WOOD RIVER VALLEY AQUATIC HABITAT STUDY
2008 MONITORING REPORT

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WOOD RIVER VALLEY AQUATIC HABITAT STUDY
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1.0 INTRODUCTION

The Wood River Valley is located within the Upper Klamath Basin on the eastern slopes of the Cascade Mountains in South Central Oregon. The Wood River Valley once contained over 60,000 acres of wetlands; however, throughout the last century most of its marshes have been eliminated and many of its stream systems have been modified as a result of diking, draining, channelization, irrigation diversion and other activities primarily associated with agricultural management practices. By 1989 the wetland area had been reduced to about 44,000 acres (Carlson 1993). In addition to the reduction of wetland habitat, the hydrology and channel form within many of the important creeks and rivers, such as Sevenmile Creek, Crooked Creek, and the Wood River have been significantly impacted and modified by these management actions.

In 2002, the Klamath Basin Rangeland Trust (KBRT) developed a new land and water management plan for the Wood River Valley, and began a pilot project to evaluate the feasibility and effectiveness of the new plan. The goal of the program is to increase the quantity and quality of water in the Klamath Basin by conserving irrigation water in the Wood River Valley, while restoring pastures and wetlands to maximize ecological value. The primary means to accomplish this goal was eliminating irrigation diversions for project lands, thus leaving this water instream, providing important ecological benefits and increased flows for downstream use. Other actions include various cattle management strategies, including substantial reductions in cattle numbers, riparian fencing, and active stream restoration.

Extensive monitoring of the project lands was begun in 2002, including surface water, water quality, fish habitat, and stream condition. Initial thoughts on the potential timeframe until changes caused by KBRT management were detectable suggested a 5-10 year period. Now that over five years have passed since initiation of the KBRT program, it is appropriate to evaluate changes. This current monitoring and comparison to 2002/2003 data has been funded by the USDA Natural Resources Conservation Service.

1.1 Previous Work

Baseline conditions were established in 2002 and 2003 (Pacific Groundwater Group, et al 2003, Kann and Reedy 2004) for fish habitat and geomorphic conditions of Crooked Creek and Sevenmile Creek (Figure 1), two streams affected by management actions of KBRT. Additional monitoring work has occurred on Crooked Creek since the late 1990s, primarily associated with planning and implementation of stream restoration work on the Root Ranch.

1.2 Scope and Objectives

This report describes the monitoring objectives, methods, results, and analyses. Most of the methods were established in the 2003 Fisheries Habitat Monitoring Report (Kann and Reedy 2004) and the basics will not be reiterated here unless methods were altered or new methods added. The results are compared to those from 2003 to evaluate general trends for predictive purposes. Figures follow the body of the report. Tables are included in the text. Photo point comparisons are included in appendices.

The primary objective of the present study was to measure changes in fish habitat and fish numbers on Crooked Creek and fish habitat on Sevenmile Creek after five years of the KBRT program. Monitoring efforts included repeating surveys of geomorphic conditions, fish habitat, and fish abundance.

2.0 SEVENMILE CREEK STUDY AREA

2.1 Sevenmile Monitoring Locations

Sevenmile Creek was delineated into seven contiguous segments for the 2003 study (Kann and Reedy 2004) differentiated by hydrologic and morphological characteristics. Three of those segments (Figure 2) were selected for detailed measurements and one reach from each (Reaches 2, 5, and 6) was chosen which contained at least 1000 linear feet of stream, 30 or more habitat units and conditions that were representative of the overall segment. 2008 monitoring in reaches 2, 5, and 6 consisted of repeating survey methods used in 2003 and comparing results to determine changes.

2.2 Sevenmile Monitoring Methods

2.2.1 Geomorphic Survey Methods

Channel mapping focused on repeating the survey methods from 2003 with some minor changes. Mapping was performed with survey-grade real time kinematic (RTK) GPS (Trimble 4700/4800) almost exclusively and focused on surveying tops and toes of banks, water surface elevations and thalweg (deepest part of channel). Ten cross sections had been surveyed in 2003 but were based on the top, toe, riveredge, and thalweg points only and were not monumented in the field. In 2008, the endpoints were approximately located using the coordinates from 2003 and resurveyed in a more traditional manner with considerable more detail. Cross section changes were difficult to determine between the 2003 and 2008 surveys since the survey methods were so different (one fairly crude (2003), and one fairly detailed (2008) but they should serve to detect geomorphic changes in the future.

The baseline parameters of depth, width, and width to depth ratio were established in 2003 for geomorphic monitoring and were repeated for 2008 with some changes to the widths and width to depth ratios. In 2003, the mapping data was used to generate channel widths from the left edge of the water to the right edge every 100 feet and then generating width to depth ratios using those widths and depths below the water surface. These parameters were felt to be non-standard geomorphic measurements and, since both widths and depths were dependant on discharge, difficult to repeat during later monitoring. Thus, for the 2008 effort, a more standard bankfull channel width was generated every 50' (along the 2003 thalweg line) between the tops of banks, while depths for width to depth ratios were calculated from the top of the bank surface to the thalweg depth. These same width and width to depth ratios were generated from the 2003 survey data at the same 50' locations along the 2003 thalweg for comparison.

In 2003, depths were generated using AutoCAD by comparing a digital terrain model (DTM) from the tops, toes and thalweg points and to a DTM built from water surface elevations. The difference between the two surfaces equals the depth along the thalweg and points (with elevation equal to depth) were generated every foot along the thalweg. Since water stage was higher in 2003 than during the August, 2008 survey period, it was felt that the 2008 top, toe and thalweg DTM was best compared to the 2003 water surface DTM to generate standardized depths along the thalweg to properly compare changes between the two years. 2008 widths, depths, and width to depth ratios were compared to the equivalent 2003 parameters for each reach.

2.2.2 Habitat Typing Methods

Fish habitat typing used the same methods from 2003 but delineated habitat units using more accurate survey-grade RTK GPS rather than the handheld units used in 2003. Habitat units were typed as either lateral pools, straight pools, glides, or riffles and the quality was determined based on combined depth and cover factors. The presence and number of large wood pieces and rootwads were counted for each unit and the composition of the streambed substrate was estimated as the percentage of cover by various sediment size classes and aquatic vegetation. The length of undercut banks and eroding stream banks was measured for each unit using the RTK GPS. Habitat types measured in 2008 were sorted and compared to the 2003 habitat types.

2.2.3 Photo Point Monitoring

Photo points were established in representative locations in 2003 and marked with 5/8” rebar topped with yellow plastic caps stamped “PHOTOPOINT”. These were relocated where possible, and at each location, 3 or more photographs were taken of the stream reach in an upstream, across and downstream orientation to duplicate the 2003 efforts and visually compare the photos to detect changes.

2.3 Sevenmile Monitoring Results

Planform 2008 survey maps of the three reaches along Sevenmile Creek are shown in Figures 3, 4, and 5 for Reaches 6, 5, and 2 respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section, control point, and photo point locations.

2.3.1 Longitudinal Profile and Cross Section Results

Lest the water surface levels in the longitudinal profiles and cross sections for Reaches 5 and 6 confuse, it must be pointed out that the 2003 surveys were conducted in October after the irrigation season while the 2008 surveys were completed in mid July at a lower streamflow.

The Reach 6 longitudinal profile (Figure 6) documents a noticeable thalweg deepening as evidenced in Table 1. The downstream end of Reach 6 has steepened as virtually all of the higher points of the channel (not technically riffles) in the lower 800 feet of the reach have dropped in elevation in 2008. The average bed slope has increased from .0023 to .0026, while the water surface slope has remained the same. The number and depth of pools has also increased. Data in Table 1 show that the mean channel depth has increased by 0.33 feet, primarily in the lower half of the reach, and that the percent of channel thalweg deeper than 4 feet has doubled from 0.76% to 1.53%. The thalweg length increased by 57 feet, or 0.38%, from 2003 to 2008, although this change could be an artifact of survey methods.

The Reach 5 longitudinal profile (Figure 7) has experienced a similar drop in elevation at the "riffles" in its lower section. The mean bed slope of this quite low-gradient reach has more than doubled from .0002 to .0005, while the water surface slope remained the same at .0004. Four pools deepened, while three filled in a little. Overall, though, there was essentially no change in mean depth (Table 1). The percentage of the channel thalweg greater than 4 feet deep decreased from 8.9% to 5.4%.

There is little change in the longitudinal profile of Reach 2 (Figure 8) except several of the deeper pools have filled in and some bed features in the upper half of this reach have shifted around somewhat, resulting in a thalweg length 65 feet (4%) longer than in 2003. Overall, mean channel depth declined from 4.68 feet to 4.44 feet.

Comparison of the cross sections (Figures 9a, 9b, and 9c) from all three reaches do not provide any useful trends since they were generated in much different manners between the two study periods. The following section on channel geometry involves analysis of reach-wide depths, widths, and width to depth ratios, which reveal changes over time better than the present cross sections. Future monitoring can take more advantage of the improved cross section survey methods.

2.3.2 Channel Geometry Results

Table 1 summarizes the 2003 and 2008 widths, depths from water surface, width to (channel) depth ratio, and thalweg length. Some of the parameters from 2003 are different than reported in the 2003 report, due to differing methods in determining channel widths, width to depth ratio, and using slightly different channel lengths. The differences represent results using methods that should be more repeatable in future monitoring efforts.

Table 1: *Width, Depth, Length and W/D Ratio Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft) [1]	DEPTH Std.Dev.	MEAN WIDTH (ft) [2]	WIDTH Std.Dev.	MEAN WIDTH TO DEPTH RATIO [3]	W/D Std.Dev.	PERCENT THALWEG > 4' DEEP
2	2003	1487	4.68	1.54	60.43	10.39	8.20	1.98	64.40
2	2008	1552	4.44	1.30	59.54	10.98	7.98	2.34	58.36
5	2003	2157	2.75	0.83	27.04	7.18	10.16	5.12	8.87
5	2008	2174	2.78	0.68	19.30	3.34	6.47	1.96	5.44
6	2003	1580	2.11	0.72	26.90	7.82	6.19	2.01	0.76
6	2008	1637	2.44	0.70	23.05	7.84	5.00	2.03	1.53

1) Depths calculated every 1’ along thalweg based on 2003 water surface survey.
2) Bankfull channel widths determined every 50’.
3) Width to depth ratio uses bankfull channel widths and matching bankfull channel thalweg depths every 50’.

Figures 10 through 15 chart the distribution and changes of depths, widths, and width to depth ratios for the three reaches over the monitoring period from 2003 to 2008. Figures 10, 12, and 14 are box and whisker plots, where the outsides of the box are 25 and 75 percentile values, the line through the box is the 50% value or median, the blue diamond is the mean, and the whiskers are the maximum and minimum values. Figures 11, 13, and 15 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

In 2003, Reach 6 and Reach 5 both had mean bankfull channel widths around 27 feet and in both the channel width has decreased: to 23 feet in Reach 6 and 19 feet in Reach 5 (Table 1 and Figure 10). Photo comparison also demonstrates this channel narrowing which is likely a result of reduced or eliminated grazing pressure, encroaching vegetative growth, and consequently less bank erosion. Reach 2 had a slight (less than 1 foot) decrease in mean channel width. Figure 11 shows the shift in the frequency histogram towards narrower widths in Reach 6 and 5. This is particularly noticeable for Reach 5, where 63% now are in the 20 foot width bin, while only 15% had been in 2003.

Overall, depths still increase downstream from Reach 6 to Reach 2 (Table 1 and Figure 12). Pools >3' deep are important for large adult trout (KBRT 2003) and the percentage of thalweg depths greater than or equal to 3' deep has increased in Reach 5 (80% to 88%) and 6 (52% to 72%) since 2003 (Figure 13). Depths increased in Reach 6, remained essentially constant in Reach 5, and declined slightly in Reach 2, over the study period.

The width to depth ratios follow accordingly with the narrowing of Reach 6 and 5 (Table 1 and Figure 14). The mean ratio has dropped slightly from 6 to 5 in Reach 6 but significantly from 10 to 6.5 in Reach 5 indicating a narrower, deeper channel in 2008. In addition, the range of width to depth ratio values was much greater (Figure 14) in Reach 5 in 2003 compared to 2008. 73% of the ratio values are now in the 6 and 8 bins (Figure 15).

The most downstream Reach 2 is still the deepest and widest of the three study reaches. Mean depth has decreased slightly and the percentage of depths >4' has dropped 6% to 58%. There has been very little change in channel width and width to depth ratio.

2.3.3 Habitat Typing Results

The results of habitat typing are presented in Table 2 and Figures 16 and 17. The most significant changes in fish habitat between 2003 and 2008 occurred in Reach 6 where large woody debris (LWD) increased substantially, rising from 2.8 to 18.9 pieces per 1000 feet (Table 2). This large wood presence resulted in glides (50% of the habitat units in 2003, but only 29% in 2008) changing into lateral scour pools (formerly 31%, now 52%) (Figure 16). Pool numbers increased sharply from 19 to 32 and their quality also increased from 2 to 2.5. Bank stability improved as evidenced by a doubling of the percentage of undercut banks and a large decrease in the percentage of bank erosion (Table 2). Coupled with less erosion is a coarsening of the substrate, as gravel and sand now dominate with a large reduction in silt and aquatic vegetation. Figure 17 shows that in Reach 6, gravel substrate increased from 2.8 to 22%, while combined silt and aquatic vegetation dramatically declined from 54.6 to 15.6%.

Table 2. *Habitat Summary for Sevenmile Creek Reaches 2, 5, and 6 for 2003 and 2008.*

Reach	Sample Year	Habitat Units	Number of Pools	Mid-Channel Length (ft)	Mean Pool Quality	Mean Pool Max. Depth (ft)	Percent Undercut Bank[1]	Percent Eroding Bank[1]	Large Wood per 1000 Ft.
2	2003	17	10	1461	2.11	na	1.9	17.8	16.4
2	2008	15	9	1461	3.33	6.8	6.3	19.1	4.1
5	2003	35	19	1997	2.6	4.5	8.4	0.3	8.5
5	2008	38	20	1997	2.5	4.1	7.8	0.0	5.5
6	2003	37	19	1428	2	3.3	3.5	16.1	2.8
6	2008	50	32	1428	2.53	3.5	7.1	6.8	18.9

1) Percentages of undercut and eroding banks are based on accumulated occurrences from both sides of the creek and percentage calculated using the mid-channel length and halving it. Percentages are lower than presented in KBRT 2003 which were based incorrectly on one mid-channel length.

Reach 5 habitat remained generally similar to conditions in 2003 with the exception of a loss of LWD, which declined from 8.5 to 5.5 pieces per 1000', a small increase in the amount of gravel substrate (0 % in 2003, 2.5% in 2008), and a small decline in percent undercut bank.

Reach 2 habitat conditions improved with a large pool quality increase from 2.1 to 3.3 due to increased percentage of undercut bank (from 1.9% to 6.3%) even while the amount of LWD decreased from 16 to 4 pieces per 1000'. In terms of substrate, a substantial increase in aquatic vegetation occurred thereby reducing the percentage of exposed silt.

2.3.4 PhotoPoint Monitoring

The photos are assembled in two PowerPoint files (Appendix 1), for 2003 and 2008. Photos from the nine photopoints along the three reaches suggest a general trend of channel narrowing, increased vegetative cover, and reduced bank erosion, particularly in Reach 6. Figure 18 shows an example of the photo point comparisons.

2.4 Sevenmile Discussion

2.4.1 Changes in Streamflow

Figure 19 compares streamflow (mean daily discharge or MDQ) at the Sevenmile Creek at Sevenmile Road gage for 2003 and 2008. The most noticeable change is the summer baseflow. Between July 1 and September 10, 2008 streamflow was essentially double that of 2003. However, because the 2003 surveys were made in October, well after the end of the irrigation diversion season, while the 2008 surveys were completed in July-August, streamflows were actually higher in 2003 than in 2008 at the time of field work. Significantly more habitat was available in the summer of 2008 than in 2003 due to the large increase in flow.

2.4.2 Riparian Management Changes

Decreased grazing pressure has had the most impact on Reaches 5 and 6 by allowing riparian vegetation to grow and stabilize banks thereby reducing erosion, narrowing and deepening the channel, and reducing the width to depth ratio.

2.4.3 Summary of Channel and Habitat Changes

Reach 6 has experienced the most dramatic changes resulting from the KBRT Project land management changes, which directly affected water diversions and grazing practices. Fish habitat greatly improved as shown by increased pool numbers, pool quality, pool depth, large woody debris, and presence of gravel substrate. As glides scoured into pools, existing pool depths increased, and silt substrate was scoured into gravel, substantial amounts of sediment were released. Some of these sediments were trapped by the improved riparian vegetation, contributing to the narrowing of the channel, while others were flushed downstream.

Reach 6 clearly demonstrates the possible improvements in channel and riparian conditions over a 5 year period with new management prescriptions. We believe Reach 6 saw the most significant improvements for several reasons: (1) it is the most upstream reach, thus having less sediment to move through it from upstream reaches, (2) it has a much steeper gradient than the other reaches (4-5 times steeper) thus providing considerably more energy with the increased streamflows to scour the bed, and (3) it likely saw the highest percentage increase in baseflow, as prior to the management changes, it was essentially dewatered much of the summer.

Reach 5 showed relatively little habitat improvement although channel widths and the width to depth ratio did improve considerably. This is likely due to the very low gradient of this reach. With less energy available to promote change, change will take a much longer period of time. Although the mean depth and LWD decreased in Reach 2, there was an increase in pool quality, partly due to an increase in percentage of undercut banks. Being the most downstream (and lowest gradient) reach, one would expect Reach 2 to improve the slowest, both due to low energy available and that much of the sediment released from upstream as those reaches recover will move through the downstream reaches.

A significant increase in amount of habitat available, although not directly measured, is suggested by the increase of base stream flow during the critical summer months as shown in Figure 19. To evaluate such changes this directly, habitat would need to be measured at the same time of year, then, not only would the physical changes be apparent, but the available habitat (not just physically based but also dependent on the base flow amount) during critical periods could also be determined.

3.0 CROOKED CREEK STUDY AREA

3.1 Crooked Creek Monitoring Locations

Crooked Creek was delineated into four contiguous segments for the 2003 study differentiated by hydrologic and morphological characteristics (Figure 20). Data were collected through all 4 reaches (1-4). Reach 4 contains two sites where channel restoration work (channel narrowing) was performed in 2001. Reach 4 also contains 4 other sites where habitat improvement work (large wood placed, willows planted, and eroding banks sloped and stabilized) was undertaken in 1998.

3.2 Crooked Creek Monitoring Methods

3.2.1 Geomorphic Survey Methods

In 2003, it was determined that the channel morphology was different than Sevenmile Creek and that somewhat different methods be used to characterize the system. Four contiguous reaches were delineated for study encompassing 3.2 miles measured as the centerline of the channel. Mapping surveys varied for the previous study period which was spread out over several years but will be referred to as 2003 in this report. The current study mapped the four reaches in August 2008 exclusively using the RTK GPS system referred to earlier. In Reaches 1 to 3 (numbered from upstream), tops, toes and thalweg points were mapped, while in the lowest Reach 4 only toes and thalweg were mapped to repeat the 2003 procedures. During the survey, the extents of any exposed stream banks exhibiting soil erosion were also mapped. Six cross sections in Reaches 1 and 2 were monumented and surveyed in 2003 and were recovered and resurveyed for this study.

As on Sevenmile Creek, the 2003 study established depth, width, and width to depth ratio as parameters to assess and monitor geomorphic conditions on Crooked Creek. The methods established during 2003 were more appropriate for Crooked Creek and thus were more closely duplicated than on Sevenmile. Depths were developed every foot along the 2008 thalweg by comparing the 2008 water surface DTM with a DTM developed from the top, toe and thalweg points. Bankfull channel widths were calculated at the same 2003 locations every 100’ along the 2003 thalweg line between channel tops. The depths used for the width to depth ratios were the thalweg depths described above at the location of the channel width.

3.2.2 Habitat Typing Methods

The most important fish habitat variables for Crooked Creek were determined to be undercut banks and pool depths in 2003. Fish habitat surveys then, and in 2008, focused on undercut banks in pools that were >3’ deep. One person with a mask waded with a stadia rod in an upstream direction looking for undercut banks and, when one was located, would have a second walking person survey the upstream and downstream margin of the undercut with a RTK rover unit. The diver then used the stadia rod to probe the horizontal depth of the undercut bank at several locations and call them out to the bank person who recorded the measurements in a fieldbook. From these data, average water depth, average width (depth of undercut) and length were calculated and then the area (length * average width) and volume (area * average water depth) were calculated. Results for undercuts and exposed soil areas were standardized on a per mile basis in order to compare different length reaches.

3.2.3 Snorkel Surveys

A fish abundance survey of the four reaches was conducted in late September 2008 using snorkeling methods established between 2000 and 2002 on Crooked Creek. The objectives were to quantify differences in abundance and habitat use among the four reaches and to compare fish numbers to those of past counts in order to detect changes resulting from KBRT project activities. Two snorkelers moved downstream together counting all fish observed by species and age class. The lower section of Reach 4 was an index section in which repeat counts were made to determine a coefficient of variation.

3.2.4 Macroinvertebrate Surveys

Repeating the effort of the August 2002 macroinvertebrate assessment, sampling was performed in Reaches 1 and 4. Five sites were sampled in Reach 4, including four sites within the restoration treatment area (XS #22, XS #23, XS #26, and XS #40) and one reference site immediately upstream of the treatment area (XS #19). One site was sampled in Reach 1, just below the old bridge on the Thomas property (XS #1). At each sample site, a series of three replicate transects, extending laterally across the active channel, was established. An effort was made to avoid large macrophyte beds when placing transects. Wetted channel width was determined for each transect, and benthic macroinvertebrates were collected at distances of 0.25, 0.50, and 0.75 times the total wetted width using a 15.2 cm x 15.2 cm ($0.0023 m^2$) Petite Ponar dredge. For a given transect, all three dredge samples were composited to produce a single sample per transect (effective sampling area = $0.0069 m^2$), with three replicate samples per sample site. Dredge contents were passed through a 500 µm sieve and the retained material was preserved in 95% ethanol for later processing in the laboratory.

Samples were later sorted to remove a 500-organism subsample from each preserved sample following the procedures described in Oregon DEQ’s Level 3 protocols (WQIW 1999) and using a Caton gridded tray (Caton 1991). Contents of each sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were removed to a Petri dish which then was placed under a dissecting microscope at 7-10X to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted. Macroinvertebrates were then identified to the lowest practical taxonomic level under 10-110X magnification.

Raw macroinvertebrate data were entered into an Excel Spreadsheet, and then all taxonomic determinations were standardized to those used in the 2002 assessment in order to compare 2008 results with those obtained in 2002. Raw taxonomic count data were converted to density estimates for each replicate sample from each site, and then the average density of each taxon was calculated. Ten metrics were computed for each site from these site-wide average density data. Taxonomic attribute coding (Table 6) and metric calculations were identical to those performed on the 2002 data to facilitate comparisons between the two sampling periods.

3.3 Crooked Creek Monitoring Results

Planform 2008 survey maps of the four reaches along Crooked Creek are shown in Figures 21 and 22, for Reaches 1-2, and 3-4, respectively, presented in a downstream direction. The maps are overlain on a 2005 orthophoto and show top, toe, and thalweg point groups connected by line work, as well as cross section and control point locations.

3.3.1 Longitudinal Profile and Cross Section Results

The only change that stands out from the longitudinal profile (Figure 23) is that the channel bed high points in Reach 4 have deepened thereby causing a slightly steeper bed slope. The change seems to be limited to that reach. Cross sections 1-3 in Reach 1 and 4-6 in Reach 2 do not reflect the rather large channel narrowing in both reaches (Figure 24).

3.3.2 Geomorphic Survey Results

Table 3 summarizes the 2003 and 2008 thalweg lengths, channel widths, depths from water surface, width to (channel) depth ratio, and percent thalweg greater than 4' deep. Figures 25 through 32 chart the distribution and changes of depths, widths, and width to depth ratios for the four reaches over the monitoring period from 2003 to 2008 and also include comparisons within Reach 4 of restored (4B) versus un-restored areas (4A). It should be noted that the 2003 channel dimensions for reach 4 were actually surveyed in 2001, soon after the channel restoration was completed. In some cases, the channel width was reduced by more than 30' during the project construction. Figures 25, 26, 28, 30, and 31 are again box and whisker plots. Figures 27, 29, and 32 are frequency plots, showing the relative frequency of computed values that have been divided into various bins.

Channel widths decreased in all four reaches (Table 3 and Figure 25) indicating the reduction in grazing under the KBRT program has helped to stabilize banks. Mean widths decreased about 10% in Reaches 1 and 2, almost 15% in Reach 3, but only 2% in Reach 4. Reach 4 remains the narrowest section but only slightly now that the other reaches have narrowed over the past 5 years. In addition, it should be noted that the Reach 4 channel widths are taken from the channel toes because the tops of the banks are in many places under water and difficult to distinguish. Figure 26 compares Reaches 4A and 4B and shows very slight changes from 2003, with un-restored areas slightly decreasing in width and restored areas slightly increasing in width. These values are well within the range of measurement error. The frequency distribution of channel widths for the 4 reaches (Figure 27) show that the range of the population of widths has been reduced as the channel narrowed, many of the wider channel areas (the upper tail of the histogram) have disappeared, leaving the channel narrower and more consistent in width.

Table 3. *Width, Depth, Length and W/D Ratio Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

REACH	YEAR	THALWEG LENGTH (ft)	MEAN DEPTH (ft)[1]	DEPTH Std Dev	MEAN WIDTH (ft)[2]	WIDTH Std Dev	MEAN WIDTH TO DEPTH RATIO[3]	W/D Std Dev	PERCENT THALWEG >4' DEEP
1	2003	2071	3.95	0.69	42.37	9.10	11.51	4.12	41.02
1	2008	2010	4.04	0.62	38.26	6.64	9.90	2.67	48.76
2	2003	6052	3.93	0.74	41.02	7.19	11.11	3.27	40.86
2	2008	5806	3.99	0.61	37.58	5.57	9.73	2.26	43.30
3	2003	5240	3.53	0.74	47.55	8.76	14.09	4.13	19.94
3	2008	5156	3.32	0.68	41.39	8.28	12.89	3.84	15.22
4	2003	4994	3.59	0.85	37.87	8.65	10.77	3.06	29.17
4	2008	4768	3.88	0.71	36.97	5.29	10.00	2.32	39.84

1) Depths below current water surface (2003 or 2008) calculated every foot along the thalweg.
2) Channel widths from top of left bank to top of right bank every 100’ along 2003 thalweg line.
3) Width to depth ratio uses channel widths every 100’ and depth from 1’ depths at channel width location.

Overall, mean thalweg depths changed only slightly, with Reaches 1, 2 and 4 increasing in depth while Reach 3 decreased (Table 3 and Figure 28). Interestingly, the maximum depths measured decreased by over a foot in Reach 2 and 3, while Reach 1 and 4 had smaller declines, however, overall the percentage of the thalweg deeper than 4' substantially increased in Reach 1 and 4 and less so in Reach 2, while Reach 3 declined considerably. All of the frequency distributions, with the exception of Reach 3, have shifted towards an increased percentage of deeper depths (Figure 29).

Channel width to depth ratios decreased accordingly with the width decrease and the depth increase (Figure 30). The size of the boxes as well as the range shown by the min-max values indicate that the channels are becoming more homogeneous as they narrow and deepen. This is particularly true for Reach 4A and 4B (Figure 31), as the range between the max and the min values has decreased by about two-thirds. The frequency distribution clearly depicts this shift as the percentages for bin 12 increased substantially, into a very sharp peak.

3.3.3 Habitat Typing Results

Although it doesn’t show up in the habitat summary (Table 4), large woody debris remains sparse throughout most of the Crooked Creek study area with the notable exception of lower Reach 4 where channel narrowing projects established numerous new rootwad features along the restored banks. This lack makes undercut banks especially important as adult fish habitat throughout the study reaches.

Table 4. *Habitat Summary for Crooked Creek Reaches 1, 2, 3, and 4 for 2003 and 2008.*

Reach Number	Year	Habitat Feature	Number of Segments	Total Length (ft)	Total Area (ft2)	Total Volume (ft3)	Number of Segments per Reach Mile	Total Length per Reach Mile (ft)	Total Area per Reach Mile (ft2)	Total Volume per Reach Mile (ft3)
1	2003	UCR	2	55	51	199	5.6	154	142	555
1	2003	UCL	4	135	225	1043	11.2	377	630	2914
1	2003	ESR	1	63			2.8	176		
1	2008	UCR	8	119	217	901	22.3	332.4	606.2	2517.1
1	2008	UCL	4	267	549	2577	11.2	745.9	1533.7	7199.2
1	2008	ESR	2	63			5.6	176.0		
1	2008	ESL	1	17			2.8	47.5		
2	2003	UCR	9	295	379	1034	8.6	283.3	364.4	992.9
2	2003	UCL	14	754	1134	4685	13.4	724.1	1088.6	4498.9
2	2003	ESR	8	1263			7.7	1212.9		
2	2003	ESL	1	225			1.0	216.1		
2	2008	UCR	10	251	522	2391	9.6	241	501	2296
2	2008	UCL	18	334	655	2847	17.3	321	629	2734
2	2008	ESR	14	1060			13.4	1018		
2	2008	ESL	3	300			2.9	288		
3	2003	UCR	1	14	16	56	1.1	15.3	17.6	60.7
3	2003	UCL	7	288	313	1263	7.7	314.8	342.2	1380.4
3	2003	ESR	4	635			4.4	694.0		
3	2003	ESL	1	111			1.1	121.3		
3	2008	UCR	6	171	306	1045	6.6	186.9	334.4	1142.1
3	2008	UCL	6	197	338	1309	6.6	215.3	369.4	1430.7
3	2008	ESR	6	455			6.6	497.3		
4	2003	UCR	6	148	182	670	6.9	169.7	209.1	768.6
4	2003	UCL	4	148	259	1182	4.6	169.7	297.6	1355.9
4	2003	ESR	2	149			2.3	170.9		
4	2003	ESL	1	92			1.1	105.5		
4	2008	UCR	4	192	463	1744	4.6	220.2	531.0	2000.1
4	2008	UCL	6	127	208	923	6.9	145.6	238.5	1058.5

UCR = Undercuts on Right Bank, UCL = Undercuts on Left Bank, ESR = Exposed Soil on Right Bank, ESL = Exposed Soil on Left Bank

Figures 33-35 standardize undercut banks and eroded banks per reach mile to better compare the different length study reaches. Total length of undercut banks has decreased overall but the loss is entirely in Reach 2, particularly along the right bank. The other three reaches have experienced an increase in total length of undercuts. The largest increase in undercuts since 2003 was in Reach 1, in particular along the right bank where cattle grazing was more dominant prior to the KBRT program. In the 2003 study, Reach 2 had the most undercut length and area and is now second to Reach 1.

Bank erosion has overall decreased in length through the four reaches since 2003. The number of exposed soil segments increased in Reaches 1 and 2 (and slightly in 3) but the length of erosion per reach mile decreased in all four reaches. The right bank of Reach 2 continues to have the most bank erosion.

3.3.4 Snorkel Survey Results

Annual snorkeling surveys of fish present in Crooked Creek began in 2000, focusing on the Root Ranch section (Reach 4) first and then in 2002 expanding to include all four reaches. The main objectives have been to: 1) quantify differences in abundance and habitat use among the four reaches, and 2) provide baseline and continued monitoring data for the detection of changes resulting from the KBRT project activities.

The 2008 snorkel survey was conducted in late August with water temperature ranging from 46-53° F. Visibility was generally around 9' and when it dropped much below that, diving ceased for the day. The diving necessarily had to proceed downstream because velocities were too high to swim upstream but several problems arose. Any time the bed was disturbed, turbidity increased thereby lowering visibility and probably causing fish movement away from the disturbance. It is likely that snorkeling downstream alarms fish anyway and consequently some fish were probably not seen and counted. On the other hand, the index section 4B was repeat snorkeled 3 times with more than an hour between dives and the coefficient of variation for adult counts was 0.05 indicating that the snorkel counts were not missing many adult fish.

Very few juvenile fish (<100mm and 100-200mm) were observed so either they are rare at this time of year or more likely they are better able to avoid divers with limited visibility. The remaining discussion includes only adult trout (> 200mm). Of the 43 adult trout observed (Table 5), 49% were identified as redband rainbow, 1 as a definite brown trout and the rest counted as unknown trout (assumed to be rainbow or brown). Approximately 19% were positively associated with woody debris and about 21% with undercut banks but it is likely that many of the remaining adult trout were associated with wood since they were observed moving from areas with wood present.

Table 5. *Adult Trout Snorkel Counts for Crooked Creek Reaches 1, 2, 3, and 4 from 2000 to 2008.*

Reach	Top	Bottom	Jul-00	Jul-01	Aug-02	Oct-02	Jul-03	Oct-03	Aug-08
1	Old Bridge	Departure from Terrace				4	4		2
2a	Departure from Terrace	Agency Creek			24	21	25	20	7
2b	Agency Creek	Thomas Bridge				30	44	45	1
3	Thomas Bridge	Root prop. Line					25		5
4a	Root prop. Line	Index top	12	8			28	11	12
4b	Index top	Index bottom	15	16	10	19	39	36	18

It is notable that total numbers of adult trout are considerably lower than in summer or fall, 2003 and that the Reach 4 numbers are similar to the counts in 2000-2002. This is probably not surprising since anecdotal evidence suggests that fish numbers are down throughout the Wood River system. Despite the lower numbers, the index Reach 4B which has undergone restoration by channel narrowing and installation of LWD, encompasses 13% of the total length studied but contained almost 42% of the adult trout present in 2008. This reach contains a much higher density of LWD than the rest of the study reaches. When the 2008 fish counts are standardized per reach mile, Reach 1 through 3 had 5.6, 6.7, and 5.5 fish/mile respectively, yet Reach 4A has 27.7 fish/mile and Reach 4B (Index) has 41 fish/mile. The obvious indication is that the addition of LWD in Reach 4B has improved the fish habitat and has attracted more adult trout.

3.3.5 Macroinvertebrate Results

Across all six Crooked Creek sample sites, 16 insect taxa representing 8 orders were collected from Crooked Creek in August 2008. This is similar to the insect richness (18 families) reported in 2002, and suggests that the significant increase in insect diversity has been maintained over the 1999 levels of 8 families representing 3 orders. Including other phyla and orders, 25 families were collected, which is very similar to that reported in 2002 (24 families). Family richness was highest at two sites within the restoration treatment reach (XS #23 and XS #40) and lowest for XS #1, the upstream Thomas property site (Table 7). Total family richness was similarly low in the reference site, XS #19, immediately upstream of the restoration treatment area. Total family richness in each of the restoration sites exceeded that from either of the reference sites in 2008 (Table 7). This pattern is generally similar to that observed in 2002, with treatment sites generally supporting a higher richness than did reference sites (Figure 36).

Total macroinvertebrate densities in 2008 ranged from 2,569 organisms per m^2 (XS #26) to 19,967 organisms per m^2 (XS #19), and averaged 11,986 organisms per m^2 across all six sites. Densities were generally higher than those reported in 2002, which ranged from 1,909 to 3,766 organisms per m^2. Higher densities in 2008 are attributable to a significant increase in the Amphipoda species, *Hyalella azteca*, which exceeded densities of 8,000 organisms per m^2 in four of the six sites. Increases in densities to this extent suggest a potential increase in nutrient loading into the system or an increased capacity for nutrient retention within Crooked Creek.

Ten macroinvertebrate families were sampled from the reference site (XS #19) and 8 were sampled from the upstream Thomas property site (XS #1). Each of these reference reaches supported 2 mayfly families (*Baetis tricaudatus* from the Baetidae family and *Ephemerella excrucians* from the Ephemerellidae family), while no stonefly or caddisfly families were sampled from either reach. In contrast, four or five Ephemeroptera, Plecoptera, and Trichoptera (collectively referred to as "EPT") families were collected from each of the 4 sites within the treatment reach (Table 7). A number of EPT taxa were collected from one or more treatment reach sites that were not sampled from the reference site (XS #19) or the Thomas property site (XS #1), including the mayflies *Pseudocloeon dardanum* and *Centroptilum* sp., the stonefly genera *Sweltsa* (Chloroperlidae) and *Malenka* (Nemouridae), and the caddisflies *Glossosoma* (Glossosomatidae), *Hydroptila* (Hydroptilidae), and *Psychoglypha subborialis* (Limnephilidae).

All sites were numerically dominated by Amphipoda, Oligochaeta, Chironomidae, and Pelecypoda. Treatment reach sites XS #22, XS #23, and XS #40 also supported moderately high densities of Baetidae mayflies and Simuliidae. Community dominance by the two most abundant families was high across all sites, ranging from 75% at XS #26 to 92% at XS #1 (Table 7). These values are generally higher than those reported in 2002 (Figure 36) and are likely the result of the significant increase in abundance of Amphipoda. The contribution of EPT orders to the observed assemblage (% EPT) was generally lower in 2008 than in 2002, also a result of the increased Amphipoda abundance (Figure 36). Among all sites, % EPT was lowest in XS #1 and highest in XS #26.

HBI values ranged from 4.8 in XS #40 to 5.5 is XS #22, and were similar between reference and treatment sites (Table 6), suggesting that benthic communities at the six sites are similarly tolerant to organic enrichment pollution. HBI values were slightly lower at all sites in 2008 than in 2002, again a result of the increase in Amphipoda densities. It is noteworthy that, while the HBI tolerance value (TV) for the order Amphipoda is 4 (that used to calculate HBI in 2002 and 2008 for this study) the tolerance value for the Amphipoda species, *Hyalella azteca*, occurring in the study area is 8 (Clark and Maret 1993). Therefore, while HBI values have slightly decreased using the order-level HBI tolerance value, using a tolerance value of 8 for both years (this is the TV for both the species, *Hyalella azteca* and the family, Talitridae) results in an increase in the HBI score from 2002 to 2008.

Collectively, results of the 2008 macroinvertebrate sampling suggest that benthic conditions have not significantly changed since the 2002 sampling; the significant increase in Amphipoda densities was the only noteworthy deviation from 2002 assemblage conditions. Furthermore, 2008 results once again suggested that the restoration area potentially supports a higher taxonomic richness and higher EPT richness than do the upstream reference sites.

Table 6. *Functional Feeding Group (FFG) designations and pollution tolerance values (TV) of organisms collected from Crooked Creek in August 2008.*

Class	Order	Family	FFG	TV
OLIGOCHAETA			Collector-Gatherer	10
HIRUDINEA		Erpobdellidae	Predator	10
ARACHNOIDEA	Acarina		Predator	8
CRUSTACEA	Amphipoda		Collector-Gatherer	4
	Ostracoda		Collector-Gatherer	8
INSECTA	Coleoptera	Dytiscidae	Predator	5
		Elmidae	Collector-Gatherer	4
		Haliplidae	Macrophyte Herbivore	7
INSECTA	Diptera	Chironomidae	Omnivore	6
		Empididae	Predator	6
		Simuliidae	Collector-Filterer	6
		Tipulidae	Omnivore	3
INSECTA	Ephemeroptera	Baetidae	Collector-Gatherer	4
		Ephemerellidae	Collector-Gatherer	1
INSECTA	Plecoptera	Chloroplerlidae	Predator	1
		Nemouridae	Shredder	2
		Perlodidae	Predator	2
INSECTA	Trichoptera	Glossosomatidae	Scraper	0
		Hydroptilidae	Collector-Gatherer	4
		Limnephilidae	Omnivore	3
INSECTA	Megaloptera	Sialidae	Predator	4
MOLLUSKA	Gastropoda	Ancylidae	Scraper	6
		Planorbidae	Scraper	7
	Pelecypoda	Pisidiidae	Collector-Filterer	8
NEMATA			Parasite	5

Table 7. *Macroinvertebrate community metrics calculated from samples collected from six Crooked Creek sites in August 2008.*

	Sample Site					
Metric	XS 1	XS 19	XS 22	XS 23	XS 26	XS 40
Family Richness	8	10	14	17	12	17
EPT Richness	2	2	4	5	4	4
EPT/Chironomidae + Oligochaeta Ratio	0.01	0.02	0.11	0.18	0.05	0.26
% Dominance	92.05	80.24	77.33	82.56	74.89	85.32
% Filterers	2.07	11.06	9.69	10.16	6.74	7.49
% EPT	0.15	0.46	2.94	2.19	1.50	2.93
% Ephemeroptera	0.15	0.46	2.77	1.70	1.12	2.74
% Plecoptera	0	0	0.06	0.11	0.19	0.15
% Trichoptera	0	0	0.11	0.38	0.19	0.04
Hilsenhoff's Biotic Index	5.4	5.1	5.5	4.9	5.2	4.8

3.4 Crooked Creek Discussion

3.4.1 Changes in Streamflow

Comparison of mean daily discharge between 2003 and 2008 (Fig. 37) indicates that streamflow was higher in the spring and fall of 2008 but about the same both years during the critical summer period July through September.

3.4.2 Riparian Management Changes

Decreased grazing pressure has caused channel narrowing and a decrease in width to depth ratio throughout the monitoring reaches. There is a current effort to increase the cattle exclusion area along the right bank through most of reaches 3 and 4 which should further reduce bank erosion and increase bank undercuts.

3.4.3 Summary of Channel and Habitat Changes

Overall, channel widths and width to depth ratios decreased as bank erosion has decreased. Undercut banks have not increased as much as one would expect except in Reach 1 where the difference is significant.

The most dramatic change between 2003 and 2008 has been with the distribution of adult trout in the four reaches. Although the number of fish was lower than in 2003, a much higher percentage of the fish counted were in the index section of Reach 4. It is likely that the increase in depth and decrease in width and even more so the increase in LWD incorporated with the channel narrowing projects have improved the fish habitat and encouraged fish use.

4.0 CONCLUSIONS

The changes in irrigation and grazing management through the KBRT program have had several positive effects on the channel morphology and fish habitat for Sevenmile Creek and Crooked Creek. On Sevenmile Creek, Reach 6, the uppermost section studied, showed the most improvement in fish habitat with increases in pool numbers, depth, large woody debris, and a decrease in deleterious fine sediment. Reaches 5 and 6 both have more stable banks and narrower, deeper channels.

The effects of the new management were somewhat less but still substantial for the Crooked Creek study reaches. Channel width and width to depth ratios decreased and bank erosion decreased. The areas of Crooked Creek Reach 4 that have undergone restoration in the form of channel narrowing and LWD enhancement showed an increase in adult trout usage.

The rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate change. Sevenmile Creek has a more extensive watershed and higher winter storm and spring snowmelt runoff compared to the spring-dominated Crooked Creek. In addition, upstream areas have higher gradients, providing more energy to scour the bed, creating deeper pools and improving substrate by selectively winnowing fines. As a result, lower gradient reaches will take longer to recover.

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