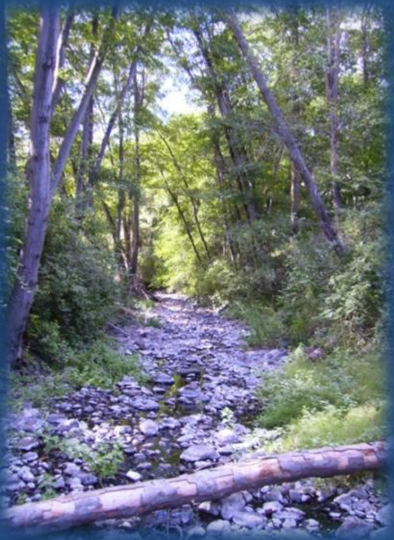
Middle Snake Watershed Instream Habitat Assessment

WRIA 35





Submitted to:
Middle Snake Watershed
Planning Unit

Submitted by:
Dr. Jeffery L. Ullman &
Dr. Michael E. Barber
Washington State University
Pullman, Washington

2009

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Final

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Executive Summary

This document presents the findings of an instream habitat assessment conducted for select tributaries in the Middle Snake Watershed (Water Resource Inventory Area 35 [WRIA 35]). Initiated by the WRIA 35 Planning Unit, the purpose of this report is to provide technical information on streamflow and its relation to salmonid populations, principally steelhead, in the following low-flow streams: Almota, Alpowa, Couse, Deadman, George, Joseph, Pataha and Tenmile Creeks. This mandate is in accord with the WRIA 35 Unit goal of identify minimum and target streamflows for salmonid management. These "instream flows" are a regulatory and managerial tool established by Washington State statute to protect and preserve instream resources and values. The instream flow determination process requires complex negotiations that address factors concerning fish habitat and other uses deemed important by watershed stakeholders. The data, analysis and recommendations presented in this report are intended to provide a supporting scientific body of knowledge on the aquatic habitats found in these streams for use in the instream flow negotiation process.

Guidance is lacking for establishing instream flow recommendations for low-flow and intermittent streams in semi-arid/arid environments, such as those found in the Middle Snake Watershed. Draining the extreme southeastern corner of Washington into the Snake River and its major tributaries, this region exhibits geologic, hydrologic and climatic conditions unique for streams containing anadromous salmonids. Moreover, steelhead in these tributaries can be found in habitat exhibiting flow conditions that are typically not recognized as being able to sustain salmonids, and standard fish habitat models are unable to accommodate these conditions. Method selection is further confounded by the distinct characteristics displayed by each of the sub-basins due to their geographic setting and differing land-uses. Thus, three standard, widely-used instream flow assessment techniques – the Wetted Perimeter, Toe-Width and Tennant methods – were utilized to develop a suite of instream flow recommendations.

The instream flow assessment methods selected employ disparate approaches to deriving recommended instream flows. The Wetted Perimeter method requires site-specific hydrologic and physical data to determine a wetted perimeter versus discharge relationship for a given stream cross-section. When this relation is plotted, visual breakpoints can be identified that theoretically correspond with critical streamflows below which habitat becomes unsuitable for fish. This clear mathematical definition relating habitat to discharge makes this a popular method that can easily be explained to diverse audiences. The Toe-Width method, similarly involves the use of site-specific data, but directly relates streamflow to the biological component based on a series of regression equations developed for steelhead streams in western Washington. In this case, the width between the toes of the banks, based on changes in slope, substrate particle size and vegetation in the channel, are measured at several transects and averaged to provide the input parameter for the model. The Tennant method is a statistical technique using discharge – time series values from hydrologic records to prescribe instream flows based on a percent criterion that corresponds to a given habitat condition. This method maintains a flexible framework that allows for selection of different flow regimens depending on management goals.

The recommended instream flows derived from the three instream flow assessment methods were compared to each other in relation to the respective hydrologic conditions and existing fish communities to evaluate their applicability to the Middle Snake Watershed tributaries. Based on this analysis, prescribed instream flow criteria were developed for each tributary as initial starting points for discussions regarding the establishment of instream flows. It is stressed though that these recommendations are not intended as definitive values due to the negotiation process inherent to the setting of instream flow rules. Thus, the flows presented are termed here as "discussion flows". While the inclusion of a seasonal component is essential to effective instream flow standards, the "discussion flows" only represent average annual flow rates, which is an artifact of the instream flow assessment methods used. This would be the case with any of the potential assessment techniques that could be used based on the circumstances. Therefore, the "discussion flows" are intended as a framework to guide the development of seasonal instream flow criteria based on a series of monthly flow statistics that were calculated in relation to the priority steelhead life-stages.

Several data sources were used to characterize the respective flow regimes, generate the recommended instream flows from the three instream flow assessment methods and derive the "discussion flows". Paired monitoring sites were established as part of this study along the length of each stream. Streamflow and accompanying data were measured at each site between September 2008 and June 2009 at roughly monthly intervals using standard velocity-area methods. Stream discharge data collected by the State of Washington Department of Ecology (Ecology) from 2003 to 2009 supplemented this hydrologic dataset. These records were obtained from a combination of telemetric and manual stage-height stations located near the mouths of each stream. Available fish surveys conducted by the Washington Department of Fish and Wildlife (WDFW) between 2000 and 2009 were compiled to elucidate the status of the salmonid populations in each stream, and for comparison with hydrologic trends, the prescribed flows obtained from the different assessment methods and the "discussion flows". Reports from a variety of sources were used to provide supporting information on the streams where available.

Each of the three instream flow assessment methods contained significant limitations that are discussed in this report. These ultimately resulted in the generation of instream flow values that failed to capture the unique conditions and salmonid populations inherent to the Middle Snake Watershed tributaries. The Wetted Perimeter method yielded overly-restrictive and unrealistic values, while the Tennant method conversely generated flow rates that appear not to be restrictive enough and could consequently prove inadequate in protecting water resources in the streams. The Toe-Width method yielded flow rates that fell between those of the other techniques, but the percent exceedance values were highly variable and generated a combination of recommendations that were overly-restrictive and not restrictive enough.

Due to the limitations inherent to applying these instream flow assessment techniques developed in other regions to the Middle Snake Watershed, none of the methods sufficed for recommending appropriate instream flow values for the study streams. Therefore, it was decided that a combination of the techniques should be used, and the resultant "discussion flows" were calculated by taking the average of the recommended instream flows generated by all three methods. This is a pragmatic means to deal with the situation, as any means selected would have been arbitrary. The "discussion flows" obtained by merging the different methods yielded values that corresponded well with the average annual flow rates for most of the streams. The table on the following page displays the "discussion flows" in relation to the instream flow recommendations provided by the different assessment techniques and the average annual flow rates for each stream. When used in conjunction with the monthly flow statistics in relation to the priority steelhead life-stages, it appears that this framework provides a strong basis for initiating instream flow negotiations.

Recommended "discussion flows" presented in relation to instream flow recommendations provided by the different assessment techniques and average annual flows.

Creek	Wetted Perimeter[1]	Toe-Width	Tennant[2]	Recommended "discussion flows" (cfs)	Average annual flows from Ecology data (cfs)[3]
	------------------	cfs	------------------		
Almota	7	1.9	0.6	3	3.0
Alpowa	17	3.7	1.8	8	9.1
Couse	4	2.3	0.5	2	2.3
Deadman	8	1.8	0.7	4	3.7
George	19	7.9	2.1	10	10.6
Joseph	100	14.3	22.6	45	113.2
Pataha	15	2.0	2.5	6	12.6
Tenmile	7	3.2	1.0	4	5.2

[1] Wetted Perimeter method derived values are for the most downstream locations only
[2] Tennant Method values based on 20% Q_{Avg}, which represents "good" habitat during low-flow season
[3] Ecology data collected at monitoring stations near mouths of streams, 2003-2009

The compiled fish surveys and characterized flow regimes used to conduct this assessment revealed several pertinent points that should be considered when determining instream flow standards for the Middle Snake Watershed tributaries. Among these, numerous examples illustrate the unique character of the Middle Snake Watershed salmonid populations. The intermittent streams exhibited sizeable numbers of rainbow/steelhead that frequently use habitat located above stretches that become dewatered on an annual basis. Fish displaying good body condition were found to occupy isolated pools containing negligible flow and in depths that are not recognized by established fish habitat models. Also, temperature regimes typically considered to be inadequate for steelhead were measured in reaches where steelhead are known to exist. Essentially, the fish reside where water is accessible during dry periods, and subsequently migrate when flows allow. This does not discount the need for instream flow standards to protect steelhead habitat, but it does highlight the point that the Middle Snake Watershed tributaries should not be compared to other systems containing steelhead that are not adapted to low-flow or intermittent conditions.

Since instream flow values will be negotiated on a stream-by-stream basis, summaries of the respective tributaries are provided that include a description of the existing flow regimes, description of the current steelhead population status and specific recommendations. These are encapsulated as follows:

- Almota Creek is located in an arid landscape, which leads to it exhibiting some of the lowest flow rates in the Middle Snake Watershed. Despite these low-flow conditions, a small but seemingly sustained steelhead population exists in Almota Creek. Evidence suggests that agriculture in the watershed has altered the natural flow regime, but it is unclear to what extent. Thus, it must be decided whether management of the system should be protective (i.e., maintain present conditions to preserve the current population) or restorative (i.e., promote activities that will increase fish production). The selection of a management goal will have bearing on the appropriateness of the 3 cfs "discussion flow", as well as seasonal components to the instream flow adopted.

- Alpowa Creek was previously described as a degraded stream that sustained a very small steelhead population. Recent efforts exemplify the positive impacts riparian restoration activities can impart on stream ecosystem health. Once considered a “flashy” stream devoid of streamside vegetation, Alpowa Creek now has a developing riparian system that presumably contributed to some of the most uniform flows measured in the study. Correspondingly, a strong steelhead run has emerged that consisted of an estimated 410 returning adults in 2009. It is recommended that when determining instream flow management criteria for Alpowa Creek the WRIA 35 Planning Unit consider that uniform flows consistently exceeded the presumably conservative 8 cfs recommended “discussion flow”, and that instream fish habitat has significantly improved.

- Couse Creek epitomizes the paradox found in the Middle Snake Watershed, wherein sustained steelhead populations exist under flow regimes that typically are deemed unable to support salmonids. At the same time, the stream appears sensitive to perturbations in the ecosystem, as it exhibits the smallest flows in the study, conveys elevated flows for short periods and contains large intermittent stretches. Thus, it is suggested that emphasis be placed on protecting existing habitat, rather than striving to significantly increase streamflow in this severely water-limited system. The nature of the Couse Creek flow regime makes use of the derived “discussion flow” impractical, and instead it is recommended that monthly flow statistics be used exclusively to guide “best judgment” decisions in developing instream flow criteria.

- Deadman Creek has been significantly impacted by multiple stressors and a recent emphasis on conservation practices in the watershed is just starting to elicit a response. It remains unknown to what degree the flow regime has changed, but evidence indicates other factors likely played a larger role in the systemic degradation of the stream. Irrigation activities do not appear to exert a noticeable effect on streamflow, but the recent invasion of noxious weeds in the riparian zones has been implicated in altering stream hydrology. Due to the complex interaction of factors that have contributed to very low steelhead production, it is recommended that the 4 cfs “discussion flow” (the only of which that exceeded the annual average flow in the study) be considered in the context of a holistic, restorative management strategy.

- George Creek presents an excellent illustration of an intermittent stream being able to produce a vibrant steelhead population. Recorded flows remained remarkably constant at an annual average of 4.6 cfs until 2009, at which time a series of extreme flow events occurred that skewed data analysis. Since the available dataset for George Creek was of a shorter duration, it is not possible to determine which characteristics best represent the true nature of the stream. Since the system is water-limited, yet the steelhead population remains by far the strongest of the study streams, it is recommended that instream flow management focus on protecting fish habitat rather than attempting to increase summer flow rates. Also, the instream flow value should remain tentative until more data elucidates the true nature of the flow regime.

- Joseph Creek yields significantly higher streamflows than the other study streams, and irrigation withdrawals do not appear to exert an impact on the system. While fish data for the stream is limited to one survey in the State of Washington, the steelhead population was found to be almost non-existent in this portion of Joseph Creek. Since stream discharge remains substantial year-round and the 45 cfs “discussion flow” was 60 percent lower than the average annual flow rate, it appears that streamflow is not the limiting factor to salmonid production in the reaches of Joseph Creek that lie within Washington. Rather, high water temperatures, poor riparian buffers with eroding banks in the lower reaches, and competing fish species appear to significantly impact steelhead numbers. If steelhead restoration is identified as a management goal in the stream, efforts should focus on these factors rather than water availability.

- Pataha Creek expresses the greatest human water demand of the study streams, supporting a total of 625 acres of irrigated land in the watershed that appears to significantly impact flow rates in the stream. While winter and spring streamflows are substantial in the middle and lower reaches, water levels are precariously low during the summer. Thus, several salmonids successfully use the protected headwaters sections, but can only use the lower 50 miles of the stream as migratory habitat. Since existing water rights are guaranteed under instream flow provisions, the ability to improve flows in the lower reaches is severely limited and the 6 cfs “discussion flow” will have little effect. Thus, it is recommended that a protective management strategy be used that focuses on the existing upstream steelhead population.
- Tenmile Creek represents a significantly water-limited, intermittent stream that sustains a respectable steelhead population. Despite the relative disparity between the lowest and highest average flow rates being the highest in the study, flow records demonstrate the most moderated response to different controlling factors. Although sections are dewatered yearly, steelhead utilize habitat along the continuity of the stream for spawning, so management goals should focus on the entire system rather than select reaches. The innate hydrologic nature, limited development and lack of notable diversions will likely prohibit increasing streamflow in Tenmile Creek. Therefore, the 4 cfs “discussion flow” is recommended to be used in a protective management approach to preserve the current steelhead population.

Overall, it is stressed that realistic, obtainable instream flow goals based on commonsense should be developed for each of these streams.

A partial list of potential management options are provided in relation to the findings of this assessment. Among other recommendations, it is strongly urged that hydrologic and fish monitoring activities be continued in the Middle Snake Watershed tributaries to provide much need information. The lack of both comprehensive and long-term data for these streams limits the ability to fully characterize these streams. However, myriad scientific data is provided in this report, which represents the best available scientific information on streamflow and its relation to salmonid populations in the Middle Snake Watershed tributaries, Thus correspondingly provides a strong foundation to support the instream flow determination process.

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Acknowledgements

This instream habitat assessment was developed through the participation and input of numerous stakeholders from the Middle Snake Watershed. This report could not have been completed without their time and effort.

The authors would like to thank the WRIA 35 Planning Unit for supporting this project. Additional acknowledgment and appreciate is given to the following who provided tremendous input throughout this study (in alphabetical order): Terra Hegy (WDFW), David Karl (WDFW), Kent Mayer (WDFW), Glen Mendel (WDFW), William Neve (Ecology), James Pacheco (Ecology), Jaime Short (Ecology), Timothy Simpson (Asotin PUD) and Mimi Wainwright (Ecology).

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Finally, the most sincere thank you is given to the numerous landowners who allowed access to their property, without which this study would not have been possible. The establishment of Water Resource Inventory Area (WRIA) Planning Units by the State legislature was intended to allow watershed stakeholders the opportunity to participate in the development of local solutions to water resources issues. These landowners who accommodated the needs of this study have fulfilled this concept of local participation and should be commended for their generosity.

Abbreviations

ACCD	Asotin County Conservation District
BMP	Best Management Practice
BPA	Bonneville Power Administration
cfs	cubic feet per second
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
D.O.	Dissolved oxygen
Ecology	State of Washington Department of Ecology
IFIM	Instream Flow Incremental Methodology
in.	inch
m^2	meter squared
mg/L	milligram per liter
NRCS	Natural Resource Conservation Service
PCD	Pomeroy Conservation District
PHABSIM	Physical Habitat Simulation
Planning Unit	WRIA 35 Planning Unit
Q_{Avg}	Average annual flow rate
$Q_{Avg,M}$	Average monthly flow rate
Q_{dv}	Preferred flow rate for spawning as delineated by the Toe-Width method
Q_r	Flow rate associated with sufficient rearing habitat as delineated by the Toe-Width method
Q_S	Flow rate associated with sustainable spawning as delineated by the Toe-Width method
Q_V	Preferred flow rate for spawning in regards to velocity (i.e., depth criterion omitted) as delineated by the Toe-Width method
QAPP	Quality Assurance Project Plan
R.M.	River Mile
Rainbow/steelhead	Juvenile stages of rainbow trout and steelhead are essentially non-distinguishable and are thus reported together
SWCA	NRCS Soil & Water Conservation Assistance Program
WDFW	Washington Department of Fish and Wildlife
WDOE	Abbreviation used for the State of Washington Department of Ecology when citing documents
WRIA	Water Resource Inventory Area
WRIA 35	WRIA designation for the Middle Snake Watershed

1. Introduction

1.1. Background

The Middle Snake Watershed (WRIA 35) represents the area in southeastern Washington that drains into the Snake River above the confluence of the Palouse River. The State of Washington instituted a framework for developing local solutions to watershed issues based on hydrologic units designated as Water Resource Inventory Areas (WRIAs), codified by the state legislature in Chapter 90.82 RCW. This law provided for the establishment of Watershed Planning Units that allow watershed stakeholders to jointly assess water resources in their watershed and determine appropriate management plans.

One of the basin-wide goals set by the WRIA 35 Planning Unit is to identify minimum and target streamflows, and manage streamflows to enhance habitat conditions for salmonids, with emphasis on steelhead and Chinook salmon (MSWPU, 2007). This objective corresponds with the intent to set instream flows throughout the State to protect and preserve instream resources and values (Chapters 90.22RCW and 90.54RCW).

“Instream flow” is a regulatory and managerial term that identifies a specific streamflow condition at a specific location on a given stream. An instream flow is typically presented as a range or regime that accounts for natural variations that occur throughout the year. “Streamflow” simply refers to the existing flow in a stream. Thus, while streamflow is a physical condition, instream flows are more abstract. Instream flow development is a process wherein a WRIA planning unit considers scientific data and incorporates this with other watershed information that includes broader water management strategies. An instream flow recommendation is intended to “protect and preserve instream resources”, which includes the needs of fish and wildlife, water quality, recreation, navigation, livestock watering and aesthetics (WDOE, 2007). Once formalized, the instream flow is adopted as a regulatory rule used primarily to define streamflows that need to be met in the stream and to evaluate potential new out-of-stream water uses (WDOE and WDFW, 2003).

Study purpose

The WRIA 35 Planning Unit decided to assess instream flows in select tributaries of the Middle Snake Watershed as a component of its watershed planning efforts (MSWPU, 2008). Conducted in the context of the statutes outlined above, this process necessitates the compilation of data, analysis of instream flow needs and development of recommendations on establishing minimum instream flow regulations.

This report represents the culmination of the *Middle Snake Watershed Instream Habitat Assessment* study. In accord with the goals of the WRIA 35 Planning Unit, the purpose of this project was to assess instream habitat and its relation to salmonid populations in select Middle Snake Watershed tributaries. This assessment focuses on characterizing streamflow conditions in the tributary streams of Alpowa, Almota, Couse, Deadman, George, Joseph, Pataha and Tenmile Creeks. Corresponding relations to salmonid populations emphasize the status of steelhead populations in these tributaries, as this is the focal species driving the development of minimum instream flow regulations in these streams; however, spring Chinook and redband rainbow trout are also considered (Section 1.3 provides information on these fish populations).

This instream flow assessment provides a foundation from which the WRIA 35 Planning Unit can evaluate instream flow issues in the select Middle Snake Watershed tributaries from an aquatic habitat perspective. The analysis and accompanying recommendations represent scientific information for use in discussions concerning the setting of instream flow standards for these streams, and the prescribed instream flows are not intended as definitive values. Thus, the flows presented are termed “discussion flows”. Actual setting of instream flow regimes requires negotiations between watershed stakeholders, the Planning Unit, the State of Washington Department of Ecology (Ecology), the Washington Department of Fish and Wildlife (WDFW) and other entities. Therefore, this document should be viewed as supporting material for use in the complex process of setting instream flows for the tributaries addressed.

This report was commissioned by the Asotin County Public Utility District on behalf of the Middle Snake Watershed (WRIA 35) Planning Unit through funds provided by Ecology grant number G0800220.

Report structure

This report documents streamflow conditions in the select Middle Snake Watershed tributaries, describes these flow regimes in the context of instream habitat and salmonid use, and discusses management options to help maintain adequate streamflows to protect quality habitat in these streams. The following topics are included in this document:

- A regional overview and individual stream descriptions, a depiction of the salmonid populations in the tributaries, and a general project description (Sections 1.2 – 1.4);
- A description of the study design, including: field methods employed in the study, other data sources used, the different instream flow assessment methods applied to the data, and data interpretation (Section 2.0);
- A summary of the results: stream flow regime descriptions, prescribed flows derived from the different instream flow assessment methods, and status of existing salmonid populations (Section 3.0);
- A discussion of the Middle Snake Watershed tributaries, including: relationships between salmonid populations and streamflow, a comparison of the instream flow assessment methods; and additional considerations pertinent to the streams addressed (Section 4.0);
- Recommendations and conclusions, including: prescribed instream flow values, seasonal considerations, general considerations and potential management options, summary of the current status and recommendations for the respective streams, and concluding remarks (Section 5.0); and,
- Appendices of data and accompanying supporting material (Appendices A - G).

1.2. Regional overview and stream descriptions

The Middle Snake Watershed is an important water resource that has been designated as one of the State’s 16 critical basins exhibiting a shortage of water for fish. Located in the extreme southeast corner of Washington, WRIA 35 occupies approximately 2,250 square miles that include tributaries to the Snake River. Land-use is represented by approximately 50 percent rangeland, 33 percent cropland, 15 percent forest and one percent urban area (MSWPU, 2008). Population density is low over the extent of the geographic area, comprised of approximately 25,000 residents.

The streams addressed in this study include Almota, Alpowa, Couse, Deadman, George, Joseph, Pataha and Tenmile Creeks (Figure 1.1). These sub-basins exhibit a range of climatic conditions and geographic settings. WRIA 35 is bordered by the Blue Mountains, with a number of the streams descending about 4,000 feet as they flow to the Snake River or one of its principal tributaries. Precipitation regimes correspondingly vary across the region, with average rainfall varying from 10 to 15 inches in the lower elevations to 45 inches in the higher elevations (ACCD, 2004). Due to the relative sizes and locations of the different basins, annual averages differ considerably between the streams; however, specific precipitation data for the respective watersheds is not well documented. Similarly, snowfall and subsequent snowmelt trends fluctuate significantly both within and between the sub-basins. Salient to this streamflow assessment, 90 percent of the precipitation occurs between September and May, which results in considerable dry periods during the summer and early fall. Overall, the streams are characterized as arid or semi-arid, especially in the lower reaches monitored.

In addition to climatic and geologic variations, each stream in this study displays unique characteristics. Low-flow conditions supporting salmonid populations represent the primary common feature that relates the streams; otherwise, the watersheds range in size, land-use, land-cover, irrigation use and flow regimes. The following descriptions provide a brief overview of each of the streams addressed in this report.

Almota Creek is the only tributary in this study that discharges into the Snake River from the north. This sub-basin contains numerous side canyons and tributaries, including Little Almota Creek which joins the mainstem near the confluence with the Snake River. Agricultural lands are scattered among wooded draws in the headwaters, and it has been implied that conversion of native prairie to farmland has altered the natural flow regime (SRSRB, 2006). However, riparian buffers are generally well established and average over 35 feet wide from the mouth to about 5 miles upstream. While salmonids have been found 8 miles upstream on the mainstem (Mendel et al, 2004), Little Almota Creek has so many fish passage barriers that restoration efforts are likely futile (Kuttel, 2002). Irrigation diversions are reported for both Almota and Little Almota Creeks (SRSRB, 2006), but the extent of associated stream withdrawals is uncertain. Due to the prevalence of Little Almota Creek in the watershed, this tributary was included in the study.

Alpowa Creek is distinct from other streams in the region in that the headwaters are not wooded. The stream descends over 2,500 feet over its course to the Snake River, flowing through a 128 square mile (81,820 acre) basin that is covered entirely by land in agricultural use. Alpowa Creek was described in 2001 as a “flashy” stream prone to flash floods that sustained a very small steelhead population (Kuttel, 2002). However, extensive riparian restoration efforts conducted in conjunction with landowners have rapidly begun to transform this watershed (WDOE, 2005). Native riparian vegetation is returning along the stream, and steelhead runs have expanded (Mendel et al., 2008). Irrigation withdrawals, comprised of an estimated 10 surface water diversions, occur in the lower reaches (Kuttel, 2002).

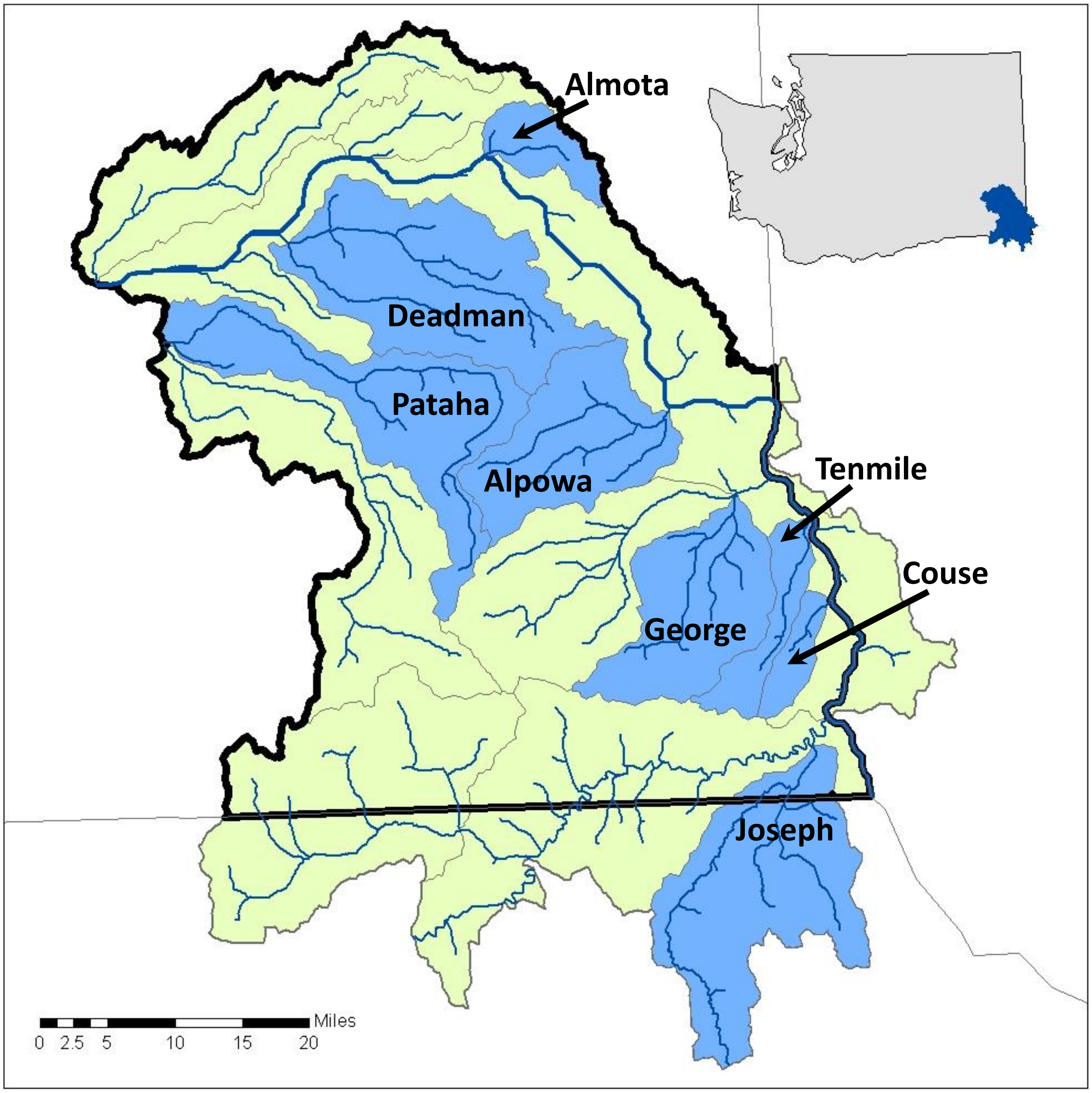

Figure 1.1. Map depicting the regional location of the Middle Snake Watershed and the respective sub-basins considered in the instream habitat assessment.

<u>Couse Creek</u> is a small tributary of the Snake River that cuts through a steep valley. Encompassing approximately 26 square miles (16,600 acres), this sub-basin supports dryland agriculture on the overlooking plateaus. Riparian habitat is patchy, with scattered trees intermixed with grasses and shrubs. Conservation efforts to improve the surrounding habitat has resulted in initial success, with sizable acreage enrolled in the Conservation Reserve Program (CRP) and riparian restoration efforts increasing vegetative cover (WDOE, 2005b). Natural flow regimes have presumably been maintained due to limited development, but inherently low-flow conditions and intermittent characteristics restrict salmonid movement in the watershed.

Deadman Creek originates from springs in the surrounding Palouse hills, which supports expansive cropland and pasture that abuts the stream in many sections. Irrigation diversions are actively used in this 204 square mile (130,300 acre) watershed, and discussions with landowners suggest irrigation return flows help maintain summer flow. A relatively broad valley with poorly developed riparian habitat distinguishes this sub-basin below the confluence of the North and South Forks. Anecdotal evidence indicates aggressive noxious weed growth has led to diminished streamflow (SRSRB, 2006) and the creek has reaches that are shallow, wide and muddy due to access by cattle. Restoration efforts have recently fenced much of the stream, creating over 25 miles of riparian buffer (WDOE, 2005c).

George Creek begins in the Umatilla National Forest and is a major tributary to Asotin Creek. Draining about 139 square miles (89,000 acres), the stream flows through riparian habitat that shifts from predominantly conifers to deciduous trees to sparse grasses as one progresses downstream (Kuttel, 2002). Riparian vegetation along the lower reaches remains in transition following extensive disturbance caused by flooding in 1996-1997. George Creek is an intermittent stream that often goes dry for a half mile downstream from Pintler Creek, and upstream portions are known to become dewatered (Kuttel, 2002).

Joseph Creek is the largest and least developed stream in this study, flowing out of Oregon through a remote area to the Grande Ronde River. All references to Joseph Creek in this report are limited to the reaches that lie within Washington. Land-use within Washington in this sub-basin is limited to two private landowners and WDFW, which has helped maintain a natural flow regime (Kuttel, 2002). A significantly higher flow rate further distinguishes this stream from the other study streams. Cottonwood Creek, a major tributary to Joseph Creek, exhibits a fairly uniform riparian buffer of deciduous trees, while a narrow band of trees lines the mainstem. Some irrigation withdrawals exist in the watershed, with WDFW using water to maintain wildlife habitat. Cottonwood Creek is a major tributary to Joseph Creek, and is correspondingly included in this study.

Pataha Creek arguably contains the greatest diversity of the streams in terms of land-cover and land-use. Forested dells characterize the high-elevation headwaters of this 185 square mile (114,166 acres) sub-basin, which transition into agricultural land in a broadening valley as the stream descends toward the Tucannon River. The towns of Pomeroy and Pataha present an urban component that the rest of the study streams primarily lack. A total of 625 acres are currently being irrigated with surface water (SRSRB, 2006).

Tenmile Creek encompasses a 42 square mile (26,900 acres) drainage that originates in the foothills of the Blue Mountains before dropping over 2,000 feet to the confluence with the Snake River. Dryland farming and livestock production dominate the bluffs over the steep canyon of the mainstem, which has contributed to degraded riparian habitat and sediment accumulation generated by the disturbance of highly erodible soils. Although heavy sedimentation was observed in the Mill Creek tributary during site reconnaissance for this study, riparian restoration around the town of Anatone and parallel efforts downstream (WDOE, 2005d) have increased tree growth along the stream. Riparian cover still remains patchy in the lower reaches, and intermittent conditions during the summer often correspond with poor streamside habitat (Mendel, 2001). Tenmile Creek is an intermittent stream that goes dry in portions upstream of river mile 2 (R.M. 2) during the summer and leaves fish stranded in isolated pools (Kuttel, 2002).

1.3. Middle Snake Watershed salmonid populations and the relation to streamflow

Pursuant to State legislation, fish habitat comprises a primary emphasis underlying the development of instream flows. The streams addressed in this study all support steelhead, the anadromous form of rainbow trout (*Oncorhynchus mykiss*). Some of the streams also contain resident populations of the non-anadromous redband form of rainbow trout, which are essentially non-distinguishable from steelhead during juvenile stages; therefore, references are often made in this report to rainbow/steelhead. Chinook salmon (*Oncorhynchus tshawytscha*) are also present or were historically present in some of these streams. Both steelhead and Chinook populations are designated as "threatened" under the Endangered Species Act, which mandates the conservation of "the ecosystems upon which endangered and threatened species depend". Little information exists on the historic distribution and size of these salmonid populations.

Streamflow is a critical habitat component for salmonid species. The flow regime represents the primary variable influencing ecological integrity, interacting with water quality, energy, habitat and biotic variables (Figure 1.2). Low flows can affect fish by blocking passage, interfering with migration of anadromous species, degrading habitat, increasing competition for food and intensifying wildlife predation. In addition, elevated water temperature is often associated with low flows, which in turn amplifies fish stress and increases susceptibility to disease and mortality. These factors reinforce the importance of developing instream flow criteria to protect salmonid populations.

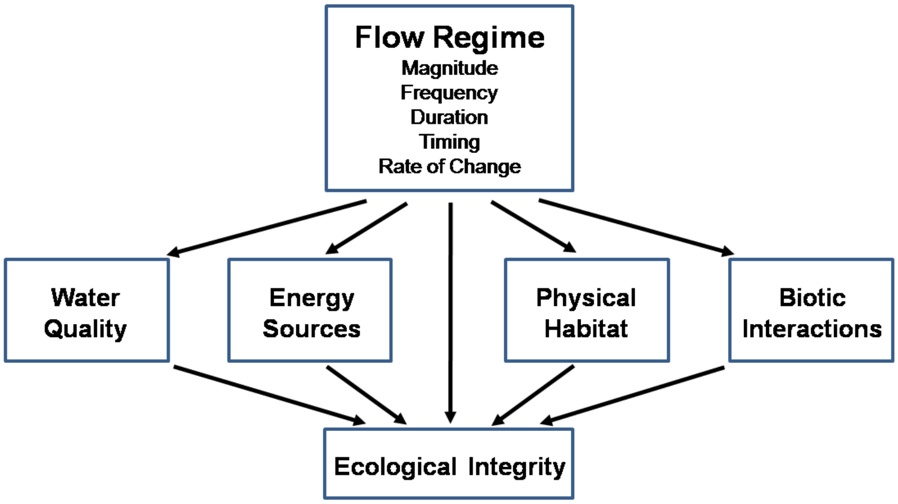

Figure 1.2. Schematic relating ecological integrity to flow regime (modified from Karr, 1991).

The Middle Snake Watershed steelhead are a typical Snake River "A-run" strain (ACCD, 2004). In general, returning adults migrate up the specific streams and spawn between February and May, and fry usually emerge from spawning gravels in May or June. However, this timing can vary between streams. For instance, the steelhead spawning run in the Asotin Creek sub-basin, which includes George Creek, follows a bi-modal distribution pattern. An initial run begins in late December with a peak in January, followed by a second (typically larger) peak that begins in March and can continue through May (K. Mayer, WDFW, pers. comm., 2009). Correspondingly, the months during which incubation and emergence occur can vary. Juveniles usually out-migrate in their second year between October and June, but limited water availability often shortens this time-period depending on the stream. For instance, Asotin Creek juveniles migrate from October through June with a peak in May (K. Mayer, WDFW, pers. comm., 2009), while Tenmile and Couse Creek populations tend to migrate from March through May (ACCD, 2004). Variations between years can also exist. For instance, observations in the Asotin Creek sub-basin indicate that the number of juvenile steelhead out-migrating in the fall can exceed that in the spring for certain years (K. Mayer, WDFW, pers. comm., 2009).

Little is known about the life history of spring Chinook in the Middle Snake Watershed, although limited data is available from Asotin Creek (the receiving waterbody for George Creek). Indications are that adult salmon enter the stream from late April through early June and proceed to reaches with sufficiently cool summer water temperatures (ACCD, 2004). Spawning takes place from late August through September with fry emerging the following spring. Juvenile rearing takes place for one year before they migrate out of the streams from October to June, with a peak from March through May. Table 1.1 illustrates the generalized life history patterns exhibited by steelhead and Chinook in the Middle Snake Watershed.

Table 1.1. Generalized life history patterns of steelhead and Chinook in the Middle Snake Watershed streams[1].

Steelhead

Life history phase	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult upstream migration[2]			▒	▒	█	█	█	█				
Spawning				▒	█	█	█	█				
Emergence						▒	▒	█	█	▒		
Juvenile rearing	█	█	█	█	█	█	█	█	█	█	█	█
Juvenile out-migration	▒	▒	▒	▒	▒	█	█	█	▒			

Spring Chinook

Life history phase	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Adult upstream migration[2]							█	█	█	█		
Spawning	█										█	█
Emergence	█	█	█									
Juvenile rearing	█	█	█	█	█	█	█	█	█	█	█	█
Juvenile out-migration	▒	▒	▒	▒	▒	█	█	█	▒			

Key: Primary times █ Potential or non-primary times ▒

[1] Times will vary both within and between streams based on life history cycles or water availability limitations

[2] Upstream migration refers to migration in the respective Snake River tributary stream only and not entire freshwater migration

Source: ACCD (2004); K. Mayer, WDFW, pers. comm.. (2009)

It is salient to note that a variety of other contributing factors have led to the decline of steelhead and salmon populations throughout the Pacific Northwest. A standard axiom used to explain impacts on Pacific salmonids is the 4-H's: habitat, harvest, hatcheries and hydropower. Hatchery stocks that compete with naturally spawning fish and alter genetic diversity are not an issue in these streams. However, the impacts of harvest and hydropower could impact the Middle

Snake Watershed populations, but to what extent cannot be quantified for the respective stocks during migration and their time in the ocean. Moreover, the altered Snake River flow regime caused by downstream dams may have interfered with natural cycles and processes occurring at the stream mouths. Although this report evaluates instream habitat in regards to streamflow, other habitat parameters not assessed also influence fish dynamics (e.g., sedimentation, physical structure). Recently, recognition of fluctuating ocean conditions has also been implicated in salmonid survival. These other factors do not discount the importance of protecting adequate streamflow, but it is important to consider the complex situation impacting salmonid populations when comparing historic reports and anecdotes to current conditions. Therefore, it is stressed that care be taken in extrapolating results presented in this document beyond the scope of the study.

1.4. Project description

The purpose of this study was to assess instream habitat and its relation to salmonid populations in the select Middle Snake Watershed tributaries. This report documents streamflow conditions, determines relations between flow quantity and habitat, and discusses adequate streamflow requirements to maintain quality aquatic habitat in these streams. The evaluation integrates field data collected as part of this study with additional information obtained from Ecology and WDFW to characterize hydrologic conditions in relation to salmonid populations. Quality control measures were instilled to provide an accurate determination of surface water discharge rates and ensure rigorous data analysis.

Monitoring sites were established on the respective streams and streamflow was measured between September 2008 and June 2009. Sampling events took place at approximately one month intervals, but varied between streams due to logistical reasons (e.g., weather restrictions). Toe-widths were recorded on two occasions to assess changes that occurred in the respective channels during the course of the study. Transect plots were also taken at select locations along each stream to provide further insight into channel geometry. Discharge rates recorded near the mouths of these streams from 2003 to 2009 by Ecology were assembled and integrated with the collected field data to provide a more robust hydrologic dataset.

Guidance is lacking for establishing instream flow recommendations for low-flow and intermittent streams, particularly those in semi-arid and arid climates. The difficulty in selecting an appropriate instream flow assessment technique is further confounded in the Middle Snake Watershed by the different flow regimes presented by the respective streams. Thus, three standard instream flow assessment techniques – the Wetted Perimeter, Toe-Width and Tennant methods – were used in conjunction with the combined hydrologic dataset to provide respective instream flow recommendations. These prescribed values were then evaluated in regards to the unique characteristics inherent to the Middle Snake Watershed. Although these assessment methods do not produce results that can be evaluated for bias and precision, they provide insight into the appropriateness of their use for small, low-flow and often intermittent, southeast Washington streams.

Since one of the driving factors behind the establishment of instream flows is to protect habitat for fish, it is important to relate the recorded streamflow and the resultant instream flow recommendations to critical species in the stream ecosystems. Fish surveys conducted by WDFW between 2000 and 2009 were compiled to provide a summary of salmonid populations present in the streams. This biological data was integrated into the stream habitat assessment to provide a preliminary understanding of the links between steelhead and Chinook populations and current streamflow conditions, as well as potential future flow regimes. The anadromous nature of these species dictates that flow requirements differ between the freshwater life-stages on a seasonal basis. Although emphasis for instream flows is placed on low-flow periods, the natural fluctuations in stream discharge that occur throughout the year must be evaluated in order to account for sufficient streamflow for salmonid migration, spawning and rearing.

Based on this comprehensive assessment, preliminary “discussion flow” recommendations are presented. Due to the instream flow assessment methods used, these prescribed flows represent an annual average flow rate for these streams. However, a seasonal component is essential to instream flow regulations, typically set on a monthly basis. Thus, the “discussion flows” are intended as a framework for developing the monthly instream flow requirements derived from monthly flow statistics provided.

It is important to stress that the “discussion flows” are intended as initial starting points for discussions regarding the establishment of instream flow criteria and are not intended as definitive values. As discussed previously, instream flow values are a regulatory and managerial tool that considers a variety of watershed resources, some of which are beyond the scope of this study (e.g., existing water rights). Thus, this report serves as a supporting technical document to be used by the Planning Unit and others during the process of setting instream flows for the select WRIA 35 tributaries.

2. Data Collection and Methods

2.1. Methods overview

Recommendations for appropriate instream flow values for stream habitat protection depends on an understanding of the relations between streamflow and habitat availability and quality. However, instream flow transcends fish habitat and involves a variety of environmental, cultural and socio-economic factors. Thus, no universally accepted method or combination of methods has been established for establishing instream flows, and method selection should be decided on a case-by-case basis (Annear et al., 2004). Selection of appropriate methods for WRIA 35 is compounded by the unique nature of this watershed; instream flow procedures for low-flow, intermittent streams is poorly defined. Moreover, the streams examined in this study display varying characteristics that may warrant different assessment criteria. Therefore, three selected instream flow methods (Wetted Perimeter, Toe-Width and Tennant) were used in conjunction with flow measurements, observations and available fish data to provide a watershed assessment to begin discussions that are part of the instream flow determination process.

2.2. Site reconnaissance and site locations

Reconnaissance for determining site locations consisted of discussions with the WRIA 35 Watershed Planning Director (Brad Johnson) and the Ecology Watershed Lead (Mimi Wainwright), evaluation of topographic and road maps, and communication with landowners. Extensive travel was conducted in each watershed to determine the adequacy of access points and to assess site suitability for the study. Site selection criteria consisted of appropriateness for surveying and representativeness of the general stream conditions for the given stream segment. Access was a limiting factor in the region due to steep and rugged terrain, impenetrable brush, lack of nearby roadways, and reluctant landowners (most of the stream reaches are under private ownership). Several of the study streams were characterized by intermittent flow, which further limited site selection (the site selection process was conducted in August 2008, a period of low flows). Natural differences in streams has to be accounted for in a multi-stream study which prohibit direct comparisons, but general trends can be made for stream habitat assessment based on inherent characteristics of each watershed.

The coordinates for selected sites were recorded using a Garmin model Colorado® 400c GPS unit (Table 2.1). Satellite images that indicate the site locations in each watershed and photographs of the sites can be found in Appendix A. Sites were paired to represent two distinct channel unit types to help verify flow rates. Eight locations were established in each watershed except for Almota and Pataha Creeks. The Almota Creek Watershed had locations on both Almota Creek and Little Almota Creek due to the orientation of this sub-basin. Two locations were established on Cottonwood Creek in the Joseph Creek Watershed because of the prominence of this tributary in the sub-basin. Reaches were classified as riffles, runs or pools at the beginning of the study, but these categories may have changed during seasonal variations based on changes in water flow.

Table 2.1. Locations and channel type for stream site locations.

Creek	Site #	R.M.[1]	Type	Long. (N)	Lat. (W)
Almota	1	0.05	Riffle	46°42'188"	117°28'075"
Almota	2	0.06	Run	46º42'185"	117º28'079"
Almota	3	0.07	Pool/Run	46°42'198"	117°28'064"
Little Almota	1	0.07	Run	46°42'200"	117°28'071"
Little Almota	2	1.3	Run	46°43'236"	117°27'927"
Little Almota	3	1.32	Riffle	46°43'255"	117°27'925"
Alpowa	1	5.25	Run	46°25'545"	117°17'609"
Alpowa	2	5.28	Riffle	46°25'540"	117°17'645"
Alpowa	3	7.26	Riffle	46°25'467"	117°20'043"
Alpowa	4	7.28	Run	46°25'454"	117°20'055"
Alpowa	5	7.92	Run	46°24'976"	117°20'466"
Alpowa	6	7.95	Riffle	46°24'955"	117°20'504"
Alpowa	7	11.45	Run	46°23'939"	117°24'571"
Alpowa	8	11.47	Riffle	46°23'897"	117°24'580"
Couse	1	0.02	Run	46º12'287"	116º58'062"
Couse	2	0.06	Run	46º12'284"	116º58'007"
Couse	3	0.08	Pool	46º12'286"	116º58'086"
Couse	4	1.48	Run	46º11'722"	116º59'521"
Couse	5	1.53	Riffle	46º11'734"	116º59'541"
Couse	6	3.35	Pool	46º10'371"	117º00'579"
Couse	7	3.37	Riffle	46º10'362"	117º00'618"
Deadman	1	1.1	Riffle	46°37'087"	117°45'692"
Deadman	2	1.12	Run	46°37'115"	117°45'650"
Deadman	3	4	Riffle	46°37'581"	117°43'482"
Deadman	4	4.02	Run	46°37'593"	117°43'452"
Deadman	5	6.38	Run	46°37'575"	117°40'803"
Deadman	6	6.4	Riffle	46°37'547"	117°40'776"
Deadman	7	10.67	Run	46°36'298"	117°36'505"
Deadman	8	10.7	Pool	46°36'290"	117°36'488"
George	1	0.08	Run/Riffle	46º19'487"	117º06'424"
George	2	0.1	Riffle	46º19'467"	117º06'431"
George	3	1.87	Riffle	46º18'174"	117º07'041"
George	4	1.92	Riffle	46º18'150"	117º07'046"
George	5	3.29	Run	46º17'251"	117º08'159"
George	6	3.31	Pool	46º17'238"	117º08'162"
George	7	4.76	Run	46º16'622"	117º09'794"
George	8	4.82	Pool	46º16'618"	117º09'791"
Joseph	1	2.11	Run	46º01'651"	117º01'082"
Joseph	2	2.18	Riffle	46º01'611"	117º01'154"
Joseph	3	3.31	Riffle	46º00'830"	117º01'761"
Joseph	4	3.32	Run	46º00'824"	117º01'748"
Joseph	5	4.37	Run	46º00'409"	117º02'543"
Joseph	6	4.4	Riffle	46º00'428"	117º02'565"
Cottonwood	1	0.02	Riffle	46º00'366"	117º02'510"
Cottonwood	2	0.07	Run	46º00'340"	117º02'544"
Pataha	1	32.03	Run	46º26'604"	117º28'028"
Pataha	2	32.06	Riffle	46º26'584"	117º28'027"
Pataha	3	41.68	Run	46°20'673"	117°32'491"
Pataha	4	41.71	Riffle	46°20'659"	117°32'475"
Pataha	5	46.92	Run	46º16'519"	117º31'189"
Pataha	6	46.94	Riffle	46º16'511"	117º31'192"
Tenmile	1	0.2	Riffle	46º17'794"	116º59'524"
Tenmile	2	0.22	Run	46º17'797"	116º59'546"
Tenmile	3	1.11	Pool	46º17'153"	117º00'054"
Tenmile	4	1.14	Riffle	46º17'152"	117º00'054"
Tenmile	5	1.56	Run	46º16'833"	117º00'273"
Tenmile	6	1.6	Riffle	46º16'825"	117º00'277"
Tenmile	7	2.55	Riffle	46º16'076"	116º59'931
Tenmile	8	2.59	Pool	46º16'080"	116º59'930

[1] R.M. = River mile

2.3. Flow measurements

Study streamflow measures

Streamflow was determined using a velocity-area approach through cross-section measurements performed in accordance with Gallaher and Stevenson (1999). An estimate of streamflow (Q) can be determined by multiplying a cross-sectional area (A) of the stream by the average water velocity (V), such that: Q =V*A. However, water velocity and depth vary across a cross-section, and it is necessary to determine flow at different subsections to account for this discrepancy. The sum of these incremental subsections provides the total streamflow.

Permanent pins were established at each site location on the left and right banks perpendicular to streamflow at the beginning of the study. A tape measure was stretched level and taut across the stream and anchored to the two stakes during each sampling event; interfering brush was cleared. The width of the stream was measured and divided into subsection intervals with a goal of having no interval contain more than 10 percent of the total discharge. Generally, 12 to 15 intervals were sought at each transect. The distance from the left bank, water depth and water velocity were recorded for each subsection as the stream gauger moved across the stream. Sampling occurred between 8 to 10 times for each stream, except for Pataha Creek (7 times) and Joseph Creek (5 times), in accordance with the Quality Assurance Project Plan (QAPP).

Flow was measured using balanced bucket wheel current meters attached to a portable flow meter, representative of the primary units used in USGS gauging operations. The mini current meter (minimum depth 3 inches; minimum water velocity of 0.05 feet per second) is designed for low-flow conditions and was the primary model used in this study. When stream depth was less than 2 feet, water velocity was measured at 0.6 times the water depth at each interval, based on the established relationship that the average stream velocity occurs at 60 percent of the depth measured from the water surface. When depths exceeded 2 feet, velocity was measured at 0.2 and 0.8 times the water depth. The meters had been sent to a certified lab for calibration. In situ flow measures followed standard quality control protocol.

Figure 2.1 provides a diagram illustrating the cross-section of a stream showing locations for water depth and velocity. The total streamflow for each subsection was determined according to:

$$Q_n = d_n \times \left(\frac{b_{n+1} - b_{n-1}}{2}\right) \times v_n$$

where: Q_n = discharge for subsection *n*,
d_n = depth at subsection *n*,
b_n = distance along the tape measure from the initial point on the left bank to point *n*,
v_n = mean velocity of subsection *n*.

The average velocity found along the midpoint location of each subsection is assumed to be valid for the entire subsection.

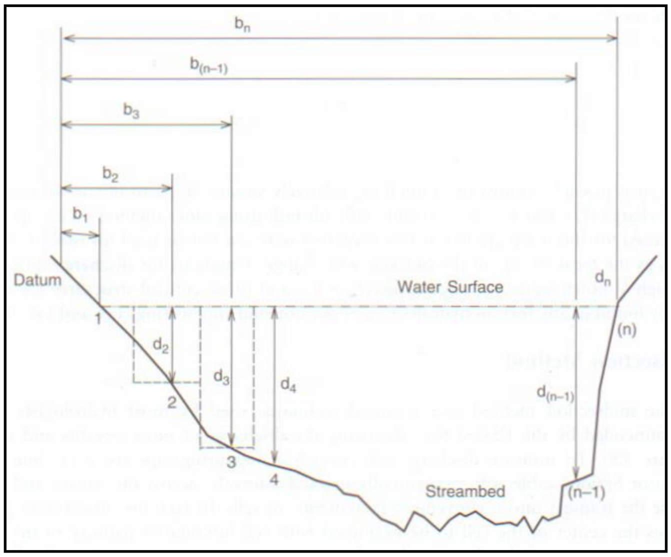

Figure 2.1. Cross-section of a hypothetical stream showing sampling locations for water depth (d) and velocity. Flow measures are taken at regular intervals across the width of the stream.

Rigorous transect surveys were made for at least two locations for each stream as required by the QAPP, and figures representing cross-sections of streambed configuration can be found in Appendix B. The number of transect surveys per watershed consist of: Almota (6), Alpowa (5), Couse (2), Deadman (4), George (4), Joseph (4), Pataha (4) and Tenmile (2). These profiles were developed using standard surveying methods. Briefly, a laser level was placed at a standard datum position selected in the stream with a clear sight of both banks. The laser was leveled on a tripod above the highest bank point. A measuring tape was strung across the channel so linear distance could be measured. Starting at the left bank pin, an individual with a laser detector fixed to a surveyor's rod moved across the stream and relative elevation measures were made. Measurements were taken at standard intervals and at each unique point between the two pins. Unique points included changes in slope, bank toes, erosion points, water edges and any other point that indicated a significant elevation change.

Department of Ecology streamflow data

Flow data collected by Ecology for the respective streams from 2003 to 2009 is incorporated in this report to provide information over a longer time-period and to contribute to streamflow analysis. Ecology streamflow monitoring in WRIA 35 consists of a combination of telemetry stations that transmit data every fifteen minutes and manual stage-height stations monitored periodically (typically weekly or biweekly, but occasionally larger gaps in data occur). Telemetry stations are established near the mouths of Almota, Alpowa, Deadman, Joseph and Pataha Creeks, and manual stage-height stations are established near the mouths of Couse, George and Tenmile Creeks. It should be noted that while all of the other streams have been monitored by Ecology since 2003, stream discharge records for George Creek only extend back to 2006. Several extreme flow events between January and May of 2009 have significantly skewed the dataset for George Creek, and care should be taken when using this information

The data collected at the Ecology gauging stations were used to estimate average annual flows and monthly average flows. These values are helpful in identifying inter- and intra-annual trends in the flow regimes based on the limited data available. Exceedance curves that plot discharge against the percentage of time equaled or exceeded were also created.

2.4. Instream flow assessment techniques

Wetted Perimeter method

The Wetted Perimeter method uses a graphical representation of the wetted perimeter versus discharge measured at established stream transects. The slope of the wetted perimeter versus discharge curve for natural streams tends to have one or more transitions from a steep slope at low discharges to a more gradual slope at larger discharges. Visual breakpoints, or inflection points, that occur when the slope of the curve changes are then used as potential instream flow recommendations (Figure 2.2). This point represents the state where small reductions in flow lead to progressively greater decreases in wetted perimeter (i.e., habitat). Below this critical discharge, conditions rapidly become unsuitable for fish and other aquatic organisms.

It is assumed that the inflection point represents the flow preferred by salmonids and is necessary to protect riffle habitats supporting food sources (Annear et al., 2004; Gordon et al., 2004). A principle component of juvenile and adult salmonid diets includes aquatic invertebrates that are primarily produced in stream riffle areas; this method relates streamflow to the carrying capacity of the stream in regards to food production associated with the amount of wetted perimeter in riffles. Thus, this instream flow assessment method provides a visual aid representing flow in relation to the spatial distribution of available habitat.

The wetted perimeter of a stream is the distance around the outside edge of the cross-section where the water contacts the streambed (Figure 2.2). This distance was determined for every flow measurement event in this study using trapezoidal geometry (Wilde and Radrke, 1998). Briefly, a stream cross-section is theoretically divided into a series of trapezoids with the depth measurements (as shown in Figure 2.1) forming the sides and the water surface each of the tops; geometry is then used to calculate the length of the side formed by the stream bottom for each section, which are subsequently summed to get the distance that represents the wetted perimeter. Wetted perimeter versus discharge plots were produced for each site location in this study.

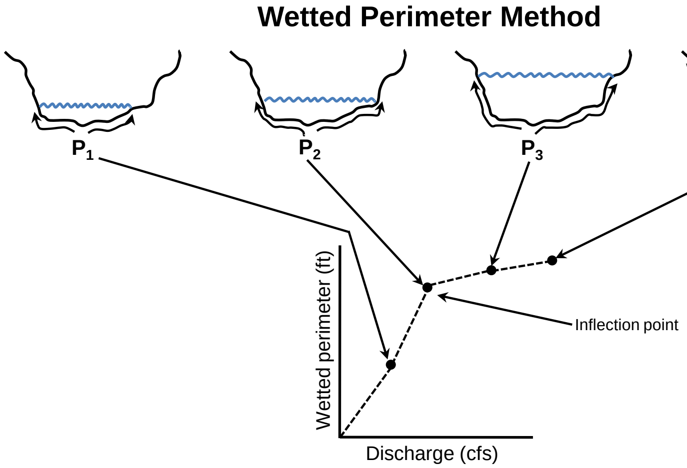

Figure 2.2. Diagram of a wetted perimeter versus discharge plot that demonstrates identification of inflection points, as used in the Wetted Perimeter method.

Toe-Width method

The Toe-Width method (or Toe-of-Bank Width method) was developed for western Washington streams supporting steelhead populations (Swift, 1976). The toe of the bank is generally regarded as the point at the base of a streambank where the bank becomes more level as it forms the channel bed; this typically differs from width of the streambank corresponding to the bank-full depth. The Toe-Width method assumes that hydraulic characteristics corresponding to the distance between the bank toes (i.e., bank width) is related to spawning habitat over gravel bars in the context of flow velocity and depth.

The bank toes were determined based on changes of slope, substrate and vegetation, and appropriate criteria was discussed and agreed upon with Ecology and WDFW staff in the field. The distance between the toes were measured at each site location perpendicular to the stream, with additional toe-widths taken along Joseph Creek. Toe-width measurements were determined twice during the study period during the beginning and end of the project to compare changes over time. Figures 2.3 and 2.4 display photographs of typical scenarios encountered when selecting bank toes for this method; these photographs demonstrate the use of slope, substrate and vegetation in determining locations for the toes of the respective banks.

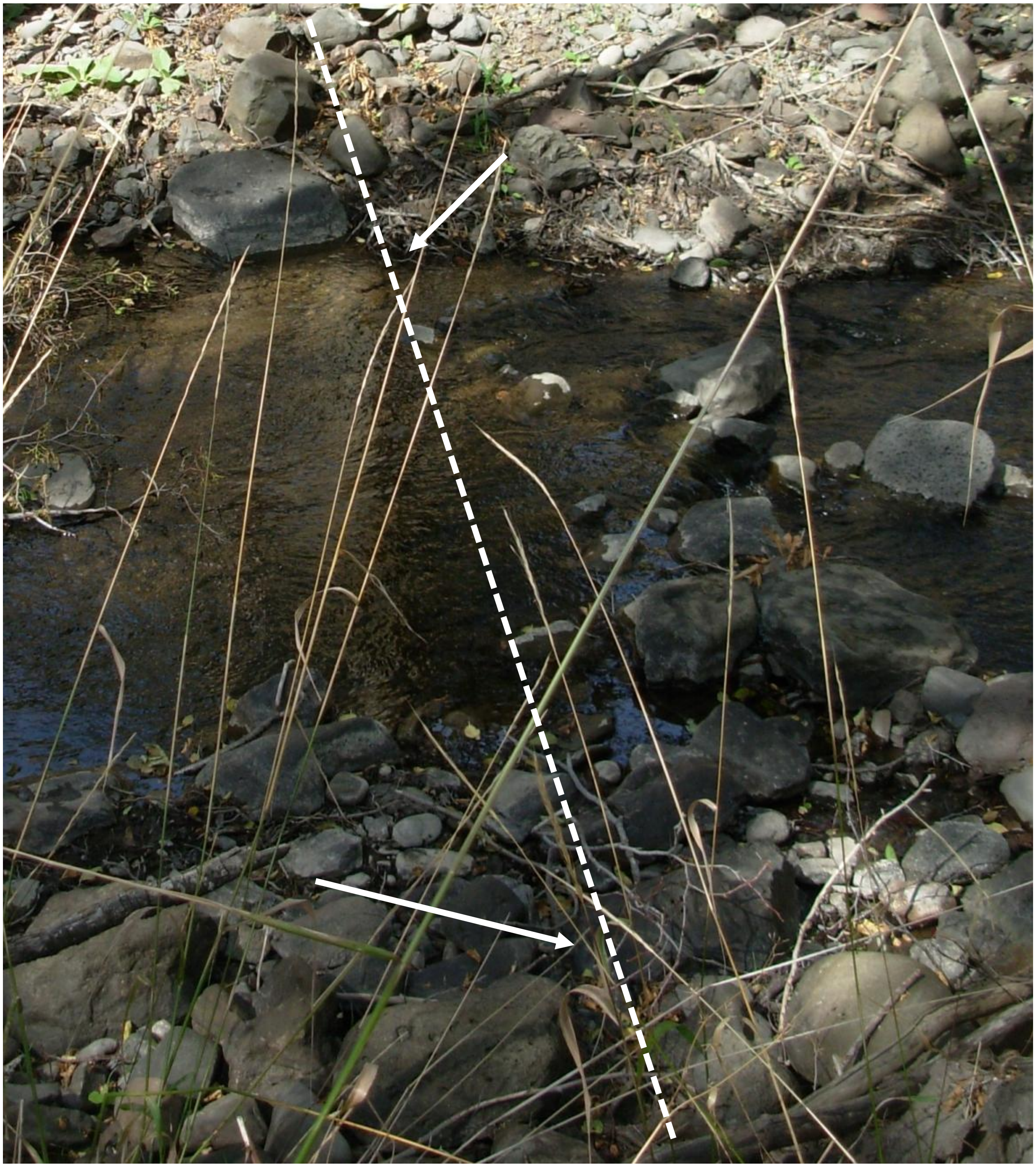

Figure 2.3. Photograph demonstrating the selection of bank toe locations. The left bank toe (upper arrow) is easily identified by presence of a defined cut bank; the water's edge and bank toe correspond in this instance. The right bank toe (bottom arrow) is defined by a change in slope and change in substrate size (i.e., stone sizes above toe are noticeably larger in general than those below toe); the water's edge is below the bank toe in this instance. The dotted line represents a perpendicular line to streamflow.

Figure 2.4. Photographs of a stream segment from varying perspectives to demonstrate bank toe locations (represented by dotted lines). a) The right bank (far side) has a clearly defined toe just below the water surface delineated by a strong change in slope, which can be seen behind the field technician. The near side has a more subtle change in slope, but particle size differentiation can be seen (i.e., generally, larger stones above) and vegetation starts to emerge at this point (difficult to ascertain in black-and-white copies, but green vegetation can be seen in color versions). b) Looking across at the left bank, particle size differentiation can be observed. c) Looking upstream, the strong change in slope on the right bank (left in photo) and particle size differentiation with subtle, but definite change in slope on left bank (right in photo) can be seen.

The toe-width measures were then used to calculate the estimated preferred streamflows for steelhead rearing using the following relationship determined by Swift (1976):

$$Y = a(TW)^b \pm SE$$

where: Y = preferred discharge (cfs),
a = regression constant of 0.164 for rearing habitat, 1.55 for preferred habitat,
TW = toe-width distance (ft),
b = regression constant of 1.42 for rearing habitat, 1.16 for preferred habitat.

A correlation coefficient of 0.90 was determined during development of this instream flow assessment technique using multiple-regression analysis on data collected from 18 streams in western Washington (Swift, 1976).

Tennant method

The Tennant method (also referred to as the Montana method) recommends minimum flows based on a percentage of the average annual flow derived from hydrologic records. Although usually credited to Donald Tennant, development of this method actually started in the 1950's using data collected from hundreds of streams in the northern U.S. between the Atlantic Ocean and the Rocky Mountains (Tennant, 1976).

This assessment technique provides seasonally adjusted instream flow recommendations based on the relationships shown in Table 2.2. Yearly average flows were estimated from the Ecology 2003-2009 streamflow monitoring datasets for each stream, and the respective percentages were calculated. Seasonal averages based on the same April-September and October-March periods were also calculated using Ecology flow data for comparison.

Table 2.2. Instream flow regimens for fish, wildlife, recreation, and related environmental resources from Tennant (1976).

Narrative Description of Flow	October to March	April to September
Flushing or maximum flow	200% of the average flow	
Optimum range of flow	60-100%	60-100%
Outstanding habitat	40%	60%
Excellent habitat	30%	50%
Good habitat	20%	40%
Fair or degrading habitat	10%	30%
Poor or minimum habitat	10%	10%
Severe degradation	<10%	<10%

2.5. Data interpretation

The instream flow recommendations derived from the three assessment techniques were interpreted in the context of setting instream flows for the unique Middle Snake Watershed tributaries. Since little guidance exists for prescribing instream flows for low-flow streams located in semi-arid/arid climates or under intermittent conditions, the resultant instream flow recommendations for the different methods were related to the recorded flow conditions. This comparison, and an accompanying discussion addressing method advantages and limitations, helps elucidate the applicability of the different approaches for the WRIA 35 sub-basins. This analysis was conducted to ensure the development of realistic instream flow values for the environmental and geologic conditions presented by the Middle Snake Watershed.

Data collected by WDFW on rainbow/steelhead and Chinook in the Middle Snake Watershed streams was incorporated into the data interpretation to examine the linkage between existing salmonid populations and current streamflow conditions, as well as potential future flow regimes associated with instream flows. Salmonid density estimates calculated using electrofishing survey results and steelhead spawning propensity based on redd counts was used to provide information on the distribution and abundance of fish stocks (Mendel et al., 2001; Mendel et al., 2004; Mendel et al., 2006; Mendel et al., 2008). Estimates for returning adult steelhead in Alpowa Creek for 2008 and 2009, and the number of captured steelhead in George Creek for 2009 were also included (K. Mayer, WDFW, pers. comm., 2009).

Current flow conditions were then related to the compiled fish data. Although relations between streamflow and various salmonid species are well established in other regions, little is known about this interaction in low-flow conditions exhibited by the Middle Snake Watershed. Salmonid populations have evolved in their respective home streams over time and specific habitat needs vary by stock (Miller, 1965; Wydoski and Whitney, 2003). It appears that the steelhead and Chinook populations in theses streams have adapted to conditions that are not fully recognized by existing instream flow assessment techniques. Thus, this evaluation is pertinent to the determination of instream flow criteria.

Following these assessments, recommended “discussion flows” were created to provide a starting point for discussions regarding instream flows by watershed stakeholders in a regulatory framework. These prescriptive instream flow values were developed based on analysis of the available streamflow data, the recommended instream flow values derived from the different assessment methods and the status of the existing salmonid populations for each tributary. It should be noted that the “discussion flows” only represent annual average flow rates, which is an artifact of the instream flow assessment methods use. However, these recommended values are still of considerable value, as they provide a framework from which seasonally relevant instream flow criteria can be delineated. Monthly streamflow statistics were also calculated to facilitate development of a seasonal component to the instream flows.

This comprehensive evaluation represents the best available technical assessment of flow regimes in relation to existing salmonid populations for the Middle Snake Watershed tributaries.

3. Results

3.1. Flow data

Streamflow data collected in this study for the respective WRIA 35 streams are shown in Appendix C. This report will not compare data between streams in regards to either flow or instream flow recommendations. Although flow could be normalized based on drainage area, the intrinsic characteristics (e.g., land-use and cover) of each creek differ significantly enough to preclude obtaining any relevant information. However, general trends and notable findings will be discussed here on a stream-by-stream basis.

Almota Creek at the most downstream site location (RM 0.05) was found to have negligible flow in the first three months of the study period. This finding is indicative of a bore, a phenomenon in which water travels up-river against the direction of the current, originating from the Snake River mainstem. This occurrence provides one example wherein flow data does not necessarily equate to fish habitat, as a substantial water volume was present despite no flow measured. Little Almota Creek exhibited consistent flow throughout the study period, likely due in part to the small watershed drainage area. The mainstem of Almota Creek displayed greater variability than its tributary, reaching a maximum flow rate during April. Little difference was observed between the up-stream and downstream sites on the mainstem, which is an artifact of relatively little contribution from Little Almota Creek and the small distance upstream in which sampling was conducted due to site restrictions.

Two of the tributaries sampled, Alpowa and Deadman Creeks, exhibited relatively constant flow, both seasonally and longitudinally along the length of the streams. On the contrary, George Creek underwent significant changes in streamflow during the study, presumably due to its larger drainage area. For instance, at RM 1.92 flow rose from 5.3 cfs in February to 124.2 cfs in April. This spike in stream discharge was paralleled by measurements obtained from the Ecology monitoring site, which will be discussed in further detail later in this report. Intermittent reaches were also observed in upstream reaches of George Creek during the summer and fall dry period.

Couse Creek displayed uniform low flows, with the exception of the March sampling date. It appeared that much of the water supply for this stream was derived from springs based on observations, and it is assumed that precipitation contributes minimally to streamflow except immediately following a storm-event. Reaches along Couse Creek were found to be intermittent and cases of negligible flow were found throughout the study period, particularly in the upstream sampling locations. However, negligible flows did not indicate that no water was present. Pools with negligible flows supported fish, as will be discussed later in this document.

Tenmile Creek, which displays similar characteristics as those found in Couse Creek, also exhibited predominantly low flows. However, high-flow conditions in Tenmile Creek lasted for a longer duration that spanned from February to April, tapering off in May. Dewatered reaches were observed and were particularly evident around R.M. 2, which corresponds with similar observations recorded in 2001 (Mendel et al., 2001). Pataha Creek exhibited low flows for much of the study (<5 cfs for most locations and dates), but displayed significantly higher flow rates during February and March that ranged up to 70.0 cfs at RM 41.68.

Data collected for Joseph Creek was limited compared to the other streams, primarily due to weather conditions restricting travel or access to the stream. Significant variations in streamflow were observed, but overall flows were much larger than for the other streams. This can be attributed to a larger watershed drainage area and greater proportion of snowfall in upper portions of the sub-basin. Large discharge volumes were encountered several times that inhibited measuring flow rates, and a high of 315.7 cfs was recorded at RM 2.18 in March. Cottonwood Creek contributed a fairly constant flow that typically ranged from 16.8 to 38.5 cfs, peaking in May at 63.6 cfs.

Longer-term data was collected by Ecology from 2003 to 2009 (except for George Creek, where data only exists from 2006 to 2009) near the mouth of each stream and thus doesn't display variations along the length of each stream (Figure D.1). However, measurements were taken over shorter durations with telemetry measures recorded every fifteen minutes at many sites (see Section 2.3). Strong seasonal variations in flow were recorded for Joseph and Pataha Creeks, and while this seasonal pattern held true for the other streams the trend was more subdued. Alpowa and George Creek exhibited significantly higher flow rates for late 2008 and early 2009 compared to earlier dates. Although precipitation records for the respective streams are not available, anecdotal accounts claim that the past decade has been considerably drier than previous years. These higher flow rates may indicate that the region is coming out of a prolonged dry-period, which also has implications on setting instream flows as will be discussed later.

It should be noted that the Ecology streamflow dataset for George Creek is the smallest of those for the Middle Snake Watershed streams. As mentioned above, flow rates have only been collected at the manual stage-height station since 2006. All of the documented discharge rates remained between 4.0 and 8.0 cfs (the majority between 4.0 and 5.0 cfs) until a series of extreme flow events occurred during the winter and spring of 2009. Several of these high-flow events exceeded 108 cfs, which consequently skewed the data significantly. Therefore, caution should be taken when referring to this dataset, as the true character of the stream remains undocumented due to the short duration over which flow rates have been recorded.

The Ecology data collected from the streams between 2003 and 2009 were plotted as exceedance curves on a semi-logarithmic scale (Figure D.2). These curves are a convenient means of portraying flow characteristics for a stream, as these plots represent discharge versus the percentage of time that a given discharge is equaled or exceeded. Ideally the flows used to construct exceedance curves are comprised of an extended record of daily mean flows. Thus, the manual stage-height stations used for measuring streamflow on Couse, George and Tenmile Creek severely constrain the accuracy of the resultant exceedance curves due to patchy and inconsistent data. However, the telemetry stations on the remaining streams provide a robust dataset that is only hampered by the six-year record; it is usually regarded that an absolute minimum of 10 years of data be used when assessing stream hydrologic conditions. Table 3.1 provides the 10-, 50- and 90-percent exceedance probabilities for each stream in relation to average annual flow (Q_{Avg}) determined using the Ecology data.

In addition to providing a means to calculate the probability of a given flow, other interpretations of exceedance curves can be used to gain insight into the hydrologic regime of the watershed. The high-flow side of the curve can indicate the frequency of overbank flows, while estimates on the availability of stream habitat can be derived from the low-flow side (Gordon et al., 2007). The curve shapes can also help describe flow characteristics of a stream in relation to watershed hydrology. Generally, a steep slope at the high-flow end of the curve typically indicates a watershed that conveys a large amount of direct runoff to the stream, while a relatively flat slope at the high-flow end suggests more water storage in the basin as stream recharge occurs more slowly (Gordon et al., 2007; Gore, 2007). Inferences on groundwater contribution to a stream can also be determined by observing the low-flow end of the curve. A steep slope at the low-flow end of the curve suggests minor groundwater input, with a flatter slope pointing to a significant groundwater recharge component contributing to the hydrologic regime (Gordon et al., 2007).

Table 3.1. Average annual flows (Q_{Avg}) and associated 10-, 50- and 90-percent exceedance probabilities based on Ecology stage data collected from 2003-2009.

Creek	Q_{Avg}	Flow at 10% exceedance probability	Flow at 50% exceedance probability	Flow at 90% exceedance probability
	---- (cfs) ----			
Almota	3.0	6.8	1.6	0.8
Alpowa	9.1	12.1	8.7	5.4
Couse[1]	2.3	4.7	1.0	0.6
Deadman	3.7	6.5	3.5	1.1
George[1]	10.6	8.0	4.39	4.05
Joseph	113.2	318	40.6	17.7
Pataha	12.6	33.4	4.3	0.7
Tenmile[1]	5.2	16.1	1.4	0.6

[1] Manual stage-height gauges with limited data

Couse, George and Tenmile Creeks all displayed flat low-flow exceedance curve ends that suggest a strong groundwater component to the system, which is consistent with the observations of many springs and seeps in these watersheds made during the study. However, the limited data provided by the manual stage-height stations on these three streams leads to uncertainty when extrapolating information from the respective curves. Joseph Creek has a relatively constant slope throughout the entire exceedance flow curve, which suggests both good water storage and stream recharge in the watershed. This is not surprising due to the undeveloped character of this large sub-basin and the forested headwaters in Oregon. The Pataha sub-basin also appears to limit the amount of runoff entering the stream during storm-events. Almota and Deadman Creek both display a steeper slope at the high-flow end of the exceedance curve, which suggests stormwater runoff may be an issue in these watersheds. Even more significant is the extremely steep slope generated for Alpowa Creek, which corresponds with previous characterizations of it acting as a flashy stream (Kuttel, 2002). Although restoration efforts have been conducted in this sub-basin, it appears that further riparian development and the implementation of best management practices (BMPs) need to continue. Each of these hydrologic characterizations can be related to instream habitat, and will be discussed in more detail later in the report.

3.2. Wetted Perimeter method

Field streamflow data were plotted against the measured bed-profile for each sampling event to produce the wetted perimeter versus discharge curves for each site location (Appendix E). A degree of subjectivity often exists using the Wetted Perimeter method, as the inflection points in the wetted perimeter – discharge relationship can be challenging to define. Consequently, flow requirements were obtained here for each paired site location by integrating the two inflection points, with more weight placed on riffle sites. No clear inflection points were observed for some locations and streamflow estimates were accordingly not calculated. Table 3.2 summarizes the derived instream flow recommendations using the Wetted Perimeter method, where applicable.

Table 3.2. Instream flow estimates derived from the Wetted Perimeter method based on inflection point approximations.

Creek	Sites	Flow (cfs)	Creek	Sites	Flow (cfs)	Creek	Sites	Flow (cfs)
Almota	1-3	7	Deadman	1 & 2	8	Joseph	1 & 2	100
Alpowa	3 & 4	17	Deadman	3 & 4	8	Joseph	3 & 4	100
Alpowa	5 & 6	17	Deadman	5 & 6	8	Pataha	1 & 2	15
Alpowa	7 & 8	12	George	1 & 2	19	Pataha	3 & 4	12
Couse	1-3	4	George	3 & 4	17	Tenmile	1 & 2	7
Couse	4 & 5	4	George	5 & 6	17	Tenmile	3 & 4	5
Couse	6 & 7	3	George	7 & 8	8	Tenmile	5 & 6	5
						Tenmile	7 & 8	5

The curves for Couse, George and Pataha Creeks exhibited fairly noticeable inflection points. The breakpoints in the Couse Creek curves were not only defined, but the paired site locations yielded similar results that support confidence in the findings (Figure E.3). The riffle, run and pool/run series comprising Sites 1-3 is a good example, wherein each site displayed inflection points at about 4 cfs. George Creek displayed the most ideal curves of all of the streams, generating easily defined curves with no outliers present for any of the sites (Figure E.5). Values for Pataha Creek were well distinguished for the lower four sites (Figure E.7), and the only drawback to the plots for the upper sites was a lack of data points due to frequent weather restrictions limiting access to the upper portions of the watershed.

Alpowa, Deadman and Tenmile Creeks displayed more subtle breaks in their respective wetted perimeter – discharge curves, yielding a more constant slope (Figures E.2, E.3 & E.8). However, an inflection point was discernable for each of these streams and a fair degree of confidence can be placed in the resultant values. The plots generated for Almota Creek were relatively flat for Sites 1 and 2 (with one anomalous outlier for Site 1), but Site 3 demonstrated a clearly distinguishable flow value suitable for calculating “discussion flows” for the stream (Figure E.1). On the contrary, the relationship for Little Almota Creek was non-existent and the results were ambiguous. Joseph Creek similarly yielded a plot displaying little slope (Figure E.6), but this is likely an artifact of limited data points and its comparably larger size.

The streamflow values corresponding to the instream flow estimates shown in Table 3.2 theoretically relate to adequate water levels in riffles that can maintain suitable fish passage corridors and ensure habitat protection for invertebrate food sources. However, flows derived from this method do not account for different riffle cross-sectional shapes. Although flow rates may be low, it is uncertain whether the associated water depths will be able to provide adequate habitat in portions of the channel, or conversely result in unfavorable conditions across the entire width of the stream. Transect plots (Figures B.1-B.8) illustrate how non-uniform geometries can complicate habitat assessment. For instance, Almota Creek at RM 0.06 exhibits an undulating streambed that appears to have suitable water levels along the left bank, but insufficient water depth toward the right bank.

3.3. Toe-Width method

Table F.1 displays toe-width measurements taken at the beginning and end of the study. Measurements were taken twice to investigate potential changes in stream channel shape during the course of the study. However, the June 2009 values were determined under substantially higher flow conditions, which placed the bank toes under water in most cases and made them difficult to determine. Thus, calculations for recommended streamflows shown in Table 3.3 used the measurements recorded in the fall of 2008.

Table 3.3. Recommended streamflow rates for steelhead rearing (Q_r) and preferred spawning (Q_{dv}) habitat derived using the Toe-Width method.

Creek	Average toe-width (ft)	Q_r (cfs)	Q_{dv} (cfs)
Almota	5.6	1.9	11.3
Little Almota	4.5	1.4	8.8
Alpowa	8.9	3.7	19.6
Couse[1]	6.5	2.3	13.6
Deadman	5.4	1.8	10.9
George	15.3	7.9	36.6
Joseph	23.3	14.3	59.6
Cottonwood	5.4	1.8	10.8
Pataha	5.8	2.0	11.9
Tenmile	8.1	3.2	17.6

[1] Toe-width for Couse site #3 (R.M. 0.08) was removed from calculations, as the width of this large pool was determined to not be representative of the stream as a whole.

Two flow rates were calculated following the method outlined by Swift (1976). Rearing discharge (Q_r) is defined as the flow rate that just covers the streambed, which relates to the habitat needed to support invertebrate communities acting as a fish food supply. This value is the flow rate often used for instream flow studies (WDOE, 2008). The preferred discharge for steelhead spawning (Q_{dv}) was provided for comparison; this flow rate relates to the amount of water covering the greatest streambed area with corresponding depth and velocities.

Joseph Creek yielded the largest toe-width (23.3 ft), which is consistent with this stream being the largest in the study. This yielded a recommended rearing discharge for steelhead of 14.3 cfs, far below the estimated annual average flow rate of 113 cfs. Recommended instream flows using the Toe-Width method were also significantly below the average annual flows for Alpowa and Pataha Creeks. All of the other streams generated recommended instream flow below their average annual flow rates, with the exception of Couse Creek which yielded a prescribed flow that matched the average annual flow.

Although the first toe-width measurements were used to calculate the instream flow recommendations, a comparison between the results from the two sampling periods was conducted to determine reproducibility of the field protocol supporting the Toe-Width method. Alpowa, Almota and Little Almota Creeks yielded almost equivalent values both times, being within 4, 7 and 7 percent, respectively. Values obtained from Couse, Deadman, and George Creeks all varied by just over 15 percent when comparing the two datasets. These results are acceptably close, especially regarding the difficulty in measuring toe-widths during the second sampling period, as well as the inevitable shifts in stream channel geometry that occurred during the high-flow periods. These results provide confidence in the consistency of the measurement protocol outlined in conjunction with Ecology and WDFW.

3.4. Tennant method

The Tennant method bases its streamflow recommendations on the theory that stream habitat conditions are related to a proportion of average annual flow (Q_{Avg}). The method establishes instream flow criteria by means of a predetermined percentage of the average annual flow (Table 2.2), dividing the year into winter (October to March) and summer (April to September) periods. Table 3.4 summarizes Q_{Avg} values for the streams based on the 2003-2009 Ecology stage data.

Table 3.4. Average annual flow (Q_{Avg}) estimates based on Ecology stage data collected from 2003-2009, and annual flow statistics[1] used in the Tennant method based on a percentage of the average annual flow to derive seasonal habitat conditions.

	Q_{Avg}	60% Q_{Avg}	50% Q_{Avg}	40% Q_{Avg}	30% Q_{Avg}	20% Q_{Avg}	10% Q_{Avg}
Creek	(cfs)						
Almota	3.0	1.8	1.5	1.2	0.9	0.6	0.3
Alpowa	9.1	5.5	4.6	3.6	2.7	1.8	0.9
Couse	2.3	1.4	1.2	0.9	0.7	0.5	0.2
Deadman	3.7	2.2	1.9	1.5	1.1	0.7	0.4
George	10.6	6.4	5.3	4.2	3.2	2.1	1.1
Joseph	113.2	67.9	56.6	45.3	34.0	22.6	11.3
Pataha	12.6	7.6	6.3	5.0	3.8	2.5	1.3
Tenmile	5.2	3.1	2.6	2.1	1.6	1.0	0.5

[1] Percentage of Q_{Avg} in regards to seasonal flow relations to habitat condition:
Oct.-Mar.: 60%-100% optimum, 40% outstanding, 30% excellent, 20% good, 10% poor or minimum
Apr.-Sept.: 60%-100% optimum, 50% excellent, 40% good, 10% poor or minimum

Minimum flows for small streams during summer are usually identified based on the 40-, 30- and 10-percent Q_{Avg} values, which relate to good, fair and poor habitat conditions, respectively (Annear and Conder, 1984). Tennant (1976) indicated that most stream substrate is submerged at 30-percent Q_{Avg}, but half or more of the stream substrate is exposed at 10-percent Q_{Avg}.

3.5. Streamflow relations to fish data

A key component of this study was to evaluate the biological relevance of potential instream flow recommendations in regards to salmonid populations indigenous to the WRIA 35 tributaries. Instream flow assessments require consideration of two distinct but interrelated topics: 1) the hydrology of the stream, and 2) stream flow habitat requirements of fish (WDOE & WDFW, 2003). Although the instream flow assessment methods used in this study theoretically relate to the fish communities, a comparison of the resultant instream flow recommendations and hydrologic data to existing salmonid populations ensures that various potential flow regimes are appropriate to support rainbow/steelhead and Chinook salmon. Moreover, habitat assessments, such as the methods used in this instream flow study, need to be complemented with biological monitoring to adequately describe stream ecosystem health (Karr and Chu, 1999).

The relation between fish populations and streamflow in the WRIA 35 streams remains undefined due to limited data and the absence of long-term monitoring of both salmonids and hydrologic conditions. All of the streams in this study have been designated as supporting presumed steelhead populations (Figure G.1). Recent adult and juvenile steelhead surveys (Mendel, 1999; Mendel et al., 2001; Mendel et al., 2004; Mendel et al., 2006; Mendel et al., 2008) have subsequently documented that steelhead utilize existing habitat in all of the study streams. This section will summarize available data and provide additional information gained during this study to help relate these fish populations to the flow regimes of the respective streams. A full compilation of the WDFW data can be found in Tables G.1 through G.7.

Spawning surveys conducted between 2000 and 2007 assessed adult steelheads returning to the Middle Snake Watershed tributaries (Table 3.5). Surveyors walked along the streams and visually identified the presence of redds or spawning steelhead, and calculated an average density on a per mile basis. Surveys were inconsistently conducted through this time period, and the number of surveys performed for each stream varied during a given year. However, this information provides an initial assessment of spawning activity in the streams.

Table 3.5. Summary of steelhead redd surveys conducted by WDFW, 2000-2007.

	2000	2001	2002	2005	2006	2007
Creek	------------------------- Number of redds (Redds per mile) -------------------------					
Almota		25 (5.3)	14 (2.5)			
Alpowa					25 (2.3)	34 (4.0)
Couse	6 (1.1)	0 (0)	3 (1.0)		10 (2.5)	
Deadman		9 (1.4)	1 (0.1)			
George	21 (1.3)	42 (4.8)	1 (0.3)	30 (4.6)	12 (1.8)	6 (0.9)
Joseph					0 (0)	
Tenmile	36 (2.3)	29 (4.8)	25 (4.2)		7 (1.0)	9 (1.5)

Sources: Mendel et al. (2001), Mendel et al. (2004), Mendel et al. (2006) and Mendel et al. (2008)

George Creek provides a prime example of existing habitat supporting a strong rainbow/steelhead population (Mendel et al., 2001; Mendel et al., 2004; Mendel et al., 2006; Mendel et al., 2008). Unfortunately, irregular data collection prevents the identification of any trends that relate steelhead spawning activity (Table 3.5) to streamflow. George Creek was the most extensively studied stream for which redds were examined, with surveys conducted every year WDFW assessed any of the study streams. Comparing these figures to streamflow collected by Ecology (Figure D.1), it can be seen that all but two flow measures were between 4.0 and 6.0 cfs for George Creek; however, discharge data is only available for 2006 and 2007 which makes relating spawning activity to streamflow data difficult. Moreover, since streamflow monitoring consists of a manual stage-height station, the data do not truly capture the hydrologic conditions encountered by returning adult steelhead over the relatively short duration of their migration.

It is interesting to note the significant variance displayed by the number of returning adult steelhead to George Creek over this period. The surveys documented 21, 42, 1, 30, 12 and 6 redds in 2000, 2001, 2002, 2005, 2006 and 2007, respectively. Although the George Creek dataset is the most extensive out of the study streams, relating the number of returning adults to juveniles in the stream remains difficult. Table 3.6 summarizes the juvenile rainbow/steelhead stock densities determined based on the fish surveys conducted in 2000, 2005 and 2007. Since redd surveys were not conducted in 1999 or 2004, it is not possible to relate the declining numbers shown in the table to the abundance of returning adults the previous year. Similarly, the potential impact streamflow conditions could have exerted is uncertain, as Ecology did not began monitoring stream discharge in George Creek until 2006. However, these statistics can be deceiving, since the values disseminate fish density rather than an absolute number. In actuality, Mendel et al. (2001) estimated that in 2000 George Creek supported a rainbow/steelhead population of 49,305. More recently, WDFW captured 91 adults in the spring of 2009 with suspicions that additional steelhead were in the system (K. Mayer, WDFW, pers. comm., 2009).

Table 3.6. Summary of rainbow/steelhead fish surveys conducted by WDFW during June to September, 2000-2007.

	2000	2001	2005	2006	2007
Creek	----------	Average number of rainbow/steelhead per 100 m^2 based on locations surveyed			----------
Almota		30.1			
Alpowa					46.6
Couse	40.0			103.9	
Deadman		14.0			
George	56.2		12.3		5.8
Joseph				0.14	
Tenmile	89.6		8.2		

Sources: Mendel et al. (2001), Mendel et al. (2004), Mendel et al. (2006) and Mendel et al. (2008)

The robust steelhead population present in George Creek illustrates the rare conditions presented by the Middle Snake Watershed sub-basins, as this tributary is an intermittent stream, yet it sustains a viable fish community. Although no known alterations in the flow regime have occurred (Kuttel, 2002), lower reaches of George Creek are often dewatered during dry months.

During this study, dry reaches were observed below R.M. 3.3, and it has been reported that flow has consistently gone subsurface downstream of Pintler Creek most summers since at least 1981 (Kuttel, 2002).

Similar to George Creek, Alpowa and Tenmile Creeks support strong steelhead runs (Tables G.2 and G.7); Alpowa Creek rainbow/steelhead juvenile density estimates increased from 17.1 fish per 100 m^2 in 1998 (Mendel, 1999) to 46.6 fish per 100 m^2 in 2007 (Mendel et al., 2008). This improvement was followed by a strong return of an estimated 410 adult steelhead in 2009 (K. Mayer, WDFW, pers. comm.). Likewise, salmonid populations in Tenmile Creek have been healthy and productive. Electrofishing surveys conducted in 2005 between the headwaters to a mile above the mouth on Tenmile Creek yielded 268 age +1 rainbow/steelhead (WDFW, 2006). Even more surprising for this low-flow stream, 16,837 rainbow/steelhead were projected to live in Tenmile Creek in 2000 (Mendel et al., 2001). Tenmile Creek acts as an intermittent stream and consistently has reaches dewater during the summer. Dry reaches were observed during this study, while previous reports have described similar findings (Mendel et al., 2001).

Almota is another small stream able to support fish populations under current hydrologic conditions. Despite its small size compared to most of the other streams in WRIA 35, the greatest density of redds (5.3 redds per mile) determined during WDFW’s surveys was recorded in Almota Creek (Table 3.5). However, moderate intensity fish surveys conducted on Little Almota Creek in 2001 revealed no steelhead redds or adults in this tributary (Mendel et al., 2004). While two 0+ rainbow/steelhead were found in the lower reaches of Little Almota Creek, it is possible that these juveniles moved into this section from the mainstem seeking new habitat.

In addition to steelhead, WDFW has more recently captured juvenile Chinook salmon while conducting electrofishing surveys. An age 0+ Chinook was found in the lower reaches of Tenmile Creek in 2005 (Mendel et al., 2006). Similarly, wild Chinook were captured during electroshocking fish surveys in the lower reaches of Alpowa Creek (1.3 fish per 100 m^2) in 2007 and Couse Creek (5.0 fish per 100 m^2) in 2006 (Mendel et al., 2008).

Observations of fish presence were recorded when measuring streamflow during this study. The associated notes are somewhat limited, because: 1) the focus of field technicians was on measuring streamflow, 2) most of the technicians had no fisheries background, and 3) flow levels or fish movement often made visual observation and identification difficult. However it is important to mention the variety of fish seen under these conditions. Positive or potential identification of rainbow/steelhead occurred during sampling events on Couse, Deadman, George and Tenmile Creeks (Table 3.7), while various unidentified fish species were observed at different locations and dates for these streams, as well as Patah Creek. This diversity is represented by the photograph shown in Figure 3.1, where a juvenile salmonid was noted during a site reconnaissance on Tenmile Creek (R.M. 1.1) along with a multitude of other fish species.

A noteworthy observation during the study included the upstream migrating of a large salmonid, presumably a returning adult steelhead, which swam between the legs of one of the field technicians in Tenmile Creek (Jan. 23, 2009). Another significant event involved the viewing of numerous rainbow/steelhead in a large, isolated pool on George Creek near R.M. 3.2 that was located above intermittent reaches that had become dewatered (Sept. 5, 2008). This isolated pool contained an estimated 200 fish, comprised of about six species; the high fish density made it impossible to enumerate or identify the different species.

Table 3.7. Observations of salmonids or potential salmonids during study.

Creek	Observation	Date	Creek	Observation	Date
Couse (R.M. 1.5)	Potential salmonid	9/25/08	Tenmile (R.M. 1.1)	Several dozen salmonid juveniles & other unidentified fish species	6/30/08
Couse (R.M. 1.5)	20-30 fish, mostly salmonid juveniles (2-3 in.)	11/10/08	Tenmile (R.M. 2.6)	One rainbow/steelhead & 3 unidentified fish species	9/26/08
Deadman (R.M. 10.7)	Five possible salmonids	10/2/08	Tenmile (R.M. 2.6)	Upstream migrating rainbow/ steelhead (~20 in.)	1/23/09
George (R.M. 3.2)	~200 fish – included salmonids & ~6 species	9/5/08			

Perhaps the most interesting observation during the study was of three rainbow/steelhead that ranged in length from 5 to 10 inches in Couse Creek during a site reconnaissance near R.M. 3.3 (Aug. 23, 2008; Figure 3.2). This finding is particularly notable, due to the small size of the pool (~6 in. deep, ~15 ft^2), negligible flow rate and the dry streambed that stretched about 1.5 miles (from R.M. 3.1 to R.M. 1.6) below the site. This finding was similar to another in July 2000 where juvenile steelhead/rainbow were found in an isolated pool despite Couse Creek being dry from about 1.5 miles above the mouth to just past the bridge at Montgomery Gulch (Kuttel, 2002). Even under such low-flow conditions, an estimated 2,409 rainbow/steelhead lived in the lower 1.5 miles of Couse Creek in 2000 (Mendel et al., 2001).

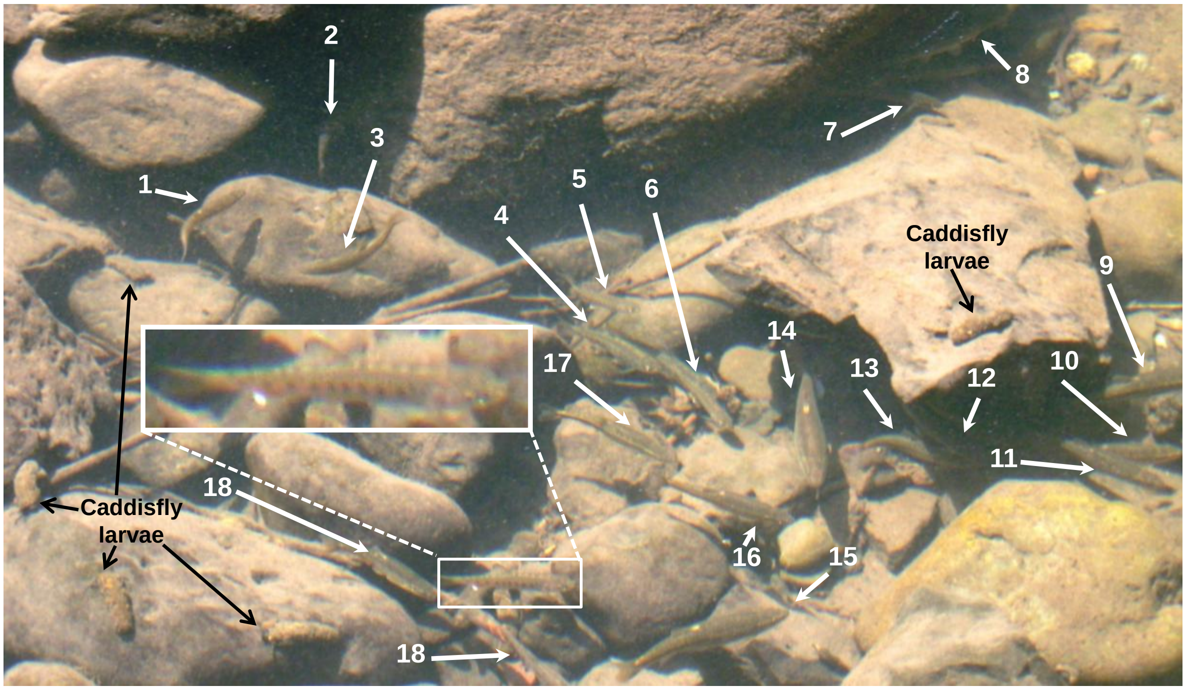

Figure 3.1. Fish observed in Tenmile Creek at R.M. 1.1, including a juvenile salmonid (June 30, 2008). Eighteen cyprinids (i.e., minnows) are indicated by arrows, along with five caddisfly larvae. The juvenile salmonid is outlined by a box and enlarged to highlight parr marks that help identify this as a young salmonid (photo by Ullman).

Water quality parameters

Along with flow measurement equipment, a YSI Professional Plus Handheld Multiparameter Instrument was brought into the field when taking streamflow measures to analyze for temperature, dissolved oxygen and conductivity to better assess instream habitat (Figures G.2-G.11). These parameters typically relate to streamflow and the data presented should be viewed in this context, and not as an evaluation of water quality.

Temperature is perhaps the most critical determinant influencing salmonid health. Therefore, when assessing instream habitat it is important to consider water temperature in addition to streamflow. Increased temperatures are often associated with low flows, which exasperate fish stress and enhances susceptibility to disease and mortality. Optimum temperatures that maintain healthy physiology and behavior range from 10°C (50°F) to 20°C (68°F) for rainbow trout (Barton, 1996), while steelhead prefer temperatures on the lower end of this range (Pauley et al., 1986). Upper threshold temperature limits are 26.5°C (80°F) and 24°C (75°F) for rainbows and steelhead, respectively (Barton, 1996).

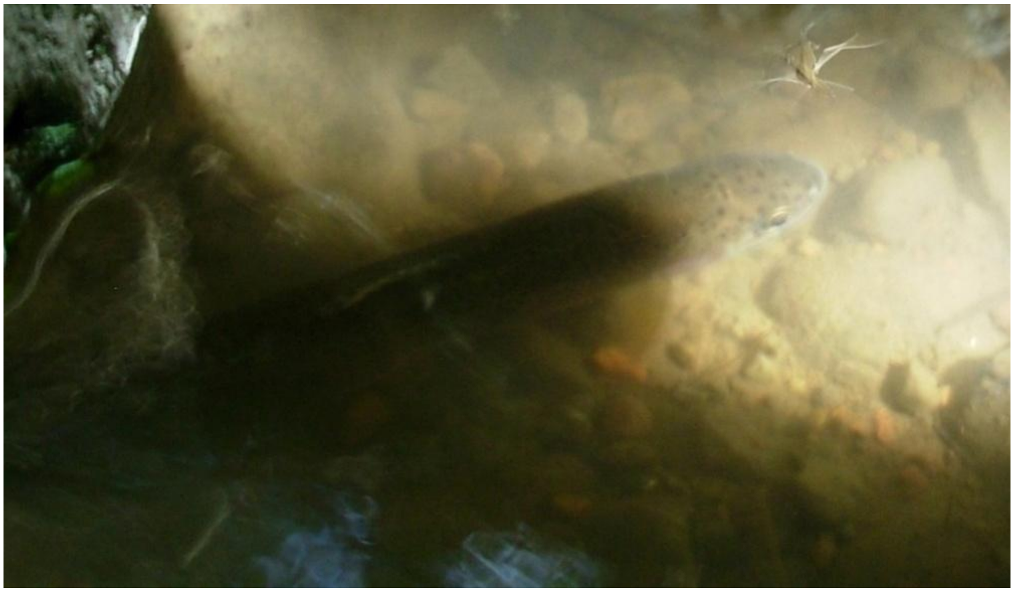

Figure 3.2. Rainbow/steelhead observed in small pool in Couse Creek near R.M. 3. Intermittent sections below this reach were dry at the time this photograph was taken (August 23, 2008; photo by Ullman).

While Almota, Alpowa, Couse and George Creeks all reached temperatures in the 18°C to 19°C range, these measurements were all within the optimal temperature range for rainbow trout. However, even though water temperatures remained well below the critical upper threshold for steelhead, the temperature regimes of these streams may present difficulties for steelhead. Temperature conditions in Deadman and Tenmile Creeks approached 16°C while Pataha Creek never rose above 13°C, indicating better salmonid conditions in these streams. Conversely, Joseph Creek exhibited temperatures above 20°C in June 2009, which is at the upper preference range for rainbow trout. Temperature was not strongly correlated to flow rates for any of the streams, and rather higher water temperatures corresponded simply with the summer months. However, some of the temperatures recorded present a definite concern.

Another key water quality parameter to consider during instream fish habitat assessments is dissolved oxygen (D.O.), which acts as a limiting factor in metabolism. Although salmonids typically require a highly oxygenated environment, rainbow trout are more tolerant and concentrations of about 4 to 4.5 mg/L suffice (Chang, 2006). Although D.O. levels occasionally fell slightly below 4 mg/L, the streams consistently displayed adequate concentrations during the study. However, the upper reaches of Couse Creek dropped to about 2 mg/L during one sampling event and Tenmile Creek exhibited D.O. concentrations around 3 mg/L along its entire length on two consecutive sampling events (Figures G.5 & G.11). An explanation for these dangerous levels remains elusive and may be due to equipment error during these sampling events. Elevated water temperatures, which promote low D.O. levels, were not recorded on these dates. Groundwater seeps introducing low D.O. water into the streams is one possible explanation, as these anomalies occurred during dry periods when streamflow would depend on groundwater recharge.

It should be noted that the water quality data collected during this study is of an extremely limited scope. More robust datasets have been collected by WDFW for some of the Midde Snake Watershed tributaries, and this information should be referred to for more definitive stream characterizations.

4. Discussion

4.1. Consideration of Middle Snake Watershed salmonid populations

The information on the Middle Snake Watershed fish communities presented in this report demonstrates the ability of these rainbow/steelhead populations to survive and reproduce under the low-flow and often intermittent conditions found in the study streams. Moreover, it is unlikely that the existing data adequately characterizes the true status of the salmonid populations. Redd counts are notorious for under-representing spawning activity in a stream, because surveys only occur at given points in time and accurate counts are only possible under certain conditions (e.g., high flow can impede counts). Due to the timing and methodology of the surveys, WDFW also acknowledges that the fish numbers documented via electrofishing are likely conservative (Mendel et al., 2001), and the populations may be larger than currently projected. Salmonid populations adapt to their respective watersheds (Miller, 1965; Wydoski and Whitney, 2003), and it appears that the Middle Snake Watershed fish community can utilize habitat that is not traditionally thought of as suitable for these species.

Numerous examples illustrate the uncommon character of the Middle Snake Watershed salmonid populations. Couse, George and Tenmile Creeks all exhibit intermittent conditions on an annual basis, yet maintain sizeable numbers of rainbow/steelhead. Furthermore, the rainbow/steelhead shown in Figure 3.2 exhibited good body condition despite being limited to a pool that consisted of about 55 gallons with negligible flow. Furthermore, this study documented temperature regimes in Almota, Alpowa, Couse and George Creeks that are typically considered to be inadequate for steelhead, yet steelhead are known to exist in the reaches where the elevated temperatures were measured. In addition to potentially being better adapted to these environments, it is possible that the juvenile steelhead utilize microhabitats that maintain cool temperatures even when streamflow becomes negligible and the stream warms as a whole. Groundwater seeps can introduce cool water where fish can escape from elevated temperatures.

However, even if the Middle Snake Watershed salmonid populations can tolerate lower flows and higher temperatures than other stocks, this does not discount the need for instream flows. The fish populations are still considered “threatened” and it is vital to preserve their habitat. Regardless of whether these salmonid communities are able to tolerate greater stresses than other populations, threshold limits still exist. For instance, the failure to observe any 0+ rainbow/ steelhead in Tenmile Creek during 2005 was attributed to extremely low flows that spring, which may have inhibited adult steelhead upstream migration and spawning (Mendel et al., 2006). Other streams face issues as well. Although Deadman Creek contains steelhead, a lack of riparian habitat and sedimentation has reduced its production capacity (Bartels, 2008).

Therefore, the importance of considering seasonal fluctuations when establishing instream flows is particularly relevant to anadromous salmonid populations. Although a cool, well-oxygenated flow is required for all freshwater life-stages, specific needs will vary for egg incubation, juvenile rearing, juvenile outmigration, adult migration to spawning areas and spawning. Consequently, it is essential that migration, spawning and rearing habitat requirements be considered when developing instream flow criteria. For instance, low-flow rates that would create barriers to adults returning to spawn may not preclude summer rearing, a situation exemplified by the examples given above.

Specific flow requirements for the salmonid populations in these streams are relatively unknown, but it is clear that accepted standards for steelhead and Chinook that were developed in other regions cannot simply be applied to the Middle Snake Watershed populations. For instance, depth preference curves developed for juvenile steelhead by WDFW do not recognize extreme shallow stream water depths in certain instances (WDFW & WDOE, 2004), but reaches of certain streams addressed in this study often are only a few inches deep or go dry during the summer yet still support steelhead (Mendel et al., 2001; Mendel et al., 2004; Mendel et al., 2006; Mendel et al., 2008). Observations during this study further support this premise that flow requirements derived for other regions are not applicable to the WRIA 35 streams, as rainbow/steelhead were documented in exceptionally shallow pools and reaches exhibiting negligible flow. Clearly, the fish surveys and hydrologic results documented in this report indicate that in general there is more useable habitat for rainbow/steelhead in these streams than traditional assessment techniques would indicate. This is a critical point to consider when setting instream flows from a regulatory perspective.

4.2. Comparison of instream flow methods

Virtually no guidance has been established for recommending instream flows appropriate for inherently low-flow or intermittent streams in a semi-arid/arid climate. Development of any instream flow assessment technique necessitates extensive supporting research, which often limits data collection to a small geographic area. For instance, the development of the Toe-Width method relied on data collected for stream depth, flow, spawning habitat and other watershed and channel variables on 18 similar streams in western Washington (Swift, 1976). Similarly, comprehensive examination of hundreds of streams in the northern U.S. between the Atlantic Ocean and the Rocky Mountains was used to optimize the Tennant method (Tennant, 1976). Although this method incorporated a greater geographic range, it failed to encompass streams that display characteristics similar to the Middle Snake Watershed or its acclimated fish populations. Literature reviews revealed no information that relates the Wetted Perimeter method to conditions commonly found in WRIA 35. Therefore, the transferability of any of these methods to the study streams is uncertain without rigorous analysis that is beyond the scope of this study. However, this section provides insight into the applicability of instream flow assessment methods for the Middle Snake Watershed.

Wetted Perimeter method

Variations of the Wetted Perimeter method have been widely applied for some time and this technique is useful for determining low flows. Although little information exists supporting the premise that the slope breakpoints in the wetted perimeter versus discharge curves provide water levels preferred by salmonids (Gordon et al., 2004), flow rates determined by the inflection points have been related to invertebrate populations (Dunbar et al., 1998). Nelson (1980) found that minimum flow recommendations derived from the Wetted Perimeter method tended to agree with a river’s capacity to sustain trout, but discounted any relation to invertebrate populations as a food source. Ultimately, he failed to contrive a physical explanation for the phenomena and accepted the method solely on the basis that it yielded consistent results. It is this consistency and its relative simplicity that has led to its acceptance as the third most widely used instream flow assessment technique in North America (Reiser et al., 1989). Correspondingly, the Wetted

Perimeter method was included in this study, even though it is not a primary technique used in Washington (although other WRIA instream flow studies have used it (e.g., Golder, 2003)).

The popularity of the Wetted Perimeter method stems largely from the clear mathematical definition relating habitat to discharge, which can easily be explained to diverse audiences. Essentially, below the critical point (i.e., the inflection point in the wetted perimeter versus discharge curve), habitat conditions rapidly diminish because a small alteration in streamflow corresponds to a large change in the wetted perimeter. Conversely, above the critical point, a large alteration in stream discharge corresponds to a minor change in the wetted perimeter. Since the ecological aim of this technique is to optimize habitat corresponding to the wetted perimeter, and therefore productive stream locations, the derived discharge value theoretically denotes a threshold to be protected by the prescriptive instream flow. Ultimately, this association provides a good method to establish low-flow requirements (Annear et al., 2004).

The inherent subjectivity of selecting an inflection point in the wetted perimeter – discharge relation presents a common criticism of the Wetted Perimeter method. This ambiguity is particularly pronounced in parabolic channels where the relationship does not display well defined inflection points. Such situations likely account in part for indistinct results acquired for some reaches assessed in this study (e.g., Little Almota Creek). It is also possible that shifting bed types inserted uncertainty into wetted perimeter analysis. Under low flows, the channel may experience substrate settling that results in an uneven streambed; although flow measures were taken at small intervals, undulations at random locations could yield wetted perimeter values that don't fully characterize the streambed. However, accurate discharge estimates would still be obtained, as the variations would be averaged out when calculating flow rates. Similarly, changes in streambed geometry may have occurred in some locations due to the dynamic nature of these systems. For instance, soft streambed substrate that was originally encountered during the initial low-flow periods of the study would have been scoured and flushed during high-flow events. This could result in either a smoother stream bottom or one that is more uneven due to a greater influence of cobbles that resist movement by the stream current.

Overall, the Wetted Perimeter method yielded relatively non-ambiguous wetted perimeter versus discharge curves, albeit subtle inflection points occasionally resulted. Rather, the primary factor limiting its application in WRIA 35 lies in the obviously unrealistic discharge requirements obtained from the model. The derived recommendations were all greater than the average annual flows, except for Joseph Creek (Table 4.1). The Wetted Perimeter method generates a single flow value theoretically designated to be appropriate for all fish life-stages (although this assertion may not always hold true), which consequently corresponds to a low-flow minimum value. Thus, the study results suggest that the lowest prescribed instream flow recommendations would need to be greater than the yearly average, which is a nonsensical premise. Looking at this contradiction from another perspective, the percentage of time each prescriptive instream flow would be exceeded was found to be small for all of the streams, which would analogously place the low-flow recommendations in the upper range of the respective flow regimes. Alpowa Creek represents the most striking example of the unrealistic instream flow values produced by the Wetted Perimeter method, wherein the suggested low-flow seasonal discharge would only be exceeded 3 percent of the time (i.e., flood conditions). Meanwhile, Alpowa Creek sustains a respectable steelhead population that undoubtedly does not require such high flows.

Table 4.1. Comparison of resultant instream flow recommendations derived from the Wetted Perimeter, Toe-Width and Tennant methods, percentage of time the respective prescriptive flows would be exceeded under existing conditions, and relation to current average annual flows for each stream.

	Wetted Perimeter[1]		Toe-Width[2]		Tennant[3]		Average annual flows from Ecology data (cfs)[4]
Creek	(cfs)	% exceeded[4]	(cfs)	% exceeded[4]	(cfs)	% exceeded[4]	
Almota	7	10%	1.9	43%	0.6	97%	3.0
Alpowa	17	3%	3.7	98%	1.8	99%	9.1
Couse	4	12%	2.3	17%	0.5	95%	2.3
Deadman	8	5%	1.8	78%	0.7	95%	3.7
George	19	8%	7.9	11%	2.1	97%	10.6
Joseph	100	26%	14.3	97%	22.6	81%	113.2
Pataha	15	25%	2.0	67%	2.5	61%	12.6
Tenmile	7	23%	3.2	31%	1.0	66%	5.2

[1] Wetted Perimeter method derived values are for the most downstream locations only
[2] Toe-Width values correspond to rearing discharge (Qr), as this would correspond with low-flow conditions
[3] Tennant method values based on 20% Q_{Avg}, which represents "good" habitat during low-flow season
[4] Based on Ecology data collected at monitoring stations near the mouths of each stream, 2003-2009

No definitive explanation could be identified to describe why the Wetted Perimeter method yielded such overly conservative (i.e., high) instream flow recommendations for the study streams. Since the Wetted Perimeter method is typically applied to riffle habitat, the question was raised whether applying this technique to non-riffle habitat locations could have promoted the generation of the excessively high values. To the contrary, the mathematical principles behind the Wetted Perimeter method dictate that inclusion of non-riffle habitat produces significantly lower instream flow recommendations, rather than higher (Reinfelds et al., 2004). Parker et al. (2004) reported that when the Wetted Perimeter method is applied to locations with low to moderate flows, the resultant instream flow recommendations can exhibit greater variability. This statement fails to characterize why the instream flow recommendations were generally so high, but it raises an interesting question concerning the use of this method during extreme low-flow conditions. Although no information was found regarding a lower flow limit under which the Wetted Perimeter method becomes ineffectual, it is interesting to note that the recommendation for Joseph Creek, the lone "high-flow" stream in the study was the only value obtained that was lower than the average annual flow for the stream. However, Parker et al. (2004) also asserted that the Wetted Perimeter method tends to under-estimate streamflow requirements in smaller drainages, which further confounds efforts to explain the situation.

Returning briefly to the topic of non-riffle habitat, this issue was addressed due to circumstances encountered in the field. Differences in riffle, run and pool reaches were often diminutive under low-flow conditions (such as during site location establishment), and thus wetted perimeter – discharge relations were calculated for each study site. Resultant prescriptive flow rates were then produced by integrating the values obtained for the paired site locations, with extra weight placed on the value obtained for the riffle component. The incorporation of non-riffle reaches during application of the Wetted Perimeter method is not without precedent (e.g., Liu et al., 2006), and this substantiates the approach selected. In addition, this method can be used in streams where the stage is flow sensitive (Annear, 2004), and has been extended to include non-riffle sites where fish passage is likely to be limited (Gippel and Stewardson, 1998), situations that largely characterize the study streams during low-flow periods.

Toe-Width method

The Toe-Width method is one of the three primary instream flow recommendation techniques used in Washington, along with the Tennant method and Instream Flow Incremental Methodology (IFIM). The primary advantage of this technique is the significant protection typically provided by the prescriptive streamflows, and the minimal effort required (Annear et al., 2004). Whereas the Wetted Perimeter method addresses hydrologic conditions in relation to habitat, the Toe-Width method directly addresses the biological component that is the impetus behind instream flows. This technique is designed specifically for assessing steelhead habitat requirements during different life-stages (Swift, 1976), which unequivocally relates stream hydrology to the seasonal needs of the focal species in the Middle Snake Watershed. A suite of regression equations yields recommended discharge rates associated with sufficient rearing habitat (Q_r) and preferred streamflow for spawning (Q_{dv}) as presented in this report, as well as theoretical values related to sustainable spawning (Q_S) and preferred stream spawning velocities in which the depth criterion is omitted (Q_V).

However, the Toe-Width method was developed for western Washington, and although Swift (1976) found excellent agreement between flow rates and fish habitat, questions remain about its transferability to other locations. In fact, Annear et al. (2004) state that this “method should not be used in other regions”. The salmonid populations in the Middle Snake River have presumably adapted to conditions significantly different to those on the western side of the Cascade Mountains, where the streams receive significantly greater rainfall and extensive mountain snowmelt. Consequently, “preferential” habitat is relative based on location, and it is difficult to compare the requirements of the distinct salmonid populations. Moreover, the great disparity exhibited by the percentage of time the prescribed flows are projected to be exceeded for the respective streams denotes inconsistency in the method (Table 4.1).

Modifications would clearly have to be made before the Toe-Width method could be applied with confidence in WRIA 35. Instream flow assessment studies in the WRIA 54 Spokane River Tributaries (SCPWD, 2007) and the WRIA 59 Colville River Watershed (WDOE, 2008) have employed this technique, but adaptations were not made in either case to account for regional differences. Although streamflow recommendations in those studies may or may not have been adequate, those systems still vary considerably from WRIA 35. Thus, until research uses the basic approach supporting the Toe-Width method to develop a suite of equations appropriate for southeastern Washington, this technique lacks credence in the Middle Snake Watershed. Even if a relevant regional model is constructed, one should keep in mind that this tool is used primarily as a reconnaissance level method in Washington, and should be used in conjunction with other assessment techniques that incorporate additional ecosystem components (Annear et al., 2004).

Tennant method

The Tennant method is the second most popular instream assessment technique in the United States (Reiser et al., 1989), and one of the three primary methods used in Washington (although it is the most infrequently applied of the trio). This tool differs from the Wetted Perimeter and Toe-Width method in that it relies on natural hydraulic variability as a surrogate for stream biology and habitat (Annear et al., 2004). Based on the premise that various percentages of the average annual flow correspond with different degrees of habitat quality, the Tennant method requires hydrologic records of sufficient duration. This may be the biggest drawback to using this method as a standard-setting model in WRIA 35. Flow rates measured by Ecology only comprise a relatively short period (2003-2009; 2006-2009 for George Creek), with less frequent monitoring of the manual stage-height stations on Couse, George and Tenmile Creeks further diminishing the data quality on those streams. Also, this timeframe falls within a 10-year dry period and may not represent the true long-term character of the flow regimes. Annear et al. (2004) emphasized the use of datasets that span extensive lengths of time to capture the range of representative conditions exhibited by a watershed when applying the Tennant method. Despite this significant limitation and the other disadvantages discussed below, the derived instream flow recommendations displayed a combination of realism and consistency that surpassed the Wetted Perimeter and Toe-Width methods, although perhaps not stringent enough.

After examining the original Tennant (1976) paper, it became apparent that this method is often mis-cited and poorly understood. Several salient items of note include:

1) The tool is intended as, “a quick, easy methodology…for determining flows to protect the aquatic resources in both warmwater and coldwater streams”. This broad application is not specific to salmonid bearing streams.
2) The method was developed using data from hundreds of streams, but all of these were located between the Atlantic Ocean and the Rocky Mountains. Precipitation regimes will vary greatly across regions, particularly in reference to southeastern Washington.
3) Often cited as a method for determining instream flows in regards to fisheries, this paper explicitly states it is for, “fish, wildlife, recreation and related environmental resources”. Recreation (e.g., whitewater rafting, floating larger boats) is discussed extensively throughout the publication.
4) Although this technique is best applied to unregulated streams, many of the recommendations made relate to regulating water release from dams, and it does not focus solely on hydrology driven by “natural” conditions.

It appears that Tennant designed this technique to be flexible in adjusting instream flow recommendation criteria to specific geographic locations, but no guidelines on transferability are provided and only limited information is available from other sources. Therefore, best judgment will be required to relate derived recommendations to the WRIA 35 streams.

The prescribed instream flows shown in Table 4.1 correspond to the 20-percent Q_{Avg} values, which represent “good” habitat during the low-flow season. Tennant (1976) suggested that instream flow recommendations should remain at or above the 10-percent Q_{Avg}, which has led others to often use the 10-percent Q_{Avg} figure as the representative criterion (Orth and Maughan, 1981; Li et al., 2009). However, due to the sensitive disposition of salmonids, a 20-percent Q_{Avg} standard was selected here to ensure adequate protection. Although others have selected a 30-percent Q_{Avg} standard, this proportion appeared to be overly restrictive for the Middle Snake Watershed, particularly since this method was not developed in semi-arid/arid regions and would not account for the unique fish communities that are acclimatized to lower flow conditions.

The selection of appropriate percent Q_{Avg} standards for a particular stream is intentionally left undefined by Tennant (1976), and a range of choices have been made in other studies. A 25-percent Q_{Avg} was designated as the minimum streamflow requirement in modifications implemented by the Canadian Atlantic Provinces (Dunbar et al., 1998), but the dissimilarity between that region and the Middle Snake Watershed does not clarify the applicability of this value in WRIA 35. Tessmann (1980) and Estes (1998) used a modified form of the Tennant method that relates Q_{Avg} to site-specific conditions based on monthly variability. This recalibration based on monthly flows is shown in Table 4.2. However, the transferability of this approach to the low-flow and intermittent streams in this study is still questionable and would require additional long-term research.

Table 4.2. Modified version of Tennant method, which relates minimum monthly flows to mean annual flows.

Flow conditions	Minimum monthly flow
MMF[1] < 40% MAF[2]	MMF
MMF > 40% MAF and 40% MMF < 40% MAF	40% MAF
40% MMF > 40% MAF	40% MMF

[1]MMF = mean monthly flow; [2]MAF = mean annual flow
Based on Tessmann (1980)

An advantage of the Tennant method is the derivation of seasonally adjusted instream flow recommendations, yet ambiguity remains. Presumably the October-March and April-September seasonal periods were selected by Tennant to correspond with the water year (October 1 to September 30 is the most widely used period in the U.S.), but this was not related to either precipitation regimes or life-cycle stages of fish (a reference is made to 60 percent of the average annual flow providing “excellent to outstanding habitat for most aquatic life forms during their primary periods of growth”, but this statement is left ambiguous). When describing the Tennant method Gordon et al. (2004) listed “dry season” and “wet season” for the October to March and April to September periods, respectively, but actual names of the months were omitted and no reference was made on how this seasonal classification relates to specific watersheds.

The percent of time the 20-percent Q_{Avg} standard would be exceed was between 95 and 99 percent for Almota, Alpowa, Couse, Deadman and George Creeks, 81 percent for Joseph Creek and in the 60 percent range for Pataha and Tenmile Creeks (Table 4.1). Based on this evaluation, instream flow recommendations using the 20-percent Q_{Avg} standard would be readily met for the majority of streams. Therefore, it would not be unreasonable to increase the criterion to a 30-percent Q_{Avg} standard. On the other hand, the Planning Unit may want to consider applying a 10-

percent Q_{Avg} standard (Table 3.4) to Pataha and Tenmile Creeks to compensate for the more stringent prescribed flows generated by the 20-percent Q_{Avg} standard. The ability to alter criteria is flexible and ultimately depends on the steelhead management goals selected for the streams. However, the remainder of this report will refer to the 20-percent Q_{Avg} values for consistency.

It is also important to note that the seasonal periods developed by the Tennant method do not relate to instream flow recommendations for southeastern Washington, because: 1) they do not adequately capture the precipitation regime of the Middle Snake Watershed, and 2) they do not capture salmonid life-stages in this watershed (refer to Table 1.1). Table 4.3 juxtaposes the average seasonal flow rates derived for both the standard Tennant seasonal delineation and an adjusted seasonal characterization that corresponds to salmonid migration/spawning periods in WRIA 35 (i.e., February to May). This data illustrates the importance of accurately linking existing biological cycles to a stream's hydrology when determining appropriate instream flows, rather than choosing arbitrary seasons as many publications do when using the Tennant method. Flow rates during the February to May period are greater than the average annual flows, which correspond well with steelhead migratory requirements, and this seasonal delineation eliminates the need to extrapolate between the standard six-month divisions. However, since the primary focus of this study is on low-flow events, the standard dry-month values were primarily used in this study to correspond with previous instream flow studies in Washington.

Table 4.3. Seasonal flow estimates derived from Ecology stage data collected from 2003-2009. The Tennant method suggests providing seasonal instream flow recommendations based on the periods October to March and April to September. February to May and June to January periods are also shown, which related to salmonid life-history stages in WRIA 35 streams.

	Oct.-Mar.	Apr.-Sept.	Feb.-May	June-Jan.
Creek	-------------- (cfs)	--------------	-------------- (cfs)	--------------
Almota	3.8	2.3	5.4	1.9
Alpowa	10.2	8.2	12.0	7.7
Couse	2.3	2.3	4.3	1.0
Deadman	4.2	3.6	5.2	3.0
George	7.7	13.1	19.9	5.7
Joseph	92.7	133.1	251.2	44.4
Pataha	11.8	13.3	24.7	6.7
Tenmile	6.0	4.5	10.1	2.5

While the Tennant method requires calibration when using it in different regions in order to account for the distinct habitat needs of the new location, Mann (2006) found that hydrologic parameters similarly differed based on geographic location. When Mann applied this model to 70 high-gradient river segments in the western United Stated (including Washington) she found that recommendations generated by the Tennant method were non-conservative and over-estimated available habitat. However, when used on low-gradient reference sites the results were favorable.

Thus, Mann concluded that this assessment technique should not be used on streams exhibiting gradients greater than one percent unless limiting its use to a reconnaissance tool. The Middle Snake River tributaries are generally considered higher-gradient streams, so values derived in this study should be considered with caution. However, a comparison of instream flow recommendations with discharge and fish data indicates that significant over-estimates of available habitat is not an issue in this study.

Other methodological considerations

Instream Flow Incremental Methodology (IFIM) is generally accepted as the best available instream flow recommendation method in Washington, describing spatial and temporal habitat features under different flow scenarios. Since biological principles serve as the basis of this method, the physical habitat simulation component (PHABSIM) represents the most widely applied instream flow technique in the United States (Reiser et al., 1989). However, the use of IFIM can present difficulties because it comprises a suite of computer models, manuals and procedures that link flow regime, physical habitat (e.g., cover from riparian vegetation, substrate distribution), water quality and energy inputs (e.g., sediment transport) to estimate instream flows. Collecting site-specific values for these different parameters requires extensive monitoring and the cost of obtaining meaningful data can be enormous. Some of these factors are often neglected and modelers instead rely on default values. However, use of IFIM in this study would still not be possible even if variables are overlooked. IFIM lists the depth preference factor for juvenile steelhead as zero for certain shallow water depth conditions (WDFW & WDOE, 2004), and since this critical parameter is multiplied by other factors in the model the results would be nonsensical in many cases for these low-flow streams. It would be ideal to adapt IFIM to low-flow and intermittent streams in the future, but a cost-extensive, multi-year research study would be required to modify the model for the Middle Snake Watershed.

Summary of methods comparison

The regulatory and managerial context that governs the establishment of minimum instream flow standards creates an environment wherein determination of apposite flow recommendations transcends science. This setting has led to the development of many instream flow assessment methods, none of which are universally accepted. Moreover, much remains unknown about the complex biological and physicochemical interactions inherent to stream ecosystems. This knowledge gap confounds the selection of appropriate assessment techniques. Such is the case in this study. Little information exists concerning the hydrologic regimes and fish populations found in the Middle Snake Watershed, and guidance describing how to develop streamflow requirements in low-flow and intermittent streams under semi-arid/arid conditions remains to be established. Similarly, regionally pertinent instream flow assessment methods have yet to be developed. This report is the first known investigation into this realm and a robust approach was used to provide the best available data to support instream flow negotiations.

Thus, three commonly employed instream flow assessment methods were selected for use in this study, representing the second and third most popular models in the United States and a primary technique utilized by Ecology that was developed in the Pacific Northwest. However, it ultimately became clear that all of these displayed disadvantages that fail to capture the unique setting presented by the Middle Snake Watershed tributaries. The Wetted Perimeter method yielded overly restrictive and unrealistic values, while the Tennant method conversely generated flow rates that appear to be not restrictive enough and could consequently prove inadequate in protecting water resources in the streams. The Toe-Width method yielded flow rates that fell between those of the other techniques, but the percent exceedance values were highly variable and generated a combination of recommendations that were overly-restrictive and not restrictive enough. Moreover, each of these displayed degrees of subjectivity and were developed in regions dissimilar to those exhibited by the study streams.

Despite the limitations presented by these instream flow assessment methods, a data management and interpretation solution was developed (see Section 5.1) that integrated this information with other sources to provide a useful perspective on the state of the watersheds studied. Moreover, selection of any other assessment technique would have likely resulted in similar inadequacies due to the uniqueness of the Middle Snake Watershed, and it appears that a method specifically designed for this region needs to be developed. Unfortunately, the amount of time and effort to construct such a model makes this an implausible aspiration at this juncture. In the mean time, results found here can be used to help modify the existing methods to better adopt them for these low-flow streams.

4.3. Additional considerations relating assessment methods to instream flow development

Use of a single management point

Instream flow criteria are intended to incorporate the temporal and spatial nature of streamflows. The temporal dimension that reflects variations in stream discharge and extreme low-flow events, as well as steelhead life history stages, is discussed in more detail throughout the remainder of this document. However, the spatial component that considers upstream-downstream variability was necessarily omitted in the final “discussion flow” recommendations (although it is discussed later in the report as well). Logistics mandate the setting of a single management point in each sub-basin, which will typically be located near the stream mouth, following the establishment of the final instream flow standard. Therefore, while prescribed flows were initially generated for all study sites using the Wetted Perimeter method, this geographic perspective was ultimately eliminated as only data from the most downstream location was used to calculate “discussion flows” for each stream. On the other hand, flow rates derived using the Tennant method lacked a spatial component from the onset, as analysis was dependent on Ecology data collected at a single location in each sub-basin. Meanwhile, spatial aspects inherent to the Toe-Width method were maintained but diluted, as an average of the values determined for each site represents the final flow recommendation. Thus, essentially none of the methods captured key spatial dynamics innate to each watershed due to the need to provide information for a single management point.

Although it is understood that resources limit the ability to manage multiple points in a watershed, an innate spatial component should be considered during instream flow negotiations. After the final minimum instream flow standard is set for a tributary, the dependence on a single management point will not fully account for variations in habitat and fish requirements along the stream length, and will fail to capture stream connectivity (as well as dis-connectivity, as will be discussed in the following section). Thus, it is important to consider this aspect during the instream flow development process.

Intermittent conditions, hyporheic and sub-surface flows and their relation to fish habitat

Fish passage, as well as the transport of energy and matter, depends on the continuity and connectivity of longitudinal flow in a stream from its headwaters to its confluence. Longitudinal connectivity is particularly important in streams that sustain anadromous salmonid species in order to provide migration corridors for upstream passage of adults returning to spawn and downstream transit of out-migrating juveniles. Thus, steelhead are not typically known to utilize extreme low-flow streams for habitat, because of the resultant obstacles that can impede longitudinal movement in the system. Moreover, the presence of steelhead in intermittent streams is not widely documented in the readily available literature. Therefore, the steelhead found in the intermittent study streams, which consist of Couse, George and Tenmile Creeks, present a unique situation for determining instream flow recommendations. Not only are depth preference curves unavailable for fish in these low-flow streams, an extensive literature search failed to reveal any description of how to manage instream flows when the stream channel becomes devoid of surface water.

The annual cycle of certain reaches in these streams becoming dewatered is evidently a natural phenomenon and not an artifact of anthropogenic water withdrawals. The drainage basins for each of these tributaries exhibit minimal development (e.g. a handful of small, single-family houses), contain no irrigation diversions and have reportedly undergone no known change in their original flow regime (Kuttel, 2002). Despite the lack of water withdrawals from these systems, observations during this study confirm previous claims that stream reaches in these streams become completely dry at the same locations on a yearly basis during the summer and fall months (Kuttel, 2002; Mendel et al., 2001; Mendel et al., 2004). Yet, Couse, George and Tenmile Creeks each support respectable to strong steelhead production. Rainbow/steelhead juveniles were observed in upstream locations during this study, supporting previous reports by WDFW. Meanwhile, WDFW spawning surveys documented multiple redds in reaches that extended up to R.M.s 5.5, 19.5 and 15.0 for Couse, George and Tenmile Creek, respectively (Mendel et al., 2001; Mendel et al., 2004). These findings verify that steelhead migration extends above sites that are dewatered during dry periods by waiting for flows to rise and renew stream connectivity. Clearly the longitudinal passage of these fish occurs when flows allow and instream flow criteria are easier to establish. However, establishment of instream flow standards during dry periods when this surface connectivity is interrupted remains a perplexing problem.

A more in-depth examination of the dominant hydrologic processes in these sub-basins is thus required. The annual exceedance curves for these intermittent streams provide a tool that can help elucidate the situation (Figure D.2). Although discussions concerning George Creek will be conducted based on these annual exceedance curves and available data, it should be noted that uncertainty surrounds this limited dataset as mentioned previously in this report. As discussed in Section 3.1, a steep slope at the high-flow end of the curve generally indicates that the watershed conveys a large amount of direct runoff to the stream and a flat slope at the low-flow end of the curve implies a significant groundwater contribution to the stream (Gordon et al., 2007; Gore, 2007). Based on the available data, Couse and Tenmile Creeks display relatively steep high-flow end slopes, while George Creek reveals an exceptionally steep slope. These curve characteristics suggest that little storage of precipitation occurs in these watersheds. Looking at the other end of the curves, all the streams show flat slopes, particularly Couse and George Creek. These results support the presumption that these are groundwater dependent systems. Thus, maintaining instream habitat ceases to be an instream flow concern and rather a hydrogeologic issue. The observation of numerous springs and seeps along each of these streams during this study supports this notion.

Questions were consequently raised by the Middle Snake Watershed Planning Unit concerning the nature of the groundwater – surface water interaction. Specifically, when downstream reaches are completely dewatered is the interaction occurring laterally at the riparian zone interface or is the water lost at the downstream extent of the watered sections moving beneath the streambed longitudinally only to reemerge further downstream? Determination of this subsurface interaction is beyond the scope of this report, but a brief discussion is warranted.

Stream subsurface flows at the groundwater – surface water interface is termed hyporheic flow, which technically considers the water found both beneath the channel alluvium and within the riparian zone (Dahm et al., 2007). However, the lateral and longitudinal components are often generally referred to as hyporheic and subsurface (or interstitial) flow, respectively. This terminology will be used here for the sake of clarification. Although streamflow is generally regarded as the visible free running water (rheic flow) in a stream, in actuality it encompasses longitudinal, lateral, vertical and chronological components (Locke et al., 2008). Although methods exist to distinguish between the physical dimensions (Dahm et al., 2007), the techniques are laborious and complicated. Thus, without extensive research only speculations can be made. While subsurface connectivity could be clearly identified if water was found just below the surface of the dewatered reaches in these intermittent streams, anecdotal evidence suggests that water is not found for several feet below the channel surface in the dry portions. Since these dewatered reaches can extend for over a mile (e.g., Couse Creek), it is possible that water found at significant depth so far removed from a potential upstream source may simply be lateral hyporheic interactions (or vertical interactions with underlying groundwater) occurring at that specific location. However, past floods have deposited large amounts of rubble in the sections of these streams that typically go dry. Thus, the water may rather be following the original channel bottom that now lies below several feet of cobble and assorted alluvium. If this is the case, longitudinal connectivity would be maintained and only the surface continuity would be broken.

While debate over whether longitudinal subsurface flow is occurring or not in these intermittent streams is an interesting academic exercise, the issue is rather moot in the context of immediate managerial needs. Dewatering of different stream sections interrupts the connectivity of free flowing water irrespective of the true answer. The natural barriers to fish passage represented by the dewatered reaches are seasonal. It is important that instream flow criteria maintain adequate discharge during steelhead priority life-stages where adults migrate upstream to spawn and juveniles out-migrate downstream to reach the Snake River and beyond. Since the streams display connectivity during these migratory periods, establishment of minimum instream flow values based on downstream management points becomes intuitive. On the other hand, management of isolated upstream rearing habitat during intermittent periods appears to leave the domain of "instream flows" and enters the realm of hydrogeology. Thus, it is important to reference recent hydrogeological assessments that have occurred in the Middle Snake Watershed.

Seasonal variability and steelhead priority life-stages

Natural flow variations are inherent to ecological integrity in stream systems, and water resource managers must recognize the importance of inter- and intra-annual flow variability when determining instream flows (Annear et. al, 2004). While inter-annual variability should be considered during instream flow negotiations, the lack of historic data for the Middle Snake Watershed tributaries makes quantification of yearly fluctuations infeasible at this time. On the other hand, intra-annual trends can be derived from available data for these sub-basins and should be a key component in the finalized instream flow standards. While the incorporation of a seasonal factor in instream flow prescriptions is true for all stream ecosystems, the anadromous life-cycles of steelhead and Chinook salmon amplify the need to ensure the appropriate timing of sufficient streamflows (refer to Table 1.1 for a description of the life history patterns of steelhead and Chinook in the Middle Snake Watershed).

Although the importance of incorporating seasonal variability into instream flow recommendations is widely acknowledged, most assessment techniques fail to adequately consider this aspect, including all of the methods used in this study. The Tennant method superficially addresses the topic by suggesting different percent Q_{Avg} standards can be used on a biannual basis and the Toe-Width method indirectly acknowledges its importance by generating disparate flow rates based on habitat needs, but neither provides a robust seasonally-based delineation (see Section 4.2 for more detail). This is not surprising, as fish community composition varies widely between streams and regional differences impart even greater diversity that cannot easily be captured by an assessment method. Nevertheless, this report required a method that adequately captures the streamflow requirements for the distinct steelhead life history phases, as protection and restoration of this species is the driving factor behind the development of instream flow standards in the Middle Snake Watershed.

Thus, an alternative technique of using monthly average exceedance flows was adopted, which will be discussed further in Section 5.1. Instream flow recommendations should provide variable flow patterns that reflect the natural hydrograph of a stream to maintain its ecological integrity (Annear, 2004). The employment of monthly average exceedance flows provides the simplest means by which the natural trends can be mimicked. Moreover, these can be directly compared to charts identifying the months during which principle salmonid life history activities occur (e.g., Table 1.1) or related to the most survival limited months. However, it should be noted that considerable limitations still exist using this method. Since it is based on field data collected near the mouth of each stream, it fails to address upstream conditions. This is particularly true in regards to maintaining rearing habitat during low-flow periods where groundwater – surface water interactions become more dominant. Therefore, seasonal considerations are incorporated in the recommendations provided in Section 5. Yet, this discussion on intra-annual fluctuations in relation to fish life-stage presents another example of how stream management based on conditions at its confluence (i.e., a single management point) may lead to either over- or under-estimates when developing instream flow standards.

5. Recommendations and Conclusion

5.1. “Discussion flows”

The purpose of this report is to provide technical information on streamflow and its relation to salmonid populations in the selected tributaries of the Middle Snake Watershed. This data in turn is intended to provide a scientific body of knowledge to be considered among a range of other factors deemed important by watershed stakeholders during instream flow negotiations. Thus, recommending instream flow values is beyond the scope of this document, and rather the suggestions made are designed to provide supporting technical material for use in determining appropriate instream flow criteria. Therefore, the prescribed flows presented are termed “discussion flows”. It should be stressed that these are not definitive values and should not be perceived as flow rates that can simply be used to set minimum instream flow standards.

Moreover, several confounding factors inherent to the Middle Snake Watershed emphasize the point that these values are not definitive. Section 4.2 reveals a range of shortcomings inherent to any method used in WRIA 35. Also, limited information exists that describes historic flow regimes and salmonid populations in the region. Although Ecology has begun to collect an excellent database, the flow data only comprises a short period, while multiple-decade time-series are preferred to adequately characterize a watershed. Moreover, the timeframe over which flow rates have been measured falls within a 10-year dry period that further impedes delineating a long-term baseline. Similarly, WDFW has done an exemplary job in beginning to assess salmonid populations in the streams, but the extensive effort required to conduct fish surveys limits the amount of information that has been collected. Thus, many questions remain regarding the distribution and abundance of salmonids in these systems. Finally, virtually no guidance has been established for recommending instream flows appropriate for inherently low-flow or intermittent streams in a semi-arid/arid climate. Instream flow assessment tools have been developed in regions displaying significantly different climatic conditions and fish populations.

In order to compensate for these limitations, several steps were taken to provide the best possible technical framework to support instream flow negotiations. There is nothing that can be done about the lack of data for the Middle Snake Watershed, so the available information was taken at face-value and limitations were identified where appropriate. To help fill knowledge gaps that exist for the tributaries, information was incorporated from a wide range of resources to present a comprehensive evaluation. Since no instream flow assessment techniques have been designed specifically for the region, three methods were utilized and compared to distinguish potential biases. Finally, information on salmonid populations in the streams was compiled and related to existing streamflows and prescribed instream flow rates when possible.

Due to the limitations inherent to applying instream flow assessment techniques developed in other regions to WRIA 35, no clear-cut method appears to suffice for recommending appropriate instream flow values for the study streams. Careful evaluation of all of the methods raised considerable questions regarding their applicability in the Middle Snake Watershed. Therefore, it was decided that a combination of the techniques should be used, and the resultant “discussion flows” were calculated by taking the average of the recommended instream flows generated by all three methods (Table 5.1). These values were then rounded to the nearest integer. This is a pragmatic means to deal with the situation, as any means selected would have been arbitrary.

Table 5.1. Recommended “discussion flows” presented in relation to instream flow recommendations provided by the different assessment techniques and average annual flows based on 2003-2009 data.

Creek	Wetted Perimeter[1]	Toe-Width	Tennant[2]	Recommended “discussion flows” (cfs)	Average annual flows from Ecology data (cfs)[3]
	----------------	cfs	----------------		
Almota	7	1.9	0.6	3	3.0
Alpowa	17	3.7	1.8	8	9.1
Couse	4	2.3	0.5	2	2.3
Deadman	8	1.8	0.7	4	3.7
George	19	7.9	2.1	10	10.6
Joseph	100	14.3	22.6	45	113.2
Pataha	15	2.0	2.5	6	12.6
Tenmile	7	3.2	1.0	4	5.2

[1] Wetted Perimeter method derived values are for the most downstream locations only

[2] Tennant method values based on 20% Q_{Avg}, which represents “good” habitat during low-flow season

[3] Ecology data collected at monitoring stations near the mouths of each stream, 2003-2009

It was interesting to find that the “discussion flows” obtained by merging the three methods closely corresponded with the average annual flow rates determined from the Ecology data for most of the streams. The “discussion flows” for five of the streams were within 15 percent of the average annual flow, with a sixth being within 25 percent. Overall, the lower-flow streams displayed greater agreement between the “discussion flow” and annual average flow rate. This trend was exemplified by the prescribed rate for Almota Creek equating exactly with the average annual flow rate, while only an 8 percent disparity between the values was found for Deadman Creek. Correspondingly, the two highest-flow streams in the study, Joseph and Patah Creek, yielded divergences of 40 and 48 percent, respectively. All of the “discussion flows” were lower than the average annual flow rate, except for Deadman Creek which was slightly higher.

As discussed in Section 4.2, all of the instream flow assessment methods used in this study incorporate a degree of subjectivity during their application. For instance, the determination of bank toe locations often vary considerably between individuals using the Toe-Width method based on different interpretations of what constitutes the bank toe. Meanwhile, bias can be introduced into instream flow calculations when selecting inflection points on the wetted perimeter – discharge curve using the Wetted Perimeter method. Similarly, the Tennant method allows freedom in selecting the desired flow regimen when developing instream flow recommendations. A 20-percent Q_{Avg} criterion was selected for use in this report to correspond with a “good” habitat classification during the low-flow season. However, any of the percent Q_{Avg} standards can be chosen depending on management goals for the stream. As mentioned previously, Pataha and Tenmile Creek exceeded the 20-percent Q_{Avg} criterion for low-flow conditions just over 60 percent of the time. Thus, these two streams would be candidates for using a surrogate percent Q_{Avg} standard; in this case a 10-percent Q_{Avg} criterion would be used to provide a more realistic management goal. This would correspondingly decrease the overall recommended “discussion flow” for each of these streams.

Seasonal flow variations are a natural and important attribute in stream ecosystems, and this should be reflected in the development of minimum instream flow criteria. Incorporation of these intra-annual fluctuations into the final instream flow rule is especially critical for salmonid management in the Middle Snake Watershed tributaries to ensure appropriate streamflow during priority life-stages of the respective species. However, the "discussion flows" presented in Table 5.1 represent recommended flows as averaged over the entire water year and do not necessarily signify relevant flows at a given point in time; this limitation is an artifact of the methods used. These flow rates still provide a valuable tool for determining overall stream requirements, and can be used as a guide to design seasonal regimes. Yet, since steelhead are the focal species driving instream flow development in WRIA 35, specific monthly flow rates are required.

The application of exceedance flows calculated on a monthly basis provides a simple, easily understood method that can elucidate streamflow requirements in relation to steelhead priority life-stages. Values for the 10-, 50- and 90-percent exceedance probabilities were calculated using the Ecology flow data that was collected from 2003 to 2009 for each stream. Linear interpolation was used to estimate the respective values when needed; this computation was not required when calculating the annual exceedance flow values because of the significantly larger datasets used. Uncertainty in these calculations is greater for Couse, George and Tenmile Creeks because of the patchy and inconsistent data associated with the manual stage-height stations on these streams. Moreover, data for George Creek has only been collected since 2006; thus, monthly exceedance flows for this stream are based on very few data points and should be considered with caution.

The monthly exceedance flows are presented in relation to the various steelhead priority life-stages prevalent during the respective months to provide a visual representation (Table 5.2). Relations to Chinook priority life-stages can similarly be ascertained from the information presented in Table 1.1. Monthly average flows are also provided, which can be used to calculate percent $Q_{Avg,M}$ standards (i.e., percent criterion of monthly average flow) for use in a modified Tennant method approach that can relate the monthly values to habitat conditions under disparate flow regimens. However, one should remember the spatial constraints associated with these data. Values were calculated based on the Ecology flow monitoring stations situated near the mouth of each stream, and are germane only to that location. Caution should be taken in extrapolating this information to upstream locations, particularly in the intermittent streams where longitudinal discontinuities occur. One should also note that the values derived for George Creek are in question due to skewed data, and that the 149.2 cfs 10-percent exceedance flow for January is based on linear extrapolation due to limited data (the highest recorded flow was 117 cfs).

Another advantage to calculating monthly exceedance flows is that these values are applicable to projecting potential future conditions under different scenarios, either respective or irrespective of how flow relates to the fish community. The 90-percent exceedance flow is an indicator of expected low flows in the future, and can be used to project streamflow behavior during extreme summer dry conditions. This can then be used to relate the salmonid habitat requirements to other water resources needs. For instance, instream flow negotiations can consider contingency management plans for a potential drought that balance steelhead instream flow requirements with allocated irrigation withdrawal water rights. Correspondingly, this monthly exceedance flow approach is the basis for the Ecology guidance for determining water availability above minimum instream flows (WDOE, 2004).

Table 5.2. Monthly exceedance flows in relation to steelhead priority life-stages.

		Exceedance Flows (cfs)			Priority Life Stage							Exceedance Flows (cfs)			Priority Life Stage				
	$Q_{Avg,\,M}$	10%	50%	90%	M	S	E	R	O		$Q_{Avg,\,M}$	10%	50%	90%	M	S	E	R	O
Almota										**Couse**									
October	1.2	1.7	1.2	0.8				✔	✓	October	0.9	1.3	0.9	0.7				✔	
November	1.7	2.3	1.5	1.1				✔	✓	November	1.2	2.1	1.1	0.8				✔	
December	2.6	4.3	2.2	1.5				✔	✓	December	1.0	2.0	0.9	0.7				✔	
January	5.4	10.6	4.1	1.6	✓			✔	✓	January	1.3	2.5	1.0	0.7	✓			✔	
February	6.1	11.1	5.7	1.5	✔	✔		✔	✓	February	4.8	23.5	2.0	0.8	✔	✔		✔	
March	6.2	11.6	5.6	1.5	✔	✔		✔	✔	March	4.3	14.7	3.8	1.5	✔	✔		✔	✔
April	6.0	13.2	4.1	2.1	✔	✔	✓	✔	✔	April	5.8	17.0	2.3	1.0	✔	✔	✓	✔	✔
May	3.4	6.0	2.7	1.6	✔	✔	✔	✔	✔	May	1.7	3.3	1.4	1.0	✔	✔	✔	✔	✔
June	1.7	3.2	1.5	1.0			✔	✔	✓	June	1.1	1.7	1.0	0.8			✔	✔	
July	1.4	1.3	0.9	0.6				✔		July	0.9	1.3	0.9	0.7				✔	
August	0.9	1.2	0.8	0.5				✔		August	0.7	0.9	0.7	0.6				✔	
September	1.1	1.5	0.9	0.7				✔		September	0.7	0.9	0.7	0.6				✔	
Alpowa										**Deadman**									
October	8.7	10.0	8.7	7.2				✔	✓	October	2.7	4.0	2.7	1.4				✔	✓
November	9.1	10.9	8.9	7.7				✔	✓	November	3.8	4.9	3.9	2.2				✔	✓
December	8.8	10.5	8.7	7.2				✔	✓	December	3.9	5.6	4.1	1.4				✔	✓
January	10.6	12.6	10.4	8.3	✓			✔	✓	January	4.7	8.3	4.2	1.4	✓			✔	✓
February	11.2	13.8	11.0	9.4	✔	✔		✔	✓	February	5.2	7.2	5.2	3.4	✔	✔		✔	✓
March	12.7	14.0	12.0	10.2	✔	✔		✔	✔	March	4.9	7.1	4.6	2.3	✔	✔		✔	✔
April	14.7	29.6	11.2	9.4	✔	✔	✓	✔	✔	April	6.1	13.5	4.5	2.8	✔	✔	✓	✔	✔
May	9.5	12.5	9.2	6.9	✔	✔	✔	✔	✔	May	4.7	9.6	3.8	2.9	✔	✔	✔	✔	✔
June	7.4	9.2	7.2	5.9			✔	✔	✓	June	4.0	6.3	4.0	1.8			✔	✔	✓
July	5.1	6.7	5.3	3.3				✔		July	2.0	4.6	1.6	0.6				✔	
August	5.5	6.9	5.6	4.1				✔		August	1.3	2.4	1.1	0.3				✔	
September	7.1	8.3	7.2	5.7				✔		September	2.1	2.7	2.0	1.1				✔	

Key: $Q_{Avg,\,M}$ = Average flow rate for month (cfs)
✔ = primary time
✓ = potential or non-primary times
M = adult upstream migration
R = rearing
S = spawning
O = juvenile out-migration
E = emergence

Table 5.2 (cont.) Monthly exceedance flows in relation to steelhead priority life-stages.

		Exceedance Flows (cfs)			Priority Life Stage				
	$Q_{Avg,\ M}$	10%	50%	90%	M	S	E	R	O
George									
October	4.2	4.2	4.2	4.1				✔	✔
November	4.3	4.4	4.3	4.2				✔	✔
December	4.6	5.4	4.5	4.2	✓			✔	✓
January	21.3	149.2	4.6	4.4	✔	✔		✔	✓
February	8.3	26.6	5.0	4.4	✓	✓	✔	✔	✓
March	11.7	67.3	5.2	5.1	✔	✔	✔	✔	✓
April	29.9	103.1	5.4	4.8	✔	✔	✓	✔	✔
May	22.8	97.9	5.5	4.4	✔	✓	✔	✔	✔
June	4.6	5.3	4.6	4.3			✔	✔	✔
July	4.3	4.5	4.2	4.1				✔	
August	4.2	4.4	4.1	4.0				✔	
September	4.1	4.4	4.1	4.0				✔	
Joseph									
October	27.1	32.8	25.8	23.9				✔	✓
November	33.7	40.3	33.9	26.3				✔	✓
December	46.8	72.7	34.2	28.5				✔	✓
January	80.1	164.0	52.1	35.5	✓			✔	✓
February	102.9	222.0	72.9	36.1	✔	✔		✔	✓
March	260.5	464.0	248.0	40.7	✔	✔		✔	✔
April	384.2	854.0	203.0	95.8	✔	✔	✓	✔	✔
May	248.8	549.8	170.0	52.8	✔	✔	✔	✔	✔
June	105.0	247.0	61.6	32.2			✔	✔	✓
July	25.7	41.1	22.1	14.3				✔	
August	17.4	22.1	17.6	12.8				✔	
September	20.7	27.2	19.9	16.2				✔	

		Exceedance Flows (cfs)			Priority Life Stage				
	$Q_{Avg,\ M}$	10%	50%	90%	M	S	E	R	O
Pataha									
October	4.3	15.1	2.3	1.0				✔	✓
November	6.7	16.3	4.4	1.8				✔	✓
December	8.2	20.2	4.8	1.4				✔	✓
January	17.8	43.9	12.5	1.2	✓			✔	✓
February	13.4	33.5	11.1	3.8	✔	✔		✔	✓
March	20.6	47.4	21.9	1.6	✔	✔		✔	✔
April	36.8	110.8	20.0	4.5	✔	✔	✓	✔	✔
May	25.8	65.1	11.0	4.1	✔	✔	✔	✔	✔
June	7.5	23.8	2.6	0.8			✔	✔	✓
July	2.0	4.5	1.0	0.1				✔	
August	2.5	7.8	1.4	0.7				✔	
September	5.4	15.7	1.8	0.5				✔	
Tenmile									
October	0.9	2.3	0.8	0.2				✔	
November	3.8	9.9	2.4	1.0				✔	
December	3.3	12.1	1.5	0.9				✔	
January	6.8	28.6	1.6	0.9	✓			✔	
February	10.1	34.0	5.5	1.1	✔	✔		✔	
March	10.1	24.1	11.1	0.9	✔	✔		✔	✔
April	13.4	30.3	9.1	1.2	✔	✔	✓	✔	✔
May	5.9	23.2	4.2	1.4	✔	✔	✔	✔	✔
June	1.9	4.6	1.5	1.0			✔	✔	
July	0.7	0.9	0.7	0.5				✔	
August	0.6	0.8	0.6	0.5				✔	
September	1.1	4.6	0.8	0.6				✔	

Key: $Q_{Avg,\ M}$ = Average flow rate for month (cfs)
✔ = primary time
✓ = potential or non-primary times
M = adult upstream migration
R = rearing
S = spawning
O = juvenile out-migration
E = emergence

5.2. General recommendations and considerations

Although the "discussion flows" presented in the previous section provide an initial starting point for discussing potential instream flow values, it is critical to consider the distinct nature of the streams throughout the negotiation process. The Middle Snake Watershed presents an unusual setting, where healthy rainbow/steelhead populations are sustained in the low-flows inherent to these small tributaries (e.g., George Creek). Salmonid populations appear to have adapted to the existing flow regimes, including the naturally intermittent systems. The fish reside where water is accessible during dry periods, and subsequently migrate when flows allow. There is a finite amount of water in the semi-arid/arid environments that comprise the Middle Snake Watershed, and it may not be feasible to accommodate additional out-of-stream uses. Flow rates for some streams may simply be what they are and have been immemorial, and additional water may not be available in the system to augment current conditions. Thus, it is prudent to set attainable, commonsense instream flow goals. This in turn will promote further engagement of landowners in realistic conservation programs and encourage others to participate in habitat restoration efforts.

The adaptation of native rainbow/steelhead to the region's relatively harsh environmental conditions does not discount the need to ensure adequate streamflow to maintain viable fish populations and promote recovery of degraded areas. However, options to increase flow during critical periods (or even to maintain current conditions under potential scenarios) are restricted by the water-limited conditions innate to the Middle Snake Watershed. It should also be recognized that management activities appropriate in some sub-basins may not be applicable in others sub-basins due to inherent differences (e.g., degree of urban development, presence of irrigation). In order to ensure that the agreed upon minimum instream flow goals are reasonable and attainable, it is vital to consider potential management options appropriate for each stream prior to finalizing the instream flow criteria. Correspondingly, it is recommended that streams be addressed systematically and prioritized according to where resources should be placed to best meet potential instream flow goals. The remainder of this section provides some general recommendations and considerations related to potential action items that can be incorporated into instream flow negotiations to help define management goals based on limited resources. This is by no means an exhaustive list, and other alternatives presented by watershed stakeholders should be welcome during discussions.

More numerous and flexible management options may exist for the irrigated sub-basins (e.g., Alpowa, Deadman, Joseph). Irrigation use likely played a role in diminishing Pataha Creek streamflow, and correspondingly has been implicated in contributing to reduced Tucannon River flows (SRSRB, 2006). Water rights have been appropriated for this sub-basin, but many of these rights are not being exercised (SRSRB, 2006). Water resource managers could capitalize on this inactivity by offering incentives that encourage these landowners to continue restricting their water use. Similarly, enticements could be offered that promote modified water use behavior. For instance, documents filed with Ecology allocate a 4.11 cfs instantaneous/766.5 acre-feet yearly withdrawal allowance from Pataha Creek (Kuttel, 2002). Although the total yearly water extraction may pose a minimal risk (the yearly allotment equates to 8.4 percent of the total yearly streamflow based on a 12.6 cfs average annual flow rate), the instantaneous appropriation could devastate stream habitat during low-flows (4.11 cfs was only exceeded once between September and January in this study). Incentives could be offered to motivate the water rights holders to avoid exercising the instantaneous allotment during critical periods. It is vital that established water rights are not infringed upon, but these examples illustrate potential options that mutually benefit landowners and stream habitat. Watershed-wide programs that promote improved irrigation efficiency can supplement such agreements and engage a wider stakeholder audience.

Even though it may or may not be possible to significantly increase streamflow in the Middle Snake River tributaries through managing water withdrawals, other activities can be used to enhance streamflow. Dry stream reaches observed in this study tended to be found in association with poorly vegetated riparian habitat. Although it is uncertain if healthier riparian habitat in these streams relates to better water supplies (e.g., springs) or increased streamflows result from greater streamside vegetation, it is generally regarded that robust riparian buffers enhance summer streamflow by improving water infiltration and storage (Tomer et al., 2005). Riparian buffers also provide additional functions that benefit salmonid habitat, including stabilized streambanks, improving water quality and maintaining cooler water temperatures by shading the stream. Efforts to improve riparian habitat in some of the study streams which have been conducted by landowners, local conservation districts, the Natural Resource Conservation Service (NRCS) and Ecology have generated successful ecological transformations (e.g., WDOE, 2005a; WDOE, 2005b; WDOE, 2005c; WDOE, 2005d). The connection between healthy riparian habitat and streamflow was particularly palpable in Couse, George and Tenmile Creeks during the study (Figure 5.1), and supported by observations by Mendal et al. (2001). Continued land management improvements, such as enhanced riparian buffers, will help maintain and possibly improve streamflows through the year.

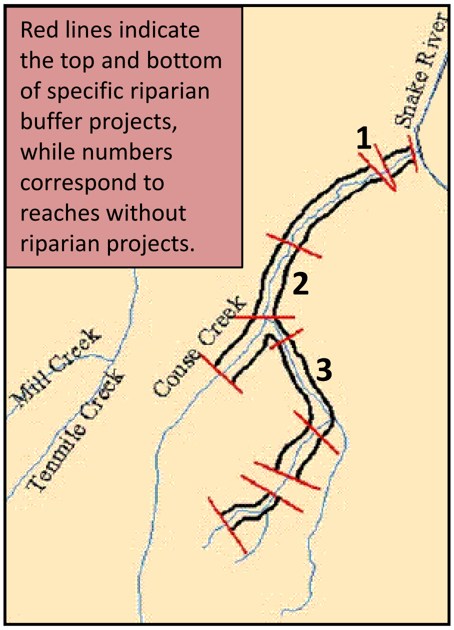

Figure 5.1. Diagram representing where locations along Couse Creek maintained water during study in relation to riparian buffers. Section #2, which has poor riparian habitat, exhibited no surface water during the dry periods of the study, while the reaches above and below maintained surface water (modified from WDOE, 2005a).

Good vegetative cover at greater distances from stream edges can also contribute to stabilized stream baseflows. Well managed vegetation increases water storage in the soil profile by enhancing infiltration and decreasing surface runoff from surrounding areas during storm-events (Knapen, 2008). This in turn may promote sub-surface flow that augments stream water recharge over a longer period of time, and correspondingly limits runoff that would otherwise be lost from the watershed as quickflow (Chow et al., 1988). Therefore, the continued support of conservation programs in the WRIA 35 tributary watersheds, such as the Conservation Reserve Enhancement Program (CREP), is recommended. Similar responses can result from the implementation of conservation tillage practices, and outreach to local producers encouraging adoption of these cropping methods should also be conducted.

It is hoped that this brief description of management alternatives will stimulate discussion on potential management options, and that dialogue will identify additional alternatives. For instance, the Washington Water Acquisition Program may present an attractive option in the Middle Snake Watershed. This voluntary program provides farmers and other water rights holders the opportunity to sell, lease or donate their water rights to streams where low-flows impact fish habitat. While other management activities exist, it is important to stress the need to incorporate specific management goals and corresponding management options into the instream flow discussion to avoid setting unattainable standards.

5.3. Summary of the current status and recommendations for the respective streams

Relevant information on all of the study streams can be found throughout this document. However, since instream flow values will be negotiated on a stream-by-stream basis, this section is designed to highlight key points on streamflow, fish populations and potential management issues for each respective stream in order to facilitate discussions. It should be noted that additional critical information presented earlier in the report may not be found in the following sub-sections, but the material provides a basic reference on the current status of the streams and specific recommendations for each.

Almota Creek

The Almota sub-basin encompasses a largely arid landscape, yet Almota and Little Almota Creeks both maintain continuous flow throughout the year (SRSRB, 2006). Although these streams are classified as perennial, dry conditions create low summer and fall discharge rates that are among the lowest in the Middle Snake Watershed tributaries. Almota Creek streamflow averages 1.7 cfs or less from June to November, and reaches a minimum of 0.9 cfs in August (Table 5.2; based on Ecology 2003-2009 monitoring data). These rates contribute to Almota Creek exhibiting the second lowest average annual flow (3.0 cfs) displayed in the study streams.

Despite these low-flow conditions, a small but seemingly sustained steelhead population exists in Almota Creek. WDFW surveys revealed a respectable 30.1 rainbow/steelhead juveniles per 100 m^2 during electrofishing efforts, as well as the greatest redd density (5.3 redds per mile) found in the study streams (Tables 3.5 & 3.6). Seasonal streamflow variability apparently ensures adequate habitat during migratory and spawning periods (i.e., January to May), with these winter and spring flow rates being several times greater than the summer and fall baseflow conditions (Figures C.1 & D.1). Juveniles presumably utilize scattered pools for rearing habitat during the dry season, which occur at average frequencies of 8 and 12 pools per mile in the lower and upper reaches, respectively (Kuttel, 2002).

The elimination of native prairie vegetation by farming has been implicated in altering the natural flow regime of Almota Creek (SRSRB, 2006), but lack of historic data prohibits speculating on the original flow conditions. Similarly, it is not feasible to determine how the fish community has changed over time in relation to the modified stream hydrology. The recent WDFW surveys verified steelhead presence in Almota Creek, but it remains unclear if the management focus should be protective (i.e., maintain present conditions to preserve the current population) or restorative (i.e., promote activities that will increase fish production). Thus, it is recommended that the Planning Unit identify which of these management goals is appropriate for Almota Creek prior to determining an instream flow value. Such a determination is particularly relevant for this stream, because the recommended "discussion flow" generated by this study coincidentally corresponds exactly with the average annual flow rate of 3.0 cfs.

Future regulatory and managerial activities should consider at least the following two items. First, although observations during study reconnaissance and discussions with watershed stakeholders (e.g., Brad Johnson, WRIA 35 Watershed Planning Director) identified no irrigated fields, SRSRB (2006) reported that 5 cfs is allowed to be continuously diverted from Almota Creek. This potential diversion should be investigated further, because the quantity of this allowance is significant enough that it could interrupt the precarious continuous flow that currently connects stream habitat during the dry season in this small stream. Second, although riparian buffers are established along Almota Creek, Kuttel (2002) reported that streambank erosion intensified as one proceeds downstream. During this study, the bank at Little Almota Creek Site 3 collapsed in May, exemplifying the ongoing riparian damage occurring in the sub-basin. This degradation presents a primary concern, as it not only increases sedimentation that impairs salmonid habitat, but it also can interfere with hydrologic processes and associated instream flow goals.

Although Little Almota Creek was a lesser consideration when the Almota Watershed was selected by the WRIA 35 Planning Unit for assessment, it represents a primary tributary in this sub-basin that deserves mention. Although Kuttel (2002) indicated that salmonids are known to be present in Little Almota Creek, WDFW found little evidence suggesting that steelhead use this stream as habitat (Mendel et al., 2004). This is due to several factors. Consistently low flows likely limit fish passage, which is already significantly obstructed by numerous barriers. At the same time, severe bank erosion (86 to 100 percent) has led to a substrate consisting primarily of "boulders and mud" (Kuttel, 2002). This systemic degradation will likely make any restoration activities ineffective. Even if stream discharge could be increased it would have no bearing on habitat conditions in Almota Creek, because Little Almota Creek joins the mainstem just above the confluence with the Snake River. Thus, it is recommended that protection and/or restoration efforts in the greater sub-basin should focus strictly on Almota Creek.

Alpowa Creek

Alpowa Creek was described as a "flashy" stream in 2001 due to extensive agricultural activity occurring throughout the watershed (Kuttel, 2002). Concerted conservation efforts by landowners, the Pomeroy Conservation District (PCD) and the Natural Resource Conservation Service (NRCS), with the support of the Conservation Reserve Enhancement Program (CREP), NRCS Soil & Water Conservation Assistance Program (SWCA) and Ecology, resulted in rapid riparian habitat improvement following initial implementation in 2001 (WDOE, 2005a). These activities apparently have also yielded hydrologic dividends, as Alpowa Creek exhibited some of the most uniform flows throughout the study (Figure C.2). Streamflow data collected by Ecology from 2003 to 2009 paralleled this trend, exhibiting the smallest relative difference between the lowest and highest average monthly flow rates of the Middle Snake Watershed tributaries; values range from 5.1 to 14.7 cfs for July and April, respectively (Table 5.2). However, the yearly exceedance flow curve displayed the steepest slope of all of the study streams, indicating runoff events are still occurring and restoration efforts should continue (Figure D.2).

Steelhead abundance in Alpowa Creek was identified as "very low" in 2001 (Kuttel, 2002). Fish survey data collected from 2006 to 2009 indicate that the salmonid populations are rebounding in conjunction with the hydrologic and habitat improvements (Table G.2). Twenty-five redds were documented in 2006, but only 1 live steelhead was observed. This increased to 34 redds and 26 live fish the following year, and estimates for returning adult steelhead grew to 170 in 2008 and 410 in 2009. In addition, Alpowa Creek is one of three streams in this study where wild Chinook salmon have been recently observed (Mendel et al., 2008).

The recovery of Alpowa Creek exemplifies the positive impact riparian restoration activities can impart on stream ecosystem health. Whether streamflows have correspondingly increased cannot be ascertained since flow data is not available prior to 2003; however, stabilized stream discharge clearly has improved instream fish habitat. It is recommended that the following points be considered when developing instream flow management criteria for Alpowa Creek. First, the 8 cfs recommended "discussion flow" is assumed to be conservative and higher than required to protect instream habitat. This likely over-estimate results from the prescribed flow value derived using the Wetted Perimeter method (17 cfs) being significantly elevated compared to those calculated using the Toe-Width (3.7 cfs) and Tennant (1.8 cfs) methods. This discrepancy is partially an artifact of comparatively flat wetted perimeter – discharge curves that exhibit weak inflection points. Second, Alpowa Creek exhibits the most uniform flow throughout the year of the study streams. Moreover, most of the monthly average flow rates exceed the "discussion flow", keeping in mind that the "discussion flow" represents a recommended yearly average. Third, intra-monthly variations are also minimal, displaying remarkably close values for the 10-, 50- and 90-percent exceedance flows for all of the months (Table 5.2). Fourth, instream fish habitat has significantly improved and currently supports an improving steelhead run.

Despite this being an overall positive review, regular hydrologic and fish surveys should continue to ensure that the positive recovery experienced in recent years persists. Also, documents filed with Ecology allocate a 6.98 cfs instantaneous/866.8 acre-feet yearly withdrawal allowance from Almota Creek (Kuttel, 2002). Every flow measurement taken for Almota Creek during the study exceeded this instantaneous value, and the extent of withdrawal over this period is unknown (i.e., a significant portion of this appropriation may have been extracted concurrent to sampling and did not negatively impact the assessment). Thus, this diversion likely presents little risk; however, if this allotment was not exercised during the study and withdrawals are later extracted at the full 6.98 cfs during a critical time it could significantly impact stream health.

Couse Creek

Couse Creek represents the smallest sub-basin addressed in this report, and correspondingly presents the lowest streamflow of the Middle Snake Watershed tributaries considered. The uniform low-flow conditions recorded throughout the study period, with a sharp elevated peak in March (Figure C.3), reflect the general pattern shown by the Ecology collected data. The average annual flow rate of 2.7 cfs calculated from the Ecology data was dominated by average monthly flow rates that did not exceed 1.3 cfs from June to January (Table 5.2). Field measurements frequently documented negligible flows, and observations that the stream channel remained dry during the summer and fall from approximately R.M. 1.5 to R.M. 3 supports previous claims that this reach annually exhibits intermittent characteristics (Kuttel, 2002; Mendel et al., 2001; Mendel et al., 2004). Moreover, Couse Creek does not convey elevated flows for extended periods, as illustrated by the exceedance curve (Figure D.2), and rather rapidly transmits water from storm-events or snowmelt out of the watershed. This trend deviates minimally even during the high-flow months (Table 5.3). Discrepancies between the 50-, 40-, 30- and 20-percent exceedance flows during the wet season are comparatively small relative to the 10-percent exceedance flow value, except during April where the contrast is more subtle. Thus, rather than displaying uniform high flows during the wet season, significant variability exists.

Table 5.4. Detailed monthly exceedance flows for Couse Creek during the high-flow months of February to April.[1]

	$Q_{Avg, M}$ (cfs)[2]	-------------------- Exceedance Flows (cfs) --------------------						
		10%	20%	30%	40%	50%	75%	90%
February	4.8	23.5	5.2	4.8	4.3	2.0	1.0	0.8
March	4.3	14.7	6.3	4.7	4.0	3.8	2.7	1.5
April	5.8	17.0	12.0	8.6	5.5	2.3	1.3	1.0

[1] Ecology data collected at monitoring stations near the mouths of each stream, 2003-2009

[2] $Q_{Avg,M}$ = Average monthly flow rate

Salmonid populations in Couse Creek remain persistent despite significant flow-related habitat impairments. Migratory corridors for returning adults and out-migrating juveniles are only open for short periods, while intermittent conditions interrupt the connectivity of rearing habitat on an annual basis. Despite these obstacles, WDFW estimated that 2,409 rainbow/steelhead lived in the lower 1.5 miles of the stream in a 2000 census (Mendel et al., 2001). Moreover, half of the steelhead redds counted that year were between R.M. 2.6 and 5.5, indicating that steelhead are utilizing habitat above the intermittent reaches. A 2006 survey revealed a respectable 120 rainbow/steelhead per 100 m^2 in the lower mile (Mendel et al., 2008). That same study also recorded a low density of age 0+ Chinook, making Couse Creek one of the few tributaries currently serving as salmon habitat in the Middle Snake Watershed.

Couse Creek epitomizes the paradox presented in the Middle Snake Watershed, wherein sustained steelhead populations exist under flow regimes that typically are deemed unable to support salmonids (e.g., IFIM, Section 4.2). However, it should be noted that while the reported status of the fish community is encouraging, Couse Creek appears sensitive to potential perturbations in the ecosystem. While juvenile fish numbers appear to be strong, redd and adult steelhead counts were small in the four years surveyed (2000-2002 and 2006), and these were primarily found in the lower 1.6 miles of the stream (Table G.3). Similarly, Mendel et al. (2008) cautioned that overall production may be low even though juvenile densities are high, and suggested that intermittent conditions concentrate the fish in reaches that maintain water year-round. Thus, careful management is required to safeguard the habitat that sustains salmonid species in Couse Creek.

It is recommended that emphasis be placed on protecting existing habitat when determining instream flow criteria for Couse Creek, rather than striving to significantly increase streamflow. This suggestion is based on the fact that the natural flow regime appears to have been retained (SRSRB, 2006), no irrigation diversions exist and development in the watershed is minimal (landownership consists of four households along the creek who display vigilant stewardship practices and approximately five other two-person households in the rest of the watershed). Thus, options to augment flow in Couse Creek are not only extremely limited, but existing flow conditions are likely similar to what they have been immemorial. When developing a protective management strategy, two key points should be considered, as described below.

First, judicious seasonal management is critical for Couse Creek. The steelhead migratory life-stages face several issues in regards to streamflow that are largely absent in the other study streams. Recall that adults typically migrate up the Middle Snake Watershed tributaries between February and May, while the juvenile out-migration period for Couse Creek is abbreviated compared to other streams and only runs from March to May (ACCD, 2004). Although February through April experiences higher discharge rates, the flow is more variable and occurs for a shorter duration following precipitation events compared to other regional creeks (Table 5.2). Meanwhile, flow rates have diminished considerably by May, which exhibits a monthly average of 1.7 cfs and a 10-percent exceedance flow of 3.3 cfs. Based on amplified intra-month flow variations, rapid flow subsidence in May, and the abridged juvenile out-migration life-stage, it is recommended that streamflow during migratory periods be protected to ensure a sufficient fish passage window exists. Yet, the prescribed 2 cfs “discussion flow” makes little sense in this context from February to April, as it is lower than most of the percent exceedance flows during these primary migratory months (Table 5.3). On the other hand, managing rearing habitat is complicated by portions existing above intermittent reaches where it consists of isolated reaches and pools that cannot be adequately managed by an instream flow standard implemented at the stream mouth. Moreover, even the rearing areas in the lower reaches that retain connectivity cannot be appropriately managed using the 2 cfs “discussion flow”. This would lead to an unrealistic instream flow goal, since it exceeds the monthly average flow rates for nine months of the year and is equivalent to or greater than the “high-flow” rates experienced during seven months of the year as expressed by the 10-percent monthly exceedance flows. The portrayal of “discussion flows” as a yearly average is an artifact of the assessment methods used and correspondingly is intended as a framework for determining seasonal instream flow values. However, it appears that the “discussion flow” for Couse Creek is nonsensical based on the hydrologic conditions described in relation to steelhead life-stages. Thus, it is recommended that monthly flow statistics be used exclusively to guide “best judgment” decisions for selecting instream flow criteria (Table 5.2). Special attention should focus on May streamflows, because late-migrating adults and juveniles may experience fish passage problems as water levels recede.

Second, while remedying intermittent conditions may not be feasible (or desirable if this is the stream’s true character), it is critical to protect the springs and seeps that maintain vital rearing habitat during the dry season, even if it only consists of isolated pools. Since many of the flows associated with these groundwater sources are below measurement detection limits and/or they are involved in the subsurface flow paradigm discussed in Section 4.3, this component falls largely outside the scope of instream "flows". It is thus important to reference recent hydrogeological assessments to gain a better understanding of the complete hydrologic system influencing habitat conditions in Couse Creek.

This report also recommends the continued promotion of riparian restoration activities and BMP implementation in the sub-basin, which have begun to improve instream habitat. Beginning in 2001, landowners, the Asotin County Conservation District (ACCD) and NRCS initiated a collaborative effort to better protect the stream with support from CREP, Bonneville Power Administration (BPA) and Ecology. This partnership subsequently established over 8 miles of riparian buffers, fenced large areas to exclude livestock from the creek and planted thousands of native trees (WDOE, 2005b). At the same time, 2,300 acres were enrolled in the Conservation Reserve Program (CRP), taking farmland out of production. These conservation efforts may augment baseflow during dry periods (see Section 5.2), as well as promote other instream habitat enhancements that transcend streamflow. Recently stabilized streambanks have started to reduce erosion and should help alleviate elevated sediment loads prevalent in Couse Creek (Kuttel, 2002). Also, improved riparian habitat should contribute to lower stream temperatures, a key attribute to enhancing fish habitat in isolated, intermittent pools subject to heat stress.

Deadman Creek

The Deadman Creek sub-basin is a watershed currently undergoing transformation. The status of the stream and associated riparian areas has been widely characterized as "poor", because of increased runoff rates and massive sediment deposition resulting from extensive cropping and grazing throughout the sub-basin (Kettel, 2002; Mendel et al., 2004; WDOE, 2005c; SRSRB, 2006). In response to this degradation, landowners, PCD and NRCS partnered in 2001 to implement a variety of conservation practices that included installation of over 25 miles of riparian buffers using CREP, CRP and Ecology funds (WDOE, 2005c). Water quality has subsequently improved, helping to enhance fish habitat (WDOE, 2005c); however, hydrologic impacts remain inconclusive. Ecology data collected from 2003 to 2009 does not indicate any significant change in the magnitude of flow, but erratic variability exhibited throughout the years of 2004 and 2005 has been tempered to a more typical seasonal cycle (Figure D.1). Measured streamflow was remarkably uniform during the course of this study, with slightly elevated flows in April and May (Figure C.4). However, the steep slope at the high-flow end of the exceedance curve denotes that Deadman Creek is still prone to runoff events (Figure D.2).

Information on the fish distribution and prevalence in Deadman Creek is restricted to WDFW surveys conducted in 2001 and 2002, which revealed extremely low steelhead production in the stream and its tributaries (Mendel et al., 2004). Several steelhead redds were observed in the mainstem in 2001, while only one was documented in 2002 along the 8.9 miles of stream surveyed; neither the North nor the South Fork yielded a single redd. Electrofishing surveys resulted in similar meager findings, with only a small number of age 0+ rainbow/steelhead collected at one of five sites along the stream (R.M. 1.2) in 2001 and 2002 (Table G.4). A few salmonids were collected upstream in 2002, while the combined catch in the North and South Forks over both years tallied only 4 individuals. Mendel et al. (2004) reported that moderate to high sediment loads resulted in fair to poor spawning habitat in Deadman Creek, and a series of beaver dams partially blocked fish passage that “cut off miles of usable habitat”. These scant findings are disappointing, but one should consider that these surveys were conducted immediately after the widespread implementation of conservation practices. Ongoing activities in Deadman Creek warrant on updated assessment of the sub-basin to investigate whether salmonid numbers have rebounded in response to restoration efforts.

The influence of a potentially altered hydrologic regime on the aquatic ecosystem and the degree to which such flow modifications would relate to the small salmonid population are uncertain. The original seasonal flow patterns for Deadman Creek are unknown, but discussions with landowners suggest that hydrologic conditions have recently changed. Flow has reportedly declined in recent years, which has been attributed to the aggressive invasion of noxious weeds (e.g., false indigo) in riparian corridors that cattle previously controlled (SRSRB, 2006; WDOE, 2005b). However, the Ecology flow data covers an insufficient duration to verify such assertions. Concurrently, local landowners interviewed during this study claim that irrigation return flows augment summer streamflow. Although irrigation diversions exist in the sub-basin, withdrawals have not been implicated in reducing streamflow (SRSRB, 2006), and these anecdotes suggest that irrigation may actually benefit instream habitat (it was not ascertained by this report whether groundwater is also used as an irrigation water source, which would help explain this phenomenon). If stream recharge is occurring as a result of irrigation activities, this would likely have contributed to the uniform flows observed during this study. At the same time, it should be remembered that Deadman Creek is the only stream in the study where the recommended “discussion flow” (4 cfs) exceeds the annual average flow rate (3.7 cfs), albeit by a small margin.

Clearly, a restorative approach is required to help return steelhead numbers to historic levels, which one can safely assume was greater than the current population size based on anecdotal accounts provided by local landowners. Yet, multiple stressors (e.g., lack of physical habitat, sedimentation, poor water quality) have impacted the stream system, which necessitates adoption of a holistic strategy. The instream flow component of this greater management plan presents a difficult situation due to limited data describing streamflow and fish communities (both historic and recent), ongoing transformations in the watershed and confounding hydrologic anecdotes. It is recommended that the following factors be considered during instream flow negotiations. First, this is the only case where the “discussion flow” exceeds the average annual flow. Second, irrigation activities appear to negligibly impact streamflow (potential benefits of augmented summer flow may even occur, but such claims should be taken with caution without further validation). Third, the variation among the average monthly flow rates is the smallest of the study streams except Alpowa (Table 5.2), which has implications when setting seasonally adjusted instream flow rates. Fourth, further information should be obtained on the influence of invasive weeds on stream hydrology, as their elimination may present a management objective to improve streamflow that would present no detrimental impact on watershed stakeholders in regards to water use. The final and primary recommendation is to support continued conservation activities on what has been a significantly degraded system. These efforts will in turn help moderate extreme runoff events, reduce sedimentation and improve physical instream habitat.

George Creek

George Creek presents an excellent illustration of an intermittent stream being able to produce a respectable steelhead population. While some scattered reaches are prone to dewatering during drought years, the reach from Pintler Creek to its confluence with Asotin Creek reportedly has gone dry most summers since at least 1981 (Kuttel, 2002). The proximity of this dewatered section near the mouth is salient, as this denotes that all of the steelhead in the stream must migrate through this area and the juveniles subsequently become entrapped upstream until flow rates rise. In contrast, the majority of steelhead in Couse Creek remain concentrated in the lower 1.5 mile reach that retains year-round flow, with a much smaller number migrating above intermittent reaches (Mendel et al., 2008). Thus, the fish appear to use what water is available to them during the dry periods and wait until higher flows return before migrating to new locations.

Development remains limited in this sub-basin, and beautiful conifer stands can be found in the headwater areas. These evergreens transition to deciduous trees as one progresses downstream, and together these woodlands present a functional riparian buffer along the upper half of George Creek (Mendel et al., 2001). Meanwhile, no agricultural irrigation diversions exist within the watershed. This combination of factors has helped George Creek maintain its natural flow regime (Kuttel, 2002). Good flow conditions and shading from the established riparian zones results in excellent salmonid habitat in these upper reaches. Summer water temperatures in these sections remain cool; continuous measurements taken in the summer of 2000 revealed that the average water temperature remained below 15.5 °C (60 °F) and only once did a maximum temperature exceed 18 °C (65 °F) (Mendel et al., 2001). Correspondingly, steelhead redds have been observed above R.M. 17.5 in multiple years (Mendel et al., 20001; Mendel et al., 2004).

Moving into the bottom half of the watershed, streamside habitat and land-use activities begin to change. Riparian vegetation in the lower reaches of the stream is often sparse and overgrazing has reportedly led to bank instability and created problems along some stretches (Kuttel, 2002). However, despite being listed as one of the most significant producers of fine sediment in WRIA 35 (SRSRB, 2006), George Creek has been reported to contain good spawning habitat in the lower reaches of the stream as well (Mendel et al., 2006). Consequently, estimates in 2000 projected a rainbow/steelhead population in George Creek in excess of 49,000 (Mendel et al., 2001). However, it is recommended that exclusion fencing and riparian restoration efforts be implemented where possible in the degraded portions of the stream to help protect fish habitat in these lower reaches. This will not only help alleviate sedimentation issues that will adversely impact the fish community, but should also help moderate runoff events. Moreover, the low-flow conditions that support such abundant salmonid numbers may be sensitive to perturbations. For instance, flooding in 1996-1997 created extensive disturbances along portions of the lower section that are still in the recovery process.

Although it is suspected that the original flow regime has been retained in the George Creek sub-basin, little information exists that adequately describes its true character. As mentioned earlier in this report, the Ecology stream discharge dataset for George Creek is the smallest of all of the study streams, consisting of only manual stage-height measurements that began in 2006 (rather than 2003 for all of the other streams). Prior to January 31, 2009, all of the recorded flow rates ranged from 4.0 to 8.0 cfs, and remained below 6.0 and 5.0 cfs for 97 and 81 percent of the time, respectively. This constant flow pattern is appreciably more uniform than any of the other study streams. However, a series of extreme flow events occurred between January and May, 2009, several of which exceeded 108 cfs, and subsequently skewed the dataset significantly. The apparent change in flow variability and the short duration covered by the Ecology dataset, confound efforts to determine the actual character of the George Creek flow regime. Therefore, it is strongly recommended that the existing Ecology stream discharge data be regarded carefully, particularly during instream flow negotiations. Similarly, the monthly exceedance curve data in Table 5.2 should be used cautiously, especially in regards to the 10-percent exceedance flow values for January through May which were skewed due to the extreme flow events.

One should also consider that the aforementioned extreme flow events have other ramifications on the data analysis conveyed in this report, and accordingly on instream flow negotiations. When the high flow measurements collected in 2009 are removed from the Ecology dataset, the average annual flow rate for George Creek changes from 10.6 cfs to 4.6 cfs. Consequently, a shift occurs in the relationship between the average annual flow rate and the prescribed "discussion flow" of 10 cfs. Rather than having the "discussion flow" being slightly lower, but comparable to the average annual flow rate, it subsequently becomes over two times greater. Even if the "discussion flow" is corrected to account for a change in the recommended instream flow generated by the Tennant method, the "discussion flow" is only decreased to 9 cfs, which is still about twice as large as the annual flow rate. Therefore, an agreement must be reached during instream flow negotiations on how to consider the recent (and perhaps anomalous) extreme flow events. If it is decided to include the Ecology data as is, then there should be little concern over whether management goals can be met. However, if it is decided that the three year trend of uniform flows better represents the system, then the "discussion flow" becomes substantially greater than existing conditions, which should raise some apprehension on how to meet potentially more stringent objectives. At the same time, it should be considered that the steelhead population in George Creek is the strongest among the study streams (the steelhead population in the Oregon portions of Joseph Creek are stronger (G. Mendel, pers. com, 2009); however, this report only considers waters that lie within Washington), and either option would likely pose much of a threat regardless of this discussion. It is recommended that Ecology be consulted in regards to the perplexing flow data to shed more light on the situation.

Setting instream flow standards for George Creek becomes more complicated when incorporating the steelhead priority life stages (Table 5.2). As described above, the lower reaches typically go dry during the summer, after which all of the fish will be in upstream habitat that no longer maintains connectivity with the location where the management control point will be set. Consequently, instream flow criteria managed from a single point at the mouth will be largely inappropriate and other protective measures will have to be implemented if there is a perceived threat to the salmonid habitat or its resident fish community. Since there are no significant water withdrawals in this sub-basin and the intermittent conditions are presumably natural, it is unlikely that reasonable management options would be able to increase flow near the mouth during the summer months. Thus, the Planning Unit may want to focus on establishing appropriate instream flow criteria for the migratory periods to ensure that sufficient fish passage exists for returning adults and out-migrating juveniles. Again it should be noted that the skewed stream discharge data occurs during some of the months that correspond with these migratory life-stages. Therefore, it is suggested that the agreed upon instream flow criteria be considered tentative and subject to change as additional flow data is collected and the stream is better characterized.

Joseph Creek

Less information is known about Joseph Creek (for the portion that lies within Washington) than any of the other Middle Snake Watershed tributaries considered in this study. At the same time this may be the most distinct sub-basin in the study due to its remoteness, its origins in Oregon and its discharge into the Grande Ronde River. Not only is limited information available regarding Joseph Creek, but considerably less data was collected during this study in the watershed as a result of weather impediments and occasional extreme high flows that prohibited measuring flow rates.

One attribute about Joseph Creek is clear; discharge rates in this stream are significantly larger than the other study streams. The average annual flow rate of 113.2 cfs is nine-fold greater than that of Pataha Creek, the next largest stream system. Even Cottonwood Creek, a major tributary incorporated into this survey, exhibited generally higher streamflow than the other study streams that ranged from a low of 16.8 cfs to a high of 63.6 cfs. Although it has been suggested that Joseph Creek has maintained its natural flow regime (SRSRB, 2006), irrigation withdrawals occur in this sub-basin, including an allocation used by WDFW to water winter range for wildlife. However, it was not ascertained by this study the extent of the diversions, and it is possible that the large flow rate remains unimpeded.

Although it would make sense that the large flows and remote setting of Joseph Creek would promote a respectable salmonid population, little is known about the fish community in the Washington portions of the stream. WDFW conducted one redd and one electrofishing survey in 2006, but little information was garnered (Mendel et al., 2008). Survey crews encountered similar problems as those experienced in this study, wherein high streamflows prohibited other planned sampling events. When the team was able to access the stream, no redds were found along a 6.8 mile stretch of the stream; however, it was acknowledged that the survey occurred at the end of the spawning season (May 16, 2006). The subsequent fish survey captured only 5 rainbow/steelhead, which yielded estimated densities that ranged from 0.0 to 0.3 fish per 100 m^2. However, smallmouth bass (*Micropterus dolomieui*) were found to be common to abundant at all of the sites sampled (Mendel et al., 2008), and perhaps this population exerts a competition pressure that limits salmonid production. Other environmental parameters may also impact salmonids in Joseph Creek. For instance, stream temperatures measured in this study reached 20 °C (68 °F) in June, which exceeds the optimum range for steelhead. It is interesting to note that anecdotal accounts from the 1950s and 1960s suggest that a spring Chinook run occurred on Joseph Creek (Kuttel, 2002), but its extent and whether a small run potentially still exists is unknown.

The “discussion flow” of 45 cfs is 60 percent lower than the average annual flow rate calculated from Ecology data collected from 2003 to 2009. This discrepancy, combined with the elevated flows observed during this study, suggest that streamflow is not a limiting factor to salmonids in Joseph Creek. Thus, it is recommended that resources not be used in regards to streamflow for this system. If steelhead restoration is identified as a management goal by the Planning Unit for this stream, other limiting factors should be addressed. As noted above, other fish species may present competition pressure on salmonids, which may make any restoration activities ineffective. Similarly, temperature may inhibit use of instream habitat in Joseph Creek. The narrow riparian buffer along the stream is relatively thin and enhancements to these areas that increase shading may help alleviate temperature restrictions. Mendel et al. (2008) described numerous incised and actively eroding banks along Joseph Creek, which would also benefit from riparian restoration efforts.

Pataha Creek

Anthropogenic water demand is greater in the Pataha Creek sub-basin than any other of those in the study. A total of 625 acres is reportedly irrigated in the watershed, primarily drawing water from the stream during the summer months to support hay, alfalfa and orchard production (SRSRB, 2006). As discussed in Section 5.2, an instantaneous withdrawal allowance of 4.11 cfs exists for Pataha Creek, which could present a significant threat to instream flows if not managed appropriately. Although it may be unlikely that a large portion of this allocation would be utilized at one time, a series of small withdrawals could add up to create a strain on the system, particularly when one considers the low flow rates exhibited by Pataha Creek during the summer. For instance, July has an average monthly flow of 2.0 cfs and exhibits a 50-percent exceedance flow of 1.0 cfs (Table 5.2). This means that Pataha Creek conveys a flow of 1.0 cfs or less for half of the time during July. Hence, even seemingly small water withdrawals could have a devastating impact on instream habitat, which is likely to already be at or below a critical point where conditions rapidly diminish with small alterations in flow. It is clear that the low-flow conditions found in Pataha Creek and the associated irrigation withdrawal potential creates a precarious situation. Thus, it is not unexpected that irrigation withdrawals have been implicated in reducing flow rates in the stream (SRSRB, 2006).

While this report has not viewed Pataha Creek as an intermittent stream, other reports suggest that portions of Pataha Creek occasionally go dry during the summer months (SRSRB, 2006). Stream discharge measurements recorded in this study would not contradict this assertion, as streamflows were about 1.5 cfs in both September and October of 2008. Flow data collected by Ecology from 2003 to 2009 displays similar findings. Although July represents the most extreme low-flow conditions during the year in the watershed, the period from June to October similarly exhibits reduced streamflow with all of the 50-percent exceedance flows for these months being at or below 2.6 cfs. Using the annual exceedance curve (Figure D.2) to assess the hydrologic processes in the watershed reveals that limited groundwater inputs are likely to exist, which is indicated by the steep slope at the low-flow end of the curve. This premise is supported by reports that the groundwater table has dropped in the lower reaches of the sub-basin as a result of extensive channel incision (Kuttel, 2002), which would break the hyporheic connectivity that links groundwater – surface water exchanges. The corresponding low recharge potential from subsurface water sources suggests that Pataha Creek is probably sensitive to disturbances in the flow regime during the summer months when precipitation is scarce.

Relating the flow conditions in Pataha Creek to salmonid populations is difficult, as this is the only stream in the study for which recent WDFW fish survey data is not readily available. However, a general description of the fish community can be obtained from various sources. Steelhead utilize the upper reaches of the stream (Bartels, 2000) where forested riparian areas extend out of the Umatilla National Forest, shading large portions of these reaches and cooling water temperatures. A naturally reproducing brook trout (*Salvelinus fontinalis*) population also resides in these upper portions and extends down to the middle reaches (Mendel, 1999; Kuttel, 2002). Similarly, rainbow trout live in the headwaters and represent a popular fishing attraction for the public (USDA-NFS, 2009). The lower portions of Pataha Creek are apparently devoid of salmonids, and rather are inhabited by suckers, pikeminnows and shiners (Bartels, 2000). However, it is hoped that upland conservation efforts, instream habitat restoration and removal of fish barriers will eventually transform the lower reaches into suitable spawning and rearing habitat for Chinook (Bartels, 2000), although this is unlikely to happen in the foreseeable future.

Starting in 1993, the sub-basin was selected as the site for a conservation demonstration project titled the Pataha Creek Model Watershed. A wide range of management activities and restoration efforts have been implemented throughout the sub-basin, including riparian fencing and restoration, streambank protection, and adoption of conservation tillage methods, among others. While these practices have been successful in certain areas (Bartels, 2000), streamside habitat has been severely damaged and denuded of vegetation in much of the middle and lower watershed. The resultant loss of riparian function promotes sediment transport from intensively cropped fields to the stream, which in turn has led to the sub-basin being labeled as one of the most significant sediment producers in the region (SRSRB, 2006). Ongoing degradation continues to limit salmonid production in Pataha Creek, as well as disrupt the hydrologic regime.

Water resource management in Pataha Creek faces many challenges and many competing demands. Although the number of steelhead using the sub-basin is uncertain, it appears that good spawning and rearing habitat exists in the upper portion of the watershed; however, migration between this habitat and the confluence with the Tucannon River entails a swim that can exceed 50 miles through extensive agricultural land. At the same time, existing water rights holders cannot be infringed upon by the adoption of instream flow standards, as mandated by the legislature. This, of course, includes those possessing the irrigation water rights; these individuals are pivotal to ensuring the maintenance of appropriate streamflow during the summer months since their guaranteed allocations either exceed or would significantly impact the average monthly flows from June through the end of the irrigation season. At the same time, the cattle and livestock owners along the middle and lower reaches of the stream presumably possess livestock watering rights that need to be considered. Also, unlike the other sub-basins in this study, this watershed contains an “urban” component consisting of the towns of Pomeroy and Pataha. The potential impact of these population centers on streamflow and guaranteed water rights are not presented in this report, but these entities would certainly need to be considered when determining appropriate instream flow criteria for Pataha Creek.

The innate paradigm existing in Pataha Creek, wherein guaranteed water rights holders are essentially able to control streamflow in a watershed supporting a “threatened species” (i.e., steelhead), appears to have the greatest potential for a direct confrontation to develop between the water flow needs of fish and human water use among the sub-basins addressed in this report. However, the complexity of the situation will ultimately depend on the steelhead management goal selected at the beginning of the instream flow negotiations. Two basic options exist: focus management on either protective value or restorative potential. The steelhead in Pataha Creek currently use habitat in the upper reaches of the watershed, an area that presents well established riparian buffers, little development and maintains connection to headwater areas in the federally controlled Umatilla National Forest. Administrating instream flows in this relatively protected area from a management point miles downstream makes little sense. Habitat utilization in the middle and lower reaches currently appears to be limited to fish passage by returning adults and out-migrating juveniles, based on the information presented (the true condition of the steelhead population in Pataha Creek should be confirmed with WDFW). Presumably, steelhead historically used habitat in the middle reaches. Brook trout, another salmonid, have been observed in this portion of the river (Kuttel, 2002), which indicates the potential for future use by steelhead depending on how conditions improve.

If a protective management strategy is selected, the issues regarding extremely low, precarious summer flow and irrigation withdrawal in the middle and lower reaches become insignificant in regards to steelhead management. This is because under this scenario, only the upstream reaches are considered for spawning and rearing habitat, and focus will be placed on ensuring adequate fish passage through the other segments during migratory periods. Pataha Creek displays a fairly strong seasonal cycle, wherein flows fluctuate between essentially negligible levels in the summer to consistent, elevated levels during the winter and spring. The monthly average flow rates from January to May, the period representing critical steelhead migratory life-stages, range from 13.4 to 36.8 cfs, while the 50-percent exceedance flows over the same timeframe range from 11.0 to 21.9 cfs. Thus, if the protective management approach is selected, the instream flow setting process should not be controversial, because plentiful flow during critical times is typically available to accommodate steelhead passage and there will be no need to consider the use of the low-flow portions of the stream during the summer by steelhead.

If the restorative management strategy is selected, a large number of factors require consideration. Socio-economic aspects that are beyond the scope of this report will play a major role in the instream flow negotiations. Streamflow rates will need to be increased in order to provide for steelhead needs, and this will present a considerable challenge. As described earlier, it appears that Pataha Creek maintains poor connectivity with potential groundwater recharge sources, which further impedes the ability to provide adequate baseflows. Since existing water rights are guaranteed, creative approaches will need to be taken to ensure adequate flows; Section 5.2 outlines some initial considerations. Moreover, Pataha Creek has become fairly degraded in the middle and lower reaches, wherein riparian habitat is often nonexistent and sedimentation is excessive. Thus, a comprehensive management plan will need to be developed that integrates efforts to enhance flow rates with those designed to improve physical habitat.

It is recommended that the protective steelhead management strategy be selected at this time due to the poor conditions that presently exist downstream. Based on this approach, the “discussion flow” of 6 cfs (which is to be viewed as a yearly average) is well below the 50-percent monthly exceedance flows during the steelhead migratory period; thus, no minimum flow recommendations are critically needed. However, irrespective of whether plans exist to switch to a restorative goal at a later date or not, the conditions in the lower sections of Pataha Creek require continued attention. Although salmonids may not currently use the low-flow habitat in these sections of the tributary, the overall stream ecosystem is under extreme stress and appears to be sensitive to perturbations. It is recommended that additional water rights requests be considered very carefully and in regards to the situation described here. It is also advised that potential options for securing more streamflow during the summer months be actively investigated to help alleviate this problem (e.g., Washington Water Acquisition Program; irrigation efficiency programs). In addition, continued support should be given to ongoing conservation and restoration projects to promote riparian recovery in the middle and lower reaches, as well as to reduce sedimentation in the Patah Creek.

Tenmile Creek

Tenmile Creek represents a significantly water limited stream that sustains a priority steelhead population of respectable size. The average annual flow rate of 5.2 cfs fails to adequately characterize the natural flow regime of this system. Tenmile Creek exhibits the greatest relative disparity between the lowest and highest average monthly flow rates of the Middle Snake Watershed streams, varying from 0.6 cfs in August to 13.4 cfs in April (Table 5.2). At the same time, however, flow records demonstrate the most moderated behavior of the tributaries in regards to different controlling factors. This is denoted by Tenmile Creek generating the most uniform annual exceedance flow plot in the study, signifying an abated response to rapid runoff and groundwater recharge (Figure D2; note, although the annual exceedance flow curve for Joseph Creek may appear more uniform, when plotted on the same scale the curves are roughly equivalent). Recharge processes do occur, as evidenced by springs and seeps observed at various locations along the stream during the study, but the dampened exceedance curve suggests that subsurface water sources do not exclusively dominate the system as in Couse Creek. A pond in the upper reaches has been suggested to temper peak flows downstream (Kuttel, 2002), helping to dampen "flashiness" that might otherwise be more prevalent. It should also be noted that the data used to create the exceedance plots was obtained from a manual stage-height monitoring station, and consequently peak run-off events are more likely to be missed compared to the telemetry stations on other streams.

Meanwhile, Tenmile Creek acts as an intermittent stream, which presents a controlling factor to steelhead production. Portions of the lower reaches go dry during the summer and fall starting upstream from around R.M. 2, an annual episodic occurrence witnessed during this study and similarly recorded by others (Kuttel, 2002; Mendel et al., 2001). Dewatering of assorted sections can strand fish in isolated pools during the dry season, leaving them susceptible to various potential threats or lethal conditions. However, salmonids in the system are able to overcome these periodic breaks in surface water connectivity, supporting an estimated rainbow/steelhead population of almost 17,000 in a 2000 census (Mendel et al., 2001). Numerous redds have been observed during multiple years in locations that stretch from the mouth up to R.M. 15.0 (Mendel et al., 2001; Mendel et al., 2004; Mendel et al., 2008), demonstrating steelhead utilize habitat along the continuity of the stream for more than just migration corridors.

The innate hydrologic nature and lack of notable diversions will prohibit increasing streamflow in Tenmile Creek. Moreover, little development exists in this sub-basin, with less than 10 homesteads existing in close proximity to the stream. Analogous to Couse and George Creeks, this is an inherently water-limited, intermittent tributary where fish utilize what water is available to them as flows fluctuate throughout the year. Therefore, a protective steelhead management scenario is mandated. The 4 cfs "discussion flow" appears reasonable considering the hydrologic character of the sub-basin on a yearly basis. As discussed in Section 4.2, the prescribed flow produced by the Tennant method appeared potentially excessive, and using a 10-percent Q_{Avg} surrogate would not be unreasonable for this stream. Substituting this criterion yields a revised "discussion flow" of 3.5 cfs. Similar to Couse Creek, juvenile steelhead in Tenmile Creek exhibit an abridged out-migration period that runs from March to May (ACCD, 2004). Steady, reasonable flows during March and April appear suitable for the protection of the migratory life-stages, but flow starts to diminish in May and hence this may be a key month to consider. However, overall it is recommended that instream flow negotiations focus on the summer and fall stream discharges that average 1.1 cfs or less from July to October. These low flow rates appear to be sufficient based on the status of the steelhead population in Tenmile Creek, but care must be taken to protect what instream habitat is available during this timeframe.

As with the other Middle Snake Watershed tributaries, regular hydrologic and fish surveys should be maintained to monitor habitat conditions and steelhead population health in Tenmile Creek. It is recommended that ongoing conservation projects in the watershed should continue. Decent streamside habitat consisting of conifers, cottonwoods and willows extend from the headwaters to Mill Creek (SRSRB, 2006), but riparian buffers along the lower reaches comprise patchy sections ranging from stands of deciduous trees to no vegetation. However, good land stewardship in the sub-basin has resulted in marked improvements, and this example should be followed into the future. CREP, BPA and Ecology funding has successfully supported restoration activities conducted by landowners, ACCD and NRCS, which have promoted the recovery of riparian buffers and enhanced bank stability in many areas (WDOE, 2005d), an outcome mirrored in upstream locations around the town of Anatone. Meanwhile, 3,500 acres of cropland have been enrolled in CRP. It is also recommended to increase efforts to reduce upland erosion. Heavy sedimentation was observed in the Mill Creek tributary during reconnaissance for this study, yielding a thick, muddy substrate along a sizeable reach that was often 6 inches to a foot deep. Likewise, (SRSRB (2006) identified Tenmile as one of the most significant sediment sources in the Middle Snake Watershed. Greater adoption of conservation tillage and implementation of other BMPs in the sub-basin will likely help reduce sediments that impair fish habitat and interfere with streamflow.

5.4. Concluding remarks

The instream flow determination process involving the respective tributaries in the Middle Snake Watershed will require complex negotiations that address a variety of factors concerning the preservation of instream resources and uses. Although steelhead protection is the driver behind the establishment of instream flows in WRIA 35, other values deemed important by watershed stakeholders necessitate consideration. The purpose of this report is to provide technical information on streamflow in relation to salmonid populations to support the instream flow negotiations. Field data collected in this study, hydrology and fish data collected by Ecology and WDFW, and information from a variety of other sources have been compiled and analyzed to generate the recommended “discussion flows” that characterize the relationships between stream hydrology and fish communities in the Middle Snake Watershed tributaries. These are not definitive values and should not be perceived as flow rates that can simply be selected as appropriate instream flow standards, and rather should be used as an initial starting point for discussion. Hydrologic and fish data for the region is exceptionally limited and much remains to be learned about the streams in this region. However, this report represents the best available scientific information describing the flow regimes of the Middle Snake Watershed tributaries and the corresponding relationship with critical salmonid species.

Many recommendations have been made throughout this document regarding streamflow and potential management options. This section is not intended as a comprehensive summary of these suggestions, but rather as a collection of some key points of consideration relevant to instream flow negotiations. The first of these is in regard to the use of this report. Although the "discussion flows" and recommendations in Section 5 represent a compendium of information relevant to the instream flow determination process, myriad data exists in the rest of the text and the appendices that should not be disregarded. Thus, it is advised that reference be made to the entire document to provide a more robust discussion during the instream flow negotiations.

It is recommended that the Planning Unit outline specific management goals for each stream prior to initiating instream flow negotiations. It is important that the final instream flow standards be viewed in a more holistic watershed management context. The connection between upland activities and stream ecosystems is often negated, but these systems are integrally linked. Thus, the discussions should be conducted in the context of long-term water resource and fishery goals that are decided on by the Planning Unit, as well as those that have been developed by other relevant agencies. The relation of these goals to existing water rights holders should also be recognized, as these rights are guaranteed and it cannot be mandated that water be put back in the stream even if diversions decrease flows below the agreed upon instream flow criteria. The final standards will only apply to new water rights after the date the instream flow rule is adopted. Ultimately, the instream flow standards should correspond with the greater watershed management plan, while being based on commonsense so that the flows can realistically be met.

Correspondingly, ecologically protective flows, such as those provided by adopted instream flow standards, are intended to represent streamflows that support target management species (i.e., steelhead) at densities similar to those expected under natural conditions. It should be recognized that natural streamflow may not always be optimal and natural fluctuations may adversely impact the stream ecosystem even in the absence of human influence. Accordingly, minimum instream flows are not meant to be met at every point in time, and streamflows may occasionally drop below the set criteria due to natural conditions even if it impacts stream biota. On a similar note, while the importance of incorporating natural intra- and inter-annual variations into instream flow scenarios is widely recognized, it is often overlooked that the seasonal instream flow standards should mimic the stream hydrograph. This is particularly relevant in regards to the intermittent systems in the Middle Snake Watershed, assuming the evidence indicating this is their true character is correct. The indigenous fish have adapted to the episodic dewatering of certain reaches, and it is not appropriate to try to provide additional water for the stream if the management goal is to maintain the original integrity of the system. Inclusion of natural stream discharge fluctuations into instream flow standards not only accounts for the habitat needs of different steelhead life-stages, but also recognizes that variability is critical to stream ecosystem function, which may include periodic disappearance of surface water.

Acknowledging the physical setting of a stream during instream flow negotiations is similarly important. The Middle Snake Watershed represents a unique environment that is formed by a distinct combination of geomorphology, hydrology and climate. Concurrently, the inherently low-flow, and sometimes intermittent, streams in this region support a uniquely adapted biological community. Therefore, the temptation to compare these tributaries to other stream systems should be avoided. Resident steelhead can be found in habitat exhibiting flow conditions that are typically not recognized as being able to sustain salmonids, and standard fish habitat models are unable to accommodate these conditions. Thus, prescribed flows may seem implausible to be able to maintain steelhead populations when considered from a conventional perspective, but they should not be discounted and rather contemplated in the context of the inherent stream conditions.

Finally, it is strongly urged that hydrologic and fish monitoring activities be continued in the Middle Snake Watershed tributaries to provide much need information. The lack of both comprehensive and long-term data for these streams limits the ability to fully describe these streams. For instance, hydrologic assessment methods stress the need for flow data that covers several decades to fully characterize the flow regime of a system, and at a minimum at least 10 to 15 years should be included in the evaluation. The available flow data used in this report only covers 6 years that occurred during an alleged prolonged dry period, which impedes delineating a long-term baseline. Also, effective administration of instream flows from a single management point requires a greater understanding of how downstream observations represent the status of critical reaches upstream. Identification of such predictive patterns necessitates additional monitoring along the lengths of the tributaries. Insufficient data on salmonid populations similarly inhibits the characterization of fish communities in the tributaries. A better understanding of species distribution and abundance will not only help indicate the health of these populations, but will also provide a foundation from which management efforts can be evaluated based on the biotic response observed in the stream ecosystem. As understanding of the unique tributaries in the Middle Snake Watershed increases, management goals and strategies can be adjusted accordingly to better protect the steelhead populations in these systems.

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Appendix A. Satellite Images Indicating Study Site Locations

Figure A.1. Satellite image of study sites (red pins), Ecology monitoring (green pin) and WDFW fish sampling (yellow pins) locations on Almota and lower Little Almota Creeks.

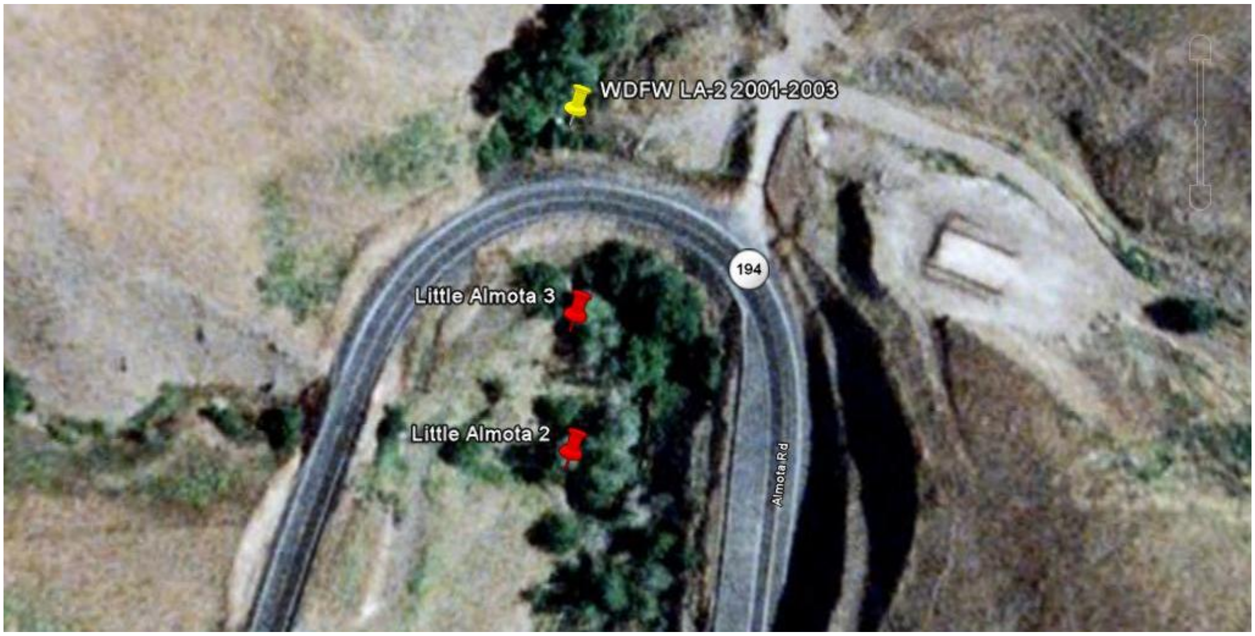


Figure A.2. Satellite image of study sites (red pins) and WDFW fish sampling (yellow pin) locations on upper Little Almota Creek.

Figure A.3. Satellite image of study sites (red pins) locations on Alpowa Creek.

Figure A.4. Satellite image of study sites (red pins) and WDFW fish sampling (yellow pins) locations on Couse Creek.

Figure A.5. Satellite image of study sites (red pins), Ecology monitoring (green pin) and WDFW fish sampling (yellow pins) locations on Deadman Creek.

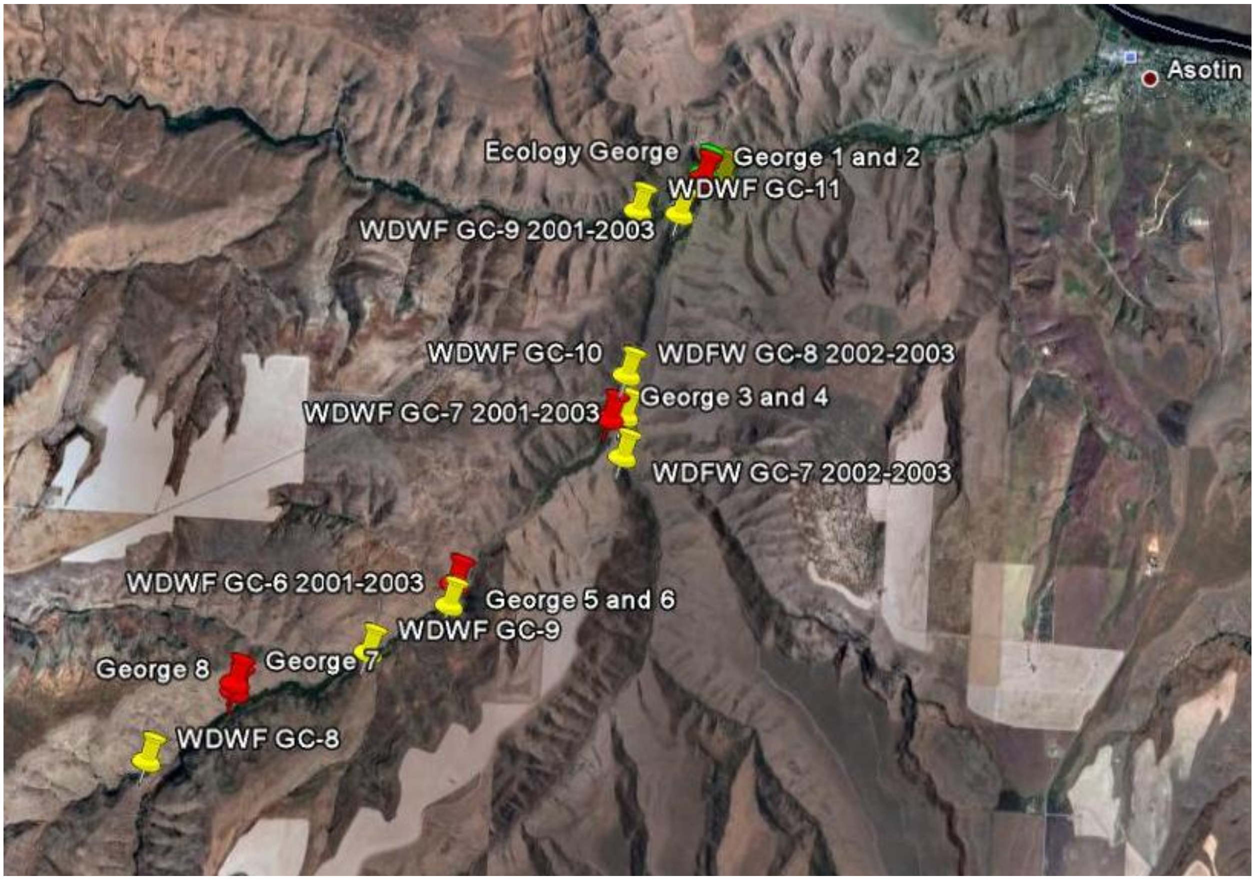


Figure A.6. Satellite image of study sites (red pins), Ecology monitoring (green pin) and WDFW fish sampling (yellow pins) locations on George Creek.

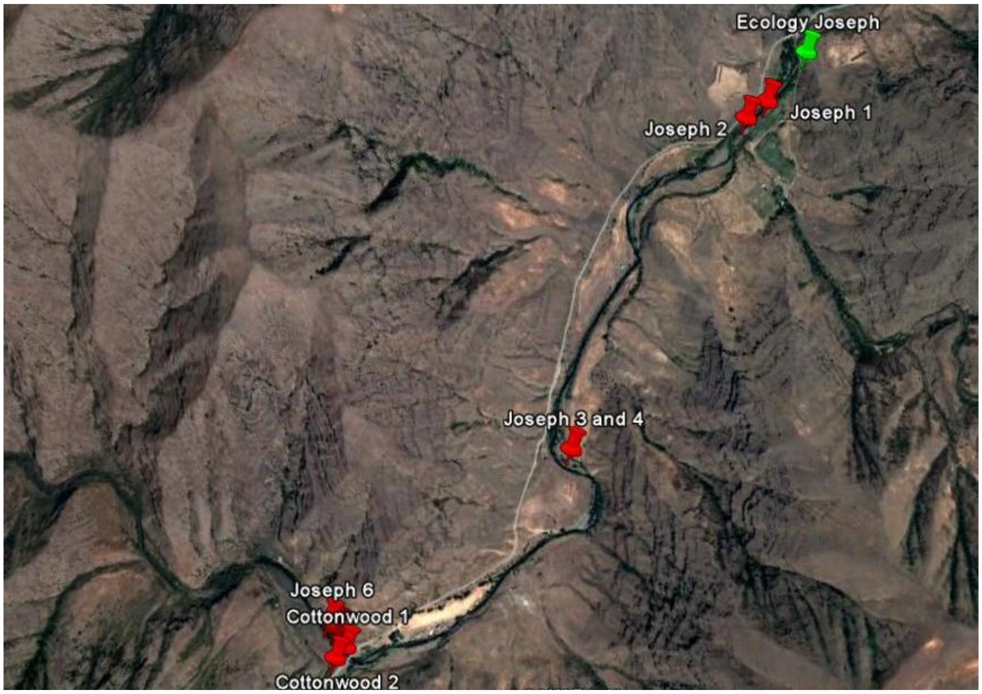


Figure A.7. Satellite image of study sites (red pins) and Ecology monitoring (green pin) locations on Joseph and Cottonwood Creeks.

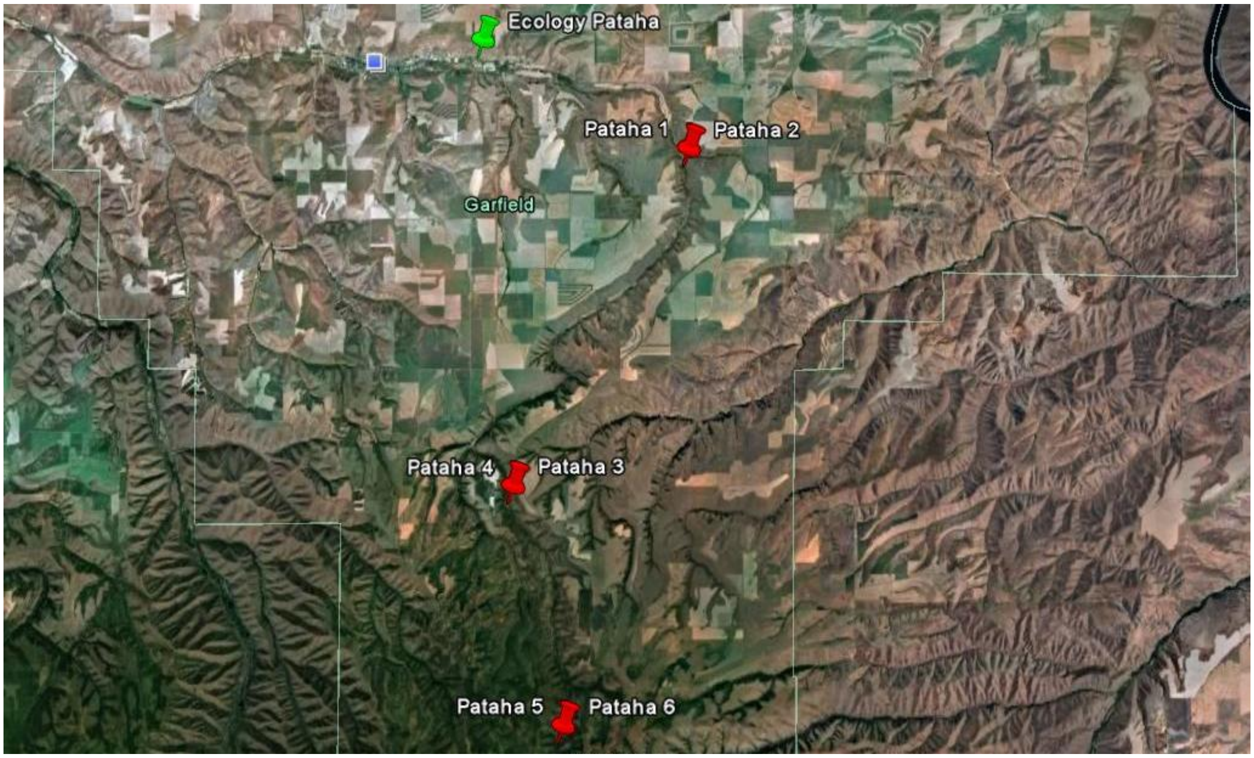


Figure A.8. Satellite image of study sites (red pins) and Ecology monitoring (green pin) locations on Pataha Creek.

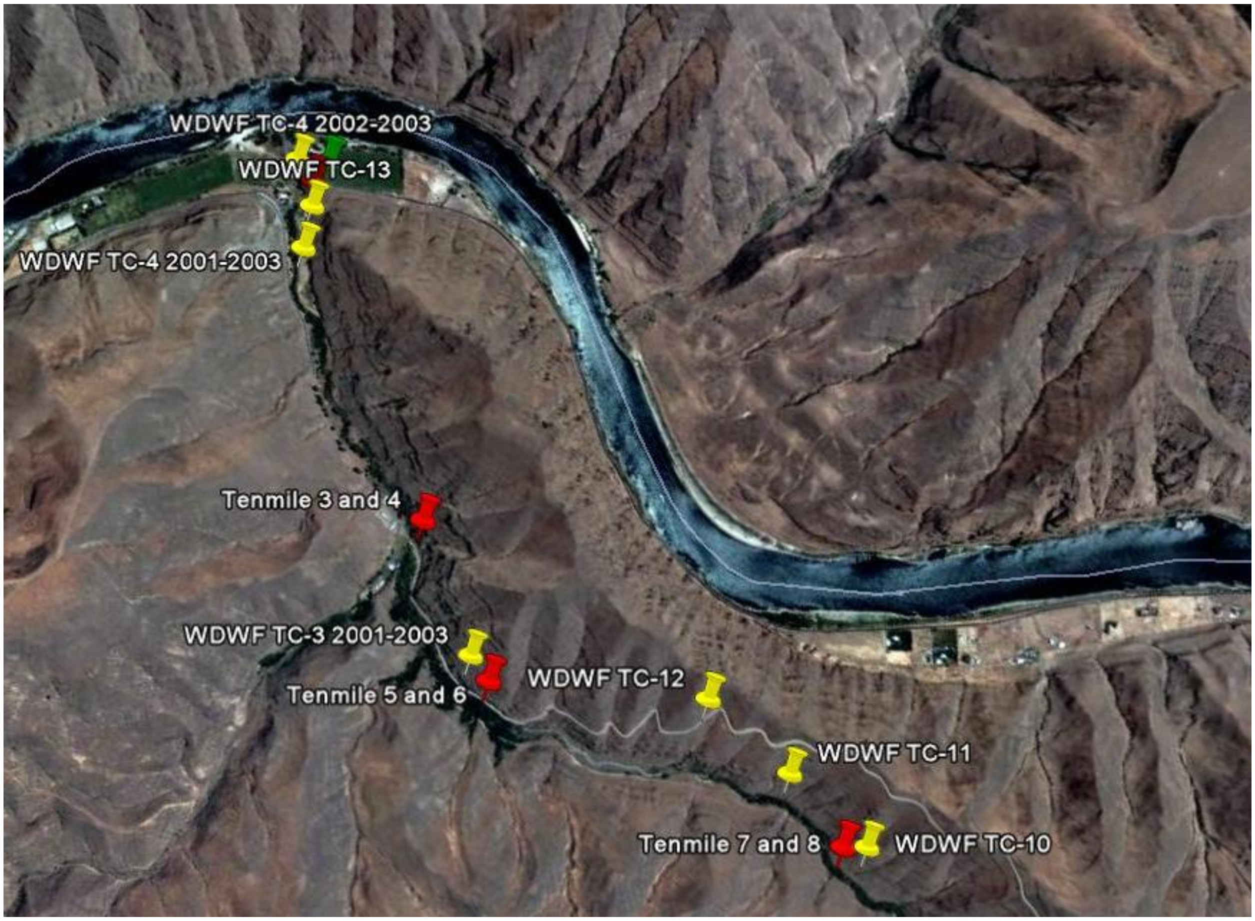


Figure A.9. Satellite image of study sites (red pins), Ecology monitoring (green pin) and WDFW fish sampling (yellow pins) locations on Tenmile Creek.


Almota Creek site 1


Almota Creek site 2


Almota Creek site 3


Little Almota Creek site 1

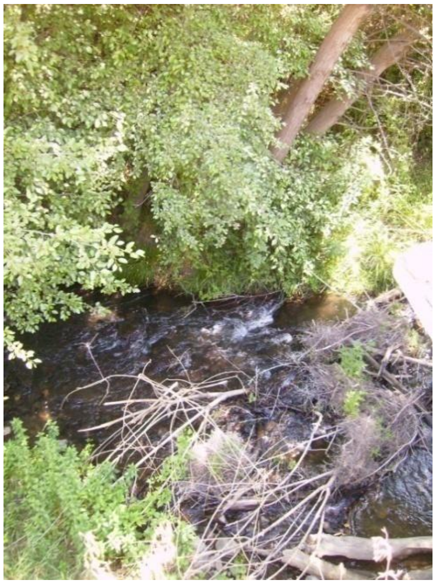

Little Almota Creek site 2


Little Almota Creek site 3

Figure A.10. Photographs of Almota Creek and Little Almota Creek sampling sites.


Alpowa Creek site 1


Alpowa Creek site 2


Alpowa Creek site 3

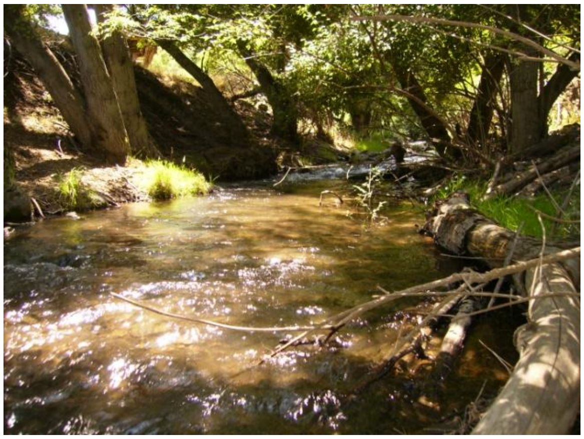

Alpowa Creek site 4

Figure A.11. Photographs of Alpowa Creek sampling sites.


Alpowa Creek site 5


Alpowa Creek site 6


Alpowa Creek site 7

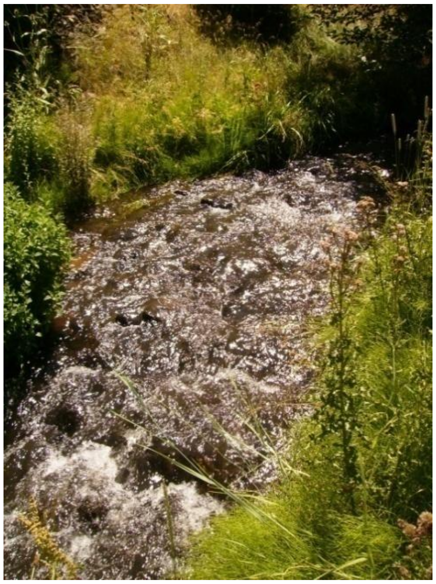

Alpowa Creek site 8

Figure A.11. (continued) Photographs of Alpowa Creek sampling sites.


Couse Creek site 1


Couse Creek site 2


Couse Creek site 3


Couse Creek site 4


Couse Creek site 5


Couse Creek site 6

Figure A.12. Photographs of Couse Creek sampling sites.


Deadman Creek site 1


Deadman Creek site 2


Deadman Creek site 3


Deadman Creek site 4


Deadman Creek site 6


Deadman Creek site 7

Figure A.13. Photographs of Deadman Creek sampling sites.

George Creek site 1

George Creek site 2

George Creek site 3

George Creek site 4

Figure A.14. Photographs of George Creek sampling sites.


George Creek site 5


George Creek site 6


George Creek site 7


George Creek site 8

Figure A.14. (continued) Photographs of George Creek sampling sites.


Joseph Creek site 1


Joseph Creek site 2


Joseph Creek site 3


Joseph Creek site 4


Cottonwood Creek site 1


Cottonwood Creek site 2

Figure A.15. Photographs of Joseph Creek and Cottonwood Creek sampling sites.


Pataha Creek site 1


Pataha Creek site 2


Pataha Creek site 3


Pataha Creek site 4


Pataha Creek site 5


Pataha Creek site 6

Figure A.16. Photographs of Pataha Creek sampling sites.


Tenmile Creek site 1


Tenmile Creek site 2


Tenmile Creek site 3


Tenmile Creek site 4

Figure A.17. Photographs of Tenmile Creek sampling sites.

Tenmile Creek site 5

Tenmile Creek site 6

Tenmile Creek site 7

Tenmile Creek site 8

Figure A.17. (continued) Photographs of Tenmile Creek sampling sites.

Appendix B. Transect Plots for Study Sites

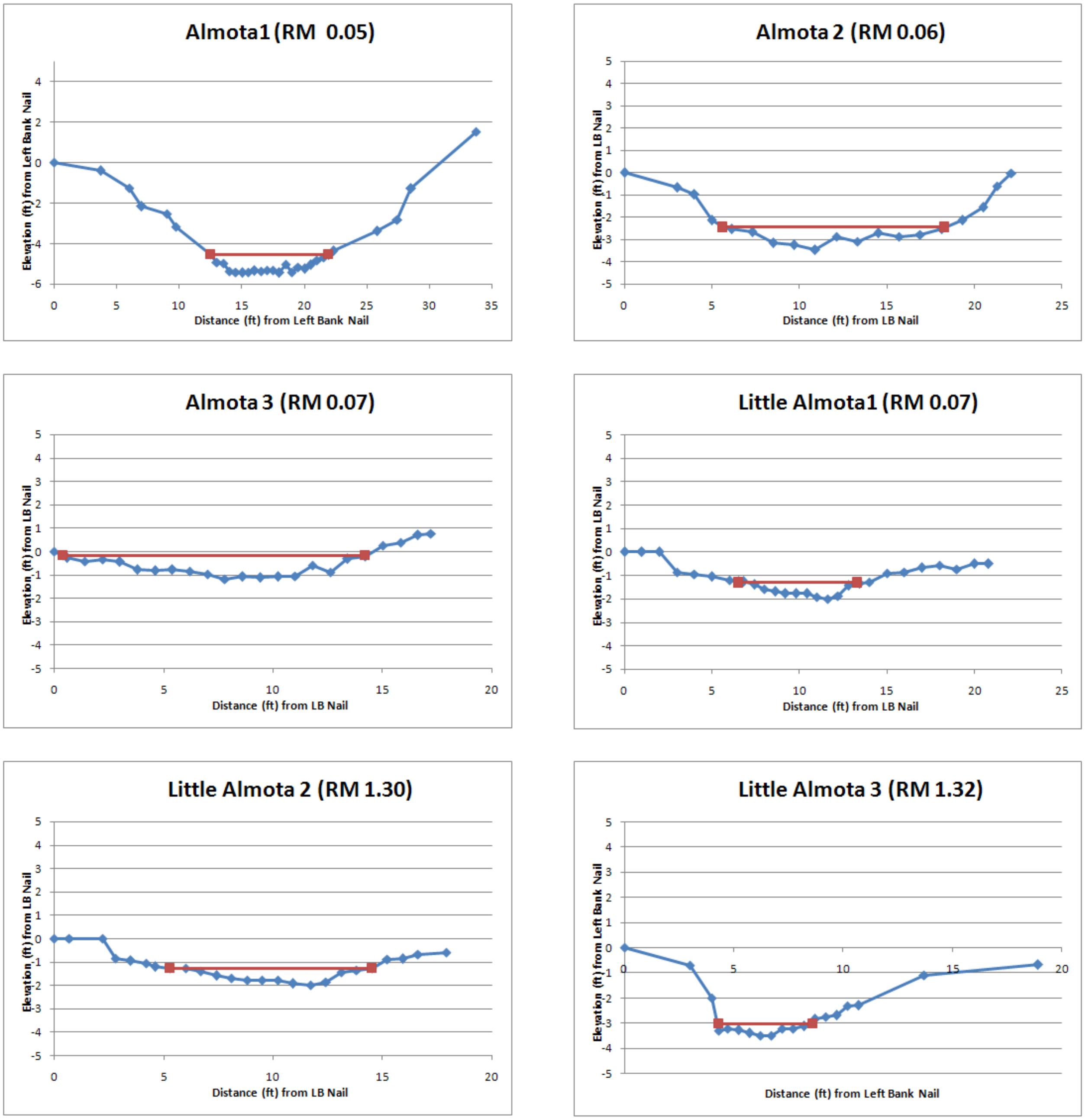


Figure B.1. Transect plots for Almota and Little Almota Creeks with water level at time of measurements shown by red line.

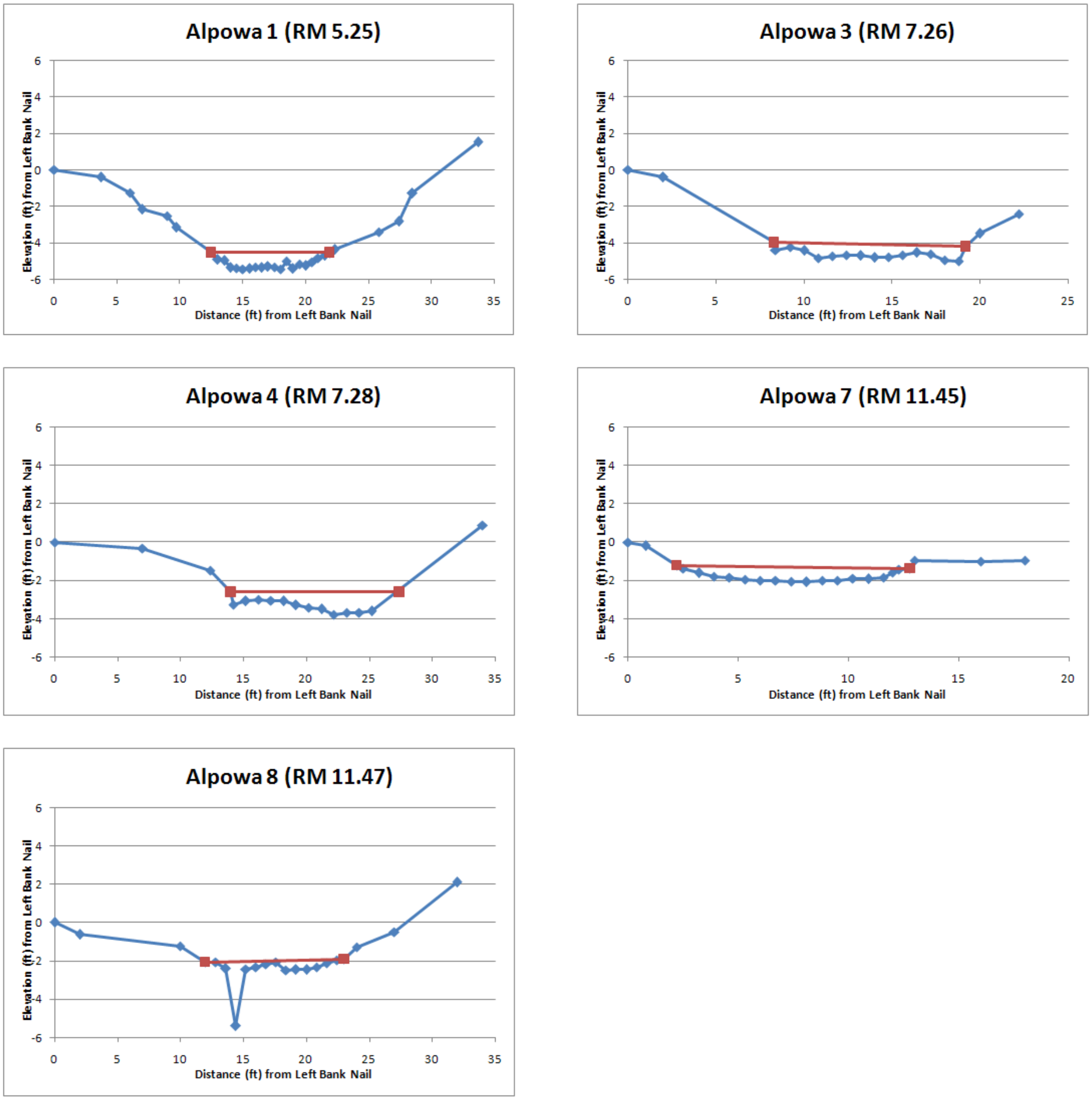


Figure B.2. Transect plots for Alpowa Creek with water level at time of measurements shown by red line.

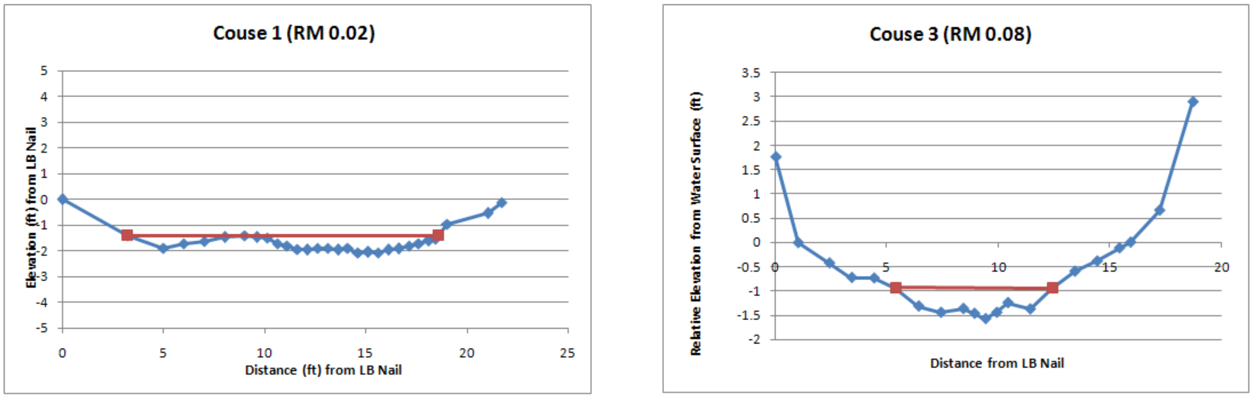


Figure B.3. Transect plots for Couse Creek with water level at time of measurements shown by red line.

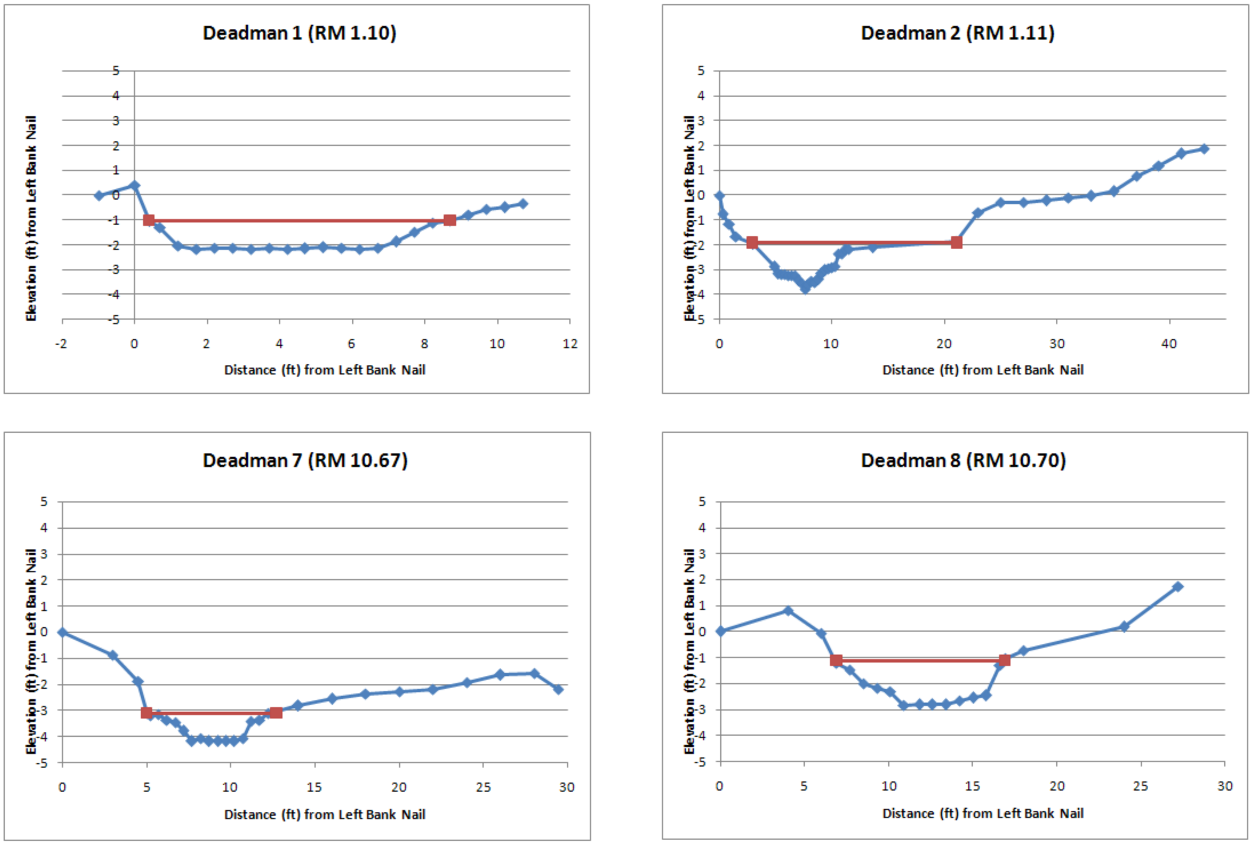


Figure B.4. Transect plots for Deadman Creek with water level at time of measurements shown by red line.

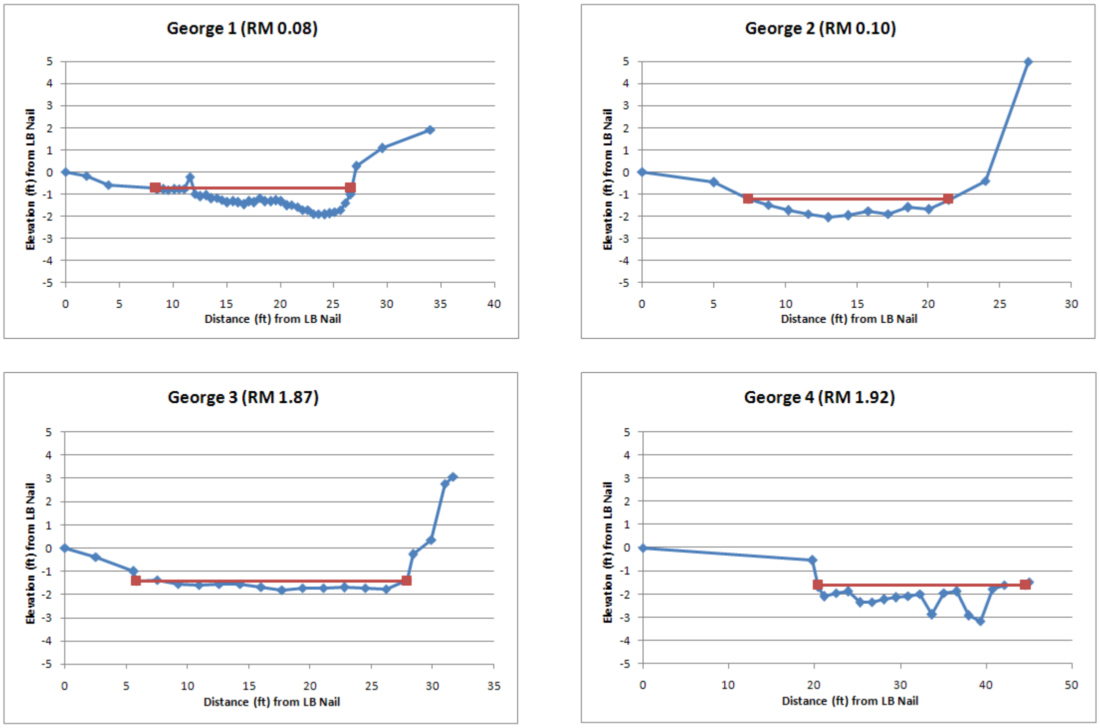


Figure B.5. Transect plots for George Creek with water level at time of measurements shown by red line.

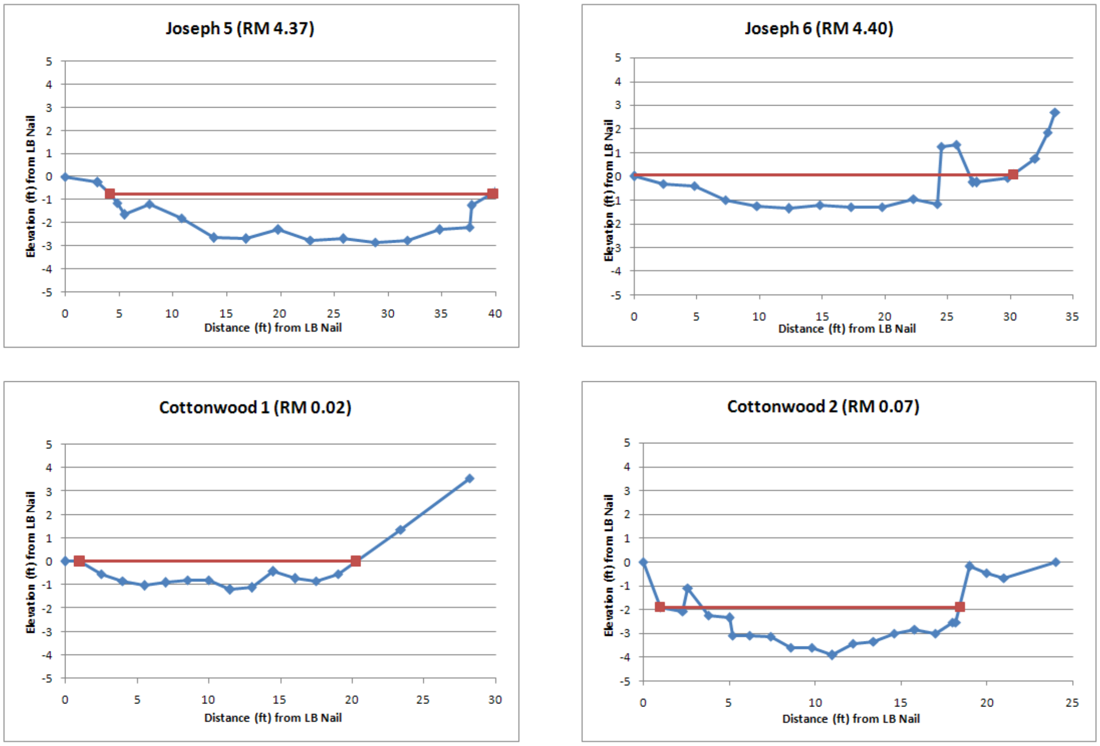


Figure B.6. Transect plots for Joseph and Cottonwood Creeks with water level at time of measurements shown by red line.

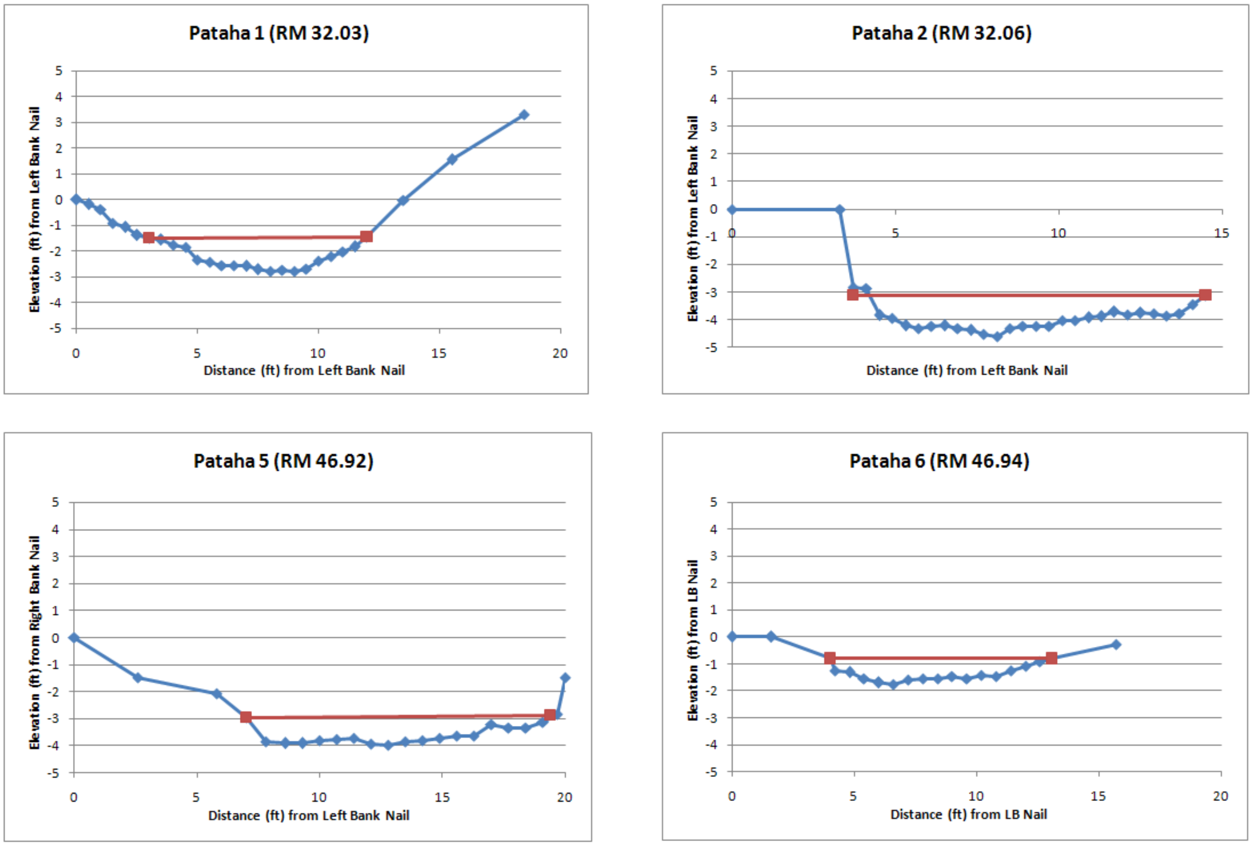


Figure B.7. Transect plots for Pataha Creek with water level at time of measurements shown by red line.

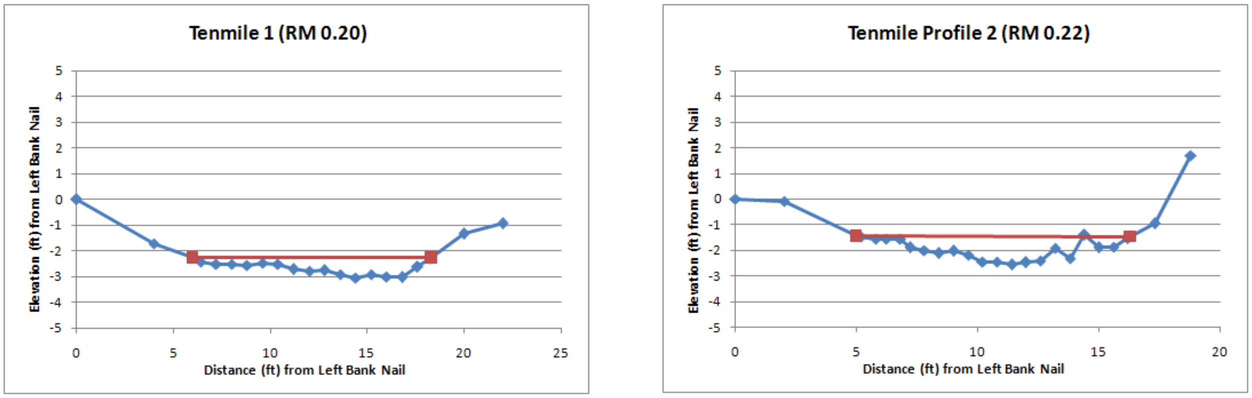


Figure B.8. Transect plots for Tenmile Creek with water level at time of measurements shown by red line.

Appendix C. Streamflow Data Collected at Study Sites

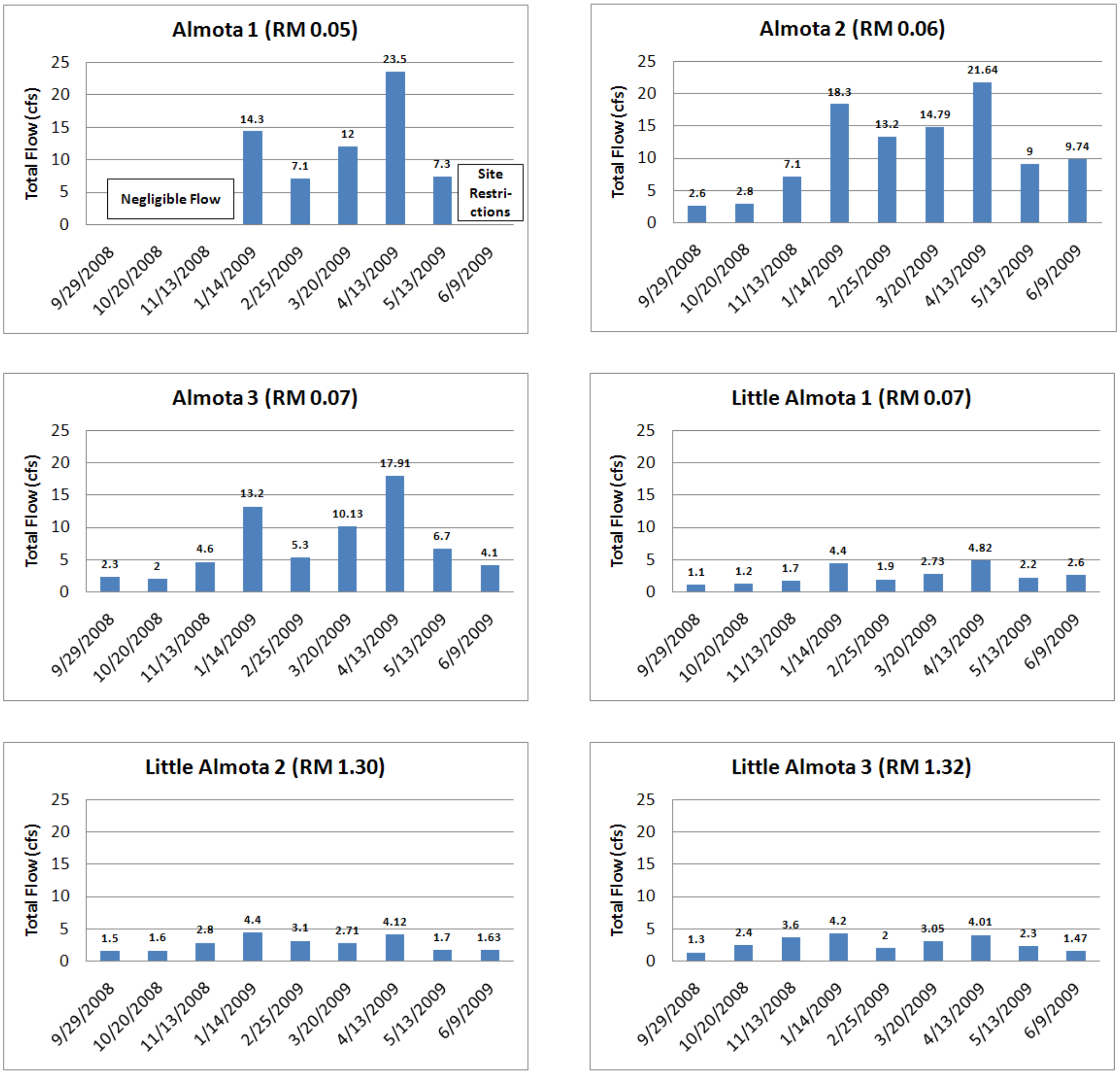


Figure C.1. Study streamflow data for Almota and Little Almota Creeks.

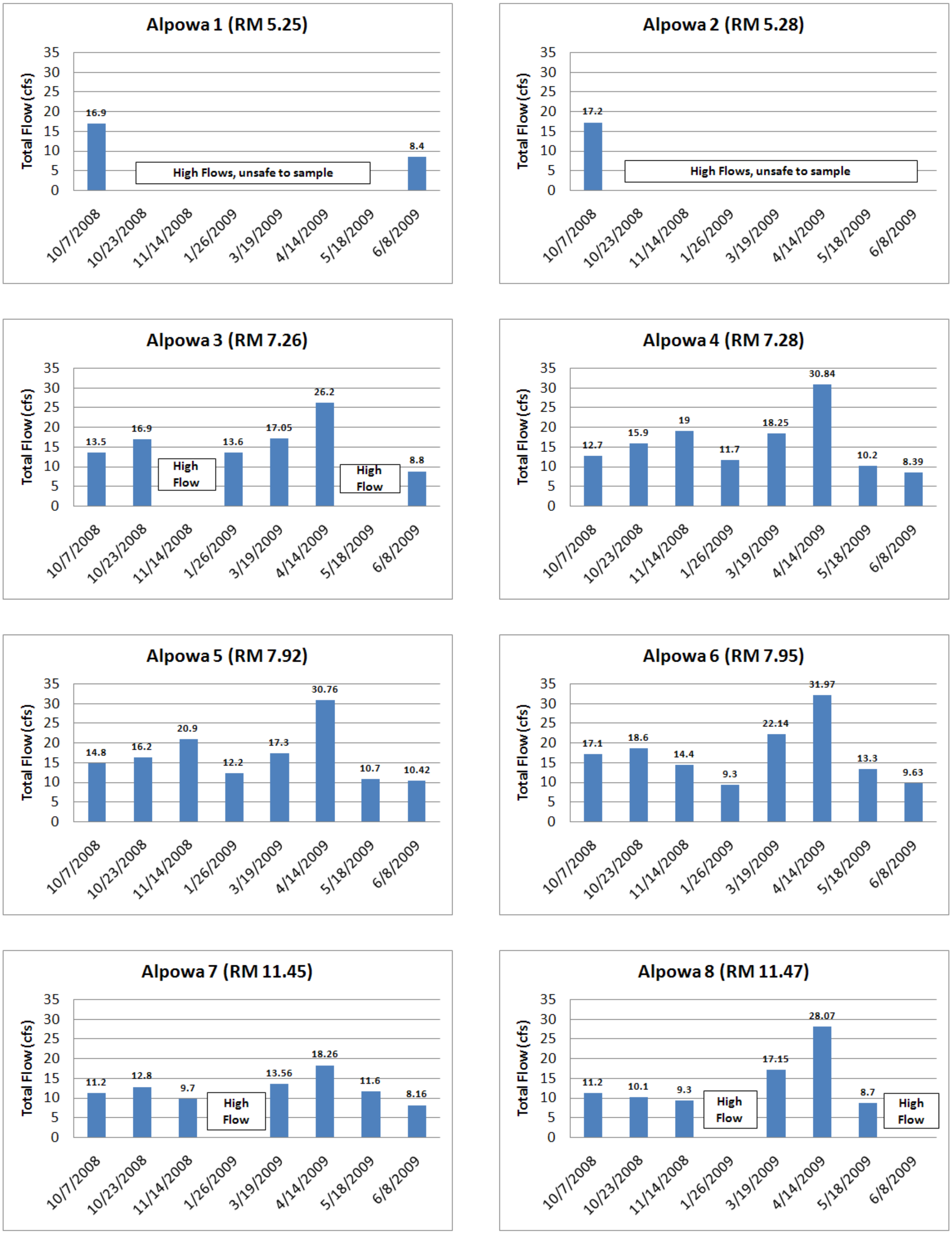


Figure C.2. Study streamflow data for Alpowa Creek.

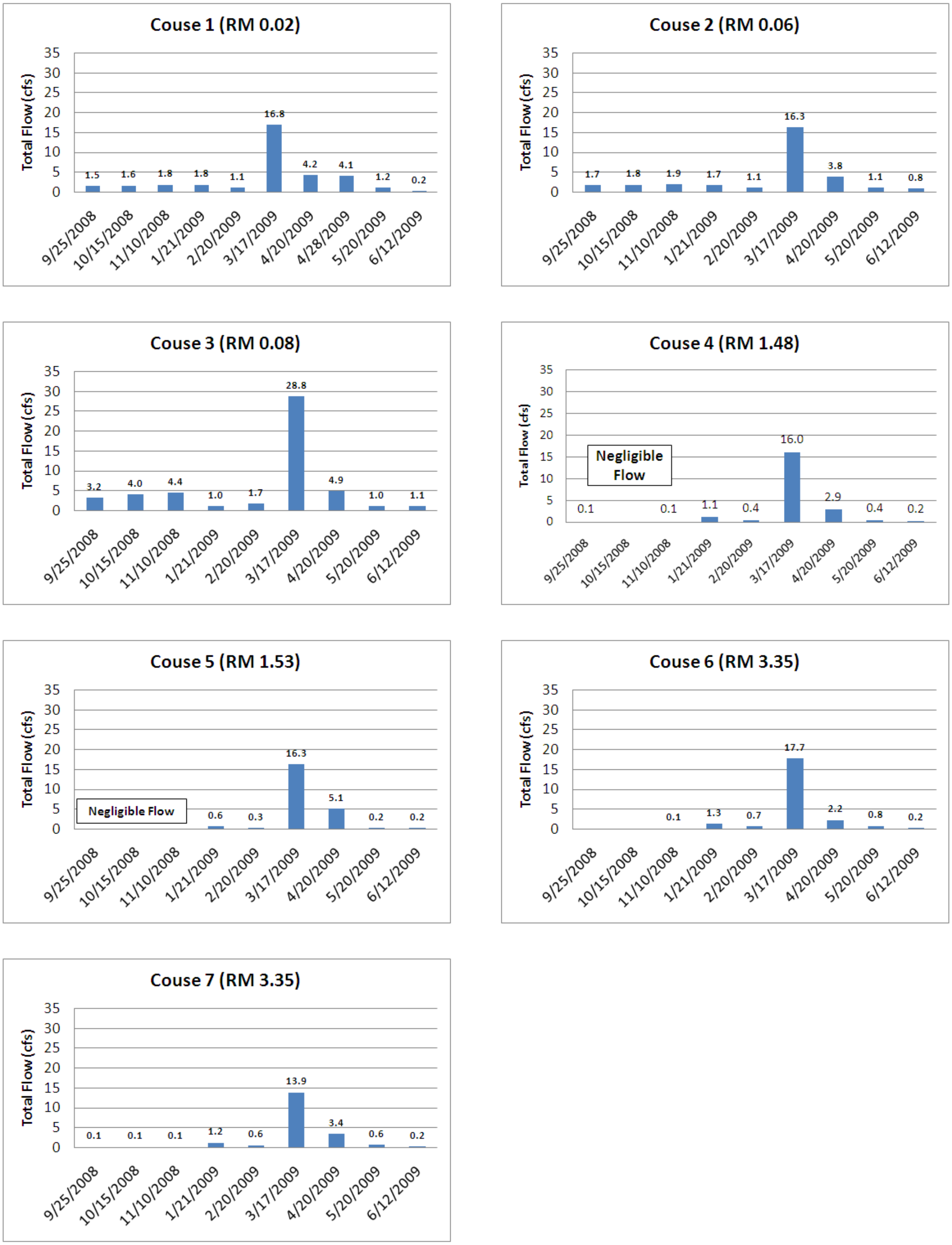


Figure C.3. Study streamflow data for Couse Creek.

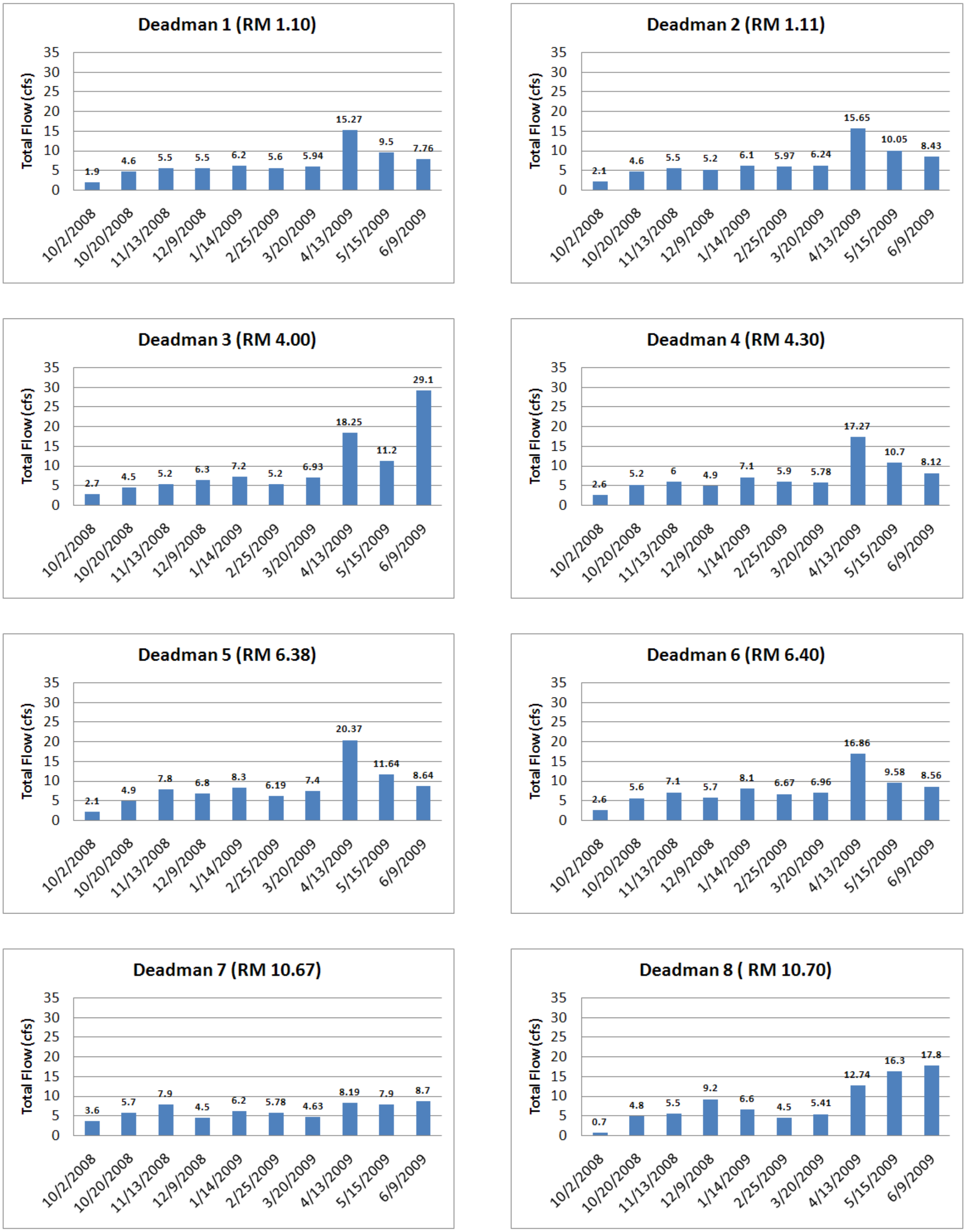


Figure C.4. Study streamflow data for Deadman Creek.

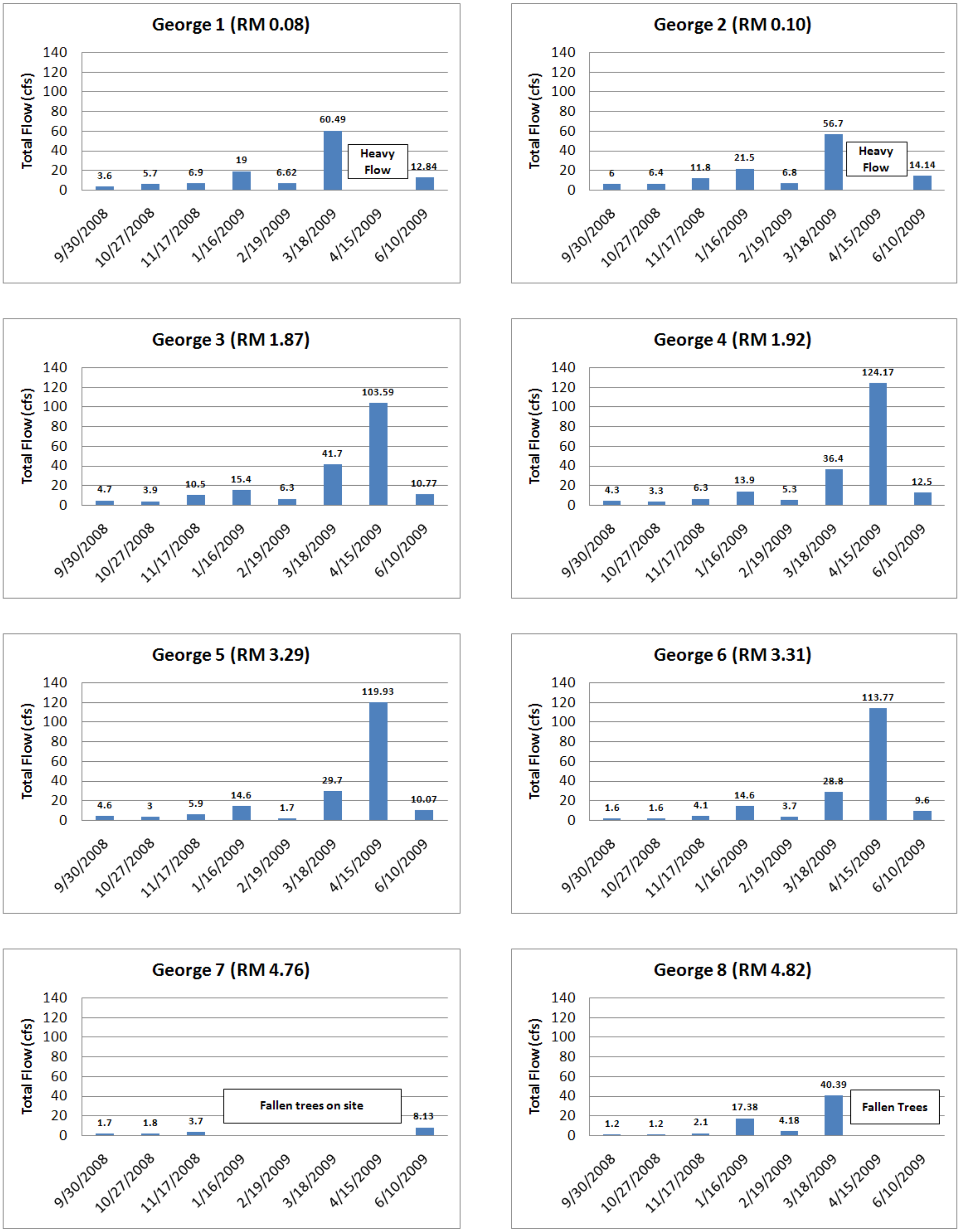


Figure C.5. Study streamflow data for George Creek.

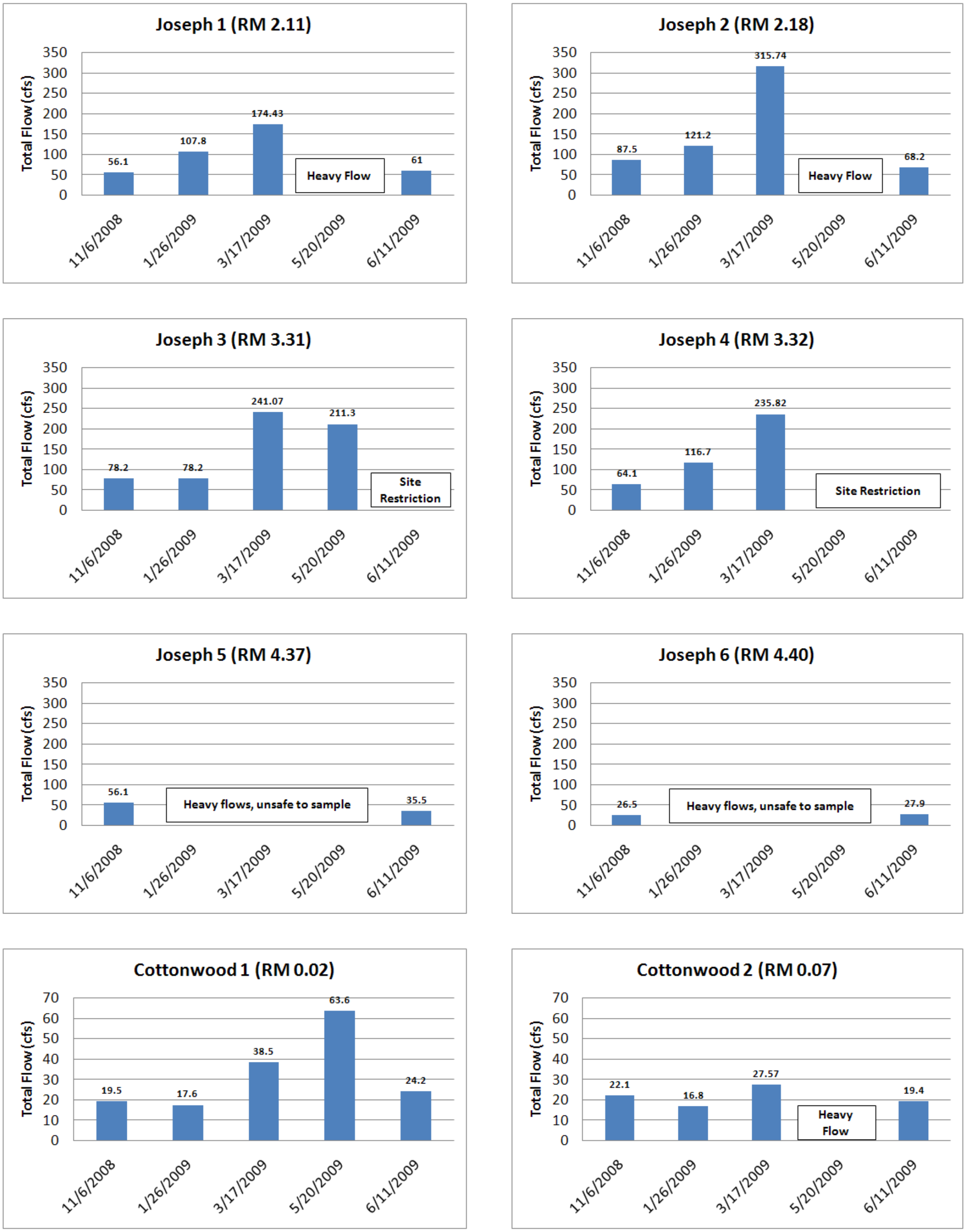


Figure C.6. Study streamflow data for Joseph and Cottonwood Creeks.

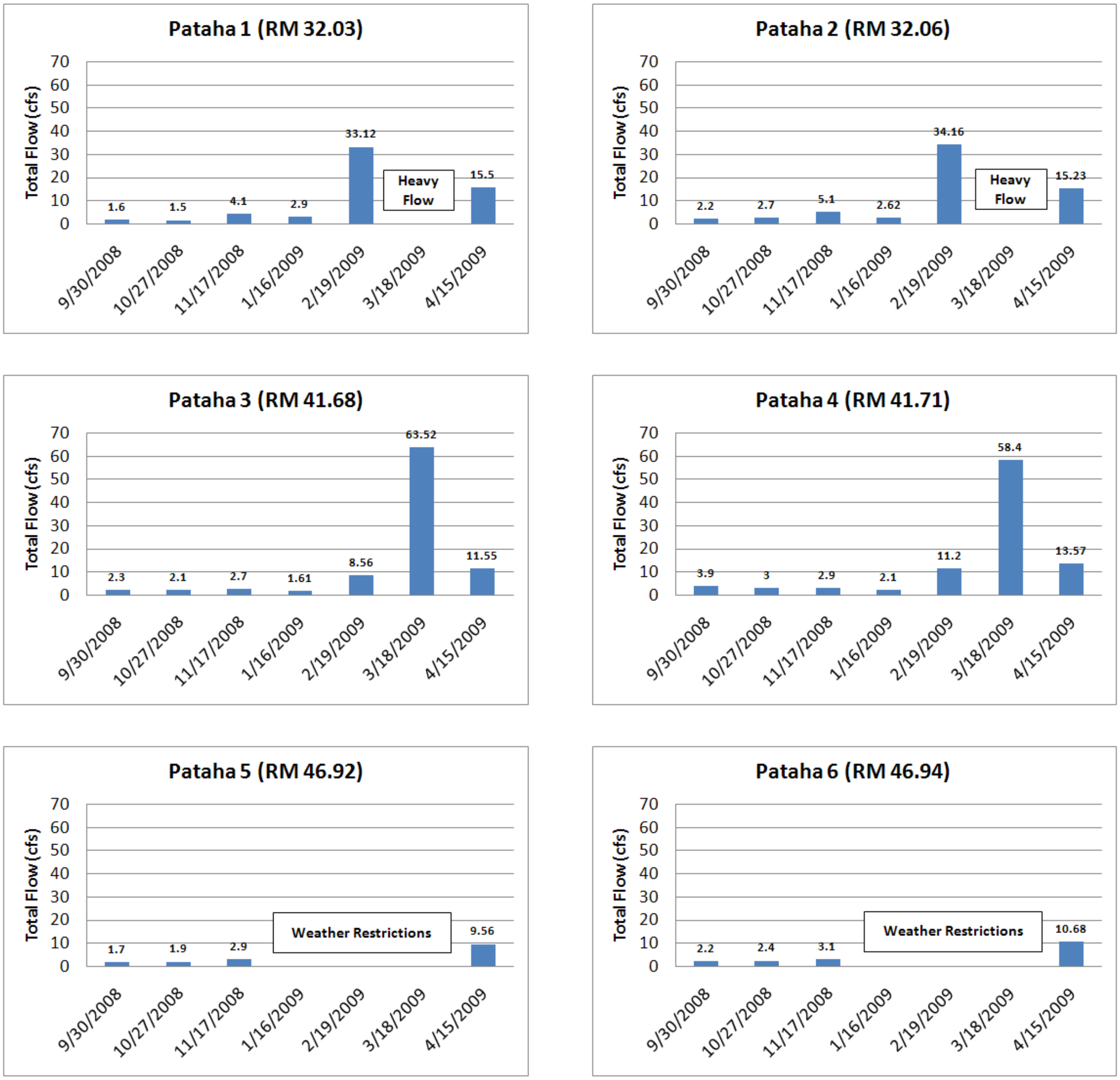


Figure C.7. Study streamflow data for Pataha Creek.

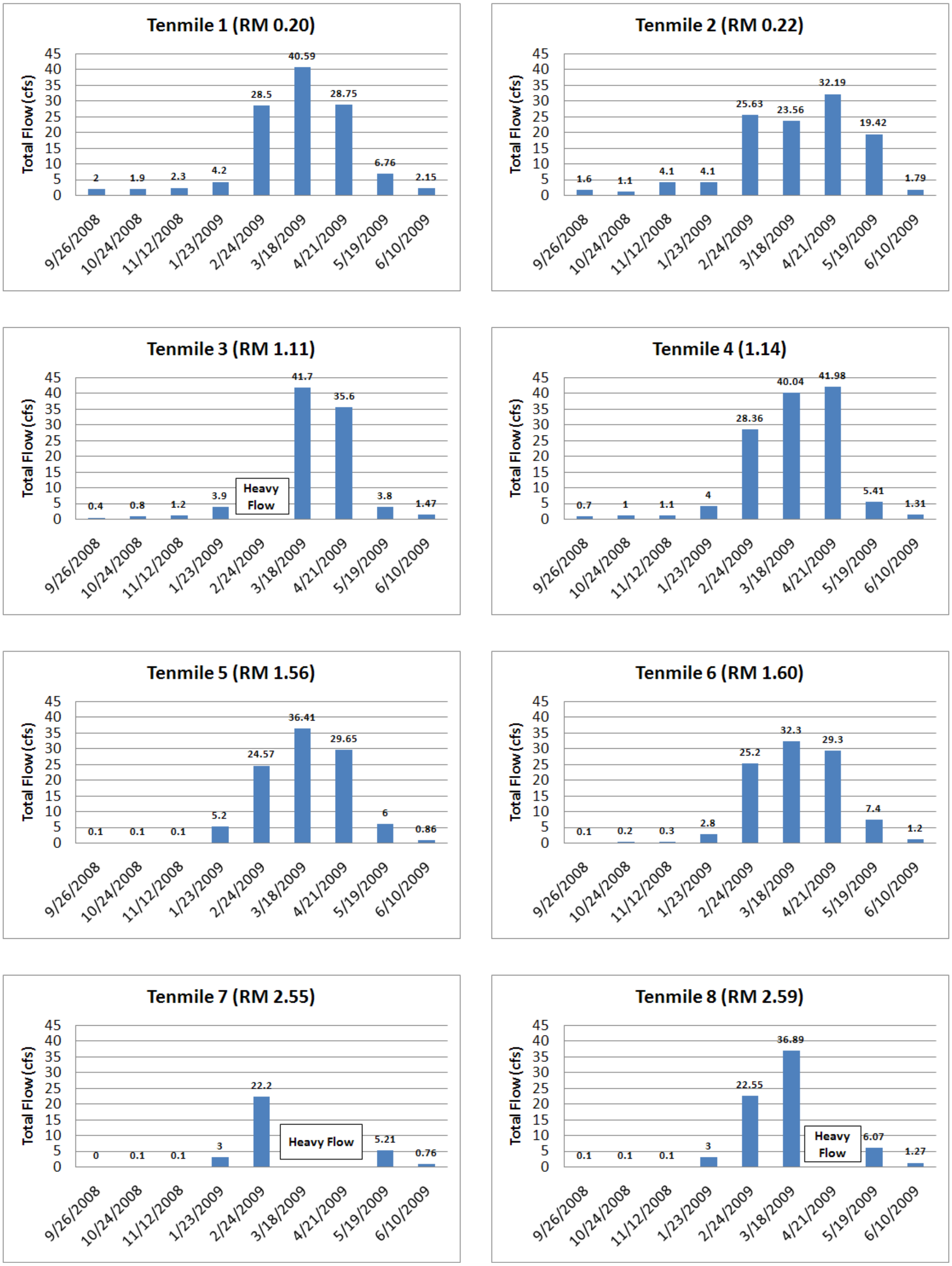


Figure C.8. Study streamflow data for Tenmile Creek.

Appendix D. Washington State Department of Ecology Streamflow Data for WRIA 35 Streams, 2003-2009

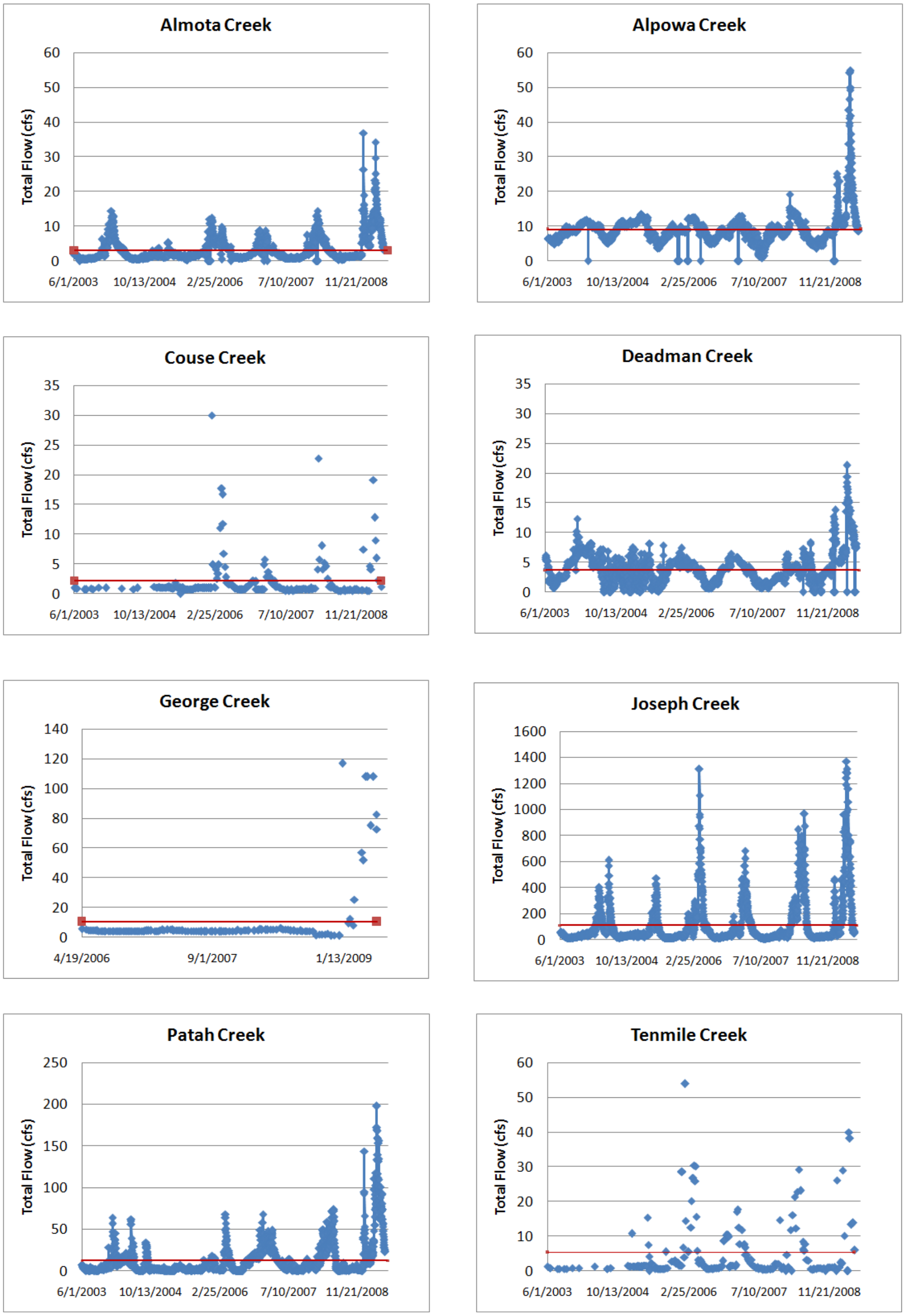


Figure D.1. Streamflow data collected by Washington State Department of Ecology for WRIA 35 streams. The red line represents the average flow over the 2003-2009 period for which data is available.

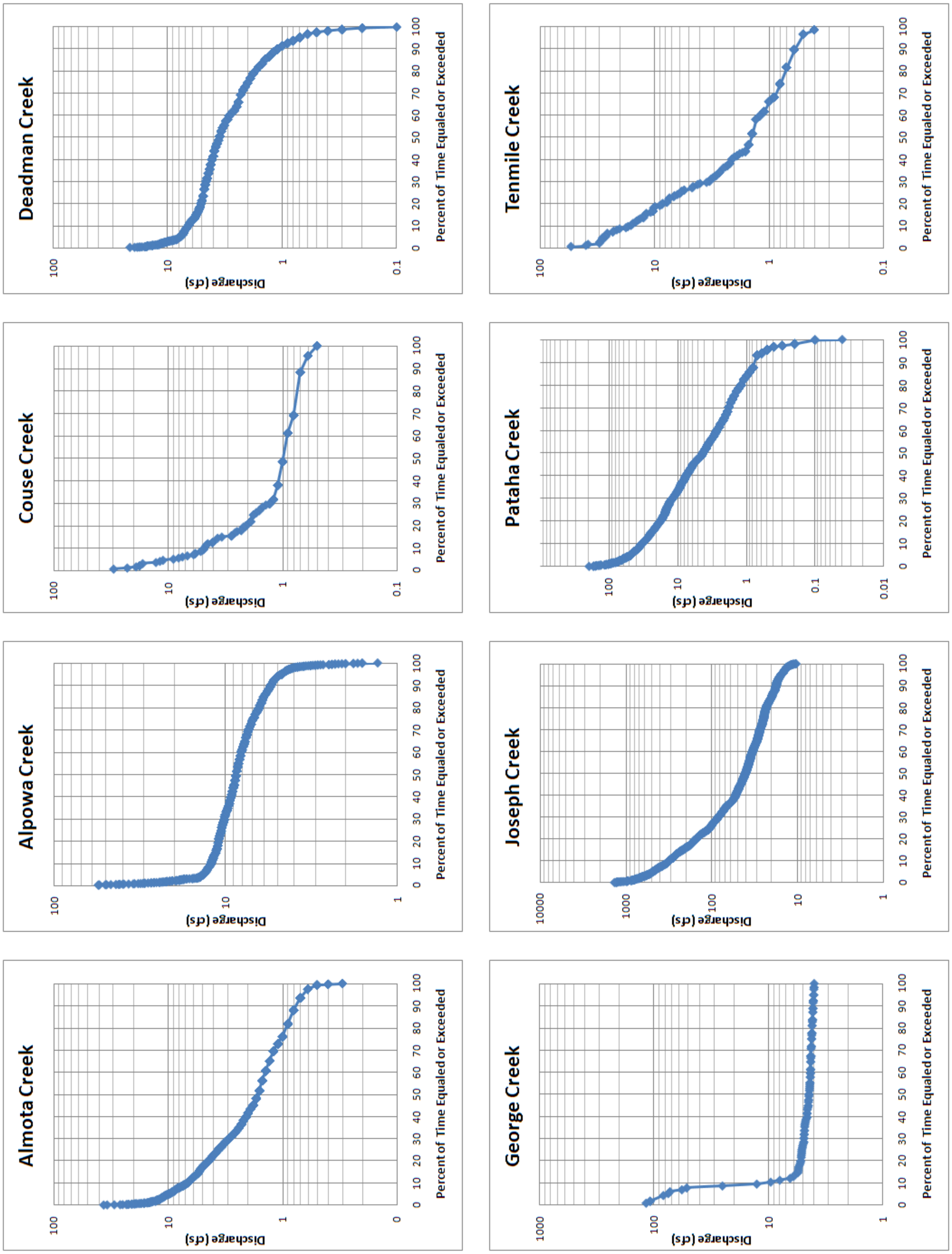


Figure D.2. Exceedance flow curves based on streamflow data (2003-2009) collected by Washington State Department of Ecology for WRIA 35 streams.

Appendix E. Wetted Perimeter-Discharge Plots for Study Sites

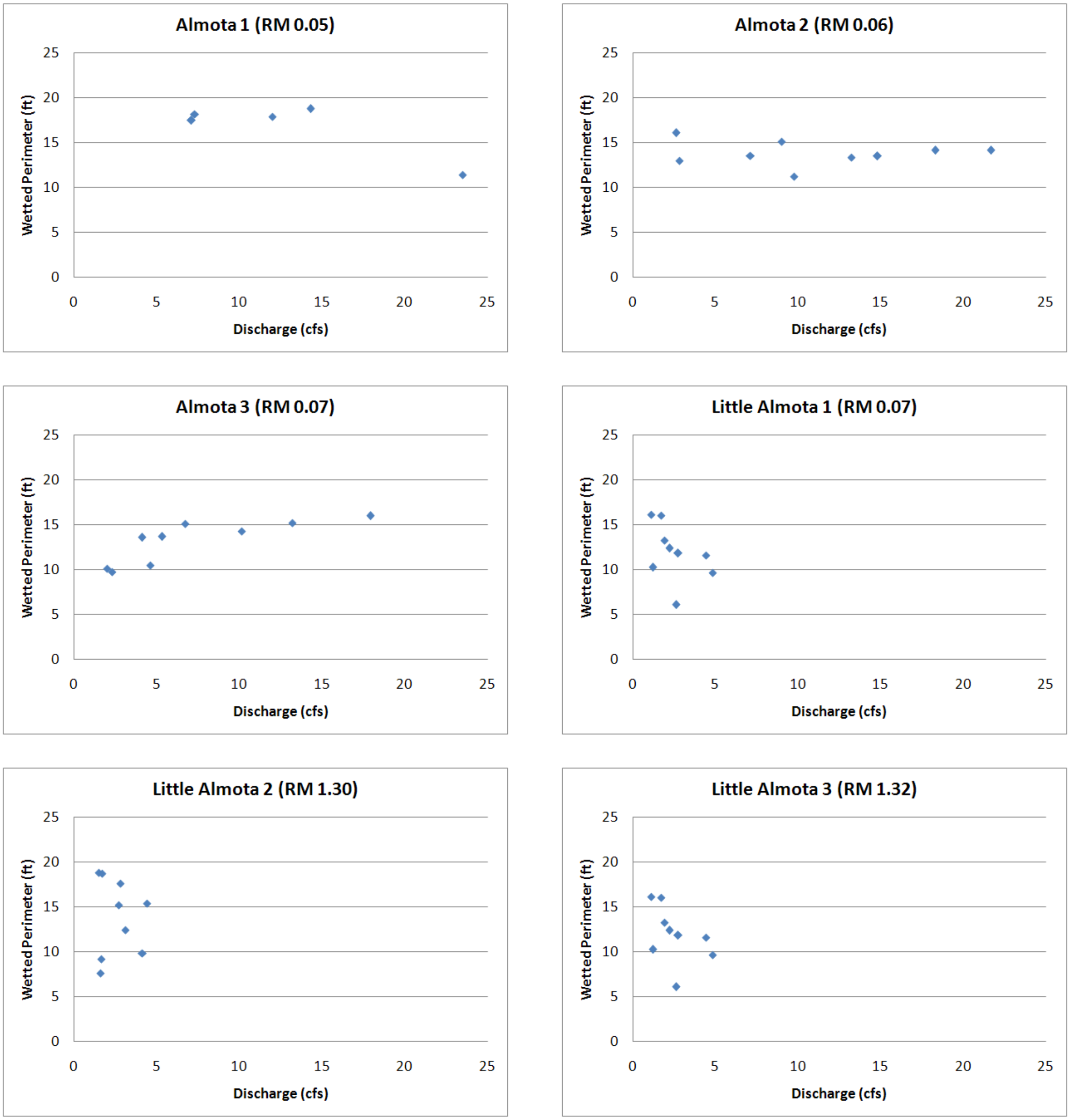


Figure E.1. Wetted perimeter versus discharge plots for Almota and Little Almota Creeks.

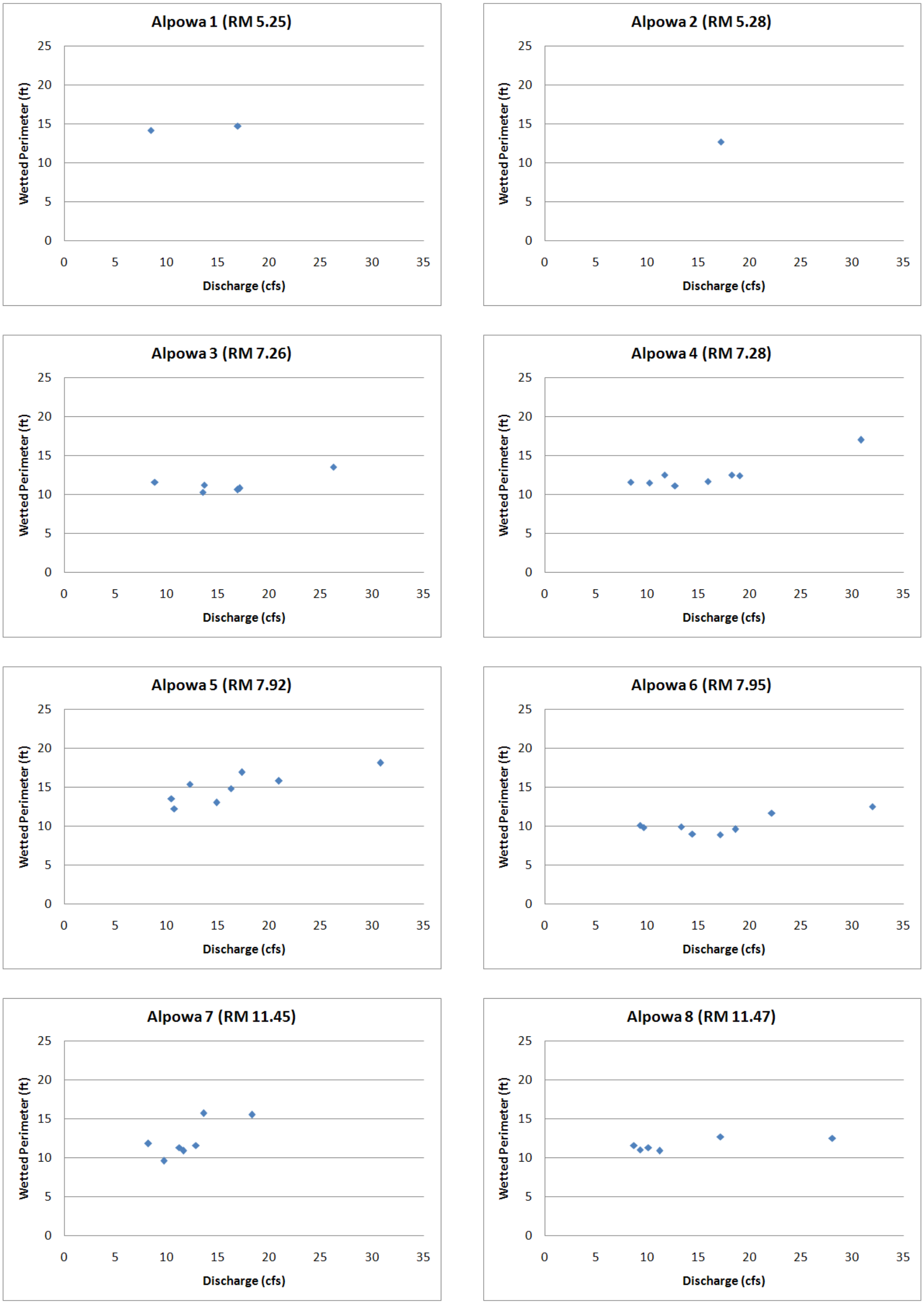


Figure E.2. Wetted perimeter versus discharge plots for Alpowa Creek.

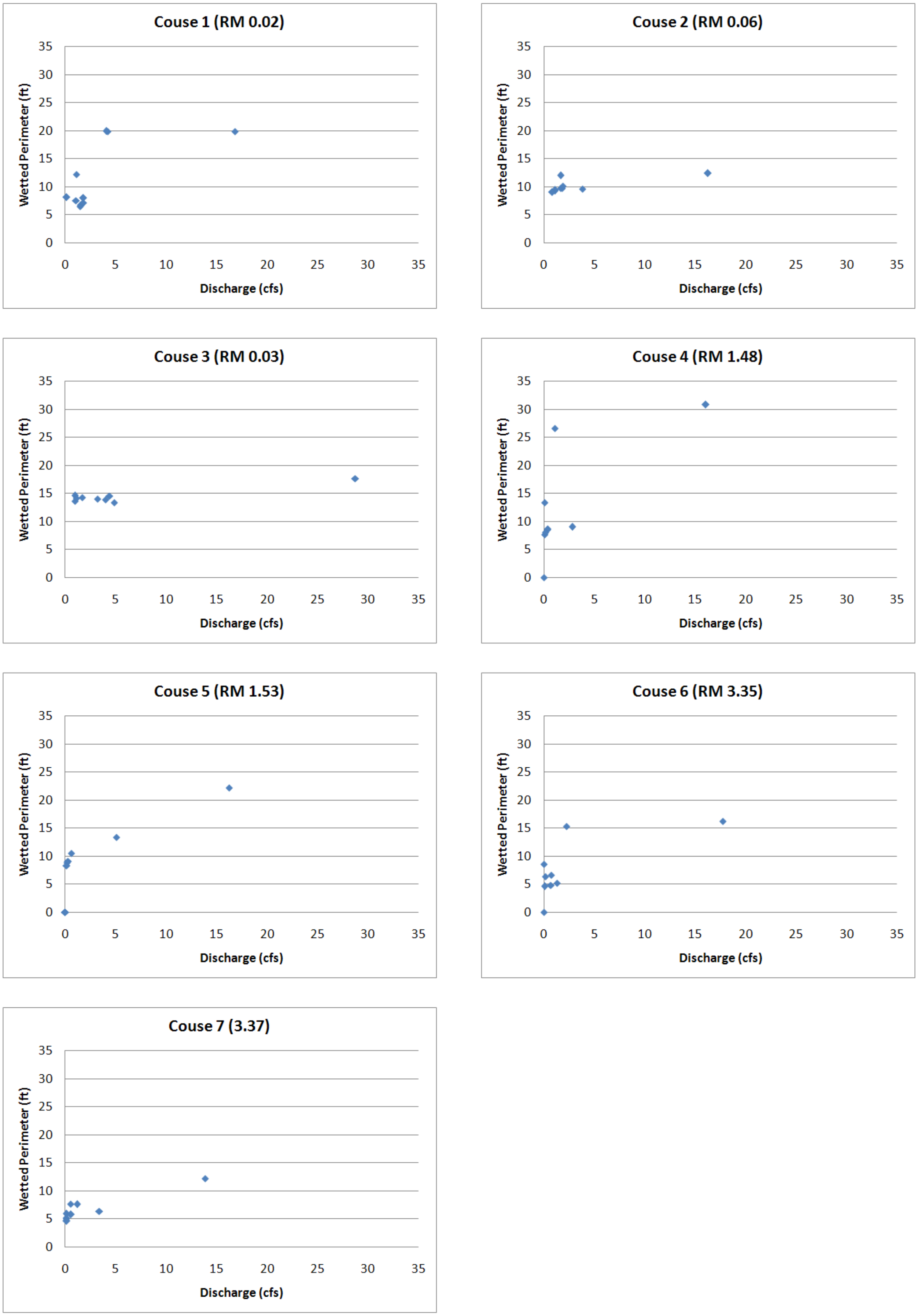


Figure E.3. Wetted perimeter versus discharge plots for Couse Creek.

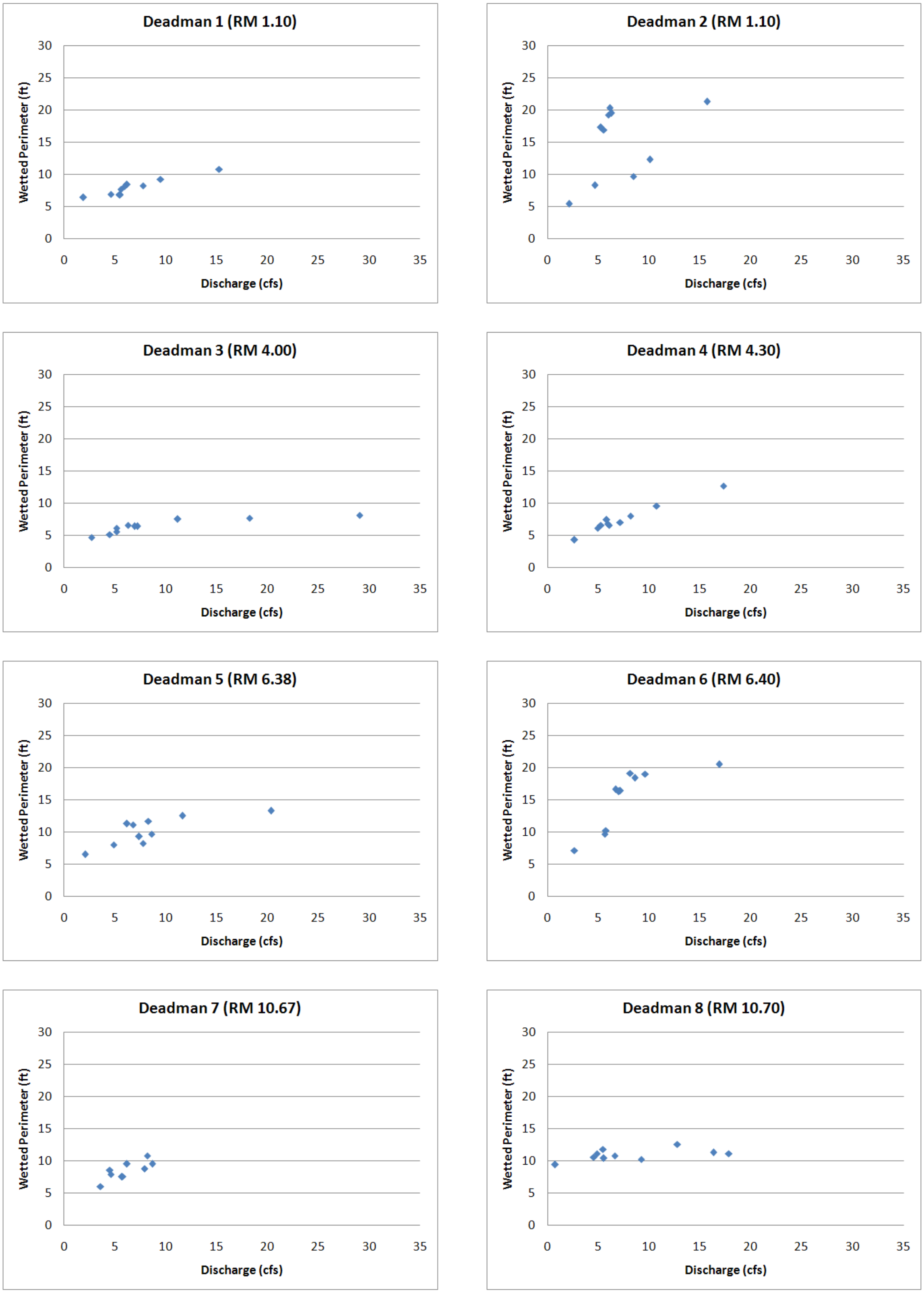


Figure E.4. Wetted perimeter versus discharge plots for Deadman Creek.

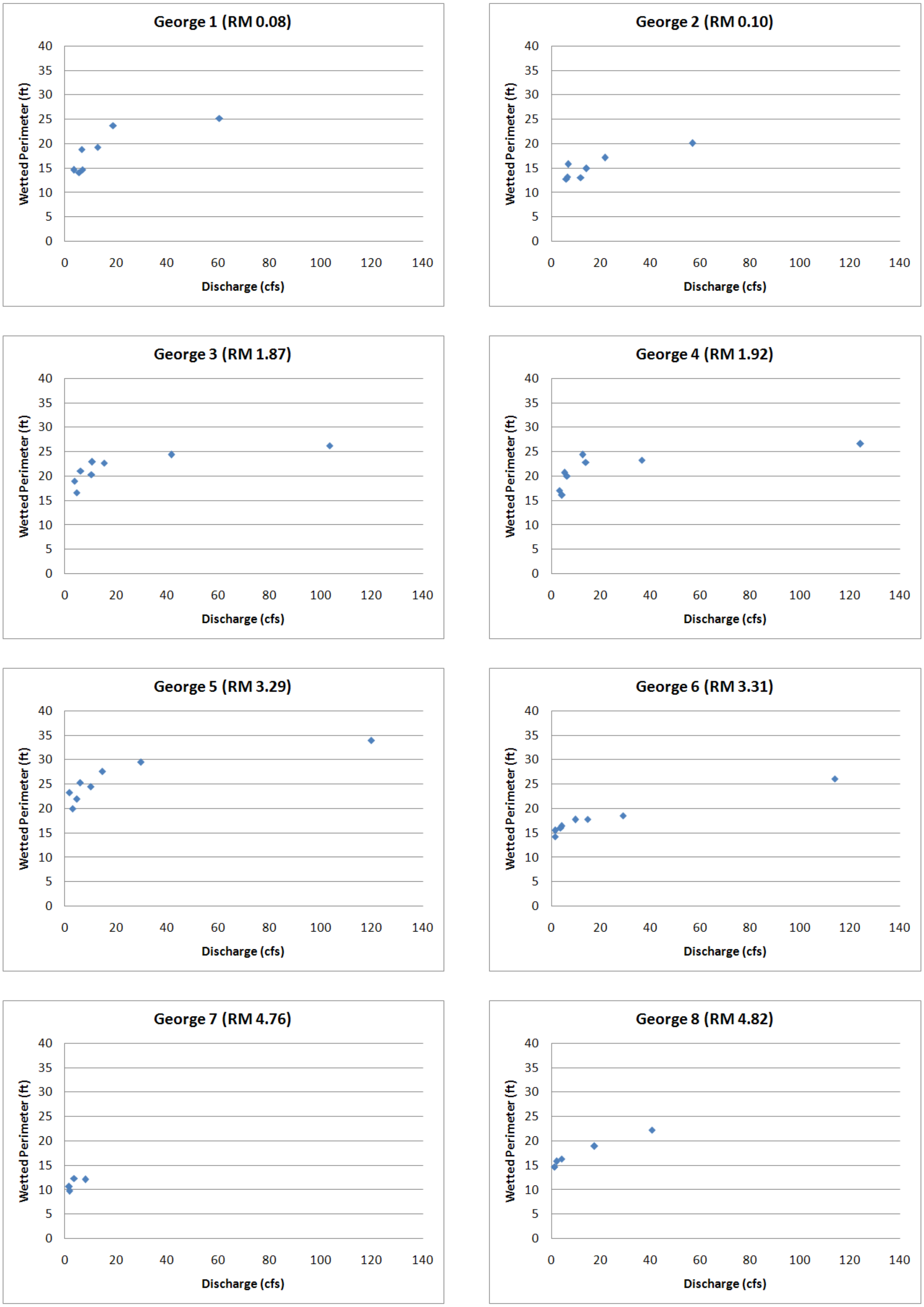


Figure E.5. Wetted perimeter versus discharge plots for George Creek.

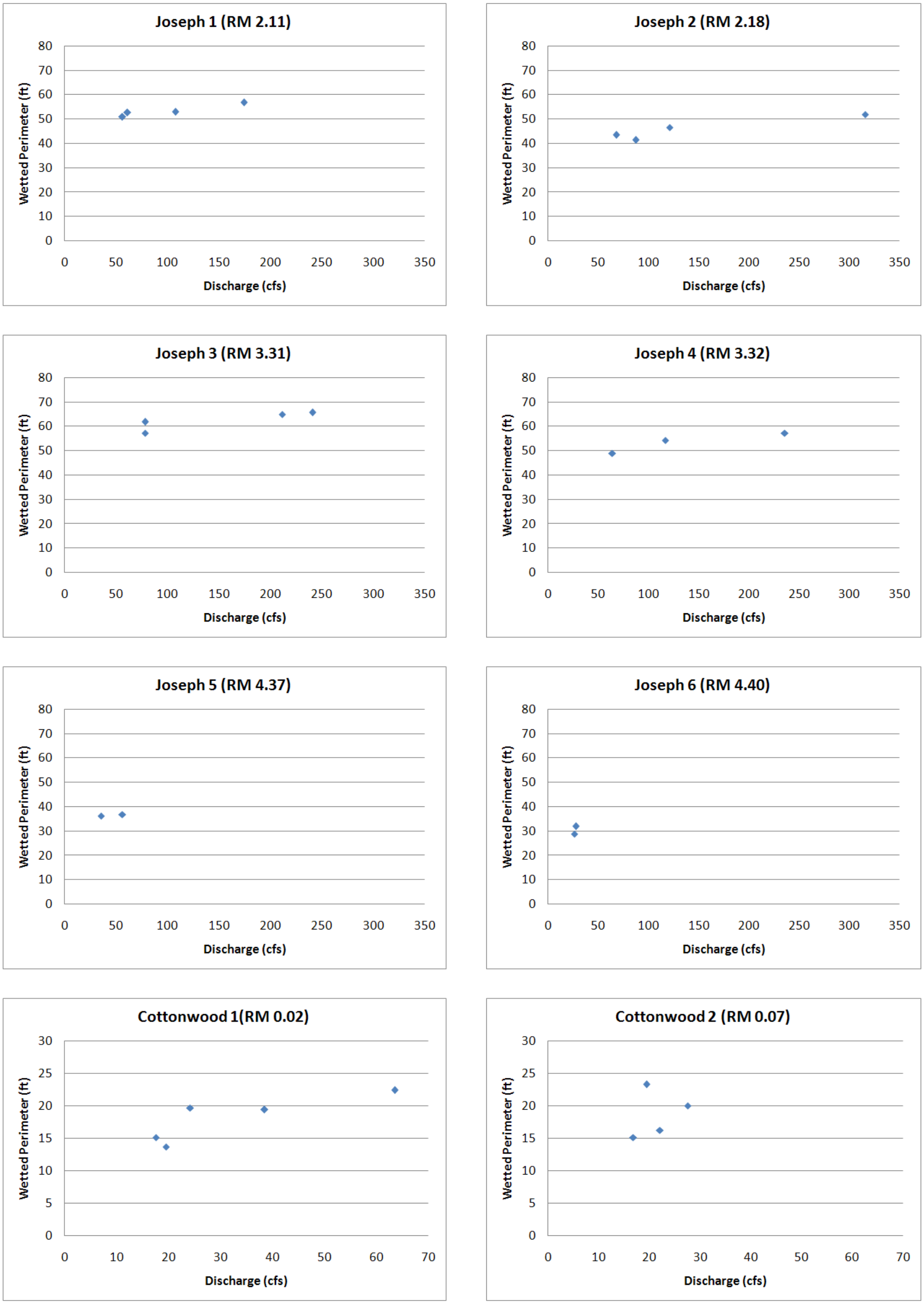


Figure E.6. Wetted perimeter versus discharge plots for Joseph and Cottonwood Creeks.

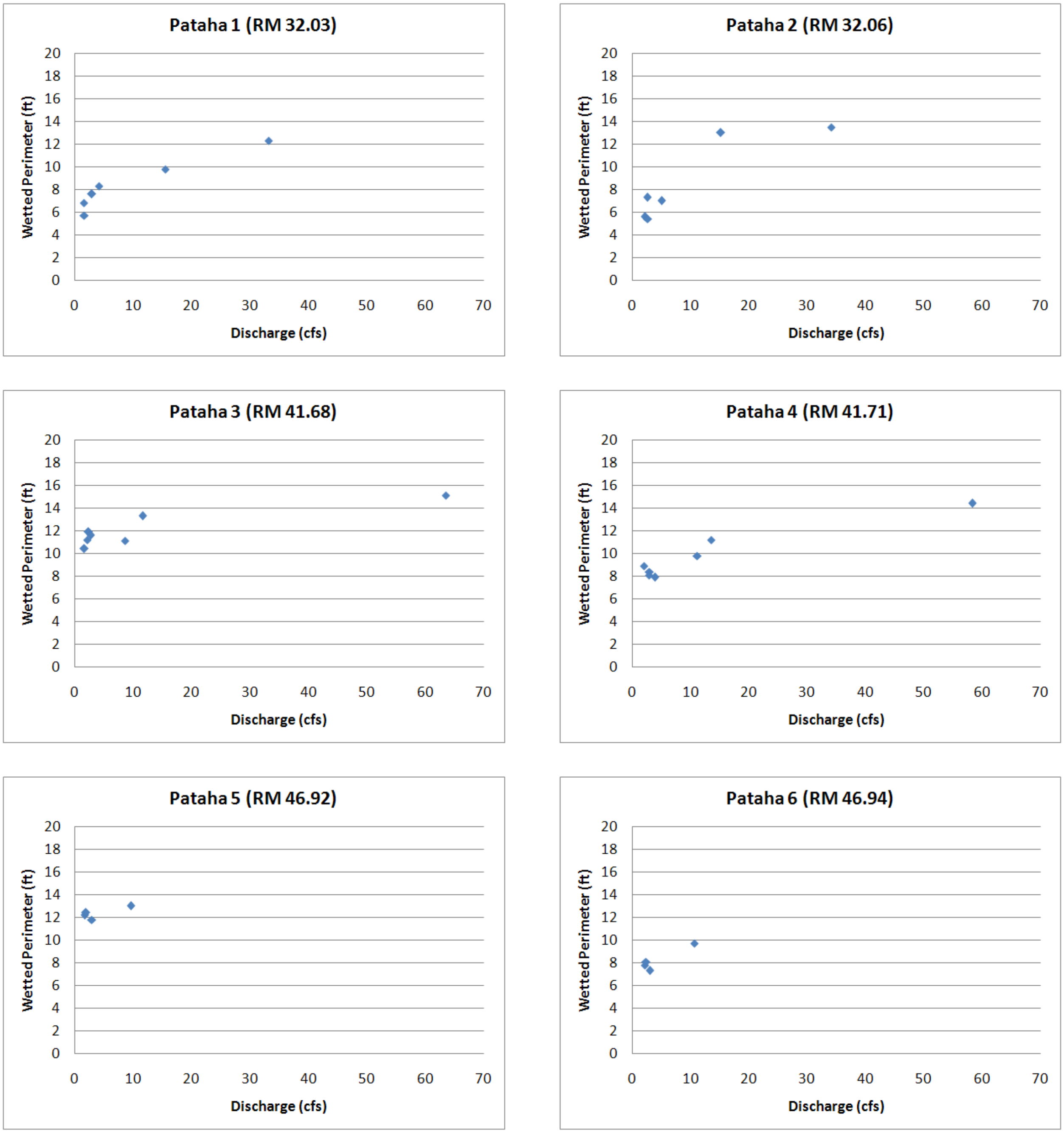


Figure E.7. Wetted perimeter versus discharge plots for Pataha Creek.

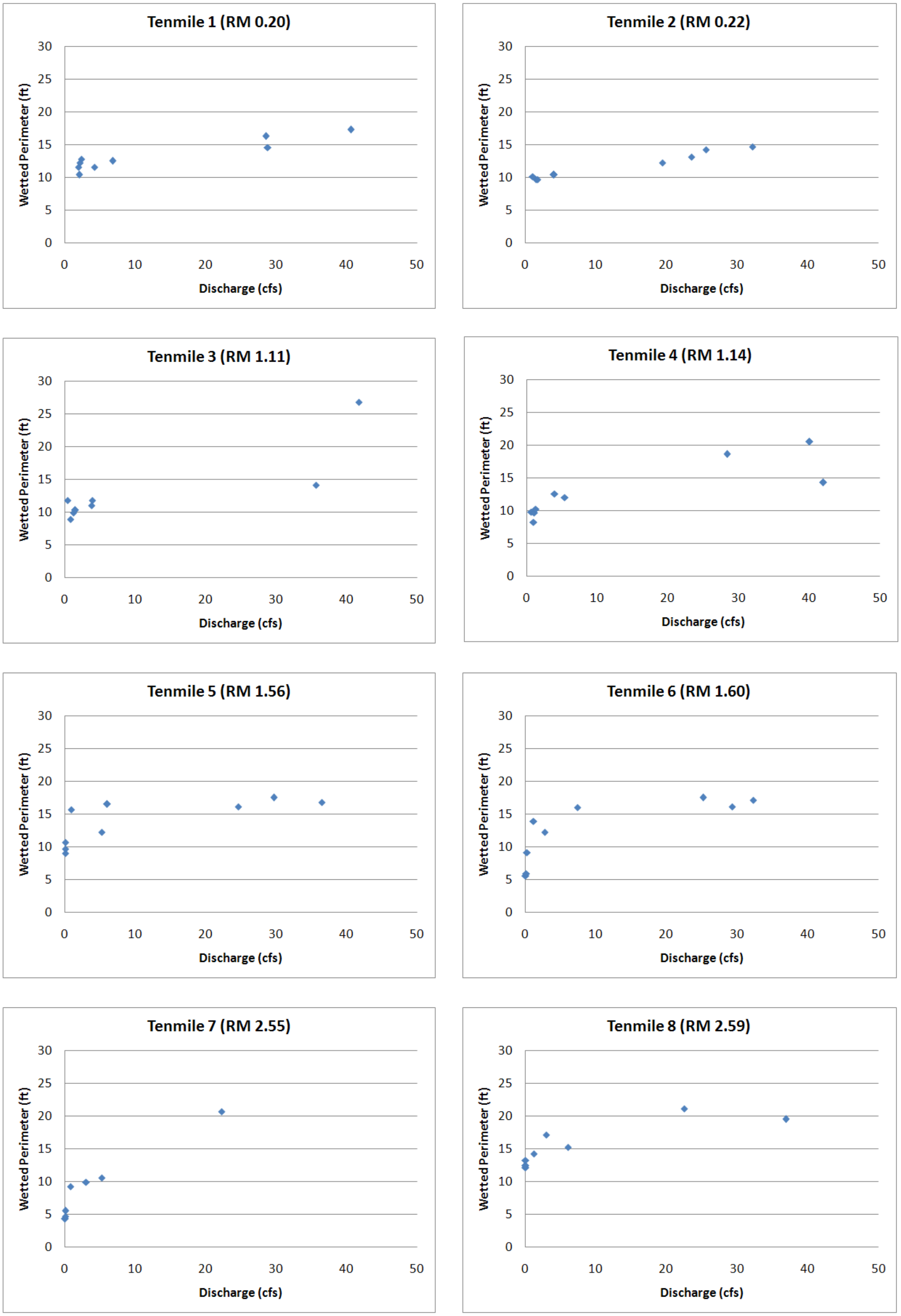


Figure E.8. Wetted perimeter versus discharge plots for Tenmile Creek.

Appendix F. Toe-Width Measurements for Study Sites

Table F.1. Toe-width measurements recorded for the study streams. The values taken in June 2009 tended to be under higher water levels, which increased uncertainty compared to Fall 2008 values. Fall 2008 values were used for instream flow calculations.

Almota

Site	9/15/2008	6/9/2009
1	5.9	--
2	--	6.5
3	5.2	5.4

Little Almota

Site	9/15/2008	6/9/2009
1	4.2	2.8
2	4.2	4.9
3	5.0	4.8

Alpowa

Site	9/15/2008	6/8/2009
1	11.1	11.3
2	7.4	--
3	9.5	--
4	8.4	10.2
5	11.3	10.9
6	9.3	8.3
7	8.1	9.3
8	6.2	--

Couse

Site	8/23/2008	6/12/2009
1	6.0	4.0
2	9.9	11.6
3	14.5	15.9
4	7.3	6.6
5	8.1	5.0
6	3.3	3.2
7	4.5	2.7

Deadman

Site	9/17/2008	6/9/2009
1	5.6	5.9
2	2.2	5.8
3	4.1	4.3
4	4.5	4.0
5	6.8	4.3
6	5.5	3.9
7	4.8	3.0
8	9.4	5.4

Pataha

Site	10/7/2008	6/8/2009
1	1.6	14.5
2	1.4	9.2
3	9.4	10.9
4	7.7	--
5	8.8	8.7
6	5.8	11.4

George

Site	9/5/2008	6/10/2009
1	20.8	12.1
2	14.8	8.5
3	17.5	16.8
4	14.1	14
5	19.6	21.4
6	13	13.1
7	8.2	6.5
8	14.2	--

Tenmile

Site	8/28/2008	6/10/2009
1	6.6	8.6
2	9.0	--
3	10.3	5.6
4	9.0	3.5
5	8.1	5.5
6	3.8	9.5
7	4.7	4.1
8	13.4	3.8

Joseph

Site	11/6/2008	6/11/2009
1	14.0	48.8
2	14.0	36.5
3	43.0	--
4	22.0	--
5	--	32.1

Cottonwood

Site	8/28/2008	6/10/2009
1	7.0	18.7
2	3.7	10.5

Appendix G. Fish Habitat and Water Quality Data for Study Sites

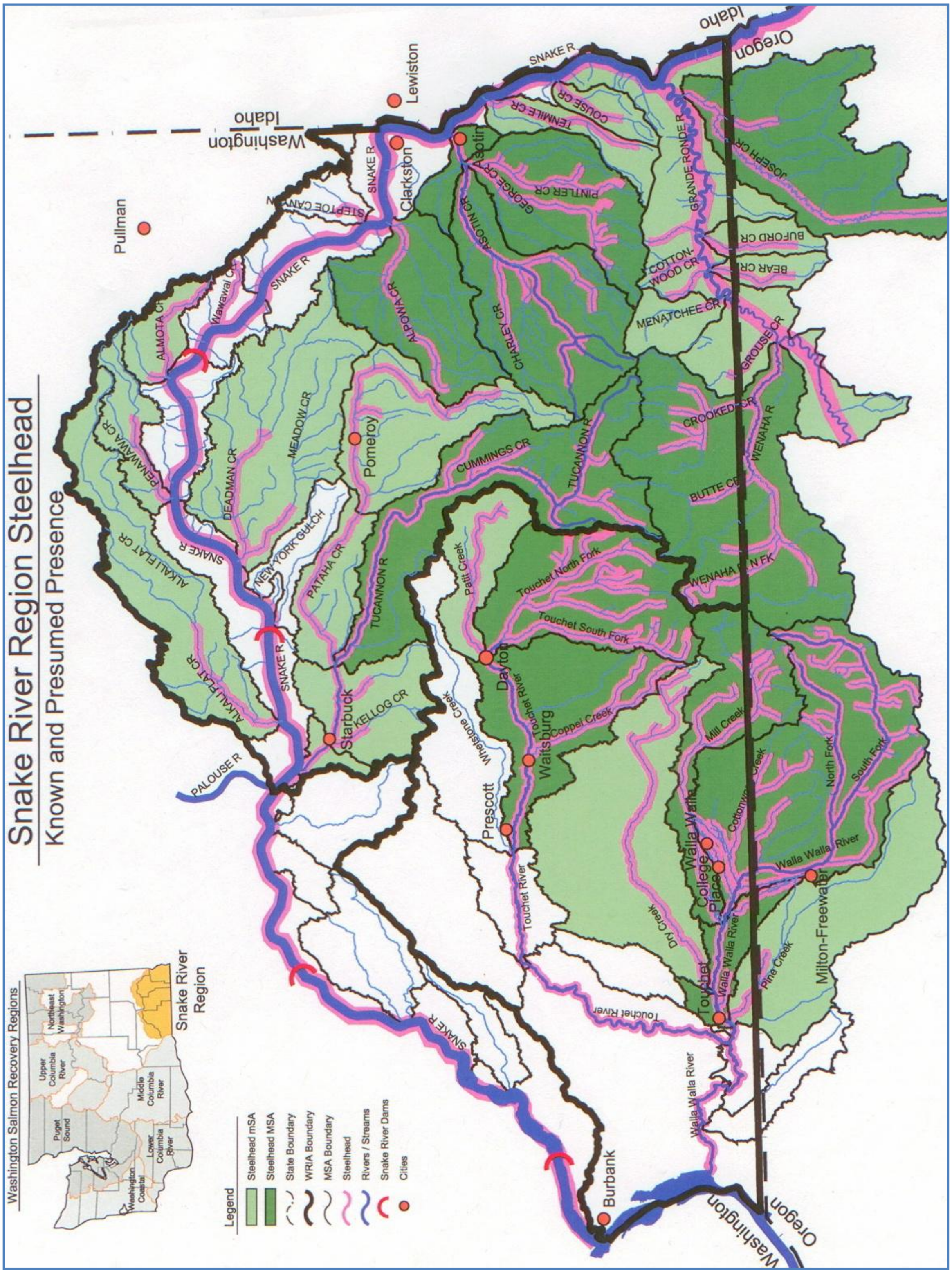


Figure G.1. Map of known and presumed presence of steelhead in WRIA 35.

Table G.1. Steelhead redd and fish survey data for Almota Creek (WDFW).

ALMOTA CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
4/24/2001	R.M. 4.7 to 1.0	3.7	8	2.2	5	0
4/24/2001	R.M. 1.0 to 0.1	0.9	15	16.7	3	1
4/24/2001	R.M. 0.1 to 0.0	0.1	2	20.0	1	0
	2001 Total:	4.7	25	5.3	9	1
5/8/2002	R.M. 5.7 to 4.7	1.0	1	1.0	0	2
5/8/2002	R.M. 4.7 to 1.0	3.7	9	2.4	0	10
5/8/2002	R.M. 1.0 to 0.1	0.9	4	4.4	1	3
	2002 Total:	5.6	14	2.5	1	15

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) for respective age/size classes 0+	1+	>8in	Total
9/27/2001	7.4	35	3.0	106.4	0.0	20.7	7.5	28.2
9/18/2001	2.8	50	2.8	142.0	43.7	3.5	0.7	47.9
9/18/2001	2.2	30	2.3	69.6	38.8	10	1.4	50.2
9/18/2001	1.7	30	2.6	78.0	12.8	3.8	0.0	16.6
9/18/2001	1.4	35	2.2	78.4	8.9	5.1	0.0	14.0
9/18/2001	0.4	30	2.5	75.6	15.9	7.9	0.0	23.8

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
9/27/2001	7.7	30	N/A	N/A	--	Five age 1+, three adults
9/18/2001	0.2	30	3.0	90	--	Three age 0+, six age 1+

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
8/14/2002	8.0	30	1.3	39	--	No salmonids found
8/14/2002	6.9	30	1.6	48	--	No fish found
8/14/2002	6.5	30	2.2	66	--	No fish found
8/14/2002	6.2	30	1.4	42	--	Three age 0+, Four age 1+

LITTLE ALMOTA CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
4/24/2001	R.M. 5.2 to 1.4	3.8	0	0	0	0
	R.M. 1.4 to 0.0	1.4	0	0	0	0
	2001 Total:	5.2	0	0.0	0	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
9/18/2001	1.4	30	1.9	57.0	--	No fish found
9/17/2001	0.1	100	2	200.0	--	Two age 0+

Source: Mendel et al. (2004)

Table G.2. Steelhead redd and fish survey data for Alpowa Creek (WDFW).

ALPOWA CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
2/16/2006	R.M. 13.1 to 10.4	2.7	0	0.0	0	0
2/16/2006	R.M. 10.4 to 7.6	2.8	0	0.0	0	0
2/16/2006	R.M. 6.6 to 3.4	3.2	1	0.3	0	0
2/16/2006	R.M. 3.4 to 1.0	2.4	3	1.3	0	0
3/9/2006	R.M. 13.1 to 10.4	2.7	0	0.0	0	0
3/9/2006	R.M. 10.4 to 7.6	2.8	1	0.4	0	0
3/9/2006	R.M. 6.6 to 3.4	3.2	2	0.6	0	0
3/9/2006	R.M. 3.4 to 1.0	2.4	12	5.0	0	0
4/27/2006	R.M. 13.1 to 10.4	2.7	0	0.0	0	0
4/27/2006	R.M. 10.4 to 7.6	2.8	2	0.7	0	0
4/27/2006	R.M. 6.6 to 3.4	3.2	3	0.9	1	1
4/27/2006	R.M. 3.4 to 1.0	2.4	0	0.0	0	0
5/10/2006	R.M. 13.1 to 10.4	2.7	0	0.0	0	0
5/10/2006	R.M. 10.4 to 7.6	2.8	0	0.0	0	0
5/10/2006	R.M. 6.6 to 3.4	3.2	1	0.3	0	0
5/10/2006	R.M. 3.4 to 1.0	2.4	0	0.0	0	1
	2006 Total:		25	2.3	1	2
3/29/2007	R.M. 10.4 to 7.6	2.8	6	2.1	4	0
3/29/2007	R.M. 6.6 to 3.4	3.2	8	2.5	8	1
3/29/2007	R.M. 3.4 to 1.0	2.4	17	7.1	10	2
4/13/2007	R.M. 10.4 to 7.6	2.8	3	1.1	2	0
4/13/2007	R.M. 6.6 to 3.4	3.2	0	0.0	2	2
4/13/2007	R.M. 3.4 to 1.0	2.4	0	0	0	0
	2007 Total:	8.4	34	4.0	26	5

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) for respective age/size classes 0+	1+	>8in	Total
7/18/2007	10.5	30.0	3.5	106.2	16.0	11.3	0.0	27.3
7/18/2007	8.3	34.0	3.2	110.2	29.9	16.3	0.0	46.2
7/18/2007	6.7	42.0	4.3	178.9	42.5	7.3	0.0	49.8
7/19/2007	3.5	30.0	3.6	109.2	48.5	11.0	0.0	59.5
7/19/2007	2.5	50.5	5.0	250.5	45.1	4.8	0.0	49.9
7/19/2007	1.3	30.0	4.6	138.6	43.3	3.6	0.0	46.9

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
7/18/2007	5.2	43	4	171.1	--	27 age 0+, 16 age 1+

WDFW estimates of adult steelhead (K. Mayer, personal communication)

2008	170 adult steelhead
2009	410 adult steelhead

Wild Chinook Salmon fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Wild Chinook densities (#/100 m^2) for 0+	1+	>8in	Total
7/19/2007	3.5	30.0	3.6	109.2	1.8	0.0	0.0	1.8
7/19/2007	2.5	50.5	5.0	250.5	0.8	0.0	0.0	0.8

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Salmon/100 m^2	Abundance by year class
7/18/2007	5.2	43	4	171.1	--	Four age 0+

Source: Mendel et al. (2008)

Table G.3. Steelhead redd and fish survey data for Couse Creek (WDFW).

COUSE CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/3/2000	R.M. 5.5 to 3.2	2.3	2	0.9	0	0
4/12/2000	R.M. 3.2 to 2.6	0.8	1	1.3	0	0
4/12/2000	R.M. 2.6 to 1.6	1.0	0	0.0	0	0
4/12/2000	R.M. 1.6 to 0.9	0.7	1	1.4	1	0
4/12/2000	R.M. 0.9 to 0.1	0.8	2	2.5	0	0
	2000 Total:	5.6	6	1.1	1	0
4/3/2001	R.M. 5.5 to 3.2	2.3	0	0.0	0	0
4/3/2001	R.M. 3.2 to 1.6	1.6	0	0.0	0	0
4/3/2001	R.M. 1.6 to 0.1	1.5	0	0.0	0	0
4/18/2001	R.M. 3.2 to 1.6	1.6	0	0.0	0	0
4/18/2001	R.M. 1.6 to 0.1	1.5	0	0.0	0	0
	2001 Total:	5.4	0	0.0	0	0
5/2/2002	R.M. 3.2 to 2.8	0.4	2	5.0	0	1
5/2/2002	R.M. 2.8 to 2.1	0.7	1	1.4	0	0
5/2/2002	R.M. 2.1 to 1.0	1.1	0	0.0	0	3
5/2/2002	R.M. 1.0 to 0.1	0.9	0	0.0	1	1
	2002 Total:	3.1	3	1.0	1	5
3/22/2006	R.M. 4.1 to 3.1	1.0	0	0.0	0	0
3/14/2006	R.M. 3.1 to 1.6	1.5	0	0.0	0	0
3/14/2006	R.M. 1.6 to 0.1	1.5	7	4.7	2	0
4/21/2006	R.M. 4.1 to 3.1	1.0	0	0.0	0	0
3/22/2006	R.M. 3.1 to 1.6	1.5	0	0.0	0	0
3/22/2006	R.M. 1.6 to 0.1	1.5	2	1.3	1	0
4/21/2006	R.M. 3.1 to 1.6	1.5	0	0.0	0	0
4/21/2006	R.M. 1.6 to 0.1	1.5	1	0.7	0	0
5/9/2006	R.M. 1.6 to 0.1	1.5	0	0.0	0	0
	2006 Total:	4.0	10	2.5	3	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) for respective age/size classes 0+	1+	>8in	Total
7/26/2000	0.1	31.0	2.5	77.5	31.0	9.0	0.0	40.0

Population estimates for rainbow/steelhead in 2000

Location (R.M.)	Miles	Rainbow/steelhead densities (#/100 m^2) for age/size classes 0+	1+	>8in	Total/ reach
R.M. 1.5 to 0	1.5	1,245	361	-	2,409
				Total:	2,409

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) 0+	1+	>8in	Total
7/31/2006	1.5	30.0	2.9	86.4	64.8	0.0	0.0	64.8
7/31/2006	1.0	30.0	3.0	88.8	121.6	0	1.1	122.7
7/31/2006	0.1	30.0	2.7	79.8	121.6	2.5	0	124.1

Wild Chinook Salmon fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Wild Chinook densities (#/100 m^2) for 0+	1+	>8in	Total
7/31/2006	0.1	30.0	2.7	79.8	5.0	0.0	0.0	5.0

Sources: Mendel et al. (2001), Mendel et al. (2004) and Mendel et al. (2008)

Table G.4. Steelhead redd and fish survey data for Deadman Creek (WDFW).

DEADMAN CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/22/2001	R.M. 9.4 to 8.2	1.2	0	0.0	0	0
5/22/2001	R.M. 6.7 to 4.5	2.2	1	0.5	0	0
4/17/2001	R.M. 4.5 to 2.9	1.6	8	5.0	0	0
5/22/2001	R.M. 4.5 to 2.9	1.6	0	0.0	0	0
5/22/2001	R.M. 2.9 to 1.4	1.5	0	0	0	0
	2001 Total:	6.5	9	1.4	0	0
5/7/2002	R.M. 9.4 to 6.4	3.0	0	0.0	0	1
5/7/2002	R.M. 6.4 to 3.2	3.2	0	0.0	0	0
5/7/2002	R.M. 3.2 to 0.5	2.7	1	0.4	1	10
	2002 Total:	8.9	1	0.1	1	11

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m²)	Rainbow/steelhead densities (#/100 m²) for respective age/size classes 0+	1+	>8in	Total
8/27/2001	0.5	30	2.9	85.8	10.5	3.5	0	14.0

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m²)	Trout/100 m²	Abundance by year class
8/30/2001	9.4	70	3.5	245	--	No salmonids found
8/30/2001	6.8	30	3.9	117	--	No salmonids found
8/27/2001	3.3	30	1.7	51	--	No salmonids found
8/30/2001	1.4	250	N/A	N/A	--	No salmonids found
8/30/2001	1.2	75	3.0	225	--	22 age 0+, two age 1+

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m²)	Trout/100 m²	Abundance by year class
7/30/2002	9.4	70	1.6	112	--	One age 0+
7/30/2002	4.0	65	4.6	299	--	Three age 0+, four age 1+
7/30/2002	1.2	34	3.4	116	--	13 age 0+

NORTH FORK DEADMAN CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/22/2001	R.M. 1.4 to 1.0	0.4	0	0.0	0	0
	2001 Total:	0.4	0	0.0	0	0
5/7/2002	R.M. 4.2 to 1.9	2.3	0	0.0	0	0
	2002 Total:	2.3	0	0.0	0	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m²)	Trout/100 m²	Abundance by year class
7/30/2002	4.2	64	0.8	51	--	No salmonids found
7/30/2002	1.9	72	1.5	108	--	One age 1+
8/30/2001	0.5	60	2.5	150	--	Two age 0+

SOUTH FORK DEADMAN CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/22/2001	R.M. 1.5 to 0.8	0.7	0	0.0	0	0
	2001 Total:	0.7	0	0.0	0	0
5/7/2002	R.M. 3.7 to 1.6	2.1	0	0.0	0	0
	2002 Total:	2.1	0	0.0	0	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m²)	Trout/100 m²	Abundance by year class
9/10/2001	7.9	200	N/A	N/A	--	One adult
8/30/2001	7.3	100	N/A	N/A	--	No salmonids found
9/10/2001	6.7	200	3.5	700	--	No salmonids found
8/6/2002	2.7	60	1.7	102	--	No salmonids found
8/6/2002	1.6	76	1.9	144	--	No salmonids found
8/30/2001	1.2	60	N/A	N/A	--	No salmonids found

Source: Mendel et al. (2004)

Table G.5. Steelhead redd and fish survey data for George Creek (WDFW).

GEORGE CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/2/2000	R.M. 18.5 to 17.4	0.6	0	0.0	0	0
5/2/2000	R.M. 17.4 to 15.1	2.3	1	0.4	0	0
5/8/2000	R.M. 15.1 to 13.0	1.9	2	1.1	1	0
5/8/2000	R.M. 13.0 to 10.0	3.0	10	3.3	0	0
4/27/2000	R.M. 6.0 to 4.2	2.5	3	1.2	2	0
4/27/2000	R.M. 4.0 to 1.5	2.5	5	2.0	5	0
4/26/2000	R.M. 1.5 to 0.0	1.5	0	0.0	0	0
5/8/2000	R.M. 1.5 to 0.0	1.5	0	0.0	0	0
	2000 Total:	15.8	21	1.3	8	3
5/17/2001	R.M. 19.5 to 17.5	2.0	2	1.0	0	0
5/8/2001	R.M. 17.5 to 14.9	2.6	11	4.2	4	0
4/18/2001	R.M. 5.7 to 3.6	2.1	14	6.7	9	0
4/18/2001	R.M. 3.6 to 1.6	2.0	15	7.5	3	2
	2001 Total:	8.7	42	4.8	16	2
5/2/2002	R.M. 19.0 to 15.4	3.6	1	0.3	4	0
	2002 Total:	3.6	1	0.3	4	0
3/18/2005	R.M. 7.2 to 4.3	2.9	0	0	0	0
3/18/2005	R.M. 4.3 to 1.4	2.9	0	0	0	0
4/21/2005	R.M. 1.4 to 0.7	0.7	1	1.4	0	0
4/6/2005	R.M. 7.2 to 4.3	2.9	4	1.4	4	0
4/6/2005	R.M. 4.3 to 1.4	2.9	19	6.6	9	0
4/21/2005	R.M. 7.2 to 4.3	2.9	2	0.7	2	3
4/21/2005	R.M. 4.3 to 1.4	2.9	4	1.4	3	2
	2005 Total:	6.5	30	4.6	18	5
3/8/2006	R.M. 7.4 to 4.4	3.0	0	0	0	0
3/8/2006	R.M. 4.4 to 1.5	2.9	0	0	0	0
3/21/2006	R.M. 1.5 to 0.8	0.7	0	0	0	0
3/21/2006	R.M. 7.4 to 4.4	3.0	10	3.3	1	0
3/21/2006	R.M. 4.4 to 1.5	2.9	2	0.7	0	0
5/4/2006	R.M. 1.5 to 0.8	0.7	0	0	0	0
5/4/2006	R.M. 7.4 to 4.4	3.0	0	0	0	0
5/4/2006	R.M. 4.4 to 1.5	2.9	0	0	2	0
	2006 Total:	6.6	12	1.8	3	0
3/21/2007	R.M. 7.4 to 4.4	3.0	1	0.3	1	0
3/21/2007	R.M. 4.4 to 1.5	2.9	0	0	0	0
3/21/2007	R.M. 1.5 to 0.8	0.7	0	0	0	0
4/4/2007	R.M. 7.4 to 4.4	3.0	4	1.3	0	0
4/4/2007	R.M. 4.4 to 1.5	2.9	1	0.3	0	0
4/4/2007	R.M. 1.5 to 0.8	0.7	0	0	0	0
	2007 Total:	6.6	6	0.9	1	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) for respective age/size classes 0+	1+	>8in	Total
7/25/2000	18.6	36.8	2.5	92.0	6.5	31.5	0.0	38.0
7/25/2000	17.6	33.0	3.3	108.9	16.5	15.6	0.0	32.1
7/25/2000	16.5	35.2	2.7	95.0	14.7	28.4	0.0	43.1
7/25/2000	15.9	45.7	3.0	137.1	8.8	14.6	0.0	23.4
7/25/2000	14.9	25.0	3.0	75.0	33.3	68.0	4.0	105.3
7/26/2000	5.5	52.8	2.9	153.1	20.2	38.5	1.3	60.0
7/26/2000	4.0	61.7	4.2	259.1	61.8	29.7	0.0	91.5

Population estimates for rainbow/steelhead in 2000

Location (R.M.)	Miles	Rainbow/steelhead densities (#/100 m^2) for age/size classes 0+	1+	>8in	Total/ reach
R.M. 18.8 to 16.8	2.0	537	1,099	0	3,272
R.M. 16.8 to 13.2	3.6	886	1,726	61	9,623
R.M. 8.0 to 2.7	5.3	2,375	1,976	38	23,261
				George Creek total:	36,156

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) 0+	1+	>8in	Total
8/27/2002	19.5	30.0	2.5	76.2	21.0	35.4	0.0	56.4

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
8/27/2002	20.9	25	3.8	27.5	--	Two age 0+, seven age 1+
8/27/2002	18.7	26	2.6	67.6	--	Five age 0+,ten age 1+
8/27/2002	7.2	26	2.6	67.6	--	Six age 0+, 17 age 1+

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
6/29/2005	20.9	100	1.8	180	1.1	Two age 1+
6/29/2005	19.5	100	2	200	7	One age 0+, 13 age 1+
6/29/2005	18.7	100	2	200	9	18 age 1+
6/21/2005	7.2	100	3.5	350	15.1	Nine age 0+, 44 age 1+
6/21/2005	5.7	100	3.5	350	20.3	Five age 0+, 66 age 1+
6/21/2005	4.5	100	4.3	430	18.4	21 age 0+, 58 age 1+
6/21/2005	3.9	100	4.6	460	13	24 age 0+, 36 age 1+
6/21/2005	1.8	100	6	600	14.5	58 age 0+, 29 age 1+
6/21/2005	1.2	N/A	N/A	N/A	N/A	One age 0+, six age 1+
7/19/2005	0.7-1.5	805	N/A	N/A	N/A	~2,000-3,000 trout
8/17/2005	0.7-1.5	805	N/A	N/A	N/A	~200 trout

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
7/17/2007	23.3	59	1.8	103.8	2.9	Three age 1+
7/17/2007	22.7	42	1.7	72.2	13.9	10 age 1+
7/17/2007	22.2	56	1.5	81.8	2.4	Two age 1+
7/17/2007	21.6	32	2.3	73.6	4.1	Three age 1+

Sources: Mendel et al. (2001), Mendel et al. (2004), Mendel et al. (2006) and Mendel et al. (2008)

Table G.6. Steelhead redd and fish survey data for Joseph Creek (WDFW).

JOSEPH CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
5/16/2006	R.M. 8.0 to 4.4	3.6	0	0.0	0	1
5/16/2006	R.M. 4.4 to 1.2	3.2	0	0.0	0	0
	2006 Total:	6.8	0	0.0	0	1

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average Width (m	Area (m^2)	Trout/100 m^2	Abundance by year class
8/1/2006	5.0	66.2	8.4	556.1	0	No salmonids found
8/1/2006	3.4	57.6	11.8	679.7	0.3	Two age 1+
8/1/2006	2.6	55	10.1	555.5	0.2	One age 1+
8/1/2006	1.8	68	13.2	897.6	0.1	One age 1+
8/1/2006	1.2	61.2	15.1	924.1	0.1	One age 1+

Source: Mendel et al. (2008)

Table G.7. Steelhead redd and fish survey data for Tenmile Creek (WDFW).

TENMILE CREEK

Steelhead spawning surveys

Date	Stream section	Miles Surveyed	Redds	Redds per mile	Fish observed Live	Fish observed Dead
4/21/2000	R.M. 15.0 to 8.6	6.4	7	1.1	0	3
4/27/2000	R.M. 0.5 to 0.0	0.5	0	0.0	0	0
5/3/2000	R.M. 0.5 to 0.0	0.5	0	0.0	0	0
4/13/2000	R.M. 8.6 to 6.6	2	2	1.0	4	0
4/13/2000	R.M. 6.6 to 1.5	5.1	24	4.7	6	0
4/12/2000	R,M. 1.5 to 1.0	0.5	2	4.0	0	0
4/12/2000	R.M. 1.0 to 0.1	0.9	1	1.1	1	0
	2000 Total:	15.9	36	2.3	11	3
4/3/2001	R.M. 6.1 to 0.1	6.0	9	1.5	7	0
4/23/2001	R.M. 6.1 to 3.7	2.4	16	6.7	0	0
4/23/2001	R.M. 3.7 to 1.3	2.4	4	1.7	5	0
4/23/2001	R.M. 1.3 to 0.7	0.6	0	0.0	2	0
4/23/2001	R.M. 0.7 to 0.1	0.6	0	0.0	0	0
	2001 Total:	6.0	29	4.8	14	0
4/4/2002	R.M. 6.1 to 3.7	2.4	3	1.3	10	0
4/4/2002	R.M. 3.7 to 0.1	3.6	5	1.4	6	0
4/24/2002	R.M. 6.1 to 3.7	2.4	11	4.6	6	1
4/24/2002	R.M. 3.7 to 0.1	3.6	6	1.7	10	1
	2002 Total:	6.0	25	4.2	32	2
3/14/2006	R.M. 7.1 to 3.3	3.8	2	0.5	3	0
3/14/2006	R.M. 3.3 to 1.1	2.2	0	0.0	3	0
3/14/2006	R.M. 1.1 to 0.2	0.9	0	0.0	1	0
4/25/2006	R.M. 7.1 to 3.3	3.8	4	1.1	5	3
4/25/2006	R.M. 3.3 to 1.1	2.2	1	0.5	2	0
5/9/2006	R.M. 7.1 to 3.3	3.8	0	0.0	1	0
5/9/2006	R.M. 3.3 to 1.1	2.2	0	0.0	3	1
	2006 Total:	6.9	7	1.0	18	4
4/2/2007	R.M. 7.1 to 3.3	3.8	4	1.1	0	0
4/2/2007	R.M. 3.3 to 1.1	2.2	5	2.3	0	0
	2007 Total:	6.0	9	1.5	0	0

Rainbow/steelhead trout fish surveys

Date	Location (R.M.)	Site length (m)	Average width (m)	Area (m^2)	Rainbow/steelhead densities (#/100 m^2) for respective age/size classes 0+	1+	>8in	Total
7/27/2000	6.8	58.8	3.9	229.3	25.3	52.8	1.7	79.8
7/27/2000	5.7	30.7	3.0	92.1	43.4	56.5	5.4	105.3
7/27/2000	2.3	30.6	2.5	76.5	52.3	31.4	0	83.7

Population estimates for rainbow/steelhead in 2000

Location (R.M.)	Miles	Rainbow/steelhead densities (#/100 m^2) for age/size classes 0+	1+	>8in	Total/ reach
R.M. 6.0 to 4.0	2.0	1,937	3,081	203	10,442
R.M. 1.9 to 0.0	1.9	2,103	1,263	-	6,395
			Tenmile Creek total:		16,837

Date	Location (R.M.)	Site length (m)	Average Width (m)	Area (m^2)	Trout/100 m^2	Abundance by year class
6/23/2005	14.5	30	0.8	24	4.2	One age 1+
6/23/2005	14.3	100	1.9	190	1.1	Two age 1+
6/23/2005	6.9	100	3.1	310	0.3	One age 1+
6/23/2005	6.5	100	5.0	500	24.4	122 age 1+
6/23/2005	5.8	95	4.4	418	19.4	81 age 1+
6/23/2005	4.6	100	4.3	430	2.1	Nine age 1+
6/29/2005	1.5	100	3.5	350	5.1	18 age 1+
6/29/2005	1.1	100	3.7	370	9.2	34 age 1+

Sources: Mendel et al. (2001), Mendel et al. (2004), Mendel et al. (2006) and Mendel et al. (2008)

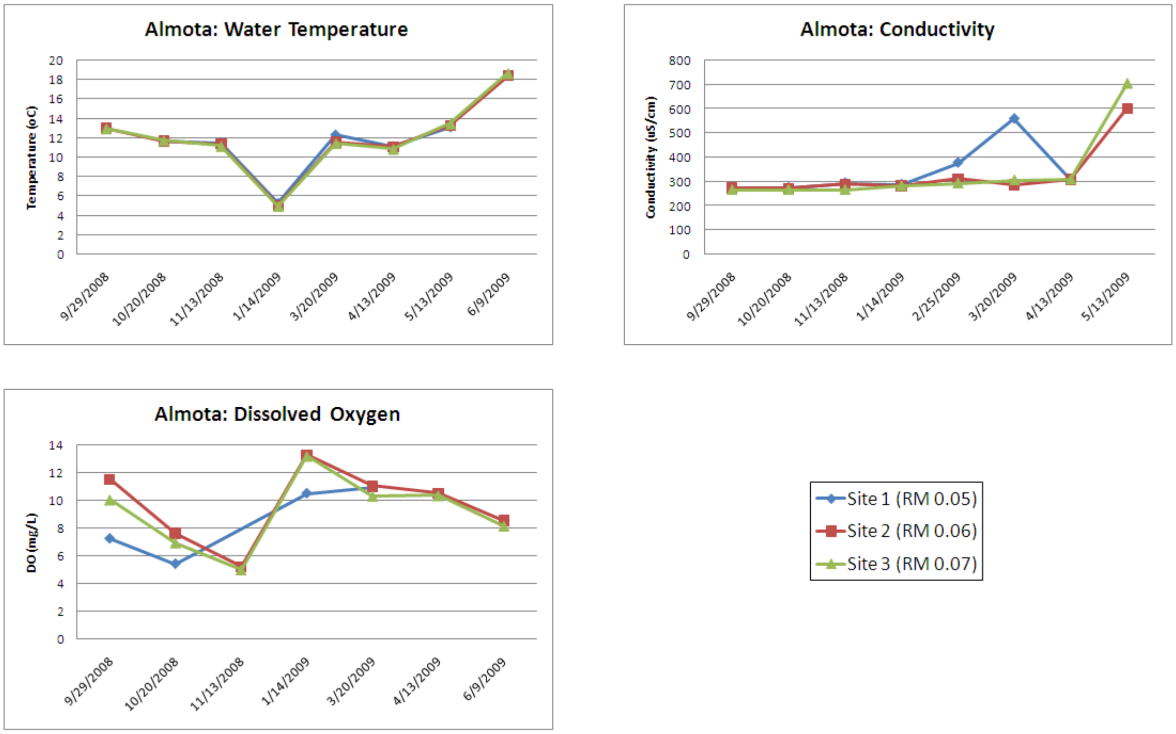


Figure G.2. Water temperature, dissolved oxygen and conductivity data for Almota Creek.

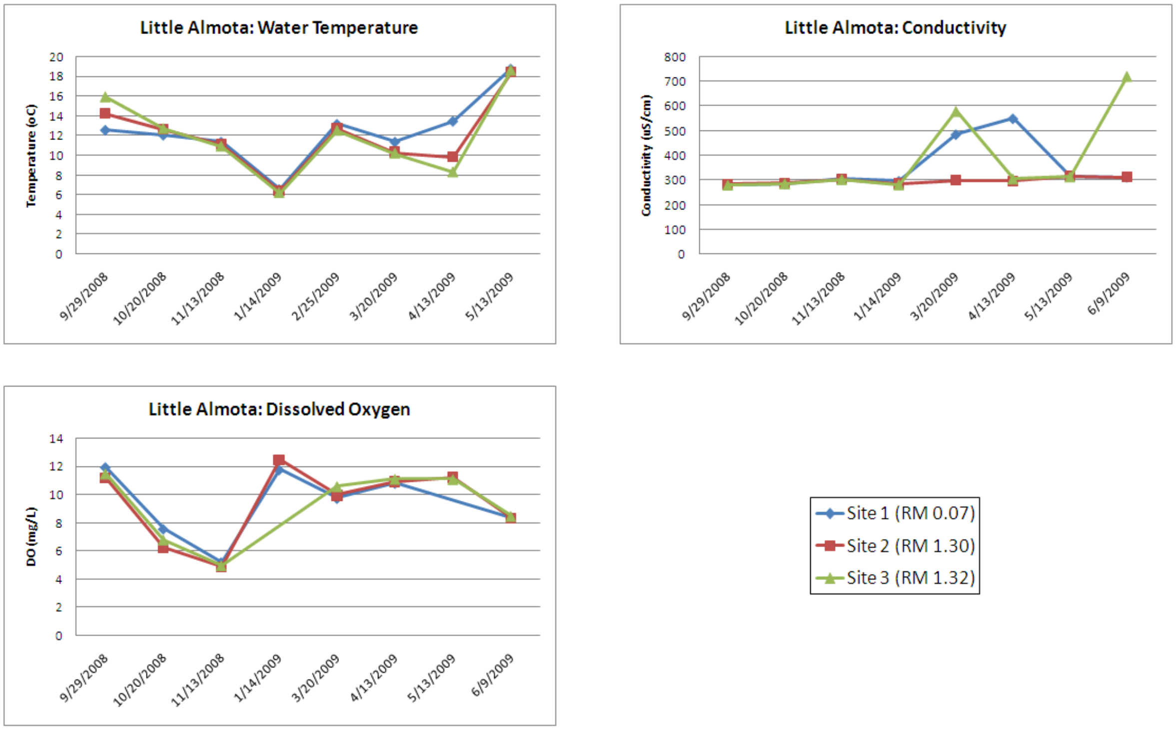


Figure G.3. Water temperature, dissolved oxygen and conductivity data for Little Almota Creek.

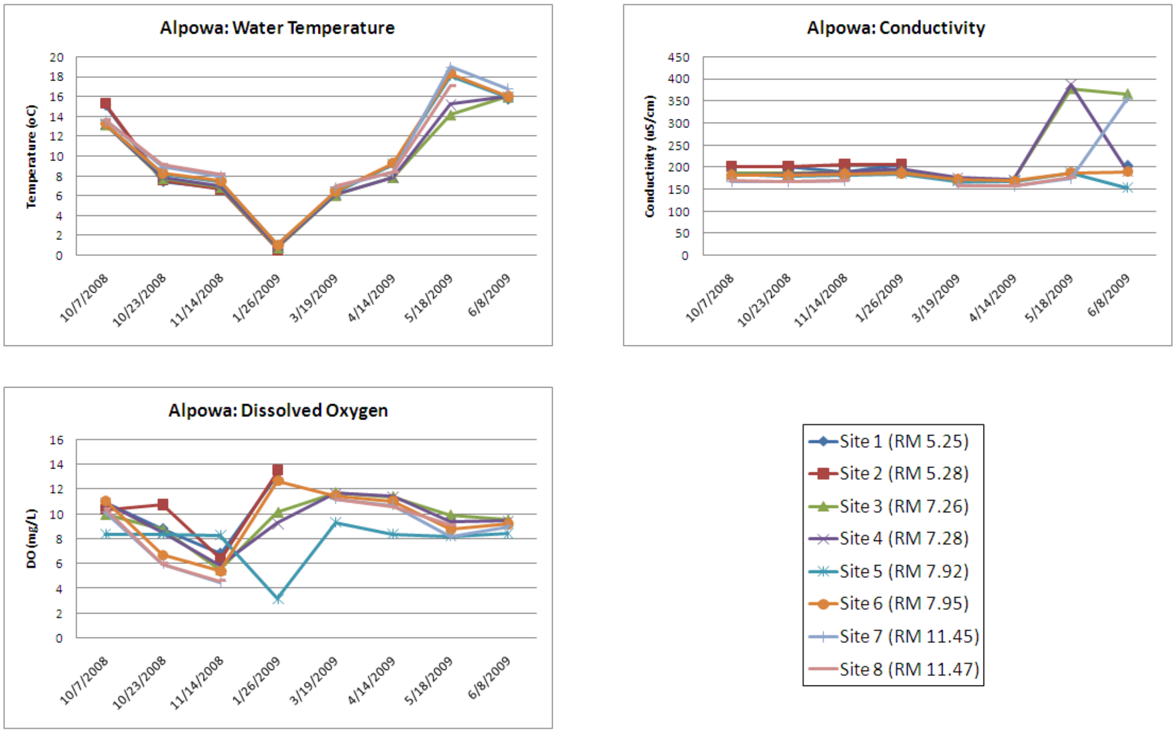


Figure G.4. Water temperature, dissolved oxygen and conductivity data for Alpowa Creek.

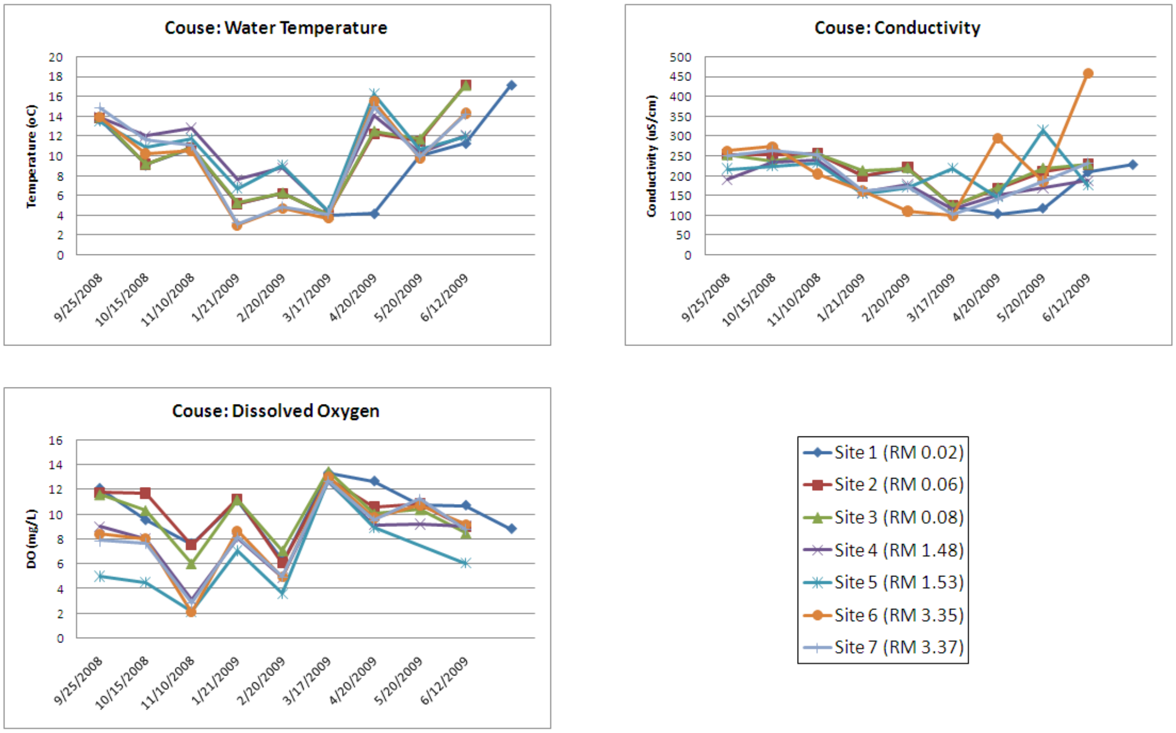


Figure G.5. Water temperature, dissolved oxygen and conductivity data for Couse Creek.

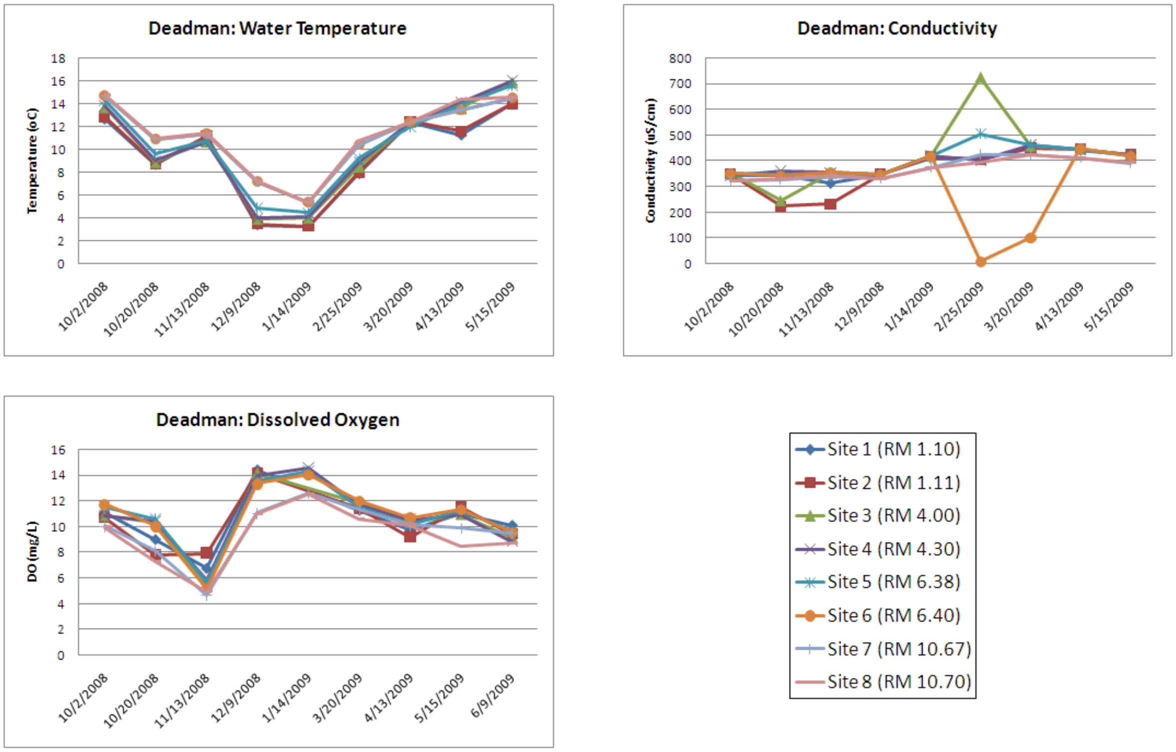


Figure G.6. Water temperature, dissolved oxygen and conductivity data for Deadman Creek.

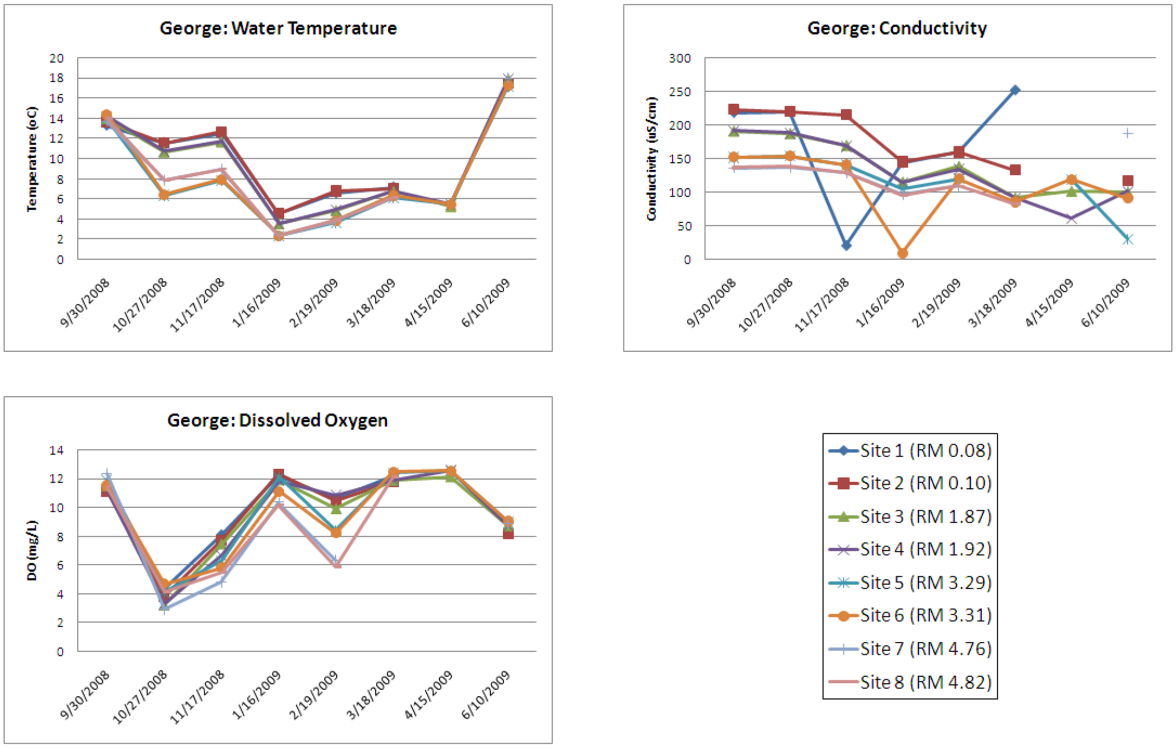


Figure G.7. Water temperature, dissolved oxygen and conductivity data for George Creek.

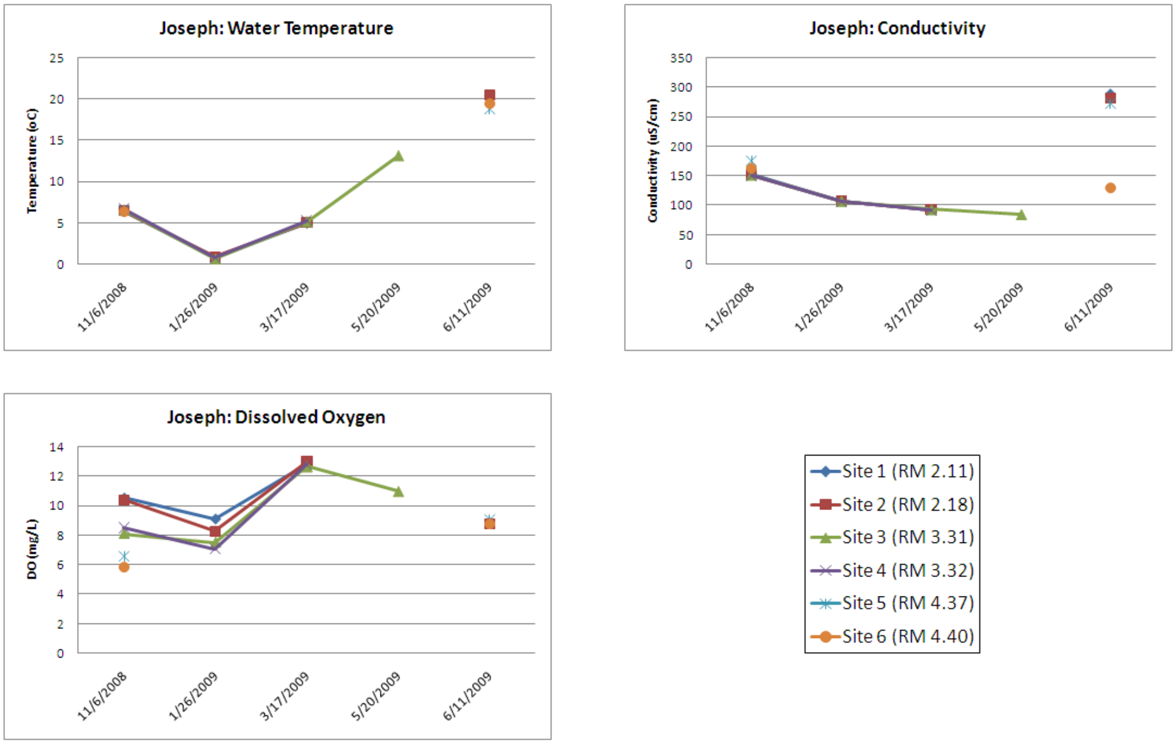


Figure G.8. Water temperature, dissolved oxygen and conductivity data for Joseph Creek.

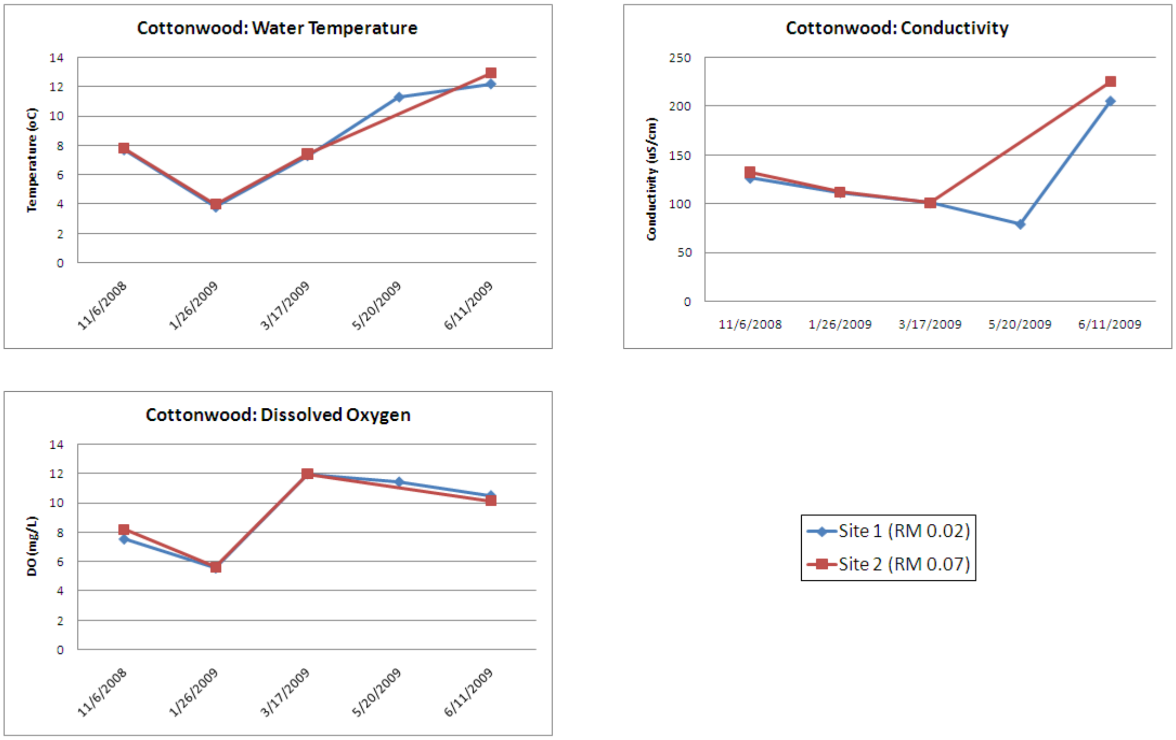


Figure G.9. Water temperature, dissolved oxygen and conductivity data for Cottonwood Creek.

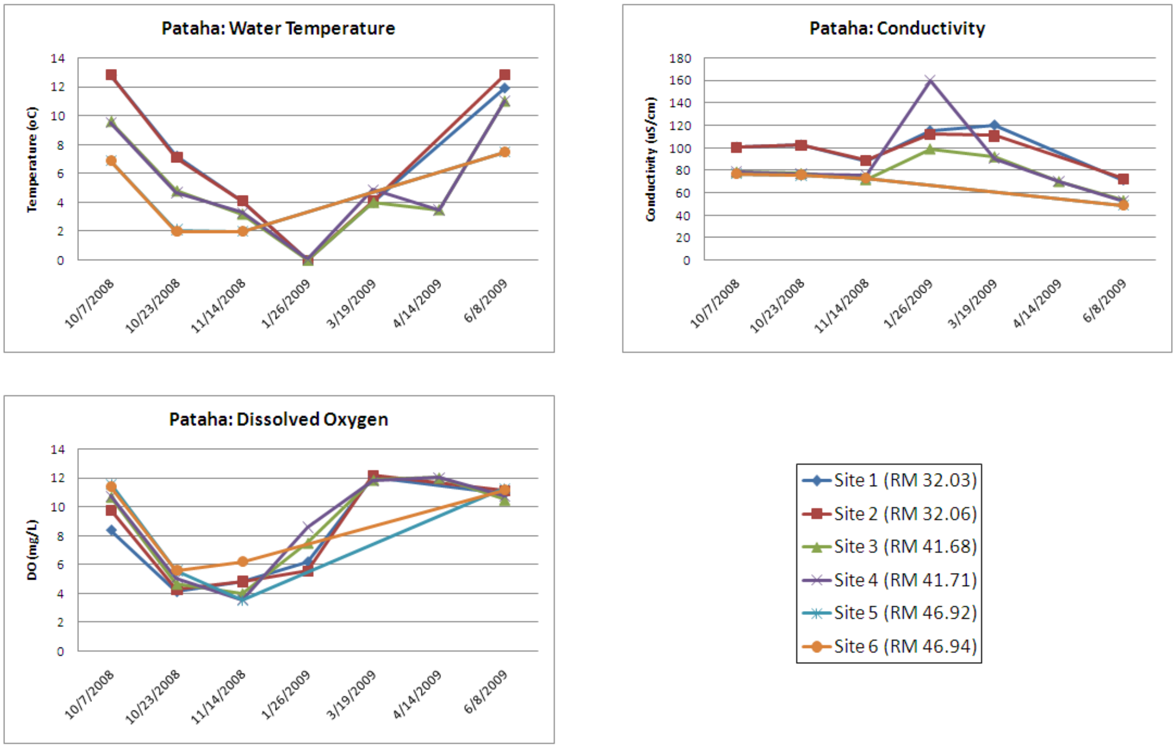


Figure G.10. Water temperature, dissolved oxygen and conductivity data for Pataha Creek.

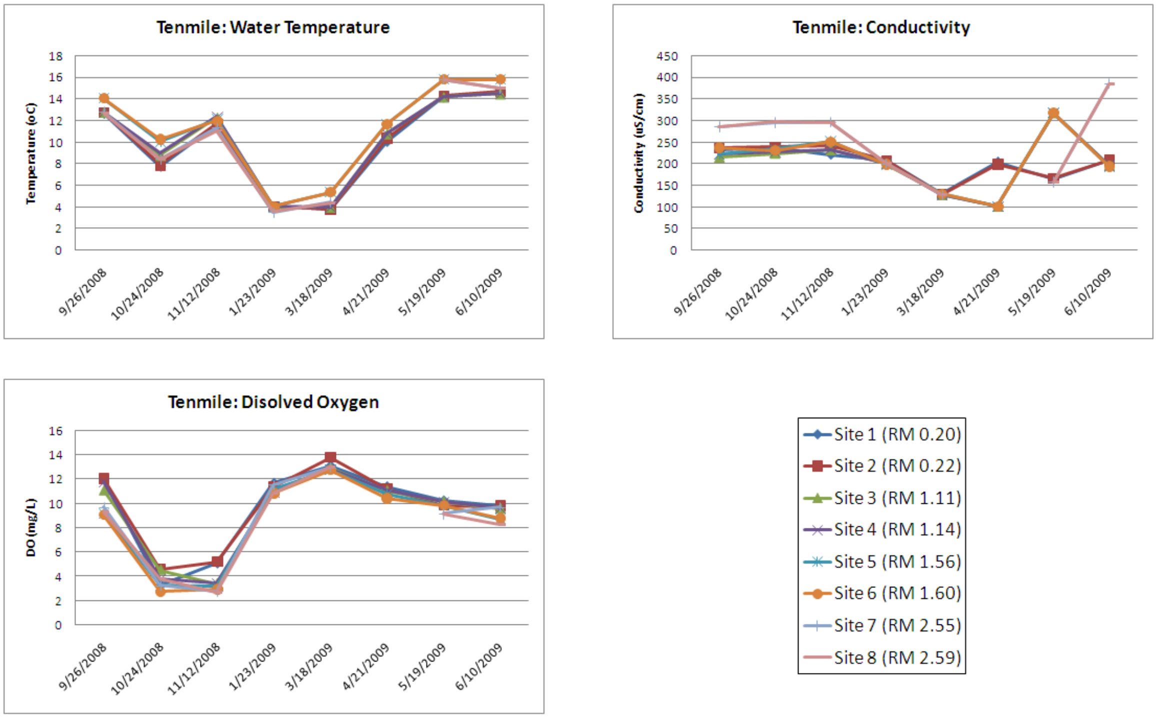


Figure G.11. Water temperature, dissolved oxygen and conductivity data for Tenmile Creek.