To The Graduate School:

The members of the Committee approve the thesis of Andrew J. Massey presented on March 28, 2000.

Richard A. Marston, Chairman

William L. Baker

Thomas A. Wesche

APPROVED:

Ronald E. Beiswenger, Head, Department of Geography and Recreation

Stephen E. Williams, Dean, The Graduate School

Massey, Andrew J., Large Woody Debris Loading in Forest Streams Due to 1997 Routt Divide Blowdown, Routt National Forest, Colorado, M.A., Department of Geography and Recreation, May, 2000.

The importance of large woody debris (LWD) in forested streams has been studied extensively in the past several decades. These studies have shed light on the relationships between LWD and stream channel morphology, salmonid habitat and overall biological productivity. The knowledge gained has been an important factor in developing best management practices and guiding forest management decisions along these watercourses. Despite the attention LWD in streams has received, few studies have focused on the effects of massive loading of LWD resulting from forest blowdown. LWD studies in the Rocky Mountain region have generally lagged behind other areas (e.g. Pacific Northwest, Alaska) as well.

The Routt National Forest in north central Colorado experienced a large-scale forest blowdown during a late October 1997 storm. Over 20,000 acres of sub-alpine forest along the western slope of the Continental Divide and the Mount Zirkel Wilderness Area was blown over by winds in excess of 120 mph.

Field data was collected on stream channel characteristics and the number, volume and location of LWD pieces along three headwater creeks in the North Fork Elk River drainage during the summer of 1998 and 1999. One non-blowdown wilderness reach (control), one blowdown wilderness (88% of trees blow over) and one blowdown with past timber harvest (92% of trees blow over) were studied.

Results indicate that blowdown can deliver up to 17 times more new LWD than the pre-existing old LWD volume to these streams. The stream in an area with a history of past timber harvest had less old LWD and smaller diameter new LWD than the two wilderness streams. Pieces of new LWD from forest blowdown are often entire trees that may remain suspended above small headwater streams for many years. It was also apparent that small pieces of woody debris may have important morphological impacts in small streams within forests impacted by forest blowdown.

The USDA Forest Service, Routt National Forest and Forestry Sciences Laboratory funded the project to record the location of individual pieces of LWD in relation to the pattern of the underlying streams. These data will serve as a benchmark so that future re-surveys may address channel change and the significance of LWD to stream form. Insights gained from, and the continuation of this study will enable the Forest Service to make more informed decisions as to the best management options to be carried out in watersheds of the Rocky Mountain region.

LARGE WOODY DEBRIS LOADING IN FOREST STREAMS
DUE TO 1997 ROUTT DIVIDE BLOWDOWN

ROUTT NATIONAL FOREST, COLORADO

by
Andrew J. Massey

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INTRODUCTION

The form that streams and rivers develop is a product of their relationship with the surrounding environment. The riparian forest influences channel form and stream function by contributing particulate organic matter and large woody debris (LWD), by providing shade, bank stability, sites for storage of organic matter, sediment and water, and by regulating the movement and transformation of nutrients (Gregory et al. 1991). LWD plays an important role in channel morphology by creating pools, storing sediment and forming log steps that reduce the amount of potential energy available for conversion to kinetic energy used for sediment routing (Marston 1982). LWD influences various aspects of stream channel form including the average condition and variance in channel dimensions (Keller and Swanson 1979; Hogan 1986; Nakamura and Swanson 1993). Woody debris influences the magnitude and distribution of pools and riffles (Andrus et al. 1988; Robison and Beschta 1990; Bisson et al. 1982, 1987). LWD can also affect the overall stability of river channels (Bilby 1984; Heede 1985) and the duration and intensity of overbank (Hickin 1984) and underbank (Harvey and Bencala 1993) flows. Accumulations of LWD are valuable in forest streams because they enhance biological diversity and productivity, regulate flow and water quality and increase the range of habitats within and along the channel (Gurnell et al. 1995; Master and Sedell 1994; Sullivan et al. 1987).

Large woody debris enters fluvial systems through natural processes including fire and disease, mass movements on slopes, erosion of stream banks and blowdown. Wind events that result in large-scale forest disturbance are quite rare, especially at a landscape scale. The forest blowdown that occurred in and around the Mount Zirkel Wilderness in the Routt National Forest on October 25, 1997 is one such example. This storm, with its easterly winds estimated at greater than 120 miles per hour, disturbed more than 20,000 acres of sub-alpine forest. The resulting distribution of downed trees is not uniform throughout the area (now referred to as the Routt Divide Blowdown) rather the pattern has been described as a mosaic of smaller patches of wind thrown trees ranging in size from 50-4000 acres within an otherwise undisturbed forest (Flaherty 2000). Blowdown events, although rare, are natural disturbances that have always been a part of forest ecosystems. The Routt Divide Blowdown is the largest ever recorded in the Rocky Mountain region.

The blowdown presents a unique opportunity to learn how this type of disturbance affects forest and aquatic habitats, including stream channel morphology. In some areas of the blowdown, all of the previously standing trees were knocked to the forest floor and associated stream networks. Channels that would normally experience a more gradual supply of LWD over years received all of the available LWD in a matter of minutes.

Purpose and Objectives

My study establishes baseline conditions prior to widespread blowdown through a survey of channel dimensions and old large woody debris (OLWD) and new (blowdown-caused) large woody debris (NLWD). My survey comparing the pre-blowdown LWD and the NLWD is the first step to:

- determine the quantity of NLWD in the streams

- describe the distribution of the NLWD
- explain how the tremendous addition of LWD will affect stream morphology

This information will then serve as a benchmark to compare and note changes in stream channel morphology over time. The survey may also be used to evaluate how a massive loading of LWD functions in small sub-alpine fluvial systems.

The hypotheses tested in conducting this research include:

- volume of new LWD pieces will be greater than old LWD pieces
- length of individual LWD pieces related to the blowdown will be greater than pre-blowdown LWD pieces
- pre-blowdown LWD pieces will be located in the drift configuration more often than the ramp or bridge configurations
- blowdown related LWD will be in a bridge or ramp configuration more often than a drift configuration

The potential exists for significant stream channel adjustment to the new conditions of massive woody debris loading. Tracking these changes will contribute substantial information to further the understanding of northern Colorado Rocky Mountain forested stream environments. This information can then be used to guide management decisions on streams in these forests. This project represents the first step in a long-term commitment to learn how a natural, widespread loading of LWD affects sub-alpine forest stream channel morphology.

STUDY AREA LOCATION AND DESCRIPTION

This study was conducted on tributary streams of the North Fork Elk River drainage in the Park Range of north central Colorado. The study reaches are all located at high elevations (2877-2928 m) on the west slope of the Continental Divide in the Routt National Forest (Figures 1 and 2). One study stream is located in spruce-fir forest community where harvest of the resource began in the 1940s with the bulk of the harvesting occurring from 1960-1985, while the other two streams are located within the designated Mount Zirkel Wilderness area where no past forest management has occurred (USFS 1998b). The Mount Zirkel Wilderness Area in the Routt National Forest has a relatively long history of protective management. In 1905, President Theodore Roosevelt established the Park Range Forest Reserve, and later in 1931, the Mount Zirkel-Dome Peak Primitive Area was established (Warren 1992). In 1964 the Mount Zirkel Wilderness was designated as one of the original wilderness areas. Overall, the area affected by the blowdown is managed by the USFS for objectives including wildlife, range and timber, scenic river values along the Elk River (eligible for Scenic River designation under the 1968 Wild and Scenic Rivers Act), and backcountry recreation where vegetation structure is influenced primarily by natural processes (USFS 1998b).

Average annual precipitation, most of which falls in the form of snow, is over 125 cm in the high elevations of this area (USFS, 1998b). The annual hydrograph is typical of snowmelt-dominated systems and the Elk River watershed is one of the most productive in the state for water quality (USFS 1998b). US Geological Survey stream gauge records

Study Area Location

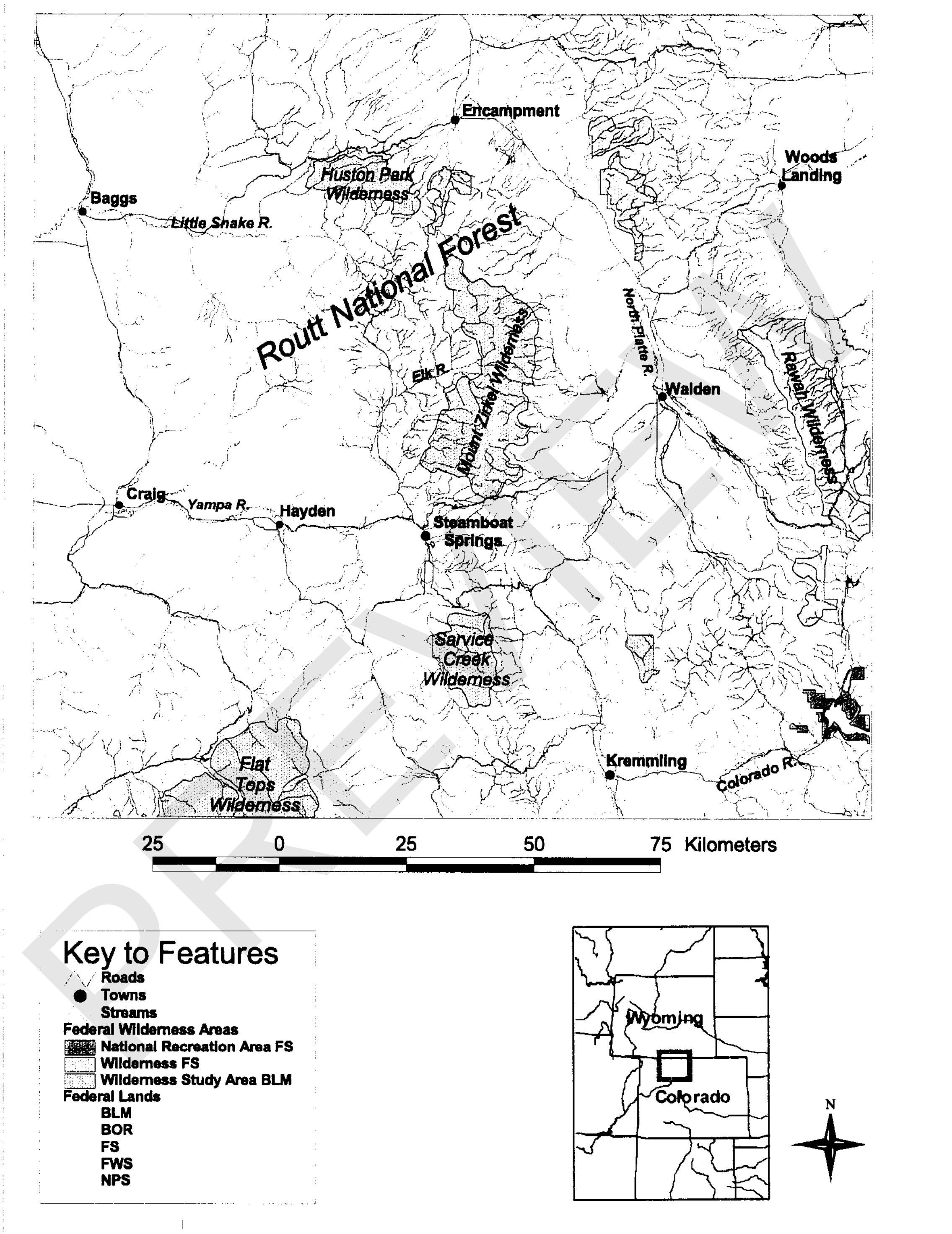

Figure 1. Regional map of the study area.

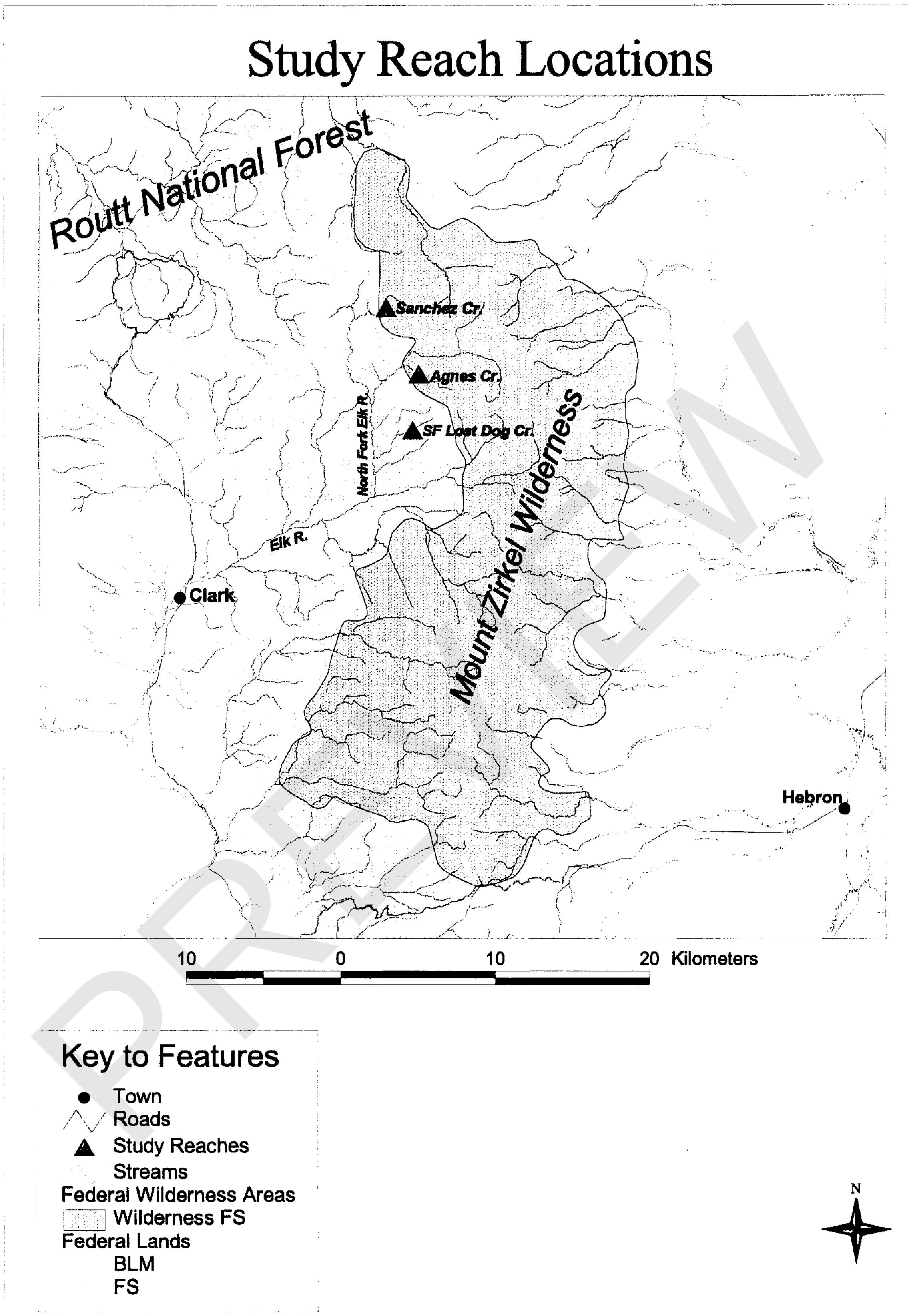

Figure 2. Map of location of study reaches.

indicate that watersheds in this area produce two acre-feet of water per year. State designated beneficial uses for all forks of the Elk River include aquatic cold life, recreation, water supply and agriculture (USFS 1998b).

Glacial formed topography in the area includes lateral moraines, terminal moraines and U-shaped valleys in the lower gradients (USFS 1998b). Shallow soils are common throughout the area and generally overlay glacial drift deposits. These drift deposits often have perched water tables, particularly in the spring, which result in the development of small riparian areas and wetlands not adjacent to stream channels (USFS 1998b). Streambeds are generally composed of gravels, cobbles, and boulders, with occasional large boulders (>100 cm) present.

The geology of the area consists of pre-Cambrian granite, schist and gneiss. The nature of the landforms and geology has resulted in a large amount of rock outcrop and rubbleland within the area (USFS 1998b). The Park Range is a faulted anticline, similar to other mountain ranges in this area of the Rocky Mountains. The range forms part of the Continental Divide for several miles separating the Yampa (Colorado River) and North Platte (Mississippi River) River basins.

The upper reaches of the North Fork Elk River watershed, within the wilderness, are characterized by steep-walled canyons (Agnes Creek for example) with spruce fir communities (type A and B stream types (Rosgen 1994)). Further down the drainage, the North Fork is a low gradient C stream type. Other tributaries to the North Fork are a mix of A and B3 or B4 channel types that originate on steep slopes with stable stream channels and high bedloads (South Fork Lost Dog Creek, for example). The bright chroma of substrate gravels indicates that they are mobile during peak flows. High bedload streams are consistent with a snowmelt-dominated hydrograph in watersheds with high runoff potential and high water yield (USFS 1998b).

The blowdown area is located approximately 40 km north of Steamboat Springs, Colorado. The primary access to the area is from Steamboat Springs on Routt County Road 129 and then Seedhouse Road (FDR 400-Routt County Road 446) (USFS 1998a). USGS 1:24,000-scale topographic map coverage of the three first- and second-order study streams is (clockwise from northwest) Farwell Mountain, Mount Zirkel, Mount Ethel and Floyd Peak, Colorado quadrangles. USGS 1:100,000-scale topographic map coverage is Walden, Colorado-Wyoming, 1981.

METHODS

Site Selection

In several areas, or patches of the Elk River drainage, nearly 100% of the pre-existing forest was blown down as a result of the high winds associated with the October 1997 storm. Three streams in and around this blowdown area were chosen to study. Two reaches with nearly 100% blowdown were selected; one in wilderness, the other with past timber harvest. A third non-blowdown, wilderness reach was chosen for comparison. Stream site selection was based on locating reaches with a high degree of blowdown within close proximity to one another and with similar basin characteristics. Routt National Forest hydrologists, fisheries biologists and soil scientists provided valuable, first-hand information on possible survey stream choices. USFS interpretive maps, based on aerial photographs taken shortly after the blowdown event, overlain on USGS topographic maps, were also used during the initial stream selection. Field visits to the proposed streams were conducted prior to the final selections to evaluate logistical concerns, including accessibility and maneuverability within the stream valleys.

The streams chosen were Agnes Creek, the blowdown-wilderness stream, Sanchez Creek, the non-blowdown-wilderness stream, and South Fork Lost Dog Creek (SFLDC), the blowdown-harvested stream. The streams are similar in size and watershed characteristics (Table 1), and SFLDC and Agnes Creek have similar blowdown patterns. Length of the stream reaches examined was approximately 0.5 km.

Table 1. Basin characteristics.

Creek Name	Elevation Range*	Valley Slope*	Drainage Area*	Aspect **	Drainage Density*	%Blow-down***
Agnes Creek	2867 m-3508 m	18%	3.847 km^2	N48°W	0.92 km/ km^2	88%
S. F. Lost Dog Creek	2865 m-3305 m	18%	2.053 km^2	S67°W	1.18 km/ km^2	92%
Sanchez Creek	2905 m-3466 m	14%	4.137 km^2	S28°W	1.23 km/ km^2	0%

* Above lowest point of the survey

** Applies to study reach only

***Percent of total volume of trees blown over adjacent to study reach (Flaherty 2000)

The study reach on Agnes Creek is a blowdown impacted first-order stream reach within the Mt. Zirkel Wilderness. Little human disturbance was observed while conducting fieldwork during summer, 1998. The results of future investigations of channel form change and woody debris recruitment should continue to be unaffected by direct human impacts due to the federal wilderness protection.

The SFLDC is in a blowdown-impacted watershed that is scheduled to be salvage logged, however, a buffer has been established around all wetland areas where no tree removal will occur. Like Agnes Creek, the SFLDC is a first-order stream that experienced nearly 100% blowdown within the study reach. The stream is located in a portion of the Routt National Forest that has been logged in the past. The logging operation required road construction within the watershed; there are, however, no roads that cross the stream above the study reach. At the onset of this project, it was assumed that records of past timber harvest could be used as a variable in the analysis. However, after further investigation it became clear that the Routt National Forest kept sketchy or no records of timber harvest, at the reach scale, for the project area.

The study reach on Sanchez Creek, located within the wilderness area, was not affected by the blowdown. Like Agnes Creek, no past human disturbance was noted while visiting the site in August and September 1999. Sanchez Creek data are intended as a control. Undisturbed channel processes in Sanchez Creek should continue normally while the two blowdown-impacted streams adjust to the disturbance.

Data Acquisition

Once suitable stream reaches were identified, a random survey starting point (distance 0 m) was established. Permanent monuments were then set at two or three points per reach. The coordinates and elevation of monument points were established using a Trimble™ geographic positioning system (GPS) employing base station techniques or real time positioning. This resulted in real world horizontal and vertical errors in the range of 0.1 to 0.4 m. The monument markers are numerically stamped 5-cm (diameter) brass caps that were permanently cemented to large stable boulders or bedrock outcrops. These points later served as control points for the survey.

Stream Channel Measurements

Stream cross-section profiles, longitudinal profile and gradient were measured at each stream reach using a Topcon™ total station with a Hewlett Packard™ HP48 data logger pole and prism and a 100-m tape measure. A minimum of 10 transects were taken across each stream reach at approximately 50-m intervals, covering a total reach length of at least 450 m. The 50-m interval was measured and marked with flagging using a 100-m tape measure. Each transect consisted of channel profile measurements perpendicular to the channel and extended to rebar posts that were driven into stream banks above the bankfull margin. Aluminum caps were put on top of each rebar post to avoid injury and to aid in future transect relocation. Indicators of bankfull stage included tops of point bars, change in vegetation from riparian to upland, slope of topographic breaks along the bank, bank undercuts and stain lines on the lower extent of boulders (Harrelson et al. 1994). The cross-section profiles were developed by surveying approximately 15 points across the transects. All major breaks in slope, edges of water at the time of the survey, channel bed elevation and the bankfull margins were surveyed. The survey was extended to the valley walls at 150-m intervals (Appendix A).

Pebble Counts (Wolman 1954) were made at each cross-section, following a procedure described in Harrelson et al. (1994). The intermediate axis of 100 randomly selected bed particles within one meter up and down of each transect was measured with a millimeter ruler. Samples were taken along lines parallel to the cross-section at 1.0 m, 0.75 m, 0.5 m, 0.25 m above, below and along each cross-section transect (Appendix B). At least 3 photographs were taken up, down and perpendicular to the channel, showing each transect in the foreground.

The longitudinal survey involved measuring thalweg points along the channel, and left and right bankfull points, along each survey reach (Appendix C). Bankfull margin points were surveyed at breaks in slope, as well as at significant changes in flow direction (meander), so that a fine-scale plan-view map and longitudinal profile of each reach could be developed. The survey points were managed and mapped in the Teramodel™ CAD drafting package.

Large Woody Debris Measurements

All pieces of LWD were measured for a continuous 300-m length of each study reach. Large woody debris was defined as logs at least 10 cm in diameter and at least 1 m in length, similar to other LWD research conducted in the Northern Rocky Mountain region (Richmond and Fausch 1995). All pieces of wood that met the LWD size criteria were measured if any portion occurred within, or was suspended above the bankfull stream channel. The mid-length diameter of each piece was measured using a 50-cm tree caliper. The length of each piece was found by surveying both ends of the log with the