

CHANGES IN RIPARIAN VEGETATION AND CHANNEL MORPHOLOGY
WITHIN AND BETWEEN SUBBASINS WITH DIFFERENT LAND-USE
HISTORIES IN THE MOSBY CREEK BASIN, OREGON

by

JAMES LOUIS STARK

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Dr. Patricia F. McDowell, Chair of the Examining Committee

March 6, 1995

Date

Committee in charge: Dr. Patricia F. McDowell, Chair
Dr. Alan Dickman



Vice Provost and Dean of the Graduate School

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Changes in riparian vegetation and channel morphology from 1955 to 1993 were evaluated and compared between subbasins in the Mosby Creek Basin dominated by different land-uses.

Large woody debris recruitment potential and canopy closure remained moderately poor for mainstem and tributary segments in the agriculturally managed lower subbasin. The upper basin, managed for forest products, experienced dramatic declines in LWD recruitment potential and canopy closure. Canopy closure recovered to values greater than preharvest on tributaries, but only moderately recovered on mainstem segments. LWD recruitment potential has not recovered appreciably within the upper

subbasin. Deciduous species were more abundant in riparian vegetation regrowth associated with 1964 flood sediment deposits than channel segments without sediment deposits.

Isolated but severe channel widening occurred in the upper subbasin following the 1964 flood. Unvegetated channel width had mostly recovered to pre-flood values by 1993.

CURRICULUM VITA

NAME OF AUTHOR: James Louis Stark

PLACE OF BIRTH: Los Angeles, California

DATE OF BIRTH: December 11, 1954

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon
Oregon State University
University of California, Irvine

DEGREES AWARDED:

Master of Science in Environmental Studies, 1995, University of Oregon
Bachelor of Science in Biology, 1977, University of Oregon

AREAS OF SPECIAL INTEREST:

Watershed Processes
Riparian Function

PROFESSIONAL EXPERIENCE:

Watershed Analysis Technical Coordinator, Weyerhaeuser Co., Springfield,
Oregon, 1994-95
Environmental Intern, Weyerhaeuser Co., Springfield, Oregon, 1991-93
Salmon Rancher, Oregon-Aqua Foods, Springfield, Oregon, 1978-1991

AWARDS AND HONORS:

J.E. Zimmerman Scholarship 1991/92
Bosard Scholarship 1992/93

PUBLICATIONS:

- Light, J., and J. Stark. 1994. Upper Mohawk River Watershed Analysis, Fish Habitat Assessment. Appendix F in Upper Mohawk River Watershed Analysis, Part 1 - Resource Assessment Report. Weyerhaeuser Company. Springfield, Oregon.
- Severson, D., J. Stark and L. Poole. 1986. The use of oxygen to commercially rear coho salmon. Bonneville Power Authority, Special Pub. 27 pp.
- Stark, J. 1994. Upper Mohawk River Watershed Analysis, Riparian Function Assessment. Appendix D in Upper Mohawk River Watershed Analysis, Part 1 - Resource Assessment Report. Weyerhaeuser Company. Springfield, Oregon.
- Stark, J. 1994. Lower McKenzie River Watershed Analysis, Riparian Function Assessment. Appendix D in Lower McKenzie River Watershed Analysis. Weyerhaeuser Company. Springfield, Oregon.

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CHAPTER I

INTRODUCTION

During the last 30 years, scientists and land managers have increased their knowledge of how management activities can affect the productivity of aquatic ecosystems. Prior to this recent awareness, timber harvest, road construction, agriculture and recreational activities occurred without consideration of their consequences for stream resources such as fish habitat (Meehan 1991). This legacy of land-use activities has altered the physical, chemical and biological components that interact in aquatic ecosystems. Riparian vegetation and stream morphology are two key components of fluvial systems that have been substantially altered.

The Mosby Creek basin was mostly harvested before Oregon's Forest Practices Act initiated streamside protection. This harvest activity co-occurred with the 1964 flood (~100 yr. recurrence interval) and greatly altered the condition of riparian vegetation and channel morphology in particular areas. This study evaluates changes in these characteristics and compares changes within subbasins experiencing different land-uses. It is my intent that this historical analysis of disturbance in this basin will provide an

understanding of temporal and spatial changes in key riparian functions and that this may aid in designing appropriate strategies for restoring these functions.

Stream channel morphology and riparian vegetation composition are influenced by a basin's climate, geology and disturbance history. Within a drainage basin, these factors interact along a wide range of spatial and temporal scales (Gregory et al. 1991). A basin's landform features can be organized into a hierarchical framework based on the temporal and spatial scale of the processes that create them (Frissell et al. 1986). Valley form is determined by tectonic processes and long-term climate patterns (e.g. glacial periods) in time scales of 1,000 to 100,000 years. Lower mainstem stream channels in unconstrained valley bottoms provide a setting for sediment deposition, soil development and establishment of heterogeneous plant communities. Tributary channel segments, nested in the basin, reflect localized geomorphic constraints such as valley bottom confinement and higher gradient. These local geomorphic features interact with climate and natural disturbance events (1 to 100 year scale) to produce localized variability in plant community composition and structure along the stream network.

Riparian Vegetation Function

Riparian vegetation occupies the interface between the aquatic and the terrestrial environment. Several important functions occur at this interface, including modification of the microclimate (i.e. light, air and water temperature, humidity) (Beschta et al. 1987),

alteration of nutrient inputs (Bilby and Bisson 1992), contribution of large woody debris (Bilby 1981), and protection of stream channel banks from erosion (Beschta and Platts 1986).

Riparian plant communities are subject to frequent disturbance from flooding and less frequent upslope disturbances such as fire, wind, and disease (Gregory et al. 1991). The natural disturbance regime has a strong influence on riparian plant community composition and structure. In unconstrained channel reaches, where high flows can influence a broad area, riparian vegetation is distributed in heterogeneous patches of different successional stages (Kauffman 1988). Constrained channels are bordered by a narrower band of fluvially influenced vegetation (Naiman et al. 1992). Deciduous species such as red alder (*Alnus rubra*) are early colonizers of disturbed riparian sites, particularly where mineral soil is exposed or deposited (Zavitkovski and Stevens 1972, Cline and Swanson 1979, Gecy and Wilson 1990). This swift establishment by deciduous woody vegetation stabilizes the exposed sediments and the plant community proceeds along a successional pathway to more mature seral stages (Miller and Murray 1981, Fonda 1974) until it is reset by subsequent disturbances. This successional pathway has different trajectories depending on initial conditions and subsequent types of disturbance that occur (Newton et al. 1968).

Channel Geomorphology

Channel morphology, particularly channel width, is primarily a function of near bankfull flow (typically a 1-2 year recurrence interval) and its interaction with the resistance of the bed and bank to scour (Leopold and Wolman 1957). Larger magnitude flows, however, also influence the channel and riparian zone. Studies in the Central Appalachians and Maryland Piedmont identify high magnitude flows (much greater than bankfull), that severely damage streamside vegetation, as an important channel forming process (Hack and Goodlett 1960, Gupta 1974). However, stream channels in northern California, southern Oregon and other humid regions showed swift (5-10 years) recovery of channel width to pre-event dimensions following similarly high magnitude flows (Wolman and Gerson 1978, Lisle 1981).

High sediment loads can produce unstable, wide, and often braided channels, especially when they are associated with high flows (Harvey 1991). Streambank erosion in higher gradient stream segments can produce a downstream increase in channel width due to decreased depth from channel aggradation (Patrick et al. 1982). Established riparian vegetation can reduce this bank erosion by increasing bank resistance with large roughness elements (e.g. woody root biomass and large downed wood) and reducing stream power through turbulence (Smith 1976, Beschta and Platts 1986, Elmore and Beschta 1987). The effects of a high flow event, therefore, depend on the erodibility of the watershed and the amount of time since the last high flow (Wolman and Gerson

1978, Sullivan et al. 1987). The erodibility of the watershed and its streambanks will be a function of geology, topography, soil types, climate, vegetation and any modification to these parameters by previous land-use activities.

Disturbance and Recovery

Disturbance exists as a natural process in riparian ecosystems (Gregory et al. 1991). Pacific Northwest watersheds experience disturbances such as floods, fire, disease and windthrow at frequencies of 1 to 1000 years. Plants and animals associated with the fluvial system can experience significant disturbances to their environment on the order of 1 to 50 years. Plant and animal communities evolved under these conditions and have adapted to survive and reproduce within these environmental parameters.. For example, riparian species such as willow (Salix spp.) and cottonwood (Populus spp.) show adaptations to flooding and require flood conditions for successful germination and growth (Densmore and Zasada 1983, Bradley and Smith 1986, Blom et al. 1990).

Anthropogenic disturbance, such as agriculture, timber harvest and urbanization can alter environments in ways that appear similar to natural disturbances. The recurrence interval of anthropogenic disturbance can be substantially more frequent (or chronic) than similar natural disturbances (Swanston 1991). Human alterations of riverine ecosystems such as channelization, modified discharge regimes and changes to vegetation affects watershed response to natural disturbance (Naiman et al. 1992).

Understanding how human disturbances affect a watershed requires long-term data sets that analyze trends in ecological attributes (Stanford and Ward 1992). Analyzing these trends in the context of historical land-uses can improve our understanding of human influences on watershed health and provide valuable information for lessening the negative effects of management activities.

Objectives of This Study

This study analyzes changes through time in riparian and fluvial characteristics within a small watershed in western Oregon and compares trends between areas with different land-use history.

Objective 1. Describe changes in riparian structure and composition for the Mosby Creek basin at selected intervals from 1955 to present.

- A. Summarize trends in riparian stands along Mosby Creek and its tributaries in terms of species, age and density from 1955 to present.
- B. Compare trends in riparian stand characteristics between the mainstem and its tributaries and between subbasins with different land-use history.
- C. Characterize changes in riparian stand characteristics affected by high flow events and associated sediment delivery.

Objective 2. Describe changes in stream shading for the Mosby Creek basin at selected intervals from 1955 to present.

- A. Summarize trends in riparian stands along Mosby Creek and its tributaries in terms of percent canopy closure from 1955 to present.
- B. Compare trends between the mainstem and its tributaries and between subbasins with different land-use history.

Objective 3. Describe changes in channel morphology as affected by land-use and flood events.

- A. Identify selected stream segments where channel widening occurred and evaluate changes from pre-widening to present.

Objective 4. Review the analyzed effects of anthropogenic and natural disturbance in this watershed and its implications for future management activities, including stream restoration projects.

CHAPTER II

STUDY SITE AND METHODS

Study Site

Description of the Study Area

Mosby Creek drains a 247 square kilometer subbasin in the Upper Willamette basin southeast of Cottage Grove, Oregon (Figure 1). The 35.3 km mainstem flows into the Row River below Dorena Dam, 5.6 km above the confluence of the Row River and the Coast Fork of the Willamette River. Mosby Creek is listed in the American Rivers Outstanding Rivers List because of its undammed, free flowing connection to the Pacific Ocean (Echeverria and Fosburgh 1988).

The Upper Willamette Valley lies between the Coast Range on the west and the Cascade Range on the east. It experiences a temperate, maritime climate with mild, wet winters and warm, dry summers. Annual precipitation increases with elevation due to orographic influences, as does the relative proportion of snow. The percentage of annual precipitation which falls as snow is approximately one third at 1200 meters elevation

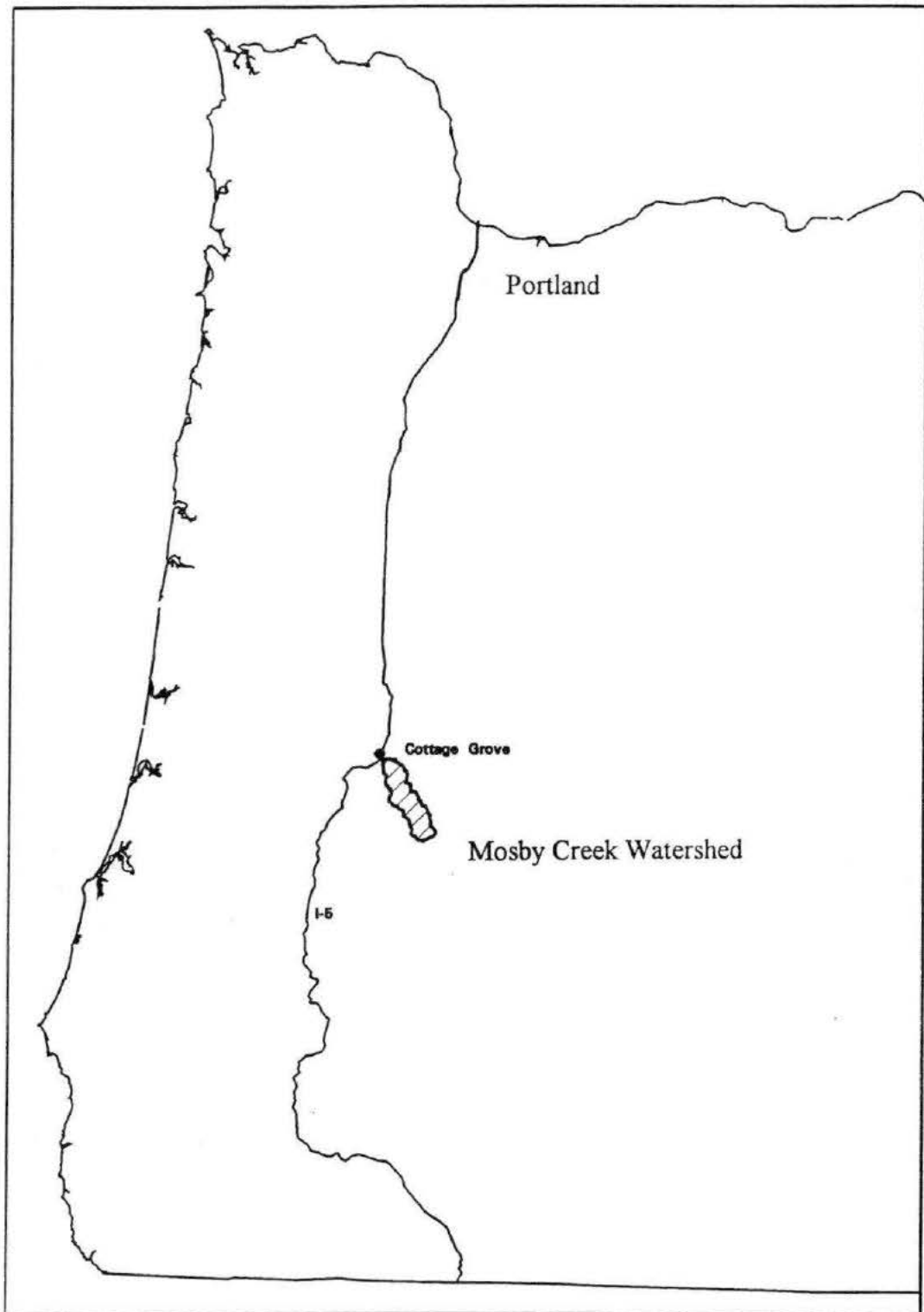


Figure 1. Location of the Mosby Creek watershed in western Oregon

decreasing to about one-tenth on the valley floor. Eighty percent of annual precipitation occurs from October through March (State Water Resources Board 1961).

The Mosby Creek basin ranges in elevation from 200 meters at the mouth of Mosby Creek to 1430 meters at Huckleberry Mtn. on the Calapooya Divide. Mean basin elevation is 650 meters and mainstem average slope is 0.8 percent. Mean annual precipitation ranges from 125 cm at low elevations to 200 cm at the watershed divide (Taylor 1993).

Mosby Creek basin's climate and elevation place most of it in the western hemlock (Tsuga heterophylla) zone, except the lowest elevations which are associated with the Willamette Valley zone (Franklin and Dyrness 1973). The western hemlock zone, common in western Oregon and western Washington, is typically dominated by its subclimax species Douglas-fir (Pseudotsuga menziesii). The shade tolerant, climax species, western hemlock, would grow through the overstory of Douglas-fir and dominate, but disturbance such as fire frequently resets the stand to Douglas-fir. However, even when undisturbed for 500 years or more, long-lived Douglas-fir and western red cedar (Thuja plicata) are often present. Hardwoods are not common, except on recently disturbed sites and riparian areas. Chinquapin (Castanopsis chrysophylla) is common to more xeric disturbed locations. Red alder and bigleaf maple (Acer macrophyllum) prefer mesic sites and are frequently found in riparian areas.

The lowest elevation areas in the Willamette Valley are in the Pine-Oak-Douglas-fir zone. Because of early settlement, climax plant communities have been

extensively modified and are unclear. It is likely that coniferous stands were mostly Douglas-fir with grand fir (*Abies grandis*) and bigleaf maple also present.

Land-Use History

The earliest recorded inhabitants of this area were the Calapooya Indians (Forster 1986). This broad designation encompasses most of the small nomadic tribes that were scattered throughout the southern Willamette valley and the Umpqua valley. They numbered in the hundreds and villages dotted the banks of the Coast Fork Willamette River, Row River, Mosby Creek and other small streams. The Calapooyas regularly burned, or allowed to burn, the floodplain prairie of the valley. This enhanced forage for game and abundance of preferred food plants (e.g. tarweed pods and camas bulbs). These fires would occasionally spread up the lower river valleys, creating a patchwork of younger stands within the old-growth Douglas-fir.

Early settlement by Euro-americans occurred in the middle of the 19th century. The first settlers chose the productive soils of valley floodplains for subsistence farming and raising livestock. Lowland rivers provided a valuable transportation network for people and goods (Schwantes 1989). This settlement, in the late 1800s, began the earliest transformation of streamside vegetation in the lower Mosby Creek basin for rural/agricultural uses. Valley bottom land was cleared of trees and converted to pasture for livestock grazing. The land was also cultivated for grain and other food crops. These

activities still dominate land-use along the lower valley bottom today. Widely dispersed farm houses from early settlement, are now interspersed with multiple residences on subdivided lots.

Timber harvest became commercially viable when the Oregon-California railroad came through Cottage Grove in 1871. The second sawmill built in the area was on Mosby Creek in 1890. It was run by water power and sawed one log at a time. Logs were hauled down to Mosby Creek by four yoke of oxen and then transported down the creek to the mill (Staff Writer 1938). By 1914, there were 31 lumber mills in the vicinity with a payroll of over \$50,000 per month (Writers Discussion Group 1970). Working with oxen, then steam powered machinery, logging progressed slowly up accessible terrain in the lowland valleys and foothills. The upper two-thirds of the Mosby Creek basin remained mostly uninhabited and unharvested until Booth-Kelly, the major private land owner, began operations in 1954. Georgia-Pacific purchased Booth-Kelly's large holdings in 1959 and completed the harvest of the upper Mosby Creek basin by the early 1980s (pers. comm. Mitch Allen, Weyerhaeuser Co.). Weyerhaeuser Company purchased Georgia-Pacific's Mosby Creek timberlands in 1985 and now owns most of the private land in the upper basin.

As a part of this analysis, the Mosby Creek basin was divided into upper and lower subbasins that represent these different land-use histories (Figure 2). The lower basin is dominated by urban/agricultural land-uses and the upper basin is exclusively

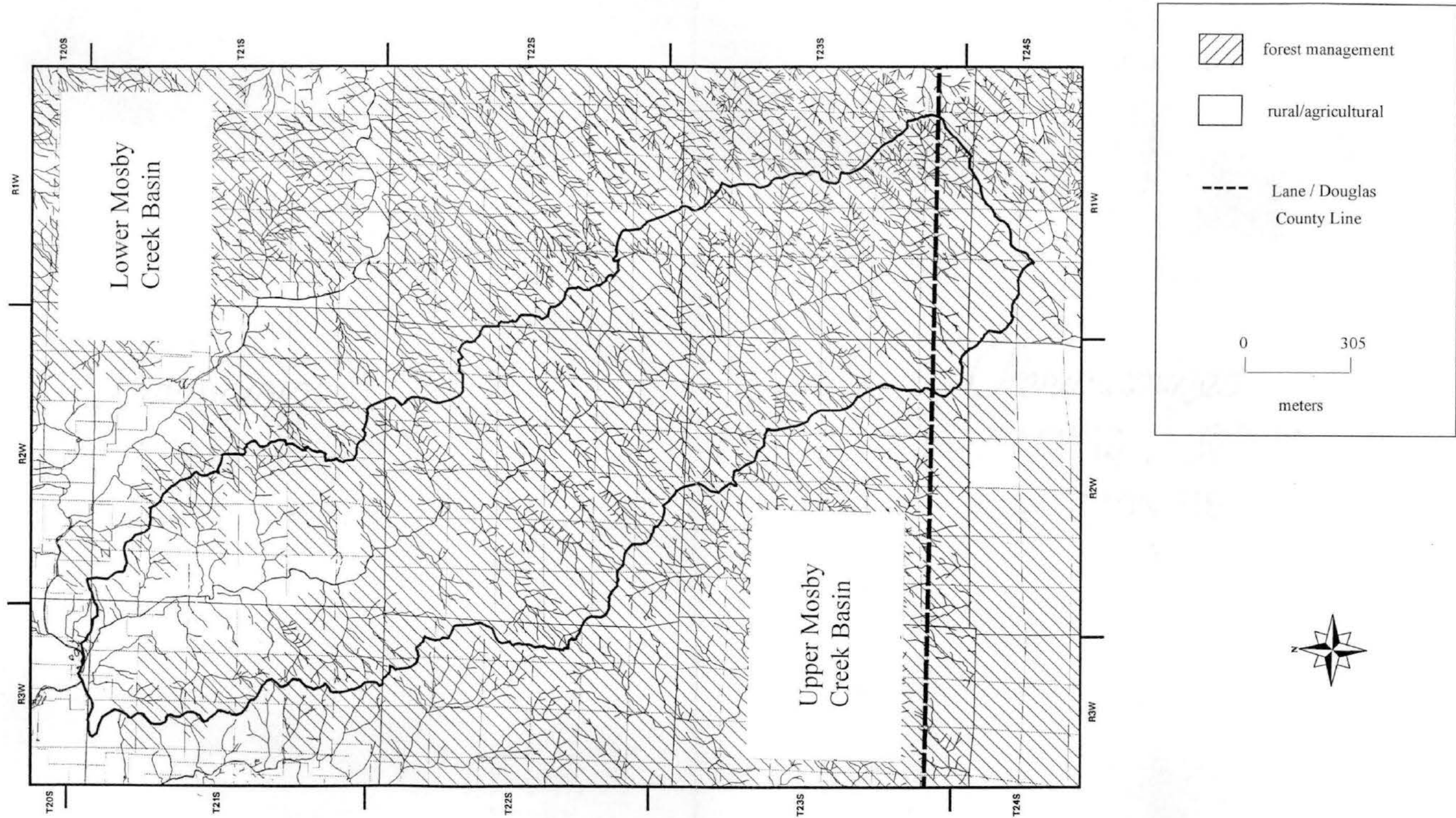


Figure 2. Evaluated subbasins and stream network in the Mosby Creek watershed

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under forest management. The lower basin extends 12.6 km up from the mouth and includes all tributaries draining to this section of the mainstem. Land-use along the lower mainstem is 94.2% rural and agricultural. Tributaries within the lower basin flow through a patchwork of managed forest (55.1%) and agricultural land uses (44.9%). Land-use categories were summarized from data (Oregon State Department of Revenue 1974) that represent conditions at a midpoint in the study period. Distribution of the evaluated stream network within the upper and lower subbasins is summarized in Table 1. Most of the stream channel length lies within the forested upper basin.

Table 1. Stream network distribution in Mosby Creek basin

Area	Tributary Length		Mainstem Length		Total Stream Length	
	km	%	km	%	km	%
Lower Basin	16.6 km	15.8 %	12.6 km	35.7 %	29.1 km	20.7 %
Upper Basin	88.8 km	84.2 %	22.7 km	64.3 %	111.6 km	79.3 %
Total Basin	105.4 km	100.0 %	35.3 km	100.0 %	140.7 km	100.0 %

Hydrologic History

Streamflow information is available for Mosby Creek from 1936 to 1981 from two USGS gaging stations (14156000 and 14156500). The highest recorded flow occurred on December 22, 1964 (Figure 3), when much of the northwest experienced its

greatest flow on record. That peak flow on Mosby Creek was approximately a 100 year event (Wellman et al. 1993). Much of the upper Mosby Creek basin was recently roaded and harvested in 1964. This vulnerability resulted in many road and slope failures during the intense climatic event.

The timing and magnitude of high flows previous to this period of measured flow on Mosby Creek are not known. It is likely, however, that large floods along the Willamette River were accompanied by flooding in its tributaries. Significant floods have been documented on the Willamette River in 1813, 1861, and 1890. The 1861 flood is the largest of known magnitude on the Willamette River, the 1890 flood is the second largest and the 1813 was unmeasured, but considered to be similar (U.S. Geological Survey 1993). If Mosby Creek experienced extreme flows during these events, then 1890 may have been the last extreme flow event before the 1964 flood.

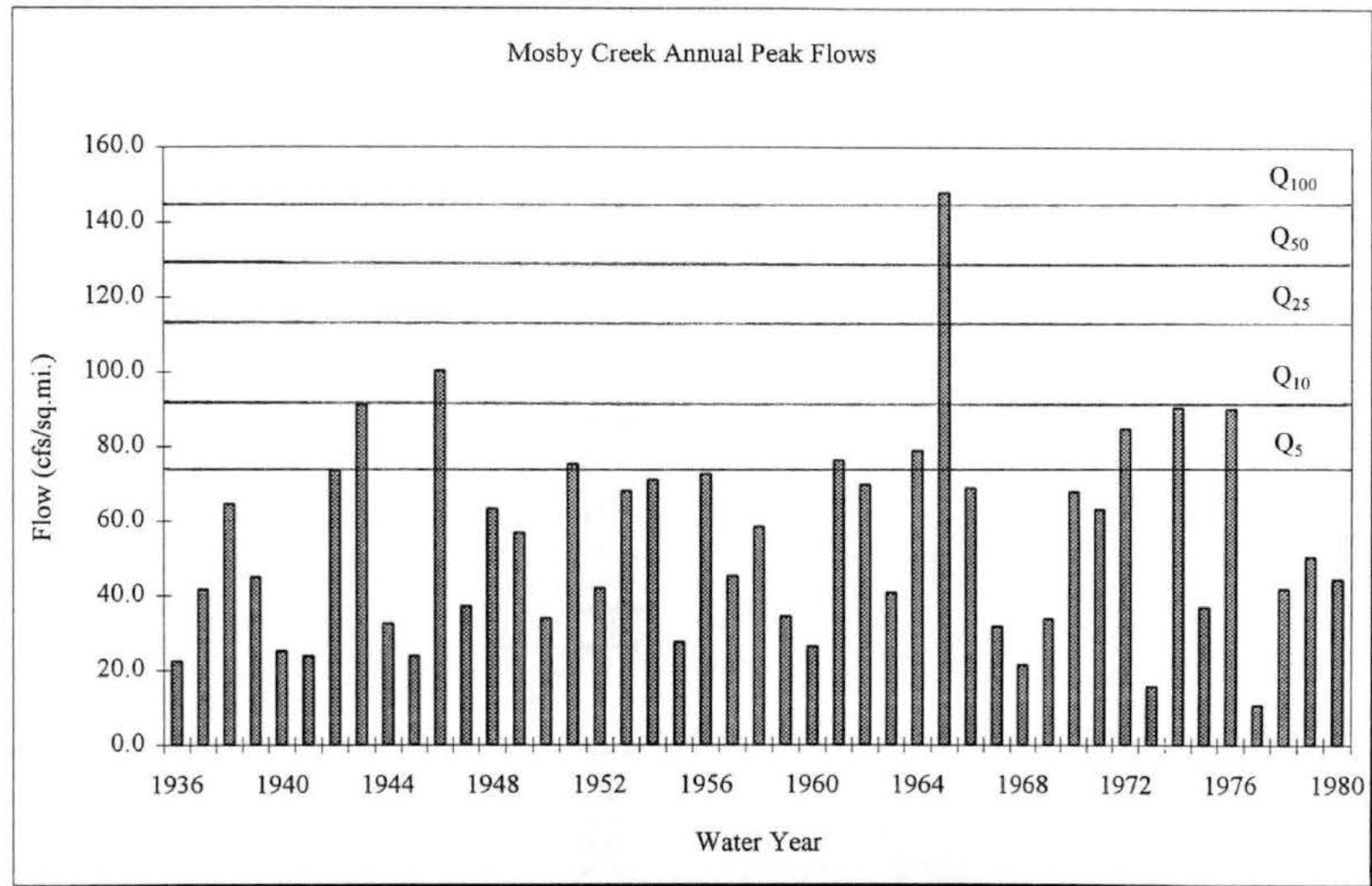


Figure 3. Mosby Creek annual peak flows for 1936 to 1980. Calculated recurrence intervals are inserted on horizontal bars.

Methods

Riparian Stand Typing

Riparian vegetation is described in terms of age, species and density. These parameters measure the potential of a riparian stand to supply persistent large wood to the adjacent stream channel. Age describes the size of trees and density quantifies the number of trees available. Species designation identifies how persistent the wood will be after entering the stream channel because conifer trees decay much more slowly than hardwoods. These attributes, measured at certain intervals through time, will provide information for describing temporal and spatial changes in riparian structure and function.

Riparian vegetation was classified following the protocol developed for watershed analysis in the State of Washington (Washington Forest Practices Board 1993) using 1:12000 scale aerial photos from 1952-55, 1964-65, 1979 and 1993. The 1952-55 and 1964-65 photos are black and white, and the 1979 and 1993 photos are color. The 1952-55, 1964-65 and 1979 photos were obtained from the University of Oregon, Map Library, Eugene, Oregon. 1993 photos are filed with the Planning and Inventory Department, Weyerhaeuser Timberlands, Springfield, Oregon.

Although other methods are available (Platts et al. 1987), the riparian vegetation typing method used in Washington State for watershed analysis was used here for three

reasons. First, it captures all necessary parameters needed for this study (species, age, density). Second, this method was developed and approved by a broad range of natural resource management organizations including government agencies, tribal organizations, environmental groups, and private industry. This method is part of a process required by law in Washington State and is in wide use. Lastly, it is simple, unambiguous and should be repeatable by other researchers.

Vegetation was classified according to species, age and density within a 70 foot wide corridor along either side of the stream (Tables 2, 3 & 4). The total length of classified riparian areas is twice the stream channel length because each side of the stream is considered separately.

Table 2. Tree species classification method

> 70% Coniferous Species Cover	Conifer Dominated
> 70% Deciduous Species Cover	Hardwood Dominated
All Other Cases	Mixed

Percent species was determined from percent crown cover within 70 feet of the channel margin. Overstory vegetation is considered the dominant species even if it represents less than a majority of the riparian vegetation. For example, a narrow row of overstory conifer along the stream, with a greater width of young deciduous vegetation adjacent to it, would be typed as conifer dominant as opposed to deciduous dominant.

When overstory vegetation covered less than approximately 20% of the crown cover, understory vegetation was considered dominant.

Table 3. Age-class groups for each species class

Vegetation Class	Age Class (years)		
	Young	Mature	Old
Conifer	< 40	40 - 120	> 120
Mixed	< 40	40 - 80	> 80
Deciduous	< 40	40 - 80	> 80

Trees less than 40 years old are assumed to be less than 12 inches diameter at breast height (dbh). Mature trees are between 12 inches and 20 inches dbh and old trees are greater than 20 inches dbh. These sizes are based on growth characteristics of Douglas-fir and red alder in Western Washington, which is similar to growth conditions in this western Oregon watershed.

Tree age was determined from aerial photos using several techniques in an iterative process. Conifer stands older than 120 years have an uneven, rough texture in 1:12000 scale aerial photos. Hardwood stands, particularly red alder, typically reach senescence prior to 120 years (Newton et al. 1968) and no old (>120 yrs.) hardwood stands were identified. Conifer, hardwood and mixed stands older than 40 years can be distinguished from stands younger than 40 years by height estimated in stereo photo pairs (Paine 1981). Most stands are clearly in a given age category. Stands that appeared to be close to an age break could often be tracked through the photo record to determine when they originated.

Some of the current (1993) stands were verified on the ground. This field verification calibrated the photo interpretation procedure with actual stands and improved interpretation of historical photos.

Riparian stand density is classified as sparse or dense depending on how much of the 70 foot wide riparian area is covered. If more than one third of the ground is exposed, the stand is considered sparse. Otherwise, it is dense. Exposed ground does not necessarily mean that bare mineral soil is visible. The method simply refers to the ground below the tree canopy.

This vegetation typing scheme is written as a three letter code, in this order: species, age, density. The code letters are identified in Table 4. For example, CMD would identify a riparian stand that is conifer dominant, mature and dense. DYD would define a stand that is deciduous, young and dense. A fold out key to riparian stand codes is in Appendix A and may be useful for interpreting some of the charts in this report.

Table 4. Summary of three letter coding scheme for riparian vegetation typing

Species	Age	Density
Conifer	Young	Sparse
Deciduous	Mature	Dense
Mixed	Old	

One more stand type was added to this method. Because most riparian areas were completely harvested, they showed no visible tall shrubs or trees if the aerial photos were

taken within a few years of harvest. These areas were typed NVV to describe No Visible Vegetation (more precisely, no visible trees) present. In the 1993 aerial photos all riparian areas were well vegetated and stand typing using the watershed analysis stand type code was sufficient.

The potential for the riparian stand to supply persistent, large woody debris (LWD) to the stream channel can be ranked by the riparian stand type. Conifer decays more slowly than hardwood and is therefore more persistent in the channel. Old trees have a larger dbh than mature ones and mature trees are larger in diameter than young trees for size of material available to the stream channel. Dense stands have more trees available than sparse stands to be recruited into the stream. Considering these qualities, a ranking of the stand types was generated for the watershed analysis process (Table 5).

Table 5. Riparian stand type ranking describing near-term LWD recruitment potential.

Dominant Tree Type	Age/Size Class and Density					
	Young		Mature		Old	
	Sparse	Dense	Sparse	Dense	Sparse	Dense
Conifer	Poor	Fair	Fair	Good	Fair	Good
Mixed	Poor	Poor	Poor	Good	Fair	Good
Deciduous	Poor	Poor	Poor	Fair	Poor	Fair

Effects of Sediment Deposition on Riparian Stand Composition

Hardwood stands have been shown to quickly establish on exposed mineral soil following hillslope or road failures (Zavitkovzky and Stevens 1972, Cline and Swanson 1979, Gecy and Wilson 1990). Riparian areas that experienced sediment deposition from road or slope failures were followed through subsequent photo years to determine if stand types on these sites differed from non-sediment influenced sites.

On December 22, 1964, a flood event with a recurrence interval of 100 years was recorded at the Mosby Creek gaging station, USGS Gage 14156500 (Wellman et al. 1993). This flood triggered many road and slope failures in the upper Mosby Creek basin. There were three 5-10 yr. flood events between 1965 and 1979 which produced more failures. Some of these failures (1964 and subsequent years) delivered sediment to the stream network. Prior to the 1964 flood (1955 photos), a total of three slides were identified in the headwaters of the Middle Fork Mosby Creek. The slides were sufficiently old that any possible debris flow tracks or fresh sediment deposits were unidentifiable from the photos.

Riparian stand composition along channel segments which showed debris flow tracks and/or sediment deposition along 50% or more of their length were compared to segments influenced on less than 50% of their length. No road or slope failures were observed in the lower Mosby Creek basin. Although there was evidence of sediment deposition (likely from upper basin sources) along the lower mainstem, the affected areas

covered far less than 50% of any one channel segment. Sediment affected channels, identified in the 1965 and 1979 aerial photos, were evaluated in the 1993 aerial photos to determine what types of riparian stands had established on these two conditions (sediment influenced and non-influenced).

The use of 50% as a threshold for identifying sediment influenced and non-influenced channel segments effectively segregated the stream network into two distinct groups (Table 6). Those segments affected along 50% or more of their length actually averaged 63% and 81% for mainstem and tributaries, respectively. Channel segments that were affected along less than 50% of their length averaged 9% for mainstem segments and 4% for tributaries (for a list of affected channel segments see Appendix B, Table 17).

Table 6. Total length of channel segments within the sediment influenced and non-influenced groups and mean percent of segment length influenced within each group

Location	Total Influenced Channel Length	Mean Percent of Length Influenced	Total Non-influenced Channel Length	Mean Percent of Length Influenced
Upper mainstem	9.7 km	63%	13.0 km	9%
Upper tributaries	28.9 km	81%	60.0 km	4%

Canopy Closure Determination

Mosby Creek is considered to be poorly shaded and subject to summer maximum temperatures that are generally higher than those experienced prior to timber harvest (Jeff

Ziller, Oregon Department of Fish and Wildlife, pers. comm. 1993). Canopy closure was measured along the stream network in 1955, 1964, 1979 and 1993 to evaluate spatial and temporal changes within areas subjected to different land-uses.

In this study, canopy closure was measured as percent closure of open sky. This parameter can be estimated from aerial photography using a general guide developed for watershed analysis (Table 7)(Washington Forest Practices Board 1993). The 1952-55, 1964-65, 1979 and 1993 sets of aerial photos used for riparian stand typing were also used for interpreting canopy closure. In this document, the terms “shade” and “canopy closure” will be considered equivalent.

Table 7. Categories for estimating canopy closure from aerial photos

Stream surface not visible	> 90% canopy closure
Stream surface slightly visible or visible in patches	70-90% canopy closure
Stream surface visible but banks are not visible	40-70% canopy closure
Stream surface visible and banks visible at times	20-40% canopy closure
Stream surface and banks visible	<20% canopy closure

These general guidelines are insufficient unless they are combined with a subsample of local variability. Ground measurements are performed on designated stream segments with a concave spherical densiometer (Lemmon 1956a and 1956b) to cross-check and calibrate the aerial photo interpretation. Repeated comparisons between ground measurements and photo-interpreted canopy closure values provide the feedback necessary for achieving accurate photo-interpreted results.

Composite shade values were computed as a weighted mean combining percent of stream length in each shade category. These composite values were calculated for several subsets of the Mosby Creek Basin. The general equation used to compute composite shade is:

$$S = (A \times 0.1) + (B \times 0.3) + (C \times 0.55 \text{ or } 0.65) + (D \times 0.8) + (E \times 0.95)$$

Where:

S = Composite shade value for a given stream segment

A = Percent of stream length in 0-20% shade category

B = Percent of stream length in 20-40% shade category

C = Percent of stream length in 40-70% shade category
(0.65 is used for upper mainstem old-growth conditions
and 0.55 for all other conditions)

D = Percent of stream length in 70-90% shade category

E = Percent of stream length in 90-100% shade category

Composite shade ("S") could vary from a low of 0.1 (10%) to a maximum of 0.9 (90%). The multipliers for each category are the mean values for that range. This is a reasonable method for combining values unless there is reason to believe there is bias within a category for a given area or time. There is a bias for the case for the Mosby Creek mainstem under mature to old conifer stand conditions. Much of the Mosby Creek upper mainstem is in the 40-70% shade category in pre-harvest conditions visible in the 1955 aerial photos. However, most of the stream channel appeared to be in the upper range of this category. To confirm this aerial photo interpretation, it was necessary to locate channel segments currently bordered by mature to old conifer.

Mature to old (40-200+ yrs.) conifer stands are presently sparse along the mainstem of Mosby Creek. Canopy closure under old-growth conditions, present in earlier photos, could not be ground-truthed within the Mosby Creek basin. Sharps Creek, an adjacent drainage to the east, is bordered by several thousand meters of mature to old conifer riparian stands. Canopy closure and bankfull width were measured at 28 stations, spaced 100 meters apart, within these older stands on Sharps Creek. Elevation and channel bankfull width of this sampled area on Sharps Creek are similar to the elevation and bankfull channel width of average conditions on Mosby Creek (Table 8). Canopy closure values for the 28 stations averaged 63%, ranging from 42% to 93% (Appendix C). This modification was applied to Mosby Creek for old-growth riparian stands that existed in 1955. Because Mosby Creek has a slightly narrower mean channel width than the evaluated Sharps Creek segment, a multiplier of 0.65 (65%) was used when calculating composite mean shade for the upper Mosby Creek mainstem in 1955.

Table 8. Comparison of sampled reach on Sharps Creek to mean and range of conditions on Mosby Creek

Condition	Mosby Cr.	Sharps Cr.
Mainstem mean elevation	341 m	427 m
Mainstem elevation range	207m to 476m	420m to 435m
Mean channel width	13.8m	16.5m
Channel width range	7.6 to 30.9m	12.6 to 23.0m

Channel Morphology

On December 22, 1964, a flood magnitude with a recurrence interval of 100 years was recorded at the Mosby Creek gaging station, USGS Gage 14156500 (Wellman et al. 1993). Aerial photos are available from August, 1964, and May, 1967. The 1964 photos are approximately 1:13000 scale and the 1967 photos are approximately 1:21000.

Segments of the Mosby Creek mainstem, with adequate photo coverage, were reviewed to identify channel responses to the 1964 flood. Three focus areas were selected which exhibited a conspicuous change in channel morphology. These focus areas do not represent channel changes throughout the basin. They represent particularly severe adjustments in channel form, adjustments that could be quantified from the photos available.

The three focus areas are identified as site 1, site 2, and site 3 (Figures 21, 22, and 23). Site 1 is a 550 meter long section of Mosby Creek immediately downstream from the confluence of the East Fork and Middle Fork of Mosby Creek. Site 2 extends from 500 meters above to 100 meters below the confluence of Lilly Creek and Mosby Creek. Site 3 is 650 meters long and is roughly centered at the confluence of Cow Creek and Mosby Creek. All three sites were completely harvested prior to the 1964 flood. Sites 2 and 3 had gravel pits immediately adjacent to the stream channel, separated by a narrow (~ 10 meters) width of intact land.

For each photo in a focus area, photo scale was determined by measuring distance between identifiable road intersections on USGS 7-1/2' topographical maps that were situated at similar elevation and spanning roughly the same longitudinal stream section. Both sets of photos (1964, 1967) were then enlarged on a 1% increment photo copier until photo scales approximated each other in the 1:5000 scale range. These enlargements were recomputed for actual scale and subset stream sections measured to confirm minimum distortion (<2%) across the enlargement (Paine 1981). The photo enlargements were simplified to line drawings by overlaying the enlargements with acetate and outlining key stream channel features. Changes in unvegetated channel width, simple sinuosity and total sinuosity were measured on the overlays to document direct effects of the 1964 flood on channel morphology. The same channel sections were then measured in the 1955 photos to document pre-harvest conditions, and again in the 1993 photos to evaluate recovery from 1967 to the present. The 1955 and 1993 photos are the same 1:12000 scale photos used for riparian vegetation typing.

Unvegetated channel width is the distance between the lines of visible vegetation on either side of the stream channel. Streams that have not recently experienced a disturbance, such as flooding or timber harvesting, are typically vegetated to the bankfull flow stream margin. Unvegetated channel width, as measured on the mainstem of Mosby Creek, quantifies the loss of stream adjacent riparian vegetation. This loss may result from sediment deposition on top of low vegetation and/or removal by scour of taller vegetation during the high flow. Three cross-sections were chosen in each focus area.

Unvegetated channel width was measured perpendicular to the stream channel at each cross-section and the three measurements were averaged to produce one representative value.

Simple sinuosity describes the curviness of a stream channel and total sinuosity characterizes the amount of channel braiding (Hong and Davies 1979). Simple sinuosity is the ratio of main channel length to the length of a straight line down the midpoint of the valley bottom. Total sinuosity is the ratio of all channel lengths (including side channels and multiple channels) to the midline length. Distances were measured on the overlays with a map wheel.

CHAPTER III

RESULTS

Changes in riparian vegetation from 1955 to 1993 are summarized according to the percent abundance of the different stand types along the stream channel. These stand types are then functionally combined into good, fair and poor large, woody, debris (LWD) recruitment potential groups. Canopy closure is reported as the percent of stream length in each canopy closure category and then combined into composite mean canopy closure values for particular areas. These riparian condition summaries are compared between the forest management land-use in the upper basin and rural/agricultural land uses dominant in the lower basin. Each basin is further subdivided into mainstem and tributary groups to distinguish conditions along wide, mainstem channel segments from narrow, higher gradient tributary channel segments.

Changes in Riparian Stand Composition

Nearly three quarters of Mosby Creek basin riparian stands were in good condition to provide large woody debris (LWD) to the stream channel in 1955 (see

Methods for definitions of good, fair and poor riparian condition). This fraction declined to one sixth by 1979 and has remained at this proportion to the present (Figure 4). Stand composition changes in the upper basin represent almost all of this decline. Unlike declines in canopy closure which showed varying degrees of recovery (see Canopy Closure below), riparian stand composition has not yet shown recovery to previous levels of LWD recruitment potential.

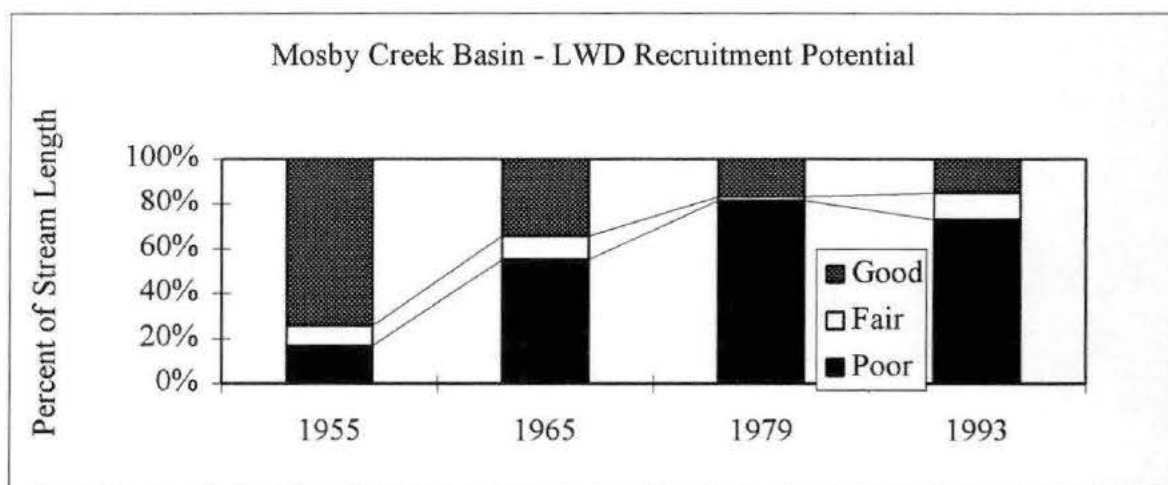


Figure 4. Mosby Creek basin LWD recruitment potential from 1955 to 1993.

Lower Mosby Creek Basin

Most riparian stands along the lower mainstem were harvested and converted to residence/agriculture in the late 1800s and early 1900s. Residential and agricultural

activities discourage any forest regeneration and maintain these stands in a slowly maturing, but otherwise steady-state condition. The dominant observable change in lower mainstem riparian stands is the shift from mixed/young/sparse (MYS) to mixed/mature/sparse (MMS) as these stands mature (Figure 5).

Riparian stand types in the lower basin tributaries experienced greater variability (Figure 6) than the lower mainstem because of the mix of agriculture and forest management land-uses. Frequency of young stand types (MYS, MYD, DYS, DYD) fluctuated as timber harvest activity occurred throughout the lower basin. The percentage of the stream bordered by conifer/old/dense (COD) riparian stands declined to zero by 1979. Conifer/mature/dense (CMD) stands also decreased from 1965 to 1993. Mixed/mature stands (MMS, MMD) increased in frequency as stream buffers were left, beginning in the 1970s. Early stream buffers consisted of small conifers and hardwoods retained within 25 to 100 foot wide stream adjacent areas. These riparian management areas (RMAs) required some streamside protection, including minimal ground disturbance and retention of shade providing vegetation. The percentage of stream length in good condition to supply LWD decreased from 1955 to 1965 as remaining old-growth was harvested, but increased from 1979 to 1993 as some early stream buffers matured to mixed/mature/dense (MMD) stands (Figure 7).

Mosby Creek Basin - Lower Mainstem

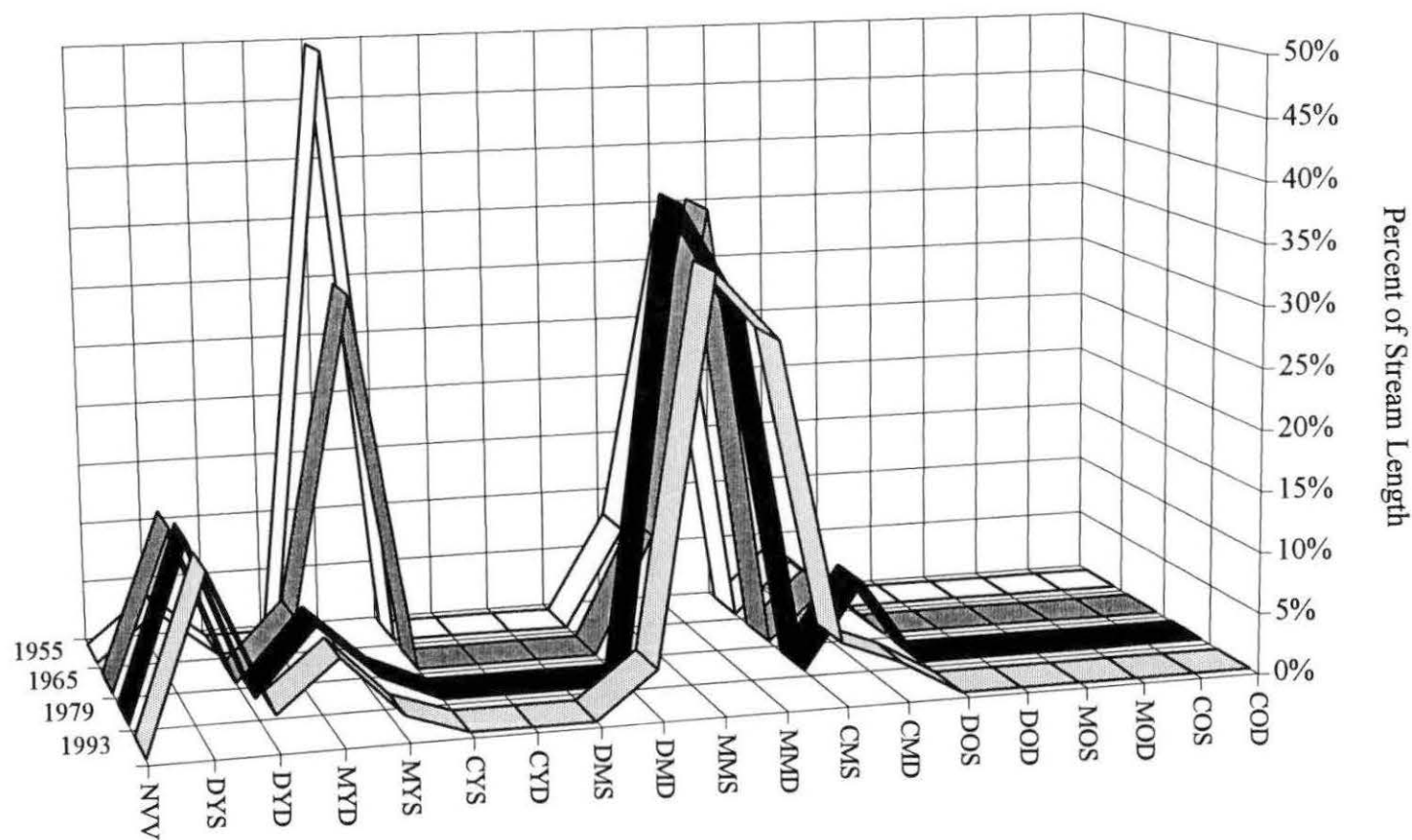


Figure 5. Percentage of riparian stand types along the lower mainstem of Mosby Creek from 1955 to 1993

Mosby Creek Basin - Lower Tributaries

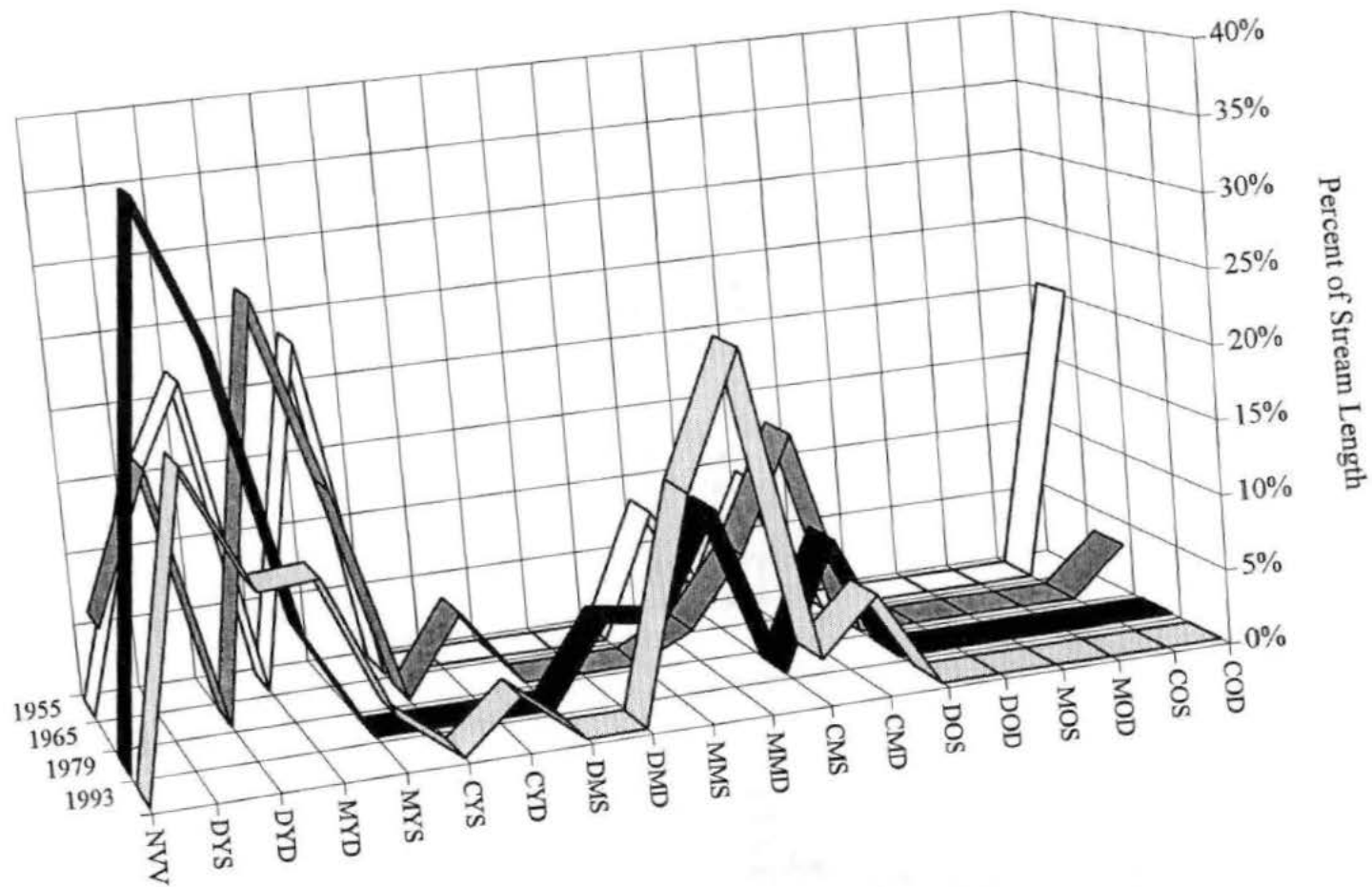


Figure 6. Percentage of riparian stand types along the lower tributaries of Mosby Creek from 1955 to 1993

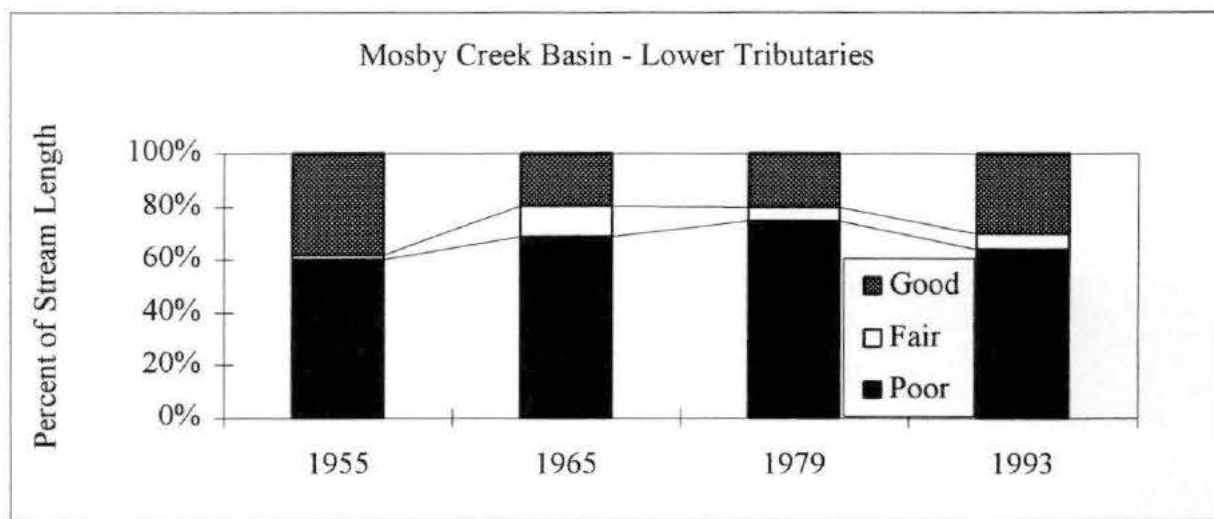


Figure 7. Mosby Creek lower tributaries LWD recruitment potential from 1955 to 1993.

Upper Mosby Creek Basin

Riparian stand types in the upper basin changed substantially during the period of evaluation. The upper basin was almost completely unharvested in 1955 and timber harvest was mostly complete before streamside protection was legislated in the early 1970s (Oregon Forest Practices Act 1972). Streamside vegetation was removed during harvest and in some cases riparian soils were disturbed when ground machinery (cat-logging) harvest techniques were used. This type of activity favors the establishment of post-disturbance colonizers such as red alder, vine maple and big-leaf maple (Newton et al. 1968, Gecy and Wilson 1990). The additional effects of flood-generated sediment deposition in the riparian area are discussed below.

Most of the upper mainstem was unharvested in 1955. However, some portions of the lower 40% of the upper mainstem had been logged by 1955 (river miles 8 through 14). In 1955, the upstream 60% of the upper mainstem represented riparian stands uninfluenced by anthropogenic disturbance. Seventy-eight percent of this uninfluenced upper mainstem stream length was vegetated by mature or old conifer (CMD, CMS, COD, and COS) in 1955 (Figure 8). Fifty-seven percent of the riparian stands were categorized as old-growth (COD or COS) which is similar to the 62% estimated for western Oregon and western Washington pre-logged forestwide conditions (Booth 1991). The remaining riparian areas supported dense, mature stands dominated by deciduous (11%) or mixed deciduous and conifer (8%) stands.

Riparian stand types along the upper mainstem of Mosby Creek regenerated following timber harvest as mixed and deciduous young stands (DYS, DYD, MYS, MYD total 90% of the stream length). There is little evidence of conifer returning to dominance as of 1993 (Figure 9).

The loss of conifer and regrowth of mixed and deciduous young stands along the upper mainstem of Mosby Creek substantially reduced the LWD recruitment potential along these channel segments (Figure 10). Conditions reached a minimum in 1979 and have remained at a similar level through 1993.

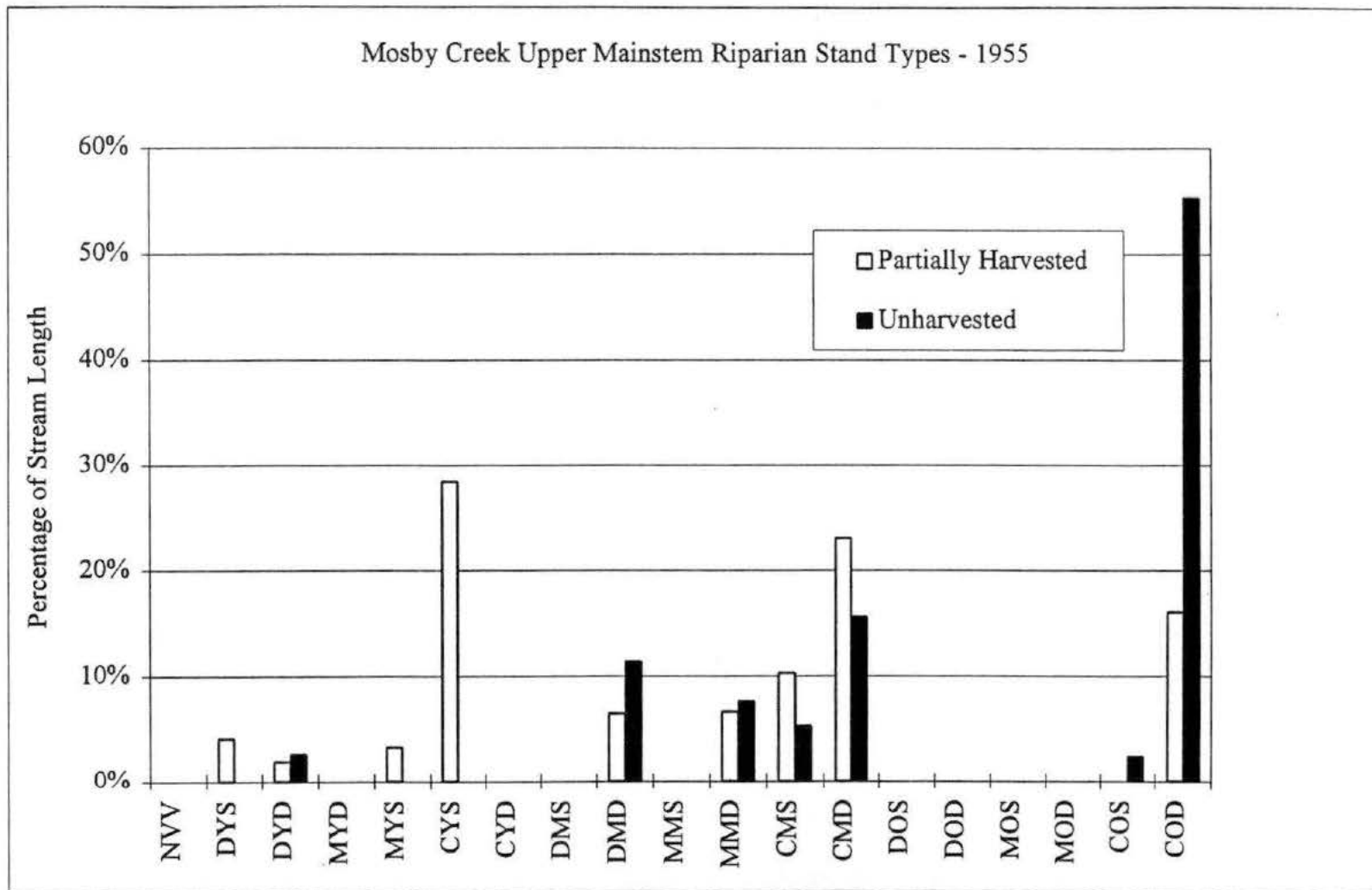


Figure 8. Mosby Creek upper mainstem riparian stand types within areas partially harvested and unharvested in 1955

Mosby Creek Basin - Upper Mainstem

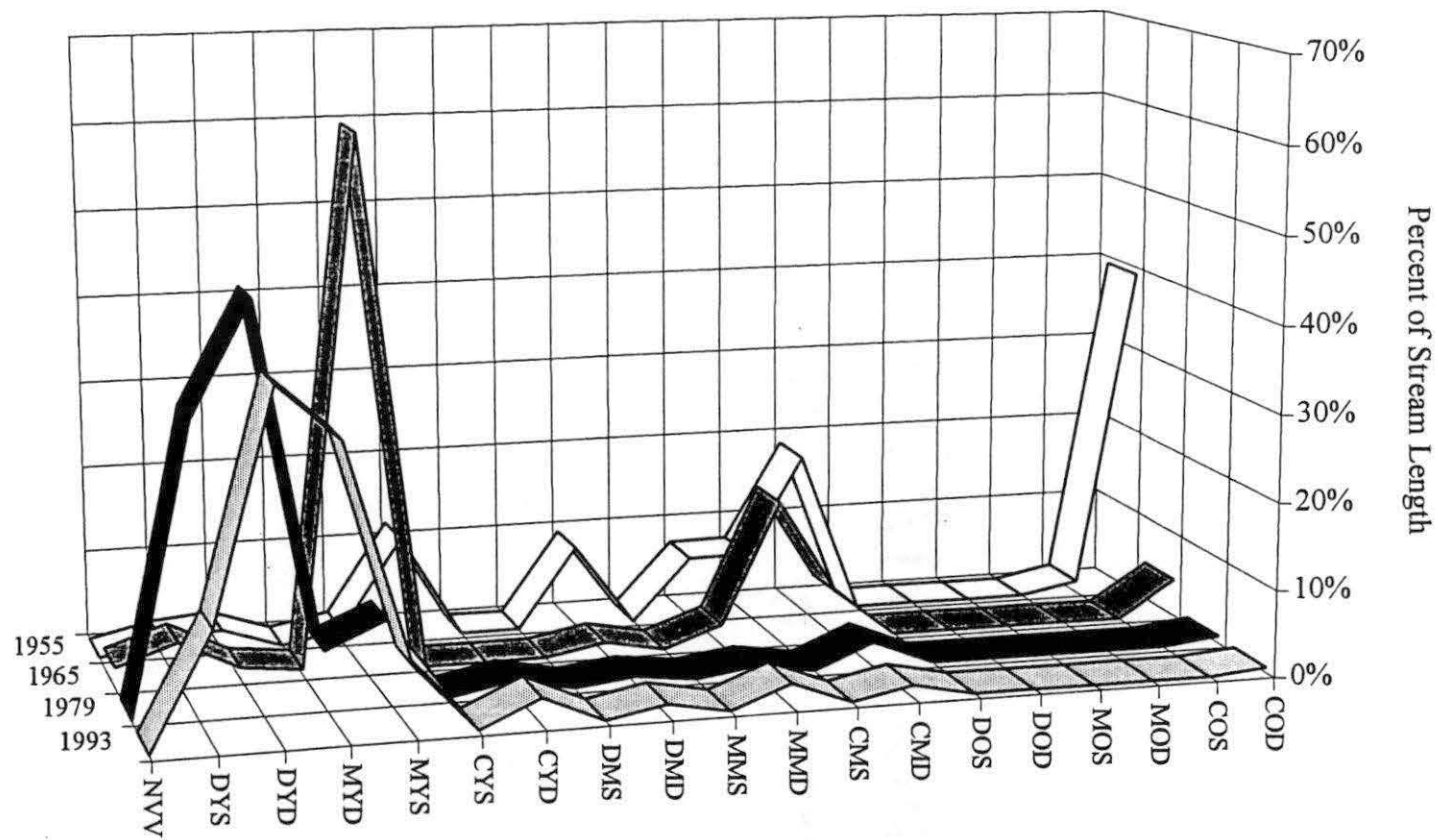


Figure 9. Percentage of riparian stand types along the upper mainstem of Mosby Creek from 1955 to 1993

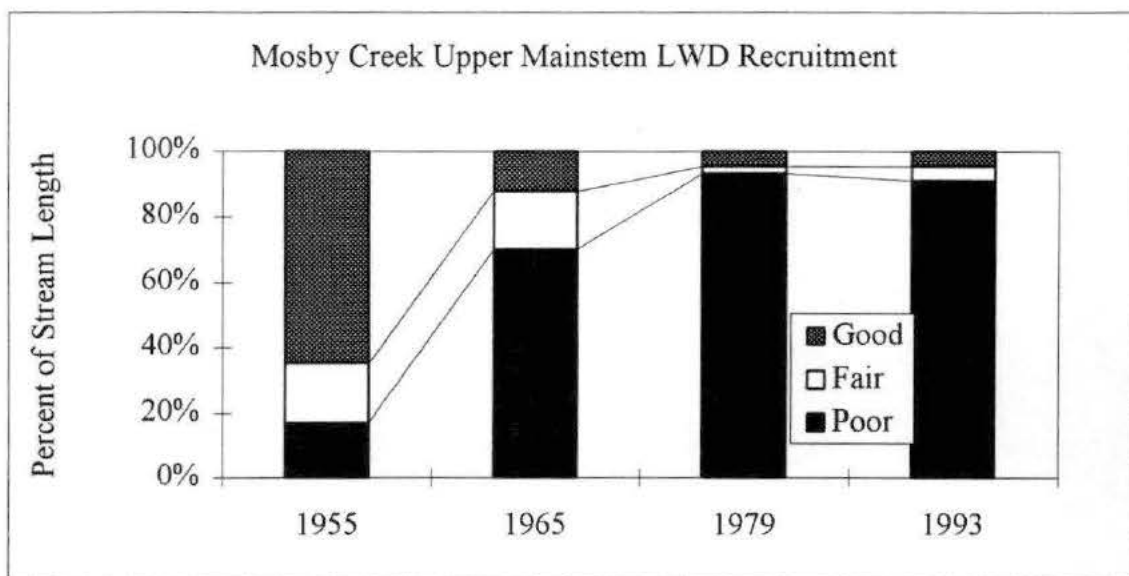


Figure 10. Mosby Creek upper mainstem LWD recruitment potential from 1955 to 1993.

Mature and old conifer riparian stands (CMS, CMD, COS, COD) occupied 97% of the stream length along the upper basin tributaries in 1955 (Figure 11). This has dropped to 13% in 1993. LWD recruitment potential followed this same trend, as 78% of the tributary network is now dominated by deciduous and mixed species (Figure 12). The increase in the fair LWD recruitment category is the result of young conifer (CYD) dominating riparian stands that were previously dominated by deciduous or mixed stands. This transition is occurring where fast growing deciduous vegetation established following timber harvest, but planting of seedlings established conifers within the 70 ft evaluated riparian width. As these CYD stands mature they will move into the good LWD recruitment category.

Mosby Creek Basin - Upper Tributaries

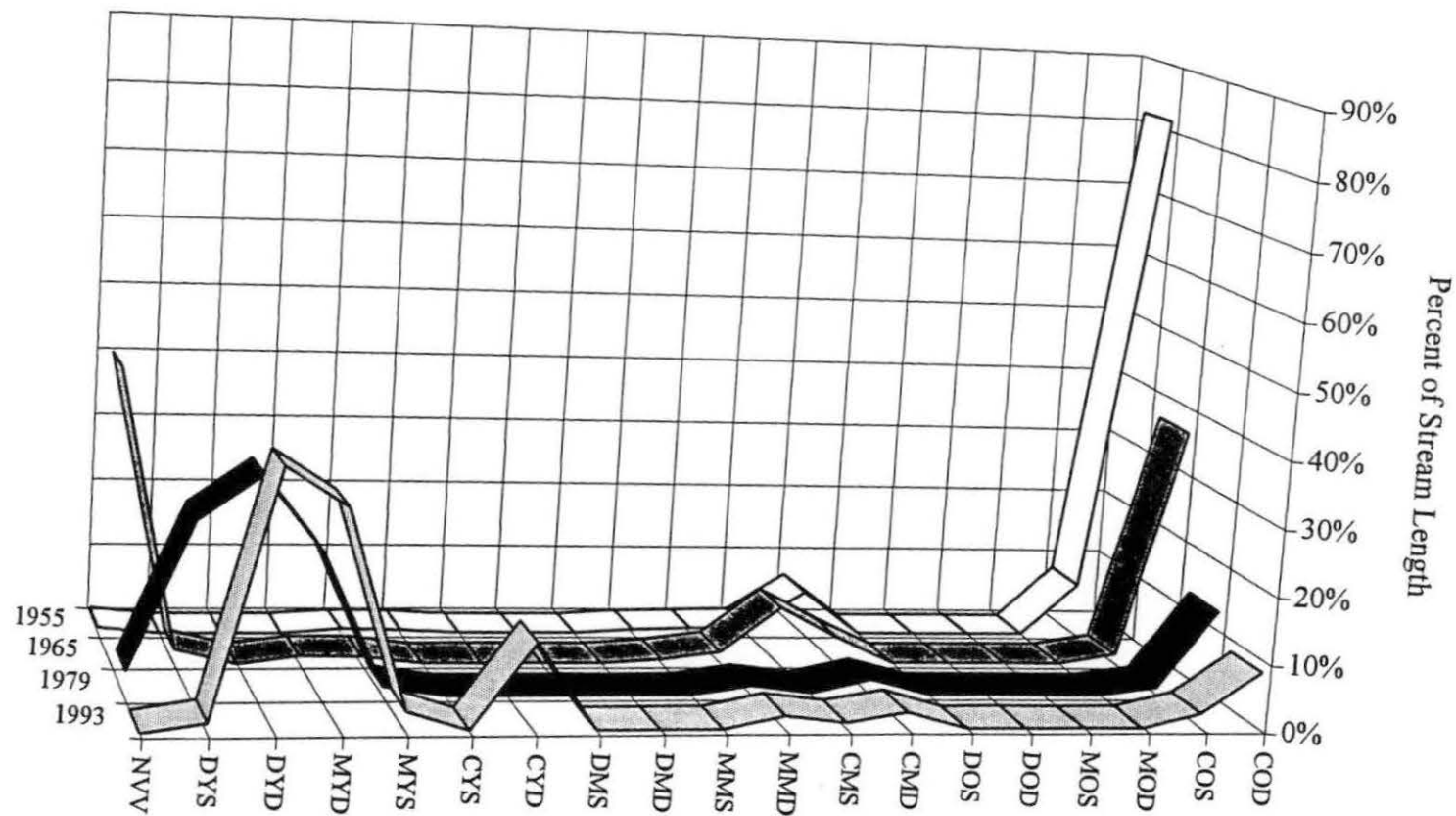


Figure 11. Percentage of riparian stand types along the upper tributaries of Mosby Creek from 1955 to 1993

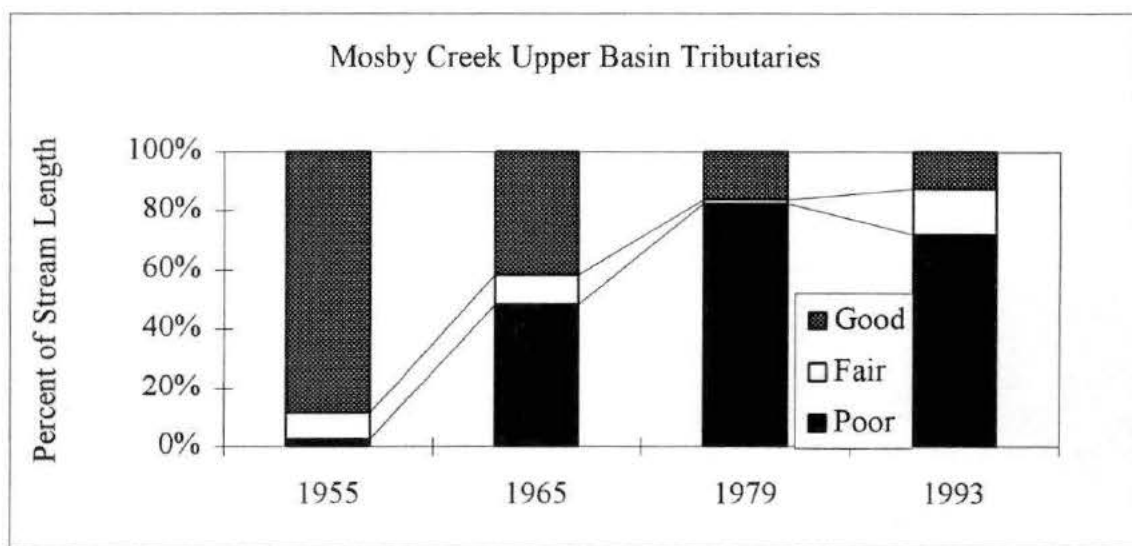


Figure 12. Mosby Creek upper basin tributaries LWD recruitment potential from 1955 to 1993.

Effects of Sediment Deposition

The severe 1964 flood event triggered many road and slope failures. High flows of 5 to 10 year recurrence interval in 1972, 1974 and 1976 also produced road and slope failures. Some of these failures delivered sediment to the stream channel network. Channel segments affected by this sediment deposition show differences in riparian stand composition from unaffected segments (Figure 13).

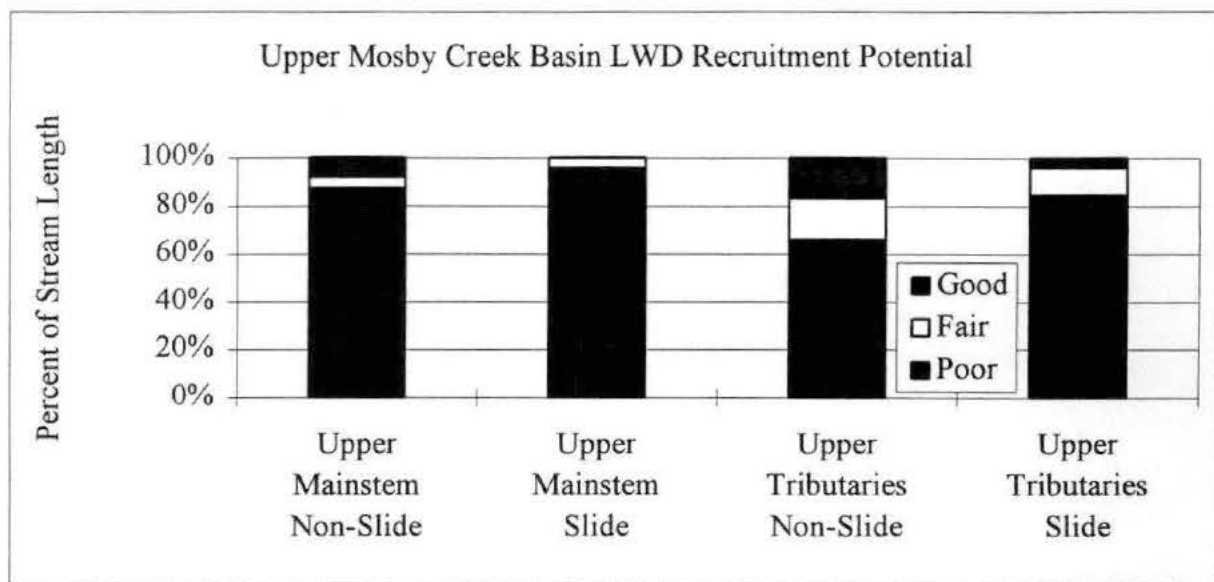


Figure 13. LWD recruitment comparison of sediment influenced and non-influenced channel segments of the Mosby Creek upper mainstem

Ninety-six percent of sediment-influenced segments in the upper mainstem have poor LWD recruitment potential, compared to 88% in non-influenced segments. Eighty five percent of sediment influenced segments in upper tributaries have poor LWD recruitment potential, compared to 66% in non-influenced segments. Channel segments which experienced sediment deposition, particularly tributary segments, have a greater abundance of riparian stand types considered poor suppliers of LWD. These stand types are predominantly deciduous/young/dense and mixed/young/dense (Figures 14 and 15). Post-harvest conversion of riparian stands to hardwoods was further exacerbated by the sediment deposited from road and slope failures triggered during high flow events.

Riparian stands within the lower Mosby Creek basin experienced little change in composition from 1955 to 1993. The frequency of riparian stand types along the lower mainstem remained relatively constant except for a shift from mixed/young/sparse (MYS) stands to mixed/mature/sparse stands. Lower tributaries showed greater variability as continuing timber harvest created a patchwork of new young stand types while remaining mature to old conifer stands were harvested. The upper basin experienced a substantial decrease in LWD recruitment potential as old conifer was harvested and young, deciduous trees regenerated in the riparian areas. Upper tributary riparian stands exhibited a slight increase in LWD recruitment potential as conifer/young/dense (CYD) stands increased in 1993.

Changes in Changes in Canopy Closure

The Mosby Creek basin went from a moderately high canopy closure in 1955 to very low values in 1965 and in 1993 had recovered to a basin wide average that is similar to 1955 (Figure 16). Changes in canopy closure are similar to changes in riparian stand composition in that they are not the same across the Mosby Creek basin. The upper basin experienced greater magnitude change than the lower basin and tributaries showed different trends than the mainstem channel segments.

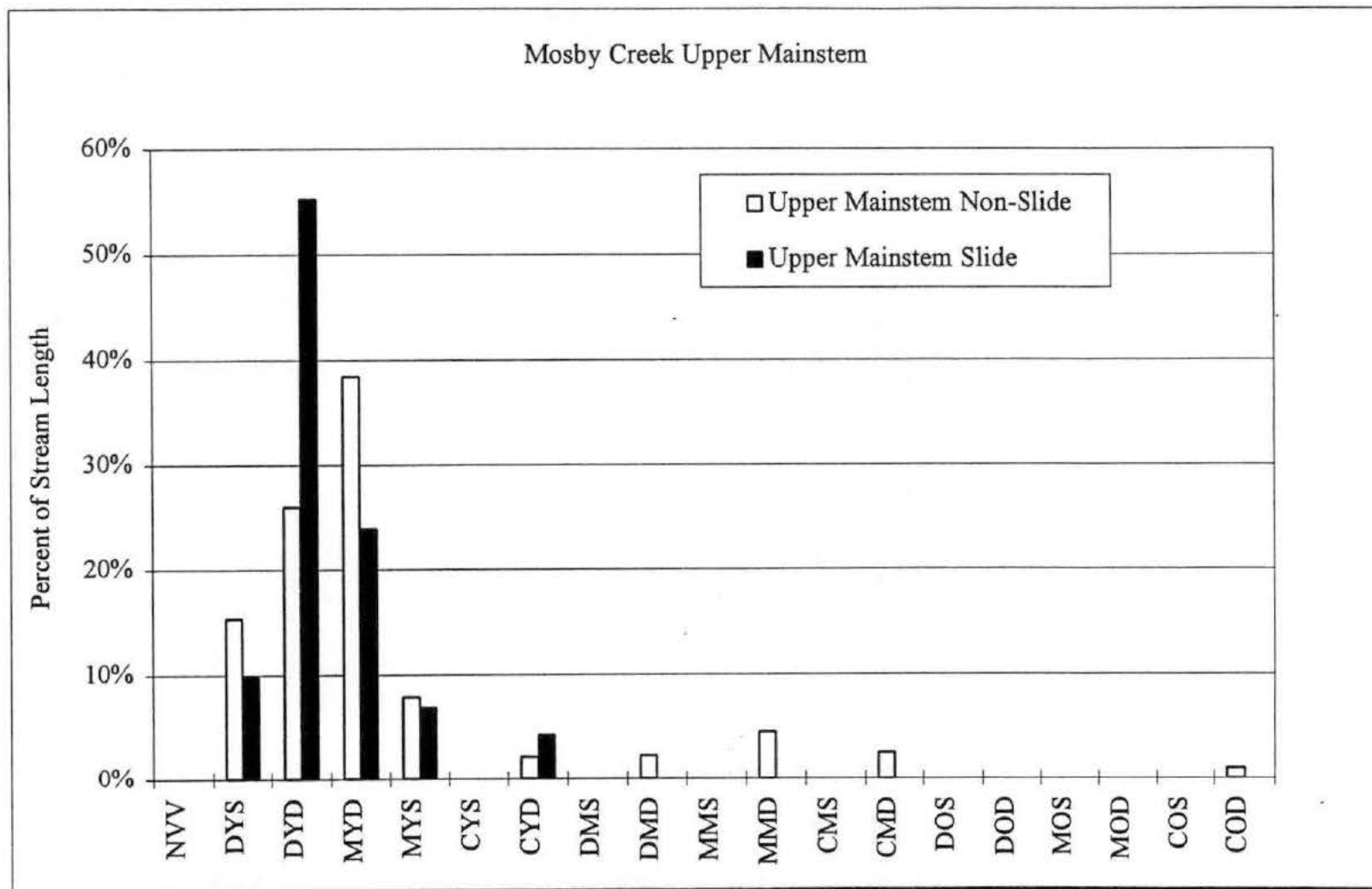


Figure 14. Upper Mosby Creek mainstem riparian stand types along sediment influenced and non-influenced segments

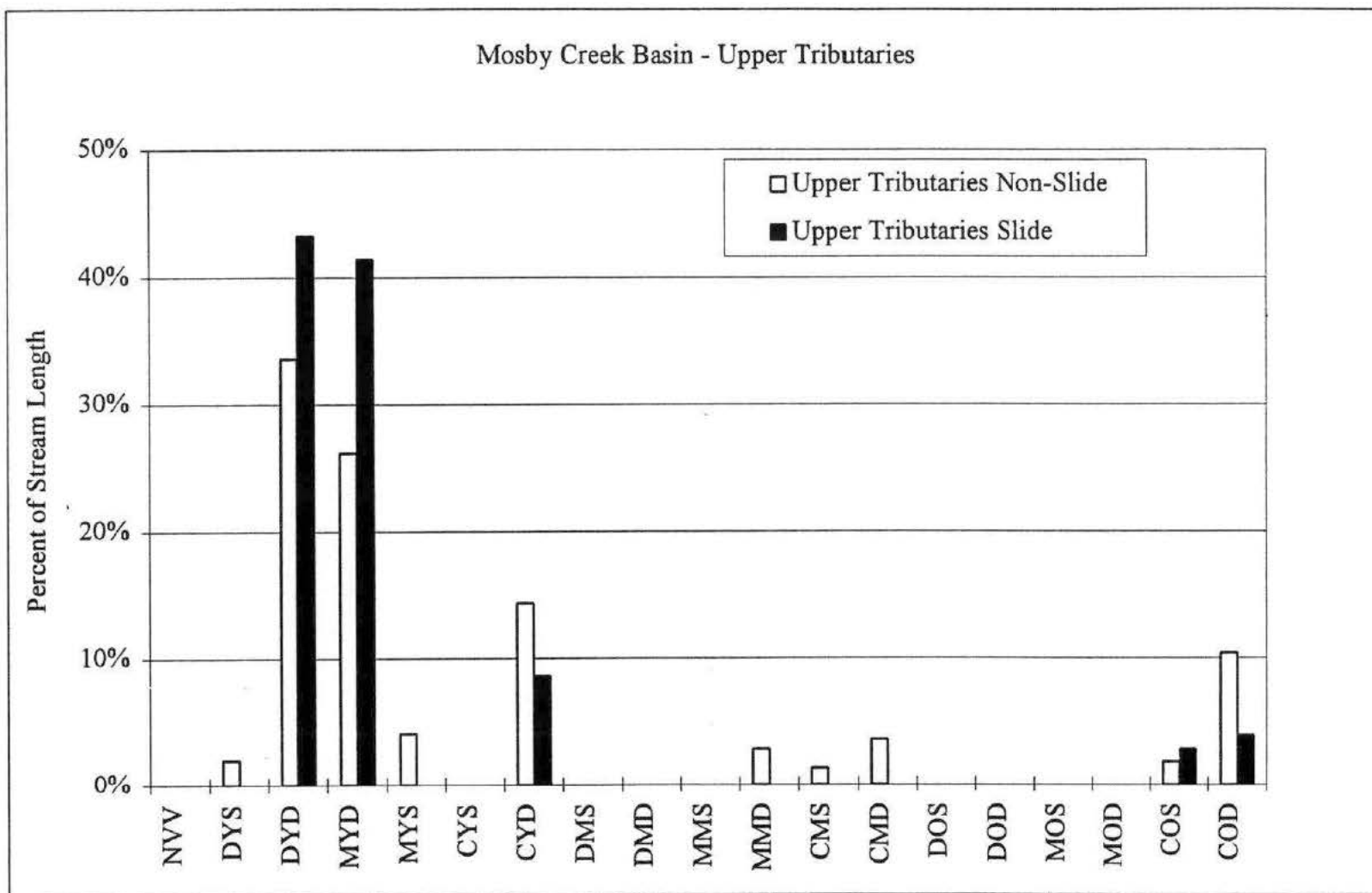


Figure 15. Upper Mosby Creek tributary riparian stand types along sediment influenced and non-influenced segments

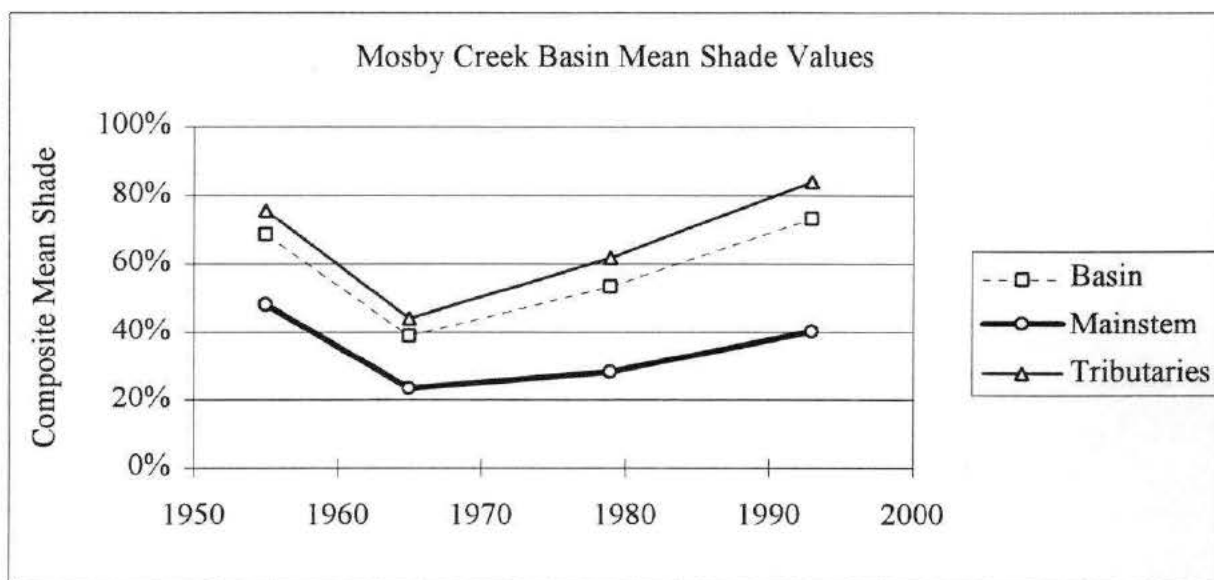


Figure 16. Composite mean canopy closure values for areas within the Mosby Creek basin. "Basin" values are combined values of mainstem and tributaries.

Lower Mosby Creek Basin

Timber harvest and conversion to agriculture and residences was substantially complete along the lower mainstem by 1955. There has been little change in canopy closure through time, even following the 1964 flood (Figure 17). Riparian vegetation had been altered decades earlier, was well established and supported some mature riparian stands (Figure 3) when the 1964 flood event occurred. Observations from 1967 aerial photos of the lower basin indicated some localized scour and sediment deposition. Outside of these localized areas, riparian vegetation appeared to remain intact.

None of the lower mainstem channel segments have canopy closure values greater than the 40-70% category during the period evaluated. This situation results from a wide bankfull channel and an absence of old-growth conifer or other trees of comparable height sufficient to shade the mainstem channel.

Tributaries in the lower basin flow through a mix of agricultural and forest management land-use. Agricultural areas changed little during the evaluation period. Stream shading in these locations remained stable in the less than 40% shade category. Areas under forest management experienced some change as a few remaining old-growth stands and maturing second growth stands were harvested. This harvest activity altered riparian stand composition on less than 10% of lower basin tributary stream length and produced the decline in composite shade on lower basin tributaries from 1955 to 1965. Canopy closure returned to higher values by 1993 as hardwood stands established on those and subsequent streamside harvest areas.

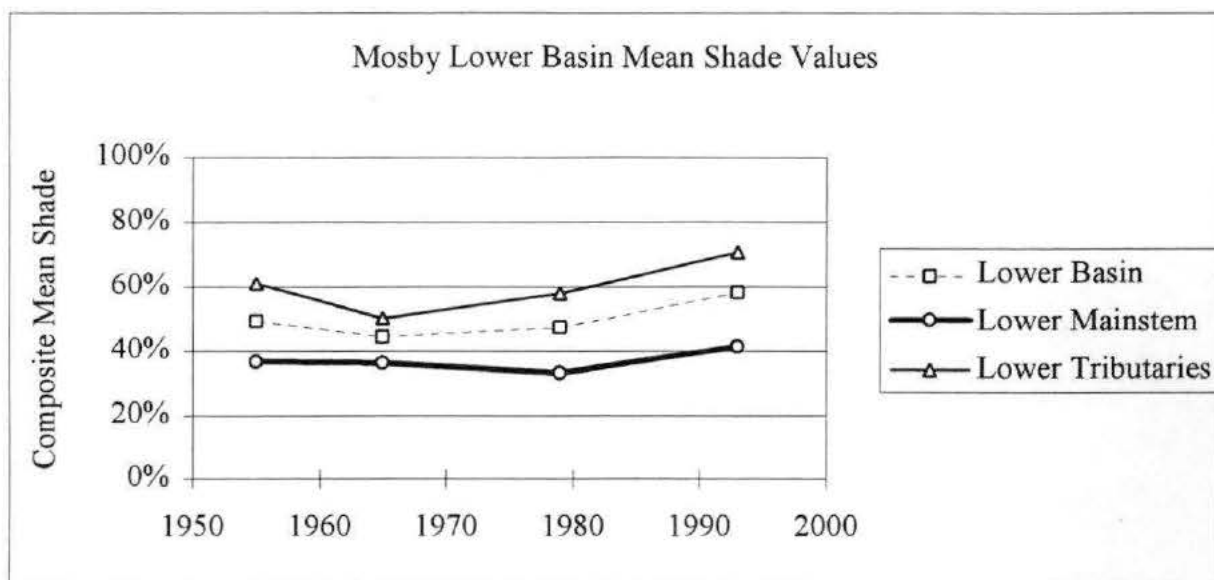


Figure 17. Composite mean canopy closure values for areas within the lower Mosby Creek basin. "Lower Basin" values are combined values of the lower mainstem and its tributaries.

Upper Mosby Creek Basin

In contrast to the conservative changes experienced in the lower basin, the upper basin went from basin-wide composite canopy closure values of 72 % in 1955, down to 38% in 1965, and back to 77% in 1993 (Figure 18). Tributary values dominate the upper basin trends because they represent 80% of total stream length in the upper basin. The tributaries also show high initial values, a substantial drop and return to a high composite shade value of 87%. The upper mainstem dropped to a low of 17% canopy closure in

1965 and has recovered to a composite shade value of 40%, less than the initial value of 54%.

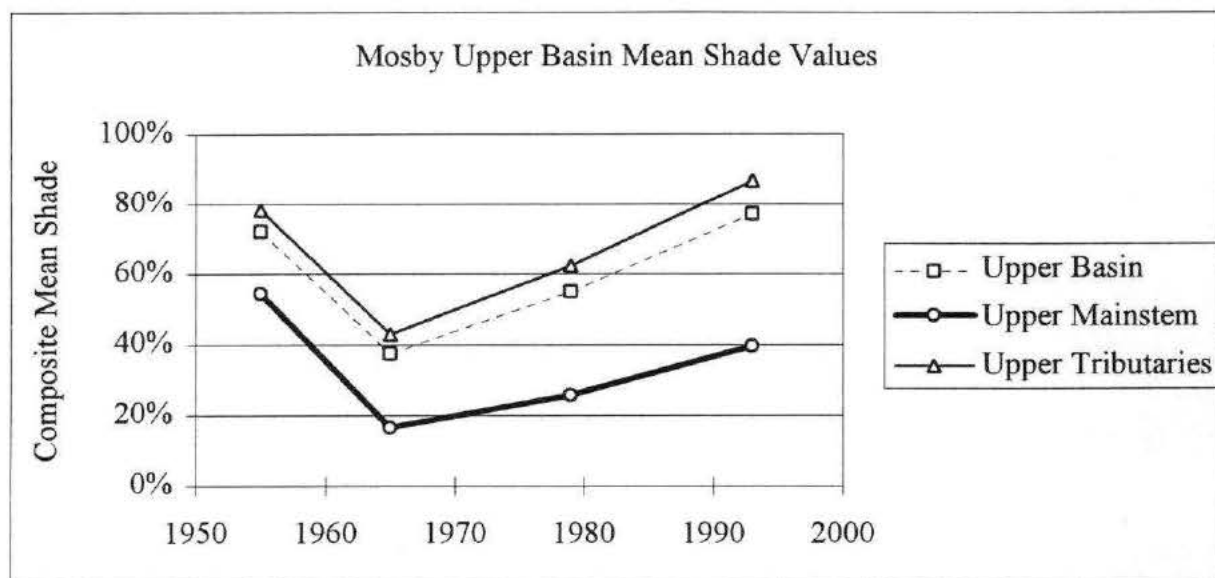


Figure 18. Composite mean canopy closure values for areas within the upper Mosby Creek basin. "Upper Basin" values are combined values of mainstem and tributaries.

The 1955 composite mean shade value for the upper basin mainstem channel segments is 54% (Figure 18). Some portions of the lower 40% of the upper mainstem had already been logged by 1955 (river miles 8 through 14, in Figure 19). Composite mean shade for the non-harvested segments is 68% and it is 36% for the segments partially harvested. Extremely low mainstem shade values, following timber harvest, were evident in the 1965 photos. The one elevated value at river mile 18 represents a

short channel segment that is partially bordered by unharvested public lands (Bureau of Land Management).

Almost 30 years after harvest along the Mosby Creek upper mainstem was completed, composite mean shade is only 40%. This rate of shade recovery along the upper mainstem does not agree with previous work done in western Oregon (Summers 1982). That research showed stream shading returning to old-growth conditions by roughly 22 years following harvest and burning. The key distinction between the upper Mosby Creek mainstem and streams reported by Summers is channel width. The Mosby Creek upper mainstem averages 15 meters bankfull width, while streams evaluated by Summers were 3 to 6 meters bankfull width. Summers found old-growth shade on these small streams to be about 85%, this is similar to aerial photo interpreted data reported here which shows 80% of the 1955 unharvested Mosby Creek tributaries having greater than 70% shade (composite mean shade equals 75%).

Eighty percent of the upper basin tributary stream network was shaded by old (>120 years) conifer in 1955 (Figure 11). The photo-interpreted composite shade value of 78% and shade recovery following harvest (Figure 18) is similar to other results measured on small streams in western Oregon (Summers 1982). Upper basinwide timber harvest of private timberland was complete before 1970, prior to Oregon's Forest Practices Act passed in 1972. Timber harvest removed most streamside woody vegetation and reduced canopy closure values to almost zero. Composite mean shade values for the

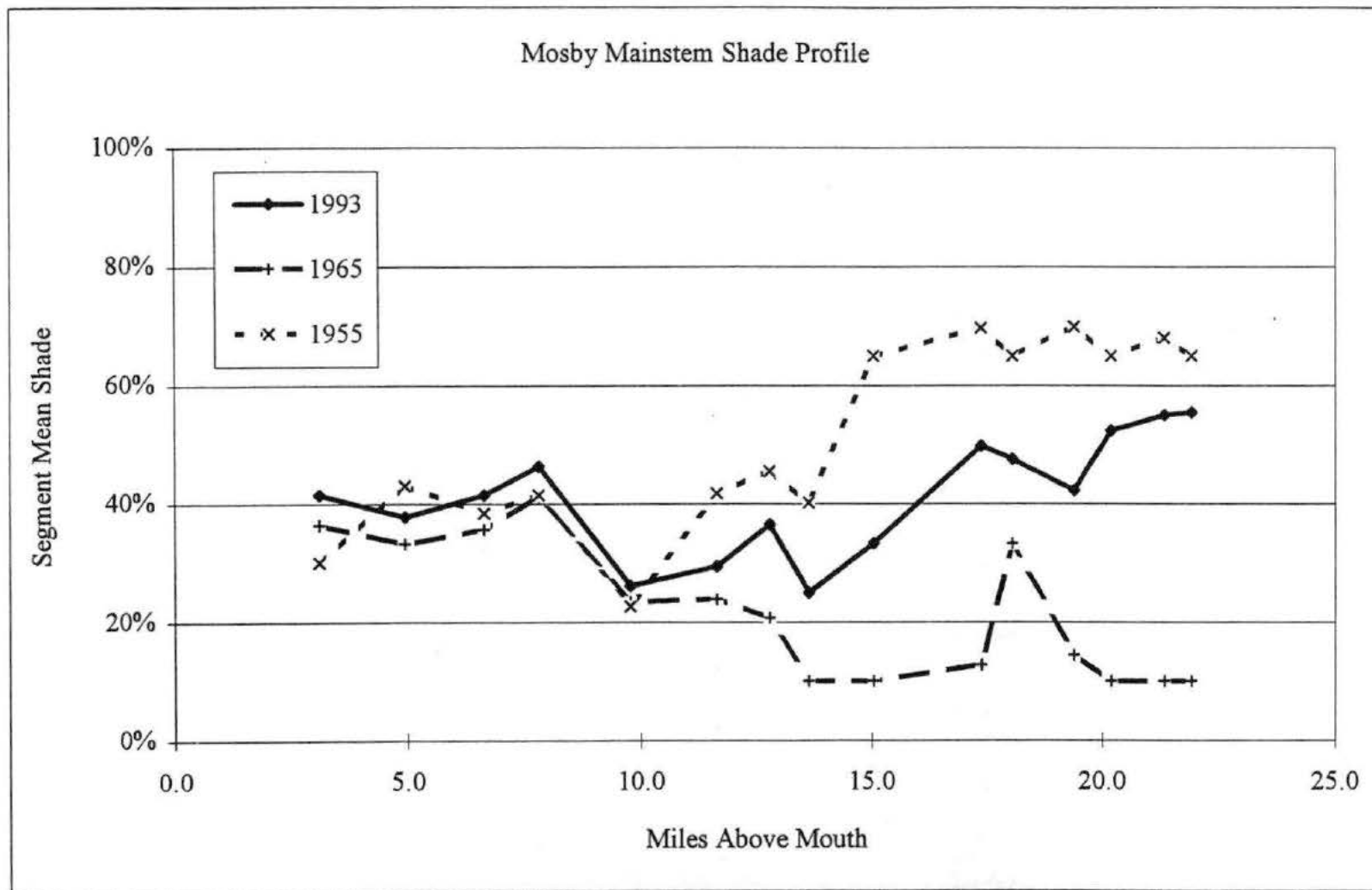


Figure 19. Mosby Creek mainstem shade profile for years with highest (1955), lowest (1965), and recent (1993) shade values

upper basin did not drop to zero for two reasons. First, harvest took place in a patchwork pattern over a 15 year period and smaller stream channels harvested early in this period regained some shade within 10 to 15 years. Also, some of the upper basin is in public ownership and these areas experienced very little harvest activity.

Following harvest, hardwoods dominated vegetation regrowth in the upper basin tributary riparian area (Figure 11). Hardwoods show a different growth form than conifers: they lean out over the stream channel when competing for light. Along smaller streams less than approximately 8 meters bankfull width, the alder trees completely close the stream canopy (Stewart and Skeesick 1981). This is illustrated by the shift in shade categories of upper basin tributaries (Figure 20). Data from 1955 and 1993 show almost 90% of the stream network shaded greater than 70 %. However, in 1955 most of this shade is in the 70-90% category common in old-growth conditions. In 1993, most of the tributaries are in the 90-100% shade category found under dense, hardwood stands. This shift from conifer dominant riparian stands to hardwood dominant vegetation has increased composite shade values along upper basin tributaries from 78% in 1955 to 87% in 1993 (Figure 18).

Canopy closure along the lower mainstem showed little change during the study period. Lower tributaries increased modestly from 1965 to 1993. Upper mainstem canopy closure decreased dramatically (from 54% to 17%) during timber harvest and was partially recovered (40%) in 1993. Canopy closure on upper tributaries also decreased substantially, however, by 1993, canopy closure was higher than initial conditions.

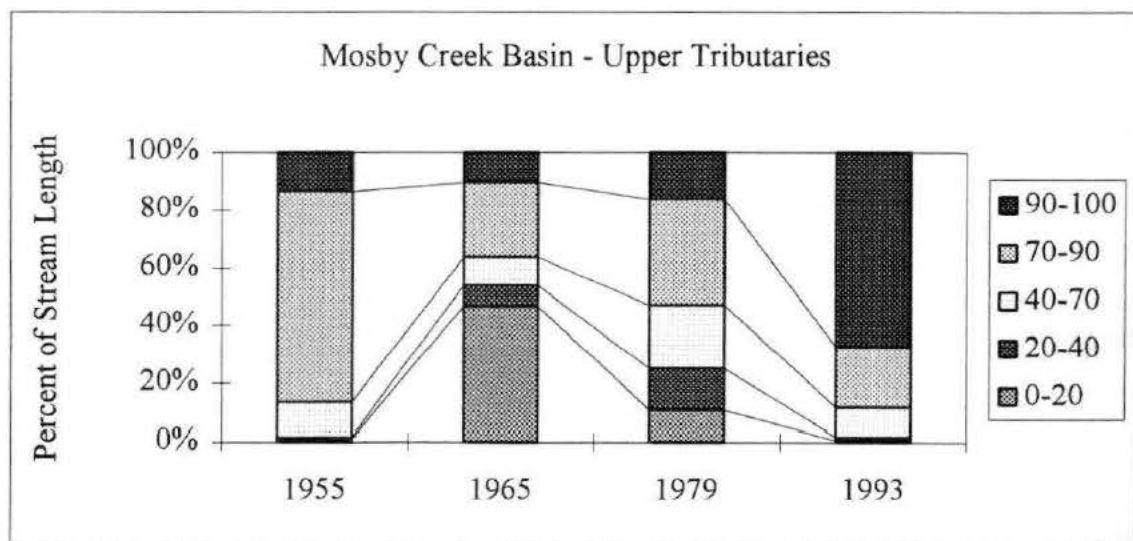


Figure 20. Mosby Creek upper basin tributary canopy closure as percent of stream length in each shade category.

Changes in Unvegetated Channel Width, 1964 to 1993

The three selected focus areas along Mosby Creek exhibited conspicuous and measurable (from aerial photos) changes in channel location, sinuosity and unvegetated channel width following the 1964 flood (Table 9 and Figures 21, 22 and 23).

Table 9. Summary of changes in channel morphology at three sites on the upper mainstem of Mosby Creek.

Location	Parameters	1952/1955	1964	1967	1993
Site 1	Simple Sinuosity	1.08	1.13	1.07	1.08
	Total Sinuosity	1.08	1.13	1.11	1.08
	Channel Width (m)	< 6	15	51	9
Site 2	Simple Sinuosity	1.07	1.10	1.10	1.06
	Total Sinuosity	1.07	1.39	1.68	1.06
	Channel Width (m)	< 6	27	86	15
Site 3	Simple Sinuosity	1.09	1.09	1.10	1.13
	Total Sinuosity	1.09	1.19	1.69	1.33
	Channel Width (m)	28	93	107	20

Following the 1964 flood, simple sinuosity changed substantially only at site 1. This is the uppermost reach, immediately below the confluence of the East Fork and Middle Fork of Mosby Creek. The original narrow, meandering channel straightened (in 1967 photos). Existing woody vegetation was partially removed, and there were abandoned channel meanders evident in the fresh sediment deposits. These abandoned meanders, visible in the 1967 photos, did not match the channel pattern present before the flood event. The wavelength of the abandoned meanders were longer than the pre-flood meander wavelength. The abandoned meander may have developed during rising flood waters as woody debris that helped to form the more sinuous pre-flood pattern was washed downstream. Also, the longer meander wavelength may have resulted from the higher discharge experienced during the flood. Moderate channel widening occurred at

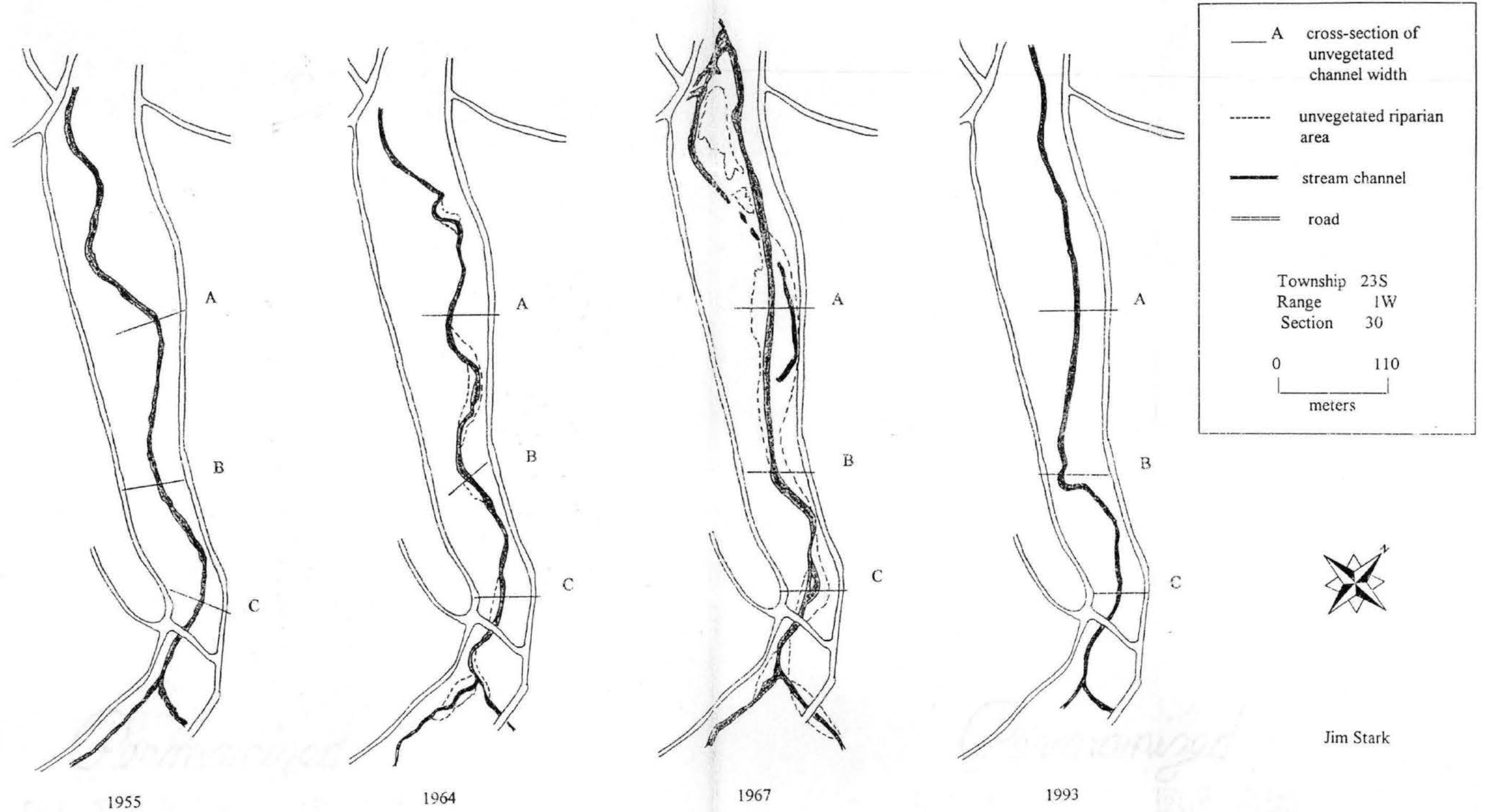


Figure 21. Changes in planform stream channel features of Mosby Creek near the East Fork of Mosby Creek. The 1964 flood occurred between the 1964 and 1967 channel drawings

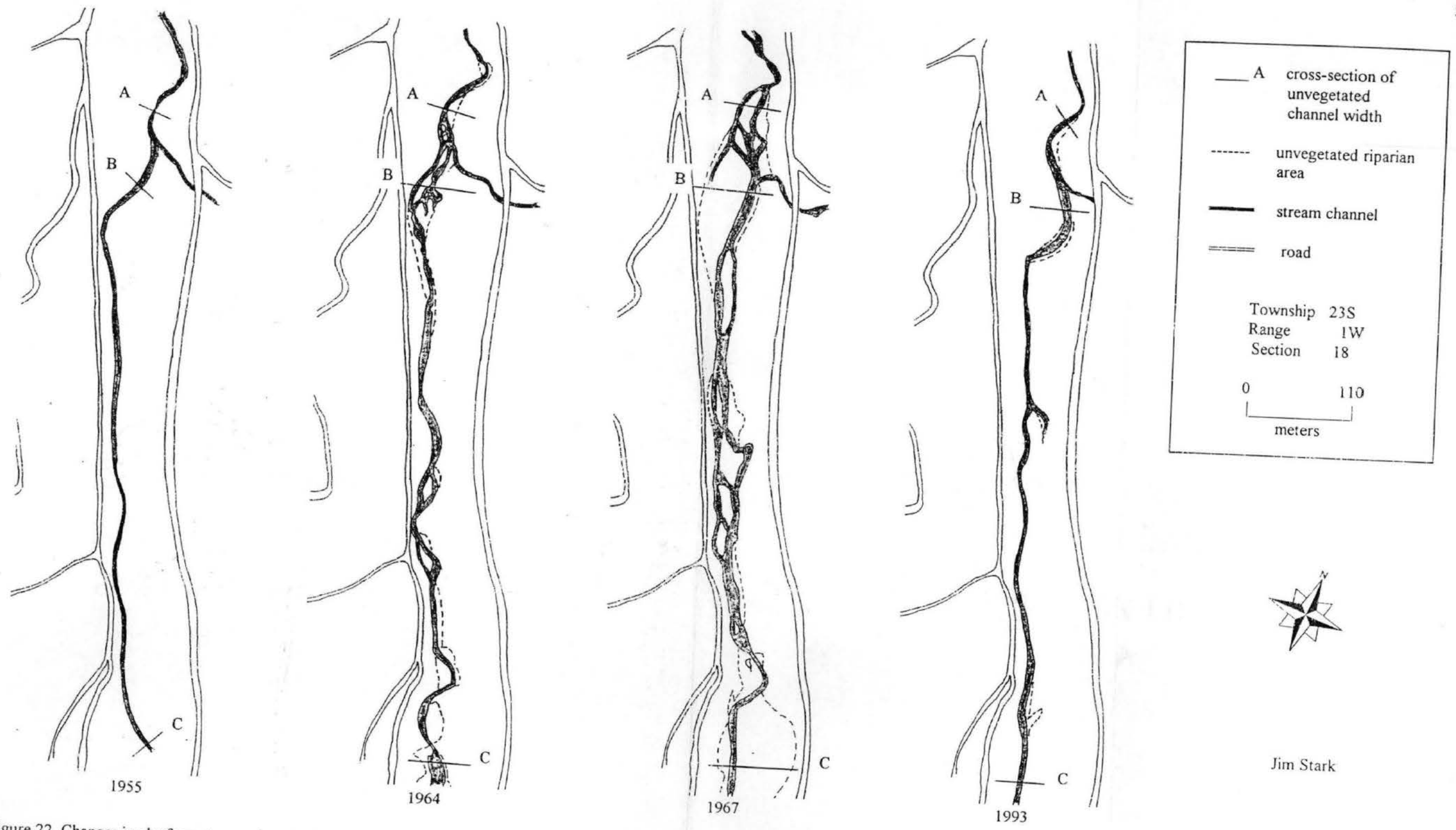


Figure 22. Changes in planform stream channel features of Mosby Creek near the confluence with Lilly Creek. The 1964 flood occurred between the 1964 and 1967 channel drawings

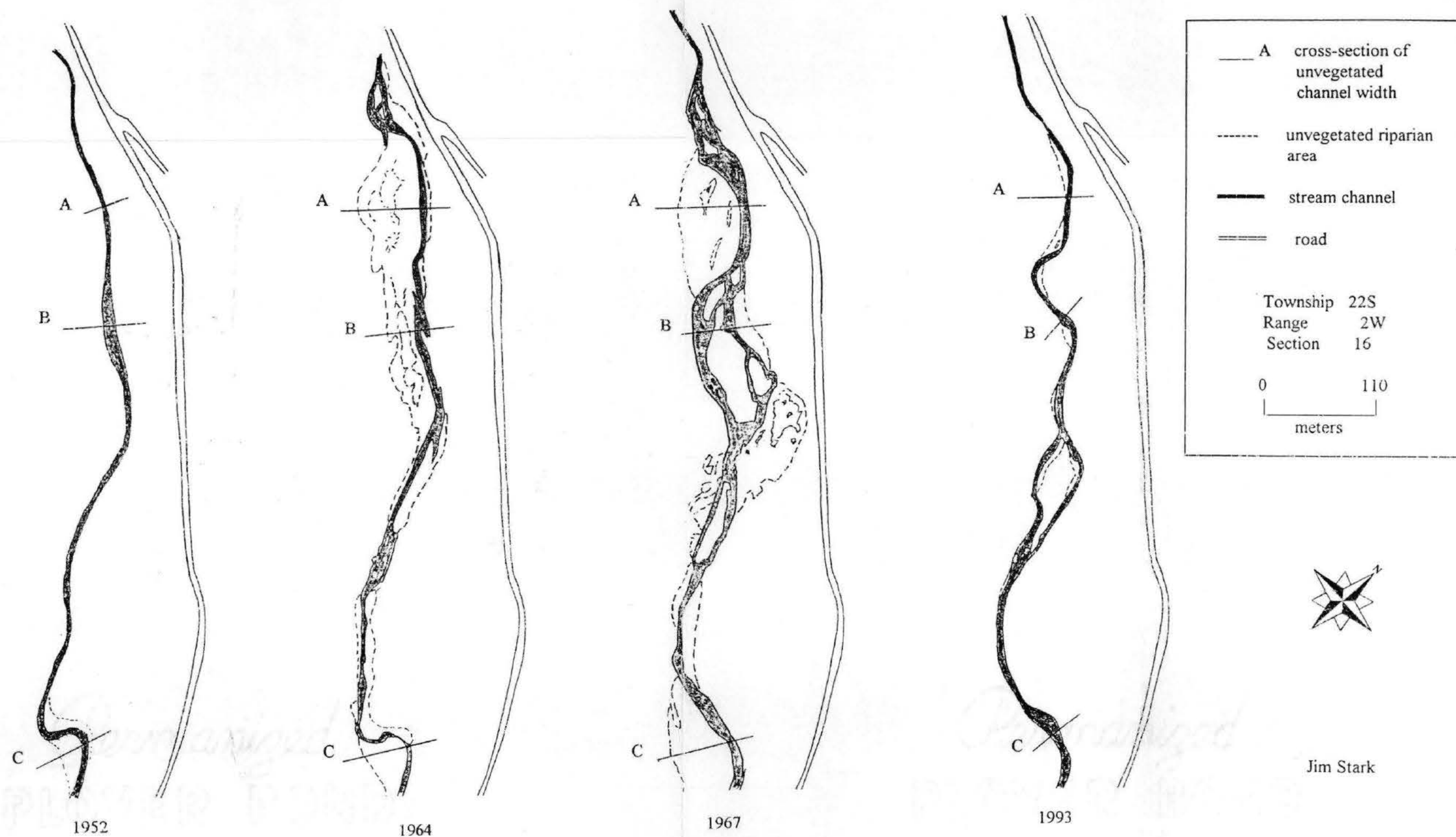


Figure 23. Changes in planform stream channel features of Mosby Creek near the confluence with Cow Creek. The 1964 flood occurred between the 1964 and 1967 channel drawings

this site, though the unvegetated channel width had mostly recovered by 1993.

At site 2, channel width increased from 1952/55 to 1964, prior to the 1964 December flood. This increase in width appeared to be related to vegetation removal and sediment deposits from recent, elevated flows (possibly the 5 to 10 year flow recorded during the 1963/64 winter). Following the 1964 flood, total sinuosity increased dramatically at site 2. High sediment loads from road and slope failures during the flood caused the stream channel to braid as bedload increased and the stream aggraded. Channel width expanded significantly, particularly where there were gravel pits next to the channel. Although the channel did not flow through these adjacent gravel pits in 1967, fresh sediment deposits in the area indicate that at some previous flow the stream did flow through the pits. There was substantial recovery of unvegetated channel width from 1967 to 1993. Current channel width is less than the 1964 pre-flood value, but still greater than preharvest conditions of 1955.

Site 3 experienced a sequence of channel changes very similar to site 2. High sediment loads aggraded the channel and produced a braided pattern. An adjacent gravel pit (present in the 1964 pre-flood photos) was not incorporated into the post-flood channel (1967), but appears to show signs of splays, probably formed during the high flood flow. A tight meander at the upstream end of this focus reach appeared to be associated with a large log jam visible in the 1952 and 1964 photos. The 1964 flood washed out the log jam and created a larger amplitude meander (present in the 1967 photos). Unvegetated channel width widened dramatically to over 100 meters. As in site

2, much of this widening had already occurred before the 1964 flood. The previous winter (1963/64) there was a 5 year recurrence interval peak flow. This moderately high flow must have been sufficient to trigger many road and slope failures. The high sediment loads, lack of riparian vegetation and moderate flow produced substantial channel widening prior to the December 1964 flood.

At site 3, open pasture next to the stream in the 1955 photos indicated some animal grazing activity next to the stream. This activity may have altered the channel, possibly widening it. The current channel has now recovered to a width slightly less than the original value in 1955.

All three sites experienced some widening of the unvegetated channel width. Site 3 had already widened prior to the 1964 flood and changed less dramatically between 1964 and 1967. The stream channel at each site changed location and sinuosity. Changes in simple sinuosity were minor, but total sinuosity increased considerably at sites 2 and 3. These sites developed braided channels during the large sediment loads input during the 1964 flood.

CHAPTER IV

DISCUSSION

Riparian Stand Composition

Changes in riparian vegetation, stream canopy closure and channel morphology have resulted from anthropogenic influences, natural causes and their interactions. How much each condition changed was reported in the previous chapter. This discussion will focus on how the changes in riparian condition are related to different land-uses occurring in the basin. This discussion will also review the low canopy closure values on mainstem channel segments and consider its future trajectory.

Riparian vegetation along the lower Mosby Creek mainstem was altered in the early part of this century when settlers arrived and converted the land to agricultural uses. Logging activities in the late 1800s and early 1900s were concentrated in the lowland areas that were easily accessible. This local area supported 31 sawmills in 1914 (Writers Discussion Group 1970). The lowlands around Cottage Grove, including lower Mosby Creek, likely supported extensive stands of conifer. These conifer stands supplied the local mills with logs for the first half of this century. Land-use activities since that time

have maintained riparian composition in a relatively steady-state condition (Figure 24). Conifer dominated stands occupy less than 10% of the lower mainstem riparian area in all years evaluated, with no recent increasing trends. There are some maturing stands of mixed species (MYS → MMS), but they occur as sparse stands occupying nearly 50% of streamside vegetation (Figure 3). The ability of these stands to supply large, woody debris to the lower mainstem of Mosby Creek has been poor to moderate for the 40 years evaluated in this study.

Recent changes to the Forest Practices Act (Oregon Dept. of Forestry 1994) and Lane County riparian rules (Lane Code 1992) provide greater protection for riparian vegetation than previously required. Neither of these regulations apply to exclusive farm use land. Considering that adjacent land-use remains predominantly agricultural, there is little indication that these riparian conditions will be improving under the current regulatory framework.

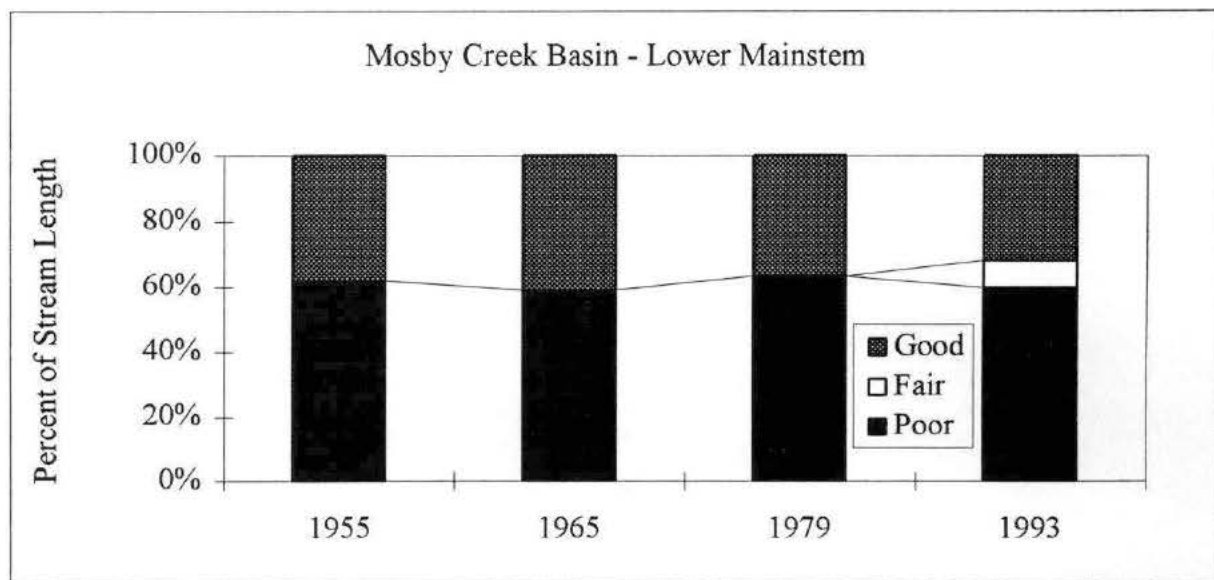


Figure 24. Mosby Creek lower mainstem LWD recruitment potential 1955 to 1993.

Tributaries in the lower basin flow through a patchwork of agricultural and forest management land-uses. Both activities have been practiced in this area for many decades. Old-growth conifer was all harvested before 1979 and current forest harvest is of trees that regenerated following activities early in this century. Riparian stands became poorer providers of LWD to the stream channels after the old-growth conifer was removed and are now showing minor improvements as the modest stream buffers left in the 1970s and 1980s are maturing to mixed, mature, and dense (MMD) stands (Figures 6 and 7). Trends are difficult to identify in this area of mixed land-use. Based on observations made from other areas in this basin under single, dominant land-use, most variations in riparian stand condition are probably due to forest management activities. Lower tributaries

flowing through agricultural lands are likely experiencing little variation, being maintained in poor to moderate condition similar to the lower mainstem.

During the period of this study, 90% of the previously unlogged upper basin was harvested. Pre-harvest riparian vegetation consisted of 57% old-growth conifer, 21% mature conifer, 19% mature hardwoods or mixed conifer and hardwoods and 3% young hardwoods. Hardwoods bordered 21% of the stream length in the upper basin before there was any evidence of agriculture, roading or timber harvest. In similar areas, the presence of deciduous species in the riparian area has been associated with recent and/or recurring disturbance such as natural flooding (Fonda 1974, Harris 1987, Gecy and Wilson 1990). The mature (> 40 yrs. old) deciduous and mixed riparian stands within the unharvested upper mainstem of Mosby Creek in 1955 may represent channel segments that experienced significant disturbance at the same time large floods were documented on the Willamette River in 1813, 1861 and 1890.

Post harvest forest regeneration in the upper basin riparian areas has been dominated by hardwoods (Figures 9 and 11). The upper mainstem flows through an unconfined valley bottom. This flat terrain allowed for ground-based harvest techniques which severely scarified the soils and provided conditions for robust hardwood establishment. Currently, 51% of the upper mainstem streamlength is dominated by young, deciduous stands and 39% by young, mixed vegetation. Upper basin tributaries, which experienced less ground based harvest techniques, are 38% young, deciduous dominated and 34% young, mixed dominated. The riparian areas that experienced less

ground disturbance exhibit less dominance by deciduous species. There are old-growth conifer stands (8%) where the tributaries flow through public land and young conifer stands (12%) where minimum ground disturbance and intensive silviculture have provided conditions for their establishment. LWD recruitment potential charts (Figures 10 and 12) show little improvement in conditions from 1979 to 1993. If we look at details of upper basin stand typing (Figure 25), there are indications of some improvement. Deciduous/young/dense (DYD) stands have decreased in abundance. There is a compensating increase in mixed/young/dense (MYD) and conifer/young/dense (CYD) stands. The increase in MYD and CYD stands shows an increasing presence of conifer in some locations. In spite of this shift in stand types, there still remains 41% deciduous dominated stands and 35% mixed stands.

Conifers in the mixed stands will eventually overtop the shade intolerant deciduous trees and suppress their growth. Surviving young conifer will be slow growing, shade tolerant species such as western redcedar or western hemlock. Deciduous stands will exclude shade intolerant conifers and slow the growth of shade tolerant conifer species. Both of these scenarios delay the establishment of dense conifer stands for at least several decades (Newton et al. 1968). The mixed stand, however, will provide some LWD recruitment potential in the interim.

Mosby Creek - Upper Basin

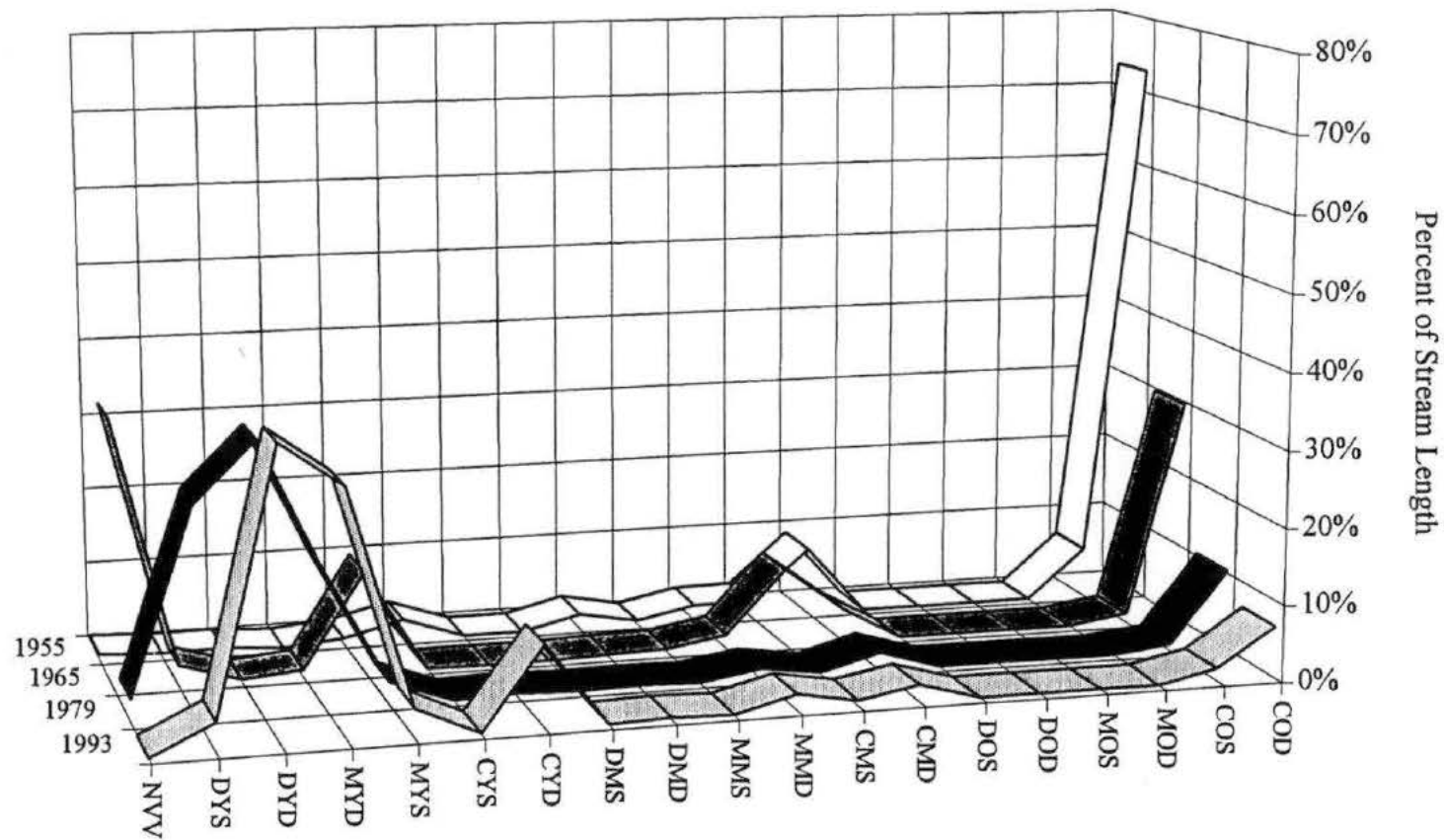


Figure 25. Percentage of riparian stand types along the Mosby Creek upper basin stream network from 1955 to 1993

Canopy Closure

The Mosby Creek basin went from a moderately high canopy closure in 1955 (69%) to very low values in 1965 (39%) and has recovered to a basin wide average (73%) that is slightly higher now (1993) than in 1955.

Timber harvest, conversion to agriculture, and continued agricultural land-uses in the lower Mosby Creek basin have maintained canopy closure at low values, particularly along the mainstem. None of the lower mainstem channel segments have canopy closure values greater than the 40-70% category. The wide bankfull channel and absence of old-growth conifer or other trees of comparable height maintains this condition. Shading along tributaries in the lower basin are stable at low values where the tributaries flow through agricultural lands. Current forest practice rules (Oregon Department of Forestry 1994) require streamside buffers to be left during harvest. These regulations will maintain and increase stream shading only where lower tributaries flow through forest lands.

Recent timber harvest in the upper basin produced a greater magnitude change in shade values than the lower basin (Figures 26 and 27). Preharvest upper mainstem shade was 68% in mostly old-growth conditions. It dropped to 17% near the end of harvest activities in 1965 and has returned to 40% in 1993.

Canopy closure on tributaries in the upper basin was 78% in preharvest old-growth riparian stand conditions. This value decreased to 43% in 1965 and in 1993 was

86%. Most of this increased canopy closure resulted from dense alder stands that established following disturbance from streamside timber harvest and the 1964 flood.

The transition from conifer to hardwood dominated riparian stands increased shade along tributaries in the upper Mosby Creek basin. This same shift in riparian vegetation has limited the recovery of shade along the upper mainstem of Mosby Creek. Hardwood trees such as red alder reach mature heights of only 60-80 feet (Newton et al. 1968) as compared to 150-250 feet for mature conifer trees (Randall et al. 1976). The spreading, phototropic habit of red alder is inadequate to compensate for its relatively low mature height when shading wide streams.

Canopy closure has increased slowly during the 30 years following harvest along the upper mainstem (Figure 27). Hardwood stands are limiting this shade recovery. Red Alder stands reach mature height in 30 to 40 years and suppress conifer growth until they reach senescence at about 60 to 80 years (Newton et al. 1968). Harvest of the Mosby Creek upper mainstem was mostly complete by 1965. Hardwood stands that regenerated following harvest are reaching their mature height. This means current shade conditions along the upper mainstem of Mosby Creek are no longer increasing and will not increase unless riparian vegetation is converted to species that reach greater height at maturity. Active riparian management could accelerate the transition out of this potentially long-term period of hardwood dominance (Oliver and Hinckley 1987, Bilby and Bisson 1991).

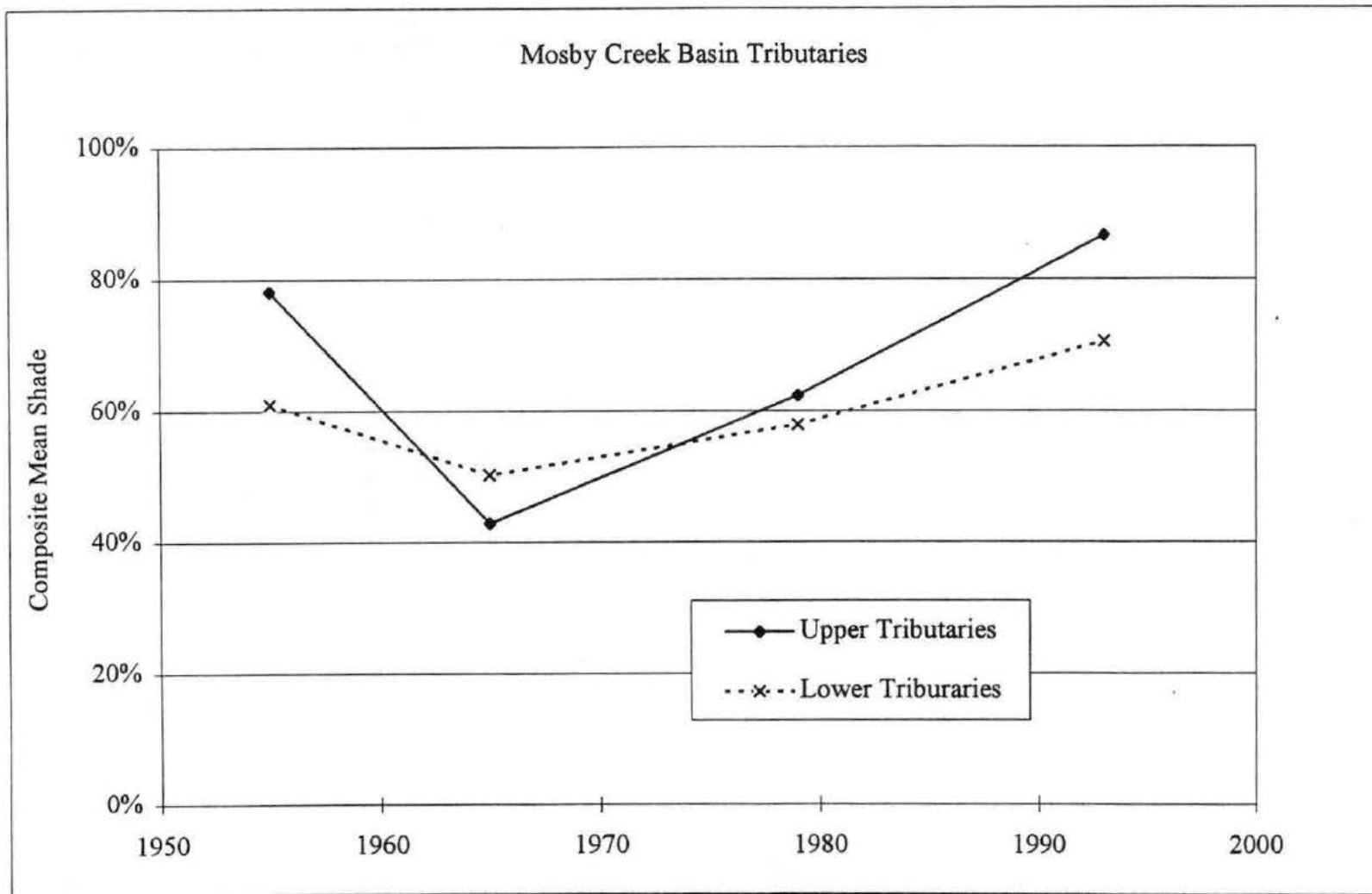


Figure 26. Comparison of changes in canopy closure along tributary channel segments within the Mosby Creek basin

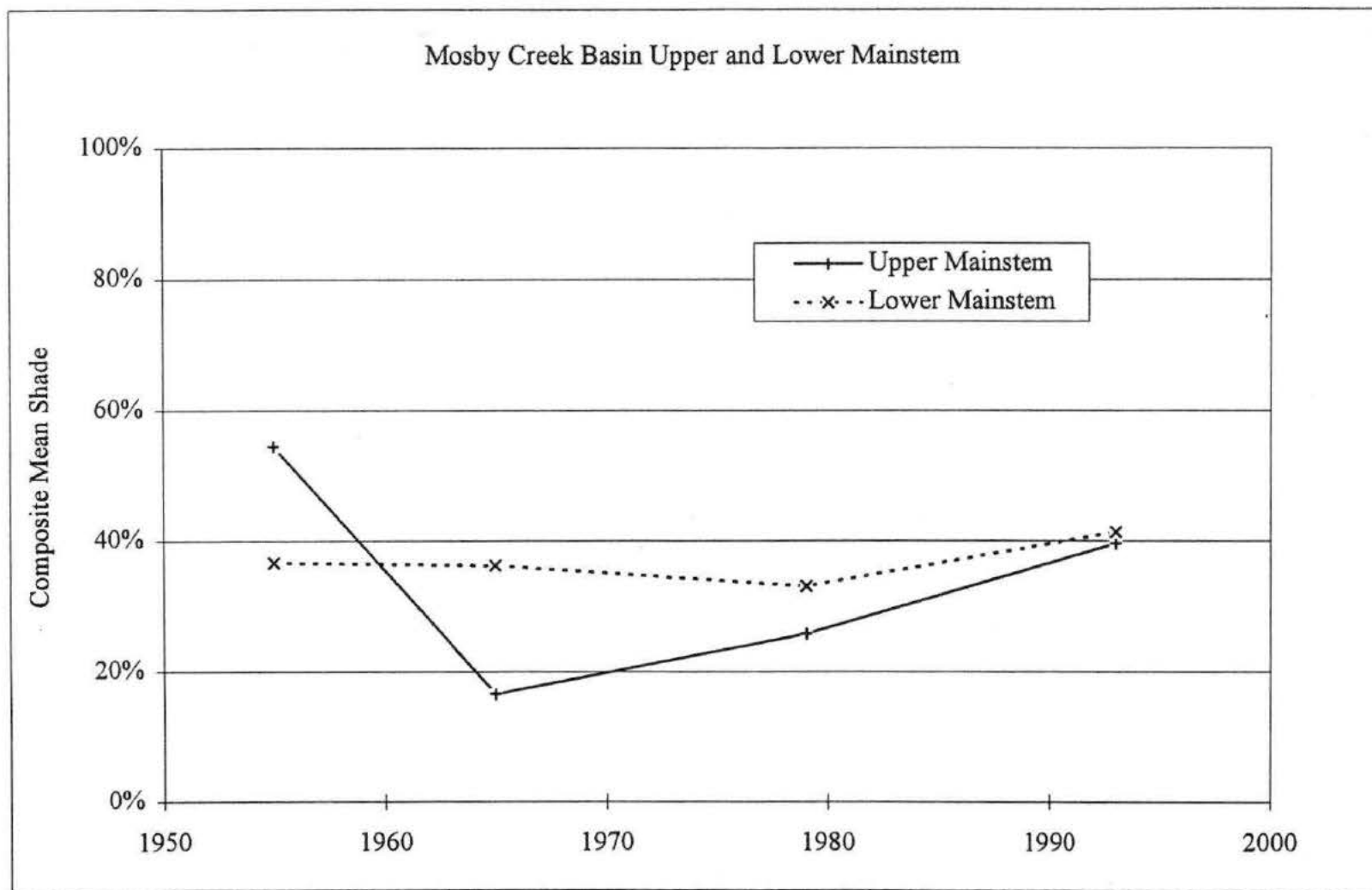


Figure 27. Comparison of changes in canopy closure along mainstem channel segments within the Mosby Creek Basin

Unvegetated Channel Width

Timber harvest and conversion to agriculture and residences were substantially complete along the lower mainstem by 1955. The relatively flat lines in Figure 14 show the effects of chronic anthropogenic disturbance and little change following the 1964 flood. Riparian vegetation had been altered decades earlier, was well established and supported some mature riparian stands (Figure 3) when the 1964 flood event occurred. The altered but intact riparian vegetation apparently buffered erosive forces during the flood and helped to protect stream channel banks. Aerial photo observations showed channel widening was limited to a few isolated locations on the lower mainstem.

Most of the riparian vegetation along the upper Mosby Creek mainstem had been removed just prior to the 1964 flood. Channel widening was severe (Table 9) where the extreme flows and high sediment loads scoured and deposited sediment along the poorly vegetated channel segments. This illustrates that the order and timing of hydrologic events and watershed disturbance (e.g. timber harvest) is important in determining the magnitude and types of effects experienced during a given event (Lyons and Beschta 1983, Sullivan et al. 1987). Unvegetated channel width recovered to values similar to pre-disturbance by 1993. These results are similar to channel width recoveries measured after floods elsewhere in the northwest (Lisle 1981, Lyons 1981).

Disturbance, Recovery, and Implications for Stream Restoration

Chronic anthropogenic disturbance in the lower basin is maintaining riparian stands in poor to moderate condition for providing shade and large wood. The continuation of these land-use activities prevents recovery of more mature and robust stands that would provide these riparian functions (Decamps et al. 1988). However, the time lapse since acute disturbance in the lower basin, such as vegetation removal, was sufficient to buffer some of the effects of severe flows during the 1964 flood.

Complete removal of riparian stands during timber harvest and its coincidence with the 1964 flood set up conditions for extensive hardwood establishment throughout much of the upper Mosby Creek basin. Important riparian functions associated with mature conifer stands common in the basin prior to harvest have been altered or removed. Although shading has recovered along smaller tributary channels, main channel shading remains poor. Cool water refugia may be associated with these well shaded tributaries (Bilby 1984), but mainstem temperatures are elevated (Beak Consultants 1993), likely above historical, pre-harvest conditions. Supplies of large wood to provide functions such as fish habitat and organic matter retention (Bisson et al. 1987) are not present and may not recover for several decades under current stand trajectories. Deliberate restoration projects may be appropriate and needed to accelerate the return of conditions necessary to support a healthy riparian/stream system (Oliver and Hinckley 1987).

Recent Oregon stream protection rules for state and private forest lands (Oregon Department of Forestry 1994) are designed to provide and maintain mature streamside conifer stands. Where conifers are lacking the rules encourage methods to accelerate their establishment. These rules require a specific amount (basal area) of conifer trees to be left during harvest so shade, large wood supplies and other riparian functions will be maintained. If a preharvest stand contains insufficient conifer basal area within a designated distance from the channel (e.g. hardwood dominated), then all trees in the designated area must be left. Leaving all trees would only maintain the hardwood dominated condition. Anticipating this scenario, the Department of Forestry encourages alternate plans that remove the hardwoods and establish conifers.

The history of land-use and natural disturbance in Mosby Creek basin is similar to many basins in the Pacific Northwest (Bisson et al. 1992). Conversion of lowlands to agriculture early in the century, and upland timber harvest continuing through periodic advancements in management practices, are common throughout this region. The timing of these land-use activities and natural disturbances such as the 1964 flood are variable. Some basins were harvested decades before the 1964 flood event (Polley 1984), while others were partially influenced by timber harvest activities at that time (Lyons and Beschta 1983). There is some historical commonality among basins. However, evaluating the historical record is necessary to understand the basin's particular sequence of events and how they have determined current conditions.

During the last 10 to 15 years, many stream restoration projects have been pursued in the Pacific Northwest (Andrus 1991), with mixed results or little evaluation (Frissell and Nawa 1992). Most of these projects focus on placing structural elements in the stream channel to provide fish habitat where there is an apparent lack of pools and cover. Mosby Creek is lacking these types of fish habitat features (ODFW 1990) and is a candidate for similar projects (pers. comm. Neil Armantrout, BLM aquatic biologist). It is my intent that this historical analysis of disturbance in this basin will provide a temporal and spatial understanding of changes in key riparian functions and that this may aid in designing appropriate strategies for restoring these functions.

Public and private interest in restoring degraded conditions is largely based on people's perception of change during their lifetime. Timber harvest during the last 40 years altered our view of the landscape and triggered a public interest in regulating this activity (Oregon Forest Practices Act 1972, Bisson et al. 1992). Agriculturally managed lowlands, and the streams that flow through them, have been in their current condition since before most of us were born (Sedell and Froggatt 1984). Today's population has not witnessed a change in this lowland setting, generally does not perceive degraded conditions and therefore is mostly unaware of any restoration needs or regulatory protection. This study has described severe changes to forestland riparian stands and the need to develop management techniques that will accelerate the return of riparian functions. Once returned, these attributes should be protected by continually improving forest management and associated regulations (Oregon Department of Forestry 1994).

This report should also illuminate the generally poor conditions that have existed in our own backyards for decades and highlight the need to restore and protect these areas as the downstream extension of the same stream network.

APPENDIX A

KEY TO STREAM SEGMENTS

Table 10. Key to stream segment code

	Key to Stream Segment Code		
	Mosby Creek		
Code	Mainstem	Tributary	Sub-trib
101000	Mouth to Kizer		
101010		Champion	
101020		Kizer	
102000	Kizer to Perkins		
102030		Unnamed (19-21S-2W)	
102040		Perkins	
103000	Perkins to Kennedy		
103050		Kennedy	
104000	Kennedy to Unnamed (32-21S-2W)		
104060		Smith	
104070		Unnamed (32-21S-2W)	
105000	Unnamed (32-21S-2W) to Lewis		
105080		Blue	
105090		Simpson	
105100		Lewis	
106000	Lewis to Cow		
106110		Rock	
106111			North Fork
106112			South Fork
106120		Palmer	
106130		Cow	
107000	Cow to Cedar		
107140		Clearing	
107150		Cedar	
108000	Cedar to Allen		
108160		Allen	
109000	Allen to Table Rock		
109170		Steel	
109171			North Fork
109172			Middle Fork
109173			South Fork
109180		Table Rock	
109181			Bark Shanty

Table 10 (cont.). Key to stream segment code

Key to Stream Segment Code (cont.)			
	Mosby Creek		
Code	Mainstem	Tributary	Sub-trib
110000	Table Rock to Dahl		
110190		Big Dry	
110191			West Fork
110192			Middle Fork
110193			East Fork
110200		Unnamed (26-22S-2W)	
110210		Little Dry	
110220		Dahl	
111000	Dahl to Norwegian		
111230		Norwegian	
112000	Norwegian to Lilly		
112240		Gray	
112250		Shea	
112260		Brownie	
112261			North Fork
112262			South Fork
112270		Lilly	
113000	Lilly to Tom		
113280		Jones	
113290		Miles	
113300		Tom	
114000	Tom to Cove		
114310		Unnamed (19-23S-1W)[R]	
114320		Unnamed (19-23S-1W)[L]	
114330		Cove	
115000	Cove to East Fork Mosby		
115340		West Fork Mosby	
115350		Middle Fork Mosby	
115351			Broken Leg
115352			Upper Mid Fork
115360		East Fork Mosby	

APPENDIX B

KEY TO RIPARIAN STAND TYPE CODES

Table 11. Fold-out riparian stand type key

Riparian Stand Type Key

Code	Stand Type
COD	Conifer/Old/Dense
COS	Conifer/Old/Sparse
MOD	Mixed/Old/Dense
MOS	Mixed/Old/Sparse
DOD	Deciduous/Old/Dense
DOS	Deciduous/Old/Sparse
CMD	Conifer/Mature/Dense
CMS	Conifer/Mature/Sparse
MMD	Mixed/Mature/Dense
MMS	Mixed/Mature/Sparse
DMD	Deciduous/Mature/Dense
DMS	Deciduous/Mature/Sparse
CYD	Conifer/Young/Dense
CYS	Conifer/Young/Sparse
MYS	Mixed/Young/Sparse
MYD	Mixed/Young/Dense
DYD	Deciduous/Young/Dense
DYS	Deciduous/Young/Sparse
NVV	No Visible Vegetation

Riparian Stand Type Key

Code	Stand Type
COD	Conifer/Old/Dense
COS	Conifer/Old/Sparse
MOD	Mixed/Old/Dense
MOS	Mixed/Old/Sparse
DOD	Deciduous/Old/Dense
DOS	Deciduous/Old/Sparse
CMD	Conifer/Mature/Dense
CMS	Conifer/Mature/Sparse
MMD	Mixed/Mature/Dense
MMS	Mixed/Mature/Sparse
DMD	Deciduous/Mature/Dense
DMS	Deciduous/Mature/Sparse
CYD	Conifer/Young/Dense
CYS	Conifer/Young/Sparse
MYS	Mixed/Young/Sparse
MYD	Mixed/Young/Dense
DYD	Deciduous/Young/Dense
DYS	Deciduous/Young/Sparse
NVV	No Visible Vegetation

APPENDIX C

RIPARIAN STAND SUMMARIES

Table 12. Length of riparian stand types in 1952/1955 for each channel segment

Channel					Riparian Stand Type (length in thousand feet)																
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total	
101000		3.25			17.90					0.70	7.40		3.65							32.90	
101010					23.40						4.70									28.10	
101020		12.00	2.40										6.00							20.40	
102000					5.45					6.00	7.85									19.30	
102030					2.30						4.60									6.90	
102040			21.50																	21.50	
103000					13.30						4.50									17.80	
103050		3.80										1.70	4.40							9.90	
104000					4.30						8.10									12.40	
104060																			15.70	15.70	
104070																			6.40	6.40	
105000			1.15			15.15					1.15		3.35							20.80	
105080												5.20							1.60	6.80	
105090																			12.50	12.50	
105100						2.45													14.45	16.90	
106000		2.30			1.80	2.30			1.15				2.30						9.85	19.70	
106110																			10.70	10.70	
106111																			9.90	9.90	
106112																			11.90	11.90	
106120													4.90						10.70	15.60	
106130					3.40														11.80	15.20	
107000		0.20			0.20				2.80		2.90		5.90							12.00	
107140													4.00						11.30	15.30	
107150																			30.80	30.80	
108000												6.30	2.60							8.90	
108160	5.2																		20.50	25.70	
109000												2.65	8.35						3.90	14.90	
109170																		5.20	2.20	7.40	
109171																			17.30	17.30	
109172																			8.60	8.60	
109173																			11.50	11.50	
109180																			14.40	14.40	
109181																			8.80	8.80	

Table 12 (cont.). Length of riparian stand types in 1952/1955 for each channel segment

Channel Segment	NVV	DYS	DYD	MYD	Riparian Stand Type (length in thousand feet)										DOS	DOD	MOS	MOD	COS	COD	Total
110000			2.25								3.00	1.95								17.50	24.70
110190																			5.60	13.90	19.50
110191																				9.30	9.30
110192																				7.20	7.20
110193													2.80							4.80	7.60
110200																				5.90	5.90
110210													10.20								10.20
110220																				30.20	30.20
111000																			0.95	6.05	7.00
111230																			4.60	11.30	15.90
112000								0.75					1.05						1.10	11.20	14.10
112240													1.40							15.10	16.50
112250																			6.40	8.50	14.90
112260																			4.00	7.60	11.60
112261																				13.50	13.50
112262																				10.50	10.50
112270																			13.60		13.60
113000								4.05			0.80		0.35							3.50	8.70
113280																				4.30	4.30
113290																			7.00	14.00	21.00
113300																				8.40	8.40
114000								0.25			2.15		3.20							6.30	11.90
114310																				6.20	6.20
114320																				7.20	7.20
114330																				14.50	14.50
115000								4.90			0.70		0.70								6.30
115340										3.30	2.00		7.20							16.00	28.50
115350													3.20							4.20	7.40
115351																				20.10	20.10
115352													3.80							15.50	19.30
115360											2.20									18.00	20.20

Table 13. Percent of riparian stand types in 1952/1955 for each channel segment, summarized by subbasin

					Riparian Stand Type (total length in 1000 ft and percent of subarea)																
Subarea	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total	
Basin	5.2	21.6	27.3	0	72.1	19.9	0	0	13.9	10	52.05	17.8	79.35	0	0	0	0	48.5	555.55	923.1	
Basin	1%	2%	3%	0%	8%	2%	0%	0%	2%	1%	6%	2%	9%	0%	0%	0%	0%	5%	60%	100%	
Mainstem	0	5.75	3.4	0	43	17.5	0	0	13.9	6.7	38.55	10.9	31.45	0	0	0	0	2.05	58.3	231.4	
Mainstem	0%	2%	1%	0%	19%	8%	0%	0%	6%	3%	17%	5%	14%	0%	0%	0%	0%	1%	25%	100%	
Tributaries	5.2	15.8	23.9	0	29.1	2.45	0	0	0	3.3	13.5	6.9	47.9	0	0	0	0	46.4	497.25	691.7	
Tributaries	1%	2%	3%	0%	4%	0%	0%	0%	0%	0%	2%	1%	7%	0%	0%	0%	0%	7%	72%	100%	
Upper Basin	5.2	2.5	3.4	0	5.4	19.9	0	0	13.9	3.3	14.9	16.1	65.3	0	0	0	0	48.5	533.45	731.8	
Upper Basin	1%	0%	0%	0%	1%	3%	0%	0%	2%	0%	2%	2%	9%	0%	0%	0%	0%	7%	73%	100%	
Upper Mainstem	0	2.5	3.4	0	2	17.5	0	0	13.9	0	10.7	10.9	27.8	0	0	0	0	2.05	58.3	149	
Upper Mainstem	0%	2%	2%	0%	1%	12%	0%	0%	9%	0%	7%	7%	19%	0%	0%	0%	0%	1%	39%	100%	
Upper Tributaries	5.2	0	0	0	3.4	2.45	0	0	0	3.3	4.2	5.2	37.5	0	0	0	0	46.4	475.15	582.8	
Upper Tributaries	1%	0%	0%	0%	1%	0%	0%	0%	0%	1%	1%	1%	6%	0%	0%	0%	0%	8%	82%	100%	
Lower Basin	0	19.1	23.9	0	66.7	0	0	0	0	6.7	37.15	1.7	14.05	0	0	0	0	0	22.1	191.3	
Lower Basin	0%	10%	12%	0%	35%	0%	0%	0%	0%	4%	19%	1%	7%	0%	0%	0%	0%	0%	12%	100%	
Lower Mainstem	0	3.25	0	0	41	0	0	0	0	6.7	27.85	0	3.65	0	0	0	0	0	0	82.4	
Lower Mainstem	0%	4%	0%	0%	50%	0%	0%	0%	0%	8%	34%	0%	4%	0%	0%	0%	0%	0%	0%	100%	
Lower Tributaries	0	15.8	23.9	0	25.7	0	0	0	0	0	9.3	1.7	10.4	0	0	0	0	0	22.1	108.9	
Lower Tributaries	0%	15%	22%	0%	24%	0%	0%	0%	0%	0%	9%	2%	10%	0%	0%	0%	0%	0%	20%	100%	
Upper (partially harvested)	0	2.5	1.15	0	2	17.5	0	0	3.95	0	4.05	6.3	14.15	0	0	0	0	0	9.85	61.4	
Partially Harvested	0%	4%	2%	0%	3%	28%	0%	0%	6%	0%	7%	10%	23%	0%	0%	0%	0%	0%	16%	100%	
Upper (unharvested)	0	0	2.25	0	0	0	0	0	9.95	0	6.65	4.6	13.65	0	0	0	0	2.05	48.45	87.6	
Unharvested	0%	0%	3%	0%	0%	0%	0%	0%	11%	0%	8%	5%	16%	0%	0%	0%	0%	2%	55%	100%	

Table 14. Length of riparian stand types in 1964 for each channel segment

Channel																				
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total
101000		10.80		4.10	5.90						8.90		3.20							32.90
101010		9.10		19.00																28.10
101020		1.50			11.10		5.80				2.00									20.40
102000					6.10					5.75	7.45									19.30
102030													6.90							6.90
102040		4.80		11.70	5.00															21.50
103000					11.10						6.70									17.80
103050		4.00										3.40	2.50							9.90
104000					2.55					2.30	7.20		0.35							12.40
104060	4.00											3.70	4.40						3.60	15.70
104070	4.55												1.85							6.40
105000					16.40						1.00		3.40							20.80
105080				1.60							4.35	0.85								6.80
105090		12.50																		12.50
105100	11.00				5.90															16.90
106000			1.95		15.80				1.95											19.70
106110	6.30																		4.40	10.70
106111	9.30																		0.60	9.90
106112	11.30																		0.60	11.90
106120	12.70												2.90							15.60
106130	11.40										3.80									15.20
107000		0.95		0.90	1.55						2.60	4.55	1.45							12.00
107140	9.00																		6.30	15.30
107150	24.60																		6.20	30.80
108000		6.10										1.10	1.70							8.90
108160	11.30			4.70															9.70	25.70
109000					11.00							2.40	1.50							14.90
109170	7.40																			7.40
109171												1.60							15.70	17.30
109172	1.50																		7.10	8.60
109173	7.90																		3.60	11.50
109180	14.40																			14.40
109181	8.80																			8.80

Table 14 (cont.). Length of riparian stand types in 1964 for each channel segment

Channel Segment	NVV	DYS	DYD	MYD	Riparian Stand Type (length in thousand feet)								CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total
110000	3.50				17.70								2.10							1.40	24.70
110190	6.95												6.40						2.20	3.95	19.50
110191																				9.30	9.30
110192	1.60																			2.00	3.60
110193	2.90													2.90						1.80	7.60
110200	5.90																				5.90
110210	6.90												3.30								10.20
110220	18.70																			11.50	30.20
111000					3.50															3.50	7.00
111230	3.80												4.45							7.65	15.90
112000					12.55															1.55	14.10
112240	4.50													6.00						6.00	16.50
112250	4.00																		6.60	4.30	14.90
112260													11.60								11.60
112261													2.10							11.40	13.50
112262													3.20							7.30	10.50
112270	13.60																				13.60
113000					8.50								0.20								8.70
113280	4.30																				4.30
113290	8.90																			12.10	21.00
113300	8.40																				8.40
114000					4.00								7.90								11.90
114310	6.20																				6.20
114320																				7.20	7.20
114330	7.25												1.75							5.50	14.50
115000													6.30								6.30
115340										3.40	1.80			7.40						15.90	28.50
115350													5.05							2.35	7.40
115351																				20.10	20.10
115352														3.90						15.40	19.30
115360													8.75							11.45	20.20

Table 15. Percent of riparian stand types in 1964 for each channel segment, summarized by subbasin

Subarea	Riparian Stand Type (total length in 1000 ft and percent of subarea)																			Total
	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	
Basin	263	49.8	1.95	42	138.7	0	5.8	0	1.95	11.45	45.8	80.7	50.35	0	0	0	0	8.8	219.45	919.5
Basin	29%	5%	0%	5%	15%	0%	1%	0%	0%	1%	5%	9%	5%	0%	0%	0%	0%	1%	24%	100%
Mainstem	3.5	17.9	1.95	5	116.7	0	0	0	1.95	8.05	33.85	24.55	11.6	0	0	0	0	0	6.45	231.4
Mainstem	2%	8%	1%	2%	50%	0%	0%	0%	1%	3%	15%	11%	5%	0%	0%	0%	0%	0%	3%	100%
Tributaries	259	31.9	0	37	22	0	5.8	0	0	3.4	11.95	56.15	38.75	0	0	0	0	8.8	213	688.1
Tributaries	38%	5%	0%	5%	3%	0%	1%	0%	0%	0%	2%	8%	6%	0%	0%	0%	0%	1%	31%	100%
Upper Basin	254	19.6	1.95	7.2	96.9	0	0	0	1.95	3.4	13.55	73.6	31.15	0	0	0	0	8.8	215.85	728.2
Upper Basin	35%	3%	0%	1%	13%	0%	0%	0%	0%	0%	2%	10%	4%	0%	0%	0%	0%	1%	30%	100%
Upper Mainstem	3.5	7.05	1.95	0.9	91	0	0	0	1.95	0	3.6	24.55	8.05	0	0	0	0	0	6.45	149
Upper Mainstem	2%	5%	1%	1%	61%	0%	0%	0%	1%	0%	2%	16%	5%	0%	0%	0%	0%	0%	4%	100%
Upper Tributaries	251	12.5	0	6.3	5.9	0	0	0	0	3.4	9.95	49.05	23.1	0	0	0	0	8.8	209.4	579.2
Upper Tributaries	43%	2%	0%	1%	1%	0%	0%	0%	0%	1%	2%	8%	4%	0%	0%	0%	0%	2%	36%	100%
Lower Basin	8.55	30.2	0	34.8	41.75	0	5.8	0	0	8.05	32.25	7.1	19.2	0	0	0	0	0	3.6	191.3
Lower Basin	4%	16%	0%	18%	22%	0%	3%	0%	0%	4%	17%	4%	10%	0%	0%	0%	0%	0%	2%	100%
Lower Mainstem	0	10.8	0	4.1	25.65	0	0	0	0	8.05	30.25	0	3.55	0	0	0	0	0	0	82.4
Lower Mainstem	0%	13%	0%	5%	31%	0%	0%	0%	0%	10%	37%	0%	4%	0%	0%	0%	0%	0%	0%	100%
Lower Tributaries	8.55	19.4	0	30.7	16.1	0	5.8	0	0	0	2	7.1	15.65	0	0	0	0	0	3.6	108.9
Lower Tributaries	8%	18%	0%	28%	15%	0%	5%	0%	0%	0%	2%	7%	14%	0%	0%	0%	0%	0%	3%	100%

Table 16. Length of riparian stand types in 1979 for each channel segment

Channel					Riparian Stand Type (length in thousand feet)																	
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total		
101000		8.95		3.55	1.05					7.50	8.90		2.95							32.90		
101010		9.20	13.10	5.80																28.10		
101020		9.35	1.80										9.25							20.40		
102000		1.75			0.75					11.30	5.50									19.30		
102030		1.20							5.70											6.90		
102040		4.20	2.30							5.00	10.00									21.50		
103000			1.10							9.85	6.85									17.80		
103050		2.30	4.90								2.70									9.90		
104000		1.05		2.00						3.20	3.35		2.80							12.40		
104060		13.60		2.10																15.70		
104070			6.40																	6.40		
105000		12.05	3.50		1.10								4.15							20.80		
105080		1.80	3.50	1.50																6.80		
105090			12.50																	12.50		
105100			5.80	11.10																16.90		
106000		5.50	8.70	2.90					1.15		1.45									19.70		
106110		3.30	7.40																	10.70		
106111				9.90																9.90		
106112		0.60	3.60	7.70																11.90		
106120			15.60																	15.60		
106130			7.80	7.40																15.20		
107000		4.85	7.15																	12.00		
107140		2.20	7.90																5.20	15.30		
107150		3.00	11.80	13.10															2.90	30.80		
108000		3.00	5.90																	8.90		
108160		2.60		14.10															9.00	25.70		
109000		1.10			12.60														1.20	14.90		
109170				4.60	2.80															7.40		
109171			17.30																	17.30		
109172		7.50		1.10																8.60		
109173		4.40		7.10																11.50		
109180				14.40																14.40		
109181				8.80																8.80		

Table 16 (cont.). Length of riparian stand types in 1979 for each channel segment

Channel					Riparian Stand Type (length in thousand feet)																		
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total			
110000		6.45	9.90	6.30			2.05													24.70			
110190		19.50																		19.50			
110191		3.05																3.05	3.20	9.30			
110192																			7.20	7.20			
110193	1.90	4.30	1.40																	7.60			
110200				5.90																5.90			
110210		2.20		6.70								1.30								10.20			
110220		14.10	9.60																6.50	30.20			
111000		3.50	3.50																	7.00			
111230		11.40	4.50																	15.90			
112000		4.95	9.15																	14.10			
112240		10.40									1.70		4.40							16.50			
112250		2.20			4.10													3.40	5.20	14.90			
112260			11.60																	11.60			
112261	8.70		2.10																2.70	13.50			
112262		1.00	3.40																6.10	10.50			
112270			13.60																	13.60			
113000		7.10	1.60																	8.70			
113280			4.30																	4.30			
113290		12.00	9.00																	21.00			
113300			8.40																	8.40			
114000			11.90																	11.90			
114310				6.20																6.20			
114320		6.00			0.60								0.60							7.20			
114330	1.55	5.65	7.30																	14.50			
115000			6.30																	6.30			
115340		20.00	1.70								4.00								2.80	28.50			
115350			7.40																	7.40			
115351	0.30	2.40	3.50								1.90								12.00	20.10			
115352	3.40	1.50											8.00						6.40	19.30			
115360	5.70	6.00	3.40																5.10	20.20			

Table 17. Percent of riparian stand types in 1979 for each channel segment, summarized by subbasin

Subarea	Riparian Stand Type (total length in 1000 ft and percent of subarea)																			Total
	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	
Basin	21.6	247	282	142	23	0	2.05	0	6.85	36.85	46.35	1.3	32.2	0	0	0	0	6.45	75.5	923.1
Basin	2%	27%	31%	15%	2%	0%	0%	0%	1%	4%	5%	0%	3%	0%	0%	0%	0%	1%	8%	100%
Mainstem	0	60.3	68.7	14.8	15.5	0	2.05	0	1.15	31.85	26.05	0	9.9	0	0	0	0	0	1.2	231.4
Mainstem	0%	26%	30%	6%	7%	0%	1%	0%	0%	14%	11%	0%	4%	0%	0%	0%	0%	0%	1%	100%
Tributaries	21.6	187	213	128	7.5	0	0	0	5.7	5	20.3	1.3	22.3	0	0	0	0	6.45	74.3	691.7
Tributaries	3%	27%	31%	18%	1%	0%	0%	0%	1%	1%	3%	0%	3%	0%	0%	0%	0%	1%	11%	100%
Upper Basin	21.6	196	252	129	21.2	0	2.05	0	1.15	0	9.05	1.3	17.2	0	0	0	0	6.45	75.5	731.8
Upper Basin	3%	27%	34%	18%	3%	0%	0%	0%	0%	0%	1%	0%	2%	0%	0%	0%	0%	1%	10%	100%
Upper Mainstem	0	48.5	67.6	9.2	13.7	0	2.05	0	1.15	0	1.45	0	4.15	0	0	0	0	0	1.2	149
Upper Mainstem	0%	33%	45%	6%	9%	0%	1%	0%	1%	0%	1%	0%	3%	0%	0%	0%	0%	0%	1%	100%
Upper Tributaries	21.6	147	184	120	7.5	0	0	0	0	0	7.6	1.3	13	0	0	0	0	6.45	74.3	582.8
Upper Tributaries	4%	25%	32%	21%	1%	0%	0%	0%	0%	0%	1%	0%	2%	0%	0%	0%	0%	1%	13%	100%
Lower Basin	0	51.6	29.6	13.5	1.8	0	0	0	5.7	36.85	37.3	0	15	0	0	0	0	0	0	191.3
Lower Basin	0%	27%	15%	7%	1%	0%	0%	0%	3%	19%	19%	0%	8%	0%	0%	0%	0%	0%	0%	100%
Lower Mainstem	0	11.8	1.1	5.55	1.8	0	0	0	0	31.85	24.6	0	5.75	0	0	0	0	0	0	82.4
Lower Mainstem	0%	14%	1%	7%	2%	0%	0%	0%	0%	39%	30%	0%	7%	0%	0%	0%	0%	0%	0%	100%
Lower Tributaries	0	39.9	28.5	7.9	0	0	0	0	5.7	5	12.7	0	9.25	0	0	0	0	0	0	108.9
Lower Tributaries	0%	37%	26%	7%	0%	0%	0%	0%	5%	5%	12%	0%	8%	0%	0%	0%	0%	0%	0%	100%

Table 18. Length of riparian stand types in 1993 for each channel segment. Sediment influenced segments are shaded

Channel					Riparian Stand Type (length in thousand feet)																	
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total		
101000		7.75	1.05		1.40					8.20	12.20		2.30							32.90		
101010		7.20								5.35	15.55									28.10		
101020		13.40											7.00							20.40		
102000		3.85								9.00	3.40	3.05								19.30		
102030		2.10									4.80									6.90		
102040				5.40						10.70	5.40									21.50		
103000			1.10						1.60	9.15	5.40	0.55								17.80		
103050			3.40		3.50							3.00								9.90		
104000				5.45					1.45	2.20	3.00	0.30								12.40		
104060			7.60	4.50			3.60													15.70		
104070			2.50	3.90																6.40		
105000		5.95	5.00	3.35	2.20						2.15		2.15							20.80		
105080							1.60				5.20									6.80		
105090			12.50																	12.50		
105100			15.50	1.40																16.90		
106000		3.80	9.80	2.50					1.90		1.70									19.70		
106110			10.70																	10.70		
106111				2.40			7.50													9.90		
106112			4.20	7.70																11.90		
106120			15.60																	15.60		
106130			7.90				7.30													15.20		
107000		3.35	6.75	1.90																12.00		
107140			5.90	8.40														1.00		15.30		
107150			5.20	18.20			4.40												3.00	30.80		
108000		2.65	2.40	3.65															0.20	8.90		
108160		2.20					16.50											2.90	4.10	25.70		
109000		0.70		9.90	2.40		1.25												0.65	14.90		
109170				7.40																7.40		
109171			3.30	14.00																17.30		
109172				1.70			6.90													8.60		
109173				11.50																11.50		
109180			9.70	2.00			2.70													14.40		
109181							8.80													8.80		

Table 18 (cont.). Length of riparian stand types in 1993 for each channel segment. Sediment influenced segments are shaded

Channel	Riparian Stand Type (length in thousand feet)																			Total
Segment	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total
110000		2.85	11.05	5.85	2.25		2.70													24.70
110190			2.90	16.60																19.50
110191			2.85									1.15						1.60	3.70	9.30
110192			2.00																5.20	7.20
110193			5.90	1.70																7.60
110200							5.90													5.90
110210				5.80			4.40													10.20
110220			22.50	2.50															5.20	30.20
111000			1.30	4.10	1.60															7.00
111230			7.70	8.20																15.90
112000			3.70	9.30	0.50		0.60													14.10
112240			4.10	7.00							1.70		3.70							16.50
112250			4.40	1.80														4.30	4.40	14.90
112280			11.60																	11.60
112261			2.10	3.00	5.60														2.80	13.50
112262			1.50	1.90	3.10							4.00								10.50
112270			13.60																	13.60
113000			8.05	0.65																8.70
113280				4.30																4.30
113290				21.00																21.00
113300			6.90	1.50																8.40
114000			6.30	5.00	0.60															11.90
114310							6.20													6.20
114320				7.20																7.20
114330			7.10	6.95			0.45													14.50
115000			3.00	1.80	1.50															6.30
115340		0.60	7.10	16.70							4.10									28.50
115350			7.40																	7.40
115351			5.20	0.60	1.80								2.00						10.50	20.10
115352		3.60			0.90								8.20					2.60	4.00	19.30
115360		1.40	8.90		4.60														5.30	20.20

Table 19. Percent of riparian stand types in 1993 for each channel segment, summarized by subbasin and sediment influence

					Riparian Stand Type (total length in 1000 ft and percent of subarea)																	
Subarea	NVV	DYS	DYD	MYD	MYS	CYS	CYD	DMS	DMD	MMS	MMD	CMS	CMD	DOS	DOD	MOS	MOD	COS	COD	Total		
Basin	0	61.4	287.25	248.7	31.95	0	80.8	0	4.95	44.6	64.6	12.05	25.35	0	0	0	0	12.4	49.05	923.1		
Basin	0%	7%	31%	27%	3%	0%	9%	0%	1%	5%	7%	1%	3%	0%	0%	0%	0%	1%	5%	100%		
Mainstem	0	30.9	59.5	53.45	12.45	0	4.55	0	4.95	28.55	27.85	3.9	4.45	0	0	0	0	0	0.85	231.4		
Mainstem	0%	13%	26%	23%	5%	0%	2%	0%	2%	12%	12%	2%	2%	0%	0%	0%	0%	0%	0%	100%		
Tributaries	0	30.5	227.75	195.25	19.5	0	76.25	0	0	16.05	36.75	8.15	20.9	0	0	0	0	12.4	48.2	691.7		
Tributaries	0%	4%	33%	28%	3%	0%	11%	0%	0%	2%	5%	1%	3%	0%	0%	0%	0%	2%	7%	100%		
Upper Basin	0	27.1	271.6	229.45	27.05	0	77.2	0	1.9	0	14.85	5.15	16.05	0	0	0	0	12.4	49.05	731.8		
Upper Basin	0%	4%	37%	31%	4%	0%	11%	0%	0%	0%	2%	1%	2%	0%	0%	0%	0%	2%	7%	100%		
Upper Mainstem	0	19.3	57.35	48	11.05	0	4.55	0	1.9	0	3.85	0	2.15	0	0	0	0	0	0.85	149		
Upper Mainstem	0%	13%	38%	32%	7%	0%	3%	0%	1%	0%	3%	0%	1%	0%	0%	0%	0%	0%	1%	100%		
Upper Tributaries	0	7.8	214.25	181.45	16	0	72.65	0	0	0	11	5.15	13.9	0	0	0	0	12.4	48.2	582.8		
Upper Tributaries	0%	1%	37%	31%	3%	0%	12%	0%	0%	0%	2%	1%	2%	0%	0%	0%	0%	2%	8%	100%		
Lower Basin	0	34.3	15.65	19.25	4.9	0	3.6	0	3.05	44.6	49.75	6.9	9.3	0	0	0	0	0	0	191.3		
Lower Basin	0%	18%	8%	10%	3%	0%	2%	0%	2%	23%	26%	4%	5%	0%	0%	0%	0%	0%	0%	100%		
Lower Mainstem	0	11.6	2.15	5.45	1.4	0	0	0	3.05	28.55	24	3.9	2.3	0	0	0	0	0	0	82.4		
Lower Mainstem	0%	14%	3%	7%	2%	0%	0%	0%	4%	35%	29%	5%	3%	0%	0%	0%	0%	0%	0%	100%		
Lower Tributaries	0	22.7	13.5	13.8	3.5	0	3.6	0	0	16.05	25.75	3	7	0	0	0	0	0	0	108.9		
Lower Tributaries	0%	21%	12%	13%	3%	0%	3%	0%	0%	15%	24%	3%	6%	0%	0%	0%	0%	0%	0%	100%		
Mainstem Clean	0	24.7	24.35	38.25	8.1	0	1.85	0	4.95	28.55	27.85	3.9	4.45	0	0	0	0	0	0.85	167.8		
Mainstem Clean	0%	15%	15%	23%	5%	0%	1%	0%	3%	17%	17%	2%	3%	0%	0%	0%	0%	0%	1%	100%		
Mainstem Slide	0	6.2	35.15	15.2	4.35	0	2.7	0	0	0	0	0	0	0	0	0	0	0	0	63.6		
Mainstem Slide	0%	10%	55%	24%	7%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%		
Tributaries Clean	0.00	30.50	145.75	116.80	19.50	0.00	59.90	0.00	0.00	16.05	36.75	8.15	20.90	0.00	0.00	0.00	0.00	7.10	40.80	502.20		
Tributaries Clean	0%	6%	29%	23%	4%	0%	12%	0%	0%	3%	7%	2%	4%	0%	0%	0%	0%	1%	8%	100%		
Tributaries Slide	0.00	0.00	82.00	78.45	0.00	0.00	16.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	7.40	189.50		
Tributaries Slide	0%	0%	43%	41%	0%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	4%	100%		
Upper Mainstem Clean	0.00	13.10	22.20	32.80	6.70	0.00	1.85	0.00	1.90	0.00	3.85	0.00	2.15	0.00	0.00	0.00	0.00	0.00	0.85	85.40		
Upper Mainstem Non-Slide	0%	15%	26%	38%	8%	0%	2%	0%	2%	0%	5%	0%	3%	0%	0%	0%	0%	0%	1%	100%		
Upper Mainstem Slide	0.00	6.20	35.15	15.20	4.35	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.60			
Upper Mainstem Slide	0%	10%	55%	24%	7%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%		
Upper Tributaries Clean	0.00	7.80	132.25	103.00	16.00	0.00	56.30	0.00	0.00	0.00	11.00	5.15	13.90	0.00	0.00	0.00	0.00	7.10	40.80	393.30		
Upper Tributaries Non-Slide	0%	2%	34%	26%	4%	0%	14%	0%	0%	0%	3%	1%	4%	0%	0%	0%	0%	2%	10%	100%		
Upper Tributaries Slide	0.00	0.00	82.00	78.45	0.00	0.00	16.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	7.40	189.50		
Upper Tributaries Slide	0%	0%	43%	41%	0%	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	4%	100%		
Upper Basin Clean	0.00	20.90	154.45	135.80	22.70	0.00	58.15	0.00	1.90	0.00	14.85	5.15	16.05	0.00	0.00	0.00	0.00	7.10	41.65	478.70		
Upper Basin Clean	0%	4%	32%	28%	5%	0%	12%	0%	0%	0%	3%	1%	3%	0%	0%	0%	0%	1%	9%	100%		
Upper Basin Slide	0.00	6.20	117.15	93.65	4.35	0.00	19.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30	7.40	253.10		
Upper Basin Slide	0%	2%	46%	37%	2%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	3%	100%		

Table 20. Summary spreadsheet of LWD recruitment potential for Mosby Creek basin and all evaluated subbasins

LWD Recruitment Potential											
Basin				Upper Basin				Lower Basin			
Year	Poor	Fair	Good	Year	Poor	Fair	Good	Year	Poor	Fair	Good
1955	17%	9%	74%	1955	5%	11%	84%	1955	61%	1%	38%
1965	55%	11%	34%	1965	53%	12%	36%	1965	64%	7%	29%
1979	82%	2%	17%	1979	85%	1%	14%	1979	70%	3%	27%
1993	73%	12%	15%	1993	76%	13%	11%	1993	62%	7%	31%
Mainstem				Upper Mainstem				Lower Mainstem			
Year	Poor	Fair	Good	Year	Poor	Fair	Good	Year	Poor	Fair	Good
1955	33%	12%	55%	1955	17%	18%	65%	1955	62%	0%	38%
1965	66%	11%	22%	1965	70%	18%	12%	1965	59%	0%	41%
1979	83%	1%	16%	1979	93%	2%	5%	1979	63%	0%	37%
1993	80%	6%	14%	1993	91%	4%	5%	1993	60%	8%	32%
Tributaries				Upper Tributaries				Lower Tributaries			
Year	Poor	Fair	Good	Year	Poor	Fair	Good	Year	Poor	Fair	Good
1955	12%	8%	81%	1955	2%	9%	89%	1955	60%	2%	38%
1965	51%	10%	38%	1965	48%	10%	42%	1965	69%	12%	20%
1979	81%	2%	17%	1979	82%	1%	16%	1979	75%	5%	20%
1993	71%	14%	15%	1993	72%	15%	13%	1993	64%	6%	30%

APPENDIX D

CANOPY CLOSURE SUMMARIES

Table 21. Length of stream in each shade category in 1955
summarized for each channel segment

Channel	1955	Stream Shade (%)			(length in 1000's feet)		Segment	
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean	
101000	5.30	8.10	3.05			16.45	30%	
101010	2.55	7.40	1.65	0.80	1.65	14.05	40%	
101020		2.80	3.20	4.20		10.20	58%	
102000		6.05	3.60			9.65	43%	
102030			1.15		2.30	3.45	82%	
102040			10.75			10.75	55%	
103000		6.75	2.15			8.90	38%	
103050		2.75			2.20	4.95	59%	
104000	2.65		3.55			6.20	41%	
104060					7.85	7.85	95%	
104070				3.20		3.20	80%	
105000	5.65	3.70	1.05			10.40	23%	
105080			2.60	0.80		3.40	61%	
105090				6.25		6.25	80%	
105100			2.45	6.00		8.45	73%	
106000	4.15		5.70			9.85	42%	
106110					5.35	5.35	95%	
106111					4.95	4.95	95%	
106112				4.35	1.60	5.95	84%	
106120				7.80		7.80	80%	
106130		1.70		5.90		7.60	69%	
107000	0.60	2.40	3.00			6.00	46%	
107140				7.65		7.65	80%	
107150				15.40		15.40	80%	
108000		3.15	1.30			4.45	40%	
108160	2.60			10.25		12.85	66%	
109000			7.45			7.45	65%	
109170				3.70		3.70	80%	
109171				8.65		8.65	80%	
109172				4.30		4.30	80%	
109173				5.75		5.75	80%	
109180				7.20		7.20	80%	
109181				4.40		4.40	80%	
110000			8.45	3.90		12.35	70%	
110190			2.80	6.95		9.75	73%	
110191					4.65	4.65	95%	
110192					3.60	3.60	95%	
110193					3.80	3.80	95%	
110200				2.95		2.95	80%	
110210				3.40	1.70	5.10	85%	
110220				7.70	7.40	15.10	87%	
111000			3.50			3.50	65%	
111230			2.30	5.65		7.95	73%	
112000			4.75	2.30		7.05	70%	
112240				5.50	2.75	8.25	85%	
112250			3.20	4.25		7.45	69%	
112260			2.00	3.80		5.80	71%	
112261				6.75		6.75	80%	
112262				5.25		5.25	80%	
112270			6.80			6.80	55%	
113000			4.35			4.35	65%	
113280				2.15		2.15	80%	
113290			3.50	3.30	3.70	10.50	77%	
113300				4.20		4.20	80%	
114000			4.75	1.20		5.95	68%	
114310				3.10		3.10	80%	
114320				3.60		3.60	80%	
114330				7.25		7.25	80%	
115000			3.15			3.15	65%	
115340			2.60	11.65		14.25	75%	
115350			1.60	2.10		3.70	69%	
115351				10.05		10.05	80%	
115352			1.00	8.65		9.65	77%	
115360			3.45	6.65		10.10	71%	

Table 22. Percent of stream length in each shade category in 1955 summarized for each subbasin

Channel	1955	Stream Shade (%)			(length in 1000's ft)			Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total		Mean
Basin	23.50	44.80	110.85	228.90	53.50	461.55		67%
Basin	5%	10%	24%	50%	12%	1.00		67%
Mainstem	18.35	30.15	59.80	7.40	0.00	115.70		48%
Mainstem	16%	26%	52%	6%	0%	100%		48%
Tributaries	5.15	14.65	51.05	221.50	53.50	345.85		75%
Tributaries	1%	4%	15%	64%	15%	100%		75%
Upper Basin	13.00	10.95	81.75	220.70	39.50	365.90		72%
Upper Basin	4%	3%	22%	60%	11%	100%		72%
Upper Mainstem	10.40	9.25	47.45	7.40	0.00	74.50		54%
Upper Mainstem	14%	12%	64%	10%	0%	100%		54%
Upper Tributaries	2.60	1.70	34.30	213.30	39.50	291.40		78%
Upper Tributaries	1%	1%	12%	73%	14%	100%		78%
Lower Basin	10.50	33.85	29.10	8.20	14.00	95.65		49%
Lower Basin	11%	35%	30%	9%	15%	100%		49%
Lower Mainstem	7.95	20.90	12.35	0.00	0.00	41.20		34%
Lower Mainstem	19%	51%	30%	0%	0%	100%		34%
Lower Tributaries	2.55	12.95	16.75	8.20	14.00	54.45		61%
Lower Tributaries	5%	24%	31%	15%	26%	100%		61%

Table 23. Length of stream in each shade category in 1965
summarized for each channel segment

Channel	1965	Stream Shade (%)		(length in 1000's feet)			Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean
101000	3.7	5.55	7.2			16.45	36%
101010	4.55		9.5			14.05	40%
101020		5.5	3.7	1		10.2	44%
102000		8.4	1.25			9.65	33%
102030					3.45	3.45	95%
102040			10.75			10.75	55%
103000		6.9	2			8.9	36%
103050	2.05		1.65	1.25		4.95	43%
104000	1.9		4.3			6.2	41%
104060	2		1.85	2.2	1.8	7.85	60%
104070	2.15				1.05	3.2	38%
105000	6.85	0.8	2.75			10.4	23%
105080				3.4		3.4	80%
105090	6.25					6.25	10%
105100	8.45					8.45	10%
106000	7.9			1.95		9.85	24%
106110	3.15		2.2			5.35	29%
106111	4.65		0.3			4.95	13%
106112	5.65		0.3			5.95	12%
106120	6.35			1.45		7.8	23%
106130	5.7		1.9			7.6	21%
107000	2.8	3.2				6	21%
107140	4.5			3.15		7.65	39%
107150	12.3			3.1		15.4	24%
108000	4.45					4.45	10%
108160	5.65	2.35			4.85	12.85	46%
109000	7.45					7.45	10%
109170	3.7					3.7	10%
109171		0.8		7.85		8.65	75%
109172	0.75			3.55		4.3	68%
109173	3.95			1.8		5.75	32%
109180	7.2					7.2	10%
109181	4.4					4.4	10%
110000	11.6		0.75			12.35	13%
110190	3.6	6.15				9.75	23%
110191					4.65	4.65	95%
110192	0.8				2.8	3.6	76%
110193		2.9			0.9	3.8	45%
110200	2.95					2.95	10%
110210	3.45		1.65			5.1	25%
110220	9.35				5.75	15.1	42%
111000		3.05	0.45			3.5	33%
111230	1.9		6.05			7.95	44%
112000	5.5	1.55				7.05	14%
112240	2.25			3	3	8.25	66%
112250	2.1		2.75		2.6	7.45	56%
112260		5.8				5.8	30%
112261		1.05		5.7		6.75	72%
112262		1.6		3.65		5.25	65%
112270	6.8					6.8	10%
113000	4.35					4.35	10%
113280	2.15					2.15	10%
113290	4.45				6.05	10.5	59%
113300	4.2					4.2	10%
114000	5.95					5.95	10%
114310	3.1					3.1	10%
114320				3.6		3.6	80%
114330	3.6		1.75	1.9		7.25	39%
115000	3.15					3.15	10%
115340			2.65	11.6		14.25	75%
115350	1.4		2.3			3.7	38%
115351				10.05		10.05	80%
115352			1.1	8.55		9.65	77%
115360	1.25		6.05	2.8		10.1	56%

Table 24. Percent of stream length and total length (1000's ft) in each shade category in 1964 summarized for each subbasin

Channel		1965	Stream Shade (%)				Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean
Basin	212.35	55.60	75.15	81.55	36.90	461.55	39%
Basin	46%	12%	16%	18%	8%	1	39%
Mainstem	65.60	29.45	18.70	1.95	0.00	115.70	24%
Mainstem	57%	25%	16%	2%	0%	100%	24%
Tributaries	146.75	26.15	56.45	79.60	36.90	345.85	44%
Tributaries	42%	8%	16%	23%	11%	100%	44%
Upper Basin	196.00	29.25	32.95	77.10	30.60	365.90	38%
Upper Basin	54%	8%	9%	21%	8%	100%	38%
Upper Mainstem	60.00	8.60	3.95	1.95	0.00	74.50	17%
Upper Mainstem	81%	12%	5%	3%	0%	100%	17%
Upper Tributaries	136.00	20.65	29.00	75.15	30.60	291.40	43%
Upper Tributaries	47%	7%	10%	26%	11%	100%	43%
Lower Basin	16.35	26.35	42.20	4.45	6.30	95.65	44%
Lower Basin	17%	28%	44%	5%	7%	100%	44%
Lower Mainstem	5.60	20.85	14.75	0.00	0.00	41.20	36%
Lower Mainstem	14%	51%	36%	0%	0%	100%	36%
Lower Tributaries	10.75	5.50	27.45	4.45	6.30	54.45	50%
Lower Tributaries	20%	10%	50%	8%	12%	100%	50%

Table 25. Length of stream in each shade category in 1979
summarized for each channel segment

Channel Segment	1979	Stream Shade (%)			(length in 1000's ft)			Segment
	0-20	20-40	40-70	70-90	90-100	Total		Mean
101000	4.65	3.00	8.80			16.45		38%
101010		4.60	2.90	6.55		14.05		58%
101020		3.85	0.90	5.45		10.20		59%
102000	1.40	8.25				9.65		27%
102030	0.60			2.85		3.45		68%
102040		2.10	5.00	3.65		10.75		59%
103000	1.35	7.55				8.90		27%
103050	1.15			1.60	2.20	4.95		70%
104000		4.00	2.20			6.20		39%
104060		6.80	1.05			7.85		33%
104070				3.20		3.20		80%
105000	5.50	3.55	1.35			10.40		23%
105080	0.90				2.50	3.40		73%
105090			2.35	3.90		6.25		71%
105100				8.45		8.45		80%
106000	1.90	4.90	3.05			9.85		34%
106110		1.65		3.70		5.35		65%
106111					4.95	4.95		95%
106112		0.30	5.65			5.95		54%
106120				3.35	4.45	7.80		89%
106130					7.60	7.60		95%
107000	4.25	1.75				6.00		16%
107140	1.10			2.60	3.95	7.65		78%
107150		1.50		13.90		15.40		75%
108000		4.25	0.20			4.45		31%
108160		1.30		7.05	4.50	12.85		80%
109000	3.95	2.80	0.70			7.45		22%
109170			2.70	1.00		3.70		62%
109171			4.15	4.50		8.65		68%
109172	3.75			0.55		4.30		19%
109173		2.20		3.55		5.75		61%
109180			7.20			7.20		55%
109181			4.40			4.40		55%
110000	3.35	9.00				12.35		25%
110190		9.75				9.75		30%
110191		3.05			1.60	4.65		52%
110192					3.60	3.60		95%
110193	0.95	2.15	0.70			3.80		30%
110200				2.95		2.95		80%
110210		0.75	4.35			5.10		51%
110220	2.75		9.00	3.35		15.10		52%
111000	3.50					3.50		10%
111230	2.35		3.30	2.30		7.95		49%
112000	2.00	5.05				7.05		24%
112240		5.20		2.20	0.85	8.25		50%
112250			4.85		2.60	7.45		69%
112260				5.80		5.80		80%
112261	4.35			2.40		6.75		35%
112262	0.50			4.75		5.25		73%
112270			6.80			6.80		55%
113000		4.35				4.35		30%
113280				2.15		2.15		80%
113290		6.00	3.75		0.75	10.50		44%
113300				1.50	2.70	4.20		90%
114000	2.00	3.95				5.95		23%
114310			3.10			3.10		55%
114320	3.00	0.60				3.60		13%
114330	1.55		2.05	3.65		7.25		58%
115000			3.15			3.15		55%
115340	4.35	5.60		4.30		14.25		39%
115350				3.70		3.70		80%
115351		0.90		3.75	5.40	10.05		84%
115352	1.70	0.75		7.20		9.65		64%
115360	3.70			4.70	1.70	10.10		57%

Table 26. Percent of stream length and total length (1000's ft) in each shade category in 1979 summarized for each subbasin

Channel		1979	Stream Shade (%)				Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean
Basin	66.55	121.45	93.65	130.55	49.35	461.55	53%
Basin	14%	26%	20%	28%	11%	1	53%
Mainstem	33.85	62.4	19.45	0	0	115.7	28%
Mainstem	29%	54%	17%	0%	0%	100%	28%
Tributaries	32.7	59.05	74.2	130.55	49.35	345.85	62%
Tributaries	9%	17%	21%	38%	14%	100%	62%
Upper Basin	57.40	81.30	72.80	107.25	47.15	365.90	55%
Upper Basin	16%	22%	20%	29%	13%	100%	55%
Upper Mainstem	26.45	39.60	8.45	0.00	0.00	74.50	26%
Upper Mainstem	36%	53%	11%	0%	0%	100%	26%
Upper Tributaries	30.95	41.70	64.35	107.25	47.15	291.40	62%
Upper Tributaries	11%	14%	22%	37%	16%	100%	62%
Lower Basin	9.15	40.15	20.85	23.30	2.20	95.65	47%
Lower Basin	10%	42%	22%	24%	2%	100%	47%
Lower Mainstem	7.40	22.80	11.00	0.00	0.00	41.20	33%
Lower Mainstem	18%	55%	27%	0%	0%	100%	33%
Lower Tributaries	1.75	17.35	9.85	23.30	2.20	54.45	58%
Lower Tributaries	3%	32%	18%	43%	4%	100%	58%

Table 27. Length of stream in each shade category in 1993
summarized for each channel segment

Channel	1993	Stream Shade (%)		(length in 1000's ft)			Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean
101000	0.80	7.45	8.20			16.45	41%
101010		3.60		5.75	4.70	14.05	72%
101020		6.70			3.50	10.20	52%
102000		6.65	3.00			9.65	38%
102030		1.05	2.40			3.45	47%
102040			5.35	2.70	2.70	10.75	71%
103000		4.80	4.10			8.90	42%
103050		2.00			2.95	4.95	69%
104000		2.15	4.05			6.20	46%
104060				1.80	6.05	7.85	92%
104070					3.20	3.20	95%
105000	3.65	5.45	1.30			10.40	26%
105080				0.80	2.60	3.40	91%
105090					6.25	6.25	95%
105100					8.45	8.45	95%
106000	1.70	7.00	1.15			9.85	29%
106110					5.35	5.35	95%
106111				2.65	2.30	4.95	87%
106112					5.95	5.95	95%
106120					7.80	7.80	95%
106130					7.60	7.60	95%
107000		4.45	1.55			6.00	36%
107140				2.65	5.00	7.65	90%
107150				3.45	11.95	15.40	92%
108000	1.75	2.20	0.50			4.45	25%
108160	1.10		1.45	3.50	6.80	12.85	79%
109000		6.45	1.00			7.45	33%
109170					3.70	3.70	95%
109171			3.60	1.95	3.10	8.65	75%
109172					4.30	4.30	95%
109173					5.75	5.75	95%
109180					7.20	7.20	95%
109181				4.40		4.40	80%
110000		5.20	4.55	2.60		12.35	50%
110190				3.15	6.60	9.75	90%
110191			2.80		1.85	4.65	71%
110192					3.60	3.60	95%
110193					3.80	3.80	95%
110200					2.95	2.95	95%
110210			2.90	0.70	1.50	5.10	70%
110220					15.10	15.10	95%
111000		1.05	2.45			3.50	48%
111230				1.40	6.55	7.95	92%
112000		3.60	3.45			7.05	42%
112240					8.25	8.25	95%
112250					7.45	7.45	95%
112260					5.80	5.80	95%
112261			2.80	1.50	2.45	6.75	75%
112262		1.55	2.00	0.95	0.75	5.25	58%
112270					6.80	6.80	95%
113000		0.45	3.90			4.35	52%
113280					2.15	2.15	95%
113290				8.10	2.40	10.50	83%
113300					4.20	4.20	95%
114000			5.95			5.95	55%
114310					3.10	3.10	95%
114320				3.60		3.60	80%
114330				2.80	4.45	7.25	89%
115000	1.00		0.30	1.85		3.15	55%
115340			5.05	6.40	2.80	14.25	74%
115350					3.70	3.70	95%
115351	0.75		1.80	5.75	1.75	10.05	73%
115352		1.85	2.55	4.00	1.25	9.65	66%
115360			3.50	3.50	3.10	10.10	76%

Table 28. Percent of stream length and total length (1000's ft) in each shade category in 1993 summarized for each subbasin

Channel		1993	Stream Shade (%)				Segment
Segment	0-20	20-40	40-70	70-90	90-100	Total	Mean
Basin	10.75	73.65	81.65	75.95	219.55	461.55	73%
Basin	2%	16%	18%	16%	48%	1	73%
Mainstem	8.9	56.9	45.45	4.45	0	115.7	40%
Mainstem	8%	49%	39%	4%	0%	100%	40%
Tributaries	1.85	16.75	36.2	71.5	219.55	345.85	84%
Tributaries	1%	5%	10%	21%	63%	100%	84%
Upper Basin	9.95	39.25	54.55	65.7	196.45	366	77%
Upper Basin	3%	11%	15%	18%	54%	100%	77%
Upper Mainstem	8.10	35.85	26.10	4.45	0.00	74.50	40%
Upper Mainstem	11%	48%	35%	6%	0%	100%	40%
Upper Tributaries	1.85	3.40	28.45	61.25	196.45	291.40	87%
Upper Tributaries	1%	1%	10%	21%	67%	100%	87%
Lower Basin	0.80	34.40	27.10	10.25	23.10	95.65	58%
Lower Basin	1%	36%	28%	11%	24%	100%	58%
Lower Mainstem	0.80	21.05	19.35	0.00	0.00	41.20	41%
Lower Mainstem	2%	51%	47%	0%	0%	100%	41%
Lower Tributaries	0.00	13.35	7.75	10.25	23.10	54.45	71%
Lower Tributaries	0%	25%	14%	19%	42%	100%	71%

Table 29. Canopy closure summary for all years and all evaluated subbasins

Canopy Closure Summary - All Years																			
Basin					Upper Basin					Lower Basin									
Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100		
1955	5%	10%	24%	50%	12%	1955	4%	3%	22%	60%	11%	1955	11%	35%	30%	9%	15%		
1965	46%	12%	16%	18%	8%	1965	54%	8%	9%	21%	8%	1965	17%	28%	44%	5%	7%		
1979	14%	26%	20%	28%	11%	1979	16%	22%	20%	29%	13%	1979	10%	42%	22%	24%	2%		
1993	2%	16%	18%	16%	48%	1993	3%	11%	15%	18%	54%	1993	1%	36%	28%	11%	24%		
Mainstem					Upper Mainstem					Lower Mainstem									
Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100		
1955	16%	26%	52%	6%	0%	1955	14%	12%	64%	10%	0%	1955	19%	51%	30%	0%	0%		
1965	57%	25%	16%	2%	0%	1965	81%	12%	5%	3%	0%	1965	14%	51%	36%	0%	0%		
1979	29%	54%	17%	0%	0%	1979	36%	53%	11%	0%	0%	1979	18%	55%	27%	0%	0%		
1993	8%	49%	39%	4%	0%	1993	11%	48%	35%	6%	0%	1993	2%	51%	47%	0%	0%		
Tributaries					Upper Tributaries					Lower Tributaries									
Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100	Year	0-20	20-40	40-70	70-90	90-100		
1955	1%	4%	15%	64%	15%	1955	1%	1%	12%	73%	14%	1955	5%	24%	31%	15%	26%		
1965	42%	8%	16%	23%	11%	1965	47%	7%	10%	26%	11%	1965	20%	10%	50%	8%	12%		
1979	9%	17%	21%	38%	14%	1979	11%	14%	22%	37%	16%	1979	3%	32%	18%	43%	4%		
1993	1%	5%	10%	21%	63%	1993	1%	1%	10%	21%	67%	1993	0%	25%	14%	19%	42%		

Table 30. Canopy closure data from Sharps Creek comparison site

Sharps Creek Canopy Closure Data						
Distance (m)	Dnstrm	Densimeter Readings			Mean	Adjusted Mean
		R. Bank	Upstrm	L. Bank		
0	10	56	33	64	41	42
100	30	78	37	80	56	59
200	37	60	26	69	48	50
300	54	69	74	85	71	73
400	19	77	29	64	47	49
500	30	71	37	78	54	56
600	41	59	28	67	49	51
700	29	62	52	87	58	60
800	49	81	47	77	64	66
900	42	71	51	77	60	63
1000	49	85	50	68	63	66
1100	47	77	46	80	63	65
1200	41	67	53	84	61	64
1300	56	57	27	72	53	55
1400	39	47	45	80	53	55
1500	52	75	39	87	63	66
1600	41	82	45	57	56	59
1700	75	96	96	89	89	93
1800	35	78	36	70	55	57
1900	45	88	44	69	62	64
2000	50	82	48	65	61	64
2100	45	79	39	72	59	61
2200	32	77	42	79	58	60
2300	55	91	56	92	74	76
2400	41	88	64	94	72	75
2500	53	74	33	71	58	60
2600	29	59	57	63	52	54
2700	70	96	92	96	89	92
2800	29	82	49	79	60	62
Canopy Closure Grand Average						63%

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