THE EFFECTS OF OWNERSHIP PATTERN ON FOREST ROAD NETWORKS IN WESTERN OREGON

by

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TABLE OF CONTENTS

FIGURES

TABLES

ABSTRACT

The pattern of ownership imposed on the forest landscape of Western Oregon defines the boundaries in which differences in jurisdiction, regulation, and land use operate. Road building is controlled by these factors, and in turn has an effect on the cumulative effects of human utilization of the forest. This study examined the differences in road density and slope position between areas with different ownership patterns.

Land ownership pattern can vary according to the size, shape, and mixture of parcels in an area. The forested lands of Western Oregon have areas with a unique checkerboard pattern, resulting from Federal land grant programs to help build railroads and settle the area in the late nineteenth century. These lands now have alternating, one square mile ownership parcels, split between public agencies such as the Bureau of Land Management or the United States Forest Service and private timber companies. This study used analysis of variance of road density, stream density and the ratio of the two.

A GIS system was used to sample and analyze existing data for BLM and industrial lands, as well as Forest Service and industrial holdings. Tukey ANOVA tests and parametric statistics were used on randomly sampled areas of each ownership type to find out which ownership types were significantly different for total area, and classified by slope position.

The large industrial and large BLM parcels were found to be consistently different across most slope positions, with higher road densities found on the industrial lands. The checkerboard of the two was shown to be intermediate between to the two. The large Forest Service and checkerboard area were not consistently different in total density, but they showed difference in the distribution of roads by slope position. These checkerboard areas had more roads in valley areas while the large USFS parcels had higher road densities on ridges.

INTRODUCTION

The pattern of land ownership in a region defines the way in which different pieces of the landscape are managed, and defines the goals and methods used to administer them. The focus of resource management is moving from the local, limited scale within the bounds of single owners, to a more integrated mode at a larger, multi-jurisdictional level (Davis & Gao, 1991). This has engendered a need to examine the ways in which variation in ownership patterns results in a corresponding pattern in the physical landscape, which in turn affects the functional processes determining the state of these resources.

One of the fundamental steps in the utilization of natural resources in Western Oregon is the imposition of a network of roads (Megahan, 1987). Roads provide access for timber harvest, recreation, and resource appraisal, and have historically been the first step in converting wild lands into managed areas. Although roads are necessary in the use for resources, they also contribute to the impacts which result from these activities (Hagans & Weaver, 1984). Among these impacts, the effects of roads on stream networks include alteration of watershed function (Harr & Harper, 1975), the introduction of sediment to aquatic ecosystems (Duncan et al., 1987), and interference in riparian buffer zones (Swift, 1986). The density and placement of roads in an area therefore greatly affect the immediate and cumulative impacts that their addition creates in the landscape (Ziemer, 1991).

The potential for resource degradation stemming from these impacts has resulted in numerous different levels of regulation and standards addressing the building and maintenance of roads on resource lands. In order for the governing bodies enacting these regulations to have the authority to enforce them, there must be a clear jurisdiction over lands which are affected. The pattern of ownership and jurisdiction is a strong determinant of the way in which roads have been introduced into the landscape. The objective of this study is to develop methods for examining the degree to which the distribution and pattern of ownership boundaries corresponds to the pattern of road placement at a landscape level. The comparison of densities of road and stream networks across lines of jurisdiction was used as an indicator to quantify the way in which variation in title over land results in differences in effect on physical and ecological processes.

Due to the lack of coordination and cooperation between the diverse owners of forest resource lands in Western Oregon, there has been little motivation for multi-jurisdictional studies. With the growing movement toward management at the watershed and regional scale, the need for an understanding of the ways in which ownership boundaries shape the landscape is becoming increasingly clear. This study and the further investigation of associated processes which vary by ownership will aid in the understanding the results of past management and the possible result of changes in regulation.

BACKGROUND:

STUDY AREA:

The physiographic regions in which the research was conducted are the mountains and foothills surrounding the Willamette Valley in Western Oregon. The general boundaries of the study area are defined by ridge of the Coast Range to the west, and above the 300 meter elevation contour in the Cascades to the east, with the non-forested valley floor being included with non-industrial forest lands (Figure 1). The northern and southern boundaries were set by the limits of the available data; they are therefore arbitrary in regards to physiography, and correspond to the boundaries of Linn, Lane, and Douglas counties, Oregon.

This region is covered by northern temperate forests above 100 meters of elevation, with the principal forest type being the association of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) (Burns & Honkala, 1990). Other important conifers include western redcedar (*Thuja plicata*) and true firs (*Abies sp.*) with hardwoods such as red alder (*Albus rubra*) and big leaf maple (*Acer macrophyllum*) common in wetter, riparian areas.

The area has a maritime climate, with relatively cool, dry summers, and mild, wet winters, accompanied by a long growing season with a narrow diurnal temperature flux (Baldwin, 1973). Precipitation falls mostly as rain, and the average annual precipitation is in a range from between 76 to 340 centimeters in the Coast Range, and from 61 to 304 centimeters in the lower Cascades (Burns & Honkala, 1990).

In the Coast Range, parent materials are mainly marine sandstones and shales, while to the east in the Cascades, igneous material of volcanic origin have been deposited by colluvial and residual action. These materials have weathered to produce well drained, fine-textured, clayey soils of the Haplohumult, Haplumbrept, and Haplorthod great groups (Schwartz, 1983). Topography is variable, with slopes up to %100. Short slopes dominate the Coast Range, while longer more gentle slopes predominate in the western Cascades.

These conditions all contribute to the creation of an extremely productive and high quality forest resource. Timber from these conifer species is strong and durable, watersheds yield consistent and pure supplies of water, and the rich, temperate climate supports a wide variety of wildlife (Higsmith, 1965). The abundant precipitation and nutrient rich streams have supported a large anadromous fish population, providing extensive spawning and rearing grounds far up into both the Coast Range and Cascades. Although these resources are vast in area, and resilient in their ability to recover after use by humans, resource use and environmental protection often have come into conflict (Sidle & Sharpley, 1991).

PURPOSE AND USE OF ROADS:

The introduction of roads into the forest landscape is one of the first steps in the transformation of wilderness to a tangible, accessible resource with definite benefits to humans. If "resources are not, they become" (Zimmerman, 1951), than roads are fundamental to the process of appraising, utilizing, and managing the various aspects of the forest. The extensive and continuous nature of the forests of Western Oregon, and the bulk nature of the commodities extracted from them have made the construction of roads necessary and pervasive. Early logging techniques involved selective cutting of high quality, accessible tracts utilizing splash dams and watercourses to transport logs. Since the 1940s, the major form of timber harvest in the Pacific Northwest has been high-lead logging on 20 hectare accessed by roads (Sedlak, 1981). Timber transportation evolved with the development of internal combustion vehicles to move trees off steep slopes, necessitating the building of access road networks. Sedlak states that 'the main function of a road-net is to develop the forest area internally', and points out that access roads connect forest resources with the greater body of industry. Forest roads also provide opportunities for other uses such as recreation, fire control, and the management of water supplies and wildlife however, the high costs of road construction means that timber harvest has largely determined road location in this area (Carow & Silen, 1957).

DEVELOPMENT OF CHECKERBOARD OWNERSHIP PATTERN

A secondary determinant of the way in which roads have been introduced in the region is the variation in land ownership. During the development of the

Western United States in the second half of the nineteenth century, large areas of resource land came under the ownership of federal and state agencies and industrial corporations, and provided one of the first motivations for road construction to access forest resources. The construction and operation of a railroad network began in the 1860s (Ganoe, 1924). Timber was needed for railroad ties to lay the track on, and logging wastes were used to power early steam engines. In addition, railways were used to move lumber and raw logs out of the interior to ports, and people and goods into the newly opened territory thus contributing to the settlement of Western Oregon.

The federal government, which controlled most of the land in Oregon before 1860, recognized the importance of the railroads to the development of the West. Beginning in the Midwest and toward the Pacific, millions of acres of public land were transferred to private railroad companies through a system of land grants run by the Department of the Interior and the General Land Office. In 1866, the Congress authorized a land grant for the State of Oregon which was intended to stimulate the growth of railroad lines up from California, throughout the timber lands in Southern Oregon and up to the emerging urban centers in the Willamette Valley (Ganoe, 1924). Once the patent rights had been granted, 3.7 million acres were disbursed from federal ownership in 640 acres parcels (Richardson, E., 1980). Primary grants were distributed in alternate sections with a forty mile buffer around the planned railway. Interspersed within these sections were 1.6 million acres of secondary or indemnity grants. These lands were designated in the act as lands to be used to compensate preexisting claims holders in the buffer, or to be sold at $2.50 per acre to homesteaders or lumber men. The state legislature was given the right to name the recipient and executor of the grant, and within a few months these lands were ceded to the Oregon Central Railroad company (later the Oregon and California, and then Southern Pacific companies).

The alternation of one square mile sections between the primary and secondary grants established the distinctive 'checkerboard' pattern of ownership which is still apparent on the landscape. Intended to encourage development of the railroad and then settlement by migrants along the tracks, this strategy led to management difficulties for decades to come. As control of the primary and secondary lands diverged through a complex process of the grant's execution, a corresponding pattern of contrasting management and regulation emerged.

OWNERSHIP PATTERNS AND MANAGEMENT

From the outset, the checkerboard ownership pattern created problems for managers and resource users. As the railroad companies defaulted on commitments to finish the lines, the government sued to recover much of the granted lands. Within one year of the final major land revestment in 1917, the secretary of the Interior complained that the pattern of ownership was an obstacle to access for logging (Richardson, 1980). The Department of the Interior and Congress attempted to consolidate the federal holdings, but they met with little success due to problems of surveying and appraising the land's value. Rights-of-way, access easements and fee arrangements for cooperative road building were not clarified until the Bureau of Land Management consolidated the Grazing and Land Offices and formalized regulations from four different Congressional acts in 1950 (Dept. of the Interior, 1954). These regulations allowed for the use of public roads by private companies, but they did not provide standards or regulations for connecting roads outside the public domain.

As timber harvest accelerated in the 1920's with the introduction of new technology for yarding and transportation, management of the private and public lands diverged. The growing realization of the need to manage extractive uses of public lands led to regulation on the former O&C lands in one of the earliest example of sustained forestry regulations in America (Dept. of the Interior, 1954). The Department of Interior forest plan of 1938 provides for conservation of timber, water, forage and soil on a permanent basis. The plan stipulates that timber harvesting activities should be "sold, cut and removed in conformity with the principle of sustained-yield for the purpose of protecting watersheds, regulating stream flow, providing for the economic stability of communities, and providing recreational facilities" (Dept. of the Interior, 1954). This plan gave a unified and well defined management directive for the O&C lands retained in the public domain. However, no such regulation existed for the interspersed indemnity lands, which were left in the hands of a variety of private timber interests. This led to an ownership pattern in which alternating sections had different management regulations and objectives, with further variation introduced by the fact that a tangle of private owners was mixed in with the federal owners (Figure 1).

LANDSCAPE SCALE ANALYSIS OF ROADS

The history of ownership and regulation on the Oregon and California Railroad Company lands presents a unique opportunity to examine the result of contrasting management and regulation policies on lands of similar physical type. Of the many ways in which human use of the forest resource alters the landscape, few are more stable and persistent than the building of roads (Miller, 1987). Variation in topography, soil conditions, geology, and precipitation patterns largely determines the extent to which roads contribute to off-site and cumulative effects such as erosion, mass wasting, alteration of channel morphology and basin hydrology (Grant, Crozier, & Swanson, 1984). Although these conditions are beyond the reach of management, road placement can be controlled to limit construction in areas with a high risk of unintended impacts (Kochenderfer, 1970).

Many factors, including hillslope position (Rice & Lewis, 1991), construction and design methods (Pyles & Skaugset, 1972), and surfacing techniques (Kochenderfer, 1987) may contribute to roads' effects. Careful planning of these factors may help to limit the long-term impact of forest roads.

The localized nature of landform conditions such as erodability and soil physics mean that even the most stringent corresponding management prescriptions will vary significantly across the landscape. These factors therefore do not significantly influence the effect of ownership on the total road network seen at a landscape scale, even in large areas under control of a single owner. The placement of roads in relation to stream channels can be evaluated by examining factors such as the number of road-stream crossings, road placement within riparian zones, and road distribution on hillslope positions such as ridge, midslope or valley areas. These aspects of road networks can be used to examine the landscape scale variations that ownership, regulation, and management create in the interaction between human activities and natural processes.

As the scientific understanding of the ecological significance of forest roads has become better known, it has become clear that logging roads contribute to cumulative impacts. Unlike direct impacts, cumulative impacts occur over longer amounts of time, and are only detectable when wider areas are examined (Ziemer, 1991). Although local effects of forest roads can seriously damage portions of the hydrologic system, they can be seen as isolated and temporary in a vast, forested landscape. However these processes, functioning on large areas and produced by a combination of local impacts, increasingly appear to be responsible for cumulative problems caused by forest roads to water resources (Gosselink, et al. 1990).

The imposition of a road network on a forested watershed can alter the fundamental hydrology of a basin by changing the way that precipitation drains from the ridge to the channel. Although the complex variations in conditions at a landscape level make generalizations difficult, several different effects have been observed. Changes in the yield of water available for irrigation or municipal supply is of great concern, and there is some evidence that roads decrease overall volume (King & Tennyson, 1984.) A stronger connection has been established between forest roads and peak flows. Paired basin studies have shown that as road length in a basin increases, local effects such as compaction, culverts, and subsurface flow interception combine to increase peak flows, and to shorten the hydrologic response to storms (Wright et al., 1990). Also, the routing of water in ditches and over slope faces may simplify the path of flow downstream. Since road length is correlated with timber harvest, some components of these changes are no doubt due to other aspects of timber harvest, such as the exposure of snow packs on unvegetated slopes. In addition, changes in timing of runoff may not significantly disrupt total volumes, but rapid runoff may deplete stored soil moisture in a watershed, decreasing flows during dry periods (Harr, 1976). The loss of downstream volume during crucial summer months when water demands are the highest, and when high water temperature and still flows hurt fish the most, can be more important than changes in annual yield. Overall, the ways in which road building changes the hydrologic function of whole basins are still poorly understood, but existing research shows that subtle but serious impacts have been generated.

Road building may be responsible for cumulative impacts to populations of organisms or whole ecosystems. Repeated local impacts to fish populations over large areas such as killing of eggs or loss of upstream passage increase the risk of losing biodiversity, or even entire species (Delong & Brusven, 1991). Most research in this area is based on modeling and population dynamic theory, but declines in many inland and anadromous fisheries suggests that road building is a contributing factor to these problems (Platt et al., 1987). Statistics compiled for Western Oregon showed that up to five percent of timberlands had been converted to roads from 1960 to 1990 (Maclean, 1990). Some of this area was reclaimed by the forest, but the fact that riparian zones may occupy less than 10 percent of total forest area (Delong & Brusven, 1991), the loss of this important protection for water resources is proportionally much higher. As new management objectives for natural resources begin to shift the focus both of science and utilization, better understanding of the complexity of cumulative impacts will be possible.

The degree to which all of these effects can be expected on various areas in a region are greatly influenced by the density and placement of roads, as well as their extent relative to stream density (Sessions et al., 1987). This study examines the variation in road density and their relationship to stream density on areas of various owner types as a first step to understanding the influence of ownership patterns on these geomorphologic, hydrologic, and ecological processes.

GOALS AND HYPOTHESIS

The goal of this study is to determine what relationship, if any, exists between land ownership and the density and placement of roads. If a relationship does exist, it may be due to local ownership or perhaps to the ownership pattern in the larger surrounding area.

The comparison will be performed on two different grouping of public and private lands. The first will compare large tracts of BLM land, large industrial tracts, and an area of checkerboard ownership mixing the two. The second will compare areas sampled within the Willamette National Forest with an area dominated by a checkerboard of industrial and U.S. Forest Service lands. A large industrial replicate for the second comparison was not available, but the inholding of a checkerboard is a unique opportunity to see the interaction of private and public owners.

Five alternative hypotheses will be evaluated:

A. The checkerboard parcels are different from large BLM parcels
B. The checkerboard parcels are different from large industry parcels
C. The checkerboard parcels are different from both
D. The checkerboard parcels are not different from either large owner, and the large parcels are not different from each other.
E. The checkerboard parcels are not different from either large owner, and the large parcels are different each other.

If A, B, or C are true, they would indicate that an owner's road building rules on its large, continuously managed areas do not extend to its small parcels in the checkerboard. If D is accepted, it would imply that no effect on road placement and density could be detected due to any ownership pattern. If E is true, it suggests that parcels in checkerboard lands are managed by rules intermediate between those of the two intermingled owners.

METHODS

The analysis consisted of two experiments. One compared large BLM parcels, large industrial parcels, and a checkerboard area split between the two. The second compared large areas of the Willamette National Forest with an checkerboard an area of Forest Service and industrial lands within the National Forest boundaries. The blocks representing the various ownership types were located as closely as possible, and were on forested lands open to harvesting.

Checkerboard parcels were defined as being 1 mile square in area with ownership alternately public or private. Some pieces surrounded by the township sized parcels were included to form large, contiguous areas for sampling. Large parcels types were at least 20 square miles in size, with no included parcels larger than 1 square mile. The large USFS parcels were sampled in areas not designated as wilderness or special reserves, and in the northern districts of the Forest nearest to the checkerboard area.

DATA SOURCES

In order to examine differences in the road data by ownership over wide areas, it is necessary to begin with a consistent spatial database which provides an appropriate level of detail and desired attributes for all jurisdictions. Since most existing coverages have been created by single agencies or owners for their own lands, this necessitated some combination of data from different sources. An effort was made to find consistent datasets which covered at least two hundred square miles, and mapped all the ownership patterns to be compared for each experiment. Each separate theme, such as roads or ownership, had to be from a single source for each experiment, and the registration of overlaid coverages from different sources was tested.

The first data set assembled was a vector polygon layer portraying the ownership of forest lands in the three county study area based on assessor descriptions of legal parcels in county records in 1991. An existing coverage created by Attenbury Consultants, Inc. (NIPFL Database Documentation, 1992) for the Oregon Department of Forestry's Inventory of Productive Forest Lands project was found through the State GIS Service Center, and brought into UNIX ARC/INFO. The data were appended into a single, regional coverage, projected into Universal Transverse Mercator coordinates and meter units, and extraneous sliver polygons were eliminated. With the regional coverage, areas of the three different ownership types in experiment 1 were selected out for sampling. The existing OWNER attribute was used to create the OWNTYPE field, which distinguished 'checkerboard' parcels one square mile in size from larger agency and industry parcels. The RESELECT command was used to create a new coverage of parcels which are owned by the Bureau of Land Management, a single large industrial owner, and an area dominated by alternating 'checkerboard' parcels of the two.

Once the areas representative of the ownership patterns were selected, the next data sets needed were continuous road and stream layers. The WOODBE GIS database was made available through the Oregon regional office of the Bureau of Land Management, and imported from the MOSS format to UNIX ARC/INFO (Yee & Blackburn, 1991). This database was created by the BLM to manage the diverse and somewhat scattered lands they administer, and the fact that so many of their parcels are interspersed with private land led them to map across ownership boundaries. This made it an ideal database for this analysis, so the BLM was selected as the public agency owner to examine in experiment one. The layers were digitized from 1:4800 scale orthophotos, and were attributed and checked for accuracy with existing BLM maps (Wright & Blackburn, 1990). This provided a uniquely accurate and detailed landscape level database covering lands with of different ownership patterns at a large scale. A number of themes were mapped for a variety of future analyses, and made available as public information. We obtained the HYD (streams and rivers) and TRB (roadways) with permission from the Northwest Regional office.

The road and stream coverages were processed in a similar manner. After the data was imported using the MOSSARC command, the attribute files were delimited and brought into the INFO database system. These files were tied to the vector line coverages using JOINITEM on the arc-id numbers, and then the separate township coverages were appended into regional layers. These were projected into Universal Transverse Mercator coordinate and meter units to correspond with the ownership layer. An example area is shown in Figure 2 with the ownership, roads and streams depicted.

The same themes of ownership, roads, and streams were needed for the second experiment. The Willamette National Forest has created an ARC/INFO database for use in planning and ecological analysis. The legacy of the O&C railroad lands has left areas of checkerboard ownership as inholdings within the large tracts of forest managed by the Forest Service. These intermingled lands have been mapped to aid in cooperative use of roads for fire protection and timber access. The WNF's ADMN layer mapped the ownership of private land within the forest, and the Linn county assessors office provided information on the ownership of these parcels. Layers describing road and stream networks for the entire forest and private inholdings were also obtained from the WNF. These coverages were in Universal Transverse Mercator coordinates and ARC/INFO format when obtained. An example of these three themes is illustrated in Figure 3.

In order to have a degree of confidence in the spatial relationship between the ODF and BLM layers, a simple accuracy assessment was conducted to assure that there was sufficient registration. The PLS (Public Land Survey) theme was mapped during the WOODBE implementation to distinguish the ownership of BLM lands within the regional coverages. This data set was imported and projected as previously described, and then overlaid with a coverage of BLM ownership reselected from the ODF ownership layer using the INTERSECT command for test area covering eight townships.

Results summarized with the STATISTICS command showed that 93% of the area identified in the BLM WOODBE layer and the ODF OWNER layer as owned by BLM overlapped, and that the total areas from both data sets was different by 4%, suggesting an acceptable level of registration.

The last coverage needed was a layer describing the drainage density and slope position of the area. A slope class attribute based on the area of land draining through a given location from higher elevations was needed to separate how roads were placed across the topography of the landscape. A Digital Elevation Model of the study area was created from USGS 1:250000 DEM files, and projected into the same units and coordinates as the other coverages. Using the ARC/INFO GRID module, this raster dataset was processed with the standard hydrologic modeling system (ESRI, 1992). The DEM was smoothed to remove 'sink' cells in the raw data, and then used to create a flow direction grid in which each raster contains a value describing the adjoining cells that would contribute water flow to it. This layer was then used to create a flow accumulation grid, with each cell containing a value which quantifies the number of cells draining into it. The flow accumulation grid was classified into three classes based on drainage density: (1) ridges, defined as cells draining zero to one other cells, (2) midslope defined as cells draining two to ten other cells, and (3) valleys cells draining greater than ten other cells. These classes distinguish areas of high drainage and low relief in the valleys from areas of low drainage and high relief on the ridges, with an intermediate mid slope class. This resulting grid was smoothed using a MAJORITYFILTER function with an eight raster window to remove single, scattered cells, and the converted to vector polygon format with the GRIDPOLY command. A large, regional coverage was created which mapped all the land to be sampled in both experiments.

SAMPLING DESIGN AND ALLOCATION

With the regional database assembled, a sampling scheme was designed to provide data to use in the statistical analysis of ownership effects on road placement and density. Random sampling was utilized to help control for bias caused by the selection of the blocks of each ownership type. Differences in size and geographic location among the blocks might make them unrepresenative samples if they were inventoried in their entirety and compared. Sixteen one square mile units were randomly selected the from the area of each ownership type, covering at least twenty percent of the total area. This set the grain of the analysis at the size of the typical 'checkerboard' parcel, and allowed a comparison of equal area between the ownership types. Sample units were allocated proportionally to the size of the blocks of each ownership types where the blocks were not contiguous. Samples were distributed between non contiguous blocks by multiplying the number of samples by the relative size of each parcel to the total area of each type using the following formula:

$$n \ * \ \text{(Area of parcel)} / \text{(Total area for owner type)}$$

With the samples allocated to the various parcels, a random placement within these parcels was performed. The parcels were converted to a raster format of square meter resolution using the POLYGRID command, and each raster was assigned a random number between one and ten with the RND function of ARC/INFO GRID. Rasters with the number closest to the allocation of samples for that parcels were chosen as sample units, and then converted to polygons using the GRIDPOLY command. These one square mile polygons were then overlaid on the ownership data, and moved within the boundaries in a straight horizontal or vertical direction to lie completely within the ownership polygons. In the checkerboard area, eight samples were assigned to each of the two owners, and centered on the parcel which had the most area within the randomly located sample area. Separate vector polygon coverages were created from these sixteen samples for each of the three types, and assigned a sample unit number. The sample allocation and study area for experiment 1 are shown in Figure 4, and for experiment 2 in Figure 5.

GIS ANALYSIS

Once the data had been prepared and the sample units allocated and placed, an analysis was undertaken using the ARC/INFO AML program listed in Appendix 1. This first part of the program allows for the execution of a body of commands for a list of coverages, in this case the sampling units from the three ownership types, and is based on code written by George Lienkaemper and Barbara Marks at the U.S. Forest Service Pacific Northwest Research Station. The group of commands within this control loop takes the stream, road and slope coverages for the entire study area and clips them with the sample unit coverage. Statistics files are generated to quantify road length, stream length, and area in the three slope class for each sample, and a sample number attribute is attached to the arcs and polygons. Next, the roads and streams are overlaid with the slope coverage to add a slope class attribute separating them by topographic position, and these results are reported to statistics files. The result is five ASCII data files for each of the three owner types: road length, stream length, slope area, road length by slope class, and stream length by slope class for each of the sixteen samples.

STATISTICAL ANALYSIS

Once data describing road density and placement from a representative sample of ownership and type was compiled, they were subjected to an analysis of variance to determine how ownership types differ with respect to road, stream, and road-stream densities. In addition, basic parametric statistics were used to find out what relative relationships exist between owner types.

The analysis of variance test gave a probability that samples grouped by owner type are significantly different ($\alpha < .05$). A matrix of similarity comparisons can then be created to demonstrate the relationship between groupings of these types for road density, and the ratio of road to stream density. The means for all of the variable analyzed were calculated and help in the interpretation of the ANOVA results and to see if a trend exists beyond the tests of differences.

The numerical results of the GIS analysis were brought into a spreadsheet program for summary and display. Appendix 2 contains graphs derived from the data files produced in ARC/INFO for the three types, and show the distribution of each attribute for the sampling units.

In order to perform the statistical analysis of similarity between owner types, the spreadsheet files were imported into the SYSTAT software package. Road and stream length values for the slope classes were converted to densities by dividing by the area per sample in each class. This allowed for a variable quantifying the ratio of road density to stream density for the sample, as well as relating them to the standard units used in other hydrologic and road network studies. Box plots was created to portray the basic relationship between the three owner types for these variables as shown in Appendix 3. The boxes represent the sample values within the ninety-fifth percentile of their distribution for each group, intersected by a line at the sampling median, with the whiskers showing the limit of values within 1.5 times the interquatrile range (Wilkinson, 1992 (1)).

The first test of the data was to see if the stream and road lengths were correlated by owner. If they were significantly dependent, this relationship would mean that roads most likely followed stream channels regardless of ownership, and that the effects of the ownership pattern would be impossible to isolate.

An analysis of variance was performed to test the hypothesis that there are significant differences between the ownership patterns. A series of analysis of variance tests were designed to determine if road density, stream density and the ratio of road to stream density in the three slope classes differed between the owner types. The SYSTAT software package was used to create a Tukey matrix of pairwise comparisons for each two-way combination of owner types: large parcels of BLM and industry, BLM with the checkerboard, and industry with the checkerboard. The Tukey test compares sample means weighted by the f-ratio of mean square error to determine the probability that the averages of a pair of sample sets are distinct are greater than ninety-five percent (Wilkinson, 1992(2)). The test was run for total road density, total road to stream density (road length / area divided by stream length / area), and for both variables broken down by ridge, mid slope, and valley slope classes. If the pairwise comparison for two owner types resulted in a .05 or smaller probability, then the pair was accepted as being significantly different for that variable.

RESULTS

Road length varied from .0184 to 15.01 km, with a mean of 2.69 ± .97 in the 60 sampled 2.58 km^2 parcels (Figure 6). Road length in the 16 blocked up BLM parcels ranged from 2.371 to 13.312 km with a mean of 6.653 ± 2.201 (Figure 6a). Road length in the 16 blocked up industry parcels (Weyerhauser Inc.) ranged from 1.963 to 10.471 km with a mean of 6.195 ± 2.710 km (Figure 6b). Road length in the BLM/industry checkerboard ranged from .0187 to 8.085 km with a mean of 6.107 ± 2.570 in the 8 BLM parcels and from 4.679 to 13.237 km with a mean of 8.782 ± 2.506 km in the 8 industry parcels (Figure 6c). Road length in the 16 blocked up USFS parcels ranged from 4.521 to 15.007 km with a mean of 6.900 ± 2.426 (Figure 6d). Road length in the USFS/industry checkerboard ranged from 3.286 to 9.783 km with a mean of 6.984 ± 1.345 in the 8 USFS parcels and from 4.482 to 9.430 km with a mean of 7.573 ± 1.657 in the 8 industry parcels (Figure 6e). Average road density on blocked up industry parcels (Timber Services, Inc.) was significantly higher than on BLM lands (3.55 km km-2 compared to 2.56 km km-2, $p < .009$) and weakly higher than on checkerboard lands (2.88 km km-2, $p < .095$) (Table 1, Figure 6). Average road density between the two owners checkerboard on the checkerboard parcels (Table 4) was not significantly different (2.52 km km-2 for BLM compared to 2.061 km km-2 for Weyerhauser, Inc.). There was no significant difference in average road length between the blocked up USFS lands and the checkerboard (Table 1), or between the two owners within the checkerboard (2.92 km km-2 for Timber Services, Inc. compared to 2.81 km km-2 for the USFS.

Stream length varied from 155.404 to 12.968 km, with a mean of 6.449 ± 2.569 in the 60 sampled 2.58 km^2 parcels (Figure 7). Stream length in the 16 blocked up BLM parcels ranged from 2.768 to 10.312 with a mean of 6.650 ± 2.013 (Figure 7a). Stream length in the 16 blocked up industry parcels (Weyerhauser Inc.) ranged from 6.733 to 13.270 with a mean of 9.126 ± 1.843 (Figure 7b). Stream length in the BLM/industry checkerboard ranged from .0187 to 11.01 km with a mean of 6.672 ± 3.307 in the 8 BLM parcels and from 2.342 to 8.022 with a mean of 5.462 ± 2.130 in the 8 industry parcels (Figure 7c). Stream length in the 16 blocked up USFS parcels ranged from 1.66 to 7.73 km with a mean of 4.55 ± 1.68 km (Figure 7d). Stream length in the USFS/industry checkerboard ranged from 2.55 to 9.07 km with a mean of 4.95 ± 1.62 in the 8 USFS parcels and from 3.05 to 5.19 with a mean of 4.59 ± 1.18 in the 8 industry parcels (Figure 7e). Stream density on blocked up industry parcels was significantly higher than on BLM lands (3.47 km km-2 compared to 2.51 km km-2, $p < .009$) but not significantly different than on checkerboard lands (Table 2), and did not differ between the two owners on the checkerboard (Table 4). There was no significant difference in stream length between the blocked up USFS lands and the checkerboard (Table 2, Figure 7), not did the two owners on the checkerboard.

The areas occupied by ridges, midslopes, and valleys differed by parcel and by owner (Figure C) . Midslope areas occupied from 40.92 to 82.1 % of the sampled parcels with a mean of 60.71% ± 9.34 (Figure 8). Ridge areas occupied from 5.73 to 41.23 % of the sampled parcels with a mean of 20.45 ± 8.95, while valleys occupied from 1.43 to 45.3 % of the sampled parcels with a mean of 18.08 ± 9.28 (Figure 8). There was not a significant difference between owner groups in the area occupied by each hillslope class (Table 3), except between large BLM parcels and the BLM-industry checkerboard ($\rho = .048$). Figure 26 illustrates the distribution of slope classes by owner type. Road length was not related to stream length for any slope class (Figures 14, 15 and 16) or for any particular owner.

Accounting for differences between parcels in the amounts of land in various hillslope positions, road density on all hillslope positions (ridges, midslopes and valleys) was significantly higher on blocked up industry parcels than on blocked up BLM parcels ($p < .05$) (Table 1, Figure 11). Average road density in all hillslope positions on checkerboard lands was intermediate between industry and BLM and not significantly different from either (Table 1), with only slightly higher road densities on the BLM parcels of the checkerboard (2.52 km km-2 compared to 2.01 km km-2). Road density on midslopes and in valleys was significantly higher on USFS/industry parcels than on blocked up USFS lands ($p < .05$) (Table 1).

Accounting for differences between parcels in the amounts of land in various hillslope positions, stream density on midslope positions was significantly higher on blocked up BLM parcels than on blocked up industry parcels or checkerboard parcels averaged across both owners ($p < .05$) (Table 2, Figure 12). Average stream density in valleys was significantly higher in checkerboard parcels than on either blocked up industry or blocked up BLM parcels ($p < .029$) but the industry samples had a very high coefficient of variation at 0.412 (Table 2, Figure 12). There were no significant differences in stream density by hillslope position between the USFS and USFS/industry checkerboard (Table 2).

These differences between owners are preserved when road length is indexed by stream length (Table 3, Figure 13). On midslope positions, the ratio of road length to stream length was significantly higher on blocked up industry parcels than on blocked up BLM parcels ($p < .05$) (Table 3). In valleys, the road-stream ratio was significantly higher on blocked up industry parcels than on blocked up BLM parcels or checkerboard parcels (Table 3). Overall, road-stream ratios were significantly higher on blocked up industry parcels than on the other two. The road-stream density showed a significant difference between the two owners within the checkerboard (Table 4). This is due to the lower density of streams on the BLM checkerboard parcels, and may indicate that there is higher density of road building near streams within this area by BLM.

In summary, road density in this random sample of parcels was highest on large blocked up industry lands, and lowest on federal lands (BLM and USFS) when differences in landform configuration are accounted for (Tables 1 to 4). Large blocked up industry parcels had about 38.6 % more roads on average than federal land. Accounting for differences in the amount of lands on ridges, large industry parcels had about 40.1% more roads on midslope positions. Accounting for differences between parcels in the amount of streams by hillslope position and owner, large industry parcels had 38.2% higher road-stream densities than federal lands and 225% higher road-stream densities in midslope positions than federal lands.

Checkerboard lands had intermediate road densities when federal and industry owner parcels were averaged. The checkerboard parcels of both owners had road densities intermediate to those of the large industry and BLM areas (Table 1).

DISCUSSION

The causes of the relationships observed in this study most likely have components linked to ownership, but not inherently explained by it. The extent and temporal distribution of timber harvest activities on these lands certainly has a great influence on the degree to which they have been roaded. Timber harvest records combined with analysis of classified satellite imagery could determine when portions of the road network were constructed, as well as linking the development of the area to road density. Although ownership and ownership pattern contribute to the way in which development occurs on forest lands, the stage that the development has reached is not determined by jurisdiction alone.

Although the findings of this study were consistent across all comparisons, and point to a single contingency, further examination of the basic statistical analyses will be show other trends in the data. In order to expand on these results, several additional factors should be noted. Examination of the average road density and ratios of road to stream densities indicates that the checkerboard areas fall in between the large parcels samples on six of the eight tests, and six of seven excluding the road/stream test on the ridge classes. The large industry samples had higher densities than BLM on all of the test showing them to be distinct, and the checkerboard pattern seems to be an intermediate of the two consistently. The intermediate position of the checkerboard parcels suggests that these areas are either bringing down the densities on the industry pieces, or raising them on the BLM sections. There is a strong indication that the checkerboard ownership pattern is creating some difference between the road networks both owners built on their own lands and the ones within the multi-jurisdictional matrix. The fact that the means for the checkerboard parcels separated by owner are still between the larger parcels indicates that this is true. The sampling may have been biased by the need to center the units on parcels; additional studies over larger areas could provide the opportunity to distribute the samples in a totally random fashion. The extent of this study precluded this technique since the areas were too small to support the sample size needed to keep area between the owners even in a unrestricted random sample.

The results for experiment two are less consistent, but suggest a different relationship between checkerboard dominated lands and those owned in large parcels. The strongest differences between owner types were seen in the road densities on the ridge and valley slope positions. This indicates differences in road placement relative to streams and slope position between owners with very similar stream densities, and similar total road densities. Again, a tighter relationship between the two owners within the checkerboard was found than between the total checkerboard and larger parcels. The limited extent of this pattern still extant within the Willamette National Forest means testing in other areas will be needed to confirm these findings.

These findings suggest that ownership pattern has potential consequences for the hydrology and aquatic habitat of the landscape. The potential for increasing surface flow and increasing hydrologic response time may exist on areas with higher road densities, especially in areas with high stream densities as well. The passage of fish and rearing of young salmonids may be affected by the roads at these densities as well. Studies which link the placement of high density areas within watershed boundaries could show if the practices of upstream owners is affecting those below, and if blockages in habitat might decrease the quality of streams upslope from these areas. Integration of hydrologic data such as flow records, and information on fish populations with study like this one can help to determine if these effects exist.

FURTHER RESEARCH

The limits of existing data sets which were created for purposes other than a particular analysis range from inconsistent photo interpretation to insufficient or irregular precision and accuracy. In order to place a confidence interval on existing data sets, it is highly desirable to confirm the spatial accuracy through ground truthing and field confirmation of roads, streams, and ownership boundaries. This would be accomplished by allocating sample in the GIS based on random preliminary sampling stratified by slope class, and then surveying with Global Positioning System equipment or standard surveying gear. With a measure of expected and observed locations of road and stream intersections, and ownership corners, a known level of accuracy could then be calculated.

In addition to gauging the quality of the data, additional experiments would be undertaken to determine if this relationship exists for other landholders with similar ownership patterns. The experiment on Forest Service land lacked a comparison with large, proximate parcels held by the same industrial owner in the checkerboard area. The use of road and stream data generated from air photos could provide a sampling area of this ownership type. This would establish if the trends observed in experiment one were unique to the owners examined in this study, or were more widely evident.

The conclusion reached in experiment one is that the large parcels of different owners were more closely linked than another pairing, and that the checkerboard areas tended to be intermediate between the two. In the second experiment, the differences between types was more varied by slope position and not as consistently related. This result can be interpreted to mean that the pattern of road density and placement is more closely tied to the pattern of parcels size and contiguity than to actual ownership. It can be construed that the way in which parcels are arranged over that landscape has a greater effect on how an owner must plan and construct a forest road network than specific priorities or regulations. Acceptance of this stipulation would imply that landscape level planning or analysis of road networks should focus on ownership pattern as well as the differences in management and land use between owners.

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TABLE 1 -- ROAD DENSITY (KM/KM^2)

	TOTAL	RIDGE	MIDSLOPE	VALLEY
BLM	2.56 **a**	3.12 **a**	2.39 **a**	1.67 **a**
INDUSTRY	3.55 **b**	4.21 **b**	3.35 **b**	3.34 **b**
BLM / IND	2.88 **ab**	3.46 **ab**	2.74 **ab**	2.28 **ab**

USFS	2.67 **a**	2.79 **a**	2.52 **a**	2.06 **a**
USFS/IND	3.01 **a**	2.87 **a**	3.08 **b**	2.76 **b**

Key to tables: Sampling means are noted for each variable.
Lower case letters in bold indicate differences found by Tukey ANOVA test on sample size $n = 16$. Owners with like letters showed no significant difference, those with unlike letters were significantly different ($\rho = .05$).

TABLE 2 -- STREAM DENSITY (KM/KM^2)

	TOTAL	RIDGE	MIDSLOPE	VALLEY
BLM	2.51 **a**	2.00 **a**	3.39 **a**	4.97 **a**
INDUSTRY	3.47 **b**	1.63 **a**	2.26 **b**	17.36 **a**
BLM / IND	2.81 **ab**	1.52 **a**	2.37 **b**	3.67 **b**

USFS	1.74 **a**	0.92 **a**	1.42 **a**	3.29 **a**
USFS/IND	1.91 **a**	1.26 **a**	1.62 **a**	3.50 **a**

Key to tables: Sampling means are noted for each variable.
Lower case letters in bold indicate differences found by Tukey ANOVA test on sample size $n = 16$. Owners with like letters showed no significant difference, those with unlike letters were significantly different ($\rho = .05$).

TABLE 3 -- ROAD DENSITY / STREAM DENSITY (KM/KM^2) / (KM/KM^2)

	TOTAL	RIDGE	MIDSLOPE	VALLEY
BLM	0.72 **a**	2.08 **a**	0.83 **a**	0.34 **a**
INDUSTRY	1.47 **b**	3.31 **a**	1.87 **b**	1.42 **b**
BLM / IND	0.90 **b**	1.98 **a**	1.33 **ab**	0.28 **a**

USFS	1.73 **a**	6.42 **a**	2.68 **a**	0.68 **a**
USFS/IND	1.18 **a**	3.62 **b**	2.33 **a**	1.05 **b**

TABLE 4 - DENSITIES FOR CHECKERBOARD OWNERS

	ROAD DENS.	STREAM DENS.	ROAD-STRM. DENS.
BLM IN CHECK	2.51 **a**	2.31 **a**	1.13 **a**
IND IN CHECK	2.06 **a**	3.31 **a**	0.67 **b**

Key to tables: Sampling means are noted for each variable.

Lower case letters in bold indicate differences found by Tukey ANOVA test on sample size $n = 16$. Owners with like letters showed no significant difference, those with unlike letters were significantly different ($\rho = .05$).

APPENDIX ONE

AUTOSAMP.AML

```
/* AUTOSAMP.AML  by M. Freid  at PNWFSL     4/3/94
/*    with code by B.Marks and G.Lienkaemper 1993

/*  open lists of files to process
&sv hydfile = [open hydlist status -read]
&sv trbfile = [open trblist status -read]
&sv slopfile = [open sloplist status -read]
&sv sampfile = [open samplist status -read]
&sv flag = .true.

/* loop control for passes thru process code
&do &while %flag% = .true.
  &sv hydcov = [unquote [read %hydfile% status]]
  &sv trbcov = [unquote [read %trbfile% status]]
  &sv slopcov = [unquote [read %slopfile% status]]
  &sv sampcov = [unquote [read %sampfile% status]]

  &if %status% ne 102 &then &do
    &type cover: %hydcov%
    &type cover: %trbcov%
    &type cover: %sampcov%
    &type cover: %slopcov%

/* clip road coverage with sampling box coverage... build topology
clip %trbcov%  %sampcov% %trbcov%clp line 2

build %trbcov%clp line

/* clip stream coverage with sampling box coverage... build topology
clip %hydcov% %sampcov% %hydcov%clp line 2

build %hydcov%clp line

/* clip slope coverage with sampling box coverage... build topology
clip %slopcov% %sampcov% %slopcov%clp poly 2

build %slopcov%clp poly

/* add sample unit number attribute to road coverage... build topology
intersect %trbcov%clp %sampcov% %trbcov%smp line 2 join

build %trbcov%smp line


/*generate statisitics of road length for sampling units
```

```
statistics %trbcov%smp.aat %trbcov%smp.sta sample
sum length
~
n
n

/* add sample unit number attribute to stream coverage... build topoplgy
intersect %hydcov%clp %sampcov% %hydcov%smp line 2 join

build %hydcov%smp

/* generate statistics of stream length for sampling units
statistics %hydcov%smp.aat %hydcov%smp.sta sample
sum length
~
n
n

 /* add sample unit number attribute to slope coverage... build topoplgy
intersect %slopcov%clp %sampcov% %slopcov%smp poly 2

build %slopcov%smp

/* generate statistics of slope class area for sampling units
frequency %slopcov%smp.pat %slopcov%smp.sta table#
sample
grid-code
end
area
end

/* add slope class attribute to road coverage
intersect %trbcov%clp %slopcov%smp %trbcov%slop line 2

build %trbcov%slop line

frequency %trbcov%slop.aat %trbcov%slop.sta
sample
grid-code
end
length
end
```

```
/* add slope class attribute to stream coverage
intersect %hydcov%clp %slopcov%smp %hydcov%slop line 2

build %hydcov%slop line

frequency %hydcov%slop.aat %hydcov%slop.sta
sample
grid-code
end
length
end


  &end
  &else
    &sv flag = .false.
&end
```

APPENDIX TWO

GIS OUTPUT GRAPHS

Figure 6a.

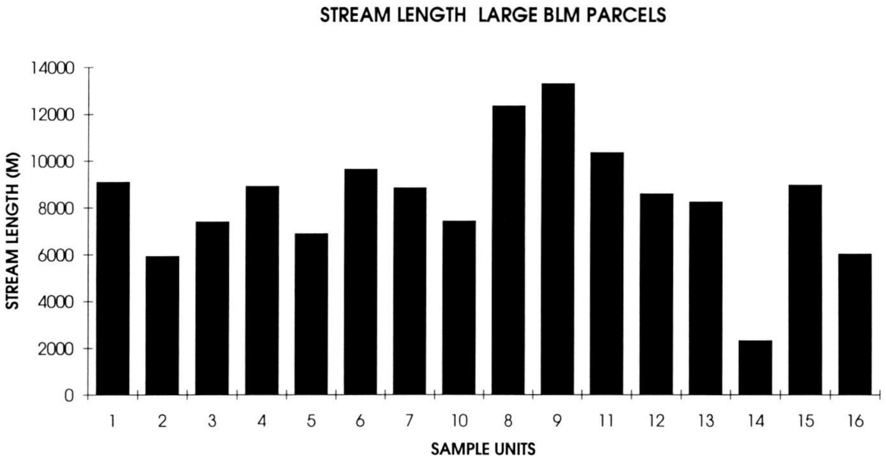


Figure 6b.

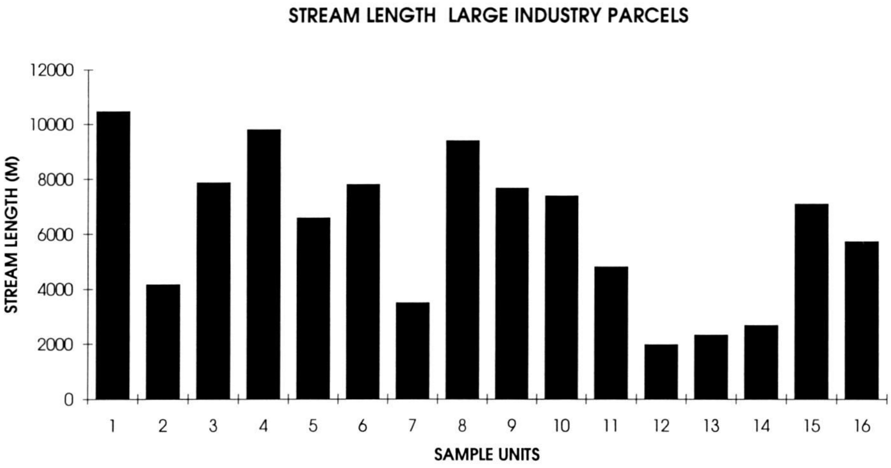


Figure 6c.

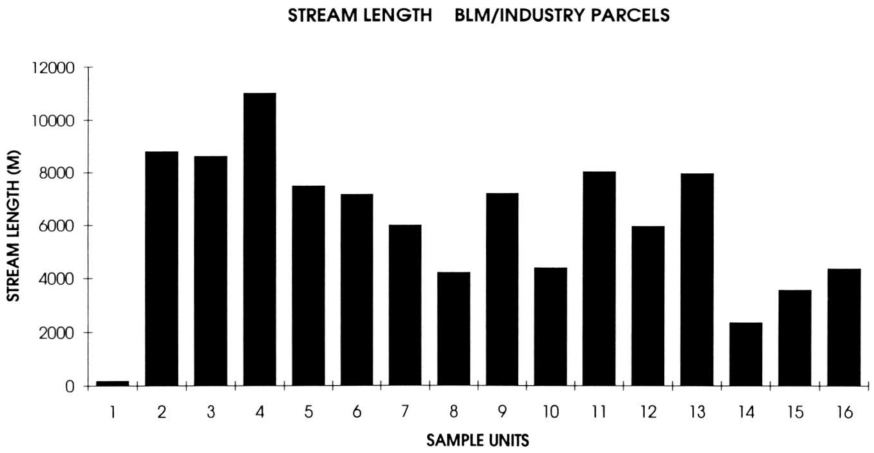


Figure 6d.

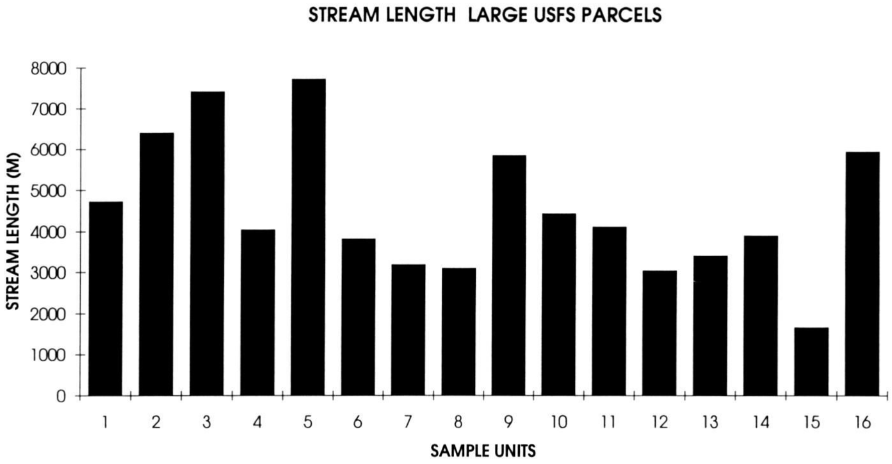


Figure 6e.

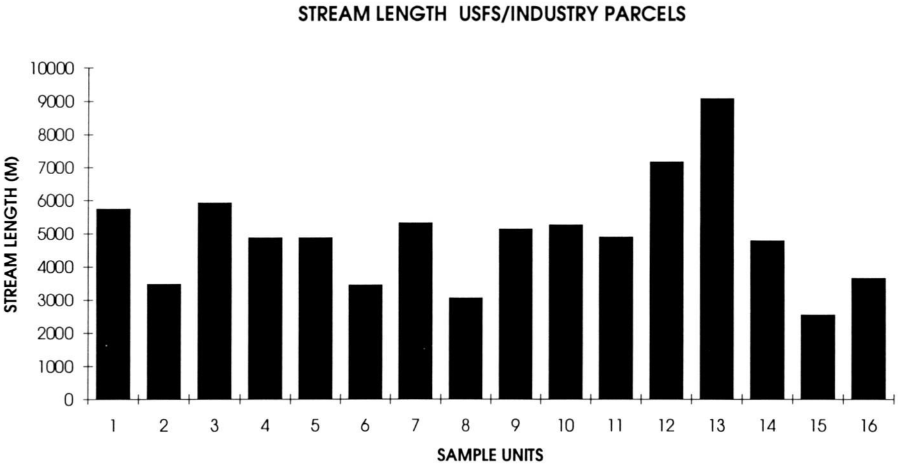


Figure 7a.

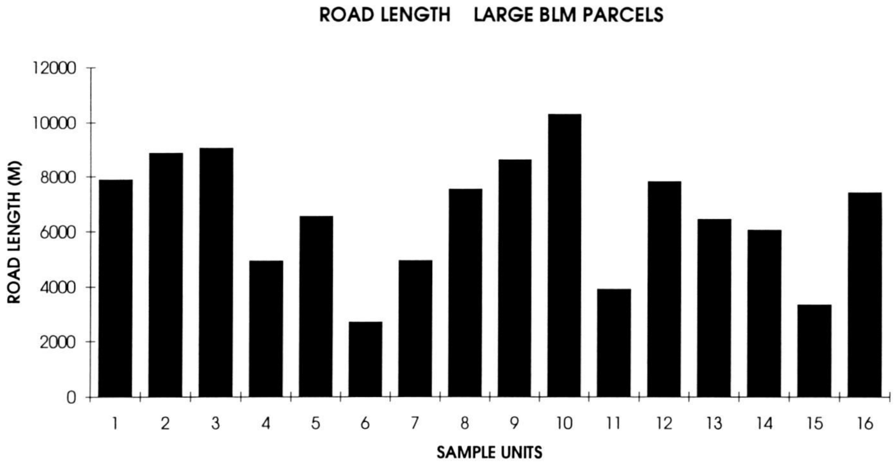


Figure 7b.

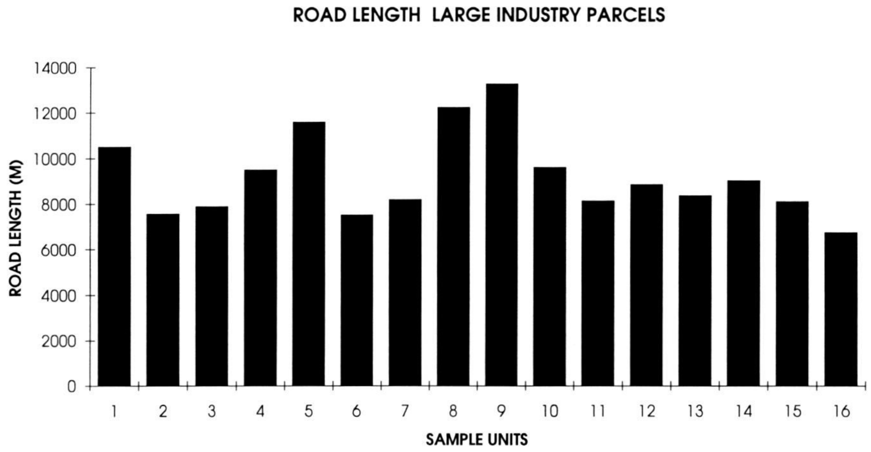


Figure 7c.

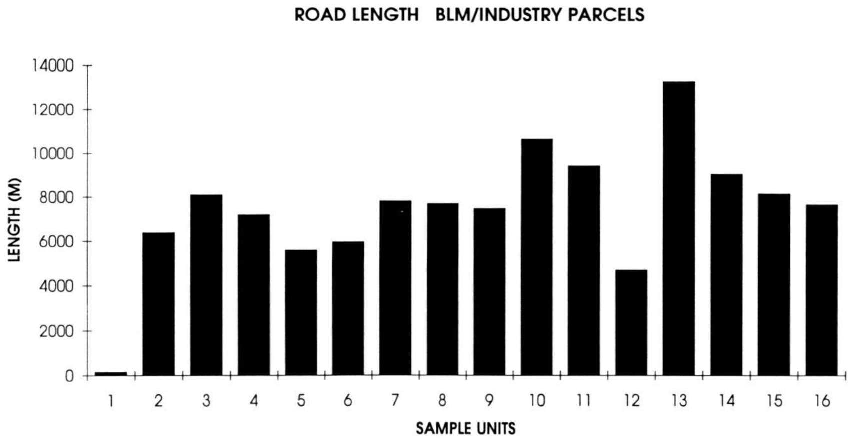


Figure 7d.

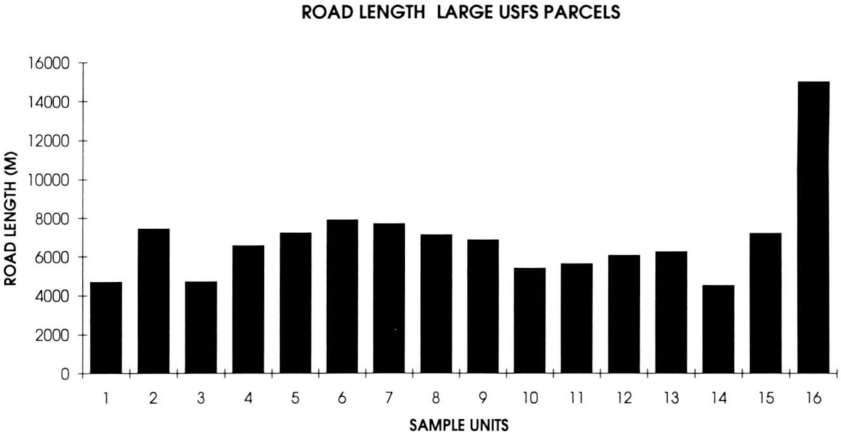


Figure 7e.

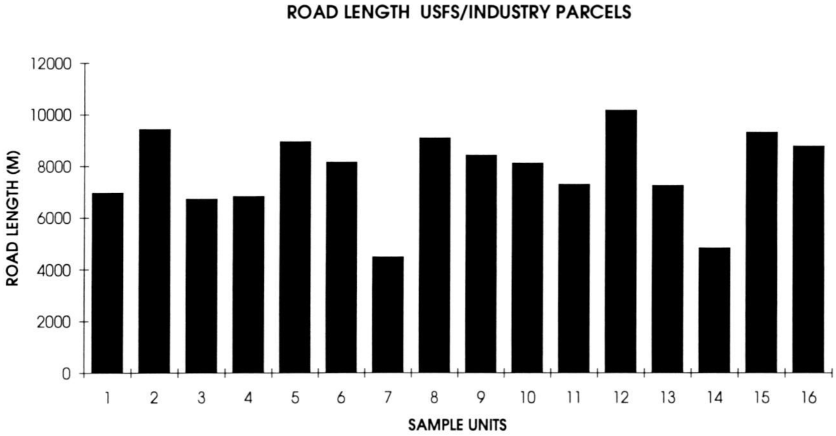


Figure 8a.

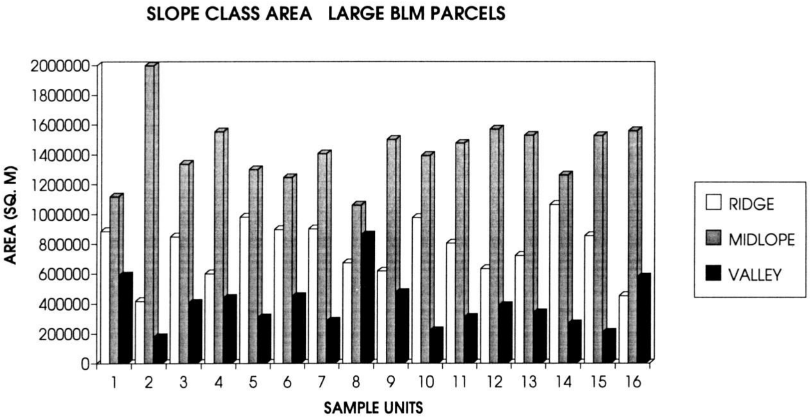


Figure 8b.

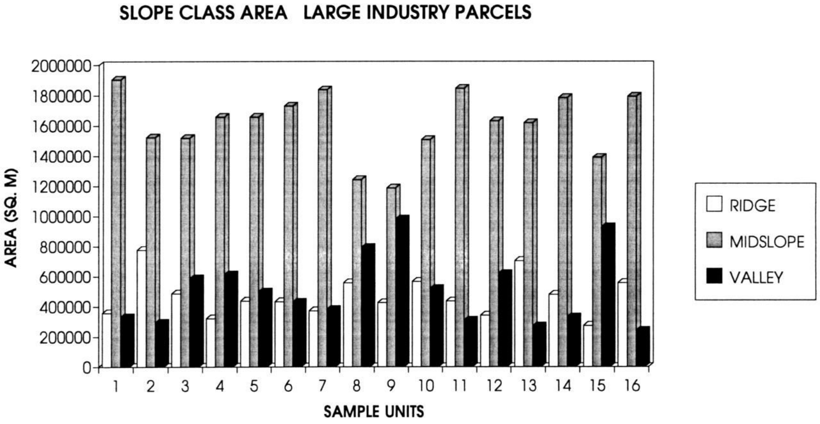


Figure 8c.

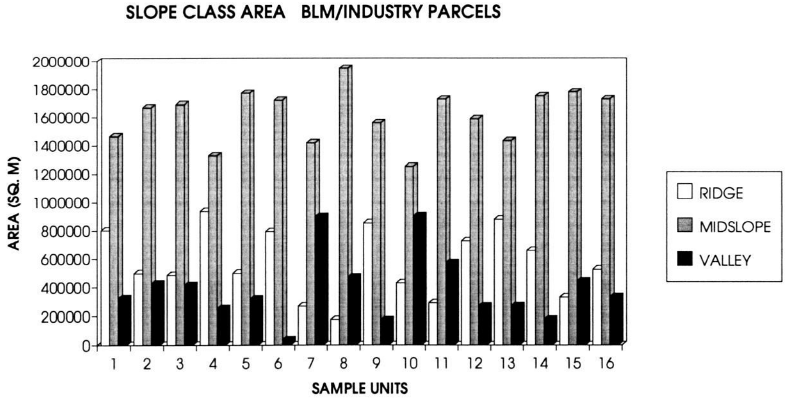


Figure 8d.

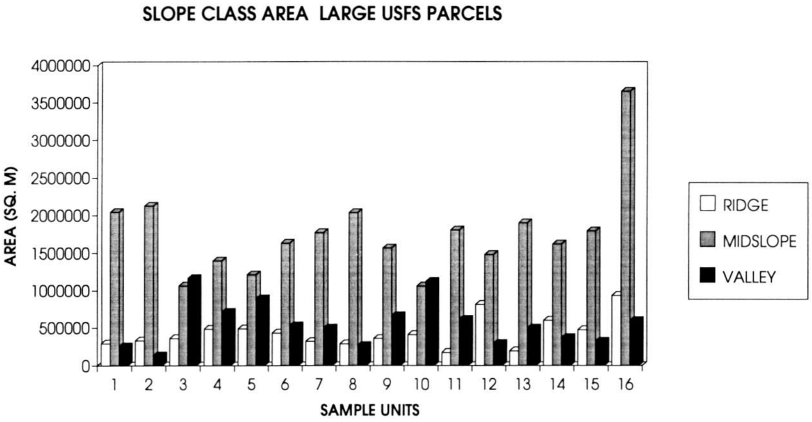


Figure 8e.

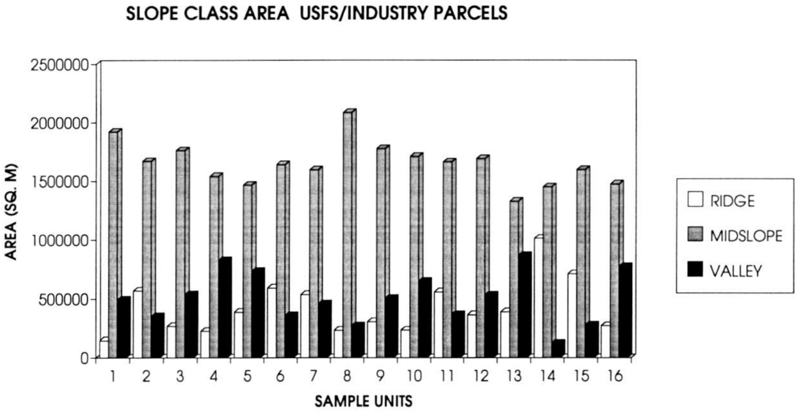


Figure 9a.

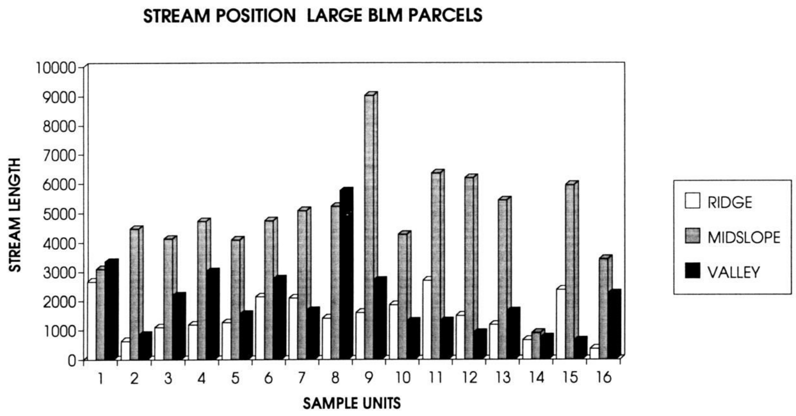


Figure 9b.

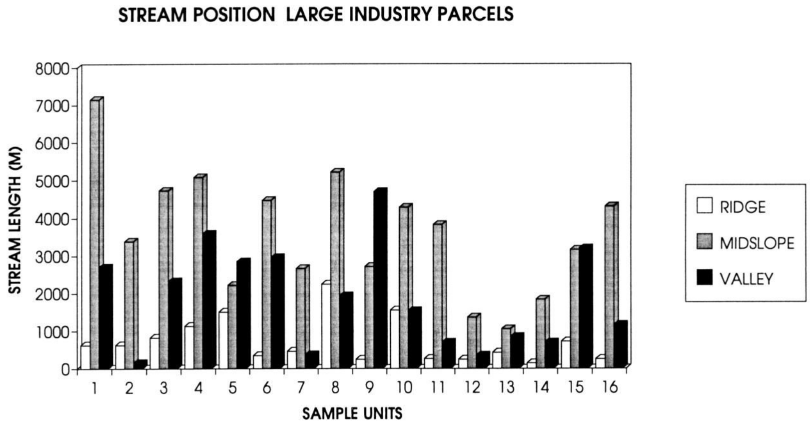


Figure 9c.

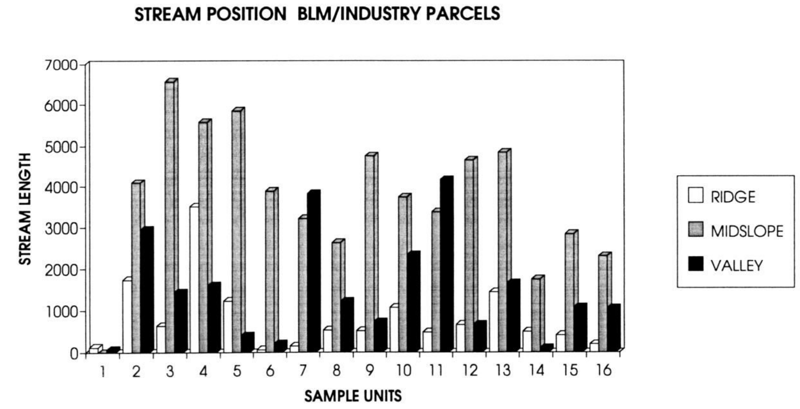


Figure 9d.

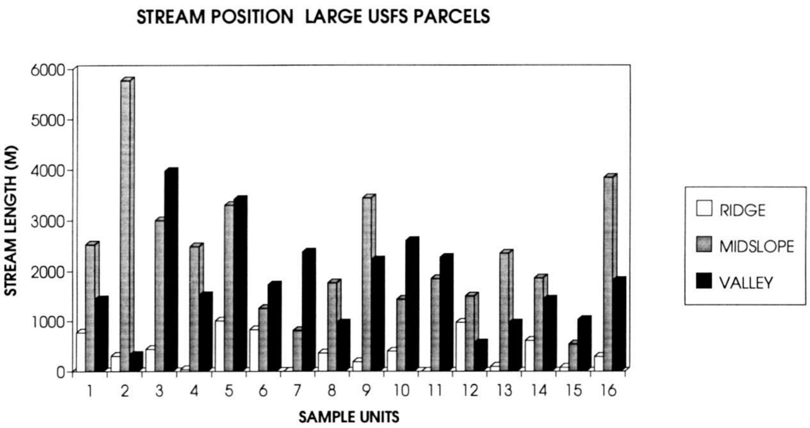


Figure 9e.

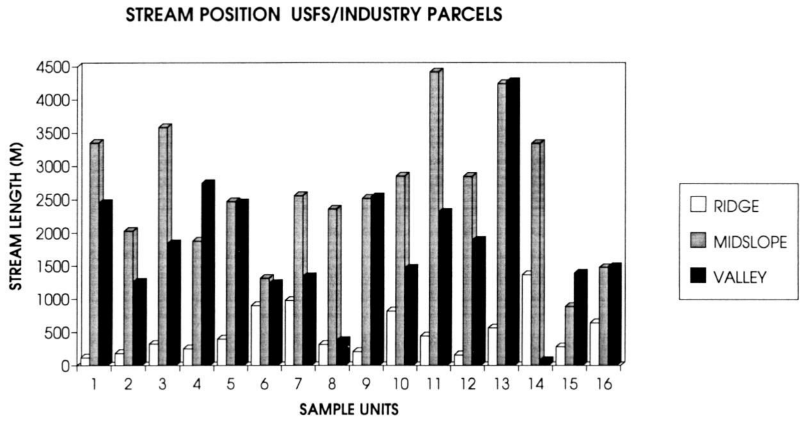


Figure 10a.

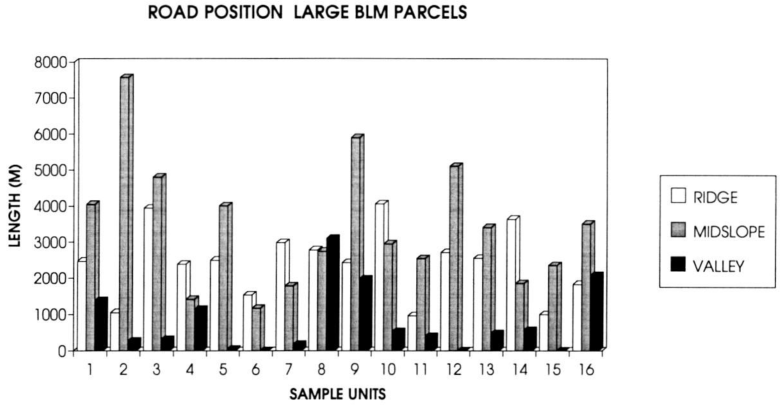


Figure 10b.

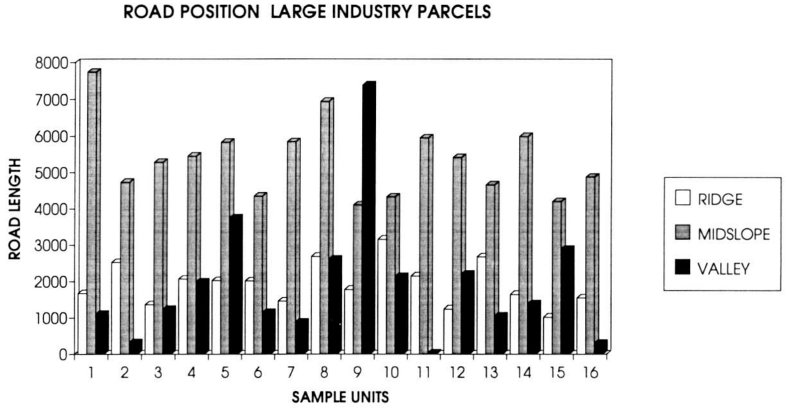


Figure 10c.

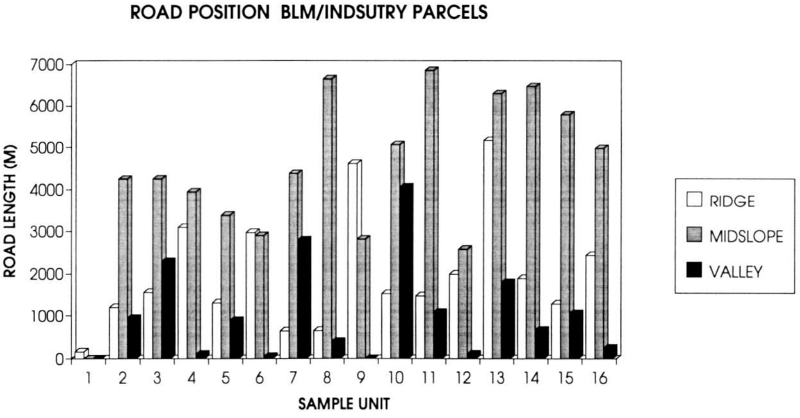


Figure 10d.

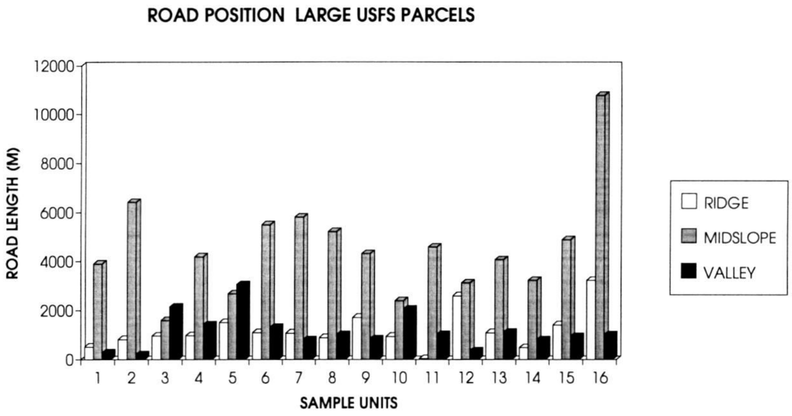
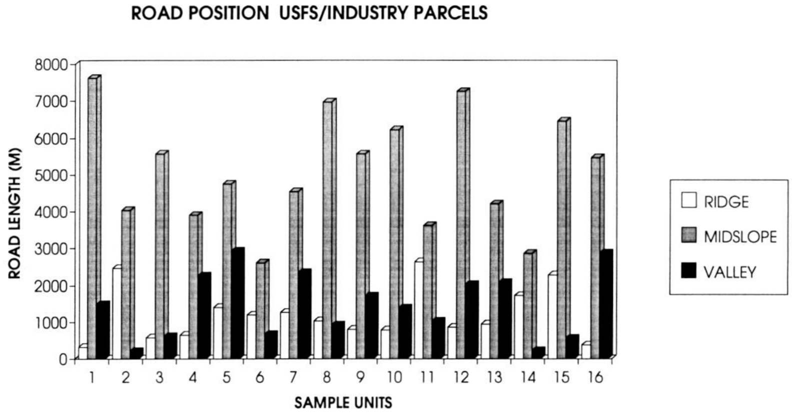


Figure 10e.

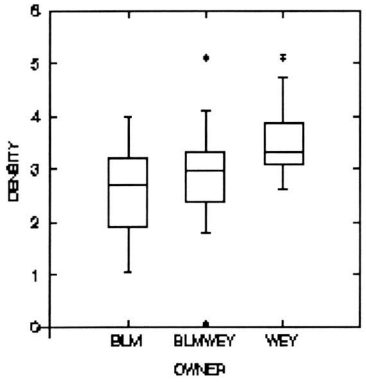


APPENDIX THREE

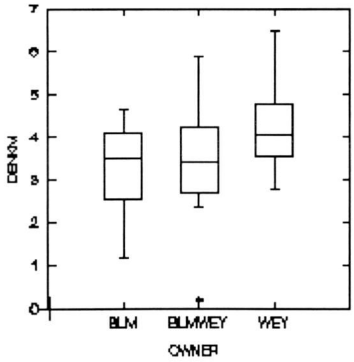
WHISKER BOX PLOTS

Figure 11.

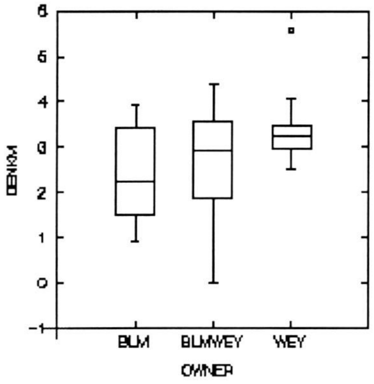
ROAD DENSITY (KM/KM2) TOTAL SAMPLE AREA



ROAD DENSITY (KM/KM2) RIDGE SLOPE CLASS



ROAD DENSITY (KM/KM2) MID SLOPE CLASS



ROAD DENSITY (KM/KM2) VALLEY SLOPE CLASS

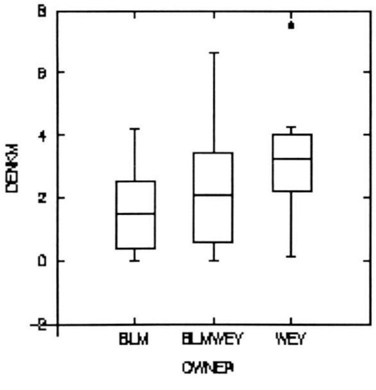
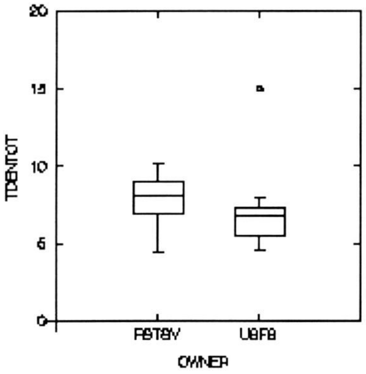
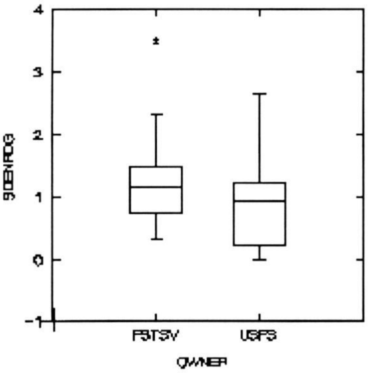


Figure 12.

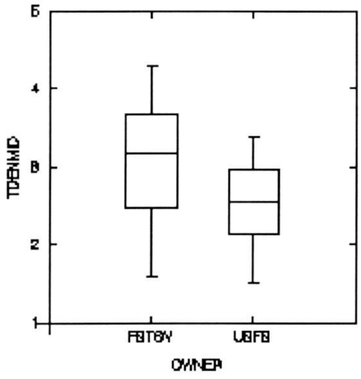
ROAD DENSITY (KM/KM2) TOTAL SAMPLE AREA



STREAM DENSITY (KM/KM2) RIDGE SLOPE CLASS



ROAD DENSITY (KM/KM2) MID SLOPE CLASS



ROAD DENSITY (KM/KM2) VALLEY SLOPE CLASS

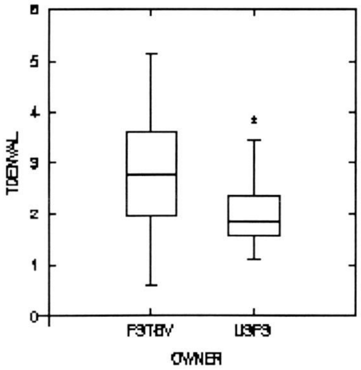
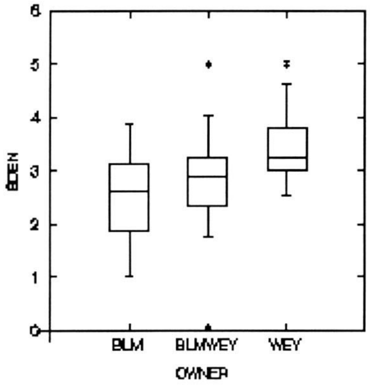
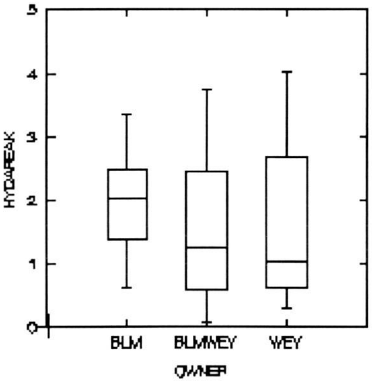
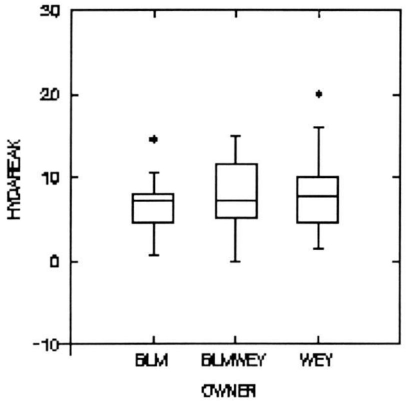


Figure 13.


STREAM DENSITY (KM/KM2) TOTAL SAMPLE AREA


STREAM DENSITY (KM/KM2) RIDGE SLOPE CLASS

STREAM DENSITY (KM/KM2) MID SLOPE CLASS



STREAM DENSITY (KM/KM2) VALLEY SLOPE CLASS

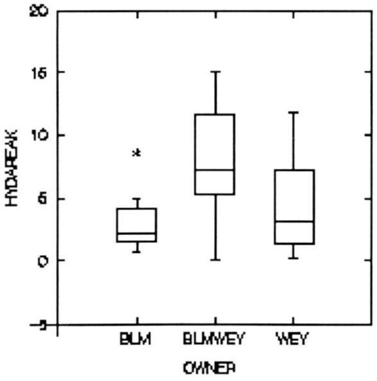
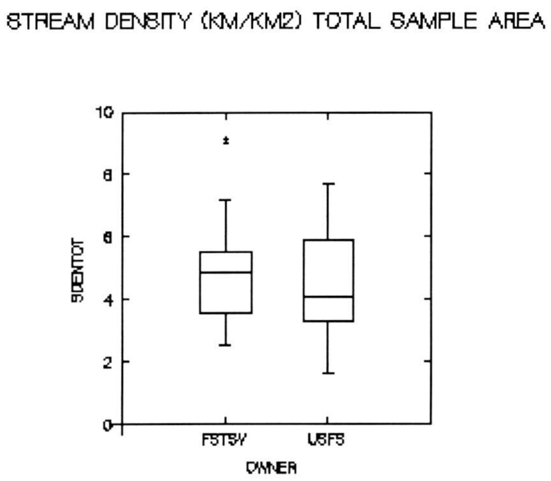
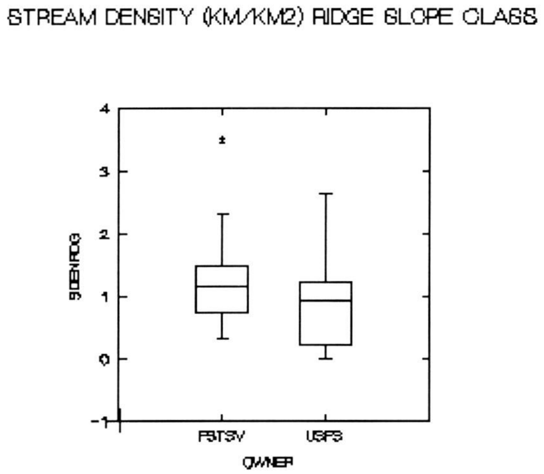
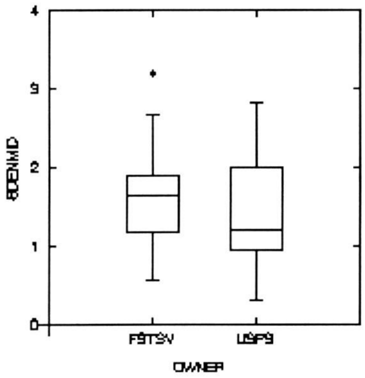


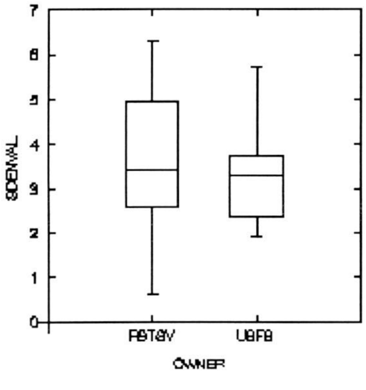
Figure 14.


STREAM DENSITY (KM/KM2) TOTAL SAMPLE AREA
10
8
6
4
2
0
SDENTOT
FSTSV
USFS
OWNER


STREAM DENSITY (KM/KM2) RIDGE SLOPE CLASS
4
3
2
1
0
-1
SDENRDG
FSTSV
USFS
OWNER

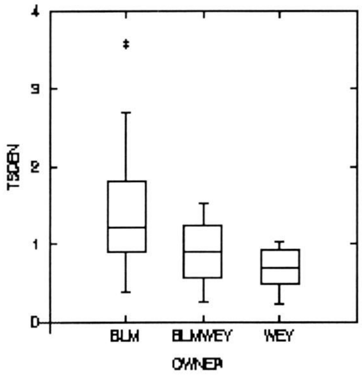


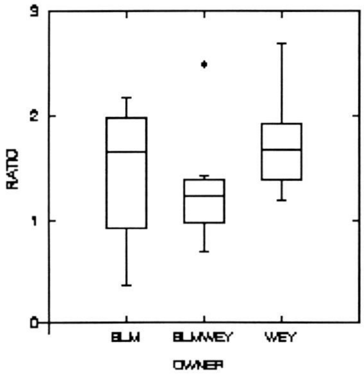
STREAM DENSITY (KM/KM2) MID SLOPE CLASS



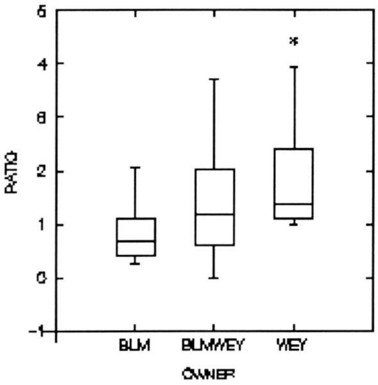
STREAM DENSITY (KM/KM2) VALLEY SLOPE CLASS

Figure 15.


ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) TOTAL AREA


ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) RIDGE CLASS

ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) MID CLASS



ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) VALLEY CLASS

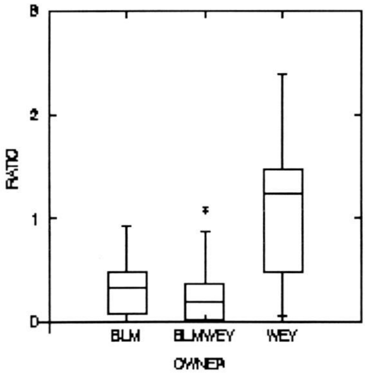
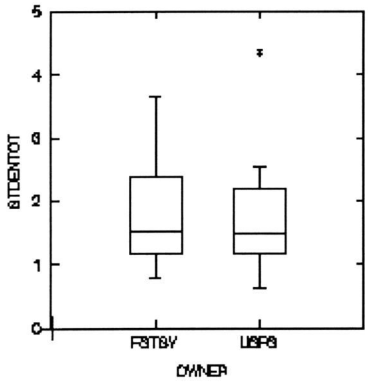
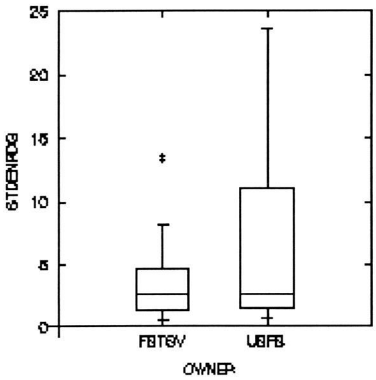


Figure 16.

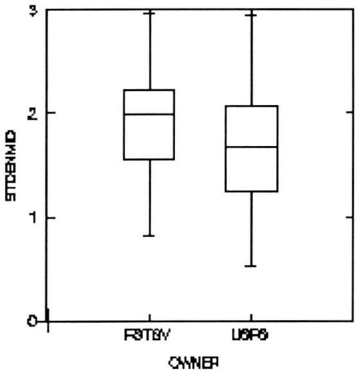
ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) TOTAL AREA



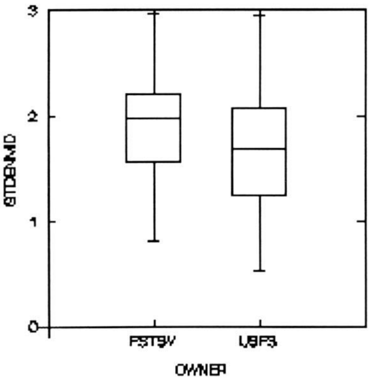
ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) RIDGE CLASS



ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) MID CLASS



ROAD/STREAM DENSITY (KM/KM2)/(KM/KM2) VALLEY CLASS



APPENDIX FOUR

ROAD / STREAM CORRELATION GRAPHS

Figure 17. Road Length vs. Stream Length, Ridge Slope Class

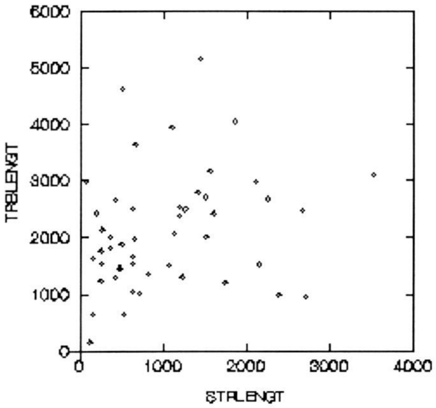


Figure 18. Road Length vs. Stream Length, Mid Slope Class

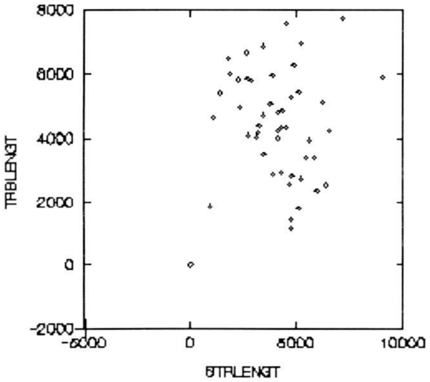
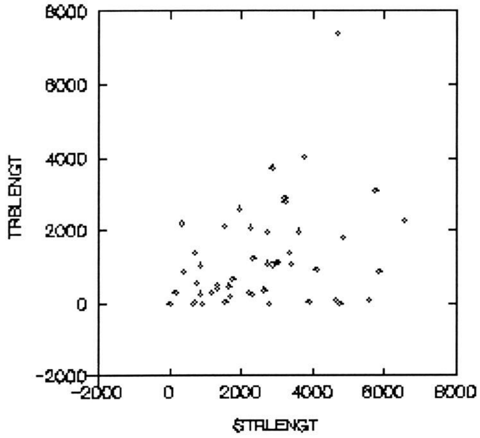


Figure 19. Road Length vs. Stream Length, Valley Slope Class



APPENDIX FIVE

GRAPHS OF SAMPLING MEANS

Figure 20.

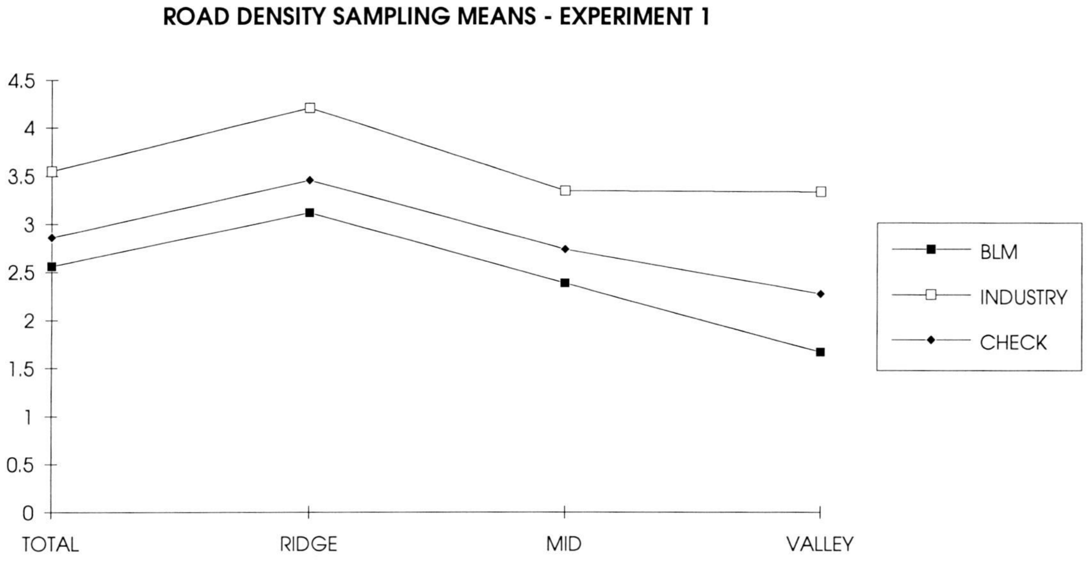


Figure 21.

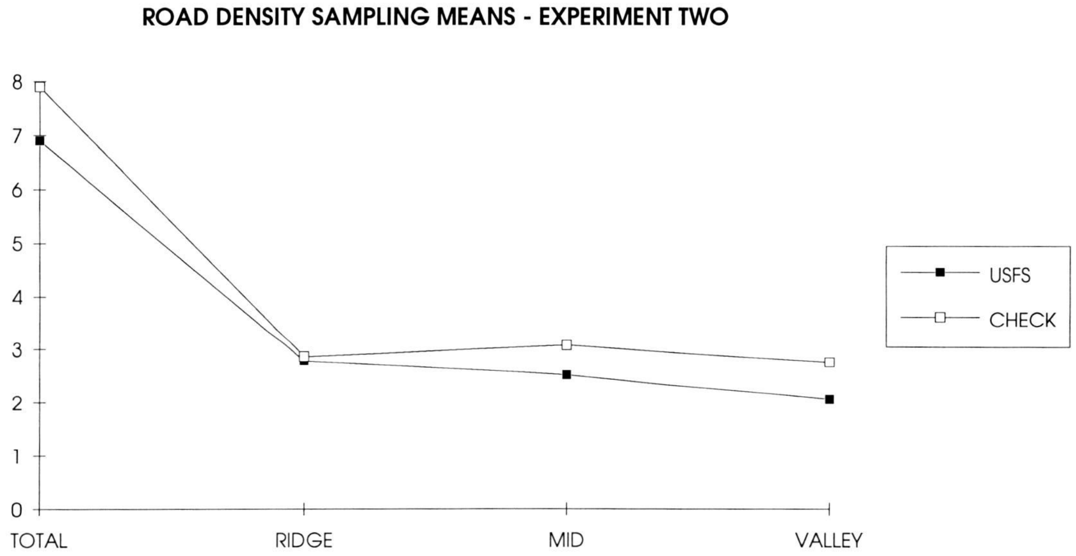


Figure 22.

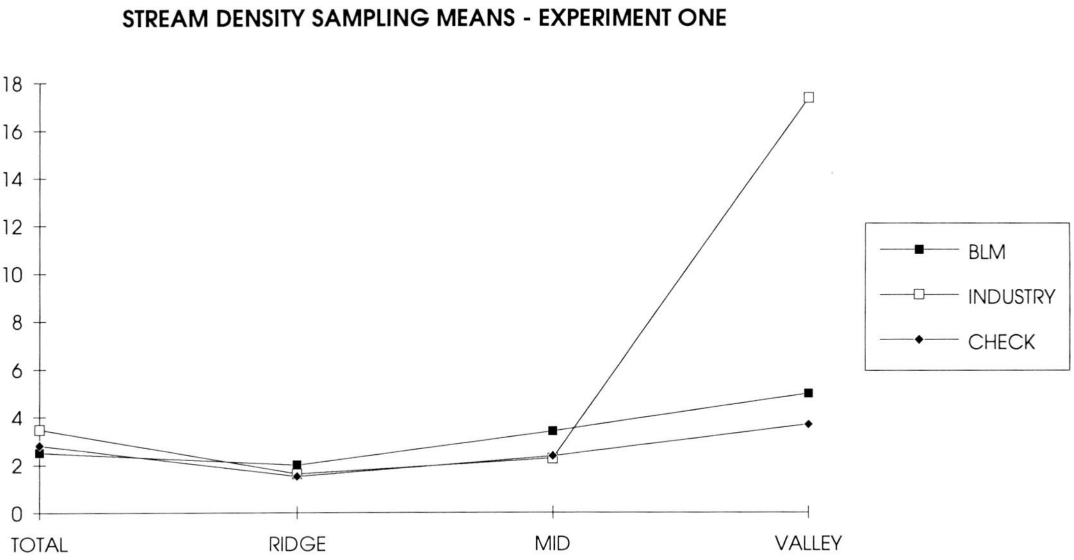


Figure 23.

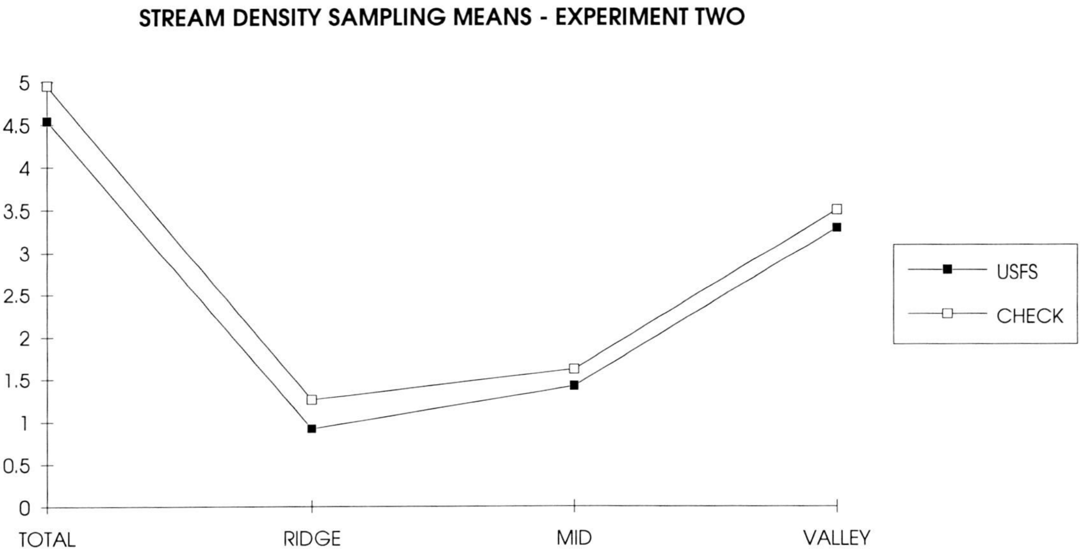


Figure 24.

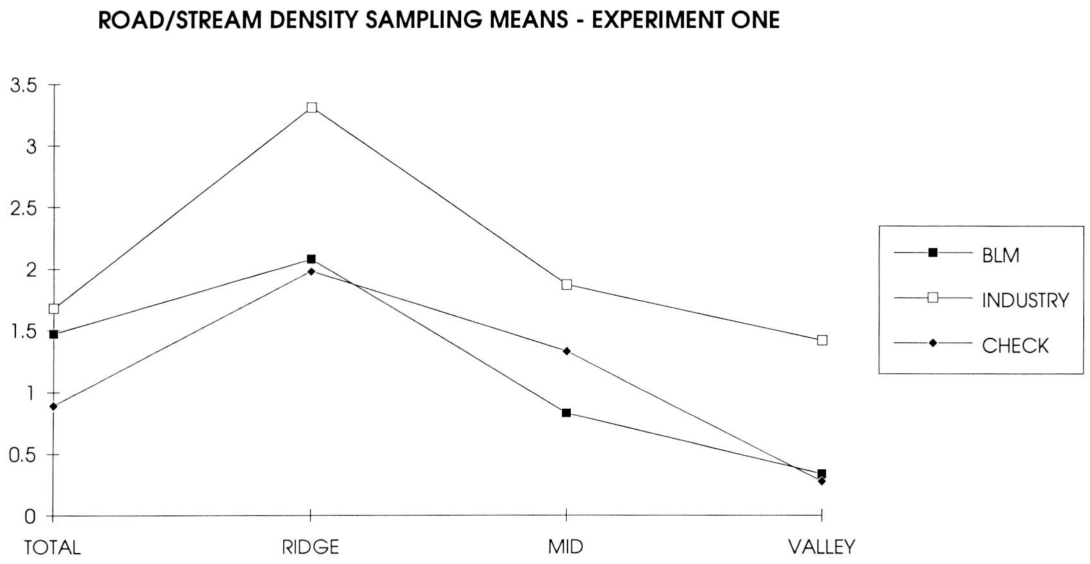


Figure 25.

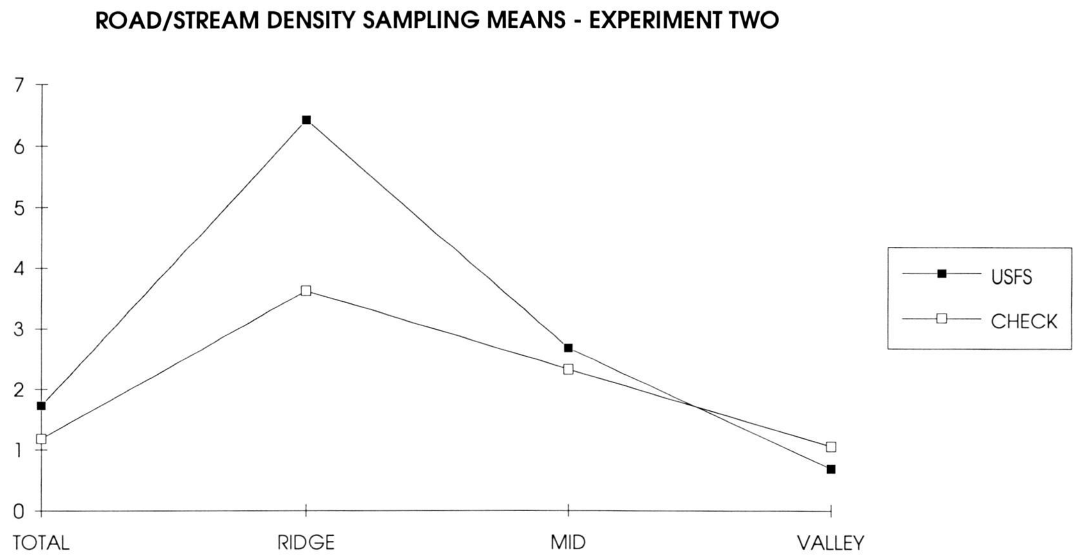
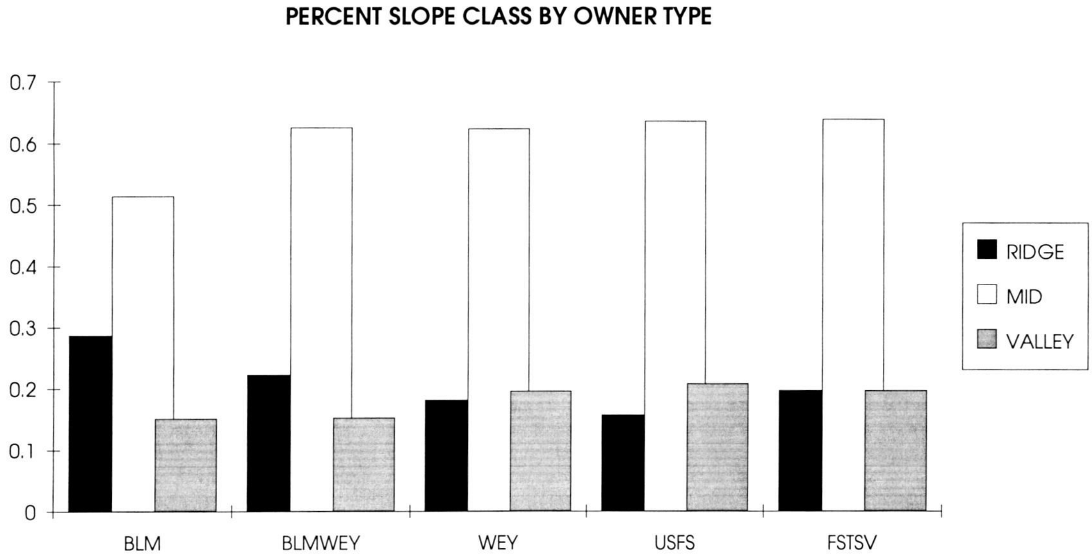


Figure 26.


PERCENT SLOPE CLASS BY OWNER TYPE
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
RIDGE
MID
VALLEY
BLM
BLMWEY
WEY
USFS
FSTSV