Natural Streamflow Estimates for Watersheds in the Lower Yakima River

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Executive Summary

Irrigation in the Yakima Valley has altered the regional hydrology through changes in streamflow and the spatial extent of groundwater. Natural topographic features such as draws, coulees and ravines are used as drains to discharge irrigation water (surface and groundwater) back to the Yakima River. Salmonids are documented in some of the drains raising the question of irrigation impacts on habitat as there is speculation that the drains were historic habitat. We assessed the volume and temporal variability of streamflow that would occur in six drains without the influence of irrigation. We used gage data from other streams that are not influenced by irrigation to estimate streamflow volume and timing, and we compared the results to two reference streams in the Yakima River Valley that have a small amount of perennial streamflow. We estimate that natural streamflow in the six study drains ranged from 33 to 390 acre·ft/year depending on the contributing area. Runoff occurred infrequently often spanning years between flow events, and was unpredictable. The geology of the study drains was highly permeable indicating that infiltration of what runoff occurs would be rapid. For fish to use intermittent streams, there must be local groundwater to maintain perennial pools and a reliable connection to other perennial water bodies. The study drains did not have local groundwater, perennial pools or a reliable surface flow connection to the Yakima River prior to irrigation. We therefore conclude that there was no salmonid habitat within the study drains prior to irrigation.

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Introduction

Irrigation can have a substantial effect on regional hydrologic processes including the alteration of streamflow volume and temporal patterns and changes in groundwater elevations. In the Yakima River Basin, groundwater elevations and spatial extent were increased with introduction of agricultural irrigation (Kinnison and Sceva 1963; Tom Ring as cited by Snyder and Stanford 2001). As a result, natural depressions such as draws, coulees, ravines, and gullies that intersected the elevated groundwater surface became drainage points for irrigated water. These natural features are the result of landscape scale geomorphic processes occurring over long time periods. In locations were natural depressions did not exist, drains were excavated to reduce the groundwater surface elevation (Kinnison and Sceva 1963). Thus, changes in groundwater resulting from irrigation contributed to flow in preexisting and newly excavated drainage networks (irrigation drains) that terminate in the Yakima River. For the purposes of this study, we will be considering irrigation drains that occur in natural drainage points only.

The occurrence of fishes (resident and anadromous) within the irrigation drains has been widely reported and the subject of some debate. One question that is asked regards the impacts of irrigation on fishes within the irrigation drains. One obvious potential impact is the change in discharge, and how this change has altered habitat availability and use within the drains. Unfortunately, there are no gage records of the irrigation drains prior to irrigation. Thus, there is speculation that the drains had historic value as fish habitat, particularly as it relates to salmonids of the genus *Oncorhynchus*.

The goal of this study is to assess the potential habitat value of drains prior to irrigation. Since the irrigation drains currently have perennial flow due to irrigation, we have to estimate what flow would be currently without irrigation. To do this, we answer the following questions:

1) What was the mean annual runoff resulting from precipitation and groundwater discharge (i.e. natural streamflow)?

2) What is the temporal variability in mean annual runoff?

3) How does the current perennial runoff volume compare to estimates of natural streamflow?

4) What is the influence of geology?

Methods

Eight drains were considered in this analysis: DR JT 2, Corral, Zintel, E.F. Amon, W.F. Amon, Snipes, Spring, and Amon (Figure 1). With the exception of Zintel drain which flows into the Columbia River, all drains flow into the Yakima River. Lmuma Creek and Selah Creek were added as reference streams for comparative purposes since both are Yakima River tributaries located in a region of similar precipitation, and that have no influence from irrigation. Lmuma Creek maintains a perennial flow near its mouth, while Selah Creek maintains perennial pools in reaches distant from the Yakima River with no perennial flow near its mouth.

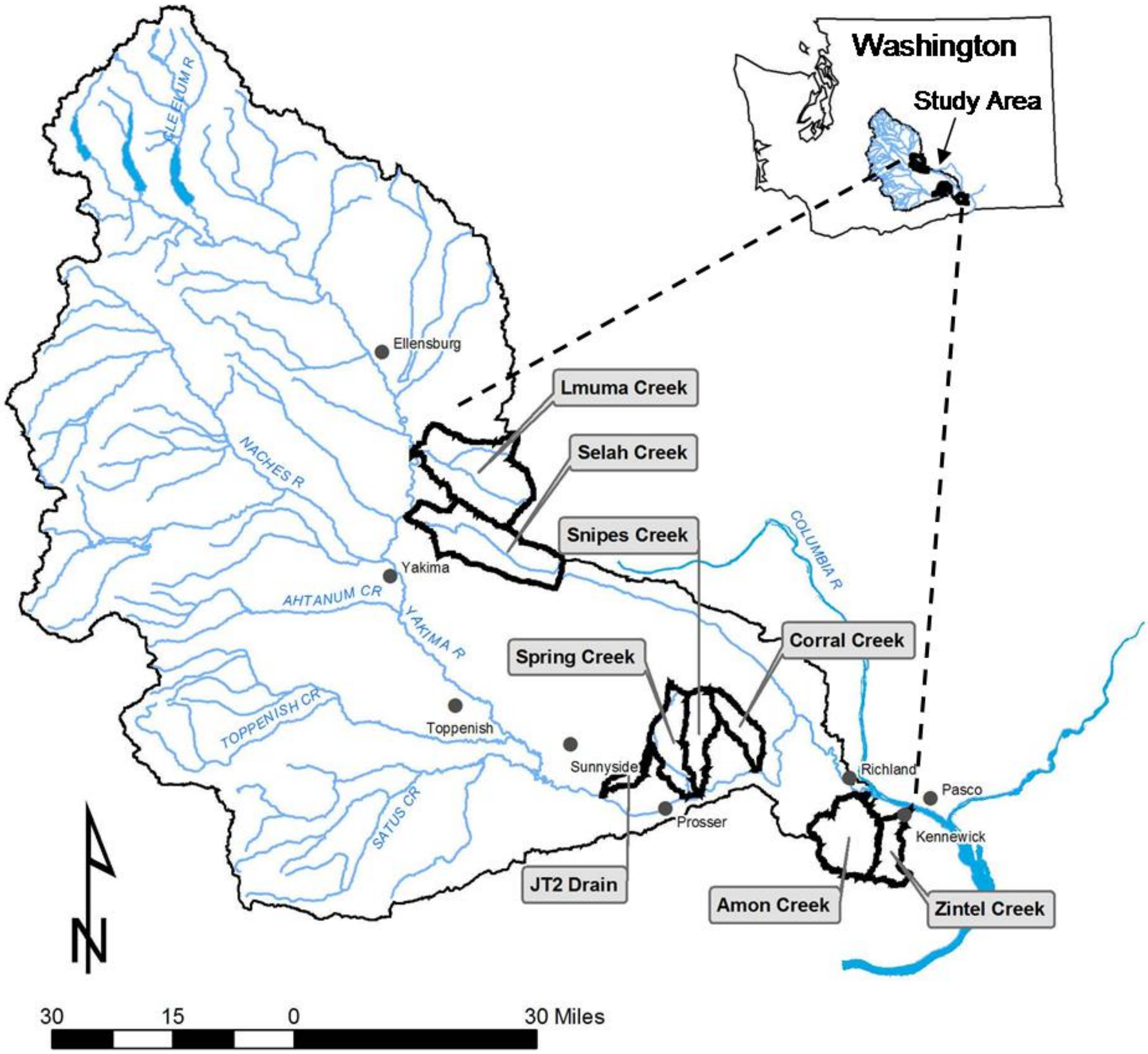

Figure 1. Location of the study drains (DR JT 2, Spring, Snipes, Corral, Amon, and Zintel) and reference streams (Selah and Lmuna)

Runoff Estimation

GIS layers were downloaded from multiple agencies listed in the Table 1. Watershed boundaries were refined for the selected drainages in the Yakima Basin by comparing the watershed boundaries to the topographic maps for the areas. Once the watersheds were finalized we calculated the area for each basin and created maps for the watersheds.

Table 1. Source of data used in the GIS.

Layer	Agency
Rivers and streams	Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP)
Topo	USGS via University of Washington
Roads	Washington State Department of Transportation
Major Towns	Washington State Department of Transportation
Watershed	Washington Department of Ecology

Mean annual runoff was estimated using Dinicola (1997), Nelson (1991), USACE (1993), and water yield approach based on three other gage sites located in eastern Washington (One gage on Esquatzel and two on Providence Coulee). Dinicola (1997) was a study of Cold and Dry Creeks located on the Hanford Site. A mass balance approach to simulating streamflow was developed using a computer model, and calibrated to 4.5 years of gage data from Cold and Dry Creeks. The calibrated model was then used to estimate runoff for the years 1958-1993. From these simulations, mean annual runoff per unit area for Dry and Cold Creek were estimated to be 6.90 and 6.64 acre · ft/mi^2. Mean annual runoff was estimated by simply by multiplying the run off estimate in acre · ft/mi^2 by the watershed area in square miles.

Nelson (1991) studied numerous gage sites located throughout the interior portions of Idaho, Washington and Oregon. Two regression equations were developed that related average annual precipitation to runoff in inches per year. For areas receiving less than 17.9 inches mean annual precipitations (which included all of the study drains) the regression equation was $RO = 0.107(P\text{-}6.03)$ where RO is mean annual runoff (inches), and P is the mean annual precipitation (inches). P was estimated from data from the nearest weather station. To convert inches of runoff to volume of runoff in acre feet inches is converted to feet by divided by 12, then multiplied by the watershed area in acres.

USACE (1991) studied the hydrology of Zintel Canyon located within the City of Kennewick in order to design and build a flood control dam. The design criteria used to estimate mean annual runoff from the Zintel Canyon watershed was stated as "probably less than 0.1 inch in depth for the drainage area per year". Therefore the estimate of 0.1 inch per year runoff was assumed to represent runoff volumes for all of the study streams. To convert inches of runoff to volume of runoff in acre feet inches is converted to feet by divided by 12, then multiplied by the watershed area in acres.

The final three estimates of runoff were obtained by looking at runoff characteristics for three other eastern Washington gages located in basins with similar precipitation patterns. Dinicola (1997) summarized data from these gages (water years 1958-1993) and reported the following mean annual runoff estimates of 4.2 acre · ft/mi^2, 5.0 acre · ft/mi^2 and 7.9 acre · ft/mi^2 for Esquatzel Coulee (gage 12513000), Providence Coulee (gage 12512500) and Providence Coulee (gage 12512550) respectively. These runoff estimates were multiplied by the watershed size to obtain an estimate of mean annual streamflow for each of the study drains.

Hydrologic variation was assessed by looking at runoff timing from gaged streams and coulees in eastern Washington and included Dry Creek and Cold Creek and Esquatzel and Providence Coulee. These four basins were used because they represent intermittent or ephemeral streams that are comparable to the study sites in terms of climate, topography and vegetation to the study drains minus the influence of irrigation.

In summary, seven different estimates of mean annual runoff were made based on watershed area and/or precipitation recorded at the nearest weather station for eight drains and two reference streams. The seven estimates were then averaged to provide an overall estimate of mean annual streamflow.

Geological and morphological considerations

Geological influences on streamflow were evaluated by examining published geology maps and calculating the percent of high and low permeability substrates in each of the watersheds. These calculations were done within a geographic information system, (GIS). In addition, maximum, minimum and average elevations, elevation bands, and channel gradient were calculated. Elevation was examined because it is correlated with increased precipitation and watersheds with greater elevations tend to have greater precipitation (Viessman and Lewis 1996). However, the area the study drains at high elevations was small so no elevation based adjustments for precipitation were made.

Results

Mean annual runoff

Maps for each of the study drains were made (Figure 2-Figure 6) and reference streams (Figure 7 and Figure 8). Watershed area ranged from 5.8 to 104.8 mi2. Watershed area, weather station, and precipitation data are summarized in Table 2. Mean annual runoff values are summarized in Table 3. Estimates of mean annual runoff varied from 33 to 390 acre · ft/year for the six drains. The two intermittent streams (Lmuma and Selah) had mean annual runoff estimates of 597 to 662 acre · ft/year. Estimates of runoff per unit area were relatively constant (Table 4).

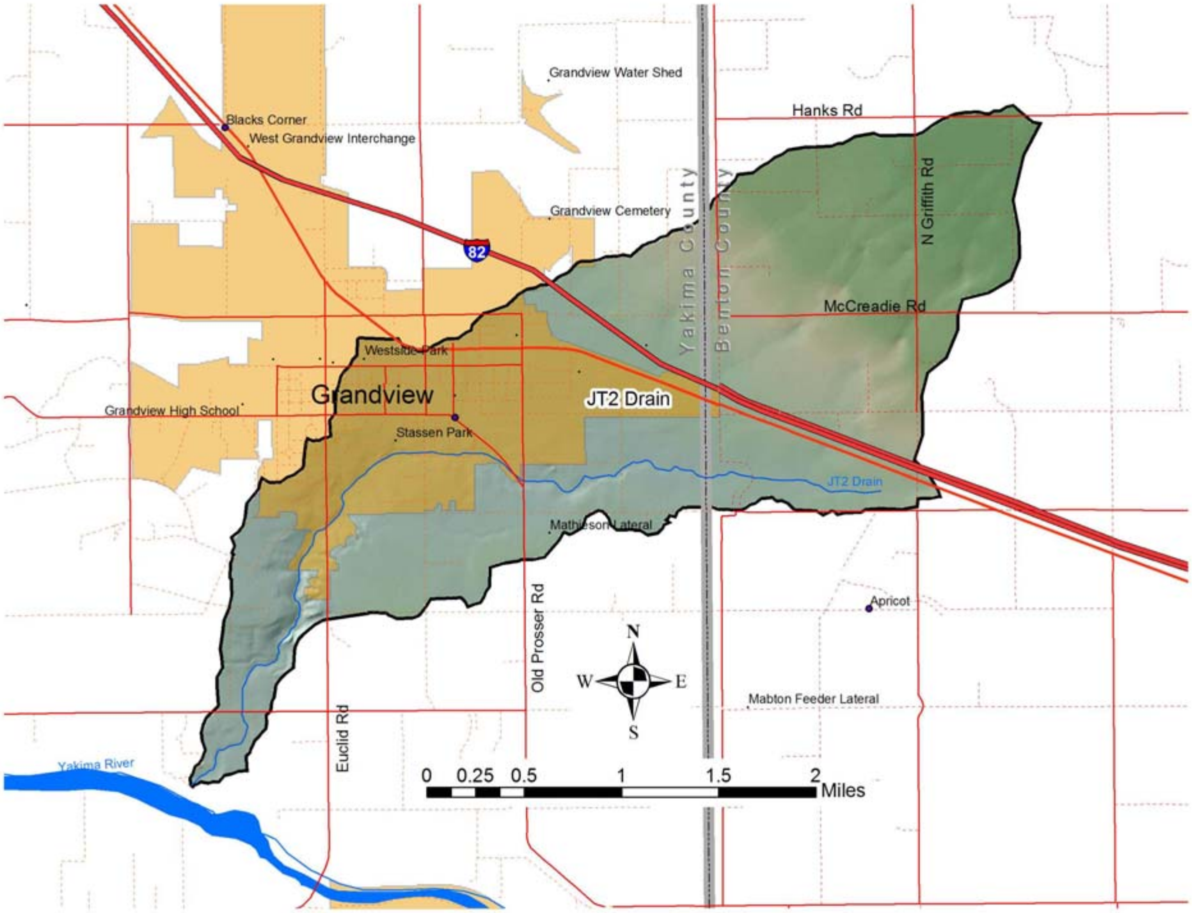

Figure 2. DR JT 2 Drain.

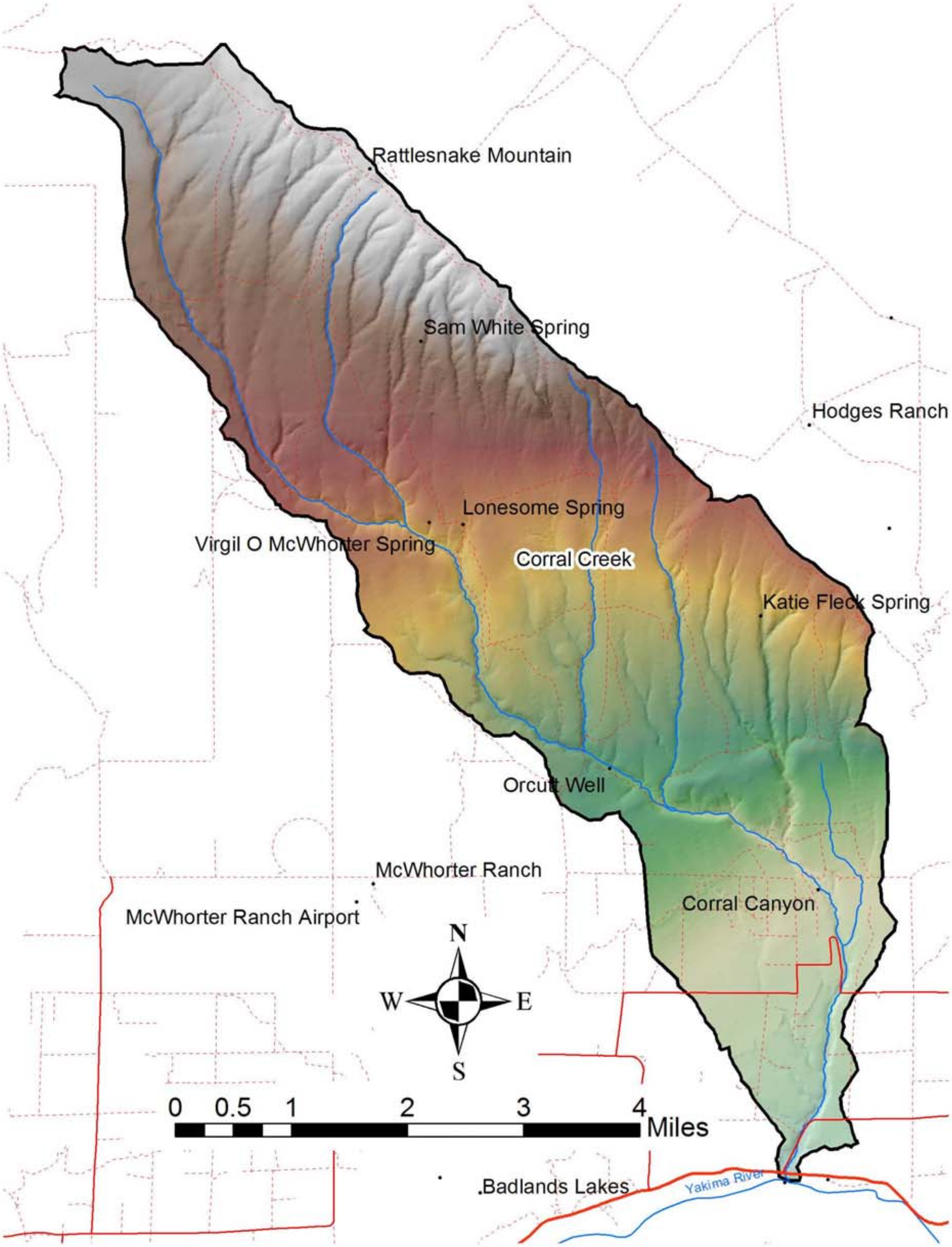

Figure 3. Corral Drain.

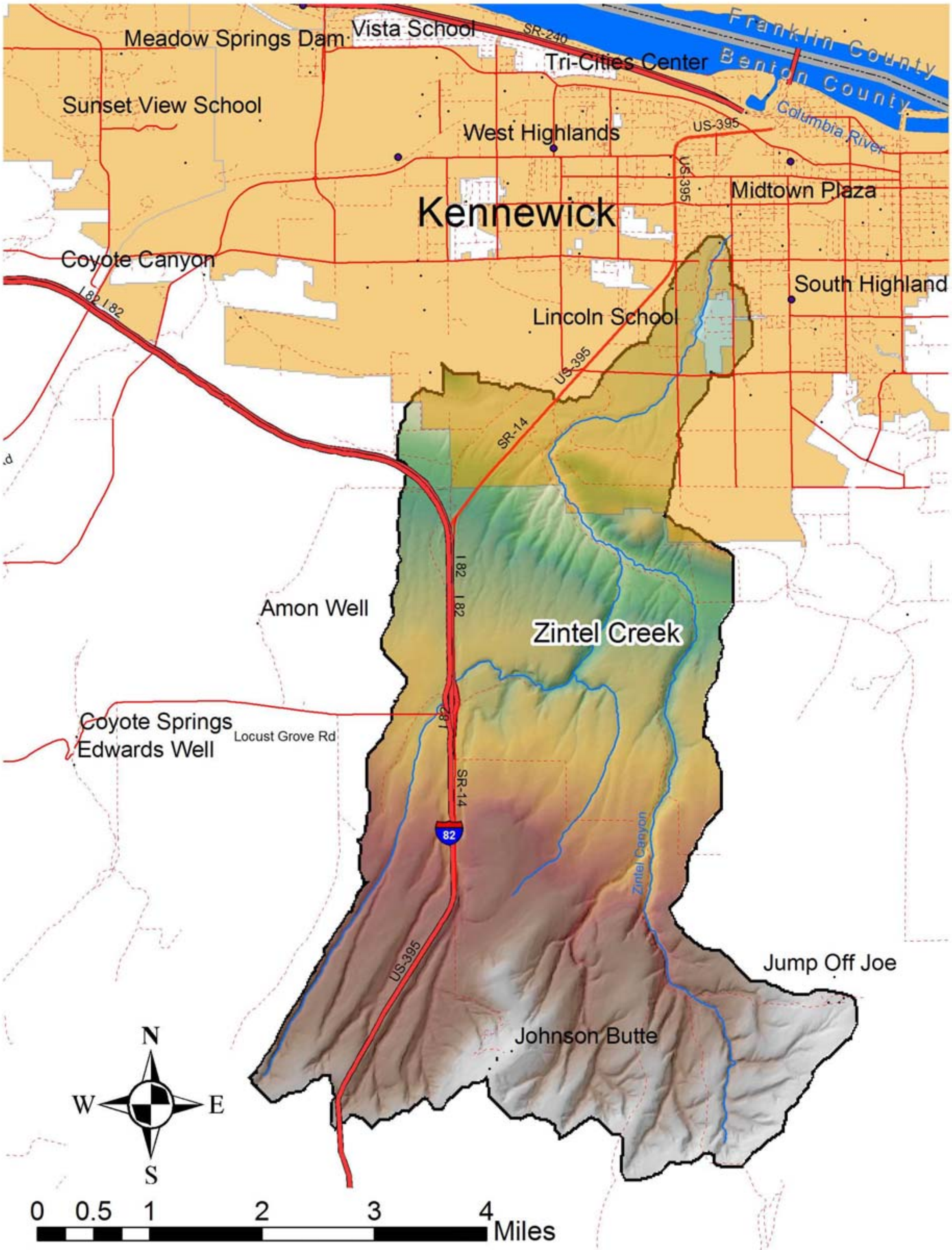

Figure 4. Zintel Drain.

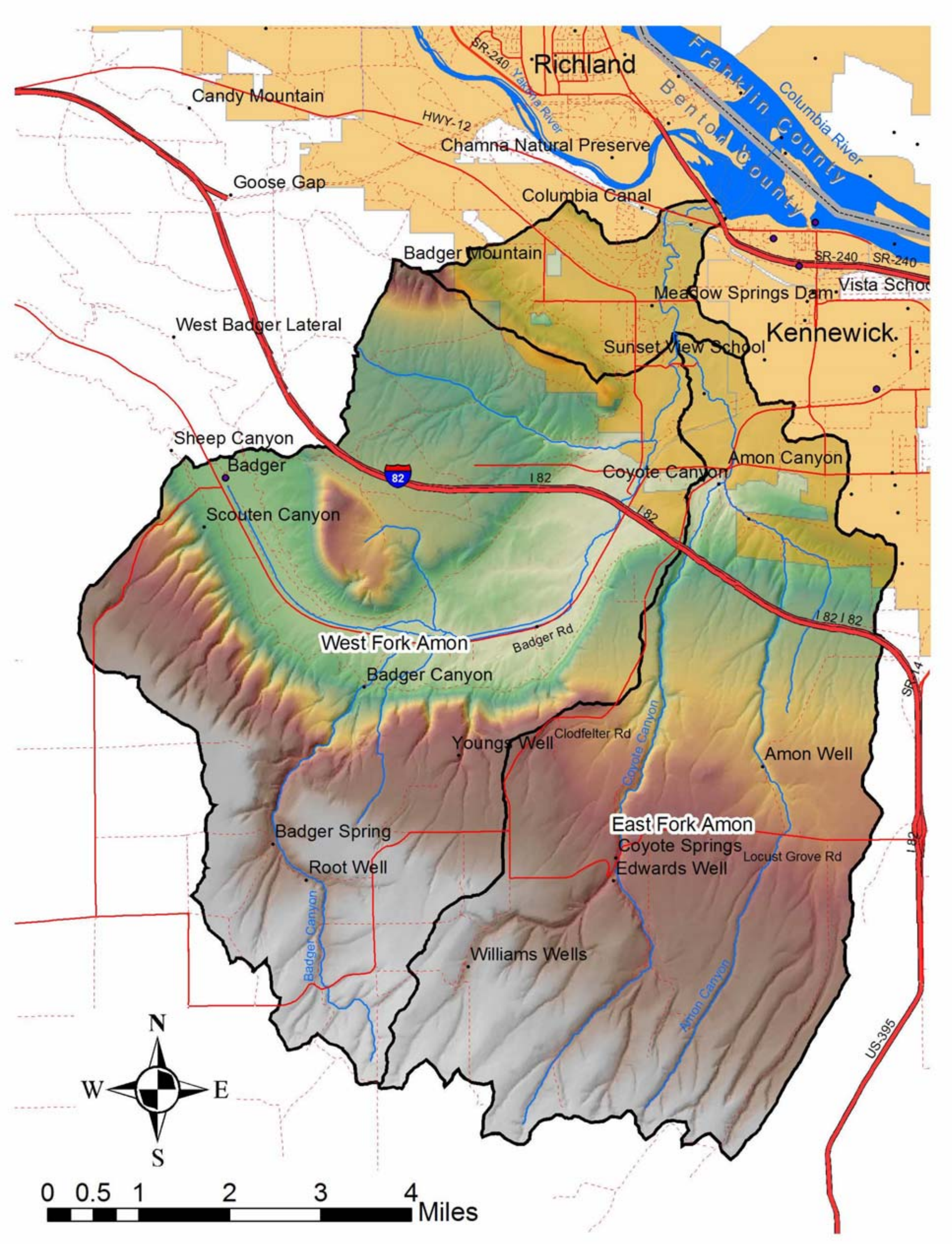

Figure 5. Amon Drain.

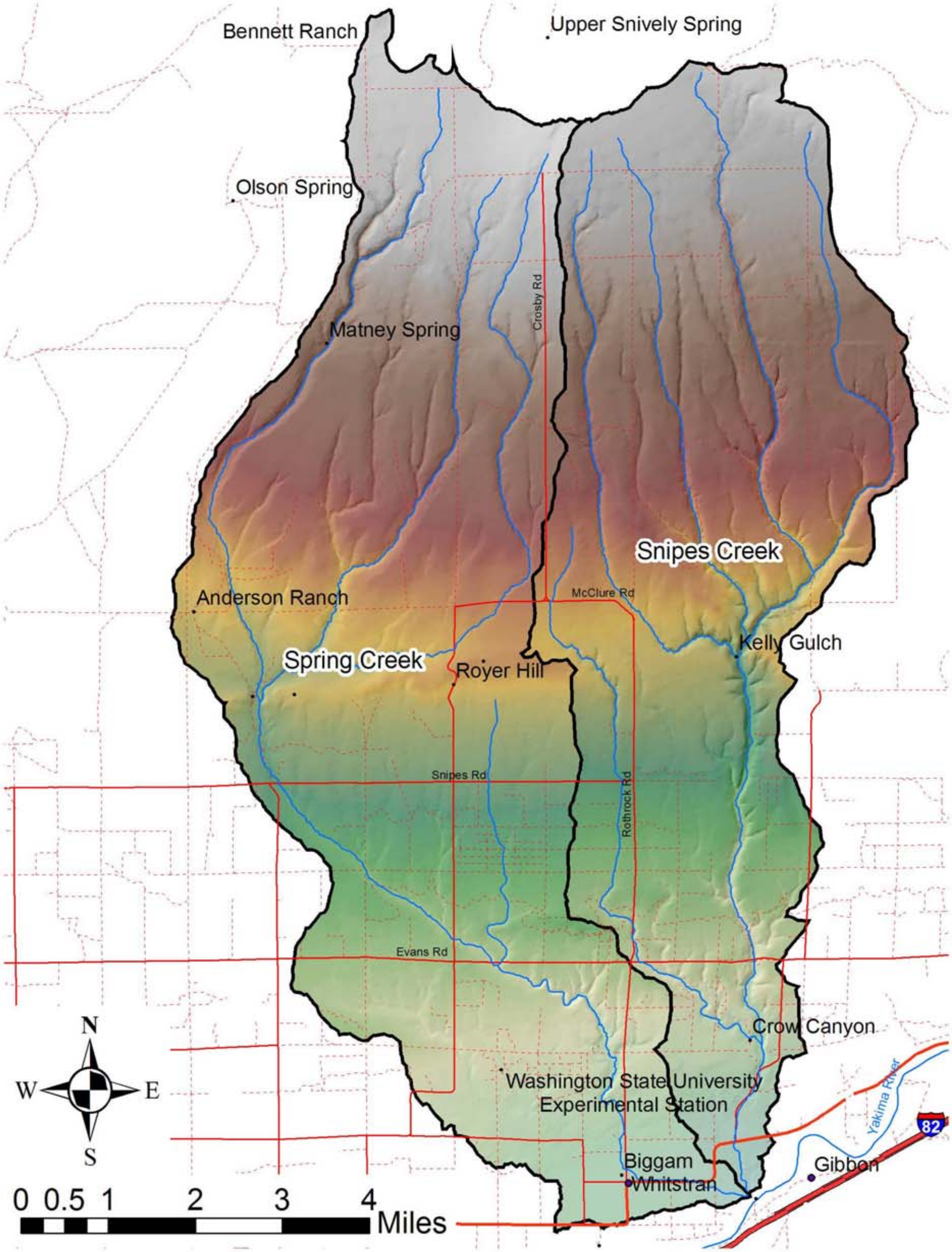

Figure 6. Spring and Snipes Drains.

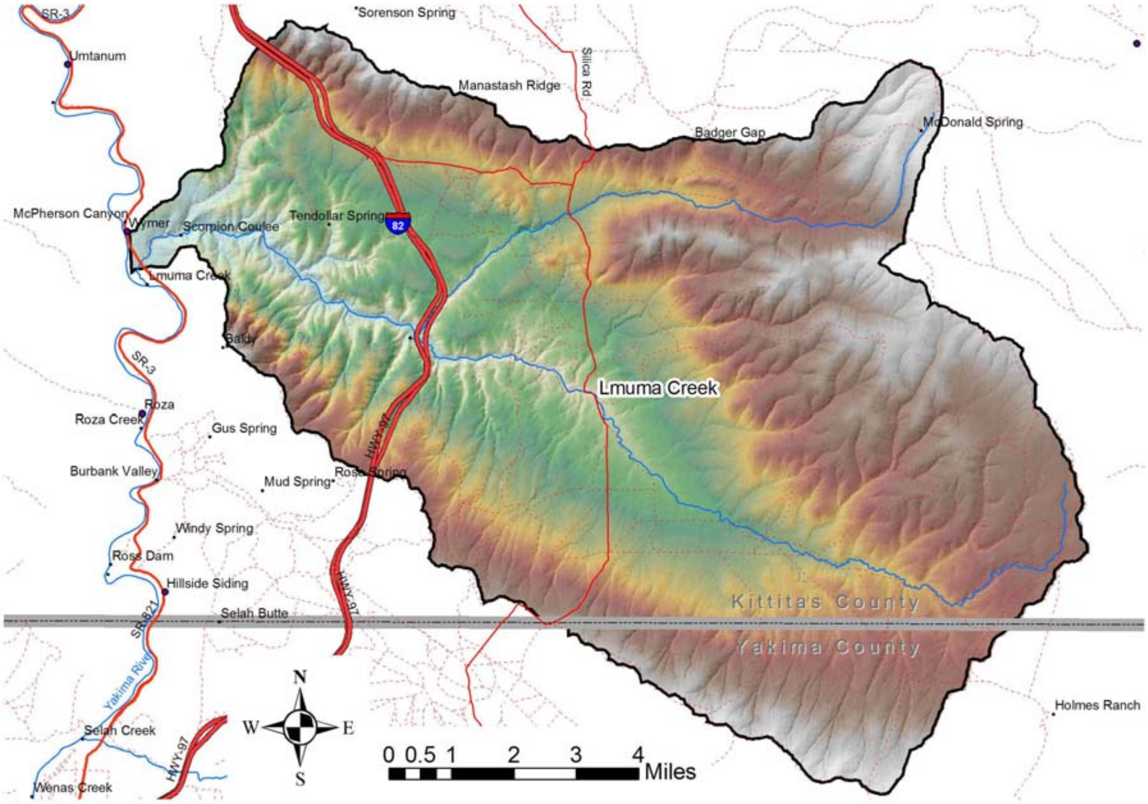

Figure 7. Lmuma Creek

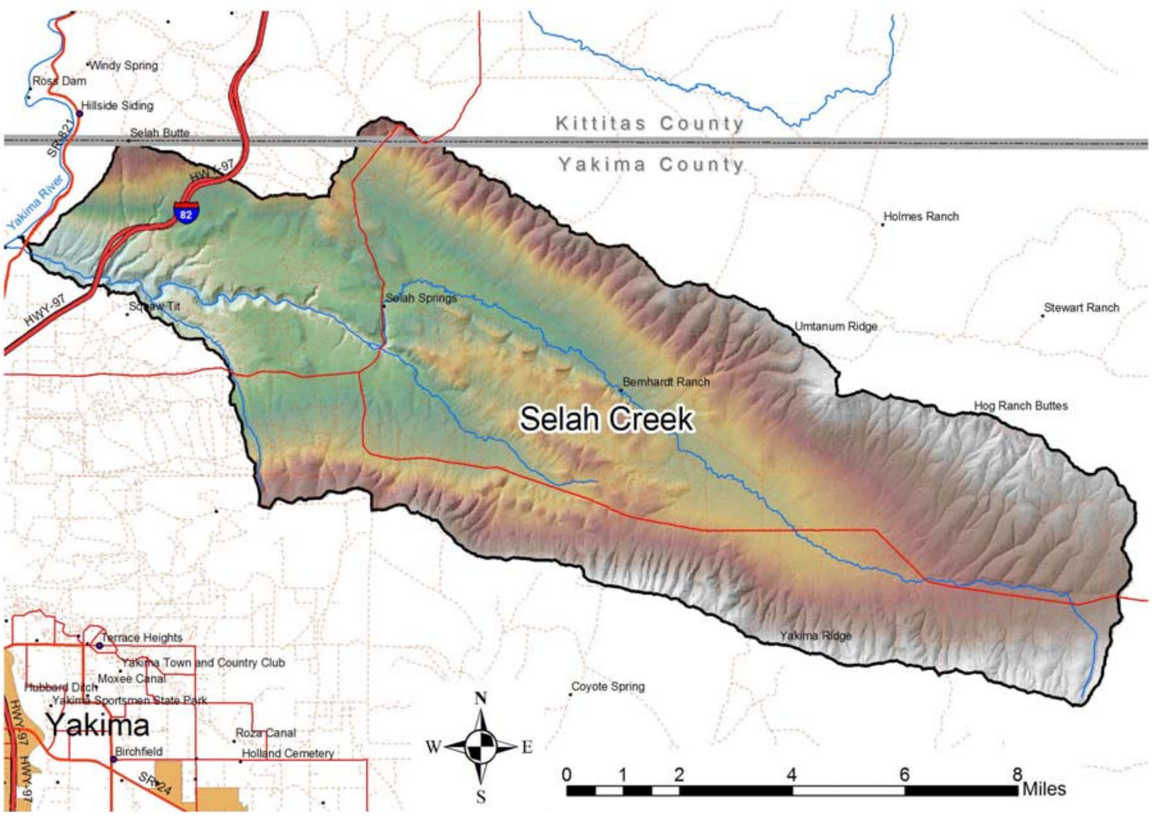

Figure 8. Selah Creek.

Table 2. Watershed Area and Precipitation Data.

Watershed	Drainage Area (mi²)	Drainage Area (acre)	Weather station	Precipitation (in)[1]	Period of record (years)
Dr Jt 2	5.84	3738	Sunnyside	6.91	1948-2004
Corral	25.33	16211	Richland	7.11	1948-2004
Zintel	26.52	16973	Kennewick	7.58	1948-2004
E. F. Amon	26.66	17062	Kennewick	7.58	1948-2004
W.F. Amon	31.8	20352	Kennewick	7.58	1948-2004
Snipes	34.69	22202	Prosser	7.87	1931-2004
Spring	42.96	27494	Prosser	7.87	1931-2004
Amon	62.24	39834	Kennewick	7.58	1948-2004
Selah	94.5	60480	Selah	7.63	1998-2004
Lmuma	104.8	67072	Selah	7.63	1998-2004

[1] Data from Western Regional Climate Center (www.wrcc.dri.edu)

Table 3. Mean Annual Runoff Estimates.

Watershed	Method: Dincola 1997 Cold Creek (acre-ft/yr)	Dincola 1997 Dry Creek (acre-ft/yr)	Nelson 1991 (acre-ft/yr)	USACE 1993 (acre-ft/yr)	Esquatzel (acre-ft/yr)	Providence (acre-ft/yr)	Providence (acre-ft/yr)	Mean (acre-ft/yr)
Dr Jt 2	41	39	29	31	25	29	41	33
Corral	176	167	156	135	106	127	177	149
Zintel	184	175	234	141	111	133	186	166
E. F. Amon	185	176	236	142	112	134	187	168
W.F. Amon	221	210	281	170	134	159	223	200
Snipes	241	229	364	185	146	174	243	226
Spring	298	284	452	229	181	215	301	280
Amon	432	411	550	332	261	311	435	390
Selah	656	624	863	504	397	473	662	597
Lmuma	727	692	957	559	440	524	734	662

Table 4. Runoff per Unit Square Mile.

Watershed	Method						
	Dincola 1997		Nelson 1991	USACE 1993	Esquatzel	Providence	Providence
	Cold Creek (acre-ft/mi^2)	Dry Creek (acre-ft/mi^2)	(acre-ft/mi^2)	(acre-ft/mi^2)	(acre-ft/mi^2)	(acre-ft/mi^2)	(acre-ft/mi^2)
Dr Jt 2	6.94	6.60	5.02	5.33	4.20	5.00	7.00
Corral	6.93	6.59	6.16	5.33	4.20	4.99	6.99
Zintel	6.93	6.60	8.84	5.33	4.20	5.00	6.99
E. F. Amon	6.95	6.61	8.86	5.34	4.21	5.01	7.01
W.F. Amon	6.94	6.60	8.85	5.33	4.20	5.00	7.00
Snipes	6.94	6.60	10.50	5.33	4.20	5.00	7.00
Spring	6.95	6.61	10.51	5.34	4.20	5.00	7.01
Amon	6.94	6.60	8.84	5.33	4.20	5.00	7.00
Selah	6.94	6.60	9.13	5.33	4.20	5.00	7.00
Lmuma	6.94	6.60	9.13	5.33	4.20	5.00	7.00

In order to better visualize the amount of streamflow that the estimate of mean annual streamflow represented, we calculated the discharge in cfs and gpm. Estimates of mean annual streamflow for the study streams range between 0.05 and 0.54 cfs, or 21-242 gpm. The two reference streams, Lmuma and Selah Creeks, are 0.82 to 0.91 cfs (Table 5). For Lmuma Creek, the estimate of 0.91 cfs is similar to observed streamflow found therein (Pat Monk personal communication).

Table 5. Discharge Estimates based on Mean Annual Runoff.

Watershed	Runoff (acre-ft/yr)	Runoff (acre-ft/day)	Discharge (cfs)	Discharge (gpm)
Dr Jt 2	33	0.09	0.05	21
Corral	149	0.41	0.21	92
Zintel	166	0.46	0.23	103
E. F. Amon	168	0.46	0.23	104
W.F. Amon	200	0.55	0.28	124
Snipes	226	0.62	0.31	140
Spring	280	0.77	0.39	174
Amon	390	1.07	0.54	242
Selah	597	1.63	0.82	370
Lmuma	662	1.81	0.91	410

Estimates of mean annual runoff and discharge are similar to those obtained by Mastin and Vaccaro (2002) which were based in part on Nelson's (1991) analysis of mean annual discharge in the Columbia River Plateau region. For the region where the study drains are located, Mastin and Vaccaro (2002) report mean annual discharge of less than 2 cfs.

Mean annual runoff estimates provide no information about the temporal variation of the hydrograph. Even though there is a certain level of discharge predicted on average, examination of the hydrographs from Dry, Cold Esquatzel Coulee and Providence Coulee indicate that flow is infrequent, and unpredictable with long periods of zero discharge (Figure 9). In general, ephemeral drainage networks of eastern Washington are described as having flow during localized thunderstorms and snowmelt over frozen ground. If flow occurs, it is almost always between December and March (Nelson 1991; Dinicola 1997). Since Cold, Dry, Esquatzel Coulee and Providence Coulee represent gaged analogues for the study streams, the temporal distribution of streamflow of these streams is likely comparable to the study drains.

Current runoff data were available for two of the study streams, Amon and Spring Creek Drain. Gage data for Amon spans 3/1/86 to 4/11/87 (# USGS 12512150 Amon Wasteway near Richland, WA). One year of streamflow for Amon resulted in 23,012 acre · ft. On Spring Creek Drain, one year of streamflow was estimated to be approximately 22,944 acre · ft (Sunnyside Valley Irrigation District unpublished data). Contrast these estimates with the natural streamflow estimates for Amon and Spring Creek Drains of 390 and 280 acre · ft/yr (Table 3) and it becomes clear that natural streamflow contributes a very small portion (~1%) of the overall streamflow present on average. It is expected that similar findings would apply to the other study streams.

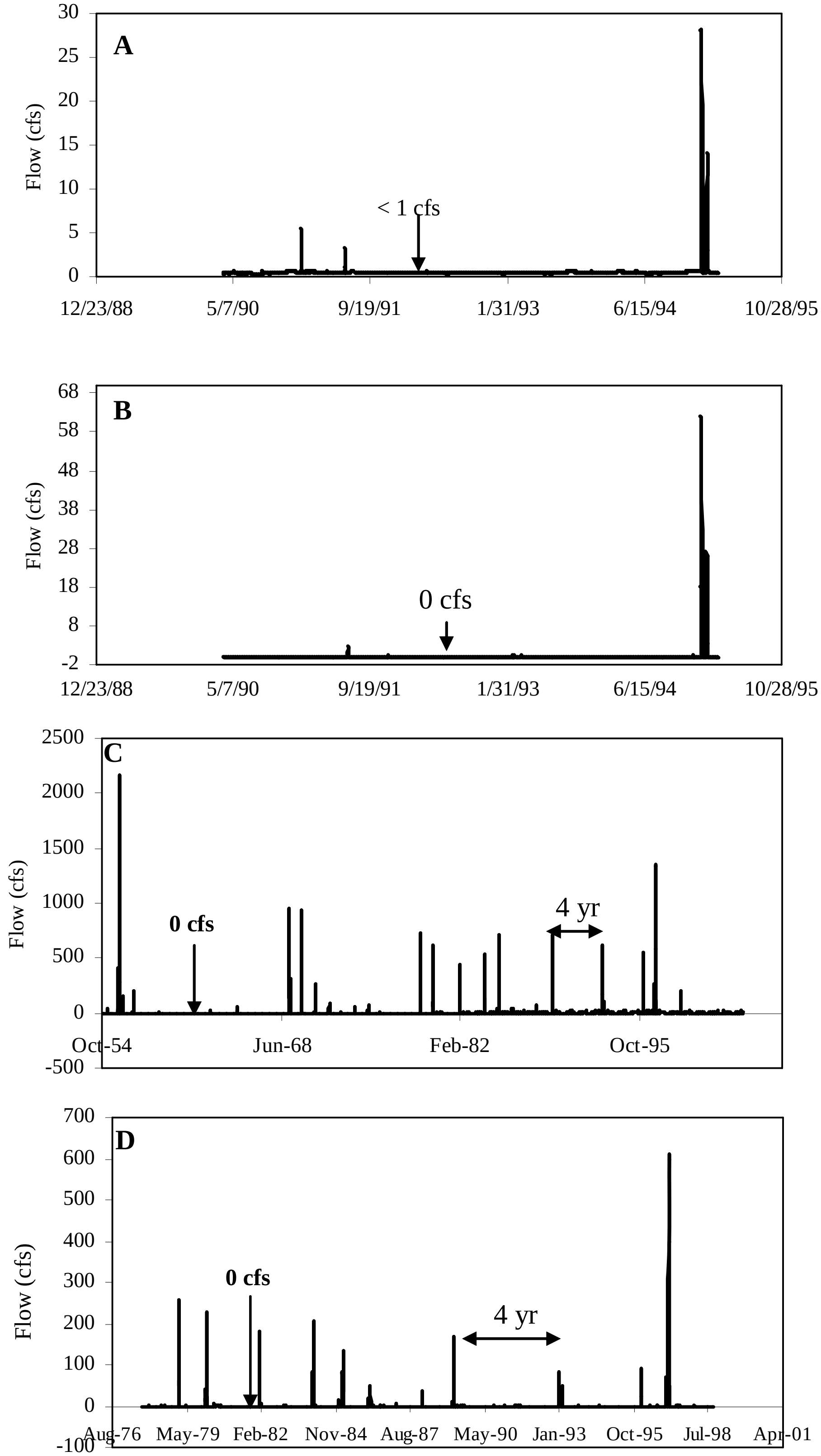

Figure 9. Gage data for Dry (A), Cold (B), Esquatzel (C), and Providence Creeks or Coulee (D).

Geological and morphological considerations

The study drains have an average elevation ranging from 846 to 1906 feet above MSL (mean sea level) with DR JT 2 having the lowest average elevation and Corral having the highest (Table 6). Maximum elevations ranged from 1020 to 3576 feet above MSL with DR JT 2 having the lowest and Corral having the highest. Minimum elevations ranged from 338 to 646 feet above MSL reflecting the location at which each drain entered the Yakima River. The average stream gradient was 2.25 to 13.3 percent for DR JT 2 drain and Corral respectively. Compared to the study drains, the reference streams (Selah and Lmuma Creeks) have greater elevations and with the exception of DR JT 2 Drain, have similar gradients (Figure 10**).** Higher elevations tend to receive greater precipitation amounts thus Lmuma and Selah Creeks may receive greater precipitation on average across their respective watersheds than the study drains.

Table 6. Elevation Data

Elevation Band		Basin									
				Amon							
(feet)	(meters)	Zintel	Amon (total)	EF	WF	Corral	Snipes	Spring	JT2 Drain	Selah	Lmuma
<492	<150		2%								
492-738	150-225	10%	23%	12%	28%	3%	2%	5%	4%		
738-984	225-300	16%	20%	14%	26%	9%	6%	13%	96%		
984-1230	300-375	27%	14%	21%	10%	7%	14%	16%			
1230-1476	375-450	17%	15%	21%	11%	11%	9%	13%		1%	1%
1476-1722	450-525	19%	15%	20%	12%	12%	11%	14%		2%	2%
1722-1969	525-600	11%	12%	12%	13%	14%	11%	10%		3%	9%
1969-2214	600-675	2%				9%	12%	9%		20%	26%
2214-2461	675-750					8%	11%	7%		24%	26%
2461-2706	750-825					7%	11%	7%		17%	21%
2706-2953	825-900					7%	11%	7%		13%	12%
2953-3199	900-975					7%	1%			10%	3%
3199-3445	975-1050					4%				5%	1%
3445-3691	1050-1125					1%				3%	
3691-3937	1125-1200									1%	
3937-4193	1200-1275										
Maximum Elevation (feet)		2198	1942			3576	3084	3140	1020	4216	3747
Minimum Elevation (feet)		443	338			482	568	568	646	1161	1296
Average Elevation (feet)		1247	1122			1906	1864	1614	846	2543	2356
Average Watershed Slope (%)		13	11.2			13.3	9	6.78	2.25	15.1	13.2

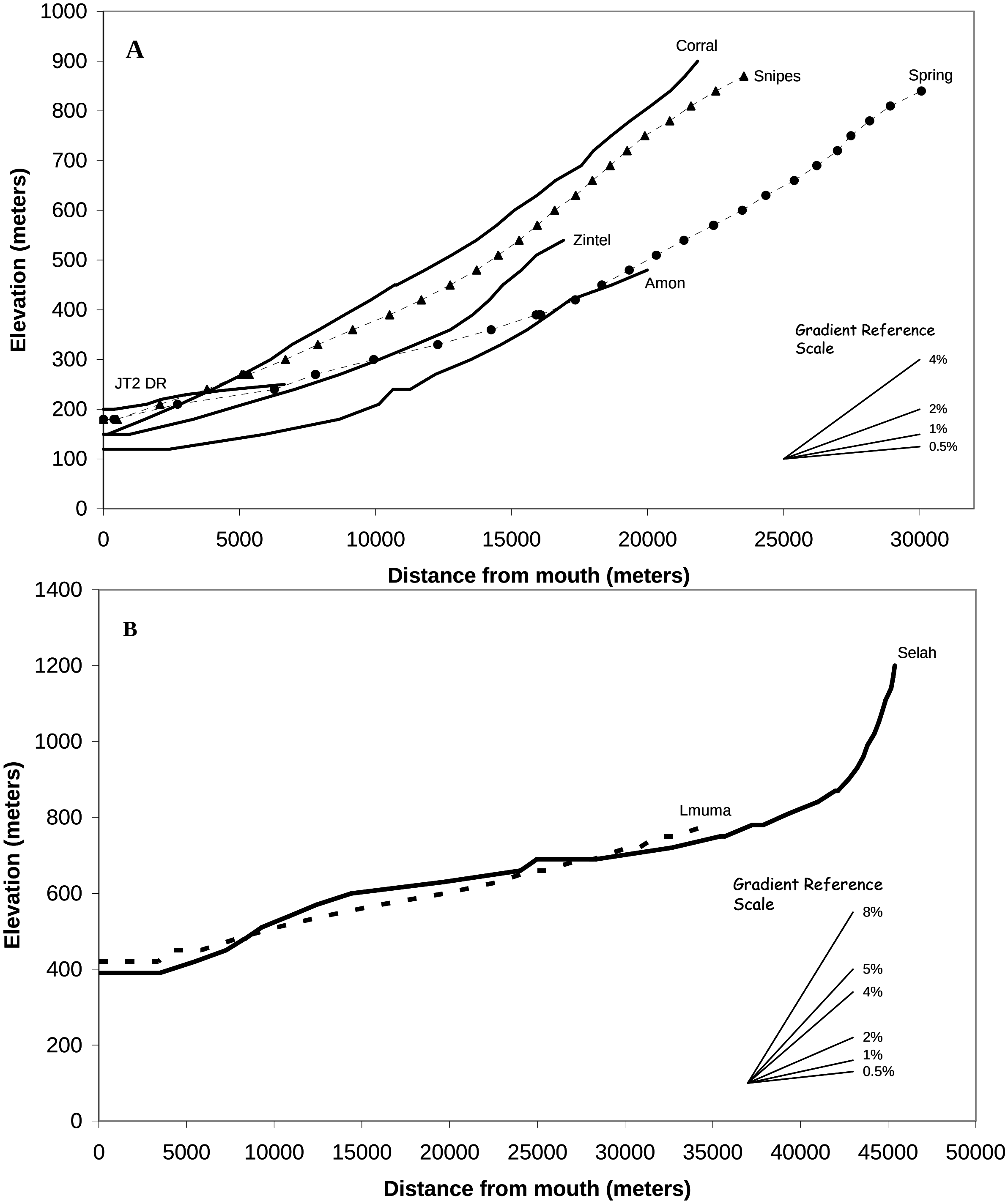

Figure 10. Gradients of the Study Drains (A) and Reference Streams (B)

Watershed substrates varied between the study drains and the reference streams. The study drains in general had higher percentages of highly permeable substrates than the reference streams (Table 7). In addition, the study drains flow into the Yakima River in locations characterized by highly permeable substrates (Figure 11). Regarding the reference streams, Lmuma and Selah Creek have a larger proportion of the watershed characterized by low permeability basalts which may minimize infiltration of runoff and contribute to surface flows. A primary difference between Lmuma and Selah Creeks is that Selah Creek flows into highly permeable substrates near its confluence with the Yakima River and subsequently does not maintain perennial surface flow all the way to the Yakima River. In this respect, Selah Creek is similar to the study drains. Conversely, Lmuma Creek flows over low permeability substrates all the way to its confluence with the Yakima River and maintains a perennial flow (Figure 12). None of the study drains have the extent of low permeability substrates near the confluence with the Yakima River.

Table 7. Geology Data

	High Permeability				Low Permeability	
Watershed	*alluvium*	*outburst flood deposits*	*mass wasting deposits*	*loess*	*sedimentary rock*	*basalt*
Zintel Creek	5%	31%	0%	55%	0%	9%
Amon Creek	2%	41%	1%	46%	0%	10%
East Fork Amon	3%	24%	0%	67%	0%	6%
West Fork Amon	1%	50%	2%	33%	0%	15%
Corral Creek	1%	13%	0%	57%	1%	29%
Snipes Creek	1%	7%	0%	72%	0%	20%
Spring Creek	2%	18%	0%	67%	0%	13%
JT2 Drain	0%	98%	0%	1%	0%	1%
Selah Creek	22%	0%	4%	8%	8%	59%
Lmuma Creek	4%	0%	1%	4%	1%	91%

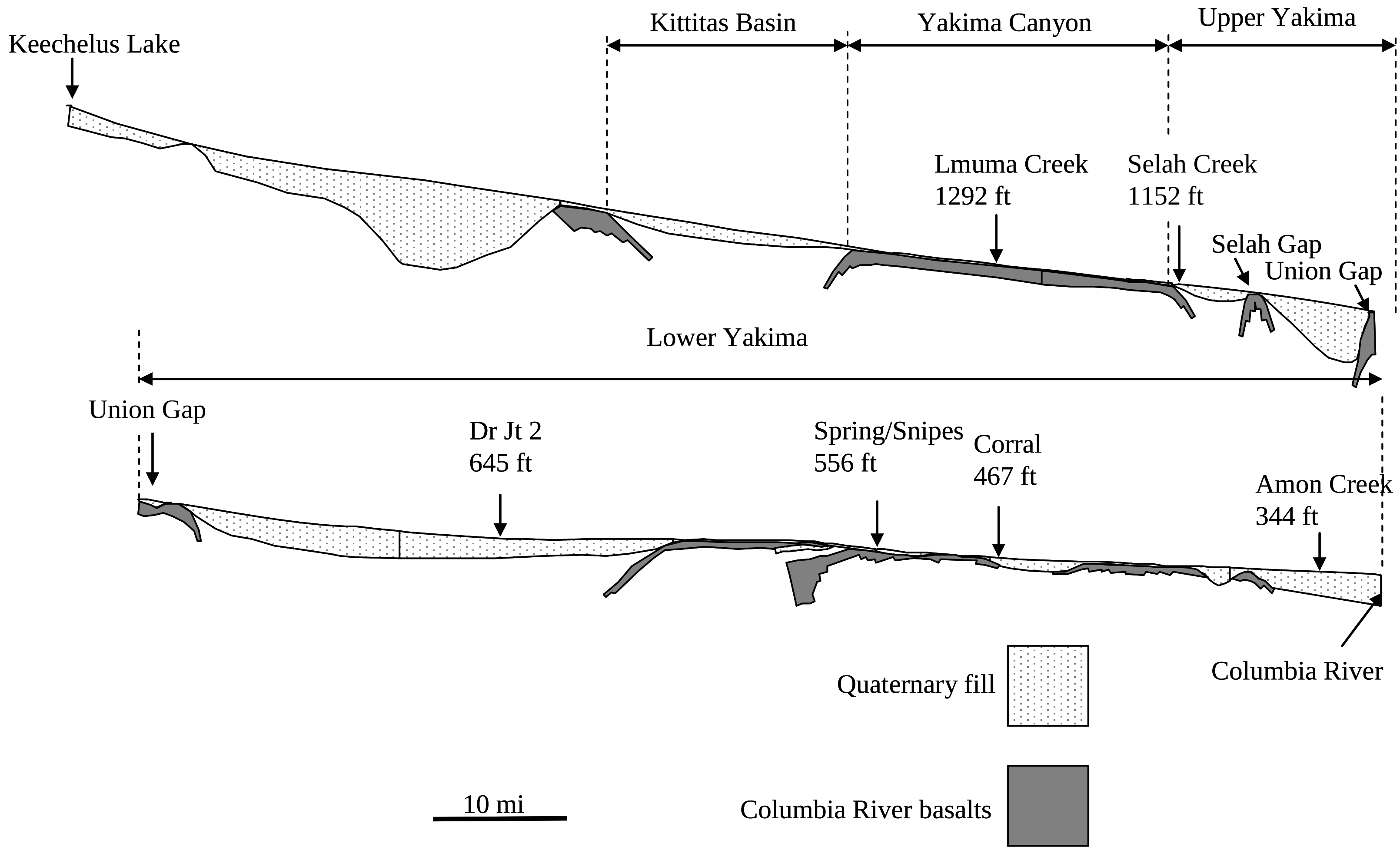

Figure 11. Geological Cross-Section of the Yakima River Showing the Study Drains and Reference Stream Locations

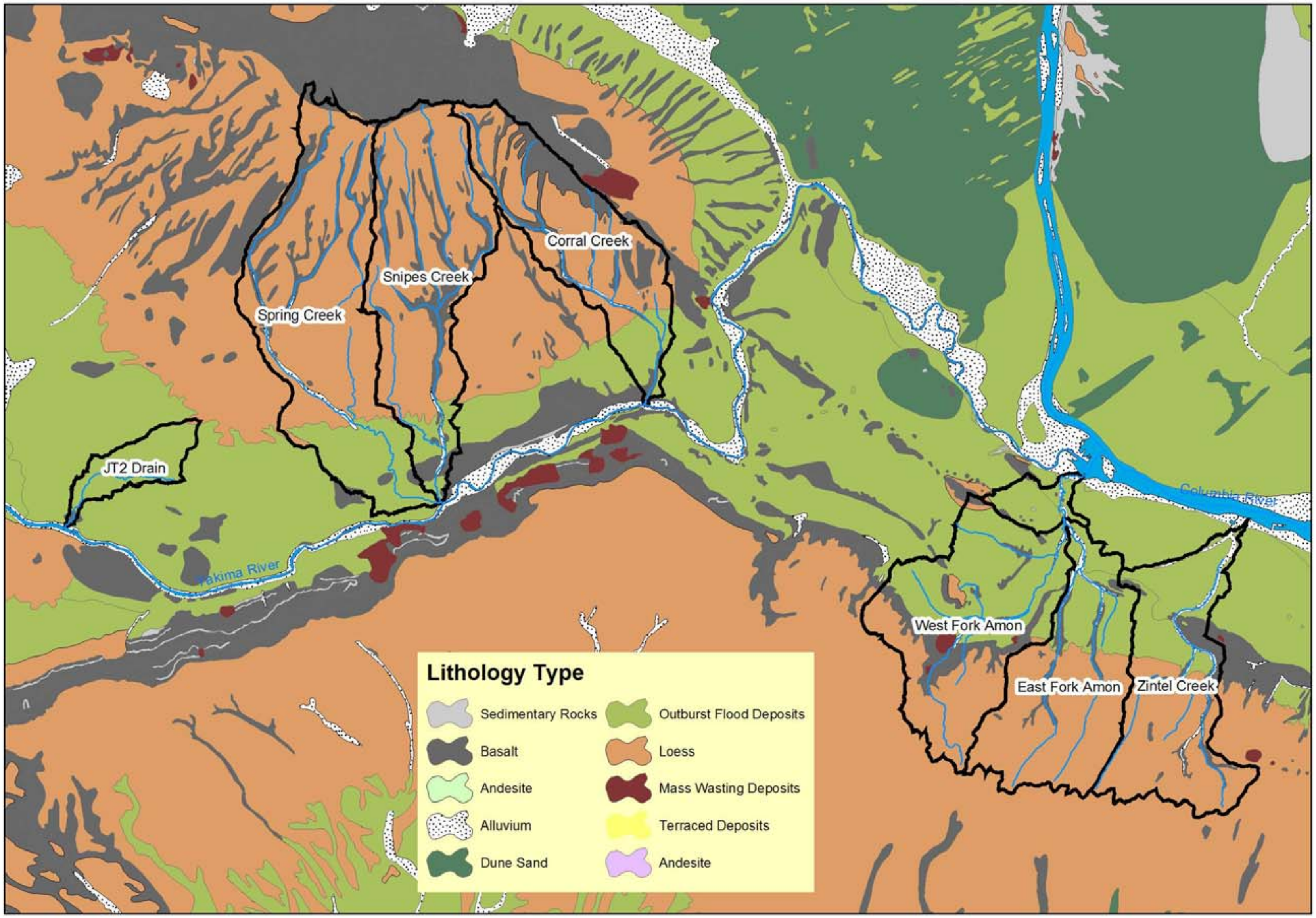

Figure 12. Geology of the Study Drains

Potential for aquatic habitat resulting from natural streamflow

We can infer that natural streamflow within the study drains consisted of low runoff volumes occurring infrequently and unpredictably and with no base flow (i.e groundwater input) within watersheds consisting in large part of high permeable substrates. What aquatic habitat would have this provided?

Evaluation of the habitat resulting from natural streamflow in the study drains can be made by comparison to habitat found in intermittent streams, and then evaluating if any of the study drains might share some of the same characteristics. In general, the use of intermittent streams by fish has not been studied as extensively as perennial streams (Schlosser, 1982; Bain *et al.*, 1988; Poff and Ward, 1989). What is known is that pools are critical to the persistence of fish in intermittent streams, and pools are maintained by local groundwater (Meffe and Minckley 1987; Chapman and Kramer 1991; Lohr and Fausch 1997). Perennial pools need to be connected predictably with other perennial pools and downstream water bodies in order for fish to persist in intermittent streams (Labbe and Fausch 2000).

Selah and Lmuma Creeks were added to the analysis because they represented tributaries to the Yakima River that were not influenced by irrigation, and that were located in a portion of the Yakima watershed that receive similar precipitation amounts as the study drains. Both drain larger areas than the study drains (Table 2), but have different streamflow characteristics that relate to the presence of fish. Selah Creek does not maintain a perennial connection to the Yakima River but does have reaches with perennial pools and streamflow. Lmuma Creek is perennial for the last six miles of its length (TCWRA 2000). Selah Creek does not have a documented fish population but Lmuma Creek has a population of longnose dace, rainbow trout and mountain sucker (YTC 2002).

What factors contribute to these differences and what were the implications of these differences to the study drains? We believe that the differences are related to the combined effects of watershed size and geology and the frequency and stability of a streamflow connection to the Yakima River.

Watershed size influenced the volume of natural streamflow (Figure 13A). Natural streamflow was not influenced by runoff per unit area (Figure 13B) or precipitation (Figure 13C). This means that larger watershed produce greater estimates of natural streamflow, and that runoff per unit area is equal across the study drains and reference streams, and that precipitation is equal across study drains and reference streams. Lmuma Creek has the largest watershed size, and Lmuma Creek is the only stream with a perennial flow and reliably connection to the Yakima River. Selah Creek has the second largest watershed and maintains perennial pools but not a perennial connection to the Yakima River.

Geology plays an important role in the hydrology of Lmuna Creek. Lmuma Creek flows into the Yakima River in the Yakima River Canyon between Ellensburg and Yakima (Figure 14). The canyon reaches represent lava flows that were deformed into anticlinal ridges whereas the valleys between the anticlinal ridges contain large deposits of highly permeable substrates (Kinnison and Sceva 1963). In addition, 91% of the substrates within the Lmuna Creek watershed are classified as low permeability basalts (Table 7). Thus, in the lower reaches of Lmuma Creek, bedrock may keep the runoff derived from the watershed near the surface where it is recognized as a perennial stream. The nearby Selah Creek, with a slightly smaller watershed, was located at the bottom end of the Yakima Canyon and flows into highly permeable substrates near it mouth despite the fact that 67% of the watershed is classified as low permeability basalts and sedimentary rock. Thus for Lmuma Creek, the occurrence of bedrock combined with the

large watershed size and a lack of high permeability substrates at the mouth may allow for intermittent flow (tending toward perennial) in the lower reaches while for Selah Creek the presence of permeable substrates causes any flow to drain to groundwater before reaching the Yakima River, and the infrequent and unpredictable occurrence of surface flow reaching the Yakima River would not have facilitated fish access into Selah Creek.

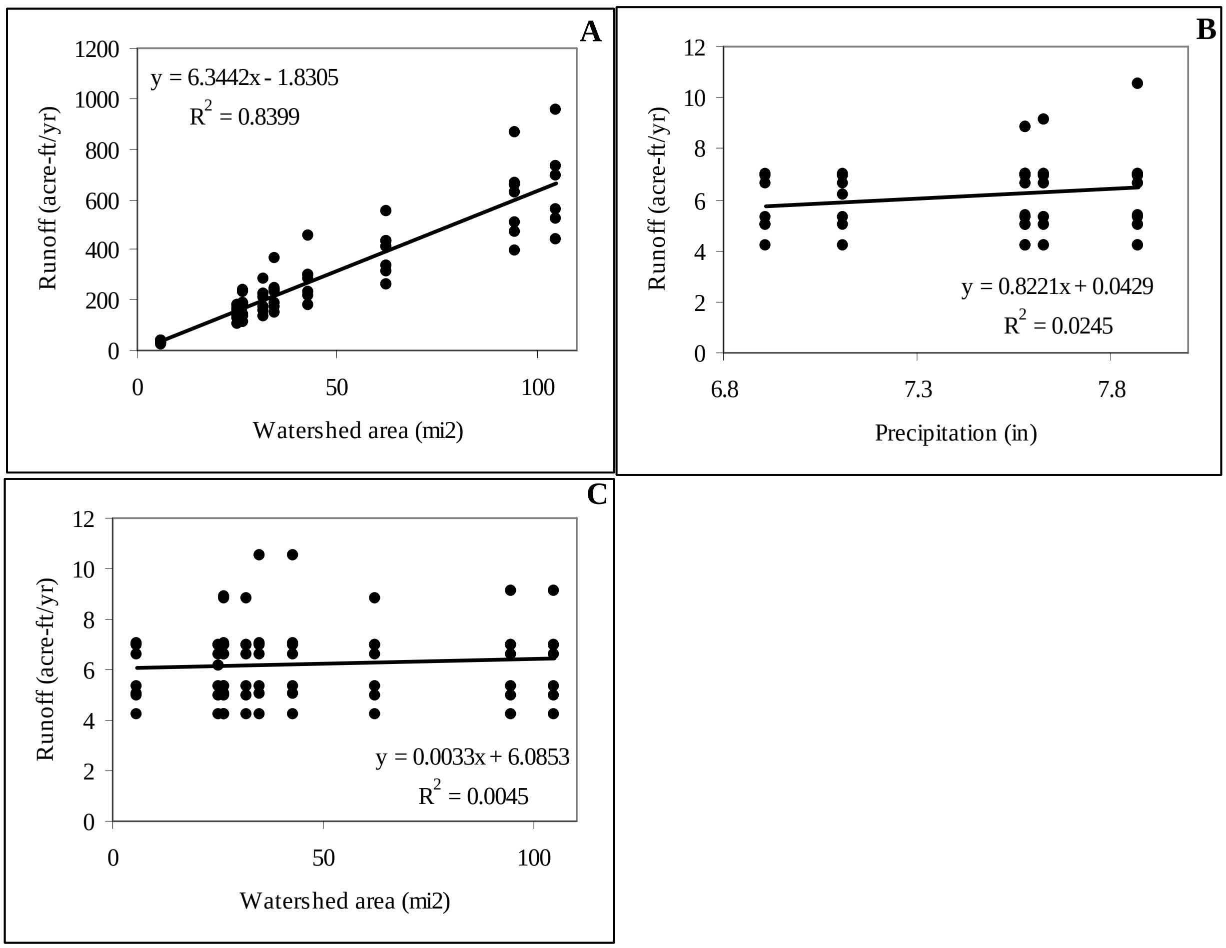

Figure 13. Best fits for predicted mean annual discharge as a function of watershed size (A), runoff per unit area and precipitation (B), and runoff per unit area and watershed area.

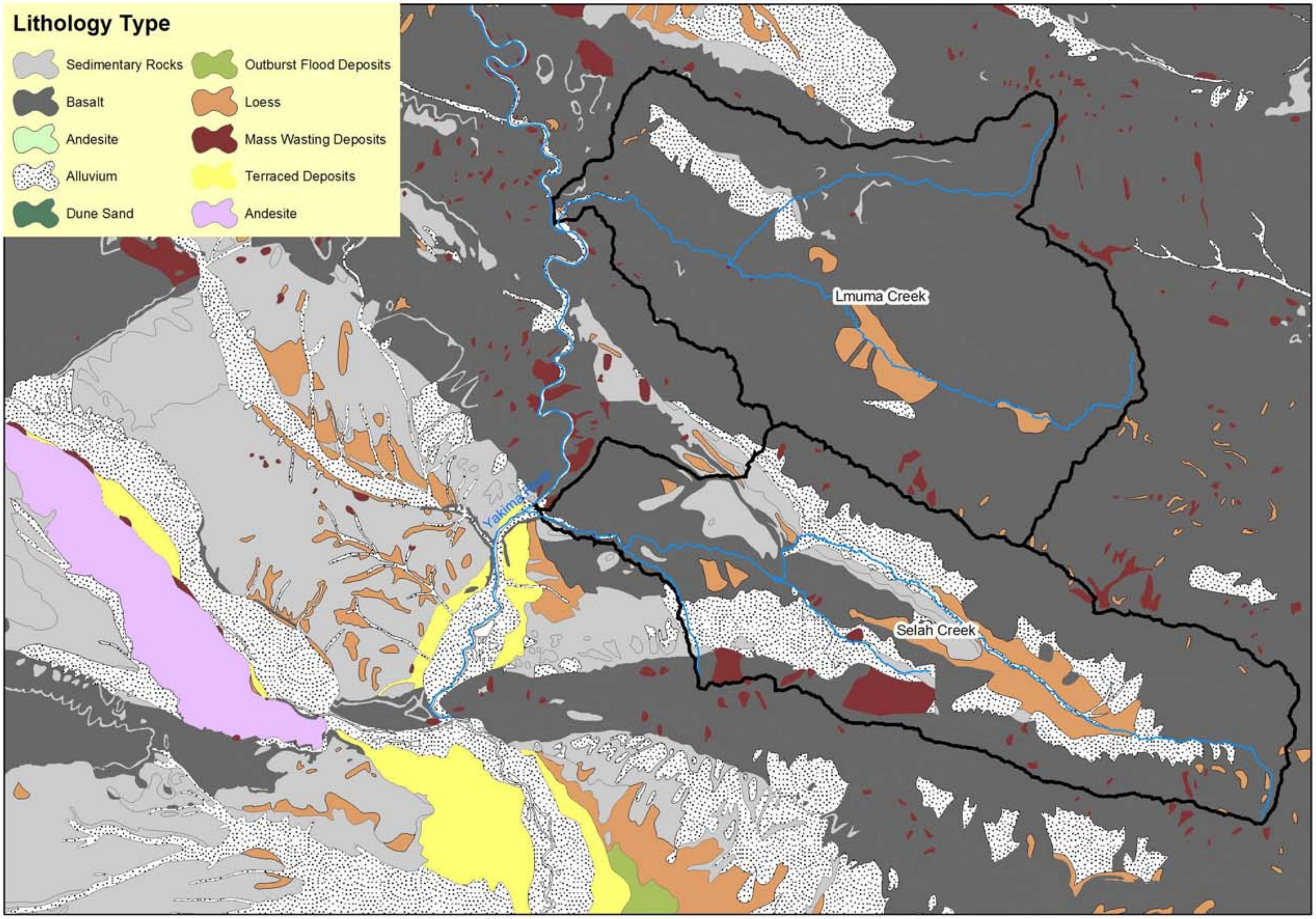

Figure 14. Geology of the reference streams

In comparison to the reference streams, the study drains have smaller watersheds (Table 2), lower elevations (Table 6), drain a higher percentage of highly permeable sediments (Table 7), and have permeable sediment near their confluence points with the Yakima River (Figure 12**).** Smaller watersheds produce less natural streamflow, lower elevations receive less precipitation, and permeable substrates allow what precipitation occurs to infiltrate local groundwater limiting surface runoff to infrequent and unpredictable thunderstorms or rain and snow events. All of these facts do not favor the occurrence of perennial flows near the mouth (as at Lmuma Creek), the occurrence of perennial pools (as in Selah Creek), or a reliable connection between perennial pools and the Yakima River (as in Lmuma Creek). This indicates that that fish habitat resulting from natural streamflow would not have occurred in the study drains.

Administrative considerations

Streamflow regimes are described as intermittent, ephemeral and perennial. Perennial streams flow throughout the year. The distinction between intermittent and ephemeral, however, was less clear with intermittent streams having dry reaches punctuated with perennial pools or reaches while ephemeral streams flow only with heavy precipitation (Amantorut 1998; Ward and Elliot 1995; Leopold and Miller 1956). In Washington State, stream channels were more finely divided into five types (Type 1- 5)[1]. Stream types 1 through 3 are perennial streams. Type 4 streams probably fit the intermittent classification and were described as having value as fish habitat, and Type 5 waters were probably best described as ephemeral having no fish habitat value. It is important that the study drains be correctly stream typed since it impacts the permitting requirements for performing work within the waterbody of interest. Typing requiring and the permitting requirements are provided in Appendix 1 and 2 respectively.

[1] Washington Administrative Code WAC 222-16-031

Conclusions

1) Mean annual runoff for the study drainages was less than 400 acre · ft/yr (range 33-391 acre · ft/yr).
2) Natural streamflow contributed approximately 1% of the current streamflow in the study drainages.
3) Watershed area is important in determining mean annual runoff. Precipitation or runoff per unit area was not correlated with mean annual runoff. Larger watersheds have greater natural streamflow.
4) The temporal distribution of natural streamflow was unpredictable and several years can pass between flow events.
5) The role of geology on streamflow was important. Watersheds with greater than 80% low permeability substrates may support perennial surface flow. None of the study drains have a high percentage of low permeability substrates.
6) Study drains would be ephemeral with negligible benefit as fish habitat without the influence of irrigation.

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Appendix 1

WAC 222-16-031 Interim water typing system. Until the fish habitat water type maps mentioned above are available, waters will be classified according to the interim water typing system described below. If a dispute arises concerning a water type, the department shall make available informal conferences, which shall include the departments of fish and wildlife, ecology, and affected Indian tribes and those contesting the adopted water types. These conferences shall be established under procedures established in WAC 222-46-020.

For the purposes of this interim water typing system see the following table:

Water Type Conversion Table

Permanent Water Typing	**Interim Water Typing**
Type "S"	Type 1 Water
Type "F"	Type 2 and 3 Water
Type "Np"	Type 4 Water
Type "Ns"	Type 5 Water

*(1) **"Type 1 Water"** means all waters, within their ordinary high-water mark, as inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated pursuant to chapter 90.58 RCW, but not including those waters' associated wetlands as defined in chapter 90.58 RCW.

*(2) **"Type 2 Water"** means segments of natural waters which are not classified as Type 1 Water and have a high fish, wildlife, or human use. These are segments of natural waters and periodically inundated areas of their associated wetlands, which:

(a) Are diverted for domestic use by more than 100 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and only considered Type 2 Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(b) Are diverted for use by federal, state, tribal or private fish hatcheries. Such waters shall be considered Type 2 Water upstream from the point of diversion for 1,500 feet, including tributaries if highly significant for protection of downstream water quality. The department may allow additional harvest beyond the requirements of Type 2 Water designation provided by the department of fish and wildlife, department of ecology, the affected tribes and interested parties that:

(i) The management practices proposed by the landowner will adequately protect water quality for the fish hatchery; and

(ii) Such additional harvest meets the requirements of the water type designation that would apply in the absence of the hatchery;

(c) Are within a federal, state, local or private campground having more than 30 camping units: Provided, That the water shall not be considered to enter a campground until it reaches the boundary of the park lands available for public use and comes within 100 feet of a camping unit.

(d) Are used by fish for spawning, rearing or migration. Waters having the following characteristics are presumed to have highly significant fish populations:

(i) Stream segments having a defined channel 20 feet or greater within the bankfull width and having a gradient of less than 4 percent.

(ii) Lakes, ponds, or impoundments having a surface area of 1 acre or greater at seasonal low water; or

(e) Are used by fish for off-channel habitat. These areas are critical to the maintenance of optimum survival of fish. This habitat shall be identified based on the following criteria:

(i) The site must be connected to a fish bearing stream and be accessible during some period of the year; and

(ii) The off-channel water must be accessible to fish through a drainage with less than a 5% gradient.

*(3) **"Type 3 Water"** means segments of natural waters which are not classified as Type 1 or 2 Waters and have a moderate to slight fish, wildlife, or human use. These are segments of natural waters and periodically inundated areas of their associated wetlands which:

(a) Are diverted for domestic use by more than 10 residential or camping units or by a public accommodation facility licensed to serve more than 10 persons, where such diversion is determined by the department to be a valid appropriation of water and the only practical water source for such users. Such waters shall be considered to be Type 3 Water upstream from the point of such diversion for 1,500 feet or until the drainage area is reduced by 50 percent, whichever is less;

(b) Are used by fish for spawning, rearing or migration. The requirements for determining fish use are described in the board manual section 13. If fish use has not been determined:

(i) Waters having any of the following characteristics are presumed to have fish use:

(A) Stream segments having a defined channel of 2 feet or greater within the bankfull width in Western Washington; or 3 feet or greater in width in Eastern Washington; and having a gradient of 16 percent or less;

(B) Stream segments having a defined channel of 2 feet or greater within the bankfull width in Western Washington; or 3 feet or greater within the bankfull width in Eastern Washington, and having a gradient greater than 16 percent and less than or equal to 20 percent, and having greater than 50 acres in contributing basin size in Western Washington or greater than 175 acres contributing basin size in Eastern Washington, based on hydrographic boundaries;

(C) Ponds or impoundments having a surface area of less than 1 acre at seasonal low water and having an outlet to a fish stream;

(D) Ponds of impoundments having a surface area greater than 0.5 acre at seasonal low water.

(ii) The department shall waive or modify the characteristics in (i) of this subsection where:

(A) Waters have confirmed, long term, naturally occurring water quality parameters incapable of supporting fish;

(B) Snowmelt streams have short flow cycles that do not support successful life history phases of fish. These streams typically have no flow in the winter months and discontinue flow by June 1; or

(C) Sufficient information about a geomorphic region is available to support a departure from the characteristics in (i) of this subsection, as determined in consultation with the department of fish and wildlife, department of ecology, affected tribes and interested parties.

*(4) **"Type 4 Water"** means all segments of natural waters within the bankfull width of defined channels that are perennial nonfish habitat streams. Perennial streams are waters that do not go dry any time of a year of normal rainfall. However, for the purpose of water typing, Type 4 Waters include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow. If the uppermost point of perennial flow cannot be identified with simple, nontechnical observations (see board manual, section 23), then Type 4 Waters begin at a point along the channel where the contributing basin area is:

(a) At least 13 acres in the Western Washington coastal zone (which corresponds to the Sitka spruce zone defined in Franklin and Dyrness, 1973);

(b) At least 52 acres in other locations in Western Washington;

(c) At least 300 acres in Eastern Washington.

*(5) **"Type 5 Waters"** means all segments of natural waters within the bankfull width of the defined channels that are not Type 1, 2, 3, or 4 Waters. These are seasonal, nonfish habitat

streams in which surface flow is not present for at least some portion of the year and are not located downstream from any stream reach that is a Type 4 Water. Type 5 Waters must be physically connected by an above-ground channel system to Type 1, 2, 3, or 4 Waters.

*(6) For purposes of this section:

(a) "Residential unit" means a home, apartment, residential condominium unit or mobile home, serving as the principal place of residence.

(b) "Camping unit" means an area intended and used for:

(i) Overnight camping or picnicking by the public containing at least a fireplace, picnic table and access to water and sanitary facilities; or

(ii) A permanent home or condominium unit or mobile home not qualifying as a "residential unit" because of part time occupancy.

(c) "Public accommodation facility" means a business establishment open to and licensed to serve the public, such as a restaurant, tavern, motel or hotel.

(d) "Natural waters" only excludes water conveyance systems which are artificially constructed and actively maintained for irrigation.

(e) "Seasonal low flow" and "seasonal low water" mean the conditions of the 7-day, 2-year low water situation, as measured or estimated by accepted hydrologic techniques recognized by the department.

(f) "Channel width and gradient" means a measurement over a representative section of at least 500 linear feet with at least 10 evenly spaced measurement points along the normal stream channel but excluding unusually wide areas of negligible gradient such as marshy or swampy areas, beaver ponds and impoundments. Channel gradient may be determined utilizing stream profiles plotted from United States geological survey topographic maps. (See board manual section 23.)

Appendix 2

WAC 220-110-020 Definitions. As used in this chapter, unless the context clearly requires otherwise:

(42) "Hydraulic project" means construction or performance of other work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state. Hydraulic projects include forest practice activities, conducted pursuant to the forest practices rules (Title 222 WAC), that involve construction or performance of other work in or across the ordinary high water line of:

(a) Type 1-3 waters; or

(b) Type 4 and 5 waters with identifiable bed or banks where there is a hatchery water intake within two miles downstream; or

(c) Type 4 and 5 waters with identifiable bed or banks within one-fourth mile of Type 1-3 waters where any of the following conditions apply:

(i) Where the removal of timber adjacent to the stream is likely to result in entry of felled trees into flowing channels;

(ii) Where there is any felling, skidding, or ground lead yarding through flowing water, or through dry channels with identifiable bed or banks with gradient greater than twenty percent;

(iii) Where riparian or wetland leave trees are required and cable tailholds are on the opposite side of the channel;

(iv) Where road construction or placement of culverts occurs in flowing water;

(v) Where timber is yarded in or across flowing water;

(d) Type 4 and 5 waters with identifiable bed or banks that are likely to adversely affect fish life, where the HPA requirement is noted by the department in response to the forest practice application.

Hydraulic projects and associated permit requirements for specific project types are further defined in other sections of this chapter.

(43) "Hydraulic project application" means a form provided by and submitted to the department of fish and wildlife accompanied by plans and specifications of the proposed hydraulic project.

(44) "Hydraulic project approval" (HPA) means:

(a) A written approval for a hydraulic project signed by the director of the department of fish and wildlife, or the director's designates; or

(b) A verbal approval for an emergency hydraulic project from the director of the department of fish and wildlife, or the director's designates; or

(c) The following printed pamphlet approvals and any supplemental approvals to them. See "supplemental approval":

> (i) A "Gold and Fish" pamphlet issued by the department which identifies and authorizes specific minor hydraulic project activities for mineral prospecting and placer mining; or
>
> (ii) An "Irrigation and Fish" pamphlet issued by the department which identifies and authorizes specific minor hydraulic project activities.