Staff Papers Series

Staff Paper P91-8

February 1991

A HEDONIC APPROACH TO URBAN WETLAND VALUATION

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EXECUTIVE SUMMARY

Some of the many beneficial services provided by urban wetlands accrue to adjacent upland properties. The existence of such nonmarket benefits should increase the relative value of properties in the vicinity of wetlands. In this report, we examine the extent to which the relationship between property values and wetlands can be used to measure the economic value of these nonmarket benefits of wetlands.

The principal reason for interest in the wetland/property value relationship is that knowledge of the nonmarket benefits of urban wetlands will improve decision making regarding wetland use. Similarly, the relationship can be utilized to explore the extent to which public intervention in wetland management decisions is warranted. If the effects of wetlands on immediately adjacent property values are substantial, the need for public intervention in wetland management decisions may be lessened because benefits are more easily captured by private decision makers. Conversely, if the effects of wetlands on property values in a larger, more general neighborhood are substantial, the need for public intervention may be greater because such values would be more difficult for a private decision maker to capture and would likely be ignored.

Statistical techniques were used to estimate the relationship between residential property values and property characteristics, especially lake and wetland characteristics. The analysis was applied to a set of property characteristics data for the over 18,000 residential properties sold in Ramsey County (Minnesota) during the period 1987-89. In addition to conventional market data such as sale price, housing size, type, and age, each property also had associated with it several environmental characteristics: whether a property was lakeside or not, the total lake acreage in that property's survey section, and the total wetland acreage in that property's section. Lake and wetland acreage per section information is from the Minnesota Department of Natural Resources's Protected Waters Inventory (PWI) and therefore includes only those waterbodies registered under the criteria of the PWI.

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Research was supported under contracts 54336 & 54337 from the Minnesota Department of Natural Resources. The authors are responsible for any errors.

A statistically significant positive relationship was found to exist between PWI wetland acres per section and property values. Holding housing density per section constant, changes in wetland acreage are relatively more valuable in sections with low wetland acreage than in sections with higher wetland acreage. Since these effects are estimated on a per residence basis, given the same wetland acreage, changes in wetland acreage are relatively more valuable in sections with higher housing density than in sections with lower housing density.

From the estimated relationship and from the number of residences per section, the estimated economic value of small changes in wetland acreage in a given section can also be obtained. These estimates are theoretically valid for "small" changes in wetland acreage only. Since restoration or drainage of an entire wetland may not be a "small" change, the estimates developed here are not well suited to deriving the values of such decisions.

More importantly, the estimated values are for the section-wide effect on property values of a change in total PWI wetland acreage per section. Thus, on the surface at least, the estimates yield little information about the effects of changes in an individual wetland. However, since PWI wetland acres per section are shown to have a statistically significant positive effect on property values, individual wetlands on average must also have positive effects on property values.

Both lake variables also have statistically significant positive effects on property values, suggesting that for lakes, a "neighborhood" effect exists in addition to an effect on adjacent property. The similarity of many lake services to those of wetlands suggests that a similar relationship exists for wetlands. If wetlands also provide beneficial services to properties several blocks away, then the social benefits of restoration or preservation are more likely to outweigh the social benefits of drainage than if the beneficial effects accrued only to adjacent property. Furthermore, these more diffuse benefits would be difficult for private wetland owners to capture and would likely be ignored.

In summary, the existence of some positive relationship between wetlands and nearby property values was established. Available wetland data does not allow us to distinguish i) the exact effects of individual wetlands, ii) the effects of smaller unprotected wetlands not in our data set, and iii) the precise effects of being close to wetlands as opposed to being in the neighborhood of wetlands. However, future efforts utilizing the upcoming geocoded data from the National Wetlands Inventory would greatly improve our understanding of all three of these effects.

Finally, although the existence of some positive relationship between wetland acreage per section was established, precisely which values were captured is not clear (i.e., open space, view, habitat, etc.). Thus, it would be premature to conclude from these results that the socially most productive use of wetland acreage is as wetlands, per se.

A HEDONIC APPROACH TO URBAN WETLAND VALUATION

I. Introduction

Increasingly, the socially beneficial aspects of wetlands are being invoked as a rationale for public policies designed to increase wetland preservation and restoration. In particular, rural wetlands have received considerable attention lately in both the policy arena and in empirical valuation studies. While urban wetlands are also recognised as socially beneficial, they have received considerably less attention empirically.

In fact, a thorough search of over 40 bibliographic abstract databases, a wetlands annotated bibliography (Leitch and Ekstrom), and other sources, uncovered only a handful of studies that addressed urban wetlands. Most urban wetland valuation efforts considered the effects of urbanization on wetlands not the effect of wetlands on urban land values. The preponderance of the economic and real estate studies examined investigated either the private benefits obtained from draining rural wetlands or the public benefits obtained from not draining rural (and sometimes urban) wetlands. However, regarding the valuation studies, Shabman and Batie, in a comprehensive review article, caution that many such studies are not economically sound, in either their theoretical or empirical dimensions.

Since many of the beneficial services provided by urban wetlands accrue to adjacent upland properties, the value of properties in the vicinity of wetlands should reflect some of these benefits. The aim of this report is to examine the extent to which the relationship between property values and wetlands can be used to measure these nonmarket benefits in a manner that is consistent with well established economic theory.

II. Wetland Functions and Economic Values

There are two basic reasons for interest in the relationship between wetland areas and property values. The first is to document the positive effects of wetlands in an urban setting and to use the hypothesized relationship to measure the benefits of public programs to maintain and enhance the availability of urban wetlands.

The second is that private landowners may be able to capture wetland values to some extent, which in some sense reduces the cost of public programs of wetland preservation. For policy purposes, a relevant concern is the social cost of preservation, as measured by the private opportunity costs to landowners, i.e., the foregone benefits of development. This is the sum of expected development gains less expected development costs less the known current market value, plus the privately capturable increase or decrease in the value of adjacent developed property as a result of the elimination of the wetland. To the extent that most of the services of a wetland are reflected in immediately adjacent private property values, the need for public intervention in wetland drainage decisions is lessened if these values could be captured by private decision makers. Alternatively, if the effects of a wetland on property values in a more diffuse neighborhood of the wetland are substantial, the need for public intervention may be increased because such values would be more difficult for a private decision maker to capture and therefore would be ignored.

What are the possible relationships between wetland services and property values? In general, the value of a piece of property on a market is equal to the discounted value (discounting at the market rate of interest) of the stream of net incomes that the property can generate.

There are two basic routes via which wetlands affect land values. First, holding the wetland can generate income itself, (e.g. from trapping animals which inhabit the wetland). The present value of this income is the capitalized value of the wetland for trapping, which could then be compared to the value of alternative land uses. Second, the wetland could provide services which increase the value of nearby land, by increasing the net income the adjacent land can generate. This could accrue either to the same person that owns the wetland, or could constitute a spillover from one owner to another. In this latter instance, the increased value to the adjacent owner often will not affect the decisions of the wetland owner, and economically inefficient outcomes will result without some sort of side-payments between the owners or some sort of public intervention (however, this does not imply that side-payment or government intervention always improves efficiency).

In general, wetlands provide a great many services and disservices, some of which are listed in Table 1. Of course, any given wetland may supply only a few from this broader list. Of the services listed, only a few can be captured directly by the private landowner, and those that can be so captured (such as timber, grazing, fee hunting, trapping, and growing crops) have little applicability in an urban setting. Some are inherent in the wetland as a wetland, while others (such as ratio land) are associated with adjacent upland properties. The rest are public in nature and so are presumably reflected in the land market only as they lead to regulations and other government activities that influence wetland use and/or drainage, or as the benefits of wetlands and private property share the same location, as will be discussed in more detail below.

Table 1 Some services of wetlands that have been identified in the relevant literature.

- Hydrologic
  - Flood control
  - Shoreline anchoring
  - Groundwater recharge
- Water Quality
  - Water purification
  - Sediment trapping
  - Stormwater storage
- Habitat
  - Furbearer and other wildlife
  - Waterfowl and other birds
  - Fish and shell fish
  - Micro-organisms
- Income Generation
  - Crops
  - Grazing
  - Trapping
  - Timber
  - Fee recreation
- Amenities
  - View
  - Open space
  - Recreation
- Disamenities
  - Cultivation problems
  - Odor problems
  - Insect nuisances
  - Mammal nuisances
- Other
  - Satisfaction of public land requirements for development (ratio land)
  - Scientific research
  - Development potential

In this report, we will be concerned solely with the effect of wetlands on nearby developed (or potentially developed) parcels, and not on the ability of a wetland to generate income directly. The reason for this focus is that few of the direct income services of wetlands appear to be relevant in an urban setting, at least at the current time.

Several of the wetland functions in this list are relevant in the urban context, and may be reflected in adjacent property values. These can be classified into direct and indirect effects.

Direct Effects

Direct effects of wetlands on property values occur when individuals experience the positive and negative services of wetlands due to their physical proximity. Leading examples are in the habitat, amenity and disamenity categories. Individuals may value positively the opportunity to view waterfowl and other birds associated with wetlands, their open space and recreational aspects, and the views they provide. As well, odors, insects, and nuisance animals may provide negative direct values.

Because some real estate is favorably located vis a vis wetlands and other real estate is not, and there is a limit on available locations, it is reasonable that property values may reflect these direct wetland values.

Indirect Effects

The influence of indirect effects of wetlands on property values is more subtle and speculative. They are based on a bio-physical relationship between wetlands and other attributes of location that are directly experienced by landowners. As an example, consider water quality services of a wetland. An individual landowner may not perceive the relationship between wetland areas and water quality, but they may perceive the water quality itself. A relationship between water quality of an adjacent lake and housing values may therefore be discernable. Then, one could use the technical relationship between wetland acres and water quality to infer the value of wetlands in this role.

Other wetland values indirectly related to property values are, inter alia, the flood control and shoreline anchoring functions, all of the water quality functions, and all of the habitat functions.

Having specified some of the services of wetlands, it is important to recall the reasons for inquiring into the wetland-property value relationship. We are interested most basically in how society at large values a wetland in economic terms; this value could then be compared to the value of alternative uses of wetland areas. As just discussed, some of these social values may be reflected in private property values.

Before discussing how the value of wetlands might be recovered from property values, we need to clarify what we mean the concept of value. Our concept of the social value of wetlands will be based on the sum of individuals' values of wetlands. Following the approach of most economics literature, individual values are based on individuals' preferences and are defined in terms of willingness to make trades. Since it is generally convenient to measure these trades in terms of money, we seek a money metric for individual values. We will refer to this money metric as willingness to pay (WTP), where we use WTP as shorthand for individual values defined in terms of willingness to trade money (Freeman).

III. Hedonic Valuation Methods

This section begins with a brief description and outline of the hedonic technique for valuing nonmarket goods. The hedonic technique is one of a class of methods for valuing goods that are not traded on markets. These methods fall into two categories: direct and indirect. In the direct approaches, individuals are asked directly, using sample survey methods, their WTP for a change in the level of provision of a nonmarket good. In the indirect techniques, this WTP is inferred from observations of their behavior.

In all of the indirect economic valuation techniques a technical relationship is posited between an nonmarket good (services of a wetland) and a private good (property). The technical relationship in the hedonic approach is based on shared location. The technique relates property values to a vector of characteristics of the property, one of which is the level of nonmarket good. Then, changes in the nonmarket good generally will induce changes in the value of the property, from which can be deduced demand for the nonmarket good itself.

There are several situations in which the hedonic approach has been used. Notable are the relationship between property values and air pollution, airport noise, proximity to toxic waste disposal sites, proximity to parks and shoreline, and water quality in nearby water bodies.

A number of issues need to be resolved in the use of the hedonic approach to valuing nonmarket goods (our discussion follows closely McConnell et al.). All of these questions revolve around an empirical entity: in a given real estate market, the relationship between the price of the ith parcel of land, p^i, and the characteristics of that land. Let z^i be a vector of relevant characteristics. In the urban context, where property values are largely set in housing markets, relevant characteristics might include housing type, size, neighborhood, etc., as well as the level of the nonmarket good. The hedonic price equation is

[1] $$p^i = f(z^i; \beta),$$

where β is a vector of parameters. Given a number of observations on property prices and their characteristics, ß can be estimated by statistical techniques.

Given that the entity in [1] can be observed empirically, how can one interpret it, and of what use is it? The hedonic price equation shows the extent to which wetland values are being incorporated into property values as a result of private decisions and market forces. This is of interest in and of itself, since it can be used to assess the ability of market forces to provide wetlands. A second question concerns how welfare measures for changes in one or more of the z^i can be obtained from the hedonic price equation.

There are two situations that arise which are very different in terms of their implications for the answers to the second of these two questions. The first occurs when the change in the nonmarket good to be evaluated is marginal, or "small." The second occurs when one wishes to value nonmarginal changes in the supply of the nonmarket good.

In the case of marginal changes, it can be shown that the derivative of the hedonic price equation with respect to the relevant characteristic is equal to individual marginal WTP for the good (Small). There is no need to re-solve for the new equilibrium rent gradient for the whole market area, even if the level of provision of the nonmarket good changes at more than one location. Thus, valuation requires estimation of the hedonic price equation, taking its derivative, and adding up the estimated WTP over the population of households.

If the quantity change for the nonmarket good cannot be considered "small", several substantial research questions arise. What is needed in this case is an estimate of the entire demand (or preference) schedule for the nonmarket good. The key question here is whether this information can be recovered from market data when there is just one market (e.g. the housing market in a single metropolitan area).

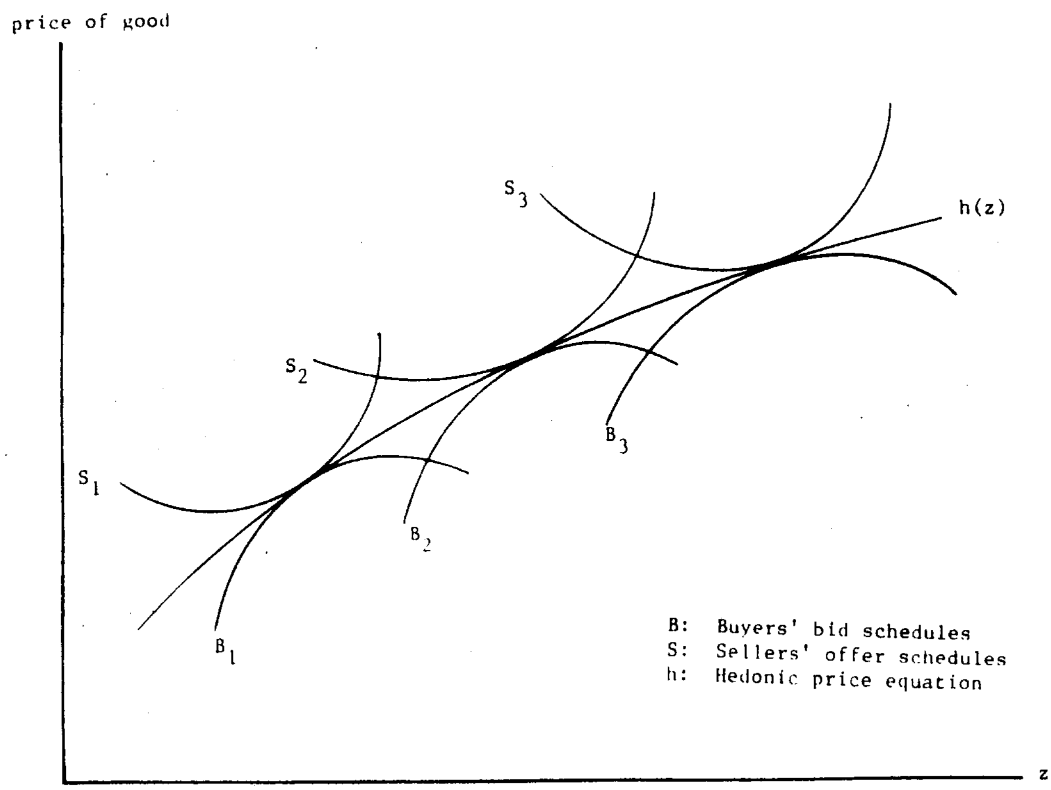
While a complete analysis of this issue is beyond the scope of this report (see McConnell et al.), some discussion helps to define the issues involved. The basic interpretation of the hedonic price equation has been provided by Rosen.

Imagine a group of consumers with different preferences and incomes and therefore different WTP for marginal units of the characteristics of goods. Let these bid functions be B_i for the consumers $i = 1,\ldots,N$. Suppliers of the good face a production technology implying a marginal cost of providing the characteristics. At different prices for the good with different characteristics, different quantities will be supplied. These are summarized by offer schedules S_j, for suppliers $j = 1,\ldots,M$. Equilibrium in the real estate market occurs when the bid functions of consumers are tangent to the offer schedules of suppliers. This is shown in Figure 1.

The equilibrium price equation is p_i; both buyers and sellers take this as given, solve their respective maximization problems, and the markets for characteristics clear.

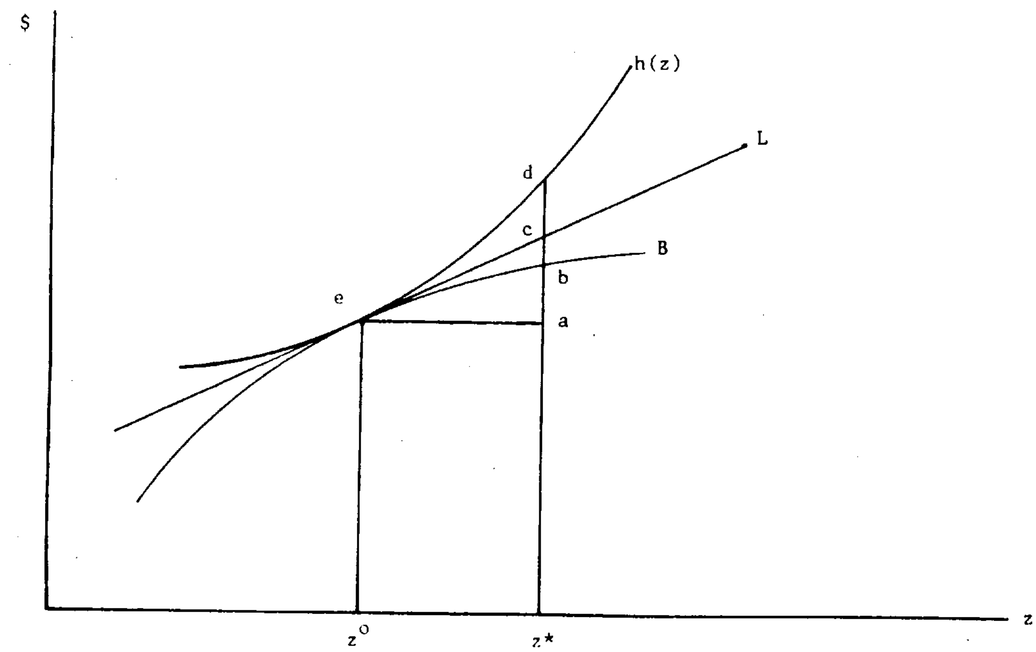
Now, having interpreted how individual preferences for wetland values might become translated into housing prices in a market environment, it is reasonable to inquire into the ability to infer WTP from the information embodied in the hedonic price equation. To do this, take a closer look at the juxtaposition of the individual bid equation and the hedonic price function in Figure 2.

Figure 1 The hedonic price equation (from McConnell *et. al.*)



The point e is the initial equilibrium position for this consumer, where the quantity of wetland services (somehow measured) is at z. Suppose that the level of wetland services is increased to z*. What one really wants to measure is the distance a-b along the individual's bid curve; this is their WTP for the increase in z to z*. To obtain this requires a means of determining the whole function B(z). Alternatively, one can use the movement along the hedonic price function h(z). This is the difference in property values at z* relative to z, and is given by the distance a-d in Figure 2. This is an overestimate of the true value of wetlands. Finally, one can use the slope of the hedonic price function at the point e,

Figure 2 Valuation of attribute changes via the hedonic function (from McConnell *et. al.*)



extrapolated out to different levels of z. This is given by the locus of points labeled L, and would result in the welfare measure a-c, which is an approximation of a-b. It can be shown mathematically that the approximation provided by L improves substantially as z becomes closer to z*. Since all one needs to compute the approximation provided by L is an estimate of the hedonic price equation h(z), small changes are easy to evaluate, as discussed previously.

If z* is far from z, however, one can go pretty far wrong using L, depending on the curvature of the two functions. Advanced statistical techniques, combined with some special technical assumptions about the shapes of the functions B(z) and h(z) can allow one to recover the function B(z). Discussion of these issues is beyond the scope of the current paper.

IV. Methodology

A complete list and short description of all the variables used in the statistical analysis is presented in Table 2 in the Appendix. Most are self explanatory; however, some discussion of the data sources, and the variables is warranted. The presentation is divided into two parts; the first part relates to property characteristics and price data specific to individual property sites, while the second relates to wetland and other environmental characteristics included in the data set.

Property Data

There are essentially two types of data sources for property values and characteristics: average data for some geographic area and individual data for specific sites. Most hedonic studies make use of the former, principally because the U.S. Census of Population and Housing provides mean and median values of property values, structural characteristics, and socioeconomic factors for all U.S. census tracts and census blocks. The two primary problems with census data are: 1) the loss of detail due to the aggregation results in limited ability to control for relevant housing characteristics, and 2) the degree of accuracy of property values estimated and reported by individual owners (Freeman). The second problem may be meliorated by using average taxable values; however, even these values do not necessarily represent value in exchange, as captured by equilibrium market prices.

Because of these problems with census data, individual site data is preferable if available. Such data for Ramsey County (Minnesota) residential properties was obtained from a private firm which monitors recorded sales at the county tax assessors office and maintains the information for residential properties on a computer data system called the PINpoint™ Property Information Network. The data for Ramsey County residential housing units is quite complete; it includes, among other items, a site location code, sale price, age, square footage, number of rooms, construction type, property type, condition, and garage capacity.

The data set contained all 18,985 Ramsey County residential property sales in 1987-9 for which the sales price was known. After screening for missing data on the property characteristics employed in the analysis, the number of usable observations was 18,863. Price data was adjusted to 1989 dollars by multiplying each property's price by the ratio of the average price for 1989 to the average price for that year.

Wetland and Other Environmental Data

The best available wetland data was the MDNR's Protected Waters and Wetlands Inventory (PWI) for Ramsey County. The PWI includes information on any waters where state law requires a permit for changes in the water's course, current, or cross-section. For wetlands in the Metro area, the PWI includes only those wetlands 2.5 acres or greater in size and classified as types 3,4, or 5 (as defined in Circular 39, U.S. Department of Interior, 1971). Obviously, not every wetland that might affect property values is included in the PWI, but enough are to warrant selection of this data for the present study.

Information for each wetland in the PWI includes size in acres and location to the survey section level. Since specific wetland location data commensurate with property lot ID's is not available, acres of PWI wetlands per section was selected as the relevant wetland characteristic. This measure serves as a proxy for the amount of wetlands in a property's "neighborhood". Although not an ideal measure of wetlands, it is the best available and should capture many of the effects of wetlands on property values. The PWI "lake acres per section" measure is used to control for the quantity of lakes in the same area.

The PWI lake and wetland acres per section variables were constructed and added to the site-specific data for each observation. In addition, a dummy variable was created by map inspection to indicate whether or not the Mississippi River passes through a given section. Since all these variables use township, range, and section numbers to match them with property ID numbers, they capture neighborhood effects at the section level (a one square mile area) for all residential properties in that section.

Some PWI waterbodies lie across section boundaries. For all waterbodies such as these, the total acreage was assigned to each section that contained some portion of the waterbody. An alternative approach would be to proportionally allocate acreage to sections, but such an approach would be difficult to justify behaviorally. It seems more reasonable that any affects of such waterbodies will depend on the whole waterbody, not just the portion in a particular section. The chosen approach was felt to more realistically capture the neighborhood aspect of PWI waters.

Some site-specific location and environmental information is also included in the data. Lot location was translated into dummy variables for corner lots and cul-de-sac lots. Inner lots represent the base case. Additionally, dummy variables indicating whether a lot was flat or not, and whether a lot was lakeside or not were included for each observation in the property data. A lot is defined as lakeside if it is lakefront property, has a view of a lake, or has specific lake access rights. The lakeside variable represents an important environmental amenity for which we have site specific information in addition to neighborhood level information.

To account for any remaining environmental and neighborhood effects at a broader level, dummy variables were created to indicate which of the counties six school districts a property lies in. These variables will capture broad differences in school districts along with any omitted regional differences that might vary along with school districts.

Statistical Technique

Recall from expression [1] that the hedonic price equation is

[1] $$p^i = f(z^i; ß),$$

where ß is a vector of parameters. The dependant variable in the estimation of the hedonic function is price. Given a our 18863 observations on property prices and their characteristics, ß can be estimated by statistical techniques. One such technique is the ordinary least squares (OLS) regression technique. The statistical model is then

[2] $$p^i = f(z^i; ß) + \epsilon^i,$$

where ϵ^i is an additive error term for each observation. In our case, the use of (OLS) is justified under the following conditions: the function f(.) is linear in the parameters ß, the error term is normally distributed, the error term has zero mean, and the errors are homoskedastic.[1]

Since we generally do not observe negative housing prices, there exists a potential for a censored price distribution. In our case, this means that only the portion of the price distribution greater than or equal to zero is

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[1] Violation of normality does not have serious consequences for the use of OLS (Kmenta). In addition, violating the assumption of homoskedasticity still produces results that are unbiased and consistent.

observed, with zero's reported when price may otherwise have been negative. In such a situation OLS is not the appropriate statistical technique because the errors do not have zero mean, and as a result, the estimates are biased and inconsistent. The effect of the censoring problem was deemed minimal in our application because 1) the minimum price in the population is $2900, and 2) there is not an inordinate number of observations near 0 or any other lower bound.

The LIMDEP^{tm} software program was used to estimate a hedonic function linear in all variables except wetlands. The wetland variable included a squared term to allow for nonlinearity and yet remain linear in estimable parameters. Since the sign of the squared is not constrained, concavity or convexity will be determined by the sample.

V. Results

Regression results are provided in Table 3 in the Appendix. Listed in Table 3 are the short name, estimated coefficient, and standard error of each variable. The sum of the variables times their coefficients represent the estimated hedonic price equation. Considering that the data is cross sectional and for individual site data rather than averaged data over some area, the fit of the estimated equation is quite good ($R^2 = 0.718$ and the F statistic for the regression is 1230). In addition to the estimated coefficients and standard errors for each variable, Table 3 also presents the mean and standard deviation of the data for each variable. Finally, t-ratio statistics for a two-sided test that the corresponding coefficient is zero, along with the probability level that just makes a coefficient insignificant are also presented in Table 3.

Most of the variables have coefficients that are quite significant; these are discussed below. Variables which are not significant at a 95% level of confidence are: air conditioning, 1/4 basement, 1/2 basement, walkout basement exit, and White Bear Lake school district (#624). The most interesting of these results is that having central air conditioning has no significant effect on price. The insignificance of air conditioning is consistent with O'Byrne et al's hedonic airport noise results for Atlanta.

Many of the results have an effect on price that is in the direction one might expect. Variables having a positive effect on price include: total area, open screened porch area, enclosed porch area, deck area, pool area, garage capacity, no. fireplaces, above average condition, 3/4 or full basement, and all story types in increasing order. Variables having a negative effect on price include: age, below average condition, non-single family housing (such as duplex's and townhouses), and frame construction.

While additional bathrooms has a substantial positive effect on price, additional rooms and bedrooms have negative effects on price. One possible explanation for these puzzling results is that the effects generally attributed to higher numbers of rooms are being captured by other size related variables included in the analysis, all of which have positive signs. Another, possibly complementary explanation is the fact that the sample contains some extremely high priced units with only a few bedrooms, and some relatively low priced units with a great many bedrooms. If a positive relationship were estimated, these extreme observations would result in substantial residuals. When other effects (total area, number of baths, basement size, stories, garage capacity, etc.) are controlled for these extreme observations seem to be very influential.[2]

If coefficients on bedrooms and rooms were more important to the study, alternative modeling approaches and/or influential observations techniques could be employed to further analyze the variables. However, our purpose for including the property characteristic data in this analysis is to control for effects other than wetlands so that the estimates for the wetlands variables will be as accurate as possible. Therefore, although the estimates of the coefficients on number of rooms and number of bedrooms are counter-intuitive, they are not central to the analysis.

Further results indicate that a property located in a section that the Mississippi River passes through has a positive effect on price relative to a lot that is not. In fact, all else equal, the price of property is $5,000 higher if the property lies in a section with the Mississippi river passing through it. This variable is intended to capture the neighborhood effects at the section-level of the amenity value of the Mississippi.

All else equal, lakeside properties sell for $41,000 more than lots that are not lakeside. Recall that a property is considered lakeside if it is lakefront property, has a view of a lake, or has specific lake access rights. In addition, each acre of PWI lakes in the section of a property contributes $3.28 to the price of the property. This effect holds for every property in a section and not just those lots that are lakeside. Thus, lakes are seen to have a statistically significant positive effect on price at both the "neighborhood" level and on immediately adjacent property.

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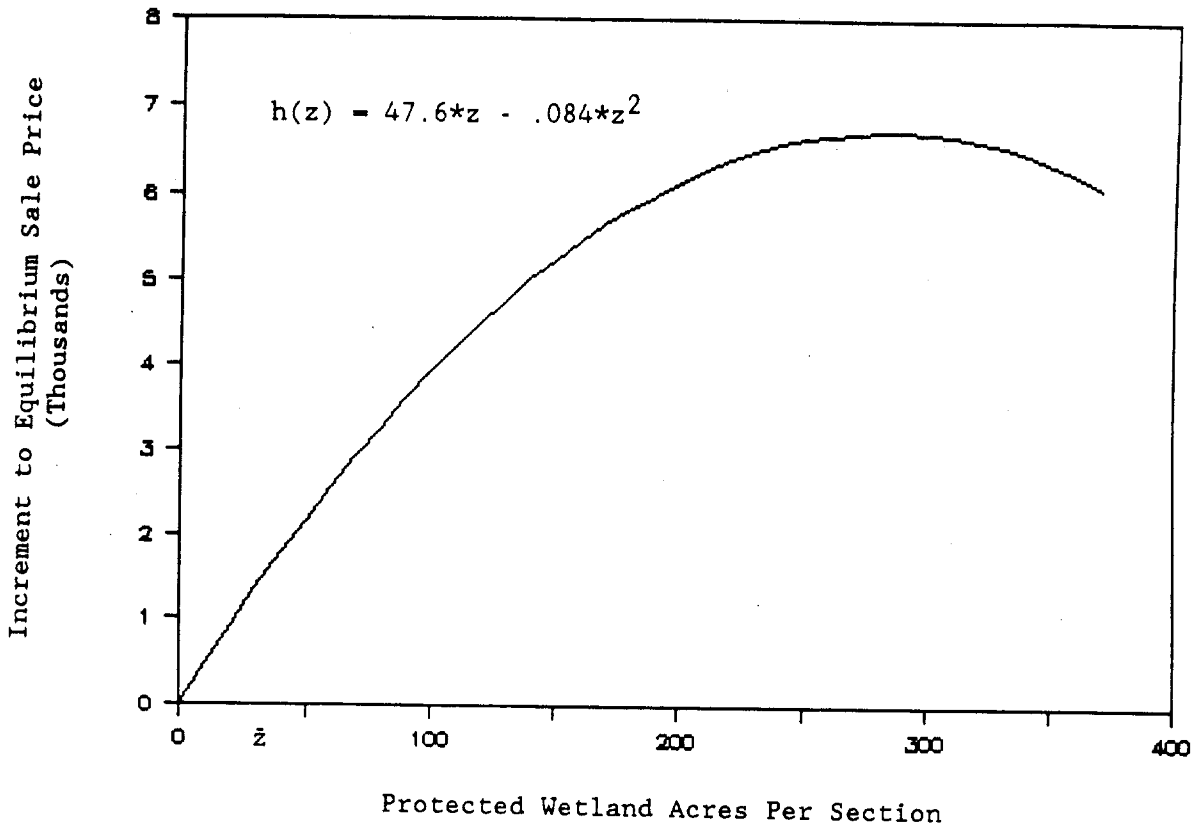
[2] A series of regressions were run to check for multicollinearity among the size related variables. An R^2=0.4 was the best fit that could be achieved. Thus, multicollinearity was not deemed responsible for the unexpected signs of the rooms and bedrooms coefficients.

The effects of PWI wetland acres in the section of a property on that property's price are reflected in two terms, PWI wetland acres and PWI wetland acres squared. This specification permits the estimation of a nonlinear relationship which will be concave if the second term's coefficient is significantly negative and convex if the second term's coefficient is significantly positive. Since the estimated coefficients are $47.57 and $-0.08, respectively, the estimated relationship between a property's equilibrium price and PWI wetland acres in that property's section is a concave function. A graph of the estimated function is depicted in Figure 3. This is the graph of the hedonic function with respect to PWI wetland acres with the effect of all other attributes normalized to zero. This aspect of hedonic function is increasing over most of it's domain, peaking at 283 PWI wetland acres per section. Fewer than 4% of the observations lie in sections with acres above 283, but PWI wetland acres in such sections still contribute over $6000 to the equilibrium price of properties in those sections.

The estimated hedonic function can be used to calculate estimates of the value of small changes in wetland acreage in a given section. To do so one would evaluate the slope of the function (given by $47.5734 - $.084*2*Z, where Z = PWI wetland acres per section) at the level of PWI wetland acres for the section in which small changes in acreage are contemplated. The resulting value represents the estimated willingness to pay (WTP) of a representative property owner in the chosen section. Since the relationship is estimated on a per residence basis, multiplying this WTP by the number of residential properties in that section yields an estimated of the total WTP for the section in which small changes in wetland acreage are considered.

Figure 3 The estimated hedonic price equation with respect to wetlands.



$\bar{z}$ = 29 is the mean protected wetland acres per section from the sample.

Further observations on WTP can be made from the graph of the hedonic function. For some sections the WTP for additional wetland acreage is negative, but these sections already have very high wetland acreage (44% or more of these sections are wetlands) and comprise only 4% of the sample properties. More importantly, holding housing density per section constant, changes in wetland acreage are relatively more valuable in sections with low wetland acreage than in sections with higher wetland acreage. Furthermore, since the effects are estimated on a per residence basis, given the same initial wetland acreage, changes in wetland acreage are relatively more valuable in sections with higher housing density than in sections with lower housing density. Thus, all else equal, wetland acreage has a decreasing effect and housing density has an increasing effect on the total WTP for changes in wetland acreage per section.

Unfortunately, at this juncture, we do not have the data on the density of residential properties per section which would allow statements on the total WTP for small acreage changes for desired sections. However, we could answer the following hypothetical question: what is the total WTP of residential property owners for an additional acre of wetlands in each section of Ramsey County? Given that the sample is representative of the actual distribution of residential properties in Ramsey County, we can proceed by evaluating the hedonic function's slope at our sample's mean PWI wetland acreage per section of 29.26 acres, yielding a per property WTP of $42.66. Multiplying this by the (roughly) 157,000 residential properties in the county gives an estimate of 6.7 million dollars as the value of a hypothetical one acre per section increase in wetlands in all sections of Ramsey County.

VI. Implications

Even with the limited wetland data currently available, a link between wetlands and property values has been firmly established. Total protected wetland acres per section has a significantly positive effect on the equilibrium price of residential property in Ramsey County.

The estimated relationship between property values and wetland acres per section suggests the following rule of thumb, target preservation and restoration projects to sections with relatively few if any wetland acres.

However, the estimated relationship only relates to the effect on individual properties, while the effect is valid for all properties within a section. Therefore, the total effect on all properties in a section must be accounted for before qualitative recommendations can be made. Map and data inspection indicate that the distribution of sections with lesser amounts of wetlands seems to coincide with the areas of higher housing concentration. In general then, a public program aimed at preserving (or restoring) wetlands would have a greater effect on property values if targeted to sections with the least amount of wetlands, assuming that preservation costs are the same across sections (such sections are likely to have the higher costs as measured by the opportunity costs of foregone development).

What cannot be determined with available data is the contribution of specific wetlands to the prices of specific properties. However, we can make some inferences about the nature of such specific effects by drawing upon the discussion above regarding the two lake variables, PWI lake acreage per section and the lakeside indicator. Lakes were shown to have positive effects on property values at a section level, and on immediately adjacent property. We can think of the lakeside variable as representing as appropriable private effect attributable to being "very close" to a lake, and lake acres per section as a public good effect attributable to being in the general vicinity of the lakes. (Large values of the latter might mean that a lot is fairly close to a number of smaller lakes or that it is fairly close to a large lake.)

The estimated coefficients for lakes can be used to examine the effect of omitting the lakeside variable on the coefficient of the section lake acreage, leaving a situation more akin to the available wetlands data. We would expect that omitting the lakeside variable would increase the coefficient of the section lake acreage variable that must now capture both effects. If the coefficient changes greatly, we can conclude that much of the estimated neighborhood effect is biased upward by the averaging over the section of the more direct affects of being "very close". On the other hand, if the change in the section variable's coefficient is not large, then we can infer that, while the averaging out of the "very close" effect increases the parameter estimate of the section effect, the section-level effect is legitimate in its own right.

The estimated coefficient for PWI lake acres per section when lakeside is omitted from the analysis is $4.92 per acre and $3.28 when lakeside is included in the estimation. Thus, even though accounting for the more direct affect of being "very close" to a lake reduces the estimated coefficient on the section level effect by 33%, the neighborhood variable is still sizable and has significant explanatory power.

Using this information to draw inferences about the wetlands coefficients suggests that the neighborhood aspect of wetlands, though overestimated by the omission of "very close" effects, is significant in its own right. Hence, the neighborhood effect can represent a substantial portion of the value of wetlands captured by property values. Yet, in general, this value would be difficult to appropriate from a private developer's standpoint because of the public good aspects of the neighborhood value.

An additional implication is that, under some assumptions, the positive results for PWI wetland acres per section provides some information about how wetlands which were not included in the PWI affect property values. If the location of smaller unprotected wetland acreage is positively correlated with PWI acres, and if they also have a positive effect on price, then the estimates for PWI acres themselves are biased upward by the omission of the smaller wetlands. Under such conditions, the estimates presented here will also capture some of the section level effects on property values of smaller, unprotected wetland acreage per section.

However, if smaller wetlands have a negative effect on property values at the section levels, their omission has biased our estimates downward. Smaller wetlands may provide more disamenities (odor, mosquitos) relative to amenities (open space, habitat), which may make their overall effect on properties at the section level difficult to predict. Thus, the net effect of their omission on the results presented here is uncertain.

VII. Limitations and Further Research Needs

A positive relationship has been established between a property's value and protected wetland acres in the section of that property. However, due to constraints on data availability, our understanding of the exact nature of the relationship is not precise. Given our data we can not distinguish i) the effects of an individual wetland on a specific property's value, ii) the exact relationship between distance to a wetland and property values, iii) the effects on property values of wetlands not included in the PWI, and iv) the effects of different types of wetlands on property values.

In addition, the results shed no light on which benefits of wetlands are being captured by property values. For instance, more wetland acres in a section implies that all else equal, a section has more open space, less developed land, less commercial property, more scenic amenities, more potentially developable land in the future, lower population density, and less of anything positively related to density, etc.. Alternative uses of wetland acres, such as parks, might yield similar benefits. Consequently, simply showing that wetland acreage in a section has positive effects on nearby property values does not imply that wetlands are the most socially productive use of those acres.

The hedonic price equation (the relationship between property value and property characteristics) represents the locus of equilibrium price between the supply and demands for characteristics. As we discussed above, the relationship can be used to value marginal or small changes in the level of a characteristic. However, when considering changes in wetland acreage, one typically would be considering nonmarginal changes for which the hedonic approach employed here is not suited. For example, the decision to restore (or remove) a wetland will be nonmarginal (given that the estimated relationship applies to PWI wetlands which must be at least 2.5 acres). Thus, extrapolating the marginal value of restored wetlands based on the hedonic function would overestimate the value of a nonmarginal change.

While there are limitations inherent in the hedonic approach to wetland valuation, more detailed wetland characteristics data within a geographic information system would alleviate most of the limitations due to the existing data. Upcoming geocoded data from the National Wetlands Inventory should improve knowledge of how property values diminish as wetland distance increases. Such data would also aid in discerning the property value effects of wetland types, and wetland sizes-- especially for wetlands too small to be included in the PWI. Thus, future analysis using geocoded data from the National Wetlands Inventory would be beneficial.

There are several additional research questions that should be investigated using the framework developed identified here. These include:

i) The proper use of hedonic price functions in identifying the value of individual wetlands;

ii) The role of imperfections in housing markets in distorting the wetland-property value relationship;

iii) The incorporation of indirect effects in the valuation of wetlands;

iv) The valuation of wetlands versus other public and/or open space uses of land using a property value approach.

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APPENDIX

TABLE 2 Description of variables contained in hedonic data set for Ramsey County.*

Variable	Type	Description
PRICE89	Integer	Sale price adjusted using 1989 base year
AGE	Integer	Age of the house at time of sale
TOTAL AREA	Integer	Total interior area of house in square feet
OSP. AREA	Integer	Open screened porch area in square feet
EP. AREA	Integer	Enclosed porch area in square feet
DECK AREA	Integer	Deck area in square feet
POOL AREA	Integer	Pool area in square feet
GARAGE CAP.	Integer	Garage capacity in number of whole cars
FIREPLACES	Integer	Number of fireplaces
# ROOMS	Integer	Number of rooms excluding bedrooms & bathrooms
# BEDROOM	Integer	Number of bedrooms
# BATH	Real	Number of bathrooms
NONSINGLEF	Dummy	Single family housing = 0, all other = 1
FRAME	Dummy	Frame housing = 1, other =0
CENTRAL AIR	Dummy	Central Air = 1, no central air = 0
COND. POOR	Dummy	Property condition, below average = 1
COND. GOOD	"	Property condition, above average = 1
SPLIT LEVEL	Dummy	Type, = 1 if split level
ONE STORY	"	Type, = 1 if one story
1.5 STORY	"	Type, = 1 if one and one half stories
1.75 STORY	"	Type, = 1 if one and three quarters stories
TWO STORY	"	Type, = 1 if two stories
1/4 BSMT.	Dummy	Basement, = 1 if one quarter
HALF BSMT.	"	Basement, = 1 if one half
3/4 BSMT.	"	Basement, = 1 if three quarter
FULL BSMT.	"	Basement, = 1 if full
WALKOUT B.	Dummy	Basement has walkout exit = 1, none = 0
LOT CULD.	Dummy	Lot location, on cul-de-sac = 1
LOT CORNER	"	Lot location, on corner = 1
DIST. 282	Dummy	School district, =1 if St. Anthony Village
DIST. 621	"	School district, =1 if Mounds View
DIST. 622	"	School district, =1 if North St. Paul-Maplewood
DIST. 623	"	School district, =1 if Roseville
DIST. 624	"	School district, =1 if White Bear Lake
TOPO. FLAT	Dummy	Lot topography, flat=1, all other =0
MISS. RIV.	Dummy	Miss. river passes through section = 1
LAKESIDE	Dummy	Property is lakeside** = 1, otherwise 0
LAKE ACRES	Integer	PWI Lake acres in property's section
WET. ACRES	Integer	PWI Wetland acres in property's section

* The base case omitted dummy variables are for average condition, split entry, no basement, inner lot, and St. Paul school district (#625).

** Lakeside is defined as property that is lakefront, has a lake view, or has explicit lake access rights.

TABLE 3 LIMDEP^{tm} regression output for PRICE89 - Beta*[variables]

Dependent Variable	PRICE89	Number of Observations	18863
Mean of Dep. Var.	88949.229762	Std. Dev. of Dep. Var.	46433.480413
Std. Error of Regr.	24674.202301	F(39,18863)	1230.1302
R - squared	.718210	Adjusted R - Squared	.717627

Variable	Coefficient	Std. Error	T-ratio	Prob|t|≥x	Mean of X	Std.D.of X
ONE	11219.5	2739.69	-5.500	.00000	1.00000	.00000
AGE	-354.744	11.3766	-31.182	.00000	41.79022	30.40104
TOTAL AREA	42.3491	.799233	52.987	.00000	1170.33165	462.58527
OSP. AREA	29.5391	2.71638	10.874	.00000	30.76950	71.77623
EP. AREA	20.4781	2.61829	7.821	.00000	41.73042	78.37319
DECK AREA	11.8115	2.15810	5.473	.00000	37.14849	93.40734
POOL AREA	14.9955	2.29742	6.527	.00000	8.19488	79.88313
GARAGE CAP.	5893.91	304.171	19.377	.00000	1.56433	.70458
FIREPLACES	10200.8	321.344	31.744	.00000	.49101	.68111
# ROOMS	-988.330	228.119	-4.333	.00003	3.33568	1.18011
# BEDROOM	-3381.31	248.458	-13.609	.00000	2.96310	.96361
# BATH	14472.8	510.253	28.364	.00000	1.45229	.58236
NONSINGLEF	-26288.4	615.270	42.727	.00000	.85448	.35264
FRAME	-6172.58	2070.83	-2.981	.00304	.99226	.08764
CENTRAL AIR	-311.418	472.240	-.659	.51706	.27647	.44726
COND. POOR	-14470.6	1367.52	-10.582	.00000	.01845	.13457
COND. GOOD	5302.93	1077.46	4.922	.00000	.02932	.16870
SPLIT LEVEL	7481.95	861.211	8.688	.00000	.07660	.26597
ONE STORY	10819.0	671.917	16.102	.00000	.42570	.49446
1.5 STORY	24900.8	1022.38	24.356	.00000	.06929	.25395
1.75 STORY	31911.7	1018.29	31.338	.00000	.09654	.29534
TWO STORY	48163.3	876.755	54.934	.00000	.20999	.40731
1/4 BSMT.	691.834	1928.68	.359	.71870	.01638	.12694
HALF BSMT.	1793.16	1613.68	1.111	.26570	.03499	.18376
3/4 BSMT.	6673.85	1378.43	4.842	.00000	.12145	.32666
FULL BSMT.	4692.27	1276.81	3.675	.00034	.80348	.39738
WALKOUT B.	-263.153	640.146	-.411	.68336	.13359	.34023
LOT CULD.	11034.7	1105.51	9.981	.00000	.02953	.16929
LOT CORNER	-1263.13	501.525	-2.519	.01140	.15438	.36132
DIST. 282	-8112.06	2471.30	-3.283	.00120	.00557	.07440
DIST. 621	4364.54	705.318	6.188	.00000	.17076	.37631
DIST. 622	-1657.30	778.890	-2.128	.03150	.07708	.26673
DIST. 623	-3252.70	743.434	-4.375	.00003	.09028	.28659
DIST. 624	-1607.42	842.093	-1.909	.05324	.12241	.32777
TOPO. FLAT	1889.57	667.540	2.831	.00473	.90039	.29949
MISS. RIV.	5008.03	725.484	6.903	.00000	.07167	.25796
LAKESIDE	41383.8	1547.97	26.734	.00000	.01521	.12241
LAKE ACRES	3.28016	.714513	4.591	.00001	111.09262	307.97490
WET. ACRES	47.5734	11.1107	4.282	.00004	29.25929	70.85243
WETACRE^SQD	-.084044	.0345371	-2.433	.01435	5875.90617	21279.29640