AQUATIC HABITAT SURVEY OF IRRIGATION DRAINAGE NETWORKS LOWER YAKIMA RIVER BASIN

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Roza-Sunnyside Board of Joint Control and
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EXECUTIVE SUMMARY

Features of stream habitat were surveyed in 43 miles of irrigation return-flow channels in the lower Yakima Basin during February and March of 2001 to determine their suitability for rearing salmon and trout. Six drain networks were surveyed in the Roza and Sunnyside irrigation districts with three located in flat low-lands of the northwest area (Sulphur, Granger, and Moxee) and three in natural stream gullies of the southeast area (Snipes, Spring, and Corral). Consistent differences in habitat features were found between drains in these two sets of drains and the differences were related to gradient and geology of the channels.

Stream habitat was generally unsuitable for salmonids in drains to the northwest (low flatlands) of the area surveyed. These excavated drain channels, Moxee, Granger, and Sulphur creeks, had gradients of only 0.3-0.4% and flowed through areas with geology dominated of silt and sand deposits. Glides composed greater than 60% of stream surface area there. Riffles are the primary areas for producing the invertebrate drift that salmonids feed on, and the percentage of riffle in these channels was less than 30% in most reaches, was far below that found in most salmon and trout streams (greater than 50%). Fines composed 45%-100% of substrate in every reach of Moxee, Granger and Sulphur drains. Embeddedness in the few riffles present in the three northwest drains averaged 32% in Moxee Drain, 46% in Granger Drain, and 64% in Sulphur Wasteway. Experiments in laboratory stream channels have demonstrated that percentage emergence of fry placed in a gravel-sand mixture will decrease to zero when fines reach 40% or higher.

In contrast, stream habitat was fair to good for natural production of salmonids in the southeast drains, Corral, Snipes and Spring creeks. These natural channels had gradients around 1%, flowed through areas of basalt geology, and had suitable amount of gravel and cobble substrate. Habitat type was dominated by riffles (44-75%). Numerous beaver ponds, favored

by coho for rearing, were present in Snipes and Corral drains. The majority of riffle habitat in Snipes Creek (southeast drain) was less than 20% embedded, and embeddedness was less than 30% in most riffles of Spring and Corral creeks.

The differences in habitat between these two sets of drains parallels differences found in a study of streams in western Oregon with similar gradients. The percentage fines in the substrate of Oregon coastal streams was highly related to gradient, and the percentage of fines jumped from <10% in riffles within reach gradients ≥1% to >25-61% fines in reaches < 1% gradient. Further, that study found that salmonids were present in all sites with gradients ≥1%, but were absent at 8 of 10 sites with gradient under 1%. A study by Monk (2001) of fish assemblages in most of the drains we surveyed likewise found few salmonids in the low gradient drains (Sulphur and Granger), while salmonids were common in the higher gradient Snipes and Spring creeks.

Migration barriers and low flows limit the potential for salmonid production in the drains. Forty potential barriers were identified in the drains surveyed, with 26 of those in Sulphur Creek Wasteway and its lateral drains. During the non-irrigation season, flows range between drains from approximately 1cfs (Snipes Creek) to near 70cfs in Sulphur Creek Wasteway. During the Irrigation season, flows range from 276 - 375 cfs in Sulphur Creek Wasteway to 30 - 60 cfs in all other drains surveyed. Water temperatures in all drains generally remained within ranges tolerated by salmonids.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The survey described in this report was commissioned by Roza-Sunnyside Board of Joint Control to characterize the availability of stream habitat suitable for salmonids in 43 miles of irrigation return-flow channels in the lower Yakima Basin. These surveys were performed February and March of 2001 to reflect stream conditions during the low flow (non-irrigation) season. Habitat surveys were not performed during the irrigation season because high flows and turbidity in the drains would not allow the ease observation of depth and substrate composition.

NEED FOR THE STUDY

As part of the Yakima Project irrigation system, a network of drains and wasteways were developed to convey irrigation return flows back to the Yakima River. Return-flow channels are characterized by two functions: those known as drains that collect water coming off of the fields, and those known as wasteways that carry overflow water directly back to the river before it enters the fields. Wasteways provide a water bypass route back to the river for those times when there is a temporary excess of water arriving down the main canal compared to the demand by all users connected to that canal. Thus, any water returning to the river in wasteways would have characteristics similar to that of the Yakima River where water was diverted. We will separate drain operations based on irrigation season and non-irrigation season use. The drains are located in flat low-lands (Sulphur, Granger, and Moxee) and in natural stream gullies (Snipes, Spring, and Corral). The extent that drains were historically natural streams in lowland areas is currently being investigated. Maintenance activities, such as dredging of fines and armoring the banks to reduce erosion, has also increased the difficulty in classifying the channels as natural or man made.

Irrigation activities may have adversely affected some fish habitat attributes (e.g.,

channelization, regulated flows, increased siltation, substrate cementing) in the drains and wasteways. However, irrigation activities may have improved other fish habitat attributes (warmer, ground water supplementation during winter months, year-round flows, etc.), which have a favorable impact on salmon production in irrigation return flow streams.

Salmon and steelhead, as well as other species of fish, spawn and rear to an uncertain extent in irrigation delivery networks in the lower Yakima River Basin. Interest in fish using irrigation delivery systems has increased since native summer steelhead in the Yakima have been listed under the Endangered Species Act. Although adult salmon and steelhead have been observed in some irrigation return-flow channels, it has not been determined whether these are hatchery or natural fish. An extensive hatchery program is developing in the basin, and may contribute strays into the irrigation drainage network. Most often salmonid use of the irrigation network occurs in lower reaches of channels carrying return water back to the river, where there is open access for fish migrating in the upstream direction. Salmonids migrating downstream in the mainstem Yakima River are prevented by fish screens from entering the points of water diversion. However, resident and anadromous fish species may persist in the irrigation delivery and drainage network year-round.

Species, stocks, distribution, abundance and seasonality of fish using irrigation return-flow channels have not been sampled until the recent work by Monk (2001). Adult fall chinook and coho salmon were observed spawning in several return-flow channels during fall 2000. In addition to coho and fall chinook, Monk (2001) found that brown trout, rainbow/steelhead, carp, chiselmouth, redside shiners, two species of dace, northern pikeminnow, three species of sucker, mosquito fish, two species of bass and pumpkinseed were present in the irrigation system. Approximately 300 coho salmon spawned in Sulphur Creek wasteway and Spring/Snipes Creek drains in the fall of 2000 and summer steelhead were observed in Sulphur Creek wasteway in the spring of 2001. The appearance of these

fish raised the question as to whether habitat in these channels could support natural reproduction and rearing of salmon or whether these fish were straying into unsuitable habitat where little or no natural production would result. Habitat conditions in irrigation return flow channels appear to be unfavorable for the production of large numbers of salmonids, but this observation is speculative.

The purpose of the habitat survey described in this report was to characterize available habitat and its potential to support salmon and steelhead migration, spawning, egg incubation, and parr rearing in select drain reaches of the Roza and Sunnyside Valley irrigation districts during the non-irrigation season. This baseline survey had four objectives:

1. Conduct a physical habitat survey of Snipes, Spring, Corral, Sulphur, Granger, and Moxee drains during the non-irrigation season.
2. Determine from physical surveys if drain reaches have appropriate habitat for fish spawning, egg incubation and parr rearing during the non-irrigation season.
3. Assess irrigation structures that may affect fish access, migration, and production.

BASIN DESCRIPTION

The Yakima River drains an area of 15,900 square km (or 6,155 square miles) and contains about 3,058 km (about 1,900 river miles) of perennial streams. Originating near the crest of the Cascade Range above Keechelus Lake, the Yakima River flows 344 km (214 miles) southeastward to its confluence with the Columbia River (RM 335.2).

The Roza and Sunnyside irrigation districts are located on the lower east side of the Yakima Basin. The Roza and Sunnyside Irrigation Districts provide irrigation water to a combined total of 176,570 acres of agricultural and municipal land in the Yakima River basin. The majority of the land serviced by the Roza District is above and adjacent to the

Sunnyside District. The Roza-Sunnyside Board of Joint Control (RSBOJC) was formed in 1997 for the purpose of developing a management program to consider, plan, and implement more effective and efficient management and use of irrigation water.

SURVEY AREA

Our study area is located in the lower Yakima River Basin and includes 5 major return-flow drains including Snipes Creek (plus it's tributary, Spring Creek), Corral Creek, Sulphur Creek Wasteway, Granger Drain, and Moxee Drain (Figure 1). The most upstream (North) drain surveyed (Moxee) was located just upstream of Union Gap near the city of Yakima, and the most downstream (southeast) drain (Corral Creek) was located just a few miles upstream of Benton City. There is roughly 43 miles of drain in these return-flow channel. The total length would increase slightly (approximately 5 to 10 miles) If all sub-laterals were to be included. Actual length of channel we surveyed was 38.6 miles of drain (Table 1). Following, we give a brief description of the physical setting for each drain surveyed.

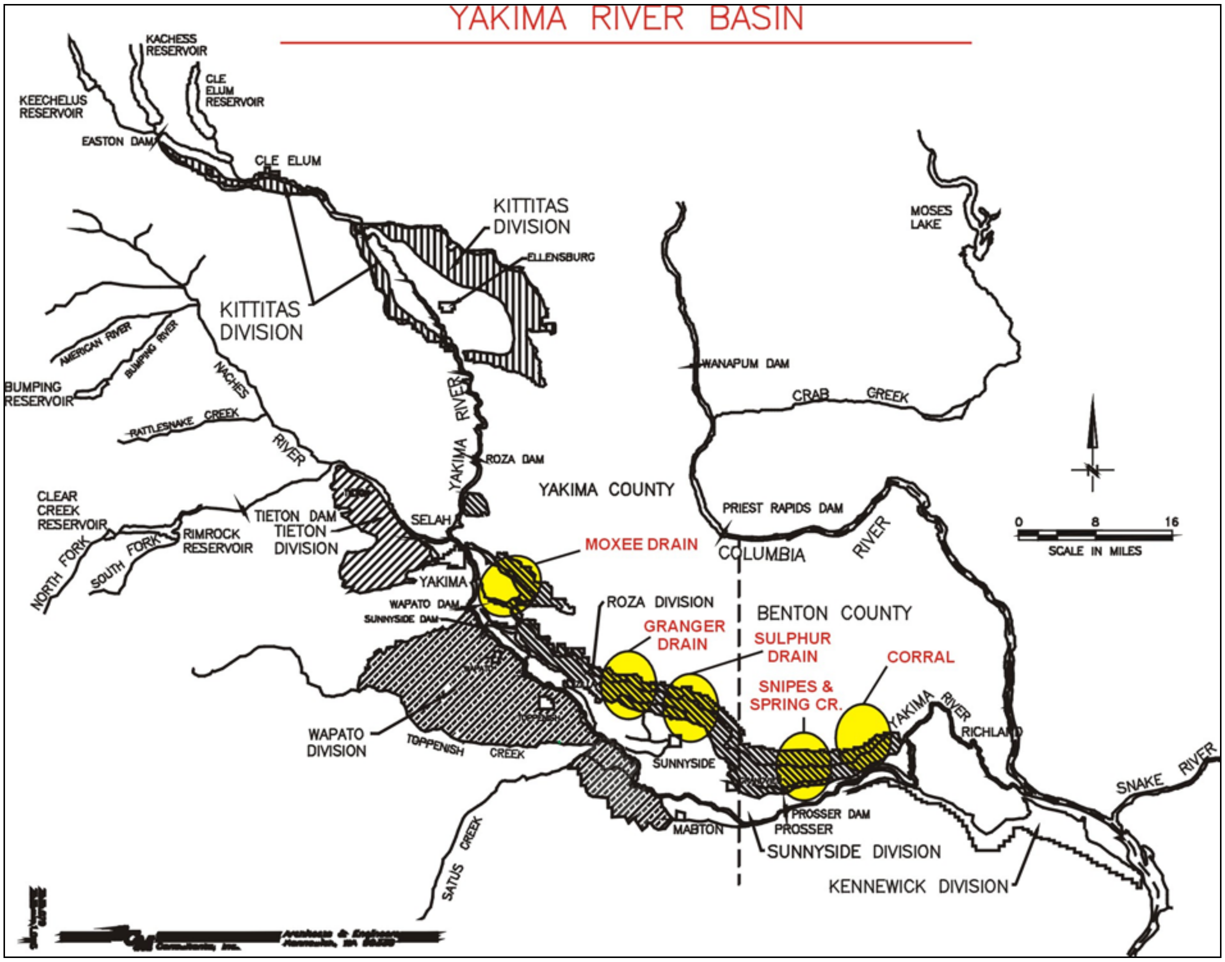

Figure 1. Location of drains surveyed within the Roza and Sunnyside irrigation districts, Yakima River Basin, Washington.

Table 1. Lengths of channel surveyed in lower Yakima basin drains. Length of lateral and sub-lateral surveys are included.

Basin	Study Area	Survey Length (m)	Survey Length (mi.)
Corral Creek	southeast	2,812	1.74
Snipes Creek	southeast	6,552	4.07
Spring Creek [1]	southeast	5,176	3.22
Sulphur Creek Wasteway	northwest	38,944	24.2
Granger Drain	northwest	4,166	2.59
Moxee Drain	northwest	4,529	2.81
Total		**62,179**	**38.6**

[1] Tributary to Snipes Creek

Corral Creek

Corral Creek originates just above the Roza canal, flows through an upper meadow, then through a heavily vegetated constrained valley before joining with the Yakima River at RM 33.8 (Figure 1). Corral Creek is at the end of the irrigation delivery system and is used mainly for expelling excess water out of the main canal back to the Yakima River. The drain flows in a southerly direction and is approximately 3 miles long. Beaver activity is present in the middle section (1.25 miles upstream) where small ponds are created with the abundant vegetation growing near the stream. Flows in the upper extent of this drain are reduced to less than 2 cfs during the non-irrigation season. Corral Drain has no major tributaries contributing flow to the main channel.

Snipes And Spring creeks

Snipes Creek originates near the Roza canal approximately 0.5mi above Hanks Road and continues downstream to the Yakima River (RM 41.8) near the town of Whitstran (Figure 2). At 175m upstream of the Yakima River, it is joined by Spring Creek, which is the only tributary to Snipes Creek. The lower half of Snipes Creek runs through a broad floodplain. Land use is primarily private medium sized parcels (1-5 acres). The upper half enters a valley constrained by hillslopes where land use is dominated by large vineyards which are offset from the active channel 100+ meters. Much of this upper reach is dominated by a large beaver complex with multiple dams. The Roza regulating reservoir located at the head of Snipes Creek supplies nearly all the surface flow during the irrigation season.

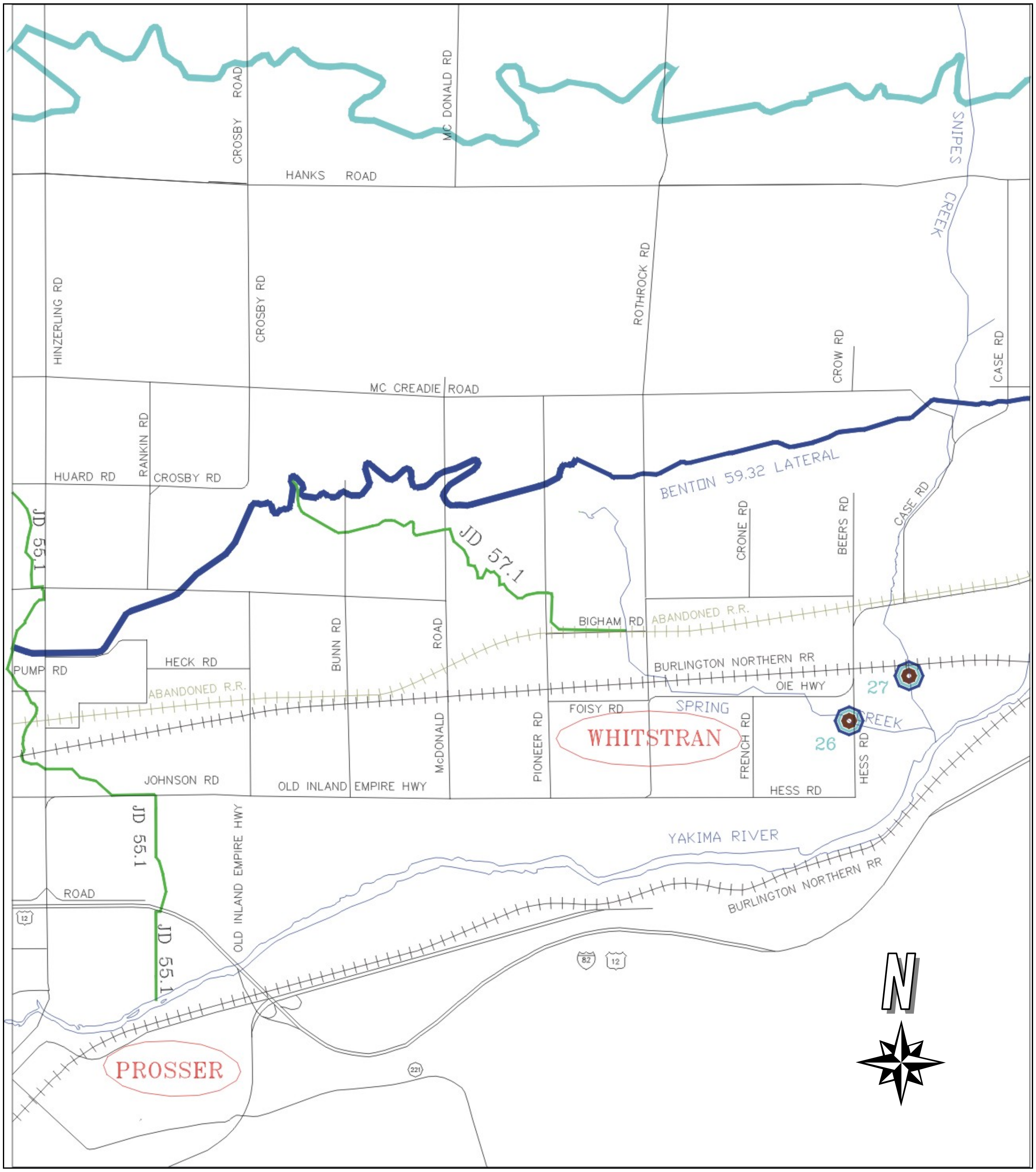

Figure 2. Snipes and Spring creeks light blue, with Spring Creek lateral drain JD 57.1 shown in green.

Spring Creek begins near the Roza canal and ends at it's junction with Snipes Creek, 175m upstream from the Yakima River (Figure 2). Spring Creek has only one major tributary, lateral drain JD 57.1 which enters on the right bank just upstream of Bigham Road. Some reaches of the stream run through pasture land. For approximately 0.75 miles the stream is channelized and runs adjacent to Old Inland Empire Hwy. During the irrigation season, Spring Creek receives nearly all surface flow from a pump station that supplies water to a lateral of the Sunnyside Canal.

Sulphur Creek Wasteway

The mainstem of Sulphur Creek Wasteway extends 7.5 miles upstream from the Yakima River (RM61.0) to the concrete flumes at Sheller Road (Figure 3). The concrete flumes at Sheller Road are a barrier to upstream passage for both anadromous and resident fish. The section of drain just below the concrete flumes is lined with crushed rock to reduce erosion. The mainstem of Sulphur Creek Wasteway is continually maintained to reduce the chance of water eroding the channel bank and flooding private land during the irrigation season. Sulphur Creek Wasteway has five main lateral drains (JD 33.4, JD 43.9, JD 40.2, JD 35.4, and JD 37.9). We surveyed all main laterals and sub-laterals with potential salmonid habitat.

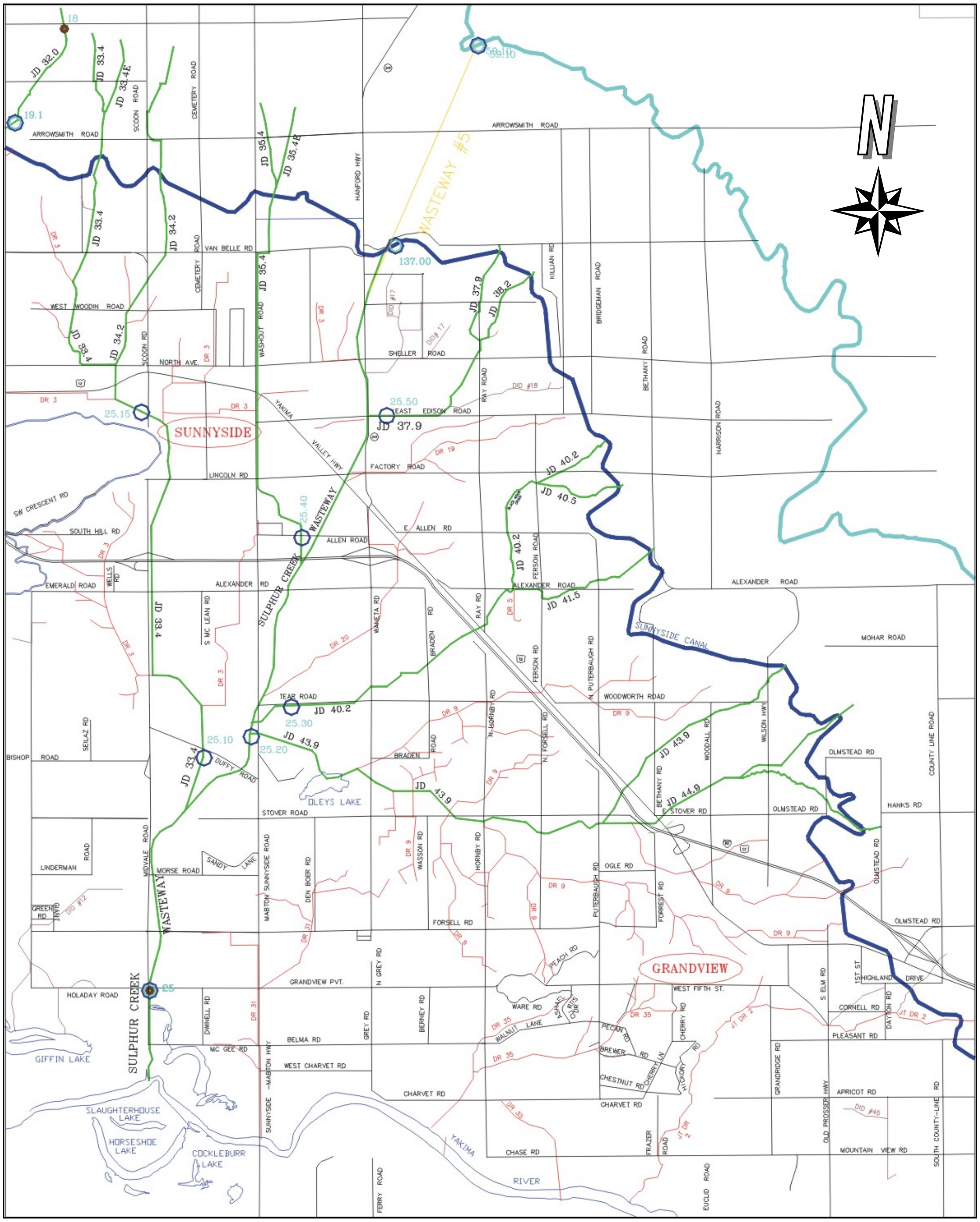

Figure 3. Sulphur Creek Wasteway area location map. The wasteway and major subdrains are shown in green, minor drains appear in red.

Land use along Sulphur Creek Wasteway and its laterals is primarily agricultural with some urban areas around the city of Sunnyside. Sulphur Creek Wasteway, and its laterals, has been heavily channelized with a high percentage of silt and sand dominating the substrate. This is also the same for the majority of lateral and sub-lateral drains.

Granger Drain

Granger Drain originates in the low hills approximately 8 miles east of the town of Granger (Figure 4). There are three major laterals (JD 26.6, JD 27.5, and JD 28.0) which enter the main drain along the railroad and Hwy 82. The total length of these laterals is 8.5 miles. From Liberty road down to the confluence with the Yakima River (RM 83.0) the drain flows through irrigation land and along the railroad. Portions of the main section of Granger Drain was originally excavated to drain the wetlands that the railroad passed through.

Overall, Granger Drain is characterized by silt and sand substrate and an artificially constrained channel. Land use for the first two reaches is mostly urban as the drain passes through the town of Granger. The middle and upper reaches run near or along Interstate 82 and the railroad resulting in a channelized stream with little or no sinuosity.

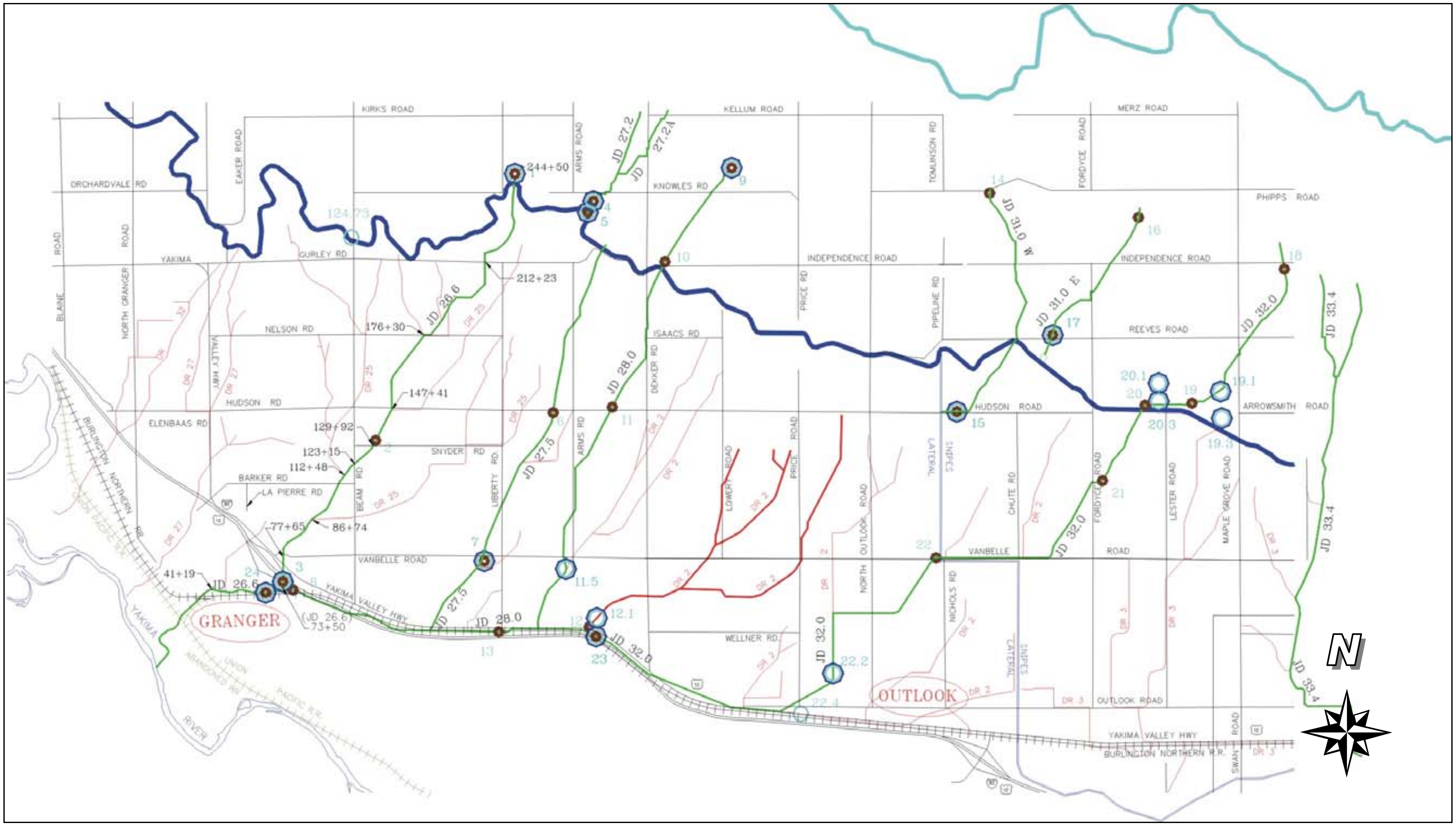

Figure 4. Granger Drain and main laterals JD 26.6, 27.5, 28.0 and 32.0 shown in green, with minor drains shown in red.

Moxee Drain

Located just southeast of the city of Yakima, Moxee Drain begins at the confluence with the Yakima River (approx. RM 106) and continues upstream to the Roza Canal. Land use throughout this drain is primarily agricultural. Moxee has no tributaries throughout this surveyed segment. In the lower sections of Moxee, near the Yakima River, the drain channel meanders and has a substrate of cobble and gravel with some fines. As the channel enters agricultural areas it became channelized, meanders less, and has a substrate dominated by silt, sand, and some hardpan.

METHODS

HABITAT SURVEY

Physical habitat was classified and measured by a team of one biologist and one technician during February and March 2001 following methods adapted from those described by Pleus et al. (1999), Oregon Department of Fish and Wildlife (ODFW) (ODFW 1997), USFS Forest Service Region 6 (1994), and Hawkins (1993). Habitat units were classified in categories as fast turbulent (riffle), fast non-turbulent (glide), slow scour pool, slow dam pool, and small stream units (Figure 5). When a stream section was encountered that had a high number of small habitat units over a short distance we used a small stream unit typing protocol (ODFW 1997). This method made it possible to efficiently type habitat without having to measure a habitat unit every few meters. We recorded length, width and depth for each habitat unit (Appendix E). A hip chain was used to obtain quick and precise distances measurements. Water depth was estimated with a wading rod, and recorded as averages for riffles and glides, and maximums for pools. Stream gradient was measured for riffles with a hand-held clinometer.

Figure 5. Hierarchical habitat typing classification key modified from Hawkins (1993) and ODFW (1997). Each level number corresponds to specific habitat types presented in data Appendix E.

Stream banks were classified as described by ODFW (1997) for each habitat unit on both the left and right banks looking downstream. The classifications were: vegetatively stabilized, boulder cobble, actively eroding, or non-erodible.

Field crews made quantitative estimates of active in-stream wood for each habitat unit as they proceeded upstream following a modified form of the methods outlined in USFS Region 6 Stream Inventory Handbook (1994). We defined active wood as pieces of wood greater than 10cm in diameter, at least 3m in length, in contact with the water and contributing to the hydrology of the system, or acting as a cover component for fish. Pieces of wood that fit the size category described above but were not included in observations were either one meter or greater above the water surface, or were greater than 1 meter in horizontal distance from the active water surface. A wood class rating from 1 to 5 was recorded for each habitat unit observed (ODFW 1997, Table 2).

Observers recorded substrate in each habitat unit and noted percent composition through visual estimation of each of six categories: silt/organics, sand, gravel, cobble, boulder, and bedrock. In addition, a visual estimate of embedded substrate was recorded for each riffle, glide, and pool tailout.

Table 2. Wood Class rating as described by ODFW (1997) methodology.

Rating	Description
1	Woody debris absent or very low. No habitat complexity or cover created.
2	Wood present, but contributes little to habitat complexity. Ineffective at moderate to high discharge.
3	Wood present as combinations of single pieces and small accumulations. Provides some complex habitat at low to moderate discharge.
4	Wood preset with medium and large pieces comprising accumulations and debris jams that incorporate root wads and branches. Good cover and complex habitat that persists over most stream discharge levels.
5	Wood present as large single pieces, accumulations, and jams that trap large amounts of additional material and create a variety of cover and refuge habitats. Complex habitat and flow patterns exist at all discharge levels.

Cover available to fish in each habitat was scored visually and was defined as any habitat feature that obscures visibility of the fish. Two cover scores were given; the vertical score was for overhead cover (bank vegetation, woody debris or surface turbulence) and horizontal cover score (submerged wood, boulders, brush or cut banks). We recorded the amounts of vertical and horizontal cover as low, medium, or high.

The end points for surveys on each drain were chosen for one of the following reasons: 1) the canal extended upstream beyond the jurisdiction of the water district 2) a decrease in flow eliminated potential salmonid habitat 3) there was a barrier to migration 4) the habitat was unsuitable to any stage of the salmonid life cycle.

Where reach features were homogenous for more than 200 meters we only recorded data on channel units in every other 100m of length. A 100-meter length of reach was measured and all physical parameters observed were measured. The next 100 meters was measured for length, but not for all other physical parameters.

Breaks between reaches were defined as those points where one of the following applied: a tributary with >15% flow entered, valley form changed, there was a major change in vegetation type, or land use changed. Active channel width, active channel height, land form, channel form, and valley form were all recorded once per reach as described by ODFW (1997) protocol.

Streamside vegetation was recorded following a modification of ODFW (1997) classification of streamside vegetation. This method recommends that vegetation observed in the area within one active channel width of either side of the channel be used to define the riparian zone. Dominant and subdominant types were recorded as a two-letter code (Appendix D). Vegetation height was recorded as the average height of the overstory riparian vegetation above the water surface. In many instances we encountered reaches in which the vegetation was entirely dead, annual grasses. We calculated vegetation height as the live height of the grass. Vegetative offset was recorded as the distance of the dominant shading vegetation from the active channel. Vegetative density was visually estimated as low, medium, or high.

Reach azimuth was a measure of the average departure angle of the stream from a north-south reference line when looking south. This measurement was taken using a compass and map with reach start and end points marked.

The topographic altitude was measured as the vertical angle from a level line at the streambank to the general top of the local terrain when looking at a 90-degree angle from the general stream reach azimuth. Vegetative altitude is the same measure, only the measurement is taken to the top of the dominant shading riparian vegetation. Both of these measures were taken for each bank using a hand held clinometer.

Other pertinent data, such as fence crossings, grazing, culverts, and beaver activity were also recorded. All observations were recorded on waterproof field paper and transferred to electronic format at the end of each day.

RESULTS

HABITAT FEATURES

Channel morphology varied from ditch-like to near natural conditions. Data was analyzed at the habitat unit, reach, and drain level in order to identify areas of differing habitat quality. Consistent differences in habitat features were found between drains to the southeast (Corral, Spring and Snipes Creeks) and drains to the northwest (Moxee, Granger and Sulphur drains) in the study area.

Slope

Channel slope, which strongly influences channel morphology, was relatively low in the channels surveyed. The drains on the southeast of the study area (Corral, Spring and Snipes) had the highest slopes around 1% (Table 4). In general, the drains in the northwest of the study area (Moxee, Granger, and Sulphur) had lesser slopes of approximately 0.4%. Some lateral drains on Sulphur Creek Wasteway (e.g., JD 46.4) had a drain slope near 1%. As drains approached the base of the surrounding hills, their slope increased (Appendix A).

Morphology

The substrate composition differed substantially between drains, and was related to slope and geology. Corral, Snipes, and Spring creeks that had the most slope (0.9-

1.0%) among drains surveyed, also had the greatest amount of gravel and cobble substrate (Figure 8). These drains were also dominated by basalt geology. Granger, Moxee, and Sulphur drains with the lesser slopes of 0.3 – 0.4 %, had substrate that was predominantly silt and sand combined (Figure 9). There were individual reaches in the Granger (reach 1), Moxee (reach 3), and Sulphur (reach 4 and 5) in which gravels reached 20-40% of substrate (Appendix A). However, the source of gravels and cobble in these southeast drains was largely crushed rock added to stabilize the canal banks.

The drains in the northwest of the area surveyed (Sulphur Creek Wasteway, Granger, and Moxee drains) were dominated by glide habitat (>60) (Table 3, Figure 7). In contrast, the southeast drains were dominated by riffles (44.9-74.9%; Table 3). Pool habitat was limited in all drains with Granger having the largest percentage (18%) and Sulphur the lowest (10%). Beaver ponds in Snipes and Corral Creeks contributed 21% and 10% of total habitat, respectively. Corral Creek had 13 beaver dams (average height= 0.56 m) while Snipes Creek had 17 with an average height of 0.76 m (Figure 8). Beaver ponds in Snipes Creek had a mean depth (1.1m), slightly deeper than Corral Creek (0.56m).

Table 3. Percentage of drain area for each habitat type surveyed during non-irrigation season (February and March), 2001.

Drain	% Survey Area For Each Habitat Unit Type				
	Pool	Riffle	Glide	Fall	Beaver Pond
Corral	13.0	44.9	21.6	0.0	20.6
Snipes	10.3	68.1	11.5	0.0	10.1
Spring	14.6	74.9	10.4	0.0	0.0
Sulphur	10.2	21.8	67.8	0.1	0.1
Granger	18.0	17.0	64.9	0.1	0.0

Moxee	14.3	22.1	60.2	3.5	0.0

The percent of area composed by riffles, which is important for production of drifting invertebrates eaten by juvenile salmonids, tends to be greater in drains to the southeast of the area surveyed than in those to the northeast (Figure 6). The number of reaches with >50% riffle was 7 of 8 in Snipes Creek, all in Spring Creek, and 2 of the 3 in Corral Creek. In contrast, riffles composed >50% of area in 0 of 4 reaches in Moxee drain, 2 of 6 reaches in Sulphur Creek, and 1 of 5 reaches in Granger Drain.

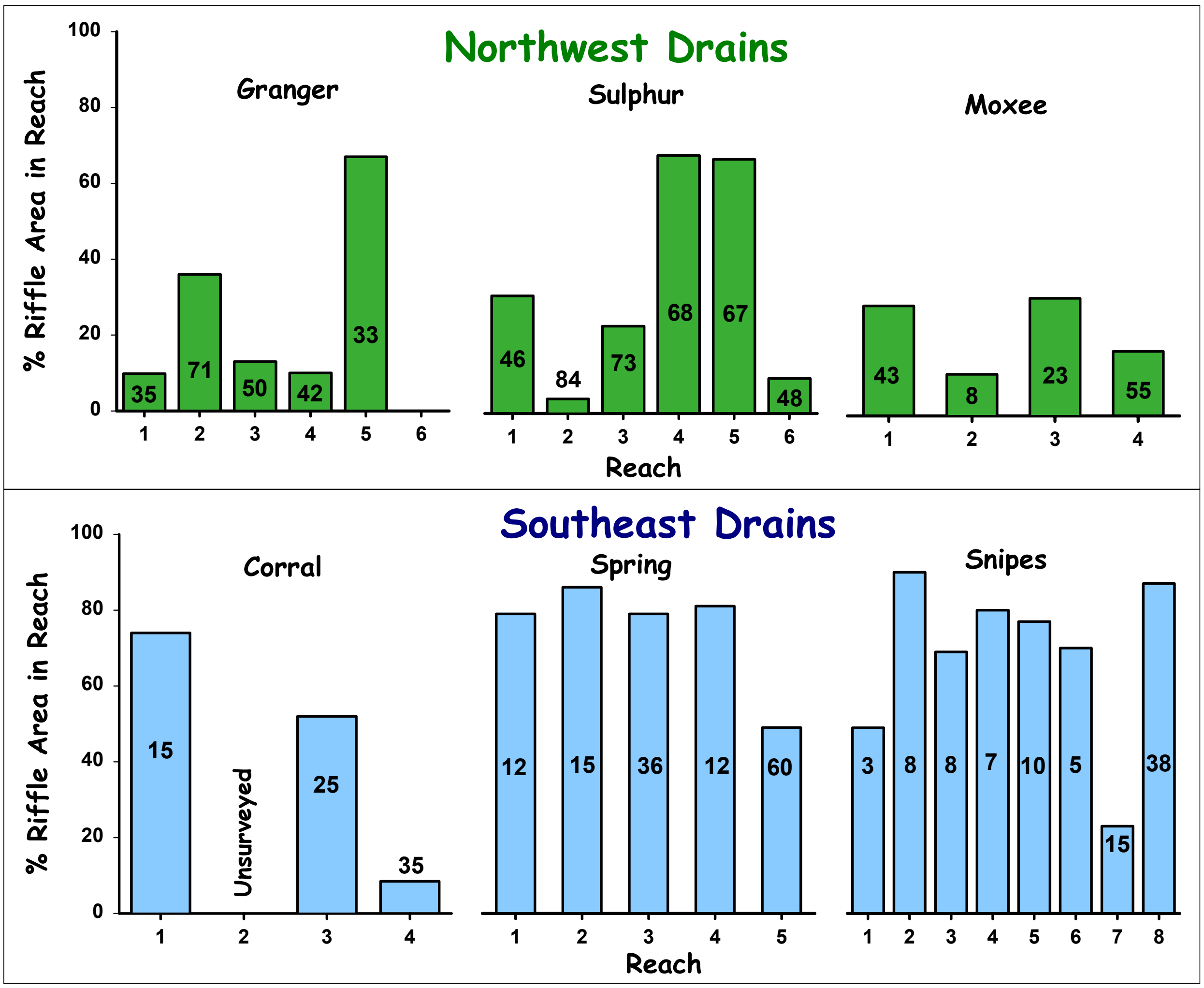

Figure 6. Mean percent embedded substrate (number on bar) observed for riffle area in each reach of 3 northwest and 3 southeast drains in the lower Yakima Basin.

Figure 7. Representative glide habitat in Sulphur Creek Wasteway during non-irrigation habitat survey, February-March, 2001.

Figure 8. Beaver ponds observed in Snipes Creek during non-irrigation habitat survey, February-March, 2001.

Substrate

The substrate composition differed substantially between drains, and was related to slope and geology. Corral, Snipes, and Spring drains had the most slope (0.9 – 1.0%), and also had the greatest amount of gravel and cobble substrate (Figure 9). These drains were also dominated by basalt geology. Granger, Moxee, and Sulphur drains with slopes 0.3-0.4% had substrate that was predominantly silt and sand combined (Figure 10). There were individual reaches in Granger (Reach 1), Moxee (Reach 3), and Sulphur (Reach 4 and 5) in which gravels reached 20-40% of substrate (Appendix A). However, the source of gravel and cobble in these southeast drains was largely crushed rock added to stabilize the canal banks. Silt content in the northwest drains was high at time of survey and may decrease during irrigation season when flows increase.

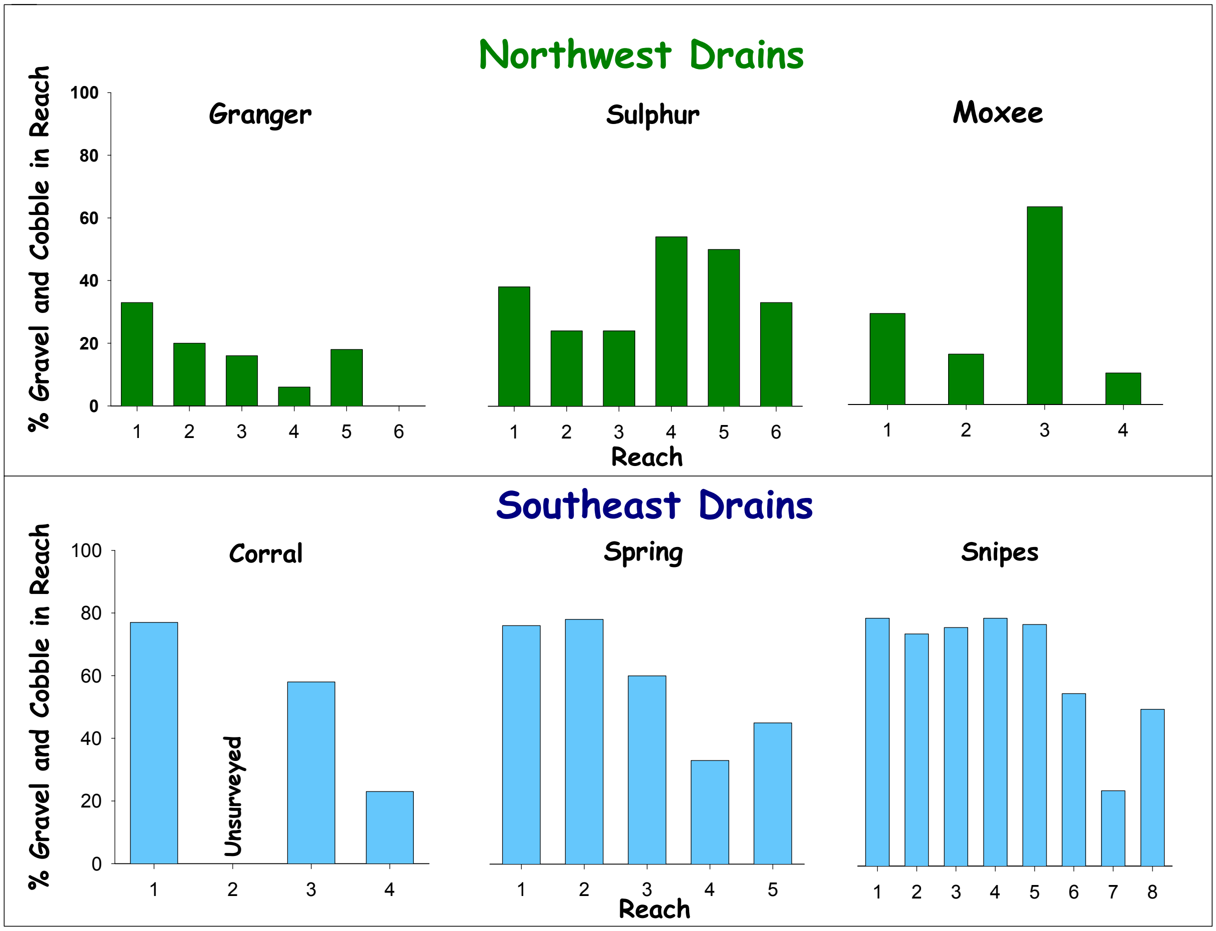

Figure 9. Mean percentage of substrate composed by gravel and cobble combined in each reach of the three northwest and three southeast drains surveyed in the lower Yakima Basin. Data from Appendix A.

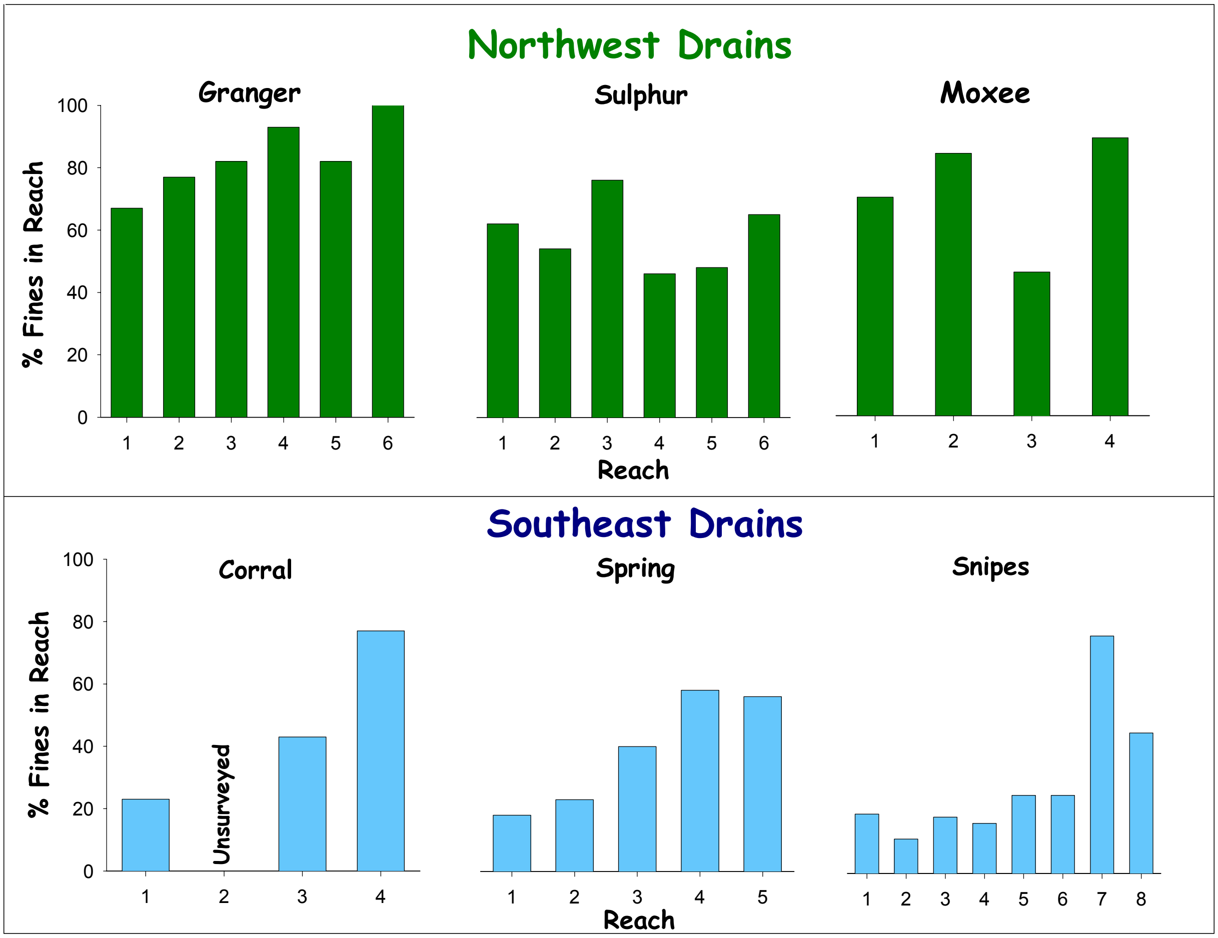

Figure 10. Mean percentage of substrate composed by silt and sand combined in each reach of the three northwest and three southeast drains surveyed in the lower Yakima Basin. Data from Appendix A.

Our habitat survey observations revealed that all drains throughout the study area have a high percentage of embedded substrate. Sulphur has the highest percent of embedded substrate with all habitat units frequently upwards of 70% or higher for mean embedded substrate (Table 4). Snipes and Spring have the least amount of embedded substrate with many of the units with less than 30 percent. Drain riffle habitat in the northwest of the study area is embedded with fines much more than drain riffle habitat in

the Southeast. For comparison, the majority of riffle habitat in Snipes Creek (southeast drain) is below 20 percent embedded while Sulphur Creek Wasteway (northwest drain) has the majority of riffle habitat embedded well above 50 percent (Figure 11).

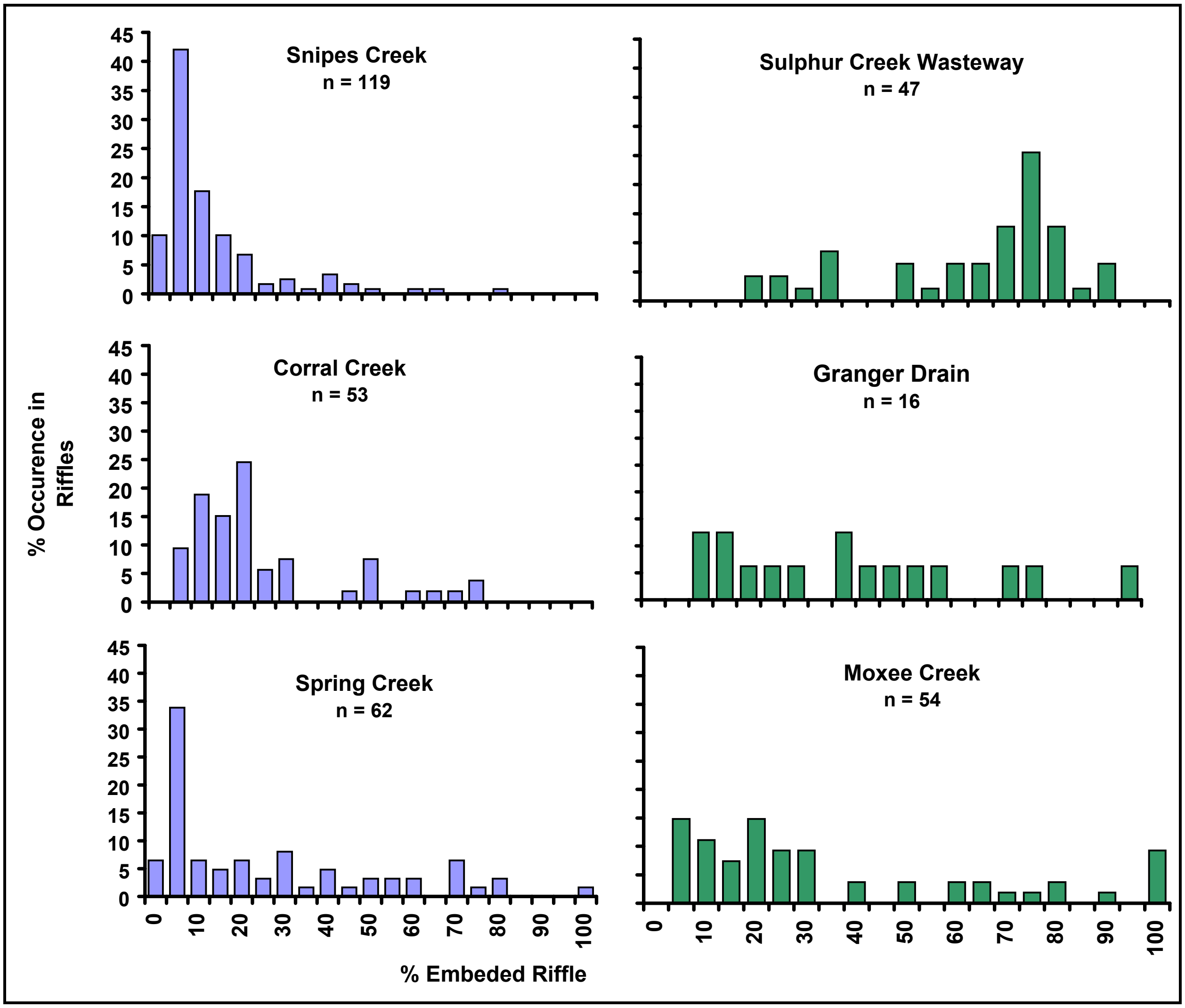

Figure 11. Frequency distribution of substrate embeddedness in riffles for three drains in the northwest (green) and three in the southeast (blue) of the Yakima Basin project area.

Directly related to embeddedness is the percentage of fines that make up the substrate. Substrate in all drains surveyed was composed of 50% or more fines (Appendix A). Fines comprised half of the substrate in Granger, Moxee, and Sulphur. Ninety percent or more of the substrate in the main lateral drains of Sulphur (JD35.4, JD 37.9, JD 43.9 and JD 44.9), and Granger drains (JD 27.5 and JD 28.0) was composed of fines.

Table 4. Summary of habitat features measured in drains during February and March 2001. Lateral drain information is presented below their respective primary drain (i.e., JD 27.5 is a lateral drain to Granger).

Drain	Survey Length (M)	Percent Sampled	Average Width (m)	Average Depth (m)	Average Stream Gradient (%)	Average Wood Class	Average % Embedded Substrate
Corral	3761	72	2.3	0.28	0.9	2	25
Snipes	6552	100	3.0	0.38	1.0	1	12
Spring	5176	83	3.2	0.41	0.9	1	27
Sulphur	11207	99	6.8	0.56	0.3	1	64
JD 33.4	3844	95	3.5	0.60	0.3	1	28
JD 35.4	2807	43	2.1	0.27	0.2	1	14
JD 37.9	1596	69	2.5	0.51	0.5	1	49
JD 40.2	7365	98	2.6	0.42	0.4	1	54
JD 43.9	7864	83	2.9	0.44	0.7	1	46
JD 44.9	2315	82	2.0	0.51	0.6	1	56
JD 46.4	1627	89	2.7	0.38	1.2	1	29
Granger	3966	89	3.8	0.56	0.3	1	46
JD 27.5	100	100	2.2	0.15	0.0	1	--
JD 28.0	100	100	3.1	0.15	0.0	1	--
Moxee	4529	98	3.8	0.44	0.4	1	32

Cover

All drains had a wood complexity of 1 (little to no wood present) with the exception of Corral which had a wood complexity score of 2 (Wood present, but contributes little to habitat complexity) (Table 4).

Barriers

Structures that posed potential migration barrier for either upstream or downstream migration of adults or juvenile salmonids were noted and described by the type of barrier encountered. Throughout the drains, 40 potential barriers were identified (Table 5). Sulphur Creek Wasteway and its lateral drains had the highest number of potential barriers observed (26).

Each barrier surveyed was also given a passability rating according to how difficult adult salmonid passage is at different flows. The rating score ranges from 1 (passable at most flows) to 4 (complete barrier at all flows). Sulphur Creek Wasteway had the largest number of barriers with a rating above 3 (impassable at most flows) with most occurring on lateral drains. Although, Sulphur Creek Wasteway main channel is barrier free until drain mile (DM) 7 (Large concrete flumes). In comparison, Spring Creek has 3 mainstem barriers at 0.4, 1.2, and 2.7 miles upstream of the confluence with Snipes Creek. The lowest barrier on Spring Creek is likely to impair fish passage at most flows, so the potential fish habitat above that point may be largely inaccessible to anadromous fish. Only 1 possible fish barrier was observed on Moxee drain (DM1.8), and 2 on Snipes Creek main channel at 1.6 and 3.8 miles upstream. The lower barrier on Snipes Creek is below the beaver ponds, while the upper barrier was upstream of them. The lower barrier likely permitted passage during flows that occurred in most years. Seven possible barriers were observed on Granger drain and all were culverts over 24-m long having a rating of 2

(impassable at some flows).

Table 5. Adult and juvenile salmonid barrier, type, and locations for the drains surveyed in the lower Yakima Basin, Washington. Scores are for passability by adults and are: 1=generally passable, 2=impassable at some flows, 3=impassable at most flows, and 4=Complete barrier.

Drain	Barrier #	Passability	Meters Upstream	Mile Upstream	Barrier Location	Description
Snipes	1	2	2,642	1.64	Rch 6, Unit 8, 110m below McReadie Rd.	1.0m high by 4.5m wide, concrete diversion dam
Snipes	2	3	6,169	3.83	Rch 8, Unit 16, Square CVT 380m below end survey.	1.1m high by 1.4m long, step into a concrete square CVT
Spring	3	3	588	0.37	Rch 1, Unit 38, at Hess Rd.	1.1m high by 0.85m long, step into a concrete square CVT
Spring	4	2	1,859	1.15	Rch 2, Unit 6, Along Old Inland Empire Hwy.	0.55m man made step
Spring	5	2	4,336	2.69	Rch 5, Unit 42, Just below the pump house	0.95m high, by .3m long weir
Sulphur	6	4	11,188	6.95	Rch 6, Unit 12, Flumes at Sheller Rd.	Large concrete flume
JD 33.4	7	4	108	0.07	Rch 1 of JD 33.4, Drain on Right Bank	Concrete flume. First step is 1.3m high, second is @2m high
JD 33.4	8	2	3,685	2.29	Rch 1, Unit 55	82m Culvert, 1.5 meter diameter
JD 33.4	9	3	3,843	2.39	End of Rch 1	3m diameter tin culvert going underground
JD 35.4	10	3	85	0.05	Rch 1, Unit 1 (Unsampled) Hwy 82 Culvert	76m long concrete culvert
JD 35.4	11	1	1,462	0.91	Rch 1, Unit 19, just donwstream of Lincoln and 16th.	.25m step into a tin culvert
JD 35.4	12	3	1,463	0.91	Rch 1, Unit 20, Near corner of Lincoln and 16th st.	3m diameter tin culvert which is 915m long
JD 37.9	13	3	0	0.00	Rch 1, Unit 1, Confluence with Sulphur	1m high step into tin culvert
JD 37.9	14	4	1,596	0.99	End of Rch 1, Unit 23	Metal debris screen on upstream end of 400m CVT
JD 40.2	15	3	3,280	2.04	Rch 2, Unit 27, Interstate 82 Culvert	73m long culvert
JD 40.2	16	3	3,396	2.11	Rch 2, Unit 31, Hwy 12 Culvert	66m long culvert
JD 40.2	17	2	5,871	3.65	Rch 7, Unit 9, 300m below Ferson Rd.	0.65m high concrete weir
JD 40.5	18	3	Un-typed	Un-typed	Untyped lateral JD 40.5	Step into a dented culvert coming from Sunnyside canal
JD 43.9	19	2	5,055	3.14	Rch4, Unit 8, Interstate 82	75m long culvert
JD 43.9	20	1	5,163	3.21	Rch 4, Unit 13, Just upstream of I82	0.35m step into a tin culvert
JD 43.9	21	3	5,164	3.21	Rch 4, Unit 14	100m long culvert
JD 43.9	22	2	5,680	3.53	Rch 5, Unsampled Rch, 75m downstream of Bethany Rd.	1.0m step into culvert
JD 43.9	23	1	6,566	4.08	Rch 6, Unit 19, Woodall Rd.	.25m step into culvert
JD 43.9	24	1	7,198	4.47	Rch 6, Unit 36, Woodworth Rd.	.25m step into culvert
JD 43.9	25	3	7,243	4.50	Rch 6, Unit 40, 130m upstream of Woodworth Rd.	1m step into a culvert
JD43.9	26	3	7,566	4.70	Rch 6, Unit 48,	Steep shallow cascade into a CVT
JD 44.9	27	3	469	0.29	Rch 1, Unit 5, Interstate 82/Hwy 12 Culvert	200m long culvert
JD 44.9	28	3	734	0.46	Rch1, Unit 7, Stover Rd.	200m long culvert
JD 44.9	29	1	1,590	0.99	Rch 1, Unit 19, Woodall Rd.	0.3m step into culvert
JD 46.4	30	3	0	0.00	Rch1, Unit 1	134m long culvert
JD 46.4	31	1	1,237	0.77	Rch 1, Unit 19	0.3m step into culvert
JD 46.4	32	3	1,627	1.01	Rch 1, End of Survey at Sunnyside Canal	1m step into a culvert
Granger	33	2	396	0.25	Rch 1, Unit 9, Main St.	85m long culvert
Granger	34	2	578	0.36	Rch 2, Unit 4, East A St.	50m long culvert
Granger	35	2	711	0.44	Rch 2, Unit 7, New Culvert	73m long culvert
Granger	36	2	899	0.56	Rch 2, Unit 9, Culvert	24m long culvert
Granger	37	2	967	0.60	Rch 2, Unit 12, Culvert	Small (1.0m diameter) 24m long culvert
Granger	38	3	1,093	0.68	Rch 2, Unit 17 Culvert	Small (0.7m diameter) 25m long culvert
Granger	39	2	1,272	0.79	Rch 2, Unit 23, Hwy 223	50m long culvert
Moxee	40	2	2,835	1.76	End of Rch 3, 380m below Birchfield Rd.	0.6m high concrete weir

WATER QUALITY

Temperature

Temperature and flow data for the drains were obtained from the SVID, and the United States Bureau of Reclamation. We were unable to obtain temperature data for Moxee Drain and Corral Creek for this report. During our survey period, the water temperature in all drains varied from 4^{o}C to 12^{o}C.

During the irrigation season, temperatures reached daily averages as high as 23^{o}C. Snipes and Spring, which are the smallest of the four drains, had the most variable temperature patterns ranging from 0 to 23^{o}C (Figure 12). Sulphur and Granger have temperature patterns varying between 5 to 21^{o}C.

Water temperatures are similar between drains throughout much of the year. In the summer, the temperature regimes are separated on average by only a few degrees with the smaller drains becoming warmer near the middle of July. Average summer temperatures are 16-21^{o}C in Granger, and 18-23^{o}C in Snipes. In the winter the temperature spread between drains is slightly higher with the smaller drains (Snipes, Spring) getting colder than the larger Sulphur and Granger drains. Average winter temperatures are 8-10^{o}C in Granger, and 2-6^{o}C in Snipes. The temperature regimes in the drains fall within the range to support salmon and steelhead (Figure 12).

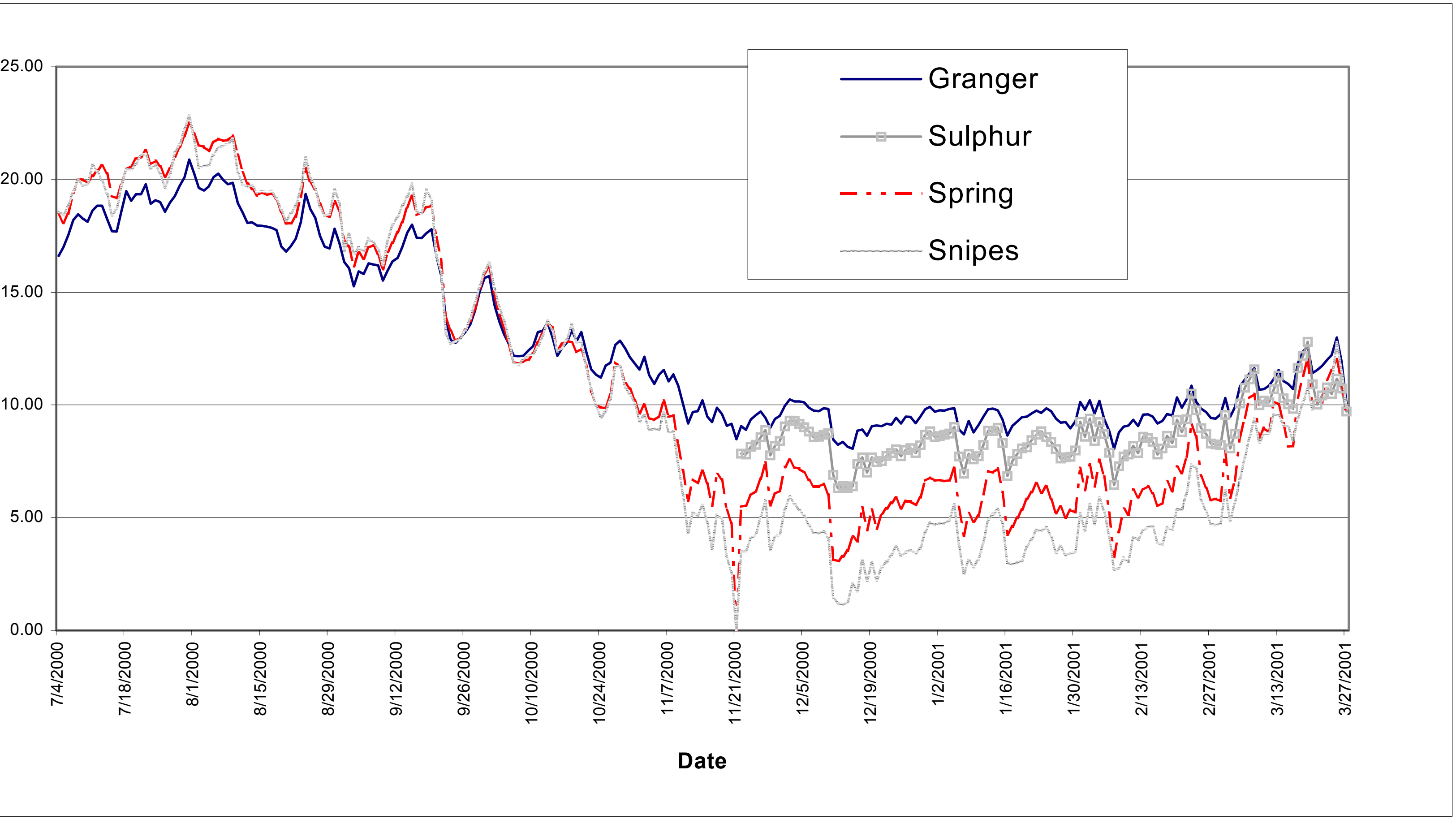

Figure 12. Average weekly mean water temperature for four irrigation drains (Snipes, Spring, Sulphur, and Granger) in the lower Yakima Basin, Washington State. Non-irrigation begins around October 15th and ends near March 15th. Data ranges from July 4th, 2000 to March 27th, 2001, with the exception of Sulphur (Nov. 21,2000 to March 27th ,2001)

Flow

Flows in drains during the irrigation season are several times higher than during the non-irrigation season. Source of water for the drains during October 21 through March 14 (non-irrigation season) is mostly ground water that rises to the surface. During the non-irrigation season flows range between drains from approximately 1cfs (Snipes Creek, Figure 13) to near 70cfs in Sulphur Creek Wasteway (Table 6, Figure 7). During the Irrigation season flows are greatest in Sulphur Creek Wasteway averaging 276 to 375 cfs. Summer flows in all other drains generally range from 30 to 60 cfs. Flow data for Corral Creek was not available for this report.

Chemistry

RSBOJC has collected water quality data on a bi-weekly and tri-weekly basis from 3 of the 5 study drains (Granger, Sulphur, Snipes/Spring). Data for Moxee Drain and Corral Creek were not available for this report. A summary of observations for pH, dissolved oxygen, turbidity, and nitrate levels are presented in Table 6.

Table 6. Water quality information for drains during irrigation and non-irrigation season, 1997 to2001. All data is presented as means for each respective drain.

Drain/ Year	Discharge (cfs) Irrigation	Discharge (cfs) Non-irrig.	pH Irrigation	pH Non-irrig.	DO (ppm) Irrigation	DO (ppm) Non-irrig.	Turbidity (NTU) Irrigation	Turbidity (NTU) Non-irrig.	NO3+2 (mg/L) Irrigation	NO3+2 (mg/L) Non-Irrig.
Snipes										
1997	51.2	2	8	--	9.9	12.2	15.5	3.3	0.9	3.9
1998	48.8	1.5	8.2	8.6	9.7	13.8	14.4	2	0.7	4.1
1999	38.6	1.5	8.4	8.8	10.2	14	11.2	2.4	0.4	3.2
2000	30.2	1.5	8.2	8.7	10	13.3	8.7	1.9	0.4	2.7
2001	--	0.8	--	8.6	--	13.7	--	2	--	2.4
Spring										
1997	55.5	5.8	8.1	--	10.1	12.2	33.9	4.6	1.6	7.3
1998	46.6	3.8	8.3	8.8	9.8	13.6	27.2	3.5	0.9	5.8
1999	51.4	4.1	8.6	8.9	10.4	13.6	27.3	4.7	0.7	5.9
2000	53.9	5.8	8.3	8.7	10.2	13	17	3.8	0.8	5.8
2001	--	3.7	--	8.8	--	14.1	--	3.4	--	6.4
Sulphur										
1997	307.5	71.1	7.9	8.5	9.7	10	50.6	17.8	2.8	8.1
1998	276.6	70.7	8.2	8.6	9.4	12.1	37.2	22.6	2.2	7.6
1999	357.2	67.5	8.1	8.6	10.2	11.7	31.5	9.8	1.7	7.4
2000	375.4	58.1	8.2	8.5	10.4	11.3	13.9	17.3	1.6	7.4
2001	--	49.5	--	8.4	--	11.5	--	12.4	--	7.5
Granger										
1997	61.5	24.4	7.9	8.3	8.6	8.7	131.1	23.8	3	6.2
1998	52.9	24.7	8	8.3	9	9.7	81.1	27.1	2.5	6.2
1999	58.1	22.8	8.1	8.4	9.2	10.5	83.7	15.7	2.1	5.9
2000	55.3	24.5	8	8.4	9.3	9.9	34.4	15.8	2.5	5.9
2001	--	21.9	--	8.4	--	10.4	--	22.9	--	6
Moxee										
1999	47.3	12.2	--	--	--	--	--	--	--	--
2000	63.4	14.4	--	--	--	--	--	--	--	--
2001	48.9	16.9	--	--	--	--	--	--	--	--

RIPARIAN VEGETATION

Riparian vegetation was dependant on land use and location within each basin. Farming and ranching dominate the land use in our study areas and influenced the extent of vegetation growth. In some areas, animal grazing or landscaping keeps the riparian vegetation low and well back from the bank. Vegetation has also been removed from some drains for the purpose of improving the flow capacity. The dominant vegetation throughout all study drains were annual grasses and shrubs, with few deciduous small trees (Appendix D).

Stream shading was provided not only by vegetation but also by the height of the stream bank. Corral Creek had the most vegetation and also had the highest amount of stream shading for all drains surveyed. Approximately 76% of the stream was shaded. Stream shading in the other drains was 20% in Snipes Creek (Figure 13), 29% in Sulphur Creek Wasteway, 48% in Spring Creek, 51% in Granger Drain, and 42% in Moxee drain. In some drains, such as Sulphur Creek Wasteway (Figure 7), the bank was the only source of shade.

Figure 13. Stream riparian area on Snipes Creek during non-irrigation drain habitat survey of February and March, 2001.

DISCUSSION

Attributes of instream habitat indicate there is little potential for natural producing of salmonids in Sulphur, Granger and Moxee drains, but there is fair to good habitat for natural production in Corral, Snipes and Spring drains. The primary habitat factors in Sulphur, Granger, and Moxee drains that negate their potential to rear salmonids are their predominance of silt and sand substrate, high embeddedness of the limited amounts of gravel and cobble substrate, and paucity of riffle habitats that produce most food for juveniles salmonids. Each of these factors is more favorable in Snipes, Spring and Corral creeks. Beaver ponds present in Snipes, Spring, and Corral drains add a valuable dimension to rearing habitat for juvenile salmonids.

The most notable adverse habitat feature limiting salmonids production was the poor substrate quality for spawning and incubating eggs, or for providing cover for invertebrates. Substrate quality is a function of substrate supply (geology of the area) and stream power to transport sediment. Thus, in a stream that drains consistent geology, fine sediments increase as gradient decreases (gradient drives the velocity component of stream power). In the drains we surveyed the percentage of fines increased as the geology changed from basalt to sedimentary deposits. Gradient in the Northwest drains (Sulphur, Granger , and Moxee) was less than half that in the southeast drains (See Table 4). Further, the southeast drains flow predominantly through basalt geology while the northwest drains flow through sedimentary deposits (Monk 2001).

Both the percentage that fines composed of the substrate (categories of silt and sand combined), and the percentage that gravels in the riffles were embedded were often in the range that severely impairs egg incubation and juvenile rearing. Fines cement gravel and suffocate eggs, and embeddedness blocks flow of water and movement of invertebrates through streambed gravels. We measured embeddedness in the riffles,

because that is where drifting invertebrates (food for salmonids) would be produced, where some spawning would occur, and where water velocity would keep gravels cleaned in a productive stream. Fines composed 45%-100% of substrate in every reach of Moxee, Granger and Sulphur drains (Figure 10). Embeddedness in the few riffles present in the three northwest drains averaged 32% in Moxee Drain, 46% in Granger Drain, and 64% in Sulphur Wasteway (Table 4). Further, the frequency distribution of embeddedness observed in individual riffles indicated that over half of the riffles in the Sulphur Creek Wasteway, and about one third of riffles in the Granger and Moxee drains were over 50% embedded (Figure 10). The percentage of fines and embeddedness were similarly high in all of the lateral channels entering these drains (Appendix A).

Bjornn and Reiser (1991) showed that percentage emergence of fry placed in a gravel-sand mixture decreased to zero when fines reached 40% or higher (Figure 14). Further, Bjornn and Reiser (1991) found that density of juvenile steelhead and chinook in experimental stream channels during summer and winter was reduced by roughly half when enough sand was added to embed the large cobble substrate to 50% in an experimental stream (Bjornn et al 1977). These findings indicate that the amount of fines and embeddedness within Moxee, Granger and Sulphur drains would effectively prevent any meaningful production of salmonids in those channels.

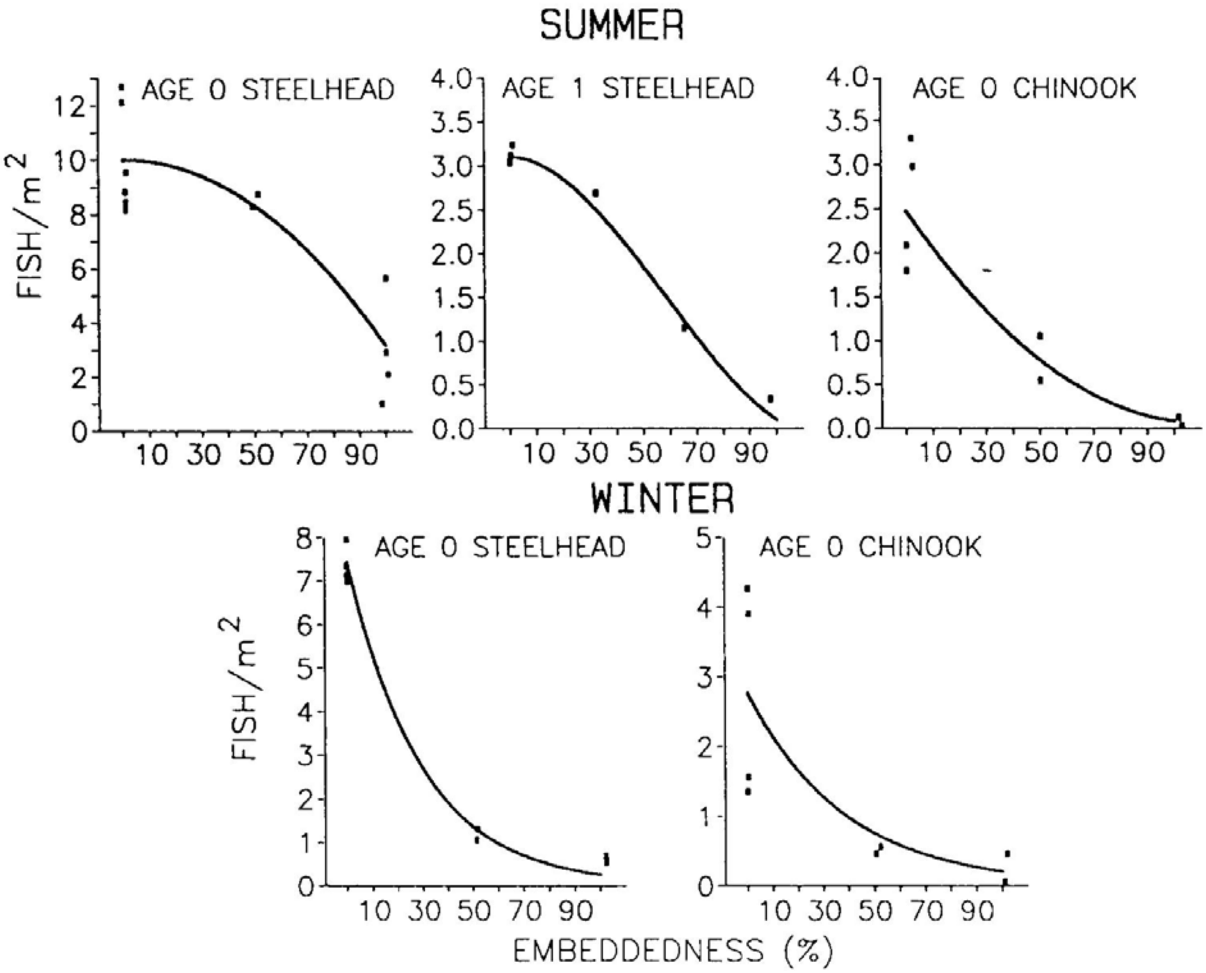

Figure 14. Densities of chinook salmon and steelhead juveniles remaining after 5 days during summer (top) and winter (bottom) tests in laboratory stream channels with varying amounts of embeddedness by fines < 6mm. From Bjornn et al. (1977).

The levels of fines in the substrate and embeddedness in the riffles were more satisfactory of salmonids production in many of the reaches within Snipes, Corral, and Spring creeks drains. Fines composed <25% of substrate in one reach of Corral Creek, two reaches of Spring Creek and six reaches of Snipes Creek (Figure 6). Embeddedness was <30% in 65-75% of riffles in those drains (Figure 11). The differences in amounts of fines and embeddedness in these major drains can be explained by their gradient

differences. Corral, Spring and Snipes creeks, which had less fines and embeddedness, averaged about 1% gradient, while Moxee, Granger and Sulphur drains with high amounts of fines and embeddedness, averaged under 0.4% gradient.

Hawkins et al. (1983) present data from natural streams in western Oregon showing that salmonids were present in all sites with gradients ≥1%, but were absent at 8 of 10 sites with gradient under 1%. Further, Hawkins et al. (1983) found the percentage fines in the substrate was highly related to gradient, and the percentage of fines jumped from <10% in riffles within reach gradients ≥1% to >25-61% fines in reaches < 1% gradient. The high percentage of fines in the low gradient reaches was sufficient to reduce production of both invertebrates and juvenile salmonids (Hawkins et al. 1983). These findings by Hawkins et al in Natural streams of western Oregon are similar to those for the drains we surveyed in the Yakima Basin. Thus, it is likely that substrate quality of the Yakima drains is driven by gradient and geology rather than land use practices.

In channel reaches having low levels of fines and embeddedness, we examined data on the percentage of substrate composed by gravel or cobble as indicators of potential spawning and rearing habitat. The differences in substrate in these major drains can be explained in part by their differences in geology. The drains in to the southeast (Corral, Snipes, and Spring) are dominated by basalt whereas the drains to the northwest (Sulphur, Granger, and Moxee) are dominated by silt and sand. Gravel and cobbles composed >70% of the substrate in many reaches of Corral, Spring and Snipes creeks (Figure 8). These levels are suitable for salmonids production. In contrast, most reaches of Granger, Sulphur and Moxee drains had <30% cobble and gravel. Favorable levels of gravel and cobble (33-60%) were also found in the upper reaches of Lateral JD 40.2 of the Sulphur Wasteway, but fines exceeded 35% and embeddedness ranged from 35% to 75% in those reaches.

USFWS (1990) concluded from winter studies in the Trinity River, "For steelhead, by far the most important criterion of (*winter*) habitat utilization is the presence of cobbles from six to twelve inches in diameter free of sand or silt." The preferred winter habitat for steelhead differed sharply from that for coho (USFWS 1990). Coho were found in still water with aquatic vegetation or woody debris as the main cover, and in 0.5 to 2.5 ft depth. Coho were rarely found beneath cobbles, although steelhead were usually found among cobbles. Coho were often found in schools in winter, while steelhead were solitary. These differences between steelhead and coho were also reported in other studies by Hartman (1965) and Bustard and Narver (1975a). The preference of steelhead to overwinter in the interstices of cobbles was also reported by Bjornn (1971), Bustard and Narver (1975a), Hartman (1965), and Swales et al. (1986).

The amount of riffle habitat is also a good indicator of potential for salmonid production. Riffles are the factories of production for drifting invertebrates that salmonids feed on and Cramer (2001) deduced from a broad range of studies that the capability of a stream to support salmonids begins to decline as the area composed by riffles drops under 50%. All but two of the 16 reaches surveyed in the Corral, Spring, and Snipes creek drains had >50% riffles (Figure 6). In contrast, only 2 of 15 reaches in Granger, Sulphur, and Moxee drains had >50% riffles, and 7 of 15 had <20% area in riffles.

Many studies have shown that riffle habitats are the primary food producing areas for salmonids. Although salmonids can forage on prey on the substrate surface, they feed predominantly on drift in streams (Elliott 1973 as cited by Murphy and Meehan 1991). Hawkins et al (1983) found in 13 coastal streams that salmonid density was correlated to invertebrate density in riffles (collector-gatherers), but not to invertebrates typically found in pools. Further, most invertebrates in pools were in shells or protective casings, and did not drift, while invertebrates found in riffles were those most likely to drift (Hawkins et al 1983). Similarly, Rader (1997) found that invertebrates qualifying in the guild most highly

available as food for salmonids were produced primarily in riffles, and were swimmers and frequent intentional drifters. Waters (1962) found that *Baetis* mayflies were produced in riffles, and that 60% of stream area had to be in riffles in order to produce the abundance of *Baetis* mayflies consumed by fish in pools.

Given that Corral, Spring, and Snipes creek drains have suitable substrate and amount of riffles for salmonids production, we next examined the species of salmonids they might be capable of supporting. The radical change in flow that occurs in these channels during the change from the irrigation to the non-irrigation season would influence their hydraulic suitability by anadromous salmonids. The non-irrigation season begins in mid October, and flows drop to about 5 cfs in Spring Creek, 1-2 cfs in Snipes Creek, and perhaps 1 cfs in Corral Creek (Table 6). Gage data were not available for Corral Creek, but flows appear to be less in Corral Creek than in Snipes Creek. Low flows would generally exclude chinook, although an occasional fall chinook has been observed to enter these channels prior to the drop in flow about mid October (Monk 2001). If chinook and coho spawned successfully when flows were 40-60 cfs, survival of the eggs would be unlikely after flows dropped to 1-5 cfs. We observed adult salmon skeletons in brush along Snipes Creek below the beaver ponds, indicating that salmon had spawned while flows were still dropping in November after the irrigation season (Monk 2001). Some coho that entered in early November might also be able to hold in the beaver ponds and spawn in the limited opportunities available in Snipes or Corral Creek when flows have dropped. Spring Creek has enough flow at 5 cfs to provide for migration and spawning of coho, steelhead, and trout, but low flows in Corral and Snipes creek would probably prevent adult migration. Juvenile salmon and trout, particularly coho, are well known for there ability to migrate up and rear in small tributaries that are not used for spawning. Therefore, each of these drains could be used for rearing by juvenile salmon and steelhead.

Corral, Spring, and Snipes Creek drains have suitable substrate and habitat for

salmonid production, but there is potential barriers in Spring and Snipes creeks that may block upstream migration of adults to spawning habitat. Snipes has 2 barriers and Spring has 3 barriers (Table 5) that are rated as either partial barriers at some flow or full barriers at most flow. Potential barriers on Spring Creek are of most concern, since the first is located just upstream (RM 0.4) of the confluence with Snipes Creek and is rated as a barrier to adult salmon at most flows. However, lower Snipes barrier is passable at most flows and upper barrier is above the majority of suitable fish habitat. Multiple barriers compound the difficulty of accessing upstream spawning habitat and can therefore reduce the amount of available spawning habitat for adult to utilize.

The number of salmon and steelhead smolts that these drains are capable of producing could be estimated by applying the models developed by Cramer (2001) to the data on habitat features reported here. Those estimates are beyond the scope of this report. However, we have described habitat features in these drains that would determine their capacity to produce smolts. In general, rearing densities of juvenile salmon and steelhead differ between habitat types (pools, riffles, and glides), and these differences can be used as a starting point to estimate the number of smolts a stream can produce. The model developed by Cramer (2001) used habitat features and known fish densities for each habitat feature to estimate production. Bjornn and Reiser (1991) present data on the densities of chinook parr and yearling steelhead found within stream unit types averaged over 22 streams surveyed in Idaho during 1985 and 1986 (Figure 15). They found that relative densities between unit types was consistent across streams and years. Chinook were most abundant in pools (21-22 fish/100m^2) and runs (14 fish/100m^2) and least abundant in pocket water (5-10 fish/100m^2) and riffles (2-5 fish/100m^2). Pocket water is a type of riffle in which boulders create pockets of calm water within the riffle. Age 1+ steelhead were most abundant in pocket water (2 to 5.5 fish/100m^2), and varied from 2-3.5 in pools, 1.5-2.5 in runs, and 0.5-2.0 in riffles.

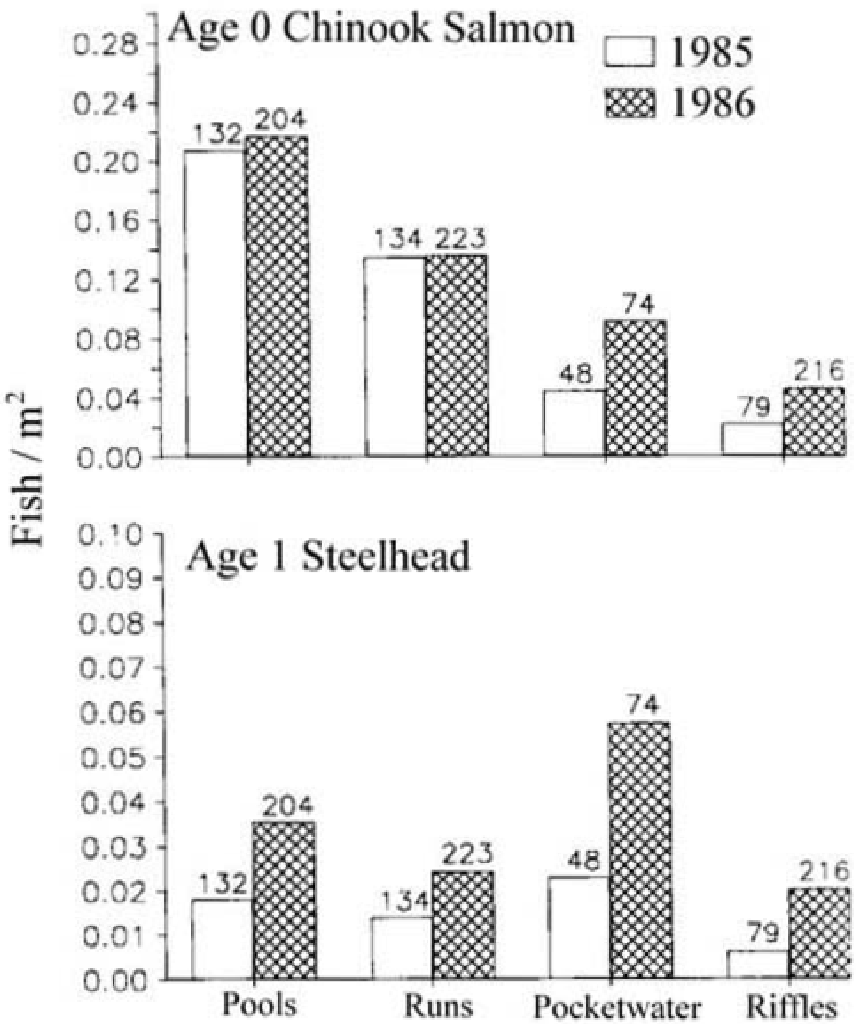

Figure 15. Densities of chinook parr and age 1+ steelhead in various channel unit types averaged for 22 Idaho streams. Numbers above bars are the number of units sampled. From Bjornn and Reiser (1991).

Further, the suitability for each habitat unit to produce juvenile salmonids is influenced by depth, substrate and cover, among other factors. In general, juvenile chinook

and steelhead seek faster and deeper water as they grow larger (Chapman and Bjornn 1969; Everest and Chapman 1972) (Figure 16). Thus, the size of small streams can become more constraining to juvenile salmon and steelhead as they increase in size. Age 1+ steelhead juvenile production at the oldest age that juveniles reach before smolting. Age 1+ steelhead are generally 100-150 cm long, and prefer depths from 50 to 100 cm (1.5-3 ft) deep. Steelhead and chinook parr tend to completely avoid areas that are less than 15 cm (6 inches) deep. Depths we observed in Corral and Snipes Creeks (Appendix A) indicate that only the pools and some glides would be suitable for rearing of parr during the non-irrigation season, because depths in riffles and glides would be too shallow to hold parr. The greater flows in Spring Creek result in some riffles and glides exceeding 15 cm of depth, so some production could occur there, but most production would still be limited to pools.

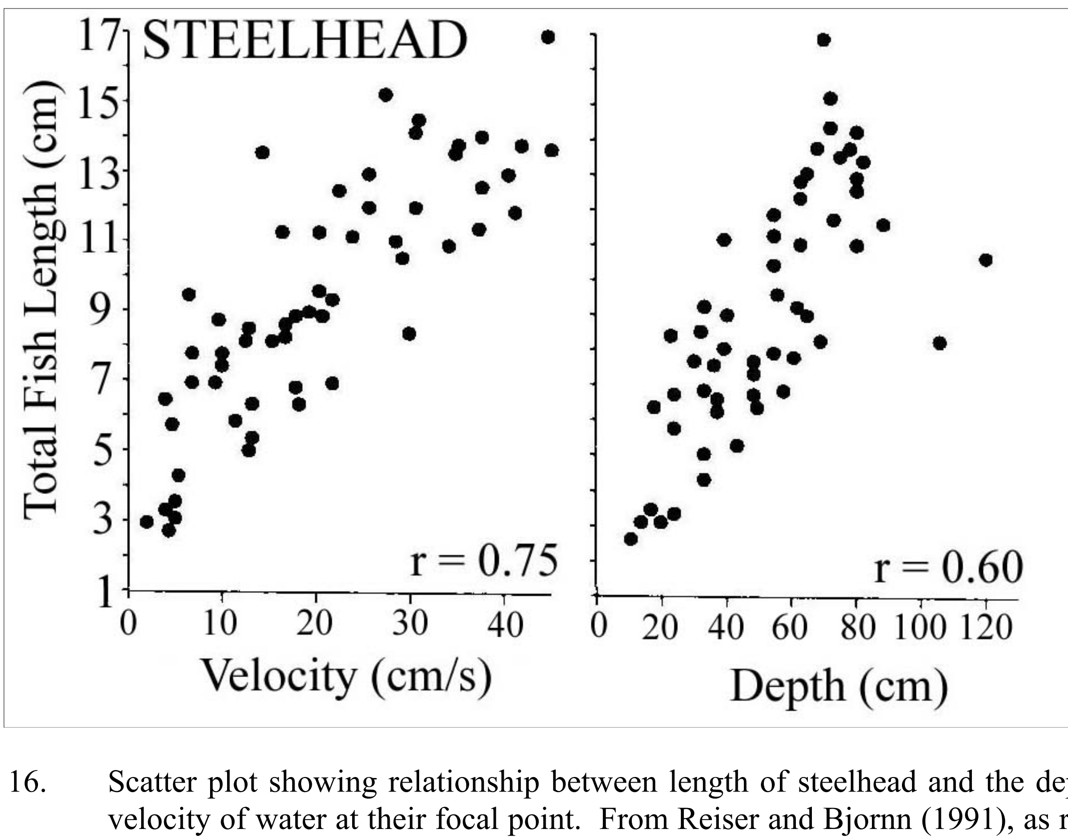

Figure 16. Scatter plot showing relationship between length of steelhead and the depth and velocity of water at their focal point. From Reiser and Bjornn (1991), as redrawn from Everest and Chapman (1972).

The capacity for these streams to rear coho would also be dependent on the area of pools, and would be increased by the area in beaver ponds. Coho juveniles prefer rearing in slow moving pools, and make high use of beaver ponds. The Oregon Department of Fish and Wildlife Research Division (Solazzi et al. 1998) developed a model that would identify limiting habitat and estimate carrying capacity for juvenile coho salmon. That model uses coho rearing densities specific to each habitat type by life stage, as derived from the data of Nickelson et al. (1992) (Table 7). The data obtained by Nickelson et al. (1992) show that coho strongly prefer beaver ponds and alcoves during winter. Further, follow-up studies to test the limiting factors model on four coastal steams in Oregon indicated that smolt production was limited by winter habitat in all four streams (Solazzi et al. 1998). Those findings suggest that the beaver ponds on Snipes and Corral Creeks may provide good winter habitat for juvenile coho that migrate upstream to those ponds. Such migration is typical behavior for juvenile coho.

Table 7. Rearing densities and density-independent survival rates used in the habitat limiting factors model developed by ODFW (Solazzi et al. 1998).

Juvenile density (fish/m^2) by habitat type			
Habitat type	Spring	Summer	Winter
Cascades	0.0	0.2	0.0
Rapids	0.6	0.1	0.01
Riffles	1.2	0.1	0.01
Glides	1.8	0.8	0.1
Trench pools	1.0	1.8	0.2
Plunge pools	0.8	1.5	0.3
Lateral scour pools	1.3	1.7	0.4
Mid-channel scour pools	1.3	1.7	0.4
Dammed pools	2.6	1.8	0.6
Alcoves	2.8	0.9	1.8
Beaver ponds	2.6	1.8	1.8
Backwater pools	5.8	1.2	0.6
Spawning Gravel	2,500 eggs/redd / 3m^2/redd = 833 eggs/m^2		

Density independent survival rates	
Egg to smolt	0.32
Spring fry to smolt	0.46
Summer parr to smolt	0.72
Winter presmolt to smolt	0.90

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