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VALUATION OF LAKE RESOURCES THROUGH HEDONIC PRICING

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This report describes the application of the hedonic pricing technique (property values) to the evaluation of lake resources. Hedonic models are developed to test three hypotheses: Hypothesis 1) Land value of lakefront property is greater than nonlakefront property. Hypothesis 2) The effect of lake characteristics (size and water quality) is realized in land values. Hypothesis 3) Water resource related impact on land value will diminish with distance from the water sources. Results confirmed all three hypotheses and illustrated the use of the hedonic technique for evaluating such environmental amenities as lake resources.

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VALUATION OF LAKE RESOURCES THROUGH HEDONIC PRICING

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PREFACE

This report was prepared as part of the U.S. Army Corps of Engineers (COE) Evaluation and Formulation of Environmental Projects Work Unit, within the Planning Methodologies Research Program. Mr. William Hansen and Mr. Darrell Nolton of the COE Water Resources Support Center (WRSC), Institute for Water Resources (IWR), manage this Work Unit under the general supervision of Mr. Michael Krouse, Chief, Technical Analysis and Research Division; Mr. Kyle Schilling, Director, IWR; and Mr. Kenneth Murdock, Director, WRSC. Mr. Robert Daniel, Chief of the Economic and Social Analysis Branch (CECW-PD) and Mr. Brad Fowler, Economist (CECW-PD) served as Technical Monitors for Headquarters, COE.

The work was performed by Planning and Management Consultants, Ltd. (PMCL), under Task Order 0029, Contract No. DACW72-89-D-0020. Mr. Timothy Feather was the principal investigator and author, supported by Mr. Edward Petit and Mr. Panagiotis Ventikos, all of PMCL. The support of the Orange County, Florida, Commissioners Office and Mr. John Crissey of the Orange County Property Appraisal Office in releasing and providing the property sales data that served as a basis for this study is also gratefully acknowledged.

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I. INTRODUCTION

A process for determining the benefit or value of certain water resource characteristics has not yet been established or clearly accepted by water resource planners. On the one hand, when used as an input to production, water resource benefits are derived as production cost savings. For example, the benefits or savings can accrue from irrigating instead of transporting water in some agricultural production settings. Similarly, valuation of flood control benefits from a water resource is also relatively straightforward. A dollar value can be computed to represent foregone flood damage. On the other hand, quantification of certain benefits can elude traditional solutions. The quandary occurs because society places worth on certain features of water resources that have no direct monetary value, such as aesthetic value and some recreation benefits. In other words, these are perceived benefits that are not bought or sold in a market setting. Therefore the challenge to water management decision makers is to justifiably place value on unpriced goods.

What is the value of a water resource such as a lake? How much money should be spent on cleaning up a waterway? These questions must be answered by those who manage the environment. One response to this challenge is the use of a benefit assessment methodology called hedonic pricing. The central assumption in hedonic pricing is that the value of a water resource is captured implicitly within the value of surrounding property. Thus the value of an unpriced environmental good, a water resource, is measured through priced complementary goods, property values. The development and application of this technique are the topics of this research effort.

ECONOMIC ANALYSIS IN WATER RESOURCE MANAGEMENT

Economic analysis in water resource management has evolved significantly since the U.S. Army Corps of Engineers was initially ordered to keep account of project benefits and costs as mandated by the Rivers and Harbors Act of 1902. The Flood Control Act of 1936 supplemented the Act of 1902, making approval of a project contingent upon benefits outweighing costs. The idea of economically justifying policy decisions was generally accepted, making benefit-co analysis a popular and necessary agent for allocation of government monies to water projects.

In the late 1940s, representatives from several federal water resource agencies created a guide for planners and managers to benefit-cost analysis, referred to as the "Green Book" (U.S. Interagency Committee on Water Resources 1950). Subsequently, in the late 1950s and early 1960s individual valuation procedures, as well as the total process, underwent close examination and formalization by water resource economists, engineers, and policymakers (Eckstein 1958; Krutilla and Eckstein 1958; McKean 1958; Hirshliefer et al. 1961; Maass et al. 1962). Techniques were redefined and became rooted in widely acceptable economic theory. The "Green Book" was revised in 1958, and other similar methodological "guides" were written (Sewell et al. 1962; Howe 1971). The 1960s and 1970s, often referred to as the

"Environmental Era" (Veissman and Wetly 1985), were marked by increased concern for the maintenance and preservation of the environment. Emphasis shifted from water supply augmentation to water pollution control. Measurement of the benefits of water quality became a volatile topic in the water management literature (Kneese and Bower 1968, Kneese et al. 1970). The federal government mandated environmental impact statements for all proposed projects, with the passage of the National Environmental Policy Act of 1969. In 1970, the intrinsic and extrinsic values of the environment were proclaimed by the federal government, and the Environmental Protection Agency was established to set and administer policy to maximize that value. Other important legislative advancements, such as the Water Pollution Control Act of 1972 and Executive Orders 10244 and 12291 (ratified in 1978 and 198., respectively), emphasized water quality value and the need for efficient management of water resources.

The federal government delegated greater water management responsibility to state and local governments during the 1980s. To support management decisions at all government levels, the U.S. Water Resources Council (1983) published the latest evolution of guidance, the "principles and guidelines," continuing the long line of guidelines that started with the "Green Book." Water resource management decision-making processes, methodologies, and assumptions involved are, as they have been for decades, under constant scrutiny and development.

STATEMENT OF THE RESEARCH PROBLEM

This study falls within the realm of water resource management evaluation techniques and continues the careful development of these techniques. It is an in-depth evaluation and application of hedonic valuation. Specifically, the purpose of this study is to identify the empirical relationship between lake water resource attributes and the land values of surrounding residential properties. In econometric terms, the study will assign monetary benefit estimation of lake water resources via hedonic pricing. Specific statistical hypotheses are developed in Chapter V.

In a critical examination of the property value (hedonic) technique, Freeman (1977) states that "few studies so far published are fully satisfactory in terms of their use of data, empirical technique, and interpretation", but the technique "offers promise as a means of estimating demands" and encourages further work and application of the methodology. The intent of this study is to show that hedonic pricing can successfully be applied to lake resources, and that a strong relationship between the presence of water resources and property values exists and should be considered in the planning setting. This study, while sensitive to the successes and failures of past studies, demonstrates that valid theory exists and that modeling applications are feasible, resulting in a versatile tool for water resource managers.

II. LITERATURE REVIEW AND JUSTIFICATION

This chapter discusses pertinent economic concepts related to environmental appraisal. The first section is a general discussion of the concept of economic consumer surplus. The second section details the role of land values in environmental analysis. Two more sections provide critical appraisal of applications of land value analysis for evaluation of the general environment and water resources, respectively. Last, a brief statement of justification is made for this study based on the stimuli of previous work.

ECONOMIC TECHNIQUES IN ENVIRONMENTAL ANALYSIS

Economic theory and concepts are used extensively in environmental valuation. Thus the analyst can determine the economic benefit or demand of the good at hand (Walsh 1986). The gross economic benefit of a good is estimated as the area under the demand curve and is designated by area (abc) in Figure II-1 (top). Assuming a price (or cost) P', the net benefit (or consumer surplus) of the good is equivalent to the area (abc) under the demand curve less the area (decb) representing costs. If the quality of an environmental good is altered, this will affect demand. The net benefit (or disbenefit) caused by a change in the environmental good is derived by comparing respective consumer surplus estimates. For example, if the quality of swimming is enhanced through cleaner lake water, the demand curve for swimming at the lake will likely shift to the right. The economic gain from this increased demand, shown in Figure II-1 (bottom), is equivalent to the consumer surplus of the altered state (abe) less the consumer surplus of the unaltered state (cde) represented by the shaded area.

Techniques used to measure consumer surplus related to environmental changes are broadly categorized as market value based, survey based, and surrogate value based (Bentkover et al. 1985; Freeman 1979; Hufschmidt et al. 1983). Market value techniques rely upon market transactions to determine value. Their use is dependent upon the existence of a market for the pertinent environmental good. If prices determined by the market do not exist, survey-based techniques can be used to create hypothetical markets. Carefully worded questionnaires are developed that ask respondents what they would be "willing-to-pay" for the set of quantities of goods. The last group of techniques—surrogate value based—use priced complementary goods to determine the value of a good that is not defined in the market.

Development of analytical methodologies has been a prominent part of environmental valuation and allocation analysis in the recent past. In addition to the above techniques, methodologies such as linear programming, optimization models, and trade-off analysis (Cohon 1978; Goodman 1984) are used to provide the best solution, or combination of solutions, for allocation of environmental goods.

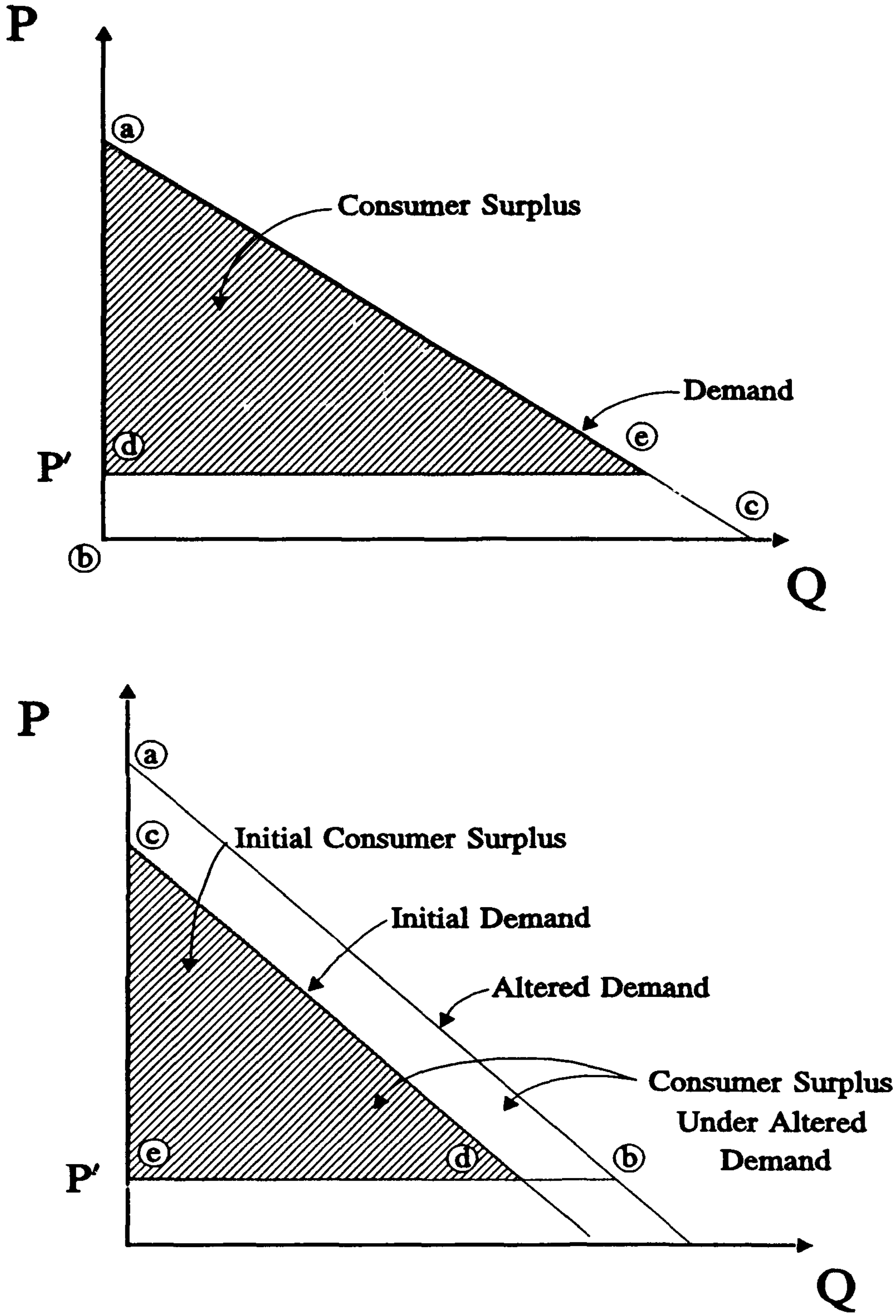


FIGURE II-1

GENERAL PRINCIPLES OF ENVIRONMENTAL ECONOMICS

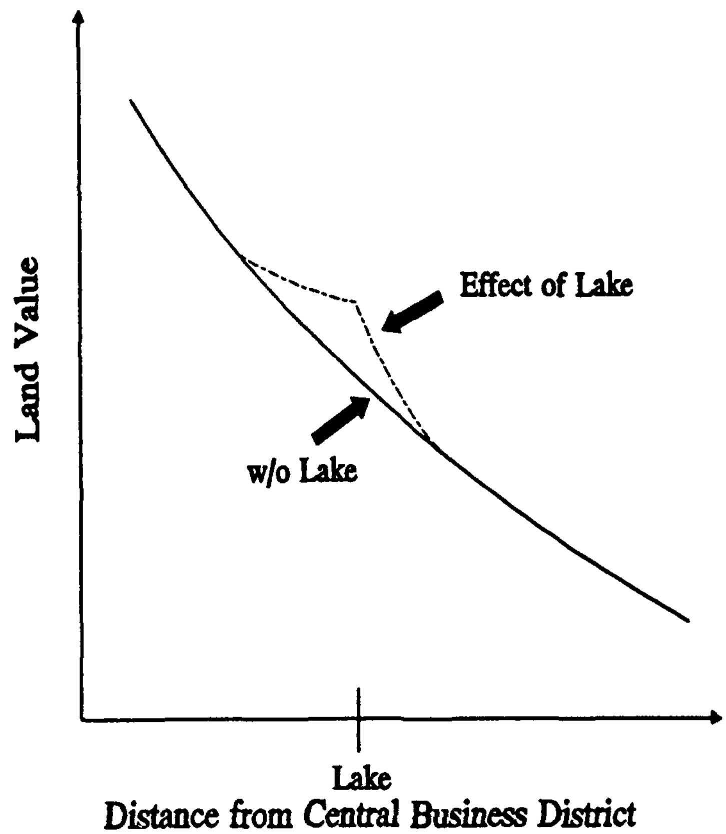
IMPACT OF ENVIRONMENTAL FEATURES ON LAND RENT

Following the apparent need for more data sources and development of economic techniques for environmental analysis, research centered around the response of land rents to the environment has taken place. This section introduces the theory, and the next two sections describe applications of land value techniques in environmental analysis.

Natural and man-made features of the landscape affect household utility and are considered during residential choice decisions. If demand for the goods and services provided by environmental resources exists, then they are capitalized in the value of the land. Identification of the "spatial linkages" between land value and features of the landscape provides valuable input for planning landscape use of a region. Distribution of land values across the landscape is studied by many disciplines, including economics, geography, and regional science. Most researchers cite Von Thunen's (1821) work on agricultural land values as the seminal work in land rent theory. He postulates that land rents decrease with distance from the central business district (CBD), *ceteris paribus*. This gradient was the result of market compensation for increased transportation costs. Early advances in urban land rent theory centered on a central business district were made by Hoyt (1939), who included neighborhood status variables, along with accessibility, as determinants of land rent. Several formalized mathematical explanations of urban land rent structure appeared in the 1960s. Alonso (1964) maximizes household or firm utility through a set of bid-rent functions. Muth (1969) discusses urban land rent in equilibrium and presents the theoretical implications of relaxing some common assumptions found in standard urban land rent models (e.g., monocentric city and a featureless landscape). Empirical verification using the urban landscape of Chicago was common. Richardson (1976) presents a comprehensive overview of the many extensions to this formal mathematical approach to land value modeling.

Impacts of environmental features have been introduced into the development of land rent theory, for example, Papageorgiou (1973) and Thrall (1987). A good displaying uniform impact among all households is categorized as a "public good" for which Mishan (1971) and Samuelson (1954) provide theoretical underpinnings for evaluation purposes. An environmental good such as a clean lake has a spatially nonuniform influence on households and is considered a special type of public good: an "externality." Thrall (1982, 1987) discusses and differentiates the influences of public goods and externalities on household land values. The presence of a "desirable" lake on an imaginary direct path from the central business district will inflate the land rents in the immediate vicinity of the lake in a manner similar to what is shown in Figure II-2.

An econometric technique, referred to as "hedonic pricing," substitutes external effects of the environment on land value to estimate value for the environmental good. The value of the environmental good at hand (e.g., lake, river, forest, air, sound) is assumed to be implicitly captured in adjacent property values. Thus the price differential due to the presence of the environmental good is assumed to be the surrogate value of that environmental good. Theoretical background and econometric explanation are presented by Griliches (1971) and Rosen (1974). Property value impacts and hedonic valuation are the central methodological theories of the present research.



Source: Adapted from Thrall (1987)

FIGURE II-2

THEORETICAL IMPACT OF DESIRABLE LAKE ON NORMAL LAND RENT GRADIENT

GENERAL APPLICATIONS IN PROPERTY VALUE ANALYSIS

The value of many types of environmental goods has been measured through property values. The majority of studies have focused on the value of air quality. Ridker and Henning (1967) provided the first application of evaluating the land value-air quality relationship. They reveal a positive relationship between the two: as air quality improves, so do property values. Some researchers found this relationship to be just marginally evident (Smith and Deyak 1975; Milliman and Sipe 1979). A close look at these studies reveals data definition problems or limited variability in air quality. There are many other successful applications of the property value technique to air quality, many of which are summarized by Freeman (1979).

Harrison and Rubinfeld's (1978a) analysis of air quality in Boston pays particular attention to methodological issues surrounding air quality-property value analyses. Several equations are used to illustrate the significance of the inclusion of certain variables in calculating air quality benefits. Exclusion of the distance to employment, accessibility index, and socioeconomic class variables causes errors in the dependent variable of between 20 and 30 percent. Definition of submarkets for accessibility, income, and socioeconomic status is found to decrease estimated air improvement benefits as compared with the aggregated "basic" equation.

Benefits from air quality improvements across income groups are examined in detail by Harrison and Rubinfeld (1978b). Their inclusion of a Charles River locational categorical variable provides an unintentional contribution to the study of water resources. The variable indicated riverside tracts to be of significantly higher value than those tracts not along the Charles, thereby implying a positive demand for the amenities of the river.

Havlicek et al. (1971) evaluate negative external effects on nearby land values of waste disposal sites examined near sanitary landfills in Fort Wayne, Indiana. Variables considered are size of house and lot, number of bathrooms and bedrooms, age of house, ownership-tenant occupancy, year of sale, sale price. Distance from the disposal site and degrees (angle) from the prevailing wind describe the relationship between the parcel and the disposal site. Each degree from the direction of the prevailing wind is associated with a $10.30 increase and a $0.61 increase in value is found for each foot away from the disposal site. Since the areal units are not reported, it is unclear if these values are in dollars per acre, dollars per front-foot, or some other unit.

Effects of hazardous waste dump sites have been the subject of many studies. Payne et al. (1987) conduct an analysis of the property value response to proximity to a radioactive waste site. Awareness of the site was intensified by heightened publicity in the region and resulted in a decrease in the value of older homes within a two-block region of the disposal site. Damages due to nuclear waste disposal locations and accidents are reviewed in Hageman (1981). Using the Delphi technique, a panel of experts reveal many cases where residents were compensated for decreased property values as a result of nuclear waste in the vicinity of their land. Though the documentation and evidence are convincing, due to the nonempirical method of research employed and the exclusive conditions of each case, very few generalities are revealed.

Where the above examples of property value analysis have focused on man-made aberrations on the landscape, natural hazards have been evaluated using property value techniques as well. Rubin and Yezer (1987), who evaluated natural hazards in general, report the land value response to the hazard to be significantly less in the case of an expected disaster compared with an unexpected disaster. Effects of flooding hazards are discussed below.

WATER RESOURCE APPLICATIONS IN LAND VALUE ANALYSIS

Land value analysis as applied to water resource evaluation has been subject to limited research. Some attention has been through simple description or recognition that resource-impacted land value differentials do in fact exist. Other applications have been more aggressive empirically, ranging to formal econometric application of hedonic valuation. This section summarizes these applications. Because the empirical results of past hedonic pricing studies are critical to the development of the models in the present research, model profiles were created that list the dependent and independent variables, the functional form of the mathematical equation, the regression parameter estimates, and goodness of fit statistics. These profiles are found in Appendix A and are cataloged alphabetically by author.

Application to Flood Control

Flood control projects, in broad terms, provide benefits related to inundation reduction, land use intensification, and location as outlined by the U. S. Water Resources Council (1983). Each of these categories of benefits can be measured through land values. Flood-free versus flood-prone land is an obvious example of a land value differential caused by water resources. Generally a flooding hazard is expected to be capitalized negatively in land values. Montz (1987) discusses important issues of measurement in relating flood hazard and land values. During development of a theoretical framework for analysis of flooding and land values, Tobin and Newton (1986) found the rate of land value recovery to hinge upon the magnitude and frequency of flooding. This confirms the findings of Rubin and Yezer's analysis of natural hazards discussed above.

The federal government subsidizes residents of qualified floodplains through the Flood Insurance Administration. Beyond this subsidy, a price differential remains between floodplain and nonfloodplain lands. Thunberg and Shabman (1990) derived a willingness-to-pay for flood control for relief of anxiety and community disruptions—these findings were developed while controlling for flood insurance impacts. In evaluating a potential flood control project for the Passaic River in New Jersey, it was discovered that nonfloodplain residential lands possess an average market value 30-40 percent higher than in the floodplain (U.S. Army Corps of Engineers 1987). The land value analysis is used to derive possible residential intensification benefits of the proposed project. These benefits are considered in the assessment of project-related regional economic impacts (Apogee Research et al. 1990).

Antle (1977) presents a case study of the Chester Creek Basin in Pennsylvania. The impact of flooding on average land value was estimated to be approximately $5,100 per floodplain parcel. Another important result was the identification of other important variables as determinants of land value. Property size, township, number of floors, and transportation location were all found to be statistically significant in the multiple regression model. An apparent shortcoming of this study, which is common to many analyses of this sort, is data availability. Various sources of property value data were sought and used, each with different assumptions about land valuation. As a result, inconsistencies were introduced to the least-squares regression results.

As part of a closer look at the impact of flooding on property net of flood insurance, Donnelly (1989) finds an average floodplain parcel to be valued $6,000 less than property outside the floodplain. The statistical model appears to be very sound, as all parameter estimates are statistically significant and the r-square value is strong at 0.84. The author further explains how adjustments are made to some of the independent variables to control for multicollinearity, though no empirical justification is made for the linear functional form of the final model. Annual flood insurance payments are analyzed at a 10 percent interest rate for the average property—the resultant value being approximately $3,500. The difference between the $6,000 and $3,500 is the residual negative impact of floodplain property. Donnelly refers to this as a "hassle premium," which echoes the findings of Thunberg and Shabman (1990) discussed above.

Application to Irrigation Projects

Milliman (1959) discusses the theoretical possibilities of measuring the primary benefits of irrigation through increased agricultural land values. Existing approaches require estimation of net returns from the crops being irrigated, involving assumptions of yield, output factors, factor costs, and coefficients of production for future seasons. Milliman suggests that the use of the land value method could require as many assumptions as the "existing" methods, and that accuracy of the results may be adversely influenced by data problems, such as inaccurate land value and land use data. He concludes that choice of the appropriate technique would have to be made on a case-by-case basis.

Application to Water Resources in General

Knetsch (1964) attempts to estimate the impact of Tennessee Valley Authority reservoir projects on land values by means of multiple regression. Two equations are calibrated: one for reservoir land and the other for nonreservoir land. Differences between the equations summed over all tracts of land near a reservoir are considered the land value enhancement attributed to the reservoir. The general conclusion is that reservoir presence enhances property values.

Generally the statistical results of the Knetsch model are encouraging. The structure of the Knetsch model, though, appears to have a few shortcomings. Except for the distance variable in the reservoir model, each variable is stated as having a linear influence on land values; this does not allow for nonlinearities, or "leveling off," of influence on the dependent variable. Another problem lies in the use of two models to estimate the influence of a reservoir on land values. A more desirable approach would have been to use one function that allows the inclusion of both reservoir and nonreservoir properties. Finally, the reservoir model most likely possesses multicollinearity between the reservoir/nonreservoir and distance variable, which raises concerns about the accuracy of the parameter estimates.

David (1968) expands on the work of Knetsch in a study of Wisconsin lakes. Improvements in the independent variables employed include knowledge of water quality and topography variables in the model. Water quality parameters are based upon "good," "moderate," and "poor" classifications made by representatives from state environmental agencies. Average lakefront slope is included as a measure of topography, and ease of access, population, and the presence of swamp and other lakes are also included.

The structure of the model is developed through successive substitutions of a series of equations. This approach was taken in order to exclude the "value-of-improvements" variable used in the Knetsch model and thus curtail an overinflated r-squared value. The "value-of-improvements" variable accounted for approximately 70 percent of the variance in the Knetsch study. David's objective is to focus on the relationship between lake characteristics and property values. All variables except "access to lake" are found to be statistically significant. David's study suffers from poor-quality environmental data in the study area. Some necessary data were unavailable, resulting in numerical aggregations and simplifying assumptions. Pendl (1971) suggests important factors in lakeshore property appraisal are lake type, size, nutrient content, depth, clarity, and shoreline. The value of riparian rights might also be considered, as discussed by Holden (1973).

David's justification for excluding the "value of improvements" variable is unclear. The physical characteristics of a lake probably have little affect on property prices relative to other variables such as "value-of-improvements." To identify the effect of lake characteristics, other variables that are capitalized into property values must be identified and controlled for through inclusion in the model. The omission of "value of improvements" from the model appears to only lower the r-squared value (David 1968).

A formal econometric approach is used by Brown and Pollakowski (1977) in the valuation of shoreline property. They estimate implicit price functions via hedonic price regressions for waterfront-housing services. Variables used in the model emphasize housing structural characteristics of housing. The only parameter directly related to water is a distance to water variable (or setback). By assuming identical utility functions, the marginal implicit price function is used as a marginal willingness-to-pay curve.

Brown and Pollakowski find property values to decrease with distance from the lake, which is the expected relationship. This decreasing utility of lake impacts is used to develop an estimate of the optimal amount of open space—comparing private household benefits with the general public's utility for open space. The Brown and Pollakowski model contained no water characteristic variables. Though the main intent of the study was valuation of open space (indicated by setback), water characteristic variables would have added considerable insight into the open space values.

Dornbush and Barranger (1973) perform a nationwide property value analysis and find that abatement of pollution in all waters to a level "not inhibiting to desirable life forms or practical users and which are aesthetically agreeable" would increase the capital values of aggregate property value by approximately $1.3 billion. They sampled twelve areas adjacent to five water bodies that have experienced significant water quality improvement from 1960 to 1970. A regression equation was developed in each area using property value change as the dependent variable and independent variables of lot size, distance to water body, and distance to local features that were considered influential to property values (e.g., distance to local park, distance to school, distance to shopping center).

The Dornbush and Barranger study suffers from a lack of generality in the models. Variables, such as "distance to State and Commercial Street intersection," are included that are unduly restrictive in geographic application. Though recognition of a transportation hub's influence on land values is desirable, the utilization of such variables (in that form) severely limits the model's external validity.

A somewhat separate component of the same study is an examination of the public perception of water quality. Residential property owners were interviewed as to how they perceived water quality changes. Unfortunately results from the water quality perception exercise are not included in the model. Thus it is impossible to establish, for instance, the marginal relationship between property value and water clarity.

Epp and Al-Ani (1979) also evaluated the relationship between perceived and technical water quality. Perceived water quality was arranged through a survey asking a yes-no question as to whether they thought the level of water quality inhibited recreational or aesthetic use of the water resource. The parameter estimate indicated negative perceptions of water quality were associated with lower property values. Many technical measures of water quality were examined, including dissolved oxygen, biochemical oxygen demand, nitrate, and phosphorous. The only technical water quality parameter found to be an important explainer of property value was pH. It was transformed into categories of 5.5 or lower and greater than 5.5. The more acidic (5.5 or lower) value was significantly associated with lower property value. Thus the perceived and technical water quality variables had a consistent impact on property value.

The value of urban water parks is measured by Darling (1973). Two methods of valuation are compared and contrasted: property value method and an interview method. The study constitutes a respectable comparison of the two methods with actual empirical verification, which is oftentimes absent from this type of analysis. Furthermore, the author provides valuable insights for further research.

The interview method, which is often referred to as contingent valuation, relies on survey data to develop a demand curve for the water park. The property value method employed generally followed the approaches described above. Variables used in the property value model are property value, improvements, size, crime, neighborhood quality, distance to water, and an inflation variable. The general conclusion is that urban water parks greatly enhance the value of nearby property values.

Properly contrived questionnaires for the interviews and sound representation of land values across space should provide similar demand curves for the water park. However, results did not support this. In two of the three areas analyzed, the property value method produces a much higher value then the interview method. In the third area, the opposite is the case. Questionnaire bias often causes these types of inconsistencies. Meticulous questionnaire design is vital in estimating the demand of an environmental good. Extensive discussions and applications of interviewing techniques in water resource valuation are found in Mitchell and Carsen (1989), Cummings, Brookshire, and Schulze (1986), and Smith and Desvouges (1986).

Data concerning property value transactions were difficult to obtain in Darling (1973); thus a mix of assessed value and selling price was necessary to calibrate the property value model. This inconsistency would likely introduce additional errors in the results and may have contributed to the misalignment of the demand estimates for Darling's two methods.

The area of greatest concern regarding Darling's study is variable selection (or lack thereof). First, the study employs use of assessed value of property versus actual market transactions. Actual sales price is certainly the metric of choice, as assessed valuation techniques often inhibit inclusion of unique parcel characteristics and do not reflect actual market demand. Also, inclusion of a technical measurement of water quality would have been useful for water resource management application (which is often based upon technical water quality goals).

Addressing the allocation of the Kissimmee River Basin in Florida among user groups, Reynolds et al. (1973) measure the value of the river to proximate landowners. Two analyses are conducted. The first, in a similar manner to Darling (1973), measures the vacant land value response to the presence of water through a multiple regression function. Lake frontage is found to increase property values by 64 percent. An obvious shortcoming of this portion of the analysis is the absence of a distance-to-water variable. The second analysis is a survey that asks respondents the value of their lakefront property. When asked what they felt the value would be if the lake were drained, the price dropped 48 percent. The authors attribute the apparent difference between the results of the two analyses to the fact that the second analysis includes structures on the property that "hide" the influence of water on the land value.

Another comparison of water resource valuation techniques is provided by d'Arge and Shogren (1989). Following Darling (1973), they compare the property value technique with a contingent valuation approach. They also interview realtors, in a third tier of the analysis, to gather another perspective to the valuation question. The basic focus of this study was to evaluate the differences in demand around two glacial lakes called East Okoboji and West Okoboji in Iowa. The water quality in West Okoboji is substantially higher than East Okoboji. Thus the Okoboji case study provides a seemingly pure opportunity to compare the demand for higher quality lake attributes.

Estimates from the survey realtors attribute 23 percent of house value to water quality, while the hedonic price attributes 21 percent. These two approaches were expected to be close to one another, and the results support this hypothesis.

The authors also hypothesize that buyers are able to adjust the amount of water quality they want as part of their bundle of goods by simply adjusting location, which causes the rent gradient for water quality to be concave downward. This, coupled with the "thin" market in the Okoboji region, causes the willingness-to-pay estimates for water quality to be exceeded by the hedonic price estimates. This hypothesis is supported, as the willingness-to-pay estimates revealed a 13 percent contribution of water quality to the price of property. These findings could help support the downward bias of the willingness-to-pay estimate that Darling (1973) found when comparing it with a hedonic method.

The purpose of a study by Rich and Moffitt (1982) was to determine a portion of the regional benefits associated with a water pollution control program through hedonic valuation. Regional benefits are calculated to be $600,000 for the 26.5 square miles that were defined as the study area. The total regional benefit is based on the results of the hedonic regression analysis, which assigns $37 per acre for riparian land and $31 per acre for nonriparian land. The models developed had a pre- and postabatement categorical variable that serves as the operational determinant of the $600,000 abatement benefits.

Rich and Moffitt's binary indication for riparian land is not statistically significant, since they have a limited number of observations (N = 49). It may have been worthwhile to replace the binary variable with a continuous distance to water body variable. Also, aligned with the discussion surrounding d'Arge and Shogren (1989), a technical measurement of water quality might have enhanced the engineering application of the results.

Falcke (1982) closely follows the econometric theory and procedure of hedonic pricing presented by Rosen (1974) to measure water resource benefits and also follows the work of Dornbush and Barranger (1973) in derivation of a perceived water quality index. Survey data show that laypersons and technical experts often have differing conceptions of the conditions of a water body; that is, in an extreme case, residents felt the water quality of the lake improved, while the experts felt quality had deteriorated. A statistical relationship was found between the expert's and layperson's perceptions and is adopted into the analysis. A time-series investigation of 17 estuaries, rivers, and lakes that have undergone significant water quality change was conducted. Site-specific equations are calibrated, with the percent of property price change as the dependent variable. Each equation uses distance from the water body and perceived water quality change as independent variables, as well as a subset of the following variables: distance to school, distance to shopping, location on busy street, location on corner lot, previous property value, lot size, distance to new highway, distance to nearest highway access, distance to environmental nuisance, distance to other new facilities like a bridge, boat-launching area, or country club. The "distance-to-water-body" parameter estimate for each site is regressed against perceived water quality change, water body type, public access, and region indicator. This statistically meshed the site-specific equations into a single function.

Some applications of hedonic valuation focus on the damaging impact of water resources on property values. The impact of flooding was discussed above. Khatri-Chetri and Hite (1990) examine the negative effects of reservoir regulation schedule on residential property values. In this case, the needs for hydropower caused greater variability in reservoir stage, which impacted the utility of waterfront property owners. Each one foot decrease in stage from normal pool caused about $5,434 decreases in sales price per acre. Young and Teti (1984) examined the impact of degraded water on property values in the St. Albons Bay region of Vermont. In comparison of two water resource sites that provided a marked differential in water quality, the lower water quality caused approximately 20 percent lower property value. Young and Teti did not specify other important locational variables (e.g., distance to shopping, distance to CBD, storm protection), which could have an impact (positive or negative) on the parameter estimate for water quality. Though oceanfront property is expected to be associated with higher property value, Jack Faucett Associates (1991) related beach erosion to decreases in property value. This decrease in property value was felt not only by oceanfront residents, but also residents throughout the community (but to a lesser extreme). This analysis was used to justify erosion control measures in oceanfront communities.

FINAL COMMENTS

Upon examination of the literature on pricing environmental goods through hedonic pricing using property values, the following issues are apparent:

- In nearly each study, quality of data was a significant hinderance.

- Applications of water resource valuation are less prevalent.

- Studies that did examine water resources

    * have, for the most part, ignored hedonic pricing theory.
    * have not explicitly used water quality or characteristic data in the models.
    * have not attempted the development of a model that could be applied in areas other then the study site.
    * rarely consider distance to water as a continuous variable.

The general exception to the above observations is the Falcke (1982) study. The present study is designed to overcome the common data problems while working within the econometric bounds of hedonic pricing. This study advances Falcke's results by examining cross-sectional data in an attempt to control for the shifting housing markets and other exogenous forces that alter land values over time. It also concentrates on a single geographic area rather than sites throughout the United States. Demand and supply for property and water resources vary throughout the nation. Examination of a single county market will increase the reliability of the water resource parameters.

A considerable effort is made to compile the database for statistical analysis, both in terms of the variables chosen and the data gathered to represent these variables. The models, data, and results of this analysis are presented in the following chapters.

III. THE MODEL

This chapter develops the formal model used in assigning hedonic value to water resources. Propriety of the technique and approach are demonstrated, as are the assumptions required under the model. The first subsection provides an overview of the theoretical principles supporting hedonic pricing, based upon Freeman (1979) and Falcke (1982). The second subsection discusses issues surrounding the calibration of the model.

THEORETICAL OVERVIEW

No direct market value or price exists for many environmental goods and services. Hedonic-pricing techniques utilize observed property values to indirectly estimate the price of environmental goods. In particular, this study applies the technique to the estimation of demand for various lake characteristics and permits positive and negative benefits related to changes in these characteristics to be calculated.

The most empowering assumption of the hedonic technique is that the good being measured is realized by the consumer and is part of the bundle of goods the land provides. Two further assumptions about the housing market are made: (1) a single housing market dictates housing choice in the study area; and (2) the housing market is in equilibrium (buyers and sellers are optimally satisfied with each transaction in which they are involved).

The technique, given the conditions stated above, involves two steps. First, a hedonic price function (also referred to as implicit price function) of the lake characteristic at hand is derived. Second, a willingness-to-pay function, or inverse demand curve, is derived. The point of intersection of these two curves is the equilibrium price of the good being measured.

The hedonic (implicit) price function can be stated mathematically as

$$V_{ij} = f(S_{ij}, L_{ij}, W_j)$$

where:

	V_{ij}	=	land value at site i with lake characteristics j
	S_{ij}	=	set of site characteristics at site i with lake characteristics j
	L_{ij}	=	set of location characteristics at site i with lake characteristics j
	W_j	=	level of lake characteristics j

The form of this function varies but is generally multivariate. Thrall (1988) provides an appraisal of theoretical issues pertaining to land rent function development. Box and Cox (1964) make significant progress on proper functional form assignment, and Halvorsen and Pollakowski (1981) present an application of the Box and Cox procedures.

Value of a desirable water characteristic, such as water quality, increases with the level of quality up to a point where the benefits of increased water quality begin to "tail off" as shown in Figure III-1 (top). Thus the hedonic price function (of a "desirable" good) generally increases at a decreasing rate reflecting marginally diminishing utility.

Differentiating the calibrated hedonic price function with respect to the lake characteristics defines the marginal implicit price, V_m

$$\delta P/\delta W = V_m(W)$$

Figure III-1 shows the hedonic (implicit) price (top) and marginal implicit price (bottom) curves with respect to lake characteristics.

The second step is to derive willingness-to-pay curves, or inverse demand curves, for lake characteristics. Individual households or groups of households possess different tastes and preferences for the good *W*. The marginal implicit price denotes the aggregate market value assigned to an additional unit of *W*; it does not directly account for individual household demand for *W*. A single observation for each household *i* is made, which, given its socioeconomic makeup, is an insufficient number of observations to estimate demand for that particular group. Grouping of households by income class (following Harrison and Rubinfeld 1978) provides an aggregated demand estimate by group/individual household type.

A variety of possibilities exist as to the shape and empirical nature of willingness-to-pay curves (Freeman 1974, 1979; Rosen 1974; Bartick 1988). It is assumed here that the lake characteristics are independent of a household's willingness-to-pay. This means that lake characteristics are considered exogenous to their implicit price and can be estimated without regard to a supply-side function (as assumed by Harrison and Rubinfeld 1978). Thus the willingness-to-pay curve can be estimated by the function below.

$$P_{ij} = P(S_i,L_i,W_{ij},H_i)$$

where:
- P_{ij} = willingness-to-pay for level of water characteristic *j* by household/group *i*
- P = willingness-to-pay function
- S_i = site characteristics at site *i*
- L_i = location characteristics at site *i*
- W_{ij} = observed marginal implicit expenditure on lake characteristic *j* by household/group *i*
- H_i = set of household characteristics for household/group *i*

Household willingness-to-pay functions are fitted in a manner similar to the fitting of implicit price functions. The intersection of a household's willingness-to-pay function and the marginal

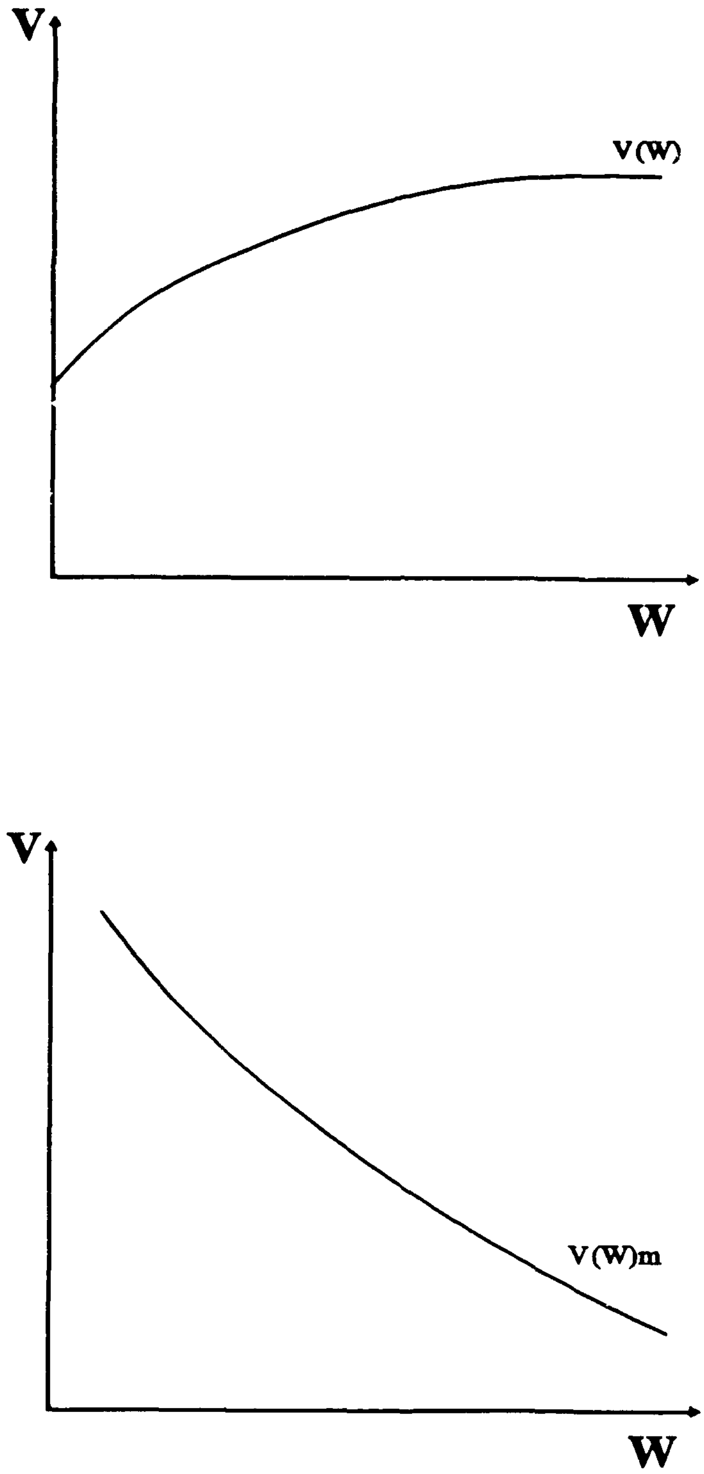


FIGURE III-1

MARGINAL PRICE AND MARGINAL IMPLICIT PRICE CURVES

implicit price function defines the equilibrium state for the household in terms of lake characteristics (Figure III-2). Households will buy quantities of *W* at the aggregate marginal implicit price, moving along their willingness-to-pay curve to the point where the two curves intersect. This is the level of lake resource the household will choose to obtain.

The benefits received by household/group *i* through a nonmarginal change in lake characteristics from W_1 to W_2 are the integral of the willingness-to-pay function from W_1 to W_2. The aggregate benefits are the sum of this integral for each household.

$$B_i = \sum_{i=1}^{n} \int_{W_1}^{W_2} P_i(w)dw$$

where: B_i = the regional economic benefit due to the change in lake characteristics for household/group *i*
W_1 = initial lake characteristic level
W_2 = lake characteristic level after change
P_i = willingness-to-pay for household/group *i*
n = number of households/groups in region

The economic benefit is depicted graphically as the area under the demand curve between the initial and final states of *W* (area abcd in Figure III-3). Summing for each household/group affected provides the aggregate benefit of changing the lake characteristic *W*.

Assumption of Like Willingness-to-Pay among Households

Due to the complexity of revealing individual/group demand for various levels of lake resources, an alternative approach will be taken in this analysis. The major assumption is that all households possess like willingness-to-pay functions for lake resources. Thus the hedonic price function, or the aggregate market demand curve, represents all individual households' willingness-to-pay. Falcke (1982) uses a form of this assumption to assume that households at equal distances from the water resources possess like willingness-to-pay functions. Freeman (1979) recommends this method as an approximation of benefits.

The assumption is graphically depicted in Figure III-4. Assume that $V(W)_m$ and P_{ij} represent the marginal implicit price and household willingness-to-pay functions for *W* (water resource), respectively. If the initial state of water resource, W_1, were enhanced to W_2, the actual household benefit would be represented by the area (abcd). The assumption of this analysis, given that P(W) will not be formally defined, is that $V(W)_m$ represents household willingness-to-pay. Consequently the household benefit resulting from a move from W_1 to W_2 would be represented by the area (abed). Two potential errors may occur. First, if the demand

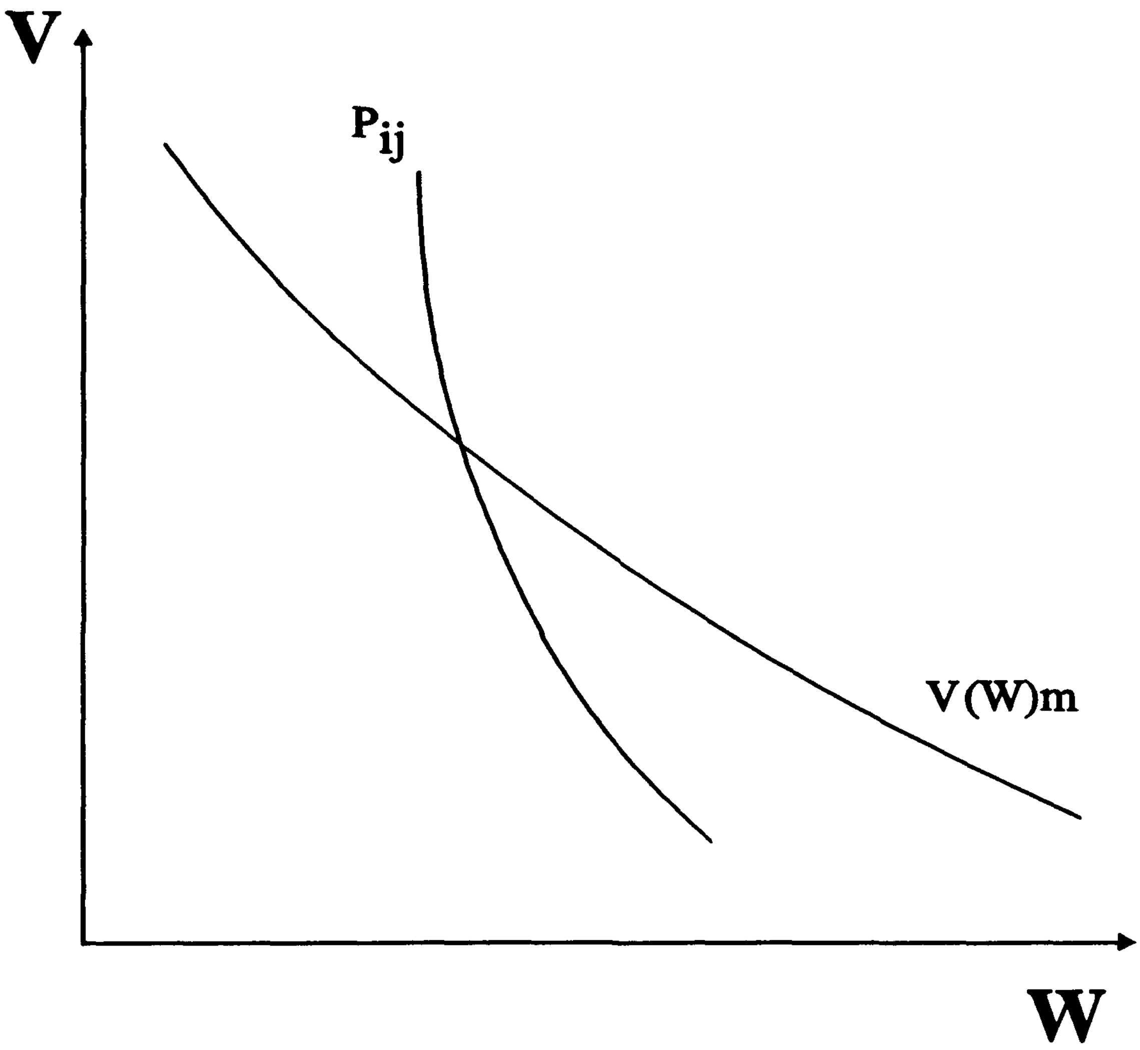


FIGURE III-2

INTERSECTION OF HOUSEHOLD DEMAND AND HEDONIC PRICING

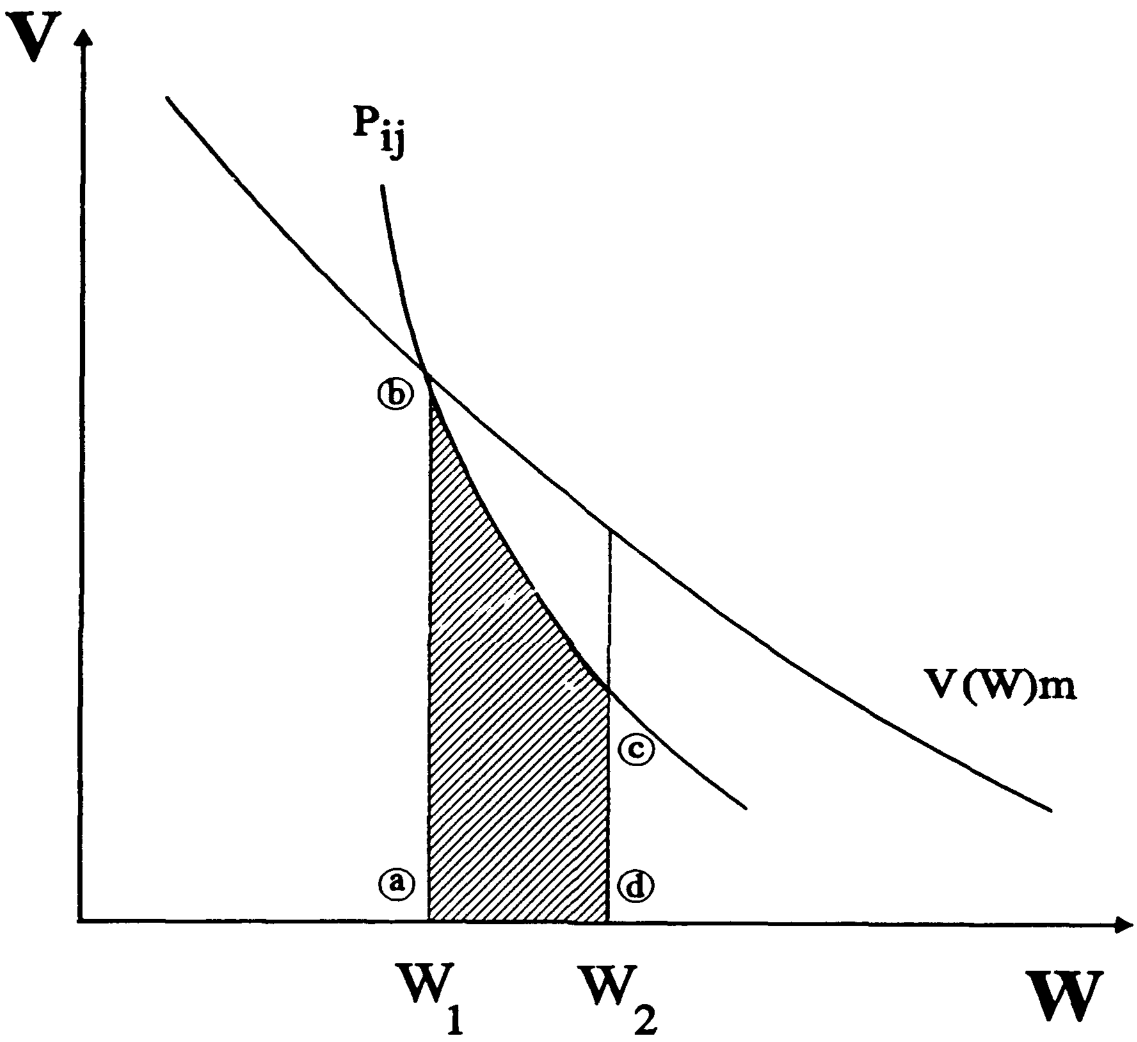


FIGURE III-3

WILLINGNESS TO PAY FOR CHANGE IN LAKE CHARACTERISTIC (W_1 TO W_2)

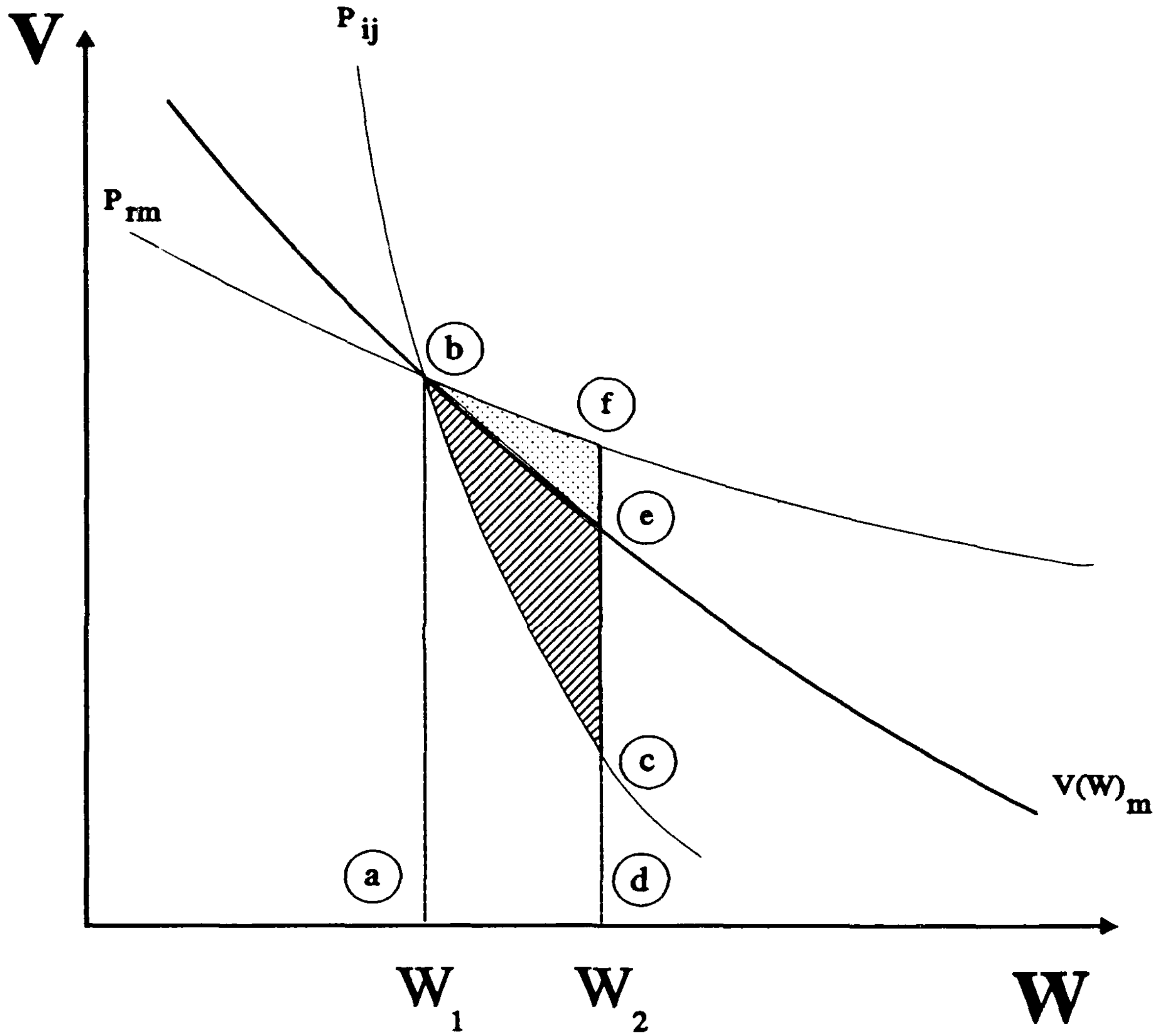


FIGURE III-4

ASSUMPTION OF AGGREGATE MARKET DEMAND CURVE

is more responsive to price than the implicit price function, the benefits will be overestimated by the area (bec). Alternatively if the demand is less responsive to price following P_{rm}, the benefits will be underestimated by the area (bef). Calibration of $V(W)_m$ will employ least-squares regression; thus the error term will be randomly distributed, both positively and negatively, around the regression line. Therefore many of the overestimates and underestimates of benefits will cancel.

IV. THE DATA

Data requirements for a hedonic valuation study are crucial to successful and acceptable application. Omission of a critical component of the dependent variable—some form of property value—can cause harmful bias in parameter estimates. The vast requirements for data oftentimes cause researchers to shy away from this approach. But in recent times, development of geographic information systems (GIS) and access to large databases, such as property assessors' records, allow integrated access to a comprehensive vector of parcel level attributes.

This chapter describes the data used to test the model presented in the previous chapter. The source, necessary formatting, and filtering of the data are presented. The intent of this chapter is to clearly indicate the evolution of the data and to conclude with the data set required to calibrate the models that are presented in the following chapter.

CHIEF DATA SOURCES

The Study Area

Orange County, located in central Florida, is the study area. This county contains a large number of lakes, thus providing a cross-section of lake characteristics. Residential development has been quite significant, especially in the Orlando area, again rendering a desirable sample of transacted residential land values.

The director of the Orange County Property Appraiser's Office and the chairman of the Orange County Commissioner's Office were contacted about data needs for this study and, subsequently, collaborated in providing the parcel-level property data used in this effort. While acknowledgment of their contribution to this study is certainly warranted, the main point here is that identification of a good data source, and the support of those who maintain the data, provide tremendous advantage to the research effort. In fact, because the hedonic approach is so data intensive, discovery of a strong database and associated support could be considered an *ex post* justification for choice of study site.

Property Assessor's Database

The Orange County Property Appraiser's database is stored on three 9-track magnetic tapes. Each of the 253,000 records in the database is 1,641 columns wide. The County Appraiser's Office is responsible for updating and maintaining this database—transactions are made and recorded daily. An example of a single record is shown in Figure IV-1. These hard-copy records, kept on file at the County Appraiser's Office, are made available to the general

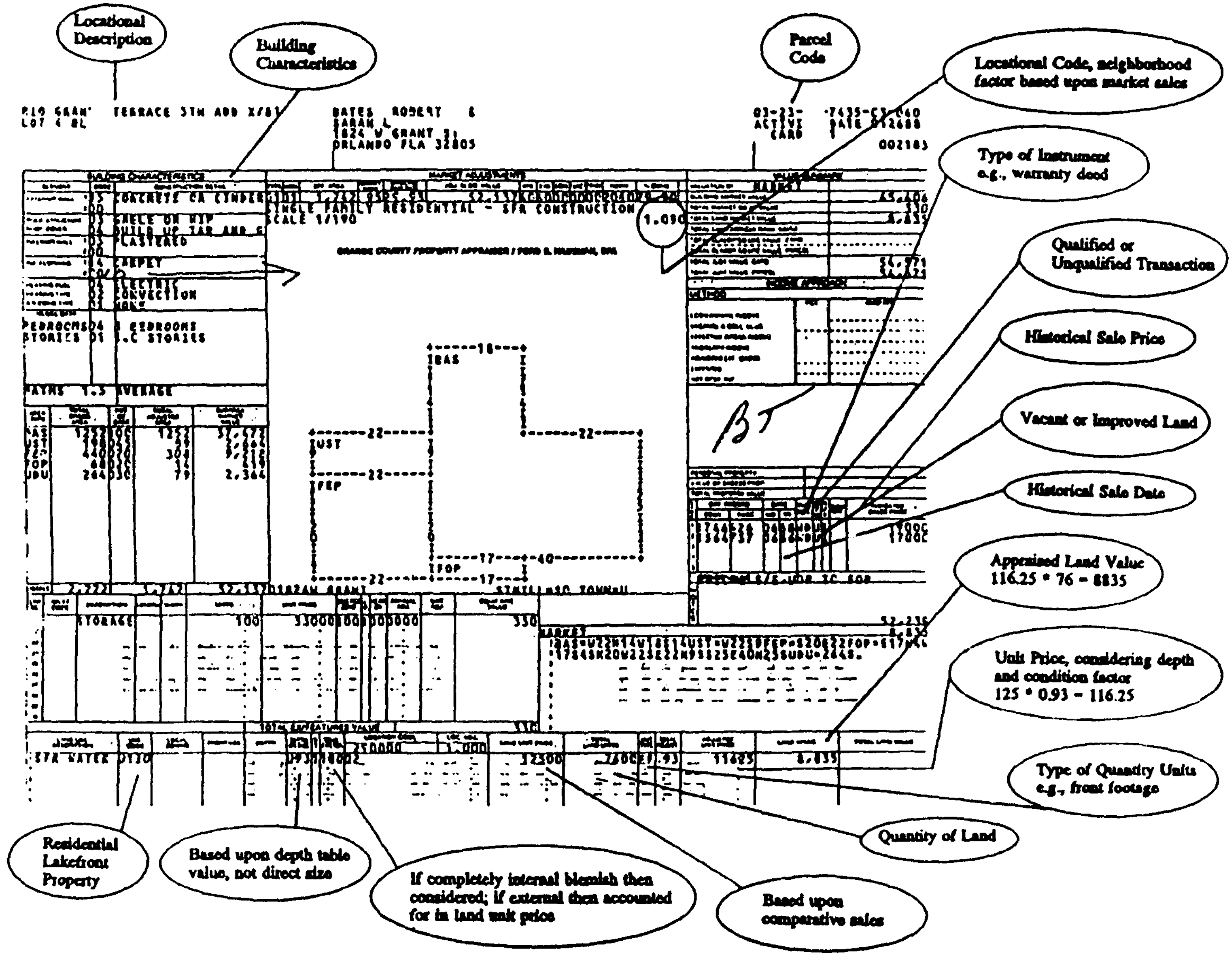


FIGURE IV-1

SAMPLE PROPERTY APPRAISER'S RECORD

public. This research effort requires data describing the locational structures and economic features of property, as noted in Figure IV-1. The data shown in Figure IV-1 are categorized in Table IV-1 according to these descriptive dimensions.

Lake Characteristics Data

Associated with the property value data are characteristics of the environmental resource at hand. This study is aimed at describing the implicit value of lake resources; therefore data describing lake resources are needed. There are 7,748 lakes in Florida (Shafer et al. 1986). In terms of data describing these lakes, many have only locational (latitude and longitude) and surface area measurements. In fact, only 3,261 of the lakes are named. Water quality data for 788 of Florida's lakes are compiled by Huber et al. (1982). Another substantive source of water quality data is the annual water resource assessment required of each state by the Federal Environmental Protection Agency (Hand et al. 1988). Data for 101 lakes in Orange County exist, ranging from simply a size parameter to detailed water chemistry analysis. A subset of these lakes is used in this analysis.

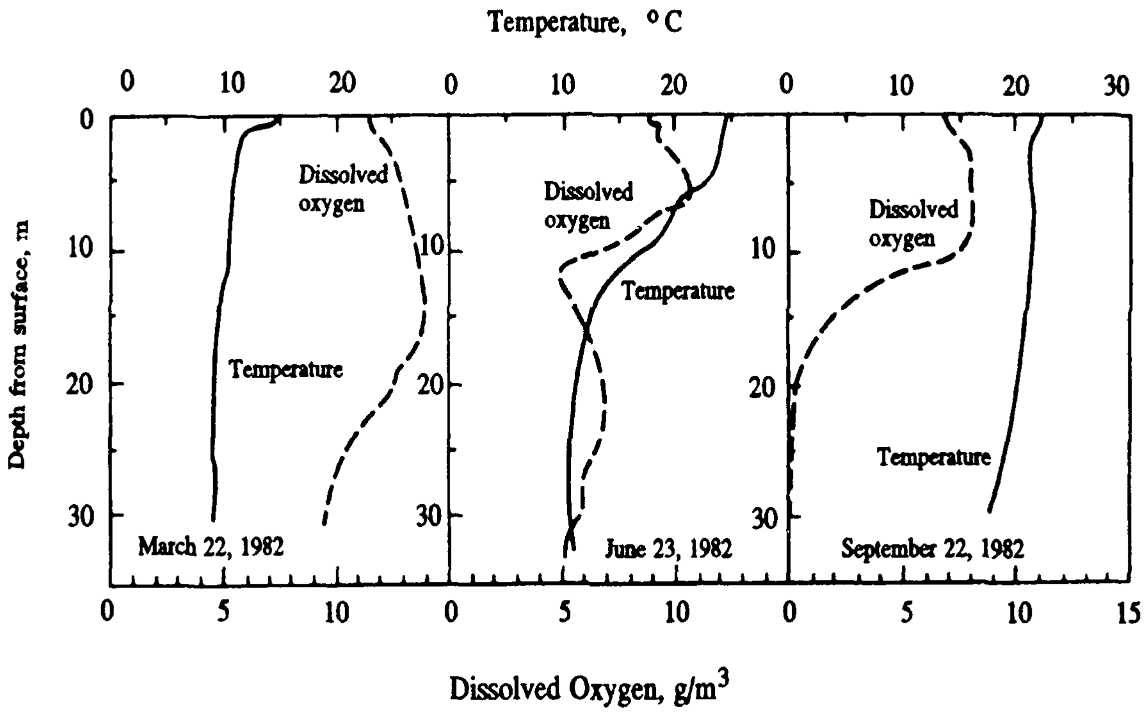
TABLE IV-1

SELECTED DATA FROM PROPERTY APPRAISER'S DATABASES

Locational
Parcel code
Parcel address
Lakefront indicator
Structural
Structure type
Building characteristics/size
Parcel characteristics/size
Economic
Historical sale values
Historical sale dates
Transaction type
Assessed property value

Choice of technical water parameters for the model should be made conscientiously. Heaney (1988) describes the difficulty in using single measures of water quality to analyze water management effectiveness. Dierberg et al. (1988) describes the case in Florida, where lake management practices have had an impact on only 7 of 43 lakes. This small impact is attributed partially to ineffective lake management strategies, but the main question raised concerns technical water quality measurement practices.

Looking at the seasonal variability of technical water quality measures raises concern as to the applicability of annual averaging of water quality parameters. Stratification and mixing of water and organisms within a lake cause seasonal trends in temperature and dissolved oxygen (a common measure of water quality), not only temporally but also by depth of sample, as shown in Figure IV-2 (Tchobonoglous and Schroeder 1985).



Source: Tchobonoglous and Schroeder (1985)

FIGURE IV-2

VARIABILITY OF TEMPERATURE AND DISSOLVED OXYGEN IN LAKES

Not only are there problems with the technical measurement of water quality, but a layperson's perception of water quality adds another dimension of complexity (Falcke 1982; Dornbush and Barranger 1973). Water resource characteristics being purchased as part of the "bundle of goods" constituting property value should be measured in terms that laypersons can understand. For example, a change in concentration of dissolved oxygen in a lake may not be recognized in terms of milligrams per liter (the scientific unit measure of dissolved oxygen) by a layperson; but if it causes a change in the amount of algae and weeds in the lake, this can easily be recognized. Lant and Mullens (1991) suggest easily perceivable water quality characteristics as color, odor, algae, litter, and temperature.

Eutrophication is the term used by limnologists to describe the natural aging process of lakes. Just as aging of humans is inevitable, so is aging of lakes. The state of eutrophication describes the water body's ability to sustain life (Tchobanoglous and Schoeder 1985), and the three main phases, or states, are shown in Figure IV-3. The oligotrophic state of eutrophication is the youngest. It can be thought of as relatively clean water, but so clean that it cannot support the threshold of food and nutrients to sustain large populations of life forms. Oligotrophic lakes are "in-waiting" for the natural growth and decay to take place that will cause food production to increase, and the trophic state will move to mesotrophic. A mesotrophic lake will support the largest level of life in terms of population and diversity; an optimal balance of nutrients and life forms occupy the lake. As the availability of nutrients exceeds what is needed for consumption, the lake reaches a eutrophic state, the final phase of eutrophication. This causes dominance of algae and plant growth. The highly variable oxygen availability characterized by the eutrophic state can sometimes cause fish kills.

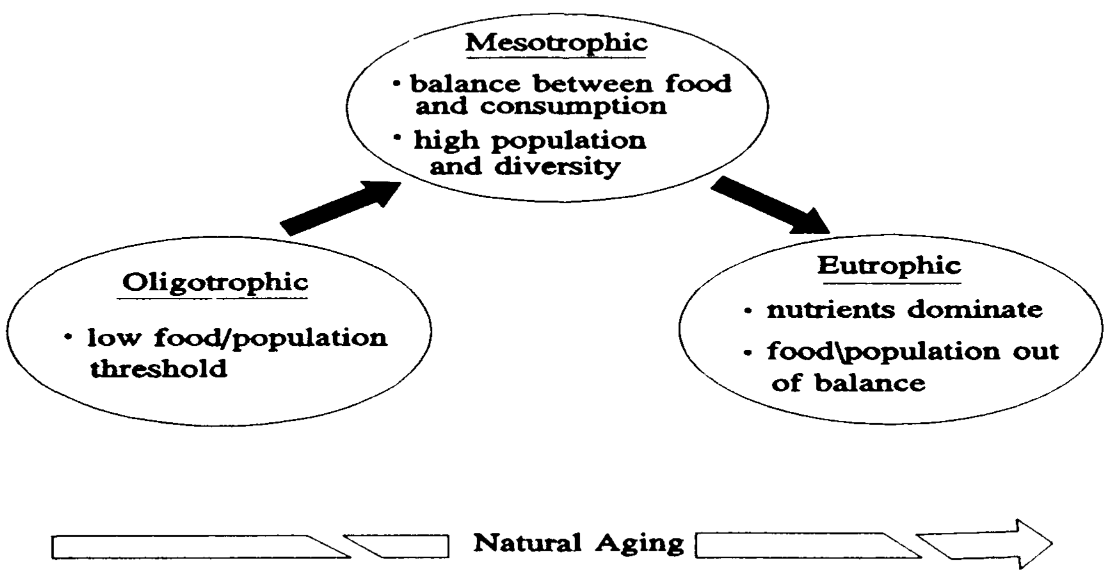


FIGURE IV-3

STAGES OF LAKE EUTROPHICATION

There are many facets of eutrophication that are easily perceived by laymen, mainly because the eutrophic trend begins with a generally clean appearance and evolves to a green, soupy state. For example, the differences between Lake Tahoe, an oligotrophic lake, and Lake Okeechobee, a highly eutrophic lake, are certainly evident to the common man. Changes in the perceived water quality attributes suggested by Lant & Mullens (1991) above—color, algae, odor, temperature—can be detected by laymen and are indicators of eutrophication.

Trophic state indices (TSI) are used to enumerate the level of eutrophication in a lake. These indices typically range from 0 to 100, where 0 indicates very good water quality and 100 very poor water quality. TSIs are designed to reflect a doubling or halving of algae biomass with each 10-unit change in index (Carlson 1977). Though the environmental engineering community uses TSIs with caution, they are generally accepted as a representative indicator of lake trophic state. Consequently water quality management programs are often evaluated in terms of TSI (Dierberg et al. 1988).

Huber et al. (1982) provide an in-depth analysis of various constructs of TSI. A combination of physical, chemical, and biological parameters meshed through a statistical weighting procedure laced with assumptions is the typical means of TSI development. Huber et al. evaluated the more popular indices, paying particular attention to their statistical validity in application to Florida lakes. The recognized TSI configuration for Florida lakes is provided in Figure IV-4.

The TSI is the water quality metric used in this study. Salient points of justification are as follows: first, lake eutrophication can be perceived by the general public, which is a necessary component of hedonic valuation; second, TSI is a combination of several technical water quality parameters that limit (but definitely does not eliminate) the metric's volatility tied to sampling patterns; third, TSIs are used by the scientific community in evaluating water quality management programs (e.g., Shannon and Brezonik 1972). Therefore the suggestion of Brezonik (1976) that "TSI is helpful in conveying lake quality information to the non- and semi-technical public," appears to support selection of TSI as the water quality parameter applied in hedonic valuation of lake water resources.

FILTERING THE DATA

The property appraiser's database yields sales transactions and parcel description for over 253,000 parcels of land in the study area. Unfortunately, the required associated lake characteristic data are not as comprehensive. Therefore the sample selected for analysis is controlled by availability of water quality data.

Three separate but tangential analyses are conducted in this research effort, each using different data sets. Detailed documentation of these analyses is provided in the following chapter. Specific definition of the data set employed for these analyses also follows in the next chapter. Prior to the portioning design of the data set for the three analyses, three levels of filtering of the property appraiser's database are conducted, as is diagramed in Figure IV-5. The first "global" filter isolates single-family residential parcels from the population of parcels. This

I. PHOSPHORUS - LIMITED LAKES (TN/TP>30)

TSI (AVG) = 1/3 [TSI (chl a) + TSI(SD) + TSI(TP)]

Where: TSI(Chl a) = 16.8 + 14.4 ln chl a, (mg/m^3)

TSI(SD) = 60.0 - 30.0 ln SD, (m)

TSI(TP) = 23.6 ln TP - 23.8, (ug/l)

II. NITROGEN - LIMITED LAKES (TN/TP<10)

TSI(AVG) = 1/3 [TSI (chl a) + TSI(SD) + TSI(TN)]

Where: TSI(TN) = 59.6 + 21.5 ln TN, (mg/l)

III. NUTRIENT - BALANCED LAKES (10<TN/TP<30)

TSI(AVG)= 1/3[TSI(chl a) + TSI(SD)
+ 0.5(TSI(TP) + TSI(TN))]

Where: TSI(TN) = 56 + 19.8 ln TN, (mg/l)

TSI(TP) = 18.6 ln TP - 18.4, (ug/l)

Also: TSI(CARLSON) = 0.65TSI(Florida) + 23.2

Note:

TSI	=	Trophic State Index
chl a	=	Chlorophyll a
SD	=	Secchi Disk
TP	=	Total Phosphorus (unfiltered)
TN	=	Total Nitrogen
ln	=	Natural Logarithm

Source: Huber et al. 1982

FIGURE IV-4

THE FLORIDA TROPHIC STATE INDEX

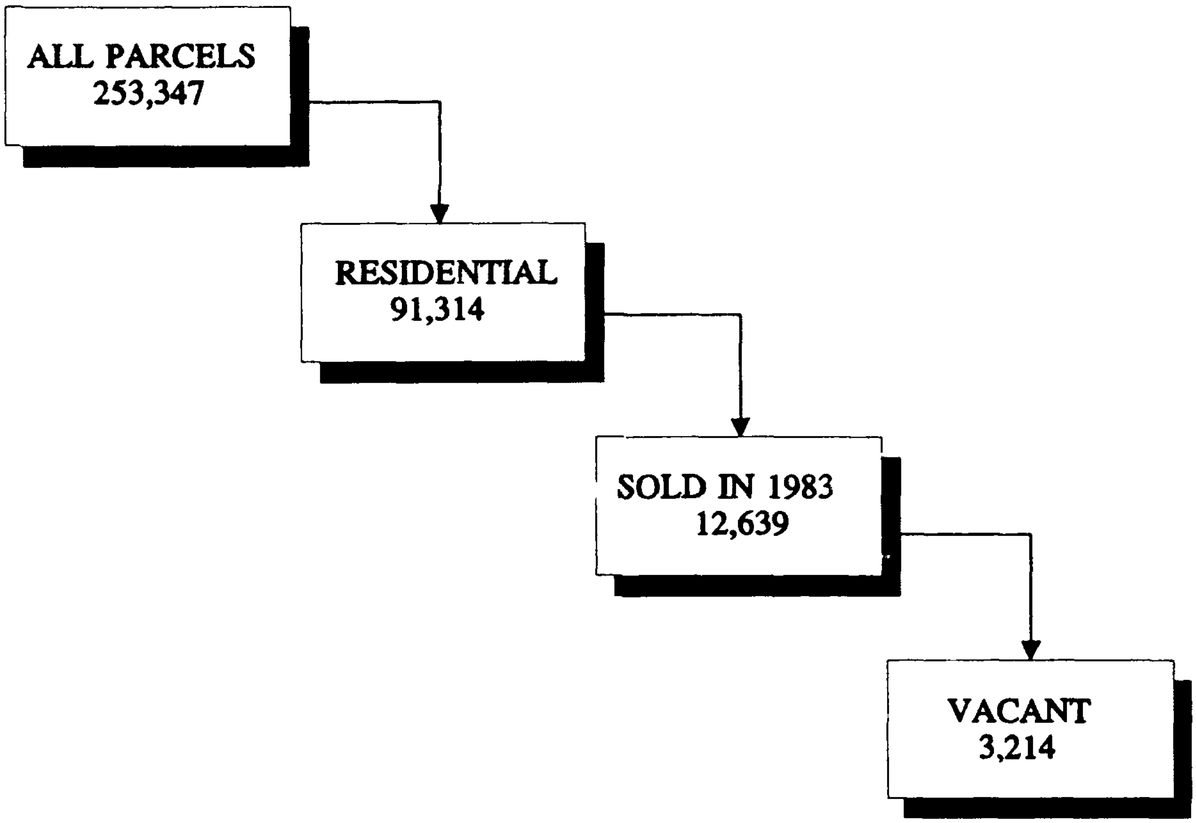


FIGURE IV-5

FILTERING PROPERTY APPRAISER'S DATABASE

follows nearly all the studies directed at hedonic valuation of water resources. Nonresidential users of land will in most cases place a different value on land, depending on their business, industrial output, or other purpose. Also, property tax schedules typically vary by land use type. These differences in land use purpose and resultant tax responsibility are capitalized into land value, and this causes market value segmentation. To control for this, single family residential properties are selected for the analysis.

Another reason for disaggregating parcels by land use type is that the exogenous impact of water resources varies. Residential occupants benefit from the recreation and aesthetic opportunities that a water resource provides (assuming it is attractive and not a nuisance, as described by Young and Teti 1984). An industrial user may take advantage of the water resource for transportation, cooling, or wastewater disposal. Industrial transportation and recreational opportunity are different services and exist in different markets. Comparison of the value of a variety of water-related services would be statistically unwieldy and is not the intent of this work; therefore only single-family residential properties are analyzed. Thus it should be noted that the application of the results of this work should be applied to water resources surrounded by residential land uses only.

The residential parcels are subsetted further in a second "global" filter that isolates properties sold in 1983. First, let us address the issue of selection of a single year. Demand for housing changes with time. Certain areas may, for one reason or another (e.g., supply fluctuation, new transportation opportunities, new jobs), experience surges in market value for property. To control for this, a single year, 1983, is examined.

Only vacant parcels are considered because the focus of the research is the locational relationship with the lake resource. Inclusion of developed parcels would introduce variance in market price of property that is not needed. Many other studies include structural characteristics that typically are easily explained in terms of square footage and age. This, in turn, inflates the explanatory power of the calibrated model. By using only vacant parcels, the present effort and resultant model will explain the locational value of the lake resources.

A last note on the data is that only qualified market transactions are considered. A "qualified" sale is one that reflects on actual market transaction. On the other hand, "unqualified" sales, which are relatively common, are formulated under nonmarket conditions. For example, a father may sell his daughter a parcel of land for $100. This is actually a gift, but the transaction is recorded in the property appraiser's database. It is recorded, though, as an "unqualified" sale.

Actual sales price is used instead of assessed value. See Berry and Bednary (1976) for a discussion of these issues. Though the goal of most assessment techniques is to reflect market values, they are sometimes biased to meet political goals. This study uses actual qualified market sales to avoid this bias and get a true representation of what the market bears for a particular parcel and its water resource attributes.

V. MODEL CALIBRATION AND RESULTS

CHAPTER OVERVIEW

The influence of lake resources is looked at incrementally in this chapter from a very simple perspective to a multidimensional perspective, as shown in Figure V-1. Thus three hypotheses are tested with as many models:

Hypothesis 1: Land value of lakefront property is greater than nonlakefront property.
Hypothesis 2: The effect of lake characteristics (size and water quality) is realized in land values.
Hypothesis 3: Water resource related impact on land value will diminish with distance from the water source.

First, the question of whether the present lake resources influence land value—yes or no? To address this question, lakefront property values are compared with nonlakefront property values. An affirmative answer to this question moves us to the next dimension: Is lake quality recognized in land values? If so, lakes of varying attributes are correlated to adjacent property values.

The final dimension builds upon the previous two while adding space or location. The proximity of the parcels of land to the lakeshore, and other traditional rent- influencing components of the urban landscape are considered (e.g., distance to central business district). The calibration of this third model constitutes the hedonic value function.

The three models:

1. Lakefront-nonlakefront
2. Lake characteristics
3. Lake influence land rent gradient

are presented in this chapter individually. As mentioned in the previous chapter, each model works from a separate data set. The definition of the respective data set is given as are the statistical arguments, and final model results are presented for each.

Lakefront-Nonlakefront

Before any complex land value-water quality model, or distance decay rent gradients are determined, the issues of whether any relationship between land value and the presence of lake resources exists at all must be settled. It is hypothesized that a desirable water resource will

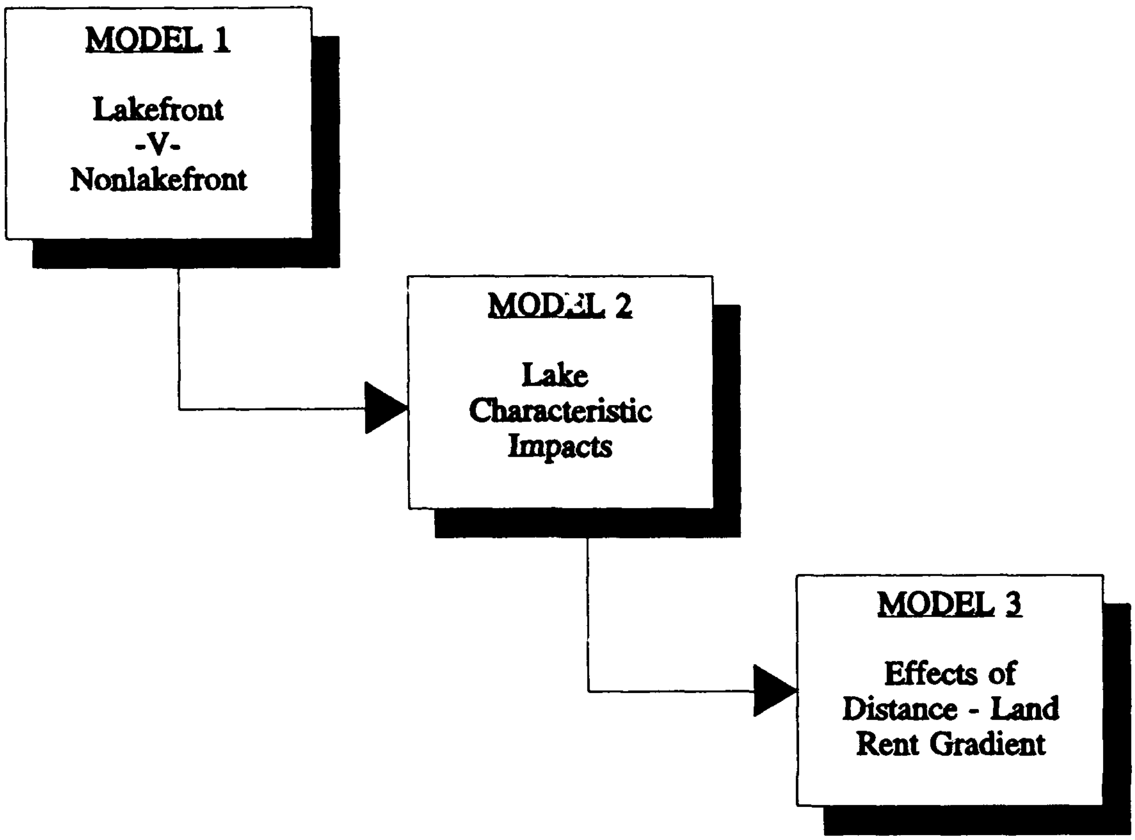


FIGURE V-1

MODELS EVALUATED IN THIS RESEARCH EFFORT

enhance proximate property values. This simple relationship has been proven in the past (e.g., Knetsch 1964; David 1968; Reynolds 1973) and is shown to hold true in this study.

This question is addressed by comparing means of the two groups of data: lakefront parcels versus parcels not on lakefront. From the global filter presented in the previous chapter, there are 3,241 single-family residential, vacant parcels sold in 1983. A very convenient "special use" code in the property appraisers database allows specific identification of lakefront property. Of the 3,241 parcels, 174 are lakefront. Statistical Analysis System's (SAS) PROC TEST procedure is used to test the means of the two groups. The results shown in Table V-1 indicate a strong difference in property value between the two groups. The near lakefront parcel selling price is $26,085 compared with $15,406 for nonlakefront property. This difference, as shown by the t-statistic, is highly significant.

TABLE V-1

COMPARISON OF MEAN PROPERTY VALUES OF LAKEFRONT AND NONLAKEFRONT PARCELS

		Sales Price	
	N	Mean	Standard Deviation
Lakefront parcels	174	26,085.2	22,942.3
Nonlakefront parcels	3,067	15,406.0	12,383.4

F = 3.43 Prob > F = 0.0000
T = -6.00 Prob > T = 0.0001

It should be noted that the t-statistic reported in Table V-1 is an approximation used in the case where the variances of the two groups are different. The statistic reported in Table V-1 indicates this difference to exist between the lakefront and nonlakefront samples. Thus the t-statistic is approximated as:

$$t = (\overline{X_1} - \overline{X_2}) \;/\; [(S_1^2/n_1 + S_2^2/n_2)]^{0.5}$$

where: $\bar{X}_{1,2}$ = the sample means of samples 1 and 2, in this case lakefront and nonlakefront parcels
$S^2_{1,2}$ = the sample variance of samples 1 and 2
$n_{1,2}$ = the number of observations of samples 1 and 2

In the case of (statistically) equal variances between the two groups, a pooled variance term is used:

$$t = (\overline{X_1} - \overline{X_2}) \;/\; \left[S^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]^{0.5}$$

where: S = pooled variance of the two groups

All other variables were defined above. The first equation yields a more conservative t-statistic (more difficult to reject null hypotheses), but strong significance is still shown.

Thus the existence of lake resources increases residential property values. Nonlakefront property is valued at about 59 percent of lakefront property. Knetsch (1964) found nonreservoir land to be 54 percent the value of reservoir land, and Khatri-Chetri and Hite (1990) indicated this value to be about 40 percent. The differential between lakefront and nonlakefront found in the present effort is probably conservative because the presence of a lake influences more than lakefront parcels only. As land rent theory describes (Thrall 1982), and is shown later in this report, a distance-decay effect occurs over the landscape; so parcels not on the lakefront, but very near it, will receive some inflationary influence by a lake's presence. This distance-decay influence is not realized in the statistics of Table V-1 because of the way the samples are defined—either lakefront or not. Therefore it is expected that the mean nonlakefront value, ($15,406) harbors some of the distance decay impact that, in turn, biases the nonlakefront mean upward.

Lake Characteristics Impact

It is expected that the quality and magnitude of service or benefits provided by lake resources will vary. The lake analysis of the Lake Okoboji Region (d'Arge and Shogren 1989) illustrates a significant increase in demand for cleaner lake water quality. This increased demand was found to be capitalized in land values.

For this portion of the analysis, the question of whether lake characteristics are revealed in property values is examined. The lake characteristics examined are TSI and lake size and are regressed on lakefront parcels only. Most of the 174 observations of lakefront parcels (see Figure IV-5) were next to lakes for which no TSI data were available. Therefore the original 91,314 single-family residential observations (shown in Figure IV-5) were accessed to obtain observations for 1982 and 1984. The final data set used in this analysis contains 45 observations for lakefront parcels around 19 lakes sold during the years 1982 through 1984. This data set is provided in Appendix B.

Examination of simple plots of the raw data reveals some obvious outliers. Selling price versus selling price per square foot of lot and selling price versus square feet of lot are plotted in Figures V-2 and V-3, respectively. The outliers shown in these plots occur because (1) there was an error made in recording the data in the property appraiser's database; and/or (2) these observations represent property transactions that are unique. In either case, these data points are empirically separate from the remaining points for reasons outside the realm of where this analysis is targeted. Therefore they are removed from the data set, causing the final database to contain 42 observations.

Variable name assignment and descriptive statistics of each are shown in Table V-2. Simple correlation among all the variables are shown in Table V-3. Each of the variables, with the exception of the year-of-sale categorical variables, exhibits significant correlation to parcel selling price (ACTPR), at the 1 percent significance level. The direction and magnitude of the correlations vary. Lot size (FTSQ) is positively correlated to ACTPR, an obvious relationship that is verified here. The negative sign of the TSI variable indicates that trophic state index (TSI) is higher for lower-priced parcels. This is expected, as lake quality generally decreases with increasing TSI. The lake size (SIZE) correlation coefficients indicate selling price around larger lakes is higher compared with selling price around smaller lakes. The year-of-sale variables, Y82, Y83, and Y84 simply reflect time-dependent inflation.

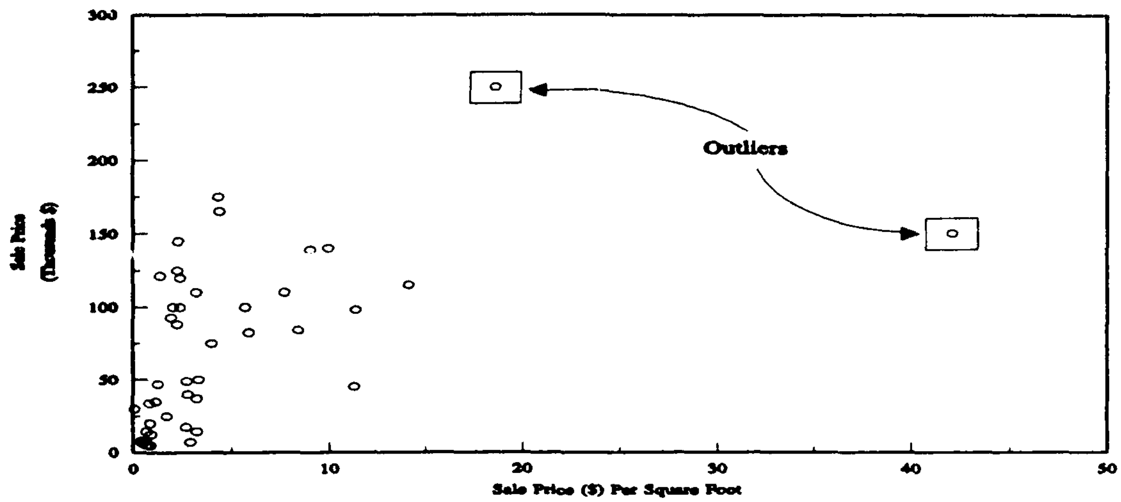


FIGURE V-2

SALE PRICE VERSUS UNIT PRICE FOR LAKE CHARACTERISTICS ANALYSIS

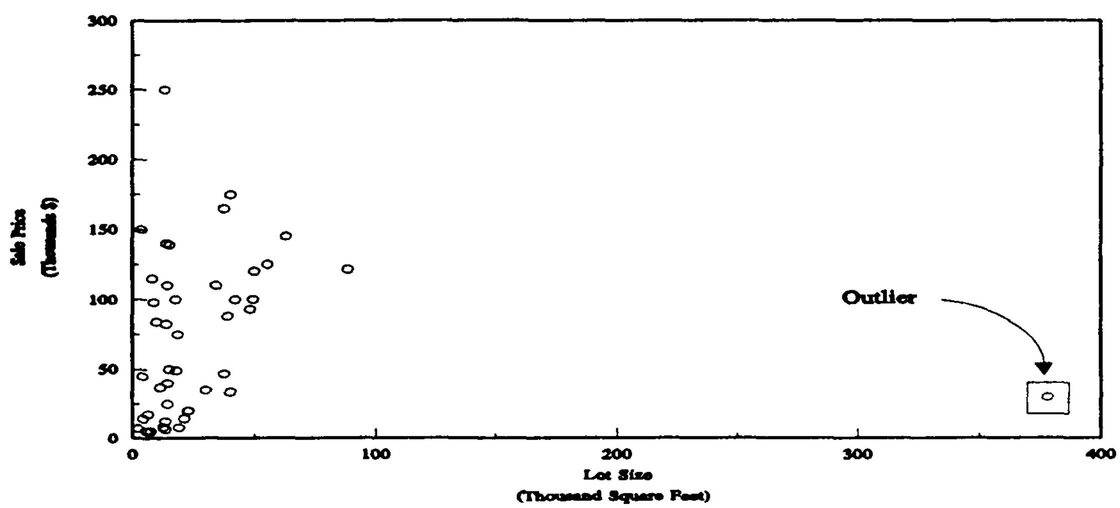


FIGURE V-3

SALE PRICE VERSUS LOT SIZE FOR LAKE CHARACTERISTICS ANALYSIS

TABLE V-2

DESCRIPTIVE VARIABLES USED IN LAKE CHARACTERISTICS ANALYSIS

Description	Variable	Mean	Std. Dev.	Minimum	Maximum
Parcel selling price	ACTPR	66,445	51,107	5,000	175,000
Lake trophic state index	TSI	49.5	10.9	33.0	75.0
Parcel footage	FTSQ	24,070	18,792	2,436	88,305
Lake acreage	SIZE	554	597	1	1,757

TABLE V-3

PEARSON CORRELATION COEFFICIENTS AND SIGNIFICANCE STATISTICS FOR VARIABLES IN LAKE CHARACTERISTICS ANALYSIS

	ACTPR	TSI	FTSQ	Y82	Y83	Y84	SIZE
ACTPR	1.0000	-0.5028	0.5456	-0.2648	-0.0187	0.2391	0.4215
	0.0	0.0007	0.0002	0.0901	0.9060	0.1271	0.0054
TSI	-0.5028	1.0000	-0.6233	0.0822	-0.2155	0.1696	-0.2686
	0.0007	0.0	0.0001	0.6045	0.1704	0.2829	0.0854
FTSQ	0.5456	-0.6233	1.0000	-0.3251	0.3067	-0.0697	0.4323
	0.0002	0.0001	0.0	0.0356	0.0482	0.6609	0.0042
Y82	-0.2648	0.0822	-0.3251	1.0000	-0.4920	-0.2828	-0.2677
	0.0901	0.6045	0.0356	0.0	0.0009	0.0695	0.0864
Y83	-0.0187	-0.2155	0.3067	-0.4920	1.0000	-0.6958	0.0837
	0.9060	0.1704	0.0482	0.0009	0.0	0.0001	0.5980
Y84	0.2391	0.1696	-0.0697	-0.2828	-0.6958	1.0000	0.1286
	0.1271	0.2829	0.6609	0.0695	0.0001	0.0	0.4168
SIZE	0.4215	-0.2686	0.4323	-0.2677	0.0837	0.1286	1.0000
	0.0054	0.0854	0.0042	0.0864	0.5980	0.4168	0.0

TSI is significantly correlated to parcel size. There is no physical explanation for this. There is also a somewhat significant relationship between lake size and TSI. While this is interesting, there is no apparent reason why larger lakes would be more eutrophic than smaller lakes.

The correlation matrix alone provides affirmation of the impact of lake characteristics on property values. Lake size and water quality are both strongly correlated to selling price. To indicate their relative importance and to further quantify their impact, a multivariate regression is developed. ACTPR is the dependent variable that is regressed upon by the remaining variables. The year of sale variables are included, with 1983 being the base case and therefore part of the intercept.

The PROC REG procedure in SAS is used to produce the ordinary least-squares parameter estimates to the multivariate model. The results are shown in Table V-4. The signs of each parameter estimate are as expected. TSI is the stronger of the two lake characteristic variables. *In fact, the t-statistic for SIZE is only 1.2260, which makes it only weakly* significant. TSI, on the other hand, is significant at the 5 percent significance level. Each unit of TSI increase causes the selling price to drop about $1,549. Unit change in FTSQ causes the selling price to increase $0.76. The t-statistic for FTSQ reveals a moderately strong relationship at most. It is significant at the 12 percent level. Y82 is insignificant, but Y84 picks up some of the fast-paced inflation in property value that was experienced in Orange County during that time period. Note that the large magnitude of the parameter estimate for Y84 should be used cautiously because the sample sizes by year are relatively small (Y82, Y83, and Y84 have 7, 28, and 12 observations, respectively). These time-related dummy variables are of secondary importance as compared to the remaining continuous variables. They are included to simply control for any time-related trends.

The functional form of the model shown in Table V-4 is linear. Double-log and semilog forms of the model were examined with marginal improvement in r-square (0.47 and 0.49, respectively). These configurations significantly reduce the strength of the t-statistic for TSI. Since the objective of this portion of the analysis is simply to prove the existence of a relationship between lake characteristics and property value, sacrifice of a few percent points of goodness-of-fit is considered warranted for stronger parameter estimates for the variables of interest.

LAND RENT GRADIENT

The final model evaluated incorporates locational variables in explaining property value. If land values are thought of as a surface over the landscape, one would expect aberrations in the surface. The simplistic Von Thunen (1821) model suggests a single peak at the CBD (see the theoretical land rent gradient shown in Figure II-2). A land rent gradient reflecting reality has more peaks and valleys than the single CBD peak. This portion of the analysis defines the peaks and valleys caused by water resources while trying to control for other influences on property value.

TABLE V-4

PARAMETER ESTIMATES FOR LAKE QUALITY MODEL

Variable	Parameter Estimate	Standard Error	T-Statistic	Prob > |T|
INTERCEP	107,938.00	45,867.92	2.353	0.0242
TSI	-1,549.22	749.07	-2.068	0.0459
FTSQ	0.76	0.48	1.602	0.1179
Y82	-2,697.02	18,705.98	-0.144	0.8862
Y84	32,102.00	14,694.66	2.185	0.0355
SIZE	14.51	11.84	1.226	0.2281

Dependent variable = selling price
N = 43
F-statistic = 6.2370
Prob > F = 0.0030
r-square = 0.4642

In the previous two sections, the existence of a lake and its characteristics have both been proven to impact land value. The ability to indicate lakefront or nonlakefront has been facilitated by a special code in the property appraiser's database. For this segment of the analysis, a more precise representation of the parcel locations is needed to "fill in" a continuous land rent surface.

The parcel number contains the township, range, and section delineation, which places the parcel in a square-mile area. The expected influence of a lake may vary locally, and therefore further locational definition is needed. The parcel number also contains subdivision, block, and lot specification that, unlike the township, range, and section numbers, are not tied to a numerically consistent map location. These specific attributes serve as an index to the property appraiser's parcel maps that were supplied by the Orange County Property Appraiser's Office on microfilm. Maps on the microfilm are each quarter-corners, or one-half mile by one-half mile squares, a map scale that allows identification of individual parcels. Thus each parcel of land considered was defined in terms of X-Y coordinates.

Referring back to Figure IV-3, it is indicated that 3,241 parcels are available, which are located randomly throughout the study area. This defines the starting point from which the final sample of observations is drawn. As expected, the lakes with TSI data limit the number of applicable parcel observations. A region of at least one mile around each lake for which TSI data were available was specified. The one-mile specification followed the one-mile-square sections defined on the detailed county map. The sections that bordered the lake of interest, plus one more section beyond the border sector, make up the region associated with the particular lake of interest. The relatively large band of surrounding land ensured consideration of all possible parcels that might be impacted by the lake of interest. Many of the regions blended together because their regions of interest overlapped. The final lake regions considered for analysis are shown in Figure V-4.

At this stage, parcels were downloaded to another electronic file according to township, range, and section, and were further investigated through parcel maps. Approximately 1,300 parcels were sought out in the parcel maps. These were subsetted further because (1) several parcels were located in an individual subdivision for which a random number of parcels were selected; (2) the parcel was situated next to a lake for which no TSI data were available; (3) the parcel was not found on the map. Thus information for approximately 570 parcels was taken from the parcel maps. The X-Y coordinates of the approximate center of each parcel were recorded. The unit of size measurement recorded in the property appraiser's database is not consistent for all parcels and in many cases cannot be converted to a consistent area metric. For instance, many parcels are recorded as "one lot." There is no way of knowing the size of this "lot." Therefore while finding the X-Y location of parcels, lot areas were measured and recorded in square feet.

All lakes within the region were considered because, though the lake may not have TSI data recorded, it is a competing amenity within the region and needs to be considered in the statistical analysis. The result is a set of X-Y boundary coordinates for the 96 lakes in the study area.

The intent of defining all objects of interest according to X-Y coordinates is to compile a simple geographic information system (GIS). This not only provides the capability of determining relative distance among all the objects, but graphic capabilities as well. Three other pieces of information are added to the GIS. X-Y coordinates for the major shopping malls are places on the database. Similarly, major transportation junctures are entered. Major transportation and shopping hubs serve as proxies for CBD. The CBD of Orlando, the major metropolitan area in Orange County, is also placed in the GIS. Lake boundaries, shopping centers, and transportation hubs are shown in Figure V-5.

A computer program, written in BASIC, was used to calculate the shortest distance between each parcel and its first, second, and third closest lakes; nearest shopping center; nearest transportation hub; and the CBD. The code for this program is found in Appendix C. This set of distances for each parcel, compiled with parcel size, sales information, lake size, and TSI, makes up the variables used in the analysis.

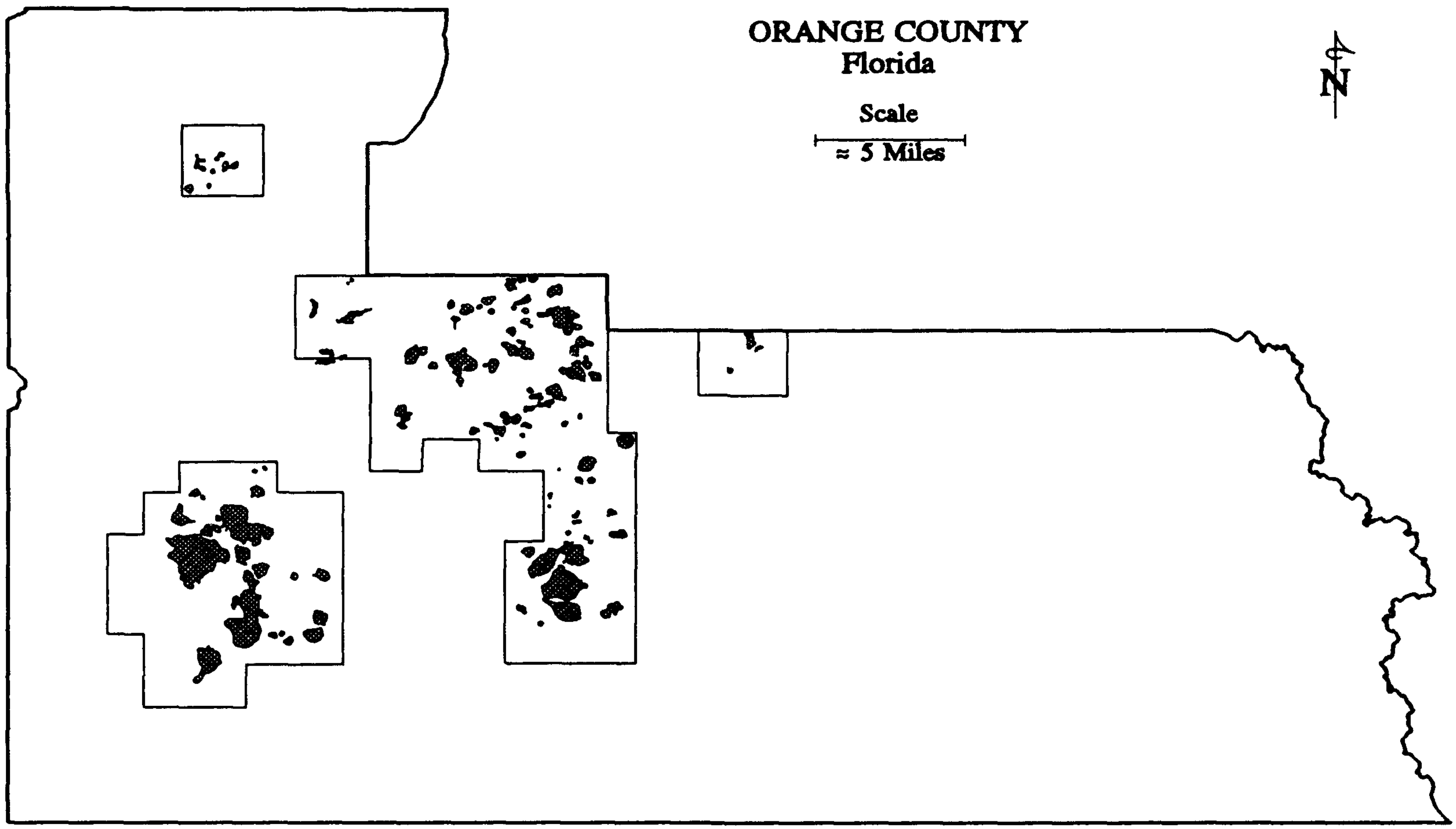


FIGURE V-4

LAKE REGIONS IN STUDY AREA

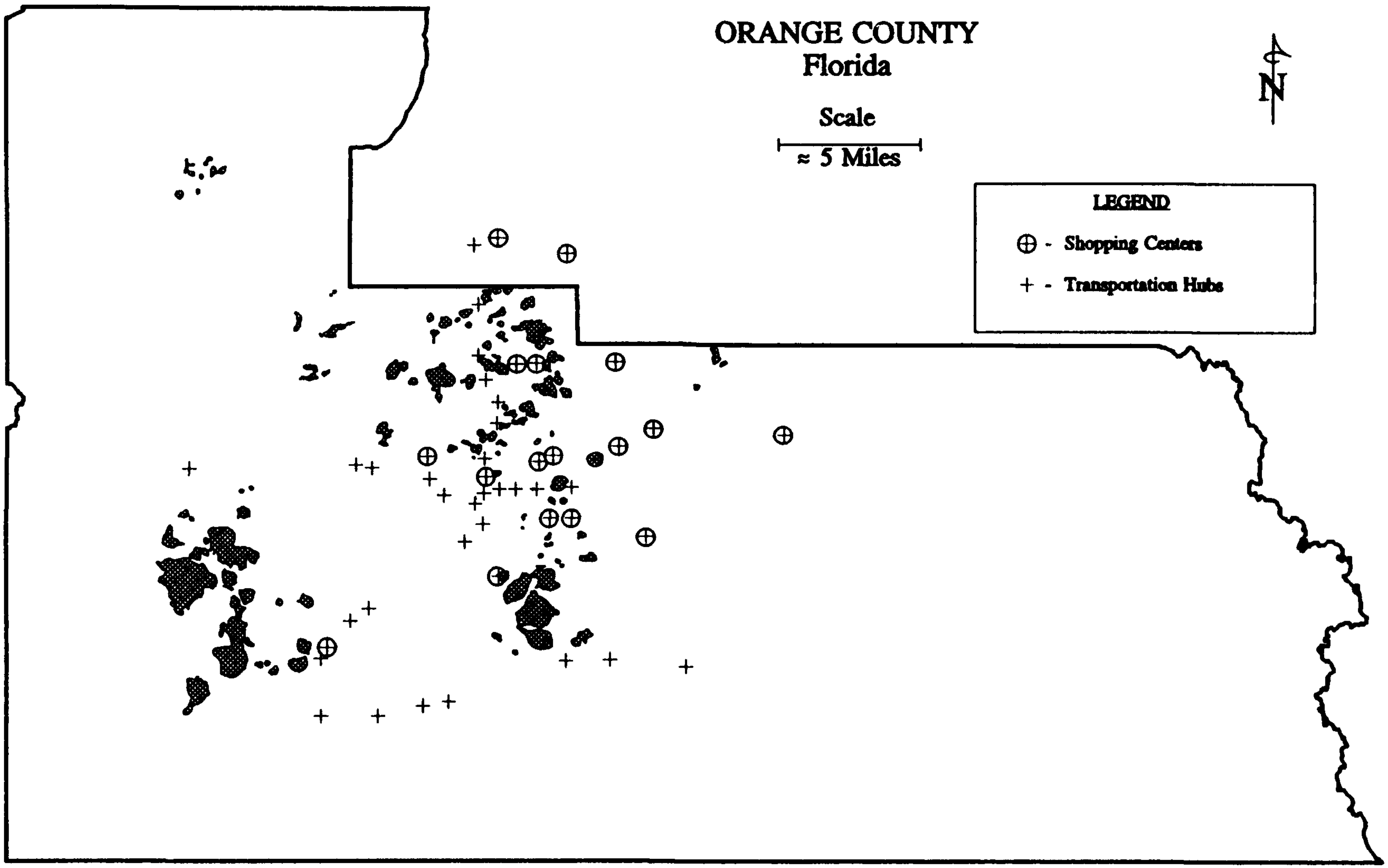


FIGURE V-5

LAKES, SHOPPING CENTERS, AND TRANSPORTATION HUBS IN STUDY AREA

Observations that had parcels closest to lakes for which no TSI data were available were eliminated. Close examination of the sales price revealed several observations that were sold for $100 and one parcel for $114. The next highest sales price was $5,000, and the prices increase continually from there. One explanation for this is that they may be unqualified sales, such as sales to family members for a nominal charge. It should be noted, though, that this was controlled for during the initial filtering process (described in Chapter IV) by including only "Q," or qualified sales, in the working database. These may have been miscoded. In any event, these observations are removed from the database.

Examination of selling price versus selling price per square foot, shown in Figure V-6, reveals a couple of observations that are suspect. These points are approximately $18 per square foot, where the next highest values are about $10 per square foot and then the values continually decrease. As stated above, these points consist of effects outside the intent of the model (most likely errors in coding) and are therefore deleted. The final data set contains 153 points and is provided in Appendix D.

Variable name assignment and descriptive statistics are shown in Table V-5. Pearson correlation coefficients among all variables are shown in Table V-6. All of the variables except CBD are strongly correlated to ACTPR. The signs of the coefficients for the variables used in the lake characteristics analysis (see Table V-2) are repeated at this stage. The distance to closest and next closest lake variables (LAKE1D and LAKE2D, respectively) both have strong

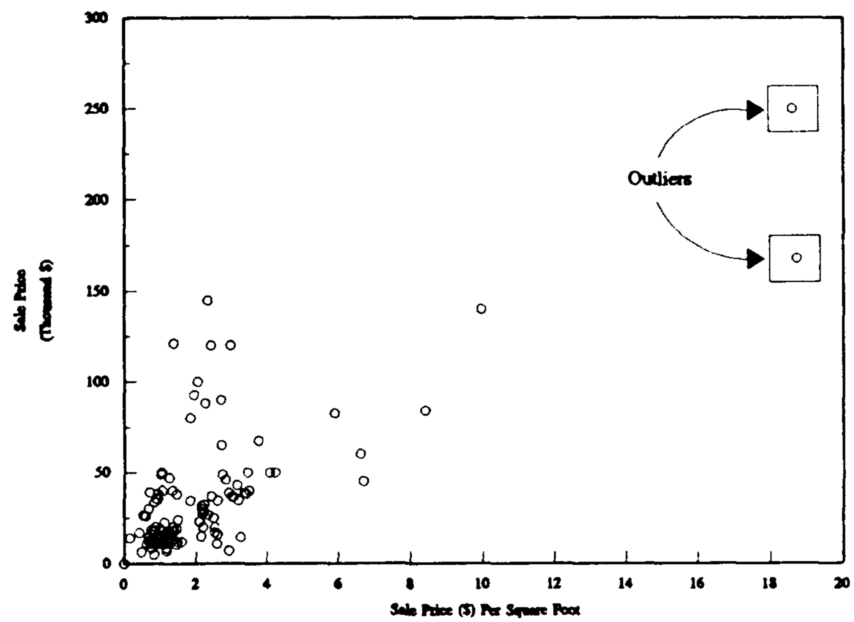


FIGURE V-6

SALES PRICE VERSUS UNIT PRICE FOR LAND RENT GRADIENT ANALYSIS

TABLE V-5

DESCRIPTIVE STATISTICS OF VARIABLES USED IN LAND RENT GRADIENT MODEL

Description	Variable	Mean	Std. Dev.	Minimum	Maximum
Parcel selling price	ACTPR	27,614	26,906	5,000	145,000
Parcel square footage	FTSQ	18,144	14,437	2,436	91,476
Trophic state index of nearest lake	TSI1	54.54	10.14	33.00	66.00
Distance to nearest lake in feet	LAKE1D	1,715	1,496	50	7,807
Size of nearest lake in acres	SIZE1	402	541	1	1,757
Distance to next nearest lake	LAKE2D	4,204	1,692	1,006	9,732
Distance to shopping center in feet	SHOP	23,694	14,575	1,325	56,661
Distance to major transportation in feet	HUB	21,087	13,038	2,328	52,867
Distance to Orlando central business district in feet	CBD	40,340	16,209	10,573	77,467

TABLE V-6

PEARSON CORRELATION COEFFICIENTS AND SIGNIFICANCE STATISTICS FOR VARIABLES IN LAND RENT GRADIENT ANALYSIS

	ACTPR	FTSQ	TSI1	LAKE1D	SIZE1	LAKE2D	SHOP	HUB	CBD
ACTPR	1.0000 0.0	0.5593 0.0001	-0.5794 0.0001	-0.2278 0.0046	0.2570 0.0013	-0.1908 0.0181	-0.2153 0.0075	-0.2454 0.0022	0.0718 0.3776
FTSQ	0.5593 0.0001	1.0000 0.0	-0.4396 0.0001	0.0479 0.5558	0.2243 0.0053	-0.0070 0.9314	0.0759 0.3507	-0.0012 0.9879	0.2589 0.0012
TSI1	-0.5794 0.0001	-0.4396 0.0001	1.0000 0.0	0.3040 0.0001	-0.2236 0.0055	0.4735 0.0001	0.0331 0.6841	0.0106 0.8965	-0.3674 0.0001
LAKE1D	-0.2278 0.0046	0.0479 0.5558	0.3040 0.0001	1.0000 0.0	0.2789 0.0005	0.5497 0.0001	-0.3247 0.0001	-0.2254 0.0051	-0.3833 0.0001
SIZE1	0.2570 0.0013	0.2243 0.0053	-0.2236 0.0055	0.2789 0.0005	1.0000 0.0	0.0335 0.6802	-0.2693 0.0008	-0.3859 0.0001	-0.0570 0.4836
LAKE2D	-0.1908 0.0181	-0.0070 0.9314	0.4735 0.0001	0.5497 0.0001	0.0335 0.6802	1.0000 0.0	-0.2904 0.0003	-0.2431 0.0025	-0.4298 0.0001
SHOP	-0.2153 0.0075	0.0759 0.3507	0.0331 0.6841	-0.3247 0.0001	-0.2693 0.0008	-0.2904 0.0003	1.0000 0.0	0.9469 0.0001	0.8846 0.0001
HUB	-0.2454 0.0022	-0.0012 0.9879	0.0106 0.8965	-0.2254 0.0051	-0.3859 0.0001	-0.2431 0.0025	0.9469 0.0001	1.0000 0.0	0.8527 0.0001
CBD	0.0718 0.3776	0.2589 0.0012	-0.3674 0.0001	-0.3833 0.0001	-0.0570 0.4836	-0.4298 0.0001	0.8846 0.0001	0.8527 0.0001	1.0000 0.0

negative correlation coefficients with ACTPR that supports their hypothesized relationship. Distance to transportation hub (HUB) and distance to shopping (SHOP) each indicate decreasing property value with increasing distance. Proximate shopping and transportation areas are typically considered a convenience. The negative correlation coefficients of HUB and SHOP associated with ACTPR support this notion.

Looking at correlation among the explanatory variables warns of potential multicollinearity. CBD, HUB, and SHOP are all correlated with one another. This is not surprising, since SHOP and HUB possess the same type of convenience benefit that CBD does. Variables like SHOP and HUB are used to describe cities that do not possess well-defined CBDs due to suburbanization and outward expansion. This is the typical case of most large U.S. cities. LAKE1D and LAKE2D are correlated simply because, as distance to the nearest lake increases, distance to the second nearest lake also increases. The correlations between TSI, size of nearest lake (SIZE1), and FTSQ have no apparent physical justification.

The multivariate regression model is developed with a primary focus on statistically strong parameter estimates for the independent variables. The next level of concern is directed at controlling for correct functional form, goodness of fit, and multicollinearity and heteroskedasticity.

Inclusion of LAKE1D and LAKE2D, which were shown to be correlated, caused volatility with the LAKE1D parameter estimate. Therefore LAKE2D, the lesser important variable, is dropped from the model. SIZE1 and SHOP were found to be insignificant variables in the model. The final model has ACTPR as the dependent variable and FTSQ, TSI1, LAKE1D, CBD, and SHOP as independent variables.

Following the suggestions of Halvorsen and Pollakowski (1981) and Milon et al. (1984), consideration of the Box and Cox (1964) procedures (referred to as BOX-COX) for functional form selection is made. Milon et al. (1984) customize BOX-COX for application to water resource amenities that is used in this research.

$$P_k^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i Z_{ki}^{(\lambda)} + \sum_{i=1}^{n} \beta_i W_{ki}^{(\lambda)} + \epsilon_k (\theta,\lambda)$$

where:

where:	P	=	sale price
	Z	=	vector of nonwater-related attributes
	W	=	vector of water-related attributes
	m,n	=	number of independent variables
	α,β	=	parameter estimates
	λ,θ	=	BOX-COX transformation factors
	k	=	number of observations
	ϵ	=	error term

This is an iterative procedure that varies functional form by changing λ and θ. The choice of functional form is made based upon the maximum of the log-likelihood statistic.

$$L_{max}(\theta,\lambda) = -\frac{1}{2} \ln\sigma^2 (\lambda,\theta) + (\theta - 1) \sum_{j=1} \ln P_j$$

where:	L_{max}	=	log-likelihood statistic
	K	=	number of observations
	P	=	sale price
	σ^2	=	standard deviation
	θ,λ	=	BOX-COX transformation factors

FTSQ and ACTPR are found to be linearly correlated and therefore share equal transformations through the procedure. Thus

$$Y_\theta = \frac{Y^\theta - 1}{\theta}, \text{ if } \theta \neq 0$$

$$Y_\theta = \log(y) \quad , \text{ if } \theta = 0$$

for the dependent variable ACTPR and FTSQ. The remaining independent variables are transformed as follows:

$$X_\lambda = \frac{X^\lambda - 1}{\lambda}, \text{ if } \lambda \neq 0$$

$$X_\lambda = \log(x) \quad , \text{ if } \lambda = 0$$

The algebraic expression delivered for each of the values for λ and θ are summarized at the bottom of Table V-7. The PROC REG procedure in SAS is used to develop ordinary least-squares parameter estimates. Programming in SAS is used to create the BOX-COX mechanics and develop the log-likelihood statistic. This SAS code is listed in Appendix E. The log-likelihood statistic for the iterations of θ and λ is provided in Table V-7.

The results indicate $\theta = 0$, $\lambda = 1$ as the best functional form. Thus the land rent gradient model takes the form:

$$\ln(ACTPR) = \alpha + \beta_1\, TSI + \beta_2 \ln(FTSQ) + \beta_3\, LAKEID + \beta_4\, SHOP + \beta_5\, CBD$$

TABLE V-7

BOX-COX PROCEDURE SUMMARY FOR LAND RENT GRADIENT MODEL

θ	λ	L
0	-1	-1,399.0
0	0	-1,384.4
0	1	-1,356.5
0	2	-1,366.5
1	-1	-1,515.0
1	0	-1,508.9
1	1	-1,493.5
1	2	-1,496.9
2	-1	-1,703.2
2	0	-1,701.1
2	1	-1,694.3
2	2	-1,694.0

θ,λ
$2 \sim \alpha^2$
$1 \sim \alpha$
$0 \sim \log(\alpha)$
$-1 \sim 1/\alpha$

where: α = intercept term
β_n = parameter estimates

Since increasing TSI is expected to cause ACTPR to decrease, the sign of β_1 should be negative. FTSQ and ACTPR are expected to move the same way, and the sign associated with FTSQ should be positive. LAKE1D, SHOP, and CBD are all expected to cause decreases in ACTPR and, therefore, β_3, β_4, and β_5 should be negative.

The ordinary least square regression results for the final model, shown in Table V-8, indicate all variables are strong indicators of ACTPR, and the t-tests indicate statistical significance. The F-test and r-square values also indicate a strong model. The expected parameter estimate signs of each variable except CBD are revealed.

TABLE V-8

PARAMETER ESTIMATES FOR LAKE QUALITY MODEL

Variable	Parameter Estimate	Standard Error	T for H_o: Parameter = 0	Prob > |T|
INTERCEP	5.740308	0.69457899	8.264	0.0001
TSI1	-0.012500	0.00573203	-2.181	0.0308
LOGFTSQ	0.000120	0.00002243	8.798	0.0001
LAKE1D	-0.000120	0.00002243	-5.366	0.0001
SHOP	-0.000050371	0.00000780	-6.459	0.0001
CBD	0.000031232	0.00000753	4.149	0.0001

Dependent variable = log of selling price
N = 153
F-statistic = 97.0430
Prob > F = 0.0001
r-square = 0.76

The sign of CBD indicates that increased distance from the city center causes increased property value. This is not a surprise because the correlation coefficient for CBD and ACTPR is positive. The measure of CBD distance as a convenience is somewhat antiquated (discussed above). In fact, suburbanization and city center congestion has caused the traditional land rent gradient to be reversed in many cities. This increasing land rent gradient with distance from the CBD is in the study area and is statistically significant.

A couple of technical items regarding the final model should be noted. First, $\theta = -1$ was not considered as a functional form because the parameter estimates were very small, on the order of 10^{-8}, which created difficulties in interpretation and conducting sensitivity analysis. The improvement in the likelihood statistic was marginal, and the decision to sacrifice the "best" functional form for ease of application and interpretation was considered justified.

CBD is cautiously included in the model because it appears to be strongly correlated with SHOP. CBD is traditionally an important variable in urban geographical research, and its inclusion in the model is considered important for *a priori* reasons. The large sample size helps to minimize the collinearity impact on the parameter estimates. The degree of collinearity gauged through derivation of a condition index, described by Belsley et al. (1980), indicates an acceptable level of collinearity. The condition index of 9.2, shown in Table V-9, is considerably less than the rule-of-thumb value of 30 recommended by Belsley et al. The result is CBD is an important contributor in the final model with marginal multicollinearity impact.

A necessary condition of a properly defined least squares regression model is that the error term is randomly distributed. This condition is referred to as heteroskedasticity. Any pattern in the error term indicates homoskedasticity which causes specification errors in the parameter estimates. Following Hannett and Murphy (1985), predicted Y (the model's prediction of selling price for each observation) is plotted against the model's error term in Figure V-7. No strong pattern exists, indicating very limited homoskedasticity. Plots of the error term versus the independent variables are shown in Figure V-8, further indicating randomness in the error term.

A final consideration in evaluating the model's robustness involves examination of autocorrelation based upon the location of each observation. This is termed spatial autocorrelation and is described in detail by Griffith (1987). This process quantifies the randomness of the model error in terms of each observation's location. If a pattern exists, model specification problems may exist and appropriate statistical remedies are required. The Moran coefficient (Moran 1948) is used to test for spatial autocorrelation.

$$MC = \left[n \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} W_{ij}\, e_i e_j \right] / \left[\sum_{i=1}^{i=n} \sum_{j=1}^{j=n} W_{ij} \cdot \sum_{i=1}^{i=n} e_i^2 \right]$$

TABLE V-9

COLLINEARITY DIAGNOSTICS FROM SAS

Number	Eigen Value	Condition Number	Proportion of Variance TSI1	FTSQ	LAKE1D	SHOP	CBD
1	2.39380	1	0.0118	0.0348	0.0408	0.0070	0.0087
2	1.2[illegible]83	1.39289	0.0844	0.1583	0.0085	0.0131	0.0014
3	0.93209	1.60257	0.0236	0.1617	0.4840	0.0041	0.0015
4	0.41202	2.41038	0.177	0.6230	0.4428	0.0008	0.0108
5	0.02826	9.20386	0.7025	0.0222	0.0240	0.9750	0.9775

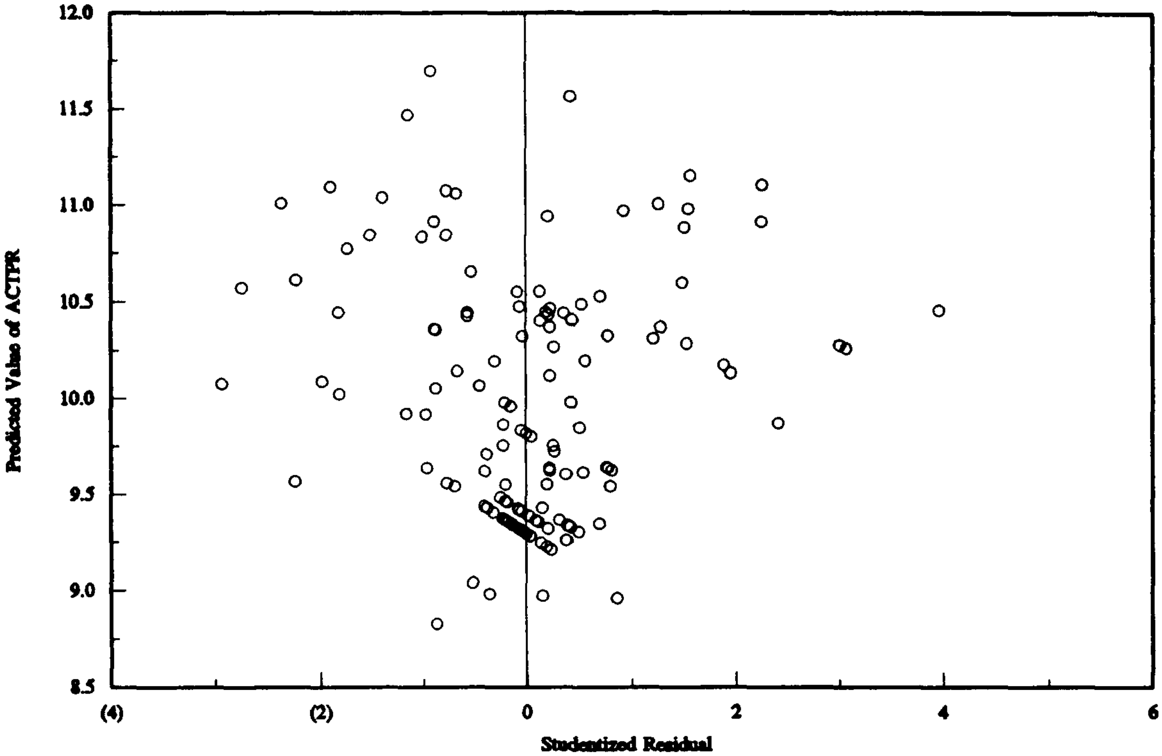


FIGURE V-7

PREDICTED SELLING PRICE VERSUS MODEL RESIDUAL

where:	MC	=	Moran coefficient
	W_{ij}	=	inverse of the distance between points *i* and *j*
	e_i	=	model error for observation *i*
	e_j	=	model error for observation *j*

The Moran coefficient can range between -1 and +1 where a value of 0 indicates a purely random pattern. A z-statistic is used to determine if there is a non-zero indicator of spatial autocorrelation. The Moran coefficient value for the present model is 0.05, which is very close to zero, and the associated z-statistic indicates there is no significant spatial pattern in the error term.

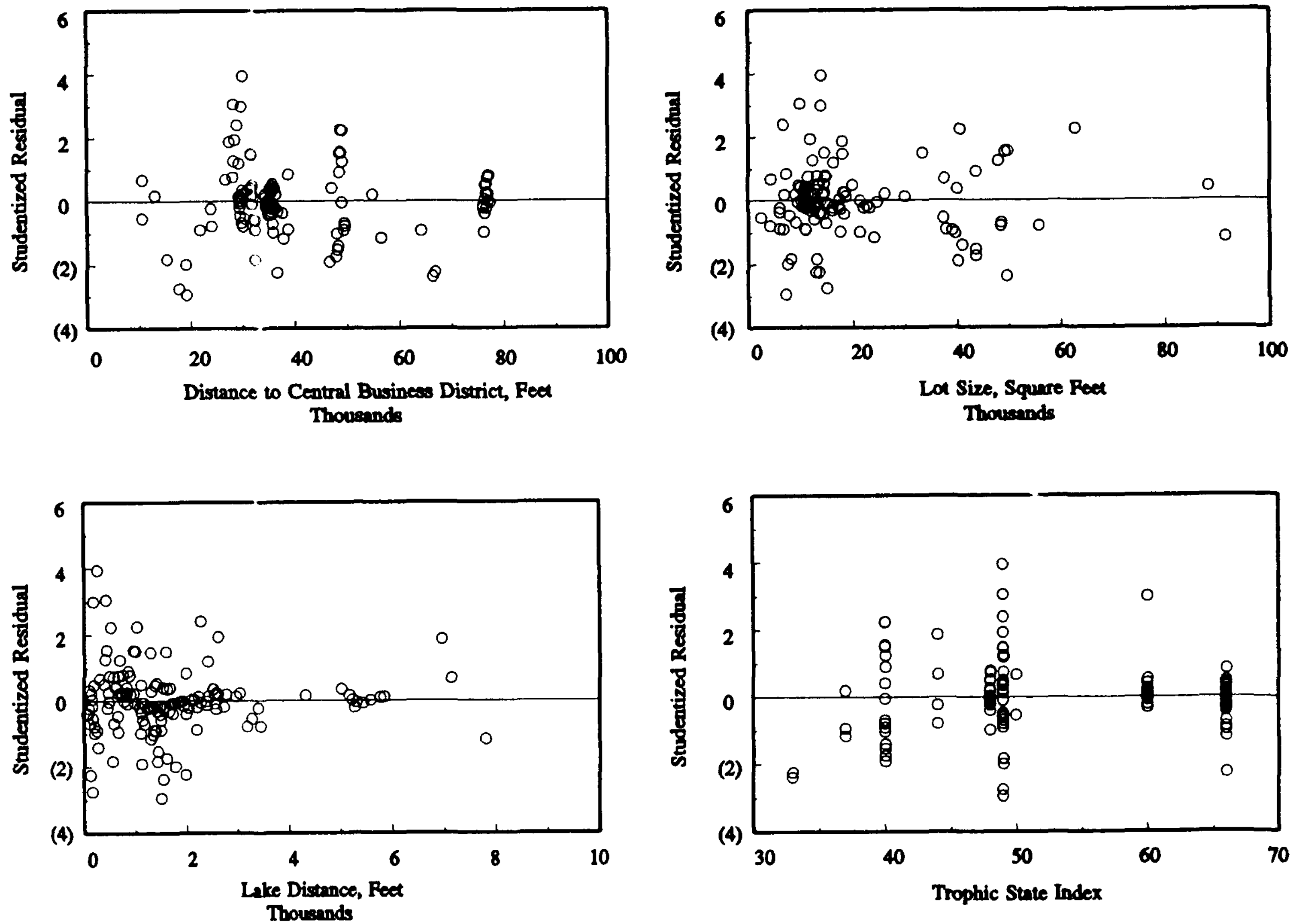


FIGURE V-8

MODEL RESIDUAL VERSUS INDEPENDENT VARIABLES

VI. DISCUSSION OF RESULTS

The first two chapters provided a setting for the present effort by describing the problem in environmental benefits estimation, theory, and past empirical application of hedonic valuation. Chapters III through V presented the data, methods, and final models as part of the present research. This chapter discusses these results by examining specific components of the model: the distance decay gradient and water quality influence. These results are presented in terms of the theory, past work, and application issues.

HYPOTHESES RESULTS

Three hypotheses were introduced at the beginning of Chapter V.

Hypothesis 1:	Land value of lakefront property is greater than nonlakefront property.
Hypothesis 2:	The effects of lake characteristics (size and water quality) are realized in land values.
Hypothesis 3:	Water resource-related impact on land value will diminish with distance from the water source.

Each hypothesis was proven true through presentation of analysis and models in Chapter V. Results relating to the hypotheses are summarized in Table VI-1. Therefore lake characteristics are capitalized in proximate land values, and the magnitude of the impact varies according to distance to lake, water quality, and lake size. The product of the first two hypotheses feeds into the land rent gradient model results that are the focus of the discussion below.

Beneficiaries of Lake Resources

The issue of "who benefits and who pays?" is a challenging issue in environmental valuation. The "who pays" part is often convoluted with political agendas or local taxing issues. This issue is not addressed here, rather the "who benefits" question is addressed. The types of benefits provided by lake resources are primarily recreation and aesthetics. Water resources can also provide, for example, flood control benefits, but the focus here is on recreation and aesthetics.

It is important to emphasize here that the benefits calculated through hedonic value represent only a part of the total benefits picture. The magnitude of the benefit to those in proximity, as measured through this hedonic valuation procedure, is valid and can be interpreted through the statistical parameter estimates. Those "who benefit" according to this procedure though are only those who live in proximity to a lake. The recreation and aesthetic benefits

TABLE VI-1

SUMMARY OF HYPOTHESIS RESULTS

Hypothesis Number	Description	Type of Analysis	Selected Results
1	Lakefront - Nonlakefront	Comparison of means	Nonlakefront property is 59 percent of lakefront property
2	Lake quality	Multiple regression	TSI is negatively correlated with property value; lake size is positively correlated with property value
3	Land rent gradient	Multiple regression	TSI and distance are negatively correlated with property value

associated with those who travel to the lake site from a significant distance (approximately one mile or more) are not considered here. Thus any lake resource benefits derived from hedonic valuation are a partial estimate of the total benefit value of the lake.

According to the parameter estimate on LAKE1D (distance in feet to the nearest lake), the impact of the lake diminishes with distance. Thus as distance to lake increases, the benefit received from the lake decreases. This is illustrated in the scatter plot of observed land values to lake distance in Figure VI-1 (top). A line drawn through this scatter plot would obviously have a negative nonlinear slope. Recognizing there are other influences on property value, this line cannot be interpreted literally, but the general trend exists. Dornbush and Barranger (1972) indicate the impact of lakes to be negligible beyond 4,000 feet from the lake boundary. This appears to be the general trend of data shown in Figure VI-1. To look at the relationship more closely through the calibrated land rent model, the lake distance impact is shown in Figure VI-1 (bottom). This curve is created by holding independent variables constant (at their respective averages) while varying LAKE1D. This plot shows a nonlinear-decreasing relationship. The change in slope is less pronounced than expected. At 4,000 feet on the x-axis, the curve continues to decrease, where according to Dornbush and Barranger (1972) the line should be parallel with the x-axis. These results indicate that the lake impact in Orange County, Florida, goes beyond 4,000 feet. This should be viewed cautiously, though, as only a few observations in the sample have LAKE1D greater than 4,000 feet. Extrapolation beyond observed LAKE1D values should be done only for theoretical purposes, and little weight should be given to the associated dependent variable estimates.

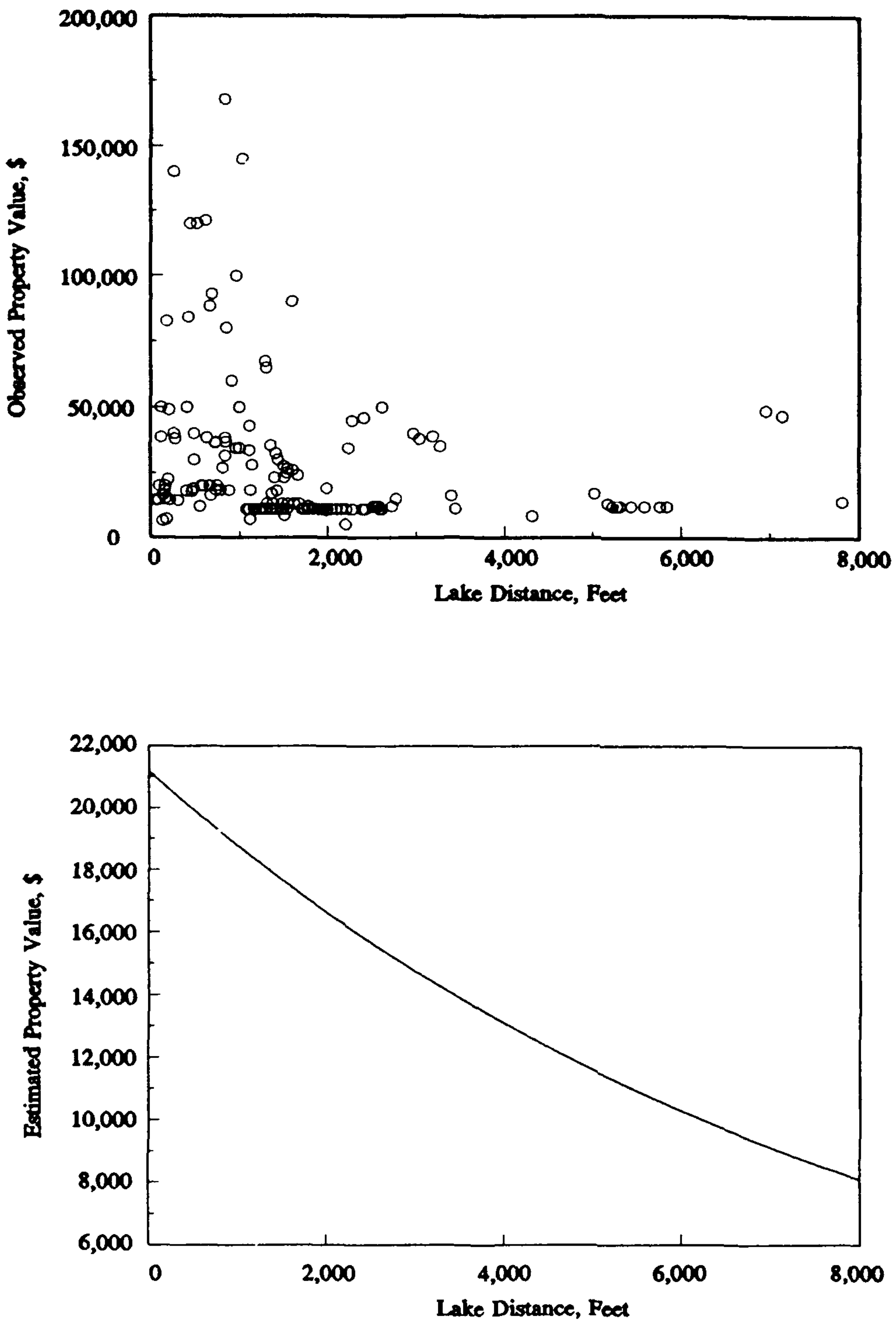


FIGURE VI-1

OBSERVED AND ESTIMATED RELATIONSHIP BETWEEN PROPERTY VALUE AND DISTANCE

The results of the lake-no lake analysis, discussed in the beginning of Chapter V, indicate nonlakefront property to be 59 percent of the value of lakefront property. The point along the curve in Figure VI-1 (bottom) at which the property value is 59 percent of the value of the lakefront property (lakefront property is where distance from the lake equals 0) is at approximately 4,400 feet. This point on the curve compares favorably with Dornbush and Barranger (1972), but the remaining portion of the curve beyond 4,400 feet indicates benefits greater than those reported by Dornbush and Barranger (1972).

The empirical curve shown in Figure VI-1 (bottom) can be expanded three-dimensionally to develop a surface, which is termed the land rent surface. This concept is often referred to in theory but is rarely shown with actual empirical data. This is the case because continuous data on distance are typically not made part of the model. With use of continuous data in the present effort, empirical land rent surfaces can be explored. The land rent surface produced in the following figures are a means to present the concept and results of the land rent gradient model. The precise shape of the surfaces are a function of the interpolation used in the mapping software (Gossette 1992). Therefore any empirical analysis should be based on the mathematical models versus data pulled from the land rent surface maps.

The land rent surface for Long Lake is shown two-dimensionally in Figure VI-2 through isovalue lines (where like land values are connected through interpolation). The values associated with each line are in $1,000, thus the first band around Long Lake indicates property values of $18,000. The isovalue lines are created by using: the average values for FTSQ, SHOP, and CBD; the observed TSI value for Long Lake (66); and selectively varying LAKE1D. Therefore, the variance in isovalues is caused by distance from the lake only. The deflationary impact of distance is indicated by the continual decreasing bands of isovalues as distance from Long Lake increases.

Lake quality as measured through TSI has a negative relationship with property value. The observed data for TSI and property values are shown in Figure VI-3 (top) which indicates a decreasing trend. Property value versus TSI is shown in Figure VI-3 (bottom) by holding all independent variables at their mean and varying TSI. This shows the inverse relationship according to the calibrated model. The relationship is nonlinear as was specified through the semilog functional form of the statistical model. Movement of 10 TSI results in about a 20 percent impact on price.

The difference in land values associated with a changing TSI from 66 (the value for TSI shown in Figure VI-2) to the 54.5 (the sample average in this study) for the Long Lake region is shown in Figure VI-4. This causes increases in property value throughout the Long Lake region that are more pronounced near the lakefront. The first isovalue line from the lake indicates a $2,750 increase in property value associated with the enhanced water quality conditions. The isovalue lines decrease with distance from the lake, which follows the trend of decreasing lake impact with lake distance as shown in the statistical model.

To further illustrate the impact of distance and TSI of lake resources on land values, a four-lake region is shown in Figure VI-5 (again, all variables are held constant except for LAKE1D and TSI). Lakes Underhill, Como, Giles, and Arnold with a TSI range of 62 to 75

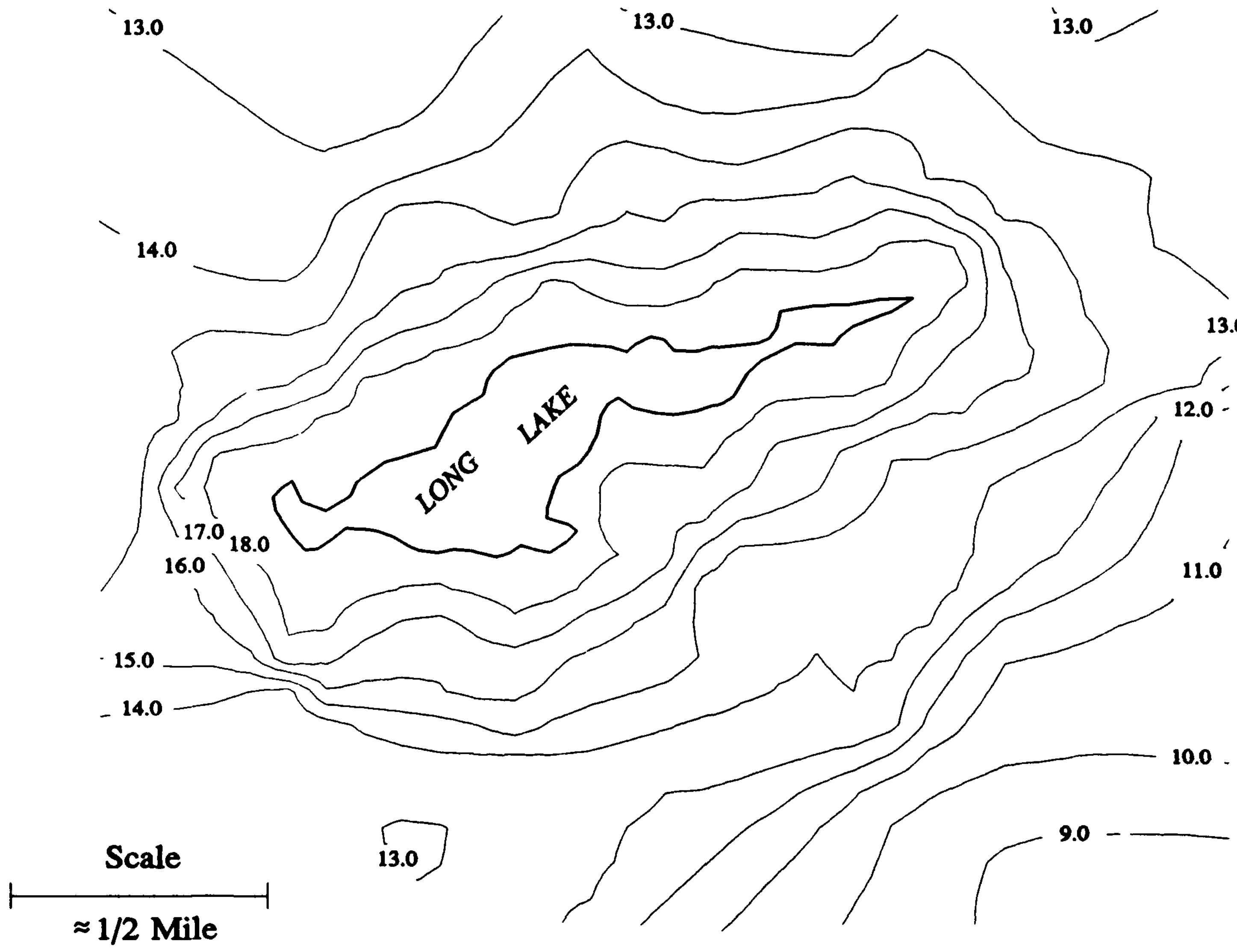


FIGURE VI-2

EMPIRICAL ISOVALUE LINES FOR LONG LAKE ($1,000) IN 1983

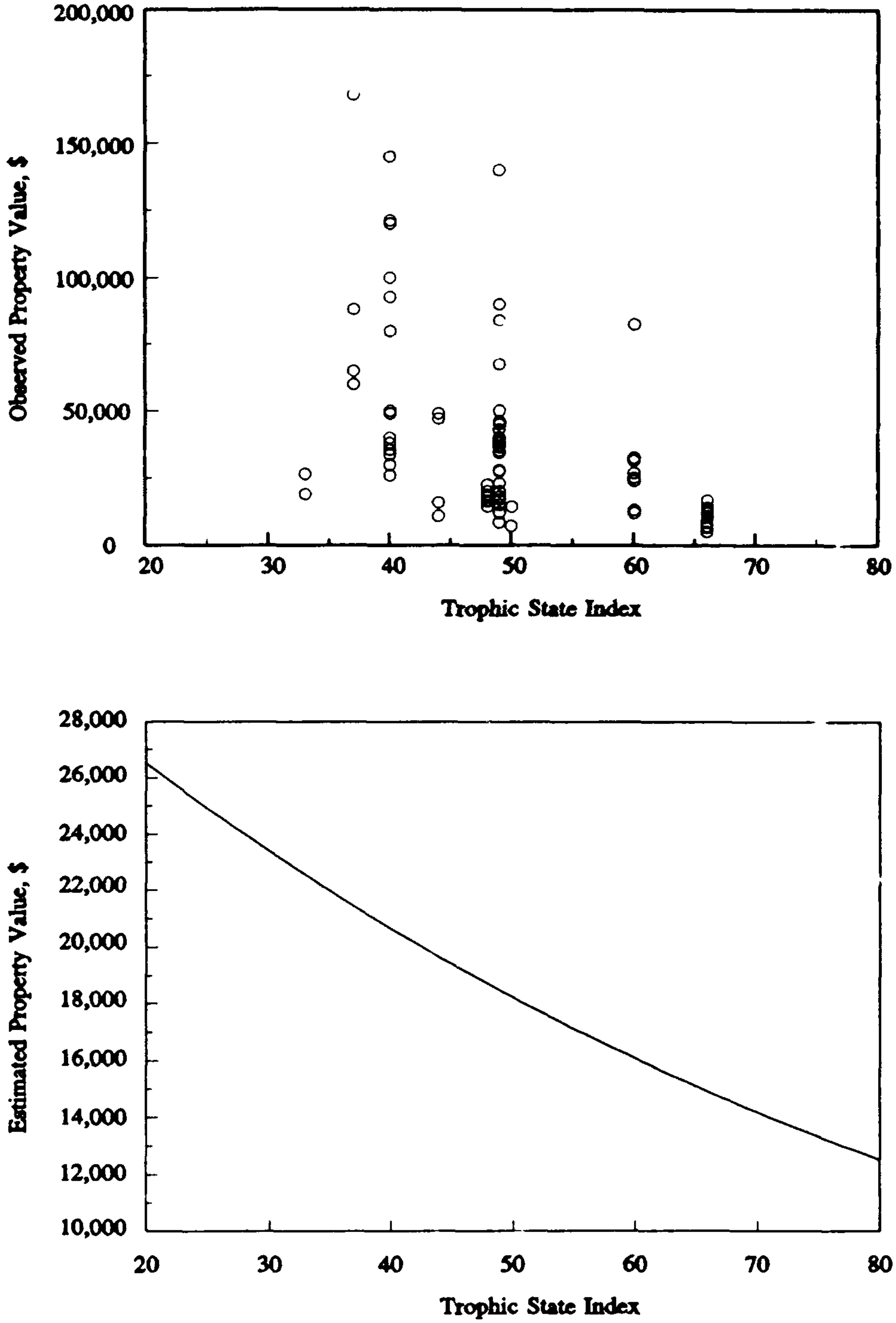


FIGURE VI-3

OBSERVED AND ESTIMATED RELATIONSHIP BETWEEN PROPERTY VALUE AND TSI

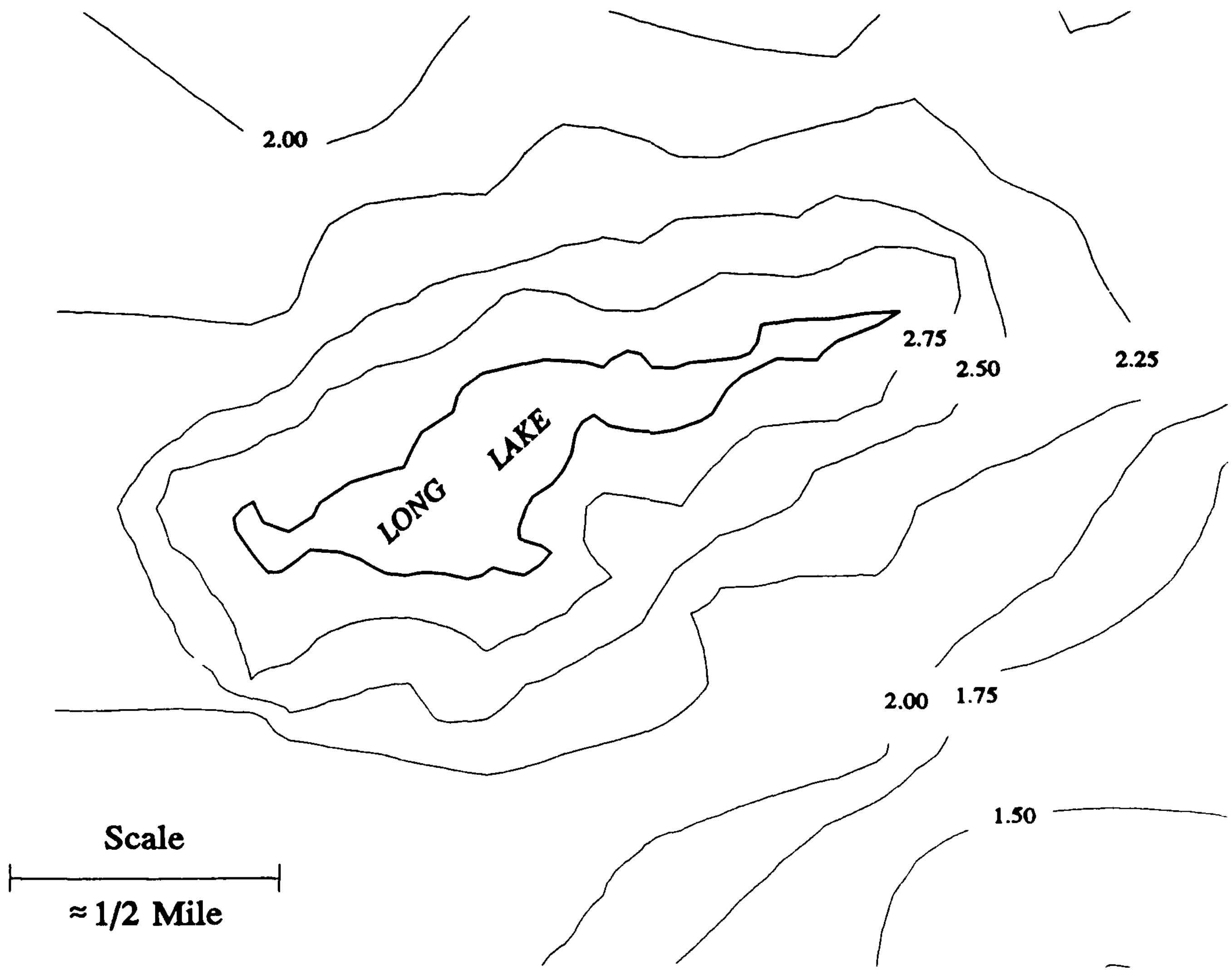


FIGURE VI-4

TSI STIMULATED VALUE CHANGES AT LONG LAKE ($1,000) IN 1983

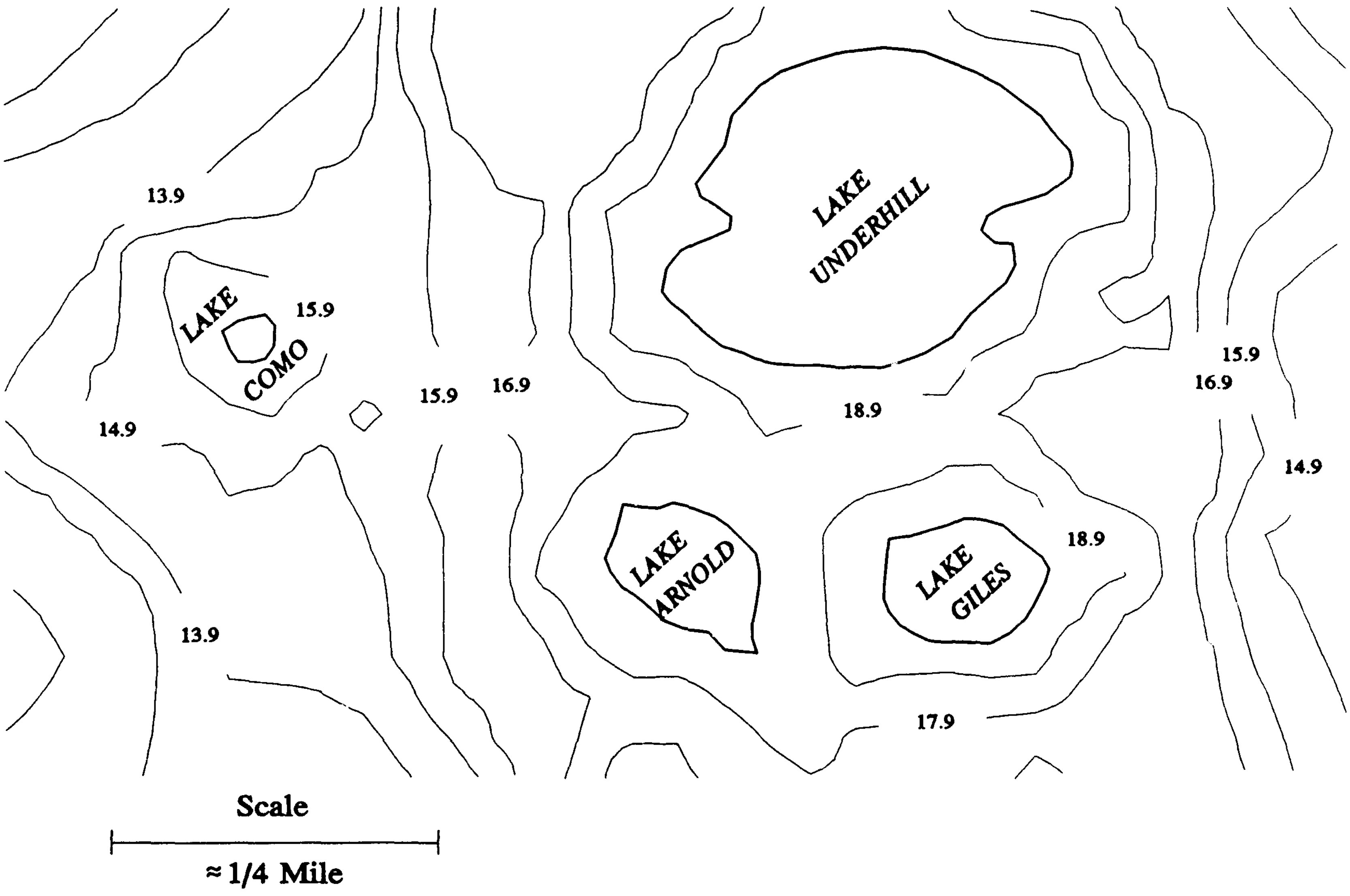


FIGURE VI-5

EMPIRICAL ISOVALUE LINES FOR FOUR LAKE REGIONS ($1,000) IN 1983 show the varying demand for higher-quality lakes. TSI for Lakes Underhill and Giles is 62, and TSI is 65 and 75 for Lakes Arnold and Como, respectively. The higher plateaus are shown at the lesser eutrophic, higher-quality lakes: Giles and Underhill. Lake Como, which is the most eutrophic lake, causes the lowest peak in the region's land rent surface.

Performance of Trophic State Index

TSI was highly significant in both the lake quality model and the land rent gradient model. The difficulties in finding an appropriate water quality metric were discussed in Chapter IV, and the decision to use TSI was made. The results described above indicate TSI is recognized in the residential property market and is therefore, applicable in hedonic valuation framework. As the engineering community becomes more comfortable with TSI development, the exact form will likely change, which would in turn affect the parameter estimates. Certainly, though, this study supports the use of TSI as an indicator of water quality in the hedonic valuation framework.

HEDONIC VALUATION AS A PLANNING TOOL

Probably one of the more encouraging results to surface from this research is that hedonic valuation can be used by water resource managers to measure a portion of water resource benefits. (As discussed earlier, the precise type of benefits being measured by hedonic valuation may not be clear). This point has not received attention until now because the intricacies of the data and statistical analysis have received a majority of the discussion. If the study area of interest has an active GIS with parcel level property value information, the planner has a tremendous advantage because the required data are in a digitized form and can readily be used in empirical analyses. Provided below is a summary of the suggested procedure for conducting hedonic valuation for lake resources.

Step 1: Determine the Purpose of Application

Generally, hedonic method is used to estimate a portion of the benefits attributed to lake resources as discussed earlier in this chapter. If a particular application is intended, this should be explored fully to determine exactly which benefits are being measured. If, for example, hedonic valuation is being used in conjunction with a contingent valuation survey to estimate the value of a reservoir, the overlap of the two valuation methods must be carefully examined. Another case might apply hedonic valuation, alone to determine "who pays" for a lake clean-up effort. In either case (all cases), a full understanding of the application purpose is critical and will also dictate data needs.

Step 2: Determine Study Area

The study area is dependent on the purpose of the analysis (step 1). If the focus is on a single site, then possibly a region of ten miles or so around the lake is required. If a wider regional demand specification is derived, then a county or multiple county study area is needed. The most likely situation will be that the planner will be controlled by the amount of data available. Databases with parcel level information are not typically formed for more than one county.

Step 3: Define Data Sources and Create Working Databases

A comprehensive database is essential for application to hedonic valuation. The database should be structured so that any combination of variables can be compared and evaluated. Property data should include sales price, size of parcel, type of sale, and time of sale. The relative distances between parcels and lakes are needed. It is also important to include distance to other important factors that may influence property value (e.g., distance to shopping).

Technical lake characteristic data are required as part of the database. TSI is a recommended starting point based upon the successful application in the present effort. Lake characteristics data are typically available through environmental or regulatory agencies at the local, state, or federal levels. All avenues should be pursued, as lake characteristic data, especially describing water quality, are scarce.

If a GIS is available and the property appraiser's information is part of it, a large part of the data gathering is complete. It is important to exclude the property value data of nonmarket transactions. This research also shows that examination of vacant parcels greatly reduces the data needed to control for the variance that structures add to the parcel selling price. Determine first which lakes' data are available, which in turn dictates the property value data needed. This greatly reduces the value of required property value data. If a relatively small region is being examined, the property quantity data needed may be quite manageable, even if they are gathered from hard copy sources.

Step 4: Calibrate Model

Given the database developed in step 3, run a statistical model using sale price as the dependent variable. This may require careful statistical insight—the processes presented in Chapter V (land rent gradient model) can be used as a guide. Parameter estimates should be compared with past work. Most importantly, check that the model provides realistic results and recognize its limitations.

Step 5: Examine Benefits of Alternative Projects

The effects of proposed engineering projects on the lake are then evaluated in terms of the model. If TSI is a parameter, the TSI values, before and after the project, are plugged into the model and the difference is a measure of project benefits. All assumptions and benefit calculations should be carefully documented. This will allow for reasonable application of the results to benefit-cost analysis and will also aid in future application of the model.

VII. CONCLUSIONS AND RECOMMENDATIONS

The benefit estimation challenges of environmental projects faced by environmental managers will probably exist for decades to come. The question posed in the introduction of this report — "What is the value of a water resource such as a lake?" — has received the attention of researchers in many disciplines.

Certainly there are environmental goods and services to which no monetary value could (or should) be assigned. But as the field of environmental analysis matures, certain "truths" surface that can aid in water resource planning decisions. One such "truth" is that lake resources are capitalized in the market value of proximate land. Economics refers to this as hedonic valuation. The premium paid for property near lakes is an implicit price/value for the lake and is consequently a willingness-to-pay estimate for lake resources.

Contingent valuation, a contemporary technique to elicit the demand for goods and services not sold in a market, is applied in similar cases to which hedonic valuation can be applied. It is apparent though that because of data problems faced creating hedonic models, the method has not received the application attention it deserves. A properly specified hedonic model measures the price <u>actually paid</u> for the lake resource, where contingent valuation uses a hypothetical market. Thus from this perspective hedonic valuation is a superior approach.

This research does not seek to prove that hedonic valuation is the best method, rather it is aimed at promoting applications to lake resources. Successful application of the method is made to Orange County, Florida. Many past attempts at using hedonic valuation have suffered from constrained data and misspecification of the hedonic methodology. Probably the greatest shortcoming of past studies is the absence of a continuous distance to lake variable. This study expands on past work through development of a complete database and careful statistical model specification.

The distance to lake variable indicates a diminishing lake impact as distance increases. This distance decay gradient supports economic and geographic theory. Lake quality, as measured through TSI, is also shown to significantly impact property values. Less eutrophic lakes have higher surrounding property values than more eutrophic lakes. Generally, technical water quality parameters in many cases cannot be perceived by laymen and therefore cannot be realized empirically in market property values. The use of TSI as an indicator of lake quality appears to alleviate this hurdle.

Before application of hedonic valuation can readily be used, a better understanding of the benefits measured by the technique must be formed. Another way of looking at it is, the benefits it shares with other techniques must be understood. It appears that hedonic valuation defines some of the recreation benefits of nearby landowners. These benefits would need to be netted out of recreation benefits defined through an alternative technique (e.g., travel-cost, unit-day value, or contingent valuation). Therefore, it is recommended that a set of case studies using several techniques, with special attention paid to separating the benefits, be conducted.

As research on hedonic valuation continues, additional areas that might need further elaboration include:

1. Continued examination of water quality metrics and further refinement of TSI
2. Enhancement of water quality data collection efforts, possibly in accordance with hedonic valuation studies
3. Continued comparison of hedonic valuation with other benefit estimation techniques
4. Continued application of the hedonic valuation with an emphasis on identifying regional variation in parameter estimates
5. Examination of enhanced interface with GIS to allow periodic updates of the hedonic models
6. Comparison of cross-sectional and time-series approaches to hedonic valuation models

Continued research on alternative benefit estimation methods helps to make use of many data sources in a data-poor field. Methods that allow the water resource planner to draw upon data already collected for other management purposes fills an important analytical gap. This application of hedonic valuation continues the theory and application potential of the method. Tools from engineering, economics, and geography were borrowed to put together this research product, which highlights the importance of interdisciplinary research in environmental valuation.

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APPENDIX A

MODEL PROFILES OF PAST WORK

AUTHORS/SITE

Antle (1977)/Chester Creek Basin, Pennsylvania

FINAL MODELS

$$\underset{}{PV} = \underset{(11.99)}{13124.89} + \underset{(26.06)}{2.06SF} - \underset{(-4.16)}{5148.33FP} - \underset{(-10.97)}{30{,}380.12L1} + \underset{(8.15)}{15{,}110.18L2} - \underset{(-0.74)}{3{,}381.93L3} + \underset{(0.32)}{727.12L4}$$

$R^2 = 0.31$ $\quad$ $n = 1{,}625$

VARIABLE DEFINITIONS

PV	=	property value
SF	=	square feet of property
FP	=	1 indicates in floodplain
L1	=	locational variable: in Goshen Township
L2	=	locational variable: in Chester Township
L3	=	locational variable: east of I-95
L4	=	locational variable: in Chester City

AUTHORS/SITE

Blomquist (1988)/Chicago, Illinois

FINAL MODELS

$$HE = \underset{(6.79)}{108.00RM} + \underset{(0.85)}{30.20BTH} + \underset{(2.63)}{0.014LV} + \underset{(1.29)}{29.40CPT} - \underset{(-0.56)}{19.20DW} + \underset{(0.02)}{0.492AIR} - \underset{(-0.13)}{5.77FUR} + \underset{(2.44)}{3.14FLR} + \underset{(1.66)}{0.024VW}$$

$$- \underset{(-0.82)}{0.011WA} + \underset{(3.72)}{100.00OWN} - \underset{(-3.33)}{134.00BGA} - \underset{(-3.48)}{143.00BGB} - \underset{(-1.43)}{48.80BGC} - \underset{(-0.55)}{22.20BGD} - \underset{(-0.88)}{44.60BGE}$$

$R^2 = 0.85$ $\quad$ $n = 15.9$

NOTE: Because of complex transformation and calibration, parameter estimates are based upon a mean of HE.

VARIABLE DEFINITIONS

RM	=	number of rooms excluding bathrooms
BTH	=	number of bathrooms
LV	=	living area, square meters
CPT	=	1 if carpeted
DW	=	1 if dishwasher exists
AIR	=	1 if window air-conditioner exists
FUR	=	1 if furnished
FLR	=	floor/story of building
VW	=	unobstructed view of Lake Michigan in square meters
WA	=	total window area in square meters
OWN	=	1 if owned
BGx	=	1 if building A, B, C, D, E

AUTHORS/SITE

Brown and Pollakowski (1976)/Seattle, Washington

FINAL MODELS

$$\begin{aligned} PVS = {} & \underset{(4.61)}{16{,}500.00} + \underset{(2.27)}{4.17LV} - \underset{(-1.87)}{74.60AGE} - \underset{(-1.19)}{13.80RS} + \underset{(0.69)}{417.00FP} + \underset{(2.45)}{1{,}510.00GAR} - \underset{(-0.11)}{44.40ROM} + \underset{(4.30)}{5{,}120.00BR} + \underset{(0.36)}{300.00BAS} \\ & + \underset{(0.37)}{308.00DW} + \underset{(0.45)}{289.00QUA} + \underset{(0.36)}{298.00OVN} + \underset{(1.71)}{5{,}790.00HOT} - \underset{(-0.54)}{540.00FUR} - \underset{(-2.03)}{2{,}250.00HT} + \underset{(2.26)}{0.24LOT} \\ & + \underset{(1.12)}{1{,}340.00VW} - \underset{(-2.45)}{1{,}730.00HL} - \underset{(-5.09)}{2{,}790.00DIS} \end{aligned}$$

$R^2 = 0.78$ $n = 89$

NOTE: Observations weighted by 1/LV

VARIABLE DEFINITIONS

PVS = selling price
LV = living area, square feet
AGE = age of house
RS = average room size
FP = number of fireplaces
GAR = number of car garages
ROM = number of rooms on first story
BR = number of bathrooms

BAS = 1 if basement exists
DW = 1 if dishwasher exists
QUA = 1 if good or excellent building quality
OVN = 1 if range or oven exists
HOT = 1 if hit water heating exists
FUR = 1 if well or floor furnishing exists
HT = 1 if electric heating exists
LOT = lot size, square feet

VW = 1 if view exists
HL = 1 if haller lake in area
DIS = log of distance to water front

AUTHORS/SITE

d'Arge & Shogren (1989)/Okoboji Lakes, Iowa

FINAL MODELS

$$PV = \underset{(-1.09)}{-\,20{,}657} + \underset{(10.09)}{84{,}139.00EOW} + \underset{(2.76)}{15.93HSF} + \underset{(1.83)}{3{,}836.00TR} - \underset{(-5.21)}{850.00AGE} + \underset{(5.79)}{1{,}037.00FF} + \underset{(0.22)}{1{,}600.00OB}$$

$R^2 = 0.87$ $\quad$ $n = 66$

VARIABLE DEFINITIONS

PV = assessed value of property
EOW = 1 indicates West Lake Okoboji
HSF = house square footage
TR = total rooms
AGE = age of house
FF = lakefront footage
OB = number of other buildings

AUTHORS/SITE

Darling (1987)/Lakes Merritt, Murray & Santee, California

FINAL MODELS

$$\underset{}{PV} = \underset{(NR)}{1{,}301.5} - \underset{(0.15)}{71.6DI} - \underset{(2.13)}{1{,}914.2YR} - \underset{(0.92)}{95.7YRB} + \underset{(2.33)}{2.1SFL} + \underset{(1.44)}{2.6SFH} + \underset{(0.26)}{511.9NB} + \underset{(0.71)}{4{,}558.2Z13} - \underset{(-0.28)}{1{,}286.6Z15} - \underset{(-0.17)}{542.4Z17}$$

$$+ \underset{(0.93)}{4{,}734.8CT27} - \underset{(-0.25)}{1{,}639.3CT31} - \underset{(-0.22)}{13.2CR}$$

$R^2 = 0.85$ $\quad$ $n = NR$

VARIABLE DEFINITIONS

PV	=	property value
DI	=	lake distance
YR	=	year sold
YRB	=	year built
SFL	=	lot square footage
SFH	=	house square footage
NB	=	number of bathrooms
Zx,CTx	=	geographical variables
CR	=	crime rate

AUTHORS/SITE

David (1968)/Wisconsin

FINAL MODEL

$$PV = -83.00 - 84.00SW + 10.00ALL + 0.08SWI - 73.00TOP + 28.00WQM + 74.00WPG + 364.00SL$$

$$R^2 = NR \qquad n = 2{,}131$$

NOTE: Standard error or t-statistics were not reported. All coefficients were reported as significant with the exception of *ALL*

VARIABLE DEFINITIONS

PV	=	weighted sum of land values per tract
SW	=	1 indicates swamp exists
ALL	=	1 indicates lake access
SWI	=	surface-water index
TOP	=	1 indicates steep topography
WQM	=	1 indicates moderate water quality
WQG	=	1 indicates good water quality

AUTHOR/SITE

Donnelly (1989)/LaCrosse, Wisconsin

FINAL MODELS

$$\underset{(2.97)}{PV = 20{,}044} + \underset{(12.64)}{34.44RTAX} - \underset{(-3.25)}{259.53AGE} + \underset{(10.96)}{20.41LIV} + \underset{(3.28)}{6.94GAR} + \underset{(4.38)}{0.87LOT} + \underset{(7.23)}{7{,}096.80AC} + \underset{(8.24)}{9045.4FP}$$

$$- \underset{(-3.02)}{5.53FLD} + \underset{(2.07)}{1{,}952.40STH} - \underset{(-2.16)}{1{,}960.00YR}$$

$R^2 = 0.84$ $\quad$ $n = 224$

VARIABLE DEFINITIONS

PV	=	selling price
RTAX	=	residual regressing property
AGE	=	age of house
LIV	=	finished floorspace
GAR	=	size of garage
LOT	=	size of lot
AC	=	air-conditioning
FP	=	fireplace
FLD	=	floodplain variable
STH	=	southside location
YR	=	year of sale

AUTHOR/SITE

Epp and Al-Ani (1979)/Pennsylvania

FINAL MODELS

$$\log(PV) = -\ 7.84 + \underset{(4.47)}{0.25\log(WQ)} + \underset{(5.86)}{0.13\log(PWQ)} - \underset{(-2.87)}{0.49\log(FH)} + \underset{(3.69)}{0.32\log(LOT)} + \underset{(5.53)}{0.59\log(RM)} + \underset{(5.32)}{0.13\log(EMP)}$$

$$+ \underset{(5.40)}{2.18\log(PUP)} - \underset{(-0.13)}{0.002(APO)} - \underset{-1.62)}{0.27\log(AG1)} - \underset{(-3.19)}{0.53\log(AG2)} - \underset{(-5.01)}{0.82\log(AG3)} - \underset{(-3.25)}{0.17\log(INC)}$$

$R^2 = 0.69$ $\qquad$ $n = 212$

VARIABLE DEFINITIONS

WQ	=	perceived water quality, 1 indicates no water problem exists
PWQ	=	interaction factor between APO and WQ
FH	=	flood hazard probability
LOT	=	lot size in acres
RM	=	number of rooms
EMP	=	potential employment measured in number of jobs
PUP	=	per pupil tax expenditure on schools
APO	=	percent change in population 1960-70
AG1	=	indicates age of house is 10-24 years
AG2	=	indicates age of house is 25-49 years
AG3	=	indicates age of house is more than 50 years
INC	=	1 indicates family annual income greater than $10,000

AUTHOR/SITE

Jack Faucett Associates (1991)/Chesapeake Bay Region

FINAL MODEL

$$\underset{}{PV} = \underset{(3.76)}{25{,}387.00} + \underset{(4.39)}{8.05HA} + \underset{(4.91)}{37{,}619.00PB} - \underset{(-2.43)}{3{,}473.51ER} - \underset{(-4.78)}{42166.00GR} + \underset{(2.44)}{6{,}621.63BQ} + \underset{(2.77)}{62{,}815.00WF} - \underset{(-2.80)}{17{,}762.00NB}$$

$$+ \underset{(7.88)}{97{,}156.00CS} + \underset{(4.11)}{43{,}755.00DP} + \underset{(1.99)}{4{,}234.75YR} + \underset{(15.21)}{47{,}774.00HS} - \underset{(-2.55)}{73{,}314.00CL} - \underset{(-1.81)}{36{,}188.00REV} + \underset{(2.30)}{42{,}537.00SW}$$

$R^2 = 0.58$ $\quad$ $n = 33$

VARIABLE DEFINITIONS

PV = transaction price
HA = house area in square feet
PB = 1 if public beach exists
ER = beach erosion rate in feet per year
GR = 1 if grocer is within 1 mile
BQ = beach quality on scale of 1 to 5 (5 = good)
WF = 1 if waterfront property
NB = 1 if North Beach community
CS = 1 if Chesapeake Station Community
DP = 1 if Drum Point community
YR = year of sale
HS = house exists
CL = 1 if cliff exists
REV = 1 if revetment
SW = 1 if sandy place to walk

AUTHORS/SITE

Khairi-Chetri and Hite (1990)/Lake Keowee, South Carolina

FINAL MODELS

$$PV = \underset{(6.05)}{408{,}000} - \underset{(-1.99)}{5{,}434DEV} - \underset{(-5.14)}{137{,}444SIZ} - \underset{(-3.33)}{16{,}122MR} + \underset{(3.08)}{55{,}762SHP}$$

$$R^2 = 0.24 \qquad n = 170$$

$$logPV = \underset{(29.16)}{13.53} - \underset{(-1.68)}{0.03DEV} - \underset{(-4.18)}{1.18SIZ} - \underset{(3.17)}{0.11MR} + \underset{(3.08)}{0.38SHP}$$

$$R^2 = 0.29 \qquad n = 170$$

VARIABLE DEFINITIONS

PV	=	price per acre of a lakefront vacant lot sold
DEV	=	a measure of deviations of lake stage obtained by subtracting monthly average levels from full pool level
SIZ	=	size of lot sold in acre
SHP	=	a dummy variable classifying lot shape, either regular irregular
MR	=	annual mortgage rate in percent

AUTHORS/SITE

Knetsch (1964)/Tennessee Valley

FINAL MODELS

$$\underset{(NR)}{UPV = 1{,}239.56} + \underset{(13.46)}{65.42RF} - \underset{(-16.23)}{87.00DIS} + \underset{(14.40)}{18.72DIS^2} + \underset{(21.96)}{81.48TOP} - \underset{(-10.98)}{35.81WW} + \underset{(9.50)}{0.004UV} + \underset{(303.25)}{1.21VI} + \underset{(49.2)}{1.33CD}$$

$R^2 = 0.76$ $\quad$ $n = 519$

VARIABLE DEFINITION

UPV = property value in dollars per acre
RF = 1 indicates reservoirfront property
DIS = distance from reservoir in miles
TOP = topography index
WW = workweek
UV = urban proximity metric
VI = value of improvement in dollars per acre
CD = cost of development in dollars per acre

AUTHORS/SITE

Rich & Moffitt (1982)/Housatonic River, Massachusetts

FINAL MODELS

$$\underset{}{\mathrm{LN(UPV)}} = -\,0.45 \underset{(0.73)}{+\,0.19\mathit{RL}} \underset{(3.31)}{+\,1.05\mathit{CU}} \underset{(-0.86)}{-\,0.18\mathrm{LN}(\mathit{LOT})} \underset{(3.15)}{+\,0.54\mathrm{LN}(\mathit{BLG})} \underset{(3.68)}{+\,0.74\mathrm{LN}(\mathit{ALV})} \underset{(-3.21)}{-\,0.62\mathrm{LN}(\mathit{HPI})}$$

$$R^2 = 0.81 \qquad n = 42$$

VARIABLE DEFINITIONS

UPV = sales price per acre
RL = 1 indicates riparian land
CU = 1 indicates sold after river cleanup
LOT = size of lot in acres
BLG = assessed value of buildings in previous year
ALV = assessed value of land in previous year
HPI = U.S. homeownership price index first difference

AUTHORS/SITE

Reynolds et al. (1973)/Kissimmee River Region

FINAL MODELS

$$\underset{}{PV} = 863.85 + \underset{(38.77)}{102.75YR} + \underset{(10.12)}{342.89LOT} + \underset{(17.59)}{3231.51LF} + \underset{(3.15)}{808.59CF} - \underset{(-1.71)}{143.95NPR} + \underset{(4.50)}{370.60UTL} - \underset{(-1.38)}{4.04WDH}$$

$R^2 = 0.63$ $\quad$ $n = 316$

VARIABLE DEFINITIONS

PV	=	property value
YR	=	year of sale (1966 = 1, 1967 = 2, 1968 = 3, 1969 = 4, 1970 = 5)
LOT	=	size of lot in acres
LF	=	1 if lakefront property
CF	=	1 if canal-front property
NPR	=	distance to paved road, miles
UTL	=	number of utilities in subdivision
WDH	=	percent of wood homes in subdivision

AUTHORS/SITE

Young and Teti (1984)/St. Albons Bay, Vermont

FINAL MODELS

$$\underset{}{PV} = \underset{(4.11)}{-\ 23{,}841.50} + \underset{(1.83)}{16.38LFT} + \underset{(2.02)}{6.76SIZ} + \underset{(2.53)}{1{,}417.08WQ} + \underset{(3.90)}{7{,}985.02POR} + \underset{(3.60)}{9{,}836.14EXB} + \underset{(4.26)}{529.20QDW}$$

$R^2 = 0.68$ $\quad$ $n = 93$

VARIABLE DEFINITION

PV = selling price
LFT = lakefront in feet
SIZ = square feet of living space
WQ = water quality rating: 1 indicates poor, 10 indicates excellent
POR = enclosed porch
EXB = extra buildings
QDW = quality of construction: 1 indicates poor, 100 indicates excellent

APPENDIX B

LAKE QUALITY MODEL DATABASE

PARCEL	YEAR	ACTPR	TSI	SIZE	FTSQ	UNITPR
272313411000180	84	175000	33	1665	40200	4.3532
282032252000100	83	20000	48	1	23205	0.8619
282032252000110	83	20000	48	1	22725	0.8801
282032252000120	83	14375	48	1	21300	0.6749
282136520303060	82	8000	66	122	12750	0.6275
282136520303070	83	6500	66	122	13600	0.4779
282136520303070	84	12500	66	122	13600	0.9191
282304440600160	83	92900	40	872	47916	1.9388
282305054500020	84	100000	40	872	41850	2.3695
282305439600090	84	100000	40	872	17600	5.6818
282305481800100	84	165000	40	872	37500	4.4000
282305481800220	83	110000	40	872	34200	3.2164
282305550200010	83	145000	40	872	62726	2.3116
282305550200020	83	100000	40	872	49223	2.0316
282307561601640	83	125000	33	1665	55250	2.2624
282309000000008	83	121304	40	872	88305	1.3737
282309000000021	83	33696	40	872	40095	0.8404
282309440800040	83	120000	40	872	49766	2.4113
282328060000200	83	250000	37	1198	13440	18.6012
282332187200290	83	88195	37	1198	39000	2.2614
292125000000028	84	30000	43	36	377665	0.0794
292201000000030	82	5000	49	237	5625	0.8889
292201000000031	82	5000	49	237	7600	0.6579
292201000000032	82	5000	49	237	6400	0.7813
292209052400080	84	35000	35	36	30000	1.1667
292223001602080	84	98000	55	23	8650	11.3295
292227000000059	83	45000	68	44	4000	11.2500
292232460803040	82	7800	50	244	19150	0.4073
292301407600090	84	37000	75	8	11375	3.2527
292301407600100	84	40000	75	8	14400	2.7778
292303140000100	83	17500	55	339	6480	2.7006
302130567601430	83	84000	49	96	9990	8.4084
302130887200160	83	140000	49	96	14080	9.9432
302130887200190	82	110000	49	96	14300	7.6923
302130887200220	84	139000	49	96	15400	9.0260
302205004200030	82	150000	49	451	3564	42.0875
302207890808090	82	115000	48	233	8160	14.0931
302218067200020	83	7111	50	140	2436	2.9191
302218067200040	83	14322	50	140	4408	3.2491
302318716001110	84	50000	60	1757	15000	3.3333
302318716002050	83	25000	60	1757	14500	1.7241
302320439500270	83	82500	60	1757	14000	5.8929
302330169201030	84	75000	60	1757	18700	4.0107
312206000000081	83	47000	44	157	37500	1.2533
312206444400220	83	49000	44	157	17955	2.7290

APPENDIX C

DISTANCE PROGRAM IN BASIC

```
LIST
10  INPUT "THE NUMBER OF PARCELS = "; NPARC
20  INPUT "THE NUMBER OF LAKES = "; LK
30  INPUT "THE NUMBER OF TRANSPORTATION HUBS= "; HUB
40  INPUT "THE NUMBER OF MULTI-PURPOSE SHOPPING CENTERS= "; SHOP
45  DEFDBL P
50  DIM CENT(LK,3),CDIS(LK,2),XLOSE(6,2),HUBDAT(HUB,2),SHOPDAT(SHOP,2)
60  DIM HUBDIST(NPARC,1), SHOPDIS(NPARC,2), PARCEL(NPARC,17)
70  DIM DIS(LK), LNUM(LK), DISD(6), LNUMD(6)
80  REM ACCESS TO LAKE CENTROID FILE TO FILE ARRAY
90  OPEN "D:\DISS\ANALYSIS\BASIC\ACTUAL\CENTROID.DAT" FOR INPUT AS #1
100 FOR J=1 TO LK
110   INPUT #1, CENT(J,1), CENT(J,2), CENT(J,3)
120   REM PRINT CENT(J,1), CENT(J,2), CENT(J,3)
130 NEXT J
140 CLOSE #1
150 REM ACCESS TO PARCEL FILE
160 OPEN "D:\DISS\ANALYSIS\BASIC\ACTUAL\SECTIN.DAT" FOR INPUT AS #1
170 REM INPUT #1, NPARC
180 FOR K=1 TO NPARC
190   INPUT #1, PARCEL(K,1), PARCEL(K,2), PARCEL(K,3)
195   PRINT "START", K, PARCEL(K,1), TIME$
200   FOR LAKE=1 TO LK
210 CDIS(LAKE,1)=((PARCEL(K,2)-(CENT(LAKE,2)*5280))^2+(PARCEL(K,3)-(CENT(LAKE,3)
*5280))^2)^.5
220 CDIS(LAKE,2)=CENT(LAKE,1)
230   REM PRINT "DISTANCE TO CENTERS"
240   REM PRINT CDIS(LAKE,1) CDIS(LAKE,2)
250   NEXT LAKE
260   REM TANDEM SORT OF CENTROID DISTANCES TO EACH LAKE FOR PARCEL K
270   FOR LAKES=1 TO LK
280       DIS(LAKES)=CDIS(LAKES,1)
290      LNUM(LAKES)=CDIS(LAKES,2)
300   NEXT LAKES
310   G=0
320   S=0
330   G=INT(LK/2)
340   FOR L=1 TO LK
350     FOR M=1 TO (LK-G)
360       IF DIS(M) >= DIS(M+G) THEN GOTO 440
370         S=DIS(M)
380         DIS(M)=DIS(M+G)
390         DIS(M+G)=S
400         REM BRING LAKE NUMBER WITH THE DISTANCE VALUE
410         Z=LNUM(M)
420         LNUM(M)=LNUM(M+G)
430         LNUM(M+G)=Z
440      NEXT M
450   NEXT L
460   G=INT(G/2)
470   IF G>0 THEN GOTO 340
480   REM TANDEM SORT IS ENDED
490 FOR ZZZ=1 TO LK
500  REM PRINT "SORTED DISTANCES TO LAKES"
510  REM PRINT LNUM(ZZZ)  DIS(ZZZ)
520 NEXT ZZZ
530   REM USE PETE'S TRICK TO CHOOSE APPROPRIATE BOUNDARY FILE
540   FOR TOP=1 TO 6
550   MIND=5000000!
560     B$=STR$(LNUM(LK+1-TOP))
570     LENB=LEN(B$)
580     B1$=RIGHT$(B$,(LENB-1))
590     BORDF$="D:\DISS\ANALYSIS\BASIC\ACTUAL\LAKE"+B1$+".PRN"
600     REM PRINT "FILENAME =", BORDF$
610     OPEN BORDF$ FOR INPUT AS #2
620     INPUT #2, NLI
```

```
630     FOR JI=1 TO NLI
640       INPUT #2, DX, DY
650       DISX=((PARCEL(K,2)-(DX*5280))^2+(PARCEL(K,3)-(DY*5280))^2)^.5
660       REM PRINT "DISTANCE TO BORDER POINT, DISX =",DISX
670       IF DISX>=MIND GOTO 690
680       MIND=DISX
690     NEXT JI
700     XLOSE(TOP,1)=MIND
710     XLOSE(TOP,2)=LNUM((LK+1)-TOP)
720     CLOSE #2
730     REM PRINT "DISTANCE TO CLOSEST BOUNDARY FOR LAKE",XLOSE(TOP,1)
740   NEXT TOP
750 REM TANDEM SORT OF 6 DISTANCES
760 FOR XX=1 TO 6
770   DISD(XX)=XLOSE(XX,1)
780   LNUMD(XX)=XLOSE(XX,2)
790 NEXT XX
800 G=0: S=0
810 G=INT(6/2)
820 FOR LD=1 TO 6
830     FOR SD=1 TO (6-G)
840       IF DISD(SD)>=DISD(SD+G) THEN GOTO 920
850       S=DISD(SD)
860       DISD(SD)=DISD(SD+G)
870       DISD(SD+G)=S
880       REM BRING LAKE NUMBER WITH THE DISTANCE VALUE
890       ZD=LNUMD(SD)
900       LNUMD(SD)=LNUMD(SD+G)
910       LNUMD(SD+G)=ZD
920    NEXT SD
930  NEXT LD
940  G=INT(G/2)
950  IF G>0 THEN GOTO 820
960  REM FOR LP = 1 TO 6
970    REM PRINT LNUMD(LP),DISD(LP)
980  REM NEXT LP
990 REM TANDEM SORT IS ENDED
1000 REM FILL THE PARCEL ARRAY WITH THREE CLOSEST LAKES
1010 PARCEL(K,4)=LNUMD(6)
1020 PARCEL(K,5)=DISD(6)
1030 PARCEL(K,6)=LNUMD(5)
1040 PARCEL(K,7)=DISD(5)
1050 PARCEL(K,8)=LNUMD(4)
1060 PARCEL(K,9)=DISD(4)
1070 REM CALCULATE THE SHORTEST MULTI-PURPOSE SHOPPING DISTANCE
1080 OPEN "D:\DISS\ANALYSIS\BASIC\ACTUAL\MALLS.DAT" FOR INPUT AS #2
1090 MNSHOP=50000000#
1100 FOR SH=1 TO SHOP
1110  INPUT #2, NMSH, SHX, SHY
1120  SHPDIS=((PARCEL(K,2)-SHX)^2+(PARCEL(K,3)-SHY)^2)^.5
1130  IF SHPDIS>=MNSHOP THEN GOTO 1150
1140  MNSHOP=SHPDIS
1150 NEXT SH
1160 PARCEL(K,10)=MNSHOP
1170 CLOSE #2
1180 REM CALCULATE THE SHORTEST TRANSPORTATION HUB DISTANCE
1190 OPEN "D:\DISS\ANALYSIS\BASIC\ACTUAL\INTER.DAT" FOR INPUT AS #2
1200 MNHUB=500000000#
1210 FOR HB=1 TO HUB
1220   INPUT #2, NMHB, HBX, HBY
1230   HBDIS=((PARCEL(K,2)-HBX)^2+(PARCEL(K,3)-HBY)^2)^.5
1240   IF HBDIS>=MNHUB THEN GOTO 1260
1250   MNHUB=HBDIS
1260 NEXT HB
1270 PARCEL(K,11)=MNHUB
1280 CLOSE #2
```

```
1285  PRINT "FINISH", K, PARCEL(K,1), TIME$
1290 NEXT K
1300 REM PRINT OUT PARCEL ARRAY
1310 REM FOR JP-1 TO NPARC
1[illegible]   REM PRINT "PARCEL NUMBER -";PARCEL(JP,1)
1[illegible]   REM FOR ELEM-1 TO 11
1340       REM PRINT ,,, PARCEL(JP,ELEM)
1350    REM NEXT ELEM
1360 REM NEXT JP
1365 OPEN "D:\DISS\ANALYSIS\BASIC\ACTUAL\SECTOUT.DAT" FOR OUTPUT AS #2
1370 FOR BVD-1 TO NPARC
1390    PRINT#2, USING "##############.";PARCEL(BVD,1);PARCEL(BVD,2);PARCEL(BVD,
3);PARCEL(BVD,4);PARCEL(BVD,5);PARCEL(BVD,6);PARCEL(BVD,7);PARCEL(BVD,8);PARCEL(
BVD,9);PARCEL(BVD,10);PARCEL(BVD,11)
1400 NEXT BVD
1405 CLOSE #2
1410 END
Ok
```

APPENDIX D

LAND RENT GRADIENT MODEL DATABASE

PARCEL	ACTPR	TS11	SIZE1	LAKE1D	LAKE2D	UNITPR	FTSQ	SHOP	HUB	CBD
282328060000200	250000	37	1198	415	3243	18.6012	13440	14941	13952	57260
282328054900170	168000	37	1198	831	3839	18.7291	8970	13828	13198	54998
282305550200010	145000	40	872	1031	3785	2.3116	62726	25491	16045	48767
302130887200160	140000	49	96	262	3338	9.9432	14080	10960	9988	30079
282309000000008	121304	40	872	614	4715	1.3737	88305	19967	19798	47183
282305550200050	120000	40	872	518	3285	2.9622	40511	26233	15306	49081
282309440800040	120000	40	872	439	4708	2.4113	49766	23555	18022	48708
282305550200020	100000	40	872	961	3587	2.0316	49223	25712	15822	48781
282304440600160	92900	40	872	685	3766	1.9388	47916	25763	15785	49080
302130650000120	90000	49	96	1597	4457	2.7024	33304	9112	11831	31555
282332187200290	88195	37	1198	667	2985	2.2614	39000	20012	18398	64131
302130567601430	84000	49	96	423	1827	8.4084	9990	9800	9199	28293
302320439500270	82500	60	1757	181	3362	5.8929	14000	11754	9786	29777
282304506000130	80000	40	872	851	4354	1.8364	43564	24739	16799	48547
302130650000090	67500	49	96	1290	4641	3.7500	18000	9172	11466	31619
282328053301850	65000	37	1198	1300	1746	2.7083	24000	13285	12166	56489
282328054900180	60000	37	1198	906	3888	6.6043	9085	13746	13119	54931
302130948600050	50000	49	96	405	1863	4.0568	12325	9808	9084	28254
282305550200150	50000	40	872	115	3423	1.0300	48544	26419	15146	49509
282304933200550	50000	40	872	997	2545	3.4341	14560	26609	14925	48533
302132133800080	50000	49	451	2618	5677	4.2173	11856	8950	16076	28444
312206444400220	49000	44	157	6954	8187	2.7290	17955	2647	20814	27343
282305550200260	49000	40	872	205	3925	1.0107	48480	25968	15620	49581
312206000000081	47000	44	157	7136	7748	1.2533	37500	2441	20574	26776
302129181200320	46000	49	451	2412	3616	2.8264	16275	9677	13722	29223
302129181200302	45000	49	451	2277	3779	6.6964	6720	9407	13808	28963
302130862400010	43000	49	96	1112	4506	3.1525	13640	9137	10929	31949
282305550200160	40000	40	872	259	3436	1.0582	37800	26298	15259	49375
302130948600060	40000	49	96	484	1790	3.4858	11475	9728	9094	28175
302129181200230	40000	49	451	2968	3849	1.3331	30005	10193	14064	29753
302129181200210	39000	49	451	3186	3805	0.6995	55757	10488	14078	30044
302130887200130	38750	49	96	113	3149	2.9135	13300	10923	10382	29950
302130862400150	38500	49	96	623	3960	3.4056	11305	9708	10307	31559
302130862400090	38500	49	96	836	4268	3.3478	11500	9438	10639	31713
282309440800080	38000	40	872	270	4953	0.9281	40946	24020	17519	48363
302129181200200	38000	49	451	3038	3590	1.4539	26136	10437	13861	29978
302130862400170	37000	49	96	843	3879	2.4269	15246	9557	10310	31784
302130862400110	36600	49	96	727	4200	3.0000	12200	9552	10545	31615
302130862400160	36500	49	96	726	3927	3.0417	12000	9632	10314	31666
282304506000050	35500	40	872	1352	3867	0.8968	39585	24913	16617	48078
302129181200050	35000	49	451	3275	3295	0.9390	37275	10100	13624	30366
302130862400200	34500	49	96	962	4168	3.1944	10800	9353	10598	31867
302129181200480	34500	49	451	2238	3236	1.8419	18731	9723	13358	29235
302130862400210	34500	49	96	1002	4265	2.6077	13230	9290	10693	31890
282309000000021	33696	40	872	1113	5226	0.8404	40095	19608	19311	46653
302330933000460	32500	60	1757	1413	1429	2.2377	14524	14501	7743	35810

302330933000130	31500	60	1757	839	1961	2.1620	14570	14316	7414	35524
282304000000022	30000	40	872	1436	3222	0.6887	43560	25642	15890	48214
282304933200760	30000	40	872	488	2636	2.1739	13800	26890	14641	49100
302130652000120	28000	49	96	1145	4195	2.2148	12642	9186	10679	32057
302130652000160	27500	49	96	1504	4217	2.1770	12632	8886	10797	32432
302330061000280	26800	60	1757	811	3038	2.3304	11500	15442	6061	36443
272311000000039	26500	33	1665	1545	4418	0.5337	49658	36464	18895	66396
282304000000026	26000	40	872	1603	2225	0.5969	43560	26446	15124	47928
302330061000110	25000	60	1757	1538	1555	2.4945	10022	14887	7504	36183
302330061000840	24000	60	1757	1664	2114	1.4981	16020	15558	6892	36783
302130652000150	23000	49	96	1397	4191	2.0921	10994	8980	10747	32325
302130652000030	23000	49	96	1508	4490	2.1028	10938	8795	11032	32380
282031252100150	22500	48	1	195	1733	1.1250	20000	55898	52080	76532
282031252100260	20000	48	1	749	1906	1.3569	14740	56134	52341	77023
282031252100250	20000	48	1	659	1798	1.3468	14850	56152	52353	76972
282031252100240	20000	48	1	569	1747	1.3619	14685	56126	52322	76898
292125320003160	20000	49	96	659	2301	2.5253	7920	11470	7360	29537
292125320100080	20000	49	96	584	2217	2.1978	9100	11742	7518	29821
282032252000110	20000	48	1	161	1649	0.8801	22725	54837	51067	76152
282032252000100	20000	48	1	97	1675	0.8619	23205	54785	51018	76143
272324782002030	19000	33	1665	1988	9732	1.4593	13020	29701	28139	66830
282031252100180	18800	48	1	479	1342	1.0307	18240	56238	52411	76722
282031252100400	18300	48	1	1125	1592	0.7427	24640	56661	52867	77467
282031252100360	18300	48	1	882	1575	1.3864	13200	56464	52663	77224
282031252100270	18300	48	1	781	1985	0.8535	21440	56169	52382	77122
282031252100940	18300	48	1	156	1777	1.0427	17550	55513	51717	76458
282031252100490	18300	48	1	731	1006	0.9853	18573	56500	52662	76829
282031252100130	18000	48	1	398	1818	1.3501	13332	55963	52156	76717
302130652000190	18000	49	96	1424	3992	1.3774	13068	9052	10575	32365
282031252100230	17800	48	1	459	1686	0.8051	22110	56091	52281	76800
292136211212160	17000	49	451	1367	2858	2.5185	6750	3585	8254	21783
292131276800090	16800	66	122	5019	5250	0.4200	40000	23741	19288	31095
282031252100750	16500	48	1	141	2077	1.3095	12600	55518	51745	76711
282031252100080	16300	48	1	676	2158	1.1399	14300	56063	52282	77100
302206116803030	15925	44	157	3398	4457	2.5983	6129	6246	17001	23958
292212499604220	15000	49	237	2774	2851	2.1429	7000	5186	2757	13122
292201522400055	15000	49	237	166	4030	0.9921	15120	1991	4691	17764
282032252000120	14375	48	1	209	1634	0.6749	21300	54906	51132	76173
282032252000140	14375	48	1	50	1881	1.0432	13780	55036	51272	76394
282032252000150	14375	48	1	87	1886	1.0417	13800	54934	51174	76350
302218067200040	14322	50	140	302	1412	3.2491	4408	8677	4992	10710
292129000000003	14000	66	122	7807	8173	0.1530	91476	23477	18212	37845
302316252000320	13090	60	1757	5172	5548	1.2020	10890	13817	12714	29362
282136891200220	13020	66	122	1676	5479	1.1972	10875	26332	22789	35277
282136891200230	13020	66	122	1619	5445	1.1890	10950	26385	22799	35347
282136891200250	13020	66	122	1485	5412	0.7115	18300	26517	22854	35506
282136891200260	13020	66	122	1380	5498	1.3354	9750	26622	22963	35598

282136891200270	13020	66	122	1311	5580	1.1972	10875	26692	23049	35651
282136891200240	13020	66	122	1550	5428	0.8037	16200	26451	22827	35427
282201613800190	12000	66	122	2518	3606	1.0695	11220	26429	21677	35989
282201613800160	12000	66	122	2578	3581	0.6810	17620	26736	21762	36375
282201613800150	12000	66	122	2731	3428	0.6928	17322	26624	21613	36291
282201613800170	12000	66	122	2556	3594	0.9367	12811	26680	21756	36300
292212407602130	12000	49	237	550	4191	1.4643	8195	4167	2328	15356
282201613800220	12000	66	122	2523	3635	1.0695	11220	26260	21627	35777
302316252000820	12000	60	1757	5587	5801	1.0947	10962	13880	12830	29655
302316252000390	12000	60	1757	5313	5977	1.1014	10895	14113	12547	29784
302316252000900	12000	60	1757	5280	5661	1.0044	11948	13859	12722	29471
302316252000860	12000	60	1757	5437	5661	1.0670	11247	13781	12840	29463
282201613800260	12000	66	122	2557	3714	0.7815	15355	26004	21556	35455
302316252000380	12000	60	1757	5228	5979	1.1730	10230	14156	12482	29790
282201613800230	12000	66	122	2531	3649	1.0695	11220	26204	21611	35707
302316252000450	12000	60	1757	5840	5864	1.1014	10895	14021	12842	29934
302316252000440	12000	60	1757	5761	5884	1.1014	10895	14024	12803	29901
292201000000071	12000	49	237	1778	3238	1.5949	7524	1325	6165	19049
282136891200510	10850	66	122	1776	6065	0.9819	11050	26386	23159	35152
282136891200490	10850	66	122	1925	6144	0.9922	10935	26286	23144	35016
282136891200500	10850	66	122	1850	6104	0.9922	10935	26336	23151	35084
282136891200570	10850	66	122	1424	5816	0.8954	12118	26627	23153	35501
282136891200520	10850	66	122	1736	6003	0.8013	13541	26398	23130	35185
282136891200560	10850	66	122	1488	5850	0.9963	10890	26576	23144	35433
282136891200640	10850	66	122	1709	5770	0.9963	10890	26357	22972	35213
282136891200670	10850	66	122	1851	5917	0.9963	10890	26267	23004	35067
282136891200410	10850	66	122	1539	6109	0.9270	11704	26610	23314	35388
282136891200400	10850	66	122	1480	6081	0.9977	10875	26651	23321	35443
282136891200390	10850	66	122	1423	6054	0.9977	10875	26691	23328	35497
282136891200110	10850	66	122	2282	5516	0.9042	12000	25771	22472	34648
282136891200090	10850	66	122	2393	5683	0.8346	13000	25706	22524	34526
282136891200150	10850	66	122	2043	5835	0.8490	12780	26069	22837	34874
282136891200140	10850	66	122	2098	5759	0.9936	10920	25998	22750	34820
282136891200130	10850	66	122	2155	5682	0.9819	11050	25926	22662	34766
282136891200120	10850	66	122	2211	5582	0.8346	13000	25852	22560	34716
282136891200170	10850	66	122	1952	5644	0.9042	12000	26106	22751	34974
282136891200100	10850	66	122	2400	5597	0.9042	12000	25680	22459	34524
282136891200030	10850	66	122	2427	5861	0.9936	10920	25725	22636	34492
282136891200370	10850	66	122	1297	5995	0.9977	10875	26782	23344	35620
282136891200050	10850	66	122	2591	6175	1.0169	10670	25694	22792	34362
282136891200040	10850	66	122	1374	5323	0.9936	10920	26634	22864	35668
282136891200020	10850	66	122	2614	5881	0.9936	10920	25557	22538	34306
282136891200160	10850	66	122	1994	5716	0.7535	14400	26083	22778	34927
282136891200380	10850	66	122	1351	6020	0.9977	10875	26742	23337	35566
282136891200300	10850	66	122	1106	5754	0.6165	17600	26901	23265	35834
282136891200340	10850	66	122	1079	5981	1.0433	10400	26973	23439	35842
282136891200180	10850	66	122	1900	5613	0.9977	10875	26146	22757	35029

282136891200360	10850	66	122	1229	5963	0.9874	10988	26834	23354	35689
282136891200350	10850	66	122	1165	5933	1.1322	9583	26885	23363	35758
282136891200190	10850	66	122	1834	5574	0.9977	10875	26198	22766	35098
282136891200210	10850	66	122	1735	5515	0.9977	10875	26281	22780	35208
282136891200290	10850	66	122	1180	5744	0.7282	14900	26831	23222	35757
282136891200200	10850	66	122	1784	5544	0.9977	10875	26239	22773	35153
282136891200280	10850	66	122	1257	5646	0.9977	10875	26748	23119	35694
302206116803032	10840	44	157	3444	4501	2.5797	4202	6198	17045	23991
282125925203010	10500	66	122	1984	3745	1.4483	7250	30909	24889	38779
292201371205191	8500	49	237	1509	2781	1.1708	7260	1955	5544	19244
292131730801100	8300	66	122	4310	6380	0.7632	10875	25136	19369	32106
302218067200020	7111	50	140	177	1271	2.9191	2436	8823	5020	10573
282125925208230	7000	66	122	1117	4805	1.1667	6000	29887	24077	37682
282136520303070	6500	66	122	131	6221	0.4779	13600	28475	24849	36729
282125925202200	5000	66	122	2203	3754	0.8333	6000	30985	24405	38696

APPENDIX E

BOX-COX PROCEDURE PROGRAM IN SAS

```
options ps=66 ;
*********************************************************************
* BOX COX PROCEDURE. THIS PROGRAM COMPUTER MAX LIKELIHOOD        *
* ESTIMATORS FOR GIVEN VALUES FOR THETA AND LAMDA. INPUT DIF-   *
* FERENT COMBINATIONS OF THETA AND LAMDA; RUN THE PROGRAM TO
*
* OBTAIN THE MAXIMUM LIKELIHOOD ESTIMATOR. FINALLY CHOOSE THE    *
* TRANSFORMATION THAT PRODUCES THE LARGEST MAXIMUM LIKELIHOOD
 *
* ESTIMATOR.                                              *
*********************************************************************;
***** KEEP TRACK OF THE THETAS AND LAMDAS                          ;
/* THETALAMDA 22 21 20 2-1
           12 11 10 1-1
           02 01 00 0-1
          -12-11-10-1-1

                                         */
***** INPUT THE DATA                                    ;
DATA STORE;
inFILE 'C:\diss\analysis\round3\tsidist.OUT' LRECL=200;
inPUT
  @1 PARCEL $15. @17 ACTPR 6.
  @24 LAKE1 $12. @37 TSI1 4. @42 SOURCE1 1. @44 SIZE1 4.
  @49 LAKE2 $12. @62 TSI2 4. @67 SOURCE2 1. @69 SIZE2 4.
  @74 UNITPR 10. @85 FTSQ 7. @93 CFACTOR 4. @98 LAKE1D 10.
  @109 LKNM1 2. @112 LAKE2D 10. @123 LKNM2 2. @126 SHOP 10.
  @137 HUB 5. @143 NHOOD 6. @150 CBD 10.;
***** CHOOSE THE THETA AND LAMDA PARAMETERS FOR TRANFORMING THE
;
***** DEPENDENT AND INDEPENDENT VARIABLES                         ;

THETA = -1;
LAMDA = -1;
***** STORE THETA AND LAMDA IN THE DATA SET THETA. THE REASON IS;
***** TO OUTPUT THESE TWO VARIABLES LATER.                       ;
DATA THETA(KEEP = THETA LAMDA );
 SET STORE;
   IF _N_ EQ 1;
***** CLEAN THE RAW DATA, IN THIS CASE RAW DATA INCLUDE OUTLIERS;
DATA ONE;
 SET STORE;
  IF ACTPR GE 400 AND TSI1 NE . AND UNITPR LE 18;

***** TRANSFORM THE VARIABLES OF THE MODEL ACCORDING TO BOX-COX ;
***** METHODOLOGY                                       ;
DATA TRANS;
```

```
  SET ONE;
IF THETA NE 0 THEN TRACTPR = ((ACTPR**THETA) -1.0)/THETA;
IF THETA EQ 0 THEN TRACTPR = LOG(ACTPR);
IF LAMDA NE 0 THEN TRTSI1  = ((TSI1 **LAMDA) -1.0)/LAMDA;
IF LAMDA EQ 0 THEN TRTSI1  = LOG(TSI1 );
IF THETA NE 0 THEN TRFTSQ  = ((FTSQ **THETA) -1.0)/THETA;
IF THETA EQ 0 THEN TRFTSQ  = LOG(FTSQ );
*IF LAMDA NE 0 THEN TRFTSQ  = ((FTSQ **LAMDA) -1.0)/LAMDA;
*IF LAMDA EQ 0 THEN TRFTSQ  = LOG(FTSQ );
IF LAMDA NE 0 THEN TRLAKE1D= ((LAKE1D **LAMDA) -1.0)/LAMDA;
IF LAMDA EQ 0 THEN TRLAKE1D= LOG(LAKE1D);
IF LAMDA NE 0 THEN TRSHOP  = ((SHOP **LAMDA) -1.0)/LAMDA;
IF LAMDA EQ 0 THEN TRSHOP  = LOG(SHOP);
IF LAMDA NE 0 THEN TRCBD   = ((CBD  **LAMDA) -1.0)/LAMDA;
IF LAMDA EQ 0 THEN TRCBD   = LOG(CBD );
IF LAMDA NE 0 THEN TRSIZE1   = ((SIZE1  **LAMDA) -1.0)/LAMDA;
IF LAMDA EQ 0 THEN TRSIZE1   = LOG(SIZE1 );
lactpr=log(actpr);

/*PROC MEANS MEAN SUM;
  VAR LACTPR; */

***** SCALE THE TRANFORMED DATA TO A MEAN OF ZERO, IN ORDER TO ;
***** AVOID COMPUTATION PROBLEMS DUE TO SMALL VARIABLE VALUES  ;
*PROC STANDARD MEAN=0 NOPRINT;

***** RUN REG PROCEDURE TO OBTAIN _RMSE_                    ;
PROC REG OUTEST=TES ;
MODEL TRACTPR = TRTSI1  TRFTSQ  TRLAKE1D  TRSHOP TRCBD;

***** INCLUDE THE VALUES OF THETA AND LAMDA IN THE OUPUT FILE AND;
***** CALCULATE SSR(SUM OF SQUARED RESIDUALS)              ;
                    ;
DATA LKL;
 MERGE TES THETA;
SSR = (_RMSE_**2)*147;
LIKELIH= -(1.0/2.0)*153*LOG(((_RMSE_**2)*147)/153)+(THETA-1)*1517.41;

***** CALCULATE THE VALUE OF THE LOG LIKELIHOOD ESTIMATOR     ;
***** NOTE: 1517.41=SUM OF LOG OF DEPENDENT VARIABLES        ;
*****       153 = NUM OF OBSERVATIONS                        ;
*****       (_RMSE_**2)*147 /N = SSR;                        ;
*****       147 = (NUM OF OBS)-(NUM OF DEPENDENT VAR)-1        ;
PROC PRINT;
DATA PREV;
 INFILE 'C:\diss\analysis\round3\MAXLKL.OUT' LRECL=200;
 INPUT
```

```
  THETA LAMDA SSR LIKELIH;

DATA ALLLKL(KEEP = THETA LAMDA SSR LIKELIH);
  FILE 'C:\diss\analysis\round3\MAXLKL.OUT' LRECL=200;
   SET PREV LKL;
  PUT
  THETA LAMDA SSR LIKELIH;
/*PROC SORT ; BY LIKELIH;   */
PROC PRINT DATA = ALLLKL;




RUN;
```

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