Role of Land Use Planning in Noise Control

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ABSTRACT.—A method for controlling outdoor noise through land use planning is presented. The method utilizes a computer model that broadly assesses the likely noise environments of a community on the basis of generalized land use and highway noise production and transmission conditions. The method is designed to enable town planners and other community decision-makers to identify those general areas that are potentially unsuitable for noise-sensitive types of development such as housing. The method also predicts probably changes in noise environments and in the suitability of those environments due to general changes in land use (development). The method does not require site-specific measurements.

AS THE INTEREST of this conference in the acoustic environment indicates, noise pollution is one of the hazardous and disagreeable byproducts of human activity that warrants control. Historically, noise has been an undesirable feature of city life. Since World War II, however, it has become an undesirable feature of communities in general. The population explosion of recent decades and the subsequent process of decentralized development have brought increasingly large numbers of suburban as well as urban residents into objectionable proximity to proliferating sources of noise.

Insofar as the actual noise levels of offending sources in the environment are not likely to be reduced for some time, the abatement of noise pollution today depends largely on our ability to control noise in transmission. Controlling sound in transmission involves manipulating the effective proximity of a noise source and the noise-sensitive receiver. In the outdoor environment, this manipulation constitutes the role of land use planning in noise-pollution control.

Noise planning controls may operate at either of two scales. At a larger planning scale are general land use allocation noise controls. These are primarily allocations of various types of development within a larger landscape context (such as a town) to appropriate noise-environment zones. In other words, noise-sensitive land uses are allocated to quieter zones and noisier land uses are allocated to noisier zones. Noise control is for the most part a matter of isolating or aggregating land uses to prevent the undesirable exposure of noise-sensitive areas. At this scale, specific types of noise buffers between uses are not considered.

At a smaller planning scale are what might be called land use management noise controls. These include the provision or enhancement of various types of noise buffers between acoustically incompatible land uses. In other

words, barriers, forests, fields, distances, and other buffers are maintained or managed between noisy land uses (factories, highways, shopping centers) and noise-sensitive land uses (neighborhoods, schools, hospitals). Generally at this scale, a particular noise problem is either controlled (for example, by constructing a berm between a housing development and a highway) or prevented (for example, by siting a school at a suitable distance from a factory).

To date, these opportunities for noise control through land use planning have not been presented in terms particularly useful to planners and other decision-makers. With the exception of a highway-noise-simulation model developed by the firm of Bolt Beranek and Newman *(Galloway et al. 1969)*, previous outdoor noise assessment techniques, notably "community noise reaction models" *(Great Britain Committee 1963, EPA 1972)*, have relied entirely on site-specific measurements. Such measurements are both time-consuming and costly and therefore highly impractical for many planning purposes. In addition, site measurements are really useful only in defining existing noise problems such as the extent to which noise from an airport affects the noise character of the surrounding landscape. Moreover, measurements require that each noise problem be evaluated separately on the basis of measurements pertaining only to that particular problem. In general, present noise models cannot be used practically to assess multiple noise problems. Nor can they be used to predict the probable effects of proposed noise intrusions (airports, industries, and shopping centers) on surrounding environments.

Planning, however, relies upon tools that are both practical and predictive; that is, assessment techniques and planning guidelines that can be used with relative ease to evaluate in a general way a wide variety of existing or potential landscape situations. The almost total lack of such tools for noise-related planning purposes has led to the research reported here. A computerized technique or methodology for controlling outdoor noise through land-use planning is discussed.

This technique is intended to provide a practical basis for larger scale noise-related land use planning. Specifically, our methodology is designed to enable planners and other decision-makers to broadly identify those areas of the landscape within a community context that are potentially unsuitable for noise-sensitive types of development (for example, housing). It is further designed to predict probable changes in noise environments and in the suitability of those environments due to general changes in uses of the landscape. The notable feature of the methodology is that it does not require site-specific measurements.

We have also developed a nonmeasurement technique to aid smaller scale noise-related land use-planning and management decisions *(Fabos and Caswell, 1977)*. However, this technique, which is designed to enable users to estimate and avoid (through buffering) potential noise conflicts between adjacent but different uses of the landscape, is not discussed here.

This noise-pollution planning technique was developed as part of a larger interdisciplinary research effort (ongoing at the University of Massachusetts) known as the Metropolitan Landscape Planning Model Project *(Fabos 1973)*. For a discussion of the nature and operation of the Metropolitan Landscape Planning Model, which deals with a variety of resource, hazard, and use-suitability aspects of the landscape, see the paper by Fabos and Ferris included in these proceedings.

THE NOISE ENVIRONMENT ASSESSMENT METHODOLOGY

Noise is a dynamic phenomenon that, once generated by a source, travels over

a number of transmission paths to receivers located at various distances from the original point or area of noise output. The noise level at a given receiver therefore depends upon the original strength of the noise at the source and upon the degree of loss in this strength that is caused by the physical characteristics (trees, hills, pavement) of the transmission path along which the noise has traveled.

The present noise methodology is based on this acoustic principle. For any given community, procedures were developed for determining: (1) noise source areas and the likely strengths of these sources, (2) transmission loss areas and the likely degree of noise reduction provided by these areas, and (3) the probable noise environments that result from the transmission of noise from noise source areas through transmission-loss areas to other parts of the community.

The basis for these three procedures is described below. An exemplary application of the methodology to the Town of Burlington (located in the northwestern section of the Boston metropolitan region) for data relating to 1971 is used to illustrate each procedure.

Procedure for determining noise source areas

The procedure for determining noise source areas is based on two general types of noise sources that may appear in the landscape: (1) land uses and (2) highways.

Noise source areas were determined first by assigning a characteristic noise level to each land use and highway type, and second by aggregating those land uses and highways having similar noise levels into land use and highway noise groups (tables 1 and 2). The mapping of these groups for any town would

Table 1.—Assigned land use noise levels and resultant land use noise groups for land uses in the Town of Burlington in 1971

[A 1971 land use map aggregated according to these land use groups would yield a map showing the various land use noise source areas comprising the town for that year.]

Land uses in land use noise group	Assigned land use noise level
	dBA
Open space (wetland, forest, openland, abandoned land)	35
Farmland Orchard Nursery Cemetery Estate	40
Low-density housing	45
Medium-density housing; low-intensive recreation (golf course, driving range, drive-in)	50
Townhouse Garden apartment Public institution	55
Lighter industry	60
Shopping center Medium intensive recreation (playground, athletic field)	65
Strip commercial Intensive recreation (amusement park)	70
Core commercial Heavier industry	75
Mining (sand and gravel and traprock)	80

Table 2.—Estimated highway noise levels and resultant highway noise groups for secondary and primary roadways in the Town of Burlington in 1971

[Noise levels are based on near-peak to peak-hour conditions of road use. A 1971 road map (USGS toposheet), aggregated according to these highway groups, would yield a map showing the various highway noise sources comprising the town for that year. It should be noted that at the time of this mapping, the topography of the town would be used to make noise adjustments for steep roadway gradients.]

Highway (HW) characteristics	Noise level (listener location = 12.5')
	dBA
HW_1: 25 mph, 5-10 vehicles per mile; No % heavy trucks or buses; even flow; good road surface; shallow gradient	60
HW_2: 30 mph, 10-15 vpm; 2.5% heavy trucks or buses; even flow; good road surface; shallow gradient	65
HW_3: 35 mph, 20 vpm; 5% heavy trucks or buses; even flow; good road surface; shallow gradient	70
HW_4: 35 mph, 30 vpm; 5% heavy trucks or buses; even flow; good road surface; shallow gradient	72
HW_5: 35 mph, 30 vpm; 5% heavy trucks or buses; uneven flow; good road surface; shallow gradient	76
HW_6: 40 mph, 35 vpm; 10% heavy trucks or buses; even flow; good road surface; shallow gradient	
HW_7: 35 mph, 40 vpm; 10% heavy trucks or buses; uneven flow; good road surface; shallow gradient	79
HW_8: 50-55 mph, 60 vpm; 10% heavy trucks or buses; even flow; good road surface; shallow gradient	
HW_9: 60-65 mph, 90 vpm; 10% heavy trucks or buses, even flow; good road surface; shallow gradient	85

then yield the various noise source areas occurring within that town.

Land use noise levels were assigned on the basis of results of a recent outdoor noise-environment measurement survey undertaken by the State of California *(EPA 1972)*. Although the noise produced by a noise environment varies greatly over a 24-hour period, this survey statistically reduced the time-varying noise output of each measured environment to a single composite noise level in dB(A). (DB(A)'s are frequency-weighted decibels measured on an A-network sound-level meter.) In cases where the surveyed environment was a single-use environment comparable to a land use type, the measured statistical noise level was assumed to be a valid expression of the noise generally associated with that land use type. The noise levels of land use types not specifically sampled by the measurement survey were estimated on the basis of the similarity of their noise-producing characteristics to one or another of the measured environments.

Highway noise levels were assigned according to the highway noise simulation model developed by Bolt, Beranek, and Newman *(Galloway et al. 1969)*. This model estimates the noise level in dB(A) of any highway on the basis of the typical noise contributions of its road and traffic characteristics. These include vehicular density (in vehicles

Table 3.—Transmission loss groups and figures based on dominant land use characteristics for land uses in Burlington in 1971

[A 1971 land use map aggregated according to these groups would yield a map showing the transmission loss areas comprising the town for that year. Transmission loss figures are given in decibels per thousand feet (dB/1000') or decibels per doubling of distance (dB/dd), depending upon which rate of noise reduction is more appropriate for the predominant landscape characteristic.]

Dominant physical characteristic	Land uses in transmission loss group	Transmission loss figure	
		dB/1000'	*dB/dd*
Wet land	Wet land	—	1.0
Grass/low vegetation	Farmland, open land, golf course, playground, cemetery, athletic field	—	3.0
Trees (less than 30% crown closure)	Orchard, nursery, abandoned land, estate	—	4.0
Trees (30-80% crown closure)	Forest	—	4.5
Trees (greater than 80% crown closure)	Very dense forest	—	5.0
Hard ground/pavement	Amusement park, drive-in	1.0	—
1-2 story structures (scattered)	Low-density housing	3.0	—
1-2 story structures (less scattered)	Medium-density housing	5.0	—
1-2 story structures (very large)	Shopping center, strip commercial, heavy industry	6.0	—
2+ story structures	Townhouse, garden apartment, light industry, public institution, core commercial	10.0	—
Land form	Sand and gravel, traprock mining	8.0	—
Water	Open water	0.0	—

per mile), vehicular speed (in miles per hour), traffic composition, traffic flow, road surface, road gradient, and listener location.

Procedure for determining transmission loss areas

The procedure for determining transmission loss areas is similar to that used for determining land use noise source areas. Transmission loss areas were determined first by grouping land use types according to the similarity of their dominant physical characteristics (pavement, grass, trees, one-story buildings, etc.), and second by assigning to each group a figure of transmission loss that reflected in a very general way the rate of noise reduction provided by that group's dominant physical characteristic (table 3). The mapping of these groups for any town would then yield the various transmission loss areas occurring within that town.

Transmission loss figures were extrapolated wherever possible from the results of previous studies concerned with the transmission of noise in the outdoor environment *(Simonson 1955, Embleton 1963, Winterbottom 1965, Sexton 1969, Robinette 1972, Aylor 1971 and 1972)*. They are, however, only very general estimates of average landscape transmission loss and do not account for noise reductions due to air, temperature, wind, or possible differences in terrain.

Procedure for calculating noise environments

A computer model was developed to compute the various noise environments that would result when noise from

source areas traveled through transmission loss areas to other parts of the town. The model assumes that each noise source area mapped for a town can be represented as an aggregate of smaller individual noise sources or sourcelets distributed either within that area (in the case of land use noise sources) or along the length of that area (in the case of highway noise sources).

To establish a basic acoustical relationship between the noise level corresponding (assigned) to a noise source area and the noise strengths of the sourcelets necessary to produce that noise level, the model further assumes that the noise strengths of sourcelets comprising a land use noise source area are such that, if the entire mapped region were composed of the same sourcelet strengths and the same rate of transmission loss, the noise level corresponding to that land use source area would result. Analogously, the model assumes that the noise strengths of sourcelets along a highway noise source are such that, if the highway were straight, the noise level corresponding to that highway source would result.

Input to the computer model includes sets of digitized data corresponding to numerous points (sourcelets) on the noise source and transmission loss maps. These digitized points serve to locate on an x-y coordinate system the sourcelets distributed within each land use noise source area and transmission loss area and along each highway noise source area mapped for a town. The sets of digitized data corresponding to each map are then successively manipulated by four computer programs run in a prescribed sequence.

The final printout is a spatial display of originally digitized points. At each point, the "new" noise level resulting from the transmission of sourcelet noise through the landscape is given in symbolic form. The computation of these new noise levels includes the effects of spatial attenuation — the natural reduction in noise due to spherical spreading as noise travels away from a source.

Each symbol on the final printout represents a 10-dB(A) range of noise levels. By manually tracing a line along the interface of different printed symbols and by converting these symbols to the noise-level ranges they represent, a noise map is produced. This map illustrates what are in effect the various general noise environments of the region represented by the original noise source and transmission loss map (fig. 1).

Utility of the noise map

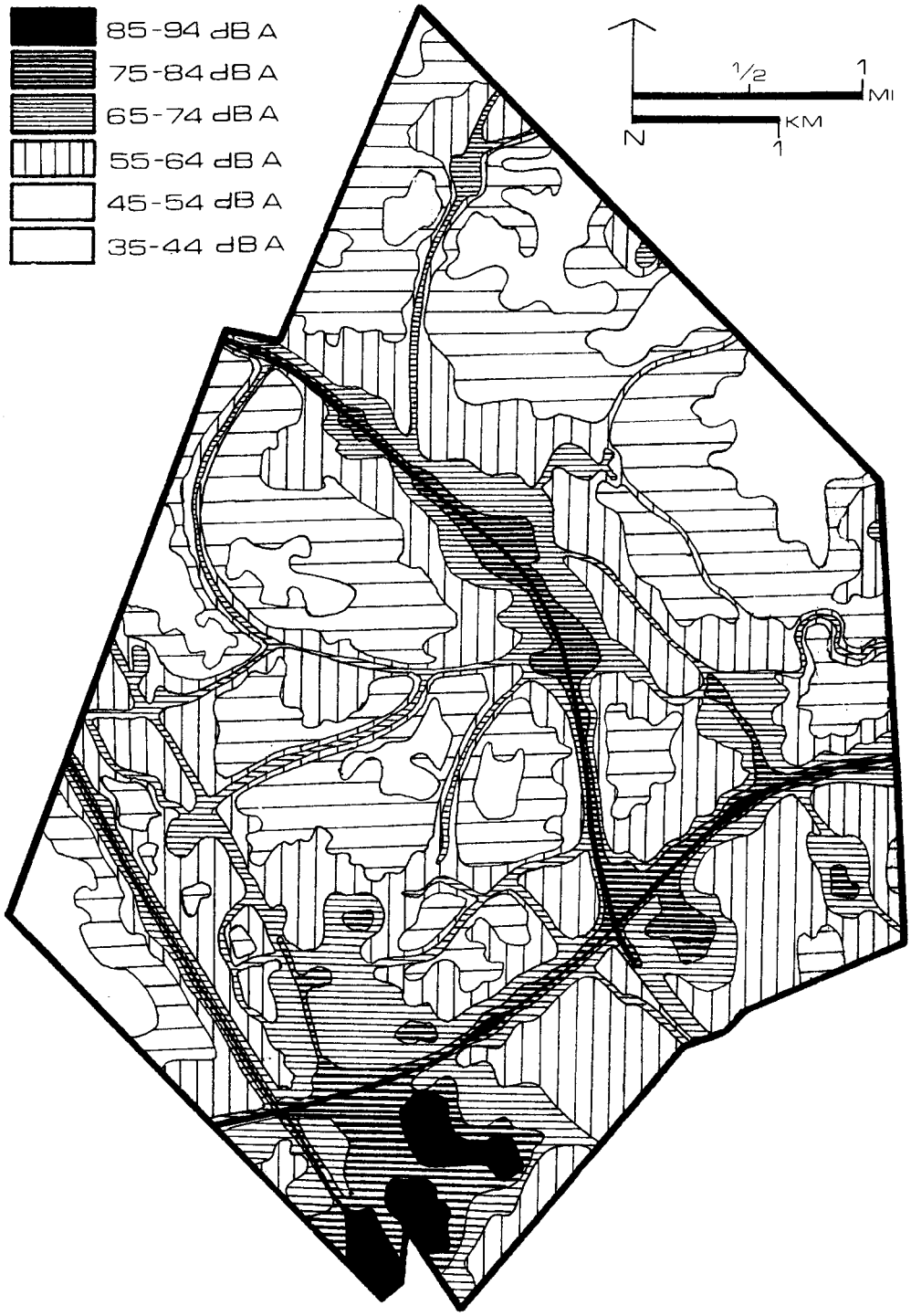
With the noise map, a planner or other decision-maker is for the first time provided with the information necessary to carry out planning policies that reflect the potential noise suitability of different parts of a town for different types of development.

For example, a planner might decide that it is desirable to restrict all future noise-producing landscape uses such as airports, shopping centers, and certain industries to already noisy areas. The noise map of the town shows where these existing noisier environments are. Alternatively, the planner might decide to set aside quite areas of the town for the location of proposed noise-sensitive uses such as low-density housing, hospitals, schools, and libraries. Again, the noise map of the town shows where these quieter environments are.

In his approach to these noise control planning decisions, the planner may be as specific or as general as the noise map allows. On one hand, he may establish detailed development policies for each of the different noise environments appearing on a noise map. On the other hand, he may choose to group several noise environments into a few major noise categories, which generally summarize his noise planning objectives for the town.

A review of pertinent literature indicates that there are two views or concepts of environmental noise pollution

Figure 1.—The 1971 noise map produced by computer for the Town of Burlington, Massachusetts. The map is based on the noise interaction among land use and highway noise source areas and transmission loss areas occurring in the town in 1971.



that might be used to provide a basis for a more specific approach to noise control planning and decision-making.

The first view or planning concept is based on noise-complaint history and urban noise-annoyance surveys *(Great Britain Committee 1963, EPA 1972)*. This view suggests that all acoustically different uses of the landscape are to varying degrees incompatible and so should not occur adjacent to one another without some buffering. In other words, the various noise environments on a noise map would be to some extent degraded if land uses or highways having noise levels (tables 1 and 2) above 10-decibel noise level ranges were allocated to those environments. The greater the difference between the noise level of the proposd use and the noise-level range typical of the existing environment, the greater the loss in noise quality to the affected part of that environment, assuming no noise buffering landscape devices (trees, hills, berms, etc.) are already present or are intended to be used.

The second view or planning concept is based on people's reactions to aircraft noise *(Kryter 1968)*. This view suggests that intrusive outdoor noise constitutes no perceivable impact when below a basic annoyance threshold of about 55 dB(A). In other words, the introduction of a use having a typical noise level of 55 dB(A) or less would not be expected to negatively affect the noise quality of any noise environment appearing on a noise map, even if the environment in question were substantially quieter than the proposed use.

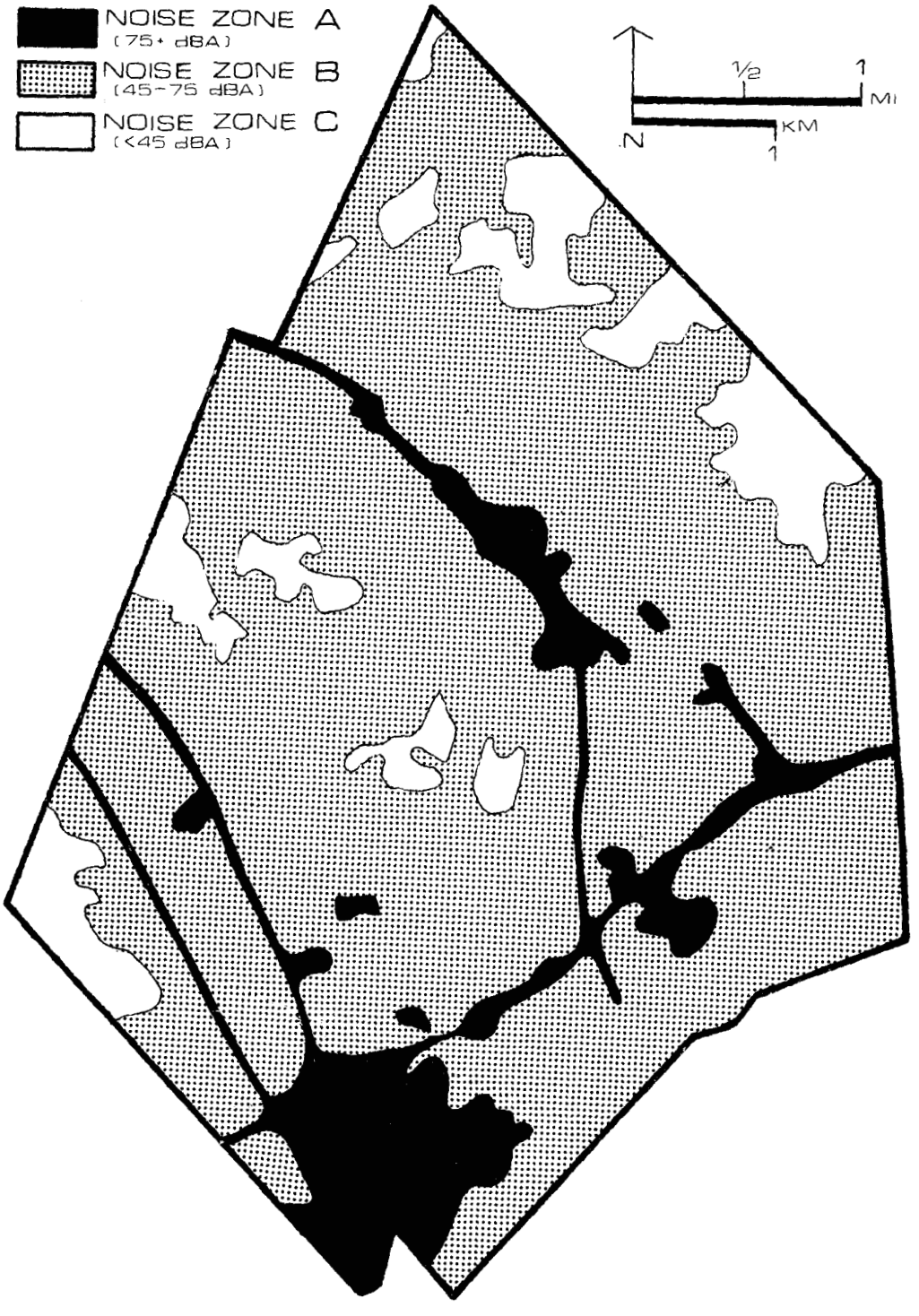
According to the first of these noise control planning concepts, a town planner may reasonably establish a development policy whereby only uses that are as quiet as or quieter than an existing noise-map environment may be introduced into that environment unless special measures are taken. Alternatively, according to the second planning concept, the planner may reasonably establish a similar but less stringent (and perhaps less ideal) development policy affecting only those proposed uses whose typical noise levels exceed 55 dB(A). Either way, the point is that the planner is enabled by spatial information in the form of a noise map to formulate specific noise pollution prevention policies and plans for all sectors of his community.

A more general approach to noise control planning and decision-making would be to use the noise map in a somewhat different way. A practical example of this type of approach might be as follows.

On the basis of the range of noise environments that may occur on a noise map, the planner identifies three general zones — A, B, and C — to summarize his noise-planning objectives for the community. Zone A would include those noise environments that are potentially hazardous or unsafe in terms of people's hearing. It has recently been established that an exposure of several hours to noise levels of about 75 dB(A) on a daily basis results in some degree of permanent hearing loss in most people *(EPA 1972)*. Zone A would therefore be composed of noise environments having general noise levels of 75 dB (A) or more. These are areas of the landscape that are potentially unsuitable for residential and other noise-sensitive types of development unless buffers of some kind are provided. As a general rule, the planner would restrict zone A landscapes to noisier commercial, industrial, and recreational activities.

Zone B would include those noise environments that are potentially annoying to people residing in them. Some noise-annoyance studies suggest that the first signs of annoyance in persons living in quiet low-density residential neighborhoods are produced by noise levels exceeding 45 dB(A) *(Great Britain Committee 1963, EPA 1972)*. Other studies suggest that annoyance in sensitive (quiet) community areas begins only with noise levels exceeding

Figure 2.—The 1971 noise map for the Town of Burlington aggregated according to three noise-level zones. (It should be noted that had the B zone begun at 55 dBA rather than 45 dBA as shown, the area represented by the zone would have been considerably smaller.)



55 dB(A) *(Kryter 1968)*. Depending on the planner, zone B would therefore be composed of noise environments having general noise levels between 45 or 55 dB(A) and 75 dB(A). These are areas of the landscape that are probably suitable but not always ideal for a range of development types. In general, the planner would allocate higher density housing, industrial parks, recreation uses such as golf courses, and the like to zone B landscapes. The decision to allocate quieter uses to B zones would reflect the overriding quality of other physical and cultural aspects of the landscape.

Finally, zone C would include the remaining noise environments, those that are neither potentially hazardous nor potentially annoying. These are areas of the landscape that are entirely suitable for all types of development. Insofar as possible, the planner would reserve zone C for activities that would not degrade the existing noise environment.

In cases where a planner is interested in assessing a town from several environmental standpoints in addition to that of noise (for example, potential air pollution, flooding, water supply, sand and gravel supply, etc.), the A-B-C noise-zone map that results from this summarization of a noise map may be of even greater planning use than the more detailed noise map from which it is derived (fig. 2).

DISCUSSION

There are three basic features of the noise enviroment assessment methodology that recommend it as a technique for larger scale noise-related land use planning.

First, it requires no measurements and so is practical to use. The only source information required is a land use map and a U.S.G.S. quadrant map or other roadway/topography map (corrected for highway noise characteristics) of the town to be assessed. Although a certain amount of traffic-data collection and digitizing is required, the time/cost involved is small compared to that of multiple on-site measurements and measurement analyses.

Second, the methodology is designed to operate at the community scale. The noise environments comprising an entire community or even a group of communities can therefore be assessed at once. This provides a useful overview of the noise situation and a context for subsequent decision-making.

And third, the effects of any proposed change in land use/highway development on the surrounding noise landscape (changes in noise environments) can be predicted simply by redigitizing the points on the land use or highway noise source maps and the transmission loss may where the change is to occur. Rerunning the program sequence yields a new noise map. In this way, the noise consequences of any land use allocation decision (and its alternatives) can be evaluated before changes in the landscape are actually made.

Each of these features makes the methodology a useful tool for landscape planning and therefore a useful method of noise pollution control. However, as the first noise-environment simulation technique of its kind, the methodology understandably exhibits one apparently significant limitation: it lacks the accuracy provided by site-specific measurements.

Unfortunately, the noise-producing and transmitting characteristics of the landscape do not often easily lend themselves to generalization. For this reason, we have sometimes been forced in our methodology to make assumptions about the noise landscape that do not necessarily represent reality. This is especially true of the assignment of transmission loss values and certain land use noise levels.

The issue of accuracy as a methodological limitation, however, must be considered in light of two important

facts. In the first place, as acousticians acquire more land use noise data and better expressions of transmission loss, these can be easily incorporated into the present assessment procedure.

In the second place, the noise methodology is not designed for smaller scale land use allocation/management purposes. Although better base data are always desirable, the likely noise environments now illustrated by the computer-generated noise map are in all probability quite suitable for the level of decision-making that they are intended to influence.

CONCLUSION

We believe that our environmental noise assessment methodology provides a much-needed basis for large scale land use-related noise pollution evaluation and prevention. We recognize, however, that in the absence of standard noise-environment modelling procedures, numerous assumptions and generalizations were made about the relationship between the production/transmission of noise and certain characteristics of the physical landscape, primarily land use. With the exception of highway noise simulation, no precedent exists for making such generalizations. Those made here represent what is in effect a professional interpretation of available site-specific (measured) noise production and attenuation data. The validity of the assessment methodology is therefore based largely on analogies and inferences made from empirical noise-related research.

This approach to noise tends to be problematic from several points of view. First, the nature of generated and transmitting noise in the outdoor environment is often highly variable. Although various examples of some types of land uses, such as low- and medium-density housing, can be reasonably said to contribute on the average a similar amount of noise to the environment, various examples of other land use types, such as industry, may be responsible for very different amounts of noise output. For example, the difference in the outdoor noise levels generated by a plastics factory and a paper mill may be substantial. Generalizing about the noise output of a land use typed "industry" is therefore likely to underestimate the noise contributions of some industrial land uses while overestimating the noise contributions of other industrial land uses.

The variability in transmitting noise is even more of a problem. Noise in transmission is complexly affected not only by all the elements of the landscape with which it comes in contact, but also by the arrangement of those elements, that is their location and orientation with respect to the noise source area. Furthermore, the degree to which noise is affected by the landscape depends upon the kind of noise that is generated (its predominant frequencies) as well as the areal extent of the source itself. To estimate the effect of a land use noise source on a receiver located some distance away is therefore far from simple.

Second, the body of data pertaining to those aspects of the outdoor noise environment (particularly noise in transmission) which are of interest in noise pollution control is not large. Since generalizations better approximate reality when drawn from numerous observed results, especially where the observed phenomenon is as complex as is noise, this is a fundamental problem.

Third, the lack of pertinent noise data is compounded by the fact that the comparability among investigated situations is low. Different measuring instruments are often used. Different source and receiver conditions are often sampled under still different landscape conditions. Even observed results are sometimes expressed in terms that to the non-engineer appear to bear little resemblance to one another. Drawing

generalizations that can be applied easily to the problem of outdoor noise pollution control is made difficult by these experimental differences.

Finally, among the somewhat comparable noise experiments that have been undertaken, results are at times conflicting. For example, measured reductions of point-source noise in forests range from as little as 1.0 dB/100 feet of vegetation to as much as 7.0 dB/100 feet of vegetation *(Smith 1970)*. Until such experimental discrepancies are explained and resolved, attempts to apply empirical noise data must always be rather frustrating.

Despite these problems, it is felt that the approach taken in formulating the assessment technique presented here is entirely appropriate for and necessary to larger scale noise control planning purposes. In fact, if understood as a preliminary effort to translate observed acoustical data into a usable form for planners and others whose decisions influence the noise environment, we believe our methodology is an extremely valuable noise-planning tool even as it now stands. Without question, however, more empirical noise data and better expressions of landscape noise characteristics are needed, particlularly as regards (1) the noise-producing tendencies of acoustically complex and highly variable land use types such as industry and (2) all aspects of noise in transmission through the landscape. With more observed and comparable results, more representative generalizations about those results can be made.

Greater interaction between planners and accoustical engineers/scientists is therefore warranted. The apparent lack of communication between these professionals to date is responsible for many of the problems described above and encountered in our research. If noise pollution is to be practically controlled in the forseeable future, it is the responsibility of planners to articulate their noise-information needs, while it is the responsibility of acoustical scientists to generate the necessary information and translate it into understandable and easily applied terms.

LITERATURE CITED

Aylor, Donald F.
1971. How plants and soil muffle noise. Front. Plant Sci.: 6-7.

Aylor, Donald F.
1972. Noise reduction by vegetation and ground. J. Acoust. Soc. Am. 51: 197-205.

Embleton, T. F. W.
1963. Sound propagation in homogenous deciduous and evergreen woods. J. Acoust. Soc. Am. 35: 1119-1125.

Fabos, Julius Gy.
1973. Model for landscape resource assessment. Univ. Mass. Agric. Exp. Stn. Res. Bull. 602. 141 p.

Fabos, Julius Gy., Stephanie J. Caswell, et. al.
1977. Composite landscape assessment. Univ. Mass. Agric. Exp. Stn. Res. Bull. 637. 320 p.

Galloway, William J., Weldon F. Clark, and Jean S. Kerrick.
1969. Highway noise measurement, simulation, and mixed reactions. Natl. Acad. Sci. Highway Res. Bd., Natl. Coop. Highway Res. Prog. Rep. 78. 78 p.

Great Britain Committee on the Problem of Noise.
1963. Noise, final report. Her Majesty's Stationery Off. 300 p.

Kryter, Karl.
1968. Concepts of perceived noisiness, their implementation and application. J. Acoust. Soc. Am. 43: 344-361.

Robinette, Gary O.
1972. Plants/people/and environmental quality. U. S. Natl. Park Serv. 140 p.

Sexton, Burton H.
1969. Traffic noise. Traffic Quart.: 427-439.

Simonson, Wilbur H.
1955. Abatement of highway noise with special reference to roadside design. Highway Res. Bd. Bull. 110: 1-14.

Smith, William H.
1970. Trees in the city. AIP J.: 429-436.

U.S. Environmental Protection Agency.
1972. Report to the president and congress on noise. U. S. Govt. Print. Off. 431 p.

Winterbottom, D. W.
1965. The nuisances of traffic in residential areas. Traffic Quart. 19: 384-395.