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A CASE STUDY OF ADJUSTING THE ANNOYANCE OF ARTILLERY NOISE TO THE ANNOYANCE OF AIRCRAFT NOISE

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1. INTRODUCTION

The sounds of military training are more varied than those from transportation. In addition to the sounds of jet or propeller aircraft and trucks, civilians living near military installations may hear the sounds of helicopters, generators, tracked vehicles, amplified speech from range towers and impulses ranging from the crack of rifles to the boom of high explosives. This variety of sources poses a problem for those in charge of policies on noise limits - how to set the limits on each type of noise in a way that is fair and equitable to every citizen.

Within the U.S. Department of Defense (DOD), policy on land use planning around airfields was developed before policy regarding firing ranges. In order to be fair to the owners of both undeveloped and developed residential properties, the framers of DOD and Army policy try to set the acoustic "dividing line" between residentially-compatible and residentially incompatible firing range noise at the same level of annoyance as already accepted for airfield noise. At the time the firing range policy was developed in the mid 1970s and early 1980s, there was little research on the annoyance of weapons noise. Most of the published studies were about the annoyance of sonic booms. Consequently, the initial policy on the booms of large guns and explosions had to be developed through assumption and extrapolation.

The following case study describes the response of the first community to have its blast noise environment evaluated under the Army's initial policy. The community was Lawton, Oklahoma, the largest community in the vicinity of the U.S. Army's Artillery Center and School, Fort Sill. In 1974 and again in 1982, this community rejected the Army's evaluation of weapons noise. In retrospect, it appears that the community was correct. There was a problem in a key assumption about the growth in annoyance of aircraft noise and blast noise as the level of each source increased. The assumption was that the annoyance of both sources increased at the same rate. With this assumption in place, the effect of artillery noise on the quality of residential life in Lawton was overestimated. The following case study describes the initial rejection by the community, subsequent Army research on the validity of the key assumption, and the ultimate resolution of disparity between the prediction and community perception.

2. INITIAL REJECTION

The Army's first procedure for assessing annoyance from the noise of large guns was an extrapolation from two aircraft noise assessment procedures, Effective Perceived Noise Level (EPNL) and Composite Noise Rating (CNR) [1]. The only community response data available at that time were sonic boom studies and weapons noise complaints from three areas with low ambient noise: Gibson Island (a relatively exclusive, private island community in the Chesapeake Bay), the area around Fort Belvoir, Virginia, and the area around Wildflecken Training Area, Hesse, Germany. In 1974, this procedure was used to assess the firing at Fort Sill, and a significant portion of developed housing in Lawton was found to be within a Noise Exposure Forecast (NEF) 40 contour. Although the NEF-40 contour pointed to a degraded quality-of-life due to noise, local officials disagreed, pointing out the paucity of noise complaints (3 during 1974). In response, the U.S. Department of Housing and Urban Development (HUD) conducted an independent measurement study, finding that artillery noise "tended to mingle and was nearly indistinguishable from neighborhood noise in other areas."[2] As a result of this study, HUD lifted loan restrictions on housing located within the NEF-40.

3. INITIAL RESEARCH

While Lawton was rejecting the Army's initial analysis, the Army was funding a laboratory study on the relationship between the annoyance from aircraft and artillery noise [3]. Subjects sitting in a simulated living room judged the annoyance of electronically-reproduced aircraft flyovers and simulated artillery blasts. The researcher used a unique cam and plunger drive mechanism to shake one wall of the test chamber to mimic the house vibration experienced in typical U.S. wood frame residential construction. Magnitude judgements for annoyance were correlated with the indoor Sound Exposure Level (SEL) measured with several weighting scales. In the artillery noise class, annoyance was found to double for every 5.4 to 5.7 dB increase in the C-weighted SEL. In the case of aircraft noise, annoyance was found to double for every 9.8 dB increase in SEL.

The observation of a faster growth function for response to artillery noise echoed an earlier study comparing aircraft noise with sonic boom [4]. In the sonic boom study, Kryter found that about a 7-dB change in peak amplitude was equivalent to a 10-dB change in EPNL for the flyover of a control aircraft. Nevertheless, it was possible to bring both the sonic boom and artillery blast growth functions into line with the 10 dB growth function of aircraft noise by converting the sonic boom data to C-weighted SEL and dropping the two lowest SEL values from the 8 data points in the artillery data set [5]. This reanalysis of the data established the equivalence of growth functions for large amplitude impulse noise and aircraft noise. Both types of sound were viewed as doubling in annoyance for each 10 dB increase in SEL.

The reanalysis of the artillery and sonic boom data opened the door to assessing artillery noise exposures using a simple, equal energy calculation. For example, a homeowner experiencing a day with 100 blasts, each having a CSEL of 85 dB would be expected to be as annoyed at the end of the day as when the homeowner experienced one blast at a CSEL of 105. Armed with this concept, a new computer model that calculated the C-weighted Day Night Sound Level (DNL) from all the large weapons firing points on Fort Sill [6], and a relationship showing the offset of the "percentage highly annoyed"

for C-weighted DNL from the "percentage highly annoyed" with the Schultz curve [7], the Army approached the community of Lawton with a second assessment of the artillery noise environment.

4. SECOND REJECTION

The analysis of the Fort Sill blast noise environment was completed in 1982. Although the analysis was based on CDNL rather than NEF, the outcome was the same as it had been seven years earlier - large tracts of developed residential property within a "normally incompatible" zone. Once again, community leaders asserted that artillery noise was not annoying for people living within the "normally incompatible" contour [8]. The chairman of the Lawton Metropolitan Area Planning Commission noted that very few people in Lawton had complained about artillery noise, and he said, "I doubt that 15% of our people are annoyed." Officials from the Departments of Defense and HUD met with community leaders "in an attempt to sooth fears about the Army's study."

The reason the "normally incompatible" zone around Fort Sill was so large was because so much ammunition was expended on its ranges. Some of this ammunition was fired at night, thus requiring a 10 decibel penalty. Yet the level of the typical blast was low enough to be masked by other background sounds, such as air conditioners and traffic noise. By summing the C-weighted energy of hundreds of low level blasts over the 24 hour day, the assessment procedure gave the appearance of a significant exposure. Siding with the prevailing sentiment of the community leaders, HUD officials decided against any mortgage restrictions on existing housing. At the same time, HUD officials endorsed noise reduction measures in new housing construction, to include storm windows, insulation, and air conditioning.

5. SECOND ROUND OF RESEARCH

The community's rejection of the CDNL methodology was followed by a new round of Army research on the annoyance of artillery blasts. At first, the focus was on the interaction between the annoyance of the sound and the annoyance of the rattles experienced inside a house. Using a specially-constructed test house and a shake table converted into a large impulsive source, Schomer and Averbuch [9] found that rattles had a more significant effect on low level blasts than on high level blasts. In explaining their results, the authors speculated that "to the extent that the low-blast level without rattles is barely detectable, then the rattles make it highly detectable and, hence, more annoying." In effect, this was the same conclusion reached by the HUD officials, who had endorsed measures to make Fort Sill's artillery noise less detectable.

The Army researchers also joined with German researchers to study the annoyance of weapons blasts experienced inside the more solid construction typical of Germany. Using real buildings and the actual military sound sources, the group demonstrated that the subjective annoyance of a blast grows at a faster rate than the subjective annoyance of other sources [10].

6. RESOLUTION

In 1996, the Army Center for Health Promotion and Preventive Medicine (CHPPM) reassessed the noise environment at Fort Sill using the relationship derived from the U.S.-German research [11]. In

contrast to the contours published 14 years earlier, the "normally incompatible" zone was much reduced.

The relationship used to generate the new Fort Sill contours was a slope of 0.5, i.e., a 1-dB change in the CSEL of high-energy impulsive sound was equated to a 2-dB change in the ASEL for an aircraft sound of equivalent annoyance. Equivalent annoyance was set at an (outdoor) ASEL (for aircraft noise) and CSEL (for blast noise) of 103 dB.

Although some of the shrinkage in the size of the "normally incompatible" zone was due to a reduction in the number of rounds fired at Fort Sill and to improvements in the algorithms for predicting blast propagation, the primary factor was the new psychoacoustic relationship. The resulting contours are now aligned with community response. Although the analysis still shows a need for land use planning in some areas, only a small portion of the existing residential housing stock in Lawton is affected by training noise. As in the past, the number of complaints about blast noise is relatively low (none in 1994, four in 1995). Although the road was a rocky one, the Installation Compatible Use Zone effort at Fort Sill can be viewed as an Army "success story."

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