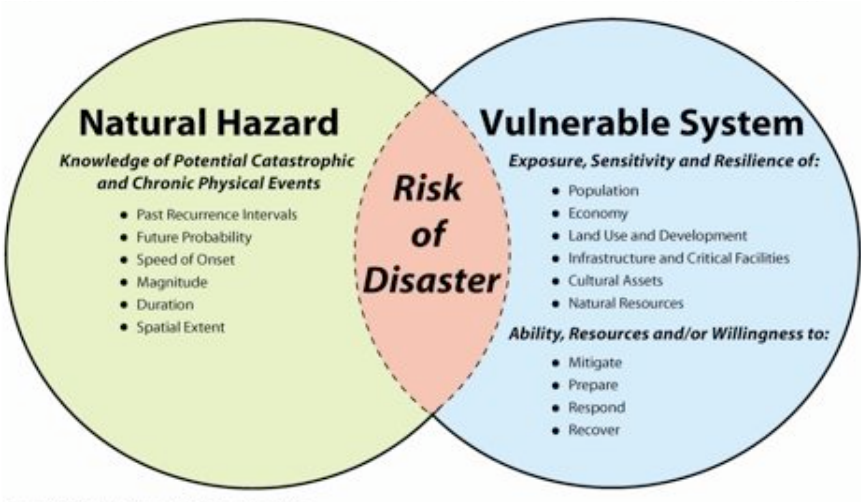
Introduction and Summary

Risk assessments provide information about the geographic areas where hazards may occur, the value of existing land and property in those areas, and an analysis of the potential risk to life, property, and the environment that may result from natural hazard events. This section identifies and profiles the location, extent, previous occurrences, and future probability of natural hazards that can impact Garfield County, as highlighted in Exhibit 1 below.

Methods and Process

A risk assessment consists of three phases: *hazard identification, vulnerability assessment, and risk analysis*, as illustrated in the following graphic.

Exhibit 1: Risk Assessment summary



Source: USGS - University of Oregon Community Service Center, 2006

The first phase of developing a comprehensive risk assessment involves the identification of the geographic extent of a hazard, its intensity, and its probability of occurrence. This *hazard identification* typically involves producing a map. The outputs from this phase can also be used for land use planning, urban growth management, and regulation; public awareness; and defining areas for further study.

In the summer of 2009, Garfield County contracted with ECONorthwest (ECO) to begin the process of developing a Garfield County Risk Assessment. The first step of identifying hazards was accomplished in a two-day workshop with County department representative. Through these workshop discussions, ECO gathered information about hazards that impact the County, and the vulnerable infrastructure and populations that are likely to be impacted by hazard events. Based on the results of the workshop, the hazards most likely to affect the County are: wildfire, flood (especially flash flood), hazardous materials spills, and landslide / rock fall.

Other hazards that have lower frequency or lower severity but might affect the County, include: Snow storms/severe weather, Infectious disease (including agricultural and livestock outbreaks)/ pandemic, Terrorism/eco-terrorism/school safety and security, and Airport safety and security. This Risk Assessment focuses on natural hazards and will not discuss the human induced hazards included in the initial ranking process. However, increasing the resiliency of the County in the face of natural hazards will contribute to the ability of the County to recover from other kinds of disruptions.

It should be noted that when describing hazard events, it is not always easy to separate causality from occurrence. Severe natural hazard events can alter the environment and trigger other, secondary hazards. For example, winter rain storms often cause flooding and within hours or days over-saturated ground at steep grades can sink or slide.

The second phase combines the information from the hazard identification with an inventory of the existing (or planned) property and population exposed to a hazard, and attempts to predict how different types of property and population groups will be affected by the hazard. This *vulnerability assessment* can also assist in justifying

changes to building codes or development regulations, identifying properties or structures appropriate for acquisition or relocation, policies concerning critical and public facilities, taxation strategies for mitigating risk, and informational programs for members of the public who are at risk.

The vulnerability assessment used the results of a survey conducted during the 2009 summer workshop.. Participants were given worksheets organized by potentially vulnerable systems (e.g.: population, economy, land use and development, infrastructure and critical facilities, etc) that asked specific questions about how that system might be impacted by natural hazards. Exhibit 2 provides and example of the worksheet.

Exhibit 2: Issue Identification Worksheet

The third phase involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. This *risk*

Infrastructure & Critical Facilities

Instructions: Identify specific response and recovery issues your community could face in the event of a disaster in the left hand column below. For each issue, use the columns on the right hand side to check the potential period of time each issue could affect the community. Check all that apply.

Issues	Community Impacts Felt (Check all that Apply)		
Framing Questions: • What infrastructure and critical facilities are impacted? • What critical facilities will be operational post-disaster? • Will critical facilities be accessible post-disaster? Will certain access roads and bridges be damaged? Will there be significant debris on access roads and bridges? • What critical facilities and infrastructure need to be operational first?	0 - 72 hours - Response	72 hours – 1 month - Response/Recovery	1 month – on-going - Recovery

analysis has two measurable components: (1) the magnitude of the harm that may happen to people and property identified in the vulnerability assessment, and (2) the likelihood or probability of the harm occurring. An example of a product that can assist communities in completing a risk analysis is HAZUS, a risk assessment software program for analyzing potential losses from floods, hurricane winds and earthquakes. In HAZUS-MH, current scientific and engineering knowledge is coupled with the latest geographic information systems (GIS) technology to produce estimates of hazard- related damage before, or after a disaster occurs.

In the fall of 2009, Garfield County Emergency Management and ECO again conducted a survey of department representatives. This time, participants completed a Risk Assessment Matrix like the one pictured below in Exhibit 3. The Risk Assessment Matrix asked questions about the relative impact on community systems of various hazards and the probability of the hazard occurring. Hazard probability, or the likelihood that the hazard will occur, was ranked on a scale of 1-4 with the following definitions: 1 indicating no likely occurrence or doubtful occurrence, 2 indicates a possible occurrence, 3 indicates a probable occurrence, and 4 indicates that the hazard occurrence is inevitable. The combined responses resulted in a relative ranking of hazards by their severity of impact on the County, its residents, and the economic and physical resilience of the community systems. The rankings determined which hazards would be considered as part of an in depth Risk Assessment and included in the NHMP

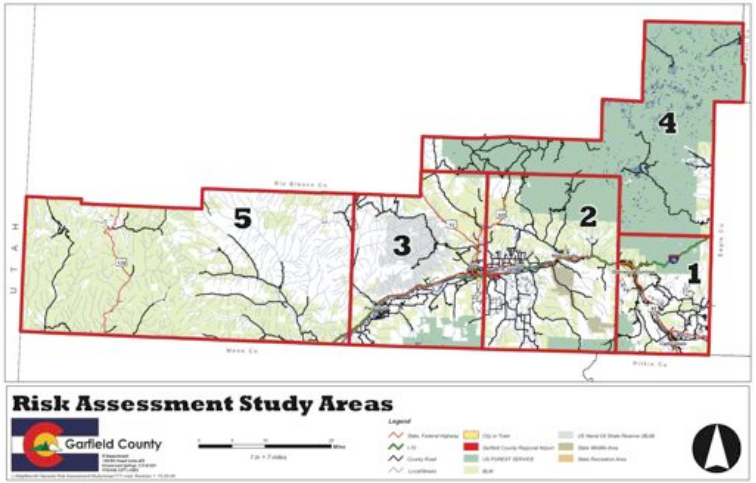
In one final step of analysis, ECO cross-referenced the percent of County characteristics and assets that are at risk from hazards with their relative importance to the County. It should be noted here that the ranking and ordering of hazards and community assets is primarily a qualitative exercise in comparing relative risk of particular places or assets to natural hazards.

No direct accounting was made for dollar values of capital investments, revenue or tax generation, replacement costs, or intangible value of County characteristics. However, after discussions with County department representatives, several modifications were made to the ranking and weighting. Throughout the analysis, multifamily dwelling units and tourism were weighted higher and - in the analysis of assets at risk from wildfire, gas wells and pipeline miles - were also given extra weight.

As Garfield County moves forward to building a more resilient community, this Risk Assessment will provide a base of knowledge about what areas of the community face higher risk of impact from what kinds of threats. The Multihazard Mitigation Council has determined that every $1 spent on mitigation saves $4 in recovery and rebuilding costs[1]. For the purposes of taking action to mitigate impacts from hazards, this Risk Assessment will help to prioritize those areas that need immediate attention.

Exhibit 3: Risk Assessment Matrix

Exhibit 4: Study Areas of the County Risk Assessment



Study Areas At Risk By Hazard

Exhibit 5 highlights the risk experienced by each Study Area within each hazard type. The Study Area that has highest risk of a particular hazard is marked with red and the next highest risk is marked in bold black. Average overall risk for an area is listed at the bottom of the table. This table illustrates that Area 1 has the highest overall hazard risk both in terms of the percent of assets at risk (38%) and in terms of the value – community value – of those assets as noted in the hazard index number (1.4).

Exhibit 5: Study Area Risk

	Area 1		Area 2		Area 3		Area 4		Area 5	
	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index
Wildfire	**24%**	**0.86**	9%	0.34	13%	0.43	**40%**	**1.42**	**40%**	**1.29**
Flood	**19%**	**0.81**	16%	0.74	8%	0.35	16%	0.79	**23%**	**1.09**
Slope	**46%**	**1.63**	24%	0.83	7%	0.21	5%	0.15	**31%**	**1.17**
Soil	48%	1.71	**65%**	**2.36**	**58%**	**2.08**	.	.	5%	0.18
Landslide	**11%**	**0.37**	9%	0.22	2%	0.06	.	.	**10%**	**0.33**
Debrisflow	**27%**	**1.05**	6%	0.27	.	.	.	.	1%	0.05
Average	**29%**	**1.07**	**21%**	**0.79**	18%	0.63	20%	0.79	18%	0.69

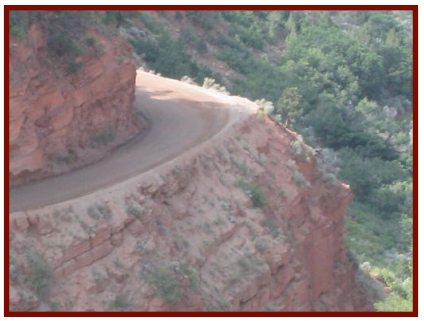
KEY:
Primary
Secondary

The following is a summary description of the highest risk areas by hazard type. The detailed tables and discussion that accompany each hazard section in the body of this document provide additional information.

- **Wildfire**: Study Areas 4 and 5 experience the greatest risk of wildfire. In those Study Areas, the infrastructure most at risk are gas wells, pipelines, and roads.
    - Economic drivers of Area 1 face risk as well. Tourist sites, tram, oil and gas infrastructure, water infrastructure, and the highways are most vulnerable to wildfire.
- **Flood**: Roads (both high traffic asphalt and low traffic gravel) in Area 5 are at a high risk of damage from flood.
    - A flood in Area 1 would impact road and rail infrastructure most significantly as well as carry a direct impact for County residents.

- **Geologic**: Overall, Area 1 has the greatest quantity and types of assets at risk that are at the same time located on hazardously sloped terrain or have soil types that could amplify hazards.
  - ***Slope***: A significant number of assets in Area 1 are located in slope hazard zones. This high risk is felt across all community systems: infrastructure (e.g., communication/information sites, federal/ municipal buildings, water infrastructure, and highways), population sites (e.g., schools and churches), economic assets (e.g., shopping mall and tourism), and development (residential). Primarily, risk in Area 5 is to the federal FAA facility and the road network (both high traffic and low traffic).
  - ***Soil***: In Area 1, the soil type may amplify various hazards and put municipal buildings, water infrastructure, roads and information/ communication facilities, residential development, some industrial and commercial zones at risk of damage and disruption of service. The airport in Area 2 as well as the road network are at risk of soil-aggravated hazards. Additionally, the landfill is at risk. Residential developments including single family, multi-family, and a nursing home, have potentially unstable soil.
  - ***Landslide***: Communication facilities and the road network in Area 1 incur specific risk from landslides. In Area 5, it is structures (homes, storage facilities, ,man-camps) as well as the road network essential to access those structures that is at risk of damage from landslides.
  - ***Debris Flow***: In Area 1, infrastructure such as the federal and municipal buildings, fire stations and information sites experience greatest risk of debris flows. Additionally, population centers such as churches and schools also experience greater than average risk.

Landslides and rockfall below an access road



Access road carved into a hillside

Highway and railroad in the floodplain

Highest risk areas above a threshold hazard index of 1.00

A hazard index number is assigned to each hazard type for each Study Area. An index of greater than 1 emphasizes the greatest risk as it exists anywhere across the County, regardless of the hazard type or Study Area. Exhibit 6 highlights when the risk index is greater than 1.

Exhibit 6: Relative Ranking of Risk: Hazard Index +1

	Area 1		Area 2		Area 3		Area 4		Area 5	
	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index	% of asset at risk	Index
Wildfire	24%	0.86	9%	0.34	13%	0.43	**40%**	**1.42**	**40%**	**1.29**
Flood	19%	0.81	16%	0.74	8%	0.35	16%	0.79	**23%**	**1.09**
Slope	**46%**	**1.63**	24%	0.83	7%	0.21	5%	0.15	**31%**	**1.17**
Soil	**48%**	**1.71**	**65%**	**2.36**	**58%**	**2.08**	.	.	5%	0.18
Landslide	11%	0.37	9%	0.22	2%	0.06	.	.	10%	0.33
Debrisflow	**27%**	**1.05**	6%	0.27	.	.	.	.	1%	0.05

With this method of data analysis, Areas 1 and 5 are at high risk of multiple hazards.

Area 1 experiences the highest risk from geologic hazards – soil, slope, and debris flow. The risk is spread across all community systems including infrastructure, population assets, economic drivers, and development potential.

Geologic hazards can be triggered in various ways, which can complicate mitigation. There may however, be some overlap in terms of the physical assets at risk in Area 1. Mitigation actions can focus on those specific assets, their location, and environment. For example, the steeply sloped hills around Glenwood Springs are susceptible to landslides at any time during the year. Also, the same hazard zone may be at risk of debris flows after heavy rains.

Assets in Area 5 are threatened by several different hazards - wildfire, flood, and sloped landscapes - that can become unstable for any number of reasons. Even though there is very little population in Area 5, it holds the majority of the oil and gas infrastructure. As a central component to the economy of Garfield County, this infrastructure is extremely valuable and mitigation against the impact of a natural hazard can build on the partnerships that already exist between the County and the industries that rely on the resources in Area 5.

Wildfire in Area 5 has the potential to affect the entire County. Air quality is not only important to the health of County residents, but also to the tourism industry. Oil and gas infrastructure may also be directly threatened by wildfires. Wells and pipelines are at a serious risk and any interaction of oil and fire would be a deadly mix.

Area 5 is characterized by step ravines and narrow valleys. Within that landscape are wells and pipelines that are the underpinning of the County economy. These assets are at risk of landslide, debris flow, rock falls, and general soil instability from the steep slopes that have been carved to provide truck roads and well platforms. Because the roads are so delicately woven along the walls of the canyons and ravines, one incident of a road washed out or a slide can cut off entire sections of the area from road access. A flood in Area 5 could induce landslides and damage the road network, cutting off access to oil and gas sites.

The remainder of this section steps through recent hazard events that have impacted the County, and provides an overview of recent scientific data about the hazards and vulnerabilities faced across the County.

Wildfire Hazard

Even though wildfires are a natural part of the ecosystem in the Rocky Mountain West, they can present a substantial hazard to life and property, especially along the Wildland Urban Interface area. In 2006 the Colorado State Forest Service and Garfield County Sheriff's Department developed the Garfield County Community Wildfire Protection Plan (CWPP). The CWPP summarizes the current state of fire prevention, preparedness, and suppression in the County; identifies and prioritizes areas most at risk of wildland-urban interface fires; presets a strategy for appropriate fire response; and articulates mitigation actions. The CWPP is the authoritative document on wildfire hazards in Garfield County and represents a comprehensive hazard profile, vulnerability analysis, risk assessment, and statement of mitigation actions. This portion of the NHMAP incorporates sections of the CWPP.

Wildfire characteristics

Wildfire is defined as any fire occurring on wildlands that requires suppression response. The wildfire hazard is often characterized by an increased fire risk in the urban interface zone. The interface is the urban-rural fringe where homes and other structures are built into a densely forested or natural landscape. If left unchecked, it is likely that fires in these areas will threaten lives and property.

There are three categories of interface fire:

- The classic wildland-urban interface exists where well-defined urban and suburban development presses up against open expanses of wildland areas;
- The mixed wildland-urban interface is characterized by isolated homes, subdivisions, and small communities situated predominantly in wildland settings; and
- The occluded wildland-urban interface exists where islands of wildland vegetation occur inside a largely urbanized area.

Certain conditions must be present for significant interface fires to occur. The most common are: hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, other conditions influence its behavior, including fuel, topography, weather, drought, and development

Garfield County experiences an increased fire risk seasonally, typically April through October. Lightning is the primary source of ignition; secondary causes include agricultural burns and other human-caused ignitions. County-wide, fuel sources are trees, ladder brush, underbrush, cheat grass, and beetle-killed trees.

Another particular concern in Garfield County are coal seam fires. The coal seam is an underground coal deposit that is close enough to the surface to be ignited by a lightning strike or even extreme temperatures. Once ignited, these fires challenge traditional firefighting techniques by continuing to smolder underground for extended periods of time and traveling along the coal deposit to ignite brush or dry ground cover nearby. Coal seam fires have affected Study Areas 1 and 2.

History of wildfire in Garfield County[2]

Garfield County is a fire-prone area. Statistics show that between the years of 1980 to 2003, the Upper Colorado River (UCR) Interagency Fire Management Unit (of which Garfield County is a part) averaged 180 fires per year (BLM Glenwood Springs FO, 2004). During the most recently reported fire season (2005), the UCR reported more than 250 vegetation fires. There are undoubtedly many more fires occurring that are unaccounted for through the federal/state reporting system. While the majority of fires are relatively insignificant in terms of size and fire intensity, several high-intensity fires have not only burned thousands of acres but also posed significant threats to structures or other human developments. Historically notable fires are: the Battlement Creek Fire (1976: 3 firefighter fatalities): Battlement Mesa Fire (1987); the South Canyon Fire (1994: 14 firefighter fatalities); and the Coal Seam Fire (2002) that burned into the town limits of Glenwood Springs and covered over 12,000 acres. Most large fires in the County quickly cross ownership lines and require a multi- jurisdictional response.[3]

Data sources[4]

Several recent mapping efforts have attempted to delineate wildfire hazard in Garfield County. In 1996, the Garfield County Geographic Information Services department created a set of "Wildfire Hazard Maps" of the County. These maps were based on a combination of fuel and slope data. Although the maps are a good overall indication of the relative flammability of areas within the County, there are a number of factors that were not taken into account (such as housing density, disturbance regimes, or ignition sources) that contribute to overall risk within the wildland-urban interface.

In 2002, the Colorado State Forest Service produced a statewide "Colorado Wildland Urban Interface Hazard Assessment" that combined data from fuel, slope, aspect, disturbance regime, lightning strike density, proximity to roads and railroads, and housing density. The assessment shows the general areas of concern in the County. The 2006 CWPP combines the previous data and mapping to develop a list of "Communities at Risk" from wildfire, and articulates wildfire mitigation actions.

Vulnerability assessment

Vegetative conditions vary widely throughout the County, ranging from semi-desert grass and shrubland to sub-alpine forests. Much of the development in the County is located in the lower- elevation zones of sagebrush, Gambel oak, and pinyon-juniper woodlands. The combination of steep terrain, highly flammable vegetation, and hot, dry summers creates a high-risk situation for wildland fire.[5]

People living in or near wildland settings in Garfield County are vulnerable to the threat of wildfire. The development of homes and other structures is encroaching into the forest wildland and natural areas and is expanding the wildland-urban interface. Problems can arise if this new development increases the amount of fuel without coordinated thinning of the forests and creation of defensible space around homes.

Interface neighborhoods are characterized by a diverse mixture of varying housing structures, development patterns, ornamental and natural vegetation, and natural fuels. People moving from more urban areas frequently have high expectations for fire protection services. Often, new residents do not realize that they are living outside of a fire protection district, or that the services provided are not the same as in an urban area. The CWPP identifies the County code and regulations that impact the vulnerability of interface areas.

Several oil and gas companies have drilling operations in wildfire interface areas. The 2006 CWPP focuses on residential vulnerability and does not account for the increased risk due to the presence and activity of the oil and gas industry.

The diversity and amount of equipment and the number of personnel can be substantially limited in rural areas. Fire protection may rely more on the landowner's personal initiative to take measures to protect his or her own property. Therefore, public education and awareness may play a greater role in rural or interface areas. The CWPP documents past and ongoing efforts, such as Firewise Community workshops that inform County residents about wildfire risk and engage property owners in wildfire mitigation.

In the event of a wildfire, vegetation, structures, and other flammables can merge into unwieldy and unpredictable events. Factors relevant to the fighting of such fires include access, firebreaks, proximity of water sources, distance from fire station, and available firefighting personnel and equipment. The vulnerability of structures and homes in the interface area is increased by: combustible roofing and constriction material; no/insufficient defensible space; poor access to structures; heavy natural fuel types; steep slopes; limited water supply; and winds over 30 miles per hour.

Hazard probability

As part of the Risk Assessment process, Garfield County representatives completed a Risk Matrix that compiled the relative impact on community systems of various hazards and the probability of the hazard occurring. Fire, including wildfire, was assessed with a combined probability rating of 3.73, or that a wildfire occurrence is nearly inevitable in Garfield County.

Risk assessment

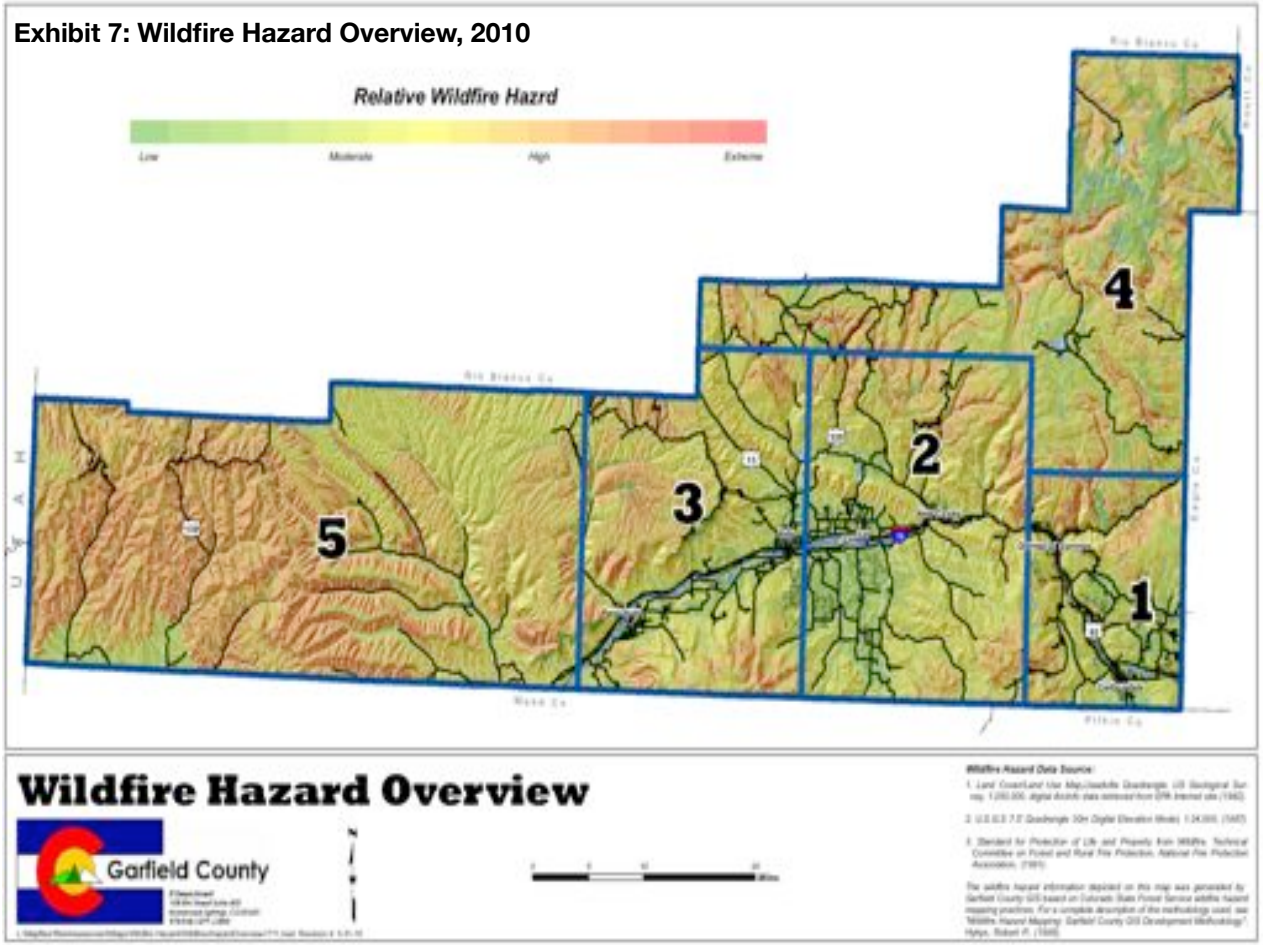
In 2006 the Colorado State Forest Service and Garfield County Sheriff's Department developed a County-wide Community Wildfire Protection Plan (CWPP). The CWPP drew from the 2002 "Colorado Wildland Urban Interface Hazard Assessment" and additional data provided by local fire department and agency personnel to further define the most at-risk wildland-urban interface areas within the County.

In each of the Study Areas, a wildfire could potentially impact the suburban, rural, and isolated developments of single houses or farms more quickly and severely than the development in the urban communities. The canyons create narrow and steep ingress and egress under normal conditions and access roads can quickly become perilous during a fire for both residents and fire personnel. In each Study Area, the gravel paved roads, which are more prevalent in the rural portions of the County, experience the highest risk of damage from wildfire.

Exhibit 7 displays the wildfire hazard risk overview developed in 2010 for this Risk Assessment. As described earlier, Study area 5 experiences the highest fire risk. While this area has no population centers, the potential impact from wildfire affects the oil and gas industry. The wildfire risk profile of the County, and particularly Study Area 5 is heightened due to the presence and activity of the oil and gas industry. Sufficient data was not available to conduct an evaluation of risk incurred due to oil and gas activities. A more complete risk assessment in the future should evaluate the specific oil and gas resources to not only assess the risk they pose to the County, but the potential for cascading hazards due to the interaction of fire and the industry.

Exhibit 8 (next page) from the CWPP highlights "Communities at Risk" that have the highest potential for catastrophic wildfire events. There are 21 areas specifically listed on the map. These areas are an idea focus for hazard mitigation. Targeted outreach, fuel reduction projects, fire suppression resource staging, or additional development restrictions are examples of possible fire mitigations steps.

Exhibit 7: Wildfire Hazard Overview, 2010



Also, in Study Area 1, the highway and tunnels along I-70 through the Glenwood Canyon are at risk and could become unusable during a fire incident, affecting the regional and national movement of goods and people through the county.

Urban areas may experience the residual effects of a nearby fire in several ways. The canyons can trap smoke, ash, and fire particulates in the air for extended periods of time. Poor air quality is not only a health concern for residents, but can deter tourism activities. Additionally, in Study Area 1, the Glenwood Springs viaduct which is a primary source of water for the community, is at high risk of damage from fire. Silt, in Study Area 2 experiences fire risk due to the location of the coal seam that runs East-West just to the North of town.

Much of the land in Garfield County is publicly owned and managed under federal regulations. While this land may have higher fire risk, the risk incurred by people, economic factors, or physical infrastructure is minimal. The key to managing fire risk on these lands and the impacts on communities in Garfield County will be coordination between the County administration, the fire districts, and the federal agencies that have ultimate responsibility for the public land.

Continued on page 3-13

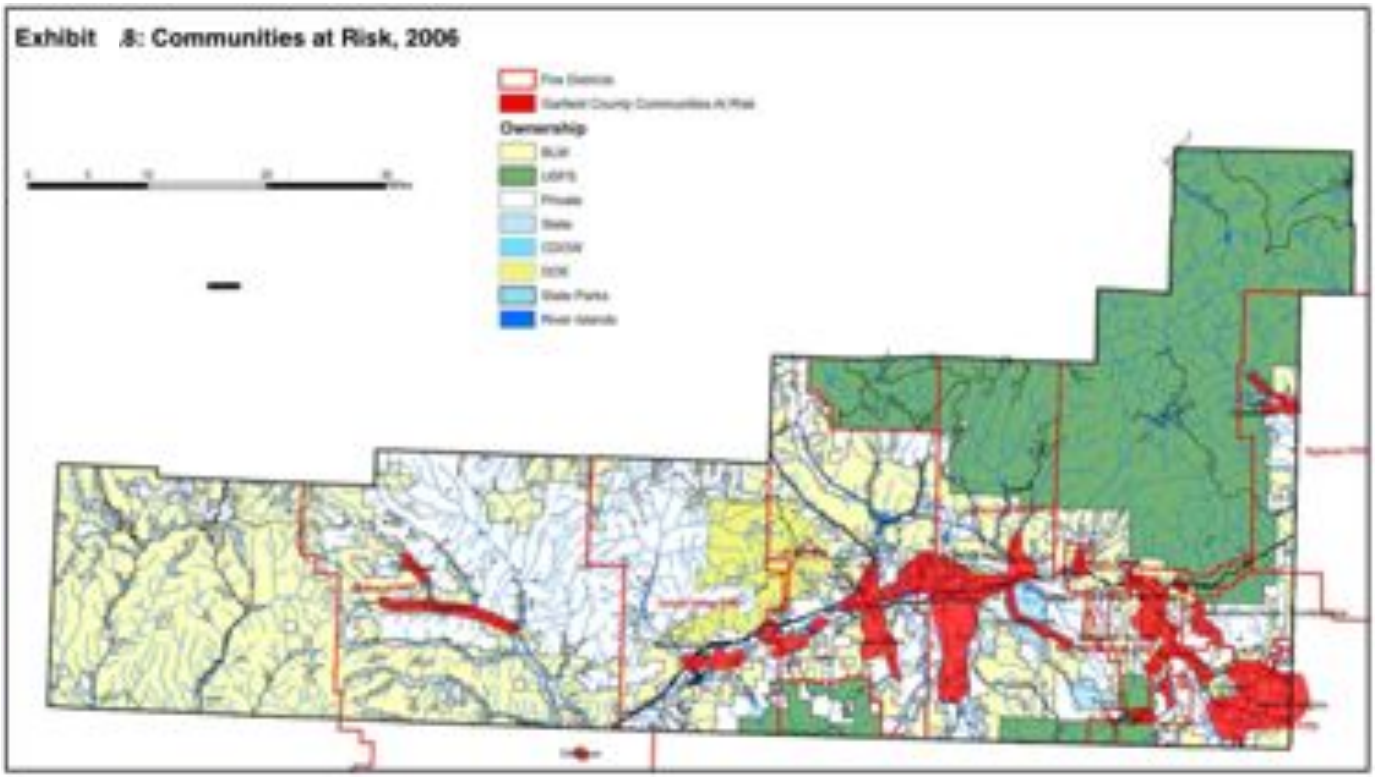
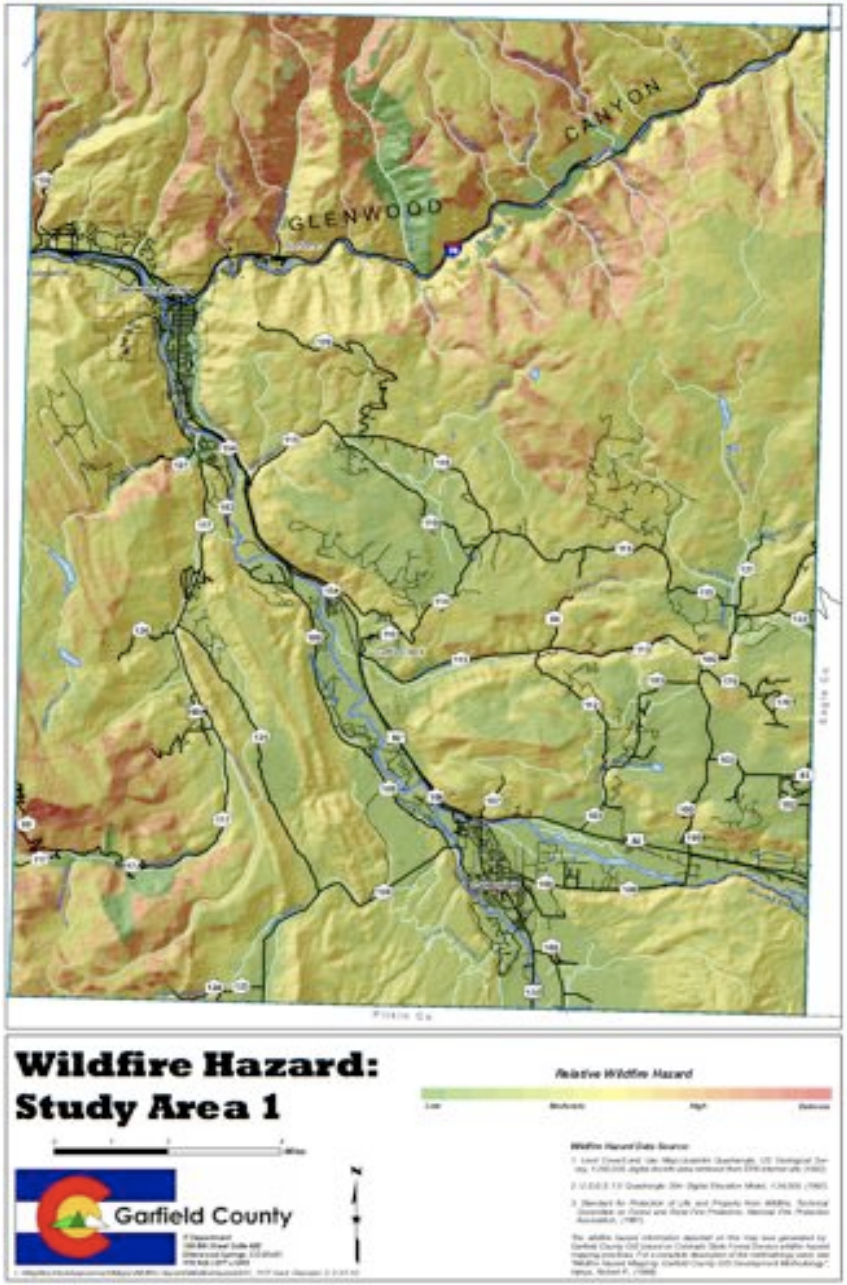
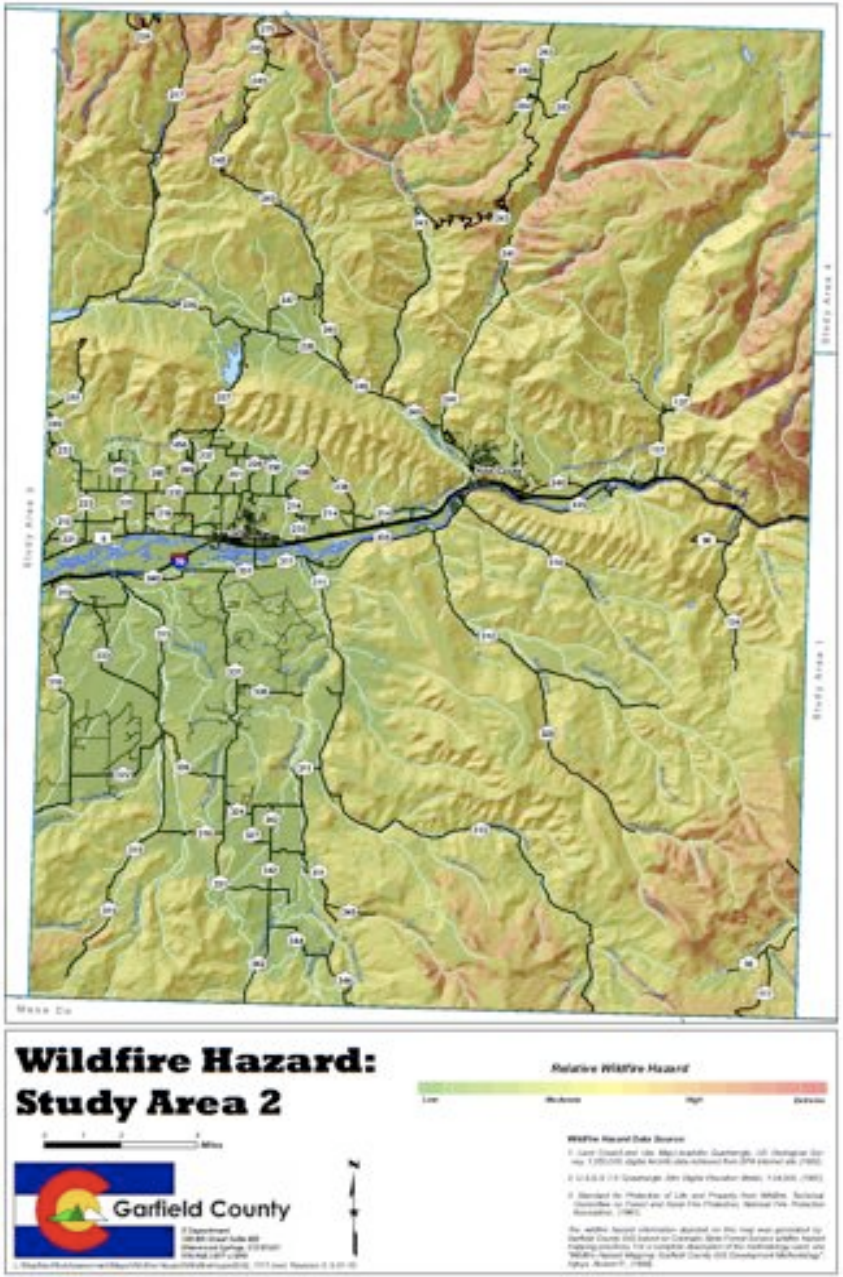


Exhibit 9: Study Area 1 Wildfire Hazard Map
Exhibit 10: Study Area 1 Wildfire Hazard Risk Matrix



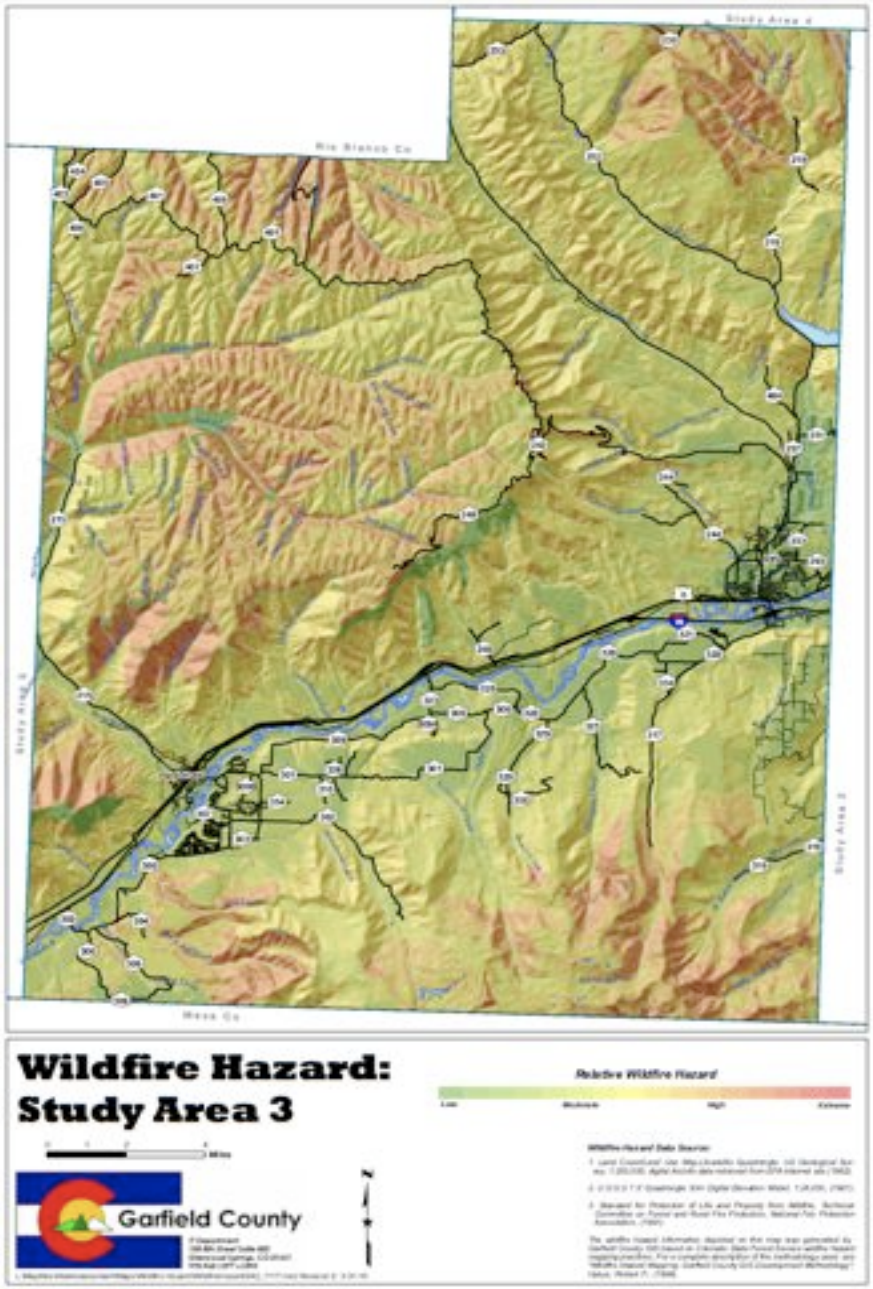
Wildfire - High / Extreme Hazard	Weighting	Total Area % of asset at risk	Index
Infrastructure	**5**	29%	1.44
Electric Utility Lines (Miles)	5	12%	0.62
Electrical Utility Substations	5	14%	0.71
Right-of-Way	1	17%	0.17
Pedestrian Bridge	1	17%	0.17
Communications Facilities	5	21%	1.04
Water Tanks	5	38%	1.88
GS Water Viaduct (miles)	5	77%	3.85
Highway Bridges	5	24%	1.20
Highway Tunnels	5	40%	2.00
Road Miles (Asphalt-High Traffic Volumes)	5	17%	0.87
Road Miles (Chipseal-Moderate Traffic Volumes)	5	7%	0.37
Road Miles (Gravel-Low Traffic Volumes)	5	26%	1.28
Population	**4**	7%	0.29
Public Building	4	8%	0.33
Structures	4	4%	0.16
Residential Land Use (MultiFam)	5	7%	0.33
Residential Land Use (SingleFam)	4	19%	0.76
Residential Land Use (Misc)	4	1%	0.04
Mixed Use	4	4%	0.16
Economy	**3**	39%	1.16
Commercial and Retail Land	3	18%	0.55
Industrial	3	43%	1.29
Gas Wells	4	20%	0.80
Pipeline Miles	4	26%	1.03
Tram	3	129%	3.88
Tourism Site	3	17%	0.50
Ag and Natural Resource Land	3	17%	0.50
Land and Development	**2**	27%	0.53
City Zoning	2	20%	0.39
Public Lands	2	58%	1.17
Planned Development	2	32%	0.63
Planned Unit Development	2	19%	0.37
Residential/Suburban	4	31%	1.23
Residential/Urban	4	7%	0.27
Rural	2	21%	0.42
Cultural Resources	**1**	6%	0.06
Park	1	6%	0.06
TOTALS		24%	0.86

Exhibit 11: Study Area 2 Wildfire Hazard Map
Exhibit 12: Study Area 2 Wildfire Hazard Risk Matrix



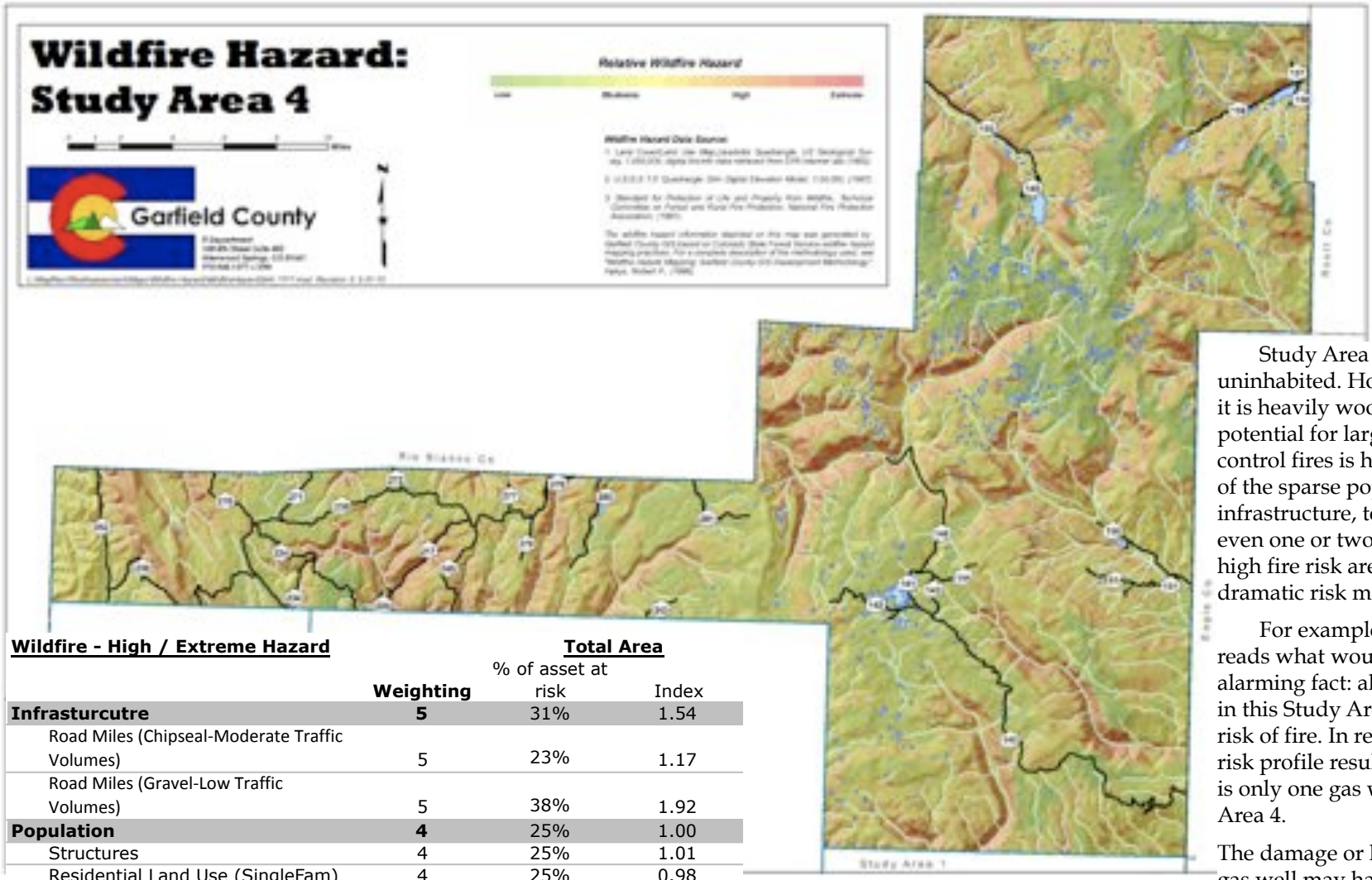
Wildfire - High / Extreme Hazard	Weighting	Total Area % of asset at risk	Index
Infrastructure	**5**	12%	0.59
Road Miles (Asphalt-High Traffic Volumes)	5	5%	0.26
Road Miles (Chipseal-Moderate Traffic Volumes)	5	7%	0.33
Road Miles (Gravel-Low Traffic Volumes)	5	24%	1.18
Population	**4**	7%	0.28
Structures	4	3%	0.12
Residential Land Use (SingleFam)	4	9%	0.36
Residential Land Use (MultiFam)	5	1%	0.03
Residential Land Use (Misc)	4	4%	0.15
Mixed Use	4	0.1%	0.00
Church	4	25%	1.00
Economy	**3**	11%	0.34
Commercial and Retail Land	**3**	6%	0.19
Gas Wells	4	1%	0.05
Pipeline Miles	4	8%	0.32
Ag and Natural Resource Land	3	25%	0.75
Land and Development	**2**	7%	0.14
Public Lands	3	11%	0.32
Rural	2	3%	0.06
TOTALS		9%	0.34

Exhibit 13: Study Area 3 Wildfire Hazard Map
Exhibit 14: Study Area 3 Wildfire Hazard Risk Matrix



Wildfire - High / Extreme Hazard		Total Area	
	Weighting	% of asset at risk	Index
Infrasturcutre	**5**	7%	0.37
Right-of-Way	1	3%	0.03
Road Miles (Asphalt-High Traffic Volumes)	5	4%	0.18
Road Miles (Chipseal-Moderate Traffic Volumes)	5	1%	0.06
Road Miles (Gravel-Low Traffic Volumes)	5	22%	1.09
Population	**4**	1%	0.02
Structures	4	1%	0.02
Residential Land Use (SingleFam)	4	1%	0.02
Economy	**3**	18%	0.55
Gas Wells	4	15%	0.60
Pipeline (miles)	4	16%	0.63
Commercial and Retail Land	3	2%	0.07
Resource Land	3	56%	1.68
Ag and Natural Resources Land	3	3%	0.08
Land and Development	**2**	21%	0.43
City Zoning	5	3%	0.13
Planned Unit Development	4	0.1%	0.01
Public Lands	3	58%	1.75
Rural	2	24%	0.48
TOTALS		13%	0.43

Exhibit 15: Study Area 4 Wildfire Hazard Map
Exhibit 16: Study Area 4 Wildfire Hazard Risk Matrix



Wildfire - High / Extreme Hazard	Weighting	Total Area % of asset at risk	Index
Infrasturcutre	**5**	31%	1.54
Road Miles (Chipseal-Moderate Traffic Volumes)	5	23%	1.17
Road Miles (Gravel-Low Traffic Volumes)	5	38%	1.92
Population	**4**	25%	1.00
Structures	4	25%	1.01
Residential Land Use (SingleFam)	4	25%	0.98
Economy	**3**	68%	2.03
Commercial and Retail Land	3	57%	1.72
Gas Wells	4	100%	4.00
Ag and Natural Resource Land	3	46%	1.37
Land and Development	**2**	29%	0.57
Public Lands	2	15%	0.30
Rural	2	42%	0.84
TOTALS		40%	1.42

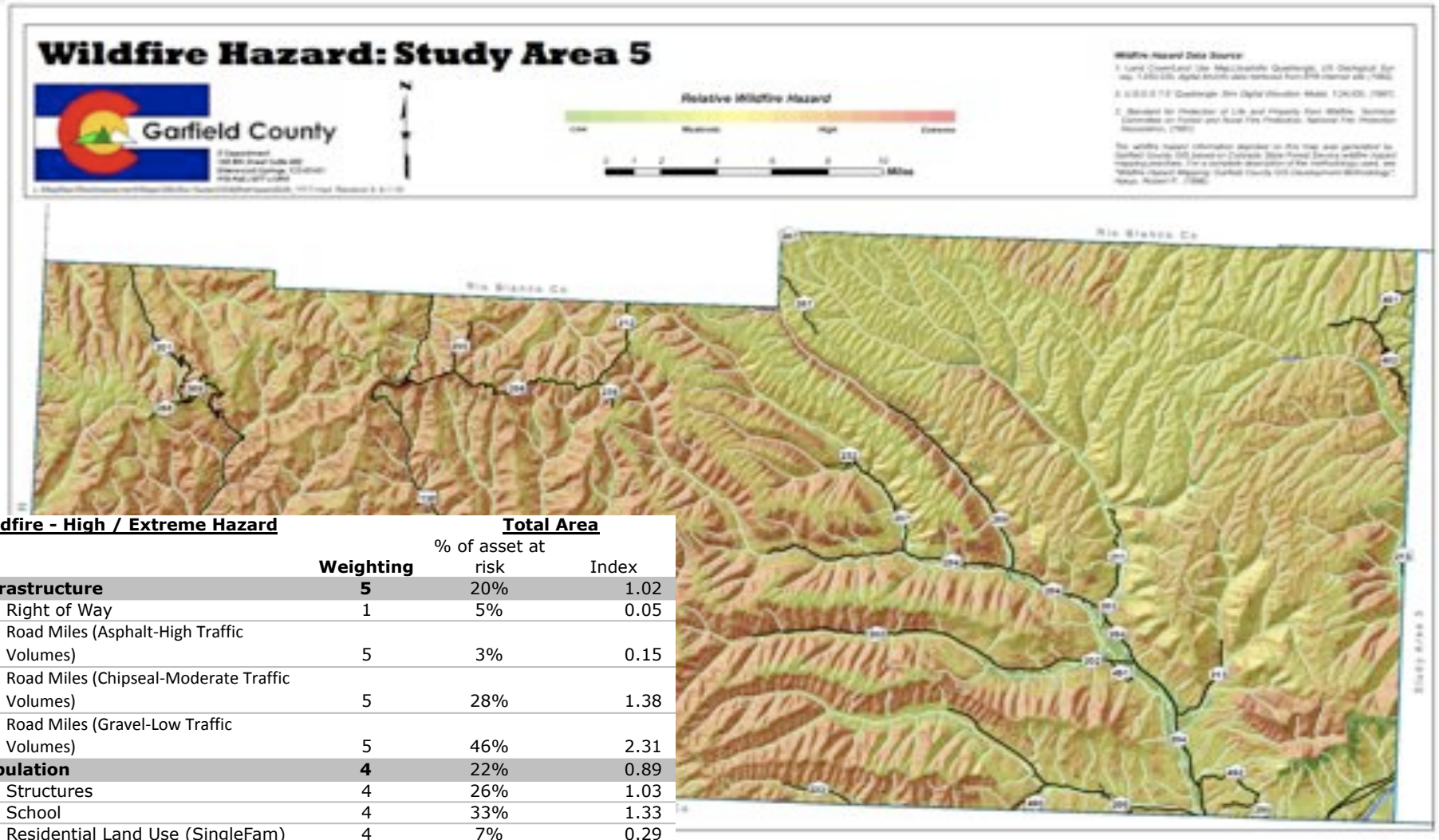
Study Area 4 is mostly uninhabited. However, because it is heavily wooded, the potential for large and hard to control fires is high. As a result of the sparse population and infrastructure, teh presence of even one or two buildings in a high fire risk area results in a dramatic risk matrix.

For example, the risk matrix reads what would seem to be an alarming fact: all of the gas wells in this Study Area are at high risk of fire. In reality, the 100% risk profile results because there is only one gas well in Study Area 4.

The damage or loss of this single gas well may have an environmental or economic impact, but it is unlikely to be as severe as in other Study Areas with more assets and population.

Continued on page 3-14

Exhibit 17: Study Area 5 Wildfire Hazard Map
Exhibit 18: Study Area 5 Wildfire Hazard Risk Matrix



Wildfire - High / Extreme Hazard		Total Area	
	Weighting	% of asset at risk	Index
Infrastructure	**5**	20%	1.02
Right of Way	1	5%	0.05
Road Miles (Asphalt-High Traffic Volumes)	5	3%	0.15
Road Miles (Chipseal-Moderate Traffic Volumes)	5	28%	1.38
Road Miles (Gravel-Low Traffic Volumes)	5	46%	2.31
Population	**4**	22%	0.89
Structures	4	26%	1.03
School	4	33%	1.33
Residential Land Use (SingleFam)	4	7%	0.29
Economy	**3**	55%	1.64
Pipelines	4	55%	2.21
Gas Wells	4	40%	1.60
Resource Land	3	59%	1.78
Ag and Natural Resource Land	3	64%	1.93
Land and Development	**2**	74%	1.47
Public Lands	2	78%	1.55
Rural	2	69%	1.39
TOTALS		40%	1.29

Flood Hazard

Flooding occurs when climate (or weather patterns), geology, and hydrology combine to create conditions where water flows outside of its usual course. A flood is a temporary condition of partial or complete inundation of normally dry land areas. Types of floods include riverine flooding (the overflow of stream banks), urban flooding (rapid accumulation of runoff of surface waters from any source), and mudflows or the sudden collapse of shoreline land.

Flooding results when the flow of water is greater than the normal carrying capacity of the stream channel. Rate of rise, magnitude (or peak discharge), duration, and frequency of floods are a function of specific geographic characteristics. Generally, the rise in water surface elevation is quite rapid in small (and steep gradient) streams and slow in large (and flat sloped) streams. The causes of floods relate directly to the accumulation of water from precipitation, rapid snowmelt, or the failure of manmade structures, such as dams or levees. Floods caused by precipitation are further classified as coming from: rain in a general storm system; rain in a localized intense thunderstorm; melting snow; rain on melting snow; and ice jams.[6]

Each of these causes result in floods that have distinct characteristics relative to flow rate, rate of rise, volume, duration, and flood season.[7]

- **General Rain floods** are characterized by a slow steady rise in stream stage and a peak flood of long duration. They typically result from moderate to heavy rainfall occurring over a wide geographic area lasting several days. Capacity of a given waterway is altered both by accumulated precipitation and by the various minor streams or channels that feed into the waterway. The general rain flood season is historically from the beginning of May through October. Because the rate of rise is slow and the time available for warning is great, few lives are usually lost, but millions of dollars in valuable public and private property are at risk.

Flood Hazard 101

What is a *floodplain*?

A floodplain is a land area adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. These areas, if left undisturbed, act to store excess floodwater. The floodplain is made up of two sections: the flood fringe and the floodway.

What is the *floodway*?

The floodway is one of two main sections that make up the floodplain. Unlike floodplains, floodways do not reflect a recognizable geologic feature, but are defined for regulatory purposes. For National Flood Insurance Program (NFIP) purposes, floodways are defined as the channel of a river or stream, and the overbank areas adjacent to the channel. The floodway carries the bulk of the floodwater downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures so that flood flows are not obstructed or diverted onto other properties. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot. Floodways are not mapped for all rivers and streams but are generally mapped in developed areas.

What is the *flood fringe*?

The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken.

- **Thunderstorm floods** are caused by intense rain over basins of relatively small area. They are characterized by a sudden rise in stream level, a short duration, and a relatively small volume of runoff. Because there is little or no warning time, the term "flash flood" is often used to describe thunderstorm floods. The thunderstorm flood season in Colorado is from the middle of July through October.
- **Flash floods** are an annual concern for the waterways in Garfield County. They are often more severe following a fire event, when the vegetation that normally slows the flow of water into waterways is burned.
- **Snowmelt floods** result from the melting of the winter snowpack in the high mountain areas. Snowmelt floods typically begin as spring runoff

appears, after the first spring warming trend. If the trend continues up to 8 to 10 consecutive days in a basin where the snowpack has a water content more than about 150% of average, serious flooding can develop. The total duration of snowmelt floods is usually over a period of weeks rather than days. They yield a larger total volume in comparison to other types of floods in Colorado. Peak flows, however, are generally not as high as flows for the other types. A single cold day or cold front can interrupt a melting cycle causing the rising water to decline and stabilize until the cycle can begin again. Once snowmelt floods have peaked, the daily decreases are moderate, but fairly constant. Snowmelt flooding usually occurs in May, June, and early July.

- **Rain on snowmelt flooding** occurs most often in Colorado during the months of May and June. It is at this time of year that large general rainstorms occur over western Colorado. These rainstorms are most often caused when warm moist air from the Gulf of Mexico combines with cold fronts moving into Colorado from the Pacific Northwest. When these weather phenomena collide, long lasting general rainstorms can often occur. Rain on snowmelt exacerbates an already tenuous situation as snowmelt waters rush down heavily incised stream channels. Usually such rain is over a small part of a basin, and the resulting flood is of short duration and may often go unnoticed in the lower reaches of a large drainage basin.

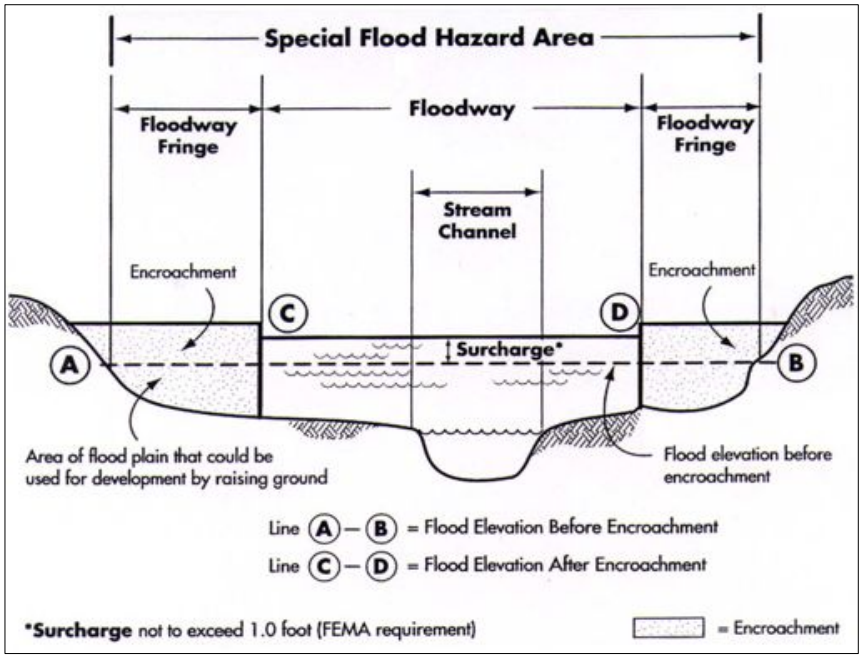
- **Ice Jam floods** can occur by two phenomena. Streams in mountain floodplains ice over during extended cold periods of 20 to 40 degrees below zero. Channels become frozen solid and overbank flow occurs, resulting in ice inundation in the floodplains. Ice jam floods occur when frozen water in the upper reaches of a stream abruptly begins to melt due to warm Chinook winds. Blocks of ice floating downstream can become lodged at constrictions and form a jam. The jam can force water to be diverted from the stream channel causing a flood. The ice jam can also break up, suddenly causing a surge of water as the "reservoir" that was formed behind it is released. Ice jamming occurs in slow moving streams where prolonged periods of cold weather are experienced.

Flood Hazard 101

When structures or fill are placed in the floodway, water is displaced. Development raises the base flood elevation by forcing the river to compensate for the flow space obstructed by the structures and/or fill. When structures or materials are added to the floodway and no fill is removed to compensate, serious problems can arise. Floodwaters may be forced away from historic floodplain areas. As a result, other existing floodplain areas may experience floodwaters that rise above historic levels.

In highly urbanized areas, increased paving can lead to an increase in volume and velocity of runoff after a rainfall event, exacerbating the potential flood hazards. Care should be taken in the development and implementation of stormwater management systems to ensure that these runoff waters are dealt with effectively.

Floodplain Schematic



History of flooding in Garfield County

The Colorado Flood Mitigation Plan of 2007 reported 23 significant flood events across the state between 1864 and 2006.[8] While there has never been a presidential declaration of a flood emergency in Garfield County, flash floods are an annual concern, as is the seasonal height of the Colorado River.

Data sources

Several sources were used to develop this flood hazard risk assessment. Garfield County staff generated a 100-year floodplain map using data from the FEMA HAZUS-MultiHazard model. A map layer of Dam inundation areas (as assessed by FEMA in 1986) was then added to produce the final flood and inundation maps included here.

Additionally, data from the 2007 Colorado Flood Hazard Mitigation plan provided supplemental information about the history of flooding and the characteristics of floods in Colorado.

Vulnerability assessment

People become vulnerable to hazards when they choose (knowingly or unknowingly) to live near the areas where these extreme events occur. Vulnerability is also related to preparedness. People who prepare for the occurrence of an extreme event are less vulnerable to it than those who do not. The vulnerability of Colorado's population is rooted in a relationship between the occurrences of extreme events, the proximity of people to these occurrences, and the degree to which these people are prepared to cope with the event.

To help mitigate vulnerability, local governments can require proposed developments to obtain an engineering review to certify developments will not cause the base flood (100-year flood) elevation to rise. Displacement of only a few inches of water can mean the difference between no structural damage occurring in a given flood event, and the inundation of many homes, businesses, and other facilities. Careful attention should be paid to development that occurs within the floodway to ensure that structures are prepared to withstand base flood events.

- **Property loss** from floods affects both private property and public property. The type of property damage caused by flood events depends on the depth and velocity of the floodwaters. Fast floodwaters can wash buildings off of foundations and sweep cars downstream. Pipelines, bridges, and other infrastructure can be damaged when high waters contain flood debris. Extensive floods can cause basement flooding and landslide damage related to soil saturation. Seepage into basements is common during flood events, even on hillsides and other areas that are far removed from floodplains. Most flood damage is caused by water saturating materials susceptible to loss (e.g., wood, insulation, fabric, furnishings, floor coverings, and appliances).

- **Residential structures** with access to rivers and creeks may be located in areas especially at risk to flooding. Homes in frequently flooded areas can suffer damage to septic systems and drain fields. Inundation of these systems may result in leakage of wastewater into surrounding areas. In many cases, flooding damage to homes renders them unlivable. Manufactured homes have a lower level of structural stability than stick-built homes. Manufactured homes in floodplain zones must be anchored to provide additional structural stability during flood events.

  Flood insurance studies are one tool used to identify flood-prone areas. The National Flood Insurance Program (NFIP) was established in 1968 as a means of providing low cost flood insurance to the nation's flood-prone communities. The NFIP also reduces flood losses through regulations that focus on building codes. NFIP regulations (44 Code of Federal Regulations (CFR) Chapter 1, Section 60.3) require that all new construction in floodplains must be elevated at or above base flood level. Communities participating in the NFIP may adopt regulations that are more stringent than 44 CFR 60.3, but not less stringent. As of March 31, 2010, FEMA reports that there are 133 National Flood Insurance Policies in force in Garfield County.

Hazard probability

As part of the Risk Assessment process, Garfield County representatives completed a Risk Matrix that compiled the relative impact on community systems of various hazards and the probability of the hazard occurring. Flood, including flash floods, was assessed with a combined probability rating of 2.64, or that floods are considered probable in Garfield County.

Exhibit 19: National Flood Insurance Claims and Payments, 1978-2010[9]

Area	Claims	Paid Claims	Total Paid
Unincorporated Garfield County	8	4	$5, 729
Glenwood Spring	9	4	$26,590
Rifle	6	5	$44,686.15

- **Business and industry** may experience property damage and interrupted business due to flood events. Flood events can cut off customer access to a business as well as close a business for repairs. A quick response to the needs of businesses affected by flood events can help a community maintain economic vitality in the face of flood damage. Responses to business damages can include funding to assist owners in elevating or relocating flood-prone business structures.

- **Infrastructure and publicly owned facilities** are a key component of daily life for all citizens of the County. Damage to public water and sewer systems, transportation networks, flood control facilities, emergency facilities, and offices can hinder the ability of the government to deliver services. Government can take action to reduce risk to public infrastructure from flood events by introducing public policy that reduces risk to private property from flood events.

  The I-70 interstate highway is the main transportation corridor through Garfield County, and it plays a significant role in the smooth functioning of the County and regional economy. The highway was built along the bank of the Colorado River and numerous bridges criss-cross the river along its route. Though built with environmentally sensitive components, flooding can impact this critical piece of transportation infrastructure.Railroad tracks built alongside the river face similar flood hazards.

  Public parks and publicly owned open spaces can provide a buffer between flood hazards and private property. Preserved open space in the floodplain can help mitigate flood impacts by reducing the amount of allowable development in flood hazard areas.

Dam inundation

Dam failure floods are primarily a result of hydrologic or structural deficiencies. The operation of a reservoir can also influence the safety of the structure. Dam failure by hydrologic deficiency is a result of inadequate spillway capacity, which can cause the level of a reservoir to exceed the capacity or height of the dam - also known as overtopping, - during large flows into the reservoir. Dam failure by hydrologic deficiency occurs from excessive runoff after unusually heavy precipitation in the basin. Large waves generated from landslides into a reservoir, or the sudden inflow from upstream dam failures, are other causes of dam failure by overtopping. Overtopping is especially dangerous for an earth dam because the down-rush of water over the crest erodes the dam face and - if continued long enough - beaches the dam embankment and releases all the stored water suddenly into the downstream floodplain.

The mechanics of a structural failure depends on the type of dam and the mode of failure. Dam failure floods due to structural deficiencies are characterized by a sudden rise in stream level and relatively short duration similar to a thunderstorm flood. They can occur at any time, but earthen dams appear to be most susceptible to structural failure during the fall and spring freezing and thawing cycles.

Examples of structural deficiencies include seepage through the embankment, piping along internal conduits, erosion, cracking, sliding, overturning, rodent tunneling, or other weakness in the structure. Old age is often at the root of structural deficiencies. Seismic activity in Colorado has also been recognized as a potential source of structural problems due to liquefaction of sand layers in the embankment of a dam.

The State of Colorado has identified six Class-O, and 11 Class-II dams in Garfield County. The map on page 3-20 depicts the Flood and Inundation Hazard in Garfield County.

Exhibit 20: Classification of Dams[10]

Classification	Description
Class I - High	Loss of human life is expected.
Class II - Significant	Significant damage is expected, but not loss of human life. Significant damage refers to structural damage where humans live, work, or recreate or public or private facilities exclusive of unpaved roads and picnic areas. Damage refers to making the structures uninhabitable or inoperable.
Class III - Low	Loss of human life and damage to structures and public facilities not expected.
Class IV - No public hazard	No loss of human life is expected and damage will only occur to the dam owner's property in the event of dam failure.

Risk assessment

The relationship between flood hazards and population identifies patterns of risk. These relationships are not a new phenomenon. Flooding has occurred here long before people settled in high-risk areas. Risk grows from the increasingly close association between natural phenomena and a growing population.

The Colorado River is a foundation of the physical and economic structure of the County. It is a source of drinking water and draws tourists to the communities that lie along the river's route. In Garfield County, the river flows through Study Areas 1, 2, and Therefore those are the Study Areas that are likely to experience the most risk from flooding of the Colorado River. Additionally, steep slopes around the river have funneled development, in some cases, dangerously close the flood zone.

The risk matrices on the following pages show the relative flood risk incurred across different assets in Study Areas 1, 2, and High traffic roads in all three areas are at risk of damage from flood. Additionally, railroad bridges and municipal buildings in Study Areas 1 and 2 rise to the top as assets with a high risk profile.

Additionally, even though the Colorado River does not flow through Study Areas 4 and 5, the roads are at risk of flooding. The highest risk in these Areas comes from flash floods that overwhelm culverts and roadside detention ponds, and as smaller streams through canyons and ravines reach and exceed their carrying capacity.

Garfield County does not have a large number of repetitive loss properties or National Flood Insurance Claims, but there are other assets in addition to homes and private property at risk of damage from floods, namely roads and bridges.

Exhibit 21 Flood Hazard Overview, 2010

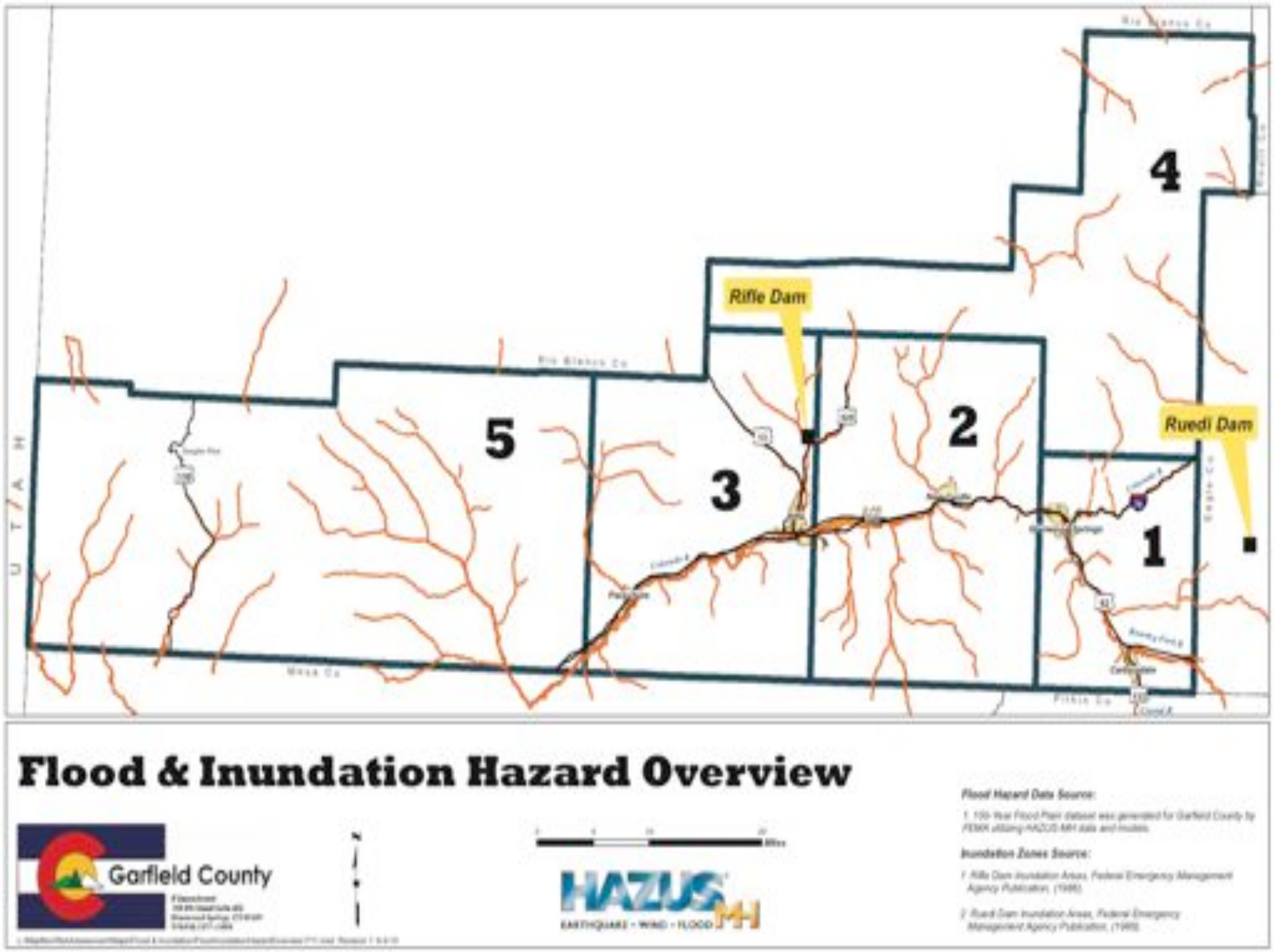
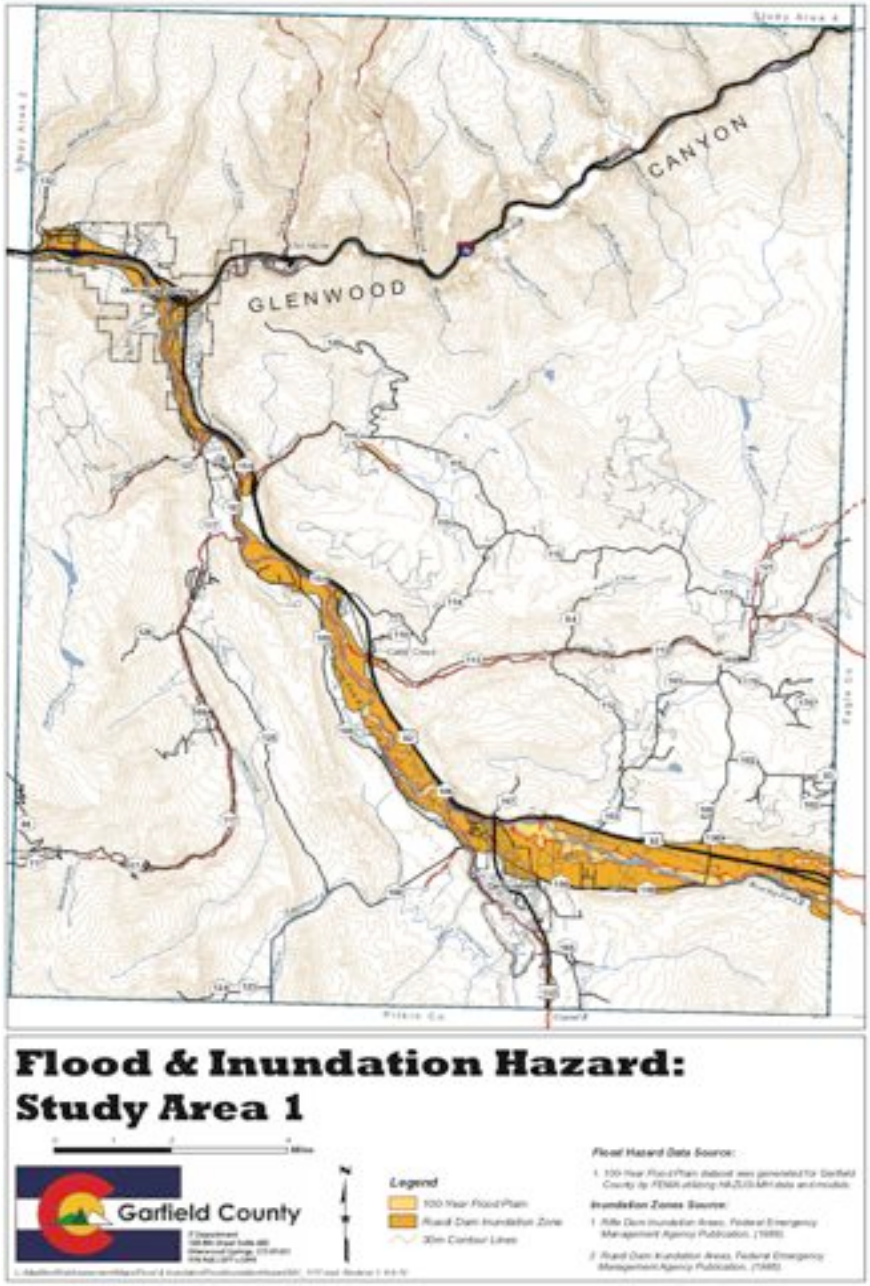
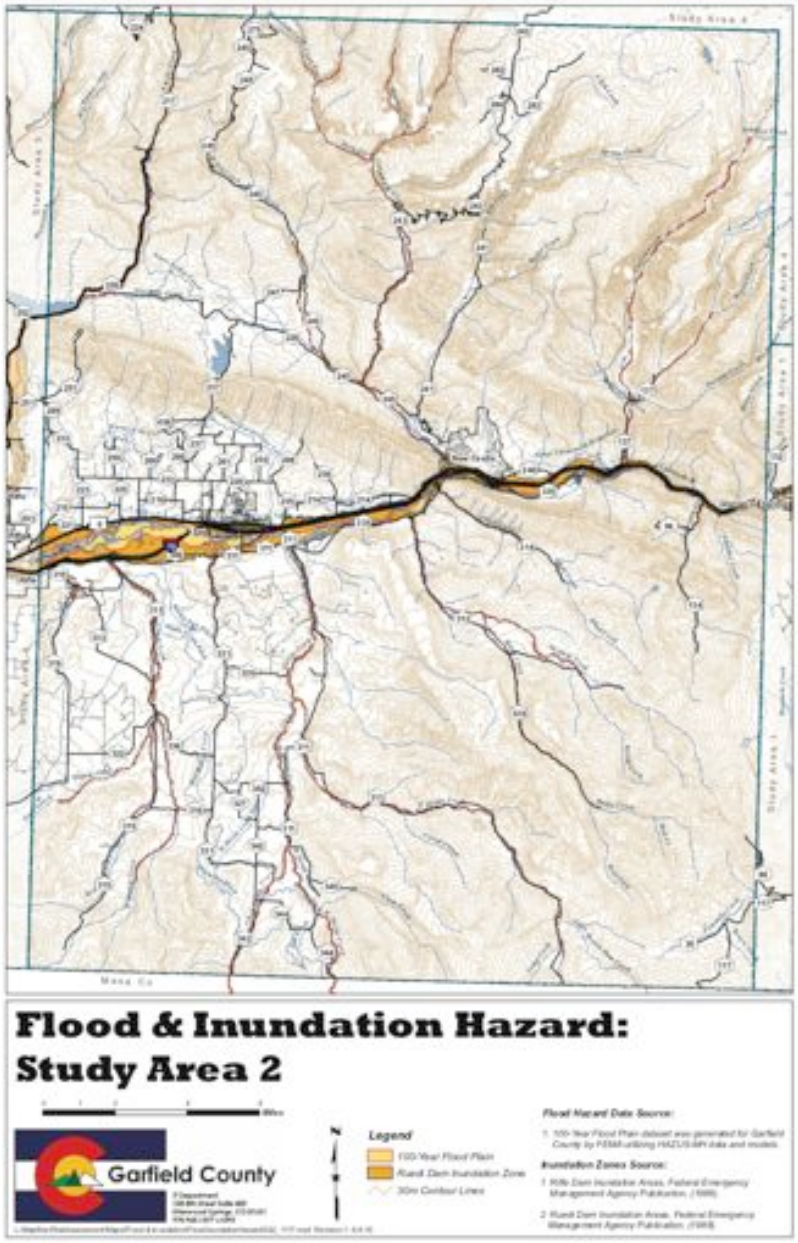


Exhibit 22: Study Area 1 Flood Hazard Map
Exhibit 23: Study Area 1 Flood Hazard Risk Matrix



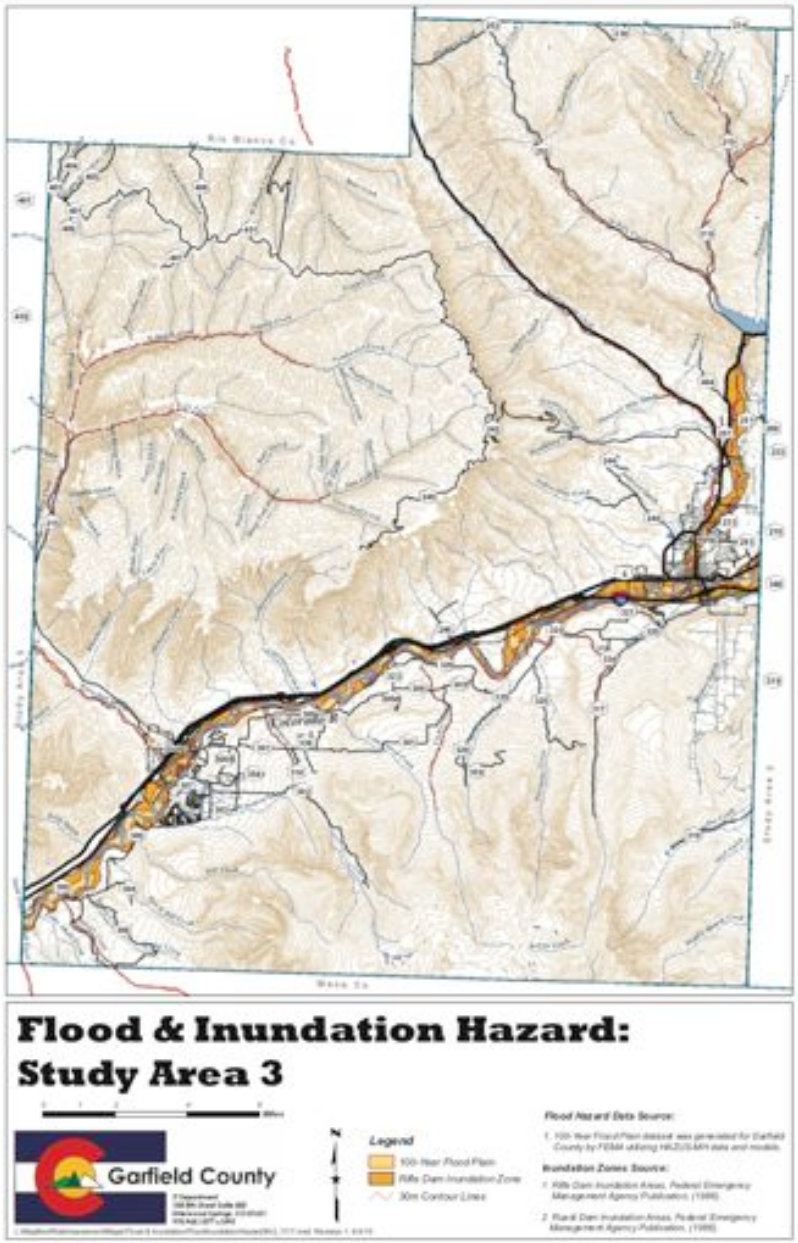
		Total Flood		Total Inundation	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	42%	2.10	46%	2.30
Right-of-Way	1	8%	0.08	41%	0.41
Communications Facilities	5	5%	0.24	21%	1.04
Municipal Buildings	5	50%	2.50	50%	2.50
Railroad Bridges	5	67%	3.33	100%	5.00
Railroad Miles	5	9%	0.44	42%	2.12
Railroad Tunnel	5	100%	5.00	.	.
Pedestrian Bridge	3	83%	2.50	67%	2.00
Highway Bridges	5	24%	1.20	27%	1.33
Electric Utility Lines (Miles)	5	.	.	3%	0.17
Federal Building	5	.	.	100%	5.00
Fire Station	5	.	.	50%	2.50
Police	5	.	.	100%	5.00
Road Miles (Asphalt-High Traffic Volumes)	5	69%	3.43	32%	1.59
Road Miles (Chipseal-Moderate Traffic Volumes)	5	30%	1.52	8%	0.41
Road Miles (Gravel-Low Traffic Volumes)	5	18%	0.88	2%	0.11
Population	**4**	5%	0.21	41%	1.62
Structures	4	2%	0.09	40%	1.60
Residential (MultiFam)	5	3%	0.14	17%	0.85
Residential (SingleFam)	4	2%	0.09	10%	0.38
Residential (Misc)	4	14%	0.54	73%	2.90
Mixed Use	4	5%	0.19	62%	2.46
Church	4	.	.	9%	0.36
School	4	.	.	48%	1.90
Public Building	4	.	.	67%	2.67
Economy	**3**	3%	0.08	29%	0.88
Pipeline Miles	3	3%	0.10	20%	0.60
Commercial and Retail Land	3	5%	0.15	34%	1.02
Tourism Site	4	.	.	83%	3.33
Industrial	3	.	.	4%	0.11
Shopping Mall	3	.	.	33%	1.00
Ag and Natural Resource Land	2	0.3%	0.01	1%	0.02
Land and Development	**2**	4%	0.07	18%	0.36
City Zoning	5	6%	0.30	31%	1.56
Planned Unit Development	4	4%	0.15	17%	0.68
Residential/Suburban	2	6%	0.11	24%	0.48
Residential/Urban	4	4%	0.15	32%	1.29
Public Lands	3	0.4%	0.01	0.04%	0.00
Rural	2	2%	0.03	4%	0.09
Cultural Resources	**1**	8%	0.08	55%	0.55
Cemetery	1	.	.	40%	0.40
Park	1	6%	0.06	44%	0.44
Recreation Land	1	9%	0.09	41%	0.41
Library	1	.	.	50%	0.50
Museum	1	.	.	100%	1.00
TOTALS		19%	0.81	39%	1.38

Exhibit 24: Study Area 2 Flood Hazard Map
Exhibit 25: Study Area 2 Flood Hazard Risk Matrix



		Total Flood		Total Inundation	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	38%	1.92	53%	2.63
Right-of-Way	1	23%	0.23	29%	0.29
Public Airport	5	5%	0.23	.	.
Municipal Buildings	5	100%	5.00	100%	5.00
Highway Bridges	5	26%	1.30	29%	1.45
Communications Facilities	5	.	.	40%	2.00
Electric Utility Lines (Miles)	5	.	.	3%	0.13
Railroad Miles	5	13%	0.67	92%	4.59
Railroad Bridge	5	.	.	75%	3.75
Road Miles (Asphalt-High Traffic Volumes)	5	51%	2.56	47%	2.36
Road Miles (Chipseal-Moderate Traffic Volumes)	5	37%	1.86	9%	0.44
Road Miles (Gravel-Low Traffic Volumes)	5	34%	1.70	.	.
Population	**4**	8%	0.34	66%	2.65
Structures	4	1%	0.04	68%	2.71
Residential (MultiFam)	5	3%	0.15	27%	1.36
Residential (SingleFam)	4	2%	0.06	4%	0.17
Residential (Misc)	4	.	.	2%	0.06
Schools	4	20%	0.80	200%	8.00
Public Buildings	4	17%	0.67	133%	5.33
Church	4	.	.	25%	1.00
Mixed Use	4	.	.	70%	2.81
Economy	**3**	3%	0.08	17%	0.50
Commercial and Retail	3	2%	0.07	55%	1.64
Gas Wells	3	5%	0.16	.	.
Pipeline Miles	3	1%	0.03	4%	0.12
Industrial	3	.	.	6%	0.17
Ag and Natural Resource Land	3	1%	0.04	2%	0.06
Shopping Mall	3	.	.	100%	3.00
Land and Development	**2**	7%	0.14	185%	3.71
City Zoning	5	8%	0.39	54%	2.71
Planned Unit Development	4	2%	0.09	53%	2.13
Public Lands	3	0.2%	0.01	0%	.
Residential/Suburban	2	0.0%		631%	12.62
Residential/Urban	4	11.9%	0.48	373%	14.90
Residential/Mobile	4	25.1%	1.00	.	.
Rural	2	2%	0.04	2%	0.04
Cultural Resources	**1**	.	.	100%	1.00
Library	1	.	.	50%	0.50
Museum	1	.	.	50%	0.50
Park	1	.	.	88%	0.88
Cemetery	1	.	.	100%	1.00
TOTALS		16%	0.74	79%	2.56

Exhibit 26: Study Area 3 Flood Hazard Map
Exhibit 27: Study Area 3 Flood Hazard Risk Matrix



		Total Flood		Total Inundation	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	8%	0.42	35%	1.74
Right-of-Way	1	6%	0.06	18%	0.18
Highway Bridges	5	11%	0.53	.	.
Railroad Miles	5	8%	0.42	50%	2.51
Electric Utility Lines	5	.	.	9%	0.43
Municipal Building	5	.	.	33%	1.67
Public Buildings	5	.	.	33%	
Police Station	5	.	.	67%	
Fire Station	5	.	.	33%	1.67
Road Miles (Asphalt-High Traffic Volumes)	5	53%	2.65	17%	0.85
Road Miles (Chipseal-Moderate Traffic Volumes)	5	6%	0.28	2%	0.12
Road Miles (Gravel-Low Traffic Volumes)	5	20%	0.99	1%	0.05
Population	**4**	5%	0.21	21%	0.83
Structures	4	4%	0.17	7%	0.26
Residential (MultiFam)	5	2%	0.09	21%	1.05
Residential (SingleFam)	4	1%	0.04	4%	0.17
Mixed Use	4	13%	0.54	51%	2.05
Economy	**3**	3%	0.10	25%	0.74
Commercial and Retail	3	11%	0.32	36%	1.09
Ag and Natural Resource Land	3	2%	0.05	5%	0.14
Shopping Mall	3	.	.	100%	3.00
Resource Land	3	1%	0.02	0.1%	0.00
Pipeline Miles	3	2%	0.06	4%	0.12
Gas Wells	3	1%	0.04	4%	0.11
Land and Development	**2**	5%	0.10	10%	0.20
City Zoning	5	11%	0.57	27%	1.36
Planned Unit Development	4	5%	0.19	7%	0.26
Residential/Suburban	2	.	.	20%	0.40
Residential/Urban	4	.	.	1%	0.04
Public Lands	3	0.14%	0.00	0.02%	0.00
Rural	2	5%	0.09	6%	0.12
Cultural Resources	**1**	.	.	50%	0.50
Library	1	.	.	50%	0.50
TOTALS		8%	0.35	23%	0.74

Exhibit 28: Area 4 Flood Risk Matrix

		Total Flood		Total Inundation	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	25%	1.24	1%	0.05
Highway Bridges	5	20%	1.00	.	.
Road Miles (Chipseal-Moderate Traffic Volumes)	5	35%	1.73	1%	0.03
Road Miles (Gravel-Low Traffic Volumes)	5	20%	1.00	1%	0.06
Population	**4**	5%	0.19	1%	0.05
Structures	4	1%	0.05	1%	0.05
Residential (SingleFam)	4	8%	0.32	.	.
TOTALS		16%	0.79	1%	0.05

Exhibit 29: Area 5 Flood Risk Matrix

		Total Flood		Total Inundation	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	43%	2.14	2%	0.12
Highway Bridges	5	33%	1.67	.	.
Road Miles (Asphalt-High Traffic Volumes)	5	68%	3.42	2%	0.11
Road Miles (Chipseal-Moderate Traffic Volumes)	5	9%	0.45	.	.
Road Miles (Gravel-Low Traffic Volumes)	5	60%	3.02	3%	0.13
Population	**4**	15%	0.58	15%	0.58
Structures	4	15%	0.58	15%	0.58
Economy	**3**	2%	0.05	.	.
Gas Wells	3	1%	0.02	.	.
Pipeline	3	3%	0.08	.	.
Ag and Natural Resource Land	2	1%	0.02	.	.
TOTALS		23%	1.09	7%	0.31

Earthquake Hazard

Ground shaking, landslides, liquefaction, and amplification are the specific hazards associated with earthquakes. The severity of these hazards depends on several factors, including soil and slope conditions, proximity to a fault, earthquake magnitude, and the type of earthquake.

- **Ground shaking** is the motion felt on the earth's surface caused by seismic waves generated by an earthquake. It is the primary cause of earthquake damage. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault, and distance from the epicenter (where the earthquake originates). Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.
- **Earthquake-induced landslides** are secondary earthquake hazards that occur from ground shaking. They can destroy the roads, buildings, utilities, and other critical facilities necessary to respond to recover from an earthquake.
- **Liquefaction** occurs when ground shaking causes wet granular soils to change from a solid state to a liquid state. This results in the loss of soil strength and the soil's ability to support weight. Buildings and their occupants are at risk when the ground can no longer support these buildings and structures.
- **Amplification** is the phenomenon when soils and soft sedimentary rocks near the earths surface increase the magnitude of the seismic waves generated by the earthquake. The amount of amplification is determined by the thickness of geologic materials and their physical properties. Buildings and structures built on soft and unconsolidated soils can face greater risk.

Geologists have identified 14 faults within Garfield County. However only one of them, the "Grand Hogback-Fourmile Creek" fault has been active within the last 12,000 years.[11]

History of earthquakes in Garfield County

In 1984, 19 small earthquakes were recorded in the Carbondale area.

- Oct. 19, 1990 New Castle (#450- 451)
- Dec. 12, 1990 New Castle (#453)
- Mar. 8, 1994 Douglas Pass (#472)
- Dec. 5, 2000 Carbondale (#514)
- Aug. 2001 Glenwood Springs Earthquakes (#516-519)
- Mar. 19, 2002 Douglas Pass (#536)

In August 2001, a 4.0 earthquake was recorded 5 miles northwest of Glenwood Springs.

Data sources

The data used in this risk assessment came from the FEMA HAZUS MultiHazard model. It estimates damage and loss to buildings, lifelines, and essential facilities. The model takes a regional perspective and therefore cannot provide detailed, community specific hazard assessment information in the same level of detail as the data used for other hazards included in this risk assessment.

Vulnerability assessment

Earthquake damage occurs when humans build structures that cannot withstand severe shaking. Buildings, airports, schools, and lifelines (highways and phone, gas, and water lines) suffer damage in earthquakes and can cause death or injury to humans.

The welfare of homes, major businesses, and public infrastructure is very important. Addressing the reliability of buildings, critical facilities, and infrastructure, and understanding the potential costs to government, businesses, and individuals as a result of an earthquake, are challenges faced by every community.

Garfield County has several unique social and physical characteristics that affect earthquake hazard vulnerability:

- **Oil and Gas Infrastructure** represents a large portion of Garfield County's economic base as both an employment sector and a source of revenue for the County and support industries. The pipelines carry high pressure liquid and gas throughout the County, both above ground and buried. The proximity of these pipes to communities and to the Colorado River increase the vulnerability of contamination of the air or water if the infrastructure is damaged in an earthquake.
- **Transportation Infrastructure** in Garfield County is not only of critical importance to the County and its residents, but I-70 is a key regional and national highway. An earthquake could greatly damage the bridges and highway surfaces, hampering the movement of people and goods. Damaged infrastructure strongly affects the economy of the community - it disconnects people from work, school, food, and leisure, and separates businesses form their customers and suppliers.

More generally, any community assessing the vulnerability of its systems to damage from and earthquake should consider:

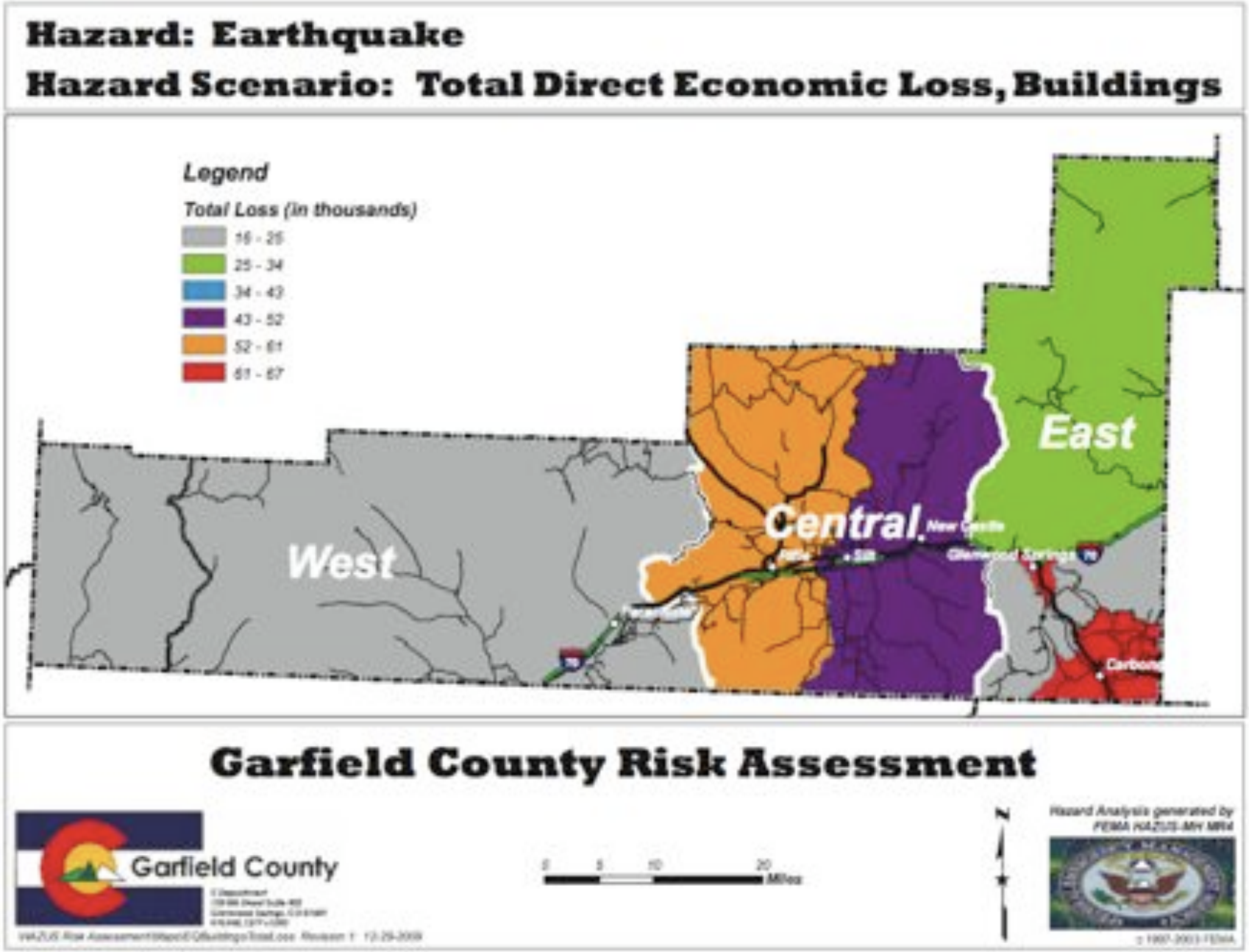
- Buildings: The built environment is susceptible to damage from earthquakes. Buildings that collapse can trap and bury people. Lives are at risk and the cost to clean up the damages is great.
- Damage to Lifelines: Lifelines are the connections between communities and outside services. They include water and gas lines, transportation systems, electricity, and communication networks. Ground shaking and amplification can cause pipes to break open, power lines to fall, roads and railways to crack or move, and radio and telephone communication to cease. Disruption to transportation makes it especially difficult to bring in supplies or services. All lifelines need to be usable after an earthquake to allow for rescue, recovery, and rebuilding efforts and to relay important information to the public.
- Disruption of Critical Services: Critical facilities include police stations, fire stations, hospitals, shelters, and other facilities that provide important services to the community. These facilities and their services need to be functional after an earthquake event. Many critical facilities are housed in older buildings that are not up to current seismic codes.
- Businesses: Seismic activity can cause great loss to businesses, large and small. Even one day of disruption can cause have enormous economic losses. Earthquake damage can presents a significant burden to small shop owners who may have difficulty recovering from their losses.
- Death and Injury: Death and injury can occur both inside and outside of buildings from falling equipment, furniture, debris, and structural materials. Damaged infrastructure can also endanger human life.
- Fire: Downed power lines or broken gas mains can trigger fires. When fire stations suffer building or lifeline damage, quick response to suppress fires is less likely.
- Debris: After an earthquake, efforts focus on cleaning up building elements (brick, glass, wood, steel or concrete), office and home contents, and other materials. Developing strong debris management strategies can assist in post-disaster recovery.

Hazard probability

As part of the Risk Assessment, Garfield County representatives completed a Risk Matrix to compile the relative impact on community systems of various hazards and the probability of the hazard occurring. Earthquake was assigned a combined probability rating of 1.82, or that earthquakes are considered possible in the County.

Risk assessment

The Colorado Geological Survey's 2007 Earthquake Evaluation Report estimated that a magnitude six earthquake on the North Sawatch fault would induce $0.5 million in direct and indirect economic losses. A magnitude seven along the same fault could cause $8.8 million in economic losses in Garfield County. Even though Garfield County is not identified as a County with high earthquake risk (high monetary loss, casualties, and loss ratios), an earthquake centered somewhere else in the region does have the potential to inflict damage in the County. Because seismic events are relatively infrequent in Colorado, and the historical earthquake record is short (only about 130 years), it is not possible to accurately estimate the timing or location of future earthquakes across the state.[12] Even so, continuing population and economic growth in Garfield County warrants further analysis of the vulnerability of community systems and research to increase knowledge of earthquake risk.


Hazard: Earthquake
Hazard Scenario: Total Direct Economic Loss, Buildings
Legend
Total Loss (in thousands)
16 - 25
25 - 34
34 - 43
43 - 52
52 - 61
61 - 67
West
Central
East
Garfield County Risk Assessment
Garfield County
Miles
Hazard Analysis generated by
FEMA HAZUS-MH MR4

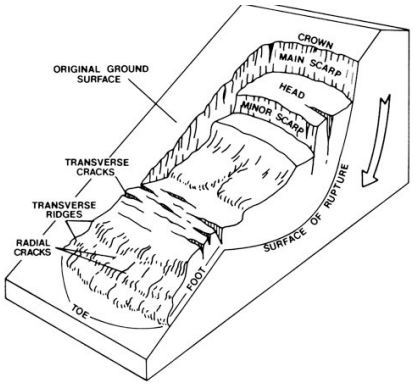
Landslide Hazard

Landslides are downhill or lateral movements of rock, debris, or soil mass. The size of a landslide usually depends on the geology and the landslide triggering mechanism. Landslides initiated by rainfall tend to be smaller, while those initiated by earthquakes may be very large. Slides associated with volcanic eruptions can include as much as one cubic mile of material.

Landslides are typically triggered by periods of heavy rainfall or rapid snowmelt. Earthquakes, changes to the hydrology, removal of vegetation, and excavations may also trigger landslides. Certain geologic formations are more susceptible to landslides than others. Human activities, including locating development near steep slopes, can increase susceptibility to landslide events. Landslides on steep slopes are more dangerous because movements can be rapid.

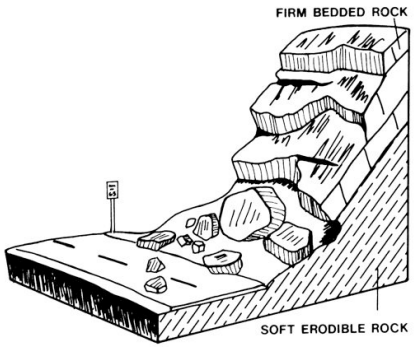
Some characteristics that determine the type of landslide are slope of the hillside, moisture content, and the nature of the underlying materials. Landslides are given different names depending on the type of failure and their composition and characteristics. Types of landslides include slides, rock falls, and flows.

Exhibit 31: Rotational Slide



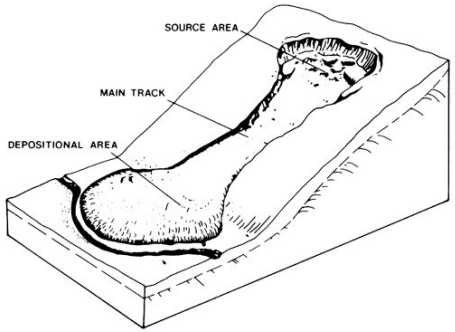
A **Slide** is a downslope movement of soil or rock mass occurring dominantly on the surface of rupture or on zones of intense shear strain. These movements include rotational slides where sliding material moves along a curved surface, and translational slides where movement occurs along a flat surface. These slides are generally slow moving and can be deep. Slumps are small rotational slides that are generally shallow. Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage, but are far less likely to result in serious injuries than rapidly moving landslides that can leave little time for evacuation.

Exhibit 32: Rock Fall



Rock falls occur when blocks of material come loose on steep slopes. Weathering, erosion, or excacations, such as those along highways, can cause falls where the road has been cut through bedrock. They are fast moving with the materials free falling or bouncing down the slope. The volume of material involved could be large or small, and the velocity of the fall may cause significant damage.

Exhibit 33: Earthflow



Flows are plastic or liquid movements in which land mass (e.g. soil and rock) breaks up and flows during movement. Debris flows normally occur when a landslide moves downslope as a semi-fluid mass scours soils from the slope along its path. Flows are typically rapidly moving and can occur during heavy rainfall or triggered by earthquakes. They can occur on gentle slopes, move rapidly for large distances, and increase in size as they move.

Rapidly moving landslides (debris flows and earth flows) present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Slow moving landslides can cause significant property damage, but are less likely to result in serious human injuries.

History of landslides in Garfield County

Historically, Douglas Pass-Baxter Pass landslide and debris flow areas is one of the most active landslide areas of Colorado. Affected facilities include Highway 139, a Garfield County road and numerous energy related pipe lines.[13] It is located along the drainage divide between the White River and the Colorado River. The most unstable area extends for a few miles on each side of the divide. Slope failures include earthflows, debris flows, rockfall, and a variety of rotational and translational landslides. During some years landslides are so active that the entire terrain can change within the period of year, and highways have been closed for months at a time.

Debris flows and landslides have impacted Glenwood Springs and the surrounding communities throughout history; twenty or more major debris flow events have occurred since 1900.

The Roan Creek Landslide in 1985 was a slump-earthflow complex caused by water infiltration and saturation of old landslide material. A detailed study and continued follow-up observations show no indication of serious further advance of the Roan Creek earthflow since 1985. The Sweetwater Creek area is a debris flow area in Northeastern Garfield County and Western Eagle County. This remote area is sparsely developed with recreational and residential facilities near Sweetwater Lake. No new accounts of disruptive debris flow activity have been reported for this area since the mid 1980s.[14]

In 1994, the Storm King Mountain wildfire area produced multiple debris flows and hyper-concentrated flows that engulfed three miles of I-70 with mud, rock debris, and floodwater. Debris covered many cars traveling on the Interstate, and two were swept into the Colorado River. In 2000, rockfall closed the westbound lanes of I-70 near Glenwood Springs. A rockslide on Thanksgiving Day, 2004 rolled down a nearby patch of road west of Glenwood Springs.

The most recent large rockfall incident occurred just after midnight on March 8, 2010. The incident hit I-70 in Glenwood Canyon, near mile marker 125, just west of Hanging Lake Tunnel. It is estimated that this slide brought 20 boulders onto the Interstate, ranging in size from 3 feet to 10 feet in diameter. I-70 was closed in both directions to all traffic.

Data sources

Western Colorado has a significant history of landslides, debris flows, rock falls, and various other geologic phenomenon. The United States Geological Survey (USGS), the Colorado Department of Local Affairs, and Garfield County departments have been mapping, tracking, and monitoring geologic hazards. Specific data incorporated here includes mapping collected by the Colorado Geologic Survey, the 1988 Colorado Landslide Mitigation Plan its update 2002 Review and Priority List, and the 2008 Colorado Hazard Mitigation Plan.

Vulnerability assessment

Although landslides are a natural geologic process, the incidence of landslides and their impacts on people can be exacerbated by human activities. Grading for road construction and development can increase slope steepness and decrease the stability of a hillslope by adding weight to the top of the slope, removing support at the base of the slope, and increasing water content. Other human activities affecting landslides include: excavation, drainage and groundwater alterations, and changes in vegetation.

Development sites with the greatest risk from landslides are against the base of very steep slopes, in confined stream channels (small canyons), and on fans (rises) at the mouth of these confined channels. Landslides are a constant threat in Glenwood Springs where the central business district and several residential districts are built on a debris fan. Contributing to hazard vulnerability, there are more than twenty identified steep mountain streams that converge into the Colorado River.

Three development-related actions that can put people at risk include:

- **Creating Steeper Slopes.** Excavation practices, sometimes aggravated by drainage, can reduce the stability of otherwise stable slopes. These failures commonly affect only a small number of homes. Without these excavation practices, there is little risk of landslides in areas not prone to landslide movement.
- **Development on or Adjacent to Existing Landslides.** Existing landslides are generally at risk of future movement regardless of excavation

practices. Excavation and drainage practices can further increase risk of landslides. In many cases, there are no development practices that can completely assure stability. Homeowners and communities in these situations accept some risk of future landslide movement.

- **Development on Gentle Slopes**. Development on gentle slopes can be affected by landslides that begin a long distance from the development.

Landslides can affect utility services, transportation systems, and critical lifelines. Communities may suffer immediate damages and loss of service. Disruption of infrastructure, roads, and critical facilities may also have a long-term effect on the economy. Utilities, including potable water, wastewater, telecommunications, natural gas, and electric power are all essential to service community needs. Loss of electricity has the most widespread impact on other utilities and on the community as a whole. Natural gas pipes may also be at risk of breakage from landslide movements as small as an inch or two.

Roads and bridges are subject to closure during landslide events. Because many Washington County residents are dependent on roads and bridges for travel to work, delays and detours are likely to have an economic impact on County residents and businesses. To evaluate landslide mitigation for roads, the community can assess the number of vehicle trips per day, detour time around a road closure, and road use for commercial traffic or emergency access.

Lifelines and critical facilities should remain accessible if possible during a natural hazard event. The impact of closed transportation arteries may increase if the closed road or bridge is a critical lifeline to hospitals or other emergency facilities. Therefore, inspection and repair of critical transportation facilities and routes is essential and should receive high priority. Losses of power and phone service are also potential consequences of landslide events. Due to heavy rains, soil erosion in hillside areas can be accelerated, resulting in loss of soil support beneath high voltage transmission towers in hillsides and remote areas. Flood events can also cause landslides, which can have serious impacts on gas lines.

Hazard probability

As part of the Risk Assessment process, Garfield County representatives completed a Risk Matrix that compiled the relative impact on community systems of various hazards and the probability of the hazard occurring. Geologic hazards, including landslides, mudslides, and subsidence, was assessed with a combined probability rating of 3.1, or that geologic hazards are considered probable in Garfield County.

Risk assessment

In 2002 the Colorado Geological Survey and the Colorado Office of Emergency Management updated the Colorado Landslide Mitigation Plan. The updated plan contains a ranked list of communities, areas, and facilities most at risk from landslides.[15] Hazard areas are grouped by relative severity into three tiers:

- **Tier One** listings are serious cases needing immediate or ongoing action or attention because of the severity of potential impacts.
- **Tier Two** listings are very significant but less severe; or where adequate information and/or some mitigation is in place; or where current development pressures are less extreme.
- **Tier Three** listings are similar to Tier Two but with less severe consequences or primarily local impact.

The plan identified three areas in Garfield County that should be targeted for mitigation activities:

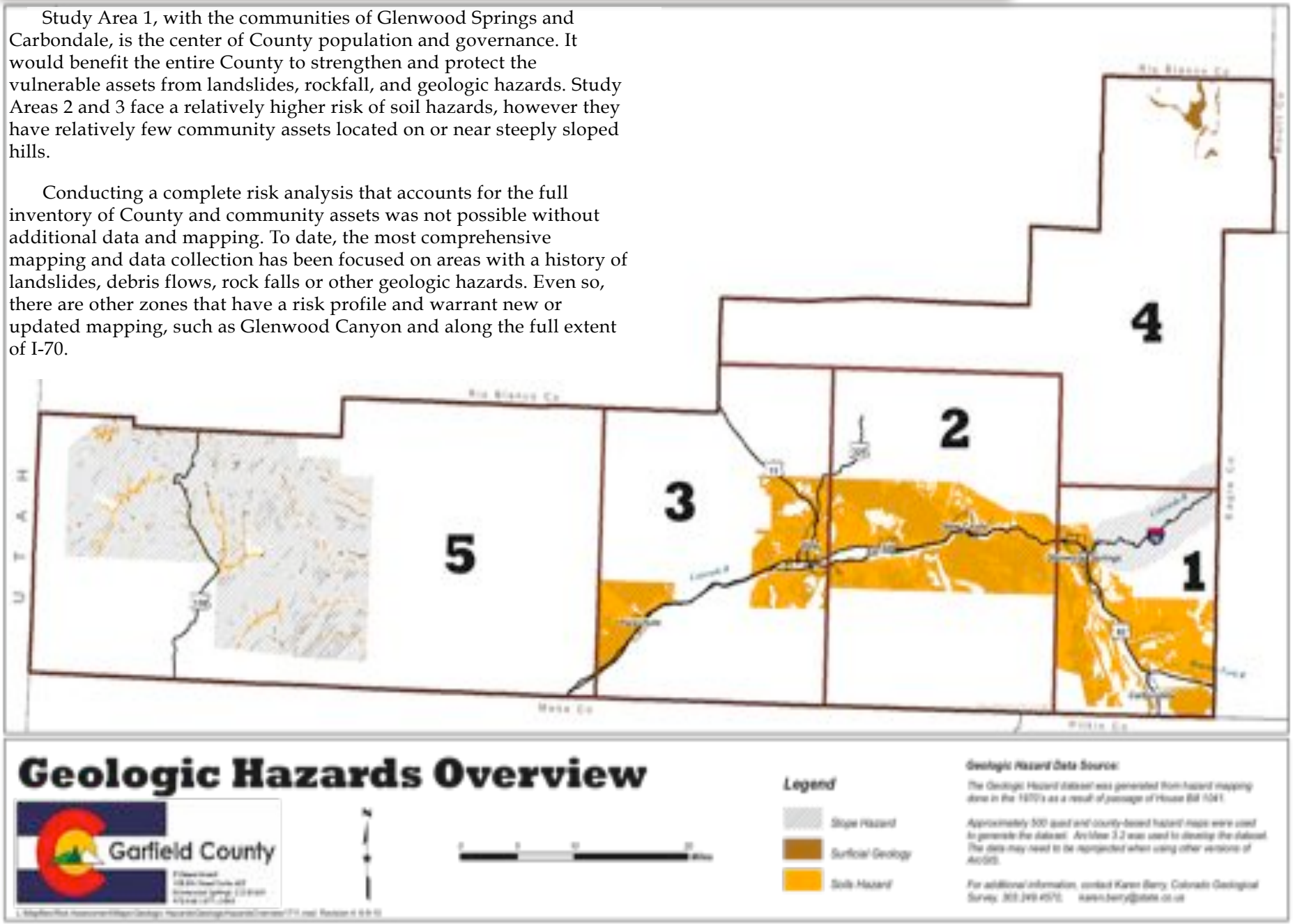
- **Tier One Landslide / Rockfall Area**: Douglas Pass-Baxter Pass Region, landslide and debris flow areas.
- **Tier One Debris Flow Area**: Glenwood Springs and vicinity, multiple debris flows and associated hydrocompactive soils.
- **Tier Three Debris Flow Area**: Sweetwater Creek area, debris flows.

Finally, the risk assessment process conducted for this NHMP determined that Study Area 1 is most at risk of damage from the four identified types of geological hazards (landslide, debris flow, soil, slope). All categories of assets are at risk, including infrastructure, private development, retail and industrial sites, and cultural and tourism sites such as museums and churches.

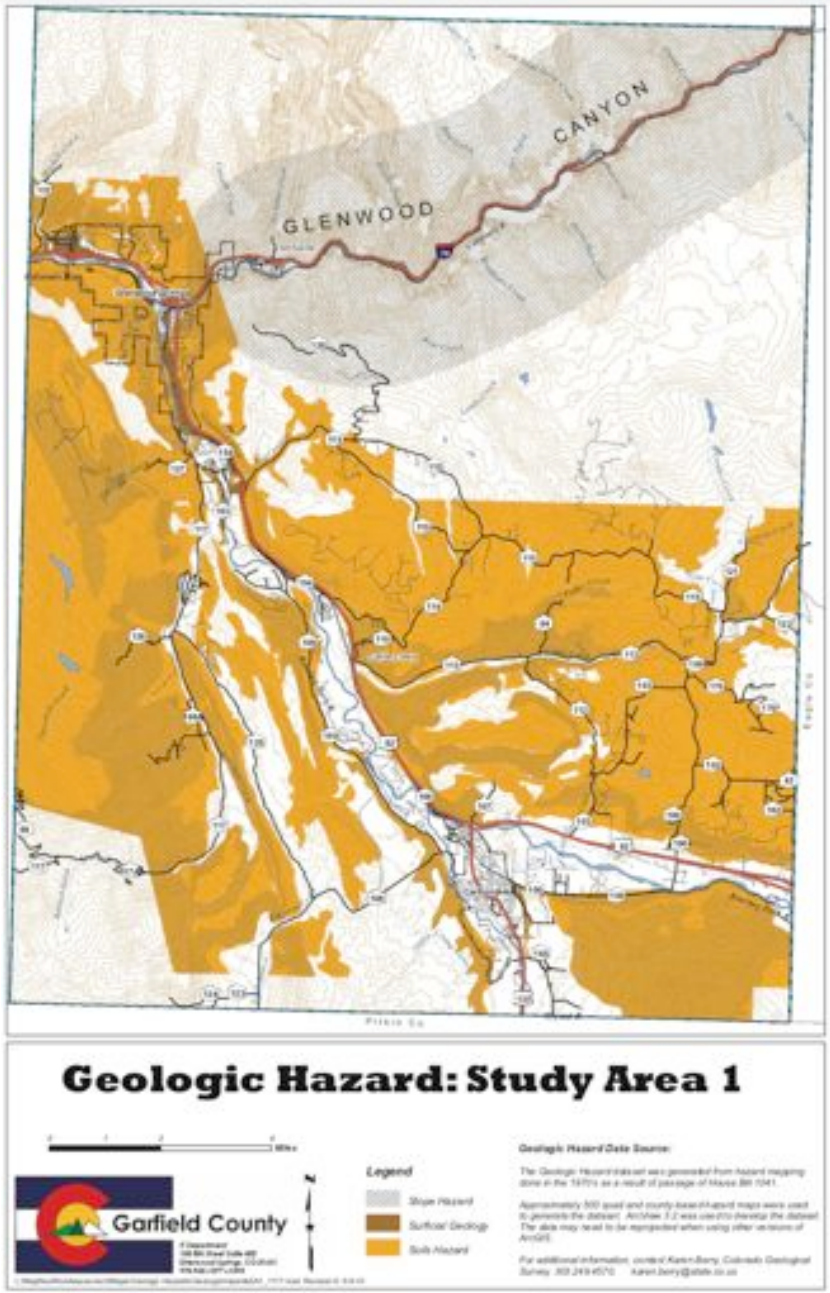
Exhibit 34: Geologic Hazard Overview, 2010

Study Area 1, with the communities of Glenwood Springs and Carbondale, is the center of County population and governance. It would benefit the entire County to strengthen and protect the vulnerable assets from landslides, rockfall, and geologic hazards. Study Areas 2 and 3 face a relatively higher risk of soil hazards, however they have relatively few community assets located on or near steeply sloped hills.

Conducting a complete risk analysis that accounts for the full inventory of County and community assets was not possible without additional data and mapping. To date, the most comprehensive mapping and data collection has been focused on areas with a history of landslides, debris flows, rock falls or other geologic hazards. Even so, there are other zones that have a risk profile and warrant new or updated mapping, such as Glenwood Canyon and along the full extent of I-70.



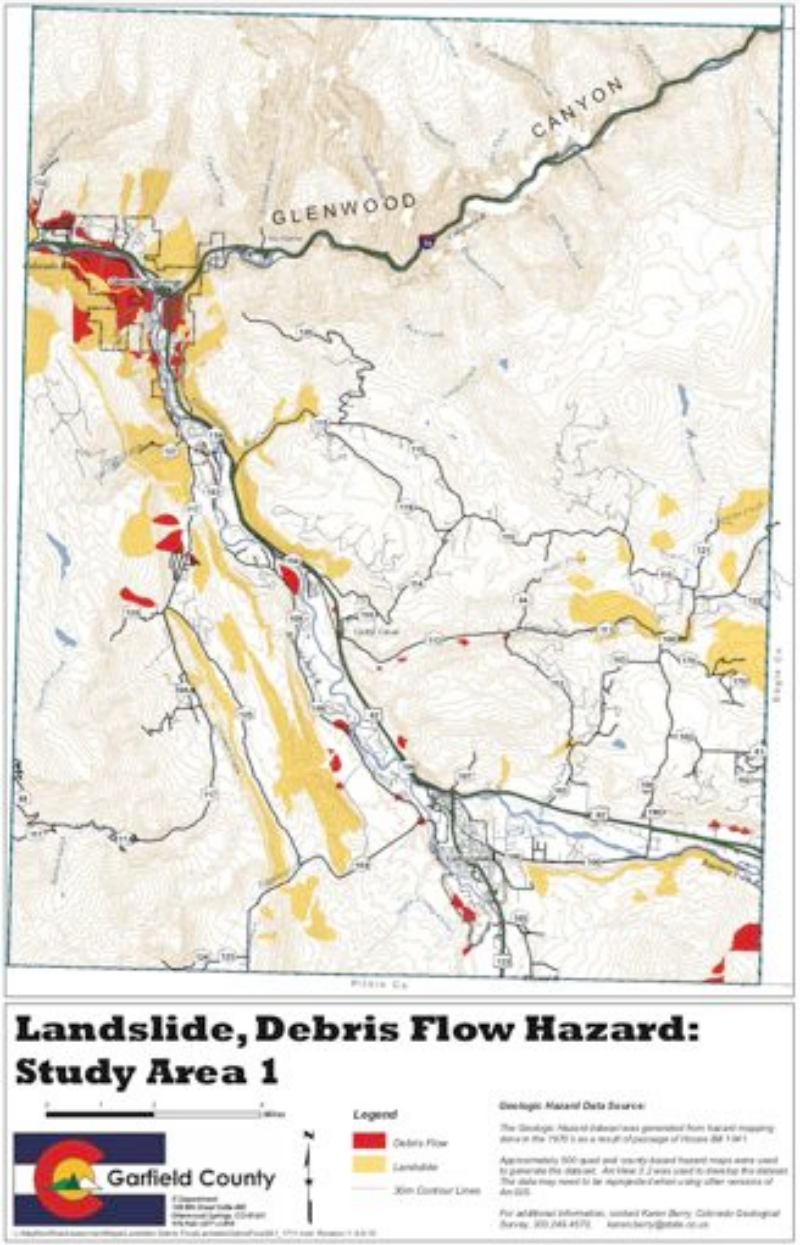
Geologic Hazards Overview



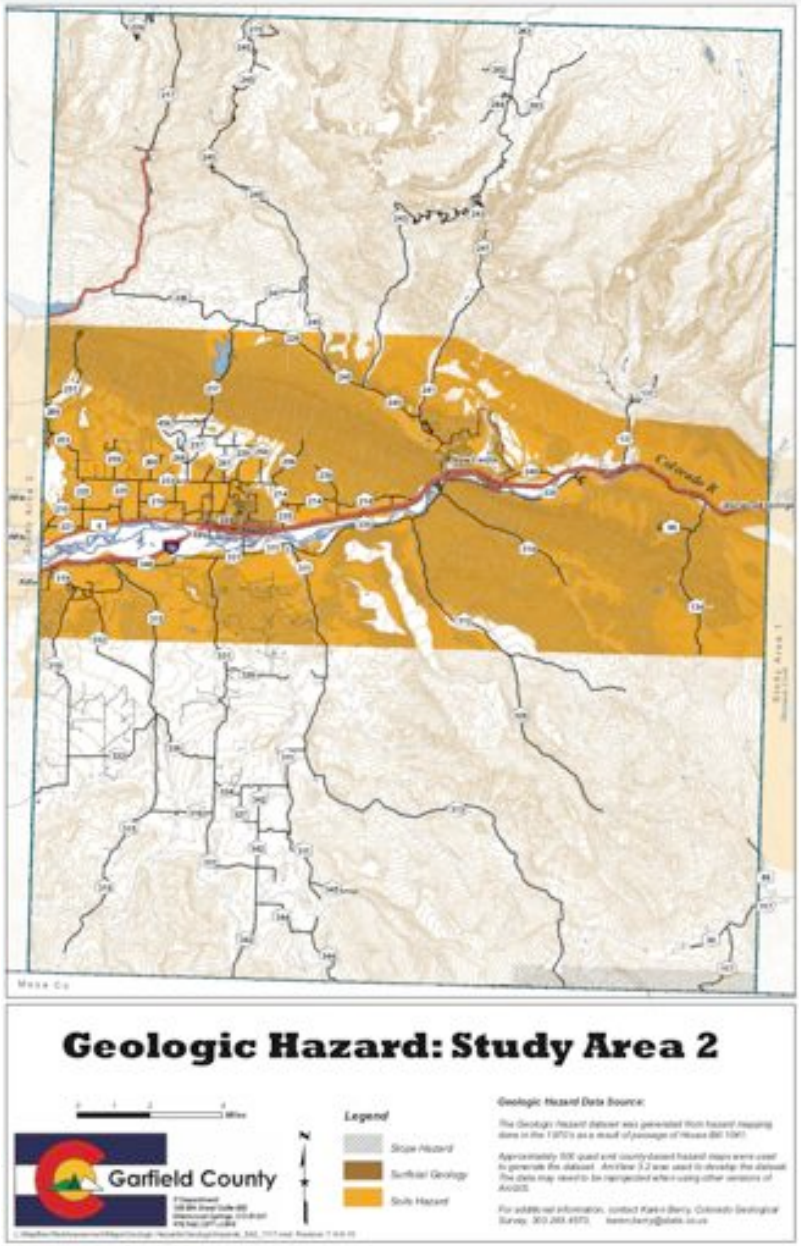
Geological Hazard

		Slope		Soil	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	51%	2.53	42%	2.12
Right-of-Way	1	37%	0.37	46%	0.46
Fire Station	5	25%	1.25	25%	1.25
Municipal Building	5	50%	2.50	50%	2.50
Federal Building	5	100%	5.00	.	.
Electrical Utility Substations	5	29%	1.43	43%	2.14
Water Tanks	5	75%	3.75	50%	2.50
Information Site	5	100%	5.00	100%	5.00
Communications Facilities	5	68%	3.40	46%	2.31
Pedestrian Bridge	5	17%	0.83	17%	0.83
Railroad Miles	5	51%	2.57	31%	1.55
Road Miles (Asphalt-High Traffic Volumes)	5	42%	2.08	43%	2.15
Road Miles (Chipseal-Moderate Traffic Volumes)	5	26%	1.28	66%	3.29
Road Miles (Gravel-Low Traffic Volumes)	5	23%	1.15	31%	1.54
Highway Bridges	5	65%	3.27	3%	0.13
Population	**4**	30%	1.18	39%	1.55
Structures	4	25%	0.99	38%	1.51
Residential Land Use (MultiFam)	5	22%	1.10	62%	3.08
Residential Land Use (SingleFam)	4	38%	1.52	70%	2.80
Residential Land Use (Misc)	4	10%	0.41	15%	0.58
Schools	4	10%	0.38	33%	1.33
Church	4	82%	3.27	64%	2.55
Public Buildings	4	42%	1.67	17%	0.67
Pedestrian Bridge	4	17%	0.67	17%	0.67
Mixed Use	4	21%	0.86	34%	1.37
Economy	**3**	41%	1.23	56%	1.67
Commercial and Retail	3	41%	1.23	53%	1.59
Shopping Mall	3	33%	1.00	67%	2.00
Tourism	4	33%	1.33	33%	1.33
Industrial	3	95%	2.84	100%	3.00
Pipelines	3	37%	1.10	55%	1.65
Gas Wells	3	20%	0.60	40%	1.20
Ag and Natural Resources	3	27%	0.81	43%	1.28
Land and Development	**2**	51%	1.01	59%	1.18
City Zoning	5	46%	2.30	52%	2.59
Planned Development	2	86%	1.72	85%	1.70
Planned Unit Development	4	14%	0.54	65%	2.61
Public Lands	3	52%	1.57	28%	0.85
Residential/Suburban	2	56%	1.12	63%	1.27
Residential/Urban	3	71%	2.13	70%	2.09
Rural	2	30%	0.60	50%	1.00
Cultural and Historical	**1**	75%	0.75	50%	0.50
Museum	1	100%	1.00	.	.
Library	1	50%	0.50	50%	0.50
TOTALS		46%	1.63	48%	1.71

Exhibit 37: Study Area 1 Landslide/Debris Flow Hazard Map
Exhibit 38: Study Area 1 Landslide/Debris Flow Hazard Risk Matrix



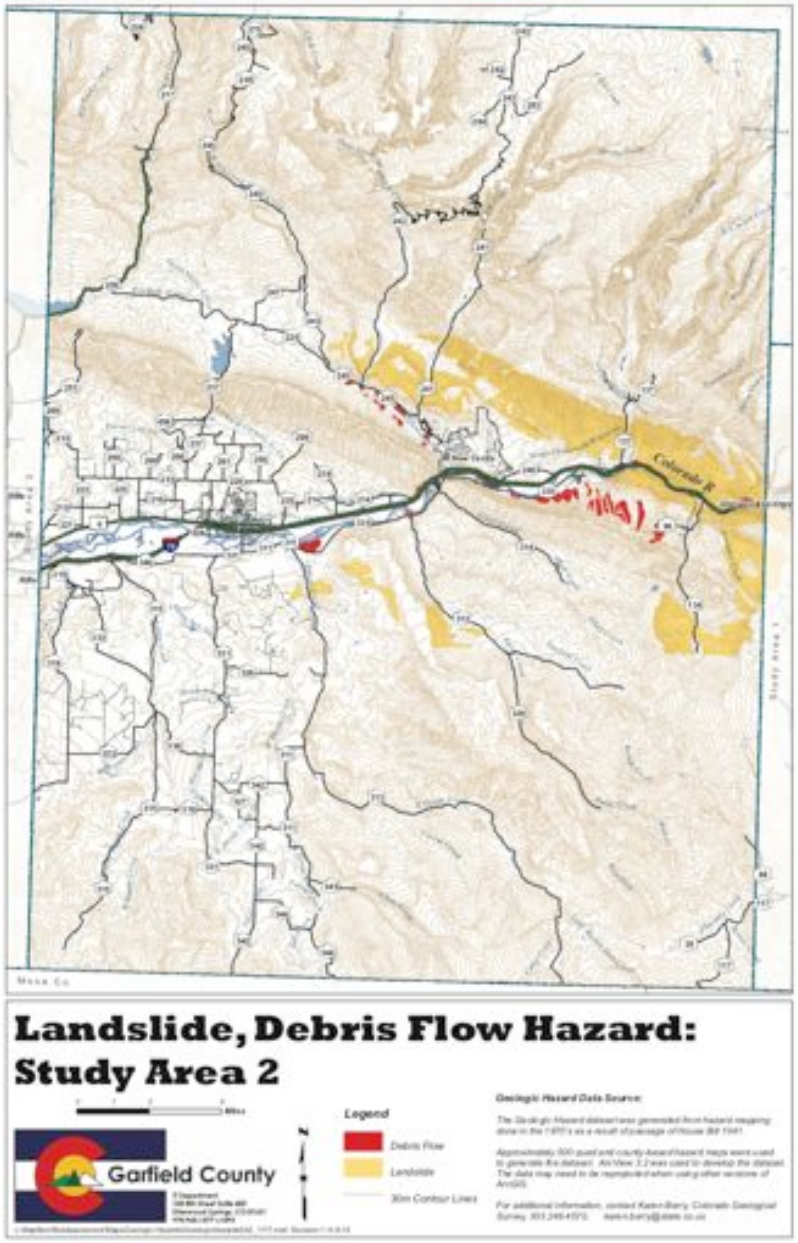
		Debris Flow		Landslide	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	43%	2.14	7%	0.34
Right-of-Way	1	4%	0.04	7%	0.07
Fire Station	5	50%	2.50	.	.
Federal Building	5	100%	5.00	.	.
Municipal Building	5	50%	2.50	.	.
Police	5	33%	1.67	.	.
Electrical Utility Substations	5	.	.	14%	0.71
Water Tanks	5	38%	1.88	.	.
Information Site	5	100%	5.00	.	.
Communications Facilities	5	11%	0.57	22%	1.08
Railroad Bridges	5	33%	1.67	.	.
Highway Bridges	5	8%	0.40	.	.
Road Miles (Asphalt-High Traffic Volumes)	5	9%	0.45	5%	0.27
Road Miles (Chipseal-Moderate Traffic Volumes)	5	1%	0.04	9%	0.46
Road Miles (Gravel-Low Traffic Volumes)	5	0.5%	0.02	7%	0.37
Population	**4**	37%	1.50	5%	0.20
Structures	4	15%	0.61	5%	0.20
Schools	4	29%	1.14	.	.
Church	4	73%	2.91	.	.
Public Buildings	4	33%	1.33	.	.
Residential Land Use (MultiFam)	4	13%	0.51	6%	0.24
Residential Land Use (SingleFam)	4	5%	0.20	7%	0.29
Residential Land Use (Misc)	4	11%	0.44	2%	0.07
Mixed Use	4	12%	0.49	6%	0.25
Economy	**3**	17%	0.52	14%	0.42
Shopping Mall	3	33%	1.00	.	.
Commercial and Retail	3	17%	0.52	19%	0.57
Industrial	3	.	.	5%	0.16
Pipelines	3	1%	0.04	14%	0.43
Tourism Site	3	.	.	17%	0.50
Ag and Natural Resource Land	3	0%	0.00	14%	0.42
Land and Development	**2**	13%	0.27	13%	0.26
City Zoning	5	50%	2.51	16%	0.79
Public Lands	2	1%	0.02	5%	0.10
Residential Suburban	2	6%	0.13	27%	0.53
Residential Urban	4	21%	0.82	8%	0.32
Rural	2	1%	0.01	9%	0.18
Planned Development	2	2%	0.03	14%	0.28
Cultural and Historical	**1**	50%	0.50	.	.
Library	1	50%	0.50	.	.
Recreation Land	1	1%	0.01	.	.
Museum	1	100%	1.00	.	.
TOTALS		27%	1.05	11%	0.37



Geological Hazard

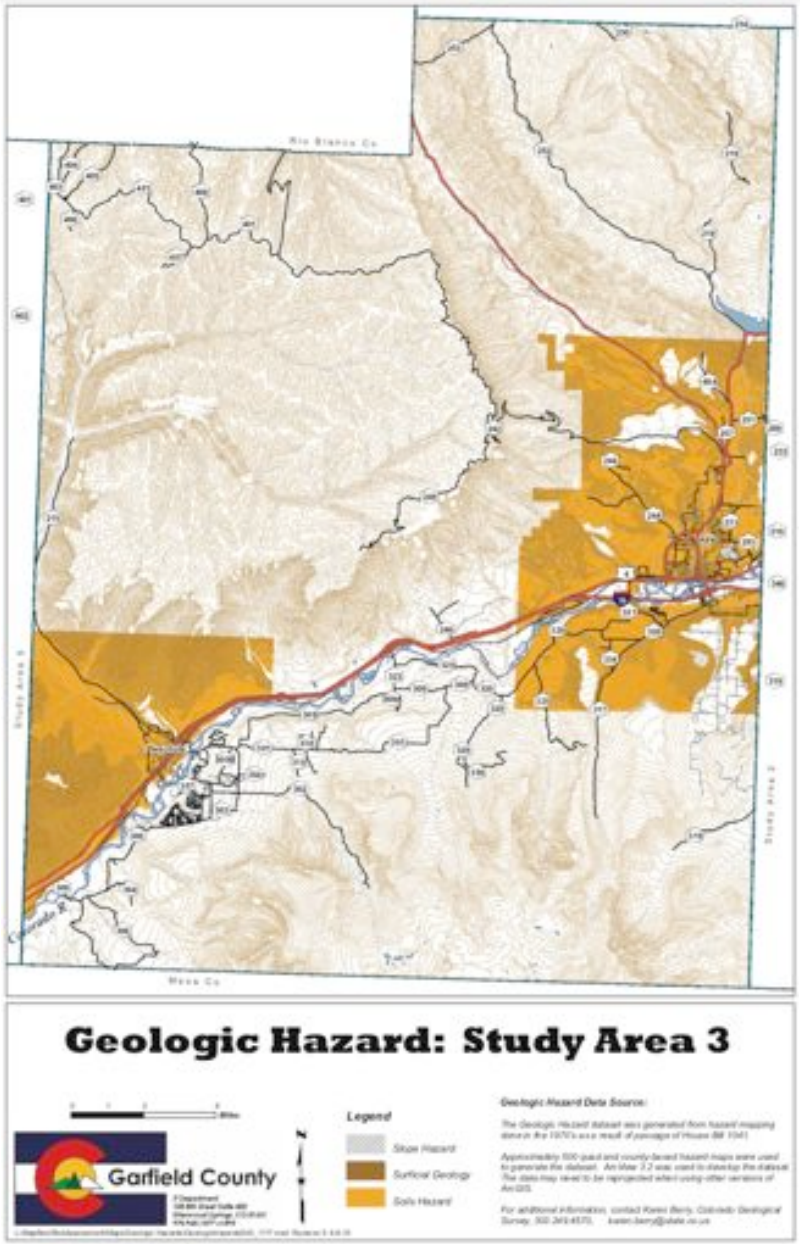
		Slope		Soil	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	40%	2.02	101%	5.06
Right-of-Way	1	12%	0.12	47%	0.47
Public Airport	5	9%	0.46	99%	4.96
Fire Station	5	.	.	60%	3.00
Police	5	.	.	100%	5.00
Landfill	3	100%	3.00	200%	6.00
Railroad Miles	5	17%	0.87	40%	2.02
Road Miles (Asphalt-High Traffic Volumes)	5	10%	0.50	43%	2.16
Road Miles (Chipseal-Moderate Traffic Volumes)	5	14%	0.71	52%	2.59
Road Miles (Gravel-Low Traffic Volumes)	5	5%	0.24	13%	0.66
Population	**4**	16%	0.66	67%	2.67
Structures	4	11%	0.44	67%	2.67
Residential Land Use (MultiFam)	5	35.54%	1.78	78%	3.88
Residential Land Use (SingleFam)	4	27%	1.09	51%	2.04
Residential Land Use (Misc)	4	3%	0.14	44%	1.77
Schools	4	.	.	80%	3.20
Public Buildings	4	.	.	33%	1.33
Nursing Home	4	.	.	100%	4.00
Mixed Use	4	5%	0.21	80%	3.21
Economy	**3**	9%	0.28	67%	2.00
Commercial and Retail	3	2%	0.07	146%	4.39
Industrial	3	4%	0.11	100%	3.00
Pipelines	3	16%	0.48	32%	0.95
Gas Wells	3	8%	0.23	27%	0.81
Ag and Natural Resource Land	3	17%	0.50	28%	0.83
Land and Development	**2**	38%	0.76	55%	1.11
City Zoning	5	21%	1.03	72%	3.60
Planned Unit Development	4	44%	1.75	81%	3.24
Public Lands	3	16%	0.48	15%	0.46
Residential/Suburban	2	83%	1.66	92%	1.83
Residential/Urban	4	57%	2.26	61%	2.43
Residential/Mobile	4	24%	0.98	33%	1.32
Rural	2	23%	0.45	34%	0.68
Cultural and Historical	**1**	.	.	50%	0.50
Museum	1	.	.	50%	0.50
Library	1	.	.	50%	0.50
TOTALS		24%	0.83	65%	2.36

Exhibit 41: Study Area 2 Landslide/Debris Flow Hazard Map
Exhibit 42: Study Area 2 Landslide/Debris Flow Hazard Risk Matrix



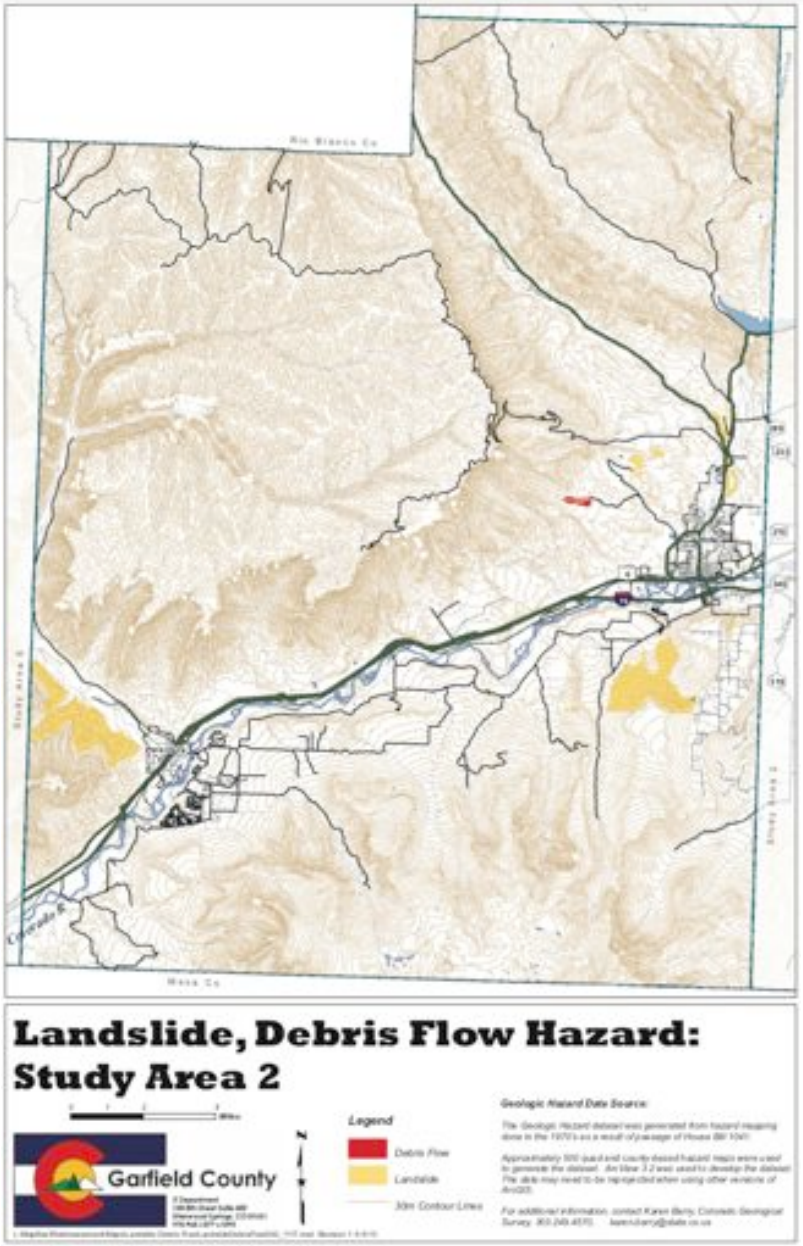
Geological Hazard

		Debris Flow		Landslide	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	2%	0.12	3%	0.15
Right-of-Way	1	2%	0.02	7%	0.07
Highway Bridges	5	.	.	1%	0.07
Communications Facilities	5	.	.	7%	0.36
Road Miles (Asphalt-High Traffic Volumes)	5	.	.	2%	0.10
Road Miles (Chipseal-Moderate Traffic Volumes)	5	4%	0.21	2%	0.11
Road Miles (Gravel-Low Traffic Volumes)	5	.	.	0.05%	0.00
Population	**4**	12%	0.50	2%	0.07
Structures	4	1%	0.03	1%	0.05
Residential Land Use (MultiFam)	5	36%	1.78	.	.
Residential Land Use (SingleFam)	4	1%	0.04	3%	0.10
Mixed Use	4	3%	0.11	.	.
Economy	**3**	0%	0.01	2%	0.07
Ag and Natural Resource Land	3	0.2%	0.01	6%	0.18
Gas Wells	3	.	.	1%	0.02
Pipelines	3	0.1%	0.00	0.5%	0.01
Land and Development	**2**	0%	0.00	22%	0.44
City Zoning	5	0.1%	0.01	.	.
Planned Unit Development	5	7%	0.35	3%	0.16
Public Lands	2	0.2%	0.00	4%	0.08
Residential Suburban	2	5%	0.11	83%	1.66
Residential Urban	4	41%	1.63	16%	0.63
Rural	2	0.3%	0.01	4%	0.09
TOTALS		6%	0.27	9%	0.22



Geological Hazard

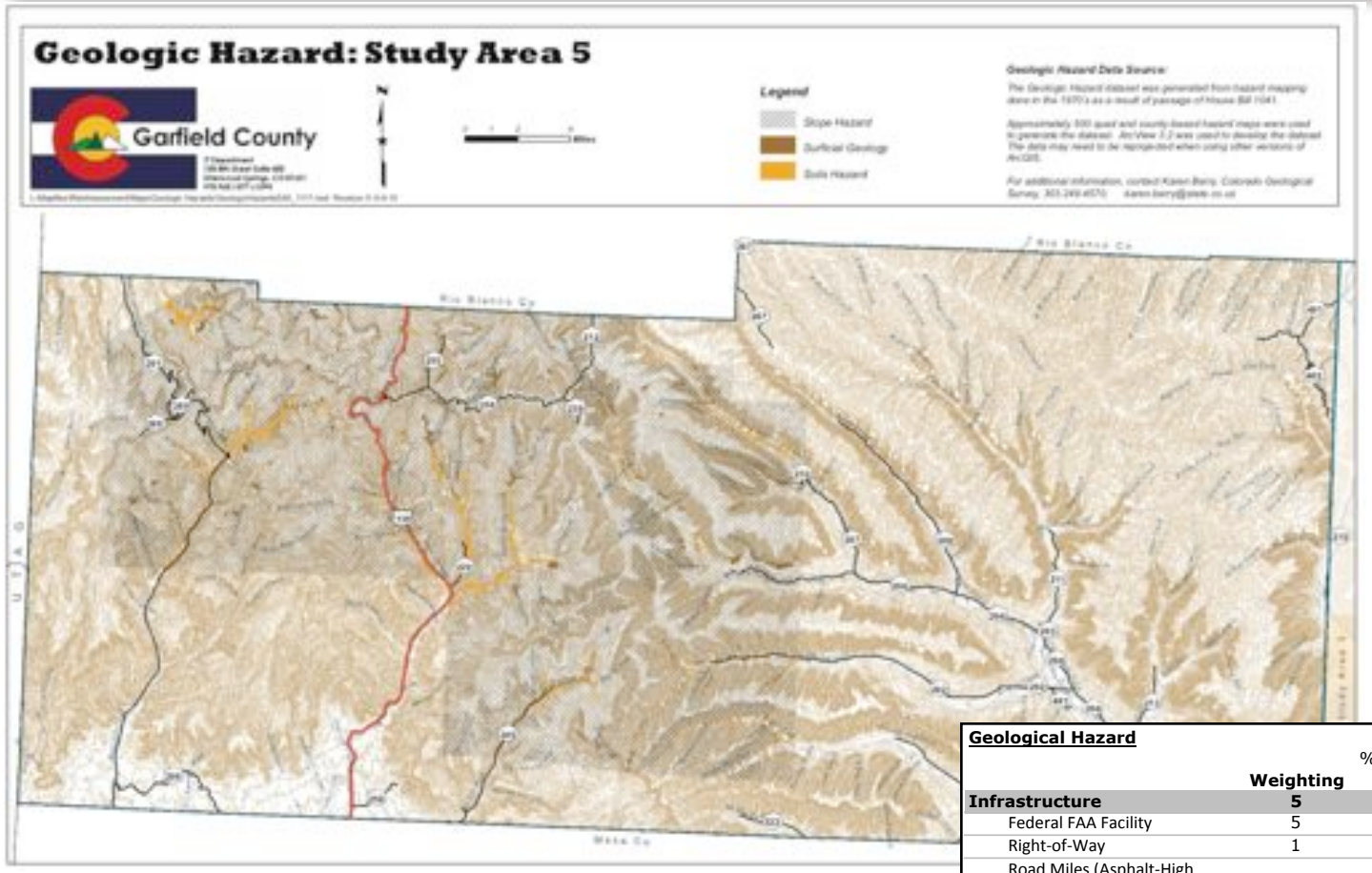
		Slope		Soil	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	3%	0.16	51%	2.56
Right-of-Way	1	2%	0.02	48%	0.48
Dispatch	5	.	.	100%	5.00
Fire Station	5	.	.	33%	1.67
Hospital	5	.	.	100%	5.00
Information	4	.	.	.	.
Police Facility	5	.	.	33%	1.67
Railroad Miles	5	.	.	65%	3.26
Road Miles (Asphalt-High Traffic Volumes)	5	4%	0.19	43%	2.15
Road Miles (Chipseal-Moderate Traffic Volumes)	5	4%	0.19	25%	1.27
Road Miles (Gravel-Low Traffic Volumes)	5	3%	0.17	12%	0.61
Population	**4**	6%	0.24	76%	3.03
Structures	4	1%	0.04	58%	2.33
Residential Land Use (MultiFam)	5	.	.	85%	4.24
Residential Land Use (SingleFam)	4	11%	0.44	41%	1.65
Residential Land Use (Misc)	4	.	.	99%	3.97
Church	4	.	.	100%	4.00
Nursing Home	4	.	.	100%	4.00
Public Building	4	.	.	67%	2.67
School	4	.	.	73%	2.91
Mixed Use	4	.	.	59%	2.35
Economy	**3**	7%	0.22	33%	0.98
Commercial and Retail	3	1%	0.03	66%	1.97
Resource Land	3	10%	0.29	19%	0.58
Gas Wells	3	11%	0.33	27%	0.82
Pipeline Miles	3	13%	0.39	40%	1.21
Ag and Natural Resource Land	3	3%	0.09	11%	0.32
Land and Development	**2**	8%	0.17	48%	0.96
City Zoning	5	6%	0.32	81%	4.03
Planned Unit Development	4	0.1%	0.00	0.2%	0.01
Public Lands	3	12%	0.37	14%	0.43
Residential/Suburban	2	26%	0.52	79%	1.58
Residential/Urban	4	1%	0.03	100%	4.00
Rural	2	5%	0.11	14%	0.29
Cultural Resources	**1**	.	.	100%	1.00
Library	1	.	.	100%	1.00
Museum	1	.	.	100%	1.00
TOTALS		7%	0.21	58%	2.08



Geological Hazard (landslide)

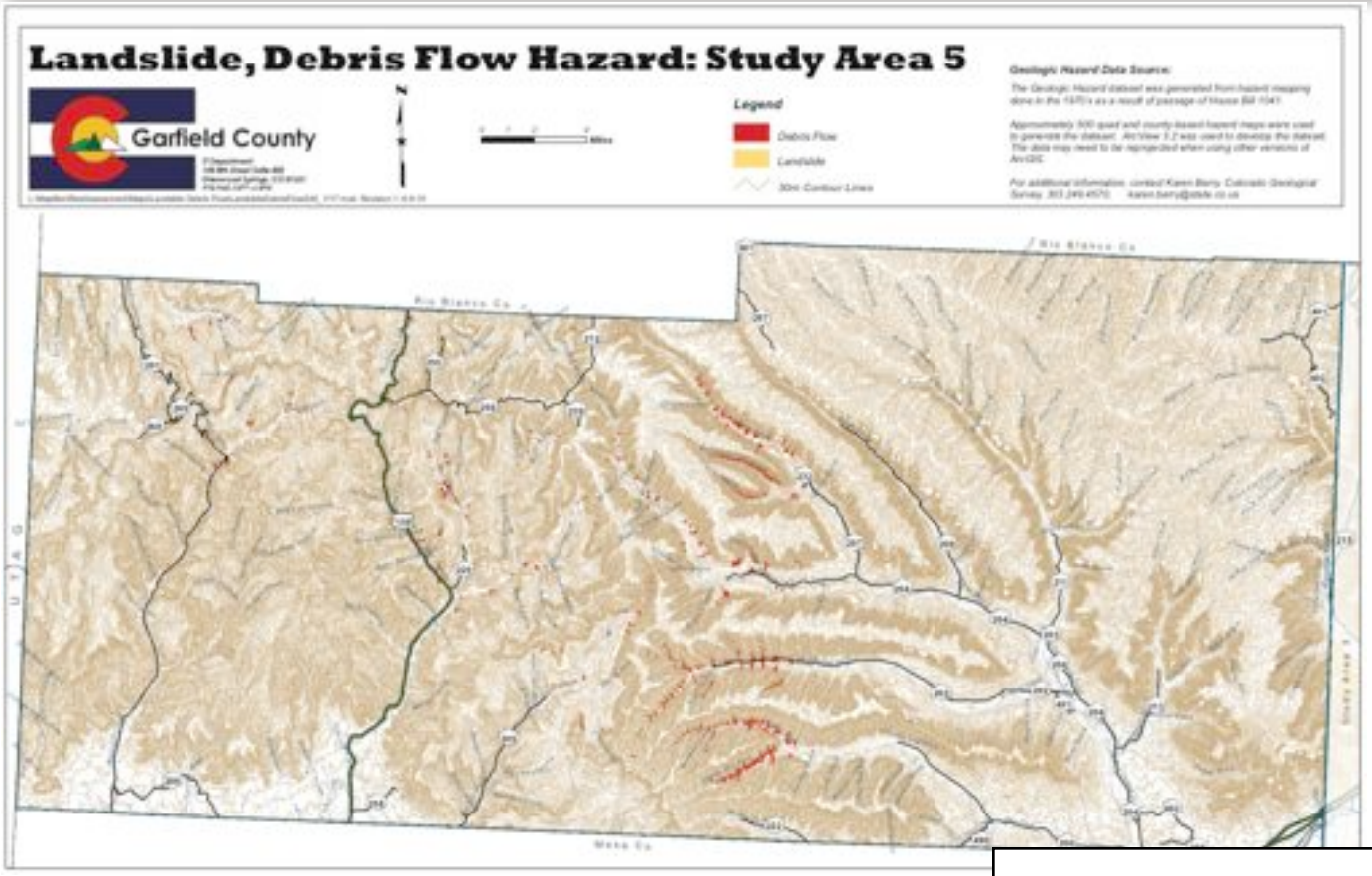
		Landslide	
	Weighting	% of asset at risk	Index
Infrastructure	**5**	2%	0.10
Road Miles (Asphalt-High Traffic Volumes)	5	0.3%	0.01
Road Miles (Chipseal-Moderate Traffic Volumes)	5	6%	0.29
Road Miles (Gravel-Low Traffic Volumes)	5	0.02%	0.00
Population	**4**	1%	0.03
Structures	4	0.2%	0.01
Residential Land Use (SingleFam)	4	1%	0.05
Economy	**3**	2%	0.07
Gas Wells	3	4%	0.11
Pipelines	3	3%	0.08
Ag and Natural Resource Land	3	0.1%	0.00
Land and Development	**2**	2%	0.03
Public Lands	2	2%	0.04
Rural	2	1%	0.03
TOTALS		2%	0.06

Exhibit 47: Study Area 5 Geologic Hazard Map
Exhibit 48: Study Area 5 Geologic Hazard Risk Matrix



Geological Hazard		Slope		Soil	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	49%	2.44	1%	0.06
Federal FAA Facility	5	100%	5.00	.	.
Right-of-Way	1	.	.	1%	0.01
Road Miles (Asphalt-High Traffic Volumes)	5	18%	0.88	25%	1.24
Road Miles (Gravel-Low Traffic Volumes)	5	29%	1.45	10%	0.52
Population	**4**	17%	0.69	2%	0.06
Structures	4	27%	1.10	2%	0.06
Residential Land Use (SingleFam)	4	7%	0.29	.	.
Economy	**3**	15%	0.46	3%	0.08
Pipelines	3	20%	0.60	5%	0.14
Gas Wells	3	6%	0.17	2%	0.06
Resource Land	3	15%	0.44	1%	0.03
Ag and Natural Resource Land	3	21%	0.64	3%	0.09
Land and Development	**2**	49%	0.97	3%	0.07
Public Lands	3	42%	1.27	1%	0.03
Rural	2	55%	1.10	6%	0.12
TOTALS		31%	1.17	5%	0.18

Exhibit 49: Study Area 5 Landslide/Debris Flow Hazard Map
Exhibit 50: Study Area 5 Landslide/Debris Flow Hazard Risk Matrix



		Debris Flow		Landslide	
	Weighting	% of asset at risk	Index	% of asset at risk	Index
Infrastructure	**5**	3%	0.13	8%	0.40
Dams	5	.	.	10%	0.50
Road Miles (Gravel-Low Traffic Volumes)	5	3%	0.13	11%	0.56
Population	**4**	2%	0.06	13%	0.52
Structures	4	2%	0.06	13%	0.52
Residential Land Use (SingleFam)	4	.	.	3%	0.12
Economy	**3**	1%	0.03	4%	0.12
Gas Wells	3	0.5%	0.01	3%	0.08
Pipelines	3	1%	0.03	7%	0.21
Resource Land	3	1%	0.03	3%	0.08
Ag and Natural Resource Land	3	2%	0.05	.	.
Land and Development	**2**	1%	0.02	19%	0.38
Public Lands	2	1%	0.01	13%	0.27
Rural	2	1%	0.03	24%	0.48
TOTALS		1%	0.05	10%	0.33

Hazardous Material Hazard

Chemicals are found everywhere. They purify drinking water, increase crop production, and simplify household chores. But chemicals also can be hazardous to humans or the environment if used or released improperly. Hazards can occur during production, storage, transportation, use, or disposal.

Hazardous materials are substances that are either flammable or combustible, explosive, toxic, noxious, corrosive, oxidizable, an irritant or radioactive. A hazardous material spill or release can pose a risk to life, health or property. An incident can result in the evacuation of a few people, a section of a facility, or an entire neighborhood.

Data sources

The maps and data used for this risk assessment were collected by the Environmental Protection Agency (2009) as well as the Colorado Department of Public Health and Environment (2008). The included maps of hazardous material identify sites and facilities with certain potentially harmful substances. To protect the sensitivity of this information, the maps do not depict the type or extent of the material.

Vulnerability assessment

There are two main vulnerabilities in Garfield County - existing sites and facilities and substances moving through the County.

Existing sties and facilities such as chemical manufacturers are one source of hazardous materials, but there are many others, including service stations, hospitals, and hazardous material waste sites. These are existing, stationary vulnerabilities.

The second type of vulnerability comes from the trains and trucks on hazardous materials routes. The routes designated for hazardous material in Garfield County are I-70 and SH 1 Hazardous materials are also shipped daily on I-7 and along the railroad. These hazardous materials routes run near the County's major population centers and adjacent to the rivers that serve as the County's drinking water sources.

Should anything happen to hazardous waste cargo en-route through the County, the canyon may trap contaminants in the air or hamper a safe and timely evacuation.

Hazard probability

As part of the Risk Assessment process, Garfield County representatives completed a Risk Matrix that compiled the relative impact on community systems of various hazards and the probability of the hazard occurring. Hazardous material hazards, including spills and releases, was assessed with a combined probability rating of 3.36, or that hazardous material related hazards are considered highly probable in Garfield County.

Risk assessment

Based on the sheer number of stationary hazardous material sites, the communities of Glenwood Springs and Rifle (in Study Areas 1 and 3) face the highest risk from hazardous materials contamination. Study Areas 1, 2, and 3 share an increased risk due to the proximity of communities along the I-70 hazardous materials route.

More complete data is needed to support the development of a full, comprehensive hazards material risk assessment. In partnership with the Environmental Protection Agency, the County can assess risk from the types of materials traversing the County. Additionally, the County and oil and gas industries can continue to collaborate and identify at-risk sites, and to strengthen the industry's infrastructure to prevent contamination of environmental resources.

	HazMat sites	Gas wells	Pipeline
Area 1	33	5	510
Area 2	15	5226	11,909
Area 3	24	5,768	44,9892
Area 4	1	1	na
Area 5	2	3053	235,675

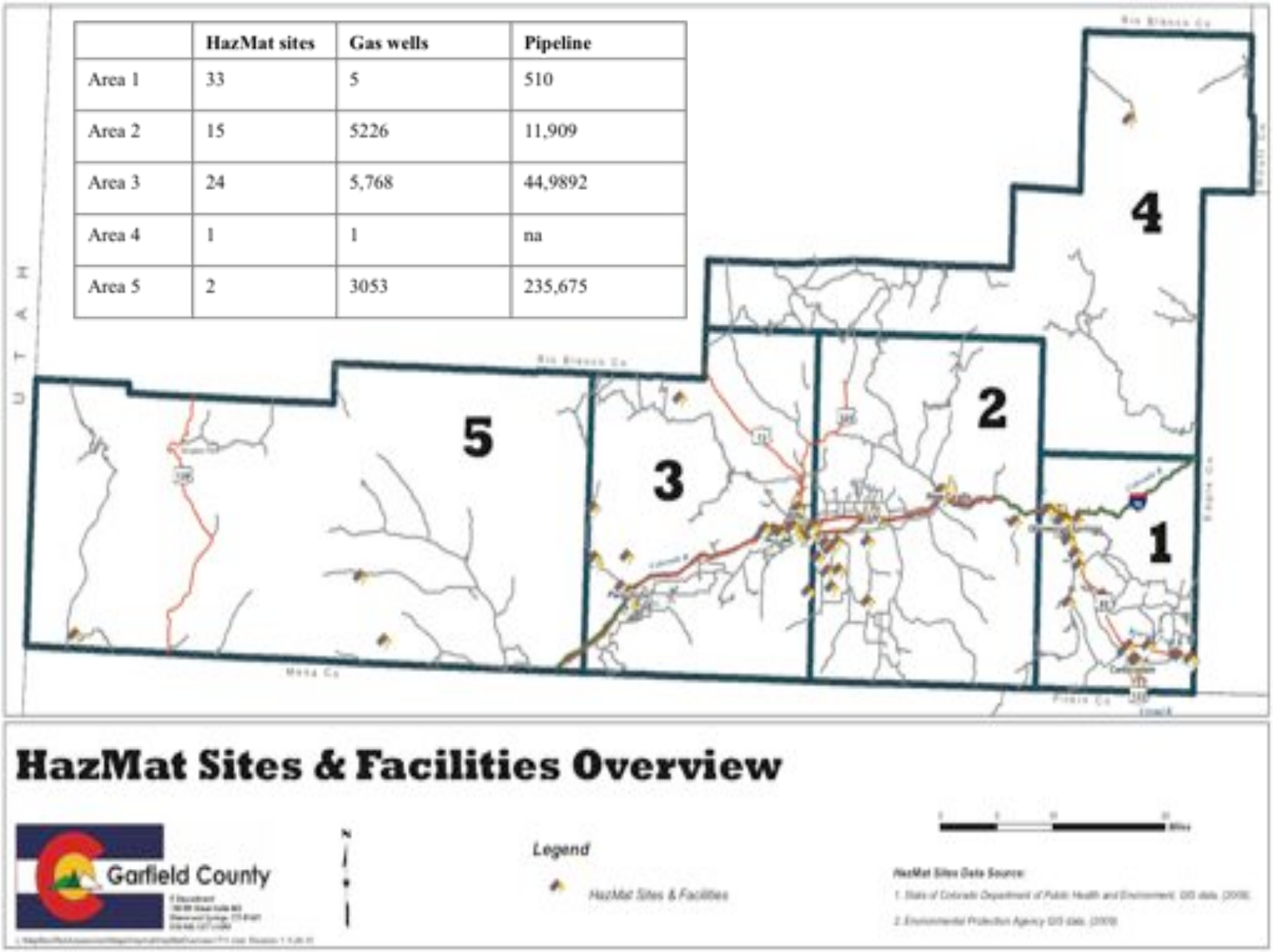
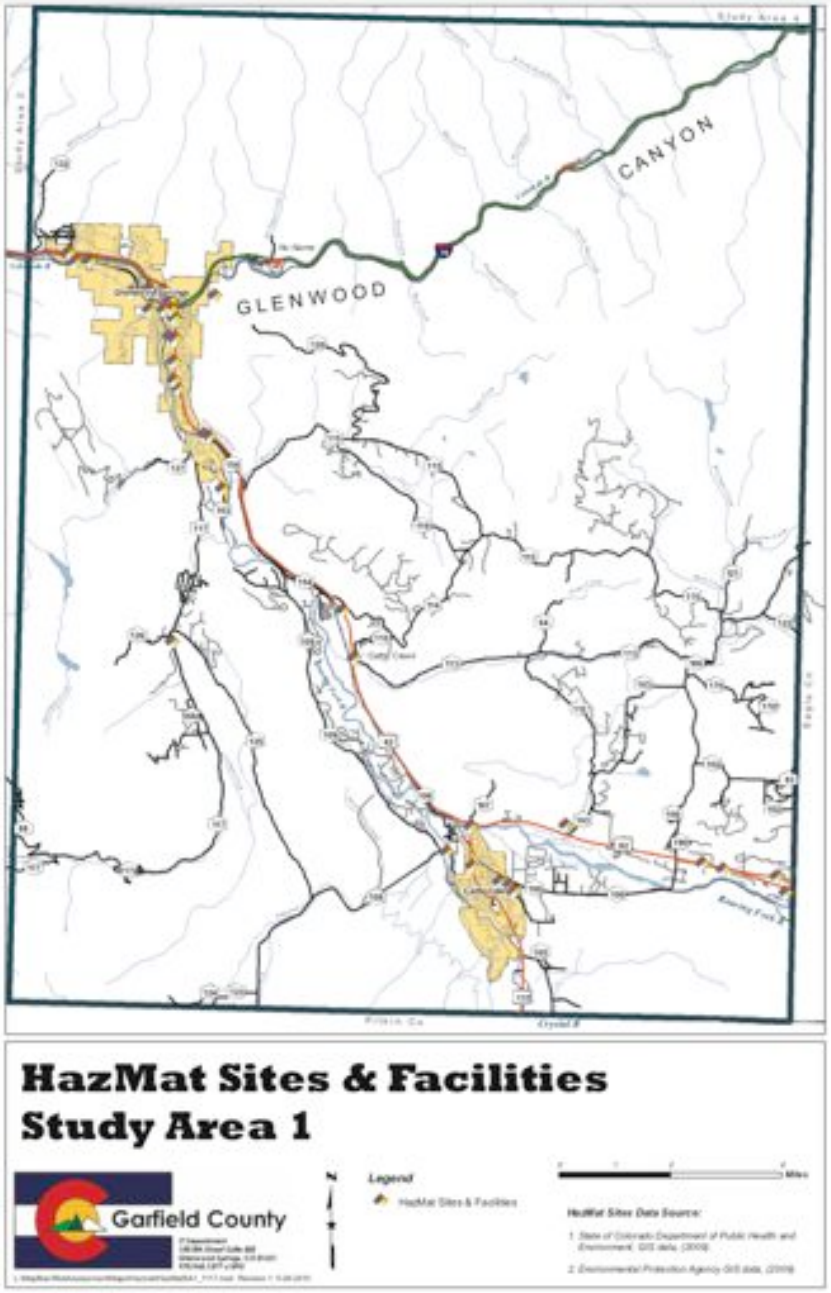
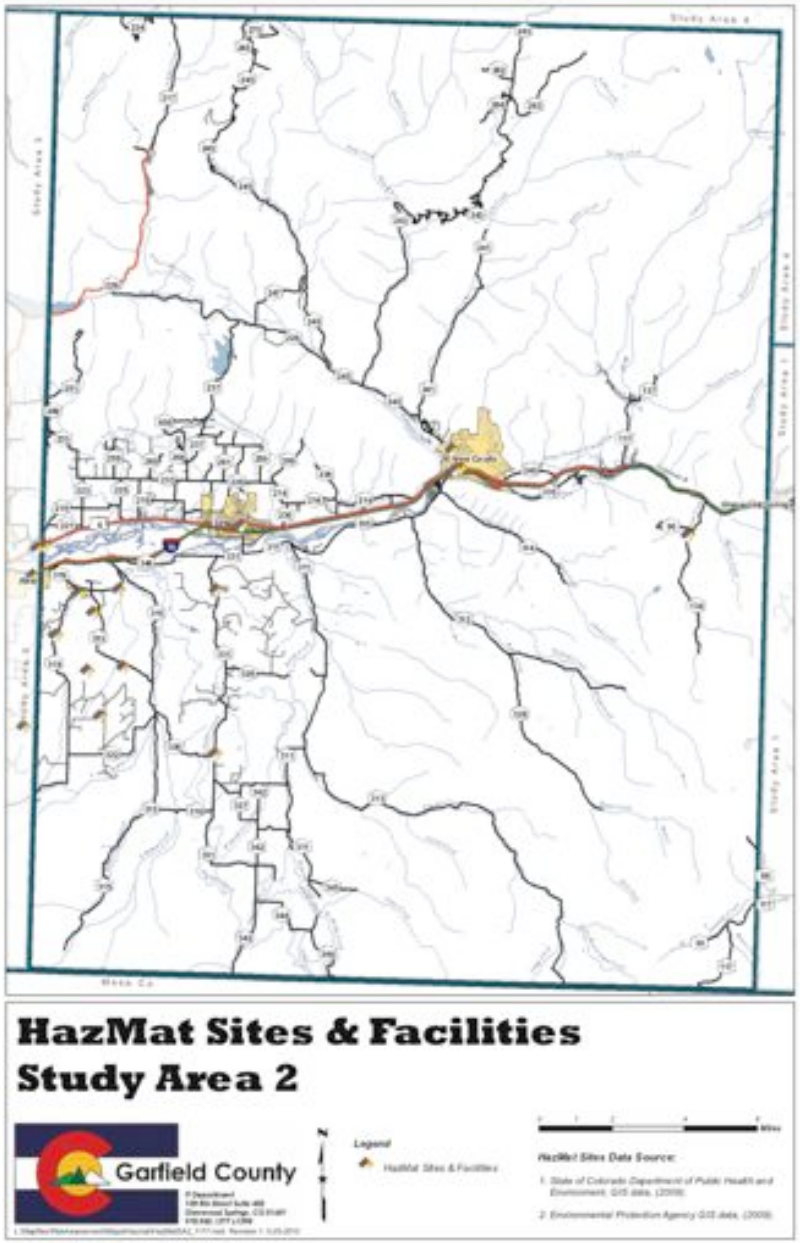


Exhibit 52: Study Area 1 Hazardous Material Site Map
Exhibit 53: Study Area 1 Infrastructure at Risk



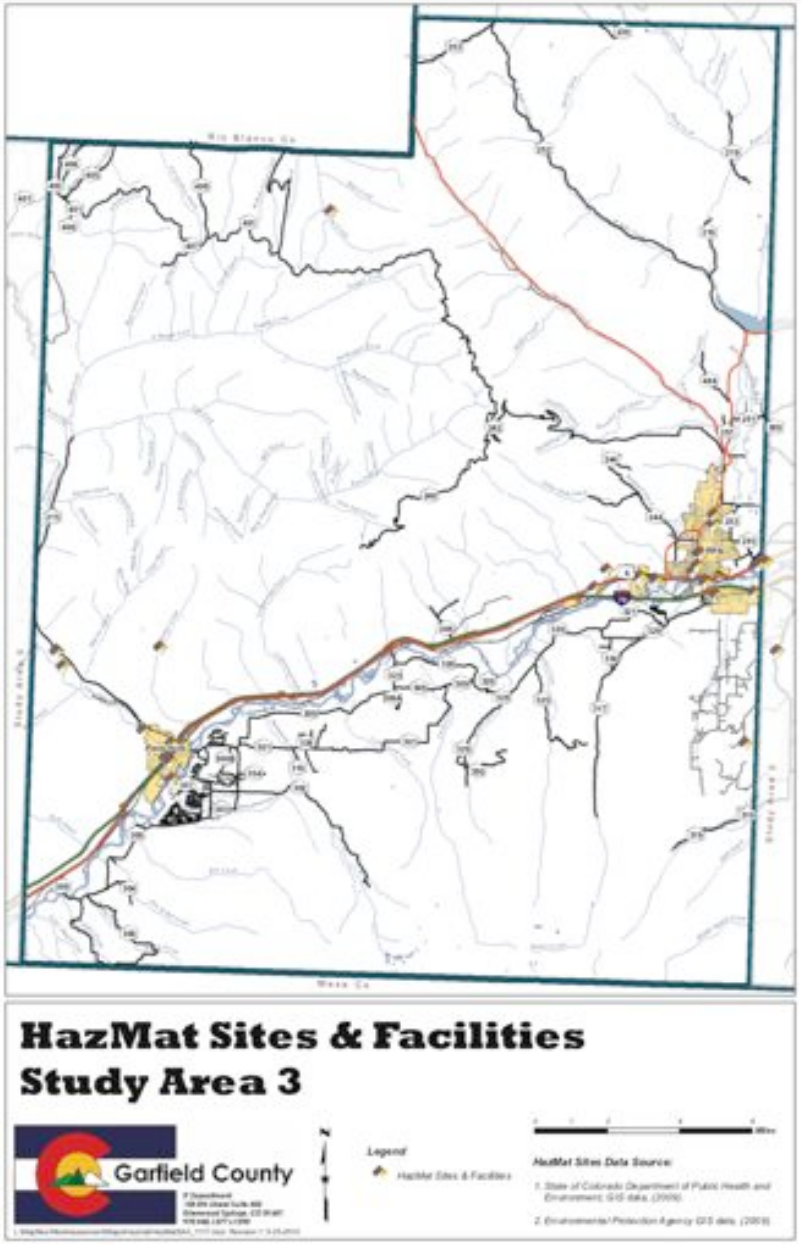
Infrastructure in Area 1	
Airport	1
Cemetery	5
Church	11
Communications Facilities	106
Dams	5
Electric Utility Lines (Miles)	62
Electric Utility Substations	7
Federal Building	1
Fire Station	4
Gas Wells	5
Glenwood Springs Water Viaduct (Miles)	1
Heli Pad	1
Highway Bridges	75
Highway Tunnels	5
Hospital	1
Information Site	1
Library	2
Municipal Building	2
Museum	1
Natural Gas Facility	1
Parks	32
Pedestrian Bridge	6
Pipelines (Miles)	45
Police	3
Public Building	12
Rail Station	1
Railroad (Miles)	35
Railroad Bridge	3
Railroad Tunnel	1
Road Miles (Asphalt-High Traffic Volumes)	84
Road Miles (Chipseal-Moderate Traffic Volumes)	57
Road Miles (Gravel-Low Traffic Volumes)	36
School	21
Shopping Mall	3
Structures: Homes, Businesses, Barns, Garages, etc	8,768
Tourism Site	6
Water Storage Tanks	8

Exhibit 54: Study Area 2 Hazardous Material Site Map
Exhibit 55: Study Area 2 Infrastructure at Risk



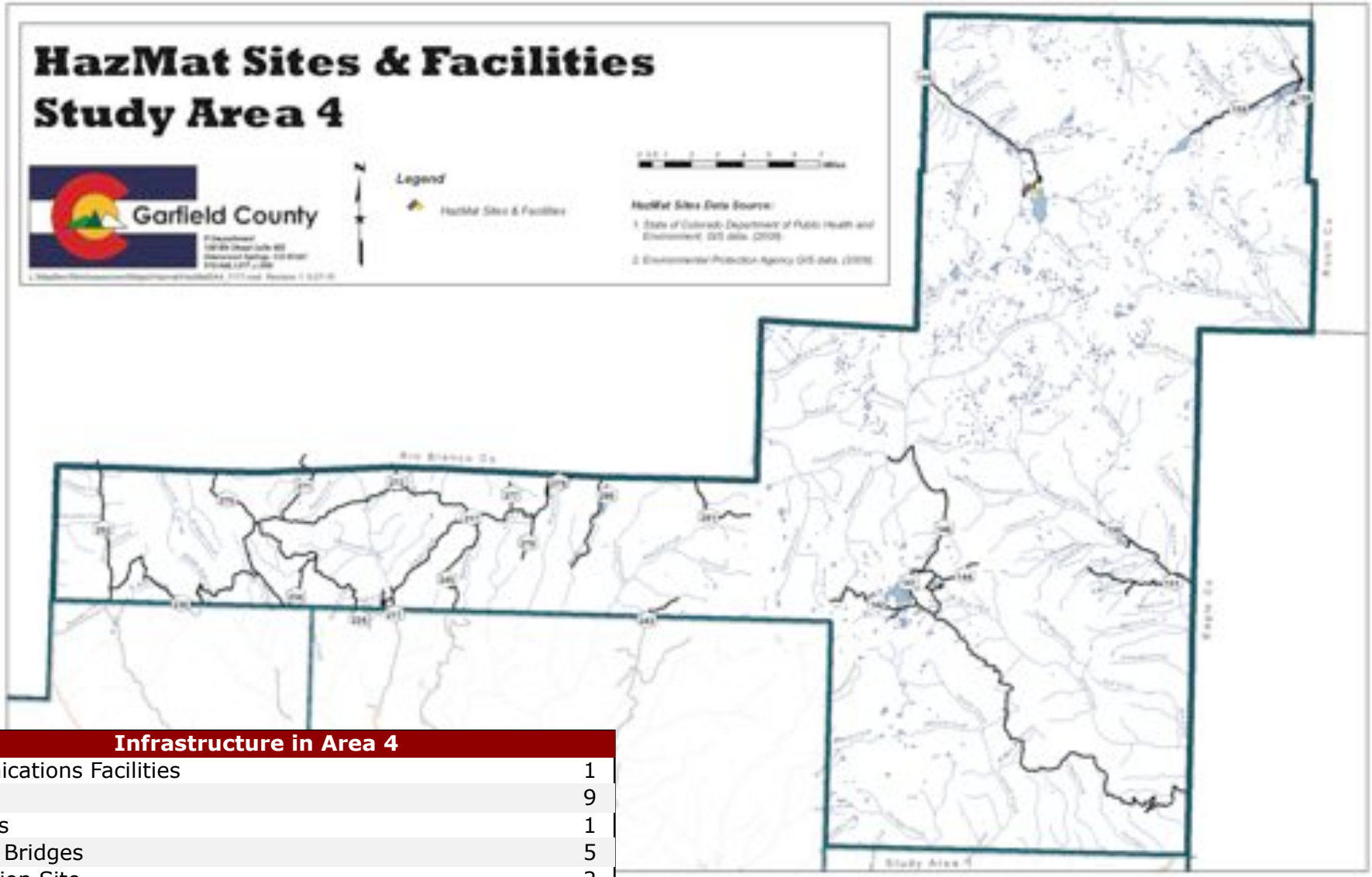
Infrastructure in Area 2	
Airport	2
Cemetery	2
Church	4
Communications Facilities	55
Dams	9
Electric Utility Lines (Miles)	44
Electric Utility Substations	4
Fire Station	5
Gas Wells	2,526
Heli Pad	1
Highway Bridges	69
Landfill	1
Library	2
Municipal Building	1
Museum	2
Natural Gas Facility	2
Nursing Home	1
Parks	16
Pipelines (Miles)	224
Police	1
Public Building	6
Railroad (Miles)	18
Railroad Bridge	4
Road Miles (Asphalt-High Traffic Volumes)	107
Road Miles (Chipseal-Moderate Traffic Volumes)	83
Road Miles (Gravel-Low Traffic Volumes)	107
School	5
Shopping Mall	1
Structures: Homes, Businesses, Barns, Garages, etc	5,175
Water Storage Tanks	4

Exhibit 56: Study Area 3 Hazardous Material Site Map
Exhibit 57: Study Area 3 Infrastructure at Risk



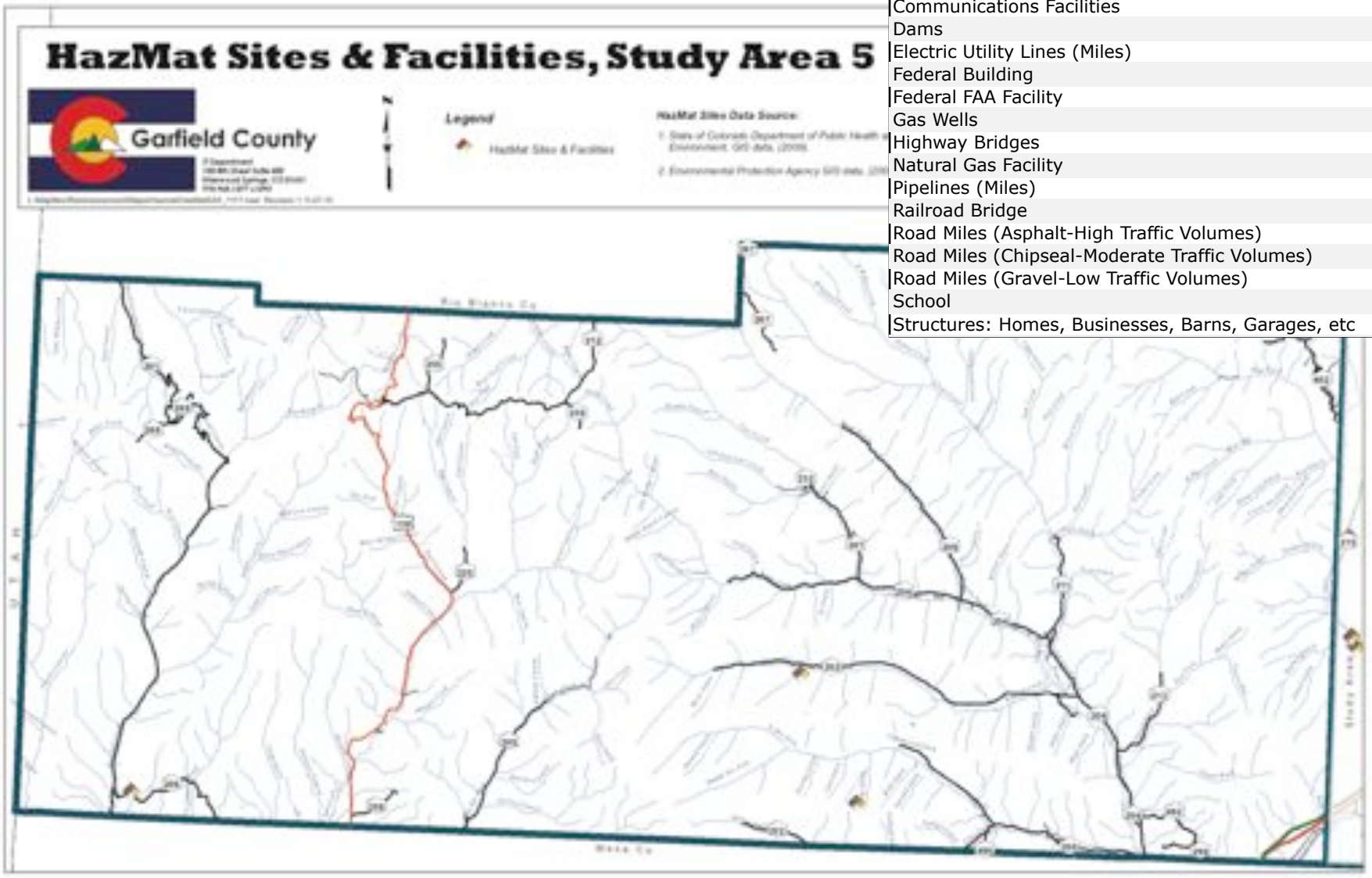
Infrastructure in Area 3	
Cemetery	3
Church	5
Communications Facilities	45
Dams	9
Dispatch	1
Electric Utility Lines (Miles)	93
Electric Utility Substations	3
Fire Station	3
Gas Wells	5,768
Heli Pad	1
Highway Bridges	47
Highway Tunnels	
Hospital	1
Landfill	1
Library	2
Municipal Building	3
Museum	1
Natural Gas Facility	4
Nursing Home	3
Parks	11
Pedestrian Bridge	1
Pipelines (Miles)	981
Police	3
Public Building	9
Railroad (Miles)	43
Railroad Bridge	6
Road Miles (Asphalt-High Traffic Volumes)	153
Road Miles (Chipseal-Moderate Traffic Volumes)	46
Road Miles (Gravel-Low Traffic Volumes)	89
School	11
Shopping Mall	1
Structures: Homes, Businesses, Barns, Garages, etc	6,403
Water Storage Tanks	1

Exhibit 58: Study Area 4 Hazardous Material Site Map
Exhibit 59: Study Area 4 Infrastructure at Risk



Infrastructure in Area 4	
Communications Facilities	1
Dams	9
Gas Wells	1
Highway Bridges	5
Information Site	2
Road Miles (Chipseal-Moderate Traffic Volumes)	6
Road Miles (Gravel-Low Traffic Volumes)	85
Structures: Homes, Businesses, Barns, Garages, etc	75

Exhibit 60: Study Area 5 Hazardous Material Site Map
Exhibit 61: Study Area 5 Infrastructure at Risk



Infrastructure in Area 5	
Communications Facilities	24
Dams	10
Electric Utility Lines (Miles)	3
Federal Building	1
Federal FAA Facility	1
Gas Wells	3,053
Highway Bridges	12
Natural Gas Facility	3
Pipelines (Miles)	1,082
Railroad Bridge	1
Road Miles (Asphalt-High Traffic Volumes)	46
Road Miles (Chipseal-Moderate Traffic Volumes)	4
Road Miles (Gravel-Low Traffic Volumes)	96
School	3
Structures: Homes, Businesses, Barns, Garages, etc	62

Severe Winter Weather

A severe winter storm is generally a prolonged event involving snow or ice. The characteristics of severe winter storms are determined by a number of meteorological factors including the amount and extent of snow or ice, air temperature, wind speed, and event duration. Even though Garfield County does not typically experience crippling winter weather, some winter weather is a regular occurrence and has the potential to disrupt day-to-day life throughout the county.

Severe winter storms pose a significant risk to life and property in by creating conditions that disrupt essential regional systems such as public utilities, telecommunications, and transportation routes. Severe winter storms can produce rain, freezing rain, ice, snow, cold temperatures, and wind. Ice storms accompanied by high winds can have destructive impacts, especially to trees, power lines, and utility services.

History of severe weather in Garfield County

Garfield County has never been included in a presidentially declared disaster relating to winter storms. The county was not included in the dclarations related to the 2001, 2003 or 2007 storms that significantly impact the county in Eastern Colorado. But winter weather is a chronic hazard that impacts communities across the county. Recently, on March 17, 2011 a storm produced three to nine inches overnight that caused power outages for as many as 1,100 customers and several multi-vehicle accidents. The Post Independent newspaper reported 13 accidents in the stretch of highway between Parachute and Glenwod Springs during the morning commute, and 18 incidents of single car accidents, the majority in the area from Silt to New Castle and Canyon Creek. The accidents resulted in temporary closures of I-70.[16]

Exhibit 62: Record Snowfall at Garfield County NOAA Monitoring Stations

Location	1-Day Snowfall	2-Day Snowfall	3-Day Snowfall
Glenwood Springs	15.0	28.0	41.0
Rifle	16.7	22.0	24.0

Source: NOAA/ National Climatic Data Center Cliamte Services and Monitoring Division (www.ncdc.noaa.gov/ussc/USSCAppController). Accessed August 2011.

Data sources

Unlike most other hazards, it is not simple to systematically map winter storm hazard zones. The entire county is susceptible to damaging severe weather. Winter storms that bring snow and ice can impact infrastructure, business, and individuals. Those resources that exist at higher elevations or at greater slopes will experience more risk of snow and ice, but the entire County can face damage from winter storms and, for example, the hail or life threateningly cold temperatures that winter storms bring. Inventorying the structural integrity of County infrastructure that is exposed to high snow loads and cataloguing the health and maturity of trees near to that infrastructure will assist the County in focusing mitigation actions on areas that may incur the most damage due to severe winter weather.

Vulnerability assessment

Winter storms which bring snow, ice and high winds can cause significant impacts on life and property. Many severe winter storm deaths occur as a result of traffic accidents on icy roads, heart attacks which shoveling snow, and hypothermia from prolonged exposure to the cold. The temporary loss of home heating can be particularly hard on the elderly, young children and other vulnerable individuals.

Property is at risk due to flooding and landslides that may result if there is a heavy snowmelt. Additionally, ice, wind and snow can affect the stability of trees, power and telephone lines and TV and radio antennas. Down trees and limbs can become major hazards for houses,

cars, utilities and other property. Below freezing temperatures can also lead to breaks in uninsulated water lines serving schools, businesses, and industry and individual homes. Such damage in turn can become major obstacles to providing critical emergency response, police, fire and other disaster recovery services.

Severe winter weather also can cause the temporary closure of key roads and highways, air and train operations, businesses, schools, government offices and other important community services. All of these effects if lasting more than several days can create significant economic impacts for the communities affected as well for the surrounding region. In the rural areas of Garfield County severe winter storms can isolate small communities. Even the larger communities can become cut off when severe weather closes I-70 or Highway 82 as those are the primary transportation routes in and through the county. Additionally, rising population growth and new infrastructure in the county creates a higher probability for damage to occur from severe winter weather as more life and property are exposed to risk.

Hazard probability

As part of the Risk Assessment process, Garfield County representatives completed a Risk Matrix that compiled the relative impact on community systems of various hazards and the probability of the hazard occurring. Severe winter weather, including snow and ice, was assessed with a combined probability rating of 3.91, or that severe winter weather hazards are considered nearly inevitable in Garfield County.

Risk assessment

Given current available data, no quantitative assessment of the risk of severe weather was possible at the time of the development of this NHMAP. However, assessing the risk to the County from winter storms should remain an ongoing process determined by community characteristics and physical vulnerabilities. Weather forecasting can give County resources (emergency vehicles, warming shelters) time to prepare for an impending storm, but the changing character of the County population and resources will determine the impact of winter storms on life and property in Garfield County. For more information on the winter storm hazard, please visit the Colorado Natural Hazard Mitigation Plan.

References

[1] Multihazard Mitigation Council, 2005 and 2009

[2] Garfield County Community Wildfire Protection Plan, 2006

[3] Ibid

[4] Ibid

[5] Ibid

[6] Flood Hazard Mitigation Plan for Colorado, 2007

[7] Ibid

[8] Colorado Flood Hazard Mitigation Plan, 2007

[9] FEMA, Policy and Claim Statistics for Flood Insurance, *Claim Information by State (1978 - Current Month).* Accessed 1/1/2010

[10] Colorado Natural Hazard Mitigation Plan, 2007

[11] Earthquake Evaluation Report, 2007

[12] Colorado Natural hazard Mitigation Plan, 2008

[13] Ibid

[14] Critical Landslides in Colorado: A year 2002 Review and Priority List, Colorado Geological Survey and the Colorado Office of Emergency Management

[15] Colorado Landslide Hazard Mitigation Plan, 2008

[16] *Snowstorm closes I-70 near Glenwood, cuts power.* Colson, John. Post Independent. March 19, 2011