# ANALYSIS OF THEORIES AND METHODS FOR ESTIMATING BENEFITS OF PROTECTING URBAN FLOODPLAINS

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U.S. Army Engineer Institute for Water Resources
Kingman Building
Fort Belvoir, Virginia 22060

by

Institute for Urban and Regional Studies
Washington University (St. Louis, Mo.)

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From the theoretical model developed in this paper and a review of the relevant literature, it was concluded that subject to problems caused by externalities, benefits of floodplain protection can be appropriately measured by direct estimation or by examining changes in site values, with and without protection, on the affected areas. Since the two studies reviewed in detail, Weisz and INTASA, each makes use of these measurements, in principle we conclude that conceptual differences between the two studies are minor. Both rely on

on changes in land values in the final analysis; Weisz does so explicitly, and INTASA uses such changes in estimating the value of amenities and social environment effects, although the precise way in which the changes are used is not adequately explained.

Although the basic conceptual models are similar, there are considerable differences in implementation. Weisz sets up a linear programming model which maximizes the benefits as measured by land values. On the other hand the INTASA approach rather explicitly eschews the maximization approach, and prefers to work within the framework of very detailed planner projections and rankings.

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# CHAPTER I

## NATURE OF THE PROBLEM

Beginning in the late 1930's, the U. S. Army Corps of Engineers began investing in a major way in projects importantly directed--in some cases solely directed--at the control of flood waters. These projects incorporated a variety of flood control techniques--dams, levees, channelization, etc.--but projects consisted primarily of physical structures to contain or regulate the flow of flood waters. Obviously, some criteria had to be developed to select from the vast number of flood prone areas, those that should be selected for protection projects.

The criteria to be employed, as established by the Flood Control Act of 1936, was that the benefits "to whomsoever they may accrue" must exceed the costs of the project construction and maintenance. Application of this principle involved a number of technical issues, such as the need to determine a present value of all benefits and costs since the benefits and costs would occur at different points in time, determining the effective life of the project and any residual value the facilities might have after that time, and a variety of complications in estimating construction and land acquisition costs. But by far the most difficult problem was that of estimating the stream of expected benefits, and that will be the major focus of attention in the analysis in this report.

Despite the seemingly simple and straightforward principle of building only projects where benefits exceed costs (actually prospective projects are assigned priorities roughly in accordance with the level of their benefit-cost ratios or excess of benefits over costs) a paradox has emerged: despite the billions of dollars invested in flood control projects, expected annual flood damages per capita in constant dollars are now higher than they were in the 1930's, and the death rate from floods also is higher. In part this could be due to a systematic tendency to overestimate benefits and/or underestimate costs. Though there is reason to believe that pressures for project approval would encourage such biases in estimating benefits and costs, it is difficult to believe that this could come anywhere close to explaining the paradox, even though exhaustive *ex post* analysis of realized benefits and costs has not been made.

It is also hard to account for the paradox in terms of any problem in the way that a benefit is defined. For flood control projects the concept of "benefit" has been extremely simple, with very few exceptions being confined simply to an estimate of the value of damage reduction to land and property on the affected flood plain. Moreover, the record for estimating frequencies of realized flood stages has been good as has the record for estimating the loss to any particular type of property from any given degree of inundation, though the amount of flooding and unit damage may have tended to exceed estimates. But here too, even in the absence of more definitive study, it is difficult to imagine that underestimation could be serious enough to explain the secular increases in flood damage.

The major explanation for the paradox lies partly in underestimation of the amount of property locating on floodplains subsequent to their protection and also on the measurement of benefits on a somewhat more comprehensive basis than is appropriate in certain circumstances; this latter point will be explained more fully presently.

The first point is a simple one. When a floodplain is protected, the probability of inundation of any given degree of severity goes down. But since the reduction in flood risk will encourage additional investment on the plain, the damage resulting from a flood of any given severity will rise. Depending on the rate of increased floodplain occupancy relative to the proportionate reduction in flood stage frequency curves an absolute increase in average annual damage could easily result. And this could result without irrational investor behavior to the extent that private investors are risk myopic and/or that investors anticipate subsidizing of their losses through governmental flood relief outlays. It should be noted that the increase in annual flood damage does not necessarily imply that flood control investment has been socially disfunctional. It is possible that the excess social value accruing from the occupancy of protected floodplains over the value of occupying alternative off-plain locations could exceed the excess damages occurring as a result of such occupancy. This is doubtful, but more will be said on this point later.

The other problem has to do with the particular calculus employed in benefit estimation. This can be explained if we think of benefits as being represented by

$$B = \sum_{i=1}^{N} \frac{\Delta d_i \cdot P_d \cdot K_i}{(1+r)^i}$$

where

$B$ = benefits from flood control

$\Delta d_i$ = reduction in flooding in the $i^{th}$ year

$P_d$ = value of property loss from a unit of flooding (for convenience we regard this as constant over time and linear with respect to $\Delta d_i$)

$K_i$ = stock of capital on the floodplain in the $i^{th}$ year

$r$ = social rate of discount

$N$ = life of project.

Earlier we indicated that questions about the appropriate level of r were beyond the scope of our inquiry and that we were assuming engineering competence in the determination of $\Delta d_i$, $P_d$ and N. Thus, the problem, and the heart of the paradox, lies in the specification of $K_i$. On the one hand, if we estimate $K_i$ as the amount of capital that would locate on the floodplain even <u>without</u> protection, we necessarily assume a zero social value of expanding the set of flood-free feasible locations; this would give an underestimate of benefits. On the other hand, estimating benefits as damage reduction to estimates of the stock of capital on the plain <u>with</u> protection will represent an overestimate of benefits so long as locators on the plain pay less than the full cost of protection or are provided relief payments in the event of flooding. Conceptually, benefits should be calculated (abstracting from discounting to present values) as

$$B = \Delta d^1 P_d K_o + (\psi - \Delta d^2 P_d)\Delta K$$

where

$\Delta d^1$ = reduction in flooding on the floodplain

$\Delta d^2$ = increase in residual flooding on floodplain over flooding at alternative location

$K_o$ = capital that would locate <u>without</u> protection

$K_o + \Delta K$ = capital that would locate <u>with</u> protection

$\psi$ = unit differential locational advantage of locating on the flood plain of the additional capital that would locate there relative to alternative location of that capital

In essence, this says that benefits would consist of damage reduction to capital that would be on the plain anyway plus the locational advantage of being on the plain to that capital that would locate only with protection (one could imagine projects with $\Delta dP_d K_o$ sufficiently large so that $\psi$ could be negative) less any excess damages over those in its alternative location that would accrue to that capital increment. In general, this would give estimates of B such that $\Delta d^1 P_d K_o < B < \Delta d^1 P_d (K_o + \Delta K)$.

The general equilibrium nature of the problem

At first glance it would seem that in order to determine $\psi$ -- and indeed $\Delta K$ -- it would be necessary to develop a general equilibrium locational model over the set of all feasible locations for the incremental capital locating on the flood-plain. Indeed, in most cases, especially where urban residential land is being protected, benefit calculations must be calculated in something like a general equilibrium framework, though a theoretical scheme much simpler than might be expected will suffice in most circumstances. This theoretical model will be presented in Chapter II. It will include, moreover, provision for "amenity" as well as "locational" advantages of flood control, it will consider floodproofing as well as containment structures as a damage reduction technique, and it will consider restriction of floodplain occupancy as an alternative to control of flood waters.

In Chapter III we will describe the theory underlying the two major completed methodological studies herein reviewed--INTASA and Weisz--in terms of the theory we develop in Chapter II. We will conclude that the theory underlying these two methodologies is substantially the same and is generally sound in Chapter III. Chapter IV will review the empirical techniques used in applying each of these methodologies and serious criticisms will be presented. Chapter V will present a regression model of the effect of flood risk on land values developed with St. Louis area data. Empirically it will be seen as much more satisfactory than the approach used either by INTASA or Day-Weisz, though its data requirements will be more extensive than either of those two approaches. Finally, Chapter VI will include some general conclusions and recommendations to IWR on how to develop approaches to the analysis of floodplain protection or management benefits that are theoretically sound, empirically viable, and operationally practical. Interdependence of locational utility will be seen as a continuing theoretical problem, data requirements for land value models will be seen as a continuing empirical problem, and sensitivity of estimated benefits to planners' projections will be seen as a continuing operational problem. Recommendations for practically dealing with these problems will be made.

Before proceeding to Chapter II, it will be useful to articulate some of the reasons why the general equilibrium aspects of floodplain protection benefits have emerged so recently. This discussion will also indicate the conditions under which a simpler, more conventional calculus of benefits will be applicable.

Emergence of a general equilibrium problem

To a considerable extent the fact that the general equilibrium aspects of floodplain protection benefits only emerged recently is tied up with the history of flood protection projects. Initial flood protection projects were of two types. First, many projects were directed at protection of already settled inner-city areas. In these cases the capital investment on the plain is substantially unchanged by protection so that both with and without projections of facilities at risk are the same. Accordingly

$$B = \Delta d \cdot P_d \cdot K_o$$

and the general equilibrium issue does not arise. Often B is estimated as the increase in site values on the floodplain. This is purely a matter of estimation strategy, however, since in anything close to a competitive equilibrium increase in site value should equal the present discounted value of damage reduction.

The other class of property protected by earlier flood control projects was agricultural land (protection of farm buildings is both relatively small and is a fairly constant proportion of land values). Here too there is no general equilibrium problem, and in this case, site value enhancement should be the same regardless of whether with or without projections of agricultural land use and output are used.

In the case of an existing farm with the same cropping with or without protection, it is clear that benefits are equal to the increase in yield coming with protection. Conceptually, one might want to consider compensating decreases in yields in off-plain locations, but so long as price of output from the plain were invariant with its quantity, such compensating decreases would necessarily approximate zero.

Second, consider an existing farm, but where cropping patterns would be expected to be altered as a consequence of protection. This is the case considered in a recent ERS study[3]. Then there would be both protection (less water damage) and "betterment" (switch to higher valued crops or more land intensive cropping techniques) benefits. A common example of "betterment" would be a switch from woodlots to cropland. But both of these could be captured simply by the difference between estimated "with" and "without" net output value, at least so long as all crops were such that price elasticity of demand for them from the floodplain was infinite.

Finally, consider the case of a floodplain which could be cultivated only if there were protection. This is little different than the preceding case, except that the increase in output would be the estimated total output with protection. Again, so long as this output was sold under competitive conditions no general equilibrium considerations would arise. In all of the agricultural cases, of course, benefits could be estimated as the increase in land value of directly affected land <u>or</u> as the present values of the increase in output, but under an assumption of a competitive market for land this is a question simply of empirical convenience.

In all of the foregoing, the general equilibrium problem is avoided by properties of the situations discussed which leave both the demand for and supply of off-plain locations essentially unaffected by protection of the plain. In the rural examples, it is the infinitely elastic demand for output produced at any given site which simplifies matters. In the case of fully developed urban sites it is that the demand for site occupancy is essentially inelastic with respect to protection which simplifies matters. And even where the extent and/or type of settlement of an urban floodplain depended on the extent of its protection, there would still be no problem, so long as the area of the floodplain were small enough relative to the supply of off-plain locations in the same market, so that changes in the extent of floodplain occupancy would not noticeably alter the quantity of off-plain sites demanded. Where that condition held, protection benefits would simply amount to

$$B = \Delta d^1 P_d (K_o + \Delta K),$$

that is, reduction of damages to estimated occupancy with protection, or, alternatively, to the differential of land value on the plain with over land value without protection.

The real problem comes with the consideration of benefits from protecting a floodplain where the extent and nature of occupancy is highly dependent on the degree of protection and either the area of the floodplain is a non-negligible proportion of the total supply of locations for the potentially locating activities or the output of the on-plain activities is a non-negligible share of the total output of those activities. Except for very large and very specialized irrigation projects, the latter condition is unlikely to hold. The first condition and the former version of the second condition (appreciable proportion of the available land supply), however, is likely to obtain in the case of proposed protection of marginal residential areas within an urban land market.

Accordingly, we will here be concerned with the question of assessing benefits from protection of urban floodplains where the area of the plain is a non-negligible share of the total land supply within the limits of settlement of the urban area and where its occupancy depends on the extent of protection. In a larger context, we could consider benefits of locating on an urban floodplain relative to alternative locations not only within the urban area containing the plain, but in (all?) other urban (rural?) areas as well. This would be equivalent to regarding the population of the urban area itself as dependent on the degree of floodplain protection within it.

If it could be demonstrated or argued that those who would occupy the floodplain _with_ protection necessarily would not locate anywhere in that urban area _without_ protection, the general equilibrium problem again would disappear. Necessarily the floodplain would be a trivial proportion of the national urban land space, and benefits could be estimated as total damage savings (total increase in land value) to property locating on the plain _with_ protection.

The condition outlined in the preceding paragraph, however, is an extreme one and it is unlikely to be satisfied except in very unusual circumstances. At most, the availability of protection on an urban floodplain would only partially affect the area's total population. But to handle this kind of situation would require estimating an area's population as a function of the set of urban site locations contained within it. Clearly this could be accomplished only by considering all potential floodplain protection projects in all urban areas simultaneously in the context of an inter-urban population location model. Such modelling capability, much less the data to implement it, simply is not possible at the present state of knowledge.

Thus, we will confine ourselves to assessing benefits from protection of urban floodplains where the area of the plain is a non-negligible share of the total land supply within the urban area and where occupancy of the plain depends on its protection, but where total population of the urban area is independent of protection of the floodplain, and is determined exogenously of the floodplain analysis. This situation does not, however, involve particularly restrictive assumptions, since in most cases while urban floodplain protection would involve changes in an urban area's land use pattern (off as well as on the plain), it probably would not be so extensive as to affect the total population of the urban area. This does, of course, rule out area development benefits of floodplain protection. Where these might be thought to exist they could be handled by a separate analysis and the adjusted population and activity totals used for the floodplain protection analysis as in an earlier IWR study [11]. Thus, here we will confine ourselves to land use, damage reduction and amenity benefits. A theoretical framework for analyzing such benefits in the indicated context is presented in the next chapter.

# CHAPTER II

## A THEORY OF URBAN FLOODPLAIN PROTECTION BENEFITS

The purpose of this section is to consider the appropriateness of using land rents to measure benefits of floodplain protection. This is the approach adopted by Weisz and, to some extent, also by INTASA. We first present a simple model which illustrates the major issues, and then discuss complications. The model employed is similar to that of Mohring [17].

We assume all employment to be located at a central business district (CBD), and that all people live along a road out from the CBD (the generalization to a 2-dimensional city only complicates matters without adding insight). We further assume that all lot sizes are equal, either due to identical tastes or to zoning; that the only characteristics of the land which enters the consumer's decision is the cost of travel, including the value of time, to the CBD; and that the travel cost is proportional to distance.

The purpose of these assumptions, as will become apparent, is to insure that a monotonic rental gradient can be drawn for the city; that is, our theory will require that sites can be arranged in a unique, monotonic order from one point in a way which can be a priori identified and which is stable with respect to the kinds of changes occurring as a result of floodplain management. We adopt the CBD parable for expository convenience, but any other assumptions which yield the proper rental gradient are acceptable. Moreover, local identifiable causes of departure from monotonicity, such as particular site amenities, can be accommodated under appropriate conditions, and are considered below.

In these circumstances, equilibrium land rentals would require that the sum of rent and travel costs be constant along the road between the CBD and the end of the city. If this were not true, consumers would bid up the price of land closer to the CBD in an attempt to save on travel costs, and would bid down prices of land further out from the CBD for the same reason. We also assume that a floodplain exists within the populated area. In our first approximation we will assume that the probability of extensive damages due to flooding are so high that the plain is used only for farmland. For convenience, we assume that the supply of equally good farmland is infinitely elastic, and so treat the price of this land as zero. Figure 1 represents the model graphically. Total rental payments are measured from the top of the figure to the diagonal line, and travel costs are measured from the bottom. Areas A and C are the settled parts of the city, and B is the floodplain. Rent is $A_1 + C_1$, and travel costs are $A_2 + C_2$.

Next, assume that floodplain protection is introduced such that the former floodplain is as secure from flood as the rest of the city. Also assume that there is no population growth and that people can move quickly and costlessly (e.g., they all live in mobile homes or tents). Then, in the new configuration, the city will shrink to fill in the floodplain, and the situation is as illustrated in Figure 2. B now represents the former floodplain, now settled, and area D represents the formerly inhabited, but now vacated, end of the city. Rents are now $A_2 + B_2 + C_2$, and travel costs are $A_3 + B_3 + C_3$. Note that the general level of rents has now fallen as the result of protection. It is easy to see why: rents in this model are of the Richardian variety, they exist because of differential distance from the CBD. As the result of the protection, the periphery of the city is closer to the CBD than it was previously, thus the locational advantage of non-peripheral areas has been reduced. Loosely, the supply of close-in land has increased, causing a fall in its price.

In this parable, there is an unequivocal measure of social benefits: the savings in travel costs. These savings permit the consumers to increase their consumption of other goods by the same amount minus the cost of the flood protection. Under reasonable principles of welfare economics, the project should be undertaken, abstracting from income distribution, if the present value of the savings exceeds the present value of the costs of protection. Note that we have assumed that the rent on the floodplain will rise to the competitive rate, so that all travel cost savings will be capitalized. Indeed,

**Figure 1**

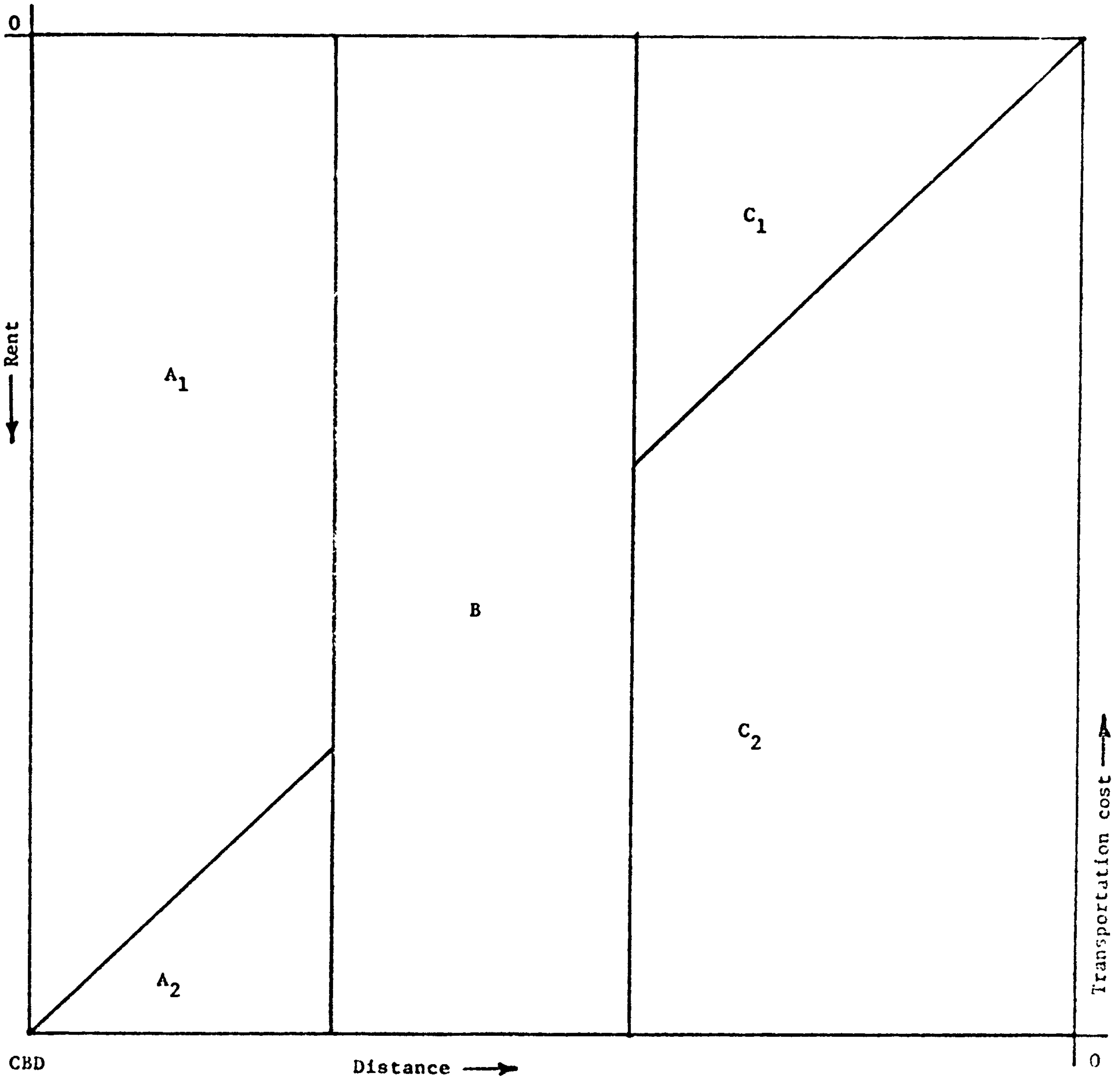
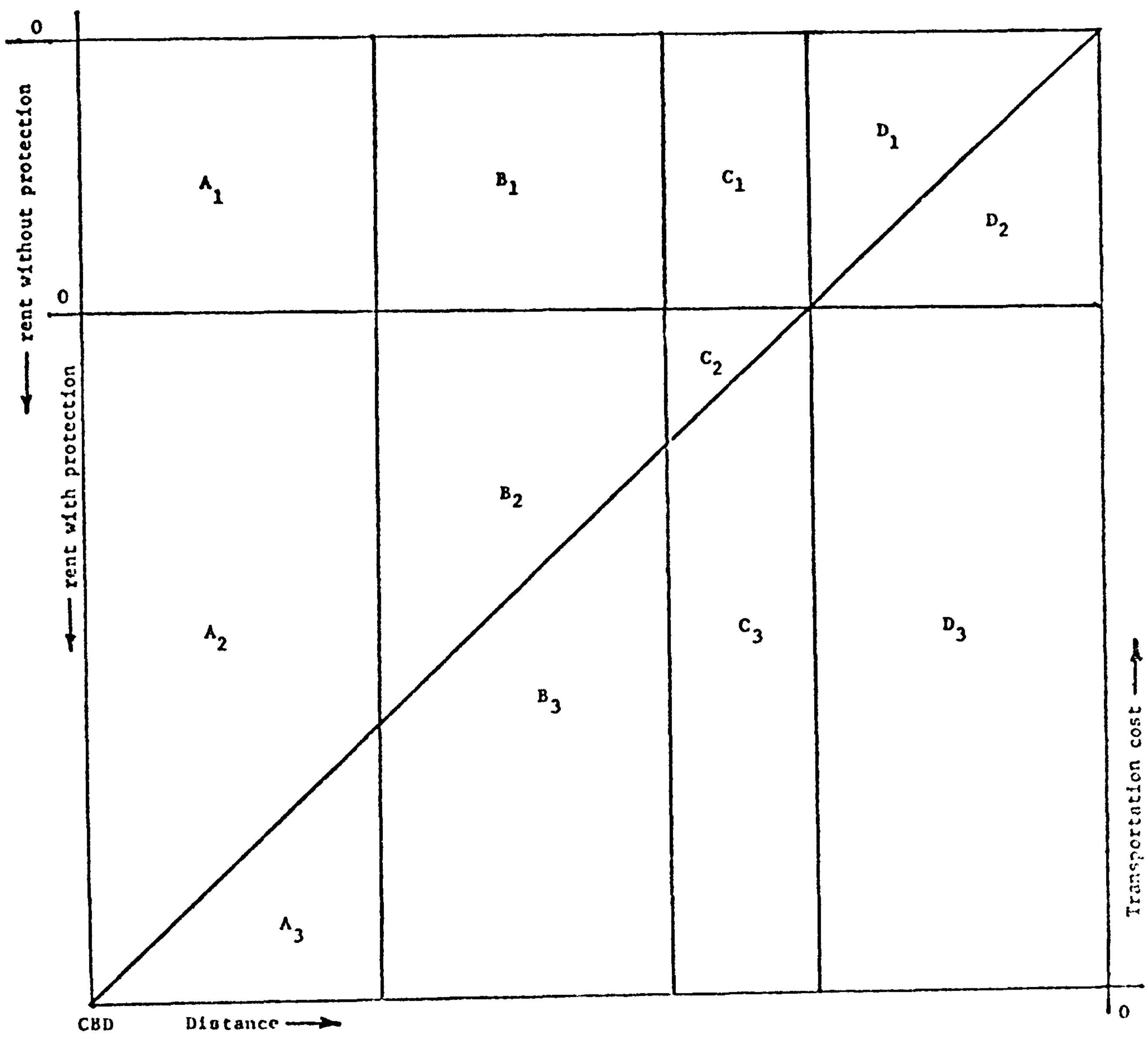


Figure 2


0
rent without protection
0
rent with protection
A1
B1
C1
D1
D2
C2
B2
A2
C3
D3
B3
A3
Transportation cost
CBD
Distance
0

it is difficult to see what else might be assumed. Harberger [5] has argued strongly for the use of competitive prices to value output: although arbitrary to some degree, one can visualize a process (i.e., competitive markets) which would cause this result, whereas the assumption that there is some division of the savings between renters and owners would appear to lead to extremely difficult problems of determining the division and difficulties in constructing a process which would maintain the distribution. The problem would not arise, of course, if the travel costs could be observed directly, for then we need not consider the rents at all. INTASA's approach is largely to estimate travel costs directly, but methodology for this purpose is not well developed, and the empirical problems are quite serious. It is worth considering how rents could be used to measure benefits.

To relate the cost savings to the rent changes, we refer to Figure 2. We can compute the benefits in terms of the savings in travel costs as follows:

Travel costs before protection: $A_3 + C_3 + D_2 + D_3$

Travel costs after protection: $A_3 + B_3 + C_3$

Savings in travel costs =

benefits of protection: $D_2 + D_3 - B_3$.

The benefits are simply the travel costs paid by those formerly living on the periphery minus the costs paid by the new inhabitants of the floodplain.

A similar calculation can be made for the change in rent:

| Region | Rent: After protection | Rent: Before protection | Change |
|---|---|---|---|
| A | $A_2$ | $A_1 + A_2$ | $-A_1$ |
| B | $B_2$ | 0 | $B_2$ |
| C | $C_2$ | $C_1 + C_2$ | $-C_1$ |
| D | 0 | $D_1$ | $-D_1$ |
| | Rent Change | | $B_2 - (A_1 + C_1 + D_1)$ |

Unfortunately, the total rent change bears no simple relation to the benefits, but consider the rent changes only on the "affected" areas, B and D. Suppose we measure the rent on the former floodplain at the "old" values, $B_1 + B_2$, and subtract the rent lost on the periphery, $D_1$, i.e., $B_1 + B_2 - D_1$. Now, as is evident,

$$B_1 + B_2 + B_3 = D_1 + D_2 + D_3, \text{ so that}$$

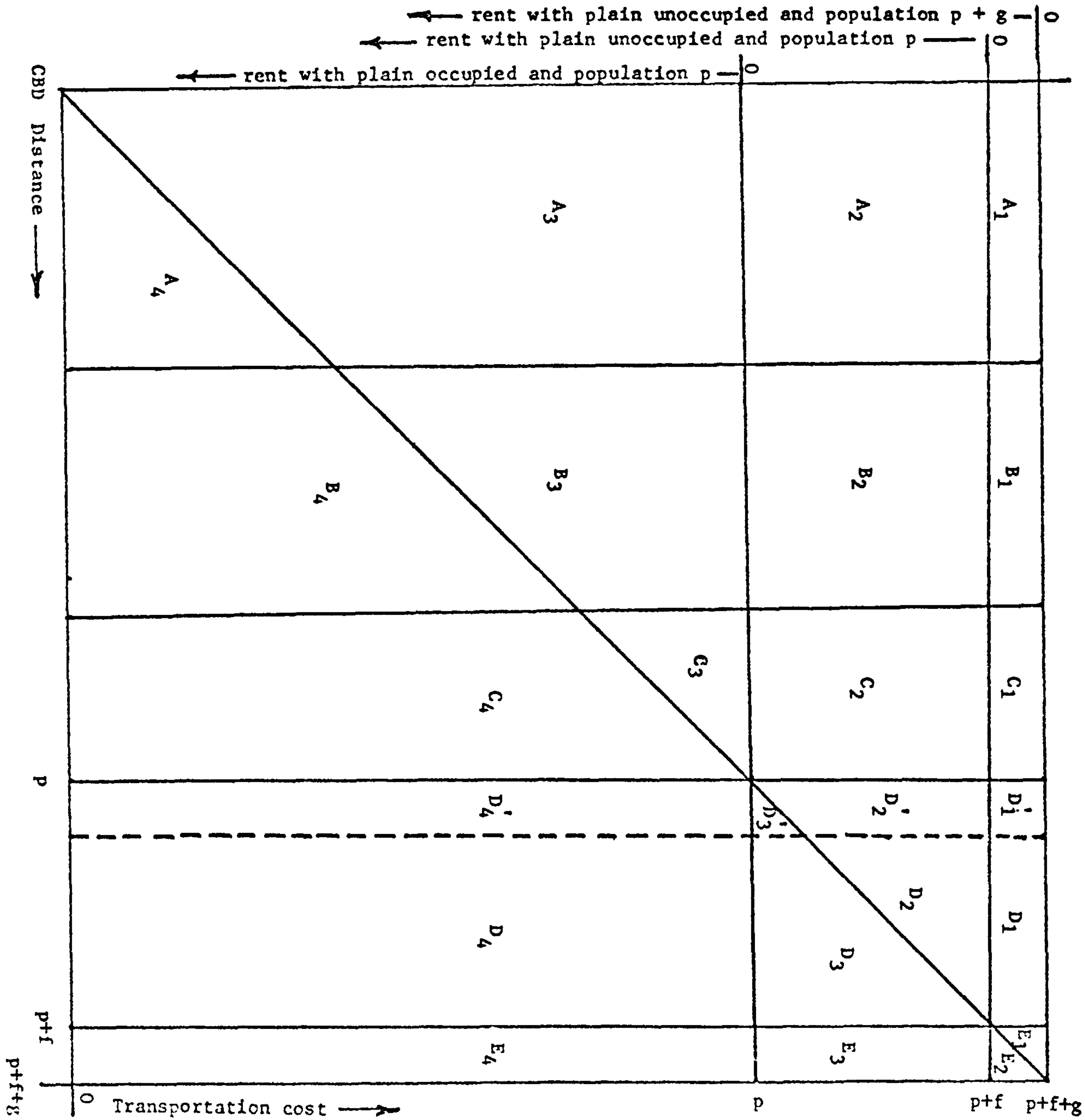
$$B_1 + B_2 - D_1 = D_2 + D_3 - B_3,$$

and the latter is the measure of benefits derived above. Thus the net change in the rental value of the affected areas of the city's land, <u>valued at pre-protection prices</u>, is in this model an accurate measure of benefit. (Note that the result follows if a more general rent gradient, such as the negative exponential suggested by Muth [18], is assumed.) It is remarkable that the benefits can be measured without the necessity of considering the effect of the newly supplied land on the general level of rents, and that only the rents on the affected areas need be considered. This simplifies considerably the data gathering problems involved in making an evaluation.

In this simple story, it is easy to see how a project evaluator might proceed. He could set up a "programming" problem which assigns people to land so as to maximize rents, or minimize travel costs. In the absence of population increase, and with costless transfer of housing, it is clear that the floodplain would be filled up and the edge of the city vacated. The difference between the new rentals (evaluated at the old prices) and the original rental measures the benefits of the project, and would be obtained as the solution to the programming problem.

Several kinds of complications can be readily incorporated into this framework. Assume that housing is not mobile in the short run. Then the benefits of the project will be delayed until replacement is necessary, and this replacement will take place on the higher value land to take advantage of the lower travel costs. The usual present value calculation will accurately reflect this situation: the delay in the cost savings is matched by the delay in increased rental payments.

The effect of growth in population on travel cost savings and rent is displayed in Figure 3. Here p is the initial length of the city assuming the floodplain _is_



rent with plain unoccupied and population p + g
rent with plain unoccupied and population p
rent with plain occupied and population p
0
0
0
CBD Distance
p
p+f
p+f+g
0 Transportation cost
p
p+f
p+f+g
A1 A2 A3 A4
B1 B2 B3 B4
C1 C2 C3 C4
D1' D2' D3' D4'
D1 D2 D3 D4
E1 E2 E3 E4


Figure 3

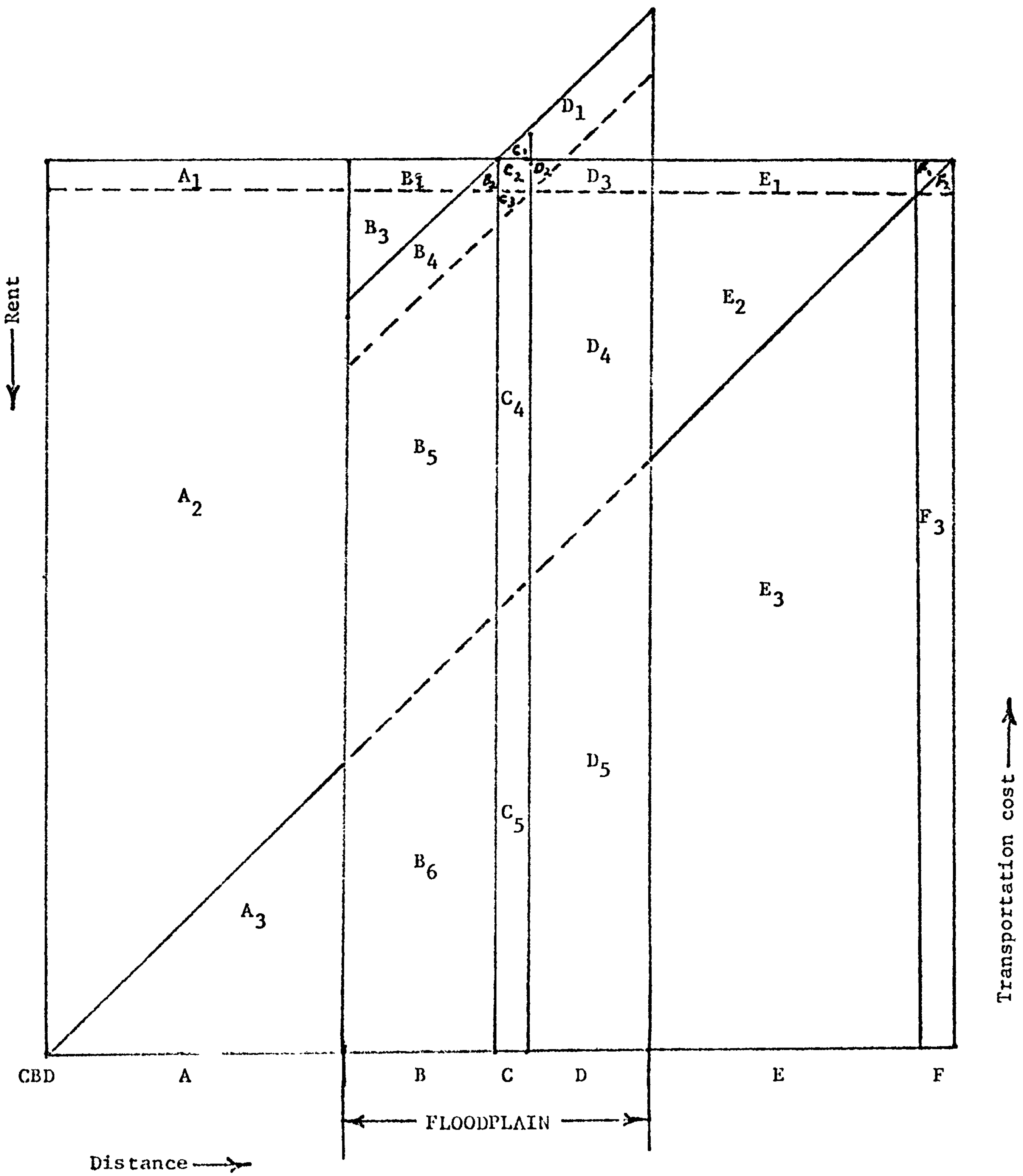
occupied. With floodplain of length f and the plain not occupied, city length would be (p + f). By the same analysis as above, the difference in travel costs, with and without protection, when the population increases by g (which under assumption of fixed density means an increase in linear city size of g distance units) is equal to the areas $D_3 + D_4 - B_4 + E_2 + E_3 + E_4$, $D_3 + D_4 - B_4$ is independent of growth, but $E_2 + E_3 + E_4$ is a function of the assumed growth rate: the heights of both $E_2$ and $E_3$ depend on distance from the CBD, and in our simple model, this depends on the amount of growth. Thus, the assumed rate of growth affects predicted benefits directly. In our example, if t is the unit transportation cost, g the increase in the size of city, and f the length of the floodplain, $E_2 + E_3 + E_4 = (1/2)gt[2p+2f+g]$, so that the damage in benefits is a function of g. The importance of working with reasonable growth rates is apparent: clearly, a floodplain can appear to have a desirable benefit-cost relationship if a high enough growth rate is assumed. The rent plus travel cost calculation should remind us that a predicted increase in size of city has definite implications for the rent plus travel costs which residents will have to pay, and might provide a check on whether the assumed growth rate is reasonable.

The strong results obtained thus far depend heavily on the assumption that property has value only as a function of its distance from the CBD or, more generally, that a unique rental gradient can be determined. This simplification enabled us to treat location choice and travel time as a single decision. In effect, the consumer is indifferent about where he lives, since any move would result in offsetting changes in rent and the cost of travel and travel time, and the latter is assumed to reflect fully the value to a consumer of travel and travel time. Once these assumptions are relaxed, the results become less clear. Without assumptions of this type, it appears that nothing short of a complete general equilibrium model will be satisfactory. If individuals prefer living near different locations or near different people, there is little that can be said on the basis of a partial analysis. In particular, benefits can no longer be associated only with savings in travel time and costs, and may not always be measured adequately by rents. Thus, if some people prefer to live near the edge of the city, because of nearness to rural amenities, they will benefit from the low rents paid there if most people prefer to save on travel. Rent will not be a good measure of the benefits received since they might be willing to pay more to live in that spot, but do not have to. This difference, consumer surplus, is difficult to measure, and it may be quite large. Lind [12] and INTASA explicitly provide for it in their models, but measurement appears, in the current state of the art, to be largely on the basis of judgment. Although there are techniques for measuring consumer surplus in some situations, there appear to be particular difficulties when the spatial dimensions are included.

On the other hand, any amenity at some locations which everyone agrees is an amenity can easily be handled by subtracting from the travel costs the value of the amenity over the relevant area of the city. This, of course will add to the rent at those locations, so that the general principle of rents equalling benefits is preserved.

The last model we consider is one in which the floodplain is partially settled before protection, and an additional part becomes inhabited after protection. Figure 4 illustrates the situation. Regions A, B, and E are settled before and after protection. The curve which previously measured travel costs now also includes flood damage, and has a discontinuity at the floodplain (B, C, and D). The resident farthest to the right in B incurs the same total cost (travel plus flood damage) as the resident farthest to the right in F (travel). Suppose the damage in the floodplain is reduced, so that the dashed line represents the new travel costs and flood damages curve. (It is assumed that the market rentals appropriately reflect expected flood damage. If this is not an accurate assumption, the rent data would need to be adjusted.) As a result of the reduction, people will move from the periphery (F) to the floodplain (C). In

Figure 4


D1
A1
B1
C1
C2
D2
B2
C3
D3
E1
F1
F2
B3
B4
Rent
E2
D4
C4
B5
A2
F3
E3
D5
C5
B6
A3
Transportation cost
CBD
A
B
C
D
E
F
FLOODPLAIN
Distance

equilibrium, assuming no growth, the length of segment C equals the length of segment F, and the total costs for the right-hand-most inhabitant of C and E are again equal. This cost is given by the dashed horizontal line. The general principle, that benefits can be measured by rents still follows, as may be seen in Table 1.

The table indicates that benefits, in terms of travel cost savings, are equal to $B_2 + B_4 + F_2 + F_3 - (C_4 + C_5)$. And since, $C_2 + C_3 + C_4 + C_5 = F_1 + F_2 + F_3$, the savings can also be expressed as $B_2 + B_4 + C_2 + C_3 - F_1$. But the second section of the table shows that the changes in rents of the "affected" areas (B, C, and F), valued at pre-protection rents, is equal to the latter expression. Thus, even in this more general situation, an appropriate measure of rental change can be used to estimate benefits.

The same Figures can be used to estimate the value of zoning, a nonstructural approach to floodplain management in the following way. Suppose that people systematically underestimate flood damages, as has often been argued. In particular, assume people believe the dashed line in Figure 4 reflects damages, whereas the true expected value is given by the solid line. With this underestimate, people will inhabit area C, and leave F unsettled. A "zoning" law, which prohibits residential use in areas C and D will, in this model, cause people to live in F rather than C. We can compute the benefits on the affected areas (C and F) as follows:

Table 1

Benefits

| Region | Travel costs Before | After | Benefits | Flood Damage Before | After | Benefit | Total Benefit |
|---|---|---|---|---|---|---|---|
| A | $A_3$ | $A_3$ | -- | -- | -- | -- | -- |
| B | $B_6$ | $B_6$ | -- | $B_2+B_4+B_5$ | $B_5$ | $B_2+B_4$ | $B_2+B_4$ |
| C | -- | $C_5$ | $-C_5$ | -- | $C_4$ | $-C_4$ | $-(C_4+C_5)$ |
| D | -- | -- | -- | -- | -- | -- | -- |
| E | $E_3$ | $E_3$ | -- | -- | -- | -- | -- |
| F | $F_2+F_3$ | -- | $F_2+F_3$ | -- | -- | -- | $F_2+F_3$ |
| Totals Benefits | | | $F_2+F_3-C_5$ | | | $B_2+B_4-C_4$ | $B_2+B_4+F_2+F_3$ $-(C_4+C_5)$ $= B_2+B_4+C_2+C_3-F_1$ |

Rents* of Affected Areas

| Region | Before | After | Change (After-before) |
|---|---|---|---|
| B | $B_1+B_3$ | $B_1+B_2+B_3+B_4$ | $B_2+B_4$ |
| C | 0 | $C_2+C_3$ | $C_2+C_3$ |
| F | $F_1$ | 0 | $-F_1$ |
| | | | $B_2+B_4+C_2+C_3-F_1$ |

*Computed on the assumption that inhabitants pay old rentals.

Travel costs plus flood damage without zoning:

$$C_1 + C_2 + C_3 + C_4 + C_5$$

Travel cost plus flood damage with zoning:

$$F_2 + F_3.$$

Savings $= C_1 + C_2 + C_3 + C_4 + C_5 - (F_2 + F_3) = F_1 + C_1$
These savings can be rationalized in terms of rent also. $F_1$ represents the increase in rent caused by the settlement of F. On the other hand, $-C_1$ represents what the rent would have been to get region C settled with correct knowledge of flood damage; people would require payment of $C_1$ to live on the floodplain. Thus, the differences between gains and losses, $F_1 - (-C_1) = F_1 + C_1$ measures benefits. Note, for benefit estimation purposes, it would be necessary to have estimates of actual flood damages to correct rental gradients which reflect systematic market underestimation of flood damage.

The comparison between zoning and flood protection can be carried out by taking the benefits of zoning $(F_1 + C_1)$ compared to the costs of zoning (presumably negligible) on the one hand, and the benefits and costs of structural protection on the other.

Finally, since an important aspect of many approaches to floodplain management requires prediction of land uses with and without protection, it is important to note that benefits will be underestimated if anything other than the <u>optimal</u>

land use plan is used as the prediction. Optimal, in this context, of course, refers to the rent-maximizing or travel cost-minimizing land use plan. Thus, if after protection, it is assumed that twice as many people move to the floodplain as are indicated in Figure 4, the benefits will be estimated as $B_2 + B_4 + C_3 - F_1$, which is less than $B_2 + B_4 + C_2 + C_3 - F_1$, the estimate obtained previously. The assumption previously used was that people would locate so as to minimize travel costs plus flood damage, and the "last" settler on C paid the same costs as the "last" settler on E. On the other calculation, the last settler on D paid more than the last settler on E, so that benefits could have been increased. This is not to say that people will in fact act to minimize costs, but it is a useful exercise to compute maximum benefits, and this type of assumption is often used as the basis for prediction of behavior in many other economic applications. Certainly, other information should be considered, but the differentials between maximum and predicted benefits, or between maximum and predicted rents, might be considered as a guide to the accuracy of the prediction. Very large differences may be a signal that the forecasts should be revised.

# CHAPTER III

## BENEFIT DETERMINATION THEORIES IN INTASA AND WEISZ STUDIES

### Conceptual Issues in INTASA Approach

The INTASA [6] approach is based on the theoretical work of R. C. Lind; the most convenient reference is his QJE article, [12]. The approach described in Section II of this report is consistent with Lind's; in fact, given the assumption of no consumer surplus, it is identical. As Lind remarks [12 (p. 202)]:

> This result is sufficiently powerful to deserve restatement. What has been demonstrated is that, if we assume that rents are established on land directly affected by the project so as to eliminate profits and consumer surplus, then benefits can be measured in terms of the change in the value of that land alone. One does not have to consider changes in land values throughout the system.

Lind's paper also notes that measurement of benefits can be restricted to affected areas. In the INTASA approach, benefits are estimated by differentials in net economic rent (which is not land rent, but corresponds to the travel cost savings of our example) which accrue to activities locating in different places as a result of floodplain management, or which locate on the floodplain before and after protection. Components of economic rent include those considered above--travel costs and flood damage--as well as a number of other factors: site development costs, natural amenities, area development cost, and social environmental effects. A discussion of measurement and empirical problems appears in a later section of the present report. Land rents are also considered as measures of benefits by INTASA, but are considered unreliable because of measurement difficulties; these issues are taken up in a later section.

Thus, the basic difference between INTASA and Weisz [22], or between INTASA and this report is not in the basic theory. There is general recognition that benefits are conceptually equal, whether measured directly (travel cost savings, etc.) or as rent differential (with the assumption of no consumer surplus). The main issue is whether more accurate measures can be obtained one way or the other, and this is discussed below.

The most interesting conceptual issue raised by INTASA is the decision to allocate land use on the basis of projections of planners, rather than by an assumption of optimizing behavior. It was pointed out above that an incorrect projection by planners can lead to an underestimate of benefits. On the other hand, the dependence of benefits of projected growth has also been noted, and these projections are often provided by the same planners.

Let us consider the combination of planner inputs and optimizing behavior used by INTASA in the NED test case. For each economic growth area, inputs to the SIMULATOR include [7 (p. 99)]:

1. Data on existing land uses in the year of the study
2. Additional land uses by the initial year of the floodplain management (FPM) plan
3. Land use requirements over time after the plan is in effect
4. Ultimate land use plans

The SIMULATOR computes net economic rents for activity/ subarea combinations, and then ranks subareas by rents. Activities are ranked by planners as to sequence of assignment, and the first activity is assigned to the subarea which yields the highest net economic rents until either the subarea is filled or the activity is fully allocated. In the former case, the activity is allocated to the next best subarea; in the latter, allocation begins for the second activity, etc. The final level of allocation is by parcel; it seems that this is accomplished by an ordering from outside the model or by an economic rent calculation [7 (p. 76)].

The allocation thus is a blend of judgment and maximization. In terms of our theoretical analysis, an example might be the judgment that some of the inhabitants of E would settle in D, but, having done this, would settle on that part of D which minimizes travel costs plus flood damages. As was seen in that case, however, this procedure resulted in an underestimate of benefits. In the NED case, for example, the assignment of a particular activity to a particular area may result in a lower benefit than if the activity located in a different area; and the order in which activities are assigned may also affect the measure of benefits. This problem was recognized by INTASA in the NED test case [7 (p. 117-8)]:

> The initial test run shows that, by specifying an improper ultimate land use for the study area, the benefit estimate will be off by a large amount. The undesirability of the ultimate land use plan could also have been identified at an earlier stage by studying a table...of present values of net economic benefits for relevant activity types.

Thus, although the use of planner inputs may permit recognition of factors not easily included in a maximization model, it would appear desirable to have available the option of a relatively unconstrained optimization to obtain estimates of benefits against which more constrained programs can be assessed. Moreover, as was noted earlier, such an optimizing solution can be interpreted as a forecast based on optimizing behavior, rather than on a possibly unsupported projection by planners.

Finally, forecasts of growth should be subject to some type of consistency check. It may be, for example, that with sufficient growth, the travel costs become so high that the net economic rent of an area is higher for agriculture than for housing. This would suggest a limit to growth--or a change in the type of housing permitted on tracts closer to the CBD.

Conceptual Issues in Weisz Approach

Weisz views the community as attempting to maximize the efficiency of its land resources, including the floodplain, with different levels and types of protection, subject to its requirements for housing and public services. Since the floodplain is assumed to represent a significant part of the total urban land resource, policies affecting floodplain location decisions can affect the optimal solution.

The main tool of analysis is a linear programming model which attempts to optimally assign the planner's specified housing, commercial, and public use land requirements. It represents an explicit mathematical optimization model used as a planning tool. Weisz points out that this is not a model of the real estate market in which each location is considered separately and used by the activity which can bid the highest rent. In that type of model, the urban land area is sequentially filled by a bidding process, with the lowest ability-to-bid activity placed last in whatever locations are remaining.

The programming model considers all sites simultaneously, and determines the land use pattern which will maximize the economic efficiency of the community's land resources [22 (Appendix A, P. 181 and P. 16-27)]. Given the importance of government action and planning in an urban area, Weisz views the mathematical optimization approach as a more correct analysis. The solutions represent a normative view, that is, what the idealized pattern to achieve maximum efficiency should be.

Economic efficiency is defined as being equal to the maximized sum of the economic productivities of all land units. The operational measure of a land unit's efficiency for each activity is its economic rent; the discounted stream of annual net returns it receives. As seen in Chapter II of this report, the use of rent as a theoretical measure of benefits and an efficiency criterion can be justified. The specific form of Weisz's land use regulation model is indicated in Appendix A. It allows the determination of aggregate site rent, which is the value of the linear programming objective function. The final measure of a land use pattern efficiency, aggregate economic rent, is determined by:

$$AER_s = ASR_s - RDED_s - C_s + OB_s - OC_s$$

where

$_s$ = index denoting a particular development policy and/or engineer-alternative

$AER_s$ = aggregate economic rent of the land use pattern give $_s$

$ASR_s$ = aggregate site rent determined from the linear programming problem

$RDED_s$ = residual damages, given $_s$, to existing development

$C_s$ = cost of the engineering measures associated with $_s$

$OB_s$ = Other benefits not captured in the three preceding terms

$OC_s$ = Other costs not captured in the three preceding terms

A discussion of the AER equation is in Weisz [22 (P. 111-118)].

These solutions of aggregate economic rent allow alternative floodplain management policies to be compared. Alternative policies will generate specific values of AER and the differences between these levels of aggregate rent can be compared. Of particular interest may be the effect as measured by aggregate economic rent between a solution with no protection to the floodplain except as is currently available, and the value for a particular protection measure under consideration. The solution with little or no protection to the floodplain can act as a benchmark from which to compare policy effects. The Weisz model follows the general procedure therefore as noted in this report to measure policy effects.

The linear programming problem used by Weisz is summarized in Appendix A of this report. It is quite sensitive to planner's projections and estimates. The constraints given to the model are equalities which must be satisfied. The population to be accommodated in each type of residential land use is given as an exogenous constraint. (Constraint 2a). Note that planners not only have to estimate total population, but also how this population will be distributed by type of urban housing. The model does not determine the total amount of each land use, but only how the prespecified levels are to be allocated among available locations, though equilibrium values and sensitivity tests are calculated for a variety of planner specifications, which include differing levels of aggregate land-use. It acts as an assignment model for the planner's estimates. The specified population per business acre coefficient, PPBA, could significantly affect the solutions if misspecified.

As mentioned in this report (p. 20), overly high population estimates could introduce a bias towards a more favorable benefit-cost relationship. Suppose, for example, we are considering as policies, leaving the floodplain alone or implementing an engineering protection measure. Assume we have a fixed city size in land area and planners overestimate the population forecasts for each land use. The model could use up available adjacent land and have to fill the floodplain area. Since there is little or no protection in this area, the calculation of flood damage costs would be high. These resulting high damages without protection could well bias the project evaluator towards a solution calling for the engineering measure.

Alternatively, suppose the planner exogenously expands the delineation of the city land area and the model places the excess population in the "boondocks." Again, a bias toward protection would exist due to the high saving in transportation cost which would occur by relocating in the now protected floodplain, assuming that rents decline with distance from the city.

The planner may make exogenous land use assignments for land requirements in public investments (Constraint 5). Any misspecification removes land available for endogenous land use assignments. Any overestimate which results in removing land from the relatively risk free flood zones would again cause a possible bias for protection to the degree the model is forced to use the floodplain area or city outskirts as discussed above.

It is reasonably assumed that to insure open space land in any given location, that public acquisition of this acreage is required. The cost is assumed equal to the average value of the other land uses in that area. Since benefits to open space land in the Weisz application are considered to be zero, this results in the economic benefit of open space land being negative; essentially it is equal to the full value of acquisition cost. Weisz is not content with this treatment of open space valuation, but leaves the proper determination of benefits from open space outside the scope of his main concerns. In any application where such allocations, either exogenously made by planners or left as endogenous to the model, are important, then additional effort on the valuation of open space benefits would be necessary.

All land in the model must be assigned to some land use activity. The model, attempting to maximize rent, will try not to assign open space activity due to its negative value.

Open space therefore acts as a residual activity which absorbs any and all excess land in a location remaining after the housing and commercial services have been assigned to it. This land, required to be purchased by the local government, could be quite substantial and an unreasonable level of open space use might result. The addition of an activity for excess land might be desirable, with a value perhaps of zero in the objective function (instead of the negative of its cost) representing its role simply as an excess land assignment. The model would then place any excess land in the excess activity rather than open space, since the zero value is greater than the negative open space value. What then might be considered is a constraint specifying a minimum level of open space land to be endogenously assigned. Alternatively, a constraint reflecting a maximum for the excess activity could be used.

The model does provide a flexible tool for the modification of activity and location specifications. If there is one area of the city which is of particular interest, the land can be disaggregated to whatever degree of delineation is considered desirable. The incorporation of the concept of areas and subareas within a general flood risk zone framework can be easily handled to get an areal scheme equivalent to INTASA. Alternative zoning regulations which would limit the types of housing or commercial activities can be handled by not allowing particular activities to be placed by the model in the specified locations. Changes in the types of urban housing and their associated land requirements and population coefficients can be altered easily. Weisz employs a single activity termed business and commercial. If greater detail were desired, the model's methodology could incorporate the additional activities.

We have seen the crucial role of planner estimates in providing key information to the model. The model is quite flexible in allowing a consideration of the sensitivity of the solutions to the planner's estimates for each of the land uses can be considered as well as possible changes in the PPBA coefficient. Similar to the statistician's confidence interval sensitivity analysis on the parameters would provide a range around the planner's estimate which leaves the solution unaltered.

The theoretical section of this report noted the problem of using rent as a benefit measure where there are considerations of interdependent utilities (p. 23). Locational interdependencies and externalities among land uses in the model are difficult to handle due to the linear structure. Nonlinear models are quite expensive to solve even for fairly high levels of aggregation, and problems in attempting to find optimal solutions occur in such models [22 (p. 47)].

Weisz suggests two ways to handle these difficulties. The first is that "predictable externality-producing" land uses be considered as activities to be located exogenous to the model. The second approach is to analyze such factors during the sensitivity analysis after the optimal solution has been found. Weisz adopts this approach and considers an example involving variations in hydrologic state conditions [22 (P. 166-173)].

The Weisz model is a very useful tool for analyzing floodplain management policies and objectives in a consistent manner. We have emphasized its reliance on planner estimates, yet it provides a means to vary these estimates and to check the sensitivity and stability of the solutions with respect to them. Changes in parameters, activities, and location delineation are quite readily handled.

# CHAPTER IV

# EMPIRICAL ESTIMATION METHODS IN INTASA AND WEISZ-DAY: A CRITICAL ANALYSIS

## Empirical Issues raised by INTASA

The empirical issues raised by INTASA are best discussed with reference to the test which was run for Reach 13 of the Connecticut River Basin (NED test case). To implement the model, the following steps are required:

1) Areas, subareas, and parcels are delineated
2) Each geographic region in (1) is characterized by:
   a) available acreage
   b) amenity zone
   c) site development zone
   d) flood damage zone
   e) percentage in agricultural use
   f) transportation zone
   g) social environmental effect zone
3) Detailed activity types are identified
4) For each geographic region, land use is identified:
   a) in the initial year of the study
   b) over time after the plan is in effect
   c) at the end of the time horizon.

The interesting empirical issues arise in connection with estimates of net economic benefits. We next turn to these.

## Site Development Cost and Flood Damage

Considerable attention is devoted by INTASA to the estimation of these components of net economic rent. Detailed input data are collected for each parcel to assure accurate estimates. For example, the input data used to compute site development cost for the NED test case include, for each zone [7 (pp. 91-93)].

average slope
California bearing ratio
clearing requirements
need for disposal of debris
number of trees to be planted or protected
road excavation
need for waterproofing of basements

Moreover, for each activity, information is needed for:

average ground flood space
excavation requirements
cost of waterproofing
length of connecting trenches
average linear feet of public road
number of feet of main utility trench per foot of public road
average linear feet of private road

Similarly, great care is expended on the estimation of flood damage. Since the results indicate that reductions in flood damage are responsible for the greatest share of benefits from floodplain management in the NED test case, it is comforting to know that these have been estimated carefully.

## Amenities, Transportation, and Social Environmental Components

Unfortunately, considerably less confidence can be placed in the estimates of these components. This is primarily a conceptual problem: in the present state of economics there are no well-developed techniques which can be used to estimate these amenities, and the conditions of the social environment have only recently attracted attention of economists at all; transportation cost measurement is complicated by the difficulty (impossibility?) of specifying such costs in the abstract without reference to destinations. In the NED case, the only activities considered are various kinds of residential uses, which simplifies the discussion. Each of these components are next discussed.

Amenities are defined [7 (p. 61)] as "the difference in economic rent as a result of physical amenities that are the same with and without protection." The INTASA program does not determine these "because of the localized and subjective nature of this component." They go on to say that "amenity values are quantified by transforming land price differences into annual land value differences..." For the NED case four amenity zones are chosen, yielding the following [7 (Table V-13, P. 97)]:

Amenity values in dollars per acre

| Amenity Zone | Middle Income Community |
|---|---|
| 1 | 1000 |
| 2 | 1500 |
| 3 | 2000 |
| 4 | 1500 |

INTASA does not supply any information about the way in which these estimates are derived, except for a vague reference to land price differences.

To estimate the transportation cost component of net economic rents, it is assumed that all activity types have the same centers of gravity of destination and that the transportation network is the same throughout the planning horizon. For commuters, the following parameters are used [7 (Table V-12, P. 96)]:

| | |
|---|---|
| Number of working days per year | 250 |
| Number of commuters per family | 1 |
| Number of commuters per car | 1.2 |
| Running cost per mile in dollars | .10 |
| Value of travel time per hour in dollars | 1.50 |

Although most of these are not controversial, the value of travel time set at $1.50 poses some problems. In particular, it appears to be a purely judgmental number and no support is offered for it. These are attempts in the literature to estimate a value for travel time; these are frequently based on rental values and have yielded diverse results. It is difficult to place much confidence in the $1.50 figure--it may or may not be reasonable. In the absence of further information or a methodology for its estimation, we are in the dark.

Social environmental effects are intended to measure "the influence of different neighboring activities on economic rent of a residential activity" [7 (p. 61)]. In principle, INTASA discusses a procedure for estimating these effects [7 (p. 62)]. This procedure involves the identification of subareas that could influence economic rents of a particular subarea as a result of land use. Next, land use is determined for those areas which might influence economic rents in a particular subarea. Finally, the effects of this interdependency are determined from "a residential activity's willingness to pay for proximity to or distance from each influencing activity." For this purpose, change in land price resulting from the proximity of influencing activities is required. It is also noted that the estimation of willingness to pay is a major difficulty. For the NED case, no social environmental effects were identified.

As remarked above, INTASA has carefully estimated site development costs and flood damages, but their estimates of the remaining components of net economic rents leave one somewhat uncomfortable. Two main points might be made about the latter. First, they are concerned with individual subjecture valuations, e.g., value of travel time, value of pleasant views, and the value of having desirable neighbors. Methods of estimating such values are not well developed but a technique, at least for the latter will be discussed in Chapter V of this report. Further, those existing techniques which are other than judgmental often must make rather drastic simplifying assumptions, such as the assumption of identical preferences. INTASA's estimate of value of travel time and amenities is an example: they assume that everyone values travel time equally, and that everyone in a particular zone values amenities equally, but the valuation used seems to be arbitrary. Certainly INTASA cannot be faulted for the lack of progress economics has made at solving these problems, but one can question the decision to attempt to estimate benefits directly rather than indirectly from land value data. The use of land values leads to our second point.

It will have been noticed that INTASA uses land price differentials for estimating the value of amenities and social environmental effects. Such differentials are relied on heavily by Weisz, and were shown in Chapter 2 to be equivalent under certain circumstances to direct measures of benefits, but the extent of INTASA's reliance on land prices is at variance with opinions expressed in its reports.

> Observed land prices may be useful as guides to estimating land value differences with different physical amenities. However, land prices may not reflect people's willingness to pay now or in the future for such amenities. Additional information, based on interviews with residents for example, may be needed to arrive at realistic amenity values. [7 (p. 61)]

> Practical methods for directly estimating either economic rents or economic rent differences as defined in this report are virtually non-existent. Most of the existing methodologies deal with the problem of appraising market values of land and/or structures using standard appraisal techniques such as Cost, Income and Market Data Approaches... Because the relationship between market values and annual economic rents is in general not well defined and quite complex, appraisal techniques are of little value for benefit evaluation outside of providing background information as to data availability and significance of certain parameters...They are

> more useful in cases where forecasted market values are of interest rather than for the actual measurements of flood control benefits, such as in land use planning where market values determine the allocation of activities.
>
> In the case of residential activities where most of the existing work has been done, market values, such as house sales prices, rents to be paid or residential land prices, can be used in an attempt to isolate value-components paid for differences in locational attributes. However, a search of existing literature has shown that existing models have two important limitations: first, attributes such as aesthetic amenities have not been included, and, second, they are tailored to specific situations without arriving at a general body of knowledge that would be applicable to a variety of situations. Both these limitations are significant for the purpose of this study.
> [6 (pp. 71, 72)]

Clearly, the present state of economics does not allow us to decide conclusively whether direct or indirect estimates are more accurate. However, INTASA's criticisms of the use of land values is not entirely convincing; INTASA itself uses land prices to estimate the value of amenities and social environment effects and as was pointed out above, their own reliance on direct measures is not without its faults. For example, while it may be true that "land prices may not reflect people's willingness to pay" for amenities, there is no assurance that their responses to questionnaires reflect their demand curve more accurately.

Moreover, there is no reason why measures of aesthetic amenities cannot be included in such analyses; the objection that such studies have been tailored to specific situations is also applicable to the inputs needed for the INTASA approach.

With respect to the former, a study by Knetsch and Parrott [10] includes distance from reservoir, topography, and urban proximity as variables in a multiple regression to explain land value. And additional regression estimates showing even better explanatory power will be presented in the next chapter of this report.

Empirical Issues Raised by Weisz-Day

As was noted in the previous Chapter, the model developed by Weisz is theoretically sound (at least within the limits of assuming independence of individual locational preferences as described in Chapter II) and was constructed so as to permit the simulation of a wide variety of floodplain protection and/or management decisions. In particular, one may look at the effect on aggregate area rent with varying degrees of protection of a floodplain, varying levels of landfill and floodproofing, and imposition of full or partial open-space reservation. Also, the effects of various combinations of these devices could be examined under alternative assumptions about future population levels and alternative zoning and land-use regulation provisions. That the model permits looking at a variety of policy alternatives, and that it analyzes the effects of these alternatives specifically in the context of local planning projections and land-use decisions are important strengths of the model. At the same time, however, achieving empirical results from the model depends on the capability of generating reliable estimates of $LV_i$, the value of land at any given location, i, independent of the effect on its value of flood risk. The other limitation on the applicability of the method is that empirical results in any particular case will depend heavily on just what values are contained in local planner projections of population and just what specifications of future zoning constraints are specified. This section will deal with the evaluation of the methodology dealing with the suggested way of handling these problems as explained by Weisz and Day [23].

## Estimating Land Values

Weisz-Day estimate the value of flood-free parcels of land for six separate cases. They consider three land-use types: suburban residential (sites of more than four acres), urban residential (sites of less than four acres), and commercial. For each of these zoned use types they consider, as separate cases, developed but unimproved (vacant) parcels and improved parcels. Industrial sites are eliminated on the assumption that their size, at least in Tucson, is small in the aggregate, and their location and value are largely unaffected by floodplain policy.

The main empirical problem is in the regression equations used for estimating the values of $LV_i$ the value of a flood-free parcel in the $i^{th}$ location. That a log-linear estimating form is used seems to present no special problem nor evoke particular criticism, though it can be defended on little other than "fit" to the particular data set used, and there is no reason to expect that a log-linear form would be generally applicable in other situations. The use of only observations which were in flood-free locations is an obvious requirement of the technique used by Weisz-Day, though an alternative technique using observations both on and off the plain will be suggested in Chapter V. And even in the Weisz-Day context the identification of "flood-free" is rather crude - simply all observations in any one of the 25 zones through which a water course passed were eliminated. There seems to be some inconsistencies in following this criteria. Specifically, some of the zones from which observations were used for zone G15. In Map 3.2, that zone shows the Pantano Creek passing through. In all, there seems to be about 33 out or 147 observations in Table 5 with this problem.

The really serious problem with the regression estimates is in the specification of the form of the dependent variable and in the identification of the independent variables. Let us use their estimate of unimproved urban residential property as an example [23 (pp. 70-80)]; essentially the same problems arise in all of the examples. The basic estimating equation used was

$$LV = a_0 + \sum_{i=1}^{6} a_i \log X_i$$

where

LV = sales value of a conveyed parcel of unimproved property

$X_1$ = miles north of SW corner of Tucson area

$X_2$ = miles east of SW corner of Tucson area

$X_3$ = dummy equal to 1 if in city and 0 if outside

$X_4$ = traffic volume in zone in which parcel is located

$X_5$ = month of sale of parcel measured as number of months since first observation used

$X_6$ = size of parcel in acres

A quite good fit is claimed using $X_1$, $X_2$, $X_5$ and $X_6$ as independent variables; all signs are as expected direction and R is 0.63 with n=109, though the fit indicated in their Table 3 is not impressive by casual observation and no F-Test is employed. With respecification of the independent variables, as discussed presently, the model would be very unsatisfactory and the W-D defense of their estimates, even as they stand, seems to make little sense. They admit that their regression does a poor job of estimating LV in a particular zone (the unweighted mean error for individual zones is about 30%) but defend it on the basis that it "does a reasonably good job of estimating total and average sales prices." Leaving aside the issue of whether the 12% error in aggregate LV is reasonably close, this is not the only relevant test of reliability, since estimates of the value of sites on the floodplain also are required; not just the value of a given type of use at an average location.

The other problems have to do with the variable specification itself. First let us consider $X_5$, the month of sale. This variable is included to adjust for the general rise in land prices over the period of observation, even though all observations were within a period of about 2 years. An alternative treatment would simply have been to adjust the observations on the dependent variable by dividing each observation by a monthly price index constructed from all observations; this would have been the usual and probably more superior technique.

In the case of $X_6$, lot size, a really serious misspecification is involved. It is the unit value of property that is relevant not the sale price of a parcel of undetermined size. Accordingly, the dependent variable should have been stated in terms of price per acre. It should be noted that lot size might have an effect on price per acre and it might be tried in a regression, though there is no obvious reason why it should be expected to have much of an effect. This latter problem also applies to $X_3$ and $X_4$ (in/out city limits dummy and traffic volume) even though they were not retained in the final equation used in this case. Whether a parcel were in or out of the city limits might make a difference, say as a proxy for value of public services net of taxes, but it would be a fairly crude measure at best. Traffic volume seems to have been tried without any particular rationale, and none seems very obvious; it is difficult to imagine what its expected sign would be.

In any event, in the case being examined (equation 2.3 in DW) if we redefined the dependent variable as price per acre in constant dollars the <u>only</u> independent variables with which we are left are $X_1$ and $X_2$, miles north and east of the SW corner of the area. Theoretically this makes no sense at all, and a rationale for this being so would be hard indeed to construct. That they get significant coeffficients on these variables seems to be an idiosyncratic result of the highly non-random nature of the geographic distribution of their observations. Most of them are either in far north or east zones or clustered near the SW corner itself (see attached map). Unfortunately just where downtown Tucson is located is not indicated, but the sample probably contains very few observations near it. All that the regression reflects is that lots are worth more (maybe only because they are bigger) in the wealthier suburban areas than in the poorer, older areas in the SW area.

Even so, a regression of constant dollar price per acre on miles north and east would probably not fit well since almost all of the explained variance in price per parcel is accounted for by date of sale and lot size. With the data at our disposal, rerunning is not possible but WD should be asked to do this to see what results are obtained.

For the other two cases for unimproved properties the form of the dependent variable and the regression equation are the same as in the foregoing, but the "best" estimating equation utilizes different independent variables. These are as follows:

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|
| Unimproved: | | | | | | |
| Urban residential | x | x | | | x | x |
| Suburban residential | | x | | | | x |
| Commercial | x | | | x | | x |

The equation for suburban lots is even more astounding. In properly adjusted form it would say that price is a function only of distance east! The explanation, of course, is that virtually all of the variance is being picked up by lot size. For commercial sites it is distance north and traffic volume that do the real job, though how much is doubtful given that the greatest part of the variance again is taken up by lot size.

The rather radically different results for the determination of value at a particular location for different classes of unimproved property raises a somewhat different, but related issue. Why is it that values should be different for different planned uses? Without any zoning restrictions vacant land should be worth the same amount for any use. Differences in values at the same location could come from differences in the topographical or subsoil nature of a site, its shape, etc.; but these kinds of considerations are outside the analysis considered here. Thus, we can say that at any location, a parcel would be worth its site value (the same for any use) plus the value of the zoning use assigned to it. In this regard especially where higher uses are permitted anyway (we do not know if this is the case in Tucson, but it is in most places) it should be the case that a commercial permit would be more valuable than an urban residential permit, which would be more valuable than a suburban residential permit <u>at any given location</u>. Accordingly, one should expect that the commercial value surface should everywhere lie above the urban surface which everywhere should lie above the suburban surface. Simply by examining the intercept terms of the equations we can see that this property is seriously violated, with urban land the least, commercial land next least, and suburban land worth most near the SW corner. Perhaps this is simply due to differences in lot size (this cannot be ascertained from the data in the report), but all three of the surfaces intersect with each other, which is quite difficult to explain.

This suggests another alteration in the estimating techniques; a switch to a single equation for estimating the value of unimproved sites with the dependent variable being price per acre in constant dollars and the independent variables consisting of 1) some sensibly defined distance variables, 2) other variables, like whether or not in-city, traffic volume, perhaps parcel size, etc., and 3) dummy variables for the type of development permitted by zoning. Some experiments using this form were attempted in Weisz and Day [23].

Finally, let it be suggested that discarding observations on the floodplain might not necessarily have been a necessary, or even the best strategy. Specifically they could have been included along with the addition of another independent variable, namely a measurement of flood risk at each location. This would not only enrich the sample but also would give an independent estimate of the value differential due to flood risk. In Chapter V we will report on some experiments with this specification using St. Louis data that we have made. At the very least one might try estimations both ways, including and excluding observations on the floodplain.

WD also includes regression estimates of the values of improved parcels in each of their three use categories. They are not entirely clear on why they do this, but presumably it is a way of estimating the value of improvements (if we know the value of improved and unimproved sites, by subtraction we know the value of the improvements) which are necessary to estimate residual flood damages. This latter step is not included in the study, but would be a necessary later step. Again, the dependent variable is specified simply as price of the property and is regressed log linearly on the same six variables as before and $X_7$ (age of building) and $X_8$ (square feet of floor space) as well. After trying a number of variable combinations the regressions selected contained independent variables as follows:

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|---|---|---|
| Improved: | | | | | | | | |
| Urban residential | x | x | x | x | | x | x | |
| Suburban residential | x | | | | | x | | |
| Commercial | | x | | | | x | | x |

Again, the same problems emerge as for unimproved lots. Much more than half of the explained variance is due to lot size or floor space, which gives us almost no predictive power at all. Clearly, at a minimum the regressions should be rerun in terms of trying to explain price per square foot of floor space, though this would be complicated by the fact that the dependent variable is the sum of site plus structural value. It would seem that a much better way of approaching this is to subtract estimated site value from the observations and then simply attempt to estimate structural value as a function of the physical characteristics of the structure. Cross section observations might show up some effect of location on structural value, but this should be interpreted as a correctional factor on site value rather than asset value. We might note that the fact that the value surfaces for improved properties also intersect in peculiar ways is not necessarily a problem since there is no a priori expected relationship between values of different kinds of structures over space.

## Dependence on Planning Estimates

That the empirical results obtained in Weisz-Day depend heavily on planner specifications of population and land use was claimed as a strength of the method, and earlier in this report it was acknowledged that in principle that is so. On the other hand, uncritically accepting a single set of planner's projections is highly unwarranted, as recognized by Weisz. This can be seen by reflecting on the three ways in which planner's specifications critically affect the estimated values obtained from the model.

First, and perhaps most basic, is the projection of population over the life of the project. Quite clearly, if higher levels of population are projected, higher estimates of property value will be obtained. Weisz would argue, that this might not make any difference, since his method is comparing aggregate rents _with_ various improvements to aggregate rents _without_ any improvements and that both would be biased upward by larger estimates of population. But the discussion in Chapter II shows that even the estimated first differences would be sensitive to population scale and sensitivity testing should be employed. Also, even in those cases where some form of treatment may be unambiguously the most preferred outcome, it might yield benefits less than project costs if the estimates of benefits were based on a more realistic (lower?) estimate of population.

The second way in which planner specification enters is with respect to the zoning assignment in each analysis zone. In particular, the maximum land available for all three uses is specified in each zone. By extension of the argument on population above, this should not introduce a bias on estimating first differences. But again, it could introduce a bias even by assignment and certainly could affect the amount assigned to each use in total over the whole area. Again, sensitivity testing is in order. So too is the effect on the absolute magnitude of benefits for the most preferred outcome.

Finally, planner's specifications are necessary in establishing a priori finite limits of settlement. In general, this would not necessarily be the case, but with the particular regressions used in WD it clearly is needed. Since those regressions indicate monotonic increases in value for all uses moving either north and/or east, there could be no solution without a prespecified limit; otherwise all uses would move as far from the SW corner as possible. In this case sensitivity testing is unnecessary since we know by inspection that the model will explode without an a priori limit on the extent of settlement. On the other hand, it is clear that this specification needs close scrutiny since the level of benefits of the most preferred alternative, and possibly even estimates of first differences between alternatives, depends on how closely or distantly this line is drawn.

We have indicated at a number of points that the link-up with planner specifications has some advantages, but allowance for error in those specifications, including error purposely introduced to bias benefits upward, must be considered. Accordingly, much more examination of these specifications and testing sensitivity to them is called for before they can be assumed to be applicable. Also, it might be possible to put constraints on rules for local share in project cost that would remove any incentive for deliberate biasing of projections on the part of locally interested planners. These possibilities will be discussed in Chapter VI.

# CHAPTER V

## A REGRESSION MODEL OF IMPACT OF FLOOD RISKS ON URBAN LAND VALUES: A CASE STUDY FOR ST. LOUIS COUNTY

An important part of the rationale for the use of judgmental estimates of amenity value in particular subareas in the INTASA model was their claim that estimates of site values at alternate locations within an urban area could not be made satisfactorily using regression techniques. In sharp contrast, the Weisz model [22] requires estimates of site value in different uses at different locations in order to be operational at all, and in its application to the Tucson area, regression estimates of land value by zone which were developed from Weisz-Day [23] were utilized. In Chapter IV we criticized the WD regression estimates rather severely. But the reader should not assume from that criticism that we concur with the INTASA position that such estimates necessarily would be invalid. Quite the contrary, in this Chapter we will: 1) briefly summarize a model developed by the Institute for Urban and Regional Studies at Washington University which does estimate differences in rental value differentials between small subareas in the St. Louis area quite reliably and 2) present the results of our attempt to utilize that model for estimating the marginal impact on site value of location of a parcel on a floodplain.

The St. Louis residential site rent model

Since a full description of this model developed by Little [13] is available elsewhere, only its main features will be summarized here, along with a discussion of the applicability of this kind of model to the problem of estimating site rents, with and without protection, on urban floodplains.

The information available for implementing the model consisted of:

a. sales prices of single-family residential properties (renter and owner-occupied), including all properties insured by FHA or guaranteed by VA and a majority of properties conveyed by conventional mortgages. Source: St. Louis HUD district office FHA appraiser's file.

b. numerous physical descriptors of the above properties, such as number of rooms, square footage, lot size, types of appliances and heating plant, type of garage and basement, etc. Source: St. Louis HUD district office FHA appraiser's file.

c. assessed property tax for the above properties. Source: St. Louis City and relevant county tax assesor's offices.

d. demographic and social-economic characteristics of the population in Census Tracts, Enumeration Districts and Blocks, as reported by the U. S. Census of Population and Housing.

e. total receipts by type and public expenditures by object or function for municipalities in which the exchanged properties are found. Source: Census of Governments and local government reports.

Items (a) and (b) are available for the St. Louis district area (most of eastern Missouri) for the period from 1962 to 1973. Items (c) and (e) are available, in principle, for all years, though considerable clerical effort is involved in their assembly. Items (d), except for fragmentary selected estimates, are available only for Census years.

The Institute for Urban and Regional Studies has developed a regression model based on 1970 observations in St. Louis City and St. Louis and St. Charles Counties in Missouri, utilizing parts of the data base described above. Specifically, the data items used were:

Dependent variables:

1. sales price

2. gross sales price = sales price + property tax/0.08

Independent variables:

3. sq. ft. of living area

4. no. of rooms

5. no. of bedrooms

6. no. of bathrooms

7. % of housing units in the Census tract which are renter occupied

8. % of dependent (under 19 or over 65) population in the Census tract

9. % of non-white population in the Census tract

10. Highest % of non-white population in an adjoining Census tract

11. Median family income in the Census tract

12. Age of unit

13. Public school expenditures per pupil in the school district

As might be expected there was very substantial covariance between most of the independent variables. Accordingly, by means of factor analysis variables (3) to (11) above were reduced to three factors: $F_1$ (structural characteristics), $F_2$ (neighborhood class) and $F_3$ (neighborhood risk), as reported in Little [13]. The regression equation estimated for 1970 with 2550 observations was:

$$\text{Gross Price} = 15{,}000.49 + \underset{(516.0)}{2785.88F_1} - \underset{(830.3)}{4853.62F_2}$$

$$- \underset{(338.6)}{2850.01F_3} + \underset{(390.7)}{0.65\ (\text{Lot size})} + \underset{(3.10)}{2.49\ (\text{Exp.per pupil})}$$

All of the coefficients are of the expected sign and are significant (F-statistics are indicated in parentheses) and the correlation was $R^2 = 0.544$.

Note that the foregoing equations estimate prices of improved rather than unimproved properties, and it is the latter that are relevant for computing rent differentials stemming from changes in zonal occupancy in the analysis of the impact of floodplain protection. But this poses no problem since it is possible to estimate site rent differentials directly from the above equations, essentially by estimating the differentials in the value of a "standard" house at different locations; these calculations too are spelled out in Little [13].

It also should be noted that coordinate location or "distance" variables do not appear in the regression analysis. Thus, with this equation we cannot estimate site values as a function of distance from some fixed point (center?). The most immediate reason for the absence of an explicit distance variable simply is that none was experimented with. The St. Louis area is extremely diffused geographically with many major employment locations and many centers offering CBD-level services. Perhaps at a later stage of research on the land value differential model the influence of locational variables might be tested for, but from what is known of the St. Louis region it is doubtful that a priori sensible relationships can be found except on very localized bases within individual subareas. In applying this method to other areas distance might well emerge as a significant variable in its own right, but simply looking for an arbitrary origin from which distances might appear significant statistically would make little sense without a reasonable underlying theoretical hypothesis as to the significance of that point as a central node.

In any event, as was remarked in Chapter II, it is not necessary that site values of parcels be discreetly orderable in terms of geographic distance from a point, but only that they be discreetly orderable in terms of some a priori sensible independent variables; and there seems no doubt that that can be accomplished. On the other hand, that some of the independent variables themselves relate to the nature of settlement within zones can cause computational problems. Specifically, while we can establish an initial uniquely ordered ranking of site values of parcels in individual subareas defined on very narrow geographic lines, the values within that rank ordering would shift as a consequence of reassignment of residential populations to particular subareas as something like a Weisz assignment model was worked through (it would cause somewhat different, but related problems for an INTASA type system). There are two ways in which this could be handled. First, we could assume, that site values in all off floodplain areas would remain unchanged even with reassignment. This assumption might be workable where the size of the floodplain was small relative to the urban area, but as we noted in Chapter I, where the floodplain is small most of the analytical problem disappears anyway. The other possibility is to seek for an iterative solution where first uses are assigned to an initial ordering of site values, the site values are then recomputed and uses reassigned, then values are recomputed, etc. Where convergence occurred - it could not be guaranteed in advance that this would be so - the equivalent of a general equilibrium solution could be achieved. Where convergence did not occur in this framework, we would either have to resort to the crude estimate made possible by a single iteration only, or move to a very difficult and expensive explicitly simultaneous general equilibrium model.

We might note another use that this kind of regression model could have. Because it incorporates physical characteristics of housing variables, it is possible to reconstruct estimates of the value of different kinds of housing independent of site value, and where time series data exists, of trends in these values. These estimates could be used directly in calculating residual flood damages to properties remaining on floodplains. They have, in fact, been so used in a recent report for the St. Louis District, U. S. Army Corps of Engineers [14].

In the next Chapter we will strongly recommend that Corps district offices experiment with the development of land value models of the type developed by Little [13] and of the variant of it discussed below, but in the meantime we should point out two aspects of this recommendation. First, it is extremely unlikely that a single set of parameter estimates, or indeed, even a single set of relevant independent variables will be applicable across many different urban areas; but the same methodology can be applied. Second, the data set required is fairly extensive, at least compared to the Weisz-Day data base, but it should not be out of reach for at least the several large urban areas with significant unprotected floodplains. The main data problem is with the physical characteristics of housing data which come from the FHA appraiser's files. Though not generally available publicly, researchers are using them in at least a few areas and it would be hoped that the Corps could secure their availability through HUD. Barring that possibility, it might be feasible for the Corps to establish a recording file of its own on the characteristics of exchanged properties working through local real estate organizations or recorder's offices. Note that in the model discussed here very significant statistical results were achieved using considerably less than all of the data in the FHA file.

### Adaptation of the St. Louis model for estimating floodplain site values

An alternative to the rather complicated process of estimating land values independent of flood risk and then estimating the differential in aggregate land value from reassignment of uses off to uses on the floodplain, is simply to estimate the enhancement of the value of floodplain sites directly as a consequence of the removal (reduction) of flood risk. Such an estimate is reported on in this section.

Specifically, the model described in the preceding section was rerun for 1970 but including a dummy variable for observations located on floodplains. The observations used in this experiment were a subset of the 2550 observations used initially; they consisted of the 1671 observations for St. Louis County. Observations in the City of St. Louis were not used as there are no floodplains at all within the City limits. Observations in St. Charles County were eliminated for practical reasons; only a small number of such were in the original sample and including them would have required mapping all of the floodplains in that county.

Since only St. Louis County data were being used it was decided that the components of $F_1$, $F_2$ and $F_3$ should be recomputed to allow for the possibility that the relevant factor loadings would not necessarily be the same in the County alone as in the County and City of St. Louis combined. This proved to be the case, though the differences were not spectacular; the mean values for the independent variables for St. Louis County observations are shown in Table 1, their correlation matrix in Table 2, the rotated factor matrix in Table 3 and the factor score coefficients for the three factors in Table 4.

Table 1

Variables in Factor Analysis

| Variable | Mean | Standard Dev. |
|---|---|---|
| Living Area (sq.ft.) | 1155.2063 | 328.8347 |
| Rooms (#) | 5.7008 | 1.0801 |
| Bedrooms (#) | 2.7666 | 0.6821 |
| Baths (#) | 1.2418 | 0.4297 |
| Renters (%) | 0.2010 | 0.1091 |
| Dependent population (%) | 0.4739 | 0.0427 |
| Nonwhite population (%) | 8.0180 | 14.4095 |
| Nonwhite population in adjoining tract (%) | 26.8136 | 32.3327 |
| Median Income ($) | 10960.9063 | 2321.8320 |
| Years old (1970 = 0) | -20.6158 | 14.9034 |

n = 1671

Table 2

Correlation Coefficients

| | LIVAREA | ROOMS | BEDROOMS | BATHS | RENT% | DEPEND% | NONWHITE | ADJNON% | MEDIANIN | YEARSOLD |
|---|---|---|---|---|---|---|---|---|---|---|
| LIVAREA | 1.000 | 0.817 | 0.634 | 0.525 | -0.010 | 0.009 | -0.081 | -0.078 | 0.289 | -0.024 |
| ROOMS | | 1.000 | 0.747 | 0.521 | -0.064 | 0.016 | -0.122 | -0.144 | 0.328 | 0.101 |
| BEDROOMS | | | 1.000 | 0.446 | -0.059 | 0.058 | -0.199 | -0.230 | 0.269 | 0.200 |
| BATHS | | | | 1.000 | -0.103 | 0.016 | -0.198 | -0.237 | 0.379 | 0.289 |
| RENT % | | | | | 1.000 | -0.351 | 0.029 | 0.061 | -0.434 | -0.203 |
| DEPEND % | | | | | | 1.000 | 0.252 | 0.077 | 0.026 | 0.015 |
| NONWHITE | | | | | | | 1.000 | 0.758 | -0.520 | -0.397 |
| ADJNON % | | | | | | | | 1.000 | -0.487 | -0.431 |
| MEDIAN IN | | | | | | | | | 1.000 | 0.407 |
| YEARS OLD | | | | | | | | | | 1.000 |

Table 3

Varimax Rotated Factor Matrix

| | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| LIVAREA | 0.880 | 0.008 | -0.011 |
| ROOMS | 0.943 | -0.065 | 0.028 |
| BEDROOMS | 0.742 | -0.168 | 0.018 |
| BATHS | 0.562 | -0.256 | 0.089 |
| RENT % | -0.016 | 0.220 | -0.819 |
| DEPEND % | 0.025 | 0.118 | 0.444 |
| NONWHITE | -0.071 | 0.883 | 0.244 |
| ADJNON % | -0.102 | 0.798 | 0.112 |
| MEDIAN IN | 0.293 | -0.642 | 0.320 |
| YEARS OLD | 0.079 | -0.529 | 0.140 |

Table 4

Factor Score Coefficients

| | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| LIVAREA | 0.307 | 0.118 | -0.039 |
| ROOMS | 0.618 | 0.071 | -0.045 |
| BEDROOMS | 0.069 | -0.024 | 0.026 |
| BATHS | 0.056 | -0.075 | 0.033 |
| RENT % | 0.044 | 0.088 | -0.703 |
| DEPEND % | 0.008 | -0.010 | 0.099 |
| NONWHITE | 0.059 | 0.589 | 0.372 |
| ADJNON % | 0.005 | 0.218 | -0.020 |
| MEDIAN IN | 0.003 | -0.177 | 0.182 |
| YEARS OLD | 0.028 | -0.089 | 0.050 |

The results of the step-wise regression analysis explaining sales price as an additive sum of the three factors, lot size, expenditures per pupil and a dummy variable is shown in Table 5. Of the total of 1671 observations, 101 were located on flood-plains. Note that even though we criticized Weisz-Day for using parcel size as an independent variable we did use lot size as one. Since we were estimating site value differentials from sales of improved properties adjusting to value per square foot directly in the initial estimating equation would have been very awkward. Also, with our more complete specification, lot size contributes virtually nothing to $R^2$, (only 0.01174) though its coefficient is significant. In fact, all of the coefficients are significant at least at the 5% level and are of the expected sign. EXPPUPIL is expenditures per pupil in the relevant school district. The F factors, however, would lend themselves to slightly different interpretations than in the case of the original model. $F_1$

Table 5

Multiple Regression on Sales Price

| Variable | B | Beta | Std Error B | F |
|---|---|---|---|---|
| F1 | 3737.185 | 0.629 | 92.782 | 1622.427 |
| F2 | -2279.324 | -0.375 | 96.986 | 552.327 |
| F3 | 1067.381 | 0.158 | 103.108 | 107.166 |
| Lot Size (sq.ft.) | 0.163 | 0.118 | 0.023 | 52.198 |
| EXPPUPIL ($) | 2.898 | 0.050 | 0.898 | 10.418 |
| DV (=1 if on floodplain) | -743.003 | -0.031 | 367.433 | 4.089 |
| (Constant) | 14385.807 | | | |
| $R^2$ | 0.79459 | | | |

Table 6

Multiple Regression on Gross Price

| Variable | B | Beta | Std Error B | F |
|---|---|---|---|---|
| F1 | 4785.310 | 0.637 | 116.558 | 1685.524 |
| F2 | -2741.227 | -0.357 | 121.840 | 506.189 |
| F3 | 1487.646 | 0.174 | 129.531 | 131.903 |
| Lot Size (sq.ft.) | 0.217 | 0.125 | 0.028 | 58.962 |
| DV (=1 if on floodplain) | -895.302 | -0.029 | 461.593 | 3.762 |
| EXPPUPIL ($) | 2.044 | 0.028 | 1.128 | 3.284 |
| (Constant) | 19497.684 | | | |
| $R^2$ | 0.79727 | | | |

would still reflect structural characteristics and $F_2$ would represent neighborhood socio-economic class, but $F_3$ would represent neighborhood family type - i.e., predominantly homeowners mostly with children and with moderately high incomes - rather than a risk factor. Equivalent results with gross price as the dependent variable are shown in Table 6.

Originally we had planned to include a series of dummy variables for differing degrees of flood hazard, e.g., within 10-year, 20-year, 50-year, etc. flood stage contours. The contours were so close together, however, relative to the accuracy of the Geological Survey maps with which we were working, that only a single dummy was used, equal to 1 if within and 0 if not within the 100-year flood stage contour. The procedure used to identify the observations that were so located is described in Appendix C to this report.

But even with the fairly crude identification of observations on floodplains significant results were achieved. The dummy variable is of the expected sign and significant in the case both of sale price and gross price with values in these two formulations of \$743 and \$895, respectively. Theoretically one should prefer the gross price specification as it adjusts for the effects of property tax differentials. This means that being on a floodplain in St. Louis County would lower site values by about \$4000 to \$4500 per acre; average lot size was about 1/5 of an acre. These amounts, however, would be average amounts for all of the water courses charted in the county. Differentials due to flood risk might be somewhat different on individual streams. In fact we made some cruder estimates in which a flood risk dummy value of 1 was assigned to all parcels in any Census tract through which a floodplain passed [14]. For Census tracts along Maline Creek the value of the dummy was a reduction on gross price of $1892 and for tracts along River Des Pere it was $1537, though the latter was only barely significant statistically. We cite these figures simply as additional evidence that the per acre figures cited above probably are of the right order of magnitude. Only a quite modest effort went into preparing these estimates and great precision cannot be claimed. But as a pilot effort it seems most promising and further attempts at applying it are likely to prove fruitful. This can be done, of course, only where an operational regression model of land value differentials is available, but where it is, estimates of the value of floodplain protection can be made without any assignment model at all, albeit of a somewhat cruder nature - but much simpler. It should be noted that in such a procedure the general equilibrium effects of reallocations of land-use would not really be "left out"; they would be implicit in a non-identifiable way in the estimating functions themselves.

# CHAPTER VI

## CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

1. From the theoretical model developed in this paper and a review of the relevant literature, it was concluded that subject to problems caused by externalities, benefits of floodplain protection can be appropriately measured by direct estimation or by examining changes in site values, with and without protection, on the affected areas. Since the two studies reviewed in detail, Weisz and INTASA, each makes use of these measurements, in principle we conclude that conceptual differences between the two studies are minor. Both rely on changes in land values in the final analysis; Weisz does so explicitly, and INTASA uses such changes in estimating the value of amenities and social environment effects, although the precise way in which the changes are used is not adequately explained.

2. Although the basic conceptual models are similar, there are considerable differences in implementation. Weisz sets up a linear programming model which maximizes the benefits as measured by land values. The Weisz model requires planners' projections for total population and the distribution of that population among classes of residential housing. Given these, it allocates housing to sites in a relatively unconstrained way. Moreover, since a linear programming model is employed, it is easy to specify constraints on

particular land uses if planners have additional information. If such constraints are added, the shadow prices of such constraints, which are standard output in linear programming models, provide information about the cost of their enforcement and may suggest changes in the planners' configurations. On the other hand, the INTASA approach rather explicitly eschews the maximization approach, and prefers to work within the framework of very detailed planner projections and rankings. In particular, activities and areas are ranked by planners, and the first activity is first allocated to the most favorable sites until the activity is entirely allocated or the area is filled, in which case the next most favorable area is started. Allocation begins for the second activity only after the first is fully allocated. Thus, the INTASA model is largely an accounting device which computes the estimated benefits for a specific set of projections by planners. Of course, a considerable number of calculations are made for the purpose of computing the various components of net economic rent, but there is very little of what is ordinarily called maximization in the procedure. The output from the INTASA SIMULATOR does provide some information on whether the planner allocation was reasonable, but in contrast to output from linear programming the output is not easy to use for this purpose.

It might be noted that a benefit estimate which results from a relatively unconstrained maximization - something more like the Weisz application - is a useful benchmark for planners even if it is not assumed that individuals actually practice maximizing behavior. Presumably, one could analyze the impacts of zoning as a means of bringing about rational behavior. Moreover, much economic theory is based on the idea of maximization, either of profits or utility, and this theory has provided many insights into behavior of individuals and firms which have been useful in empirical work.

3. Turning next to the empirical questions raised in the two studies, both have serious shortcomings. Weisz's land value equation, as developed by Weisz and Day, is badly misspecified. The details of this criticism have been thoroughly spelled out above, and will not be repeated here. Further, open space is not treated at all well in the Weisz model. It is assumed that the government buys all unallocated land at a fixed price, and no benefits are included. These are not objections in principle: we believe that sensible land value models can be developed, and there are reasonable ways to value the open land. On the other hand, our criticisms of the INTASA approach go deeper. Although the INTASA measure of benefits appears somewhat more refined than what is obtained from changes in land values, they do not present a satisfactory method of measuring the value of amenities

and of social environment effects. Rather, in the NED test reported, amenities are valued on the basis of land values, although we are not told how, and social environment effects are assumed to be zero. Whether there is any empirical content to these concepts, or whether they are merely another set of empty theoretical boxes, remains to be seen. Certainly, the practice of assuming equal transportation costs for each commuter and adding an arbitrary value for amenities seems very little different from relying on market prices of land. We have concentrated on the controversial aspects of benefit measurement; both INTASA and Weisz appear to do a thorough job of measuring flood damages and the costs of developing sites.

4. At several points in our report, we drew attention to the great importance of planner projections of population increase. We attempted to show in our theoretical work that the estimate of benefits is extremely sensitive to these projections. It should also be pointed out that these projections have been accepted rather uncritically by the two studies reviewed herein. Of course, it might be argued that the data used were merely for the purpose of illustration, but it would have been useful if some thought had been given to whether output from the computer programs could be used to provide a check on the reasonableness of the projections.

For example, we suggested that the implied land values in areas near the CBD could be examined; if assumed growth rates were unrealistically high, these values would become unreasonably large compared with land values in similar cities. Although some reliance must be placed on planners, we believe that research directed to all aspects of the use of planner projections in this type of model is worthy of support. In particular, the following topics might be mentioned:

a. An examination of the record of planners projections regarding projects which have been completed, and those which have been rejected. Are there biases? Do planners tend to overstage projections?

b. As suggested above, thought should be given to the kind of output from computer programs which would provide readily available information with which to check the reasonableness of planner projections.

c. The "net fiscal benefits" [16] approach should be more thoroughly examined. In some respects it makes the estimation of benefits irrelevant, inasmuch as the burden falls on the planners to make accurate projections because the local area must contribute to a project according to their estimates of benefits. Of course, models of the sort described in this report will be necessary for the planner's use--accurate projections are merely input into benefit estimation; a model which allocates uses to sites is still necessary. Although the net fiscal benefits proposal is ingenious, there are a number of administrative questions it raises. For example: at what point in the project's life should the municipality make its contribution? Would the government be willing to bankrupt a city if actual growth fell short of projected growth?

5. More work needs to be done in developing models which determine land values. Criticism has been made of the Weisz-Day study, and INTASA has made a number of claims about the impracticality of the approach. We believe, however, that the model presented in Chapter V is promising. Its explanatory power is very great, especially considering the large number of observations included, and the signs of the independent variables are consistent with theory. Unfortunately, from the point of view of the Corps' interest, the model does not emphasize such factors as distance from employment centers or natural amenities. It was largely developed for a study of the effect of neighborhood change on housing values, and so emphasizes such factors as race, income, and neighborhood features. However, a large body of data has been assembled, and experimentation with other relevant variables could be undertaken. The use of simple dummy variable

indicating whether a site is on or off the floodplain yielded a significant coefficient. This result is suggestive that additional insights are possible from more intensive use of these data.

6. Perhaps the messiest problem turned up is the question of externalities, the problem that land values for a particular site may not be independent of the uses made of other sites, particularly adjacent ones. That this phenomenon is important is clearly indicated by the regression model used in Chapter V. In that model, characteristics of adjoining neighborhoods are found to affect housing values. Other studies conducted at Washington University, have also discussed this point. The Weisz linear programming model is not designed to cope with this kind of problem, and although it is emphasized by INTASA, no appropriate solution is provided by them either. An iterative procedure was suggested earlier, but we feel that considerable research effort is necessary to develop techniques for dealing with this type of problem.

## Appendix A

### The Weisz Land Use Regulation Model

The linear programming model which determines the optimal land use pattern in Weisz's study has the following algebraic form:

$$\text{Maximize } ASR_s = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} R_{ijfpts} \; X_{ijfpts}$$

Subject to:

Constraint 1:

$$\sum_{t=1}^{T} \sum_{i=1}^{I-1} X_{ijfpts} + X_{ijfpts} = A_{js} \quad j = 1 \ldots J$$

Constraint 2(a):

$$\sum_{j=1}^{J} d_i \cdot X_{ijfpts} = P_{it} \quad \begin{matrix} i = 1 \ldots I-2 \\ t = 1 \ldots T \end{matrix}$$

Constraint 2(b):

$$PPBA \cdot X_{I-1,jfpts} - \sum_{i=1}^{I-2} d_i \cdot X_{ijfpts} = 0 \quad \begin{matrix} j = 1 \ldots D \\ t = 1 \ldots T \end{matrix}$$

Constraint 2(c):

$$\sum_{j=D+1}^{D+12} PPBA \cdot X_{I-1,jfpts} - \sum_{i=1}^{I-2} \sum_{j=D+1}^{D+12} d_i \cdot X_{ijfpts} = 0 \quad t = 1 \ldots T$$

Constraint 2(d):

$$\sum_{j=D+13}^{D+16} PPBA \cdot X_{I-1,jfpts} - \sum_{i=1}^{I-2} \sum_{j=D+13}^{D+16} d_i \cdot X_{ijfpts} = 0 \quad t = 1 \ldots T$$

Constraint 2(e):

$$\sum_{j=D+17}^{D+20} PPBA \cdot X_{I-1,jfpts} - \sum_{i=1}^{I-2} \sum_{j=D+17}^{D+20} d_i \cdot X_{ijfpts} = 0 \quad t = 1 \ldots T$$

Constraint 3(a): $X_{ijfpts} \geq 0$ for all i, j, f, p, t, s

Constraint 3(b): $X_{ijfpts} = 0$ for all $t > 1$

Constraint 4: Choose $X_{\underline{ijfpts}}$ s.t. $R_{\underline{ijfpts}} \geq R_{\underline{ij}fp\underline{ts}}$ for all $fp \neq \underline{fp}$

Constraint 5: $A_{js} = A_j - EXOG_{js}$ $\quad j = 1 \ldots J$

where:

i = index denoting a specific land use,

j = index denoting a specific location,

f = index denoting a specific level of fill,

p = index denoting a specific level of floodproofing,

t = index denoting a specific time period during which development for land use i may begin at a site at location j,

s = index denoting a specific development policy and/or engineering measures considered,

I = total number of land uses (i),

J = total number of locations (j),

T = total number of time periods (t),

D = number of locations (j=1...D) that are outside the floodplain,

$ASR_s$ = aggregate site rent of all parcels of land within the planning area that are subject to land use regulations given public investment in s,

$R_{ijfpts}$ = rent per acre to the ijfpt activity given public investment in s,

$X_{ijfpts}$ = acres of land assigned to the ijfpt activity given public investment in s,

$A_{js}$ = acres of land in location j available for assignment by the model to regulated land use activities given public investment in s,

$P_{it}$ = population growth forecast associated with land use i in time period t,

$d_i$ = population per acre of residential land use i,

PPBA = population per business acre coefficient,

$A_j$ = total acres of land presently suitable for site development in location j, and

$EXOG_{js}$ = total acres of land in location j which will be publicly acquired by public investment in s.

The first constraint gives the land available in each location which the model can consider for endogenous activity assignment. Total land in each location is initially reduced by the amount of exogenous land assignments, as shown in constraint 5. The land requirements for public investment purposes are included as exogenous assignments. The land use forecasts which are to be met are given in constraint 2a. Constraints 2b-e require the location of a sufficient commercial-business activity level to satisfy population in each of four specified areas. Prior to solving for an optimum, the number of possible activities is reduced by constraint 4, where the efficient landfill (f) and floodproofing (p) is selected for each ijT combination. The nonnegativity constraint and a requirement to acquire all endogenous open space use activities in the first period, since it would be cheapest, are reflected in constraints 3a-b.

## Appendix B

## Summary Statement of INTASA Model

The INTASA approach utilizes concepts of economic rent and locational advantage. We reproduce below selections from IWR 73-1 which discusses the concepts:

> Economic rent, given by the net earnings to both the activity i and location k, is expressed as follows:
>
> $$S_{ik} = G_{ik} - C_{ik} \tag{2.1}$$
>
> where
>
> $G_{ik}$ represents the gross income to activity i and location k;
>
> $C_{ik}$ represents all costs incurred by activity i and location k except land rent and flood damages.
>
> The correct use of damage reduction and locational advantage in measuring benefits is obtained by considering the net earning to all activities and locations that can be affected by a specific plan, where the net earnings are defined as the economic rent net of flood damages. Thus the net earnings to activity i and location k are given by:
>
> $$\hat{s}_{ik}(p) = s_{ik}(p) - r_{ik}(p) \tag{2.3}$$
>
> where
>
> $\hat{s}_{ik}(p)$ is the net earnings to activity i and location k;
>
> $s_{ik}(p)$ is the economic rent to activity i and location k;
>
> $r_{ik}(p)$ is the flood damage incurred by activity i and location k;
>
> p denotes a FPM plan;
>
> k indicates the location of activity i with plan p.

The benefits are then defined as the difference between the total net earnings with and without the plan, or

$$B(p) = \sum_i \hat{S}_{ik}(p) - \sum_i \hat{S}_{ik}(0) \qquad (2.4)$$

$$= \sum_{i \in A} \left[ \left\{ s_{ik}(p) - s_{ik}(0) \right\} + \left\{ r_{ik}(0) - r_{ik}(p) \right\} \right] +$$

$$\sum_{i \in B} \left[ \left\{ s_{ik}(p) - s_{i\ell}(0) \right\} + \left\{ r_{i\ell}(0) - r_{ik}(p) \right\} \right]$$

where

B(p) are the benefits resulting from plan p;

A indicates the set of activities that locate the same with and without the plan;

B indicates the set of activities that locate differently with and without the plan;

0 denotes no FPM plan.

The first sum in Equation (2.4) measures the benefits to activities that locate the same irrespective of the plan with the first term measuring intensification benefits and the second term damage reduction. The second sum measures locational advantage for activities that locate differently with and without the plan, with the first term measuring economic rent differences and the second term differences in flood damages.

To estimate economic rents, INTASA computes flood damages, fixed area development cost, amenity value, site development cost, transportation cost, and social environment effect. These are described [7 (pp. 33-36)].

The INTASA program allocates activities to sites in the following way:

Allocation of land use is performed at two levels. The first level is used to arrive at a realistic land use over time, and the second level is used to provide the detail required for benefit evaluation. No overall optimal land use model is used, because available models cannot include all social and political constraints or account for the many interactions between land uses. Furthermore, the model should provide an estimate of what is likely to happen in the future rather than what would happen in an idealized situation. For these reasons, the land use model developed by INTASA is flexible and depends on interaction with the planner. The planner will consider changes in input data to the land use allocation model, such as ultimate land use plans, based on information presented by the SIMULATOR. This may result in improved land use plans and increased total net economic rents.

The procedure for allocating land uses is presented in Figure 2.7. Data used at level 1 are ultimate land use plans for the study area in terms of acres reserved for each aggregate activity in different subareas; land requirements at the end of each allocation period by aggregate activity type; economic rent differences and flood damages by aggregate activity type and subarea; and sequence in which areas with fixed development cost will be used. Using the above information, activities are located by the highest present value of net economic rent to subareas included in the first area to be developed. Once the first area is filled, the next one is considered, and so on. Alternatively, the sequence of subarea development may be provided externally, thus allowing the planner to evaluate alternative patterns of development. This is useful when performing sensitivity studies on FPM plans, especially related to flood plain zoning. At the end of allocation at level 1, the program can be stopped to review the resulting allocation over time. The ultimate land use plan may be changed then, if desired. Allocation at level 1 is therefore an iterative procedure, and requires close interaction between the land use planner and the model.

Allocation at level 1, which is the crucial part of the model, concentrates on the first order of influence of regional infrastructure, interdependency of activity types and locations, and future land use potential. It locates aggregate activities to subareas for each allocation period. Aggregating activities assures that activities depending on each other locate together, i.e., residences and local commercial activities. Subareas are used to assure that the area develops along reasonable patterns and that contiguous areas develop as a unit. Ultimate land use plans constrain land use and make it possible to reserve land for future uses. The planner interacts with the land use model

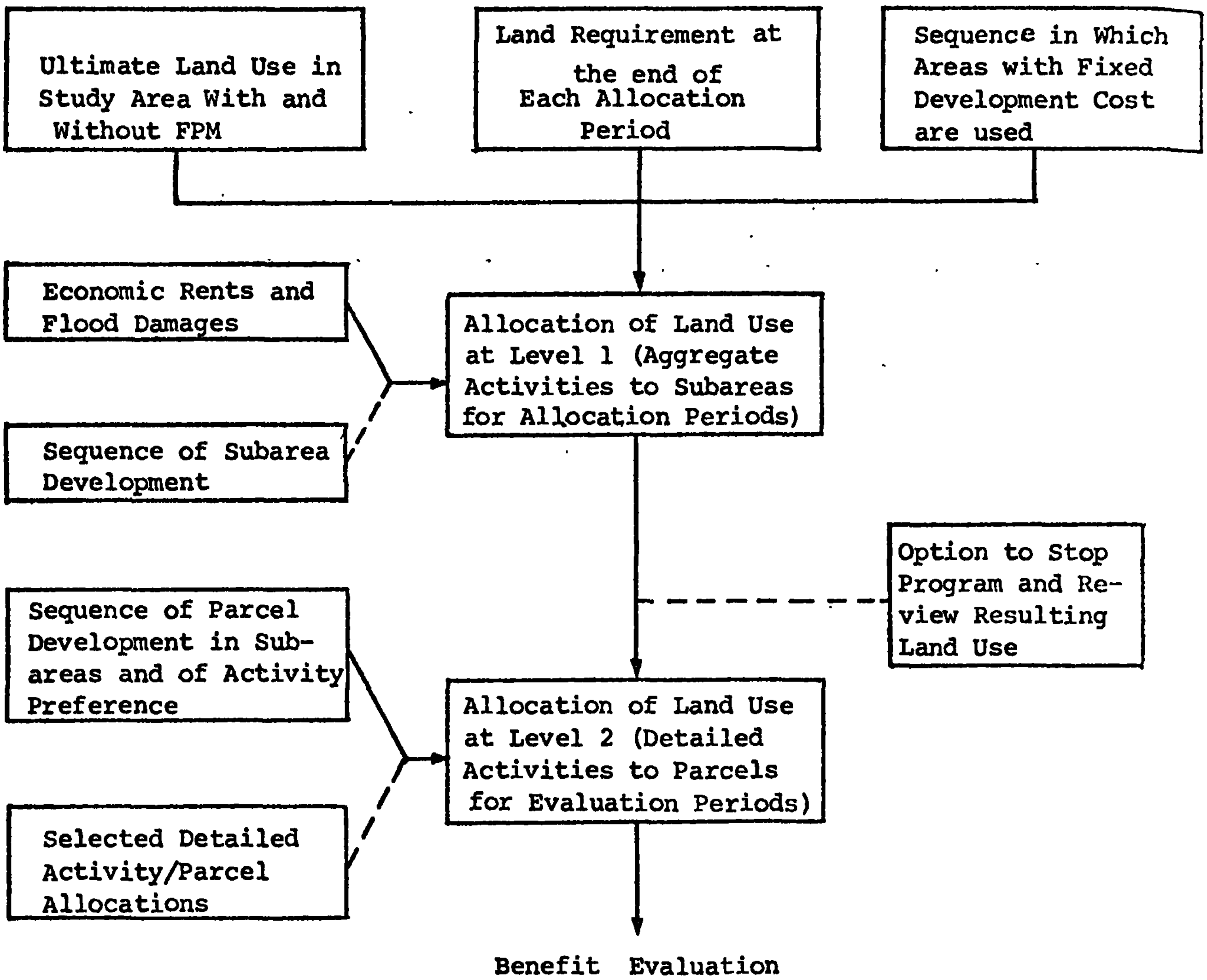



Figure 2.7 LAND USE ALLOCATION

by specifying alternative ultimate land use plans. The results of allocation at level 1 are used to determine the location of detailed activities to parcels for each evaluation period.

Allocation at level 2 uses the results of the allocation at level 1 together with input data provided by the planner on ordering of parcels within each subarea, and the sequence in which detailed activities may choose their location in a subarea. By providing this data, the planner can include his knowledge on special conditions and interdependencies. At the same time, benefits from FPM are not expected to be very sensitive to the exact sequence of parcel development, and thus a simple allocation procedure is desirable. When more information on location of certain detailed activities is available, this data may be specified separately and be included in the allocation, as indicated in the Figure 2.7. Level 2 provides the benefit evaluation procedure with the allocation of detailed activity types to parcels at the end of every evaluation period.

For benefit evaluation, land uses that are the same with and without FPM, and land uses that are different are needed. For this purpose, existing uses of the flood plain at the time of the study as well as its future uses before the start of the project are provided as input to the SIMULATOR. Additional land uses during each evaluation period with and without FPM are compared, and the list of detailed activity/parcel combinations that locate the same and that locate differently with and without FPM is kept current.

The summary measure of benefits is the present value of floodplain management benefits over the planning horizon. Several approaches to benefit measurement are utilized. If land use is unchanged with and without the plan, damage reduction is the only benefit measure used. If land use is changed, locational advantages is used. Three approaches to its measurement are utilized:

1) Economic rent and flood damages

"Contributions of economic rent components and damages are determined during the evaluation period for land uses with the plan. Then these same contributions for land uses without the plan are subtracted. The result is the difference in economic rents and in flood damages associated with land uses with and without FPM. The sum of these two differences provides the locational advantage."

2) Land values and flood damages

"Land values are determined for the evaluation period under the assumption that there is no flooding. The procedure followed in estimating locational advantage is the same as when using economic rents, except that economic rent components are displaced by land values."

3) Economic rents, land values, and flood damages

"Economic rents and flood damages are used for activities that are expected to contribute heavily to benefits, that is for activities that locate in the flood plain with the plan, and outside the flood plain without the plan. In addition, if there is any change in an activity's location within the flood plain as a result of the plan, the associated change in flood damages to that activity is included as a part of locational advantage. The benefits due to relocation of the remaining activities are expected to contribute only a small part to the total benefits, and are approximated by land value differences."

## Appendix C

### Procedure for Identifying Properties on Floodplain

Of the 1671 St. Louis County transactions, a total of 101 houses were located on verified 100 year floodplains. An additional 25 observations should be deleted—20 were in or near non-verified floodplains and 5 were bad addresses.

The floodplains were drawn on U. S. Geological Survey 7½ minute topographical maps. These maps have 10 foot elevation contours which are accurate to plus or minus 5 feet. The floodplains were drawn using three different types of information. The Meramec floodplains were drawn with the aid of aerial photographs. For all other rivers and streams the contours were either copied from U. S. Army Corps of Engineers floodplain maps, or were drawn from tabular and graphical data on stream heights.

With few exceptions only data for one contour, usually the 100 year, was available. Where more than one reading was available, the 10 and 100 year levels were so close that more than one line could not be drawn. For example:

| Meramec at mile 31 | |
|---|---|
| 10 year | 431.5 |
| 20 | 434.5 |
| 50 | 438.5 |
| 100 | 441.0 |
| 200 | 442.5 |

| Caulks Creek at mile 3.59 | |
|---|---|
| 10 year | 497.8 |
| 20 | 498.4 |
| 50 | 499.4 |
| 100 | 499.9 |
| 200 | 500.4 |

There are only two major watercourses in the City of St. Louis. The railroad tracks serve as an effective levee along the Mississippi. Furthermore, there is virtually no residential property near the river. The

River Des Peres drainage channel does flood, but the Corps has no data on this. The only thing which can be said is the 100 year level of Mississippi backwash at this channel is 422'. For these two reasons the observations were drawn entirely from St. Louis County.

To say the least the distributions of both observations and on plain houses were neither random nor uniform. Of the 1881 observations the vast majority of them are in the North County area, the same can be said of the on plain houses. Census tracts numbered under 2150 are roughly north of Olive Blvd., and up to 2178.03 are north of Manchester Road.

| Census tracts | Observations | On Plain |
|---|---|---|
| 2101-2149 | 1320 | 79 |
| 2150-2178.03 | 186 | 0 |
| 2179.01-2216 | 375 | 22 |

Heavy concentrations of observations come from Hazelwood, Florissant, Pine Lawn, and Hillsdale. There were virtually no observations in the area between Olive and Manchester, along the Missouri, along the Meramec, or in the far West County area. Substantial portions of Valley Park, Times Beach, Fenton, and Pacific get flooded, though only a small portion of Pacific is in St. Louis County. There were no observations in Times Beach or Pacific, and only three each in Valley Park and Fenton.

Of the 101 on plain observations they were distributed among the various watercourses as follows:

| | |
|---|---|
| Coldwater system | 57 |
| Maline system | 22 |
| Gravois system | 12 |
| River Des Peres Channel | 3 |
| Meramec River | 2 |
| Fishpot Creek | 2 |
| Shady Grove Creek | 2 |
| Deer Creek | 1 |

The vast majority of on plain observations are thus in the Florissant and Ferguson areas.

There are 25 observations which had to be deleted. Twenty of these are in non-verified floodplains. Of these 8 are along Gingras Creek and 3 are on branches of River Des Peres; no elevation data are available for either stream.

## Documentation on 100 Year Floods

For the entire length of the Meramec River from the mouth to Pacific the Corps had aerial photographs. There were twenty of these, each covered an area of approximately four square miles, and each had the 100 year flood contours drawn on it. Additional data on the lower Meramec to near Fenton is contained in "Flood Plain Information, Meramec River, Jefferson County, Missouri, Technical Report," U. S. Army Corps of Engineers, St. Louis, 1965. This report has data on the 5 and 50 year floods also.

Data on the Meramec near Fenton, Fenton Creek, and Yarnell Creek was provided by "Flood Plain Information, Meramec River, Yarnell Creek, and Fenton Creek, Fenton, Missouri, Technical Report," U. S. Army Corps of Engineers, St. Louis, April, 1971.

Profiles on the upper Meramec and Fox Creek were provided by "Flood Plain Information, Meramec River, Brush Creek and Fox Creek," U. S. Army Corps of Engineers, St. Louis, June, 1968. Fox Creek is a perennial stream as far as Manchester Road, but the study went only as far as Interstate 44. Little Fox Creek, also a perennial stream, was not covered in the report.

Data on Gravois Creek, Kirkwood Creek, Musick Creek, and Mulberry Creek was found in "Floods in Gravois Creek Basin, St. Louis County, Missouri," Open File Report by Leland D. Hauth and Donald W. Spencer, U. S. Department of the Interior, Geological Survey, 1969.

100 year profiles on the following creeks--Coldwater, Watkins, Fountain, Deer, Two Mile, Shady Grove, and Black--and some of River Des Peres (airport to Heman Park) were given by "Floods in Coldwater Creek, Watkins Creek, and River Des Peres Basins in St. Louis County, Missouri," Open File Report by Leland D. Hauth and Donald W. Spencer, U. S. Department of the Interior, Geological Survey, 1971.

Data on Dellwood Creek, Blackjack Creek, Carsonville Creek and Maline Creek was provided by "Floods in Maline Creek Basin, St. Louis County, Missouri," Open File Report by Donald W. Spencer and Leland D. Hauth, U. S. Department of the Interior, Geological Survey, 1968.

Information on the following creeks--Mattese, Creve Coeur, Caulks, Fishpot, Smith, and Grand Glaize to the Manchester line--was given by "Flood Insurance Study, St. Louis County, Missouri, Unincorporated Areas," U. S. Army Corps of Engineers, St. Louis, June, 1973. This report has not been officially released and thus is not for quotation or imputation. This report also gives 10 and 100 year flood levels on the Mississippi.

The 100 year profile of Grand Glaize Creek in Ballwin is given by "Special Flood Hazard Information Report, Grand Glaize Creek, Ballwin, Mo.," U. S. Army Corps of Engineers, St. Louis, August, 1972. There was no data available for Grand Glaize Creek as it goes through Manchester, though data for both up and down stream existed. Interpolation was deemed too risky. This creek runs just south of Manchester Road at the intersection of Woods Mill Road.

In most cases the Missouri floodplain was drawn bluff to bluff using data from "Flood Insurance Study, St. Louis County, Missouri, Unincorporated areas." Most of the land in question is agricultural, and there was some question as to which levees were effective. Staff at the Corps office said the water would break through a levee rather than topping it. They also said soil quality was such that water would rise up through the soil behind the levees making them ineffective. There are a number of small airports in the Missouri floodplain and Corps staff said that last spring they were under several feet of water. All this seems to justify drawing the floodplain from bluff to bluff. Along the first 50 miles of the Missouri the 10 and 100 year flood levels are about seven feet apart.

Very little can be said about the River Des Peres drainage channel. The 100 year flood level of the Mississippi where the channel joins it is 422', hence this is the 100 year flood backwash level. From the mouth to Interstate 55 was mapped from an aerial photograph of last year's flood. The only other fact that could be ascertained was that the water did not go over the River Des Peres Parkway along the western bank. Nothing can be said about the eastern bank or the upper branch of the drainage channel.

Data was not available on the following creeks--Martigney, MacKenzie, Kiefer, Williams, Antire, Carr, Hamilton, Forby, Upper Fox, Wildhorse, Bonhomme, Caulks West Branch, Fee Fee, Mill, Augusta Tavern, Gingras, Northwoods, Spanish Lake, and two branches of River Des Peres. Many of these are in unpopulated areas of far west St. Louis County.

Table C-1

Distribution of Observations

| Census tract | observations | on plain | delete |
|---|---|---|---|
| 2101 | 11 | 0 | |
| 2102 | 10 | 0 | |
| 2103 | 7 | 0 | |
| 2104 | 9 | 2 | |
| 2105 | 20 | 3 | |
| 2106 | 9 | 1 | |
| 2107 | 17 | 0 | |
| 2108.01 | 13 | 0 | |
| 2108.02 | 11 | 0 | |
| 2109.01 | 4 | 1 | |
| 2109.02 | 18 | 0 | |
| 2109.03 | 24 | 5 | |
| 2110 | 26 | 5 | |
| 2111 | 29 | 3 | |
| 2112 | 23 | 6 | |
| 2113.01 | 49 | 18 | |
| 2113.02 | 19 | 0 | 1 |
| 2113.03 | 61 | 2 | 1 |
| 2114 | 14 | 0 | |
| 2115 | 0 | 0 | |
| 2116 | 26 | 0 | |
| 2117 | 11 | 0 | |
| 2118 | 20 | 4 | |
| 2119 | 10 | 0 | |
| 2120 | 24 | 3 | |
| 2121 | 26 | 0 | |
| 2122 | 128 | 0 | 8 |
| 2123 | 2 | 0 | |
| 2124 | 11 | 0 | |
| 2125 | 9 | 1 | |
| 2126 | 22 | 0 | |
| 2127 | 32 | 10 | |
| 2128 | 3 | 0 | |
| 2129 | 0 | 0 | |
| 2130 | 3 | 0 | |
| 2131.01 | 19 | 0 | |
| 2131.02 | 8 | 0 | |
| 2132.01 | 19 | 0 | |
| 2132.02 | 11 | 0 | 3 |
| 2133 | 20 | 4 | |
| 2134 | 24 | 0 | |
| 2135 | 26 | 0 | |
| 2136 | 13 | 2 | |
| 2137 | 22 | 0 | |
| 2138 | 116 | 0 | |
| 2139 | 16 | 0 | 1 |
| 2140 | 2 | 0 | |
| 2141 | 5 | 0 | 1 |

| Census tract | observations | on plain | delete |
|---|---|---|---|
| 2142 | 17 | 0 | 1 |
| 2143 | 12 | 0 | |
| 2144 | 20 | 6 | |
| 2145 | 10 | 0 | |
| 2146 | 35 | 0 | |
| 2147 | 31 | 3 | |
| 2148 | 21 | 0 | |
| 2149 | 16 | 0 | |
| 2150.01 | 8 | 0 | |
| 2150.02 | 12 | 0 | |
| 2150.03 | 7 | 0 | |
| 2151.01 | 18 | 0 | 1 |
| 2151.02 | 17 | 0 | |
| 2151.03 | 6 | 0 | |
| 2151.04 | 6 | 0 | |
| 2152.01 | 0 | | |
| 2152.02 | 6 | 0 | |
| 2152.03 | 2 | 0 | |
| 2153.01 | 1 | | |
| 2153.02 | 0 | | |
| 2154 | 2 | 0 | |
| 2155 | 1 | 0 | |
| 2156 | 0 | | |
| 2157 | 4 | 0 | |
| 2158 | 4 | 0 | |
| 2159 | 2 | 0 | |
| 2160 | 0 | | |
| 2161 | 1 | 0 | |
| 2162 | 5 | 0 | |
| 2163 | 0 | | |
| 2164 | 0 | | |
| 2165 | 0 | 0 | |
| 2166 | 0 | | |
| 2167 | 9 | 0 | |
| 2168 | 6 | 0 | |
| 2169 | 5 | 0 | |
| 2170 | 7 | 0 | |
| 2171 | 2 | 0 | |
| 2172 | 4 | 0 | |
| 2173 | 10 | 0 | |
| 2174 | 7 | 0 | |
| 2175 | 2 | 0 | |
| 2176 | 13 | 0 | |
| 2177.01 | 0 | | |
| 2177.02 | 5 | 0 | |
| 2178.01 | 0 | | |
| 2178.02 | 7 | 0 | 1 |
| 2179.01 | 11 | 0 | |
| 2179.02 | 10 | 2 | |
| 2180.01 | 0 | | |
| 2180.02 | 3 | 0 | |
| 2181 | 3 | 2 | |

| Census tract | observations | on plain | delete |
|---|---|---|---|
| 2182 | 11 | 0 | |
| 2183 | 9 | 0 | |
| 2184 | 17 | 0 | 2 |
| 2185 | 12 | 0 | |
| 2186 | 7 | 0 | |
| 2187 | 1 | 0 | |
| 2188 | 20 | 0 | |
| 2189 | 24 | 0 | |
| 2190 | 5 | 1 | |
| 2191 | 8 | 0 | 1 |
| 2192 | 7 | 2 | |
| 2193 | 9 | 0 | |
| 2194 | 10 | 0 | |
| 2195 | 15 | 0 | |
| 2196 | 4 | 0 | |
| 2197 | 0 | 0 | |
| 2198 | 6 | 0 | 2 |
| 2199 | 12 | 0 | |
| 2200 | 0 | 0 | |
| 2201 | 6 | 2 | |
| 2202 | 12 | 3 | 1 |
| 2203 | 0 | | |
| 2204.01 | 13 | 0 | 1 |
| 2204.02 | 0 | | |
| 2205 | 14 | 0 | |
| 2206.01 | 3 | 0 | |
| 2206.02 | 5 | 1 | |
| 2207.01 | 1 | 0 | |
| 2207.02 | 2 | 0 | |
| 2207.03 | 7 | 3 | |
| 2208.01 | 3 | 0 | |
| 2208.02 | 9 | 1 | |
| 2208.03 | 7 | 0 | |
| 2209 | 15 | 4 | |
| 2210 | 20 | 1 | |
| 2211 | 0 | | |
| 2212.01 | 0 | | |
| 2212.03 | 0 | | |
| 2213.01 | 0 | | |
| 2213.02 | 0 | | |
| 2213.03 | 0 | | |
| 2214.01 | 3 | 0 | |
| 2214.02 | 3 | 0 | |
| 2215 | 0 | | |
| 2216 | 1 | 0 | |
| totals | 1671 | 101 | 25 |

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