SIMULATION OF COTTAGE LOT SUBDIVISION: A SYNTHESIS OF SOCIAL, ECONOMIC, AND ENVIRONMENTAL CONCERNS

by

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ABSTRACT

Concern with the inability of traditional measures of value to reflect environmental quality led to this search for another measure to be used in the rapidly developing Gulf Islands of British Columbia. The measure identified, our subjective preference for cottage lots of various sizes, is defined mathematically and compared with the more traditional measures—development cost and market price.

A set of 35mm colour slides, all apparently taken from the same cottage porch, were manufactured by superimposing images of various numbers of neighbouring houses on four background scenes. When shown the slides and asked which view they would prefer from their own cottage porch, subjects were found to respond to the number of neighbours and distance to the nearest according to Weber's law. By transforming nearest neighbour distance to a measurement of area, a relationship between subjective preference and lot size is established.

To compare the above subjective preference - lot size relationship with more traditional measures of value, a generalized total cost function for cottage lots is built and then tuned with data from the literature. From the total cost function both average and marginal cost equations are derived and plotted for lots of varying size. As might be expected, there is no apparent similarity between subjective preference and development cost for lots of any particular size.

With the cooperation of the Provincial Assessor and Registrar of Lands, market price, lot size, date of sale, and other data were collected for 579 parcels of the Gulf Islands. An analysis of this data suggests that, under conditions of very rapid development, the subjective preference - lot size relationship, might be reflected in the market prices. But this traditional measure of value is not a reliable reflection of subjective preference.

In an effort to learn some of the conditions under which subjective preferences could be satisfied, a measure of the impact of development upon environmental quality is conceived and incorporated in a mathematical model of the development of the Gulf Islands. Within the model, developers subdivide land in response to demand for cottage lots, their desire for profit, and the cost of producing the lots. The sensitivity of the model to various policy interventions is then tested.

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INTRODUCTION

The Gulf Islands of British Columbia lie in the most protected waters of the Pacific Coast of North America, and in the most gentle climatic region of Canada. Their beauty is widely acclaimed. It is not surprising, therefore, that these islands are experiencing an accelerating influx of summer and permanent residents. So rapid has been this development recently that one frequently hears stories of "deteriorating quality" and the growing "suburban environment". The same story is heard elsewhere with reference to rich agricultural lands as well as idyllic holiday regions.

Using our society's traditional measures of value, the market and ballot box, no justification can be found for claims of lost quality. On moving from agricultural or extensive recreational use to more intensive suburban uses, value acrues to the land, for prices certainly rise and political campaigns are never fought on such mundane battlefields as "land use". Governments seldom make permanent policy adjustments to slow or stop such shifts in the use of land, yet stories of lost quality continue and seem intuitively correct.

The work described here was undertaken in consequence of the above intuition and is part of a larger study of recreational land use in the Gulf Islands of British Columbia. The aim of the larger study was to develop a simulation model of land moving from agriculture and forestry to more intensive use as summer cottage sites. In achieving its goal, the parent study identified and linked processes which describe the supply of land to developers, the subdivision of parcels suitable for cottage use, consequent changes in their recreational quality, the demand for them, and an auction or market in which supply and demand interact. The resulting Gulf Islands Recreational Land Simulator (GIRLS) mimics the development of the Islands for cottage use from 1900 to 2000, given certain assumptions concerning future rates of taxation, population and economic growth, the distri-

bution of wealth, and the availability of the Islands to developers. More briefly, the model simulates the distribution of a recreational resource as privately-owned parcels of land.

Within such a distribution system, a key process is that which subdivides the resource into individual parcels. There the environment receives the impact of economically expressed social demands. It is my hypothesis that the development (subdivision) of a recreational resource in response to economic forces alone can result in the deterioration of that environment. The following objectives were designed first to test that hypothesis; then, if true, to provide empirically tested mathematical expressions which could be used to build the subdivision and environmental change processes in GIRLS. This study therefore brings into being a major portion of GIRLS, and represents part of my contribution to the development of that simulation model. The objectives of this study were:

1. To identify some visually perceivable measure of the intensity of development of the environment in question.
2. To identify some unconstrained measure of preference for that environment.
3. To quantitatively relate intensity of development to:
   (a) the above unconstrained measure of preference;
   (b) market value; and,
   (c) development cost.
4. To express the above relationships in mathematical form, then link equations in a mathematical model of recreational land use (GIRLS).
5. To simulate development of the Islands for cottagers from 1900 to 2000 under a variety of supply and demand conditions in an attempt to learn some of the conditions under which market values reflect subjective preferences.

LOT SIZE AS A MEASURE OF ENVIRONMENTAL QUALITY

To many people, there is a cause and effect relationship between change in human population density and changed environmental quality. To pursue empirical verification of that relationship one must first specify the qualitative attribute under study and the areal extent of density, hence quality measurements. Here quality is defined as an aggregate of preferences collectively beyond analysis. One dimension of the aggregate, privacy or the availability of solitude, may be viewed as a function of population density over a rather small area.

Traditional population density measurements are expressed as the number of individuals per unit area of land surface. Much more convenient in the study of human populations is the inverse, or units of land area per individual, family, or other social unit. Such an expression has practical application in the planning of communities, and historical data concerning the size of individual parcels of land (and changes in municipal boundaries) are available for the past century or more. In the outdoor recreational context of this study, the family is the pertinent social unit, solitude the qualitative attribute, and lot size the applicable measure of population dispersion.

Questioning Methods

To simply ask people what intensity of development, spatial distribution of families, or lot size they would prefer in a given environment, makes little sense. To ask them to graphically relate the change in their preference with changing lot size seems more ridiculous. Even if respondents' understanding of spatial measurement were detailed, the mental images upon which answers were based must certainly differ as would the units of value used to reply. Two key problems were therefore: (1) the identification of some method of measuring an unconstrained subjective response; and (2) the visual representation of lot size. The latter receives attention first.

The visual representation of different lot sizes for subjective evaluation requires some unmistakable areal index and a high degree of spatial reality. All other aspects of the environment should be held constant. Accordingly, three possibilities were apparent.

1. A field situation where observers were asked to evaluate actual lots.
2. A three-dimensional model.
3. Photographs.

The first alternative, ideal in many respects, would not provide an environment uniform in characteristics other than lot size and its use would be prohibitively expensive. Although the representation of spatial relationships by photographs seems questionable, they can mimic the remaining environment with greater realism than can three-dimensional models. If, therefore, a two-dimensional photograph can adequately represent different lot sizes, that presentation medium would seem best.

The choice of signs by which to indicate various lot sizes was limited to a fence or a neighbouring house. Since lot size is used here as a measure of privacy available, a fence would be inadequate, for although property boundaries can be thus defined, the proximity of a neighbour cannot. The distance to a neighbouring house was therefore considered the best available indicator of spatial distribution, hence lot size. But can such distances be revealed in photographs?

Distance perception is dependent on monocular as well as binocular vision (Gibson, 1958). Indeed, binocular vision dominates the judgment of distances less than 10 meters from an observer (Appendix I). Beyond that range, monocular cues (the size of familiar objects, texture gradients, and others) subjugate distance judgments (Appendix I; Holoway and Boring, 1941; Gibson, 1958; Berry, 1948). So long as the distance to a neighbouring house

is not less than 10 meters, therefore, that distance can be correctly perceived by monocular cues alone. In a photograph, changes in the distance to that neighbouring house would be represented by the expansion or contraction of the building's image. Such a change would be perceived by a human observer as a change in the distance to the house (Schiff, 1965; Appendix I), particularly if glare and other cues for flatness (Schlosberg, 1941) were avoided through the use of rear projection. Photographs were therefore chosen as the most acceptable alternative for the display of different lot sizes.

Response Measurement

The use of photographs to present environments for evaluation is certainly not new (Fines, 1968; Lacey, et al., 1963; Levi, 1965; Sanoff, 1969; Shafer, et al., 1969). Neither is their modification by re-touching (Hermann, et al., 1968) or montage (Jacobs and Way, 1969) techniques. Such methods seem destined to become a standard tool for investigating environmental values. The methods by which responses or evaluations are measured, however, are extremely diverse. They vary from the semantic differential (Berlyne and Peckham, 1966; Osgood, 1952; Sanoff, 1969) common in the architectural literature, through various psychophysical techniques (Stevens, 1951), to the endocrinologists' measurement of catecholamine excretion (Levi, 1965). Of these methods, those found in the psychophysical literature seem most appropriate for this study. There, measurements of physical stimuli and psychological response are quantitative and related by a well-documented law (Ekman and Sjoberg, 1965; Stevens, 1960; Treisman, 1966). The quantitative attributes are a necessary requirement for mathematical modelling and, if data collected were found to conform to established psychological laws, the dangers associated with disciplinary trespass would be minimized.

Experimentally, psychophysical investigators expose observers to a range of intensities of some stimulus. During the exposure, observers' involuntary responses can be recorded on an electrocardiograph, electro-

encephalograph, or similar device. Alternatively, observers may be asked to respond voluntarily by assigning to each stimulus level presented some position on a response continuum provided by the investigator. Response continua used vary from brightness of light, loudness of sound, or force of handgrip, to a range of numbers (Stevens, 1960). Because the best measures of subjective response do not require the observer to make numerical estimations (Stevens, 1960), yet some comparatively simple system by which the observer left a permanent record of his judgment was desirable for this study, observers were asked to record their preference for each stimulus presented by marking levels in columns of "preference" (Appendix II). In this way the use of elaborate apparatus and the inaccuracies of numerical estimations were avoided, while simplicity was preserved.

Response Variability

In undertaking a study such as this, one is constantly plagued by notions of individuality, that people, unlike other animals, do not respond predictably to the same stimulus on different occasions and that cultural diversity implies response dissimilarities. If the fear promotes hesitation, it also emboldens the investigator since great variation in results can be attributed to diversity in the experimental organism and shoddy technique thus disguised. In either event, when significant response variation is expected between population strata, those strata should be identified and monitored as data collection proceeds.

Considering the strata likely to correspond with response differences, the extent of crowding in childhood and present home situations assume immediate importance. People reared or living in an extremely large city may feel ill at ease without the knowledge that others are near or, conversely, may have grown misanthropic. Similar speculation can be made with respect to other childhood and present home environs. The size of community in which respondents were reared, and the size of community in which they live, are therefore important classifications of the population.

Variation in respondents' ages might also coincide with differences in response to the proximity of neighbours, not only because age reflects the time during which, say, misanthropy could have developed, but age also reflects different functional stages in an individual's life. Pre-puberty responses might be different from those of individuals of mating age, pre-courtship responses might differ from those of mated individuals, and couples with young might respond differently from couples who have no children. Age, sex, marital status, and family size were therefore added to the list of strata in which personal information was to be collected.

Income, a traditional correlate of response differences, and the use a parcel of land is to serve, would seem important conditions upon which a preference response was based. Because the study is directly concerned with recreational, or cottage use, respondents had to be asked to respond in that context. At the same time it would be interesting to test for different preference functions if the properties were to be used not as summer homesites but permanent residences. Lastly, responses might be conditioned by current cottage ownership, or by lack of interest in owning a summer cottage. These three factors, income, use, and cottage ownership, were therefore added to the six previously derived to form the building blocks from which the personal information questionnaires were built. The spacing of sampling points within these nine strata was purely subjective and resulted in the questionnaires displayed in Appendix II.

Just as response might be correlated to the population strata discussed above, it might be correlated with qualities other than privacy (lot size), hence the questions: (1) what additional quantifiable parameters can be considered part of the assemblage which constitutes environmental quality, and (2) which of these, if any, should be included in this study, the objective of which is to isolate and describe variation in preference due to lot size alone?

Two such measures are the slope of a parcel of land and its proximity to water. The former perhaps because it reflects the opportunity to view one's surroundings, the difficulties associated with building, or the ease with which the land may be tilled; the latter because it reflects opportunity for water-oriented recreation and/or food gathering activities. Indeed, slope alone has been found to be a fairly reliable predictor of on-site subjective evaluations of waterfront property (Chambers, 1969).

Another measure or group of measures of quality involves vegetation, not only as it relates to shelter from the elements, available food, or pastoral beauty, but also as a purveyor of privacy (Darling, 1951). Accordingly, a vegetation screen might be an appropriate vegetation characteristic to use here. Within GIRLS, however, slope, distance to water, and vegetation characteristics are used to determine initial land qualities and are not considered here. The qualitative features studied were, therefore, reduced to (1) the distance to, and (2) number of neighbouring houses. Lot size is a function of the first.

Slide Manufacture

To maintain continuity between pictures, a standard visual reference has been found useful in similar studies (Jacobs and Way, 1969). The appropriate standard in this case was a cottage proch from which all pictures appeared to be taken. The slide manufacturing procedure employed was to photograph an 8x10 inch colour print of some basic landscape upon which the cottage proch foreground and neighbouring cottage images had been arranged. Basic scenes, with the exception of one, were chosen to maximize the possibility of superimposing building images at various distances. Scene four was selected because it represented waterfront property.

Nearest neighbour distances tested fell in the range from 50 to 500 feet. The lower limit was chosen as a result of the investigation reported in Appendix I, the upper by subjective considerations, and the knowledge that

such nearest neighbour distances would require lot sizes of about 5 acres. Within that range, distances chosen were 50, 90, 124, 180, 300, and 500 feet. Because all semblance of reality was lost if more than five houses were included, the number of neighbours ranged from zero to five. Within the constraints imposed by basic scenes and photographic technique, scenes, distances and number of neighbours were combined as shown in Figure 1 to produce the picture set displayed in Plate 1.

Experimental Procedure

A university "Open House" provided an excellent opportunity to obtain responses from a large number of people from a range of age, income and other population strata, provided the procedure employed could utilize a continuous flow of respondents. The following randomized split-plot design was therefore employed.

Four pictures were selected randomly from within each of two systematically selected scenes (Plate 1). These two groups of four pictures each were displayed on a rear projection screen, and thirty respondents asked, through questionnaires (Appendix II) to grade the pictures according to their preference. After these thirty questionnaires had been returned, the procedure was repeated using another two groups of four randomly selected pictures. Because a wider range of neighbour distances and numbers was available in scenes 1 and 2, these were sampled twice as intensively as were scenes 3 and 4.

Results and Discussion

Of the 720 questionnaires distributed, 681, or 94 per cent, were returned and usable. Preferences were measured in hundredths of the preference column heights, and all information coded on computer cards. Preliminary multiple regression revealed the bulk of the variability to be associated with the distance to, and number of neighbours, the background scene,

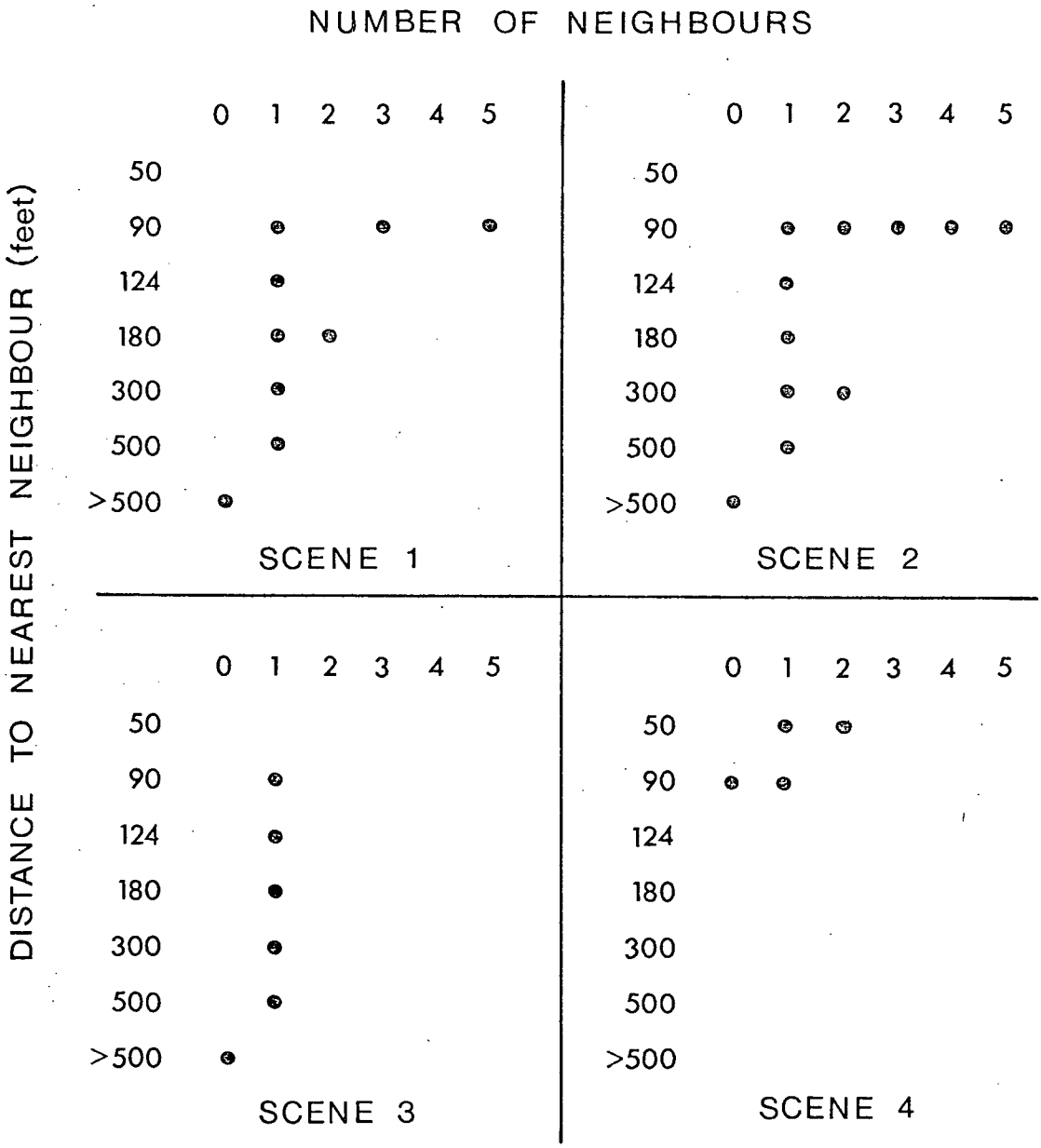

Figure 1. Combinations of scene, distance to, and number of neighbours represented by pictures reproduced in Plate 1.

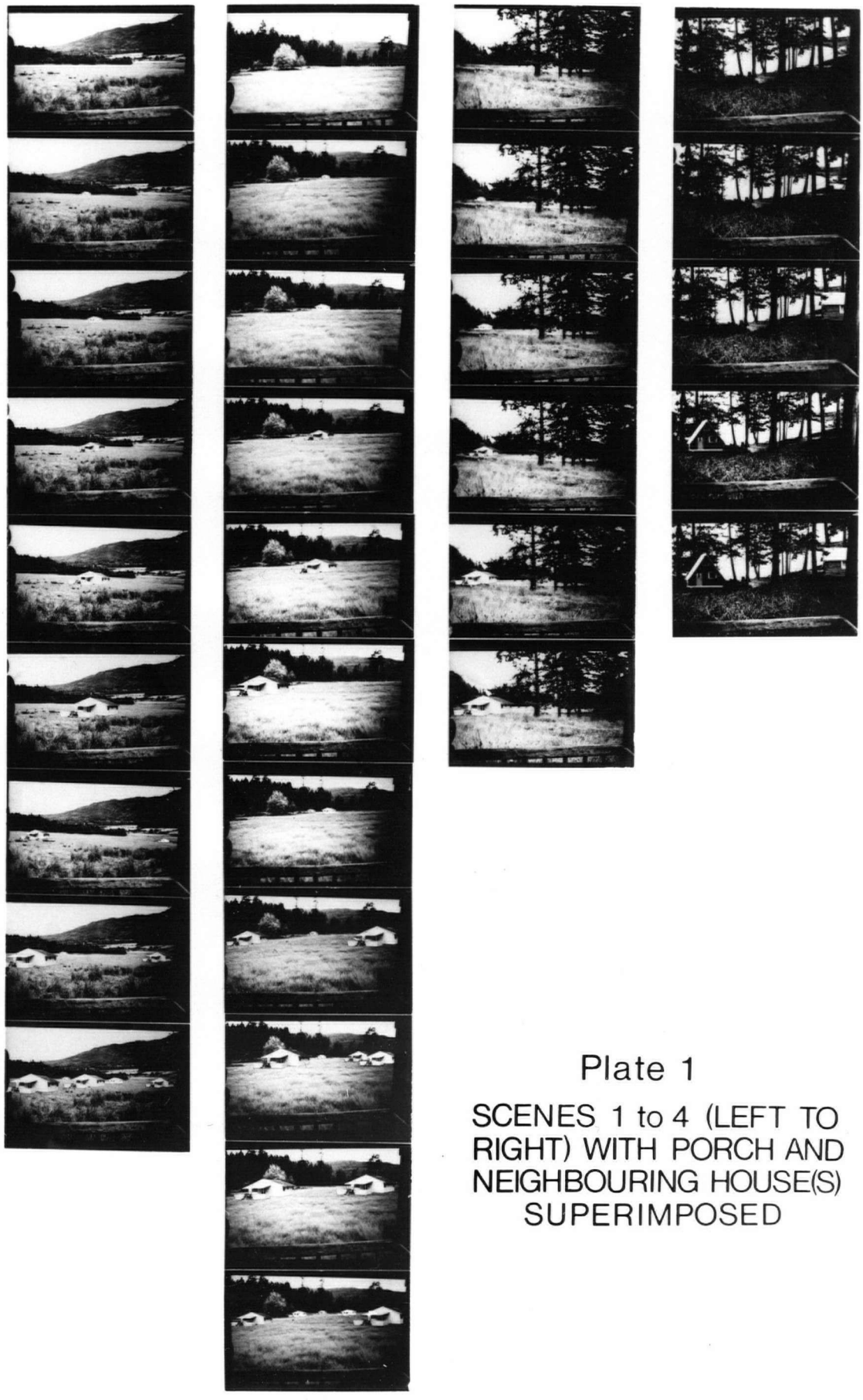

Plate 1

SCENES 1 to 4 (LEFT TO RIGHT) WITH PORCH AND NEIGHBOURING HOUSE(S) SUPERIMPOSED

and picture group. There was no indication that a significant proportion of the response variation was associated with age, sex, marital status, income, or any of the "people" variables. That is to say, variation in response to a specific stimulus on a given occurrence was very low and apparently not the result of differences in respondents. However, significant response differences did occur between occurrences of a specific stimulus. That is, the preference rating given a particular picture varied with the group of four pictures with which it was shown. Initial efforts were therefore directed toward an explanation of this source of variation, so that responses might be adjusted and pooled for the analysis of variability associated with neighbour number, distance, and background scene.

Preferences are relative. Something can be preferred only after comparing it with something else. Accordingly, preferences recorded within each group of four pictures were made with reference to other pictures in that group. Suppose a recorded preference (E) is a transformation on a real preference (R), so that

$$(E_1 - E_2) = \text{constant} \times (R_1 - R_2) \qquad (1)$$

where the constant is dependent only upon the particular group of four pictures. Then all such transformations are

$$E(I, J) = P(I) \times R(I, J) + Q(I) \qquad (2)$$

where P and Q are constants specific to each particular group (I) of pictures of scene (J). Those values of P(I) and Q(I) which minimize variation between mean responses to separate occurrences of the same picture were found iteratively and the set of adjusted preferences (R) obtained (Table IV).

Table I illustrates the significance of the P, Q transformation.

TABLE I. Significance of data adjustment by the P, Q transform. (All variation between occurrences of given pictures.)

Source of Variation	d.f.	ss	ms	F	Significance
Removed by fitting P, Q (regression)	96	1.8639	0.0194	4.04	99.9 %
Remaining after fitting (residual)	65	0.3095	0.0048		
Before fitting P, Q (total)	161	2.1734			

Table IV and the above analysis of variance illustrate the advantage of the P, Q transform. Indeed, the reduction in response variation between occurrences of a specific stimulus (picture) is such that adjusted responses can be pooled for analysis of variation attributable to the number of and distance to neighbouring houses.

Again, preferences are relative. The adjusted set (R) reflects preference for one picture in comparison with others sharing the same background scene. Considering only the effect of distance to nearest perceived neighbour, suppose a change in preference (ΔR) depends upon:

(1) the level of preference prevailing before the change (R);

(2) the magnitude of the change in nearest neighbour distance (ΔD); and,

(3) the nearest neighbour distance existing before the change (D),

such that

$$\frac{\Delta R}{R} = \alpha \frac{\Delta D}{D} \qquad (3)$$

where R, ΔR, D, and ΔD are as defined above, and α is some constant. By assuming small ΔR and ΔD, and a continuous function, then re-arranging, we obtain

$$\frac{1}{R}dR = \alpha\frac{1}{D}dD \tag{4}$$

which, upon integration, yields

$$\ln R = \alpha \ln D + c. \tag{5}$$

Consider the integration constant c to be related to a second constant k as follows:

$$c = \ln k. \tag{6}$$

Substituting (6) in (5) above and taking antilogs, we obtain

$$R = kD^{\alpha}. \tag{7}$$

Using similar assumptions and argument, a hypothetical relationship between the adjusted preference set (R) and the number of neighbours visible (N) can be expressed as

$$R = k'N^{\beta} \tag{8}$$

where k' and β are constants comparable with k and α in equation (7).

Equations (7) and (8) are precisely the form taken by Weber's Law (Stevens, 1960). This now classic "power function" of psychophysics is generally expressed as

$$\Psi = k\Phi^{m} \tag{9}$$

where Ψ is the psychological response to some physical stimulus Φ, k a constant, and m some power which varies between stimuli. Given their similarity with this well-documented law of psychology (Ekman and Sjoberg, 1965), equations (7) and (8) offered promise as components of a mathematical description of the relationship between subjective preference and the independent variables under study. Multiple regression models initially tested therefore employed these variables in a variety of combina-

tions and with a range of parameter values, representatives of which are shown in Table II. Of the variations possible, the form offering the greatest promise was

$$R = A + BD^{\alpha}N^{\beta}. \qquad (10)$$

TABLE II. Multiple regression models initially tested, variance ratios (F), significance levels (Signif.), and coefficients of correlation. (Considering only within scene variation.)

Model	F	Signif.(%)	Coefficient of Correlation
$R = A + B_1 D^1 + B_2 N^1$	19.5	95	.68
$R = A + B_1 D^{-1} + B_2 N^1$	46.9	95	.79
$R = A + B_1 D^{-.5} + B_2 N^1$	47.4	95	.79
$R = A + BD^{-1} N^1$	53.3	95	.80

Using equation (10) as the model and fitting α and β to all data, values of those parameters were sought which minimized residual sums of squares. Trial values of β converged quite rapidly to an optimum $0.5 \pm .2$ (90 per cent C.I.). The parameter α converged very slowly to an optimum $-1.0 \pm .5$ (90 per cent C.I.).

The extremely high correlations between dependent and independent variables (Table III and Figure 2) are initially cause for alarm. Such correlations are seldom found except when comparing something with itself. There is indeed the possibility that people were responding to the questions, "How many houses are there?", and, "How far away is the neighbour?" But, since scores were recorded on "preference" columns, these may be valid questions. Such high correlations are not uncommon in psychological

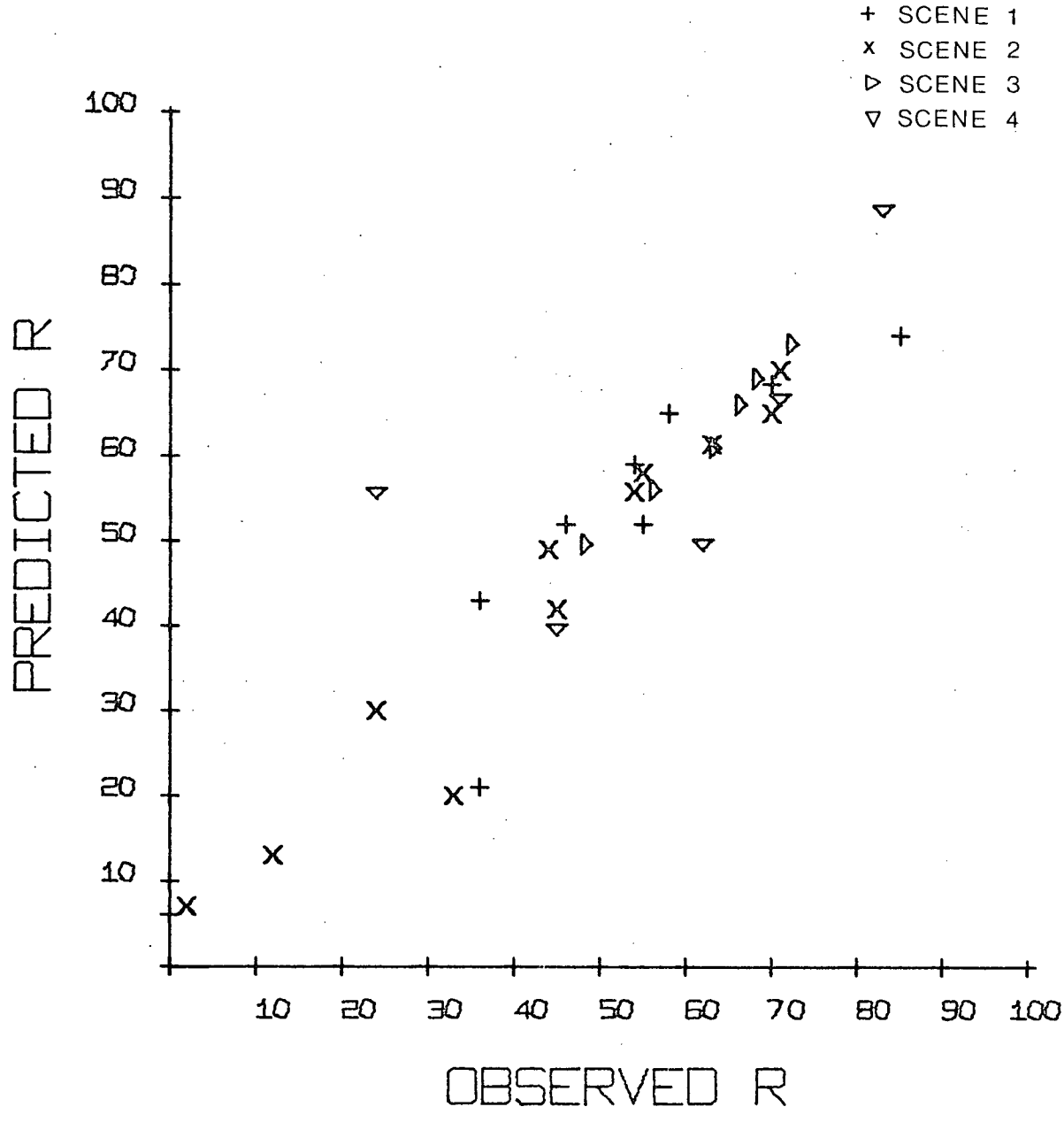

Figure 2. Observed (adjusted) preferences versus those predicted by the regression equation for each scene.

investigations, or those whose techniques are borrowed from that field (Masuda and Holmes, 1967).

TABLE III. Parameters A and B of the regression model $R = A - BD^{-1}N^{.5}$, variance ratios (F), significance levels (Signif.), and coefficients of correlation for each of the scenes in Plate 1.

Scene	F	B	F	Signif. (%)	Coefficient of Correlation
1	74	2750	52.6	99	.93
2	70	2550	157.8	99	.97
3	73	2100	230.2	99	.99
4	88	1950	17.6	95	.92
All	72	2150	77.4	99	.85

Interpreting Table III and Figure 3, one might attribute variation in parameter A to different initial qualities of the scenes presented, but little significance can be attached to those differences here. Studies like those of Fines (1968) and Shafer, et al., (1969), are directed toward an understanding of the process by which initial preferences for different scenes or landscapes are made. Variation in the parameter B (Table III) can be interpreted as a measure of the sensitivity of a particular scene (or environment) to the effects of population pressure, a concern of Peterson and Neumann (1969). The comparatively low weight given B in scene 4 might be a result of the proximate waterfront, reflecting a greater capacity of that environment to absorb population pressure or, conversely, to supply people with the recreational resource they seek. Alternatively, B can be considered a measure of the impact of development upon the recreational quality of an environment. Jacobs and Way (1969) initiated most important work into the capacity of an environment to absorb or mask signs of development or, in the context of this study, to identify the environmental determinants of the parameter B.

TABLE IV. A tabular comparison of unadjusted (E), adjusted (R), and predicted mean evaluations of pictures shown in Plate 1.

Scene	Picture	Unadjusted Mean (E)	SE	Adjusted Mean (R)	SE	Predicted Mean $R=A+BD^{-1}N^{.5}$	Number Houses	Distance to nearest (ft.)
1	1	88	5	85	2	74	0	
	2	70	8	70	5	69	1	500
	3	55	10	58	3	65	1	300
	4	55	18	54	7	59	1	180
	5	43	12	46	4	52	1	124
	6	33	13	36	3	43	1	90
	7	57	13	55	4	52	2	180
	8	30	16	36	2	21	3	90
	9	21	8	0	3	6	5	90
2	1	73	11	71	1	70	0	
	2	78	8	70	3	65	1	500
	3	74	8	63	2	62	1	300
	4	57	12	54	2	56	1	180
	5	55	8	44	4	49	1	124
	6	53	10	45	3	42	1	90
	7	63	12	55	1	58	2	300
	8	37	8	33	2	20	3	90
	9	21	7	12	2	13	4	90
	10	26	13	24	2	30	2	90
	11	13	6	2	6	7	5	90
3	1	75	4	73	0	73	0	
	2	66	3	69	2	69	1	500
	3	64	11	67	3	66	1	300
	4	57	12	64	2	61	1	180
	5	43	10	57	0	56	1	124
	6	37	14	49	1	50	1	90
4	1	82	8	83	5	88	0	
	2	71	9	71	5	66	1	90
	3	63	7	62	3	49	1	50
	4	46	13	45	8	39	1	50
	5	23	9	24	3	55	2	50

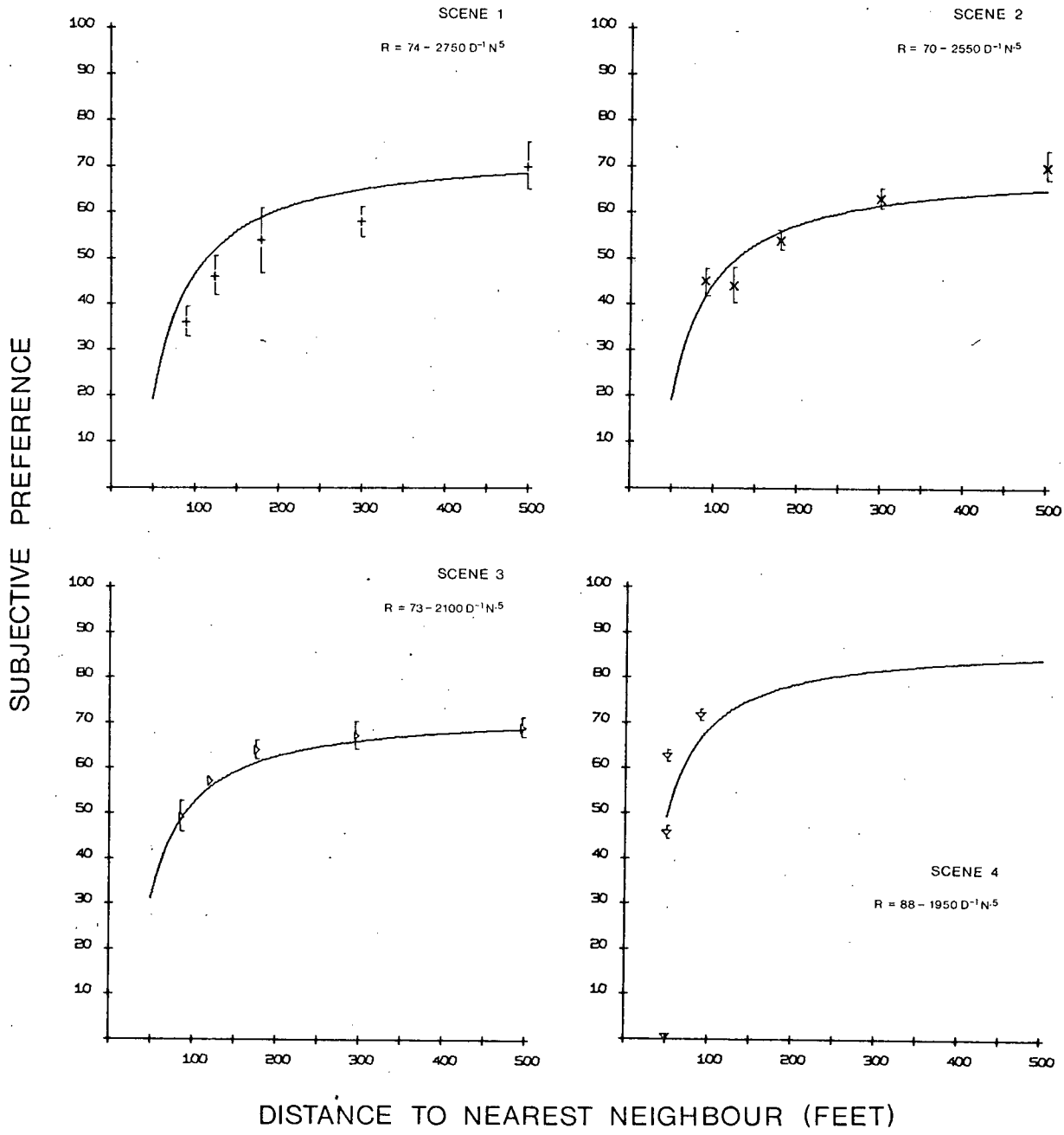

Figure 3. Subjective preference versus distance to nearest neighbour, scenes 1-4, one house visible.

Finally, the distance between neighbouring houses (D) can be transformed to the size of the lots they occupy (LS) by assuming lot area to be that of a circle the diameter of which is the given distance. Hence,

$$LS = \pi(D/2)^2. \tag{11}$$

Substituting this relationship in equation (10) yields the expression

$$R = A + B \left(2\sqrt{\frac{LS}{\pi}}\right)^{\alpha} N^{\beta} \tag{12}$$

to describe the relationship between subjective preference and lot size (Figure 4).

All of the foregoing supports the notion that environmental quality is affected by perceived population density. Indeed, subjective preference for summer cottage lots decreases with their perceived size according to a relationship which obeys a well established law of psychology. Two principal conclusions may be drawn:

(1) The subdivision of lots to sizes below two acres may be accompanied by a rather rapid decrease in quality.

(2) Change in the quality of subdivided land is at least partly density dependent.

The implications of the first conclusion seem initially obvious. But let me be the first objector to an implied bylaw prohibiting subdivision of land into parcels less than two acres. Only one of a multitude of dimensions which collectively constitute quality is considered here. Certainly, there are those who argue quite fervently, and I believe rightly, that a suburban environment where the population is uniformly distributed is sterile. In the context of the Gulf Islands of British Columbia, a two-acre minimum lot size for future subdivisions might indeed be valid, for there is relief from the higher densities of the cities, and the capability of recreational lands to function in that capacity must be maintained.

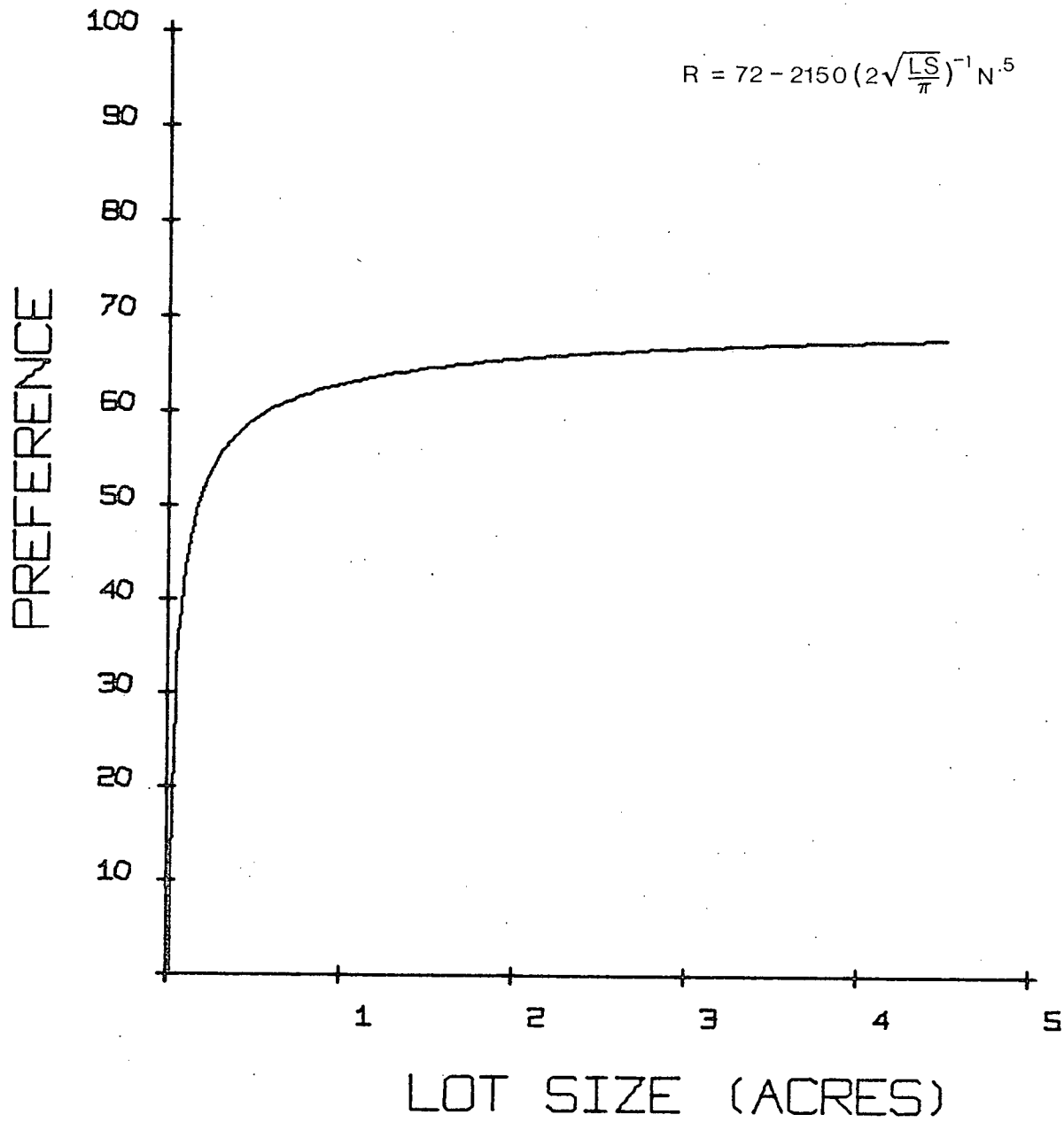

Figure 4. Preference versus lot size. All scenes, one house visible.

Most important, however, is the implication of the second conclusion. The mathematical expression found to relate unconstrained preference to visible signs of density suggests a method for handling many dimensions of quality in the context of a simulation model. By simply expanding the parameters of equation (10) to vectors, matrices or equations, defining A as relative quality before development begins, and B the rate at which the signs of increasing density (visual, audio, or olifactory) improve upon or detract from A, the skeleton of a simulation model appears, an experimental program surfaces, and a useful tool for those concerned with environmental quality is promised. Such a tool could be infinitely valuable both to those who seek to preserve environments, and to those who wish to develop them, for it could foster more effective communication between them.

PRODUCTION COST VERSUS LOT SIZE

Since the quality of cottage lots is at least partly determined by their size, those economic forces influencing lot size assume new importance. If the production or maintenance of environmental quality is, or should come to be, a social priority, then response to economic forces alone might produce a less than optimum lot size distribution. Definition of the relationship between production cost and lot size is therefore necessary for comparison with the quality-size function developed earlier.

The empirical definition of a generalized total cost function for the subdivision of cottage lots seems an impertinent undertaking. The tremendous number of variables involved and the reluctance of developers to disclose data predict failure from the outset. Yet rules of thumb and general approaches to production cost estimations are not uncommon (Bliss, 1957; Mashke, 1963; Wagner, 1957); detailed treatments of the specifications and requirements of some communities can be found (McKeever, 1968); and, indeed, mathematical models of cash flows have been built to optimize the return from long-term, large-scale developments (Wendt, 1967). However, available models of development costs consider specific services (sewers) and only the region of increasing returns to scale (Downing, 1969), or retreat to the untestable (Smith, 1969).

One practitioner (Thomsen, 1968) has found and published the general form of a cost curve predicted by classical economic theory[1], and Pearson (1965) has detailed the costs of subdividing several acreages into various sized lots at servicing levels required by local governments (Table V). The first provides the impetus to attempt mathematical description of a generalized total cost function, the second empirical data with which to test its worth.

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[1] Ferguson, C.E. 1966. Microeconomic Theory. Irwin. Homewood, Illinois. p. 170.

Let the total cost (TC) of producing a number of lots be comprised of land purchase (P) and subdivision (S) costs, so that

$$TC = P + S \tag{13}$$

Now consider land purchase (P) alone, and let the area to be subdivided be g acres. If these g acres are purchased for b dollars per acre,

$$P = bg \tag{14}$$

and the total cost function becomes

$$TC = bg + S. \tag{15}$$

Now allow g acres to be subdivided into n lots of size s, and let some unstated proportion of s represent that land used for roads, parks, schools, and other public property so that

$$g = ns. \tag{16}$$

Substituting (16) in (15) above, we obtain

$$TC = bsn + S. \tag{17}$$

Next, consider the contribution of legal, survey, and realty fees to subdivision costs (S). Such fees are frequently calculated as a proportion of the market price of the property in question and can therefore be modelled as some proportion (k) of the selling price (r) of the n lots produced.

$$S = krn \tag{18}$$

This relationship holds even for the particular case where g acres are bought and then sold intact, for there just one lot is produced.

Now consider that land and labour are the two inputs required for cottage lot production. One of these inputs may be decreased and a given

level of production maintained only by increasing the other input.[2] That is to say, ten lots might be produced from fifty acres of land with a small amount of labour. To produce ten lots from one acre, additional water must be transported to the site, more elaborate waste disposal systems must be built, and roads must be more durable. The cost of servicing a single lot may therefore be considered inversely proportional to its size (s). This relationship is conveniently included in the subdivision costs (S) by modifying equation (18) as follows.

$$S = krn\left(1 + \frac{L}{s}\right) \tag{19}$$

where L is a constant describing the technology available for servicing lots. The expression $\frac{L}{s}$ represents additions to subdivision costs which result from lot smallness. Where technology is inexpensive and highly developed, or not required to adequately service small lots, L is very small. But where additional water must be imported, sewage exported, or other expensive technological problems arise as lots become smaller, L may be adjusted upward to account for those difficulties.

Turning finally to the relationship between total cost and number of lots produced, tradition suggests regions of increasing and decreasing returns to scale. Because such a curve is complex mathematically, the other cost-production relationships highly simplified, and production always in the region of diminishing returns anyway,[3] no region of increasing returns is included here. Since the aim of this exercise is to produce a generalized total cost function which can be tuned to a given set of conditions, all features of the function must be flexible. With respect to a region of diminishing returns, this flexibility must provide opportunity to adjust (1) the level of production where diminishing returns begin to occur, and (2) the rate at

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[2] Ferguson, op. cit., p. 157.

[3] Ferguson, op. cit., p. 197.

which returns diminish. These objectives are met simply and conveniently by modifying equation (19) as follows:

$$S = krn\left(1 + \frac{L}{s}\right) + m(e^{pn} - 1) \qquad (20)$$

where m and p are constants. The parameter m effectively determines entrepreneur efficiency, or the number of lots which can be produced before diminishing returns begin to occur. Once begun, the rate at which returns diminish is determined by the parameter p. Substituting (20) in (17), the total cost equation now becomes

$$TC = bsn + krn\left(1 + \frac{L}{s}\right) + m(e^{pn} - 1). \qquad (21)$$

Although euqation (21) is highly simplified, the input constants provide the flexibility required to accommodate subdivision problems of different regions. A graphical representation (Figure 5) of equation (21), using a not unrealistic set of input values, matches Pearson's (1965) data (Table V) with reasonable accuracy.

If asked to place a value on something, one might well cite its production cost. Two measures of cost with which to compare subjective preferences are therefore marginal and average development costs of cottage lots. Average cost is simply the total cost of a subdivision divided by the number of lots it contains. Marginal cost is the addition to total cost attributable to the production of one more lot.

Comparison of Figure 6 with Figure 4 leads rapidly to the conclusion that subjective preference changes with diminishing lot size quite differently from the way in which average and marginal costs change with diminishing lot size. Moreover, a developer responding to economic forces alone would produce lots of a size dictated by the intersection of marginal revenue with marginal cost above average cost. That is to say, under the conditions listed below Figure 5, a developer would only produce lots less than 1-3/4 acres,

TABLE V. Subdivision Costs (160 acres)*

Lot Size	No. Lots	Cost per lot ($) Servicing Level			Total Subdivision Costs ($) Servicing Level		
		Full	Partial	Minimal	Full	Partial	Minimal
2,500 ft.² (.06 ac)	1614	1135	685	401	1,831,933	1,105,433	647,325
5,000 ft.² (.11 ac)	939	1588	984	603	1,491,543	923,892	566,061
10,000 ft.² (.23 ac)	532	2196	1457	905	1,168,356	775,060	481,625
40,000 ft.² (.92 ac)	150	5421	3594	2419	813,143	539,084	362,818
5. ac	30			7833			235,000

* After Pearson (1965). The 5 acre costs were calculated using that author's figures and providing gravel roads only, and developer's land costs are assumed to be $160,000. The boxed figures are those which provide adequate servicing to lots of corresponding size (Pearson) and are plotted in Figures 9 and 10.

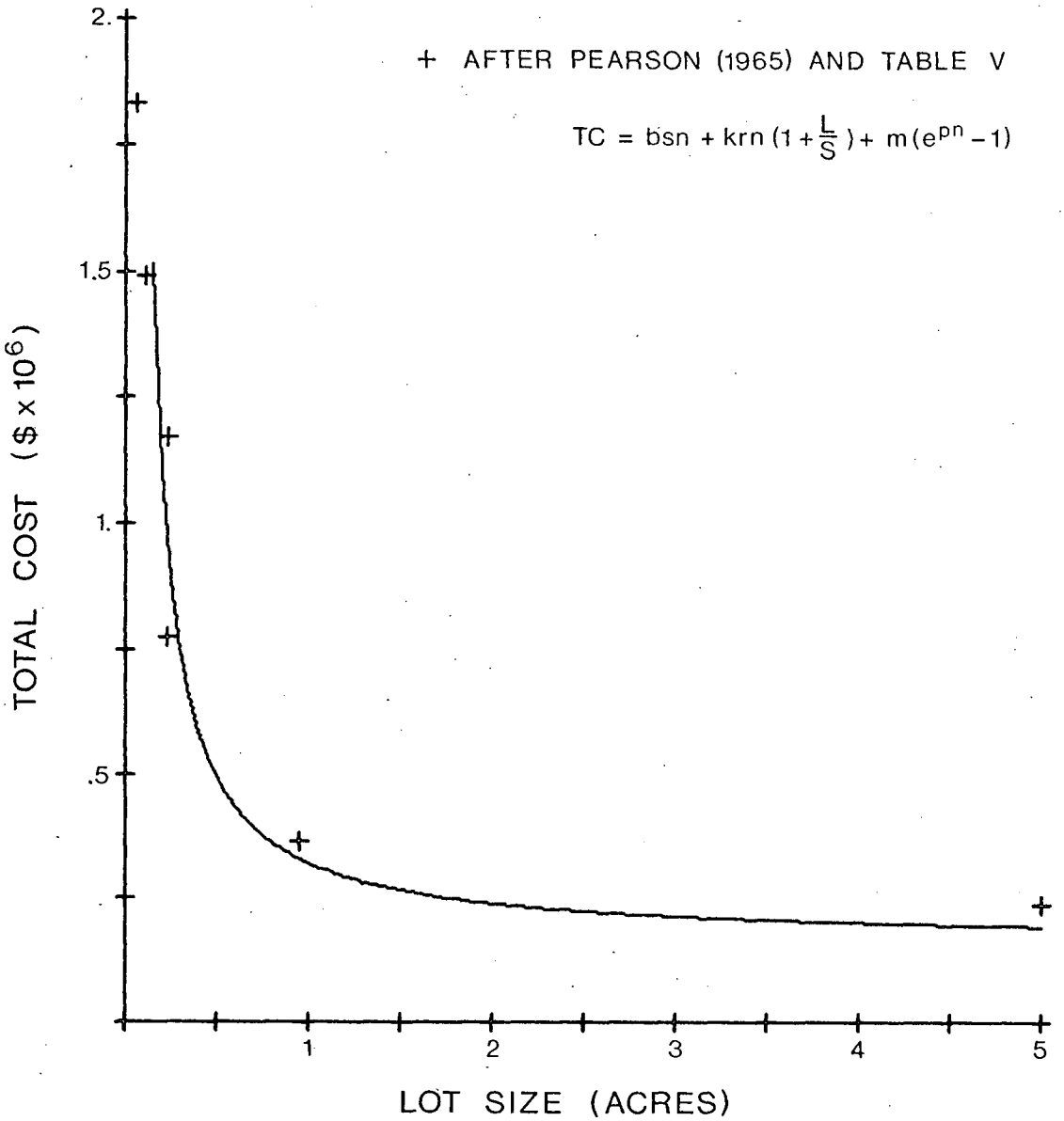

Figure 5. Development cost versus lot size, 160 acre subdivision.

Assumptions:

1. expected selling price per lot $6,000;
2. developer's land cost $1,000 per acre;
3. legal, survey and realty fees = 15% of selling price;
4. lot size at which marginal cost has increased 10% because of smallness = 0.5 ac.;
5. 10% penalty at the margin, for diminishing returns to scale after developing 1000 lots;
6. 20% penalty at the margin, for diminishing returns to scale after developing 2000 lots.

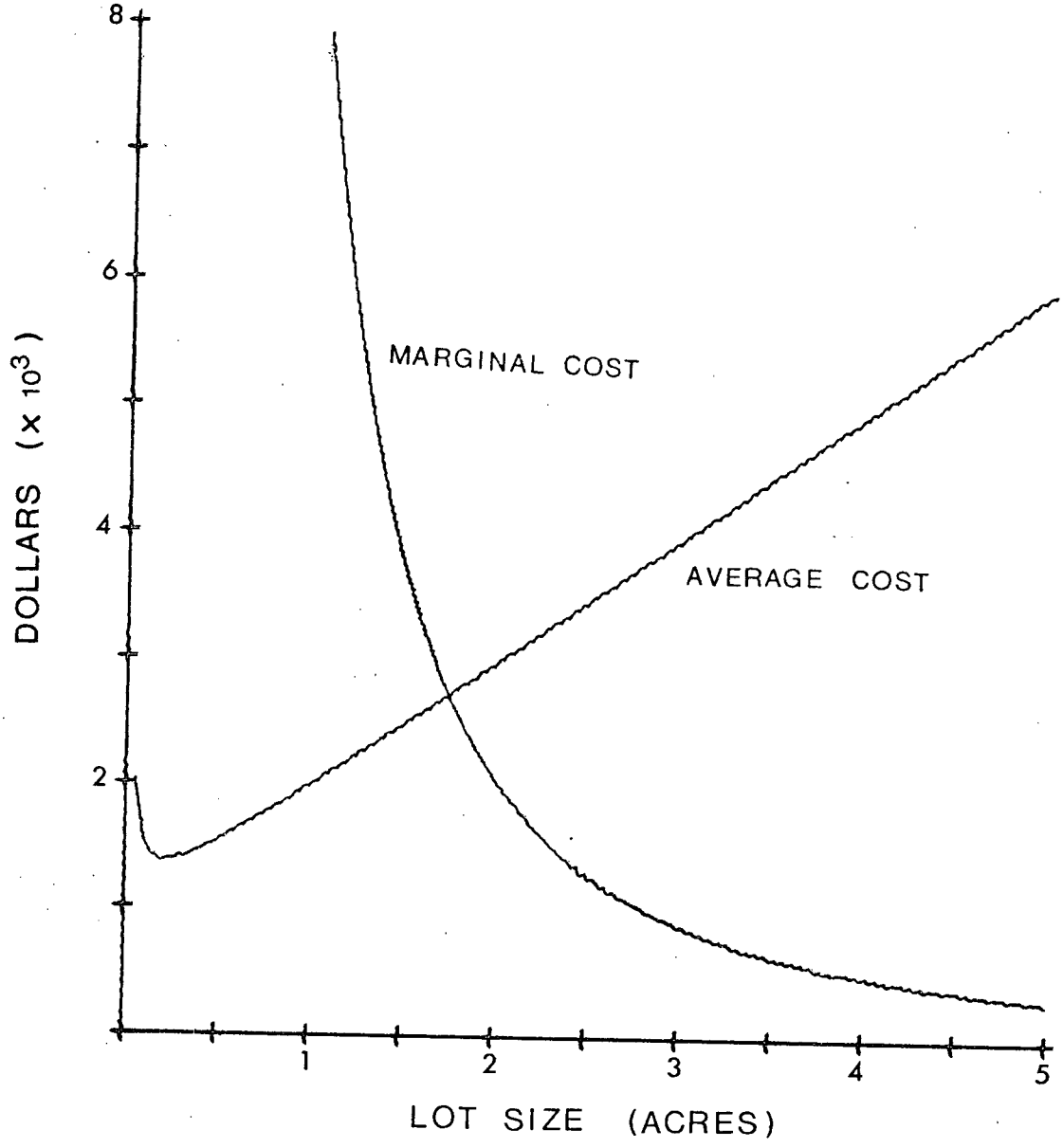

Figure 6. Average and marginal development cost versus lot size, 160 acre subdivision. Assumptions as listed beneath Figure 5.

and often very much smaller than that. To prevent concomitant environmental quality losses, cost criteria must be modified and traditionally we look to the market to provide the necessary correcting influence. The following section therefore examines the influence of parcel size in market price determinations.

MARKET VALUE VERSUS LOT SIZE

Because land tenure assumes such a dominant role in our society, it is not surprising that extensive data concerning land ownership are to be found in governmental offices. Although record keeping systems have changed, there is sufficient continuity to carry out intensive studies of the history of land development. This investigation examines the relationship between the size and market price of parcels of Gulf Island land.

If the price paid for a given parcel of land is expected to vary with its size, it must also be expected to vary with the suitability of the parcel for the buyer's needs. An agriculturalist would likely pay a higher price for tillable land than he would for a steep rocky hillside. As developed earlier, slope, proximity to water, and certain vegetative characteristics are three determinants of quality in the context of outdoor recreation. Since market data available for this study include precise descriptions of parcel locations, slopes and proximity to water could be defined for each. Vegetational characteristics, however, are subject to rather rapid changes, particularly if one considers the presence of trees to be important. Because vegetational characteristics at the time sales took place are unknown, their influence on market price must appear as unexplained variance.

Because the overall study was confined to the Gulf Islands of British Columbia, sampling was of parcels on Galiano, Saltspring, Mayne, Saturna, North Pender and South Pender Islands, and the small islands in their immediate vicinity. Data required were: (1) parcel size; (2) average slope; (3) distance from the nearest water (lake or ocean); (4) purchase price; and (5) date of sale. In addition, some method of standardizing dollar values through time was required.

Historical records of land ownership, the size of individual parcels, dates of land sales, prices paid, and a wealth of other data occur partly in tax assessment records and partly in Provincial Land Registry files. The

latter, although containing all information required for the study described here, are a chronology of land subdivision and ownership changes within the province. They are therefore independent of specific geographical areas of the province. Tax assessment records, on the other hand, are keyed to a grid established in original land surveys. Although these records do not contain market prices and dates of land sales, they do state the size and precise location of parcels of land, and the "Certificate of Title" number under which that document is filed in the Land Registry. In addition, assessed values are usually recorded separately for land and "improvements." While assessed values do not necessarily mimic market prices at any point in time, they do permit some estimate of that proportion of the price which bought the land and that proportion which bought the buildings on it.

Data Collection and Analysis

Assessment rolls of the appropriate islands for 1930, 1940, 1950, 1960, and 1970 were available for the study. Of these, the 1930 and 1940 rolls did not include "Certificate of Title" numbers required to gain access to market values filed in the Land Registry. Sampling was therefore restricted to the last three assessment rolls. Required information was recorded from a ten per cent systematic sampling of each ledger. Market values and transaction dates were later obtained from Land Registry files along with plans of subdivisions which included sampled lots. Average slope and distance to water were recorded for each parcel after locating it on a topographic map.

At least four types of transactions occur in Land Registry data: (1) regular sale; (2) inheritance; (3) sale for $1 and "natural love and affection"; and (4) the subdivision of one parcel into several which are initially registered in the name of the subdivider. Since the latter three types of transfer do not provide a market-determined price, they are excluded from the analysis.

Another effect which could bias the analysis is change in the relative value of dollars through time. Market prices were therefore standardized

using the Dominion Bureau of Statistics total consumer price index (CPI) adjusted to a common base year (Canada Year Books 1914, 1946, and 1969). Because the relationships developed here are to be examined in the context of the Gulf Islands Recreational Land Simulator (Resource Science Centre, University of British Columbia), and prices in that model are in 1961 dollars, market values collected in this study were also brought to that standard, as follows:

$$\text{Price (1961 dollars)} = \frac{\text{Transaction price} * \text{CPI (1961)}}{\text{CPI (Transaction year)}}$$

The proportion of the price which brought the "improvements" on each parcel was then removed to obtain land values (LV) as follows:

$$\text{LV (1961 dollars)} = \frac{\text{Price (1961 dollars)} * \text{land assessment}}{\text{total assessment}}$$

The validity of this last "correction" to observed prices is questionable since assessment and market price determinations used were not necessarily made in the same year. But by using assessments made in, or after, the year of sale, and assuming that many more improvements were added than removed through time, land values obtained will consistently underestimate land prices, and trends in market prices which appear from the analysis should reflect actual trends.

To examine corrected prices for trends along the independent variable "lot size", it is necessary to group the data in parcel or lot size classes. That is, individual land holdings vary in size from less than 0.1 to over 1000 acres, while the size-price comparisons upon which this study concentrates are those of small parcels where the size-preference relationship developed earlier should be reflected. Therefore, if-size classes are constructed from the size-preference relationship

$$R = A + BD^{-1}N^{.5}$$

such that the range of R is similar for each class, the simplest hypothesis is that the relationship between average market price and size class is linear with unity slope. Price variation within size classes is attributable to factors other than those under investigation.

Considering equation (12), Table III and only those cases where one neighbour is visible, the general relationship between preference and lot size becomes

$$R = 72 - 2150 \left(2\sqrt{\frac{LS}{\pi}}\right)^{-1} .$$

Now let us say, quite arbitrarily, that those parcels of land less than five acres in size are of greatest interest and that a desirable degree of resolution requires six size classes below five acres. Convenient class limits are determined by adopting a preference interval of seven units for each size class.

Preference	0	37	44	51	58	65	72
Parcel Size (Acres)	0	.07	.11	.19	.43	1.70	5.00

Table VI reveals the results of an analysis of price variation in the blocked data. Both parcel size and year of sale explain a significant proportion of within-block price variation, while distance to water and per cent slope do not. Between size classes, price variation appears to be size independent, indicating the inadequacy of the simple size-price hypothesis.

Most important is the dependence of market price upon the independent variable "year of sale" between size classes. Of fundamental importance to the interpretation of this dependence is the notion that market price represents the intersection of supply and demand, and that historical market price data trace the locus of this intersection through time. Temporal changes in either

TABLE VI: Analysis of market price variation after blocking data in size classes defined above.

Source of Variation	dof	MS	F
Year of Sale (Regression)	1	37.67	13.21**
Between Size Classes (Blocks)	6	10.77	3.77**
Residual	571	2.86	
Distance to Water (Regression)	1	9.26	3.19
Between Size Classes (Blocks)	6	6.08	2.09
Residual	571	2.91	
Percent Slope (Regression)	1	.94	.32
Between Size Classes (Blocks)	6	5.24	1.79
Residual	571	2.92	
Parcel Size (Regression)	1	72.04	25.8**
Between Size Classes (Blocks)	6	.34	.12
Residual	571	2.80	

supply or demand or both therefore determine the path which market prices follow through time. For the past century or more, the demand for parcels of land on the Gulf Islands has increased, if only because the resident population has grown. While the supply of land remains fixed, the supply of individual parcels has increased with a resultant shift in parcel size distribution. This shift can be seen by comparing the frequency distributions of parcel sizes shown in Table VII and Figure 7.

As subdivision and the resulting shift in parcel size distribution take place, the capacity for future supply response is reduced. In addition, more parcels of less than optimum size are produced, setting the stage for the size-preference relationship to begin operation. These two effects combine with sustained population, hence demand growth to cause the size-preference relationship to begin to reflect in market price. Such an interpretation of the time dependence of market price between size classes (Table VI) is supported by the average price-size class relationship displayed in Figure 7.

Clearly the market does not, under all circumstances, provide developers with a discernible measure of quality lost because of parcel smallness. And even when prices do indicate a quality change, the signal might be too weak to modify the influence of cost criteria. Subdivision in response to the combined forces of development cost and market price alone can therefore result in degradation of environmental quality.

Given this apparent incompatibility of laissez-faire subdivision with the maintenance of environmental quality, the policy maker might well cry, "help". Should he set policy which would prohibit small lot subdivison, or could some other policy achieve the desired goal more efficiently? And what would be the economic and social consequences of these alternative policies designed to protect environmental quality? Will the situation correct itself if left alone? Answers to such questions can be found using simulation models such as that described in the next section.

TABLE VII. Number of parcels, average price and price range by size class and assessment year. Prices shown are in 1961 $ and represent land values only.

Number of Parcels	Average Price	Price Range Maximum	Price Range Minimum	Standard Deviation	Parcel Size (acres)
Assessment Year 1950					
129	3646	26,449	198	4,599	5.00 +
40	928	3,867	86	844	1.70 - 4.99
37	702	2,399	44	571	0.43 - 1.69
9	591	2,224	23	773	0.19 - 0.42
4	516	1,472	19	651	0.11 - 0.18
1	159	159	159	0	0.07 - 0.10
0	0	0	0	0	0.00 - 0.06
Assessment Year 1960					
85	4,079	43,405	97	7,208	5.00 +
44	1,516	11,090	103	1,941	1.70 - 4.99
27	682	2,516	41	568	0.43 - 1.69
15	1,176	10,844	3	2,691	0.19 - 0.42
4	327	650	12	308	0.11 - 0.18
1	4,662	4,662	4,662	0	0.07 - 0.10
2	710	1,075	345	516	0.00 - 0.06
Assessment Year 1970					
37	19,785	397,496	275	64,671	5.00 +
29	4,303	14,461	336	3,561	1.70 - 4.99
82	2,319	9,573	33	2,068	0.43 - 1.69
32	1,479	4,379	141	1,048	0.19 - 0.42
1	485	485	485	0	0.11 - 0.18
0	0	0	0	0	0.07 - 0.10
0	0	0	0	0	0.00 - 0.06

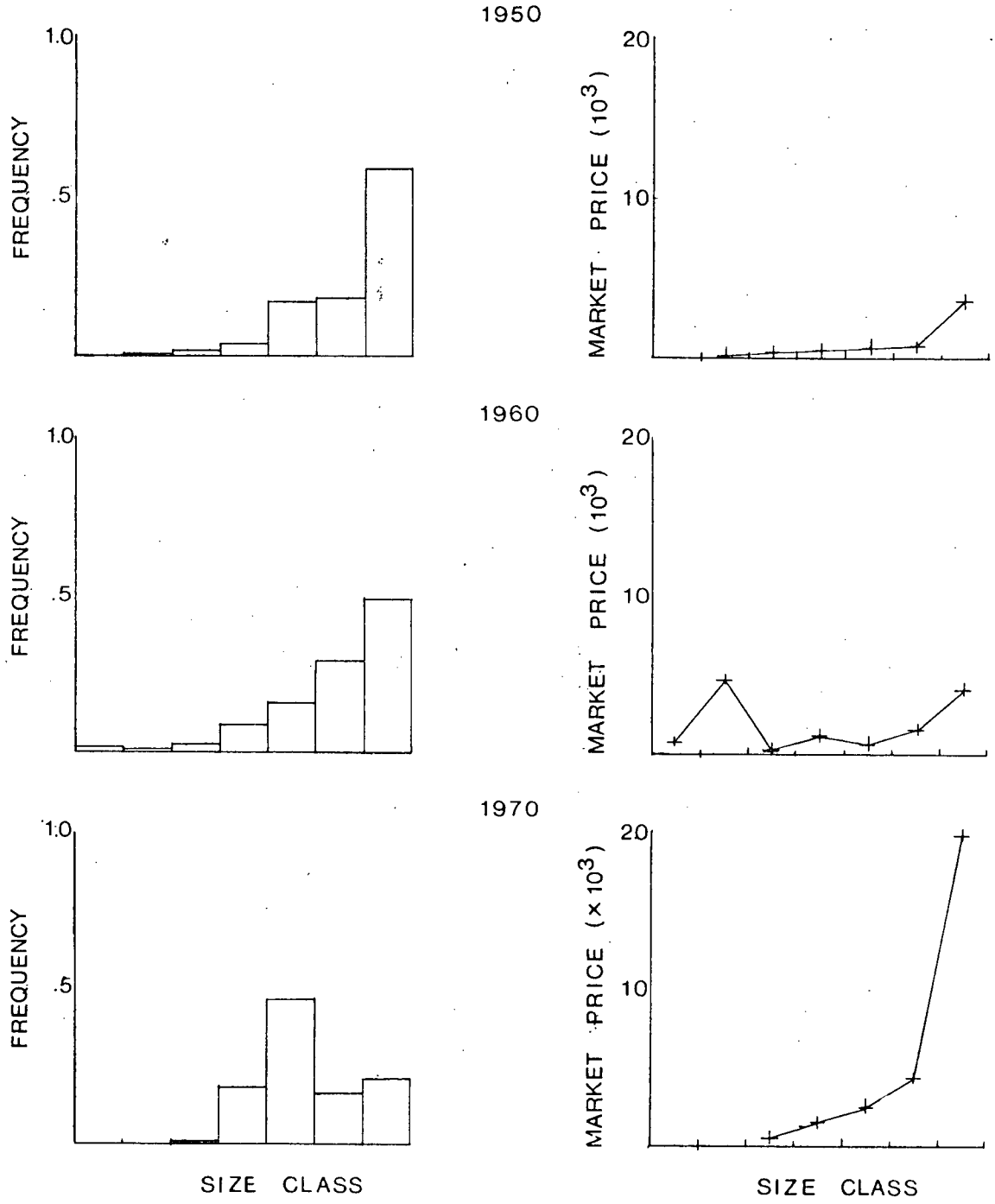

Figure 7. Size distribution and average parcel price by assessment year.

THE GULF ISLANDS RECREATIONAL LAND SIMULATOR

"Supply and demand" has become an expression used when comprehension of these market processes becomes difficult. To answer questions concerning change in supply, or demand, or their effect on the price of any commodity, a look at their dynamic rather than traditional static relationship is necessary. To obtain this view, both supply and demand must be dissected into sub-processes that can be described, then rejoined to produce a model of the parent processes. A most useful approach to such problems has been described as an experimental components analysis (Holling, 1966).

> It is based on the belief that the characteristics of any specific example of a complex process can be determined by the action and interaction of a number of discrete components. Some of these components are shared by all examples of the process and can be called basic, in that they underlie all manifestations of the process. Others are present in some situations and not others and can be termed subsidiary. By initially dividing the components into universally occurring, or basic ones, and sporadic, or subsidiary ones, generality of a high order becomes at least theoretically possible. Some of the features of every example of the process will arise from the action of various combinations of the subsidiary ones.
>
> Once the basic components and some of the subsidiary ones are tentatively identified on the basis of general observation and experimentation, a simple example is selected that includes only the basic components. Preliminary experiments suggest hypotheses to explain the action of each component, and these postulates are then tested experimentally in the classical scientific manner. When a set of postulates is finally proved adequate, they are then expressed in a mathematical form and the equations synthesized to produce a model of the basically simple example chosen. This provides a base from which to explore more complex examples where additional, subsidiary components operate, for these new components can be analyzed in the same way and the basic model expanded to include them. In this way a more and more complex structure is built, each progressive step being taken only when a valid explanation has been obtained for the previous step.

In brief, the whole approach may be likened to the continued differentiation of a complex mathematical relationship until definable terms appear. Once defined, these terms may be integrated to build the final product or simulation model.

The application of the above experimental components analysis to the demand for and supply of cottage lots in the Gulf Islands climaxed with the production of a Gulf Islands Recreational Land Simulator (GIRLS). As stated in the introduction to this thesis, the model simulates the distribution of the Gulf Islands as privately-owned parcels of land. Within such a distribution system a key process is that which subdivides the resource into individual parcels. There the environment receives the impact of economically expressed social demands. When those demands are strongly expressed, the subdivision of small lots is likely to take place with a concomitant loss of environmental quality. If the economic forces are made weak by some monetary or other policy, environmental health might be preserved at the expense of, say, the health of the economy. In this sense, then, the combined processes of subdivision and environmental deterioration may be viewed as a synthesis of social, economic, and environmental considerations.

Figure 8 relates the subroutines (rectangles) and linkages (hexagons) which comprise GIRLS. Here the "Subdivision" and "Ecological Feedback" (environmental deterioration) subroutines are developed in detail since they are based upon the cost-lot size and subjective preference-lot size functions developed earlier in this thesis. Only cursory explanation is given the remaining subroutines, since they are developed in detail elsewhere (Resource Science Centre, University of British Columbia).

Demand for Cottage Lots

Each year (iteration) GIRLS generates a number of families with a range of incomes, desirous of purchasing cottage lots on the Gulf Islands. To generate this demand, three sub-processes, or subroutines, are involved.

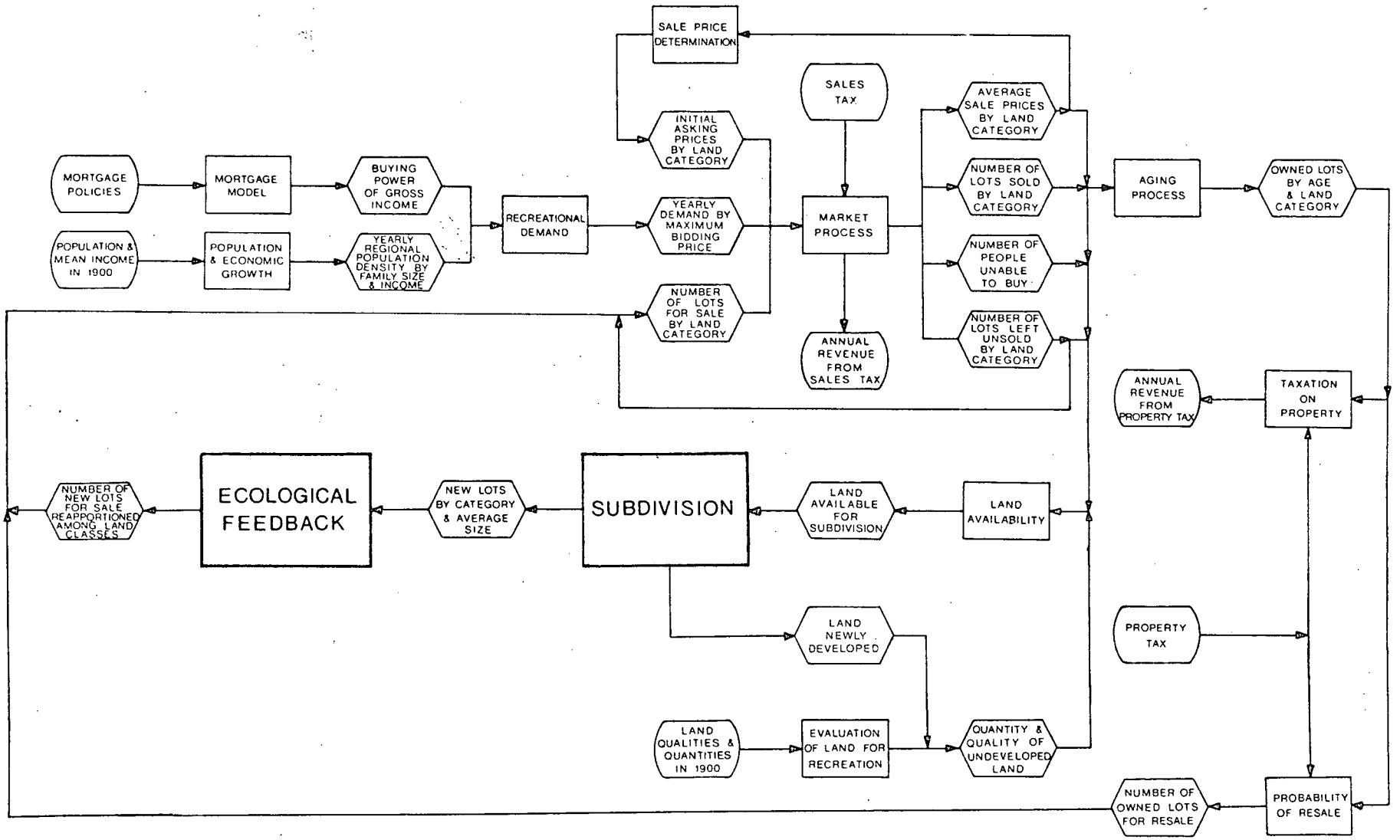

Figure 8. Flow diagram of the Gulf Islands Recreational Land Simulator (GIRLS).

1. The "Population and Economic Growth" subroutine mimics historical census figures until 1961. Beyond that year rates of population and economic growth can be changed at will, so that booms and depressions, pestilence or population explosions can be introduced.

2. The "Mortgage Model" provides opportunity to manipulate interest rates and amortization periods, hence the maximum price of property a family with a specified income can purchase. It simply provides an opportunity to introduce or remove "tight money" policies.

3. The subroutine labelled "Recreational Demand" is analogous with a sieve through which the population is strained to find the number, size, and income of families wishing to purchase a cottage lot on the Gulf Islands. The sieve's mesh is adjustable using income and family size, which, in combination with a proportionality constant, specify those families in the market for Gulf Island property.

Supply of Cottage Lots

Similarly, for each year GIRLS generates a number of parcels of Gulf Island land for sale. Seven submodels or subroutines perform this task.

1. The "Aging Process" simply returns existing lots to the market according to an age-dependent probability which grows to 1 over a 60-year period.

2. "Taxation on Property" allows tax rates to be increased or decreased, generating revenue for government services.

3. "Probability of Resale" simply speeds the return of existing lots to the market when property taxes are high.

The three submodels above deal only with parcels already in service as

cottage sites. The following four are concerned with the subdivision of "Undeveloped" land into parcels sold to cottagers.

4. The subroutine labelled "Evaluation of Land for Recreation" divides the land area studied into seven quality classes. Differentiation of qualities is based on the slope of the terrain, distance to water (lake or ocean), and certain characteristics of the vegetation. Thus, gently sloping waterfront property clothed in the Arbutus and shore pine typical of the region, is more desirable recreational property than a steep, nearly treeless, rocky hillside several miles from the waterfront.

5. "Land Availability" calculates an amount of land available for subdivision each year. A developer's effort to buy land for subdivision is assumed to be proportional to the size of and trends in recent markets. But attempts to purchase are not always successful. As the amount of "Undeveloped Land" declines, its availability to developers also declines.

6. "Subdivision" mimics the process by which a developer looks at lot prices, the size of the market, the area and price of land available for subdivision, and anticipated development costs (equation (21)). Two levels of developer sophistication are included in the submodel. The most sophisticated buy undeveloped land and hold it for future development, while smaller, less well financed developers can only buy, subdivide, and market in the same market period.

   Both large and small developers produce a size and number of lots which are expected to yield a specified minimum profit. That minimum is defined as a proportion of the expected selling price. Lot size is determined by the pursuit of this minimum profit, given the demand and amount of land available for subdivision, and may be constrained by a policy intervention which

specifies a size below which lots cannot be subdivided. A flow diagram (Figure 9) serves as a focus for a more detailed description of the subroutine.

Looking first at the last market, the hypothetical developer observes the number of lots sold and the rate of price increase, estimating for each land quality (I), the number of lots which will be sold in the next market. This number, received from the previous subroutine, is DMAND (I). If no demand is anticipated in quality class (I), no development takes place. If a demand is anticipated, the developer sets DMAND (I) equal to WN, the initial number of lots he expects to produce, and asks what price he must pay for undeveloped land. That price (XXB) is assumed to rise and fall at half the rate of change in cottage lot prices during the last two market periods.

From a previous examination of the market for undeveloped land, ("Land Availability"), the developer "knows" that AVLND (I) acres of quality (I) land are for sale if he should decide to buy them. If there are any large-scale developers involved, then an alternative source of land for development resides in HOLD (I), the number of acres of quality (I) land which they bought previously. An initial amount of land available for subdivision (XG) is therefore established.

With the number of lots to be produced (WN) and the land area available for their production (XG), the hypothetical developer then calculates the size (WS) of these proposed lots using equation (16). If the lot size (WS) is equal to or greater than the minimum size permitted by government policy (SZMIN), profit anticipated from the proposed venture (TPROF) is calculated as the difference between total cost (equation (21)) and expected revenue (TREV). Total revenue (TREV) is simply the product of expected demand (WN) and expected selling price (XR).

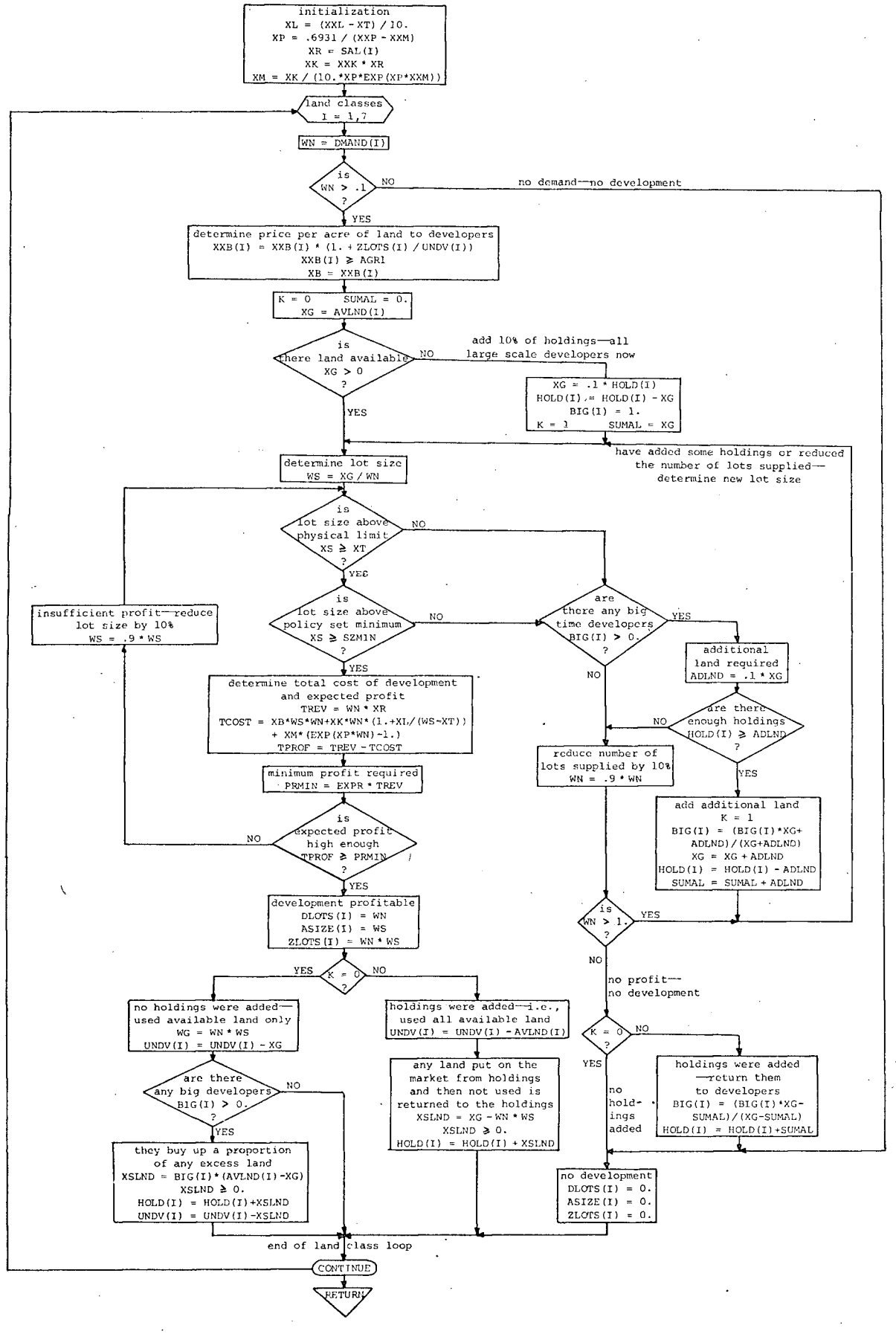

Figure 9. Flow diagram of the "Subdivision" process.

The minimum profit which will prompt developers to subdivide (PRMIN) is calculated as a proportion (EXPR) of anticipated total revenue (TREV). If the difference between costs and revenue (TPROF) is equal to or greater than the minimum required for subdivision to occur (PRMIN), subdivision takes place and the remainder of the subroutine performs the bookkeeping chores. If, however, there is insufficient profit, lot size is reduced 10 per cent and the anticipated profit recalculated. This process of lot size reduction continues until subdivision occurs, or until lot size falls below the policy minimum.

In the event that lot size becomes too small, and big developers with land holdings are operating, the amount of land available for subdivision (XG) is increased and the process of profit calculation and size reduction is repeated. When the large developers' holdings have thus been disposed of, and still no subdivision has taken place, or in the event the large speculator option is not in use, the number of lots to be produced (WN) is reduced by ten per cent and the process of profit calculation and lot size reduction repeated yet again.

By reducing the size and number of lots to be developed in response to the combined forces of market price, development costs and profit expectation, the stage is set for simulated degradation of environmental quality. While this subroutine, like that following and all others in GIRLS, presents a terribly simple, suspect view of the processes it is supposed to describe, it improves upon the "supply and demand" cliché, if only because it remains suspect after moving through one level of complexity and from the static to dynamic situation.

7. The "Ecological Feedback" submodel is conceptually comprised of many parts. Only one, the impact of small lot subdivision on

quality is included in this version of GIRLS. "Ecological Feedback", therefore, simply revises the recreational quality of newly subdivided parcels according to the lot size class-subjective preference relationship developed earlier. A flow diagram of the subroutine (Figure 10) punctuates this simplicity. The quality class (I) of newly subdivided lots (DLOTS (I)) is decreased if those lots are smaller than 1.7 acres (see page 34 in market price section). The number of quality classes lost equals the number of size classes through which the lots have moved, but in no case does the quality drop below class six.

By reducing the quality class of lots subdivided into small sizes, the market in which they are sold changes. That is, within GIRLS there are seven markets in each market period, one for each quality of land. Lots which suffer a quality reduction will, therefore, incur a price reduction as well because of the market change. This consequence reflects in market information received by developers, hence their assessment of the next market period.

As stated previously, this and all GIRLS subroutines are terribly simple descriptions of complicated processes. The extent of reductions in quality due to lot smallness may be excessive or conservative. Much more experimental work will be necessary to verify relationships between determinants of quality after their identities have been determined.

Interaction of Supply and Demand

Having generated a number of lots and a demand for them, the subroutine labelled "Sale Price Determination" calculates an initial or "asking" price for lots each year. Calculations are based on price trends over the past three years (market periods) and a constant which indicates the degree

SUBROUTINE PRVCY
Ecological Feedback
Subroutine

Dec. 9, 1970

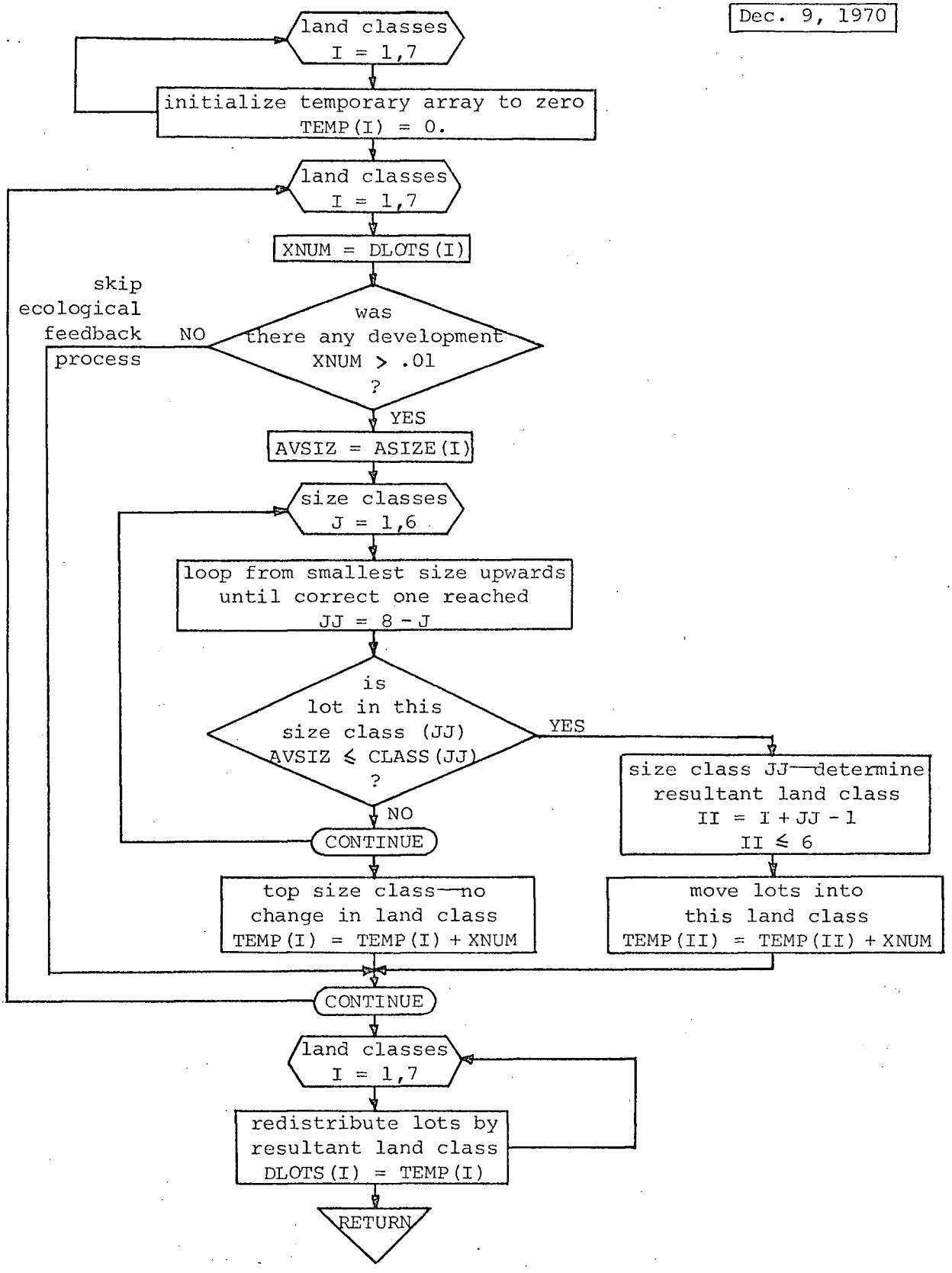

Figure 10. Flow diagram of the one component of "Ecological Feedback" now included in GIRLS.

of optimism among developers. The subroutine labelled "Market Process" then receives three pieces of information:

1. initial asking price;
2. the demand for cottage lots (a vector of the number of buyers by price of property they are able to buy); and,
3. the supply of cottage lots (a vector of the number of lots by quality category).

Proceeding from highest to lowest quality lots, supply is compared with demand. At each comparison three situations can occur. These situations and subsequent action of the "Market Process" are as follows:

(a) When expressed demand exceeds supply, there are fewer lots than buyers able to pay the initial asking price. Lots are then sold on a "first come, first serve" basis. That is, the number of lots sold to each income category is proportional to the number of bidders therein.

(b) When demand equals supply, there are equal numbers of lots and buyers able to pay the prices asked. The initial asking price therefore becomes the market price, and lots are sold to all bidders.

(c) When supply exceeds demand, there are more lots than buyers able to pay the initial asking price. In this event, lots are sold to those bidding the initial asking price, which is then lowered and more lots sold. This process is repeated until all lots are sold or until the price drops to a floor (half the selling price two years before), below which no one will sell. In this event, unsold lots are carried forward to next year's market.

This view of the market, although oversimplified, provides a convenient meeting place for cottage lots and buyers generated in the other submodels.

Simulation Models

Although its resemblance with the real world is only anecdotal, the Gulf Islands Recreational Land Simulator is a useful tool with which to explore the effects of change. By allowing one component to change, or by imposing change on another, we can see how such changes might affect yet other parts of the system. In this way, simulation studies can aid the process of anticipation.

Here lies the great strength of simulation models and their propensity for abuse. So long as it is recognized that predictions are made only for those parts of the system the builder has chosen to include in his model, that the interactions between these and the excluded parts are therefore absent, and that because the model is incomplete and comprised of mathematical caricatures, predictions of magnitude are highly suspect, simulation studies can aid the anticipation of the effects of natural or induced change. If much credibility is given the predicted time of appearance and magnitude of these effects, the dangers associated with belief in any falsehood or half truth arise. With this cautionary note firmly made, attention can be diverted to the real value of the model, the prediction of trends given different policies.

A listing of GIRLS, including parameter values, may be found in Appendix III. More pertinent here is the graphical output shown in Figure 11. The abscissa of all three graphs is time and represents the interval 1900 - 2000. On the uppermost graph the proportion of the total land area that has been developed is plotted for each of four quality classes. (Plotting the other classes serves only to clutter the diagram.) The remaining locus on the upper graph (with data points plotted) represents the proportion of cottage lot buyers unable to find a suitable purchase in spite of their ability to pay. The area of land developed in each quality class each year is plotted on the central graph, and on the lowest, the price of lots in each of the four quality classes.

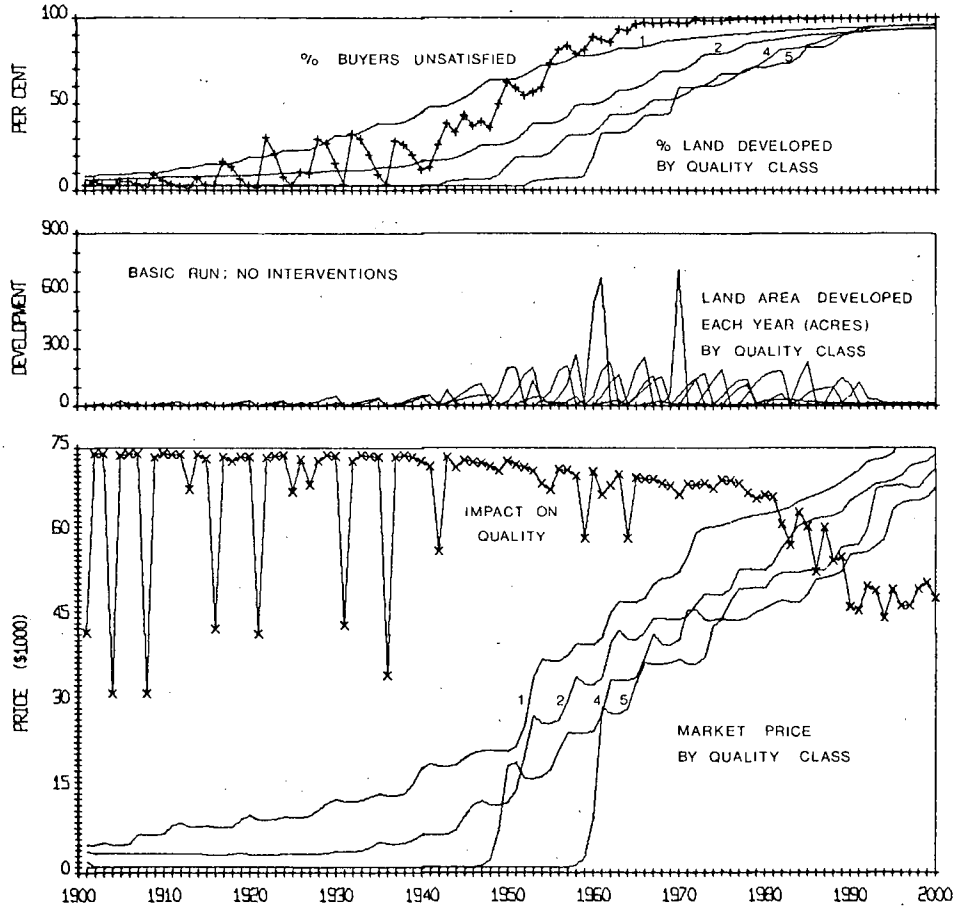

Figure 11. Graphical output of the Gulf Islands Recreational Land Simulator, no interventions.

Graphical Representation of Quality

In developing the measure of quality traced by the remaining locus on the lower graph of Figure 11, three notions are required:

1. In the context of GIRLS, the quality of the system at any time can be represented by the "quality area" therein. As shown in Table VIII, this measure is simply the sum of the products of weighting factors and areas of land in each quality class. First quality land is given twice the weight of second quality land, three times that of third quality land, and so on. Weighting factors are therefore the quality class numbers in reverse order. Since quality is lost (within GIRLS) according to the number of size classes through which a parcel moves, and size class intervals represent equal preference intervals, such a weighting seems justified.

2. The total quality of the system may be divided in two parts. The first is that portion of the total which has been developed (sequestered by individual families) and is a measure of quality in direct use. The second is that portion of the total which remains undeveloped and is a measure of the capacity of the system to absorb or "bounce back" from quality losses resulting from the subdivision of small lots.

3. Total quality and each of its parts are subject to change.

Several "barometers" with which to monitor the system's quality are apparent. The first possibility which springs to mind, total quality, is not appropriate for three reasons. The first and most important is that people perceive differences, not total quantities, an assertion amply supported by an earlier section. The second and third reasons concern the larger parcels of highest quality land which are developed early in the history of the system. Much of the total quality is contained in these parcels which, in reality, are

TABLE VIII. Calculation of the "quality area" in a system at one point in time.

(1) Land Class	(2) Area (acres)	(3) Weighting factor	(2) x (3)
1	1000	7	7000
2	2000	6	12000
3	9000	5	45000
4	1000	4	4000
5	1000	3	3000
6	1000	2	2000
7	1000	1	1000
		Total "quality area"	74000

returned to subdividers more slowly than "undeveloped" land. They therefore act as a buffer, or delaying mechanism, in the degradation of total quality. Within GIRLS, the delay is complete. Once developed, parcels are never returned to developers. Such recycling would require computing facilities larger than those available (IBM 1130) and would add little of consequence to the model. People perceive and evaluate differences. Rates of change rather than total amounts are therefore the appropriate measures of quality.

Suppose some land area A is subdivided in a given year. Depending upon the land classes from which A is drawn, its undeveloped quality can be calculated (as in Table VIII) and expressed as the quality-area developed (QAD) in that year. If, after subdivision, some of that quality is lost because lots produced are too small, the quality lost can also be calculated and expressed as quality area lost (QAL). Then the proportion P^* of the undeveloped quality of A, which is retained after subdivision, is

$$P = \frac{QAD - QAL}{QAD} \tag{24}$$

While the above proportion is important, alone it is insufficient. Early in the development of a region small lots are produced, but these "errors" would (intuitively) have minimal impact on the whole system. As more and more of the region is developed, its resilience or capacity to absorb quality losses is diminished. Small lots produced late in the history of development have much greater impact than those produced earlier. The proportion P should therefore be modified by some measure which reflects the changing resilience of the system.

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* Note that the proportion P is related to the instantaneous rate of change in quality, r, as follows:

$$P = 1 - r$$

where

$$r = \frac{QAL}{QAD}$$

Consider the land area which remains undeveloped at the start of the given year. Its quality area is a measure of the system's resilience (page 52), some part of which (QAD) is withdrawn for development that year. Then the proportion R of the undeveloped quality area (QAR) which remains unsequestered at the year end is

$$R = \frac{QAR - QAD}{QAR} \qquad (25)$$

The quality impact line (Figure 11) represents the product of the two proportions P and R, and is plotted on an ordinate scaled from zero (at the origin) to one (at $74,000).

GIRLS Validity

Having manufactured GIRLS and obtained the basic output shown in Figure 11, the first question concerns the accuracy with which the model mimics actual trends. Figure 7 reveals the two trends which the model should mimic. First, the shifting parcel size distribution implies that smaller and smaller parcels of land are subdivided through time. Secondly, prices increase and price differences between size classes increase to 1970. Because of the link between parcel size and quality, evidence of the first trend in GIRLS may be seen as depressions in the quality impact line of Figure 11. While prices increase more rapidly in GIRLS than in reality (Figures 7 and 11), the correct trend is certainly present in the model and, if one takes imaginary cross sections through the lowest graph in Figure 11, there is, between 1900 and 1970, an increasing spread in prices of lots of different qualities. While magnitudes remain in question as I think they should, GIRLS does mimic the direction of shifts in price and parcel size to the present.

Because the supply of land within the Gulf Islands is finite, and the model provides for a limited range of policy interventions, the questions posed at the end of the last section must be recast. They therefore become:

1. Is the subdivision of small lots, hence the degradation of environmental quality, discouraged by a growing, constant, or declining demand for cottage lots? With reference to GIRLS and Figure 8, the question becomes more specific. What manipulations of population and economic growth discourage the degradation of environmental quality?

2. Which of the following policies can be used to discourage the subdivision of small lots (and consequent degradation of environmental quality), and what other effects can be anticipated if they were used?

   (i) The manipulation of mortgage interest rates.

   (ii) The imposition of a sales tax on cottage lots.

   (iii) The manipulation of property taxes.

   (iv) The imposition of a minimum lot size.

Because the principal focus of this thesis has been the impact of a shifting lot size distribution upon environmental quality, first attention was given to that effect when making and interpreting various interventions. But equal emphasis must be given the economic and social consequences of various policies as reflected by prices and the proportion of buyers unsatisfied (uppermost graph) respectively. Because there is a sustained depression in the quality impact locus from about 1950 (Figure 11), and the course of events late in the development of the system are of greatest interest, all interventions were made at the end of the 1965 market period. As has been the case throughout discussions of GIRLS, the interpretations which follow refer to the model and its internal workings. Where obvious deficiencies in the analogy with reality occur, they must be interpreted as just such deficiencies and not statements about reality.

Simulation Studies

Figures 12 through 20 show the results of the simulated development of the Gulf Islands with interventions of various kinds. For convenient comparison each Figure also displays the uninterrupted output. To minimize searching through text and Figures, all Figures are grouped at the end of this discussion.

Consider question one, above, and the effect of a reduced rate of population growth on the development of the Gulf Islands. Figure 12 represents the GIRLS output under such circumstances. Because of the large proportion of unsatisfied buyers already present, the subdivision of small lots continues as does the sustained depression of quality. Prices, however, rise more slowly and the percentage of unsatisfied buyers is slightly lower than in the uninterrupted run. The increased rate of population growth simulated in Figure 13 reveals a more severely depressed quality, higher prices, and more unsatisfied buyers.

The influence of economic growth upon quality appears to be even more dramatic than that of population growth. A reduction in the rate of economic growth from three to one per cent (Figure 14) eases the sustained depression of quality, and prices increase more slowly. Both these events are the consequence of a reduction in the number of people able to buy, a trend reflected in the percentage of buyers unsatisfied. When the rate of economic growth is increased (Figure 15), quality is most severely depressed and prices skyrocket.

Perhaps more interesting than any other intervention is that shown in Figure 16, where both economic and population growth were eliminated. Because the resource develops more slowly under these conditions, the sustained depression of quality is replaced with the large oscillations characteristic of early development. That is, although small lots are produced, their rate of production is comparatively low, hence the rate of change

in quality is also low. The comparative resilience of quality is maintained so that there is recovery. The system can "bounce back". Accompanying the above events is a price reduction and gradual reduction in the percentage of unsatisfied buyers in the market, a most significant trend if one considers people to be important. By reducing the rates of population and economic growth to zero, the maintenance of quality and satisfaction of the population can be achieved, a conclusion in direct contradiction with popular belief.

The interventions represented in Figures 17 through 30 were made to answer the second question asked earlier. Governments can manipulate the supply and apparent demand for a particular resource through monetary, tax, and resource development policies. The imposition of a sales tax (Figure 17) effectively increases the price a buyer must pay for a lot. A sales tax, therefore, simply reduces the number of buyers in the market, but with the large number already there and continued growth, the long-run effect of a sales tax is negligible. The number of buyers can also be reduced by increasing interest rates, an event simulated in Figure 18. Again, any reduction in the degradation of quality is momentary at best. The eventual outcome is essentially unchanged.

The imposition of a property tax within the model simply hastens the recycling of lots in use. That is, a property tax, within GIRLS, is a tool by which supply can be manipulated. Its use (Figure 19) increases the rate of quality degradation and lowers prices. A possible explanation for this unusual combination of effects is that lowered prices, the result of a more rapid recycling of properties, bring a summer homesite within the reach of a larger proportion of the population. In response to this increased market size, developers quickly produce more, therefore smaller lots, which exert more pressure on environmental quality.

Only the imposition of a minimum lot size, Figure 20, previdés nearly complete relief from the impact of further development and small lot size on environmental quality. Anticipated economic and social effects, an

increase in prices and proportion of buyers unsatisfied, do not occur largely because most buyers are unsatisfied anyway. In examining this last simulation, its comparison with that in which population and economic growth were eliminated (Figure 16) proves interesting. In the latter case, free market conditions prevail and sustained degradation of environmental quality does not take place. In the former case, market restrictions are imposed which, according to the one simple qualitative measure used here, prevent the deterioration of environmental quality. Considering environmental quality alone, a decision-making body capable of either manipulation might choose the market restriction and impose a minimum lot size. Such a decision would certainly be taken if the profit motive were involved because a rising market is maintained along with quality. Where better to make a profit? Should importance be accorded the proportion of the population whose desire for a summer homesite was fulfilled, then depending upon the weight given that criteria, the elimination of population and economic growth would have to be given serious consideration.

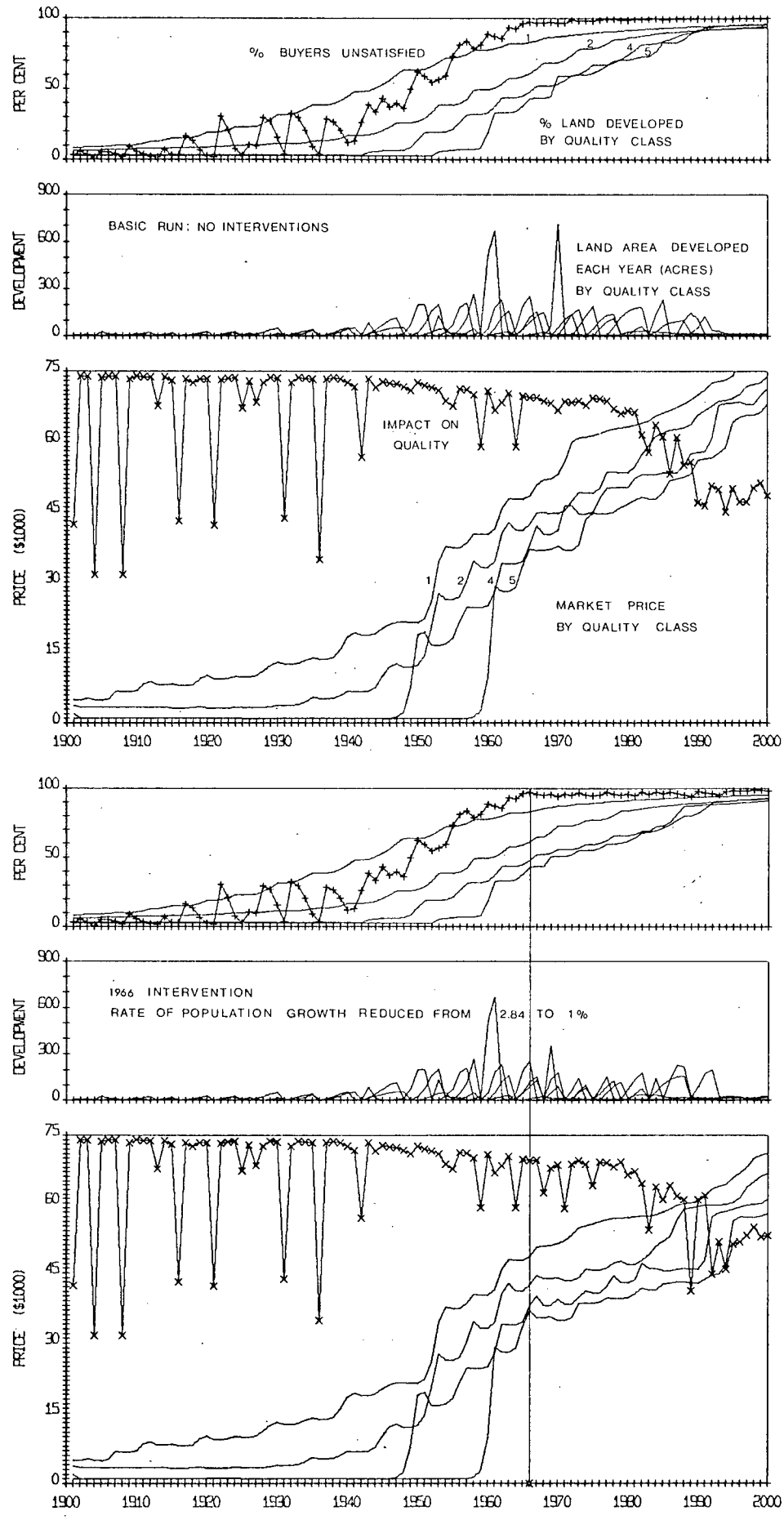

Figure 12. GIRLS output showing the effect of a reduced rate of population growth from 1966.

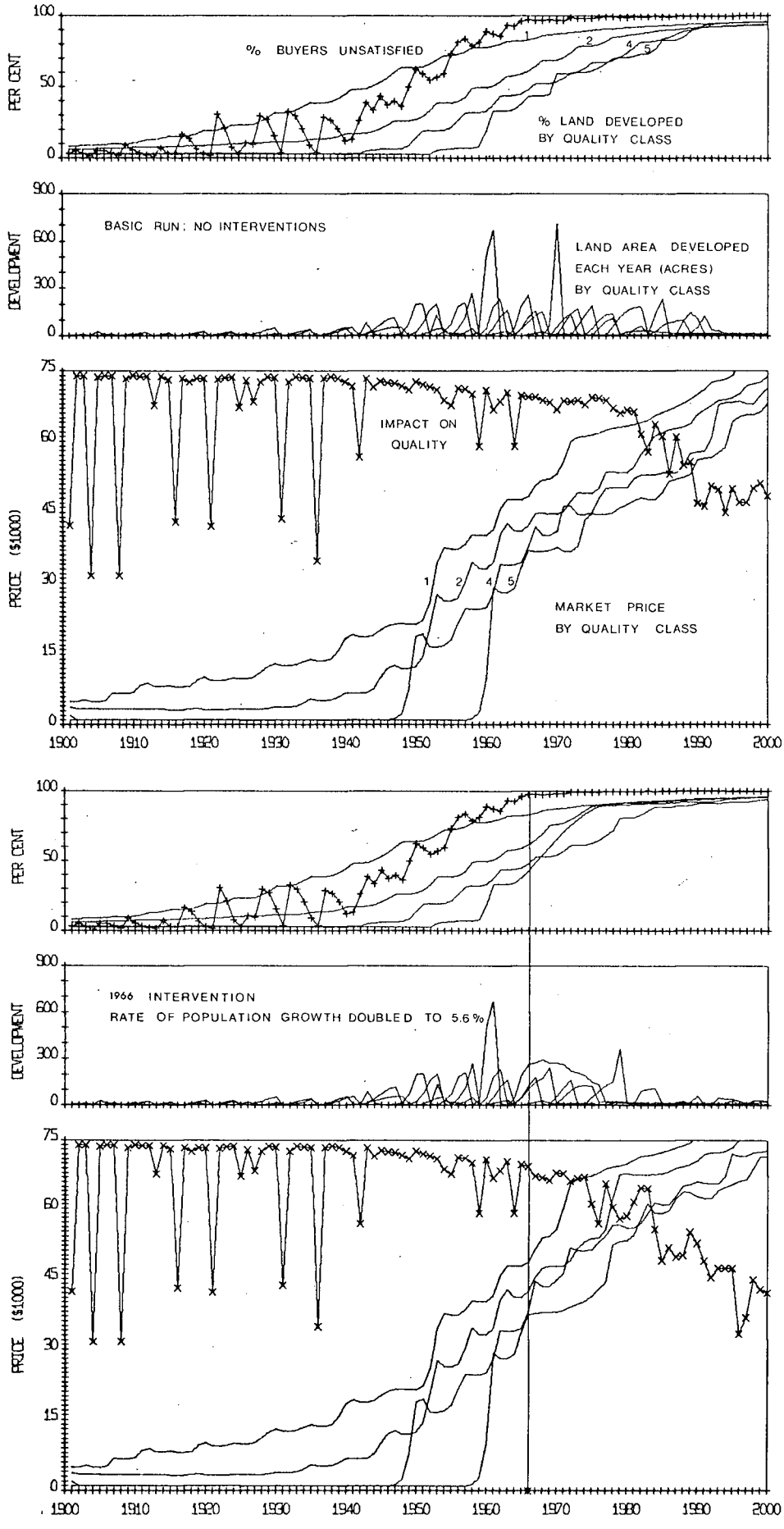

Figure 13. GIRLS output showing the effect of an accelerated rate of population growth from 1966.

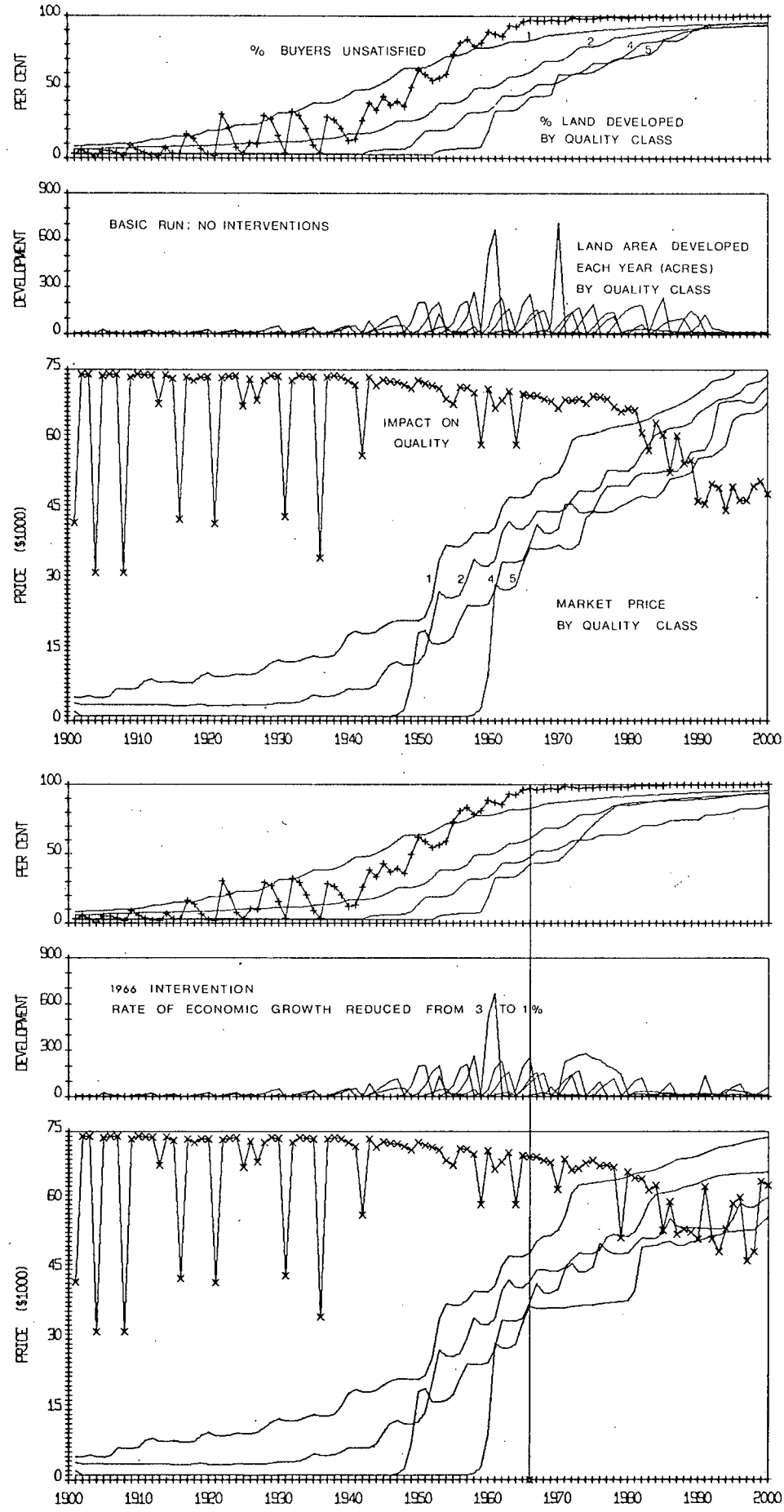

Figure 14. GIRLS output showing the effect of a reduced rate of economic growth from 1966.

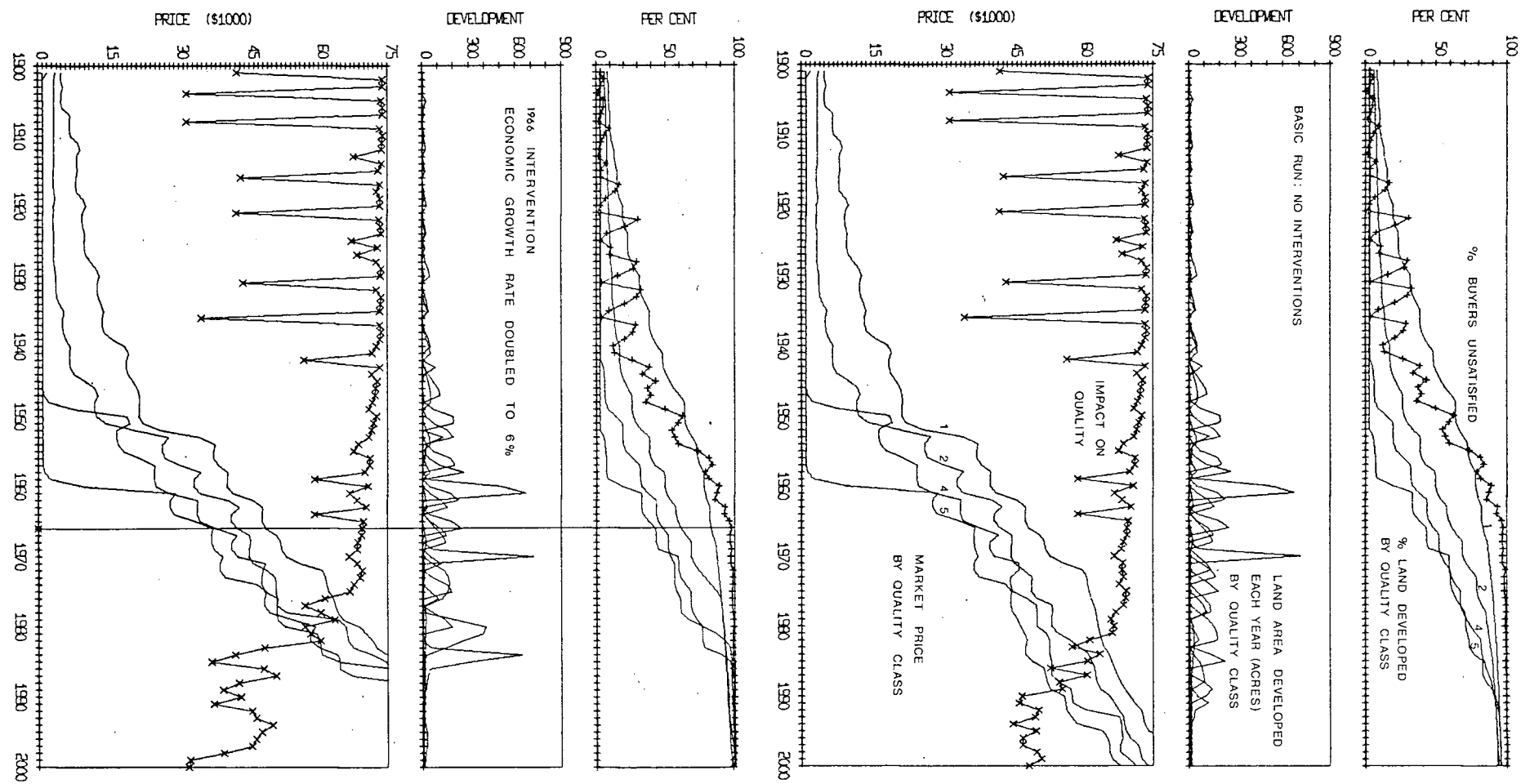

Figure 15. GIRLS output showing the effect of an accelerated rate of economic growth from 1966.

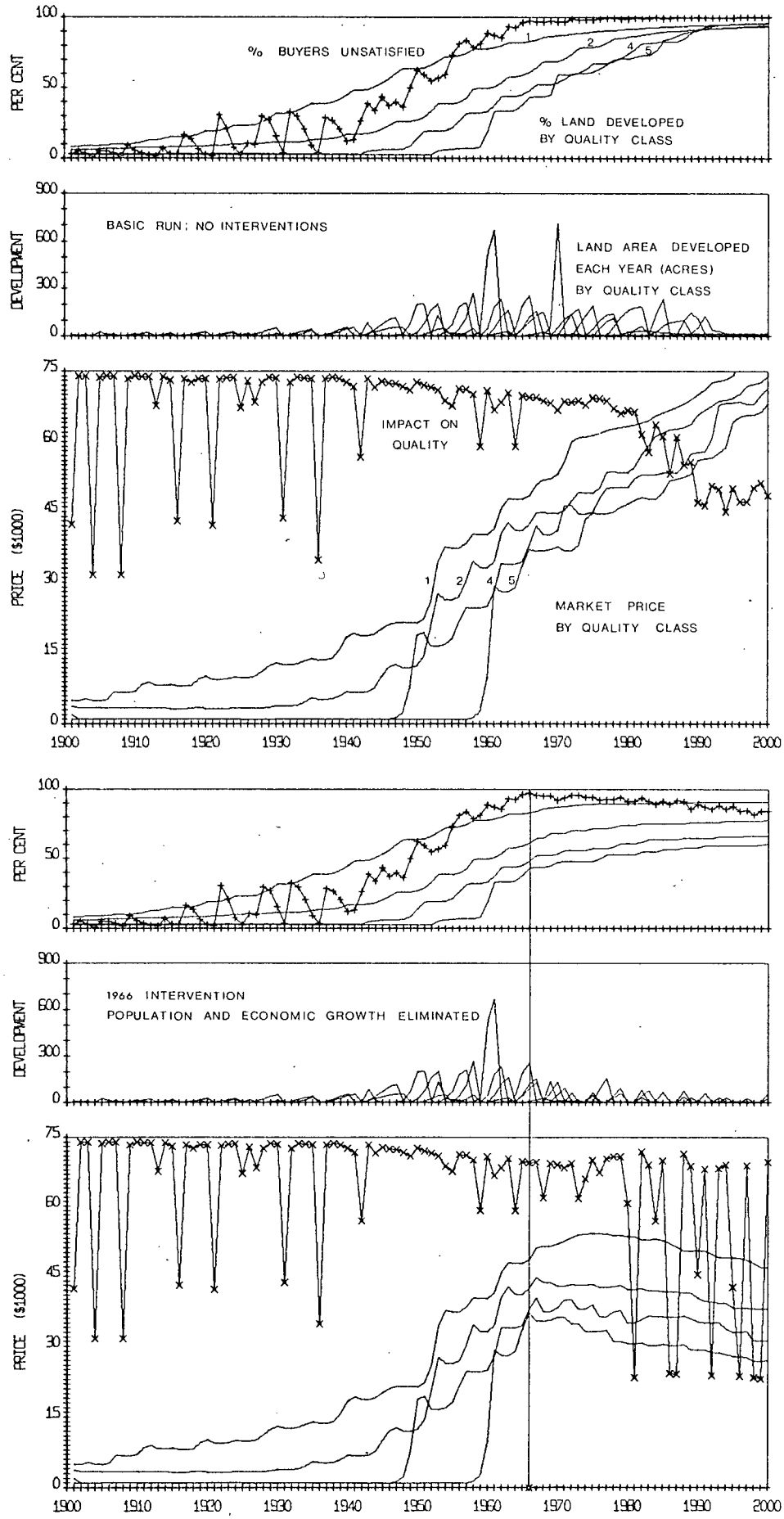

Figure 16. GIRLS output showing the effect of zero population and economic growth from 1966.

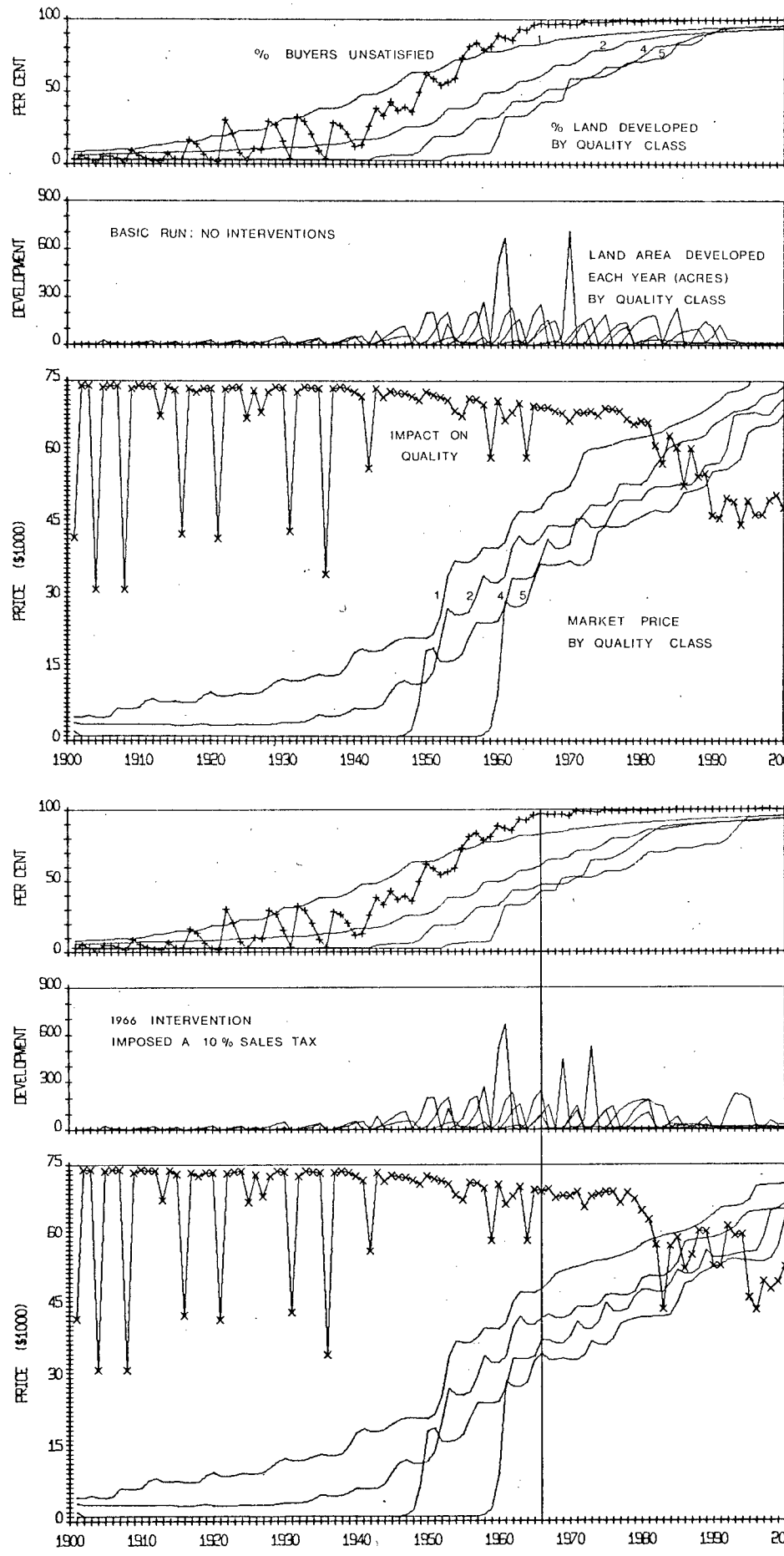

Figure 17. GIRLS output showing the effect of a 10 per cent sales tax from 1966.

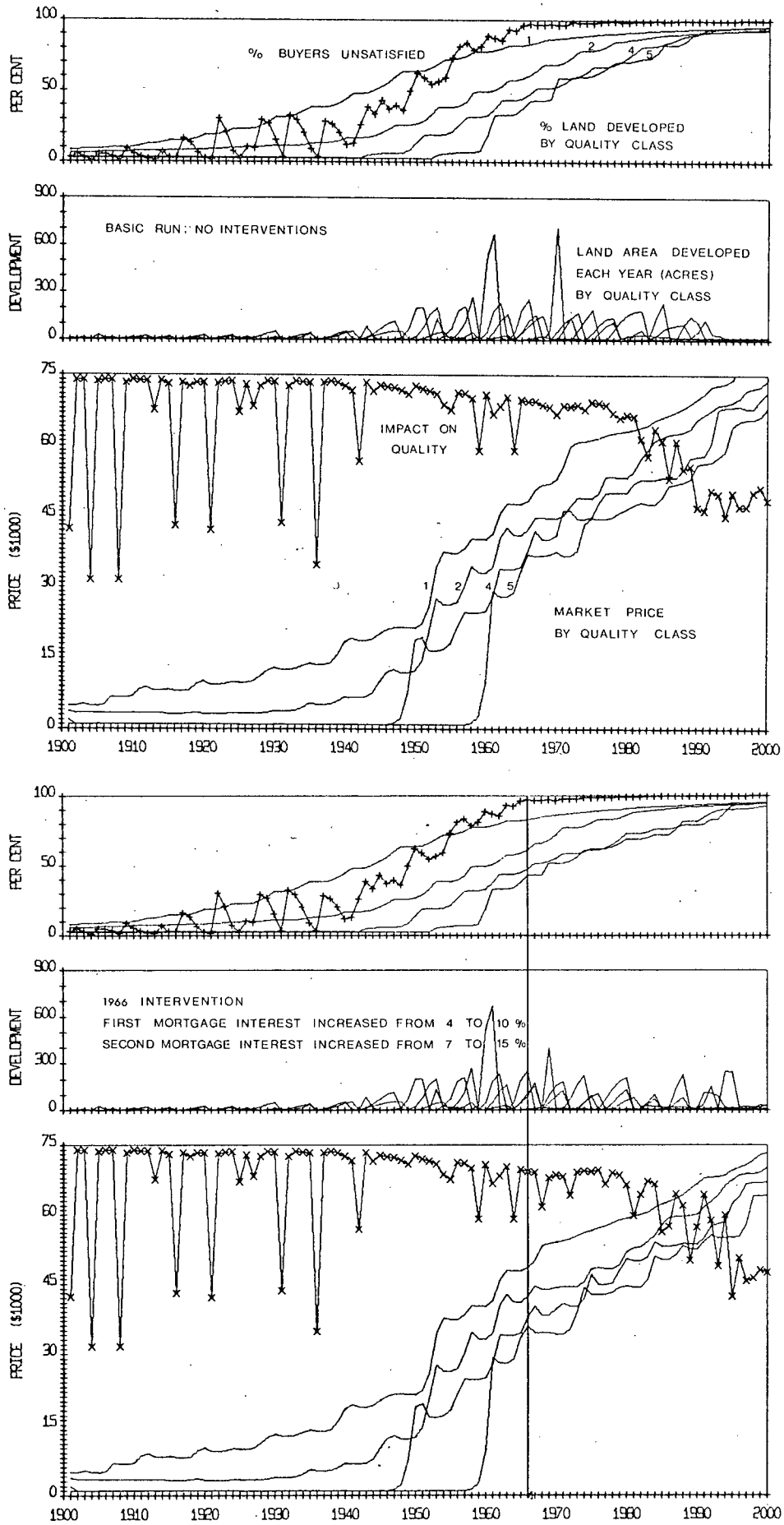

Figure 18. GIRLS output showing the effect of increased mortgage interest rates from 1966.

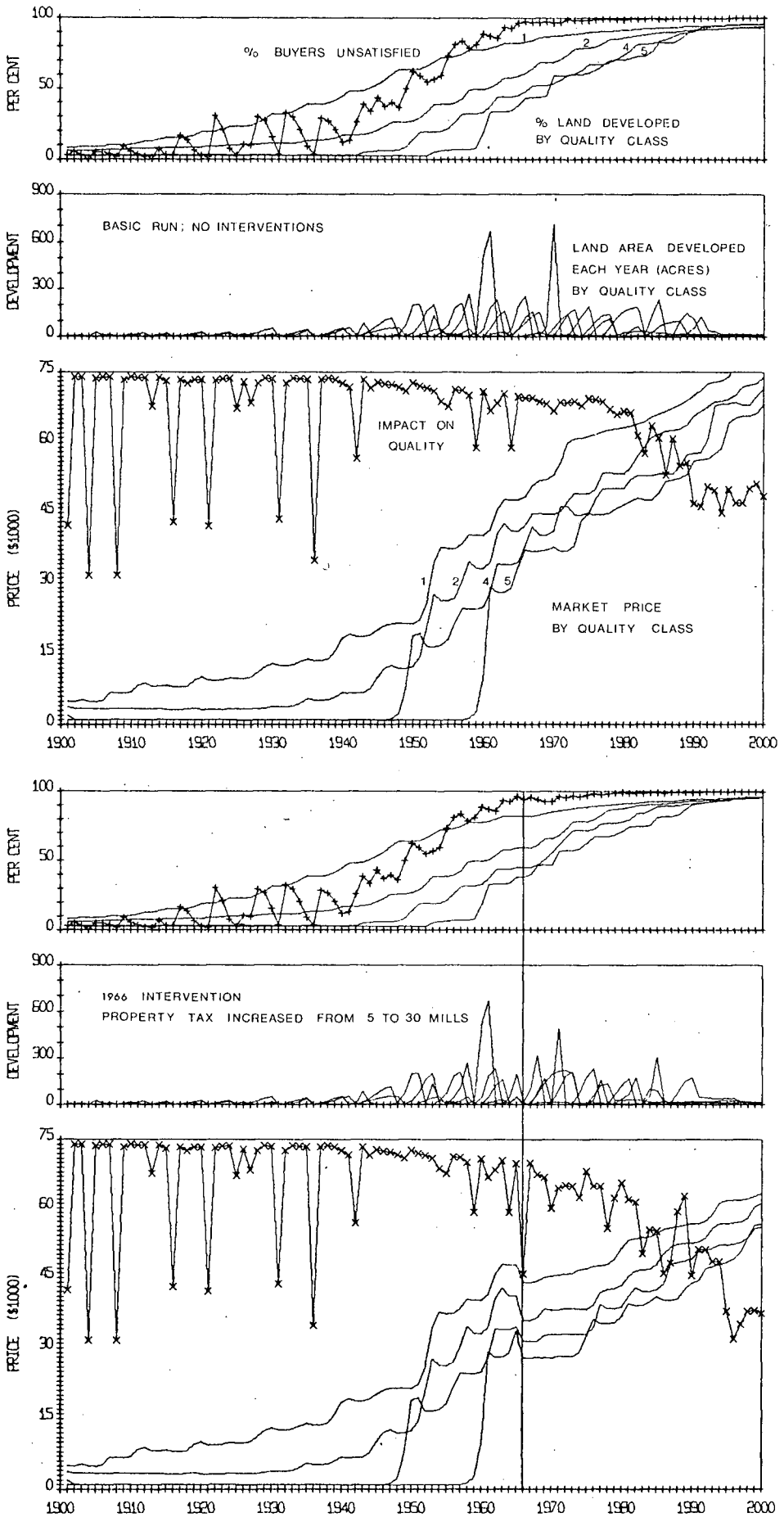

Figure 19. GIRLS output showing the effect of increased property taxes from 1966.

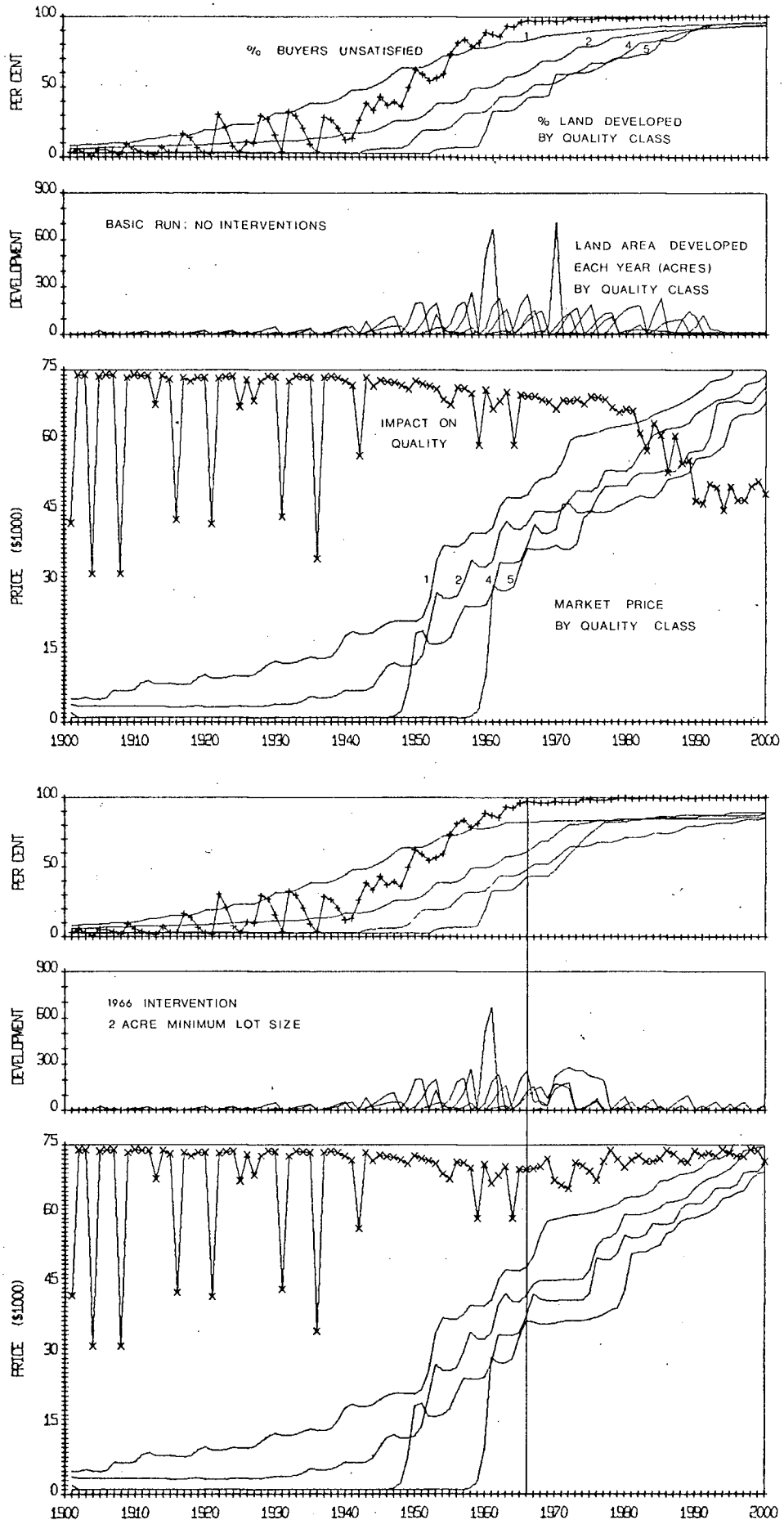

Figure 20. GIRLS output showing the effect of a policy imposing a minimum lot size.

CONCLUSIONS

1. The quality of an environment used for outdoor recreation depends in part upon perceived population density. Without the use of techniques first developed by psychophysicists, it might be impossible to support such a statement with empirical evidence. Because their methods are unconstrained, they make it possible to trace changing environmental quality as some component of the environment is changed. Such documentation is not possible using traditional economic or political methods.

   Because of the success of this attempt to define environmental quality using psychophysical techniques, continued effort in this direction seems certain of great success. The use of more refined methods to document the effects of visual, audio and olifactory perception on man's judgment of his environment will lead to an extremely useful model of environmental quality. With such a tool, the environmental consequences of many different kinds of resource development may be viewed, as are dollars, in cool, numerical terms.

2. Given a simulation package dealing with environmental quality, a second step is possible as demonstrated by the Gulf Islands Recreational Land Simulator. That is, the environmental, social and economic consequences of resource development may be integrated in a larger simulation model which can then be used to anticipate various effects of alternate policies. However, this second step is possible only when key independent variables can be identified which tie the appropriate system components together.

   The key variable in the study just completed was "lot size". To that independent variable the economic and environmental consequences were firmly tied. The social consequence is indirectly related to lot size in that many people may be provided with small lots, fewer with

larger lots. Such key variables may in some cases be impossible to identify. In all but such cases, simulation models provide a powerful integrative framework within which all three components of our society can be viewed in concert. In this context, the Gulf Islands Recreational Land Simulator stands as a unique example, not of a panacea, but of a new and powerful addition to the tools available to resource developers.

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APPENDIX I

THE CONTRIBUTION OF BINOCULAR VISION TO THE PERCEPTION OF DISTANCE

Depth, or distance perception, has long been thought dependent on binocular vision, although monocular cues have been demonstrated to be important as well (Gibson, 1958). The purpose of this exercise is first to calculate the contribution binocular vision can make to distance judgments. Then, by comparing this relationship with actual field judgments, the relative importance of monocular cues may be assessed.

Consider two objects A_1 and A_2 at distances D_1 and D_2 respectively from an observer (Figure 1). Their binocular perception is dependent upon the total retinal disparity (both eyes) of the images a and b (Hallert, 1960). This disparity is comprised of components in three planes: vertical, lateral, and longitudinal. Displacement in the last, or longitudinal plane, is the component giving rise to binocular perception of the distance

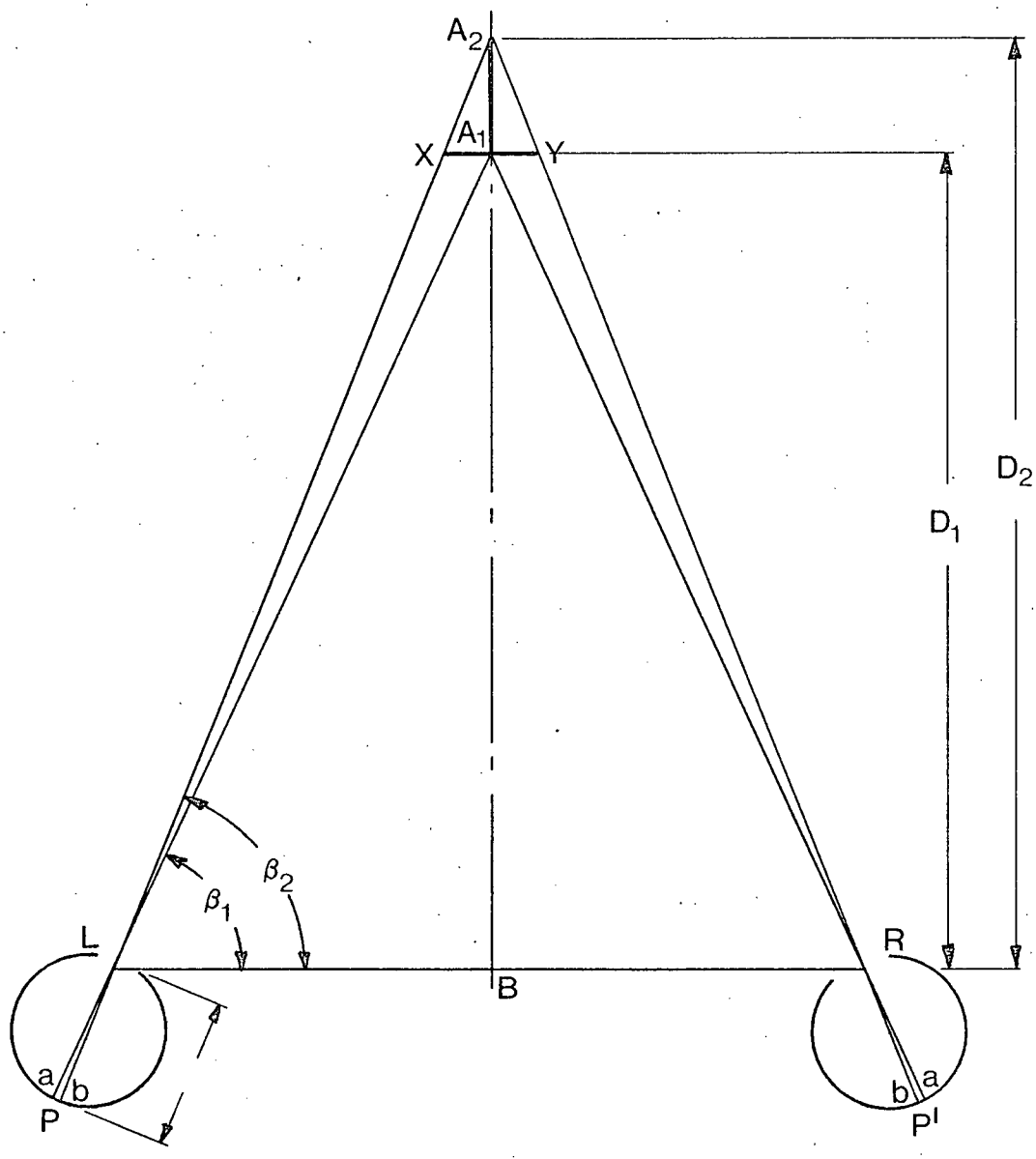
$$D_{i+1} - D_1 = \Delta D_i .$$

Diagrammatically, therefore, A_2 is drawn directly above A_1. Two further observations which explain the symmetry of Figure 1:

a) If asked what distance separated the objects, an observer would turn to face them directly. By so doing he would maximize the effective separation of his eyes, consequently, his binocular vision. A_2B is therefore perpendicular to LR.

b) Distances D_i are much greater than the eye separation LR. A_2B is therefore considered to bisect LR.

Retinal disparity (p) in the left eye (Figure 1) is clearly related to the angle $\beta_2 - \beta_1 = \Delta\beta$ and the focal length of the eye (f).



Appendix
Figure 1. The geometry of binocular vision.

$$p = f\Delta\beta$$

The same is true for the right eye so that the summed disparity is

$$P = p + p^1 = 2f\Delta\beta.$$

Intuitively, one might expect a minimum detectable P to exist. Such intuition is supported by data (Moessner, 1954) which suggests 0.00021 radians[1] to be the minimum $\Delta\beta$ which trained observers can detect with some consistency. The contribution of binocular vision to the perception of distance may therefore be related to changes in the function

$$\beta_i = \arctan \frac{2D_i}{LR}$$

or

$$\Delta\beta = \frac{2LR}{(LR)^2 + 4D_i^2} \qquad \Delta D_i$$

which becomes

$$\Delta D_i = \Delta\beta\,(LR^2 + 4D_i^2)\,LR^{-1}.$$

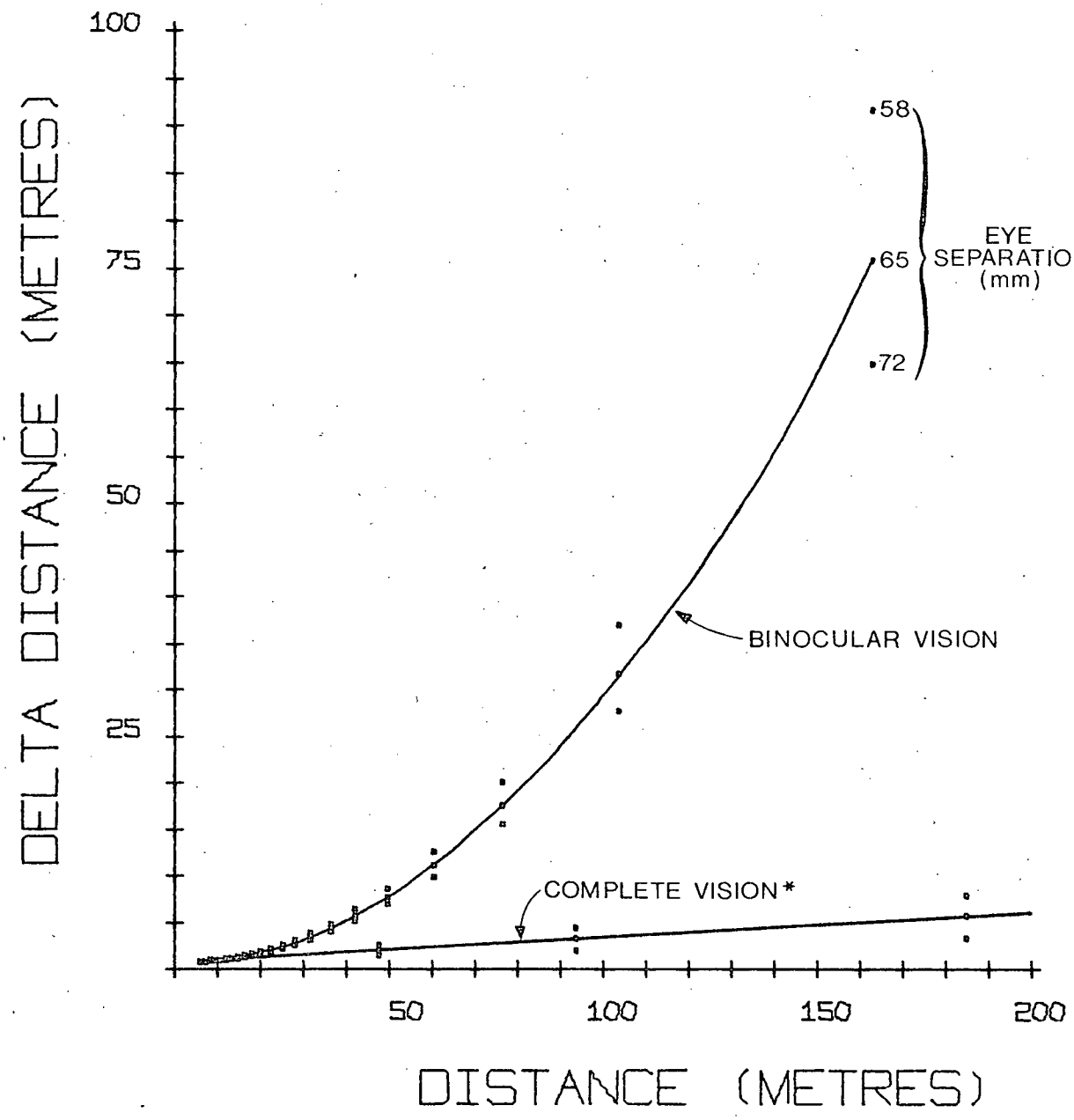
That is, an object at some distance D_i from an observer must be moved through a distance ΔD_i sufficient to produce the minimum angular change $\Delta\beta$ before binocular detection of ΔD_i can occur. Variation in binocular acuity can be expected as a consequence of variation in (1) eye separation (LR), the range of which is 65 ± 7 mm (Howard, 1919), and (2) $\Delta\beta$.

Figures 2 and 3 depict the relationship between distance (D), the change (ΔD) required to produce an ambitious $\Delta\beta_{min} = 0.00010$ radians, and the influence of eye separation on binocular distance perception. Also shown

---

[1] Moessner's data suggest $\Delta\beta$min is reached when D_1 (Figure 1) is 122 mm and XY lies between 0.0254 and .0127 mm viewed through two power lenses. The determination of D_1 was through personal correspondence with Dr. Moessner and the Abrams Instrument Corporation.

$$\frac{0.127\text{mm}}{122\text{mm}} = 0.00010 \text{ radians} \qquad \frac{0.254\text{mm}}{122\text{mm}} = 0.0127 \text{ radians}$$



Appendix
Figure 2. The minimum change in distance (ΔD) an observer could detect using binocular cues alone, and that ΔD which can be detected, at various distances (D) from the observer.

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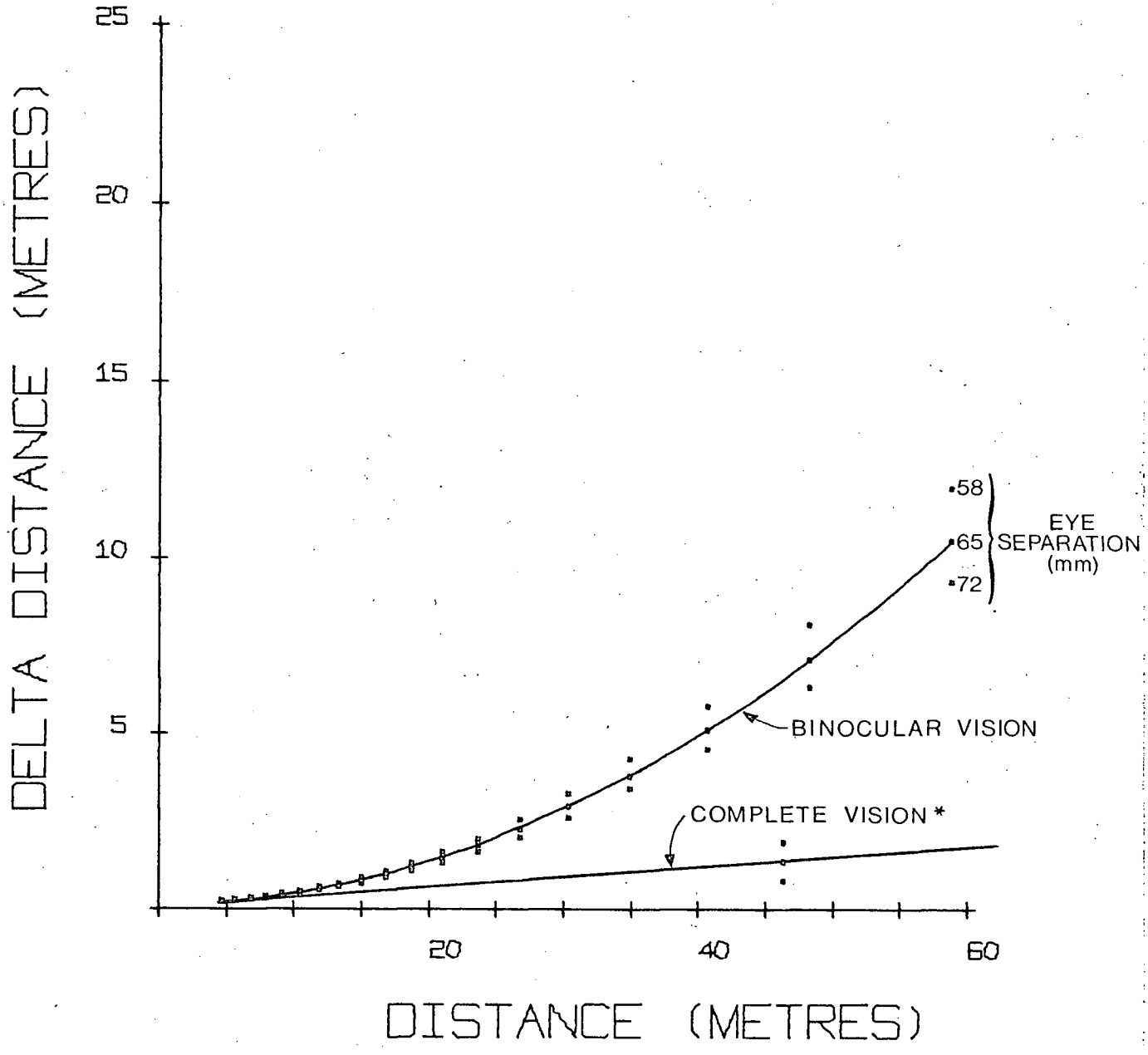
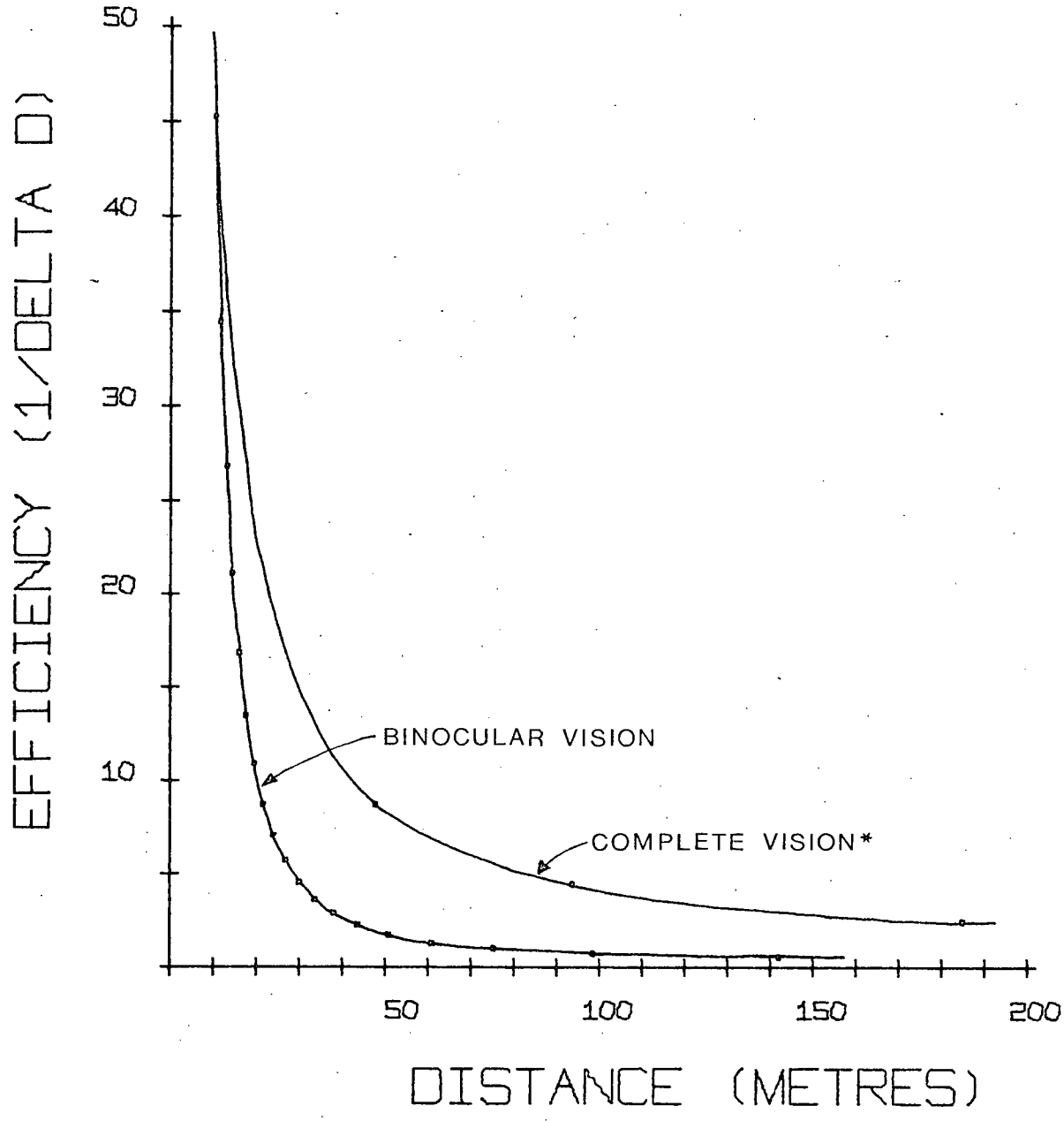
*After Gibson, et al. (1)



Appendix
Figure 3. The minimum change in distance (ΔD) an observer could detect using binocular cues alone, and that ΔD which can be detected, at various distances (D) from the observer.

---

*After Gibson, et al. (1)



Appendix
Figure 4. The efficiency of binocular vision alone compared with that of complete vision in the judgment of distance.

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*After Gibson, et al. (1)

are data of Gibson, et al., (1955) who found subjects capable of distinguishing much smaller ΔD's at much greater distances than would be possible through binocular vision alone.

To make the above comparison more transparent, the reciprocal of ΔD may be considered a measure of the efficiency with which distance is perceived; that is, at close quarters distance judgments are very efficient and a very small ΔD may be detected easily. The reverse is true of judgments involving remote objects. Figure 4, therefore depicts the relationship between distance and the efficiency with which its change is perceived.

The inference of the above figures is that binocular vision dominates distance judgments up to 9 or 10 metres. Beyond that distance, moncular cues assume dominance and the contribution binocular vision can make to the perception of distance diminishes rapidly.

APPENDIX II

QUESTIONNAIRES USED IN THE STUDY OF LOT SIZE AS A MEASURE OF ENVIRONMENTAL QUALITY

QUESTIONNAIRE I. Subjective Evaluation of Landscape and Development.

You will be presented with two series of pictures in which certain changes have been made, and asked to grade them according to your preference. But first, would you please answer the following questions?

1. Where did you grow up?

In the country ☐

In a town or city, population under 10,000 ☐
10,000 - 50,000 ☐
50,000 - 100,000 ☐
100,000 - 250,000 ☐
over 250,000 ☐

Or specify .....

2. Where do you live now?

In Greater Vancouver (please specify, e.g., Kitsilano, North Surrey, Burnaby, etc.) .....

Elsewhere (please specify).....

3. Would you mind telling me how old you are?

Under 12 years ☐
12 - 20 ☐
21 - 30 ☐
31 - 40 ☐
over 40 ☐

4. Are you married? ☐
single? ☐
other? ☐

Are you male? ☐
female? ☐

5. Do you have any children?

No ☐ Yes ☐ Ages.....

6. What is your family's yearly income?

under $7,000 ☐
$7,000 - 10,000 ☐
$10,000 - 15,000 ☐
over $15,000 ☐

7. Do you own, or are you interested in owning a summer cottage?

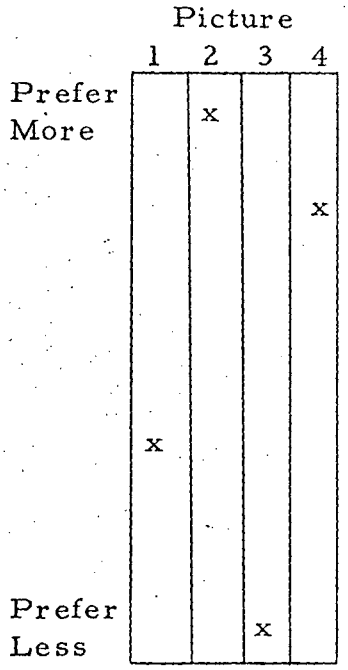
already own ☐ interested in owning ☐ not interested ☐

QUESTIONNAIRE I (continued)

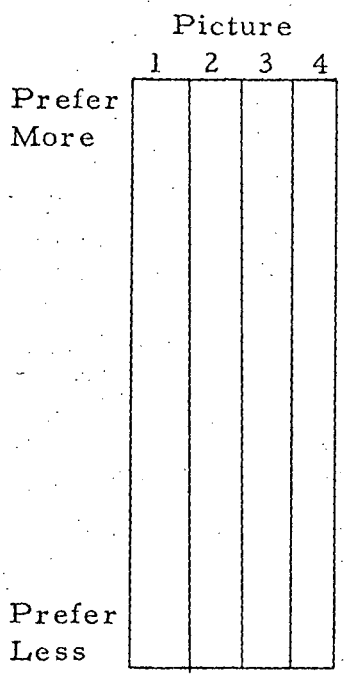
Now consider thatyou are shopping for a summer cottage. On the screen are two groups of pictures, all supposedly taken from the same porch; the porch of a cottage which pleases you in its design and construction, and which you might therefore buy.

I would like to know <u>which</u> locations (pictures) you prefer for your cottage and <u>how</u> <u>much</u> you prefer them over the others. Would you therefore please grade the pictures within each group on the scales provided.

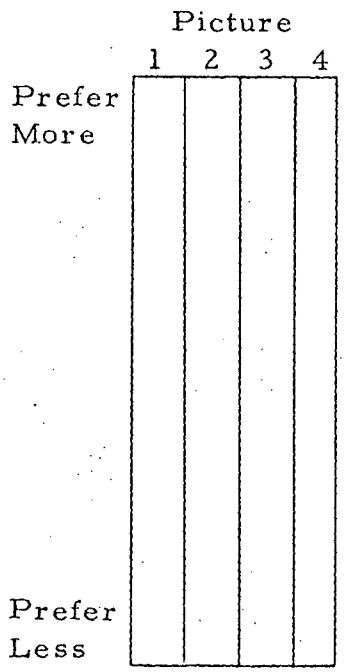
EXAMPLE



GROUP I



GROUP II



Comments:.....

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QUESTIONNAIRE II. Subjective Evaluation of Landscape and Development.

You will be presented with two series of pictures in which certain changes have been made and asked to grade them according to your preference. But first, would you please answer the following questions?

1. Where did you grow up?

In the country ☐

In a town or city, population under 10,000 ☐
10,000 - 50,000 ☐
50,000 - 100,000 ☐
100,000 - 250,000 ☐
over 250,000 ☐

Or specify .....

2. Where do you live now?

In Greater Vancouver (please specify, e.g., Kitsilano, North Surrey, Burnaby, etc.) .....

Elsewhere (please specify).....

3. Would you mind telling me how old you are?

Under 12 years ☐
12 - 20 ☐
21 - 30 ☐
31 - 40 ☐
over 40 ☐

4. Are you married? ☐
single? ☐
other? ☐

Are you male? ☐
female? ☐

5. Do you have any children?

No ☐ Yes ☐ Ages.....

6. What is your family's yearly income?

under $7,000 ☐
$7,000 - 10,000 ☐
$10,000 - 15,000 ☐
over $15,000 ☐

7. Do you own, or are you interested in owning a summer cottage?

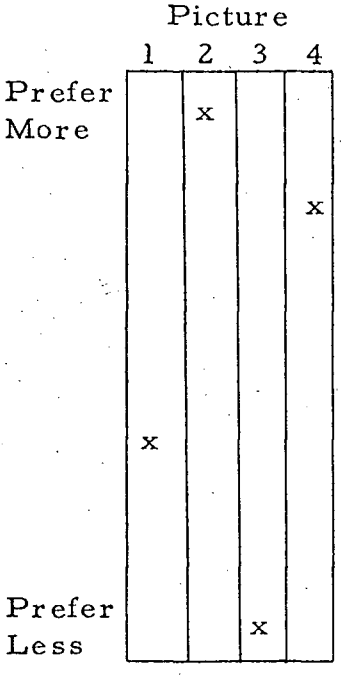
already own ☐ interested in owning ☐ not interested ☐

QUESTIONNAIRE II. (continued)

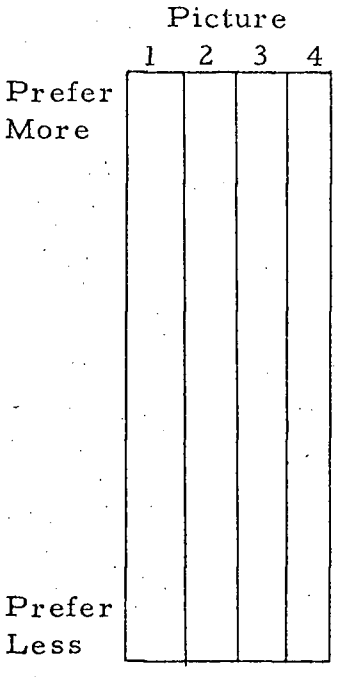
On the screen are two groups of pictures, all supposedly taken from the porch of <u>your</u> summer cottage.

I would like to know <u>which</u> views you prefer and <u>how much</u> you prefer them over the others. Would you therefore please grade the pictures within each group on the scales provided.

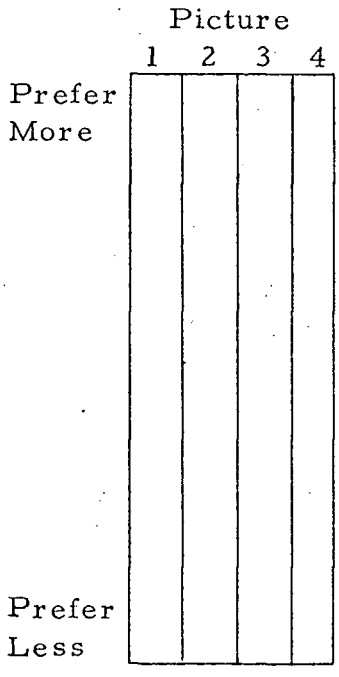
EXAMPLE



GROUP I



GROUP II



Comments:.....

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QUESTIONNAIRE III. Subjective Evaluation of Landscape and Development.

You will be presented with two series of pictures in which certain changes have been made and asked to grade them according to your preference. But first, would you please answer the following questions?

1. Where did you grow up?

In the country ..... ☐

In a town or city, population under 10, 000 ..... ☐
10, 000 - 50, 000 ..... ☐
50, 000 - 100, 000 ..... ☐
100, 000 - 250, 000 ..... ☐
over 250, 000 ..... ☐

Or specify .....

2. Where do you live now?

In Greater Vancouver (please specify, e.g., Kitsilano, North Surrey, Burnaby, etc.) .....

Elsewhere (please specify).....

3. Would you mind telling me how old you are?

Under 12 years ☐ 31 - 40 ☐
12 - 20 ☐ over 40 ☐
21 - 30 ☐

4. Are you married? ☐ Are you male? ☐
single? ☐ female? ☐
other? ☐

5. Do you have any children?

No ☐ Yes ☐ Ages.....

6. What is your family's yearly income?

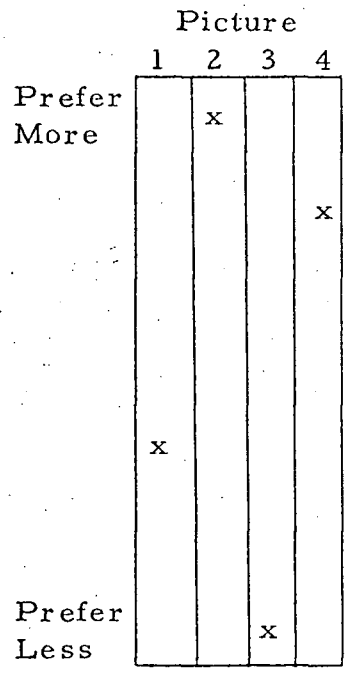
under $7, 000 ☐ $10, 000 - 15, 000 ☐
$7, 000 - 10, 000 ☐ over $15, 000 ☐

QUESTIONNAIRE III (continued)

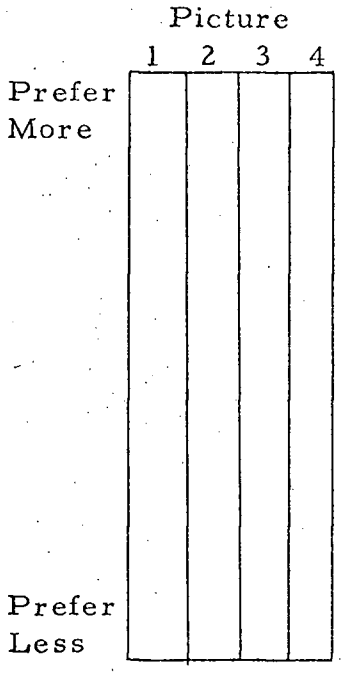
Now consider that you are shopping for a house. On the screen are two groups of pictures, all supposedly taken from the same porch; the porch of a house which pleases you in its design and construction, and which you might therefore buy.

I would like to know <u>which</u> locations (pictures) you prefer for your house, and <u>how much</u> you prefer them over the others. Would you therefore please grade the pictures within each group on the scales provided.

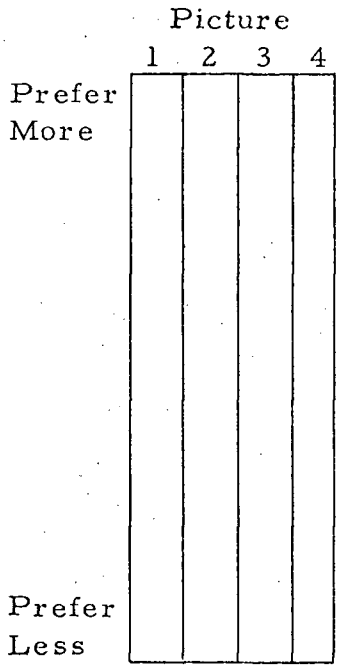
EXAMPLE



GROUP I



GROUP II



Comments:.....

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.....

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APPENDIX III

A LISTING OF GIRLS

```
// FOR INCOM
*ONE WORD INTEGERS
      SUBROUTINE INCOM
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      EQUIVALENCE(RMNIN(22),R22),(RMNIN(32),R32),(RMNIN(42),R42),
     1 (RMNIN(52),R52),(RMNIN(62),R62)
C     INPUT OF KNOWN MEAN INCOMES (RMNIN)
C     FOR CENSUS YEARS 1921,1931,1941,1951,1961
      R22=2209.
      R32=2687.
      R42=2608.
      R52=2424.
      R62=5222.
C     YEAR = I+1899
C     DETERMINATION OF MEAN INCOMES (RMNIN)
C     FOR PRECENSUS YEARS 1900-1920
      FAC10=R32/R22
      FAC1 = FAB10**0.10
      DO 3 J = 1,21
      I = 22-J
3     RMNIN(I) = RMNIN(I+1)/FAC1
C     FOR YEARS BETWEEN CENSUSES 1922-1930
      DO 4 I = 23,31
4     RMNIN(I) = RMNIN(I-1)*FAC1
C     FOR YEARS BETWEEN CENSUSES 1932-1940,1942-1950,1952-1960
      DO 6 J=1,3
      L = J*10 + 20
      FAC10=RMNIN(L+12)/RMNIN(L+2)
      FAC1 = FAC10**0.10
      L3 = L + 3
      L11 = L + 11
      DO 5  I = L3,L11
      RMNIN(I) = RMNIN(I-1)*FAC1
5     CONTINUE
6     CONTINUE
      RETURN
      END
// DUP
*DELETE              INCOM
*STORE      WS  UA   INCOM
```

```
// FOR INITL
*ONE WORD INTEGERS
      SUBROUTINE INITL
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      GO = 1900.
      D=279288.
      GROTH=.02844
      ECDEV=.03
      AGR1=1000.
      CONSB=.0001
      CONSS=0.007
      ICT=1
      DO 11 I = 1,7
      HAPY(I) = 0.0
      HOLD(I) = 0.0
      CON(I) = 0.
      UNDV(I)=ORIG(I)-FRSLE(I)*ASIZE(I)
      DEV(I) = 0.0
      SAL(I)=SAL1(I)
      DO 11 J = 1,60
11    OLOT(I,J)=0.
      TOLOT = 0.0
      BK=1.5E-06
C---  F2(I) IS THE PROPORTION OF PEOPLE EARNING (I*1000) WHO WISH TO BUY
C--   LAND,  INITIALLY MAXIMUM PROPORTION OF .8 AT I=15
      PMAX=.8
      OPINC=15.
      DO 20 I=1,100
      XX=I
      F2(I)=PMAX*EXP((-.6366/OPINC**2)*(XX-OPINC)**2)
20    CONTINUE
      SALTX=0.
      PTX=0.005
C--   MOTGAGE SUBROUTINE PARAMETERS
      ALPHA=.25
      BETA=.5
      THETA=.35
      FINT=.02
      SINT=.035
      MORT1=15
      MORT2=10
      RETURN
      END
```

```
// DUP
*DELETE              INITL
*STORE      WS  UA   INITL



// FOR PROBS
*ONE WORD INTEGERS
      SUBROUTINE PROBS
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

C--   SUBROUTINE COMPUTES THE POROBABILITY OF RESALE OF OLD LOTS BASED
C     ON THE SIZE OF PROPERTY TAX WHICH MUST LIE IN THE RANGE 0. TO .059
C--   MEAN=30.*(1.-PTX/.082)+.5
      MEAN=30.5-340.9*PTX
      M2=MEAN*2
      XBAR=MEAN
      XBAR1=MEAN+1
      SD=XBAR/3.
      P(1)=GAUS((1.-XBAR)/SD) - GAUS(-XBAR/SD)
      DO 10 I=2,M2
      XX=I
      P(I)=GAUS((XX-XBAR)/SD)-GAUS((XX-XBAR1)/SD)
10    CONTINUE
C--   SET REMAINING P(I) TO 1.
      M2=M2+1
      DO 20 I=M2,60
      P(I)=1.
20    CONTINUE
      RETURN
      END
// DUP
*DELETE              PROBS
*STORE      WS  UA   PROBS
```

```
// FOR MORTG
*ONE WORD INTEGERS
      SUBROUTINE MORTG
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

C-------------------------------------------------------------------------
C--   ALPHA  MAX. FIRST MORTGAGE DEBT/SERVICE  U.-1.  GEN. .25
C--   BETA  MAX. FIRST LOAN TO VALUE  U.-1.  GEN. .66
C--   THETA  MAX. TOTAL DEBT/SERVICE  U.-1.  GEN. .35
C--   FINT  HALF FIRST MORTGAGE INTEREST RATE
C--   SINT  HALF SECOND MORTGAGE INTEREST RATE
C--   MORT1  FIRST MORTGAGE AMORTIZATION PERIOD IN YEARS
C--   MORT2  SECOND MORTGAGE AMORTIZATION PERIOD IN YEARS
C--   FMORG IS THE SMALLER OF THE MULTIPLYING FACTORS FRAC1,FRAC2
C-------------------------------------------------------------------------
      DEN1=12.*BETA*(((1.+FINT)**.166-1.)/(1.-(1.+FINT)**(-2*MORT1)))+PT
     1X
      DEN2=12.*(1.-BETA)*((1.+SINT)**.166-1.)/(1.-(1.+SINT)**(-2*MORT2))
      FRAC1=THETA/(DEN1+DEN2)
      FRAC2=ALPHA/DEN1
C--   SELECT SMALLER OF TWO FRACTIONS
      IF (FRAC1-FRAC2) 50,50,60
50    FMORG=FRAC1
      GO TO 70
60    FMORG=FRAC2
70    CONTINUE
      RETURN
      END
// DUP
*DELETE              MORTG
*STORE      WS  UA  MORTG




// FOR POPIN
*ONE WORD INTEGERS
      SUBROUTINE POPIN
      DIMENSION VFAM(8)
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
```

```
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      DATA VFAM/0.340,0.200,0.216,0.132,0.0650,0.0262,0.0116,0.00976/
      DATA PRO/.24/
      DATA SD61/2816./
C--   THIS SUBROUTINE COMBINES THE OLD POPI AND ECON2, AND DETERMINES
C     POPULATIONS AND ECONOMIC GROWTH
C-----THIS SECTION REPLACES POPI
C--   D  TOTAL POPULATION
C--   GROTH  PERCENTAGE GROWTH RATE OF POPULAION. PRIOR TO 1966, GROWTH
C--   RATE IS 2.844 ( FROM BASE OF 279,288 IN 1900
C--   PRO  RECIPROCAL OF AVERAGE FAMILY SIZE
C--   VFAM(I)  PROPORTION OF POPULATION WITH I PEOPLE IN THE FAMILY
      IF (GO-1951) 10,10,20
10    D=D*1.02844
      GO TO 30
20    D=D*(1.+GROTH)
30    POOP=D*PRO
C--    ETERMINE NUMBER OF FAMILIES IN EACH FAMILY SIZE CATEGORY
      DO 40 I=1,8
      POP(I)=POOP*VFAM(I)
40    CONTINUE
C-----THIS SECTION REPLACES ECON2
      IF (IY-62) 60,60,50
C     DETERMINATION OF MEAN INCOME (RMNIN) FOR POST CENSUS YEARS 1962-2000
C--   ECDEV  PERCENTAGE RATE OF ECONOMIC DEVELOPMENT
50    RMNIN(IY)=RMNIN(IY-1)*(1.+ECDEV)
60    CONTINUE
C     DETERMINE MEAN (RM) AND STANDARD DEVIATION (STDEV) OF NORMAL
C     DISTRIBUTION FROM MEAN(RMNIN) AND CONSTANT STANDARD DEVIATION
C     (SD61) OF LOG NORMAL DISTRIBUTION. CALCULATIONS BASED ON 1961 DATA
C     SD61  STANDARD DEVIATION OF INCOMES IN 1961
      RM=0.989*ALOG(RMNIN(IY))
      STDEV=0.974*SD61/RMNIN(IY)
C     DETERMINATION OF FAMILY INCOME VECTOR (VFIN)
      VFIN(1)=GAUS((ALOG(1000.)-RM)/STDEV)-GAUS(-RM/STDEV)
      DO 70 I=2,100
      RI = I
      VFIN(I) =GAUS((ALOG(RI*1000.) - RM)/STDEV)
     1        - GAUS((ALOG((RI-1.)*1000.) - RM)/STDEV)
70    CONTINUE
      RETURN
      END
// DUP
*DELETE              POPIN
*STORE      WS  UA   POPIN
```

```
// FOR BUYER
*ONE WORD INTEGERS
      SUBROUTINE BUYER
      DIMENSION F1(8),BYER(100)
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

C     THIS SUBROUTINE REPLACES BIDDW AND SALEW
C     THIS SECTION REPLACES BIDDW AND CONVERTS POTENTIAL BUYERS TO
C     BIDDERS BY EXPRESSING GROSS INCOME IN TERMS OF THE MAXIMUM
C     MORTGAGE IT CAN SERVICE
C--   F1,F2,F3  ARE FUNCTIONS DETERMINING THE PROPORTION OF PEOPLE
C     INTERESTED IN BUYING COTTAGE LOTS.  F1 IS A FUNCTION OF FAMILY SIZ
C     F2 IS A FUNCTION OF INCOME, F3 IS THE PROPO TION
C     INTERESTED IN BUYING GULF ISLAND LAND

      DATA F1/.88,.98,1.,1.,1.,1.,1.,1./
      F3=A/(1.+100.*EXP(-BK*D))
      B=0.
      DO 30 I=1,100
      BIDN(I)=0.
      VF=VFIN(I)
      FACT=F3*F2(I)
      SUM=0.
      DO 20 J=1,8
      SUM=SUM+POP(J)*F1(J)*VF*FACT
20    CONTINUE
      BYER(I)=SUM
      B=B+SUM
30    CONTINUE
C--   ELIMINATE THOSE WHO HAVE ALREADY BOUGHT LOTS
C--   PROR IS PROPORTION REMAINING
      IF (B-TOLOT) 99,99,40
40    PROR=1.-TOLOT/B
      DO 90 I=1,100
      KAT=I*FMORG+.5
      IF (KAT-1) 72,75,75
72    KAT=1
75    IF (KAT-100) 80,80,78
78    KAT=100
80    BIDN(KAT)=BIDN(KAT)+BYER(I)*PROR
90    CONTINUE
99    CONTINUE
```

```
C--    THIS SECTION CALCULATES THE NUMBER OF LOTS COMING UP FOR RESALE
C      FRSLE(I) IS NO. OF DEVELOPED LOTS OF RECREATION CATEGORY I, FOR
C      SALE.  SAL(I) ARE SALE PRICES, P(J) ARE PROBABILITIES OF LOTS OF
C      OWNERSHIP J COMING FOR SALE.
C      RESAL  NO. OF OWNED LOTS OF CATEGORY I,AGE J, COMING UP FOR RESALE
C      OWNED  OWNED LOTS OF CATEGORY I, AGE J
C      SUM  SUM OF LOTS OF CATEGORY I FOR SALE
       DO 160 I=1,7
         SUM=FRSLE(I)
         DO 120 J=1,60
           OWNED=OLOT(I,J)
           RESAL=OWNED*P(J)
           SUM=SUM+RESAL
           OLOT(I,J)=OWNED-RESAL
120      CONTINUE
         FRSLE(I)=SUM
160    CONTINUE
       RETURN
       END
// DUP
*DELETE              BUYER
*STORE       WS  UA  BUYER



// FOR AGING
*ONE WORD INTEGERS
       SUBROUTINE AGING
       COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
       COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
       COMMON GO,A,NY,ACON,BCON,BK,IY
       COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
       COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
      1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
      2(7),TOLOT,F3
       COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
      1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
       COMMON REVPT,REVST,PTX,SALTX
       COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
       COMMON QTOT

C      SUBROUTINE ADVANCES VALUES OF OLOT AND ACCUMULATES TOTAL
C--    IT ALSO CALCULATES TOTAL REVENUE FROM PROPERTY TAXES
C      SUM  DEV(I), I.E. OLOT(I,J), SUMMED OVER J AGES
C      TOLOT OLOT(I,J) SUMMED OVER I AND J
       REVPT=0.
       TOLOT=0.
       DO 80 I=1,7
         SUM=0.
         OWNED=OLOT(I,60)+OLOT(I,59)
         OLOT(I,60)=OWNED
         SUM=SUM+OWNED
```

```
          DO 70 K=2,59
            J=61-K
            OWNED=OLOT(I,J-1)
            OLOT(I,J)=OWNED
            SUM=SUM+OWNED
70        CONTINUE
          OLOT(I,1)=SOLD(I)
          SUM=SUM+SOLD(I)
          DEV(I)=SUM
          TOLOT=TOLOT+SUM
          IF (PTX) 80,80,75
C--    REVENUE 'REVPT' IS COLLECTED EVERY YEAR FROM PROPERTY TAX 'PTX' ON
C--    ALL OWNED LOTS 'DEV(I)' EVALUATED AT HHE AVERAGE SELLING PRICE FOR
C--    LOTS OF THAT CATEGORY 'SAL1(I)'
75        REVPT=REVPT+PTX*SAL1(I)*SUM
80      CONTINUE
        RETURN
        END
// DUP
*DELETE              AGING
*STORE      WS  UA   AGING




// FOR MARKT
*ONE WORD INTEGERS
        SUBROUTINE MARKT
        DIMENSION DESR(7)
        COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
        COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
        COMMON GO,A,NY,ACON,BCON,BK,IY
        COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
        COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
       1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
       2(7),TOLOT,F3
        COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
       1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
        COMMON REVPT,REVST,PTX,SALTX
        COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
        COMMON QTOT

        DATA DESR/1.,.95,.85,.7,.5,.25,0./
C**     DESR(I)  PROPORTION OF BIDDERS IN CATEGORY (I+1) WHO WOULDCONSIDER
C**     BUYING LAND IN CATEGORY I IF UNSATISFIED IN THEIR HIGHER CHOICE
C       SUBROUTINE SELLS LOTS FRSLE TO BIDDERS BIDN
C       SAL(I)=PRICE INITIALLY ASKED FOR LOTS OF CATIGORY I
C       SAL1(I)=AVERAGE PRICE ACTUALLY PAID
C       SOLD(I)=NO. SOLD
C       FRSLE(I)=NO. LOTS OF CATEGOTY I FOR SALE
C       BIDN(KAT)=NO. BIDDERS PREPARED TO PAY$1000*KAT (MAXIMUM OF
C       $100,000)
C       SBID(I)=NO. BIDDERS INITIALLY BIDDING FOR LAND OF QUALITY I AND
C       ABLE TO OFFER A PRICE GREATER THAN AGR1
```

```
C       AGR1=SALE PRICE FOR UNDEVELOPED LAND.
        KAG=AGR1/1000.+.5
        REVST=0.
        DO 1305 I=1,7
        SAL2(I)=SAL1(I)
        TSBID=0.
        SOLD(I)=0.
C       NO. OF BIDDERS FOR EACH RECREATIONAL CATEGORY IS CHANGED BY
C       PROPORTION DESIRING LAND OF THAT QUALITY
        IF (I-1) 150,150,151
151     DESIR=DESR(I)
        DO 152 J=1,100
152     BIDN(J)=BIDN(J)*DESIR
150     DO 230 J = KAG,100
230     TSBID=TSBID+BIDN(J)
        SBID(I)=TSBID
C--     ADD SALES TAX TO INITIAL SALE PRICE TO GET TRUE ASKING PRICE
        SAL(I)=SAL(I)*(1.+SALTX)
        ASKPR=SAL(I)
C       DETERMINE INITIAL PRICE CATEGORY FOR LOTS IN CATEGORY I
C       FIRST DETERMINE DOLLAR CATEGORY (K) THAT IS COMPARABLE TO INITIAL
C       SALE PRICE.
        K=ASKPR/1000.  +.5
        IF(K)11,11,12
   11   K=1
   12   IF(K-100)10,10,20
20      K = 100
C--     TOT(I  = TOTAL = TOTAL NO. OF BIDDERS FOR LAND OF QUALITY I AND
C       WITH BIDDING PROCE GREATER THAN INITIAL PRICE
C       JMIN = MINIMUM FLOOR SALE PRICE BELOW WHICH LAND WILL NOT BE SOLD
10      TOTAL =0.
        JMIN = 1
        CASH = 0.0
C       FIND TOTAL INTERESTED BIDDERS AT THAT PRICE
        DO 30 J = K,100
30      TOTAL=TOTAL+BIDN(J)
        TOT(I)=TOTAL
C       COMPARE NO. BIDDERS WITH NO. LOTS
        TFRSL=FRSLE(I)
        IF (TOTAL-TFRSL) 40,40,50
C       IF TOO FEW BIDDERS, THEY ALL BUY AND PRICE THEN DROPS
40      FRSLE(I)=TFRSL-TOTAL
C       PROP IS PROPORTION OF SATISFIED BIDDERS WHO ARE ABLE TO MATCH
C       INITIAL SALE PRICE
        PROP(I)=1.
        SOLD(I)=TOTAL
C       START REDUCING PRICE UNTIL ALL LOTS SOLD OR PRICE TOO LOW(IE=JMIN)
        J = K-1
        IF (J) 101, 101, 134
101     SAL1(I) = JMIN*1000
        DO 102 J=K,100
102     BIDN(J)=0.
        GO TO 130
134     JMIN=.5*SAL2(I)/1000.
        IF(JMIN)42,42,45
42      JMIN = 1
```

```
45      IF (J-JMIN)100, 60, 60
60      TFRSL=FRSLE(I)
        TBIDN=BIDN(J)
        IF (TFRSL-TBIDN) 70,70,80
C       IF MORE BIDDERS THAN LOTS, SELL ALL LOTS AND GO TO 100
70      SOLD(I)=SOLD(I)+TFRSL
        BIDN(J)=TBIDN-TFRSL
        CASH=CASH+TFRSL*J*1000.
        FRSLE(I) = 0.0
        GO TO 100
C       IF MORE LOTS THAN BIDDERS, SATISFY THOSE BIDDERS AND REDUCE PRICE
80      SOLD(I)=SOLD(I)+TBIDN
        FRSLE(I)=TFRSL-TBIDN
        CASH=CASH+TBIDN*J*1000.
        BIDN(J) = 0.0
        J = J-1
        IF(J) 100, 100, 45
C       IF TOO MANY BIDDERS, THEY BUY ALL LOTS PRO RATA (NOT RICHEST
C       BIDDERS FIRST)
50      PROP(I)=TFRSL/TOTAL
        SOLD(I)=TFRSL
        FRSLE(I)=0.
100     TPROP=PROP(I)
        DO 110 J=K,100
        TBIDN=BIDN(J)
C       TRANS IS NO. TO TRANSACTIONS IN THIS CATEGORY
        TRANS=TBIDN*TPROP
        CASH=CASH+TRANS*ASKPR
110     BIDN(J)=TBIDN-TRANS
        IF (SOLD(I)) 131, 131, 140
C--     DEDUCT SALES TAX TO GIVE TRUE VALUE OF LAND
140     REV=CASH*SALTX/(1.+SALTX)
        REVST=REVST+REV
        CASH=CASH-REV
        IF (CASH) 128,129,129
128     CASH=0.
129     CONTINUE
        SAL1(I)=CASH/SOLD(I)
        GO TO 130
131     SAL1(I) = 1001.*JMIN
C       (1.-HAPY) IS THE PROPORTION OF BIDDERS WITH BIDDING PRICE GREATER
C       THAN AGR1 WHO COULD NOT BUY
130     HAPY(I)=SOLD(I)/TSBID
1305    CONTINUE
C       IF SOME BIDDERS FOR 1ST CAT. PLOTS ARE UNSATISFIED, INCREASE CON
        UNHAP = 0.
        DO 135 I = 1,7
C       UNHAP IS THE SUM OF THE PEOPLE WHO WERE UNABLE TO ACQUIRE LANK OF
C        THE QUALITY THEY DESIRED. DISAT IS THE PROPORTION OF THESE PEOPLE
C       IN RELATION TO THE NO. ORIGINALLY INTERESTED (= SBID(1)).
        IF (I-1) 135, 135, 200
200     UNHAP = UNHAP+SBID(I-1)*(1.-HAPY(I-1))*(1.-DESR(I))
135     CON(I)=ACON*EXP(BCON*(1.-PROP(I)))
        UNHAP = UNHAP+SBID(7)*(1.-HAPY(7))
        DISAT = UNHAP/SBID(1)
        DO 350 I=1,7
```

```
        AVSP1=SAL1(I)
        AVSP2=SAL2(I)
      IF (AVSP1+.1-AVSP2) 330,340,340
330     SAL(I)=AVSP1
        GO TO 350
340   SAL(I)=AVSP1*(1.+CON(I)*((AVSP1-AVSP2)/AVSP1+.01))
350   CONTINUE
      RETURN
      END
// DUP
*DELETE              MARKT
*STORE      WS  UA   MARKT



// FOR DEVEL
*ONE WORD INTEGERS
      SUBROUTINE DEVEL
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

C--BUYING PROCESS     - LOOP OVER CATEGORIES. INITIALISE SLUMP COUNTER
      ISLMP=0
      DO 100 I=1,7
C--CALCULATE RATE OF PRICE APPRECIATION, AND EXCESS RATE.
C--MARKET ONLY IF RATE OF APPRECIATION EXCEEDS SOME THRESHOLD.
C--    NO - DETERMINE AMOUNT OF LAND AVAILABLE  AND EFFECTIVE DEMAND
        RATEB=(SAL1(I)-SAL2(I))/SAL1(I)
        RATES=RATEB-THRSH
      DMAND(I)=(SOLD(I)+1.)*(1.+(.4*RATEB))
      DMAND(I)=DMAND(I)-FRSLE(I)
      IF(DMAND(I)-1.)20,20,30
20    DMAND(I)=0.
      GO TO 100
30    CONTINUE
      AVLOT=UNDV(I)
C--CALCULATE RATE OF ATTACK OF BIG SPECULATORS
      RAB=RATEB*XLARG+CONSB
C--ARE THERE ANY SMALL TIME DEVELOPERS
        IF (RATES) 40,50,50
40      CONTINUE
        RAS=0.
        BIG(I)=1.
```

```
        GO TO 60
50      CONTINUE
C--CALCULATE RATE OF ATTACK OF SMALL DEVELOPERS AND PROPORTION OF DEVEL
C--WHICH IS LARGE SCALE
        RAS=RATES*SMALL+CONSS
        BIG(I)=RAB/(RAB+RAS)
60      CONTINUE
        RA=(RAS+RAB)*DMAND(I)*AVLOT
        AVLND(I)=AVLOT*(1.-(1.+RA/(AVLOT*AK))**(-AK))
100     CONTINUE
110     RETURN
        END
// DUP
*DELETE              DEVEL
*STORE      WS  UA   DEVEL



// FOR SUBDV
*ONE WORD INTEGERS
        SUBROUTINE SUBDV (SZMIN,EXPR,XXB,ZLOTS)
        DIMENSION XXB(7),ZLOTS(7)
        COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
        COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
        COMMON GO,A,NY,ACON,BCON,BK,IY
        COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
        COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
       1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
       2(7),TOLOT,F3
        COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
       1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
        COMMON REVPT,REVST,PTX,SALTX
        COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
        COMMON QTOT

C--SUBDIVISION SUBROUTINE
C--     INITIALISE
        XL=(XXL-XT)/10.
        XP=.6931/(XXP-XXM)
        DO 300 I=1,7
C--     INITIALISE FOR CLASS I
        WN=DMAND(I)
        IF (WN-.1) 150,150,3
3       CONTINUE
        XB=XXB(I)
        K=0
        SUMAL=0.
        XG=AVLND(I)
        IF (XG) 6,6,8
6       CONTINUE
7       XG=.1*HOLD(I)
        HOLD(I)=HOLD(I)-XG
        BIG(I)=1.
```

```
      K=1
      SUMAL=XG
8     CONTINUE
      XR=SAL(I)
      XK=XXK*XR
      XM=XK/(10.*XP*EXP(XP*XXM))
      KJ=0
10    CONTINUE
      WS=XG/WN
20    CONTINUE
      IF (WS-XT) 100,30,30
30    IF (WS-SZMIN) 100,35,35
35    CONTINUE
C--   SZMIN IS A MINIMUM LOT SIZE - POLICY RESTRICTION
      TREV=WN*XR
      TCOST=XB*WS*WN+XK*WN*(1.+XL/(WS-XT))+XM*(EXP(XP*WN)-1.)
      TPROF=TREV-TCOST
C--   EXPR IS MINIMUM ACCEPTABLE PROFIT AS A PROPORTION OF TREV
      PRMIN=EXPR*TREV
      IF (TPROF-PRMIN) 40,50,50
40    CONTINUE
C--   INSUFFICIENT PROFIT - REDUCE LOT SIZE BY TEN PERCENT AND TRY AGAIN
41    WS=.9*WS
      GO TO 20
50    CONTINUE
      IF(WN-1.)130,130,43
43    CONTINUE
C--   DEVELOPMENT PROFITABLE
      DLOTS(I)=WN
      ASIZE(I)=WS
      ZLOTS(I)=WN*WS
      XXB(I)=XXB(I)*(1.+2.*(ZLOTS(I)/UNDV(I)))
      IF (XXB(I)-1000.) 4,5,5
4     CONTINUE
      XXB(I)=1000.
5     CONTINUE
      IF (K) 70,70,60
60    CONTINUE
C--   HOLDINGS WERE ADDED - IE USED UP ALL ORIGINAL AVLND(I)
      UNDV(I)=UNDV(I)-AVLND(I)
C--   ANY LAND PUT ON THE MARKET FROM HOLDINGS AND THEN NOT USED IS
C--   RETURNED TO HOLDINGS
      XSLND=XG-WN*WS
      IF (XSLND)  63,65,65
63    XSLND=0.
65    CONTINUE
      HOLD(I)=HOLD(I)+XSLND
      GO TO 300
70    CONTINUE
C --  WORKED WITH ORIGINAL AVLND(I) ONLY - USED XG OF IT
      XG=WS*WN
      UNDV(I)=UNDV(I)-XG
      IF (BIG(I)) 300,300,80
80    CONTINUE
C--   THE BIG DEVELOPERS ADD A PROPRTION OF EXCESS LAND TO THEIR HOLDING
      XSLND=(AVLND(I)-XG)*BIG(I)
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```
      IF (XSLND) 85,90,90
85    XSLND=0.
90    CONTINUE
      HLDMX=.1*ORIG(I)
      IF(HOLD(I)-HLDMX)91,91,92
91    CONTINUE
      HOLD(I)=HOLD(I)+XSLND
      UNDV(I)=UNDV(I)-XSLND
92    CONTINUE
      GO TO 300
100   CONTINUE
      IF (BIG(I)) 125,125,110
110   CONTINUE
C--   THERE ARE BIG DEVELOPERS PRESENT - IF LAND IS AVAILABLE IN THEIR
C-    HOLDINGS INCREASE XG BY 10 PERCENT AND TRY AGAIN
      ADLND=.1*XG
      IF (ADLND-HOLD(I)) 120,120,125
120   CONTINUE
      K=1
C--   INCREASE PROPORTION OB IBG DEVELOPERS
      BIG(I)=(BIG(I)*XG+ADLND)/(XG+ADLND)
      XG=XG+ADLND
      HOLD(I)=HOLD(I)-ADLND
      SUMAL=SUMAL+ADLND
      GO TO 10
125   CONTINUE
C--   INSUFFICIENT PROFIT - NO HOLDINGS LEFT
C--   REDUCE NUMBER OF LOTS SUPPLIED AND RRY AGAIN
      WN=.9*WN
      IF (WN-1.) 130,130,10
130   CONTINUE
C--   INSUFFICIENT PROFIT - NO HOLDINGS LEFT - HAVE REDUCED SIZE AND NUM
      IF (K) 150,150,140
140   CONTINUE
C--   RETURN HOLDINGS TO HOLD(I) - DECREASE PROPORTION OF BIG DEVELOPERS
C-    - DO NOT SUBDIVIDE
      BIG(I)=(BIG(I)*XG-SUMAL)/(XG-SUMAL)
      HOLD(I)=HOLD(I)+SUMAL
150   CONTINUE
      DLOTS(I)=0.
      ZLOTS(I)=0.
      ASIZE(I)=0.
300   CONTINUE
      RETURN
      END
// DUP
*DELETE              SUBDV
*STORE      WS  UA   SUBDV
```

```
// FOR PRVCY
*ONE WORD INTEGERS
      SUBROUTINE PRVCY
      DIMENSION TEMP(7),CLASS(7)
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
     , COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      DATA CLASS/5.,1.7,.43,.19,.11,.07,0./
C**   INITIALISE QLOSS TO ZERO
      QLOSS=0.
      QAD=0.
C--   INITIALISE TENPORARY ARRAY TO ZERO
      DO 10 I=1,7
      TEMP(I)=0.
10    CONTINUE
C--   LOOP OVER LAND CLASSES - DO CALCULATIONS ONLY IF SUBDIVISION OCCURRED
      DO 80 I=1,7
      XNUM=DLOTS(I)
      IF (XNUM-.01) 80,80,20
20    CONTINUE
C**   CALCULATE QUALTY AREA  DEVELOPED THIS YEAR
      KJ=8-I
      QAD=QAD+KJ*ASIZE(I)*DLOTS(I)
      AVSIZ=ASIZE(I)
C--   LOOP OVER SIZE CLASSES FROM SMALLEST SIZE UPWARDS UNTIL CORRECT
      DO 40 J=1,6
      JJ=8-J
      IF (AVSIZ-CLASS(JJ)) 50,50,40
40    CONTINUE
C--   TOP SIZE CLASS - NO CHANGE IN LAND CLASS
      TEMP(I)=TEMP(I)+XNUM
      GO TO 80
50    CONTINUE
C--   SIZE CLASS JJ - DETERMINE RESULTANT LAND CLASS
      II=I+JJ-1
      IF (II-7) 60,60,55
55    II=7
C**   II IS DESTINATION CLASS NUMBER
60    CONTINUE
      TEMP(II)=TEMP(II)+XNUM
C**   CALCULATE QUALITY AREA  LOST
      DROP=II-I
      IF(DROP)80,80,70
70    QLOS=XNUM*AVSIZ*DROP
      QLOSS=QLOSS+QLOS
80    CONTINUE
```

```
C**    CALCULATE QUALITY AREA  REMAINING UNDEVELOPED
       QAR=0.
       DO 85 I=1,7
       JK=8-I
       QAR=QAR+JK*UNDV(I)
85     CONTINUE
C**    QTOT = IMPACT ON QUALITY
       QTOT=((QAD-QLOSS)/QAD)*((QAR-QAD)/QAR)
       IF(QTOT)86,86,87
86     QTOT=1.
87     CONTINUE
C--    LOOP OVER LAND CLASSES
       DO 90 I=1,7
       DLOTS(I)=TEMP(I)
       FRSLE(I)=FRSLE(I)+DLOTS(I)
90     CONTINUE
       RETURN
       END
// DUP
*DELETE              PRVCY
*STORE      WS  UA   PRVCY
```

```
// FOR GRAPH
*ONE WORD INTEGERS
       SUBROUTINE  GRAPH (ZLOTS)
       DIMENSION ZLOTS(7)
       DIMENSION YP(6),YS(6),YVAL(6)
       COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
       COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
       COMMON GO,A,NY,ACON,BCON,BK,IY
       COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
       COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
      1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
      2(7),TOLOT,F3
       COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
      1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
       COMMON REVPT,REVST,PTX,SALTX
       COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
       COMMON QTOT

C-- GRAPHICAL UOTPUT SUBROUTINE - PLOTS ONLY EVERY FIFTH YEAR
       RY=IY
       DO 40 I=1,5
       IF (I-3) 5,40,5
5      CONTINUE
C  SCALE POINTS TO BE PLOTTED
       YVAL(I)=SAL1(I)
       YP(I)=GS3+GSC3*(1.-UNDV(I)/ORIG(I))
       YS(I)=GS2+GSC2*ZLOTS(I)
C  TEST THAT POINTS ARE NOT OFF SCALE
       GMX12=GMX1*2.
```

```
      IF (YVAL(I)-GMX12) 20,20,10
10    YVAL(I)=GMX12
20    IF (YS(I)-GMX12) 40,40,30
30    YS(I)=GMX12
40    CONTINUE
C--   SCALE PERCENT BUYERS UNSATISFIED
      YM=GS3+GSC3*DISAT
C**   SCALE IMPACT ON QUALITY  (0,74000)
      YQ=QTOT*74000.
      IF(YQ-GMX1)46,46,45
45    YQ=GMX1
46    CONTINUE
C--   IS IT A FIFTH YEAR
      IF (ICT-5) 50,60,60
50    CONTINUE
C--   INCREMENT COUNTER
      ICT=ICT+1
      GO TO 160
60    CONTINUE
C  PLOT LAND VALUES
      IF (IY-5) 61,61,62
61    LJ=2
      GO TO 63
62    LJ=1
63    CONTINUE
      DO 80 I=1,5
      IF (I-3) 65,80,65
65    CONTINUE
      KK=-2
      DO  70 J=LJ,5
      XPT=IY-6+J
      CALL FPLOT(KK,XPT,SAVE(I,J))
      KK=0
70    CONTINUE
      CALL FPLOT (-1,RY,YVAL(I))
80    CONTINUE
C**   PLOT IMPACT ON QUALITY
      KK=-2
      DO 85 J=LJ,5
      XPT=IY-6+J
      CALL FPLOT(KK,XPT,SAVEY(3,J))
      KK=0
      CALL POINT(1)
85    CONTINUE
      CALL FPLOT(0,RY,YQ)
      CALL POINT(1)
      CALL FPLOT(-1,RY,YQ)
C  PLOT NEW LAND PLACED ON THE MARKET
      DO 110 I=1,5
      IF (I-3) 90,110,90
90    CONTINUE
      KK=-2
      DO 100 J=LJ,5
      XPT=IY-6+J
      CALL FPLOT(KK,XPT,SAVES(I,J))
      KK=0
```

```
100   CONTINUE
      CALL FPLOT (-1,RY,YS(I))
110   CONTINUE
C  PLOT PERCENT OF LAND DEVELOPED
      DO 140 I=1,5
      IF (I-3) 120,140,120
120   CONTINUE
      KK=-2
      DO 130 J=LJ,5
      XPT=IY-6+J
      CALL FPLOT (KK,XPT,SAVEY(I,J))
      KK=0
130   CONTINUE
      CALL FPLOT (-1,RY,YP(I))
140   CONTINUE
C  PLOT PERCENT BUYERS UNSATISFIED
      KK=-2
      DO 150 J=LJ,5
      XPT=IY-6+J
      CALL FPLOT(KK,XPT,SAVE(3,J))
      KK=0
      CALL POINT (0)
150   CONTINUE
      CALL FPLOT (0,RY,YM)
      CALL POINT (0)
      CALL FPLOT (-1,RY,YM)
C  RESET COUNTER
      ICT=1
160   CONTINUE
C  STORE THIS YEAR'S RESULYS
      SAVEY(3,ICT)=YQ
      DO 180 I=1,5
      IF (I-3) 170,180,170
170   CONTINUE
      SAVEY(I,ICT)=YP(I)
      SAVES(I,ICT)=YS(I)
      SAVE(I,ICT)=YVAL(I)
180   CONTINUE
      SAVE(3,ICT)=YM
      RETURN
      END
// DUP
*DELETE              GRAPH
*STORE      WS  UA  GRAPH




// FOR GULF1
*IOCS(CARD,1132 PRINTER,PLOTTER)
*ONE WORD INTEGERS
      DIMENSION IYEAR(11)
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
```

```
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      DATA IYEAR/1900,1910,1920,1930,1940,1950,1960,1970,1980,1990,2000/
      READ (2,101) ORIG
      READ (2,101) FRSLE
C--   READ ASIZE
      READ (2,101) ASIZE
101   FORMAT (8F10.0)
      READ (2,101) SAL1
      READ (2,101) SAL2
      WRITE (3,102)
102   FORMAT ('1INITIAL SALE PRICES')
      WRITE (3,101) SAL1
      READ (2,10) A,ACON,BCON,AK,NY
10    FORMAT (4F10.5,I10)
      WRITE (3,11)
11    FORMAT(/5X,'A',7X,'ACON',6X,'BCON',8X,'AK',10X,'NY')
      WRITE (3,10) A,ACON,BCON,AK,NY
C--   READ DEVELOPMENT SUBROUTINE PARAMETERS
      READ (2,101)XXK,XXL,XT,XXM,XXP,XLARG,SMALL,THRSH
      WRITE (3,21)
21    FORMAT(/6X,'XXK',9X,'XXL',9X,'XT',9X,'XXM',9X,'XXP',9X,'XLARG',
     17X,'SMALL',7X,'THRSH')
      WRITE (3,20) XXK,XXL,XT,XXM,XXP,XLARG,SMALL,THRSH
20    FORMAT (8F12.5)
      WRITE (3,901)
901   FORMAT (/' HECTARES OF LAND AVAILABLE')
      WRITE (3,101) ORIG
C     GMX2 SCALES THE DEVELOPMENT GRAPH
      READ (2,101) GMX1,GMX2
      IGM1 = GMX1*.001+0.5
      GS2 = 1.1*GMX1
      GSC2 = GMX1*0.4/GMX2
      IGM2 = GMX2*0.01+0.5
      GS3 = 1.6*GMX1
      GSC3 = 0.4*GMX1
      RY = 0
      CALL SCALF (10./100.,5./GMX1,-20.,-GMX1/10.)
C--   IF DATA SWITCH 14 IS ON, THE AXES ARE NOT PLOTTED
      CALL DATSW (14,JKL)
      GO TO (55,25),JKL
25    CALL FCHAR (0.,0.,.1,.15,1.57)
      CALL FPLOT (+1,-6.,GMX1/3.)
      WRITE (7,107)
107   FORMAT ('PRICE  ($1000) ',27X,'DEVELOPMENT',17X,'PER CENT')
      CALL FCHAR (0.,0.,.1,.15,0.)
      CALL FPLOT (0,-2.,-GMX1/15.)
```

```
      WRITE (7,110) IYEAR
110   FORMAT (11(I4,6X))
      Y=-GMX1*.0005
      CALL FPLOT (0,-4.,Y)
      IP=0
      WRITE (7,115) IP
115   FORMAT (I3)
      Y1=GMX1/5.
      DO 30 J=1,5
      Y=Y+Y1
      CALL FPLOT (0,-4.,Y)
      IP=Y*.001+.5
      WRITE (7,115) IP
30    CONTINUE
      Y=GS2
      CALL FPLOT (0,-4.,Y)
      IP=0
      WRITE (7,115)IP
      Y2=Y1*.6666
      DO 40 J=1,3
      RJ=J
      Y=Y+Y2
      CALL FPLOT (0,-4.,Y)
      IP=RJ*GMX2/3.+.5
      WRITE (7,115) IP
40    CONTINUE
      Y=GS3
      CALL FPLOT (0,-4.,Y)
      IP=0
      WRITE (7,115) IP
      DO 50 J=1,2
      Y=Y+Y1
      CALL FPLOT (0,-4.,Y)
      IP=IP+50
      WRITE (7,115) IP
50    CONTINUE
      YMAX2=GS2+GSC2*GMX2
      YMAX3=2.0*GMX1
      CALL FGRID (0,0.,0.,1.,100)
      CALL FPLOT (2,100.,GMX1)
      CALL FPLOT (-1,0.,GMX1)
      CALL FGRID (0,0.,GS2,1.,100)
      CALL FPLOT (2,100.,YMAX2)
      CALL FPLOT (-1,0.,YMAX2)
      CALL FGRID (0,0.,GS3,1.,100)
      CALL FPLOT (2,100.,YMAX3)
      CALL FPLOT (-1,0.,YMAX3)
      CALL FGRID (3,0.,YMAX3,.04*GMX1,10)
      CALL FGRID (3,0.,YMAX2,100.*GSC2,IGM2)
      CALL FGRID (3,0.,GMX1,1000.,IGM1)
55    CALL FPLOT (0,0.,0.)
      CALL INITL
      CALL INCOM
      CALL LINK(GULF2)
      END
// DUP
```

```
*DELETE              GULF1
*STORECI    WS  UA  GULF1     1
*LOCAL,SFIO,INITL,INCOM



// FOR GULF2
*IOCS(1132 PRINTER,TYPEWRITER,KEYBOARD)
*ONE WORD INTEGERS
      DIMENSION SUMDL(7)
      DIMENSION AVEGI(7)
      DIMENSION XXB(7),ZLOTS(7)
      COMMON GMX1,IGM1,GS2,GMX2,GSC2,IGM2,GS3,GSC3
      COMMON SAVE(6,5),SAVES(6,5),SAVEY(6,5),ICT
      COMMON GO,A,NY,ACON,BCON,BK,IY
      COMMON D,POP(8),VFIN(100),RMNIN(100),ECDEV,GROTH,BIDN(100),F2(100)
      COMMON FRSLE(7),SAL(7),SAL1(7),SAL2(7),AGR1,SOLD(7),PROP(7),OLOT(7
     1,60),P(60),UNDV(7),DEV(7),CON(7),TOT(7),SBID(7),HAPY(7),DISAT,ORIG
     2(7),TOLOT,F3
      COMMON THRSH,XLARG,SMALL,AK,PROF,AVLND(7),BIG(7),HOLD(7),DLOTS(7),
     1ASIZE(7),DMAND(7),XXK,XXL,XT,XXM,XXP,CONSB,CONSS,KODE,DAREA
      COMMON REVPT,REVST,PTX,SALTX
      COMMON ALPHA,BETA,THETA,FINT,SINT,MORT1,MORT2,FMORG
      COMMON QTOT

      DATA SUMDL/7*0./
      CALL SCALF (10./100.,5./GMX1,0.,0.)
      SZMIN=.1
      EXPR=.1
      DO  815 I=1,7
      XXB(I)=100.
      ZLOTS(I)=0.
815   CONTINUE
C--   INITIALISE VECTOR OF PROBABILITY OF RESALE
      CALL PROBS
      CALL MORTG
      DO 99 IY = 1,NY
      IF(IY-66)2,1,2
1     PAUSE
2     CONTINUE
      RY=IY
C-----IF DATA SWITCH 14 IS ON, PROGRAM DOES NOT TEST OTHER SWITCHES
      CALL DATSW (14,JKL)
      GO TO(250,240),JKL
240   CONTINUE
C**   DATA SWITCH 0 CONTROLS ADDITION OF NEW LAND
C     WHEN DATA SWITCH 0 IS ON J0=1, WHEN OFF J0=2
      CALL DATSW(0,JKL)
      GO TO (300,600),JKL
300   CALL FPLOT (0,RY,0.0)
      CALL FPLOT(2,RY,2.0*GMX1)
      CALL FPLOT(1,RY,2.0*GMX1)
      WRITE (1,60) UNDV
```

```
      WRITE (3,305) IY
305   FORMAT (/' HECTARES OF NEW LAND ENTERING IN YEAR ',I3/)
      WRITE (1,310)
310   FORMAT ('ENTER CATEGORY, SPACE, NO. OF HECTARES')
      DO 400 I = 1,7
      READ (6,500) I, AAAAA
500   FORMAT (I1, 1X, F10.0)
      LAND=AAAAA
      WRITE (3,800) I,LAND
800   FORMAT ('0',I1,I10)
      ORIG(I)=ORIG(I)+LAND
      UNDV(I)=UNDV(I)+LAND
400   CONTINUE
      CALL DATSW (0,J0)
      GO TO (300,600),J0
  600 CONTINUE
C**   TYPE OF POPULATION GROWTH AFTER 1966 CONTROLLED BY DATA SWITCH 2
      CALL DATSW (2,JKL)
      GO TO (610,620),JKL
610   WRITE (1,615)
615   FORMAT ('ENTER POPN. GROWTH RATE - .0XX')
      READ (6,616) GROTH
616   FORMAT (F10.0)
      CALL FPLOT (-2,RY,0.)
      CALL POINT (1)
      CALL FPLOT (+1,RY,0.)
620   CONTINUE
C**   TYPE OF ECONOMIC GROWTH AFTER 1961 CONTROLLED BY DATA SWITCH 3
      CALL DATSW (3,JKL)
      GO TO (625,630),JKL
625   WRITE (1,627)
627   FORMAT ('ENTER ECONOMIC GROWTH RATE - .0XX')
      READ (6,616) ECDEV
      CALL FPLOT (-2,RY,0.)
      CALL POINT (1)
      CALL FPLOT (+1,RY,0.)
630   CONTINUE
C---  DATA SWITCH 4 CONTROLS PROPORTION OF PEOPLE INTERESTED IN BUYING
C--   OPTIMUM INCOME.
C--   LAND AND OPTIMUM INCOME BRACKET. ENTER MAXIMUM PROPORTION AND
      CALL DATSW (4,JKL)
      GO TO(635,660),JKL
635   WRITE (1,640)
640   FORMAT ('ENTER PMAX')
      READ (6,616) PMAX
      WRITE (1,645)
645   FORMAT ('ENTER OPINC, WITH DECIMAL')
      READ (6,616) OPINC
      DO 650 I=1,100
      XX=I
      F2(I)=PMAX*EXP((-.6366 /OPINC**2)*(XX-OPINC)**2)
650   CONTINUE
      CALL FPLOT (-2,RY,0.)
      CALL POINT (3)
      CALL FPLOT ( 1,RY,0.)
      CALL DATSW (4,J4)
```

```
      GO TO (635,660),J4
660   CONTINUE
C--   DATA SWITCH 5 - MAXIMUM DEMAND CONSTANT A
      CALL DATSW (5,JKL)
      GO TO (665,675),JKL
665   WRITE (1,670)
670   FORMAT ('MAX. PROPORTION OF PEOPLE INTERESTED IN GULF IS. LAND')
      READ (6,616) A
      CALL FPLOT (-2,RY,0.)
      CALL POINT (4)
      CALL FPLOT (1,RY,0.)
675   CONTINUE
C--   DATA SWITCH 6 CONTROLS PROPERTY TAX AND SALES TAX
      CALL DATSW (6,JKL)
      GO TO (685,695),JKL
685   WRITE (1,690)
690   FORMAT ('ENTER PROPERTY TAX RATE  0.-.059')
      READ (6,616) PTX
691   CALL PROBS
      CALL MORTG
692   WRITE (1,693)
693   FORMAT ('ENTER SALES TAX')
      READ (6,616) SALTX
      CALL FPLOT (-2,RY,0.)
      CALL POINT (5)
      CALL FPLOT (1,RY,0.)
695   CONTINUE
C--   DATA SWITCH 8 CONTROLS MORTGAGE OPTIONS
      CALL DATSW (8,JKL)
      GO TO (730,735),JKL
730   WRITE (1,731)
731   FORMAT (' (ALPHA)(BETA )(THETA)(AINT1)(AINT2)(MORT1)(MORT2)')
      READ (6,732) ALPHA,BETA,THETA,FINT,SINT,AMRT1,AMRT2
732   FORMAT (7F7.0)
      MORT1=AMRT1
      MORT2=AMRT2
      FINT=FINT*.5
      SINT=SINT*.5
      CALL MORTG
      CALL FPLOT (-2,RY,0.)
      CALL POINT(4)
      CALL FPLOT (1,RY,0.)
735   CONTINUE
C--   DATA SWITCH 9 CONTROLS SUBDEVELOPMENT OPTIONS
      CALL DATSW (9,JKL)
      GO TO (740,755),JKL
740   WRITE (1,745)
745   FORMAT(' (XXK  )(XXL  )( XT  )(XXM  )(XXP  )')
      READ (6,732) XXK,XXL,XT,XXM,XXP
      CALL FPLOT (-2,RY,0.)
      CALL POINT (4)
      CALL FPLOT (1,RY,0.)
755   CONTINUE
      CALL DATSW (10,JKL)
      GO TO (760,770),JKL
760   CONTINUE
```

```
      WRITE (1,765)
765   FORMAT ('(THRSH)(XLARG)(SMALL)(CONSB)(CONSS)')
      READ (6,732) THRSH,XLARG,SMALL,CONSB,CONSS
770   CONTINUE
C--   DATA SWITCH 11 - DISPERSION COEFFICIENT OF -VE BINOMIAL
      CALL DATSW (11,JKL)
      GO TO (780,790),JKL
780   CONTINUE
      WRITE (1,785)
785   FORMAT ('AK')
      READ (6,616) AK
790   CONTINUE
C--   DATA SWITCH 12 - SZMIN AND EXPR
      CALL DATSW (12,JKL)
      GO TO (801,810),JKL
801   CONTINUE
      WRITE (1,805)
805   FORMAT ('(SZMIN)(EXPR )')
      READ (6,732) SZMIN,EXPR
810   CONTINUE
250   CONTINUE
      CALL POPIN
      CALL BUYER
      CALL MARKT
      KODE=1
      CALL DEVEL
      IF (KODE) 11111,22222,11111
11111 CONTINUE
      CALL SUBDV (SZMIN,EXPR,XXB,ZLOTS)
      CALL PRVCY
22222 CONTINUE
      DO 255 I=1,7
      SUMDL(I)=SUMDL(I)+DLOTS(I)
255   CONTINUE
      CALL AGING
      CALL GRAPH (ZLOTS)
      CALL DATSW (13,JKL)
      GO TO (24,26),JKL
24    CONTINUE
      DO 25 I=1,7
25    WRITE (3,60) AVLND(I),SAL(I),DMAND(I),ASIZE(I),DLOTS(I),SAL1(I),
     1HOLD(I),XXB(I),PROP(I),QTOT
26    CONTINUE
      IF (IY-5*(IY/5)) 99, 30, 99
30    WRITE (3,40) IY, TOLOT , D
40    FORMAT (//' YEAR 'I3,' TOTAL LOTS 'F8.0,'REGIONAL POP.'F10.0/)
      WRITE (3,15)
15    FORMAT(//' NO. DEVEL.',3X,'PERCENT',3X,'PERCENT',3X,'AVERAGE',3X,
     1'PERCENT',3X,'NEW LOTS',6X,'UNSOLD',3X,'LOTS',5X,'LOTS',3X,'AVERAG
     2E',4X,'AVERAGE')
      WRITE (3,16)
16    FORMAT (4X,'LOTS',6X,'DEVELOPED  BUYERS',3X,'PRICE',5X,'PRICE',19X
     1,'LOTS',3X,'FOR SALE',3X,'SOLD',3X,'GROSS',6X,'LOT')
      WRITE (3,17)
17    FORMAT (23X,'SATISFIED',11X,'INCREASE  DEVELOPED',31X,'INCOME',5X,
     1'SIZE'/)
```