	4065329	1506	
South Canyon Spring	LES	1	Little Park Lake	NKNF	406906.7	4021960.2	2569	This is a rheocrene spring, visited by Larry Stevens.
Lookout Lakes unnamed spring	BM	1	De Motte Park	NKNF	393684	4036193.7	2668	This site is not listed as a spring on any other layer, but was included in the Brown and Moran study, listed as a spring.
Lower Two Spring 1	LES	1	King Arthur Castle	NKNF	382711.9	4025471.6	2316	The coordinates were provided by Larry Stevens. This may be a duplicate of a spring depicted on the DRG, although it is called Two Spring.
North Canyon Spring middle	BM	1	Dog Point	NKNF	402776.1	4028587.9	2534	This is the middle of three springs in a steep area of North Canyon, visited by Larry Stevens and included in the Brown and Moran study.
Locust Spring	BM	1	Timp Point	NKNF	384679.3	4029086.9	2452	Possibly a hillslope spring at the end of a FS road in Locust Canyon. Included in Brown and Moran study.
Sowats Upper Unnamed Spring	NHD	1	Sowats Spring	NKNF	369708.3	4042979.1	1828	This Rheocrene spring is marked very lightly on the dRG, in the upper reaches of the same drainage as Sowats Spring, about 550 meters upstream. We believe this was surveyed by RJ Johnson et al for Grand Canyon Wildlands Council in 2000 as Sowats A.
Bear Spring lower	LES	1	Kanabownits Spring	NKNF	394579	4025565.5	2658	This is a rheocrene spring, visited by Larry Stevens.
Spring Canyon 2 unnamed	BM	1	Kanabownits Spring	NKNF	393840	4023811.2	2607	This is a rheocrene spring in Spring Canyon, included in Brown and Moran study.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Bear Spring	BM	1	Kanabownits Spring	NKNF	394738.2	4025619.6		This is a rheocrene spring, included in Brown and Moran study.
Slide Spring	LES	1	Gunsight Point	NKNF	360362.3	4058063.5	1491	The coordinates were provided by Larry Stevens. Brian Healy also visited the site in August 2009.
Lower Jumpup Spring below	NPS	1	Jumpup Point	NKNF	357966.7	4043971.9	1195	We have no coordinates for this site, but it is said to be below Lower Jump-up Spring, and was surveyed by Brian Healy in August 2009.
Oquer Spring	LES	1	Warm Springs Canyon	NKNF	388745.9	4042990.3	2536	According to the NPS, this named spring has little or no riparian vegetation. It is depicted on the DRG.
pair springs south unnamed	BM	1	De Motte Park	NKNF	392208.1	4034947.2	2678	These are likely two springs, as they were both included in the Brown and Moran study. They are in a relatively low gradient area, and are not marked on the DRG, nor are they included on any other layer.
Riggs Spring	NHD	1	Big Springs	NKNF	381266.4	4047111.5	2264	According to the USFS, this is a perennial Spring with riparian vegetation. This named spring is depicted on the DRG.
pair springs north unnamed	BM	1	De Motte Park	NKNF	392062.2	4035051.4	2674	These are likely two springs, as they were both included in the Brown and Moran study. They are in a relatively low gradient area, and are not marked on the DRG, nor are they included on any other layer.
Wildband Spring	NHD	1	Gunsight Point	NKNF	365178.1	4064476.4	1557	

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
East Rim hillslope unnamed	BM	1	Dog Point	NKNF	402272.9	4029844.4	2628	This spring, located on a very steep slope near the East Rim viewpoint, was included in the Brown and Moran study.
Rosilda Spring	GEO	1	Big Springs	NKNF	403247	3892979.7	2047	According to the USFS, this is a perennial Springs with riparian vegetation. This named spring is depicted on the DRG.
Burro Spring	NHD	1	House Rock Spring	NKNF	4025323	4075002	1937	
rocky Tule spring unnamed	NHD	1	White Horse Lake	SKNF	397604	3879880	2012	The spring has been heavily manipulated, with a vertical pipe about 20 inches in diameter. Glenn Rink surveyed the site in September 2010.
East Elk Spring	GEO	1	Moritz Ridge	SKNF	410308.3	3915233.1	2219	This named spring, depicted on the DRG, was said to be a perennial spring with riparian vegetation, but the spring was dry during a USFS 2008 survey.
Upper McDermit Spring	DLG	1	Parks	SKNF	416890.9	3903774.2	2207	According to the USFS, this spring has little or no riparian vegetation.
Lower McDermit Spring	DLG	1	Parks	SKNF	416544.5	3902040.7	2177	According to the USFS, this spring has little or no riparian vegetation. This named spring is depicted on the DRG.
Bear Springs	NHD	1	May Tank Pocket	SKNF	392428.7	3883313.9	2013	According to the NPS, this is a perennial Spring with riparian vegetation. This named spring is depicted on the DRG.
McDougal Spring	DLG	1	Williams South	SKNF	398254.9	3888183.8	2141	According to the USFS, this named spring, depicted on the DRG, has little or no riparian vegetation.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Hitt Spring	NHD	1	White Horse Lake	SKNF	401783.5	3885959.1	2096	According to the NPS, this is a perennial Springs with riparian vegetation. This named spring is depicted on the DRG.
Little Spring SKNF	GEO	1	Parks	SKNF	412937.7	3907077.2	2234	This named spring is on the north base of Wright Hill. It is depicted on the DRG, and was included in the AZ State Land Office shapefile.
Calcord Spring	NHD	1	Sycamore Point	SKNF	411067	3882166	1928	This is likely an excavated spring that forms a perennial pool. According to Glenn Rink, the pool supported frogs, bullfrogs, and fish; he also found several more pools within 200 m upstream from the site.
Willow Spring SKNF	DLG	1	Davenport Hill	SKNF	406333	3888376	1980	This is a small pool-forming perennial spring, emerging from a basalt ledge orifice. Glenn Rink confirmed the site in September 2010.
Upper Two Spring	LES	2	King Arthur Castle	NKNF	383482	4025215	2377	
Mourning Dove Spring	NHD	2	Big Springs	NKNF	379325.6	4053230.9	2208	
Crane Lake	LES	2	Telephone Hill	NKNF	397074.9	4043349.2	2605	
Mountain Sheep Spring	LES	2	Jumpup Point	NKNF	359593	4043126	1130	Two small gushets and additional seepage flow from the contact at the base of the Supai Wescogame formation on creek right. This is the main source; an additional seepage emerges upstream in the channel, and in the colluvial hillslope (D) immediately upslope from the gushets.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Castle Spring	NHD	2	Big Springs	NKNF	379981.8	4049754.9	2191	
Franks Lake	RNK	2	Telephone Hill	NKNF	394102	4041560.9	2641	This is a limestone spring that emerges in a lake in a meadow.
North Canyon Spring all	DLG	2	Dog Point	NKNF	402768.3	4028617.2	2508	All three North Canyon springs (Upper, Middle, and Lower) were surveyed as one site by Larry Stevens (Grand Canyon Wildlands Council) in 2000.
Watts Spring	LES	2	Timp Point	NKNF	385567.6		2442	Small contact spring, visited by LES
Pasture Spring	LES	2	Timp Point	NKNF	383577.4	4026594.2	2386	Contact/fracture spring; surveyed by Larry Stevens and included in Brown and Moran study.
Timp Spring	GEO	2	Timp Point	NKNF	383778.1	4027746.6	2416	This named spring was surveyed by RJ Johnson et al in 2000. This site has been heavily manipulated with a concrete spring box and troughs.
Parissawampitts Spring	GEO	2	Timp Point	NKNF	381964	4030562	2364	This spring has been enclosed in a concrete box. The site was surveyed by RJ Johnson et al. for Grand Canyon Wildlands Council in 2000.
Larkspur unnamed springs	BM	2	Dog Point	NKNF	403129	4028925.7	2376	This site was surveyed by Larry Stevens in 2000, and included in Brown and Moran study.
Crystal Spring	NHD	2	Dog Point	NKNF	401709.5	4027668.7	2682	The site is located on an east facing slope. The flow is captured by a pipe into a spring box. The site contains perennial Springs with riparian vegetation. It was surveyed in 2000 by Larry Stevens et al (Grand Canyon Wildlands Council), and in 2010 by Barb Phillips, Glenn Rink, and others.

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
North Canyon Spring lower	BM	2	Dog Point	NKNF	402804.6	4028652.6	2485	This spring is the lowermost of three in a steep area of Upper North Canyon, visited by Larry Stevens and included in the Brown and Moran study. The slope above the spring is 44 degrees.
Warm Springs	NHD	2	Warm Springs Canyon	NKNF	382799.6	4061787.1	2109	Springs with little or no riparian vegetation. The spring source is diverted for private use.
Tater Canyon Springs	BM	2	Cane	NKNF	404241.7	4039404.3	2260	Site was visited by LES et al in 2005 for Grand Canyon Wildlands Council, and was included in Brown and Moran study.
Sowats Spring	LES	2	Sowats Spring	NKNF	369705	4043437	1835	This spring was surveyed by RJ Johnson et al for Grand Canyon Wildlands Council in 2000.
Quaking Aspen Spring	LES	2	Timp Point	NKNF	384954	4026664	2372	
Big Spring	GEO	2	Big Springs	NKNF	379355.5	4051596.3	2150	This is a contact seepage gushet emerging from the base of the Coconino sandstone and flowing 50 m down a steep talus slope to a NFS station and pond. Larry Stevens has visited this site 3 times, and completed a comprehensive survey in 2005 with RJ Johnson.
Bee Spring	DLG	2	Timp Point	NKNF	381870.6	4034743.7	2388	This named spring was surveyed by RJ Johnson et al (Grand Canyon Wildlands Council) in 2000. The site has a well, 1.22 m in diameter, with corrugated metal around concrete.
Dog Lake	LES	2	Dog Point	NKNF	401648.3	4027641.8	2682	

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Rock Spring Lower	GEO	2	Gunsight Point	NKNF	359506	4060936	1328	This spring provides the main source of flow in Snake Gulch. It was surveyed by Larry Stevens in 11/2009.
Rock Spring Upper Bowl	LES	2	Gunsight Point	NKNF	359561	4060945	1345	Seeping walls in an overhang contact, cemented colluvium in a limestone horizon in Hermit Shale.
Jumpup Spring	LES	2	Jumpup Point	NKNF	361543	4049463	1547	This named spring is depicted on the DRG.
Bear Lake	LES	2	Kanabownits Spring	NKNF	397114.2	4025626.9	2775	
Murrays Lake	LES	2	Jacob Lake	NKNF	394897.9	4054579.5	2598	
27 Mule Spring	USG	2	Jumpup Point	NKNF	361590	4040837	1379	This tiny rheocrene seep emerges under a Gooddings willow 100 m SE of the larger stand of fremont cottonwood that is conspicuous at the site. Larry Stevens surveyed the site in the fall of 2009.
Camp Navajo pipe unnamed spring	NHD	2	Bellemont	SKNF	421660.6	3899092.9	2167	This spring is marked on the DRG and included in the NHD Database. It is in a heavily developed area within the military reservation boundary. This is a piped spring that emerges under a gravel road and flows into two troughs, then 50 m into a LGC.
West Lake (east)	LES		Sowats Spring	NKNF	376515.9	4043013.6	2293	
West Lake (west)	LES		Sowats Spring	NKNF	376515.9	4043013.6	2294	

Site Name	Data Source	Inventory Level	Quad Name	District	UTM East	UTM North	Elevation (m)	Site Description
Deer Lake	LES		De Motte Park	NKNF	398587.8	4029158.9	2652	Check to see if this is spring-fed, or at least partially so
North Kaibab Ranger District	92							
Tusayan	1							
Williams	74							
Total		167						
Inventory Level								
-2 Dry at time of survey	10							
0 Not verified	91							
1 Verified, not surveyed	35							
2 Some survey data	28							
May not be spring-fed	3							
Total		167						