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INITIAL WATERSHED ASSESSMENT
WATER RESOURCES INVENTORY AREA 46
ENTIAT RIVER WATERSHED

Open file Report 95-02

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Introduction

This report is the product of a recent initiative by the Department of Ecology (Ecology) to assess the availability of ground and surface water for each watershed within Washington State. This initiative is part of a larger overall effort to make the water rights decision making process more efficient. The watershed assessment process will not only reduce the time needed to make decisions, but also will allow Ecology to make better informed decisions based on a more comprehensive understanding of each watershed. Ecology also believes these reports will be useful to local governments for planning purposes.

The scope of this report was limited to a review of existing information. With the exception of one field survey, no new field work or data collection efforts were conducted. The information reviewed includes water resource data, some water quality data, and fisheries data.

Watershed Description

Area Description

The Entiat River Watershed lies along the eastern slopes of the Cascade Mountains in the northeast portion of Chelan County. The Entiat River is bounded on the north by the Chelan Mountains and on the south by the Entiat Mountains. Originating high in the Cascade Mountains, near Spectacle Buttes and Mt. Maude, the Entiat River flows southeast and discharges to the Columbia River near the town of Entiat. The confluence is located about 20 miles southwest of the town of Chelan. The drainage area of the watershed is about 419 square miles (U.S. Department of Agriculture, 1979). Elevation extremes range from about 9,000 feet in the headwaters area to about 700 feet near the confluence with the Columbia River. With the exception of valley floors, the terrain is mountainous and mostly forested (see Map 1).

The primary geologic components that comprise the Entiat River Watershed are metamorphic and plutonic rock, sediment of glacial and alluvial origins, and volcanic ash. Volcanic ash from Glacier Peak volcano covers most of the slopes within the watershed. The valley bottoms contain sediments eroded from the surrounding hills by streams and glaciers (U.S. Department of Agriculture, 1979). These sediments now form the principal aquifers within the watershed. Underlying the mantle of ash and valley sediments is a basement of crystalline bedrock.

Land Use

The primary land uses within the Entiat Watershed are agriculture, range, timber, and recreation. Approximately 87% of the land area within the Entiat Watershed is forested. Most of this land is managed by the National Forest Service (U.S. Department of Agriculture, 1979). The majority of irrigated agricultural use is located along the Entiat River and down stream from the town of Ardenvoir. Most of the 9,000 acres of range land are located in the lower part of the basin near the town of Entiat, although much of the forested land is also used for grazing. Recreational uses, such as cabins and campgrounds, are mostly updrainage of Ardenvoir.

Climate and Precipitation Trends

The climate of the Entiat Watershed varies markedly and is largely influenced by topography. Precipitation is heaviest in the northwest portion of the watershed and decreases in the lower elevations toward the Columbia River. Average annual precipitation ranges from about 100 inches in the higher elevations to about 10 inches near the town of Entiat (see Map 2). Precipitation is light during the summer months, increases to a maximum in winter, and then decreases in the spring. Much of the winter precipitation occurs as snowfall. Summer precipitation frequently occurs as rain showers associated with thunderstorms. During the summer months, temperatures in the higher elevations are typically in the 50s, while temperatures in the 90s are frequent in the lower parts of the watershed. Growing seasons in the lower parts of the watershed average about 150 days in duration (U.S. Department of Agriculture, 1979).

Records from three climatological stations in the surrounding area do not show any definitive increasing or decreasing trend in precipitation. Precipitation at the Plain Station has gradually increased, precipitation at the Lake Wenatchee Station has gradually decreased, and there has been no change at the Chelan Station (see Figure 1).

Hydrogeology

Hydrology

Hydrology is the study of the occurrence, circulation, distribution and properties of the earth's waters and their reaction with the environment. Water occurs in the form of rain and snow and then circulates as ground water and surface water. In the Entiat River Watershed, precipitation mostly falls as snow and accumulates to create the winter snowpack. The warmer temperatures and rain of spring and early summer melt the snowpack, generating water to supply streamflow. A significant portion of the melt water, as well as some of the rain water, also infiltrates down through the soil to become ground water. Later on, this same ground water discharges to the river and tributaries, and supplies much of the streamflow from late summer through winter (see Figure 2).

An important aspect of hydrology is the pattern of water circulation. For instance, when the ground water table is higher than the water level in an associated stream (or river), ground water will discharge to that stream. This is most likely what happens in the higher elevations

of the Entiat River Watershed. Conversely, an associated stream will give off or lose water to the ground water aquifer if the water level in the stream is higher than the water table. Since we know water tends to shift back and forth from underground to surface locations based on the volumes of water in each location, we can see how our actions might affect water movement. For example, taking water from an aquifer through well pumping could lower the water level in the river by either reducing the amount of ground water that discharges to the river, or increasing the quantity of water that leaks out of the river into the aquifer.

Approximately 75% of the mean annual runoff for the Entiat River watershed originates from an area that represents somewhat less than 50% of the watershed area. For the period of 1957-1993, the 203-square-mile area above the USGS gauge near Ardenvoir yielded an annual mean of 267,800 acre-feet (USGS, 1993). By comparison, data from the old USGS gauging station near Entiat (1911-1925) shows that the mean annual runoff for the entire 419 square mile watershed was 355,866 acre-feet (USGS, 1985). The Entiat River gauging station near Entiat was discontinued after 1925 and then restarted for the short period of 1951-1958. The gauge was again discontinued after 1958, and has not been in operation since that time.

Runoff within the watershed can vary widely from one year to the next. Data from the gauge near Ardenvoir show that in water year 1972 the runoff was 451,140 acre-feet. The next year the runoff was 178,970 acre-feet, a reduction of 272,170 acre-feet (see Figure 3).

Geology and Ground Water

Geology

The Entiat River Watershed is composed of the crystalline bedrock of the Mad River, Swakane, and Chelan Mountains geologic terrains. These rocks are metamorphic and plutonic in nature and primarily consist of quartz diorite and tonalite, schist, granodiorite, gneiss, and migmatite. A large pluton of granodiorite, known as the Duncan Hill pluton, has intruded into the Chelan Mountains terrain. This pluton underlies the Entiat River near Brief and for many miles up stream as well (U.S. Geological Survey, 1987).

During the Pleistocene Epoch the upper Entiat River Valley was home to a thirty-mile-long glacier (Long, 1969). The glacier extended from Mt. Maude to a point about five and one fourth miles above Ardenvoir where it left a well defined terminal moraine across the valley (Long, 1951). The ice sculpted the pre-existing river valley into its present form, the characteristic glacial U-shape with a broad valley floor. Below this area of glacial activity the river valley has retained the typical stream incised V-shape (U.S. Department of Agriculture, 1979).

The Entiat River Valley contains alluvial and glacial sediments. A review of regional well reports indicates that these sediments are primarily composed of sand, gravel, and cobbles. Clay and silt are also present, but their occurrence and extent appear to be considerably less relative to the rest of the sediment types. While it appears there is a greater occurrence of

clay in the tributary valleys than in the main valley, sand and gravel are still predominant in the tributary valleys. The alluvial and glaciofluvial sediments were deposited by running water, and therefore are likely to be fairly well stratified and sorted. Contrasting this are the glacial moraine deposits, which tend to be poorly sorted and unstratified.

The depth to bedrock in the unglaciated lower portion of the Entiat River Valley is typically between 50 and 100 feet. In glaciated areas of the valley the depth to bedrock seems to be somewhat greater. Some wells encounter bedrock between 50 and 100 feet, yet many of the deeper wells, generally between 100 and 150 feet, are still in sediment.

Aquifer Characteristics

The capacity of the various types of bedrock to serve as aquifers are similar, and generally speaking, none of them produce high yield wells. Wells constructed with unperforated casing extending into the bedrock are reported to produce between 1 and 17 gallons per minute (gpm). Most did not produce more than several gpm. The ability of one bedrock well to produce more than another is due primarily to factors such as weathering and fracturing. In general, as bedrock decomposition and fracturing increase, the ability of that bedrock to store and transmit water also increases.

Within the Entiat Watershed the extent of bedrock weathering is variable. A zone of weathered bedrock appears to exist at about half of the locations where wells have encountered the interface between bedrock and sediment. When present, the thickness of weathered bedrock reportedly varies from 13 to 110 feet, with a median of about 20 feet. Wells completed into this weathered zone tend to yield more water than wells completed into more competent bedrock.

The alluvial and glaciofluvial sediments in the valleys serve as the primary aquifers and contain the vast majority of ground water in the Entiat Watershed. Well yields in the Entiat River Valley reportedly range from 10 gpm to 600 gpm; a yield of about 35 gpm for a domestic well is typical. Several pump tests were performed by Tumwater Drilling in the upper Entiat Valley. Estimates of transmissivity from these tests were 12,000 gallons per day per foot (gpd/ft), and 60,000 gpd/ft. The first was reported to be completed in clay and gravel, while the second was in sandy gravel. By comparison, the estimated transmissivity at one of the bedrock wells near Ardenvoir was 400 gpd/ft.

Ground Water/Surface Water Interaction

It is reasonable to assume that the ground water of the Entiat River Watershed is moving, and eventually discharges to either a surface water body or another aquifer. There are two major controls on the direction of ground water movement: gravity and bedrock. The bedrock below the zone of weathering is largely impermeable and constrains the movement of ground water. Given that the bedrock valley floors are sloped in the same direction as the Entiat River and its tributaries, it is therefore likely that ground water is flowing in the same general direction as surface water. This means the ground water under the Entiat Watershed tributaries probably discharges to the aquifer that underlies the Entiat River. The Entiat River

aquifer either discharges to the Entiat River, or the Columbia River aquifer, or both. The coarse nature of the sediments which make up the Entiat River most likely allow fairly unrestricted interaction between the river and the aquifer to occur.

Water Demand

Water Use: Water Rights and Claims

Claims

The Claims Registration Act, Chapter 90.14 RCW, sought to document existing surface water and ground water uses prior to adoption of the State Surface Water Code, Chapter 90.03 RCW, and the State Ground Water Code, Chapter 90.44 RCW. These laws were adopted in 1917 and 1945 respectively. During the Claims Registration period, water users completed a long form to claim detailed uses for domestic and irrigation needs, and completed a short form for a single domestic use with up to ½ acre non-commercial lawn and garden.

While the accuracy of the data on some Claims is questionable, the final determination of the validity and extent associated with a Claim registered in accordance with RCW 90.14 ultimately lies with the Superior Court through the general adjudication process provided for by RCW 90.03.110 through 90.03.240. Therefore, for the purpose of this report, the quantities shown on the Claims documents were used. If a Claim did not specify a water quantity, Ecology used the estimates shown in Table 1, below.

Table 1: Estimates used for Claims not specifying a water quantity

Type of Use	Ground Water Claim	Surface Water Claim
Single domestic use (up to ½ acre)	10 gallons per minute (gpm) instantaneous use and two acre-feet annual use	0.02 cubic feet per second (cfs) instantaneous use and two acre-feet annual use
Irrigation (per acre)	10 gpm instantaneous use and four acre-feet annual use	0.02 cfs instantaneous use and four acre-feet annual use

Ecology received 303 Claims for uses in the Entiat River Watershed. These Claims were divided into 161 Ground Water Claims, which claimed approximately 2,878 acre-feet of water per year and 142 Surface Water Claims, which claimed approximately 12,254 acre-feet per year. See Table 2. These claimed quantities have been further delineated by purpose of use on Figure 4.

Table 2: Claims received for uses in Entiat River Watershed

Of the 303 Claims, 16 have their points of withdrawal or points of diversion above the gauging station near Ardenvoir and claim a total of 688 acre-feet of water per year. The locations of these claims and the others can be seen in Map 3.

Rights (Permits and Certificates)

Since the adoption of the state surface and ground water codes, the only means of acquiring a water right within the state is by filing for, and receiving, a Permit and or subsequent Certificate from Ecology or one of its predecessors. One exception is allowed under the domestic exemption to the ground water code (RCW 90.44). For this portion of the report only Permits and Certificates were used.

When a water user or future water user (applicant) expects to use any amount of surface water for any purpose, or in the case of ground water (well) use more than 5,000 gallons per day for domestic or industrial purposes and/or irrigate more than ½ acre; the applicant must file a Water Right Application with Ecology. If Ecology determines that water is available for a beneficial use, that the use will not impair other rights and is not detrimental to public interest, it issues a Water Right Permit, which allows the applicant to proceed with the project. Upon project completion Ecology issues a Certificate documenting the actual perfected, authorized water use.

For the purpose of this report the quantities shown on the Permit and Certificate documents were used. If a quantity was not shown on the application, Ecology used the same estimates as those used for Claims (see Table 1). The 105 Permits and Certificates were divided into 30 Ground Water rights for approximately 1,106 acre-feet per year and 75 Surface Water rights for approximately 2,252 acre-feet per year (see Table 3). As with the claims, the rights are further delineated by purpose of use in Figure 5.

Table 3: Rights received for uses in Entiat River Watershed

Existing Rights	Number of Rights	Volume in Acre-Feet/Year
Surface water	75	2,252
Ground water	30	1,106

Of these Certificates and Permits there are four with points of withdrawal and five with points of diversion above the gaging station near Ardenvoir, for a total of 274 acre-feet per year. The locations of these uses and the others can be seen in Map 4.

Total Rights and Claims

The total number and volume of rights and claims is summarized in Table 4.

Table 4: Total number of rights and claims

Type	Number	Volume in Acre-Feet/Year
Surface water	217	14,506
Ground water	191	3,984
Totals	408	18,490

Applications

As described above, a prospective water user must file a Water Right Application with Ecology prior to taking any water. The Water Right Applications used to prepare this portion of the report have not been issued a Permit and the quantities are estimates of what might be reflected on a Permit if and when it was issued.

For the purpose of this report the requested quantities shown on the Applications were used. If a quantity was not shown on the application, the same estimates shown in Table 1 were used. The 19 Applications were divided into 12 Ground Water applications for 460 acre-feet per year and 7 Surface Water applications for 152 acre-feet per year (see Table 5). The requests for water by purpose of use can be seen in Figure 6. There are no applications for consumptive use above the gaging station near Ardenvoir. All consumptive use applications are located below the gauging station in Map 5.

Table 5: Applications received for uses in Entiat River Watershed

Application Type	Number of Applications	Volume in Acre-Feet/Year
Surface water	7	152
Ground water	12	460

Minimum Flows

The Washington Departments of Fish and Wildlife and Ecology studied several instream flow methods for evaluating effects of various streamflows on fish before concluding that the best available methodology is the Instream Flow Incremental Method (IFIM). The IFIM, when used in accordance with Instream Flow Study Guidelines developed by the state, provides a framework for considering stream ecology as it affects an instream resource of interest (e.g., a species of fish). The IFIM provides an excellent framework for problem-solving because it is flexible, allows existing information to be incorporated, and generates a

substantial amount of new information. The state's decision to use the IFIM method was reviewed and approved by two federal agencies (National Marine Fisheries Service and U.S. Fish and Wildlife Service), as well as by biologists for several Indian tribes and the Northwest Indian Fisheries Commission.

Ecology completed an IFIM study for several sites on the Entiat River (Caldwell et al, in progress). The lower site, located at river mile 1.0, represents the lower 10 miles of the river. This reach of the river is characterized as mostly boulder/cobble riffle due to channelization and riprap from past flood control activities. The old USGS gauge site (12453000) near Entiat was located at river mile 0.25. The Upper Entiat River site is located at river mile 17.2; this is above Ardenvoir, which is at river mile 10. The upper river site represents the river from about river mile 10 up to Fox Creek at river mile 27.7. This reach contains gravel/cobble bars and more typical pool/riffle sequences. Recommended river flows on this reach would be measured by the present USGS gauge (12452800) above Ardenvoir, which is located at river mile 18 (Map 6).

Based on the results of the IFIM studies, representatives from Ecology and the Department of Fish and Wildlife have recommended the following flows as needed to protect fish habitat on these two reaches of the river. Flows recommended to protect fish habitat at the Upper Entiat River site (RM 17.2) and the Lower Entiat River site (RM 1.0) are shown in Table 6.

Table 6: Recommended Flows for Upper and Lower Entiat River

Upper Entiat River	July 1 to March 15	275 cfs
	March 16 to April 15	325 cfs
	April 16 to May 31	375 cfs
	June 1 to June 30	325 cfs
Lower Entiat River	July 1 to March 15	185 cfs
	March 16 to April 15	250 cfs
	April 16 to May 31	325 cfs
	June 1 to June 30	250 cfs

Water Quality

The 303(d) report is a list submitted by Ecology to the U.S. Environmental Protection Agency (EPA) required by Section 303(d) of the Federal Clean Water Act. The list contains all those surface water body segments that are not expected to attain water quality standards after implementation of technology-based pollution controls, and therefore require additional management activities. Ecology uses the Section 303(d) list to help set priorities for total maximum daily load (TMDL) development on a watershed approach basis. The Entiat River at monitoring station 46A070 (located at RM 1.5) is on the list for exceeding temperature and pH parameters. See Table 7.

Table 7: Water Quality Parameters Exceeded in Entiat River

Water body Name/ Segment Number	Parameters Exceeding Standards	Basis For Listing
Entiat River WA-46-1010	pH	2 excursions beyond criteria at Ecology ambient monitoring station 46A070 between 1/1/90 and 1/1/92.
same	Temperature	3 excursions beyond criteria at Ecology ambient monitoring station 46A070 between 1/1/90 and 1/1/92.

Fisheries

There have been a number of recent studies regarding the health of fish stocks in Washington State. In this section data from two of the more prominent studies are compared for the Entiat River. The primary means of comparison is through a table which lists all of the stocks identified by the two studies as being in some degree of decline. A very brief description of the studies is presented below, followed by Table 8 and an explanation of each of the columns in Table 8.

The two studies compared in Table 8 are: 1) a paper published in the March-April 1991 issue of Fisheries under the title of "Pacific Salmon at the Crossroads: Stocks at risk from California, Oregon, Idaho, and Washington"; and 2) the "1992 Washington State Salmon and Steelhead Stock Inventory," published in March 1993. In addition, a paper prepared by Thom Lufkin of Ecology (1993) titled "Declining Fish Stocks in Washington State: A Comparison of the American Fisheries Society List and the Salmon and Steelhead Stock Inventory", was used to compare the two studies.

Although separate, these studies are each part of ongoing analysis of the status of anadromous fish stocks. Consequently, the information in Table 8 is essentially a snapshot of what was known or believed at the time the reports were prepared; some of the information may be revised as the analyses continue.

The "Pacific Salmon at the Crossroads" paper (referred to hereafter as the "AFS study") was prepared by the Endangered Species Committee of the American Fisheries Society. The paper ". . . provides a list of depleted Pacific Salmon, Steelhead, and sea-run cutthroat stocks from California, Oregon, Idaho and Washington . . ."; 214 stocks were identified ". . . that appear to be facing a high or moderate risk of extinction, or are of special concern." The AFS study sounded the alarm regarding the significant depletion of anadromous species of the Pacific coast.

The Salmon and Steelhead Stock Inventory (SASSI) was prepared by the Washington State Departments of Fisheries and Wildlife, with the assistance of twenty three Indian Tribes and Tribal organizations. The SASSI is a ". . . summary report on the status of wild salmon and

steelhead populations in Washington State." The inventory was prepared as the ". . . first step in a statewide effort to maintain and restore wild salmon and steelhead stocks and fisheries. The inventory's intent is to help identify currently available information and to guide future restoration planning and implementation."

Table 8: Comparison of American Fisheries Society List and Salmon and Steelhead Stock Inventory

Water Body	Stock	AFS Status	SASSI Status	AFS Factors	SASSI Origin	SASSI Type
Entiat River	Chinook, spring		Depressed		Native	Wild
Entiat River	Steelhead, summer	High risk	Depressed	1, 4	Mixed	Wild

Table 8 Definitions

Water body – A river, creek, lake, etc. that is named as the place of origin for the identified stock (i.e., where the stock returns to spawn).

Stock – A population of fish that spawns in a particular season and generally does not breed with fish that spawn in a different body of water or different season. These populations possess adaptive genetic differences based on the relatively unique characteristics of the location and season in which they spawn.

AFS Status – A set of ratings ranging from "Of Special Concern" to "Extinct". The rating "High Risk" (at high risk of extinction) refers to those populations whose spawning escapements are declining; fewer than one adult fish returns to spawn from each parent spawner. Populations with escapements of less than 200 in the last one to five years were placed in this category unless the escapements were historically small. A stock in this category is likely to meet the threshold for listing as endangered under the Endangered Species Act.

SASSI Status – A set of status ratings ranging from "Healthy" to "Extinct." The rating "Depressed" refers to a stock of fish whose production is below expected levels based on available habitat and natural variations in survival rates, but above the level where permanent damage to the stock is likely.

AFS Factors – Those factors that threaten the at-risk populations. AFS has listed only those factors which are currently most threatening. Numbered as 1 through 4, these are as follows:

1. The present or threatened destruction, modification, or curtailment of the stock's habitat or range, as well as main stem passage and flow problems, and predation during reservoir passage or residence.

2. Over-utilization for commercial, recreational, scientific, or educational purposes, including over-harvest in mixed stock fisheries.

3. Diseases, such as Creatomyxa shasta.

4. Other natural or manmade factors affecting the stock's continued existence, such as hybridization, introduction of exotic or translocated species, predation not primarily associated with main stem passage and flow problems, and competition. This category includes poor ocean survival conditions, as well as negative interactions with hatchery fish, including hybridization, competition and disease.

SASSI Type – This designation refers to the type of spawning and rearing that produced the fish.

SASSI Origin – Stock origin definitions were developed to attempt to categorize the genetic history of stocks. The assessments of stock origin presented in Table 8 should be considered as preliminary until such time as more detailed information confirms or refutes the current origin designations.

Native	A stock that has become established outside of its original range
Mixed	A stock whose individuals originated from commingled native and non-native parents and/or by mating between native and non-native fish (hybridization); or a previously native stock that has undergone substantial genetic alteration.
Wild	A stock that is sustained by natural spawning and rearing in the natural habitat, regardless of parentage (includes native).
Cultured	A stock that depends upon spawning, incubation, hatching, or rearing in a hatchery or other artificial production facility.

Streamflow Status

River flow data from the USGS gauging station near Ardenvoir (1957-1993) and recommended IFIM flows for the upper river reach were compared. The comparison reveals that river flows are often below the IFIM recommended flows for much of the year. Data from Table 9 show that during the time period of July 1 – March 15 the river flows were below the IFIM flows for 221 days or 86% of the time. It also shows that on an average annual basis, the IFIM flows are not met for 261 days of the year. Graphical comparisons of river flow and IFIM flows are presented in Figures 7 and 8. Figure 7 simply shows the average monthly flows plotted against the IFIM flows. Figure 9 shows the probability of a certain flow occurring at some time of the year in relation to the IFIM flows.

Table 9: Entiat River at Ardenvoir Gage

Season Analyzed	Minimum Flow (cfs)	Avg. days per season instream flow not met	Percent of time instream flow not met during season
July 1 – March 15	275	221	86
March 16 – April 15	325	28	89
April 16 – May 31	375	12	26
June 1 – June 30	325	<1	0.50

The same comparison was made for Entiat River flow data from the old USGS gaging station near Entiat (1911 – 1925) and (1951 – 1958) and the recommended IFIM flows for the lower reach. Once again the river flows were found to be below the IFIM flows for much of the time. Tables 10 and 11 show that during the period of July 1 -–March 15 the river flows are below IFIM flows for over 50% of the time, and more than 170 days of the year. Again, the same types of graphical comparisons described above are presented in Figures 9 and 10.

Table 10: Entiat River at Entiat Gage (1911-1925)

Season Analyzed	Minimum Flow (cfs)	Avg. days per season instream flow not met	Percent of time instream flow not met during season
July 1 – March 15	185	174	67
March 16 – April 15	250	16	52
April 16 – May 31	325	4	7.8
June 1 – June 30	250	0	0.0

Table 11: Entiat River at Entiat Gage (1951-1958)

Season Analyzed	Minimum Flow (cfs)	Avg. days per season instream flow not met	Percent of time instream flow not met during season
July 1 – March 15	185	147	57
March 16 – April 15	250	22	71
April 16 – May 31	325	5	10
June 1 – June 30	250	0	0.0

CONCLUSIONS

The following conclusions can be drawn from the information contained in this report:

- The Entiat River Watershed is a bedrock basin with alluvial and glacial sediments occupying its main valley and side valleys. These valley sediments form the principle aquifers within the watershed. The coarse nature of the sediments in the main valley leads to the conclusion that pumping wells located there will likely impact river flow.

- More clay appears to be present in the side valley sediments than in the main valley sediments. Based on this presumed soil structure, and Ecology's experience in similar watersheds, it is possible (depending on physical circumstances) that well pumping in the side valley sediments may not impact flows in the side streams. However, side stream ground water is tributary to either the main valley aquifer or the Entiat River directly. In either case, it is likely that the removal of this ground water will eventually reduce flows in the Entiat River.

- It is likely that the ground water present in the "weathered zone" of the bedrock, and other bedrock fractures, is in hydraulic connection with the overlying sediments.

- Precipitation is the source of ground water and surface water within the Entiat Watershed. The heaviest concentration is located in the northwest half of the watershed. Precipitation appears to have remained fairly consistent over the long term.

- Surface water irrigation is the dominant use of water within the watershed.

- Most applications for new water rights are located in the lower part of the watershed.

- Some water quality criteria have been violated.

- The Entiat runs of spring Chinook and summer Steelhead have been listed as "depressed" and "high risk".

- For much of the year Entiat River flows are below the recommended IFIM flows on a regular basis.

RECOMMENDATIONS

The following recommendations for further action are made based on the information contained in this report:

- Re-establish the old USGS gauging station on the Entiat River near the Town of Entiat. Currently, no long term stream data exist for the lower reach of the river although this is where most of the water use exists. This lack of information prevents Ecology from making river flow trend analyses based on water right issuance, and also deprives Ecology'' Central Region of any real time monitoring and regulation of the lower reach of the river.

- Generate a synthetic annual hydrograph for the lower river reach to obtain updated information about the current situation of river flow vs. IFIM flows.

- Conduct aquifer testing to help eliminate uncertainties about hydraulic continuity. This testing would be more useful in the tributaries than along the main stem where the hydraulic situation is more clearly understood.

- Conduct tributary modeling to determine ground water timing in relation to the main stem.

BIBLIOGRAPHY

Caldwell, Brad., Beecher, H. and Mark, J. In progress. Entiat River incremental methodology: fish habitat analysis using the instream flow.

Long, W. A., 1969, A preliminary report on the glaciation of the middle Entiat Mountains, Washington [abstract]: Northwest Science, v. 43, no. 1, p. 39.

Long, William A., 1951, Glacial geology of the Wenatchee – Entiat area, Washington: Northwest Science, v. 25, no.1, p. 3 – 16.

Lufkin, Thom, 1993. Declining Fish Stocks in Washington State: A Comparison of the American Fisheries Society List and the Salmon and Steelhead Stock Inventory. Unpublished Paper, Washington State Department of Ecology.

Miles, M. B., et al., 1994. Water Resources Data, Washington, Water Year 1993. United States Geological Survey Water-Data Report WA-93-1.

Tabor, R. W., et al., 1987. Geologic Map of the Chelan 30-Minute by 60-Minute Quadrangle, Washington. United States Geological Survey.

United States Department of Agriculture – Economics, Statistics, Cooperative Service, Forest Service, and Soil Conservation Service, 1979. Entiat Co-operative River Basin Study.

Walters, Kenneth L., and Nassar, E. G., 1974. Water in the Method River Basin, Washington. Wash. St. Dept. of Ecology and U.S. Geological Survey, Water Supply Bulletin 38.

Williams, J. R., and Pearson, H. E., 1985. Streamflow Statistics and Drainage-Basin Characteristics for the Southwestern and Eastern Regions, Washington. United States Geological Survey Open-File Report 84-145-B.

Figure 1

ANNUAL PRECIPITATION

Entiat Area Stations

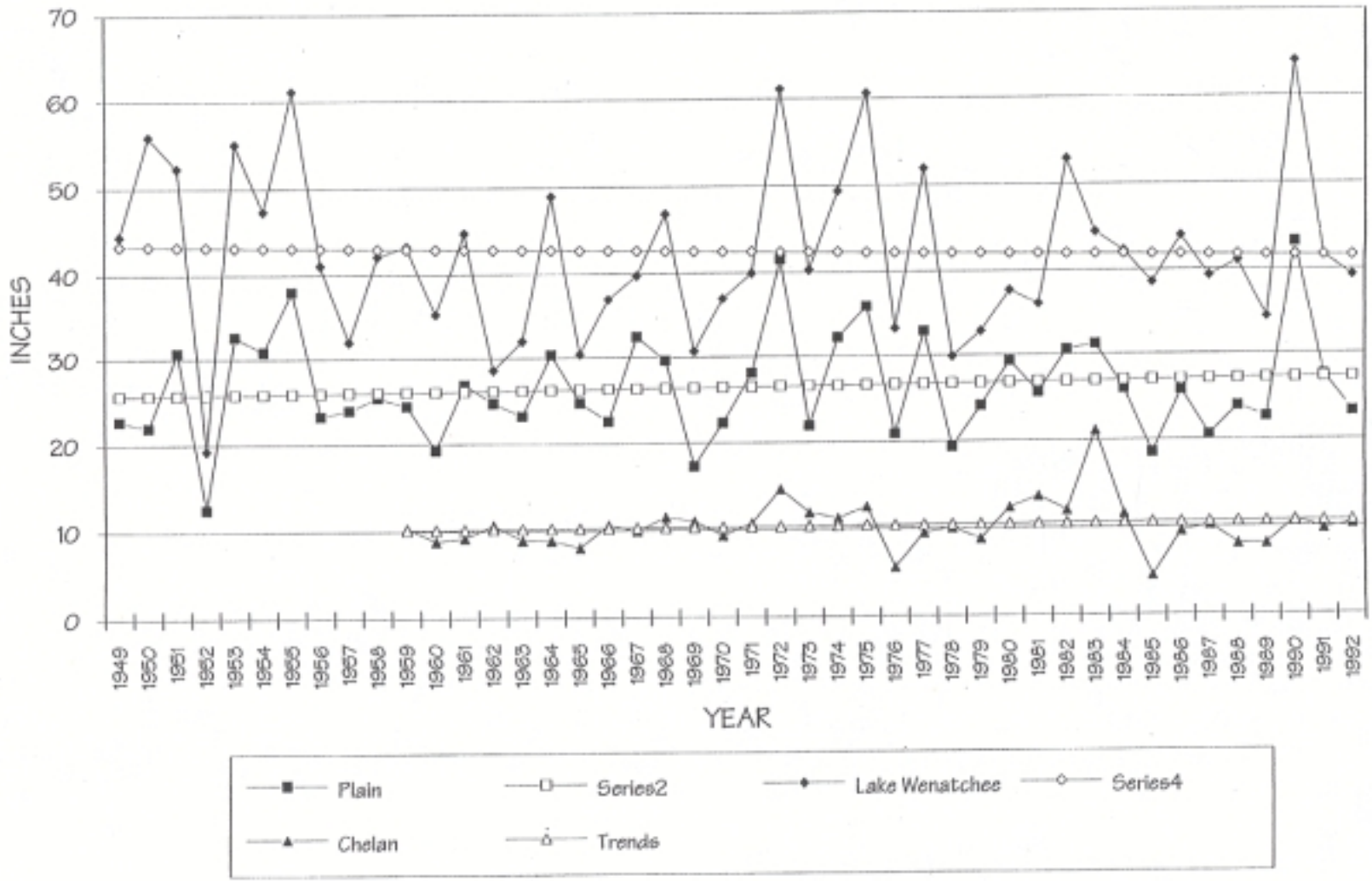


Figure 2

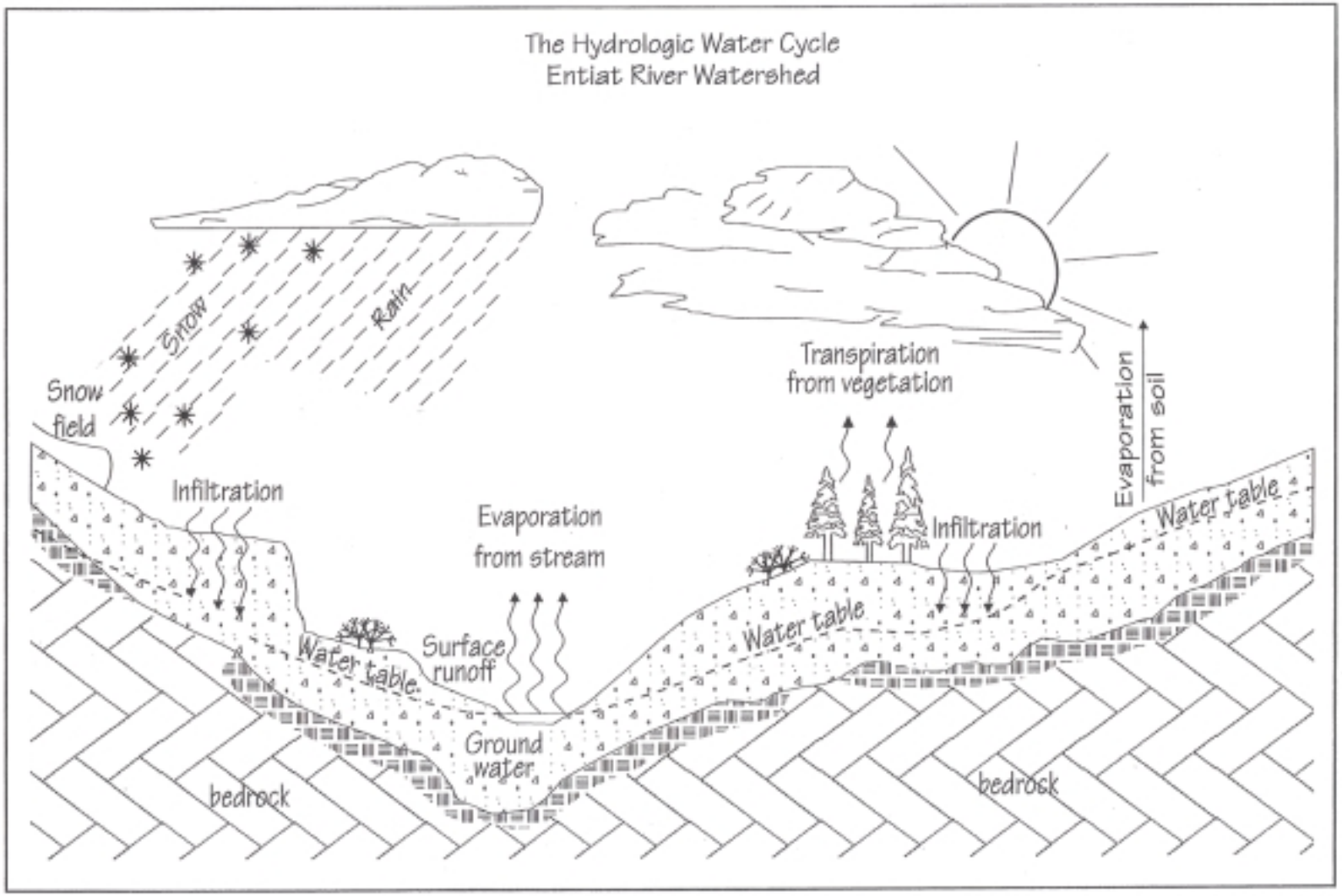

The Hydrologic Water Cycle
Entiat River Watershed
Snow
Rain
Snow field
Infiltration
Evaporation from stream
Surface runoff
Water table
Ground water
bedrock
Transpiration from vegetation
Evaporation from soil
Infiltration
Water table
Water table
bedrock

Figure 3

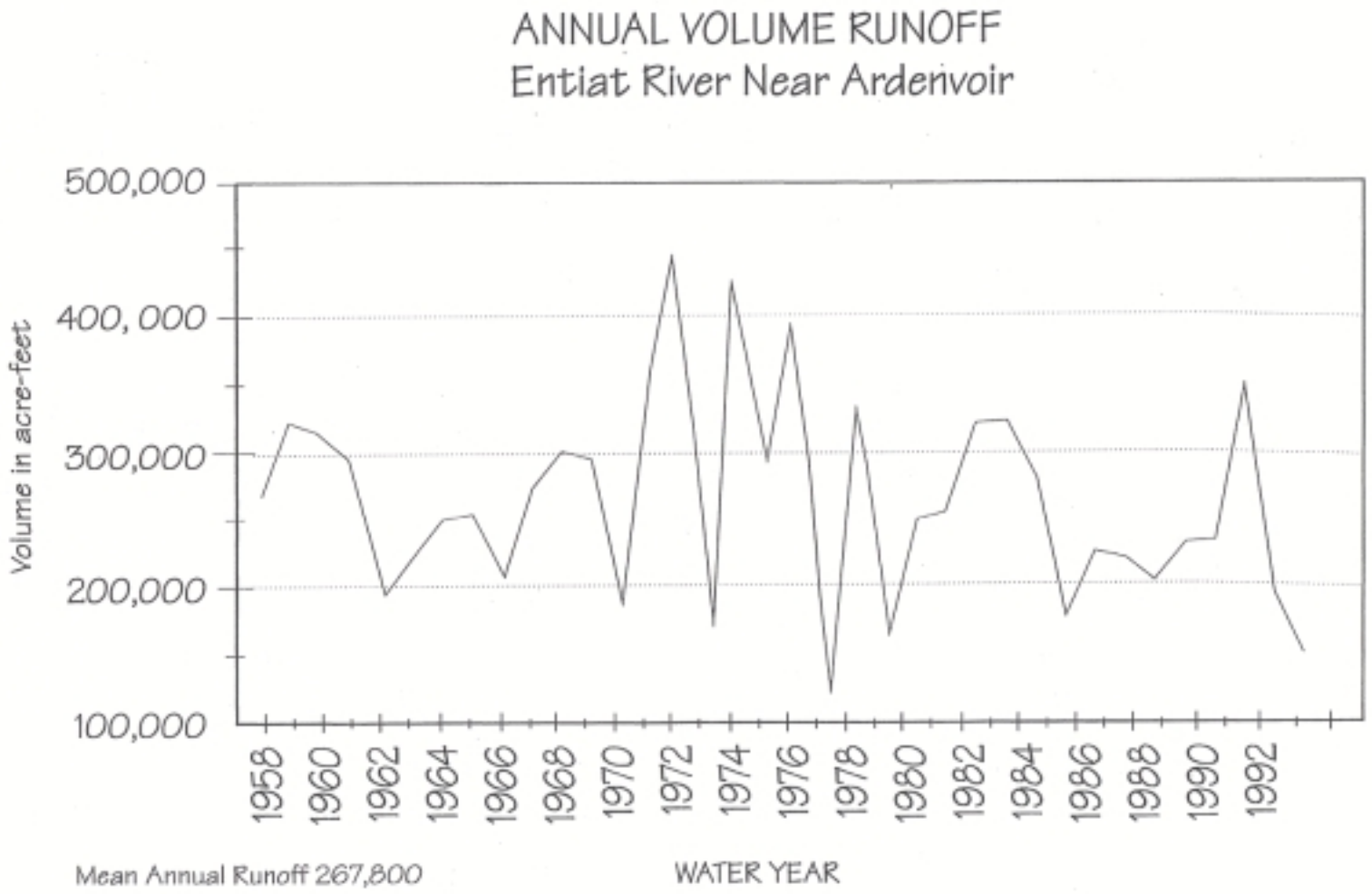
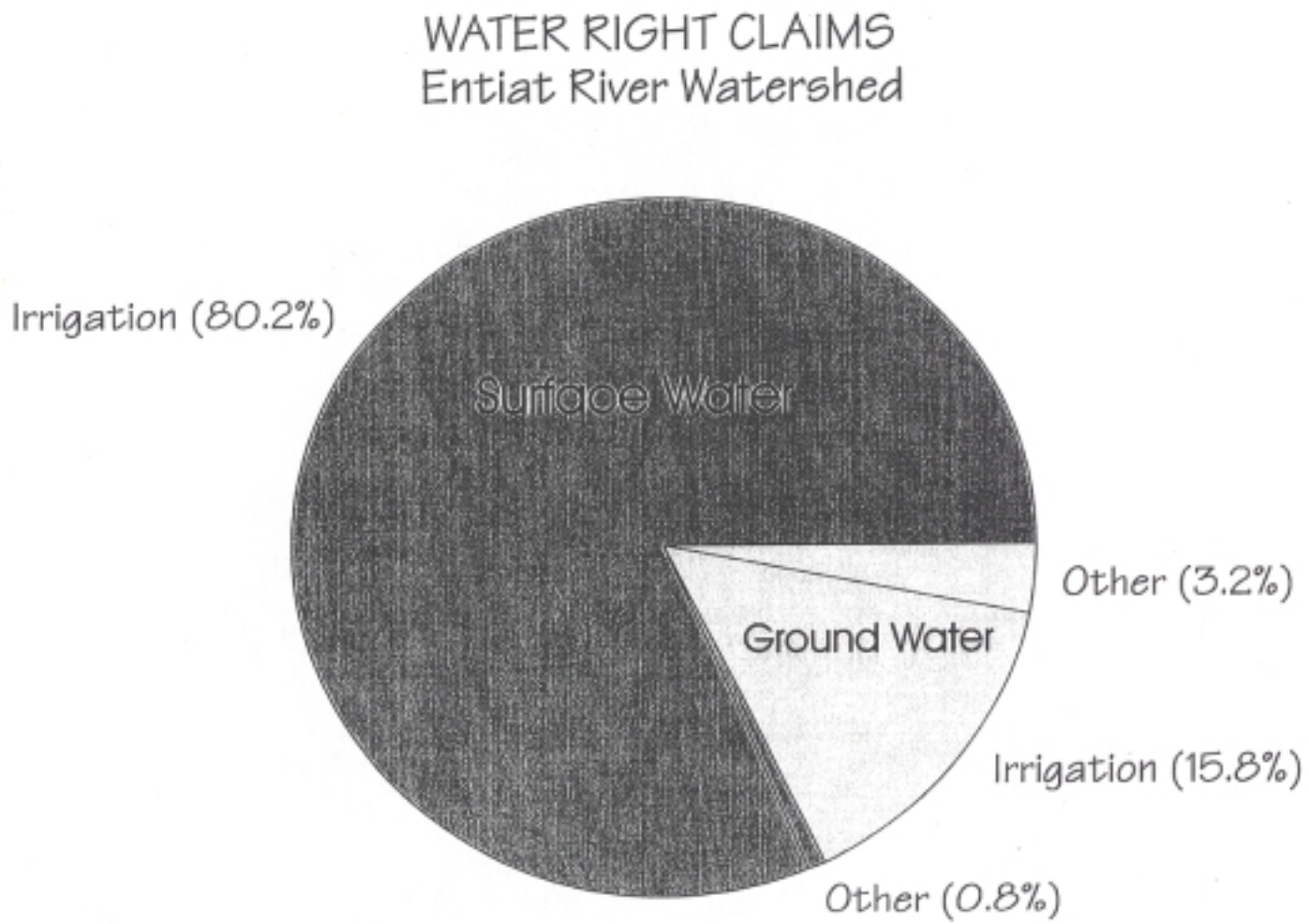

ANNUAL VOLUME RUNOFF
Entiat River Near Ardenvoir
500,000
400, 000
300,000
200,000
100,000
Volume in acre-feet
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
WATER YEAR
Mean Annual Runoff 267,800

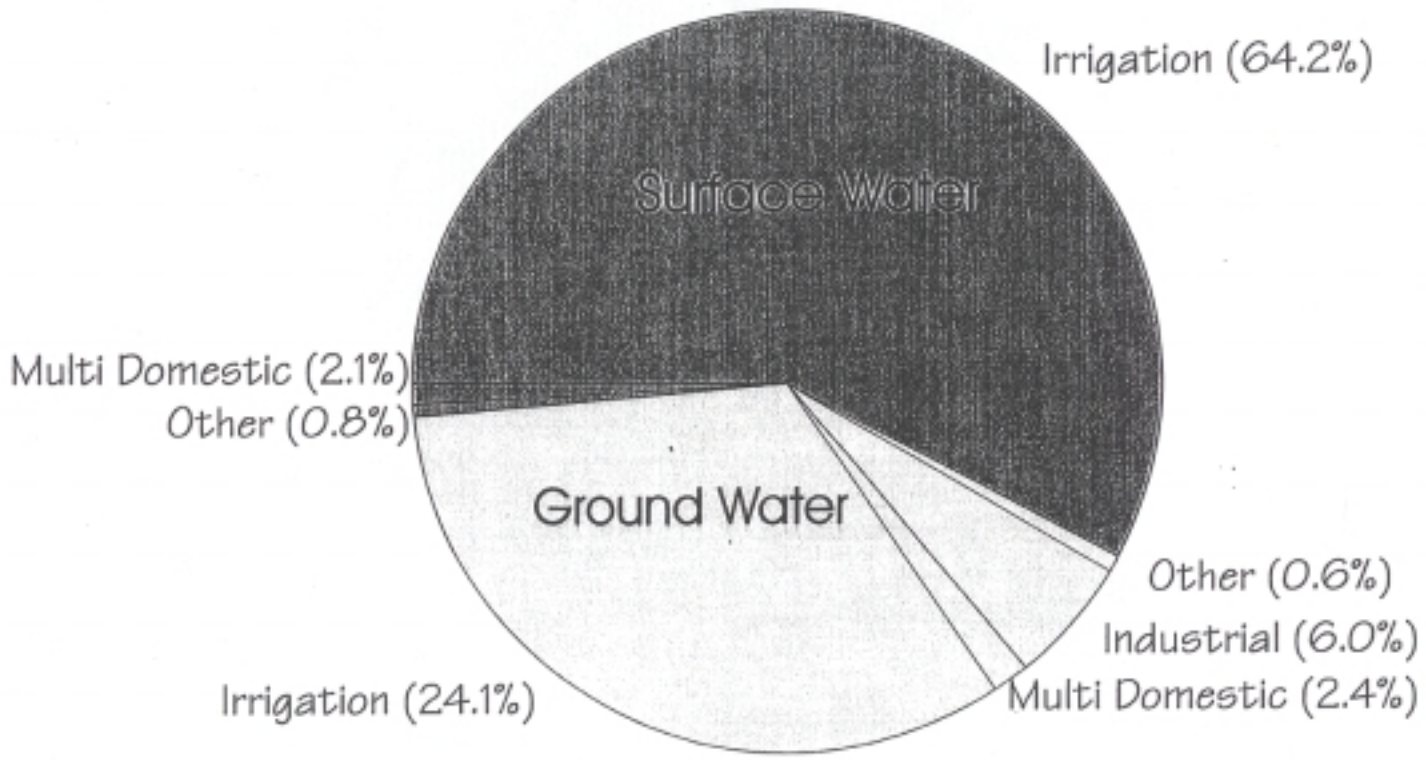
Figure 4



Ground Water Claims = 2,878 acre-feet/year
Surface Water Claims = 12,254 acre-feet/year
Total Claims = 15,132 acre-feet per year

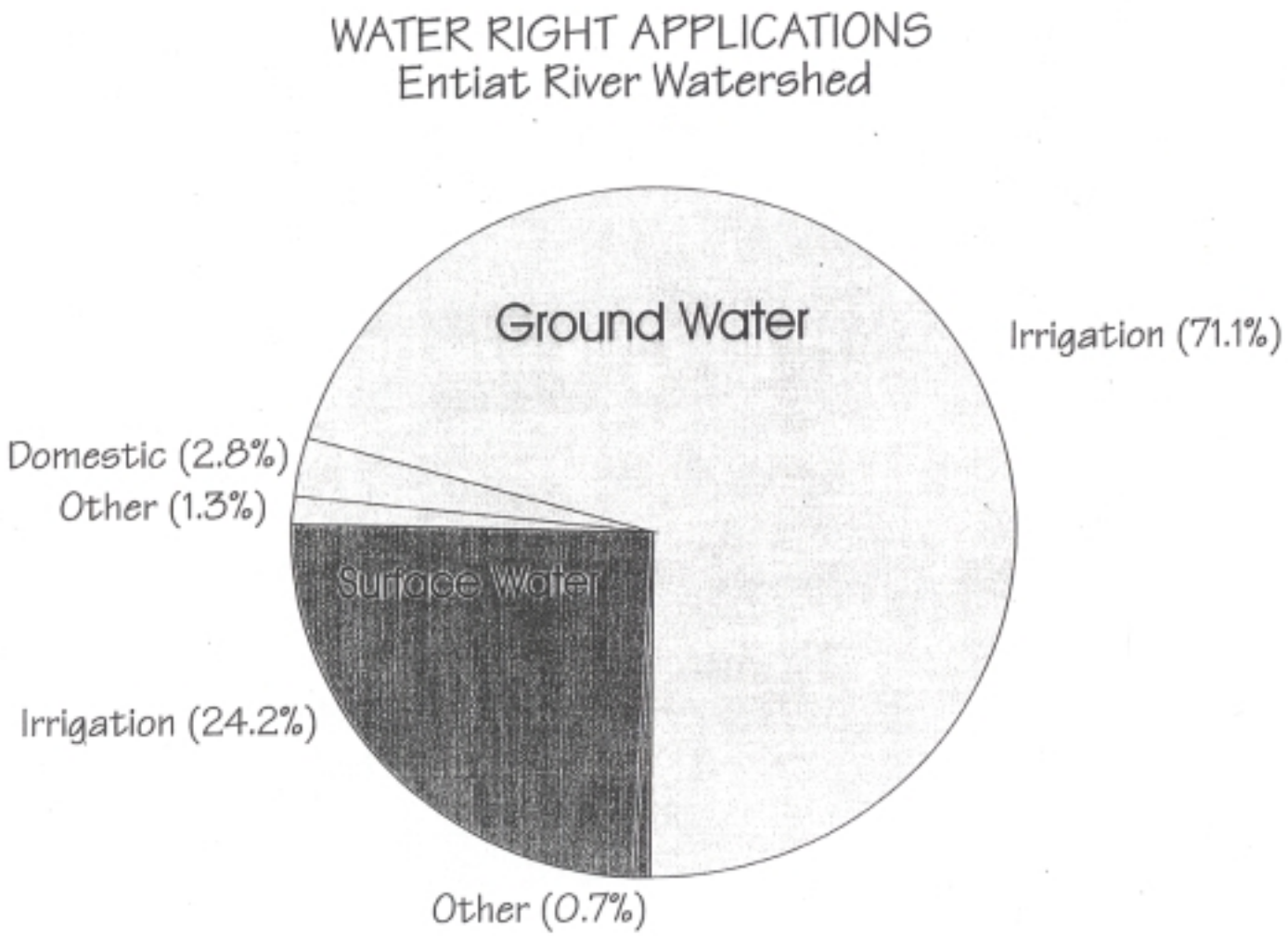
Figure 5

WATER RIGHTS
Entiat River Watershed



Ground Water Rights = 1,106 acre-feet/year
Surface Water Rights = 2,252 acre-feet/year
Total Rights = 3,358 acre-feet/year

Figure 6



Ground Water Applications = 460 acre-feet/year
Surface Water Applications = 152 acre-feet/year
Total Applications = 612 acre-feet/year

Figure 7

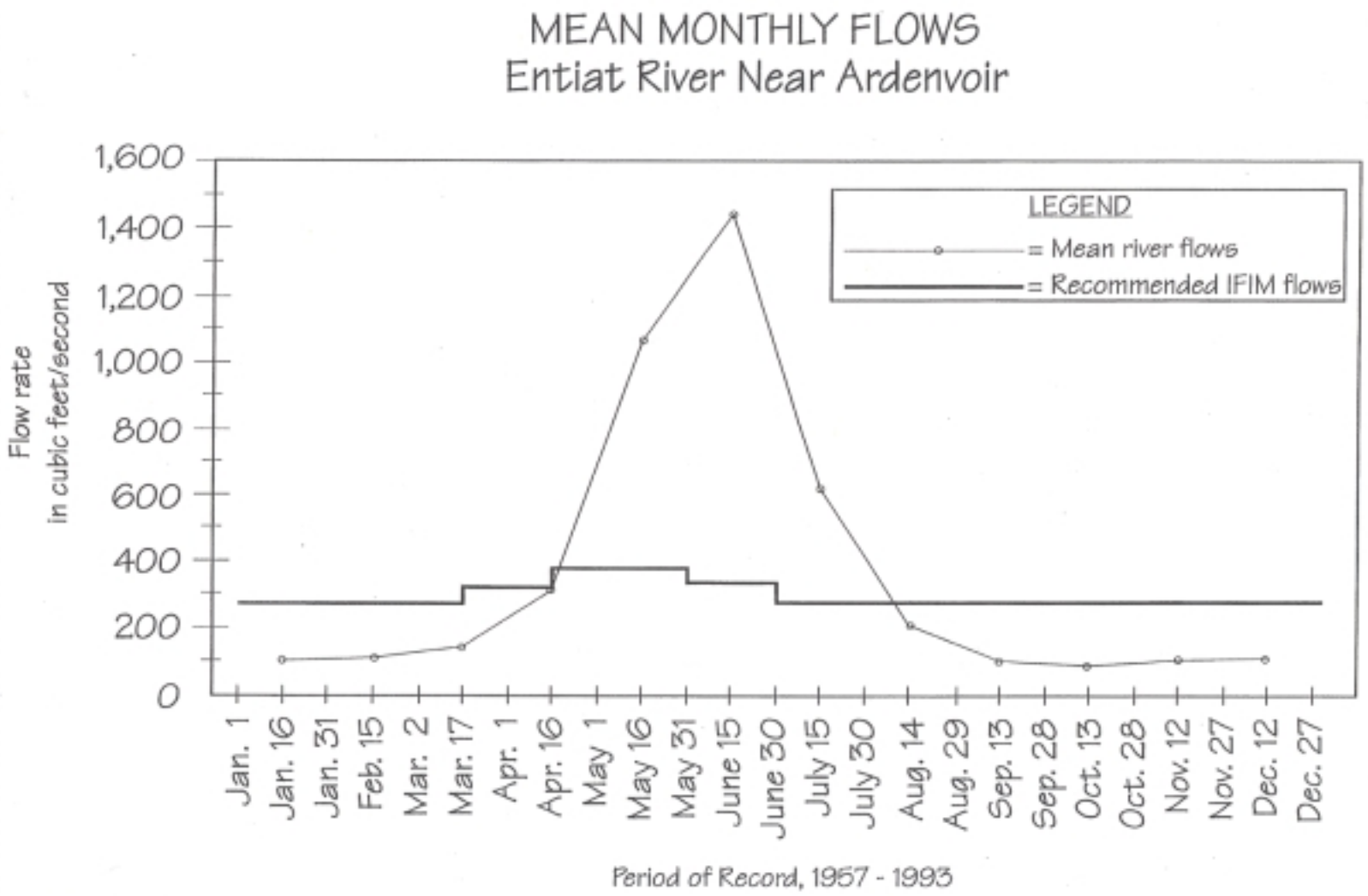

MEAN MONTHLY FLOWS
Entiat River Near Ardenvoir
Flow rate
in cubic feet/second
1,600
1,400
1,200
1,000
800
600
400
200
0
LEGEND
= Mean river flows
= Recommended IFIM flows
Jan. 1
Jan. 16
Jan. 31
Feb. 15
Mar. 2
Mar. 17
Apr. 1
Apr. 16
May 1
May 16
May 31
June 15
June 30
July 15
July 30
Aug. 14
Aug. 29
Sep. 13
Sep. 28
Oct. 13
Oct. 28
Nov. 12
Nov. 27
Dec. 12
Dec. 27
Period of Record, 1957 - 1993

Figure 8

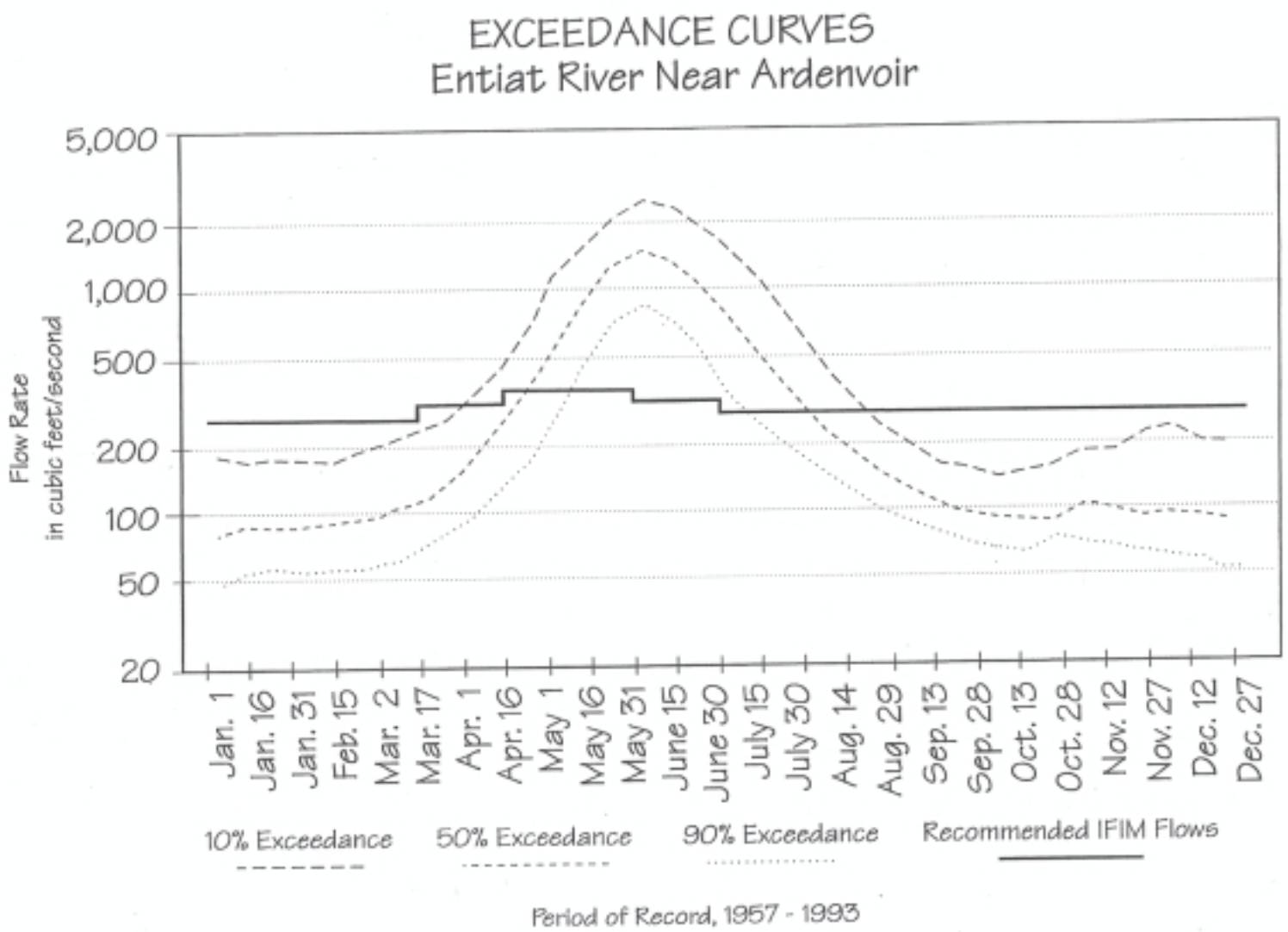

EXCEEDANCE CURVES
Entiat River Near Ardenvoir
Flow Rate
in cubic feet/second
5,000
2,000
1,000
500
200
100
50
20
Jan. 1
Jan. 16
Jan. 31
Feb. 15
Mar. 2
Mar. 17
Apr. 1
Apr. 16
May 1
May 16
May 31
June 15
June 30
July 15
July 30
Aug. 14
Aug. 29
Sep. 13
Sep. 28
Oct. 13
Oct. 28
Nov. 12
Nov. 27
Dec. 12
Dec. 27
10% Exceedance
50% Exceedance
90% Exceedance
Recommended IFIM Flows
Period of Record, 1957 - 1993

Figure 9

MEAN MONTHLY FLOWS
Entiat River Near Entiat

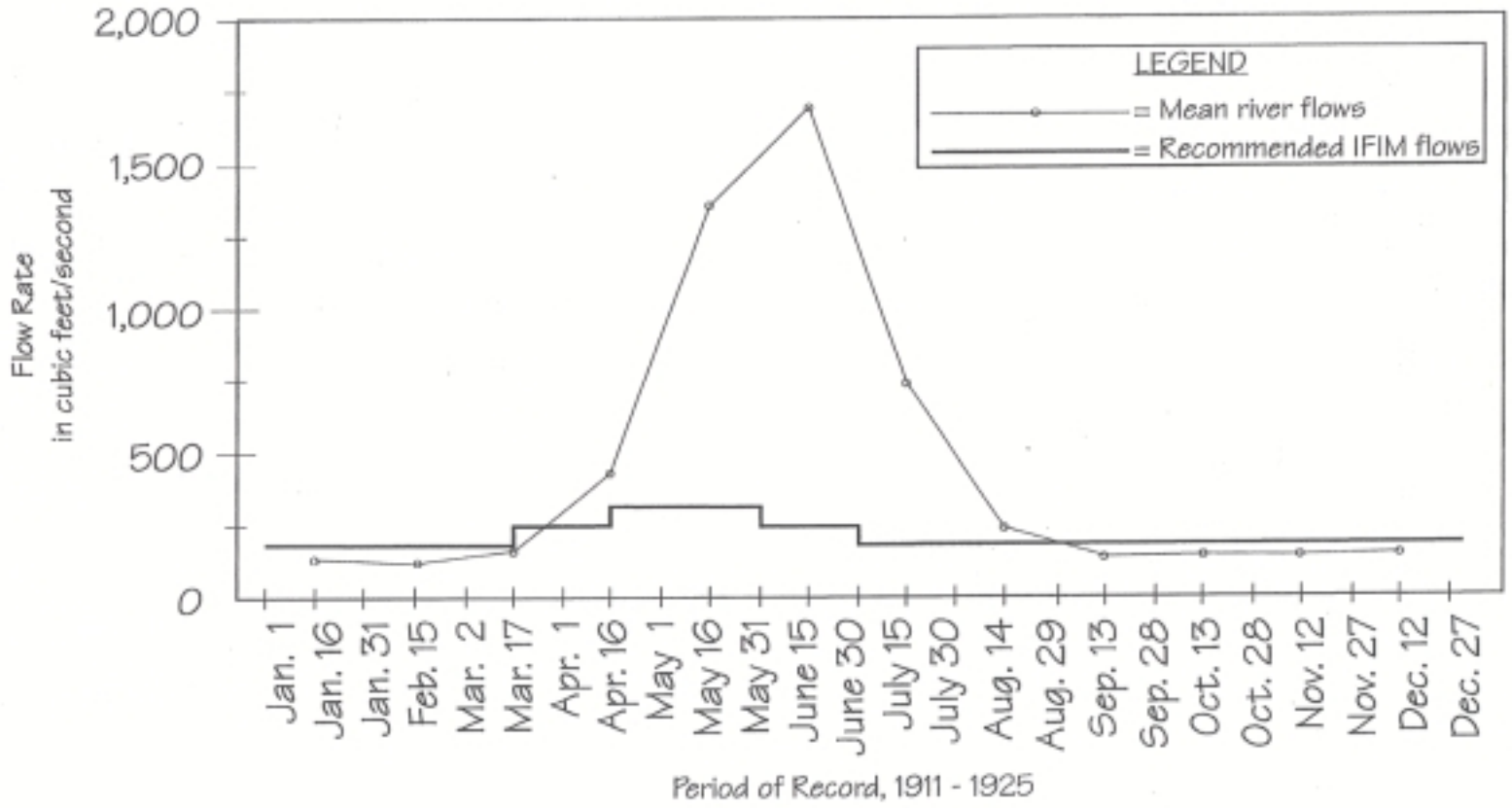
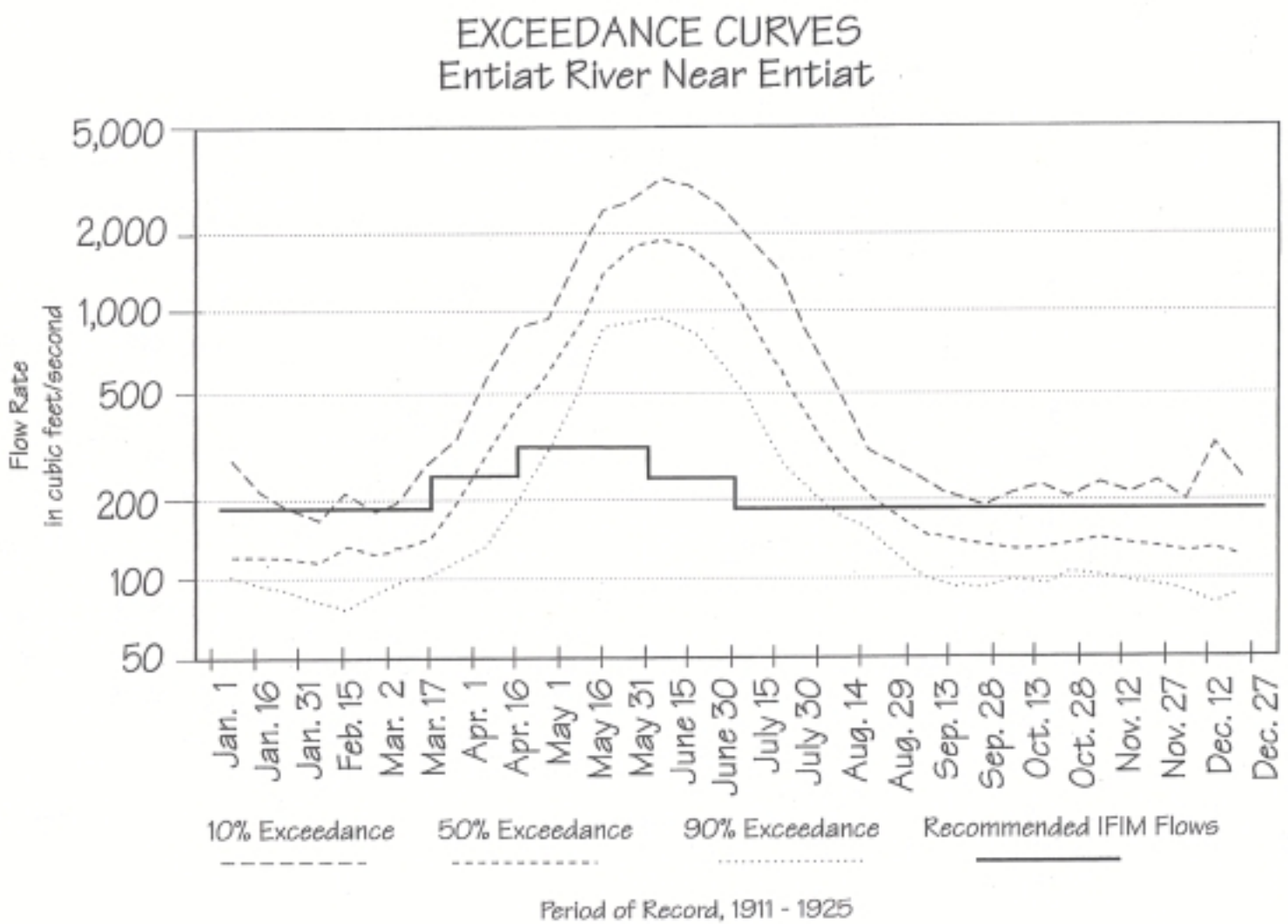
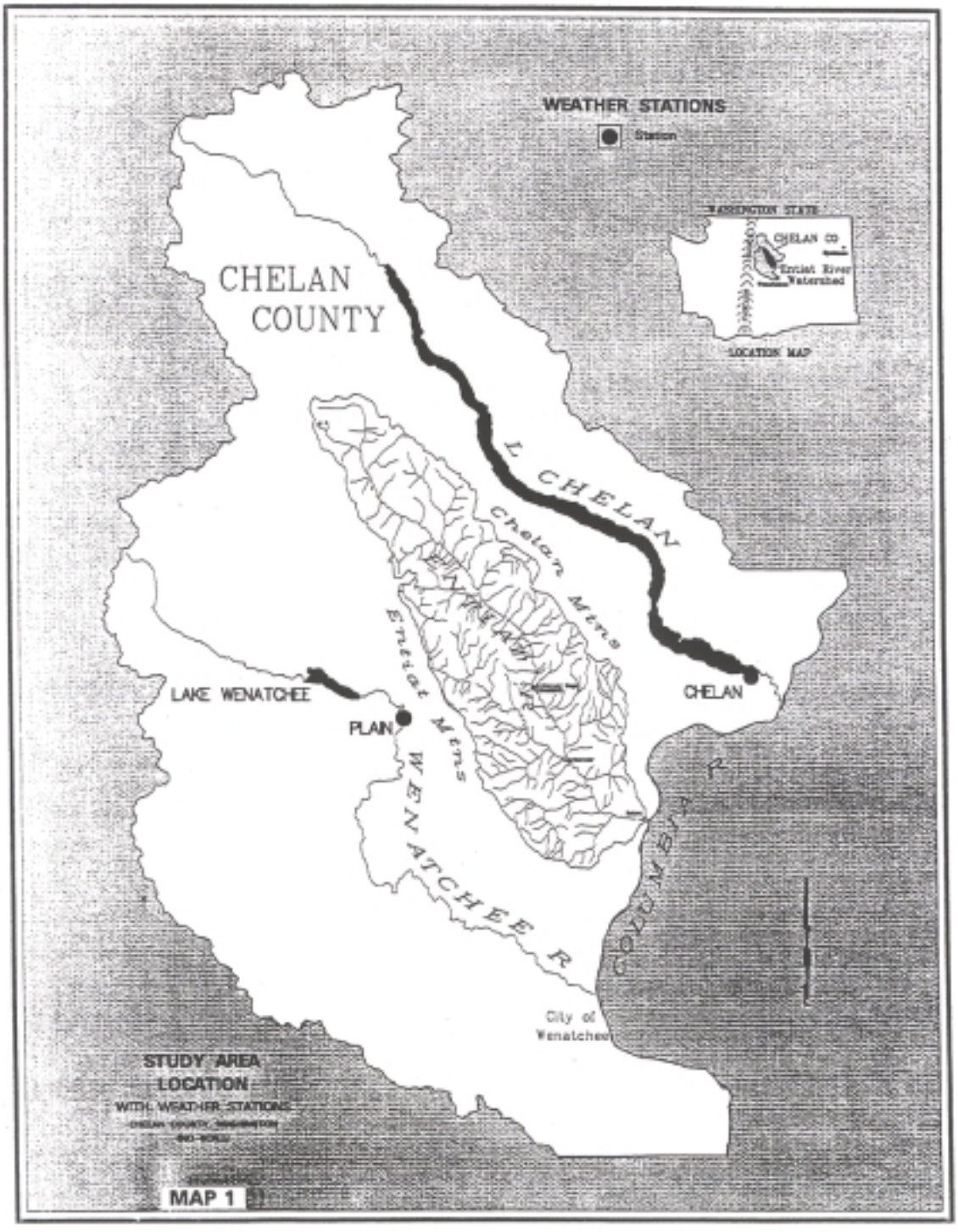
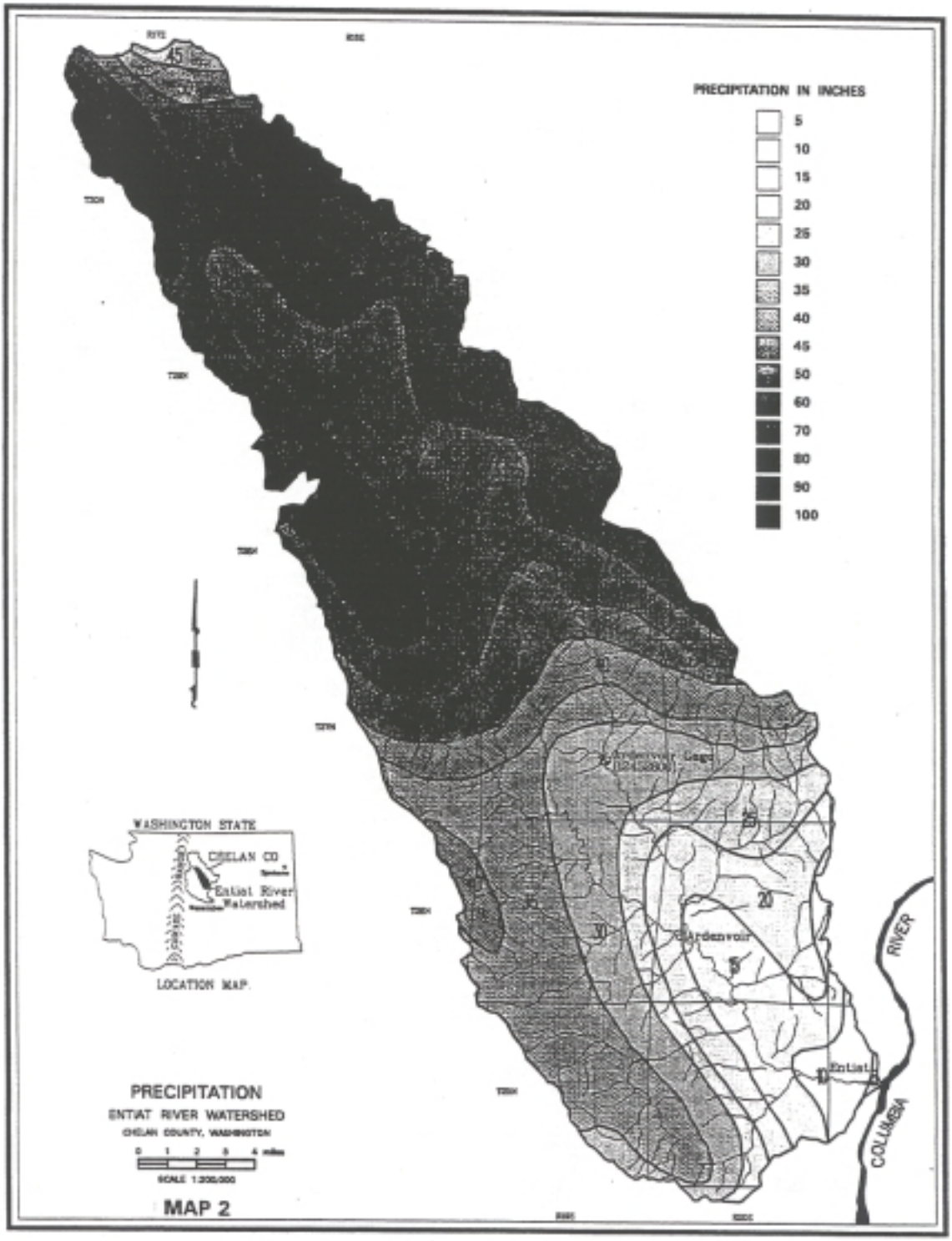
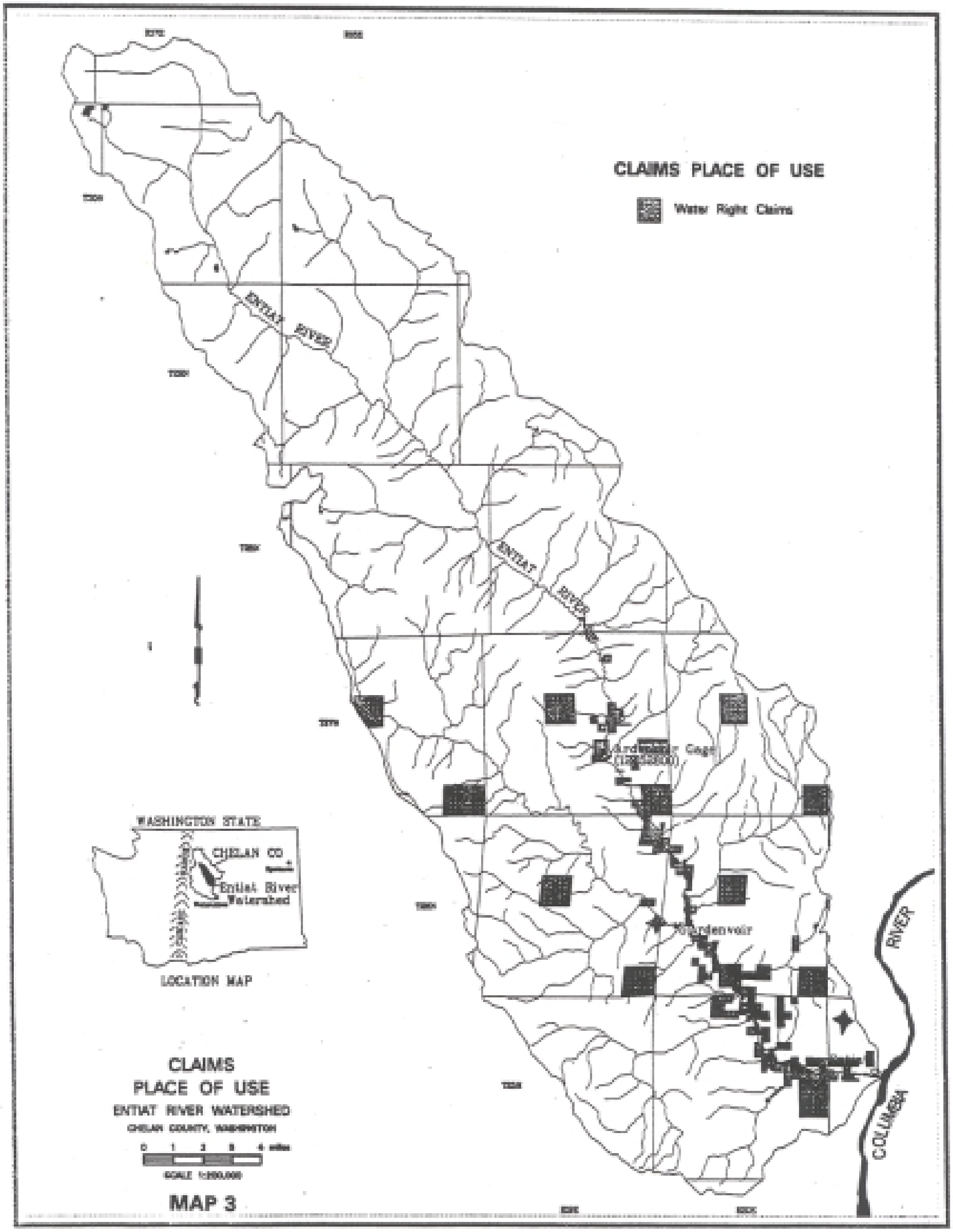


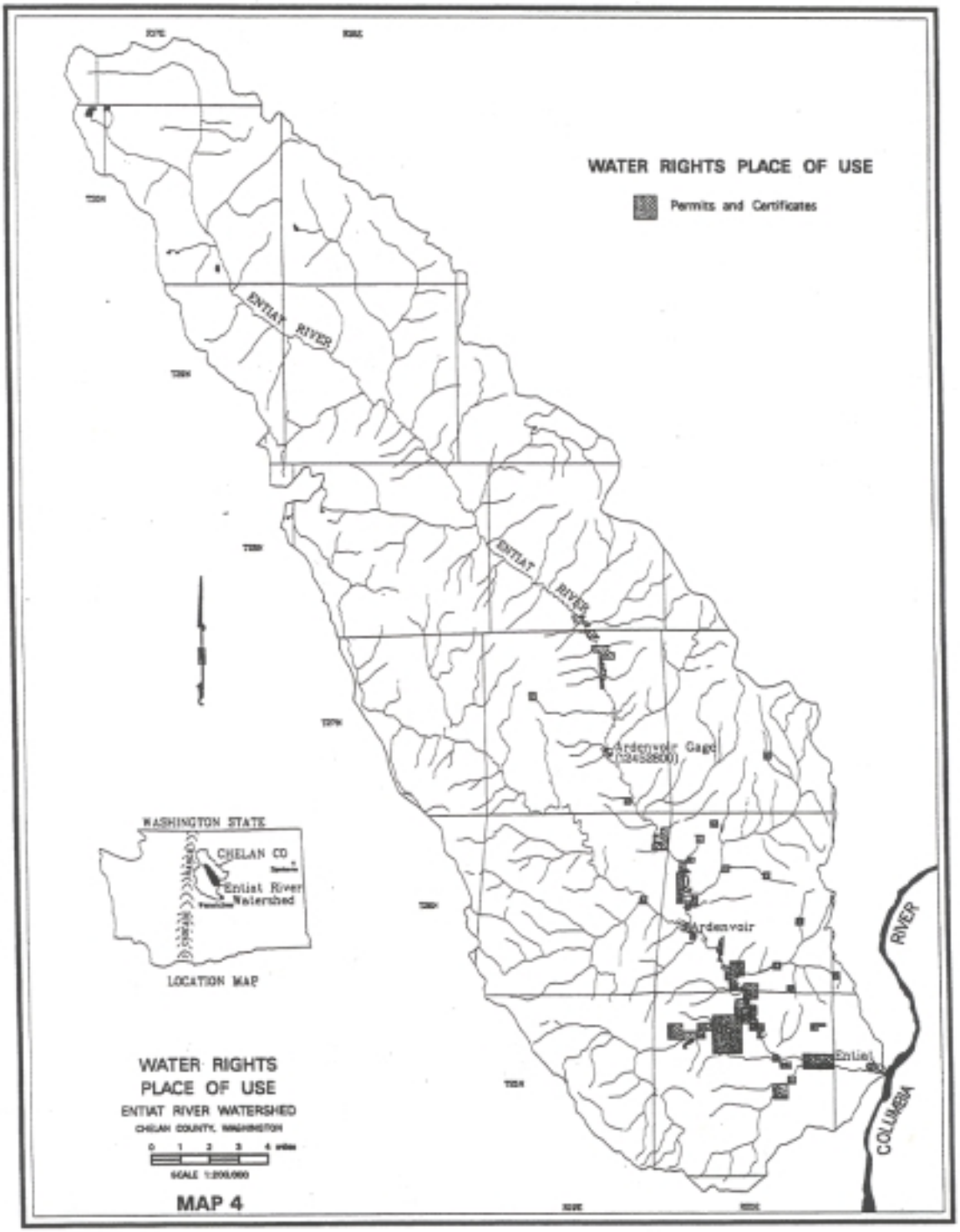
Figure 10

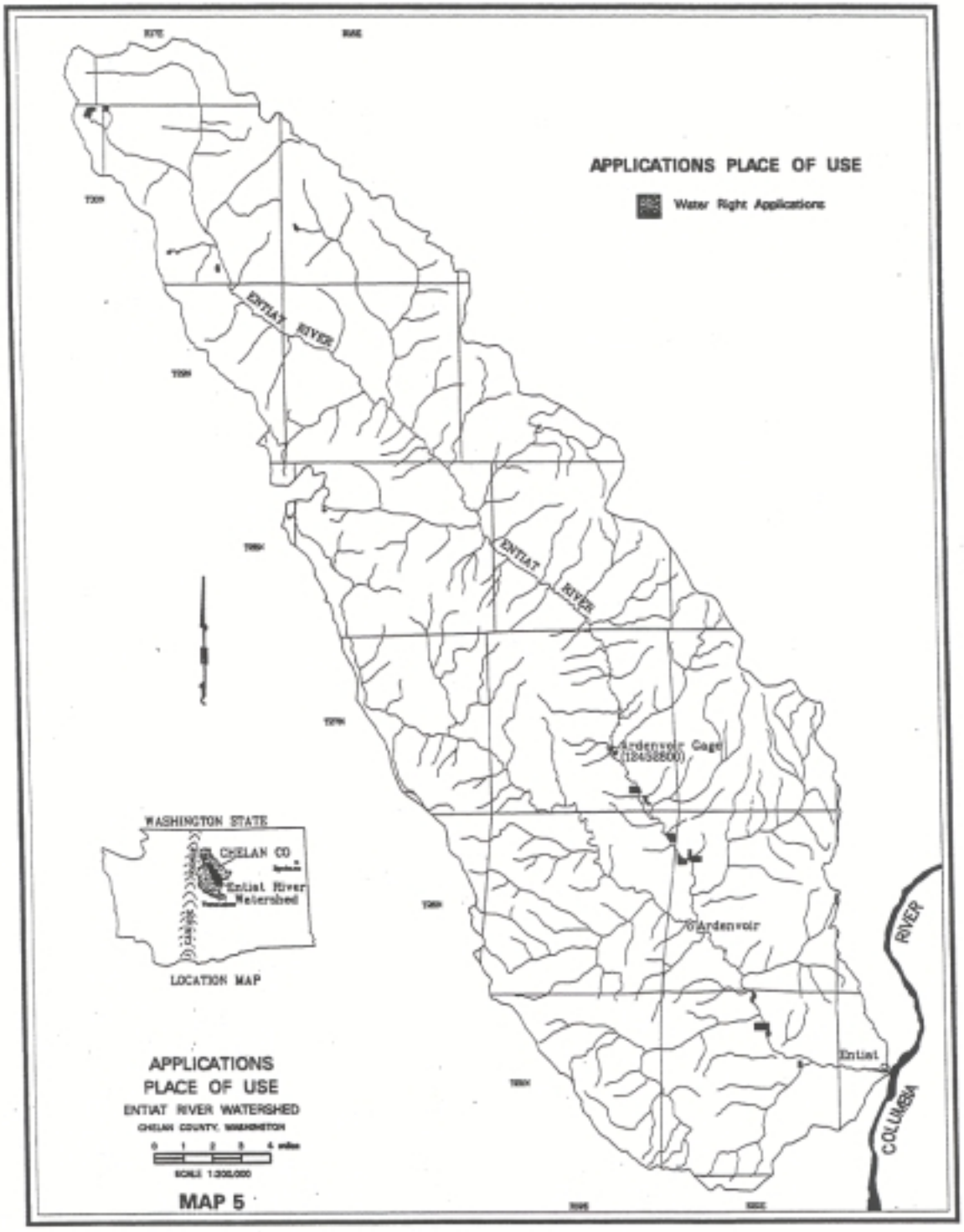

EXCEEDANCE CURVES
Entiat River Near Entiat
Flow Rate
In cubic feet/second
5,000
2,000
1,000
500
200
100
50
Jan. 1
Jan. 16
Jan. 31
Feb. 15
Mar. 2
Mar. 17
Apr. 1
Apr. 16
May 1
May 16
May 31
June 15
June 30
July 15
July 30
Aug. 14
Aug. 29
Sep. 13
Sep. 28
Oct. 13
Oct. 28
Nov. 12
Nov. 27
Dec. 12
Dec. 27
10% Exceedance
50% Exceedance
90% Exceedance
Recommended IFIM Flows
Period of Record, 1911 - 1925

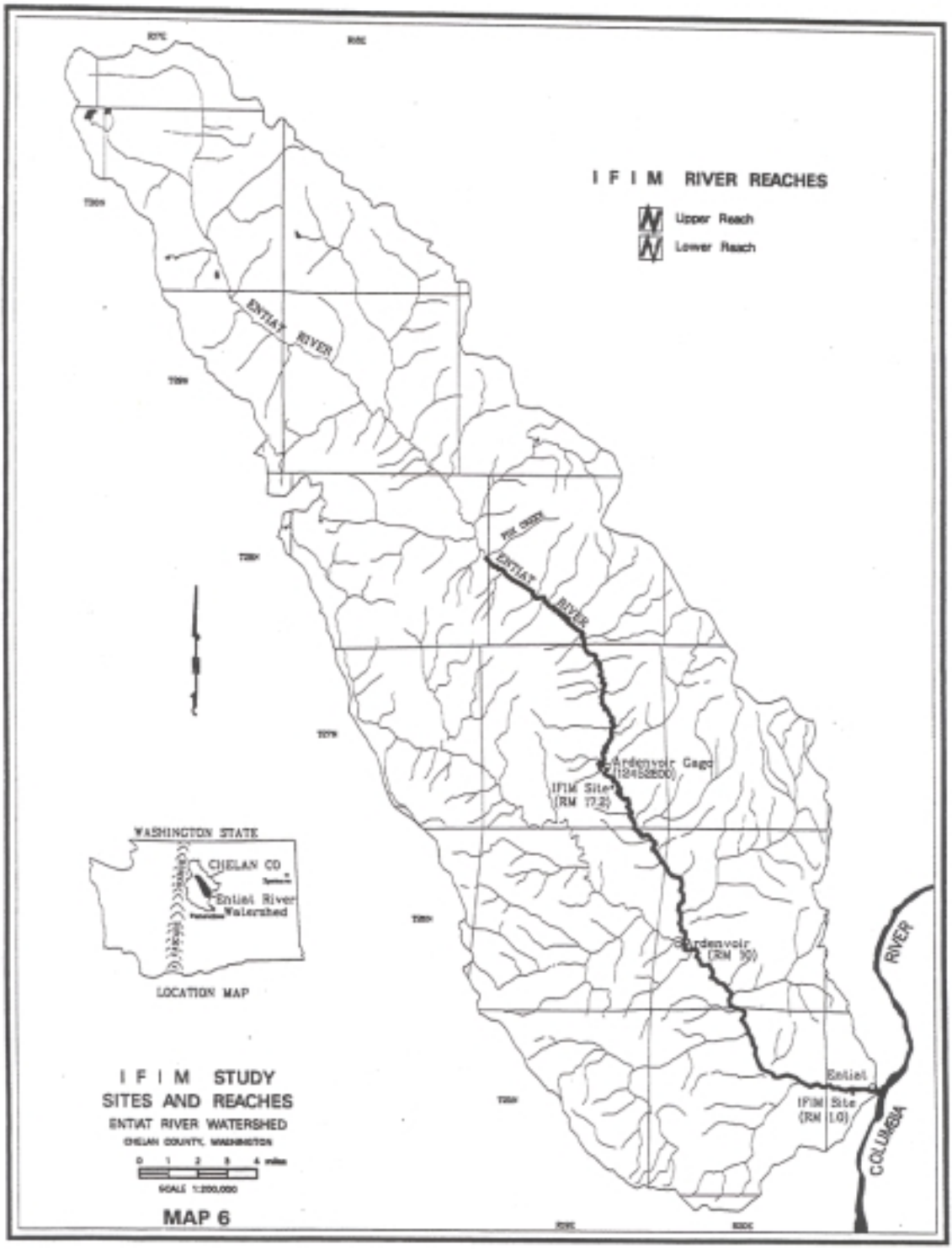

WEATHER STATIONS
Station
WASHINGTON STATE
CHELAN CO.
Entiat River Watershed
LOCATION MAP
CHELAN COUNTY
L. CHELAN
Chelan Mtns
Entiat Mtns
LAKE WENATCHEE
PLAIN
CHELAN
WENATCHEE R.
City of Wenatchee
STUDY AREA LOCATION
WITH WEATHER STATIONS
MAP 1


PRECIPITATION IN INCHES
5
10
15
20
25
30
35
40
45
50
60
70
80
90
100
WASHINGTON STATE
CHELAN CO.
Entiat River Watershed
LOCATION MAP
PRECIPITATION
ENTIAT RIVER WATERSHED
CHELAN COUNTY, WASHINGTON
0 1 2 3 4 miles
SCALE 1:200,000
MAP 2
Lake Entiat
Lake Wenatchee
Lake Chelan
Lake Roosevelt
Lake Pend Oreille
Lake Coeur d'Alene
Lake Pend Oreille
Lake Chelan
Lake Roosevelt
Lake Wenatchee
Lake Entiat
Entiat
Cardenvoir
RIVER
COLUMBIA


CLAIMS PLACE OF USE
Water Right Claims
ENTIAT RIVER
ENTIAT RIVER
Ardenvoir
WASHINGTON STATE
CHELAN CO.
Entiat River Watershed
LOCATION MAP
RIVER
COLUMBIA
CLAIMS
PLACE OF USE
ENTIAT RIVER WATERSHED
CHELAN COUNTY, WASHINGTON
0 1 2 3 4 miles
MAP 3


WATER RIGHTS PLACE OF USE
Permits and Certificates
ENTIAT RIVER
ENTIAT RIVER
Ardenvoir Gage
(12458800)
Ardenvoir
Entiat
COLUMBIA RIVER
WASHINGTON STATE
CHELAN CO.
Entiat River
Watershed
LOCATION MAP
WATER RIGHTS
PLACE OF USE
ENTIAT RIVER WATERSHED
CHELAN COUNTY, WASHINGTON
0 1 2 3 4 miles
SCALE 1:200,000
MAP 4


APPLICATIONS PLACE OF USE
Water Right Applications
ENTIAT RIVER
ENTIAT RIVER
Ardenvoir Gage
(12458000)
Ardenvoir
Entiat
COLUMBIA
RIVER
WASHINGTON STATE
CHELAN CO.
Entiat River
Watershed
LOCATION MAP
APPLICATIONS
PLACE OF USE
ENTIAT RIVER WATERSHED
CHELAN COUNTY, WASHINGTON
0 1 2 3 4 miles
SCALE 1:300,000
MAP 5


I F I M RIVER REACHES
Upper Reach
Lower Reach
ENTIAT RIVER
PIE CREEK
ENTIAT RIVER
Ardenvoir Gage
(12452800)
IFIM Site
(RM 17.2)
Ardenvoir
(RM 10)
Entiat
IFIM Site
(RM 1.0)
COLUMBIA RIVER
WASHINGTON STATE
CHELAN CO
Entiat River
Watershed
LOCATION MAP
I F I M STUDY
SITES AND REACHES
ENTIAT RIVER WATERSHED
CHELAN COUNTY, WASHINGTON
0 1 2 3 4 miles
SCALE 1:200,000
MAP 6