RECLAMATION

Managing Water in the West

Flow Characterization Study

Instream Flow Assessment Upper Lemhi River and Canyon Creek, Idaho

July 2006

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Flow Characterization Study

Instream Flow Assessment Upper Lemhi River and Canyon Creek, Idaho

Prepared for:

U.S. Department of the Interior
Bureau of Reclamation
Snake River Area Office
Boise, Idaho

by:

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July 2006

This report is dedicated to the advancement of scientific understanding for protecting and sustaining our natural resources in the memory of Janna Brimmer (1970-2006) and Jan Latham (1954-2006). You are greatly missed.

July 2006

Abbreviations

BIA	Bureau of Indian Affairs
BiOp	Biological Opinion
BLM	Bureau of Land Management
DPS	Distinct Population Segment
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCRPS	Federal Columbia River Power System
FWS	Fish and Wildlife Service
GPS	Global Positioning System
HABTAE	Habitat program option in PHABSIM for Windows
HC	Hydraulic control
HSC	Habitat Suitability Criteria
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
MANSQ	Mannings equation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PHABSIM	Physical Habitat Simulation System
Q	Discharge (flow)
Q.20	Daily mean discharge exceeded 20 percent of the time during a specified month
Q.50	Daily mean discharge exceeded 50 percent of the time during a specified month (same as median discharge)
Q.80	Daily mean discharge exceeded 80 percent of the time during a specified month
Reclamation	Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
SI	Suitability index
STGQ	Stage-discharge relation
TMDL	Total Maximum Daily Limit
TSC	Technical Service Center
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VAF	Velocity adjustment factor
WSL	Water surface elevation
WSP	Water surface profile
WUA	Weighted usable area

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Summary

The Bureau of Reclamation conducted flow characterization and habitat studies on the Upper Lemhi River and Canyon Creek, located in the Lemhi River sub-basin in Idaho, to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), spring Chinook salmon (*O. tschawytscha*), and bull trout (*Salvelinus confluentus*). Average snowpack level in the Salmon River Basin on April 1, 2005 was 78 percent, compared to 62 percent of the average snowpack in 2004. The Upper Lemhi River and Canyon Creek flows were continuously recorded using a stage recorder during the 2005 irrigation season. The Upper Lemhi River gaged flows ranged from 26 cfs on June 9 to 7 cfs on August 27. Unimpaired Canyon Creek flows ranged from 4 cfs on April 12 to 20 cfs on June 18 at the gage. Water temperatures were also monitored in 2005. Reclamation characterized flow needs for various life stages of the selected species using the Physical Habitat Simulation (PHABSIM) model at each study site. To address food resources of salmonids, streamflow needs for aquatic macroinvertebrates were assessed. Data were collected at a total of 10 study sites: five each on the Upper Lemhi River and Canyon Creek. Study sites were selected in accessible areas to represent mesohabitat types within each stream reach distinguished by unique hydrology, channel morphology, slope, or land use characteristics. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference sites. In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, these conditions typically occur during the summer irrigation season with the diversions. Habitat modeling results reflected differences in stream channel hydraulics among study sites.

1.0 INTRODUCTION

The National Marine Fisheries Service (NMFS) (currently National Oceanic Atmospheric Administration (NOAA) Fisheries) issued a Biological Opinion (BiOp) in December 2000 on continued operation and configuration of the Federal Columbia River Power System (FCRPS) (NMFS 2000). Unless actions identified in the Reasonable and Prudent Alternative (RPA) of the BiOp are taken, a jeopardy opinion may be issued for continued operation of the FCRPS. As part of the RPA, NMFS identified the need to improve migration, spawning, and rearing habitat in priority subbasins as part of an off-site mitigation program. In part to address that need, RPA Action 149 of the BiOp requires that the Bureau of Reclamation (Reclamation) "shall initiate programs in three priority sub-basins (identified in the Basinwide Recovery Strategy) per year over 5 years, in coordination with NMFS, Fish and Wildlife Service (FWS), the states and others, to address all flow, passage, and screening problems in each sub-basin over ten years." Thus, the objective of Action 149 is to restore flows needed to avoid jeopardy to listed species, screen all diversions, and resolve all passage obstructions within 10 years of initiating work in each sub-basin. Reclamation is the lead agency for these initiatives and will facilitate their implementation.

The 2000 BiOp identified priority sub-basins where addressing flow, passage, and screening problems could produce short term benefits. In addition to six other Columbia River sub-basins in Oregon and Washington, Reclamation committed to work in three Salmon River sub-basins in Idaho, including the Lemhi River sub-basin and the "Upper Salmon River sub-basin", which is defined through the BiOp as the Salmon River basin upstream from the confluence of the Pahsimeroi and Salmon Rivers, but excludes the Pahsimeroi River basin.

On November 30, 2004, NOAA Fisheries issued a new BiOp for the FCRPS in response to a court order in June of 2003. Action 149 objectives are restated in terms of specific metric goals in selected subbasins for entrainment (screens), stream flow, and channel morphology (passage and complexity) in the 2004 BiOp. The work described in this report addresses Reclamation obligations to improve stream flow in selected subbasins under both the 2000 and 2004 BiOps.

To support this work, Action 149 stated that NMFS would supply Reclamation with "passage and screening criteria and one or more methodologies for determining instream flows that will satisfy Endangered Species Act (ESA) requirement." One of the methodologies recommended in NOAA Fisheries protocol for estimating tributary streamflow to protect salmon listed under the ESA was the Physical Habitat Simulation System (PHABSIM) (Arthaud et al. 2001). The only other method suggested was the hydrology-based Tennant method (Arthaud et al. 2001). However, PHABSIM was considered a more appropriate methodology since it considers the biological requirements of the fish. The NOAA Fisheries draft protocol describes methods to estimate annual flow regimes and minimum flow conditions necessary to protect sensitive salmonid life stages using PHABSIM results for Pacific and interior northwest streams (Arthaud et al. 2001).

PHABSIM predicts changes in relationships between instream flows and fish habitat for individual species and life stages. PHABSIM is best used for decision-making when alternative flows are being evaluated (Bovee et al. 1998). Stream flow and habitat data are used in a group of computer models called PHABSIM. Hydraulic models are used to calculate water surface elevations and depths and to simulate velocities for specific discharges. Depth, velocity, substrate material, and cover data are used to determine available habitat. The model outputs proportions of suitable and unsuitable reaches of the stream and shows how often a specified quantity of suitable habitat is available. This methodology is scientifically tested and is generally an accepted technique for determining flows needed for fish. It is, however, data intensive and it does take time to achieve results. The habitat requirements of a number of species are not known; therefore, application can be limited unless emphasis is placed on developing habitat suitability criteria (HSC) for species of interest. The output of the model, habitat versus flow relationship, must be integrated with species life history knowledge.

Priority streams have been identified in the Lemhi River sub-basin based on inventory and assessment needs. Reclamation's objective in 2005 was to conduct habitat studies on the Upper Lemhi River and Canyon Creek to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), spring/summer Chinook salmon (*O. tschawytscha*), and bull trout (*Salvelinus confluentus*). Previous similar studies conducted by Reclamation (Sutton and Morris 2004; 2005) and U.S. Geological Survey (USGS) (Maret et al. 2004; 2005) are available at the following web site: http://id.water.usgs.gov/projects/salmon_streamflow/index.html. Information obtained from these studies can be used by the public, State, and Federal agencies to direct management actions addressing stream flow needs of ESA-listed anadromous and resident native fish. Study results can be used to help determine target flow objectives to improve passage, spawning, and adult holding conditions for salmon, steelhead, and bull trout.

1.1 Background

Rivers and streams in the Lemhi River sub-basin historically provided significant spawning and rearing habitat for anadromous spring/summer Chinook salmon, sockeye salmon, and steelhead trout. However, anadromous fish populations have plummeted in the last 100 years and led in the 1990s to listing of these salmon and steelhead stocks as threatened under the ESA. Wild salmon and steelhead continue to migrate into the area and depend on spawning and rearing habitat in the basin. Bull trout also inhabit many of these rivers and streams. However, human development has modified the original flow and habitat conditions thereby affecting migration and/or access to suitable spawning and rearing habitat for all of these fish.

Many Federal, State, Tribal, local, and private parties work together to protect and restore ESA- listed anadromous and native fish species in the basin. One part of this work involves providing enough stream flow for these fish. Although sufficient stream flows are essential for fish to thrive, flows in the basin are also used for agricultural, domestic, commercial, municipal, industrial, recreational and other purposes. There is considerable information available that can be used to identify the amount of stream flow needed and used by people; however, there is little information about how much stream flow is needed to support various life history stages of ESA-listed fish. A reliable identification of stream flow needs for these fish will provide a basis that the public and Federal, State, Tribal, and local parties can use to determine how to make the available water supply meet both the needs of ESA-listed fish and the needs of the people who live in these areas.

Some river reaches are more vulnerable than others to limitations in available stream flow. Fishery biologists with the Idaho Department of Fish and Game (IDFG), Bureau of Land Management (BLM), U.S. Forest Service (USFS), and Shoshone-Bannock Tribes compiled professional biological recommendations and known anadromous and resident fish population densities and Chinook redd counts (Upper Salmon Basin Watershed Project Technical Team 2005). They used this information to prioritize 11 sub-basins and to develop a list of 30 river reaches in the basin for immediate inventory and assessment for mitigation efforts (http://www.modelwatershed.org/Library.html). The geographic area covered in their report included the entire Upper Salmon River Basin upstream from the confluence of the Middle Fork and main stem of the Salmon River.

1.2 Species of Interest

Federal ESA listed species addressed in this section include the anadromous Snake River spring/summer Chinook salmon ESU; Snake River steelhead ESU; and resident Columbia River Basin bull trout DPS.

1.2.1 Steelhead

The Snake River Basin Ecologically Significant Unit (ESU) of steelhead trout was listed as threatened under ESA on August 18, 1997 (Federal Register, Vol. 62 , No. 159). Critical habitat for this ESU was designated February 16, 2000 (Federal Register, Vol. 65, No. 32), and includes all accessible portions of the project area. This critical habitat designation has been withdrawn and is currently being reviewed by NOAA Fisheries, pursuant to a consent decree on April 30, 2002 (NMFS 2002).

The Lemhi River Sub-basin summer steelhead are classified as A-run steelhead (early migrators and spawners). Specific data on spawning populations of steelhead within Lemhi River sub-basin are very limited. These fish arise from stocks that were introduced by IDFG but are now considered natural populations. Periodicity for steelhead in the Lemhi River Sub-basin is summarized in Table 1.

Table 1. Periodicity chart for steelhead in Lemhi River Sub-basin (EA Engineering 1991a).

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult			■	■	■	■						
Spawning				■	■	■						
Incubation				■	■	■	■	■				
Fry					■	■	■	■	■	■		
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Outmigrate		■	■	■	■	■						

Steelhead migrate inland towards spawning areas, overwinter in larger rivers, resume migration to natal streams in early spring, and then spawn (Nickelson et al.1992). Steelhead are widely distributed throughout the sub-basin, and juveniles are present year-round. The lower 27 miles of the mainstem Lemhi River from the mouth to Agency Creek serve mainly as a migration corridor. The 11-mile reach between Agency and Hayden Creeks provides rearing and limited spawning habitat. Tributary streams also provide spawning habitat.

Irrigation, grazing, and road construction have affected habitat conditions throughout the Lemhi Sub-basin (NPPC 2001). Limiting factors on the mainstem Lemhi River can be grouped based on three distinct river segments, each having its own limiting factors. The lower 27-mile mainstem reach is degraded because of the lack of riparian vegetation and lack of pools for rearing and adult holding. The next segment, an 11-mile reach between Agency and Hayden Creeks, provides habitat, but riparian degradation has led to elevated water temperatures and unstable banks. The third mainstem segment, 28 miles from Hayden Creek to Leadore, has fluctuating summer temperatures, unstabilized banks, and few high quality pools. Salmonid habitat threats in the tributary streams include bank erosion leading to sedimentation, elevated temperatures, and degraded riparian habitat. Irrigation withdrawals have resulted in dewatered lower reaches in most tributaries. Water does not flow into the Lemhi River from many of the tributaries except during spring runoff, substantially reducing downstream migrations of fish and creating migration barriers. Most irrigation diversions on lower reaches of tributaries are not screened to protect migrating fish.

1.2.2 Spring/Summer Chinook Salmon

Spring/summer Chinook salmon are Federally listed as threatened under the ESA and by the State of Idaho. Chinook salmon are part of the federally threatened Snake River Chinook "Spring/Summer Run" ESU (Federal Register Vol. 57, No. 78, April 22, 1992) in the Lemhi River sub-basin. Designated critical habitat for this ESU occurs in the Lemhi hydrologic unit (Federal Register Vol. 64, No. 205, October 25, 1999).

The two "races" of spring/summer Chinook salmon in the Salmon River are classified by the season of adult passage at Bonneville Dam on the Columbia River during upstream migration. Spring/summer Chinook enter the Columbia River March through July.

Chinook that pass over Bonneville Dam from March 1 to May 31 are considered "spring Chinook" and those that pass from June 1 to July 31 are considered "summer Chinook." Spring Chinook are the most prevalent and are found within the upper drainages of the Salmon basin. Summer Chinook are more limited in their distribution, being found in mainstem reaches of the upper Salmon basin (R2 Resource Consultants 2004). Spawning occurs in August through October. Eggs hatch in April and May, and the fry emerge approximately one month later. Juveniles rear for one year before out-migrating to the ocean (Simpson and Wallace 1982). Periodicity for Chinook salmon in the Lemhi River Sub-basin is summarized in Table 2.

Spring Chinook salmon spawn in the Lemhi River upstream from Hayden Creek. Over 95 percent of the salmon spawning and rearing in this sub-basin takes place in the upper 28 miles of the mainstem between Hayden Creek and Leadore (Bureau of Reclamation 2003). Most spring/summer Chinook salmon enter the sub-basin from May through September. Spawning occurs in late summer and early fall. All spawning is natural, as hatchery releases from Hayden Creek were suspended in 1982 (Bureau of Reclamation 2003). Juveniles reside in rearing areas for approximately 12 months before migrating downstream the following April and May (Bugert et al. 1990; Cannamela 1992). Other threats to Chinook salmon are the same as those discussed for steelhead in the Lemhi Sub-basin.

Table 2. Periodicity chart for Chinook salmon in Lemhi River Sub-basin (EA Engineering 1991a).

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult					X	X	X	X	X	X		
Spawning							X	X	X	X		
Incubation	X	X	X	X	X		X	X	X	X	X	X
Fry			X	X	X	X	X					
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Outmigrate			X	X	X	X						

1.2.3 Bull Trout

Bull trout are listed as threatened under the Federal ESA (Federal Register, Vol. 63, No. 111, June 10 1998) and as a species of concern by the State of Idaho. In 2002, FWS proposed critical habitat for bull trout in the Columbia River basin (Federal Register, Vol. 67, No. 230, November 29, 2002). In 2003, FWS reopened the comment period for the proposal to designate critical habitat for Columbia River Distinct Population Segments (DPS) of bull trout (Federal Register Vol. 68, No. 28, February 11, 2003). Final critical habitat designation by the FWS does not include the Lemhi River Sub-basin (Federal Register, Vol. 69, No. 193, October 6, 2004).

Bull trout in the Lemhi Sub-basin are considered fluvial stock, as they migrate between streams and larger rivers. Bull trout typically spawn in September and October but may begin their spawning migration as early as April. Spawning occurs in clean gravels, with areas of groundwater upwelling preferred. Fry emerge from early April through May. Small juveniles tend to remain in the gravels and cobbles. After reaching 4 inches (10 cm) in length, they move to backwater and sidewater channels, eddies, or pools (Goetz 1989). Periodicity for bull trout in the Lemhi River Sub-basin is summarized in Table 3.

Table 3. Periodicity chart for bull trout in Lemhi River Sub-basin (EA Engineering 1991a).

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult			■	■	■	■	■	■	■	■		
Spawning									■	■		
Incubation	■	■	■	■	■				■	■	■	■
Fry			■	■	■	■	■	■	■	■		
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■

Within the project area, bull trout are widely distributed. They are present year-round. Bull trout are found in Big Eightmile, Big Timber, Eighteen Mile, Geertson, Hauley, Hayden, Kenny, Bohannon, Kirtley, Little Eight Mile, Mill, Pattee, and Texas Creeks; their tributaries; and in the Lemhi River (NPPC 2001).

Other threats to bull trout and their habitat are the same as listed for steelhead in the Lemhi Sub-basin. Of particular concern to fluvial bull trout is dewatering of lower tributary reaches, elevated water temperatures, and un-screened diversion structures that inhibit downstream migration into mainstem waters.

2.0 STUDY REGION

The following definitions apply to the following discussion:
Study area – The study area is defined as one or more stream reaches impacted by flow alteration. Typically, a study area consists of stream reaches that represent small portions of each stream.
Stream segment – The portion of the study area that has a homogeneous stream flow and geomorphology (Bovee 1997). A study area may have one or more hydrologic segments (+/- 10% of the mean monthly flow Q).
Reach (*Study Site*) – A physical aspect of the channel within a stream segment that affects the microhabitat versus flow relationship (e.g., channel morphology, slope, or land use); contains multiple mesohabitat units (riffle, run, pool) within a stream segment.
Mesohabitat – Habitat types delineated by localized slope, channel shape, and structure (e.g., riffles, runs, pools).
Microhabitat – Habitats that represent relatively homogeneous area of about the size utilized by an individual fish (e.g., tree snags, undercut banks, velocity shelters).

Investigations were performed on two separate study regions/areas of the Lemhi SubBasin during the summer and fall of 2005. The study area consisted of five study sites on the Upper Lemhi River and five study sites on Canyon Creek. Field reconnaissance, topographic maps, and interviews with IDFG indicated that these streams could be broken up into distinct hydrologic stream segments, defined as follows:

- Upper Lemhi River: between Big Springs Creek and Canyon Creek and between Canyon Creek and Texas Creek; and
- Canyon Creek: upstream from confluence with the Lemhi River.

Using USGS topographic maps, longitudinal gradient was plotted for each stream (Figures 1-2). Within the different stream segments, several study sites were identified in accessible reaches, distinguished primarily by differences in stream channel morphology and locations of major diversions for each stream. These were distributed sequentially proceeding upstream. Each study site is described below and identified on Figures 1-2.

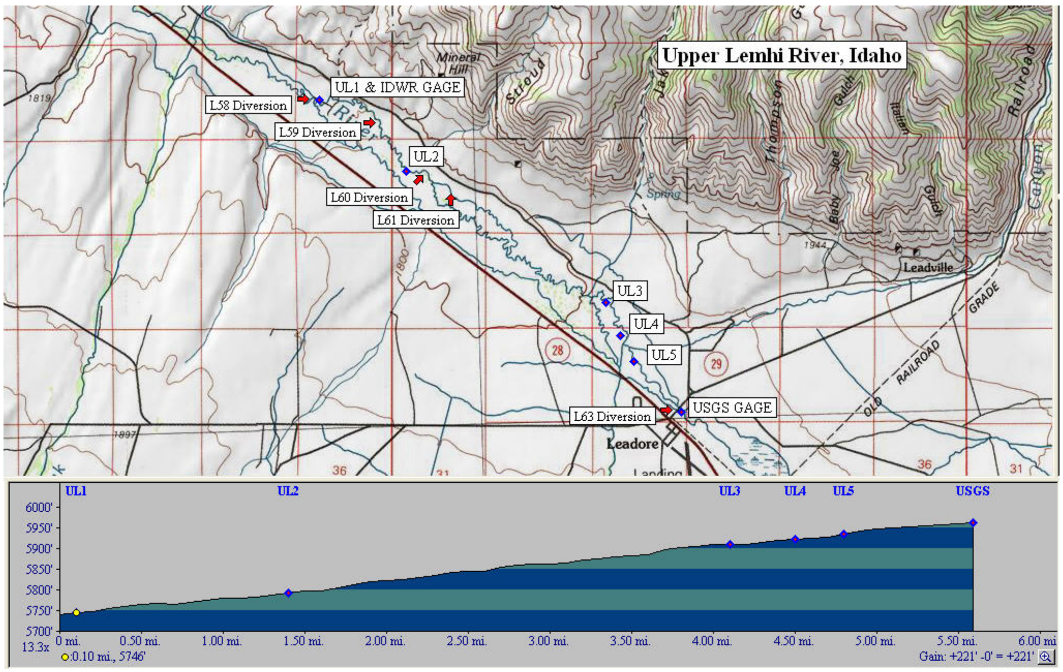

Figure 1. Upper Lemhi River study area for flow characterization study and locations of study sites 1-5.

Upper Lemhi River, Study Site 1: This reach was the most downstream segment in the Upper Lemhi River, located between Big Springs Creek confluence and the L59 diversion. It was characterized mainly by low gradient riffles, glides, and pools.

Upper Lemhi River, Study Site 2: This study site was located on private property, just downstream from a major diversion (L60). It primarily consisted of riffles and glides.

Upper Lemhi River, Study Site 3: This reach was located between diversion L60 and an unnamed tributary (groundwater fed) that defined the upstream and downstream boundaries of reaches 2 and 4, respectively. The study site was located on private property, and was a mixture of riffle, pool, and glide habitat types. Riparian vegetation is thick in areas, with willows dominant.

Upper Lemhi River, Study Site 4: This study site for this reach was located on private property and represents a mixture of riffle, pool, and glide habitat types. The upper and lower boundaries of this reach were two tributaries. Riparian vegetation was thick in areas, with willows dominant.

Upper Lemhi River, Study Site 5: This reach was located on private property, between Canyon Creek (downstream) and a major diversion (L63) (upstream). Habitat types included a mixture of pools, glides, and riffles. Willows dominated riparian areas.

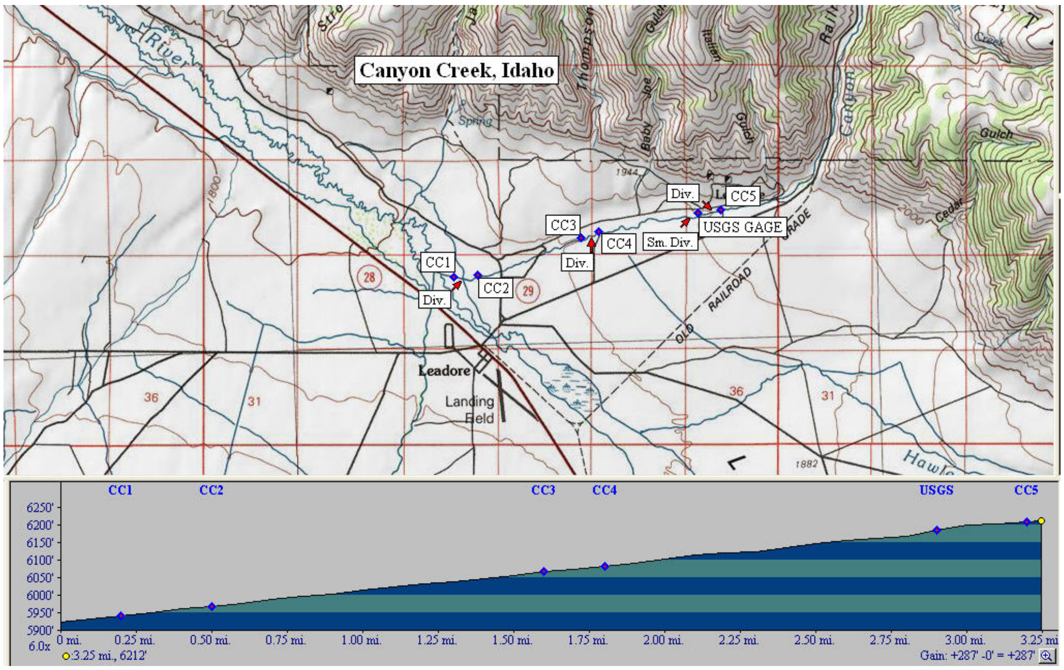

Figure 2. Canyon Creek study area for flow characterization study and locations of study sites 1-5.

Canyon Creek, Study Site 1: This reach extended from the confluence with the Lemhi River upstream to the first major diversion (White Fish Ditch). The stream channel was very narrow, consisting of primarily glides and riffles. The discharge in this reach depended heavily upon water taken from the White Fish Ditch diversion.

Canyon Creek, Study Site 2: This reach was located between White Fish Ditch diversion (downstream) and the next major diversion upstream. The discharge in this reach depended heavily upon water taken from the upper diversion.

Canyon Creek, Study Site 3: This reach was located between two major diversions and had dense riparian vegetation dominated by willows. Woody debris was abundant in the stream channel and habitat types were dominated by glides.

Canyon Creek, Study Site 4: This reach represented the stream between the next two major diversions. This reach had excellent riparian vegetation, and good quality cover around the transects. Riparian vegetation was dominated by willows.

Canyon Creek, Study Site 5 (Reference): This reach represented natural conditions unimpaired by major diversions. Habitat types included a mixture of pools, glides, and riffles. Willows dominated riparian areas.

3.0 LIMITING FACTORS ANALYSIS

The main components in this analysis were existing fish population, hydrology, and water quality data. Existing fish population data were used as an index of fish occurrence in the study streams (see Section 1.2). Existing USGS natural streamflow estimates and measured streamflows during 2005 were used to determine recent historic hydrology. Additionally, any existing water quality data, including water temperature, were evaluated to determine if water quality was limiting. Water temperature was monitored continuously at two locations in the Upper Lemhi River (near Study Site 1 and the Leadore Bridge) and two locations in Canyon Creek (near Study Site 2 and 5) by Reclamation between June and September, 2005 using Onset TidBit data loggers.

3.1 Climatic and Hydrologic Conditions

The average snowpack level in the Salmon River Basin on April 1, 2005 was 78 percent of 2004 (Natural Resources Conservation Service 2005). The April 1 value is the most commonly used indicator of snowpack conditions since, in most years, it is the final value calculated before snowmelt begins. Streamflow forecast on April 1, 2005 mirrored the deteriorating snow conditions and called for only 62 percent of average in the Salmon River Basin. The mean April 2005 air temperature at Salmon, Idaho was 4.0°C (39.2°F) (Western Regional Climate Center 2005).

Natural streamflow estimates characterize seasonal flow variability in each stream segment. Large fluctuations in flow during the year are products of variable weather and the free-flowing conditions of the Upper Lemhi River and Canyon Creek, upstream from the major diversions. An exceedance flow is defined as the flow that is equaled or exceeded a certain percentage of time. Flows estimated for 20, 50, and 80 percent exceedance for each creek at two separate locations are summarized in Tables 4-5. Flows were based on regional regression equations developed by USGS in Boise for the Forest Service (Hortness and Berenbrock 2001) (http://StreamStats.usgs.gov/html/index.html). Information on the accuracy of the regression equations is available in Hortness and Berenbrock (2001). Tables 6 and 7 are streamflows measured at temporary gage stations maintained by USGS on the Upper Lemhi River and Canyon Creek during 2005.

The hydrology of the Upper Lemhi River and Canyon Creek has changed dramatically since the mid-1840s because of diversions that resulted in a lack of stream connectivity to the floodplain. During irrigation season most of the water is diverted off-channel through diversion headgates and either used for flood or sprinkler irrigation. Figures 3-7 are graphical representations of flows for the Upper Lemhi River and Canyon Creek in summer 2005 using continuous gaging data and exceedance estimates. Flows were dramatically higher at the IDWR gage just upstream from the Big Springs Creek confluence (Figure 3) than the USGS gage at the Leadore Bridge (Figure 4), indicating groundwater accretions. Figures 3 and 5 illustrate the impact of upstream diversions on the Upper Lemhi River.

Water withdrawals have degraded the aquatic resources in the Lemhi River sub-basin by reducing flow in the river channels. Inadequate flow in the river results in conditions unfavorable to either upstream migration of spawning adults, or out-migration of juveniles (Bureau of Reclamation 2003). Intensive diversion of water for agriculture can disconnect tributaries from the mainstem river. In the Lemhi, it is estimated that fish production has been lost from at least 10 tributary creeks that previously supported anadromous fish populations (ISCC 1995), eliminating significant stretches of spawning habitat due to dewatering.

Even main river channels can be dewatered for short stretches, downstream from major diversions before any water is returned to the main channel. For example, in the past as much as a 3-mile long stretch of the lower Lemhi was vulnerable to dewatering for part of the summer during low flow years (ISCC 1995). It is not necessary for the river to be entirely dewatered for the channel to become impassable. Depending on river bottom conditions, flow can occur predominantly through river gravels during times of extremely low flow, effectively preventing fish passage.

In some river systems, much of the water flowing through tributaries is lost directly to alluvial gravels, where it sinks into underground flows. This is estimated to be the case in the Lemhi River sub-basin. Of the estimated annual water yield of 1.055 million acre-feet in the subbasin, an estimated 0.875 million acre feet (MAF) are lost to evaporation, plant transpiration, and underground flows (ISCC 1995) by the time it reaches the town of Salmon at the confluence with the Salmon River.

Table 4. . Monthly exceedance flows on Upper Lemhi River using USGS regional regression equations (Hortness and Berenbrock 2001).

Month		**Flow Value (cfs)**	
		Study Site 1	**Study Site 5**
January	Q.80=	33.6	25.2
	Q.50=	42.5	32.1
	Q.20=	70.0	53.5
February	Q.80=	34.5	25.7
	Q.50=	45.7	34.3
	Q.20=	72.3	55.4
March	Q.80=	36.4	27.2
	Q.50=	58.5	44.4
	Q.20=	88.6	68.3
April	Q.80=	77.3	59.3
	Q.50=	131.0	102.0
	Q.20=	229.0	184.0
May	Q.80=	123.0	103.0
	Q.50=	252.0	214.0
	Q.20=	467.0	399.0
June	Q.80=	141.0	121.0
	Q.50=	349.0	297.0
	Q.20=	647.0	549.0
July	Q.80=	60.1	48.4
	Q.50=	139.0	112.0
	Q.20=	263.0	212.0
August	Q.80=	38.4	31.0
	Q.50=	58.5	47.0
	Q.20=	123.0	100.0
September	Q.80=	37.0	29.3
	Q.50=	52.9	41.8
	Q.20=	103.0	82.3
October	Q.80=	31.1	23.5
	Q.50=	50.9	38.4
	Q.20=	97.7	75.1
November	Q.80=	42.9	32.2
	Q.50=	55.6	42.0
	Q.20=	94.6	72.6
December	Q.80=	35.2	26.5
	Q.50=	46.8	35.3
	Q.20=	80.2	61.3
Average annual Q average=		**145.0**	**114.0**

Table 5. Monthly exceedance flows on Canyon Creek using USGS regional regression equations (Hortness and Berenbrock 2001).

Month		Flow Value (cfs)	
		Study Site 1	**Study Site 5**
January	Q.80=	5.07	5.06
	Q.50=	6.34	6.33
	Q.20=	9.88	9.86
February	Q.80=	4.98	4.97
	Q.50=	6.53	6.52
	Q.20=	10.1	4.97
March	Q.80=	5.19	5.18
	Q.50=	8.09	8.08
	Q.20=	12.3	12.3
April	Q.80=	10.3	10.3
	Q.50=	16.9	16.9
	Q.20=	30.4	30.3
May	Q.80=	13.9	13.9
	Q.50=	33.8	33.8
	Q.20=	69.9	69.8
June	Q.80=	13.0	12.9
	Q.50=	40.8	40.6
	Q.20=	87.6	87.2
July	Q.80=	10.9	10.8
	Q.50=	21.4	21.3
	Q.20=	40.4	40.3
August	Q.80=	6.87	6.86
	Q.50=	10.0	10.0
	Q.20=	18.9	18.9
September	Q.80=	6.04	6.03
	Q.50=	8.29	8.27
	Q.20=	14.5	14.4
October	Q.80=	4.99	4.98
	Q.50=	8.34	8.33
	Q.20=	14.4	14.4
November	Q.80=	6.35	6.33
	Q.50=	8.18	8.17
	Q.20=	13.3	13.2
December	Q.80=	5.4	5.38
	Q.50=	6.99	6.97
	Q.20=	11.0	11.0
Average annual Q average=		**24.4**	**24.4**

Table 6. Water resource records for upper Lemhi River near Leadore Bridge, 2005 (source: USGS).

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 13303070 LEMHI RIVER AT LEADORE ID STREAM SOURCE AGENCY USGS STATE 16 COUNTY 059
LATITUDE 444055 LONGITUDE 1132122 NAD83 DRAINAGE AREA CONTRIBUTING DRAINAGE AREA DATUM
Date Processed: 2006-02-07 14:21 By jddoyle

Discharge, cubic feet per second
WATER YEAR OCTOBER 2004 TO SEPTEMBER 2005
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	e13	12	14	17	10	10
2	---	---	---	---	---	---	e13	12	18	13	11	10
3	---	---	---	---	---	---	e13	10	17	12	11	8.3
4	---	---	---	---	---	---	e14	10	15	14	11	8.9
5	---	---	---	---	---	---	e14	11	14	12	9.5	9.3
6	---	---	---	---	---	---	e14	13	18	12	8.7	9.5
7	---	---	---	---	---	---	e13	12	21	12	9.4	9.6
8	---	---	---	---	---	---	e13	12	26	13	10	10
9	---	---	---	---	---	---	e13	12	26	11	12	7.6
10	---	---	---	---	---	---	e12	15	21	12	9.5	12
11	---	---	---	---	---	---	e12	17	19	15	8.9	15
12	---	---	---	---	---	---	e11	17	26	15	9.3	15
13	---	---	---	---	---	---	e11	15	24	12	9.4	15
14	---	---	---	---	---	---	e11	13	20	10	11	16
15	---	---	---	---	---	---	e12	12	15	11	11	15
16	---	---	---	---	---	---	e13	13	17	12	7.5	12
17	---	---	---	---	---	---	e14	17	15	10	7.2	13
18	---	---	---	---	---	---	e14	16	17	10	8.0	13
19	---	---	---	---	---	---	e14	15	14	9.7	7.4	13
20	---	---	---	---	---	---	14	15	13	9.5	7.1	14
21	---	---	---	---	---	---	14	16	10	9.8	7.3	12
22	---	---	---	---	---	---	13	15	13	9.9	7.2	12
23	---	---	---	---	---	---	12	13	11	9.3	7.6	14
24	---	---	---	---	---	---	12	11	15	10	7.8	18
25	---	---	---	---	---	---	12	10	11	9.1	7.8	18
26	---	---	---	---	---	---	12	11	13	9.3	8.6	16
27	---	---	---	---	---	---	12	7.2	17	10	7.0	14
28	---	---	---	---	---	---	12	7.4	21	11	7.0	14
29	---	---	---	---	---	---	12	7.5	22	10	7.2	14
30	---	---	---	---	---	---	12	7.1	21	8.7	7.2	14
31	---	---	---	---	---	---	---	9.1	---	9.1	11	---
TOTAL	---	---	---	---	---	---	381	383.3	524	348.4	274.6	382.2
MEAN	---	---	---	---	---	---	12.7	12.4	17.5	11.2	8.86	12.7
MAX	---	---	---	---	---	---	14	17	26	17	12	18
MIN	---	---	---	---	---	---	11	7.1	10	8.7	7.0	7.6
AC-FT	---	---	---	---	---	---	756	760	1040	691	545	758

e Estimated

Table 7. Water resource records for Canyon Creek upstream from major diversion structures, 2005 (source: USGS).

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 13303200 CANYON CREEK NR LEADORE ID SOURCE AGENCY USGS STATE 16 COUNTY 059
LATITUDE 444203 LONGITUDE 1131837 NAD83 DRAINAGE AREA 41.9 CONTRIBUTING DRAINAGE AREA 41.9* DATUM
Date Processed: 2006-02-07 14:19 By jddoyle

Discharge, cubic feet per second
WATER YEAR OCTOBER 2004 TO SEPTEMBER 2005
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	e4.6	4.7	17	14	7.5	5.7
2	---	---	---	---	---	---	e4.6	4.7	16	13	7.3	5.6
3	---	---	---	---	---	---	e4.8	4.9	16	13	7.4	5.5
4	---	---	---	---	---	---	e4.8	4.9	15	12	7.2	5.5
5	---	---	---	---	---	---	e4.6	5.2	14	12	7.0	5.6
6	---	---	---	---	---	---	e4.8	6.3	16	12	6.9	5.6
7	---	---	---	---	---	---	e4.4	5.6	16	11	6.9	5.5
8	---	---	---	---	---	---	e4.2	6.3	17	11	7.3	5.4
9	---	---	---	---	---	---	e4.2	6.1	17	11	7.4	5.3
10	---	---	---	---	---	---	e4.0	6.9	17	11	7.4	5.8
11	---	---	---	---	---	---	e4.0	8.3	17	11	7.0	5.6
12	---	---	---	---	---	---	e4.0	7.7	19	10	6.7	5.5
13	---	---	---	---	---	---	e4.2	7.5	18	9.8	6.8	5.5
14	---	---	---	---	---	---	e4.4	7.6	18	9.5	6.7	5.5
15	---	---	---	---	---	---	e4.4	7.7	18	9.2	6.5	5.5
16	---	---	---	---	---	---	e4.4	8.4	18	9.0	6.3	5.4
17	---	---	---	---	---	---	e4.6	12	19	8.8	6.6	6.4
18	---	---	---	---	---	---	e4.6	12	20	8.7	6.9	5.8
19	---	---	---	---	---	---	e4.4	14	19	8.4	6.3	5.5
20	---	---	---	---	---	---	4.4	15	19	8.2	6.2	5.4
21	---	---	---	---	---	---	4.7	17	19	8.1	6.1	5.5
22	---	---	---	---	---	---	4.7	16	19	8.2	6.1	5.4
23	---	---	---	---	---	---	4.7	17	19	8.1	6.0	5.6
24	---	---	---	---	---	---	4.6	16	19	7.8	5.9	6.5
25	---	---	---	---	---	---	4.7	16	18	7.8	5.8	6.3
26	---	---	---	---	---	---	4.7	15	19	7.9	5.8	5.8
27	---	---	---	---	---	---	4.7	15	18	7.6	5.7	5.7
28	---	---	---	---	---	---	4.6	14	18	7.5	5.7	5.6
29	---	---	---	---	---	---	4.6	14	17	7.6	5.6	5.6
30	---	---	---	---	---	---	4.7	15	15	7.4	5.8	5.6
31	---	---	---	---	---	---	---	15	---	7.7	5.8	---
TOTAL	---	---	---	---	---	---	135.1	325.8	527	298.3	202.6	169.2
MEAN	---	---	---	---	---	---	4.50	10.5	17.6	9.62	6.54	5.64
MAX	---	---	---	---	---	---	4.8	17	20	14	7.5	6.5
MIN	---	---	---	---	---	---	4.0	4.7	14	7.4	5.6	5.3
AC-FT	---	---	---	---	---	---	268	646	1050	592	402	336

e Estimated

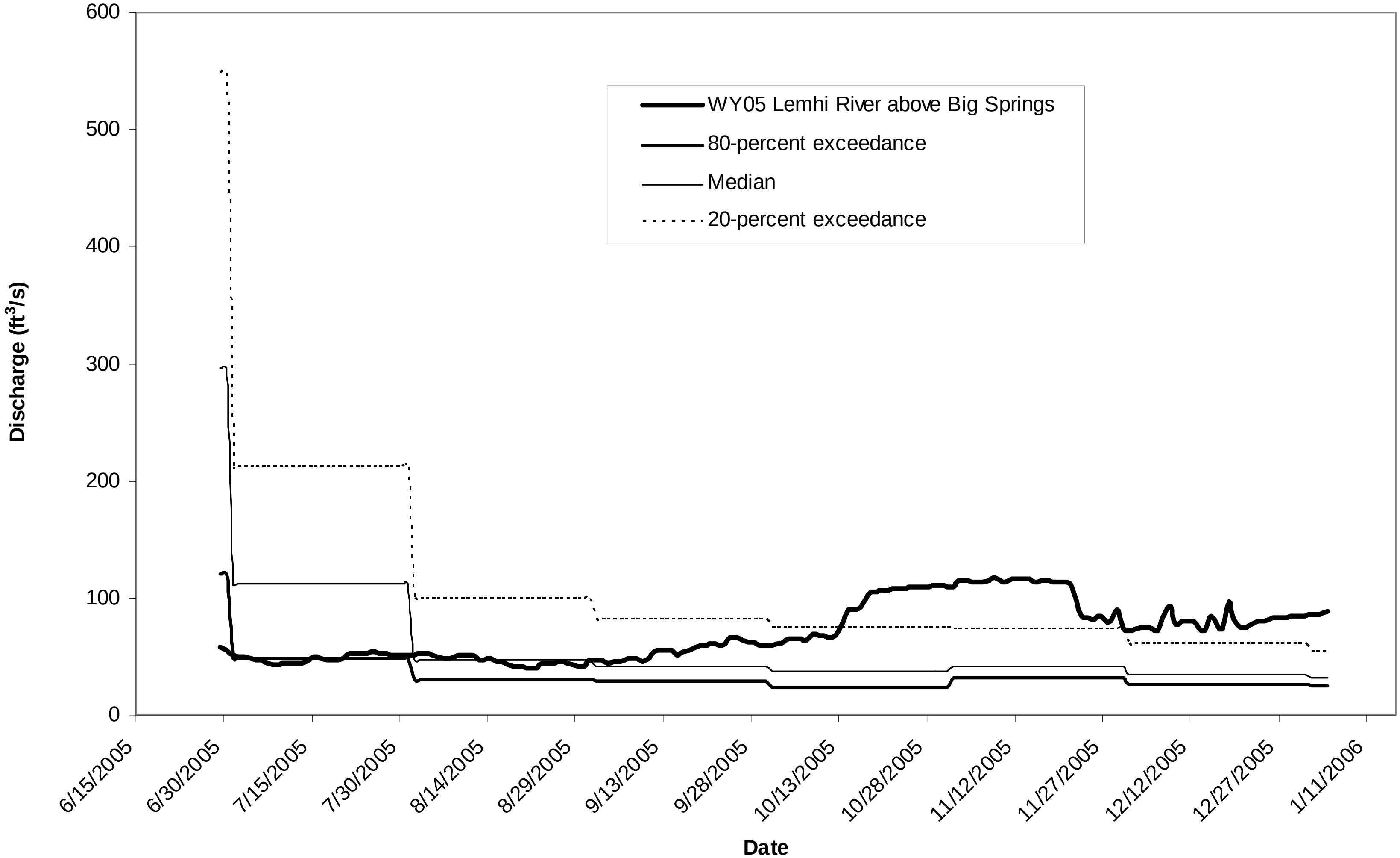

Figure 3. Daily flows (cfs) in upper Lemhi River just upstream from confluence with Big Springs Creek, 2005 (source: IDWR)

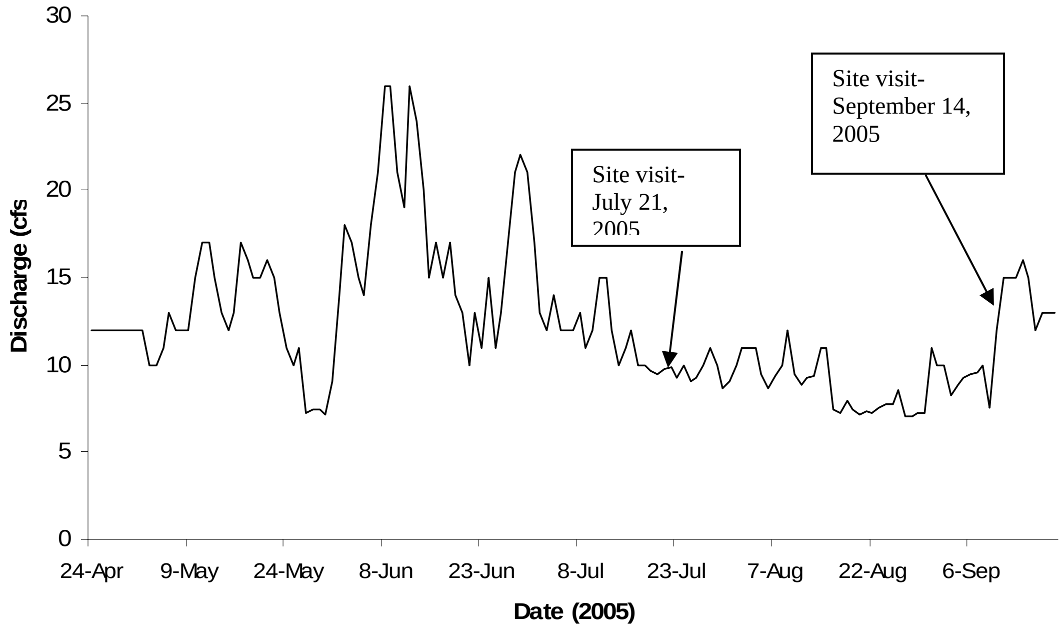

Figure 4. Graphical representation of data in Table 6 for discharge (cfs) recorded in the Upper Lemhi River (2005).

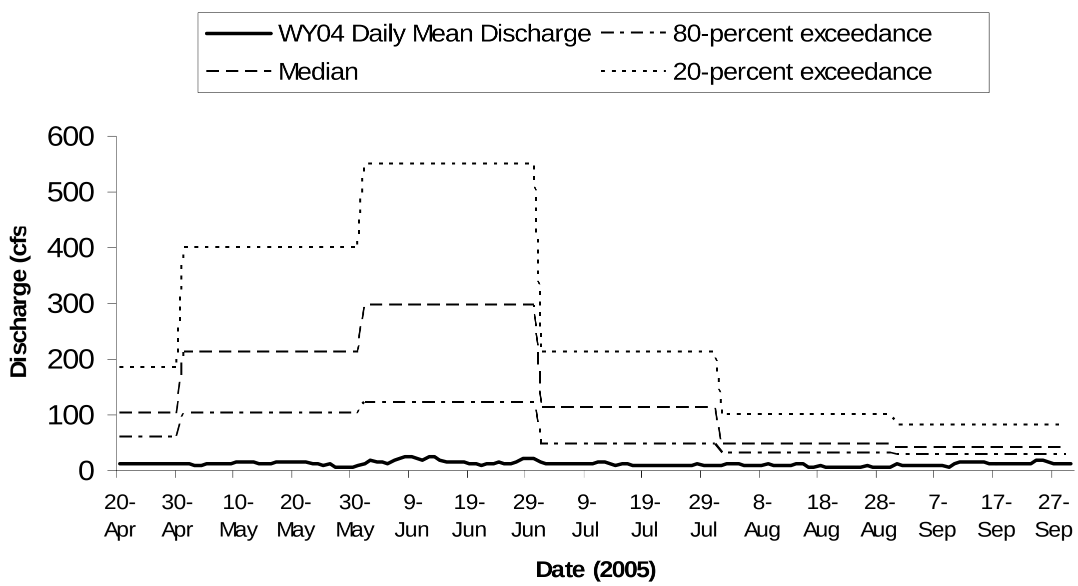

Figure 5. Graphical representation of Tables 6 and 4 for the Upper Lemhi River discharge (cfs) in spring/summer, 2005 using continuous gaging data and exceedance estimates.

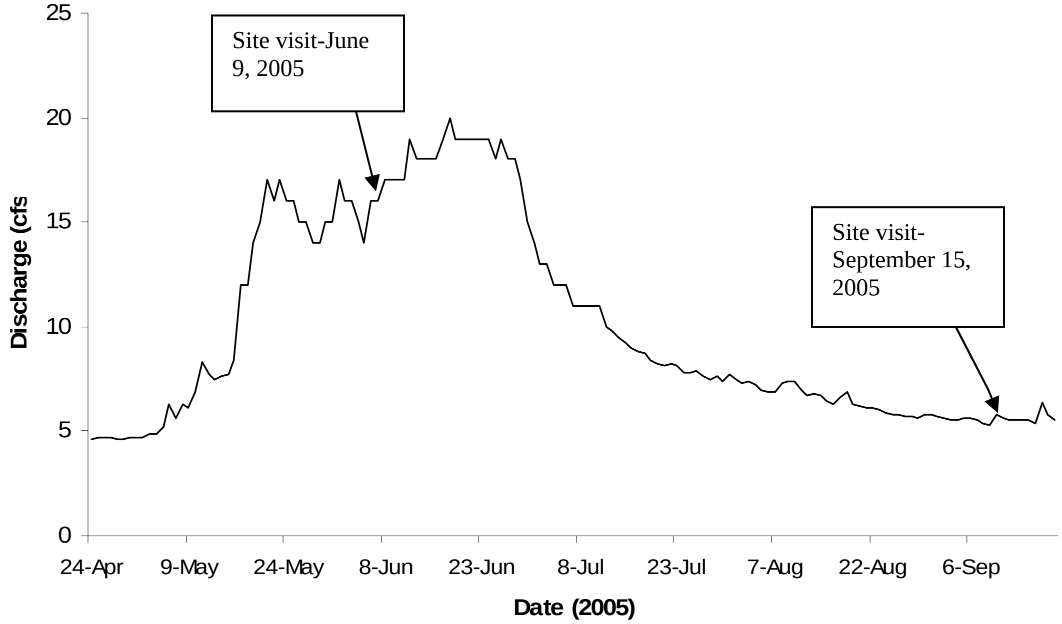

Figure 6. Graphical representation of data in Table 7 for unimpaired discharge (cfs) recorded in Canyon Creek (2005).

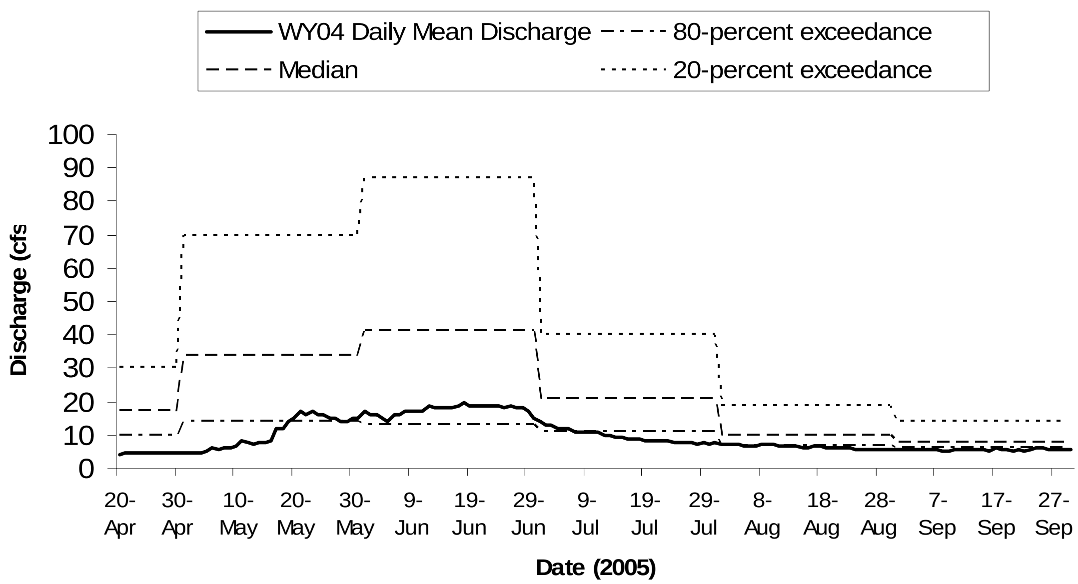

Figure 7. Graphical representation of Tables 7 and 5 for Canyon Creek discharge (cfs) in spring/summer, 2005 using continuous gaging data and exceedance estimates.

3.2 Water Quality

Water bodies are designated in Idaho to protect water quality for existing or designated uses. Canyon Creek and the Lemhi River are designated by Idaho Administrative Code (2005) - *58.01.02 - Water Quality Standards* as:

a. Cold water: water quality appropriate for the protection and maintenance of a viable aquatic life community for cold water species; and
b. Salmonid spawning: waters which provide or could provide a habitat for active self-propagating populations of salmonid fishes.

Although these streams are not listed on Idaho's 1998 303(d) list, the potential exists for elevated summer temperatures. Stream temperature is driven by the interaction of many variables, including shade, geographic location, vegetation, climate, topography, and flow. Based on *Idaho Administrative Code 58.01.02 - Water Quality Standards, Surface Water Quality Criteria for Aquatic Life Use Designations*, Idaho waters designated for cold water aquatic life are not to vary from the following characteristic: water temperatures of 22°C (72°F) or less with a maximum daily average of no greater than 19°C (66°F). Hourly temperatures measured for Canyon Creek and Upper Lemhi River are plotted in Figures 8-11, respectively. In 2005, maximum daily average temperature was not exceeded, but the lower reaches of these study areas exceeded 22°C for short periods of time in July and August (Figures 8 and 10). In general, Lemhi River and Canyon Creek water temperatures were higher in the lower reaches than in upper reaches. For the time period of July 21 – September 13, 2005, Lemhi River lower reach averaged 13.1°C (5.1-21.5°C) and the uppermost reach averaged 10.1°C (5.1-17.0°C). Upper Canyon Creek averaged 11.1°C (4.7-16.3°C) compared to lower Canyon Creek which averaged 12.8°C (5.0-25.0°C). It should be noted that surface water temperatures might have been even higher without groundwater inflow. Dewatering, irrigation return flows, and lack of riparian shading with a wide and shallow channel morphology may all act to increase water temperatures in the lower reaches of the Lemhi study area. If there were little or no groundwater influence, the lower reaches may be unsuitable for salmonids. Groundwater and surface water temperatures would need to be measured and a thermal balance analysis conducted to account for groundwater effects.

Flow levels are affected by weather, snowpack, rainfall, and water withdrawal. Diverted water can reduce water temperatures and oxygen levels. Shallow, slow water tends to warm faster than deep, fast water. Warmer water holds less dissolved oxygen than cooler water. The combination of warm water with less dissolved oxygen, especially water temperatures above 20°C (68°F) and dissolved oxygen below 5 milligrams per liter, can stress salmonids (Bjornn and Reiser 1991). For juvenile Chinook salmon acclimated to an environment where water temperatures were maintained at a constant of 15°C (59°F), 50% mortality occurred when temperatures reached 25°C (77°F) (Armour 1991). The upper lethal limit is 24°C (75°F) for steelhead (Bell 1991).

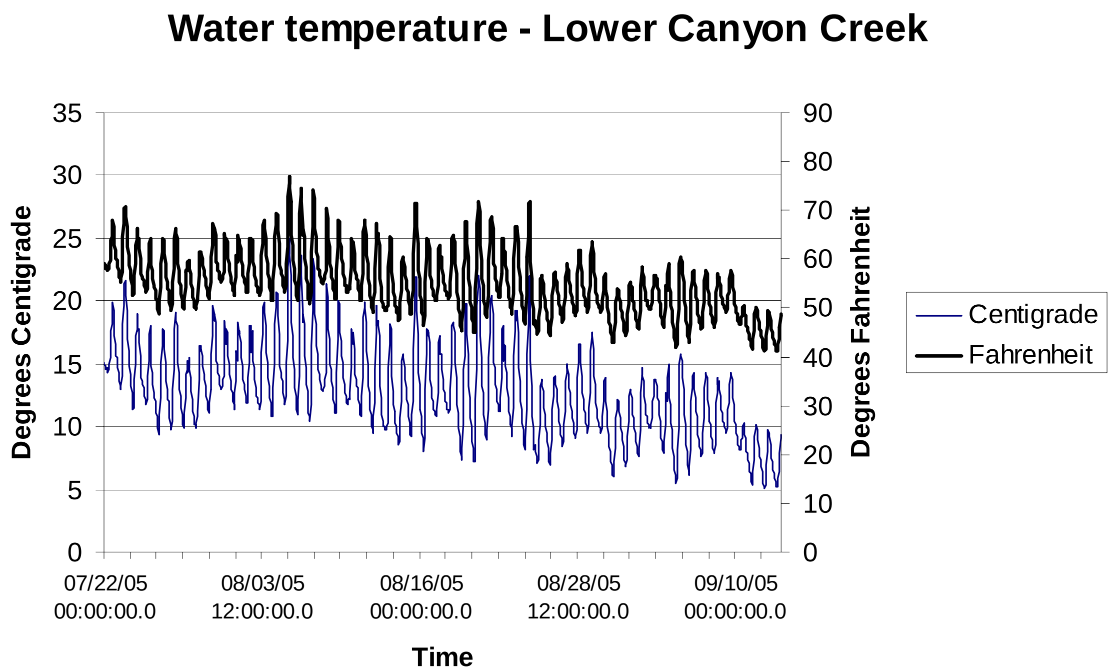

Figure 8. Water temperatures in lower Canyon Creek during summer of 2005 near Study Site 2.

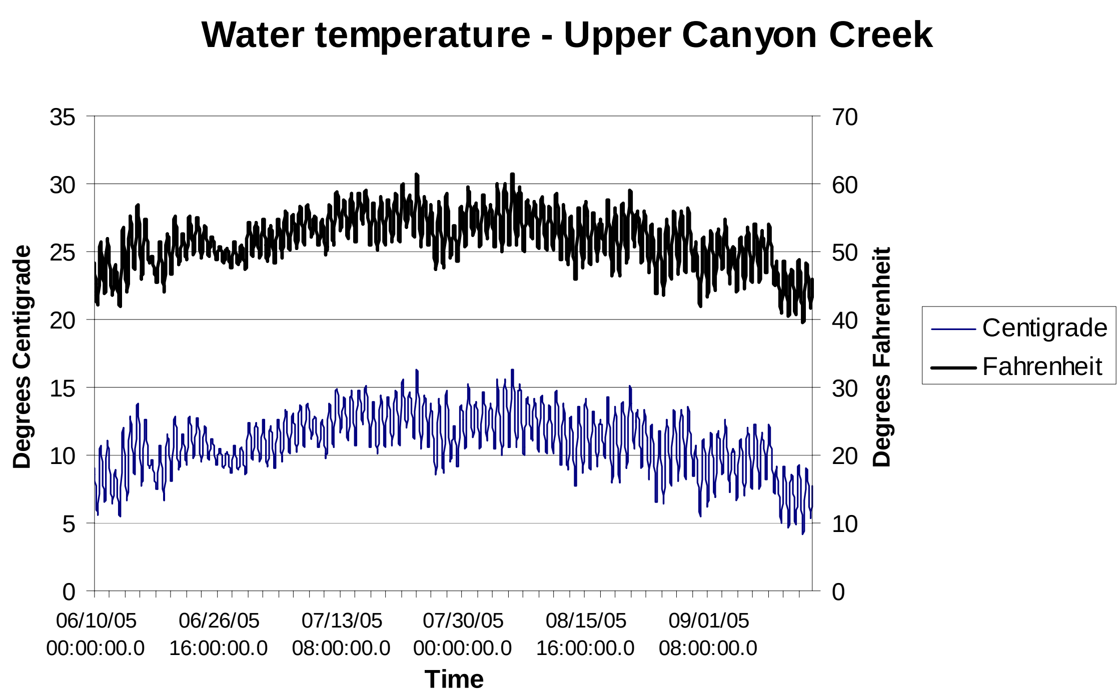

Figure 9. Water temperatures in upper Canyon Creek during summer of 2005 near Study Site 5.

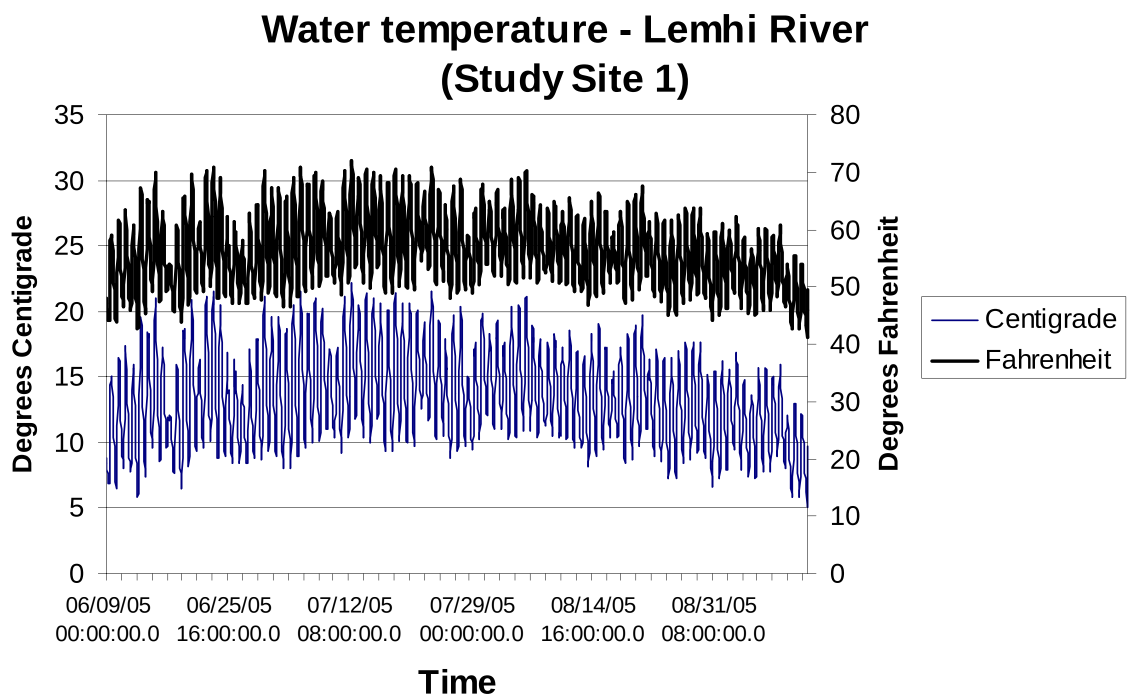

Figure 10. Water temperatures in Lemhi River during summer of 2005 near Study Site 1.

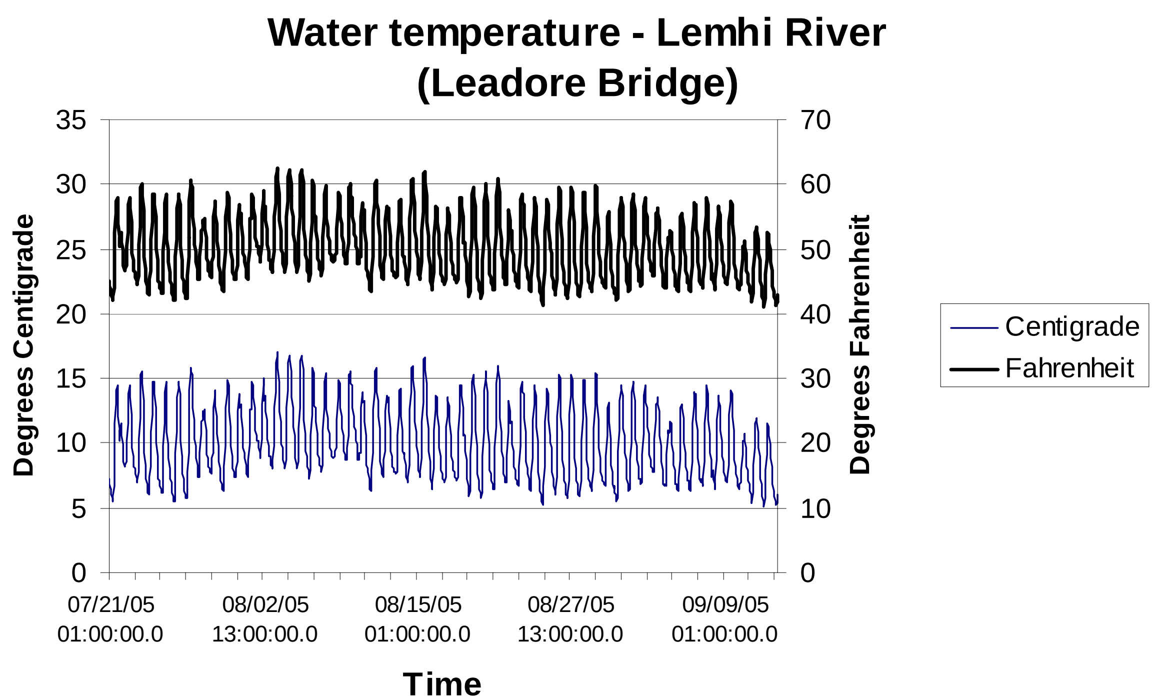

Figure 11. Water temperatures in Lemhi River during summer of 2005 near Leadore Bridge.

In general, eutrophication is a partial result of nutrient enrichment from irrigation return flow (non-point source) and possibly cattle feedlots (point source). However, agricultural runoff presents a low level of potential impact to water quality. Excessive sedimentation has reduced the quality of spawning and rearing habitat for resident trout species and exceeded the same habitat parameters for anadromous species (IDEQ 2000).

3.3 Summary

Based on this analysis, the primary limiting factors for fisheries in the Upper Lemhi River and Canyon Creek appear to be flow, summer temperature, and sedimentation. Self-sustaining fish populations exist for the species of interest with no reported fish die-offs, and there is an available water supply throughout the year upstream from the major diversions. However, warm summer water temperatures are affected partly by water withdrawals, which also affect stream flows. Although high summer water temperature may limit the fisheries in late July and early August, fish populations continue to exist within available physical habitat throughout the year. Thermal modeling would help determine the benefits of additional flow, if any, to thermal regimes within the system. However, temperature modeling is beyond the scope of this study.

4.0 METHODS

The approach for characterizing flow needs in the Upper Lemhi River and Canyon Creek involved planning and execution of a PHABSIM study in the stream segments identified above. The Technical Service Center (TSC) of Reclamation in Denver, Colorado was responsible for (1) collecting and compiling existing hydrological and biological data for salmon, steelhead, and bull trout using these streams; (2) conducting the study; and (3) providing Reclamation's Snake River Area Office in Boise, Idaho with a final report and associated data. These tasks are briefly outlined below.

4.1 Microhabitat Analysis

Studies utilizing PHABSIM require extensive data collection and analyses. The steps in a PHABSIM study are briefly outlined below.

4.1.1 Mesohabitat Classification and Inventory

Specific procedures at each study site included:

- Locate study segments for study site selection.
- Map habitat features for stream segment. Habitat mapping, or mesohabitat typing, started at the upper segment boundary and proceeded downstream. The "cumulative-lengths approach" described by Bovee (1997) was used for habitat mapping. Habitat types were defined based on the purpose of hydraulic modeling to capture hydraulic changes (e.g., backwater and slopes).
- Thus, Reclamation used the following mesohabitat classification scheme:
    - riffles (slope),

- glides/runs (slope), and
- pools (backwater).

Linear distance of each major habitat type was recorded and the total number of each habitat type and total length mapped were recorded at the end of each segment. The mapped data were used to determine percentages of each habitat type. Study sites were selected based on habitat mapping.

4.1.2 Collection of Hydraulic Data

PHABSIM requires hydraulic and habitat suitability data to determine the instream flow requirements for the species and/or life history stage of interest. Several hydraulic sub-models can be used with PHABSIM including Stage-Discharge Relation (STGQ), Step-Backwater (WSP), and Manning's Equation (MANSQ). Field data collection was designed to accommodate any of these models. PHABSIM data collection included several steps: study segment location, habitat mapping, transect (cross section) placement and data collection.

- Transects were placed in all habitat types that represented over 5 percent of the total available habitat. Transects were placed in homogeneous habitat types with the number of transects dependent upon the physical and hydraulic features of each habitat type. The number of transects necessary to capture the depth, velocity, cover and substrate distribution and variability is in large part a function of the specific river being worked on, the mesohabitat types present, and the HSCs.
- Additional non-habitat simulation transects were placed at hydraulic controls (HC) by professional judgment to aid in hydraulic calibrations. The shallowest path across riffles or shallow runs within the study site was used to address passage issues for adult salmonids.
- At each set of transects in each habitat type the following data were collected: establishment of horizontal reference points, distance between transects, field notes referencing general habitat and stream conditions in the transect areas, and reference photos of habitat at each transect within each habitat type.

Field data were collected according to Bovee (1997) using standard surveying equipment above the water surface and using depth measured from a wading rod for wet areas. An attempt was made to conduct the surveys at low, medium, and high discharges. Vertical elevations were established throughout each habitat type by using differential leveling with a total station instrument (Bovee 1997). A benchmark was established (with rebar) and assigned the arbitrary elevation of 100.00 feet. All differential leveling was referenced to this benchmark. Benchmark coordinates were recorded using a GARMIN Global Positioning System (GPS) Model 12 Navigator (NAD 83). Water surface elevations (WSL) were measured to the nearest 0.01 ft near the water's edge along each transect at all discharges. Channel cross sections were measured (vertical and horizontal) to the nearest 0.1 ft between headpins at each transect during low discharge. Discharge measurements at each transect were taken during the three surveys.

4.1.3 Depth, Velocity, Substrate, and Cover

Depths, mean velocities, substrates, and cover were measured at various points that defined cell boundaries along each transect. Although cover was measured, it was not used in the model. Stationing across transects was oriented with 0.0 on the left bank looking upstream for modeling purposes. Depths were measured using a top-setting wading rod. Streambed elevations and water depths were measured to the nearest 0.1 ft. Mean column water velocity was measured to the nearest 0.1 ft/sec using a Marsh McBirney Flo-Mate 2000 velocity meter attached to the wading rod. Substrate and cover for PHABSIM were visually assessed using a system developed by EA Engineering (1991b) and Raleigh et al. (1986) (Table 8). A temporary staff gage was installed at each site so that fluctuations in WSL could be monitored during data collection.

Table 8. Lemhi Sub-basin instream substrate and cover coding system.[1]

Code	SUBSTRATE	diameter (in)	diameter (mm)
1	Detritus	organic matter	
2	Silt	<0.0024	0-0.062
3	Sand	0.0024 - 0.125	0.062-3.2
4	Small Gravel	0.125 – 1.0	3.2-25
5	Coarse Gravel	1-3	25-76
6	Cobble	3-10	76-256
7	Boulder	>10	>256
8	Bedrock		
9	Aquatic Veg		
	COVER		
1	Woody debris		
2	Undercut	undercut bank	
3	Cobble/Boulder	(>3”)	
4	Aquatic vegetation		
5	Large gravel	(2-3”)	
6	Canopy	canopy or overhead structure	
7	Emergent vegetation		
8	No cover		

[1] Sources: EA Engineering (1991b); R2 Resource Consultants (2004); Raleigh et al. (1986)

Velocity calibration sets were collected at three different time periods between June and September, 2004 in an attempt to cover a range of flows.

Additional transect-specific data (i.e., flow and water surface elevations) were also collected during each of the velocity surveys at each site. These stage-discharge measurements provided the data necessary for model calibration. The applicability of the range of flows simulated to actual flows in the stream was dependent on the flows measured.

4.1.4 Habitat Suitability Criteria (HSC)

Species HSC are required for PHABSIM analyses. Habitat suitability criteria, or suitability curves, are interpreted using a suitability index (SI) on a scale of 0 to 1, with 0 being unsuitable and 1 being most utilized or preferred. Habitat suitability criteria that accurately reflect the habitat requirements of the life stages of interest are essential to developing meaningful and defensible instream flow recommendations. The recommended approach is to develop site specific criteria for each species and life stage of interest. An alternative approach is to use existing curves and literature to develop suitability criteria for the life stages of interest. No site-specific HSCs are available in the Lemhi River sub-basin and time and budgetary constraints precluded developing HSCs specific to the Upper Lemhi River and Canyon Creek. While such information may become available in the future through a separate study, HSC information was derived from previous Snake River Adjudication work by the Bureau of Indian Affairs (BIA) and USFS in the Salmon River Basin (EA Engineering 1991b; R2 Resource Consultants 2004; Rubin et al. 1991). Initially, upon review of this information, the Interagency Technical Workgroup (see "Acknowledgments" for list of members) recommended Reclamation to target the ESA-listed species bull trout, Chinook salmon, and steelhead trout for juvenile, adult, and spawning life stages. Results of the juvenile life stage (50-100 mm) modeling are not included in this report because of questionable HSCs that were developed during drought conditions (Rubin et al. 1991) and the potential inability to accurately measure microhabitat parameters at a scale that would be meaningful using PHABSIM. Until juvenile habitat modeling, including appropriate HSCs, can be improved, modeling results for the juvenile life stage will not be included in this report. To address food resources of salmonids, macroinvertebrate HSCs from Gore et al. (2001) were used to assess habitat for aquatic macroinvertebrates. High gradient (>0.005 slope) HSCs were used in Canyon Creek and low gradient (<0.005 slope) macroinvertebrate HSCs were used in Upper Lemhi River.

4.1.5 Hydraulic Model Selection and Calibration

Reclamation used the USGS Windows version of PHABSIM (Waddle 2001) and coordinated hydraulic modeling procedures with the USGS flow study conducted in the upper Salmon River for quality control. PHABSIM has several submodels available for hydraulic simulations. These include STGQ, WSP, and MANSQ (Waddle 2001), with STGQ being the most rigorous in terms of data requirements. Each hydraulic model requires multiple flow measurements for model calibration. Depending on model performance and site conditions, the predictive range may be restrictive, or wide ranging (i.e., 0.1 to 10 times the measured discharges) (Waddle 2001). Since water is diverted between April 1 and September 30 of each year for irrigation, the range of flows for the hydraulic simulations covered flows that typically occur during these months.

Field sampling was designed to collect data in formats suitable for application in any of the hydraulic models identified above. The following approach was used:

- Enter field data into appropriate format for water surface simulations

- Calibrate STGQ, MANSQ, or WSP (depending on site specific conditions) to measured WSL
- Document calibration procedure
- Simulate a range of flows to predict water surface elevations
- Simulate depths and velocities for range of flows that occur during the irrigation season
- Evaluate simulation range based on velocity adjustment factors (VAF's) and other calibration sub-models
- Document acceptable range of simulations
- Conduct velocity simulation production run for applicable range of flows that may occur during the irrigation season.

4.1.6 Habitat Modeling

Table 9 shows various life stages and variables used to describe microhabitat. Since the velocity HSC for adult bull trout was developed for nose velocities at 0.2 feet off the stream bottom (EA Engineering 1991b), the nose velocity option in the habitat model was used for this life stage of bull trout.

Table 9. Life stages for species of interest and microhabitat variables used to describe habitat.

Life Stage	Depth	Velocity	Substrate
Adult passage	X		
Adult	X	X	X
Adult spawning	X	X	X

The following example describes how habitat weighting factors (WF) were determined. In an example study site that had five cross sections: one deep run, three shallow runs, and one moderate gradient riffle. Within this example site, based on example habitat mapping percentages, the three shallow runs represented 340 ft (34%), the moderate gradient riffle 540 ft (54%), and the deep run represented 120 ft (12%) of a 1,000 ft idealized reach. The shallow run distance of 340 ft was divided equally by three (113', 113', and 114') to represent the three shallow runs at the example study site. Both the deep run and moderate gradient riffle distances remained the same. Weighting factors of 0.00-1.0 were calculated for each cross section to accurately represent the entire stream reach (Table 10).

Table 10. Example of setting cross section weighting factors for habitat modeling.

Cross section	Habitat type	Distance from previous cross section (ft)	Weighting factor
1	Riffle	0	1.0
2	Shallow run	540	1.0
3	Shallow run	114	1.0
4	Shallow run	113	0.48
5	Deep run	233	0.0
Total		1,000	

An assigned WF of 1.0 moved upstream, and an assigned WF of 0.0 moved downstream, or backwards from the cross section. Weighting factors greater than 0.0 up to 1.0 moved the habitat upstream in proportion to the value assigned. For instance, the X-sec 1 WF of 1.0 applied continually upstream to X-sec 2, the entire 540 ft. The same applied to X-sec 2 and 3. The final cross section was handled differently. Essentially, it was combined into one unit, and assigned two WFs to complete the study site. The distances of X-sec 4 and 5 were combined (113+120) for a total distance of 233 ft. The formula below was used for attaining a WF:

$$233(x) = 113$$

$$X = 113/233 = 0.48$$

where X represented the unknown WF, 233 ft was the combined distance (X-sec 4 & 5), and 113 ft was the distance of X-sec 4.

The WF of 0.48 applied the habitat weighting 48% upstream to represent the final run. A weighting factor of 0.0 applied the habitat weighting of the remaining area, or 52% downstream from cross section 5. Figure 12 illustrates this procedure.

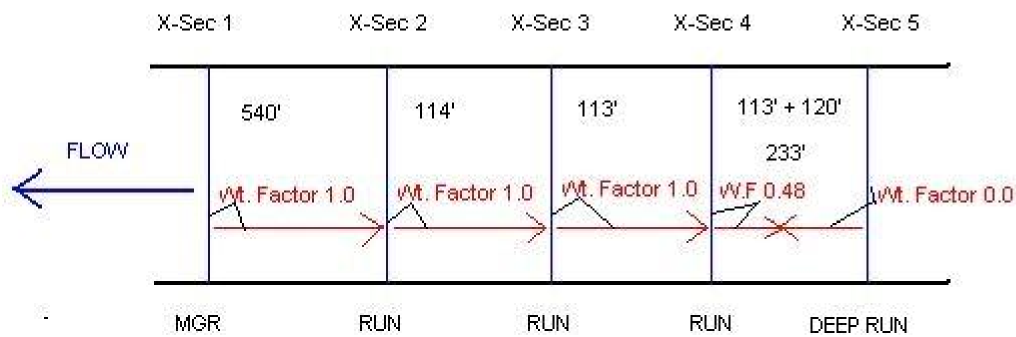

Figure 12. Example of weighting factor assignments at a PHABSIM study site.

If there was a HC cross section anywhere in the site it would not affect the habitat weighting. As for the distances (from previous cross section), the cross section immediately upstream from the HC would have a distance of '0 ft'; canceling out the HC in the model. For example, the distances and WF for the cross sections at another example study site are listed in Table 11.

Table 11. Example of setting cross section weighting factors for habitat modeling with hydraulic controls.

Cross section	Habitat type	Distance from previous cross section (ft)	Weighting factor (WF)
1	Run	0	1.0
2	Hydraulic Control (HC)	55	1.0
3	Pool	0	1.0
4	Pool	170	1.0
5	HC	170	1.0
6	Pool	0	1.0
7	Riffle	170	0.87
8	Run	435	0.0
Total		1,000	

Weighted usable area (WUA) within each representative stream reach was calculated for each discharge of interest for each species. Weighted usable area is an index of habitat availability or quantity for the selected species/life stage at each simulated flow. The WUA for each species was computed in the HABTAE sub-model of PHABSIM using the geometric mean option to multiply the depth, velocity, and substrate HSC values for a life stage at predicted hydraulic conditions, and cell surface area. The output from the HABTAE simulation was habitat area, expressed as WUA (ft^2/1,000 ft of stream). Weighted Usable Area was predicted for a range of discharges at the 13 study sites. For presentation purposes, WUAs were normalized as a percentage of maximum habitat. It should be noted that there is a level of uncertainty associated with the WUAs. Sources of uncertainty include errors in HSCs, hydraulic simulations, or selection of options to simulate microhabitat (e.g., geometric versus multiplicative means). Recognition that there is uncertainty in these sources is important in the interpretation and use of PHABSIM model results (Bovee et al. 1998).

4.2 Passage

Suggested passage criteria for adult Chinook salmon, steelhead trout, and bull trout followed guidelines adopted by Oregon Department of Fish and Wildlife and taken from Thompson (1972) and Scott et al. (1981) (Table 12). To determine the recommended flow for passage, shallow bars most critical to passage of adult fish were located, and a linear transect was measured which followed the shallowest course from bank to bank. For each transect, a flow was computed for conditions which met the minimum depth criteria in Table 12 where at least 25% of the total transect width and a continuous portion equaling at least 10% of its total width, equal to or greater than the minimum depth, was maintained (Thompson 1972). Both width criteria must be met to insure passage.

Table 12. Suggested adult salmonid passage criteria (Thompson 1972; Scott et al. 1981).

Species	Minimum Depth (ft)	Maximum Water Velocity (ft/sec)
Steelhead Trout	0.6	8.0
Chinook Salmon	0.8	8.0
Bull Trout	0.4	4.0

4.3 Flow Recommendations Using PHABSIM

The NOAA Fisheries draft protocol estimates idealized annual flow schedules for Pacific and interior northwest streams (Arthaud et al. 2001). The protocol identifies objectives for deriving minimum flow conditions necessary to protect sensitive salmonid life stages that can be quantified using PHABSIM methodologies. Results from this study can be used to help determine target flow objectives to improve passage, spawning, and adult holding conditions for salmon, steelhead, and bull trout. Table 13 provides suggested critical life stage assignments for each stream in this study which could be used to determine target flows from the PHABSIM analysis. This information was obtained through a survey of local biologists familiar with fish species of interest in these streams (J. Spinazola, Reclamation, written communication, January 12, 2005).

Table 13. Suggested critical life-stage assignments for applying flow recommendations in selected streams.

Stream	Steelhead	Chinook salmon	Bull trout
Upper Lemhi River	Passage/spawn	Passage/spawn	Passage
Canyon Creek	None	None	Passage/spawn

5.0 RESULTS AND DISCUSSION

Results of the PHABSIM analysis are summarized for each stream in separate sections below. Written descriptions and photos of each selected study site are provided in Appendix A. Habitat mapping proportions are presented in Appendix B. Cross-sectional profiles, longitudinal profiles, and measured WSLs are illustrated in Appendix C. Hydraulic model calibration results are summarized in Appendix D. Simulated WSLs were within 0.078 ft or better of measured WSLs for all transects, except the Upper Lemhi River Site 5, transect 4 at mid and high flow (WSL difference = 0.093 and -0.085, respectively) (Appendix D). The ability to simulate higher flows at some Upper Lemhi River and Canyon Creek sites was restricted due to simulation of high flows predicting water overflowing the banks and/or flowing ‘uphill’ regardless of model manipulation. Hydraulics at higher flows at Upper Lemhi sites were particularly difficult to simulate because excessive rooted aquatic vegetation interfered with the velocity measurements and extremely low slopes at some sites resulted in water surface measurement difficulties (i.e., water flowing uphill) (see Appendix D). Habitat suitability criteria (HSCs) are presented in Appendix E. Complete habitat modeling output results (i.e., WUA vs discharge and passage assessments) are summarized in Appendix F for each stream reach.

5.1 Upper Lemhi River

Measured discharges and dates of field surveys are summarized in Table 14. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference site (Study Site 5). In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, these conditions typically occur during the summer irrigation season when diversions are normally operating. Flows were always highest at the downstream-most reaches (Study Sites 1 and 2), indicating groundwater accretions. This is consistent with a previous study that demonstrated a 225% gain in flow (10.1 cfs/mi) in the 7.6-mile Lemhi River reach between Leadore and Big Springs Creek in August 1997 (Donato 1998).

Table 14. Discharges measured from highest to lowest at the Upper Lemhi River study sites during field surveys in 2005.

Stream Site	Discharge (cfs)	Survey Dates
Study Site 1	63.7 cfs	June 08
	56.0 cfs	September 13
	47.0 cfs	July 19
Study Site 2	60.3 cfs	September 13
	50.1 cfs	June 08
	41.1 cfs	July 19
Study Site 3	44.4 cfs	September 14
	37.3 cfs	June 07
	24.4 cfs	July 20
Study Site 4	32.5 cfs	September 14
	31.0 cfs	June 09
	15.5 cfs	July 20
Study Site 5	22.9 cfs	September 14
	19.0 cfs	June 09
	10.4 cfs	July 21

Graphical representations of final normalized WUA versus discharge relationships are presented in Figures 13-32 for each site. Passage flow results for total and contiguous widths at depths greater than the passage criteria (Table 12) are illustrated in Figures 33-37. Summary results, including flows required for optimal (i.e., maximum) WUAs and flows needed to meet the 0.6 feet deep passage criteria are presented in Table 15. Summary results reflected differences in stream channel hydraulics among study sites. In addition to the issues discussed above, the lack of higher calibration streamflows for some sites (e.g., Study Sites 4, and 5) limited model performance and prevented habitat simulation at higher discharges, resulting in many ">" values in Table 15.

Flows that produced optimal habitat ranged from 28 cfs for bull trout adult and spawning at Study Site 5 to over 130 cfs for bull trout adult at Study Site 1 (Table 15). Highest discharge required for adult salmonid passage using 0.6 foot depth criterion was 100 cfs at Study Site 1 (transect 1).

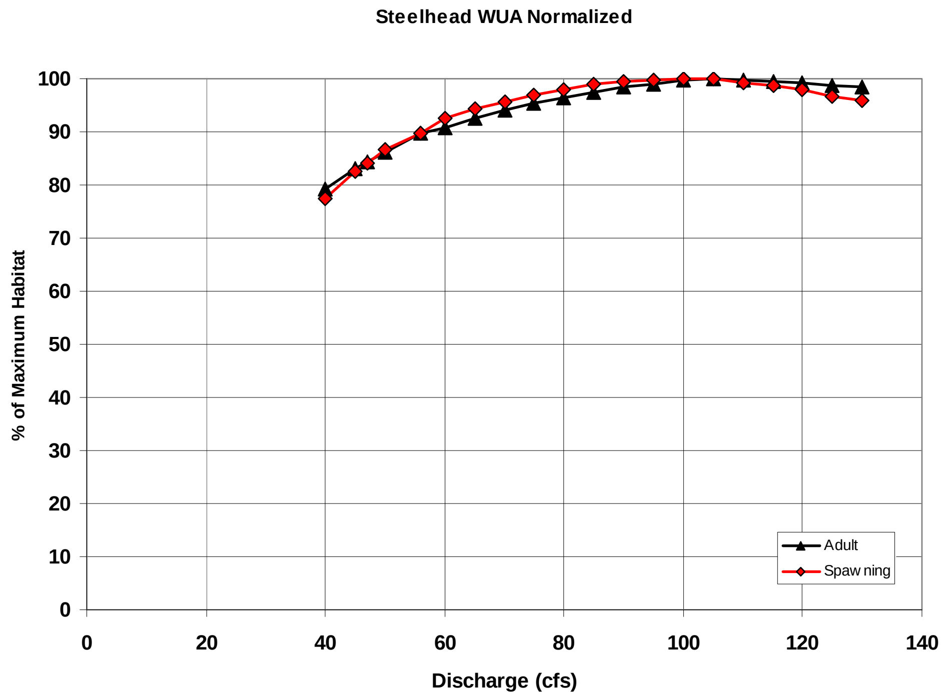

Figure 13. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in the Upper Lemhi River, Study Site 1.

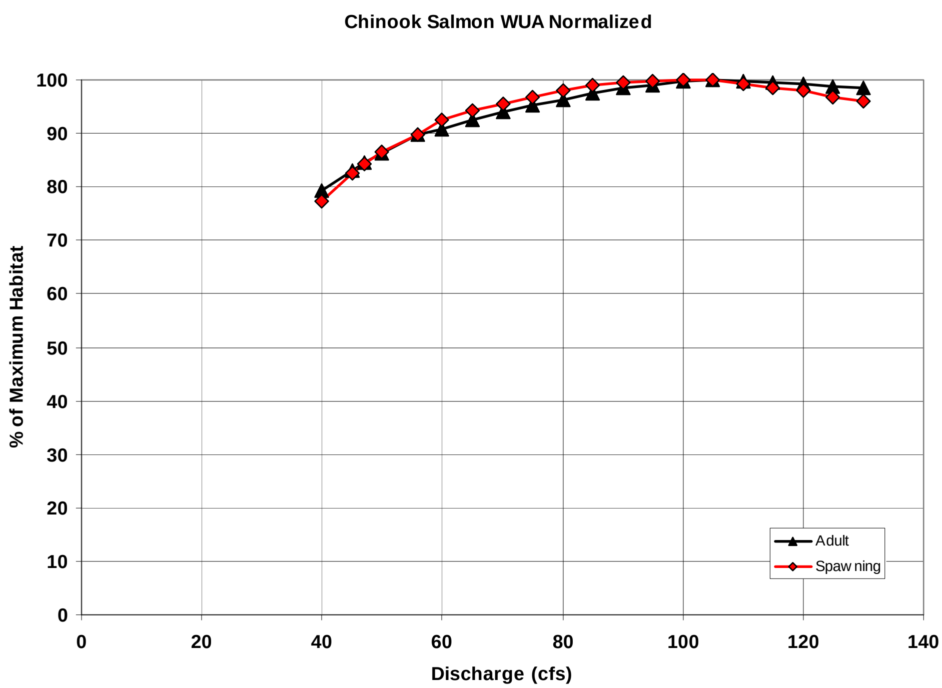

Figure 14. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in the Upper Lemhi River, Study Site 1.

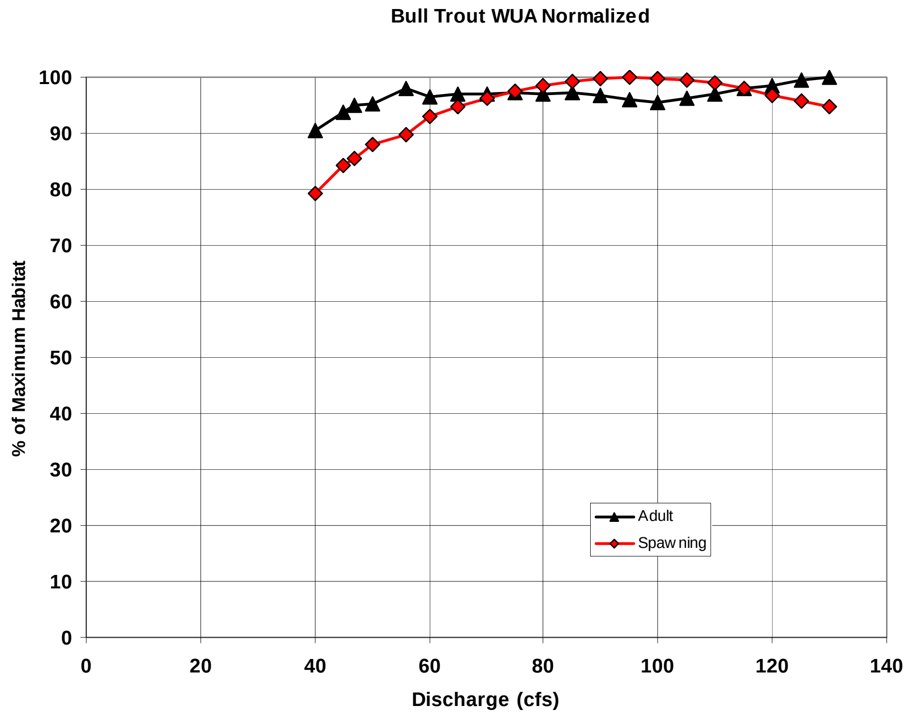

Figure 15. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in the Upper Lemhi River, Study Site 1.

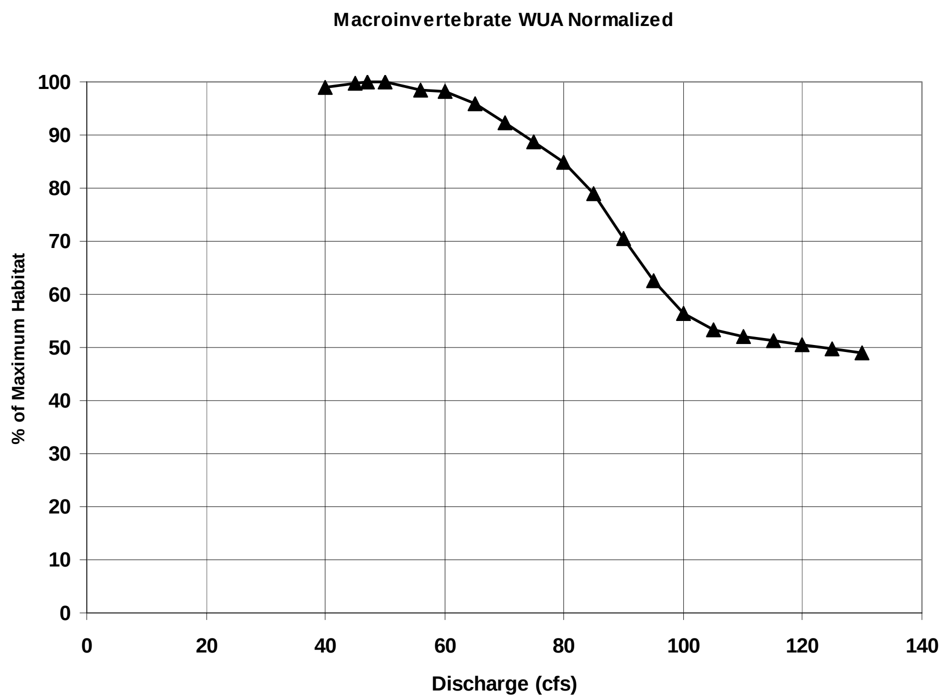

Figure 16. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in the Upper Lemhi River, Study Site 1.

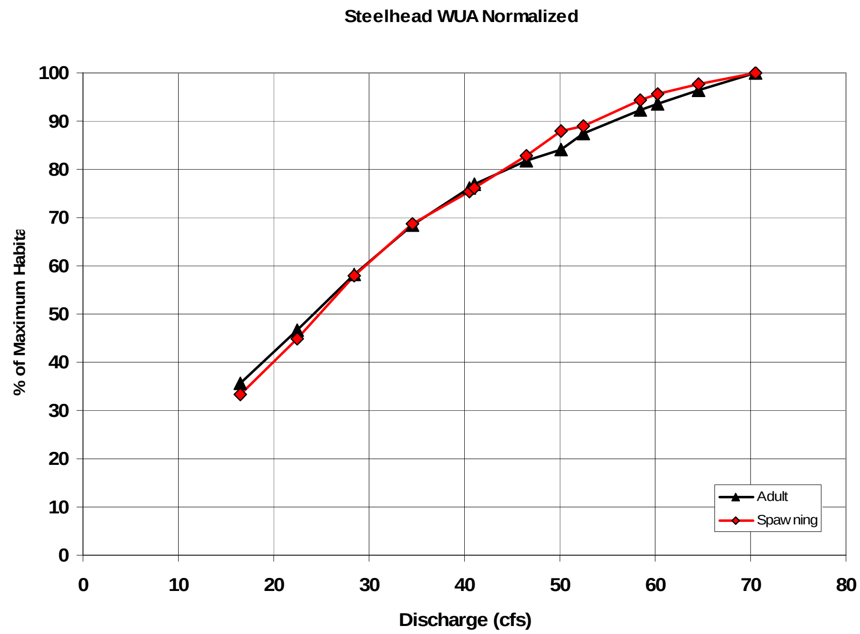

Figure 17. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in the Upper Lemhi River, Study Site 2.

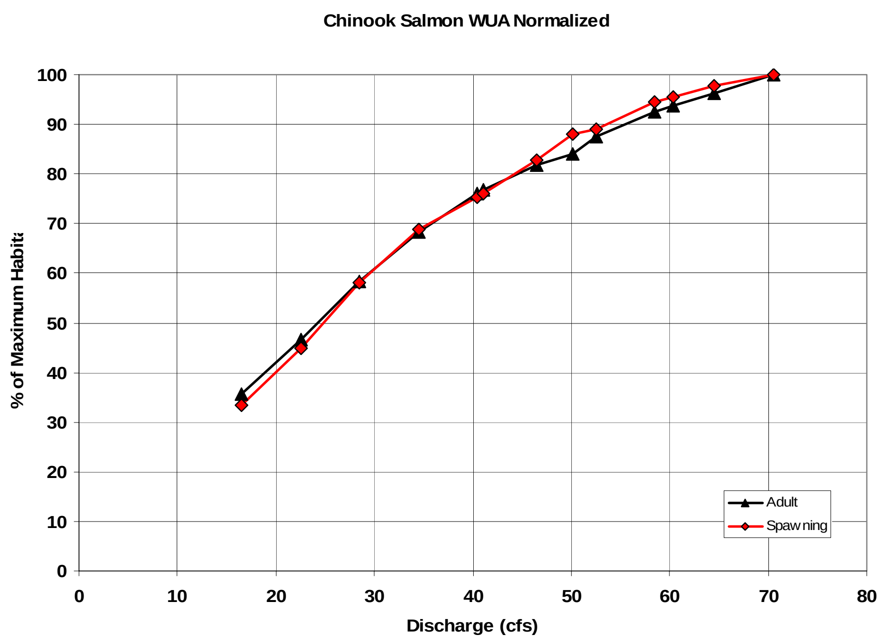

Figure 18. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in the Upper Lemhi River, Study Site 2.

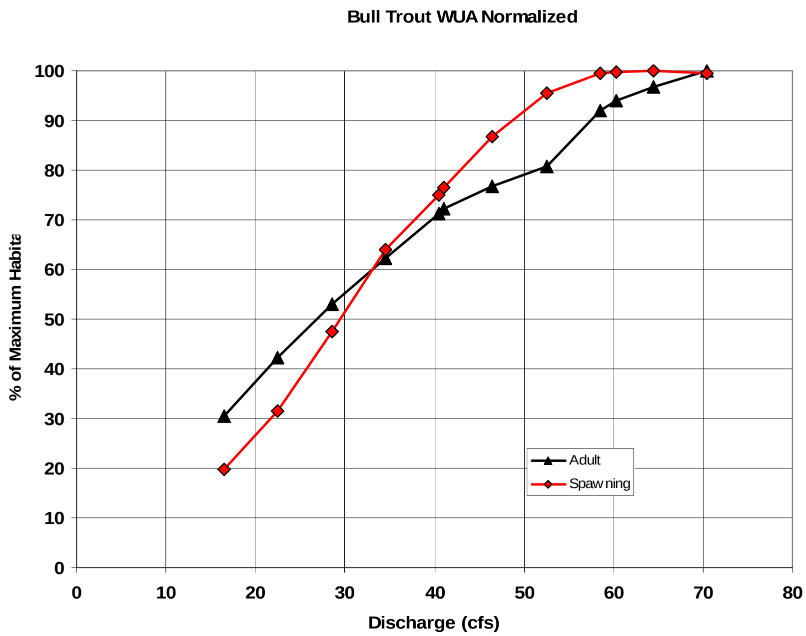

Figure 19. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in the Upper Lemhi River, Study Site 2.

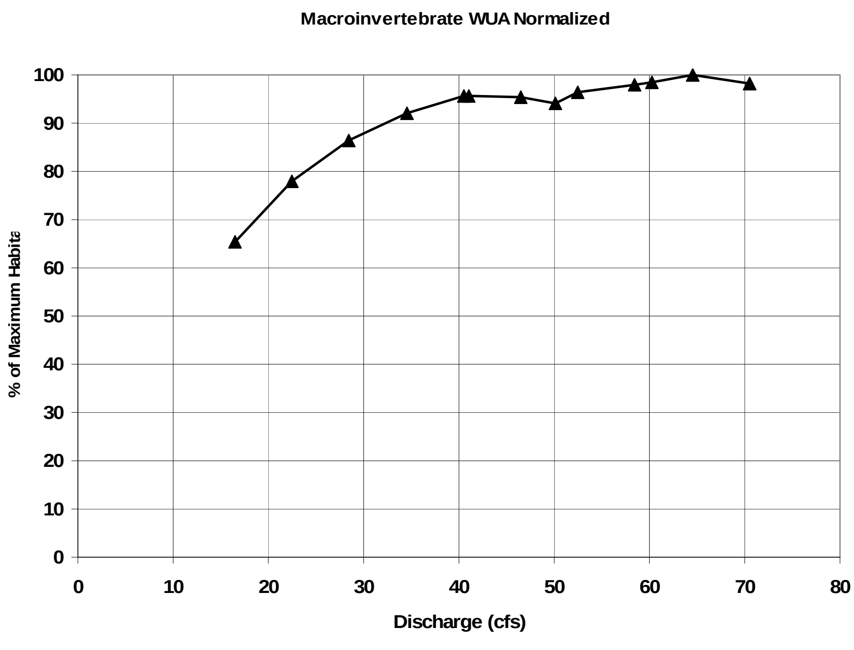

Figure 20. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in the Upper Lemhi River, Study Site 2.

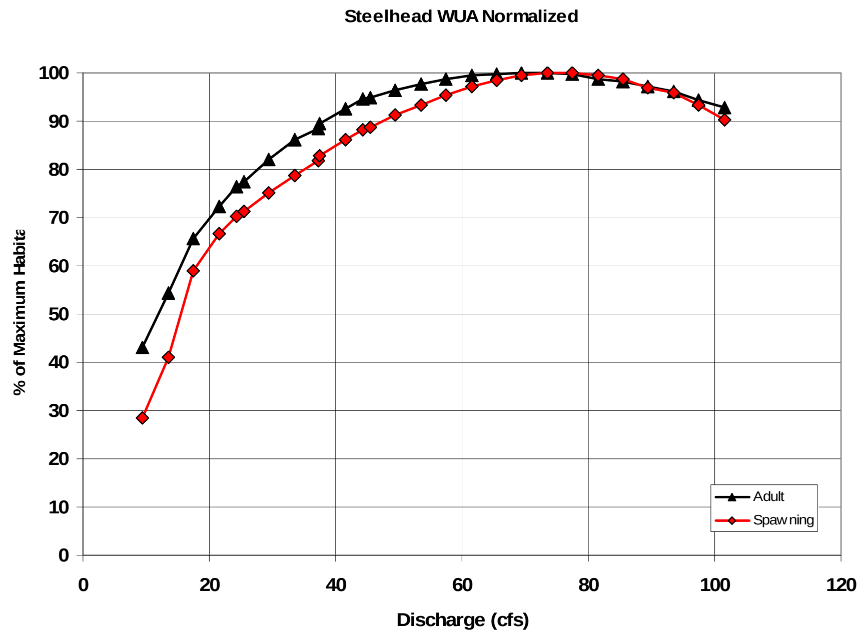

Figure 21. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in the Upper Lemhi River, Study Site 3.

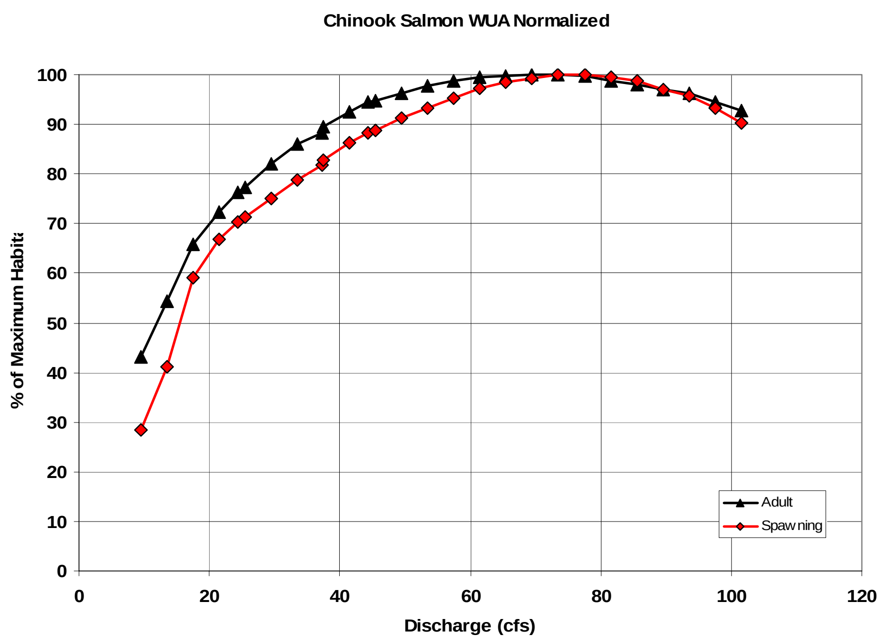

Figure 22. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in the Upper Lemhi River, Study Site 3.

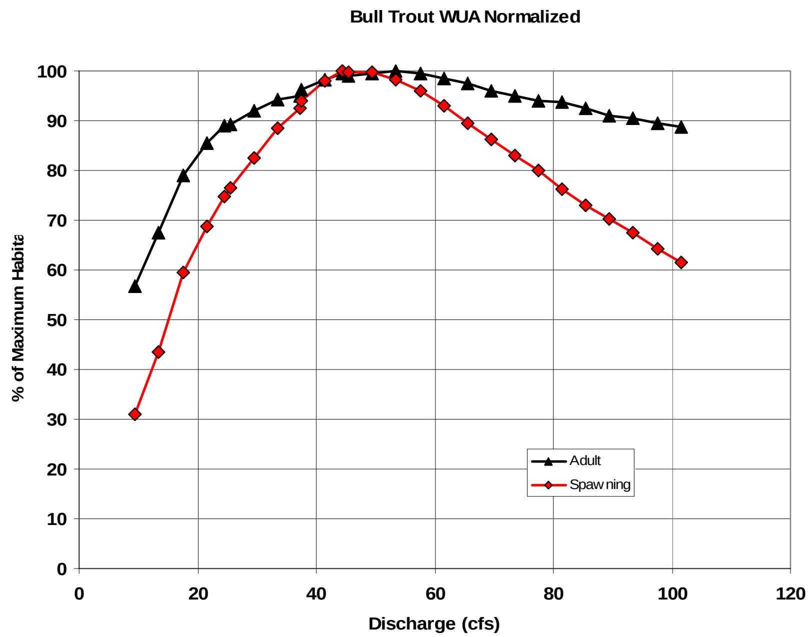

Figure 23. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in the Uppper Lemhi River, Study Site 3.

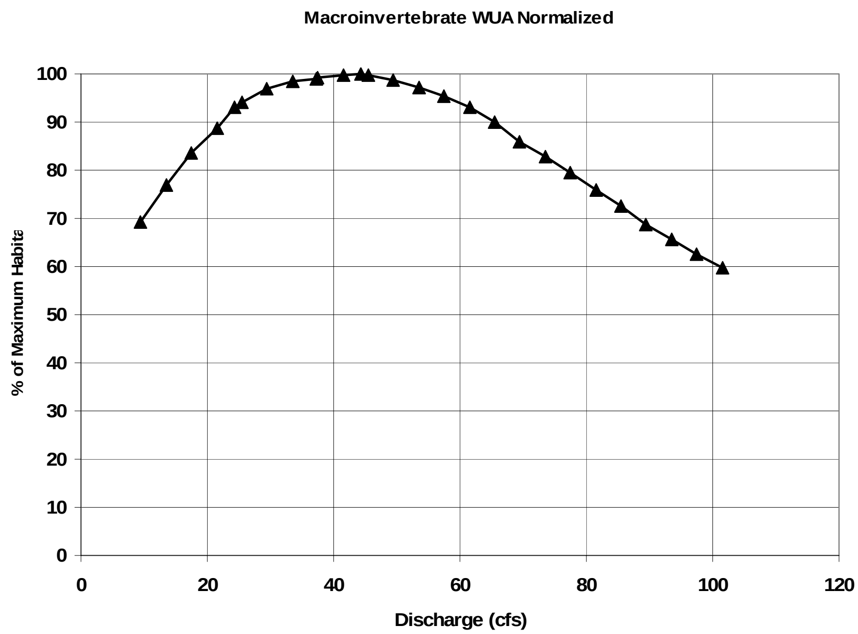

Figure 24. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in the Uppper Lemhi River, Study Site 3.

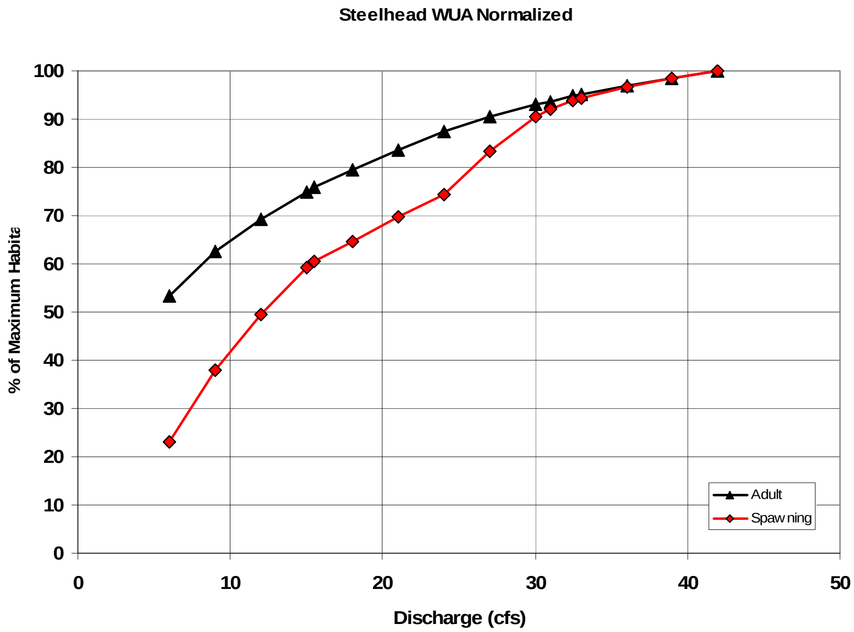

Figure 25. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in the Upper Lemhi River, Study Site 4.

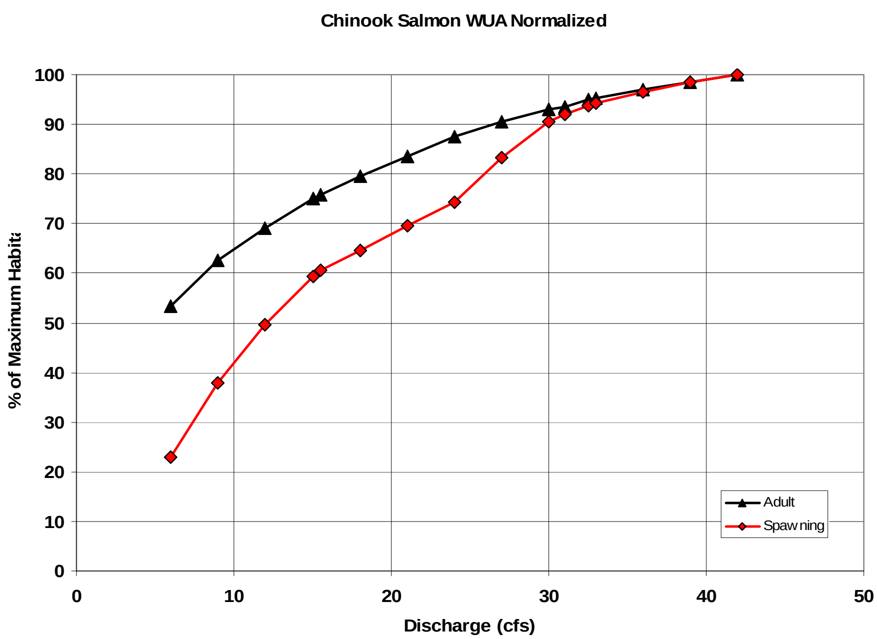

Figure 26. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in the Upper Lemhi River, Study Site 4.

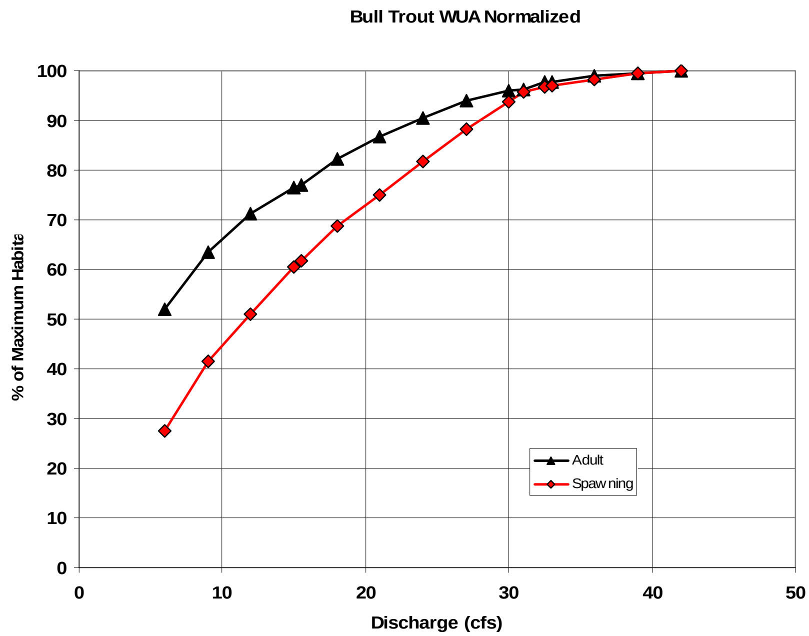

Figure 27. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in the Upper Lemhi River, Study Site 4.

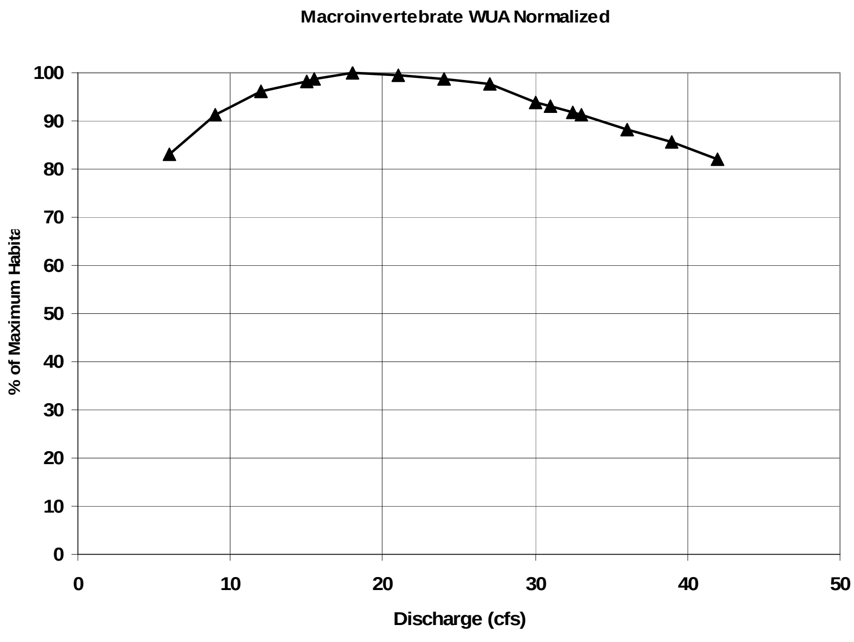

Figure 28. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in the Upper Lemhi River, Study Site 4.

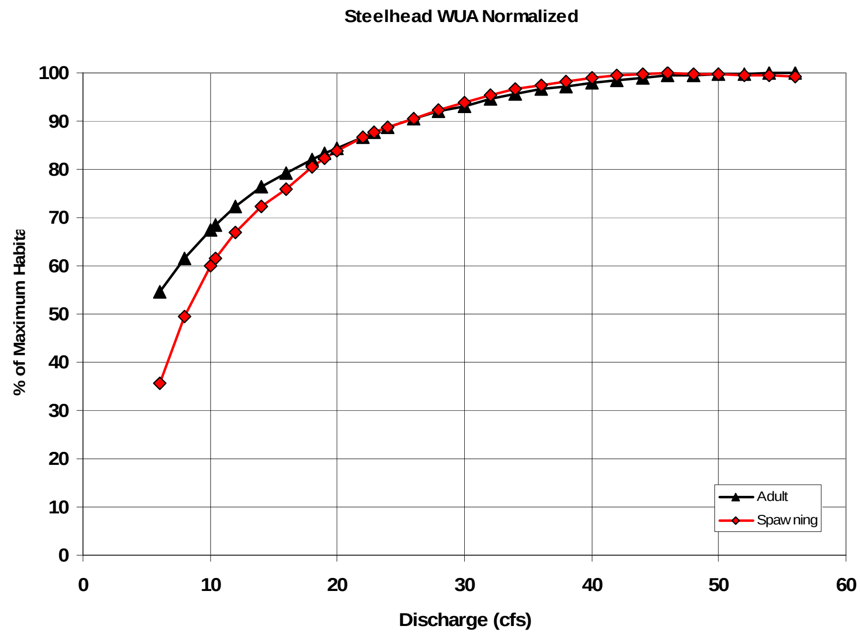

Figure 29. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in the Upper Lemhi River, Study Site 5.

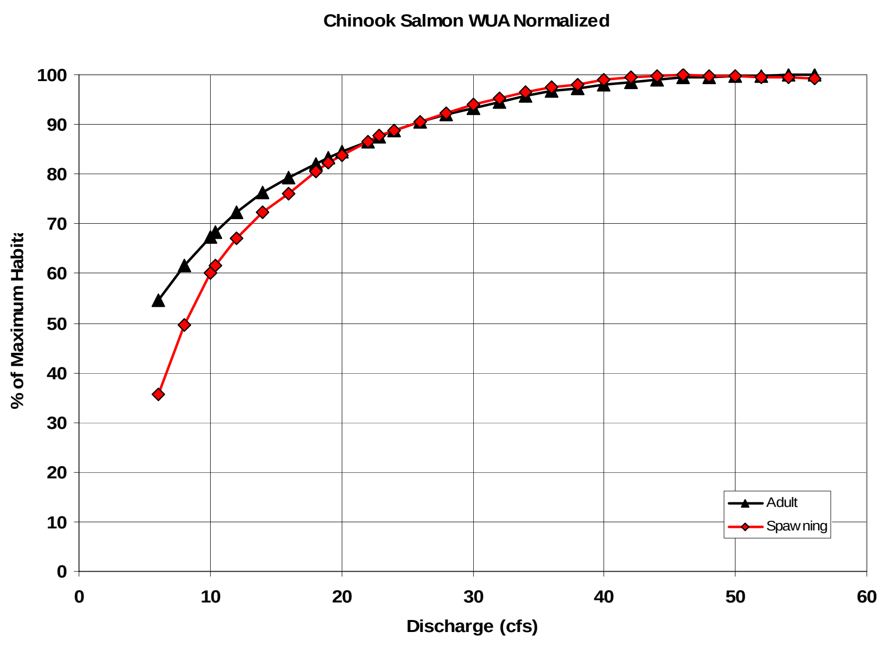

Figure 30. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in the Upper Lemhi River, Study Site 5.

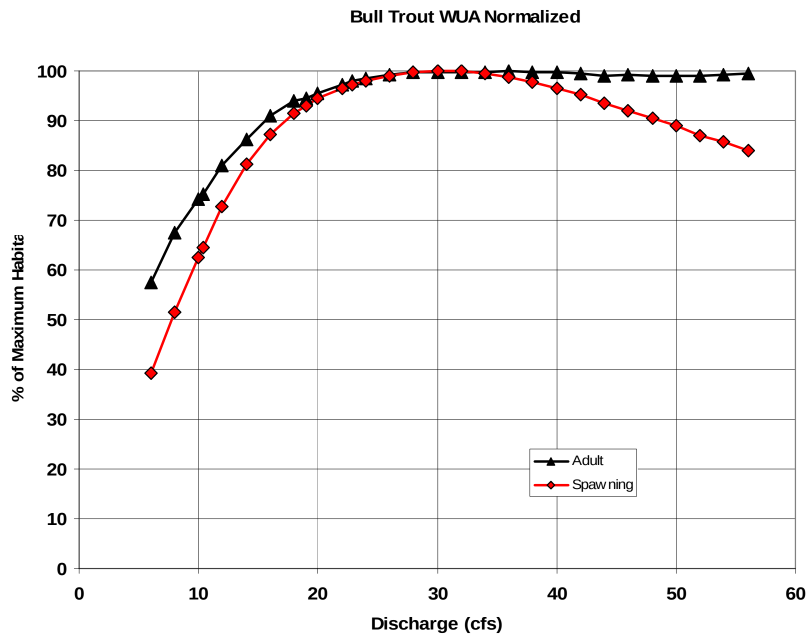

Figure 31. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in the Upper Lemhi River, Study Site 5.

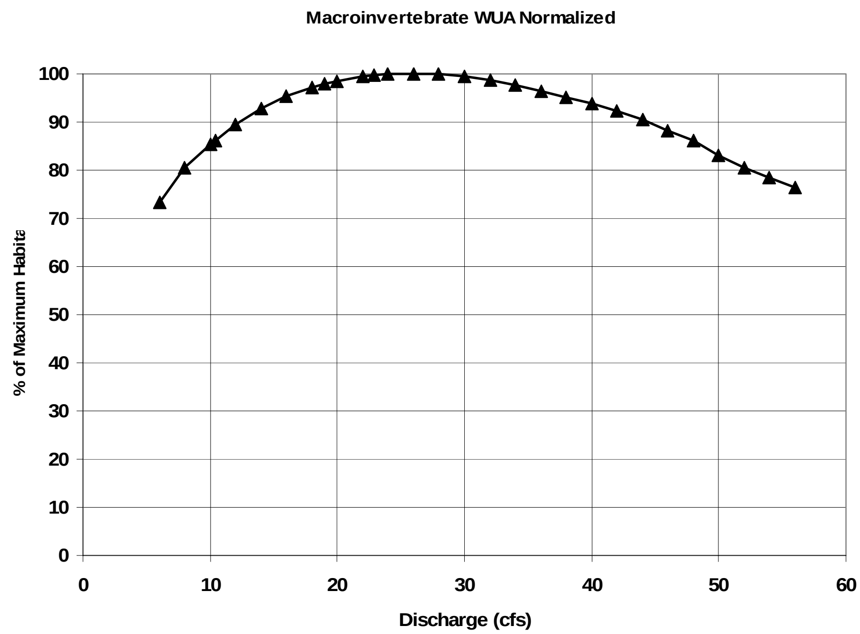

Figure 32. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in the Upper Lemhi River, Study Site 5.

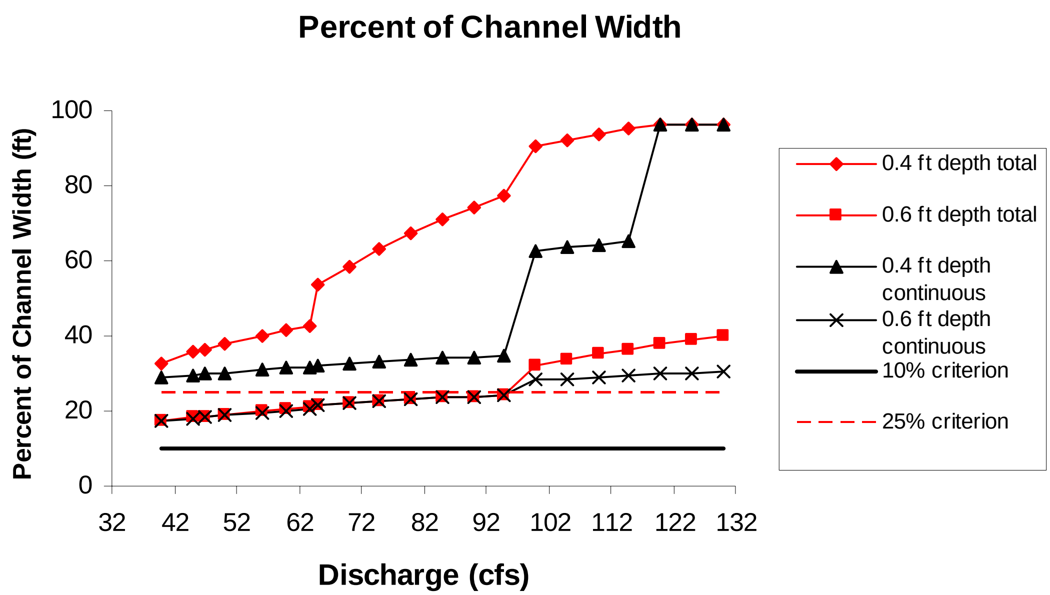

Figure 33. Total and contiguous widths at depths greater than passage criteria at a riffle transect on the Upper Lemhi River, Study Site 1.

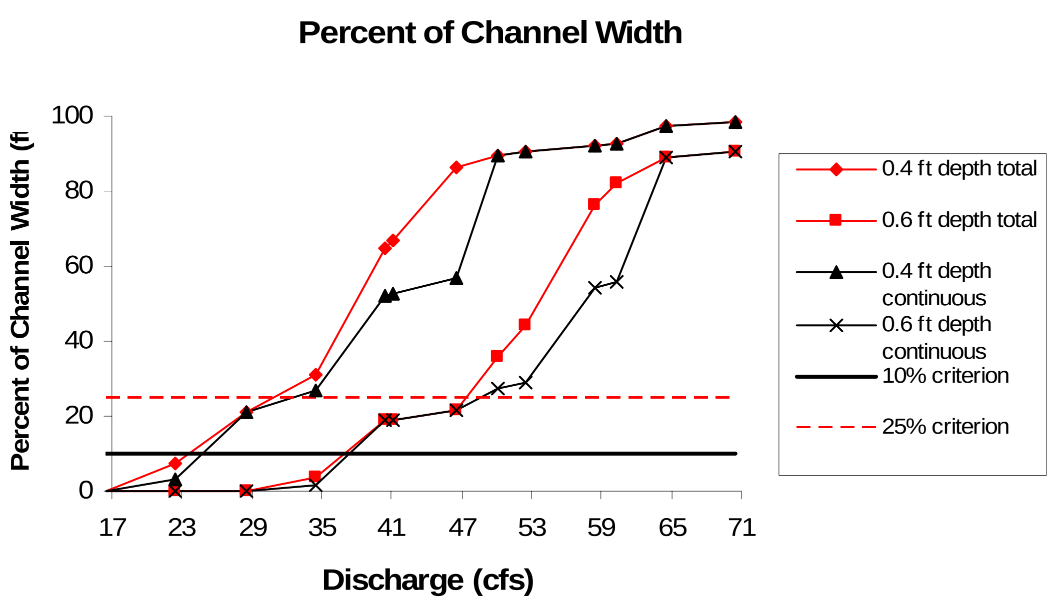

Figure 34. Total and contiguous widths at depths greater than passage criteria at a riffle transect on the Upper Lemhi River, Study Site 2.

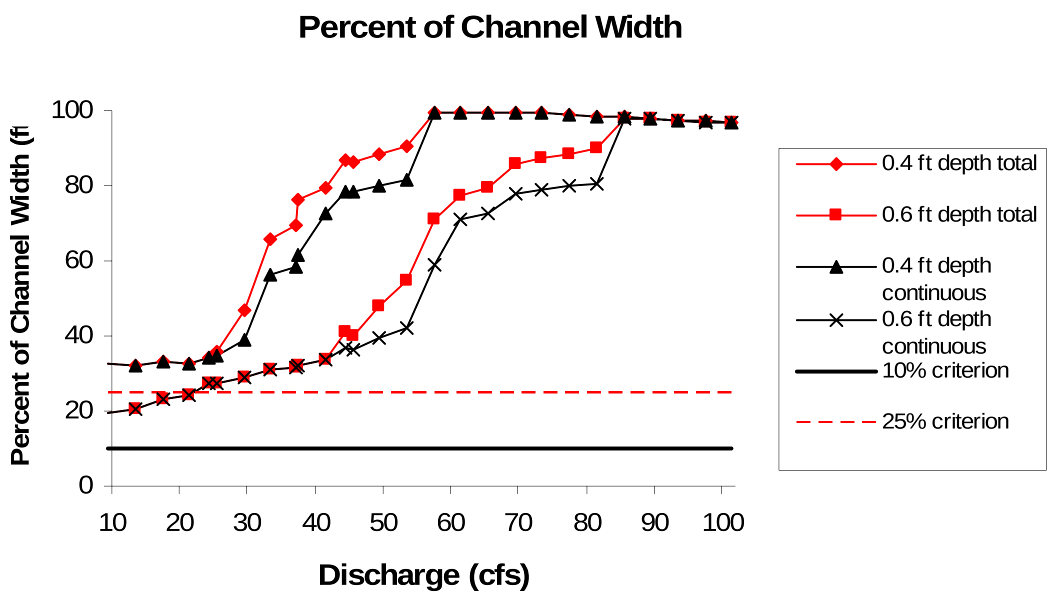

Figure 35. Total and contiguous widths at depths greater than passage criteria at a riffle transect on the Upper Lemhi River, Study Site 3.

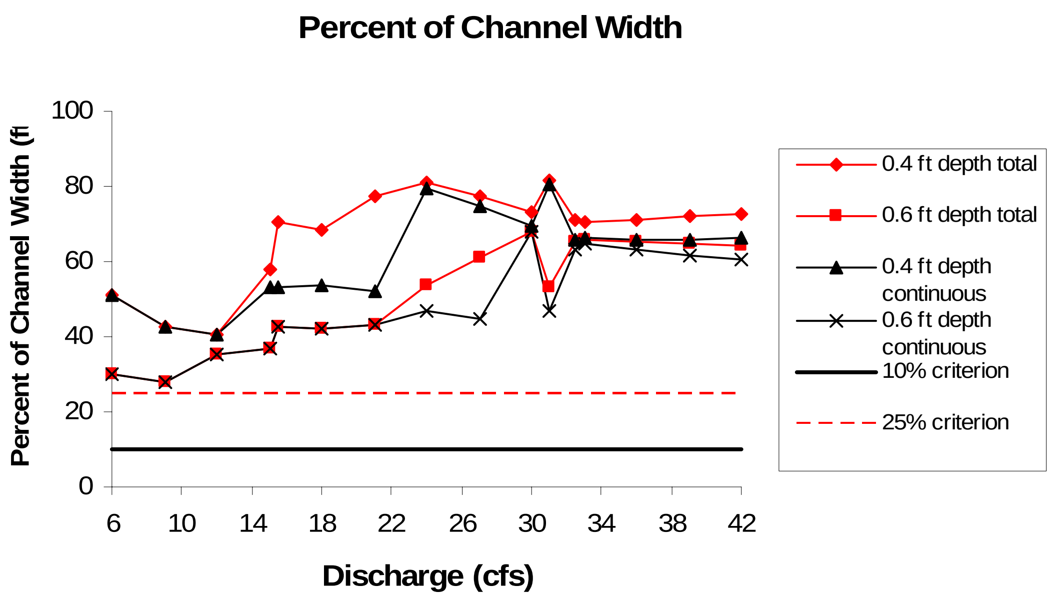

Figure 36. Total and contiguous widths at depths greater than passage criteria at a riffle transect on the Upper Lemhi River, Study Site 4.

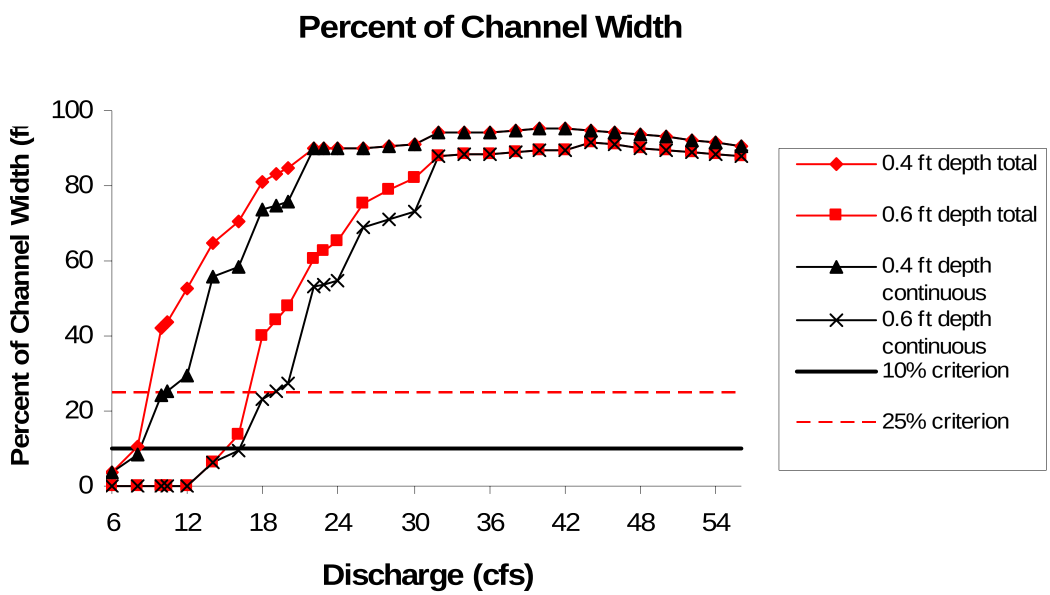

Figure 37. Total and contiguous widths at depths greater than passage criteria at a riffle transect on the Upper Lemhi River, Study Site 5.

Table 15. Habitat modeling summary on upper Lemhi River.

Life Stage	Discharge (cfs) required for optimum weighted usable area (WUA)				Discharge (cfs) required for adult salmonid passage using 0.6 foot depth criterion[1]	
	Steelhead	Chinook salmon	Bull trout	Macroinvert	>25% of total channel width	>10% of contiguous channel width
Study Site 1				47.0		
Spawning	100.0	100.0	95.0		100	<40
Adult	105.0	105.0	>130.0			
Study Site 2				64.5		
Spawning	>70.5	>70.5	64.5		50	40
Adult	>70.5	>70.5	>70.5			
Study Site 3				44.4		
Spawning	77.5	77.5	44.4		24	<9.5
Adult	69.5	69.5	53.5			
Study Site 4				18.0		
Spawning	>42.0	>42.0	>42.0		<6	<6
Adult	>42.0	>42.0	>42.0			
Study Site 5				26.0		
Spawning	46.0	46.0	28.0		18	18
Adult	>56.0	>56.0	28.0			

[1] Passage criteria taken from Thompson (1972) and Scott et al. (1981); both width criteria must be met to insure passage.

5.2 Canyon Creek

Measured discharges and dates of field surveys are summarized in Table 16. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference site in Canyon Creek. In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, these conditions typically occur during the summer irrigation season with diversions. Study site 1 was completely dewatered during the July 20, 2005 site visit (see Appendix A for photo).

Graphical representations of final normalized WUA versus discharge relationships are presented in Figures 38-57 for each site. No spawning habitat was available at any flow at Study Site 1 due to lack of suitable substrates (Figures 38-40). Passage flow results for total and contiguous widths at depths greater than the passage criteria (Table 12) are illustrated in Figures 58-62. Summary results, including flows required for optimal WUAs and flows needed to meet the 0.6 feet deep passage criteria are presented in Table 17 and reflect differences in stream channel hydraulics among study sites. The lack of higher calibration streamflows for some sites (e.g., Study Sites 2 and 3) limited model performance and prevented simulation of higher discharges, resulting in many ">" values in Table 17.

Table 16. Discharges measured from highest to lowest at Canyon Creek study sites during field surveys in 2005.

Stream Site	Discharge (cfs)	Survey Dates
Study Site 1	11.9 cfs	March 16
	5.8 cfs	June 07
	2.9 cfs	September 13
Study Site 2	3.9 cfs	March 17
	3.5 cfs	June 07
	1.0 cfs	July 19
Study Site 3	7.9 cfs	June 10
	6.0 cfs	September 14
	0.8 cfs	July 20
Study Site 4	12.0 cfs	June 10
	7.2 cfs	July 21
	6.6 cfs	September 15
Study Site 5 (Reference)	18.8 cfs	June 09
	8.2 cfs	July 21
	5.4 cfs	September 15

Examination of cross-sectional profiles of study site transects (Appendix C) showed a narrower stream channel in the lower reaches (e.g., Study Sites 1 and 2) of Canyon Creek than the upstream reaches (e.g., Study Site 5). At any given flow, more wetted area occurred at Study Site 5 than sites 1 and 2. For example, at about 3 cfs, 9,127 ft^2 of wetted area per linear 1,000 ft of stream occurred at Study Site 2. This compared with about 12,538 ft^2 of wetted area per 1,000 ft of stream at Study Site 5 (Appendix F).

Flows that met the 0.6 depth adult passage criteria ranged from 1 cfs at Study Site 1 to 13 cfs at Study Site 5.

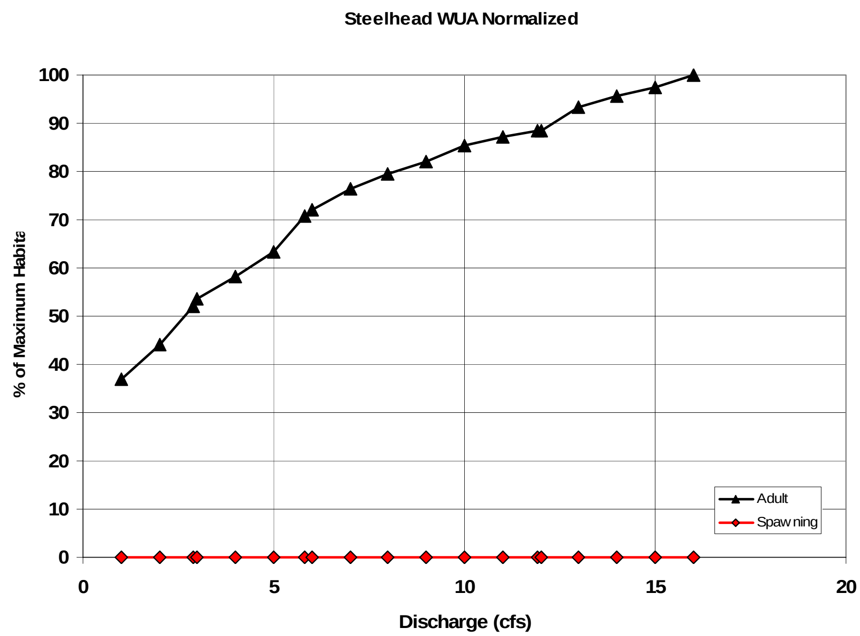

Figure 38. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Canyon Creek, Study Site 1.

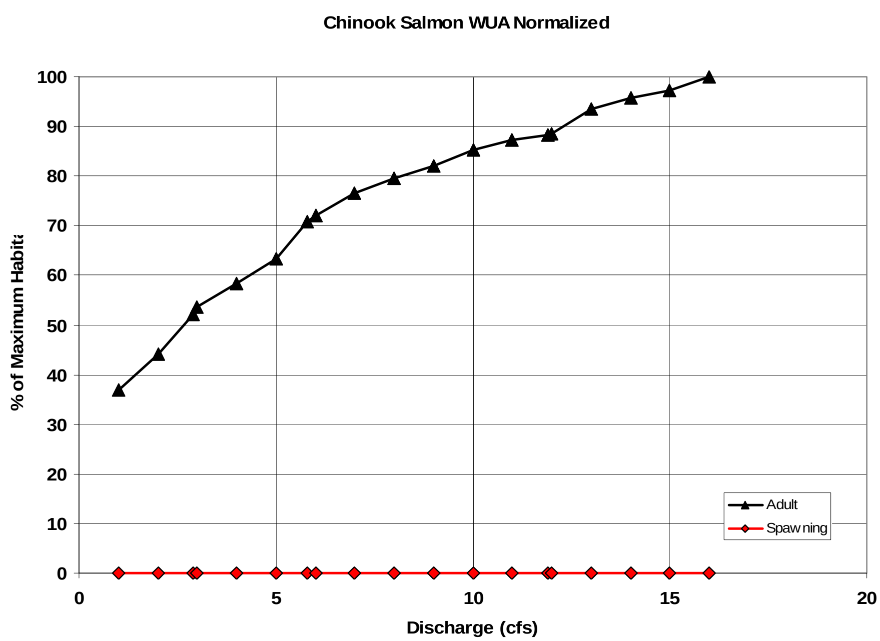

Figure 39. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Canyon Creek, Study Site 1.

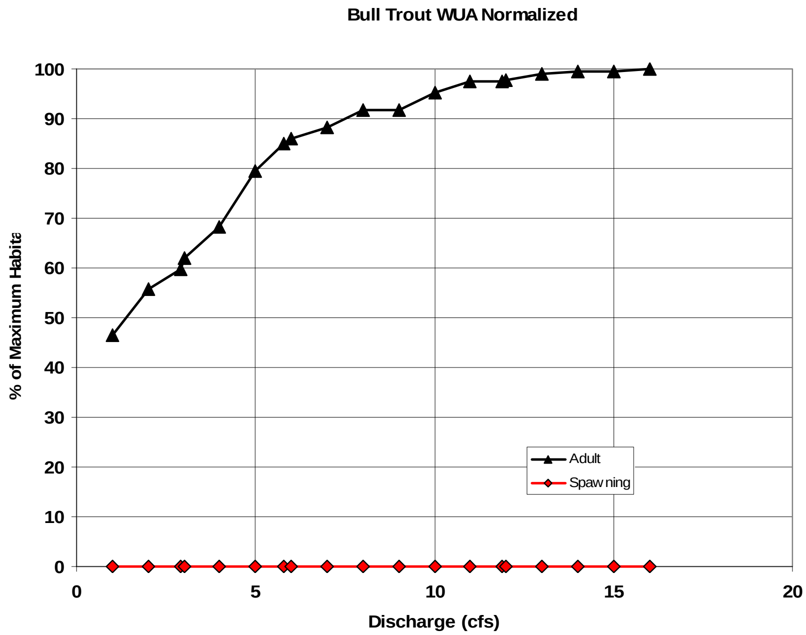

Figure 40. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Canyon Creek, Study Site 1.

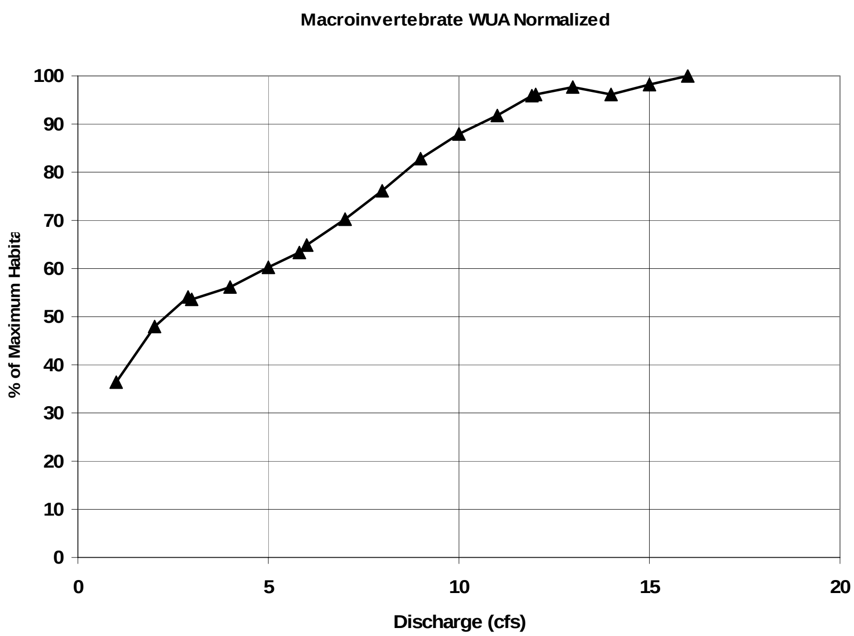

Figure 41. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Canyon Creek, Study Site 1.

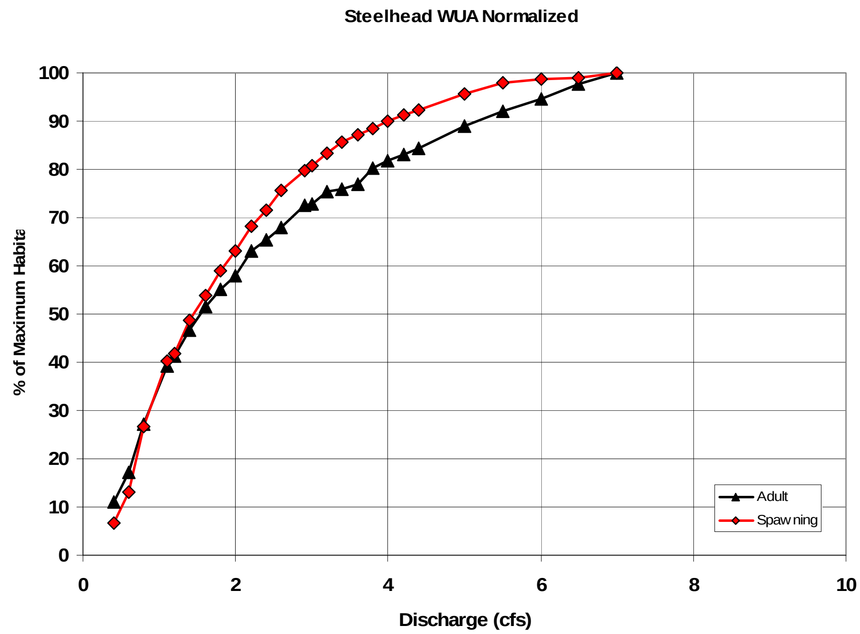

Figure 42. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Canyon Creek, Study Site 2.

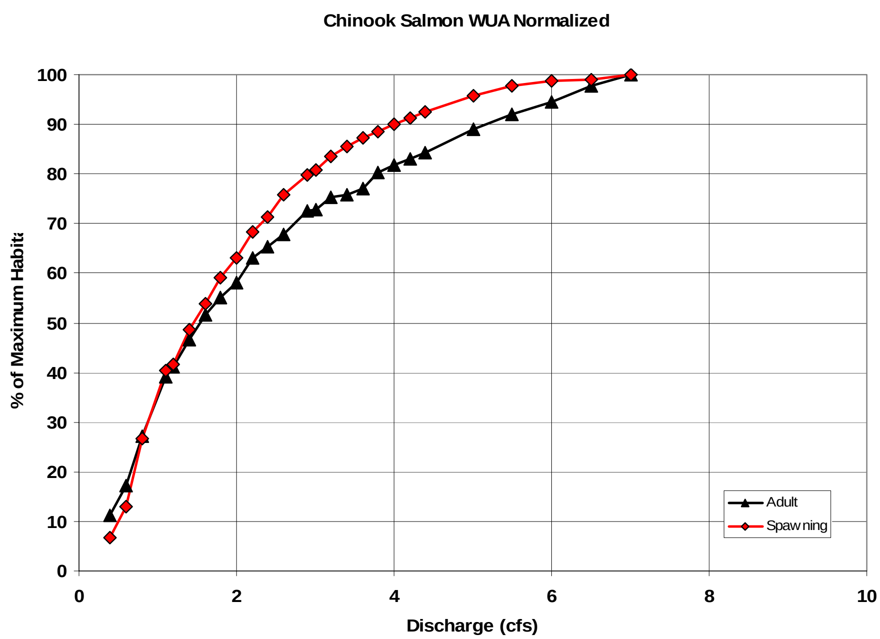

Figure 43. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Canyon Creek, Study Site 2.

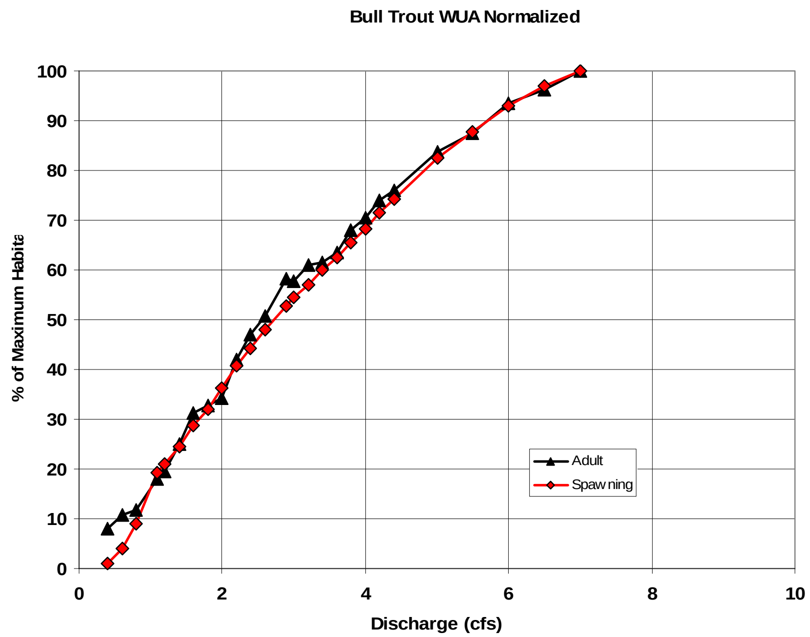

Figure 44. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Canyon Creek, Study Site 2.

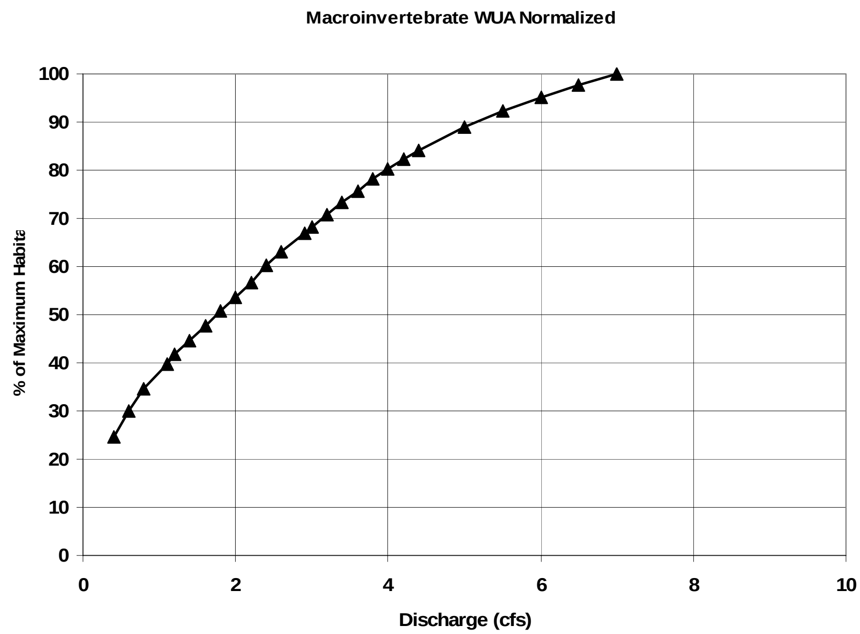

Figure 45. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Canyon Creek, Study Site 2.

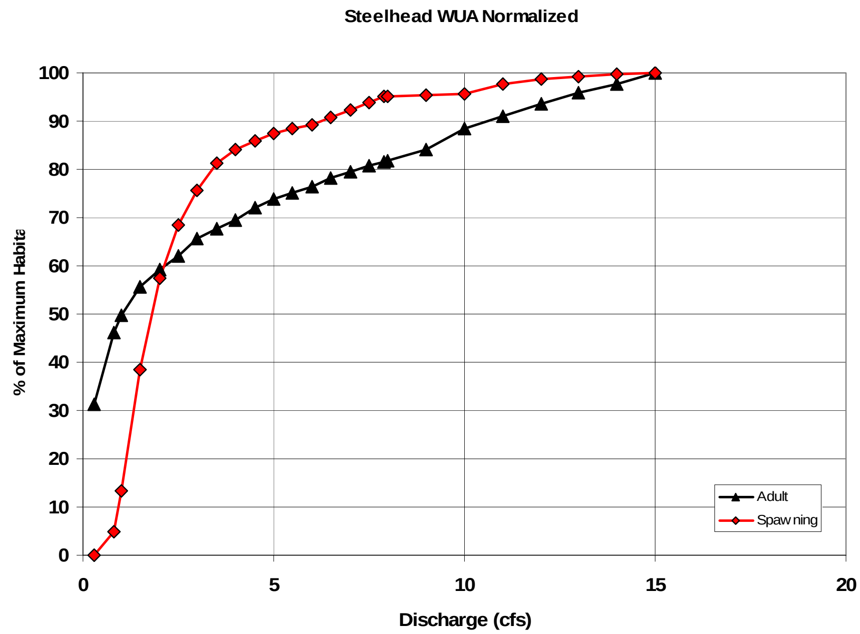

Figure 46. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Canyon Creek, Study Site 3.

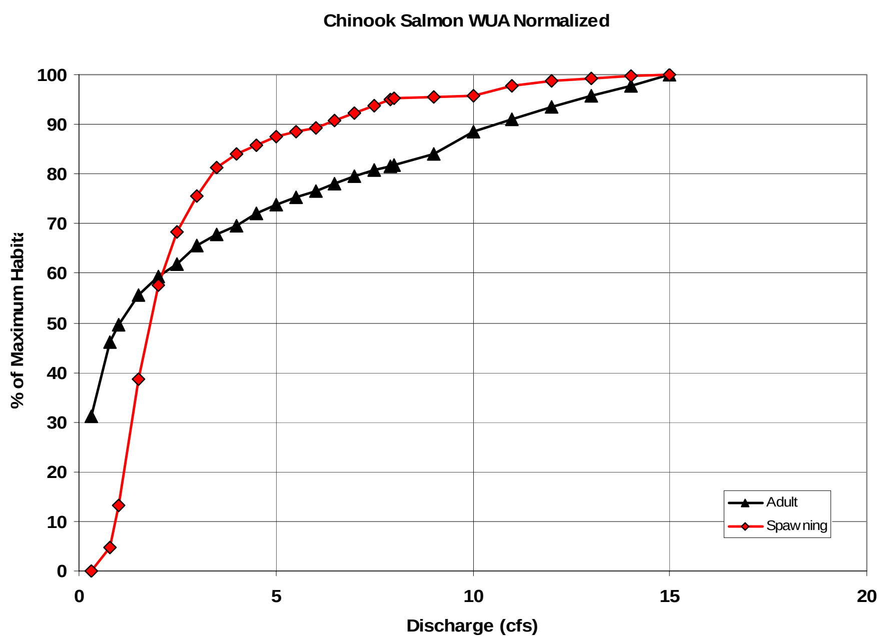

Figure 47. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Canyon Creek, Study Site 3.

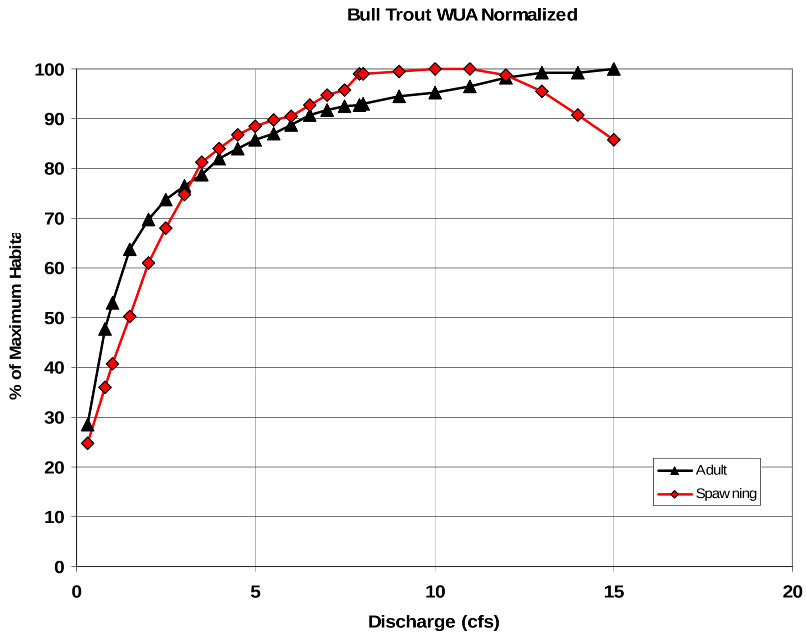

Figure 48. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Canyon, Study Site 3.

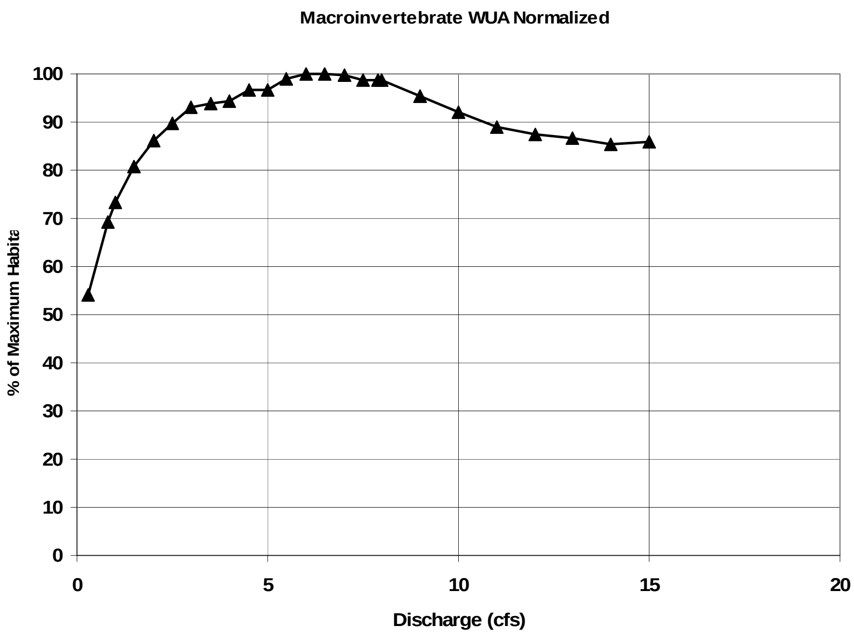

Figure 49. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Canyon, Study Site 3.

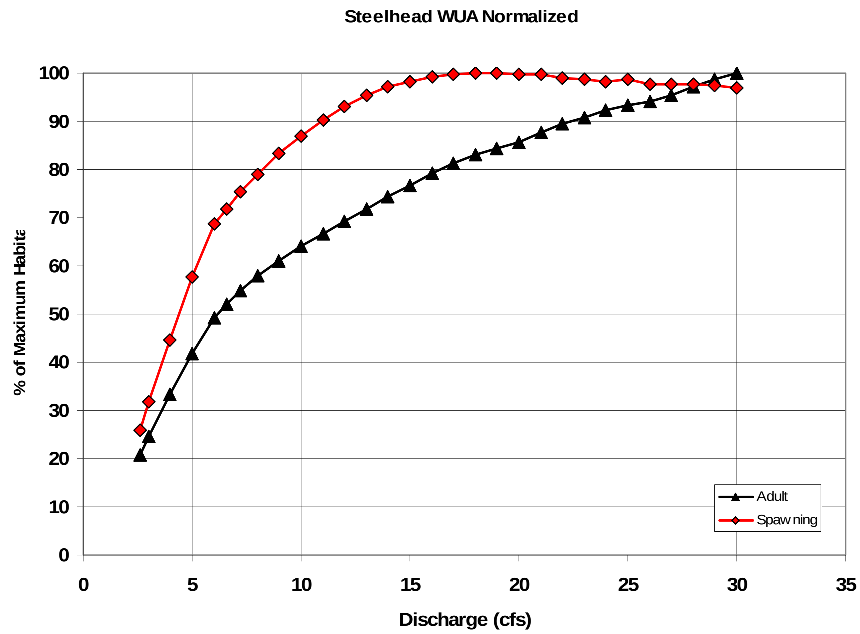

Figure 50. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Canyon Creek, Study Site 4.

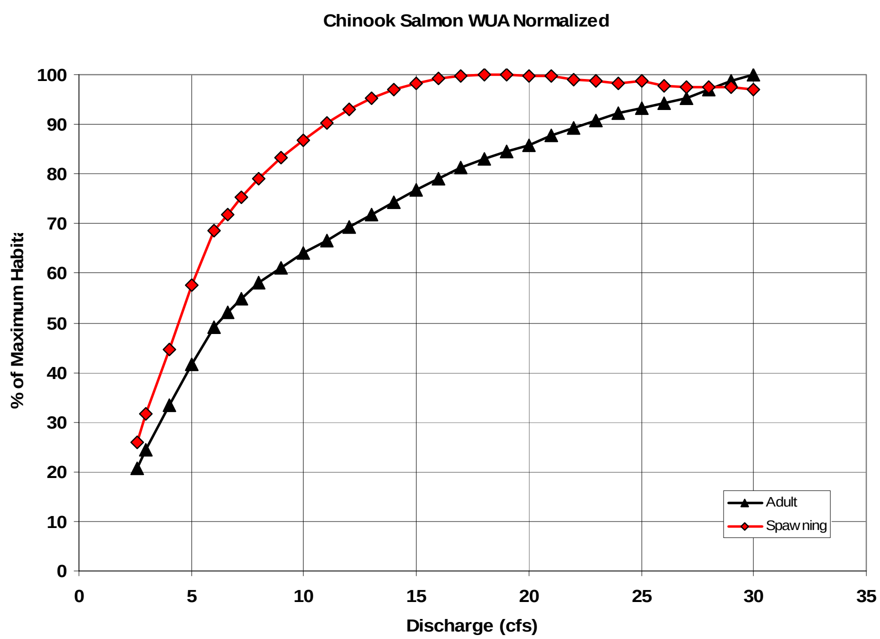

Figure 51. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Canyon Creek, Study Site 4.

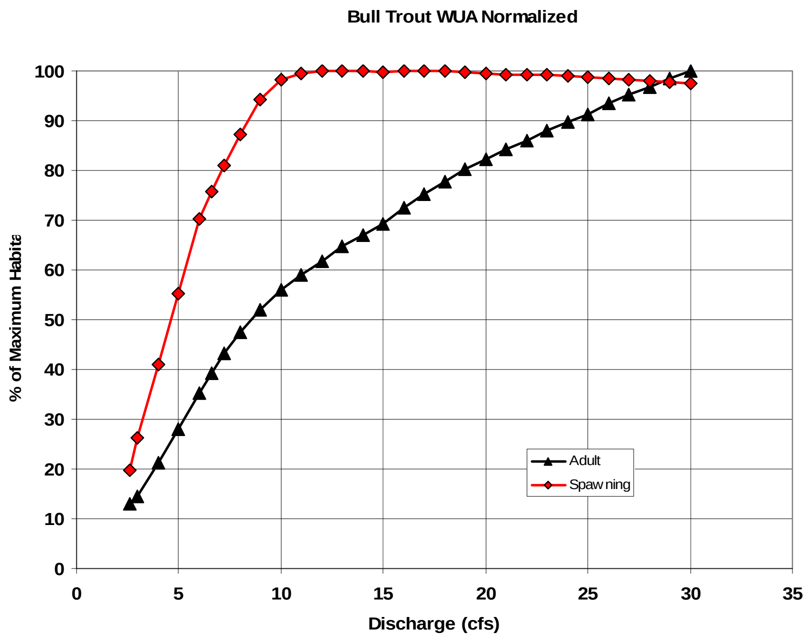

Figure 52. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Canyon Creek, Study Site 4.

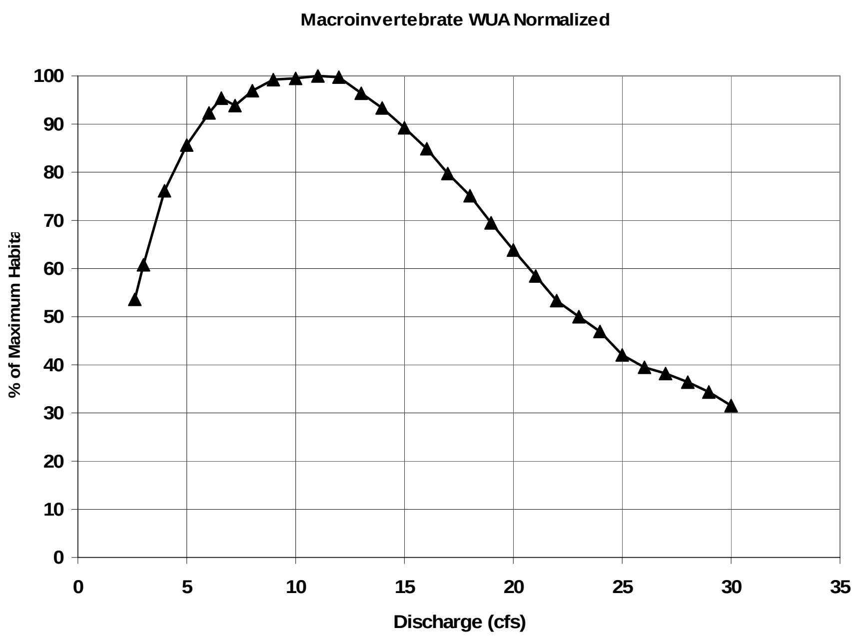

Figure 53. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Canyon Creek, Study Site 4.

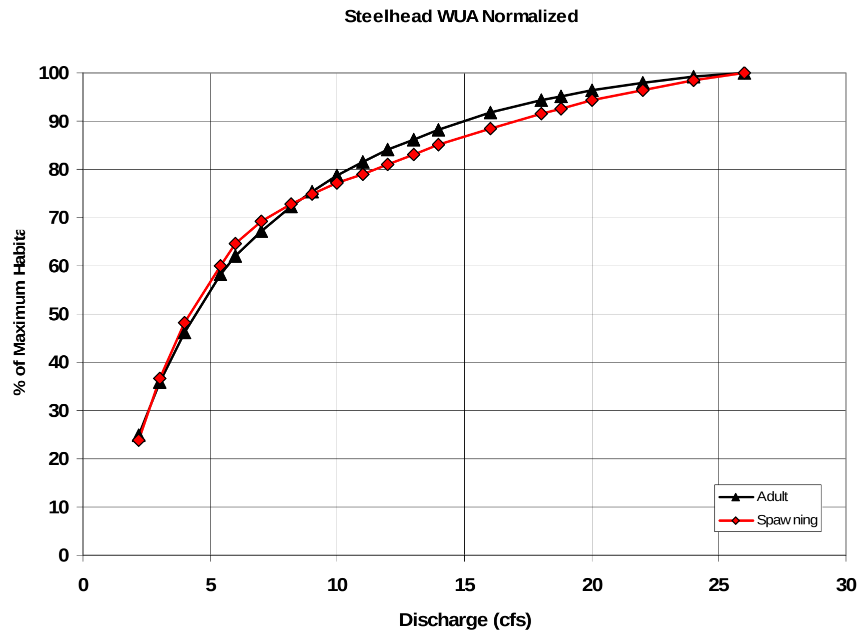

Figure 54. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Canyon Creek, Reference Site.

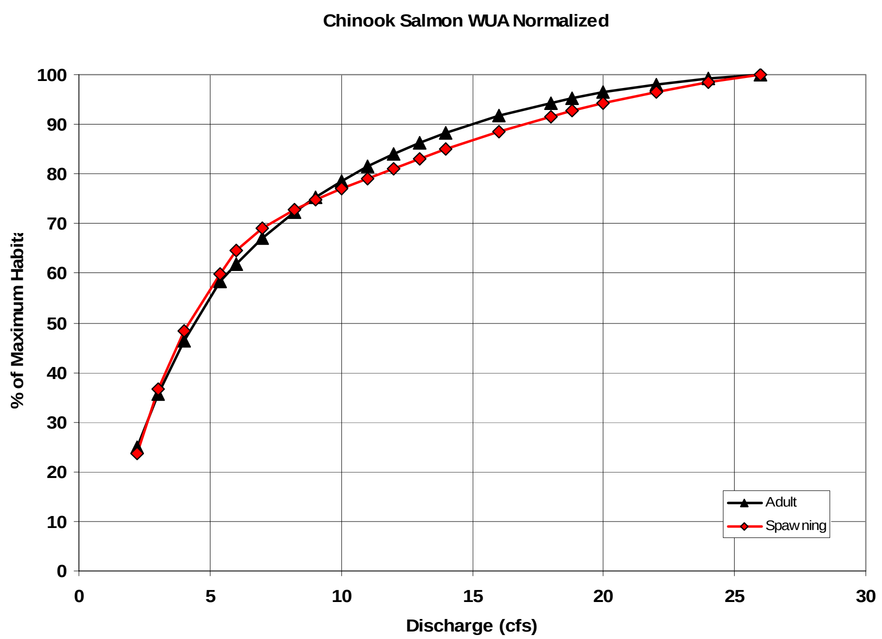

Figure 55. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Canyon Creek, Reference Site.

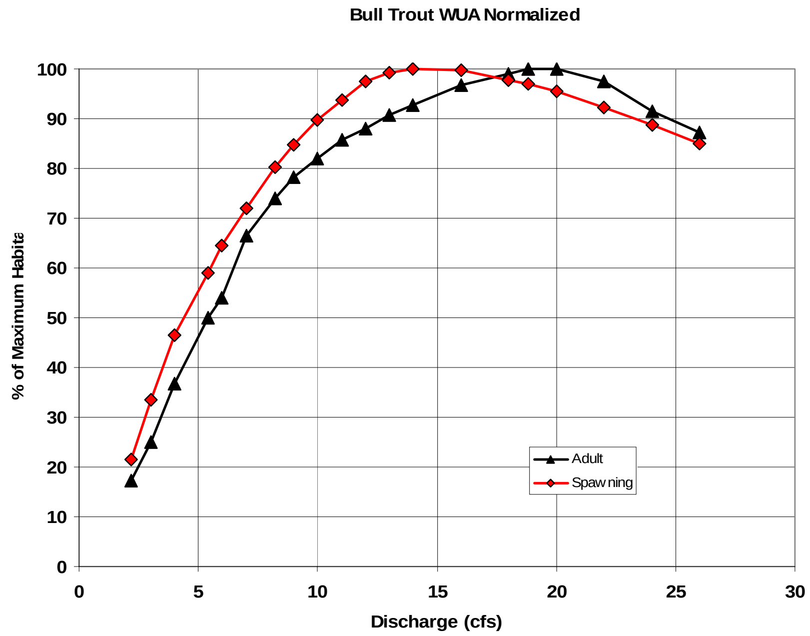

Figure 56. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Canyon Creek, Reference Site.

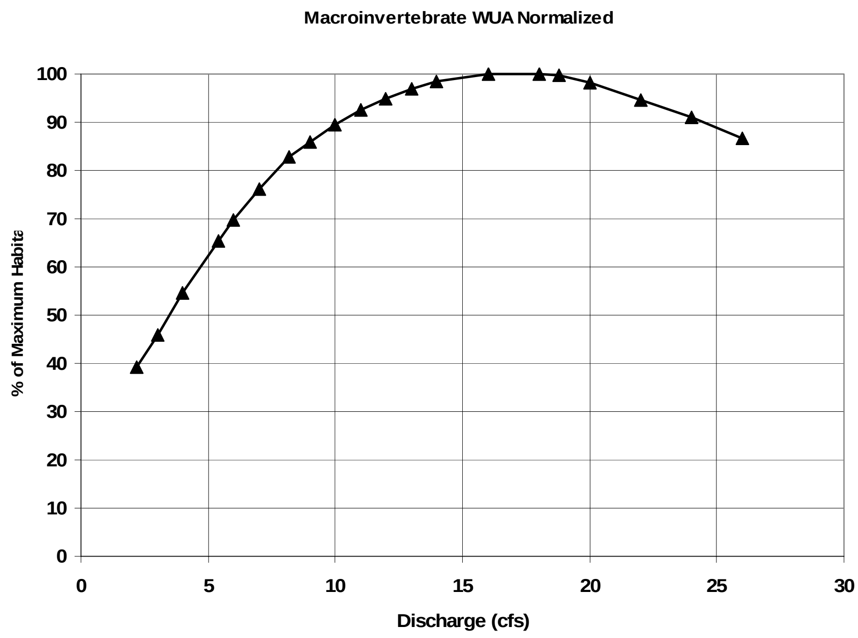

Figure 57. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Canyon Creek, Reference Site.

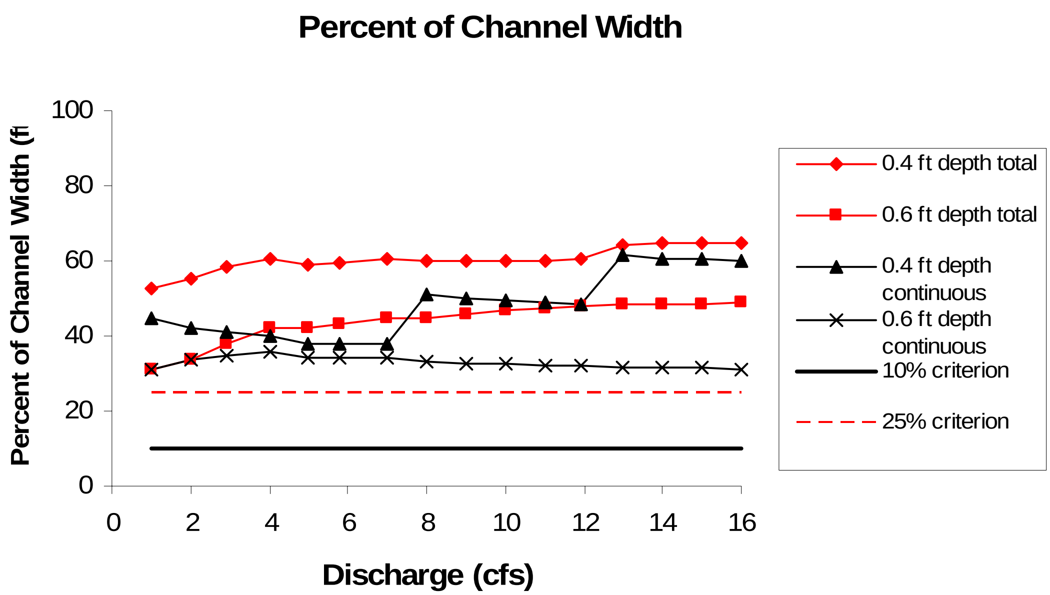

Figure 58. Total and contiguous widths at depths greater than passage criteria at a riffle transect on Canyon Creek, Study Site 1.

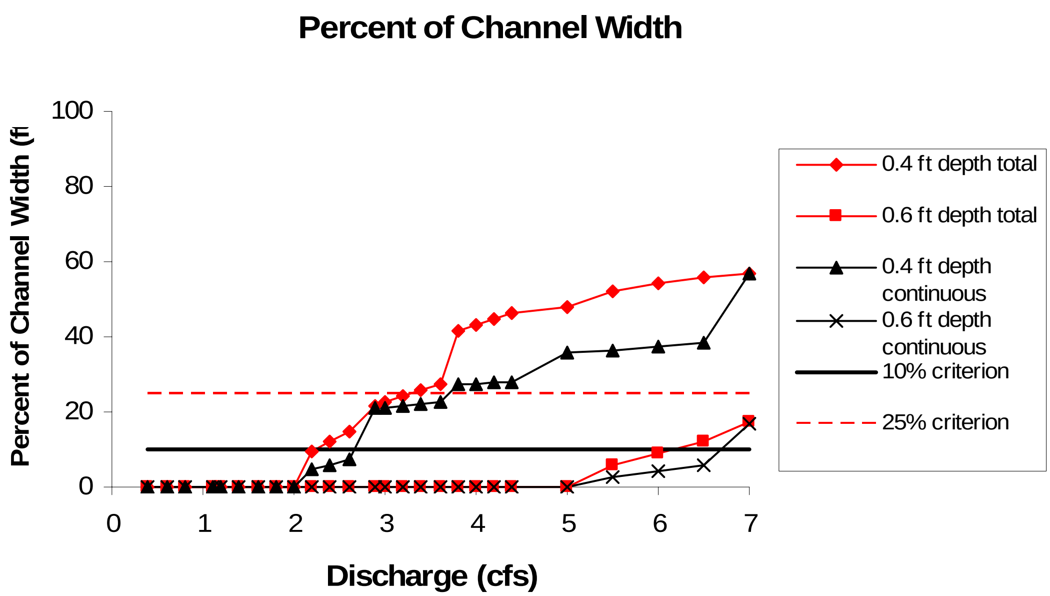

Figure 59. Total and contiguous widths at depths greater than passage criteria at a shallow transect on Canyon Creek, Study Site 2.

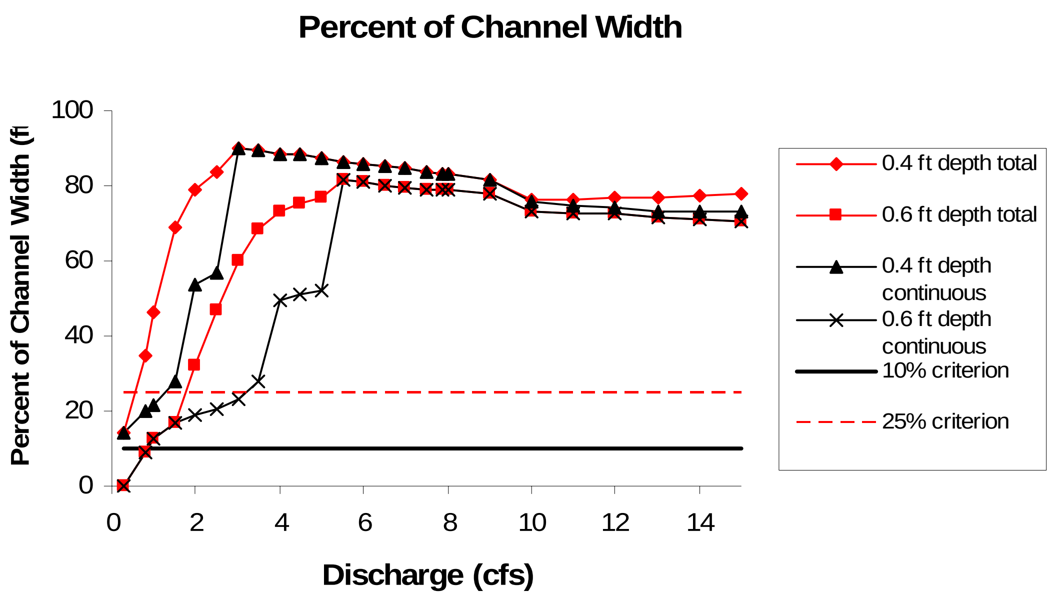

Figure 60. Total and contiguous widths at depths greater than passage criteria at a riffle transect on Canyon Creek, Study Site 3.

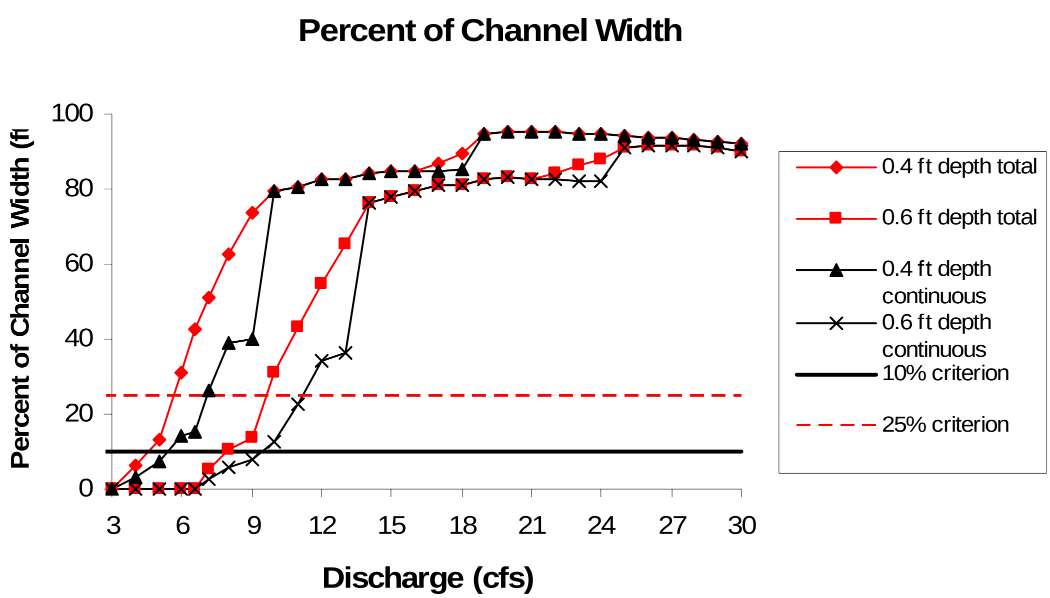

Figure 61. Total and contiguous widths at depths greater than passage criteria at a riffle transect on Canyon Creek, Study Site 4.

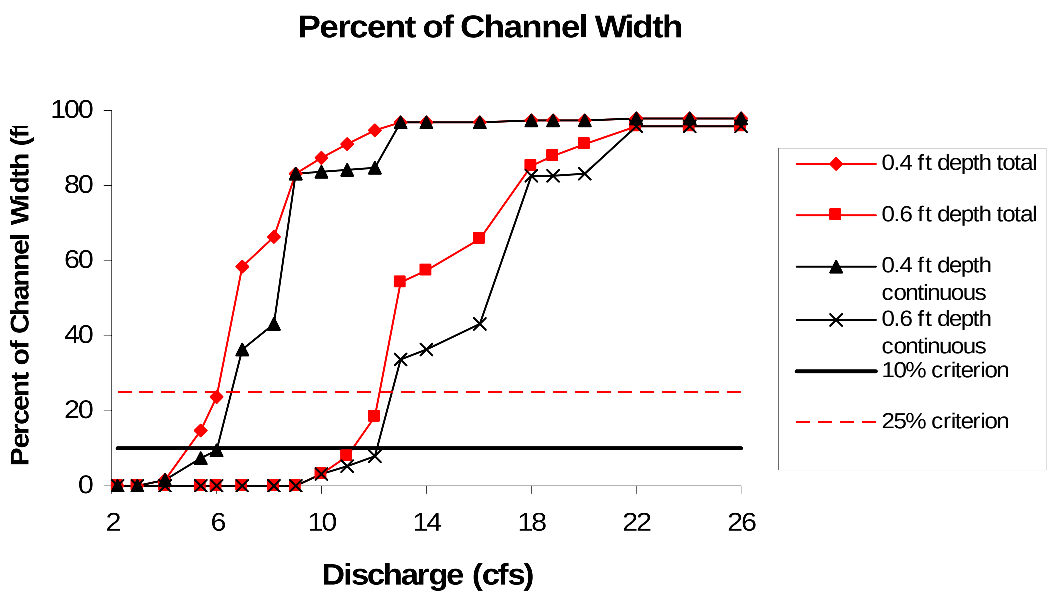

Figure 62. Total and contiguous widths at depths greater than passage criteria at a riffle transect on Canyon Creek, Reference Site.

Table 17. Habitat modeling summary on Canyon Creek.

Life Stage	Discharge (cfs) required for optimum weighted usable area (WUA)				Discharge (cfs) required for adult salmonid passage using 0.6 foot depth criterion[1]	
	Steelhead	Chinook salmon	Bull trout	Macroinvert	>25% of total channel width	>10% of contiguous channel width
Study Site 1				>16.0		
Spawning	0	0	0		1	1
Adult	>16.0	>16.0	>16.0			
Study Site 2				>7.0		
Spawning	>7.0	>7.0	>7.0		>7	7
Adult	>7.0	>7.0	>7.0			
Study Site 3				6.0		
Spawning	>15.0	>15.0	10.0		2	1
Adult	>15.0	>15.0	>15.0			
Study Site 4				11.0		
Spawning	18.0	18.0	12.0		10	10
Adult	>30.0	>30.0	>30.0			
Study Site 5 (Reference)				16.0		
Spawning	>26.0	>26.0	14.0		13	13
Adult	>26.0	>26.0	18.8			

[1] Passage criteria taken from Thompson (1972) and Scott et al. (1981); both width criteria must be met to insure passage.

5.4 Guidelines for Using Study Results

The results presented in this report summarize the hydrology, habitat, and temperature characteristics of the Upper Lemhi River and Canyon Creek during summer, 2005. PHABSIM analysis of the data collected and compiled for this study resulted in a series of graphs that illustrate relations between a dimensionless value (expressed as percent of maximum) called weighted usable area (WUA) and discharge (Figures 13-27 and 38-57). The highest point on each curve represents the discharge at which habitat is optimized for adult or spawning life stages for the fish species analyzed in this study (salmon, steelhead, and bull trout). These optimized values, summarized in Tables 15 and 17, rarely coincide among life stages for any one species. Furthermore, adult and spawning life stages for salmon, steelhead, and bull trout occur at different times of the year. These results imply that the optimum amount of water needed for adult and spawning life stages is not constant, but varies during the year. It is suggested to consider these implications during development of flow targets.

Also, WUA-discharge curves can be used to estimate how much habitat is gained or lost with incremental flow changes. In some cases, small flow changes can result in major habitat changes. WUA is an instantaneous representation of how much water it takes to create a certain amount of habitat. In general, it simply says that if there is “X” amount of flow present, that equates to “Y” amount of habitat. It is without reference to time or period of the year. WUA says nothing about how much water may or may not be present, and thus habitat, at any particular season of the year. Seasonal, monthly, daily flow regimes have to be applied to the instantaneous WUA curves to get an indication of how much habitat is actually present. The way to use that information is, if there is ”X” flow without flow restoration, that equates to “A” habitat, but “Y” amount of flow is added through restoration, that equates to “B” amount of habitat. Depending on the shape of the curve, that change in habitat from “A” to “B” may be an increase or a decrease.

Discharge estimates providing optimal WUA for juvenile salmonid lifestages are usually less than summer base flows, suggesting a disconnect between the models used and actual juvenile salmonid needs. Reasons for this may include: inability to accurately measure and/or quantify habitat parameters such as, flow velocity, cover, and substrate, at a scale that is meaningful for small fishes; inability to accurately quantify side channels, bank indentations, riparian wetlands, or other lateral habitats that are important for rearing juvenile salmonids; and inability to adequately incorporate temperature, or other water quality parameters, into the model. Thus, until juvenile habitat characterization can be improved, juvenile life stage will not be included in this study.

The selection of target flows should be based on a hierarchical system of highest priority life stage and species present for the month or period of concern, using the assumption that the priority life stage and species would require higher streamflows than other life stages and species. Table 13 provides some general guidelines for which life stage to assess. For small tributary streams of the Lemhi River sub-basin, one possible priority life stage ranking would be (from high to low): passage > spawning > adult > juvenile. Once the priority life stage and species are ranked, then each study site should be examined to determine streamflow and passage conditions for the time period of concern.

The mechanisms by which the various components are integrated and the relative importance they are assigned within the water management decision process is a matter of professional judgment and beyond the scope of this study. However, it seems reasonable that providing connectivity to the Lemhi River by providing enough water for adult fish passage would be a management priority (Table 13). Water depths are an additional consideration for times of the year when the adult life stage is present. Choice of target flows should not be reduced to the point that stream depth is reduced below the level needed for fish passage (Tables 15 and 17), depending on available water supply. In addition, providing streamflow for optimum protection of riffle habitat will ensure healthy invertebrate communities, which are a major food source for fish.

The actual habitat experienced by fish in any river depends on the flow regime of the river. The development of habitat conditions over a period of time is an integral part of the comparison of flow regimes and developing flow recommendations. Habitat time series analysis involves interfacing a time series of streamflow data with the functional relationship between streamflow and habitat (WUA) (Bovee et al. 1998). This computational process is done for each flow regime alternative and life stage. Flow and habitat duration statistics are developed that allow a direct comparison of the changes that occur in both flow and habitat under a range of conditions. The decision point in PHABSIM is a comparison of flow regimes. In streams with more than one species of interest, the results should be reviewed to ensure recommended flows balance the needs of all species.

The natural hydrograph also needs to be considered when developing flow targets. In drought years, summer flows that provide maximum possible habitat may not be attainable because of the hydrologic limits on the stream. Also, PHABSIM does not estimate flow or habitat needs of downstream migrants or spring runoff conditions necessary for maintenance of channel morphology or riparian zone functions. Arthaud et al. (2001) have shown that downstream migrant survival can significantly increase with discharge. Thus, high spring flows that mimic the natural hydrograph should be a consideration in managing streamflows outside PHABSIM analysis.

Finally, it should be noted that PHABSIM was designed as a tool to provide science-based linkage between biology and river hydraulics with results to be used in negotiations or mediated settlements (Arthaud et al. 2001).

6.0 ACKNOWLEDGMENTS

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APPENDIX A – REACH AND STUDY SITE DESCRIPTIONS AND PHOTOS

Upper Lemhi River, Reach 1: This reach was the most downstream segment in the upper Lemhi River. It was characterized mainly by low gradient riffles, glides, and pools (photos taken July 19 @ 47 cfs).

Study Site 1 – Most downstream study site (N44˚43.773' W113˚25.959')

Transect 1 – riffle/passage (downstream transect)
Transect 2 – glide
Transect 3 – glide
Transect 4 – hydraulic control/riffle
Transect 5 – pool (most upstream transect)

Upper Lemhi River, Reach 2: This study site was located on private property, just downstream from a major diversion. It primarily consisted of riffles and glides (photos taken July 19 @ 41 cfs).

<u>Study Site 2 – (N44˚43.110’ W113˚24.831’)</u>

Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – pool
Transect 4 – riffle/passage
Transect 5 – riffle
Transect 6 – island/glide
Transect 7 – island/glide


T3
T2
T1


T4
T5
T6
T7

Upper Lemhi River, Reach 3: This reach was located between diversion L60 and an unnamed tributary (groundwater fed) that defined the upstream and downstream boundaries of reaches 2 and 4, respectively. The study site was located on private property, and was a mixture of riffle, pool, glide habitat types. Riparian vegetation is thick in areas, with willows dominant (photos taken July 20 @ 24 cfs).

<u>Study Site 3 – (N44˚41.899' W113˚22.247')</u>

Transect 1 – hydraulic control/ passage riffle
Transect 2 – pool
Transect 3 – pool
Transect 4 – glide
Transect 5 – riffle
Transect 6 – hydraulic control/glide
Transect 7 – pool
Transect 8 – riffle
Transect 9 – glide
Transect 10 – glide


T4
T5
T6
T7
T8


T9
T10

Upper Lemhi River, Reach 4: This study site for this reach is located on private property and represents a mixture of riffle, pool, and glide habitat types. The upper and lower boundaries of this reach are two tributaries. Riparian vegetation is thick in areas, with willows dominant (photos taken July 20 @ 16 cfs).

Study Site 4 – (N44˚41.594' W113˚22.065')

Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – pool
Transect 4 – pool
Transect 5 – riffle
Transect 6 – riffle
Transect 7 – glide

Upper Lemhi River, Reach 5: This reach was located on private property, between Canyon Creek (downstream) and Eighteenmile Creek (upstream) tributaries. Habitat types included a mixture of pools, glides, and riffles. Willows dominated riparian areas (photos taken July 21 @ 10 cfs).

<u>Study Site 5 – (N44˚41.356' W113˚21.882')</u>

Transect 1 – riffle/passage
Transect 2 – glide
Transect 3 – glide
Transect 4 – glide
Transect 5 – riffle
Transect 6 – glide
Transect 7 – hydraulic control
Transect 8 – pool


T1
T2


T4
T3


T6
T5


T7
T8

Canyon Creek, Reach 1: This reach extended from the confluence with the Lemhi River upstream to the first major diversion (White Fish Ditch). The stream channel was very narrow, consisting of primarily glides and riffles. The discharge in this reach depended heavily upon water taken from the White Fish Ditch diversion (photo taken June 7 @ 6 cfs).

<u>Study Site 1 – Most downstream site (N44˚41.459' W113˚21.787')</u>

Transect 1 – hydraulic control (most downstream transect)
Transect 2 – pool
Transect 3 – glide
Transect 4 – riffle/passage (most upstream transect)

September 13, 2005 (3 cfs):

July 20, 2005 (dry):

Canyon Creek, Reach 2: This reach was located between White Fish Ditch diversion (downstream) and the next major diversion upstream. The discharge in this reach depended heavily upon water taken from the upper diversion (photos taken July 19 @ 1.0 cfs).

Study Site 2 – (N44˚41.474' W113˚21.473')

Transect 1 – riffle/passage
Transect 2 – glide
Transect 3 – hydraulic control
Transect 4 – pool

T1

Canyon Creek, Reach 3: This reach was located between two major diversions and had dense riparian vegetation dominated by willows. Woody debris was abundant in the stream channel and habitat types were dominated by glides (photos taken July 20 @ 0.8 cfs).

<u>Study Site 3 – (N44˚41.821' W113˚20.141')</u>

Transect 1 – glide
Transect 2 – glide
Transect 3 – glide

T1

T2

T3

Canyon Creek, Reach 4: This reach represented the stream between the next two major diversions. This reach had excellent riparian vegetation, and good quality cover around the transects. Riparian vegetation was dominated by willows (photos taken July 21 @ 7 cfs).

Study Site 4 – (N44˚41.883' W113˚19.903')

Transect 1 – glide
Transect 2 – hydraulic control
Transect 3 – pool
Transect 4 – glide
Transect 5 – riffle
Transect 6 – riffle
Transect 7 – glide (most upstream transect)

Canyon Creek, Reach 5 (Reference): This reach represented the stream upstream from all major diversions. Excellent riparian vegetation was dominated by willows. Habitat types included a mixture of pools, riffles, and glides (photos taken July 21 @ 8 cfs).

Study Site 5 – (N44˚42.081' W113˚18.321')

Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – glide
Transect 4 – glide
Transect 5 – glide
Transect 6 – riffle
Transect 7 – riffle


T3
T2
T1


T4
T5
T6
T7

APPENDIX B – HABITAT MAPPING PROPORTIONS

Upper Lemhi River

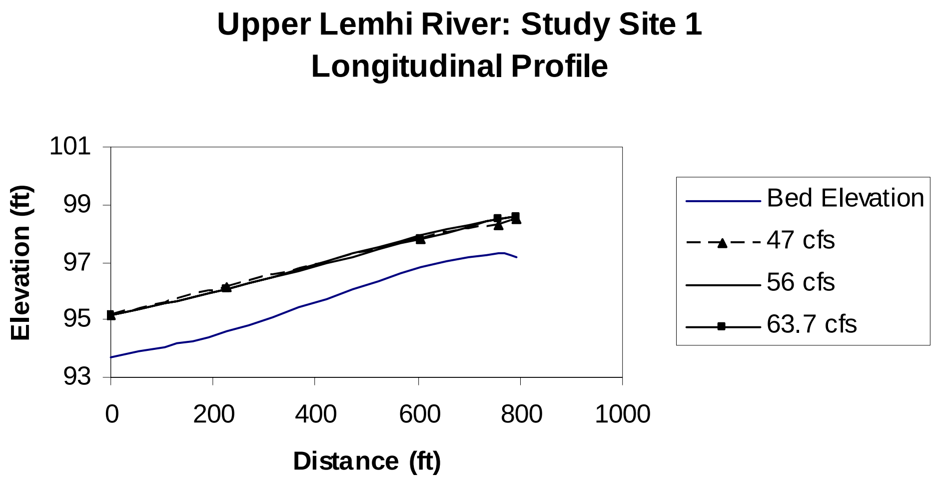
	Distance Mapped (feet)	Proportions (%)
Study Site 1		
Riffle	595	43.0
Glide	593	43.0
Pool	193	14.0
Total	1381	100
Study Site 2		
Riffle	421	34.4
Glide	620	50.7
Pool	183	14.9
Total	1224	100
Study Site 3		
Riffle	1336	51.4
Glide	843	32.4
Pool	421	16.2
Total	2600	100
Study Site 4		
Riffle	2163	70.6
Glide	600	19.6
Pool	300	9.8
Total	3063	100
Study Site 5		
Riffle	2900	57.8
Glide	1561	31.1
Pool	556	11.1
Total	5017	100

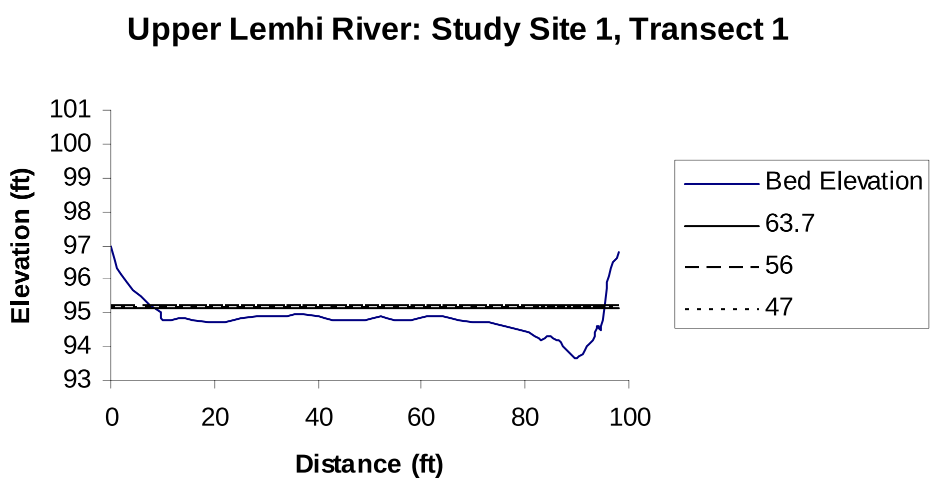
Canyon Creek

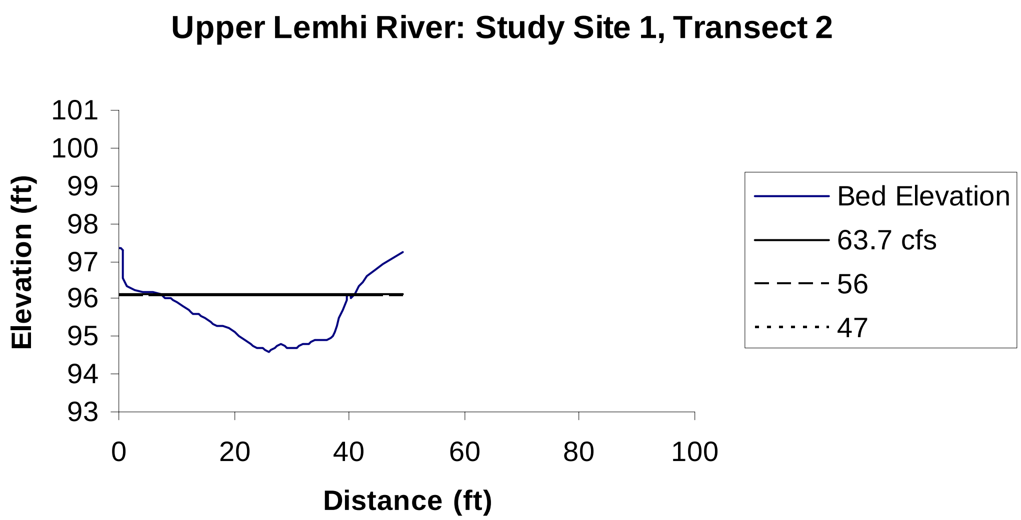
	Distance Mapped (feet)	Proportions (%)
Study Site 1		
Riffle	333	31.0
Glide	687	64.0
Pool	56	5.0
Total	1076	100
Study Site 2		
Riffle	333	31.0
Glide	687	64.0
Pool	56	5.0
Total	1076	100
Study Site 3		
Riffle	115	11.5
Glide	886	88.5
Pool	0	0.0
Total	1001	100
Study Site 4		
Riffle	331	29.9
Glide	729	65.7
Pool	49	4.4
Total	1109	100
Study Site 5		
Riffle	642	67.2
Glide	271	28.4
Pool	42	4.4
Total	955	100

APPENDIX C – CROSS-SECTIONAL PROFILES AND MEASURED WATER SURFACE ELEVATIONS

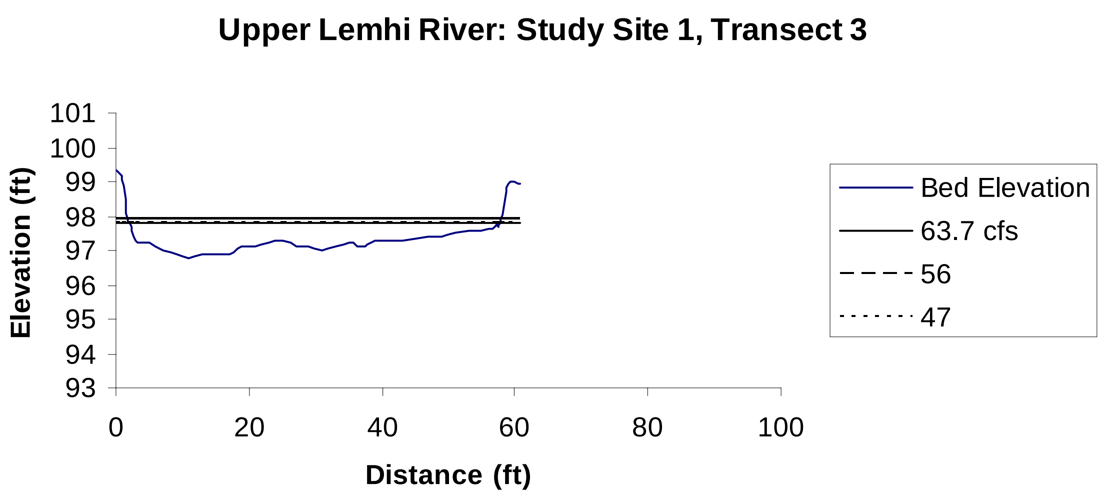
Upper Lemhi River, Site 1



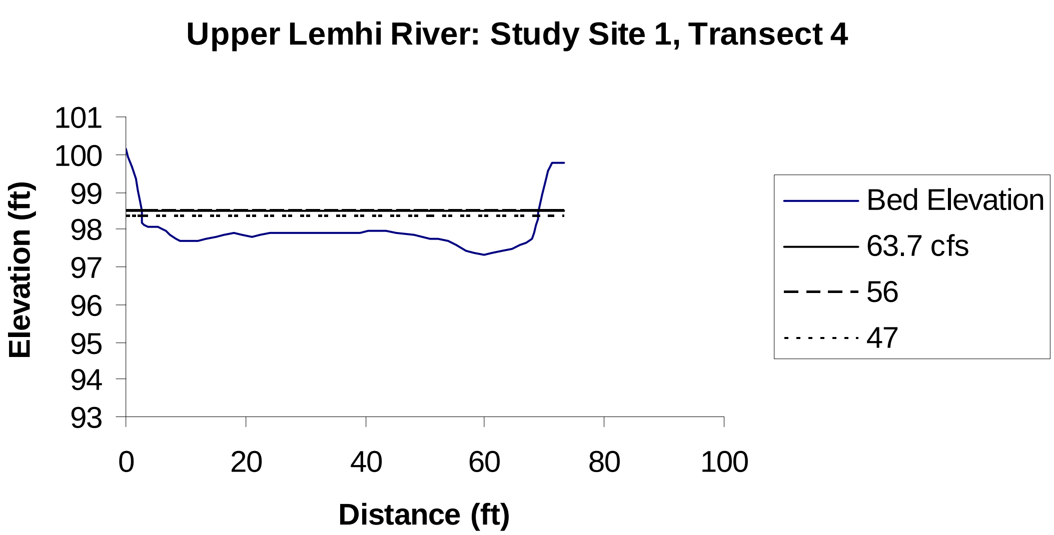




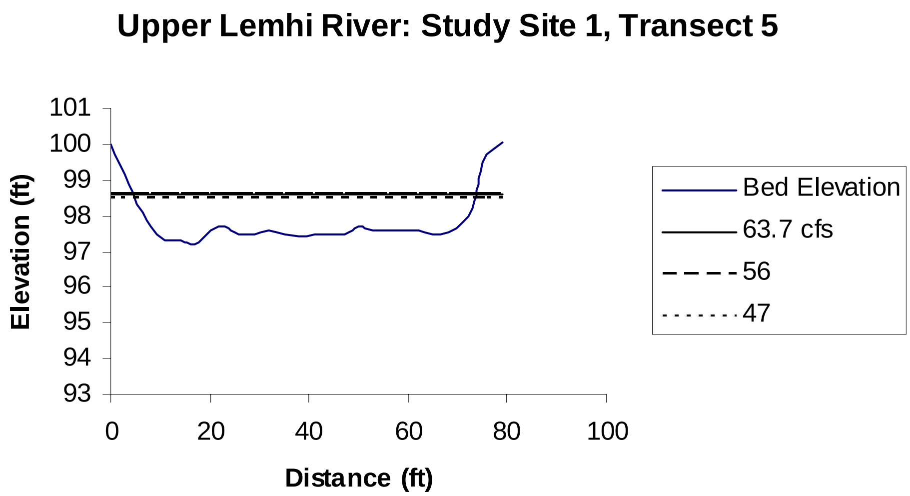
Upper Lemhi River: Study Site 1, Transect 2
Elevation (ft)
101
100
99
98
97
96
95
94
93
0
20
40
60
80
100
Distance (ft)
Bed Elevation
63.7 cfs
56
47



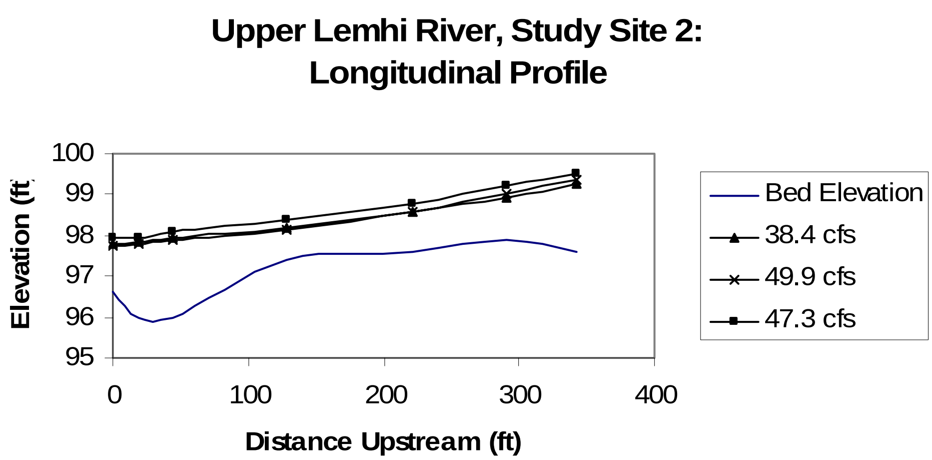
Upper Lemhi River: Study Site 1, Transect 3
Elevation (ft)
101
100
99
98
97
96
95
94
93
0
20
40
60
80
100
Distance (ft)
Bed Elevation
63.7 cfs
56
47

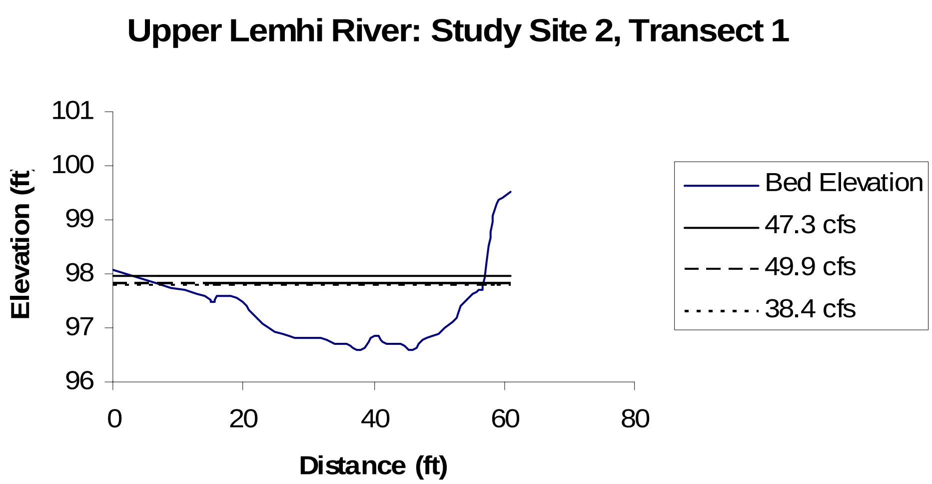


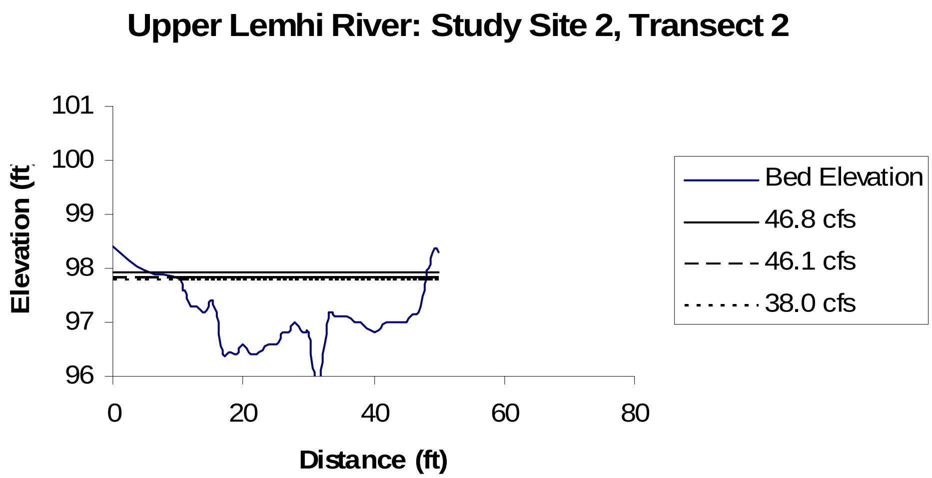
Upper Lemhi River: Study Site 1, Transect 4
Elevation (ft)
101
100
99
98
97
96
95
94
93
0
20
40
60
80
100
Distance (ft)
Bed Elevation
63.7 cfs
56
47

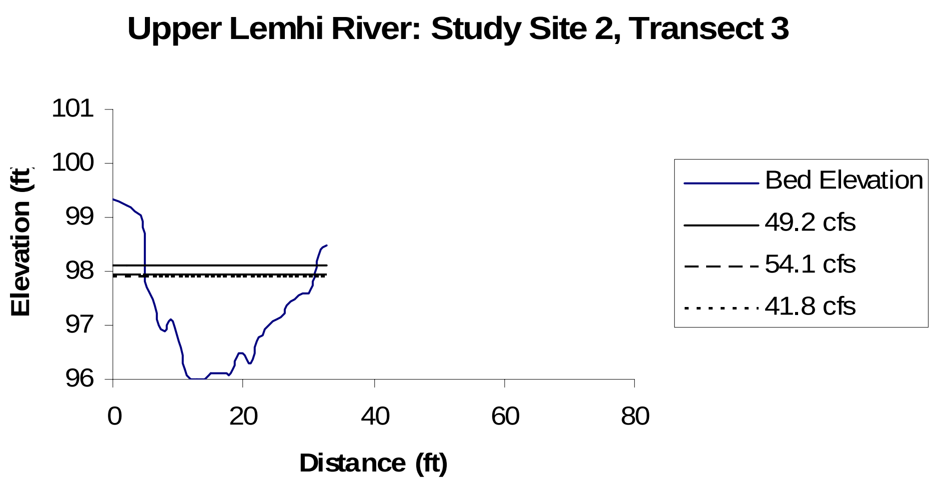


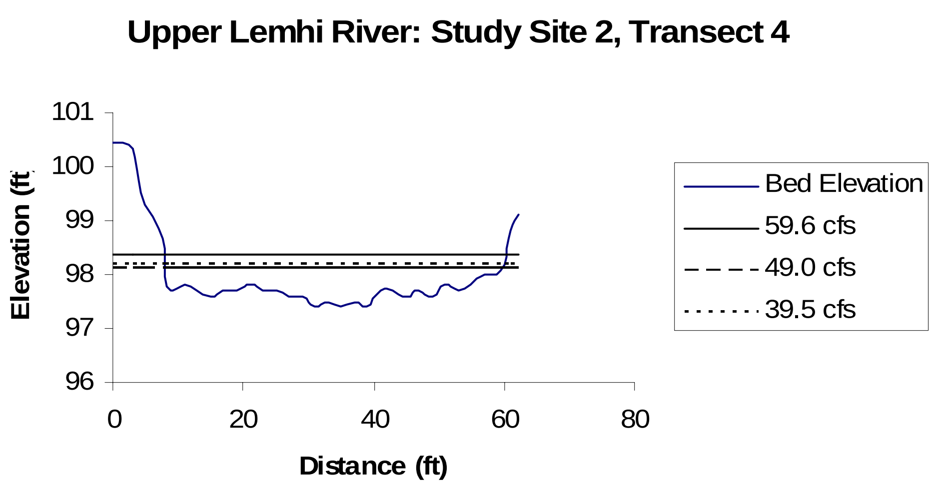
Upper Lemhi River, Site 2



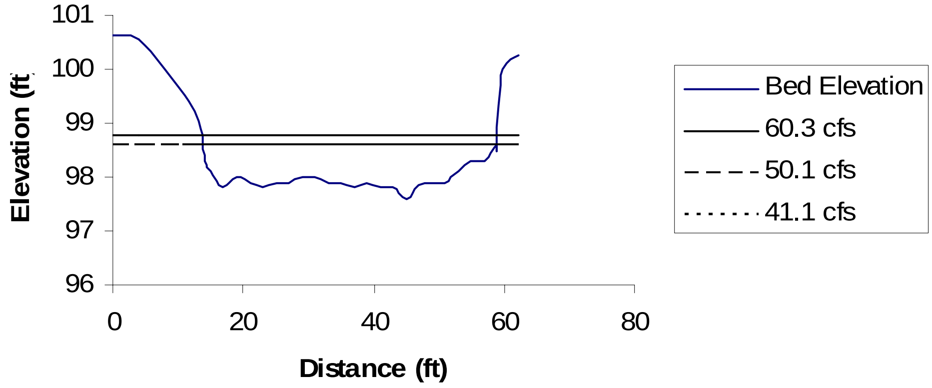



Upper Lemhi River: Study Site 2, Transect 2
Elevation (ft)
101
100
99
98
97
96
0
20
40
60
80
Distance (ft)
Bed Elevation
46.8 cfs
46.1 cfs
38.0 cfs

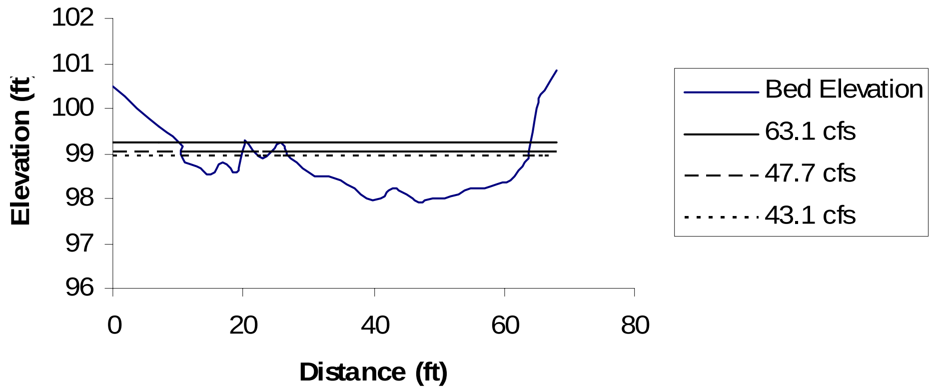

Upper Lemhi River: Study Site 2, Transect 3
Elevation (ft)
101
100
99
98
97
96
0
20
40
60
80
Distance (ft)
Bed Elevation
49.2 cfs
54.1 cfs
41.8 cfs


Upper Lemhi River: Study Site 2, Transect 4
Elevation (ft)
101
100
99
98
97
96
0
20
40
60
80
Distance (ft)
Bed Elevation
59.6 cfs
49.0 cfs
39.5 cfs

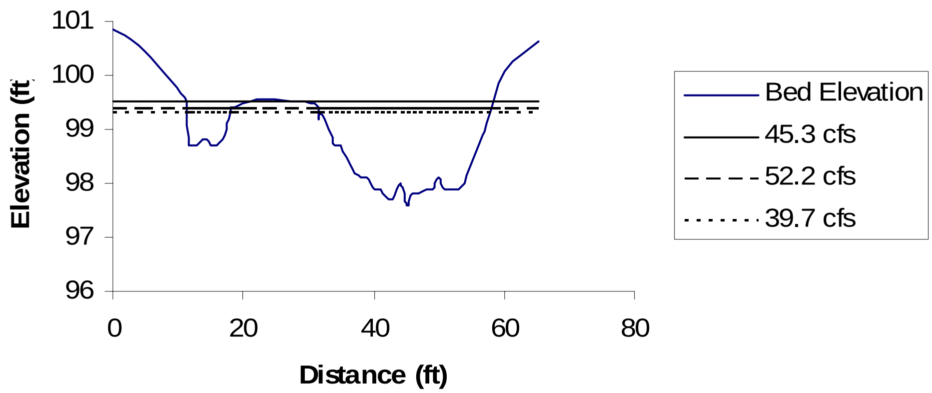
Upper Lemhi River: Study Site 2, Transect 5



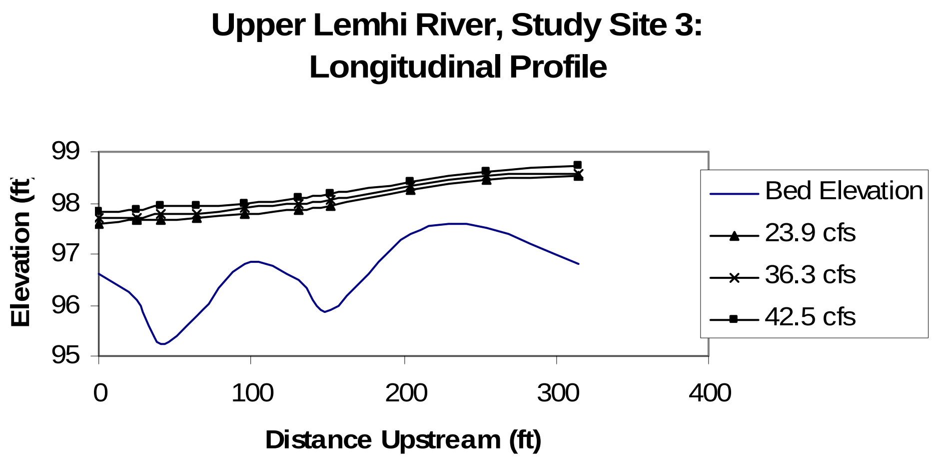
Upper Lemhi River: Study Site 2, Transect 6

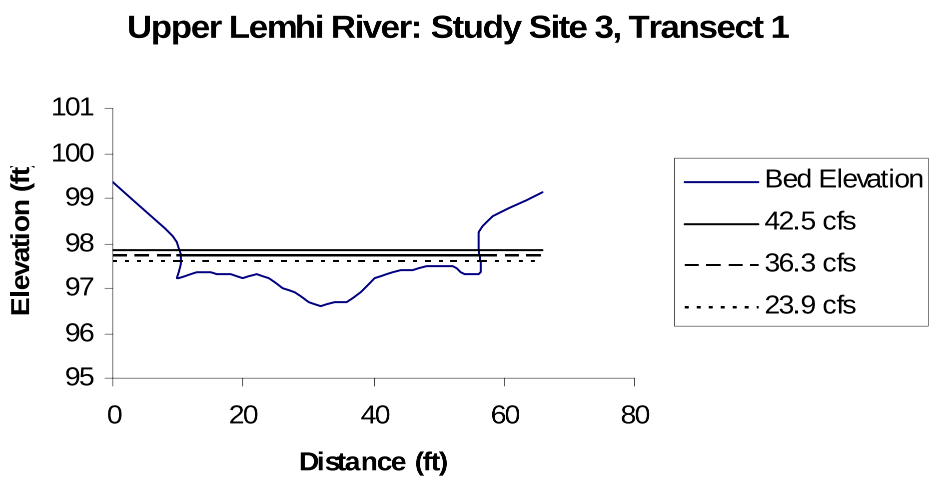


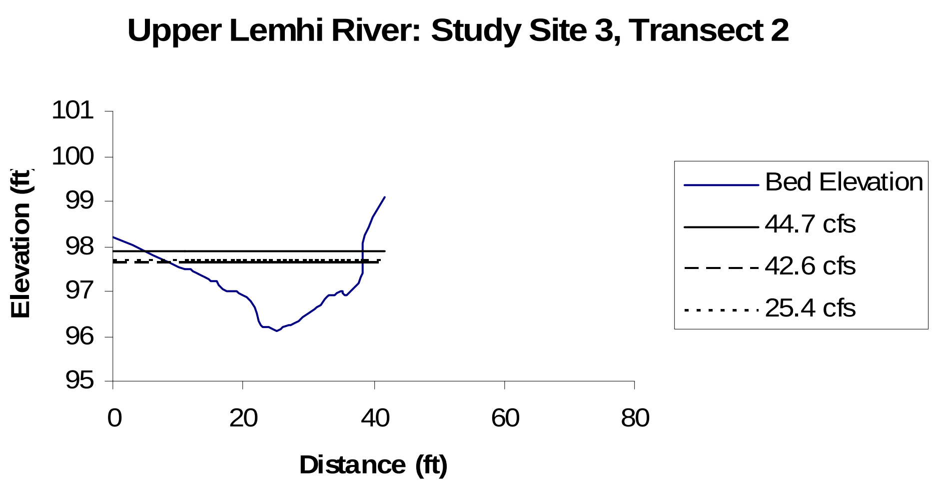
Upper Lemhi River: Study Site 2, Transect 7



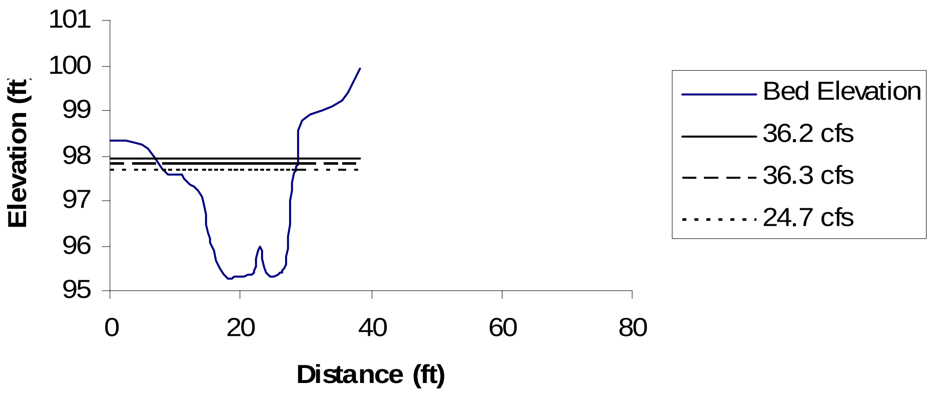
Upper Lemhi River, Site 3



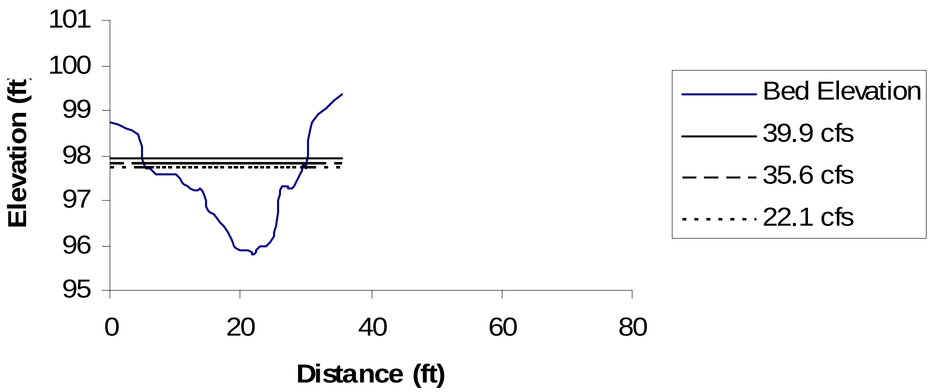




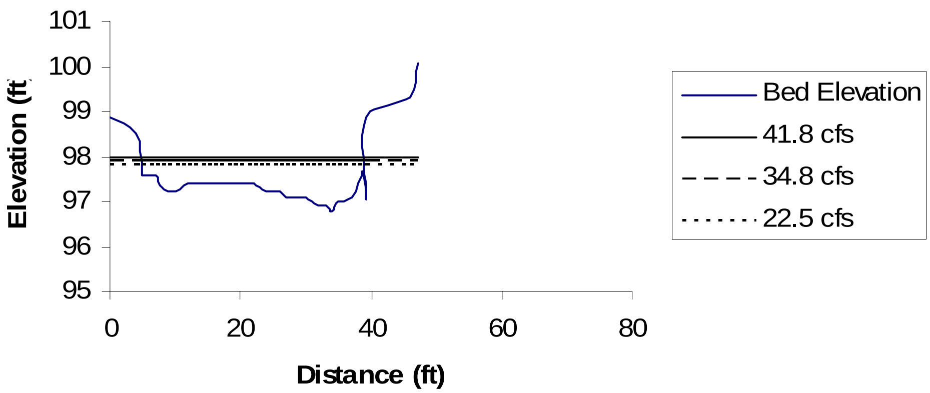
Upper Lemhi River: Study Site 3, Transect 3



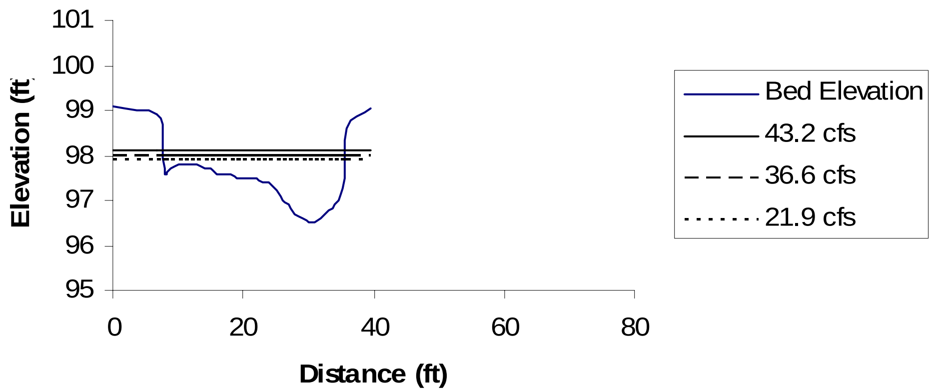
Upper Lemhi River: Study Site 3, Transect 4



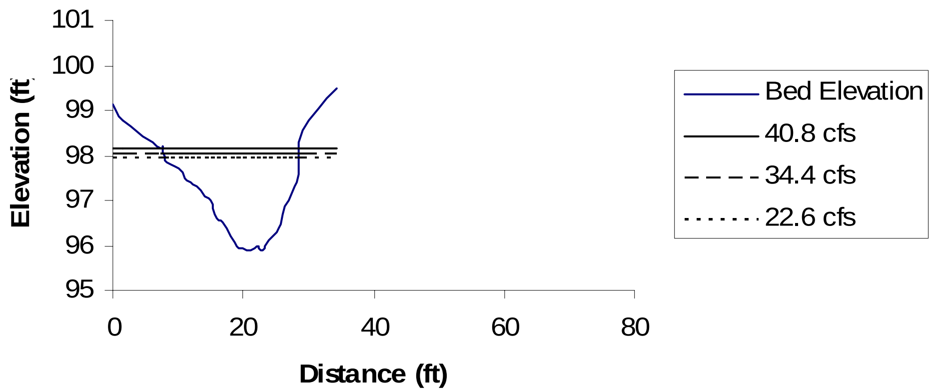
Upper Lemhi River: Study Site 3, Transect 5



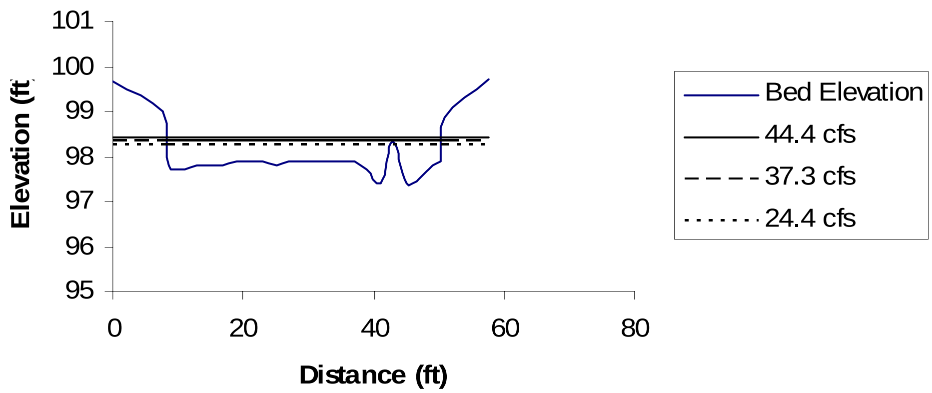
Upper Lemhi River: Study Site 3, Transect 6

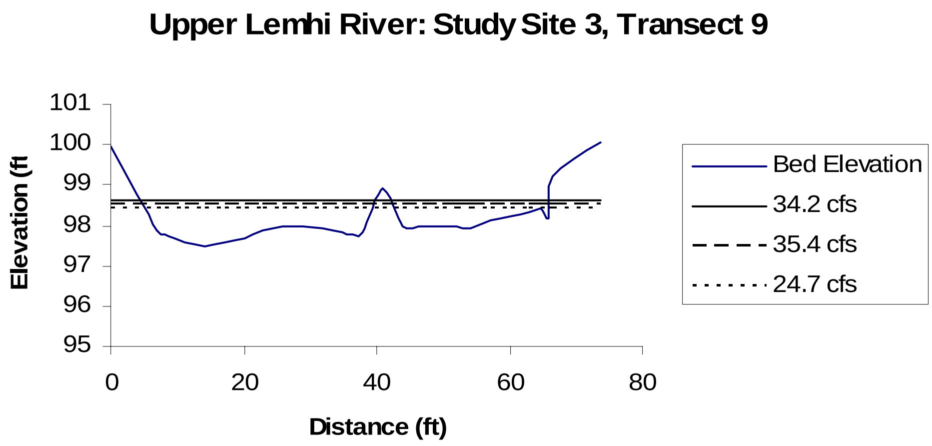


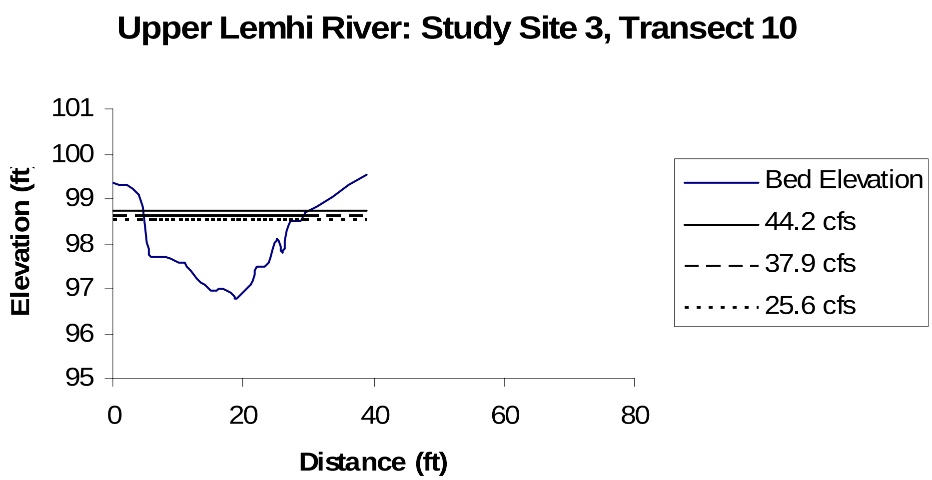
Upper Lemhi River: Study Site 3, Transect 7



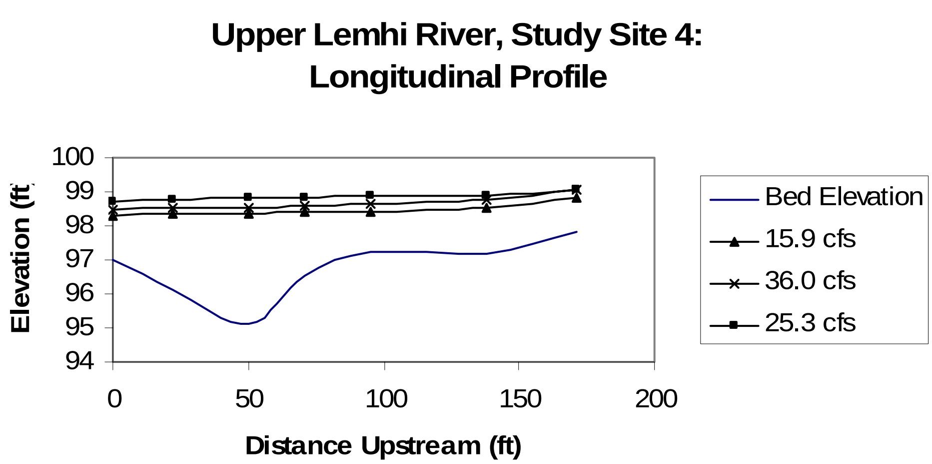
Upper Lemhi River: Study Site 3, Transect 8



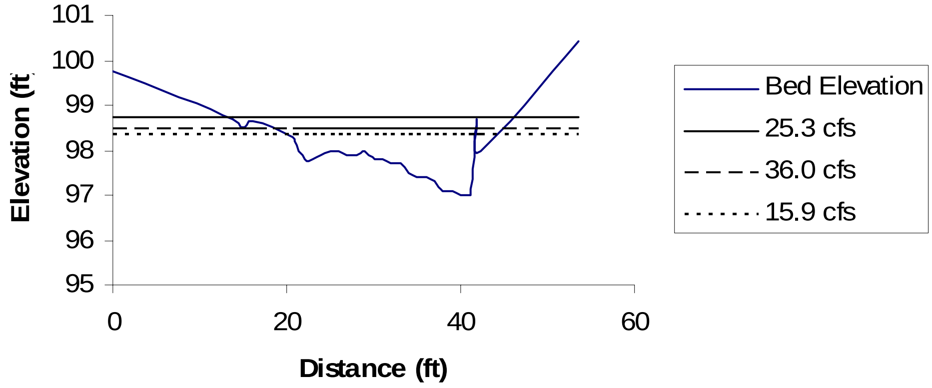




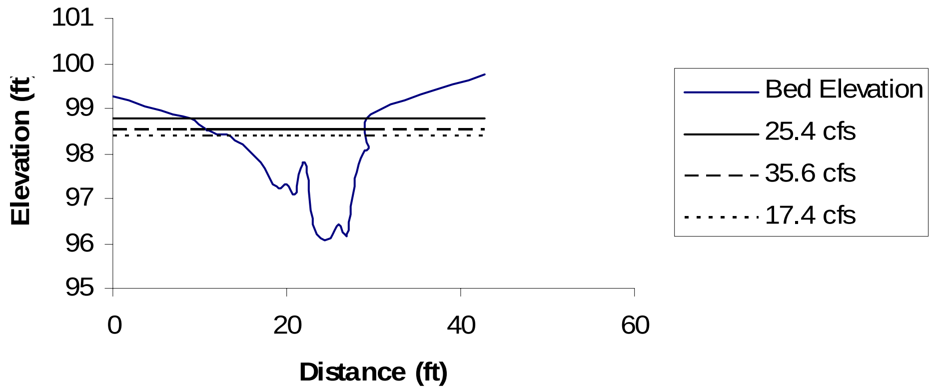
Upper Lemhi River, Site 4



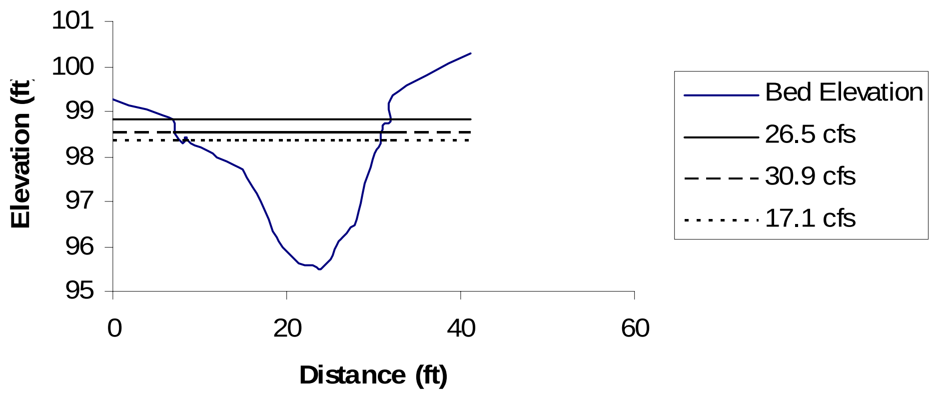
Upper Lemhi River: Study Site 4, Transect 1



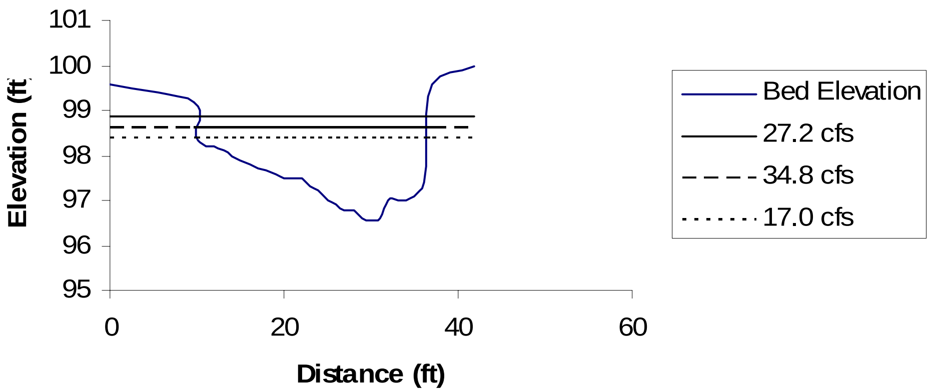
Upper Lemhi River: Study Site 4, Transect 2



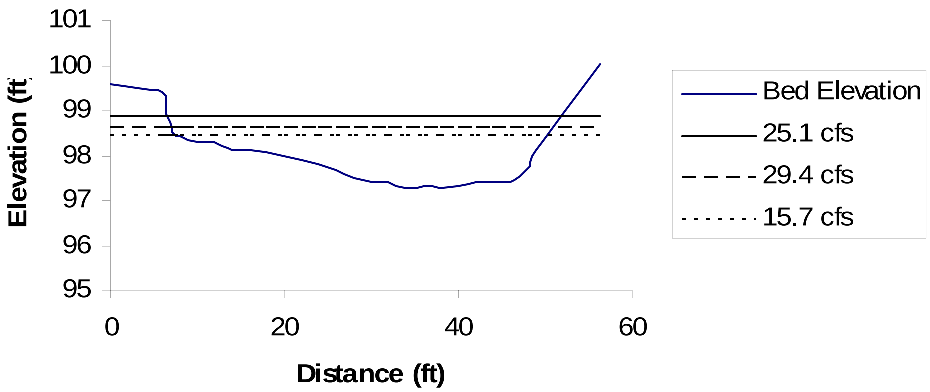
Upper Lemhi River: Study Site 4, Transect 3



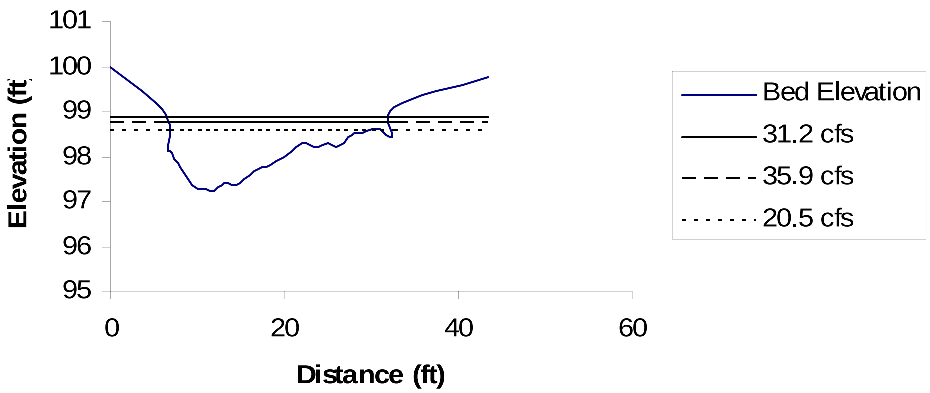
Upper Lemhi River: Study Site 4, Transect 4

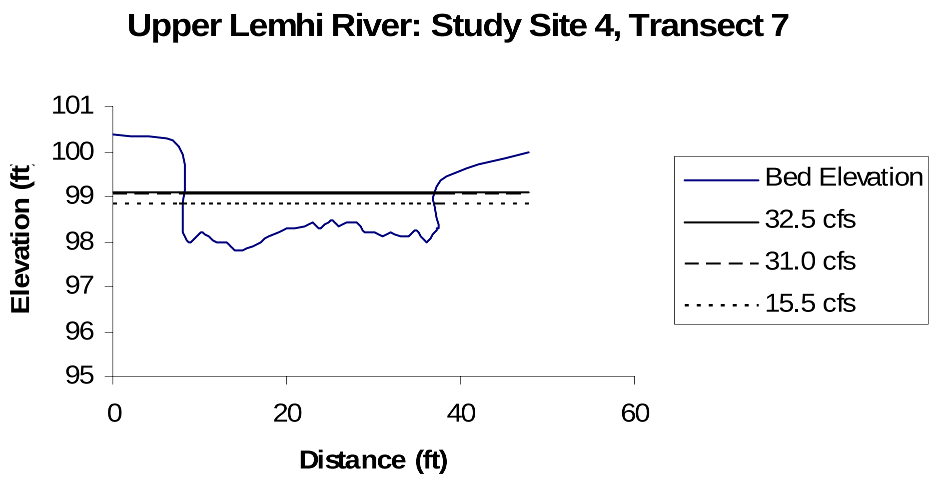


Upper Lemhi River: Study Site 4, Transect 5

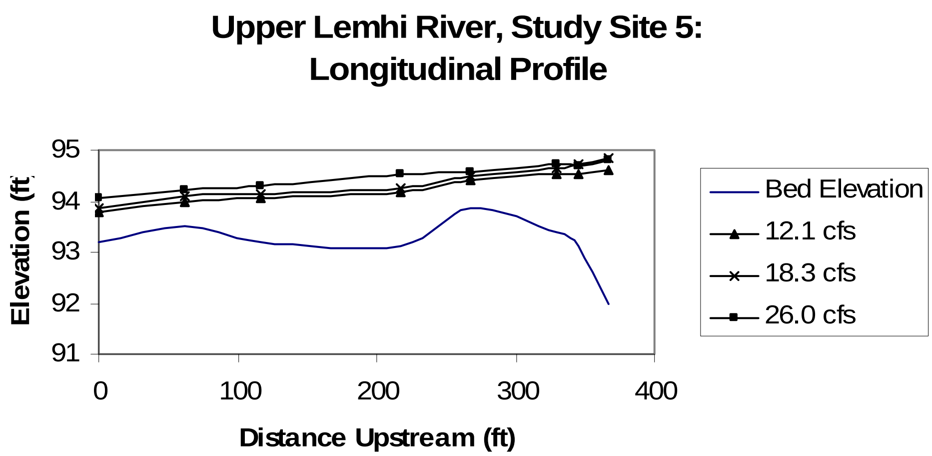


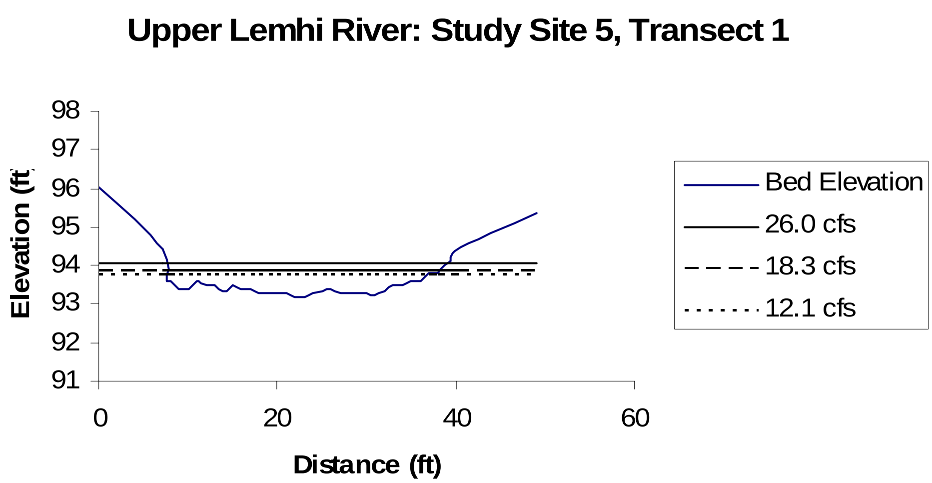
Upper Lemhi River: Study Site 4, Transect 6



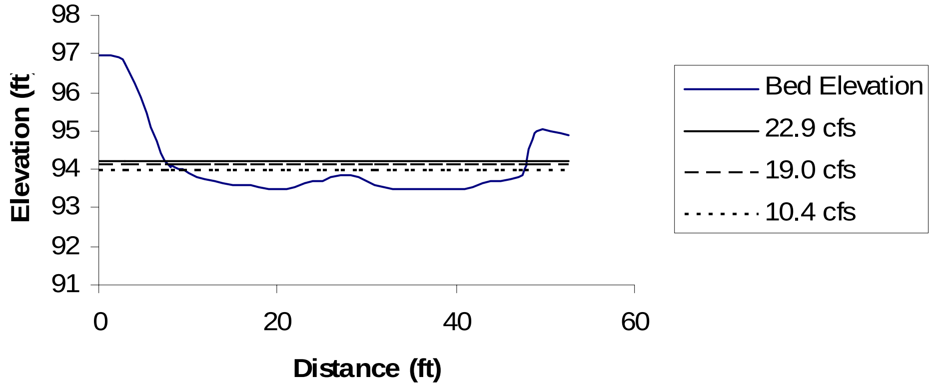


Upper Lemhi River, Site 5

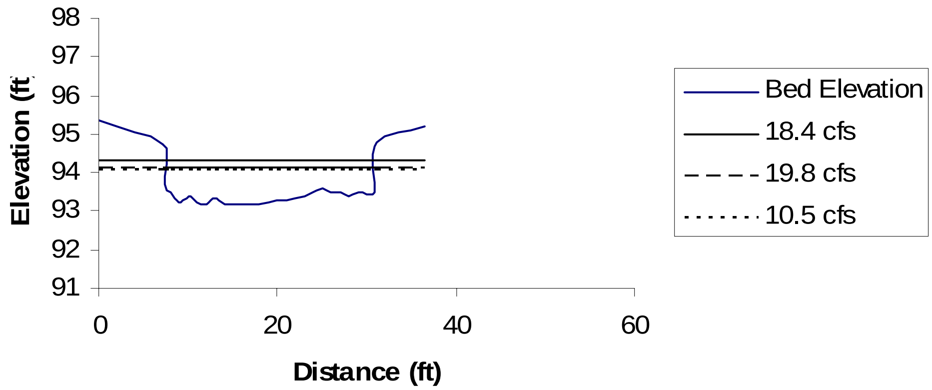




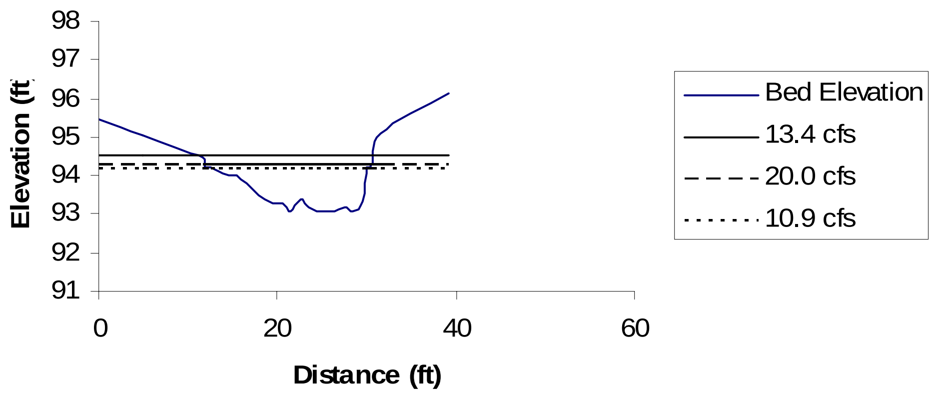
Upper Lemhi River: Study Site 5, Transect 2



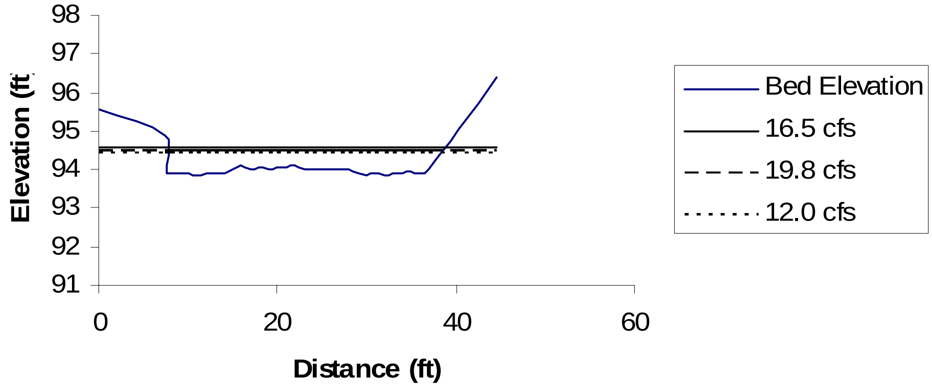
Upper Lemhi River: Study Site 5, Transect 3



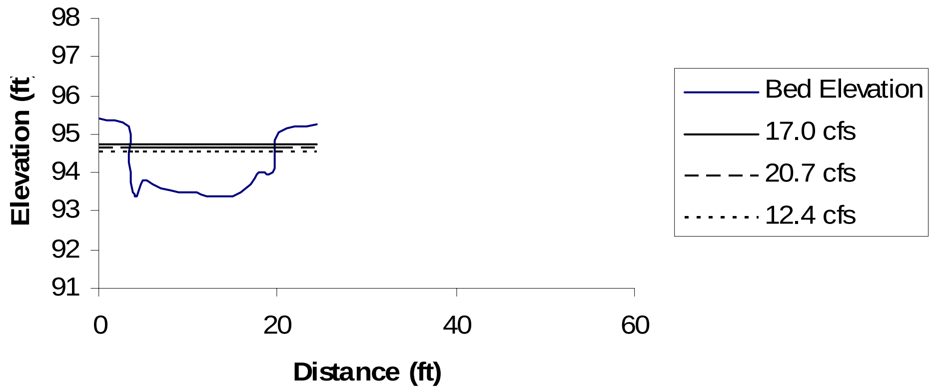
Upper Lemhi River: Study Site 5, Transect 4



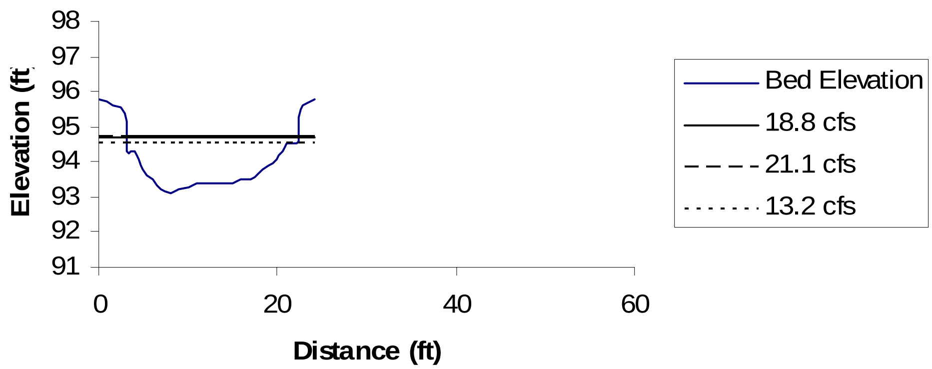
Upper Lemhi River: Study Site 5, Transect 5

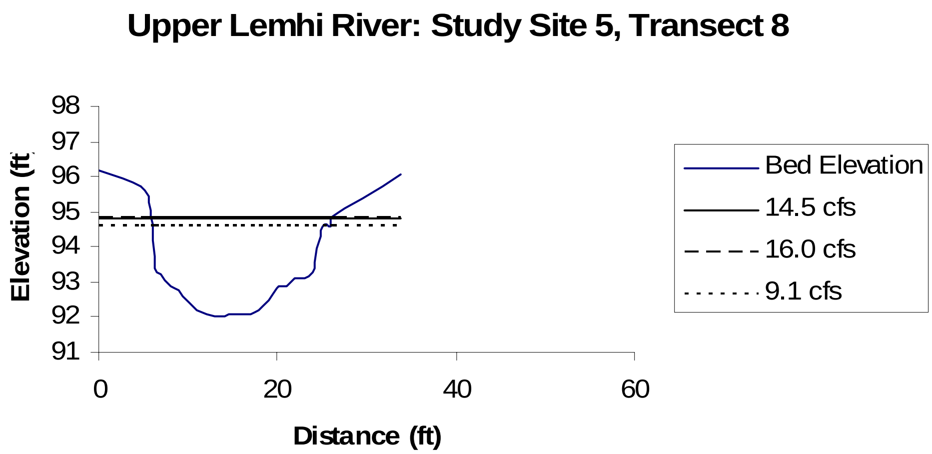


Upper Lemhi River: Study Site 5, Transect 6

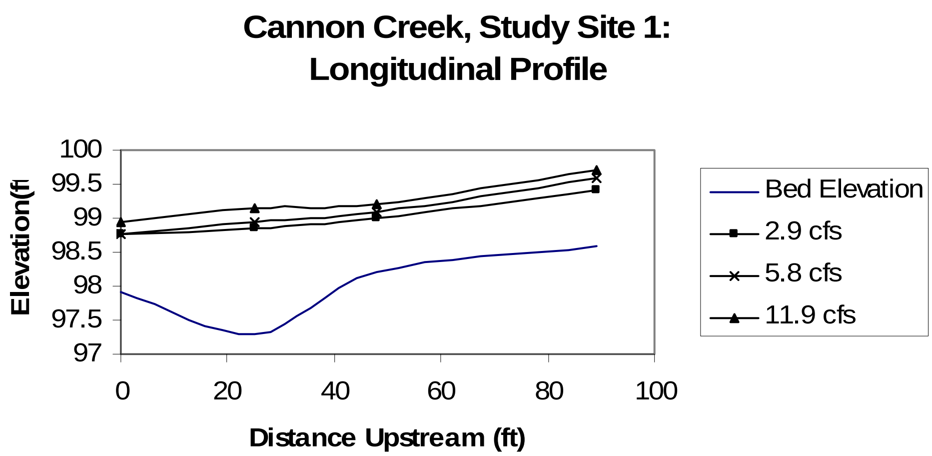


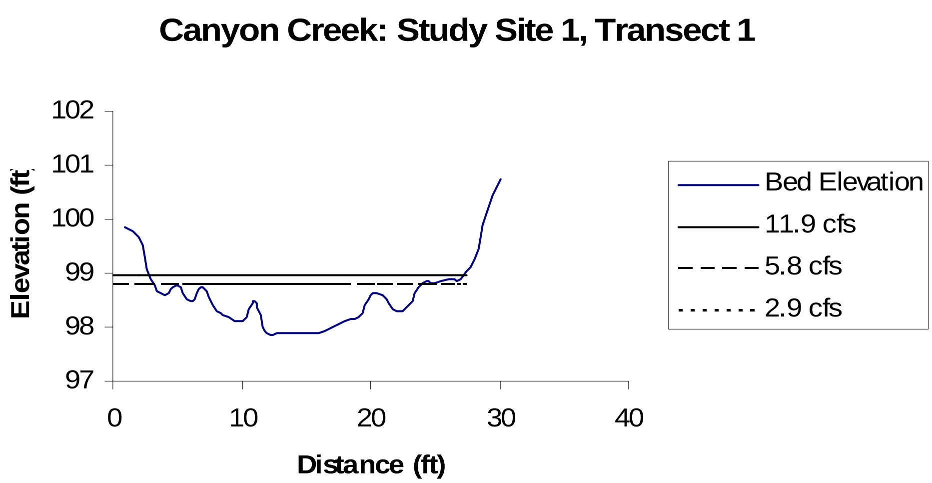
Upper Lemhi River: Study Site 5, Transect 7



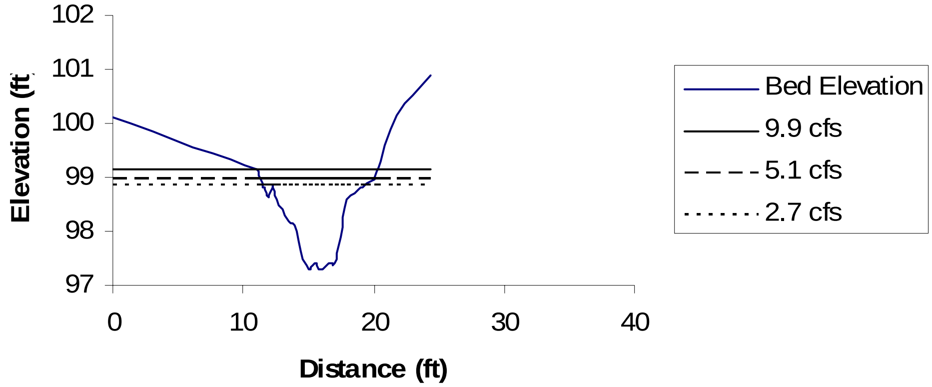


Canyon Creek, Site 1

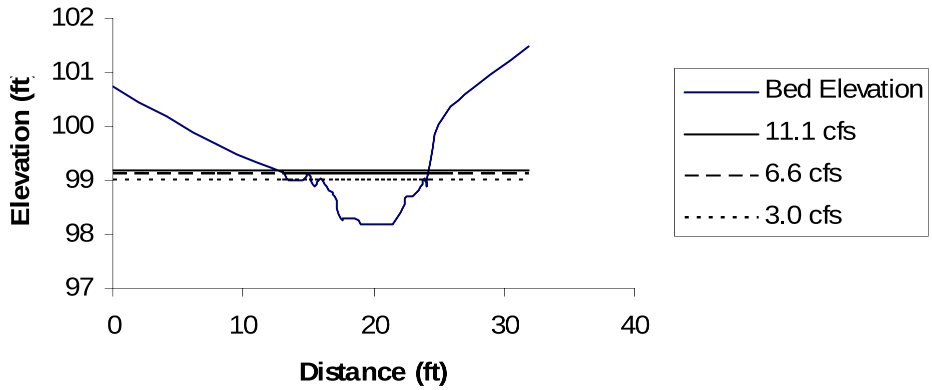




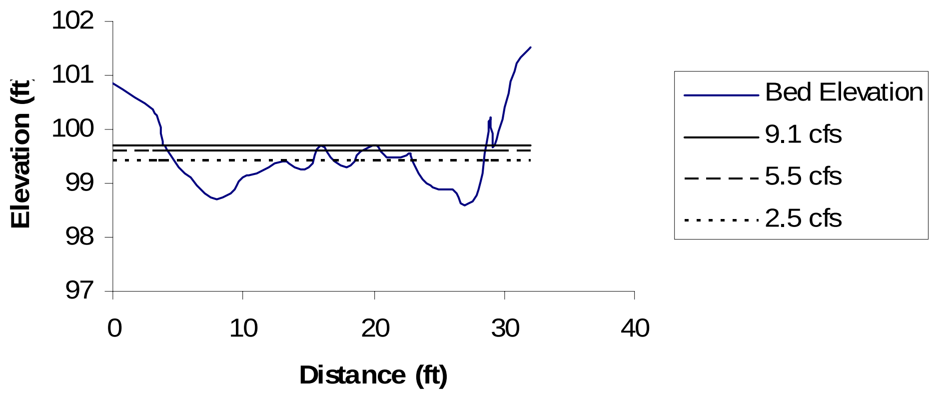
Canyon Creek: Study Site 1, Transect 2



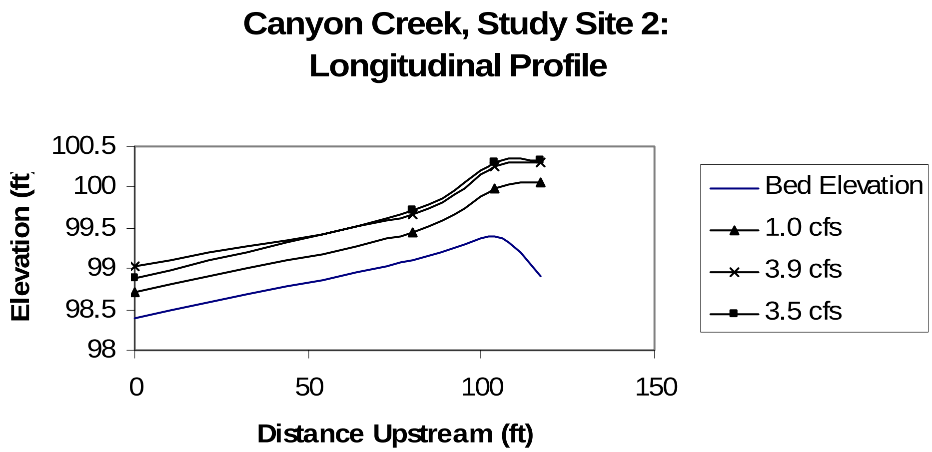
Canyon Creek: Study Site 1, Transect 3

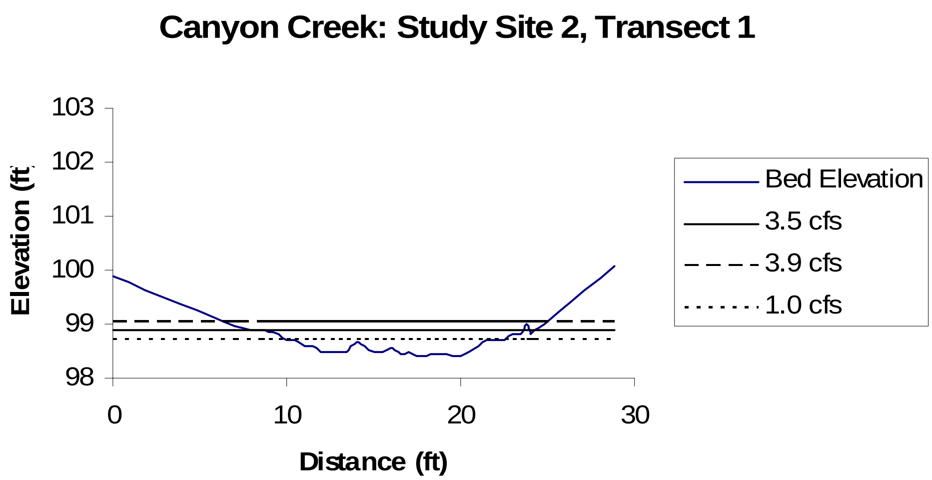


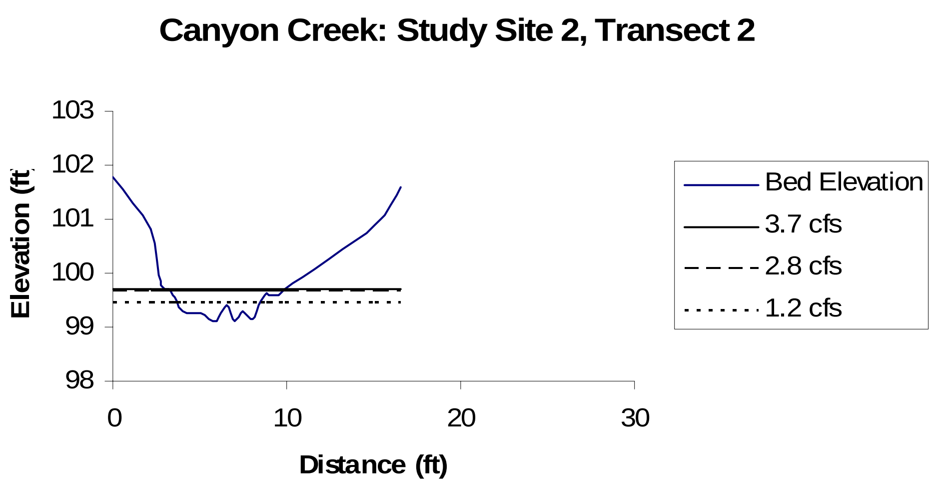
Canyon Creek: Study Site 1, Transect 4



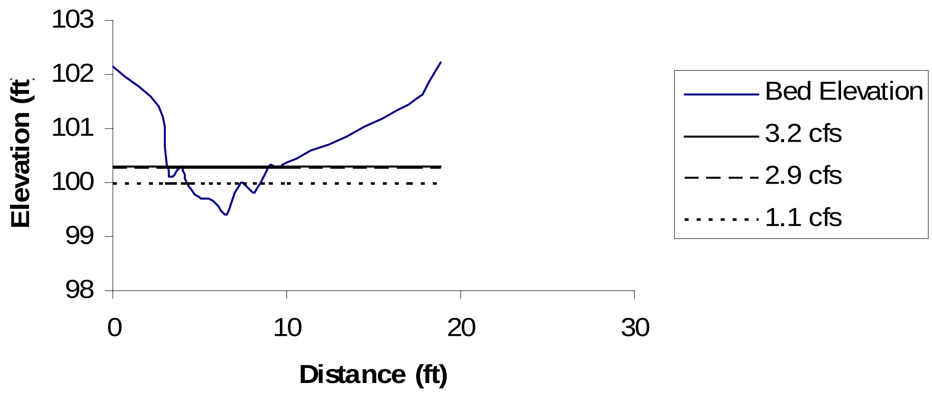
Canyon Creek, Site 2



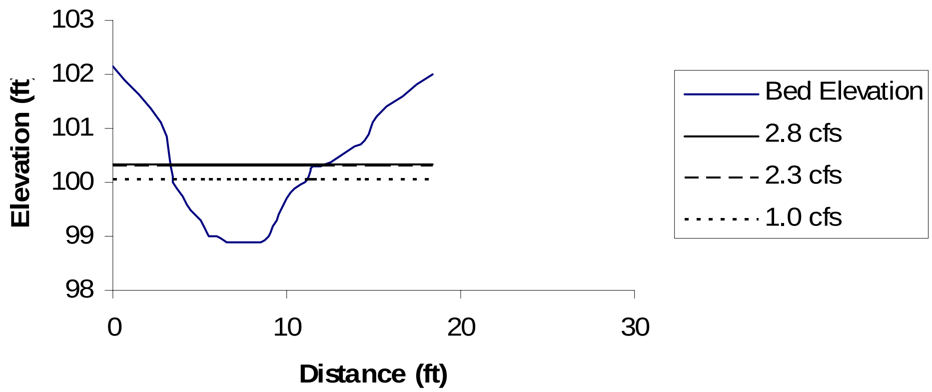




Canyon Creek: Study Site 2, Transect 3

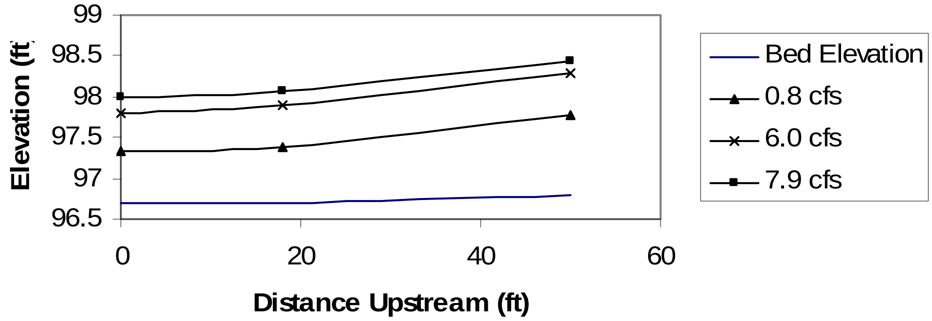


Canyon Creek: Study Site 2, Transect 4

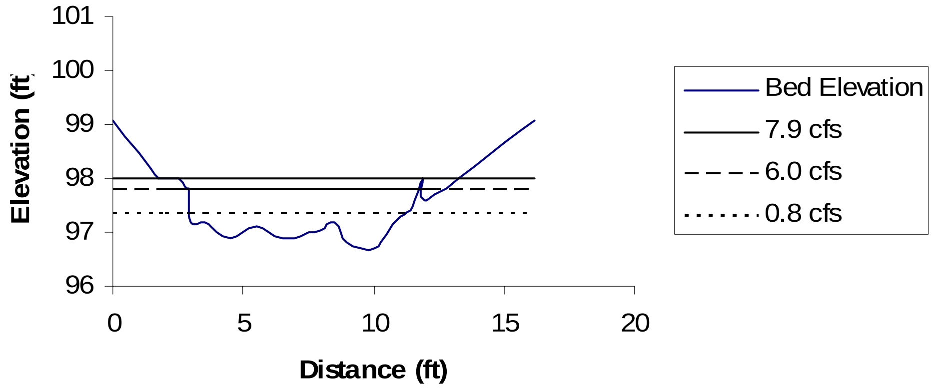


Canyon Creek, Site 3

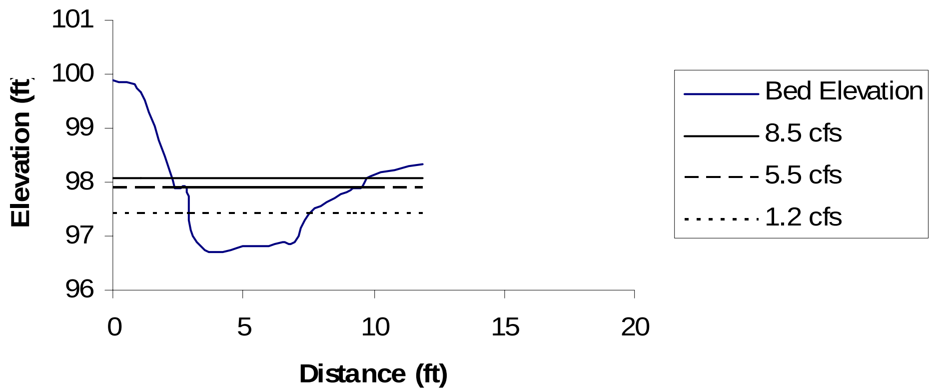
Canyon Creek, Study Site 3: Longitudinal Profile

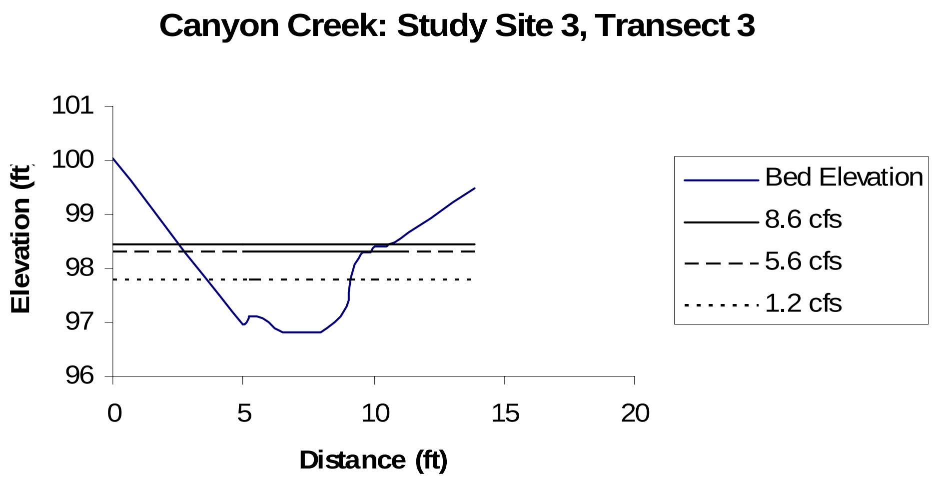


Canyon Creek: Study Site 3, Transect 1

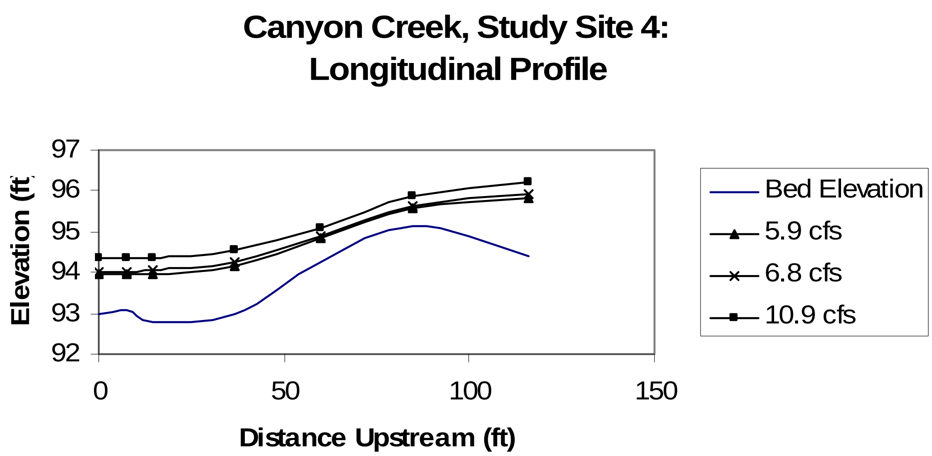


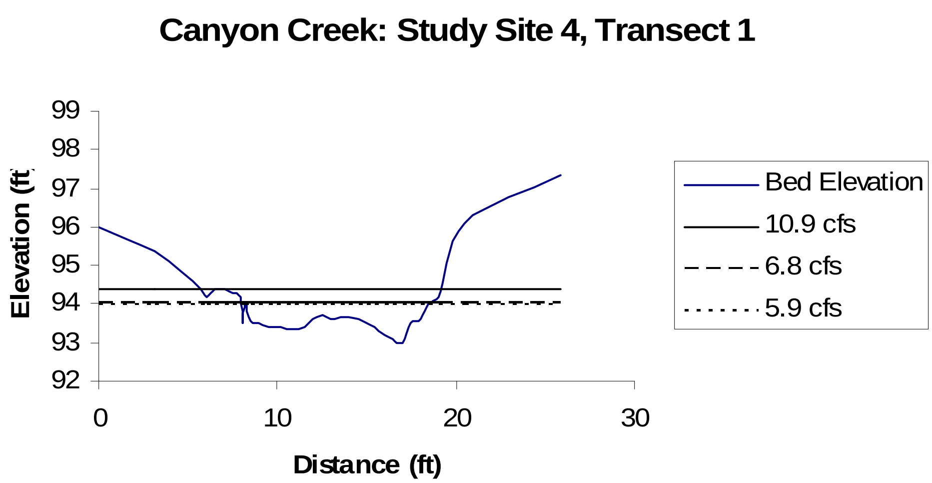
Canyon Creek: Study Site 3, Transect 2



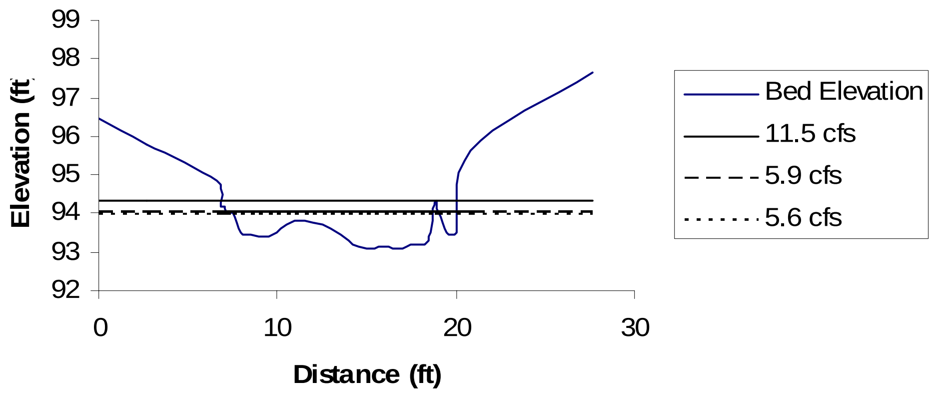


Canyon Creek, Site 4

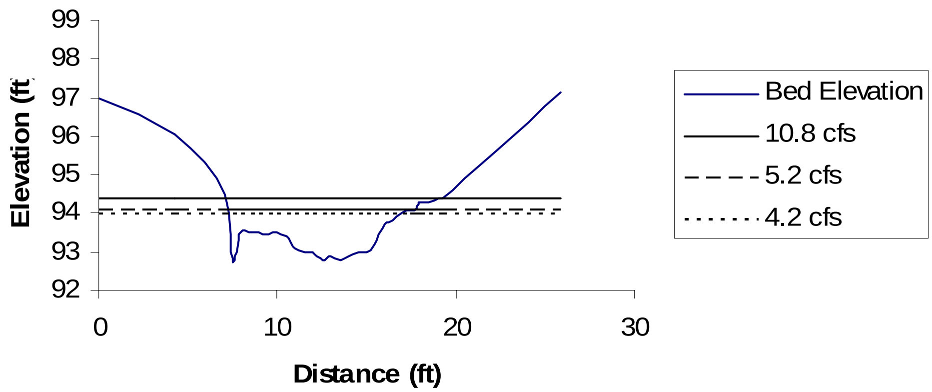




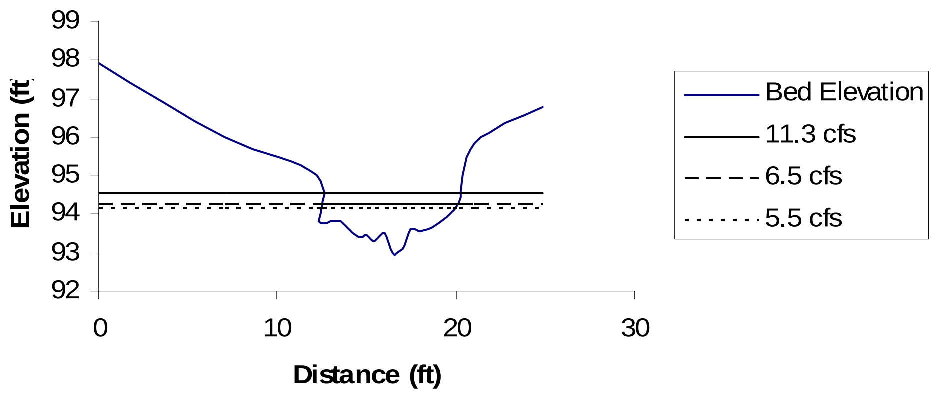
Canyon Creek: Study Site 4, Transect 2



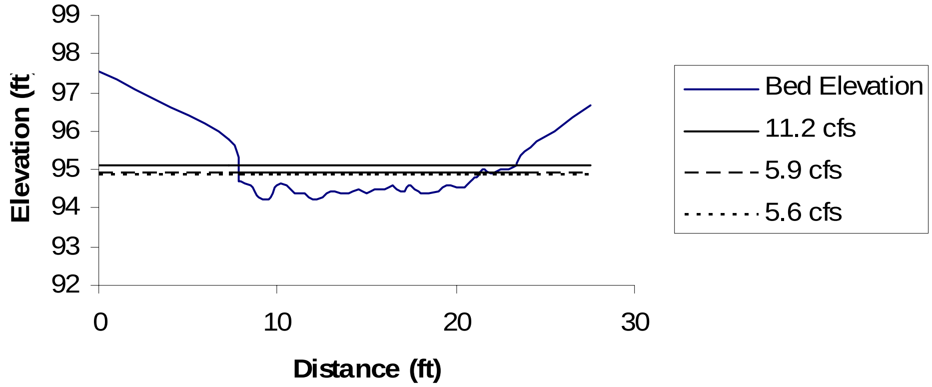
Canyon Creek: Study Site 4, Transect 3



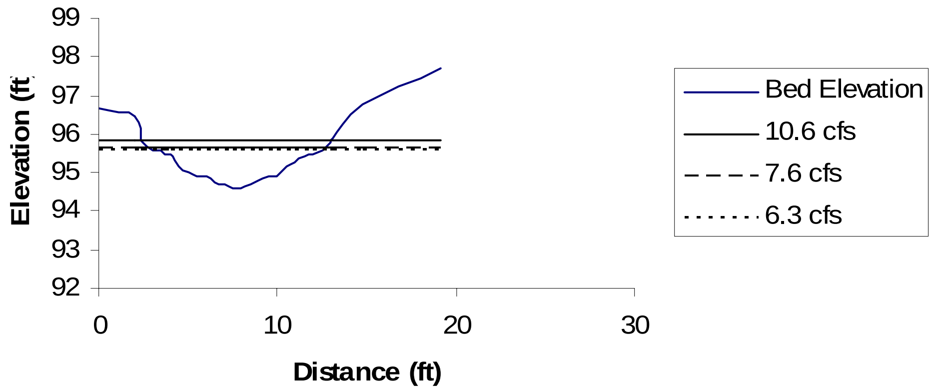
Canyon Creek: Study Site 4, Transect 4



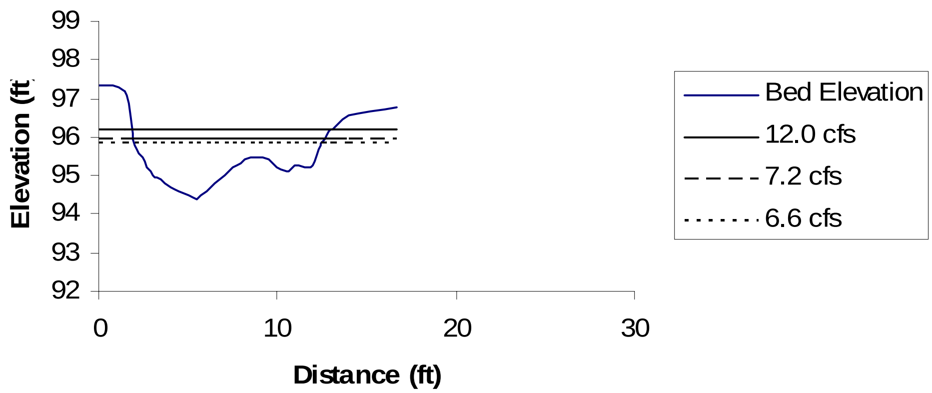
Canyon Creek: Study Site 4, Transect 5



Canyon Creek: Study Site 4, Transect 6

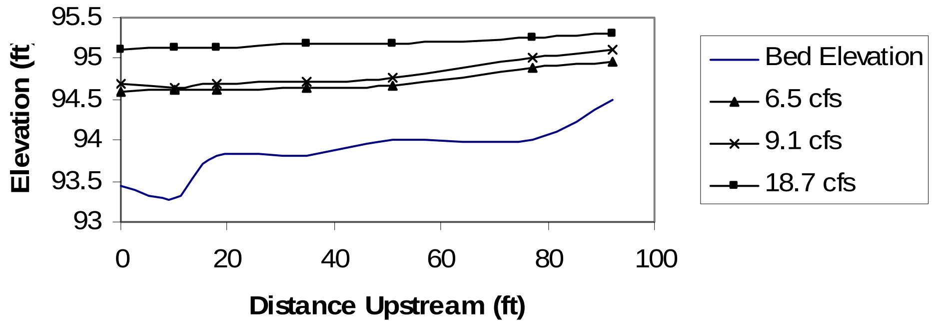


Canyon Creek: Study Site 4, Transect 7

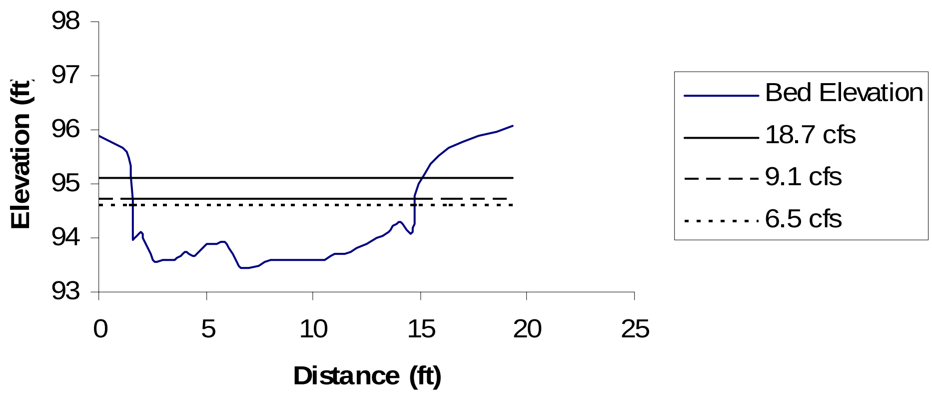


Canyon Creek, Site 5 (Reference)

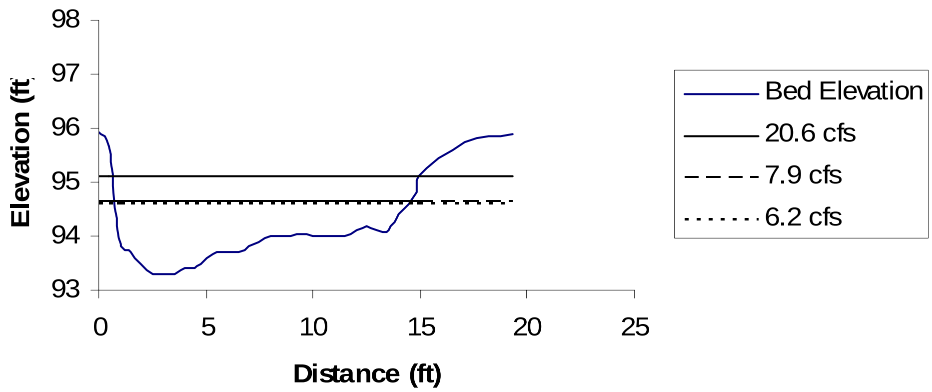
Canyon Creek, Study Site 5 (Reference): Longitudinal Profile

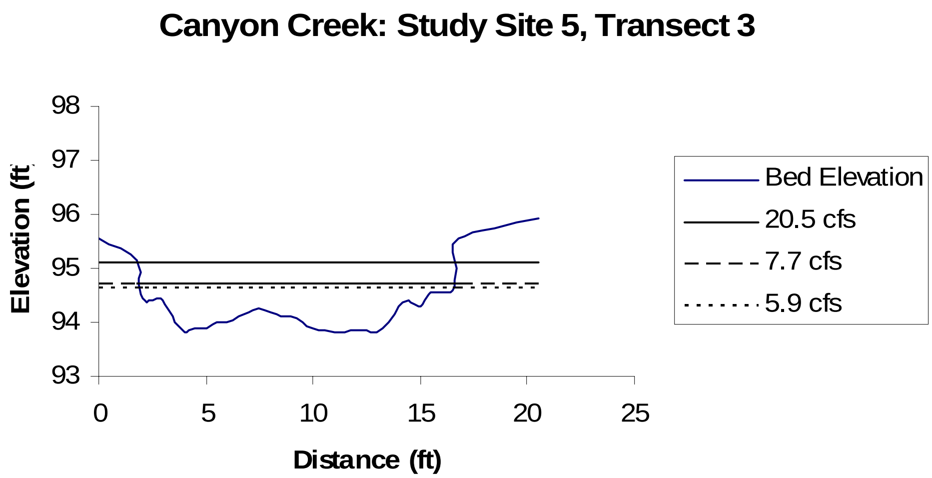


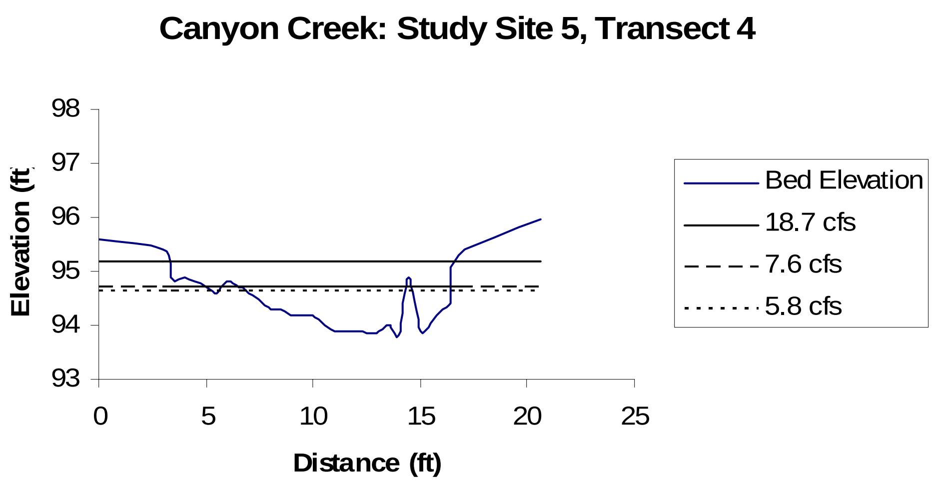
Canyon Creek: Study Site 5, Transect 1

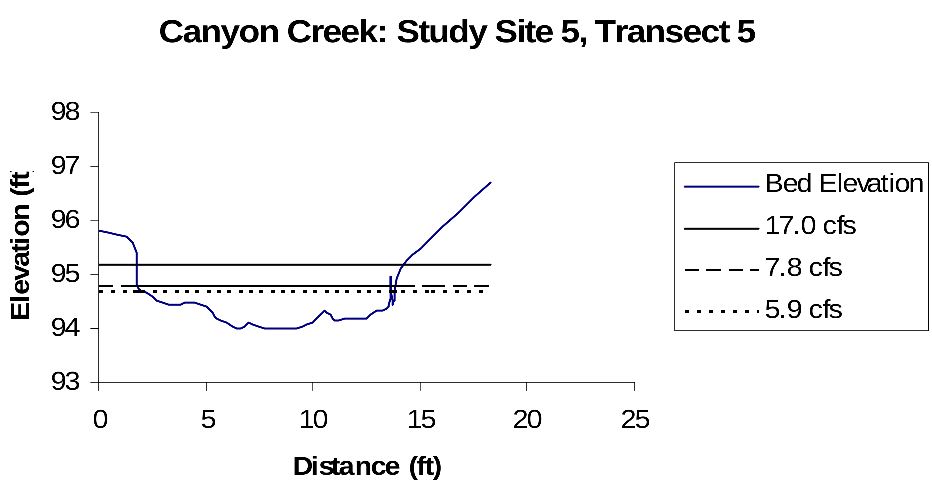


Canyon Creek: Study Site 5, Transect 2

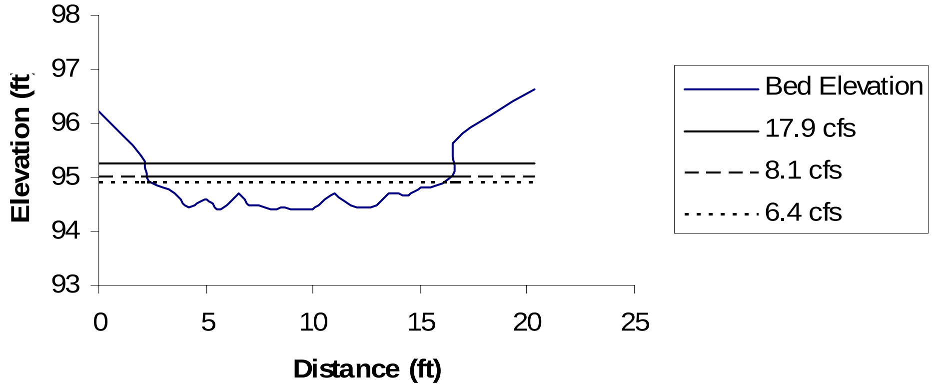



Canyon Creek: Study Site 5, Transect 3
Elevation (ft)
Distance (ft)
Bed Elevation
20.5 cfs
7.7 cfs
5.9 cfs

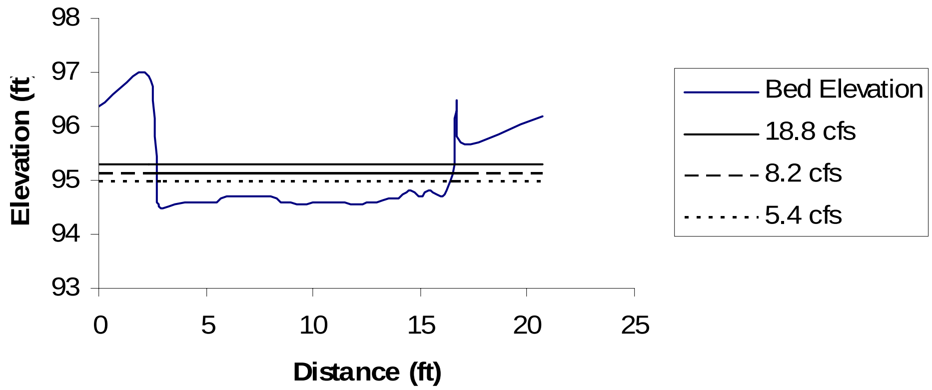

Canyon Creek: Study Site 5, Transect 4
Elevation (ft)
Distance (ft)
Bed Elevation
18.7 cfs
7.6 cfs
5.8 cfs


Canyon Creek: Study Site 5, Transect 5
Elevation (ft)
Distance (ft)
Bed Elevation
17.0 cfs
7.8 cfs
5.9 cfs

Canyon Creek: Study Site 5, Transect 6



Canyon Creek: Study Site 5, Transect 7



APPENDIX D – HYDRAULIC CALIBRATION RESULTS

Table D-1 Water surface elevation calibration results (ft) for the Upper Lemhi River Site 1 using MANSQ for transects 1-3 and WSP for transects 4-5.

Transect	Distance from next downstream transect (ft)	47.0 cfs			56.0 cfs			63.7 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	95.140	95.135	-0.005	95.170	95.170	0.000	95.150	95.197	0.047
2	226.5	96.080	96.085	0.005	96.110	96.138	0.028	96.120	96.177	0.057
3	380	97.790	97.790	0.000	97.880	97.826	-0.054	97.800	97.852	0.052
4	151	98.340	98.340	0.000	98.520	98.510	-0.010	98.490	98.490	0.000
5	34	98.460	98.409	-0.051	98.590	98.560	-0.030	98.580	98.559	-0.021

Table D-2 Water surface elevation calibration results (ft) for the Upper Lemhi River Site 2 using the WSP model for transects 1-3 and the STGQ model for transects 4-7.

Transect	Distance from next downstream transect (ft)	41.1 cfs			50.1 cfs			60.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.760	97.760	0.000	97.800	97.800	0.000	97.960	97.960	0.000
2	19	97.790	97.774	-0.016	97.830	97.818	-0.012	97.940	97.974	0.034
3	26	97.890	97.837	-0.053	97.920	97.898	-0.022	98.090	98.051	-0.039
4	84	98.140	98.114	-0.026	98.200	98.240	0.040	98.390	98.377	-0.013
5	92	98.570	98.532	-0.038	98.600	98.649	0.049	98.780	98.771	-0.009
6	70.5	98.940	98.925	-0.015	99.040	99.067	0.027	99.230	99.218	-0.012
7	51	99.280	99.269	-0.011	99.370	99.390	0.020	99.520	99.512	-0.008

Table D-3 Water surface elevation calibration results (ft) for the Upper Lemhi River Site 3 using the WSP model for transects 1-3 and 6-7 and STGQ for transects 4-5 and 8-10.

Transect	Distance from next downstream transect (ft)	24.4 cfs			37.3 cfs			44.4 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.600	97.600	0.000	97.720	97.720	0.000	97.830	97.830	0.000
2	25	97.670	97.625	-0.045	97.740	97.746	0.006	97.860	97.851	-0.009
3	16	97.640	97.641	0.001	97.800	97.769	-0.031	97.910	97.873	-0.037
4	23.5	97.720	97.693	-0.027	97.810	97.858	0.048	97.950	97.930	-0.020
5	31.5	97.780	97.764	-0.016	97.880	97.914	0.034	98.000	97.982	-0.018
6	35	97.870	97.870	0.000	97.970	97.970	0.000	98.110	98.110	0.000
7	20.5	97.940	97.911	-0.029	98.040	98.035	-0.005	98.170	98.164	-0.006
8	53.5	98.240	98.234	-0.006	98.340	98.356	0.016	98.420	98.410	-0.010
9	49.5	98.440	98.246	-0.014	98.520	98.550	0.030	98.620	98.605	-0.015
10	60	98.520	98.491	-0.029	98.590	98.638	0.048	98.720	98.702	-0.018

Table D-4 Water surface elevation calibration results (ft) for the Upper Lemhi River Site 4 using the WSP model for transects 1-4 and STGQ for transects 5-7.

Transect	Distance from next downstream transect (ft)	15.5 cfs			32.5 cfs			N/A		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	98.320	98.320	0.000	98.730	98.730	0.000	N/A	N/A	N/A
2	22.5	98.360	98.334	-0.026	98.770	98.739	-0.310	N/A	N/A	N/A
3	28	98.370	98.292	-0.078	98.810	98.735	-0.075	N/A	N/A	N/A
4	20.5	98.380	98.323	-0.057	98.840	98.767	-0.073	N/A	N/A	N/A
5	24	98.390	98.359	-0.031	98.850	98.783	-0.067	N/A	N/A	N/A
6	43	98.550	98.531	-0.019	98.890	98.847	-0.043	N/A	N/A	N/A
7	33	98.840	98.838	-0.002	99.080	99.069	-0.011	N/A	N/A	N/A

Table D-5 Water surface elevation calibration results (ft) for the Upper Lemhi River Site 5 using the STGQ for transects 1-3 and 5-6, MANSQ for transect 4 and WSP for transects 7-8.

Transect	Distance from next downstream transect (ft)	10.4 cfs			19.0 cfs			22.9 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	93.770	93.745	-0.025	93.900	93.962	0.062	94.080	94.045	-0.035
2	62.5	93.980	93.969	-0.011	94.110	94.143	0.033	94.230	94.209	-0.021
3	53.5	94.040	94.006	-0.034	94.140	94.207	0.067	94.310	94.279	-0.031
4	101.5	94.170	94.160	-0.010	94.260	94.353	0.093	94.500	94.411	-0.089
5	50	94.430	94.415	-0.015	94.500	94.532	0.032	94.590	94.573	-0.017
6	62.5	94.540	94.536	-0.004	94.640	94.653	0.013	94.700	94.691	-0.009
7	15	94.550	94.550	0.000	94.700	94.700	0.000	94.720	94.720	0.000
8	21.5	94.590	94.575	-0.015	94.790	94.759	-0.031	94.810	94.801	-0.009

Table D-6 Water surface elevation calibration results (ft) for Canyon Cr. Site 1 using the WSP model for transects 1-2 and STGQ for transects 3-4.

Transect	Distance from next downstream transect (ft)	2.9 cfs			5.8 cfs			11.9 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	98.750	98.750	0.000	98.860	98.860	0.000	98.990	98.990	0.000
2	25	98.830	98.762	-0.017	98.920	98.892	-0.028	99.120	99.089	-0.011
3	23	99.050	99.041	-0.009	99.090	99.104	0.014	99.180	99.175	-0.005
4	41	99.440	99.449	0.009	99.600	99.561	-0.039	99.660	99.692	0.032

Table D-7 Water surface elevation calibration results (ft) for Cannon Cr. Site 2 using the MANSQ model on transects 1-2 and WSP on transects 3-4.

Transect	Distance from next downstream transect (ft)	1.1 cfs			2.9 cfs			3.2 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	98.700	98.715	0.015	98.890	98.857	-0.033	98.900	98.875	-0.025
2	80	99.460	99.509	0.049	99.660	99.660	0.000	99.710	99.676	-0.034
3	24	99.980	99.980	0.000	100.250	100.250	0.000	100.290	100.290	0.000
4	13	100.050	100.003	-0.047	100.290	100.305	0.015	100.330	100.367	0.037

Table D-8 Water surface elevation calibration results (ft) for Canyon Cr. Site 3 using the STGQ model for all three (1-3) transects.

Transect	Distance from next downstream transect (ft)	0.8 cfs			6.0 cfs			7.9 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.340	97.334	-0.006	97.800	97.849	0.049	97.990	97.947	-0.043
2	18	97.390	97.387	-0.003	97.910	97.939	0.029	98.070	98.043	-0.027
3	32	97.770	97.765	-0.005	98.280	98.319	0.039	98.450	98.416	-0.034

Table D-9 Water surface elevation calibration results (ft) for Canyon Cr. Site 4 using the STGQ model for transects 1 and 4-7, and the WSP model for transects 2-3.

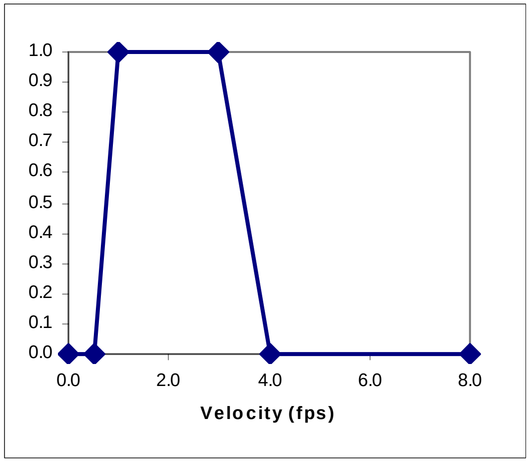
Transect	Distance from next downstream transect (ft)	6.6 cfs			7.2 cfs			12.0 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	93.970	93.976	0.006	94.030	94.022	-0.008	94.340	94.342	0.002
2	7.5	93.980	93.980	0.000	94.020	94.020	0.000	94.340	94.340	0.000
3	7	93.980	93.984	0.004	94.060	94.024	-0.036	94.360	94.341	-0.019
4	22	94.140	94.164	0.024	94.250	94.213	-0.037	94.530	94.545	0.015
5	23.5	94.830	94.844	0.014	94.900	94.878	-0.022	95.110	95.119	0.009
6	24.5	95.600	95.608	0.008	95.650	95.639	-0.011	95.860	95.864	0.004
7	31.5	95.840	95.858	0.018	95.930	95.904	-0.026	96.200	96.208	0.008

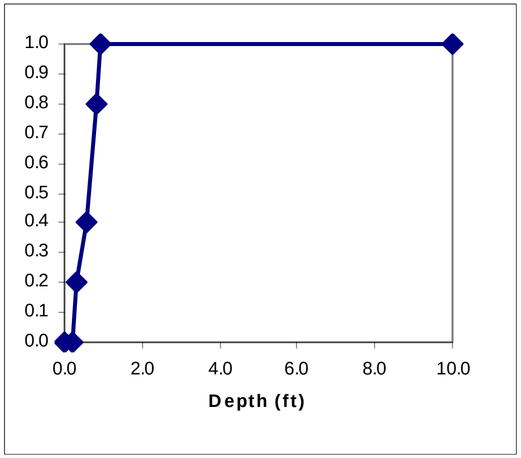
Table D-10 Water surface elevation calibration results (ft) for Canyon Cr. Site 5 (Reference site) using the WSP model for transects 1-2 and STGQ for transects 3-7.

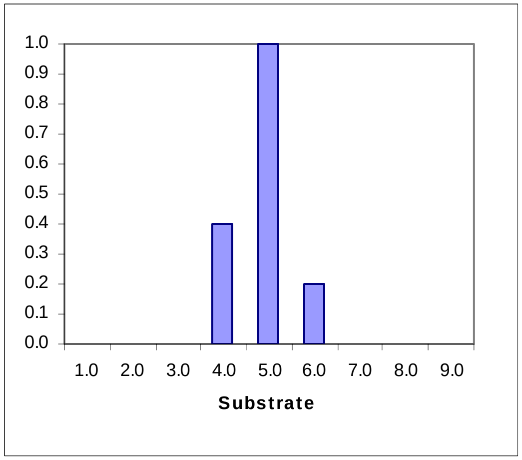
Transect	Distance from next downstream transect (ft)	5.4 cfs			8.2 cfs			18.8 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	94.600	94.600	0.000	94.680	94.680	0.000	95.100	95.090	-0.010
2	10	94.610	94.601	-0.009	94.690	94.681	-0.009	95.130	95.092	-0.038
3	8	94.620	94.587	-0.033	94.690	94.735	0.045	95.130	95.119	-0.011
4	17	94.650	94.619	-0.031	94.730	94.773	0.043	95.180	95.169	-0.011
5	16	94.660	94.642	-0.018	94.760	94.787	0.027	95.190	95.180	-0.010
6	26	94.890	94.897	0.007	95.010	94.996	-0.014	95.250	95.258	0.008
7	15	94.960	94.976	0.016	95.120	95.076	-0.044	95.310	95.342	0.032

APPENDIX E – HABITAT SUITABILITY CRITERIA

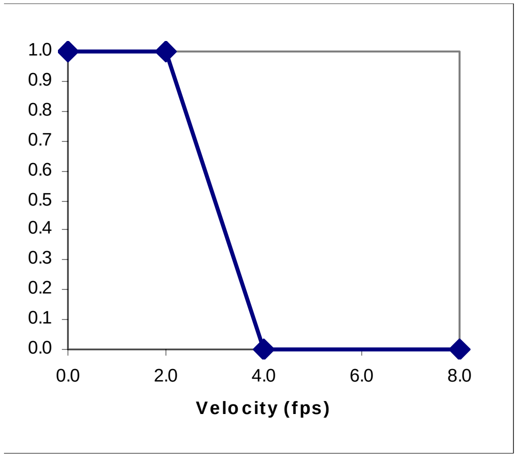
Chinook Salmon – spawning

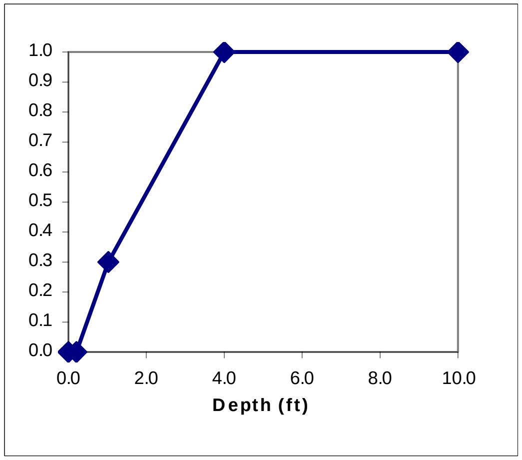


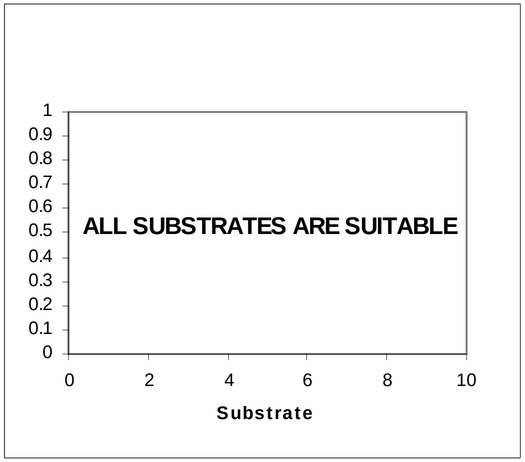




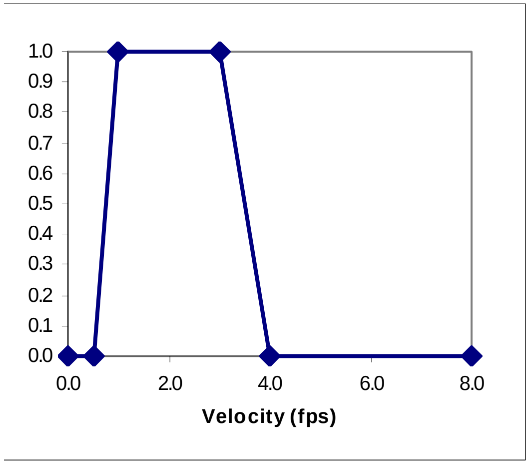
Chinook Salmon – adult holding

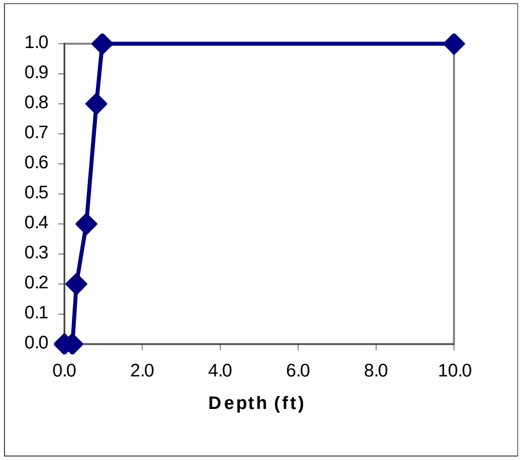


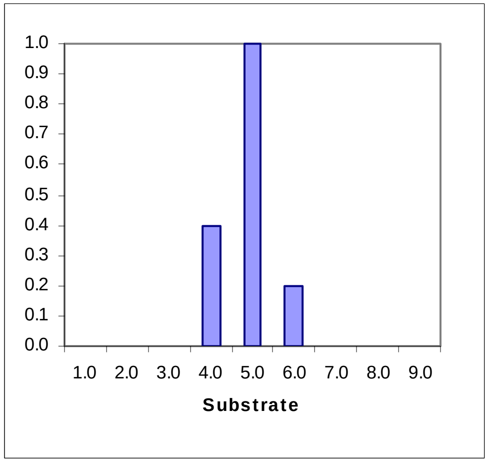




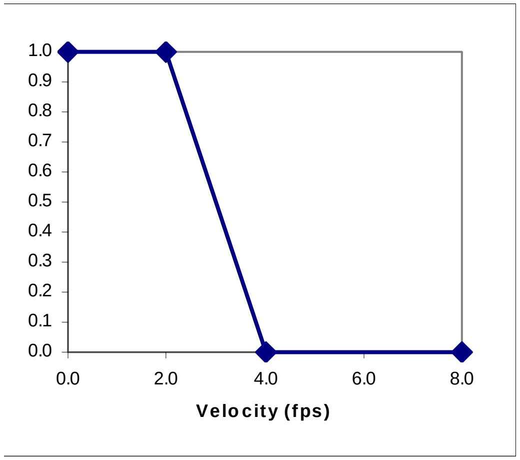
Steelhead – spawning

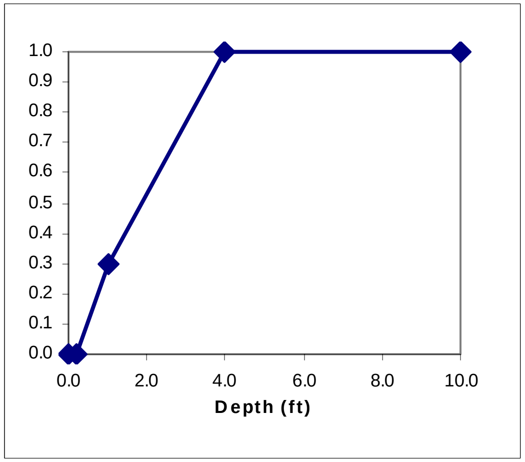


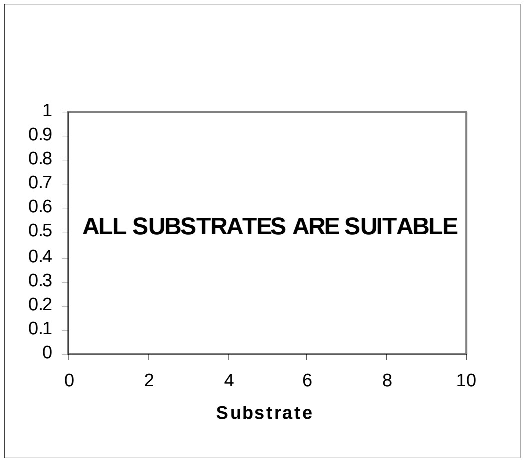




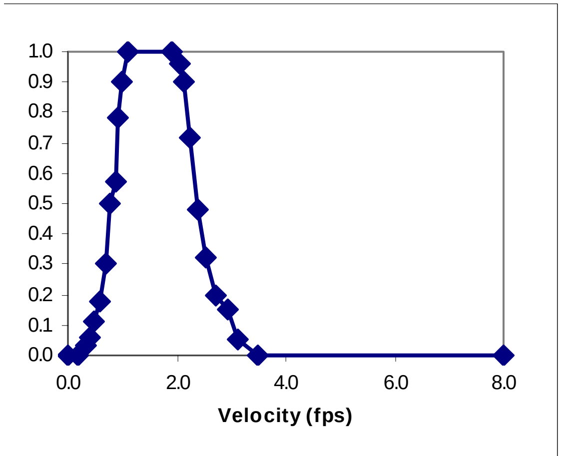
Steelhead – adult holding

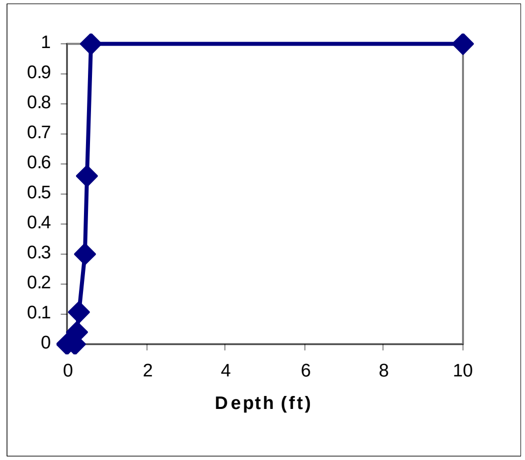


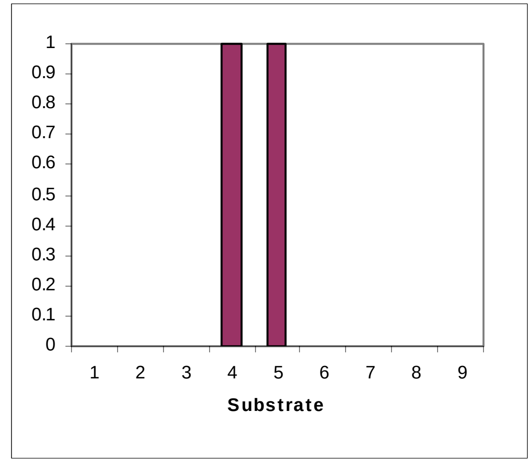




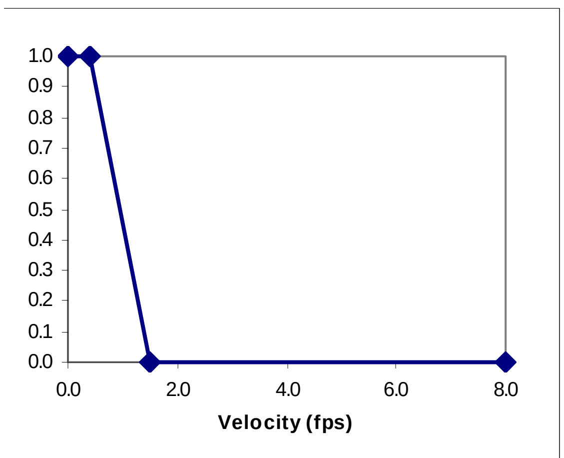
Bull trout - spawning

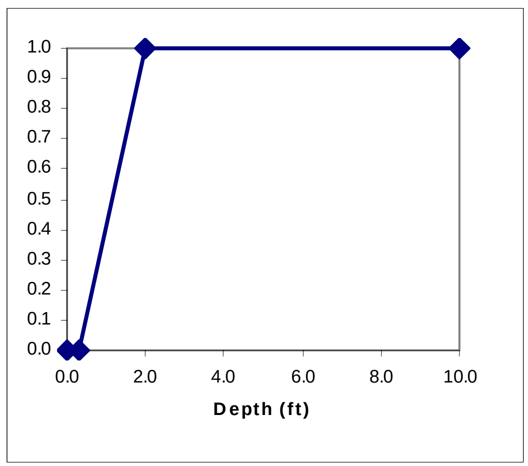


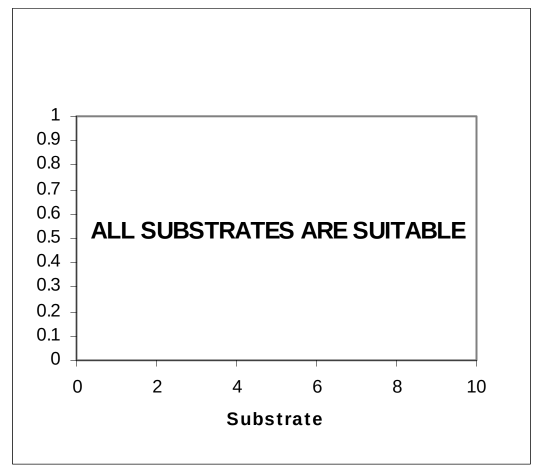




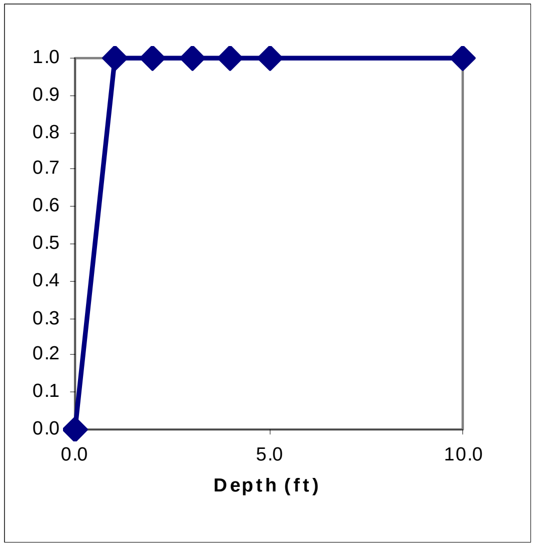
Bull trout – adult



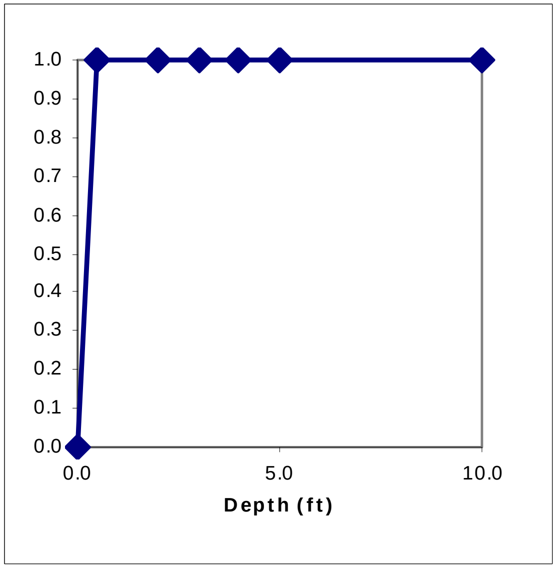




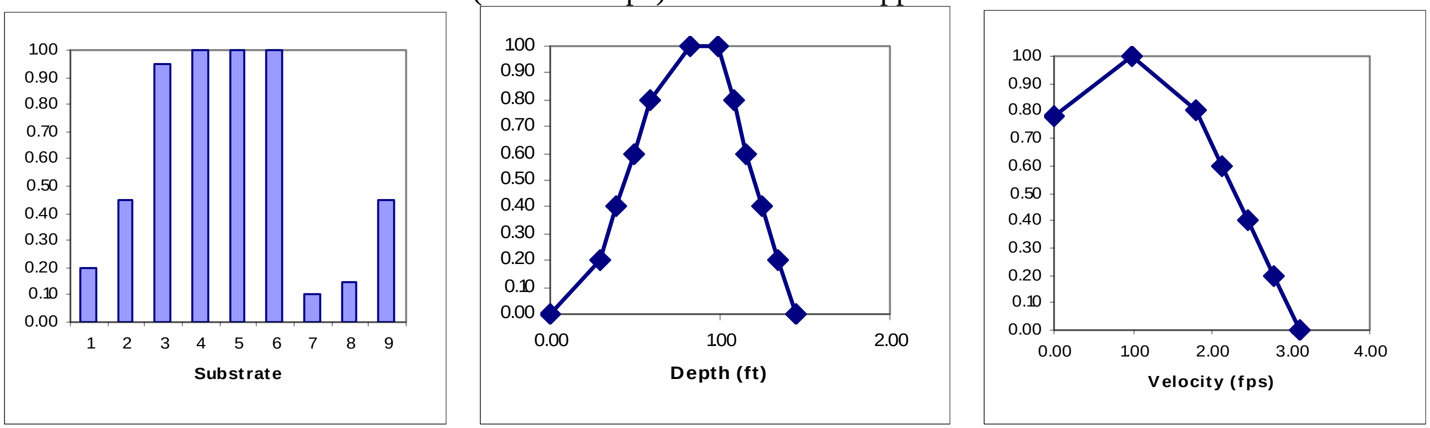
Upstream anadromous passage



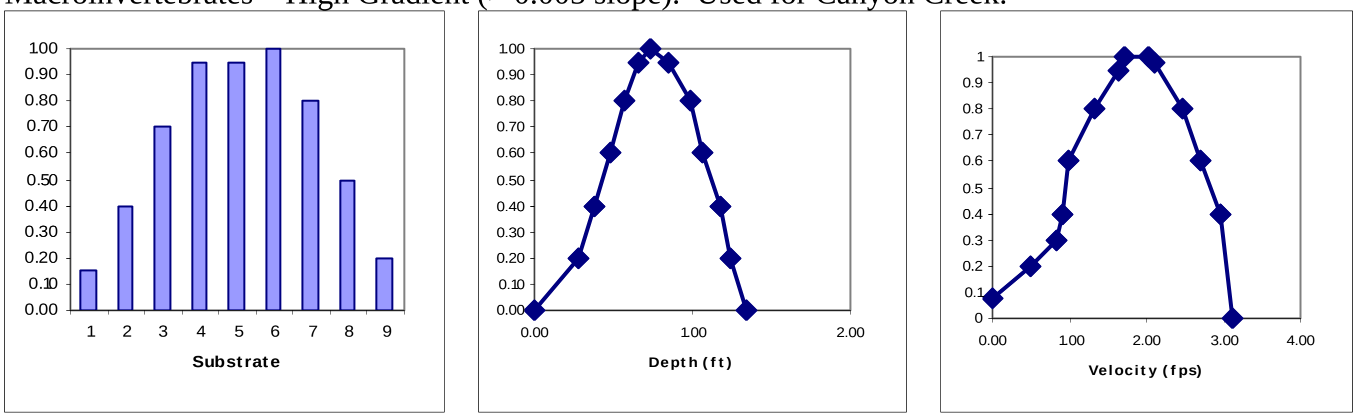
Upstream resident passage



Macroinvertebrates – Low Gradient (< 0.005 slope). Used for the Upper Lemhi River.



Macroinvertebrates – High Gradient (> 0.005 slope). Used for Canyon Creek.



APPENDIX F – WEIGHTED USABLE AREA (WUA) VERSUS DISCHARGE RELATIONSHIPS

Upper Lemhi River, Reach 1 (Study Site 1):

Table F-1. Weighted usable area (WUA) versus discharge (cfs) relationships for steelhead at the Upper Lemhi River, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
40	61395	29812	27122	79.3	77.4
45	61750	31209	28898	83.0	82.5
47	61915	31750	29492	84.4	84.2
50	62182	32415	30337	86.2	86.6
56	62725	33763	31456	89.8	89.8
60	62892	34099	32405	90.7	92.5
65	63171	34816	33034	92.6	94.3
70	63426	35377	33507	94.1	95.6
75	63672	35853	33947	95.3	96.9
80	63909	36242	34356	96.4	98.0
85	64136	36643	34653	97.4	98.9
90	64354	37007	34839	98.4	99.4
95	64564	37267	34975	99.1	99.8
100	64762	37487	35040	99.7	100.0
105	64962	37609	35032	100.0	100.0
110	65155	37514	34811	99.7	99.3
115	65348	37390	34549	99.4	98.6
120	65521	37320	34334	99.2	98.0
125	65677	37096	33884	98.6	96.7
130	65828	37039	33625	98.5	96.0

Table F-2. Weighted usable area (WUA) versus discharge (cfs) relationships for Chinook salmon at the Upper Lemhi River, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
40	61395	29812	27122	79.3	77.4
45	61750	31209	28898	83.0	82.5
47	61915	31750	29492	84.4	84.2
50	62182	32415	30337	86.2	86.6
56	62725	33763	31456	89.8	89.8
60	62892	34099	32405	90.7	92.5
65	63171	34816	33034	92.6	94.3
70	63426	35377	33507	94.1	95.6
75	63672	35853	33947	95.3	96.9
80	63909	36242	34356	96.4	98.0
85	64136	36643	34653	97.4	98.9
90	64354	37007	34839	98.4	99.4
95	64564	37267	34975	99.1	99.8
100	64762	37487	35040	99.7	100.0
105	64962	37609	35032	100.0	100.0
110	65155	37514	34811	99.7	99.3
115	65348	37390	34549	99.4	98.6
120	65521	37320	34334	99.2	98.0
125	65677	37096	33884	98.6	96.7
130	65828	37039	33625	98.5	96.0

Table F-3. Weighted usable area (WUA) versus discharge relationships for bull trout at the Upper Lemhi River, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
40	61395	25194	27160	90.5	79.3
45	61750	26078	28847	93.7	84.2
47	61915	26413	29301	94.9	85.5
50	62182	26537	30106	95.3	87.9
56	62725	27280	30755	98.0	89.8
60	62892	26853	31822	96.5	92.9
65	63171	26966	32431	96.9	94.7
70	63426	26971	32980	96.9	96.3
75	63672	27060	33404	97.2	97.5
80	63909	27025	33745	97.1	98.5
85	64136	27042	34008	97.1	99.3
90	64354	26918	34179	96.7	99.8
95	64564	26722	34256	96.0	100.0
100	64762	26571	34202	95.5	99.8
105	64962	26795	34070	96.3	99.5
110	65155	26985	33908	96.9	99.0
115	65348	27307	33552	98.1	97.9
120	65521	27452	33121	98.6	96.7
125	65677	27665	32805	99.4	95.8
130	65828	27836	32489	100.0	94.8

Table F-4. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Upper Lemhi River, Study Site 1.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
40	61395	46581	98.9
45	61750	47025	99.8
47	61915	47101	100.0
50	62182	47121	100.0
56	62725	46413	98.5
60	62892	46307	98.3
65	63171	45233	96.0
70	63426	43496	92.3
75	63672	41765	88.6
80	63909	39938	84.8
85	64136	37215	79.0
90	64354	33225	70.5
95	64564	29452	62.5
100	64762	26564	56.4
105	64962	25152	53.4
110	65155	24471	51.9
115	65348	24125	51.2
120	65521	23765	50.4
125	65677	23470	49.8
130	65828	23044	48.9

Table F-5. Passage criteria assessment for transect 1 (riffle), the Upper Lemhi River Study Site 1, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
40	86	28	33	25	29
45	86	31	36	26	30
47	86	32	37	26	30
50	87	33	38	26	30
56	87	35	40	27	31
60	87	36	41	27	31
63.7	87	37	43	28	32
65	87	47	54	28	32
70	87	51	58	28	32
75	87	55	63	29	33
80	87	59	67	29	33
85	88	62	71	30	34
90	88	65	74	30	34
95	88	68	77	31	35
100	88	79	90	55	63
105	88	81	92	56	63
110	88	83	94	57	64
115	88	84	95	57	65
120	88	85	96	85	96
125	88	85	96	85	96
130	89	85	96	85	96
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
40	86	15	17	15	17
45	86	16	18	16	18
47	86	16	19	16	18
50	87	17	19	16	19
56	87	17	20	17	20
60	87	18	21	17	20
63.7	87	18	21	18	21
65	87	19	21	19	21
70	87	19	22	19	22
75	87	20	22	20	22
80	87	20	23	20	23
85	88	21	23	21	23
90	88	21	24	21	24
95	88	21	24	21	24
100	88	28	32	25	28
105	88	30	34	25	29
110	88	31	35	26	29
115	88	32	37	26	29
120	88	33	38	26	30
125	88	34	39	27	30
130	89	35	40	27	31
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
40	86	11	13	11	13

45	86	12	14	12	14
47	86	12	14	12	14
50	87	12	14	12	14
56	87	12	14	12	14
60	87	13	15	13	15
63.7	87	13	15	13	15
65	87	13	15	13	15
70	87	13	15	13	15
75	87	14	16	14	16
80	87	14	16	14	16
85	88	14	16	14	16
90	88	14	16	14	16
95	88	15	17	15	17
100	88	15	17	15	17
105	88	15	17	15	17
110	88	16	18	16	18
115	88	16	18	16	18
120	88	17	19	16	19
125	88	17	19	17	19
130	89	18	20	17	19

The Upper Lemhi River, Reach 2 (Study Site 2):

Table F-6. Weighted usable area (WUA) versus discharge relationships for steelhead at the Upper Lemhi River, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
16.5	31510	9440	5378	35.6	33.3
22.5	34833	12384	7255	46.8	44.9
28.5	37078	15423	9367	58.2	58.0
34.5	38953	18116	11096	68.4	68.7
40.5	39978	20149	12175	76.1	75.4
41.1	40105	20366	12293	76.9	76.1
46.5	40895	21683	13360	81.9	82.7
50.1	41237	22243	14200	84.0	87.9
52.5	41921	23156	14382	87.4	89.1
58.5	42930	24476	15251	92.4	94.4
60.3	44180	24818	15435	93.7	95.6
64.5	47400	25505	15791	96.3	97.8
70.5	47895	26486	16149	100.0	100.0

Table F-7. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at the Upper Lemhi River, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
16.5	31510	9440	5378	35.6	33.3
22.5	34833	12384	7255	46.8	44.9
28.5	37078	15423	9367	58.2	58.0
34.5	38953	18116	11096	68.4	68.7
40.5	39978	20149	12175	76.1	75.4
41.1	40105	20366	12293	76.9	76.1
46.5	40895	21683	13360	81.9	82.7
50.1	41237	22243	14200	84.0	87.9
52.5	41921	23156	14382	87.4	89.1
58.5	42930	24476	15251	92.4	94.4
60.3	44180	24818	15435	93.7	95.6
64.5	47400	25505	15791	96.3	97.8
70.5	47895	26486	16149	100.0	100.0

Table F-8. Weighted usable area (WUA) versus discharge relationships for bull trout at the Upper Lemhi River, Study Site 2.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
16.5	31510	6552	2295	30.5	19.7
22.5	34833	9051	3675	42.2	31.5
28.5	37078	11371	5557	53.0	47.6
34.5	38953	13373	7477	62.3	64.0
40.5	39978	15303	8761	71.3	75.0
41.1	40105	15502	8922	72.2	76.4
46.5	40895	16495	10122	76.8	86.7
50.1	41237	15280	10898	71.2	93.4
52.5	41921	17356	11152	80.9	95.5
58.5	42930	19723	11603	91.9	99.4
60.3	44180	20181	11631	94.0	99.6
64.5	47400	20777	11674	96.8	100.0
70.5	47895	21466	11624	100.0	99.6

Table F-9. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Upper Lemhi River, Study Site 2.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
16.5	31510	17654	65.5
22.5	34833	20991	77.9
28.5	37078	23304	86.5
34.5	38953	24817	92.1
40.5	39978	25775	95.6
41.1	40105	25771	95.6
46.5	40895	25672	95.3
50.1	41237	25365	94.1
52.5	41921	25958	96.3
58.5	42930	26401	98.0
60.3	44180	26528	98.4
64.5	47400	26949	100.0
70.5	47895	26500	98.3

Table F-10. Passage criteria assessment for transect 1 (riffle), the Upper Lemhi River Study Site 2, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
16.5	38	0	0	0	0
22.5	47	4	7	1	3
28.5	48	10	21	10	21
34.5	51	16	31	14	27
40.5	52	34	65	27	52
41.1	52	35	67	27	53
46.5	52	45	86	30	57
50.1	52	47	90	47	90
52.5	52	47	90	47	90
58.5	53	48	92	48	92
60.3	53	49	92	49	92
64.5	53	51	97	51	97
70.5	53	52	98	52	98
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
16.5	38	0	0	0	0
22.5	47	0	0	0	0
28.5	48	0	0	0	0
34.5	51	2	4	1	1
40.5	52	10	19	10	19
41.1	52	10	19	10	19
46.5	52	11	21	11	21
50.1	52	19	36	14	27
52.5	52	23	44	15	29
58.5	53	40	76	29	54
60.3	53	43	82	29	56
64.5	53	47	89	47	89
70.5	53	48	90	48	90
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
16.5	38	0	0	0	0
22.5	47	0	0	0	0
28.5	48	0	0	0	0
34.5	51	0	0	0	0
40.5	52	0	0	0	0
41.1	52	0	0	0	0
46.5	52	0	0	0	0
50.1	52	4	7	2	3
52.5	52	7	13	3	6
58.5	53	11	20	11	20
60.3	53	11	21	11	21
64.5	53	18	34	14	27
70.5	53	34	65	27	52

The Upper Lemhi River, Reach 3 (Study Site 3):

Table F-11. Weighted usable area (WUA) versus discharge relationships for steelhead at the Upper Lemhi River, Study Site 3.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
9.5	29382	8920	4680	43.1	28.3
13.5	30822	11239	6789	54.3	41.1
17.5	32255	13620	9747	65.8	59.0
21.5	33847	14986	11025	72.4	66.8
24.4	34304	15826	11619	76.4	70.4
25.5	34530	16024	11787	77.4	71.4
29.5	34812	16997	12409	82.1	75.2
33.5	35047	17824	13006	86.1	78.8
37.3	35184	18297	13510	88.3	81.8
37.5	35226	18542	13682	89.5	82.9
41.5	35380	19169	14234	92.6	86.2
44.4	35533	19581	14570	94.5	88.2
45.5	35556	19626	14667	94.8	88.8
49.5	35738	19963	15050	96.4	91.2
53.5	35899	20243	15405	97.7	93.3
57.5	36051	20442	15741	98.7	95.3
61.5	36195	20599	16037	99.5	97.1
65.5	36331	20680	16260	99.8	98.5
69.5	36463	20712	16406	100.0	99.4
73.5	36589	20701	16492	99.9	99.9
77.5	36710	20647	16510	99.7	100.0
81.5	36828	20472	16440	98.8	99.6
85.5	36946	20323	16284	98.1	98.6
89.5	37060	20106	16020	97.1	97.0
93.5	37171	19921	15829	96.2	95.9
97.5	37291	19560	15399	94.4	93.3
101.5	37432	19214	14919	92.8	90.4

Table F-12. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at the Upper Lemhi River, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
9.5	29382	8920	4680	43.1	28.3
13.5	30822	11239	6789	54.3	41.1
17.5	32255	13620	9747	65.8	59.0
21.5	33847	14986	11025	72.4	66.8
24.4	34304	15826	11619	76.4	70.4
25.5	34530	16024	11787	77.4	71.4
29.5	34812	16997	12409	82.1	75.2
33.5	35047	17824	13006	86.1	78.8
37.3	35184	18297	13510	88.3	81.8
37.5	35226	18542	13682	89.5	82.9
41.5	35380	19169	14234	92.6	86.2
44.4	35533	19581	14570	94.5	88.2
45.5	35556	19626	14667	94.8	88.8
49.5	35738	19963	15050	96.4	91.2
53.5	35899	20243	15405	97.7	93.3
57.5	36051	20442	15741	98.7	95.3
61.5	36195	20599	16037	99.5	97.1
65.5	36331	20680	16260	99.8	98.5
69.5	36463	20712	16406	100.0	99.4
73.5	36589	20701	16492	99.9	99.9
77.5	36710	20647	16510	99.7	100.0
81.5	36828	20472	16440	98.8	99.6
85.5	36946	20323	16284	98.1	98.6
89.5	37060	20106	16020	97.1	97.0
93.5	37171	19921	15829	96.2	95.9
97.5	37291	19560	15399	94.4	93.3
101.5	37432	19214	14919	92.8	90.4

Table F-13. Weighted usable area (WUA) versus discharge relationships for bull trout at the Upper Lemhi River, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
9.5	29382	7135	5213	56.7	30.9
13.5	30822	8506	7332	67.6	43.5
17.5	32255	9958	10030	79.1	59.5
21.5	33847	10757	11598	85.4	68.8
24.4	34304	11207	12598	89.0	74.7
25.5	34530	11239	12884	89.3	76.4
29.5	34812	11584	13910	92.0	82.5
33.5	35047	11874	14910	94.3	88.4
37.3	35184	11953	15617	94.9	92.6
37.5	35226	12118	15851	96.2	94.0
41.5	35380	12386	16543	98.4	98.1
44.4	35533	12514	16863	99.4	100.0
45.5	35556	12469	16832	99.0	99.8
49.5	35738	12528	16826	99.5	99.8
53.5	35899	12592	16586	100.0	98.4
57.5	36051	12524	16178	99.5	95.9
61.5	36195	12405	15676	98.5	93.0
65.5	36331	12280	15101	97.5	89.6
69.5	36463	12086	14561	96.0	86.3
73.5	36589	11950	14004	94.9	83.0
77.5	36710	11829	13470	93.9	79.9
81.5	36828	11791	12861	93.6	76.3
85.5	36946	11637	12312	92.4	73.0
89.5	37060	11447	11842	90.9	70.2
93.5	37171	11397	11363	90.5	67.4
97.5	37291	11274	10833	89.5	64.2
101.5	37432	11184	10376	88.8	61.5

Table F-14. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Upper Lemhi River, Study Site 3.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
9.5	29382	15838	69.2
13.5	30822	17612	77.0
17.5	32255	19098	83.5
21.5	33847	20320	88.8
24.4	34304	21280	93.0
25.5	34530	21503	94.0
29.5	34812	22165	96.9
33.5	35047	22500	98.4
37.3	35184	22650	99.0
37.5	35226	22672	99.1
41.5	35380	22833	99.8
44.4	35533	22871	100.0
45.5	35556	22806	99.7
49.5	35738	22595	98.8
53.5	35899	22229	97.2
57.5	36051	21798	95.3
61.5	36195	21278	93.0
65.5	36331	20583	90.0
69.5	36463	19632	85.8
73.5	36589	18949	82.9
77.5	36710	18166	79.4
81.5	36828	17386	76.0
85.5	36946	16601	72.6
89.5	37060	15707	68.7
93.5	37171	15019	65.7
97.5	37291	14325	62.6
101.5	37432	13682	59.8

Table F-15. Passage criteria assessment for transect 1 (riffle), the Upper Lemhi River Study Site 3, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
9.5	32	10	33	10	33
13.5	40	13	32	13	32
17.5	42	14	33	14	33
21.5	47	15	32	15	32
24.4	47	16	34	16	34
25.5	47	17	36	16	35
29.5	47	22	47	18	39
33.5	47	31	66	26	56
37.3	47	32	69	27	58
37.5	47	36	76	29	62
41.5	47	37	79	34	73
44.4	47	41	87	37	79
45.5	47	40	86	37	79
49.5	47	41	89	37	80
53.5	47	43	91	38	81
57.5	47	47	100	47	100
61.5	47	47	100	47	100
65.5	47	47	100	47	100
69.5	47	47	100	47	100
73.5	47	47	99	47	99
77.5	47	47	99	47	99
81.5	47	47	99	47	99
85.5	48	47	98	47	98
89.5	48	47	98	47	98
93.5	48	47	98	47	98
97.5	48	47	97	47	97
101.5	48	47	97	47	97
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
9.5	32	6	20	6	20
13.5	40	8	21	8	21
17.5	42	10	23	10	23
21.5	47	11	24	11	24
24.4	47	13	27	13	27
25.5	47	13	27	13	27
29.5	47	14	29	14	29
33.5	47	14	31	14	31
37.3	47	15	31	15	31
37.5	47	15	32	15	32
41.5	47	16	34	16	34
44.4	47	19	41	17	37
45.5	47	19	40	17	36
49.5	47	22	48	18	39
53.5	47	26	55	20	42
57.5	47	33	71	28	59
61.5	47	36	77	33	71
65.5	47	37	79	34	72

69.5	47	40	86	37	78
73.5	47	41	87	37	79
77.5	47	42	89	38	80
81.5	47	43	90	38	80
85.5	48	47	98	47	98
89.5	48	47	98	47	98
93.5	48	47	97	47	97
97.5	48	47	97	47	97
101.5	48	47	97	47	97
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
9.5	32	0	0	0	0
13.5	40	0	1	0	1
17.5	42	3	8	3	8
21.5	47	7	15	7	15
24.4	47	8	17	8	17
25.5	47	8	17	8	17
29.5	47	9	20	9	20
33.5	47	10	22	10	22
37.3	47	11	23	11	23
37.5	47	11	24	11	24
41.5	47	12	26	12	26
44.4	47	13	28	13	28
45.5	47	13	28	13	28
49.5	47	14	29	14	29
53.5	47	14	30	14	30
57.5	47	15	32	15	32
61.5	47	15	33	15	33
65.5	47	16	34	16	34
69.5	47	18	38	17	36
73.5	47	21	44	18	38
77.5	47	23	49	19	40
81.5	47	26	54	20	42
85.5	48	33	69	27	57
89.5	48	35	74	29	60
93.5	48	37	76	34	70
97.5	48	37	78	34	71
101.5	48	40	83	36	76

The Upper Lemhi River, Reach 4 (Study Site 4):

Table F-16. Weighted usable area (WUA) versus discharge relationships for steelhead at the Upper Lemhi River, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	23543	10673	1866	53.3	23.0
9	25520	12542	3064	62.6	37.8
12	26414	13860	4015	69.2	49.6
15	27725	15024	4799	75.0	59.2
15.5	27884	15195	4907	75.8	60.6
18	28346	15948	5238	79.6	64.7
21	28695	16738	5641	83.5	69.6
24	28810	17525	6028	87.5	74.4
27	28913	18139	6743	90.5	83.2
30	28991	18645	7341	93.0	90.6
31	28954	18729	7463	93.5	92.1
32.5	29099	19036	7599	95.0	93.8
33	29100	19073	7637	95.2	94.3
36	29217	19446	7821	97.0	96.5
39	29341	19756	7970	98.6	98.4
42	29543	20039	8101	100.0	100.0

Table F-17. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at the Upper Lemhi River, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	23543	10673	1866	53.3	23.0
9	25520	12542	3064	62.6	37.8
12	26414	13860	4015	69.2	49.6
15	27725	15024	4799	75.0	59.2
15.5	27884	15195	4907	75.8	60.6
18	28346	15948	5238	79.6	64.7
21	28695	16738	5641	83.5	69.6
24	28810	17525	6028	87.5	74.4
27	28913	18139	6743	90.5	83.2
30	28991	18645	7341	93.0	90.6
31	28954	18729	7463	93.5	92.1
32.5	29099	19036	7599	95.0	93.8
33	29100	19073	7637	95.2	94.3
36	29217	19446	7821	97.0	96.5
39	29341	19756	7970	98.6	98.4
42	29543	20039	8101	100.0	100.0

Table F-18. Weighted usable area (WUA) versus discharge relationships for bull trout at the Upper Lemhi River, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	23543	10033	2250	52.0	27.5
9	25520	12237	3397	63.5	41.5
12	26414	13748	4182	71.3	51.1
15	27725	14754	4949	76.5	60.5
15.5	27884	14871	5044	77.1	61.6
18	28346	15864	5620	82.3	68.7
21	28695	16737	6135	86.8	75.0
24	28810	17468	6698	90.6	81.9
27	28913	18105	7227	93.9	88.3
30	28991	18517	7681	96.0	93.9
31	28954	18537	7833	96.1	95.7
32.5	29099	18841	7917	97.7	96.7
33	29100	18850	7939	97.8	97.0
36	29217	19069	8045	98.9	98.3
39	29341	19199	8146	99.6	99.5
42	29543	19282	8183	100.0	100.0

Table F-19. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Upper Lemhi River, Study Site 4.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
6	23543	14607	83.2
9	25520	16033	91.3
12	26414	16902	96.3
15	27725	17258	98.3
15.5	27884	17347	98.8
18	28346	17558	100.0
21	28695	17464	99.5
24	28810	17352	98.8
27	28913	17139	97.6
30	28991	16466	93.8
31	28954	16331	93.0
32.5	29099	16132	91.9
33	29100	16048	91.4
36	29217	15500	88.3
39	29341	15040	85.7
42	29543	14407	82.1

Table F-20. Passage criteria assessment for transect 1 (glide), the Upper Lemhi River Study Site 4, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
6.0	13	7	51	7	51
9.0	18	8	43	8	43
12.0	21	8	41	8	41
15.0	22	13	58	12	53
15.5	23	16	70	12	53
18.0	22	15	68	12	54
21.0	24	19	77	12	52
24.0	25	21	81	20	80
27.0	27	21	77	20	75
30.0	30	22	73	21	70
31.0	25	20	81	20	80
32.5	32	23	71	21	66
33.0	31	22	71	21	66
36.0	32	23	71	21	66
39.0	33	24	72	22	66
42.0	34	25	73	23	66
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
6.0	13	4	30	4	30
9.0	18	5	28	5	28
12.0	21	7	35	7	35
15.0	22	8	37	8	37
15.5	23	10	42	10	42
18.0	22	9	42	9	42
21.0	24	10	43	10	43
24.0	25	14	54	12	47
27.0	27	17	61	12	45
30.0	30	20	68	20	68
31.0	25	13	53	12	47
32.5	32	21	65	20	63
33.0	31	21	66	20	65
36.0	32	21	65	20	63
39.0	33	22	65	21	62
42.0	34	22	64	21	60
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
6.0	13	1	11	1	11
9.0	18	4	20	4	20
12.0	21	4	21	4	21
15.0	22	6	30	6	30
15.5	23	7	33	7	33
18.0	22	7	33	7	33
21.0	24	8	33	8	33
24.0	25	8	33	8	33
27.0	27	10	36	10	36
30.0	30	13	43	12	39
31.0	25	8	33	8	33

32.5	32	16	51	12	38
33.0	31	14	44	12	38
36.0	32	17	51	12	38
39.0	33	19	56	13	37
42.0	34	20	59	20	59

The Upper Lemhi River, Reach 5:

Table F-21. Weighted usable area (WUA) versus discharge relationships for steelhead at the Upper Lemhi River, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	24381	9339	3960	54.5	35.6
8	24856	10547	5523	61.6	49.6
10	25127	11550	6680	67.4	60.0
10.4	25176	11709	6852	68.4	61.6
12	25669	12400	7455	72.4	67.0
14	25958	13082	8056	76.4	72.4
16	26099	13569	8462	79.2	76.0
18	26233	14071	8955	82.1	80.4
19	26290	14285	9158	83.4	82.3
20	26343	14472	9339	84.5	83.9
22	26446	14838	9646	86.6	86.7
22.9	26486	15014	9759	87.6	87.7
24	26532	15206	9884	88.8	88.8
26	26611	15507	10090	90.5	90.6
28	26677	15763	10279	92.0	92.3
30	26724	15963	10458	93.2	93.9
32	26838	16206	10618	94.6	95.4
34	26945	16403	10753	95.8	96.6
36	27048	16558	10854	96.7	97.5
38	27148	16668	10921	97.3	98.1
40	27244	16785	11009	98.0	98.9
42	27366	16881	11072	98.5	99.5
44	27493	16956	11114	99.0	99.8
46	27630	17024	11132	99.4	100.0
48	27771	17043	11101	99.5	99.7
50	27909	17076	11095	99.7	99.7
52	28043	17082	11063	99.7	99.4
54	28175	17115	11063	99.9	99.4
56	28304	17130	11055	100.0	99.3

Table F-22. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at the Upper Lemhi River, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	24381	9339	3960	54.5	35.6
8	24856	10547	5523	61.6	49.6
10	25127	11550	6680	67.4	60.0
10.4	25176	11709	6852	68.4	61.6
12	25669	12400	7455	72.4	67.0
14	25958	13082	8056	76.4	72.4
16	26099	13569	8462	79.2	76.0
18	26233	14071	8955	82.1	80.4
19	26290	14285	9158	83.4	82.3
20	26343	14472	9339	84.5	83.9
22	26446	14838	9646	86.6	86.7
22.9	26486	15014	9759	87.6	87.7
24	26532	15206	9884	88.8	88.8
26	26611	15507	10090	90.5	90.6
28	26677	15763	10279	92.0	92.3
30	26724	15963	10458	93.2	93.9
32	26838	16206	10618	94.6	95.4
34	26945	16403	10753	95.8	96.6
36	27048	16558	10854	96.7	97.5
38	27148	16668	10921	97.3	98.1
40	27244	16785	11009	98.0	98.9
42	27366	16881	11072	98.5	99.5
44	27493	16956	11114	99.0	99.8
46	27630	17024	11132	99.4	100.0
48	27771	17043	11101	99.5	99.7
50	27909	17076	11095	99.7	99.7
52	28043	17082	11063	99.7	99.4
54	28175	17115	11063	99.9	99.4
56	28304	17130	11055	100.0	99.3

Table F-23. Weighted usable area (WUA) versus discharge relationships for bull trout at the Upper Lemhi River, Study Site 5.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
6	24381	7670	4226	57	39
8	24856	9002	5569	67	52
10	25127	9907	6748	74	62
10.4	25176	10056	6965	75	64
12	25669	10806	7851	81	73
14	25958	11504	8765	86	81
16	26099	12148	9421	91	87
18	26233	12538	9882	94	92
19	26290	12624	10048	95	93
20	26343	12749	10198	96	94
22	26446	12968	10431	97	97
22.9	26486	13078	10513	98	97
24	26532	13145	10589	99	98
26	26611	13236	10698	99	99
28	26677	13322	10768	100	100
30	26724	13294	10800	100	100
32	26838	13298	10787	100	100
34	26945	13325	10736	100	99
36	27048	13344	10664	100	99
38	27148	13327	10554	100	98
40	27244	13323	10426	100	97
42	27366	13272	10285	99	95
44	27493	13212	10110	99	94
46	27630	13229	9948	99	92
48	27771	13214	9785	99	91
50	27909	13218	9606	99	89
52	28043	13209	9408	99	87
54	28175	13236	9251	99	86
56	28304	13260	9083	99	84

Table F-24. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Upper Lemhi River, Study Site 5.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
6	24381	13987	73.2
8	24856	15356	80.4
10	25127	16302	85.4
10.4	25176	16468	86.2
12	25669	17109	89.6
14	25958	17722	92.8
16	26099	18226	95.4
18	26233	18581	97.3
19	26290	18707	97.9
20	26343	18818	98.5
22	26446	18985	99.4
22.9	26486	19036	99.7
24	26532	19076	99.9
26	26611	19099	100.0
28	26677	19091	100.0
30	26724	19014	99.6
32	26838	18868	98.8
34	26945	18668	97.7
36	27048	18401	96.3
38	27148	18176	95.2
40	27244	17907	93.8
42	27366	17622	92.3
44	27493	17277	90.5
46	27630	16856	88.3
48	27771	16431	86.0
50	27909	15868	83.1
52	28043	15399	80.6
54	28175	15004	78.6
56	28304	14615	76.5

Table F-25. Passage criteria assessment for transect 5 (riffle), the Upper Lemhi River Study Site 5, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
6.0	28	1	4	1	4
8.0	29	3	11	2	8
10.0	29	12	42	7	24
10.4	29	13	44	7	25
12.0	29	15	52	9	30
14.0	31	20	65	17	56
16.0	31	22	71	18	58
18.0	31	25	81	23	74
19.0	31	26	83	23	75
20.0	31	27	85	24	76
22.0	32	28	90	28	90
22.9	32	29	90	29	90
24.0	32	29	90	29	90
26.0	32	29	90	29	90
28.0	32	29	91	29	91
30.0	32	29	91	29	91
32.0	32	30	94	30	94
34.0	32	31	94	31	94
36.0	32	31	94	31	94
38.0	33	31	95	31	95
40.0	33	31	95	31	95
42.0	33	31	95	31	95
44.0	33	31	95	31	95
46.0	34	32	94	32	94
48.0	34	32	94	32	94
50.0	34	32	93	32	93
52.0	35	32	92	32	92
54.0	35	32	92	32	92
56.0	36	32	91	32	91
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
6.0	28	0	0	0	0
8.0	29	0	0	0	0
10.0	29	0	0	0	0
10.4	29	0	0	0	0
12.0	29	0	0	0	0
14.0	31	2	6	2	6
16.0	31	4	13	3	9
18.0	31	12	40	7	23
19.0	31	14	44	8	25
20.0	31	15	48	9	27
22.0	32	19	60	17	53
22.9	32	20	63	17	54
24.0	32	21	65	17	55
26.0	32	24	75	22	69
28.0	32	25	79	23	71
30.0	32	26	82	24	73

32.0	32	28	88	28	88
34.0	32	29	88	29	88
36.0	32	29	89	29	89
38.0	33	29	89	29	89
40.0	33	29	89	29	89
42.0	33	29	89	29	89
44.0	33	30	92	30	92
46.0	34	31	91	31	91
48.0	34	31	90	31	90
50.0	34	31	89	31	89
52.0	35	31	89	31	89
54.0	35	31	89	31	89
56.0	36	31	88	31	88
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
6.0	28	0	0	0	0
8.0	29	0	0	0	0
10.0	29	0	0	0	0
10.4	29	0	0	0	0
12.0	29	0	0	0	0
14.0	31	0	0	0	0
16.0	31	0	0	0	0
18.0	31	0	0	0	0
19.0	31	0	0	0	0
20.0	31	0	0	0	0
22.0	32	2	5	2	5
22.9	32	2	6	2	6
24.0	32	3	9	2	7
26.0	32	11	34	6	19
28.0	32	13	40	7	23
30.0	32	15	46	8	26
32.0	32	19	58	17	51
34.0	32	20	62	17	53
36.0	32	21	66	18	55
38.0	33	25	76	22	69
40.0	33	26	78	23	71
42.0	33	27	81	24	72
44.0	33	28	85	28	85
46.0	34	29	85	29	85
48.0	34	29	84	29	84
50.0	34	29	84	29	84
52.0	35	29	84	29	84
54.0	35	29	83	29	83
56.0	36	29	83	29	83

Canyon Creek, Reach 1 (Study Site 1):

Table F-26. Weighted usable area (WUA) versus discharge relationships for steelhead at Canyon Creek, Study Site 1.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12476	3582	0	36.9	0
2	16370	4288	0	44.2	0
2.9	17251	5057	0	52.1	0
3	17315	5199	0	53.5	0
4	17875	5659	0	58.3	0
5	19595	6148	0	63.3	0
5.8	20167	6872	0	70.8	0
6	20300	7004	0	72.1	0
7	20908	7433	0	76.5	0
8	21400	7727	0	79.6	0
9	21838	7957	0	81.9	0
10	22237	8291	0	85.4	0
11	22604	8466	0	87.2	0
11.9	22926	8579	0	88.3	0
12	22959	8593	0	88.5	0
13	23389	9072	0	93.4	0
14	23444	9294	0	95.7	0
15	23496	9453	0	97.3	0
16	23545	9712	0	100.0	0

Table F-27. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Canyon Creek, Study Site 1.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12476	3582	0	36.9	0
2	16370	4288	0	44.2	0
2.9	17251	5057	0	52.1	0
3	17315	5199	0	53.5	0
4	17875	5659	0	58.3	0
5	19595	6148	0	63.3	0
5.8	20167	6872	0	70.8	0
6	20300	7004	0	72.1	0
7	20908	7433	0	76.5	0
8	21400	7727	0	79.6	0
9	21838	7957	0	81.9	0
10	22237	8291	0	85.4	0
11	22604	8466	0	87.2	0
11.9	22926	8579	0	88.3	0
12	22959	8593	0	88.5	0
13	23389	9072	0	93.4	0
14	23444	9294	0	95.7	0
15	23496	9453	0	97.3	0
16	23545	9712	0	100.0	0

Table F-28. Weighted usable area (WUA) versus discharge relationships for bull trout at Canyon Creek, Study Site 1.

	WUA (ft²)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12476	3278	0	46.6	0
2	16370	3918	0	55.7	0
2.9	17251	4200	0	59.7	0
3	17315	4361	0	61.9	0
4	17875	4808	0	68.3	0
5	19595	5604	0	79.6	0
5.8	20167	5991	0	85.1	0
6	20300	6054	0	86.0	0
7	20908	6217	0	88.3	0
8	21400	6465	0	91.8	0
9	21838	6459	0	91.7	0
10	22237	6714	0	95.4	0
11	22604	6871	0	97.6	0
11.9	22926	6872	0	97.6	0
12	22959	6883	0	97.8	0
13	23389	6967	0	99.0	0
14	23444	7005	0	99.5	0
15	23496	7008	0	99.5	0
16	23545	7040	0	100.0	0

Table F-29. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Canyon Creek, Study Site 1.

	WUA (ft²)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	12476	3028	36.3
2	16370	3998	48.0
2.9	17251	4511	54.1
3	17315	4465	53.6
4	17875	4668	56.0
5	19595	5023	60.3
5.8	20167	5278	63.4
6	20300	5407	64.9
7	20908	5856	70.3
8	21400	6349	76.2
9	21838	6907	82.9
10	22237	7336	88.1
11	22604	7655	91.9
11.9	22926	7996	96.0
12	22959	8021	96.3
13	23389	8142	97.7
14	23444	8018	96.2
15	23496	8185	98.2
16	23545	8331	100.0

Table F-30. Passage criteria assessment for transect 4 (glide), Canyon Creek Study Site 1, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	8	4	52	4	45
2	9	5	55	4	42
3	10	6	58	4	41
4	10	6	61	4	40
5	11	7	59	4	38
6	11	7	60	4	38
7	12	7	60	4	38
8	12	7	60	6	51
9	12	7	60	6	50
10	13	8	60	6	50
11	13	8	60	6	49
12	13	8	60	6	49
13	13	8	64	8	61
14	13	9	65	8	61
15	13	9	65	8	60
16	14	9	65	8	60
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	8	3	31	3	31
2	9	3	34	3	34
3	10	4	38	3	35
4	10	4	42	4	36
5	11	5	42	4	34
6	11	5	43	4	34
7	12	5	45	4	34
8	12	5	45	4	33
9	12	6	46	4	33
10	13	6	47	4	33
11	13	6	47	4	32
12	13	6	48	4	32
13	13	6	48	4	32
14	13	6	49	4	32
15	13	7	49	4	31
16	14	7	49	4	31
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	8	0	0	0	0
2	9	0	0	0	0
3	10	2	23	2	23
4	10	3	25	3	25
5	11	3	25	3	25
6	11	3	26	3	26
7	12	3	27	3	27
8	12	3	28	3	27
9	12	4	30	3	28
10	13	4	31	3	28
11	13	4	32	4	28

12	13	4	33	4	29
13	13	4	34	4	29
14	13	5	34	4	28
15	13	5	35	4	28
16	14	5	35	4	28

Canyon Creek, Reach 2 (Study Site 2):

Table F-31. Weighted usable area (WUA) versus discharge relationships for steelhead at Canyon Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	6211	428	139	11.1	6.7
0.6	6537	660	269	17.2	13.0
0.8	6707	1047	553	27.3	26.8
1.1	7397	1503	832	39.1	40.3
1.2	7464	1583	862	41.2	41.7
1.4	7589	1789	1006	46.6	48.7
1.6	7704	1981	1113	51.6	53.9
1.8	7811	2114	1220	55.1	59.1
2	7911	2228	1301	58.0	63.0
2.2	8637	2421	1411	63.0	68.3
2.4	8807	2507	1475	65.3	71.4
2.6	8919	2608	1563	67.9	75.7
2.9	9111	2784	1648	72.5	79.8
3	9127	2796	1668	72.8	80.8
3.2	9297	2895	1723	75.4	83.4
3.4	9350	2914	1766	75.9	85.5
3.6	9454	2958	1800	77.0	87.2
3.8	9655	3079	1829	80.2	88.6
4	9837	3139	1857	81.7	89.9
4.2	10022	3192	1883	83.1	91.2
4.4	10191	3235	1908	84.2	92.4
5	10556	3416	1975	89.0	95.6
5.5	10760	3534	2020	92.0	97.8
6	10904	3630	2040	94.5	98.8
6.5	11046	3750	2044	97.7	99.0
7	11182	3840	2065	100.0	100.0

Table F-32. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Canyon Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	6211	428	139	11.1	6.7
0.6	6537	660	269	17.2	13.0
0.8	6707	1047	553	27.3	26.8
1.1	7397	1503	832	39.1	40.3
1.2	7464	1583	862	41.2	41.7
1.4	7589	1789	1006	46.6	48.7
1.6	7704	1981	1113	51.6	53.9
1.8	7811	2114	1220	55.1	59.1
2	7911	2228	1301	58.0	63.0
2.2	8637	2421	1411	63.0	68.3
2.4	8807	2507	1475	65.3	71.4
2.6	8919	2608	1563	67.9	75.7
2.9	9111	2784	1648	72.5	79.8
3	9127	2796	1668	72.8	80.8
3.2	9297	2895	1723	75.4	83.4
3.4	9350	2914	1766	75.9	85.5
3.6	9454	2958	1800	77.0	87.2
3.8	9655	3079	1829	80.2	88.6
4	9837	3139	1857	81.7	89.9
4.2	10022	3192	1883	83.1	91.2
4.4	10191	3235	1908	84.2	92.4
5	10556	3416	1975	89.0	95.6
5.5	10760	3534	2020	92.0	97.8
6	10904	3630	2040	94.5	98.8
6.5	11046	3750	2044	97.7	99.0
7	11182	3840	2065	100.0	100.0

Table F-33. Weighted usable area (WUA) versus discharge relationships for bull trout at Canyon Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	6211	177	21	7.9	1.1
0.6	6537	241	79	10.7	4.1
0.8	6707	263	171	11.7	8.9
1.1	7397	405	368	18.1	19.1
1.2	7464	436	406	19.4	21.1
1.4	7589	561	471	25.0	24.5
1.6	7704	699	551	31.2	28.7
1.8	7811	733	615	32.7	32.0
2	7911	770	699	34.3	36.3
2.2	8637	941	784	42.0	40.8
2.4	8807	1051	851	46.9	44.3
2.6	8919	1140	923	50.8	48.0
2.9	9111	1305	1016	58.2	52.8
3	9127	1296	1046	57.8	54.4
3.2	9297	1370	1096	61.1	57.0
3.4	9350	1380	1154	61.6	60.0
3.6	9454	1424	1202	63.5	62.5
3.8	9655	1522	1261	67.9	65.6
4	9837	1580	1314	70.5	68.3
4.2	10022	1660	1373	74.0	71.4
4.4	10191	1706	1429	76.1	74.3
5	10556	1875	1587	83.6	82.5
5.5	10760	1961	1688	87.5	87.8
6	10904	2099	1790	93.6	93.1
6.5	11046	2156	1866	96.2	97.0
7	11182	2242	1923	100.0	100.0

Table F-34. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Canyon Creek, Study Site 2.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
0.4	6211	1432	24.5
0.6	6537	1749	30.0
0.8	6707	2013	34.5
1.1	7397	2322	39.8
1.2	7464	2432	41.7
1.4	7589	2607	44.7
1.6	7704	2778	47.6
1.8	7811	2958	50.7
2	7911	3132	53.7
2.2	8637	3313	56.8
2.4	8807	3511	60.2
2.6	8919	3674	63.0
2.9	9111	3911	67.0
3	9127	3981	68.2
3.2	9297	4124	70.7
3.4	9350	4277	73.3
3.6	9454	4420	75.8
3.8	9655	4560	78.2
4	9837	4688	80.4
4.2	10022	4804	82.3
4.4	10191	4914	84.2
5	10556	5191	89.0
5.5	10760	5389	92.4
6	10904	5549	95.1
6.5	11046	5698	97.7
7	11182	5834	100.0

Table F-35. Passage criteria assessment for transect 2 (hydraulic control), Canyon Creek Study Site 2, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
0.4	10	0	0	0	0
0.6	10	0	0	0	0
0.8	11	0	0	0	0
1.1	13	0	0	0	0
1.2	13	0	0	0	0
1.4	13	0	0	0	0
1.6	13	0	0	0	0
1.8	13	0	0	0	0
2.0	13	0	0	0	0
2.2	14	1	9	1	5
2.4	14	2	12	1	6
2.6	14	2	15	1	7
2.9	15	3	21	3	21
3.0	15	3	22	3	21
3.2	15	4	24	3	22
3.4	15	4	26	3	22
3.6	15	4	27	3	23
3.8	16	7	42	4	27
4.0	16	7	43	4	28
4.2	17	7	45	5	28
4.4	17	8	46	5	28
5.0	18	8	48	6	36
5.5	18	9	52	7	36
6.0	18	10	54	7	37
6.5	18	10	56	7	39
7.0	19	11	57	11	57
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
0.4	10	0	0	0	0
0.6	10	0	0	0	0
0.8	11	0	0	0	0
1.1	13	0	0	0	0
1.2	13	0	0	0	0
1.4	13	0	0	0	0
1.6	13	0	0	0	0
1.8	13	0	0	0	0
2.0	13	0	0	0	0
2.2	14	0	0	0	0
2.4	14	0	0	0	0
2.6	14	0	0	0	0
2.9	15	0	0	0	0
3.0	15	0	0	0	0
3.2	15	0	0	0	0
3.4	15	0	0	0	0
3.6	15	0	0	0	0
3.8	16	0	0	0	0
4.0	16	0	0	0	0

4.2	17	0	0	0	0
4.4	17	0	0	0	0
5.0	18	0	0	0	0
5.5	18	1	6	1	3
6.0	18	2	9	1	4
6.5	18	2	12	1	6
7.0	19	3	17	3	17
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
0.4	10	0	0	0	0
0.6	10	0	0	0	0
0.8	11	0	0	0	0
1.1	13	0	0	0	0
1.2	13	0	0	0	0
1.4	13	0	0	0	0
1.6	13	0	0	0	0
1.8	13	0	0	0	0
2.0	13	0	0	0	0
2.2	14	0	0	0	0
2.4	14	0	0	0	0
2.6	14	0	0	0	0
2.9	15	0	0	0	0
3.0	15	0	0	0	0
3.2	15	0	0	0	0
3.4	15	0	0	0	0
3.6	15	0	0	0	0
3.8	16	0	0	0	0
4.0	16	0	0	0	0
4.2	17	0	0	0	0
4.4	17	0	0	0	0
5.0	18	0	0	0	0
5.5	18	0	0	0	0
6.0	18	0	0	0	0
6.5	18	0	0	0	0
7.0	19	0	0	0	0

Canyon Creek, Reach 3 (Study Site 3):

Table F-36. Weighted usable area (WUA) versus discharge relationships for steelhead at Canyon Creek, Study Site 3.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.3	5507	1794	0	31.2	0.0
0.8	6018	2659	50	46.3	4.8
1	6136	2856	139	49.7	13.3
1.5	6405	3200	402	55.7	38.5
2	6597	3407	600	59.3	57.5
2.5	6739	3561	713	61.9	68.4
3	6896	3770	789	65.6	75.6
3.5	7076	3898	847	67.8	81.2
4	7238	4002	877	69.6	84.1
4.5	7348	4139	896	72.0	85.9
5	7490	4241	912	73.8	87.4
5.5	7911	4325	923	75.2	88.5
6	8043	4397	930	76.5	89.2
6.5	8144	4493	948	78.2	90.9
7	8239	4571	962	79.5	92.2
7.5	8330	4642	979	80.7	93.9
7.9	8598	4691	992	81.6	95.1
8	8623	4703	993	81.8	95.2
9	8843	4830	996	84.0	95.5
10	9324	5092	998	88.6	95.7
11	9562	5230	1019	91.0	97.7
12	9785	5381	1030	93.6	98.8
13	9994	5508	1035	95.8	99.2
14	10193	5621	1040	97.8	99.7
15	10381	5749	1043	100.0	100.0

Table F-37. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Canyon Creek, Study Site 3.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.3	5507	1794	0	31.2	0.0
0.8	6018	2659	50	46.3	4.8
1	6136	2856	139	49.7	13.3
1.5	6405	3200	402	55.7	38.5
2	6597	3407	600	59.3	57.5
2.5	6739	3561	713	61.9	68.4
3	6896	3770	789	65.6	75.6
3.5	7076	3898	847	67.8	81.2
4	7238	4002	877	69.6	84.1
4.5	7348	4139	896	72.0	85.9
5	7490	4241	912	73.8	87.4
5.5	7911	4325	923	75.2	88.5
6	8043	4397	930	76.5	89.2
6.5	8144	4493	948	78.2	90.9
7	8239	4571	962	79.5	92.2
7.5	8330	4642	979	80.7	93.9
7.9	8598	4691	992	81.6	95.1
8	8623	4703	993	81.8	95.2
9	8843	4830	996	84.0	95.5
10	9324	5092	998	88.6	95.7
11	9562	5230	1019	91.0	97.7
12	9785	5381	1030	93.6	98.8
13	9994	5508	1035	95.8	99.2
14	10193	5621	1040	97.8	99.7
15	10381	5749	1043	100.0	100.0

Table F-38. Weighted usable area (WUA) versus discharge relationships for bull trout at Canyon Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.3	5507	1447	262	28.6	24.7
0.8	6018	2419	382	47.8	36.0
1	6136	2679	433	52.9	40.8
1.5	6405	3221	533	63.6	50.2
2	6597	3531	649	69.8	61.1
2.5	6739	3727	723	73.6	68.1
3	6896	3875	793	76.6	74.7
3.5	7076	3989	862	78.8	81.2
4	7238	4152	892	82.0	84.0
4.5	7348	4255	921	84.1	86.7
5	7490	4340	939	85.7	88.4
5.5	7911	4409	953	87.1	89.7
6	8043	4495	961	88.8	90.5
6.5	8144	4590	985	90.7	92.7
7	8239	4646	1007	91.8	94.8
7.5	8330	4682	1018	92.5	95.9
7.9	8598	4698	1052	92.8	99.1
8	8623	4704	1052	92.9	99.1
9	8843	4786	1056	94.5	99.4
10	9324	4820	1062	95.2	100.0
11	9562	4883	1061	96.5	99.9
12	9785	4973	1048	98.2	98.7
13	9994	5018	1013	99.1	95.4
14	10193	5024	965	99.2	90.9
15	10381	5062	910	100.0	85.7

Table F-39. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Canyon Creek, Study Site 3.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
0.3	5507	1632	54.1
0.8	6018	2093	69.3
1	6136	2212	73.3
1.5	6405	2441	80.9
2	6597	2599	86.1
2.5	6739	2708	89.7
3	6896	2813	93.2
3.5	7076	2835	93.9
4	7238	2845	94.2
4.5	7348	2921	96.8
5	7490	2918	96.7
5.5	7911	2986	98.9
6	8043	3019	100.0
6.5	8144	3018	100.0
7	8239	3009	99.7
7.5	8330	2984	98.8
7.9	8598	2983	98.8
8	8623	2979	98.7
9	8843	2878	95.3
10	9324	2781	92.1
11	9562	2690	89.1
12	9785	2643	87.5
13	9994	2619	86.8
14	10193	2574	85.3
15	10381	2592	85.9

Table F-40. Passage criteria assessment for transect 1 (riffle), Canyon Creek Study Site 3, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
0.3	7	1	14	1	14
0.8	8	3	35	2	20
1.0	8	4	46	2	21
1.5	8	6	69	2	28
2.0	9	7	79	5	54
2.5	9	7	84	5	57
3.0	9	8	90	8	90
3.5	9	8	89	8	89
4.0	9	8	89	8	89
4.5	9	8	88	8	88
5.0	9	8	87	8	87
5.5	10	8	86	8	86
6.0	10	8	86	8	86
6.5	10	8	85	8	85
7.0	10	9	85	9	85
7.5	10	9	84	9	84
7.9	10	9	83	9	83
8.0	10	9	83	9	83
9.0	11	9	82	9	82
10.0	11	9	76	9	76
11.0	12	9	77	9	75
12.0	12	9	77	9	74
13.0	12	9	77	9	73
14.0	12	9	77	9	73
15.0	12	10	78	9	73
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
0.3	7	0	0	0	0
0.8	8	1	9	1	9
1.0	8	1	13	1	13
1.5	8	1	17	1	17
2.0	9	3	32	2	19
2.5	9	4	47	2	21
3.0	9	5	60	2	23
3.5	9	6	69	3	28
4.0	9	7	73	5	50
4.5	9	7	75	5	51
5.0	9	7	77	5	52
5.5	10	8	82	8	82
6.0	10	8	81	8	81
6.5	10	8	80	8	80
7.0	10	8	80	8	80
7.5	10	8	79	8	79
7.9	10	8	79	8	79
8.0	10	8	79	8	79
9.0	11	8	78	8	78
10.0	11	8	73	8	73

11.0	12	8	73	8	73
12.0	12	9	72	9	72
13.0	12	9	72	9	72
14.0	12	9	71	9	71
15.0	12	9	71	9	71

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
0.3	7	0	0	0	0
0.8	8	0	0	0	0
1.0	8	0	0	0	0
1.5	8	0	0	0	0
2.0	9	1	8	1	8
2.5	9	1	13	1	13
3.0	9	1	15	1	15
3.5	9	1	16	1	16
4.0	9	2	27	2	17
4.5	9	3	36	2	18
5.0	9	4	43	2	19
5.5	10	5	50	2	19
6.0	10	6	57	2	23
6.5	10	6	61	2	25
7.0	10	7	65	4	44
7.5	10	7	66	5	45
7.9	10	7	67	5	45
8.0	10	7	67	5	46
9.0	11	7	69	5	47
10.0	11	8	69	8	69
11.0	12	8	68	8	68
12.0	12	8	68	8	68
13.0	12	8	68	8	68
14.0	12	8	68	8	68
15.0	12	8	68	8	68

Canyon Creek, Reach 4 (Study Site 4):

Table F-41. Weighted usable area (WUA) versus discharge relationships for steelhead at Canyon Creek, Study Site 4.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.6	7677	1846	1000	20.8	25.9
3	8640	2180	1225	24.5	31.7
4	9368	2960	1726	33.3	44.6
5	9681	3704	2228	41.7	57.6
6	9913	4375	2652	49.2	68.6
6.6	10088	4638	2779	52.2	71.9
7.2	10190	4876	2916	54.9	75.4
8	10377	5160	3058	58.0	79.1
9	10628	5434	3218	61.1	83.2
10	10924	5695	3356	64.1	86.8
11	11154	5917	3487	66.6	90.2
12	11425	6154	3596	69.2	93.0
13	11739	6391	3687	71.9	95.4
14	11868	6612	3755	74.4	97.1
15	11983	6820	3801	76.7	98.3
16	12096	7033	3837	79.1	99.2
17	12205	7232	3858	81.4	99.8
18	12311	7381	3866	83.0	100.0
19	12414	7506	3866	84.4	100.0
20	12571	7618	3860	85.7	99.8
21	12772	7805	3853	87.8	99.7
22	13018	7946	3827	89.4	99.0
23	13258	8076	3813	90.9	98.6
24	13493	8195	3801	92.2	98.3
25	13705	8297	3815	93.3	98.7
26	13831	8372	3778	94.2	97.7
27	13955	8470	3774	95.3	97.6
28	14106	8628	3773	97.1	97.6
29	14283	8783	3765	98.8	97.4
30	14475	8889	3750	100.0	97.0

Table F-42. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Canyon Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.6	7677	1846	1000	20.8	25.9
3	8640	2180	1225	24.5	31.7
4	9368	2960	1726	33.3	44.6
5	9681	3704	2228	41.7	57.6
6	9913	4375	2652	49.2	68.6
6.6	10088	4638	2779	52.2	71.9
7.2	10190	4876	2916	54.9	75.4
8	10377	5160	3058	58.0	79.1
9	10628	5434	3218	61.1	83.2
10	10924	5695	3356	64.1	86.8
11	11154	5917	3487	66.6	90.2
12	11425	6154	3596	69.2	93.0
13	11739	6391	3687	71.9	95.4
14	11868	6612	3755	74.4	97.1
15	11983	6820	3801	76.7	98.3
16	12096	7033	3837	79.1	99.2
17	12205	7232	3858	81.4	99.8
18	12311	7381	3866	83.0	100.0
19	12414	7506	3866	84.4	100.0
20	12571	7618	3860	85.7	99.8
21	12772	7805	3853	87.8	99.7
22	13018	7946	3827	89.4	99.0
23	13258	8076	3813	90.9	98.6
24	13493	8195	3801	92.2	98.3
25	13705	8297	3815	93.3	98.7
26	13831	8372	3778	94.2	97.7
27	13955	8470	3774	95.3	97.6
28	14106	8628	3773	97.1	97.6
29	14283	8783	3765	98.8	97.4
30	14475	8889	3750	100.0	97.0

Table F-43. Weighted usable area (WUA) versus discharge relationships for bull trout at Canyon Creek, Study Site 4.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.6	7677	1109	677	12.9	19.7
3	8640	1250	902	14.5	26.3
4	9368	1827	1406	21.2	40.9
5	9681	2418	1893	28.1	55.1
6	9913	3024	2412	35.1	70.2
6.6	10088	3370	2601	39.2	75.7
7.2	10190	3733	2778	43.4	80.9
8	10377	4082	2992	47.4	87.1
9	10628	4481	3239	52.1	94.3
10	10924	4816	3377	56.0	98.3
11	11154	5070	3419	58.9	99.6
12	11425	5323	3434	61.8	100.0
13	11739	5563	3434	64.6	100.0
14	11868	5763	3434	67.0	100.0
15	11983	5962	3427	69.3	99.8
16	12096	6230	3430	72.4	99.9
17	12205	6480	3430	75.3	99.9
18	12311	6691	3430	77.7	99.9
19	12414	6917	3427	80.4	99.8
20	12571	7086	3414	82.3	99.4
21	12772	7258	3404	84.3	99.1
22	13018	7401	3407	86.0	99.2
23	13258	7566	3404	87.9	99.1
24	13493	7717	3398	89.7	99.0
25	13705	7852	3390	91.2	98.7
26	13831	8056	3380	93.6	98.4
27	13955	8205	3373	95.3	98.2
28	14106	8337	3368	96.9	98.1
29	14283	8477	3361	98.5	97.9
30	14475	8607	3351	100.0	97.6

Table F-44. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Canyon Creek, Study Site 4.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
2.6	7677	3110	53.5
3	8640	3537	60.9
4	9368	4425	76.2
5	9681	4972	85.6
6	9913	5355	92.2
6.6	10088	5536	95.3
7.2	10190	5457	93.9
8	10377	5630	96.9
9	10628	5767	99.3
10	10924	5783	99.6
11	11154	5809	100.0
12	11425	5789	99.7
13	11739	5597	96.4
14	11868	5426	93.4
15	11983	5181	89.2
16	12096	4934	84.9
17	12205	4639	79.9
18	12311	4366	75.2
19	12414	4042	69.6
20	12571	3707	63.8
21	12772	3393	58.4
22	13018	3093	53.2
23	13258	2905	50.0
24	13493	2720	46.8
25	13705	2450	42.2
26	13831	2298	39.6
27	13955	2216	38.1
28	14106	2119	36.5
29	14283	1990	34.3
30	14475	1828	31.5

Table F-45. Passage criteria assessment for transect 1 (riffle), Canyon Creek Study Site 4, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
2.6	11	0	0	0	0
3.0	12	0	0	0	0
4.0	13	1	6	0	3
5.0	13	2	13	1	8
6.0	13	4	31	2	14
6.6	14	6	43	2	15
7.2	14	7	51	4	26
8.0	14	9	62	5	39
9.0	15	11	73	6	40
10.0	15	12	79	12	79
11.0	16	13	81	13	81
12.0	16	13	83	13	83
13.0	16	13	83	13	83
14.0	16	13	84	13	84
15.0	16	14	85	14	85
16.0	16	14	85	14	85
17.0	16	14	87	14	85
18.0	16	15	90	14	85
19.0	16	15	95	15	95
20.0	16	16	95	16	95
21.0	16	16	95	16	95
22.0	17	16	95	16	95
23.0	17	16	95	16	95
24.0	17	16	95	16	95
25.0	17	16	94	16	94
26.0	17	16	94	16	94
27.0	17	16	94	16	94
28.0	17	16	93	16	93
29.0	17	16	93	16	93
30.0	18	16	92	16	92
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
2.6	11	0	0	0	0
3.0	12	0	0	0	0
4.0	13	0	0	0	0
5.0	13	0	0	0	0
6.0	13	0	0	0	0
6.6	14	0	0	0	0
7.2	14	1	5	0	3
8.0	14	1	10	1	6
9.0	15	2	13	1	8
10.0	15	5	31	2	13
11.0	16	7	43	4	23
12.0	16	9	55	5	34
13.0	16	10	65	6	36
14.0	16	12	76	12	76
15.0	16	12	78	12	78

16.0	16	13	79	13	79
17.0	16	13	81	13	81
18.0	16	13	81	13	81
19.0	16	13	83	13	83
20.0	16	14	83	14	83
21.0	16	14	83	14	83
22.0	17	14	84	14	83
23.0	17	14	86	14	82
24.0	17	15	88	14	82
25.0	17	15	91	15	91
26.0	17	16	91	16	91
27.0	17	16	92	16	92
28.0	17	16	91	16	91
29.0	17	16	91	16	91
30.0	18	16	90	16	90

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
2.6	11	0	0	0	0
3.0	12	0	0	0	0
4.0	13	0	0	0	0
5.0	13	0	0	0	0
6.0	13	0	0	0	0
6.6	14	0	0	0	0
7.2	14	0	0	0	0
8.0	14	0	0	0	0
9.0	15	0	0	0	0
10.0	15	0	0	0	0
11.0	16	1	3	0	2
12.0	16	1	9	1	5
13.0	16	2	12	1	7
14.0	16	4	26	2	12
15.0	16	6	38	3	21
16.0	16	7	46	4	23
17.0	16	9	55	6	34
18.0	16	11	66	6	36
19.0	16	12	75	12	75
20.0	16	12	76	12	76
21.0	16	13	77	13	77
22.0	17	13	79	13	79
23.0	17	13	79	13	79
24.0	17	13	79	13	79
25.0	17	14	80	14	80
26.0	17	14	79	14	79
27.0	17	14	79	14	79
28.0	17	14	81	14	79
29.0	17	14	83	14	79
30.0	18	15	87	15	87

Canyon Creek, Reach 5 (Study Site 5, Reference Site):

Table F-46. Weighted usable area (WUA) versus discharge relationships for steelhead at Canyon Creek, Study Site 5.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.2	12148	2091	1895	24.9	23.8
3	12538	2998	2916	35.8	36.6
4	12852	3877	3849	46.3	48.3
5.4	13182	4883	4777	58.3	59.9
6	13291	5190	5144	61.9	64.5
7	13441	5623	5517	67.1	69.2
8.2	13583	6051	5797	72.2	72.7
9	13654	6309	5964	75.3	74.8
10	13733	6594	6145	78.7	77.1
11	13813	6834	6302	81.5	79.0
12	13846	7038	6462	84.0	81.0
13	13871	7231	6628	86.3	83.1
14	13895	7394	6781	88.2	85.0
16	13939	7685	7050	91.7	88.4
18	13988	7907	7299	94.3	91.5
18.8	14006	7978	7390	95.2	92.7
20	14041	8089	7517	96.5	94.3
22	14112	8214	7696	98.0	96.5
24	14180	8313	7847	99.2	98.4
26	14270	8381	7974	100.0	100.0

Table F-47. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Canyon Creek, Study Site 5.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.2	12148	2091	1895	24.9	23.8
3	12538	2998	2916	35.8	36.6
4	12852	3877	3849	46.3	48.3
5.4	13182	4883	4777	58.3	59.9
6	13291	5190	5144	61.9	64.5
7	13441	5623	5517	67.1	69.2
8.2	13583	6051	5797	72.2	72.7
9	13654	6309	5964	75.3	74.8
10	13733	6594	6145	78.7	77.1
11	13813	6834	6302	81.5	79.0
12	13846	7038	6462	84.0	81.0
13	13871	7231	6628	86.3	83.1
14	13895	7394	6781	88.2	85.0
16	13939	7685	7050	91.7	88.4
18	13988	7907	7299	94.3	91.5
18.8	14006	7978	7390	95.2	92.7
20	14041	8089	7517	96.5	94.3
22	14112	8214	7696	98.0	96.5
24	14180	8313	7847	99.2	98.4
26	14270	8381	7974	100.0	100.0

Table F-48. Weighted usable area (WUA) versus discharge relationships for bull trout at Canyon Creek, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2.2	12148	748	1797	17.2	21.4
3	12538	1085	2815	24.9	33.6
4	12852	1601	3899	36.7	46.5
5.4	13182	2184	4959	50.1	59.1
6	13291	2357	5419	54.1	64.6
7	13441	2893	6036	66.4	72.0
8.2	13583	3227	6739	74.0	80.3
9	13654	3408	7119	78.2	84.9
10	13733	3575	7524	82.0	89.7
11	13813	3739	7873	85.8	93.9
12	13846	3839	8174	88.1	97.4
13	13871	3958	8330	90.8	99.3
14	13895	4046	8388	92.8	100.0
16	13939	4220	8368	96.8	99.8
18	13988	4314	8206	99.0	97.8
18.8	14006	4356	8130	100.0	96.9
20	14041	4358	8005	100.0	95.4
22	14112	4244	7745	97.4	92.3
24	14180	3986	7448	91.5	88.8
26	14270	3807	7122	87.4	84.9

Table F-49. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Canyon Creek, Study Site 5.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
2.2	12148	4322	39.1
3	12538	5075	46.0
4	12852	6037	54.7
5.4	13182	7229	65.5
6	13291	7700	69.7
7	13441	8421	76.3
8.2	13583	9134	82.7
9	13654	9479	85.8
10	13733	9870	89.4
11	13813	10208	92.4
12	13846	10488	95.0
13	13871	10703	96.9
14	13895	10860	98.4
16	13939	11037	100.0
18	13988	11042	100.0
18.8	14006	11016	99.8
20	14041	10850	98.3
22	14112	10453	94.7
24	14180	10053	91.0
26	14270	9562	86.6

Table F-50. Passage criteria assessment for transect 1 (riffle), Canyon Creek Study Site 5, 2005.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
2.2	13	0	0	0	0
3.0	14	0	0	0	0
4.0	14	0	1	0	1
5.4	14	2	15	1	7
6.0	14	3	24	1	9
7.0	14	8	58	5	37
8.2	14	9	66	6	43
9.0	14	12	83	11	83
10.0	14	12	87	12	84
11.0	14	13	91	12	84
12.0	14	13	95	12	85
13.0	14	13	97	13	97
14.0	14	14	97	14	97
16.0	14	14	97	14	97
18.0	14	14	97	14	97
18.8	14	14	97	14	97
20.0	14	14	98	14	98
22.0	14	14	98	14	98
24.0	14	14	98	14	98
26.0	14	14	98	14	98
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
2.2	13	0	0	0	0
3.0	14	0	0	0	0
4.0	14	0	0	0	0
5.4	14	0	0	0	0
6.0	14	0	0	0	0
7.0	14	0	0	0	0
8.2	14	0	0	0	0
9.0	14	0	0	0	0
10.0	14	0	3	0	3
11.0	14	1	8	1	6
12.0	14	3	18	1	8
13.0	14	8	54	5	33
14.0	14	8	57	5	36
16.0	14	9	66	6	43
18.0	14	12	85	12	82
18.8	14	12	88	12	83
20.0	14	13	91	12	83
22.0	14	13	96	13	96
24.0	14	14	96	14	96
26.0	14	14	96	14	96
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
2.2	13	0	0	0	0
3.0	14	0	0	0	0
4.0	14	0	0	0	0

5.4	14	0	0	0	0
6.0	14	0	0	0	0
7.0	14	0	0	0	0
8.2	14	0	0	0	0
9.0	14	0	0	0	0
10.0	14	0	0	0	0
11.0	14	0	0	0	0
12.0	14	0	0	0	0
13.0	14	0	0	0	0
14.0	14	0	0	0	0
16.0	14	0	0	0	0
18.0	14	0	2	0	2
18.8	14	1	4	1	4
20.0	14	1	11	1	6
22.0	14	7	52	5	32
24.0	14	8	58	5	36
26.0	14	9	65	6	42