SNOW HYDROLOGY OF THE BEAR CREEK BASIN, SIERRA NEVADA

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ABSTRACT

Bear Creek is one of a few gauged streams on the west slope of the Sierra Nevada with a natural flow regime. The watershed above the gauging station is free of water management activities, roads, construction, forest harvesting, and most human influences. The streamflow record covers almost 80 years, and a few snow courses have been measured for more than 50 years. These characteristics allow Bear Creek to serve as an indicator of natural hydrologic processes in the mid- to upper-elevation portions of the Sierra Nevada snow zone. The cursory examination of the snowpack and streamflow records provide some general descriptive information that may be applicable to ungaged Sierra Nevada watersheds and suggests that there has been a slight increase in precipitation, snowpack, and streamflow in the past couple of decades.

GENERAL GEOGRAPHY OF BEAR CREEK

Bear Creek is a high-elevation tributary to the South Fork of the San Joaquin River on the western slope of the Sierra Nevada in east-central California. Its watershed is typical of subalpine-alpine terrain in the Sierra Nevada snow zone. Bear Creek is unusual by having a long-term stream gage and little human influence upstream of the gage. There are relatively few stream gages in the Sierra Nevada snow zone, and few of those have many years of record or unimpaired flow. The Bear Creek flow record and associated snowpack and climate data have the potential to provide some insights into the hydrologic characteristics of a headwater basin in the Sierra Nevada and possible changes over the past several decades.

The stream gage defines a downstream limit to the study watershed at an elevation of 2,246 m (7,367 ft). Peaks on the eastern divide extend up to an elevation of 4,181 m (13,715 ft). The drainage area of the Bear Creek watershed above the stream gage is 135 km^2 (52.5 mi^2). In a general sense, much of the catchment drains to the northwest and west. Relatively little area of the catchment has a southern aspect. From the stream gage at 2,246 m (7,367 ft) up to about 2,800 m (9,200 ft), the vegetation can be characterized as red fir / lodgepole pine forest. Above this approximate level, there is a transition in the vegetation to subalpine forest, which has an upper limit of about 3,300 m (10,800 ft). Only scattered shrubs, forbs, and grasses occur in the largely barren alpine zone.

The stream gage on Bear Creek was built in 1921 about 300 m (1,000 ft) above a diversion dam that supplies water into a major hydroelectric project. Water from Bear Creek is combined with water released from the nearby reservoirs of Lake Thomas A. Edison and Florence Lake for storage in Huntington Lake. A series of powerhouses in the Big Creek Project of Southern California Edison use the regulated water before it flows into Millerton Lake near Fresno. There are no roads, timber harvests, or other human development upstream of the gaging station.

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CLIMATE AND SNOWPACK

The Bear Creek catchment is under the influence of California's Mediterranean-type climate with dry summers and wet winters. At the elevation range of the Bear Creek basin, the great majority of the autumn and winter precipitation can be expected to occur as snow. The nearest long-term precipitation gage is located at Florence Lake, about 8 km (5 mi) to the south of the stream gage. This station has recorded an average of 570 mm (22 in) of precipitation over the past 70 years, with a range of 210 to 1220 mm (8 to 48 in). On the average, about 47% of the annual total occurs in the months of January through March, 30% in October through December, 14% in April through June, and 9% in summer. Additional climate data for the past few years is available from an automated station on Volcanic Knob, near the northern margin of the Bear Creek basin.

Two snow courses in the Bear Creek catchment have been measured since World War Two. The Rose Marie Meadow snow course at 3,050 m (10,000 ft) had an average of 730 mm (29 in) snow water equivalence on April 1, with a range of 150-1570 mm (6-62 in). The Heart Lake snow course at 3,080 m (10,100 ft) had an average of 700 mm (28 in) snow water equivalence on April 1, with a range of 130-1540 mm (5-61 in). Nearby snow courses outside of the basin, such as Pioneer Basin, Mono Pass, and Piute Pass, had similar values. Daily data from the snow sensor on Volcanic Knob allowed calculations of typical daily melt rates: 17-25 mm/day (0.6-1.0 in/day) in May and 25-33 mm/day (1.0-1.3 in/day) in June.

STREAMFLOW CHARACTERISTICS

The record of daily flows from the Bear Creek gage is remarkably complete, with only a few short periods of missing data during the past 80 years. Over this period of record, the annual average flow was 2.7 m^3/s (94 cfs) or a volume of 67,800 AF. The equivalent average depth over the basin area is 610 mm (24.2 in). The greatest annual volume occurred in 1969 and was more than twice the average, with an equivalent depth of 1290 mm (50.8 in). The minimum annual volume occurred in 1931 and was about one-third of the average, with an equivalent depth of 220 mm. The minimum annual flow at the gage averaged 13 cfs over the period of record and dropped as low as 1 cfs on rare occasions.

Over the period of record, the peak daily flow averaged 17 m^3/s (600 cfs) or 11.4 cfs per mi^2 or 10 mm/day (0.4 in/day). Peak flow in most years resulted from snowmelt runoff with the date of the peak occurring as early as May 6 and as late as July 9. The average date of occurrence of the snowmelt peak was June 6. The annual snowmelt runoff peaks ranged from 7 m^3/s (255 cfs) to 40 m^3/s (1420 cfs). The maximum snowmelt runoff peaks (daily values) were 40 m^3/s (1420 cfs) [July 9, 1975], 33 m^3/s (1180 cfs) [June 1, 1986], 31 m^3/s (1090 cfs) [July 2, 1969], 30 m^3/s (1060 cfs) [July 5, 1983]. An unusual characteristic of the snowmelt runoff pattern was a pronounced double peak in 56 out of the 78 years. On the average, the second peak occurred 23 days after the initial peak. The second peak was greater than the first in two-thirds of the cases, but there was no consistent correspondence between magnitude of the peaks and which was greater or whether a second peak even occurred. A prominent third peak was apparent in 14 of the snowmelt hydrographs. The secondary peak or peaks presumably occurred as a result of interactions between the energy available over time and the spatial distribution of snow around the catchment.

Because of the small proportion of the contributing area at elevations that are subject to mid-winter rainfall, rain-on-snow events have been rare in the Bear Creek basin. Only one warm storm has generated a daily peak exceeding the annual average peak. The four largest rain-on-snow events produced the following daily peaks: 30 m^3/s (1060 cfs) [January 2, 1997], 15 m^3/s (517 cfs) [December 23, 1955], 13 m^3/s (442 cfs) [December 23, 1964], and 11 m^3/s (400 cfs) [January 13, 1980].

Rainfall runoff from summer (or early autumn) storms has produced the two peaks of record in the Bear Creek basin that are considerably greater than the largest peak flows from snowmelt runoff. These events occurred when moisture from sub-tropical storms that would typically affect Mexico and Arizona moved north into the Sierra Nevada. Hannaford and Williams (1967) recognized the potential for such events in Bear Creek. The four largest summer storm floods were 74 m^3/s (2610 cfs) [September 26, 1982], 52 m^3/s (1,830 cfs) [September 5, 1978], 23 m^3/s (810 cfs) [September 5, 1972], and 16 m^3/s (550 cfs) [August 12, 1965]. There was a noticeable runoff response to summer rainfall in 51 of the 78 years. The flood hydrograph of September 1982 is compared to snowmelt runoff hydrographs of the adjoining snowmelt seasons in figure 1.

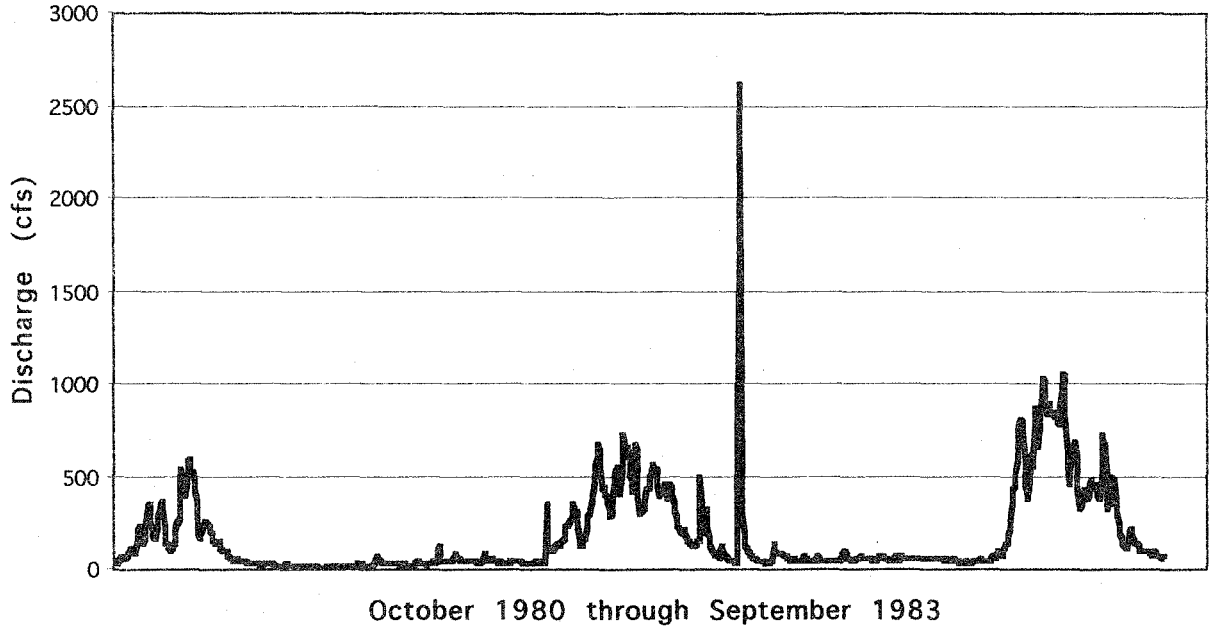

Figure 1. The snowmelt hydrographs of a below-average year (1981) and two wet years (1982 and 1983) illustrate much lower peak flows and much greater volumes than the flood of record caused in rainfall runoff in September 1982.

ANY TRENDS OR CHANGES?

The relatively long periods of record for the Bear Creek basin offer the opportunity to explore the data for changes over time. Without knowing anything about the quality of the records or changes in the measurement regime, the examination here is very simplistic and limited to comparing the averages between the first and second halves of the record. Others may wish to explore these data sets in greater detail.

Precipitation at Florence Lake (n = 70) averaged 500 mm (20 in) in the first half and 640 mm (25 in) in the second half. Snowpack water equivalence on April 1 at the Rose Marie Meadow snow course (n = 57) was 700 mm (28 in) in the first half and 760 mm (30 in) in the second half. There was great variability in seasonal snowpack storage from year to year, which is only smoothed out only somewhat with a five-year moving average (Figure 2). Snowpack water equivalence on April 1 at the Heart Lake snow course (n = 58) was 690 mm (27 in) in the first half and 710 mm (28 in) in the second half.

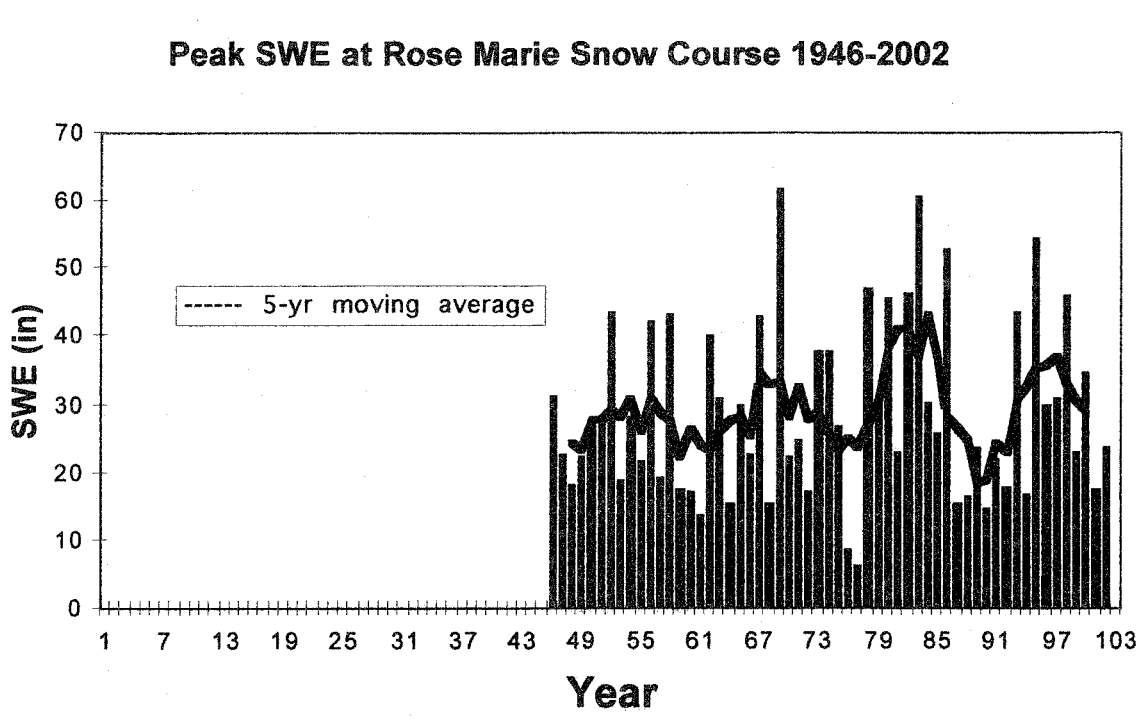

Figure 2. Although the April 1 snowpack water equivalence averaged for the period 1946-1973 was slightly greater than the average for 1974-2002, the time series shows the influence of a few wet years in the second half.

The annual streamflow depth was also greater in the second half of the period of record than the first: 570 mm (23 in) from 1922-1960 and 660 mm (26 in) from 1961-1999. The magnitude of the snowmelt runoff peak has also increased, on the average, from the first half of the record (15.5 m^3/s) [550 cfs] to the second half (17.8 m^3/s) [630 cfs]. The average date of the onset of snowmelt runoff (assessed as a sustained increase in the hydrograph over 50 cfs) was the same in the both halves of the record: April 14. The date of this onset of snowmelt runoff ranged between March 24 and May 8. The average date of the peak of snowmelt runoff was June 5 in the first half of the record and June 7 in the second half.

There appears to be a greater number of warm winter storms (assessed as those producing a noticeable increase in flow during the winter months) in recent decades than in the first decades of the flow record: 0 between 1922-29, 1 between 1930-39, 0 between 1940-49, 3 between 1950-59, 10 between 1960-69, 17 between 1970-79, 13 between 1980-89, and 5 between 1990-99.

SUMMARY

The Bear Creek catchment appears to be useful as an indicator of hydrologic processes for other ungaged basins in the higher elevation snowpack zone of the west slope of the Sierra Nevada. There are some intriguing changes over time in precipitation, snowpack, and streamflow averages that may be worthy of more careful examination.

REFERENCES

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