FACTORS AFFECTING MOTOR VEHICLE SOUND ABATEMENT IN RECREATIONAL MICROENVIRONMENTS BENEATH ELEVATED EXPRESSWAYS

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ABSTRACT

FACTORS AFFECTING MOTOR VEHICLE SOUND ABATEMENT IN RECREATIONAL MICROENVIRONMENTS BENEATH ELEVATED EXPRESSWAYS

By

Paul Kimberly Reid

The object of this research investigation is to recommend design techniques for abating motor vehicle sound in recreational microenvironments beneath elevated expressways. Recreation planners and designers are evaluating the usage of undersides of elevated expressways near urban centers for recreational development. However, the recreational use of these environments is hampered by motor vehicles emitting annoying sound levels. The resident of the urban area, identified as a potential user of these recreational areas under expressways, finds motor vehicle sound very annoying and therefore rejects the use of environments near expressways for recreation purposes.

If urban land pressures become critical, spaces beneath elevated expressways could become relatively attractive places to conduct certain neighborhood recreational activities. Such a development would generate the

need for developing nonexistent recreational design criteria capable of directing the development of recreational spaces beneath elevated expressway systems.

The protocol used in this research to recommend design criteria for these spaces relies on the assumption that motor vehicle sound has a behavioral impact upon a person recreating beneath an elevated expressway. Thus, this sound can be lessened or excluded by designing an environment that will allow the recreationist audile displacement of motor vehicle sound.

This design approach will involve a gathering of data related to sound's effects upon man; e.g., sound physics, physiology, psychology, and acoustics. Existing design will be examined and recommendations for new design techniques to abate motor vehicle sound beneath elevated expressways will be suggested.

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By

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"It is safe to estimate that no one professionally concerned with sound fully understands enough about it to escapsulate it with a single or a simple description. So the sound problem continues to be a mystery because neither the parameters nor the depth and breadth of each factor involved are understood well enough to allow comprehension of the full effect of sound stimulation on humans (and animals)."

David M. Lipscomb, Noise: The Unwanted Sounds (Chicago: Nelson-Hall Co., 1974), p. 10.

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DEFINITIONS

While much of the terminology utilized in this paper is commonly used, certain words and word combinations have specific interpretations which refer to the field explored.

Sound: (physics related) a mechanical radiant energy that is transmitted by longitudinal pressure waves in air or other material medium and is the objective cause of hearing.

Noise: any sound that is harsh, unwanted, or undesired; meaning has negative impact due to subjectiveness of the result of hearing. Noise is any sound that is regarded or treated as a nuisance.

Sound becomes noise when its physical components disturb the relationship between man and his fellow man, and man and his environment, or when the acoustic energy causes undue stress and actual physiological damage.

Motor Vehicle: an automotive vehicle not operated on rails; one with rubber tires for use on highways; such as, car, diesel truck, motorcycle, bus.

Motor Vehicle Sound: that mechanical radiant energy transmitted by automotive vehicles.

Ambient Sound Levels: those sounds surrounding on all sides; a mixture of sounds; the measurement of the sounds.

Intermittent Sound Levels: those sounds which stand out above the surrounding sounds and come and go at intervals.

Abate (abatement): exclusion or decrease.

Psychological State: a complex of many processes including sensations, perceptions, actions, thoughts, feelings, attitudes, needs, and motives. Noise, or unwanted sound, in interacting with these processes may have adverse effects resulting in work performance, annoyance, and irritability.

Bel: a scale unit used in comparison of the magnitudes of powers (decibel); 1/10 of a bel (dB), smallest change in sound intensity detectable by the human ear.

A-scale: (Angstrom scale) scale which represents one ten-billionth of a meter (39.37 inches); most nearly approximates human hearing.

Hertz: unit of frequency equal to one cycle per second.

Psychologically Abate: directed toward the will or toward the mind with a tendency to exclude or decrease.

Sound System: many types of longitudinal pressure waves forming a unified whole; a network.

Environmental Sound System: many types of longitudinal pressure waves forming a network acting upon an individual or a community.

Social Noise Survey: questionnaire distributed to residents of an area or region asking them to respond to all aspects of noise in their communities and the impact that the noise has on them individually.

Recreational Microenvironment: area of approximately (45,000 sq. ft. or less) directly located underneath an elevated expressway; area might include examples of tot-lots, vest pocket parks, playgrounds, or passive landscaped areas next to CBD, residential area, or the interim.

Psychological Barrier: directed to the mind or will that impedes or separates.

Sonic: relating to sound; having a frequency within the audibility range of the human ear.

Annoyance: a feeling of irritation, nuisance.

Recreation Experience: the totality of events that one actively volunteers in or is engaged in during leisure and primarily is motivated by the satisfaction or pleasure derived from participating.

Masking: process of superposing sound by the use of other sound.

CHAPTER I

INTRODUCTION

Sound is ubiquitous. From the softest whisper to the sonic boom of a supersonic aircraft, sound is transmitted, propagated, attenuated, absorbed, and reverberated. Man is constantly confronted by sounds of many types: an insect's hum; a jackhammer's pound; a fire siren's shrill; the acceleration of an automobile engine. These sounds contribute to a small sector of a total system of sound; a system in which man must conduct his daily routine.

Man, while attempting to accomplish his daily routine, is confronted by variations in sounds as well as in sound levels. This sound assault is capable of causing annoyance; an annoyance which may be partially alleviated when sounds are combined. An example of this annoyance element is demonstrated by a dripping kitchen faucet. When one is trying to sleep at night, the drip is annoying due to the absence of other household sounds. Contrarily the dripping during nonsleeping hours may be overlooked and may not be heard due to the presence of household sounds.

The history of sound interference can be traced to writings in the Bible. The Bible refers to "noise" in the command, "be still and know" (Psalm 46:10). Even the poet Horace fiercely denounced the "barking of the mad bitch and the squealing of the filthy sow."[1] Sound was used in the battle strategy of Joshua's victory at Jericho and the Chinese employed the use of flutes, drums, and chimes in warfare in order to cause sound trauma in their enemies. Rebel yells and Indian cries had a similar effect in warfare. In 1778, the philosopher Schopenhauer wrote,

> . . . the truly infernal cracking of whips in the narrow resounding streets of the town must be denounced as the most unwarrantable and disgraceful of all noises.[2]

In 1972 when President Richard Nixon signed the environmental pact in Moscow with the Russians, noise was included as an environmental contaminant on which the U.S. and the Soviet Union could work to alleviate. This pact initially placed international emphasis on the sound problem where two countries agreed to combat sound in a joint effort.

The most common sound contribution in man's environmental sound system are motor vehicles. Automobiles and trucks have been found to be the predominant noise

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[1]David M. Lipscomb, Noise: The Unwanted Sounds (Chicago: Nelson-Hall Co., 1974), p. 9.

[2]Ibid., p. 10.

sources in the urban center.[3] Motor vehicle sound interrupts street conversation and verbal communication within office buildings. It causes anxiety and stress and "creates variations in normal physiological processes."[4] On the outskirts of cities motor vehicles travel expressways and highways at rapid speeds causing excessive sounds from tires, brakes, and engine combustion. Consequently, motor vehicle sound encases the expressway.

The levels of motor vehicle sound have become so excessive that not even the newest and most advanced building insulations can abate it.[5] At specific times the decibel levels of diesel trucks exceed 95 dBA and automobiles exceed 85 dBA.[6] Normally these levels on expressways are 80 dBA and 70 dBA respectively. Yet, motor vehicles increase in the urban areas, and highways expand, though not as rapidly to accommodate this increase. Dr. Clifford Bragdon states, "noise is a by product of progress

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[3] Clifford Bragdon, Noise Pollution, the Unquiet Crisis (Philadelphia: University of Pa., 1970), p. 28.

[4] Lucy Kavaler, Noise, the New Measure (New York: John Day Co., 1975), p. 14.

[5] Leo L. Beranek, Noise Reduction (New York: McGraw-Hill Book Co., 1960), p. 131.

[6] J. L. Beaton and L. Bourget, "Can Noise Radiation from Highways be Reduced by Design," Highway Research Record No. 232, 1968, pp. 1-7.

and therefore we must live with it since progress cannot be tampered with."[7]

Presently "73 percent of the nation's total population lives in metropolitan areas."[8] By the year 1990 approximately 80 percent of the U.S. total population will be residing in or adjacent to urban areas. With such a population increase, land area is to become more pressured in urban environments and so the designation of urban lands for human activities is to be decided carefully.

Since many urban land areas are consumed by highways and elevated expressways, the location of expressway corridors disrupts the usage of land beneath and adjacent. Elevated expressways segment central business districts and sever residential areas, isolating the populations of urban centers. Expressway corridors locate primarily where low income neighborhoods exist, where the land is relatively accessible for highway easements, or where future expressway placement shows feasibility for least environmental impact upon the urban center. The land areas under expressways were previously open space, backyards, playfields, and street intersections but are converted to secondary streets, alleyways and byways for

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[7]Clifford Bragdon, op. cit., p. 36.

[8]"Social and Economic Characteristics of the Metropolitan and Nonmetropolitan Population - 1974-1970," (Washington, D.C.: U.S. Census Bureau, 1970), p. 11.

pedestrians, and garbage collectors linearly displayed beneath the elevated structures.

Due to the unattractive undersides of elevated expressways, people consider these areas as psychological barriers and thus refuse to enter these environments beneath expressways.[9] An example of this dilemma occurred in Boston with the completion of the John F. Fitzgerald Expressway in 1963. Pedestrians enroute to shopping areas, the waterfront, and office buildings, who knew that they must cross the Expressway, would rather circumvent the Expressway than travel under it.[10]

Therefore, in order to alleviate this psychological barrier, more inviting environments must be created beneath these structures. Not only is safe and pleasant passage through the expressway corridor desirable, but the establishment of an environment capable of attracting less transient activities should be considered. If urban land pressures become too critical, spaces beneath elevated expressways could become relatively attractive places to conduct certain neighborhood recreational activities. Such a development would generate the need for developing non-existent recreational spaces beneath elevated expressway

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[9] Downtown Waterfront Faneuil Hall Urban Renewal (Boston, Mass.: Boston Redevelopment Authority, April 15, 1964), p. 30.

[10] Ibid., p. 35.

systems. The basis for generating such criteria constitutes the purpose of this study.

The hypothetical milieu assumed in this research includes these parameters: (1) the land areas beneath elevated expressways are adjacent to a Central Business District (CBD), adjacent to a residential area, or located between the two in what is referred to as the transition zone; (2) that the area beneath has accessibility to recreationists walking or bicycling; and (3) that motor vehicle sound is psychologically harmful to the individual recreating under an expressway.

Methodology

The data for this research will gather recommendations which will show the relationship between motor vehicle sound and sound abatement in recreational areas beneath expressways. The recommendations will reflect design techniques that might be implemented so that the recreationist under an expressway is less aware of motor vehicle sound.

The methodology for this research involves a gathering of information concerning (1) the nature of sound and sound's physics domain, (2) the physiological effect of motor vehicle sound upon humans, (3) the psychological effect of motor vehicle sound upon humans, (4) acoustics related to present highway design to abate motor vehicle sound, (5) design techniques to abate motor vehicle sound under expressways, (6) an evaluation of design techniques, and (7) a summary.

Objectives

The objectives of this research are:

(1) to identify the results of medical studies of motor vehicle sound upon humans, thus demonstrating sound's effects upon peoples' pathological processes;

(2) to evaluate sound's psychological effects on stress, fatigue, and tolerance;

(3) to evaluate "social noise surveys";

(4) to identify currently employed techniques to abate motor vehicle sound on highways and elevated expressways;

(5) to establish new design techniques for decreasing or excluding the effect of motor vehicle sound upon human activity under elevated expressways.

Literature Review

The Physics of Sound

"Sound can be identified by three elements; a source, a path, and a receiver."[11] The source is the instrument vibrating; the motor vehicle. The path is the direction the sound waves or vibrations travel; the corridor or expressway Along this path the vibration might

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[11]Clifford Bragdon, op. cit., p. 34.

be diverted, reflected, absorbed, reverberated, or dissipated. Eventually, the vibrations reach a person or object; the receiver or in this case, the recreationist.

Sound waves have the capacity to travel through different media such as air, solids, or liquids and still maintain their capacity to reach the receiver. The sound waves can travel short distances or long distances and may be intermittent during transmission. The steadiness of the wavelength causes a prolonged sound, such as a fire siren. A "bleep," such as that emitted by an electrocardiograph, is an example of an intermittent sound.

Sound has different intensities and frequencies. An example of intensity and frequency can be identified by blowing a dog whistle. Only a dog or an animal with similar hearing capacity can hear the sound emitted from this whistle. The human being is unable to hear the whistle because the sound is beyond human hearing capacity. The physical make-up of the dog's inner ear is more complex than the human's, and consequently the dog's ear can detect higher pitched sounds of greater intensity.

This scale of human hearing is often referred to as the "range of sound" that one can hear. Each sound has a specific decibel level and hertz level, and the range is variable for each individual. As one ages, the ear becomes less sensitive to sound and therefore the range decreases from the extremes of the scale. For instance, a person at age 25, might be able to hear a range of 30 to 120 dBA at 300-1200 hertz. A person at age 80 might hear a range of 50 to 80 dBA at 400-900 hertz.

The Physics of Motor Vehicle Sound

When measuring the sound emitted by motor vehicles, the use of very technical instruments are of the utmost importance. These technical instruments measure motor vehicle sound in decibels as registered on the Angstrom Scale as dBA. The dBA corresponds to the intensity of the sounds (for human hearing capacity). Authorities of the sound realm state,

> . . . the A-scale or dBA measurement of sound most clearly fits the requirement for easy measurement plus the A-scale most nearly approximates human hearing and reaction to sound . . . . The A-scale is understandable to the average person, involves no transportation calculations, and A-scale meters are less expensive than other types.[12]

Motor vehicle sound is primarily caused by tires, brakes, acceleration, and deceleration. These combined factors register a specific number of decibels emitted at specific distances from the motor vehicle. For example, at 25 feet from an expressway an automobile traveling at a constant 60 mph emits an average of 81 dBA. At 50 feet the same automobile emits an average of 77 dBA. Therefore, one can understand that as distance increases between the

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[12]Melville C. Branch, Jr., "Outdoor Noise, Transportation, and City Planning," Land Use and the Environment: An Anthology of Readings (New York: Hall Co., 1969), p. 53.

source and receiver, the decibel count decreases. "But other factors enter that influence decibel levels, such as road gradient, road surface material, speed, heaviness of the vehicle, vehicles passing a certain location per hour, and the smoothness of traffic flow."[13]

The motor vehicle category also encompasses diesel trucks, buses, and motorcycles, all identified by specific decibel levels. During peak traffic periods trucks emit approximately 95 dBA. Buses emit approximately 80 dBA and motorcycles range between 80-90 dBA. These elements of "this sound system have a terrific effect on expressway environments."[14]

Motor vehicle sound is transmitted across the elevated expressway surface, reverberated among buildings, reflected by guardrails, and transmitted along the steel and concrete structures of the expressway. Overhanging buildings above the expressway inhibit sound movement upward and consequently reflect the sound onto the expressway. Due to the expressway's linearity, the sounds echo and propagate down the corridor. The streets, sidewalks, and ramps vibrate from the continual sound assault. The sound levels become so annoying that even motorists shut their automobile windows in order to listen comfortably to their

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[13]"New Housing and Road Traffic Noise," Bulletin No. 26 (London, Eng.: Dept. of the Environment, Her Majesty's Stationery Office, 1970), p. 4.

[14]Clifford Bragdon, op. cit., p. 15.

car radios. Pedestrians, particularly those suddenly exposed to the sound, may need to protect their ears from certain intense sounds. Office workers may be unable to open windows in their offices because of the relentless nature of motor vehicle sound. The complete expressway environment quakes in its own shower of sound.

The Physics of Motor Vehicle Sound Beneath Elevated Expressways

Motor vehicle sound emitted above the expressway and adjacent to the expressway travels throughout the expressway environment. The decibel levels for such sound are especially noticeable in the microenvironments created beneath elevated expressways. In some instances these spaces may entrap sound, intensifying its impact.

The Physiological Effects of Sound Upon Man

When considering the effects of sound it is necessary to explain the effects of sound upon human health. The World Health Organization quotes the definition of "health" as, "a state of complete physical, mental, and social well being and not merely an absence of disease and infirmity."[15]

"Several investigations have demonstrated that sound does change the physiological state."[16] Furthermore,

[15] William Burns, Noise and Man, 2nd ed. (Philadelphia: J. B. Lippincott Co., 1973), p. 61.

[16] "Noise As A Public Health Hazard," Proceedings of the Conference, ASHA Report No. 4 (Washington: American Speech and Hearing Association, February, 1969), p. 89.

"until it is proven that these physiological changes are negligible, sound must be considered to be a possible detrimental influence on human health."[17]

Experimental animals subjected to concentrated exposure and high, prolonged frequencies of decibels have demonstrated defects such as auditory deficiency, nervous conditions, blood circulation blockage, dilation of the pupils, and aerteriole constriction. The dosages in these cases were distributed in large quantities over a time span and not intermittently. Therefore, greater effects occurred in shorter time periods and the results were magnified beyond average means. Despite the laboratory implications, the findings on the health issues of sound are somewhat vague and "are personal beliefs rather than grounds capable of medical verification."[18]

The Physiological Effects of Motor Vehicle Sound Upon Man

Humans and experimental mice under laboratory conditions have had traffic sounds equal to 70 dBA-90 dBA inflicted upon them. Results found there to be "no conclusive evidence that exposure to urban traffic sound

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[17] Ibid., p. 90.

[18] William Burns, Noise and Man, 1st ed. (Philadelphia: J. B. Lippincott Co., 1969), p. 66.

under normal conditions produces any harmful effects."[19] Normal conditions do not mean excessive or large dosages. Thus, normal exposure to motor vehicle sound over a very long period of time, may have no effect on man.

Aram Glorig states, "As far as the physiological state is concerned, it is well known and documented that sound from 75 dBA upward will produce various temporary changes in the physiological state."[20] The majority of motor vehicle sound ranges between 60 dBA and 100 dBA. Therefore, one could state that motor vehicle sound might have an effect upon man's physiology, but that the physiological effect of motor vehicle sound is very minimal.

The Psychological Effects of Sound Upon Man

Sound has a stimulating effect upon the mental set of man. A total absence of sound stimuli "is poorly tolerated by man. His reactions are extreme apprehension, fear, and even panic."[21] However, an overabundance of sound stimuli is poorly tolerated. Since "sound stimuli

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[19] J. Lang and G. Janson, "Report on the Environmental Health Aspects of Noise Research and Noise Control," World Health Organization Report (New York: United Nations, May, 1967), p. 21.

[20] Aram Glorig, "Non-Auditory Effects of Noise Exposure," Sound and Vibration, Vol. 5, No. 5 (May 1971), p. 17.

[21] Gilbert C. Tolhurst, "Acoustic Fatigue of Humans Exposed to Noise," Naval Research Reviews (Washington, D.C.: August, 1971), p. 20.

are an intimate part of man's psychological state,"[22] such phenomena as sensations, perceptions, actions, thoughts, feelings, attitudes, needs, and motives, might effect work performance, create annoyance, or cause irritability.

A popular view of sound stimuli as a cause of stress is expressed in the following quote:

> . . . of the new diseases that human life evolves in its progress, various forms of nervous weaknesses . . . are distinctly traceable to sound . . . . The slow and almost insensible influence of sound on the nervous system tends to wear and break it down.[23]

In the vernacular of psychology, stress is identified as "the state of an organism whose reaction to the environment is characterized by anxiety and tension or a defensive behavioral response."[24] Sound might be correlated with tension and anxiety in individuals. Likewise, the stress question could be argued in the negative. There is no correlation between sound levels and stress but that the differentiation between the two is a correlation of individual perception and attitude toward sound.

Dr. Karl Kryter, an authority in the noise field, explains the perception of sound:

> . . . various psychological and sociological factors present in individuals and a community influence the

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[22]A. Carpenter, "Effects of Noise on Performance and Productivity," Control of Noise Symposium, No. 12 (London, Eng.: Her Majesty's Stationery Office, 1962), p. 12.

[23]"Noise As A Public Health Hazard," op. cit., p. 63.

[24]Ibid., p. 27.

> annoyance felt and the behavior expressed by people in response to the annoyance caused by noise. People will fairly consistently judge among themselves the unwantedness, unacceptableness, objectionableness, or noisiness of sounds that vary in their spectral and temporal nature provided that the sounds do not differ significantly in their emotional meaning and are equally expressed.[25]

Therefore, to state that the buzz of an insect might be vastly different from the sound of an automobile, is a difference in the meaning of the sound to the receiver.

There is some experimental proof of the relationship between the subjective scales of noisiness and loudness. As with loudness the scale is found to be dependent upon the experimental method used and how the sound is judged. People in sound environments base this judgement of sound upon a scale comparable to "desired, indifferent, and undesired sound levels."[26] This scale is a subjective perception scale of sound and for sound levels of varying degrees. The scale registers

> . . . the subjective magnitude of loudness and noisiness changing to a like degree; e.g., a 10 dBA increase in the physical intensity . . . causes a doubling of the subjective magnitude of its loudness and its noisiness.[27]

Fatigue is another element of sound's psychological effect upon man. Fatigue is defined as "a complex, mutually

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[25] Karl D. Kryter, The Effects of Noise on Man (Academic Press, n.p., 1970), p. 231.

[26] A. Alexander et al., Road Transportation Noise (Halsted Press, n.p., 1975), p. 25.

[27] Karl D. Kryter, op. cit., p. 256.

independent group of deteriorative damage that are ordinarily reversible (i.e., overcome by adequate rest and change of activity) but in extreme cases can cause . . . mental disturbance."[28] "Psychological fatigue is a state of an individual that will impel him to seek change."[29] If the individual is confronted by an unpleasant sound environment, that person may refuse to enter the environment, or may seek another environment that is sound free.

Auditory fatigue, defined as the result of an overload of sound upon an individual, is likely to impel the individual to seek change particularly if the sound is obtrusive. Overabundance of sound or a mixture of different intermittent sounds can cause sensory overload and consequently cause auditory fatigue. However, the human body has certain adaptive capabilities to physical pressure. This phenomenon is known as physical elasticity. "Man seems to become accustomed to meeting meaningful sound stimuli if they are repeated frequently."[30] Within limits a repeat of sound stimuli upon man increases his physical elasticity.

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[28] Encyclopedia Britannica, Vol. 9, s.v., "Fatigue," by A. G. Bills.

[29] Gilbert C. Tolhurst, op. cit., p. 20.

[30] G. Jasen, "Effects of Noise on Physiological State," Ward and Fricke, eds., in Noise As A Public Health Hazard, ASHA Report No. 4 (Washington, D.C.: American Speech and Hearing Association, 1969), p. 91.

When one is making conversation, sound interference has an immediate impact upon communication. Obtrusive sounds intermingle with the verbal network and can cause interruptions in the process. The sound interruptions may be loud or soft. But, when the two combine, one must give way. If the louder of the two sounds (motor vehicle sound) surpasses the 60 dBA of conversational sound, then the effectiveness of verbal communication is lessened.

Individual task performance is also affected by sound levels. In laboratory experiments, long exposure to sound levels caused experimental mice to disregard tasks or functions and not to finish what they were attempting. The loud and continuous sound levels broadcast during the task performances caused anxiety in some instances and apathy in others. Consequently, the mice became disoriented and uninterested with the task, and the task remained interrupted as long as the sound exposure was present. When the mice were exposed to intermittent sound levels, the task performance was interrupted momentarily but when the sound ended, the task was completed.

The degree of anxiety created by sound disturbance hinges upon the individual's adjustment to specific sound levels and attitude formulation about sound. Similarly, "changing a person's attitude toward sound under laboratory conditions can also change his personal reaction to that sound."[31] Since this attitude change is feasible, the task performance under given sound levels can be accomplished. But the feasibility of attitude change must involve educational techniques, convincing the individual before entering the sound environment, that the sound is pleasant or favorable. The individual, upon entering the environment and being confronted by the sound, can then complete the task that otherwise was interrupted by sound.[32]

Because tolerance levels (a relative capacity to endure or adapt physiologically to an unfavorable environment) are linked with adaptation (adjustment to environmental conditions) and perception (awareness of environmental elements), the difficulty in understanding tolerance is likewise subjective. The tolerance level has no objective method of measurement. Therefore, one who cannot judge perception levels will not be able to evaluate tolerance levels, because the subjectiveness of the terms allows frequent interchangeability in word usage.

The Psychological Effects of Motor Vehicle Sound Upon Man

Peoples' responses to motor vehicle sound in their neighborhoods, communities, and cities constitute one element of the urban sound system evaluation process. To

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[31]Theodore Berland, The Fight for Quiet (n.p., Prentice Hall, Inc., 1970), p. 56.

[32]Ibid., p. 57.

gather these responses concerning motor vehicle sound, a special instrument referred to as a "social noise survey" has been conducted in large metropolitan areas of the U.S.[33] The results from portions of the population sampled are of particular interest to this study.

Automobiles and trucks were the predominant noise sources in Philadelphia with the highest periods of noise emulating between 7:00 AM and 10:00 AM, and between 3:00 PM and 7:00 PM. The lowest levels were identified between 11:00 PM and 6:00 AM. People were annoyed by motor vehicle sound that had an irregular pattern. For example, horn blowing, tire squealing, motor acceleration, and muffler noise were predominant. Despite the sound created by aircraft, surface traffic was the predominant and most widespread source of noise; but not necessarily the most irritating form.

In New York City, respondents responded similarly, but also indicated that motor vehicle sound was harmful to their health and well-being. They responded further that after being exposed to motor vehicle sound, they had feelings of anger, irritability, and nervousness. These feelings caused "yelling at their spouse and children,

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[33]Clifford Bragdon, Noise Pollution, The Unquiet Crisis (Philadelphia: University of Pennsylvania Press, 1971), p. 33.

inability to sleep, and uneasiness when shopping in urban areas."[34]

In conducting a social noise survey means must be established to first test whether the respondents are responding truthfully. Secondly, that this truth corresponds in some way with the realities of social behavior must be established. Thirdly, when considering sound in anything other than an electronic sense, it must be emphasized that the survey is dealing with an environmental quality--a subject-object relationship involving attitude.

Although the responses from social noise surveys involve more than a questionnaire, one can easily see that a combination of elements must be considered. Dr. Clifford Bragdon feels that presently, in testing people about sound and its effect upon them, "the social noise survey" is the best instrument for eliciting peoples' feelings concerning sound and noise."[35]

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[34]Ibid., p. 41.

[35]Clifford Bragdon, op. cit., p. 152.

CHAPTER II

PRESENT ACOUSTICAL DESIGN OF ENVIRONMENTS NEAR EXPRESSWAYS

The expressway environment discussed in this paper includes concrete ramps and steel infrastructure, adjacent buildings within 100 feet, streets beneath the expressway ramps, multiple road crossings, and interchanges. The widths of streets passing beneath the expressways and the height of building construction adjacent to expressways causes multiple reflections of sound. The streets cause a continuous linear propagation of sound and verticle structures cause sound zones (areas of high sound concentration) and shadow zones (an area of high sound concentration created by buildings overtowering smaller buildings and creating sound reflections over these shorter buildings). Noise canyons (sound enclosures created by vertical buildings lining a street from both sides and trapping sound within) are also prevalent.

> The street that is narrow and has high buildings has a longer reverberation time than the wider street with shorter buildings lining it. It would be expected that the sound would be trapped and would be reflected in the former case than in the latter and this is

borne out by the longer reverberation time for that situation.[36]

Another important aspect of sound propagation near an expressway is the ability of sound from motor vehicles to enter streets that cross beneath an expressway. "Although the sound levels do decrease as they propagate down the cross-streets, the decrease is minimal."[37]

In the large and irregular enclosures caused by building placement adjacent to expressways motor vehicle sound is reverberated so that "the number of sound waves striking a given surface per second is so large that at each surface, sound waves from all directions are equally probable."[38] The more openings under the expressway and between adjacent buildings, the greater is sound's penetrative ability. Consequently an expressway environment with numerous spatial voids, harbors and reflects motor vehicle sound waves. The elevated expressway, serving as a roof for the areas beneath, entraps the sound and forces sound waves downward to the ground and outward to adjacent buildings. Every guardrail, concrete pillar, and steel support reflect the sound upward and outward into the expressway atmosphere.

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[36]Richard H. Lyon, Lectures in Transportation Noise (n.p., Grozier Publishing Co., 1973), p. 67.

[37]Ibid., p. 68.

[38]Leo L. Beranek, Noise Reduction (McGraw-Hill Book Co., 1960), p. 93.

During peak traffic times, particularly in "rush hours," motor vehicle sound increases by two to three decibels as the traffic flow doubles. The level of motor vehicle sound ranges as high as 95 dBA as the sound waves reverberate from the expressway pavement. At this decibel level motor vehicle sound dominates the expressway environment and allows little intervention for other sounds.

Noise Abatement and Highway Design

Highway technicians have designed much equipment utilized in expressway construction, many of which have been used to move traffic more efficiently. Consequently traffic movement has drawn the most attention from highway engineers. But recently, new design techniques have been implemented to alleviate motor vehicle sound; a greater factor of highway movement. This process of instigating new design for expressways has been forced upon highway departments by local residents living adjacent to expressways who complain that the sound levels from motor vehicles are annoying. In addition, city zoning ordinances for sound control have instigated new highway design criteria for motor vehicle sound abatement near expressways. Zoning laws have refused certain residential development near multi-laned expressways and only similar land uses with similar sound levels (e.g., industry) have been allowed to locate next to expressways. The zoning has allowed for only open space to remain adjacent to expressways.

Highway designers have minimized road shoulder gradients to curb the acute angles of sound transmitted from the road edges; the greater the acute angle, the greater the sound level. Reflective shields have been placed alongside expressways to block the sound and to transmit the sound upward and over building surfaces. This design reduces reflections among buildings and road surfaces. Sound reflector and absorber materials such as heavily weighted plastics, lead sheet, steel sheet, concrete gypsum board, rubber synthetics, and sheet asphalt have been used as sound barriers and sound insulators along expressway corridors. Experimentation with both elevated expressways and depressed expressways has been conducted to determine whether sound levels from motor vehicles vary. So far, these attempts at physically obstructing motor vehicle sound have only decreased sound levels minimally.

Noise Abatement and Expressway Landscaping

Highway beautification, erosion control, and snow drift displacement have all been accomplished through the careful use of plant materials along highway rights-of-way. Little consideration has been used in planting for the absorption of automobile sound. Presently expressways are inadequately landscaped for sound control.

> It has been frequently claimed that a line or area of trees and brush can produce sound isolation. Although it is true that there is a transmission loss in the propagation of sound through a woods, the actual

> magnitude of this transmission loss is generally only a few decibels unless the depth of the growth is considerable.[39]
>
> . . . Not only is great density of planting required with branches reaching to the ground but also an appreciable height of planting is necessary; otherwise the sound is propagated over rather than through the tree barrier.[40]

Experimentation with dense plantings has indicated that "1000 feet of woods, thick enough to limit visibility to 70 feet, will decrease sound in the 200-1000 cycles per second range by only 20 dBA, more than would the open distance alone."[41] From these examples one can see that the use of plant materials as presently practiced along expressways, does not contribute significantly to sound abatement.

A productive absorber of motor vehicle sound transmitted from expressways is the barrier or berm, a mound-like product of soil sculpturing. The berm, if built specifically to proper height above the expressway, can absorb significant quantities of motor vehicle sound. The addition of plant materials with berming allows increased efficiency of sound absorption. The Russian design for traffic sound abatement barriers consists of a

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[39] Richard H. Lyon, op. cit., p. 106.

[40] Leo L. Beranek, op. cit., p. 113.

[41] Kevin Lynch, Site Planning (Cambridge, Mass.: The MIT Press, 1962), p. 100.

> . . . 3 meter high earth bank with a reinforced concrete screen on top, built along each side of the road . . . . The bank, terracing down to the buildings, would be planted with trees. It is estimated that the barrier, standing several score meters from the buildings, would almost completely screen the sound of automobile.[42]

[42] "Screens to Cut Traffic Noise," Modern Transport/UK, Vol. 93, N2402, June 1965, p. 28.

CHAPTER III

DESIGN TECHNIQUES TO ABATE MOTOR VEHICLE SOUND BENEATH EXPRESSWAYS

Recreational activities included beneath elevated expressways might include active recreation (e.g., playgrounds, tot-lots, vest-pocket parks) and passive recreation (e.g., landscaped areas, sitting areas). But due to the extreme levels of motor vehicle sound, recreationists engaged in recreational activity beneath elevated expressways might be aware of the sound levels and consequently their experience to be gained in recreating might be hampered. Possibly the sound levels can be abated for the recreationist to allow a better recreational experience.

Utilization of selected design techniques in abating motor vehicle sound can create an atmosphere wherein the recreationist is less aware of motor vehicle sound. The injection of new design techniques will better allow the recreationist to exclude motor vehicle sound levels that otherwise would be annoying. The following discussion exemplifies some specific design techniques that might abate the sound under elevated expressways.

Landscaping

Although an "extensive amount of forested area is needed to physically decrease motor vehicle sound,"[43] plantings lend an atmosphere of pleasantness, relaxation, and beauty near highways and expressways. The greenery allows enclosed spaces between the roadway and adjacent buildings to gain greater depth (volume or area enlargement). The greenery, due to its deep hues creates a somber and mellow effect upon the environment. People surrounded by greenery experience a "cooling effect."[44] Plantings also eliminate the feeling of "emptiness" in enclosed spaces. The use of plantings creates free enclosure (a meandering volume which allows movement of the eye in any direction). Plantings combined with berming allows the areas under elevated expressways to have greater spatial accentuation. This spatial accentuation allows definition of areas that might create an atmosphere of seclusion for the recreationist from motor vehicle sound. These secluded areas could approximate areas for relaxed activity (e.g., sleeping, newspaper reading, etc.).

Masking Techniques of Water, Music, Lighting, and Floor Materials

The primary purpose of masking (process of superposing sound by the use of other sound) is to eliminate

[43]Kevin Lynch, op. cit., p. 100.

[44]Ibid., p. 101.

intermittent sound levels. For example, the sound imposed by the steady movement of traffic would be an ambient sound whereas the intervention of a passing fire truck with sirens fulminating would be an intermittent sound. Therefore, the masking might detract from the force of the siren sound, and intermingle with the traffic movement sound. By covering intermittent sounds, such as the fire siren, there is less chance of the siren startling the recreationist. The masking would eliminate the chances of sound annoyance.

The implementation of water under expressways, particularly falling water, would mask motor vehicle sound levels. The falling of water and splashing over rocks creates a sound level that might mask the sound levels. With additional support for masking, the inclusion of water in design contributes to "relaxed" atmospheres associated with recreationists' attitudes.[45] The use of terraced walls combined with planters of living plantings and falling water might easily be implemented to mask motor vehicle sound under expressways.

The injection of music beneath elevated expressways might mask sound. By piping in dreamy melodies, the recreationist might be encouraged to slow his pace (such as background music in shopping malls). Since music is a

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[45] D. Lowenthal and M. Riel, "The Nature of Perceived and Imagined Environments," Environment and Behavior, Vol. 4, No. 2, June 1972, p. 8.

mood stimulator, different tempos of music and different styles of music might be used in specific areas beneath expressways.[46] If the recreation area is basically passive (e.g., sitting, picnicking, conversation), then soft music might be appropriate. Otherwise, if the environment is active (e.g., running, jumping), then the music tempo would quicken and be more forceful. The music could be incorporated into areas beneath expressways by strategically placing speakers hidden among plantings and near walkways.

Because undersides of elevated expressways are without sunlight, the inclusion of artificial lighting techniques might create a pleasantness of these areas. Forceful lighting such as "dusk-to-dawn" lighting and subtle lighting such as fluorescent colored lighting, might be acceptable in specific given situations. Lighting adjacent to plantings might require subtle design whereas design for ceiling lighting under expressways might require powerful illumination. The choice of lighting design, as music, should compliment the recreational activity. The combination of these design techniques (water, music, and lighting) might allow the recreationist displacement of motor vehicle sound.

Another technique possible in masking motor vehicle sound might be the use of specifically designed floor

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[46] M. Southworth, "The Sonic Environment of Cities," Environment and Behavior, Vol. 4, No. 2, June 1972, p. 26.

materials for areas underneath elevated expressways. As recreationists ambulate across the flooring, the floor materials emit sounds that resemble recreational activity (e.g., pops, squeaks, rumbles). Incorporation of floor materials into environments under elevated expressways might mask sound and append an additional element to the recreation experience.

Murals

Inclusion of paintings about concrete pillars, on concrete embankments and expressway walls, and on expressway undersides might add user appeal to these sterile concrete surfaces. Presence of bold colors and artistic designs might add additional liveliness to the recreational atmosphere. The mural design might follow a theme for the recreational area and assimilate an indoor play area's design. Natural outdoor scenes, cartoon animation, and attractive signage could well add incentive for recreational use. This may not abate sound but the inclusion of this design element could create a better recreational environment under elevated expressways.

Acoustical Materials

Acoustical materials were invented "to physically decrease sound magnitude through the absorption process;"[47]

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[47] P. H. Parkin and H. R. Humphreys, Acoustics, Noise and Buildings (New York: Praeger Publishers, 1958), p. 42.

an obstruction in the path of sound transmittance before sound reaches the receiver. Consequently many materials have been designed to meet this absorption criteria. But the "most advanced acoustical materials decrease sound only minimally."[48] The result of acoustical materials' success has resulted in literature propaganda. People are educated about acoustics in such a way that they become aware of what is acoustically acceptable to themselves. A person may be instructed about a specific acoustical material and its usefulness in sound absorption. The same person is then placed in a room acoustically designed with that specific material. The person responds that the room is quiet, but in actuality, authorities of sound acoustic materials feel that the room is insufficient for sound absorption. The person has been propagandized before entering the sound environment and has responded likewise.

By making recreationists aware of acoustical materials, they might think that the environment is sound free or the sound is significantly abated. The use of acoustical tile under elevated expressways, around pillar supports, and on play apparatus might well serve the purpose of psychologically abating motor vehicle sound. The implementation of carpeting and styrofoam might have this effect as well as the use of spongy materials (e.g., cotton wool and fiber glass wool) placed in visible locations under

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[48]Ibid., p. 49.

expressways. Even lining walls with acoustical tiles and reflector materials within easy sight, may psychologically abate motor vehicle sound.

Additional Design Elements

In alley spaces and byways that cross under expressways, where pedestrians pass between shopping areas and housing, these areas under expressways might be housing, etc., these areas under expressways might be sensitized with hidden lights and speakers that would be activated by photo-electric cells planted along the walkways. A sound-light sequence would be formed each time a person passed by the photo-cells to create on explosion of lights, color, and novel sounds. Then the sounds could be amplified, distorted, or reflected and large sound and light reflections would force sound, color, and images at strategic points of play emphasis or landscape interest. Even the use of large, animated structures designed with photocells which detect passersby in play areas, would create sound that would psychologically abate motor vehicle sound.

One must consider that one, two, or all combinations of the previously mentioned designs could be implemented, but careful selection of design techniques must be emphasized. The selection must take into consideration that the use of specific combinations of designs does not increase the confusion already prevalent in these areas.

CHAPTER IV

CONCLUSIONS AND EVALUATIONS

The most effective "method for controlling airborne motor vehicle sound involves four steps: (1) quieten the source (the motor vehicle), (2) spoil the path (interpose a dense, nonpermeable barrier), (3) protect the receiver (obstruct or enclose), and (4) absorb the remainder (line the enclosure)."[49] The design techniques discussed in Chapter III might be implemented in recreational areas beneath elevated expressways to satisfy one, two, three, or all elements of the previously discussed "four step process." However, the use of each technique depends on the needs and characteristics of individual environments beneath expressways.

Landscaping

Highway and expressway motor vehicle sound has been "unsuccessfully controlled by scanty landscaping and inadequate landscaping practices"[50] resulting from the economics

[49] J. L. Beaton and L. Bourget, "Can Noise Radiation from Highways be Reduced by Design," Highway Research Record No. 232, 1968, p. 2.

[50] Ibid., p. 7.

of design implementation (high cost of plantings) and the nonavailability of large tracts of land adjacent to elevated expressways for adequate numbers of plantings to abate sound. Landscaping ranks relatively low in abating motor vehicle sound. Although a variety of plantings are aesthetically pleasing to man, the livelihood of plantings maintaining beneath expressways is virtually impossible. The use of planting materials (e.g., high grasses, trees, and short grasses) adjacent to expressways, where sunlight and precipitation is attainable might well entice the development of recreational areas beneath these structures. But due to plantings' inefficiency to absorb motor vehicle sound, landscaping beneath expressways shows minute support.

Masking Techniques

Motor vehicle sounds are very high and annoying in vicinity to expressways and little can be accomplished to design for the physical elimination (decibel decrease) of sound levels, masking design might prove the most favorable for these environments. Of the four masking techniques (water, music, lighting, and floor materials), water might prove the most feasible since water experimentation in architectural spaces is more widespread and understood.[51] Lighting might be second to water design

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[51] Scott C. Hayward and S. Samuel Franklin, "Perceived Openness-Enclosure of Architectural Space," Environment and Behavior, Vol. 6, No. 1, 1974, p. 23.

because lighting techniques have undergone little experimentation under expressways, other than lighting design that has been used for street illumination.[52] Music and floor materials might rank high for design implementation if inclusion of music and floor sound allows suitable masking levels for motor vehicle sound. If the music levels add increased sound confusion, then these design elements should be eliminated for these environments.

Murals

Mural technique, for the sake of simple implementation, might be one of the best designs for enhancing recreation beneath expressways. Covering the pillars, walls, and concrete embankments of the expressway with paintings of natural outdoor scenes, animated cartoon characters, and modern art, these environments might become more realistic for play and recreation whereas previous to painting, the environment represented a cool, gray concrete atmosphere.

Although this technique shows no ability to physically decrease decibel levels, the use of bright and colorful color media might beautify these areas and consequently increase the enjoyment of the area. The inclusion of murals might add the "vacant element" to undersides of expressways and psychologically abate motor vehicle sound.

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[52]Ibid., p. 16.

Acoustical Materials

Each acoustical material has a specific task to perform in either sound reflection, absorption, or reverberation. In vicinity to expressways, little sound decibel decrease has been accomplished through the use of acoustical materials. Acoustical materials might work well within buildings, but their use and success is questionable under elevated expressways. Consequently this design technique ranks heavily toward nonfeasibility.

Sonic Design

The inclusion of hidden lights, sound and light reflection, or large animated structures that emit masking sounds could be implemented only if careful consideration is taken concerning each specific environment under an expressway. Lighting could be used for many purposes such as:illuminating sitting areas. Large animated structures could be used in childrens' playgrounds, tot-lots, etc., for masking motor vehicle sound. As the children climb on the structure or pass by the structure, the photo-cells within the structure are triggered and stimulate a tape recorder within the animated animal. The children might therefore become so engrossed by the structure's sounds that motor vehicle sound is secondary. These examples of sonic design could be adapted to recreational areas under expressways but further testing of the design can only justify their future use.

CHAPTER V

SUMMARY

This research has attempted to introduce a concept of micro-recreational development beneath elevated expressways and to suggest design techniques for the abatement of motor vehicle sound in these environments. Thus by introducing this concept, the research has carried the reader through a series of explanations concerning the parameters of sound.

The study has evolved two basic concepts of the design process. First, before any design is implemented, the individual or groups of individuals who are to be considered in the design, must be understood (one's physiology, psychology, etc.). And second, the design during the formulation period should be adapted to suit the individual's performance capabilities in accordance with the design and the environment. Therefore the proper technique and approach to recreational microenvironment design beneath elevated expressways allows design with man in mind.

By examining the motor vehicle sound environment of expressway corridors, the intent of this research is to develop a sensory awareness in city residents toward motor vehicle sound near elevated expressways and furthermore hoped to identify an environment more responsive to human action and purpose beneath elevated expressways. Conversely the intent of this research study is not to serve as an instrument for rebuilding the socially torn and down-trodden segments of urban areas where housing and overcrowding are predominant, employment is at a low level, and crime and insecurity are demonstrated. This research would be used by such agencies as the U.S. Department of Housing and Urban Development, the U.S. Bureau of Public Roads, the Environmental Protection Agency, commissions for noise abatement, recreation planning commissions, planning commissions, and state highway departments for understanding the future placement of recreational areas under expressways or rehabilitating already existing recreational areas beneath elevated expressways in urban areas.

The following quotes, borrowed from Harold Proshansky, summarize this research.

> The study of environmental process from the point of view of a particular participation in that process creates a situation dichotomized into participant, on the one hand, and all other environmental components on the other.[53]

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[53]Harold M. Proshansky, Environmental Psychology: Man and His Physical Setting (City University of New York: Holt, Rinehart, and Winston, Inc., 1970), p. 69.

SELECTED REFERENCES

And further,

> Although the participant remains largely unaware of his surroundings in the environmental process, these surroundings continue to exert considerable influence on his behavior.[54]

In case, the participant described is the recreationist and the environment is one beneath an elevated expressway. Motor vehicle sound is the major component emphasized and this sound in turn is one element of the expressway environment that continues to exert influence on man's behavior while recreating.

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[54]Ibid., p. 70.

SELECTED REFERENCES

Acoustic 1974. Edited by R. W. B. Stephens, Eighth International Congress on Acoustics, Chelsea College, University of London, Chapman and Hill Publishing Co., 1974.

Alexandre, A. et al. Road Transportation Noise. Halstead Press, 1975.

Anthrop, Donald F. Noise Pollution. Lexington, Mass.: Lexington Books, 1973.

Aylesworth, T. G. This Vital Air, This Vital Water, Man's Environmental Crisis. Rand-McNally and Co., 1973.

Bartlett, F. C. The Problem of Noise. Cambridge Press, 1934.

Baron, Robert A. The Tyranny of Noise. St. Martins Press, 1970.

Beaton, J. L., and L. Bourget. "Can Noise Radiation from Highways be Reduced by Design." Highway Research Record No. 232, 1968.

Beranek, Leo L. Noise Reduction. McGraw-Hill Book Co., 1960.

Berland, Theodore. The Fight for Quiet. Prentice-Hall, Inc., 1970.

Bishop, Bruce A. Socio-Economic and Community Factors in Planning Urban Freeways. U.S. Department of Transportation (FHA), September, 1970.

Blake, Michael P., and W. S. Mitchell. Vibration and Acoustic Measurement Handbook. New York: Spartan Books, 1972.

Bolt, Beranek, and Newman, Inc. Noise Environment of Urban and Suburban Areas. Washington, D.C.: U.S. Printing Office, 1967.

Borsky, Paul N. "The Use of Social Surveys for Measuring Community Response to Noise Environments." Transportation Noise, James D. Chalupnik (ed.). University of Washington Press, 1970.

________. "Community Reaction to Air Force Noise." Report TR 60-689, National Opinion Research Center, University of Chicago, 1961.

Botsford, James H. "Using Sound Levels to Gauge Human Response to Noise." Sound and Vibration, October 1969, pp. 16-28.

Bragdon, Clifford. "Noise Control in Urban Planning." Seminar January 28, 1976, Urban Planning Department, Michigan State University, East Lansing, Michigan.

________. "Urban Planning and Noise Control." Sound and Vibration, Vol. 7, No. 5, May, 1973.

________. Noise Pollution, The Unquiet Crisis. Philadelphia, Pa.: University of Pennsylvania Press, 1971.

Branch, Melville C. "Outdoor Noise, Transportation, and City Planning." Land Use and the Environment: An Anthology of Readings, Virginia Curtis (ed.), American Society of Planning Officials, 1972.

Broadbent, D. E. "Effects of Noise on Behavior." Handbook of Noise Control, C. M. Harris (ed.). New York: McGraw-Hill, 1957.

Burns, William. Noise and Man, 2nd edition. Philadelphia, Pa.: J. B. Lippincott Co., 1973.

________. Noise and Man, 1st edition. Philadelphia, Pa.: J. B. Lippincott Co., 1969.

Carpenter, A. "Effects of Noise on Performance and Productivity." Control of Noise Symposium, No. 12, Her Majesty's Stationery Office, London, England, 1962.

Chedd, Graham. Sound From Communication to Noise Pollution. Doubleday Co., 1970.

"Children at Play." Design Bulletin No. 27, Great Britain Department of the Environment, Her Majesty's Stationery Office, London, England, 1970.

Dale, Edwin L., Jr. "Noise is Prevented and Reduced Only at an Economic Cost." New York Times Magazine, pt. 1, Sec. 6, Sun. 19, April 1970, pp. 27-29, 40, 42, 44, 47.

Donley, Ray. "Community Noise Regulation." Sound and Vibration, Feb., 1969.

Donovan, Jerry, P. E. "Community Noise Criteria." American Industrial Hygiene Assoc. J., Nov., 1975.

Downtown Waterfront Faneuil Hall Urban Renewal. Boston, Mass.: Boston Redevelopment Authority, April 15, 1964.

Duerden, C. Noise Abatement. London, Eng.: Butterworth and Co., 1970.

Embleton, T. "Sound Propagation in Homogeneous Deciduous and Evergreen Woods." J. Acoust. Soc. of Amer., Vol. 35, 1969.

Emme, J. H., and H. C. Blanchford. "Composite Materials for Noise and Vibration Control." Sound and Vibration, Vol. 4, No. 7, July, 1970.

Encyclopedia Britannica, Vol. 9, S. v. "Fatigue," by A. G. Bills, 1963.

Eysenck, H. J. "Personality and Tolerance for Noise." From Proceedings of the Symposium on the Psychological Effects of Noise, Cardiff, University of Wales, September, 1967.

________. "Personality and Experimental Psychology." Bulletin British Psychology Society, Vol. 19, 1966, pp. 1-28.

Findley, Roger W., and I. Michael Heyman. Open Space and and Land. Institute of Governmental Studies, University of California, Berkeley, 1965.

Foreman, Emmerson, and Dickinson. "Noise Level/Attitudinal Surveys of London and Woodstock, Ontario." Sound and Vibration, Vol. 8, No. 12, December 1974, p. 21.

Galloway, W. J., W. E. Clark, and J. S. Kerrick. "Highway Noise: Measurement, Simulation, and Mixed Reactions." NCHRP Report No. 78, Highway Record Board, National Academy of Sciences, 1969.

Garling, T. "Studies in Visual Perception of Architectural Spaces and Rooms." Scandinavian J. of Psychology, Vol. 10, pp. 250-256.

Givens, M. P., W. L. Nyborg, and H. K. Schilling. "Theory of the Propagation of Sound in Scattering and Absorbing Media." J. Acoust. Soc. of America, Vol. 18, 1967, p. 284.

Glass, David C., and J. E. Singer. Urban Stress; Experiments on Noise and Social Stressors. Academic Press, 1972.

Glorig, Aram. "Non-Auditory Effects of Noise Exposure." Sound and Vibration, Vol. 5, No. 5, May, 1971, p. 15.

Goldstein, Steven N. "A Prototype Index for Environmental Noise Quality." Sound and Vibration, Vol. 6, No. 2, February, 1972, p. 25.

Goodfriend, L. S. and Associates. Report on Social Noise Surveys. Washington, D.C., U.S. Department of Housing and Urban Development, 1971.

Harrison, Robin. "Off-Road Vehicle Noise Measurements and Effects." In Proceedings of the 1973 Snowmobile and Off-Road Vehicle Research Symposium, Dept. of Resource Development, Michigan State University, East Lansing, MI, 1970.

Hawell, W. A. Acoustic Noise and Its Control Publication 26. Institute of Electrical Engineers, Savory Place, London, England, 1967.

Hayhurst, J. D. "Acoustic Screening by an Experimental Runningups Pen." J. Royal Aeronaut. Soc., Vol. 57, 1953, p. 1.

Hayward, D. G., Marilyn Rothenburg, and R. R. Beasley. "Children's Play and Urban Playground Environments: A Comparison of Traditional, Contemporary, and Adventure Playground Types." Environment and Behavior, Vol. 6, No. 1, 1974, p. 13.

Hayward, Scott C., and S. Samuel Franklin. "Perceived Openness-Enclosure of Architectural Space." Environment and Behavior, Vol. 6, No. 1, 1974, p. 35.

Hillquist, R. K. "Objective and Subjective Measurement of Truck Noise." Sound and Vibration, Vol. 1, 1967, pp. 8-13.

Hood, J. D., and J. P. Poole. "Tolerable Limit of Loudness: Its Clinical and Physiological Significance." J. Acoust. Soc. of Amer., Vol. 40, 1966. p. 47.

Jansen, G. "Effects of Noise on Physiological State." ASHA Report No. 4 in Noise As A Public Health Hazard, Ward and Fricke (eds.), Washington, D.C., 1969, pp. 89-96.

Jenkins, M. A., and J. Pahl. "Measurement of Freeway Noise and Community Response." J. Acoust. Soc. of Amer., Vol. 58, No. 6, December, 1975, p. 11.

Johnson, D. R., and E. G. Saunders. "The Evaluation of Noise from Freely Flowing Road Traffic." J. Sound Vibration, Vol. 7, 1968, p. 287.

Jones, Arthur L. "A Highway Design Engineer's Consideration of Highway Noise." Masters Thesis, Michigan State University, East Lansing, MI, 1973.

Kavaler, Lucy. Noise, the New Menace. New York: John Day Co., 1975.

Knudsen, Vern O. "Case Study of Los Angeles with Special Reference to Aircraft." Outdoor Noise and the Metropolitan Environment, Branch et al. (eds.), Los Angeles, Department of City Planning, 1970.

Kryter, K. D. The Effects of Noise on Man. Academic Press, 1970.

Kugler, B. A., and G. S. Anderson. "Automotive Noise: Environmental Impact and Control." Highway Research Record No. 390, 1972, pp. 45-55.

Lang, J., and G. Jansen. Report on the Environmental Health Aspect of Noise Research and Noise Control. United Nations: World Health Organization Report, May, 1967.

Lipscomb, David M. Noise: The Unwanted Sounds. Chicago: Nelson-Hall Co., 1974.

Lowenthal, D., and M. Riel. "The Nature of Perceived and Imagined Environments." Environment and Behavior, Vol. 4, No. 2, June, 1972, p. 17.

Lynch, Kevin. Site Planning. Cambridge, Mass.: MIT Press, 1962.

Lyon, Richard H. Lectures in Transportation Noise. Grozier Publishing Co., 1973.

McKennell, A. C., and E. A. Hunt. "Noise Annoyance in Central London." The Government Social Survey, 1966.

Mills, C. H. G. "The Measurement of Traffic Noise." The Control of Noise. London, Eng.: Her Majesty's Stationery Office, 1962, p. 345.

Mills, C. H. G., and D. W. Robinson. "The Subjective Rating of Motor Vehicle Noise." Engineer 211, 1961, p. 1070.

"Noise As A Public Health Hazard." Proceedings of the Conference, ASHA Report No. 4, Washington, D.C.: Amer. Speech and Hearing Assoc., February, 1969.

Parkin, P. H., and H. R. Humphreys. Acoustics, Noise and Buildings. New York: Praeger Publishers, 1958.

Priede, T. "Noise and Vibration Problems in Commerce Vehicles." J. Sound Vib., Vol. 5, 1967, p. 129.

Proshansky, Harold M., Ittelson, and Rivlin. Environmental Psychology: Man and His Physical Setting. City University of New York, Holt, Rensbart, and Winston (eds.), 1970.

Robinson, D. W. "The Concept of Noise Pollution Level." Aerodynamics Division Report Ac 38. United Kingdom: National Physical Laboratory, March, 1969.

Ronan, Colin A. The Meaning of Sound. New York: Hart Publishing Co., Inc., 1967.

Rutledge, A. J. Anatomy of A Park. New York: McGraw Hill Book Co., 1971.

"Screens to Cut Traffic Noise." Modern Transport/UK, Vol. 93, N2402, June, 1965, p. 28.

Sexton, B. H. "Traffic Noise." Traffic Quarterly, Vol. 23, No. 3, 1969, p. 427.

Southworth, M. "The Sonic Environment of Cities." Environment and Behavior, Vol. 4, No. 2, June, 1972, p. 43.

Still, Henry. In Quest of Quiet. Harrisburg, Pa.: Stackpole Books, 1970.

Taylor, Rupert. Noise. Penguin Books, Inc., 1970.

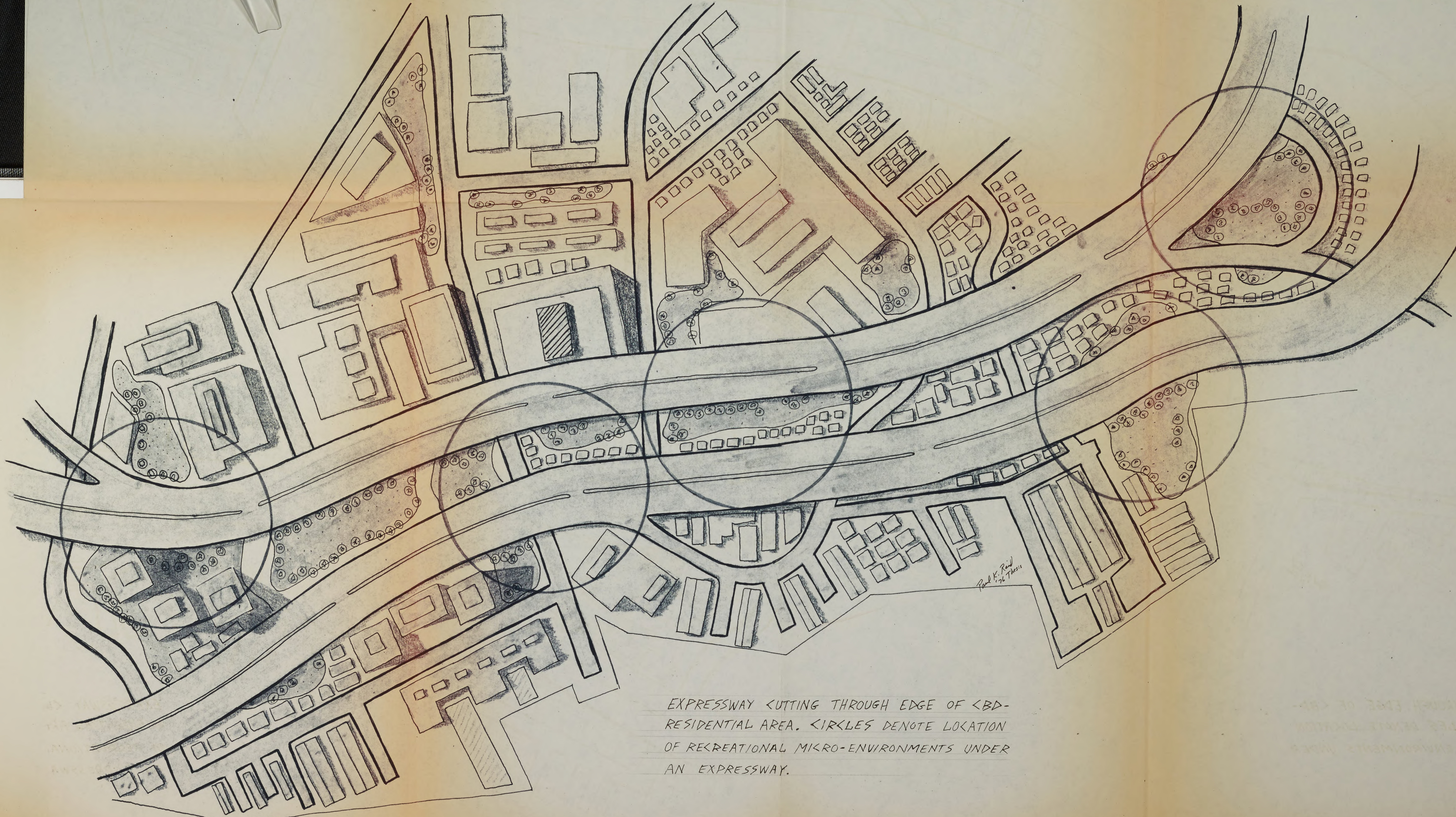
Thiessen, G. J., and N. Olson. "Community Noise-Surface Transportation." Sound and Vibration, Vol. 2, No. 4, April, 1968, p. 27.

Tolhurst, Gilbert C. "Acoustic Fatigue of Humans Exposed to Noise." Naval Research Reviews, Washington, D.C., August, 1971, p. 20.

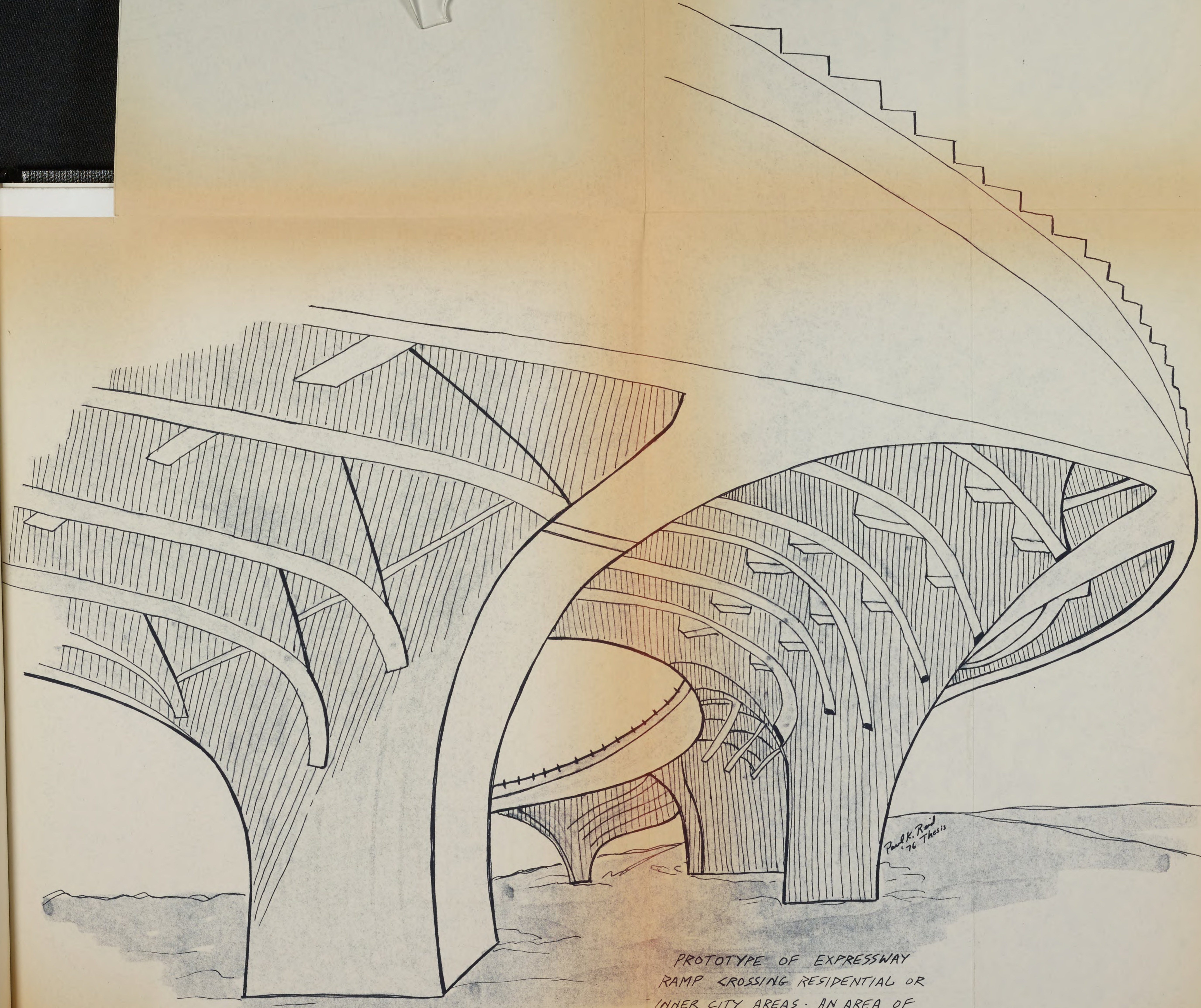
"Urban Traffic Noise, Strategy for an Improved Environment." Report of the Consultative Groups on Transportation Research, 1971.

Webster, J. C. "Effects of Noise on Speech Intelligibility." In Noise As A Public Health Hazard, ASHA Report No. 4, Ward and Fricke (eds.), Washington, D.C., 1969, p. 89-96.

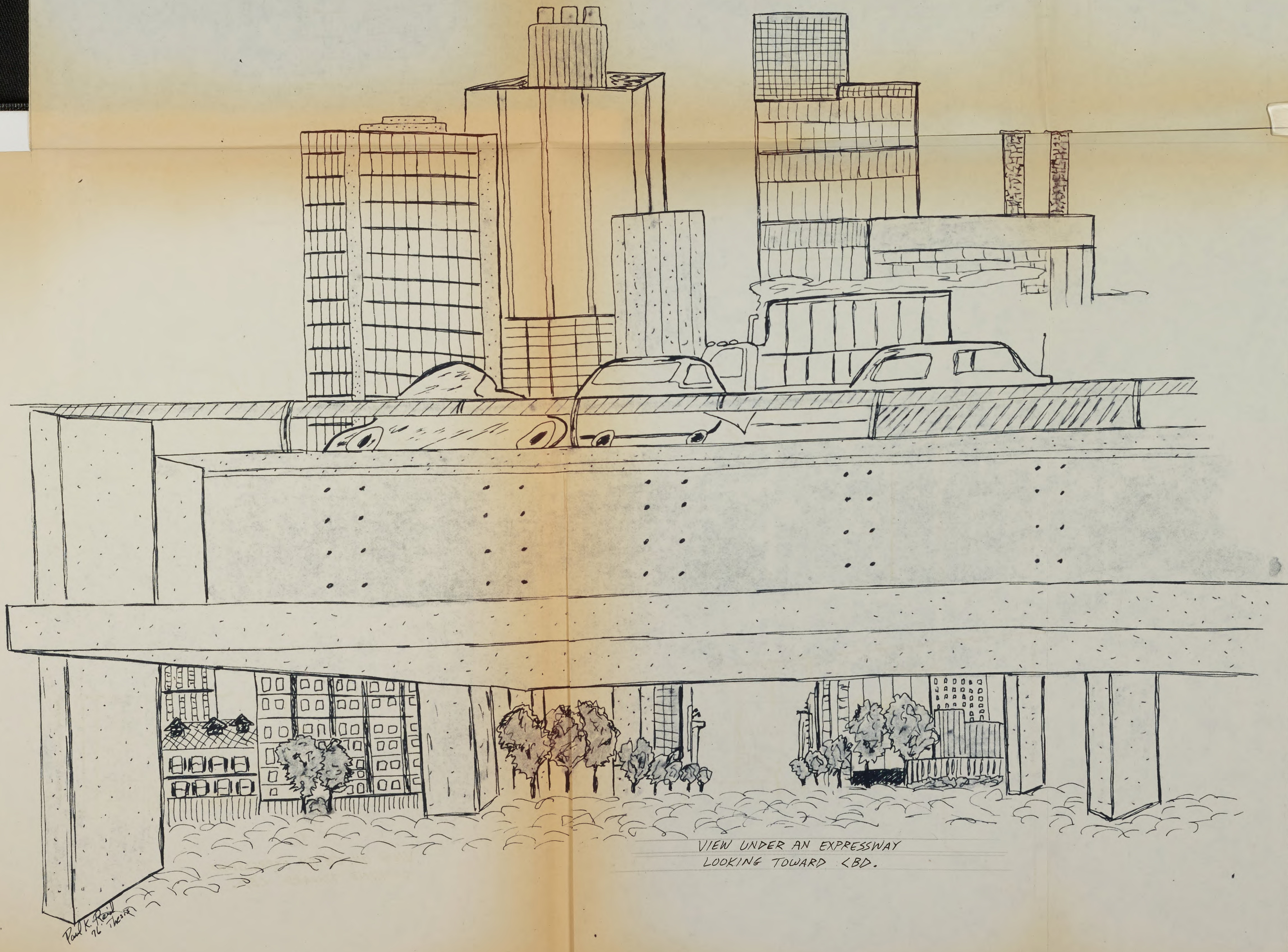
APPENDIX



EXPRESSWAY CUTTING THROUGH EDGE OF CBD-RESIDENTIAL AREA. CIRCLES DENOTE LOCATION OF RECREATIONAL MICRO-ENVIRONMENTS UNDER AN EXPRESSWAY.

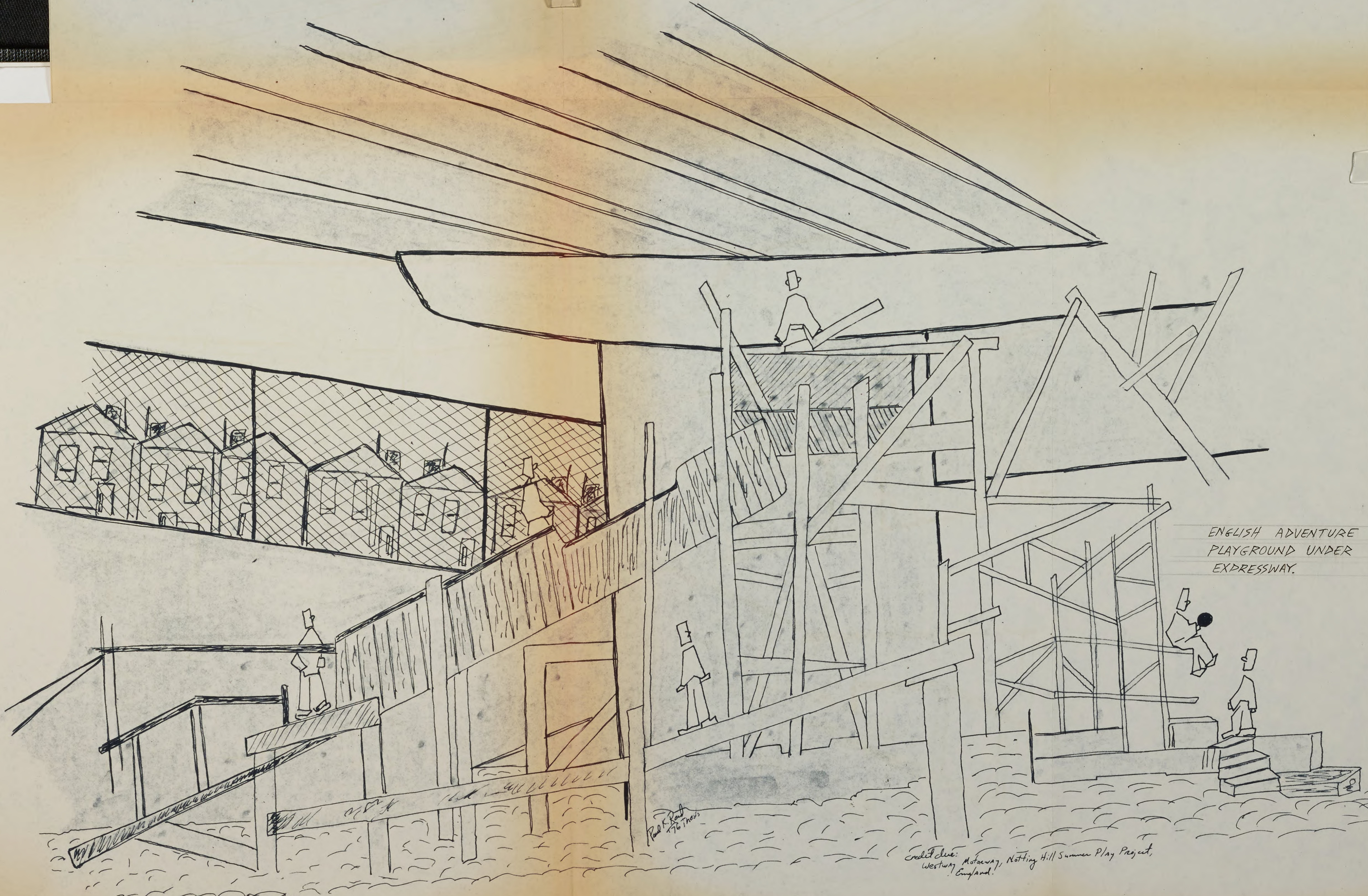


PROTOTYPE OF EXPRESSWAY RAMP CROSSING RESIDENTIAL OR INNER CITY AREAS; AN AREA OF RECREATIONAL DEVELOPMENT.

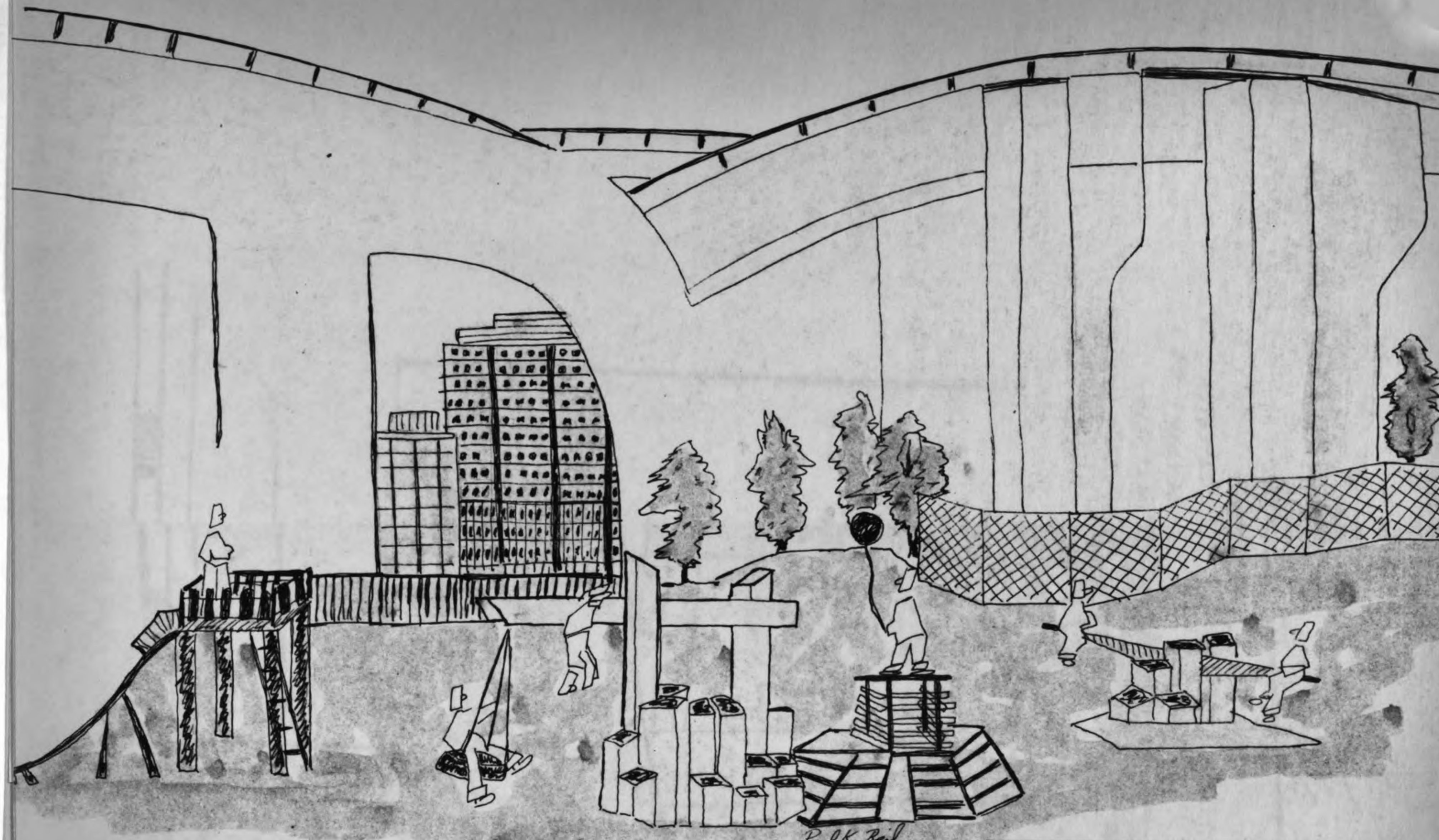


VIEW UNDER AN EXPRESSWAY
LOOKING TOWARD CBD.

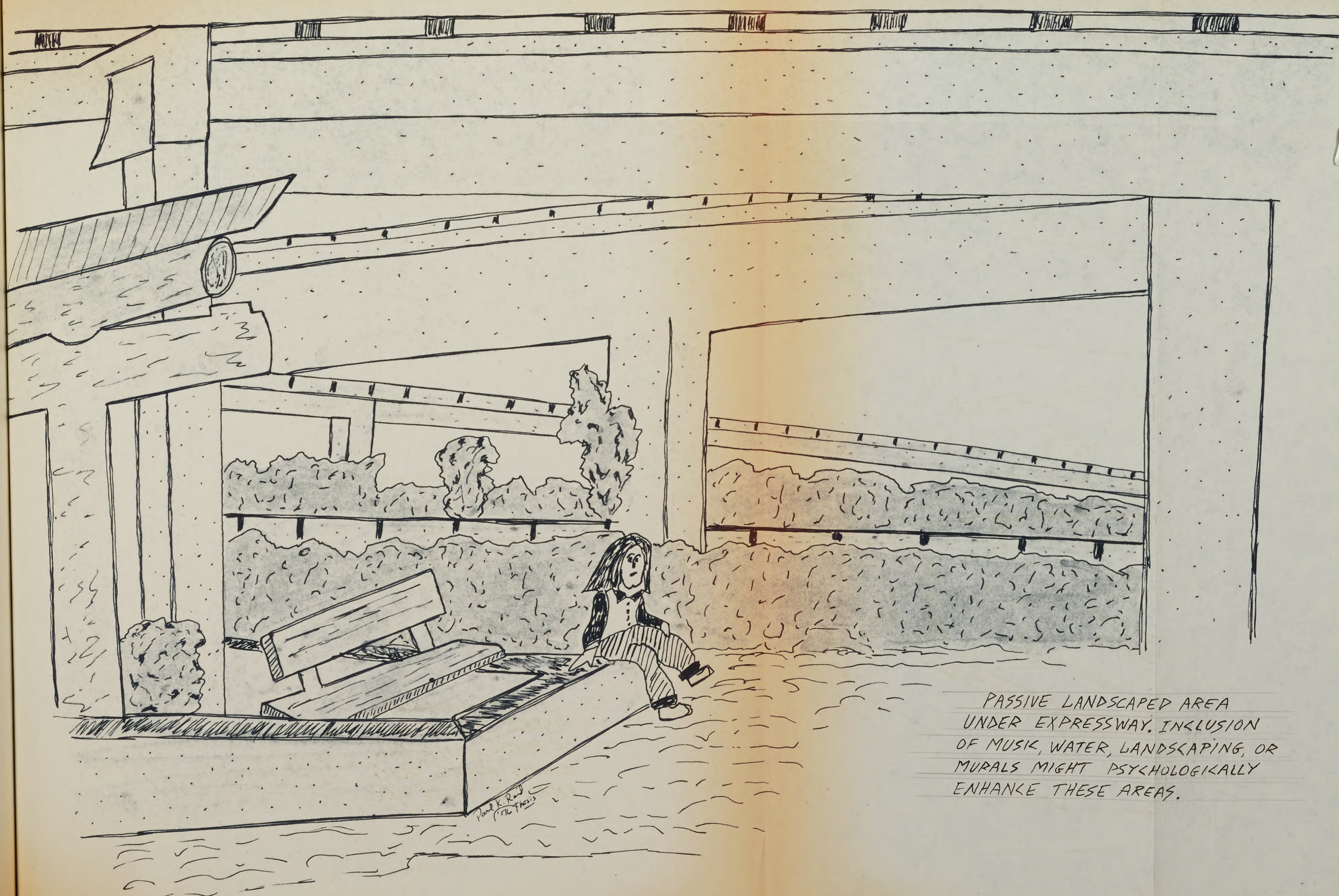
THE UNDERSIDE OF AN ELEVATED EXPRESSWAY. OPENED, UNUSED SPACE IS ABUNDANT.



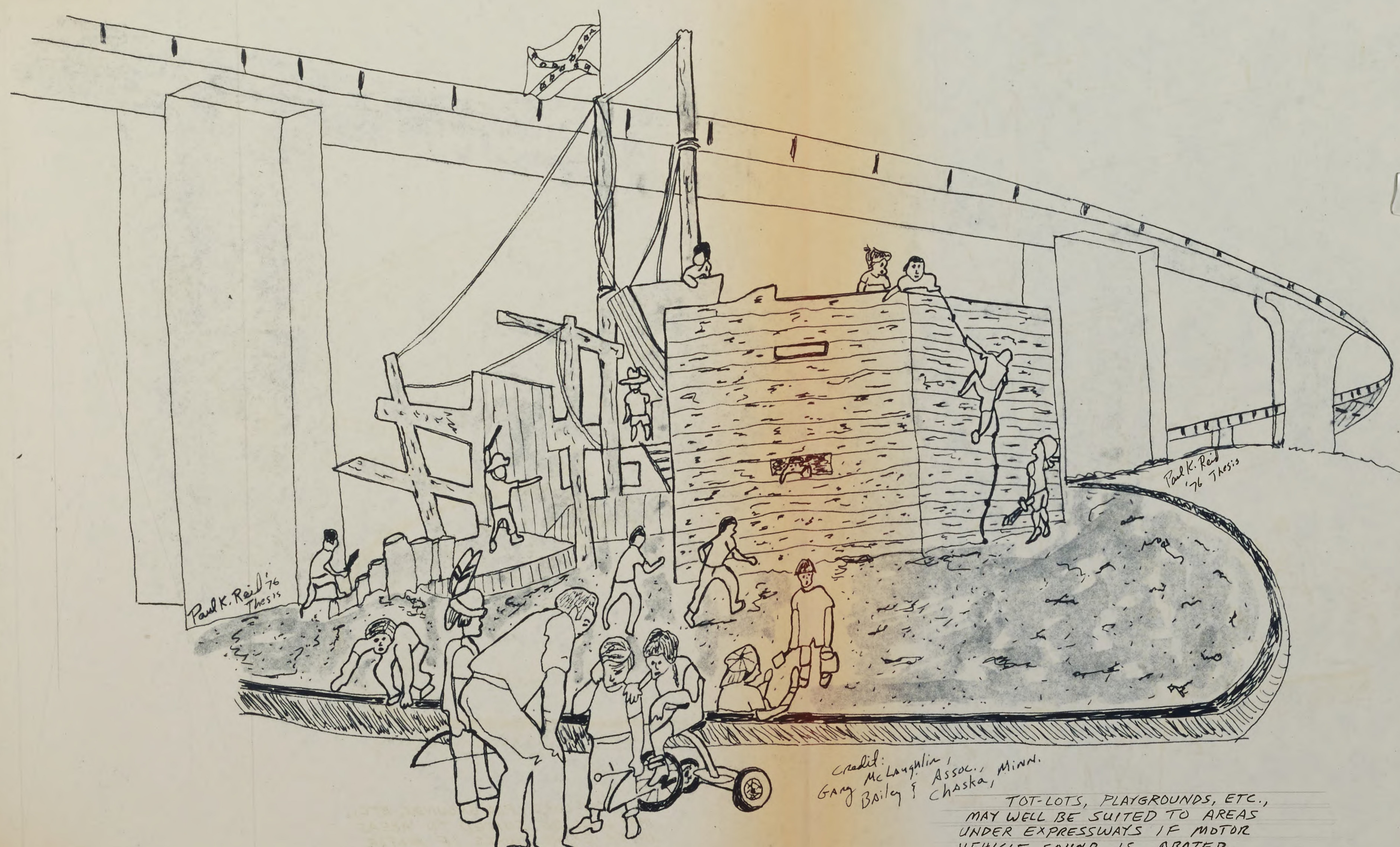
ENGLISH ADVENTURE PLAYGROUND UNDER EXPRESSWAY.



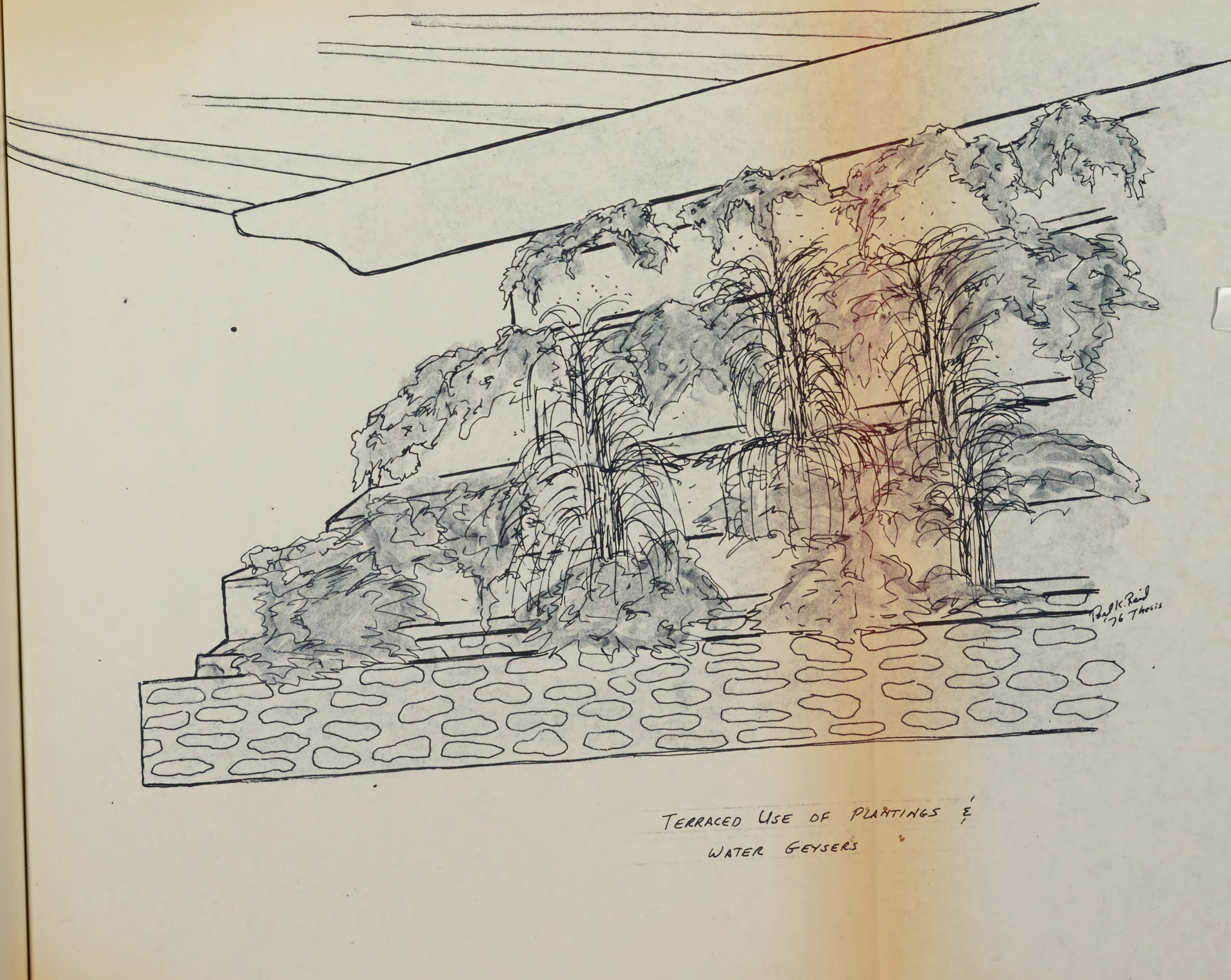
TOT-LOT UNDER EXPRESSWAY
ADJACENT TO CBD.



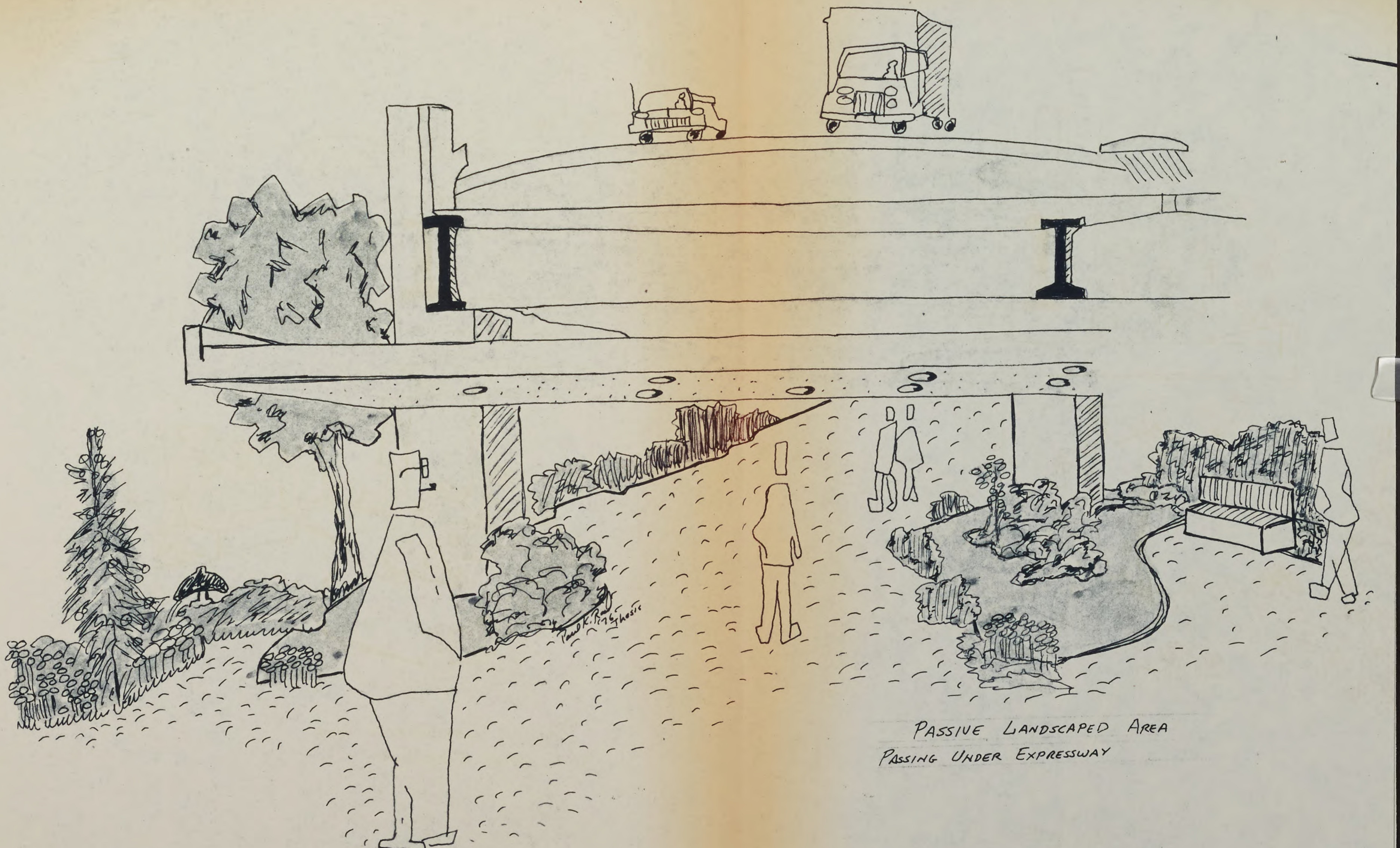
PASSIVE LANDSCAPED AREA UNDER EXPRESSWAY. INCLUSION OF MUSIC, WATER, LANDSCAPING, OR MURALS MIGHT PSYCHOLOGICALLY ENHANCE THESE AREAS.



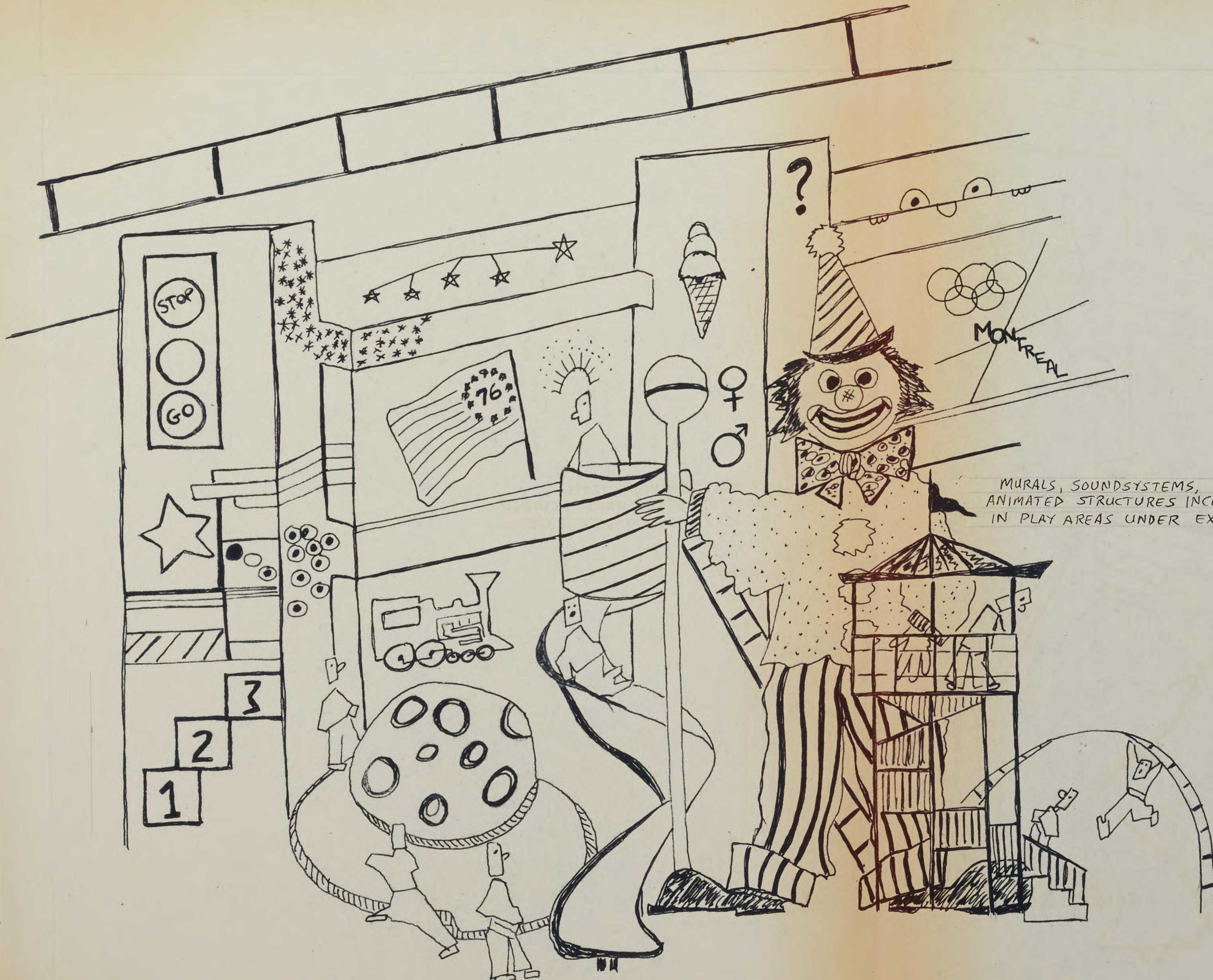
TOT-LOTS, PLAYGROUNDS, ETC., MAY WELL BE SUITED TO AREAS UNDER EXPRESSWAYS IF MOTOR VEHICLE SOUND IS ABATED.



TERRACED USE OF PLANTINGS &
WATER GEYSERS



PASSIVE LANDSCAPED AREA
PASSING UNDER EXPRESSWAY



MURALS, SOUNDSYSTEMS, ANIMATED STRUCTURES INCLUDED IN PLAY AREAS UNDER EXPRESS.