CHAPTER 5

DROUGHT

Drought is one of Wyoming's most costly natural weather-related disaster. It indirectly kills more people and animals than the combined effects of hurricanes, floods, tornadoes, blizzards, and wildfires. Unlike other disasters that quickly come and go, drought's long-term unrelenting destruction has been responsible for mass migrations and lost civilizations. The 1980 and 1988 droughts in the U.S. resulted in approximately 17,500 heat-related deaths and an economic cost of over $100 billion. Drought occurs in four stages and is defined as a function of its magnitude (dryness), duration, and regional extent. Severity, the most commonly used term for measuring drought, is a combination of magnitude and duration.

The first stage of drought is known as a meteorological drought. The conditions at this stage include any precipitation shortfall of 75% of normal for three months or longer. This criterion can be misleading if all the precipitation falls in a very short time period resulting in floods. Additionally, winter precipitation is usually two to six times less than summer precipitation and these so-called seasonal droughts are normal in our semiarid climate. Conditions are often made worse with high temperatures, high winds, low humidity, and greater sunshine; all of these factors contribute to increased evaporation and transpiration and result in reduced soil infiltration, runoff, deep percolation, and groundwater recharge.

The second stage is known as agricultural drought. Soil moisture is deficient to the point where plants are stressed and biomass (yield) is reduced. The third stage is the hydrological drought. Reduced stream flow (inflow) to reservoirs and lakes is the most obvious sign that a serious drought is in progress. The fourth stage is the socioeconomic drought. This final stage refers to the situation that occurs when physical water shortage begins to affect people.

As these stages evolve over time, the impacts to the economy, society, and environment converge into an emergency situation. Without reservoir water to irrigate farms, food supplies are in jeopardy. Without spring rains for the prairie grasslands, open range grazing is compromised. Without groundwater for municipalities, the hardships to communities result in increases in mental and physical stress as well as conflicts over the use of whatever limited water is available. Without water, wetlands disappear. The quality of any remaining water decreases due to its higher salinity concentration. There is also an increased risk of fires, and air quality degrades as a result of increased soil erosion in strong winds (blowing dust).

Drought conditions can vary considerably from region to region and location to location within Wyoming. There are multiple factors impacting moisture levels throughout the state, two of which are Wyoming's widely-varied topography and the size of the state. Wyoming lays claim to terrain consisting of mountains, rolling hills and plains, and Wyoming is ranked 10th among the states for its size with 97,818 square miles. Wyoming ranges in height from a mere 3,099 feet above sea level at the Belle Fourche River to 13,804 feet above sea level at Gannett Peak in

the Wind River Mountain Range, with the continental divide running from north to south through the state. (http://www.netstate.com/states/geography/wy_geography.htm) Moisture content varies significantly across the state due to the interaction of Wyoming's terrain with moisture content traveling across the state in weather systems. Weather systems containing rain and snow tend to interact significantly with Wyoming's terrain, and this of course, results in varied moisture from one side of the state to the other. Drought does seem to be cyclical in nature throughout Wyoming's history, though it can be expected to vary region to region within each drought cycle. Drought is addressed in an overall, state-level perspective throughout this chapter, rather than through the lens of a regional perspective. There is however, attention made to each local county's perspective of the drought hazard through review of local multi-hazard mitigation plans and extrapolation of data from them. It can be noted, all counties within Wyoming recognize drought as a local hazard, though the perceived intensity of its risk is varied.

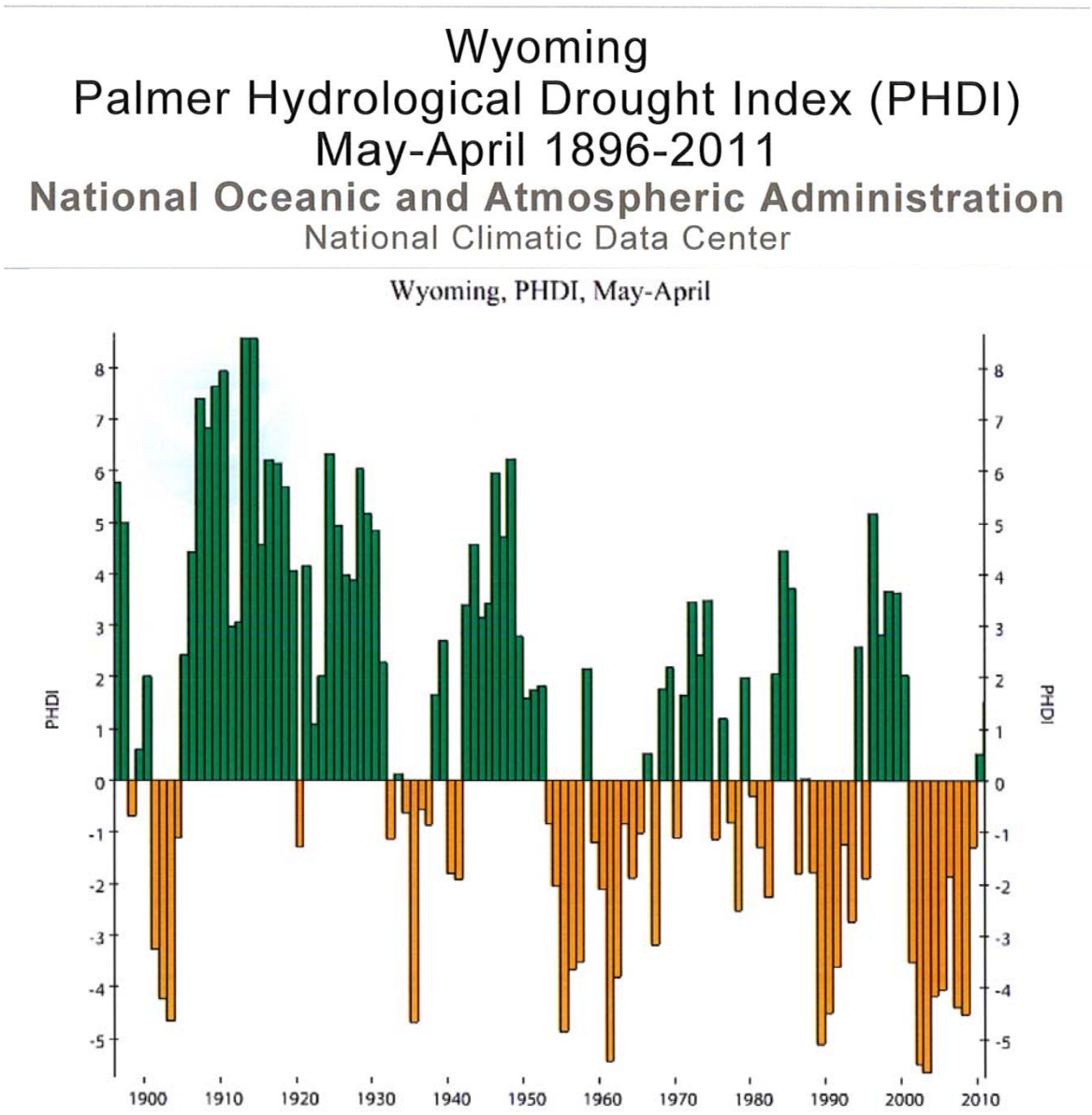
Drought Measurement

There are several methods for determining drought. One of the most popular is known as the Palmer Drought Severity Index (PDSI). Wayne Palmer developed this index in the 1960s; temperature and rainfall information are used in a formula to determine dryness. It has become the semi-official drought index. However, in the west much of the surface water is derived from mountain snowpack [i.e., the snow-water equivalent (SWE) as measured at a number of SNOTEL sites].

The PDSI is a "meteorological drought" index that responds to weather conditions that have been abnormally dry or abnormally wet. The index is calculated based on precipitation, temperature, and available water content (AWC) of the soil. The Palmer Index varies from +6.0 to -6.0 with a classification scale indicating relative meteorological and hydrological development cycles. **Table 5.1** reflects the range and extent of the PDSI classification system. There are concerns about the number of data points used to calculate the index as well as the accuracy of the data used.

Table 5.1—Palmer Drought Severity Index Classification System.	
4.00 to 6.00	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.50 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.50 to -0.99	Incipient dry spell

Table 5.1—Palmer Drought Severity Index Classification System.	
-1.00 to 1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to 3.99	Severe drought
-4.00 to -6.00	Extreme drought



The initial estimates are not considered as accurate as later updates. In Wyoming, the Palmer Index needs to be used with caution since much of surface water is derived from mountain snow pack and the PDSI does not use this as an input to the index. Additionally, the values selected for quantifying the intensity of drought and for determining a start and end of a drought were selected based on Palmer's study of central Iowa and western Kansas.

Another popular index used to determine drought is the Standardized Precipitation Index (SPI). This index measures the precipitation departure using the 1971 through 2000 average monthly totals. At this time the SPI is available for Wyoming, but there are concerns about the number of data points used to calculate the index as well as the accuracy of the data used. At this time the SPI is of limited use in Wyoming and needs to be used with caution.

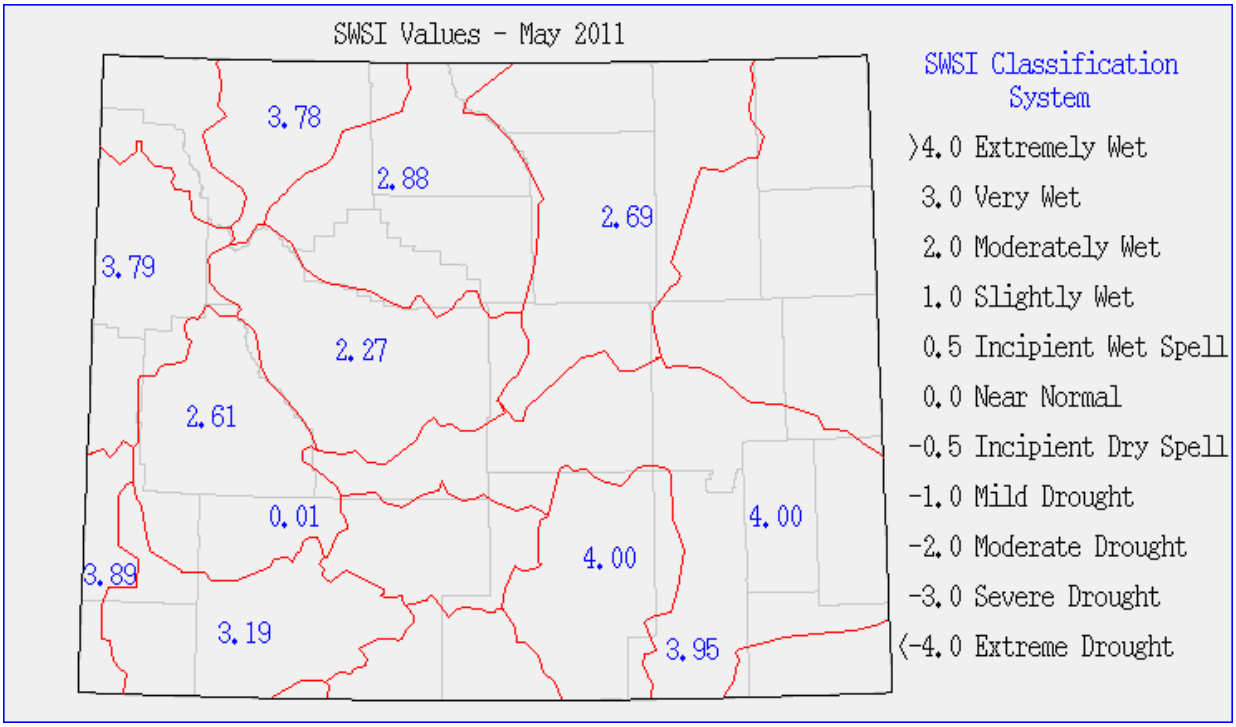
The Surface Water Supply Index (SWSI) was developed to complement the Palmer Index. The objective of the SWSI is to incorporate both hydrological and climatological features into a single index, and is intended to be an indicator of surface water conditions where mountain snowpack is a major component.

Four inputs are required for the SWSI: snow pack, stream flow, precipitation, and reservoir storage. Because it is dependent on the season, the SWSI is computed with only snow pack, precipitation, and reservoir in the winter months; stream flow replaces snow pack in the equation during the summer months. Like the Palmer Index, the SWSI is centered on zero and ranges from +4.2 to - 4.2, as shown in **Table 5.2** and in the map following.

Table 5.2—Surface Water Supply Index Classification System.

Range	Scale
+3.0 to +4.0+	Extremely wet
+2.0 to +3.0	Moderately wet
+1.0 to +2.0	Slightly wet
-1.0 to +1.0	Near average
-2.0 to -1.0	Slightly dry
-3.0 to -2.0	Moderately dry
-3.0 to -4.0-	Extremely dry

Wyoming Surface Water Supply Index



http://www.wrds.uwyo.edu/wrds/nrcs/swsimap/swsimap.html Accessed 5/25/2011

The Surface Water Supply Index (SWSI) is computed using only surface water supplies for the drainage. **(See above map)** The computation includes reservoir storage, if applicable, plus the forecast runoff. The index is purposely created to resemble the Palmer Drought Index, with normal conditions centered near zero. Adequate and excessive supply has a positive number and deficit water supply has a negative values. Soil moisture and forecast precipitation are not considered as such, but the forecast runoff may consider these values.

Another index used to measure drought involves soil moisture. This is a highly complex element that is difficult to accurately determine because there are few weather stations that directly measure surface and subsurface moisture and because precipitation and soil type are highly variable over a given region. Additionally, accuracy of direct measurement deteriorates when the soil temperature is below freezing. However, remote sensing from satellites can indicate the health of vegetation by measures of greenness, which can be used to indirectly determine soil moisture.

The final ingredients for determining drought are past accumulation and the amount of precipitation forecasted. In Wyoming, the April and May precipitation is critical for adequate prairie grassland growth. If the rains are late, the summer heat will reduce or completely eliminate any yield. Since rangeland is not normally irrigated, the short-term, spring weather

forecast must be accurate to ensure the most effective management of these lands. Farmers who depend on irrigation will know if drought can be expected if the April 1 snow pack is below normal and if the reservoirs are below 80% of their long term average levels. Percent of capacity of reservoirs is not a good standard to use because every reservoir's water level varies widely from one another throughout the year due to different management practices and environmental conditions. For example, water quality and endangered species protection requires managers to maintain minimum downstream outflow. There are also large inactive conservation reserves and dead water allocations in reservoirs that are part of total capacity but cannot be used in any way.

History

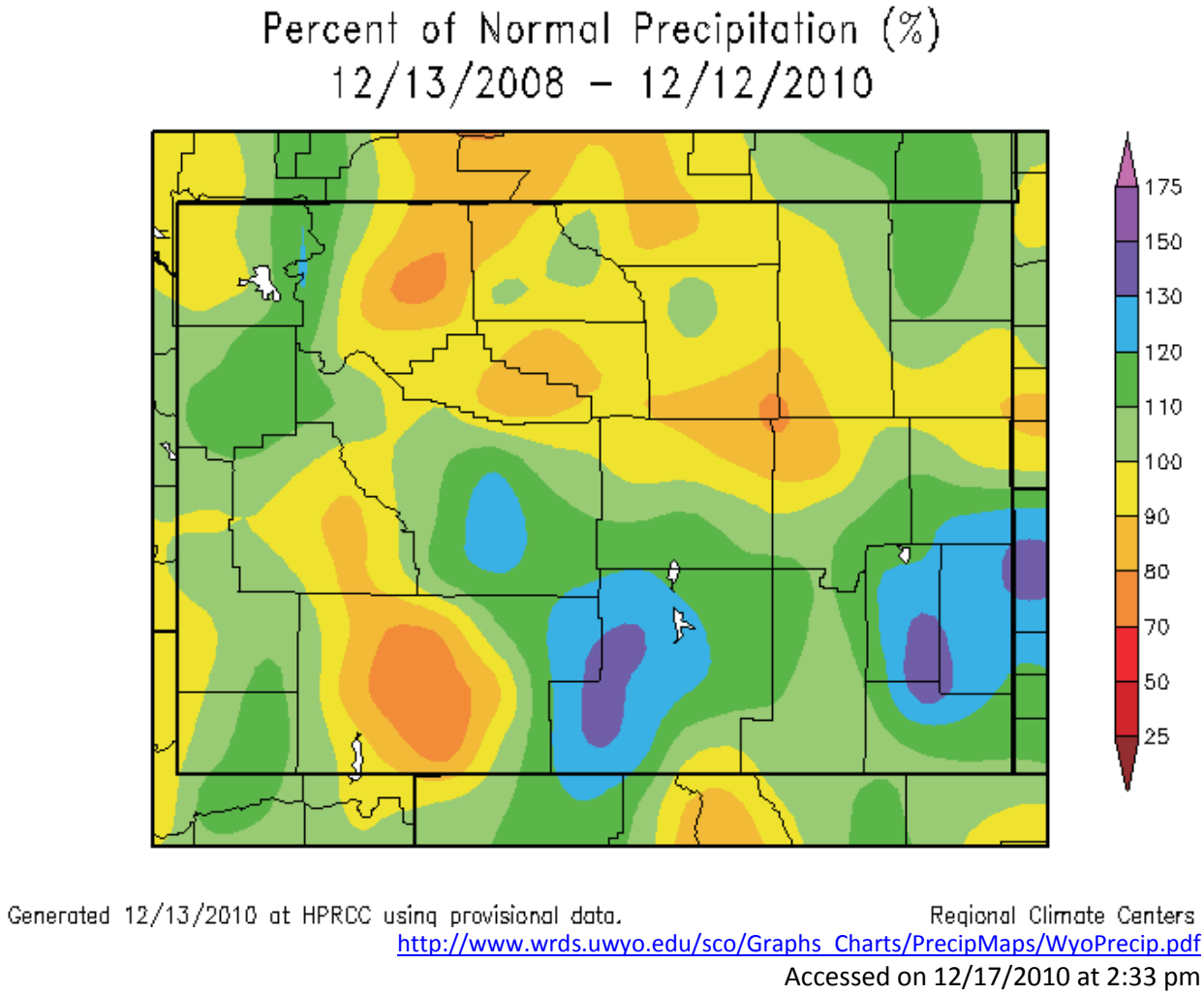
The most recent statewide drought started in 1999, but began in earnest in the spring of 2000. It is considered by many to be the most severe in collective memory. However, some longtime residents have indicated they remember streams drying up in the 1930s and 1950s. According to instrument records, there have been only seven multi-year (three years or longer) statewide droughts since 1895 (**Table 5.3**), although single wet years like 1957 (and probably 2005) have broken longer periods of drought (1952-1964 and 1999-present) into two separate events by this definition, making quantification of impacts difficult. Based on statewide average annual precipitation each of the drought periods is ranked as follows:

Table 5.3 - Wyoming's Recent Worst Multi-year, Statewide Droughts.

Drought Period	Average Annual Precipitation (Inches)	Percent of 1895-2006 Average Annual Precipitation (13.04")
1952-1956	10.65	81.69%
1900-1903	10.76	82.52%
1999-2004	11.07	84.89%
1987-1990	11.12	85.28%
1958-1964	11.67	89.49%
1974-1977	11.77	90.26%
1931-1936	11.79	90.41%

Widespread droughts in Wyoming, as determined from stream flow records, were most notable during three periods: 1929 to 1942, 1948 to 1962, and 1976 to 1982.

The years' precipitation levels from 2008 through 2010 in Wyoming are depicted in the map below:



http://www.wrds.uwyo.edu/sco/Graphs_Charts/PrecipMaps/WyoPrecip.pdf
Accessed on 12/17/2010 at 2:33 pm

Product of the Wyoming Water Resources Data System
http://www.wrds.uwyo.edu/
Data Courtesy: High Plains Regional Climate Center
http://www.hprcc.unl.edu/

Pre-settlement Drought

Numerous studies from throughout the world demonstrate that instrumental weather records are insufficient for capturing the full range of climate that the people in any region should expect and plan for. This is particularly true for understanding extreme events like droughts. The length of these instrumental records rarely exceeds 100 years and, therefore, provides only a small sample of single- and multi-year drought events. Furthermore, instrumental records cannot effectively be

used to examine long-term (>50-year) trends and cycles that may underlie year-to-year precipitation variability.

Most trees in the western U.S. produce a single layer of growth called a "tree-ring" for each year of their lives. During years of favorable climate, trees will produce wide rings compared to the narrower rings formed in years of unfavorable climate. Tree-rings, therefore, provide a means for developing long-duration climate records that can overcome most of the limitations inherent to instrumental observations. Tree-rings yield continuous, exact-dated proxies of climate that are highly replicated. When properly analyzed, tree-rings provide records of seasonal to annual climate, and can be used to assess climate variability on time scales of decades to millennia.

While, over the past 40 years, tree-rings have commonly been used to reconstruct the climate of the southwestern U.S., the systematic use of these dendrochronological (literally the "science of tree time") techniques to understand Wyoming's climate is relatively new. One recent study from the Bighorn Basin shows the promise of such methods for understanding drought in Wyoming. In this study, wood samples were collected from 95 Douglas fir, ponderosa pine, and limber pine trees at five sites in the Bighorn, Pryor, and Absaroka mountains (**Figure 5.1**). Samples from these trees were used to develop a record of annual precipitation spanning 1260 to 1998 A.D. Results from this study show that single-year dry events before the instrumental period (1895 to present) tended to be more severe than those after 1900 (**Figure 5.1**). In general, multi-year dry events were longer and more severe prior to 1900. Dry events in the late-13th to mid-18th centuries surpass both the magnitude and duration of any droughts seen in the Bighorn Basin after 1900. The 14th, 15th, and 16th centuries are also notable for large numbers of droughts having greater magnitude and duration than any events in the instrumental period.

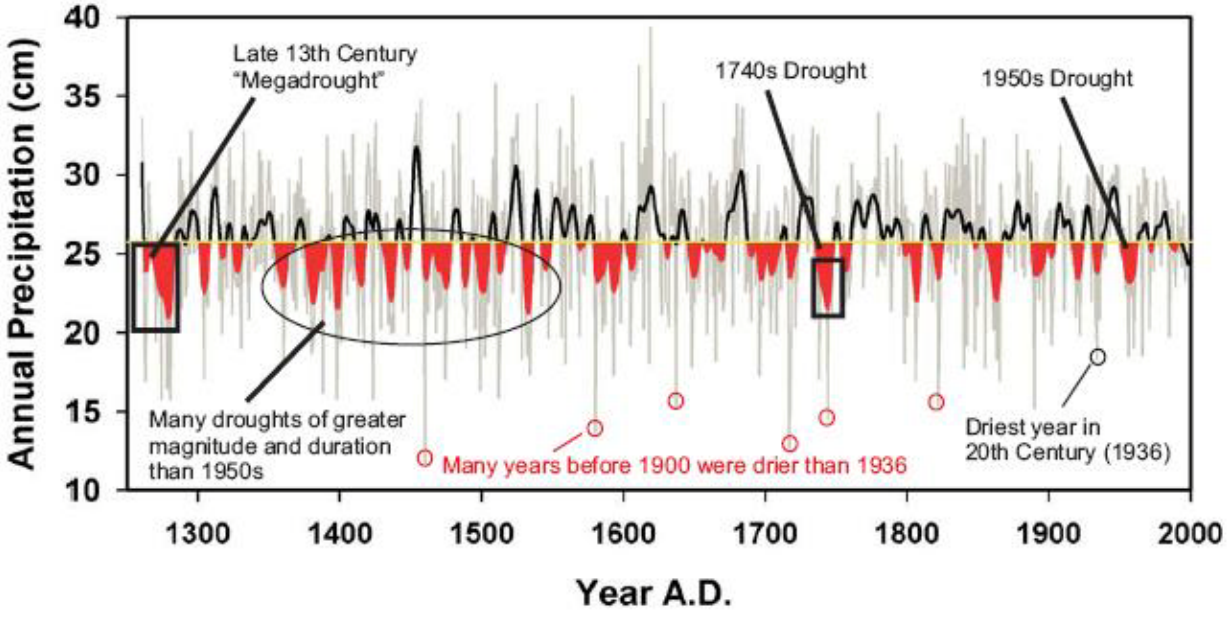
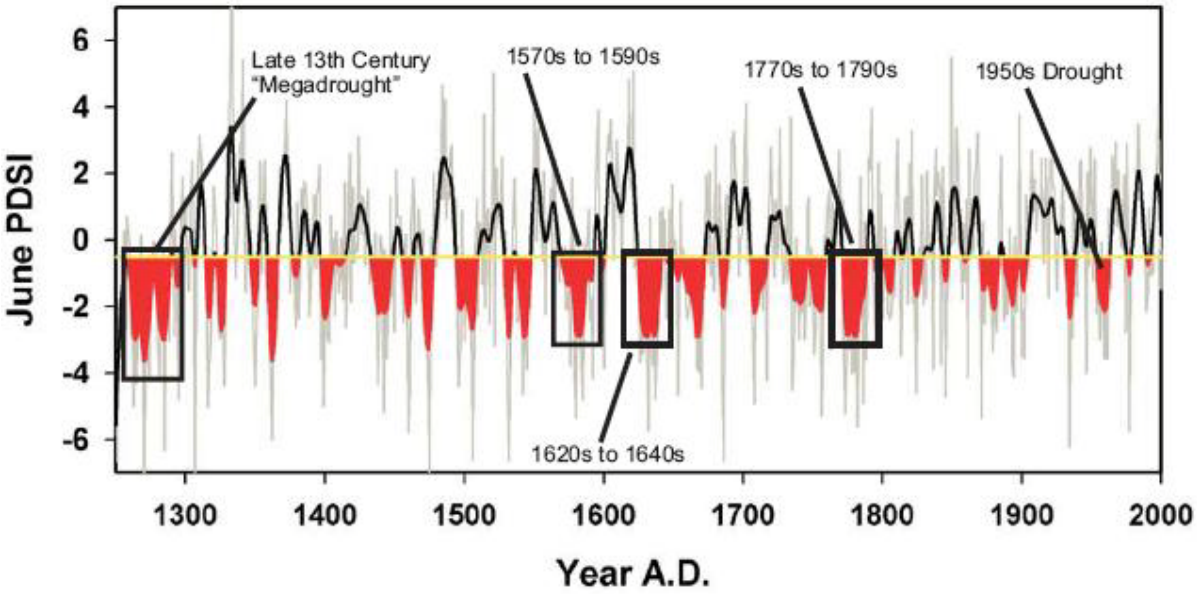


Figure 5.1—Reconstructed annual precipitation (in centimeters) for the Bighorn Basin region. Annual values are shown in gray. The 10-year running average of precipitation is plotted against the long-term mean (yellow line) with multi-year droughts shown in red.

Figure 5.2—Reconstructed (June) PDSI values for the Green River Basin region. The 10-year running average of PDSI is plotted against the long term-mean (yellow line) with multi-year droughts shown in red.



Trees from the foothills of the northern Uinta Mountains and the southern Salt Range provide insights on drought variability in southwestern Wyoming. **Figure 5.2** shows reconstructed PDSI values for the Green River Basin region from 1250 to 2000 A.D. High PDSI values indicate wet conditions while negative values represent droughts. Estimates for PDSI values prior to the instrumental period (1895 to present) were derived from the measurement of limber pine and pinion pine tree-rings at four sites surrounding the basin. Samples from 102 trees (both living and dead) are included in the reconstruction.

While the 20th Century dry-events recorded in these trees were quite severe, several droughts prior to instrumental period (*e.g.*, 1576 to 1590, 1620 to 1637, and 1773 to 1786) likely equaled or exceeded their duration. A number of pre-instrumental droughts, particularly those in the 1500s through mid 1600s, were of greater magnitude or severity than any dry events after the early 1900s. The late-13th Century is particularly notable for the occurrence of a severe 50-year drought.

These and other tree-ring studies from throughout the region suggest that severe, long-duration (>10-year) droughts are a common feature of Wyoming's climate and the climate of the Rocky Mountain West at large. While the droughts of the 1930s and 1950s were extreme events in terms of their social and economic impacts on Wyoming, the tree-ring record shows that the climate system is capable of producing longer and stronger droughts. Moreover, in some areas (*i.e.*, southwest Wyoming), parts of the 20th Century were marked by wetter than average

conditions. This means that predictions of future water availability based on stream gauge and instrumental weather observations during these years may be biased by abnormally high precipitation.

Overall, long dry spells are a normal part of life in Wyoming. This knowledge should, in turn, affect how we plan for Wyoming's economic and agricultural development. We must also incorporate this fact into our management of natural resources and include severe, sustained droughts in our plans for timber production, wildland and prescribed fires, non-native plant invasions, and water resources. Planning efforts should consider a wide range of climate scenarios, including droughts of different lengths, magnitudes, and intensities. Such scenarios may be derived from long-term proxies of climate variability such as those provided by tree-rings, but might also be obtained from model simulations of past and future climates. In any case, we must consider severe, sustained droughts to be an inevitable part of Wyoming's future.

Instrumentation Record

As a whole, Wyoming's precipitation record from 1895 to 2006 reveals that, for the first half of the 20th Century (except for the Dust Bowl years of the 1930s), there was generally a surplus of moisture. During the second half of the century there was a trend of increased periods of drought (**Figures 5.3a and 5.3b**).

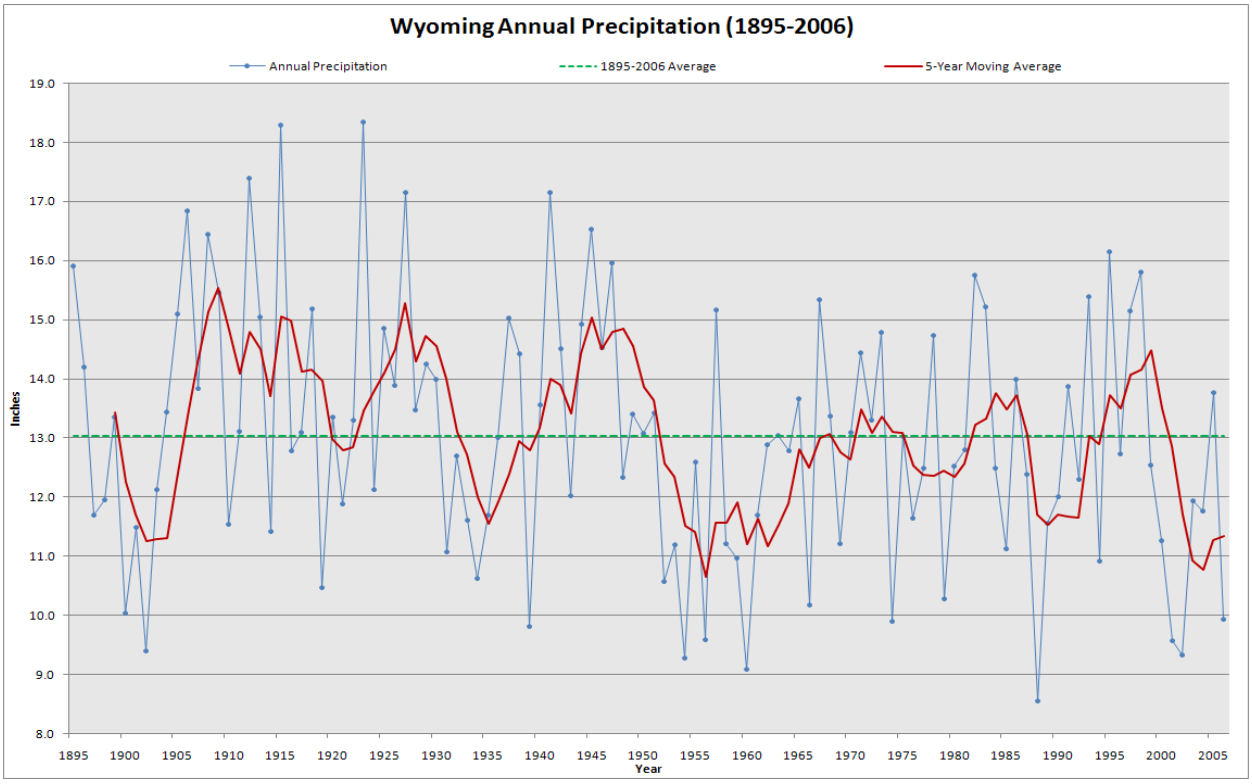


Figure 5.3a—Wyoming annual precipitation (1895 through 2006). Data Source: National Climatic Data Center

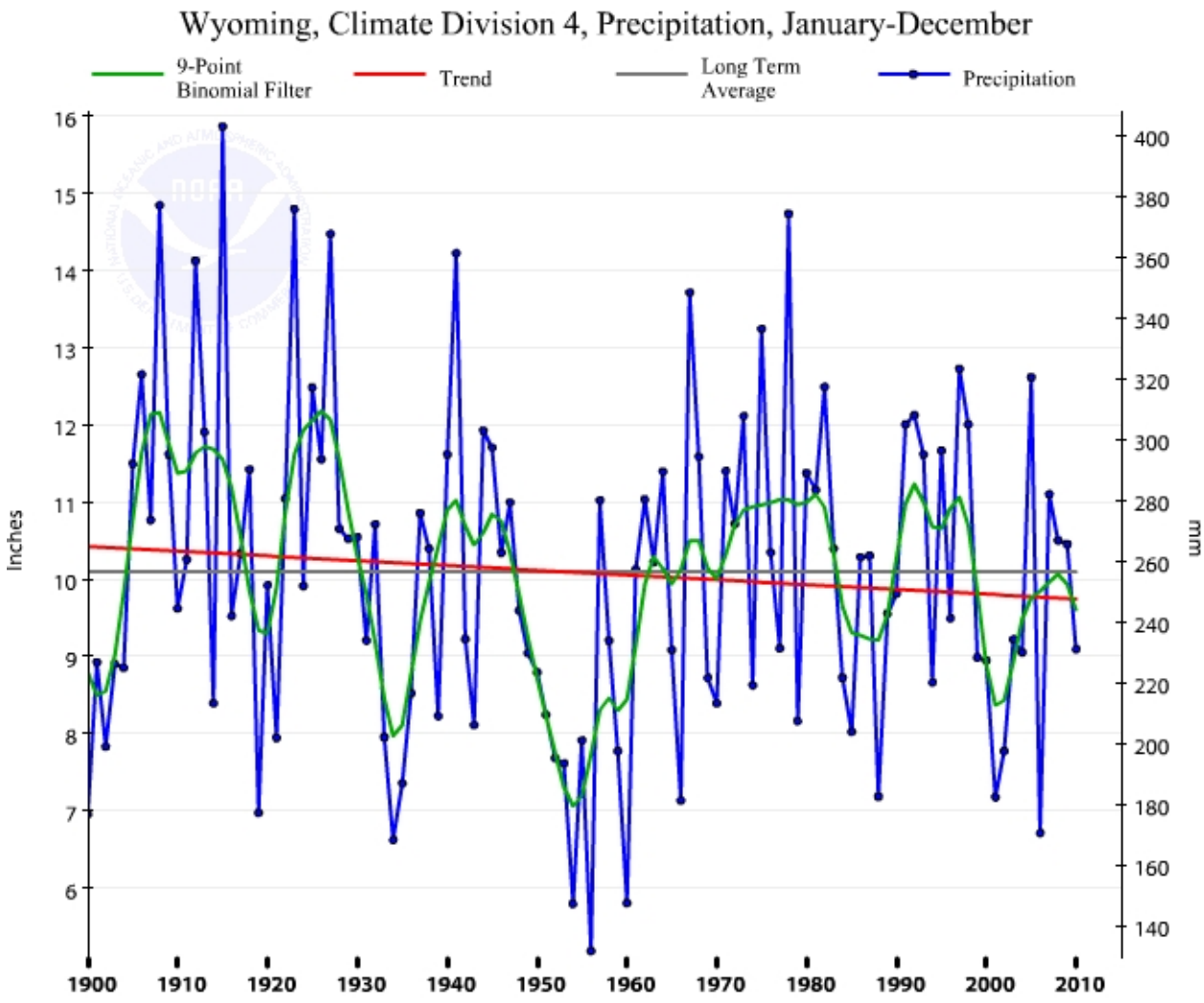


Figure 5.3b—Wyoming Annual Precipitation 1900-2010, National Climatic Data Center, Accessed 1/21/2011 http://www.ncdc.noaa.gov/temp-and-precip/time-series

Impacts

Based upon **Table 5.3** and **Figure 5.3a**, the drought of 1999 to 2009 is as significant, if not more significant than any other drought in the last 100 years. **Table 5.3**, from the *Wyoming State Climate Office*, indicates that the most significant droughts in the last century, in terms of annual statewide precipitation averages, were in 1952 to 1956, 1900 to 1903, and 1999 to 2004. In order to determine which drought period had the most significant impact on Wyoming, crop production and livestock inventory data for the 1952 to 1956 and 1999 to 2004 periods were compared. 1957 and 2005 were wetter years, with annual statewide precipitation totals above the 1895-2006 average. Those two years were used as endpoints for the droughts that started in 1952 and 1999 respectively. In both cases, the years following saw a return to drier conditions. Because of this, for the most recent drought impacts were also calculated for 2005 and 2006, and

are included in summary tables. **Tables 5.4** and **5.5** show peak decline (%) in production during drought compared to the 5-year pre-drought production average for various commodities.

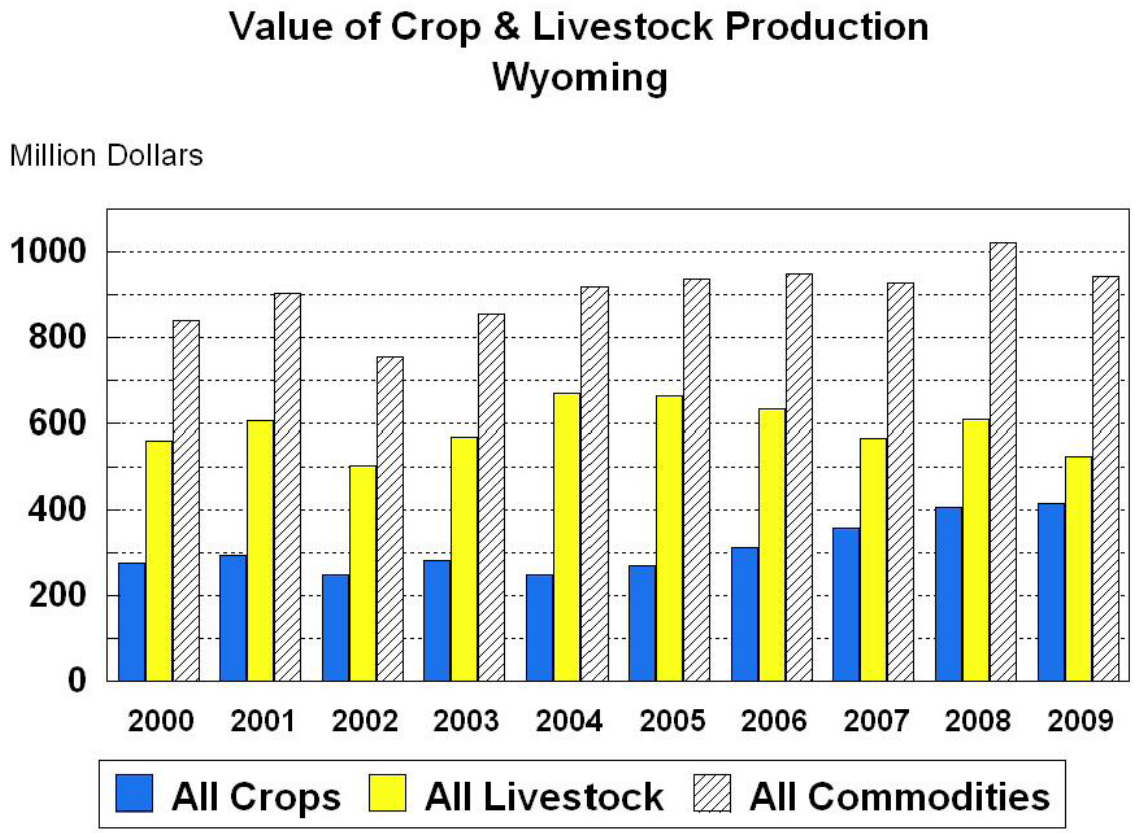
Table 5.4—Peak Commodity Production Changes From Pre-drought (1947 to 1951) to Drought (1952 to 1956).

Commodity	5-year pre-drought production average (1947 to 1951)	Units	Lowest production during drought (1952 to 1956)	Year of lowest production (1952 to 1956)	Percent change
Winter wheat	5,072	1,000 bu.	2,346	1954	-54%
Spring wheat	1,579	1,000 bu.	600	1954	-62%
Barley	4,414	1,000 bu.	2,700	1956	-39%
Oats	4,577	1,000 bu.	2,470	1954	-46%
Dry beans	1,009	1,000 cwt.	589	1955	-42%
Sugar beets	413	1,000 tons	421	1955	+2%
Corn	227	1,000 bu.	161	1953	-29%
Alfalfa hay	490	1,000 tons	675	1954	+38%
Other hay	674	1,000 tons	442	1954	-34%
Cattle/ calves inventory	1,050	1,000 head	1,096	1954	+4%

Table 5.5—Peak Commodity Production Changes From Pre-drought (1994 to 1998) to Drought (1999 to 2006).

Commodity	5-year pre-drought production average (1994-1998)	Units	Lowest production during drought (1999-2006)	Year of lowest production	Percent change
Winter wheat	6029	1,000 bu.	2375	2002	-61%
Spring wheat	648	1,000 bu.	96	2002	-85%
Barley	8383	1,000 bu.	4680	2002	-44%
Oats	1648	1,000 bu.	600	2005	-54%
Dry beans	691	1,000 cwt.	514	2001	-26%
Sugar beets	1150	1,000 tons	659	2002	-43%
Corn	6328	1,000 bu.	4165	2002	-34%
Alfalfa hay	1581	1,000 tons	1150	2002	-27%
Other hay	817	1,000 tons	450	2002	-45%
Cattle/calves inventory	1536	1,000 head	1320	2002	-14%

A comparison of **Tables 5.4** and **5.5** indicates that drought impacts to the Wyoming agricultural community were greater in the 1999 to present drought than in the 1952 to 1956 drought. With the exception of dry beans, all commodities in the worst years of the most recent drought showed a greater percentage decline in production than in the 1952 to 1956 drought. As a result, the 1999 to present drought will be used as the drought of historic record to calculate dollar impacts.



From the graph above and the table below, it is apparent the agricultural economy of Wyoming was fairly stagnant through the drought over the past 10 years.

VALUE OF PRODUCTION BY COMMODITY: WYOMING, 2000-2009

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
					1,000 Dollars					
All Commodities	**840,460**	**903,844.**	**755,084**	**856,594**	**921,207**	**938,663**	**949,471**	**927,928**	**1,021,592**	**943,332**
Livestock and Products	**561,228**	**608,331**	**503,682**	**572,055**	**670,041**	**666,138**	**633,636**	**566,772**	**611,406**	**526,648**
Cattle and Calves	497,851	542,823	449,894	481,680	556,374	566,158	525,294	436,790	462,999	399,522
Sheep and Lambs	23,479	19,155	21,412	32,044	34,092	37,055	34,575	31,896	31,170	32,119
Wool	2,143	2,015	2,738	4,015	4,259	3,530	3,082	3,969	4,380	3,248
Hogs	27,088	33,321	19,080	24,342	28,508	27,685	28,083	40,614	60,704	50,231
Chickens 1/	2	1	-	-	-	-	-	-	-	-
Eggs	165	168	146	186	182	119	138	242	193	134
Honey	2,140	1,902	3,184	4,454	3,218	1,994	3,249	3,440	3,259	2,540
Milk (farm value)	8,360	8,946	7,228	6,480	10,017	10,789	15,104	24,735	23,612	13,759
Crops	**278,606**	**295,026**	**251,028**	**283,972**	**250,386**	**271,520**	**314,946**	**359,983**	**406,533**	**416,684**
Crops (excl. sugarbeets)	241,036	263,504	223,152	252,990	216,526	237,237	277,600	333,531	371,607	381,021
Corn for Grain	15,465	14,663	10,829	16,125	16,244	16,807	15,325	24,149	29,614	26,460
Winter Wheat	11,016	7,776	8,788	13,311	11,232	15,225	16,694	20,875	24,268	23,575
Oats	2,302	2,218	1,650	1,987	1,232	960	1,471	1,060	1,956	1,800
Barley	24,286	23,140	15,116	24,134	24,041	18,302	16,085	16,308	35,052	37,632
All Hay	175,165	203,885	175,350	186,210	149,765	171,432	215,045	255,932	255,055	270,950
Dry Beans	12,802	11,822	11,419	11,223	14,012	14,511	12,980	15,207	25,662	20,604
Sugarbeets 2/	37,570	31,522	27,876	30,982	33,860	34,283	37,346	26,452	34,926	35,663

1/Value of sales.
2/The 2009 value of sugarbeet production is based on 2008 price and 2009 production. The 2009 price is not available until January 2011.

Local Mitigation Plan Risk Assessments

A review of the local plans reflects they recognize the hazard drought represents within their borders. Most of Wyoming's local multi-hazard mitigation plans reflect much of the information contained in the state plan with little additional information. It can be noted those counties with a greater agricultural economic base have a greater recognition of the economic impact drought has on their communities. Additionally, they have ranked drought risk within their borders based

on the population impacted, probability of occurrence within their borders and the property impacted.

Below is a table outlining information mined from the local plans' drought hazard sections. The table shows previous historical incidents of drought within each county's borders as outlined in their plans and extrapolates, based on population impacted, probability of occurrence within their borders, and property impacted, the risk perceived by each county relative to dam failure hazards. You will note all but three counties consider drought to rank as a 'high' hazard within their borders. This may also be because of the frequency drought is experienced within Wyoming counties and the rural, agricultural nature of many of Wyoming's counties.

Drought
Information Mined from Local Plans

COUNTY	Plan Y/N	Year Approved	Included in Plan	Rank-High, Medium, Low	Potential Loss Potential	Previous Incident(s)
ALBANY	Y	2010	Y	High	$769.6 million	Y/Multiple
BIG HORN	Approvable	2010	Y	High	Agricultural-Insurance Cov'd	Y/Multiple
CAMPBELL	Expired	2005	Y	Medium	$27.7 million-quoted from State Plan	Y/Multiple
CARBON	Y	2008	Y	High	$45.8 million	Y/Multiple
CONVERSE	N/Draft	2005			Incomplete Information	
CROOK	N/Draft	2003	Y		State-level Info from State Plan	
FREMONT	Expired	2005	Y		State-level Info from State Plan	Y/Multiple
GOSHEN	Y	2007	Y	High	$13 million	Y/Multiple
HOT SPRINGS	N					
JOHNSON	Y	2008	Y	High	$24 million	Y/Multiple
LARAMIE	Expired	2005	N			
LINCOLN	Y	2006	Y	High	$23 million	Y/Multiple
NATRONA	Approvable	2010	Y	Medium-Low	Low	Frequent
NIOBRARA	Y	2009	Y	High	historic-$1.9 million	Y/Multiple
PARK	Y	2006	Y	High	$40.15 million	Y/Multiple
PLATTE	Expired	2004	Y	Medium-Low	Incomplete Information	Y/Multiple
SHERIDAN	Y	2009	Y	High	$14.7 million	Y/Multiple
SUBLETTE	Y	2008	Y	High	$28.27 million	Y/Multiple
SWEETWATER	N					
TETON	Y	2009	Y	High	$23.7 million	Y/Multiple
UINTA	N/Draft	2011	Y		Not Stated	Y/Multiple
WASHAKIE	Expired	2005	Y	High	$7.1 million	Y/Multiple
WESTON	N					
NORTHERN ARAPAHO TRIBE	N					
EASTERN SHOSHONE TRIBE	N					

Development continues to occur in Wyoming, impacting the ratio of agricultural industry to metropolitan influences. Wyoming experienced a 14.1% population increase over the past 10 years as compared to the 9.7% population increase nationwide. While development is occurring at a greater pace in Wyoming as compared with the rest of the country, Wyoming still remains predominately rural. While drought does impact metropolitan areas, its impact tends to be more significantly felt in rural, agricultural cultures throughout Wyoming.

Wyoming's overall population remains predominately rural. The counties with the greatest percentage of increase, Campbell and Sublette Counties, remain at a density of 7 and 1.2 persons per square mile respectively. Overall, Wyoming's population density is 5.26 persons per square mile. Rural communities are more likely to have an agricultural component to their economic structure. Agricultural communities tend to be particularly impacted by drought conditions.

Future Potential Impacts

Wyoming's most recent drought, which began in 1999, can be shown to be a drought of historic record. Because drought is a slowly developing natural hazard rather than a suddenly occurring hazard, its impact is felt over a time period best measured in years rather than days or even over a single year. There have been significant impacts on the agricultural industry from this drought. The worst-case year was 2002, with a negative dollar impact of -$345.4 million. The total impact for the period 1999 to 2004 was -$769.6 million. While 2005 showed statewide average precipitation to be 0.73" above the long-term average, the following year, 2006 (9.94"), was the 10th driest in the period 1895-2006, indicating that, similar to the year 1957, 2005 is likely just a single wet year among a longer term period of drought. **Tables 5.12 and 5.13** show production in 2005 and 2006 continued to be impacted. The total impact from 1999 to 2006, therefore, has been -$1,094.3 million.

The likelihood of drought occurrence in Wyoming is 100%. According to NOAA interpretations using the Wyoming Palmer Hydrological Drought Index, Wyoming will experience critical drought cycles every 25 years, each averaging 10 years in duration. Drought years are often accompanied by an increase in wildfire activity, which occur randomly and at every elevation throughout Wyoming. The State's agricultural production, agribusiness, and support services are critically impacted as a result of these severe drought cycles. To mitigate losses to the State's economy and social structure, development of agricultural water storage capacity and infrastructure to conserve water in the process of conveyance may be the best course of action.

Proposed State Mitigation Projects

The following mitigation projects have been proposed by state, federal, and local entities in the process of generating the Wyoming Multi-Hazard Mitigation Plan. Chapter 22 has all proposed mitigation projects.

- Education.
- Deployment of solar powered well pumps in drought ridden areas.
- Wind technology study for water pumping and electrical development for water pumps.
- Development studies and projects of pipeline water distribution systems and water distribution policies for Wyoming.
- Water conservation projects and studies.
- Groundwater development.
- Study on productive use of produced water related to oil and gas industry.
- Enhanced forecasting and data distribution.
- Weather mitigation modification (cloud seeding expanded research).
- Statewide aquifer impact study.
- Build additional dams for water storage.
- Expanded or improved precipitation monitoring (Snowtel, etc.).
- Provide all-hazards weather radios to all residences in Wyoming.

- Identify and inspect shelters in hazard prone areas.
- Provide hazards info to shelters, emergency facilities in public buildings, campgrounds, and phone books.
- Develop reseeding plans for losses due to all hazard events.
- GIS training for local jurisdictions with emphasis on hazards recognition and analysis for application to mitigation planning.
- Investigate opportunities for developing or improving warning systems as a means to reduce loss of life, damage to property, and economic losses.
- Education programs encompassing multi-hazard insurance for business, resident and government application.
- Education programs encompassing multi-hazard mitigation for business, resident and government application.
- Planning studies regarding transportation of essential and/or key personnel during all hazard events.
- Continue outreach to counties on identifying cost effective and feasible mitigation projects.
- Promote Continuity of Operations and Continuity of Government, statewide.
- Maintain and continue to expand hazards databases that were generated for the State Hazard Mitigation Plan. Seek new sources of information.
- Identify, document, and advertise all volunteer agency's locations and contact information.