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RESEARCH REPORT NO. 22

PATTERNS OF LAND USE CHANGE AROUND A LARGE RESERVOIR

By

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Research Report No. 22

PATTERNS OF LAND USE CHANGE AROUND A LARGE RESERVOIR

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University of Kentucky Water Resources Institute
Lexington, Kentucky
One of a series of technical reports
on
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Dr. L. Douglas James, Principal Investigator
Dr. Don M. Soule, Dissertation Director

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INTRODUCTION

"Patterns of Land Use Change Around a Large Reservoir" is based on research performed as part of a project entitled "The Economic Impact of Flood Control Reservoirs" (OWRR Project No. A-006-KY) sponsored by the University of Kentucky Water Resources Institute and supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379. Special thanks should also be extended to the Nashville District of the U.S. Army Corps of Engineers for supplying basic data from their original topographical surveys, to the Agricultural Stabilization and Conservation Service for help in securing the necessary aerial photographs, and to the University of Kentucky Computing Center for assistance and use of their facilities in performing the computational work.

The overall project is examining the economic consequences which resulted from the construction of four existing reservoirs in the hope that the results might suggest improved techniques for the economic evaluation of proposed projects. This is the eighth of a series of reports developed from the project and deals with patterns of land use change experienced around Lake Cumberland, one of the larger reservoirs in the United States, over the last thirty years. The analysis found land use change during reservoir construction to primarily occur at points with the best road access to population centers. Once the lake was formed, access to and view of the lak also became important. In later years, development has shifted more towar larger blocks of land. Probabilities of change in specific sets of circumstan were estimated to guide simulation studies of development around a reservoi periphery to help guide right-of-way acquisition, land use planning, and environmental quality control.

Readers comment on the research problem, the approach described in this report, or the findings as presented are encouraged and should be directed to L. Douglas James, Project Director.

ABSTRACT

Reservoirs are built to control floods, provide water for irrigation and municipal supply, generate electric power, augment low flows for navigation and water quality control, and provide improved fishing and recreation opportunity. A reservoir is justified if the benefit it provides to society exceeds the cost to develop it. Much research has been done to determine the benefit of a water resources development to society as a whole. Some research has explored the benefit of such a facility to a region. Very little research exists on the effects of a reservoir on the immediately surrounding area.

It seems reasonable that effects caused by the proximity of a reservoir intensify as one draws closer to the lake. Demand for land shifts from uses unrelated to the project to project oriented uses. Property value changes, and some landowners are able to reap large profits. Others, forced to sell all their land for construction of the reservoirs are not so fortunate. Simultaneously, land use change affect the environmental quality experienced by third parties, adjacent land owners and visitors to the area. By examining the spatial patterns of land use changes around a reservoir, this study hopes to aid planners anticipate wind fall profits to landowners, improve environmental quality control, guide the land use planning of surrounding communities, and project future demands for increased services placed on local governments.

The general hypothesis of this study is that the spatial patterns of land use change are influenced by economic and geographic characteristics

of the reservoir and reservoir area. Several hypotheses concerning the effects of relative location around the reservoir, the effects of relative location on a peninsula, the effects of the characteristics of an individual site, and the effects of road access are tested using analysis of variance and multiple regression. The data used for the analysis is based on Lake Cumberland, a reservoir in Southern Kentucky.

The area immediately surrounding the lake is divided into 19 peninsulas, and each of these is subdivided into 100 quadralaterals. For each of these quadralaterals data such as slope, water frontage, and land use changes are obtained. This method of subdivision allows comparison of the patterns of land use changes on peninsulas as well as around the lake. Land use for the four years - 1938, 1951, 1960, and 1967 - provide the basis for computing the land use changes. All areas for each date are classified as residential, commercial, public, or agricultural. Any location shifting among these categories is defined as a land use change.

The analysis indicates patterns of land use change surrounding the lake. Factors such as road access, slope, view, and location on a peninsula proved to be significantly associated with different patterns of land use change. Both the patterns and their degree of association with other variables have shifted over time. The probability of experiencing land use change for each observed combination of the significant factors is calculated for three periods in project time. From such information, it is possible to simulate land use change around other reservoirs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

The completion of Hoover Dam on the Colorado River in 1936 inaugerated the era of the large multipurpose reservoir in water resources development in the United States. In the succeeding years, many such reservoirs have been built in all sections of the country to control floods, provide water for irrigation and municipal supply, generate electric power, augment low flows for navigation and water quality control, and provide improved fishing and recreation opportunity. Each reservoir produces economic benefits as it successfully functions to perform one or more of these purposes. A project is justified economically if the resulting benefits exceed the cost of its development. Every project requires some (primary taxpayers) to sacrifice so that others (primarily users of project output) might benefit. Economic feasibility requires benefits to exceed cost from the national viewpoint or after all economic consequences to all parties are considered. Scholarly research on the economics of water resources planning [23, 58] and the project evaluation procedures used by federal agencies [65] have placed first priority economic analysis on this level.

However, the geographical distribution as well as the magnitude of project benefit is significant in determining project merit. The nation may specifically seek to benefit impoverished or underdeveloped regions as a planning objective. Even where this is not the case, planners must understand the regional economic impact of project development in order to maximize net benefits. Water resources are developed to benefit people including those in the affected region, and multipurpose projects can thus be distinguished from industry which enters a community primarily for the benefit of the company. Economic impact studies have been used to evaluate the economic effects of both public and private investment within prescribed geographical boundaries. As would be expected, a large investment of public funds, which draws tax money from throughout the country to benefit inhabitants of a limited service area, stimulates the local economy. Multipurpose reservoirs produce a substantial secondary benefit from the point of view of the region utilizing project output. In fact, the esthetic and recreational attraction may stimulate the economies of counties surrounding a reservoir even when few other direct benefits are provided [82].

In addition to analysis from the national and regional points of view, it is becoming increasingly clear to water resources planners that project effects need to be evaluated on yet one more level. The stimulation of the local economy by the proximity of a reservoir, by logic and by observation, becomes more intense as one gets closer to the lake. Shoreline landowners have been able to realize substantial profits by developing their property. Planners must assess such development from the viewpoint of (1) the desirability of spending public money to personally profit the few who by chance happened to own the surrounding land before the reservoir is built and (2) the potential disruption to the esthetics of the environment of stimulating recreation oriented seasonal shoreline development. Proper project planning requires explicit determination of the measures, if any, needed to control shoreline development to achieve project objectives. Purchase of extra right-of-way and zoning are the two most common such measures.

At present, the required measure optimization cannot be achieved because of a limited understanding of the interaction between the lake and the economic development of immediately surrounding land areas. Better information is needed on the significance and relative importance of site characteristics such as location relative to the lake and the surrounding population, access, view, and slope on the potential for economic development. Better information is needed on how the potential changes with time. Without such information, planners cannot distinguish areas where land use regulation around the reservoir periphery is needed to achieve project objectives from areas where it is not needed because significant land use changes are unlikely to occur anyway. This study seeks to accumulate such information to help planners anticipate windfall profits to landowners, improve environmental quality control, guide the land use planning of surrounding communities, and project future demands for increased services placed on local governments.

OBJECT OF THE STUDY

The objective of this study is to investigate the spatial patterns of land use changes around the reservoir periphery. The general hypothesis tested is that the spatial patterns of land use changes are not produced by random events equally likely to occur anywhere along the shoreline but are rather influenced by the economic and geographic characteristics of the specific shoreline location. Chapter IV presents the specific hypotheses used to test the significance of specific characteristics and the results of the testing.

The construction of a large artificial lake requires the relocation of people, houses, farms, businesses, and roads from the flooded area and may attract new and different types of economic activity to the lake area. It is reasonable to expect that the lake influences the decision making process for both the people having to relocate and the people attracted into the area. A previous study based on Lake Cumberland in South Central Kentucky found that the counties containing the reservoir experienced a more rapid economic growth than did other counties in the same general area [82]. It is not reasonable, however, to assume that this accelerated growth is widely distributed over the affected counties. It is more likely to concentrate in the land areas contigious to the reservoir shoreline.

This study attempts to measure the pattern of land use changes in the shoreline areas. The previous study used total county wide property values because such data was readily available, of good quality, and generally representative of the aggregate economic effects of the lake. Such published county wide data, however, are not applicable to this study because it is concerned with land use changes in specific locations and how these changes are influenced by various geographical characteristics of the lake and surrounding area.

CAUSATION

In order to avoid the difficulties inherent in trying to prove that a reservoir causes specific land use changes, in a dynamic economy, the problem of causation was approached by seeking a study area remote from urban areas or major transportation routes. For such an area, the assumption can be made that the reservoir causes changes in land use other than those from one type of agriculture to another. This assumption is realistic because the remoteness of the reservoir from all other factors known to induce urban development makes such development very unlikely on land in very close proximity to the reservoir.

SCOPE

The scope of this study is limited in several ways. The study does not attempt to produce a general model for predicting land use changes. It concentrates on a particular case, Lake Cumberland -- a large reservoir in South Central Kentucky. Lake Cumberland is remotely located and is of sufficient size and has been in existence long enough for one to expect some influence on land use. Only areas immediately adjacent to the lake are studied. On the north side of the lake only the area from Greasy Creek on the west end to Fishing Creek on the east end is included; and on the south side, only the immediate area from Wolf Creek Dam on the west end to Mill Springs on the east end is included (Figure 1). The area east of Fishing Creek is excluded from the study because the proximity of the town of Burnside and a major north-south highway invalidate the assumption that negligible land use changes would have occurred without the reservoir.

Property value changes might be a suitable direct measure of the economic development of shoreline areas, but land use changes are chosen for study because reliable data can be obtained more easily and land

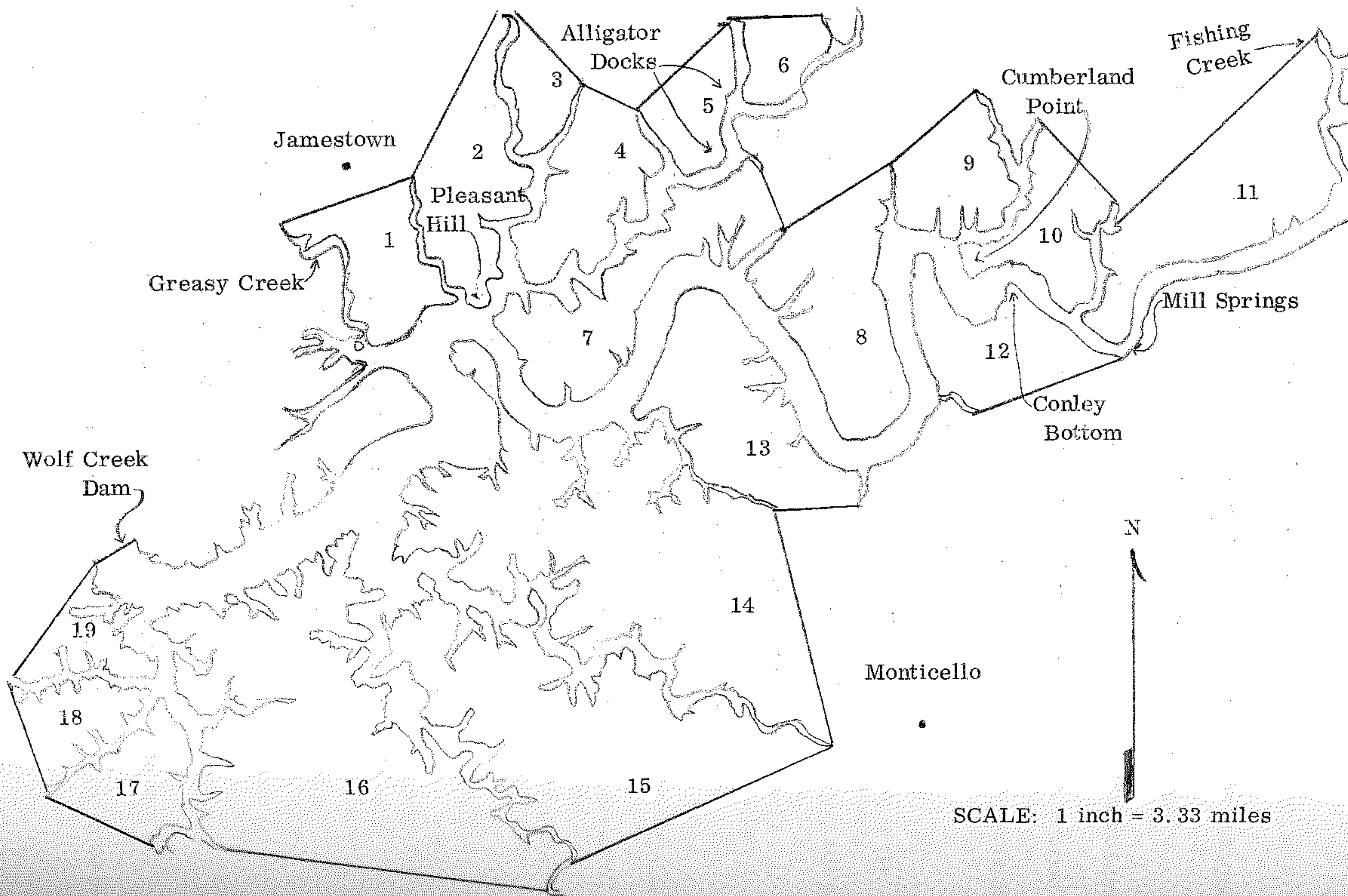

FIGURE 1: Map of Lake Cumberland Area

use is more indicative of effects on environmental quality and the need for zoning. The value of specific properties as a function of time is not easily obtained because a given parcel is sold infrequently, and independent appraisals are expensive and not necessarily certain to indicate market value. Appraisals of past value changes would be impossible to obtain. Land use, in contrast, can be observed as a function of time from available mapping and aerial photography. For these reasons, land use changes are chosen for study.

The selected period of study is 1938-1967 with three subperiods--1938-1951, 1951-1960, and 1960-1967. In 1941, construction began on Wolf Creek Dam forming Lake Cumberland, only to stop in December, 1942, because of the war. From this date until construction resumed (February, 1946), only work necessary to protect the work already completed was undertaken. The dam was closed in the fall of 1950 and by March, 1951, the lake had filled. From that time until 1960, when the project was officially completed, only certain legal disputes, completion of the power house, and settlement of property titles remained. Thus, the three subperiods represent respectively: (1) the construction period; (2) the buildup period (when the surrounding area is beginning to respond to the economic stimulation of the reservoir); and (3) the maturity period (when the project is being fully operated and the benefits are being utilized in the intended fashion).

METHOD

To determine spatial patterns of land use changes with respect to general shoreline location, the total study area is divided into peninsulas. Each peninsula is further subdivided into 100 quadralaterals in order to provide a systematic ordering of relative location on a peninsula. Potentially relevant geographical, topographical, and access information are obtained for each of these quadralaterals to evaluate the effect of these variables. Land use information is obtained for each quadralateral at each date.

Data on land use change (primarily conversions from agriculture to some other use) is analyzed by one-way analysis of variance and multiple-regression techniques to determine by time period which of the measured factors correlate significantly with the spatial distribution of land use changes around the lake and on each peninsula. Each significant factor is evaluated qualitatively and the extent of land use changes for observed combinations of site properties are summarized to depict the kinds of influence exerted on land use changes.

SOURCES OF DATA

The primary sources of data are (1) 1938, 1951, 1960 and 1967 aerial photographs obtained from the U.S. Department of Agriculture, Commodity Stabilization Service, (2) county maps, (3) U.S.G.S quadrangle maps, (4) Corps of Engineer property boundary maps, and (5) personal field observations.

ORGANIZATION OF THE STUDY

The study is divided into four remaining chapters. Chapter II presents the method used to locate and measure land use changes in the area immediately surrounding a reservoir. Chapter III describes the application of the method through developing the necessary input data for the area immediately surrounding Lake Cumberland. Chapter IV contains the results of the analysis of statistical significance and a description of the relationship among the variables. Chapter V contains conclusions and recommendations for further research.

CHAPTER II

METHODS AND PROCEDURES: GENERAL ASPECTS

The benefit-cost studies used to test economic feasibility and the economic impact studies used to evaluate effects on the regional economy are not directly applicable to the examination of spatial patterns of land use change and their relationship to the economic, geographic, and other characteristics of the area.

What method should be employed to determine the effects of a reservoir at this third level--the immediate proximity? As a first step, one may examine methods used to evaluate projects at the regional level, hoping that they will provide insight and background which will be helpful in developing a method for determining the reservoir's influence on the economic development of surrounding land areas. This chapter begins by surveying four of the major methods of regional analysis, then develops the general aspects of a method for this study, and finally gives some information on how this method is applied.

METHODS FOR ASSESSING ECONOMIC IMPACT

Several major methods are used for measuring impact on the economy of a region. Four of the more important methods are: a) the case-study method, b) the before-after method, c) the control-area method and d) the input-output method.

Case Study Method

The case study method records the events and qualitatively evaluates the causes behind the economic changes occurring during the study period. The method provides the opportunity for detailed qualitative evaluation that is very helpful in building a realistic quantitative model. The method is usually used in response to some economic event such as the introduction into a community of a highway, reservoir, or industry, but the method does not develop proof that changing conditions are caused by the event. No quantitative relationships are produced to isolate the degree of economic impact or to estimate and compare cost with benefit. Thus, if the purpose of the study is to determine whether a locality is better off or worse off because of the building of a reservoir, this method is weak. If the purpose is developing a better understanding of the processes whereby take place during the life of the reservoir, the case study method provides a useful qualitative evaluation of the economic environment.

Before-After Method

The before-after method attempts to measure economic impact from changes in a given economy between two time periods. The changes cannot be attributed to a specific project without the assumption that economic conditions would otherwise remain static. In a dynamic economy, the method cannot isolate which part of the total economic change is actually casually related to the event under study.

For example, in studying the effect of a water resource facility on income, time periods before and after the building of the facility could be chosen and the changes in income measured. But to the degree that some income changes would have occurred without the water resource facility, the before-after method suffers a basic weakness in not being able to isolate the reservoir effect. Other factors, such as improved transportation, could have caused at least some portion of the change. The method provides no way to assign the proper proportions of long-term changes to the different causes.

Control Area Method

In order to avoid this major disadvantage of the before-after method, the control area method was developed to isolate local changes caused by the event under study from changes widely distributed throughout the economy. This method chooses a control area similar in all respects, other than the existance of the event under study, to the study area. Comparison is made between the control area and the study area. Since the two areas are assumed to be exactly alike in all respects, except the factor under study, any difference is attributed to the effect of the factor under study. The fact that no control area can be like the study area in all respects is the major weakness of this method. The best one can do is find a control area with similar major features, such as population, amount of industry, and level of income, in order to minimize the problem. This method is much better than the case-study or the before-after methods for the purpose of trying to evaluate whether a region is better off or not because of a particular development such as a reservoir because it at least makes some attempt to address the question of what would have happened without the project.

Input-Output Method

Since World War II the input-output method [74] has become the dominate research tool for regional applications. W. W. Leontief [55] developed this method to study general economic equilibrium problems in a multi-industry economy [1, p. 343]. Input-output methods deal empirically with input needs and output produced by production sectors throughout an entire economy. The output from other industries used as input by each industry is estimated. Input-output analysis assesses project effect by evaluating the use industry can be expected to make of project output. The method provides a very powerful tool for assessing the influence of expansion in one economic sector (such as water resources) on the balance of the economy, but it is of little help for allocating the spatial distribution of economic growth over small areas.

Relationship to This Study

The four methods discussed represent a progression of increasingly sophisticated tools for assessing economic impact on a regional economy. On the other hand, each method is progressively less satisfactory for use in this study. If the other tools were not available, the case study method would provide the best starting point for collecting the information needed for a more thorough analysis of economic impact. This suggests an approach for beginning the analysis of the spatial distribution of lakeshore development. The experience at Lake Cumberland provides a case study. It looks at the land use changes which did take place, for whatever reason, and relates the location of these changes to the lake and its geographic and economic features. The study area, however, is so chosen that any change in land use can be reasonably assumed (the before-after method) to be due to the existence of the lake, but no proof can be, nor is, offered that the lake caused the change.

URBAN METHODS FOR ASSESSING LAND USE

Other methods have been developed and used to examine patterns of land use change--mainly with respect to growth patterns in metropolitan areas [10]. These methods generally use probabilistic information to simulate the growth and development of a metropolitan area. For example, one such model seeks to determine the patterns of residential development given the total number of households settling in a particular metropolitan area and given certain policy decisions of local governments [19, p. 1]. Such studies look at the effects of water resources development in changing growth patterns in a growing community while this study looks at the pattern of growth induced into what would otherwise be an almost static rural area.

SYNTHESIS OF METHOD FOR THIS STUDY

Changes in Land Use

A previous control area analysis of the economic impact of Lake Cumberland indicated that county-wide average land values had increased due to the presence of the lake [82]. It is reasonable, however, to expect that this increase has concentrated around the lake, and it is informative to see how this impact is evidenced through changes in land use patterns. The previous study evaluated county wide averages using published data, but this study focuses on smaller areas for which no published data tabulations are available. In fact, no practical method could be found to estimate land value changes with time for less than a county area. It is realized that other studies involving shoreline properties have used land values [16, 18, 51, 68]. It is felt, however, that assessments and assessment ratios are not sufficiently responsive to changes in value over short periods of time to be acceptable for use in the Lake Cumberland area. Through aerial photographs and other maps, however, it is possible to generate land use data for the geographical area throughout the study period. Since the majority of the land in the study area is privately owned and there are no zoning restrictions, land use changes are largely determined by economic forces.

With the addition of the lake, land use changes could be expected to occur if a large lake makes any appreciable impact in the region. Assuming that land owners act rationally, they employ their land for the purpose that gains them the highest return. The demand for land in the area is a derived demand depending on the space requirements of activities associated with the lake. For example, as more people desire to live near the lake for esthetic or recreational purposes, demand for residential land increases. More people wishing to visit the lake to participate in recreational activities creates demand for motels, restaurants and other commercial establishments. If farming had previously provided the highest return, residential or commercial use may now do so. So as the lake produces these effects, they can be measured through changes in land use.

An improved ability to predict spatial patterns of land use is important to at least two levels of policy making. First decisions must be made on where to locate and how to design projects to gain the highest return to society. Second, decisions must be made on where to locate specific facilities such as parks, residential areas, commercial establishments, etc. Due to the amount of capital needed to finance a lake, the Federal government usually makes the decisions at this first level. At the second level however, the decision makers can be either government or private. This study does not attempt to analyze the factors considered by a specific decision maker in selecting a specific site for a specific purpose. The purpose of the study is rather to investigate the factors which seems to best explain the land use pattern which finally develops through the interaction of many individual decisions. Better ability to predict consequent spatial patterns enables planners to make decisions that are better able to maximize social welfare.

A study of land use changes as an indicator of the pattern in which a lake affects the economic development of a region raises the question of which land use changes need investigating. Land use changes from one cropping pattern to another would likely be caused by changing farm markets. Land use changes from agriculture to commercial, public, or residential use serve as the most probable measures of reservoir produced change. Agriculture completely dominated this region's economy, and its land use before the lake was built. It still completely dominates the rural areas in the region but located at a distance from the lake (a sort of control area). With the addition of the lake as an esthetic and recreational attraction, visitors have been attracted into the area. Some are building seasonal or permanent homes near the lake. The result has been an increase in the demand for residential land. A nationwide increase in participation in outdoor recreation and better highways, which make it possible for people to live near the lake and yet work in town, have accelerated the trend but would not have produced significant changes without the lake. It follows that changes from agricultural to residential land use are of interest while changes among various types of agricultural land use are not.

With more people spending time in this region, there must be a tertiary economic sector to take care of the additional demand for every-day needs such as groceries, entertainment, etc. [61, p. 268]. Many people use the lake for recreation of shorter duration-- a weekend or a day of fishing or boating. These people make use of motels, restaurants, bait shops, and related places of business. Consequently, change to commercial land use is a subject for investigation.

Public land use increases with increased demand for recreation. Campsites, picnic areas, and related tourist facilities spring up to accommodate this demand. A water resource facility serves as a center of attraction for these increased demands. This study therefore considers changes to public land use.

What are the spatial patterns of land use changes around a new reservoir in an isolated rural area? Are these patterns influenced by particular geographical factors in association with the lake? What kinds of locations are most likely to experience land use changes? This study attempts to provide answers to these questions.

Geographical Factors Associated with the Lake

Many geographical factors might be proposed as potentially affecting the spatial distribution of land use around a reservoir periphery. The approach followed is to propose those which seem to be worthy of further study, to attempt to measure each one as closely as possible, and then to apply tests to determine whether the correlation between the factors as measured and the observed land use changes are statistically significant.

The properties associated with individual locations around the lake that may reasonably be proposed as influencing the spatial patterns of land use may initially be determined by visualizing how an individual might respond to the presence of the lake. An individual may enter the region with the idea of buying a home site. If he wants to use the lake for recreation, other things equal, it is reasonable to expect that he would have a higher preference for lake front sites. Coves that extend inland provide boat docking or other semiprivate recreational areas protected from the main part of the lake. Therefore, a combination of water frontage and secluded water area would seem likely to promote residential land use.

Land with steep slopes may increase building and accessability costs and the danger of slides. Sometimes, however, steep slopes add to the desirability of a site by improving the view. Roads also affect the desirability of sites. If a road exists, the added cost of building one by the developers or the necessity of getting local government to provide one is avoided. The presence or absence of this added cost influences a person's desire to build. Classification as to road type (by amount of use) may be an added factor in location, particularly for commercial activities. The overall quality of the road tends to closely correlate with its amount of use.

Finally, peninsulas affect the spatial patterns around a lake as the arms of water separating them as natural barriers to economic activity. The location of the peninsula as a whole as well as the relative location of a site on a peninsula may both be important. For this reason both are included in the analysis to determine their influence on patterns of land use change surrounding the lake.

Statistical Methods

Certain hypotheses concerning the significance or lack of significance of the hypothesized potential influences on land use changes are proposed and tested using the statistical techniques of analysis of variance and multi-regression analysis. These specific hypotheses and the statistical techniques used to test them are presented in Chapter IV. Finally the observed relationships between the significant factors and the spatial distribution of land use are presented and qualitatively evaluated.

SUMMARY

This study attempts to determine how a water resource development affects the patterns of land use changes in the immediate area. The distinctive feature of the approach is that it is concerned with changes in the immediate area of a reservoir--not at the regional or national levels. It is expected from economic analysis that there would be a movement from agriculture into other uses connected with the lake. These movements can reasonably be expected to be influenced by geographic and economic factors. The stage is now set for the empirical investigation of the changes and the factors for Lake Cumberland in Chapter III.

CHAPTER III

EMPIRICAL INVESTIGATION OF LAND USE CHANGES

A great deal of empirical data is required for the study of land use changes. Data are needed to portray spatial and time patterns of land use change. Data are needed to quantify independent variables which might potentially be used to explain the observed land use changes. Neither type of data is available in published tabulated form for the very small areas considered in this research. Land use data, as a function of time, has to be obtained from aerial photographs available through the U.S. Department of Agriculture as supplemented by land use studies or mapping made by various governmental agencies. The independent variables were evaluated from appropriate mapping, most frequently the topographical quadrangles published by the U.S. Geological Survey. As the tabulation of such data is inherently time consuming, the procedures used are described in detail to help others engaged in similar research and to help the reader evaluate the validity of the subsequent analysis.

SELECTION OF STUDY LAKE

Lake Cumberland is selected for analysis due to its size, length of time in existence, the homogeneity and rural nature of the surrounding area, and the availability of the necessary mapping and aerial photography.

This lake has a water surface area of over 50,250 acres at maximum power pool (El. 723) and collects runoff from nearly 5,789 square miles [78]. It is the largest lake within a reasonable driving distance and draws many visitors from such large urban areas as Louisville and Lexington, Kentucky, Cincinnati, Dayton, and Columbus, Ohio, and Indianapolis, Indiana. Over 2,000,000 recreation visitors a year come to Lake Cumberland. Many have summer cabins for weekend or vacation use. Thus, the lake is large enough, both physically and as a tourist attraction, to have produced significant change in shoreline land use.

Wolf Creek Dam which forms Lake Cumberland was authorized by the Flood Control Act approved June 8, 1938 [Public Law No, 761, 75th Congress, 3rd Session]. Construction and right-of-way acquisition began in the early 1940's. The almost 30 years since then allows plenty of time for the short-term effects of reservoir construction to have ended. The lake by now has had ample time to produce whatever are going to be its measurable lasting economic effects.

The area surrounding Lake Cumberland is predominantly rural and industrially undeveloped. No interstate highway system serves the area directly. North-south Federal highways (US 127 and US 27) skirt the western and eastern ends of the lake where the small county seat towns are located. The percentage of total land in farms is 59.4 percent for Wayne County, 64.9 percent for Pulaski, 75.7 percent for Russell, and 80.8 percent for Clinton, [43]. Most of the remaining area is woodland. The area does not have a diversified economy experiencing urban growth, but it is instead a very homogeneous region, predominantly agrarian. Such an isolated rural area is ideal for this study because any urban-type land development can reasonably be attributed to the reservoir. To support this assumption, the tendency for the portions of the study area nearer the highways and towns to experience more rapid land use changes is statistically tested (Chapter IV, Hypothesis 3).

A survey of available aerial photography and mapping showed the available information to be adequate for the proposed study.

BOUNDING AND SUBDIVIDING THE STUDY AREA

Establishing the Total Area

The next step in data collection is to determine the area to be considered in the detailed analysis. Generally speaking, one would expect the intensity of the effect of the reservoir on land use to diminish with distance from the reservoir. As this happens, the importance of proximity to the lake relative to other causes of land use change also diminishes, and the assumption that the lake is responsible for observed changes becomes progressively weaker. A cutoff boundary was arbitrarily selected (Figure 1).

The cutoff boundary was drawn by connecting by straight lines the furtherest extent of the backwater from the normal pool in the lake up each of the tributary streams feeding the lake. The total study area consequently comprised 19 peninsulas separated by arms of the lake. The arms of Lake Cumberland are sufficiently long so that the study area included nearly all lake oriented development noted in formerly rural areas. The study area excluded the portion of the lake upstream from Fishing Creek because of the influence of the towns of Burnside and Somerset and the very narrow width of the lake. The area also excludes the area on the north side of the lake from Wolf Creek to Greasy Creek and the area on the south side of the lake form Mill Springs to a point opposite Fishing Creek. The shoreline at both locations is too straight to form distinguishable peninsulas.

In this study area, little reason exists to believe that change, other than shifts among agricultural land uses and the construction or abandonment of a few scattered individual buildings, exists due to any factors other than the lake. People in significant numbers do not come to an isolated rural area to build homes. Because no major highways enter the study region, there is no incentive to provide motels or other tourist facilities. Only the existence of the lake provides a reason for urban development.

Peninsulas

The study area is divided into peninsulas so that land use change along different sections of the lake can be compared. It is useful to divide the total area into subareas to study regional patterns of settlement as possible influences on the changes in land use [28, p. 2]. Peninsulas as a whole can be expected to vary with respect to access, orientation toward population centers, physical properties, and other factors affecting suitability for urban development.

A peninsula may be defined as land bounded on three sides by water. The many creeks flowing into the typical reservoir produce many long arms extending, in many cases, many miles back from the main body of water with the land between these coves forming peninsulas. A straight line connecting the furtherest backwater along two adjacent arms of the lake forms a fourth side of the peninsula called the base line. In Figure 2, a line is drawn beginning at the point of highest elevation, D, on the base line and following the drainage divide between the two arms of the lake to establish a ridge line. The intersection of the ridge line with the shore line defines the tip. To establish a peninsula orientation the reader can imagine that he is standing on the tip of the peninsula facing along the ridge line with his back to the main body of the lake. The point to the left, where the base line intersects the back arm of the lake, is designated point A. The similar point on the right is C, and the tip is B. Next a line is drawn along the shore of the peninsula following the pool shown on the USGS quadrangle maps but smoothed to facilitate measurement and because the small coves extending into the peninsula because of its irregular shoreline are an integral part of the shoreline environment. Each peninsula is constructed in a like manner.

Beginning with Greasy Creek and moving clockwise around the lake, the total study area is divided into 19 peninsulas, varying in size from 1,635 to 18,575 acres (Table 1). There are 11 peninsulas on the north side of the lake and 8 on the south side.

Quadralaterals

Historically, people have tended to settle on the tips of peninsulas or at the back of coves. Coves provide seclusion and shelter. Tips of the peninsulas provide the best views and easy access to a body of water too small for shelter to be a major factor. A restaurant or motel is more likely to be able to overlook a large body of water and capitalize on the esthetics of the scene as it is located closer to the tip of a peninsula. The influence of relative location on the peninsula on the probability of land use change was studied by developing a special grid.

Each peninsula is divided into 100 sections called quadralaterals. These quadralaterals, numbered 1 to 100, provide a normalized grid for indexing relative location (Figure 2). In this way, any particular quadralateral on one peninsula can be compared with the same relative position on all other peninsulas. It is necessary to speak of relative

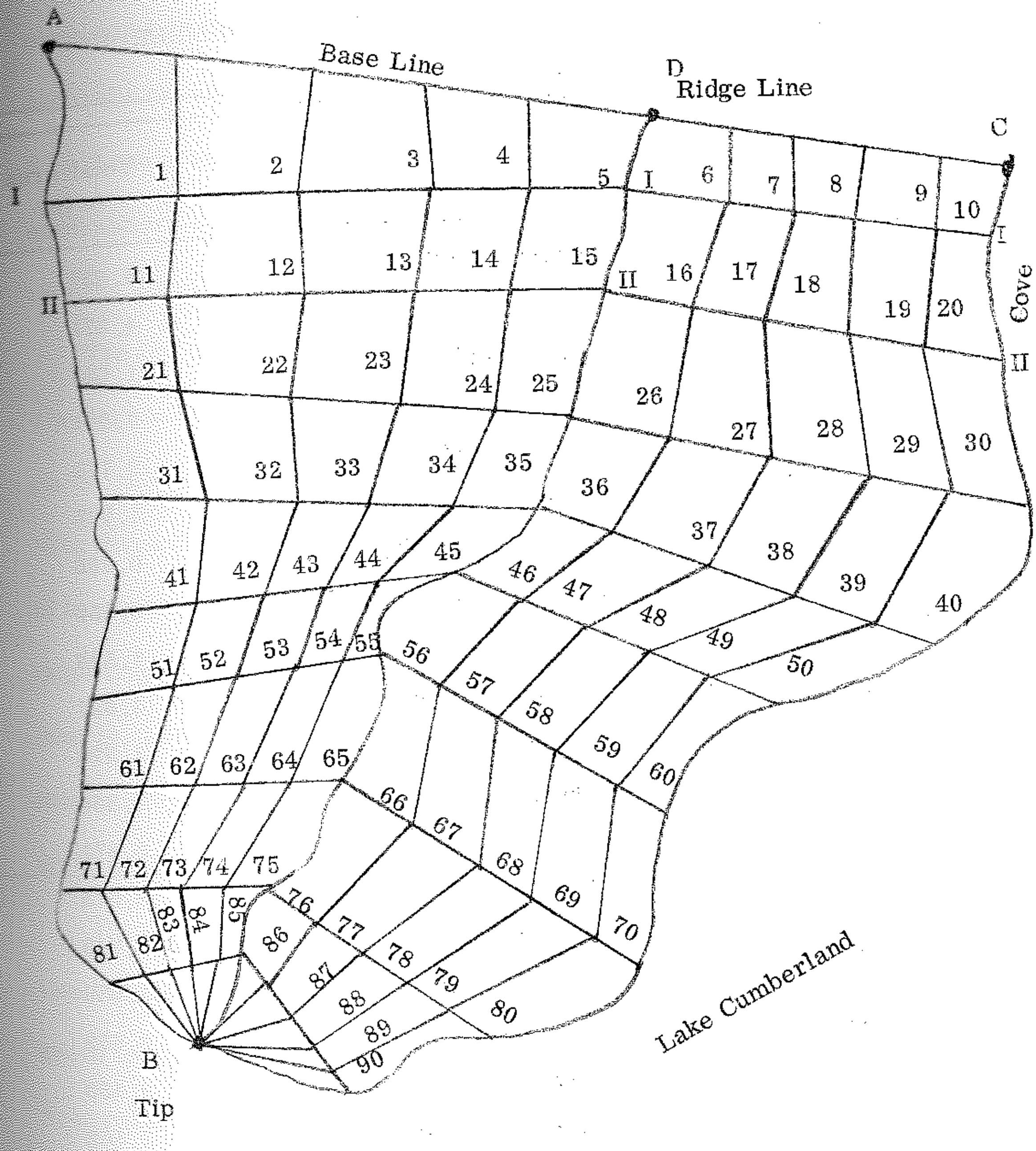

FIGURE 2: Subdivision of Peninsula 6

TABLE 1

PENINSULAS, AREAS BY NAME AND NUMBER

Peninsula Number	Peninsula Name	Total Area Acres
1	Jamestown Dock	3,537
2	Pleasant Hill	4,871
3	Parks Ridge	1,635
4	Ono Ridge	4,301
5	Tucker Ridge	2,179
6	Gosser Ridge	1,725
7	Cave Springs Ridge	6,398
8	Union Ridge	6,502
9	Panhandle	3,588
10	Cumberland Point	4,627
11	Fishing Creek	8,570
12	Conley Bottom	4,324
13	Earl Wallace	6,871
14	Parnell	18,575
15	Magalton Mountains	14,343
16	Cumberland City	17,056
17	Grider Hill	2,859
18	Aaron	2,433
19	Wolf Creek Dam	2,802

positions because each peninsula has its own distinct shape. The tip for peninsula 8 is in the same relative position to the other points on that peninsula as the tip of peninsula 9 is to any other point on peninsula 9. If land use changes tend to concentrate near the tip, the quadralaterals with higher numbers will experience land use changes significantly more often than those with lower numbers.

The 100 quadralaterals are plotted as shown in Figure 2. The distance between points A and B is divided into 10 equal parts. Lines DB and CB are also divided into 10 equal parts. Note that a division along any one of these three lines is not equal in length to a division along any other except by coincidence. Beginning at the base line, the respective points are connected (that is, I to I to I, II to II to II, etc.). The peninsula tip is common to all three lines. At this time, the peninsula is divided into ten horizontal sections.

To complete plotting the quadralaterals, each horizontal line is measured and divided into five equal parts from the shore to the ridge. Beginning on the left, near line AB, the first point on the base line is connected with the first point on the I to I line. These connections are continued from the first points for each of the lines until point B is reached.

Continuing, like numbered points on each of the horizontal lines are connected until line CB is reached on the far side of the peninsula. Now the peninsula is divided into 100 quadralaterals. Because the tip is common to all three lines, the last ten divisions are not four-sided figures; however, for ease of reference, these areas are still referred to as quadralaterals.

For each peninsula, quadralaterals are numbered from left to right beginning in the "A" corner. Quadralaterals vary widely in size on a given peninsula, but most are from 20 to 150 acres or about one percent of the total areas shown on Table 1. The quadralaterals need not have the same area nor shape. Relatively smaller areas near the tip indicate a more pointed peninsula while relatively larger areas near the tip indicate a wider nosed peninsula. A curved peninsula has relatively larger quadralateral areas on its outside. These peninsulas with their 100 quadralaterals were drawn on United States Geographical Survey quadrangles to serve as a basic reference for subsequent data collection. Data found elsewhere were located on these maps so that it could be referenced to the proper quadralateral.

DATA COLLECTION: LAND USE

Before preceeding to a description of the data collection, a brief review of the research objective is in order. Lake Cumberland is being used to provide data for a case study into the factors affecting local patterns of land use change around the periphery of a large reservoir in a rural area. In order to exclude factors other than the lake and to confine the analysis to areas where significant land use change is occurring only the immediate area is to be studied. The study area is divided into 19 peninsulas, and these are each divided into 100 quadralaterals. The data collection process is basically a determination of the land use changes and a measurement of the selected geographical factors pertaining to each quadralateral. A later statistical analysis will be used to ascertain which factors are significant.

Total Area

From the quadrangle maps, the acreage of each quadralateral was measured with a compensating polar planimeter. Once measured, the total area was held constant for each of the 1900 quadralaterals because, it, in contrast with land use, does not change from year to year. The total area includes water area where the lake protudes into the gross peninsula area as drawn.

Commercial Area

A county map compiled by the Kentucky Department of Highways (showing buildings by location and type [81]), a USGS topographic map, and aerial photographs provide the necessary information for determining the area with commercial land use. The area of commercial land use can vary from year to year as enterprises may enter or leave the market at any time. The latest county map, which serves as a primary source for determining urban land use by type, contains cultural information for 1959. The areas associated with the commercial establishments identified from the 1959 county maps were measured from the 1960 aerial photographs. One exception, Clinton county, having three peninsulas has county maps made in 1968. In this case, 1967 serves as the base year since the data for the county maps were actually collected in 1967 which corresponds perfectly with the 1967 aerial photographs. The county maps provide the location of each commercial establishment in the study area. Each location is marked on the 1951 topographic map and 1960 aerial photographs. Knowing the scale of the aerial photographs, the acreage associated with each commercial establishment is estimated and recorded. Most commercial establishments are country stores, bait shops, service stations, motels, or restaurants. No factories or other industrial establishments exist in the study area.

To obtain the 1951 commercial land use, the 1951 aerial photographs are compared with the 1960 aerial photographs. It is assumed that if a building was used commercially in 1960 and if that same building appears on the 1951 aerial photograph it existed for commercial use in 1951.

Likewise, if the 1938 aerial photograph contains a building designated for commercial use in 1960, it too is assumed to be used for commercial use in 1938. Property ownership maps made by the Corps of Engineers for surveying their land acquisition needs provide an additional verification for the 1938 land use as these maps show land use in 1938.

Commercial land use in 1967 is determined by checking the commercial land use locations for 1960 on the 1967 aerial photographs. If a commercial establishment is still present, the appropriate acreage is recorded. In addition, careful examination of the 1967 aerial photograph reveals changes in land use that have taken place since 1960. Aerial photo-interpretation techniques are used where possible to identify the type of land use associated with changes between 1960 and 1967. Field checks, conducted in 1969, provide supplemental information for doubtful cases.

Residential Land Area

A cursory survey of the area reveals a significant increase in residential land use since 1938. The year 1960 again serves as the base year with one exception--Clinton County. Residences are marked on the county maps and acreages can be measured from the aerial photographs. Following the same procedure used for determining commercial land use, the acreage of residential land use for each quadralateral for each of the four years is obtained. No distinction between permanent and seasonal residences was possible from the available data.

Public Land Area

Churches, schools, and government owned recreation areas constitute public land use. County maps show many churches and schools in the study area. One room churches situated on approximately one acre lots dot the country side. Some have cemeteries; some do not. Schools vary in size more than do churches, and country sites abandoned after 1951 explain the small reduction in public land use (Table 2). Government owned recreation areas provide camping and picnicking. With increased demand for

ch facilities, some private camping areas have also developed but are
cluded in commercial land use. However, for churches, schools
d government owned recreation area, the number of acres in each
adralateral is determined by the same procedure given for
mmercial land use.

ter Area

The difference between a smooth shoreline and an irregular one ntaining small inlets may influence land use. Water area within a adralateral results from the smoothing of the boundaries for the ninsula causing coves to fall inside the smoothed boundary. No nds, small lakes or streams are included since they are small in ea and few in number.

With this information, it is hoped to determine the relationship ween shoreline land use and the irregularity of the shoreline. ople may desire protected boating facilities or secluded water nt areas. Coves can provide both of these; thus, water area may a positive factor in location decisions.

ricultural Land Use

Agricultural land use is estimated by substracting the commercial, idential, public, and water areas from the total acreage for each dralateral. As thus defined, agricultural land includes everything from little used pasture and wood lands to intensively farmed cropland. Attempts to distinguish among such use categories did not seem warranted because changes among such uses are probably not related to the lake.

DATA COLLECTION: GEOGRAPHICAL FACTORS

Slope

One factor likely to influence decisions on where to locate is slope. Slope may affect location decisions in different ways. Some people may want an A-frame house built on steep slope overlooking and providing an uninterrupted view of the lake. At the same time, however, slope can add to costs of both buildings and roads. In any case, slope is likely to influence location preferences and should be included in any model used to determine changes in spatial patterns. All 19 peninsulas contain large acreages of very steep land (Table 16). Often the flatter land is along the ridges near the center of the peninsulas while steep bluffs occur along the lake front.

The procedure used to obtain a numerical index of quadralateral slope began by locating the highest point in each quadralateral. The lowest point within 500 feet of this high point was next determined. The difference in elevation between the two points was used to index slope and estimated from contour lines on the 1951 topographical maps. Knowing that here are 20 feet of verticle drop between contour lines and counting the number of contour lines in 500 feet gives the vertical drop distance. Ten contour lines in 500 feet indicates a 200 feet drop and a slope of 200/500 or 40 percent.

Water Frontage

Water frontage is likely to influence decisions in location. The length of lake frontage is measured for each quadralateral. Shorelines of coves are included since they still constitute part of the lake. All quadralaterals that border the peninsula have a shoreline length as do certain interior quadralaterals along very irregular shorelines. This length is normalized by dividing the measured length by the area of the quadralateral so that the frontage index will be independent of quadralateral size. By including the shoreline produced by coves, a higher ratio of shoreline length to area results. The higher ratio provides a second measure (in addition to water area) of the irregularity of the shoreline. For example, a peninsula with a very irregular shoreline might be expected to have more shoreline for lot frontage and better boating facilities. By testing water frontage in the model, its influence on changes in spatial pattern land use can be evaluated.

Roads

Farm-to-market roads have traditionally been built as a means to enhance the economic development of isolated areas. It is likely that roads influence land use changes around Lake Cumberland. All roads, however, do not provide equal access. In order to distinguish among them, roads are classified by four levels which resemble a tree with the outer limbs as lower level roads and higher levels as one approaches the main trunk. Hydrologists use a similar method to classify streams by order as an index of stream size [36]. Level one represents tiny streams, and each higher level represents a progressively larger stream.

First, level I roads have no feeder roads except private drives. This type services the tip and edges of the peninsula and are the least traveled. When two level I roads meet, a level II road results. Level II roads are the major level of roads from the lake. They carry more cars than do level I roads since those that travel on level I will also travel level II in leaving the peninsula. These roads will on the average be of better surface quality than those of level I. Level III, the third classification, occurs when two level II roads meet. Such roads usually occur on the ridge line near the base of the peninsula. Level IV are through roads. These roads "dip" into the peninsula but primarily serve as through routes fed by the lower order roads. No bridges cross Lake Cumberland in the study area.

For each quadralateral, the length of each level of road is measured from the USGS maps. Only those roads on 1960 county maps (prepared by the highway department) are measured in order to avoid inclusion of private roads. The length of roads did not seem to change much from year to year. There are no roads on the 1960 county maps that could not be found on the older aerial photographs. There have been changes in road surfaces, but specific changes could not be identified or quantified from the available information. The length of each type of road is normalized by dividing by the area of the quadralateral. A quadralateral can contain all four road classifications.

View of the Lake

The esthetic value of a home is enhanced by a view of the lake. Such visual contact is likely to promote land use changes. To measure "view of lake," a degree of view is determined for each quadralateral. Each quadralateral is qualitatively assigned a number 1, 2, or 3 depending on its view. With a poor view of the lake, a quadralateral receives a 1. With a good view of the lake, it receives a 3. An intermediate view of the lake receives a 2. A poor view of the lake means that one-third or less of a particular quadralateral area has a view of the lake. A good view of the lake means that two-thirds or more of a quadralateral area has a view. An intermediate view of the lake means that between one-third and two-thirds of the quadralateral ares has a view of the lake. Contour of the land is the only factor considered in determining the view. Trees, bushes, or man-made structures are not considered as barriers to view. Trees and bushes could be removed, in most cases, at a nominal cost; and the number of man-made structures interferring with the view is of no consequence. A profile of the site line from the quadralateral to the lake serves to establish the degree of view for each quadralateral.

LAND USE CHANGES

Land use change is defined as the acreage experiencing a change in land use, between two of the study years, divided by the total area of the quadralateral for the purpose of normalization.

The change can be from agricultural to residential, to commercial, or to public. Likewise, it can be from residential to agricultural, to commercial, or to public or any other change from one use to another. Changes within a category are not counted. Primarily the changes have been from agricultural use to one of the others (see Table 2). Changes are calculated for the periods 1938-1951, 1951-1960, and 1960-1967. Land use change serves as the dependent variable in the statistical analysis and is represented by Y. The mean of land use change for a group of quadralaterals is represented by $\bar{Y}$.

TABLE 2

LAND USE FOR DIFFERENT YEARS

	Acres			
	1938	1951	1960	1967
Agricultural	111,285	110,617	10,186	104,144
Residential	310	941	1,388	7,191
Commercial	18	39	53	127
Public	48	64	44	199
Water	5,535	5,535	5,535	5,535
Total	117,196	117,196	117,196	117,196

SUMMARY

This chapter has presented the method for obtaining the data for analyzing land use changes. First, a study lake (Lake Cumberland) is selected, and the study area around this lake is bounded and divided into 19 peninsulas. Each peninsula is subdivided into 100 quadralaterals. For each of these quadralaterals, the total area, the commercial area, the residential area, the public area, the agricultural area, and the water area are obtained. These are the land uses, and all but water area are obtained for each of the study years. Land use changes are noted whenever a location changes, from one to another above land use categories within one of the three time periods used in this study. In addition, slope, water frontage, roads, and view of the lake are obtained for each quadralateral and these remain constant for the four study years. With this information, it is now possible to test the significance of the correlation between land use changes by time period and the other quadralateral properties.

CHAPTER IV

ANALYSIS OF LAND USE CHANGES

The next step in the study is to apply the general procedure developed in Chapter II to evaluate the relationship between land use changes around Lake Cumberland and the properties of the individual sites measured empirically as described in Chapter III. This chapter presents the statistical techniques used to determine which site properties correlate significantly with the experienced land use changes. It also presents the observed relationship between the changes and the significant site properties.

HYPOTHESES TO BE TESTED

The specific approach used to determine which site properties are significant is to propose for acceptance or rejection by statistically testing for significance hypotheses that individual site characteristics influence patterns of land use change around the lake. Before proceeding further, simple statements of these hypotheses are needed.

The first three hypotheses are used to assess the significance of location with respect to the lake as a whole on land use changes.

Hypothesis 1: Different peninsulas intrinsically experience different amounts of land use change.

Hypothesis 2: The north side of Lake Cumberland has experienced a larger land use change than the south side.

Hypothesis 3: The east and west ends of Lake Cumberland have experienced a larger land use change than the middle area.

The next three hypotheses (4-6) result from the need to determine if the spatial patterns of changes in land use tend to follow a specific pattern from one peninsula to another.

Hypothesis 4: The four corners of a peninsula differ in the amount of land use change they have experienced. Corner A comprises the 25 quadralaterals in the A corner near the base line of the peninsula (Figure 2). Corner B comprises the 25 quadralaterals along the base line to the right of corner A. Corner C comprises the 25 quadralaterals toward the tip from corner A. Corner D comprises the remaining 25 toward the tip from corner B.

Hypothesis 5: The tip areas of a peninsula have experienced a larger net land use change than the base areas. The tip comprises the 50 quadralaterals beginning with quadralateral number 51 (Figure 2). The base comprises the first 50 quadralaterals beginning with quadralateral number 1.

Hypothesis 6: The area on the edges of the peninsulas has experienced a larger land use change than has the middle area. The edges comprise a band two quadralaterals wide around the shore line of each peninsula. This band begins with quadralaterals 1 and 2, 11 and 12, etc. and ends with 9 and 10 (Figure 2). The middle area comprises the remaining quadralaterals.

The remaining hypotheses are used to test the significance of measured quadralateral properties on influencing land use changes.

Hypothesis 7: Slope has produced a net contribution to land use changes in the Lake Cumberland area.

Hypothesis 8: Water frontage has produced a net contribution to land usechanges in the Lake Cumberland area.

Hypothesis 9: View of the lake has produced a net contribution to land use changes in the Lake Cumberland area.

Hypothesis 10: Road access has produced a net contribution to land use changes in the Lake Cumberland area.

Hypothesis 11: Water area, as an index of an irregular shoreline, has produced a net contribution to land use changes in the Lake Cumberland area.

APPROACH TO HYPOTHESIS TESTING

The two basic tools for testing hypotheses such as those proposed are multiple linear regression analysis, where the various factors are relatively independent, and analysis of variance, where the factors are found to be interdependent. A step-wise multiple linear regression analysis (MULTR) and one-way analysis of variance with unequal cell size (OWANOV) are both programmed for computer application and available through the Statistical Program Library for the IBM System/360 located in the University of Kentucky computing center [75].

In analyzing multivariate data, it is necessary to discover and measure the association or covariation among the variables in order to determine how they vary together [11, p. 595]. Two related, but distinct, aspects are involved in the study, regression analysis and correlation analysis [11, p. 596]. Regression analysis attempts to establish a functional relationship between a selected and the remaining variables. A mathematical function of the form

$$Y = f(X_1, X_2, X_3, \ldots X_n) \quad (1)$$

results with Y as the dependent variable and $X_1, X_2, X_3 \ldots X_n$

as the independent variables. Through the functional relationship, the most probable values of Y for different sets of values of the X's can be predicted. Correlation analysis is concerned with determining the "degree of relationship" between Y and X_1, X_2, or any other pair of variables. This determination combined with examining the diagonal elements of the inverse correlation matrix is useful in detecting multicollinearity.

The eleven hypotheses are tested for the purpose of designating the significant variables - not for deriving a predictive functional relationship. The significance tests show whether or not changes in land use are associated with the tested factor. The reader, however, should not interpret proof of association with proof of causation. For example, both factors may be caused by a third force or the association may be entirely coincidental. Frequent association will prove to be statistically significant and suggests the need for further analysis to determine whatever causal relationship may exist.

A multiple linear regression model is proposed to begin testing the hypotheses. Including all measured variables the equation is

$$Y = A_1 + B_1X_1 + B_2X_2 \ldots\ldots + B_{34}X_{34} \qquad (2)$$

where

X_1 = 1 if the location being considered is located on peninsula 1, 0 otherwise;

X_2 = 1 if peninsula 2, 0 otherwise;

X_3 = 1 if peninsula 3, 0 otherwise;

X_4 = 1 if peninsula 4, 0 otherwise;

X_5 = 1 if peninsula 5, 0 otherwise;

X_6 = 1 if peninsula 6, 0 otherwise;

X_7 = 1 if peninsula 7, 0 otherwise;

X_8 = 1 if peninsula 8, 0 otherwise;

X_9 = 1 if peninsula 9, 0 otherwise;

X_{10} = 1 if peninsula 10, 0 otherwise;

X_{11} = 1 if peninsula 11, 0 otherwise;

X_{12} = 1 if peninsula 12, 0 otherwise;

X_{13} = 1 if peninsula 13, 0 otherwise;

X_{14} = 1 if peninsula 14, 0 otherwise;

X_{15} = 1 if peninsula 15, 0 otherwise;

X_{16} = 1 if peninsula 16, 0 otherwise;

X_{17} = 1 if peninsula 17, 0 otherwise;

X_{18} = 1 if peninsula 18, 0 otherwise;

X_{19} = 1 if the location is on the north side of the lake, 0 otherwise;

X_{20} = 1 if the location is on either the east or west end of the lake, 0 otherwise;

X_{21} = 1 if the site is located in corner A of a peninsula, 0 otherwise;

X_{22} = 1 if the site is located in corner B of a peninsula, 0 otherwise;

X_{23} = 1 if the site is located in corner C of a peninsula, 0 otherwise;

X_{24} = 1 if the site is located on the tip of a peninsula; 0 otherwise;

X_{25} = 1 if the site is located on the edge of a peninsula, 0 otherwise;

X_{26} = the slope;

X_{27} = water frontage in miles per acre;

X_{28} = 1 if there exists a poor view of the lake, 0 otherwise;

X_{29} = 1 if there exists a good view of the lake, 0 otherwise;

X_{30} = road level IV in miles per acre;

X_{31} = road level III in miles per acre;

X_{32} = road level II in miles per acre;

X_{33} = road level I in miles per acre;

X_{34} = water area per acre (irregularity of the local shoreline);

Y = land use change per acre;

A_1 = intercept made by the regression on the Y axis; and

$B_1, B_2 \ldots\ldots\ldots B_{34}$ = the contribution of $X_1, X_2 \ldots\ldots X_{34}$ respectively.

The multiple linear regression procedure estimates the regression plane with

$$Y = a + b_1x_1 + b_2x_2 \ldots\ldots + b_{34}x_{34} \quad (3)$$

and can be extended to determine if the partial regression coefficients -- the b's -- are significant. That is, do they differ significantly from zero to allow the conclusion that the B's are non-zero? The intention is to determine which of the X's are significantly associated with land use changes. Each "b" estimates the net contribution of its corresponding variable. For example, b_1 estimates the net change in land use which can be associated with a site on peninsula 1.

One less than the full number of variables are needed to test the hypotheses concerning location of land use changes around the lake, (Hypothesis 1, 2, 3) location of land use changes on a peninsula (Hypothesis 4, 5, 6) and "view of the lake," (Hypothesis 9) because these variables are qualitative rather than quantitative. In general it is necessary to have (k-1) variables for k levels of a qualitative factor in order to prevent the occurrance of a singular matrix in the computation with k variables. In the case of location around the lake 19 peninsulas account for variables X_1 through X_{18}. If all of the first 18 variables are zero, the location must be on the nineteenth peninsula. The same principle applies with respect to the other hypotheses. A more detailed explanation of dummy variables is found in works by Draper and Smith [21, p. 134]

Li, [56, p. 265], Johnston, [40, p. 221], Golderger, [29, p. 218], and Klein [48, p. 172].

RESULTS OF HYPOTHESIS TESTING

The goal of the statistical analysis is to determine which of the proposed variables are associated to a significant degree with land use changes. The procedure requires testing each of the eleven hypotheses. Each hypotheses is tested for each of the three time periods (1938-1951, 1951-1960, and 1960-1967) in order to assess time patterns of variable significance. The level of significance selected for accepting an hypothesis is 5 percent.

Table 3 summarizes the "t" values obtained for each of the 34 variables in Equation 2 for each of the three time periods as well as for the overall period (1938-1967). However, it is not possible to ascertain which variables are significant directly from Table 3 because of the multicollinearity discovered among the variables. For example, a steep slope near the edge of a peninsula implies a good view. As a result, significance can only be tested by multiple regression techniques for those variables where multicollinearity does not arise, that is variables which are truly independent. It is thus necessary to examine the regression for variables exhibiting multicollinearity. The significance

TABLE 3

"t" VALUES[1] FOR VARIABLES IN EQUATION 3

Variable Name	Variable Number	1938-1967	1960-1967	1951-1960
Peninsula 1	1	8.07	7.23	1.28
Peninsula 2	2	.97	.14	3.68
Peninsula 3	3	*	.26	.09
Peninsula 4	4	.42	*	2.38
Peninsula 5	5	1.14	.71	2.97
Peninsula 6	6	-.29	-.07	-.31
Peninsula 7	7	14.58	22.51	-.10
Peninsula 8	8	-.12	.12	*
Peninsula 9	9	9.25	9.63	-.12
Peninsula 10	10	4.53	4.34	*
Peninsula 11	11	.74	.88	.12
Peninsula 12	12	5.84	6.00	.56
Peninsula 13	13	.15	.19	.14
Peninsula 14	14	.92	.75	.57
Peninsula 15	15	.07	-.01	.22
Peninsula 16	16	*	-.03	.14
Peninsula 17	17	.96	1.10	-.08
Peninsula 18	18	-.17	-.22	.20
North	19	.13	*	.05
East-West	20	-.40	-.31	-.03
Corner A	21	*	*	-.56
Corner B	22	-2.26	-2.57	*
Corner C	23	-1.32	-.55	-3.04
Tip	24	2.94	2.00	2.30
Edge	25	.32	.16	.25
Slope	26	3.90	3.92	.54
Water Frontage	27	.84	1.58	-1.81
Poor View	28	.14	.25	-.61
Good View	29	.81	.21	2.11
Road IV	30	-.76	-1.01	.35
Road III	31	.87	-1.40	5.90
Road II	32	2.84	.85	4.82
Road I	33	6.13	4.28	4.48
Water Area	34	-2.66	-2.70	-.37

* Variable Eliminated Automatically by MULTR

[1] For 5% level of significance $t_{\infty} = 1.96$; for 1%, $t_{\infty} = 2.58$.

of the truly independent variables may be determined by multiple regression techniques. The significance of the multicollinear variables has to be determined by analysis of variance techniques. In the following presentation, the testing of the eleven hypotheses is described in the order in which they were proposed.

Analysis for Multicollinearity

Equation 2 was applied to the overall time period (1938-1967) to examine the variables for independence. Each of the individual variables (other than land use change) is essentially independent of time, and thus there is no reason to differentiate the degree of interdependence among them by time period. Multicollinearity is determined by looking at the correlation matrix in conjunction with the values of diagonal elements of the inverse correlation matrix [26, p. 99]. Table 4, Column 1, shows the values of these diagonal elements for Equation 2. If all the variables were truly independent, all 34 values would be unity [26, p. 100]. In fact, many of the variables are interdependent, and many of the tabulated values are far from unity.

Some variables must be eliminated from Equation 2 to reduce the multicollinearity and thereby cause the diagonal elements to approach one. The process involves observation of high values for the diagonal elements and reasoning on probable causes of interdependence. Most of the peninsula variables (1 - 20) have high values on Table 4. It was decided to eliminate all but the north variable as it is an independent expression of peninsula orientation toward population centers. The other peninsula variables are interrelated as each peninsula is on either the north or the south side and are related to the other variables as each peninsula has a specific combination of physical properties. The corner variables were eliminated as being interdependent with each other as well as with tip and edge. Water area was eliminated as being dependent on water frontage.

With these variables eliminated, the regression equation becomes:

$$Y = A_2 + B_{19}X_{19} + B_{24}X_{24} + B_{25}X_{25} + B_{26}X_{26} + B_{27}X_{27}$$

$$+ B_{28}X_{28} + B_{29}X_{29} + B_{30}X_{30} + B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \quad (4)$$

The "t" values associated with the variables in this equation are found in Table 5. When the "t" values for north on Table 5 are compared with those on Table 3, one sees that this variable has shifted from not being significant ($t = 0.13$) to a high level of significance ($t = 8.13$). Such shifts are the primary reason for investigating multicollinearity. Comparison between the same two tables shows relatively little change for the road variables which are seen to be relatively independent of the other factors by the values near unity on Table 4.

Table 4 contains the values of the diagonal elements of the inverse correlation matrix for Equation 4. The value for the north variable has

TABLE 4

DIAGONAL ELEMENTS OF INVERSE CORRELATION MATRIX FOR DIFFERENT COMBINATIONS OF VARIABLES

Variable Name	Variable Number	Variable Combination of Equation 3	4	5	6	7	8
Peninsula 1	1	1.947	*	*	*	*	*
Peninsula 2	2	1.908	*	*	*	*	*
Peninsula 3	3	0.000	*	*	*	*	*
Peninsula 4	4	3.950	*	*	*	*	*
Peninsula 5	5	4.002	*	*	*	*	*
Peninsula 6	6	3.963	*	*	*	*	*
Peninsula 7	7	3.975	*	*	*	*	*
Peninsula 8	8	3.922	*	*	*	*	*
Peninsula 9	9	1.936	*	*	*	*	*
Peninsula 10	10	1.924	*	*	*	*	*
Peninsula 11	11	1.938	*	*	*	*	*
Peninsula 12	12	2.156	*	*	*	*	*
Peninsula 13	13	2.069	*	*	*	*	*
Peninsula 14	14	1.916	*	*	*	*	*
Peninsula 15	15	1.910	*	*	*	*	*
Peninsula 16	16	0.000	*	*	*	*	*
Peninsula 17	17	1.906	*	*	*	*	*
Peninsula 18	18	1.980	*	*	*	*	*
North	19	10.447	1.067	1.063	1.061	1.055	1.055
East-West	20	10.111	*	*	*	*	*
Corner A	21	0.000	*	*	*	*	*
Corner B	22	1.510	*	*	*	*	*
Corner C	23	1.523	*	*	*	*	*
Tip	24	2.144	1.132	1.108	1.106	1.065	1.051
Edge	25	1.597	1.552	*	*	*	*
Slope	26	1.833	1.572	1.557	1.447	1.370	1.104
Water Frontage	27	1.669	1.544	1.515	*	1.330	*
Poor View	28	2.410	2.281	*	*	*	*
Good View	29	2.642	2.507	1.689	1.482	*	*
Road IV	30	1.100	1.027	1.025	1.024	1.024	1.023
Road III	31	1.094	1.038	1.023	1.023	1.019	1.019
Road II	32	1.093	1.070	1.052	1.051	1.045	1.042
Road I	33	1.062	1.029	1.025	1.021	1.025	1.042
Water Area	34	1.615	*	*	*	*	*

*Variable Eliminated

TABLE 5

"t" VALUES[1] FOR VARIABLES IN EQUATION 4

Variable Name	Variable Number	1938-1967	1960-1967	1951-1960	[illegible]
North	19	8.13	7.77	2.04	[illegible]
Tip	24	3.47	2.99	1.33	[illegible]
Edge	25	-.27	-.34	.03	[illegible]
Slope	26	1.80	1.75	.37	[illegible]
Water Frontage	27	.75	1.44	-2.17	[illegible]
Poor View	28	-2.00	-1.91	-.64	[illegible]
Good View	29	-.17	-.86	2.68	[illegible]
Road IV	30	.24	.06	.37	[illegible]
Road III	31	.87	-1.27	6.32	[illegible]
Road II	32	4.39	2.80	4.72	[illegible]
Road I	33	4.97	3.10	5.02	[illegible]

[1] For 5 percent level of significance, $t_\infty = 1.96$; for 1%, $t_\infty = 2.58$.

dropped from 10.477 to 1.067, again illustrating that linearly dependent variables associate with this north variable have been eliminated. The edge and poor view variables are next eliminated (Table 4) in order to try to further reduce multicollinearity.

The next equation is

$$Y = A_3 + B_{19}X_{19} + B_{24}X_{24} + B_{26}X_{26} + B_{27}X_{27}$$

$$+ B_{29}X_{29} + B_{30}X_{30} + B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \qquad (5)$$

The "t" value for the regression coefficients (the b's) are given in Table 6. Table 4 shows the variables slope, water frontage, and good view of lake having the largest diagonal values for Equation 5, values which are still too large to accept the variables as independent. Most of the peninsulas are relatively flat in their interior and have steep slopes extending down to the lake front around their edges.

As a next try and in order to determine whether eliminating only one of these three variables is sufficient, water frontage is taken out of the regression equation to give

$$Y = A_4 + B_{19}X_{19} + B_{24}X_{24} + B_{26}X_{26} + B_{29}X_{29} + B_{30}X_{30}$$

$$+ B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \qquad (6)$$

The diagonal values again appear on Table 4 and the "t" values on Table 6. Significant multicollinearity still exists among slope and water frontage.

Another possibility is that view rather than water frontage should be removed. The resulting equation is

$$Y = A_5 + B_{19}X_{19} + B_{24}X_{24} + B_{26}X_{26} + B_{27}X_{27} + B_{30}X_{30}$$

$$+ B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \qquad (7)$$

TABLE 6

"t" VALUES[1] FOR VARIABLE COMBINATIONS FOUND IN EQUATIONS 5, 6, AND 7 (1938-1967)

Variable Name	Variable Number	5	6	7
North	19	8.24	8.21	8.36
Tip	24	3.74	3.78	4.03
Slope	26	2.01	2.30	2.53
Water Frontage	27	.81	*	1.26
Good View	29	1.07	1.44	*
Road IV	30	.15	.13	.12
Road III	31	.70	.70	.64
Road II	32	4.22	4.21	4.15
Road I	33	4.86	4.82	4.86

*Variable Eliminated

[1] For 5% level of significance, $t_{\infty} = 1.96$; for 1%, $t_{\infty} = 2.58$.

Diagonal values and t values appear on Tables 4 and 6 respectively. Significant multicollinearity also exists among slope and view. An equation including view and water frontage of the three variables was not tried because these two variables would logically be interdependent.

it is concluded that only one of these three variables can appear in a regression equation confined to independent variables.

Having no reason to prefer any one above the other two, all three are tried in separate equations:

$$Y = A_6 + B_{19}X_{19} + B_{24}X_{24} + B_{26}X_{26} + B_{30}X_{30} + B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \quad (8)$$

$$Y = A_7 + B_{19}X_{19} + B_{24}X_{24} + B_{27}X_{27} + B_{30}X_{30} + B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \quad (9)$$

$$Y = A_8 + B_{19}X_{19} + B_{24}X_{24} + B_{29}X_{29} + B_{30}X_{30} + B_{31}X_{31} + B_{32}X_{32} + B_{33}X_{33} \quad (10)$$

All three equations proved to have diagonal elements near unity (See Table 4 for Equation 8). The "t" values for determining variable significance are found in Table 7 for each of the three basic time periods as well as the total study period.

The conclusion of the analysis for multicollinearity is that the variables associated with the north side of the lake, the tip of the peninsula, and the four levels of road access are independent. One of the three variables slope, water frontage, and good view can also be added to the regression equation without introducing multicollinearity. The remaining variables exhibit varying levels of dependence on these

TABLE 7

"t" VALUES[1] FOR VARIABLE COMBINATIONS FOUND IN EQUATIONS 8, 9, AND 10

Variable Name	Variable Number	1938-1967			1960-1967			1951-1960			1938-1951		
		Eq. 8	Eq. 9	Eq. 10	Eq. 8	Eq. 9	Eq. 10	Eq. 8	Eq. 9	Eq. 10	Eq. 8	Eq. 9	Eq. 10
North	19	8.17	7.94	7.76	7.70	7.53	7.33	2.42	2.21	2.22	2.34	2.37	2.33
Tip	24	4.04	4.13	3.68	3.37	3.38	3.19	2.11	2.39	1.35	1.94	1.87	1.41
Slope	26	3.43	*	*	3.16	*	*	1.60	*	*	.16	*	*
Water Frontage	27	*	2.66	*	*	2.89	*	*	-.12	*	*	.54	*
Good View	29	*	*	2.96	*	*	2.19	*	*	3.54	*	*	1.86
Road IV	30	.03	.15	.16	-.13	-.01	-.02	.27	.28	.39	.59	.61	.65
Road III	31	.60	.46	.58	-1.49	-1.60	-1.56	6.10	5.95	6.32	6.05	6.09	6.23
Road II	32	4.10	3.90	4.05	2.57	2.43	2.44	4.44	4.21	4.75	5.36	5.42	5.62
Road I	33	4.80	4.67	4.62	2.91	2.84	2.70	5.06	4.86	5.17	8.23	8.28	8.40

* Variable Eliminated

[1] For 5% level of significance, $t_{\infty} = 1.96$; for 1%, $t_{\infty} = 2.58$.

variables individually or in combination. In comparing this finding with the hypotheses to be tested, one finds Hypotheses 2, 5, 7, 8, 9, and 10 can be tested by multiple regression techniques. The other hypotheses must be tested by analysis of variance techniques.

Testing Individual Hypotheses

While multicollinearity among the variables is relatively independent of time, the association between land use changes and the variables is not. Land use changes at different rates and in different places at different times. For this reason, the significance of the association between land use change and the site properties is tested for each of the three time periods. In this way, time trends in property significance can be examined.

Hypothesis 1: The first hypothesis proposes that different locations (Peninsulas) around the lake have experienced different amounts of land use change. As a great deal of multicollinearity was observed among the peninsula variables, the test for significance must be based on analysis of variance. If $\bar{Y}$ is the mean land use change experienced by a peninsula, the hypothesis expressed in equation form is

$$\bar{Y}_1 = \bar{Y}_2 = \ldots = \bar{Y}_{19} \qquad (11)$$

where each variable is subscripted by peninsula number. Rejection of the hypothesis implies a significant difference for one or more of the values of $\overline{Y}$. The results of the test (Table 8) show that at the 5 percent level of significance, there exists a significant difference in land use change among the peninsulas for each of the three time periods. Consequently the hypothesis is rejected.

When there are more than two categories in an analysis of variance problem, one needs to use the least significant difference (LSD) method to ascertain which of the possible combinations of differences is significant [11, pp. 407-409]. The above hypothesis, for example, contains 19 categories or peninsulas. This means that for one time period there are 19 items take 2 at a time or 171 possible comparisons. The difference in only one of these comparisons need be significant for the hypothesis to be rejected. It could be that the analysis thus far has only shown one peninsula to be different than all the rest. To see if this is so, the LSD for each time period is calculated, and all 171 x 3 = 513 possible absolute differences are determined. Table 9 contains a grouping of peninsulas for the three time periods. The peninsulas within a group for a certain time period do not differ significantly in land use change from one another.

Hypothesis 2: The second hypothesis proposes that the north side of the lake has been associated with a larger net land use change than the south side. As Variable 19 appears in Equation 8, the significance of the north

TABLE 8

"F" VALUES FOR HYPOTHESES1-6 FOR SELECTED TIME PERIODS

Hypothesis	1	2	3	4	5	6
Sample Size	$N_1 = \ldots = N_{19} = 100$	$N_N = 1100; N_S = 800$	$N_{EW} = 1000, N_M = 900$	$N_A = N_B = N_C = N_D =$ 495	$N_T = N_B =$ 950	$N_E = 988$ $N_M = 912$
Degrees of Freedom	18 1881	1 1898	1 1898	3 1896	1 1878	1 1898
$\alpha = 5\%$ Critical Value	1.57	3.84	3.84	2.60	3.84	3.84
1960-1967	61.09	64.76	.07	7.32	18.47	4.93
1951-1960	3.88	10.68	.00	3.65	4.18	.17
1938-1951	6.19	12.84	1.08	1.19	2.98	.38

side can be observed from the "t" values on Table 7. Results using analysis of variance are shown on Table 8. Here, one actually tests the null hypothesis that $\bar{Y}_N = \bar{Y}_S$ for each of the three time periods. If the stated hypothesis is true, then one rejects the null and accepts the alternative that $\bar{Y}_N \neq \bar{Y}_S$. The results presented in Table 8 allows us to reject each of the hypothesis for the three time periods and accept the alternative. The results on Table 9 show the faster changing peninsulas are on the north side of the lake. The north side has experienced greater land use change as the side from which most visitors to the lake come.

Hypothesis 3: The third hypothesis proposes that the change in land use for the east and west end of the lake is larger than the change in land use for the middle area. Peninsulas 1, 2, 3, 9, 10, 11, 12, 13, 18, 19 comprise the east and west areas. Peninsulas 4-8 and 14-17 comprise the middle area. The possibility being tested here is that Jamestown and Highway 127 on the west and Somerset-Burnside and Highway 27 on the east have produced a net influence on the spatial pattern of land use changes. Analysis of variance must be used to test this hypothesis because of multicollinearity. The null hypothesis is $\bar{Y}_{EW} = \bar{Y}_M$ for each of the three time periods. If the stated hypothesis is true $\bar{Y}_{EW} \neq \bar{Y}_M$, then one rejects the null hypothesis. The results presented on Table 8 show no "F" value in the rejection region. Therefore, the

TABLE 9

PENINSULA GROUPING ACCORDING TO RATE OF LAND USE CHANGE BY TIME PERIOD

	Groups Ranked in Order of Decreasing Change				
	1	2	3	4	5
1938-1951	1	2, 4, 5, 10 12	3, 6-9 11, 13-19		
1951-1960	1, 2 4, 5	3, 6-19			
1960-1967	7	9	1	10, 12	2-6, 8, 11, 13-19

hypotheses $\overline{Y}_{EW} = \overline{Y}_M$, can not be rejected for any of the time periods. In essence, no significant difference is observed between the amount of land use change on the peninsulas at the east and west ends of the lake and that on peninsulas near the middle.

Hypothesis 4: The fourth hypothesis proposes a significant difference in land use change among the four corners of the peninsulas. Multicollinearity again requires use of analysis of variance. The null hypothesis is $\overline{Y}_A = \overline{Y}_B = \overline{Y}_C = \overline{Y}_D$. Rejection of the hypothesis implies a significant difference for one or more of the corners. Again each of the time periods is tested. The results presented in Table 8 show all "F" values falling in the rejection region except the "F" value, 1.19, for the 1938-1951 change. Hence, one cannot reject the hypothesis, $\bar{Y}_A = \bar{Y}_B = \bar{Y}_C = \bar{Y}_D$, for the 1938-1951 time period. Only since 1951 is a significant difference in land use change noted among the corners. Table 10 contains the LSD results for the time periods where the hypothesis is rejected. Five of the significant differences among corners are tip-base differences. One is a difference between peninsula sides.

Hypothesis 5: The fifth hypothesis proposes that the tip areas of the peninsulas have experienced significantly more changes in land use than the base areas. As Variable 24 appears in Equation 8, the significance of the tip being associated with land use change can be observed from the "t" values on Table 7. At the 5% level, significant association is observed for 1960-1967, is observed using Equations 8 and 9 but not Equation 10 for 1951-1960, and is not observed for 1938-1951.

Results using analysis of variance are shown on Table 8. The null hypothesis is $\bar{Y}_T = \bar{Y}_B$. Rejection implies $\bar{Y}_T \neq \bar{Y}_B$. The hypothesis is accepted for 1938-1951 and rejected for the two later time periods.

Hypothesis 6: The sixth hypothesis proposes that locations on the edges of the peninsulas have experienced significantly larger changes in land use than the areas on the peninsula but farther from the lake (middle). Observed multicollinearity requires testing by analysis of

TABLE 10

LSD ANALYSIS FOR HYPOTHESIS 4
(Concerning Difference Among Corners)

Time Period	Absolute Difference	LSD	Results
	$\lvert \bar{Y}_A - \bar{Y}_B \rvert = .0291$	<.0311	not significant
	$\lvert \bar{Y}_A - \bar{Y}_C \rvert = .0310$	<.0311	not significant
1960-1967	$\lvert \bar{Y}_A - \bar{Y}_D \rvert = .0366$	>.0311	significant
	$\lvert \bar{Y}_B - \bar{Y}_C \rvert = .0601$	>.0311	significant
	$\lvert \bar{Y}_B - \bar{Y}_D \rvert = .0577$	>.0311	significant
	$\lvert \bar{Y}_C - \bar{Y}_D \rvert = .0056$	<.0311	not significant
	$\lvert \bar{Y}_A - \bar{Y}_B \rvert = .0009$	<.0058	not significant
	$\lvert \bar{Y}_A - \bar{Y}_C \rvert = .0009$	<.0058	not significant
1951-1960	$\lvert \bar{Y}_A - \bar{Y}_D \rvert = .0098$	>.0058	significant
	$\lvert \bar{Y}_B - \bar{Y}_C \rvert = .0000$	<.0058	not significant
	$\lvert \bar{Y}_B - \bar{Y}_D \rvert = .0069$	>.0058	significant
	$\lvert \bar{Y}_C - \bar{Y}_D \rvert = .0069$	>.0058	significant

variance. The null hypothesis tested for each of the three time periods is $\bar{Y}_E = \bar{Y}_M$. Rejection implies $\bar{Y}_E \neq \bar{Y}_M$. Table 4 presents the results for this hypothesis. The hypothesis is accepted for 1938-1951 and 1951-1960 and rejected for 1960-1967. Only since 1960 has land use change along the edges been significantly greater than that in the middle of the peninsulas.

Hypothesis 7: The seventh hypothesis proposes that the amount of land use change experienced varies with slope. The hypothesis can be tested by multiple regression analysis based on Equation 8. More explicitly, one sees if the partial regression coefficient b_{26}, which estimates B_{26} or the regression coefficient for the variable slope, differs significantly from zero to conclude that $B_{26} \neq 0$ and hence slope is associated with land use change, Y. The null hypothesis is that $B_{26} = 0$. On Table 7, one sees that the "t" values, for the 1960-1967 time period falls well inside the rejection region. This allows one to reject the hypothesis, $B_{26} = 0$, for this time period, with a probability of less than 1% of being wrong. The association between slope and land use change has been significant since 1960.

Hypothesis 8: The eighth hypothesis proposes that areas with water frontage have experienced greater land use change than interior areas. A much narrower band around the peninsula periphery is being used than is for Hypothesis 6. The hypothesis is tested by multiple regression analysis using Equation 9 to see if the partial regression coefficient b_{27}, which estimates B_{27}, or the regression coefficient for the variable water frontage, differs significantly from zero to conclude that $B_{27} \neq 0$, and hence water frontage is associated with greater change in land use, Y. The hypothesis tested is $B_{27} = 0$, with object being to reject it. Referring to Table 7 one sees that "t" value falls inside the rejection region for the 1960-1967 time period; therefore, the hypothesis is rejected for this period. More land use change has been experienced along the waterfront than in the interior only since 1960.

Hypothesis 9: The ninth hypothesis proposes that areas with a good view of the lake have experienced the greatest land use change. The hypothesis is tested by multiple regression analysis using Equation 10 to see if the partial regression coefficient b_{29}, which estimates B_{29}, or the regression coefficient for the variable denoting a good view of the lake, differs significantly from zero to conclude that $B_{29} \neq 0$. If so, a good view of the lake is associated with a greater change in land use, Y.

The hypothesis $B_{29} = 0$ is to be rejected if b_{29} differs from zero significantly. One must remember that X_{29} is compared to the intermediate and the poor views of the lake grouped together. The formation of a singular matrix and linear dependence necessitates this action. Referring to Table 7, one sees that a good view of the lake is significant for all but the 1938-1951 time period. A good view of the lake has been associated with greater land use change since 1951. The value for the earlier period barely misses significance at the 5% level.

Hypothesis 10: The tenth hypothesis proposes that areas with road access have experienced greater land use change. Road access is tested separately for each of the four types of access provided. The variables used for testing based on multiple regression analysis are X_{30} for road type IV, X_{31} for road type III, X_{32} for road type II, and X_{33} for road type I. Following the same format as above, b_{30}, b_{31}, b_{32} and b_{33} estimate B_{30}, B_{31}, B_{32} and B_{33}, respectively. This allows a decision on the following sub-hypotheses: $B_{30} = 0$, $B_{31} = 0$, $B_{32} = 0$, and $B_{33} = 0$. A sub-hypotheses is rejected and $B_{30} \neq 0$, $B_{31} \neq 0$, $B_{32} \neq 0$, or $B_{33} \neq 0$ is accepted if the associated road type is found to positively correlate with land use change. Referring to Table 7, one sees that the "t" values for road level IV is not significant for any of the time periods and therefore $B_{30} = 0$ cannot be rejected. For road level III, time periods 1951-1960, and 1938-1951 produce significant "t" values. Thus for those periods the hypotheses are rejected. Road level 1 and 2 have significant "t" values so the hypothesis is rejected for all time periods. The two lower levels of road access are significant for all three periods. Level III is significant before 1960. Level IV is not significant at all.

<u>Hypothesis 11:</u> The eleventh hypothesis proposes that shoreline areas where the shoreline is more irregular (have greater water area) have experienced greater land use change than other shoreline areas. As it turned out, Variable 34 is too dependent on Variable 27, water frontage, to pick up significance other than that already found for Hypothesis 8.

TABLE 11

NULL HYPOTHESES AND ALTERNATIVE HYPOTHESES

Hypothesis	Null	Alternative
1	$\bar{Y}_1 = \bar{Y}_2 = \bar{Y}_3 = \ldots = \bar{Y}_{19}$	$\bar{Y}_1 \neq \bar{Y}_2 \neq \bar{Y}_3 \neq \ldots \neq \bar{Y}_{19}$
2	$\bar{Y}_N = \bar{Y}_s$ or $B_{19} = 0$	$\bar{Y}_N > \bar{Y}_s$ or $B_{19} \neq 0$
3	$\bar{Y}_{EW} = \bar{Y}_M$	$\bar{Y}_{EW} > \bar{Y}_M$
4	$\bar{Y}_A = \bar{Y}_B = \bar{Y}_C = \bar{Y}_D$	$\bar{Y}_A \neq \bar{Y}_B \neq \bar{Y}_C \neq \bar{Y}_D$
5	$\bar{Y}_T = \bar{Y}_B$ or $B_{24} = 0$	$\bar{Y}_T > \bar{Y}_B$ or $B_{24} \neq 0$
6	$\bar{Y}_E = \bar{Y}_M$	$\bar{Y}_E > \bar{Y}_M$
7	$B_{26} = 0$	$B_{26} \neq 0$
8	$B_{27} = 0$	$B_{27} \neq 0$
9	$B_{29} = 0$	$B_{29} \neq 0$
10	$B_{33} = 0$	$B_{33} \neq 0$
	$B_{32} = 0$	$B_{32} \neq 0$
	$B_{31} = 0$	$B_{31} \neq 0$
	$B_{30} = 0$	$B_{30} \neq 0$

<u>Summary:</u> Mathematical expressions of the null and alternative hypotheses tested above are summarized on Table 11. The results indicating which factors were associated to a significant degree with land use change by time period are summarized on Table 12.

TABLE 12

RESULTS OF HYPOTHESES TESTING AT 5% LEVEL OF SIGNIFICANCE

Null Hypothesis	Time Periods	1938-1967	1960-1967	1951-1960	193[illegible]
1:	Peninsula	S	S	S	S
2:	North vs. South	S	S	S	S
3:	East-West vs. Middle	NS	NS	NS	NS
4:	Corners	S	S	S	NS
5:	Tip vs. Base	S	S	S	NS
6:	Edge vs. Middle	S	S	NS	NS
7:	Slope	S	S	NS	NS
8:	Water Frontage	S	S	NS	NS
9:	View of Lake	S	S	S	NS
10:	Roads Type I	S	S	S	S
	Roads Type II	S	S	S	S
	Roads Type III	NS	NS	S	S
	Roads Type IV	NS	NS	NS	NS

S - significant

NS - not significant

OBSERVED RELATIONSHIPS

While the multiple regression relationships described above can be used to test for the significance of the association of the amount of observed land use change with the various site properties, they do not provide a high degree of overall correlation. Several factors are responsible. The complete regression equation exhibits excessive multicollinearity. The reduced equations do not contain several significant variables. The qualitative variables are not classified into enough categories to define a quantitative relationship. Many of the quantitative relationships are curvelinear. For example, one would not expect the effect to continue to be directly proportional to slope indefinitely. The increase from 3 to 4 percent is more significant than the increase from 33 to 34 percent.

For these reasons, equations were not developed to show how the probability of land use change varied by site characteristics and by time. A different approach is used to present the quantitative relationships observed in the collected data. The significant factors have been determined for each time period. All possible combinations of significant factors can be listed. The rate of land use change experienced in each such cell can be noted from the observed data. This information is provided in Table 13 for 1938-1951, Table 14 for 1951-1960, and Table 15 for 1960-1967.

For example, Table 13 is developed for 1938-1951, the period of reservoir construction, when only variation among peninsulas and the degree of road access were found to be significant. The significant factors head the columns on the left side of the table. The three columns on the right side indicate the degree of land use experienced by the cell represented by the combination of significant factors noted to the left. Combinations of factors not found on any of the 1900 observed quadralaterals are excluded from the Table.

The peninsula groups are as defined on Table 9. The physical, economic, and other factors causing a particular peninsula to fall in a specific group are discussed in the next chapter.

The probability of land use change at a location exhibiting the tabulated combination of significant factors is tabulated in the right hand column. For example, if a location on a peninsula in Group 1 had access by Roads I and II but not by Road III, the probability of land use change during the construction period is 0.21853. A location on Group 2 with the same combination of access exhibited a probability of 0.06072. On Group 3, the value is 0.01017. Other trends can be observed by holding other sets of three of the four factors constant and varying the fourth.

Each cell represents a discrete interval. Peninsulas all fall in some group. A quadralateral either has (Y) or does not have (N) access by road

TABLE 13

LAND USE CHANGES FOR DIFFERENT COMBINATIONS OF SIGNIFICANT FACTORS, 1938-1951

Peninsula Groups*	Significant Factors			Observed Land Use Change		
				Acres		
	Road I	Road II	Road III	Changed	Total	Probability
1	Y	Y	Y	0	49	0
1	Y	Y	N	47	215	.21853
1	Y	N	Y	19	105	.18089
1	Y	N	N	41	1463	.02799
1	N	Y	Y	7	68	.10288
1	N	Y	N	20	248	.08059
1	N	N	Y	11	284	.03866
1	N	N	N	0	1105	.00000
2	Y	Y	N	57	938	.06072
2	Y	N	Y	23	153	.15024
2	Y	N	N	86	6968	.01232
2	N	Y	Y	4	60	.06657
2	N	Y	N	31	1529	.02026
2	N	N	Y	8	386	.02071
2	N	N	N	27	10288	.00262
3	Y	Y	Y	4	399	.00997
3	Y	Y	N	62	6068	.01017
3	Y	N	Y	11	1502	.00730
3	Y	N	N	110	26010	.00421
3	N	Y	Y	18	1211	.01477
3	N	Y	N	30	5485	.00544
3	N	N	Y	12	1604	.00744
3	N	N	N	48	51078	.00094

* See Table 9

If a combination of factors does not pertain to any of the 1900 quadralaterals, it is not recorded.

TABLE 14

LAND USE CHANGES FOR DIFFERENT COMBINATIONS OF SIGNIFICANT FACTORS, 1951-1960

Significant						Observed Land Use Changes		
Peninsula Group[1]	Location End[2]	Road			View	Acres		Probability
		I	II	III		Changed	Total	
1	B	Y	Y	N	I	0	112	.00068
1	B	Y	Y	N	P	3	192	.01566
1	B	Y	N	Y	P	16	95	.16827
1	B	Y	N	N	G	15	1120	.01334
1	B	Y	N	N	I	1	853	.00117
1	B	Y	N	N	P	19	1479	.01285
1	B	N	Y	N	I	0	54	.00066
1	B	N	Y	N	P	3	422	.00704
1	B	N	N	Y	P	5	322	.01551
1	B	N	N	N	G	3	1857	.00161
1	B	N	N	N	I	3	625	.00479
1	B	N	N	N	P	8	1812	.00441
1	T	Y	Y	Y	G	5	49	.10196
1	T	Y	Y	Y	G	60	225	.26657
1	T	Y	Y	N	P	3	96	.03115
1	T	Y	Y	N	P	0	82	.00068

TABLE 14 - Continued

Significant Factors						Observed Land Use Changes		
Peninsula Group[1]	Location End[2]	Road			View	Acres		Probability
		I	II	III		Changed	Total	
1	T	Y	N	Y	G	50	85	.58810
1	T	Y	N	Y	P	5	58	.08621
1	T	Y	N	N	G	48	1183	.04056
1	T	Y	N	N	I	0	174	.00000
1	T	Y	N	N	P	6	775	.00774
1	T	N	Y	Y	I	9	20	.44990
1	T	N	Y	Y	P	6	68	.08817
1	T	N	Y	N	G	2	117	.01703
1	T	N	Y	N	I	0	105	.00000
1	T	N	Y	N	P	0	323	.00000
1	T	N	N	Y	P	0	19	.00000
1	T	N	N	Y	P	4	131	.03051
1	T	N	N	N	G	1	1631	.00061
1	T	N	N	N	I	0	348	.00000
1	T	N	N	N	P	0	476	.00000
2	B	Y	Y	Y	P	3	399	.00746
2	B	Y	Y	N	G	26	407	.06380

TABLE 14 - Continued

Significant Factors						Observed Land Use Ch[illegible]		
Peninsula Group[1]	Location End[2]	Road			View	Acres		Prob[illegible]
		I	II	III		Changed	Total	
2	B	Y	Y	N	P	20	4509	[illegible]
2	B	Y	N	Y	P	13	1522	[illegible]
2	B	Y	N	N	G	11	1501	[illegible]
2	B	Y	N	N	I	21	2951	[illegible]
2	B	Y	N	N	P	38	14547	[illegible]
2	B	N	Y	Y	P	3	881	[illegible]
2	B	N	Y	N	G	0	76	[illegible]
2	B	N	Y	N	I	0	78	[illegible]
2	B	N	Y	N	P	14	3378	[illegible]
2	B	N	N	Y	I	0	95	[illegible]
2	B	N	N	Y	P	1	1707	[illegible]
2	B	N	N	N	G	10	8890	[illegible]
2	B	N	N	N	I	1	7671	[illegible]
2	B	N	N	N	P	26	15407	[illegible]
2	T	Y	Y	N	G	6	204	[illegible]
2	T	Y	Y	N	P	7	1394	[illegible]
2	T	Y	N	N	G	22	3534	[illegible]

TABLE 14 - Continued

Significant Factors						Observed Land Use Changes		
Peninsula Group [1]	Location End [2]	Road			View	Acres		Probability
		I	II	III		Changed	Total	
2	T	Y	N	N	I	1	1005	.00099
2	T	Y	N	N	P	11	5319	.00206
2	T	N	Y	Y	P	5	370	.01347
2	T	N	Y	N	G	0	94	.00000
2	T	N	Y	N	I	4	601	.00657
2	T	N	Y	N	P	12	2014	.00594
2	T	N	N	N	G	2	11649	.00017
2	T	N	N	N	I	0	5328	.00000
2	T	N	N	N	P	2	6777	.00029

[1] See Table 9. If a combination of factors does not pertain to any of the 1900 quadralaterals, it is not recorded.

[2] Tip or Base

TABLE 15

LAND USE CHANGES FOR DIFFERENT COMBINATIONS OF SIGNIFICANT FACTORS, 1960-1967

Significant Factors							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
1	B	E	F	N	N	G	10	138	.0724[illegible]
1	B	E	I	Y	N	G	149	153	.9737[illegible]
1	B	E	I	Y	N	I	53	53	1.000[illegible]
1	B	E	I	N	N	G	113	193	.5855[illegible]
1	B	E	I	N	N	I	241	330	.7302[illegible]
1	B	E	I	N	N	P	29	87	.3333[illegible]
1	B	E	S	N	Y	G	16	16	1.000[illegible]
1	B	E	S	N	N	G	375	687	.5457[illegible]
1	B	E	S	N	N	I	44	51	.8626[illegible]
1	B	I	I	N	N	P	0	99	.000[illegible]
1	B	I	I	N	N	G	48	48	1.000[illegible]
1	B	I	S	N	N	G	42	44	.9544[illegible]
1	B	M	F	Y	Y	G	7	119	.058[illegible]
1	B	M	F	Y	N	P	0	170	.000[illegible]
1	B	M	F	N	Y	P	35	35	1.000[illegible]
1	B	M	I	Y	Y	P	30	30	1.000[illegible]

TABLE 15 - Continued

Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
1	B	M	I	Y	N	P	53	53	1.00000
1	B	M	I	N	Y	I	59	59	1.00000
1	B	M	I	N	Y	P	275	318	.86473
1	B	M	I	N	N	I	54	92	.58690
1	B	M	I	N	N	P	165	229	.72049
1	B	M	I	N	Y	I	17	19	.89460
1	T	E	F	N	N	P	50	55	.90900
1	T	E	I	N	Y	G	0	16	.00000
1	T	E	I	N	N	G	280	437	.64065
1	T	E	I	N	N	I	149	351	.42445
1	T	E	I	N	N	P	146	321	.45479
1	T	E	S	N	N	G	143	375	.38129
1	T	E	S	N	N	I	217	240	.90410
1	T	E	S	N	N	P	129	147	.87745
1	T	I	I	N	Y	G	0	12	.00000
1	T	I	I	N	Y	P	0	62	.00000
1	T	I	I	N	N	G	0	57	.00000

Significant Factors: Location, Slope, Road, View. Observed Land Use Changes: Acres, Probability.

TABLE 15 - Continued

Significant Factors							Observed Land Use Change[illegible]		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Prob[illegible]
	End[2]	Edge[3]		I	II		Changed	Total	
1	T	I	I	N	N	I	99	189	.5237
1	T	I	I	N	N	P	0	115	.0000
1	T	I	S	N	Y	G	0	46	.0000
1	T	I	S	N	N	G	0	8	.0000
1	T	I	S	N	N	I	0	63	.0000
1	T	M	I	N	Y	I	45	45	1.0000
1	T	M	I	N	Y	P	373	400	.9324
1	T	M	I	N	N	I	69	69	1.0000
1	T	M	I	N	N	P	162	167	.9699
1	T	M	S	N	N	P	194	200	.96997
2	B	E	I	N	N	G	0	45	.00000
2	B	E	I	N	N	I	86	158	.54429
2	B	E	I	N	N	P	40	90	.44444
2	B	E	S	N	N	G	48	164	.29268
2	B	E	S	N	N	I	0	61	.00000
2	B	I	F	N	N	P	20	44	.45449
2	B	I	I	Y	N	P	0	166	.00000

TABLE 15 - Continued

Significant Factors							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
2	B	I	I	N	N	I	0	37	.00000
2	B	I	I	N	N	P	9	95	.09468
2	B	I	S	N	N	P	30	93	.32253
2	B	M	F	Y	Y	P	0	35	.00000
2	B	M	F	Y	N	P	14	226	.06193
2	B	M	F	N	Y	P	0	259	.00000
2	B	M	F	N	N	P	20	113	.17695
2	B	M	I	Y	Y	P	0	50	.00000
2	B	M	I	Y	N	P	0	217	.00000
2	B	M	I	N	N	P	0	334	.00000
2	B	M	S	N	N	P	0	32	.00000
2	T	E	F	N	N	P	0	50	.00000
2	T	E	I	N	N	G	6	68	.08824
2	T	E	I	N	N	I	0	164	.00000
2	T	E	I	N	N	P	0	43	.00000
2	T	E	S	Y	N	G	5	6	.83320
2	T	E	S	N	N	G	51	260	.19610

TABLE 15 - Continued

Significant Factors							Observed Land Use Cha		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Prob
	End[2]	Edge[3]		I	II		Changed	Total	
2	T	E	S	N	N	I	30	183	.163[illegible]
2	T	I	F	Y	N	P	14	14	1.00000
2	T	I	F	N	N	P	10	10	1.00000
2	T	I	I	Y	N	G	0	45	.00000
2	T	I	I	Y	N	I	6	6	1.00000
2	T	I	I	Y	N	P	19	19	1.00000
2	T	I	I	N	Y	P	0	64	.00000
2	T	I	I	N	N	G	4	34	.11765
2	T	I	I	N	N	I	4	4	1.00000
2	T	I	S	Y	N	G	0	2	.00000
2	T	I	S	N	N	G	15	15	1.00000
2	T	M	F	Y	N	P	30	39	.76910
2	T	M	F	N	Y	P	10	40	.25000
2	T	M	F	N	N	P	43	101	.42574
2	T	M	I	Y	N	P	35	133	.26316
2	T	M	I	N	N	G	0	50	.00000
2	T	M	S	N	N	G	19	19	1.00000

TABLE 15 - Continued

Significant Factors							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
3	B	E	F	Y	N	G	0	39	.00000
3	B	E	F	N	N	G	0	45	.00000
3	B	E	I	Y	N	G	3	251	.01194
3	B	E	I	Y	N	I	0	62	.00000
3	B	E	I	N	N	G	0	97	.00000
3	B	E	S	Y	N	G	10	178	.05613
3	B	E	S	Y	N	I	0	88	.00000
3	B	E	S	N	N	G	0	102	.00000
3	B	I	I	Y	Y	I	0	30	.00000
3	B	I	I	N	N	G	0	19	.00000
3	B	M	F	Y	Y	I	0	82	.00000
3	B	M	F	Y	N	P	9	126	.07136
3	B	M	F	N	N	P	3	236	.01266
3	B	M	I	Y	N	G	5	30	.16660
3	B	M	I	Y	N	I	0	103	.00000
3	B	M	I	Y	N	I	5	190	.02628
3	B	M	I	N	Y	I	0	54	.00000

TABLE 15 - Continued

Significant Factors							Observed Land Use Change		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
3	B	M	I	N	N	G	0	87	.000
3	B	M	I	N	N	I	0	32	.000
3	B	M	I	N	N	P	19	190	.099
3	T	E	F	Y	Y	G	19	20	.94
3	T	E	I	Y	N	G	35	146	.23
3	T	E	I	N	Y	G	0	49	.000
3	T	E	I	N	N	G	0	28	.000
3	T	E	I	N	N	I	22	25	.87
3	T	E	S	Y	Y	G	10	83	.120
3	T	E	S	Y	N	G	0	131	.000
3	T	E	S	N	Y	G	0	15	.000
3	T	E	S	N	N	G	112	171	.654
3	T	I	F	Y	N	G	4	4	1.000
3	T	I	F	N	N	G	28	28	1.000
3	T	I	I	Y	N	G	7	40	.174
3	T	I	I	Y	N	I	9	12	.750
3	T	I	I	N	Y	G	10	53	.18

TABLE 15 - Continued

Significant Factors							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
3	T	I	I	N	N	G	7	7	1.00000
3	T	I	I	N	N	I	38	63	.60311
3	T	I	S	Y	Y	G	44	49	.89790
3	T	M	F	N	Y	P	14	42	.33320
3	T	M	I	Y	N	G	0	53	.00000
3	T	M	I	Y	N	I	0	67	.00000
3	T	M	I	Y	N	P	0	48	.00000
3	T	M	I	N	Y	P	9	103	.08733
3	T	M	I	N	N	G	20	41	.48770
3	T	M	I	N	N	I	0	101	.00000
3	T	M	I	N	N	P	0	117	.00000
4	B	E	F	Y	N	G	11	206	.05334
4	B	E	F	Y	N	P	0	70	.00000
4	B	E	F	N	N	P	0	73	.00000
4	B	E	I	Y	N	G	0	83	.00000
4	B	E	I	Y	N	P	0	95	.00000
4	B	E	I	N	N	G	4	266	.01499

TABLE 15 - Continued

Significant Factors							Observed Land Use Ch[illegible]		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Proba[illegible]
	End[2]	Edge[3]		I	II		Changed	Total	
4	B	E	I	N	N	I	0	528	[illegible]
4	B	E	I	N	N	P	0	103	[illegible]
4	B	E	S	Y	Y	G	97	137	[illegible]
4	B	E	S	Y	N	G	26	92	[illegible]
4	B	E	S	N	N	G	43	432	[illegible]
4	B	E	S	N	N	I	3	344	[illegible]
4	B	I	F	Y	N	G	0	70	[illegible]
4	B	I	F	Y	N	I	0	80	[illegible]
4	B	I	F	Y	N	P	0	172	[illegible]
4	B	I	F	N	Y	P	9	80	[illegible]
4	B	I	F	N	N	G	0	27	[illegible]
4	B	I	F	N	N	P	0	62	[illegible]
4	B	I	I	Y	N	G	0	50	[illegible]
4	B	I	I	Y	N	P	0	186	[illegible]
4	B	I	I	N	N	I	0	35	[illegible]
4	B	I	I	N	N	P	0	149	[illegible]
4	B	I	S	Y	N	G	2	47	[illegible]

TABLE 15 - Continued

Significant Factors							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
4	B	I	S	N	N	G	0	27	.00000
4	B	I	S	N	N	I	0	28	.00000
4	B	M	F	Y	Y	P	0	135	.00000
4	B	M	F	Y	N	P	0	330	.00000
4	B	M	F	N	Y	P	0	298	.00000
4	B	M	F	N	N	P	5	573	.01830
4	B	M	I	Y	Y	P	0	88	.00000
4	B	M	I	Y	N	I	0	91	.00000
4	B	M	I	Y	N	P	0	733	.00000
4	B	M	I	N	Y	P	0	9	.00000
4	B	M	I	N	N	G	0	90	.00000
4	B	M	I	N	N	I	0	221	.00000
4	B	M	I	N	N	P	0	767	.00000
4	B	M	S	N	N	I	20	44	.45455
4	T	M	S	N	N	P	15	20	.75000
4	T	E	F	Y	N	G	0	143	.00000
4	T	E	F	Y	N	P	0	54	.00000

TABLE 15 - Continued

Significant Factors							Observed Land Use Change		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
4	T	E	F	N	N	P	0	64	.0000
4	T	E	I	Y	N	I	19	19	1.0000
4	T	E	I	N	N	G	49	239	.2050
4	T	E	I	N	N	P	10	58	.1724
4	T	E	S	Y	N	G	62	68	.9118
4	T	E	S	N	N	G	92	356	.2584
4	T	E	S	N	N	I	11	13	.8461
4	T	I	F	Y	Y	P	3	86	.0349
4	T	I	I	Y	N	G	30	91	.3297
4	T	I	I	N	Y	I	1	42	.0238
4	T	I	I	N	Y	P	0	26	.0000
4	T	I	I	N	N	G	10	65	.1538
4	T	I	I	N	N	I	60	60	1.0000
4	T	I	I	N	N	P	38	38	1.0000
4	T	I	S	Y	N	G	10	10	1.0000
4	T	I	S	N	N	G	8	21	.3809
4	T	M	F	N	Y	P	3	177	.0169

TABLE 15 - Continued

Peninsula Group[1]	Significant Factors						Observed Land Use Changes		
	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
4	T	M	F	N	N	P	0	57	.00000
4	T	M	I	Y	N	G	0	30	.00000
4	T	M	I	Y	N	I	0	135	.00000
4	T	M	I	N	Y	I	32	164	.19510
4	T	M	I	N	N	G	13	166	.07830
4	T	M	I	N	N	I	10	134	.07460
4	T	M	I	N	N	P	11	82	.13410
4	T	M	S	Y	N	G	0	12	.00000
5	B	E	F	Y	Y	P	0	142	.00000
5	B	E	F	Y	N	I	0	110	.00000
5	B	E	F	Y	N	P	0	234	.00000
5	B	E	F	N	Y	G	0	60	.00000
5	B	E	F	N	N	G	0	146	.00000
5	B	E	F	N	N	I	0	368	.00000
5	B	E	F	N	N	P	0	260	.00000
5	B	E	I	Y	Y	P	0	139	.00000
5	B	E	I	Y	N	G	0	552	.00000

TABLE 15 - Continued

Significant Factors							Observed Land Use Change		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
5	B	E	I	Y	N	I	0	1498	.0000[illegible]
5	B	E	I	Y	N	P	3	1627	.0018[illegible]
5	B	E	I	N	Y	P	0	205	.0000[illegible]
5	B	E	I	N	N	G	2	2367	.0008[illegible]
5	B	E	I	N	N	I	0	3090	.0000[illegible]
5	B	E	I	N	N	P	3	2718	.0011[illegible]
5	B	E	S	Y	N	G	25	773	.0323[illegible]
5	B	E	S	Y	N	P	0	913	.0000[illegible]
5	B	E	S	Y	N	P	2	588	.003[illegible]
5	B	E	S	N	N	G	6	5128	.0011[illegible]
5	B	E	S	N	N	I	0	1575	.0000[illegible]
5	B	E	S	N	N	P	0	1254	.000[illegible]
5	B	I	F	Y	Y	P	0	436	.000[illegible]
5	B	I	F	Y	N	P	5	373	.013[illegible]
5	B	I	F	N	Y	P	0	183	.000[illegible]
5	B	I	F	N	N	G	0	106	.00[illegible]
5	B	I	F	N	N	I	0	155	.000[illegible]

TABLE 15 - Continued

	Significant Factors						Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
5	B	I	F	N	N	P	0	303	.00000
5	B	I	I	Y	Y	P	0	368	.00000
5	B	I	I	Y	N	G	0	35	.00000
5	B	I	I	Y	N	I	0	97	.00000
5	B	I	I	Y	N	P	0	682	.00000
5	B	I	I	N	Y	P	0	261	.00000
5	B	I	I	N	N	G	0	131	.00000
5	B	I	I	N	N	I	0	425	.00000
5	B	I	I	N	N	P	0	2030	.00000
5	B	I	S	Y	Y	G	9	270	.03325
5	B	I	S	Y	N	G	0	28	.00000
5	B	I	S	Y	N	I	0	310	.00000
5	B	I	S	Y	N	P	0	45	.00000
5	B	I	S	N	N	G	15	174	.08621
5	B	I	S	N	N	I	0	285	.00000
5	B	I	S	N	N	G	5	325	.01534
5	B	M	F	Y	Y	P	6	1705	.00349

TABLE 15 - Continued

Significant Factor							Observed Land Use Change		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
5	B	M	F	Y	N	I	0	79	.00000
5	B	M	F	Y	N	P	19	4072	.00465
5	B	M	F	N	Y	P	0	1012	.00000
5	B	M	F	N	N	I	0	50	.00000
5	B	M	F	N	N	P	3	2488	.00120
5	B	M	I	Y	Y	P	7	1647	.00424
5	B	M	I	Y	N	G	2	34	.05870
5	B	M	I	Y	N	I	15	295	.05083
5	B	M	I	Y	N	P	27	6513	.00413
5	B	M	I	N	Y	P	6	2021	.00296
5	B	M	I	N	N	G	0	86	.00000
5	B	M	I	N	N	I	0	198	.00000
5	B	M	I	N	N	P	11	5294	.00207
5	B	M	S	Y	Y	P	0	206	.00000
5	B	M	S	Y	N	I	0	25	.00000
5	B	M	S	Y	N	P	5	676	.00740
5	B	M	I	N	N	G	5	98	.05100
5	B	M	I	N	N	I	0	284	.00000

TABLE 15 - Continued

Significant Features							Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
5	T	I	I	N	N	I	0	98	.00000
5	T	I	I	N	N	P	4	419	.00954
5	T	I	S	Y	Y	G	0	38	.00000
5	T	I	S	Y	N	G	0	42	.00000
5	T	I	S	Y	N	I	0	23	.00000
5	T	I	S	Y	N	P	0	23	.00000
5	T	I	S	N	N	G	0	313	.00000
5	T	I	S	N	N	I	0	108	.00000
5	T	I	S	N	N	P	0	30	.00000
5	T	M	F	Y	Y	P	0	484	.00000
5	T	M	F	Y	N	I	0	37	.00000
5	T	M	F	Y	N	P	0	1100	.00000
5	T	M	F	N	Y	P	0	441	.00000
5	T	M	F	N	N	G	9	58	.15517
5	T	M	F	N	N	P	10	35	.28565
5	T	M	F	N	N	P	0	291	.00000
5	T	M	I	Y	Y	I	0	35	.00000

TABLE 15 - Continued

Significant Features							Observed Land Use Change		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Prob[illegible]
	End[2]	Edge[3]		I	II		Changed	Total	
5	T	M	I	Y	Y	P	1	793	.0012[illegible]
5	T	M	I	Y	N	G	0	28	.000[illegible]
5	T	M	I	Y	N	I	0	37	.000[illegible]
5	T	M	I	Y	N	P	1	1731	.000[illegible]
5	T	M	I	N	Y	P	0	20	.000[illegible]
5	T	M	I	N	Y	P	49	467	.104[illegible]
5	T	M	I	N	N	G	0	38	.000[illegible]
5	T	M	I	N	N	I	21	607	.034[illegible]
5	T	M	I	N	N	P	1	1938	.000[illegible]
5	T	M	S	Y	Y	G	1	20	.04[illegible]
5	T	M	S	Y	Y	I	0	46	.000[illegible]
5	T	M	S	Y	N	G	0	19	.000[illegible]
5	T	M	S	Y	N	I	0	19	.000[illegible]
5	T	M	S	Y	N	P	0	531	.000[illegible]
5	T	M	S	N	Y	P	0	766	.000[illegible]
5	T	M	S	N	N	G	0	73	.000[illegible]

TABLE 15 - Continued

	Significant Features						Observed Land Use Changes		
Peninsula Group[1]	Location		Slope	Road		View	Acres		Probability
	End[2]	Edge[3]		I	II		Changed	Total	
5	T	M	S	N	N	I	0	161	.00000
5	T	M	S	N	N	P	0	630	.00000

[1]See Table 9
If a combination of factors involves no land area, it is not recorded.

[2]Tip or Base

[3]Edge, Intermediate, or Middle

of a given type. It is either located on the tip (T) or the base (B) of a peninsula. It either has a good (G), intermediate (I), or poor (P) view of the lake. It is either along the shoreline (E), in the tier one quadralateral in from the shoreline (I), or further inside the peninsula (M). The slope is either steeper than 29 percent (S), between 11 and 29 percent (I), or flatter than 11 percent (F).

Tables 13, 14, and 15 fulfill three functions. They provide a synopsis of the raw data collected in this study. They provide a basis for evaluating quantitatively the observed relationship between land use changes and any of the significant factors. Finally, they provide raw data for use in simulating land use change around a reservoir. The properties of a given site can be measured. Table 11 can be used to estimate the probability of land use change during reservoir construction. Table 12 can be used to estimate the probability of land use change during the years of buildup immediately following project completion. Table 13 can be used to estimate the probability of land use change during later years. Further research is needed to perfect and generalize the simulation process, but the technique provides a basic method for estimating shoreline land use changes, land value changes, and environmental quality changes. Estimates of land use and environmental quality require derivation of a relationship between these quantities and land use.

SUMMARY

In this chapter, eleven specific hypothesis dealing with how land use change is associated with site characteristics are proposed and tested by time period. Multicollinearity among site characteristics is examined. The significance of individual site characteristics is examined by testing the applicable hypothesis by multiple regression analysis where negligible multicollinearity is observed or by analysis of variance otherwise. After the significant factors are isolated by time period, tables present the probability of an occurance of land use change for different combinations of these significant factors. The next chapter examines qualitatively the meaning of the derived relationships.

CHAPTER V

SUMMARY AND CONCLUSIONS

After testing to determine which factors have to a significant degree been associated with land use change around Lake Cumberland and summarizing the observed probability of land use change for all observed combinations of factors, it is helpful at this point to look into why the observed change patterns occurred, consider how the findings might contribute to public and private policy making for planning other reservoir sites, evaluate the overall meaning and significance of the research findings, and note the unresolved issues on which further research is needed.

EXPLANATION OF OBSERVED LAND USE CHANGE PATTERNS

The observed significant associations between land use change and the other factors are summarized in Table 12. The relationship between the factors and the amount of change experienced by time period is summarized in Tables 13, 14, and 15. In this section, the associations between the tested factors and land use change found to be significant are inspected in more detail in order to attempt to deduce probable causal relationships. A better understanding of the causes provides a better basis for applying the results to the planning of future reservoirs by permitting a more accurate forecast of land use changes in the immediate area. Separate discussion follows of the spatial patterns around the lake, the spatial patterns on peninsulas, spatial patterns as affected by site characteristics, and spatial patterns as affected by road access.

Spatial Patterns Around the Lake

Table 12 shows that a significant variation in land use change patterns exists among the peninsulas around Lake Cumberland. Certain peninsulas experienced greater land use changes than did others. The north side of the lake experienced greater land use change than did the south. The peninsulas on the east and west ends of the lake, however, did not experience significantly different land use changes from the middle peninsulas.

On Table 9, the 19 peninsulas are divided into groups experiencing like degrees of land use change by applying least significant differences for each of the three time periods. The grouping on Table 9 is then used to divide the peninsulas into four groups according to the overall trend in experienced land use change (Table 16). The fraction of the land on peninsulas in each group experiencing land use change during each period is shown on Table 17. For all four groups, a trend toward accelerated land use change in the most recent period is noted. There is no way from this one case study to determine whether this acceleration is a function of project time (the length of time since project construction), calendar time (a widespread or even nationwide trend toward developing lake shore property), or some combination of the two. In all probability, the acceleration is associated with a nationwide trend toward increased participation in water-oriented outdoor recreation.

The pattern of land use change experienced by peninsulas in each of the four groups of Table 16 is discussed individually. The physical properties of the peninsulas are summarized on Table 18.

Group 1: The first group contains only Peninsula 1. This peninsula is located on the north side of the lake near Jamestown (Figure 1). Even before 1938, a boat dock was located at this point on the Cumberland River. Peninsula 1 was a center of water-oriented economic activity before the lake was formed and was thus in the best position to develop after 1938. Table 18 shows the peninsula to have the over all best view of the lake as well as the overall best road access. These factors

TABLE 16

PENINSULA GROUPING ACCORDING TO TOTAL LAND USE CHANGE

Group	Peninsulas	Land Use Change Trends
1	1	Rapid land use change in all three periods.
2	7, 9	Very slow change in the first two periods followed by very rapid change in the third period.
3	2, 4, 5, 10, 12	Slow land use change during all three periods.
4	3, 6, 8, 11, 13-19	Very slow land use change during all three periods.

TABLE 17

PERIOD CHANGES IN LAND USE BY PENINSULA GROUP

Peninsula	Fraction of Acreage Changing		
Group	1938-1951	1951-1960	1960-1967
1	0.0413	0.0199	0.1258
2	0.0003	0.0007	0.4472
3	0.0116	0.0132	0.0406
4	0.0035	0.0022	0.0053

TABLE 18

DISTRIBUTION OF PENINSULA AREA WITH RESPECT TO CERTAIN FACTORS

Peninsula	Land Area*	Fraction of Area						Total Miles of Road per 100 Acres for		
		In Tip	In Edge	With Good View	With Intermediate View	With Slope Less than 11%	With Slope Between 11% and 29%	Road 1	Road 2	Road 3
1	3430	.42	.45	.49	.22	.18	.60	.25	.07	.08
2	4744	.38	.43	.38	.16	.23	.46	.19	.07	.00
3	1618	.28	.44	.40	.18	.20	.55	.06	.05	.00
4	4105	.44	.48	.36	.12	.39	.35	.16	.10	.00
5	2125	.30	.45	.42	.16	.25	.25	.16	.02	.10
6	1714	.35	.44	.33	.14	.24	.24	.10	.06	.00
7	6005	.53	.49	.32	.25	.08	.64	.02	.11	.00
8	6179	.41	.45	.18	.21	.13	.64	.10	.07	.00
9	3466	.37	.45	.18	.17	.27	.52	.13	.06	.01
10	4555	.31	.48	.19	.24	.23	.57	.10	.07	.05
11	8521	.35	.47	.09	.20	.46	.47	.18	.09	.03
12	4258	.23	.44	.41	.16	.33	.52	.17	.04	.00
13	6400	.47	.42	.35	.19	.08	.68	.11	.07	.00
14	17433	.42	.47	.26	.21	.13	.52	.08	.02	.01
15	13874	.30	.44	.19	.08	.16	.60	.08	.04	.02
16	15884	.34	.45	.16	.13	.13	.55	.06	.01	.01
17	2726	.33	.39	.26	.10	.06	.66	.17	.02	.04
18	2239	.28	.38	.29	.18	.00	.37	.08	.01	.00
19	2422	.24	.43	.46	.10	.00	.10	.03	.00	.00

* Excludes Water Area

have helped the area experience rapid land use change since the beginning of project construction. The development was, however, associated with many small individual decisions. With buildings already scattered over the peninsula, suitable undeveloped tracts were not available for the later large scale development which came to the peninsulas in Group 2. Peninsula 1 represents the type of area likely to experience early and sustained land use change.

Group 2: The second group contains Peninsulas 7 and 9 (Figure 1). Both areas experienced very little land use change until 1960. The land use on Peninsula 7 has changed on over half its total area since then. This peninsula possesses many areas with a very good view of the lake. Table 18 shows almost 60% of the peninsula to have a good or intermediate view. Peninsula 7 is also shaped so as to have the largest fraction of its area situated on a broad nosed tip extending far out into the lake, where the water can be seen on three sides. It also has the largest fraction of its total area along the edges. Little land use change was experienced during the two earlier periods, probably because of the very poor access. The peninsula is located about halfway between the two ends of the lake and has one of the lowest road mileages per acre. Recently, some enterprising individuals recognized the advantages of the location and subdivided their farms into residential lots. Others followed suit in a large scale land development program. Peninsula 9 has experienced roughly the same history, but the growth has been much less spectacular, probably largely because the peninsula as a whole has a much poorer view.

In recent years, the nationwide trend in land use change has been toward larger scale development of large tracts of undeveloped land. Group 2 contains areas where development in the past has been restricted by poor access but recent large scale development has been able to exploit a favorable location. The process suggests a consideration which was not measured in this study: personal factors which cause some individuals to prefer to subdivide while others prefer to hold their farms. The degree to which land owners recognize the possibility of increasing their income by development is also important.

Group 3: The third group contains Peninsulas 2, 4, 5, 10, and 12. All but 12 are on the north side of the lake (Figure 1). The five peninsulas have experienced a slow but steady rate of land use change since 1938. Their characteristics were not good enough to entice the more rapid growth of Peninsula 1, but better access permitted enough heterogeneous development to discourage the large scale development experienced by the peninsulas in Group 2. Most of the peninsulas in Group 3 experienced an early development program which began shortly after the lake was formed.

Peninsula 2 had Pleasant Hill residential development; Peninsula 5 had the Alligator boat docks; Peninsula 10 had a boat launch at Cumberland Point; and Peninsula 12 had Conley Bottom boat dock.

Group 4. The fourth group contains Peninsulas 3, 6, 8, 11, and 13-19 (Figure 1). These peninsulas have experienced very little land use change. At this point, it is interesting to examine the peninsulas that still remain relatively unaffected by the lake. Using Table 16, one can see that Peninsula 3 has very few roads and very little area in the tip. Peninsula 6 has steep slopes, and more than 50% of the area has a poor, if any, view. Peninsula 8 has a relatively poor view and a relatively small flat area. Peninsula 11 has 70% of its area with a poor view and is so far upstream that the lake appears to be little more than a wide river. Peninsulas 13-19 are characterised by large areas with no view, poor road access, a remote location on the south side of the lake, and smaller areas in the tips. Some have extremely steep slopes. On Peninsula 19, 90% of the land has slopes exceeding 30 percent. These characteristics have combined to hold back land use changes on these peninsulas.

North-South Factor: The north-south factor is basically a measure of peninsula orientation toward major population centers. Most of the visitors to Lake Cumberland come from the north. The larger urban centers in Kentucky, Indiana, and Ohio are all located in this direction. In addition, several other large lakes including the entire Tennessee Valley Authority system are located not too far to the south. Through roads coming from the south are much worse than those coming from the north. In short, a definite trend toward greater development on the side of the lake oriented toward the homes of most visitors was observed (Table 19).

East-West Factor: The east-west factor is basically a measure of the proximity of the peninsula to major highways and small towns. From the results, no evidence was found that land use was influenced by this factor. Apparently the distances from Jamestown and the Somerset-Burnside area are too small to make a difference to people selecting sites for residential, commercial, or public uses. Another factor is that being near population centers is a contradiction of trying to get "away from it all."

Spatial Patterns on Peninsulas

In addition to patterns of land use changes around the lake, a definite pattern of land use change was also observed on the peninsulas. None of the peninsula variables, however, were found to be significant before 1951 when the lake was filled. After all, the peninsulas only existed on paper before that time. Since then, the tip areas of the peninsulas have

TABLE 19

PERIOD CHANGES IN LAND USE BY SIGNIFICANT FACTORS

		Fraction of Acreage Changing		
		1938-1951	1951-1960	1960-1967
North Side		0.0070	0.0082	0.1123
South Side		0.0028	0.0040	0.0114
Tip Areas		*	0.0061	0.0811
Base Areas		*	0.0036	0.0350
Edge Areas		*	*	0.0596
Intermediate Areas		*	*	0.0539
Middle Areas		*	*	0.0438
Slope > 29%		*	*	0.0563
29% > Slope > 11%		*	*	0.0610
11% > Slope		*	*	0.0206
Good View		*	0.0080	0.0753
Intermediate View		*	0.0019	0.0720
Poor View		*	0.0036	0.0341
Road I:	Access	0.0104	0.0093	0.0279
	No Access	0.0018	0.0016	0.0672
Road II:	Access	0.0145	0.0117	0.0789
	No Access	0.0039	0.0033	0.0482
Road III:	Access	0.0200	0.0305	*
	No Access	0.0050	0.0031	*
All Roads:	Access	0.0109	0.0087	0.0400
	No Access	0.0012	0.0008	0.0635

*Factor not significant during this period.

experienced a greater change in land use than the base areas (Table 19).
The tip areas are more fully surrounded by water and, on the whole, are nearer the lake. The lake can be seen from a greater fraction of the land area, and more water can be seen from a given viewpoint. An analysis of differences in land use change among the four corners provides the same distinction between tip and base but in addition, through the least significant difference analysis, slightly more development was observed on the BD than on the AC side of the peninsulas (Table 10). On Tables 7 and 9, one sees the significance of the tip becoming progressively greater from one period to the next, meaning that over time the tip is experiencing an increasingly greater rate of change in land use.

In addition to a greater change in land use on the tips of peninsulas, the edges have experienced a greater change in land use than the middle areas of peninsulas (Table 19). This association does not become significant until the 1960-1967 period, again illustrating that over time land use changes are shifting closer to the lake.

In summarizing the effect of location on the peninsula on land use change, no effect is observed during the construction phase before the peninsulas are actually formed. At first the development occurs more or less randomly over the peninsula with only a slight preference for locations near the tip or edge. The preference to be near the water seems to be nearly offset by the better road access characteristic of interior locations.

As more people locate near the water, the quality, if not the length, of the road extremities no doubt improves; and development accelerates.

Site Characteristics and Spatial Patterns

Slope, water frontage, and view of the lake were the site characteristics observed to be significantly associated with the rate of land use change. The high degree of multicollinearity observed among these variables (Table 4) makes it very difficult to distinguish among the influence of these three factors. View of the lake was not significant until after the lake was formed in 1951. Slope and water frontage became significant in 1960. Good view exhibited the highest level of the significance of the three in the second time period. Slope did in the third.

Table 19 illustrates how development in the 1951-1960 period concentrated in areas having a good view of the lake. Most land use change was associated with the development of individual building sites, and such sites were often selected to get a good view. Better access and flatter land in the interiors of the peninsulas caused the areas with a poor view to experience more development than areas with an intermediate view. In the 1960-1967 period, more of the development occurred in larger tracts. Some of the tracts spread into the intermediate view area.

The significance testing showed the rate of land use change to increase with slope. Table 19 shows how for the study area as a whole, the greatest land use change occurred on areas of intermediate slope. Flatter areas are predominately located toward the interior of the peninsulas where the lake cannot be seen. Steeper areas increase building cost and make access more difficult. Even if the effect of slope is only analyzed for areas having a good view of the lake (Table 20), the same trend toward maximum land use change on areas of intermediate slope is found. Flat areas almost inherently have a poor view. Table 20 shows how the areas with a good view have much steeper slopes than do the peninsulas as a whole (Table 18).

The trend seems to be that sites on the bluff with a view of the lake, but not necessarily water frontage, were selected first. Later development shifted more toward the shore. Probably, lakes having flatter topography around the shoreline would experience more concentrated development near the shoreline from the beginning.

TABLE 20

RELATIONSHIP BETWEEN SLOPE AND LAND USE CHANGES DURING 1960-1967 FOR AREAS WITH GOOD VIEW

	Percentage of Total Area With Good View Having Indicated Slope	Fraction of Acreage Changing
Slope > 29%	63	0.0646
29% > Slope >11%	32	0.0973
11% > Slope	5	0.0678

The dominance of view as a site characteristic affecting land use change makes particular sense in the setting of Lake Cumberland. One desiring a residential site near a lake is interested in a view. Water frontage is beneficial for boating. But because most of the shoreline of Lake Cumberland is unsuitable for boat launching and docking, even those owning lots with water frontage must take their boats to a public area. Slope is only important as it provides a view or becomes so steep as to require excessive development cost. Very few individuals - if the lake influences their decision to locate near it - locate solely due to slope.

Road Access and Spatial Patterns

Roads are associated with land use changes in a manner varying by road type and with time period. On Table 7 for the periods of 1938-1951, 1951-1960, and 1960-1967, one sees that the significance for road types I and II has declined over time. Table 19 shows a preference for areas without road access in the most recent period. This trend probably results from new land development taking place more often as part of larger scale development projects extending into many quadralaterals not originally having road frontage. Individual buildings were constructed along roads in the earlier periods; larger tracts were developed away from roads and older buildings in the latest period. Road type IV was not significant for any of the time periods, probably due to the remoteness of through roads from the lake. Road type III is significant until 1960 - not afterwards. Early development took place at locations having the best access. Later development produced an increasing rate of land use change near the lake. Road type III, being located more toward the ridges, becomes no longer significant.

The overall time trend of peninsular development seems to be that once the reservoir project is officially approved and construction begins on the dam, the first land use changes appear along the major roads in the general vicinity of the lake. Once the lake fills, a view is developed and becomes an important factor. Development gradually shifts from interior locations having better road access to shoreline locations having a better view or even water access. The greater traffic to shoreline areas gradually induces an improvement in road quality and this, in turn, encourages more extensive shoreline development. In the more static peninsulas, it is still very difficult, if not impossible to get to the shoreline by road.

APPLICATIONS TO POLICY MAKING

The primary value gained from a study of past trends is the guidance it provides to decision makers charged with forming future policy. The effects of proposed reservoir alternatives on surrounding land use are one of many considerations an economist must remember as he is allocating scarce resources to achieve maximum returns. As society becomes more conscious of environmental quality and experiences the congestion effects of an increasing population, more and more emphasis is going to have to be placed on the interaction between a reservoir and land use in the surrounding countryside. This study provides a framework for analysis and a first approximation of the data needed to explore this interaction in depth.

The federal government and other agencies responsible for reservoir construction are interested in patterns of land use change from the points of view of determining how far back from the lakeshore right-of-way should be purchased to prevent interference with project objectives. Where shoreline recreational facilities are part of the project, it is necessary to insure a buffer zone between recreational areas and areas of incompatable land use. The control of land use around the reservoir for these or other reasons involves a cost. The economic justification of such control requires that the resulting benefit exceed the cost. The benefit is measured by comparing what would happen with the control as opposed to what would happen without it. Data such as that obtained in this study is required for the analysis.

Most zoning and other community land use planning takes place at the local level. A better informed planning board will produce better decisions. The type of study provided in this report shows what patterns of land use change can be expected in an uncontrolled environment. The local planners should weigh the good and the bad characteristics of such development in seeking to determine how it should be modified to reduce undesirable external effects and improve community welfare. The results of this study indicate the land use changes consequent to the "do nothing" alternative. For example, areas on intermediate slopes with a view of the lake have higher probabilities of experiencing changes in land use. If the primary land use change was to low quality seasonal housing and commercial enterprises, these developments may deteriorate the natural surroundings, lowering property values to others. Market forces cannot compensate others for the disutility imposed by such development. Zoning becomes necessary to protect the quality of the community, and this study provides information to aid in zoning.

Planning by the private sector of the economy can also make good use of a better ability to predict future land use change patterns. Commercial properties are most profitably centered in areas experiencing economic growth. Entrepreneurs will be helped by a better ability to forecast where such development will occur. Other individuals coming into the area may be looking for seclusion and want to find a site where significant additional development is unlikely.

individuals functioning in the land market are affected by what neighboring developers are doing and can be expected to do in the future. As long as the utility of land ownership is affected by the land use of one's neighbors, individuals will be able to improve their welfare by an improved ability to forecast future changes in neighboring land use.

SIGNIFICANCE OF FINDINGS

Analysis of land use changes surrounding Lake Cumberland shows conclusively that the rate and pattern of change varies with general location around the periphery of the lake, with specific location on a given peninsula jutting into the lake, with physical characteristics of a given site, and with road access to the site. Specific factors associated with land use change were determined. Trends by factors were quantified.

While information on land value change or environmental quality change may be more useful in certain circumstances, land use can be more precisely measured and in large part closely correlates with the other two.

By partitioning the study area into peninsulas and then into quadralaterals, the land use changes can be located on a normalized grid. This method allows the identification of relative locations from peninsula to peninsula and allows the examination of spatial patterns of land use changes on and among the peninsulas.

SUGGESTIONS FOR FURTHER RESEARCH

The knowledge gained through this study needs to be extended in several ways in order to develop a more general model for forecasting consequent land use changes in the area immediately surrounding a new reservoir. Case studies at other locations are needed to separate associations peculiar to the setting of Lake Cumberland from the associations characteristic of most reservoir sites. Once the two types of effects are distinguished and quantified, a generally applicable model for simulating land use change can be developed. The study can also be extended in other ways.

1. In this study, all land use is grouped into one of the four categories of commercial, agricultural, residential, or public use. A further disaggregation could be made. For example, one can subdivide agriculture into crop land, pasture, and woodland. Residential can be subdivided into seasonal and permanent or into categories selected by building value. Commercial can be subdivided into recreational oriented and other. Public land can be

subdivided into educational, religious, and recreational. The finer breakdown would also indicate changes within the categories as defined for this study and may lead to a more complete understanding of the change process.

2. The study could also be extended to determine types of land use most often associated with various sets of site characteristic. The characteristics favoring a change to one type of land use may vary from those favoring a change to another type. For example, one would expect commercial development to be more dependent on road access than is residential development.

3. Some research is needed into the extent to which private land is held idle for future development around reservoirs and the circumstances governing the timing of the development of such property. Such a study would provide additional insight into forecasting the rapid development phenomena observed on Peninsulas 7 and 9.

4. Research is also needed into the influence of the extent of government held land around the reservoir on the patterns of land use change on private land. How does this influence vary between land held in its natural state and land developed for active recreational use?

5. The human characteristics of the owner as well as the physical characteristics of the site certainly also influence the rate of land use change. The subject could be approached by much the same procedure used in this study of proposing hypothesis and testing the experience data for degree of association.

6. Land use changes could also be approached from the point of view of evaluating returns to the owner from alternative land uses. Land ownership records and maps could be used to trace land ownership and obtain such information as the land uses for the study period, the income and occupation of the owners, the length of ownership, and the sales prices of each transaction. With this information, relationships could be determined among these variables, linking them to the lake where possible and determining the association between land values and degree of association with the lake. Where and when lake related land uses provide a higher rate of return, the market price of land should increase. Additional insight into how the lake has affected development in the area would result.

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