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PATTERNS OF FLOW, TEMPERATURE AND MIGRATION OF ADULT YAKIMA RIVER SPRING CHINOOK SALMON

By

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& WILDLIFE

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Contract ______ Washington Department of Natural Resources

Abstract

To better interpret the recent TFW-sponsored research on adult Yakima River spring chinook salmon (Berman and Quinn 1990), this report provides data on river flows, temperatures and salmon migratory timing. First, it presents graphical summaries of flow records from five gages on the Yakima River and three tributary gages for 1989. It also provides summaries from the earliest period of record (1907 or 1909 to 1911), during the mid-late 1970s and during the late 1980s for the Cle Elum and Umtanum gages. It provides yearly and mean June flows for these gages for the complete periods of record. These flow records must be viewed in the context of temperature regimes, and records are presented for the relevant months in 1989 for the Columbia and Yakima rivers (four stations on each river). Finally, the migratory timing patterns of adult chinook salmon at Prosser Dam in 1989 and Bonneville Dam from 1980-1989 are presented.

Table of Contents

Introduction

In 1989, a study of the possible impact of sub-lethal temperatures on adult spring chinook salmon in the Yakima River was undertaken (Berman and Quinn 1990). This research was sponsored by the Timber, Fish and Wildlife (TFW) Program and the University of Washington's Center for Streamside Studies. The study revealed, among other things, a clear tendency for the adult salmon to selectively occupy cool waters during the summer and a tendency for some salmon to ascend the Yakima River and spend some period of the summer in the mainstem, only to move downstream and ascend a tributary as the spawning season approached.

To better understand the overall behavior of Yakima River spring chinook salmon and this life history pattern in general, an assessment of flow, temperature and salmon migration data in the Columbia and Yakima rivers was undertaken. There is a great deal of physical and biological data but these data are collected by different agencies and reported independently. This document summarizes some of these data sets in graphical form to facilitate qualitative assessment of patterns. The records themselves have been provided to the Washington Department of Natural Resources (in LOTUS 123 format) and can be requested from this agency. It is not the purpose of this document to ascertain whether or not the current patterns of flow and temperature are injurious to spring chinook salmon.

Sources of Records

The Yakima River has an extensive series of dams and canals for storage and diversion, dating to the early 1900s. The sequence of water exploitation and details of the dams and canals may be found in US Government Printing Office (1980). The information on flows of the Yakima River and selected tributaries was acquired from the United States Geolgical Survey and Bureau of Reclamation, Department of the Interior. Temperature records for the Yakima River were acquired from the Bureau of Reclamation; those for the Columbia River were taken from the United States Army Corps of Engineers Annual Fish Passage Report for the Columbia and Snake River Projects. Data on migratory timing of chinook salmon on the Yakima River, 1989 were provided by the Yakima Indian Nation's fisheries office. Data on migration in the Columbia River were found in US Army Corps of Engineers (1989). I am grateful to the various individuals representing these organizations that courteously and promptly provided data for my use.

The metric system is now standard in scientific usage. I have therefore converted all temperature data (reported in Fahrenheit) to Celcius. However, distances and water discharges are so commonly reported in miles and cubic feet per second (cfs) that I have retained these units for the convenience of many readers. Miles may be converted to kilometers by multiplying * 1.61. Cubic feet may be converted into cubic meters by multiplying * 0.028.

Flow Patterns

Flow records on the Yakima River were examined on three temporal scales. First, 1989 daily records during the period immediately relevant to adult spring chinook salmon (April through September) were gathered and displayed for every fifth day each month for five stations on the Yakima River (Cle Elum, Umtanum, Ahtanum, Mabton and Kiona) and three tributaries: the Naches River and its tributary, the American River, and Ahtanum Creek. The locations on these gages are depicted in Fig. 1. The flow records of two gages are displayed together on each graph, in an overlapping sequence, to facilitate consideration of the degree of synchrony and increase of discharge as one moves downstream. The uppermost stations (Cle Elum and Umtanum) were closely synchronized. There was a peak flow in early-mid May at Cle Elum but a minor peak in late April was more clearly expressed downriver at Umtanum (Fig. 2). There was also a more protracted period of high flows from mid-June to the end of August. For a period in late July, upriver flows slightly exceeded those 45.2 miles downriver. The gage at Ahtanum showed the two spring peaks clearly but had a more lengthy period in the summer when flows at this station were exceeded by those at the upriver (Umtanum) gage (Fig. 3). Similarly, the flow at Mabton (RM 59.8) was dramatically lower than that at Ahtanum (RM 107.3) during the entire summer (Fig. 4). Flows at Mabton and Kiona were similar

(Fig. 5). Flows on the Naches River, tributary to the Yakima, and one of its tributaries (the American River) showed three synchronous peaks in late April, mid-May and mid-June. Ahtanum Creek, by comparison, contributes relatively little to the Yakima River's volume (Fig.6).

In addition to the intensive examination of 1989 flow patterns throughout the system, I gathered data for the two gages with the longest period or record: Cle Elum and Umtanum. These data are presented by water year (WY). For example, WY 1909 ran from October 1908 through September 1909. Cle Elum records are available since 1908 and Umtanum records are available since 1909. I selected several of the earliest years, several from the mid-late 1970s and the past 2-3 years to illustrate the general seasonal discharge patterns. Cle Elum records generally reveal a major flow period in late spring, peaking in May or June. There is often also a period of relatively high flows in December or January, though generally not as much water as flows in the late spring (Figs. 7-14).

Examination of records from Umtanum, 45.2 miles downriver from Cle Elum, showed very close correspondence with the upriver station (Figs. 15-23). This indicates that the detailed 1989 data described above were not anomalous but represent a general pattern between these sites. Both sites showed variation from year to year in flow pattern, particularly regarding the presence and magnitude of the winter flow peak. However, the flow patterns in the early years were not clearly different from the most recent ones.

Examination of the total annual flows at Cle Elum (Fig. 24) and Umtanum (Fig. 25) did not reveal any clear trends. Flows varied by about a factor of three at each site from year to year and total flows at the sites mirrored each other. The Cle Elum June flow records suggested that there has been a decrease in mean monthly flow (Fig. 26) or June flow as a percent of the annual total (Fig. 27). However, records for the early 1980s were not available. Umtanum June records (Figs. 28 and 29) indicate that June flows have been somewhat less variable in recent years than they were formerly. In particular, anomalously high June flows are less common. Based on the fact that downriver flows (e.g., Mabton and Kiona) were lower than upriver flows during the summer of 1989, it is likely that examination of 80 years of flow data on these sites would have revealed more dramatic variations in flow than were observed at the upriver sites. However, these sites did not have such records available.

Temperature Patterns

Temperature was the environmental factor of primary interest when the spring chinook salmon work was initiated. Some information was presented by Berman and Quinn (1990) but additional records were gathered for the present report to complement the flow records. I collected daily temperature records for the Columbia River Dams (Bonneville, The Dalles, John Day and McNary) from April 1 through October 31 (Figs. 30, 31, 32, 33). These data indicate the temperatures that Yakima River spring chinook salmon experience during their migration (see next section for data on migratory timing) and also indicate the temperatures that they would experience if they migrated later in the season. Early in April, temperatures are coolest at McNary (just over 6) and are progressively warmer as one moves downriver to almost 8 at Bonenville Dam. However, over the period examined, there is generally very close correspondence of temperatures among the dams (Fig. 34). Peak temperatures were generally between 20 and 22. During the likely migration period (April), temperatures rose from about 8 to 11.

Yakima River temperatures from April 1 through October 1, 1989 were examined at Parker (Sunnyside Dam), Umtanum, Ellensburg and Cle Elum. Three patterns were displayed. The lowest site of the four, Parker, showed a smooth curve with only minor changes from day to day (Fig. 35). The other three sites show more variation, including an abrupt rise in early May. The Umtanum and Ellensburg records track each other very closely (Figs. 36, 37) whereas the Cle Elum temperatures were cooler in the spring but matcher the Umtanum and Ellensburg records from early July through the end of September (Figs. 38, 39).

Adult Chinook Salmon Migrations

I examined the daily counts of adult spring chinook salmon at Prosser Dam on the Yakima River (Fig. 40). This is a low dam (structural height 9 feet, hydraulic height 7 feet) on the lower river, well below Roza Dam where the salmon for the radio telemetry study were collected (Berman and Quinn 1990). These records show a well-defined migratory peak; almost all the fish passed the dam in May.

While a large number of chinook salmon populations pass the mainstem Columbia River dams (Bonneville, The Dalles, John Day and McNary) besides Yakima River chinook, I nevertheless examined the passage records for general patterns at these four sites (Fig. 41). These data revealed the well-known spring and fall peaks, hence I chose to display the spring (January through July) separately for closer examination (Fig. 42). There is a peak of spring chinook at Bonneville Dam in April and the peak shifts towards May as one moves upriver. One could calculate a mean or median passage date at each dam using daily records. However, for simplicity, I used monthly mean counts at the four dams (using the 15th of each month as the passage date) and calculated mean passage dates (days of the year) of 125 for Bonneville Dam, 128 for The Dalles, 131 for John Day and 134 for McNary. Bonneville is 147 miles from McNary, hence this model estimates a travel rate of 16.3 miles per day. By comparison, the fall chinook salmon timing curves at the four dams are perfectly synchronous, suggesting that those fall chinook travelling upriver may do so more rapidly than the spring chinook.

Interpretation

Spring chinook salmon (and races of other salmon species that spend prolonged periods in freshwater prior to spawning) have evolved a life history pattern that is a compromise rather than the optimal life history solution that most evolutionary models presume. The ideal salmon life history strategy is to take advantage of the ocean's productivity through the summer and leave the ocean in fall when productivity drops and freshwater spawning areas become accessible and favorable, as river flows increase and temperatures decrease. However, some races forsake the ocean when it is most productive and migrate to unproductive streams, fast all summer and spawn in the fall.

In general, spring chinook salmon and summer steelhead are found in the upper reaches of watersheds. I hypothesize that these races evolved to exploit favorable spawning areas that could be reliably accessed only in the spring. It is likely that were sections of rivers which posed barriers to passage at certain water levels. Given that the salmon will not feed during the summer, they can maximize their reproductive output (crudely measured by egg mass/body weight ratio) in two ways. First, they can enter the river with as much energy stored as possible. Second, they can expend energy as slowly as possible when in freshwater.

The relatively slow upstream migration suggested by the mainstem dam passage records is consistent with energetic savings. The tendency of Yakima River spring chinook to maintain low internal body temperatures would also lead to energy conservation, as would the tendency to hold in pools and behind islands or other current-breaks. Basically, salmon fitness will be increased by tactics which result in minimal expenditure of energy.

Flow and temperature are important for adult spring chinook salmon in several regards including attraction to the river, migration rate, location of holding areas and energy expenditure during the summer. At the time when chinook salmon apparently enter the Yakima River (May), flows in the lower river are still quite high. Lower river flows are low during the summer (on the order of 1000 cfs) and the salmon seem move upriver and hold in regions where the flows are greater. This is not meant to imply a cause and effect relationship between declining lower river flows and upriver movement. Neither detailed data on salmon movements in the lower river nor pre-development migration data are available for analysis. However, it might be instructive to track adult salmon in the lower river and to examine all passage records for association between flow regime and movement patterns.

To the extent that land and water management increases water temperatures available to salmon and decreases the availability of low velocity holding areas, the reproductive success of the salmon will be affected. Detailed information on holding habitat used by the salmon was beyond the scope of the radiotracking study by Berman and Quinn. However, it would be very useful to acquire more information on the holding areas regarding depth and velocity as well as temperature.

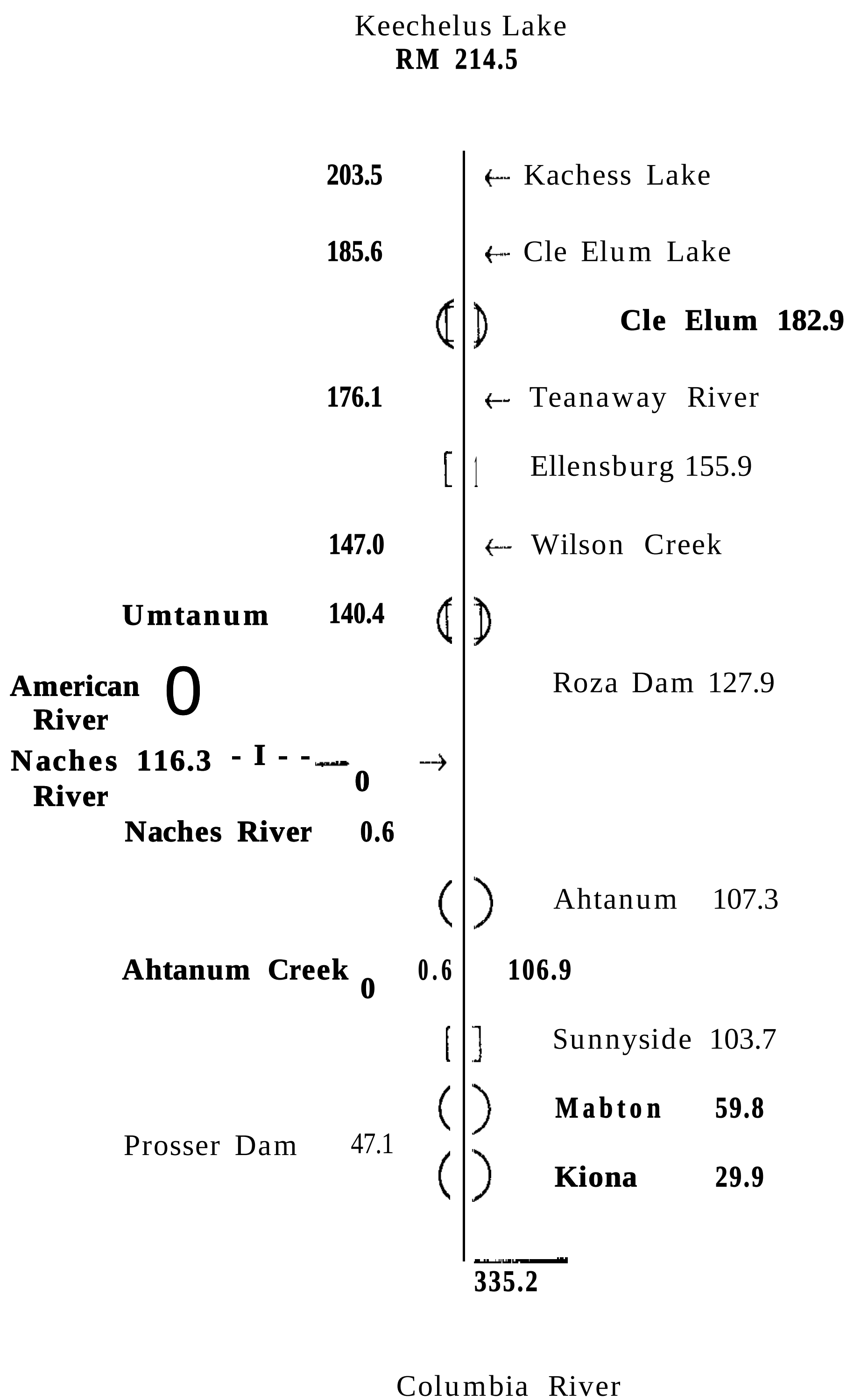
References

Berman, C.H. and T.P. Quinn. 1990. Effects of elevated temperature regimes on the reproductive success of adult spring chinook salmon. TFW report.

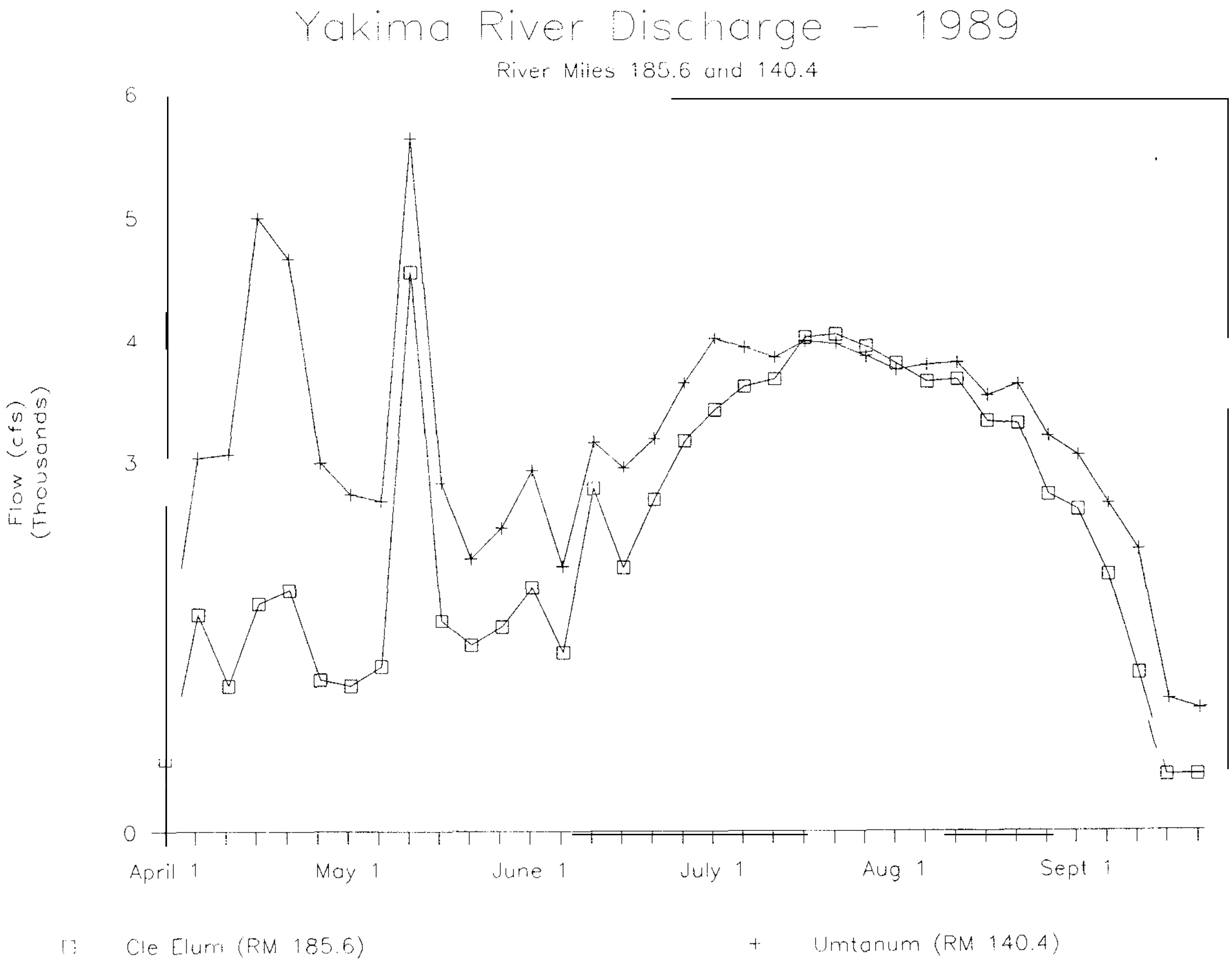
Unites States Army Corps of Engineers. 1989. Annual fish passage report - 1989. Columbia River projects, Snake River projects: Oregon and Washington. Portland and Walla Walla.

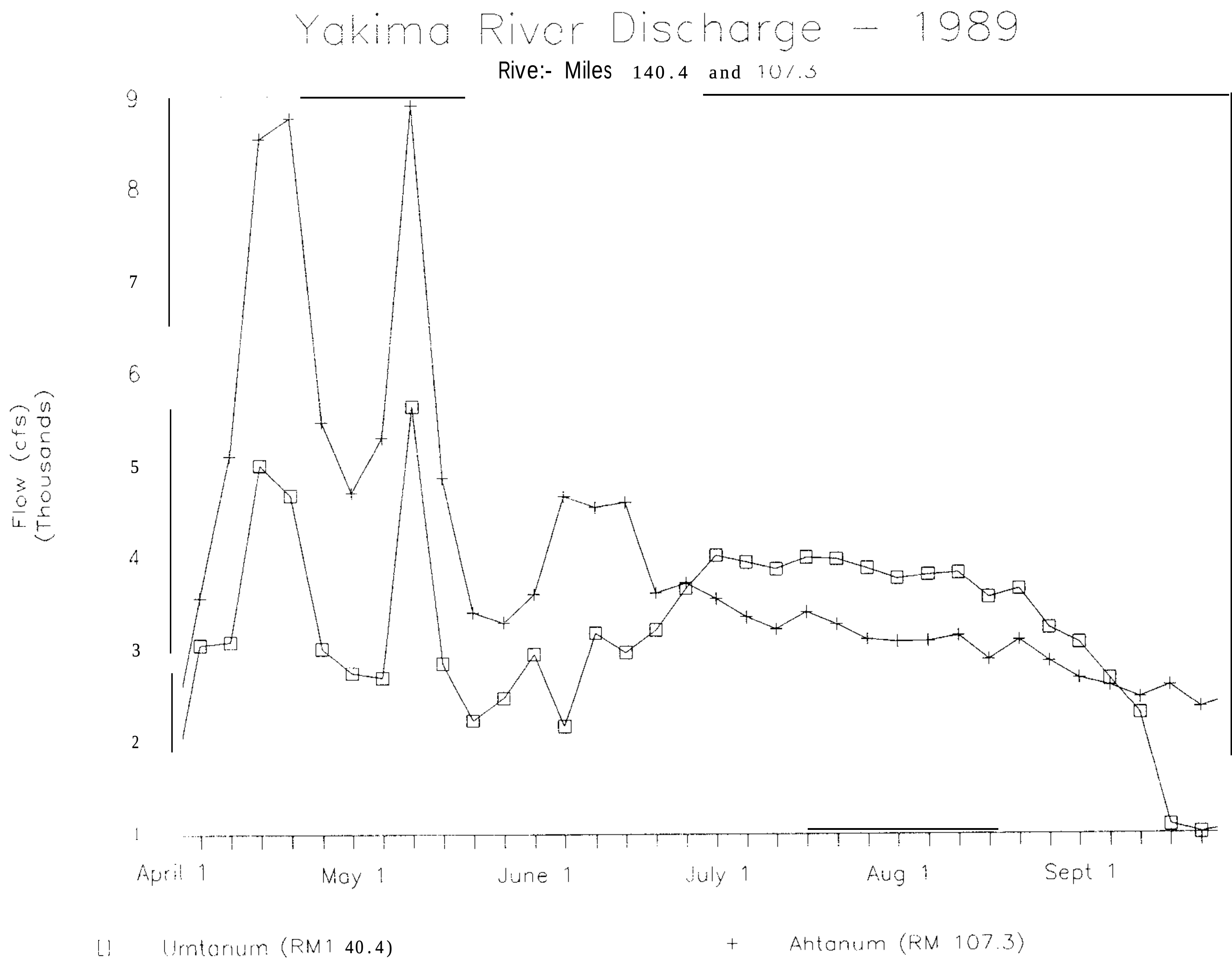
United States Government Printing Office. 1980. Yakima Project. Pacific Northwest Region, Water and Power Resources Service. 777-505.

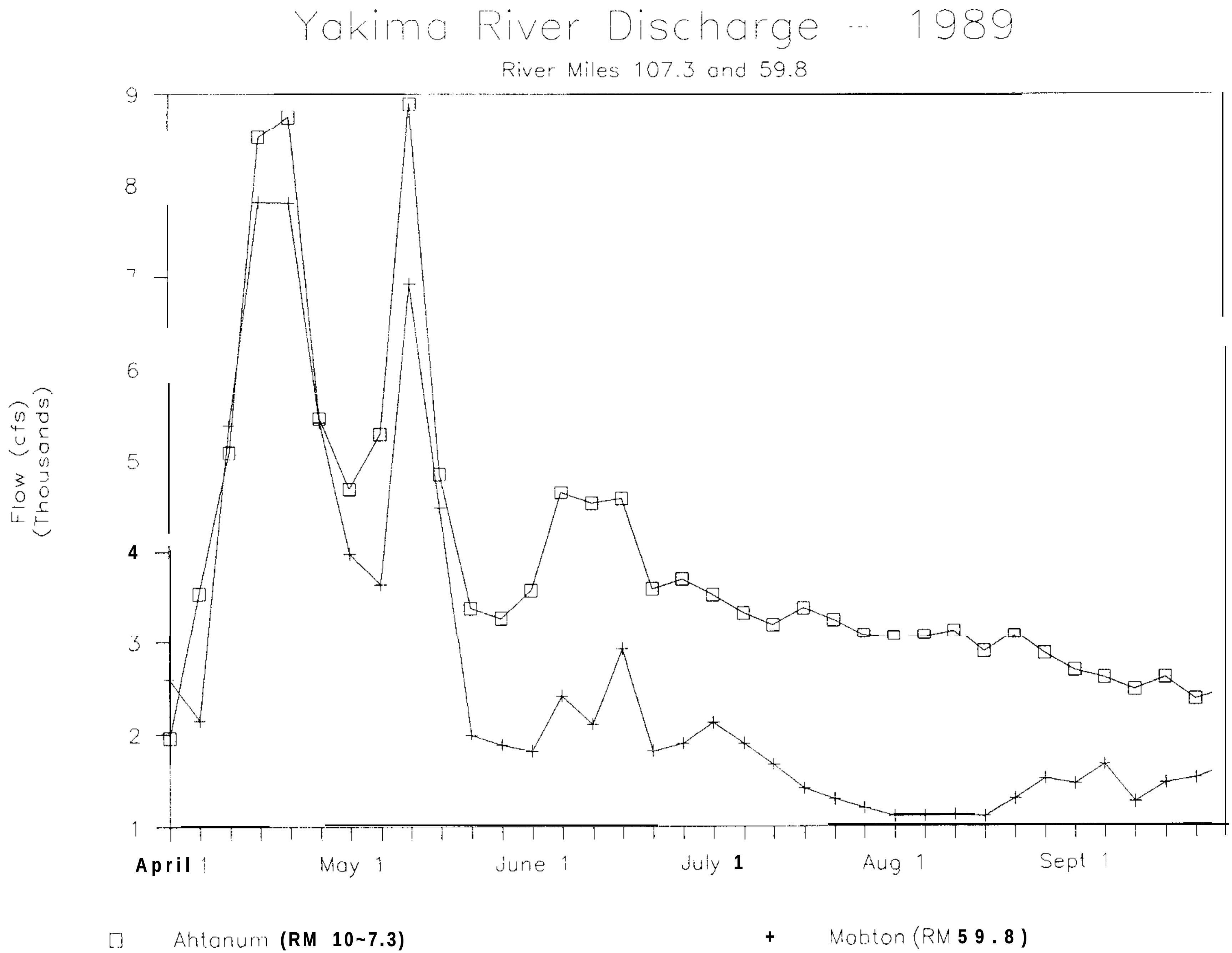
<u>List of Figures</u>



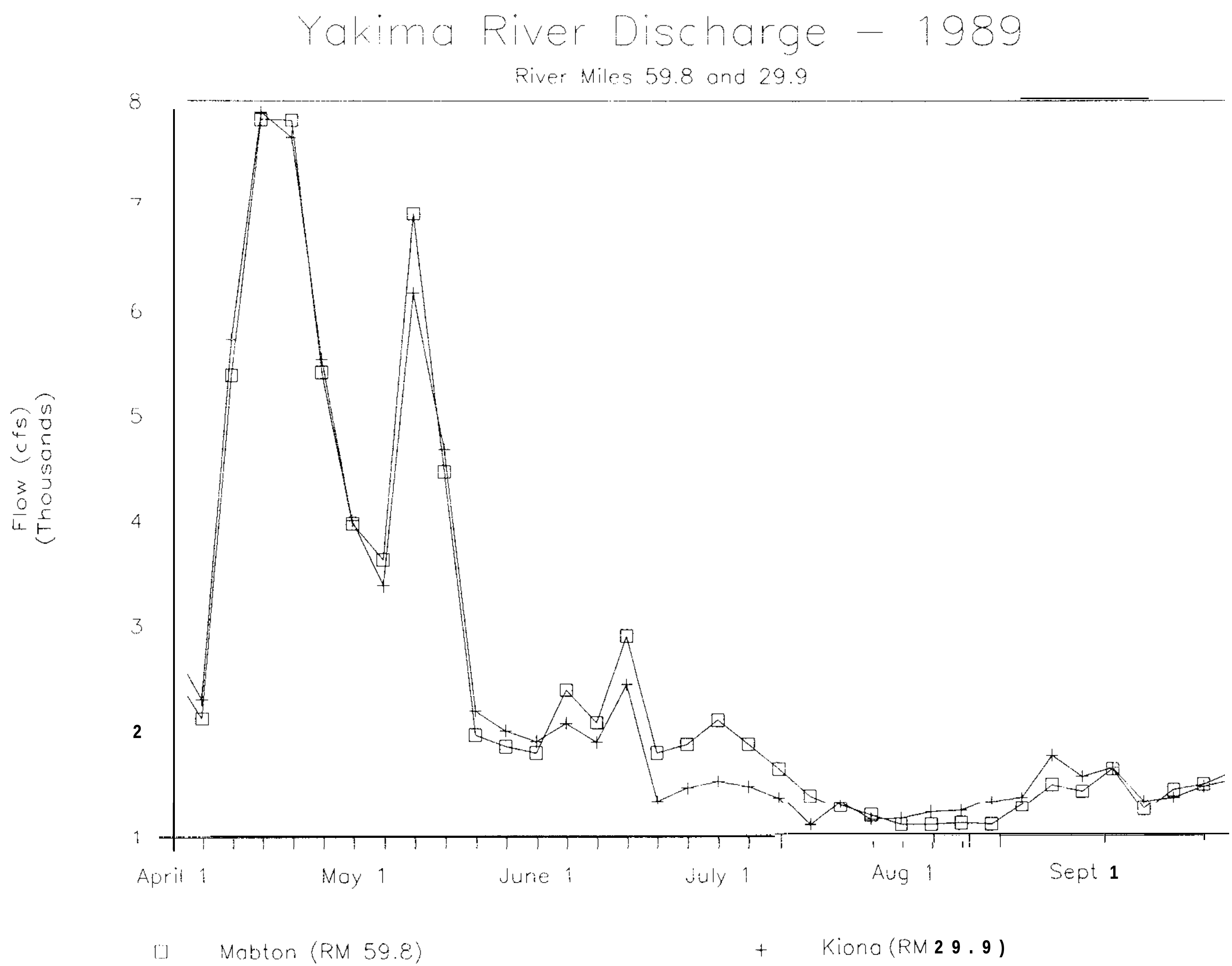
Locations of flow gages on the Yakima River, indicted by circles, and the River Mile of selected gages and tributaries. Squares indicate temperature recording stations. Not drawn to scale.


Yakima River Discharge – 1989
River Miles 185.6 and 140.4
Flow (cfs)
(Thousands)
6
5
4
3
0
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Cle Elum (RM 185.6)
Umtanum (RM 140.4)

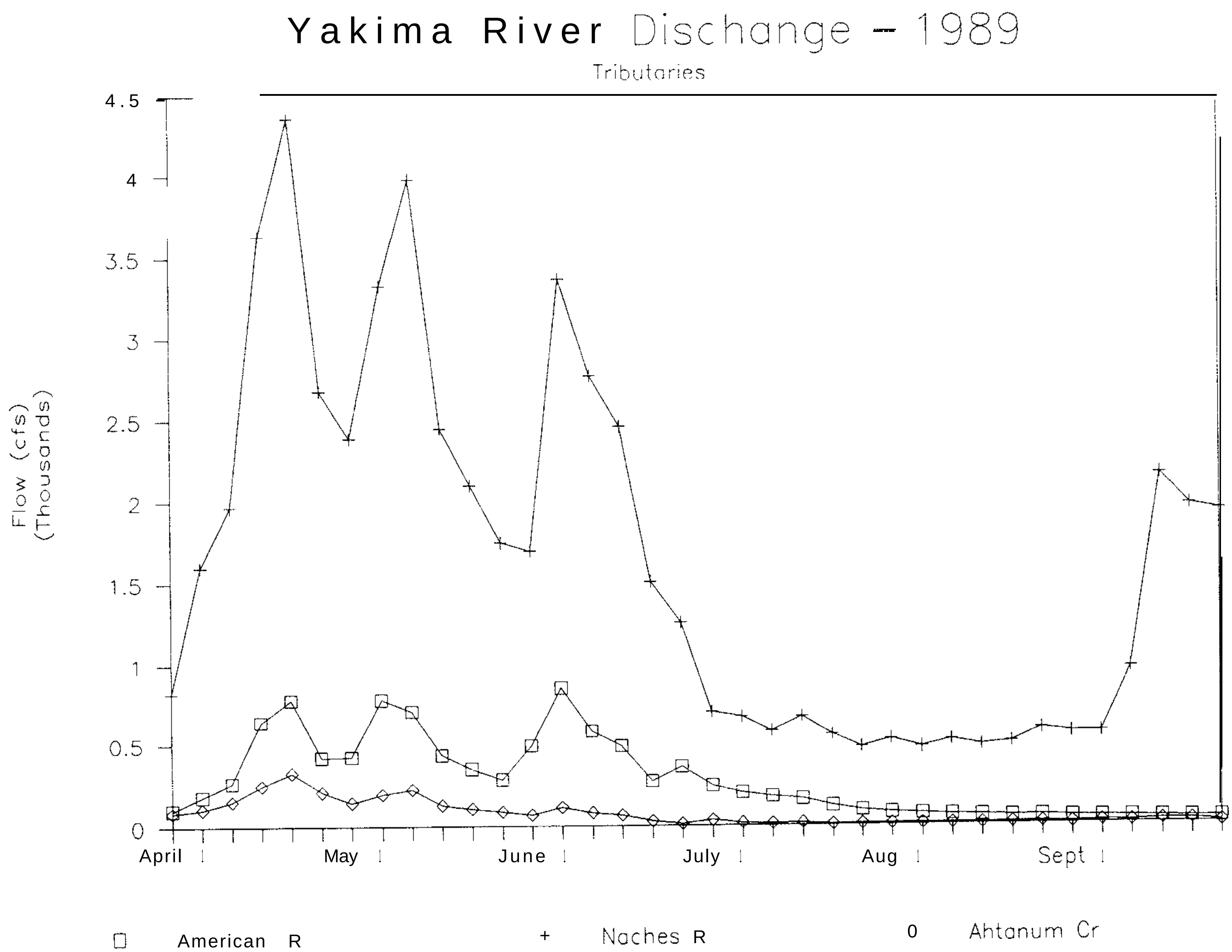

Yakima River Discharge - 1989
Rive:- Miles 140.4 and 107.3
Flow (cfs) (Thousands)
9
8
7
6
5
4
3
2
1
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Umtanum (RM1 40.4)
+ Ahtanum (RM 107.3)



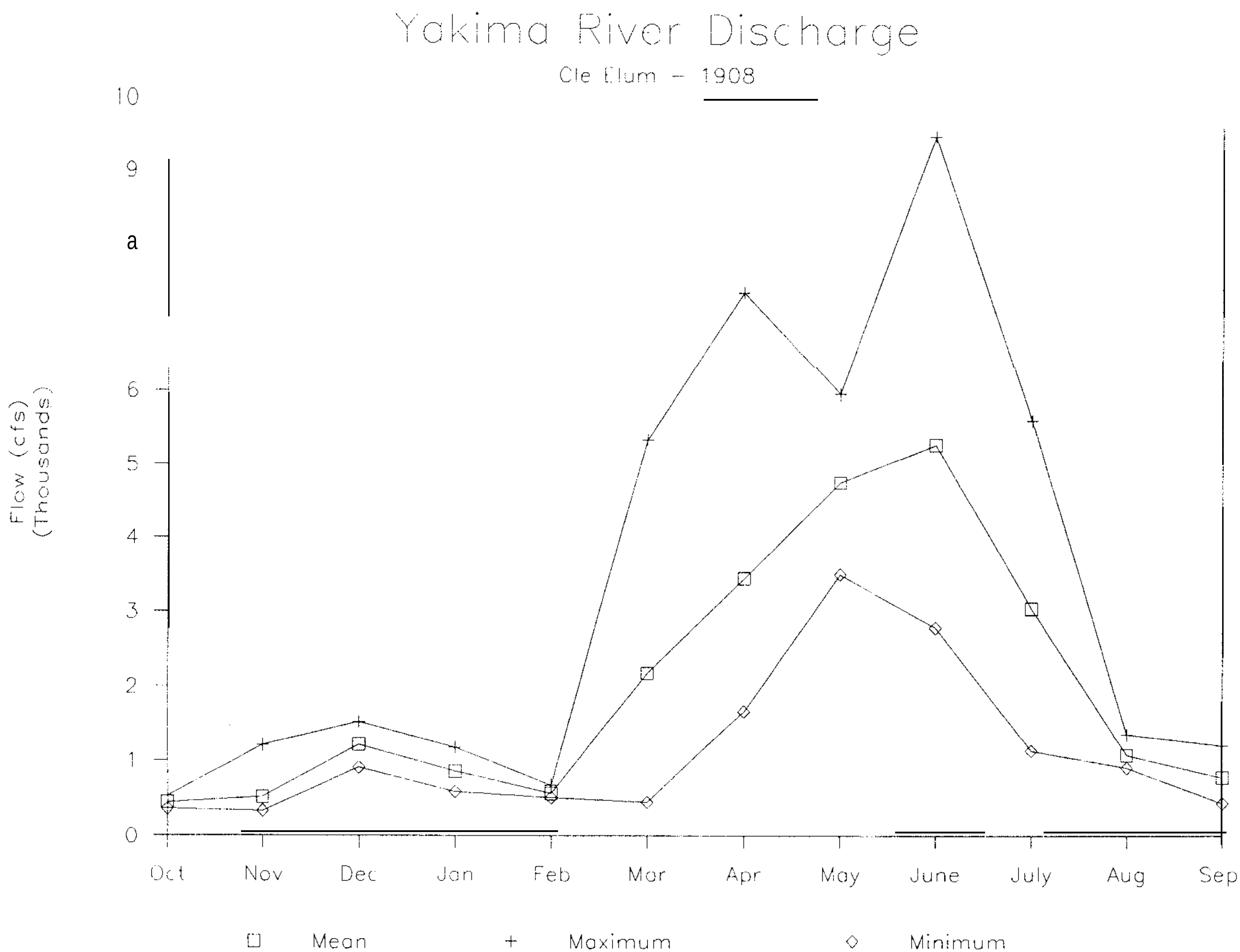
Yakima River Discharge -- 1989
River Miles 107.3 and 59.8
Flow (cfs)
(Thousands)
9
8
7
6
5
4
3
2
1
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Ahtanum (RM 10~7.3)
Mobton (RM 59.8)



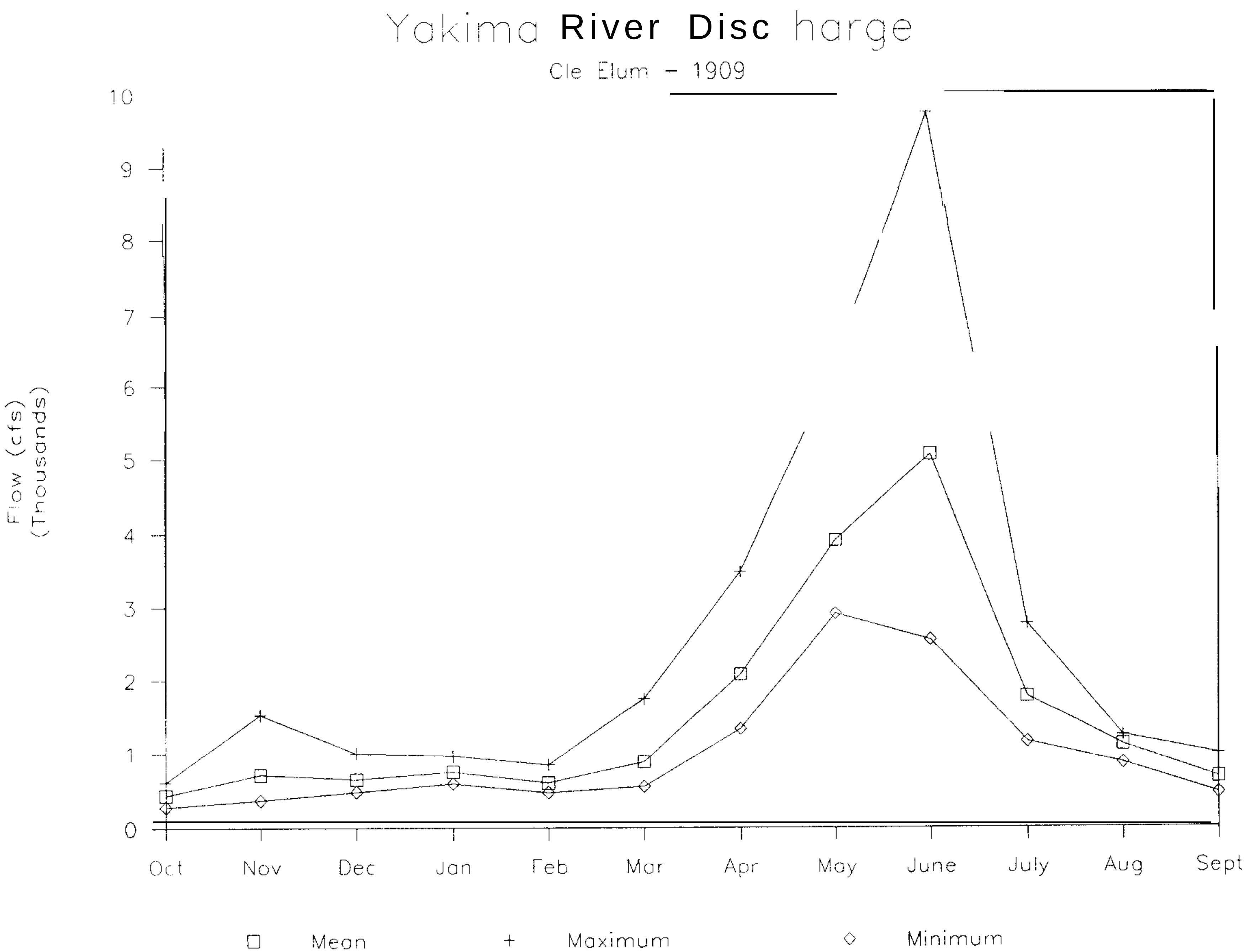
Yakima River Discharge — 1989
River Miles 59.8 and 29.9
Flow (cfs)
(Thousands)
8
7
6
5
4
3
2
1
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Mabton (RM 59.8)
Kiona (RM 29.9)

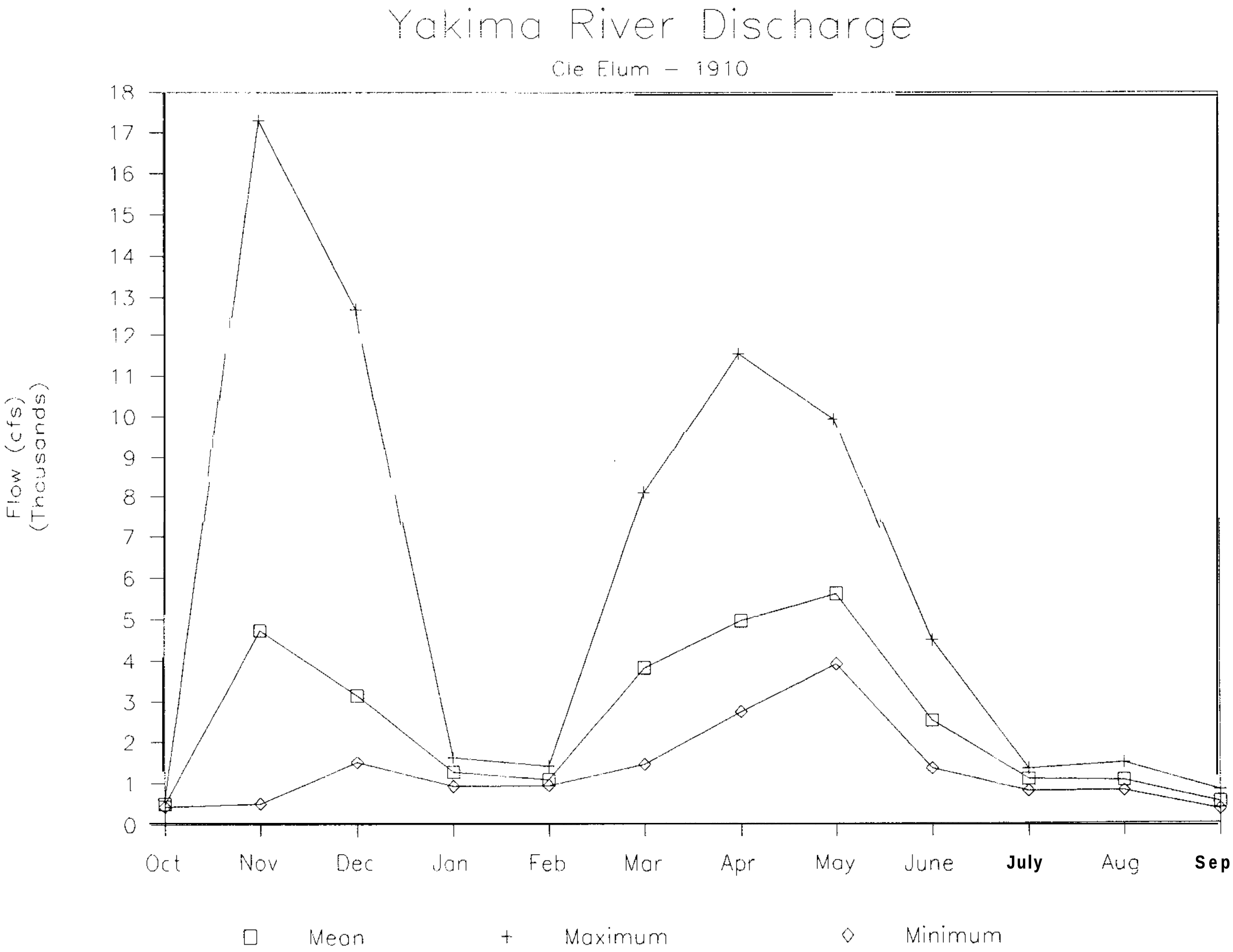


Yakima River Dischange - 1989
Tributaries
Flow (cfs)
(Thousands)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
April
May
June
July
Aug
Sept
American R
+ Naches R
0 Ahtanum Cr

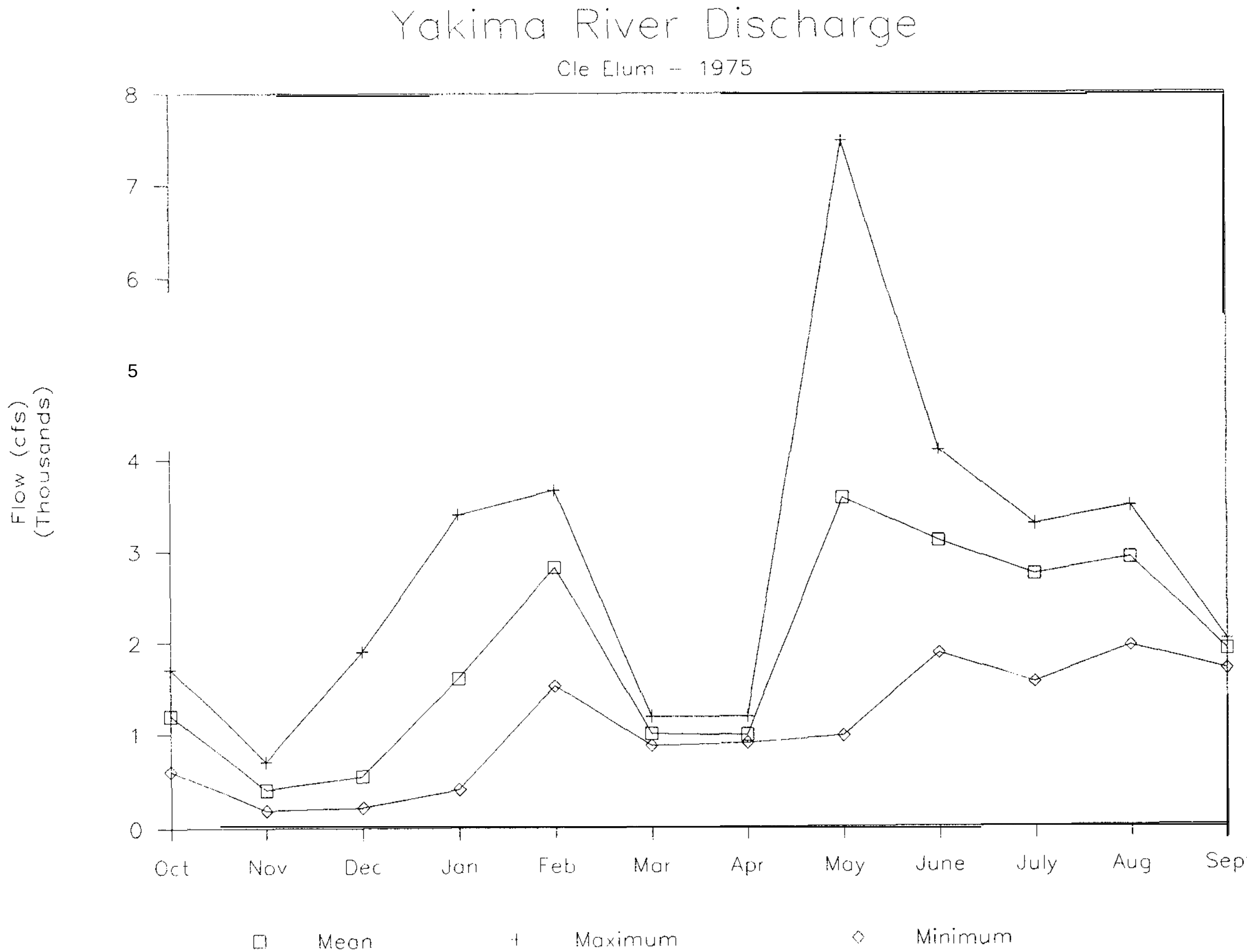


Yakima River Discharge
Cle Elum - 1908
Flow (cfs)
(Thousands)
10
9
a
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

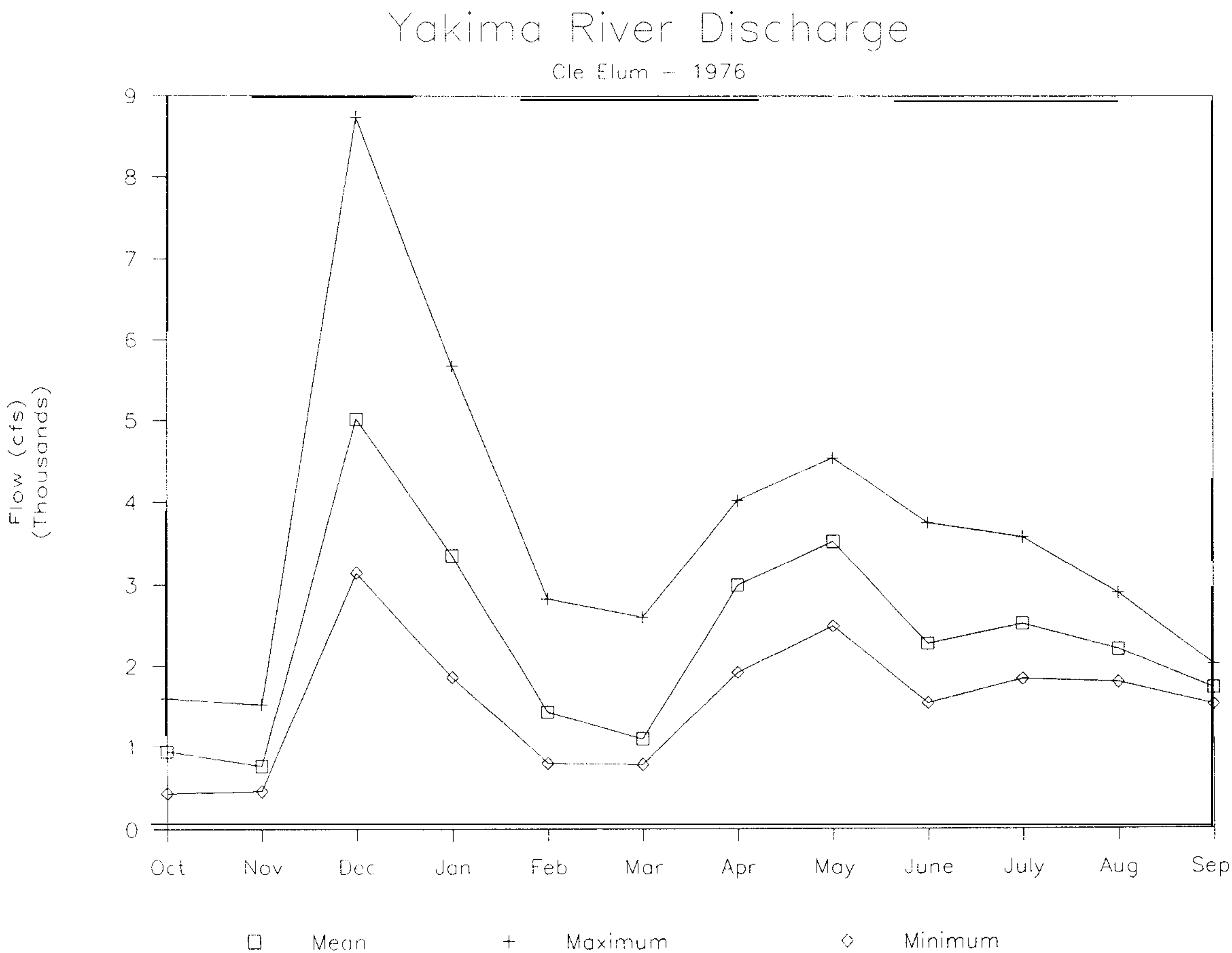

Yakima River Discharge
Cle Elum - 1909
Flow (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

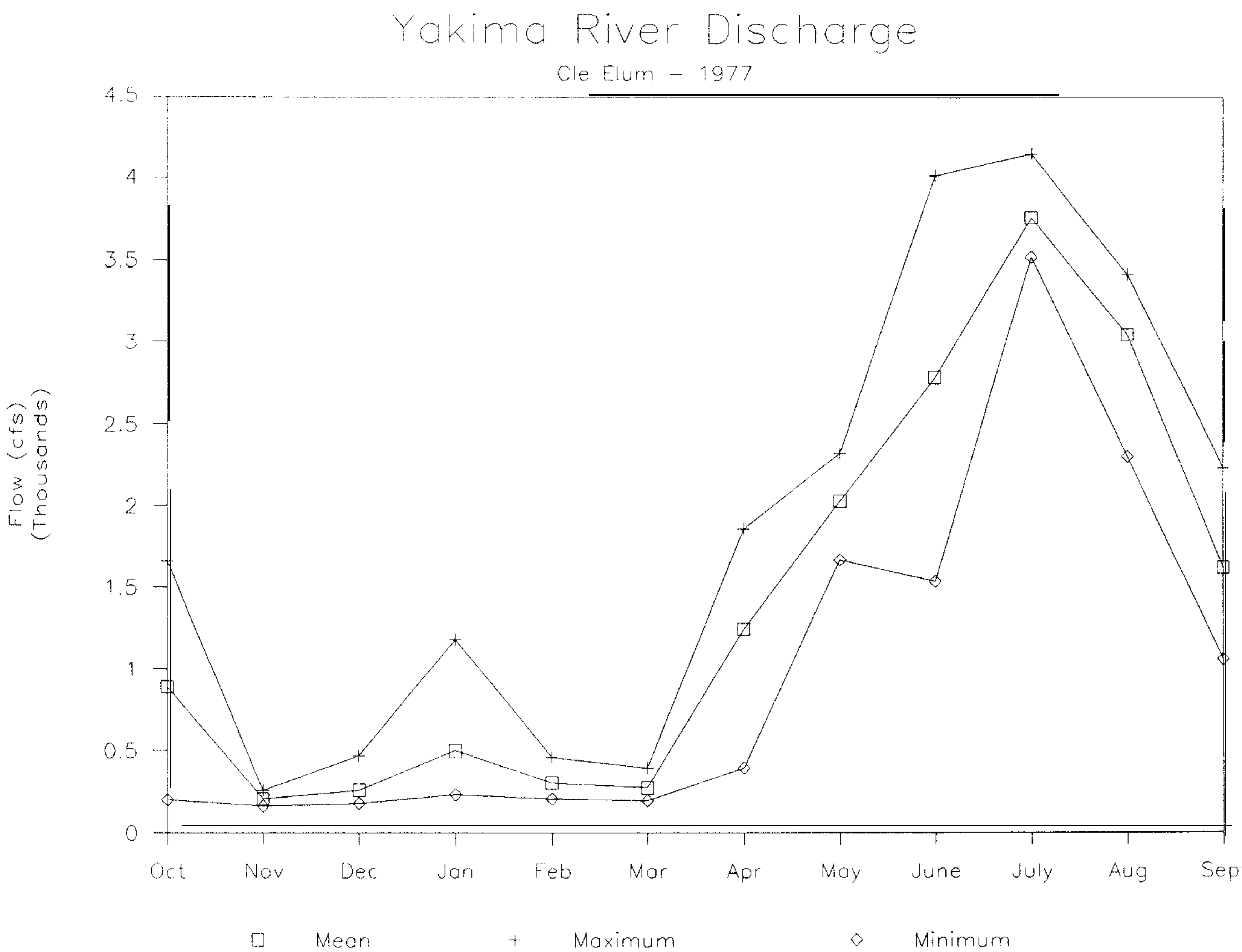


Yakima River Discharge
Cle Elum - 1910
Flow (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

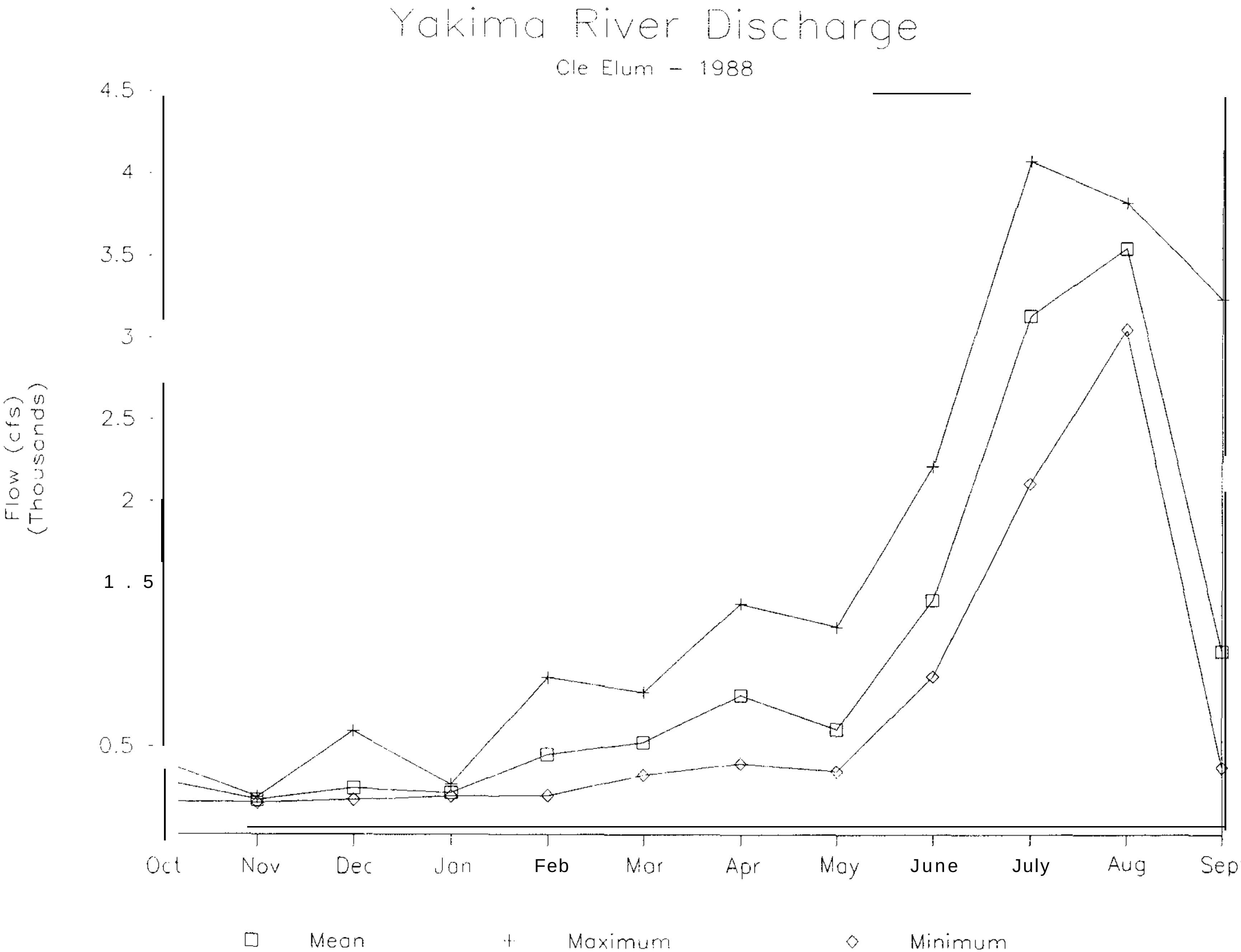


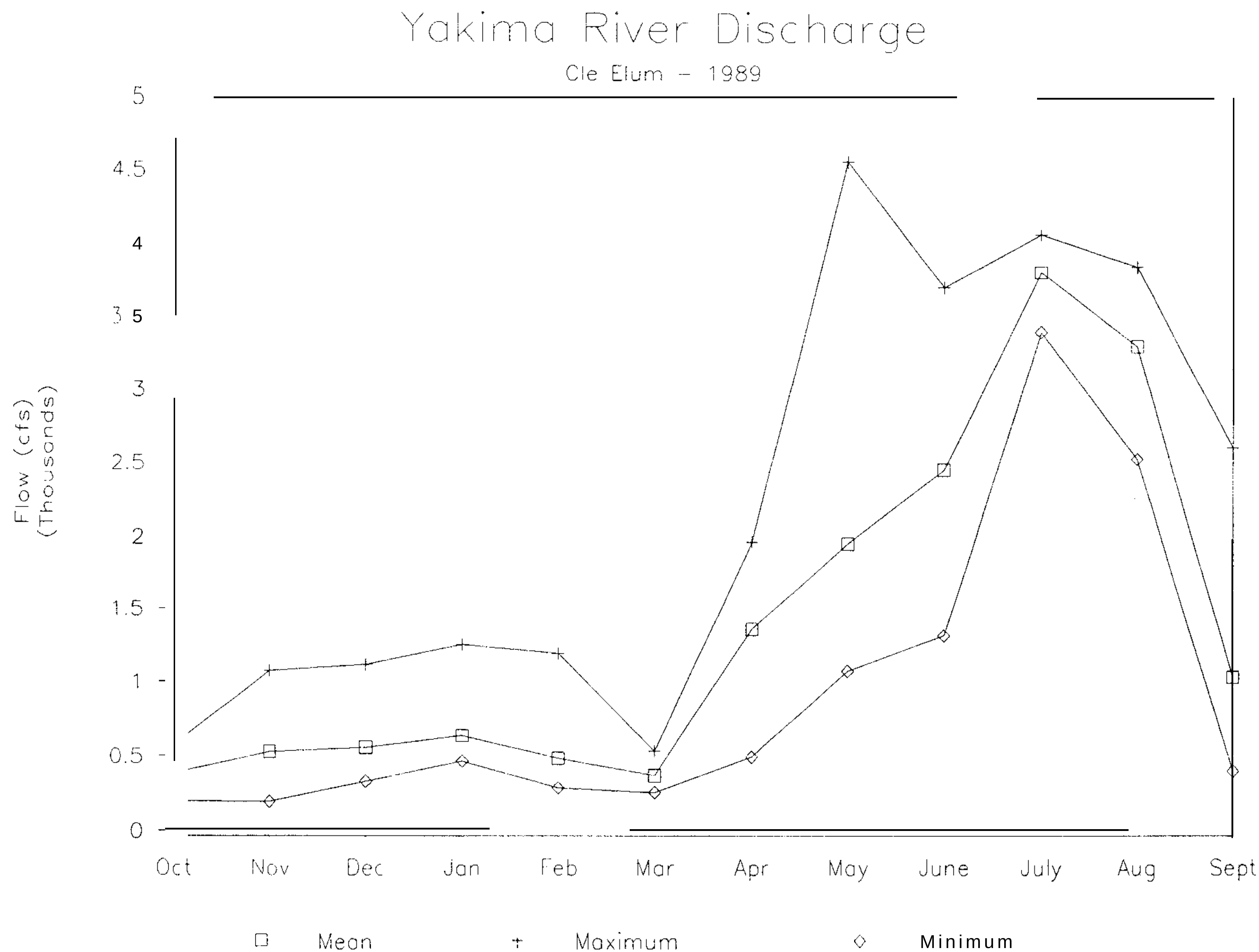
Yakima River Discharge
Cle Elum – 1975
Flow (cfs)
(Thousands)
8
7
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

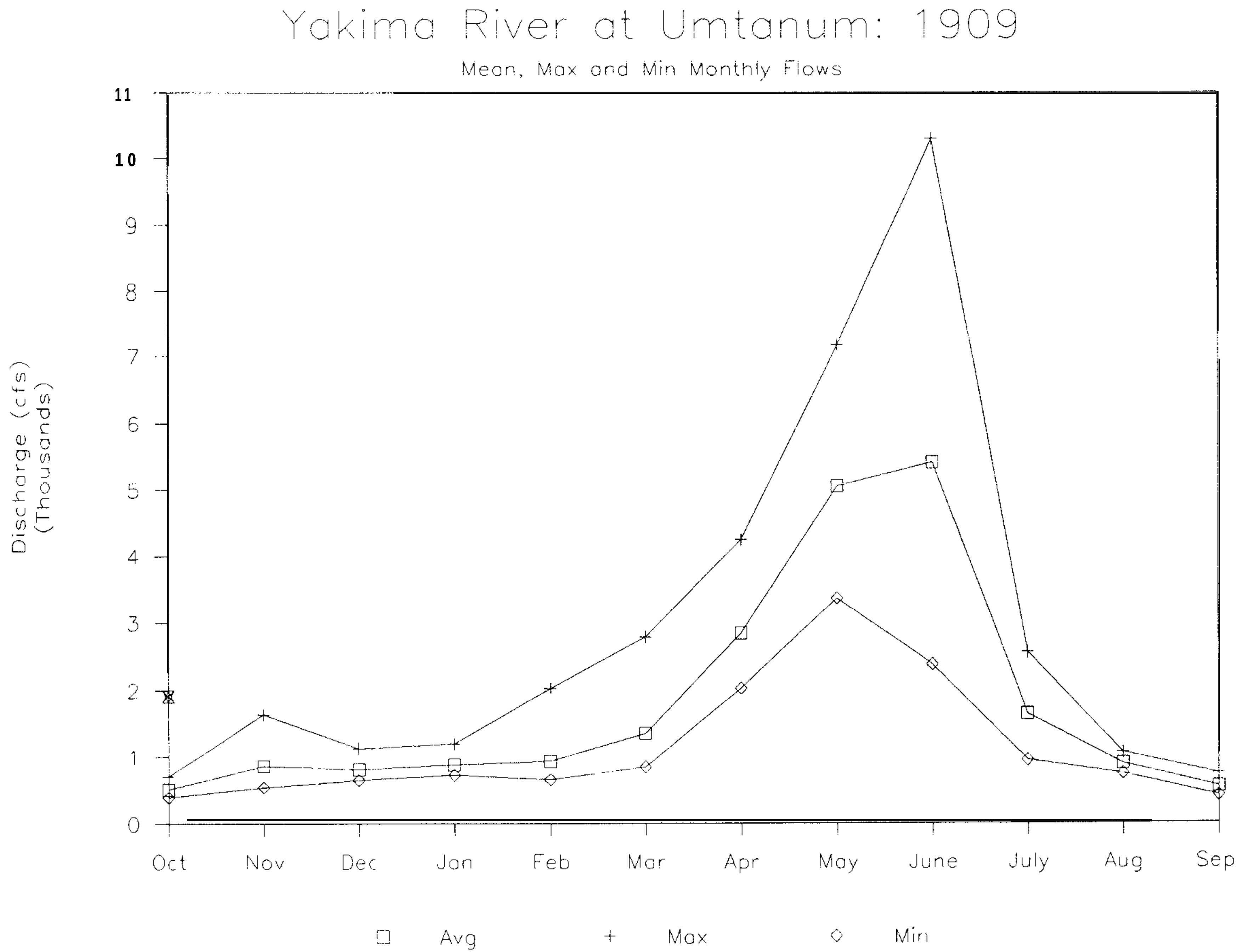

Yakima River Discharge
Cle Elum - 1976
Flow (cfs)
(Thousands)
9
8
7
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

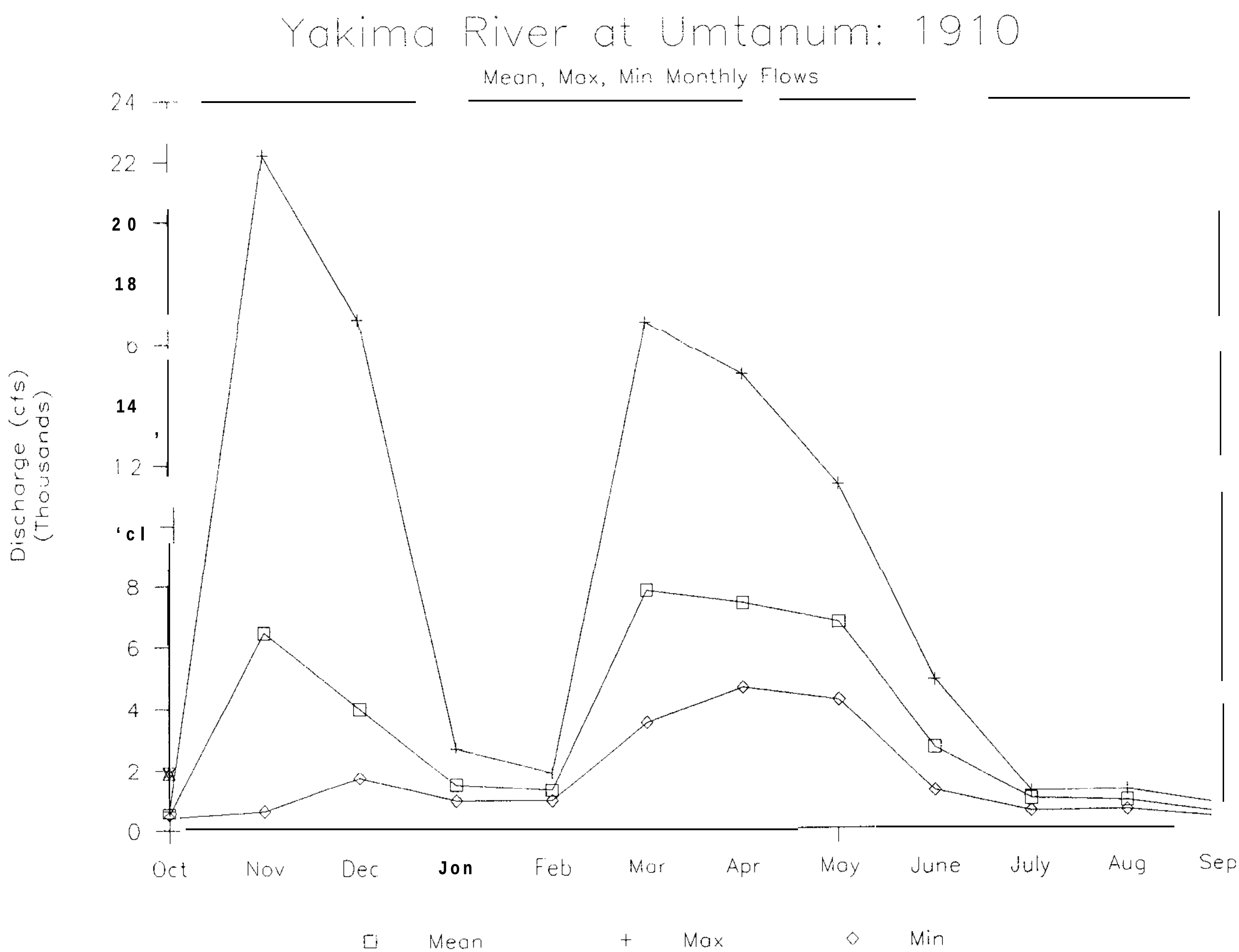


Yakima River Discharge
Cle Elum – 1977
Flow (cfs)
(Thousands)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

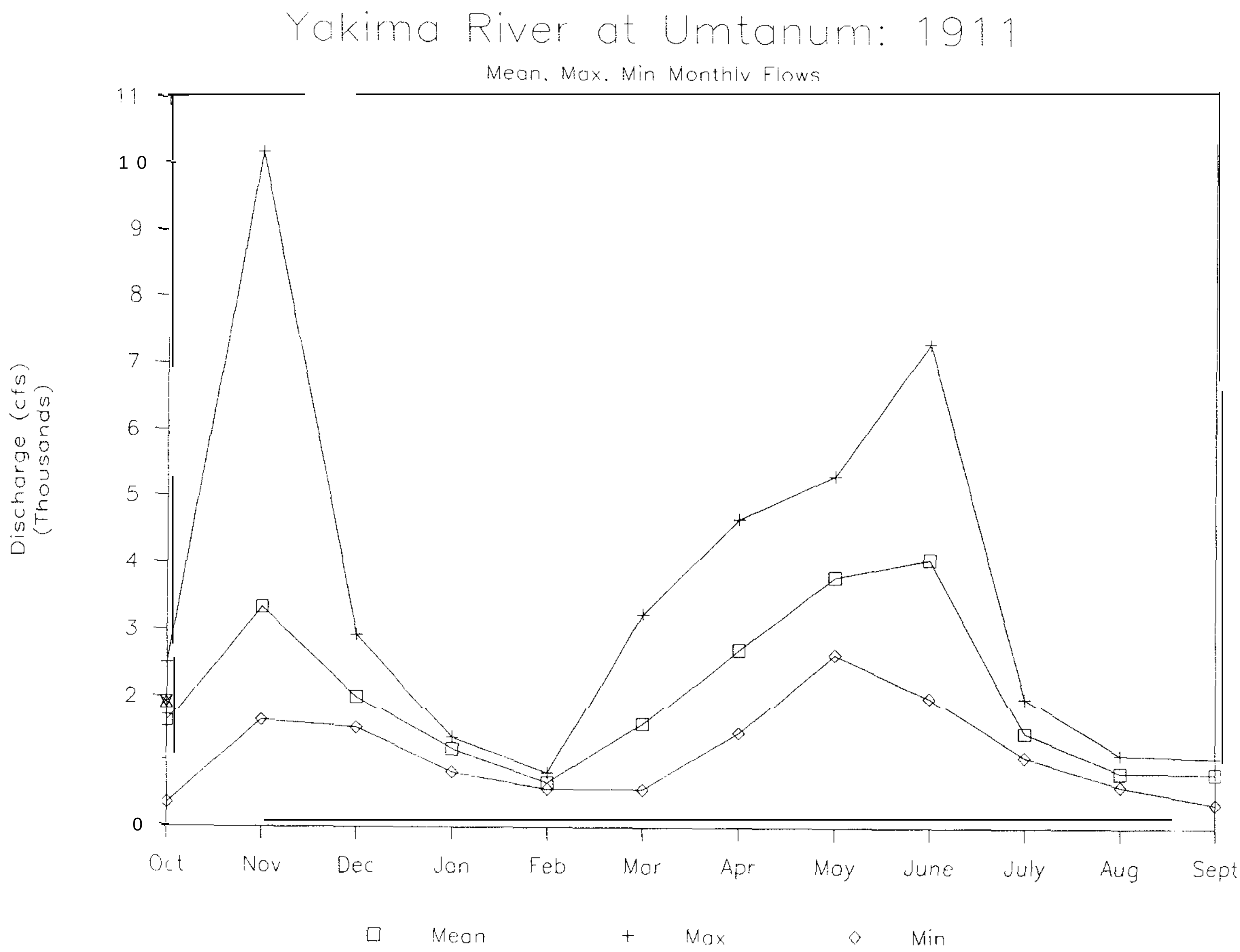

Yakima River Discharge
Cle Elum - 1988
Flow (cfs)
(Thousands)
4.5
4
3.5
3
2.5
2
1.5
0.5
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum


Yakima River Discharge
Cle Elum - 1989
Flow (cfs)
(Thousands)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Maximum
Minimum

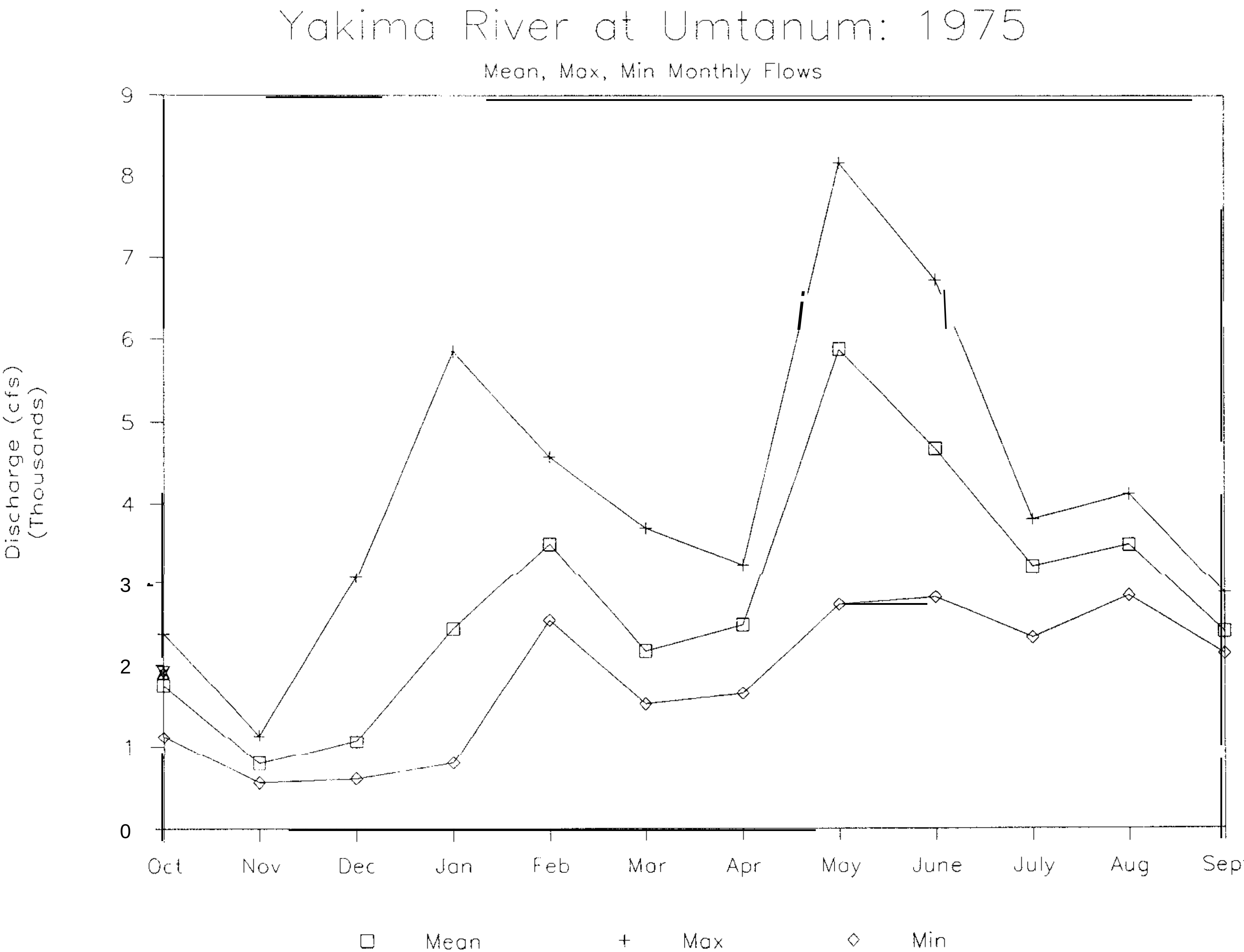

Yakima River at Umtanum: 1909
Mean, Max and Min Monthly Flows
Discharge (cfs)
(Thousands)
11
10
9
8
7
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Avg
Max
Min

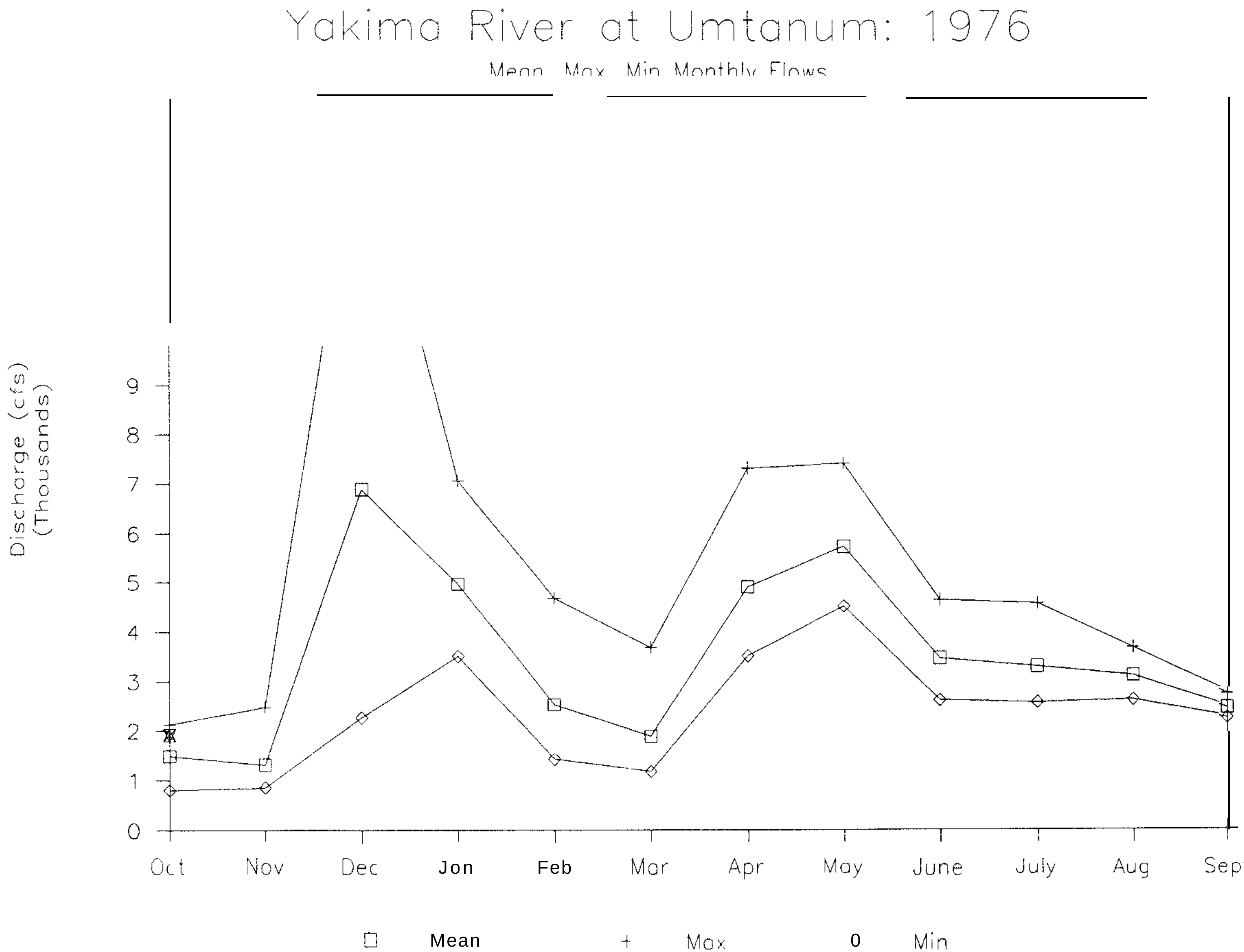


Yakima River at Umtanum: 1910
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
24
22
20
18
6
14
12
'cl
8
6
4
2
0
Oct
Nov
Dec
Jon
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min

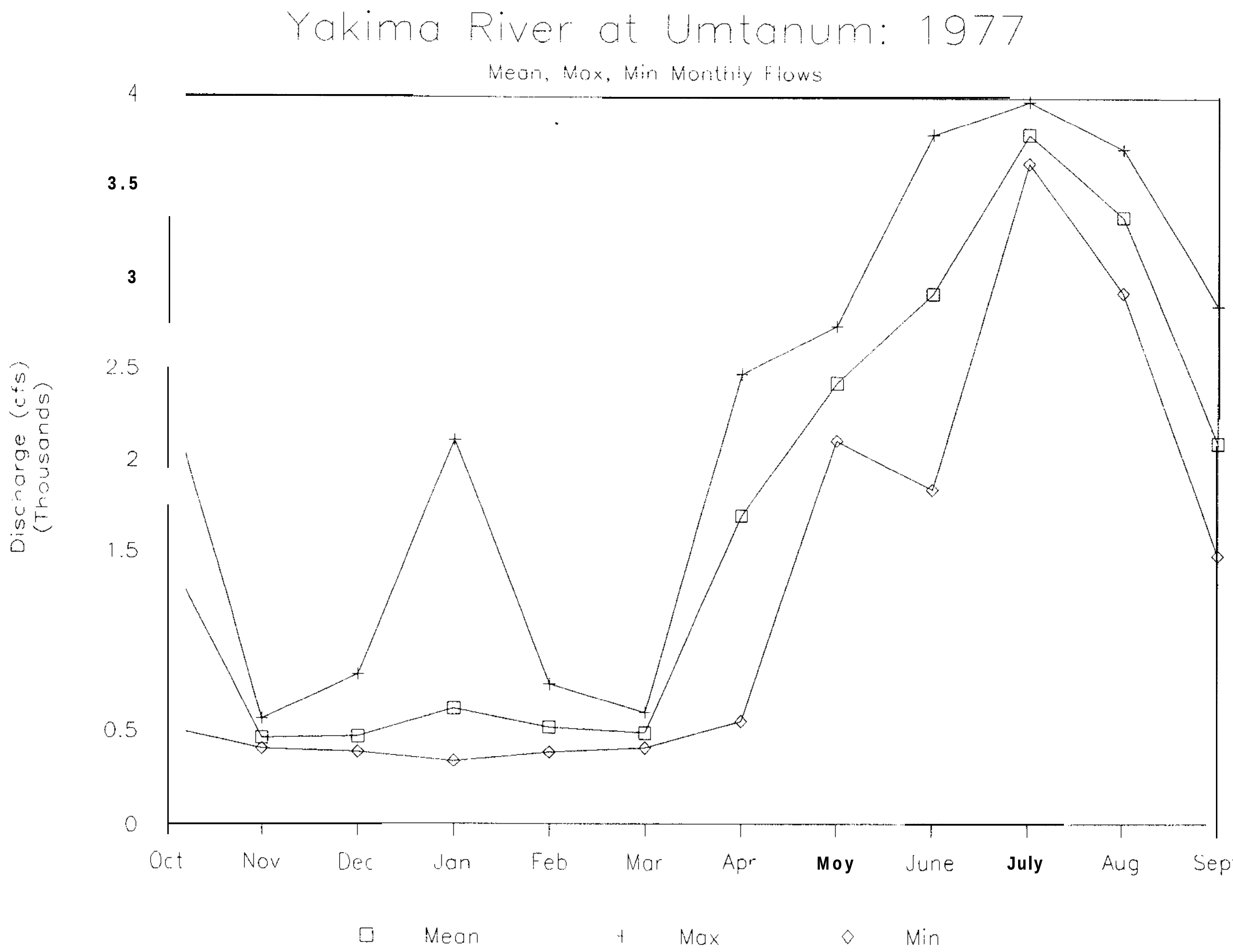


Yakima River at Umtanum: 1911
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
11
10
9
8
7
6
5
4
3
2
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min


Yakima River at Umtanum: 1975
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
9
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min



Yakima River at Umtanum: 1976
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
9
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min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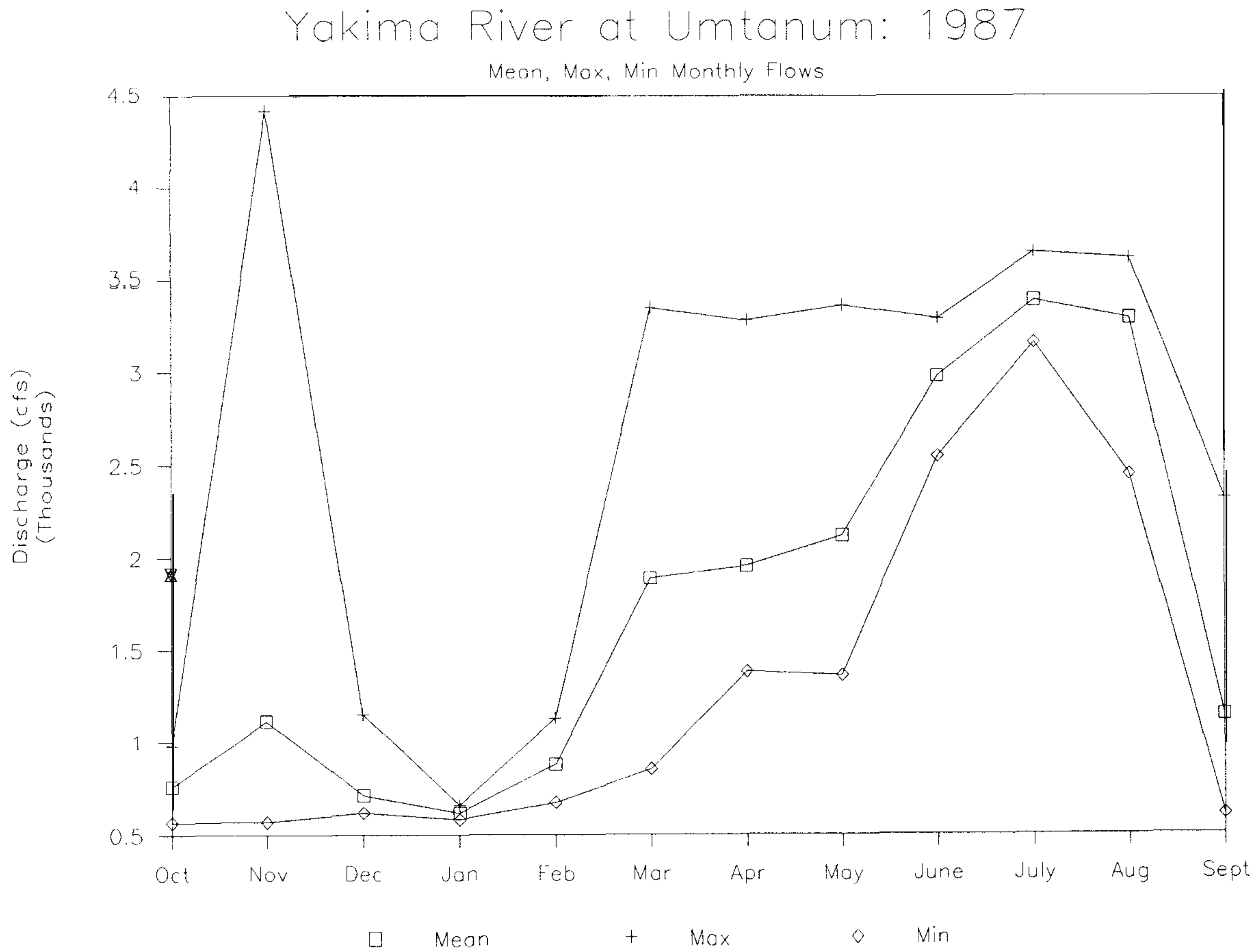
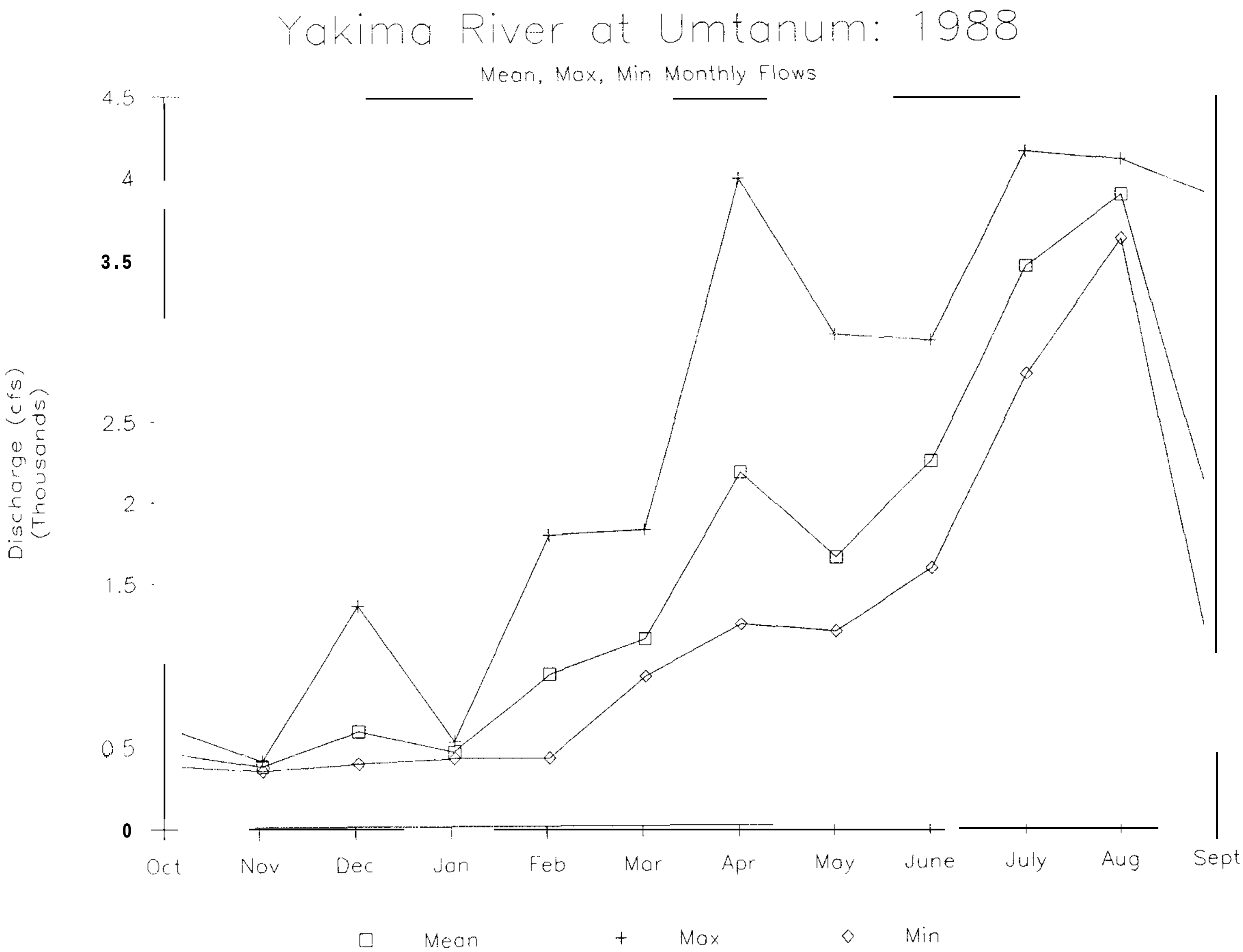
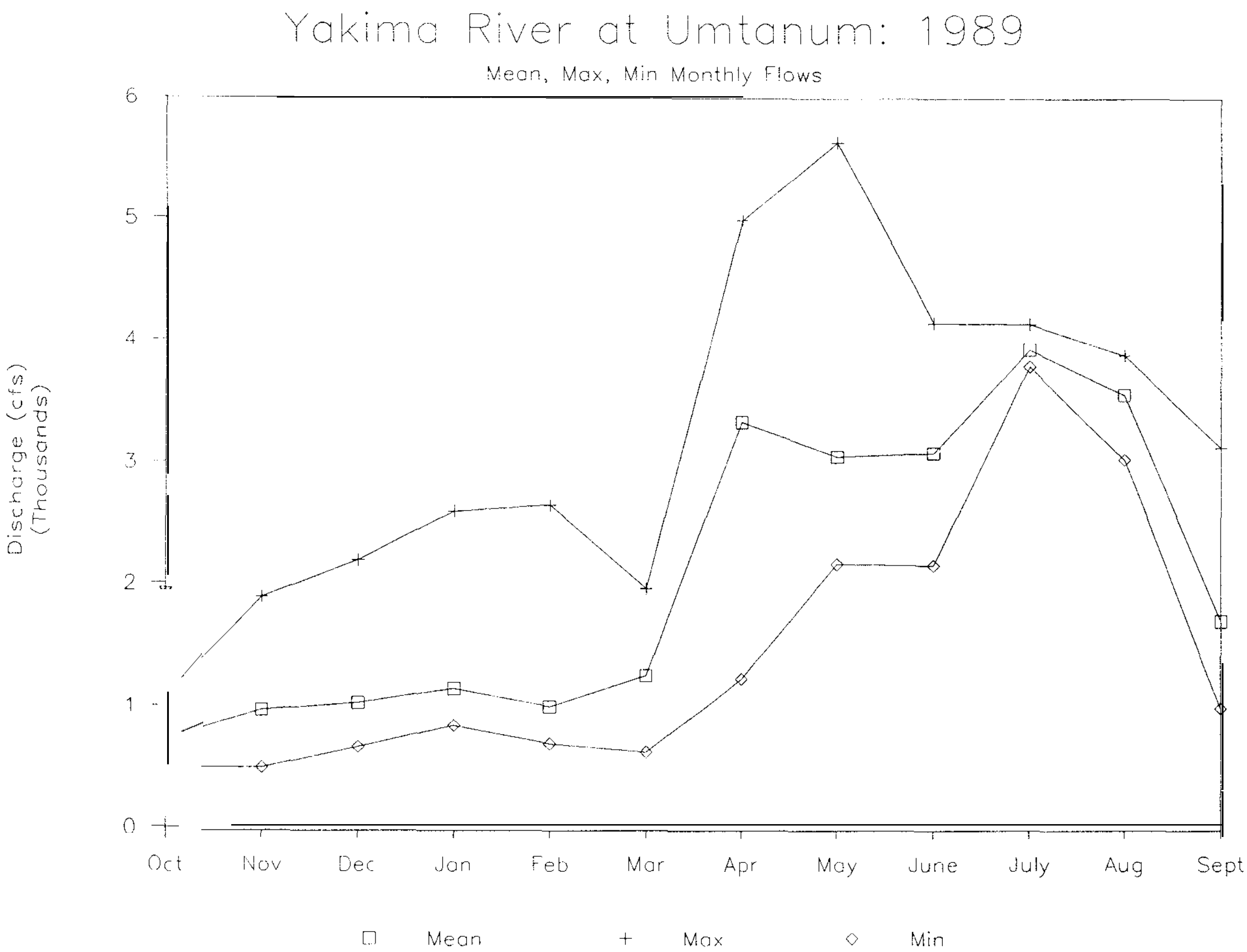
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
4
3.5
3
2.5
2
1.5
0.5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Moy
June
July
Aug
Sept
Mean
Max
Min

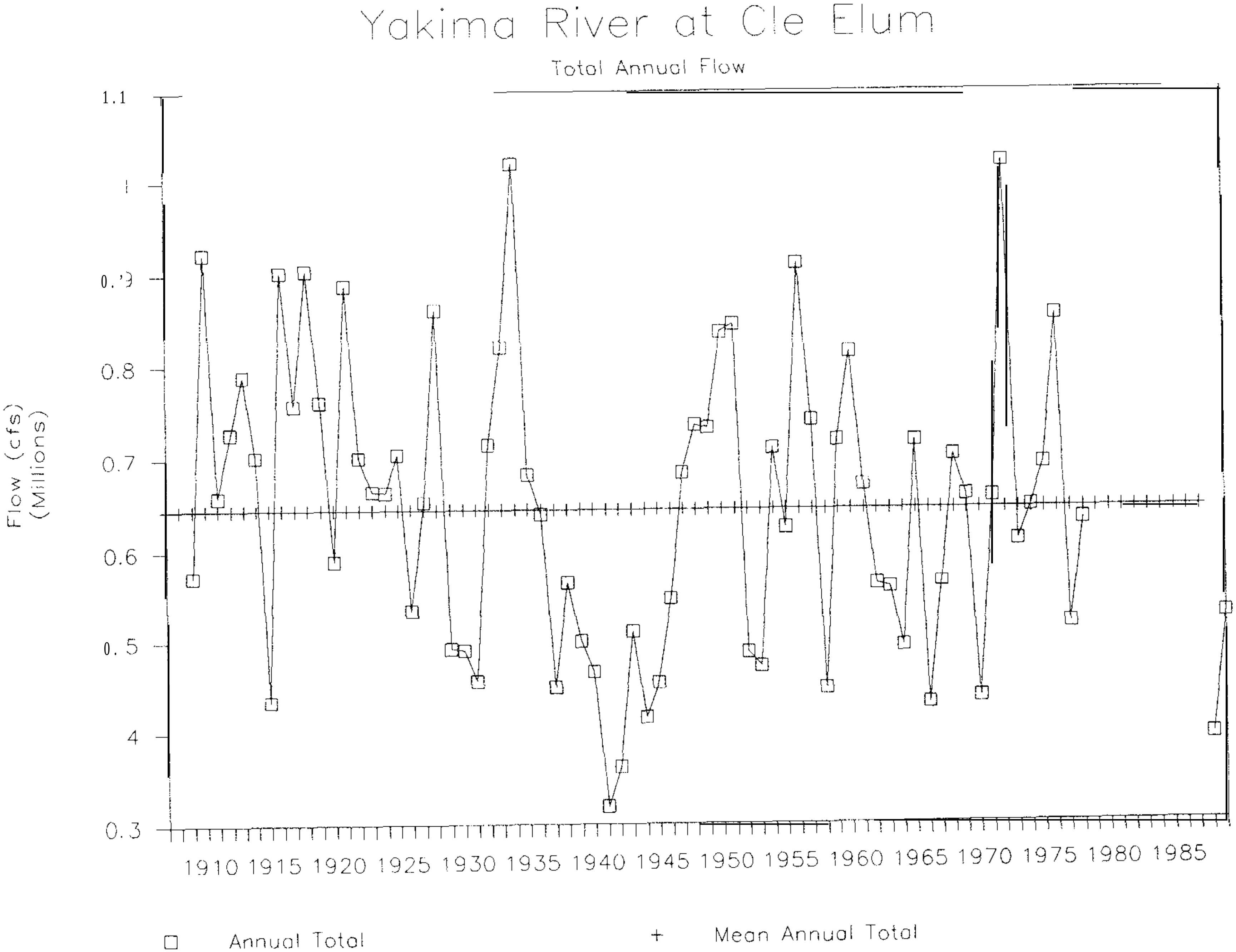


Yakima River at Umtanum: 1987
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min

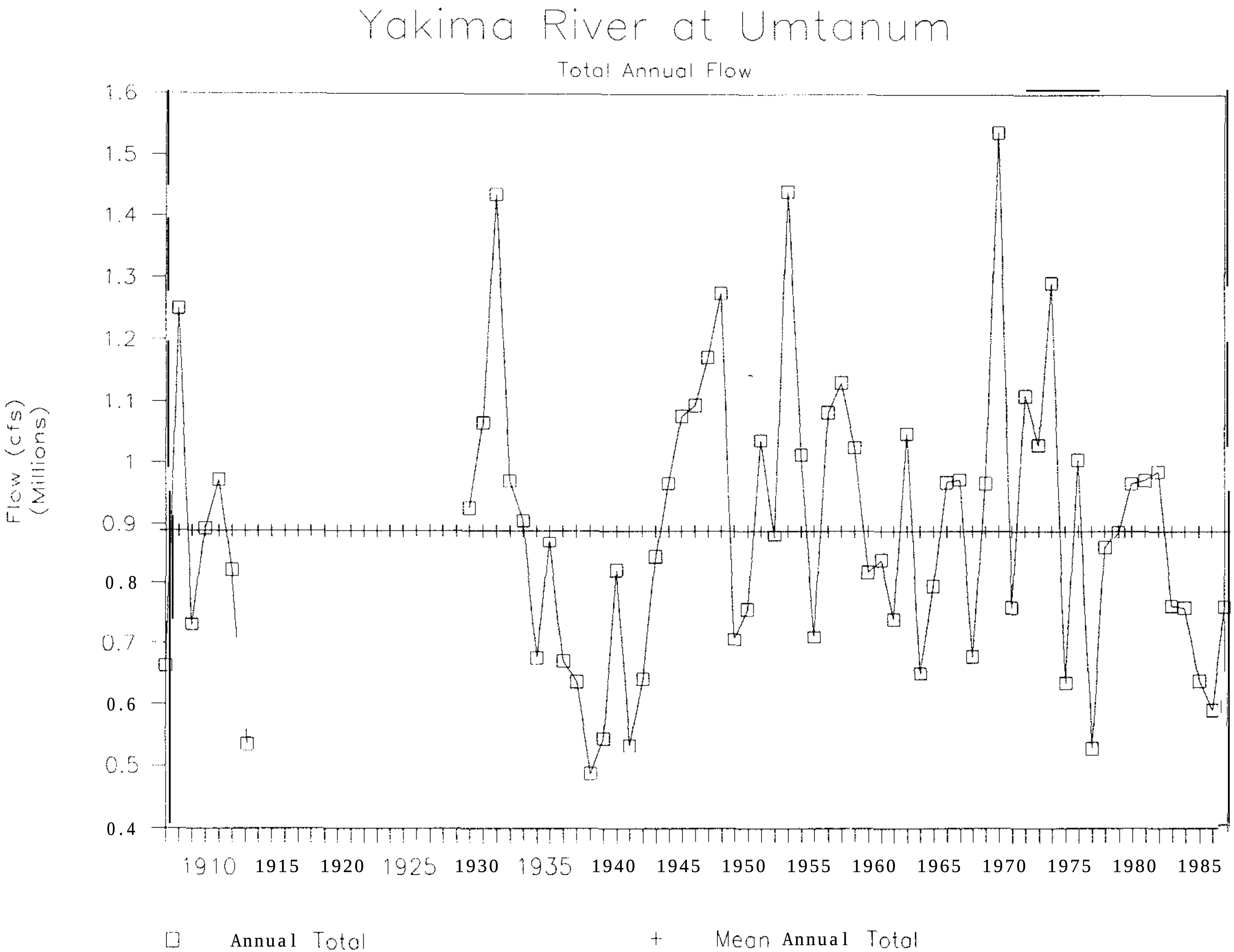

Yakima River at Umtanum: 1988
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
4.5
4
3.5
2.5
2
1.5
0.5
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min



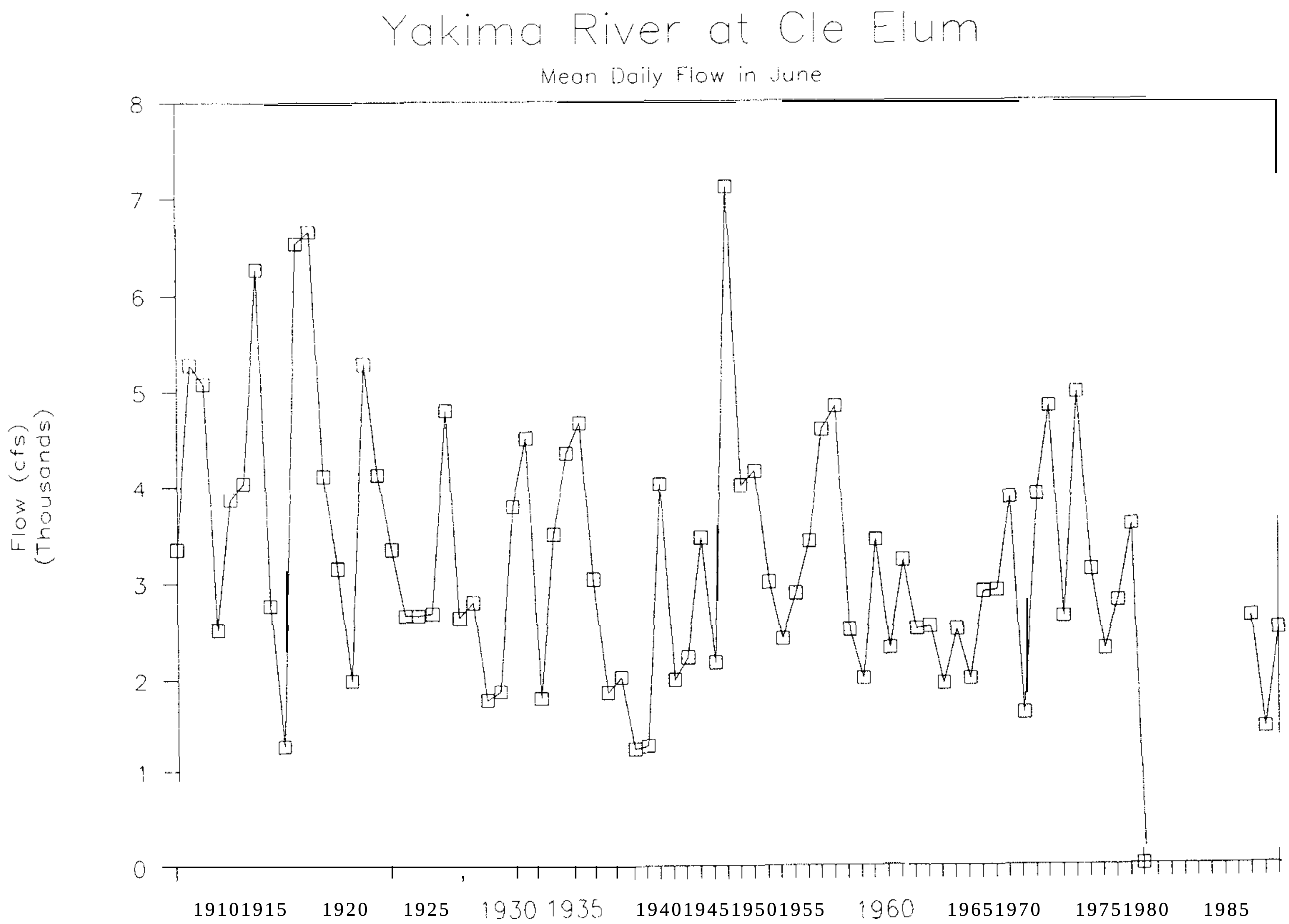
Yakima River at Umtanum: 1989
Mean, Max, Min Monthly Flows
Discharge (cfs)
(Thousands)
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Mean
Max
Min

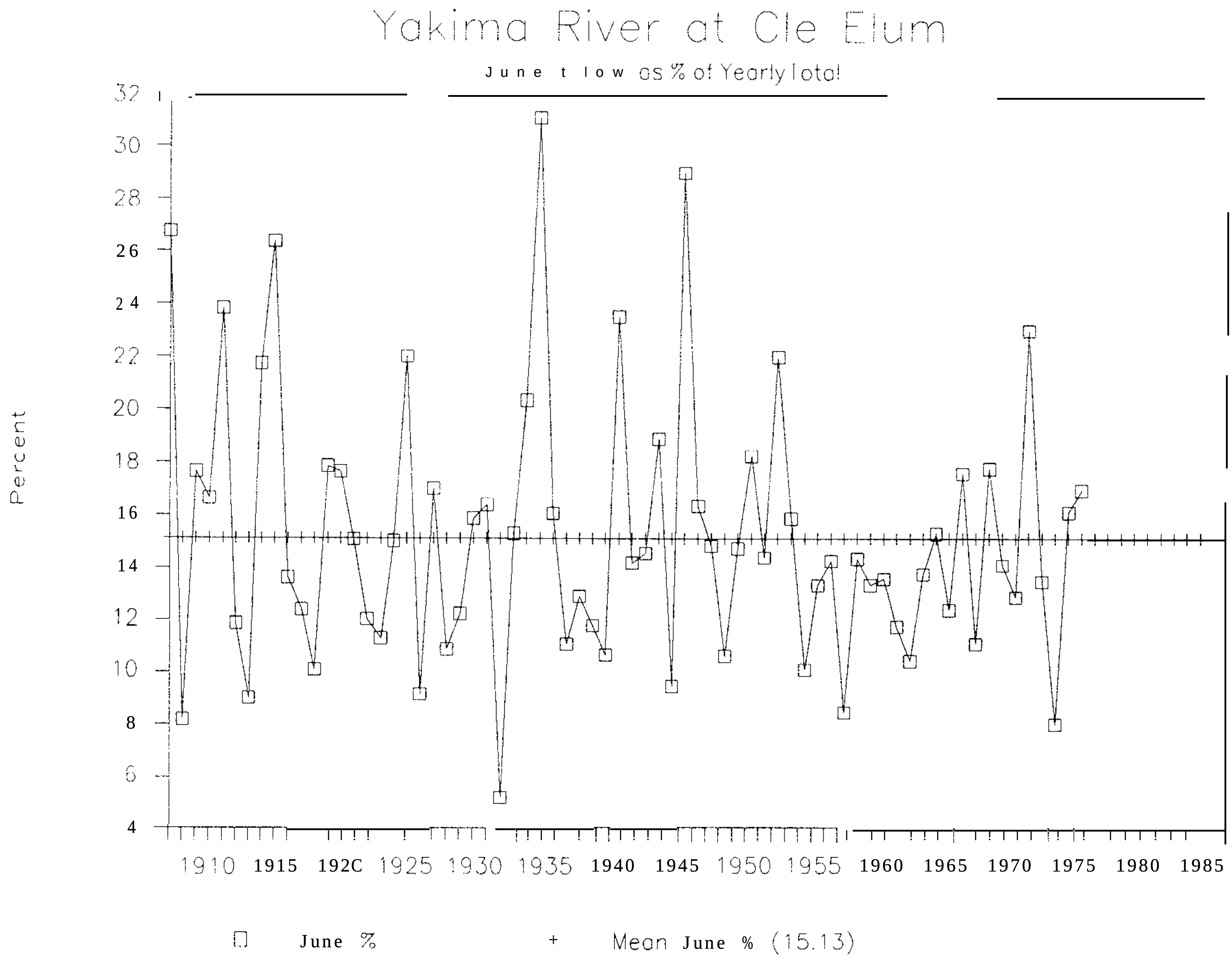


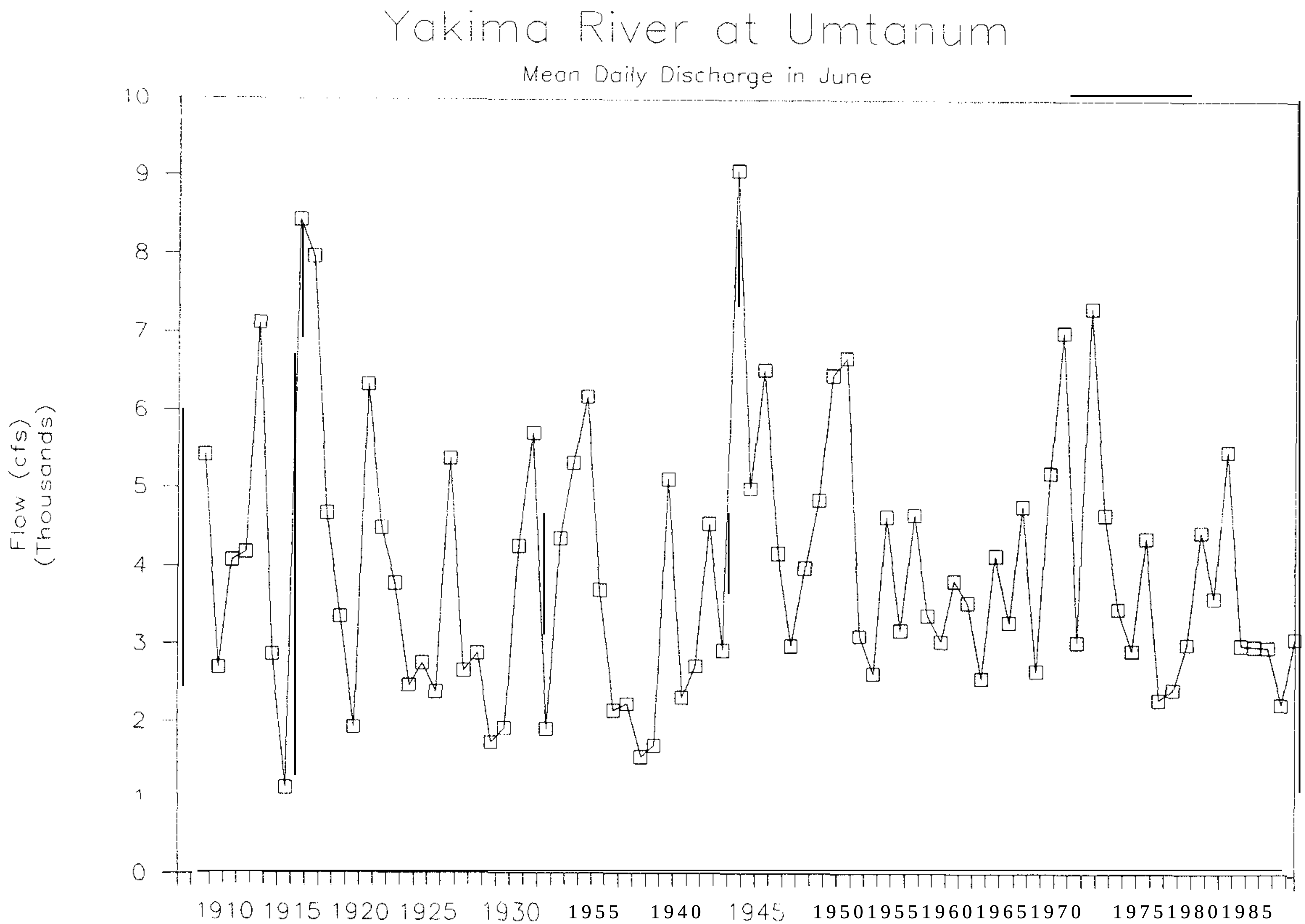
Yakima River at Cle Elum
Total Annual Flow
Flow (cfs)
(Millions)
1.1
1
0.9
0.8
0.7
0.6
0.5
4
0.3
1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985
Annual Total
Mean Annual Total

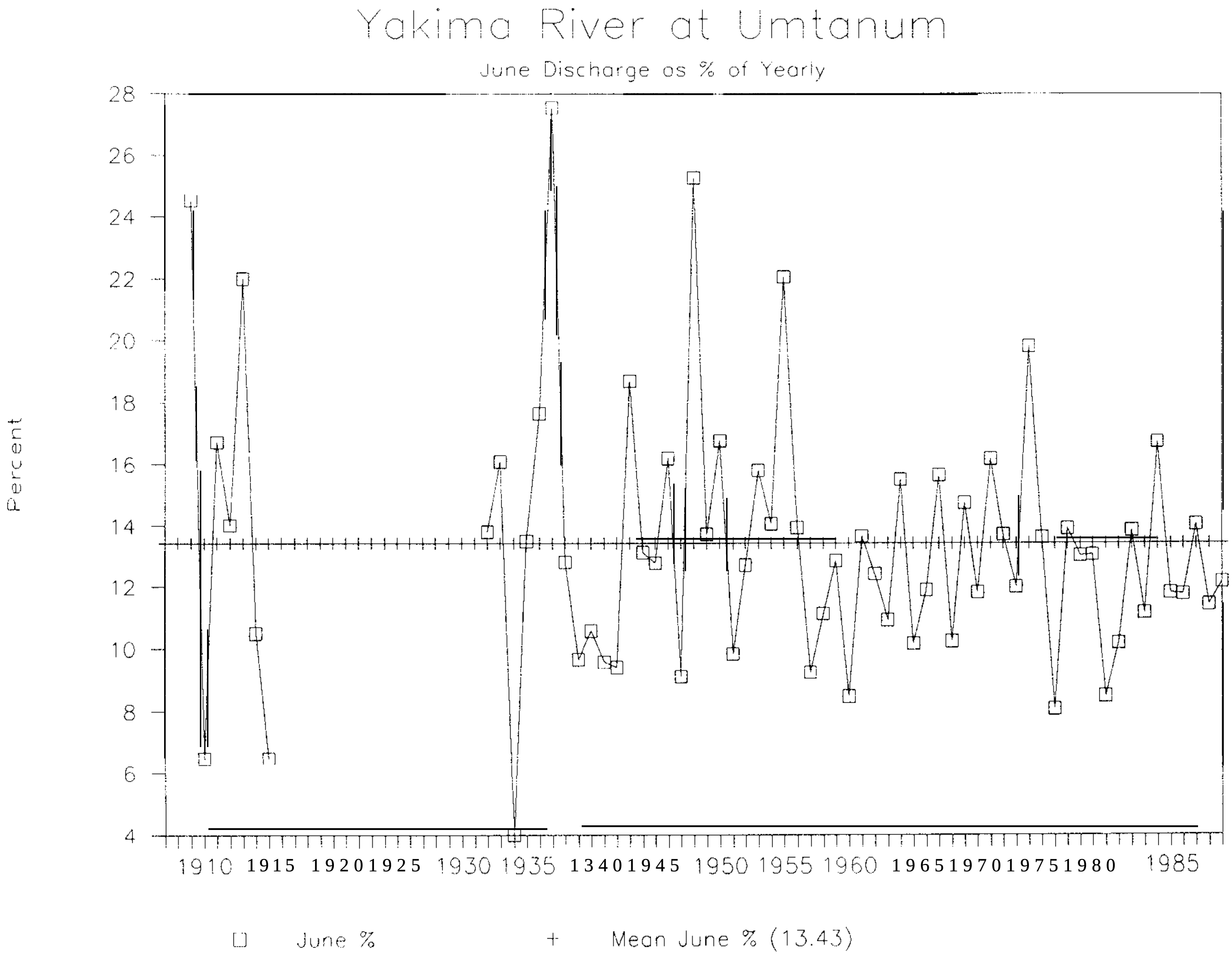


Yakima River at Umtanum
Total Annual Flow
Flow (cfs)
(Millions)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
Annual Total
Mean Annual Total

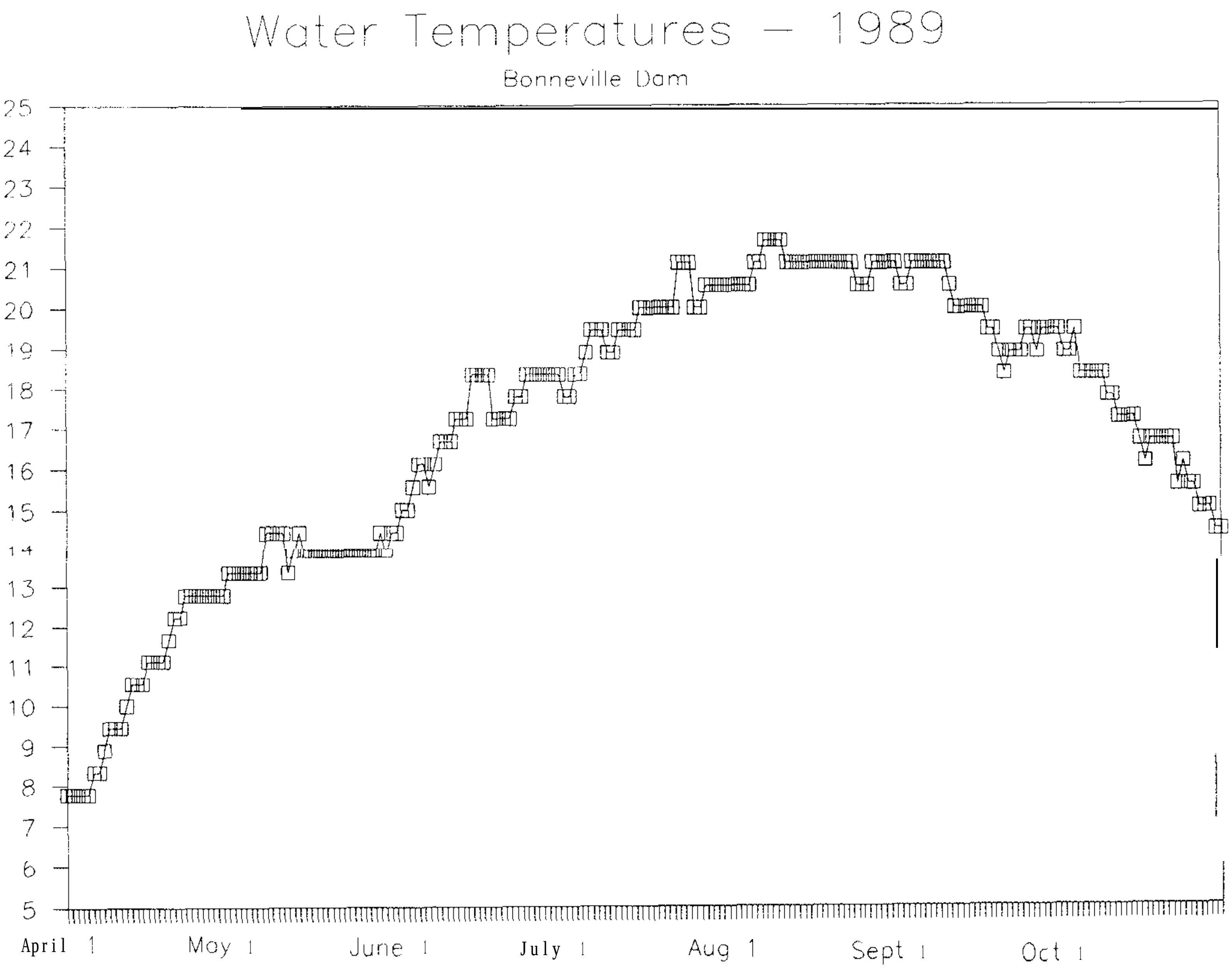

Yakima River at Cle Elum
Mean Daily Flow in June
Flow (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985


Yakima River at Cle Elum
June t low as % of Yearly Iotal
Percent
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
1910
1915
192C
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
June %
Mean June % (15.13)

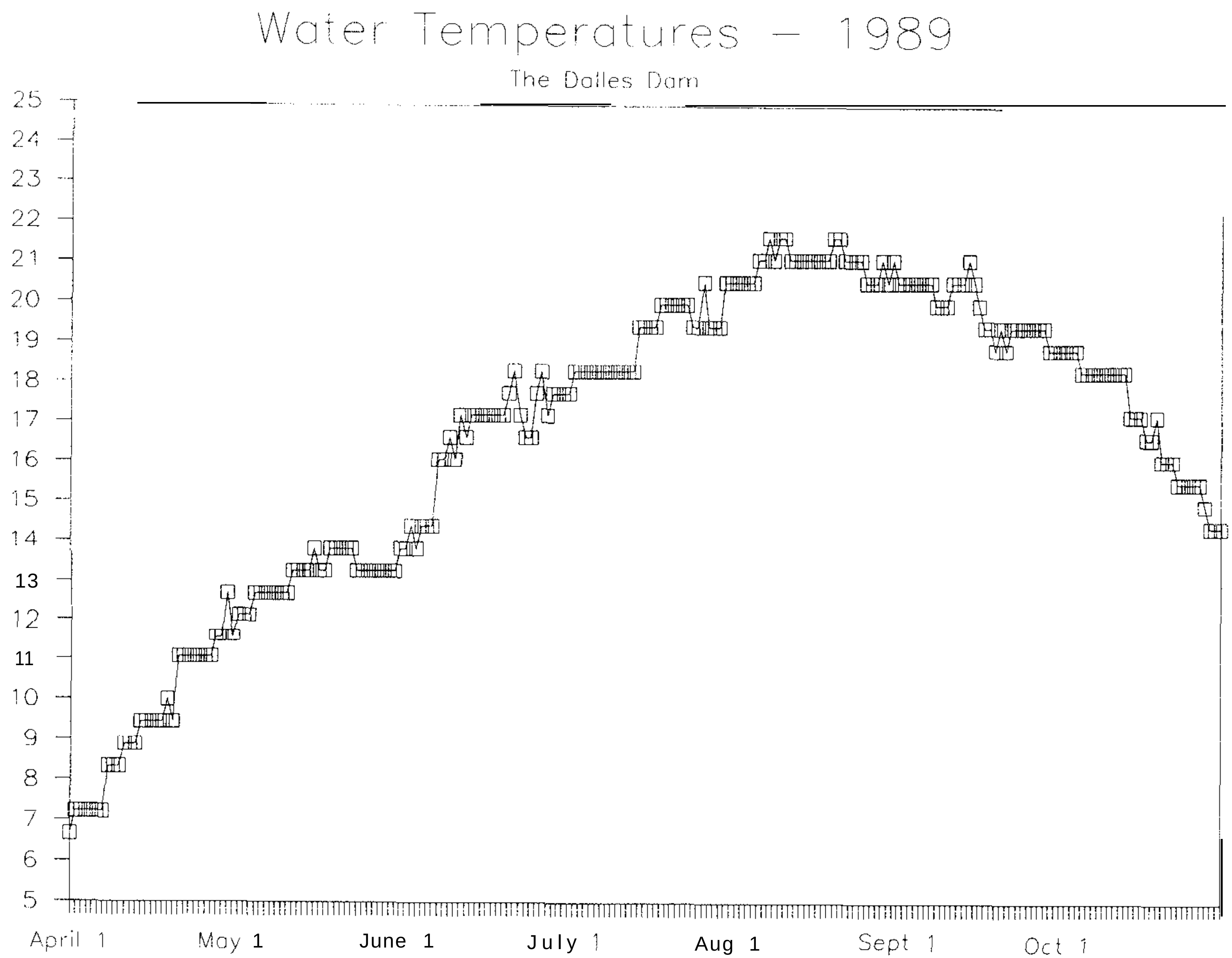

Yakima River at Umtanum
Mean Daily Discharge in June
Flow (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
1910 1915 1920 1925 1930 1955 1940 1945 19501955196019651970 197519801985

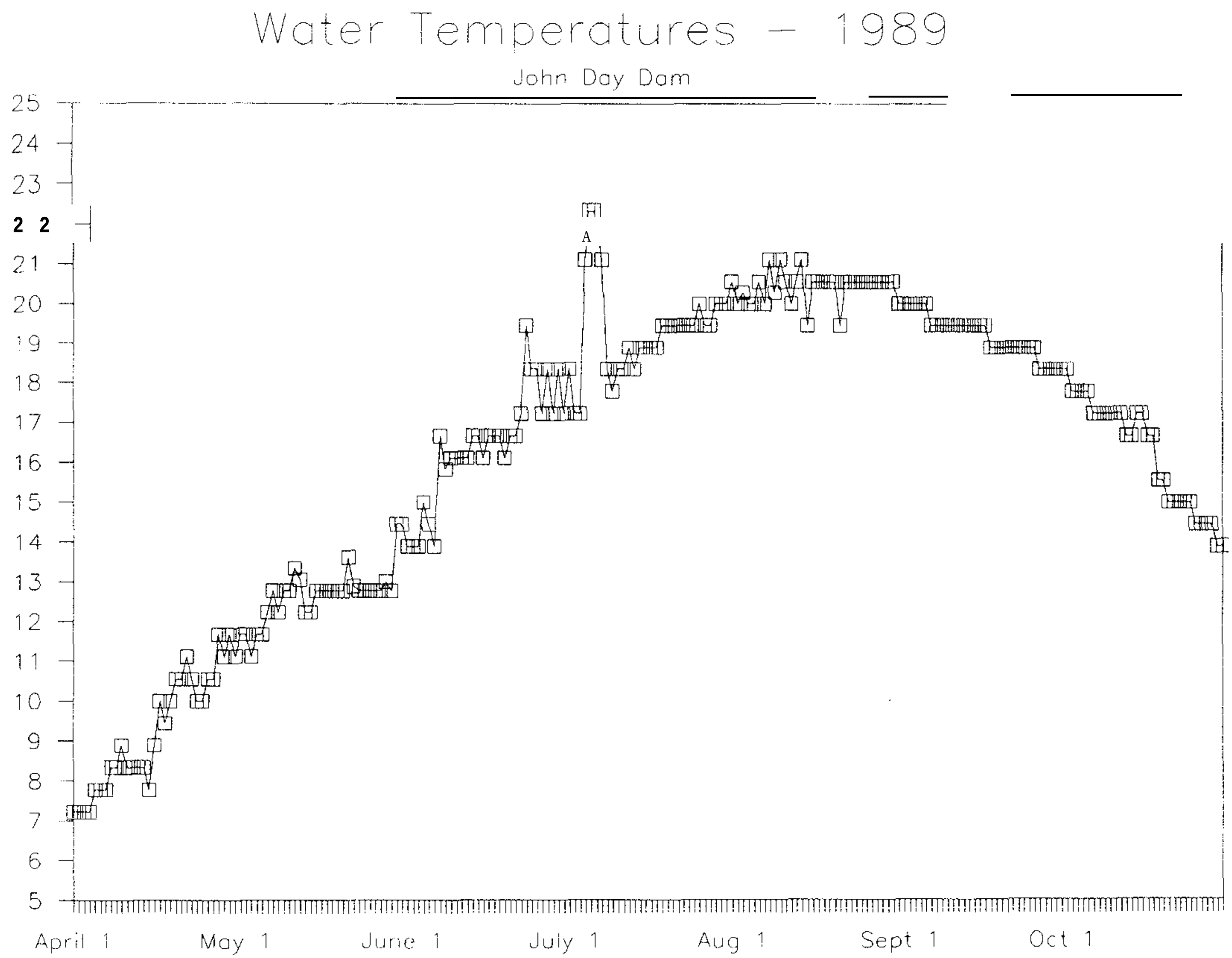


Yakima River at Umtanum
June Discharge as % of Yearly
Percent
28
26
24
22
20
18
16
14
12
10
8
6
4
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
June %
Mean June % (13.43)



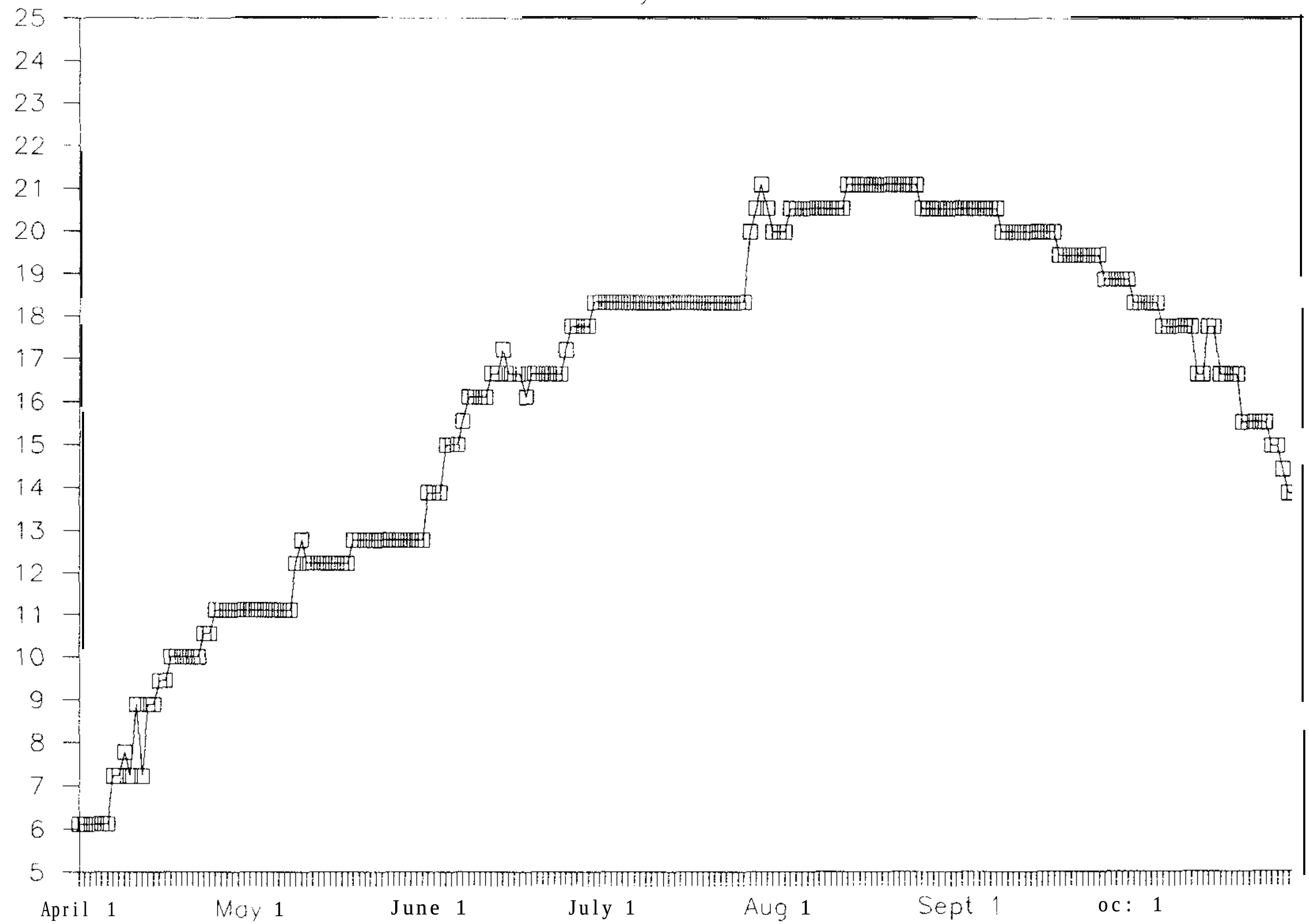
Water Temperatures — 1989
Bonneville Dam
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1

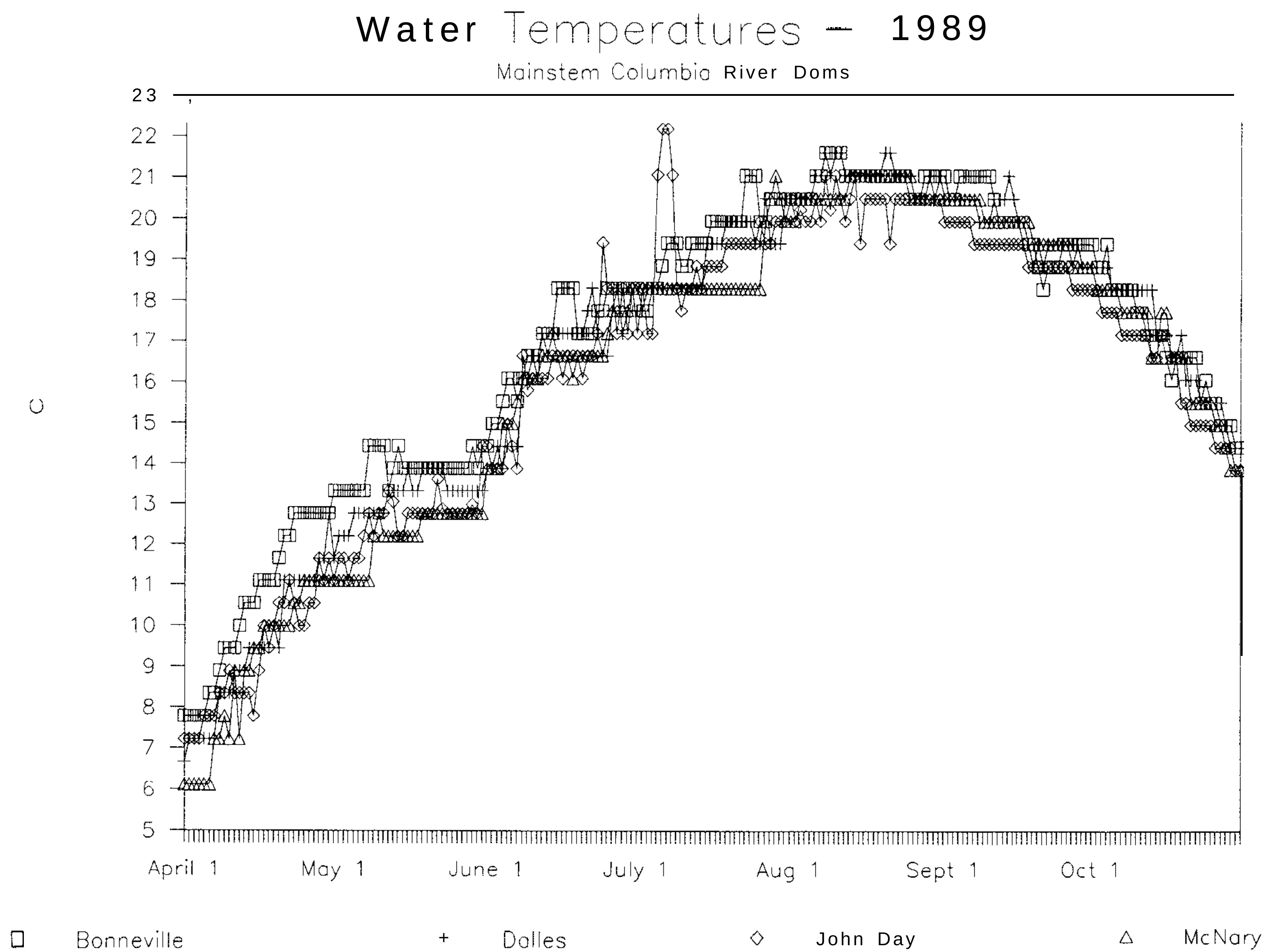

Water Temperatures — 1989
The Dalles Dam
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1


Water Temperatures – 1989
John Day Dam
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1

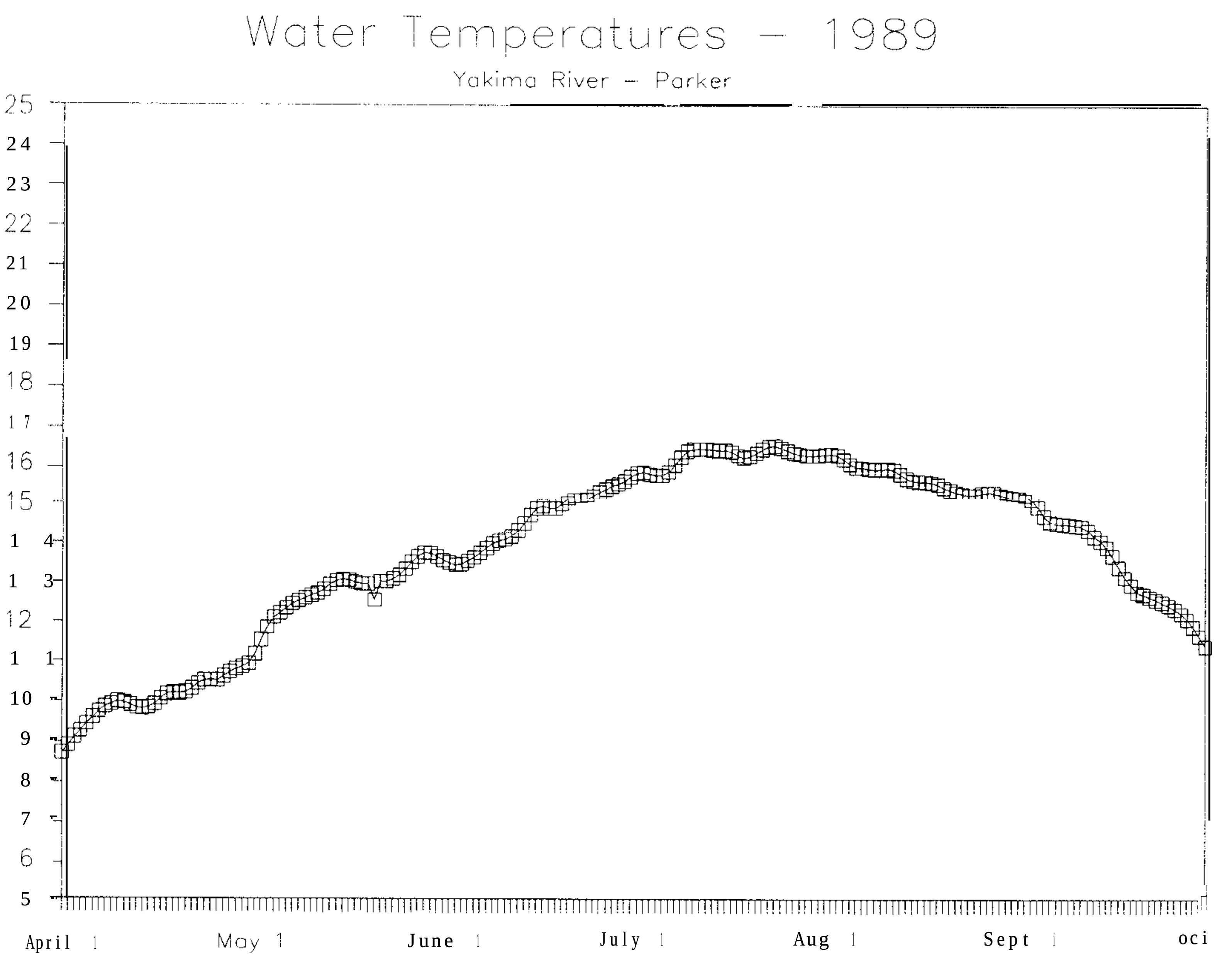
Water Temperatures – 1989

McNary Dam



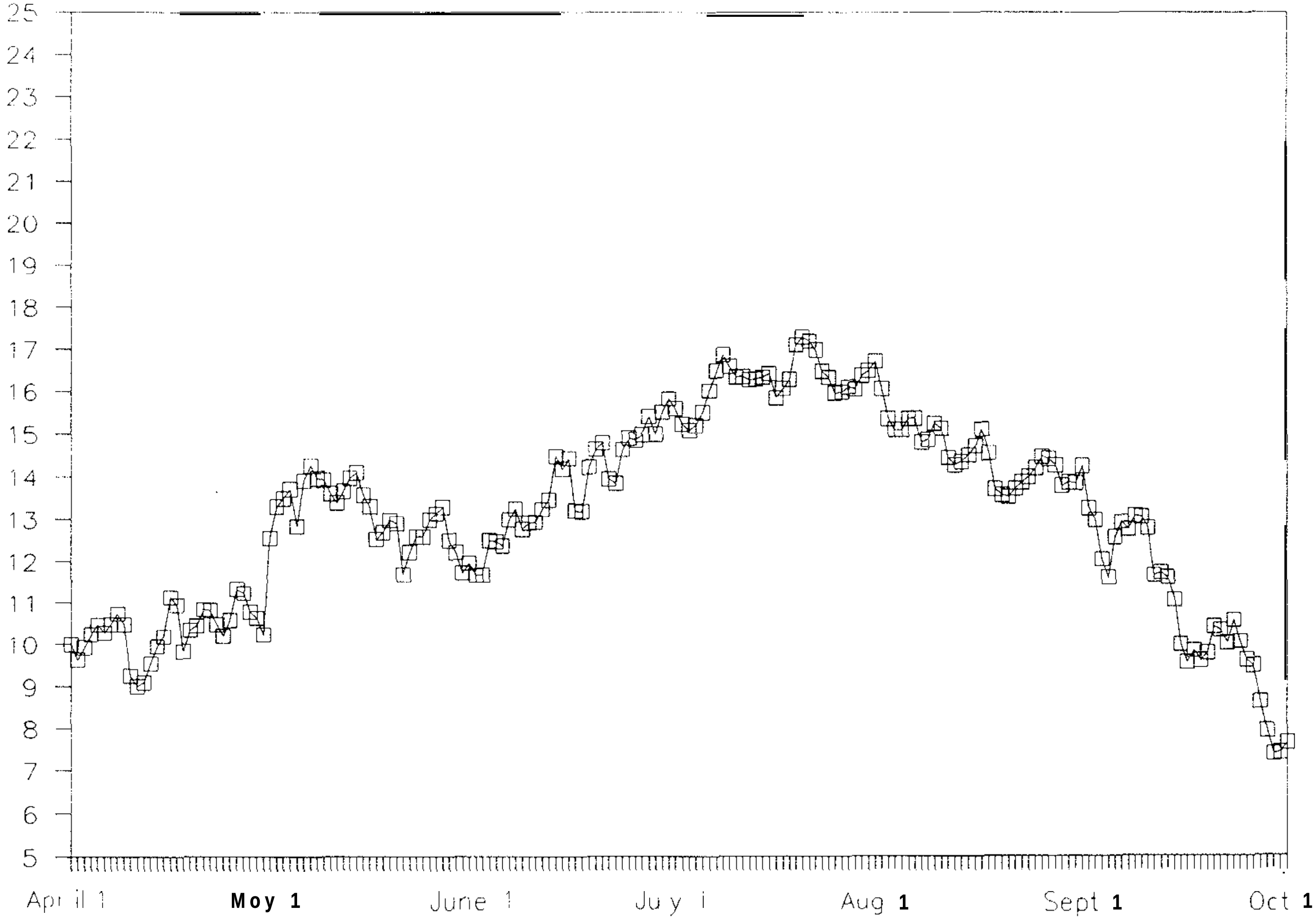


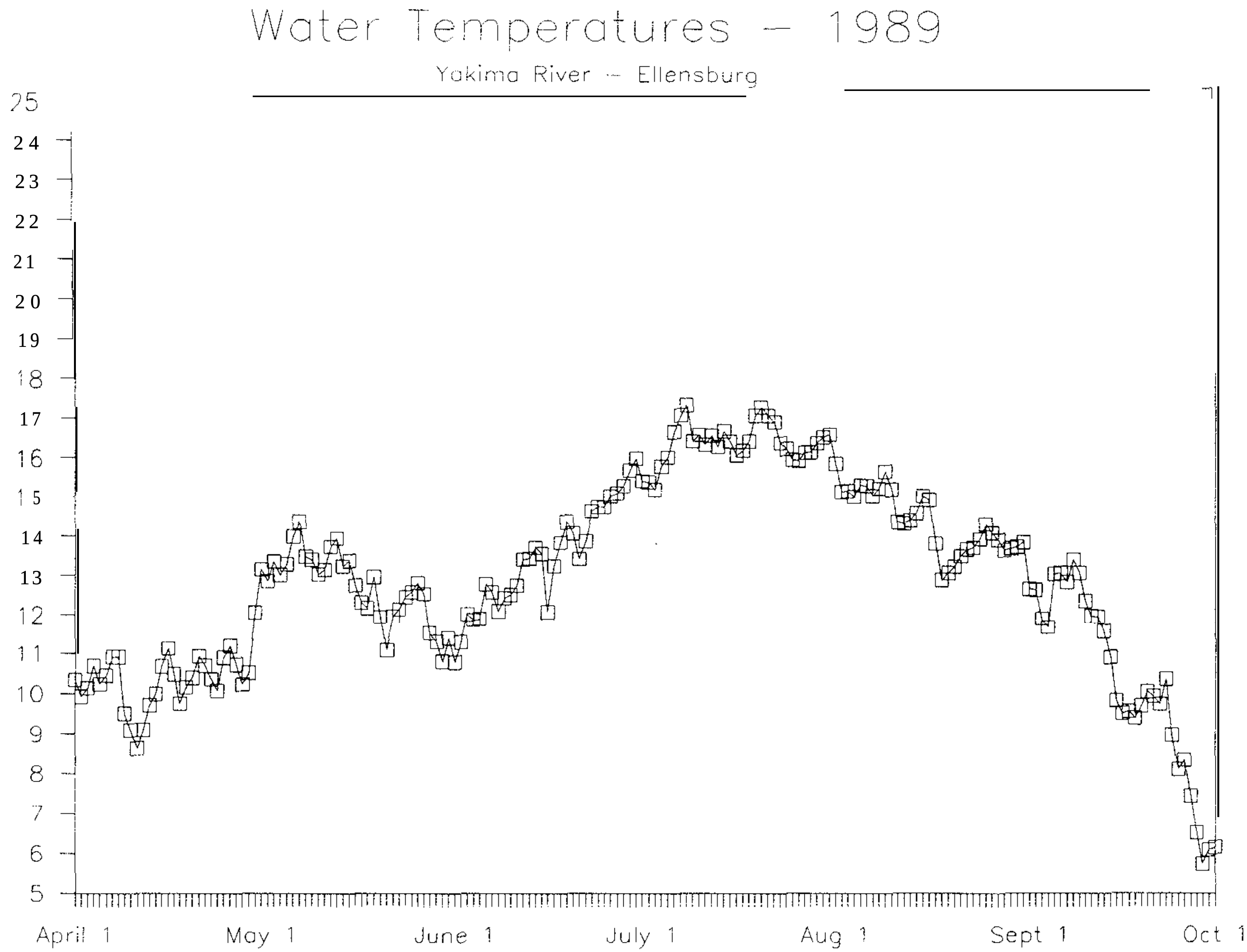
Water Temperatures — 1989
Mainstem Columbia River Doms
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
C
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1
Bonneville
Dolles
John Day
McNary


Water Temperatures - 1989
Yakima River - Parker
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1

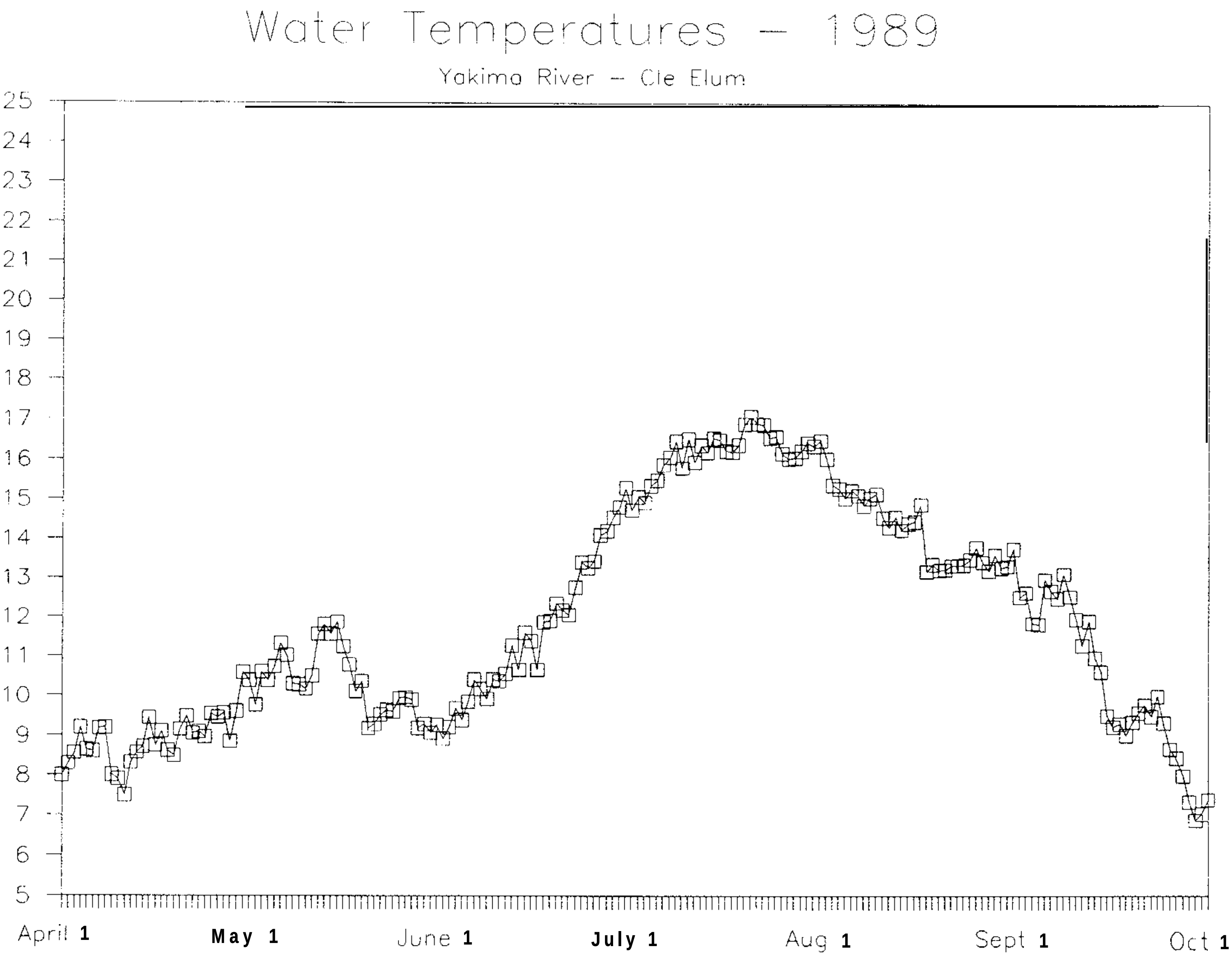
Water Temperatures — 1989

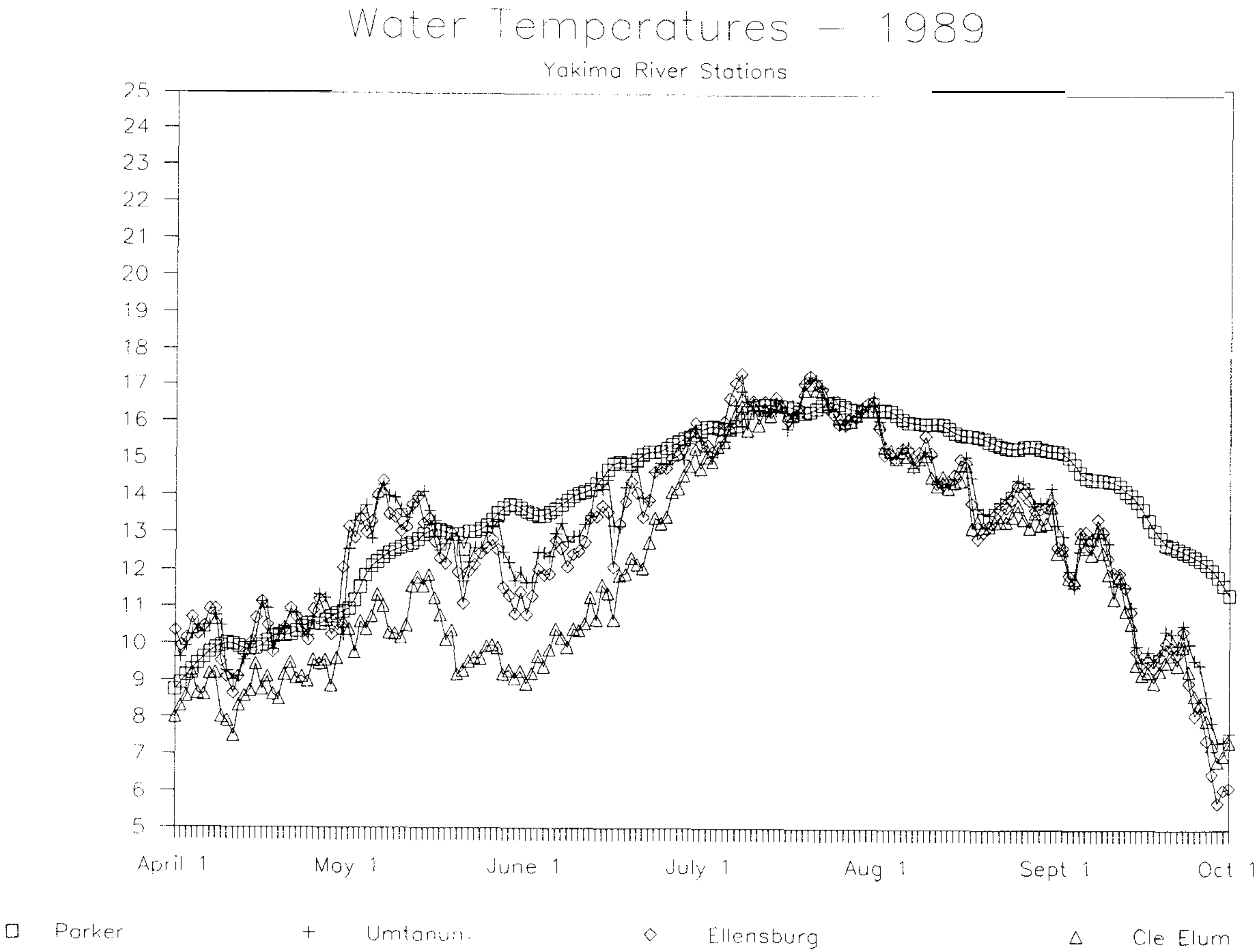
Yakima River - Umtanum

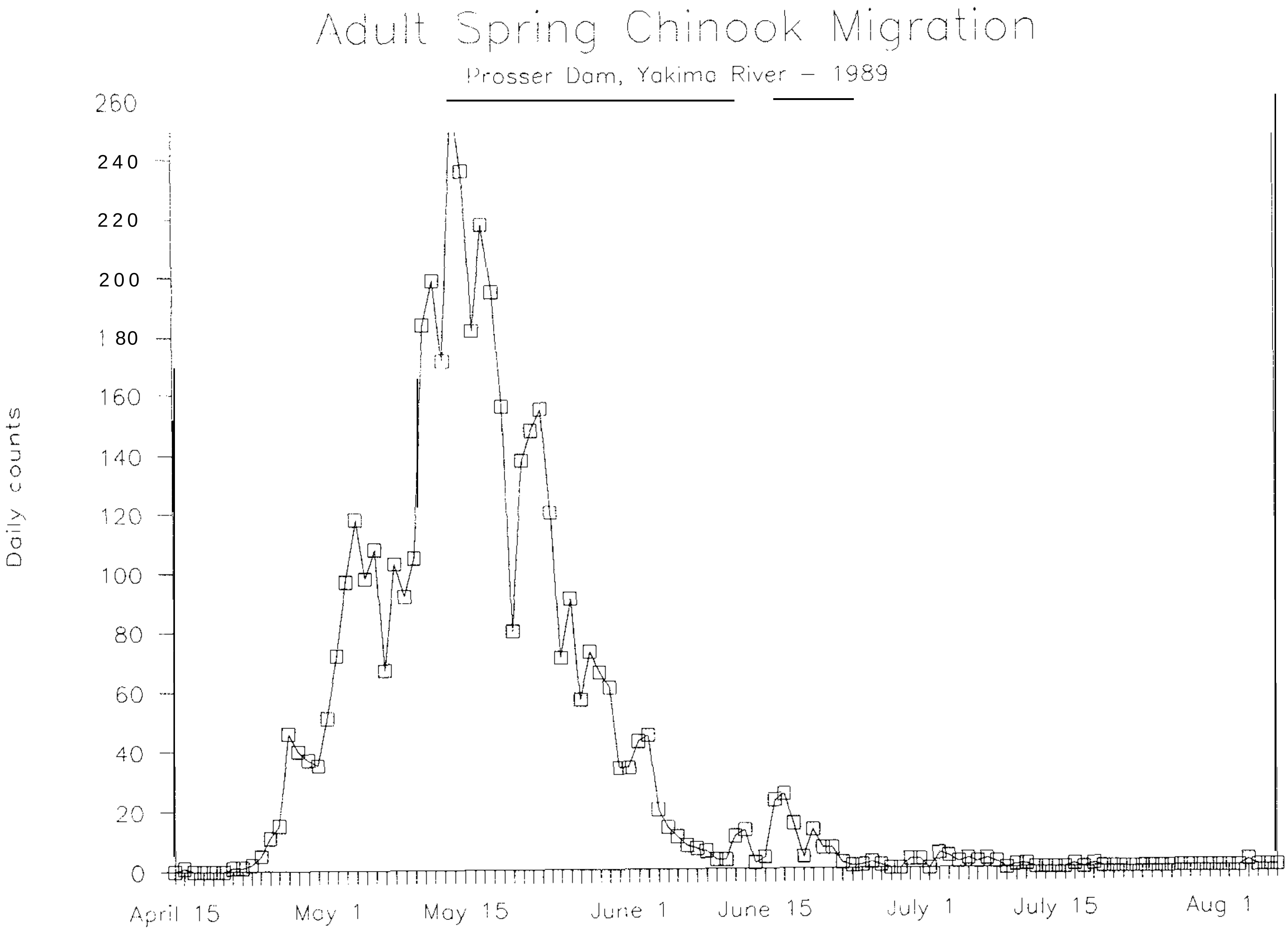




Water Temperatures – 1989
Yakima River – Ellensburg
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1

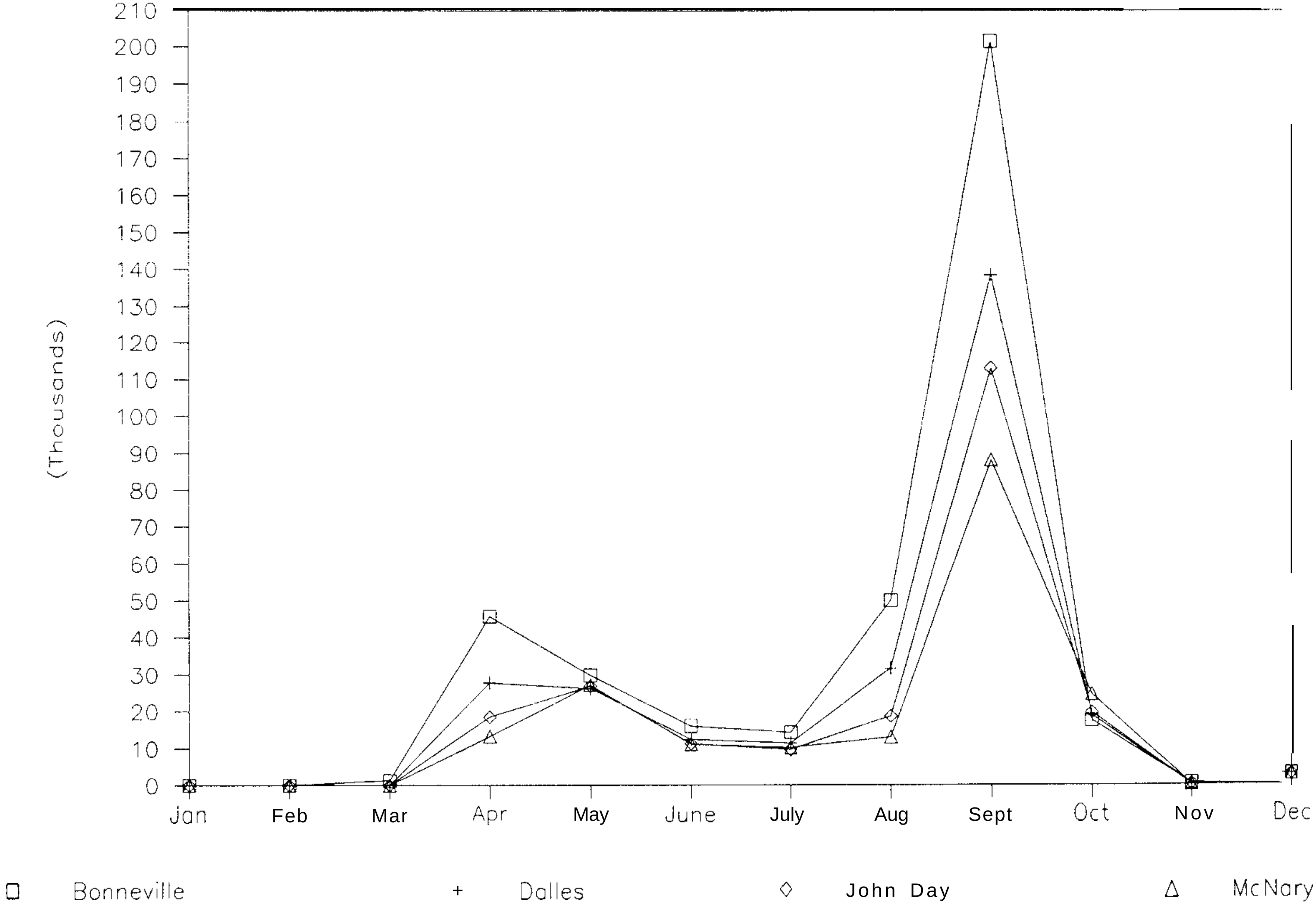

Water Temperatures — 1989
Yakima River — Cle Elum
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1

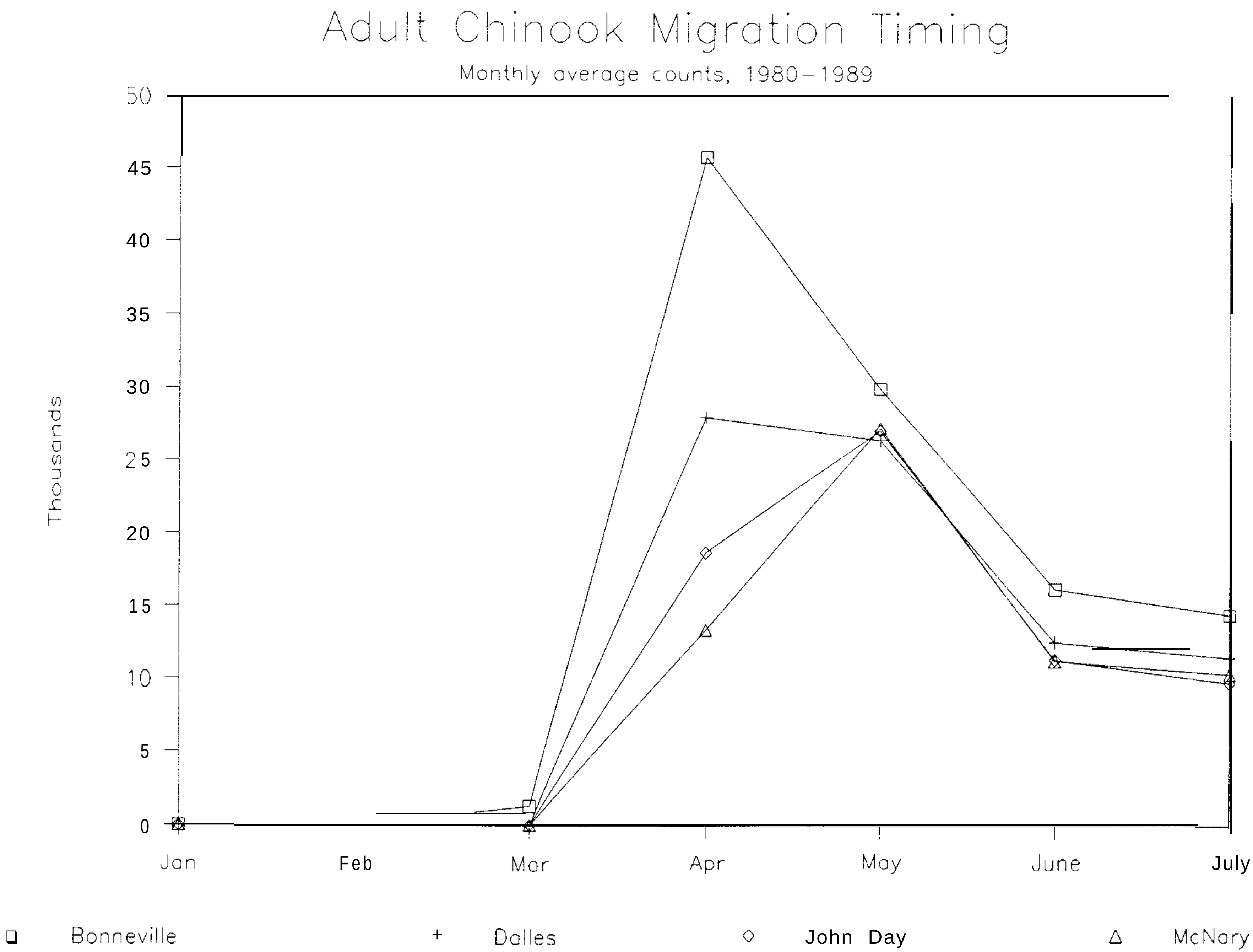

Water Temperatures — 1989
Yakima River Stations
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
April 1
May 1
June 1
July 1
Aug 1
Sept 1
Oct 1
Parker
Umtanum
Ellensburg
Cle Elum


Adult Spring Chinook Migration
Prosser Dam, Yakima River – 1989
Daily counts
0
20
40
60
80
100
120
140
160
180
200
220
240
260
April 15
May 1
May 15
June 1
June 15
July 1
July 15
Aug 1

Adult Chinook Migration Timing

Monthly average counts, 1980–1989




Adult Chinook Migration Timing
Monthly average counts, 1980–1989
Thousands
50
45
40
35
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
June
July
Bonneville
Dalles
John Day
McNary