Chapter 2. Anthropogenic Influences – Landscape Scale

Water Uses – ARW Landscape Scale

Key Findings

- In the Colorado River Basin, lands with annual precipitation levels greater than 20 inches per year provide the greatest levels of storage and spring run-off. *These upland areas are largely under the management of the Forest Service.*

- The Colorado River integrates and reflects natural and anthropogenic disturbances, *transmitting influences of disturbance and use downstream*.

- In the Upper Colorado River Basin, total water uses have been estimated by the USGS to be over 11 million gallons per day amounting to about 12 million acre feet per year.

- Water users in the Lower Colorado River Basin use more water than is available within the lower basin. Thus *Lower Basin communities have great interest in Upper Basin water uses and they have prerogative based in law and president*.

- In USGS data, ignoring export and evaporation, *irrigation accounts for over 90% percent of the consumptive water use in the Upper Colorado River basin.* Another 5% percent of water use is applied to public use and the remainder is nearly evenly between Industrial uses and power generation.

- *According to BOR data, agriculture, export and evaporation account for about 95% percent of water withdrawals from the Colorado River*. The remaining five percent are applied to power production, public use and minerals.

- Colorado River water withdrawals in the Upper Colorado basin are trending upward. Increases are principally in irrigation, public use, industry, and power generation. *One report estimates increases of about 1% per year to 2040* and this growth correlates to population growth.

- Allocation of Colorado River waters under the 1922 Compact are based on assumptions about yearly flows that appear to have been made when the river was near the maximum long-term historical flow levels rather than normal/average. Consequently, flows may well fall short of assumptions and allocations in coming years.
- There are 1,027 NID dams in the Upper Colorado River Basin. Pools behind these dams cover 434,800 acres, and drain 172,695 square miles. The combined storage is over 45 million acre feet.

- ***While the ARW Landscape area represents about 19.6% of the area of the Upper Colorado River Basin, on average, about 36.5% percent of the flow from the Upper Colorado River Basin*** can be attributed to flows originating in the ARW Landscape.

- There are 423 NID dams in the ARW Landscape. These cover over 44 thousand acres and drain an area of almost 15 thousand square miles. They store almost 3.2 million acre feet of water. The 423 dams represent about 41% percent of the total dams count in the Upper Colorado River Basin.

- The Lower Gunnison (14020005), Colorado Headwaters Plateau (14010005), North Fork Gunnison (1402004) and Mancos (14080107) 4th level watersheds have the highest ratios of number of dams per stream mile in the ARW Landscape.

- Streams systems flowing from the Grand Mesa have been altered by dams have been in place since the late 1800s up to the 1920s.

- The McElmo (14080202), Colorado Headwaters Plateau (14010005), Uncompahgre (14020006) and San Miguel (140030003) 4th level watersheds have the highest ratios of number of miles of diversion per stream mile in the ARW Landscape.

- There are eight trans-mountain diversions that carry water from five watersheds of the ARW Landscape to the Arkansas and Rio Grande River Basins. These diversions export 6,210 acre feet of water per year.

Introduction – The Upper Colorado River Basin

The ARW Landscape is perched along the eastern uplands and high watersheds of the Upper Colorado River Basin (Figure 1). These uplands receive abundant precipitation and they offer important natural storage with spring and summer run-off that contribute significantly to flows and ecologic function in the Colorado River overall.

Waters flowing from the Landscape join the Colorado River main-stem at the confluences of the Gunnison, Dolores and San Juan Rivers. These waters join the Green River, and flow downstream, through the Grand Canyon, to the Lower Colorado River Basin. The ARW Landscape covers about 19.6% percent (22,212 square miles) of the Upper Colorado River Basin (113,583 square miles).

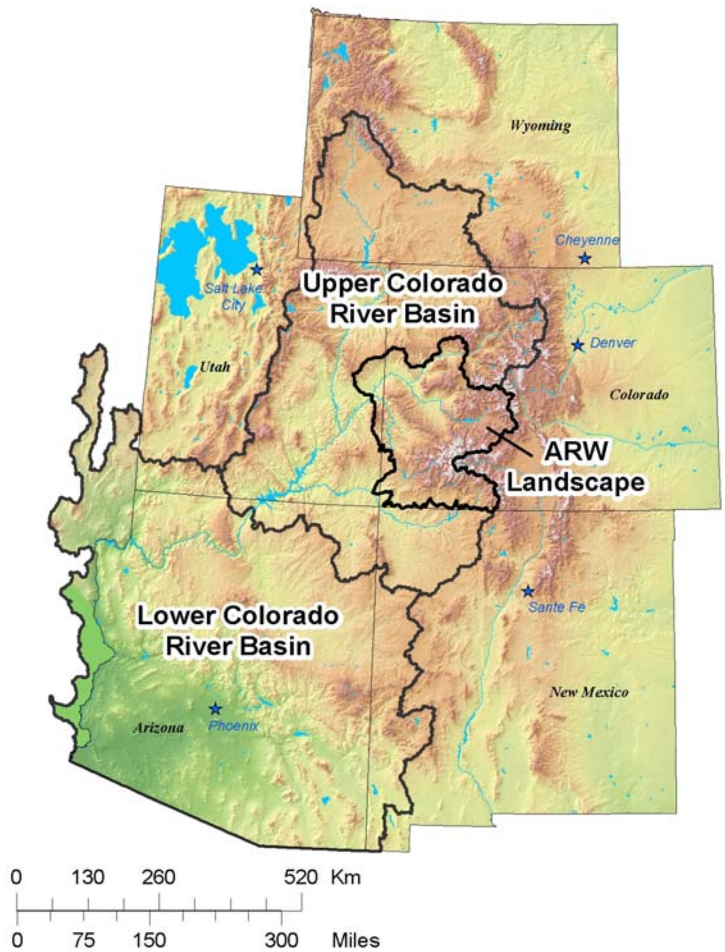

Figure 1 The ARW Landscape Scale is comprised of watersheds entirely within the Upper Colorado River Basin. Waters originating in the Landscape Scale contribute significantly to the Colorado River flow and ecosystem function. The Landscape covers just under 20% percent of the Upper Colorado River Basin.

In the Upper Colorado River Basin, land use and management decisions can not be viewed as purely local as they will be mirrored downstream to the degree that they degrade or improve the river and its flow and volume. In both the Upper and Lower Basins, the influence of the Colorado River on both ecological and human systems is difficult to overstate but may not always be fully appreciated. First, the river is ecological driver at a regional scale. It is an important conveyor of biological materials and energy and provides a rich wet corridor connecting major physical features in the arid southwest. Secondly, in modern times, with surging human populations and demands, the river has been drafted into community service for irrigation, municipal and industrial purposes, power generation, mineral extraction, livestock and recreation. These benefits have come at the expense of ecological and biological function.

Rivers and streams act as integrators of broad environmental conditions and reflect landscape condition (Neiman and Bilby, 1998). Natural disturbances such as precipitation events, seasonal change and disturbance events, such as fire and flood, create natural pulses in river volume, composition and other physical characteristics. These pulses drive changes in river level, temperature, nutrients and energy and drive plant and animal reproduction, movement and activity.

Likewise, the effects of human land and water use are integrated and transmitted downstream by rivers. Channel entrenchment, sediment infilling, tamarisk invasion, loss of almost 50% percent of riverside vegetation and concentrations of salts and pesticides from irrigated agriculture throughout the Basin are reflected in flow volumes, water quality and living communities downstream from these human induced influences (Wohl, 2004).

Just as the river transmits management effects downstream, a well developed historical, legal and treaty framework among Basin States and between the U.S. and Mexico transmits demands and requirements back upstream.

Collectively the *law of the river* or *Colorado River Compact of 1922* along with subsequent agreements, acts and court rulings provides a framework defining the Upper and Lower basins and allocation of water to users in the seven western states. This framework ensures delivery of water supplies to Mexico along with the large and growing metropolitan areas in the arid lower basin including Phoenix, San Diego and Los Angeles.

In the Lower Basin, growth combined with an arid climate drive consumptive use beyond renewable supply in the Lower Basin (Figure 2). In other words, the system has little resilience allowing up stream users discretion in water uses beyond the waters allocated to the upper basin.

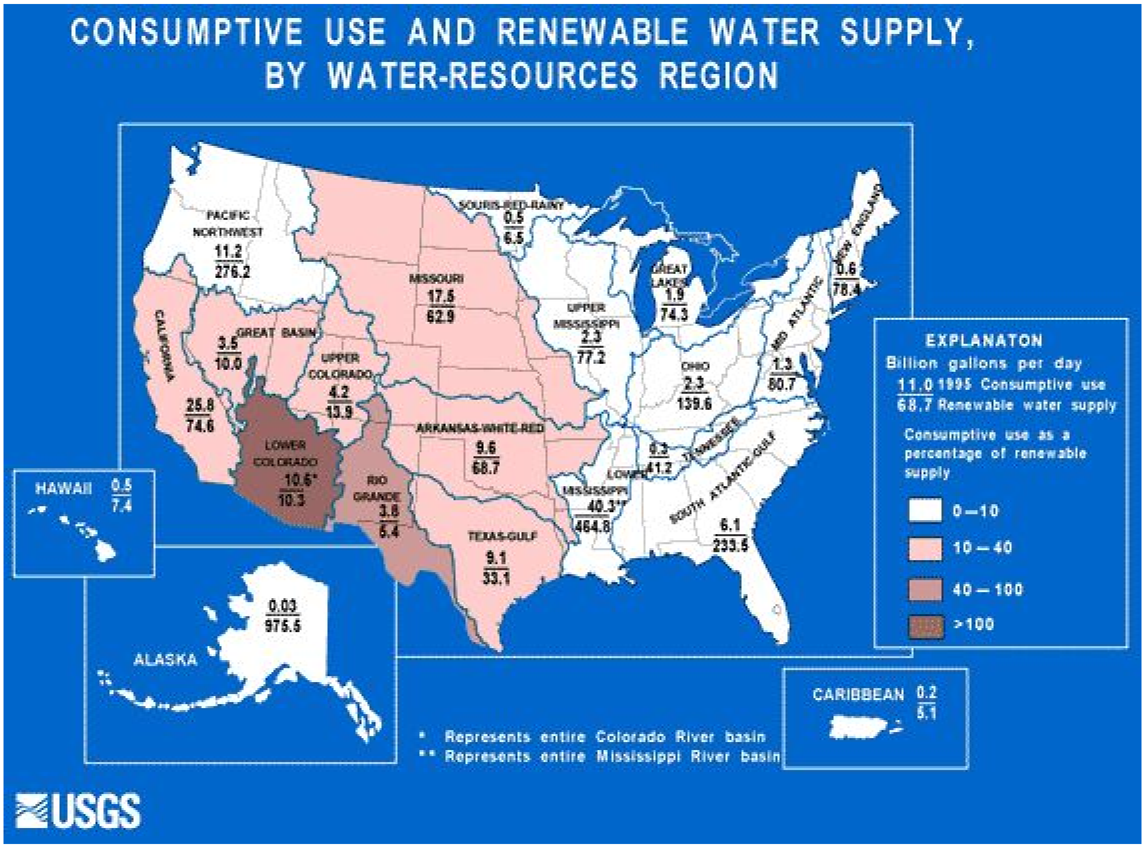

Figure 2 Comparisons of average consumptive use and renewable water supply for the 21 water-resources regions of the United States, Puerto Rico, and U.S. Virgin Islands. The Lower Colorado Region ratio of consumptive use to supply exceeds that of all other regions in the U.S. Reproduced from USGS, 1984.

The 1922 Compact apportions waters to the Upper and Lower Basins. Each year the Lower and Upper Basins may apply up to 7.5 million acre feet (maf) each to consumptive use. An additional 1.5 maf per year are to be delivered to Mexico under a 1944 treaty between the U.S. and Mexico. Overall, these allocations sum to 16.5 maf per year. Currently, demands in the Lower Basin add up to 8.0 maf and depend upon surpluses in the system. The Upper Basin demands are approaching 5.0 maf per year leaving about 2.5 million acre feet available to downstream Lower Basin and Mexican users. Demands in the Upper Basin continue to increase with growth of local communities, industry and business. (Kuhn, 2005 and CRWUA, 2005)

Moreover, recent drought conditions in the western states have placed greater downstream dependence on the winter storage capabilities of uplands in the upper reaches including the important uplands of the ARW Landscape (Kuhn, 2005).

It may be unfortunate that these river allocations to both the Upper and Lower Basins under the 1922 compact were made at a time when flows were near historical highs (Figure 3). Eventual returns to dry periods with flows in the neighborhood of 13 maf paired with continued increases in population and hence demand will strain the limits of existing agreements and water user's abilities to conform to them. It seems reasonable then to anticipate that users will turn to public land mangers to maximize storage and output of water from public lands.

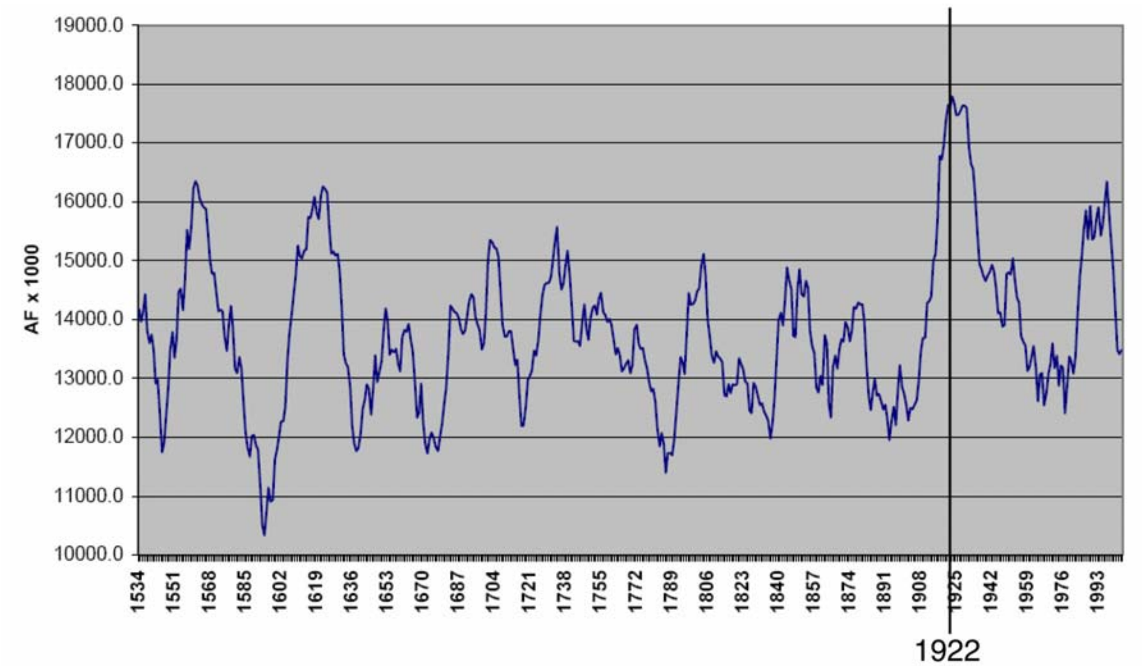

Figure 3 Un-depleted Colorado River Flow at Lee's Ferry, running 30 year average from 1534 to 2004. Flows are estimated from tree ring analysis. Note that the 1922 water compact was developed at a historical high. Graph reproduced with permission (Kuhn, 2005).

Precipitation

Annual precipitation in the Upper Colorado River Basin ranges from less than one up to fifty-six inches (Figure 4) (Daly and Gibson, 2002). Very low precipitation regimes, i.e., from 1 to 25 inches per year, occur throughout the desert table and badlands of the Colorado Plateau and dry basins of western Wyoming. Upland areas in northwestern Wyoming, north-central Utah and western Colorado have wetter precipitation levels from 25 to 56 inches per year. Over the year, these uplands capture significant levels of moisture from winter frontal air masses carrying moisture from the west and northwest during winter months and from the southwest during summer monsoons (USGS, 2004a).

Capture and storage of winter precipitation in uplands/headwaters areas is an important factor in maintaining downstream flows volumes and quality, especially during summer months. The importance of upland storage is highlighted by warming trends and drought. Conversely, warming trends also lead to accelerated spring runoff. Consequently, land-use decisions must therefore be aimed at maintaining, if not improving, upland storage capacity.

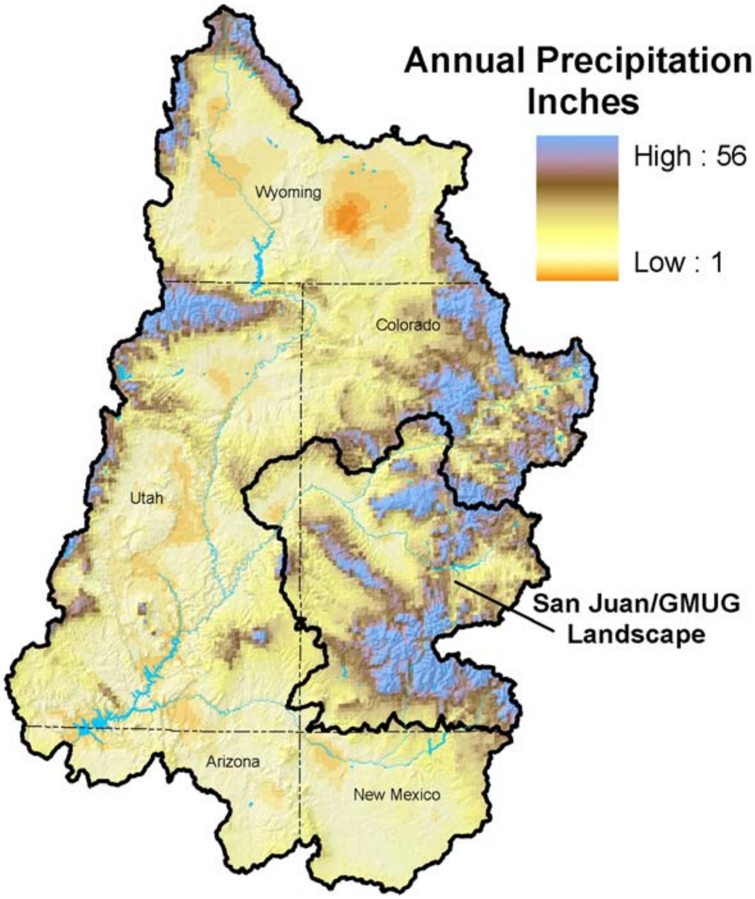

Figure 4 Average annual precipitation in the Upper Colorado River Basin.

The ARW Landscape embraces an important proportion of lands able to ensure consistent winter storage and spring/summer runoff. While comprising 19.6% percent of the area of the Upper Basin, the Landscape contains proportionately more area in precipitation regimes from 15 to 45 inches per year (Table 1). Generally those areas with precipitation levels greater than 20 inches accumulate winter snow for release through the spring and summer months. To reiterate then, management within these lands must be considerate of needs and situations and legal requirements far beyond their bounds. The bulk of this management falls on the shoulders of the U.S. Forest Service. These lands contained within the 20 inch precipitation contour correspond almost exactly to lands managed by the Forest Service (Figure 5).

Table 1 Upper Colorado River Basin and ARW Landscape annual precipitation by interval and the area covered by each interval. Subtracting percentages indicates relative contribution of the ARW Landscape to the Upper Colorado Basin.

Average Annual Precipitation Group	Upper Basin Area in PPT Group (Sq. Miles)	Percent of Upper Basin in Class	ARW Landscape Area in This PPT Group (Sq. Miles)	Percent of ARW Landscape in PPT class	Subtract Pct. of Upper from Pct of ARW
0-5	32,661	28.8%	945	4.3%	-24.5%
10-15	39,619	34.9%	5,572	25.1%	-9.8%
15-20	18,841	16.6%	7,038	31.7%	**15.1%**
20-25	10,376	9.1%	3,942	17.7%	**8.6%**
25-30	6,522	5.7%	2,393	10.8%	**5.0%**
30-35	3,443	3.0%	1,518	6.8%	**3.8%**
35-40	1,507	1.3%	674	3.0%	**1.7%**
40-45	382	0.3%	110	0.5%	**0.2%**
45-50	147	0.1%	15	0.1%	-0.1%
50-55	61	0.1%	3	0.0%	0.0%
55-60	23	0.0%	0	0.0%	0.0%
	113,583	100.0%	22,212	100.0%	0.0%

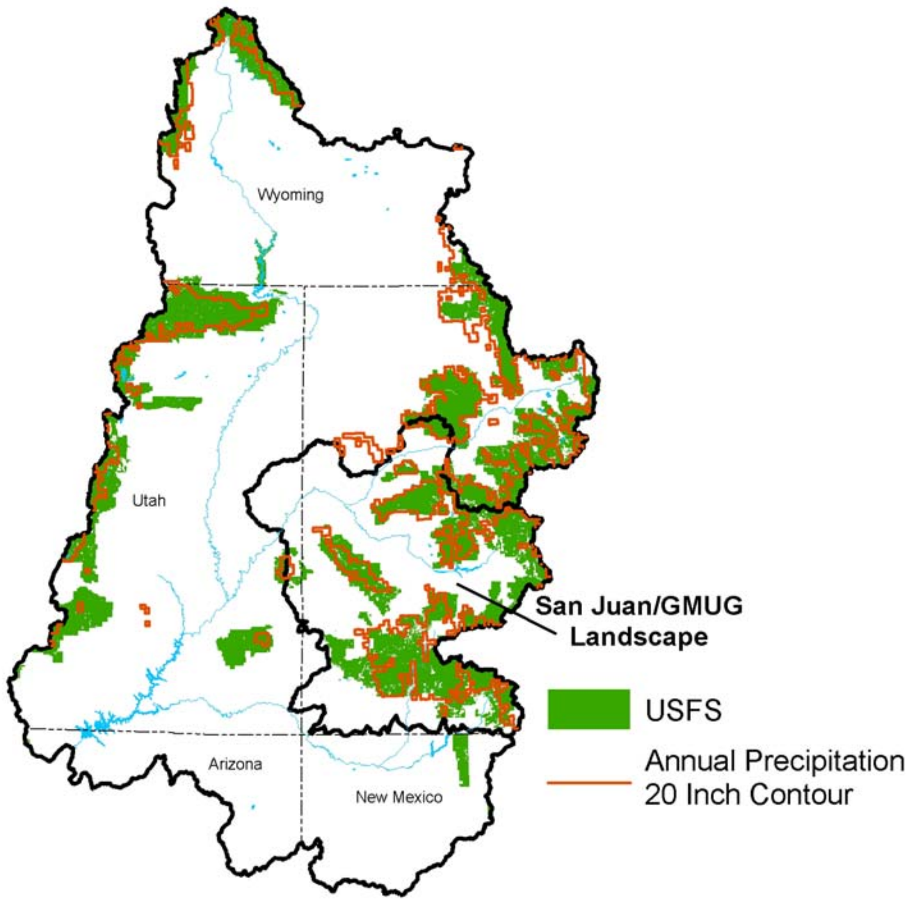

Figure 5 In the Upper Colorado River Basin, lands with 20 inches or more of rain annually correspond very strongly to the lands managed by the U.S. Forest Service. These lands have the greatest potential for winter storage.

Geography of Water Use by County

Both the U.S. Geological Survey (USGS) and the Bureau of Reclamation (BOR) report on the volumes of water in the Upper Colorado Basin. The USGS reporting is useful for identifying geographic patterns of use in the Basin while the BOR reports are indicative of changes through time.

The USGS 2004 report for U.S. water use in the year 2000 includes summaries of public supply, industrial, irrigation and power generation uses by county (Hutson et al. 2004). The report lists volumes in millions of gallons per day (Mgal/d) by source including ground-water, surface-water, and saline withdrawals. As a consequence, the report allows summary of water uses and volumes by county across the Upper Basin (please see Table A-1 in the appendix).

In the Upper Basin there are 62 counties divided among 5 states (Figure 6) Summary of the USGS report shows that the population of these Upper Basin counties was 2,397,380 in the year 2000. Broadly speaking, principal water uses in the basin, from all sources, included irrigation, public water supply, power generation and industrial uses (Table 3). Total water uses were over 11 million gallons per day amounting to about 12 million acre feet per year.

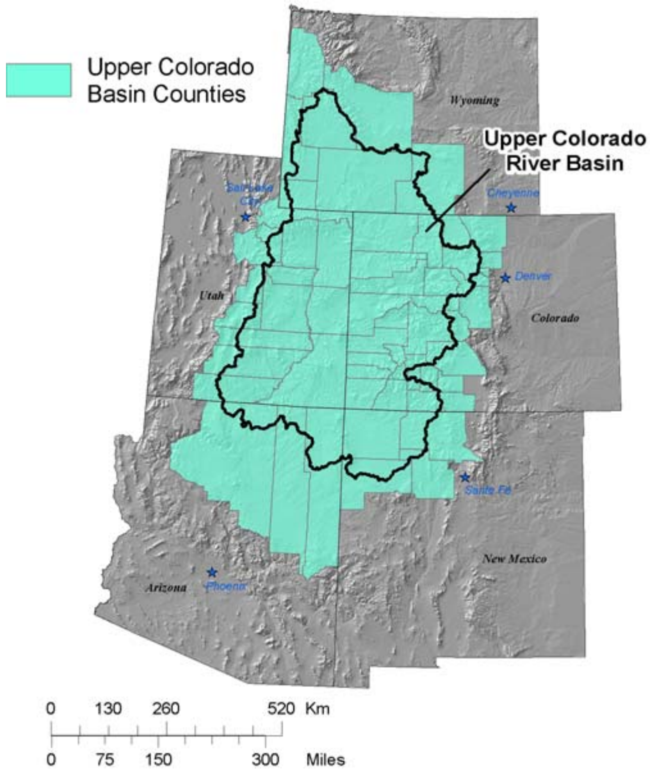

Figure 6 The Upper Colorado Basin intersects 62 counties in 5 states. The USGS report of Estimated Use of Water in the U.S. by county in the year 2000 (Hutson, et al. 2004) may be used to approximate water uses for these counties.

Table 3 Upper Colorado Basin water uses in 2000 (adapted after Hutson et al. 2004). Figures include the total withdrawals from both ground and surface water supplies.

Use	Mgal/Day	AF/Day	AF/Year	% of Total
Irrigation	10,372	31,841	11,621,941	92.9%
Public	507	1,556	567,906	4.5%
Power	241	740	270,221	2.2%
Industrial	47	143	52,251	0.4%
Total:	11,166	34,280	12,512,319	100.0%

The pattern of uses is informative (Figure 7). Generally, public supply trends with population. The heaviest use levels in all categories are concentrated around Grand Junction, Colorado and Farmington, New Mexico. Use levels fall off notably in Utah, probably reflecting land ownership pattern. Irrigation, constituting more than 90% percent of all uses is highly concentrated in counties of the ARW Landscape.

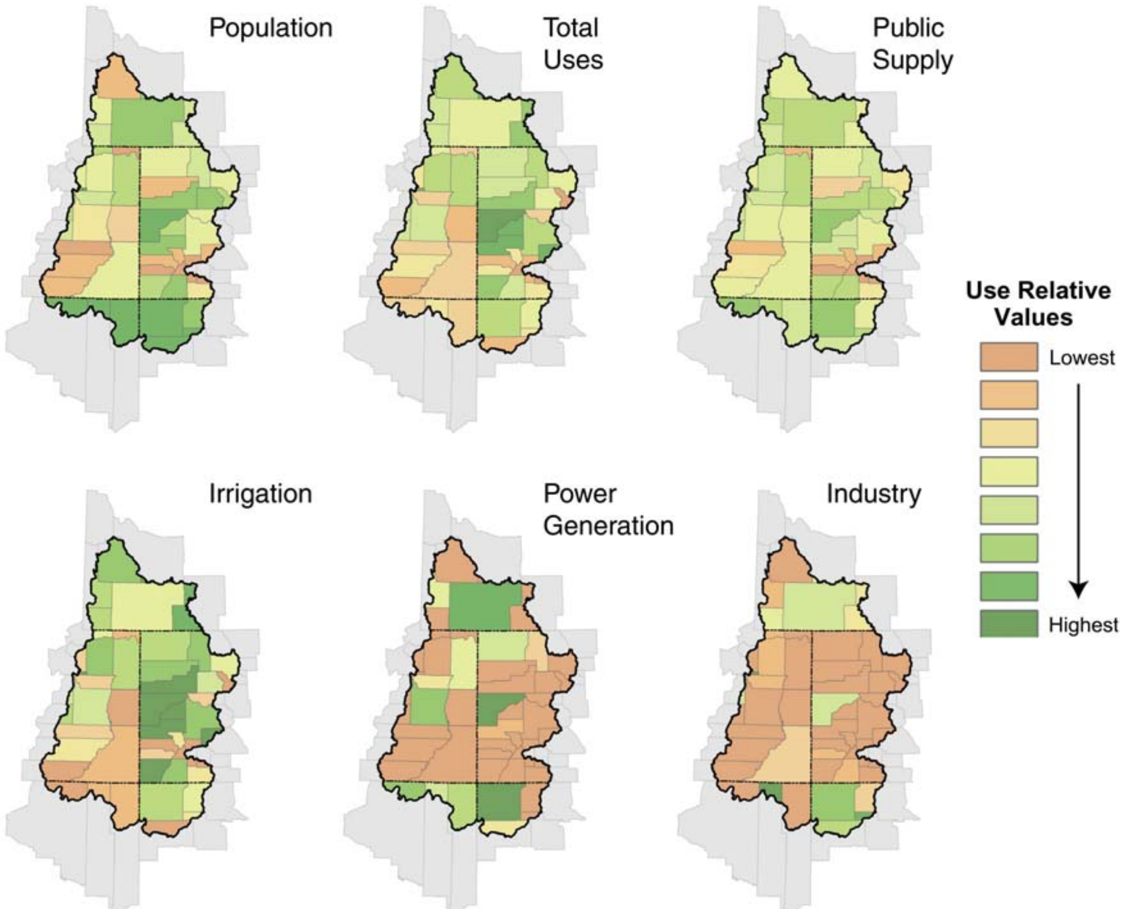

Figure 7 Relative levels of use between counties by use category. Shading indicates relative use levels within each category but not between categories.

Generally, surface waters provide the bulk of water to the four use categories cited by the USGS. Overall, surface waters contribute 90.4% percent of to the total use in Upper Basin counties (Table 4). Of the 62 Upper Basin counties, in five counties water uses consume more than 50% percent of their water from ground water sources (Table 5). Importantly, ground water uses sum up to 600.3 million gallons per day for these five counties, accounting for about 60% of the total water use. These waters are applied to irrigation and for coal slurry transport.

Table 4 Overall, water users in Upper Basin counties take over 90% percent of their waters from surface sources and about 10% percent from ground water sources.

Source	Mgal/d	AcreFeet / Year	%
Ground	1,072	1,233,933	9.6%
Surface	10,049	11,569,291	90.4%
	11,121	12,803,224	

Table 5 Five counties take more than half their waters from ground water sources.

State	Name	Ground Water Mgal/d	Surface Water Mgal/d	Total	GW / Total
AZ	Navajo	0.08	0	0.08	100.0%
NM	McKinley	62.82	1.34	64.16	97.9%
CO	Rio Grande	8.97	2.26	11.23	79.9%
CO	Saguache	170.88	113.74	284.62	60.0%
AZ	Apache	357.56	289.22	646.78	55.3%
		600.31	406.56	1006.87	59.6%

The geographic pattern of ground water use among counties shows notable differences among states (Figure 8). Twenty-six out of 32 (81.3%) of Colorado counties draw less than 10% percent of waters from ground water sources (Table 6). At the same time, Wyoming, New Mexico and Arizona counties in the Upper Basin draw nearly half of their water from ground water sources.

Table 6 The proportion of waters taken from groundwater versus surface water sources varies significantly between states.

STATE	<= 10%	> 10%	Total	Percent <= 10% GW
CO	26	6	32	81.3%
UT	12	4	16	75.0%
WY	4	3	7	57.1%
NM	2	2	4	50.0%
AZ	0	3	3	0.0%
	44	18	62	71.0%

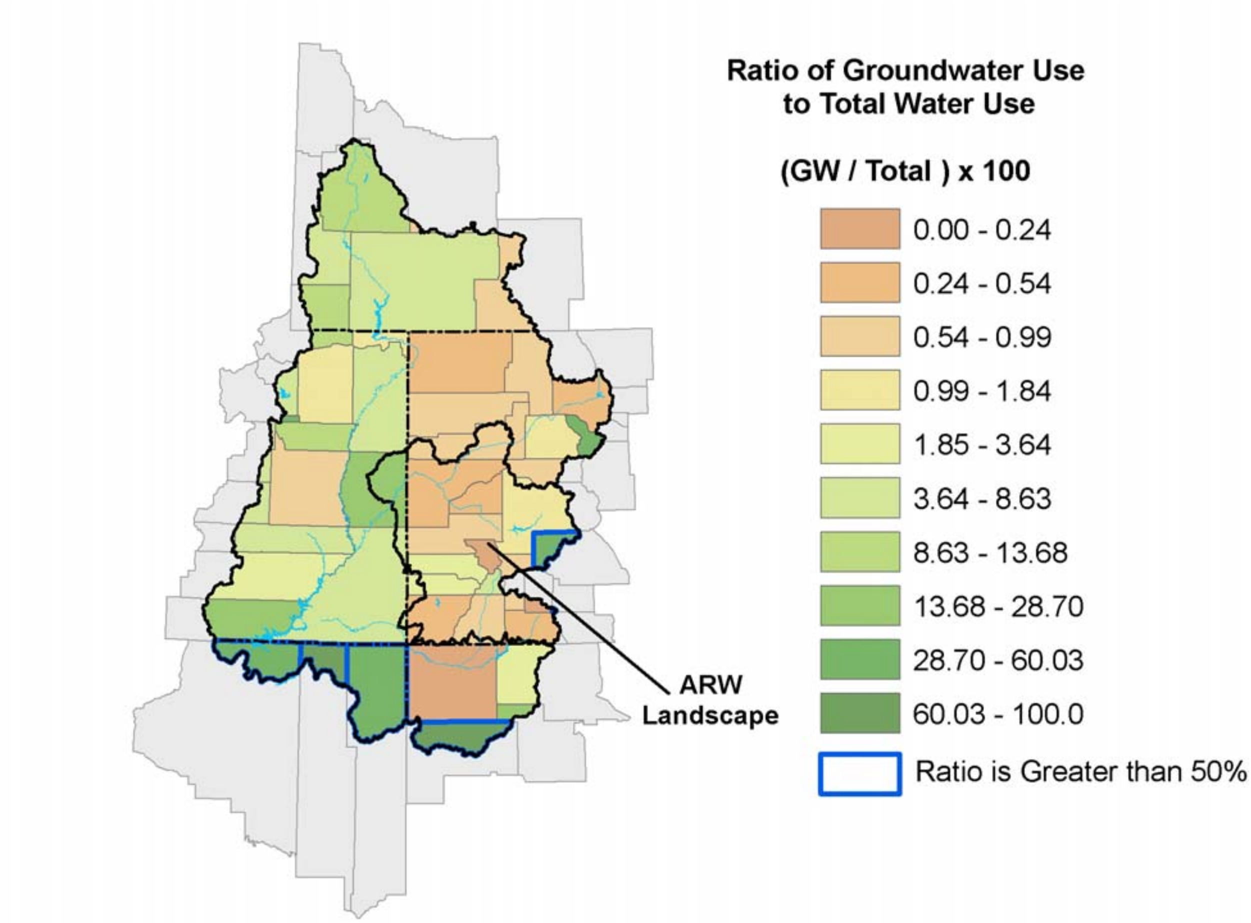

Figure 8 This figure shows by county the ratio of groundwater use to total use for all four use categories: irrigation, public use, power and industrial users. The counties outlined in blue have ratios exceeding 50% indicating that groundwater uses exceed surface water. In the ARW Landscape most waters are drawn from surface sources.

Trends in Upper Basin Water Use

The Bureau of Reclamation (BOR) prepares a Colorado River System, Consumptive Uses and Losses Report once every five years. These reports also summarize consumptive uses by major category, similar to the USGS county report, for the Colorado River System by basin, including the Upper Colorado Basin. These categories specifically include: reservoir evaporation, irrigation, municipal, industrial purposes, electric power production and mineral activities.

Here, the BOR data is especially useful for the trends that emerge over time. These Consumptive Uses and Losses reports are available online (BOR, 2005) and provide yearly summaries from 1971 to 2000. Overall, the reports show similar levels of use among major categories as the USGS county data discussed above. The principal use categories are agriculture and export outside the basin and these two account for almost 90% percent of water use in the basin. Another nearly five percent are allocated to reservoir evaporation. The remaining five percent are allocated to electrical power production, other (e.g., public use) and minerals production (Table 7 and Figure 9).

Table 7 This table shows overall use by category for the Upper Colorado Basin from 1971 to 2000 in the BOR Consumptive Uses and Losses Reports. Adapted after BOR, 2005.

Category	Total (Acre Feet, 1000s)	Percent
Agriculture	71,280	68.7%
Export	21,342	20.6%
Evaporation	5,051	4.9%
Power	3,611	3.5%
Other	1,635	1.6%
Minerals	906	0.9%
	103,826	100.0%

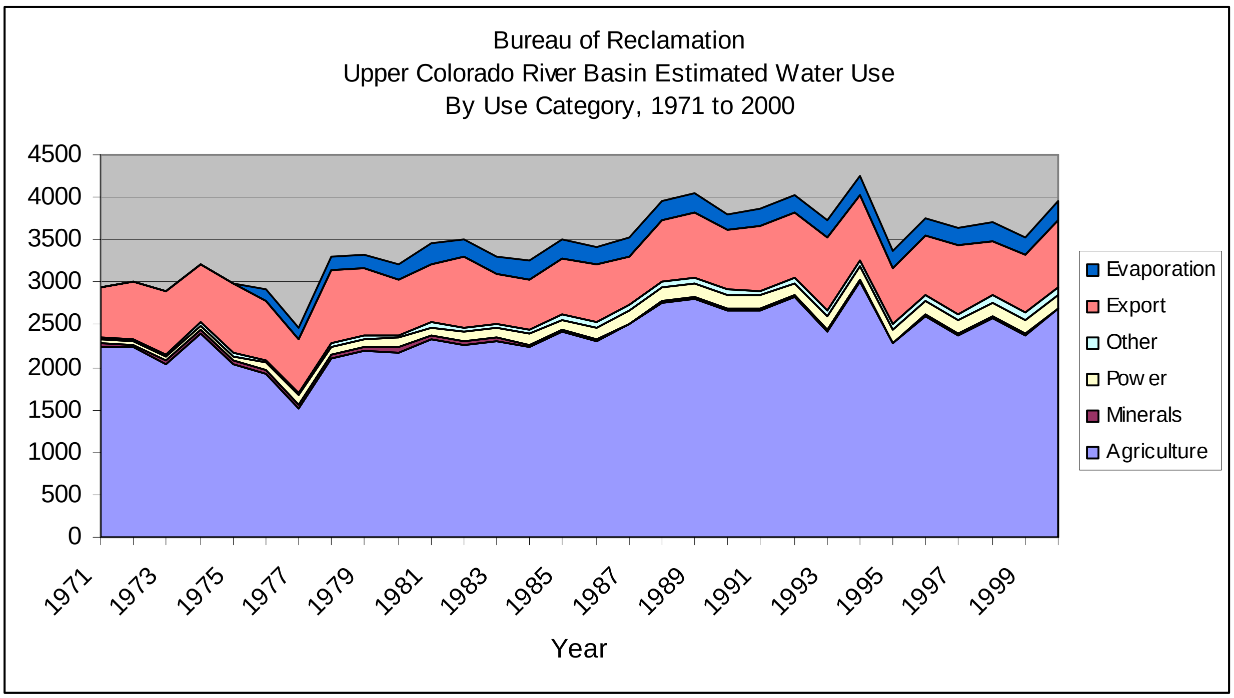

Figure 9 Stacked graph of Upper Colorado Basin water uses by category shows that relative proportions of uses have remained generally constant with some increase in "Other" near 1980. Clearly, agriculture, export and evaporation are the most significant categories.

Importantly, the BOR data reveals rising trends. The data show that overall use increases about 36,000 acre feet per year from about three to four million acre feet in the period from 1971 to 2000 (Figure 10).

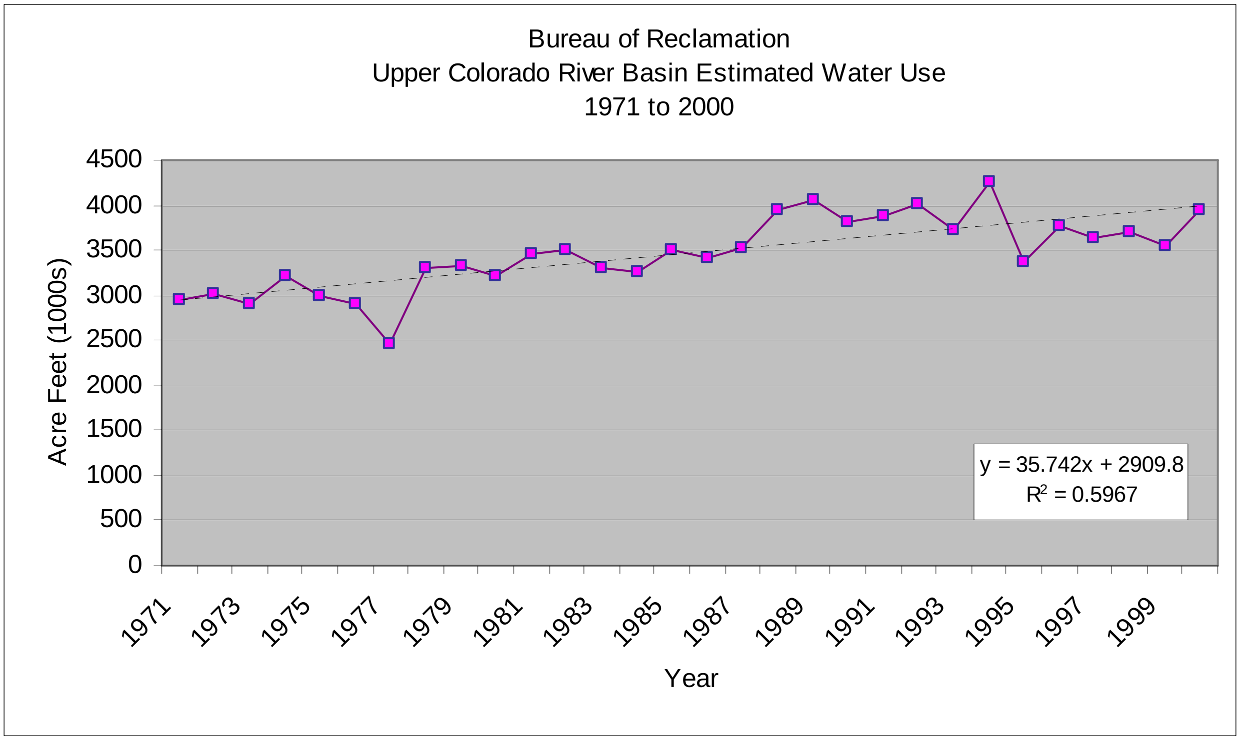

Figure 10 Stacked graph of Upper Colorado Basin water uses by category shows that relative proportions of uses have remained generally constant with some increase in "Other" near 1980. Clearly, agriculture, export and evaporation are the most significant categories.

About two-thirds of the yearly increase in water uses demand is accounted for by agriculture. From 1971 to 2000 the yearly increase in agricultural demand is about 22,000 acre feet (Figure 11). Increases of another 5,000 acre feet per year for other uses (e.g., public uses), power production and minerals development correspond to population and economic growth (Figure 12).

Anticipated growth in population and economic activities in the Upper Colorado Region are projected to continue to grow up to 2040. Overall, from 2000 to 2040 water withdrawals are expected to grow at a rate just under 1% percent per year. The greatest increases will occur in domestic and public supply and power generation (Brown, 1999). Projecting the BOR reported Upper Basin Colorado River system withdrawals of 2000 of 3,953,000 acre feet per year forward at this rate, withdrawals in 2040 would be about 5,885,000 acre feet per year.

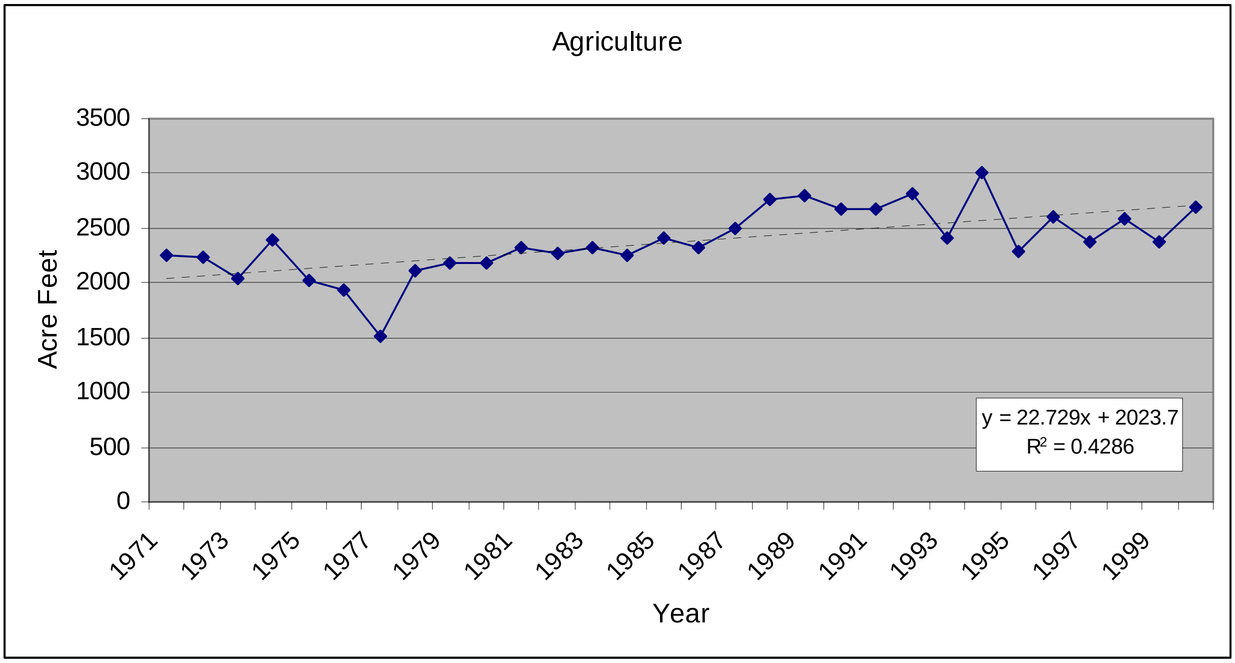

Figure 11 Agricultural water demands are increasing about 22 thousand acre feet per year.

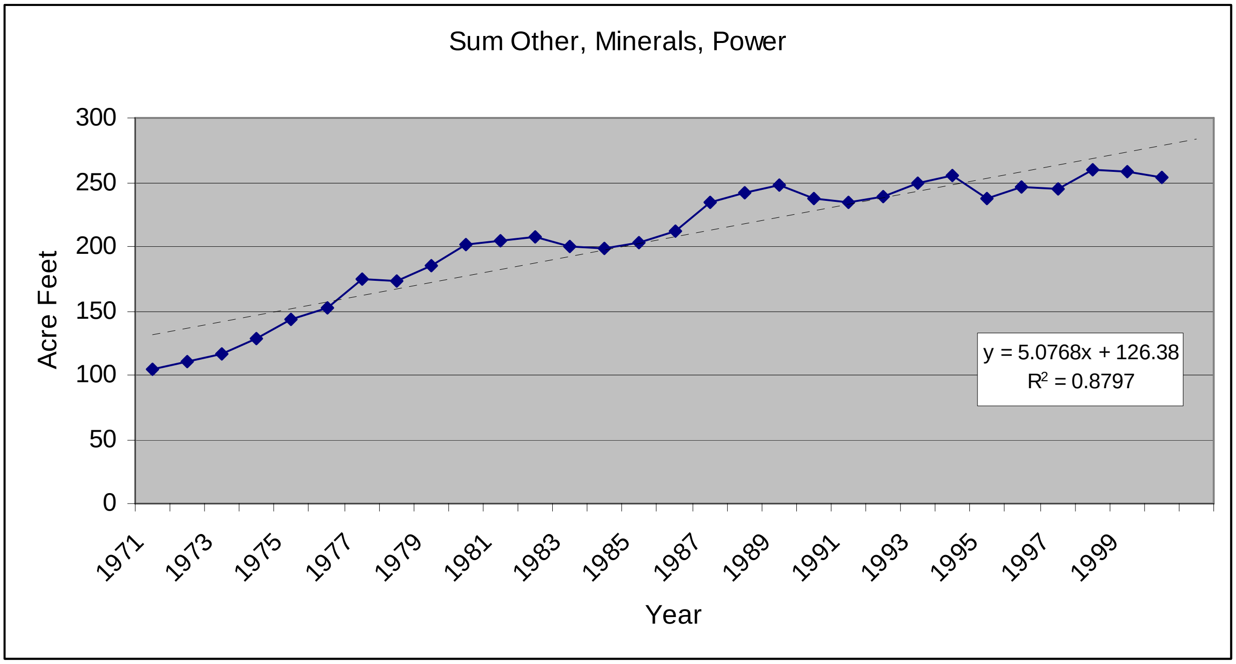

Figure 12 Water demands for other (e.g., domestic and public supply), power and minerals are increasing about 5 thousand acre feet per year.

Dams and Water Control

The Army Corps of Engineers and Federal Emergency Management Agency (FEMA) maintain a national database of dams (FEMA, 1996). The database includes dams built from 1677 to 1995. Dam heights vary from 1 to 2,727 feet and have storage capacities from 0.01 to more than 28 million acre feet. Dam purposes include debris control, fire/farm ponds, fish and wildlife, flood control, hydroelectric, irrigation, navigation, recreation, tailings and other. This Army/FEMA database is the source for the following summaries of dams in the Upper Colorado River basin and the subsequent analysis of the dams in the ARW Landscape.

Within the Upper Colorado River Basin there are 1,027 major dams (Table 8 and Figure 13). Of these, there are 17 whose primary purpose is the generation of electricity and water storage including the Glen Canyon Dam in Arizona. These major dams are an important source of power in the western states. Others provide important irrigation waters to agriculture, flood control and water supply to communities.

Table 8 Dams in the Upper Colorado Basin from the National Inventory of Dams (FEMA, 1996). Other consists of debris control, fire/farm ponds, fish and wildlife, recreation, tailings and some unclassified.

Purpose	Number of Dams	Surface Area (Acres)	Drainage Area (Sq. Miles)	Storage (Acre Feet)
Hydroelectric	17	190,779	116,011	30,272,409
Irrigation	623	164,002	34,662	9,500,923
Flood Control	25	928	2,837	29,561
Water Supply	111	56,451	15,867	4,690,941
Other	251	22,640	3,317	903,158
	1,027	434,800	172,695	45,396,992

Importantly, controlled flows introduced with the completion of large water storage reservoirs have eliminated important seasonal and yearly variation in flow. Flow regimes are further influenced on a daily basis by power production. Flow is a major factor in shaping river and channel morphology and consequently in shaping ecological communities. As a consequence, the placement of large dams through out the Colorado River Basin has placed important populations of endemic fish species at risk (CP-LUHNA, 2005).

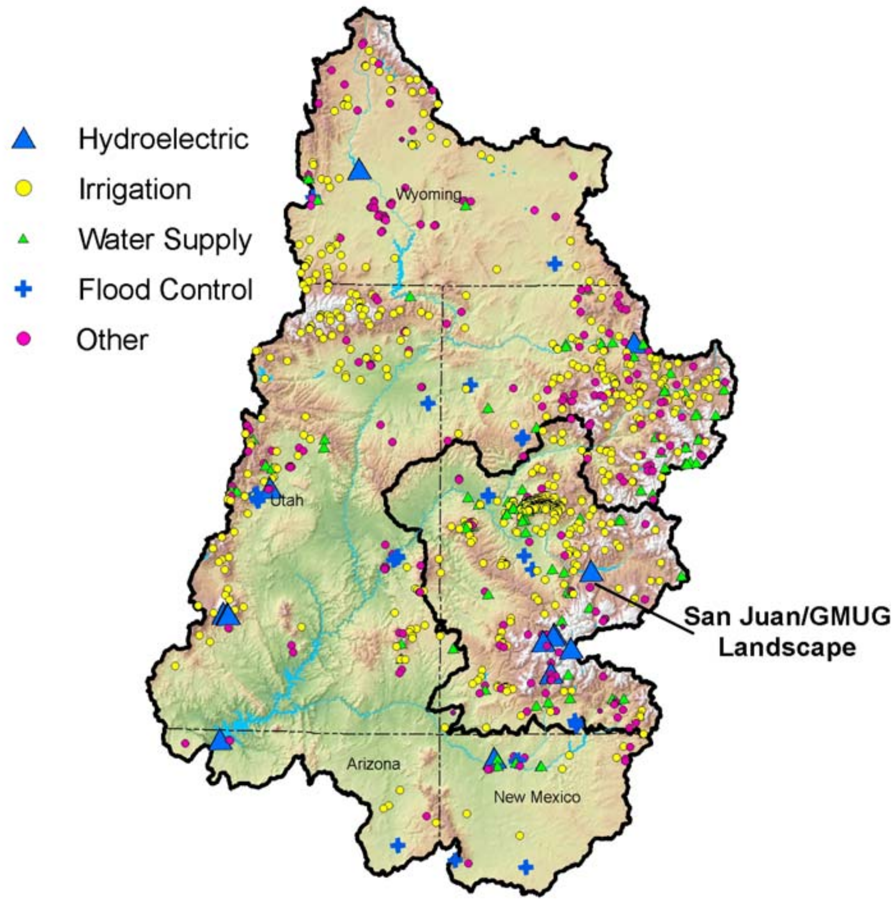

Figure 13 There are 1,027 dams in the Upper Colorado River Basin (FEMA, 1996). Most are located in foothill and upland areas aimed at irrigation and water supply.

The Contribution of the ARW Landscape to Flow

The ARW Landscape contributes proportionately more to measured flows in the Upper Colorado River than other lands in the Colorado River Basin. The volume of water measured at the Grand Canyon station represents the total flow from the Upper Basin. The volume of waters sourced in the ARW Landscape is found by adding flows from the San Juan River at Farmington, New Mexico with flows from the Colorado River at Cisco. Then the flow at the Colorado River immediately below Glenwood Springs, Colorado is subtracted to yield an approximate net flow for the ARW Landscape (Figure 14).

Figure 14 The ARW Landscape Scale is comprised of watersheds entirely within the Upper Colorado River Basin. Waters originating in the Landscape Scale join the Colorado River above the gauging stations at Cisco, Colorado and Farmington, New Mexico. The contribution of waters above the station at Glenwood Springs Colorado is subtracted from amounts measured at Cisco to obtain the net contribution for the ARW Landscape.

The proportion of Landscape net flow to total upper basin flow indicates the relative importance of the Landscape. While the ARW Landscape area represents about 19.6% percent of the area of the Upper Colorado River Basin, on average, about 36.5% percent of the flow from the Upper Colorado River Basin can be attributed to flows originating in the ARW Landscape (Figure 15). The yearly proportion contributed has been recorded as high as 73% percent and as low as 8.2% percent.

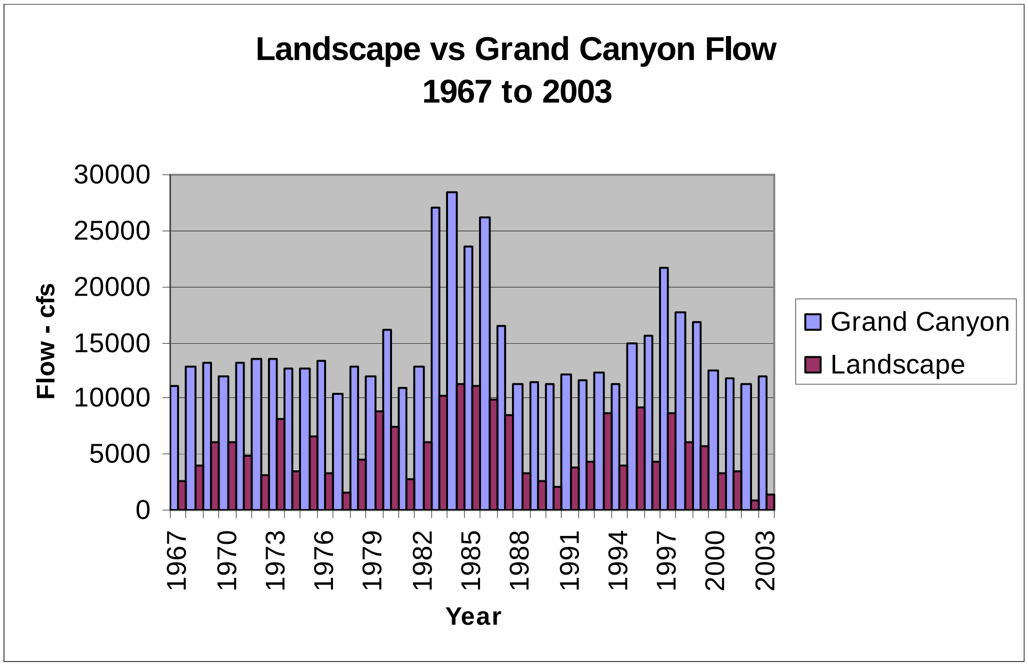

Figure 15 Flows at the USGS Grand Canyon gauging station contrasted with flows from the ARW Landscape from 1967 to 2003. Flow data adapted after USGS, 2005.

ARW Landscape Dams

According to the Army/FEMA data from 1996, there are 423 dams in the ARW Landscape. Two-thirds (281) of these dams are for irrigation. The remaining third are applied to hydroelectric generation, flood control, water supply and other uses (Table 9). In total these 423 dams have a cumulative surface area of 44,163 acres draining an area of 14,909 square miles and store over 3 million acre feet of water.

Table 9 Dams in the ARW Landscape.

Purpose	Number of Dams	Pct.	Surface Area (Acres)	Drainage Area (Sq. Miles)	Storage (Acre Feet)
Hydroelectric	17	4.0%	363	111	5,927
Irrigation	281	66.4%	30,601	11,222	2,113,188
Flood Control	9	2.1%	11,330	3,497	1,007,902
Water Supply	54	12.8%	1,869	80	43,163
Other	62	14.7%	2,314	295	58,838
	423	100.0%	44,163	14,909	3,170,180

These 423 dams in the ARW Landscape account for 41.2% percent of dams in the Upper Colorado River Basin (Table 10)

Table 10 Proportion of ARW Dam count and metrics to the corresponding metrics for dams in the Upper Colorado Basin (UCB)

Summary Figures	Percent of UCB
Number of Dams	41.2%
Surface Area	10.2%
Drainage Area	8.6%
Storage	7.0%

Generally, dams are located in and around upland areas (Figure 16). Grand Mesa has a notably high density of dams. These are aimed principally at irrigation and water supply. Furthermore, the bulk of these Grand Mesa dams were built before 1945 (Figure 17).

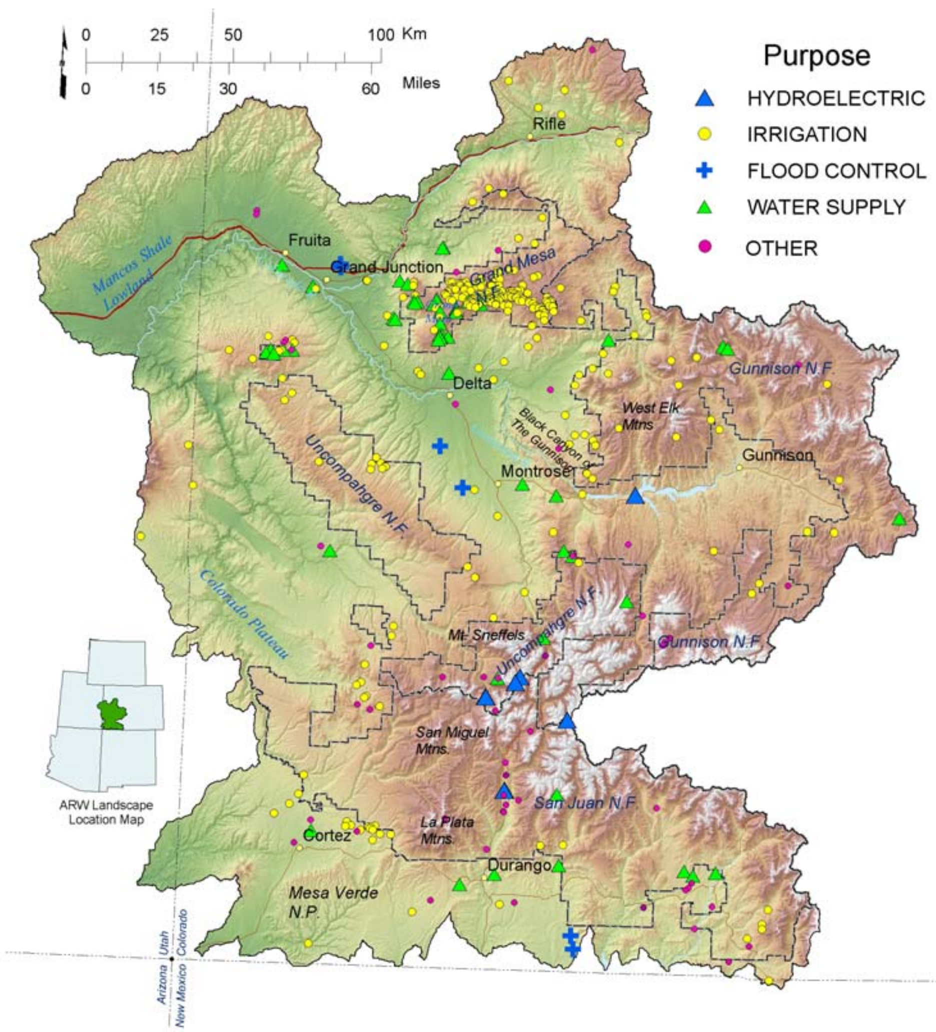

Figure 16 Dams in the ARW Landscape.

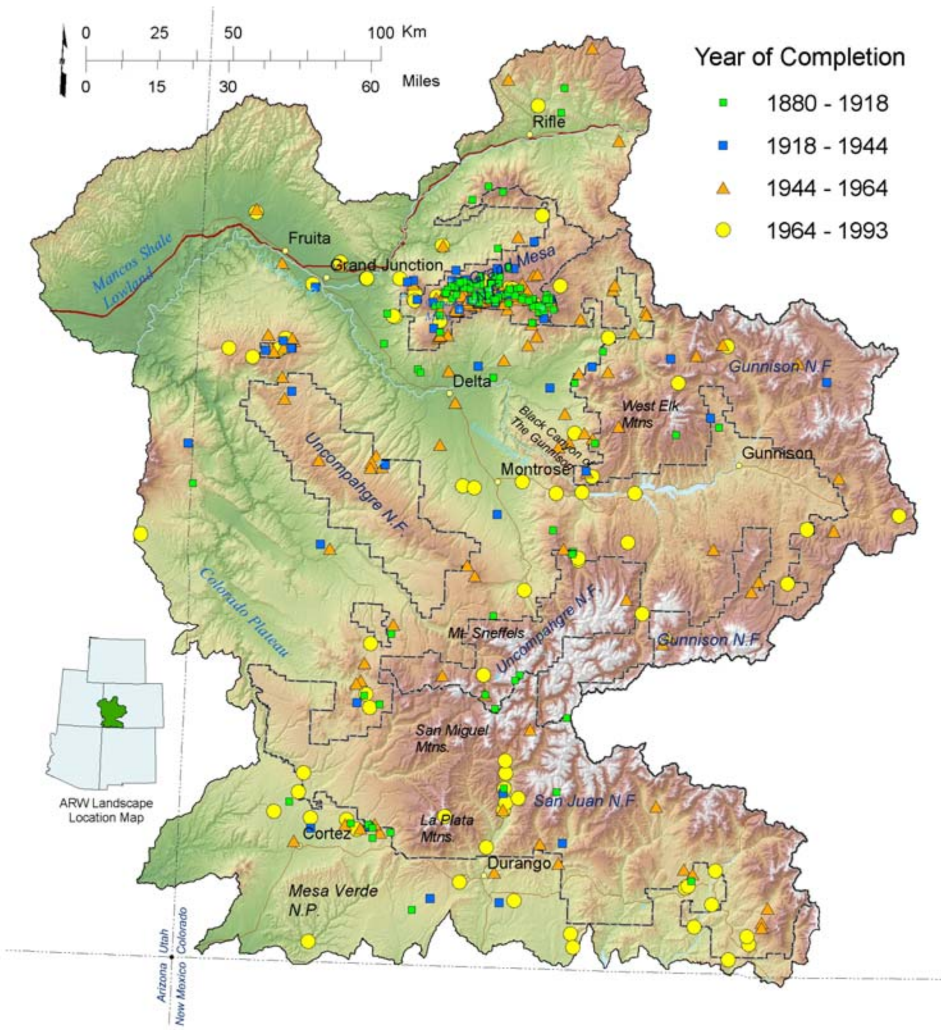

Figure 17 Dams in the ARW Landscape by completion date. A significant number of dams on Grand Mesa were completed in the earliest period of dam building.

The timing of dam construction may be important as an indicator of aquatic ecosystem health. River and stream systems obstructed by dams for longer periods of time may be more highly altered and less recoverable than others. In the Landscape, there are two recognizable periods of dam construction. The earliest period extends from the 1880s up to the middle 1920s. The subsequent period extends for about 50 years from the 1930s to the early 1990s (Figure 18).

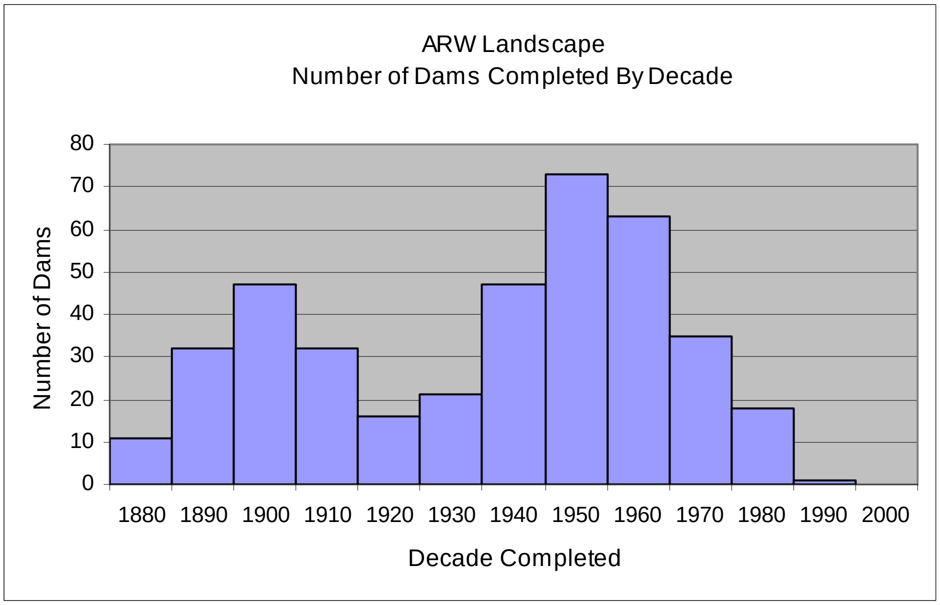

Figure 18 Two periods of dam construction are evident in the completion dates for the 396 out of 412 dams with completion date information in the ARW Landscape. The sudden truncation of completions in the 1980s reflects a dramatic shift in public and management sentiment away from dam building. The majority of dams completed before 1920 were irrigation dams in the White River Plateau east of Grand Junction.

Ratio of Dams to HUB Stream Miles

Within the eighteen 4^{th} level watersheds (HUBS) in the ARW Landscape the influence of dams may be approximated by calculation of the ratio of dams to stream mile. This ration is calculated using Army/FEMA dam counts and USGS national hydrologic DLG data where stream type is perennial stream. Overall, the 412 dams divided into 8611.2 miles of stream yields an overall ratio of 0.048 dams per stream mile. Taking the reciprocal, this ratio equals about 1 dam in every 20 stream miles in the landscape.

Measured HUB by HUB, ratios vary from a maximum of 0.222 to a minimum of 0.007 dams per stream mile (Table 11). The five 4^{th} level HUBS most highly influenced by dams are the Lower Gunnison (14020005), Colorado Headwaters Plateau (14010005), North Fork Gunnison (1402004) and Mancos (14080107). Water use in these HUBS is related to the larger population centers (Grand Junction and Durango/Farmington) water supply and agricultural irrigation (Figure 19).

Table 11 Ratio of number of dams per stream mile for the 18 4th level HUBs in the ARW Landscape.

HUB Name	HUB Code	Number of Dams	Stream Miles	Number Per Stream Mile
Lower Gunnison	14020005	135	607.9	0.222
Colorado Headwaters-Plateau	14010005	79	830.7	0.095
North Fork Gunnison	14020004	46	558.9	0.082
Mancos	14080107	11	154.2	0.071
Middle San Juan	14080105	3	58.8	0.051
Mcelmo	14080202	7	155.9	0.045
San Miguel	14030003	19	537.3	0.035
Animas. Colorado	14080104	18	635.9	0.028
Westwater Canyon	14030001	3	123.3	0.024
Upper Gunnison	14020002	31	1,290.1	0.024
Uncompahange	14020006	11	485.0	0.023
Piedra	14080102	7	323.2	0.022
Upper Dolores	14030002	12	596.6	0.020
Upper San Juan	14080101	10	503.3	0.020
Lower Dolores	14030004	5	288.5	0.017
Upper San Juan West	14080999	4	321.0	0.012
Tomichi	14020003	7	595.6	0.012
East-Taylor	14020001	4	545.1	0.007
		412.0	8,611.2	0.048

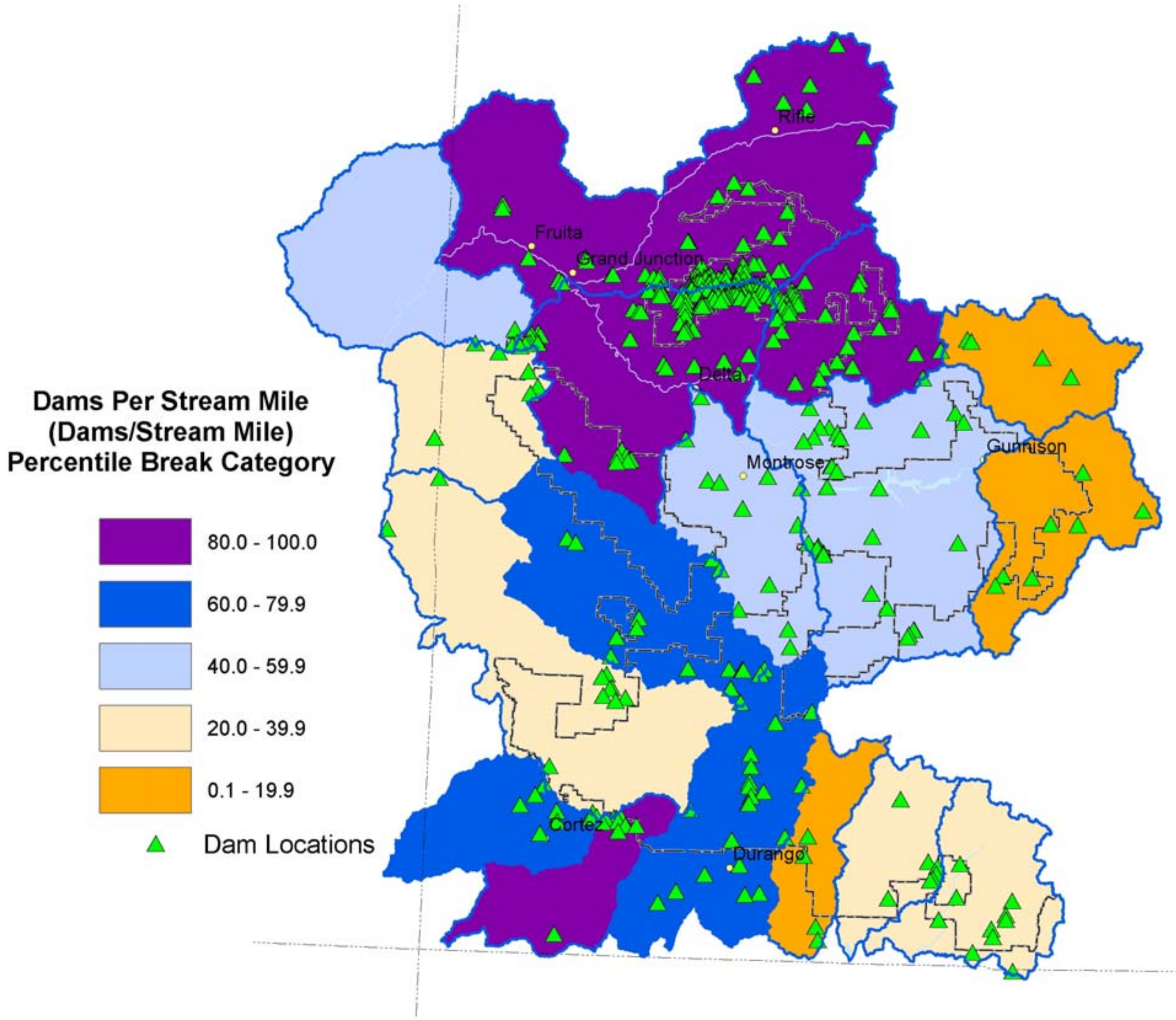

Figure 19 4th level HUBs categorized by Dams per Stream Mile percentile break category.

Ratio of Diversion Miles to HUB Stream Miles

Within the eighteen 4th level watersheds (HUBS) in the ARW Landscape the influence of diversions may be approximated by calculation of the ratio of diversion mile to stream mile. This ratio is calculated using USGS national hydrologic DLG data for both variables (i.e., diversions and perennial streams). Overall, the 1,779.6 miles of diversions are divided into 8611.2 miles of stream yielding a ratio of 0.207 diversion miles per stream mile. Taking the reciprocal, this ratio equals about 1 mile of diversion for 4.8 stream miles in the Landscape (Table 12).

Table 12 4th level HUBs categorized by Diversion Mile per Stream Mile percentile break category.

HUB Name	HUB Code	Stream Miles	Diversion Miles	Miles Per Mile
Mcelmo	14080202	155.9	111.2	0.713
Colorado Headwaters-Plateau	14010005	830.7	378.7	0.456
Uncompahange	14020006	485.0	220.3	0.454
San Miguel	14030003	537.3	207.7	0.386
Mancos	14080107	154.2	58.2	0.378
Upper San Juan West	14080999	321.0	93.5	0.291
North Fork Gunnison	14020004	558.9	156.8	0.281
Middle San Juan	14080105	58.8	15.6	0.265
Lower Gunnison	14020005	607.9	155.5	0.256
Upper San Juan	14080101	503.3	80.2	0.159
Upper Gunnison	14020002	1,290.1	160.7	0.125
Upper Dolores	14030002	596.6	69.2	0.116
Animas. Colorado	14080104	635.9	40.1	0.063
Westwater Canyon	14030001	123.3	5.7	0.046
Lower Dolores	14030004	288.5	8.1	0.028
Tomichi	14020003	595.6	15.3	0.026
East-Taylor	14020001	545.1	2.8	0.005
Piedra	14080102	323.2	0.0	0.000
		8,611.2	1,779.6	0.207

In the ARW Landscape, the bulk of diversions are located in valley bottom settings, carrying waters to agricultural users. Ditches and canals are most often headed in upland areas, many within Forest Service lands (Figure 20).

Figure 20 Water diversions

Measured HUB by HUB, ratios vary from a maximum of 0.713 to a minimum of 0.0 diversion miles per stream mile (Table 12 above). The Lower Gunnison (14020005), Colorado Headwaters Plateau (14010005), North Fork Gunnison (1402004) and Mancos (14080107) 4th level watersheds have the highest ratios of number of dams per stream mile in the ARW Landscape. The Piedra River shows no diversions in this hub.

Water use in these HUBS is related to the larger population centers (Grand Junction and Durango/Farmington) water supply and agricultural irrigation (Figure 21).

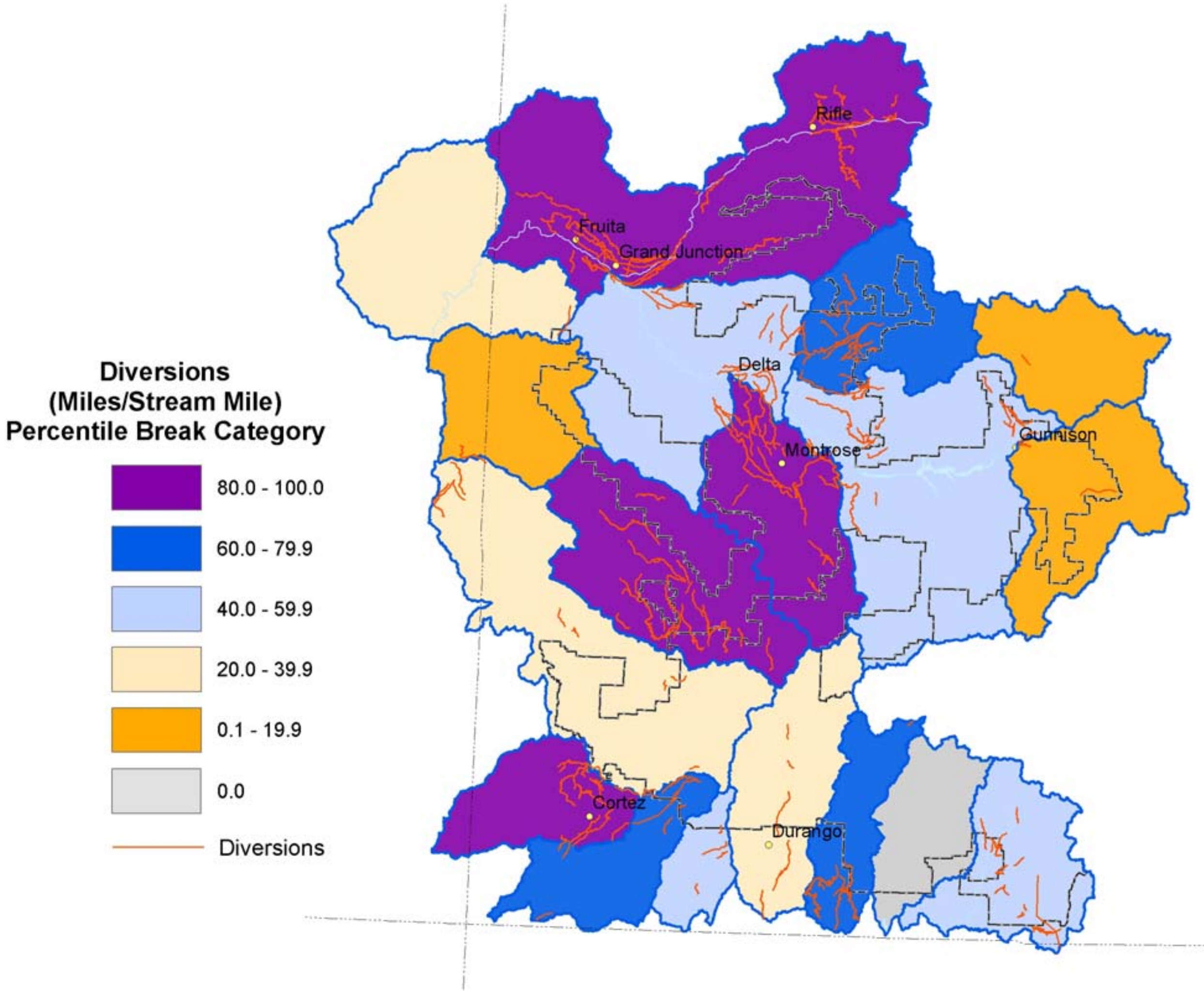

Figure 21 4th level HUBs categorized by diversion mile per Stream Mile percentile break category.

Trans-Mountain Diversions

There are eight trans-mountain diversions (Table 13 and Figure 22) that carry water from five watersheds of the ARW Landscape to the Arkansas and Rio Grande River Basins (CSU, 2005). These diversions export 6,210 acre feet of water per year. The five include the Upper Gunnison (14020002), Upper San Juan (14080101), Upper San Juan West (14080999), Piedra (14080102) and Tomichi (14020003) 4th level watersheds (Table 14).

It is difficult to quantify the relative influence of these diversions. Flow data does exist within the subject watersheds but more research is required to match existing flow stations to each diversion to quantify net loss. It is clear, however, that the scale of these diversions is significantly less than the large diversions further to the north moving waters to serve the needs to the east-side metropolitan areas.

Table 13 Transmountain diversions carry from the ARW Landscape eastward into the Arkansas and Rio Grande River Basins.

ID	Structure	Receiving Basin	Acre Feet
1	Larkspur Ditch	Arkansas River	329
2	Tarbell Ditch	Rio Grande River	172
3	Weminuche Pass Ditch	"	2,088
4	Pine River-Weminuche Pass Ditch	"	873
5	Williams Creek Squaw Pass Ditch	"	253
6	Don La Font Ditches 1 and 2	"	447
7	Treasure Pass Diversion Ditch	"	613
8	Tabor Ditch	"	1,435
			6,210

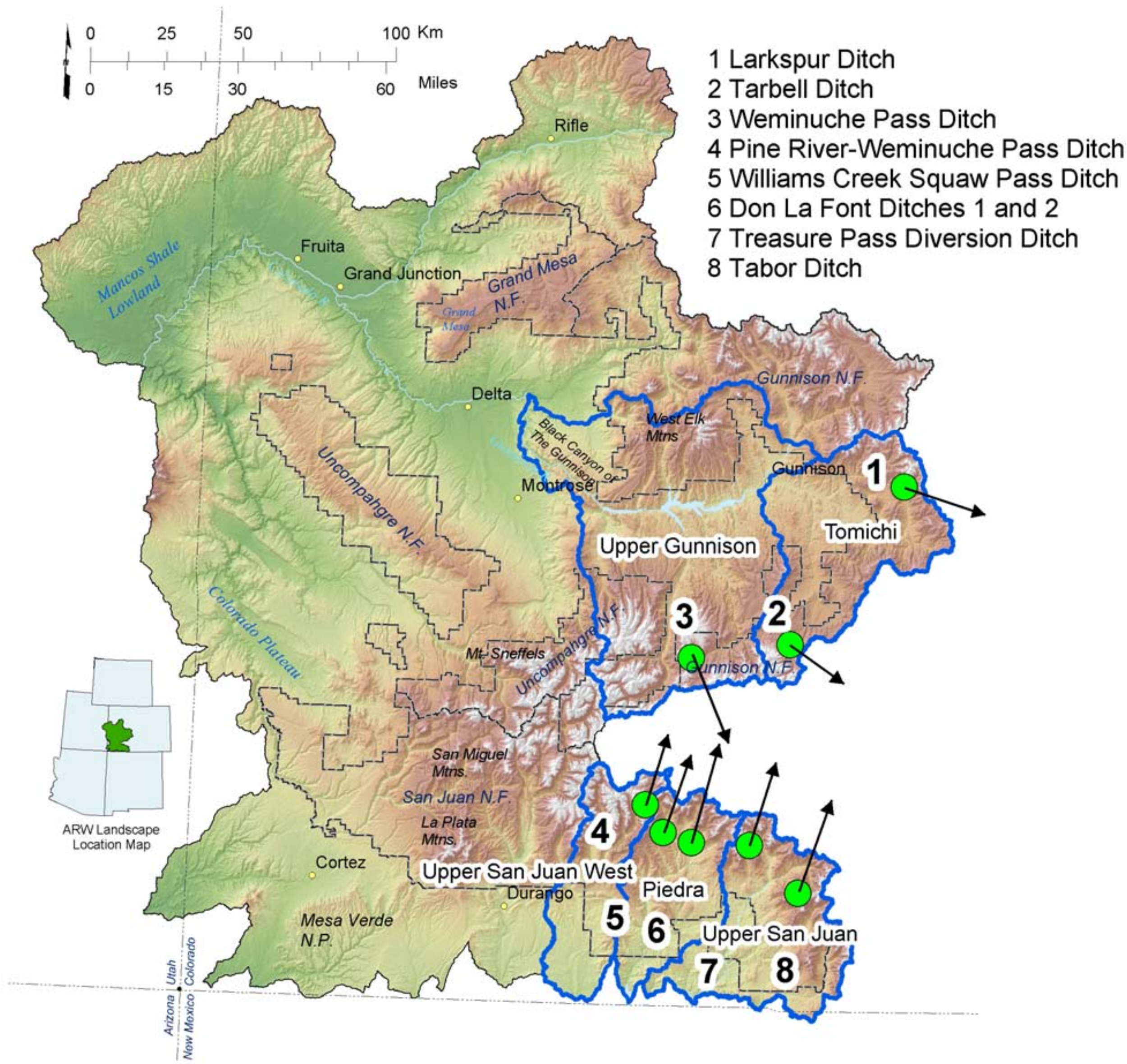

Figure 22 Eight trans-mountain diversions that carry water from five watersheds eastward to the Arkansas and Rio Grande River Basins.

Table 14 Summary by 4th level HUBs having trans-mountain diversions.

HUB Name	HUB ID	Number of Diversion Sites	Acre Feet Diverted
Upper Gunnison	14020002	1	2,088
Upper San Juan	14080101	2	2,048
Upper San Juan West	14080999	1	873
Piedra	14080102	2	700
Tomichi	14020003	2	501
		8	6,210

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Appendix

Table A-1 USGS Water uses totals for 62 counties overlapping the Upper Colorado Basin. Irrigation % of Total is Irrigation Use divided by Total Use. Water use is in millions of gallons per day (Mgal/d) (Hutson et al., 2004).

				Mgal/d						
State	Name	FIPS	Population	Public Use	Industrial Use	Irrigation Use	Irrigated Acres	Power Gen.	Total Use	Irrigation % of Total
AZ	Apache	04001	69,420	5.0	0.0	24.2	5.7	16.0	50.9	47.5%
	Coconino	04005	116,320	19.1	0.0	6.5	2.3	25.7	53.6	12.1%
	Navajo	04017	97,470	10.3	12.2	28.6	5.1	13.1	69.2	41.3%
CO	Archuleta	08007	9,900	1.5	0.0	64.5	17.0	0.0	83.0	77.7%
	Boulder	08013	291,290	71.3	2.4	105.2	33.9	2.6	215.4	48.8%
	Chaffee	08015	16,240	2.6	0.0	69.0	22.1	0.0	93.6	73.7%
	Clear Creek	08019	9,320	1.6	0.0	0.0	0.0	0.0	1.6	0.0%
	Conejos	08021	8,400	0.8	0.0	252.9	110.5	0.0	364.2	69.4%
	Delta	08029	27,830	5.2	0.0	672.2	72.2	0.0	749.6	89.7%
	Dolores	08033	1,840	0.3	0.0	54.2	13.1	0.0	67.6	80.2%
	Eagle	08037	41,660	10.1	0.0	129.5	18.0	0.0	157.6	82.2%
	Garfield	08045	43,790	9.1	0.0	409.9	43.5	0.0	462.6	88.6%
	Gilpin	08047	4,760	0.1	0.0	0.0	0.0	0.0	0.1	0.0%
	Grand	08049	12,440	2.0	0.0	107.8	27.4	0.0	137.2	78.6%
	Gunnison	08051	13,960	2.3	0.0	239.2	46.8	0.0	288.2	83.0%
	Hinsdale	08053	790	0.1	0.0	9.6	2.4	0.0	12.1	79.3%
	Jackson	08057	1,580	0.2	0.0	322.6	104.4	0.0	427.1	75.5%
	Lake	08065	7,810	1.0	0.0	39.6	34.1	0.0	74.7	53.1%
	La Plata	08067	43,940	7.0	0.0	211.3	40.1	0.0	258.4	81.8%
	Larimer	08069	251,490	57.1	1.3	212.1	81.5	0.0	351.9	60.3%
	Mesa	08077	116,260	32.0	0.5	1,121.5	89.7	45.1	1,288.8	87.0%
	Mineral	08079	830	0.1	0.0	0.0	0.0	0.0	0.1	0.0%
	Moffat	08081	13,180	3.7	0.0	193.4	36.4	11.3	244.7	79.0%
	Montezuma	08083	23,830	7.3	0.0	421.4	56.3	0.0	485.0	86.9%
	Montrose	08085	33,430	6.0	0.0	588.8	81.7	1.4	677.8	86.9%
	Ouray	08091	3,740	0.6	0.0	81.3	16.8	0.0	98.7	82.4%
	Park	08093	14,520	0.3	0.0	26.3	16.3	0.0	42.8	61.4%
	Pitkin	08097	14,870	4.2	0.0	38.8	12.0	0.0	55.0	70.5%
	Rio Blanco	08103	5,990	1.3	0.0	215.2	32.6	0.0	249.0	86.4%
	Rio Grande	08105	12,410	1.1	0.0	283.5	143.3	0.0	427.9	66.3%
	Routt	08107	19,690	4.0	0.0	264.1	48.6	2.4	319.0	82.8%
	Saguache	08109	5,920	0.6	0.0	646.2	209.9	0.0	856.7	75.4%
	San Juan	08111	560	0.2	0.0	0.0	0.0	0.0	0.2	0.0%
	San Miguel	08113	6,590	0.6	0.0	9.1	1.9	0.0	11.6	78.4%
	Summit	08117	23,550	3.4	0.0	0.0	0.0	0.0	3.4	0.0%
NM	McKinley	35031	74,800	4.8	0.9	2.3	5.1	3.3	16.3	13.8%
	Rio Arriba	35039	41,190	2.2	0.1	99.9	31.8	0.0	134.0	74.6%
	Sandoval	35043	89,910	11.1	3.2	55.7	9.4	0.0	79.3	70.2%

	San Juan	35045	113,800	17.3	1.7	197.4	72.7	45.1	334.1	59.1%
UT	Carbon	49007	20,420	6.1	0.0	35.8	12.2	3.5	57.6	62.2%
	Daggett	49009	920	0.5	0.0	22.6	10.9	0.0	34.0	66.4%
	Duchesne	49013	14,370	4.1	0.0	217.8	106.7	0.0	328.6	66.3%
	Emery	49015	10,860	2.4	0.0	161.5	45.9	25.1	234.9	68.8%
	Garfield	49017	4,740	1.6	0.0	70.4	29.6	0.0	101.5	69.3%
	Grand	49019	8,490	3.3	0.0	10.3	6.4	0.0	20.0	51.7%
	Kane	49025	6,050	2.4	0.0	12.5	9.4	0.0	24.2	51.4%
	Piute	49031	1,440	0.9	0.0	73.7	22.2	0.0	96.9	76.1%
	San Juan	49037	14,410	2.5	0.2	19.6	10.3	0.0	32.6	60.1%
	Sanpete	49039	22,760	4.0	0.5	143.4	82.0	0.0	229.8	62.4%
	Sevier	49041	18,840	5.6	0.0	171.0	59.9	0.0	236.6	72.3%
	Summit	49043	29,740	10.3	0.0	91.0	38.1	0.0	139.4	65.3%
	Uintah	49047	25,220	8.4	0.0	194.4	85.8	9.6	298.2	65.2%
	Utah	49049	368,540	103.4	22.0	399.2	110.2	0.0	634.8	62.9%
	Wasatch	49051	15,220	2.9	0.0	46.2	19.1	0.0	68.3	67.7%
	Wayne	49055	2,510	0.6	0.0	44.8	17.7	0.0	63.1	71.1%
WY	Carbon	56007	15,640	3.4	0.2	313.3	74.2	0.0	391.1	80.1%
	Fremont	56013	35,800	6.6	0.3	410.9	100.0	0.0	517.8	79.3%
	Lincoln	56023	14,570	8.0	0.0	177.4	59.6	9.7	254.8	69.6%
	Sublette	56035	5,920	2.6	0.0	238.1	90.9	0.0	331.6	71.8%
	Sweetwater	56037	37,610	8.9	0.5	92.7	21.1	27.5	150.7	61.5%
	Teton	56039	18,250	6.2	0.2	39.1	17.0	0.0	62.4	62.6%
	Uinta	56041	19,740	5.1	0.4	182.7	46.1	0.0	234.3	78.0%
	Totals:		2,397,380	507	47	10,372	2,620	241	13,786	

Chapter 2. Anthropogenic Influences – Landscape Scale

Roads

Key Findings

- There is an estimated **31,274** miles of road and trail in the ARW landscape scale based on U.S. Geological Survey 100,000 scale Digital Line Graph (DLG) data. Of these, there are **24,916** miles of road by excluding trails.
- There are an estimated **157,310** acres of disturbance result from the 31,274 miles of roads and trails in the landscape.
- Class 3 gravel roads comprise 17.2% percent and **Class 4 dirt/native surface roads comprise 52.4% percent** of all roads in the landscape scale. These two classes sum to **21,763 miles for 69.5% percent** of all roads and trails.
- **Class 4, 4WD and Trails are dirt/native surfaced and disturb 104,322 acres,** about **66%** of the total disturbance from roads in the ARW landscape scale.
- Slope may be correlated to road densities to generate a road density proxy layer. This slope proxy layer can be used by managers to anticipate areas of high road activity and augment coarse scale data.
- The highest road densities are found on **private lands**. Relatively high densities are found also on tribal, state and BLM lands. While road densities on Forest Service lands can be locally high, overall area weighted densities are low because of the relatively large areas of upland/high slope terrains on Forest Service lands.

Introduction

This section summarizes road and trail mileage, distribution and pattern and potential for the San Juan and GMUG ARW landscape scale. We estimate the area of disturbance on the landscape due to roads and trails. Mileage, pattern and Roads are further summarized by their relation to 4th level watershed and by land ownership.

The base data supporting the mapping and analysis of roads and trails on the ARW landscape is U.S. Geological Survey (U.S.G.S.) 1:100,000 scale digital line graph (DLG) data (U.S.G.S., 2004a). The DLG data provides accurate representations of Interstate, U.S. Highway, State and County roads. While these DLG data also fairly represent the over all regional pattern and distribution of backcountry dirt roads and trails, finer scale analyses within the San Juan and GMUG bounds reveal higher road densities, especially for non-system roads and tracks. Within this analysis we develop a slope based model to partially overcome these data limitations.

Road Class on the ARW Landscape

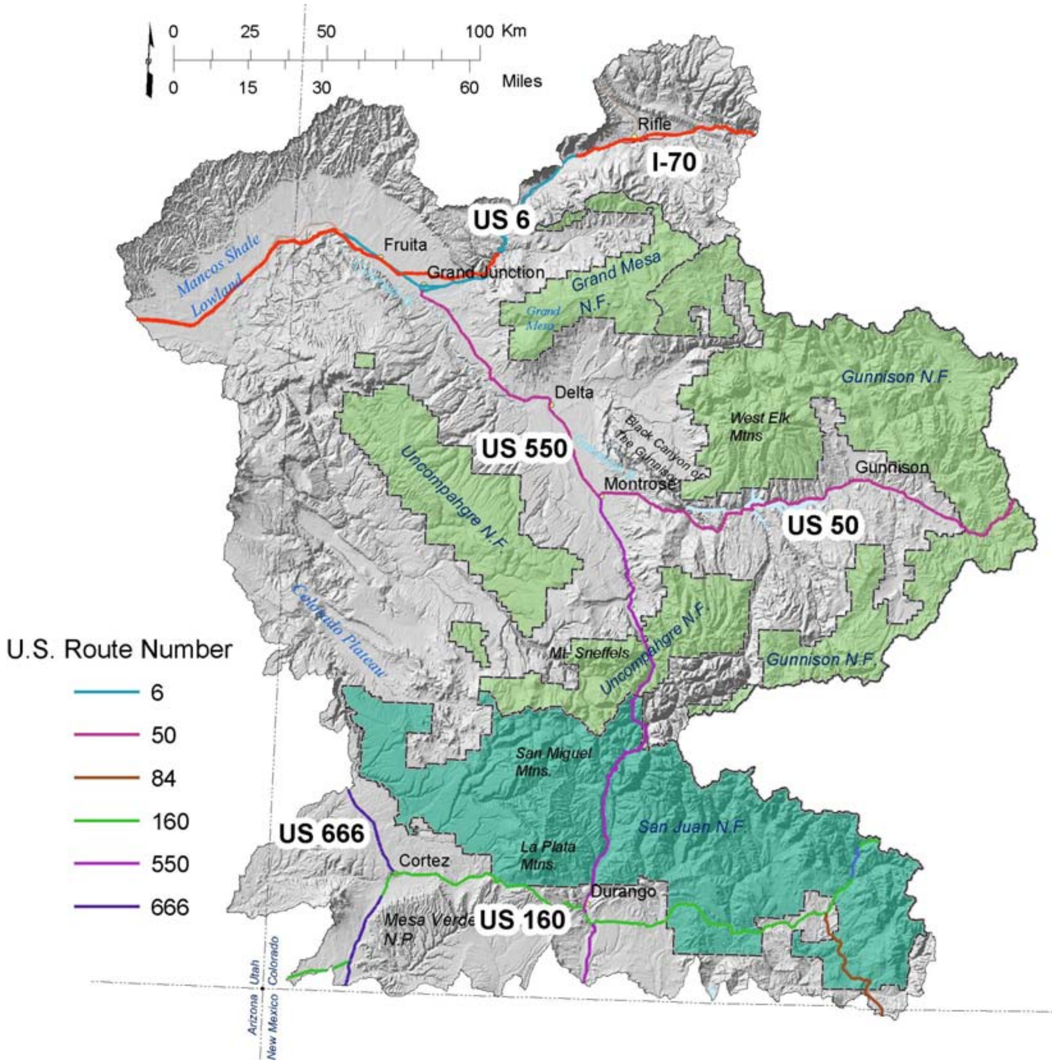
Using the U.S.G.S. DLG data, there is an estimated 31,274 miles of road, including trails, in the landscape scale. These roads are classified by the U.S. Geological Survey as primary, secondary, Class 3, Class 4, Four Wheel Drive (4WD) and trail (Table 1). A small proportion of the DLG data was not suitable for classification and is classified as "Not Defined". Subtracting trail mileage, there are a total of 24,916 miles of road in the landscape scale.

Table 1. Road Classes in the ARW landscape. Percentage values are relative to the total landscape mileage.

Road Class	Surface	Miles	Pct
Primary	Paved	833.1	2.7%
Secondary	Paved	1,362.7	4.4%
Class 3	Gravel	5,375.0	17.2%
Class 4	Dirt	16,388.2	52.4%
4WD	Native	790.5	2.5%
Trail	Native	6,358.3	20.3%
Not Defined	Not Defined	166.4	0.5%
		31,274.3	100.0%

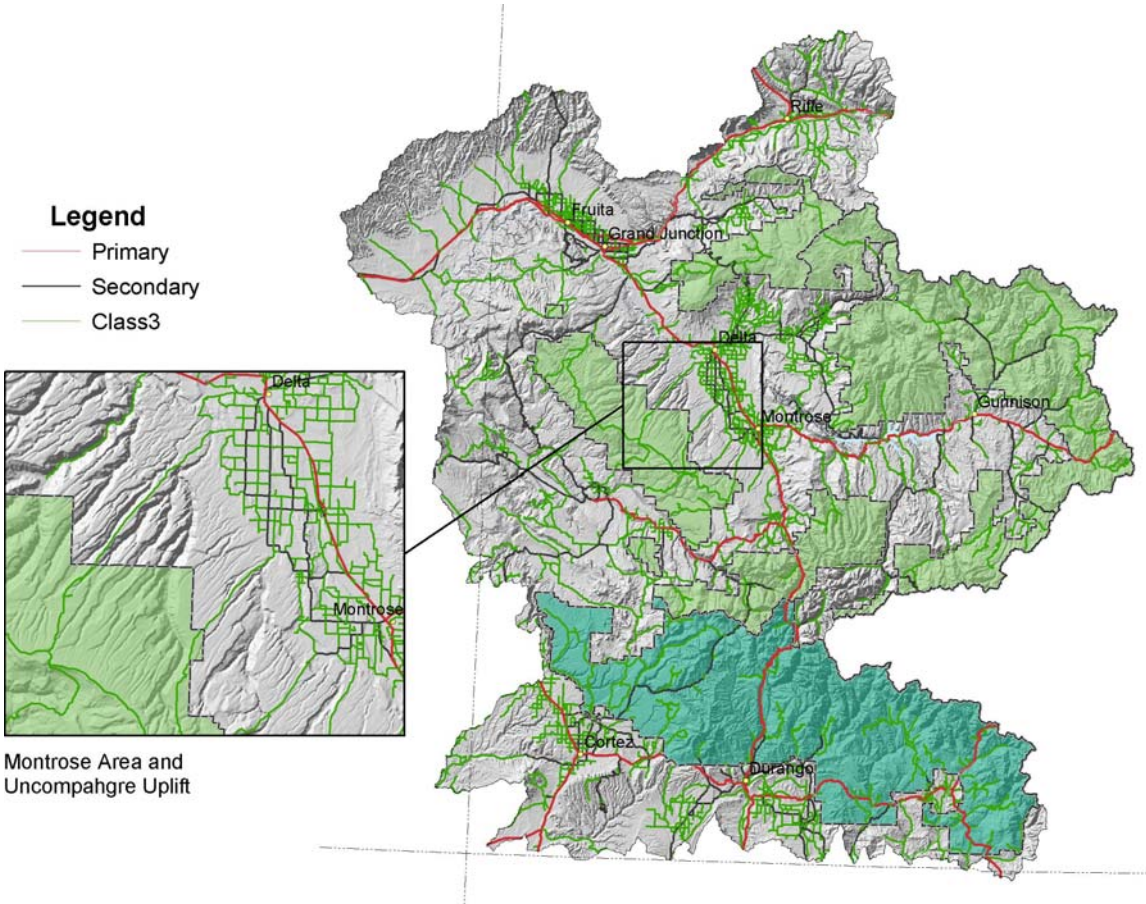
Primary roads include Interstate 70 and roads in the U.S. Federal Highway system and form the backbone of the highway network in the landscape scale. These roads comprise about 2.7% percent of all roads. They traverse 833 miles of principally low dry basin-land, foothills and follow major drainages and cross major mountain passes in the landscape scale. Primary roads are highly engineered and are fully paved, maintained and include erosion control structures and systems (Figure 1).

Figure 1. Primary roads in the landscape. These roads traverse 833 miles.



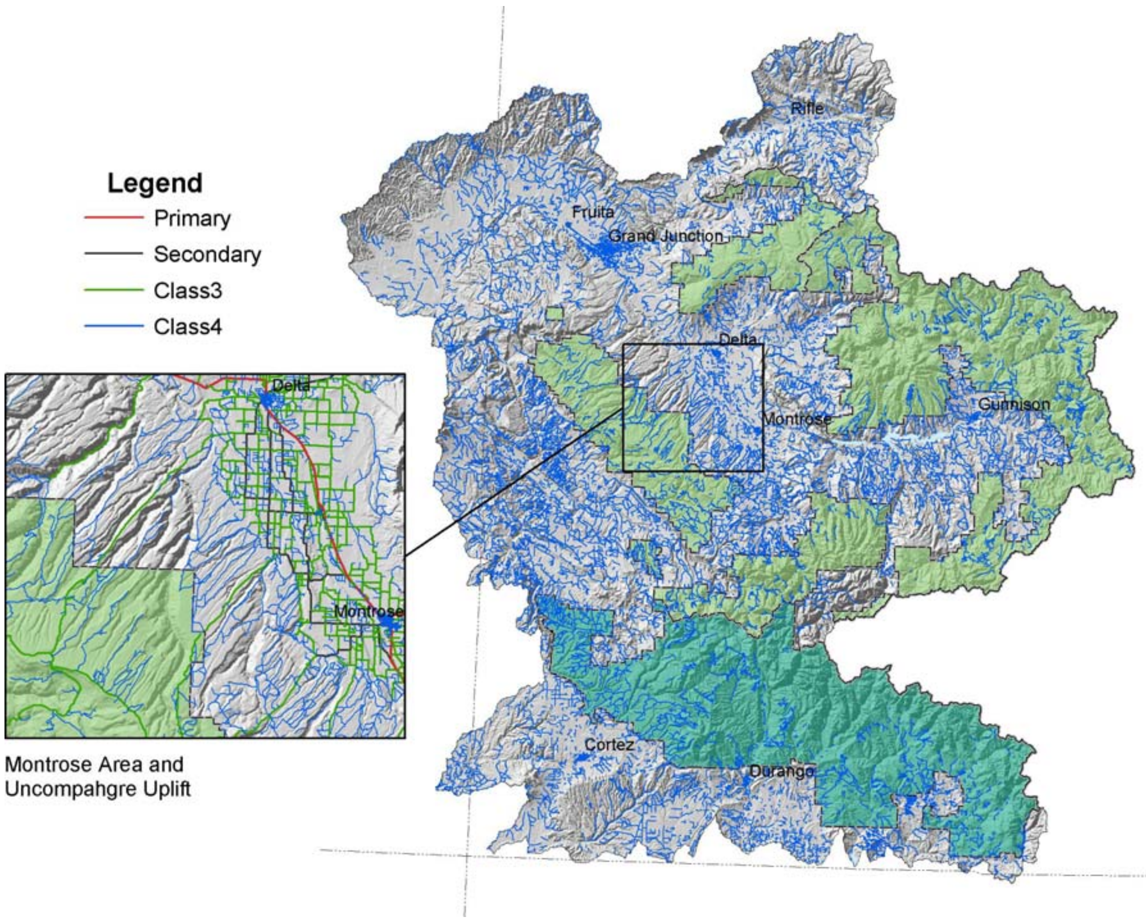
Secondary roads include paved state, county and agency roads. These roads link up communities, rural areas, agricultural areas and federal lands to the primary road network. Class 3 roads, include maintained gravel roads, maintained by local communities, counties and agencies form local community networks, interconnecting rural homes, farms, development areas, recreation areas and Forest Lands. Combined, in the ARW landscape, secondary and Class 3 roads traverse 6,737 miles and comprise about 21% percent of the total road and trail network in the landscape scale (Figure 2).

Figure 2. Primary, secondary and Class 3 roads in the ARW landscape. Combined, secondary and Class 3 roads traverse 6,737 miles, about 21% percent of all roads and trails in the landscape.



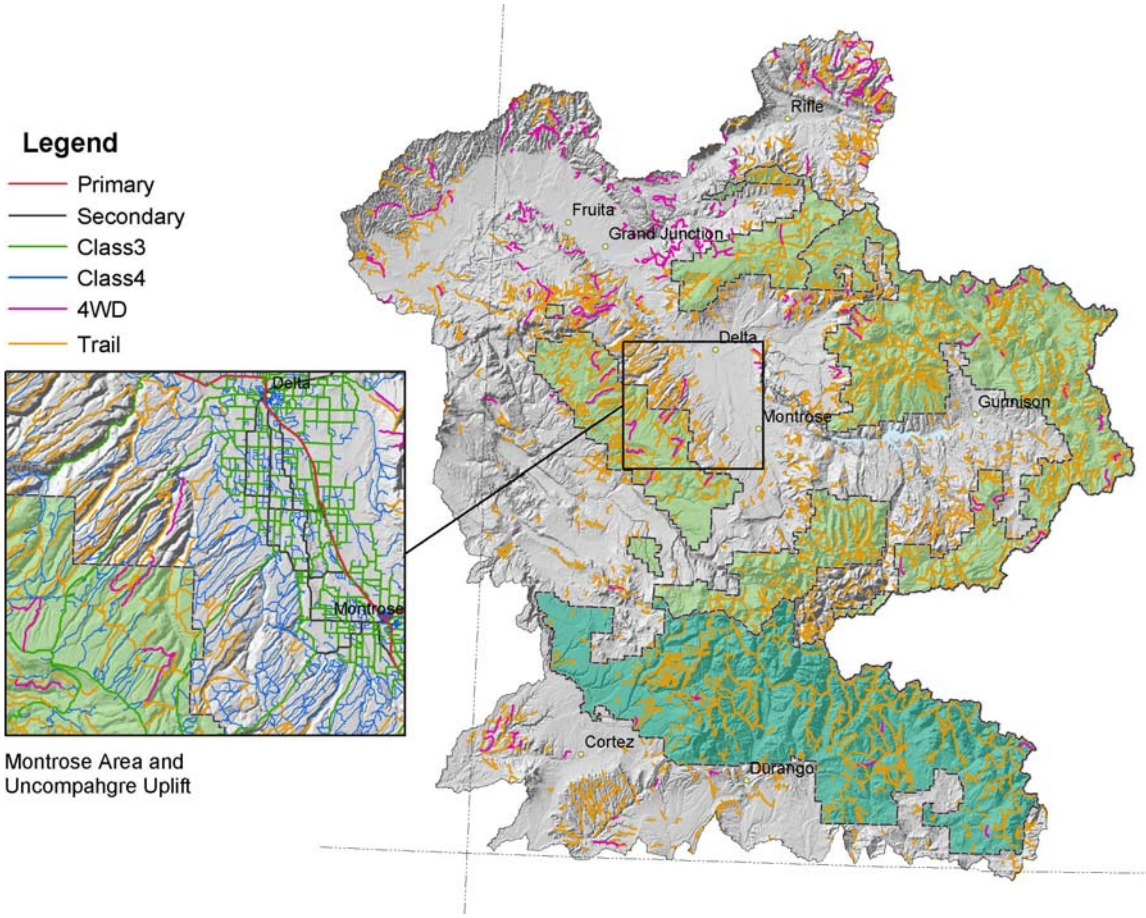
Class 4 roads are typically dirt/native surfaced and form a dense network, weaving into all but the most rugged landscapes in the landscape. This network is comprised of both private, county and agency maintained roads. These roads typically invade native terrain to support recreation, hunting, agriculture, vegetation harvest and fire control and mineral development (Figure 3). There are 16,388 miles of Class 4 roads in the landscape. On the basis of mileage, these are by far the dominant road class with 52.4% percent of the total road and trail mileage in the landscape.

Figure 3. Class 4 roads traverse 16,388 miles of the ARW landscape scale and comprise 52.4% percent of all roads and trails in the landscape scale. The highest densities of roads are evident in the landscape scale map as the blue road lines merge into fields of color.



The most primitive elements of the landscape scale transportation network are naturally, four-wheel drive (4WD) and trails. In some areas, 4WD roads have emerged as the remnants of historic mining and are popular recreational attractions and important to some local economies. More recently, some of these roads occur in areas of mineral exploration, especially oil and gas. However, many come about as recreational users of all terrain vehicles and sturdy 4WD vehicles push tracks further and further into frontier areas. Trails typically occur in areas otherwise inaccessible to large vehicles. Greater proportions of trails occur in the upland and alpine areas.

Figure 4. Four Wheel Drive (4WD) roads and Trails in the ARW landscape. 4WD roads and trails traverse 7,148 miles in the landscape (primary to Class 4 roads are not shown in the landscape view). Actual road densities are higher in some Forest areas and public lands than indicated by the U.S.G.S. 100k DLG data shown here.



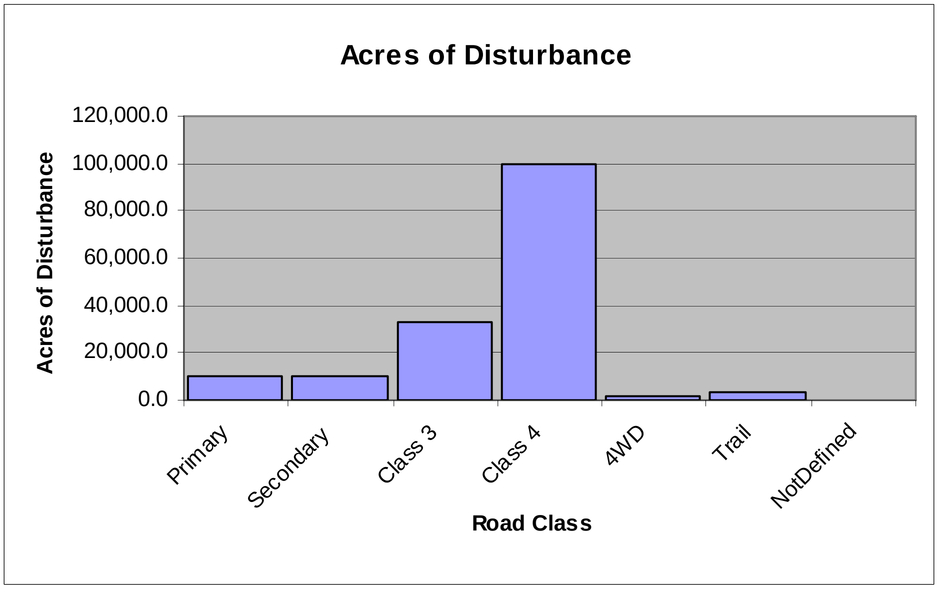
Disturbance Estimates

An overall estimate of disturbed area resulting directly from roads and trails may be estimated by multiplication of roadway lengths times estimated widths. Width estimates are based on measurement of highway widths outside of the landscape scale and therefore assumes that generally road width standards are common inside and outside of the landscape. Using these estimates there are about 157,310 acres of disturbed area in the landscape (Table 2 and Figure 5).

Table 2. Estimated disturbance area in the landscape based on disturbance widths that include the road surface and beyond to the edge of the right-of-way.

Road Class	Example Hwy.	Disturbance Width Feet	Road Length Miles	Disturbed Area Acres
Primary	U.S. 36	100	833	10,099
Secondary	Colo. Hwy. 117	60	1,363	9,911
Class 3	Broadway	50	5,375	32,576
Class 4	Saw Mill Rd	50	16,388	99,322
4WD	Two Track	20	791	1,916
Trail	Estimated	4	6,358	3,083
Not Defined	Estimated	20	166	404
			31,274	157,310

Figure 5. Relative proportions of disturbance area by road class.



About 21% percent of the disturbed areas resulting from roads are by hard surfaced roads. These roads are surfaced with asphalt and concrete and other road structures and right-of-way areas are designed to limit erosion and sedimentation in runoff. Class 3, gravel surfaced roads constitute about 21% percent of roadway disturbed area. Sedimentation levels from these roads are higher than hard surface roads but somewhat mitigated by the gravel surface and road engineering.

Significantly, the remaining 66% percent of roads and trails have dirt/native surfaces and are most subject to erosion and the generation of sediment. Moreover, many of these are not maintained and continue to degrade over time, expanding road disturbance area and consequent sedimentation (Table 3).

Table 3. Estimated disturbance areas by road surface type.

Class	Surface	Area of Disturb	Pct
Primary, Secondary & Not Def.	Paved	20,413	13%
Class 3	Gravel	32,576	21%
Class 4, 4WD, Trail	Dirt/Native	104,322	66%
		157,310	100%

Road Density

Road density models of the landscape provide important aerial measures of road distribution and pattern. These distribution measures are useful to highlight road density hotspots where road influences are the highest and where they are minimal or absent. Importantly, road density data may be overlain with watershed and ownership to gain insight into the aquatic ecosystems most influenced by roads and those agencies with the greatest responsibility and opportunity to mitigate these influences. Moreover, in this analysis, road density models can be strongly correlated to slope models to generate predictive models of road density. These predictive models allow managers to anticipate areas of greatest risk from road activity and encroachment.

Road density is expressed as unit length per unit area. The units expressed here are miles of road per square mile. In this analysis we excluded trails and examined the density of roads only. Road class and surface are all aggregated to yield gross road density estimates.

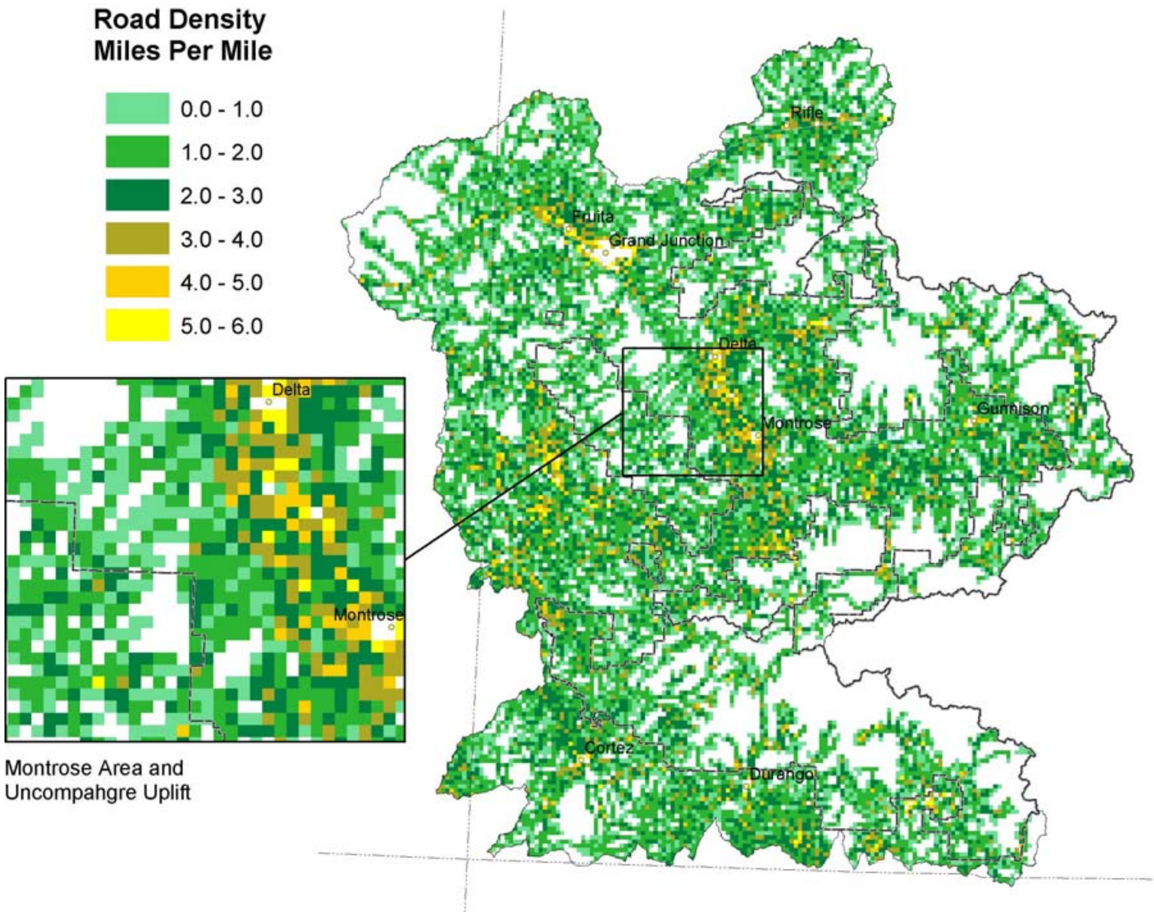
First and most generally, in the landscape, the gross road density is 24,916 road miles divided by 22,258 landscape square miles area for a gross measure of road density of 1.12 miles per square mile.

More specifically, by draping a 1 mile x 1 mile grid on the landscape we find that densities in the landscape scale range from extremes 0.0 to 24.6 miles per square mile. Values greater than 6.0, however, are rare and very high values are likely anomalous. These densities are calculated by summing miles of road (excluding trails) per grid polygon. Aggregation of the resulting densities into seven classes shows that almost one third of the landscape scale has road densities of zero. In the remaining lands, where densities are greater than zero, the average road density is 1.7 miles per mile (Table 4). Higher densities tend to be in lower elevations and basins in proximity of urban and agricultural areas. On public land, higher densities tend to be associated with mineral development, vegetative treatments and recreation areas (Figure 6).

Table 4. Road Density classes in the landscape.

Density Class	Density Mi/Mi	Acres	Percent Of Landscape	Average Road Density
0	0	4,589,443	32.22%	0.00
1	0 to 1	2,777,297	19.50%	0.51
2	1 to 2	3,904,948	27.41%	1.42
3	2 to 3	1,971,394	13.84%	2.42
4	3 to 4	668,925	4.70%	3.39
5	4 to 5	195,961	1.38%	4.39
6	> 5	137,219	0.96%	7.03
		14,245,186	100.00%	

Figure 6. Road density in the landscape.

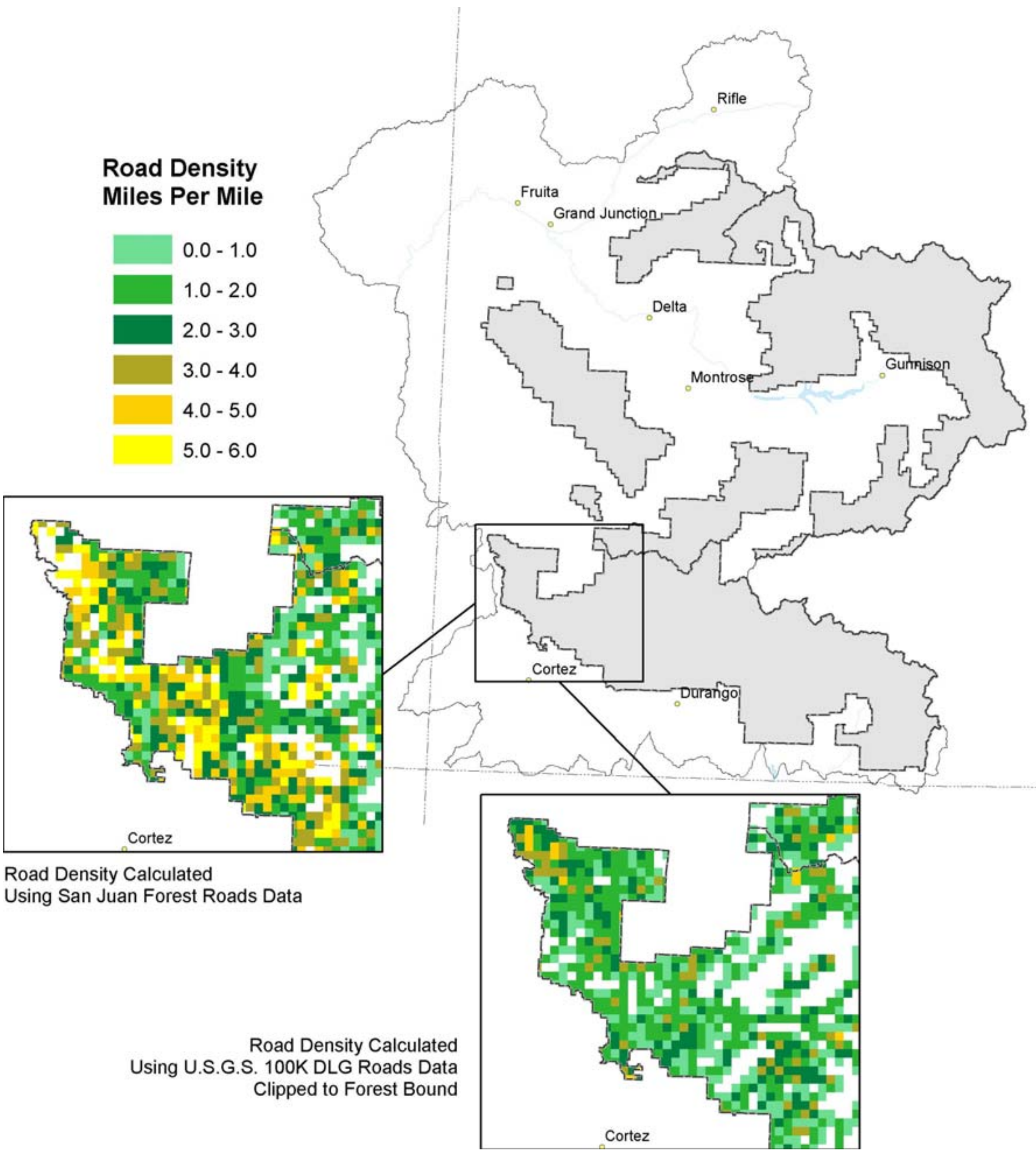


As noted above, the U.S. Geological Survey 100K DLG data does not always fully represent all road types on the landscape. These data do, however, fairly represent primary, secondary and Class 3 roads but the DLG data fall short in representing Class 4, 4WD and trails. This situation is evident where more robust local San Juan and GMUG roads data sets are compared to the regional DLG data. Unfortunately, these data are limited to the forest bounds.

As a consequence, road densities using road layers for the San Juan and GMUG are found to be higher in some areas than is evident in the landscape scale wide densities calculated using the U.S.G.S. DLG data (Figure 7).

A method to address this is discussed next.

Figure 7. Road densities calculated using San Juan Forest roads data yields densities greater than densities calculated using U.S.G.S. 100K DLG roads data. The differences are evident in the two inset maps.



First, we have noted in this analysis that Class 4 roads account for the most significant levels of mileage and disturbance in the landscape. Yet, it is evident from the discussion above, that road densities for Class 4 and 4WD roads are understated, in some cases, where the U.S.G.S. DLG data is used as foundation data.

To meet this shortcoming, in the absence of more comprehensive layers, we developed a proxy model to assess areas of highest potential road densities throughout the landscape.

Slope strongly correlates to the position of roads. Qualitatively, this relationship is self evident – roads on steep terrain are difficult to build and navigate. Correlating slope to road density we find that a strong linear relationship also exists between slope and road density. The relation holds for road densities calculated using the U.S.G.S. DLG data as well as the San Juan/GMUG roads data (Figures 8a and 8b). The shape of the relation in both functions is notable.

Figure 8a. Correlation of U.S.G.S. DLG roads layer based road density to CLC subregion wide slope. Note: this relation is mapped across the CLC subregion that fully contains the ARW landscape.

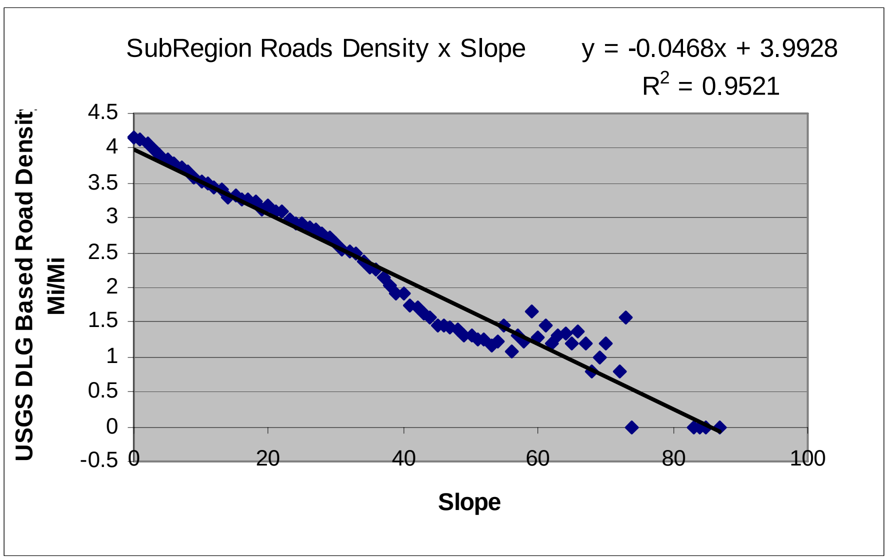
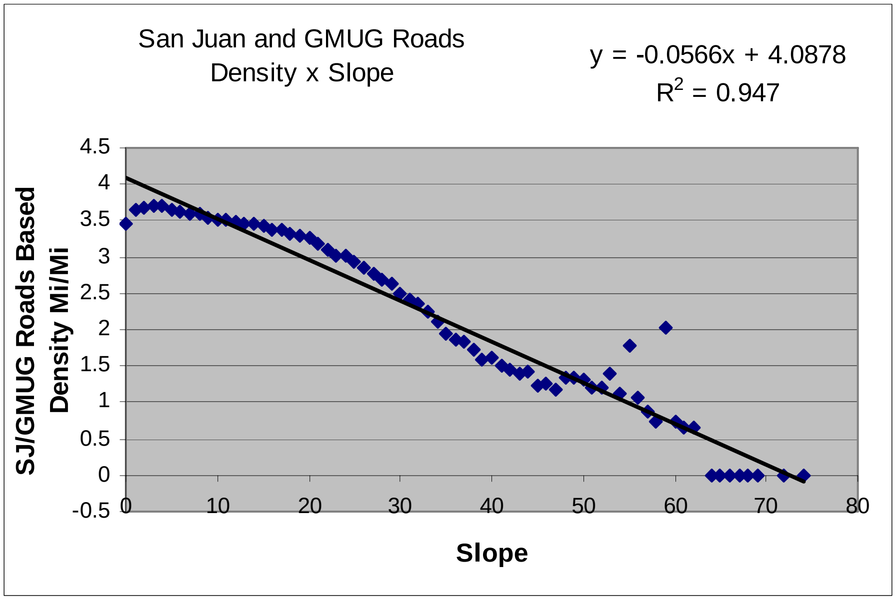


Figure 8b. Correlation of San Juan/GMUG roads layer based road density to subregion wide slope. Note: this relation is mapped across the CLC subregion that fully contains the ARW landscape.



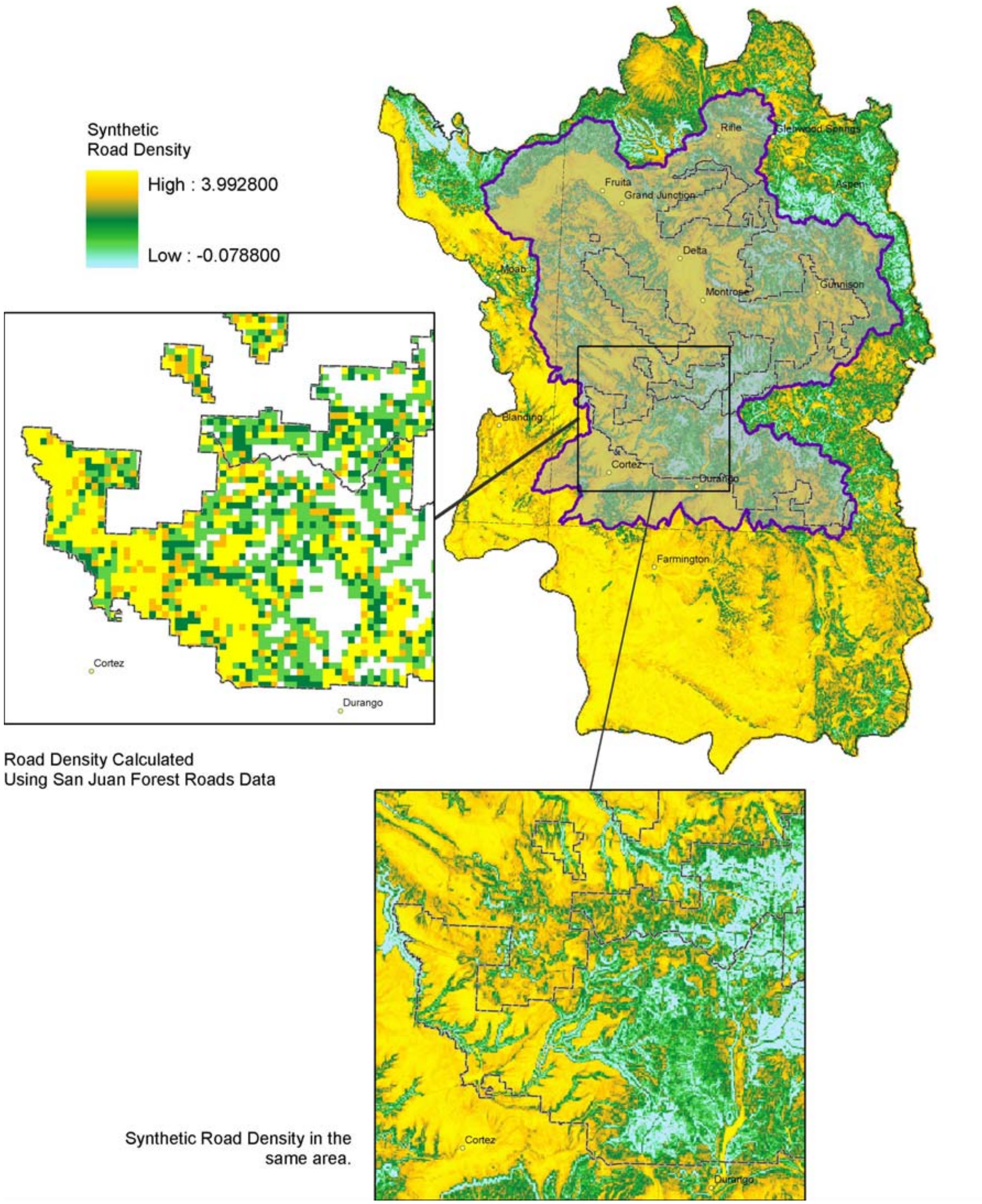
Using GRID functions in Arc/Info it is possible generate a synthetic road density layer by applying the linear functions shown in Figure 8a to a slope layer. The slope layer used is a 100 meter ARC Grid covering the entire CLC subregion. Arc/Info GRID algebra makes this operation very simple. The expression is:

RoDenGrid = = -0.0468 * SlopeGrid + 3.9928.

Patterns in the resulting CLC subregion synthetic road density grid are crudely expressed the polygon based road density layer, calculated using existing road data (Figure 9). In the figure, areas of high potential road density correspond to areas with high densities calculated from existing roads data. More significantly, areas with high slopes and the lowest densities are evident.

This higher discrimination and delineation of high potential areas allows managers to localize areas with both the highest and lowest potentials for roads. For example, it is clear, from existing data that areas of the western San Juan are significantly influenced by high road densities. What is less clear from the road data and the road density models is where future road encroachment is likely to take place. This slope based potential road density model can be aimed at that problem. Moreover, it may be used to augment data, such as the U.S.G.S. DLG data, across the subregion.

Figure 9. The CLC subregion synthetic road density layer calculated by applying the function in Figure 8a compared to high road densities in the western San Juan National Forest. The synthetic density layer allows managers the opportunity to better discriminate the likelihood of both high and low road density.



Road Density and Ownership

On the landscape scale, road mileage strongly corresponds to ownership. Just over 90% percent of all roads mileage is found in three ownerships. These include Private, BLM and U.S. Forest Service lands. Most of the remaining 17% percent of roads are found primarily upon Tribal and State lands. The total number of miles of road, by all road classes excluding trails is 24,916 miles (Table 5).

Table 5. Landscape road mileage (excluding trails) by ownership.

Ownership	Road Miles All Classes	Pct	Sum Pct
Private	11,943	47.9%	47.9%
BLM	6,404	25.7%	73.6%
USFS	4,946	19.9%	93.5%
Tribal	870	3.5%	97.0%
State	560	2.2%	99.2%
NPS	169	0.7%	99.9%
DOD	17	0.1%	100.0%
Not Defined	6	0.0%	
BOR	0	0.0%	
FWS	0	0.0%	
	24,916	100.0%	

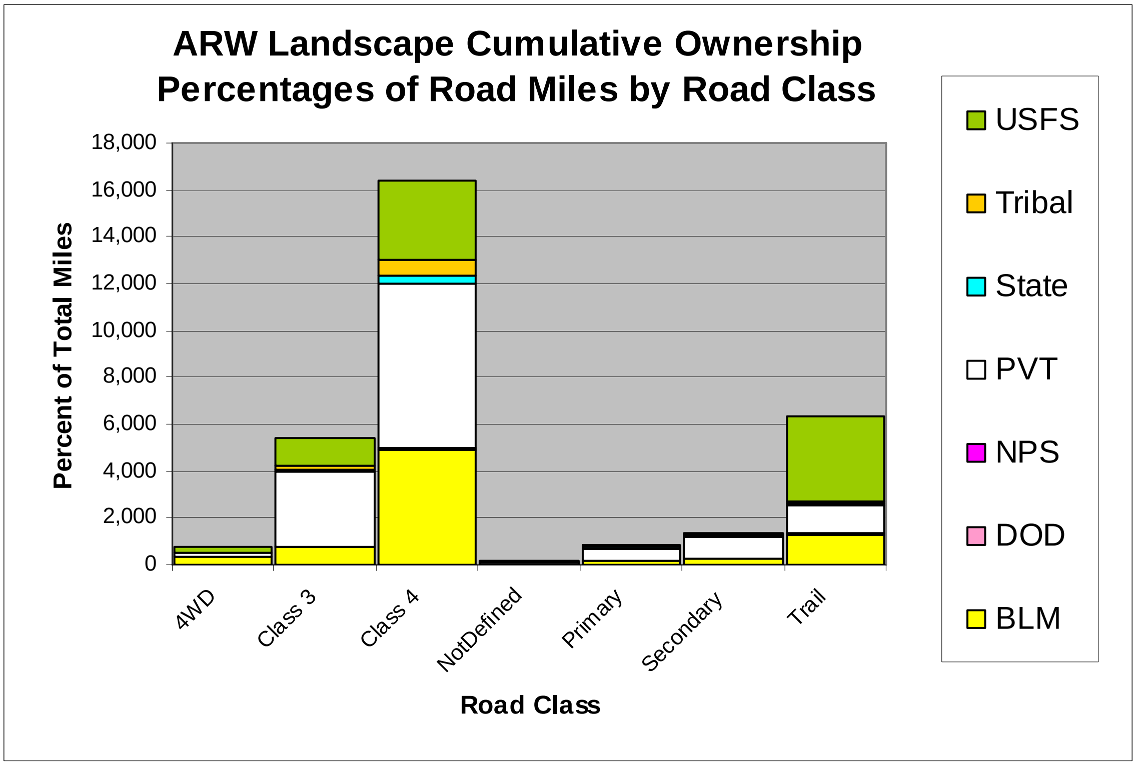
More than 75% percent of the 6,358 miles of trail in the landscape are found within public lands. The remaining 25% percent are primarily found on Private, Tribal and State land (Table 6).

Table 6. Landscape trail mileage by ownership.

Ownership	Trail Miles	Pct	Sum Pct
USFS	3,644	57.3%	57.3%
BLM	1,260	19.8%	77.1%
Private	1,167	18.4%	95.5%
Tribal	132	2.1%	97.6%
State	81	1.3%	98.8%
NPS	72	1.1%	100.0%
DOD	2	0.0%	
Not Defined	0	0.0%	
	6,358	100.0%	

When grouped by road class some important relationships may be identified. First, unsurfaced roads, including 4WD, Class3 and Class4 roads are found principally on BLM, private and Forest lands. Notably, the percentage of Tribal lands is elevated for Class 3 and Class 4 roads. More than half of all trails are found on U.S. Forest lands.

Figure 10. Cumulative road mileages by road class and ownership in the ARW landscape.



Road densities in the landscape scale are the highest on private lands. This, naturally, reflects that levels of road activity are highest in urban, residential and agricultural lands where the lands are almost exclusively private. Higher densities on tribal, state and BLM lands reflect both the lowland/low slope settings in these jurisdictions as well as elevated levels of development, especially for oil and gas. While local densities on National Forest lands can be locally high, the overall weighted mean is among the lowest, due to the amount of upland/high slope settings on the Forests (Table 7).

Table 7. Landscape Ranked road densities. Density values are the weighted mean for each ownership category in the landscape scale.

Ownership	Weighted Mean Road Density Miles/Mile
Private	1.8
NPS	1.2
State	1.2
Tribal	1.1
BLM	1.0
DOD	0.7
USFS	0.6
BOR	0.0
FWS	0.0
Other	0.0
Water	0.0

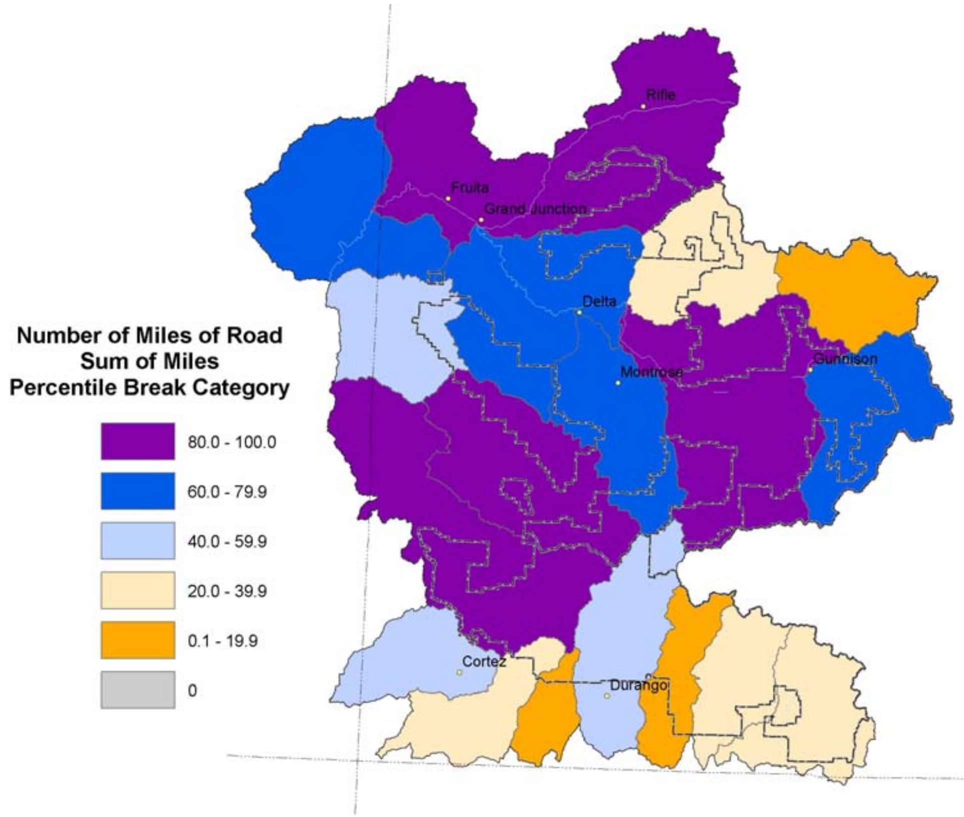
Road Mileage and Weighted Road Density by 4th Level Watershed

Roads mileage, excluding trails, varies in the landscape scale from 3,801 miles in the Colorado Headwaters-Plateau 4th level watershed down to 480 miles in the Middle San Juan watershed. Over half of all roads mileage is in five of eighteen 4th level watersheds in the landscape scale (Table 8). Watersheds spanning the full range of road mileage extremes are found in both the San Juan and GMUG (Figure 11).

Table 8. Roads Mileage by 4th level watershed in the landscape scale.

HUB	HUB Name	Sum of MILES	Pct	Sum Pct
14010005	Colorado Headwaters-Plateau	3,801	15.3%	15.3%
14030002	Upper Dolores	2,904	11.7%	26.9%
14020002	Upper Gunnison	2,329	9.3%	36.3%
14030003	San Miguel	2,200	8.8%	45.1%
14020006	Uncompahgre	2,063	8.3%	53.4%
14020005	Lower Gunnison	1,801	7.2%	60.6%
14020003	Tomichi	1,218	4.9%	65.5%
14030001	Westwater Canyon	1,159	4.7%	70.1%
14080202	Mcelmo	1,023	4.1%	74.2%
14080104	Animas. Colorado	1,015	4.1%	78.3%
14030004	Lower Dolores	1,015	4.1%	82.4%
14020004	North Fork Gunnison	762	3.1%	85.4%
14080101	Upper San Juan	741	3.0%	88.4%
14080107	Mancos	706	2.8%	91.2%
14080102	Piedra	655	2.6%	93.9%
14020001	East-Taylor	528	2.1%	96.0%
14080999	Upper San Juan West	517	2.1%	98.1%
14080105	Middle San Juan	480	1.9%	100.0%
		24,916	100.0%	

Figure 11. Sum of road mileage by 4th level HUB.

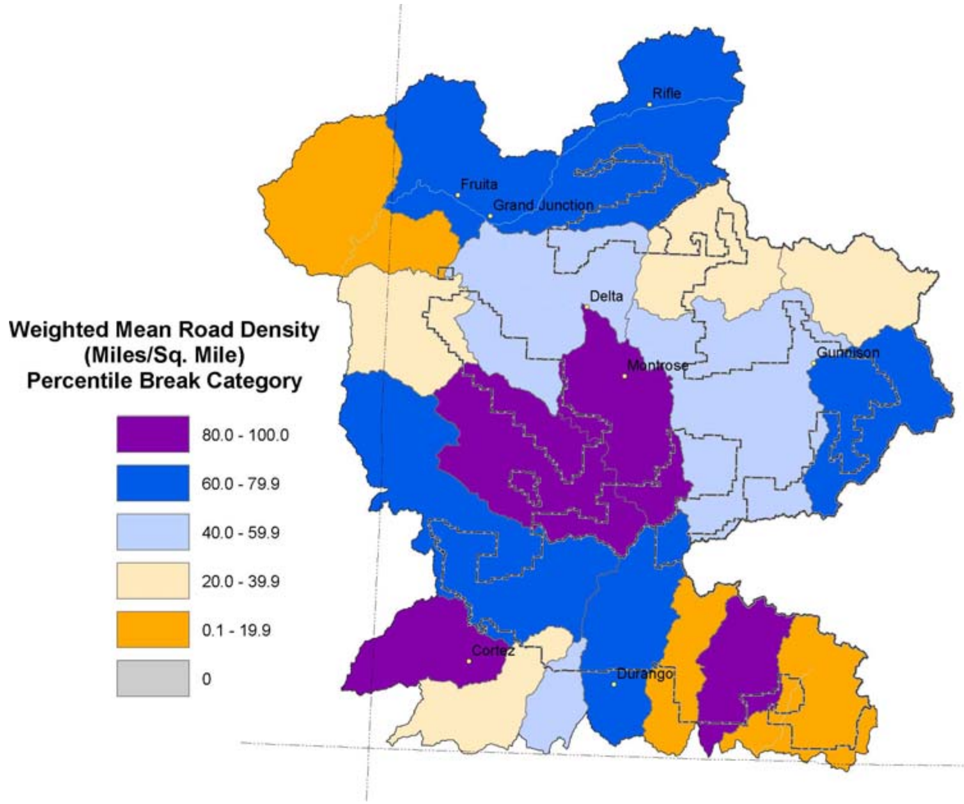


Weighted road density varies in the landscape scale from 2.21 miles per square mile in the Uncompahgre 4th level watershed down to 0.58 in the Upper San Juan West 4th level watershed (Table 9). Notably, high density watersheds are found in the western San Juan, in areas to the north and the southeastern Uncompahgre uplift and in the Piedra watershed east of Durango (Figure 12).

Table 9. Weighted road density by 4th level watershed in the landscape scale.

HUB	HUB Name	HUB Weighted Road Density
14020006	Uncompahgre	2.21
14030003	San Miguel	1.75
14080102	Piedra	1.73
14080202	Mcelmo	1.72
14080104	Animas Colorado	1.72
14010005	Colorado Headwaters-Plateau	1.68
14030002	Upper Dolores	1.67
14020003	Tomichi	1.62
14080105	Middle San Juan	1.61
14020002	Upper Gunnison	1.59
14020005	Lower Gunnison	1.56
14030004	Lower Dolores	1.55
14020004	North Fork Gunnison	1.50
14020001	East-Taylor	1.44
14080107	Mancos	1.42
14030001	Westwater Canyon	1.27
14080101	Upper San Juan	0.68
14080999	Upper San Juan West	0.58

Figure 12. Weighted mean road density by 4th level HUB.



Information Needs and Gaps

A more comprehensive survey of roads and trails is needed for the Class 4, 4WD roads and trails. These types of roads are especially problematic because of the unauthorized and invasive modes of their creation and often without mitigation. Furthermore, because these roads are continually evolving and being added, on private, state and federal lands, it is important to conduct surveys with great frequency.

The estimates of disturbance used here should be verified. Furthermore, rates of sedimentation, introduced under the different road classes should be researched and added to this characterization. Also, the overall sphere of influence should be further explored. To what degree do roads influence communities beyond the area of physical disturbance?

References

U.S.G.S., 2004a – Reference to USGS DLG roads data.

CHAPTER 2. ANTHROPOGENIC INFLUENCES – LANDSCAPE SCALE

Developed Recreation

Key Findings

- The ARW Landscape Scale is located at the margins of the Colorado Plateau and Southern Rocky Mountains. This very scenic region is a "recreational hotspot".
- The ARW Landscape Scale is at the crossroads to many important regional attractions including the Grand Canyon, Mesa Verde, Canyonlands and Arches National Parks. The landscape is geographically central to important and growing population centers including Salt Lake City, Denver, Albuquerque, Sante Fe and Phoenix.
- More than half of the visitors to National Parks adjacent to the landscape come from California, Colorado, Utah and a few eastern states. Park visitors also utilize Forest recreation opportunities.
- On Forest lands, about half the users are from local communities, especially, Durango, Montrose, Grand Junction and Gunnison. This is important because levels of visitation will likely increase significantly with continued robust growth for these communities and others in the landscape.
- Recently, while visitation to National Parks seems to be leveling off or dropping, visitation to the National Forests and BLM lands in the landscape are increasing.
- As use of National Forests and BLM lands increases and user quality of experience may eventually drop as availability of recreational resources diminishes. At the same time, current and future increases in recreational use of public lands will lead to increased disturbance and potential conflicts and competition between recreation and other management programs.
- In this analysis we've identified 175 developed recreation sites on Forest, BLM, State and National Park Service lands in the landscape scale. About 90% percent are on either Forest or BLM lands.
- Using an estimated average of 101.6 acres per site, 33,255 to 34,546 acres are currently directly disturbed and/or influenced by developed recreation.
- About two thirds of sites are found from 8,000 to 12,000 feet in upland vegetation communities.

- The East-Taylor, Upper Gunnison, Upper San Juan West and Piedra 4th level watersheds have the highest ratios of developed recreation sites per stream mile.
- Just over half of all developed recreation sites are located within 200 meters of a perennial stream. Almost two-thirds are within 400 meters.

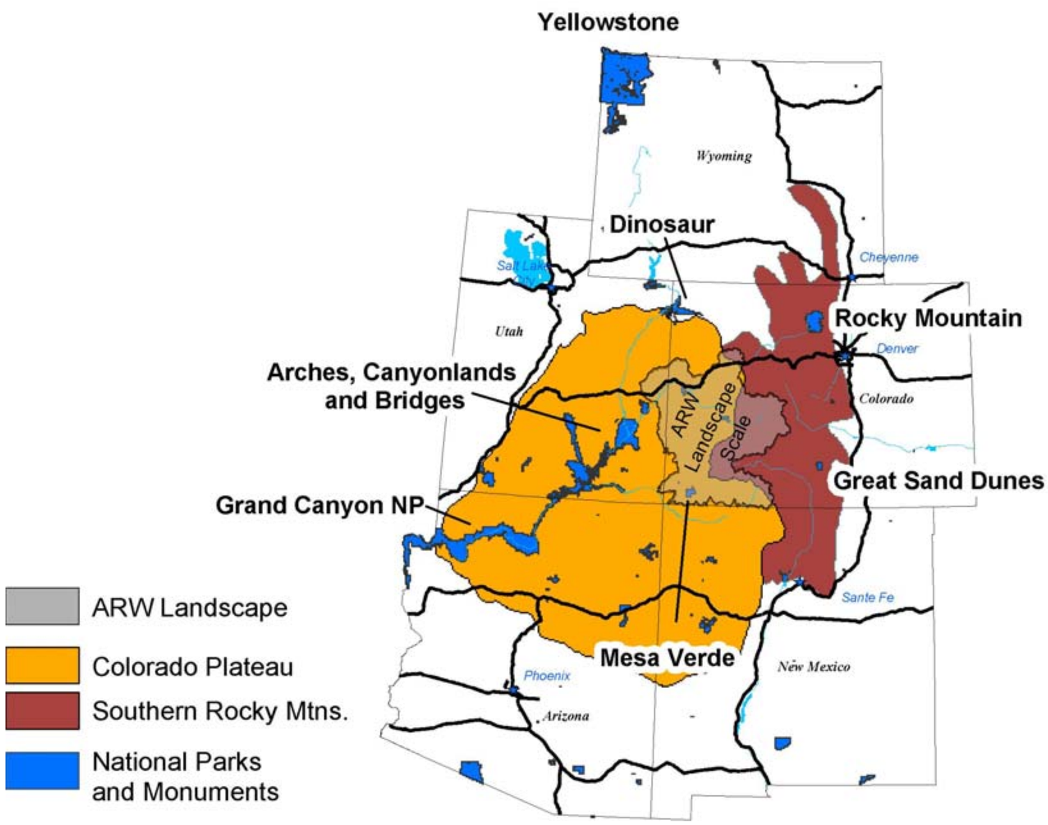
Introduction

The striking and challenging geography, scenery and recreational opportunities of the Colorado Plateau and Southern Rocky Mountains attract growing numbers of visitors to public, state and private lands in the ARW Landscape Scale. Developed recreation opportunities include camping, and picnicking in developed sites, skiing at developed resorts along with sightseeing and visits to sites of cultural and historical importance.

Recreational opportunities in and adjacent to the landscape draw visitors from both local and distant communities. Scenery, attractions and recreational opportunities in the landscape are of such a quality as to provide destinations attracting significant numbers of visitors. At the same time, the landscape is at an important crossroads for recreational visitors to well known National Parks in the surrounding five-state region (Figure 1). These Parks include the Grand Canyon, Arches, Canyonlands, Bridges, Dinosaur, Rocky Mountain and the Sand Dunes. Furthermore, the Mesa Verde National Park is in the landscape itself. Very often, these "travel-through" visitors visiting these Parks also take advantage of recreational opportunities in the landscape.

The Colorado Plateau and Rocky Mountains attract local, national and international visitors. As of 2003, 50% percent of visitors to Arches National Park were from six states. Of these, 33% percent were from California (16%), Colorado (9%) and Utah (8%) (Meldrum, et al. 2004). The remaining visitors are from three eastern states including Illinois (7%), New York (5%) and Virginia (4%). Similarly, over 50% of surveyed visitors to Canyonlands National Park are from three western states. These states include Colorado (29%), California (15%) and Utah (11%) (Canyonlands, 2005).

Figure 1. The ARW Landscape Scale straddles both the Colorado Plateau and Southern Rocky Mountains. The landscape falls at the cross-roads for travelers from large regional metropolitan centers including Salt Lake City, Phoenix, Albuquerque, Santa Fe and Denver.

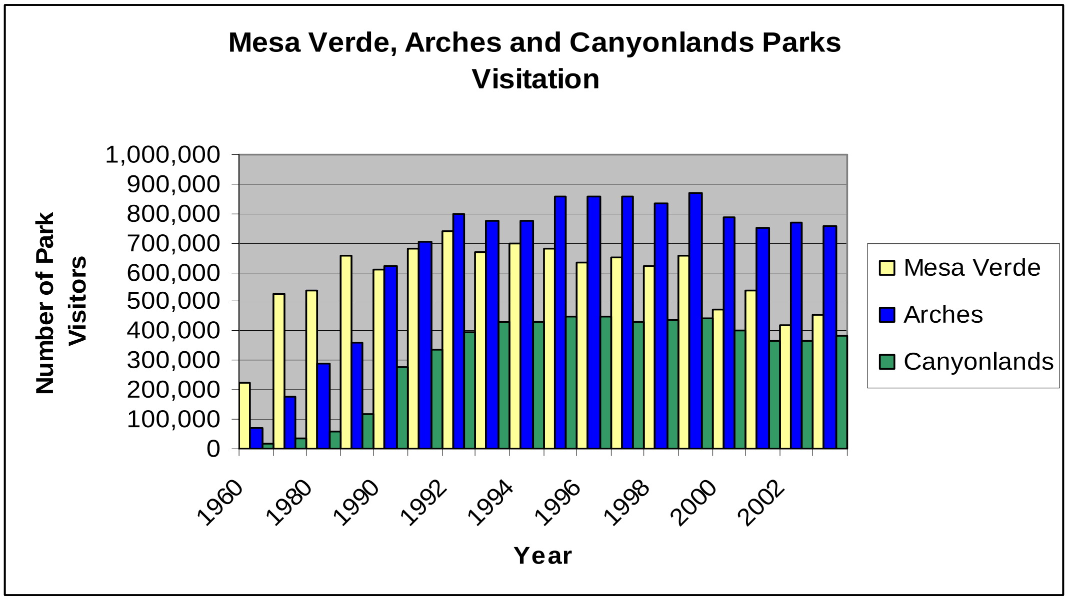


Importantly, studies show that over recent years there have indeed been significant increases in public participation in recreation activities nationally. This trend includes a wide spectrum of recreation opportunities and settings. The most significant increases in recreation activities include snow skiing, canoeing/kayaking, cycling, camping, sailing, swimming, fishing, horseback riding and hunting. With the exception of hunting, these activities have shown significant increases since 1995 (Cordell and Super, 2000). World class opportunities for these activities are found in the landscape.

This trend of increasing public interest may be combined with changes in use patterns on National Parks to show that both BLM and National Forests in the landscape are of key importance to developed recreational activities in the landscape. As a result, levels of recreational activity, demand and influences on terrestrial and aquatic ecosystems are also increasing in character, degree and extent.

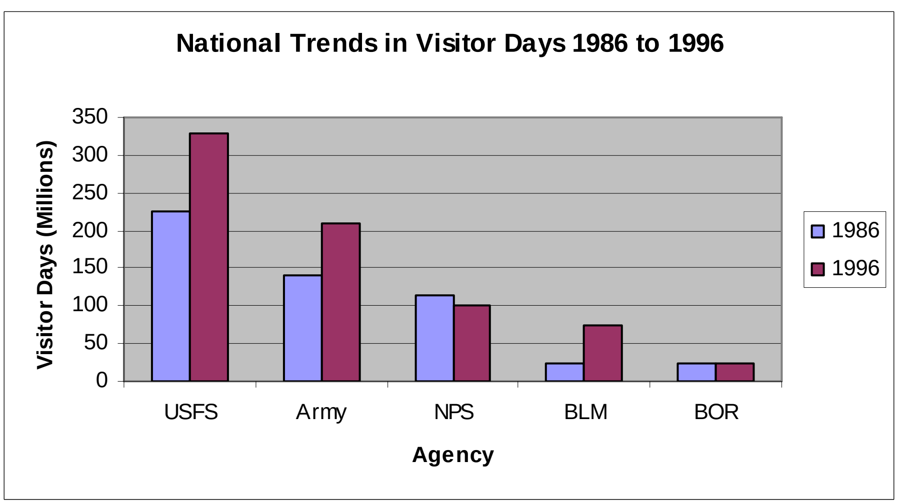
For example, visitation to Mesa Verde, Arches and Canyonlands National Parks steadily increased to maximums in the early 1990s. Then during the decade of the 1990s visitation leveled out and slumped (Figure 2). While the slump in visitation may be at least partly attributed to a down turn in the national economy, or as a response to recent drought and fire, the overall trend may also attributed to a diminishing quality of user experience in these National Parks. This diminishing quality of experience may be an indication that National Parks are at or near their capacity to provide positive recreational experiences.

Figure 2. Visitation trends for the Mesa Verde, Arches and Canyonlands National Parks. These trends show and overall trend of diminishing visitation in these three parks (NPS, 2005).



So, as overall demand for recreational resources continues to increase, and quality of experience diminishes in National Parks, recreational users are seeking out new opportunities elsewhere. From 1986 to 1996 visitation levels for the National Forests, BLM lands, Federal lands managed by the Army Corps of Engineers and the Bureau of Reclamation (BOR) all increased while visits to National Parks dropped (Figure 3).

Figure 3. National trends in visitation suggest a shift away from National Parks to National Forests, Army Corps of Engineers lands and BLM lands. (Adapted after Cordell and Super, 2000).

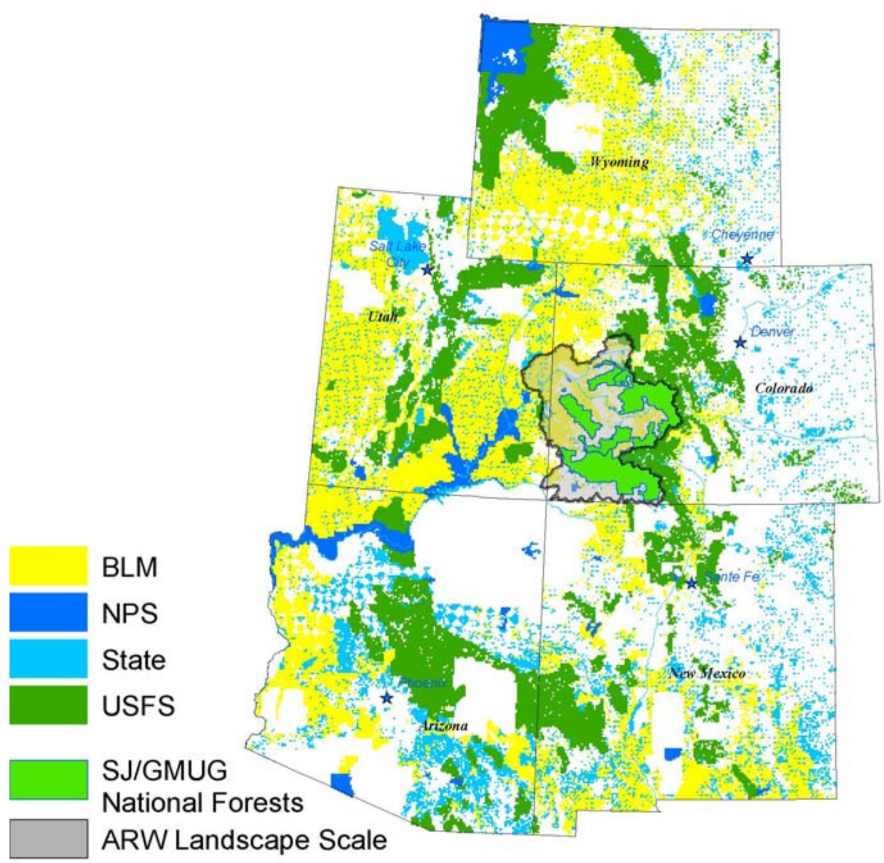


Large areas of these public lands, especially lands managed by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM), are available in and adjacent to the ARW Landscape Scale (Table 1 and Figure 4). Upland areas along the eastern margin of the landscape scale are principally in Forest Service jurisdiction while the desert basins and foothills include significant tracts of BLM land. Both the Forest Service and BLM provide developed recreation sites on these lands.

Table 1. Land Ownership/Jurisdiction by agency in the ARW Landscape Scale.

Owner	Acres	Pct	SumPct
USFS	5,142,917.0	36.1%	36.1%
BLM	4,239,507.6	29.8%	65.9%
Private	3,919,384.5	27.5%	93.4%
Tribal	526,745.2	3.7%	97.1%
State	299,072.5	2.1%	99.2%
NPS	92,624.7	0.7%	99.8%
DOD	22,077.1	0.2%	100.0%
	14,242,328.6	100.0%	

Figure 4. Significantly large tracts of public lands in and around the ARW Landscape Scale provide important recreational opportunities both locally and nationally.



Local visitation is important too. U.S. Forest Service surveys for the San Juan and GMUG show that about half the number of Forest visitors report home zip code locations that are beyond 50 miles of the Forests (Kocis, et al., 2004 and USDA, 2001). About 51% percent of visitors to the San Juan Forest (Figure 5a) and 44% of visitors to the GMUG (Figure 5b) are from communities within 50 miles. The data show that the principal source communities for Forest visits include the Colorado communities of Grand Junction, Montrose, Durango and Gunnison.

Figure 5a. Home communities by zip code of local of visitors to the San Juan National Forest.

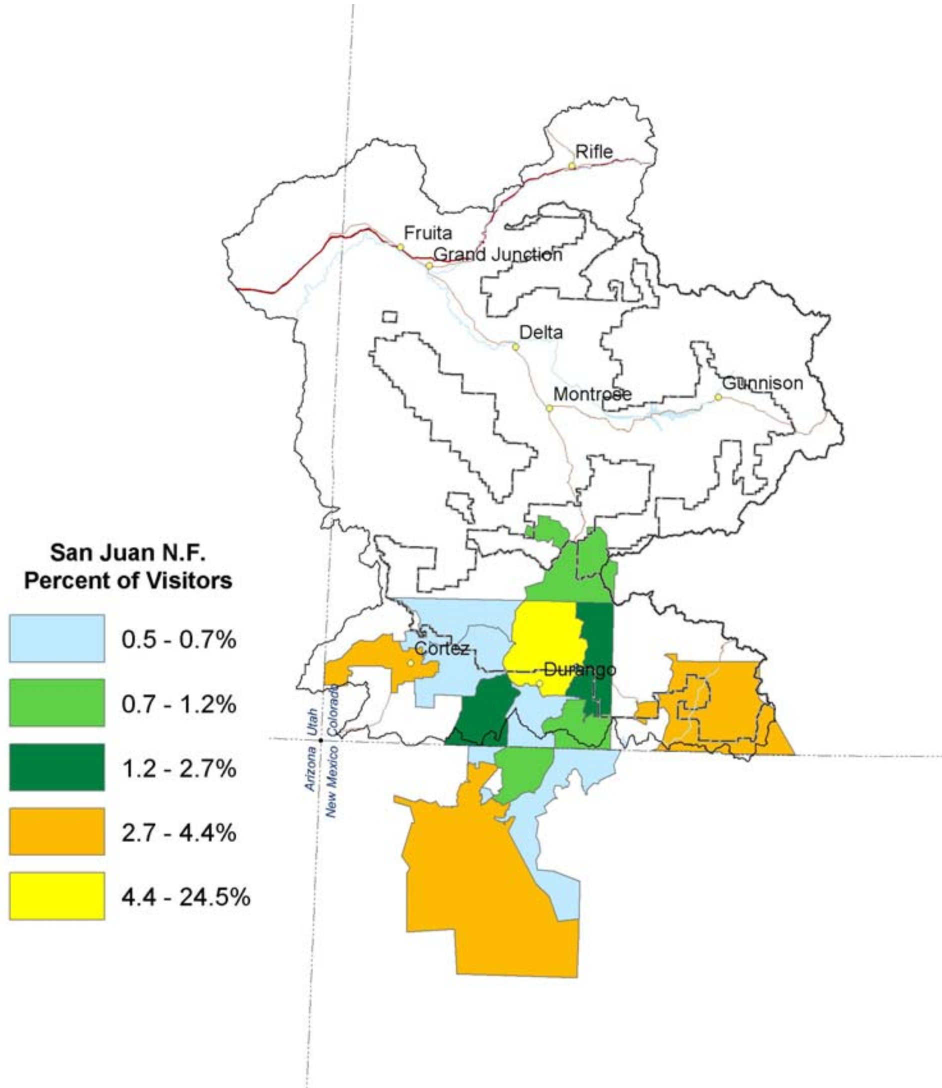
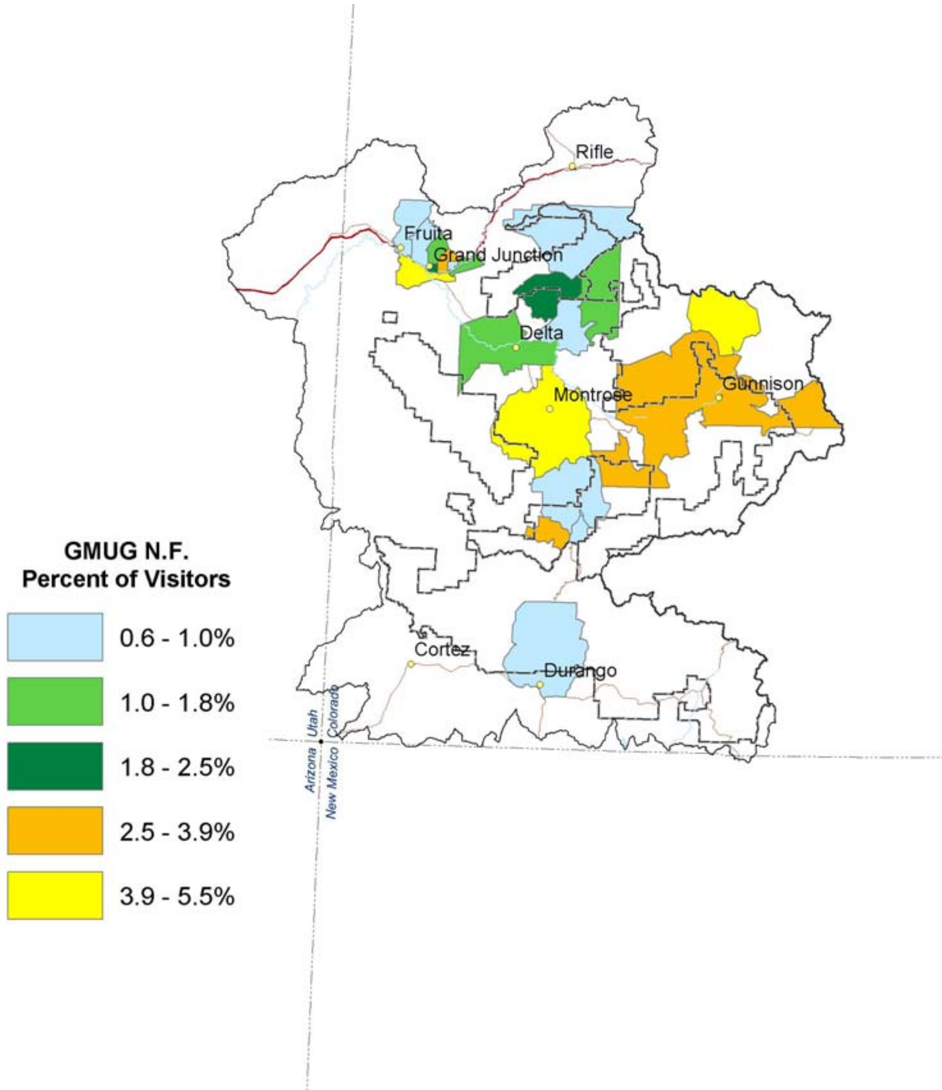
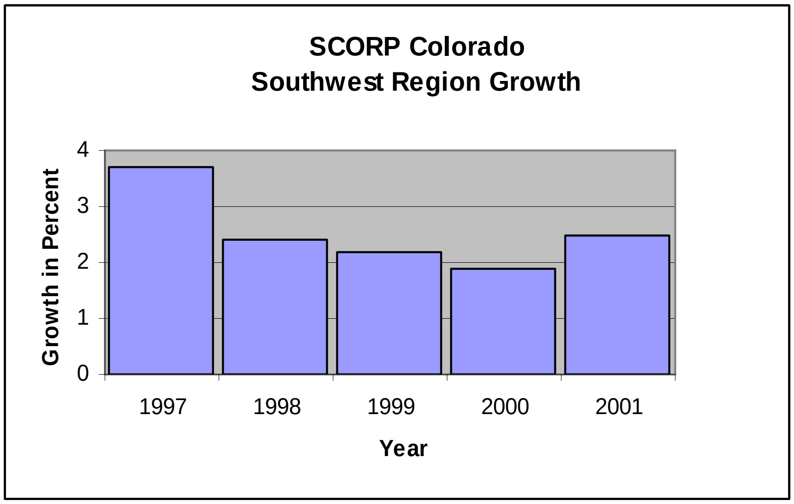


Figure 5b. Home communities by zip code of local of visitors to the GMUG National Forest.



These western slope communities are expected to grow significantly over the coming years. By 2025 the population of Colorado is expected to grow by another 48% percent. Currently reported growth in the region for five years (1997 to 2001) averages just over 2% per year (Figure 6). Much of this growth will take place in rural counties with access to public lands. (SCORP, 2003).

Figure 6. Graph showing percentage population growth in the SCORP southwest region, including the ARW Landscape Scale subject lands. Adapted after SCORP, 2003



To conclude, we can expect the demand for developed recreation on Forests in the ecoregion to continue to grow. Growth is likely to continue along upward trends as interest in National Forests and BLM lands increases. The increases will come as local communities continue to grow and as people look beyond the National Parks for their recreational experiences.

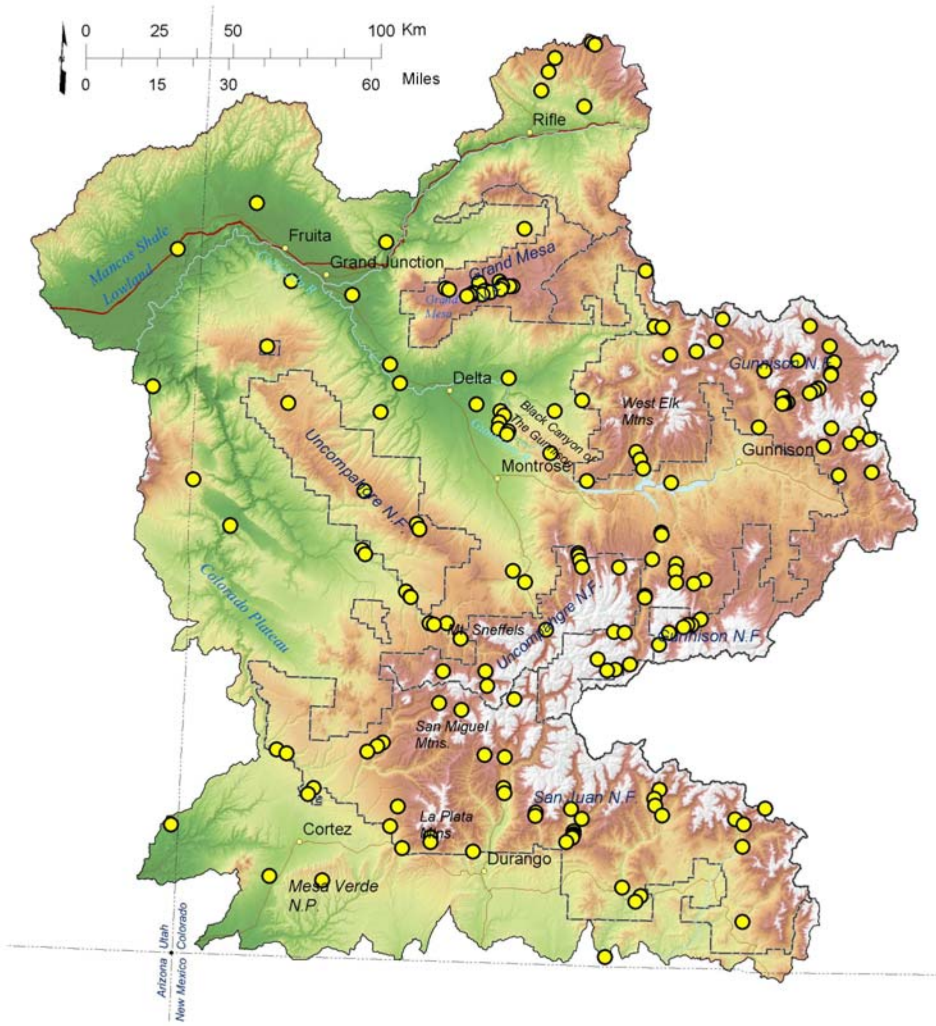
ARW Landscape Scale Analysis

In this analysis we have identified 175 developed recreation sites on public lands in the landscape scale (Figure 7). The precise number of sites is difficult to determine because not all Federal and State agencies have completed and published inventories to date. The problem is compounded by the fact that there is no universally accepted standard defining developed recreation site characteristics. Never the less, in this analysis we generally consider overnight campgrounds as developed recreation sites. These data provide a good estimate of disturbance and affected vegetation communities. Sites on private lands are not included.

Under this definition, developed recreation sites are comprised of familiar elements. They include campground features such as fire rings, parking areas, picnic tables, toilets and disturbed congregation and tent pitching areas. Some sites include day use areas and facilities for recreational vehicle parking and facilities. In surrounding areas, vegetation disturbance results from trampling, cutting and foraging for firewood.

The overall area of disturbance for a site is difficult to determine. No definite boundary exists for campgrounds and the resulting area of disturbance.

Figure 7. Developed recreation sites on public lands in the ARW landscape scale.



National Forests in the Landscape Scale

About two-thirds of developed recreation sites in the landscape scale are found on National Forests (Table 2a and 2b). An additional 23.4% percent of all sites are found on lands managed by the BLM. These two agencies combined cover about 66% percent of the land area in the landscape. The remaining sites are found on National Park Service lands and State lands. Bureau of Reclamation sites are included in the State sites because of co-management.

Table 2a. Number of sites by agency in the landscape scale. State sites include Bureau of Reclamation (BOR) sites in some cases. Almost 90% percent of sites are on either Forest or BLM lands.

Agency	Number of Developed Recreation Sites	Pct.
USFS	114	65.1%
BLM	41	23.4%
State	13	7.4%
NPS	7	4.0%
	175	100.0%

In the landscape scale, sites are distributed among four National Forests (Table 2b). These include the White River, Manti-LaSal National Forests in addition to the GMUG and San Juan. In the landscape scale, the GMUG has the greatest number of sites and about two thirds of all sites are found in the GMUG and San Juan combined.

Table 2b. Number of sites by Forest for the four National Forests in the landscape scale.

National Forest	Number Of Sites	Pct.
GMUG	73	41.7%
San Juan	40	22.9%
White River	3	1.7%
Manti-La Sal	1	0.6%
Subtotal:	117	66.9%
Outside Forests	58	33.1%
Total:	175	100.0%

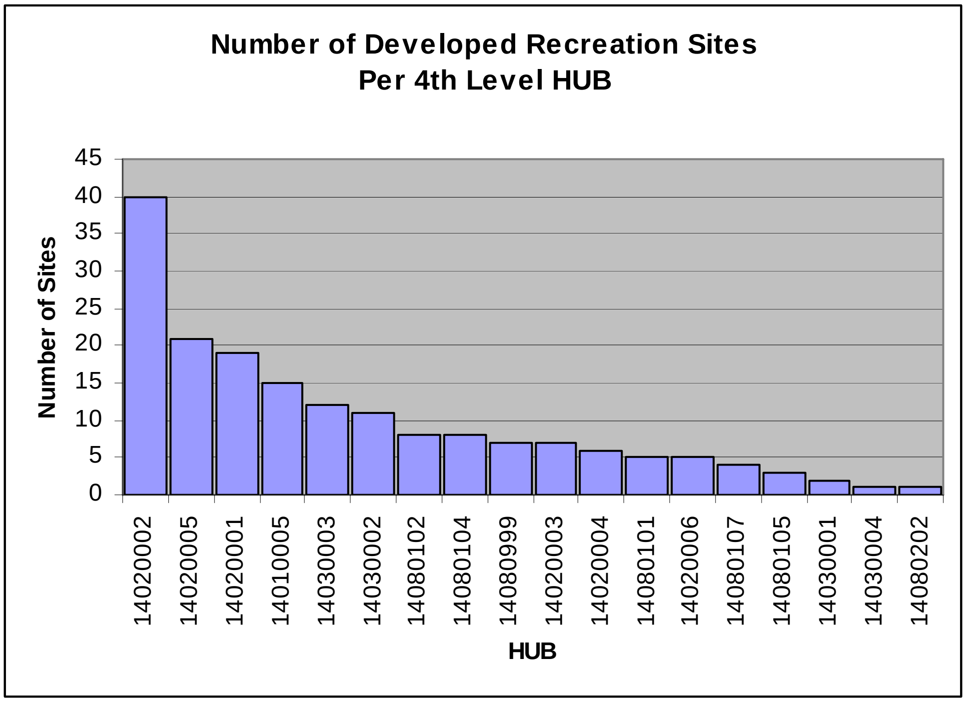
Developed Recreation Sites and 4th Code HUB

Over half (95) of the 175 developed recreation sites in the landscape scale are found in four 4th level HUBs (Table 3, Figure 8). These HUBs include the upper and lower Gunnison, East-Taylor and Colorado Headwaters-Plateau watersheds. These watersheds are located in dominantly upland settings.

Table 3. Table showing the number of developed recreation sites per 4th level HUB in the landscape scale. The table is sorted by number of sites.

HUB4	HUB Name	Number of Sites	Pct	Sum Pct
14020002	Upper Gunnison	40	22.9%	22.9%
14020005	Lower Gunnison	21	12.0%	34.9%
14020001	East-Taylor	19	10.9%	45.7%
14010005	Colorado Headwaters-Plateau	15	8.6%	54.3%
14030003	San Miguel	12	6.9%	61.1%
14030002	Upper Dolores	11	6.3%	67.4%
14080102	Piedra	8	4.6%	72.0%
14080104	Animas. Colorado	8	4.6%	76.6%
14080999	Upper San Juan West	7	4.0%	80.6%
14020003	Tomichi	7	4.0%	84.6%
14020004	North Fork Gunnison	6	3.4%	88.0%
14080101	Upper San Juan	5	2.9%	90.9%
14020006	Uncompahange	5	2.9%	93.7%
14080107	Mancos	4	2.3%	96.0%
14080105	Middle San Juan	3	1.7%	97.7%
14030001	Westwater Canyon	2	1.1%	98.9%
14030004	Lower Dolores	1	0.6%	99.4%
14080202	Mcelmo	1	0.6%	100.0%
		175	100.0%	

Figure 8. Histogram showing number of developed recreation sites per 4th level HUB in the landscape scale. The top four sites contain over half of the total number of sites. The Upper Gunnison has the greatest number of sites (40) and McElmo, the least (1).



The HUBs with the highest number of developed recreation sites do not always correspond to HUBs with the highest ratios of sites per stream mile. Within the landscape scale, the ratio of sites per stream mile is the highest among four 4th level HUBs. These HUBs include, in descending order, East-Taylor, Upper Gunnison, Upper San Juan West and Piedra. For these HUBs the ratio of sites per stream mile ranges from 0.025 to 0.0153 respectively (Table 5 and Figure 9). The HUBs: Westwater Canyon, McElmo and Lower Dolores have the lowest ratios at 0.0014, 0.00013 and 0.0010 sites per stream mile respectively.

Table 5. Table showing the number of developed recreation sites per stream mile per 4th level HUB.

HUB	HUB Name	Stream Miles	Number of Sites	Number Per Stream Mile
14020001	East-Taylor	759.0	19	0.0250
14020002	Upper Gunnison	1,920.8	40	0.0208
14080999	Upper San Juan West	454.8	7	0.0154
14080102	Piedra	523.1	8	0.0153
14020005	Lower Gunnison	1,910.0	21	0.0110
14080105	Middle San Juan	345.4	3	0.0087
14080104	Animas. Colorado	925.7	8	0.0086
14030003	San Miguel	1,524.7	12	0.0079
14020003	Tomichi	959.1	7	0.0073
14020004	North Fork Gunnison	859.8	6	0.0070
14080101	Upper San Juan	884.3	5	0.0057
14020006	Uncompahange	972.8	5	0.0051
14030002	Upper Dolores	2,212.1	11	0.0050
14080107	Mancos	817.2	4	0.0049
14010005	Colorado Headwaters-Plateau	3,294.4	15	0.0046
14030001	Westwater Canyon	1,405.6	2	0.0014
14080202	McElmo	766.9	1	0.0013
14030004	Lower Dolores	992.7	1	0.0010

The sites with the highest ratios are generally found in upland watersheds. These watersheds are located east of Durango, north to Montrose and then up the Gunnison River to Gunnison (Figure 10). To the west, the watersheds from the La Plata Mountains, northward to the Uncompahgre Uplift have relatively high ratios. Importantly, the watersheds with the highest ratios are largely comprised of Forest lands. The remaining watersheds are confined generally to foothill and lowland desert settings.

Figure 9. Developed recreation sites per stream mile by 4th level HUBS

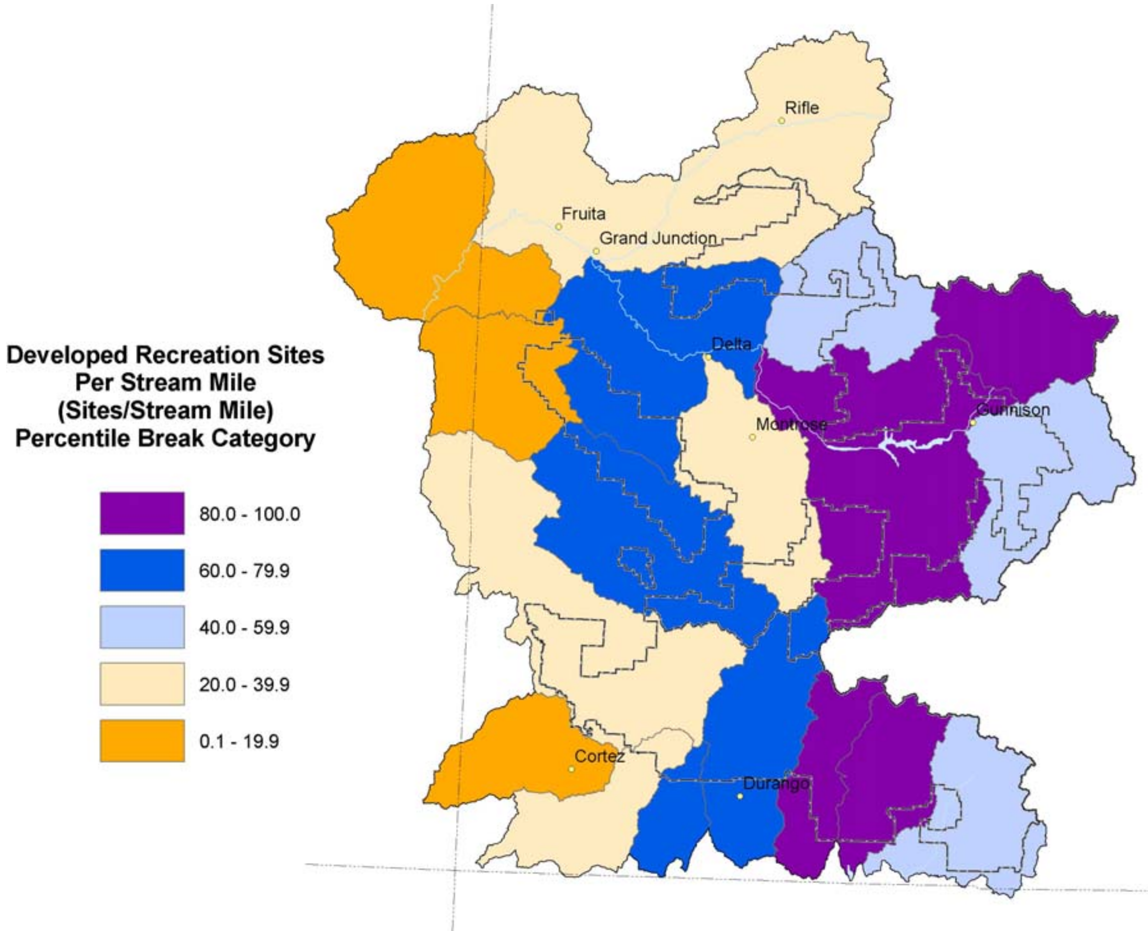
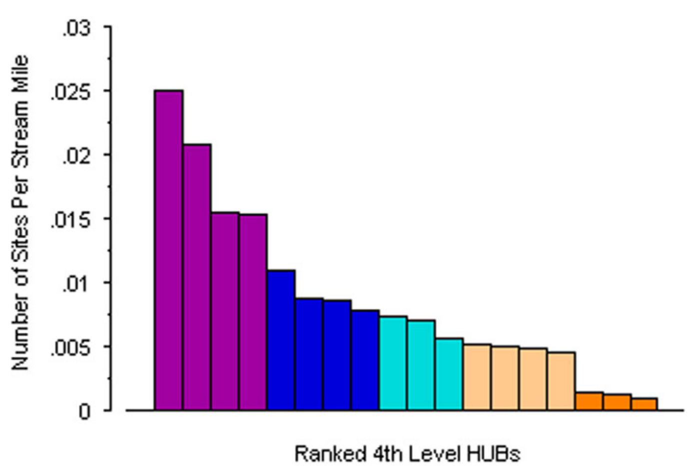


Figure 10. 4th level HUBS classified by percentile break categories



Estimation of Disturbance and Proximity to Streams

Aquatic systems are affected by activities and use of developed recreation sites by increased sedimentation and contamination. Levels of sedimentation can be correlated to overall area of disturbance. Contamination levels may also be correlated to area and distance to streams. The following analysis provides measures of area and distance.

The calculation of total area of disturbance related to developed recreation is dependent upon average site. Average area has been estimated by visual examination of a subset of sites in high resolution image data and average site size calculated in polygon data from the Rio Grande National Forest. Furthermore, these estimates, obtained by visual interpretation and averaging polygon areas, are supported by reported recreation site area size in the literature (e.g., Chelan, 2001 and Spangle, 2004).

In this analysis the average site disturbance area is estimated at 101.6 acres. This area includes highly disturbed areas such as camp sites, eating and congregation areas, paths, parking and roads. Importantly, it also includes a zone of activity and foraging where vegetation communities are subject to some level of disturbance. The estimate of 101.6 acres results from averaging the area of 71 polygons for developed recreation sites on the San Juan and Rio Grande National Forests. Multiplying 101.6 acres times 340 sites yields an overall area influenced directly by activities at developed recreation sites of about 34,546 acres.

The actual area resulting from buffering yields a collection of areas whose area sum is about 1,300 acres less than the estimate of 34,546 acres obtained by simple multiplication. That is: using the buffer model we found a total area of disturbance of 33,255 acres. The difference between the two models comes from situations where sites closer than the buffer radius of 362 meters overlap reducing the total area.

There is a strong correlation between sites and streams. Just over half (53.7%, 104 sites) of all developed recreation sites are located within 200 meters of a perennial stream. Almost two-thirds are within 400 meters (Table 6). The remainder evenly distributed among distance classes from 400 to 2,000 and above (Figure 11). Importantly, a significant proportion of those sites within 200 meters of a stream are located in upland settings (Figure 12).

Table 6. Table showing the number of developed within 100 meter distance intervals to perennial streams in the landscape scale. Disturbance acres are calculated by multiplication of the number of sites times the average site size (101.6)

Number of Sites	Distance to Perennial Streams, Meters	Pct	Sum Pct	Acres
65	100	37.1%	37.1%	6,604.0
29	200	16.6%	53.7%	2,946.4
16	300	9.1%	62.9%	1,625.6
5	400	2.9%	65.7%	508.0
8	500	4.6%	70.3%	812.8
5	600	2.9%	73.1%	508.0
3	700	1.7%	74.9%	304.8

Number of Sites	Distance to Perennial Streams, Meters	Pct	Sum Pct	Acres
6	800	3.4%	78.3%	609.6
4	900	2.3%	80.6%	406.4
4	1000	2.3%	82.9%	406.4
2	1100	1.1%	84.0%	203.2
3	1200	1.7%	85.7%	304.8
2	1300	1.1%	86.9%	203.2
2	1400	1.1%	88.0%	203.2
3	1600	1.7%	89.7%	304.8
2	1700	1.1%	90.9%	203.2
1	1900	0.6%	91.4%	101.6
160		91.4%		
15	2000 and Greater	8.6%	100.0%	1,524.0
175		100.0%		

Figure 11. Histogram showing frequency of developed recreation sites in 100 meter distance intervals to perennial streams. The 15 sites from 2000 meters and greater are not shown.

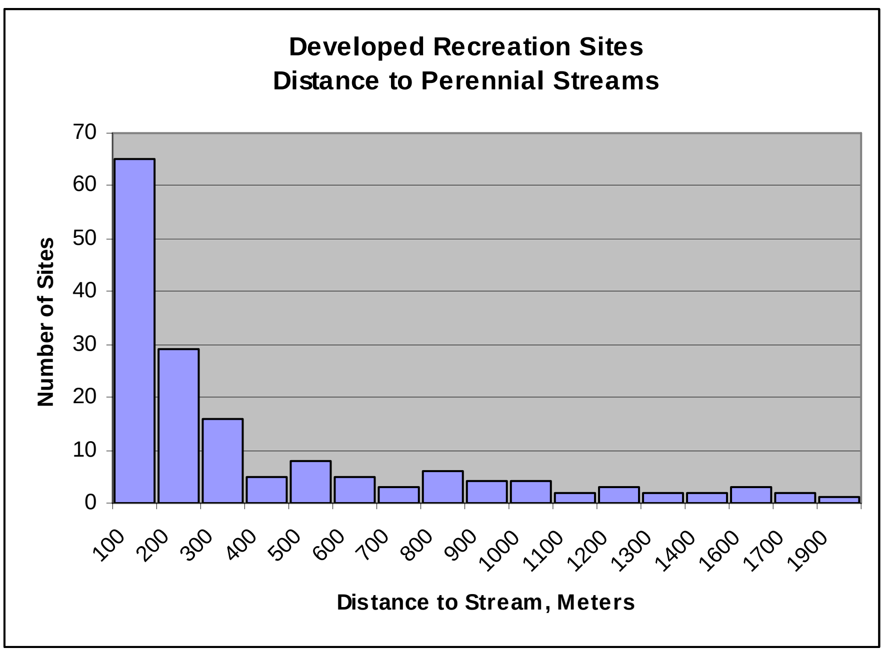
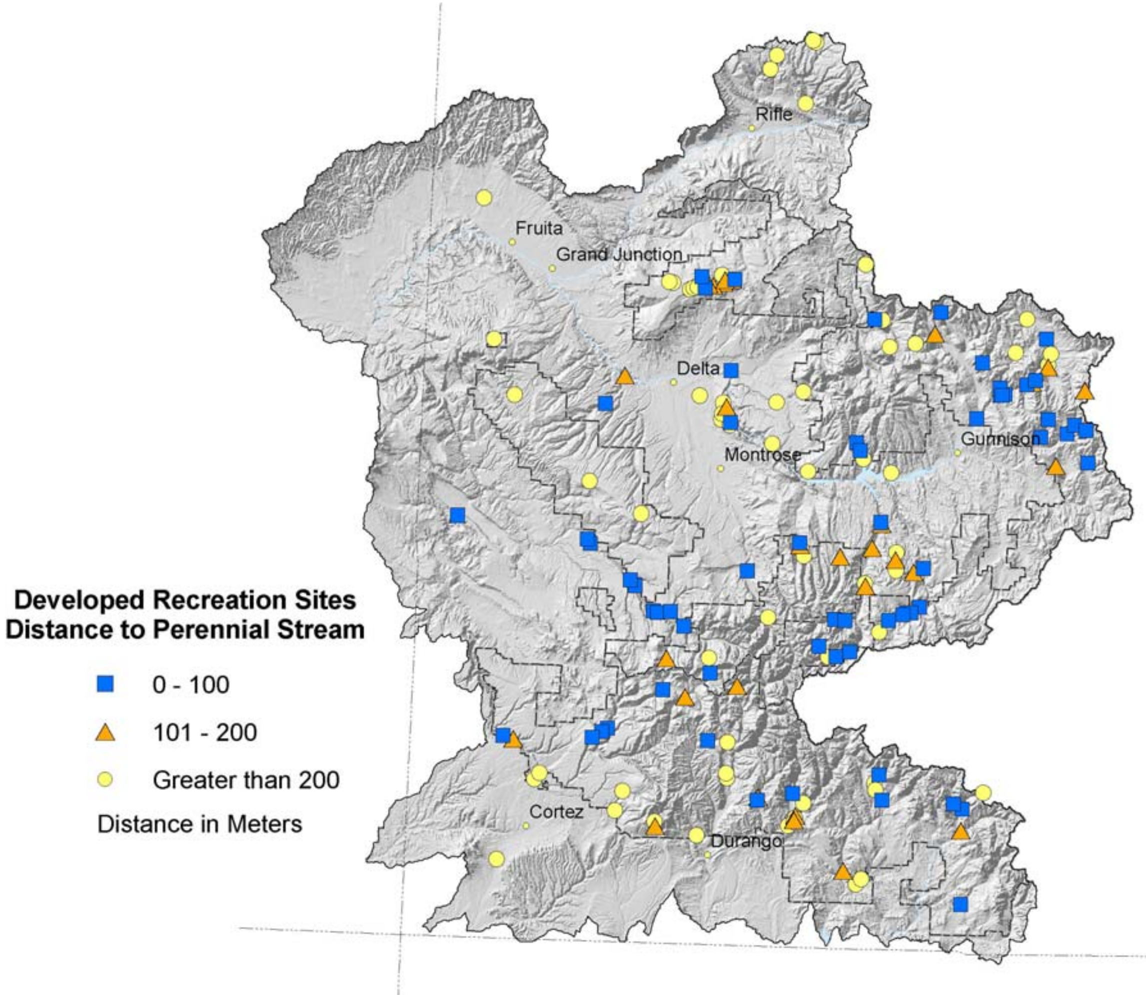


Figure 12. Map showing distribution of developed recreation sites grouped into three distance to stream classes.



Data Needs

Better estimates of developed recreation site disturbed areas are important. Current data are point location only and provide little insight into geometry and extent of use areas.

Developed recreation databases should be standardized between agencies. Inventories of privately owned and managed developed recreation sites would add to our understanding of recreation.

Future analyses would be more complete with measures of disturbance resulting from developed recreation such as boating ramps, picnic areas etc.

DISPERSED RECREATION

Key Findings

- Correlation of **3,037** known dispersed recreation sites in the San Juan and GMUG National Forests to roads, streams, slope, aspect, vegetation and ownership allows the creation of a predictive model of dispersed recreation across the CLC subregion. This model may be clipped by the ARW landscape boundary to assess the potential for dispersed recreation disturbance at that scale.

- Research and validation is required to develop a more robust statistically valid model. The existing model is only qualitative and rests on some important assumptions.

- The model estimates a total of 2,373,907 acres (3,709 square miles) with high potential for dispersed recreation sites in the CLC subregion. Of these high potential lands, **1,327,621 acres (2,074 square miles)** are found inside the ARW landscape.

- Using a ratio of **7.4** sites per square mile of high potential site area, there is a **potential** for about **15,348** sites **in the ARW landscape scale**, distributed across public lands, mostly in upland valleys.

- Dispersed recreation site average barren area is about **45** square feet per site (about 7 x 7 feet). Cumulatively, the potential barren area **across the ARW landscape scale** is about 2,159,566 square feet, or **49.6** acres.

- Overall disturbed area is about **905.32** square feet per site (about 30 x 30 feet). Cumulatively, the potential disturbed area **across the ARW landscape scale** is about 13,894,757 square feet, or **319.0** acres.

- The potential number of sites per HUB stream mile range from a high of 1.79, in the Tomichi HUB (14020003) to a low of .04 in the McElmo HUB (14080202).

- The average potential number of sites per stream mile in the ARW landscape is 0.71. **This average translates to about 100.3 square feet of barren area per stream mile and 645.4 square feet of disturbance per stream mile.**

Introduction

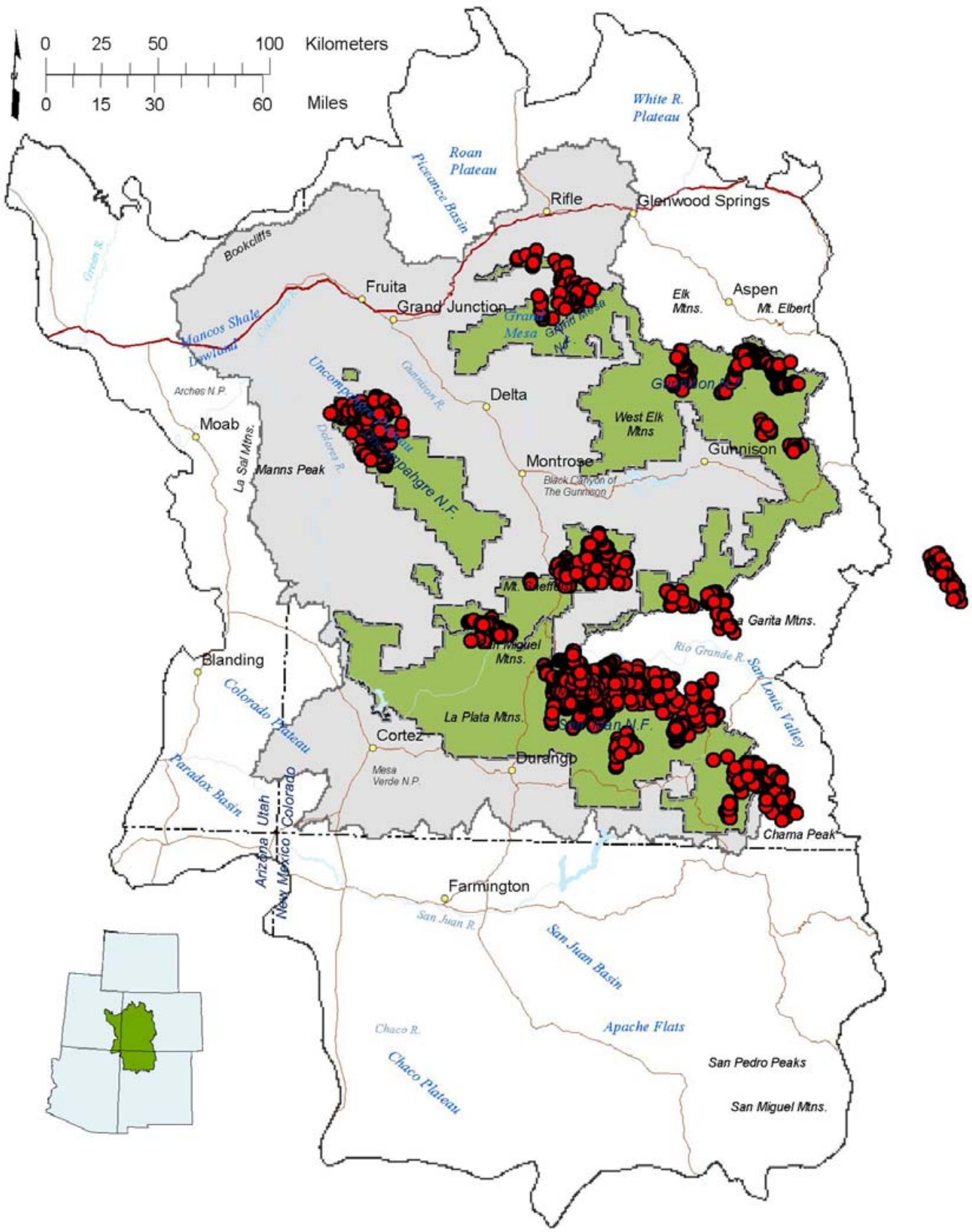
The influence of dispersed recreation on both terrestrial and aquatic systems is an emerging issue for public land managers as levels of recreational use increase on public lands. Dispersed recreation is defined here as: the ad hoc location of short-term campsites by the public. Typical sites include disturbance features such as fire rings, tent sites, areas of congregation, bare areas, parking and automobile tracks. Repeated use of sites and abusive practices can disturb important vegetation communities and lead to increased levels of sedimentation and contamination of aquatic systems. As a consequence, measures of disturbance are important to the ARW assessment.

Inventories of dispersed recreation sites are now being completed by forest staffs but large areas of public lands remain to be examined. In the meantime, an estimate of potential levels of dispersed recreation use is required to support assessments at the ARW landscape and management scales.

The model applied in this analysis relates existing dispersed recreation sites from both San Juan and GMUG surveys to landscape and cultural features. These features include streams, roads, slope, aspect, vegetation and jurisdiction. The model applied to the ARW landscape is fully developed and described at the CLC subregion scale. For a detailed description of the model please see the San Juan/GMUG CLC subregion assessment.

As an overview, the model is based on 3,037 point locations for dispersed recreation sites. Of these, 2,909 lie inside the CLC subregion and these sites are well distributed among a variety of landscape settings. These settings include alpine, upland and lowland sites and are well distributed among both forests (Figure 13). Point patterns may be correlated to drainage, road networks, elevation, slope, aspect, vegetation and ownership. The correlation demonstrates selection bias and may be used to build a model of areas with the greatest likelihood for dispersed recreation site selection.

Figure 13. Dispersed recreation sites. There are 3,037 sites shown in red. Note that 128 sites fall outside the subregion leaving 2909 inside. These 2909 known sites are the basis of the predictive model described here. The ARW landscape is shown in gray and fully contained within the CLC subregion.



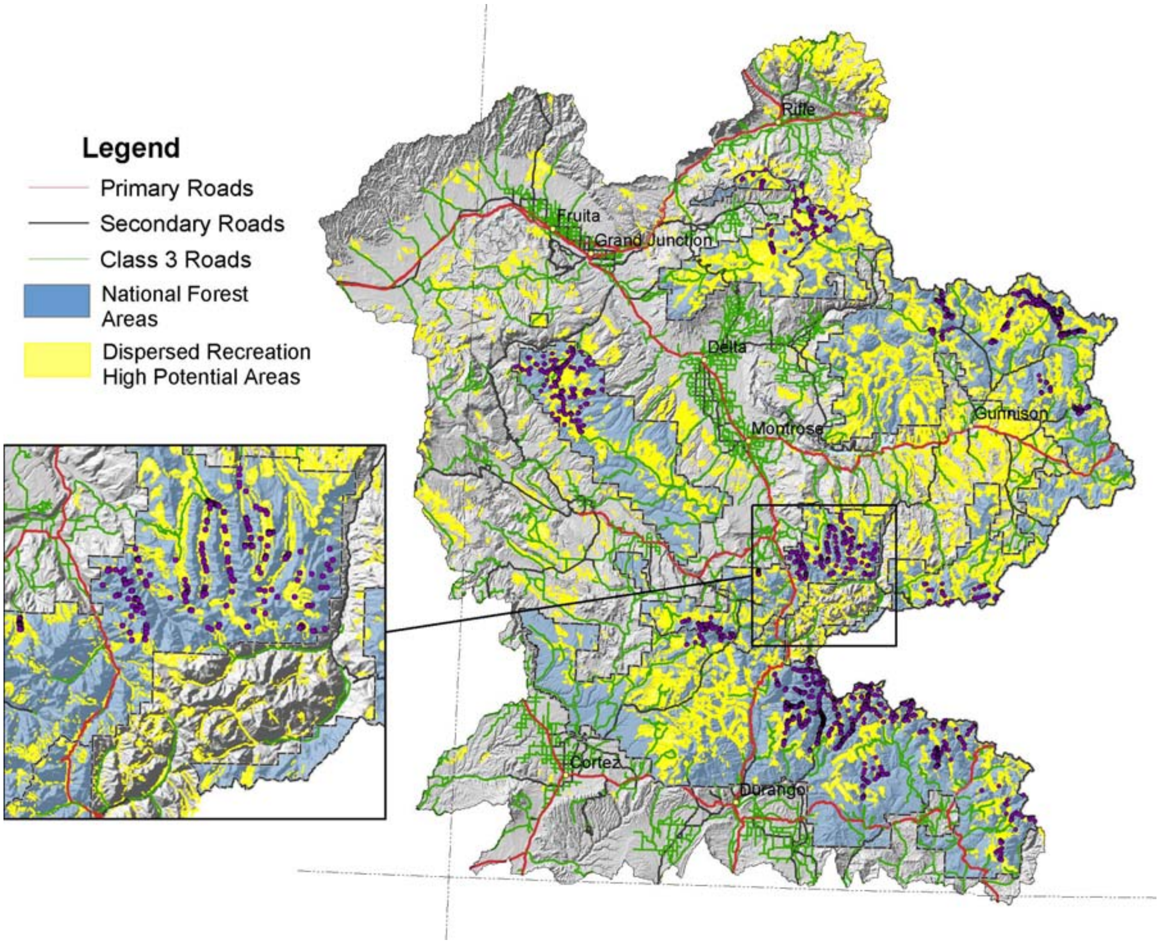
Ultimately, in the creation of the final predictive model we select from the source data sets (e.g., roads, streams etc.) areas that fall within a 90% threshold. In other words we assume a correlation to attributes of these data sets where we find that 90% or more of dispersed recreation sites occur in a given range of values. The model has been developed across the CLC sub-region to support analysis at multiple scales, including the ARW landscape scale. The dispersed recreation model extrapolates away from the known sites by selecting from the base data sets, those areas where over 90% percent of the sites occur. Contributing layers and their corresponding ranges are summarized in Table 7.

Table 7. The six layers used to define the dispersed recreation model. Over 90% percent of all inventoried sites occur within the selection ranges listed in this table. For example, over 90% percent of all inventoried dispersed recreation sites are found within 800 meters of roads.

Layer	Selection Range
Roads	Within 800 meters
Streams	Within 700 meters
Slope	0 to 17 degrees
Aspect	35 to 325 degrees
Vegetation	Spruce/Fir, Alpine, Aspen
Ownership	BLM and Forest Service

Applying these methods and criteria we find that within ARW landscape scale there are 1,327,620 acres (2,074 square miles) with high potential for dispersed recreation which are portrayed in Figure 14. Using a conversion factor of 7.4 sites per square mile, the potential number of sites in these high potential lands is 2,074 * 7.4 = 15,348 sites. The determination of the conversion factor of 7.4 sites per square mile is fully developed in the CLC write up. The CLC write up also develops factors that may be used to estimate site disturbance. These are: 140.7 square feet per site of barren area and 905.3 square feet of overall disturbance per site. Using these factors, there are cumulatively just under 50 acres of barren area for these 15,348 sites and just under 320 acres of disturbance for the same.

Figure 14. Areas with high potential for dispersed recreation in the ARW Landscape. The strong correlation to roads, streams and upland areas is evident. A significant proportion of these lands are found within the San Juan and GMUG.



Summary By 4th HUB

Areas of high potential for dispersed recreation may be summarized by 4th level HUB and by stream mile. These summaries by 4th level HUB give insight into the landscape level influences of dispersed recreation.

The area of lands with high potential for dispersed recreation sites varies among the 4th level HUBS from 353 square miles to 4 square miles. Accordingly, the corresponding potential of sites ranges from 2,612 to 32. The number of sites per HUB stream mile ranges from a high of 1.79, in the Tomichi HUB (14020003) to a low of .04 in the McElmo HUB (14080202) (see Table 2, Figure 15 and Figure 16). The average potential number of sites per stream mile is 0.71. This average translates to about 100.3 square feet of barren area per stream mile and 645.4 square feet of disturbance per stream mile.

Table 8. Table showing the number of cumulative stream miles, area of high potential for dispersed recreation sites, potential number of sites and number of sites per stream mile. The table is sorted in descending order by Num. Sites per Stream Mile.

4th HUB Code	4th HUB Name	HUB Stream Miles	Dispersed Rec. Sq. Miles	Potential Num. Sites	Num. Sites Per Stream Mile
14020003	Tomichi	959	232	1,718	1.79
14020001	East-Taylor	759	158	1,171	1.54
14020002	Upper Gunnison	1,921	353	2,612	1.36
14020004	North Fork Gunnison	860	153	1,129	1.31
14080104	Animas. Colorado	926	96	713	0.77
14080999	Upper San Juan West	455	45	331	0.73
14080102	Piedra	523	51	380	0.73
14030002	Upper Dolores	2,212	202	1,495	0.68
14020005	Lower Gunnison	1,910	163	1,208	0.63
14030003	San Miguel	1,525	119	878	0.58
14080101	Upper San Juan	884	68	505	0.57
14010005	Colorado Headwaters Plateau	3,294	242	1,787	0.54
14020006	Uncompahange	973	66	490	0.50
14030004	Lower Dolores	993	44	323	0.33
14080107	Mancos	817	28	204	0.25
14030001	Westwater Canyon	1,406	45	331	0.24
14080105	Middle San Juan	345	6	42	0.12
14080202	McElmo	767	4	32	0.04
		21,529	2,074	15,348	0.71

Figure 15. Graph showing the range of ratios of potential sites per stream mile. The average is 0.71 sites per stream mile. The Tomichi 4th level HUB has the greatest potential number of sites per stream mile while McElmo has the least.

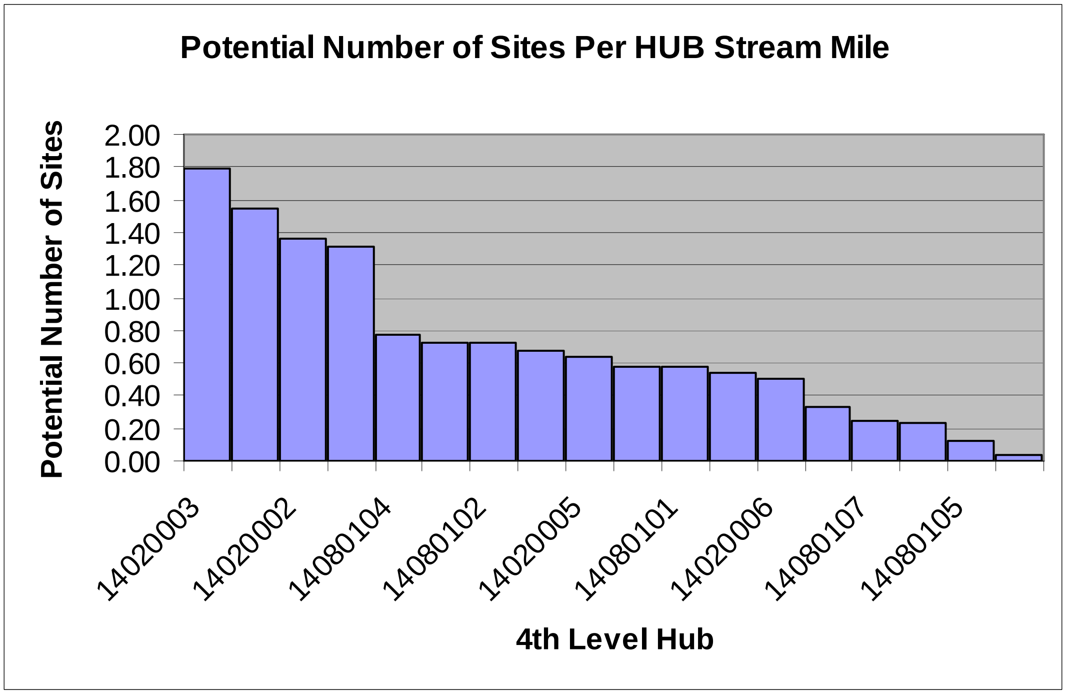
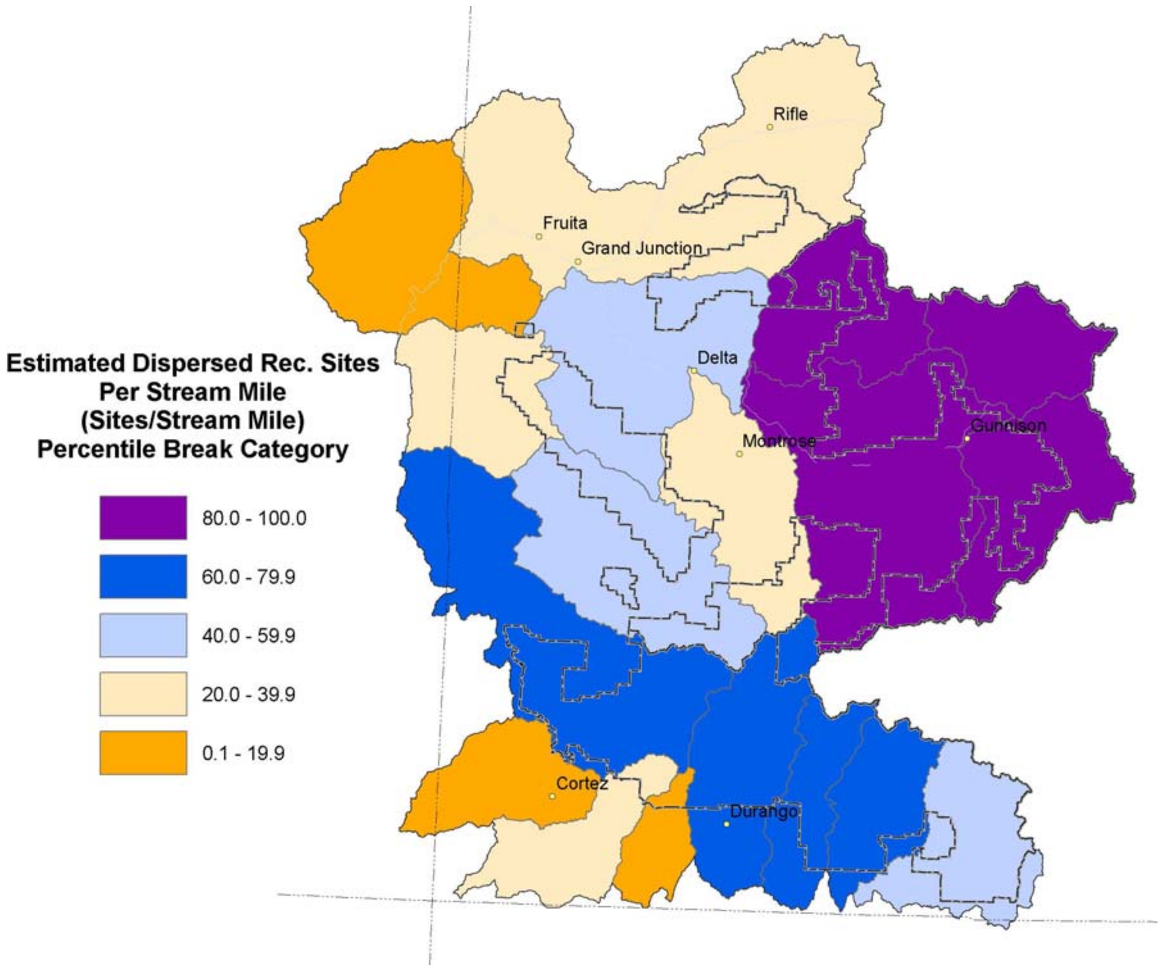


Figure 16. Areas with high potential for dispersed recreation in the ARW Landscape. The strong correlation to roads, streams and upland areas is evident. A significant proportion of these lands are found within the San Juan and GMUG.



Potential site densities per stream mile are the highest within National Forest settings (Table 9). Within the GMUG, ratios range from 1.01 sites per stream mile to 2.49. Within the San Juan, ratios range from 0 to 1.88 sites per stream mile. These relatively higher densities reflect relatively higher stream density and accessibility within Forest upland areas.

Table 9. Ratios of number of sites to stream mile inside the San Juan and GMUG National Forests.

Forest	HUB4	HUB4NM	GMUG NumSites StrMi	SJ NumSites StrMi
GMUG	14010005	Colorado Headwaters-Plateau	2.49	
	14020002	Upper Gunnison	2.10	
	14030001	Westwater Canyon	2.09	
	14020004	North Fork Gunnison	1.94	
	14020005	Lower Gunnison	1.72	
	14020003	Tomichi	1.56	
	14020001	East-Taylor	1.54	
	14020006	Uncompahange	1.30	
	14030004	Lower Dolores	1.03	
	14030003	San Miguel	1.01	
San Juan	14080107	Mancos		1.88
	14080999	Upper San Juan West		1.20
	14080104	Animas. Colorado		1.19
	14030002	Upper Dolores		1.07
	14080105	Middle San Juan		1.03
	14080102	Piedra		0.84
	14080101	Upper San Juan		0.81
	14080202	McElmo		0.00
			1.67	1.04

Information Needs

Forest inventories developed to date have provided a baseline to extrapolate potential densities used here. Inventories should continue to refine estimates and ultimately directly characterize the actual setting in the field.

While methods to develop estimates continue to be used more systematic, statistically robust, sampling methods should be used to ensure that the observed relationship of existing sites to roads is a valid correlate and not a bias introduced because the primary method to access sites is by roadway. Also, the method used to calculate an overall site density of 7.4 sites per model square mile should be evaluated. At the same time, the existing model may also be useful in the development of study plans and target areas for sampling.

Sampling systems should also be developed that develop estimates in the rate of growth or expansion in site location along with trends in site selection.

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CHAPTER 2. ANTHROPOGENIC INFLUENCES – LANDSCAPE SCALE

Mineral Development

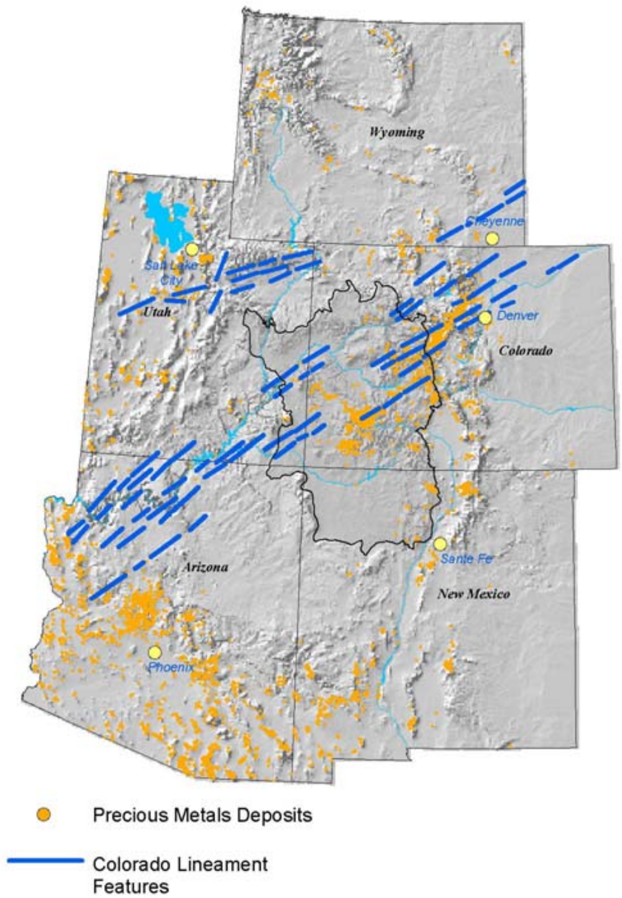
Historically, mineral exploration and development have played key roles in defining the character and landscape pattern in the Western U.S and importantly, within the ARW/CLC assessment area. Over the 19th century, prospectors combed the deserts and mountains in search of gold, silver and other precious metals (Murray, 1980; Preston, 2004). At the same time, workers developed coal, providing important energy resource to mining and other industries, agriculture and domestic needs. Deposits of limestone and aggregates were developed to build railroads, roads and provide a source for concrete along with clay for brick and ceramics. Beginning in the 1950s and 1960s, energy resources in the area, including coal, oil, gas, coal-methane and uranium deposits became the dominant mineral commodities produced in the region. Today, coal, oil, gas and common variety minerals (e.g., sand and gravel) development continues to be important in the sub-region and the surrounding western states.

The sub-region is particularly well endowed with mineral resources. World class deposits of precious and base metals occur along a northeast to southwest trend from Aspen through Silverton and Telluride southward to the La Plata Mountains. This trend follows a larger regional geologic trend called the Colorado Lineament (Warner, 1980). The *Colorado Lineament* is correlated regionally with important mineral deposits in Arizona, Colorado and Utah (Figure 1). These deposits include massive sulfides, vein and metallic replacement deposits (U.S.G.S, 2004). These deposits are largely associated with Tertiary volcanic centers. Notably, the volcanic center and mineralized areas of Silverton lay at the intersection of the Colorado Lineament and the northwest to southeast trend formed by the axis of the Uncompahgre Mountains (Ellingson, 1996).

Historical metallic mining areas and towns strongly contribute to the character of the subregion. Abandoned mines, mills and tailings are common landscape features lending themselves a sense of history and place. At the same time, abandoned hardrock mines pose a significant threat to water quality throughout the western U.S. (Schnitzer and Roberts, 2004)

Important uranium deposits of the Urvan mineral belt, along the Dolores River hosts important sandstone based deposits of uranium. These deposits were the object of significant development activity in the 1950s and 1960s leading to an economic boom at that time. The boom influenced the growth of important Colorado Plateau communities including Cortez, Durango and Grand Junction and Moab.

Figure 1. Regional Colorado Lineament features adapted after Warner, 1980 superimposed on locations of precious metals deposits. The trend also corresponds to important structural controls for non-metallic deposits.



Oil and Gas deposits occur in sedimentary basins throughout the sub-region. Development of these deposits began early in the 20th century with discoveries in the Paradox Basin. World class gas deposits are currently in development in the San Juan Basin. Significant deposits occur also in the Piceance Creek and Paradox basins. Outside these basins wells have been drilled in plays along the Bookcliffs and Gunnison River valley. More than 30,000 wells have been drilled since the first wells appeared in the region.

Coal deposits occur in late Cretaceous and Tertiary rocks throughout structural basins in the subregion. These deposits appear near the surface along basin margins and have been exploited historically throughout the subregion. Today, large scale mining operations are located in deposits of the Bookcliffs, North Fork of the Gunnison River, Nucla-Naturita, Durango and areas west of Farmington New Mexico.

Today, growth in local communities drives up demand for common variety mineral materials used for road building and building construction. Sand and gravel are developed throughout the region along with quarries for building stone.

In the following summary we draw upon various data sources to characterize patterns of mineral development activity in the subregion and ARW landscape. The U.S. Geological Survey MILS/MAS (Causey, 1998) database provides important insights into the current and historical distribution of mineral sites of all types in the region. These data are augmented by BLM mining claim records to show mining claim distributions as a measure of current interest in locatable mineral development.

Oil and gas well location data sets from the state of Colorado, the state of Utah and BLM indicate those areas most significant for development and strongly influenced by development activity. Finally, coal mining data sets are used to illustrate locations of currently active mining. In each case, the character of mineral activity is illustrated and further developed by summary by GAP vegetation class and 4th level HUB.

Distribution of Mining Sites – Recent and Historic

Within the subregion there were 8,968 mineral development sites recorded in the MAS/MILS database as of 1997. These may be categorized into four status classes. These four are:

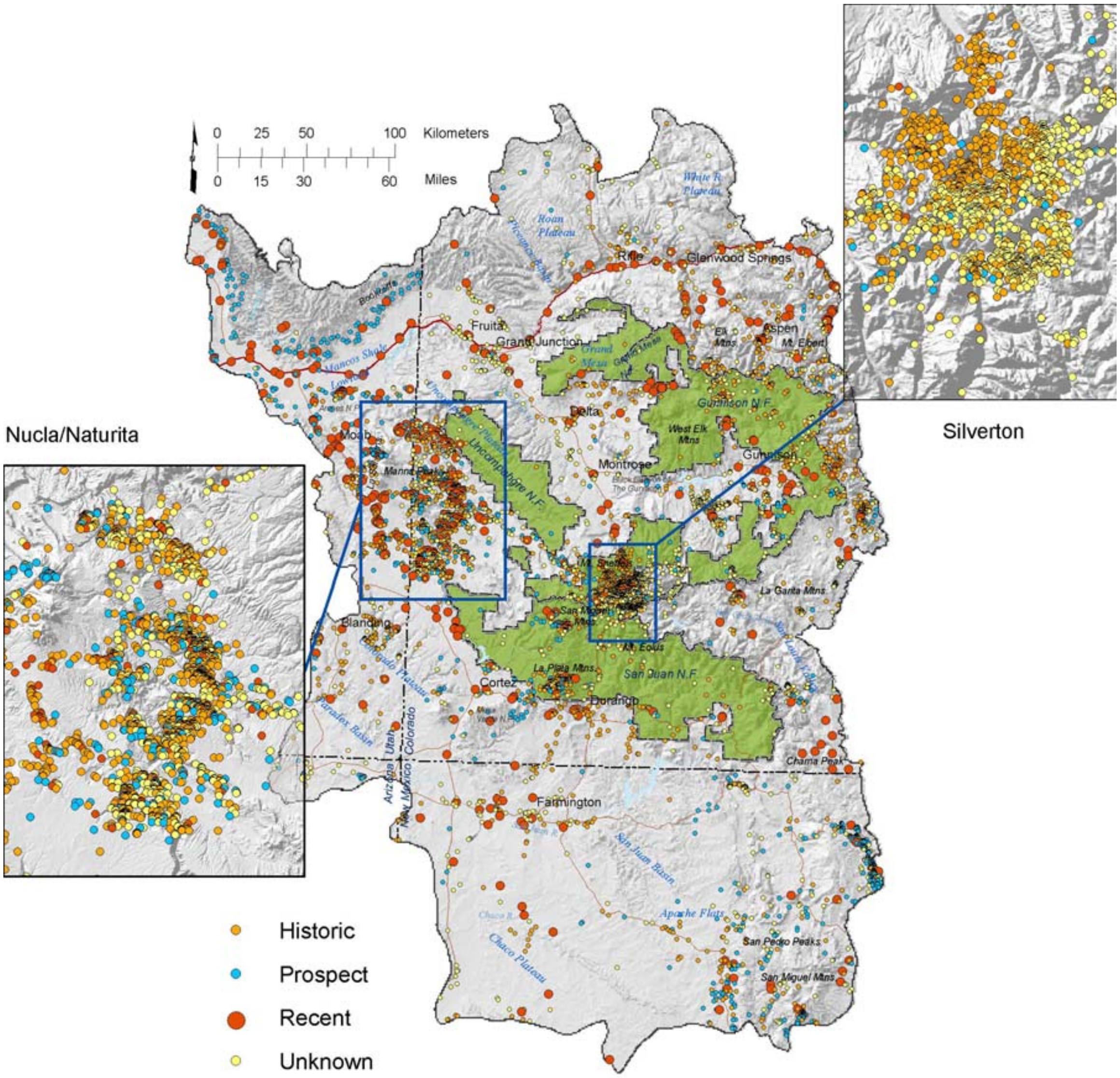
1) *Historic* – indicative of mineral development in the past;
2) *Prospect* – a site with prospecting but no development;
3) *Recent* – indicating active development currently or recently;
4) *Unknown* – indicating the possibility of prospecting and/or development. Likely to be historical.

Of the 8,968 sites, nearly 50% may be considered to be *Historic* (Table 1). Nearly fifteen percent are classified as *Prospects.* Thirty-three percent are of *Unknown* status leaving just under six percent are classified as *recent*. Historical sites tend to cluster in upland areas known for precious metals mining and in the Nucla-Naturita uranium mining areas (Figure 2). Recent sites are widely distributed and include a departure from the precious metals districts to areas of uranium, coal, mineral materials and base metals.

Table 1. Subregion mineral sites status as of 1997. Adapted after U.S. Geological Survey MILS/MAS data (Causey, 1998).

Status	Number	Percent
Historic	4211	47.0%
Unknown	2961	33.0%
Prospect	1290	14.4%
Recent	506	5.6%
	8,968	100.0%

Figure 2. MILS/MAS mineral sites status as of 1997 in the subregion (Causey, 1998). The inset maps illustrate areas of high site density.

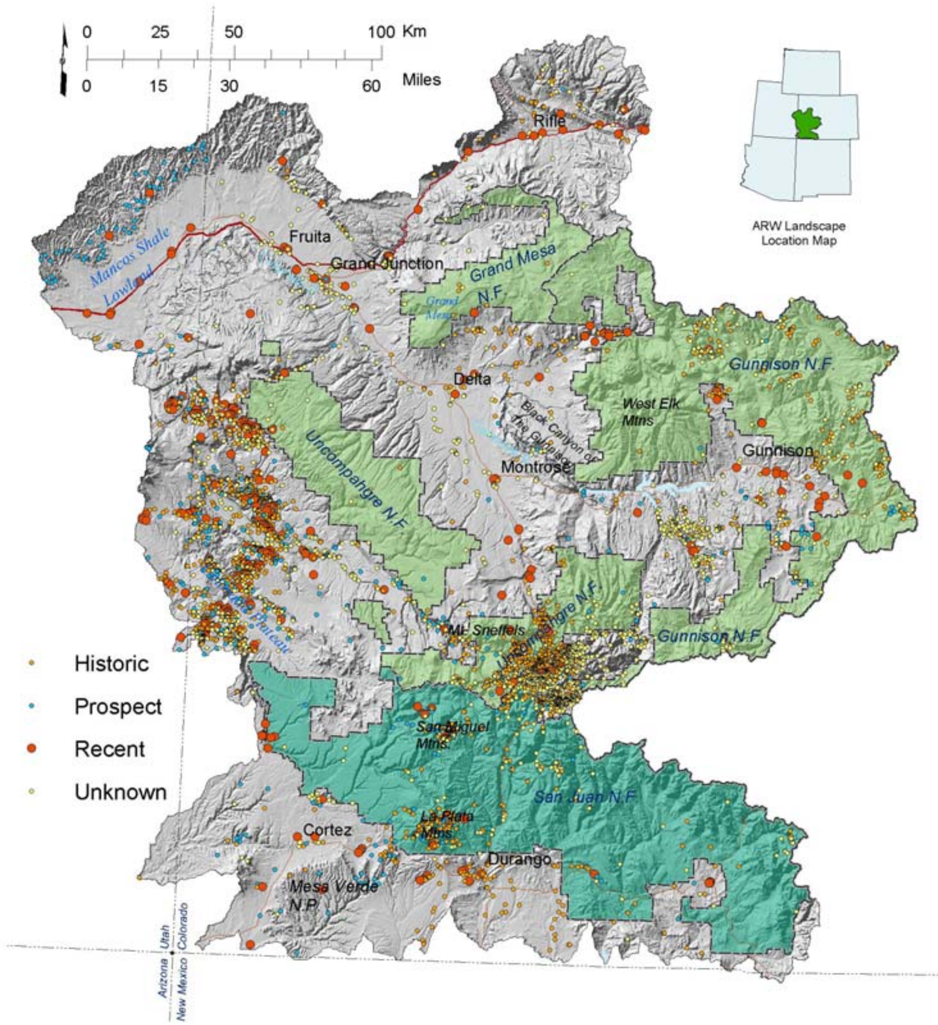


Within the ARW landscape there are 6,129 mineral development sites recorded in the MAS/MILS database. The distribution of theses by status is similar to the distribution of sites over all of the subregion (Table 2, Figure 3).

Table 2. ARW Landscape mineral sites status as of 1997. Adapted after U.S. Geological Survey MILS/MAS data (Causey, 1998).

Status	Number	Percent
Historic	2923	47.7%
Unknown	2290	37.4%
Prospect	647	10.6%
Recent	269	4.4%
	6,129	100.0%

Figure 3. Mineral sites by status in the ARW landscape as of 1997 (Causey, 1998). There are 6,129 sites in the ARW landscape.



In the subregion, most mineral sites are located outside of the San Juan and GMUG areas. About 10% of sites are located in the GMUG and about 9% are in the San Juan National Forest. The 26 sites located in the Forests and classified as "*recent*" constitute less than 1% of the 8,968 in the subregion (Table 3).

Table 3. Distribution of 8,968 mineral sites inside and outside the San Juan and GMUG by status as of 1997. Adapted after U.S. Geological Survey MILS/MAS data (Causey, 1998).

Forest	Status	Number	Pct
Other	Historic	3258	36.3%
	Prospect	1124	12.5%
	Recent	480	5.4%
	Unknown	2405	26.8%
	SubTotal:	7267	81.0%
GMUG	Historic	603	6.7%
	Prospect	38	0.4%
	Recent	14	0.2%
	Unknown	271	3.0%
	SubTotal:	926	10.3%
San Juan	Historic	350	3.9%
	Prospect	128	1.4%
	Recent	12	0.1%
	Unknown	285	3.2%
	SubTotal:	775	8.6%
	Total:	8,968	100.0%

Nearly 90% percent of the 506 sites are classified as *recent* and are comprised of common variety minerals, uranium, coal or base metal (Table 4). Common variety minerals include sand, gravel and building stone and development sites largely follow major roads. The higher proportions represented by both uranium and coal are indicative of the importance of energy development in the region today. Most uranium sites are located in the Nucla-Naturita area west of the Uncompahgre Mountains. Of the 56 coal mining sites, many constitute major operations with significant disturbance of surface and subsurface systems. The most significant of these are discussed further below.

Table 4. The principal commodities for sites classified as "Recent" across the subregion. Common Variety minerals include sand and gravel and building stone.

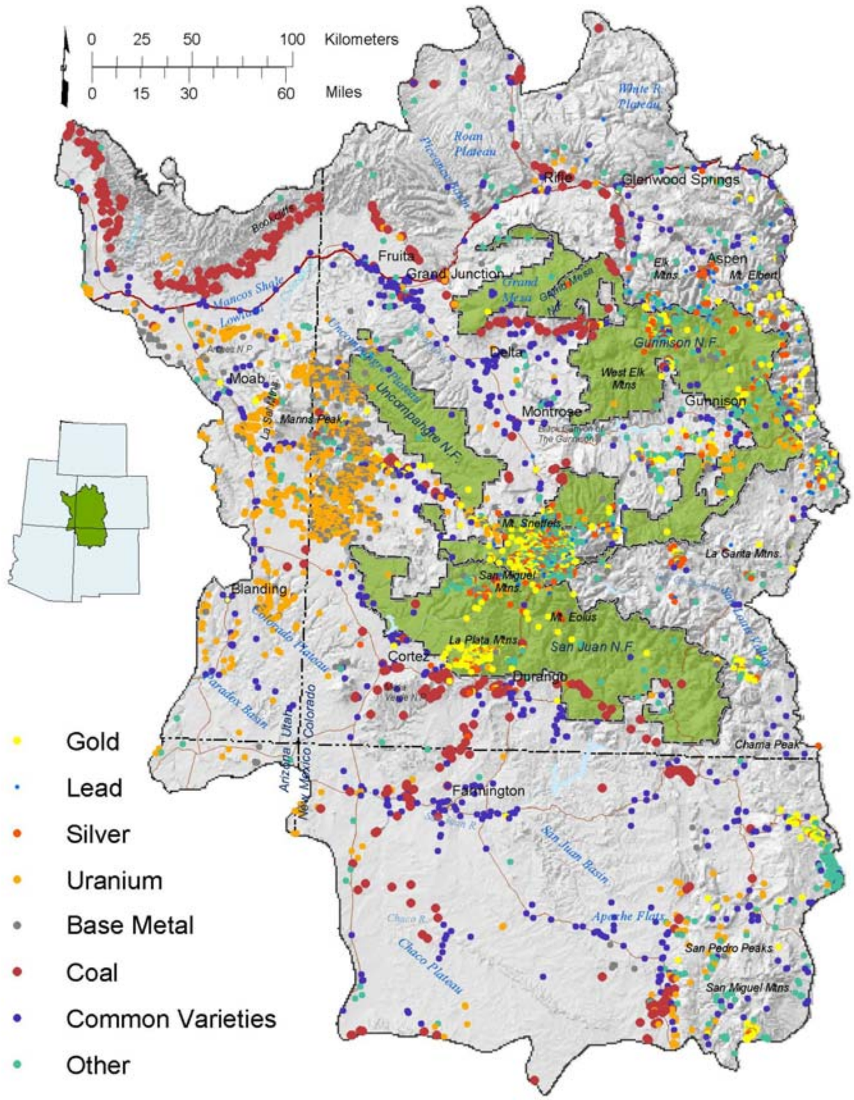
Category	Number	Pct	SumPct
Common Variety	185	36.6%	36.6%
Uranium	152	30.0%	66.6%
Coal	56	11.1%	77.7%
BaseMetal	54	10.7%	88.3%
Other	39	7.7%	96.0%
Unknown	7	1.4%	97.4%
Silver	6	1.2%	98.6%
Lead	4	0.8%	99.4%
Gold	3	0.6%	100.0%
	506	100.0%	

Of all the MAS/MILS sites in the subregion, regardless of status, nearly 90 percent fall within one of seven commodity categories. These seven include the four comprising the "recent" class plus an additional three (Table 5). Those three include: gold, silver and lead and have largely been the object of development in historical mining districts (Figure 4).

Table 5. Overall subregion principal mineral commodities.

Category	Number	Pct	SumPct
Uranium	1992	27.1%	27.1%
BaseMetal	1066	14.5%	41.5%
Gold	922	12.5%	54.1%
CommonVariety	768	10.4%	64.5%
Silver	626	8.5%	73.0%
Coal	535	7.3%	80.3%
Lead	427	5.8%	86.1%
Other	1025	13.9%	100.0%
	7361	100.0%	
Unknown	1607		
Total	8,968		

Figure 4. Seven commodity classes comprise nearly 90% of all mineral sites in the subregion (Causey, 1998). The trend formed by coal sites reveals the margins of principal sedimentary basins.



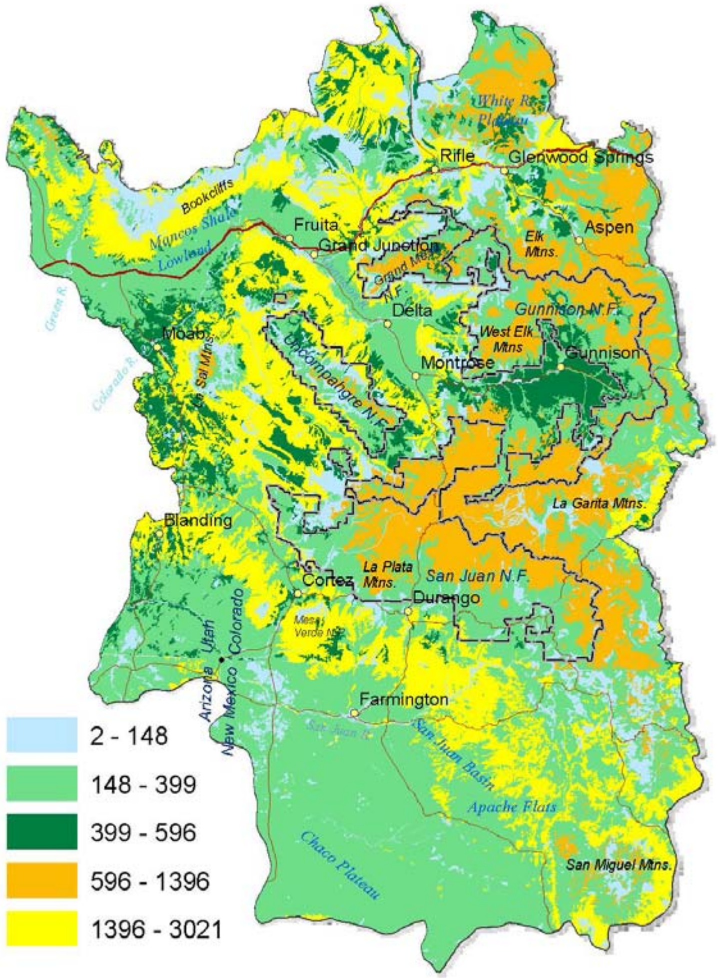
Subregion Scale GAP Vegetation Analysis

Of the 8,968 mine sites in the subregion, just over 90% of mineral sites fall in ten of twenty vegetation classes (Table 6). Of these, nearly 50% fall within two vegetation classes. These two vegetation classes include pinyon-juniper and spruce-fir (Figure 5). The sites in pinyon-juniper vegetation class are largely located outside of National Forests. Many of these are found on BLM and patented claims in the Nucla-Naturita area. Conversely, sites in the spruce-fir type are strongly correlated to upland areas, much of which is in the spruce-fir vegetation class. Mining in both areas is largely historic. Disturbance there is generally less important that mine drainage from abandoned mines.

Table 6. Distribution of 8,968 historic and recent mineral sites inside and outside the San Juan and GMUG forests by vegetation class. Adapted after U.S. Geological Survey MILS/MAS data. Note: *Historic* includes *prospects* and *Recent* includes *Unknown*

	Historic		Recent				
Veg Class	**Inside NF**	**Outside NF**	**Inside NF**	**Outside NF**	**Total**	**Pct**	**SumPct**
pinyon -juniper	6	2045	12	958	3,021	33.7%	33.7%
spruce - fir	525	309	272	290	1,396	15.6%	49.3%
alpine	347	285	156	430	1,218	13.6%	62.8%
sagebrush	16	261	13	306	596	6.6%	69.5%
aspen	115	161	54	69	399	4.4%	73.9%
desert shrub	0	196	0	179	375	4.2%	78.1%
ponderosa pine	32	206	19	76	333	3.7%	81.8%
crops	4	144	6	165	319	3.6%	85.4%
mixed conifer	19	142	19	125	305	3.4%	88.8%
desert grassland	0	152	0	60	212	2.4%	91.1%
lodgepole pine	40	105	23	33	201	2.2%	93.4%
deciduous oak	9	105	5	29	148	1.7%	95.0%
mountain grassland	0	93	2	31	126	1.4%	96.4%
urban	0	61	0	41	102	1.1%	97.6%
mountain shrubland	1	66	0	27	94	1.0%	98.6%
barren	2	26	1	30	59	0.7%	99.3%
woody riparian/wetland	0	13	0	14	27	0.3%	99.6%
water	3	4	0	12	19	0.2%	99.8%
greasewood	0	5	0	7	12	0.1%	99.9%
Not Classified	1	1	1	1	4	0.0%	100.0%
herbaceous riparian/wetland	0	1	0	1	2	0.0%	100.0%
Total:	1,120	4,381	583	2,884	8,968		
Pct:	12.5%	48.9%	6.5%	32.2%		100.0%	
Sum by Period	5,501		3,467				
Pct by Period:	61.3%		38.7%				

Figure 5. Mineral site counts by vegetation class. Over half of the sites are pinyon-juniper and spruce-fir vegclasses. Forest lands comprise significant proportions the spruce-fir vegetation type. Mine sites in upland areas including Silverton and the La Plata Mountains are strongly correlated to spruce-fir, aspen and alpine vegetation classes.



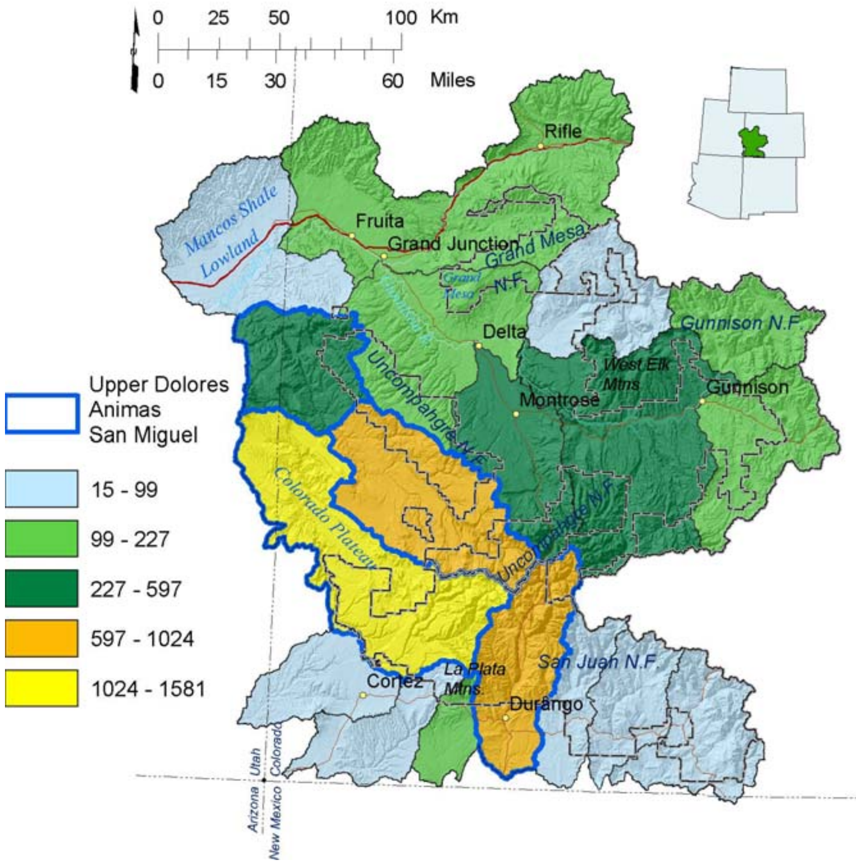
Landscape Scale 4th Level HUB Watershed Analysis

Of the 6,129 mine sites in the ARW Landscape, just over 90% of mineral sites fall in nine of seventeen fourth level watersheds (Table 7). Of these, over 50% fall within three watersheds. These three watersheds are the Upper Dolores, the Animas and San Miguel watersheds (Figure 6). Significantly, these watersheds host important proportions of both historic and recent mining operations. The Animas watershed is recognized for the impact historic precious metals sites have had and are having upon local ecosystems and especially local and downstream water quality and hydroecology (Schnitzer and Roberts, 2004; Robinson, 2002). More recent uranium mining impacts the Upper Dolores and San Miguel watersheds. Moreover, Forest lands comprise majority proportions of the headwaters of these watersheds.

Table 7. Distribution of 6,129 historic and recent mineral sites inside and outside the San Juan and GMUG forests by HUB4 as of 1997. Adapted after U.S. Geological Survey MILS/MAS data. Note: *Historic* includes *prospects* and *Recent* includes *Unknown*.

	Historic		Recent				
4th Level Watershed Name	Inside NF	Outside NF	Inside NF	Outside NF	Total	Pct	SumPct
Upper Dolores	187	901	99	394	1,581	25.8%	25.8%
Animas. Colorado	128	278	155	463	1,024	16.7%	42.5%
San Miguel	169	438	70	167	844	13.8%	56.3%
Lower Dolores	5	350	6	236	597	9.7%	66.0%
Upper Gunnison	9	93	51	328	481	7.8%	73.9%
Uncompahgre	314	55	27	54	450	7.3%	81.2%
Colorado Headwaters-Plateau	3	50	3	171	227	3.7%	84.9%
Tomichi	70	38	38	41	187	3.1%	88.0%
Middle San Juan	90	37	12	4	143	2.3%	90.3%
East-Taylor	64	0	69	0	133	2.2%	92.5%
Lower Gunnison	3	40	6	68	117	1.9%	94.4%
Mancos	48	40	4	7	99	1.6%	96.0%
Upper San Juan	18	28	22	6	74	1.2%	97.2%
Westwater Canyon	0	55	0	15	70	1.1%	98.3%
North Fork Gunnison	4	24	15	15	58	0.9%	99.3%
Mcelmo	0	21	0	8	29	0.5%	99.8%
Piedra	7	3	5	0	15	0.2%	100.0%
Total:	1,119	2,451	582	1,977	6,129		
Pct:	18.3%	40.0%	9.5%	32.3%		100.0%	
Sum by Period	3,570		2,559				
Pct by Period:	58.2%		41.8%				

Figure 6. Mineral site counts by fourth level watershed. Over half of the sites are located in the *Upper Dolores*, *Animas* and *San Miguel* watersheds. Forest lands comprise significant proportions of these watersheds. At the same time, large numbers of sites are located, recently and historically, on Forest lands.



Mining Claims

Mineral development of precious metals, uranium, base metals and some classes of common variety minerals are administered as *"Locatable Minerals"* and are subject to mining claim as lode or placer. Excluding coal and sand and gravel, most of the 8,968 sites in the subregion may be associated with the exploration or development of locatable minerals. Where these minerals occur on federal land, they are thus subject to *"claim or location"* as lode or placer mining claims.

The distribution of mining claims on federal lands provides important insight into mineral potential. More significantly, areas with ongoing active claims may be considered areas of high interest and likely development under reasonably foreseeable economic conditions. It is important to management planning to call these areas to the attention to the public and land managers (Figure 7 and 8).

Figure 7. Areas of open lode and placer mining claims in the subregion. These are areas of ongoing activity and high potential for future locatable mineral development activity as mining economics change. Naturally, these areas correspond to mine site maps above but are indicative of present and future interest while much the mine site maps are often indicative of historic interest only.

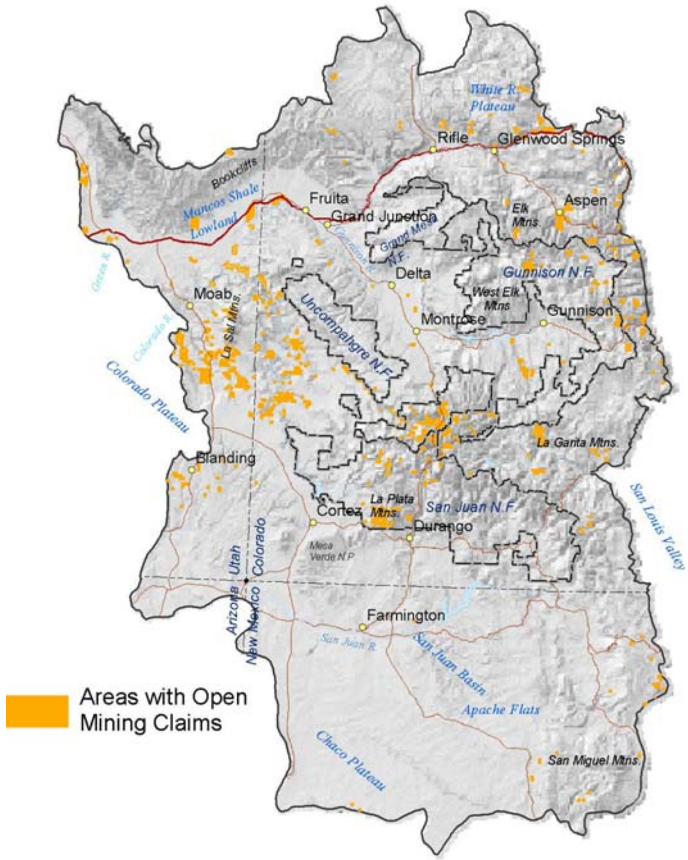
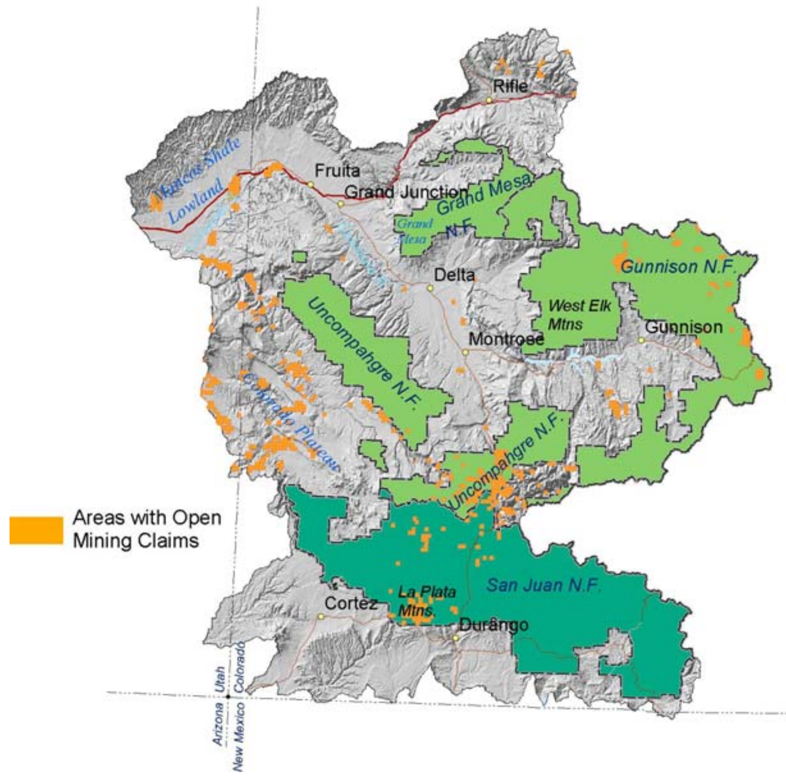


Figure 8. Areas of open lode and placer mining claims in the ARW Landscape. In general, these claims are located on either BLM or National Forest lands, with some minor exceptions.



Oil and Gas

Oil and gas development in the subregion has been ongoing since early in the last century. From the 1950s onward, development has surged and retreated periodically with new discoveries combined with swings in prices, and regulatory framework. In the 1980s, development of fields in Utah and Colorado surged. More recently, the discovery of coal-bed methane gas in the San Juan Basin has lead to a surge in development there and development in these fields is expected to continue in the San Juan Basin over the next 20 years (Engler, 2001).

According to available well data, there are 35,346 wells in the subregion and 8,870 wells in the ARW landscape (Table 8). The available data has been obtained the State of Colorado (COGCC. 2004) Utah (UTOG, 2004) and the Bureau of Land Management, New Mexico State Office (Ongard, 2001). This analysis does not include the relatively small proportion of wells located in Arizona due to data availability.

The Colorado, Utah and New Mexico data have been merged and clipped to the subregion and the ARW Landscape. Variable data standards and coding between states do not allow complete merging of all data and attributes. However, we have approximated well status to obtain a merged data set that may approximate the location of currently active wells contrasted with a backdrop of historic well sites.

Well drilling, development, production and abandonment all influence water quality and ecological integrity. Assuming about 3 acres of disturbance per well pad in developed fields (Engler, 2001) we can approximate overall disturbance of about 106,038 acres in the subregion and 26,610 acres in the ARW landscape.

Pipelines and road access adds significantly to this estimate of disturbed area.

Additionally, ground and surface water pollution can be caused by fracturing along with disposal of drilling fluids and produced water. Water loss by production of coal bed methane can be significantly higher than conventional drilling (USGS 2000). Altogether, exploration, development and production can lead to the introduction of noxious weeds, invasive species, changes in animal foraging, breeding and migration behaviors.

The following summaries and maps illustrate the distribution of wells in the subregion and landscape and current levels of activity.

Table 8. There are 35,346 wells in the subregion. Just over 1 percent of these are located in the GMUG or San Juan. In the ARW Landscape there are 8,870 wells and the proportion of wells in the Forests to the total is slightly higher at almost 5% percent.

Subregion:

Forest	Number of Wells	Pct
Other	34,906	98.8%
GMUG	110	0.3%
San Juan	330	0.9%
	35,346	100.0%

ARW Landscape:

Forest	Number of Wells	Pct
Other	8,430	95.0%
GMUG	110	1.2%
San Juan	330	3.7%
	8,870	100.0%

In the subregion and the ARW landscape more than 90% are located on BLM, Private or Tribal lands (Table 9 and 10). As a consequence many of the influences resulting from drilling and production occur downstream from Forest lands. Decisions affecting Forest lands directly may not directly influence or mitigate these influences.

Table 9. Distribution of 35,346 wells in the subregion by ownership. Over 90% percent are located on BLM, Private or Tribal lands. Notably, less than 3% percent are located on Forest lands.

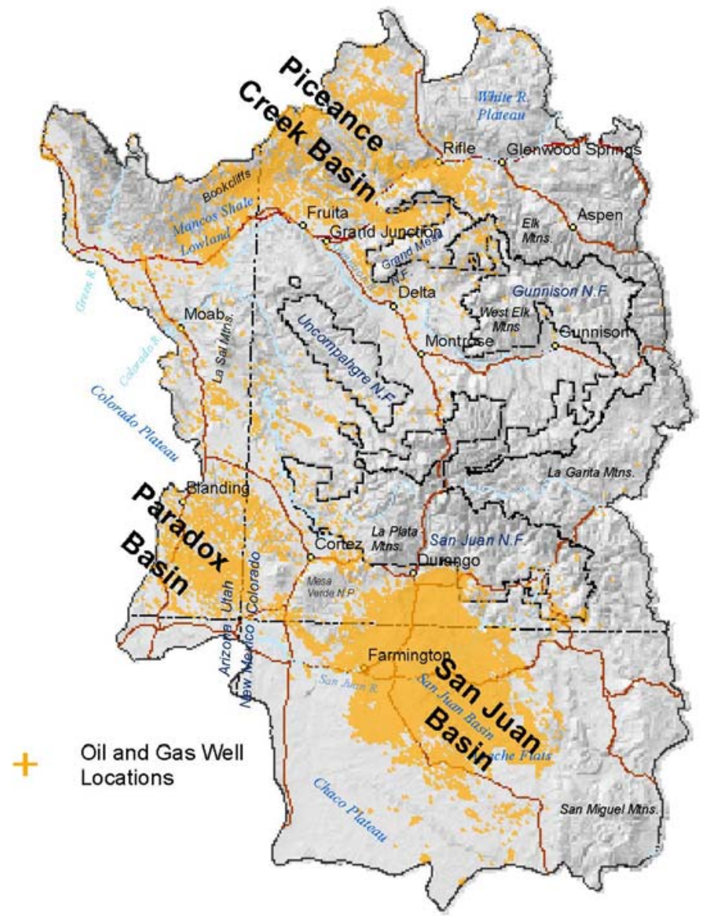
Ownership	Num Wells	Pct	Sum Pct
BLM	14,891	42.13%	42.13%
Private	10,123	28.64%	70.77%
Tribal	7,274	20.58%	91.35%
State	1,746	4.94%	96.29%
USFS	1,037	2.93%	99.22%
BOR	188	0.53%	99.75%
DOD	80	0.23%	99.98%
NPS	7	0.02%	100.00%
	35,346	100.00%	

Table 10. Distribution of 8,870 wells in the ARW landscape by ownership. The overall distribution of wells in the landscape is similar to the distribution in the subregion.

Ownership	Num Wells	Pct	Sum Pct
Private	4,859	54.78%	54.78%
BLM	2,493	28.11%	82.89%
Tribal	825	9.30%	92.19%
State	319	3.60%	95.78%
USFS	295	3.33%	99.11%
DOD	79	0.89%	100.00%
BOR	0	0.00%	100.00%
NPS	0	0	100.00%
	8,870	100.00%	

In the subregion, wells are largely concentrated within three major geologic basins. These three include the Piceance Creek, Paradox and San Juan Basins. Smaller fields are found within sedimentary rocks along local stratigraphic and structural trends beyond basin margins (Figure 9).

Figure 9. The 35,346 wells in the subregion are largely concentrated in Piceance Creek, San Juan and Paradox basins.



Today in the subregion, there are 7704 active or producing wells (Table 11) representing about 22% percent of the 35,346 wells in the subregion (Figure 10). In the ARW landscape, there are 3,427 active or producing wells (Table 12) representing almost 40% percent of the 8,870 wells in the landscape. Notably, areas with greatest well density and intensity of disturbance are on private and tribal lands. Well density and cumulative disturbance from exploration, drilling and production are most intense in the San Juan Basin.

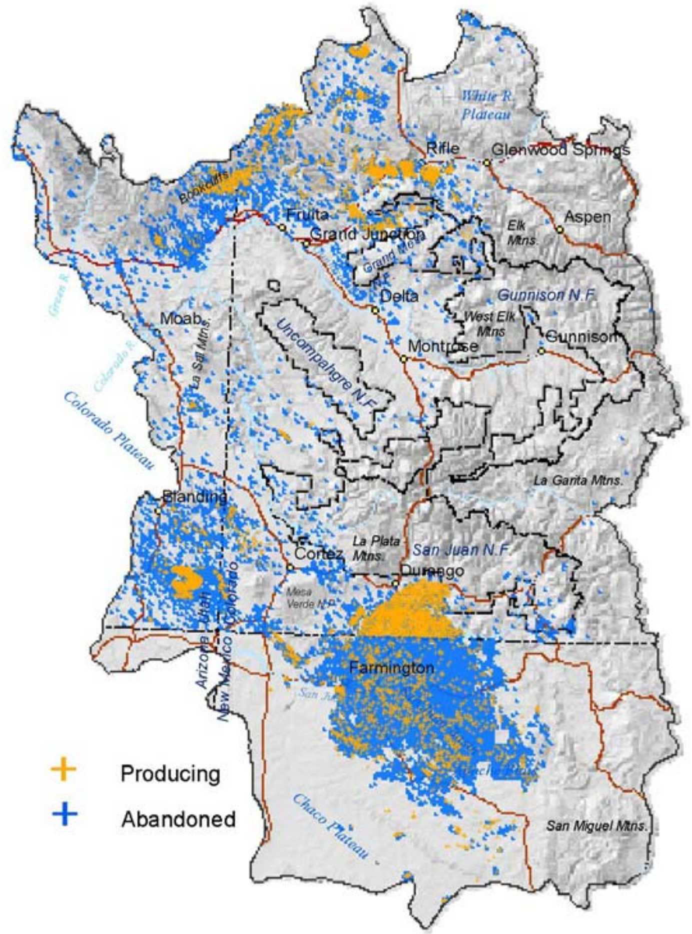
Table 11. Distribution of 35,346 wells in the subregion by status. Nearly 90% percent have been abandoned or are producing. Another 7.3%, are in *"Shut In"* or *"Permit Location"* status may become producers over time.

Status	Number of Wells	Pct	SumPct
Abandoned	23894	67.6%	67.6%
Producing	7704	21.8%	89.4%
Shut In	1428	4.0%	93.4%
Permit Location	1168	3.3%	96.7%
Unknown	765	2.2%	98.9%
Temp Abandoned	163	0.5%	99.4%
Injecting	78	0.2%	99.6%
Waiting Completion	65	0.2%	99.8%
No Designation	61	0.2%	99.9%
Domestic Well	20	0.1%	100.0%
	35,346	100.0%	

Table 12. Distribution of 8,870 wells in the ARW Landscape by status. Nearly 80% percent have been abandoned or are producing. Another 15.1% are in *"Shut In"* or *"Permit Location"* status and may become producers over time.

Status	Number of Wells	Pct	SumPct
Abandoned	3898	43.9%	43.9%
Producing	3427	38.6%	82.6%
Permit Location	800	9.0%	91.6%
Shut In	544	6.1%	97.7%
Temp Abandoned	76	0.9%	98.6%
Injecting	51	0.6%	99.2%
Waiting Completion	29	0.3%	99.5%
No Designation	33	0.4%	99.9%
Domestic Well	12	0.1%	100.0%
	8870	100.0%	

Figure 10. Nearly 67% percent of the wells in the subregion may be classified as abandoned and about 21% are currently classified as active or producing. Significant levels of production in the Paradox Basin are on Tribal lands. Very high levels in the San Juan Basin are associated permitting regimes on private and tribal lands that are relatively more permissive than on Federal and State lands.



Subregion Scale GAP Vegetation Analysis

Of the 35,346 wells in the subregion, just over 92% of these fall in five of twenty vegetation classes (Table 13). These are dominantly dry-land classes and more than half of these wells fall in two types: pinyon-juniper and dessert grassland. Figure 11 shows the distribution of vegetation classes containing the most significant levels of activity.

Table 13. Distribution of wells by vegetation class.

Gap Veg Class	Number of Wells	Pct	Sum Pct
pinyon -juniper	12,578	35.6%	35.6%
desert grassland	9,919	28.1%	63.6%
desert shrub	5,918	16.7%	80.4%
crops	2,683	7.6%	88.0%
sagebrush	1,528	4.3%	92.3%
ponderosa pine	660	1.9%	94.2%
deciduous oak	552	1.6%	95.7%
mountain grassland	462	1.3%	97.0%
aspen	236	0.7%	97.7%
woody riparian/wetland	226	0.6%	98.3%
mixed conifer	170	0.5%	98.8%
barren	104	0.3%	99.1%
urban	102	0.3%	99.4%
spruce - fir	90	0.3%	99.7%
greasewood	32	0.1%	99.8%
herbaceous riparian/wetland	32	0.1%	99.8%
alpine	28	0.1%	99.9%
mountain shrubland	19	0.1%	100.0%
water	4	0.0%	100.0%
Unclassified	2	0.0%	100.0%
lodgepole pine	1	0.0%	100.0%
	35,346	100.0%	

Within the dominantly dry-land classes, where the numbers of wells are highest, potential levels of disturbance are about 1% percent or less of the total vegetation type (Table 14). Overall levels of disturbance increase from here when accounting for roads, pipelines and other infrastructure.

Figure 11. Mineral site counts by vegetation class. Over half of the sites are pinyon-juniper and spruce-fir vegclasses. Forest lands comprise significant proportions the spruce-fir vegetation type. Mine sites in upland areas including Silverton and the La Plata Mountains are strongly correlated to spruce-fir, aspen and alpine vegetation classes.

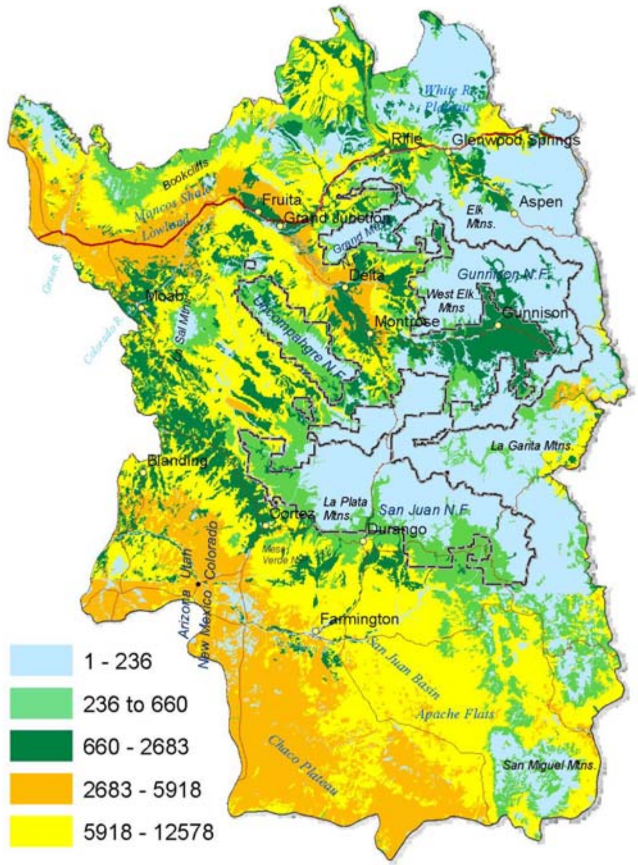


Table 14. Assuming 3 acres of disturbance per well, the following table shows the percentage of each vegetation class in the subregion potentially disturbed by wells.

Gap Veg Class	Veg Class Acres	Number of Wells	Disturbed Acres	Pct of Veg Class
desert grassland	2,694,973	9,919	29,757	1.104%
crops	1,398,015	2,683	8,049	0.576%
woody riparian/wetland	118,598	226	678	0.572%
herbaceous riparian/wetland	17,141	32	96	0.560%
pinyon -juniper	7,265,382	12,578	37,734	0.519%
urban	64,333	102	306	0.476%
desert shrub	5,503,298	5,918	17,754	0.323%
mountain grassland	589,301	462	1,386	0.235%
sagebrush	2,965,185	1,528	4,584	0.155%
greasewood	63,032	32	96	0.152%
barren	289,403	104	312	0.108%
ponderosa pine	2,064,164	660	1,980	0.096%
deciduous oak	1,760,024	552	1,656	0.094%
mixed conifer	1,209,307	170	510	0.042%
aspen	2,272,967	236	708	0.031%
mountain shrubland	222,040	19	57	0.026%
water	63,941	4	12	0.019%
spruce - fir	3,485,003	90	270	0.008%
alpine	1,606,270	28	84	0.005%
lodgepole pine	462,096	1	3	0.001%
Unclassified	0	2	0	0.000%
	34,114,473	35,346	106,038	

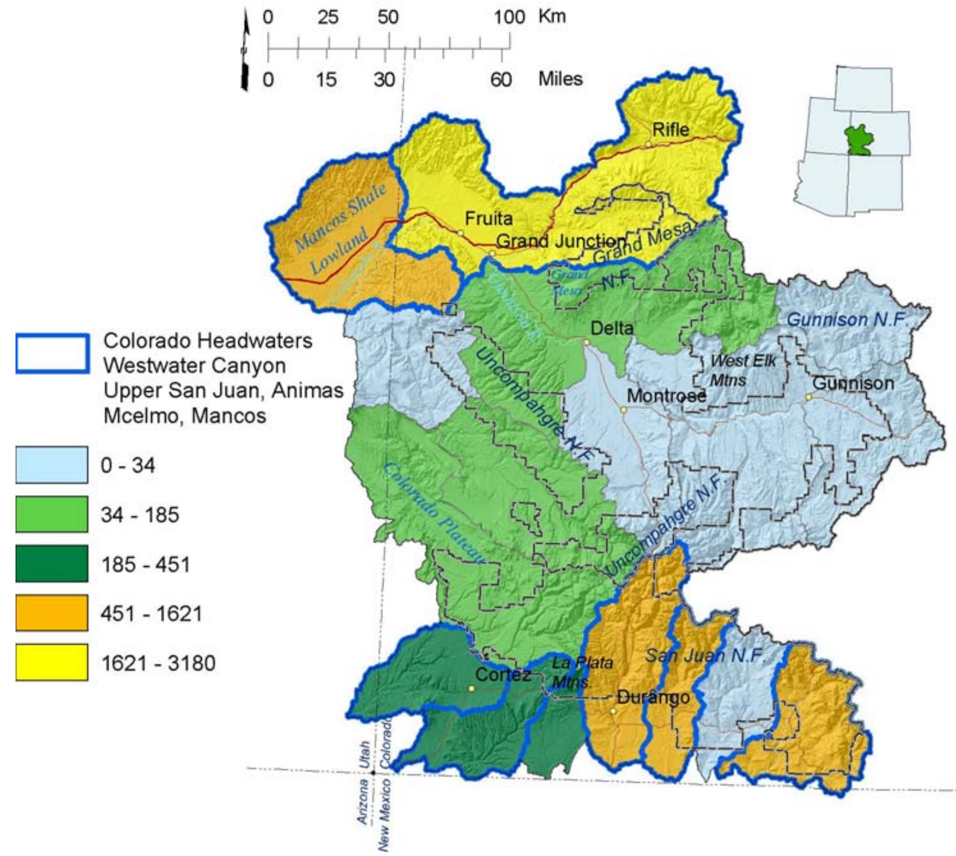
Landscape Scale 4th Level HUB Watershed Analysis

Within the ARW landscape, almost 90% percent of oil and gas wells fall within six 4th level watersheds (Table 15). These six watersheds include: Colorado Headwaters-Plateau, Westwater Canyon, Upper San Juan, Animas, Mc Elmo and Mancos (Figure 12). Well densities are highest in downstream areas of these watersheds and upland areas are generally exhibit low levels of drilling and production. Both ground and surface water quality in these watersheds may be affected by contamination, increased sedimentation, depletion and changes in reservoir function.

Table 15. The following table shows the number of wells per 4th level watershed in the ARW landscape.

HUB4	HUB4NM	Number of Wells	Pct	Sum Pct
14010005	Colorado Headwaters-Plateau	3180	35.9%	35.9%
14030001	Westwater Canyon	1621	18.3%	54.1%
14080101	Upper San Juan	1199	13.5%	67.6%
14080104	Animas	1067	12.0%	79.7%
14080202	Mcelmo	451	5.1%	84.8%
14080107	Mancos	400	4.5%	89.3%
14080105	Middle San Juan	331	3.7%	93.0%
14030002	Upper Dolores	185	2.1%	95.1%
14020005	Lower Gunnison	137	1.5%	96.6%
14030003	San Miguel	129	1.5%	98.1%
14020004	North Fork Gunnison	85	1.0%	99.0%
14020006	Uncompahgre	34	0.4%	99.4%
14080102	Piedra	31	0.3%	99.8%
14020002	Upper Gunnison	13	0.1%	99.9%
14030004	Lower Dolores	6	0.1%	100.0%
14020001	East-Taylor	1	0.0%	100.0%
14020003	Tomichi	0	0.0%	100.0%
		8870	100.0%	

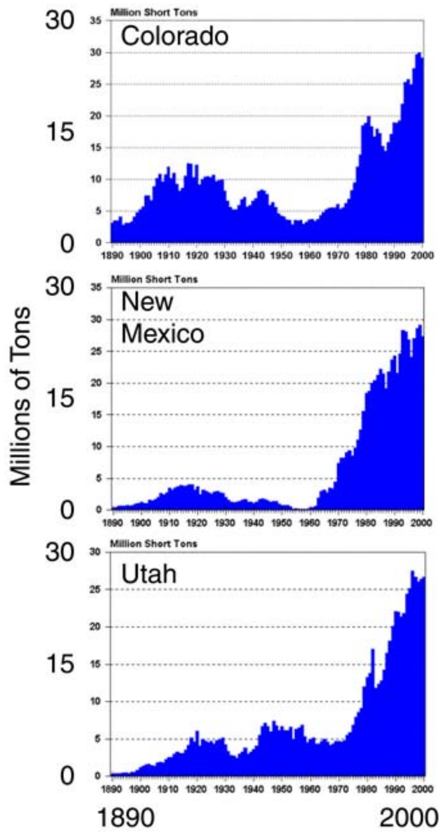
Figure 12. Well counts by 4th level watershed. Almost 90% of wells are found in six 4th level watersheds: Colorado Headwaters, Westwater Canyon, Upper San Juan, Animas, McElmo and Mancos.



Coal

Coal has been produced in Colorado, New Mexico and Utah since the middle of the 19th century. Coal production in Colorado expanded to become the largest in the West with the expansion of railroads in the region. Production in all three states grew from the turn of the century to a peak prior to the Great Depression. Production tapered off through the war years and 1950s with a resurgence beginning in the 1970s (Figure 13). Typical mine operations in the early period were small and served local markets. By contrast, modern mine operations are large and serve regional markets.

Figure 13. Coal production in Colorado, New Mexico and Utah. Adapted after EIA (2004).



Upper Cretaceous rocks throughout the subregion contain coal bearing strata. Deposits crop-out along the margins of regional structural basins. Traces of these basin edges are evident by the spatial pattern of the 535 mine sites in the subregion (Figure 14). The majority of these sites consist of abandoned prospects and small scale underground mines. Most mines developed before 1970 were underground operations (EIA, 2004).

Within the subregion there are 535 coal mine sites and in the ARW landscape there are 287 coal mine sites (Table 16). About 10% of these locations, from the MAS/MILS (Causey, 1998) database, are considered to be in *Active* status. The remainder are classified as *Historic, Prospects* or *Unknown*. Today, only a handful of commercially viable mines remain. Most coal production is aimed at electrical generation. Four mines in the subregion are associated with electrical generation plants adjacent to the source mines.

Table 16. Number of (MAS/MILS) Coal Mine sites in the subregion and ARW Landscape. Adapted after Causey (1998). About 10% percent of these are considered to be *Recent*.

Subregion

Forest	Num Sites	Pct
Outside	502	93.8%
GMUG	15	2.8%
San Juan	18	3.4%
	535	100.0%

ARW Landscape

Forest	Num Sites	Pct
Outside	254	88.5%
GMUG	15	5.2%
San Juan	18	6.3%
	287	100.0%

Today, in the subregion, four of twelve active operations are surface mining operations and eight are underground. Each of these operations are major producers of coal. From 1984 to 1987 these were among 28 operations whose cumulative production was over 221 million tons. Production over the same period from the twelve currently active operations was over 202 million tons (Table 17).

Figure 14. Subregion MAS/MILS coal sites, twelve currently producing mines and associated power plants. MAS/MILS after Causey (1997). Currently producing mines and power plants after Kirschbaum (2000).

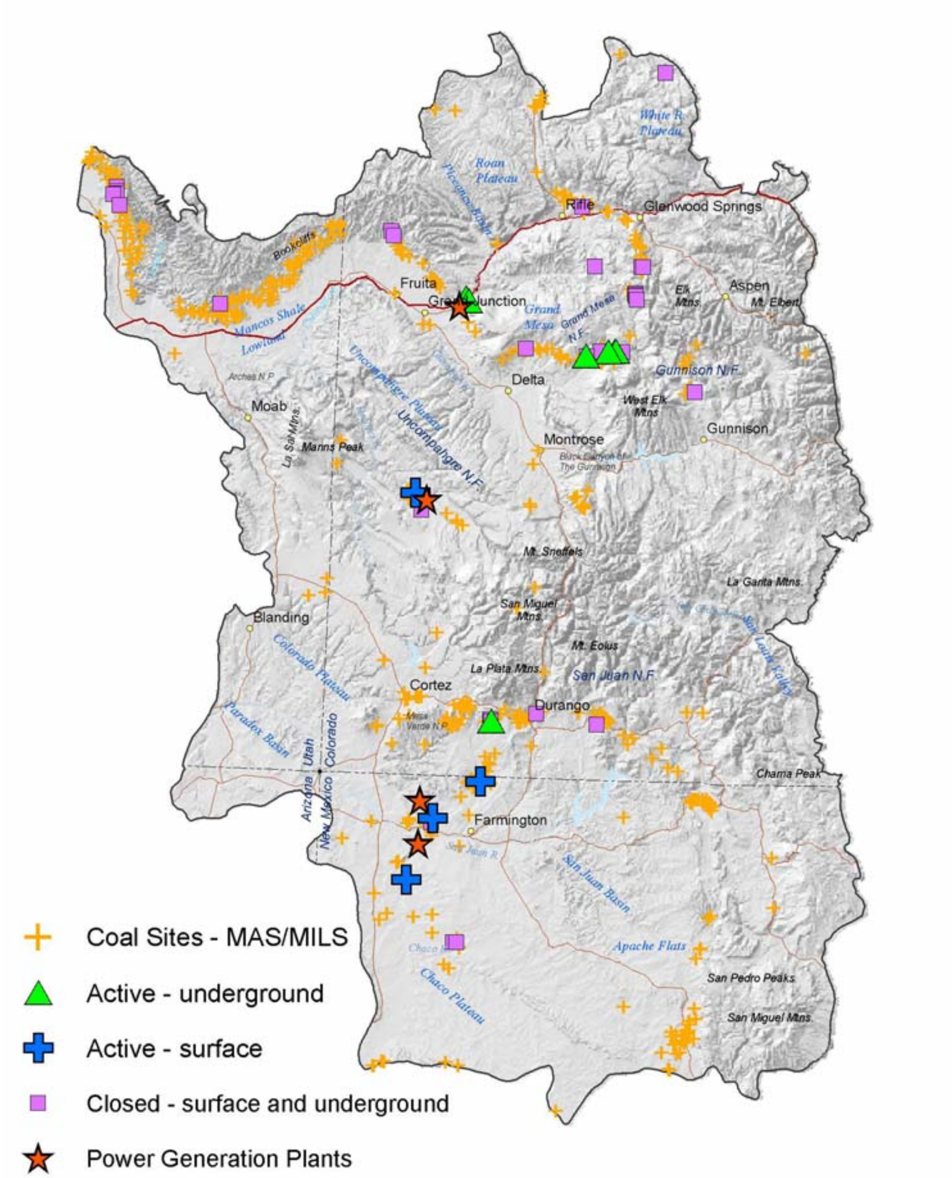


Table 17. Twenty-eight producing coal mines in the subregion from 1984 to 1997 sorted by cumulative tonnage. As of 1997 there were 12 Active mines.

MSHAID	Mine Name	Status	Type	1984 to 1997
2900097	NAVAJO MINE	Active	Surface	97,556,749
2901168	SAN JUAN MINE AND PLANT	Active	Surface	49,310,026
503672	WEST ELK MINE	Active	Underground	18,351,748
2901825	LA PLATA	Active	Surface	14,490,077
4200093	SUNNYSIDE MINE NO. 1	Permanently Abandoned	Underground	6,521,539
504184	BOWIE MINE #1	Active	Underground	6,239,472
503787	BEAR #3 MINE	Active	Underground	4,426,193
500281	ROADSIDE SOUTH PORTAL	Active	Underground	3,866,420
500301	DUTCH CREEK	Permanently Abandoned	Surface	3,449,170
504452	SANBORN CREEK MINE	Active	Underground	3,362,130
500469	DUTCH CREEK NO. 2	Permanently Abandoned	Surface	2,392,500
502898	CYPRUS ORCHARD VALLEY	Permanently Abandoned	Underground	2,084,162
500266	KING COAL MINE	Active	Underground	1,735,363
500294	SANBORN CREEK SURFACE FACILITI	Active	Underground	1,676,251
4200092	SUNNYSIDE MINE NO. 3	Permanently Abandoned	Underground	1,489,251
500299	NEW HORIZON MINE	Active	Surface	1,133,930
2901868	GATEWAY	Permanently Abandoned	Surface	819,208
4202093	SUNNYSIDE FACILITY	New - Under Construction	Surface	762,116
503013	MCCLANE CANYON MINE	Temporarily Closed	Underground	530,414
503012	ROADSIDE NORTH PORTAL	Active	Underground	365,680
2901833	DE-NA-ZIN	Permanently Abandoned	Surface	320,125
500300	L.S. WOOD	Permanently Abandoned	Underground	172,929
500259	O.C. COAL MINE	Permanently Abandoned	Underground	39,871
502421	EASTSIDE MINE	Permanently Abandoned	Underground	26,325
503683	CARBON JUNCTION MINE	Temporarily Closed	Surface	22,259
502658	THOMPSON CREEK NO. 1	Permanently Abandoned	Underground	20,724
4200094	SUNNYSIDE NO. 2 MINE	Permanently Abandoned	Underground	19,729
501962	RED CANYON #1	Permanently Abandoned	Underground	5,705
				221,190,066

Similarly, today, in the ARW landscape, 1 of 9 active operations is a surface mining operation and the remaining eight are underground. From 1984 to 1987 these were among 23 operations in the landscape whose cumulative production was over 43 million tons. Production over the same period from the twelve currently active operations was over 41 million tons (Table 18).

Figure 15. ARW Landscape MAS/MILS coal sites, nine currently producing mines and associated power plants. MAS/MILS after Causey (1997). Currently producing mines and power plants after Kirschbaum (2000).

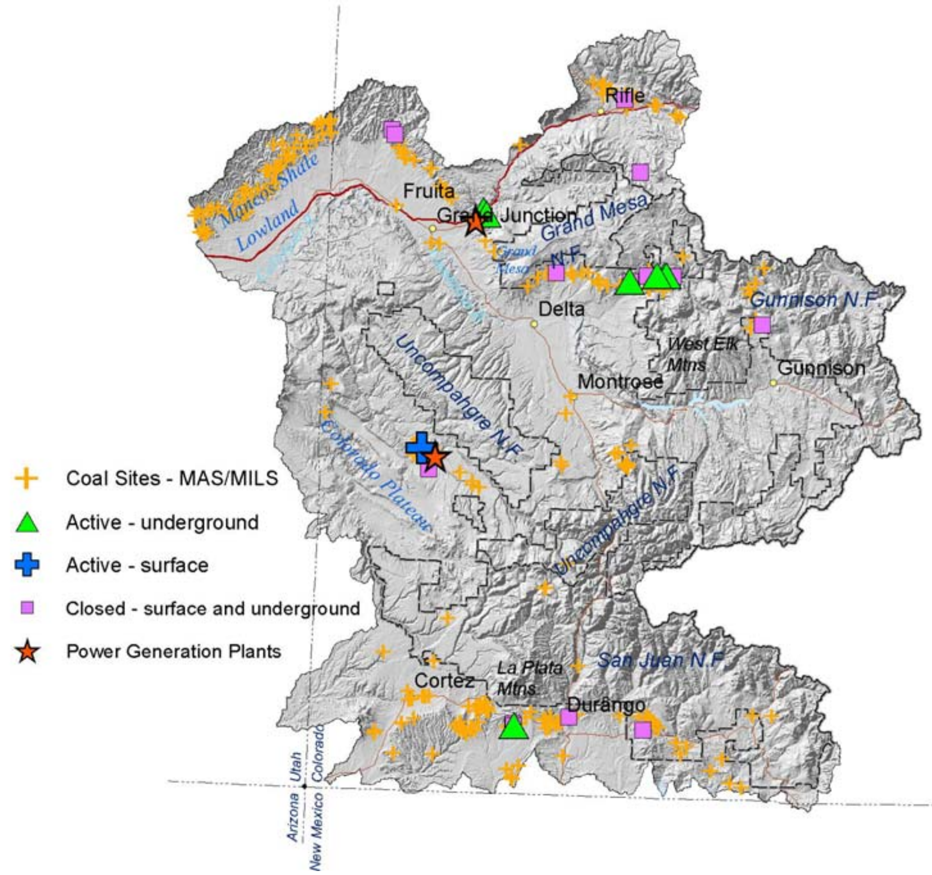


Table 18. Twenty-three producing coal mines in the ARW Landscape from 1984 to 1997 sorted by cumulative tonnage. As of 1997 there were nine active mines.

MSHAID	Mine Name	Status	Type	1984 to 1997
503672	WEST ELK MINE	Active	Underground	18,351,748
504184	BOWIE MINE #1	Active	Underground	6,239,472
503787	BEAR #3 MINE	Active	Underground	4,426,193
500281	ROADSIDE SOUTH PORTAL	Active	Underground	3,866,420
504452	SANBORN CREEK MINE	Active	Underground	3,362,130
502898	CYPRUS ORCHARD VALLEY	Permanently Abandoned	Underground	2,084,162
500266	KING COAL MINE	Active	Underground	1,735,363
500294	SANBORN CREEK SURFACE FACILITI	Active	Underground	1,676,251
500299	NEW HORIZON MINE	Active	Surface	1,133,930
503013	MCCLANE CANYON MINE	Temporarily Closed	Underground	530,414
503012	ROADSIDE NORTH PORTAL	Active	Underground	365,680
500259	O.C. COAL MINE	Permanently Abandoned	Underground	39,871
502421	EASTSIDE MINE	Permanently Abandoned	Underground	26,325
503683	CARBON JUNCTION MINE	Temporarily Closed	Surface	22,259
501962	RED CANYON #1	Permanently Abandoned	Underground	5,705
502303	BLUE FLAME COAL MINE	Permanently Abandoned	Surface	0
503119	MUNGER CANYON MINE	Permanently Abandoned	Surface	0
503133	LA PLATA #1	Permanently Abandoned	Surface	0
503644	COAL CREEK PREP PLANT	Permanently Abandoned	Surface	0
504457	HAMILTON MINE	Permanently Abandoned	Surface	0
500239	BOWIE MINE	Permanently Abandoned	Underground	0
500293	HAWKS NEST EAST	Permanently Abandoned	Underground	0
503134	COAL GULCH	Permanently Abandoned	Underground	0
				43,865,923

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