

STAFF GUIDELINES FOR THE CONSIDERATION OF TRANSPORTATION NOISE IMPACTS IN LAND USE PLANNING AND DEVELOPMENT

June, 1983

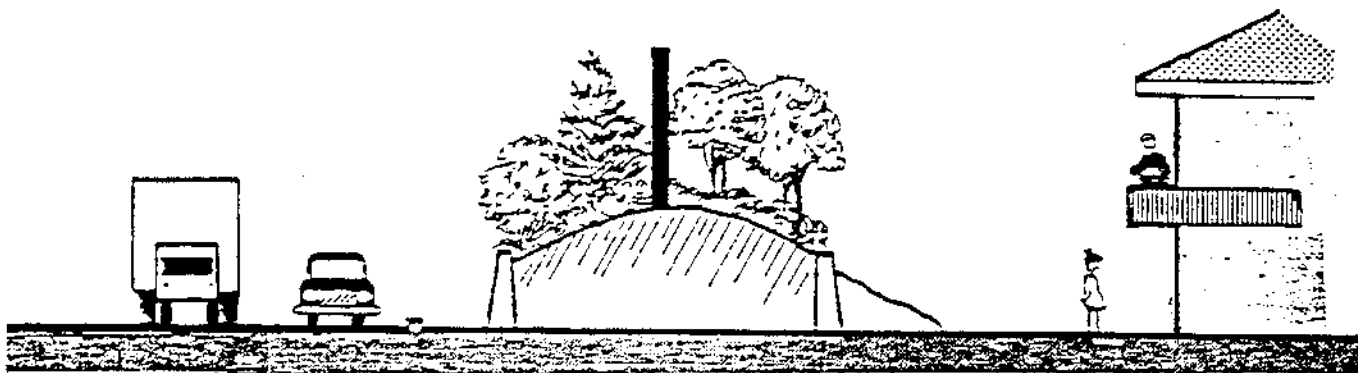


Figure 7-1. Use of Various Noise Barriers.

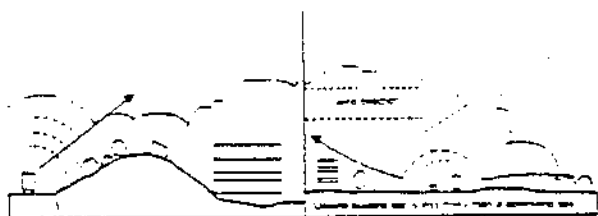
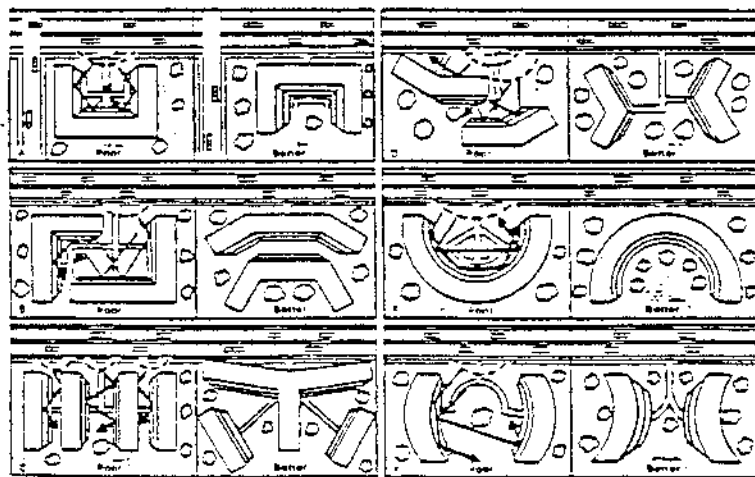
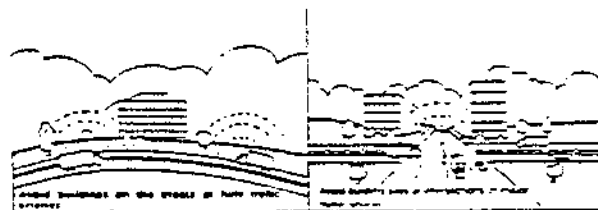


Figure 7-2. Use of Natural Noise Barriers.

Figure 7-3. Selection of Building Sites Relative to Wind Direction.



Orientation of Buildings on Sites.

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Environmental Planning Division

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SUMMARY

This document has been developed as an aid to developers, planners, and decision-makers in assessing the extent of transportation noise problems and devising appropriate solutions. This will promote greater understanding of noise pollution problems and encourage noise-conscious development which protects public health and welfare and provides a better quality living environment for the residents of Montgomery County.

Excessive noise exposure has a number of potentially serious health effects. Noise-induced hearing loss has been thoroughly researched and quantified. Other known effects of noise exposure include constricted blood vessels, faster heart rate, elevated blood cholesterol, and hyperactivity of the adrenal cortex. Research has also implicated noise as a factor in producing a number of stress-related health effects such as high blood pressure, heart disease, stroke, and ulcers.

Exclusive of its direct health-related effects, noise adversely affects the public welfare in a number of ways, interfering with sleep, conversation, and other activities. Intrusive noise may significantly reduce the use and enjoyment of indoor and private outdoor areas.

A substantial body of noise-related law has been enacted at the Federal, State, and local levels. To a great extent, current law is concerned with individual source controls or property line standards for noise emanating from a single parcel. Noise from existing public or quasi-public facilities such as highways, arterial roads, and railroads remains largely uncontrolled at present, in spite of their widespread impacts.

The known adverse effects of noise pollution on public health, welfare, and quality of life requires consideration of noise as a factor in forming land use planning decisions.

The process employed by the Environmental Planning staff to evaluate transportation noise impacts may be summarized in four steps:

- (1) A screening procedure identifies planning or site areas with potential noise impacts.
- (2) If the area is shown to be potentially impacted by high noise levels, a detailed analysis of the existing and/or future noise levels is done. An adapted version of the Federal Highway Administration's "FHWA-RD-77-108" computer model is used to compute noise levels. On-site monitoring is conducted on an "as-needed" basis. Other techniques which could provide greater detail over existing methods in noise measurements and analyses are also considered and evaluated.
- (3) The noise levels projected for the area are evaluated against the noise level guidelines recommended in Chapter II.
- (4) If the noise levels projected for the area exceed the appropriate guideline values, the Environmental Planning staff recommends the use of noise abatement techniques for the impacted area. Various means of dealing with

noise impacts are presented in Chapter III. In addition, the Environmental Planning Division recognizes that responsibility for funding and constructing noise abatement measures should be shared by the public and private sectors. A framework for determining the responsibility for implementation of noise abatement measures is presented in Appendix B.

The Environmental Planning Division will use the noise guidelines in all phases of its planning and regulatory review functions. Noise analyses, using both existing and projected traffic parameters will be initially integrated as a planning determinant at the master planning phase to facilitate implementation of the guidelines in subsequent reviews. The staff will assist developers throughout the development process in attaining these noise level guideline values.

Subdivision plans, site plans, zoning cases and other mandatory referrals will be reviewed within the evaluative framework of the guidelines. Traffic information may be evaluated in terms of both existing and future noise impacts. Existing noise conditions will be determined for each plan under review. The analysis of noise for a future year may be conducted if the property under review is adjacent to roadways which: (1) are projected (based on master plan and/or development review activities) to have significant increases in traffic volumes or changes in traffic mix within the next 10 years, and/or (2) are included in the current Capital Improvements Program, with at least 50 percent of the funding included in the CIP. In short, if substantive changes are expected in traffic (hence, noise) levels in the near future, future-year traffic data will be used in the noise evaluation.

Environmental Planning staff will prepare recommendations addressing adverse noise impacts as needed. These recommendations, along with recommendations from other appropriate planning divisions, will be included in the staff report to the Montgomery County Planning Board or forwarded to the responsible state or county agency. The Planning Board will consider these staff recommendations and balance them with other land use planning objectives and with concerns of County residents. Appropriate action will then be taken within the context of the overall responsibilities and the powers delegated to the Planning Board.

I. INTRODUCTION

The objective of this document is to foster and encourage noise-conscious development which protects public health and welfare and provides a better quality living environment. The Environmental Planning Division attempts to achieve this objective without denying development or significantly reducing density in noise-impacted areas. However, in some extreme cases where noise impact abatement options are very limited, the staff may recommend denial of some or all units proposed in a development or site plan.

This document is intended to assist developers, planners, and decision makers by:

- (1) helping in the identification of areas which may be subject to adverse noise impacts;
- (2) providing guidelines to achieve noise-conscious development; and
- (3) providing technical assistance and recommendations of various noise attenuation measures to reduce the hazards and annoyance of unnecessary noise exposure.

This information is most usefully employed early in the development planning process so that all available options for mitigating noise impacts may be evaluated before some alternatives are foreclosed without due consideration of noise attenuation opportunities.

Recognition of the need for noise guidelines in land use planning has been slow in developing. For centuries excessive noise has been recognized as a nuisance to the community beginning in early Roman times when chariot racing was prohibited at night.

With the development of modern machines for construction, industry, and transportation, many citizens have begun to object to rising levels of environmental noise encroaching on their lives. In addition, research has made clear that noise can cause hearing loss and other serious health effects. High levels of noise can interfere with sleep, communications, and other activities. Thus excessive noise can no longer be regarded as merely a nuisance. It is a problem that, left unsolved, can significantly affect public health and welfare.

This document is intended to be non-technical. However, it has been necessary to use some basic noise terminology with which lay persons may be unfamiliar. These terms are defined in the glossary (Appendix E) for easy reference.

Information on the characteristics of sound, definition of various noise descriptors, and methods for predicting sound levels are presented in the technical appendix to this document. The appendix, entitled "Noise Technical Report", is available as a separate document.

In addition, the legal basis of noise planning and regulation and the health and welfare effects of noise exposure are presented in Appendices C and D. These factors are related to the noise planning program of The Maryland-National Capital Park and Planning Commission and the guidelines recommended herein for use in the planning and regulatory review processes in Montgomery County.

II. RECOMMENDED GUIDELINES TO MANAGE TRANSPORTATION NOISE IMPACTS THROUGH LAND USE PLANNING.

Guidelines given in this document were developed to assure consistency in noise analysis of regulatory reviews and to promote greater understanding of this issue by developers and planners alike. They represent a continuation and elaboration of on-going work done by the Environmental Planning Division. First, screening criteria are introduced to assist in identifying areas where potential noise impacts exist and may merit consideration in planning and site design. Second, guidelines for acceptable noise levels are set forth. These guidelines will be used by the Environmental Planning Division in reviewing site plans, subdivision plans, zoning cases, and master and sector plans, as the basis for making recommendations to the Planning Board for noise impact abatement. Discussion on whether these guidelines are applied to existing or future transportation conditions under the various land use planning processes is presented in Chapter IV.

2.1 Screening Technique for Identifying Potential Noise Impact Areas

As mentioned above, these guidelines will help to identify areas where potential noise impacts exist and merit further consideration in development planning and site design. It must be recognized that this technique may identify some areas where noise is below recommended guideline levels or may fail to identify a few noise impacted areas. Site-specific information, including on-site monitoring in some cases, is necessary to confirm or deny the presence of adverse noise impacts. It is anticipated, however, that use of this screening technique will be effective in identifying the great majority of cases where serious transportation noise impacts exist.

Areas within the following approximate distances from major noise sources may have high noise levels requiring attenuation:

- (1) Areas within 1,000 feet of freeways
- (2) Areas within 3,000 feet of railroad tracks
- (3) Areas within 600 feet of major highways or arterial roads carrying more than 20,000 vehicles, average daily traffic (ADT)
- (4) Areas within 300 feet of arterial roads with ADT of 5,000 to 20,000
- (5) Areas within 5 miles of a general aviation airport or within 15 miles of a commercial or military airport. Areas under the paths of airport flight patterns are more highly impacted by aircraft noise than areas outside the flight paths.

Other screening criteria include:

- (6) If two or more of the above mentioned noise sources are present, the distances involved may be substantially increased.

- (7) If the line of sight between noise source and a receiver averages more than about 10 feet above ground level, the distances involved may be increased. This situation may occur, for example, when the noise receiver is on an upper level of a high-rise building.
- (8) If the line of sight is completely broken by an intervening topographic feature or line of buildings, these distances may be substantially reduced. (Noise levels may be reduced by about 5 dBA due to this break in the line of sight).
- (9) If heavy trucks comprise more than 10% of ADT, the noise impact of low-volume roads may be significant.

This screening technique is based on a technique used by the U.S. Department of Housing and Urban Development (reference #11). In addition, adjustments have been made based on a knowledge of the noise environment in Montgomery County and previous experience in dealing with noise problems here.

2.2 Recommended Noise Level Guidelines

Guidelines recommended in this document are based on the following considerations:

- Effects of noise exposure on health, welfare, and quality of life.
- Consistency with Federal, State and local noise standards.
- The relation of noise standards to the existing noise environment in Montgomery County.
- The responsibility of the Montgomery County Planning Board to consider all issues significantly affecting the public health, welfare, and quality of life. (The position of the County Council as expressed in the Noise Ordinance clearly establishes noise as one such issue.)

2.2.1 Exterior Guidelines for Residential Areas, Hospitals, Housing for the Elderly, and Other Noise-Sensitive Land Uses

The guidelines in this section will be used to protect noise-sensitive land uses including residential areas, hospitals, and housing for the elderly from the adverse effects of exposure to high levels of noise. In residential areas, consideration has been given to outdoor noise because residents should be able to enjoy the use of private outdoor areas free of the annoyance and hazards associated with high noise levels. Additionally, in this energy-conscious era, it is considered appropriate to protect the capability of residents to open windows for ventilation without being subjected to excessive noise impacts. This concept is recognized in the Montgomery County Noise Ordinance.

In recognition of the previous considerations the guidelines to be used are as follows:

TABLE 2-1

MAXIMUM LEVELS FOR EXTERIOR NOISE AT THE BUILDING LINE¹
FOR NOISE-SENSITIVE LAND USES

<u>Guideline Value</u>	<u>Area of Application</u> (see Map 6-1)
$L_{dn} = 55$ dBA	This guideline is suggested as an appropriate goal in permanent rural areas of the County where residential zoning is for five or more acres per dwelling unit and background levels are low enough to allow maintenance of a 55 dBA level. This guideline is consistent with Federal, State, and County goals for residential areas.
$L_{dn} = 60$ dBA	This is the basic residential noise guideline which will be applied in most areas of the County where suburban densities predominate. Maintenance of this level will protect health and substantially prevent activity interference both indoors and outdoors. Noise attenuation measures will be recommended to allow attainment of this level.
$L_{dn} = 65$ dBA	This guideline will generally be applied in the urban ring, freeway and major highway corridor areas, where ambient levels are such that application of a stricter guideline would be infeasible or inequitable. Significant activity interference will occur outdoors and indoors if windows are partially opened, but available evidence indicates hearing is adequately protected. Noise attenuation measures will be strongly recommended to attain this level.

The areas where these exterior guideline values would apply are shown on Map 2-1. This map should be used for general reference purposes only. Recommended exterior noise levels shown for specific areas in subsequent sector and master plans may differ from Map 2-1 due to updated, more detailed traffic information for existing and future

¹ Building line as used here refers to habitable structures only. It does not include garages, sheds, or recreational or accessory buildings.

conditions and due to the consideration of other land use planning objectives. The specific recommendations found in the subsequent master or sector plans supersede Map 2-1 and should be used to determine specific guidelines for noise levels in specific areas of the County.

2.2.2 Waiver of Exterior Guidelines for Residential Areas and Other Noise-Sensitive Land Uses

Waiver of exterior noise guidelines for residential areas and other noise-sensitive land uses in areas where transportation noise exceeds 65 dBA Ldn may be considered under the following circumstances:

- (1) In areas where land use is not based on outdoor activities and internal ventilation permits year-round closing of windows.
- (2) If use of all feasible exterior attenuation measures cannot protect noise-sensitive rooms on upper floors (e.g., bedrooms) or outdoor patio areas, or if exterior attenuation is not feasible. Exterior noise attenuation measures may be infeasible due to economics, aesthetics, or site-related constraints of size, shape, or topography.

2.2.3 Interior Guideline for Residential Areas and Other Noise-Sensitive Land Uses

If a waiver of exterior noise guidelines is granted, an interior guideline of 45 dBA Ldn will be used. Prior to approval of building permits, there shall be a certification by a professional engineer with competency in acoustical analysis that the building shell will attenuate current exterior noise levels to an interior level not to exceed 45 dBA Ldn. In addition, a written commitment signed by the builder shall be submitted assuring the construction of the units in accord with the engineer's specifications.

2.2.4 Guidelines for Office, Commercial, and Industrial Land Uses

Office, commercial, and industrial zones are generally considered to be noise compatible land uses and will not be reviewed for noise impacts with the following two exceptions: (1) Situations where it appears likely that workers will be subjected to noise levels in excess of $L_{eq} = 75$ dBA for an 8-hour period. (2) In CBD or Transit Station areas, where amenity spaces are provided, if it appears that noise impacts may be of such magnitude as to significantly reduce the usefulness or inhibit the proper function of these spaces for their intended purpose(s).

An L_{eq} or L_{10} may be used for analysis if the period of use is such that noise impacts would only occur during the daytime (for one or more hours). The appropriate standards applicable to such cases should be as consistent as possible with the corresponding L_{dn} guideline standard for the property. Staff may recommend design modifications to lessen excessive noise impacts.

III. METHODS FOR ABATING TRANSPORTATION NOISE

This chapter covers some of the measures which may be recommended by the Environmental Planning staff for reducing noise impacts. Developers will find it useful to consider these alternatives early in their planning process. In addition, the Environmental Planning staff will aid developers in evaluating other noise attenuation measures which may be proposed by developers but not covered in this chapter.

3.1 Noise Sources

Two broad classes of noise sources are pertinent to land use planning and development. Noise from point sources including the operation of industrial or construction equipment or other sources emanating from private real property can be effectively controlled by the Montgomery County Noise Ordinance. Mobile sources of noise include cars, trucks, buses, railroads, motorcycles and aircraft.

In situations where a great number of individual mobile sources use the same path of travel, the effect becomes that of a line source transmitting noise across a broad line front. Railroads, highways, and arterial roads are examples of line sources.

In Montgomery County the single most pervasive source of noise is generated by high levels of traffic on highways and arterial roads. Both Federal and State governments have adopted regulations limiting noise emissions from individual vehicles. However, the cumulative effect of many vehicles on a public road can still extend far beyond the edge of the right-of-way and is not directly controlled by any legislation or standard.

It is known that noise energy decreases at somewhat predictable rates with increasing distance from the source. Noise from an idealized line source deteriorates at the rate of 3 dBA per doubling of distance due to the effect of wave divergence alone. An additional 1.5 dBA attenuation per doubling of distance may be assumed where the height of the line of sight is less than 3 meters (about 10 feet) above ground level and the intervening ground is soft, covered with vegetation, or interrupted by isolated buildings, clumps or bushes, or scattered trees. In most cases, therefore, a total drop-off rate of 4.5 dBA per doubling of distance may be safely assumed.

3.2 Abatement Effects

Analysis of specific site plans and structures is usually required to determine the effectiveness of specific noise abatement methods. However, the following values are good indicators of abatement effectiveness:

TABLE 3-1
EFFECTIVENESS OF SOME NOISE ABATEMENT METHODS

Abatement Measure	Amount of Noise Reduction Measured in dBA
OUTDOOR NOISE	
Setback from a line source (i.e., multiple mobile sources)	3 to 4.5, per doubling of distance
Acoustical wall	5 to 20*
Earth berm**	5 to 23*
Structural barrier (i.e., building breaks line of sight between noise source and receptor)	5 to 20*
INDOOR NOISE	
Windows open	10 to 15
Double-glazed windows closed	20 to 35

Noise reductions of 5-10 dBA are usually not difficult to attain. Higher values of the range are very difficult to achieve.

** An earth berm is 2 to 3 dBA more effective than an acoustical wall of the same height.

3.3 Abatement Techniques

A variety of techniques are available to mitigate adverse noise impacts where they exist. These include the use of setbacks, site-design measures, berms, acoustic fences, walls or barriers, landscaping, and acoustical construction techniques. A number of these concepts are illustrated in Figures 3-1 through 3-6 (reference #14). Physical characteristics of the site, together with consideration of the type of development envisioned, will determine which of these techniques may be most appropriate in a particular case. These techniques may be employed alone or in combination to provide an acoustically effective, aesthetically pleasing form of noise abatement.

We will briefly discuss each of these techniques and some of their advantages and disadvantages. In general terms, techniques are described in order of desirability with consideration given to both technical and cost-effectiveness.



Figure 3-1. Use of Various Noise Barriers.

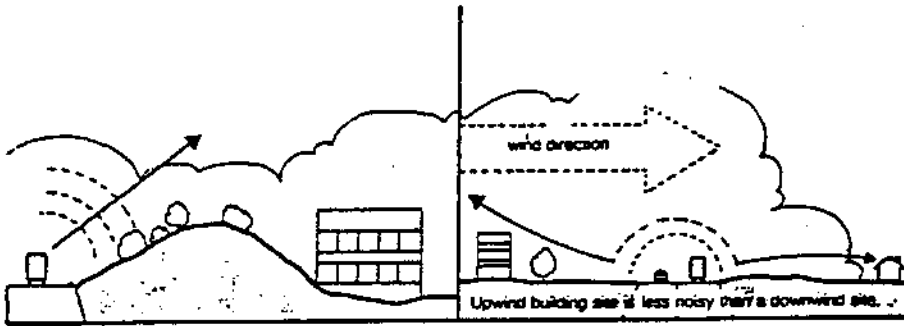


Figure 3-2. Use of Natural Noise Barriers.

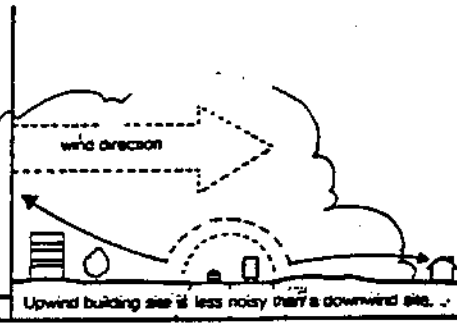


Figure 3-3. Selection of Building Sites Relative to Wind Direction.

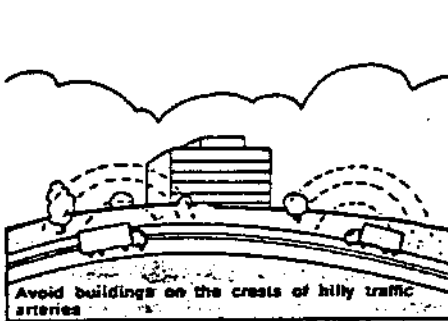


Figure 3-4. Building Sites near Hilly Traffic Areas.

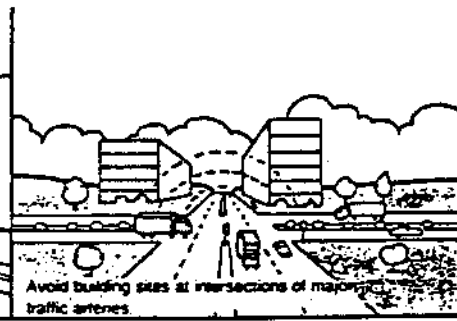


Figure 3-5. Building Sites near Traffic Junctions.

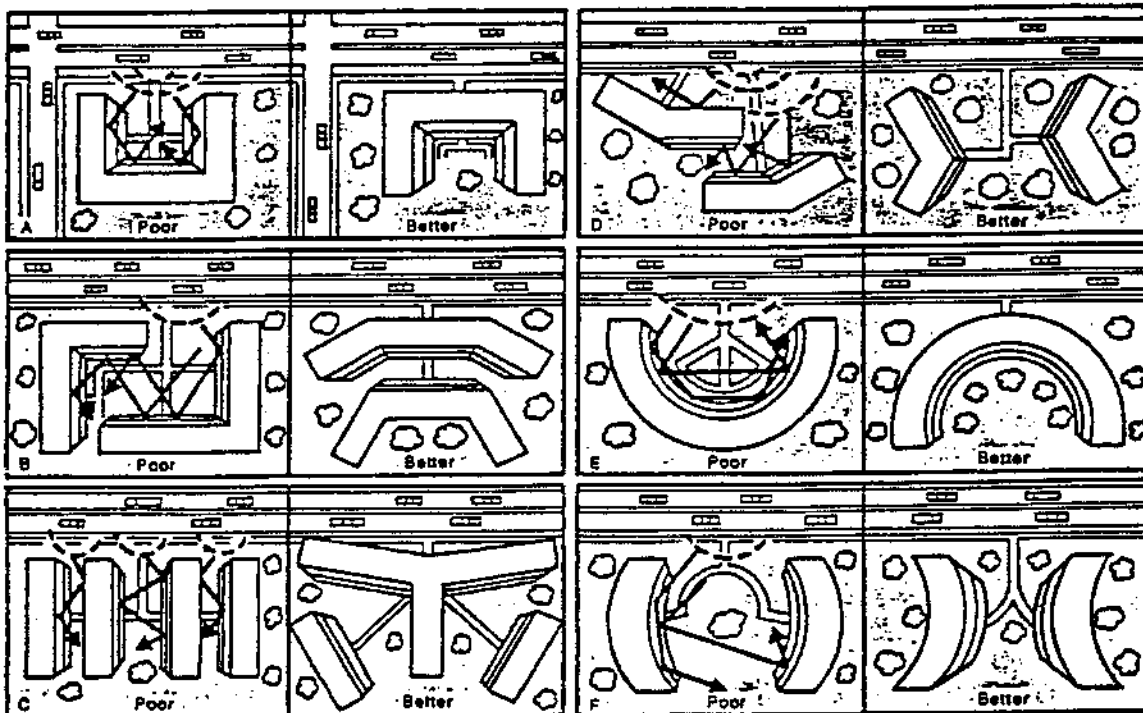


Figure 3-6. Orientation of Buildings on Sites.

Source: See Reference #14.

3.3.1 Site Design

Noise-conscious site design seeks to take advantage of any natural features of the site or the facilities planned for it to minimize noise impacts. The primary concern is the proper location of noise-sensitive areas relative to sources of noise. It may involve the preservation of noise-attenuating topographic features, retention of a belt of existing trees, and/or determination of an appropriate setback.

Active recreation areas, stormwater management ponds, or open space may be advantageously located in noise-impacted areas since these areas are less noise-sensitive than the residential units they are designed to serve. Noise-tolerant site uses, such as garages or sheds, may also be placed in noise-impacted areas to form a partial noise barrier. Site-design measures often have the greatest potential for reducing noise impacts at little or no cost depending on the zoning requirements. This is especially true when noise is considered as an integral element in the earliest site design.

3.3.2 Berms

Berms are elongated mounds of earth which can be used to block a line of sight (LOS) between a noise source and the sensitive receiver. They are capable of providing approximately 5 to 23 dBA noise attenuation, although significant (5 dBA) attenuation does not occur unless the LOS is broken. This noise-attenuating capability also applies to walls, fences, and other types of noise barriers, although the theoretical maximum noise-attenuating capability of wall-type barriers is 20 dBA.

Berms have a number of advantages for attenuating noise. They mimic natural land forms, thereby avoiding the harsh lines or "prison wall" effect sometimes associated with other (often poorly designed) wall or fence types of noise barriers. In contrast to fence type barriers, which may deteriorate over time, a landscaped berm improves with age. They provide privacy as well as noise attenuation and often give a more aesthetically pleasing view from the road as well as from the houses, especially when attractively landscaped. Berms are essentially permanent and maintenance needs are generally low depending on the slope and type of ground-cover used. In addition, berms are somewhat more effective (by approximately 3 dBA) than other barriers of the same height. The primary limitation of berms is that they require considerable amount of space, which is not always available, and they may be expensive if sufficient fill material is not available on-site.

3.3.3 Acoustic Fences, Walls or Barriers

Acoustic fences, walls or barriers can be highly effective in attenuating high levels of noise. To be effective, they must break the LOS and be solid and continuous without gaps at ground level or at joints in the structure. Good design necessarily involves both acoustic and aesthetic considerations. Barriers can be attractively designed to achieve compatibility with various architectural styles. Like berms, they offer improved privacy as well as noise protection for both indoor and private outdoor areas. Landscaping can be used to enhance their attractiveness and may also improve their effectiveness from a psychological standpoint. Because barriers require very little room, they offer flexibility of placement and may allow the preservation of trees or other attractive features of the site. A variety of materials may be used singly or in combination. Design and materials choice should reflect consideration of long-term maintenance needs.

3.3.4 Landscaping

Landscaping has long been a part of good site design. It has been used to screen out unwanted views or create attractive ones, to improve the appearance and thereby increase the marketability of new developments. Landscaping can play an important role in mitigating the adverse impacts of transportation noise. While seldom capable of physically attenuating noise to a great extent (maximum of 10 dBA reduction for a 200+ foot belt of tall, dense woods with a substantial proportion of evergreens), it can be used to form a visual barrier which is psychologically effective at reducing the perception of noise. Dense evergreens are generally more effective in this regard because of the year-round protection they afford. In addition, landscape plantings greatly enhance the attractiveness of other noise attenuation measures (berms, fences, walls, barriers) by adding variety of color and texture to the scene and breaking up harsh lines or monotonous expanses.

3.3.5 Acoustical Design and Construction

Acoustical design and construction techniques seek to prevent high levels of exterior noise from entering buildings and interfering with noise-sensitive indoor activities. Exterior noise enters buildings in two basic ways: direct transmission through materials of the building shell and leakage through openings and cracks around windows, doors, ventilation ducts, etc. In poorly constructed buildings, the amount of noise which enters through air leaks is great in spite of the small area involved. An acoustically effective design takes these facts into consideration and minimizes the opportunity for noise entry by its design features, choice of materials, and quality of construction. The following is a partial list of techniques used in acoustic design and construction:

- Elimination of features which may cause sound to reverberate between different parts of a building
- Construction with masonry or other materials that transmit little sound
- Use of air-conditioning to allow year-round internal ventilation
- Location of balconies and noise-sensitive rooms away from major noise sources
- Minimizing of door and window areas facing the dominant noise source
- Use of fixed pane or double-glazed windows, solid, tight-framed doors, and storm doors
- Use of weather stripping and caulking around doors, windows, vents, etc.
- Use of carpeting and acoustical ceilings to absorb noise which penetrates the building shell

It should be noted that a number of these measures are also energy efficient and are frequently employed for that reason alone.

IV. IMPLEMENTATION OF THE RECOMMENDED NOISE GUIDELINES

The Environmental Planning Division will use the recommended guidelines in all phases of its planning and regulatory review functions.

In the master planning process, increased emphasis will be given to identifying areas having potentially serious noise impacts on future development. Existing and projected traffic parameters determined from current and future (ultimate, if available) conditions (e.g., scheduled road improvements, planned projects) will be used in the comprehensive analysis. The feasibility of necessary noise attenuation measures will be considered in land use and zoning recommendations. It is hoped that a thorough consideration of noise at this stage will facilitate implementation of the guidelines at subsequent stages.

Zoning cases, pre-preliminary and preliminary subdivision plans, site plans, development plans and other mandatory referrals will be reviewed in accordance with the guidelines given. The best available traffic information and noise modeling techniques will be used in determining traffic noise contours. At present, the basic traffic noise model used is an adaptation of the Federal Highway Administration's "FHWA-RD-77-108" model programmed for use on a Hewlett-Packard HP-97 calculator and HP3000 minicomputer (reference #12). Work is currently underway to set up a more sophisticated highway traffic noise model, which incorporates noise barrier calculations, on the HP3000 minicomputer. Other models may be employed for special purposes as needed. Existing noise conditions will be considered for each plan under review. Future noise conditions may also be considered if the property under review is adjacent to roads which: (1) are projected (based on master plan and/or development review activities) to have significant increases in traffic volumes or changes in traffic mix within the next 10 years and/or (2) are included in the current Capital Improvements with at least 50 percent of the funding included in the CIP. In short, if substantive changes are expected in traffic (hence, noise) levels in the near future, future-year traffic data will be used in the noise evaluation.

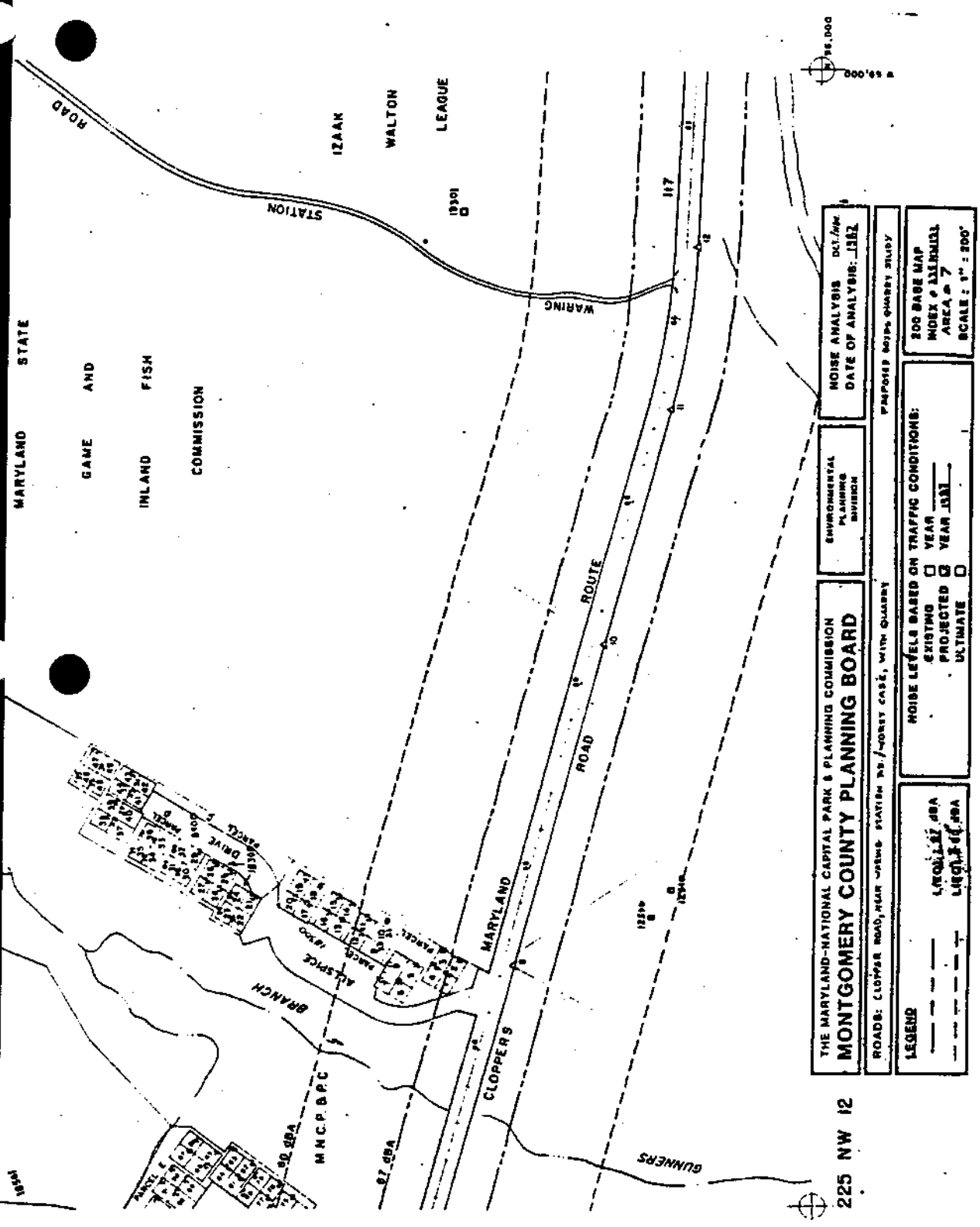
Field investigation and noise monitoring will be performed when necessary. Monitoring will be performed according to accepted practices using a 1945 Community Noise Analyzer or other appropriate equipment.

The Environmental Planning Division believes that a cooperative approach to the resolution of noise problems could benefit all parties. To this end, the Environmental Planning staff welcomes the opportunity to meet informally with developers, their consultants, or other concerned parties to discuss noise impacts and seek mutually acceptable means of addressing them. The staff will consider and evaluate noise analyses by developers/consultants which may provide more detailed data than that obtained from analyses by staff.

In addition, the Environmental Planning Division is plotting noise contours for specific roads in the County using existing and projected future-year traffic data. These traffic noise contour maps may be used by developers and other concerned parties to determine noise impact areas. An example of a noise contour map is shown in Figure 4-1.

Recommendations will be made based on monitored or projected noise levels on the property, the appropriate noise guideline, and consideration of the technical, economic, and aesthetic feasibility of abatement measures. Other factors will not ordinarily be considered during staff review except in a generalized way. Environmental Planning staff

FIGURE 4-1 Example of a Traffic Noise Contour Map



NOISE ANALYSIS DCT/AMM
DATE OF ANALYSIS: 1982

ENVIRONMENTAL PLANNING DIVISION

THE MARYLAND-NATIONAL CAPITAL PARK & PLANNING COMMISSION
MONTGOMERY COUNTY PLANNING BOARD

ROADS: CLOPPERS ROAD, HUR-WALTON STATION RD./MONEY CASE, WITH QUARRY

PMP0201 NOISE QUARRY STUDY

200 BASE MAP
INDEX # 11ENH111
AREA # 7
SCALE: 1" = 200'

NOISE LEVELS BASED ON TRAFFIC CONDITIONS:
EXISTING YEAR _____
PROJECTED YEAR 1981
ULTIMATE

LEGEND
 - - - - - 170 DBA
 - - - - - 180 DBA
 - - - - - 190 DBA
 - - - - - 200 DBA
 - - - - - 210 DBA
 - - - - - 220 DBA
 - - - - - 230 DBA
 - - - - - 240 DBA
 - - - - - 250 DBA
 - - - - - 260 DBA
 - - - - - 270 DBA
 - - - - - 280 DBA
 - - - - - 290 DBA
 - - - - - 300 DBA

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will work with the Development Review and Urban Design staff, as appropriate, to develop recommendations that are included in the staff report to the Planning Board or forwarded to the responsible state or county agency.

The Montgomery County Planning Board will consider staff recommendations based on these guidelines during its regular meetings when the staff report is discussed. Recommendations for noise attenuation will be considered together with other staff recommendations in the context of the needs of County residents, the priorities associated with other objectives of land-use planning, and the responsibility of the Planning Board to balance these and other concerns in its decisions. The Board will then exercise its judgement on whether recommendations will be accepted as given, modified, or whether an exception shall be granted on the basis of an overriding public need or concern. If accepted, the recommendations shall be considered those of the Planning Board and may be applied as conditions for plan approval or included in the Board's final recommendations to other responsible authorities.

APPENDICES A-F

APPENDIX A: NOISE PLANNING WORK AT THE M-NCPPC

The Environmental Planning Division of the Montgomery County Planning Department, conducts noise impact analyses with the aid of the Federal Highway Administration's Highway Traffic Noise Prediction Model, FHWA-RD-77-108 (reference #12). This model has been adapted for use both on a Hewlett-Packard model HP-97 programmable calculator and on the M-NCPPC's minicomputer (Hewlett-Packard HP3000). In addition, staff of the Environmental Planning and Special Projects Divisions are currently setting up a more sophisticated highway traffic noise model, which incorporates noise barrier calculations, on the HP3000. Other models and analysis procedures may be employed as needed (e.g., for evaluating noise from railroads or airports).

The Environmental Planning Division, working under the auspices of the Montgomery County Planning Board and the Montgomery County Department of Environmental Protection, has incorporated noise analysis into all elements of the land-use planning process, including master and sector plans. Since 1978, every master plan where there has been reason to consider noise has included an assessment of potential noise problems and recommendations relating to abatement of excessive noise levels. Existing and future traffic conditions are evaluated to determine projected noise impacts and their effects on future land use. All recent master and sector plans have included a noise assessment.

In addition, since 1979, noise analyses and recommendations have been gradually incorporated into the regulatory review process which includes zoning cases, special exceptions, subdivision and site plans. In this review process, traffic information may be evaluated in terms of both existing and future noise impacts. Existing noise conditions are determined for each plan under review. The analysis of a future-year noise environment for a plan may be conducted if the property under review is adjacent to roads which: (1) are projected (based on master plan and/or development review activities) to have significant increases in traffic volumes or changes in traffic mix within the next 10 years and/or (2) are included in the current Capital Improvements Program with at least 50 percent of the funding included in the CIP. In short, if substantive changes are expected in traffic (hence, noise) levels in the near future, future-year traffic data will be used in the noise evaluation.

Staff guidelines used by the Environmental Planning Division in reviewing plans were proposed in 1980 (reference #10). While these guidelines have not been formally adopted as official policy, the Planning Board has accepted them for staff use in preparing recommendations for Board consideration. As such they have been used as benchmark guidelines with the understanding that both staff and Board may vary somewhat from these guidelines where the circumstances of a particular case are deemed to warrant such action.

Recommendations have been made on numerous regulatory review cases on the basis of these guidelines. Generally, these recommendations have been directed toward achieving the appropriate exterior guideline noise level by use of site-design techniques, setbacks, berms, walls, fences, and/or other measures. Where implementation of exterior guidelines has proven infeasible, impractical, or inappropriate, acoustic design and construction measures have been recommended to achieve an indoor guideline level.

The Planning Board has already reviewed a number of cases in which recommendations for noise abatement were included. Staff recommendations have been considered in

the context of the needs of County residents, and the priorities of land-use planning. In balancing these issues with the unique characteristics of particular cases, the Board has sometimes accepted these recommendations and required them as conditions for plan approval. In other cases, staff recommendations have been modified or deleted from conditions for approval based on the above considerations.

Highway projects and other transportation referrals are also reviewed for noise impacts. Findings and recommendations are given to the Transportation Planning Division for forwarding to the responsible agency as part of the staff report.

APPENDIX B: RESPONSIBILITY FOR FUNDING AND CONSTRUCTION OF NOISE ABATEMENT MEASURES

The Environmental Planning Division recognizes that responsibility for funding and construction of noise abatement measures should be shared by the public and private sectors. The degree of responsibility with which the private sector or the public sector should take in considering and implementing noise abatement measures depends on the stage of development of both the impacting roadway and the noise-sensitive land use project.

In one case, a land use project is proposed adjacent to an existing roadway. In this case, the developer needs to assess the existing noise impacts from the road on the project; and any needed noise abatement measures for the project should be funded and constructed by the developer.

In the other extreme case, a new road is proposed next to an existing residential or other noise-sensitive site or an existing road near the site is proposed for widening. When this situation occurs, the public agency responsible for the road (State Highway Administration or County Department of Transportation) should assess the noise impact of future traffic from the road on the nearby noise-sensitive site. If it is determined that the future noise impacts will be significant, it should be the responsibility of the public agency to fund and construct appropriate noise abatement measures for the noise-sensitive site.

Between these two extreme situations are other cases in which both the land use project and the roadway are at different states of planning and development. The responsibility for the developer or the public agency to fund and construct any needed noise attenuation measures varies with each case. Guidelines for determining responsibility for funding and constructing noise abatement measures are presented in Table B-1. The table gives a framework with which both the developer and public agencies can work together to develop cost-effective strategies to implement noise abatement measures.

TABLE b-1
GUIDELINES FOR FUNDING AND CONSTRUCTION OF NOISE ABATEMENT MEASURES

	<u>Road at Facility Need/ Planning Stage</u>	<u>Road Design and Engineering</u>	<u>Road Construction</u>
Development at Planning Stage	<ul style="list-style-type: none"> • Location to consider existing and approved development (SHA/M-NCPPC). • Development should be compatible or capable of achieving compatibility (M-NCPPC). • Additional R-O-W should be requested for noise abatement. 	<ul style="list-style-type: none"> • Compatible land uses strongly encouraged (M-NCPPC). • Alternative roadway alignments evaluated for noise mitigation potential (M-NCPPC/SHA). 	<ul style="list-style-type: none"> • Compatible land use strongly encouraged. • Potentially incompatible land uses identified - potential solutions suggested (M-NCPPC).
Development at Design and Approval Stage	<ul style="list-style-type: none"> • Compatible land use encouraged (M-NCPPC). • If noise- incompatible land use proposed, encourage <u>all</u> non-structural means for noise impact abatement (M-NCPPC/Developer). 	<ul style="list-style-type: none"> • M-NCPPC to act as intermediary to SHA and developer to develop <u>cost-effective</u> noise abatement measures (M-NCPPC/SHA/Developer). 	<ul style="list-style-type: none"> • Site layout should be compatible with transportation noise, thus reducing impact. Developer should consider site layout and/or structural means of noise abatement (Developer/M-NCPPC). • When insufficient land for berm/barrier exists, SHA/County should consider allowing use of R-O-W (SHA/MC DOT) for this purpose.
Development Constructed	<ul style="list-style-type: none"> • Development that pre-exists road should be protected when cost-effective and aesthetic. Locational decisions for roadway should strongly consider this (SHA/M-NCPPC). 	<ul style="list-style-type: none"> • All highway related noise abatement strategies to be evaluated - costs borne by SHA. • Cost-effectiveness/aesthetic impact considerations (SHA/M-NCPPC). 	<ul style="list-style-type: none"> • Noise abatement project on existing road may be eligible for Federal-aid funding. Otherwise, SHA reduces noise impact upon reconstruction (SHA). • If buildings in noise impacted areas are being reconstructed, encourage acoustic treatment (M-NCPPC, homeowners).

APPENDIX C: NOISE AND PUBLIC LAW

In earlier times most "noise laws" were local ordinances which permitted prosecution when noise became a public nuisance. Recent years have seen the passage of a considerable amount of noise-related legislation at the federal, state, and local levels which go far beyond the "nuisance laws" of the past.

C.1 Federal Laws

Since 1966, Congress has passed several noise-related laws. These include:

Department of Transportation Act of 1966--authorized research and development relating to transportation noise and abatement.

National Environmental Policy Act of 1969--required federal agencies to consider noise as an influence on environmental quality.

Noise Pollution and Abatement Act of 1970--designated EPA to conduct research on noise pollution.

Occupational Safety and Health Act of 1970--designated the Secretary of Labor to establish standards for noise exposure to protect employees of companies in interstate commerce.

Noise Control Act of 1972--set general policy for federal noise abatement and control.

Up to 1982, the Noise Control Act was one of the more important noise-related laws. It gave the EPA Administrator broad responsibility to: protect the public health and welfare from hazardous noise, coordinate all federal noise research and control programs, conduct research and give technical assistance to state and local governments, and disseminate public information on noise. It also directed that regulations be established to limit noise from the operation of interstate motor carriers and railroads and to limit noise emissions of products sold in the U.S. The Act also directed study of airport/aircraft operations with recommendations to FAA to reduce aircraft noise.

However, in late 1982, EPA's noise program was terminated due to the Agency's budget constraints. Activities which had been the responsibility of the Agency's Office of Noise Abatement and Control were transferred, to the extent possible, to state and local governments. Many proposed regulations on federal noise emission standards for various sources (e.g., buses, power lawn mowers, tractors) have been withdrawn.

The termination of EPA's noise program presents a challenge to state and local officials to play a more active role in controlling noise pollution in their own jurisdictions. State and local agencies may want to establish noise emission limits for specific sources that are noise problems in localized areas.

A number of federal and state agencies have developed standards which they use to limit noise impacts on their respective areas of concern. Some of these standards are presented in Table C-1. (See glossary for explanation of noise descriptors.)

TABLE C-1
SOME STANDARDS FOR NOISE LEVELS

Agency Setting the Standards	Purpose of Standard	Noise Level Standard	
		Value (dBA)	Descriptor
EPA	To protect health and welfare with adequate (5 dBA) margin of safety.	55	L _{dn}
EPA	To protect health and welfare	60	L _{dn}
Maryland State Aviation Administration (SAA)	Maximum for approval of residential land uses in airport noise zones	65 (standard)	L _{dn}
		60 (guideline)	L _{dn}
Joint Federal Guidelines by EPA, DOT, HUD, DOD, VA	Maximum normally acceptable for residential areas	65	L _{dn}
HUD	Maximum for approval of loan	65	L _{dn}
DOT	Noise abatement required down to this level for new highways or reconstruction	70	L ₁₀
		67	L _{eq} (peak hour)

The Federal Highway Administration has a policy for funding retrofit noise abatement projects. Section 772.13(b) of Title 23 of the Code of Federal Regulations (CFR) states that "noise abatement measures may be approved for activities and land uses which come into existence after May 15, 1976, provided local authorities have taken measures to exercise land use control over remaining undeveloped lands adjacent to highways to prevent further development of incompatible activities." The publication of the Environmental Planning Division's noise guidelines satisfies the intent of this FHWA policy, and, thus, provides the basis for possible use of Federal monies in situations where existing roadways impact existing residential units.

C.2 State Law

The Maryland Environmental Noise Act of 1974 is a far-reaching and comprehensive act which forms the basis of noise law in the state.

The Act states that "the people of this state have a right to an environment free of noise that may jeopardize their health, general welfare, and property, or that degrades their quality of life."

It establishes the Department of Health and Mental Hygiene (DHMH) as the lead agency in a comprehensive state program for noise pollution control. It directs DHMH to establish sound level limits for noise from private real property and to assist local agencies with enforcement of these regulations. Further, it prohibits counties or municipalities from adopting noise regulations less stringent than the state's.

The Act also provides for the resolution of aircraft noise/land use problems near airports through adoption of noise abatement plans and noise zone regulations.

Political subdivisions of the state are given authority to incorporate noise zone regulations in their zoning ordinances.

C.3 Montgomery County Law

C.3.1 Noise Ordinance

The Montgomery County Noise Ordinance, enacted in 1974, clearly establishes the position of the County with respect to noise. Chapter 31B-1 of the Montgomery County Code (aka, the Noise Ordinance) states:

"The County Council for Montgomery County hereby declares it to be the public policy of the County that every person is entitled to ambient noise levels that are not detrimental to life, health and enjoyment of property. It is hereby declared that excessive or unnecessary noises within the County are a menace to the health, safety, welfare and prosperity of the people of the County."

Briefly, the ordinance sets limits on the permissible sound level for noise at the property line in various zones. These limits are intended to protect a receiver on one property from noise originating from an adjacent property. There are separate standards for commercial or industrial zones and residential zones as follows:

- (1) For noise emanating from sources on a property located in a commercial or industrial zone, the maximum permissible sound level at any point on the property line is 62 dBA. In any boundary separating a commercial/industrial zone from a residential zone, the maximum permissible level at this boundary is 55 dBA.
- (2) If noise is emanating from sources on a property located in a residential zone, the maximum permissible sound level is 55 dBA at any point on the property line.

The above standards are for instantaneous noise with certain specific exceptions allowed for short periods. These standards are designed to protect receiving parcels from excessive noise on adjacent properties. The ordinance also provides for penalties and enforcement. Other sections of the ordinance set limits for noise from individual motor vehicles and other localized sources. However, the ordinance does not set limits for noise received on a property from collective sources such as highways and airports.

C.3.2 Zoning Ordinance and Subdivision Regulations

A major purpose of both the zoning ordinance and subdivision regulations of Montgomery County is to protect and promote the health, safety, comfort, and welfare of the present and future residents of the County (Montgomery County Zoning Ordinance, 1972, Section 59-A-1.1; Montgomery County Code, revised 1981, Section 50-2(i)). Application of the Environmental Planning Division's noise guidelines in the regulatory review process satisfies this intent since one of the factors on which the guidelines are based is the health and welfare effects of noise exposure.

APPENDIX D: NOISE AND PUBLIC HEALTH AND WELFARE

The best understood and most thoroughly researched health effect of exposure to high levels of noise is that of hearing loss. Short-term exposure to high noise levels can cause temporary hearing losses (threshold shifts or shifts in the minimum level of noise that is audible). Repeated exposures can damage the inner ear thereby resulting in permanent hearing loss which ranges from slight impairment to near total deafness.

The noise level at which these effects begin varies according to several factors including: volume (measured in dBA), period of exposure (time), physical and temporal characteristics of the noise, and individual sensitivity of exposed persons.

The U.S. Environmental Protection Agency (reference #2) has determined that the following levels are adequate to protect virtually the entire population from significant noise-induced hearing loss of greater than 5 dBA: 70 dBA - measured as a 24-hour average ($L_{eq}(24)$); or 75 dBA - measured as an 8-hour average ($L_{eq}(8)$) with the remaining 16 hours considered quiet.

A number of other potentially serious health effects of high noise exposure have been found. However, additional research is needed to quantify the relationship between noise and these effects so that the magnitude of the hazard they represent may be properly assessed.

Known effects of noise exposure include the following:

- Constriction of blood vessels
- Increase of heart rate
- Elevation of blood cholesterol levels
- Outpouring of certain hormones from the adrenal cortex (including corticosteroids)

In addition, research has implicated noise as a factor in producing stress-related health effects such as high blood pressure, heart disease, stroke, ulcers and other digestive disorders, and possibly influencing early embryo development during pregnancy.

Environmental noise adversely affects the public welfare in a number of ways exclusive of its direct, health-related effects. It interferes with many activities including sleep, relaxation, conversation, listening to music or television, and the performance of complex tasks.

Sleep is the most noise-sensitive function of the human body. Noise levels of just 32-40 decibels have been known to cause awakening or disrupt normal sleep patterns, causing it to be less restful. Studies to date show elderly people to be markedly more sensitive than young middle-age people to sleep interference from noise. In addition, women are somewhat more sensitive than men. Contrary to popular belief, available evidence indicates people adapt very little, if any, to noise-induced sleep interference over time. The conclusion of research is that sound sleep is essential for normal daily functions and that anything which prevents or disrupts sleep can be very annoying. The hours when most people are sleeping, roughly 10 p.m. to 7 a.m., are thus considered to be particularly noise-sensitive. This is one reason for use of the Day-Night Level, or L_{dn} , as the appropriate description for community noise applications.

The Environmental Protection Agency (reference #2) reported¹ that, in general, the actual noise levels of an area with low L_{dn} values (40-55 dBA) are approximately 10 dBA lower at night than during the daytime. In an area where the L_{dn} values are higher (65-70 dBA), the difference between the actual daytime and nighttime noise levels is not as great; night noise levels may be only 4-6 dBA lower than daytime levels. So, in a high-noise area, nighttime levels will more greatly influence the L_{dn} values (which includes the 10 dBA nighttime penalty) than nighttime levels in a low-noise area. EPA also found that an average home with windows partially open for ventilation provides about 15 dBA attenuation of outdoor noise through its structure.

It can be seen, in view of the above considerations, that an outdoor L_{dn} of 55 dBA provides very good protection from sleep interference due to noise. An outdoor L_{dn} of 60 dBA also provides a substantial measure of protection in this regard. Above this level, closed windows will probably be necessary to achieve adequate protection.

Speech interference has been identified as one of the primary reasons for long-term annoyance and adverse community reactions to noise. EPA (reference #2) determined that an outdoor L_{dn} of 60 dBA allows normal conversation at distances up to 2 meters with 95 percent sentence-intelligibility, which is considered acceptable. This corresponds to an L_{dn} of 45 dBA in the home, using the previously noted assumption of 15 dBA average structural attenuation with partially open windows. Indoor speech intelligibility is 100% at this level.

- Another measure of how environmental noise affects the public welfare is community reaction as measured by response to social surveys or by the number of complaints, threats of legal action, etc. Noise levels above an outdoor L_{dn} of 62 dBA have been found to cause widespread complaints and occasional threats of legal action.

¹ Values given by EPA are considered good general guidance. It must be recognized that the actual time-distribution of noise depends on the source.

APPENDIX E: GLOSSARY

Amplitude - Measure of the change of pressure relative to atmospheric pressure (i.e., measure of the amount of energy) of a sound wave.

A-Weighting - Process of altering sound signals so that low frequencies are de-emphasized. Sound-measuring instruments using this weighting system are found to respond to low-level sounds in a manner similar to the response of the human ear.

Building line - The outdoor face of a foundation wall, enclosed or covered porch, or enclosed or covered portion of a building. In this document, building line refers to habitable structures only; it does not include garages, sheds, or recreational or accessory buildings.

B-Weighting - Processing of sound signals so that low frequencies are only slightly de-emphasized. This weighting system is similar to the way the ear processes moderate sound levels.

C-Weighting - Processing of sound signals in which all frequencies from about 30 hertz to about 8000 hertz are equally weighted.

Cycle - One sequence of a high pressure region and an adjacent low pressure region in a sound wave.

dBA - Decibel, with the A-weighting system used when measuring the sound signal.

Decibel (dB) - Unit of measuring the sound pressure level or amplitude of a sound wave. This is a logarithmic unit and expresses the actual roots-mean-square (rms) sound pressure as a ratio to a reference pressure of 0.00002 pascals:

$$\text{Sound pressure level (dB)} = 10 \log_{10} \left(\frac{\text{rms of actual sound pressure}}{\text{reference sound pressure}} \right)^2$$

Frequency - Number of cycles of a sound wave occurring per second.

Line of sight (LOS) - Imaginary straight line connecting the noise source and the noise-sensitive receiver.

L_{dn} (Day-Night Level) - The L_{eq} descriptor measured over a 24-hour period with 10 dB added for the nighttime hours (10 P.M. to 7 A.M.). This nighttime "penalty" is used to account for the apparent increased sensitivity that most people have for sound during the night.

L_{eq} - Steady sound pressure level which, for a given period of time, contains the same sound energy as the actual time-varying sound during the same time period. This descriptor may sometimes be written as L_{eq}(x), where x is the number of hours in the time period over which the sound pressure level is averaged.

L₁₀ - Sound pressure level that is equalled or exceeded in 10% of a set of observations.

L₅₀ - The median sound pressure level; sound pressure level that is equalled or exceeded in 50% of a set of observations.

L₉₀ - Sound pressure level equalled or exceeded in 90% of a set of observations.

Octave band - A range of sound frequencies in which the upper-limit frequency of the range is twice the lower-limit frequency.

APPENDIX F: REFERENCES

The following documents are the primary sources of information available concerning the technical, legal, and planning aspects of community noise. They are used by the Environmental Planning Division staff in its research.

HEALTH AND WELFARE EFFECTS OF NOISE

1. Effects of Noise on People, U.S. Environmental Protection Agency, Office of Noise Abatement and Control, December 1971.
2. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, Environmental Protection Agency, Washington, D.C. (EPA 550/9-74-004), March 1974.
3. EPA Journal, Vo. 5 Number 9, U.S. Environmental Protection Agency, October, 1979.

NOISE POLICIES, GOALS, REGULATIONS AND STANDARDS

4. "Noise Control", Chapter 31B of Montgomery County Code, 1972.
5. "Environmental Noise Act of 1974," Maryland Department of Transportation, Report No. 2784, May 1974.
6. "Rules & Regulations Governing the Control of Noise Pollutions in Maryland", Code of Maryland Regulations (COMAR) 10.20.01, 1975.
7. "Selection of Airpark Noise Analysis Method and Exposure Limits", Maryland Department of Transportation State Aviation Administration (SAA), January 1975.
8. "Federal Noise Program Report Series - Vol. II (HUD Noise Policy), and Vol. III (Federal Highway Administration Noise Policy)", Environmental Protection Agency, 1977.
9. "Guidelines for Considering Noise in Land Use Planning and Control", report of the Federal Interagency Committee on Urban Noise (Environmental Protection Agency, Department of Housing and Urban Development, Department of Transportation, Department of Defense, and Veterans Administration), May 1980.
10. "Overview of Noise Effects, Standards, Abatement, and Potential Application to Land Use Planning in Montgomery County, Maryland", Stephen D. Federline and Donald A. Downing, November, 1980.

NOISE MEASUREMENT, PREDICTION, AND REDUCTION

1. "Interim Noise Assessment Guidelines", Department of Housing and Urban Development (Galloway & Schultz), 1980.
12. "FHWA Highway Traffic Noise Prediction Model", Department of Transportation Federal Highway Administration (FHWA) Report. FHWA-RD-77-108, December 1978.
13. "National Cooperative Highway Research Program Reports #117, 114, 173 and 174, on Highway Noise", Transportation Research Board, 1971 through 1976.
14. "Design Guide for Reducing Transportation Noise In and Around Buildings", Department of Commerce, National Bureau of Standards, Series 84, April 1978.
15. "Quiet Communities: Minimizing the Effects of Noise Through Land Use Controls", National Association of Counties Research, March 1979.
16. "The Audible Landscape - A Manual for Highway Noise and Land Use", FHWA, November 1974.
17. "A Guide to Visual Quality in Noise Barrier Design", FHWA Implementation Package #77-12, December 1976.
18. "Environmental Noise Pollution", Patrick F. Cunniff, University of Maryland, 1977.
19. "Handbook of Noise Measurement", General Radio Company, 7th Edition, 1974.
20. "Fundamentals and Abatement of Highway Traffic Noise", Volumes 1, 2, and 3, FHWA National Highway Institute, 1973-1974.
21. Handbook of Noise Control Cyril M. Harris. Columbia University, 2nd Edition, 1979.

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