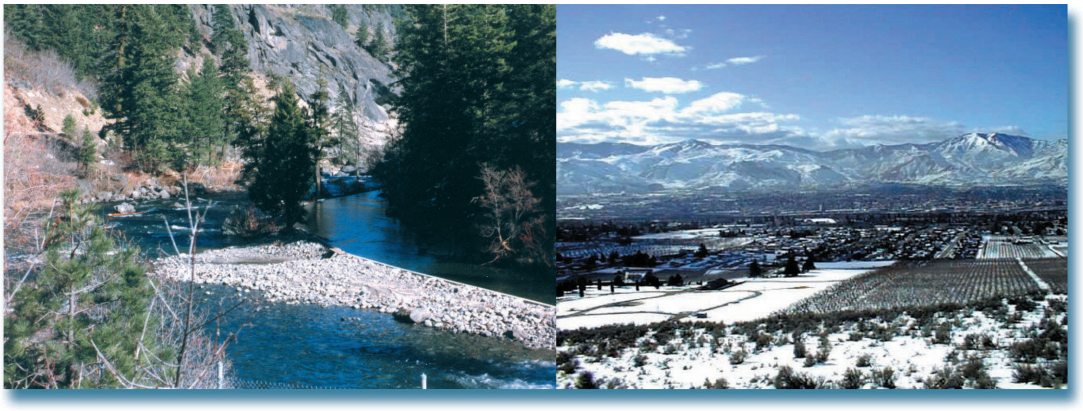
CHELAN COUNTY WATERSHED PROGRAM ■ WRIA 45

Wenatchee River Basin
WATERSHED ASSESSMENT



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Wenatchee River Basin Watershed Assessment

Prepared for:

Wenatchee Watershed Planning Unit and
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ACRONYM LIST

ADD	Average day demand
AFY	Acre feet per year
CCD	United States Census Bureau Census County Division
cfs	Cubic feet per second
CIR	Crop Irrigation Requirements
DOH	Washington Department of Health
DWAIN	Drinking Water Automated Information Network
Ecology	Washington Department of Ecology
EES	Economic and Engineering Services
ENSO	El Nino Southern Oscillation
ERU	Equivalent Residential Unit
FRD	Fruit Reporting District
GIS	Geographic Information System
gpd	Gallons per day
gpm	Gallons per minute
GWIS	Geographic Water Information System
IPCC	Intergovernmental Panel on Climate Change
IRPP	Instream Resources Protection Program
JISAO	Joint Institute for the Study of the Atmosphere and Oceans
MDD	Maximum day demand
MGD	Millions of gallons per day
NAS	National Academy of Sciences
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite Data and Information Service
NLCD	National Land Cover Data Set
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
OFM	Office of Financial Management
PDO	Pacific Decadal Oscillation
PNW	Pacific Northwest
POW	Point of Withdrawal
PWS	Public Water Systems
PUD	Public Utility District
RCW	Revised Code of Washington
RM	River Mile
SADIE	System for Automated DWAIN Information Extraction
SDWA	Safe Drinking Water Act
STORET	Storage and Retrieval System for Water and Biological Monitoring Data
USBR	United States Bureau of Reclamation

ACRONYM LIST, CONTINUED

USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDFW	Washington State Department of Fish and Wildlife
WFI	Water Facilities Inventory
WMA	Watershed Management Act
WRATS	Water Rights Application Tracking System
WRCC	Western Regional Climate Center
WRIA	Water Resource Inventory Area
WSDA	Washington State Department of Agriculture
WSU	Washington State University

1.0 Introduction

This assessment was prepared for the Wenatchee Watershed Planning Unit (WRIA 45). The purpose of this technical assessment is to characterize the water resources of WRIA 45 to provide a scientific basis for developing a watershed plan. This assessment was prepared with the data available at the time of printing. Assessment work will continue in the Wenatchee Watershed and any new data will be submitted to the planning unit as necessary.

This section presents an introduction to the Wenatchee River Basin Watershed Phase 2 Technical Assessment. Chapters 2-7 describe the physical setting, land use and land cover, summarize existing hydrologic data, characterize precipitation, streamflow, and groundwater interaction with surface water, present water rights and water use and describe existing regulatory instream flows.

1.1 Regulatory Framework

The 1998 Legislature passed Engrossed Substitute House Bill 2514 (The Watershed Management Act) to provide a framework for citizens, governments and other interest groups to collaboratively solve water related issues on a watershed-wide basis. Three phases of planning are identified in the law. Those phases are:

- Phase 1: Organizing Phase
- Phase 2: Assessment Phase
- Phase 3: Planning Phase

The Watershed Management Act identifies four elements that can be addressed as part of a Watershed Plan. Those elements are water quantity, water quality, habitat and setting of instream flows. The water quantity element is mandatory if grant funding is received. The other topics may be addressed but are optional under the law. The Watershed Management Act also specifies the type of information that must be collected for each topic to satisfy the requirements of the law.

This Watershed Technical Assessment is prepared to satisfy the requirements of the second, or assessment, phase of watershed planning and specifically the Water Quantity element.

1.2 Wenatchee River Basin Watershed Description

Water Resource Inventory Area (WRIA) 45, the Wenatchee River Basin Watershed, encompasses approximately 1,371 square miles, with 230 miles of major streams and rivers, not including those portions of WRIA 45 that drain directly into the Columbia River (Chelan County Conservation District, 1994). WRIA 45 originates in the Cascade Mountain Range with major tributaries draining from the Alpine Lakes and Glacier Peak wilderness areas. The Entiat Mountains to the northeast and the Wenatchee Mountains to the southwest flank the basin. The main surface feature of the Wenatchee River watershed is the Wenatchee River. The Little Wenatchee and White Rivers flow into Lake Wenatchee, the source of the Wenatchee River. Proceeding downstream from the lake outlet at River Mile (RM) 54.2, Nason Creek joins at RM 53.6 (just downstream of the mouth of Lake

Wenatchee) and the Chiwawa River joins about 5 miles downstream near Plain. The river descends rapidly through Tumwater Canyon, dropping into a lower gradient section in the region of Leavenworth, where Icicle Creek joins the mainstem (RM 25.6). Other major tributaries include Chiwaukum (RM 35.6), Chumstick (RM 23.5), Peshastin (RM 17.9), and Mission (RM 10.4) creeks. The river then flows southeasterly through the Wenatchee Valley and discharges into the Columbia River at Wenatchee. Map 1 provides an overview of WRIA 45. For the purposes of this Assessment, the watershed was divided into subbasins, which are shown on Map 1. Although an effort was made to use the boundaries of subbasins defined for other studies and planning efforts, the subbasins shown on Map 1 may not fit exactly with other subbasin definitions as the boundaries were prepared for the purposes of this study.

1.3 Purpose And Scope

The purpose of this Phase 2 Technical Assessment is to characterize water resources within WRIA 45 to provide a scientific basis for developing a watershed plan. This assessment was prepared for the WRIA 45 Planning Unit (formed under ESHB 2415; Chapter 90.82 RCW) and the lead agency, Chelan County, as directed by the County's Natural Resource Program. The WRIA 45 Planning Unit is made up of a diverse group of stakeholders representing a wide range of interests throughout the watershed. These interests include local governments, tribes, state and federal agencies, irrigation, agriculture, forestry, community groups, conservation groups, economic development, recreation, and individual citizens. The Water Quantity/Instream Flow Technical Subcommittee of the Watershed Planning Unit was the primary reviewer of technical work performed for this Assessment.

The Scope of Work for this Phase 2 Technical Assessment includes eight technical tasks. Those tasks are:

1. Estimate Surface and Groundwater Present
2. Estimate Water Use
3. Estimate Amount of Water Allocated
4. Assess Streamflow by Seasons
5. Summarize Administrative Status of Each Stream
6. Assess Surface Water – Groundwater Interaction
7. Assess Seasonal and Cyclical Effects of Precipitation
8. Assess Effects of Land Use Changes on Water Quantity

Those tasks are addressed in the following sections. In addition to those technical tasks, data gaps and recommendations for potential future studies are presented.

2.0 Land Use and Land Base

2.1 Land Use

The County GIS and tax parcel database was obtained and analyzed to determine zoning and land use for parcels throughout the Watershed. The primary zoned land classifications in the Wenatchee River Watershed are forestry, residential and agriculture. Eighty six percent of the watershed is classified as forest or wilderness use. Table 1 presents a breakdown of the area of different zoning classifications for the watershed. Map 2 provides an illustration of the distribution of zoning classifications throughout the watershed. The total area shown in Table 2-1 is 1,331 square miles, slightly less than the area within WRIA 45. The difference is the area at the downstream end of the Wenatchee River that does not drain to the Wenatchee River. That area has been excluded from analyses for this assessment as it does not receive water or contribute water to the Wenatchee River. Table 2-2 provides a summary of land use also from the County parcel database. Map 3 provides a representation of the agricultural land uses found in that analysis. Only the agricultural uses are shown on Map 3 as there were too many categories to show and the area within agricultural use is used in Section 6 – Water Rights and Water Use. Appendix A provides a more detailed breakdown of Zoning Classifications and land use by each individual subbasin shown in Maps 1-3.

Table 2-1
Area of Zoning in Wenatchee Watershed

Land Use Classification	Totals	% of Watershed
Commercial Agricultural	8,195	1.0%
Forest	732,209	86.0%
Public	1,226	0.1%
Rural Residential /Resource 2.5	4,411	0.5%
Rural Residential /Resource 5	19,227	2.3%
Rural Residential /Resource 10	14,619	1.7%
Rural Residential /Resource 20	59,576	7.0%
Total Rural Residential /Resource	97,833	11.5%
Rural Village	1,860	0.2%
Rural Commercial	236	0.0%
Rural Industrial	376	0.0%
Rural Recreational and Resource	853	0.1%
Rural Waterfront	1,484	0.2%
Urban Residential 1	8	0.0%
Urban Residential 3	2	0.0%
Total Urban Residential	10	0.0%
Peshastin Village Commercial	2	0.0%
General Commercial	5	0.0%
Industrial	4	0.0%
Commercial Mineral	241	0.0%
City Urban Growth Area	2,669	0.3%
Open Water	4,325	0.5%
Totals	**851,527**	**100.0%**

Source: Chelan County Planning Parcel Database

Table 2-2
Land Use Area in Wenatchee River Watershed

Land Use Designation	Area (acres)	Land Use Designation	Area (acres)
Agric In Open Space RCW 84.34	9,300.1	Other Cultural & Recreational	3.0
Agriculture Related Activities	87.2	Other Resource Production	4,812.7
Agriculture-Not In Open Space	6,562.7	Other Retail Trade	10.1
Aircraft Transportation	20.5	Other Trans, Comm, & Utilities	2.9
All Other Residential	1,556.9	Other Undeveloped Land	259.2
Amusements	4.8	Parks	435.5
Automobile Parking	2.6	Personal Services	6.2
Business Services	9.5	Petroleum Refining/Related Ind	9.6
Communication	19.9	Primary Metal Industries	7.9
Contract Const Services	39.3	Professional Services	15.9
Cultural Activities	0.0	Public Assembly	356.7
Desig. Forest Land RCW 84.33	64,606.6	Railroad/Transit Trans	118.9
Educational Services	98.4	Recreational Activities	428.2
Fabricated Metal Products	1.4	Repair Services	10.6
Finance, Ins/Real Estate Serv.	4.2	Residential Hotels-Condominium	7.3
Food/Kindred Products	8.8	Resorts And Group Camps	382.0
Furniture And Fixtures	0.6	Retail Trade-Apparel/Access	0.2
Governmental Services	344,757.1	Retail Trade-Bld. Mat.,Farm Eqpt	18.8
Highway/Street Right-Of-Way	15.4	Retail Trade-Eating/Drinking	41.8
Hotels/Motels	119.7	Retail Trade-Food	31.1
Household 2-4 Units	13.8	Retail Trade-Furniture	666.5
Institutional Lodging	82.5	Retail Trade-Gen Merchandise	4.6
Lumber/Wood Prod Exc Furniture	148.2	Retail Trade-Trans/Accessories	3.2
Mining Activities	487.9	Rubber/Misc Plastic Products	1.1
Miscellaneous Manufacturing	2.5	Single Family Units	16,807.1
Miscellaneous Services	3,284.8	Stone, Clay & Glass Products	2.4
Mobile Home Parks/Courts	76.2	Timberland In Open Sp Rcw84.34	2,017.7
Multi-Units 5 Or More	14.5	Undeveloped Land	38,040.6
Non-Residential Condominiums	0.2	Utilities	1,060.6
Noncommercial Forest	23,590.9	Vacation And Cabin	7,344.2
Open Space RCW 84.34	544.0		

2.2 Land Cover

An analysis of the type and amount of land cover in the Wenatchee Watershed was performed using data obtained from the National Land Cover Data (NLCD) Set for 1992 (USGS, http://landcover.usgs.gov/natllandcover). The NLCD was prepared by the USGS using remote sensing techniques. GIS coverage of the NLCD was obtained and analyzed for each subbasin and the entire watershed. Table 2-3 presents a summary of the analysis for the entire watershed. A summary of land cover for each subbasin is provided in Appendix A. The primary land cover is evergreen forest (67%), followed by grasslands and herbaceous cover (11.6%), shrubland (7.9%), bare rock, mines or gravel (5.3%), deciduous forest (2.1%), transitional land use (1.8%), orchards (1.4%) followed by smaller land covers. The total agricultural area mapped by the USGS is 12,836 acres. The NLCD is being updated using 2002 data but will not be available until 2004.

Table 2-3
Land Cover in Wenatchee River Basin Watershed

Classification	Area (acres)	% of Basin Area
Water	8,448.8	1.0%
Perennial Ice, Snow	2,943.5	0.3%
Low Intensity Residential	1,759.3	0.2%
Commercial, Industrial, and/or Transportation	1,496.5	0.2%
Bare Rock, Sand or Clay	45,251.7	5.3%
Quarries, Strip Mines, or Gravel	28.0	0.0%
Transitional	15,196.3	1.8%
Decidious Forest	17,416.7	2.1%
Evergreen Forest	567,650.2	67.0%
Mixed Forest	7,907.1	0.9%
Shrubland	66,487.8	7.9%
Orchards, Vineyards, Other	11,572.9	1.4%
Grasslands, Herbaceous	98,054.2	11.6%
Pasture, Hay	933.1	0.1%
Row Crops	28.1	0.0%
Small Grains	256.8	0.0%
Fallow	8.0	0.0%
Urban, Recreational Grasses	37.5	0.0%
Woody Wetlands	1,401.6	0.2%
Emergent Herbaceous Wetlands	72.5	0.0%
Total	846,950.5	100.0%

Source: USGS 1992 National Land Cover Data Set

3.0 Climate

3.1 Climate Cycles

Climate research has identified a number of somewhat-regular cycles in temperature, precipitation, atmospheric pressure, and other climate phenomena over large areas of the globe, lasting from several months to several decades. The best known is the El Niño Southern Oscillation (ENSO), an anomalous oceanographic and atmospheric event in the equatorial Pacific Ocean that usually occurs every two to seven years. El Niño is the warm phase of this cycle and is characterized by an increase in the sea-surface temperature in the eastern equatorial Pacific Ocean. The opposite or cold phase of this cycle is called either La Niña or El Viejo. A similar phenomenon, less well known but equally as important in understanding climate variability, is the Pacific Decadal Oscillation (PDO). The PDO is a pattern of varying ocean temperature that reverses on a 20-30 year timescale, is dominant in the North Pacific, and affects regions of North America. The warm phases of both cycles tend to warm the ocean off the coasts of Washington and Oregon, which leads to drier, warmer winters than average. The cold phases of both cycles tend to have the opposite effects. Because of differences in their periodicity, the two cycles may either reinforce or offset each other. Typically, warm, dry PDO phases enhance La Niña conditions and weaken El Niño conditions, while cool, wet PDO phases enhance El Niño conditions and weaken La Niña conditions (see the Joint Institute for the Study of the Atmosphere and Oceans, School of Marine Affairs, University of Washington web page: http://tao.atmos.washington.edu/PNWimpacts/CDTheme.htm#Sec3). The period of occurrence of PDO phases are listed in Table 3-1. Table 3-2 lists the years of occurrence of ENSO phases. In Table 3-2, the ENSO phases are also differentiated by their strength. For years that are not listed in Table 3-2, neither El Niño nor La Niña occurred.

Table 3-1
PDO Phase from 1900-Present

PDO Phase	Time Period
Warm, Dry	1925-1945, 1977-1995
Cool, Wet	1900-1924, 1946-1976, 1995-Present

Table 3-2
ENSO Phase from 1900-Present

Strong La Niña	La Niña	El Niño	Strong El Niño
1906	1908	1902	1905
1910	1909	1904	1911
1916	1921	1913	1914
1917	1924	1918	1923
1938	1945	1919	1940
1950	1947	1925	1941
1955	1956	1932	1965
1973	1964	1946	1972
1975	1970	1953	1977
1988	1971	1957	1982
1998	1974	1963	1987
	1981	1969	1993
	1996	1991	1994
	2000	1992	1997
		2002	

Note: Years not listed were neither El Niño or La Niña Years

The time histories of PDO and ENSO can be correlated with time histories of other meteorological parameters, like streamflow or snow depth, to gauge the impact that these year-to-year variations over the Pacific Ocean have on the region's water supply. Even though the variations in temperature and precipitation are approximately equal for PDO as for ENSO, the persistent nature of the PDO means that it has stronger impacts on some climate characteristics than does ENSO. For that reason, and because its timescale (20-30 years) is a bit closer to the climate-change timescale (50-100 years), the PDO is an important phenomenon to consider when managing water resources (Scott et al, 2000).

3.2 Pacific Northwest Climate Change

Temperature variability is significant, particularly in the Pacific Northwest (PNW), in determining whether precipitation falls as rain or snow. Temperature variability is dependent on the chemical composition of the atmosphere. One cause of temperature change is the "greenhouse effect", a natural process in which certain atmospheric gases (water vapor, carbon dioxide and methane being the most significant) allow some of the sun's radiant energy to be absorbed by the atmosphere. This leads to a natural warming of the Earth's atmosphere. Throughout history the natural warming due to the greenhouse effect has kept the planet warm enough to sustain life. What is unusual, however, is the rate at which carbon dioxide and other greenhouse gases are now increasing. In the last 150 years, the production of carbon dioxide has increased by 32% due to burning of fossil fuels.

Methane has increased by 151%, primarily through agricultural practices (Mote et al, 2001).

The 2001 report from the Intergovernmental Panel on Climate Change (IPCC), an international scientific body addressing climate change, states that the planet is indeed warming and that it is not due to natural causes. The IPCC states, "An increasing body of observations gives a collective picture of a warming world and other changes in the climate system." The evidence collected included the following (Mote et al, 2001):

- Global average surface temperature has very likely increased by 0.4 – 0.8º C
- Snow cover has decreased by approximately 10% since the late 1960's
- Glaciers and sea ice extent have decreased
- Spring, as marked by blooming or leafing-out dates of various plants, is coming earlier in much of North America

During the past 100 years, the PNW has become warmer and wetter. The average temperature has increased 0.8º C (1.5º F) (Mote et al, 2001). The warmest year in most of the PNW (especially east of the Cascades) was 1934, but the warmest decade was the 1990's, warmer than any other decade by 0.5º C (0.9º F) (Mote et al, 2001). Changes in precipitation have occurred as well, with most climatological stations showing an average annual increase of 2.9 inches over the last 100 years (Mote et al, 1999). The increase has been greater than 30% per century at approximately a dozen stations, mostly in eastern Washington, eastern Oregon, and western and northern Idaho. The changes in regional precipitation are unevenly distributed over the year (Mote et al, 2001).

Climate simulation models project temperatures in the PNW to warm 1.7 - 3.5º C with an average of 2.8º C from the 20th Century to 2050. Projected precipitation changes vary from -5% to +20% in most months between November and May, with an average of about +10%, therefore the wet season is projected to get even wetter (Mote et al, 2001). The average projected precipitation change during the dry season (i.e., June-October) is near zero. Historic and projected temperature and precipitation changes are summarized in Table 3-3.

Table 3-3
Climate Variability – Historic and Future (modeled)

	Historic Change 1900-2000	Projected Change in 2050 Range	Average
Temperature	+ 0.8º C (1.5 ºF)	1.7 – 3.5º C	2.8º C
Precipitation	+ 2.9 inches	-5 – + 20 %	+ 10 %

Climate change could significantly impact the availability of water resources in the region, particularly during summer months. The PNW relies on snowpack to transfer water from the wet season to the dry season. Modest increases in temperature dramatically affect snowpack depth and areas of accumulation as more precipitation falls as rain rather than snow during critical winter months.

Various studies have been performed at the University of Washington to understand the impacts of climate change on river basins in the Pacific Northwest. One of the studied basins is the Columbia River Basin, within which the Wenatchee River Basin is located. Water availability and streamflow in the Columbia River Basin are highly influenced by snowmelt, as most of the watershed is located at high elevations where temperatures are below freezing for most of the winter. The warming temperatures due to climate change could cause more of the precipitation to fall as rain in the winter, leaving less water stored as snowpack to supply summer streamflow. Higher spring and summer temperatures melt the snow earlier, increase the length of the growing season, and increase summer evapotranspiration, which also results in less spring, summer and fall streamflow. Projections reveal that by 2020-2030 the spring melt could occur 1-2 months earlier than it does now, with fall streamflow returning to normal levels 1-2 months later (Hamlet, no date). The maximum flows in late spring and early summer months could decrease by 17% below average historic levels in 2020, and by as much as 27% by 2050. In late summer and fall months, modeled flows decrease by an average of 25% in 2020 and 2050 (Hamlet, no date).

3.3 Precipitation Analysis

The Cascade Mountains and the prevailing westerly winds are the dominant climatic factors influencing the Wenatchee watershed. Moist air from the Pacific Ocean uplifts and cools as it moves east over the mountains. The Cascade Mountain area is characterized by heavy precipitation, with nearly 150 inches of annual precipitation and over 25 feet of snow accumulation at the crest. Winter daily temperatures average 25º F to 40º F, with summer temperatures averaging 60º F to 80º F. As air masses move east toward the Columbia Basin, moisture progressively decreases, resulting in arid conditions within the lowermost region of the watershed. In contrast to the mountainous areas, the City of Wenatchee receives 8.5 inches or less of precipitation with maximum summer temperatures reaching 95ºF to 100º F. Violent summer thunderstorms occur periodically, and can result in flash flood conditions on local watersheds.

3.3.1 Existing Precipitation Data

Several data sources were used to obtain precipitation data for WRIA 45, including the Western Regional Climate Center (WRCC) and the Natural Resources Conservation Service SNOWTEL (NRCS). Each of these data sources is discussed in more detail below.

Western Regional Climate Center

The National Oceanic and Atmospheric Administration's National Weather Service (NOAA/NWS) administers the Western Regional Climate Center. The National Climatic Data Center (NCDC) of the National Environmental Satellite, Data, and Information Service (NESDIS) provides oversight. The WRCC supports a three-tiered national climate services support program - the partners include the National Climatic Data Center, the Regional Climate Centers, and the State Climate Offices. Databases of the station data inventory listings for NOAA/NWS are posted to the WRCC web site at the following URL: http://www.wrcc.sage.dri.edu/index.html. The National Climate Data Center's Climate Data NCDC hourly precipitation are

available on CD-ROM at the University of Washington library network or can be purchased via their web page: http://www.ncdc.noaa.gov/.

There are three active climate stations in WRIA 45. One is located in Leavenworth, another in Plain, and the third is in the City of Wenatchee. There is one active climate station just outside of WRIA 45, located at the Wenatchee airport. Three inactive climate stations were also located in WRIA 45. Those stations were located at Stevens Pass, Lake Wenatchee, and at an Experimental Station in Wenatchee. Descriptions of the active and inactive stations are listed in Table 3-4. Map 4 shows the locations of the active and inactive stations.

Table 3-4
Available NWS Climate Records in/near WRIA 45

Agency	Station No.	Name/Location	Period of Record	Average Annual Precipitation (inches)
NWS	458089	Stevens Pass	1950-1994	84.5
NWS	454446	Lake Wenatchee	1948-1985	39.3
NWS	456534	Plain	1948-Present	37.0
NWS	454572	Leavenworth 3 S	1948-1973, 1979-Present	25.3
NWS	450929	Wenatchee EXP STN	1950-1951, 1971-1997	10.3
NWS	459074	Wenatchee	1931-Present	8.9
NWS	459082	Wenatchee FAA AP	1959-Present	8.4

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) provides data and performs research on climate and other environmental issues. They operate the National Water and Climate Center, which provides a variety of climate and water information. One program they run is SNOWTEL, a snowpack telemetry program providing snow and other climate data for the western United States. A site list with links to data is available from their website at:

http://www.wcc.nrcs.usda.gov/water/snow/sntllist.html .

There are four active SNOWTEL sites in or near WRIA 45. The stations in WRIA 45 are located at Stevens Pass, Blewett Pass, and Upper Wheeler. The Fish Lake station is located just outside the western boundary in Kittitas County. Descriptions of those stations are provided in Table 3-5. Map 4 shows the location of the SNOWTEL stations.

Table 3-5
Available SNOWTEL Records in/near WRIA 45

Agency	Station No.	Name/Location	Period of Record	Average Annual Precipitation (inches)
NRCS	21b01s	Stevens Pass	1980-Present	84.5
NRCS	21b04s	Fish Lake (Kittitas County)	1981-Present	64.9
NRCS	20b20s	Blewett Pass	1981-Present	35.5
NRCS	20b07s	Upper Wheeler	1981-Present	27.3

3.3.2 Spatial Distribution of Precipitation

The majority of precipitation from Pacific Ocean storms falls on the western slope and along the crest of the Cascade Mountains. The rain shadow caused by the Cascade Mountains creates a strong gradient in precipitation from west to east in the Wenatchee Watershed. Stevens Pass is the furthest west station in WRIA 45. It has the highest annual average precipitation of all of the stations examined (84.5 inches). Wenatchee, the furthest east station in WRIA 45, has 1/10th the annual average precipitation of Stevens Pass (8.9 inches). Figure 3.1 provides a time series of annual precipitation volumes recorded at climate stations listed in Table 3-4.

The geographic distribution of precipitation is a significant controlling factor in the variation of surface water runoff and groundwater recharge across the WRIA. The potential for runoff and recharge increases with increasing precipitation. Factors such as land cover, soil properties and surficial geology control how the available precipitation is distributed between runoff and recharge. In either case, the annual quantity and seasonal timing of recharge are key influences on groundwater and surface water availability. A map showing the estimated average annual precipitation throughout WRIA 45 was created with data obtained from Oregon State University's Spatial Climate Analysis Service and is plotted in Map 4.

3.3.3 Analysis of Precipitation Data

Precipitation data were analyzed to find seasonal, annual, and long-term climate trends. The seasonal analysis was conducted by water year to be consistent with surface water data analyses. Annual data were compiled by calendar year to be consistent with the format of data presented by NWS and NRCS. Long-term trends were also examined using data compiled into calendar years.

Seasonal Data Analysis

On a seasonal time scale, WRIA 45 experiences a "wet season" between the months of October and March, and a “dry season” during the intervening months. Figures 3.2 through 3.12 show monthly average precipitation at the NWS stations listed in Table 3-4, as well as monthly snow water equivalent for the SNOWTEL stations listed in Table 3-5. Figure 3.13 summarizes the seasonal variability of precipitation. For each month, precipitation is expressed as a percentage of the annual total. The figure shows similar seasonal trends among the five gages shown, with more than 70 percent of the total precipitation falling between the months of October and March.

Figures 3.14 through 3.22 illustrate the variability of precipitation by graphing low, median and high values of monthly precipitation values for each precipitation station. The low value of precipitation is defined as the precipitation values that occur once every 10 years (exceeded 90 percent of the time). The median values are those that are exceeded 50 percent of the time while the high values are those that are exceeded only 10 percent of the time. The graphs show the wide range of precipitation that can occur between dry, normal and wet months and seasons. For example, the amount of precipitation at Stevens Pass for a dry July is about 0.24 inches, while for a wet July the amount is about 2.4 inches, or a factor of 10 times greater. The amount of precipitation directly affects the amount of runoff or groundwater recharge that occurs in that month or following months.

3.3.4 Annual Data Analysis and Variations Due To Climate Cycles

Figures 3-23 through 3-32 provide a time series of annual precipitation at NWS and NRCS stations for the period of 1948 to the present. The time period of 1948 – present was selected as most gages started collecting data in 1948. The Wenatchee gage started the earliest, in 1931. Data are not available in each year for every station but they are plotted on a consistent time scale to facilitate comparison of the records. On those same plots the trends in precipitation are plotted (expressed as the 5-year moving average) and the PDO phases are highlighted. The annual precipitation can vary substantially, over 100%, from year to year at each station depending on climatic conditions. The highest volumes of precipitation experience generally occur during the cool, wet phase of the PDO and during El Niño years. The lowest volumes of precipitation generally occur during the warm, dry phase of the PDO and during La Niña years. Figure 3.33 provides a more detailed comparison of precipitation to the PDO phases. In Figure 3.33, the annual precipitation in Wenatchee is compared to the PDO Index, a numerical value for the PDO. The PDO index is compiled by the Joint Institute for the Study of the Atmosphere and the Ocean and can be found at: ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/PDO.latest.

The 5-year moving average of precipitation in Wenatchee follows the wet and dry phases of the PDO in most years. The most evident period where Wenatchee precipitation does not follow the PDO index is in 1982 and 1983. This is likely due to one of the most severe El Niño’s on record, where precipitation in Idaho, Oregon, and Washington was 25% greater than normal (CIG website, 2003). Precipitation in Wenatchee during that event was 67% higher than normal. Effects of other strong El Niño events are evident in 1940 and 1972. A strong La Niña in 1975 caused an almost 50% drop in Wenatchee precipitation. Effects of strong La Niñas can also be seen in 1938 and 1988.

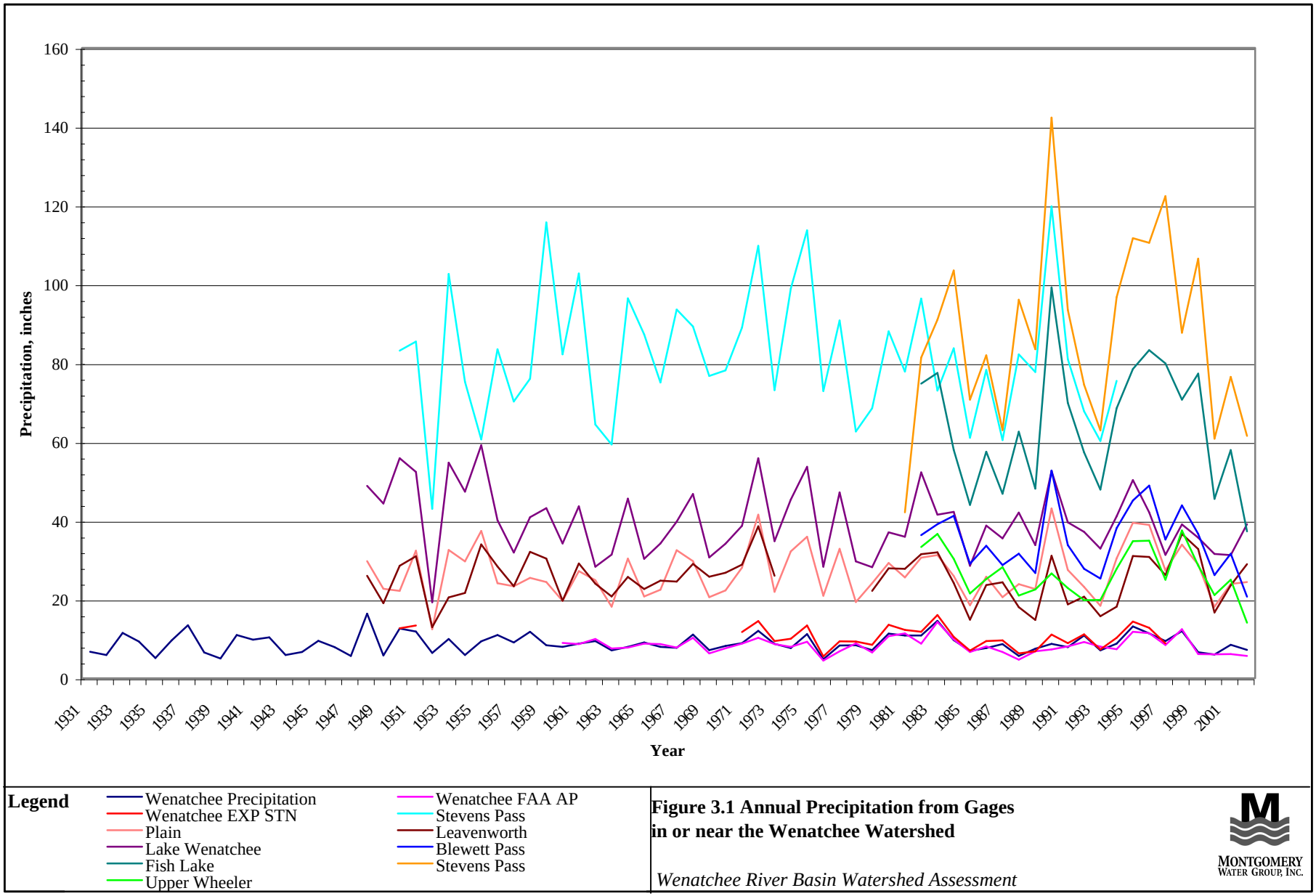
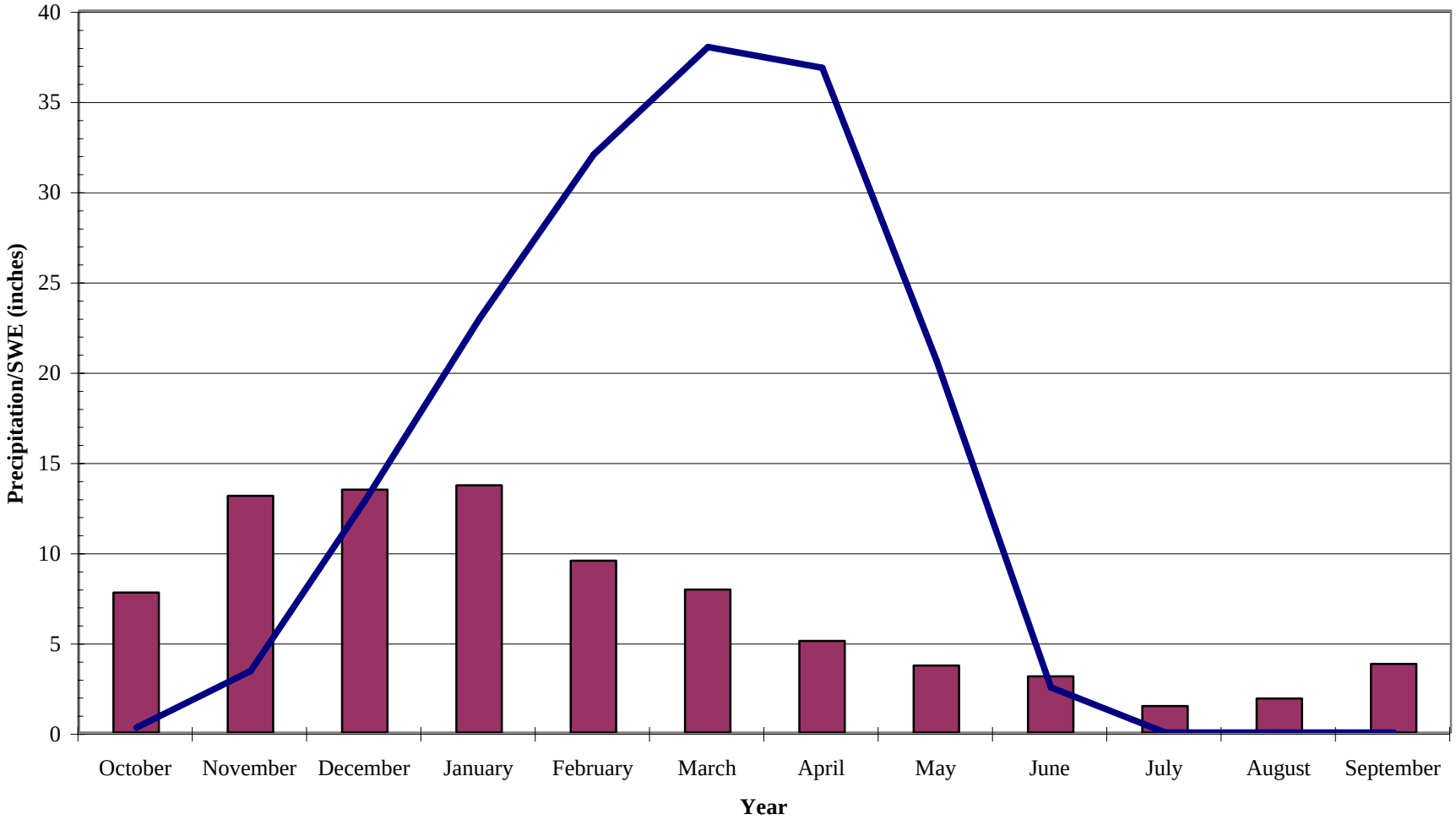


Figure 3.1 Annual Precipitation from Gages in or near the Wenatchee Watershed

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



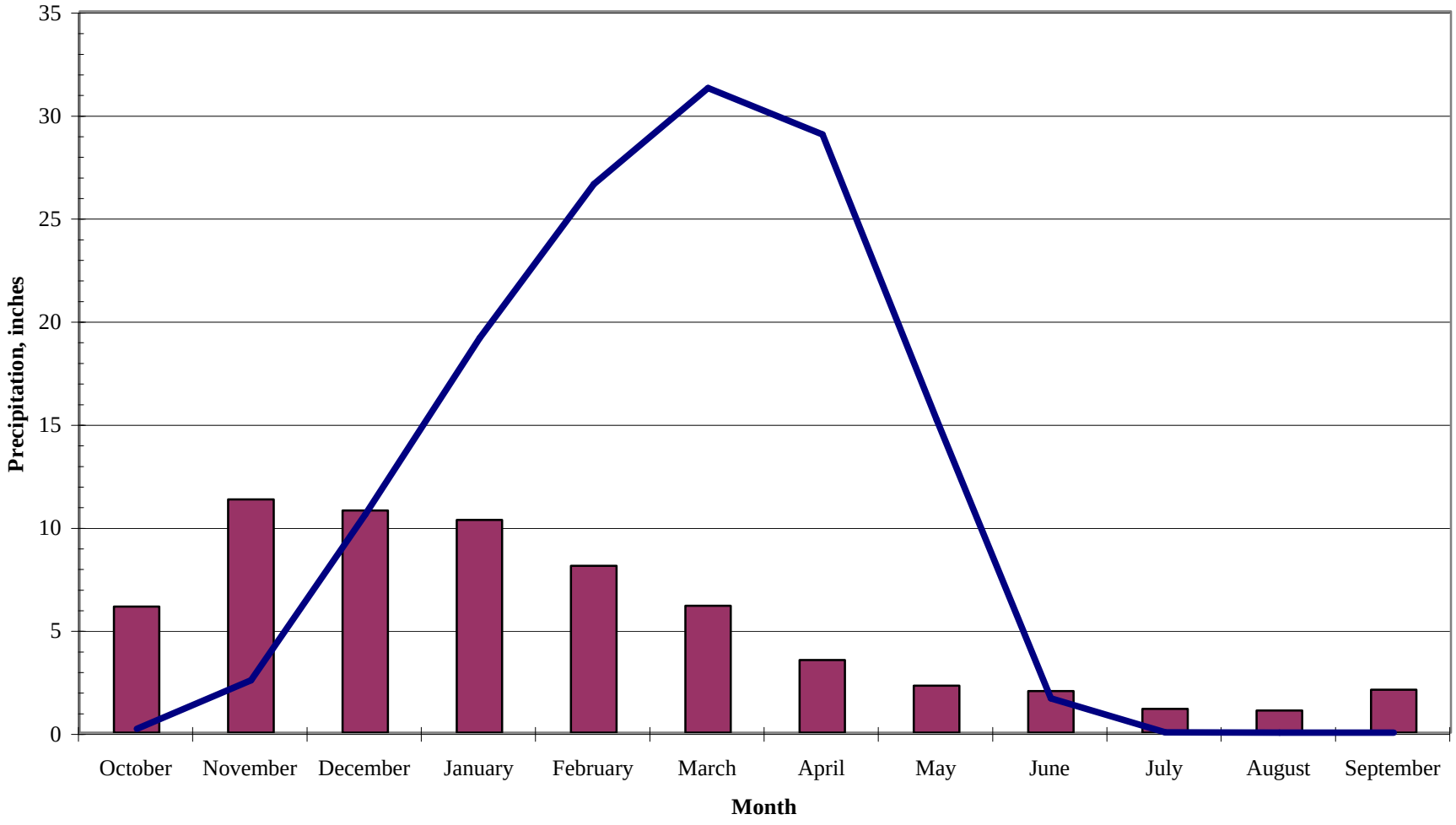
Legend
NRCS Snowtel Gage 21b01s
Period of Record 1980-Present
WRCC Station Number 458089
Period of Record 1950-1994
Mean Annual Precipitation = 84.5 in.

Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent

Figure 3.2 Monthly Average Precipitation
Monthly Average Snow Water Equivalent
Stevens Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

NRCS Snowtel Gage 21b04s
Mean Annual Precipitation = 64.9 in.
Period of Record 1981-Present

Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent

Figure 3.3 Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent
Fish Lake (Kittitas County), WA

Wenatchee River Basin Watershed Assessment

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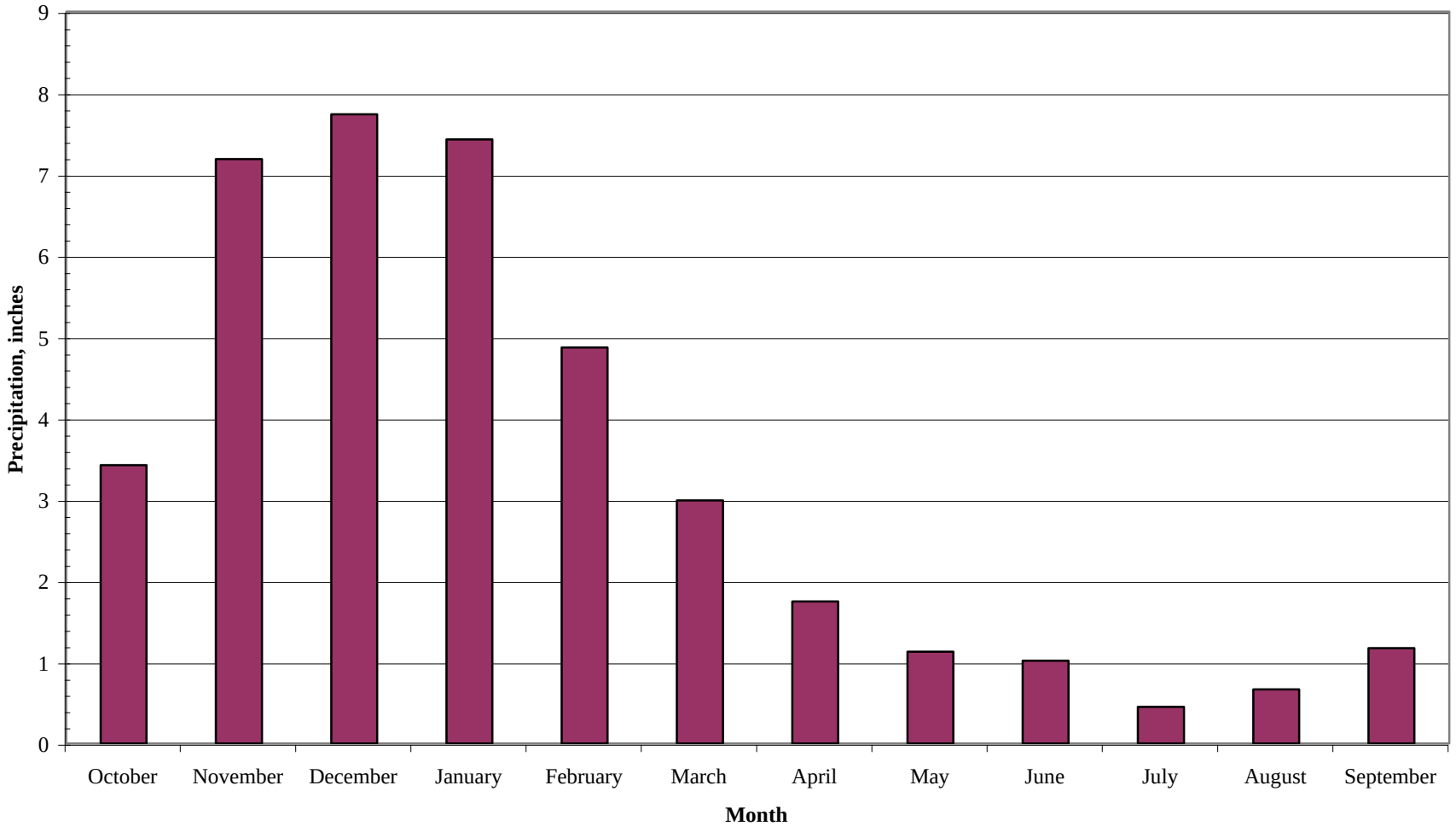


Legend

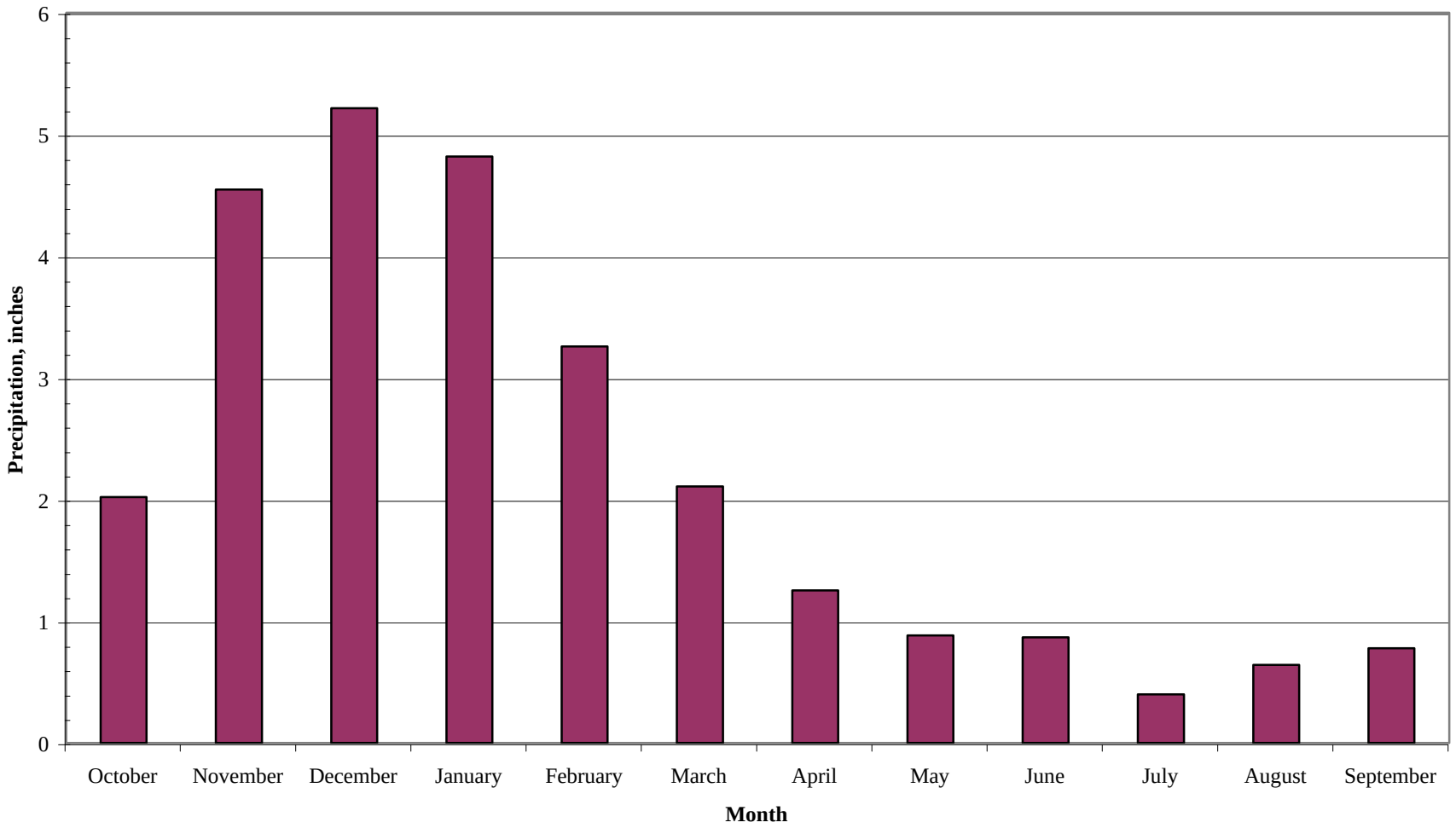
WRCC Station Number 454446
Mean Annual Precipitation = 39.3 in.
Period of Record 1948-1985

Mean Monthly Precipitation

Figure 3.4 Mean Monthly Precipitation
Lake Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY
WATER GROUP, INC.



Legend

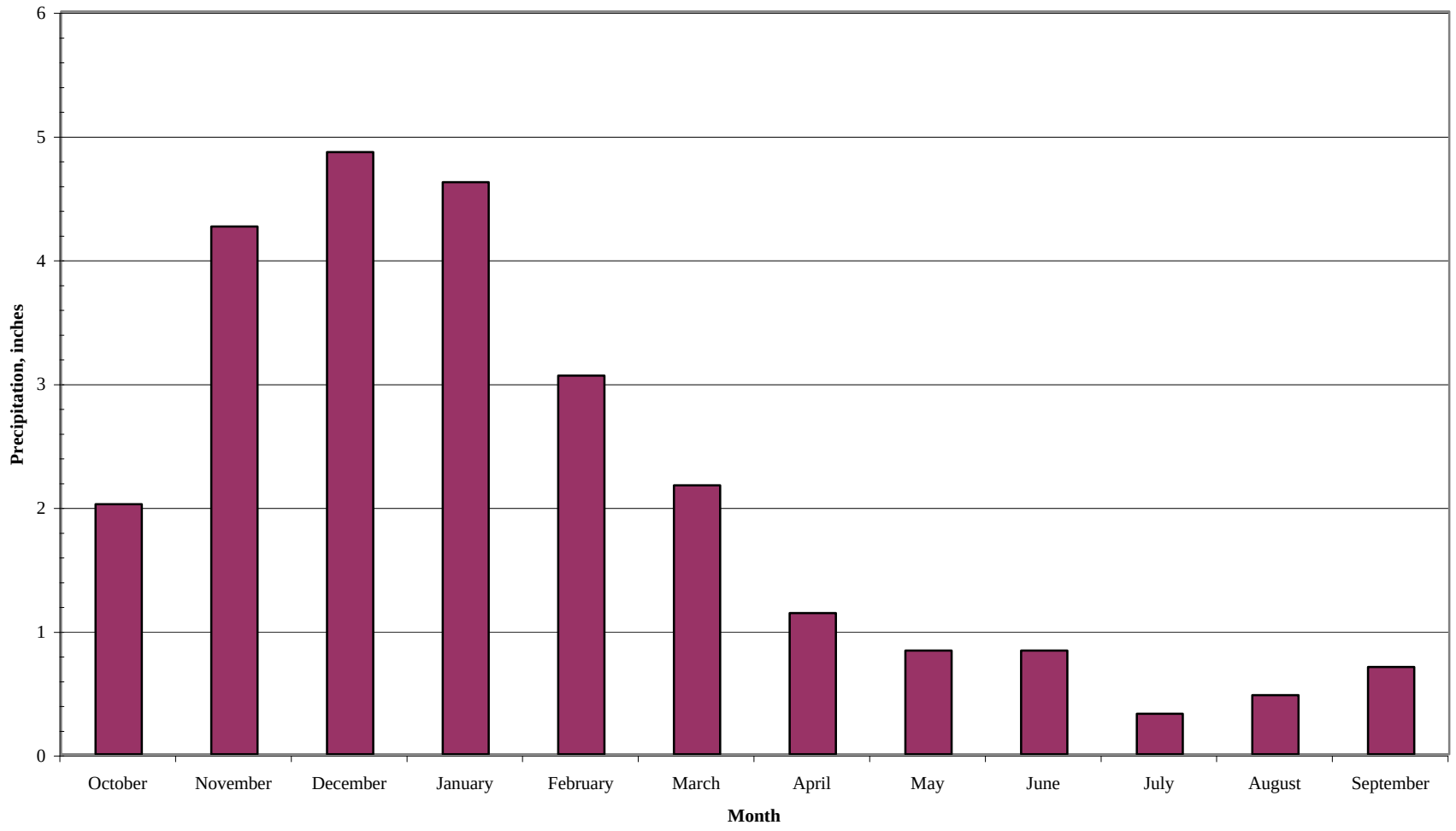
WRCC Station Number 456534
Mean Annual Precipitation = 37.0 in.
Period of Record 1948-Present

Mean Monthly Precipitation

Figure 3.5 Mean Monthly Precipitation
Plain, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

WRCC Station Number 454572
Mean Annual Precipitation = 25.3 in.
Period of Record 1948-1973, 1979-Present

Mean Monthly Precipitation

Figure 3.6 Mean Monthly Precipitation
Leavenworth, WA

Wenatchee River Basin Watershed Assessment

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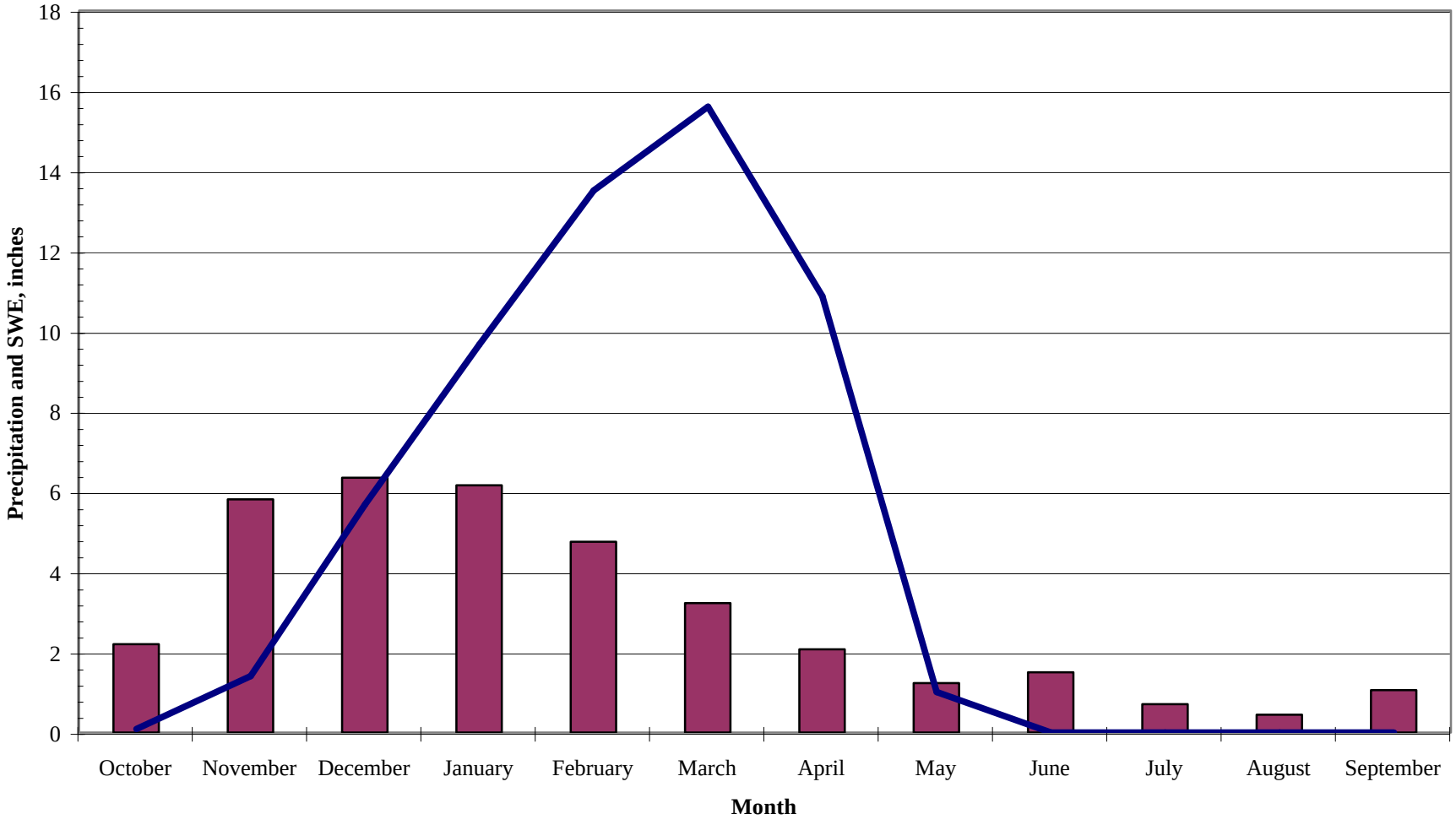


Legend

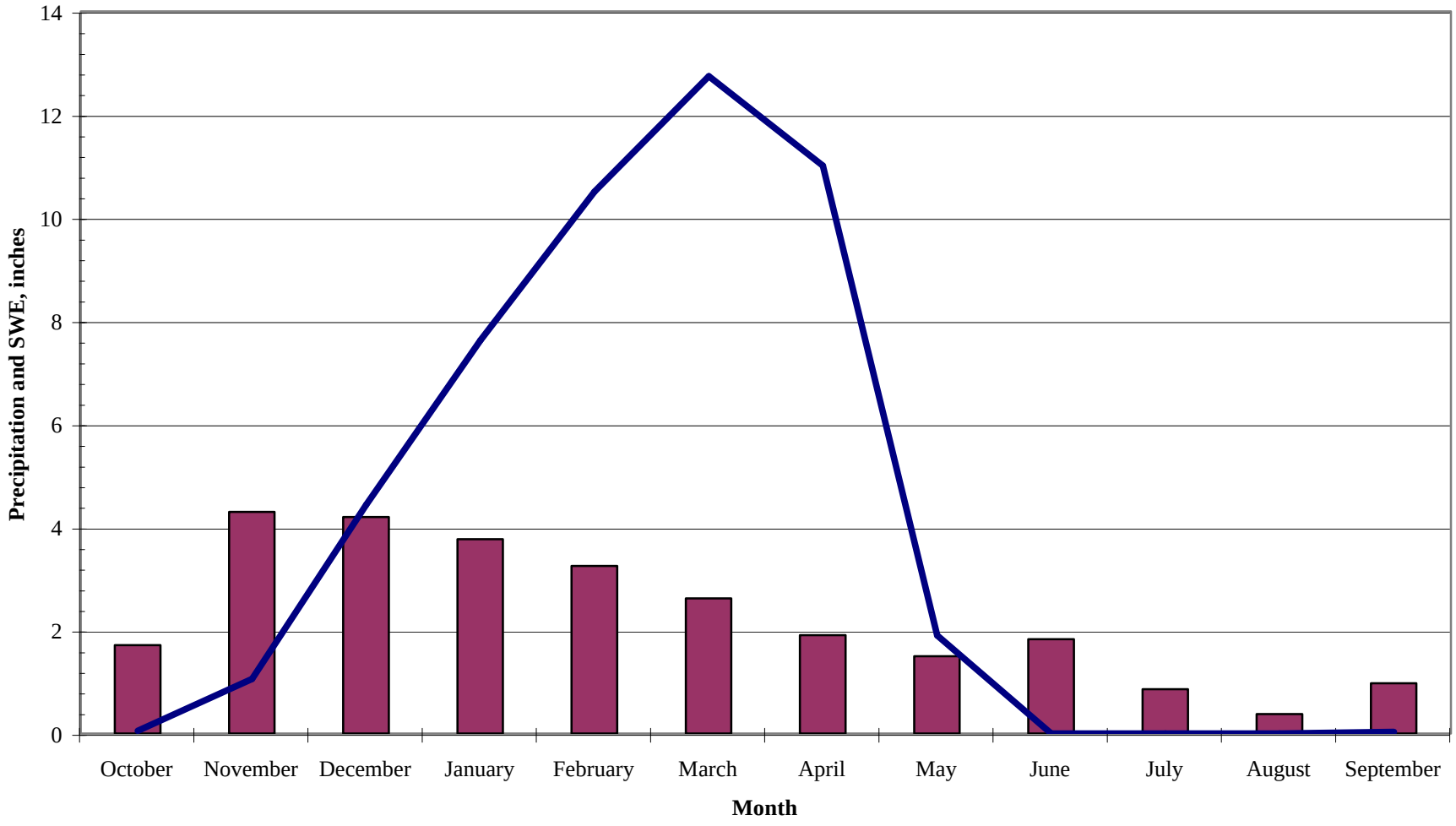
NRCS Snowtel Gage 20b20s
Mean Annual Precipitation = 35.5 in.
Period of Record 1981-Present

Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent

Figure 3.7 Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent
Blewett Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

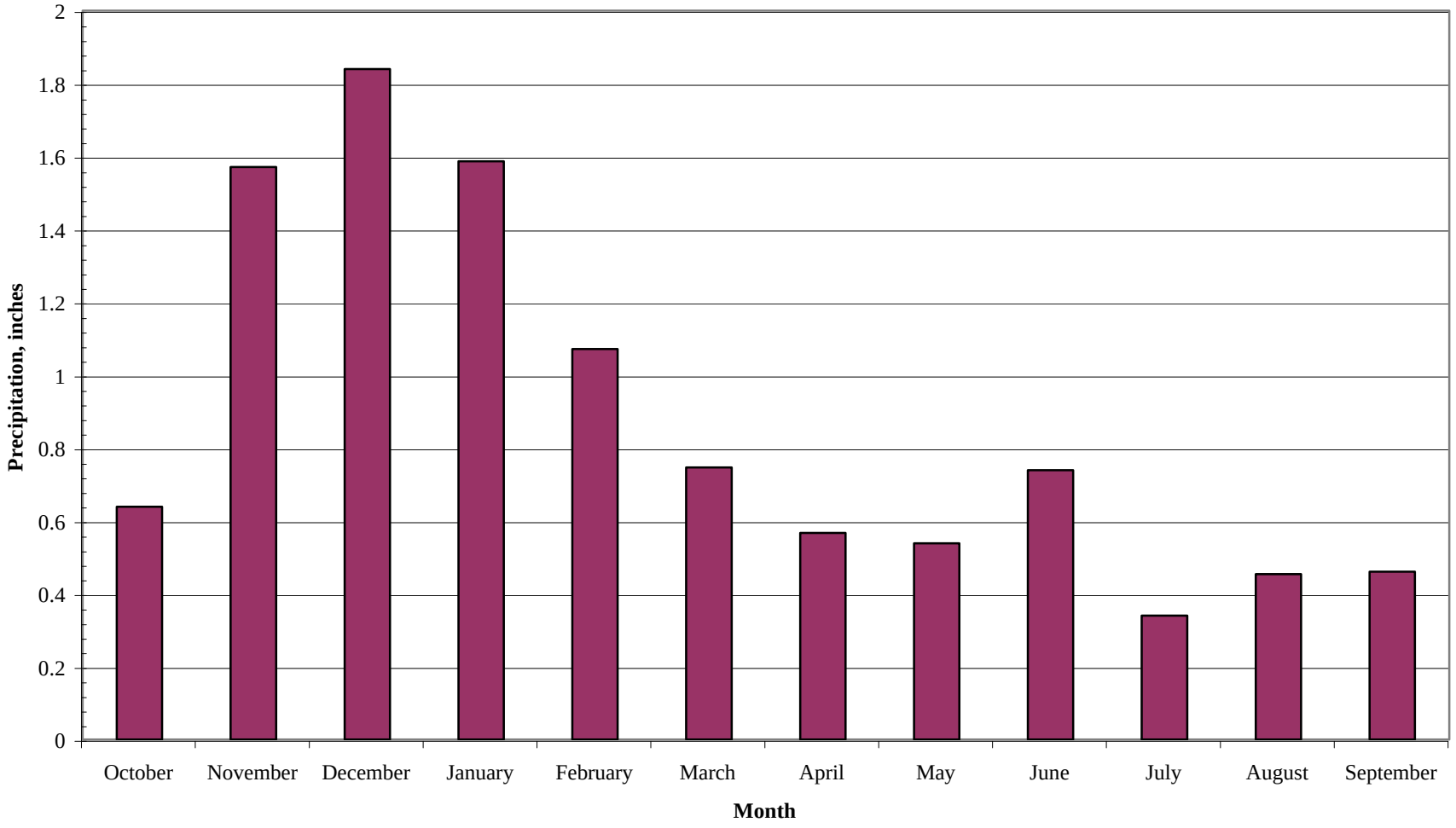
NRCS Snowtel Gage 20b07s
Mean Annual Precipitation = 27.3 in.
Period of Record 1981-Present

Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent

Figure 3.8 Mean Monthly Precipitation
Mean Monthly Snow Water Equivalent
Upper Wheeler, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

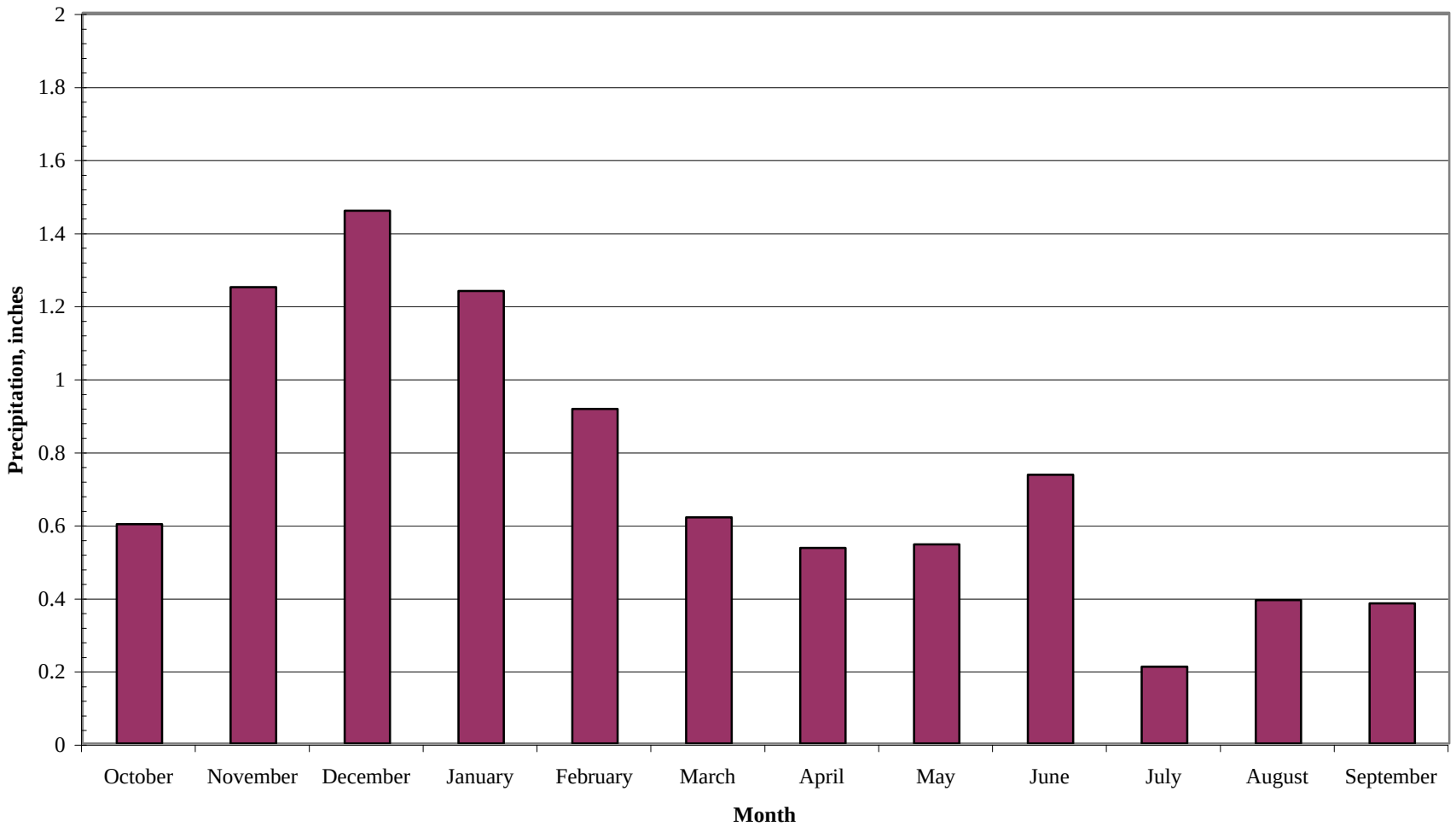
WRCC Station Number 459029
Mean Annual Precipitation = 10.3 in.
Period of Record 1950-1951, 1971-1997

Mean Monthly Precipitation

Figure 3.9 Mean Monthly Precipitation
Wenatchee EXP STN, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

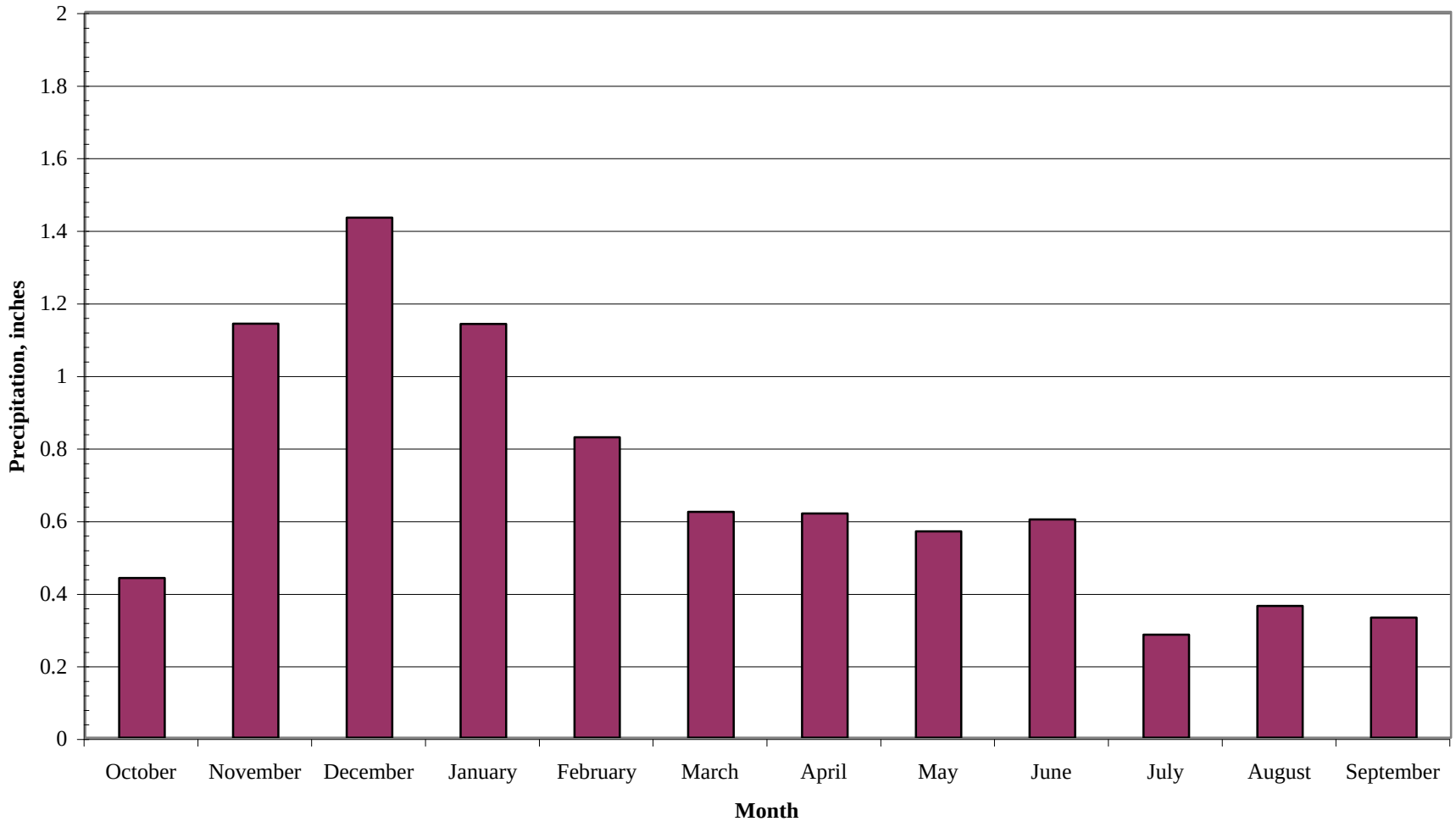
WRCC Station Number 459074
Mean Annual Precipitation = 8.9 in.
Period of Record 1931-Present

Mean Monthly Precipitation

Figure 3.10 Mean Monthly Precipitation
Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY
WATER GROUP, INC.



Legend

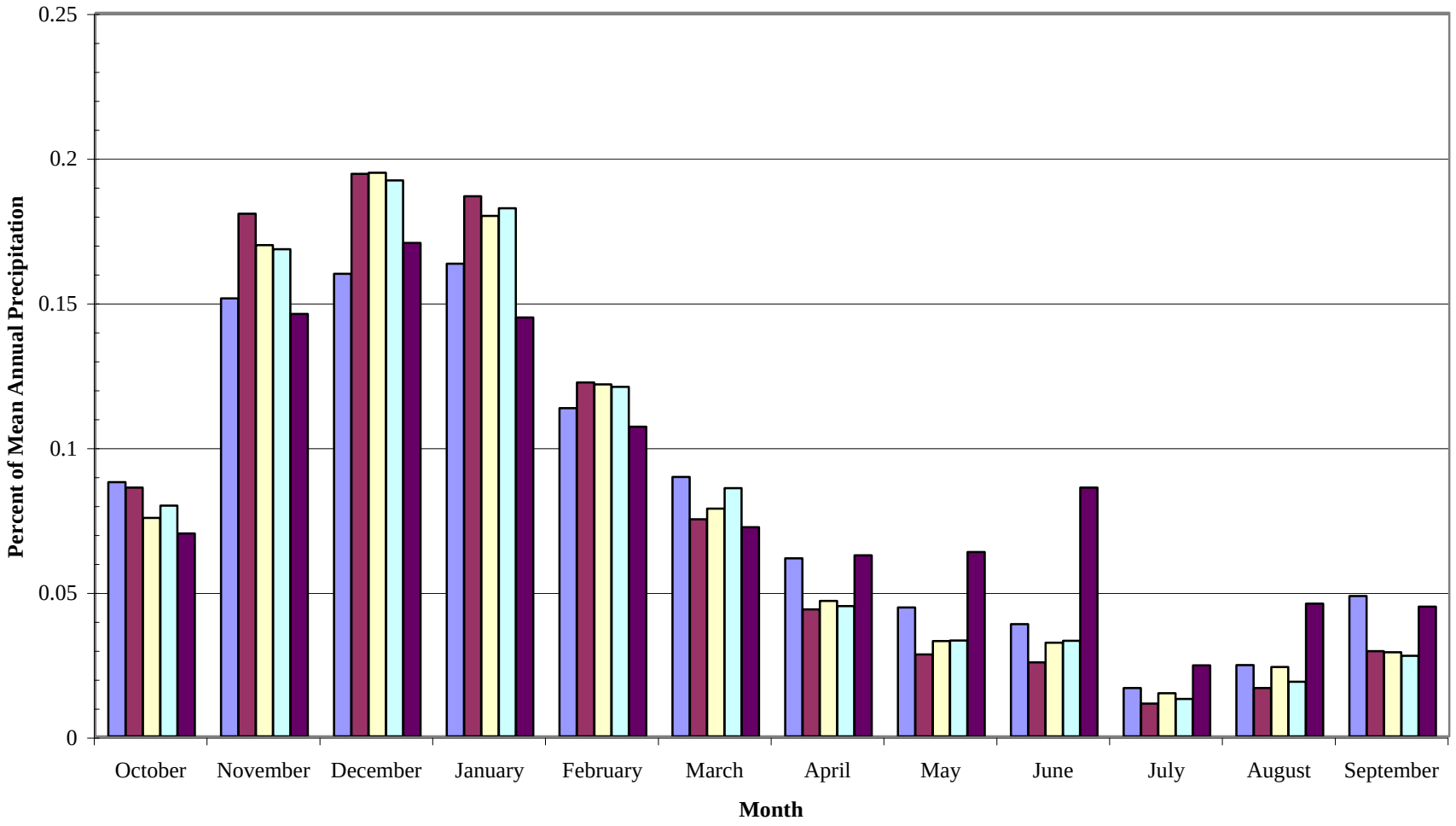
WRCC Station Number 459082
Mean Annual Precipitation = 8.4 in.
Period of Record 1959-Present

Mean Monthly Precipitation

Figure 3.11 Mean Monthly Precipitation
Wenatchee FAA AP, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



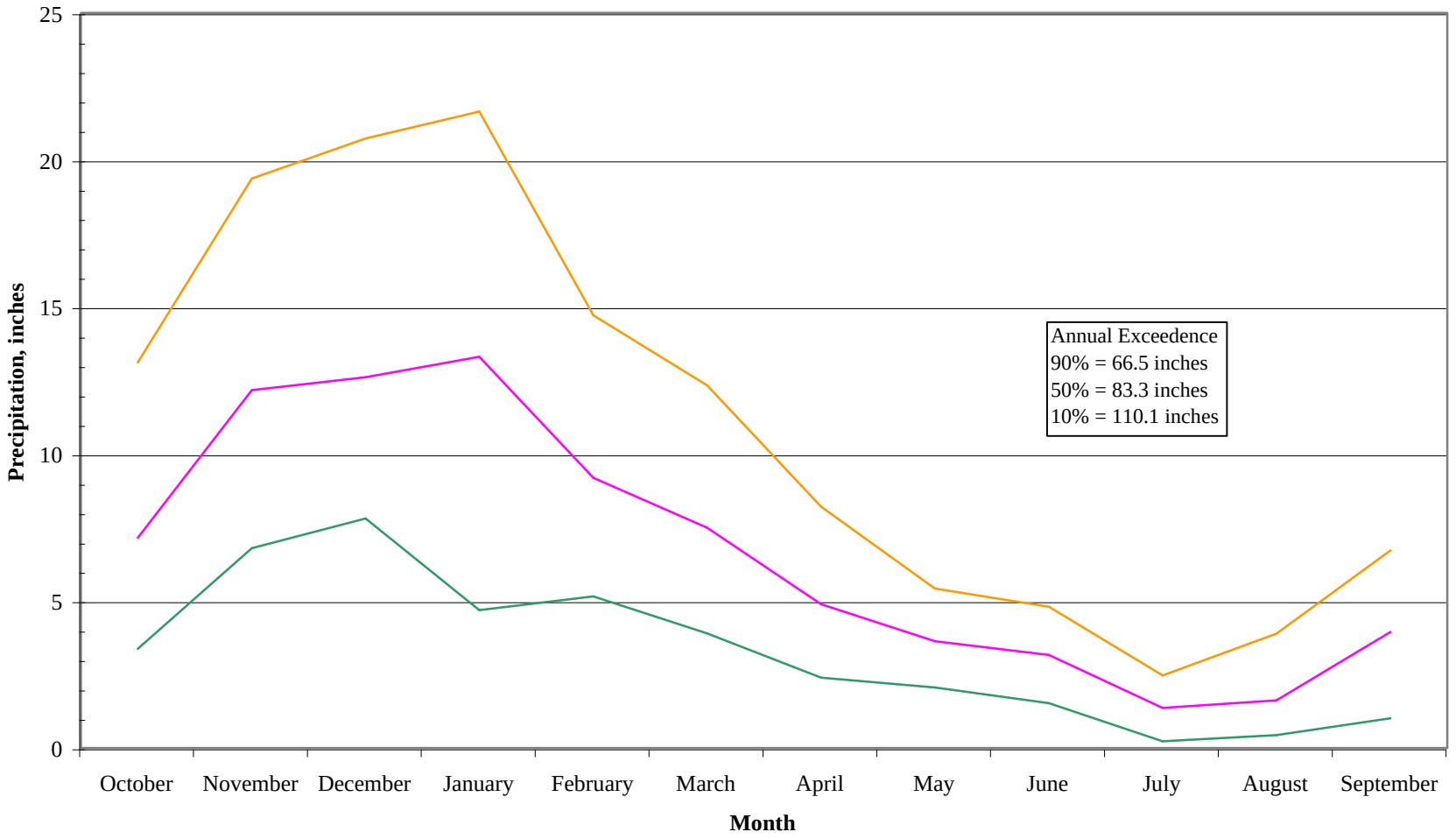
Legend

- Stevens Pass
- Lake Wenatchee
- Plain
- Leavenworth
- Wenatchee

Figure 3.12 Seasonal Variability of Precipitation at Selected WRCC Precipitation Gages

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

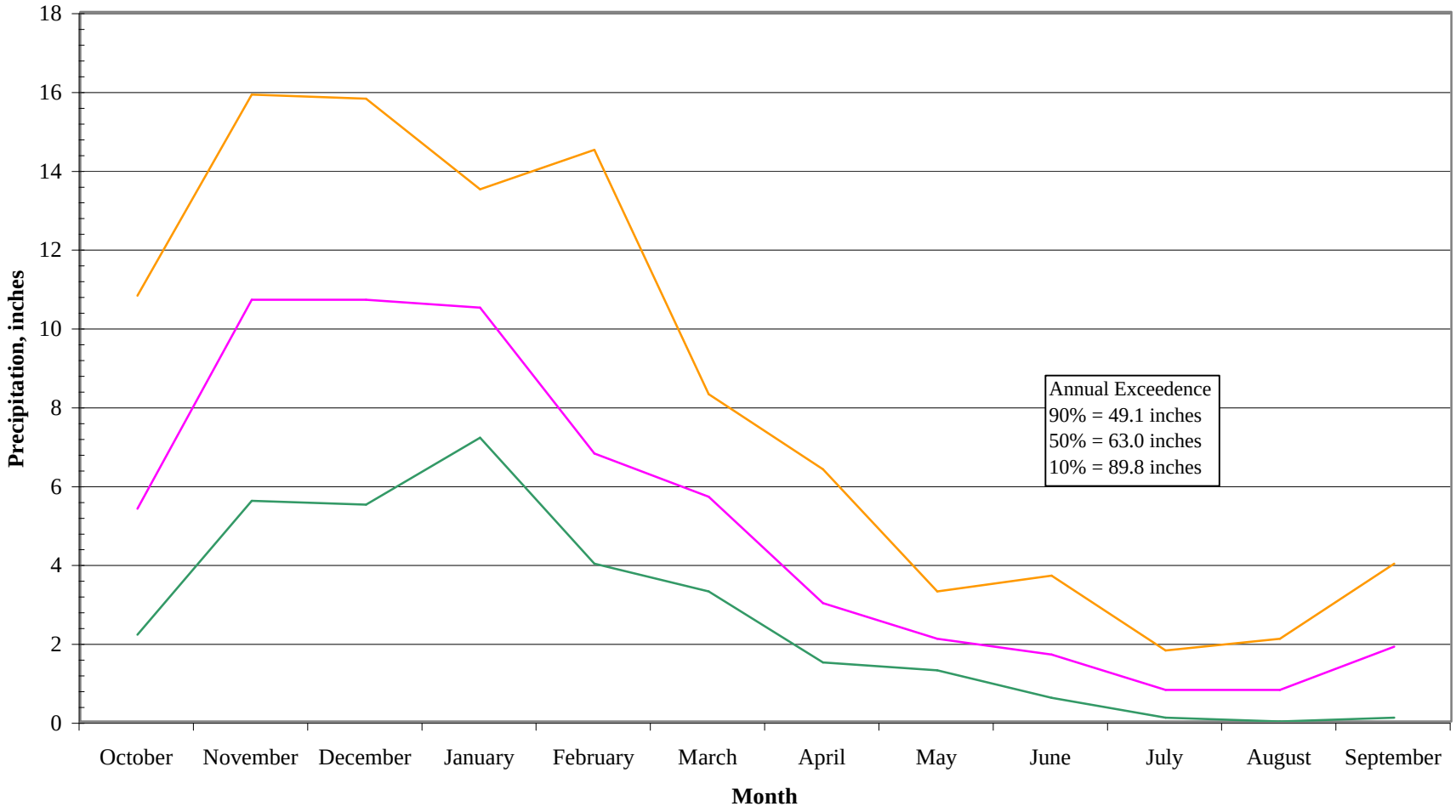
NRCS Snowtel Gage 21b01s
Period of Record 1980-Present
WRCC Station Number 458089
Period of Record 1950-1994
Mean Annual Precipitation = 84.5 in.

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.13 Monthly Precipitation Exceedence Probability Stevens Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

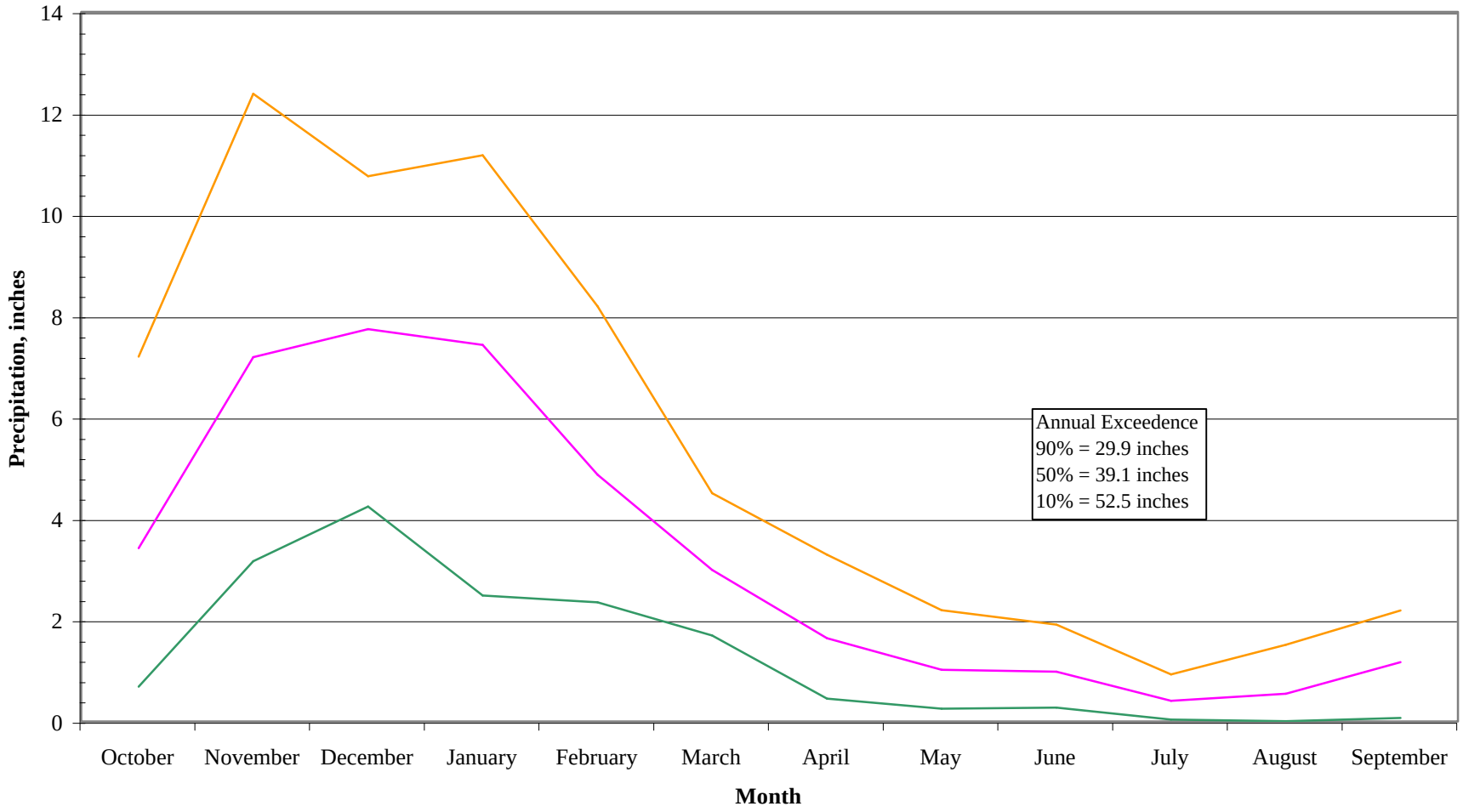
NRCS Snowtel Gage 21b04s
Mean Annual Precipitation = 64.9 in.
Period of Record 1981-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.14 Monthly Precipitation Exceedence Probability
Fish Lake (Kittitas County), WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

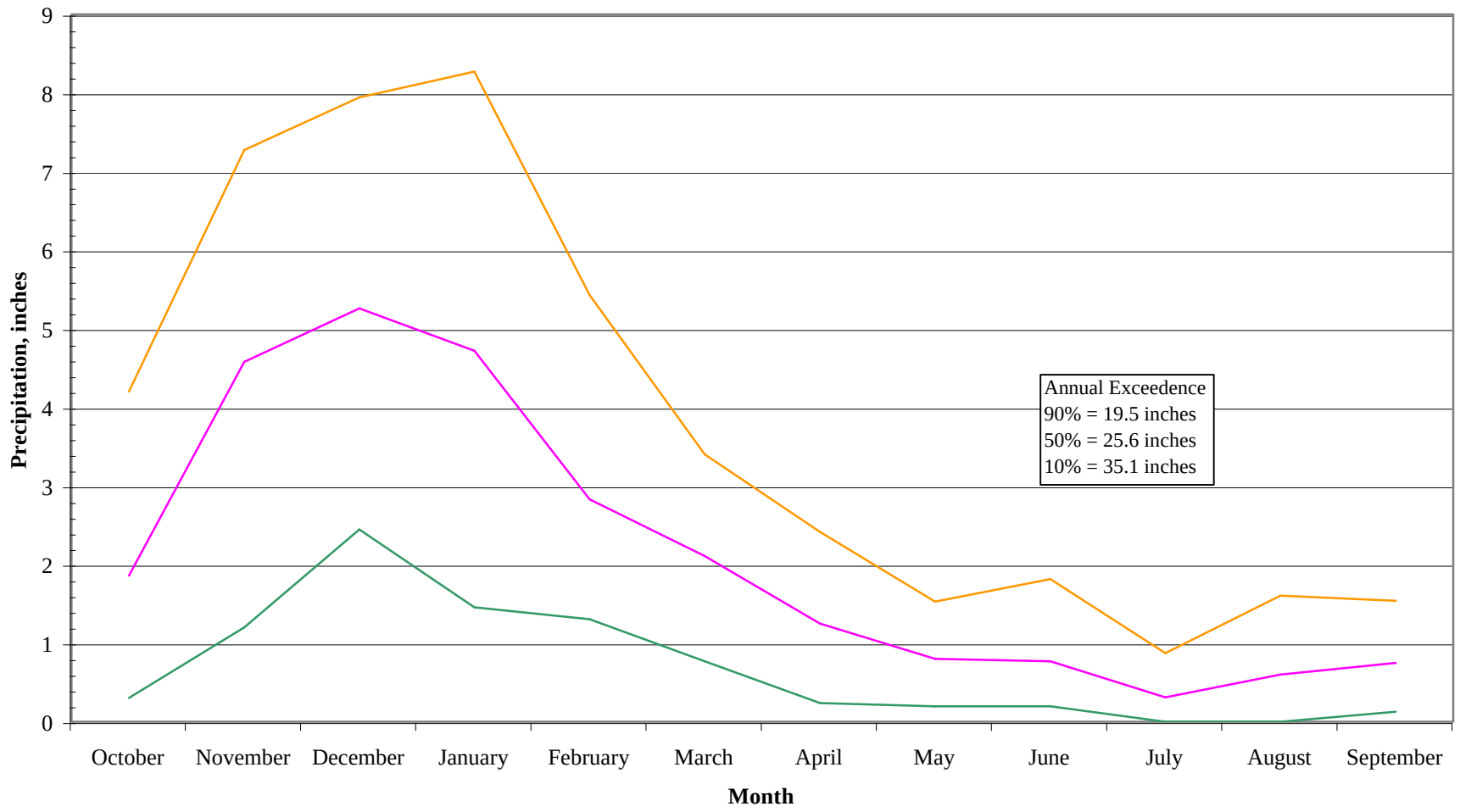
WRCC Station Number 454446
Mean Annual Precipitation = 39.3 in.
Period of Record 1948-1985

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.15 Monthly Precipitation Exceedence Probability
Lake Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

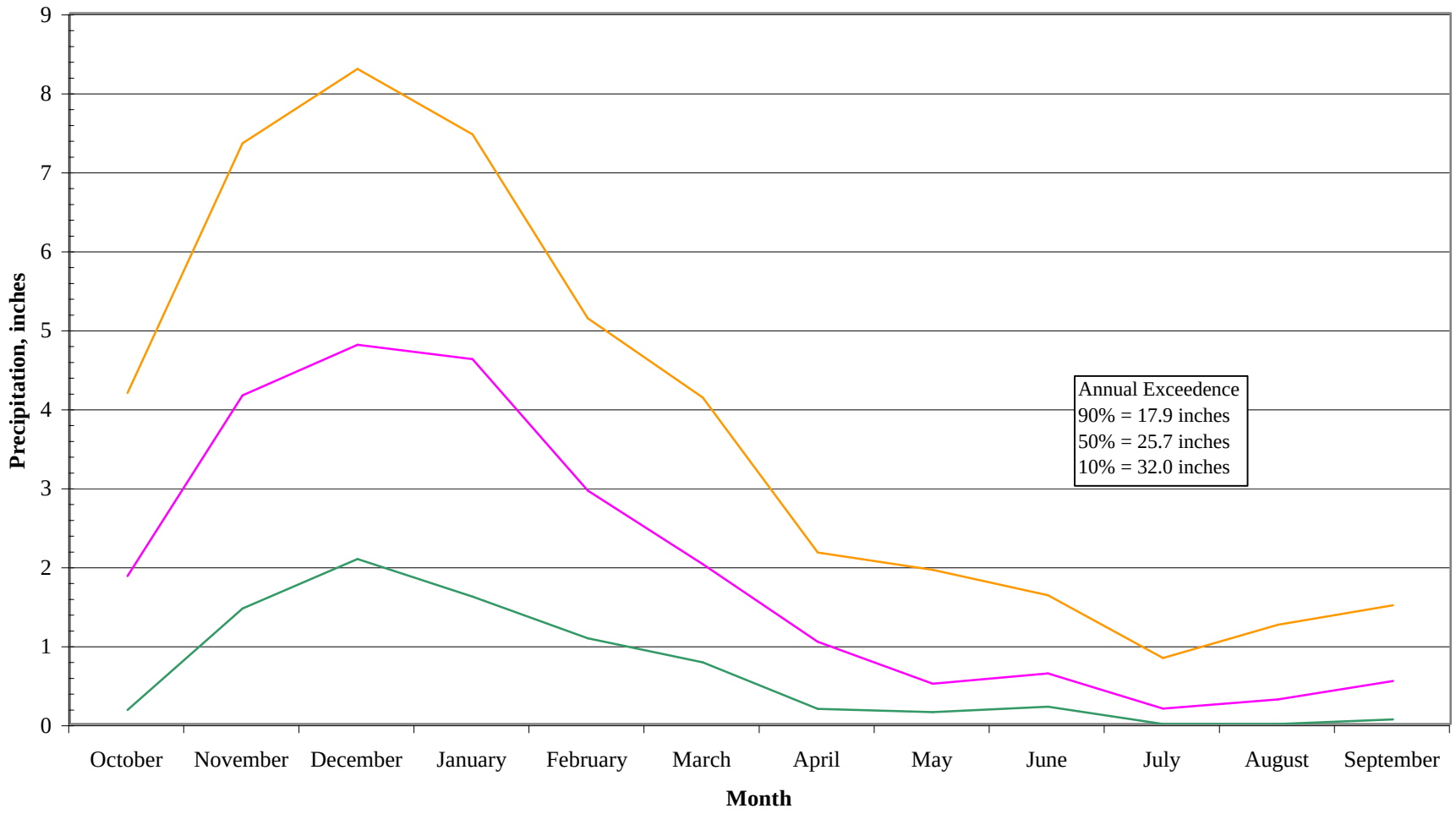
WRCC Station Number 456534
Mean Annual Precipitation = 37.0 in.
Period of Record 1948-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.16 Monthly Precipitation Exceedence Probability Plain, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

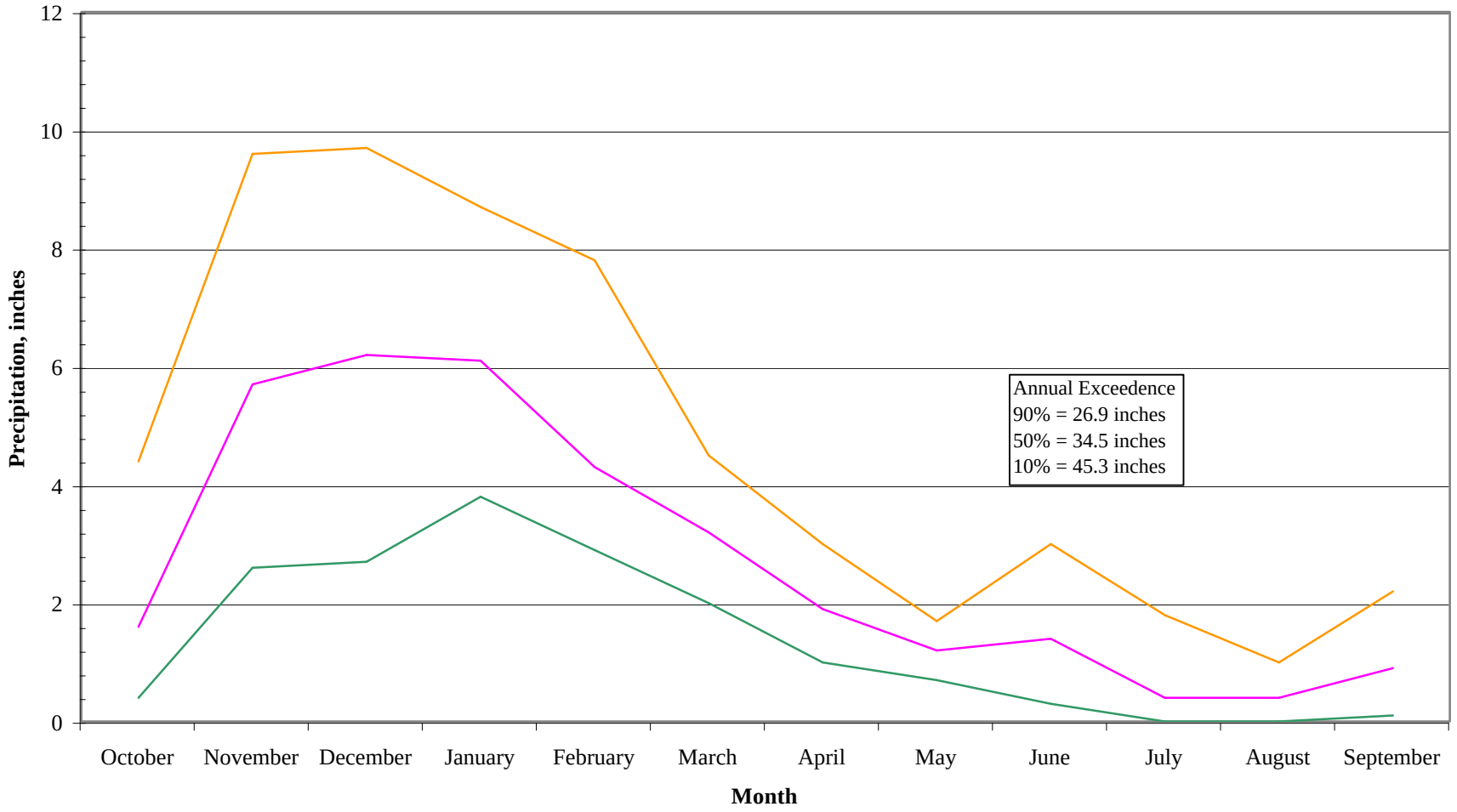
WRCC Station Number 454572
Mean Annual Precipitation = 25.3 in.
Period of Record 1948-1973, 1979-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.17 Monthly Precipitation Exceedence Probability Leavenworth, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

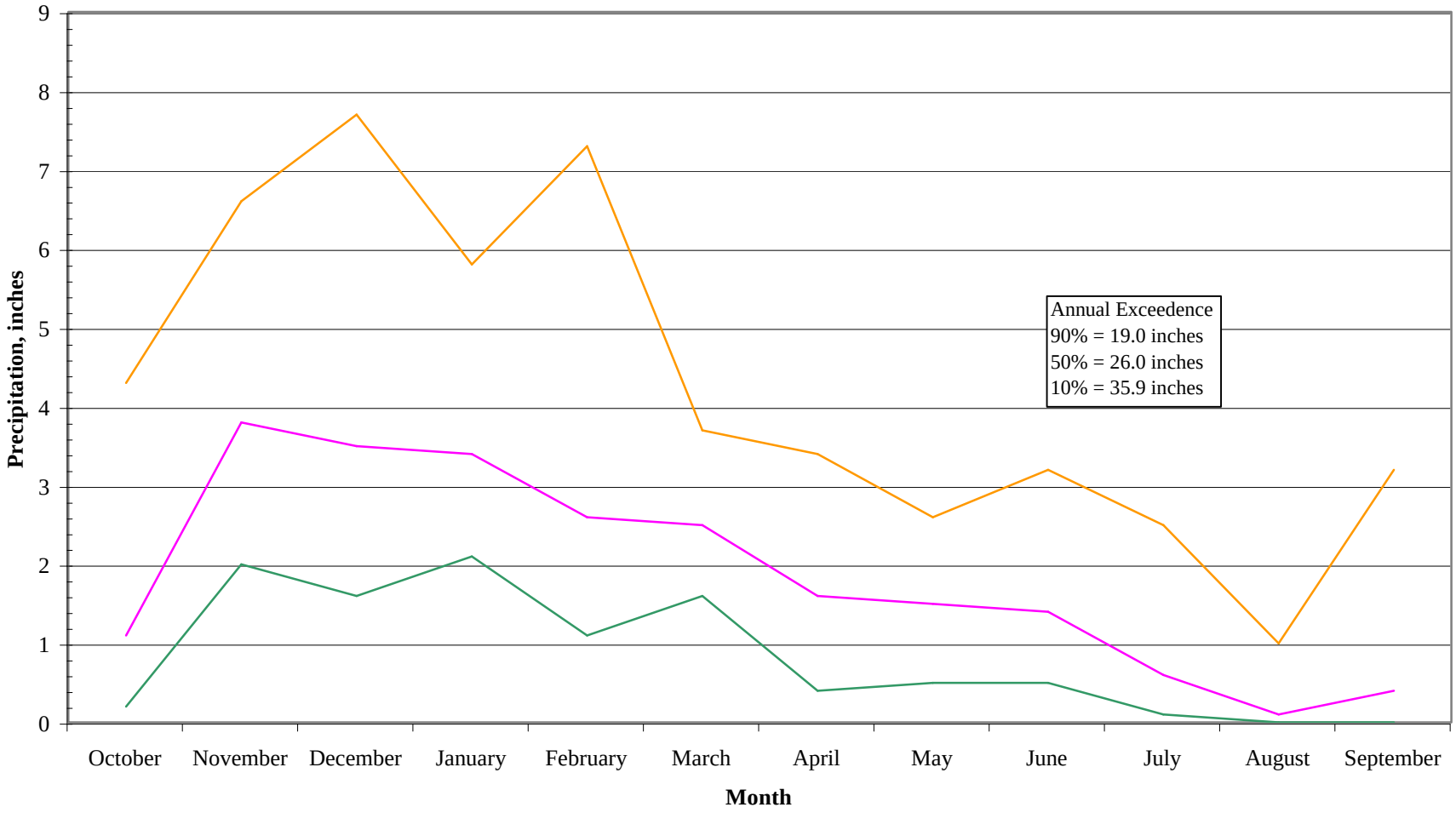
NRCS Snowtel Gage 20b20s
Mean Annual Precipitation = 35.5 in.
Period of Record 1981-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.18 Monthly Precipitation Exceedence Probability
Blewett Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

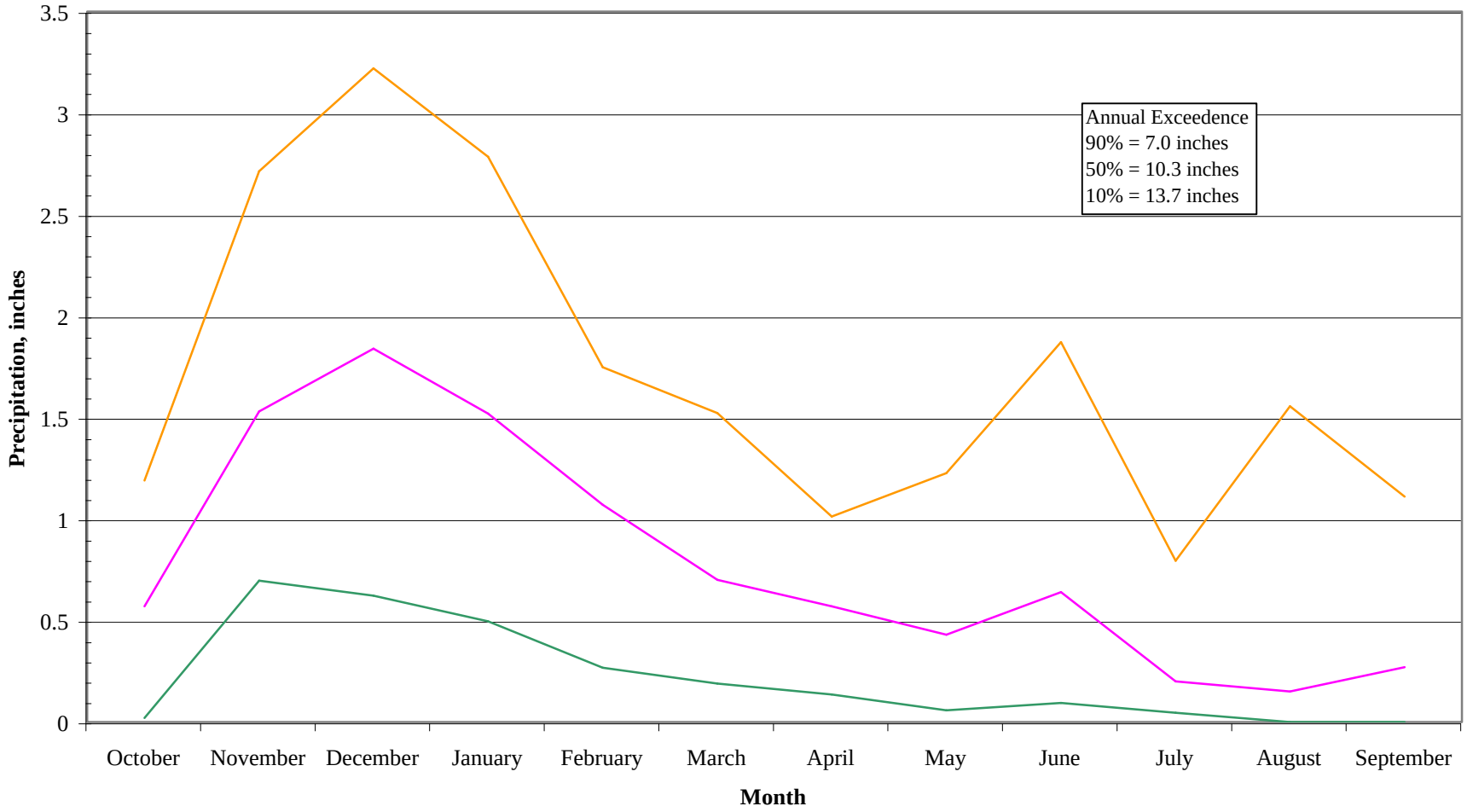
NRCS Snowtel Gage 20b07s
Mean Annual Precipitation = 27.3 in.
Period of Record 1981-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.19 Monthly Precipitation Exceedence Probability
Upper Wheeler, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

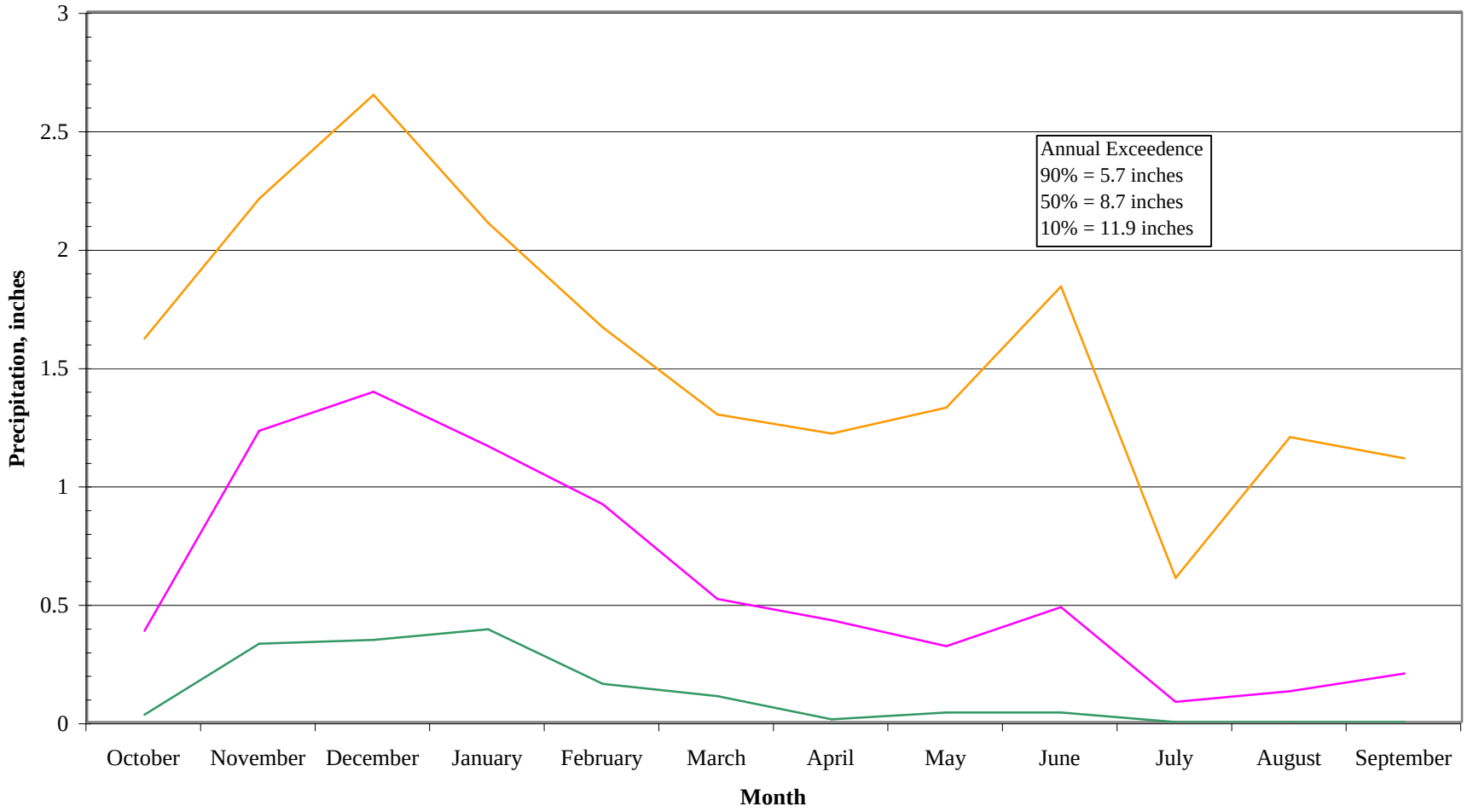
WRCC Station Number 459029
Mean Annual Precipitation = 10.3 in.
Period of Record 1950-1951, 1971-1997

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.20 Monthly Precipitation Exceedence Probability
Wenatchee EXP STN, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

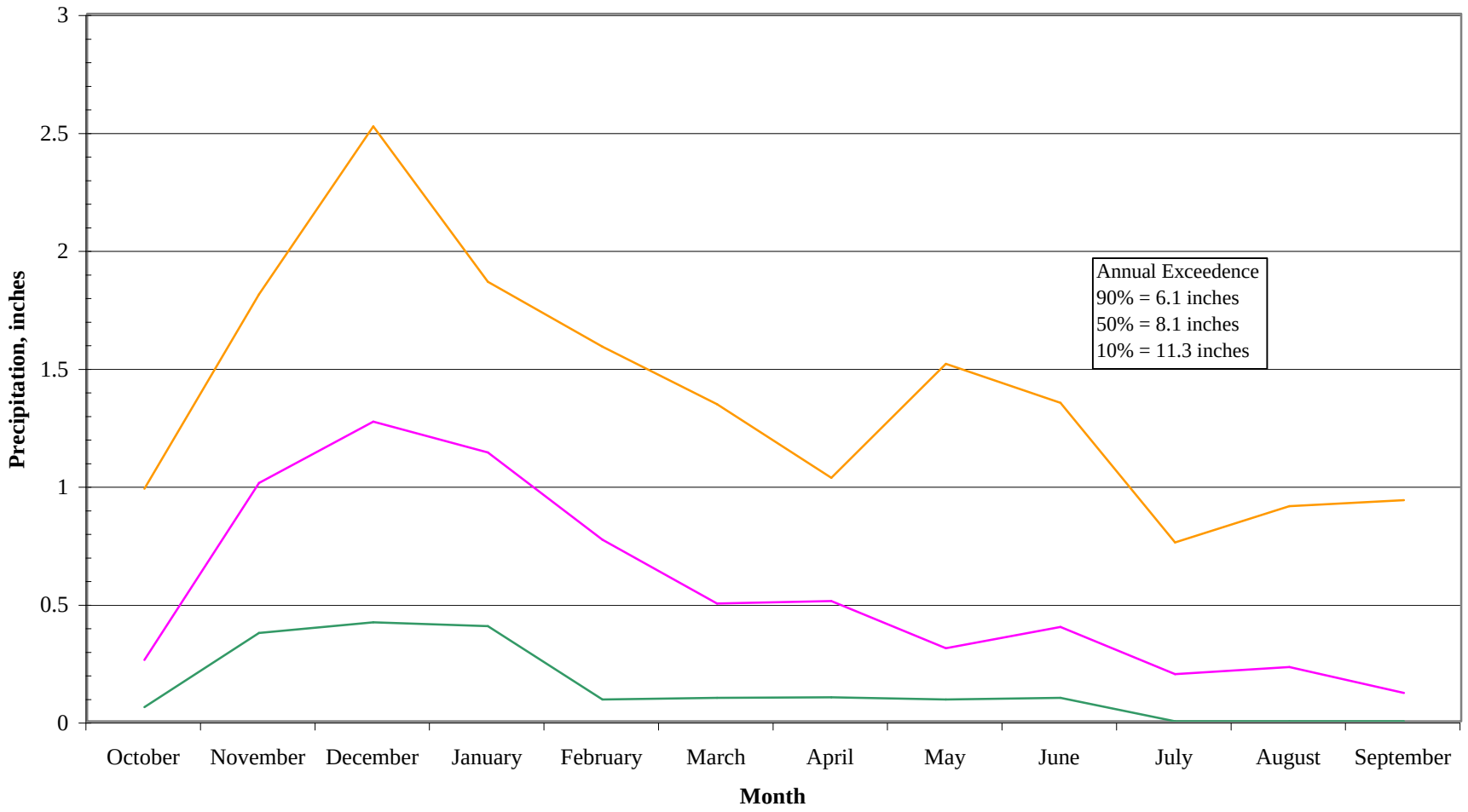
WRCC Station Number 459074
Mean Annual Precipitation = 8.9 in.
Period of Record 1931-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.21 Monthly Precipitation Exceedence Probability
Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

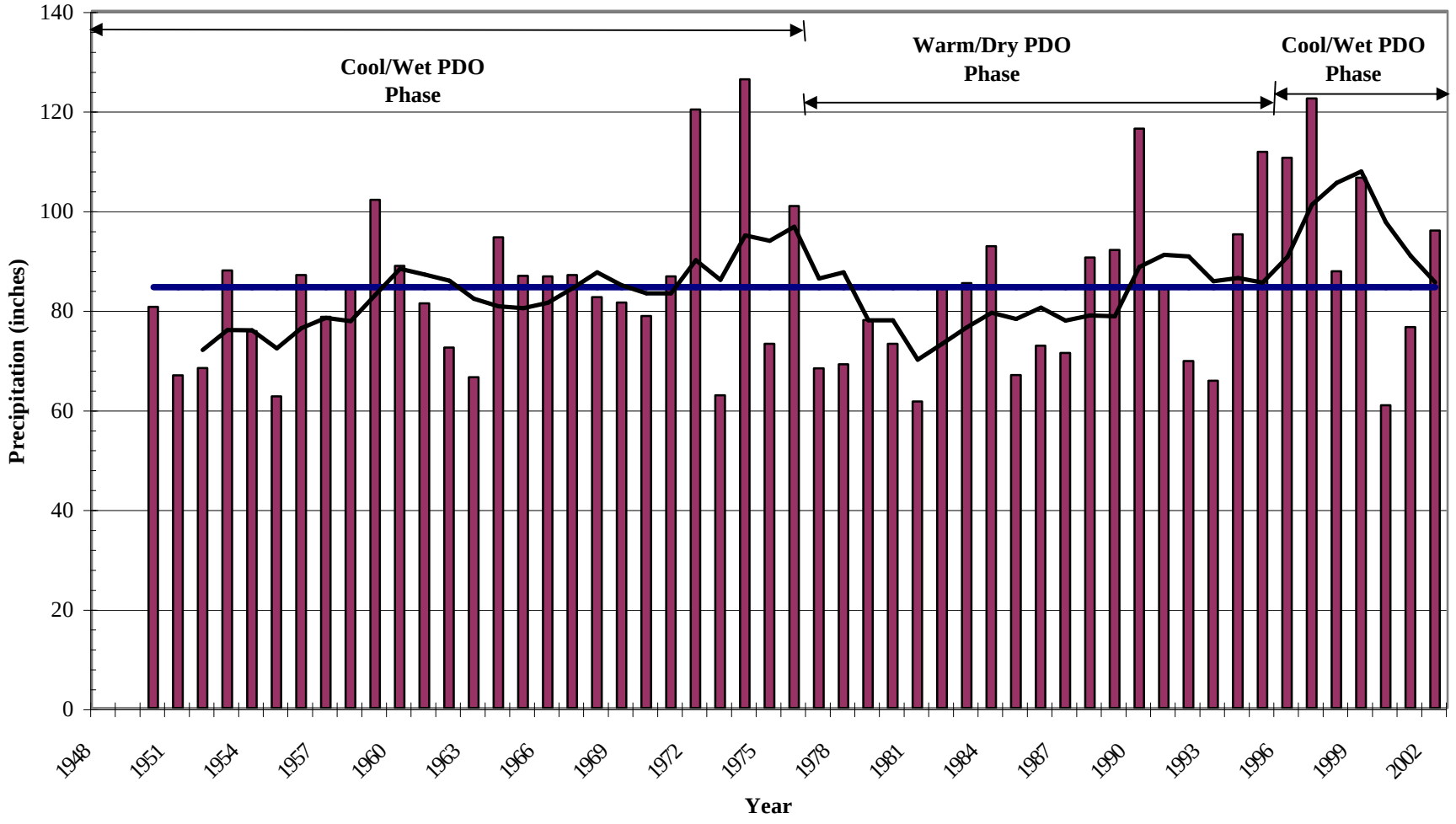
WRCC Station Number 459082
Mean Annual Precipitation = 8.4 in.
Period of Record 1959-Present

90% Exceedence
50% Exceedence
10% Exceedence

Figure 3.22 Monthly Precipitation Exceedence Probability
Wenatchee FAA AP, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

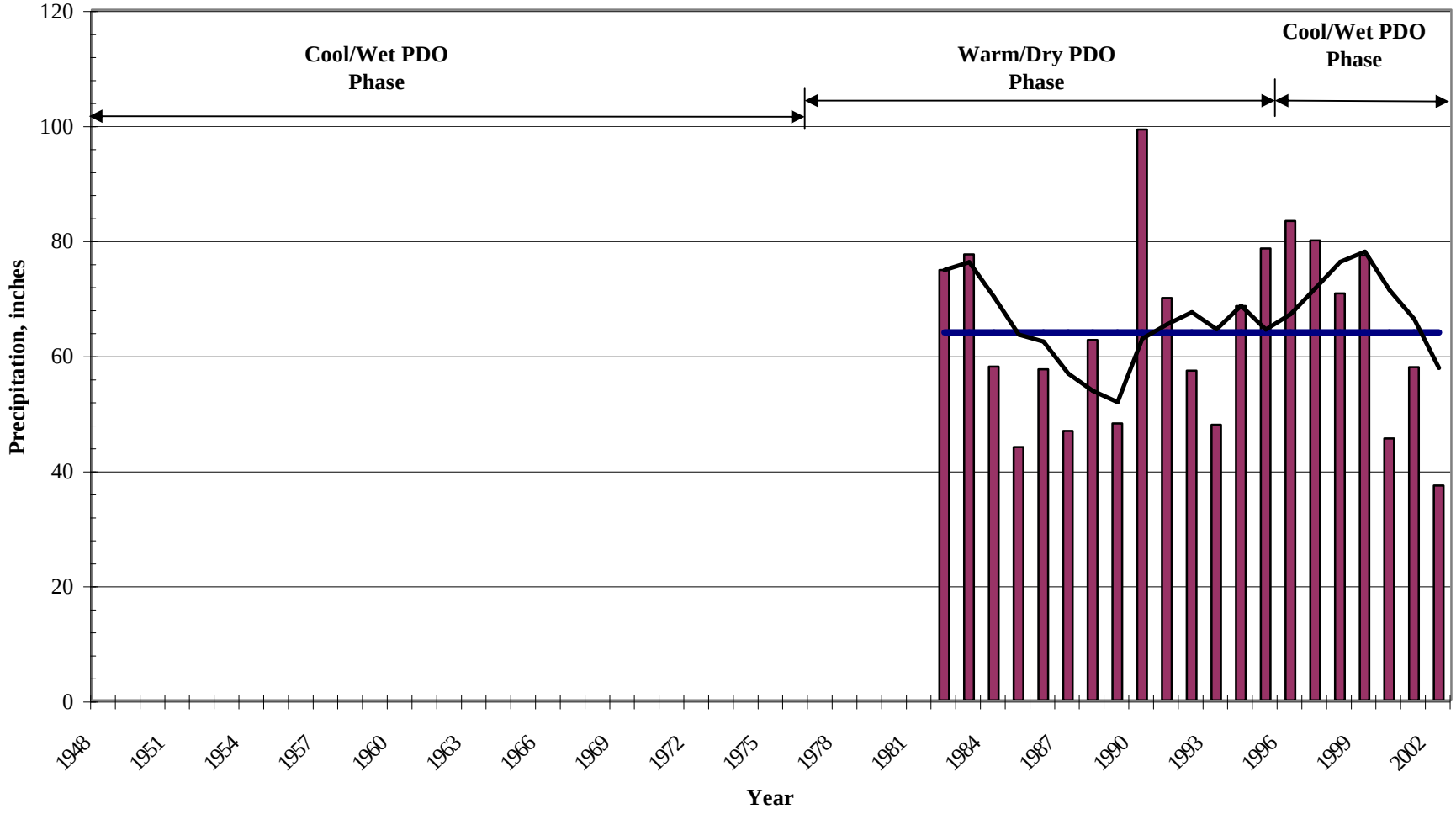
NRCS Snowtel Gage 21b01s
Period of Record 1980-Present
WRCC Station Number 458089
Period of Record 1950-1994
Mean Annual Precipitation = 84.5 in.

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.23 Precipitation Record
Stevens Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

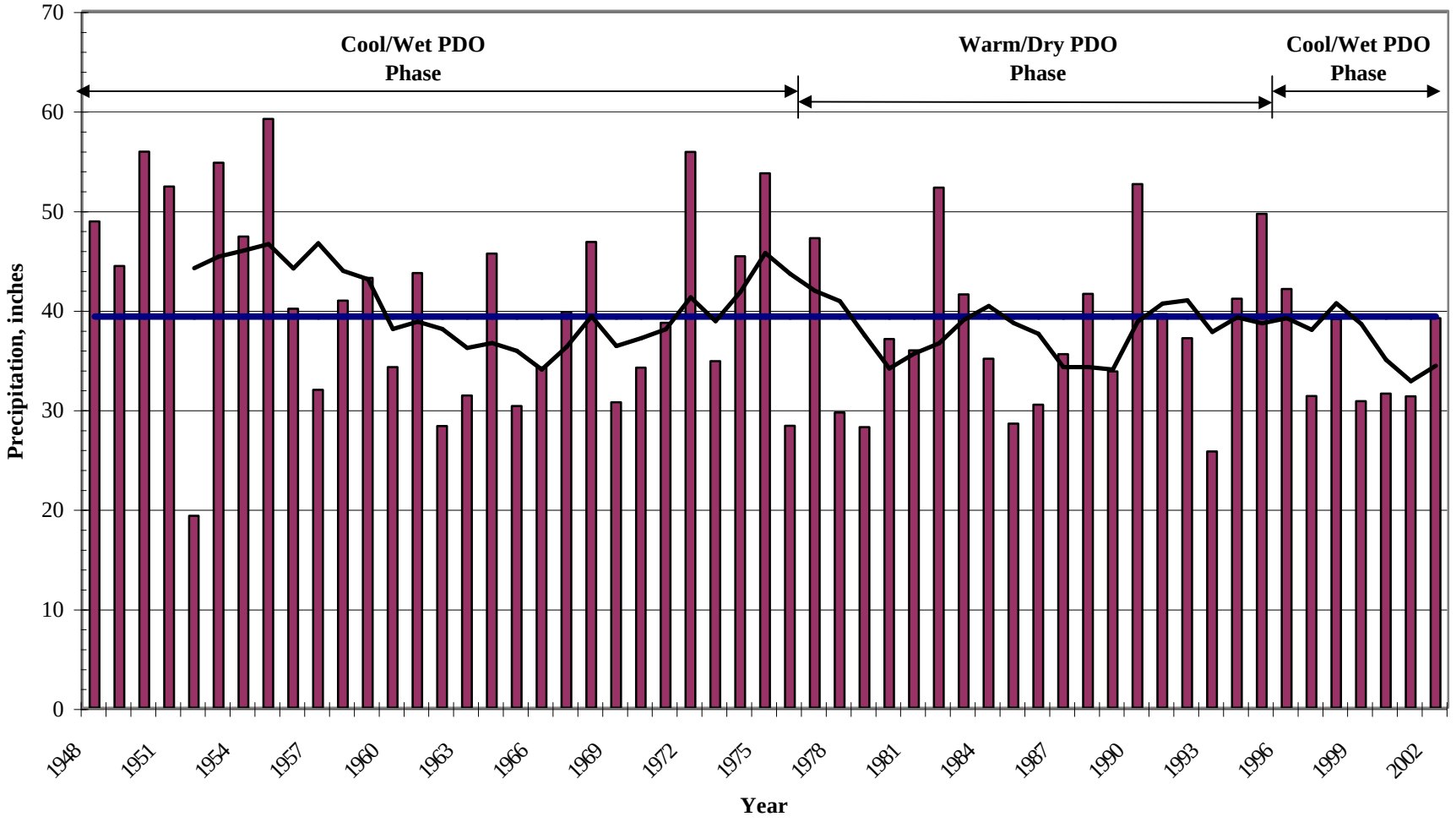
NRCS Snowtel Gage 21b04s
Mean Annual Precipitation = 64.9 in.
Period of Record 1981-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.24 Precipitation Record
Fish Lake (Kittitas County), WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

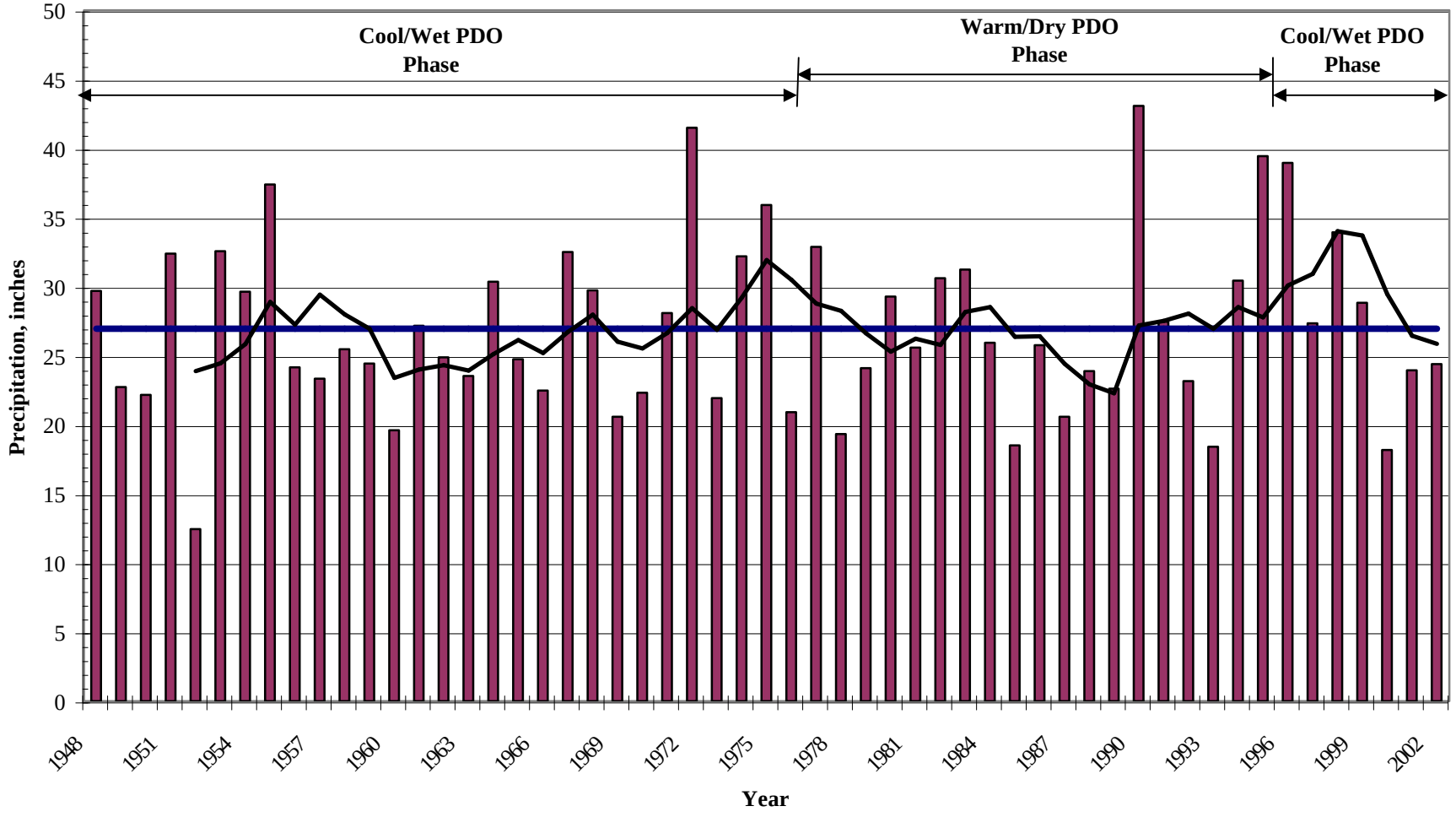
WRCC Station Number 454446
Mean Annual Precipitation = 39.3 in.
Period of Record 1948-1985

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.25 Precipitation Record
Lake Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

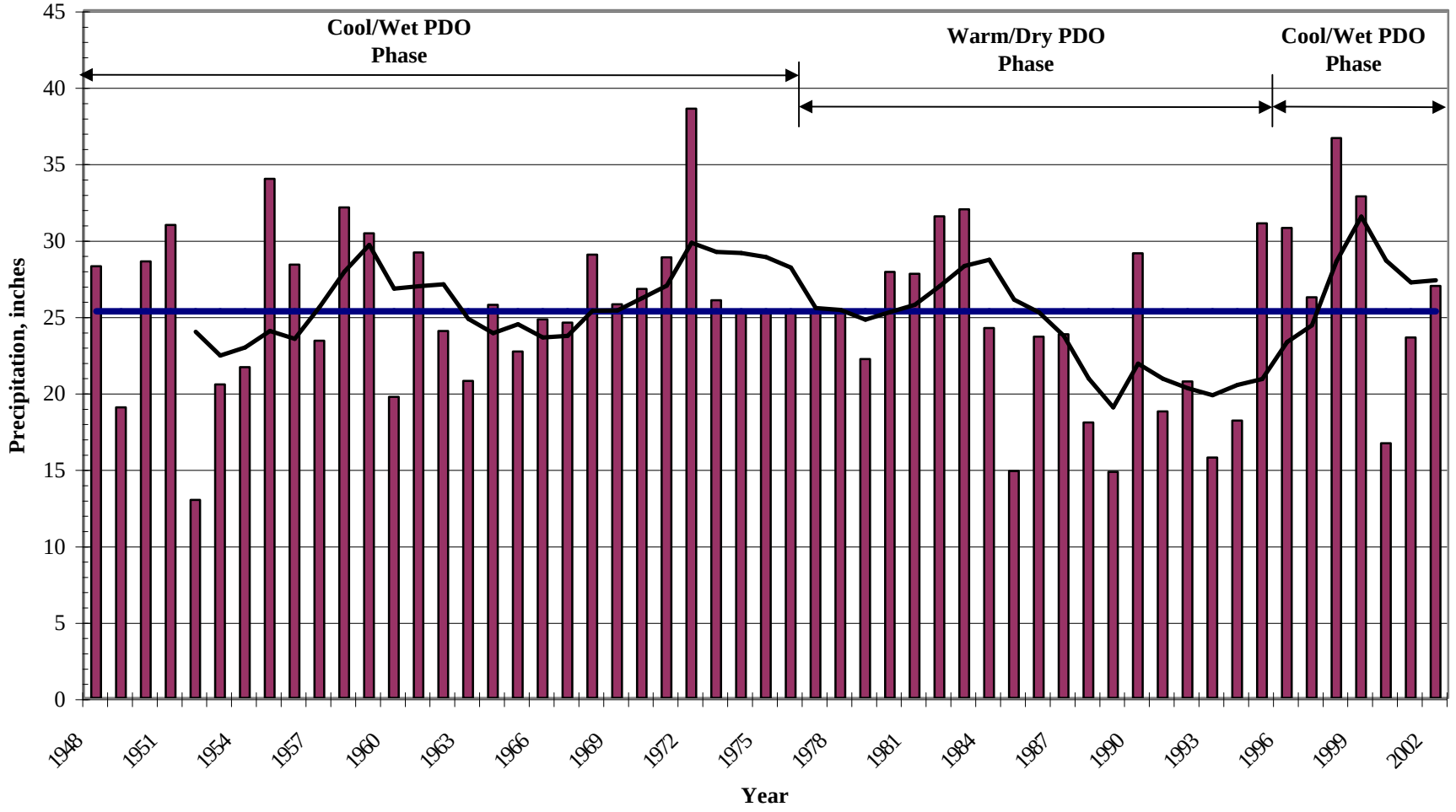
WRCC Station Number 456534
Mean Annual Precipitation = 37.0 in.
Period of Record 1948-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.26 Precipitation Record Plain, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

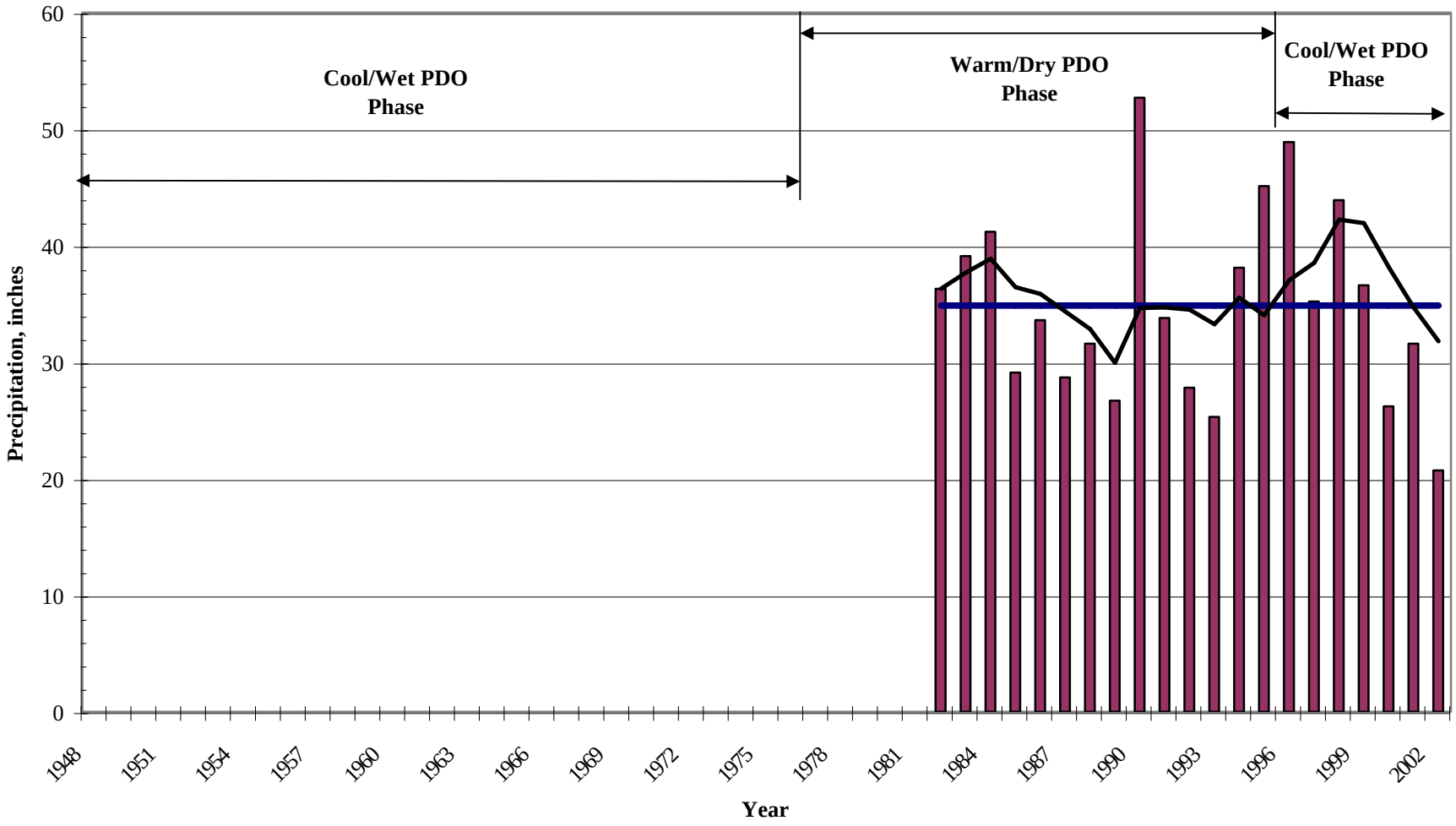
WRCC Station Number 454572
Mean Annual Precipitation = 25.3 in.
Period of Record 1948-1973, 1979-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.27 Precipitation Record
Leavenworth, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

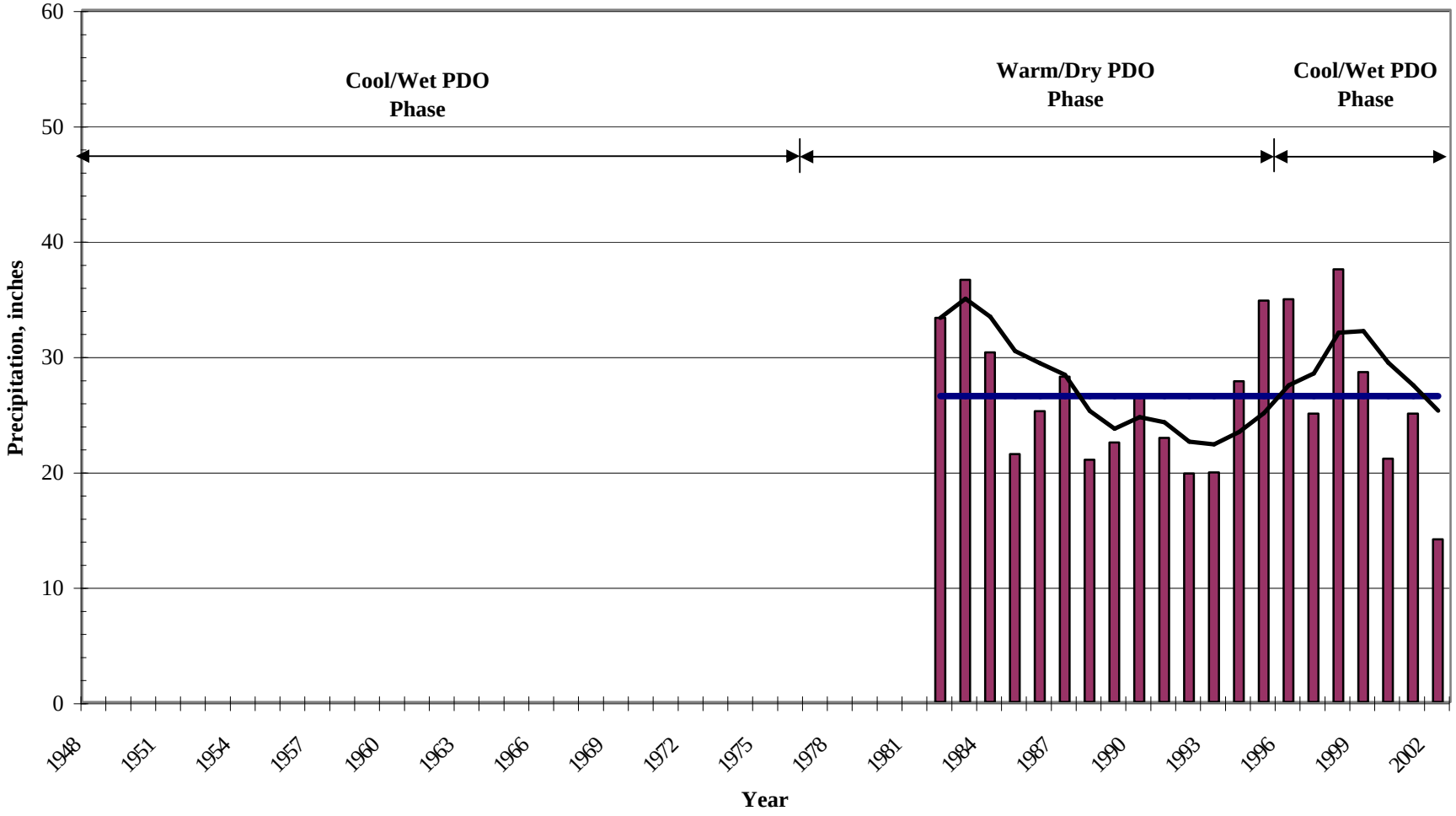
NRCS Snowtel Gage 20b20s
Mean Annual Precipitation = 35.5 in.
Period of Record 1981-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.28 Precipitation Record
Blewett Pass, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

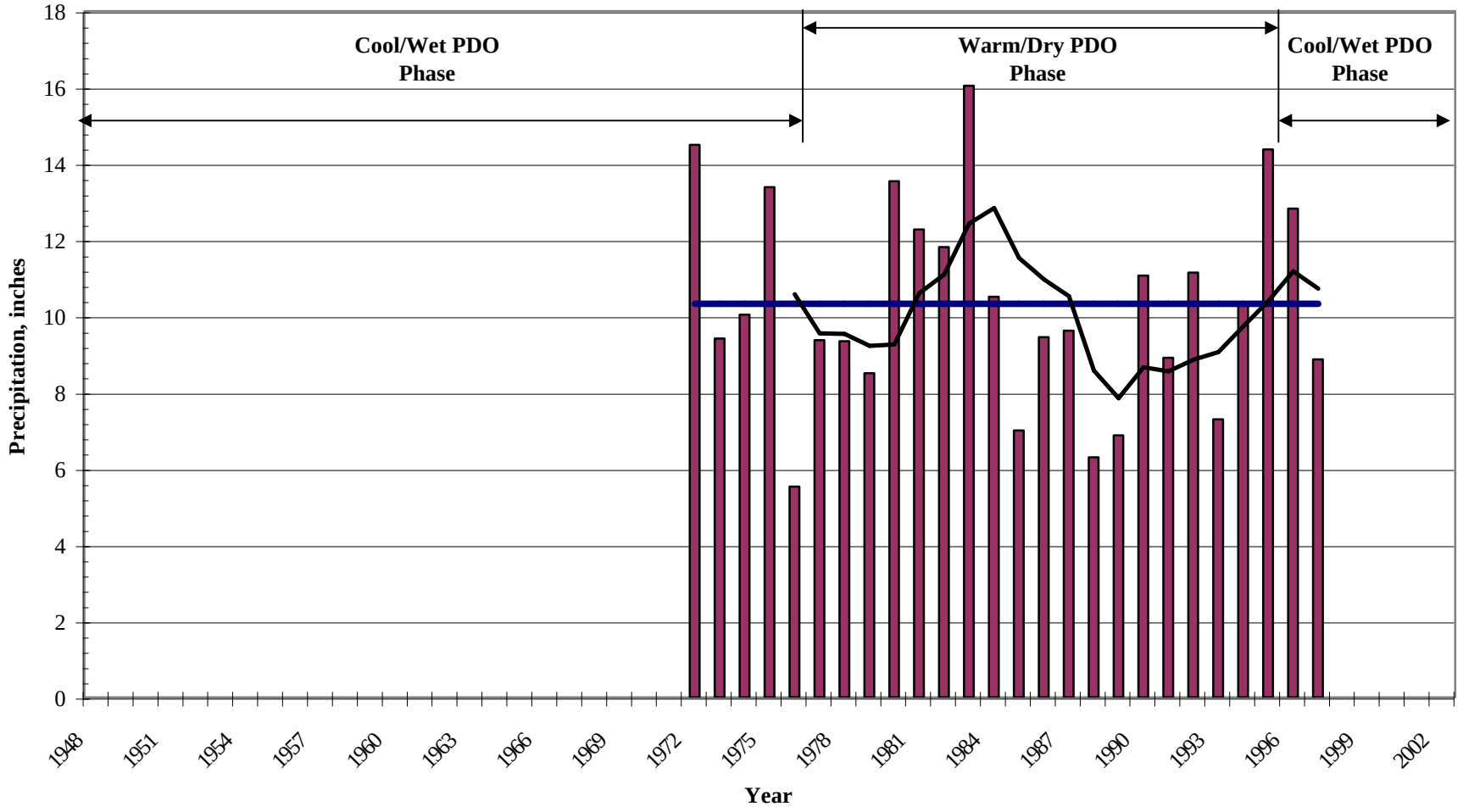
NRCS Snowtel Gage 20b07s
Mean Annual Precipitation = 27.3 in.
Period of Record 1981-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.29 Precipitation Record
Upper Wheeler, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

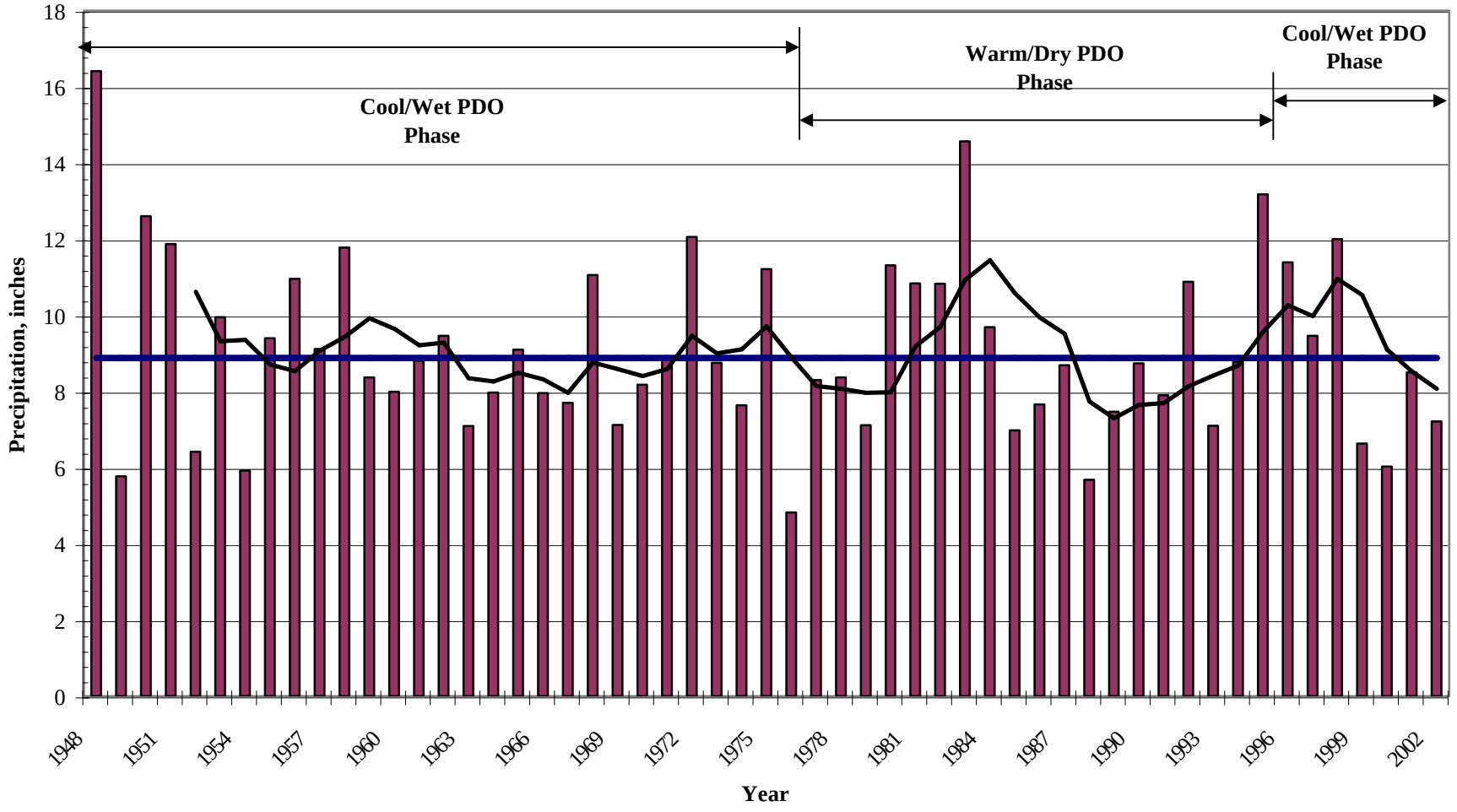
WRCC Station Number 459029
Mean Annual Precipitation = 10.3 in.
Period of Record 1950-1951, 1971-1997

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.30 Precipitation Record
Wenatchee EXP STN, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

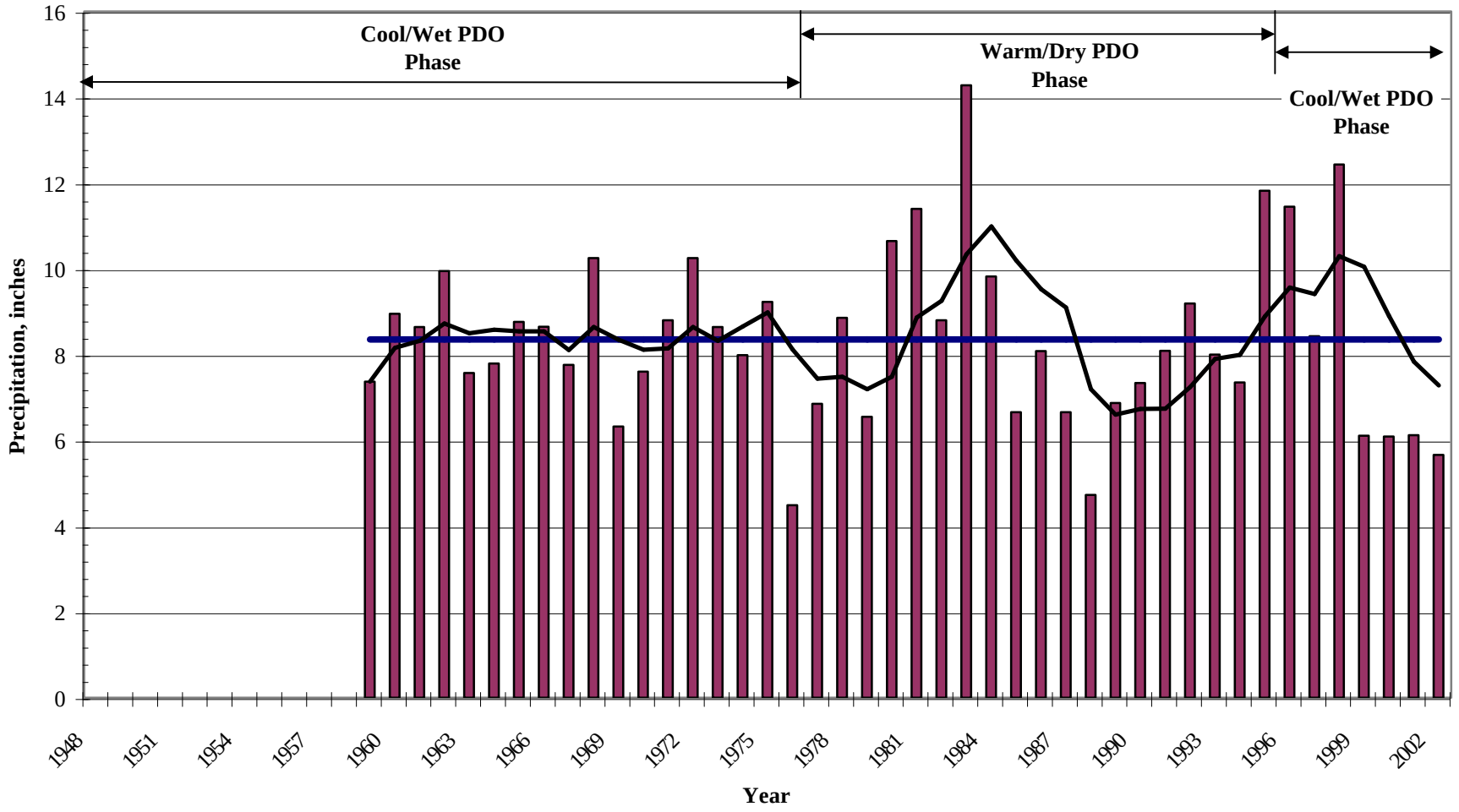
WRCC Station Number 459074
Mean Annual Precipitation = 8.9 in.
Period of Record 1931-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.31 Precipitation Record
Wenatchee, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

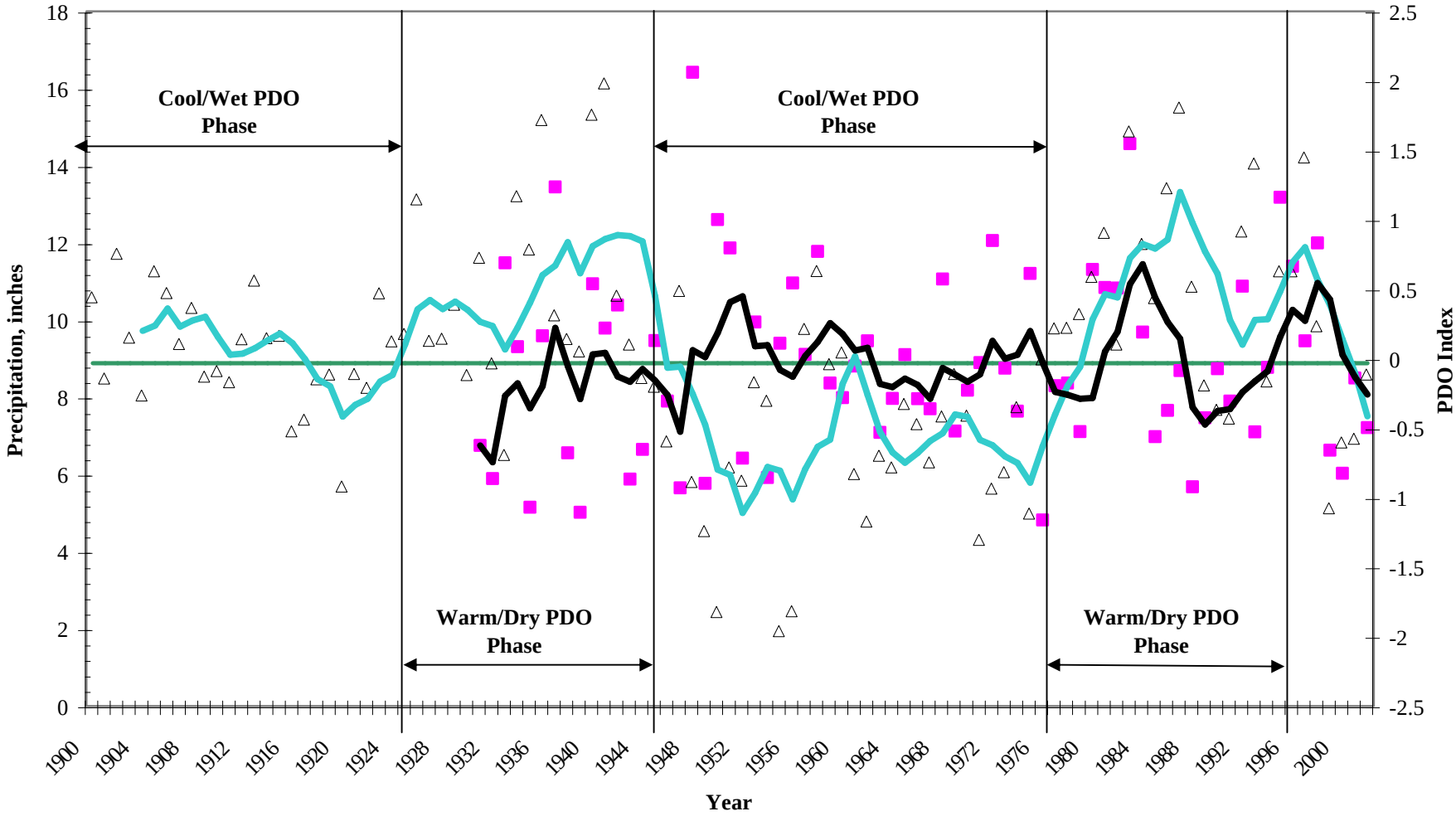
WRCC Station Number 459082
Mean Annual Precipitation = 8.4 in.
Period of Record 1959-Present

Annual Precipitation
Mean Annual Precipitation
5-Year Moving Average

Figure 3.32 Precipitation Record
Wenatchee FAA AP, WA

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.



Legend

- Wenatchee Precipitation
- Mean Annual Wenatchee Precipitation
- PDO Index: 5-Year Moving Average
- Wenatchee Precipitation: 5-Year Moving Average

Figure 3.33 Trend Analysis
PDO Index and Wenatchee Precipitation

Wenatchee River Basin Watershed Assessment

MONTGOMERY WATER GROUP, INC.