Wallowa Falls Habitat Modeling Results

Preliminary Results for IFIM Stakeholder Meeting
La Grande, OR
April 25, 2013

1.0 INTRODUCTION

This document provides the results of the instream flow incremental method (IFIM) habitat modeling in the East Fork Wallowa River bypass reach. The IFIM study was performed to support the relicensing of the Wallowa Falls Hydroelectric Project, and explores changes in habit for target fish species/lifestages over a range of flow regimes. The purpose of this document is to provide stakeholder group participating in the relicensing process with a detailed account of PacifiCorp's modeling approach, results, and flow regime recommendations. The information in this document will be presented and discussed with agency and tribal parties participating in the IFIM stakeholder meeting on April 25, 2013 in La Grande, OR.

2.0 METHODS

1.1 MODELING

1.1.1 Fish Species

The PHABSIM model was used to develop relationships between fish habitat and flows in the East Fork bypass. The fish species and lifestages that were the focus of modeling activities included juvenile, adult and spawning bull trout, and spawning kokanee.[1]

1.1.2 Calibration Flows

PHABSIM was used to quantify habitat over a range of flows between 0.8 cfs and 40 cfs. The model was calibrated using depth, velocity, and cover data collected in the field during three flow release events, which represent the low, medium, and high range of flows at which accurate calibration data can

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[1] The East Fork bypass is believed to also accommodate a small population of rainbow trout, based on the recovery of several rainbow trout during PacifiCorp's fisheries resources study (PacifiCorp, 2012). However, these fish do not appear to be native, wild rainbow trout. ODFW has suggested that the rainbow trout captured in the East Fork bypass were probably either the triploid (infertile) Cape Cod strain that is routinely stocked in Wallowa Lake, or downstream migrants from Aneroid Lake, where ODFW periodically stocks diploid (fertile) Cape Cod rainbow trout (ODFW 2013 & 2012). The diploid Cape Cod strain is a fall-spawning fish, and is therefore unlikely to establish a self-sustaining population due to the shortage of thermal degree-days necessary for successful egg incubation (PacifiCorp, 2013). In either case, the rainbow trout in the East Fork Wallowa bypass appear to be products of a routine stocking schedule, and are unable to reproduce. For this reason, it was considered biologically prudent to focus the habitat modeling efforts completely on ESA-listed bull trout and native kokanee.

be collected in the field[2]. The flow release targets for calibrating the hydraulic model were 4 cfs, 8 cfs, and 15 cfs. The field data were collected at flows of 5.3 cfs, 8.5 cfs, and 15 cfs, which was very close to the flows targeted in the study planning. Modeling Approach

The lowest flow modeled using PHABSIM, 0.8 cfs, was selected because it represented background, or baseline, conditions. Presently, PacifiCorp maintains a minimum instream flow[3] of 0.8 cfs in the East Fork bypass. The highest flow modeled, 40 cfs, was selected because (1) the model appeared to accurately predict hydraulic conditions up to approximately 40 cfs; and (2) the water surface overtops the low terraces at transect numbers one through three when flows are greater than approximately 40 cfs, thereby imparting field data limitations to accurate modeling in the lowest cross sections of the study reach.

The "one-flow" PHABSIM modeling method was used[4]. This option uses one set of measured velocities for all verticals at the calibration flow and solves Manning's equation on an individual cell basis (with cell depth in place of hydraulic radius) to derive a roughness or velocity distribution factor. The Manning's n values derived from the calibration flow are used as a template to predict velocities at all other discharges. The one-flow method produces a separate PHABSIM model for each of the three calibration flows. Habitat simulation results from the three models are then merged to produce a single, continuous flow-habitat relationship. This action is described in greater detail in the Habitat Modeling sub-section below.

<u>Transect Weighting</u>

Cross sections were equally weighted, as agreed to during the stakeholder meeting on June 12, 2012. The rationale for giving equal weighting to each transect was due to the fact that there are few distinguishable differences in habitat types (e.g. the lack of definitive riffle/pool/run complexes). At low flows, the stream consists largely of pocket water, and at higher flows, the stream transitions to alternating rapid and cascade features. Consequently, transects were established at cross-sections of stream that met the fundamental assumptions of the PHABSIM hydraulic models, represented the stream morphology as a whole, and were agreed upon in the field by resource agency personal involved in this project (see footnote 2).

A total of 13 transects were established for the study. Each was assigned a length of 100 feet, resulting in a study reach length of 1300 feet. For the kokanee habitat simulation, the same weighting scheme was applied only to the first four transects. Based on PacifiCorp's field observations and conversations

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[2] The hydraulic models used by PHABSIM assume that the water surface elevation does not change across a single transect (Waddle, 2012). In the East Fork bypass, flows greater than approximately 20 cfs create turbulent conditions that are not compatible with the PHABSIM assumption of an even water surface.
[3] The "minimum instream flow" is established as the lowest permissible flow level in the stream. In actuality, the instream flow regime often exceeds this minimum level. For example, whenever East Fork inflows exceed the Project's diversion capacity (a maximum of 16 cfs), the flow in the East Fork bypass will exceed the minimum flow level accordingly. This same condition applies to all other instream flow alternatives discussed in this report.
[4] The hydraulic model in PHABSIM was originally configured to use the three flow data sets together using a least-squares regression fit of log-velocity against log-discharge for the verticals on each transect. However, it has been well established that the three-flow regression configuration of IFG4 performs poorly when applied to high gradient streams or streams containing many large bed elements (e.g. boulders) due to the inability to accurately simulate hydraulic complexities (Milhous 1985, Payne 1987). Due to such poor performance, the Instream Flow Group issued an advisory cautioning use of three-flow velocity regression method (Milhous & Schneider, 1985).

with streamside property owners, it was determined that kokanee rarely spawned above transect number. four due to an upstream passage impediment.

Water Surface Elevation

Water surface elevations were simulated with WSL ("Water Surface Level"), which is a subroutine within the PHABSIM suite. The WSL subroutine uses a regression-based simulation, known as the stage-flow (STGQ) method to develop a log-log relationship between stage (the surveyed water surface elevations) and the measured flows. A regression that accurately simulated the surveyed water surface elevations at the three calibration flows was developed at each transect. A tabular summary of the surveyed and calibrated water surface elevations is provided in Appendix A.

Velocity Simulations

Velocities were simulated with PHABSIM's velocity subroutine, VELSIM. The low flow model was calibrated to velocities measured at the 5.3 cfs release, and the medium and high flow models were calibrated to velocities measured at the 8.5 cfs and 15 cfs releases, respectively.

After the each velocity simulation was run, the output was assessed for unusual results (e.g. a simulation flow in which the velocities in the individual cells differed from the general velocity patterns in the same cells at other simulation flows). When any irregularities or unexpected results were encountered, they were reviewed and, when appropriate, adjusted so that simulated velocities represented realistic velocities based on field observations at each site and professional judgment. A list of any adjustments was kept in the project file notes and is available for review upon request.

Habitat Modeling: Weighted Usable Area

The HABTAE subroutine of PHABSIM was used to simulate fish habitat at each transect under each of the flows simulated for the three modeling scenarios. HABTAE specifically computes the weighted usable area (WUA) in the study reach at each simulation flow for each species/lifestage. WUA is reported in units of square feet of habitat per 1000 linear feet of stream (sq. ft. per 1000 ft.).

The final products of HABTAE were predictions of WUA in the study reach for each simulated flow, specific to each target fish species and lifestage. These results are referred to in this report as either as flow-habitat relationships or WUA curves. The low, medium, and high flow WUA results were then merged into one continuous WUA curve over the entire flow range modeled by computing the geometric mean of the WUA values at flows where the simulations overlapped. The specific points of overlap/merger between two (or occasionally all three) model results were selected to produce the smoothest possible transition between the partial WUA results for each target species/life stage. The end result was a single, continuous curve of flow versus WUA for each of the four target fish species/lifestages. These four species/lifestage curves were applied to daily flows between May and October to estimate daily WUA for each target species. A different metric of habitat availability (stream wetted perimeter) was used for the months of November through April and is explained below. The habitat suitability criteria for each species/lifestage is not typically considered applicable during the "winter" months, as the fish are mostly inactive and seek refuge in pool areas or in the interstitial spaces in the substrate or woody debris.

Habitat Modeling: Wetted Perimeter

The hydraulic modeling portion of PHABSIM provided the metric of stream wetted perimeter (WP) at each transect over the range of flow simulations. Wetted perimeter is reported by PHABSIM in units of feet. The relationship between flow and wetter perimeter is applicable during the winter months (defined in section 2.1.2 as the months of November through April), when the survival of the incubating eggs of bull trout and kokanee is more sensitive to the area of streambed that is wetted, rather than the combination of velocity, depth and cover that constitute WUA values as mentioned above. A simple relationship was developed between flow and the average WP estimation of the 13 transects.

1.2 Habitat Duration Analysis

The flow-habitat relationships for WUA and WP were used to evaluate habitat availability and variability in the East Fork bypass in the context of: (1) the unimpaired flow[5] regime; (2) the current baseline regime of a minimum instream flow of 0.8 cfs; and (3) alternative flow regimes that assume minimum instream flow levels ranging from 1 cfs to 7 cfs. These calculations were used to conduct a habitat duration analysis to illustrate various flow alternatives compared to baseline conditions over the course of each season. The following subsections describe the steps of the analysis.

2.1.1 Hydrology

A historic flow record of daily average flows between WY 1924 and WY 1983 exists for the East Fork bypass (USGS gage no. 1332500) and the power house tailrace (USGS gage no. 13324500). When daily average flows from the two sites are combined, an approximation of unimpaired flows can be developed for the East Fork Wallowa River. Accordingly, the USGS developed reporting station 13325001 which combined the data from the two gages. For this study, PacifiCorp selected daily unimpeded flows from 44 complete water years from reporting station 13325001, including WY 1924 to WY 1952 and WY 1967 to WY 1983. A reliable data record was not available at both gages between WY 1953 and WY 1966, so these years were omitted from the analysis.

The 44 year record of estimated flows was used to synthesize eight additional flow records, which represented different target flow alternatives. These alternatives included 0.8 cfs (current baseline conditions), 1 cfs, 2 cfs, 3 cfs, 4 cfs, 5 cfs, 6 cfs, and 7 cfs. Flow alternatives greater than 7 cfs were not considered because it did not make logical sense to explore flow alternatives that were greater than any recurrent unimpeded low flow. Although unimpeded flows less than 7 cfs have been recorded in the bypass, such events are rare: in the 44 year record, daily average flows were less than or equal to 7 cfs on 18 days. Unimpaired flows between 7 cfs and 8 cfs occurred on 198 days, and flows between 8 cfs and 9 cfs occurred on 788 days. These statistics demonstrate that unimpaired low flows greater than 7 cfs occur frequently enough to preclude flows such as 8 cfs, 9 cfs, or greater from this analysis.

2.1.2 Time Series Analysis

The 44 years of daily flows in the unimpaired flow record, as well as the eight synthesized alternative flow records, were converted to daily habitat values according to the flow-habitat relationship produced by PHABSIM for each of the four target species/lifestages. The four WUA curves and the single WP curve, applied to the nine flow records, generated 45 separate data sets, or habitat time series.

Habitat duration curves were developed from the habitat time series data sets. Habitat duration curves display the relationship between a variable (WUA or WP) and the percentage of time it is equaled or exceeded. A more detailed description is provided by Waddle (2012). Habitat duration was assessed for

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[5] Unimpaired flow is a standard hydrologic term, which in this case is the estimated flow regime that assumes no Project-related diversions from the East Fork at any time. However, it otherwise assumes the existence of the current channel configuration and runoff conditions. Therefore, the definition of unimpaired flow is distinct from (and may differ from) "natural" or "pre-project historic" flows.

the individual months of August, September, and October. These months encompass the spawning seasons for bull trout and kokanee, and are characterized by falling flows over the period. Flows are sufficiently different each month to justify separate analyses. The winter months of November through April, referred to in this report as the baseflow season, were assessed for habitat duration (in the form of WP) as a group because the low, stable flows that characterized these months provided habitat for incubating eggs and fry that varied little throughout the six month period. The months of May through July, referred to as the spring runoff season, were also assessed as a group. Flows during these months were high, variable, and typically much greater than the power plant capacity of 16 cfs. During most of the spring runoff season, target flows were inundated by excess flows spilled at Wallowa Falls dam.

3.0 RESULTS

3.1 HYDROLOGY

The 44 years of historic flows in the East Fork bypass are summarized as the "unimpaired" data series in Figure 1. Also included are the synthesized hydrographs for each target flow alternative. A logarithmic scale was applied to the y-axis for clarity.

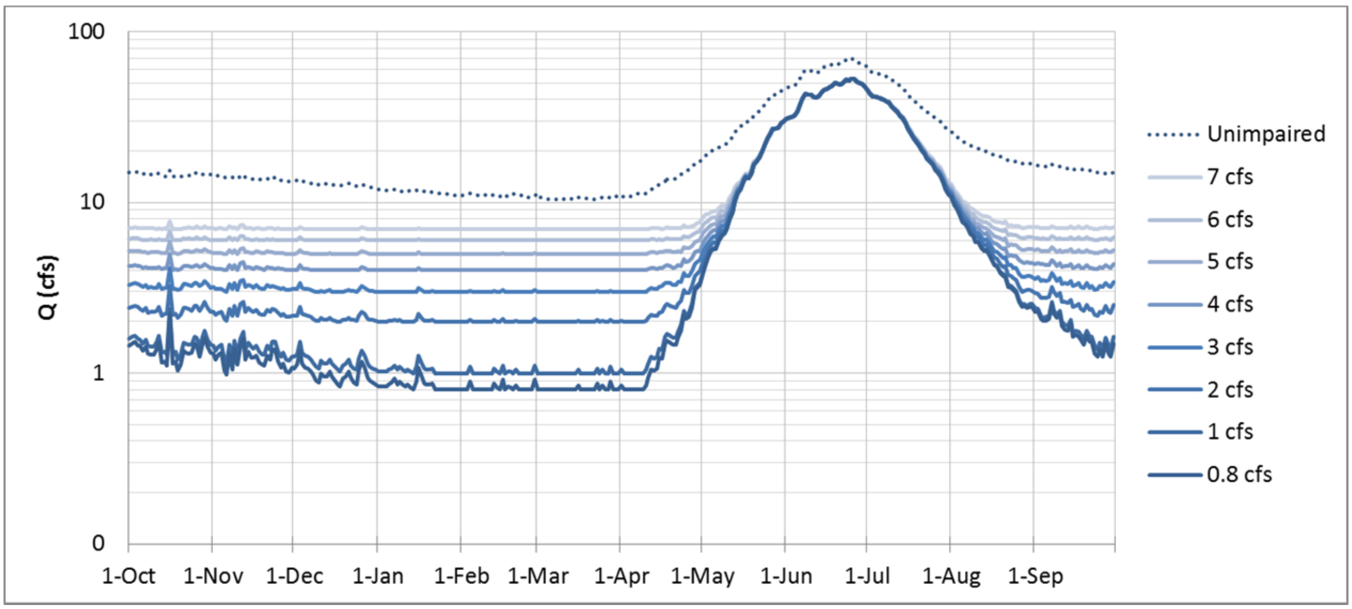

Figure 1. Hydrographs of historic daily average flows ("unimpaired") and synthesized target flow alternatives in East Fork bypass.

3.2 HABITAT-FLOW RELATIONSHIPS

The primary purpose of the PHABSIM model in this study was to produce simulated relationships between (1) discharge and WUA habitat for the juvenile, adult, and spawning lifestages of bull trout and the spawning life stage of kokanee; and (2) discharge and stream WP. The WUA results and WP results are described in the following subsections and are expressed as a percentage of the maximum WUA or WP (i.e. WUA and WP values have been "normalized" to eliminate distortions caused by graphing very different magnitudes of data on the same scale). Tables containing the numeric values of the WUA and WP results are provided in Appendix B.

3.2.1 Bull Trout

The WUA results for the three target lifestages of bull trout are presented in Figure 2. The juvenile bull trout WUA curve ascends steeply between the baseline flow of 0.8 cfs and 2 cfs. The WUA increase is more gradual between 2 cfs and 4 cfs, and reaches a peak between 5 cfs and 6 cfs. WUA declines steadily between flows 6 cfs and 40 cfs.

The WUA curve for adult bull trout includes a steep rise in habitat between flows of 0.8 cfs and 5 cfs. A more gradual, curvilinear increase occurs between 5 cfs and 17 cfs, which is the point of maximum WUA for adult bull trout. As flows increase above 17 cfs, WUA declines gradually and steadily.

The WUA curve for spawning bull trout shows a rapid increase in habitat between flows of 0.8 cfs and 7 cfs, and a distinct peak in habitat at 8 to 9 cfs. As flows increase between 10 cfs and 40 cfs, a steady decline in habitat occurs. For analysis purposes, the portion of the WUA curve for spawning bull trout above 20 cfs may have less importance than the portion below. This is because the average, unimpaired flow during the bull trout spawning months (September and October) is approximately 15 cfs, and unimpaired flows of 20 cfs or greater occur less than 5% of the time.

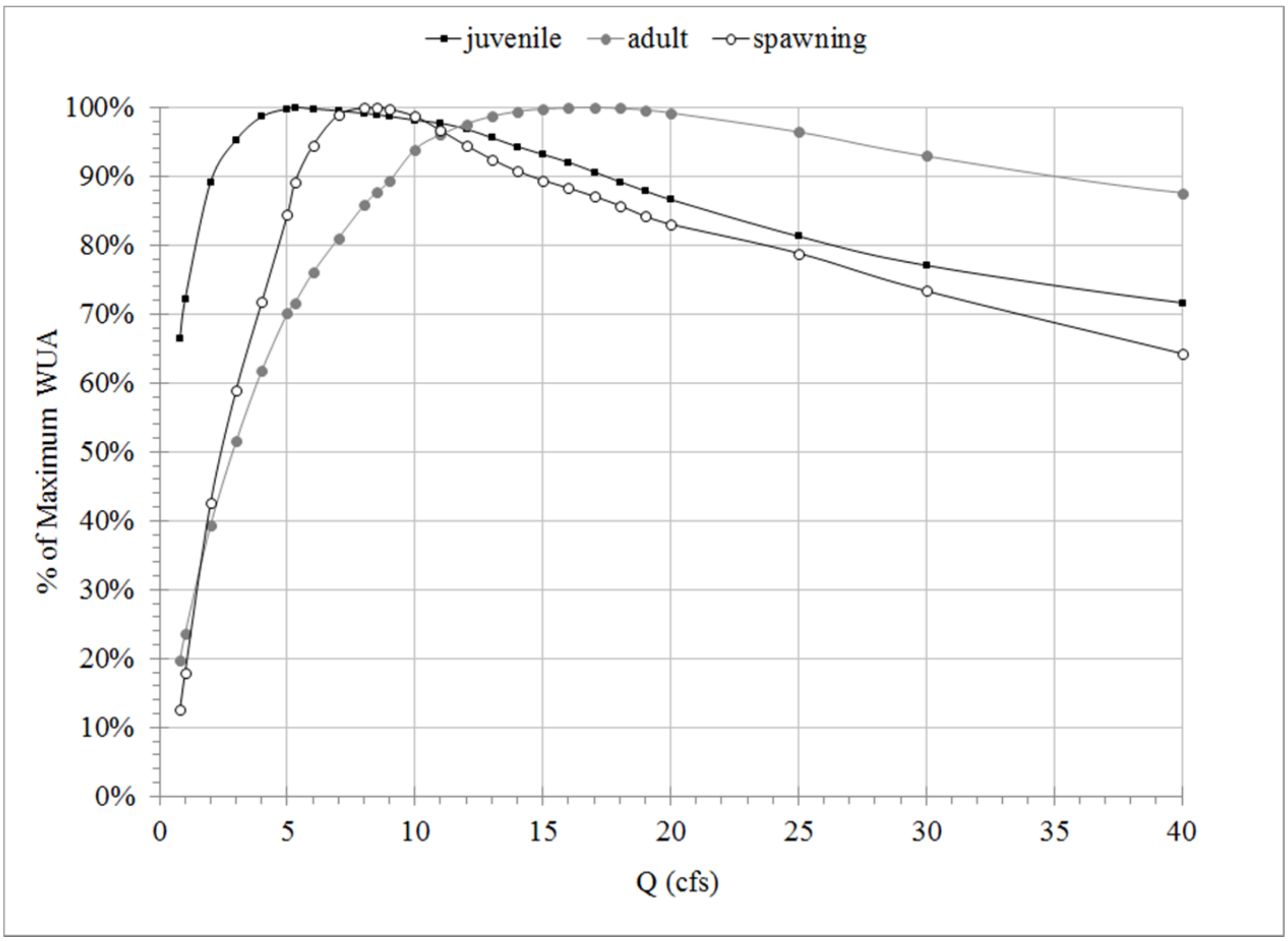

Figure 2. Normalized (% of maximum) habitat weighted useable area (WUA) curve for juvenile, adult, and spawning life stages of bull trout in East Fork Wallowa bypass.

3.2.2 Kokanee

The relationship between flow and habitat WUA for spawning kokanee is illustrated in Figure 3. Similar to the WUA results for spawning bull trout, habitat increases sharply with flow between 0.8 cfs and approximately 5 cfs, then more gradually until peak habitat is reached at 10 cfs. Habitat decreases rapidly as flows increase between 11 cfs and approximately 19 cfs. The rate of habitat decline with increasing flow is more gradual at flows between 20 cfs and 40 cfs. Unimpaired flows of this magnitude are not likely to occur during the period of maximum kokanee spawning in September and October (see Figure 1). However, some kokanee spawning occurs in August, when flows of 20 cfs or higher can occur during the first two weeks of the month.

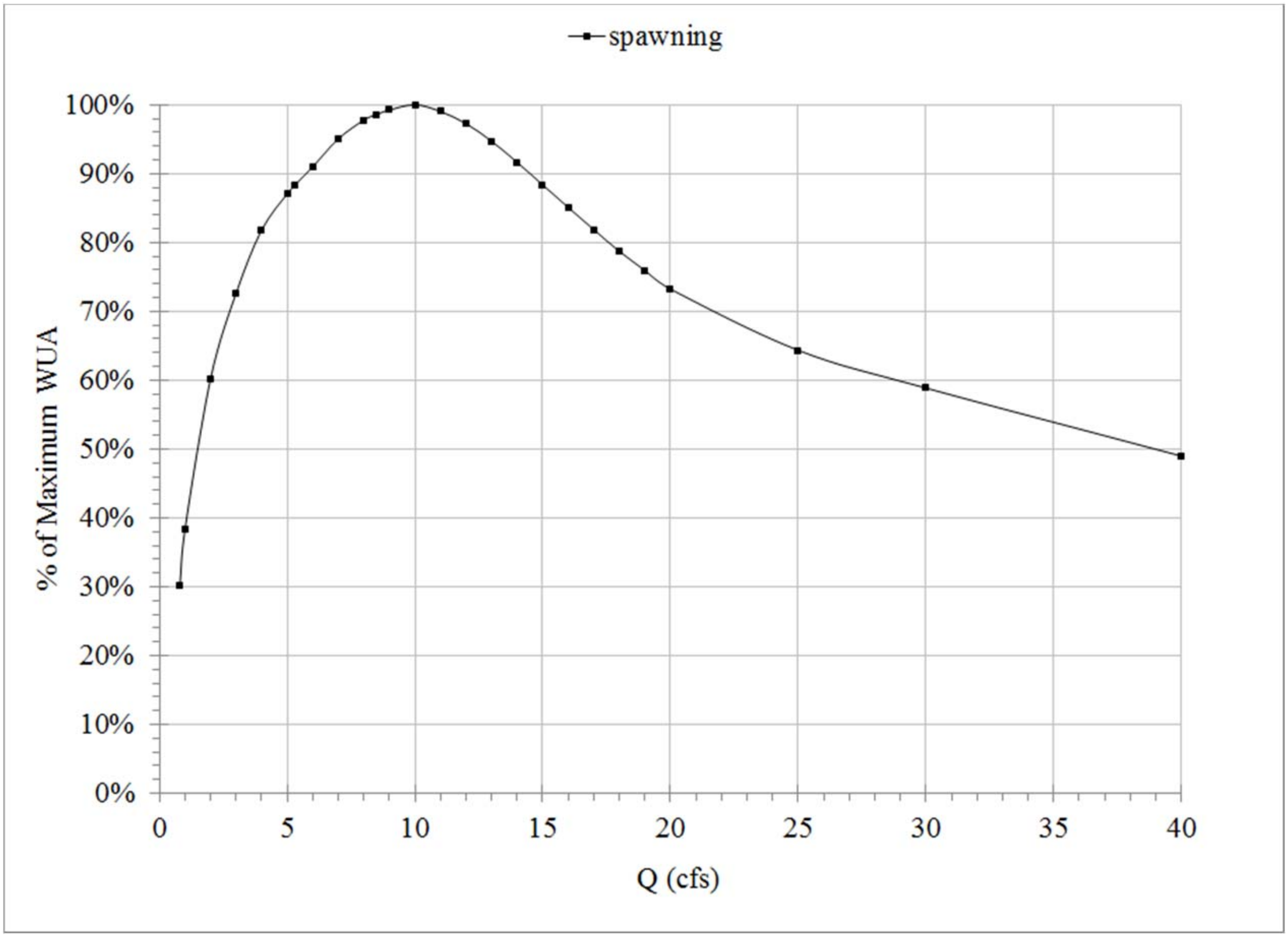

Figure 3. Normalized (% of maximum) habitat weighted useable area (WUA) curve for spawning life stage of kokanee in East Fork Wallowa bypass.

3.2.3 Wetted Perimeter

The relationship between flow and average WP in the study reach is illustrated in Figure 4. Although WP was modeled across the same range of flows as with PHABSIM (0.8 cfs to 40 cfs), Figure 4 displays WP (as percent of maximum) for flows between 0.8 cfs and 20 cfs. This flow range was chosen because 20 cfs is approximately the maximum flow that is likely to occur during the baseflow months of November through April, when WP is the relevant habitat metric.[6] A high initial value of WP was predicted (65 percent of maximum at 0.8 cfs), and steep gains in WP occurred between flows 0.8 cfs and 2 cfs. As flows increased, gains in WP became progressively more gradual.

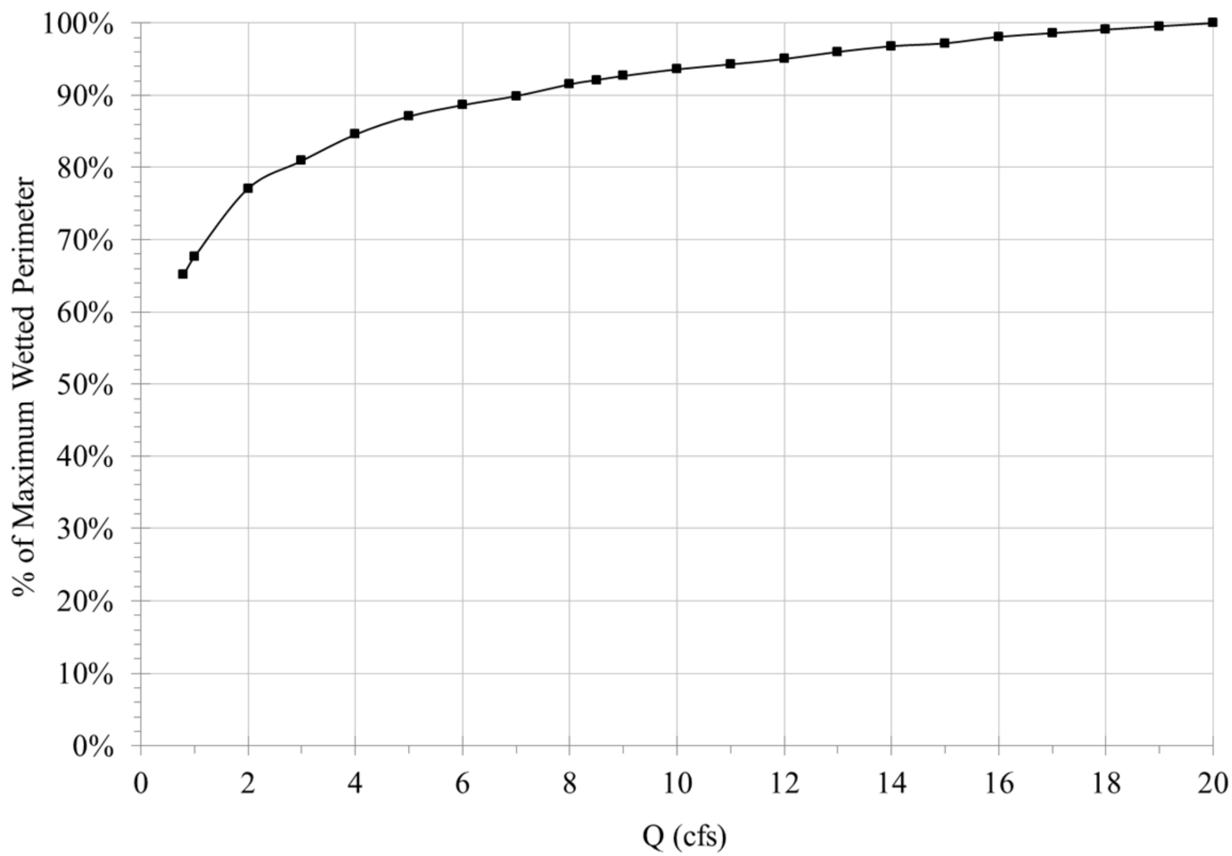

Figure 4. Normalized (% of maximum) WP curve for all target species/lifestages of fish in East Fork Wallowa bypass.

3.3 Habitat Duration

The seasonal habitat duration curves are summarized in the following subsections as total WUA or total WP. Both metrics are calculated by integrating the area under the habitat duration curve within the percentiles of 10 and 90. The complete habitat duration results, from which the following summaries were developed, are provided in tables and graphs in Appendix C.

Total WUA has been calculated for each target flow alternative during the time periods of May through July, August, September and October, and total WP has been calculated for each target flow during the winter baseflow period of November through April. Total WUA and total WP are useful statistics because they capture and integrate the numerous data points that comprise a habitat duration curve as a

[6] During the months of November through April, 20 cfs represents the 99th percentile of recorded, unimpaired flows, per the 44-year flow record utilized in this study. Flows greater than 20 cfs are likely to occur only 1 percent of the time, and therefore do not accurately portray the maximum wetted perimeter.

single quantitative value. Thus, a straightforward comparison can be graphically presented between various flow alternatives.

Total WUA and total WP were further assessed as the percent increase in habitat availability over the baseline minimum flow of 0.8 cfs. Graphically, this analysis appears similar to the respective graphs of total WUA/WP versus target flow, described above. The usefulness of this analysis is that it transforms a large number of total WUA/WP values into the more manageable statistic of percent habitat increase over existing conditions.

Finally, the percent increase in total WUA/WP per incremental increase in target flow was computed. This statistic emphasizes the inflection point (the maximum gain in total WUA/WP per a single, incremental increase in target flow), and the point of diminishing returns, where increases in target flow provided little additional benefits to habitat.

3.3.1 Juvenile Bull Trout

Seasonal habitat duration tables and curves for juvenile bull trout are provided in Appendix C-1 through Appendix C-6. These habitat duration analyses are summarized as total WUA in Figure 5. Total WUA during the individual months August, September, and October increases slightly as target flows increase from 0.8 cfs to 2 cfs, but no substantive increase in habitat availability is predicted at target flows greater than 2 cfs. During the spring runoff season (May-July), the results indicate that target flow alternatives would have little or no influence on total WUA. The habitat availability trend illustrated in Figure 5 is nearly flat during the runoff season as flows increase from 0.8 cfs to 7 cfs, with the exception of a limited increase in total WUA between 1 cfs and 2 cfs. The naturally-occurring high flows in the bypass reach during these periods tend to inundate the effects of the target flow alternatives.

Figure 6 provides a more distinct illustration of the influence of target flow alternatives by converting the large total WUA values presented in Figure 5 to percent change over baseline conditions. At the 1 cfs alternative, the increase in total WUA is less than 10% for each of the time periods that are analyzed. The results indicate that as target flows are increased, the low flow periods of August, September, and October would have rapid increases to total WUA up to 4 cfs. At target flows greater than 4 cfs, habitat levels reach a plateau, where increases in target flows provide little additional increase in total WUA. In August, the increase in total WUA is more gradual, and the plateau above 4 cfs is of a smaller magnitude than in September or October. During spring runoff, the increase to total WUA over baseline conditions reflects the unvarying trend displayed in the total WUA vs. target flow graph. Except for a slight increase in total WUA provided by a target flow of 2 cfs, further flow increases do not provide additional, substantive increases to total WUA.

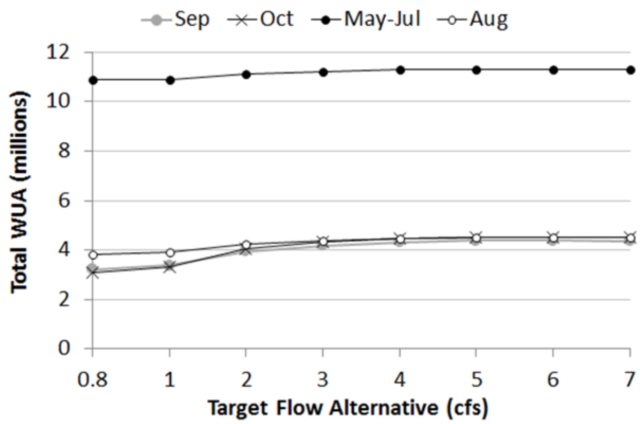

Figure 5. Juvenile bull trout: total WUA provided by target flow alternatives.

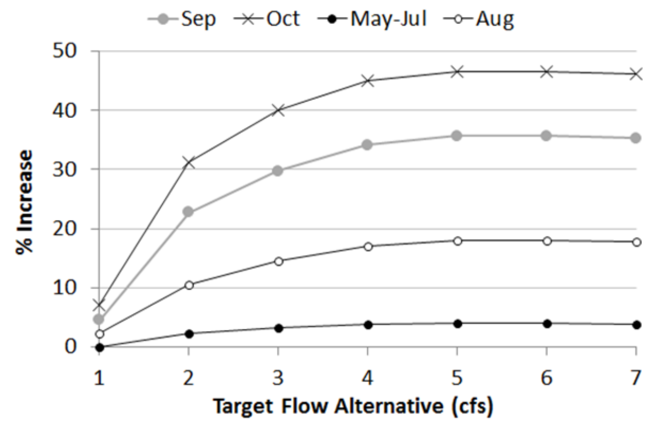

Figure 6. Juvenile bull trout: total WUA increase over baseline conditions provided by target flow alternatives.

The incremental increases of subsequently higher alternative target flows are enumerated in Table 1. An increase in target flows from 0.8 cfs to 2 cfs provides the greatest incremental increase to WUA every season. The predicted benefits to total WUA range from a 2 percent increase in spring to a 23 percent increase in October. The incremental increases to total WUA diminish at 3 cfs, and are nearly extinguished at 4 cfs, where increases are universally less than 5 percent. At target flows above 4 cfs, incremental gains in total WUA become insignificant or negative.

Table 1. Juvenile bull trout: incremental increase in total WUA between two consecutive alternative target flows.

Month(s)	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
Sep	N/A	4.6	17.3	5.7	3.4	1.1	0.0	-0.3
Oct	N/A	7.0	22.7	6.6	3.5	1.1	0.0	-0.3
May-Jul	N/A	0.0	2.2	0.9	0.6	0.2	0.0	0.0
Aug	N/A	2.3	8.0	3.5	2.3	0.9	0.0	-0.2

3.3.2

3.3.3 Spawning Bull Trout

The habitat duration tables and curves developed for spawning bull trout during the months of September and October are provided in Appendix C-15 through Appendix C-18. Figure 7 summarizes the habitat duration results for each month as total WUA over the range of target flow alternatives. Both months are characterized by a minor increase in total WUA between 0.8 cfs and 1 cfs, followed by a continuous increase in WUA as the target flow alternatives are increased. The percent increase provided by each alternative flow over the existing target flow of 0.8 cfs is illustrated in Figure 8.

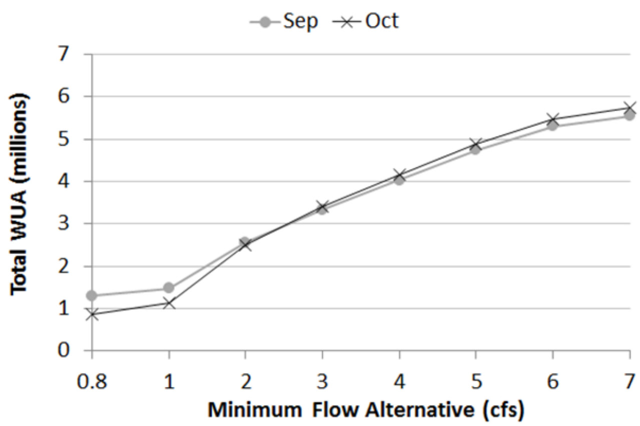

Figure 7. Spawning bull trout: total WUA provided by target flow alternatives.

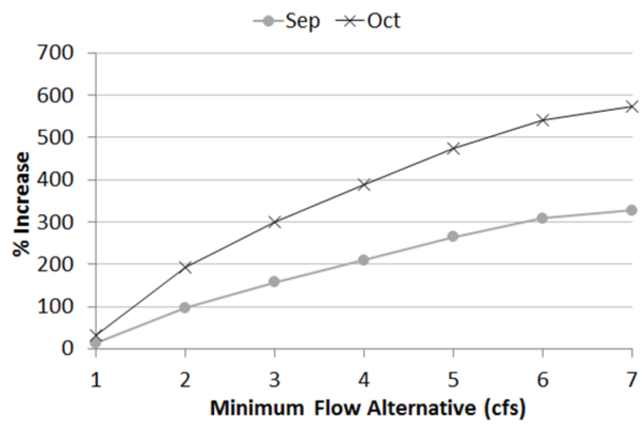

Figure 8. Spawning bull trout: total WUA increase over baseline conditions provided by target flow alternatives.

An analysis of the incremental increases to WUA between two consecutive flow alternatives indicates that the maximum single gain–a 124 percent increase–occurs in September between target flow alternatives of 1 cfs and 2 cfs (Table 2). This interval also represents the largest incremental gain in October, where a 75 percent increase in total WUA is observed. Incremental gains in total WUA remain relatively high between 2 cfs and 3 cfs and 3 cfs and 4 cfs for both months. The incremental gains to Total WUA continue to diminish throughout the remainder of the range of target flow alternatives.

Table 2. Spawning bull trout: incremental increase in total WUA between two consecutive alternative target flows.

Month(s)	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
Sep	N/A	13.9	72.9	30.3	20.8	17.7	11.9	4.7
Oct	N/A	31.2	123.5	36.8	21.6	17.7	11.9	4.7

3.3.4 Adult Bull Trout

The habitat duration analysis for adult bull trout are provided in Appendix C-7 through Appendix C-14, and are summarized in Figure 9. The period May through July includes total WUA values that are not affected by any target flow alternative. In August, total WUA increases gradually as target flows are increased. Total WUA during the months of September and October are nearly indistinguishable between the various target flow alternatives, whereby habitat availability increases slightly as target flows increased.

The gradual increases in total WUA with increases in target flow during September and October actually represent substantial increases in habitat availability over baseline conditions. Total WUA increased by nearly 100% at target flows in the range of 2 cfs (October) and 3 cfs (September). Total WUA increases over baseline conditions throughout the range of flow alternatives. In August, increases to WUA are comparatively small and gradual. Baseline habitat conditions during the spring runoff period are not appreciably affected by any target flow alternative scenario due to the overriding influence of the high seasonal flows. The magnitude of the WUA-flow relationships, particularly in September and October, is more clearly characterized in Figure 10.

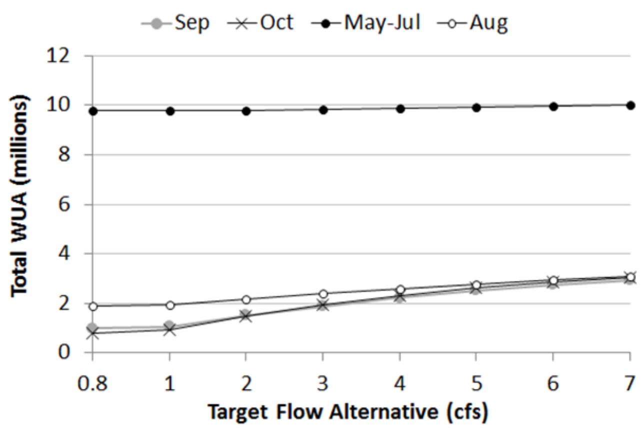

Figure 9. Adult bull trout: total WUA provided by target flow alternatives.

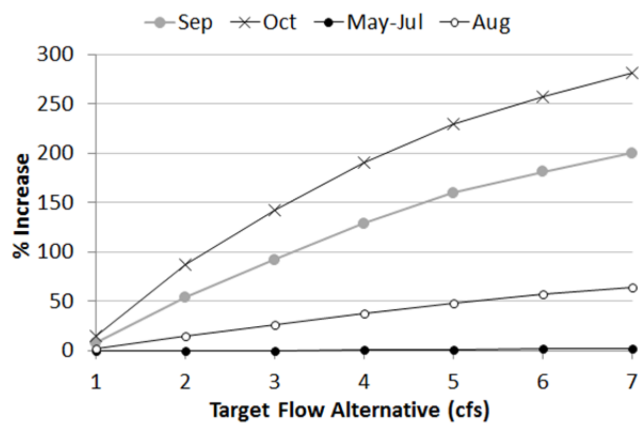

Figure 10. Adult bull trout: total WUA increase over baseline conditions provided by target flow alternatives.

Table 3 provides the percent increase in total WUA per incremental increase in target flow alternative. An increase in target flows from 1 cfs to 2 cfs yields the maximum incremental increase to total WUA during every period except for spring runoff. Incremental increases diminish substantially at target flows greater than 2 cfs during September and October. In August, the rate of diminishing returns is comparatively gradual and linear. The results indicate that incremental increases to WUA during the spring runoff period (May to July) would be absent due to spring runoff (refer to Figure 1).

Table 3. Adult bull trout: incremental increase in total WUA between two consecutive alternative target flows.

Month(s)	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
Sep	N/A	8.4	42.0	24.7	19.1	13.5	8.4	6.6
Oct	N/A	15.3	62.3	29.7	19.9	13.5	8.4	6.6
May-Jul	N/A	0.0	0.0	0.4	0.4	0.3	0.6	0.5
Aug	N/A	2.6	12.4	9.9	8.6	7.9	5.7	5.0

3.3.5 Spawning Kokanee

Habitat duration tables and curves for spawning kokanee during the months of August, September, and October are provided in Appendix C-19 through Appendix C-24. The summary of these data, provided in Figure 11, illustrates that during each of these three months total WUA increases continuously as alternative target flows are increased, although total WUA in August has a visibly different trend than the later months. In August, total WUA increases gradually with increases in target flows. However, during the months of September and October, a relatively rapid increase in total WUA is predicted between 0.8 cfs and 3 cfs. At flow alternatives greater than 3 cfs, total WUA increases at a more moderate rate, similar to the gradual trend observed in August.

Figure 12 displays the percent increase in total WUA over baseline conditions provided by each alternative target flow. This graphic emphasizes the appreciable effect that relatively small increases in target flows can have on habitat availability during periods of seasonally low flows. In September and October, increases in total WUA of 100% over baseline conditions are predicted at target flows of approximately 4 cfs and 2.4 cfs, respectively. During August, habitat availability is not as strongly influenced by increases in target flows when natural flows remain relatively high during the first half of the month due to high-elevation runoff from melting snow.

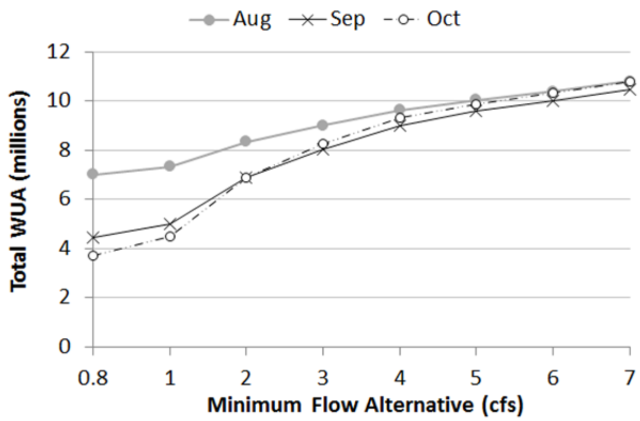

Figure 11. Spawning kokanee: total WUA provided by target flow alternatives.

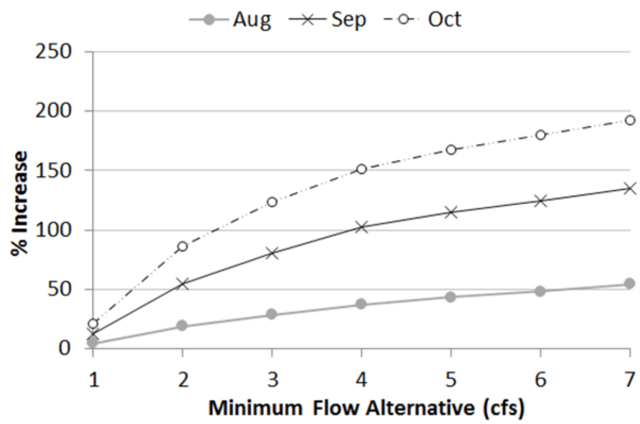

Figure 12. Spawning kokanee: total WUA increase over baseline conditions provided by target flow alternatives.

The incremental increases in total WUA are tabulated in Table 4. During each month in the spawning season, total WUA increases at a maximum rate between 1 cfs and 2 cfs. This incremental increase is most pronounced during October, where a target flow scenario of 2 cfs results in a total WUA increase of 54 percent over the consecutively lower target flow scenario of 1 cfs. The incremental increase to WUA at the simulated target flow of 2 cfs is relatively high in September (38 percent), and low in August (14 percent). Incremental increases to total WUA diminishes rapidly in September and October between simulated flows of 3 cfs and 5 cfs, and is less than 5 percent at flows greater than 5 cfs. During August, the incremental increases to total WUA diminish steadily between flows of 3 cfs and 7 cfs.

Table 4. Spawning kokanee: incremental increase in total WUA between two consecutive alternative target flows.

Month(s)	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
Aug	N/A	4.5	13.7	8.0	6.8	4.4	3.5	3.9
Sep	N/A	12.0	37.6	16.8	12.2	6.4	4.5	4.4
Oct	N/A	21.1	53.7	19.9	12.6	6.4	4.5	4.4

3.3.6 Stream Wetted Perimeter

During the baseflow conditions of the winter months, total WP was analyzed rather than total WUA. As previously discussed, WP is a suitable metric for winter months, when the viability of incubating eggs and fry is more dependent on remaining wet than on any combination of depth, velocity and cover that constitutes WUA curves. The duration analyses of WP during the winter baseflow months are provided in Appendix C-25 and Appendix C-26. The graphic summary of these results, which are applicable to all species/lifestages of fish in the East Fork bypass, is displayed in Figure 13. Total WP increases slightly between target flows of 0.8 cfs to 1 cfs, rises relatively steeply between 1 cfs and 2 cfs, and then increases gradually between target flows of 2 cfs and 7 cfs. The change in total WP over baseline conditions is expressed as percent increase in Figure 14. After a substantive increase in total WP at target flows of 2 cfs, increases over baseline conditions show a gradual, curvilinear trend.

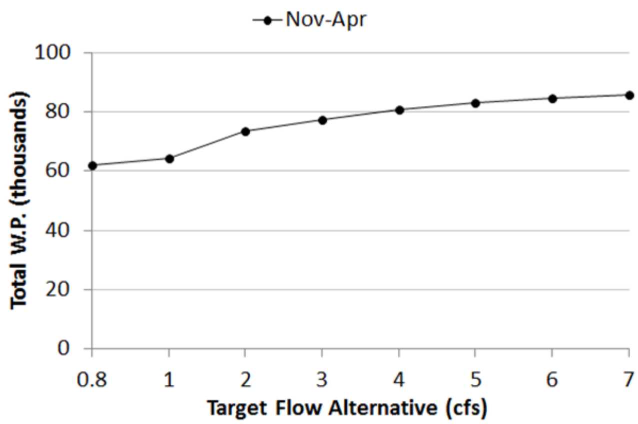

Figure 13. All target species/lifestages: total WP provided by target flow alternatives.

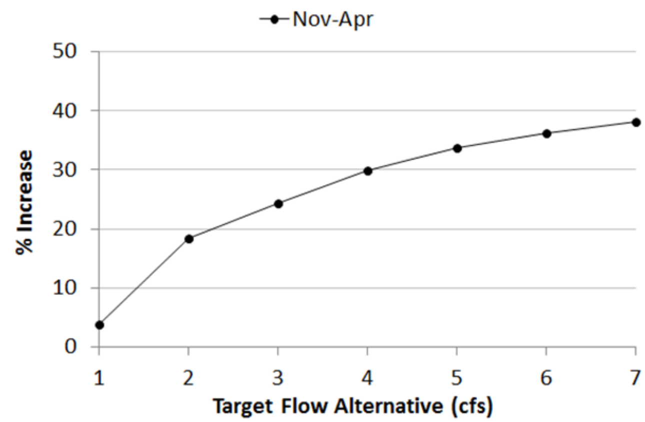

Figure 14. All target species/lifestages: total WP increase over baseline conditions provided by target flow alternatives.

The incremental increases in total WP are provided in Table 5. As suggested by Figure 13, the greatest incremental gain in total WP results when target flows increase from 1 cfs to 2 cfs. This 14% increase in total WP is an acute point of diminishing returns; subsequent incremental increases in total WP are 5% or less as alternative target flows increase.

Table 5. All target species/lifestages: incremental increase in total WUA between two consecutive alternative target flows.

Month(s)	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
Nov-Apr	N/A	3.9	14.0	5.0	4.5	3.0	1.8	1.4

4.0 FLOW REGIME RECOMMENDATIONS

4.1 May through October

Target flow scenario recommendations are described in this section and are developed on the basis of the monthly and seasonal results presented in the previous section. In these scenarios, the total WUA calculated for each season was summed to provide an estimate of habitat availability over the six month period of May through October (the months of November through April were excluded, as a different metric of habitat was utilized during this period of baseflows). Scenarios involving a single target flow for the entire period were explored, as well as three additional flow regime scenarios, which used combinations of target flows.

The additional flow regime scenarios, labeled Option A, B, and C, are defined in Table 6. The target flows in these additional options were selected based on trends observed in the total WUA analyses discussed in the previous section. The habitat duration analyses clearly demonstrates that the greatest increases in total WUA consistently occur during at target flows of 2 cfs, and that target flows of 3 cfs and 4 cfs often result in appreciable increases to total WUA. The incremental increases in total WUA demonstrate that target flows greater than 4 cfs furnish little to no additional increases in total WUA for all species/lifestages studied. For these reasons, three additional flow regime options were assessed as identified in Table 6 for target flow combinations ranging from 2 cfs to 4 cfs.

Table 6. Description of target flow combinations used for the additional flow regime options.

Flow Regime Options	Description
A.	3 cfs in Aug -Oct, 2 cfs May-Jul
B.	4 cfs in Aug-Oct, 2 cfs May-Jul
C.	4 cfs in Aug-Oct, 3 cfs May-Jul

Total WUA values for the various target flow regimes are presented for each species/lifestage in Figure 15. The four recommended options during May through October include: (1) a single target flow regime of 3 cfs; (2) a single target flow regime of 4 cfs; (3) the variable flow regime Option A; and (4) the variable flow regime Option B. These four options, highlighted in Figure 15, were based on the flow regimes that meet all of the following criteria:

1. Flow regimes that provide high levels of habitat for juvenile bull trout.[7] For the purposes of this study, high levels of habitat were identified as those options which provide greater total WUA for juvenile bull trout than (a) existing conditions and (b) unimpaired flows.
2. Flow regimes that provide at least a 100 percent increase over baseline conditions in habitat for spawning bull trout.
3. Target flows during September and October (the period of maximum spawning) that can be sustained with certainty during the six-month period of baseflow, to insure that incubating eggs and fry of bull trout and kokanee remain viable.

[7] Juvenile bull trout were the primary focus for habitat recommendations because the habitat suitability criteria (HSC) that were developed for this lifestage are now believed to represent both juvenile and adults of a resident population. Appendix D provides a detailed explanation of the applicability of juvenile and adult HSC based on the results of PacifiCorp's fisheries resources study (PacifiCorp, 2012).

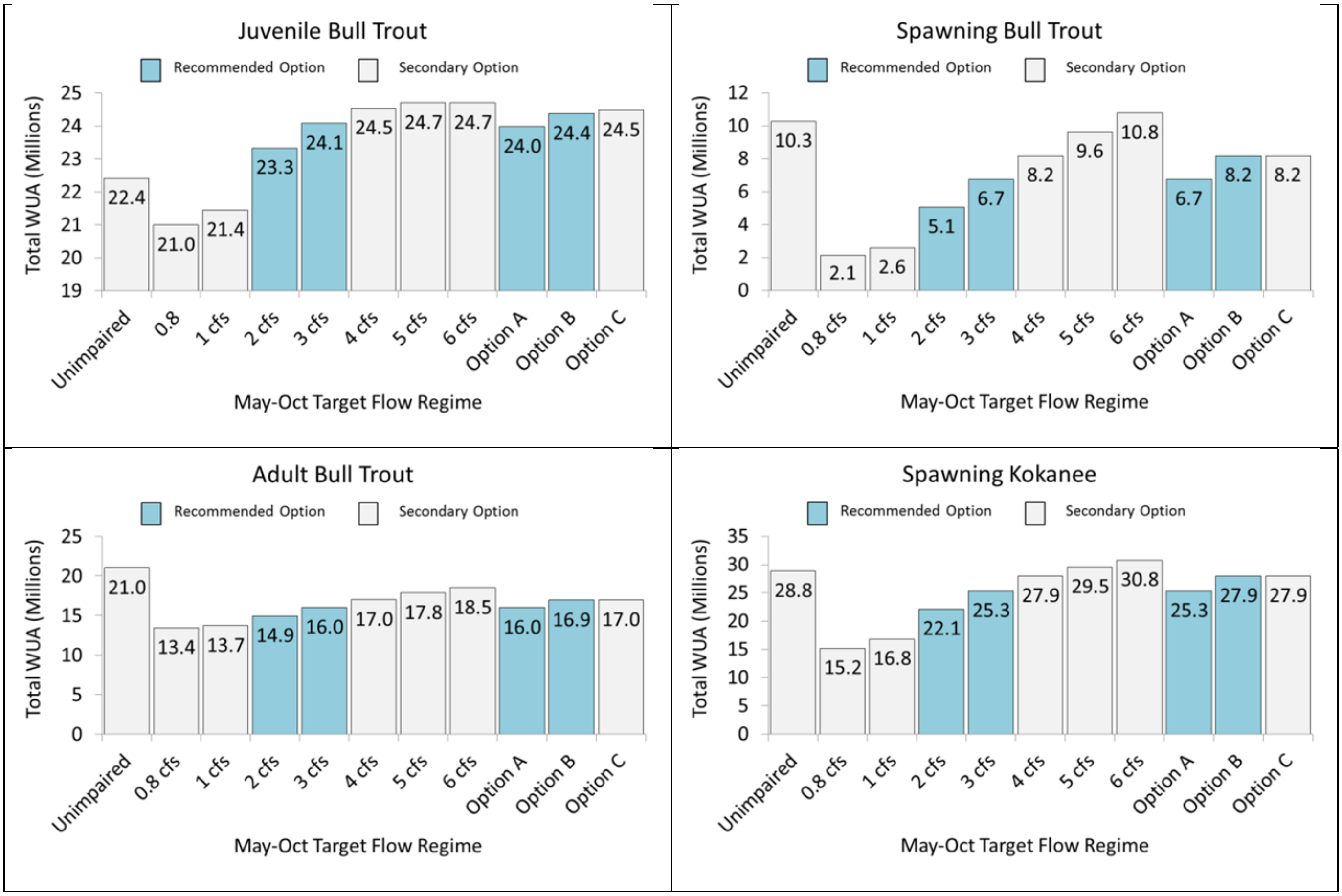

Figure 15. Sum of total WUA over the period of May-October, as provided by various target flow options.

4.2 November through April

The target flow recommendation for November through April is based on the results of the total WP analysis from section 3.3.6, in combination with daily and hourly winter flow observations from PacifiCorp's hydrology study. The WP analysis demonstrates that the greatest increase in total WP occurs between 1 cfs and 2 cfs. Inversely, the greatest *reduction* in total WP would likely occur if flows were to drop from 2 cfs to 1 cfs. The hourly data collect per PacifiCorp's hydrology study during WY 2012 indicates that an average diel variation of approximately 0.7 cfs occurs during periods of baseflow (PacifiCorp, 2012). For this reason, a target release of 3 cfs near the diversion dam is recommended to insure a minimum flow of 2 cfs during the winter months.

5.0 REFERENCES

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Appendix A. WSL Calibration Results

Transect No.	Obs. WSL (ft) 5.3	Cal. WSL (ft) 5.3	Dif (ft) 5.3	Obs. WSL (ft) 8.5	Cal. WSL (ft) 8.5	Dif (ft) 8.5	Obs. WSL (ft) 15	Cal. WSL (ft) 15	Dif (ft) 15
1	4468.215	4468.204	-0.011	4468.265	4468.283	0.018	4468.400	4468.394	-0.006
2	4468.425	4468.420	-0.004	4468.530	4468.539	0.009	4468.710	4468.706	-0.004
3	4473.680	4473.665	-0.016	4473.745	4473.770	0.024	4473.920	4473.912	-0.008
4	4477.850	4477.854	0.004	4477.970	4477.961	-0.009	4478.105	4478.110	0.005
5	4480.750	4480.735	-0.015	4480.810	4480.833	0.023	4480.970	4480.963	-0.007
6	4484.225	4484.207	-0.019	4484.250	4484.274	0.024	4484.370	4484.365	-0.005
7	4484.170	4484.180	0.010	4484.290	4484.288	-0.002	4484.440	4484.443	0.003
8	4484.910	4484.902	-0.008	4485.030	4485.045	0.015	4485.250	4485.243	-0.007
9	4506.555	4506.544	-0.011	4506.626	4506.612	-0.014	4506.705	4506.700	-0.005
10	4510.000	4509.989	-0.011	4510.080	4510.099	0.019	4510.257	4510.250	-0.007
11	4514.490	4514.509	0.019	4514.580	4514.597	0.017	4514.720	4514.713	-0.007
12	4522.280	4522.280	0.000	4522.350	4522.379	0.029	4522.515	4522.515	0.000
13	4532.825	4532.811	-0.015	4532.850	4532.907	0.057	4533.035	4533.038	0.002

Appendix B. Flow vs. Habitat WUA Relationship

Appendix B-1. Flow versus habitat WUA in East Fork Wallowa bypass for target lifestages of bull trout.

Q	WUA (ft^2 per 1000 ft)		
cfs	Adult Bull Trout	Juvenile Bull Trout	Spawning Bull Trout
0.8	662	2697	653
1	790	2926	955
2	1317	3618	2206
3	1724	3866	3069
4	2066	4003	3725
5	2346	4049	4384
5.3	2398	4057	4630
6	2543	4069	4905
7	2711	4036	5137
8	2840	4022	5191
8.5	2897	4014	5195
9	2947	4004	5182
10	3033	3982	5126
11	3150	3963	5020
12	3204	3929	4906
13	3241	3878	4803
14	3265	3825	4714
15	3279	3779	4645
16	3343	3733	4586
17	3346	3677	4525
18	3341	3619	4455
19	3334	3565	4373
20	3319	3514	4314
25	3226	3298	4095
30	3109	3127	3811
40	2931	2906	3339

Appendix B-2. Flow versus habitat WUA in East Fork Wallowa bypass for spawning kokanee.

Q cfs	WUA (ft^2 per 1000 ft) Spawning Kokanee
0.8	3076
1	3869
2	5988
3	6938
4	7790
5	8523
5.3	8645
6	9272
7	9684
8	9962
8.5	10045
9	10112
10	10188
11	10090
12	9910
13	9650
14	9337
15	9004
16	8671
17	8342
18	8022
19	7738
20	7463
25	6557
30	5998
40	4992

Appendix B-3. Flow versus average WP in East Fork Wallowa bypass

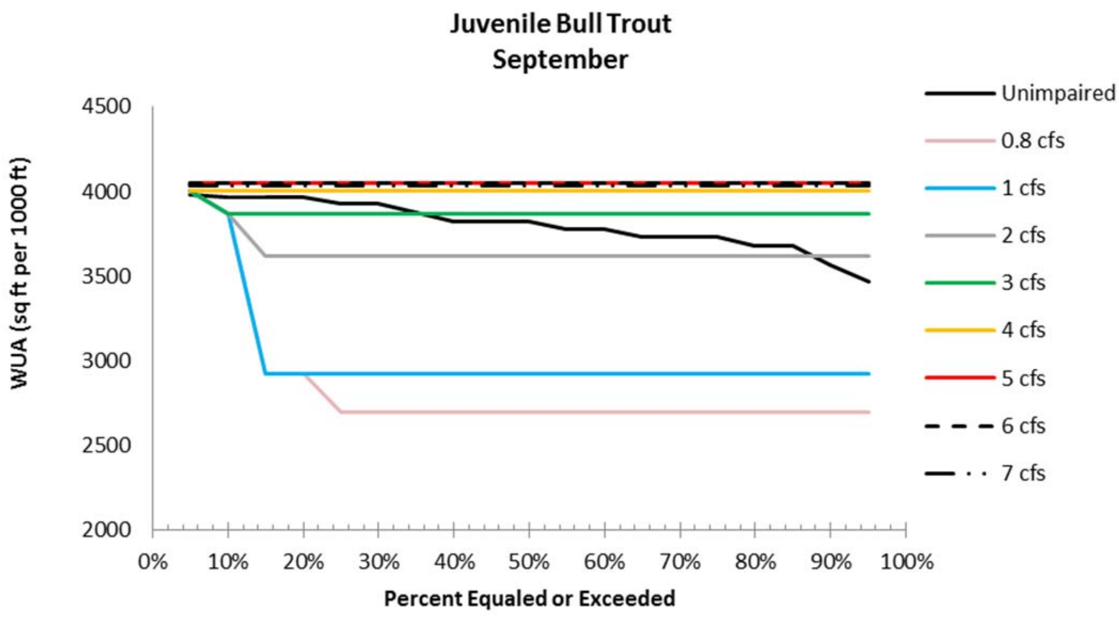
Q cfs	WP (ft) Average of 13 Transects
0.8	9.5
1	9.9
2	11.3
3	11.8
4	12.4
5	12.7
5.3	13.0
6	13.1
7	13.4
8	13.5
8.5	13.5
9	13.7
10	13.8
11	13.9
12	14.0
13	14.2
14	14.2
15	14.3
16	14.4
17	14.5
18	14.6
19	14.6
20	14.8
25	15.0
30	15.5
40	9.5

Appendix C. Seasonal Habitat Duration

Appendix C-1. Habitat duration table for juvenile bull trout during September.

Sep	1350	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3982	4004	4004	4004	4004	4004	4049	4048	4036
10%	3963	3982	3982	3982	3982	4003	4049	4048	4036
15%	3929	3866	3866	3866	3866	4003	4049	4048	4036
20%	3929	3866	3866	3866	3866	4003	4049	4048	4036
25%	3878	3618	3618	3618	3866	4003	4049	4048	4036
30%	3878	2926	2926	3618	3866	4003	4049	4048	4036
35%	3825	2926	2926	3618	3866	4003	4049	4048	4036
40%	3779	2926	2926	3618	3866	4003	4049	4048	4036
45%	3779	2697	2926	3618	3866	4003	4049	4048	4036
50%	3733	2697	2926	3618	3866	4003	4049	4048	4036
55%	3733	2697	2926	3618	3866	4003	4049	4048	4036
60%	3677	2697	2926	3618	3866	4003	4049	4048	4036
65%	3677	2697	2926	3618	3866	4003	4049	4048	4036
70%	3677	2697	2926	3618	3866	4003	4049	4048	4036
75%	3619	2697	2926	3618	3866	4003	4049	4048	4036
80%	3565	2697	2926	3618	3866	4003	4049	4048	4036
85%	3565	2697	2926	3618	3866	4003	4049	4048	4036
90%	3514	2697	2926	3618	3866	4003	4049	4048	4036
95%	3422	2697	2926	3618	3866	4003	4048	4048	4036

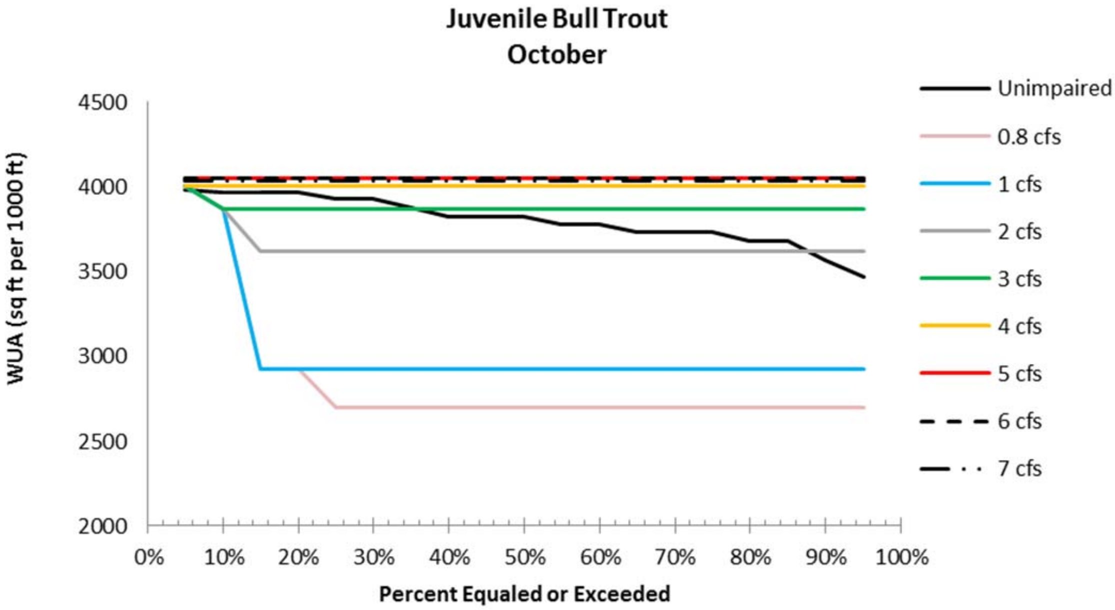
Appendix C-2. Habitat duration curve for juvenile bull trout during September.



Appendix C-3. Habitat duration table for juvenile bull trout during October.

Oct	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3982	4003	4003	4003	4003	4003	4049	4048	4036
10%	3963	3866	3866	3866	3866	4003	4049	4048	4036
15%	3963	2926	2926	3618	3866	4003	4049	4048	4036
20%	3963	2926	2926	3618	3866	4003	4049	4048	4036
25%	3929	2697	2926	3618	3866	4003	4049	4048	4036
30%	3929	2697	2926	3618	3866	4003	4049	4048	4036
35%	3878	2697	2926	3618	3866	4003	4049	4048	4036
40%	3825	2697	2926	3618	3866	4003	4049	4048	4036
45%	3825	2697	2926	3618	3866	4003	4049	4048	4036
50%	3825	2697	2926	3618	3866	4003	4049	4048	4036
55%	3779	2697	2926	3618	3866	4003	4049	4048	4036
60%	3779	2697	2926	3618	3866	4003	4049	4048	4036
65%	3733	2697	2926	3618	3866	4003	4049	4048	4036
70%	3733	2697	2926	3618	3866	4003	4049	4048	4036
75%	3733	2697	2926	3618	3866	4003	4049	4048	4036
80%	3677	2697	2926	3618	3866	4003	4049	4048	4036
85%	3677	2697	2926	3618	3866	4003	4049	4048	4036
90%	3565	2697	2926	3618	3866	4003	4049	4048	4036
95%	3466	2697	2926	3618	3866	4003	4049	4048	4036

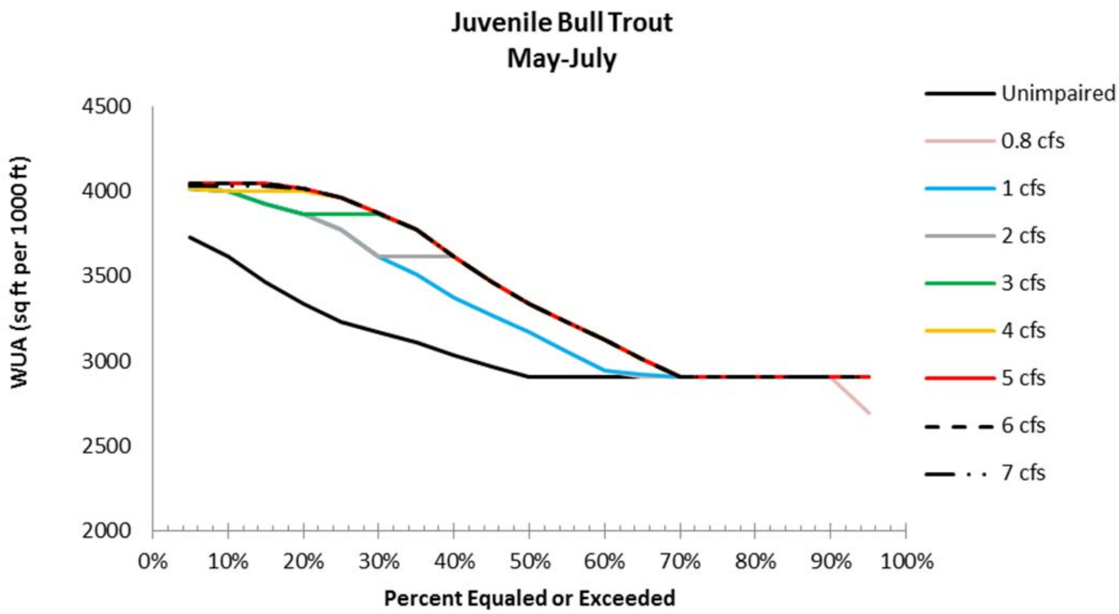
Appendix C-4. Habitat duration curve for juvenile bull trout during October.



Appendix C-5. Habitat duration table for juvenile bull trout during the spring runoff period of May through July.

May-July	4140	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3733	4022	4022	4022	4022	4022	4049	4048	4036
10%	3619	4003	4003	4003	4003	4003	4049	4048	4036
15%	3466	3929	3929	3929	3929	4003	4049	4048	4036
20%	3341	3866	3866	3866	3866	4003	4022	4022	4022
25%	3235	3779	3779	3779	3866	3963	3963	3963	3963
30%	3172	3619	3619	3619	3866	3878	3878	3878	3878
35%	3115	3514	3514	3618	3779	3779	3779	3779	3779
40%	3037	3381	3381	3618	3619	3619	3619	3619	3619
45%	2968	3269	3269	3466	3466	3466	3466	3466	3466
50%	2906	3172	3172	3341	3341	3341	3341	3341	3341
55%	2906	3062	3062	3235	3235	3235	3235	3235	3235
60%	2906	2946	2946	3127	3127	3127	3127	3127	3127
65%	2906	2906	2926	3013	3013	3013	3013	3013	3013
70%	2906	2906	2906	2906	2906	2906	2906	2906	2906
75%	2906	2906	2906	2906	2906	2906	2906	2906	2906
80%	2906	2906	2906	2906	2906	2906	2906	2906	2906
85%	2906	2906	2906	2906	2906	2906	2906	2906	2906
90%	2906	2906	2906	2906	2906	2906	2906	2906	2906
95%	2906	2697	2906	2906	2906	2906	2906	2906	2906

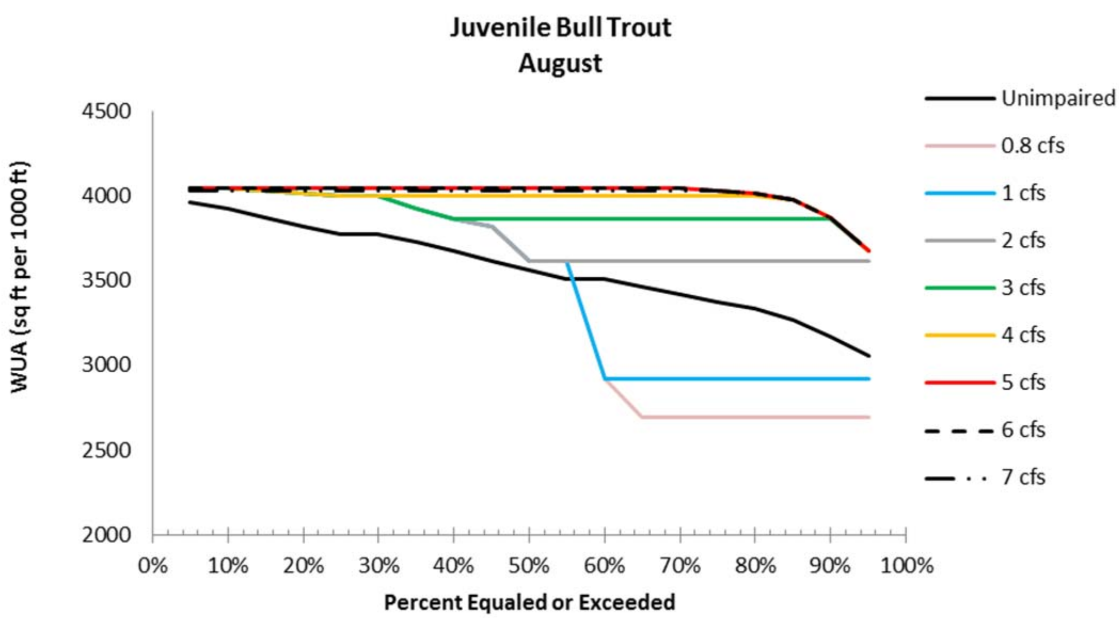
Appendix C-6. Habitat duration curve for juvenile bull trout during the spring runoff period of May through July.



Appendix C-7. Habitat duration table for adult bull trout during August.

Aug	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3963	4049	4049	4049	4049	4049	4049	4048	4036
10%	3929	4048	4048	4048	4048	4048	4049	4048	4036
15%	3878	4036	4036	4036	4036	4036	4049	4048	4036
20%	3825	4022	4022	4022	4022	4022	4049	4048	4036
25%	3779	4003	4003	4003	4003	4003	4049	4048	4036
30%	3779	4003	4003	4003	4003	4003	4049	4048	4036
35%	3733	3929	3929	3929	3929	4003	4049	4048	4036
40%	3677	3866	3866	3866	3866	4003	4049	4048	4036
45%	3619	3825	3825	3825	3866	4003	4049	4048	4036
50%	3565	3618	3618	3618	3866	4003	4049	4048	4036
55%	3514	3618	3618	3618	3866	4003	4049	4048	4036
60%	3514	2926	2926	3618	3866	4003	4049	4048	4036
65%	3466	2697	2926	3618	3866	4003	4049	4048	4036
70%	3422	2697	2926	3618	3866	4003	4048	4048	4036
75%	3381	2697	2926	3618	3866	4003	4036	4036	4036
80%	3341	2697	2926	3618	3866	4003	4022	4022	4022
85%	3269	2697	2926	3618	3866	3982	3982	3982	3982
90%	3172	2697	2926	3618	3866	3878	3878	3878	3878
95%	3062	2697	2926	3618	3677	3677	3677	3677	3677

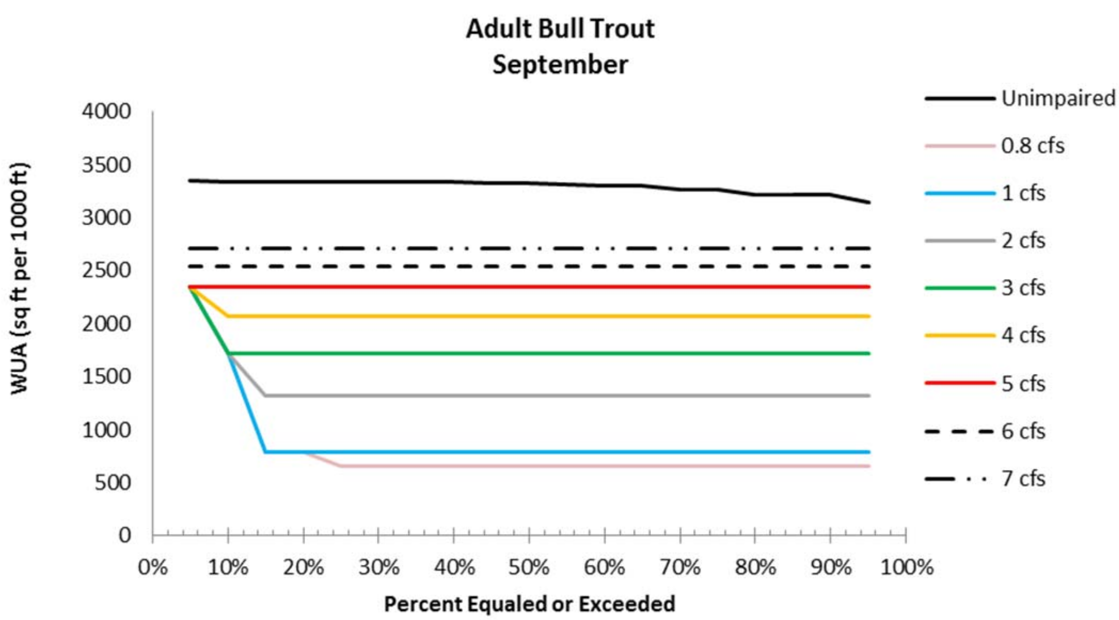
Appendix C-8. Habitat duration curve for adult bull trout during August.



Appendix C-9. Habitat duration table for adult bull trout during September.

Sep	1350	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3346	2543	2543	2543	2543	2543	2543	2543	2711
10%	3346	2066	2066	2066	2066	2066	2346	2543	2711
15%	3343	1724	1724	1724	1724	2066	2346	2543	2711
20%	3343	1724	1724	1724	1724	2066	2346	2543	2711
25%	3341	1317	1317	1317	1724	2066	2346	2543	2711
30%	3341	790	790	1317	1724	2066	2346	2543	2711
35%	3338	790	790	1317	1724	2066	2346	2543	2711
40%	3338	790	790	1317	1724	2066	2346	2543	2711
45%	3334	662	790	1317	1724	2066	2346	2543	2711
50%	3334	662	790	1317	1724	2066	2346	2543	2711
55%	3326	662	790	1317	1724	2066	2346	2543	2711
60%	3319	662	790	1317	1724	2066	2346	2543	2711
65%	3302	662	790	1317	1724	2066	2346	2543	2711
70%	3302	662	790	1317	1724	2066	2346	2543	2711
75%	3266	662	790	1317	1724	2066	2346	2543	2711
80%	3266	662	790	1317	1724	2066	2346	2543	2711
85%	3213	662	790	1317	1724	2066	2346	2543	2711
90%	3213	662	790	1317	1724	2066	2346	2543	2711
95%	3143	662	790	1317	1724	2066	2346	2543	2711

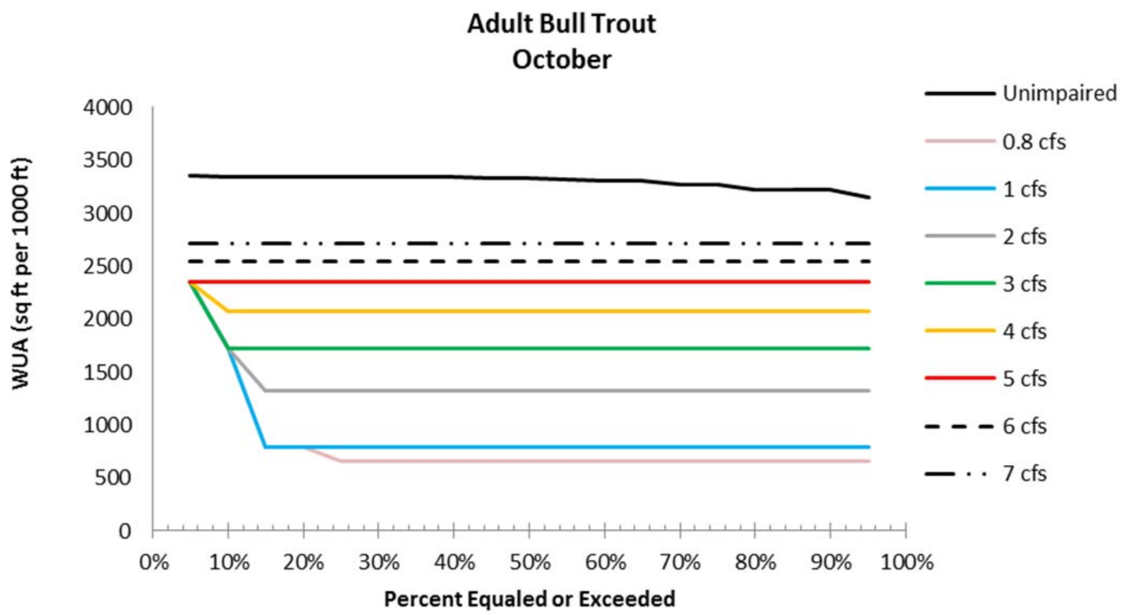
Appendix C-10. Habitat duration curve for adult bull trout during September.



Appendix C-11. Habitat duration table for adult bull trout during October.

Oct	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3346	2346	2346	2346	2346	2346	2346	2543	2711
10%	3343	1724	1724	1724	1724	2066	2346	2543	2711
15%	3343	790	790	1317	1724	2066	2346	2543	2711
20%	3343	790	790	1317	1724	2066	2346	2543	2711
25%	3341	662	790	1317	1724	2066	2346	2543	2711
30%	3338	662	790	1317	1724	2066	2346	2543	2711
35%	3338	662	790	1317	1724	2066	2346	2543	2711
40%	3334	662	790	1317	1724	2066	2346	2543	2711
45%	3326	662	790	1317	1724	2066	2346	2543	2711
50%	3326	662	790	1317	1724	2066	2346	2543	2711
55%	3319	662	790	1317	1724	2066	2346	2543	2711
60%	3302	662	790	1317	1724	2066	2346	2543	2711
65%	3302	662	790	1317	1724	2066	2346	2543	2711
70%	3266	662	790	1317	1724	2066	2346	2543	2711
75%	3266	662	790	1317	1724	2066	2346	2543	2711
80%	3213	662	790	1317	1724	2066	2346	2543	2711
85%	3213	662	790	1317	1724	2066	2346	2543	2711
90%	3213	662	790	1317	1724	2066	2346	2543	2711
95%	3143	662	790	1317	1724	2066	2346	2543	2711

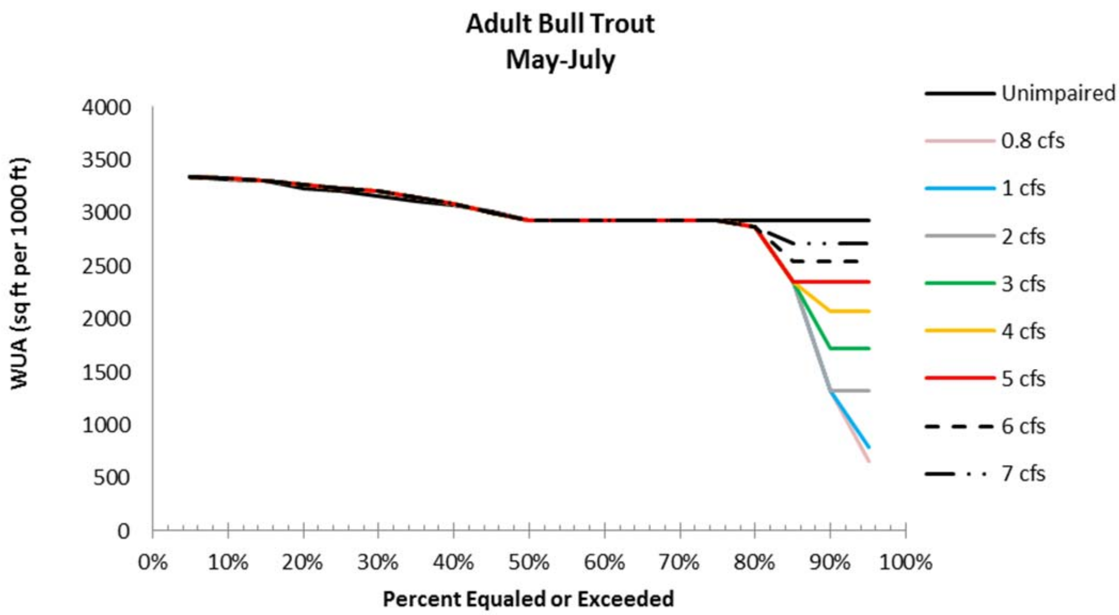
Appendix C-12. Habitat duration curve for adult bull trout during October.



Appendix C-13. Habitat duration table for adult bull trout during the spring runoff period of May through July.

May-July	4140	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	3341	3341	3341	3341	3341	3341	3341	3341	3341
10%	3319	3326	3326	3326	3326	3326	3326	3326	3326
15%	3299	3302	3302	3302	3302	3302	3302	3302	3302
20%	3226	3266	3266	3266	3266	3266	3266	3266	3266
25%	3202	3226	3226	3226	3226	3226	3226	3226	3226
30%	3164	3202	3202	3202	3202	3202	3202	3202	3202
35%	3109	3143	3143	3143	3143	3143	3143	3143	3143
40%	3070	3089	3089	3089	3089	3089	3089	3089	3089
45%	3015	2997	2997	2997	2997	2997	2997	2997	2997
50%	2931	2931	2931	2931	2931	2931	2931	2931	2931
55%	2931	2931	2931	2931	2931	2931	2931	2931	2931
60%	2931	2931	2931	2931	2931	2931	2931	2931	2931
65%	2931	2931	2931	2931	2931	2931	2931	2931	2931
70%	2931	2931	2931	2931	2931	2931	2931	2931	2931
75%	2931	2931	2931	2931	2931	2931	2931	2931	2931
80%	2931	2870	2870	2870	2870	2870	2870	2870	2870
85%	2931	2346	2346	2346	2346	2346	2346	2543	2711
90%	2931	1317	1317	1317	1724	2066	2346	2543	2711
95%	2931	662	790	1317	1724	2066	2346	2543	2711

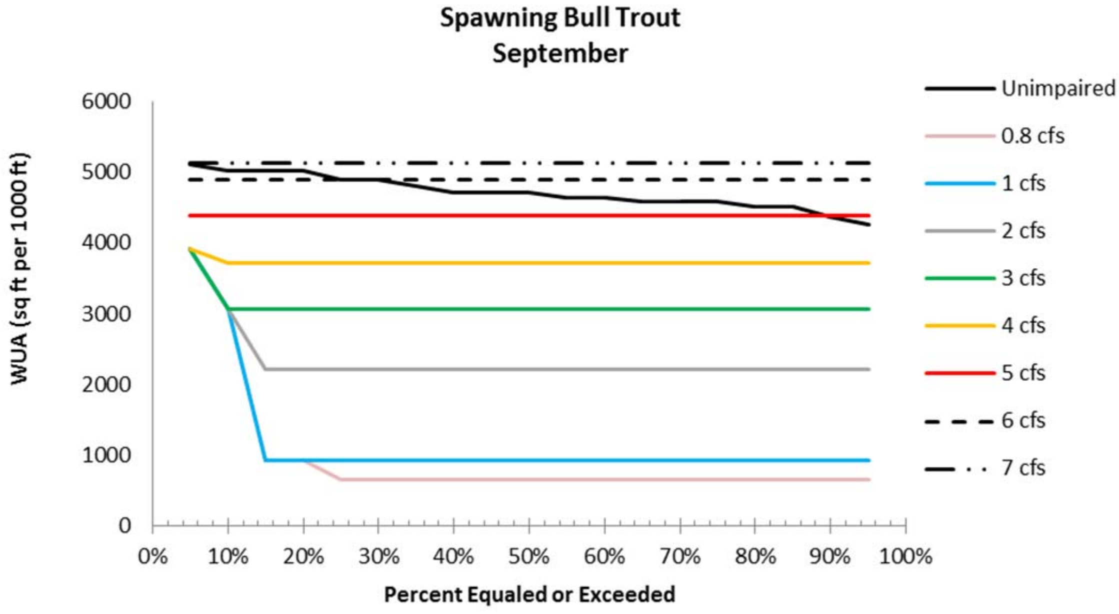
Appendix C-14. Habitat duration curve for adult bull trout during the spring runoff period of May through July.



Appendix C-15. Habitat duration table for spawning bull trout during September.

Sep	1350	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	5126	4494	4494	4494	4494	4494	4494	4905	5137
10%	5020	3725	3725	3725	3725	3725	4384	4905	5137
15%	4906	3062	3062	3062	3062	3725	4384	4905	5137
20%	4906	3062	3062	3062	3062	3725	4384	4905	5137
25%	4803	2212	2212	2212	3062	3725	4384	4905	5137
30%	4803	935	935	2212	3062	3725	4384	4905	5137
35%	4714	935	935	2212	3062	3725	4384	4905	5137
40%	4645	935	935	2212	3062	3725	4384	4905	5137
45%	4645	653	935	2212	3062	3725	4384	4905	5137
50%	4586	653	935	2212	3062	3725	4384	4905	5137
55%	4586	653	935	2212	3062	3725	4384	4905	5137
60%	4525	653	935	2212	3062	3725	4384	4905	5137
65%	4525	653	935	2212	3062	3725	4384	4905	5137
70%	4525	653	935	2212	3062	3725	4384	4905	5137
75%	4455	653	935	2212	3062	3725	4384	4905	5137
80%	4373	653	935	2212	3062	3725	4384	4905	5137
85%	4373	653	935	2212	3062	3725	4384	4905	5137
90%	4314	653	935	2212	3062	3725	4384	4905	5137
95%	4222	653	935	2212	3062	3725	4384	4905	5137

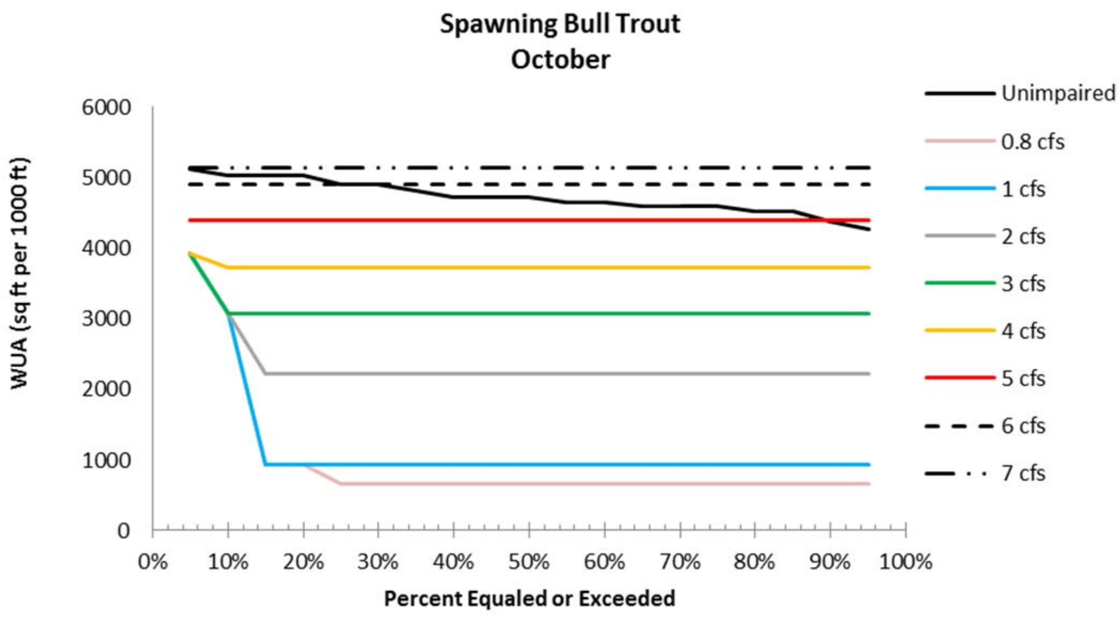
Appendix C-16. Habitat duration curve for spawning bull trout during September.



Appendix C-17. Habitat duration table for spawning bull trout during October.

Oct	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	5126	3923	3923	3923	3923	3923	4384	4905	5137
10%	5020	3062	3062	3062	3062	3725	4384	4905	5137
15%	5020	935	935	2212	3062	3725	4384	4905	5137
20%	5020	935	935	2212	3062	3725	4384	4905	5137
25%	4906	653	935	2212	3062	3725	4384	4905	5137
30%	4906	653	935	2212	3062	3725	4384	4905	5137
35%	4803	653	935	2212	3062	3725	4384	4905	5137
40%	4714	653	935	2212	3062	3725	4384	4905	5137
45%	4714	653	935	2212	3062	3725	4384	4905	5137
50%	4714	653	935	2212	3062	3725	4384	4905	5137
55%	4645	653	935	2212	3062	3725	4384	4905	5137
60%	4645	653	935	2212	3062	3725	4384	4905	5137
65%	4586	653	935	2212	3062	3725	4384	4905	5137
70%	4586	653	935	2212	3062	3725	4384	4905	5137
75%	4586	653	935	2212	3062	3725	4384	4905	5137
80%	4525	653	935	2212	3062	3725	4384	4905	5137
85%	4525	653	935	2212	3062	3725	4384	4905	5137
90%	4373	653	935	2212	3062	3725	4384	4905	5137
95%	4271	653	935	2212	3062	3725	4384	4905	5137

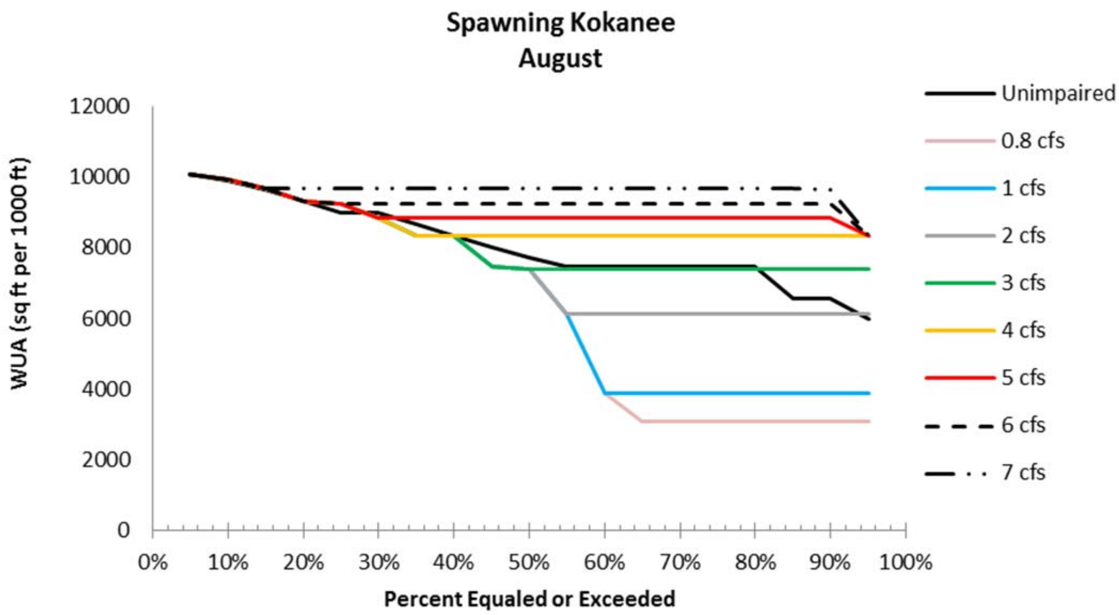
Appendix C-18. Habitat duration curve for spawning bull trout during October.



Appendix C-19. Habitat duration table for spawning kokanee during August.

Aug	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	10090	10090	10090	10090	10090	10090	10090	10090	10090
10%	9910	9962	9962	9962	9962	9962	9962	9962	9962
15%	9650	9684	9684	9684	9684	9684	9684	9684	9684
20%	9337	9337	9337	9337	9337	9337	9337	9337	9684
25%	9004	9272	9272	9272	9272	9272	9272	9272	9684
30%	9004	8870	8870	8870	8870	8870	8870	9272	9684
35%	8671	8342	8342	8342	8342	8342	8870	9272	9684
40%	8342	8337	8337	8337	8337	8337	8870	9272	9684
45%	8022	7463	7463	7463	7463	8337	8870	9272	9684
50%	7738	7401	7401	7401	7401	8337	8870	9272	9684
55%	7463	6132	6132	6132	7401	8337	8870	9272	9684
60%	7463	3907	3907	6132	7401	8337	8870	9272	9684
65%	7463	3076	3907	6132	7401	8337	8870	9272	9684
70%	7463	3076	3907	6132	7401	8337	8870	9272	9684
75%	7463	3076	3907	6132	7401	8337	8870	9272	9684
80%	7463	3076	3907	6132	7401	8337	8870	9272	9684
85%	6557	3076	3907	6132	7401	8337	8870	9272	9684
90%	6557	3076	3907	6132	7401	8337	8870	9272	9650
95%	5998	3076	3907	6132	7401	8337	8342	8342	8342

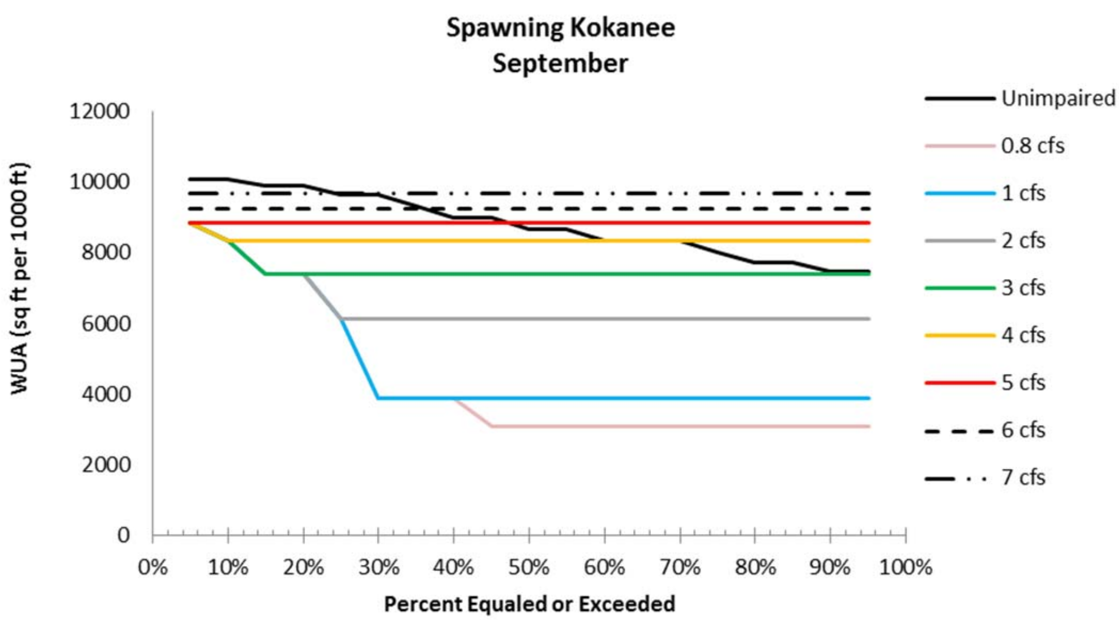
Appendix C-20. Habitat duration curve for spawning kokanee during August.



Appendix C-21. Habitat duration table for spawning kokanee during September.

Sep	1350	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	10090	8870	8870	8870	8870	8870	8870	9272	9684
10%	10090	8337	8337	8337	8337	8337	8870	9272	9684
15%	9910	7401	7401	7401	7401	8337	8870	9272	9684
20%	9910	7401	7401	7401	7401	8337	8870	9272	9684
25%	9650	6132	6132	6132	7401	8337	8870	9272	9684
30%	9650	3907	3907	6132	7401	8337	8870	9272	9684
35%	9337	3907	3907	6132	7401	8337	8870	9272	9684
40%	9004	3907	3907	6132	7401	8337	8870	9272	9684
45%	9004	3076	3907	6132	7401	8337	8870	9272	9684
50%	8671	3076	3907	6132	7401	8337	8870	9272	9684
55%	8671	3076	3907	6132	7401	8337	8870	9272	9684
60%	8342	3076	3907	6132	7401	8337	8870	9272	9684
65%	8342	3076	3907	6132	7401	8337	8870	9272	9684
70%	8342	3076	3907	6132	7401	8337	8870	9272	9684
75%	8022	3076	3907	6132	7401	8337	8870	9272	9684
80%	7738	3076	3907	6132	7401	8337	8870	9272	9684
85%	7738	3076	3907	6132	7401	8337	8870	9272	9684
90%	7463	3076	3907	6132	7401	8337	8870	9272	9684
95%	7463	3076	3907	6132	7401	8337	8870	9272	9684

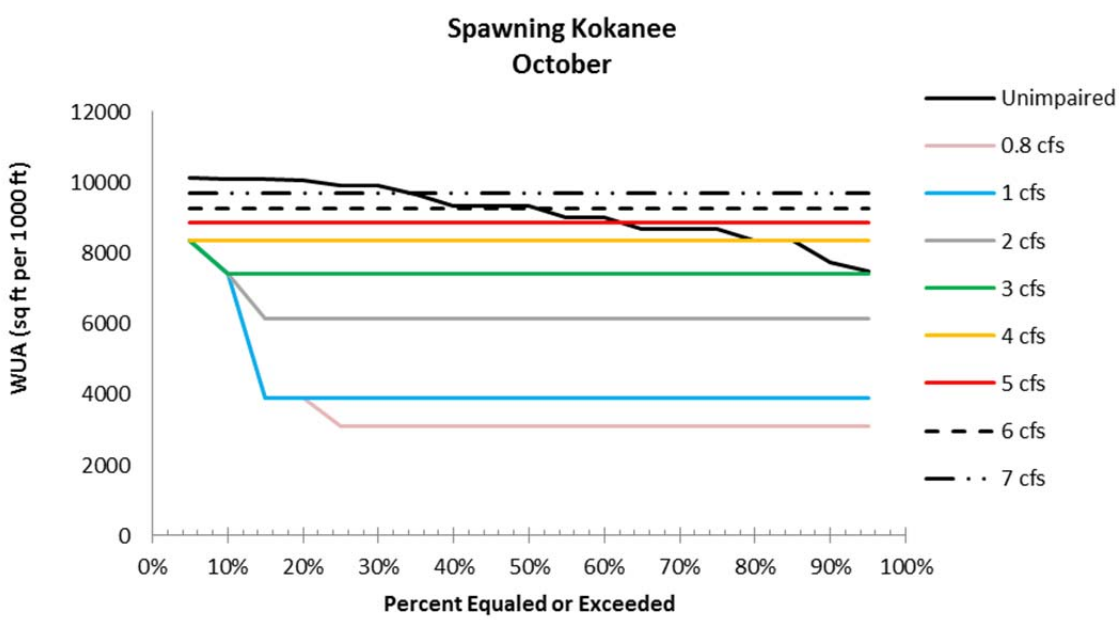
Appendix C-22. Habitat duration curve for spawning kokanee during September.



Appendix C-23. Habitat duration table for spawning kokanee during October.

Oct	1395	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	10112	8337	8337	8337	8337	8337	8870	9272	9684
10%	10090	7401	7401	7401	7401	8337	8870	9272	9684
15%	10090	3907	3907	6132	7401	8337	8870	9272	9684
20%	10045	3907	3907	6132	7401	8337	8870	9272	9684
25%	9910	3076	3907	6132	7401	8337	8870	9272	9684
30%	9910	3076	3907	6132	7401	8337	8870	9272	9684
35%	9650	3076	3907	6132	7401	8337	8870	9272	9684
40%	9337	3076	3907	6132	7401	8337	8870	9272	9684
45%	9337	3076	3907	6132	7401	8337	8870	9272	9684
50%	9337	3076	3907	6132	7401	8337	8870	9272	9684
55%	9004	3076	3907	6132	7401	8337	8870	9272	9684
60%	9004	3076	3907	6132	7401	8337	8870	9272	9684
65%	8671	3076	3907	6132	7401	8337	8870	9272	9684
70%	8671	3076	3907	6132	7401	8337	8870	9272	9684
75%	8671	3076	3907	6132	7401	8337	8870	9272	9684
80%	8342	3076	3907	6132	7401	8337	8870	9272	9684
85%	8342	3076	3907	6132	7401	8337	8870	9272	9684
90%	7738	3076	3907	6132	7401	8337	8870	9272	9684
95%	7463	3076	3907	6132	7401	8337	8870	9272	9684

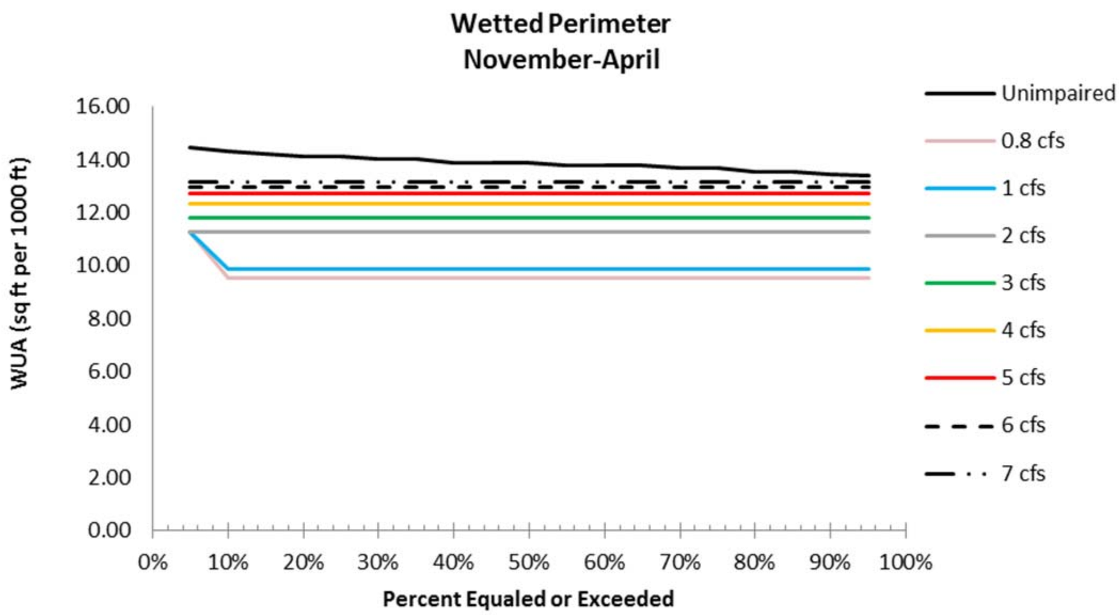
Appendix C-24. Habitat duration curve for spawning kokanee during October.



Appendix C-25. Habitat duration table for all species/lifestages during the months of November through April.

Nov-Apr	8156	(n)							
Exceedance	Unimpaired	0.8 cfs	1 cfs	2 cfs	3 cfs	4 cfs	5 cfs	6 cfs	7 cfs
5%	14.49	11.27	11.27	11.27	11.83	12.36	12.73	12.96	13.14
10%	14.34	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
15%	14.21	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
20%	14.15	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
25%	14.15	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
30%	14.04	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
35%	14.04	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
40%	13.89	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
45%	13.89	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
50%	13.89	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
55%	13.78	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
60%	13.78	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
65%	13.78	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
70%	13.68	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
75%	13.68	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
80%	13.55	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
85%	13.55	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
90%	13.47	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14
95%	13.38	9.52	9.89	11.27	11.83	12.36	12.73	12.96	13.14

Appendix C-26. Habitat duration curve for all species/lifestages during the months of November through April.



Appendix D. Memo on the Applicability of Habitat Suitability Criteria for Juvenile and Adult Bull Trout

Introduction

PacifiCorp (2012) fish sampling results from 2012 indicate that bull trout in the vicinity of the Project exhibit evidence of three life history types[8]: (1) resident; (2) fluvial; and (3) adfluvial. However, the results suggest that 90 percent of the bull trout encountered in the East Fork Wallowa River are resident life history type, although some uncertainty remains that PacifiCorp plans to address in further study during 2013[9].

The assumption that the East Fork bull trout population consists mostly of resident life history type is important for the further analysis of PHABSIM modeling results for the Project. In considering the PHABSIM results so far, PacifiCorp believes that the results generated for "bull trout adult", which are based on habitat suitability criteria (HSC) for fluvial-adfluvial life history types, do not accurately represent the East Fork bull trout resident population for two reasons. These two reasons include: (1) resident bull trout are generally much smaller in size and reach sexual maturity at an earlier age than fluvial-adfluvial types; and (2) resident bull trout are the predominant life history type in mountainous streams like the East Fork where cold water and hydraulic impediments or barriers are common. For these reasons, as discussed further in this memo, PacifiCorp recommends that both juvenile and adults of the East Fork bull trout resident population likely are more accurately represented by PHABSIM results generated for "bull trout juvenile".

Aquatic Resources

Evidence of a Resident Population

Most bull trout of resident life-history type reach maturity in about three years at about 200 mm (rarely exceeding 300 mm), and their growth rate plateaus (McPhail & Baxter, 1996). By comparison, fluvial-adfluvial bull trout reach sexual maturity in about five years, attain an average size of about 400 mm, and can exceed 600 mm (Rieman & McIntyre, 1993, McPhail & Baxter, 1996). These findings suggest that mature resident bull trout are more equivalent in size to juveniles of the fluvial-adfluvial life history types.

Results of the aquatic resources study (PacifiCorp, 2012) demonstrate that bull trout captured in the East Fork are generally small, with a length range of 84 mm to 245 mm and a mean length of 123 mm. Two bull trout of migratory life history form (lengths of 415 mm and 550 mm) were detected by a PIT tag reader in the lowest reaches of the East Fork, but only after these fish had been removed, tagged, and displaced from the powerhouse tailrace. The only evidence of a natural presence of migratory bull trout in the East Fork was found in 2010, when PacifiCorp observed a spawning pair 250 meters upstream of the mouth of the stream. Otherwise, the generally small bull trout recovered from the East Fork bypass reach suggests a resident population. Further evidence of a resident population was provided by the results of PacifiCorp's PIT tag study. None of the tagged bull trout that were captured in the East Fork were detected moving downstream into the Wallowa River. Although these findings do not rule out the occasional use of the lowest reaches of the East Fork by adfluvial bull trout, they do point strongly to the predominance of a resident bull trout population.

PacifiCorp further explored the possibility of a resident population by comparing the length distribution of fish from the East Fork to length distributions developed by ODFW from data collected in a bull trout density sampling study (Smith & Knox, 1992). ODFW's study included Big Sheep Creek. Although this stream is located in the Imnaha River basin, it is important because it is considered to be the stream from which bull trout populations in Project-affected waters were stocked. A diversion on Big Sheep Creek separates a resident bull trout population from a fluvial population. The length distributions from both of these populations are evaluated against the length distributions found in

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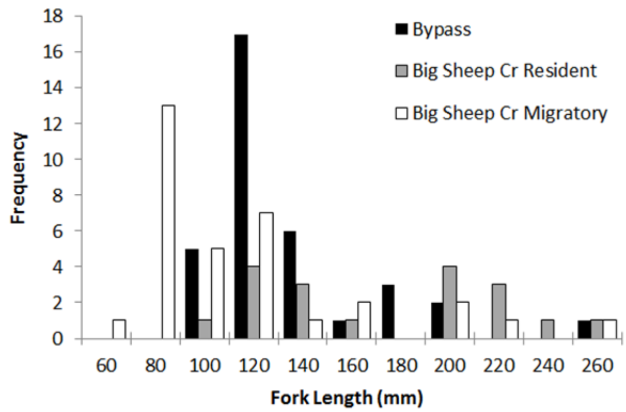
[8] As discussed in McPhail and Baxter (1996), the resident form lives out its life in small headwater streams. The fluvial form lives as an adult in large rivers but spawns in small tributary streams. The adfluvial form has a similar life-history to the fluvial form. It spawns in tributary streams but lives as an adult in lakes.

[9] It is possible that these 90 percent of bull trout in the East Fork could include rearing juveniles from fluvial-adfluvial life history types. PacifiCorp's plans to complete genetic stock assignment of the East Fork population, and to collect additional bull trout migratory data that will provide additional evidence to verify life history type.

the East Fork bypass reach in Figure 16. Although all three populations have similar distributions on the right side of the histogram, the fluvial population differs in that a 0+ age class was observed (i.e. fork lengths ≤75 mm, as per Smith and Knox). ODFW noted that "…streams containing fluvial type populations of bull trout exhibit relatively high densities of 0+ fish." The absence of a 0+ age class in sampling results from the East Fork further suggests that these bull trout may be of a resident population. The presence of a resident bull trout population is important because the adult HSC developed for the IFIM study pertain to migratory bull trout.

Figure 16. Fork length frequency distribution of bull trout in the East Fork, Big Sheep Creek above diversion (resident) and Big Sheep Creek below diversion (fluvial).



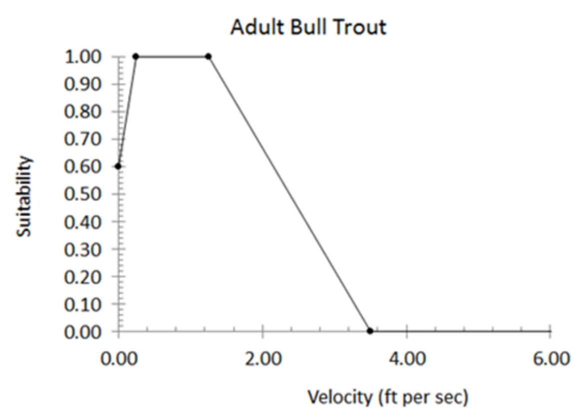
HSC Developed for Migratory Life History Form

The HSC for adult bull trout (Figure 17) were modeled after criteria used in a USGS study in the Upper Salmon River basin (ID), a study on the Flathead River basin (MT), and internal data collect on the Lewis River basin (WA). All studies were performed in tributaries accessible to larger migratory bull trout, and the criteria used in the first two studies listed above were developed for migratory adults. The Lewis River criteria were referred to for validation of the first two studies. Although it is clear that migratory bull trout are present in the Wallowa Falls Project area, as evidenced by the adfluvial bull trout found in the powerhouse tailrace, they do not appear to be the predominant life history type.

Resident bull trout are often the predominant life history type in mountainous streams like the East Fork where cold water and hydraulic impediments or barriers are common. McPhail and Baxter (1996) indicate that resident bull trout usually are separated from other populations by some barrier, either areas of high temperature or barriers caused by falls or high water velocities. Typically, these streams are smaller and have higher gradients than those occupied by fluvial-adfluvial populations. This latter situation accurately describes the section the East Fork bypass reach where the majority of bull trout were captured.

The apparent infrequency of migratory bull trout presence in the East Fork raised the question of whether appropriate HSC are being used in the IFIM study. The risk of running a habitat model with HSC specific to larger fish is that the model may incorrectly predict high levels of weighted usable habitat (WUA) at flows that do not necessarily provide good habitat for the smaller resident fish that comprise the actual population. This is particularly a concern in the East Fork because it is a steep, velocity-driven system: as discharge increases, increases in stream depth are minimal compared to increases in velocity. Thus, high velocities may be reducing habitat for resident adult bull trout when the model predicts otherwise.

Figure 17. HSC curve for adult bull trout



PHABSIM Results

Adult Bull Trout

The PHABSIM model results, shown in Figure 18, predict increases in adult WUA up to 20 cfs, and high levels of WUA up to the top model run of 40 cfs. These predictions seemed counterintuitive compared to PacifiCorp's observations during concurrent hydrology studies. At flows greater than approximately 15 cfs to 18 cfs, the pocket waters that characterized the East fork "merge" into a continuous rapid. These pocket waters, which offer the low-velocity habitat preferred by bull trout (Rieman & McIntyre, 1993) are visibly "blown out" at such flows, as demonstrated by the images of low and high bypass flows in Figure 19 and Figure 20. At 40 cfs the bypass reach is difficult to wade and overtops its banks in many areas.

Figure 18. WUA curve for adult bull trout

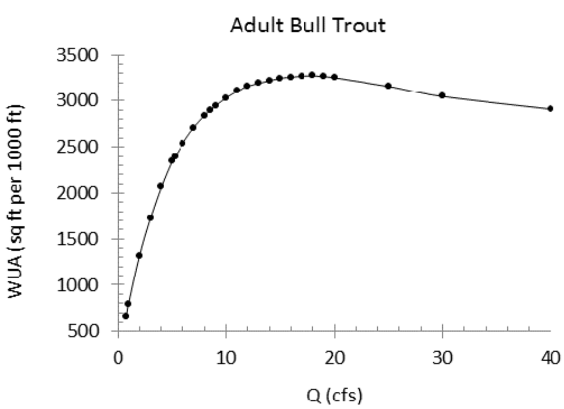


Figure 19. East Fork Bypass in May, Q ~2cfs to 4cfs (not the same location as Figure 20).

Figure 20. East Fork Bypass in July, Q ~20cfs

Juvenile Bull Trout

The HSC developed for juvenile bull trout (Figure 21) produced PHABSIM modeling predictions that make more intuitive sense for the bypass environment compared to PacifiCorp's observations during concurrent hydrology studies. Substantial increases in WUA were predicted between 1 and 3 cfs, and relatively steady WUA results were predicted between 3 and 6 cfs, above which WUA decreased (Figure 22). These results are more reflective of PacifiCorp's observations in the field, where flows around 15 cfs appear to reduce the pocket waters that are generally considered good bull trout habitat.

Figure 21. HSC curve for juvenile bull trout.

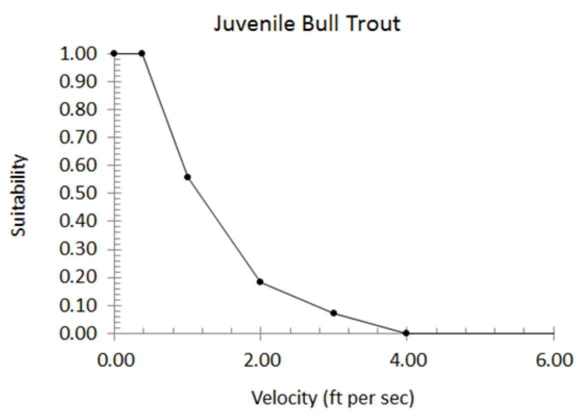
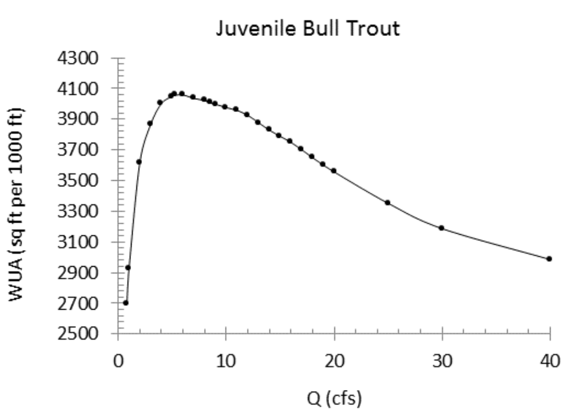


Figure 22. WUA curve for juvenile bull trout.



Alternative HSC Recommendation:

As mentioned previously, the HSC developed for adult bull trout were derived from three other studies that included migratory bull trout. For reasons discussed above, the adult HSC for these fluvial-adfluvial life history types likely do not accurately represent the resident adults in the East Fork. The juvenile HSC were also developed from sources that included streams with migratory bull trout life history forms, and may be more applicable to the adult bull trout in the East Fork. The sources for the juvenile HSC included the two studies that were also referenced for adult HSC (CH2M Hill in the Flathead River basin and USGS in the Upper Salmon River basin), as well as a study of fluvial bull trout in the North Fork Umatilla and South Fork Walla Walla Rivers (Al-Chokhachy & Budy, 2007). Instead, for reasons as discussed above, PacifiCorp recommends that PHABSIM results generated for "bull trout juvenile" should be considered to represent both juvenile and adults of the East Fork bull trout resident population. In this case, PacifiCorp believes it is reasonable to use the juvenile HSC for both adults and juveniles in the East Fork bypass reach, as the fisheries data suggests a resident population, where both life stages are likely present in the same stream throughout the year. When applied to the PHABSIM model, the juvenile HSC produce WUA results that are more consistent with the much smaller size of the bull trout in the East Fork bypass reach and PacifiCorp's concurrent observations of conditions in the reach than the model results from the adult HSC.

References

Al-Chokhachy, R., & Budy, P. (2007). Summer microhabitat use of fluvial bull trout in eastern Oregon streams. North American Journal of Fisheries Management, 1068-1081.

McPhail, J., & Baxter, J. (1996). A review of bull trout life-history and habitat use in relation to compensation and improvement opportunities. British Columbia Ministry of Envrionment, Fisheries Branch.

PacifiCorp. (2012). Wallowa Falls Hydroelectric Project Aquatic Resources Study Progress Report. Portland: PacifiCorp.

Rieman, B., & McIntyre, J. (1993). Demographic and habitat requirements for conservation of bull trout. U.S. Forest Service.

Smith, B., & Knox, B. (1992). Report of findings of bull trout density sampling. Oregon Department of Fish and Wildlife.

HSC DATA

HSC from Wallowa IFIM Stakeholder Field Meeting Adjusted

Red Text = Adjustments of originally proposed HSC data, agreed upon during stakeholder meeting

Bull Trout Spawning HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.00	0.00	0.00	0.00	*	*	0.00	0.00
0.20	0.00	0.15	0.00			0.15	0.00
0.25	0.04	0.65	1.00			0.65	1.00
0.31	0.11	1.60	1.00			1.60	1.00
0.45	0.30	2.50	0.00			2.30	0.00
0.50	0.56	4.50	0.00			4.50	0.00
0.60	1.00	10.00	0.00			100.00	0.00
100.00	1.00	0	0			0	0

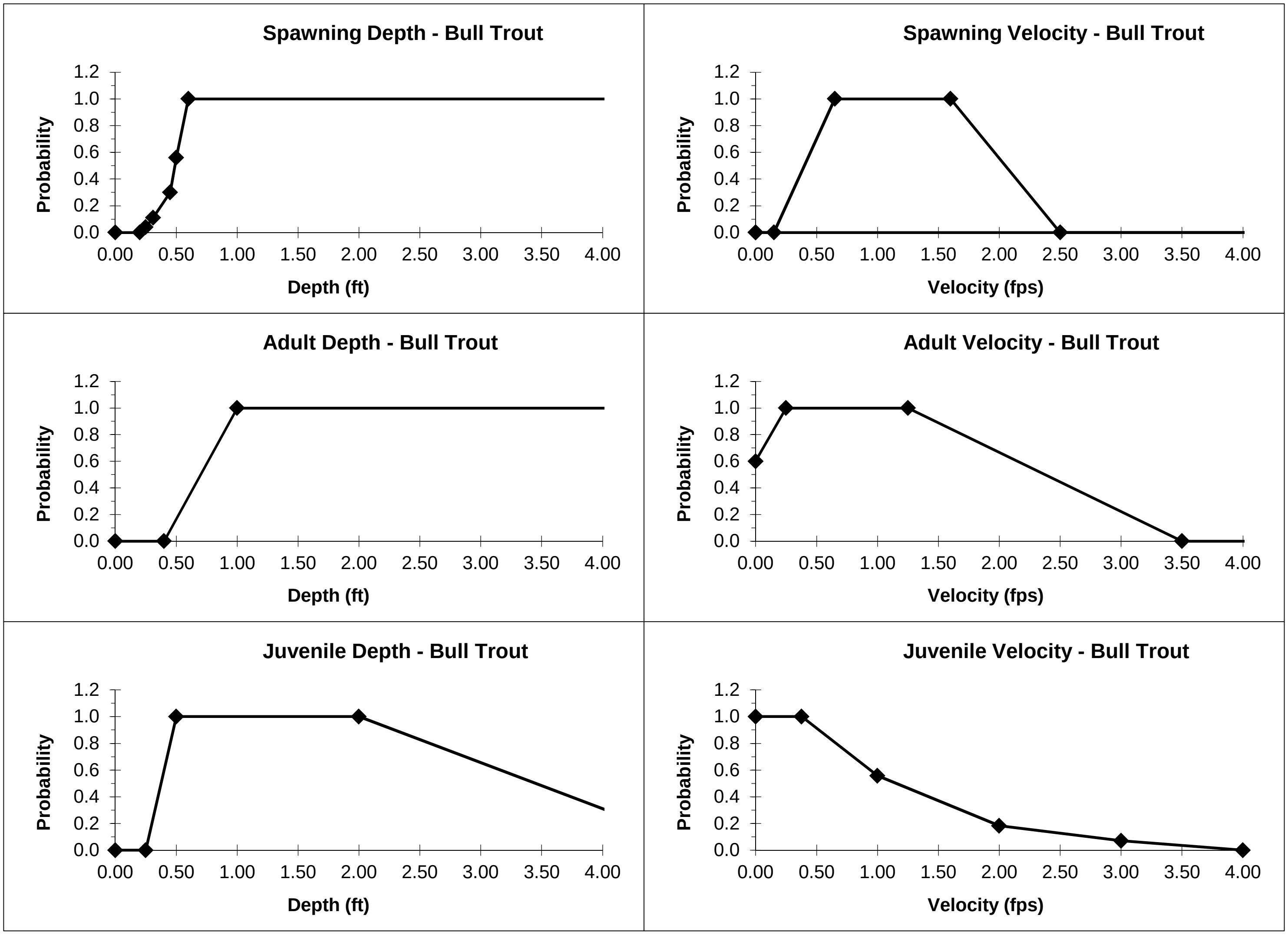
*originally proposed HSC do not differ from consensus HSC

Bull Trout Adult HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.00	0.00	0.00	0.60	0.00	0.00	0.00	1.00
0.40	0.00	0.25	1.00	0.30	0.00	1.15	1.00
1.00	1.00	1.25	1.00	2.00	1.00	3.50	0.00
100	1	3.50	0.00	100.00	1.00	6.00	0.00
0.00	0.00	100.00	0.00	0	0	100.00	0.00

Bull Trout Juvenile HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.00	0.00	0.00	1.00	0.00	0.00	*	*
0.25	0.00	0.38	1.00	0.07	0.00		
0.50	1.00	1.00	0.56	0.20	1.00		
2.00	1.00	2.00	0.18	2.00	1.00		
4.90	0.00	3.00	0.07	4.90	0.00		
5.00	0.00	4.00	0.00	5.00	0.00		
100.00	0.00	100.00	0.00	100.00	0.00		

*originally proposed HSC do not differ from consensus HSC

HSC from Wallowa IFIM Stakeholder Field Meeting Adjusted



HSC from Wallowa IFIM Stakeholder Field Meeting Adjusted

Red Text = Adjustments of originally proposed HSC data, agreed upon during stakeholder meeting

Rainbow Trout Spawning HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.0	0.00	0.0	0.00	0.0	0.00	*	*
0.2	0.00	0.5	0.00	0.2	0.00		
0.4	1.00	1.0	0.58	0.4	1.00		
0.8	1.00	1.2	0.95	0.8	1.00		
1.0	1.00	1.5	1.00	1.0	0.90		
100.00	1.00	1.9	1.00	1.4	0.60		
0	0	2.2	0.95	1.8	0.20		
0	0	2.4	0.64	2.0	0.13		
0	0	2.8	0.40	3.2	0.00		
0	0	3.0	0.18	100.00	0.00		
0	0	3.2	0.00	0	0		
0	0	100.0	0.00	0	0		

*originally proposed HSC do not differ from consensus HSC

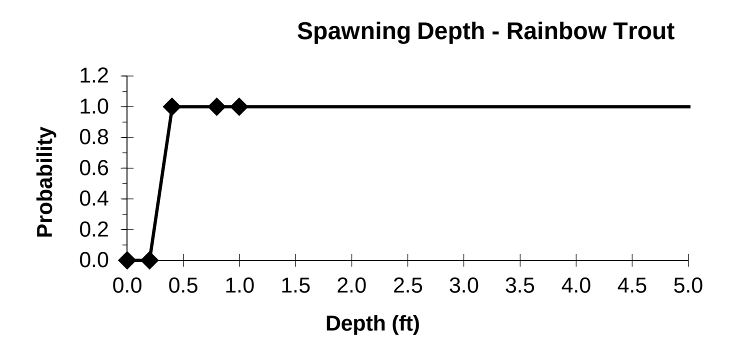
Rainbow Trout Adult HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.0	0.00	0.00	0.30	*	*	0.0	0.81
0.5	0.00	1.00	1.00			0.5	1.00
1.5	1.00	2.00	1.00			2.0	1.00
4.0	1.00	3.00	0.00			2.4	0.30
100.0	1.00	100.00	0.00			3.0	0.02
0	0	0	0			3.4	0.01
0	0	0	0			3.5	0.00
0	0	0	0			6.0	0.00
0	0	0	0			100.0	0.00

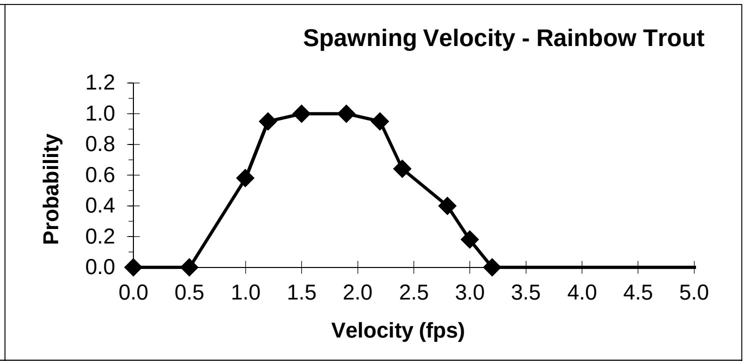
*originally proposed HSC do not differ from consensus HSC

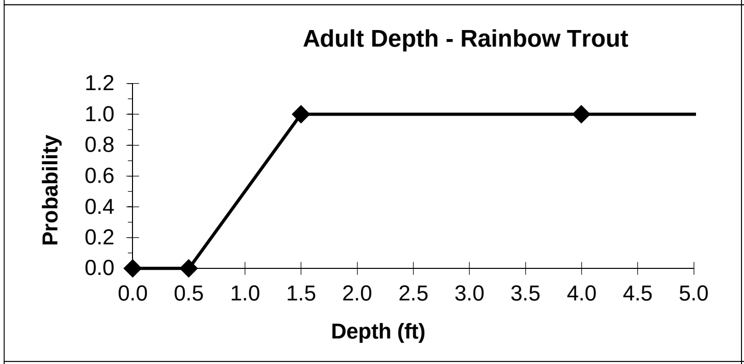
Rainbow Trout Juvenile HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.00	0.00	0.0	0.20	0.0	0.00	0.0	0.00
0.25	0.00	0.5	1.00	0.2	0.00	0.5	0.00
0.50	1.00	2.5	0.00	0.4	1.00	1.0	0.58
2.00	1.00	100.0	0.00	0.8	1.00	1.2	0.95
4.90	0.00	0.0	0.0	1.0	0.90	1.5	1.00
5.00	0.00	0.0	0.0	1.4	0.60	1.9	1.00
100.00	0.00	0.0	0.0	1.8	0.20	2.2	0.95
0	0	0	0	2.0	0.13	2.4	0.64
0	0	0	0	3.2	0.00	2.8	0.40
0	0	0	0	4.0	0.00	3.0	0.18
0	0	0	0	100.00	0.00	3.2	0.00
0	0	0	0	0	0	4.5	0.00
0	0	0	0	0	0	100.0	0.00

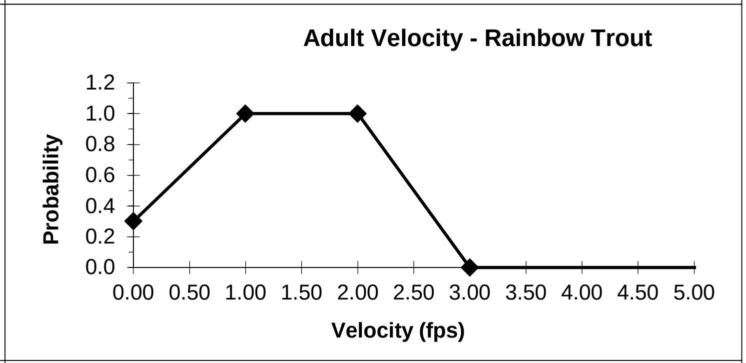
*originally proposed HSC do not differ from consensus HSC

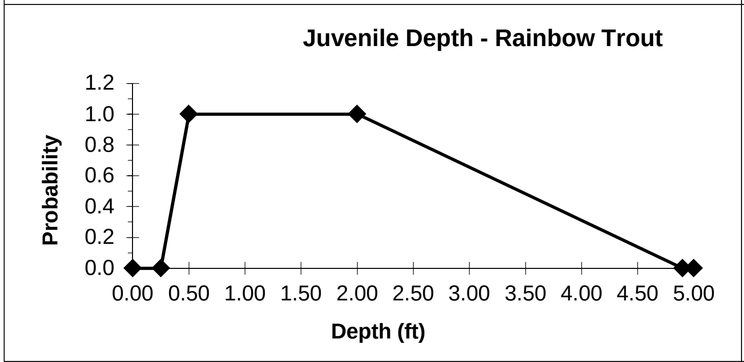
HSC from Wallowa IFIM Stakeholder Field Meeting Adjusted

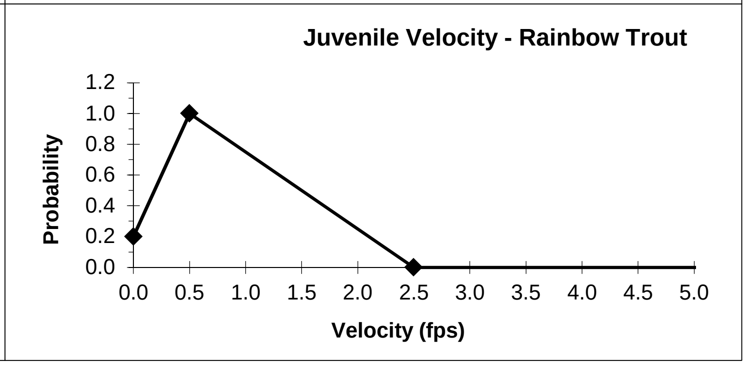












HSC from Wallowa IFIM Stakeholder Field Meeting Adjusted

Red Text = Adjustments of originally proposed HSC data, agreed upon during stakeholder meeting

Kokanee Spawning HSC							
Consensus HSC from stakeholder meeting				Originally proposed HSC			
DEPTH		VELOCITY		DEPTH		VELOCITY	
X	Y	X	Y	X	Y	X	Y
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00
0.30	1.00	0.60	1.00	0.20	0.40	0.20	0.20
1.00	1.00	2.00	1.00	0.30	0.80	0.30	0.40
2.00	0.00	3.00	0.00	0.32	0.95	0.60	0.98
100.00	0.00	3.50	0.00	0.40	1.00	0.70	1.00
0	0	100.00	0.00	0.50	0.95	0.90	1.00
0	0	0	0	0.60	0.75	1.00	0.98
0	0	0	0	0.70	0.55	1.20	0.60
0	0	0	0	0.80	0.40	1.35	0.40
0	0	0	0	0.90	0.30	1.50	0.23
0	0	0	0	1.00	0.25	1.60	0.18
0	0	0	0	1.20	0.16	1.80	0.13
0	0	0	0	1.50	0.05	2.00	0.10
0	0	0	0	1.75	0.00	2.70	0.00
0	0	0	0	100.00	0.00	100.00	0.00